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LpR

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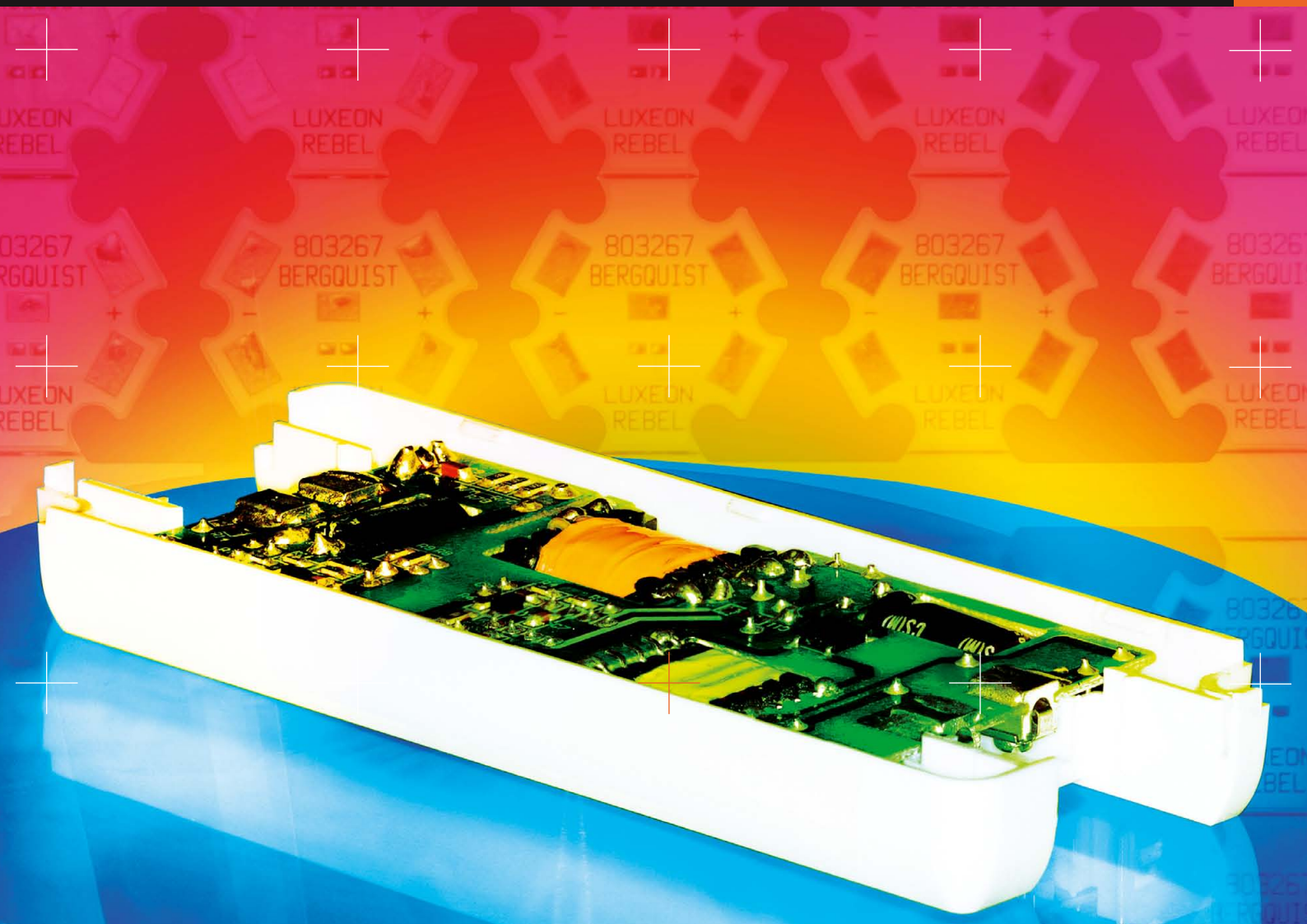

Zhaga – A Successful Strategy

Copper Bonding Wires

TRIAC Dimming - EMI

Lacquer Systems for PCBs

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With LUXEON T LEDs you can be confident you will get the system level performance you need.

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PLL/LUXT-12/12

System Trends 2013

Welcome and a Happy New Year.

The beginning of the new year is an especially interesting time to screen and forecast important trends that might influence further developments in lighting.

A well recognized approach for analyzing technologies is the “Trends of Engineering System Evolution (TESE)”. It consists of 11 major trends. A major one is called “Trend of Transition to the Super System” and it states that an Engineering System is integrated with the Super System as it evolves. At first, this happens on the integration level which gets deeper as the number of interactions increase. This means that LED systems will have to manage more interfaces like sensors and communication channels (e.g. wireless) and will have to interact more closely with the environment. This includes humans, buildings, and traffic, with or without natural light. A second aspect of this trend is related to the parameters and functions between the Engineering System and the Super System. Transition to the Super System means that these functions and parameters will become increasingly different throughout the hierarchical levels.

How does this apply to an LED lighting system?
We can expect that the trend of multi-chip arrays will continue. Due to this trend, in the future, the “multi” approach will end up with different chip-sizes, colors, power and even LED types for light-engines. Instead of uniformity we should obtain stronger differentiation.

But let’s also take a look at other drivers in general. The development of new technologies will also be driven by the needs of applications such as the requirement for a 100W incandescent replacement lamp with its difficulties for heat management and improved efficiencies.

GaN-on-Silicon technology and nano-technologies (wires, crystals, fibers) together with new production methodologies (e.g. printed OLEDs) are prepared to enter the market to some extent. Besides all these innovations the lighting industry also requires regulations and standardization. The Zhaga specification for LED light engines is especially important and should be thought of as a trend-aspect this year.

I’m confident that this will be an exciting, fascinating and valuable year in the area of LED lighting. Enjoy reading about some of the trends that are bound to have an influence on the coming year in the first issue of LpR in 2013.

Yours Sincerely,

Siegfried Luger

Publisher, LED professional
Event Director, LpS 2013

Content

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Guido Nattkemper

Guido Nattkemper is Director of LED Product Management at BAG electronics Group. The company has been a well-known supplier of luminaire manufacturers across the globe for many years, with lighting electronics for professional applications. Mr. Nattkemper has been working for BAG electronics since 2001. He completed his physics degree at the University of Dortmund in 1991. He has many years of detailed experience in the international lighting electronics sector, and accompanied the development of the first LED components and the expansion of LED expertise at BAG from the beginning.

THE MANDATORY BASIS FOR PROFESSIONAL LED LIGHTING

Platform management speeds up development, simplifies complexity, helps to manage the supply chain and improves quality.

Impressive energy savings, extremely long service life and high application flexibility are the well-known benefits of LED, and have helped the technology to achieve a rapid breakthrough and an unprecedented boom. But this euphoria will only continue if LED lighting systems are able to fulfill ambitious, industry-specified demands. This means that quality management, in itself an essential element of lighting electronics, becomes even more important, and this applies not only to the LEDs but to the LED modules used and to the same degree, the control gear.

What does 'good' LED light actually consist of? When aspects of quality are discussed then the parameters of LED service life, color temperature, color rendering index and color perception are at the fore. This, of course, is correct but is still insufficient; high light quality cannot be achieved without high quality electronics.

The diversity of requirements for qualitative LED lighting should not be underestimated: a wide spectrum of variants, highly differing application areas and the high speed of development are only some of the factors directly affecting quality assurance. In view of simultaneously high time and market-related pressure, the development of platform concepts and thus modular kit systems becomes the obvious solution.

Tried-and-true platforms help to cut down on the complexity of wide product diversity and so allow a constantly high level of quality and shortened development periods. They also enable the flexibility for manufacturers of luminaires that these require for highly differing demands and products. The Zhaga consortium, bringing together leading companies in the international lighting industry, shows , for example, possible options for defining platforms with the objective of interchangeability for LEDLight Engines. An overall, uniform understanding of definitions, components and topologies is part of that process and means that the level of transparency is improved for all participating parties.

Concurrently, does this mean that our own development activities are limited? Just the opposite. It is on the foundation of basis specifications as drawn up by Zhaga that own, individual platform concepts can be created with additional performance characteristics beyond the requirement of pure interchangeability. Intelligent functionalities and innovative solutions with regard to thermal, electrical, mechanical and photometrical platform properties open up differentiating opportunities to suit a wide array of application areas, ranging from retail outlets to industrial halls. Rapid availability coordinated precisely to specific demands is also the platform strategy of BAG in regards to LED modules and control gear. Based on many years of experience in terms of various application conditions in professional lighting and design of lighting electronics, platforms for electronic control gear units and LED modules are matched as systems.

Short cycles of innovation are elementary in the highly dynamic LED sector, while keeping the level of complexity as low as possible. Platform concepts are ideal for this as they enable rapid product development, while at the same time simplifying production planning and logistics for luminaire manufacturers by improved product availability, higher flexibility in use of components and thus reduced stock-keeping. Of course, an essential part of the platform strategy is also continuous quality management, covering product specification and product development to running quality control during manufacturing.

For LED lighting, rapid availability with high quality are conditions that future-oriented platforms are able to meet. ■

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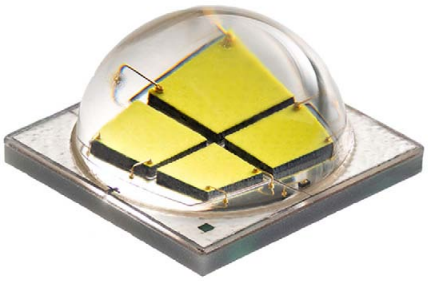
BICOM

Cree's MK-R LED Offers up to 200 Lumen-Per-Watt

Two years after breaking the 200 lumens-per-watt (LPW) R&D efficacy barrier, Cree, Inc. delivers another industry first with the introduction of the Cree XLamp® MK-R LEDs. The new MK-R LEDs leverage the SC^3 Technology™ next-generation LED platform to deliver up to 200 lumens-per-watt (at 1 W, 25°C) LEDs.



Cree's new MK-R LED is capable of delivering up to 1600 hot lumens at 15 W even at a junction temperature of 85°C

The new MK-R LEDs make the next generation of 100+ lumens-per-watt system possible for high-lumen applications, including outdoor and indoor directional applications, such as halogen replacement lamps. MK-R LEDs are available in EasyWhite® color temperatures, providing the LED industry's best color consistency for designs that use only one LED. For systems that use multiple LEDs, MK-R enables manufacturers to use fewer LEDs while still maintaining light output and quality, which translates to lower system cost.

Features:

- Available in ANSI white bins as well as 4-step and 2-step EasyWhite bins at 2700 K, 3000 K, 3500 K, 4000 K, 4500 K and 5000 K CCT
- Maximum drive current: 1250 mA
- Low thermal resistance: 1.7°C/W
- Maximum junction temperature: 150 °C
- Binned at 85°C
- Viewing angle: 120°
- Available in cool white, 70-, 80- and 90-CRI minimums
- Unlimited floor life at ≤ 30 °C/85% RH
- Reflow solderable - JEDEC J-STD-020C
- Electrically neutral thermal path

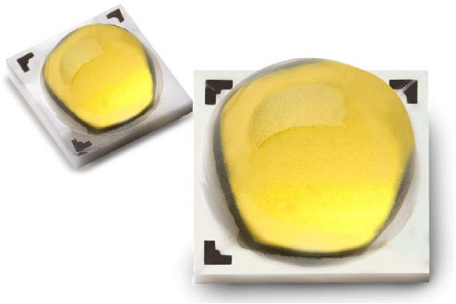
"It's amazing that Cree is able to achieve a 200 lumens-per-watt LED so quickly," said Nicola Vendrame, CEO, Linea Light group. "The high efficacy of the MK-R LED means that we can drive the LED harder for more light output without creating heat issues. In addition, the MK-R LED has the right combination of size, color consistency and optical control to enable the next generation of performance in our indoor directional luminaires."

"Cree's relentless innovation continues to push the boundaries of what is possible with LED lighting," said John Edmond, Cree co-founder and director of advanced optoelectronics. "The MK-R LED is another game-changer for the industry. An LED with this level of performance can accelerate the development of high-output lighting applications and could enable applications we haven't even thought of yet."

The MK-R LED features a 7 mm x 7 mm footprint with a 6 mm optical source and delivers up to 1600 lumens at 15 W, 85°C. Characterized at 85°C, the MK-R component is available in 2700 K to 7000 K color temperatures and offers minimum CRI options of 70, 80 and 90 (at selected color temperatures). The MK-R LED is the ninth product built on Cree's SC^3 Technology platform. The innovative platform leverages Cree's advanced silicon-carbide technology, features advancements in LED chip architecture and phosphor and boasts a new package design to deliver the most advanced LED components in the industry. ■

Philips Introduces New LUXEON T

Building on the market-leading innovations of hot testing and Freedom from Binning™, Philips Lumileds introduces LUXEON® T, the next generation illumination-grade LED tested and specified at 85°C to ensure in-application performance with tight color control, to within 3-Step MacAdams (SDCM). Optimized for efficacy and supported by the industry-leading forward voltage of 2.7 V and the lowest thermal resistance of 3 Kelvin per watt, LUXEON T allows designers to achieve the highest possible system efficacy and the flexibility to reduce the number of emitters, all without compromising on high color rendering (CRI) across the full Correlated Color Temperature (CCT) range from 2700 K to 5000 K.



The new LUXEON T from Philips Lumileds delivers performance & precise beam control for directional & efficacy driven applications

Features:

- Freedom from Binning – 3 and 5 SDCM
- Hot tested at Tj 85°C
- Typical Vf of 2.7 V and lowest thermal resistance, 3 K/W
- Proven reliability
- Exceeds ENERGY STAR lumen maintenance requirements
- UL-recognized component [E352519] with level 4 enclosure consideration

Benefits:

- Delivers color consistency
- Ensure in application performance
- Optimized for efficacy driven applications
- Superior efficacy and light output

Key Applications:

- Lamps
- Downlights
- Indoor
- Highbay and Lowbay
- Outdoor
- Architectural

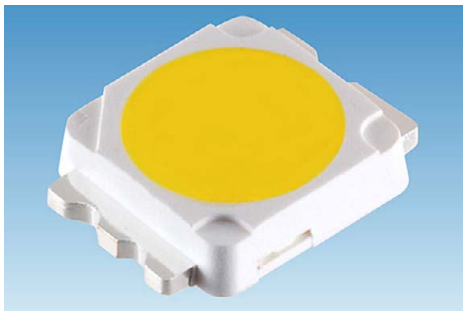
"With its high efficacy and luminance, LUXEON T is ideal for directional applications such as MR16 and PAR retrofit lamps," says Kathleen Hartnett, Product Line Director. "LUXEON T is able to deliver high center beam candle power (CBCP) and precise optical control, which are required to deliver the narrow beams desired for these systems."

LUXEON T delivers up to 140 lumens per watt at 350 mA, 85°C in neutral white at 5000 K 80 CRI minimum from a compact 3.7mm x 3.7mm package. The breakthrough performance of LUXEON T is realized through Philips Lumileds technology leadership—in epitaxial growth delivering leading wall plug efficiency and hot cold factor, new phosphors to enhance conversion efficiency, and package optimization for light extraction and lowest thermal resistance.

LUXEON T is now available in five different CCTs, 2700 K, 3000 K, 3500 K, 4000 K and 5000 K all specified at high-CRI, 80 minimum. In addition to the market-leading 80 CRI range, LUXEON T is available with 95 typical CRI and exceptional red rendering (R9) of 90, making it ideal for the professional lighting market. To enable system level performance improvements in outdoor and industrial applications including high bay, street and roadway lighting, LUXEON T was extended to the 70 CRI range in January 2013. ■

Toshiba Ships GaN-on-Si Technology LEDs

Toshiba Corporation announced that the company started sales of white light-emitting diode (LED) packages that offer makers of general purpose and industrial LED lighting solutions a cost-competitive alternative to current LED packages. Mass production started in December 2012.



Toshiba's new LED product uses GaN-on-Si technology and is manufactured on 200 mm silicon wafers

Product Outline:

Product name:	TL1F1 series (1W)
Size:	6.4x5.0x1.35 mm (LxWxH)
Light flux:	112 lm (at 350 mA)

Mass Production start: December 2012
Production capability (planned): 10,000,000 units per month

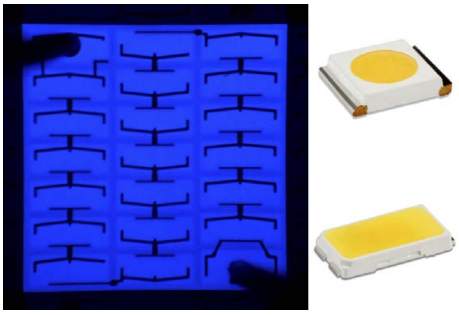
Production of LED chips is typically done on 2- to 4-inch wafers with an expensive sapphire substrate. Toshiba and Bridgelux, Inc. have developed a process for manufacturing gallium nitride LEDs on 200 mm silicon wafers, which Toshiba has brought to a new production line at Kaga Toshiba Electronics Corporation, a discrete products manufacturing facility in northern Japan. Mass production of packages using the new line's output starts this month.

Deployment of Toshiba and Bridgelux's new gallium nitride-on-silicon (GaN-on-Si) technology to produce LED chips has allowed Toshiba to replace sapphire substrates and to produce the chips on a much more cost-competitive silicon substrate.

Going forward, Toshiba will promote product development and global sales toward securing a 10% share of the world market in FY2016. ■

SSC's MJT Series Chips in Mid Power Packages

A big advantage of the MJT series is that its 5630 and 3528 packages offer LED lighting manufacturers easier production with the standard (module) size and enable lighting fixtures to deliver world-class performance up to 100 lumens per watt.



A chip of the MJT series designed using Multi Junction Technology; several cells are connected by junctions as a chip (left). The MJT series 3528 (top right) and 5630 (bottom right) package

MJT (Multi-Junction Technology):
MJT stands for Multi Junction Technology, and it can be driven higher Voltage than Conventional DC LEDs. While High Voltage LEDs in the market are designed with complicated circuit connecting many LED chips physically, MJT is using Multi Cells integrated chips to produce various Voltage types.

Unlike the conventional method that requires complicated circuitry to connect multiple LED chips, the MJT series is designed to operate at various voltage levels, which allow operation at high voltage levels using only one LED chip of which cells connected by multi-junction technology. Using one LED chip, rather than multiple LED chips, reduces the failure rate and optimized chip design help to achieve 100 lm/W light efficiency on lighting fixture level.

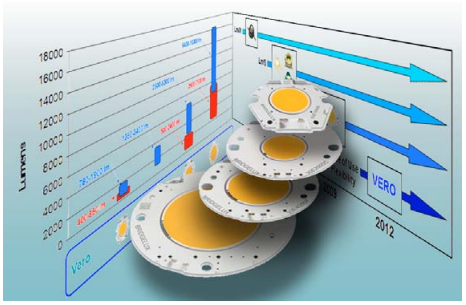
MJT series is geting a lot of attention from lighting designers all over the world because the lighting fixture that uses the MJT series requires the least amount of circuitry to be highly compatible with conventional dimmers. This reduces the cost for the system (LED + driver) remarkable.

Seoul Semiconductor's Mr. John Bae stated, "Since the high price of LED lighting is a major hindrance to extend LED market, LED lighting designers make an effort to develop higher performance and lower cost LED lightings for end users to reduce payback period. MJT series meets those demands by reducing the overall system costs. This trend is also followed by the global top lighting manufacturers".

Seoul Semiconductor's MJT mid power series runs at 19 V, 22 V and 32 V and offers a wide range of color temperatures (2700 K – 6500 K). In addition, they are optimized for general LED lightings such as A19, PAR and down light. ■

Bridgelux Introduces Ground Breaking High Performance Array LED Platform

The well-known array LED specialist, Bridgelux, announced that it is extending its existing portfolio with a game-changing next generation product line. Bridgelux is convinced that the new Vero (BXRA-5) LED will add a new quality to array LEDs. In addition to the three currently recognized criteria; efficiency, costs per Dollar and lumen per package, the new concept offers ease of use and flexibility. Combining these four disciplines will optimally advance the mass adoption of solid state lighting.



The first clients can expect the BXRA-5 Vero series in production quantities at the end of Q1/2013

Vero design goals could be fully realized:

- Efficacy
  - 110+ lm/W 3000 K 80 CRI at rated current
- Design Flexibility
  - Enable design optimization on lm/W, lm/$, lm/area or any combination
- Flux Density
  - Higher lumen density to enable improved optical control and narrow beam optics for precision lighting and miniaturized luminaires
- Light Quality
  - Radial die spacing to improve optical fill and light beam quality
  - 3SDCM Color control standard
- Ease of Use
  - Improve solder capacity and non-soldering options for connectivity
  - Improve inventory control and reduce SKU counts for arrays and drivers
- Cost of Light
  - Engineer platform to reduce cost on day one and into the future

The Vero platform provides complete application coverage from four form factors, delivering the light output and color temperatures required for retail, hospitality, commercial, industrial, residential and outdoor lighting applications. The arrays will initially be available with performance ranging from 800 lumens in warm white (3000 K) up to 20,000 lumens in cool white (5000 K) with multiple CCT and CRI options, including the 97 CRI Decor product option.

The brand new and innovative step:
"What we have done is, in effect, separated the "engine" from the "body." BXRA-5 is still an MCPCB based chip-on-board product, but we have decoupled the mechanical interface and mounting features from the engine, or in other words, the 'body' from the 'heart' of the array," explained Jason Posselt, Bridgelux Vice President of Marketing. "We will deliver the product as an assembly, with the two components reflow soldered together in our factory."

The BXRA-5 is an MCPCB based C.O.B. and the plastic component is, in effect, an insert molded lead frame. Both technologies per se are nothing new, but the skillful combination of these two technologies has its advantages and opens new opportunities. The solder pads are mounted on top of plastic, thermally isolated from both the MCPCB and the heat sink. No longer does the array need to be placed on a hot plate for soldering – it can even be pre-mounted to the heat sink prior to soldering. We have also designed a connector port directly into the plastic to enable solder free electrical connectivity.

Bridgelux made some significant changes in the array design, as well to foster the ease of use and flexibility. "While the new design also leads to more lm/W and better lm/$, it increases lm/area dramatically and, in parallel, extends flexibility, makes handling more convenient and reduces driver issues." Mr. Posselt is very enthusiastic about the new product.

There are two key measures. First, the BXRA-5 is based on a new and improved MCPCB technology. Second, Bridgelux is now using an increased quantity of slightly smaller LED chips. This enables greater flexibility in how the chips can be placed in the package, resulting in a radial die pattern for improved optical fill and light quality as well as a significant improvement to the thermal uniformity of the package. This improved thermal uniformity is part of what enables these products to be driven reliably under a higher current operation of up to two times the nominal rated test current.

The engineers have not only managed to neatly configure the arrays and align them with industry standard drive currents and voltages but they also managed to reduce the complexity and quantity of drivers required when using this family of products.

Jason Posselt also said, "While the plastic component is just an insert molded lead frame, it could also be considered as a printed circuit board because electronic traces can be routed through the material. While we don't know exactly what will be required in the future, we do expect to see convergence occur in solid state lighting, just as it has with consumer electronics. As such, it is likely that we will see a need to incorporate additional functions, sensors, communications, or other features into the LED light engine."

Asked for other ideas like a high voltage alternating current (HV-AC) version or if GaN-on-Si technology will also be part of the Vero Module, Mr. Posselt said, "While we are thoroughly checking out and discussing the demands for that, we don't know exactly what will be required in the future. But at the moment neither HV-AC versions nor the use of GaN-on-Si based LEDs are planned." ■

Everlight Presented New Products at electronica

Everlight Electronics, a leading player in the global LED and optoelectronics industry, presents highly efficient white mid power LED series 62-227B (0.4 W) and 62-217B (0.5 W) and extended its signage LED portfolio to offer five new products for indoor, semi-outdoor and outdoor applications.

The top view mid power white LED series (5630 Package) provide high efficacy, high CRI (min. 80 or min. 75), low power consumption, a high luminous flux output, high current capability, a wide viewing angle and a compact form factor. These features make this package an ideal LED for all lighting applications.

Everlight's 62-217B Mid Power LED is available in 13 versions

The design of Everlight's 0.5 W 62-217B LED provides a high lumen, high quality light solution, in particular for mid power applications. Due to its low power consumption and its ultra-thin size of 5.6 mm x 3.0 mm x 0.9 mm (LxWxH), the 62-217B top view white LED is truly ideal for many lighting applications like decorative and entertainment lighting, light bars, light tubes, light pipes, indicators and backlights in offices and family equipment as well as general lighting. 62-217B LEDs come in a PLCC-4 package, are Pb-free, RoHS compliant and match ANSI Binning.

Everlight's 62-217B Mid Power LED is available in 13 versions in warm white (2700-3000 K), neutral white (4000 K) and cold white (5700-6500 K) with typical luminous fluxes ranging from 40 lm to 60 lm.

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.

LedLink
Linking LEDs to The Real World

Omni-Dirtional Bulb Cover

Size: 60.00 x 108.00mm Beam angle: 300 degrees.

With integrating the optical design, diffused material, and injection blow moulding process, stable mass production and wider beam 300 degree spread can be achieved. Comparing with the diffused glass cover, this product has the following advantages as below:
1. Reducing the defect rate during the production.
2. Much better mechanical strength and it wouldn't hurt people once it drops.
3. The bulb cover can be manufactured and performed the same as the existing traditional one.

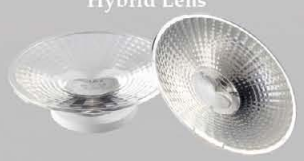
White plastic can solve problem from the light source of LED.
This cover has advantages of low defect rate, unbreakable, lighter weight, and high transmission rate as of 90% or more.
It also can prevent glare and have high strength against hit.

Reflector Series

Characteristics:

1.Choose materials per your requirements: electroplated plastic reflectors or aluminum reflectors.
2.Compatible with various brands of COB and High Power LED.
3.Tolerance of +/- 0.1 millimeters.
4.Electroplated plastic reflector has better plasticity, with less limitation of appearance.
5.Customers can design structures based on different demands.
6.Electroplated plastic reflector is an insulator and can attach the PCB directly.
7.Aluminum reflector has sufficient strength and no heat-resistant problems.
8.Lead-time of prototypes is shorter with good quality.

Hybrid Lens

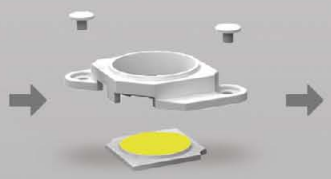


LL01ED-ASAxxL06-P
D x H (mm) 90.6x27
FWHM 12° 24° 38°
FOR PAR38

Aluminum reflectors

LL01ED-AJMxxR18
D x H (mm) 35.2x7.8
FWHM 24° 38°
FOR MR 16

LL01ED-ALJxxR18
D x H (mm) 91.5x23.2
FWHM 24° 38° 45°
FOR PAR38



Aluminum reflectors connector

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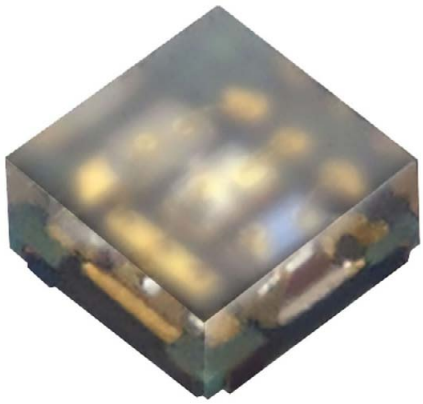
Everlight Electronics Co., Ltd., a leading player in the global LED and optoelectronics industry, has extended its signage LED portfolio to offer five new products for indoor, semi-outdoor and outdoor applications.



Everlight's SMD-Chip-LED 18-038 is just one out of five new 3-in-1 full color LEDs for signage applications

Two new SMD Chip type LEDs, the 18-038 (1010 package) and the 19-037A (1616 package) are ideally suited for indoor LED applications with highly compact board sizes. Both the 18-038 (1.0x1.0x0.5 mm) and the 19-037A (1.6x1.6x0.9 mm) LED Series are much smaller than lead frame type components, thus enabling smaller board sizes, reduced package and storage space and a higher packing density, resulting in smaller equipment. They represent the next level of SMD LED technology by implementing a black PCB which enhances the contrast and an advantageous solution for high contrast and high resolution indoor signage displays.

Two new SMD PLCC type LEDs add to Everlight's Hong LED family, designed for advanced indoor (HN0325) or semi-outdoor (HN0507) LED signage display applications. The Hong series LED package provides a perfect solution when a clear view of the signage display is required on boards of any size. Using 3-in-1 full color SMD PLCC LEDs offers a smaller pixel pitch between two LEDs to create a high resolution and better contrast with its black surface design.

The high performance 3474AH Series LED Lamp, a 3mm oval package, features an extensive wide viewing angle of 110° and UV curable epoxy with enhanced chemical resistance to best fit for outdoor applications, specifically designed for passenger information signs. The 3474AH LED Lamp has matched radiation patterns ensuring consistent color mixing in red, green and blue mixed-color applications. ■

Philips Introduces Fortimo LED Gen 3 Systems

In December, Philips announced updates to its Fortimo series, 3rd generation, starting with the LLM and SLM.

