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TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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Critical elements for LED systems P.33

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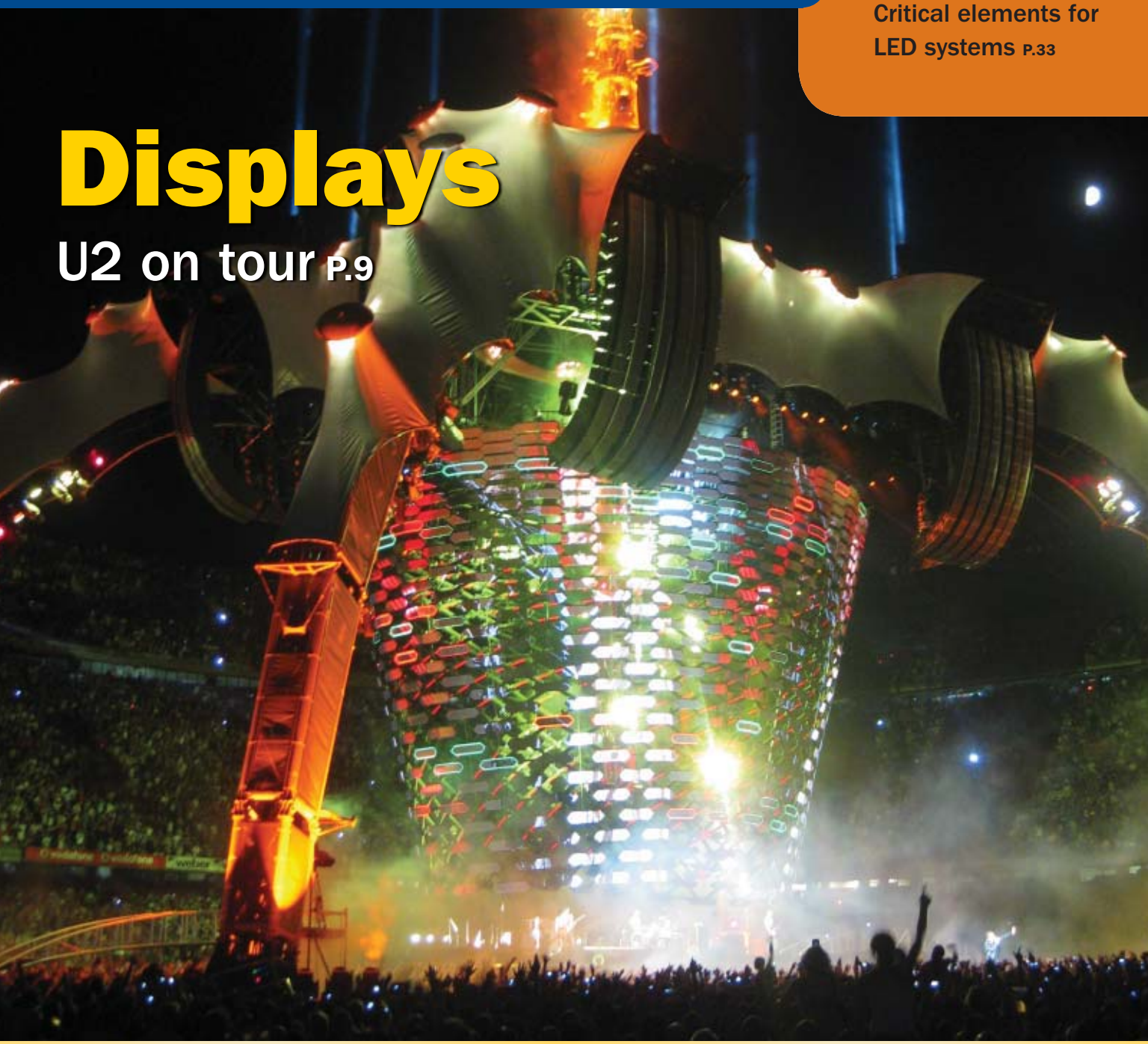

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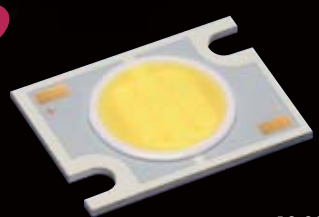

13.39W

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IF:720mA
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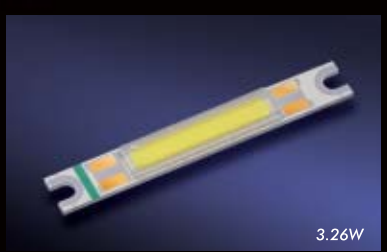

3.26W

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LEDs MAGAZINE®

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Cover Story

Barco supplied LED modules for this 360° moving display for U2's latest tour. The screen has 500,000 pixels of video, making it the biggest LED screen ever used in concert touring (see p.9).

features

columns/departments

commentary

Raising public awareness of LEDs

Many people in the LED industry often find themselves trying to explain to "the man on the street" what LEDs are all about, and may resort to examples with which people are familiar, such as traffic signals, or car brake lights, or flashlights. In consumer products, the use of LED technology is now being widely used on marketing material, and I have even seen an ad for a flashlight, in a mainstream magazine, that named the specific LED maker. Whether this name influences many (or any) purchasing decisions is not clear.

In terms of raising public awareness of LED technology, a great example is Samsung's latest campaign promoting its "LED TV" products. The term "LED TV" is a little controversial, and in the UK it is being looked at by the Advertising Standards Authority. Of course, Samsung doesn't actually make LED TVs, and is in fact talking about its new LCD TVs with LED backlights (see p.37). Our "man on the street" probably doesn't worry too much about this distinction, but the important part is that the benefits of using LEDs are clearly understood.

In laptop PCs, consumers want thin screens and low power consumption (equating to longer battery life), features that can be enabled by LED backlights. As our article on p.36 explains, it looks like the long-promised acceleration in demand for LED backlights is finally with us, which will bring some interesting changes as the industry struggles to cope with demand for billions of more LED chips. Display makers such as Samsung and LG have announced consolidation and investment in their LED production capabilities, to try and secure their supply chains for LED backlights (see p.9). Rival manufacturer Sharp already has an established in-house supply of LEDs and backlights for its own LCD panels. These companies are also looking ahead to future growth in the lighting market, an essential part of which will be to raise public awareness of the benefits of LED technology.

Light bulbs "not sexy"

Energy efficiency is back on the agenda in the USA, if it ever left. President Obama announced new rules to accelerate the phase-out of certain inefficient types of incandescent and fluorescent lamps, and at the same time allocated $50 million for solid-state lighting R&D, which the Department of Energy quickly offered in its latest funding round announcement (see p.17). "Now I know light bulbs may not seem sexy," said the President, before explaining that the planned phase-out could eliminate the need for as many as 14 coal-fired power plants.

Elsewhere throughout the USA, cities are rushing to spend stimulus finds that have been provided by the American Recovery and Reinvestment Act (ARRA) to promote energy-efficient technologies. Replacing conventional street lights with LED fixtures is the type of project that ticks all of the boxes. However, if it is done in a rush, with a focus on lowest initial cost rather than ensuring quality and performance in the long term, then the result could be disappointment. San Jose and Welland, Ontario are examples of North American cities that are taking a more considered approach (p.14).

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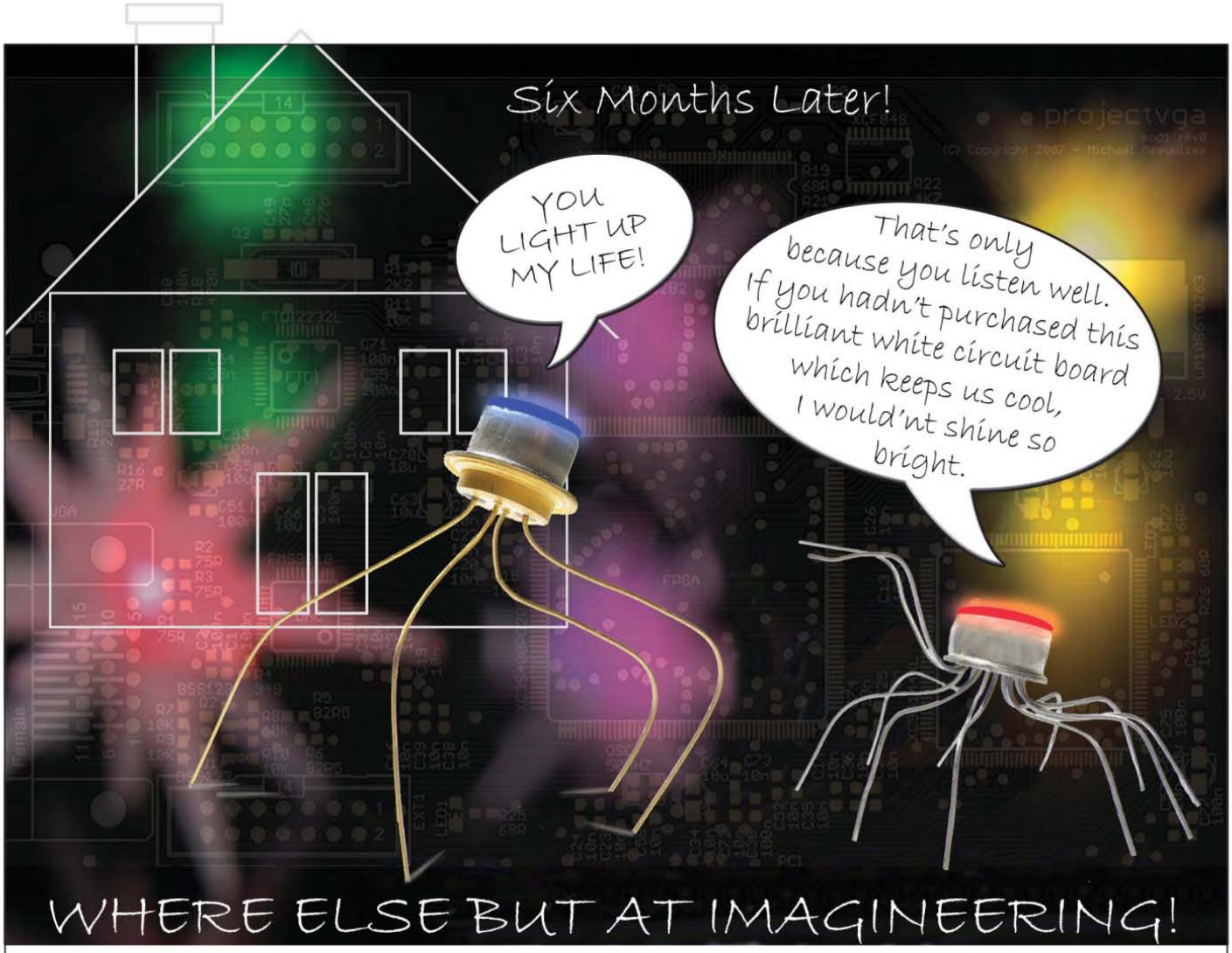

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Tomorrow's LEaDers in Canada
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Casting the SSL Net in Canada
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Featured Companies

The following have recently been added to the LEDs Magazine site as Featured Companies (see www.ledsmagazine.com/buyers/featured):
Alpha-One Electronics · Ecolighting Technology · Philips Lumileds · D-LED Illumination Technologies · LedLink Optics Inc.

ADVERTISERS *index*

FEATURED *events*

LED Japan Conference & Expo/ Strategies in Light

September 16-17, 2009
Yokohama, Japan
Participate in the leading HB LED and lighting industry event in Japan and learn about the latest innovation in HB LED markets, applications, products, and manufacturing. The 2008 conference was highly successful, attracting over 2,700 attendees and more than 54 exhibitors. The event is moving to a larger venue in 2009 — the Pacifico Yokohama — to accommodate the expected growth in attendance.
More details: www.sil-ledjapan.com

China International Optoelectronic Exposition 2009
September 06-09, 2009
Shenzhen Convention and Exhibition Center, China

IES Street and Area Lighting Conference
September 13-16, 2009
Philadelphia, PA, United States

PLASA 09
September 13-16, 2009
Earls Court, London, United Kingdom

Light Canada
September 24-25, 2009
Toronto, Canada

Organic Semiconductor Conference (OSC-09)
September 28-30, 2009
London Heathrow Marriott Hotel, United Kingdom

OLEDs World Summit 2009
September 29-October 01, 2009
Hotel Kabuki, San Francisco, United States

China SSL 2009
October 14-16, 2009
Shenzhen Convention & Exhibition Center, China

See www.ledsmagazine.com/events for event reports, latest updates and related news.

