Tricks of the trade for driving bright LEDs

There are subtleties involved in making high-brightness LEDs give off the right color and intensity.

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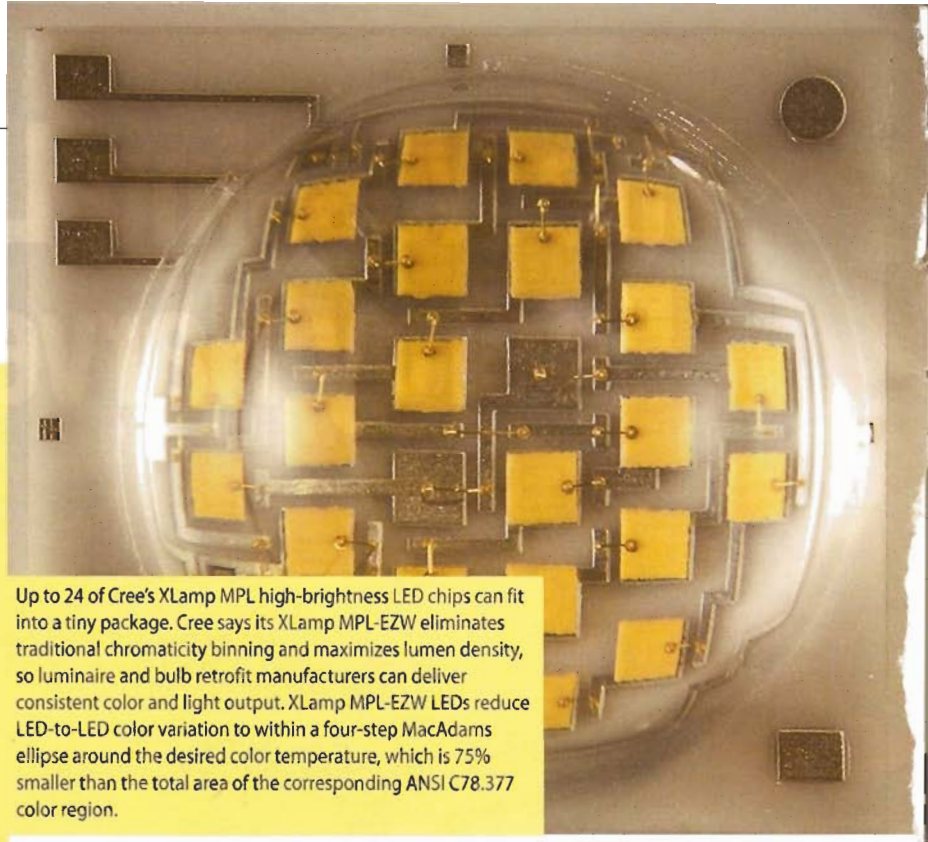


Up to 24 of Cree's XLamp MPL high-brightness LED chips can fit into a tiny package. Cree says its XLamp MPL-EZW eliminates traditional chromaticity binning and maximizes lumen density, so luminaire and bulb retrofit manufacturers can deliver consistent color and light output. XLamp MPL-EZW LEDs reduce LED-to-LED color variation to within a four-step MacAdams ellipse around the desired color temperature, which is 75% smaller than the total area of the corresponding ANSI C78.377 color region.

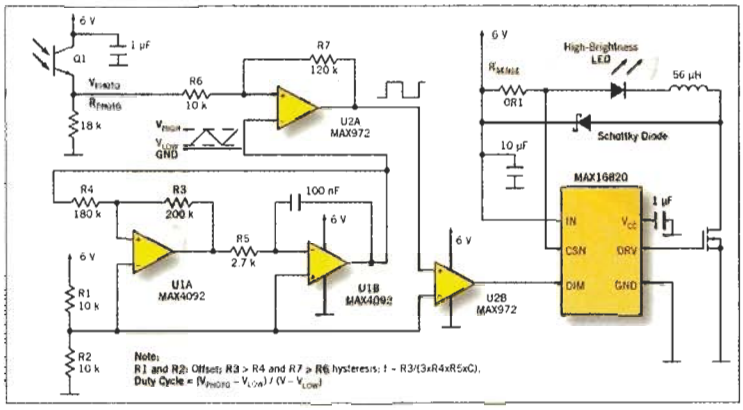
First the good news: Prices for high-brightness LEDs (HBLEDs) have dropped by a third over the last few years. As a result, they're increasingly being spec'ed into illumination for office buildings, parking lots, city streets, airports, stadiums, bridges and tunnels. The trend is opening up opportunities for engineers who understand the complex design, layout, thermal management, and driving issues of this new lighting technology.