The third generation of the Fortimo LED linear light module (LLM) delivers high quality natural white light and outstanding system performance. The remarkable energy savings achieved with high-power white LEDs are taken to the next level with precise control over light. All dedicated Fortimo LED LLM drivers have pre-programmed Constant Light Output (CLO) functionality. The Xitanium LED drivers with CLO intelligently monitor luminaire lifetime, and compensate for lumen depreciation, resulting in lower power consumption at the beginning of luminaire life. CLO prevents wasted energy due to over lighting and at the same time delivers consistent light output. Dedicated system drivers also provide dimming options, allowing for reduction in light levels during off-peak hours, providing energy savings and reducing CO2 emissions. In addition to lower energy costs, dimming results in lower levels of light pollution, improving quality of life for local residents.

With its 3rd generation of the Fortimo LLM, Philips takes LED lighting to the next level, delivering high quality natural white light and outstanding system performance

The Fortimo LED LLM system delivers high-quality, glare-free white light, and is available in four different lumen packages (1100 lm, 1800 lm, 3000 lm and 4500 lm) in a choice of warm (3000 K) or neutral (4000 K) color temperatures and high color rendering (CRI >70).

Marina Kishkovich, Product Manager Outdoor LED lighting for Philips OEM EMEA stresses: "Municipalities understand that today's LED lighting technology not only delivers fantastic energy savings but also dramatically improves the quality of life for residents. LEDs provide clear white light, which has been proven to improve both perceived and actual safety and comfort in residential and urban lighting. The Fortimo LED LLM provides excellent vertical illumination for optimal facial recognition, enhancing that feeling of safety."

The third generation of the Fortimo LED SLM system offers versatility when it comes to applications in retail lighting, as it can be used for both powerful spot lighting solutions and compact stylish downlight fixtures. The new generation comes with the latest Chip-On-Board (COB) LED technology creating a powerful, compact and uniform light source for excellent beam control and small beam angles.

The SLM Gen3 modules produce high quality of light and deliver an energy efficiency performance of over 100Lm/W on system level at application conditions

The Fortimo LED SLM Gen3 system has been designed with luminaire manufacturers needs in mind, offering many passive cooling opportunities due to its high Tc-point of 75°C and its decreased thermal load as a benefit of the improved efficiency. The Fortimo LED SLM Gen3 produces color points that are identical to the benchmark in retail lighting: the Philips MASTERColour CDM Elite lamp. Next to that the small Light Emitting Surface (LES) creates the tightest beams and delivers the highest brightness. It makes the Fortimo LED SLM an excellent alternative compared to the commonly used halogen, compact fluorescent or compact HID lighting sources within retail lighting.

Pim Kemps, Philips Product Manager for Spot and Downlight, LED systems, OEM Lighting Sources & Electronics, added: "We continuously improve the performance of our products ensuring that retailers can showcase their merchandise in bright and vivid lighting. The Fortimo SLM Gen3 portfolio includes a 2000 lm and 3000 lm CRI90 version with high R9 value, deeply enhancing red colors of merchandise. And in the beginning of 2013 we are also introducing a very powerful 4500 lm module in the SLM family with the same form factor." ■

Tridonic Introduces TALEXXengine STARK INDI

Tridonic is launching TALEXXengine STARK INDI, an LED system that produces uniform light for both direct and indirect illumination. The light is directed downwards and upwards in a ratio of 80% to 20%, or vice versa. With its slim low-profile form the LED system gives designers enormous freedom and can be used as a replacement for T5 and TCL lamps. Its main applications include offices and educational establishments.

Tridonic's slim low-profile TALEXXengine STARK INDI's unique feature is that the light is directed downwards and upwards in a ratio of 80% to 20%, or vice versa

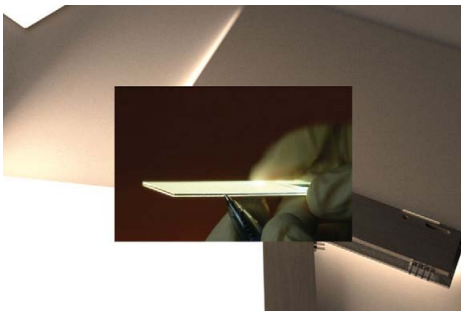
TALEXXengine STARK INDI is available in the CLASSIC version with a CRI greater than 80 and is ideal for floor-standing and pendant luminaires. The indirect portion of the light provides uniform background illumination, while the direct portion offers efficient desktop lighting. In a pendant luminaire 80% of the light is directed downwards and 20% upwards. These proportions are reversed for floor-standing luminaires. The impression is always of uniform area lighting because the combination of side edge injection and special diffuser materials means that individual points of light cannot be seen.

Precise Planning:
The LED light engine is available with color temperatures of 3000 K and 4000 K. A special feature is the highly reproducible white light quality (MacAdam 4). Withy dimensions of 564 x 100 x 8.5 mm the modules also fit in luminaires previously equipped with T5 lamps (2 x 28 W, 2 x 35 W) or TCL lamps (2 x 28 W, 2 x 55 W) and can be used as simple replacements for these lamps. Constant lumen packages of 2500 lm per module and a system efficiency of 85 lm/W provide the basis for precise planning for a long and efficient luminaire life.

The options for designing new lighting solutions are impressive. The LED modules can be used individuals or they can be arranged seamlessly next to one another. This means that strips of light with a continuous and uniform light emitting surface can be created. ■

Oree Introduces LightCell™ Plus Range

Planar lighting pioneer Oree unveiled an expanded product offering, the LightCell™ Plus, to give lighting fixture manufacturers improved and "never before" options for developing innovative LED-based planar light fixtures. LightCell Plus is geared to general lighting segments including offices, retail, hospitality and residential lighting.



Oree updates its portfolio range with LightCell™ Plus

LightCell™ Plus Features:
- Flat and thin profile
- Uniform, glare-free surface
- High CRI in all color temperatures
- Attractive lumen output

The new LightCell Plus range includes 2 different sizes:
- Solo – a square module of 70 mm x 70 mm with 350 lm
- Duo – a rectangular module of 140 mm x 70 mm with 700 lm

Planar lighting is characterized by flat and uniform illuminated surfaces that are designed to replace fluorescent lighting. LED planar modules offer the direct benefits of LEDs to end customers, such as energy savings, long life, a very attractive (flat) form factor, and high-quality, glare-free light. Fixture manufacturers using planar lighting benefit from needing less material to build fixtures, resulting in lower costs and environmental benefits.

Oree introduced its first planar lighting product, the "LightCell," last year. The LightCell Plus range is an expanded and improved range of modules that meets the needs of fixture manufacturers for higher lumen packages.

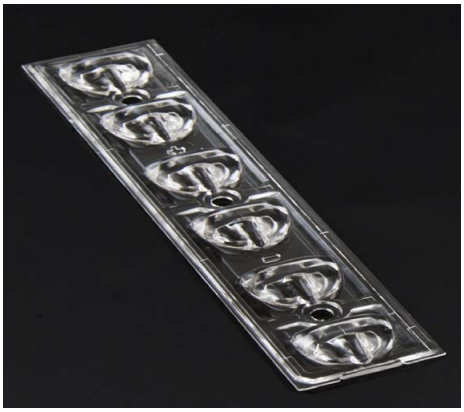
The LightCell Plus range of LED planar modules, like its predecessor, is based on a unique combination of features.

Both are available in a range of CCTs (2700-6500). Accessories such as connectors and drivers are also available, making the LightCell Plus a full plug-and-play system offering for fixture manufacturers.
Future of lighting

"Oree envisions the future of lighting in which new form factors will be developed that unleashes the full potential of LED technology," said Peter van Strijp, Oree's CEO. "Our expanded range of planar lighting modules will enable designers and fixture manufacturers to innovate and create new form factors that previously were unimaginable." ■

LEDiL's New STRADA Street Light Module

LEDiL Oy, the primary choice for secondary optics and Osram Led Light for You partner, introduces the new C13140_STRADA-T-6X1-DWC lens array optimized specifically for Osram's OSLON Square LEDs.



LEDiL's C13140_STRADA-T-6X1-DWC lens array, offers several unique benefits like outstanding cutoff to minimize glare

Features and Benefits:

- Very wide asymmetrical beam with 70° candela peak
- Great luminance/illuminance performance and uniformity
- Outstanding cutoff to minimize glare
- Low-profile and side-to-side or end-to-end stackable
- Six lenses in one array – reduced installation costs versus single lenses
- Resists excessive buildup of dust and dirt
- IP-rated sealing possible by use of the potting or sealing compounds
- High light transmission efficiency and virtually impervious to UV damage
- High scratch and abrasion resistance
- RoHS compliant and halogen-free

Lens module is based on LEDiL's proven STRADA street light optics and it has very wide light pattern suitable for long pole distances. Emitted light has an asymmetric tilt in the wide beam to efficiently direct light to the roadway surface and minimize stray light outside of target areas.

Module has light distribution ideal for the development of European ME3a and IESNA Type III Medium compliant luminaires for street lighting arrangements requiring up to and beyond 1:4.5 pole height/pole distance ratio.

Module's intended typical application range from residential street lighting to wide urban boulevard and collector roadway lighting. ■

Exar Introduces New Programmable HB LED Driver IC

Exar Corporation a leading supplier of high performance analog mixed-signal components and data management solutions introduced the XRP7613, a programmable high current, high brightness LED Driver. Capable of driving LED currents up to 1.2 A, the XRP7613 operates from input voltages up to 36 V and supports analog and Pulse Width Modulation (PWM) dimming up to 40 KHz.

Product Details:

The XRP7613 is a non-synchronous step down driver with integrated FET optimized to drive high power LEDs up to 1.2 A while supporting up to 36 V on the input. The XRP7613 has a switching frequency of up to 1MHz, a programmable output current from 150 mA to 1.2 A, and supports both analog as well as PWM dimming up to 40 KHz. A selectable LED thermal current fold-back control feature linearly reduces the LED current as temperature rises to ensure continuous lighting. The XRP7613 also provides designers with a compact and robust LED driver solution capable of fitting into the popular MR16 space constraint sockets.

Features:

- 1.2 A continuous output LED current - 150 mA to 1.2 A Programmable Range
- 7 V to 36 V single rail input voltage
- PWM & analog dimming capability - up to 40 kHz frequency
- LED current foldback thermal control - selectable automatic linear dimming of LED current with temperature
- Shutdown control
- Built-in soft start
- Open LED, LED short circuit and over temperature protections
- RoHS compliant "green"/halogen free 8-pin exposed pad SOIC package

Applications:

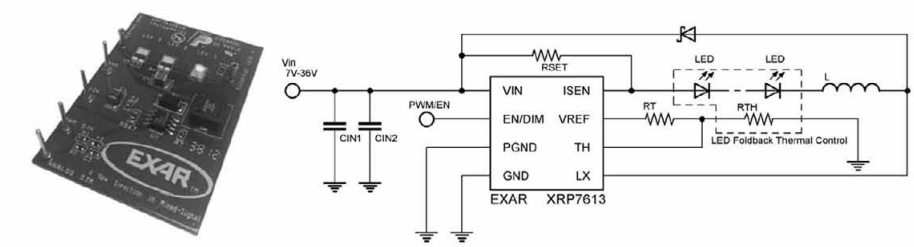
- General lighting and displays
- Architectural and accent lighting
- Medical and industrial instrumentation
- Video projectors

Designed for retail and architectural lighting applications, the XRP7613 offers a proprietary and selectable LED thermal current fold-back mode of operation that effectively reduces the programmed LED current as the ambient temperature increases. The XRP7613 supports a wide range of programmable LED currents, from 150 mA to 1.2 A, making it ideal for various LED brightness and light fixture wattage. Additionally, an extended operating voltage range of up to 36 V allows usage of the XRP7613 in industrial lighting applications where power transmission line losses are minimized through higher input voltage rails.

"The XRP7613 offers customers a number of leading features including the thermal current fold-back mode which maintains the LED lit under stressful temperature conditions where most other drivers would simply turn off," said Eric Pittana, Exar's Power Management marketing director. "Ultimately, the XRP7613 enables an enhanced consumer lighting experience with a longer lasting and more reliable lighting fixture." ■

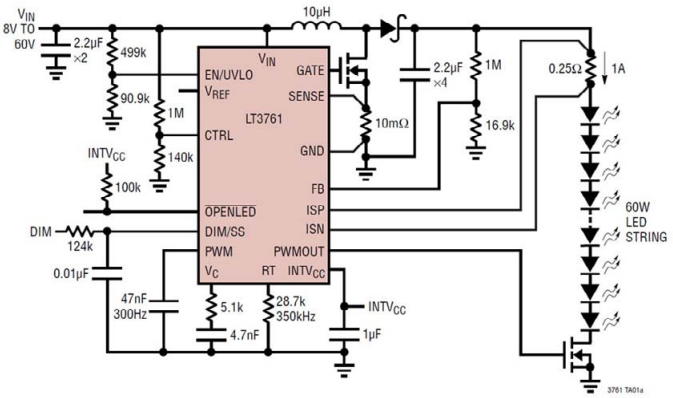
60V LED Controller with Internal PWM

Linear Technology announces the LT3761, a 60 V DC/DC controller designed to operate as a constant-current source and constant-voltage regulator. Its internal PWM dimming generator makes it ideal for driving high current LEDs, but it also has features making it suitable for charging batteries and super-capacitors. The LT3761's 4.5 V to 60 V input voltage range makes it ideal for a wide variety of applications, including automotive, industrial and architectural lighting.



Typical application schematics for Exar's XRP7613 driver IC that provides an adjustable current range from 150 mA up to 1.2 A

Application example with internal 25:1 dimming using Linear's LT3761 60V, LED controller with internal PWM generator



Features:

- 3,000:1 True color PWM™ dimming
- Wide V_{IN} range: 4.5 V to 60 V
- Rail-to-rail current sense range: 0 V to 60 V
- Programmable PWM dimming signal generator
- Constant current (±3%) & constant-voltage (±2%) regulation
- Analog dimming
- Drives LEDs in boost, SEPIC, inverting, buck mode, buck-boost mode, or flyback configuration
- Output short-circuit protected Boost
- Open LED protection & reporting
- Adjustable switching frequency: 100 kHz to 1 MHz
- Programmable V_{IN} UVLO with hysteresis
- C/10 indication for battery chargers
- Low shutdown current: <1 A
- Thermally enhanced 16-lead MSOP package

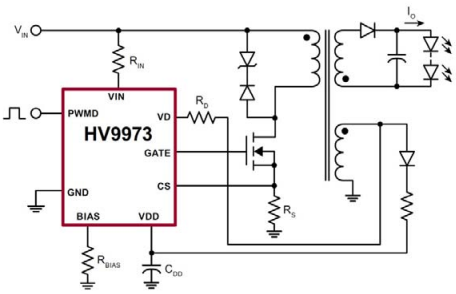
The LT3761 uses an external N-channel MOSFET and can drive up to fifteen 1 A white LEDs from a nominal 12 V input, delivering in excess of 50 watts. It incorporates a high-side current sense, enabling its use in boost mode, buck mode, buck-boost mode or SEPIC topologies. The LT3761 can deliver efficiencies of over 94% in the boost topology, eliminating the need for external heat sinking. A frequency adjust pin permits the user to program the frequency between 100 kHz and 1 MHz, optimizing efficiency while minimizing external component size and cost. Combined with a thermally enhanced MSOP-16 package, the LT3761 offers a very compact high power LED driver solution.

The LT3761 has an internal PWM generator that delivers dimming ratios as high as 50:1 or it can utilize an external PWM signal, delivering dimming ratios of up to 3,000:1. For less demanding dimming requirements, the CTRL pin can be used to offer a 10:1 analog dimming range. Its fixed frequency, current-mode architecture offers stable operation over a wide range of supply and output voltages. Output short-circuit protection and open LED protection enhance system reliability. The LT3761's ground-referenced voltage FB pin serves as the input for several LED protection features and also makes it possible for the converter to operate as a constant-voltage source for charging applications.

The LT3761EMSE is available in a thermally enhanced MSOP-16 package. Pricing starts at $3.45 each. An extended temperature version, or I grade, the LT3761IMSE, is also available, priced starting at $3.86 each. Finally a high temperature or H grade option, the LT3761HMSE is also available, starting at $4.11 each. All pricing is based on 1,000-piece quantities and all versions are available from stock. ■

Supertex's New Isolated LED Driver HV9973

Supertex, a recognized leader in high voltage analog and mixed signal integrated circuits (ICs), introduced HV9973—a patented, isolated, constant current LED driver for use in high voltage solid-state lighting applications such as incandescent bulb retrofits. The IC achieves +/-3% current accuracy through patented primary side current sensing and has internal over voltage and short circuit protection. This sensing approach eliminates the need for secondary sensing components, thus reducing component count, circuit size and cost. The patented control technique also makes the output current setting insensitive to most component tolerances and parasitic without the need of an opto-coupler feedback.



Typical application schematics of the HV9973 that controls an isolated, flyback topology which meets UL requirements for galvanic isolation and operates from 280-400 VDC

Features:

- Programmable true constant current operation
- ±3% LED current accuracy
- Adaptive to external component tolerances and parasitics
- Primary-side current sensing
- Output open circuit protection
- Output short circuit protection
- Input under voltage lockout
- PWM dimming / enable
- 280-400 VDC input

Applications:

- Lighting fixtures with 6-50W power range

"HV9973 utilizes a patented primary-side output control technique that maintains 3% control of the LED current setting and features tight line and load regulation," states Alex Mednik, Director of Applications Engineering for Supertex. "The IC also offers a logic input for dimming LED light output by low frequency pulse-width modulation of the output current."

HV9973 is available in a RoHS compliant 8-lead SOIC package (HV9973LG-G). Samples are available from stock. Lead-time for production quantities is 4-6 weeks ARO. Pricing is US$1.62 each for HV9973LG-G in 1K quantities. ■

ON Semiconductor Expands Constant Current Regulator Offering

ON Semiconductor, a premier supplier of high performance silicon solutions for energy efficient electronics, has introduced the new NSIC20xx series of linear Constant Current Regulators (CCR) designed for use in solid state lighting systems.

Fully integrated, feature-packed devices offer easy-to-use, high reliability, cost-effective alternative to discrete component approach in demanding AC off-line lighting applications

The new NSIC20XX series of CCRs offer a maximum voltage rating of 120 V, 3 W and are capable of withstanding the high peak voltages of alternating current (AC) off-line HBLED lighting applications, including digital signage systems, lighting panels and decorative illumination. These new CCRs protect against the sudden surges that are commonplace in such lighting applications. Based on self-biased transistor (SBT) technology, the NSIC20XX series of devices are capable of current regulation over a very wide voltage range; while their negative temperature coefficient helps to protect the LEDs from thermal runaway at extreme voltage and current levels.

"As the demand for solid state lighting continues to grow, design engineers must be confident that the LEDs utilized are not in danger of being damaged by extreme temperatures or excessive current and that the long-term operation of the lighting system is assured," said Dan Huettl, general manager and senior director of ON Semiconductor's Small Signal products. "Featuring voltage surge suppression and negative temperature coefficient, the higher breakdown voltage capable, NSIC20XX series of CCRs provide the protection mechanisms needed to support the most demanding lighting application environments."

The NSIC20XX series of CCRs provide a far simpler, more reliable and more cost-effective option of regulating the current of LEDs than conventional circuit design methodologies that rely on discrete and passive components. Because these devices do not require the specification of any external components, they can serve as either high or low side regulators, thus offering a streamlined solution that makes the development process more straight forward and maximizes design flexibility.

PI's LYTSwitch LED-Driver ICs for Improved Performance

Power Integrations, a leader in high-efficiency, high-reliability LED driver ICs, introduced its latest family of LED-driver ICs, aimed at consumer, commercial and industrial lighting applications. The new LYTSwitch™ IC family delivers tight regulation and high efficiency for tube replacements and high-bay lighting, while providing exceptional performance in TRIAC-dimmable bulb applications.

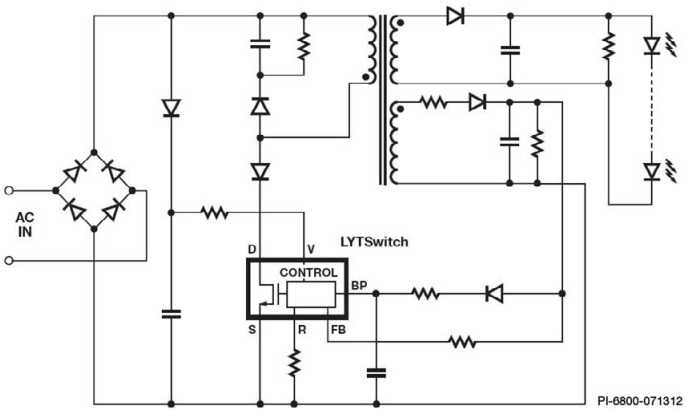
Product Highlights:

- Better than ±5% CC regulation
- TRIAC dimmable to less than 5% output
- Fast start-up
  - <250 ms at full brightness
  - <1s at 10% brightness
- High power factor >0.9
- Easily meets EN61000-3-2
  - Less than 10% THD in optimized designs
- Up to 92% efficient
- 132 kHz switching frequency for small magnetics

LYTSwitch ICs combine PFC and CC into a single switching stage, increasing driver efficiency to more than 90% in typical applications, delivering a power factor greater than 0.95 and easily meeting EN61000-3-2C requirements for total harmonic distortion (THD). Optimized designs deliver less than 10% THD. The combined single-stage converter topology also eliminates high-voltage electrolytic bulk capacitors, leading to greatly extended driver lifetimes even in high ambient temperatures. Accurate primary-side control yields true tight CC performance with better than +/- 5 percent regulation across load, a wide temperature range and production variation enabling tighter design margins and reduced system cost. High switching frequency of 132 kHz means that small, low-cost magnetics can be used in space-constrained bulb applications, while frequency jittering ensures reduced EMI filter requirements. LYTSwitch devices also offer all the usual safety features common to Power Integrations products, including overvoltage, overcurrent and over-temperature protection.

The LYTSwitch family of LED-driver ICs enables excellent dimming performance when used with leading-edge and trailing-edge TRIAC dimmers, even at low conduction angles, easily complying with NEMA SSL6. Start-up is very fast, typically less than 500 ms, even when dimmed to less than 10% output. Bulbs using LYTSwitch ICs will turn on at almost the same dimming angle as it was at turn-off, virtually eliminating pop-on. Dead band in TRIAC dimming is also eliminated as the LYTSwitch controller ensures that dimming occurs as soon as the dimmer is operated.

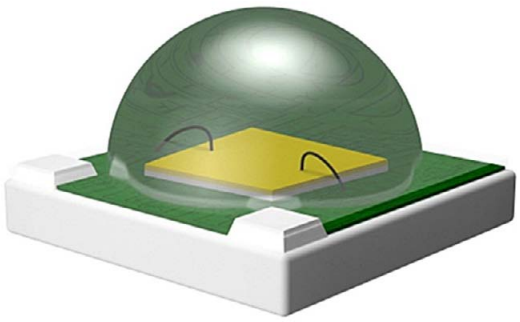
Andrew Smith, senior product marketing manager for Power Integrations commented: "LYTSwitch ICs enable small, longer-lasting lamps for a wide range of applications including consumer bulbs, commercial lighting and T8 tubes, industrial, high-bay and exterior lighting. Tight CC performance across a wide range of operating conditions greatly simplifies design and reduces cost while ensuring that lamps deliver uniform light output."



Simplified schematic for a LED driver solution using Power Integrations' new LYTSwitch ICs

New Dow Corning Optical Encapsulants

Dow Corning, a global leader in silicones, silicon-based technology and innovation, further expanded its industry-leading portfolio of phenyl silicone optical encapsulants with five new two-part, heat-curable grades. The new products offer enhanced reliability, better anti-silver corrosion and greater durability for demanding light-emitting diode (LED) designs. They also further underscore Dow Corning's commitment to driving best-in-class improvements in the performance and reliability of solid-state lighting.



Dow Corning's new high-purity optical encapsulant silicone grades are suitable for conventional dispensing and over-molding processes

Delivering improved anti-silver corrosion capabilities, Dow Corning® OE-6662 and OE-6652 optical encapsulants offer Shore D 64 and Shore D 59 levels of hardness, respectively. The improved gas barrier performance exhibited by both grades helps to protect delicate silver-plated LED electrodes from sulfur attacks. In addition to inhibiting degradation of light output efficiency, this can also help extend the overall quality and lifetime of advanced LED designs.

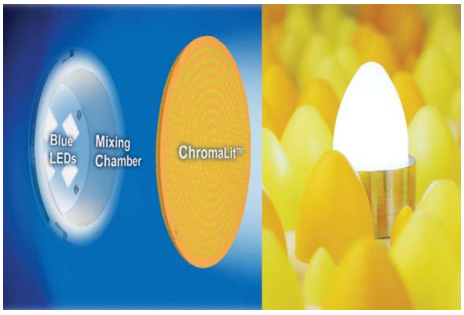
New grades of Dow Corning® OE-7620, OE-7630, OE-7640 optical encapsulants provide hardness ranges from Shore D 26, 29 and 43, respectively. The lower hardness of these materials translates into enhanced mechanical protection for emerging LED packaging designs. In addition, all three new grades in this advanced product family offer greatly improved thermal and photostability over incumbent materials, to ensure consistent high optical quality over the lifetime of an LED light source.

"As next-generation LED designs and applications grow ever more demanding, global lighting OEMs are seeking innovative new material solutions that can withstand the higher internal temperatures of new LEDs, as well as their increasingly harsh operating conditions," said Kaz Maruyama, global industry director, Dow Corning Lighting Solutions. "The latest additions to Dow Corning's broad portfolio of optical silicone encapsulants for LEDs deliver the performance and protection necessary to enable advanced lighting designs that provide reliable, high-quality illumination over the course of their expected lifetimes."

All of Dow Corning's new high-purity optical encapsulant silicone grades are available globally, and are suitable for conventional dispensing and over-molding processes. ■

Intematix Enhances Remote Phosphor Performance by 10%

Intematix, a leading innovator of patented phosphors and phosphor components for high-quality LED lighting, announced performance improvements in its ChromaLit™ Ellipse, Candle and Dome remote phosphor products. The enhancements reflect Intematix's continuous advancements in remote phosphor technology resulting in an average ten percent increase in light output and reduced system cost for lighting system manufacturers.



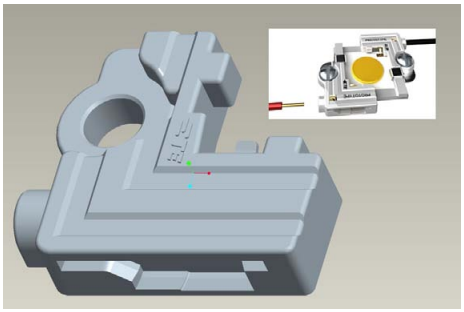
ChromaLit Ellipse, Candle and Dome products offer glare-free, omni-directional light distribution now with 10% increased efficacy

"Higher lumens-per-watt means fewer LEDs and smaller heat-sinks in our customers' products," said Herb Schlegel, Senior Director of Product Marketing at Intematix. "While lowering costs, our ChromaLit Candle and Dome products also improve light quality and uniformity in applications like light bulbs, pendants and sconces."

Intematix remote phosphors convert light from blue LEDs into white light with up to 30 percent higher efficacy than conventional white LEDs. ChromaLit products deliver up to 225 lumens per blue radiant watt while enabling very high light quality including low glare, CRI above 95 and color consistency within 2 SDCM. ■

New Solderless LED Array Holder Platform from TE Connectivity

TE Connectivity (TE), a global technology leader, has announced the release of an innovative and scalable, solderless LED array holder platform that enables connectivity to a wide range of LED arrays from industry leaders.



TE's holder eliminates soldering challenges and allows the direct attachment of LEDs to a heat sink

The TE solderless LED holder is a small, low profile, flexible LED holder that provides a quick and easy solderless connection to chip on board (COB) array LEDs. This low cost, straight forward design provides dependable power connection, mechanical attachment and reliable thermal hold down force necessary for the LED array.

TE's holder eliminates soldering challenges and allows the direct attachment of LEDs to a heat sink using standard screws, making designs more reliable, easier to user, and faster to market. They are quick and simple to install, greatly decreasing installation time while increasing reliability and quality control.

"With the growing demand and options for COB LEDs, TE is committed to expanding our holder solutions to enable customers with smarter, better, and faster products for their specific choice of LED. The scalable platform is designed with the future in mind, utilizing a scalable, flexible platform to enable fast adoption of todays and tomorrows leading LED arrays," said Bart Broeren, Global Product Manager, TE Intelligent Buildings.

In addition to their ease of use, TE's holders are robustly engineered, reliable and feature rich. Until today, TE has launched holders for 24 different LED families, including two piece corner connectors for ultimate flexibility and one piece preassembled units configured to each LED package size dramatically simplifying assembly.