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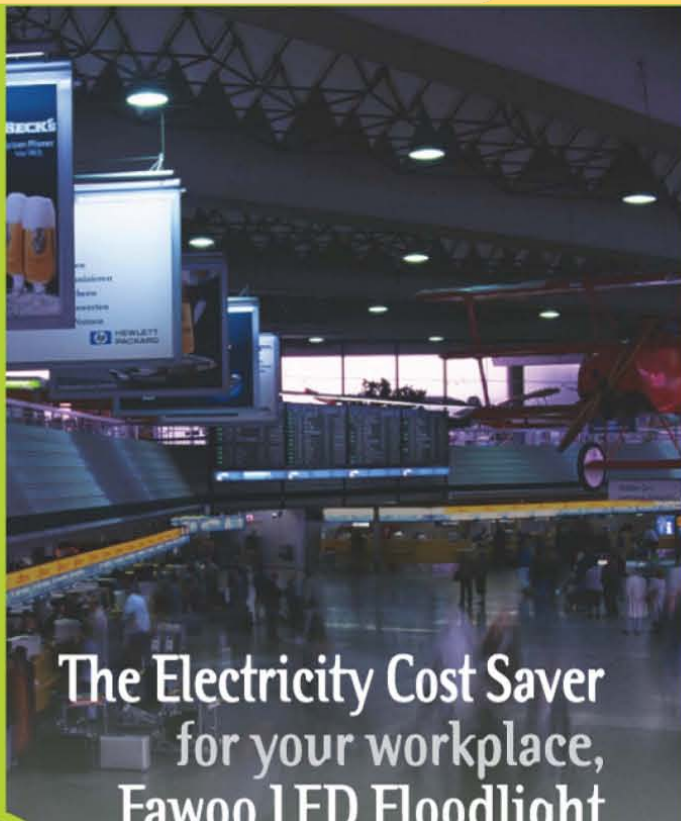

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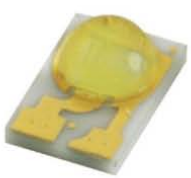

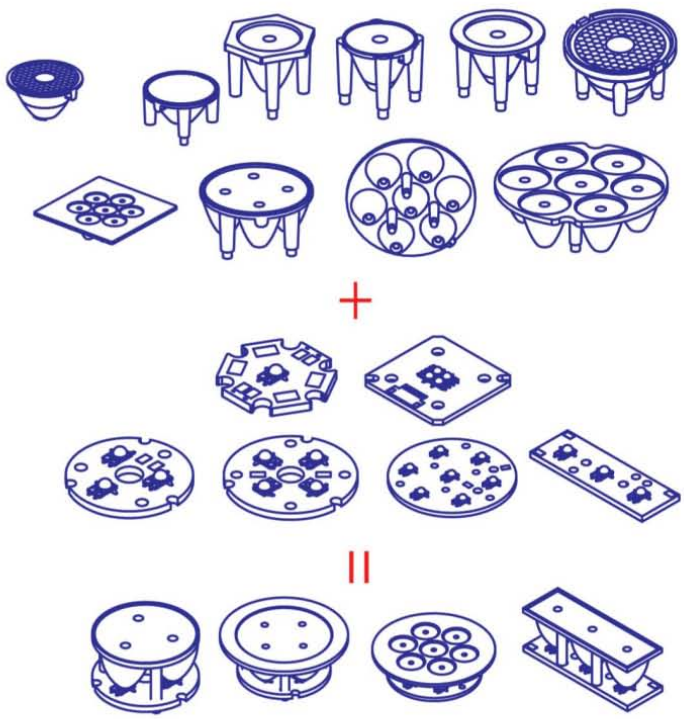

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news views

BUSINESS

Korea opportunities for Samsung LED and LG Innotek

As demand for LEDs in LCD backlighting and general illumination continues to show signs of healthy growth, two major players in Korea are realigning their businesses to benefit from the LED boom. Samsung and LG are among the world's leading TV makers and are both at the forefront of introducing LCD TVs with LED backlights (see p.36). Both also have subsidiaries that make LEDs in Korea, namely Samsung Electro-Mechanics Co., Ltd. (SEMCO) and LG Innotek Co. Ltd. Also, both companies are making investments that will focus their efforts in the LED space, helping to consolidate their supply chains in their LCD display businesses, and gearing them up to address the growing demand from the lighting market. Currently, Seoul Semiconductor is Korea's largest LED maker by some distance.

Showing Samsung's commitment to the LED business, SEMCO and Samsung Electronics Co., Ltd. (SEC) have announced the formation of Samsung LED, a 50:50 joint venture with equal investment from the two companies. The JV was first announced in February 2009 and is set to be established on August 31. SEMCO has operated Samsung's LED manufacturing business since 1995. The new Samsung LED has epitaxial wafer and chip production sites in Korea, and LED packaging sites in Korea and China.

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LED fixtures based on Acriche emitters from Seoul Semiconductor have been installed as the main interior gallery lighting on several floors of the National Palace Museum of Korea. See www.ledsmagazine.com/casestudies/18960.

AWARDS

Isamu Akasaki awarded Kyoto Prize for LED work

The Inamori Foundation has announced that Dr. Isamu Akasaki will be awarded the Kyoto Prize in Advanced Technology for 2009. This international award honors "significant contributions to the scientific, cultural and spiritual betterment of mankind." The award is presented annually in three categories, with winners receiving a gold medal and 50 million yen (around $500,000). Akasaki, 80, will receive the award for his pioneering work that led to the development of the blue LED. A semiconductor scientist, Akasaki serves as a professor at both Nagoya University and Meijo University in Japan.

The award citation reports that, in his efforts to develop the blue LED, which was once widely regarded as technologically

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DISPLAYS

Barco creates giant 360° LED screen for U2

Barco has supplied LED modules for a huge, transformable screen for U2's latest world tour, which kicked off on June 30 in Barcelona, Spain. The 360-degree screen forms a 24 x 16m oval and hangs above the stage, but can expand in the vertical direction to surround the band as they perform (see front cover).

Marking the third time this decade that Barco has supplied LED modules to a major U2 tour, the latest screen has 500,000 pixels of video, making it the biggest LED screen ever used in concert touring. The stage and show were created by long-time U2 designers Willie Williams and Mark Fisher. Barco supplied half a million FLX-24 LED pixels, which are integrated into a transformable structure designed by Barco's Innovative Designs, based on an invention by Chuck Hoberman.

The LED pixels are positioned onto hexagonal-shaped boards, with about 500 LEDs per board, which are mounted onto a giant cantilevered frame. The hexagons can form a contiguous screen 6m in height, or they can be separated to extend the screen in the vertical direction to a height of 22m, with open areas between the groups of LEDs (see photo) so that the

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news+views

Korea from page 9

Samsung expects the high-brightness LED market to grow in excess of $12 billion by 2013, with general illumination being one of the drivers. The company says it is "committed to being one of the leaders" in this market. "LEDs are at the threshold of redefining several industries, including general lighting and backlighting for televisions," said Jae Wook Kim, CEO of Samsung LED. "Samsung recognizes this growth potential in each of these markets, and is dedicating the resources to become a leading manufacturer of mid- and high-power LEDs, and LED lighting solutions."

Meanwhile, LG Innotek Co. Ltd. merged with LG Micron Ltd. on July 1, 2009 to create a comprehensive electronic parts maker with an annual turnover of more than 3 trillion won (approx. $2.3 billion). The deal was revived in April this year after being shelved in December 2008 due to the economic crisis.

The new combined company said it would focus on the LED business, and was aiming to join the world's top-ten list of electronics parts makers by 2012. According to an article on the etnews.co.kr website, LG Innotek plans to "secure [its] competitiveness in the mass production of LED BLU packaging for LCD TV sets." The company's president Hur Yung-ho promised a "large-scale investment" in the mass production of LEDs. "By enhancing the mass production capability as early as possible," he said, "we will emerge as a global player in the LED packaging market." ◄

Akasaki from page 9

impossible, Akasaki conducted decades-long research on gallium nitride (GaN) semiconductors. He eventually created GaN-based positive-negative (p-n) junctions, making the blue LED practically possible for the first time in history. This achievement stimulated research on blue LEDs worldwide, and served as the first step toward their eventual commercialization in the 1990s.

The citation says that Akasaki's pioneering research has not only led to numerous and diverse new applications in electronic equipment (not only in LEDs but also in blue lasers for Blu-ray discs), but also offers great promise for protecting the global environment as blue LEDs are adopted for general-purpose lighting with superior energy-conserving qualities. ◄

MORE: www.ledsmagazine.com/news/6/6/18

TEST & MEASUREMENT

Labsphere and Orb Optronix in measurement collaboration

Test and measurement specialists Labsphere (North Sutton, NH) and Orb Optronix (Kirkland, WA) have announced a collaboration to accelerate the development of LED measurement instruments. The two companies say they will cooperate on the development of a broad range of new LED, display and light metrology products.

Labsphere will manufacture selected Orb Optronix instruments for LED testing, while

Orb will expand its LED measurement services laboratory with the addition of several Labsphere systems. In addition, the companies will now share sales channels. Orb's LED characterization systems and software will be sold through Labsphere's worldwide sales organization while Labsphere products will be available through Orb's distribution network in the US. ◄

MORE: www.ledsmagazine.com/news/6/6/3

PERSONNEL

TerraLUX appoints new CEO

TerraLUX, a manufacturer of LED light engines, has appointed Jim Miller as president and CEO. Miller was formerly VP of sales with Philips Lumileds, and brings expertise in building high technology companies from early stage to marketplace leadership in just a few years. Anthony Catalano, founder of TerraLUX, will continue in a full time capacity as a Director and Chief Scientist. When TerraLUX closed an investment with Access Venture Partners in February this year, part of the plan surrounding the financing was to build on TerraLUX's solid core management team by adding "world class" executive talent to accelerate the company's growth in the portable and general lighting markets.

Carl Kalin, VP of Sales and Marketing, said that the tremendous demand for LED lighting in the USA is not being met today in quality, performance or efficiency by current providers. "TerraLUX is accelerating its plan to capitalize upon this situation by providing a new breed of OEM LED light engines for the general lighting industry," said Kalin. "These core modules are built upon proven expertise in thermal, electrical, optical and mechanical design coupled with high quality off-shore manufacturing. TerraLUX is committed to...delivering a return-on-investment that will grow the new LED markets."

TerraLUX designed a 12 W LED light engine to replace a 50 W MR-16 in the Cambria 203 LED, an accent and flood lighting fixture from Lumière, part of Cooper Lighting (www.ledsmagazine.com/press/18566). The light engine fits directly into the existing milled-aluminum fixture.

MORE: www.ledsmagazine.com/news/6/5/12

Barco from page 9

screen is partially transparent. Barco also provided stage lighting for the tour stage, integrating a total of 1,200 FLX-60 pixel modules, each containing 5 LEDs.

"We wanted to create something that was bigger than a conventional stage. This tour was big enough to make a purpose-built structure," says Mark Fisher, U2 stage designer. "I wanted to create a transparent stage and really needed a video screen that would fit in that environment, a round screen that would not block the view for the audience. Barco's FLX gave us the chance to create this." ◄

MORE: www.ledsmagazine.com/news/6/7/3

CHIP PRODUCTION

SemiLEDs boosts capacity

LED maker SemiLEDs Corp. has announced the opening of a third production facility in Hsinchu Science Park, Taiwan, which will bring the company's capacity for 1x1mm high-power LED chips to 15 million per month. SemiLEDs' LED chips (blue, green, UV) are manufactured and processed using

news+views

its unique and proprietary MvpLED process, which involves a vertical LED chip structure and a copper alloy base. This, says the company, enables a very low thermal resistance (0.4 K/W), as well as providing various optical and electrical advantages. The company's press release claims that packaged LEDs using SemiLEDs 1x1mm chips typically produce over 110 lumens at 5000 K and 350 mA. ◄

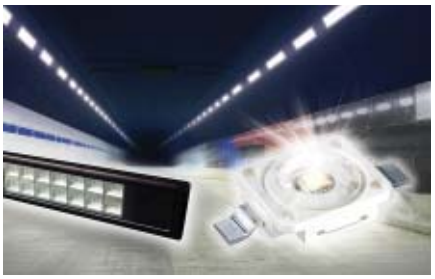
MORE: www.ledsmagazine.com/news/6/7/8

INFRASTRUCTURE

Yangzi river tunnel lit with LEDs

Osram will supply more than 400,000 LEDs for a major road tunnel project under the Yangzi River in China. Each of the twin bores of the tunnel is 8.9km long with an internal diameter of 12.7m, and carries 3 lanes of traffic. Guangzhou ZhongLong Communications Technology Co. Ltd., an established mainland China manufacturer of highway lighting, will install 5,886 luminaries containing over 410,000 Osram Golden Dragon Plus LEDs.