Now the bad news: High-brightness white LEDs are still more than an order of magnitude more expensive to mass produce than their dimmer brethren. They're also less efficient. At low driving currents of a few milliamperes, white LEDs can produce outputs of about 250 lumens/W compared with about 16 lumens/W for incandescents and 100 lumens/W for fluorescents. But when an LED is driven by hundreds of milliamperes, the level needed to produce high lumen outputs, efficiencies decline to below 100 lumens/W.

This decline in LED efficiency is caused by a malady dubbed the "droop." It may come from electron leakage within the LED structure. At least that's the theory of Rensselaer Polytechnic Institute researchers who have produced high-output LEDs converting 22% more electricity to light than those with a conventional make-up. But the topic is still under active investigation.

More bad news: It can be tricky to design a circuit able to drive HBLEDs properly. That's because the character of the light output is quite sensitive to operating parameters such as drive current, ambient temperature, and operating voltage. HBLED system design is a multidisciplined effort that must factor in colorimetry, optics, power electronics, thermal management, and control issues. These are complicated requirements. They essentially mean the design of an HBLED lamp involves more than just hooking up a simple power supply.

Robert Kollman, Texas Instruments senior applications manager and a member of the technical staff, additionally points out that isolation and power-factor correction (PFC) can be important. This applies particularly for European markets, where PFC is required for lighting over 25 W.



Here's one way to adjust the brightness of an HBLED, courtesy of Maxim Integrated Products. Phototransistor Q1 senses ambient light level, which is eventually compared with a reference and fed to the dimming input of the MAX16820 PWM LED driver.

LEDs work best when driven with a constant current, so LED manufacturers rate LED qualities like output lumens and beam pattern at a specified forward current. This is the rationale for wiring HBLEDs in series so each is driven with the same current. This approach is particularly useful for down-lighting applications, as when illuminating a work surface.

LEDs can also be driven in parallel. This approach is useful for cove lighting systems (indirect lighting of valances, ledges, and so forth) that employ strings of LEDs in different lengths. It provides a regulated voltage for each LED, regardless of the current each draws. There are also applications that may require a combination of both serial and parallel approaches.

One example of a recent high-efficiency PWM LED driver is the MIC3201 from Micrel Inc. This step-down driver for HBLEDs incorporates high-current-sense and can drive up to four 1-A LEDs in series at more than 90% efficiency.

Also in this class is the MAX16819/16820 step-down constant-current HBLED driver from Maxim Integrated Products. A modification to this chip's circuit yields a stand-alone brightness regulator. It automatically adjusts brightness levels to match changes in the ambient-to-LED output ratio.

Nearly every major semiconductor IC manufacturer offers ICs that can drive HBLEDs. One of these is the National Semiconductor LM3424 PowerWise energy-efficient LED driver with temperature-management control. The Webbench LED Designer environment is online to support it.

The device uses pulse-width modulation (PWM) techniques to drive as many as 18 HBLEDs in series with output current above 2 A in a typical application. It contains features needed to regulate currents based on buck, boost, buck-boost, flyback, and single-ended primary inductor converter (SEPIC) power-supply topologies.

Running hot and cold

One of the biggest challenges in using HBLEDs is getting a handle on how to keep them cool while operating. Heat shortens their lifetimes, worsens efficiency, reduces brightness, and changes their color output. Heat can be particularly problematic in recessed down-lighting if the ceiling above the LED fixture is insulated.