The optional metal thermal spring enhances pressure on heat sink for a variety of thermal interface materials without damage to ceramic substrates while the housing design minimizes obstructed light output from LED. TE uses white lighting grade materials with high reflectivity properties and rounded corners to minimize shadowing. An optical keep out zone provides a clear landing area for secondary optics. ■

TESS Reveals New 12 W 1200 lm Omni-Directional LED Bulb

Taiwan LED leading brand TESS revealed a new product – a 12 W 1200 lumens omni-directional LED Bulb. This remarkable product not only breaks through the current technology barrier but also reflects the demands of the lighting market. TESS proves its research and development ability in LED solutions again.

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The new TESS 12 W 1200 lm LED bulb can replace traditional 75W Incandescent bulbs

Model	12 W non dimmable AC LED Bulb	
Voltage Range	AC 100-240 V	
Frequency Range	50 Hz / 60 Hz	
Power Consumption	12 W	
Color	Cool White	Warm White
CCT	5500 K	3000 K
Luminous Flux	1200 lm	1200 lm
Beam Angle	300°	

The TESS R&D team keep challenging the technology barrier in order to provide innovative LED products and bring new concepts for energy saving to the next generation. This new omni-directional LED Bulb (12 W CW-1200lm / 12W WW-1200lm) breaks through the specs of current LED products in the lighting market. TESS unleashes the creative design and urges new technology to be utilized in LED products.

TESS's new 12 W 1200 lm LED Bulb not only leads the lighting market but also satisfies the demand of end customers. It could replace the traditional 75 W Incandescent Bulb, reducing electricity pollution and bringing a green environment to the next generation. Besides this, TESS also subverts the stereotype of the light bulb. The streamline shape and unique design make the TESS Bulb not only functional, but it also fits the home deco design. ■

'The Quintessence' of LED Technology

EBV Elektronik Presents the eleventh Edition of the Knowledge Magazine 'The Quintessence'

Highlights amongst others are:

- In conversation with Moritz Waldemeyer: Lighting design between art and technology
- Boundless possibilities: The many advantages of LEDs
- Decorative highlights for cars: New freedom in design
- Light for Africa's roads: Durban making 30 percent energy saving with LED street lamps
- Round-table discussion: Setting the course for the future

Interested?
You can order your own personal hard copy or an eco-friendly eBrochure of 'The Quintessence' at **www.ebv.com/tq**.

Interested in more product highlights and market updates from EBV Elektronik? Subscribe for our newsletter at **www.ebv.com/newsletter**.

'The Quintessence' knowledge magazine is now also available as an iPad app!

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ITRI Unveils Light&Light™ A19 All-Plastic LED Light Bulb Technology

Light&Light™ is the first A19 all-plastic LED light bulb technology with an illumination angle of 330°. It is break-resistant and weighs less than 100 grams, half of the competing LED light bulb. It uses less than 10 watts to produce the same light as other 60-watt incandescent light bulbs. Its price is 10-20 percent the cost of competing LED light bulbs. Light&Light™ can save 85% on light bulb power consumption.

ITRI's Light&Light™ uses less than 10 W providing over 800 lm at a price of about 10-20% of competing LED retrofit lamps

ITRI's mission with the Light&Light™ electricity-sipping A19 LED bulb lighting technology is to cut carbon emissions in production and lighting energy consumption. The target was to develop a technology that manufactures quality LED bulbs, that is inexpensive enough to compete not only for market share, but also to encourage voluntary LED bulb use prior to the Energy Independence and Security Act law. The law mandates elimination of incandescent bulbs by 2014.

To develop a quality A19 LED light bulb that costs less to manufacture yet delivers good performance, ITRI decided to increase the overall surface area of the LED chips combined in the bulb structure. Instead of the conventional approach of using a dozen or so "standard" LED chips, ITRI uses multiple chips over a larger portion of the bulb to generate the targeted total lighting capacity (lumens).

To create the first 820-lumen Light&Light™ prototype/demonstrator LED light bulb, ITRI constructed smaller LED chips, each rated at 0.06 watts, with a tiny dimension of 3.0 x 1.4 x 0.8 mm. The rationale behind the principle of smaller but more numerous LED chips is to expose the 160 chips to the largest-possible surface area of a bulb for open air convection cooling. Regardless of size, LED chips are normally made into a rectangular shape with one of the six surfaces soldered to the circuit board. ITRI has designed the light bulb so the chips physically secure to the plastic bulb structure, this way a portion of the heat generated as the chip lights up is transferred and dissipated. The bulb features excellent heat dissipation through ITRI's heat synch technology, which provides convection airflow for a cooler bulb, operating at 80°C.

The larger number of small chips in a 16-hand starfish-shaped configuration actually cost significantly less to produce than its counterpart of about a dozen larger chips – a cost reduction of some 55% percent. ITRI's plastic heat-sink replaces its aluminum counterpart and since the heat-sink is part of the physical structural part of the bulb, it can double as the main bulb body. The body/heat-sink dual-role plastic structure makes the bulb much lighter than a conventional bulb with a metallic heat-sink. More importantly, by adopting plastic instead of aluminum, the carbon reduction attributable to this material replacement is almost 70% – one more step toward green lighting.

"Light&Light™ is a 'purse-friendly' light bulb for the mainstream, and will help boost the adoption of LED bulbs prior to the ban on incandescent lighting to be in full effect in 2014," said Mu-Tao Chu, division director, Electronics and Optoelectronics Research Laboratories, Industrial Technology Research Institute (ITRI). "By using Light&Light™, carbon emissions can be reduced by 62 grains and the plastic body/heat-sink dual-role plastic structure provides higher carbon reduction because the used materials are recyclable." ■

Dialight's New 25,000 Lumen DuroSite® with 10 Year Warranty

The innovative global leader in LED lighting technology announced the immediate availability of its new 25,000 lumen DuroSite® LED High Bay to meet the high light output requirements of industrial applications. With its ultra-efficient 100 lumens per Watt efficacy, the new 250 W LED High Bay can dramatically reduce energy consumption and maintenance cost as a direct replacement for conventional HID and fluorescent fixtures.

Like all of Dialight's long life LED luminaires, the 25,000 lm DuroSite® High Bay luminaire is designed to meet the most demanding specification criteria

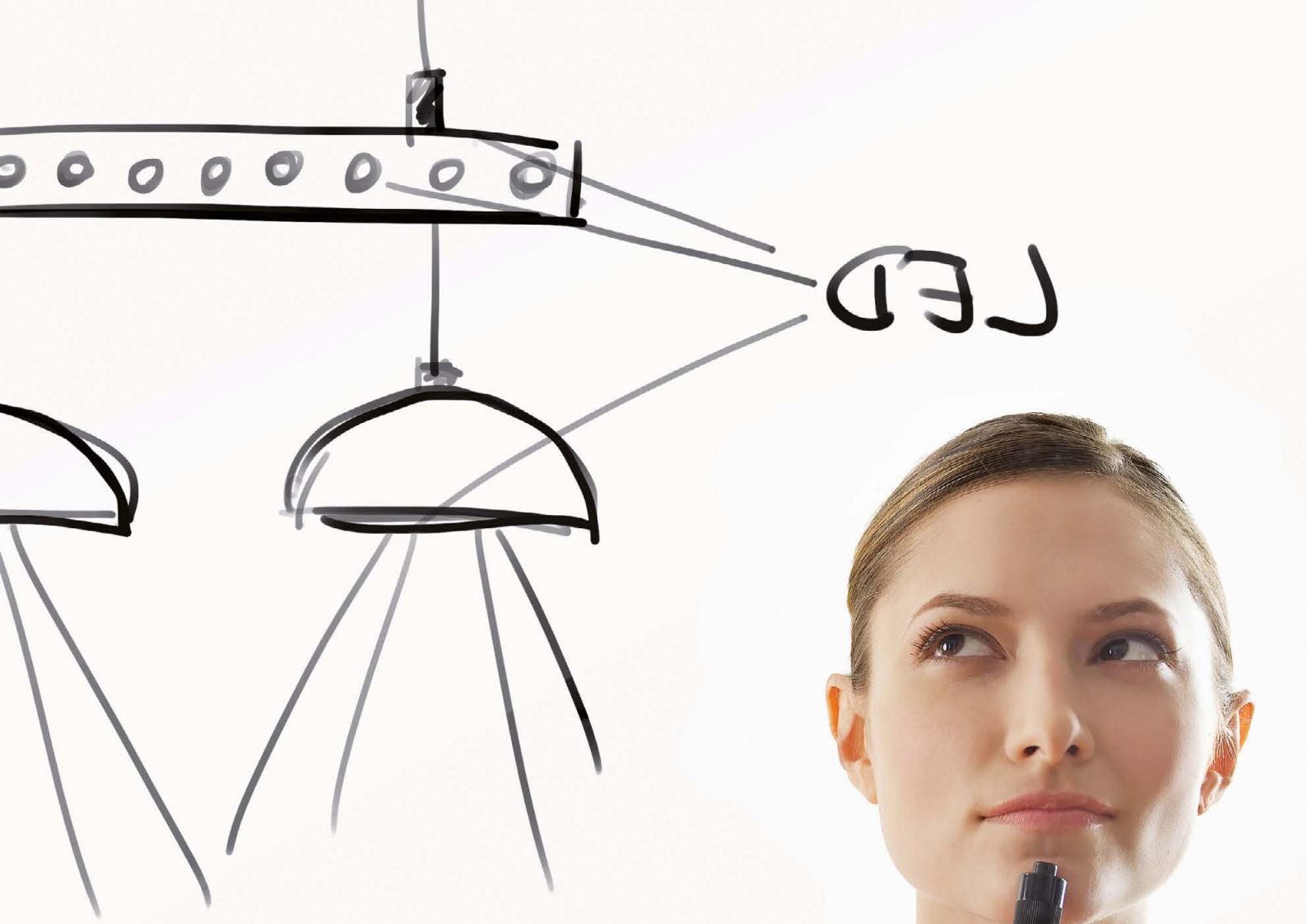
Features & Benefits:

- L70 rated for >100,000 hours @ 25°C ambient
- 10 year full performance warranty
- Instant on/off operation
- Universal power supply
- Superior color rendition index compared to HPS, LPS, MV
- Mercury free
- Resistant to shock and vibration
- Temperature compensation technology for longer life
- Factory sealed

"This latest achievement in our growing LED industrial lighting product portfolio gives our customers a broad selection of energy efficient products to meet virtually any industrial lighting requirement with a high-efficiency, high-performance, worry-free solution," said Roy Burton, Dialight's Group Chief Executive. "Backed by our comprehensive 10-year full performance warranty, our High Bay line continues to be one of the most widely installed LED fixtures on the market."

Designed from the ground up with a custom power supply to optimize both LED and fixture life, the new 25 K lumen High Bay utilizes the latest high brightness LEDs paired with Dialight's exclusive reflector-based optical design and toughened glass lens to deliver optimum illumination right where it's needed, reducing light spillage on the walls and other areas. The 25,000 lumen high bay is IP66 rated for use in outdoor and wash down locations and is rated for operating temperatures ranging from -40° to +65° C. The fixture also features 6 kV line to ground surge protection.

The 25K lumen High Bay is the latest addition to Dialight's world-class LED product portfolio that now spans 4,000 to 25,000 lumens in both High Bay and Low Bay models to suit a range of mounting heights. ■



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dilitronics Presents New Versatile and DALI-Compatible LED Driver driveDOT4

dilitronics, the high-tech company from Jena, now offers a DALIcompatible 4-channel LED driver. Thanks to the controLED technology developed by dilitronics, the driver module allows energy-saving controlling and dimming of four individual LED channels with a total output of 126 watts.

driveDOT4 is a DALI LED driver and allows up to four LED channels with a total performance of up to 126 W to be individually driven

Additional Information:	
URL Key:	drivedot4
Operation mode:	controLED
LED channels:	4
LED voltage:	6...45 VDC
LED current:	0.35 A...0.7 A (per channel)
Power per LED channel:	31.5 W (max.)
Power supply:	10...48 VDC
Operating temperature:	0...40°C
Interface:	DALI
Dimming:	1...100 % (linear logarithmic)
IP-Protection:	40
Dimension:	210 mm x 30 mm x 28 mm
Weight:	70 g

The versatile LED driver driveDOT4 is part of the new driver generation developed by dilitronics. This in-house development allows operation of LED modules with two different forward voltages. This is made possible by the automatic voltage control. As a constant-current driver, the driveDOT4 is able to dim from one to 100% without changing the color point. Four LED channels with a total output of 126 watts can be controlled with the compact LED driver. Thanks to the DALI interface, the driveDOT4 can be quickly integrated into existing illumination and building management systems and creates a pleasant atmosphere, for example in bars, hotels and restaurants.

With the installation of the new 4-channel LED driver driveDOT4, manufacturers of indoor and outdoor lamps also profit from economic retrofitting of multiflame LED lamps to dimmable DALI lamps. “Our driveDOT4 sets new standards in energy efficiency and flexibility of DALI-compatible LED drivers. Each of the four channels of the driveDOT4 corresponds to a DALI device which can be controlled and dimmed independently of the others. This enables professional and comfortable light management,” explains Stephan Schulz, CEO of dilitronics GmbH.

With the driveDOT4, dilitronics offers lamp manufacturers an LED driver that can be easily controlled via DALI. Apart from this, the driver also offers installers and architects new options of light design, both indoors and outdoors. The DALI compatibility, the individual control of the four channels as well as the possibility to use LED modules with different forward voltages make the driveDOT4 a versatile driver module. ■

LBT Begins Shipping UL-certified Ultra-Compatible Deep Dimming LED Drivers

Light-Based Technologies (LBT), a leading developer of intelligent power and control electronics for solid state lighting (SSL), has begun shipping UL recognized UC LED Drivers to specification grade lighting fixture manufacturers across North America. LBT continues to develop and deliver innovative solutions in order to overcome the significant barriers to adoption facing LED lighting. This first product demonstrates LBT’s approach to dealing with TRIAC dimming, delivering superior performance both in dimming quality and compatibility with the widest range of TRIAC dimmers.

LBT’s LED drivers offer the best dimming & compatibility for TRIAC dimmers through proprietary firmware platform

The UC LED Driver, specified at 25W, with a selectable 700 mA or 1000 mA constant current output, delivers unsurpassed deep dimming quality and dimmer compatibility, without the flicker and pops associated with other solutions.

“Scalable and versatile power and control solutions are the key enabler for Solid-State Lighting adoption,” said Art Aylesworth, CEO at LBT. “As LED technology continues to evolve, LBT is providing our customers and industry partners with flexible solutions that meet their market demands today and into the future. The UC LED driver is based on our proprietary firmware platform and showcases our superior TRIAC dimming performance. Our firmware based approach enables faster and more cost effective delivery of the many benefits of Solid-State Lighting.” ■

Next Generation LED Drivers from Thomas Research Products

Thomas Research Products has introduced the next generation of LED Drivers, a new premium driver line with a smaller case format. Thomas Research Products is a leading manufacturer of SSL power solutions.

Thomas Research Products’ new PLED Series LED drivers are remarkably smaller than the models they replace

The PLED Series 75W is 25% smaller while the PLED 96W is 33% smaller than the models they replace. Plus they use a common case design--the only difference is the length of the housing extrusion, making them attractive for use in a wider range of fixtures. Functionally, these designs offer the same or higher performance than the models they replace. Constant-current (with fixed or dimming output) and constant-voltage models are available. Also coming soon will be 120 W, 150 W and 200 W models.

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- 120W High Bay II (AL) up to 7,600lm
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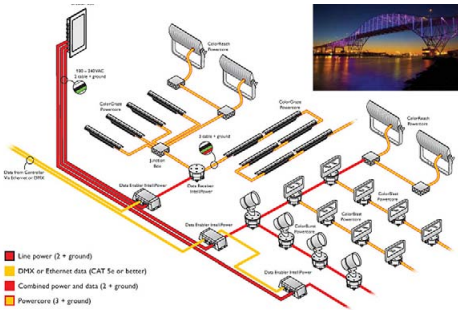
TRP's premium drivers continue to offer the features for which the company is known. They feature 100-277 V universal input voltage. The aluminum housings are IP67 rated - making them suitable for outdoor wet location applications. To keep luminaires performing, they offer over-voltage, over-current and short circuit protection with automatic recovery. All LED Drivers from TRP offer high quality, long life, high efficiency and are cost-competitive. The drivers are UL Recognized for both US and Canada, and are CE certified. ■

Philips Launches the IntelliPower Dynamic LED Lighting Solution

Philips Color Kinetics announced IntelliPower, its newest innovation for delivering high-bandwidth LED lighting control using existing electrical and physical infrastructures. IntelliPower makes it easy to deploy intelligent, digitally controllable LED lighting solutions in any situation where re-wiring is not desirable or feasible, including historic buildings, in-ground systems, bridges, and monumental exteriors. With IntelliPower, Philips Color Kinetics is building on its expertise and leadership in LED lighting to deliver the benefits of a state-of-the-art LED lighting system without requiring expensive or disruptive rewiring, renovation, or excavation work.



Installation example of an IntelliPower dynamic LED lighting solution

Philips recently debuted IntelliPower to re-light the towers on Boston's iconic Leonard P. Zakim Bunker Hill Memorial Bridge with intelligent, color-changing LED lighting fixtures from Philips Color Kinetics. With just the push of a button, the Massachusetts Department of Transportation can change the colors and intensity of the lights as well as display dynamic, color-changing light shows, while at the same time reducing energy consumption by more than 80% over the previously installed conventional lighting system. In addition, because IntelliPower uses the wiring and fixture mounting points already on the bridge, the Massachusets Department of Transportation also saved money on the installation.

"Since construction, this bridge has served as a symbol for the Commonwealth," said Richard A. Davey, Massachusetts Department of Transportation (MassDOT) Secretary & CEO. "With this relighting made possible by Philips LED technology, we renew our belief that a bridge can be more than a symbol. It can help build community. This new color technology will allow us to promote, engage and inform our community."

IntelliPower is ideal for all installations, small to large, where re-wiring may be difficult or cost-prohibitive. Unlike other LED solutions which use low-bandwidth data transmission for switching and dimming a limited number of fixtures, IntelliPower employs high bandwidth, bi-directional, Ethernetspeed data transmission for a robust solution that enables the full range of dynamic, color-changing effects. IntelliPower affords new ways to transform structures and spaces in cities and communities by lowering overall installation and maintenance costs while bringing the deployment of intelligent, digitally-controlled LED lighting systems in line with budgetary constraints. ■

KLA-Tencor Launches ICOS® WI-2280 Wafer Inspector for LEDs

KLA-Tencor Corporation announced its next-generation light-emitting diode (LED) patterned wafer inspection tool, the ICOS WI-2280. Designed specifically for defect inspection and 2D metrology for LED applications, the ICOS WI-2280 also provides enhanced inspection capabilities and increased flexibility for micro-electromechanical systems (MEMS) and semiconductor wafers spanning two inches to eight inches in size.

The ICOS WI-2280 represents KLA-Tencor's fourth generation LED wafer inspection system that is built on its market-leading WI-22xx platform, delivering sensitivity with increased throughput for reduced cost of ownership. Additionally, the tool supports handling of whole wafers in carriers and diced

The ICOS WI-2280 represents KLA-Tencor's fourth generation LED wafer inspection system that is built on its market-leading WI-22xx platform

wafers in hoop ring or film frame carriers to accommodate multiple media with minimal equipment changeover time. The WI-2280 also features an enhanced rule-based binning defect classification and recipe qualification engine, enabling manufacturers to achieve faster yield learning during production ramps, as well as improve process control and process tool monitoring strategies in their manufacturing process.

"Increasingly, LED manufacturers are demanding improved detection and classification of yield relevant defects of interest, which enables them to take faster corrective actions to improve their yields at higher inspection throughput. There is also a growing need to boost productivity by enabling faster production recipe creation," said Jeff Donnelly, group vice president, Growth and Emerging Markets (GEM) at KLA-Tencor. "The ICOS WI-2280 addresses critical market requirements — ultimately enabling LED manufacturers to achieve better lumens per watt and lumens per dollar performance. We remain committed to advancing our industry-leading ICOS product line to meet the LED community's emerging needs."

In addition to LED application environments, MEMS, semiconductor, compound semiconductor and power device markets can leverage the ICOS WI-2280 tool for back-end-of-line and post-dicing outgoing quality control or binning; front-end-of-line patterned wafer inspection for baseline yield improvement, rework, excursion control or overlay; and 2D surface inspection and metrology. As part of KLA-Tencor's LED portfolio, the ICOS WI-2280 works in conjunction with KLA-Tencor's Candela® LED un-patterned wafer inspection system and Klarity® LED automated analysis and defect data management system, leveraging over 35 years of expertise to provide manufacturers comprehensive, end-to-end inspection coverage. ■

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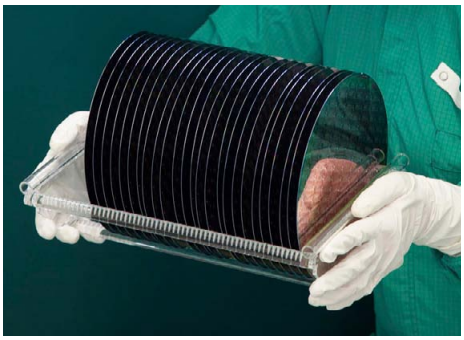
Copper, Gold and Tin for Efficient LED Chips

With gold, copper or tin and special galvanizing processes, scientists are improving the function of semi-conductors and making the manufacture of microelectronic systems, child's play. The LED industry, in particular, could profit from this.



Post processing of LED wafers with a special galvanizing process to deposit copper or compounds such as copper-tin or gold-tin allows the smallest housing while increasing the possible current flow (© Fraunhofer IMS)

They are particularly small, durable and economical. Unlike the traditional halogen or xenon lights, light emitting diodes need LED drivers. Their most important task: they must continuously supply the light diodes with power. In addition, they are to carry out complex tasks and to control, for example, several LEDs in series, or switch individual ones on in multiple stages if the interior lighting is to be dimmable.

The requirements relating to the drivers are enormous: they must be immune to the high temperature and voltage differences in a car or be resistant to aggressive chemicals. In order to guarantee reliable luminosity, a higher voltage must flow through the circuits of the LED drivers. Researchers from the Fraunhofer Institute for Microelectronic Circuits and Systems IMS offer manufacturers a process to manufacture the chips that suit these applications: it is based on galvanization, a process in the semiconductor industry, in which special metals are deposited on the semiconductors.

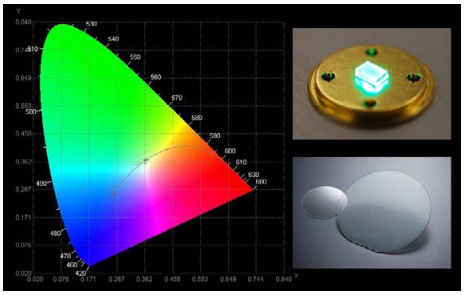
However, Prof. Holger Vogt's department at the IMS, is backing copper, in particular. "This way, we can have more current flow through the chips", explains Vogt. That is important, because for most applications the chips must become smaller and smaller – the current that flows through them, however, stays the same. However, integrating new materials, such as a layer of copper, is not always without problems, since there are limits to the regular processes for manufacturing chips. It is for this reason that the scientists at the IMS specifically constructed a manufacturing line for "post processing" – the MST Lab & Fab – to be able to subsequently improve the chips on the substrate wafers, depending on the requirements of the application.

In addition to copper, the engineers are also able to deposit other metals or compounds such as copper-tin or gold-tin onto the chips. "These layers can be soldered", explains Vogt. That offers a substantial advantage: the cover can be soldered onto the chip, right there on the wafer. "The result is the smallest housing for a chip that can be had", says Vogt.

In addition, the researchers in the MST Lab & Fab have been able to construct complex components within a single housing. They are able to solder two chips, such as an opto-chip with highly sensitive photo sensors with a CMOS-Chip (Complementary Metal Oxide Semiconductor) which can measure individual photons, to each other, using the copper galvanization process. Such microelectronic components are suitable for night-vision devices or for low-light microscope applications.

Development of GaN-Wafers Nearly Doubling Green LED Luminous Efficiency

The GaN wafers developed by NGK feature low defect density across the entire 2-inch diameter of the wafer surface and have a colorless transparency. NGK achieved this through proprietary improvements to liquid phase epitaxial technology for single crystal growth.



Up until today, the green spectrum has been the weak point of LEDs. Efficiency is far lower for the huge spectral range of about 500 to 570 nm then it is for other colors. NGKs approach promises nearly twice the efficiency then ever before

In joint research carried out with Nagoya University, green LED chips formed on the NGK GaN wafers showed a 60% internal quantum efficiency (injection current density of approximately 200 A/cm^2). This figure is roughly double that of the green LED chips currently on the market.

In previous LED chips using sapphire wafers as substrates, defects of the light emission layer were common, especially for green LEDs. These defects prevented a large operation current, which in turn prevented the LEDs from achieving sufficient brightness. This issue can be addressed by the use of the low-defect GaN wafers as substrates that enable dramatically improved light emission layer quality. The reduction in current loss that results allows for a large current, making high brightness green LED elements a reality. The result is an improvement in brightness of more than 20 times compared to previous models. Light sources can also be made more compact thanks to the simplified heat dissipation structure made possible by less heat generated from current loss. This control of heat-related degradation also enables longer product life.

The realization of high brightness green LED light sources means that high brightness LED light sources are now available for the primary colors of light (red, green and blue). We can thus expect to see advancements in the development of new applications for LEDs, specifically for use in projectors and other imaging applications.

This emerging potential for green LED applications follows on the heels of an announcement of applications for blue LEDs on April 25, 2012. NGK is now poised to apply its technology to the inverters used in hybrid and electric vehicles, power amplifiers for base stations of wireless communication, and other power devices. To this end, NGK will take steps to further reduce defect density for its GaN wafers, and to produce larger wafers that are greater than 6 inches in diameter.

Sample shipments of 2-inch-diameter wafers are already under way. Plans call for raising production capacity to a monthly output of over 1,000 wafers during fiscal 2012. By 2014, NGK plans to have a wide-ranging lineup of wafers extending from 2- to 6-inch-diameter wafers ready for LED and power device applications. ■

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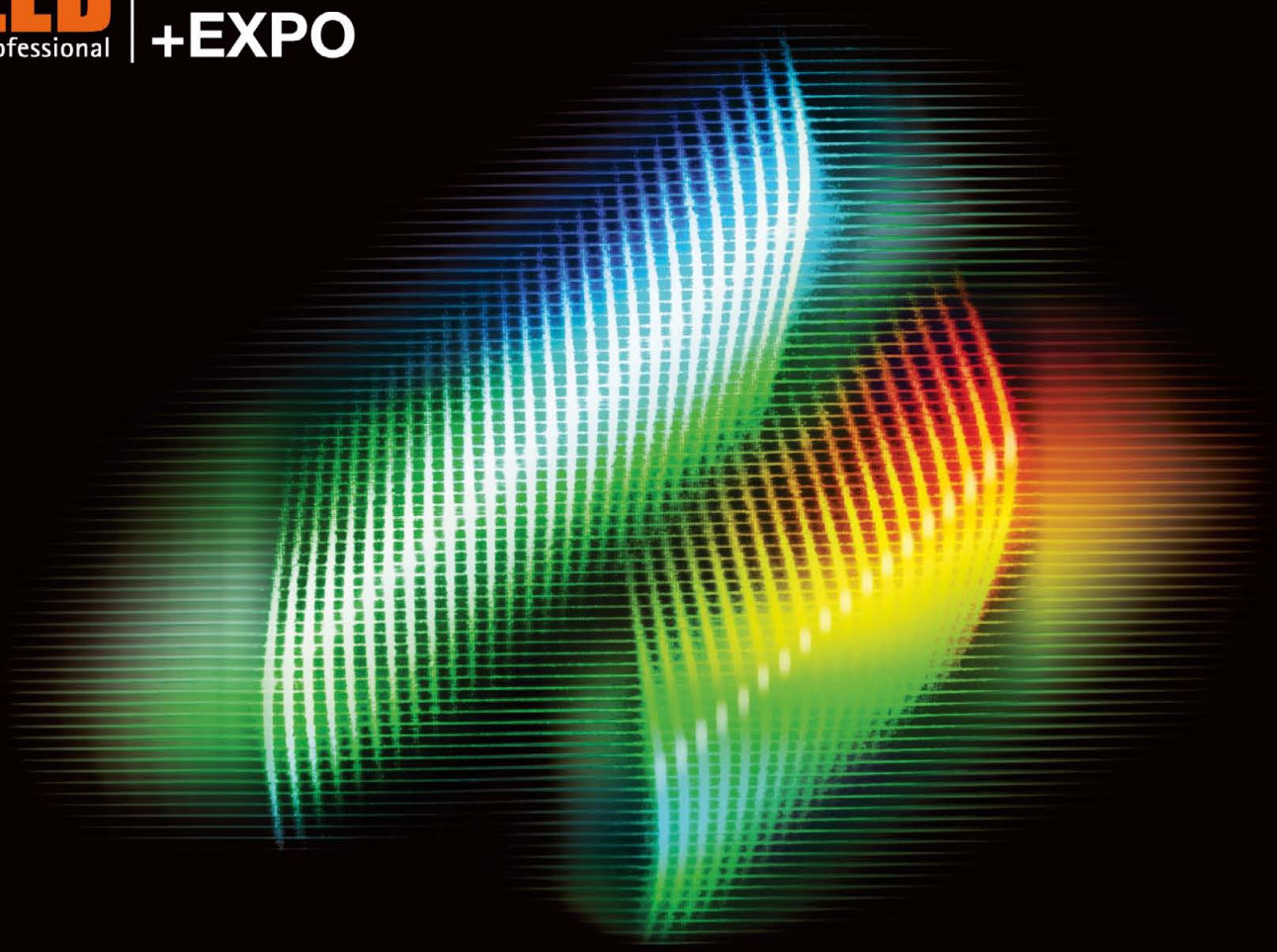

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LED Acceptance in the Global Lighting Market Continues to Grow

Alan Mills visited the Smithers-Apex LED 2012 Conference in San Diego for LED professional and prepared an overview of the lectures and discussions about technologies, applications and trends.