The Yangzi River tunnel will be the longest in the world to use LED illumination. With rising energy prices and supply shortages, the Chinese government is instructing local governments to apply energy-saving requirements to all infrastructure developments. In the Yangzi tunnel, around 40-50% of total energy consumption in the tunnel is related



to illumination, so significant energy savings are expected through the use of LEDs. ◄

MORE: www.ledsmagazine.com/casestudies/19016

COOPERATION

China and Taiwan urged to work together

LED manufacturers from Taiwan and China were urged to cooperate to develop better technologies and create a "win-win situation" during a cross-strait LED forum held in Taipei, Taiwan on June 9-10. Huang Chung-chiu, Taiwan deputy minister of economic affairs, said that Taiwan has formed a seamless LED supply chain network, with manufacturers having developed expertise in such products as LED-based back-light panels for notebook PCs and LCD TVs. Taiwan's ultra-bright LED chip production accounts for 40% of the global total.

"China can learn much from Taiwan," said Feng Jichun, an official with China's Ministry of Science and Technology. "Both sides of the strait can complement each other."

Feng mentioned five areas in which Taiwan and China can work together, including investment and the formation of an industry alliance to conduct joint research and development. The two countries should also work on common approaches to patents and to standardization, as well as developing a common certification and testing platform, he added.

Wu Ling, secretary general of the China Solid State Lighting Alliance, said governments on both sides have already built a bridge allowing greater exchanges in the future in the areas of patenting, technology and standardization. "Both sides should work together on R&D, investment, capital expansion, international markets enlargement, and the formation of international brands," she said. ◄

MORE: www.ledsmagazine.com/news/6/6/7

MARKETS

Substrates for GaN devices

The availability of high-quality sapphire and silicon-carbide substrates has enabled the rapid growth of the gallium-nitride (GaN) device market to $4.6 billion in 2008. But, according to a new report from Strategies Unlimited, increasing demand for blue-violet laser diodes, UV LEDs, and other devices will provide significant demand for advanced

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substrates such as GaN and aluminum nitride (AlN). The worldwide merchant market (excluding captive producers such as Cree) for substrates for GaN-based devices is forecast to grow from $280 million in 2008 to $470 million in 2013, says the report. Advanced substrates such as GaN and AlN are predicted to comprise more than 40% of the market in 2013. ◄

MORE: www.ledsmagazine.com/news/6/5/21

OUTDOOR LIGHTING

San Jose stimulated to convert streetlights

The City of San Jose is to spend around $2 million of stimulus funds received from the US government to help fund a project to replace streetlights with LED fixtures.

This seems to be an instance where well-placed stimulus funds will assist a well-planned project, to everyone's benefit. Concern has been expressed by some observers that, in a rush to capture and spend stimulus funds, some US municipalities are jumping on the LED bandwagon and are proposing LED streetlight projects without proper consideration of performance and product quality issues. While risking damaging the "good name" of LED lighting, this could also be a complete waste of the stimulus funds.

It was reported in February of this year that San Jose officials have been looking to replace their yellow streetlights, which are unpopular and energy-guzzling. Laura Stuchinsky, who works in the city's Department of Transportation, was quoted as saying that the city intends to dim LED lights in less trafficked areas by 50 percent at night, along with other monitoring goals to reduce costs. The city currently spends about $3.5 million on its street light program annually. The stimulus funding will allow the city to convert 1,500 lights to LED over the next three years. The city has a total of 62,000 lights.

The city has at least two pilot projects under way, one of which uses lights from Michigan-based Relume Technologies. In the second, San Jose has converted 125 lights in the city's Hillview North neighborhood to LED fixtures from BetaLED. These are embedded with power-line signaling technology from Echelon, allowing communication and control of the streetlights over the existing power lines. ◄

MORE: www.ledsmagazine.com/news/6/5/15

Hella, the German automotive lighting specialist, has announced a move into the LED street lighting market and unveiled its modular Eco StreetLine concept. More: www.ledsmagazine.com/press/18940.

OUTDOOR LIGHTING

Welland seeks proposals

When the City of Welland, Ontario, issued a Request for Proposal (RFP) in June for the conversion of all its street lighting to LEDs, more than 100 companies/agencies requested the bid documents. The RFP calls for the removal and disposal of existing HPS units and specifically requires the installation of LED lighting, making this a first of its kind. The replacement of 5903 street lights and the need for an on-hand inventory of 97 will make this a 6000-unit project over 3 years. ◄

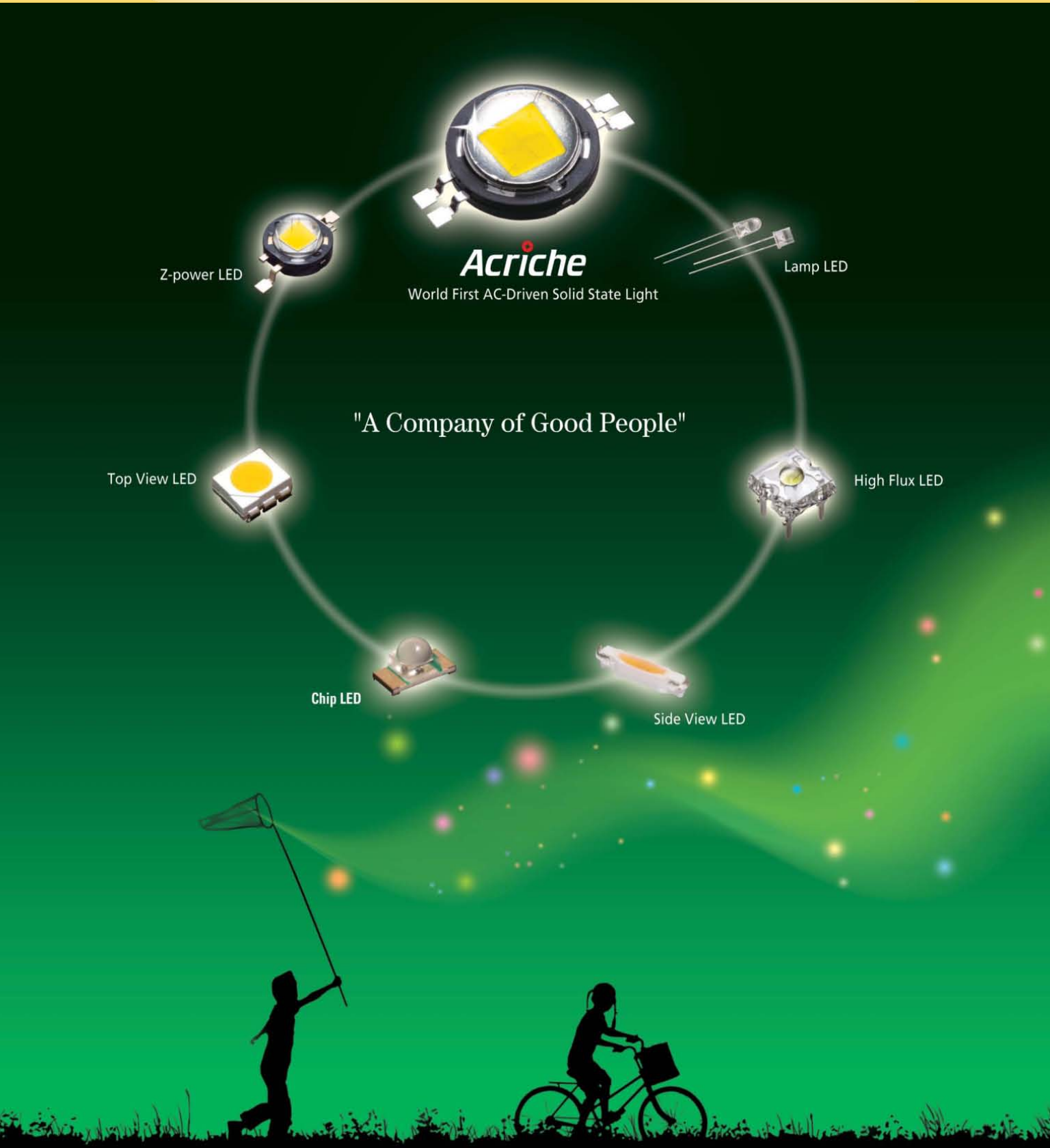
MORE: www.ledsmagazine.com/news/6/6/9

DISPLAYS

Cowboys reveal world's largest HD LED screen

Mitsubishi Electric has claimed the title of world's largest high-definition (HD) LED stadium screen, which has been unveiled at the new Dallas Cowboys stadium. The four-sided, center-hung structure weighs 544 tons and cost $40 million. The two main sideline displays measure 22m high by 49m wide (a total of 1078m^2). With a 20-mm pitch, the displays are 2450 pixels wide by 1100 pixels high, sufficient for high-definition video, and each contain a total of 2.695 million LED pixels.

MORE: www.ledsmagazine.com/news/6/6/11



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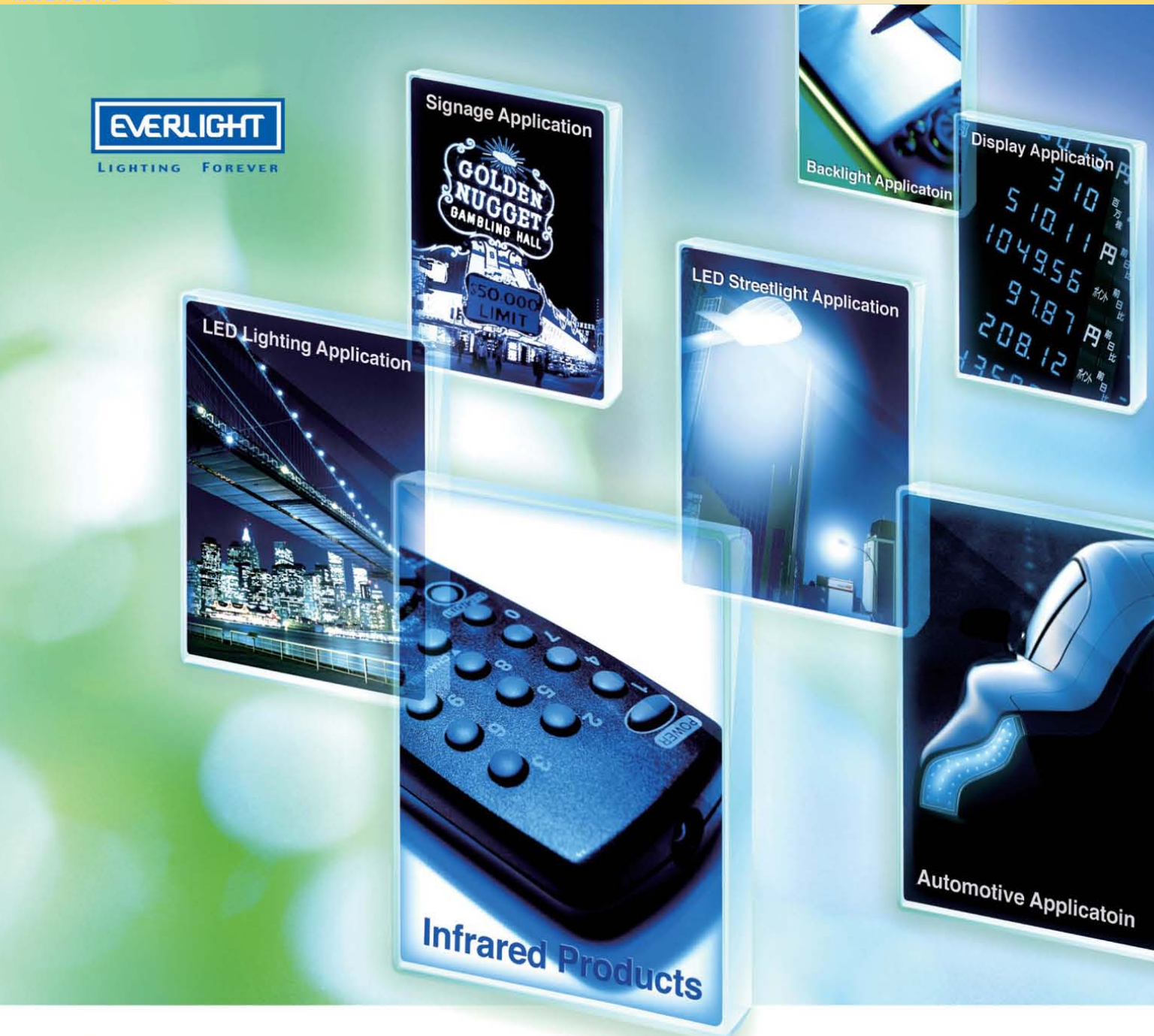

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funding + programs

Energy Saving Trust receives first LED lamp submission

The UK's Energy Saving Trust (EST) has received the first submission of an LED lighting product for its logo-based Energy Saving Recommended (ESR) program. The scheme directs consumers towards the most energy-efficient products across a wide range of sectors, and only products that meet strict criteria on energy efficiency, tested independently, can carry the logo. The scope of the ESR scheme was recently expanded to include LED lighting, with the release of a version 1.0 document in November 2008. This includes separate sets of requirements for LED lamps and modules, and for LED integral luminaires. Only domestic LED lighting is included. Manufacturers seeking ESR status for their products need to have them independently tested.