No surprise: heat sinks can be a big help. It is now possible to find heat sinks and substrate material designed specifically for HBLEDs. One in this category is the Therma Clad insulated substrate from The Bergquist Co. It is a thin thermally conductive dielectric layer bonded to an aluminum board. It serves as an alternative to commonly used FR- material, which consists of copper laminated to a glass-epoxy substrate.

Besides worrying about how heat and operating parameters affect HBLED output, designers must factor in variations of the LEDs themselves. A point to note about HBLEDs is that manufacturers sort them according to their performance qualities. The practice is analogous to the way semiconductor makers sort their products according to tested parameters. LEDs get sorted or binned at manufacture according to their flux rating, tint, forward voltage, and color. But color bins have been relatively broad, forcing some users of multiple LEDs in a single fixture to manually select them for a more uniform output.

Such uniformity issues are now being addressed, however. For example, Cree has developed a line of EasyWhite bins of 3500 K, 3000 K, and 2700 K color temperatures that are 75% narrower than standard color regions. These are specified like traditional light sources, namely with the desired color temperature and brightness level. Cree uses multiple EasyWhite LED chips in its XLampMC-E light. It can serve as a replacement for 20-W to 35-W halogen bulbs for indoor use.

Cree also provides an interactive Product Characterization Tool (PCT) that simplifies the task of relating LED performance figures to real-world conditions. Accessible on Cree's Web site, it characterizes any of the company's XLamp LED products over a wide range of operating conditions.

And the DoE is making it easier for users to compare LED products as well. On its Web site are results of the CALiPER (Commercially Available LED Product Evaluation and Reporting) program. To date, DOE has conducted seven rounds of CALiPER testing, with up to 30 products tested in each round.

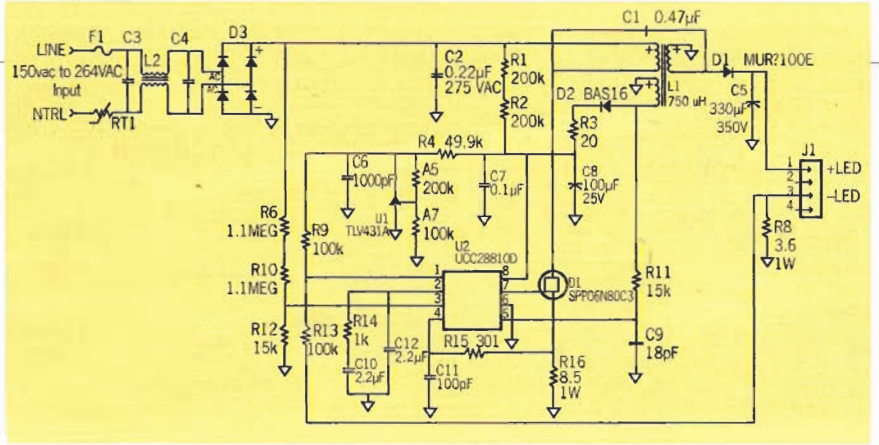
CALiPER testing has covered such products as downlights, task/desk, under-cabinet, outdoor, step/wall, directional replacement lamps, and other replacement lamps. Test reports are designed to give objective product performance information as well as benchmarking data with respect to other light source technologies.

Mixing Colors

One way to get a high-intensity white light from LEDs is by mixing red, green and blue (RGB) LED light. However, this method is

Resources

Texas Instruments, *focus.ti.com/docs/solution/folders/print/475.html*
Rensselaer Polytechnic Institute, *news.rpi.edu/update.do?artcenterkey=2526*
Micrel Inc., *tinyurl.com/yjz43q4*
Maxim Integrated Products, MAX16819/16820 reference circuit, *tinyurl.com/yz5gfmu*
National Semiconductor LM3424 PowerWise energy efficient LED driver, *www.national.com/pf/LM/LM3424.html#Overview*
The Bergquist Co., *www.bergquistcompany.com/*
Honeywell heat sink material, *tinyurl.com/yzt5epf*
Cree product characterization tool, *pct.cree.com/register.asp*
LEDtronics Inc., *www.ledtronics.com/*
Lighting Sciences Corp., *lsgc.com/*