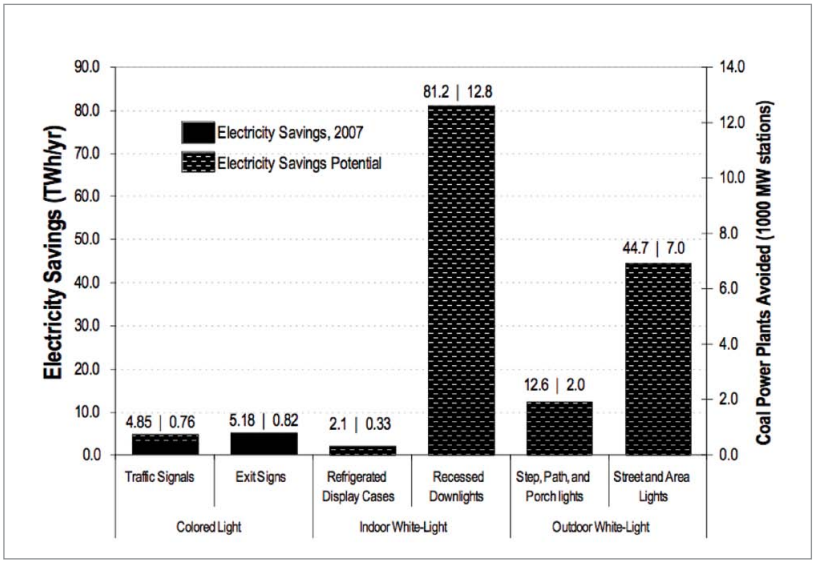


Figure 1: **Example of saved electricity and potential savings of some selected applications**

For more than a decade the white LED has proved its value as a small, very efficient and durable light source and it has dominated the mobile display industry as the preferred light source. Its efficiencies have continued to improve, concurrent with decreasing LED, package and/or back lighting unit (BLU) costs. The technical advances derived from years of BLU application have improved LED performance to where it can now penetrate the general lighting market even though it is a disruptive technology for this application due to voltages, sizes and form factors that did not fit the existing worldwide lighting infrastructure. This is a situation similar to the transistor when it was originally introduced into the field of electronics. Even though other LED markets have developed at more rapid rates, the market acceptance of the LED in general lighting has been slower due to initial stumbles, taking about 15 years to exceed 5% penetration. However, LEDs (in light engines) have recently gained market acceptance in two large market segments, street and area lighting and low and high bay use and they were some of the leading topics discussed at the Smithers-Apex LED 2012 Conference (formerly InterTech-Pira) recently held in San Diego.

Lighting Improvements

Achievements and a forward outlook for LEDs in lighting were highlighted at this meeting by a panel of LED manufacturers that gave an overview of their trends and goals in the industry. Shawn Du from Nichia forcast 184 lumens per watt (lm/W) for commercial LEDs by 2015, with 250 lm/W being a realistic target for phosphor converted LEDs. Luminaire costs should soon decrease significant due to reduced LED costs of $2 per kilolumen. At less than 35 amps per cm^2 power loadings, A-type LED lamp replacements are now easily within the reach of the US Department of Energy road map retail lamp price of $28 per kiilolumen.

Mark McClear from Cree stated that the company goal is to drive down costs with improved technology and at the same time save energy and money whilst delivering 'beautiful light'. He announced that Cree has developed a new generation SC^3 chip using better rather than more epitaxial growth. The new chip is producing light equivalent to today's 2 mm chip from the new 1 mm SC^3 chips. McClear also expects Cree to have 200 lm/W chips available by the end of 2012 using the SC^3 chip technology with new phosphors. He also reported that over 5,000 stores are retrofitting LED display lighting, where even fruit on display lasts longer and the products appear more attractive to the customer without any UV or IR radiation in the display lighting. In refrigerated displays

Table 1:
LED package metrics roadmap from the DoE Manufacturing Roadmap Report 2012

Source: DOE 2012 MYPP Metric	Unit	2011	2012	2013	2015	2020
LED Package Efficacy (warm white)	lm/W	97.0	113 .0	129.0	162.0	224.0
LED Package Price (warm white)	$/klm	12.5	7.9	5.1	2.3	0.7
LED Package Efficacy (cool white)	lm/W	135 .0	150.0	164.0	190.0	235.0
LED Package Price (cool white)	$/klm	9 .0	6.0	4.0	2.0	0.7
OEM Lamp Price	$/klm	33.0	23.0	16.5	10 .0	5.0

the LED L-70 lives are extended well beyond 25,000 hours due to the lower ambient temperatures being able to maintain lower operating junction temperatures.

Joerg Strauss, the Director of SSL Research, at Osram, highlighted the fact that phosphor conversion technology is very versatile and according to the McKinsey & Company Inc., Report, 97% of the present white LED lumens depend on phosphor conversion of near UV and blue LEDs. Similar LEDs are forecast to account for 78% of the general lighting market by 2020. It also appears that this situation will be slow to change, even though the DOE's long term outlook is for combinations of red, green and blue (RGB) LEDs to be the eventual white light source winner. New green, yellow and red phosphors have and are being developed for improved efficiency, narrower band emission, easier manufacturability and stability, less re-absorption, and also with respect to temperature, light, ambient or chemical exposure. The Osram green phosphor converted Golden Dragon LED has achieved a 175 lm/W output compared to 100 lm/W from the direct InGaN LED and it is worth noting that these new green phosphors can be used to fill the 'green gap' in high power LEDs. However, there are no phosphors that fit all uses at this time, thus different phosphors are preferred for different lighting applications.

Some dispersed phosphor combinations have demonstrated laboratory warm white efficiencies of 142 lm/W and quantum efficiencies (QEs) of 98%. The performance of phosphor LEDs continues to improve and Osram reports that in 2011 their Oslon LEDs with a 7.5 degree beam angle produced LED spot lights with a record output of 124,000 candelas and now their 3000 K warm white LEDs are up to 140 lm/W with CRIs of 82 when powered at 350 mA.

The use of ceramic phosphors remote from the LED is now widely used, but with high development costs. Application benefits from the C^2 device range include stable light conversion and better heat management that allows white LED headlamps to produce 1250 lm per amp. And, Ostar headlamp outputs of 1250 lumens per amp have been achieved. Amber LEDs for autos have a high lumen flux at high temperatures and have only a 15% loss in flux over the room temperature to 100°C range. Present outputs are 92 lm/W with test results as high as 109 lm/W at 350 mA. The Ostar 2x2 green phosphor projection chip is another high output LED and can produce 2400 lumens (85-90 lumens per mm^2) when pulsed at six amps. It improves on-screen lumens by about 50-60%. However, efficiencies for precast remote ceramic phosphors are usually lower that the dispersed phosphor by about 20%.

Quantum dots (QDs) or nano-particles are also being used to replace phosphors for wavelength conversion, but they are in the early stages of development. For light modification the particle size of the dots must be in the two to ten nanometer range with the dot size controlling the wavelength of the emitted light. Early QDs were made from cadmium selenide (CdSe), which is toxic and as formed the QDs were not very stable. They require an outer shell protection (often zinc oxide) followed by long chain organic molecule coatings to stop the powders from clumping. Because of these properties, QDs are not easy to manufacture and they are not widely used at this time even though they are efficient RGB visible wavelength producers. Several companies, including Osram, have evaluated them with interesting results, but most are reluctant to promote a toxic base material. Other core materials are being evaluated such as indium phosphide, but their conversion efficiencies are about 20% lower than CdSe.

Cost and Efficiency

Today, improved LED light engine design, including some phosphor lumen efficiencies that exceed 97% light collection, better light distribution and thermal control, allow LED benefits to overcome their disruptive properties and create significant market growth. LEDs are penetrating market segments that benefit from the efficiencies of dimming, instant-on, the inclusion of light and motion sensing, ease of colour change extended life and a continuing reduction in the dollar cost per LED lumen. The lower cost trend is forecast to further decrease the LED package cost by more than 50% between 2012 and 2015, and more than 80% until 2020.

Improving performance, such as the availability of 120+ lumens per watt (lm/W) commercial output LEDs (rising to 250 lm/W in the foreseeable future); allow them to provide very efficient light in ways never before possible. Important benefits include more uniform street lighting, indoor mood lighting and wide range dimming with or without colour changes, occupation detection assisted by photo sensors, illumination for health and/or stimulus and embedded controls. The two largest general lighting market segments at this time are street and area lighting and low and high bay lighting, with street and area lighting being termed 'the best bang for the (LED) buck'. And, agricultural use is a new, rapid growth market segment using the combination of efficient red and blue LED sources for commercial plant growth.

Street Lighting

As mentioned earlier, one of the best examples of LED lighting on a large scale has turned out to be street lighting with Raleigh NC, USA being one of the first examples of large scale installation. This is also where Cree's

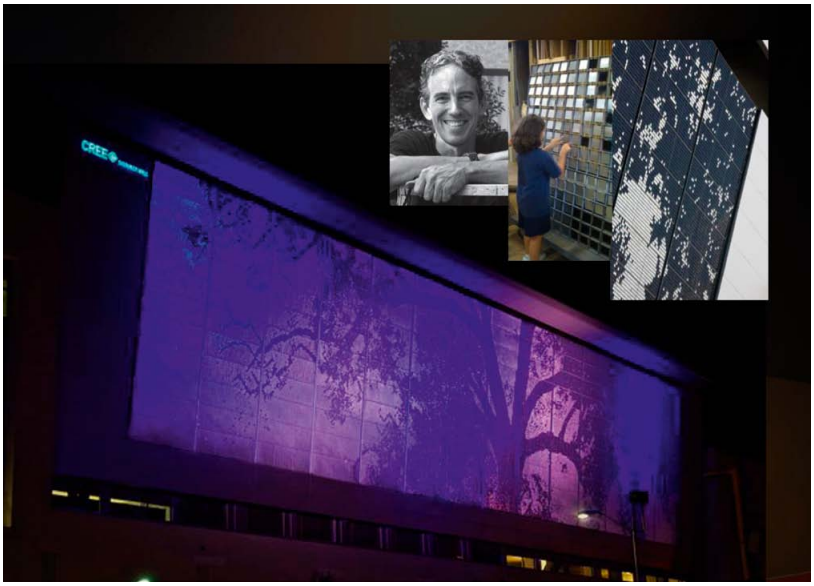


Figure 2:
The Convention Center's "Shimmering Wall" is just one example of the numerous LED lighting applications realized in Cree's hometown of Raleigh

headquarters are located.. The first project planning between Cree and the City started in 2006 with the first LED street units being installed a year later. Unfortunately the early installations were not the most reliable, mostly due to power supply failures. However, the lessons learned here helped later models of street lighting from most manufacturers to become accepted on a worldwide basis. In the case of the City of Raleigh, it has also led to an ongoing cooperation with Cree with over 75 local LED projects and five years of valuable LED experience. Daniel Howe, the Assistant City Manager reported that this cooperative effort has led to the installation of a wide range of LED lighting types, including many street lights, a Shimmering Wall using over 80,000 4-inch LED panels, city office 'can-lights', bridge lighting, and police car use. These projects received wide approval from residents and provided important information about the benefits of municipal LED use. Daniel reported that recent data from Raleigh has shown better energy and maintenance savings than planned, a better lifetime to 70% degradation (at this time it is slower than expected by almost 50%), and that LED security lighting and images are of much higher quality. Most of these benefits contribute to additional cost savings, including the use of LED hazard lights on police cars that can be operated without the need for engine idling. Maintenance cost savings were found to be the largest savings category from these installations at about 75% of prior values. Typical payback periods are reported as 5-8 years, although savings can be instant if reasonable-rate financing is available for a project.

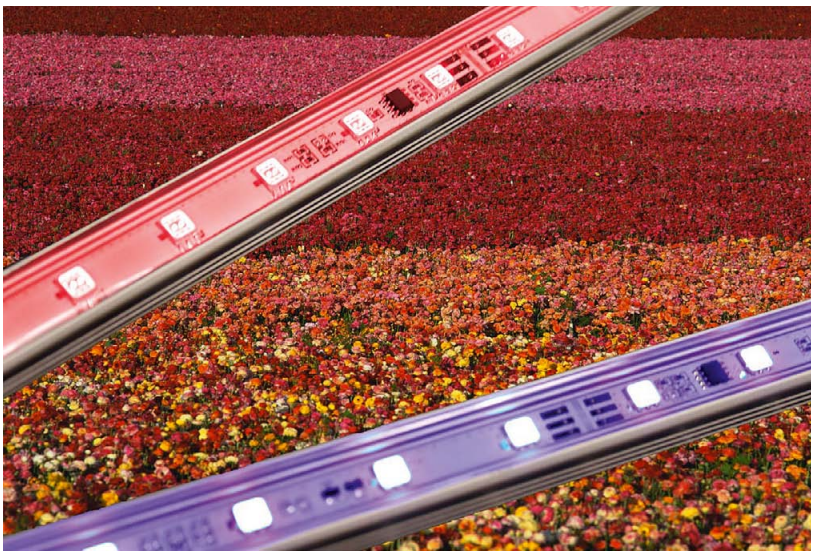


Figure 3:
While up until now it hasn't been clear whether agricultural lighting is ecologically and economically feasible, some LED manufacturers - like Lumex - are well prepared for this niche. They offer LED products with optimized wavelengths for plant growth

In more recent applications, the benefits of LEDs for municipalities shown by Raleigh have been extended by the City of Chattanooga, Tennessee to include amazing citywide controls. Chattanooga in 1969 was described as the dirtiest city with the worst air quality in the USA, but has since become a clean city 'of innovation based on service and tourism' with a widespread intelligent use of LEDs. David Crockett, a former Director of the Office of Sustainability for the City, described the replacement of 27,000 city street lamps with a mix of LED and induction lighting units plus LED traffic signals. All of these were designed to be part of a citywide safety system, where each lamp or signal can be radio controlled and monitored to allow the energy monitoring use of every light and to light up or dim specific areas or evacuation routes. As part of the Chattanooga radio control system, police glasses have cameras and microphones installed and every policeman has street lighting control from his car. At off peak times, street lights can be turned off, dimmed or run at 50% on command, allowing additional energy conservation and extended lamp lifetimes above that of continuous LED usage. All of these functions can be monitored from any PC, notebook or PDA and give dashboard status to any city authorized vehicle. The extended public safety benefits of LEDs include; raising local light intensity if needed, a flashing street lamp in front of any address with an emergency call, all lights flashing for tornado or other potential disaster situation. Street lights can stream on evacuation routes and traffic lights can be remotely controlled. This extensive use of LEDs by Chattanooga can serve as a model for global use, where the Phase I installation has demonstrated a 4.3 year payback. Even local businesses have benefitted from the widespread LED use, because some of the more sophisticated lighting units are made in the host city! The global use of LEDs in lighting is at the beginning of a 20-year growth period!

LEDs for Efficient Global Agriculture

A new, innovative and growing LED lighting market segment was described by Jean-Marc Versolato from Bailey Nurseries Inc. who discussed the benefits of LEDs for commercial plant growth, with or without the uses of greenhouses and this technology is already in use in Canada, USA, Russia, China and Europe. Growing plants only use the blue and red wavelengths of the visible spectrum, (not the green wavelengths!), therefore plant growth lighting can utilize the benefits of LED red and blue efficiencies and their small form-factor. By placing a mix of blue and red LEDs lamps, with a recommended ratio of two blue to eight red either above or embedded in the growing foliage, the LED grow-lights are very efficiently used. The above LED lamps are available from Bailey and 5 blue to 10 red ratio lamps are also available from Philips. Most crops will benefit from several unexpected advantages, including a lower labour requirement, higher plant growth rates and/or fruiting yields. For example, lilac seedling germination increased from 50% for fluorescent tubes to 70% with R&B LEDs. Additionally, plant quality was better and a significant savings was achieved with LEDs due to 25% higher germination rates. However, the typical LED energy savings will not be as high in this application, since they are competing with prior fluorescent tube use, but lamp longevity (greater than 25,000 hours) provides significant maintenance cost savings. The systems are adaptable to greenhouses, but insulated shipping containers appear to be the most suitable medium, since they can be used for growth almost anywhere, including downtown locations, which also offer lower product transportation costs. Most plant types can benefit from container cultivation, including lettuce, micro-greens, herbs, tomatoes and seedlings, with the added benefit that all plant growth should be Organic! Tomato growing can really benefit because the use of strings of LEDs at the lower levels produces higher yields of lower healthy fruit and easier harvesting.

There are a few initial concerns about this new commercial plant growth technology that include pricing, possible heat generation from the electronics, technical support, durability of the systems if pushed to the limit, and pricing, all of which can be resolved as this new LED market segment matures and as more companies offer support products for LED plant and seedling cultivation. And, the use of insulated containers can facilitate plant cultivation under a wider range of climatic conditions to provide a wide selection of plants and organic produce close to population markets. Food cultivation under these LED controlled conditions appears to be a potential new global growth market for the LED, even where agricultural quality land or suitable ambient temperatures are not available.

Summary

While the overall technical niveau of SSL seems to be already very high, many improvements were demonstrated. Some are not obvious at the first glance but still very important. For instance the luminous flux per area improved by up to four times compared to last year, efficiency increased once more for white LEDs as well as for colored LEDs. Phosphor converted green LEDs almost doubled efficency compared to green InGaN LEDs. Increasing efficiency narrowing to the projected theoretical limit helps to lower costs. New applications could further boost demand for LEDs. ■

Zhaga – A Successful Strategy for Luminary Manufacturers

Menno Treffers, General Secretary of the Zhaga Consortium, discusses the Zhaga Consortium's latest activities. He explains what successful luminary manufacturers take into account for their LED lighting strategies with the help of the Zhaga specifications. The lowest Bill-of-Material costs for a single luminary are not low enough to make a profitable portfolio in LED lighting. R&D costs, stock level costs and risk factors have to be taken into account as well.

LED professional: What is the current status of The Zhaga Consortium in terms of memberships?

Menno Treffers: Menno Treffers: The number of members has increased considerably. At the moment we can count 279 companies. Members usually meet every 6-8 weeks to ensure that things are done quickly. At these 3-day meetings there are normally about 80 to 90 participants.

LED professional: Which industry segments do these companies represent?

Menno Treffers: That is a difficult question to answer because many companies work in several segments. So that's not an easy split and furthermore it is subject to how they classify themselves.

LED professional: What about the geographical segmentation of the members?

Menno Treffers: 41% of the companies come from Europe, 16% from North America, 16% from Taiwan and 14% from mainland China.

LED professional: The Zhaga Consortium released specification books for the first time in 2012. What type of feedback or reactions did you get?

Menno Treffers: In the end, what matters to us is the adoption of the specifications. We see that a lot of people have downloaded the articles and specifications but we don't know what they actually do with the specifications until the moment the products appear on the market.

LED professional: Can you tell us anything about practical experiences from the field with Zhaga products?

Menno Treffers: The only thing we see is that the products are being used. The practical experiences have to be discussed with the members themselves.

LED professional: Some people are saying that Zhaga may hinder innovations or cost developments. How would you argue against this criticism?

Menno Treffers: Hinder innovations? I don't see any sign of this at all. The question about cost is really one of the most interesting questions. It can be dangerous to just look at the costs of materials and ignore the R&D costs.

LED professional: Can you explain this in more detail please?

Menno Treffers: It's important to analyze the percentage of R&D costs in relation to the sales of typical lighting companies or, let's say, luminary manufacturers. We discussed these analyses with manufacturers globally and they confirmed what is really happening within their companies. The fact is, we can see an increase of R&D costs over the past six years at a percentage of about 3% to 6% of sales. This increase is related to higher efforts being put into the development of LED lighting systems and its technology (Figure 2).

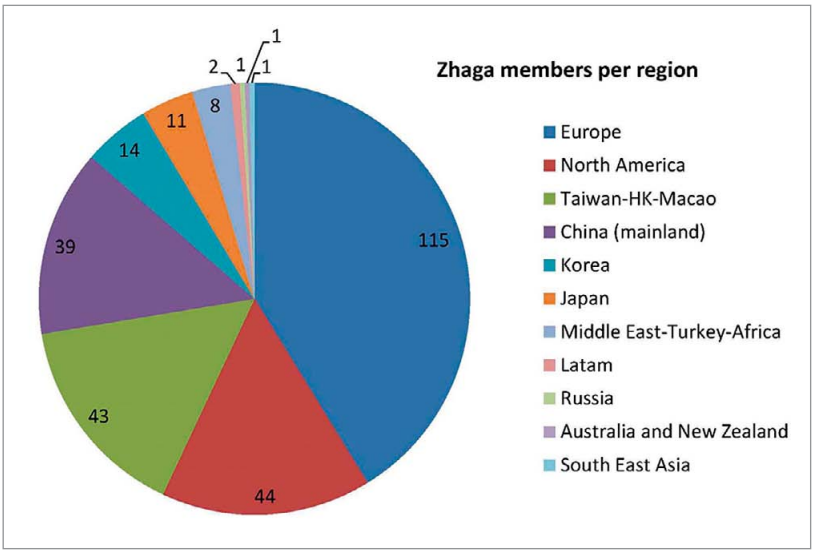


Figure 1: The Zhaga Consortium has members all around the world

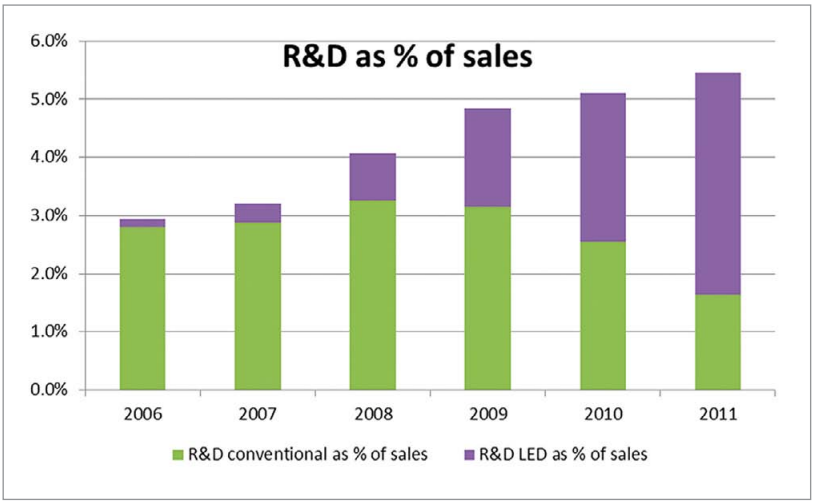


Figure 2: **R&D costs have been constantly on the rise since the introduction of LED technology (Source: "Making LED light sources interchangeable", Menno Treffers)**

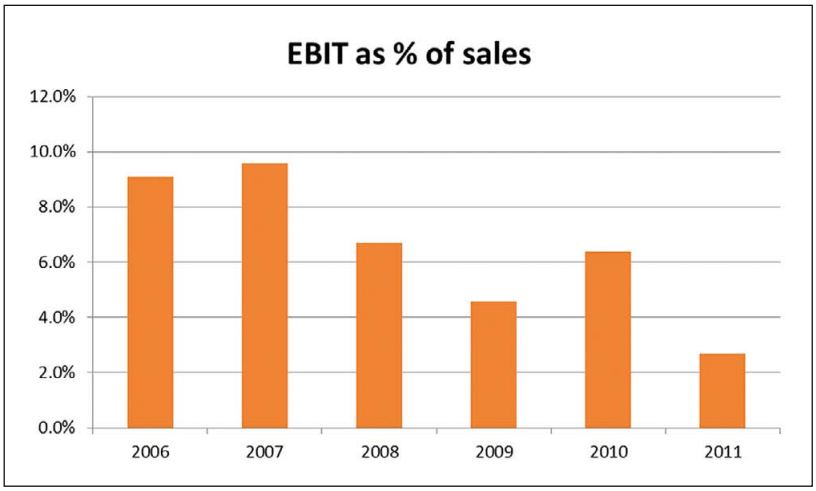


Figure 3: **At the same time, profits have significantly decreased (Source: "Making LED light sources interchangeable", Menno Treffers)**

R&D costs for conventional lighting systems are decreasing significantly. Especially over the last two years. However, the total R&D costs have increased due to the LED technology in the lighting product.

This means that companies have an increase in R&D spending which is not compensated for by higher sales. This would not be a problem if the margin of the product goes up. But at the same time, profitability within the industry has decreased (Figure 3).

LED professional: Is the decrease of profitability related to LED lighting as well?

Menno Treffers: No, there is more than that. The higher R&D costs are one part. But I've seen several companies that have difficulties with their stock levels and particularly with LED parts that have become obsolete and have to be scrapped or sold at very low prices.

LED professional: Are these all of the effects?

Menno Treffers: There is another effect on stock. If you have designed a luminary to use a specific module or to use specific LED parts, the designers know that these parts may not be available in six months time or that there might be supply problems because of a single supplier. To counter that risk companies tend to stock larger amounts of LED parts to make sure they can actually deliver. So it's not only that they are changing faster, but they also see problems with the supply of parts and the risk of being unable to get the LED parts when they need them. As a result, they tend to increase their stock levels. And that increases the risk of obsolescence and scrapping.

So it's not just the R&D efforts to develop LED technology. The significant part is having to change the luminary for new LED parts and to replace parts that are no longer available. But there is more. Some companies have noticed that they get higher levels of complaints about products that don't fulfill the expectations of life-time or color stability, or let's say, reliability and performance problems.

LED professional: What can you infer from this, then?

Menno Treffers: R&D costs are going up and profitability is going down. So the question is how Zhaga is going to help them. We, and a lot of companies that I have spoken with, see Zhaga as a way out of these problems. It's interesting that the Bill-of-Material is not the dominant factor.

LED professional: Where is the real benefit, then, for luminary manufacturers?

Menno Treffers: When luminary manufacturers start to use Zhaga modules or modules that have a Zhaga interface, what they will see is that they have easier sources and it's easier to switch suppliers. They may also have a second source supplier. This leads both to lower stock levels and possible lower prices. It's easier to source. Zhaga gives them a reduction in R&D spending because of the stability of the modules and the continued availability of the modules. They don't have to rework the luminary. They get more choice. This is because the one supplier doesn't offer the complete range of CRI, CCTs etc. that you need for your portfolio. There might be some exotic modules that are not available with the main supplier but where you have a specialized supplier for special requirements. With Zhaga it becomes interesting for the specialized suppliers to supply modules that don't fit into the main catalogues of large companies.

As luminary manufacturers you end up with more choice. Zhaga reduces overall risk and warranty risk that can be shifted to the module manufacturers.

Menno Treffers

Menno Treffers joined Philips in 1985 after completing a PhD in physics at Leiden University. As R&D manager he contributed to the creation of various industry standards, such as Super Audio CD, DVD+RW and Blu-ray Disc. Menno Treffers is senior director of standardization at Philips. He is initiator and chairman of the Wireless Power Consortium and secretary general of the Zhaga Consortium, the initiative of the lighting industry LED light sources interchangeable.

LED professional: In the end, does it reduce the costs of the modules as well?

Menno Treffers: Right now I don't see that. That's not the main result. It's likely that Zhaga modules will be less expensive in the future when there is high volume. At the moment, though, the volume is relatively low. Right now the focus is on the reduction of R&D costs and the related logistics costs as well as minimized risks.

If companies focus solely on the lowest manufacturing costs and ignore the consequences for R&D spending, they risk being unprofitable because of exploding R&D costs or a shallow portfolio. They are unable to maintain a broad and large portfolio of luminaries if they only focus on the BOM of single luminaries.

LED professional: Does Zhaga influence the design of the luminaries?

Menno Treffers: Luminary manufacturers are starting to create product architectures in which they switch modules more easily. They create luminaries that have platforms where modules heatsinks, and gears can be exchanged simply. This reduces the overall R&D costs for the complete portfolio, possibly creating a bit of a higher bill of materials for individual luminaries.

A luminary manufacturer has to balance the BOM costs against his own costs in R&D, stock and capital costs and risks. Only focusing on BOM and ignoring the other costs may not be a good strategy at the moment.

LED professional: What will the process be for further Zhaga specifications?

Menno Treffers: All of the books will be published. We will do that when the specifications are mature and products appear on the market. After that we will transfer the Zhaga specifications to IEC on a case-by-case basis.

LED professional: There is still a bottleneck when it comes to certifying products. What is the situation right now for getting products certified? Are there more labs that can certify Zhaga products?