The EST (www.energysavingtrust.org.uk) told *LEDs Magazine* that it "sees the endorsement of LED lighting as critical, when the market for domestic LEDs is developing rapidly, and the number of products available is growing quickly. When a new technology comes onto the market, it is important for customers to be directed towards the best quality products, so that the public perception of the technology is not damaged by poor quality products. We have been endorsing compact fluorescent lighting for many years and we believe that ESR has been instrumental in ensuring the majority of CFLs sold in the UK are of the highest quality."

The approval process for the ESR program requires third-party testing over 15,000 hours, although a provisional ESR logo can be awarded after 2000 hours. Once approved, products will be eligible for a manufacturer's subsidy that will effectively reduce the price paid by the consumer. The subsidy comes from subscriptions paid by energy suppliers.

The first submission is from E-Light, a UK-based company that has developed a dimmable GU10 lamp (see photo, left, with a standard GU10 at right) based on its proprietary resonant asymmetric inductive supply (RAIS) technology. As well as working with most available types of dimmers, the lamp technology offers high efficiency with a high power factor of 0.96 (see p.30). Of course, these figures need to be independently verified by third-party testing, which has not yet started.

The requirements are currently being updated based on feedback from industry. Although some comments suggest the requirements are too stringent, the Energy Savings Trust says it will not "water down" the criteria, since this would "send the wrong message" and defeat the purpose of the ESR scheme, which is to set challenging targets that only the best products can meet. For example, mains-voltage GU10 reflector lamps require a power factor of not less than 0.7, which is not easy to achieve, although E-Light claims to have already surpassed this target with room to spare. ◄

MORE: www.ledsmagazine.com/news/6/6/5

Obama spends cash on energy efficiency

At the end of June, US President Barack Obama and Energy Secretary Steven Chu announced a $346 million investment from the American Recovery and Reinvestment Act (ARRA) to expand and accelerate the development and deployment of energy-efficient technologies in commercial buildings and homes. Lighting was a major focus, with $50 million allocated specifically to solid-state lighting (SSL) R&D. This will be spent through the DOE's ongoing SSL program — see below.

Obama also unveiled a new set of rules for the phase-out of certain inefficient types of fluorescent and incandescent lamps (more details at www.ledsmagazine.com/news/6/6/25).

"Now I know light bulbs may not seem sexy," said Obama, "but this simple action holds enormous promise because 7% of all the energy consumed in America is used to light our homes and our businesses. Between 2012 and 2042, these new standards will save consumers up to $4 billion a year, conserve enough electricity to power every home in America for 10 months, reduce emissions equal to the amount produced by 166 million cars each year, and eliminate the need for as many as 14 coal-fired power plants."

Following Obama's speech, the DOE announced three SSL funding opportunities under ARRA and is seeking applications for projects to boost R&D and market adoption of SSL technology. In addition to Round 6 of the existing Core Technology Research and Product Development efforts, a third new program area will focus on accelerating SSL manufacturing improvements that lower the cost and enhance the performance of SSL products. Selected projects will address technical challenges that must be overcome before prices fall to a level where SSL can compete with existing lighting on a first-cost basis. ◄

MORE: www.ledsmagazine.com/news/6/7/1

funding + programs

UK report assesses life-cycle sustainability of ultra-efficient lighting

The UK government's Department for Environment, Food and Rural Affairs (DEFRA) has published an evidence study assessing the life-cycle sustainability impacts of residential lighting products based on ultra-efficient technologies. The study is the first to clearly show the life-cycle environmental benefits of a shift toward LED lighting, and particularly to dedicated LED luminaires. The report assumes that various performance improvements will be achieved by 2014, at which time LED-based products will have less of an impact across all stages of their life-cycle, including manufacturing, transportation, usage and in the waste stream.

The report analyzes four different ultra-efficient lighting (UEL) technologies: LED lamps with integral ballast ("replacement lamps"), dedicated LED luminaires, ceramic metal halide lamps, and T5 linear fluorescent lamps. These are compared with established technologies such as compact fluorescent lamps (CFLs) and incandescent lamps. The study assumes that the rate of improvement in efficacy and light quality from LEDs seen over recent years will continue over the next five years, taking the efficacy of lamps to over 100 lm/W — though improvements beyond this may also be envisaged.

It concludes that efforts to stimulate the developments of acceptable LED lighting solutions would further reduce the impacts from residential lighting, which has already begun with the phase-out of incandescent lamps. Because of their design, dedicated LED luminaires proved to have the least impact of all lamps. The research also demonstrates that although the market is not currently ready for domestic application, LED lighting has potential for significant benefits over CFLs, which contain mercury and have a relatively short lifetime.

Also, the report describes a series of actions which the government and others may wish to consider (in the context of EU regulations) in order to maximize the potential overall environmental benefits associated with UELs. These include research support and business incubator schemes to develop infrastructure; regulation, monitoring and enforcement to ensure good-quality products in the marketplace; information labels aimed at consumers; bulk procurement programs among government departments; and various financial incentives. ◄

MORE: www.ledsmagazine.com/news/6/6/26

funding + programs

DOE revises Energy Star criteria for SSL outdoor luminaires

The U.S. Department of Energy (DOE) has released the second draft of Energy Star performance criteria for three SSL luminaire categories: outdoor pole-mounted area and roadway luminaires, outdoor wall-mounted area luminaires ("wall packs"), and parking garage/canopy luminaires. DOE has also developed a new "fitted target efficacy" (FTE) metric for quantifying outdoor pole-mounted luminaire performance. This was needed because other existing project-independent metrics did not adequately measure the efficacy that these luminaires will deliver to intended target areas. Minimum FTEs for SSL luminaires in each category were established to achieve at least 20% energy savings compared to top-performing incumbent HID products. The second draft of the criteria also includes minimum light output values, for example, 2000 lm for parking garage/canopy luminaires. ◄

MORE: www.ledsmagazine.com/news/6/7/5

More DOE program news

- DOE has completed a new resource detailing Financial Opportunities for researchers, manufacturers and distributors of SSL products. Created in response to requests from industry, this resource describes R&D support, manufacturing support, commercialization support and tax incentives.
  MORE: www.ssl.energy.gov/incentives.html
- DOE has released revised requirements for the L Prize competition. Changes relate to the eligibility of participating companies, as well as correlated color temperature (CCT) requirements and revision to the PAR 38 minimum center beam candle power (CBCP).
  MORE: www.ledsmagazine.com/news/6/6/23
- DOE has issued guidance on the correct use of Energy Star logos following several examples, particularly at the Lightfair tradeshow, where companies implied that their LED-based products were Energy Star certified. The confusion, deliberate or otherwise, stems from the use of the Certification Mark (reserved for qualified products) and the Partnership logo (communicates a partner's commitment to energy efficiency and to the environment). **MORE:** www.ledsmagazine.com/news/6/6/19
- The DOE has released the revised draft of the Energy Star criteria for Integral LED Lamps, also known as "retrofit" or "replacement" lamps. Comments on this second draft are being assessed, and DOE anticipates publication of final criteria for integral LED lamps in August 2009. ◄
  MORE: www.ledsmagazine.com/news/6/5/14

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Wattage Range	18W~60W	30W~60W	20W~96W	30W~96W	60W~240W	150W	20W~60W
Built-in active PFC function			✓	✓	✓	✓	✓
Output Voltage Range	5V~48V	5V~48V	5V~48V	9V~48V	12V~48V	12V~48V	12V~48V
Constant Voltage / Constant Current	CV or CC	CV + CC	CV + CC	CV + CC	CV + CC	CV + CC	CV + CC
Short Circuit/ Overload Protection	✓	✓	✓	✓	✓	✓	✓
Over Voltage Protection	✓	✓	✓	✓	✓	✓	✓
Over Temp. Protection	✓ (only for LPH-18 & LPL-18)		✓	✓	✓	✓	✓ (only for 20W)
Adjustable Output Voltage/ Current		✓	✓ (PLN-20 only)	✓	✓ (>150W)		✓ (Current only)
Optional Dimming Function		✓					
Protection Level	IP67	IP64	IP64		IP65 / IP67		
UL 1310 Class 2 Compliant	✓	✓	✓	✓	✓(60/96W)		
Input / Output Connection	Wire: 18/16AWG, 60cm	Cable: 18AWG, 30cm	Cable: 18AWG, 30cm	Screw Terminal Block	Cable: 18/14AWG, 30cm	Wafer	Wafer
Safety Standards	LPS	LPS	LPS	LPS			

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Companies meshing abiliti

At Lightfair 2009, LED companies stressed more cooperation among themselves in an effort to ease industry growing pains, reports **JULIE MACSHANE.**

At the 20th annual Lightfair International tradeshow in New York City in May, deal-making was in the air among the 475 manufacturers at the sold-out show. Many LED exhibitors talked in earnest about how cooperation would lead the industry to its next level of success and enable LED technology to prove itself to a growing number of increasingly knowledgeable consumers.

A record-breaking number of industry professionals attended this year's Lightfair (~23,000 say the organizers). Many visitors were there to see whether LED lighting manufacturers and suppliers have learned to play in the sandbox with other lighting players, and maybe share some new products and technology advances.

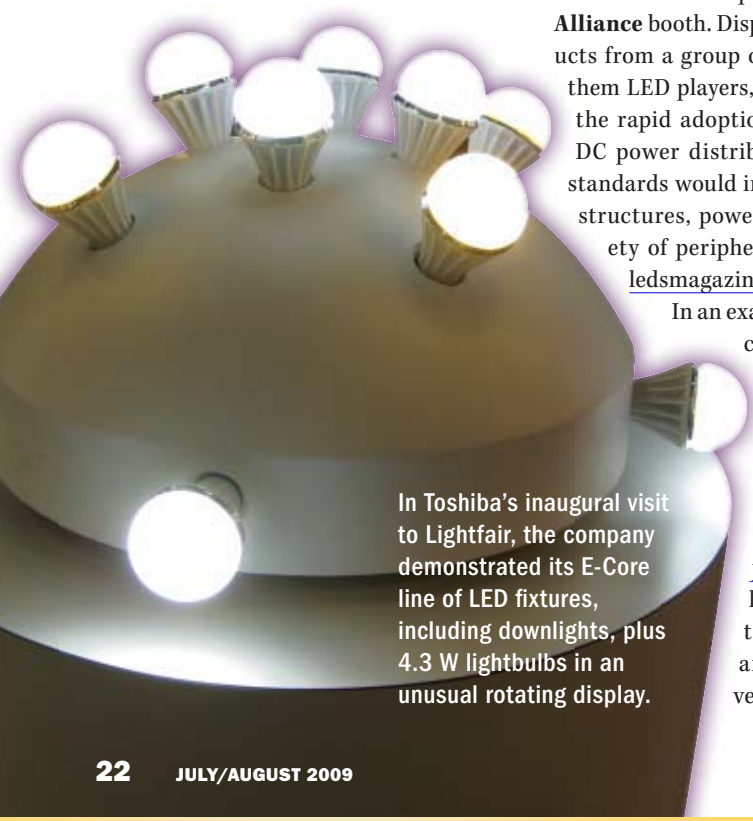
"To be successful in providing solutions, we must work closely together with our channel partners and lighting professionals," said Rudy Provoost, CEO of **Philips Lighting** at a press conference on opening day (www.ledsmagazine.com/press/18607). "We call upon the lighting industry's stakeholders to seize the tremendous opportunity to embrace the changes being brought about by a combination of government legislation and economic stimulus to build a sustainable future."

One example of industry cooperation at the show was the presence of the **EMerge Alliance** booth. Displayed there were products from a group of companies, many of them LED players, that want to promote the rapid adoption of safe, low-voltage DC power distribution standards. The standards would integrate interior infrastructures, power, controls and a variety of peripheral devices (see www.ledsmagazine.com/press/18577).