EU regulations demand that HBLED drivers incorporate power-factor correction. This transition-mode single-ended primary inductor converter (SEPIC) circuit incorporates PFC and has the advantage of clamping the switching waveforms on the power semiconductor to allow use of lower voltage and, hence, more efficient parts. Additionally, there is less ringing, which makes EMI filtering easier.

impractical for mass production because it is expensive, involving the use of sophisticated electro-optical apparatus to manage the blending and diffusion of the different LED colors.

The more practical approach uses a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, analogous to how phosphor in a fluorescent bulb works. Specifically, the technique often involves coating a blue indium-gallium-nitride (InGaN) LED with a phosphor layer of different colors. The main drawback is a lower efficiency than with the RGB method because more light gets converted to heat.

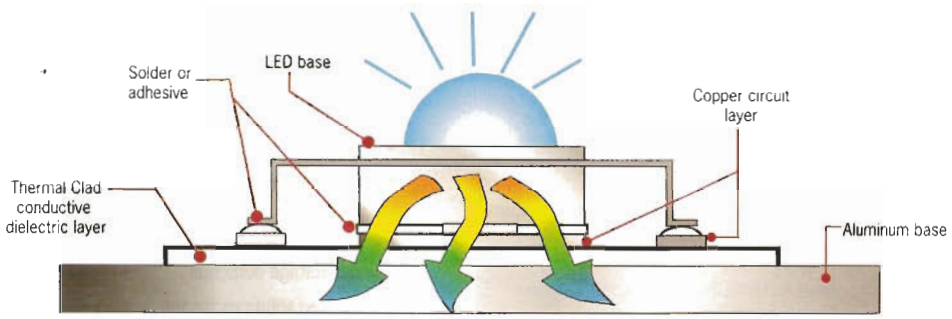
But OSRAM GmbH believes it has found an inexpensive way to produce a high-efficiency HBLED that puts out true, warm colors to boot. The company says the efficiency of the device is 104 lm/W, notable because such efficiencies have been seen only in the cold white part of the spectrum. The new LED outputs a spectrum resembling that of a halogen lamp. OSRAM says it is still in the prototype stage.

Nevertheless, it is still a challenge to come up with an LED light bulb that fits into a conventional A-19 incandescent bulb socket. "There's just not enough room in such a socket with currently available LEDs," says LEDtronics Inc. marketing manager Jordan Papanier.

Actually, nearly all HBLED illumination products today come in PAR38 and MR16 housings, each consisting of several LEDs. There are however, some direct LED light bulb replacements for a standard incandescent in an A-19 socket. Problem is, their output isn't considered high enough for good illumination before heat-management problems set in and efficiency levels drop.

Such difficulties haven't prevented several manufacturers from devising HBLED products. Among them is Philips Electronics, which has also entered the L Prize competition that will pay $10 million for the first LED able to replace a common 60-W incandescent light bulb. LED maker Cree Inc. demonstrated late last year an A-19 socket white LED with an output of 962 lumens at 102 lumens/W, the light equivalent of a 65-W incandescent bulb, but the LED consumes just 9.5W. Cree claims this is the highest lumen output and efficiency yet reported.

Lighting Sciences Corp. is the company behind some of the most notable and visible high-brightness white LED applications, such as lighting for the 2009 New York City Times Square New Year's Eve ball. It recently announced an LED that screws into a conventional A-19 socket to replace a 60-W incandescent bulb or a 13-W fluorescent light. The LED uses 7.4W of energy and is expected to last six times longer than the average compact fluorescent bulb. **EE&T**



Manufacturers are coming up with various ideas about how to better extract heat from LEDs. One recent development is The Bergquist Co.'s Therma Clad insulated metal substrate, which is designed to more quickly route heat away from an HBLED to the aluminum substrate.