Menno Treffers: We have certification in place for book 2 and book 3. For these products there are no bottlenecks that I am aware of. There are several labs that can certifiy, such as UL, Dekra and VDE. The timing problem is more about getting the certification for the other books in place. And that's what we are working on now. It's one of the highest priorities at the moment. The bottleneck is caused by the time it takes before we can start to do a product test with all the test-labs. We produce a couple of samples and all the labs measure these. Then we make sure that all the labs measure the same figures.

LED professional: Will OLEDs be covered by the Zhaga specification?

Menno Treffers: Zhaga is specifying the interfaces although the technology inside is not defined. So it's perfectly OK to implement OLED technology in a Zhaga module, but we might have to define another module type with OLEDs. If the members are interested

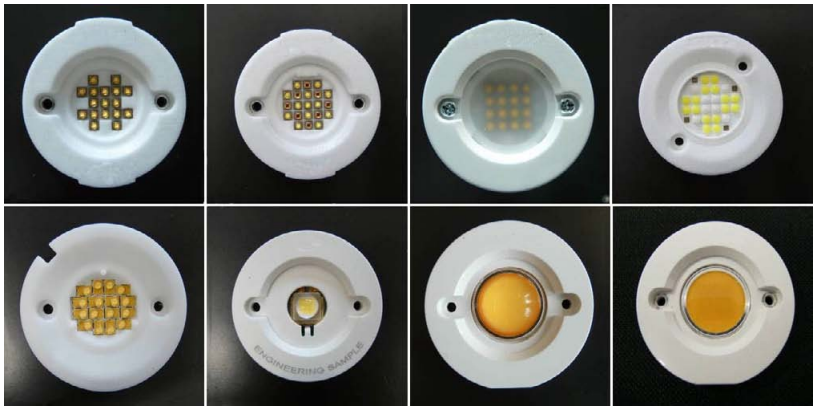


Figure 4: **Zhaga Book 3 compliant spot modules from different manufacturers**

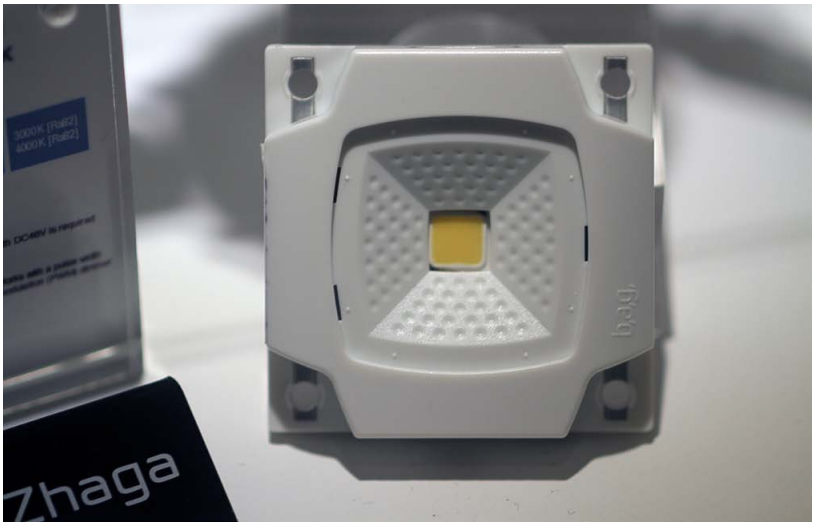


Figure 5:
Zhaga Book 7 compliant LED modules were already presented at Light+Building 2012 in Frankfurt

in defining a module that is specifically for OLEDs, we can do it. Right now, though, there are no requests to do it and therefore no work group in place.

A key differentiation for OLEDs is to use them in arbitrary shapes. If you define an OLED module in Zhaga you have to start fixing the shape and you lose the flexibility the OLED technology offers. We could possibly work on one specific module, like a 30x30cm flat-panel. But as I mentioned before, there haven't been any requests, so far. Also, would we have to specify the interfaces of a heat sink or a reflector with OLEDs? There would certainly be a reduction in the mechanical and electrical definition.

LED professional: Does the Zhaga Consortium offer design support or services to make sure the specification is applied correctly?

Menno Treffers: There is no Zhaga help desk installed. It's the same situation where a person would find support with his engineering topics right now. This is something which the industry itself can take care of. There are the industry associations which help members and there are companies specialized in engineering services. There is also the technical support given by the suppliers of the modules. The existing methods for access to engineering support are in place and I'm not sure that Zhaga would be the best place to start offering this type of support.

LED professional: Mr. Treffers, thank you for this interesting interview.

Menno Treffers: Thank you very much. ■

Copper Bonding Wires – A Feasible Solution for LED Packaging

Wire bonding is also a relevant process in LED production. It is a complex and relatively costly manufacturing step. One reason is raw material costs. Usually gold wires are used, but the price of gold is rising steadily. Dominik Stephan, Director of Application & Product Marketing, and Alon Menache, Director of R&D Engineers at RED Micro Wire propose a newly developed technology that could help to lower costs.

LEDs have been growing significantly in usage over the past years due to having a longer life, using less power and occupying smaller unit space than traditional light sources. We might say that the LED industry is in the beginning of a hype cycle. While LEDs can offer a better ROI than traditional lighting, they are still more costly. As a result, the transition from LED in display lighting to LED in general lighting is slower than it could be.

Manufacturing and packaging LEDs requires micro bonding wire. Like packaging for semiconductor chips, these wires have traditionally been gold. The move to a less costly wire material such as the copper being used in semiconductor manufacturing could reduce the cost of manufacturing and help bring LED technology to the point where it is generally recognized as the best solution for cost effective lighting. The LED industry has not done so because of drawbacks and challenges with copper bonding wire. Recently a new option, glass coated copper wire, was introduced. This article will look at the advantages of glass insulated copper wire for LEDs and discuss how lessons learned in the semiconductor industry may have a potential positive impact on the LED industry.

Background

The most common bonding wire material used in LED applications is gold, which has been the traditional choice for semiconductor chips.

For the past 30 years, gold wire has predominated in the back-end semiconductor packaging industry. However, with the price increase for noble metals, gold in particular has increased by a factor of 6 over the last decade. There has been an ever increasing drive for cost reduction by implementing conversion programs from Au wire to Cu wire. In the past years, the semiconductor industry has been transitioning from gold to copper bonding wire, mainly due to the issue of cost (Figure 1).

The mechanical advantages of Au wire, in particular its softness, have been offset by the better electrical conductivity of Cu, and its fusing current (and the drastic price increases of Au), resulting in exponential growth of Cu in the wire bonding process over the last few years (Figure 2).

Figure 1:
Gold (Au) price trend over the last decade

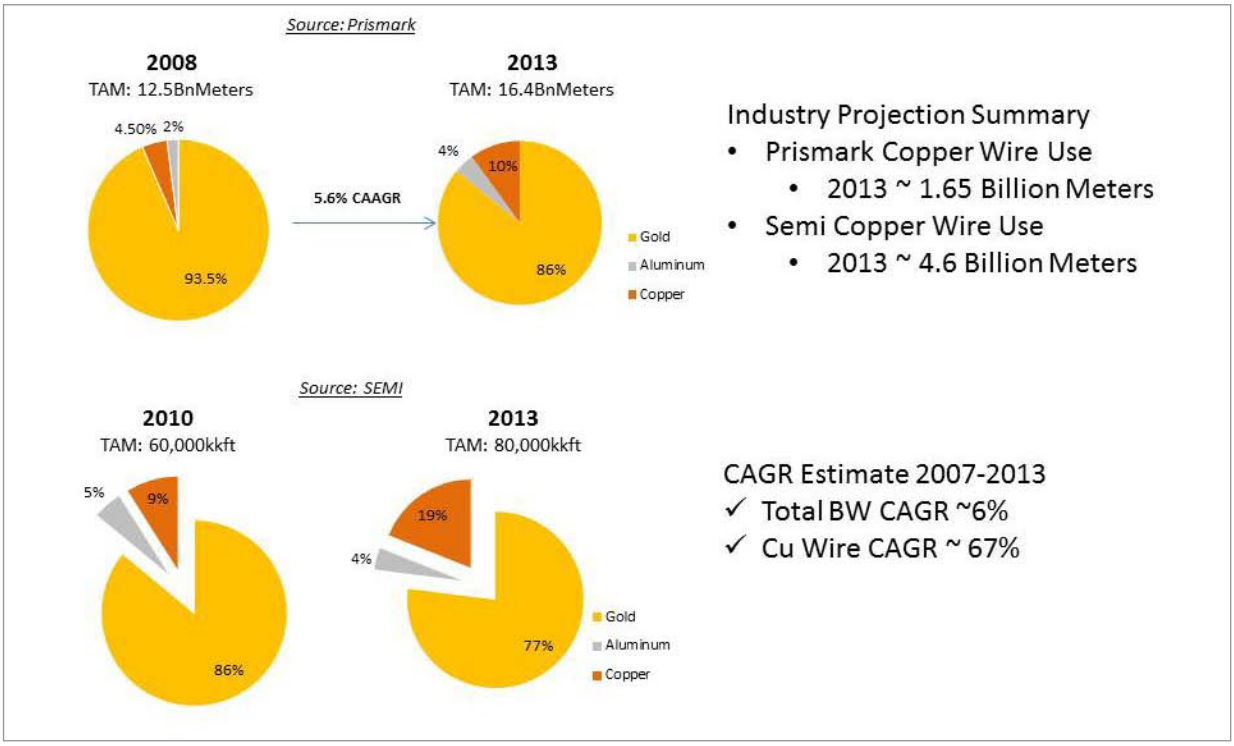


Figure 2:
Copper wire market share analysis (Prismark and SEMI)

A number of challenges, mainly in operation and materials management, have led the semiconductor industry to search for alternative solutions to copper bonding wire.

It appears that the issues of cost, material usability, and effectiveness are relevant to the LED industry. Innovations in bonding wire for semiconductors could potentially be implemented to benefit LED manufacturers as well, bringing growth and gain to both markets.

Challenges of Implementation

Due to the ever increasing cost of gold, combined with several performance advantages, copper has fast been gaining in popularity as an alternative to gold for wire bonding in semiconductor packaging. The high reliability of gold and relatively simple material management makes gold the industry's first choice. In contrast, LED applications which have a low pin count utilize much less wire than semiconductor packaging, which have a high pin count. As a result, the material cost seems to create less impact on the LED industry, resulting in lower urgency and demand for alternative solutions.

LED industry projections predict that, in the near future, high power lighting will be produced using LED clusters, for example, in street lighting. Such clusters will necessitate expanded use of bonding wire, larger amounts of wires and connections. As this trend is implemented, the cost of wire will be further highlighted and the demand to find a more cost-effective solution will grow. Already we are beginning to see discussions regarding possible alternatives to replace gold bonding wire in LED applications.

Although Cu costs approximately one tenth the price of gold, copper bonding wire has some drawbacks that have made the LED industry reluctant to replace the standard gold wire. Drawbacks include higher wire hardness, which reduces the wire process robustness, more complex application requirements due to the need for bonding under a protective gas environment, and more rigorous material management, mainly due to oxidization.

Higher hardness of copper means that the bonding process must use more energy to create the bonds, i.e. higher ultrasonic power, which can lead to pad damage problems and potentially reduced reliability. The fact that copper is less ductile and work-hardens easily leads to a major potential pitfall when using it for sensitive wire bonding applications. It is better to bond the copper wire under a protective environment since it oxidizes much more easily than gold and the presence of oxide layers predicates even higher bonding forces and potential reliability failures.

There is clear correlation between material hardness of a wire material (Au and Cu) and the size of a bonding window, where a ball can be welded to the bond pad. Both materials have different bond mechanics - Au forms the major bond strength based on inter-diffusion and intermetallic phase formation at the interface and copper, which does not show major IMC phase after bonding is believed to have its bond strength from mechanical interlocking (it does form IMC between Cu and Al at a later stage in heat treatment/reliability testing). Hence copper requires a larger amount of force to establish the bond to the Al layer. This higher force is also attributed to larger work-hardening of copper as compared to Au. In both materials, the bonded ball is harder than the FAB (Free Air Ball) but work-hardening is larger for copper. As a result, copper wire is more prone to pad cracking; subsequently we can say that softer copper wire is less prone to pad cracking.

Unfortunately, the use of higher bonding force can lead to two potential negative consequences that can impact the quality, function and longevity of the bond and hence the packaged chip: cratering and aluminum splash (or splash-out). Cratering refers to damage that penetrates through the pad and into the underlying dielectric layers. Aluminum splash occurs when the higher force used for copper causes the top aluminum layer of the pad to splash out beyond the ball footprint and potentially even beyond the edges of the pad.

Copper oxidization is a major issue that affects the entire bonding process – materials management to production of the final product (chip or LED) needs to be adapted accordingly. It is usually recommended to implement strict control over the storage of copper wires in order to assure wire usability. There is typically a limited shelf life, usually about 6 months after manufacturing, within which the wire needs to be consumed. This applies to storage with original packaging. Once the package is opened (and the wire is exposed to an oxygen-containing environment) wire lifetime for bare copper is reduced to about one week. After this there is a clear deterioration in bond performance due to oxidation of the copper.

Engineers and R&D teams dealing with LED packages have more limited resources than those available to researchers in high pin count assembly houses. As a result, overcoming technical challenges and discovering innovations are difficult and more time is required to implement new technologies.

There are some inherent problems with LED applications that are particularly related to use of Au wire and can be overcome when using copper. Intermetallic phase formation is very rapid, especially when using a soft, high purity Al pad metallization. Copper forms intermetallic phases at a much slower rate, which improves long-term reliability. Another problem is overcurrent, which damages the wire. Copper offers better electrical properties and can carry larger amounts of current. So the risk of fusing is reduced.

The LED industry can learn from the semiconductor industry, which has long been searching for an alternative to gold wire and attempting to overcome the challenges of copper wire, without inflating the cost of material. A different solution is needed, one that has the reliability of gold, at a cost like that of copper. Such a solution will ultimately benefit both the semiconductor and LED markets.

A Possible Solution

In order to find a promising solution it is necessary to think out of the box. One method of opening up new possibilities is to get away from the traditional wire drawing process. The Taylor-Ulitovsky process achieved this in an academic environment years ago. However, the process has never been duplicated for high-volume mass production until now.

The modified Adar-Bolotinsky process has made it possible to produce micro bonding wire directly from the melt - by casting instead of the traditional drawing - and taking this capability to mass production. This special manufacturing process also makes it possible for RED Micro Wire (RMW) to develop RED Copper wire which is a unique composite wire with a thin glass coating and a soft copper core. These unique composite wires can be created with other metal cores, opening a myriad of new opportunities for the wire bonding industry, some yet to even be imagined.

Glass can greatly increase wire strength and stiffness, yet still provide a smaller effective wire diameter on smaller bonds. Based on the manufacturing method, a full coverage of glass can be ensured, which in return ensures insulation. In addition, fusion current, floor and shelf life are no longer limiting factors since there is no exposure of copper and risk of oxidation.

Another special feature of the cast wire manufacturing process pertains to the mechanical properties of the wire. Hardness tests shows that the copper core is even softer than a

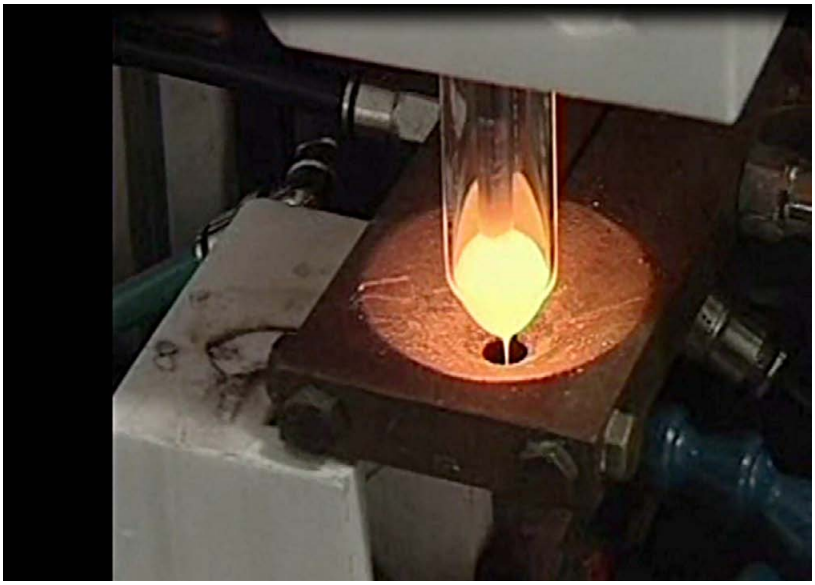


Figure 3: **Inductor unit of the RED Micro Wire (RMW) process (left)**

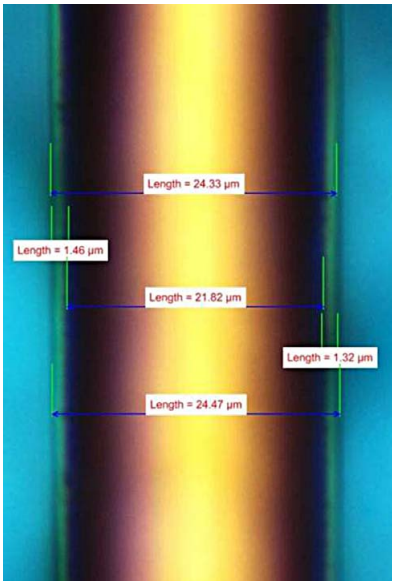


Figure 4: **RMW copper wire with glass coating (right)**

Table 1:
Wire and FAB (Fee Air Ball) hardness values of selected technologically available materials; *refers to the copper core

	Wire hardness	FAB hardness
Gold wire	70-80	60-70
Normal copper wire	90-100	90-110
Soft copper wire	85-95	85-95
RMW glass composite	75-85*	65-75

typically highly annealed copper wire, as seen in table 1. This is true for the core of the wire, which indicates good bondability but also, more critically, for the FAB. The FAB hardness is in strong correlation to the bond pad deformation and cratering, which is a huge problem for standard copper bonding wire. In other words, the unique casting process creates attractive Cu mechanical properties and it is likely that the glass coated wire will greatly improve issues related to ball hardness and pad cracking.

The special wire characteristics of glass insulation create additional benefits. A major benefit is the elimination of risk of copper oxidization, which is one of the main challenges in operation and material management of Cu wire. In addition, the insulation prevents short circuits due to wire touching, a characteristic that is an important consideration in semiconductor packaging. This enables relaxation in design rules, which is highly beneficial in high pin count applications. The impact of these benefits on LED applications is yet unknown and necessitates further testing.

Conclusion

Wire bonding has been around for many years and has remained more or less the same throughout its use – the same materials, same processes, etc. New innovations, for example LEDs, necessitate new advances.

Glass-coated wire and the wire properties it creates appear to be an interesting development for the semiconductor industry and the LED market. Achieving softness in the range of gold wire is very promising. It is necessary to test the ramifications of the glass coating in LED applications to better judge the feasibility of this solution for the LED market. Certainly a viable, cost saving solution will help place LED technology into a total cost range that is attractive to the mass market. Further research and testing will help the industry to better understand the ramifications of this innovation and the possible gains in adapting such a solution. ■

EMI Problems in TRIAC Dimmable LED Drivers

TRIAC dimming adds a dimension to Power Factor (PF) and Total Harmonic Distortion (THD) that is rarely defined by LED driver manufacturers. Bianca Aichinger, Product Marketing Manager at RECOM Lighting, examines the relationship between PF, THD and harmonics and explains why this relationship can change as soon as the LEDs are dimmed, thus causing increased EMI and undesirable visible effects such as LED flashing and flicker. The European standards for EMC and Harmonics are only specified for full load and in the non-dimmed condition. In practice, there are often dimmer/driver/LED load conditions which may meet the regulations when undimmed, but fail significantly if dimming is used.

Light is a human necessity and depending on our needs and mood we require different levels of illumination. We need much more light to read or work than in the evening when having an atmospheric dinner, for example. For this reason dimmable lighting has become one of the mainstays of daily life. Most workplaces use controllable light levels to increase productivity, increase safety or to save electricity costs, and almost every household has a wall dimmer. The most common dimming method is the TRIAC or phase angle dimmer which is a mature, well-proven technology. However, what was and still is self-evident for conventional incandescent bulbs creates new challenges when using more modern lighting solutions like LEDs, especially over issues such as compatibility and EMI performance. For a better understanding of this topic it is necessary to get to know the differences between a traditional incandescent light bulb and an LED dimmed lighting system.

The successful installation of a dimmed incandescent bulb requires only a dimmable mains power connection and a light socket. The installation is so simple because the socket sizes are all standardized and incandescent bulbs are non-electronic, purely resistive loads that have unity power factor and will work with almost any dimmer or switch combination. Installing an LED is much more complicated. Besides a more sophisticated thermal management and appropriate photometric interface, an electronic LED ballast or driver is almost always necessary to power the LEDs (the few direct AC operation LED lights suffer from a very non-linear dimming curve which makes it impractical to dim them successfully, so they will be ignored here)

Introducing an electronic power supply into the installation adds complexity and as LED ballast is essentially an AC/DC power supply, it has to meet the all the EMC Directives including the power factor and harmonics regulations for the operation of mains-powered electrical devicesn.

Introduction to Power Factor and Harmonics

Let's start with power factor (PF). Power factor measures the relationship between active and reactive power and thus shows the phase angle/load distribution in the power grid. The power utility companies are naturally anxious to keep the proportion of the active power as high as possible, as they are required to correct the power factor relationship if it deviates much from unity and common electricity meters can only measure active power, so any reactive power losses are not paid for by the customers. Note that a high PF does not mean high efficiency. They are separate entities and adding power factor correction in an LED power supply actually reduces overall efficiency.

As most LED power supplies are switching supplies operating at frequencies of 100kHz or more, they can inject high frequency current pulses into the mains if not properly filtered. This high frequency interference has a maximum at the switching frequency, but also other peaks at multiples of this frequency, or its harmonics. This means that interference frequencies in the MHz band could be easily generated which can affect other electronic equipment on the same mains wiring.

Therefore, regulations have been issued and directives have been passed which define the maximum permissible values for power factor and harmonics that all consumers installing LED luminaires with powers of 25 watts or more have to meet. In

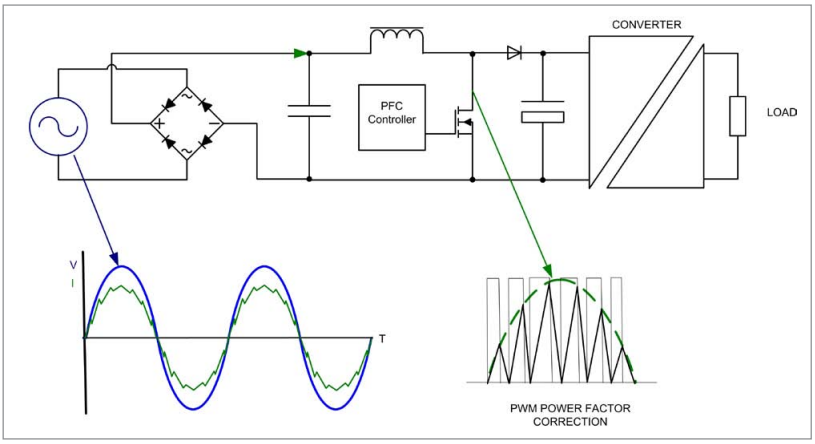


Figure 1:
Block diagram of an LED driver with active PFC showing the modulation of the current wave form

Europe, this standard is called EN61000-3-2: EMC-limits for harmonic current emissions, and for lighting applications, class C is required. The only practical way to meet the harmonics restrictions is also to add power factor correction (PFC), as the harmonics standard includes power factor in its definition.

The typical principal of an active PFC is to add a pulse width modulator (PWM) in the circuit between the rectifier and storage. This PWM generates several current pulses synchronized with the input voltage and controls the capacitor charge current such that it is close to the input voltage sine wave form (Figure 1). As the input current closely matches the input voltage, the active power is very high and the PF is close to unity.

The term THD (Total Harmonic Distortion) is often misinterpreted. Actually the THD is a figure that is reflecting the total pollution of the power grid over all frequencies. This pollution is generated by all of harmonic waves which are superimposed to the mains sine wave when voltage and current are not in phase (Figure 2).

A very common misapprehension is to confuse the EMC harmonics specification with THD. THD is defined as a simple percentage (eg. THD<10%, THD<20%) and is derived by working out the square root of the sum of the squares of each harmonic divided by the fundamental current. This gives a simple figure for total distortion, but ignores the absolute value of individual harmonics. The EMC standard EN61000-3-2 goes much more into detail and defines a maximum limit for each odd harmonic until the 39th iteration. So it might be possible that the THD is less than, say 15%, but that one of the harmonics is out of range which means that the lighting system will NOT be complaint to Class C. On the other hand the THD could be more than 20% but all individual harmonics are within their limits and so the whole system meets the EMI standard. It is therefore better to insist on Class C compliance and not to worry too much about THD. Actually, EN61000-3-2 is not an LED specific standard. It also applies to CFL lamps and is the reason why it is almost impossible to find high power CFLs as the 25 W limit was chosen to let the majority of CFL lamps off the hook.

The impact of load and dimming

So far, so good for the situation for the basic operation of LED lamps but if an additional functionality like variable load and dimming is required as well, a further dimension is added. LED ballasts are optimized to work best at “full load”, but this state is not so easy to define with constant current drivers. For example, if a 350 mA LED driver rated at 10 Watts ($V_{out\ max}$ = 28 VDC) is used with an LED Lamp rated at 7 W, then most users would consider this a good set up. With typical LEDs, the forward voltage of the 7 LEDs in series will be around 22 V. As the driver may only be able to properly regulate the output current over a range of 75%-100% load, as soon as the LEDs are dimmed down, the string voltage may be out of the regulation range and the LEDs will start to flash. It is thus vital for proper operation that the LED string voltage stays within the output voltage range of the LED driver also when the LED current is dimmed to the minimum. LED driver manufacturers rarely define the consequences which may result from this mode of operation.

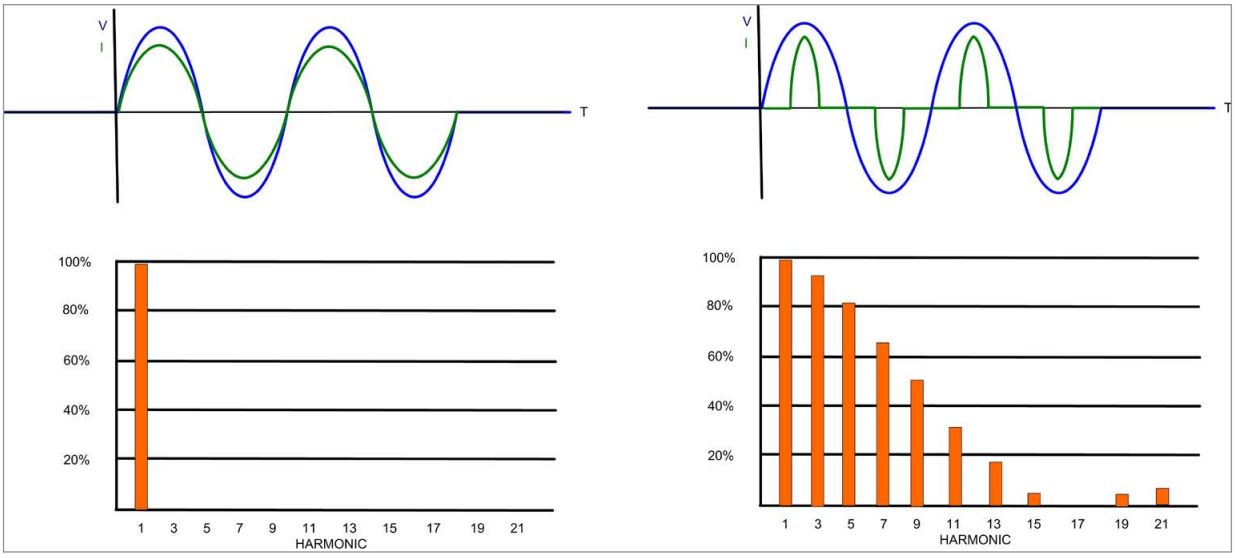


Figure 2:
Comparison between resistive load and non-PFC behaviour showing the different harmonics spectra

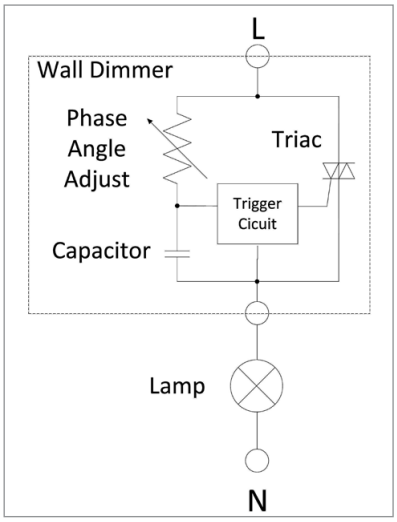


Figure 3:
Basic TRIAC dimmer circuit (left)

Figure 4:
RECOM lighting provides a video where this flicker is shown with a low cost LED driver using an oscilloscope to see the conducted interference generated on the main waveform: youtube.com/recomlighting

In residential buildings, the most common kind of dimmers are phase angle dimmers (the standard wall dimmers that almost everyone has at home). These dimmers work by delaying the switch on of the mains voltage after each half cycle. With a short delay the main part of the AC waveform gets through and the lamp burns brightly. With a long delay the lamp burns dimly because only the tail end of each half-cycle gets through. This works very well for incandescent lamps as the hot filament acts like an energy reservoir so that they respond to average power rather than the waveform shape. For phase angle dimmed LED drivers several difficulties might occur. These are typically phase angle range, TRIAC holding current and TRIAC triggering.