In an example of inter-company cooperation, **Nexxus Lighting** and **QD Vision** unveiled an LED lamp incorporating a "quantum-dot optic" (see www.ledsmagazine.com/press/18627). The Array lamp from Nexxus contains cool-white LEDs, and the light is converted to warm-white by a Quantum Light optic (containing quantum dot material) supplied by QD Vision. The result, say the companies, is a 2700K lamp with a color rendering index of 90 or greater at over 65 lm/W. Volume production is expected in early 2010.

Meanwhile, **IST Lighting** and **Lighting Science Group** announced a strategic affiliation to develop and distribute IST's products, including the new 45W iDrive Multi-DIM mains-dimmable LED driver, as well as the DL range of LED downlights (www.ledsmagazine.com/press/18602). IST benefits from LSG's global presence in the lighting industry, allowing the UK company to focus on delivering LED driver and LED lighting solutions. IST also announced a collaboration with **Bridgelux**, and will use the US-based LED maker's LED Arrays in its downlight products (www.ledsmagazine.com/press/18601).

Elsewhere, **Leviton** and **Molex** announced a partnership to offer integrated, modular LED solutions for lighting fixtures (*LEDs Magazine*, May/June, p.7), while **Lemnis Lighting** and **Digital Light** are continuing their cooperation on light bulbs with the launch of the Pharox 6W (www.ledsmagazine.com/press/18625). **National Semiconductor** and **Nuventix** unveiled a new electronic drive and thermal management reference design intended to simplify the development of LED lamps, based



In Toshiba's inaugural visit to Lightfair, the company demonstrated its E-Core line of LED fixtures, including downlights, plus 4.3 W lightbulbs in an unusual rotating display.

JULIE MACSHANE *(juliem@pennwell.com) is the managing editor of* LEDs Magazine.

es for industry growth

The Mesh RGB system of LED modules wrapped around some of the inside walls of Traxon Technologies' booth.

Crowds gather round the ribbon-cutting ceremony to celebrate the opening of the 20th annual Lightfair International tradeshow.

around National's electronic drive board and the SynJet cooling module from Nuventix (www.ledsmagazine.com/products/18585). A video describing this new reference design can be viewed at www.ledsmagazine.com/video. Nuventix also announced the general availability of the compact SynJet Universal DLM cooler for the Philips Fortimo/Lexel LED downlight module. The product is being used by fixture makers such as Philips Omega, NeonFrance, SunLux, Eurdekian and Zumtobel (www.ledsmagazine.com/products/18586).

Future Lighting Solutions announced that it has partnered with **Foresight** on "one board fits all" LED fixtures (www.ledsmagazine.com/products/18533) and with **Hadco** (a Philips company) on post-top fixtures. Future assisted Hadco in designing LED boards that can direct light properly through the distinctive prisms of Hadco's refractive globes. The resulting Hadco LumiLock LED module (see p.24) can be swapped on-site with the original HID assembly in a matter of minutes using a patented "twist-lock" mechanism. The module consists of four rectangular "light bars" housing one or two 10-LED boards each (www.ledsmagazine.com/press/18581).

At the show, Heather Goldsmith, marketing communications manager of Future Lighting Solutions, explained the company's 8-year relationship with **Philips Lumileds** on projects. "Solid-state lighting solutions are complex, especially compared to conventional solutions. The close alignment between Lumileds and Future Lighting Solutions allows us to address the lighting market's development needs from selection of the appropriate Luxeon LED to optical, electronic

LED streetlight examples included modern fixtures from BetaLED (top) and traditional designs (Evolve Post Top) from GE Lighting.

and thermal design, and even selection of integration partners," said Goldsmith.

Of course, "collaboration" is a key part of the business for distributors in the LED industry. The **Arrow** booth, 100% lit with LED fixtures, was packed with products from companies on their line card, including Triac, National Semiconductor, eldoLED, Cree and Osram Sylvania, among others. Electronics distributor **Avnet** showed products from lighting manufacturers including Affineon and Edge Lighting, and also highlighted its own engineering and technical services.

Hadco's LumiLock LED module (left) is designed as a direct replacement for HID versions (right) in post-top fixtures.

LED emitters

As usual, LED makers were out in force at Lightfair. **Cree** announced a new lighting-class LED, which will be available in the third quarter of 2009. The top bin of the cool-white XLamp XP-G will provide 139 lm and 132 lm/W at 350 mA. Driven at 1 A, the XP-G produces 345 lm (see www.ledsmagazine.com/press/18554).

Luminus Devices introduced the SST-50 white PhlatLight LED (see www.ledsmagazine.com/press/18636), as well as the CSM-360 white PhlatLight LED for high-output lighting applications, which can deliver 6,000 lm from a single LED package (see www.ledsmagazine.com/press/18635). The LEDs were shown around the company's booth in fixtures from Hubbardton Forge and Edge Lighting, among others. Another Luminus product, the SST-90-W, won an LFI Technical Innovation Award, recognizing the most forward-thinking advancement in lighting technology.

Also getting a Technical Innovation Award was Philips Lumileds' Luxeon Rebel ES LED, being selected for its "leap forward in lighting technology". The company claims it was the first product specified to deliver a minimum of 100 lm/W (see www.ledsmagazine.com/press/18698).

Osram Opto Semiconductors introduced two new LEDs, including the ultra-white and very small (3 x 3 mm package) Oslon SSL, aimed at spotlights, desk lights and ceiling floodlights. Osram says the LED uses its latest chip technology, and the 1W device has an efficacy of 100 lm/W. Also introduced was the GoldenDragon oval Plus LED with an integrated lens and an oval radiation pattern that delivers directed light, which is good for street lighting (www.ledsmagazine.com/press/18609).

Another very small device, designed to be driven at 20 mA, the LCW100Z1 from **Seoul Semiconductor**, measures 3.5 x 2.8 x 1.6mm, and has an efficacy of up to 120 lm/W when delivering up to 7.8 lm. It is aimed at panel lighting, signs and displays, and refrigerator and decorative lighting (www.ledsmagazine.com/press/18642). In the Seoul booth, Molex introduced two Transcend modules (www.ledsmagazine.com/press/18594).

Osram Sylvania displayed its new HF²Narrow Stick LED module using an OPTOTRONIC 75W, 24V power supply in an undercabinet lighting fixture by CV.

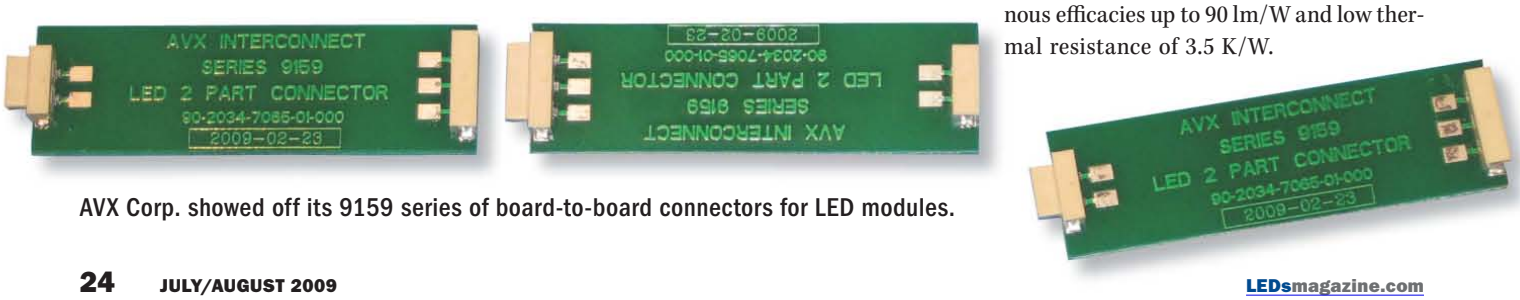
Drivers and modules

For dimming control, **Illumra** showed the wirelessly controlled LED dimmer, which responds to self-powered EnOcean compatible wireless light sensors, wireless occupancy sensors and wireless switches to control 5 A of LED lighting. The dimmer offers 65,000 dim steps (see www.ledsmagazine.com/press/18639).

eldoLED unveiled three new constant current and direct voltage controlled driver/controllers series named ECOdrive, POWERdrive and LINEARdrive (www.ledsmagazine.com/press/18487). The company's L-Dot Pico driver/controller won Lightfair's Best of Category Award in the Specialty, Hardware, Lampholders and Components section. The product is a 15 W RGBW DMX LED driver/controller with a diameter of only 25mm.

ERG introduced it family of Smart Force LED drivers that combine full-function power supplies with energy-efficient controllers. The drivers offer 1–200W unit power for driving single or multiple LED strings (www.ledsmagazine.com/press/18556).

Vossloh-Schwabe introduced the TriplePowerEmitter IP67 LED module with luminous efficacies up to 90 lm/W and low thermal resistance of 3.5 K/W.



AVX Corp. showed off its 9159 series of board-to-board connectors for LED modules.

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eldoLED's L-Dot driver/controller, with Cree MC-E RGBW and XP_E/XP-C demo LEDs at Arrow booth.

The module contains high-output LEDs encased in an impervious potting material and is available with high or low CCT, and with or without optics. At only 2-inch diameter it is easily retrofitted into an MR-16 sized housing (www.ledsmagazine.com/press/18730).

Replacement bulbs and lamps

Replacement LED lamps were prominent, in a wide variety of styles and performance levels. **Philips Lighting** unveiled its 600 lm dimmable A-shape LED bulb for incandescent replacement (see www.ledsmagazine.com/press/18582). **Osram Sylvania** also displayed an LED A-line lamp that it says is a true replacement for a 40 W incandescent A-line, while **Lighting Science Group** introduced a dimmable A19 bulb consuming just 7.5 W (see www.ledsmagazine.com/press/18612). **TerraLUX** introduced LED MR-16 replacement lamps with light output up to 525 lm. The 12 W unit replaces a 50 W halogen MR-16.

LedEngin also launched an LED MR-16 lamp, the LuxDot, which has a flux density equivalent to a 35W halogen lamp. However, says the company, the precision optical design enables LuxDot to exceed the halogen beam quality by providing a bright, uniform light distribution that eliminates hot spots and dark rings. The product is available in both 2900 K and 3100 K, with high color rendering in the warmer red and flesh-tone regions of the spectrum, often a challenge for some LED solutions (see www.ledsmagazine.com/press/18661).

Lighting fixtures

Renaissance Lighting had a busy show this year. It debuted white LED downlights with 2.5 times greater efficacy than previous generations (see www.ledsmagazine.com/press/18583), as well as square-aperture downlight fixtures, the Rhapsody Color Management System, and a brighter generation of RGB downlights.

Cooper Lighting introduced its io radii 38-LED trackhead luminaire offered in two light output options equivalent to either 90W PAR38 and 35W PAR30 ceramic metal

halide lamps (see www.ledsmagazine.com/press/18672). It is offered in three color temperatures (2700 K, 3000 K and 5000 K) and features field interchangeable optics (10°, 25° and 50° beam spreads) and shielding media (cross-blade baffle & snoot) providing beam control and flexibility without changing the lamp.

Entering the LED market was **SATCO Products**, which showed 30 prototype products at its booth (see www.ledsmagazine.com/press/18687). Premiering an architectural lighting line at Lightfair was **Iluminarc**, which demonstrated more than 20 LED-fitted products, including indoor/outdoor linear, pod and panel luminaires, and control systems (see www.ledsmagazine.com/press/18562).

Everbrite Lighting launched its new recessed LED downlight fixture for MRI suites at the show. The MedLux XLS-2 uses less than 60 W of energy to deliver 50 footcandles of light at task level.

Osram Sylvania's HF²Chain Colormix added a futuristic appearance to the fixtures in the booth. The Colormix consists of six circuit boards with four Golden Dragon LEDs per board and is good for backlighting large surfaces, cove or contour lighting. Sylvania also introduced the HF²Linear Colormix module with 18 LEDs per module on a metal core circuit board with housing and optics.

PerkinElmer introduced its LED fiber optic illuminator for medical and industrial markets. It uses an optical light engine designed to couple high intensity white light into 3–10 mm fiber optic bundles (see www.ledsmagazine.com/press/18628).

Philips Color Kinetics debuted the iW Graze Powercore, a sleek, linear fixture designed for surface grazing, wall-wash lighting, and signage illumination.

As part of a new "general illumination" product line, **Carmanah Technologies** introduced its next generation of solar-powered lights for street and parking lot applications, including the powerful EverGEN 1500 (www.ledsmagazine.com/press/18599).

OLEDs

On the OLED front, **W2 Architectural Lighting**, a division of WAC Lighting, displayed two prototypes at its booth (see www.ledsmagazine.com/press/18777). The OLED wall sconce features six color-changeable three-inch OLEDs. The mini chandelier uses eight colorful, transparent, one-inch OLEDs, including a panel that depicted the company logo. The power consumption is 0.18 W for each OLED, and together with the case, the thickness is 2 mm.