The phase angle range has to be limited for LED drivers because they are often powered from the same dimmed AC supply. If the input is dimmed down almost to zero, there is not enough input power to supply the internal electronics. The usual solution is to build dead-space at both ends of the phase angle range. At bright LED levels, the LED driver must wait until the phase angle has reached around 60° to be able to get a reliable synchronization lock and to avoid false triggering due to input voltage variations. Even if a starting phase angle of 60° sounds a lot, the delivered AC power is just dimmed to around 85% at that point. From this point the LED driver is able to calculate the required LED brightness and dim the LED linearly if the phase angle is further increased. Typically the LED system has already dimmed all the way down to zero at around 150°. At this point there is around 2% input power remaining which is just enough to power the internal electronics. From 150° to 180° the driver is in shutdown mode.

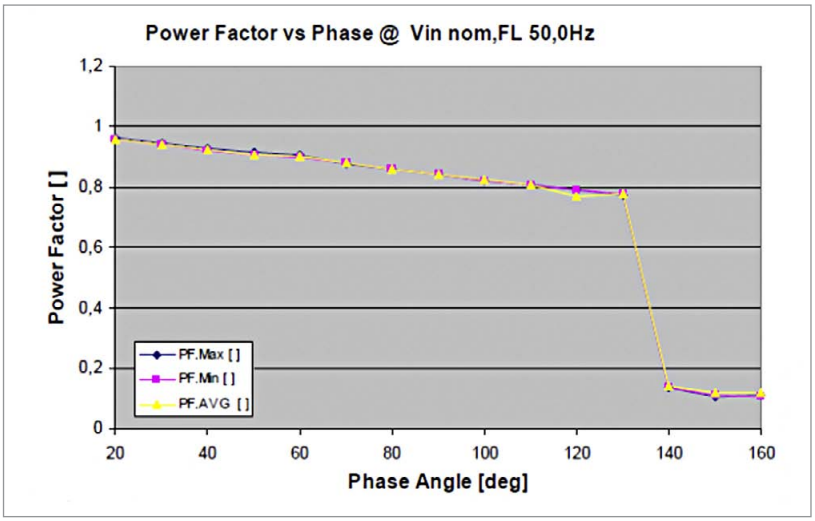
But there is also another difficulty with the phase angle range - the dimmers themselves. Most dimmers don´t actually dim down to zero because of an old specification that even a fully dimmed bulb should glow a dull red to warn electricians that power is still applied. What was a good safety idea for incandescent light makes it very difficult for LED power supplies because at 10% dimming, LEDs will still shine brightly.

Another issue with the TRIAC dimmers are the holding current and triggering threshold. As shown in figure 3, the most basic TRIAC dimmer circuits have no internal reference voltage and so the TRIAC relies on current flowing through the load to return path to neutral. TRIAC dimmers were basically invented to handle a hundred watts or more required by typical incandescent bulbs. LED loads are typically under 20 watts and so the current flow often is not enough to reliably trigger the TRIAC, even at full power. The situation can get worse at very low dimming levels where only a few watts are being dissipated by the LED load. One solution to ensure that the TRIAC triggers reliably is to add a switchable artificial load inside the LED driver, which then turns off as soon at the TRIAC fires to maintain the efficiency advantages of LED lighting. To reduce costs, several low quality LED power supply manufacturers use crude timing circuits, which can easily generate false triggering with loads less than 100% or with certain TRIAC dimmer types. This means that an additional load may be necessary for the proper dimming function. There is a common story about electricians that add an incandescent bulb hidden above the ceiling to get the dimmer working properly with LED lighting. Not the most eco-friendly solution!

Last but not least, false triggering is also a problem with TRIAC dimmable LED drivers. At 50% dimming, the AC waveform is switched on at the peak input voltage, so the rate of change of input voltage is at the maximum. The reason is that at each half cycle the input current jumps directly to the maximum and thus causes undesirable inrush currents and overvoltage spikes. This might force the input EMC filter to oscillate with the sharp changes of the input voltage. The resulting back current pulse can sometimes de-trigger the TRIAC and so the LED starts to flicker as the TRIAC switches rapidly on and off within a mains half-cycle.

Completing the circle, we are back to terms of power factor and THD. At the beginning we found out how to meet the limits of the EN61000-3-2 standard which is defined with full load and a clean sinusoidal AC Voltage input, but it is even more complicated with an irregular wave form of a TRIAC dimmed input and with less than “full load”. Actually the standard doesn´t define the test conditions in the case of dimming and simply ignores it. So test houses

Figure 5:
Test results of the Power Factor vs. Phase Angle



doing the certifications also do not check. This could lead to products which have a really good PF and THD in the datasheet but still generate significant harmonic mains distortion when dimmed – especially at 50% brightness. There are only two ways to really figure out the characteristics of a LED driver when dimmed. The first one is to build a test-rig of the lighting application to find out if LED driver and dimmer interact as expected and measure the actual PF and harmonics using a calibrated AC power meter. That's the hard way. The other possibility is to choose trustworthy manufacturers who are prepared to provide comprehensive test reports which include for example PF vs. Phase Angle as shown in figure 5.

Conclusion

Many manufacturers offer a wide range of AC/DC LED drivers from a few to some hundred watts. Although power factor correction is required only for products with more than 25 watts, high quality manufacturers integrate a PFC also below that power level, for instance RECOM's RACD series provides active PFC from 12 watts as standard.

Well-designed drivers offer flicker-free, linear TRIAC dimming from 100% down to zero. For example, the RACD 20 series is equipped with a special developed input circuit which maintains PF, Class C Harmonics and THD over a wide range of input voltage, load and dimming conditions. Such drivers are an ideal solution for many LED systems where trouble-free TRIAC dimming is needed. In addition it is relevant that products are all UL and EN certified and equipped with a long design lifetime. ■

Reliable Thermal Management of High-Power LEDs

Stefan Hörth believes that FR4 PCBs can easily replace IMS PCBs and even open new fields of LED applications. Haeusermann's HSMtec Product Manager demonstrates that common FR4 laminates, including special copper filling, will sufficiently withstand the heat of HB LEDs.

LEDs are generally considered as reliable, stable and durable, and with good reason. This is definately true for single LEDs, but lamps are comprised of multiple LEDs in a small space together with control circuits and PCBs. The small lighting components are very susceptible to high temperatures, and the PCB has to act as a cooling element. LED reliability and PCB reliability are very closely connected and pose high demands on design and development.

While LEDs offer enormous design opportunities, their light quality is crucial for their acceptance as an illuminant in general lighting. The requirements in terms of light homogeneity and color temperature are high since even a discrepancy of a few Kelvin makes a tangible color difference to the human eye. In order to keep the brilliant light quality for a long time it takes clever control electronics as well as efficient thermal management. Even though the degrees of efficiency of LEDs are constantly getting better, there's still a large part of the electric input power converted into heat. However, the functional temperature limit is the range within which the electrical circuits can be expected to meet their specified performance. The absolute maximum temperature limit is the temperature that a portion of the component may be safely exposed to.

This might pose a problem in today's arrays with many tightly packed LEDs, and UHB components (Ultra High Brightness) with ten or more Watt per package. Most UHB LEDs offer just a small area of a few square millimeters for heat dissipation, so the heat needs to be channeled away quickly directly beneath the LED through a PCB with little thermal resistance.

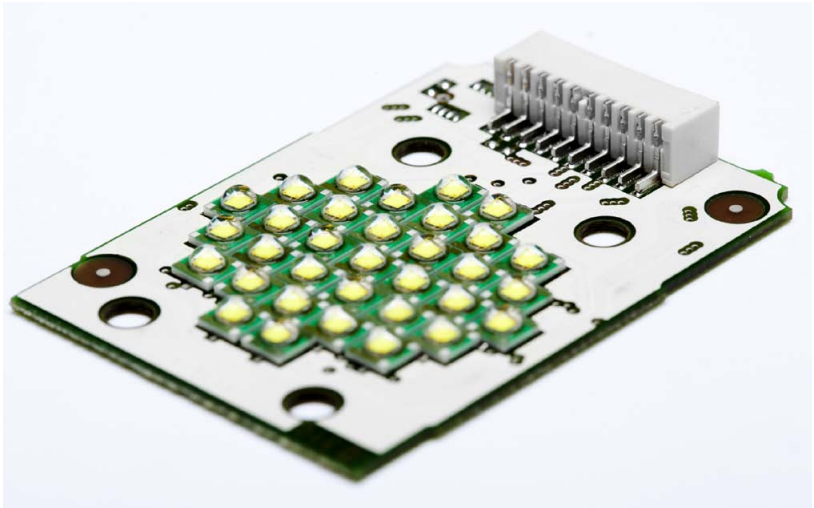


Figure 1: **HSMtec dissipates the heat of tightly packed LED arrays quickly, preserving the luminosity for a long time – for example in LDDE's LED stage spotlight SpectraWow+**

Consequently, preventing a decrease in light quality of a LED takes changes in the board's construction, optimizing heat dissipation so that the LED remains within its optimum operational parameters. In order to do this it is necessary to take into account the amount of heat that has to be dissipated, the dimensions, the components contacting and the circuit complexity. Concerning thermal management, there are some special PCB technologies around, like Insulated Metal Substrate (IMS) based on aluminum or Metal Core Printed Circuit Boards (MCPCB).

There are different types of MCPCBs available. A MCPCB consists of a number of layers including a dielectric sandwiched between two metal layers. One of the metal layers, typically a copper foil between 35µm and 1.5mm thickness, acts as a circuit layer for electrical connections, while the other serves as a heat spreader. Most of them are made of aluminum or copper alloy, but iron alloy or even carbon is also available on the market. The choice of the type of material for a heat spreader depends on the applications of the MCPCB. For instance, aluminum should be used if a lighter weight of MCPCB with gentle heat dissipation is required. By contrast, copper offers higher heat conductivity but it is heavy. The most commonly used dielectric in the thermal conductive laminate is a special filler-matrix composite. It offers a low thermal resistance path for heat conduction, acts as a bonding media, and an insulation layer between circuitry and heat spreader. In general, the

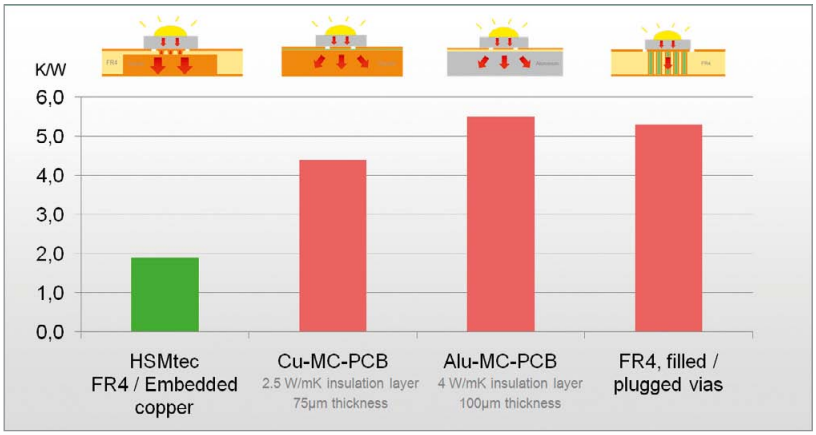


Figure 2:
Comparison of the thermal resistance of traditional two-board solutions with Haeusermann's FR4/copper combination (Measured with T3ster and heat-sink directly attached to rear side)

thermal conductivity of this special insulation dielectric is 4 to 16 times higher than conventional FR4 dielectric, thereby expediting heat conduction. Compared with ceramic substrates such as alumina, aluminum nitride, and beryllium oxide, which are also being used as a heat dissipation media, MCPCB offers lower costs and better mechanical strength.

HSMtec takes a more standard approach toward heat management, selectively integrating massive copper elements into FR4 boards in order to restrict heat to acceptable partial and system temperatures. The copper profiles or wires are being integrated into the board only where heat or strong currents actually occur. At the moment there are profiles 500 µm high and 2.0 mm to 12 mm wide in variable lengths available, wires usually have a diameter of 500 µm. Those structures, adhesively joined to the circuitry, can be applied directly onto the base copper using a patented technique and integrated into any layer of a FR4 board.

Tested by Osram

More than 90 notable companies from the "LED Light for You" network provide professional support with the development of standard solutions as well as with the realization of extraordinary ideas, adjusted to the specific application areas and individual requests.

Preliminary thermal stress tests conducted by Osram Opto Semiconductor confirmed the high reliability of HSMtec boards based on copper and FR4. Temperature variations have a strong impact on the reliability of LED boards for various reasons. Apart from the heat produced by the LED there are environmental conditions as well as frequent switching or dimming responsible for high temperature cycle stress. Those varying temperatures often are the reason for damaged solder joints, leading to breaks or cracks and failure of the affected LED or a whole serial LED chain.

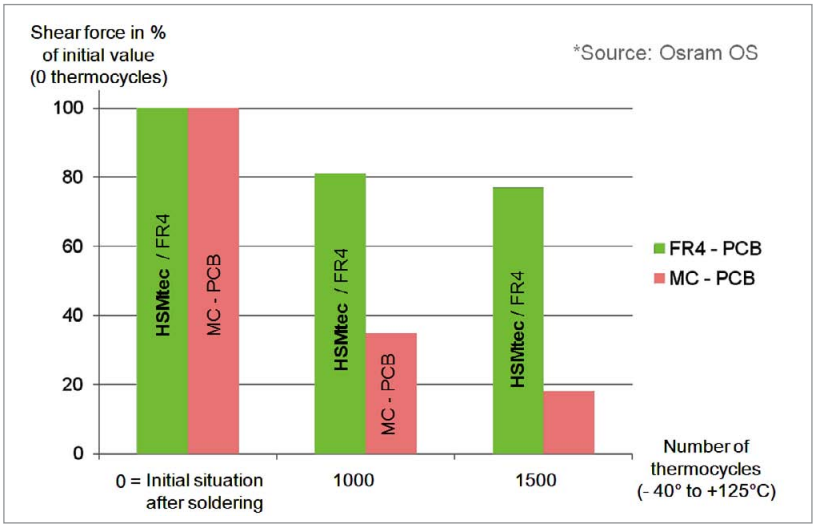


Figure 3:
A preliminary test conducted by Osram Opto Semiconductor confirms the high reliability of the solder connection with ceramic LEDs

The reason for this is the different coefficients of thermal expansion of commonly used metal core PCBs based on aluminum. Aluminum shows a very large thermal expansion, the LED ceramics does not. In consequence, the aluminum expands more than the ceramic due to the heat caused by power dissipation. Since the LED is bonded tightly to the PCB, mechanical tension builds up, resulting in enormous shearing forces acting on the solder connection and compromising the reliability of the whole assembly. The common soft solders don't react to this tension like a spring but dissipate it by creeping. This creeping changes the solder's crystal structure, enlarging the grains in the polycrystalline solder. At cooling, this process runs backwards, but the grains keep on growing. Alternating switching on and off, i.e. heating and cooling, causes cracks along the grain domain borders. After a number of cycles the solder can rupture completely.

This becomes relevant when the cracks start to impact the lamp function. The most serious consequence is the constriction of the current-carrying diameters of the cathode and anode pads. It's even possible that a pad may be torn off. Just before this happens, the LED's serial resistance increases, resulting in an open contact and a failure of the LED. Without a bypass, the whole line is compromised. The shearing forces necessary to dissolve the connection between LED and PCB have been established in thermal cycles from -40 and +125 °C. This test demonstrated that the shearing strength of aluminum-based metal core boards decreased below 20% of the initial value at 1500 cycles while the FR4 board still showed 80% shearing strength.

In a more thorough temperature test with different temperature cycles that started back in 2011, the new approach was compared to classic FR4 boards with thermal vias and typical metal core and ceramic boards. The test used two different samples with the common LED families Ostar with up to 12 W and Oslon with up to 3 W.

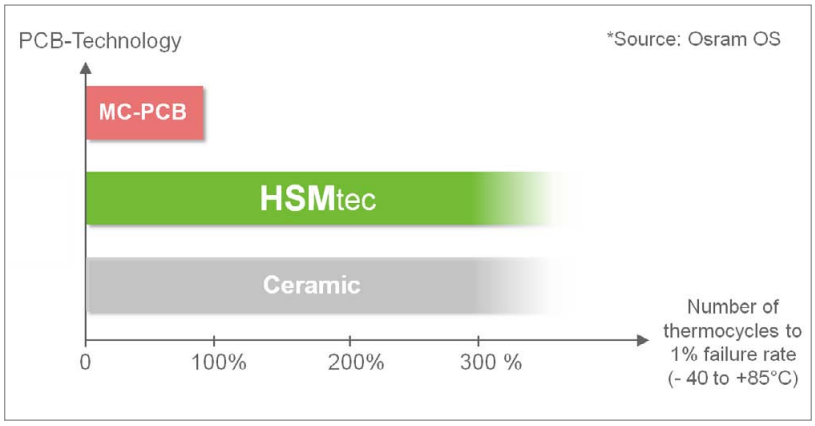


Figure 4: **Thermal cycle stabilities during a long-term test run conducted by Osram: while IMS boards reach their limits fairly soon, these boards managed more than 3000 temperature cycles during 6 months of testing**

During the temperature cycle test from -40°C to +85°C aluminum-based metal core boards showed 1% solder joint failure rate after only 850 cycles, caused by the different thermal expansions of the LED substrate and the PCB. The HSMtec boards didn't show failures even after a half year of testing and more than 3000 temperature cycles. This result came as a surprise since IMS solutions usually are the first choice for solving thermal management problems with high power LEDs.

Between 0°C and 60°C, the FR4-based PCB solutions survived more than 8000 cycles unimpaired and are on a par with ceramic substrate boards. The latter are designed for high-loss applications, e.g. power semiconductors, but very expensive compared to FR4 or high-Tg-FR4 PCBs. Since it's based on standard FR4 laminate with partially integrated massive copper elements, this is where this technology can show its advantages.

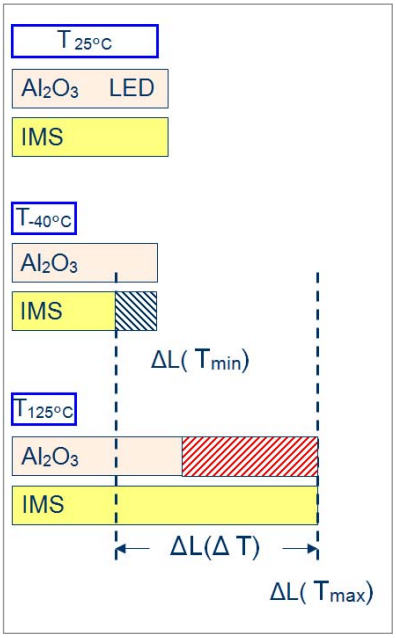


Figure 5: **Length difference depending on temperature (Source: Osram)**

What is the significance of those 8000 cycles in terms of life expectancy? Let's look at the example of a street light: Assuming a single daily temperature cycle of 60 K (e.g. a rise from 0°C to 60°C at activation during cold weather), the combination of an HSMtec board with common soldered ceramic-substrate LEDs can work for at least 22 years. With a lower maximum temperature rise, i.e. a lower junction temperature, the life expectancy grows accordingly. In consequence, the high thermal performance of these boards adds to a longer system life just like optimized PCB design.

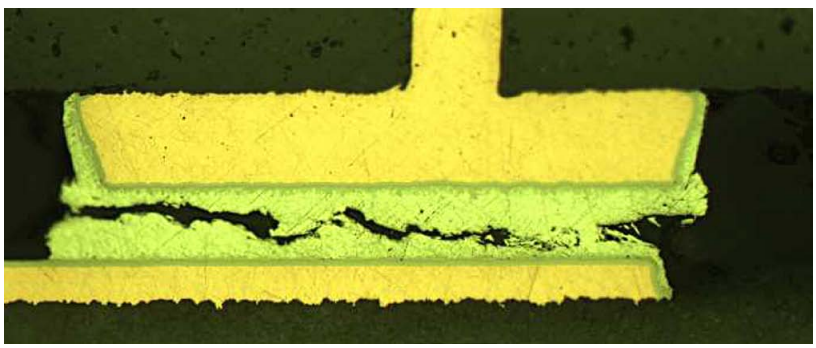


Figure 6: **Cross section polish of a broken solder joint (Source: Osram)**

The single cycle per day, however, is pure theory. Any modern lighting system makes use of intelligent lighting/dimming control, meaning that a street lamp only runs at full power when this is actually required and may be switched off and on rather more often. This kind of intelligent lighting saves power and improves a lamp's efficiency but at the same time reduces its life expectancy. While, in principle, this problem applies to the 8000 cycles of (reinforced) FR4 just like it does to the smaller number of cycles of IMS, the former does have a crucial advantage since the impact of the effect is worse the bigger the differences in expansion are.

LED and Control Electronics on a Single Board

LEDs allow for systematic control of light intensity and color without relevant drawbacks concerning life expectancy or reliability. The LED driver can be controlled by different sensors and an intelligent control circuitry. Combining control electronics and LEDs on one board often may not seem viable since the cost of typical metal core boards skyrocket with an increasing number of layers. FR4 boards on the other hand allow for complex electric circuits but often don't offer sufficient thermal performance.

The use of sophisticated PCBs based on FR4 and copper with partially embedded copper elements allows for powerful thermal management as well as a simple way of combining complex control electronics with sensors on the LED board. It is possible to realize the fine structures required for the control electronic simply on the same layer as the copper elements without any additional design tools.

A Proven Solution for Zhaga Compliant Spotlights as well

Zhaga certified "LED-Light-Engines" are rather complex: While the standardization applies to the LED module, Zhaga distinguishes between modules with and without a driver

supplying the operation current. Both variants already have their own standard, for example, defining the module's size, external diameter and its height.

These standardization efforts pose enormous challenges for PCB manufacturers and luminaire designers. A typical Zhaga compliant spot light engine couples out light on an area measuring 13.5 to 26 mm in diameter. The resulting high power density requires very efficient thermal management. On the other hand, a LED module with integrated driver has to cope with 230 V input voltage and ensure a dielectric strength conforming to standards as well as electric isolation.

There isn't much space left in the socket for multiple PCBs for LEDs and their control electronics. Usually, IMS boards are being used in order to dissipate the heat generated by the LEDs. This method requires cables and connectors to connect the LED board with a second FR4-based one containing the control electronics. There is no question that this configuration is not ideal, impairing life expectancy of the module and luminance of the LEDs.

This is where the HSMtec technology demonstrates its advantages: An LED cluster measuring 19 mm in diameter with 30 Cree XLamp LEDs type XB-D and a total power of 100 W acts as reference module. It conforms to the intended Zhaga performance goals of 50 W per module with integrated driver without difficulty, and control electronics can be mounted on the same board as the driver components.

With very similar requirements like Zhaga modules, a 28x28 mm LED array with 33 Cree XLamp XP-E-RGB high-brightness LEDs with 2 W each is already being used in the LED floodlight SpectraWow+ from LDDE which is supposed to redefine additive color mixing. The result is a functional floodlight for stage lighting and architectural lighting with integrated RGB color mixing. It is also available with white light with 3200 K and 5700 K color temperature. Combined with a special honeycomb lens, the floodlight shines very uniformly. Furthermore, undesirable color shadows, common in many LED headlights with single-lens optics, are a problem of the past

Conclusion

The presented technology proves to be reliable and versatile applicable. With more than 8000 failure-free temperature cycles, especially reliable outdoor products can be designed. In addition, the high power densities which are required for Zhaga compliant products can be managed. This is already field-proven by a module with very similar specifications in a demanding application. ■

Lacquer Systems for PCBs – Optical Requirements and Performance in Applications

It is common knowledge that the quality of an LED luminaire doesn't only depend on the LED. However, there are many components and technologies that are not taken into account from the outset. Lacquer systems for circuit carriers is one of them. Dr. Manfred Suppa and Johannes Tekath from the Lackwerke Peters demonstrate the relevance of conformal coatings, solder resists and casting compounds and how they influence LED lighting systems.

Light emitting diodes (LED) are used in a steadily growing number of applications, and it is expected that they will continue to replace conventional light sources in more and more areas. Depending on the usage, reflective, diffusing or light-absorbing properties are required for the printed circuit board as a direct support of LED components, or respectively, for the solder resist forming the surface of the substrate. Furthermore, the necessity of insulating the assembly by conformal coatings or 2-pack casting compounds depends on the later usage of the assembly. The conformal coatings or 2-pack casting compounds should not impair the optical properties of the LEDs in the long run, despite their covering effect. This paper deals with the following aspects of using lacquer systems for circuit carriers in combination with LEDs:

- What are the optical requirements with regard to the substrate surface? How can different conformal coatings, forming the "surface finish", fulfill these requirements?
- Which classical lacquer technology criteria, tests and evaluation standards can be used for an optical characterization? Are there any specific features that should be considered? What are typical results? These aspects are discussed in detail, in particular with regard to the color stability/yellowing resistance of various white solder resists under different processing and test conditions.
- Are there any specific features in processing these lacquer systems compared to conventional applications? What would the typical approaches for a solution be?
- In which applications may clear-transparent 2-pack casting compounds based on polyurethane be used for "LED covering" even when combined with effect additives? What is the experience gained in the past regarding the long-term stability under various conditions? In this paper, studies on storage temperature and UV and/or weathering resistance will be discussed in detail.

Surface Reflectivity

Bodies either reflect, diffuse or absorb electromagnetic radiation, with these processes depending, amongst others, on the wavelength. With reference to visible light, this means that a body which fully absorbs in the range of 380 to 760 nm does not throw back any radiation provoking a sensation in the eye – this body is black, while a body that sends back all incoming wavelengths (of white light!) appears to be white.

The relevant parameter describing an "optical" surface is the so-called reflectivity, which is defined as the – diffused – light thrown back from a body. While bodies of perfect white have an even reflectivity of 100% for all wavelengths, black bodies do not reflect at all. Perfect grey bodies have an even reflectivity of wavelengths between > 0 and < 100%, while colored bodies display a selective reflectivity, meaning that they absorb a part of the light in such way that the thrown-back light is composed of different wavelengths areas, thus giving the impression of color. Figure 1 shows the reflectivity graph of a photo-imageable solder resist with the reflectivity factor being higher than 90 in the color-relevant spectrum between 400 and 780 nm.

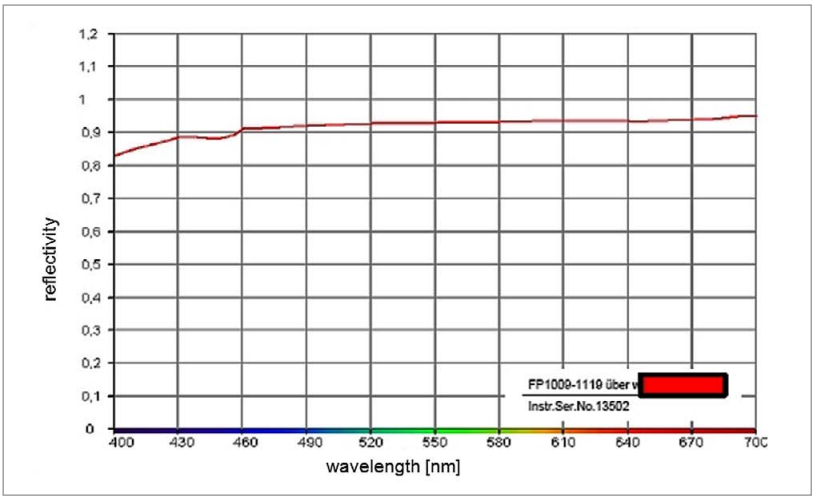


Figure 1:
Reflectivity graph of white photo-imageable solder resist

Measuring of Colors – Color Metrics

In order to quantitatively describe the color or a color difference, one may illuminate the surface to be measured by a defined light and measure the light that is thrown back, i.e. the reflected light. Mathematical calculations include both the type of light source and the color impression of the eye when measuring "color". In order to describe a color by specific parameters, the so-called CIE Lab System (more precisely, the L*, a*, b* system of CIE [A]) is usually applied, which is based on transforming the primary calculated color values X, Y, Z into the specific coordinates
L* (brightness),
a* (red-green-value), and
b* (yellow-blue-value).
The derivative of the Lab values will not be presented here, referring to [1] as an example.

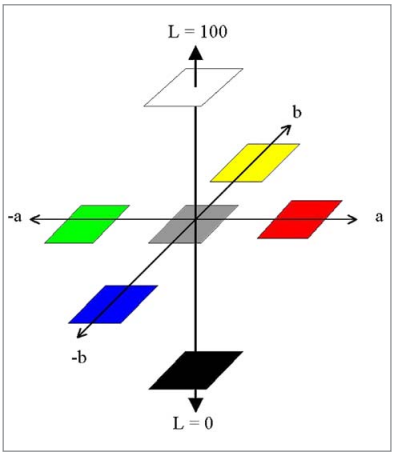


Figure 2:
Schematic figure of the CIE L*a*b* System and its color coordinates

As a major advantage, the CIE Lab System allows to describe color differences. Δ E* is the index of a color difference i.e. for the sameness or similarity of colors, calculated as spatial Pythagoras from the three values
$L_1^* - L_2^*$, $a_1^* - a_2^*$ and $b_1^* - b_2^*$:

$$\Delta E^* = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

For describing a white surface, one may either use the reflectivity graph (Figure 1), or refer to the brightness value L* from the CIE Lab System. Here a perfect white surface is characterized by the coordinates L*=100, a*=0 and b*=0.

The CIE Lab System has the advantage of limiting the parameters to three figures and of defining differences based on these values which correlate, to a large extent, with color sensation.

In the conventional lacquer industry, the method of colorimetric measuring is wide-spread and often used a criterion for specifying the quality of goods to be supplied, or for describing characteristics such as weather resistance or temperature stability.

Besides an evaluation in accordance with the CIE Lab System, there is the possibility of specifying the color change, i.e. the yellowing effect, according to DIN 6167 which is generally used by the paper industry. DIN 6167:1980-01 speaks about yellowing when an undesired yellowing of the material is noticed in consequence of a specific treatment. In this case, a yellowness value G is obtained from the primary values X, Y and Z. The change of this yellowness value between an untreated (G0) to a treated sample (G1) is calculated to give the yellowing index V designated as such.

The color coordinates of the Lab System, i.e. the values L*, a* and b*, can be directly determined by means of colorimeters. For measuring the yellowness index G, special software tools are necessary; should these not be available, this index must be calculated manually based on the X, Y, Z values.

Since the ΔE*, ΔL* and Δa* values for describing color distances and/or color changes are widely accepted, it is recommended to use these parameters. A typical L*, a*, b* evaluation of three white solder resists is displayed in figure 4. This description allows a detailed interpretation of color changes through physical measurement in connection with pre-defined values.

Colorimeters are composed of a light source, the sensor head with different geometries and a detector such as a spectrophotometer. Among the methods available for measuring, just spectrophotometers are suitable for taking a reflectivity graph in the desired wavelength range of 380 to 760 nm. To determine the color coordinates, two basic test geometries – 45°/0° and d/8° (integrating sphere) – are available, which can be easily combined as shown in the setup (Figure 3). The tests described below have been carried out based on the d/8° geometry and include an integrating sphere with gloss trap.

Both methods outlined above give a value for the difference. The smaller the difference, the yellowing index V or the ΔE* color difference, the lower is the yellowing effect or, respectively, the color change. The subject of yellowing and color measurement is described in detail in [1].

Expressed in ΔE*, the best quality (lowest yellowing) is that < 1. The grading towards lowest quality is shown by the respective color changes displayed in table 1.

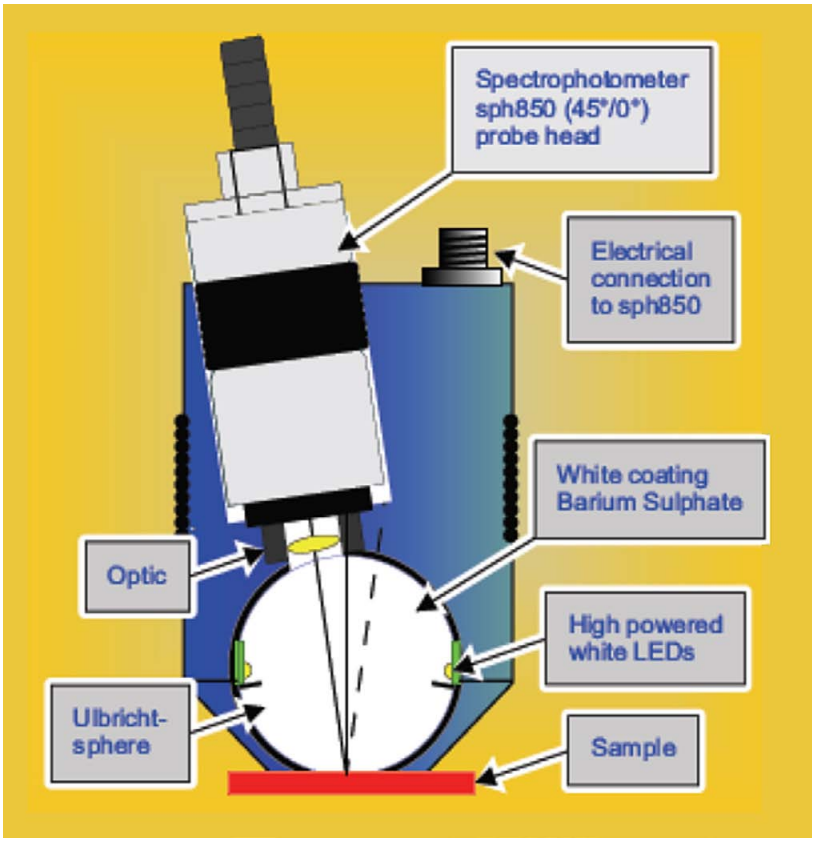


Figure 3:
Diagram of sensor head adapter with a d/8° geometry (integrating sphere) - (Courtesy of ColorLite GmbH)

Table 1:
Color differences expressed in ΔE* and their general evaluation

ΔE* Values	Description of visual appearance
ΔE* = 0 - 1	not visible in general
ΔE* = 1 - 2	little yellowing, visible by the trained eye
ΔE* = 2 - 3,5	medium difference, visible by the untrained eye
ΔE* = 3,5 - 5	distinct difference
ΔE* = > 5	strong difference

Covering Power

Another basic property of colored coating materials is the so-called covering power describing their capacity of hiding the color or any color difference with the substrate. The criterion applied here is the contrast between the contrasting fields of the substrate that is to be agreed upon. As a result of absorption and scattering, the covering power is a function of the coloring pigments. In case of white pigmented coatings, this is just a result of scattering. On the one hand, the covering power is dependent on the layer thickness, on the other it depends on the respective contrast of the substrate and has a characteristic limit. The covering power cannot be adjusted to any thinness of layer; the minimum layer thickness required for an opaque white lacquer in case of a black-white contrast is assumed to be approx. 40 µm. Unlike thermal curing solder resists, UV curing coating materials – including all photo-imageable solder resists – should be slightly transparent if a sufficient UV cross linking shall be ensured down to the substrate.

The physical limits of covering power have to be taken into account in processing: a lacquer applied in a layer of 10 µm looks less white than a 20 µm layer, while a layer of 30 µm, in turn, has a whiter appearance than that of 20 µm layer thickness. At a layer thickness of 40 µm or higher, the white color no longer depends on the thickness, thus the full covering power has been reached. If the color is to be evaluated or measurements be carried out based on a thickness of less than approx. 40 µm, the substrate shall be included in the evaluation. This means that the reflectivity graph and the L* value also depend on the layer thickness.

In figure 5, these facts are shown as an example based on the reflectivity graphs. A white photo-imageable solder resist has been applied and measured on copper in three different layer thicknesses – 20 µm, 48 µm and 60 µm. Here the lower reflectivity at 20 µm layer thickness due to insufficient covering power can be noticed clearly.

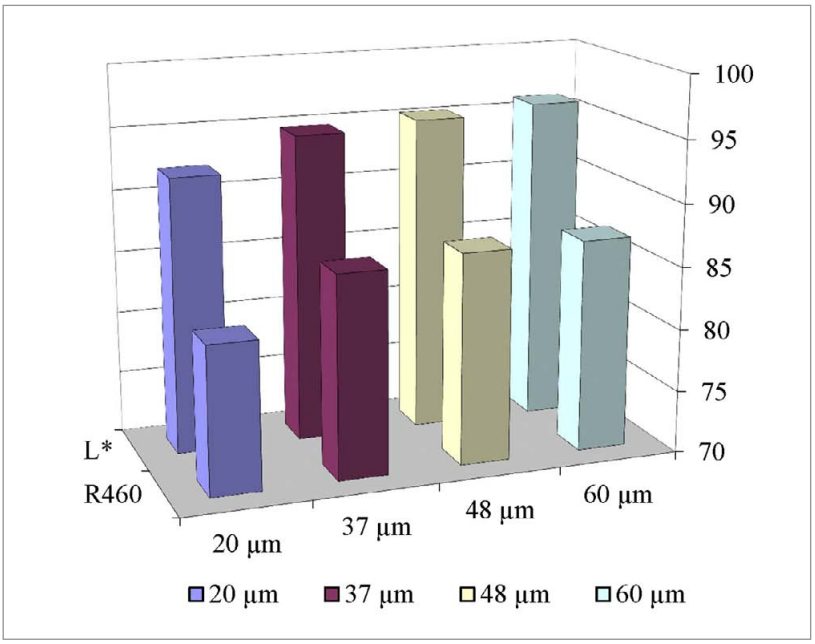


Figure 4:
The reflectivity expressed by the L* value of a white solder mask, depending on layer thickness

Solder Resists on LED Circuit Carriers

With the increasing use of SMD LEDs for illumination purposes and the request for a better luminous efficacy, it is more and more often required that the circuit carrier shall reflect, in an optimum manner, the light bound to fall on it. Reflectivity is defined as the diffuse reflection of radiation (light). In general, the circuit carrier is covered by a solder resist, which, besides

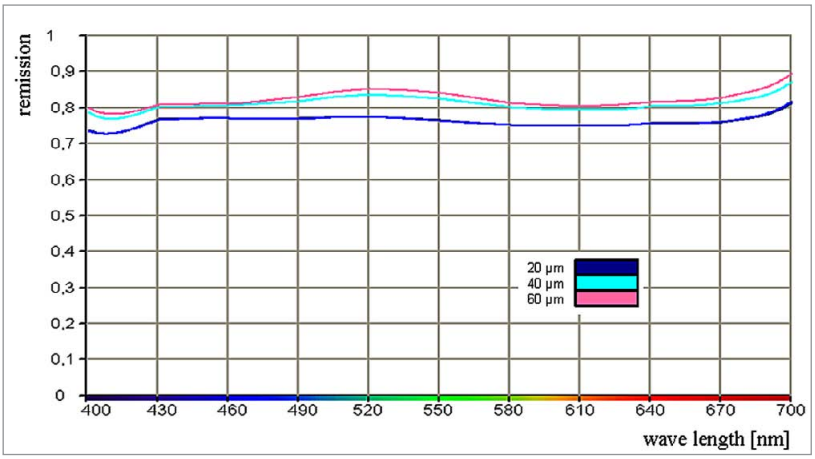


Figure 5:
The reflectivity of a white solder mask (ELPEMER SD 2491 TSW R1) applied on copper, dependent on layer thickness

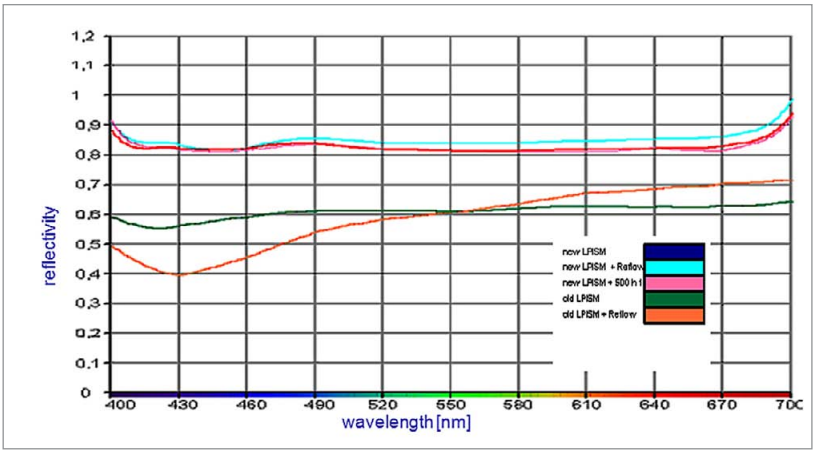


Figure 6:
Reflectivity graphs of both a classical photo-imageable solder resist and one belonging to the new generation, before and after reflow loading

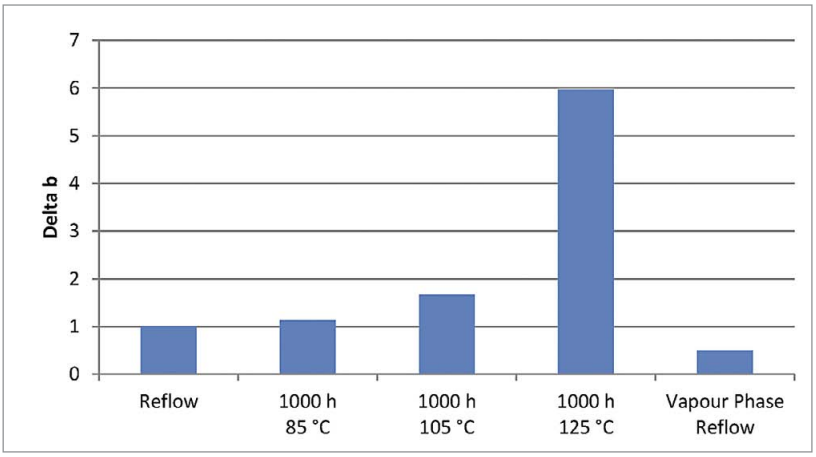


Figure 7:
Color change of a solder resist after a reflow process, vapor phase soldering and a long-term storage at different temperatures displayed as Δb (yellowing)

electrical insulation and the required chemical resistance, has to fulfill new functions for such applications.

When using a white solder resist, this may be the reflectivity of a background lighting application on the one hand, or high color stability under exposure to sunlight and/or heat on the other.

If a solder resist is white, the simple term “white“ does not fulfill the actual requirement such as an optimum reflectivity. The characteristic of reflectivity is closely connected with the color and can be described through colorimetric measurement as stated above. For this application, very high demands in terms of whiteness, reflectivity and color stability under temperature load and/or sunlight exposure can only be fulfilled by solder resists that were especially developed for this purpose.

When processed, solder resists undergo different temperature loads which may visibly affect the (white) color, one of them being the solder process. As a result, a change to the yellow color i.e. yellowing will take place, as shown in figure 6 by means of reflectivity graphs. A white solder resist supplied to an assembly company should undergo the lowest possible color change within subsequent solder processes.

As from the underlying mechanism of formation, there are different causes for yellowing:

- Heat
- Sunlight
- Environmental influence (such as moisture, chemicals)

In this context, yellowing is primarily caused by heat and sunlight, or by accelerated UV radiation simulating sunlight. The yellowing is considered to be light-induced when light rays of a wavelength below 380 nm (UV rays) are thrown on polymers. Through radical-induced photochemical reactions so-called chromophore groups are formed, creating the color effect. Heat-induced yellowing is the formation of such chromophore groups subject to polymers‘ exposure to temperatures > 100° for a longer period of time.

Such a color change can be measured either through the so-called yellowing index or via the color difference in the CIE Lab System.

For characterizing this color change, the above described color difference ΔE* may be used. In case of a pure white surface, the two values ΔL* und Δb* should receive special attention. While ΔL* describes the change of brightness, Δb* characterizes the blue-yellow shift thus yellowing in this case (Figure 2). A low Δ value indicates a high quality of the solder resist’s color stability, with differences smaller than 0.5 being hardly noticeable to the untrained eye.

It was generally found that any color change through the influence of heat – thermal yellowing – is primarily due to oxygen attack. In this way, solder processes without oxygen show less yellowing than those taking place under air exposure; this effect, however, can no longer be noticed visually for the white solder resists of the youngest generation (Figure 7).

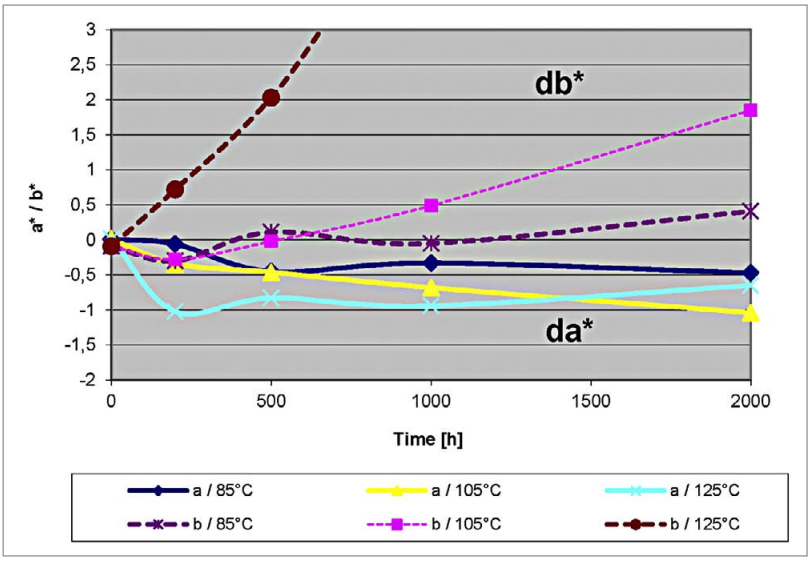


Figure 8:
Colorimetric study of the yellowing behavior of a white solder resist during long-term storage at different temperatures (85°C, 105°C, 125°C)

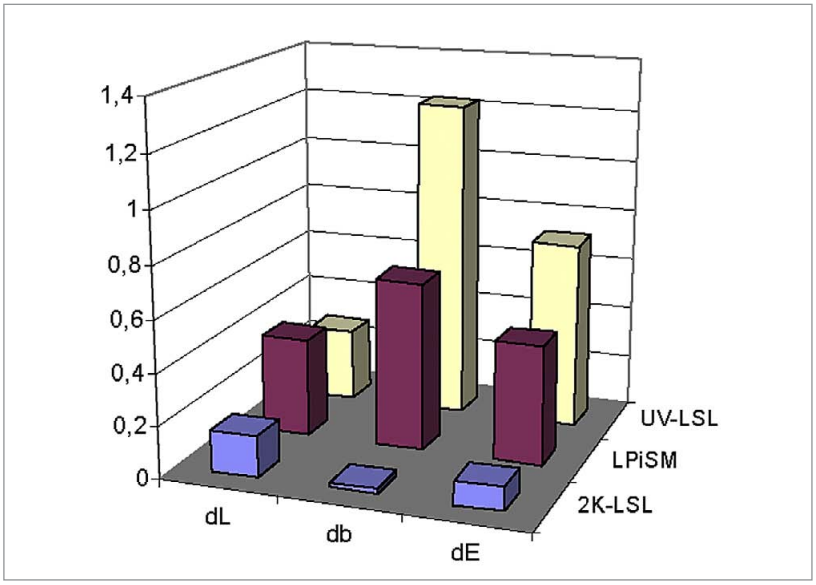


Figure 9:
Colorimetric evaluation of UV yellowing by means of the XENON test [B] (1000 h)
UV-LSL: UV curing solder mask
LPiSM: liquid photo-imageable solder mask
2K-LSL: two-component solder mask

As briefly mentioned above, color metrics are also perfectly suitable for describing the color behavior following long-term exposure to high temperature, and for determining any critical long-term temperature loads. Figure 7 is an impressive example of the shift of the b* yellowing values under different storage temperatures and two solder processes. A shift towards higher positive b* values describes a yellowing effect – in this case, temperature yellowing. As expected, the red-green-values a* have not changed. It can be clearly noticed that long-term temperature resistance is ensured up to 105 °C. A temperature load of 125 °C provokes distinct color shifts i.e. yellowing here. Colorimetric tests of this kind are suitable for measuring color resistance after long-term storage under high temperature, for example in accordance with the IEC 60216 [6] family of standards, and for determining the respective temperature index for optical characteristics.

Figures 7 and 8 further indicate that the yellowing effect occurring in solder processes is less due to temperature, but rather to a combination of temperature and air oxygen; in this way, solder processes under nitrogen show less yellowing than those carried out under a normal atmosphere.

In these examples, an acceptable temperature load is limited to 105°C; at higher temperatures the yellowing is unacceptable.

The electrical performance is not affected at all by yellowing; previous studies have revealed that there are no changes.

Under the influence of global radiation – commonly known as sunlight – many polymers display more or less distinct degeneration effects. Absorbing in the short-wave range of the visible light, the final products of the so-called photo-oxidation are the cause of yellowing processes of polymers, too. This yellowing effect particularly affects epoxy resins which are commonly used in the production of solder resists. To produce sufficiently light-stable white solder resists, these had to be developed based on a different polymer class.

In view of determining the light resistance or, respectively, the yellowing resistance, test specimens may be exposed to outdoor weathering for several years, for example within the so-called Florida test. If results shall be obtained on a short-term basis, one may choose among various accelerated weathering tests, for example the so-called Xenon test. In the frame of this test, the specimen is exposed to the radiation of a xenon arc lamp, the filtered spectrum and the irradiance of which are similar to natural sunlight. Appropriate short-term tests have been described by various DIN standards [2, 3]. According to past experience 250 h correspond, as a rule of thumb, to a one-year natural load. As an example, figure 9 shows colorimetric evaluation results of various solder resists following UV load. In this diagram, the Lab value changes have been given as numbers for simplification.

Clearly noticeable here is the yellowing effect revealed by the distinct change of the Δb value (db), while the brightness shift ΔL is much lower. For the three solder resists used as examples, the UV resistance after the 1000 h XENON test is very good; with the 2-pack solder resist being the most UV stable adjustment by far. Photo-imageable solder resists of the old generation have not been included here since their color changes of much more than 3 are out of question.

As expected, tests that were carried out based on an LED light illumination of 460 nm wavelength during 1000 h

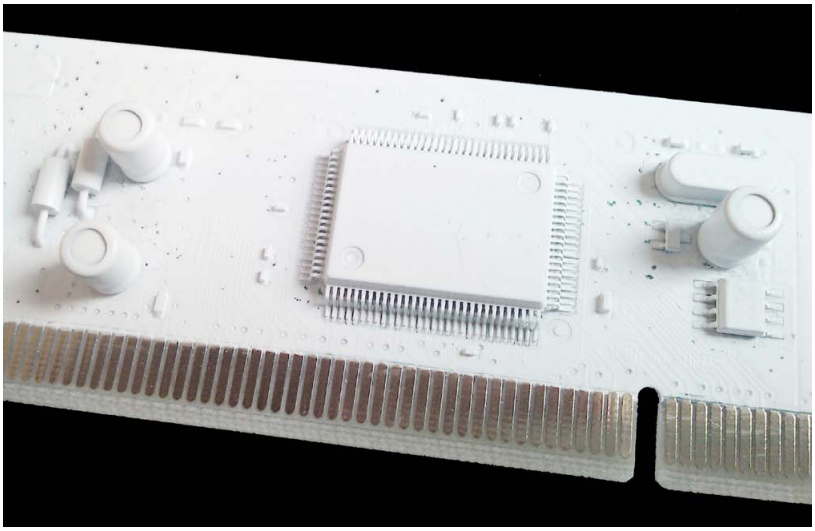


Figure 10:
Demonstration sample of a white covered conformal coating

reveal no change in reflectivity that is visually noticeable or measurable. Potential influence is not expected from the in falling light, but rather from simultaneous heat input likely to heat up the coating to 100 °C.

Protective Coating of LED Equipped Assemblies

The protective coating can be applied either on the entire circuit carrier, or on those areas left free from LEDs. If the LEDs shall be coated, too, the coating must fulfill, besides an electrical insulation under harsh environmental conditions, the requirement of a high optical performance including, for example, yellowing and gloss stability.

Another option of conformal coating is to use white opaque lacquers and to apply them by the selective coating method leaving LEDs uncoated. This method is suitable for perfectly covering dark components of single-sided LED circuit carriers. Conformal coatings or permanent coatings of this type are characterized by a high light and heat resistance featuring very high reflectivity values. As an example, a CIE Lab value of a white permanent coating for LED circuit carriers R460 is 0.92 for reflectivity, or, in terms of brightness L*, the value 97.

If printed circuit boards assembled with LEDs need to be completely coated for the protection against moisture, such conformal coatings are usually chosen which ensure an electrical insulation in different atmospheres on the one hand, and which, in terms of weathering resistance, display a very low tendency of yellowing under such loads on the other.

The colorimetric values obtained with transparent specimens cannot be compared with the traditional reflectivity measurement of white lacquers, for example. While color measurement of colored coating materials primarily reveals reflectivity characteristics, measuring of transparent materials rather display transmission or absorption properties. During measuring, rays pass through the body and reach the reflecting substrate, and pass on to the measuring value sensor (integrating sphere).

Figure 10 shows an example of a white, covering conformal coating applied on an electronic assembly, displaying the excellent covering power of this type of conformal coatings. Even black components are covered securely. It is understood that these coating materials also fulfill all general requirements placed on conformal coatings.

Conclusion

Thoroughly selected lacquers can increase system efficiency and protects the electronics. It helps to increase reliability, but there are big differences between products and their processing. While one product is very resistant against environmental influences others are not and for instance show yellowing very soon. To make the right selection and to achieve the desired results a close cooperation with specialists is mandatory. ■

Explanations:

[A] International Commission on Illumination (CIE - Commission internationale de l'éclairage)
[B] Acc. to DIN EN ISO 11341 with suntest CPS+, without humidification, irradiance: 550 W/m^2

References:

[1] Loos, Hans, Farbmessung, Verlag Beruf+Schule, Itzehoe (1989)
[2] DIN EN ISO 11341:2004-12, Beschichtungsstoffe - Künstliches Bewittern und künstliches Bestrahlen - Beanspruchung durch gefilterte Xenonbogen-Strahlung
[3] DIN 6167:1980-01 Beschreibung der Vergilbung von nahezu weißen oder nahezu farblosen Materialien
[4] Zuverlässigkeit von fotostrukturierbaren Lötstopplacken bei Belastung durch Temperaturdauer- und Temperaturwechselstress, 14. FED-Konferenz, 21.-23. September 2006 Kassel
[5] W. Berger, Untersuchungen zur Dauerwärmebeständigkeit von Anstrichen, farbe+lack, 72.Jahrg., S. 127-132 (1966)
[6] DIN EN 60216-1; VDE 0304-21:2002-09, Elektroisolierstoffe - Eigenschaften hinsichtlich des thermischen Langzeitverhaltens

DC-Grids – Challenges and Chances for LED Lighting

At the beginning of November many important aspects of DC Grids were discussed at the Fraunhofer Institute for Integrated Systems and Device Technology in Erlangen at the European Center for Power Electronics (ECPE) conference. Besides fundamental issues, very specific ones like how the introduction of DC Grids affects lighting technologies and especially LED lighting were part of the program. Below, Arno Grabher-Meyer from LED professional gives a summary of the speeches and expert discussions and gives us an idea of what the key ideas could mean to the LED lighting community.

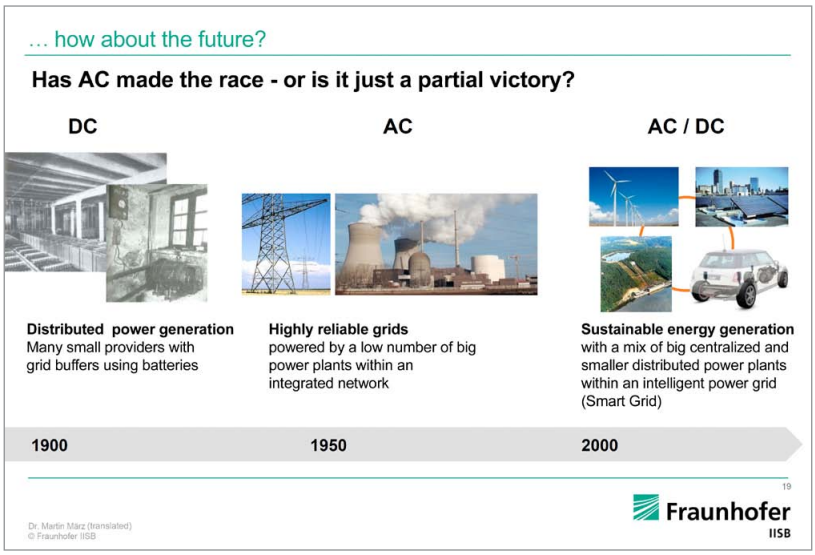


Figure 1: **History of the dominant grid current (Source: Dr. März, Fraunhofer ISB, translated)**

Since the dispute between Thomas Edison and N. Tesla more than 125 years ago, the question of whether AC or DC grids are the better approach arises from time to time. By the end of the 20th century it looked like AC had clearly won the race. But it wasn't true then and probably won't be true in the future. Before the 1950's AC and DC grids existed in parallel due to de-centralized electricity generation. From the 50's onward, centralized electricity generation became the standard and AC grids started to dominate. Since the beginning of the new century new technologies have brought DC back to the attention of technicians, economists, ecologists and politicians. Today, AC and DC grid advocates discuss this topic just as passionately as Edison and Tesla did between 1885 and 1891 although the arguments may be a little different. It is generally agreed that DC grids can reduce energy consumption but economical and ecological benefits are questioned as well as safety standards.

LEDs as semiconductors are DC driven and have additional advantages when installed in a DC grid environment. However, it is necessary to know and understand the DC grid concepts in detail and to know which one, if any, should be used to replace or complement the current AC grid. The dimensions range from room level to local, regional and even continental world-wide concepts. While the latter will probably not be realized in the short or mid-term, DC grids on a smaller scale are already being demonstrated in pilot projects and could become reality in the near future. The new trend back to de-centralized energy generation, especially from sustainable sources that provide DC current, could drive the development of local DC grids.