Getting to know LEDs

The Department of Energy (DOE) held training sessions for attendees at its booth on its various programs, including Energy Star, Caliper testing and Gateway. Attending Lightfair is a must for the DOE, said SSL program manager Jim Brodrick in his regular Postings email, because educating the consumer is a primary goal.

"The hardest part for all who come here to Lightfair is to cut through the hype, the glitz, and the glow of thousands of lighting products and sort the wheat from the chaff."

Brodrick added, "Staying current in a fast-moving market is a challenge — solid-state lighting technology changes rapidly, and it is on a fast path to the consumer."

Downlights from Renaissance Lighting illuminated shelves in its booth.

LINKS

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LED replacement lamp market to see high growth rate, says Strategies Unlimited

Legislation banning inefficient lamps, coupled with customer awareness of the cost-of-ownership analysis, will create a strong demand for LED replacement lamps.

Market conditions are right for the LED replacement lamp market to accelerate in the next few years, according to a new report from Strategies Unlimited. Although the market for LED replacement lamps is still in its early stages of development, lamp revenues are forecast to increase at a compound annual growth rate of 107% through 2013.

The report entitled "LED Replacement Lamps—Market Analysis and Forecast, 2009" analyzes five LED-based lamp types that are designed to replace lamps that currently populate billions of sockets: A-lamps and globes; PAR and R lamps; MR-16s; candelabra and decorative lamps; and linear fluorescent tubes.

Dramatic performance improvements in commercially-available LEDS in recent years, as well as significant cost reduction, have made it feasible to design LED lamps to offer comparable lumen output and to compete with other established lighting technologies on the basis of cost of ownership.

The market is in a state of flux as utilities, energy-efficiency organizations and customers look for optimum solutions which save energy, minimize the cost of ownership, and give acceptable quality of light. Customers are in the process of being educated about comparing cost of ownership, rather than looking just at the initial price of lamps.

Regulations in Europe will ban the 100W incandescent clear glass lamp starting in September 2009, and will progressively ban all inefficient incandescent lamps by 2012 and all incandescent lamps by 2016. Similarly, the Energy Information and Security Act of 2007 began the process of restricting the sale of inefficient lamps in the US. By 2012, with a few exceptions, the result of the legislation will be that inefficient incandescent lamps cannot be sold.

The EL1001 warm-white lamp from Ecomaa Lighting (Jhubei City, Taiwan) is rated at 510 lm and consumes 10 W. The company states this is equivalent to a 60 W incandescent, with an 80% energy saving. The lamp contains 6 LEDs from Nichia.

Although the marketplace does not have strong awareness of these regulations, they will create market opportunities for LED replacement lamps. Recognizing the potential of LED products to save energy, policy makers have been supporting LED technology R&D and helping its commercialization.

In the short term, while LED replacement lamps become a viable alternative, regulators are continuing to encourage the use of compact fluorescent lamps (CFLs). However, over the next five years, the advantages of LED technology over CFLs will become recognized, especially with respect to the quality of light, dimmability, controllability, lamp life and environmental cost of ownership. Some well-designed LED lamps already offer effective lumen efficacies that compete with CFLs.

The commercial and industrial segments will embrace LEDs to control costs and save energy. The LED lamps will be used for directed light applications, in hard-to-reach places and where the cost of replacement is very high.

"LED Replacement Lamps — Market Analysis and Forecast, 2009" is available for immediate delivery from Strategies Unlimited. Please contact Tim Carli, sales manager, at +1 650-941-3438 ext. 23, or visit www.strategies-u.com.

This PAR-38 replacement LED lamp from GlacialTech (Jung He City, Taiwan), contains 15 LEDs and is rated at 960 lm at 15W in cool-white. The lamp has a viewing angle of 120° and heat-sinking is provided by aluminium fins around the lamp, but even so it is not suitable for poorly ventilated light fixtures, and does not work with dimmers, according to the literature.

In the report, the markets for five categories of replacement lamps are analyzed for market drivers and challenges, trends, units and revenues for 2008. The report also offers a five-year forecast for 2009-2013.

Advances in TRIAC dimmable drivers open way for lamp subsidies

One of the main drawbacks to public acceptance of energy-saving lamps for home applications has been their inability to work properly with all types of dimmer switches. A technology known as resonant asymmetric inductive supply (RAIS) may overcome this hurdle, while also offering impressive figures for both efficiency and power factor. Developed by the Isle of Man, UK company E-Light, this technology has enabled the first dimmable GU10 application to be submitted the UK's Energy Saving Trust scheme for approval (see p.17). The company is now considering ways of taking products made with this technology to market.

The company found that RAIS technology works with all the different types of dimmers bought from high-street stores. Other LED replacement lamp products seem to work well with most of the leading-edge dimmers that turn or slide with a knob, but not with the increasingly popular touch or pushbutton leading-edge domestic dimmers or trailing-edge MOSFET dimmers. Clearly, this will be an important advantage for retail distribution networks.

RAIS is inherently compatible with dimmers because it continuously draws current in the same way as a conventional lamp, in other words it looks like a resistor to the mains. This also has an impact on the efficiency of a RAIS-controlled LED lamp. On normal load, the input to output efficiency of an RAIS system is about 91% compared with less than 74% for a typical tested specialist IC-based system. As the light is dimmed, the efficiency of the RAIS system will fall to around 63%, but an IC system can easily drop to around 10% because of this wasted power.

The high efficiency of the RAIS driver means that a smaller heatsink is required (the LEDs themselves still need to be cooled), so that lamps can be closer in size to conventional lamps. The circuitry itself is also smaller in size than standard driver approaches. Among other advantages, the RAIS topology has inherently near unity power factor. The quoted figure is 0.96, significantly higher than the 0.66 for a typical IC-driven LED lamp.

The full version of this article can be found on our website at: www.ledsmagazine.com/features/6/5/8. ◄

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LEDs 2009 will also feature **three full-day pre-conference summits** to be held on Monday, October 20, directly preceding the event. These intensive summits are designed to provide in-depth insight into selected topics that are currently of crucial importance in the LED industry. **Topics for 2009 will be**:

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drivers | BASICS

Driver design plays key role in meeting customer demands for LED lighting

LED drivers are critical elements in LED lighting control systems, and require care in their design and selection so that the final product meets customer expectations, writes TOM SHEARER.

The driver is one of the critical elements in a successful LED product and must be carefully designed and selected. A driver performs power conversion, output regulation, and facilitates user control. It must also meet many standards, and have a comparable lifetime to the LEDs themselves in order to be successful.

Dimming/luminaire control

The control of any luminaire should be considered early in the design phase, and LED luminaires are no exception. How the user may want to change the light level can impact the mechanical design of the fixture, the specification of the LEDs, and the nature of the optical and thermal systems. Providing for control options in the design phase can reduce the burden of standards, as well as costly last-minute design changes. Furthermore, the ability to provide control options allows for significant product differentiation, which brings value to the customer, the market and the manufacturer.

Incandescent lamps controlled by quality dimmers are able to easily dim well below a 1% light output, which has set a customer expectation for high performance dimming, especially in high-end applications. This means that dimmable LED drivers need to provide smooth, continuous, and flicker-free performance to 5% light output or less.

LED drivers

A primary component in any LED lighting system is the driver. Regardless of whether it comes in one module, or several, the LED driver is a power supply and a power regulation device for the LEDs. By construction, each LED can pass current in only one direction, which means that there must be some means of converting the AC power source to DC.

Even "AC" LED systems only conduct current through each LED for half of the line cycle.

For most LEDs, the driver performs a number of functions, including power factor correction (PFC), voltage isolation, and current regulation. A dimmable driver will also receive control signals for dimming, which can be either digital or analog and Class 2 or line-voltage-referenced, all dependent on the lighting system being used.

Driver types

There are two basic types of LED drivers: constant current and constant voltage. A constant current driver is a regulated current supply that provides a regulated current regardless of the voltage across the output. Conversely, the constant voltage driver is a regulated voltage supply that provides a regulated voltage regardless of the current drawn by the load.

These two types of drivers are used in different applications. For instance, an LED downlight with an array of LEDs designed to have the same forward voltage so that they share equal current will require a constant current driver. A cove lighting system, which can have different lengths of LEDs connected to it, will require a constant voltage driver.

TOM SHEARER *is a senior design and development engineer with Lutron Electronics (www.lutron.com).*

Designing LED arrays

An LED requires a voltage from its anode to cathode (the forward voltage or V_f) in order to pass current. The relationship between voltage and current is similar to a "regular" diode, in that a small change in V_f may result in a large change in current.

If a number of LEDs are connected electrically in series, any current passed through them will be the same for each diode. Therefore the sum of the forward voltages of the individual LEDs will be the voltage requirement for the array.

If a constant current source is connected to the series array, then no other circuit elements are required to create a successful electrical design. If more than one series string of LEDs is connected in parallel (a series/parallel combination), the situation becomes more complex.

If the array is intended to be run from a constant-current source, it is very important that each string of LEDs receive the current for which it is designed, and that the sum of the currents in the strings is equal to the regulated current provided by the driver.

If two strings of series LEDs are connected in parallel, individual LEDs may have a different V_f. If one string of LEDs has a significantly lower V_f than another, the string with the lower voltage will take more current, causing an imbalance in current (and light!) from the different strings.

Furthermore, LEDs in the lower-voltage string will become hotter than the others, making their V_f drop. This will cause the string to conduct more current, possibly leading to thermal runaway.

To be successful, the engineer designing the LED array must consider these properties in the earliest stages of design. ◄

Efficiency

The LED driver is designed to be as efficient as possible. However, today's LED driver designs face multiple applications on different loads, and provide many critical features, such as isolation, current regulation, and input voltage range, which can all affect the driver's efficiency.

Isolation: Many LED loads have circuit elements that can be touched by the user. This requires isolation of the output of the driver from the electrical feed (usually "Class 2" isolation). An isolated power supply is not as efficient as one that is referenced to the line, since all of the energy must be transferred through one component (typically a transformer). Conversion efficiencies for isolated power supplies are typically around 85%.

Current regulation: The LED driver must regulate the current through the load. This can be done in many ways, depending on the application. However, they all depend on passing current through some impedance that has a resistive element. The resistance causes loss in the circuit in proportion to the current. Hence, higher current drivers will be less efficient than lower current drivers.

Input voltage range: Many drivers are designed for installation in a broad range of applications and products. Since line voltages used for lighting ranges from 100 to 277 V, products must have circuits in them to meet power quality and industry standard specifications. These requirements necessitate a compromise between efficiency, cost, and product quality.

Power quality

There are important electrical specifications that a driver must meet to be installed in a building or home. Considerations include: power factor, total harmonic distortion (THD), inrush current, and radiated and conducted EMI.

An incandescent lamp is a purely resistive element, and draws current that is in phase with the AC line voltage. Electronic gear, like an LED driver, contains reactive circuit elements that cause the current drawn from the line to be out of phase with the line. This can result in power-line losses. Products should have a power factor as close to unity as possible.

Typical LED drivers contain at least one switching power supply. The high-frequency current drawn by these supplies can cause harmonic distortion of the current drawn from the line. This can result in neutral wire heating, and load imbalance in three-phase systems, as well as other challenges. The American National Standards Institute (ANSI) requires that THD be below 33%. Products should contain adequate filtering to meet this specification in an actual application.

Electronic gear that contains large input capacitance may draw a large inrush current when power is first applied, or during each line half-cycle, if operated from a phase-control (incandescent) dimmer. This inrush current can stress circuit breakers, switches, and dimmers if it is significantly higher than the peak line current.

Drivers with incandescent dimmers

There are many consumers interested in using LEDs in residential applications, and many of these homes already have incandescent dimmers (or entire lighting systems) installed. The ideal case for residential products would be to have an LED driver that is compatible with the large number of dimmers already installed (estimated at more than 100 million).

Incandescent dimmers have many requirements, which are met by most incandescent lamps by nature (such as: constant leakage current path, 40 W minimum load, resistive impedance characteristic), but which are critical to the operation of the dimmer. If an LED driver does not meet these requirements, the LED light source controlled by the driver may flash, flicker, not turn on, or fail altogether. Manufacturers must be wary of these requirements and design their driver to meet these specifications.

Conclusion

LED drivers are the critical element in an LED lighting control system, and dimmable LED drivers allow for high-performance lighting control, differentiated products, and satisfied customers. However, care must be taken when designing or selecting an LED driver in order to provide a product that will meet customer expectations.

Further reading

"Controlling consumers' expectations of LED lighting: why dimming is so important," *LEDs Magazine*, April 2009, p.21, www.ledsmagazine.com/features/6/4/5.

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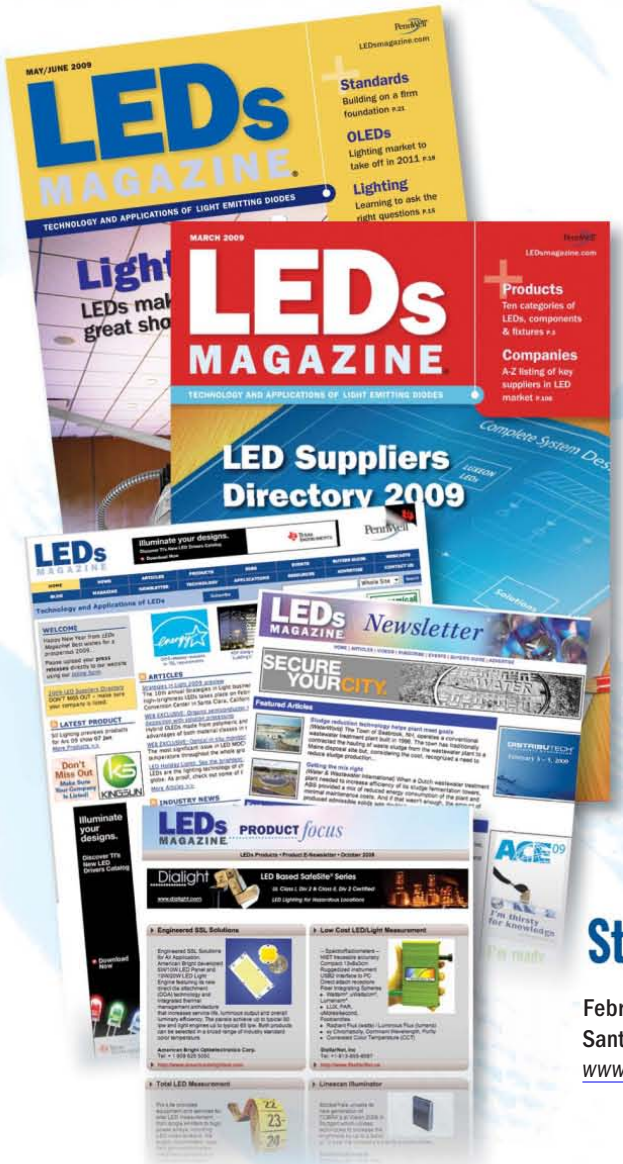

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LED technology brightens backlights as demand from LCD makers ramps up

The market for LED backlighting for LCD panels is now firmly on the strong upward growth trajectory that has been promised for several years, according to market research companies and LCD TV makers, among others.

TIM WHITAKER REPORTS.

The latest LCD TVs from LG Electronics use a full-screen LED direct backlight, enabling local dimming, but are less than one inch thick.

After several false dawns, it looks like the market for LED-backlit LCD panels is really starting to take off. Leading LCD TV makers such as Samsung and LG are convinced of the importance of LED backlights, and many laptop computer makers are already incorporating LED-backlit LCDs. Already ubiquitous in smaller LCD displays used in mobile devices, LED backlights have recently seen a tremendous growth in demand from laptop makers, and now it seems that the TV market is poised to take off as well. And due to the number of LEDs required for each TV panel, this will create a huge demand for LED chips: one market research company says that LCD backlights will require 38 billion LEDs by 2012.

Samsung, the world's biggest TV maker, says it expects to sell 2 million LED-backlit TVs this year, equivalent to 10% of the company's total LCD TV global shipments. At the start of 2009, Samsung unveiled a range of "LED TVs" (see "LED TV: What's in a name?" sidebar) with screen sizes ranging from 32 to 55 inches.

Samsung's Korean rival LG Electronics also recently launched LED-backlit LCD TVs (see photo), and said it was aiming to sell 5 million units in 2010. The new, ultra-slim 55-inch models will be launched in July 2009 in Korea, and will be priced around $5500. LG revealed its forecast that the global LED-backlit LCD TV market will grow from 3.1 million units in 2009 (2.6% of the total LCD TV market) to 30 million in 2010 (20% of the market) and to 68 million by 2011 (40% of the market).

As the pricing indicates, LG's new models are very much high-end. Each backlight contains 3360 LEDs arranged over the backplane of the LCD; this is direct backlighting, while the alternative is to place the LEDs at the edge of the display. LG says its new TVs offer a "brighter and clearer screen" because it is using seven times more LEDs than existing edge-lit LED TVs. This is a reference to Samsung, which uses the edge-lit approach with white LEDs positioned at the sides of the display. This helps to keep the cost and power consumption down, but the picture quality suffers.

Because it takes the direct backlighting approach, LG is able to employ dimming technology that divides the screen into 240 blocks, each of which can be individually dimmed, resulting in a contrast ratio of 5,000,000:1.

Slim form-factor was another reason Samsung chose edge-lighting; its LED-based TVs have a screen thickness of 1.2 inch. Slim screens are one of the most important factors influencing the purchasing decision at present. However, LG said it is employing patented technology that helps keep the overall chassis thickness down to 24.8mm (just less than 1 inch). The technology "allows the LEDs to be spread-out horizontally" and minimizes the distance between the LEDs and the screen.

Vizio, a US-based LCD maker, is also turning to LED backlights and will use the direct backlighting approach in its 55-inch VF551XVT, priced around $2,200. The model uses 960 LEDs across 80 cells (12 LEDs per cell) to illuminate the full back area of the LCD screen. The technology reduces power consumption over traditional cold-cathode fluorescent lamps (CCFL) backlighting systems, while combining with the company's Smart Dimming technology to yield greater color saturation and improved contrast and black levels. Vizio also pointed out that while edge-mounted LEDs project light from the sides of the panel, the Vizio model will have more consistently even lighting across the full width of the screen.

Sharp has also recently unveiled a range of Aquos LED-based TVs, again using a full-array direct LED backlight. The company said that its backlight enables "precise light output with higher luminance per watt so less power is needed." The TV is also equipped with a system designed to reduce power consumption during use by adjusting the screen brightness based on the level of brightness in the area where the TV is installed. In fact, despite its direct LED backlight, Sharp claims this series offers the industry's lowest power consumption of any LCD TV currently available on the market; the 52-inch model consumes 105W.

TV market

Market research company iSuppli has predicted that the use of LED backlighting in LCD TVs is set to "explode" as prices fall. The firm says that just 438,000 LED-backlit TV panels were shipped in 2008, but this will shoot up to 90 million units in 2013, while the proportion of LCD TVs using LED backlights will increase from 3% in 2009 to 39% in 2013.

"The price gap between LEDs and CCFLs has narrowed due to the higher yield rate of LEDs, as well as the oversupply that resulted in a drastic price reduction for LEDs in the second half of 2008," said Sweta Dash, senior director, LCD research, at iSuppli. "And with the advent of green technology, power savings and thinner form-factors, more branded manufacturers are looking at LED-backlit LCD TVs in 2009."

Replacing CCFL backlights with LED versions can result in savings in power consumption, weight and thickness of around 30–50%. Requirements for reduced power consumption for TVs, backed by legislation, will help drive the adoption of LED backlights.

According to iSuppli, the LED backlight supply chain is still evolving. Some panel suppliers — notably Samsung and LG (see p.9) — are either entering joint-venture partnerships or developing their own in-house LED solutions to streamline the value-chain process, reduce costs and gain better control over the supply. When launching its latest LED-based TVs, Sharp said it was able to deliver "a price-competitive yet high-performance product" by producing many of the key components of the TV, including the LED components and the LCD panel.

Billions of LEDs required

Another market research firm, DisplaySearch, estimates that a total of 34 billion LEDs will be used in LCD panels of all sizes in 2012, compared with 8 billion in 2008. The vast majority of these will be low-current LEDs, due to cost, thermal management and luminance efficiency requirements. A further 24 billion LEDs will be used in active outdoor displays (i.e. direct-view LED screens). The total global demand for LED chips will reach 167 million units in 2012.

Shipments of LED backlights for large-size (10-inch and above) TFT LCDs will exceed 368 million units in 2012, says DisplaySearch, which is 26 times the 14.1 million units shipped in 2008 (see table). The figure will rise to 80.8 million in 2009, of which nearly 60 million units will be for notebook PCs. The penetration rate of LED backlights in notebook PCs is expected to reach 52% in 2009, and will grow still further to reach 81% in 2010. Within this category, the miniature "netbook" PC already has 100% penetration of LED backlights.

"LEDs will create new growth for the TFT LCD industry due to characteristics such as lowering power consumption, meeting green requirements, adding dimming capability, improving color performance and enabling slim and light form-factors for LCD panels and applications," said Yoshio Tamura, VP of DisplaySearch and the component research team leader. TFT LCDs also provide "new vigor" to the LED industry, said Tamura, as they open up broader applications requiring higher quality and more advanced technology.

David Hsieh, VP of DisplaySearch, said, "The growing LED penetration in TFT LCD will raise new issues such as LED cost management, LED chip availability, and changes in backlight structure. As LED production shares the same capacity with the lighting market and many LED companies are evaluating the strategy for backlights, the market has some concerns over LED availability. We believe LED supply chain management will be a key success factor for panel makers and will reshuffle the competition landscape from now to 2010." ◀

LED backlight shipments for LCD panels above 10-inch diagonal

	2008	2009	2010	2011	2012
Notebook PC	8,219	59,635	122,814	185,816	225,063
LCD TV	196	3,674	15,137	39,224	64,073
Desktop monitor	8	1,322	7,716	15,674	30,860
Industrial/other	5,681	16,202	27,270	36,419	48,248
Total	14,104	80,834	172,937	277,133	368,245

Source: DisplaySearch

LED TV: What's in a name?

Samsung has attracted some flak recently through its use of the term "LED TV". As readers of this magazine are (hopefully) aware, "LED TV" actually means "LCD TV with LED backlights." Samsung hasn't invented some fancy new display type, in the sense that LCD and plasma are completely different display technologies. What they and others have done is to improve one component in an LCD — the backlighting unit — using LEDs rather than cold-cathode fluorescent lamps (CCFLs). You can of course make an LED TV, in which the viewer looks directly at the individual LED pixels. Giant versions are seen at sports stadia around the world, with the Dallas Cowboys' new center-hung display being the latest and greatest (see p.14). But there are limitations on how close you can place the individual LED pixels. If the viewer is too close, the pixels can be easily resolved. Not much good for a TV in your living room. Samsung's use of the term "LED TV" is problematic, however, because of the confusion that will arise when OLED TVs become more prominent in the marketplace. OLED is a separate display technology from LCD or plasma. And guess who is at the forefront of OLED TV development? None other than Sony, Samsung's fiercest rival. ◀

design forum | **DRIVERS**

Hybrid control techniques drive different LED applications

The different demands of LED lighting and automotive applications require hybrid control methods to take advantage of the strengths of hysteretic and current-mode control, writes **JAMES PATTERSON**.

As high brightness (HB) LEDs continue to evolve, and the world's energy conscience focuses in on lighting, there becomes a greater need for efficient, long-lasting drive circuitry. Creating a robust, efficient HB-LED driver requires analysis of the end application. The designer often has some flexibility in either the input or output specifications, therefore the driver topology and control method should be determined by weighing the advantages and disadvantages of each possible configuration.

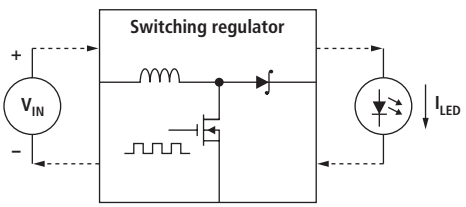

FIG. 1. Switching regulator 3-terminal network.

Hysteretic and current mode control

	Hysteretic control	Peak-current-mode control
Advantages	· Δi_{L-PP} constant over operating range · No control loop compensation · PWM dimming easy to implement	· I_{LED} extremely well regulated · Excellent V_{IN} disturbance rejection · Analog dimming easy to implement
Disadvantages	· I_{LED} subject to component tolerances · Variable f_S over operating range · Analog dimming range is limited by size of hysteretic band	· Δi_{L-PP} varies over operating range · Compensation can be difficult/ complex · PWM dimming frequency limited by speed of control loop

With any HB-LED driver, the output should be a regulated current source that can provide the necessary output voltage to the string(s) of LEDs. Though linear regulators are cheap and small, design limitations and poor efficiency usually make them non-ideal for driving HB-LEDs. In general, a switching regulator will be the best choice.