DC grids seem to be advantageous for LED lighting. LEDs, like all semiconductors, need DC current. Several concerns about AC grids don't seem to be relevant or are of minor importance in DC grids. But is a change to DC grids really that simple? Will it bring advantages for LED lighting systems with it? Or are there challenges that are not obvious at the first glance? To answer these questions it is necessary to have a closer look at current discussions and some technical issues.

Status Quo of DC Grids

DC grids can be found all around us - for instance - they are already standard in the automotive and aerospace industries. A battery is an

integrated part of such a system and energy requirements seem to be completely different to the requirements in buildings. Distances between source and load are, in general, relatively short and are very often regarded as special situations. This is correct in many cases but they are also struggling with overcoming difficulties that are relevant in immobile applications and common in all DC grids.

DC grids are also applied in island or so-called solar home systems. Although these are very often small scale systems with low voltage levels of typically 12 V to 24 V, specialist insights for these types of systems are useful for defining the crucial parameters and finding the right concepts for an optimized solution.

In addition to the areas mentioned above, several demonstration projects for DC grids have been initiated (mostly in server plants) and are running all over the world. The server plant applications especially seem to be textbook examples for DC grids. The derived results and conclusions are often questioned and sometimes considered not to be useful for other applications. These extremes must be covered by a new DC grid concept. Apparently the change to DC grids makes sense and the effort is paying off even when prototypes for switches and other equipment still need to be designed. There are similar aspects and difficulties and therefore some knowledge can be passed on to other applications.

However, there is still a lack of well-recognized results that are based on a proper scientific work. Therefore, uncertainties regarding the pros and cons of efficiency gain, costs or safety issues, are still high. In addition, some key issues have to be solved before DC grids will have a chance to be installed on a regular basis and DC products can become mainstream. This is true for some technical issues, but even more so for standardization issues. Voltage levels, grid topology, grounding, arcing, earth leakage circuit breaker requirements, over-current detection and load balancing are just a few questions that need to be solved, defined, and standardized.

Grid Topology

The first question that needs to be answered is what else can be covered by a DC grid. Does it make sense to discard our 230 VAC grid completely? Should we consider a hybrid topology? Or would it be best just to apply a DC grid on a very small scale for low power applications? To answer these questions it has to be taken into account that in the end, it is very likely that a completely changed infrastructure with de-centralized, distributed energy resources will be the result of the change to sustainable ("green") energy generation. At that stage, at least local DC microgrids [1] will make sense. As a consequence, the specifications for DC grids must incorporate the requirements for this type of system. That means that different voltage levels and the physical structures need to be defined.

Figure 2:
Evaluation of pros and cons of different DC grid topologies for an office lighting application (Source: Prof. Waffenschmidt, Cologne University of Applied Science)

Evaluation of different Aspects (incomplete example)

Application: Lighting in commercial buildings

Criterion	Ratings					Relevance
	+/-190V	+380V	-380V	380V High Imp.	380V= AC-Gnd	
Touching:						
Avoid fatal consequences	o	-	-	+	--	10
Less probable	-	+	+	+	-	7
Less burnings	+	-	-	+	-	5
Detection of 1st fault to earth	+	+	+	-	+	9
Touching after 1st fault occurred	o	o	o	--	o	5
Short Life-> PE Detection	+	++	++	-	++	9
Short 0V-> PE Detection	+	o	o	-	o	8
Rectifier simplicity	o	-	-	--	+	3
No CM-mode current (50 Hz AC)	++	++	++	++	--	2
Contact corrosion	-	-	o	o	-	1
Summary	**27**	**19**	**20**	**-16**	**-7**	

Calculation:
++ = + 2Pt
+ = + 1Pt
o = 0Pt
- = - 1Pt
-- = - 2Pt
multiplied by Relevance

Fachhochschule Köln
Cologne University of Applied Sciences

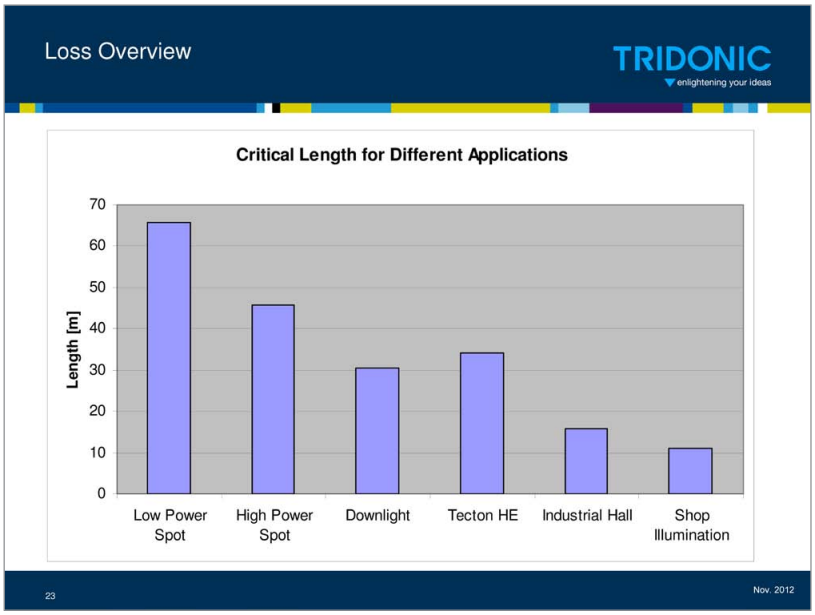


Figure 3:
In a 48 VDC grid the losses exceed an acceptable amount of 5% after a certain distance, dependant on the power requirements of the luminaire. This is the critical length (Source: John Schoenberger, Tridonic)

Voltage levels

Several voltage levels are being discussed. For low power applications of up to 100 W per line, for example, eMerge Alliance favors 24 V, and for high energy distribution 380 / 400 V. While the 380 / 400 V specification is already favored by many specialists and organizations, the 24 V approach may be questioned. Meanwhile, even the automotive industry is promoting a switch to a 48 V system.

P. Brueckmann, specialist for DC island systems, demonstrated in numerous projects the feasibility of 24 VDC grids [6]. A maximum of 1.5 kW can be realized in smaller grids. Mr. Brueckmann strictly advises using a star-topology for distribution. Arcing is no problem for most 230 VAC switches at the nominal current. Because this is already voltage standard, numerous components, especially semiconductors like Mosfets or voltage regulators, are available. If buffer batteries are part of the system, cell reversal is still detectable.

J. Schönberger from Tridonic [5] demonstrated that even when using efficient LED lighting systems, several lighting applications, like office lighting, may become impossible to be achieved with good performance and reasonable costs when applying the 24 V approach, and a challenge with 48 V DC grids (Figure 3).

These two voltage levels are of special interest due to the SELV (Safety Extra Low Voltage) classification. Above the 60 V SELV limit no other voltage 380 / 400 V is considered from specialists to be a relevant alternative to become a future standard.

Physical topology and grounding

Independent of the chosen voltage level, a DC grid can be set up as two-wire grid (+/-) or three-wire grid (+/0/-). Both systems have advantages and disadvantages and differ clearly regarding the topology and construction of safety measures.

The choice of the topology is relevant for the grounding type and its consequences. The relevance for a low voltage level may not be that big or clearly visible, but for the discussed 380 / 400 V grid the different grounding options have relevant consequences (Figure 4).

For the two wire solution, there is just a choice between a floating high ohmic (<1MΩ grounding or a single ended low ohmic (<1Ω) grounding). The single ended system bears the safety risk that a maximum current of 380 mA at 380 V can seriously endanger life.

For the three wire system there are more options possible; symmetrical low or high ohmic grounded or AC grounded. While the AC grounded solution also leads to a maximum current of 380 mA at 380 V, the low ohmic symmetrical grounded system has a maximum 190 mA at 190 V which is just a quarter of the energy, but still a lethal value. The high ohmic symmetrically grounded system limits the current to a maximum of 17 mA. Under current regulations this is currently recognized to be a safe value for DC systems.

Besides safety issues, there are also other aspects of grounding to be issued; for instance EMI. A floating system is less prone to have common mode currents. These aspects and some other arguments may have different relevance for different applications or projects. In the end, the best overall solution should be selected.

For lighting applications, Prof. Eberhard Waffenschmidt from the Cologne University of Applied Science evaluated the presented options and came to the conclusion that a three wire system with +/- 190 V would be the preferred choice in most cases. This approach, like the 380 V approach, is sufficient for higher loads and therefore could replace the existing 230 VAC grid [17].

Following that approach, one could also imagine a +/-24 V or a +/-48 V DC system, or maybe even other voltages. The main question that appears is: What for, where and when does it make sense to use one of these voltages, or does it in general make sense ?

Arcing – One of the Biggest Challenges

The problem of arcing has several issues. Arcing can be caused because of damaged isolation which leads to a short circuit. Serious risks and damages should be prevented by using an appropriate fuse. Improper contacts or a break in the line is more critical and has to be detected. Otherwise, arcing will ignite a fire with the tremendous amount of heat produced within a very short time. In addition, plugging and unplugging loads that are accidentally switched on involves a very high risk.

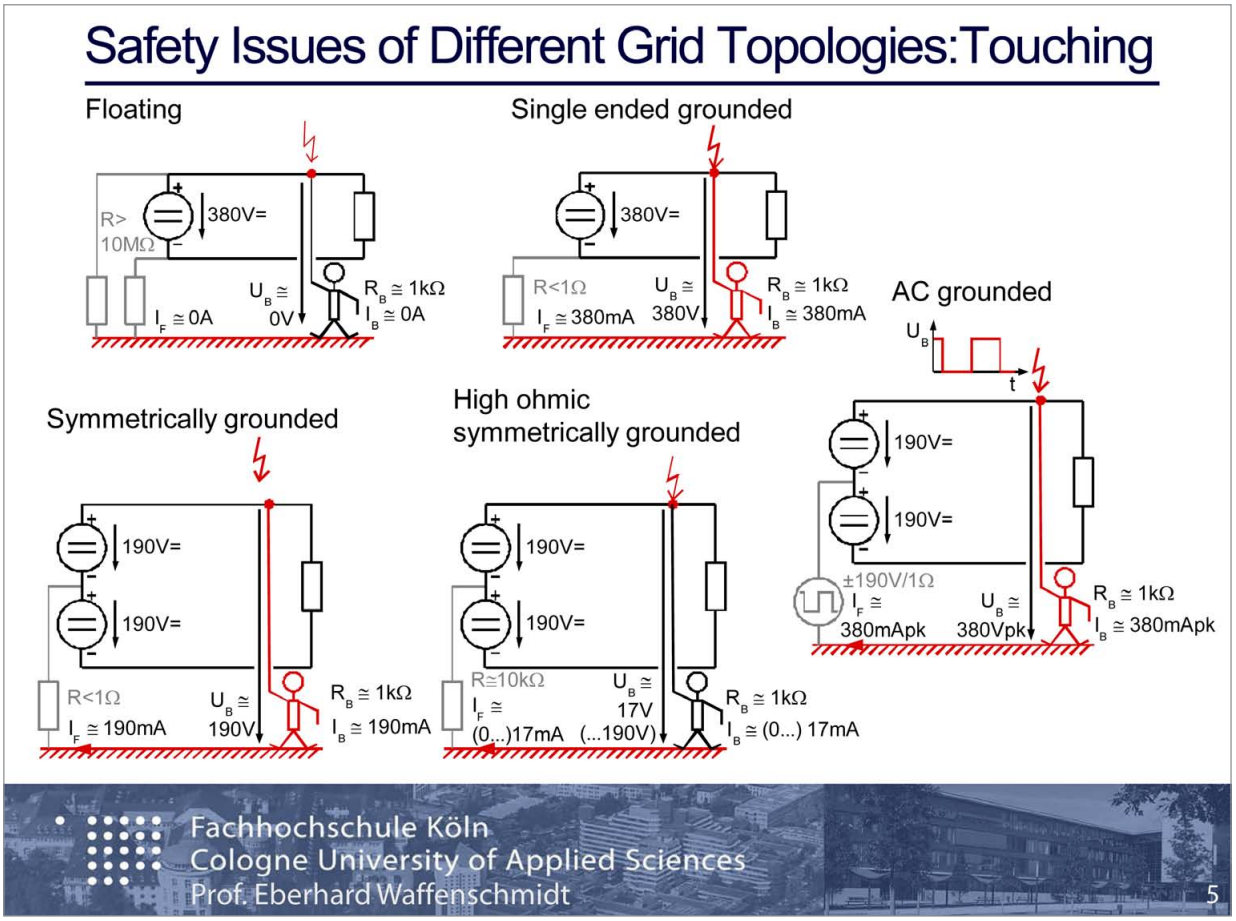


Figure 4:
380 / 400 VDC grids are the most likely option for replacing 230 VAC grids. The various topologies have relevant consequences regarding safety issues and necessary protection measures (Source: Prof. Waffenschmidt, Cologne University of Applied Science)

One might think that this would only be critical at very high voltages; maybe those beyond the SELV voltage. But this is a misapprehension. At very high currents, 24 V, and under certain conditions even 12 V [13], may cause and sustain arcing that leads to serious damage and risk.

Detection of arcing is one of the biggest issues. While there are required arcs, for instance in discharge lamps, the undesired arcs have to be distinguished properly. Especially in-series arcs are critical and can be reduced by using an appropriate driver concept and detection method.

Switching DC and Safety Circuit Breakers

The switching of DC currents, especially high currents and high voltages, is known to be very critical due to arcing. Different switching concepts are possible. They are also relevant for automatic safety circuit breakers. Currently, in many countries, only a mechanical solution that provides physical isolation fulfills the regulations. D. Leber from Systemtechnik Leber [15], P. Meckler and C. Strobl from E-T-A (Elektrotechnische Apparate GmbH) gave a comprehensive, up to date, overview in this field [12,13].

A very common method is switching with arc chutes and a magnetic blow field (Figure 5). The principle is similar to the principle of an AC circuit breaker and is relatively simple but effective. The contacts of a switch open and the arc builds up. The magnetic field causes the arc to expand into the arc chutes where the path again increases and is split up until the voltage that is necessary to keep the current flow over the given distance becomes higher than the provided voltage. The arc extinguishes. This would be physical isolation.

Electronic circuit breakers are an elegant method with which to switch DC loads. They are fast and no arcing appears. In addition, they can provide increased functionality with some integrated intelligence. They can act as a current limiter and, by that, withstand and reduce inrush current. They can also react on lower overload limits without failing because of tolerable spikes. One disadvantage is that no physical isolation appears; another is the energy losses of the electronic components.

In typical Hybrid switches an electronic component takes over the current when arcing starts and a defined voltage difference is exceeded. This causes the arc to extinguish. The electronic is deactivated and additional mechanical switches will be opened to provide physical isolation. Main disadvantages are the relatively high costs.

However, especially when having in mind a worldwide application of a safety switch, the design criteria are very challenging due to different and changing standards.

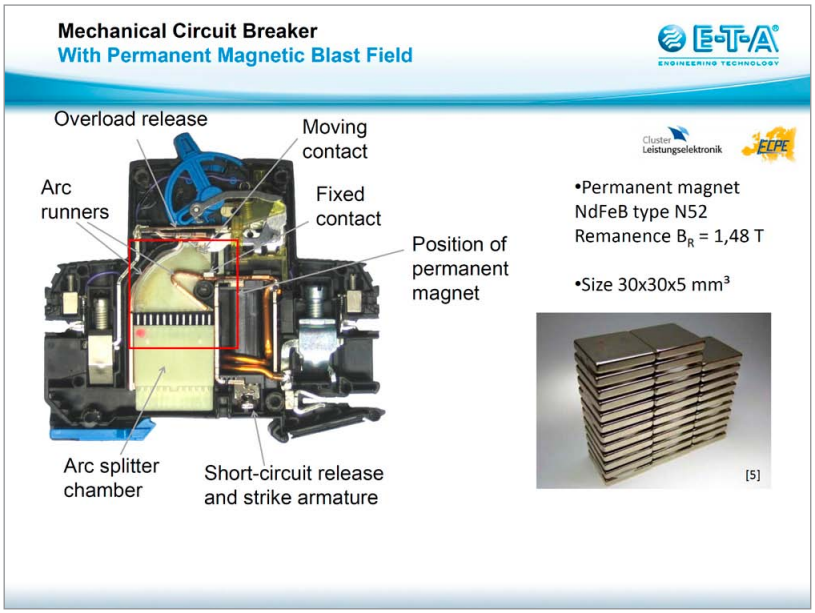


Figure 5:
Structure of a mechanical circuit breaker for DC currents (Source: Peter Meckler, E-T-A Elektrotechnische Apparate GmbH)

Personal Protection

Current knowledge regarding the health risks of electricity and DC voltage and current limits is based on research done during the 50's. These results are questioned by some specialists. We have to accept this data as being relevant until new research is done, either confirming or disproving it.

According to the existing data and regulations, there is clear evidence that DC currents may be up to three times higher than AC currents before they become lethal. Therefore limits are different for AC and DC currents. To avoid injuries, DC grids above 48 V need residual current protective devices (RCD) with sensitivity below 10 mA. Both AC and DC currents have to be detected. Unfortunately, no standard product is available today. While being costly, C. Loef from the RWTH – ISEA sees the best currently available solution in combining type B RCDs with a DC switch in series [14].

TN-S grid structures are the best solution due to a low contact voltage with accordingly low residual currents in case of a fault.

DC Grids and Efficiency

In combination with de-centralized energy generation DC grids apparently have a clear advantage over AC electricity distribution. They are more efficient because a lower number of inverter stages are necessary. Costly and space consuming PFC's can be eliminated, batteries can be directly integrated to store energy. - It looks like a perfect system!

Looking at the mentioned issues, it would be perfect if we could provide a constant voltage. But there are also reasons to allow a floating voltage between, for instance, 260 V to the nominal 400 V for minutes and up to 600 V for milliseconds. This standard is in discussion for datacenters and telecom facilities. It's possible that it could also be taken over for other types of DC grids. This means that every converter has to deal with varying voltages and again needs some energy buffer, usually a capacitor, to compensate a part of these fluctuations. Therefore efficiency is sacrificed and costs and space savings are reduced. In an example, U. Liess from OSRAM GmbH showed that a DC version of their AC FL lamp ballast gains less than 1% overall efficiency [18].

On the contrary, M. März from Fraunhofer IISB showed that DC/DC converters with efficiencies of up to 99% are possible and assumes that converters with more than 95% efficiency should be economically makeable [2]. Compared to most of today's AC/DC converters, which often have efficiencies below 70-80%, this would mean a tremendous energy saving.

However, when comparing state-of-the-art AC/DC and DC/DC converters, the difference is much smaller and the example from Mr. Liess certainly shows the technical "truth" for mass production of well-designed products. The drawback of AC/DC converters is not technical feasibility of more efficient products. It is the cost pressure on small devices that use cheap designs and components resulting in a poor efficiency of sometimes below 60-70%. DC could help to avoid that by displacing the costly structures from a converter. But we won't get rid of the AC/DC converter; it can be designed for best efficiency. But there is still one issue that remains: Even this converter follows a typical efficiency over load curve and will produce permanent losses 365 days a year. A DC grid design will be the key for system efficiency. Poor design may probably lead to comparable or even higher losses than today's conventional AC grids.

Regulations and Standards

The experts' discussion as well as the presentation from Mr. D. Barthel from VDE/DKE disclosed that there are numerous details that need to be standardized [23]. Sometimes there is even information missing to setup a standard on a proper scientific or technical basis. In addition, standardization should be aligned on a greater basis to avoid too many different regulations in different countries. Preferably, a global solution should be targeted.

For that reason the Strategic Group (SG) 4 "Low Voltage Direct Current (LVDC) distribution systems up to 1500 V DC" was established in 2009. Some very specific standards or quasi-standards have been realized for IT and server plants and mobile products or battery driven vehicles. But they do not cover all technical aspects. However, regulations should also incorporate these existing standards, or at least be aligned to them.

For a successful, wide spread, introduction of DC grids standards are necessary but they will not be realized immediately. This will still take some time.

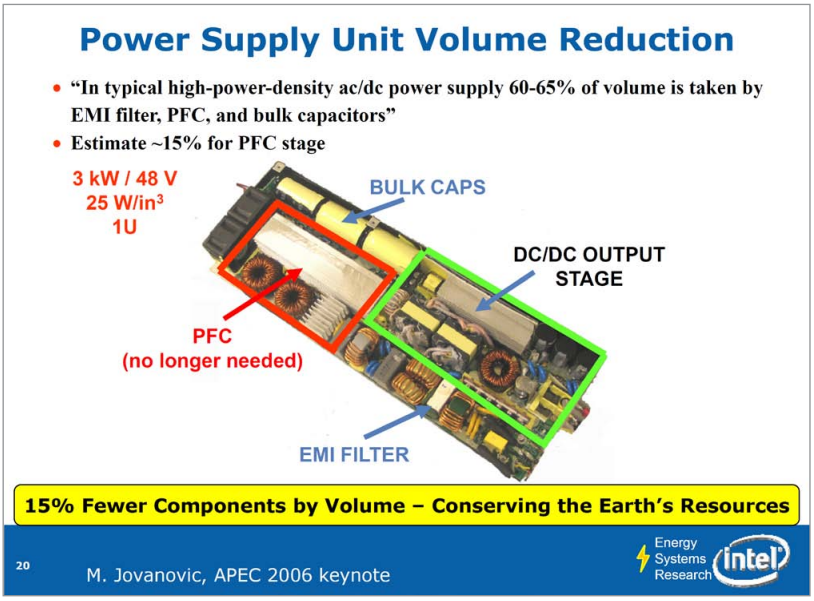


Figure 6:
In 2006 M. Jovanovich showed that a volume of between 15% and 60% less space is needed for DC supplies

DC grids make driver design simpler to a certain degree. Therefore system costs for LED lighting are lowered and can come closer to conventional lighting. Nevertheless, simplification potential is limited. Drivers need to be able to withstand and handle voltage fluctuations. For example, a 400 VDC grid of at least 260 VDC to 400 VDC.

Currently, lighting is responsible for about 20% of the overall electricity consumption worldwide and has one of the largest energy saving potentials. To optimize this potential further, it would be desirable to match the grid specification to the requirements of future lighting systems.

Conclusions

DC grids will not be a standard installation in the near future, but it could be a growing niche for which LED/OLED lighting could be the preferred method. Mainly two voltage levels may be defined. The Low Voltage domain of 380/400 V is likely to be the first choice. In the Very Low Voltage domain it is less clear if 48 V or 24 V is the favored voltage level.

DC grids definitely have an advantage when combined with alternative energy generation and local energy storage systems. Therefore, the speed of adoption also depends on political decisions. How willing are governments to support de-centralization of power generation? Or will they stick to the traditional centralized system of large power plants?

All in all, at the current time, there are many uncertainties about DC grids and no clear direction is given. While most modern AC drivers can also be powered by DC current, a dedicated DC design is necessary to gain full advantage. The lighting industry should be prepared and active collaboration of lighting organizations in standardization bodies for DC grids should be intended. ■

Definitions:

[A] A microgrid consists of interconnected distributed energy resources capable of providing sufficient and continuous energy to a significant portion of internal load demand.
[B] A microgrid possesses independent controls, and intentional islanding takes place with minimal service interruption (seamless transition from grid-parallel to islanded operation).

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Next LpR: Optics, Design & Impact of Deviations on Light Quality
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Optics: The Influence of LED Emission Characteristics on the Efficiency of Lighting Systems
In general lighting, efficiency is the main focus. Under specific operation conditions, the main issue appears to be luminous flux. This paper takes a deeper look at the influence of LED radiation characteristics. The consequences one might face in applications can lead to lower efficacies and higher $/lm on a system level.

Application: An Economical Omnidirectional A19 LED Light Bulb Technology
In this article, the award-winning Light&Light™ LED light bulb technology developed by ITRI will be illustrated. As a background, traditional light bulbs and current LED bulbs are taken a look at. The technical advantages and lower costs of the first A19 all plastic light bulb, the Light&Light™, achieved without sacrificing performance are discussed.

Optics: How Silicones are Evolving to Meet LED Lighting Industry Needs
Objective material selection for various target applications is key for successful product development. The article will explain how features of silicone materials can help designing and molding components for photonics applications, with a particular focus on recent technology challenges facing the integration of silicone resins into LED lamp and luminaire fabrication. Organics will be compared to silicones with an emphasis on differences in bulk material characteristics that are the key considerations of optical designers and process engineers.

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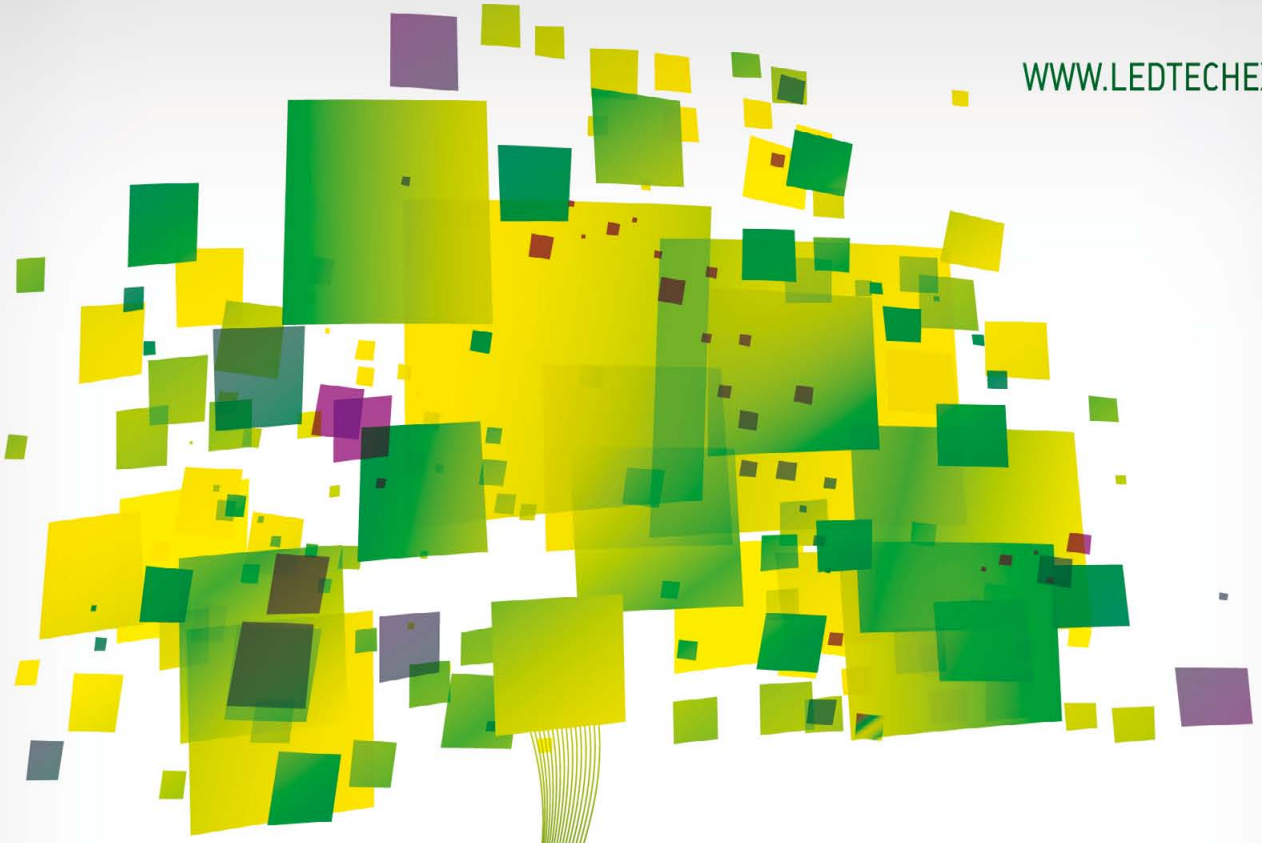

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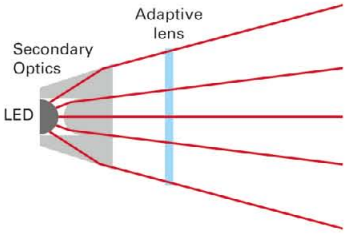
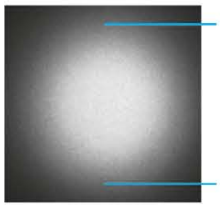
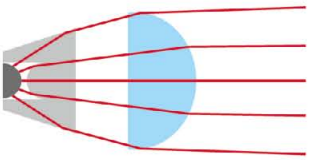
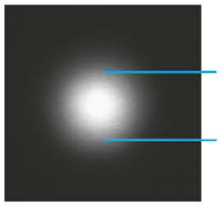




Flood angle





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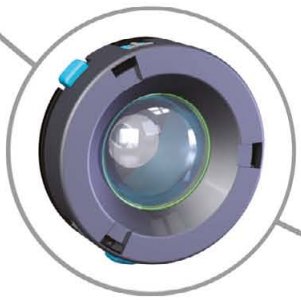

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