Deciding on a topology

A power MosFET, diode and inductor form a three-terminal network which is the basis for all switching regulators, as shown in Figure 1. There are three basic topologies derived from this network using different input/output configurations: buck (step-down), boost (step-up) and buck-boost (step-up/down). The switching regulator topology is chosen based on the specific application.

The buck regulator is always the best choice, provided the input voltage (V_{IN}) remains above the LED string output voltage (V_O). Many designers will alter their specifications to use a buck regulator because the direct connection of the inductor to the LED load emulates a true current source. This topology requires little to no output capacitance, allowing for a cost-effective design that has the most versatility for dimming applications. In addition, buck regulators provide the highest possible efficiency and least switch stresses.

If V_{IN} is always less than V_O, it is necessary to boost the output voltage. A boost regulator can also have high efficiency though the input current is higher than the buck, increasing switch stresses. The filtered input provides good suppression of EMI and minimizes the input capacitance. Unfortunately, if the LED load is opened, the boosted output will continue to rise until components are destroyed. This requires the use of output over-voltage protection (OVP).

Finally, as a last resort, a buck-boost regulator can be used if V_{IN} will be both above and below V_O. The efficiency of a buck-boost will always be worse than the buck and/or the boost due to the high switch stresses, and there is again the need for OVP.

Basic regulation methods

In all topologies, current regulation is achieved by driving the main power MosFET of the switching regulator with a pulse-width modulation (PWM) signal that varies as needed to provide the correct energy transfer from input to output.

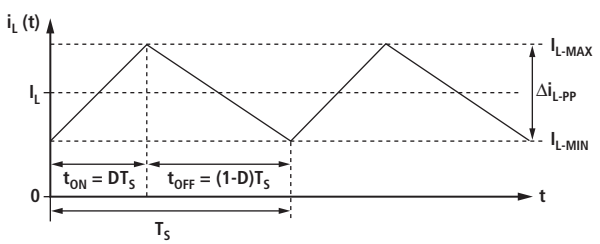

FIG. 2. Standard regulator inductor current $i_L(t)$.

JAMES PATTERSON *is a senior applications engineer with National Semiconductor Corporation (www.national.com).*

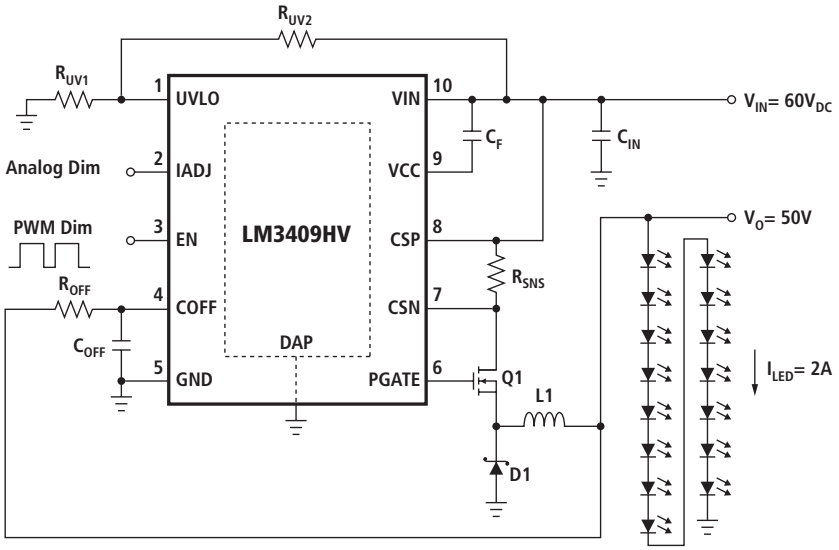

FIG. 3. Design for 100 W exterior wall-pack lighting fixture.

Figure 2 shows a switching regulator inductor current waveform, where duty cycle (D) and switching period (T_S) of the PWM gate drive signal sets the on-time (t_{ON}) and off-time (t_{OFF}) of the FET. During t_{ON}, energy from the input is stored in the inductor, increasing the inductor current $i_L(t)$, until the FET turns off. During t_{OFF}, $i_L(t)$ decreases and energy is delivered to the LED load. For all topologies, the average LED current (I_{LED}) is proportional to the average inductor current (I_L), therefore controlling I_L yields regulation of I_{LED}.

The simplest method for regulating I_{LED} is hysteretic control. The FET is turned on until $i_L(t)$ reaches the fixed peak threshold ($I_{L\text{-}MAX}$) and is turned off until it falls below the fixed valley threshold ($I_{L\text{-}MIN}$) where the process repeats.

The other end of the LED control continuum is peak-current-mode control, which regulates I_{LED} in a closed loop configuration at a fixed switching frequency (f_S). In standard peak-current-mode control, the FET is turned on until the peak transistor current reaches a threshold that is proportional to I_{LED}. The FET is then turned off for the rest of the switching period.

Since there are advantages and disadvantages to both hysteretic and current mode control (see table), hybrid methods have been developed to attempt to take advantage of the strengths of each. Depending on the application, different methods are preferred.

Lighting fixtures

For general lighting applications, a buck regulator is frequently employed to regulate from a high input voltage bus derived from the AC mains. Extreme LED current accuracy is not necessarily required, whereas minimizing cost is paramount. Frequently, analog and/or PWM dimming is also necessary.

Given these requirements, a simple control option is to fix the MosFET off-time, and regulate the peak in a hysteretic manner, as implemented by the LM3409HV PFET controller. The transistor current flows through a high-side sense resistor and when the programmed peak is reached, the FET turns off and the off-timer starts. At the end of the controlled off-time, the cycle repeats. This method is very similar to purely hysteretic control, except it has the advantage of full-range analog dimming since there is not a limiting hysteretic band. Performing peak detection provides a cycle-by-cycle current limit and, combined with a constant off-timer, constant ripple can be achieved.

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Figure 3 shows a 100 W application designed for a high intensity exterior wall-pack lighting fixture. The LM3409HV is used to regulate 15 series LEDs (~50 V) at 2 A from a 60 V DC bus generated by a front-end AC-DC converter. In this application, quasi-hysteretic control works well because the switching frequency does not need to be constant over all operating points and extremely tight current regulation (2% or less) is not required. This design is simple, robust, efficient, and there are multiple full-range dimming options.

Automotive headlights

Automotive applications, on the other hand, frequently need a boost regulator to operate from a low input voltage such as a battery. A wide input voltage range is usually necessary, and tight current regulation using a simple robust design is always preferred.

Given these specifications, an effective control method is to use a combination of standard peak current mode control and a constant-off timer, as is implemented in the LM3429 NFET controller. I_{LED} flows through a high-side sense resistor, which adjusts the peak current threshold proportional to I_{LED}. The transistor current is sensed across the MosFET on-resistance and when the peak is reached, the FET turns off and the off-timer starts. At the end of the controlled off-time, the cycle repeats. With this method, there is also a cycle-by-cycle current limit and the V_{IN}-proportional off-timer maintains a virtually constant switching frequency. The advantage to this method is less complex compensation design, yielding a wider possible operating range.

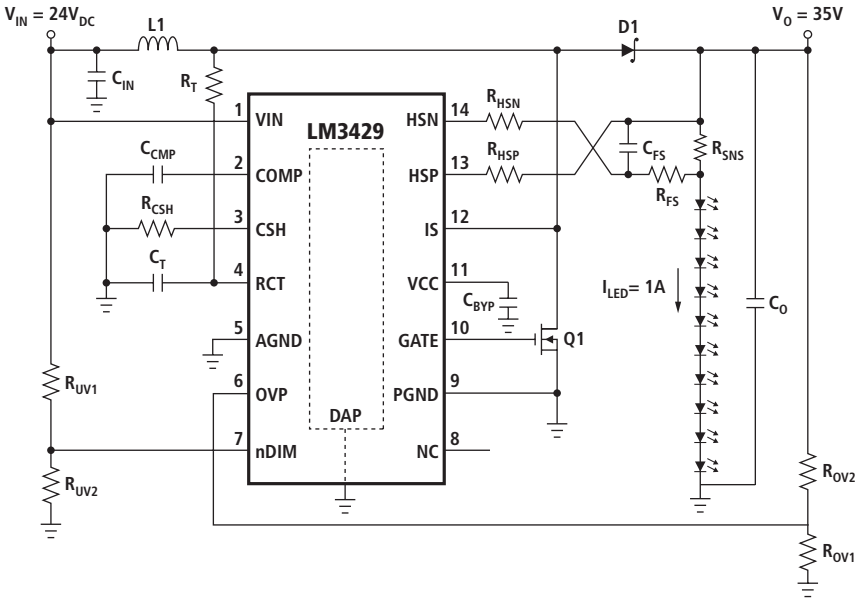

FIG. 4. Design for a 35 W automotive headlight system.

Figure 4 shows a 35 W application designed for an automotive headlight. The LM3429 in a boost configuration is used to regulate 10 series LEDs (~35V) at 1 A from a 24 V battery. Peak-current-mode control with a constant off timer ensures excellent accuracy, nearly constant switching frequency, and high system efficiency, while maintaining robustness to large variations in the input voltage.

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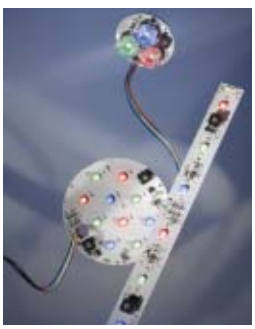

last word

Talent development playing a key role for LED lighting companies

As the LED lighting industry evolves, spending time and effort to hire the right talent is a vital exercise, says **TED KONNERTH**, president and CEO of **EGRET CONSULTING**.*

The current explosion of LED technology into the commercial lighting market has created an interesting and challenging impact on the acquisition and retention of talent in both LED companies and commercial lighting manufacturers.

LED technology is the most disruptive influence on the lighting industry since Edison. The technology and the talent within the emerging companies are predominantly from electronics backgrounds. Electronics as an industry is built on a sales channel of selling discreet components through electronics distributors (Arrow, Future, etc.) into an OEM end-user. That sales channel is completely foreign to traditional lighting manufacturers who have no OEM business applications and sell finished goods to electrical distributors. Similarly, LED companies are amazed at the apparent levels of influence in the sales channels of commercial lighting.

LED is now poised to take over the lighting industry as the lamp source of choice. This has immense impacts on talent definition. A purely LED company, staffed with solid-state industry talent, will be at a distinct disadvantage to compete against an established path to market built by the electrical manufacturers. At this point LED companies are jockeying for position by adopting one of two approaches and some are trying both. First is the OEM model, where the LED companies are promoting their products directly to the fixture manufacturers and helping them integrate LED into their product lines. Second is the direct sale model, where LED companies are developing their own fixture product lines and attempting to recruit reps to promote those products into their market.

For both of these models, there is a "talent challenge." The OEM model takes time to develop relationships with the key product management and engineering talent within the commercial fixture companies. A commercial fixture manufacturer who has no electrical or electronic engineering staff is at a bit of a disadvantage to properly assess the merits and limitations of LED technology across vendors. There is a huge disparity of quality across LED vendors right now as there are few industry standards. As such, fixture manufacturers are being inundated with product presentations, in a technology that touts life cycles that are longer than the technology has been around!

LED companies need channel expertise to get their products to market, regardless of the channel strategy they adopt. It is foreign to them to market a product that ultimately is purchased by an electrical contractor, through an electrical distributor who 'selects' products based upon factors of buying group allegiances, local rep relationships and pricing and margin support programs. A pure lumens-per-watt presentation isn't effective in garnering distributor or rep support.

Commercial lighting manufacturers have a desperate need for LED expertise and have been hiring electronics engineers rapidly for the past 1–2 years. Once the LED technology is integrated into their product line, the commercial sales and marketing channels will be able to adapt fairly quickly to understanding the technology issues. There will still remain necessary changes in policy for these companies, as they will now be selling a complete lighting "system" and are thereby responsible for the performance and warranty terms of those products. I'd predict that the claims of 50,000 hours or 100,000 hours will fade as the larger manufacturers begin to calculate the balance sheet costs of 6-10 year product warranties.

Right now, talent is pretty thin in lighting. Lighting as an industry is fairly small, but it does have many nuances that require channel expertise to be fully effective. I've watched several LED manufacturers hire lighting talent that isn't capable enough to lead them into the traditional channels.

Personally, if I were to hire a new VP of sales for an LED company, I would be looking for someone who understands commercial lighting applications. The challenge for an LED manufacturer is to recognize how to interview and screen lighting talent, when their own personal background comes from the solid-state industry. One thing is certain, in times of disruptive industry changes, there are companies who emerge as the clear victors. The time to address the right strategy for winning a place at the table of the new lighting industry is now.

**Based on an interview with Brian Owen*

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