HIGH-BRIGHTNESS LEDs usher in new applications and standards

AS HIGH-BRIGHTNESS LEDs INCREASE IN POWER, THEY WILL ENABLE NEW APPLICATIONS RANGING FROM ARCHITECTURAL LIGHTING TO MEDICAL PRODUCTS. ENERGY STAR LIGHTING STANDARDS ARE EVOLVING TO KEEP THE FOCUS ON TOTAL SYSTEM EFFICIENCY.

BY MARGERY CONNER • TECHNICAL EDITOR

The HB LED (high-brightness light-emitting diode) continues to increase in power: For example, Cree currently offers devices capable of producing 88 lm/W, and plans call for the emergence of 100-lm/W devices by year-end and 150-lm/W devices within five years. As individual components, HB LEDs are more efficient than incandescent or even fluorescent lights. However, at the system level, their advantages fade because you must factor in the power losses they entail, including ac/dc and dc/dc conversion and current regulation. In addition, the LED lighting fixture, or luminaire, introduces losses, and the LED assembly itself has thermal losses.

AT A GLANCE

- Overall lighting-system efficiency includes power conversion, current regulation, and the HB-LED (high-brightness-light-emitting-diode) fixture itself, not just the efficiency of the HB LED die.
- HB-LED-lighting systems are currently less efficient than the most efficient fluorescent lights. But the HB LEDs will catch up within three years.
- HB LEDs' additional advantages of pure light, ruggedness, and dimness control will help them move into new medical and lighting applications.

The US DOE (Department of Energy) recently finalized a new Energy Star specification for SSL (solid-state-lighting) luminaires so that system designers can use consistent comparison numbers for lighting sources and fixtures. Rather than looking at HB LEDs' luminous efficiency at the component level, the new specification looks at the overall luminaire efficacy.

Current-driven LEDs' light is directly proportional to forward current. The devices have the steep voltage-to-current curve you'd expect from a diode, in which even a small change in voltage results in a relatively large change in current and, therefore, brightness, making it important to control current rather than voltage (**Reference 1**). Many IC manufacturers, usually those in the power-controller business, have entered the LED-driver-current-regulator market. These vendors include Texas Instruments, National Semiconductor, Intersil, Cypress, Maxim, and Linear Technology.

In addition to the current regulator, the lighting system may have to include an ac/dc converter, or, for battery-powered systems, it may require a dc/dc boost converter. Overall, the system may lose 10 to 15% of the system power in conversion inefficiencies alone. In addition, the loss of as many as half the lumens in SSL can occur in the fixture itself due to reflection and lens losses.

The criteria for the Energy Star SSL specification will go into effect on Sept 30, 2008 (**Reference 2**). The specification has two parts. Category A covers parts that are available today. It states that a Category A-compliant recessed lighting fixture, or "downlight," must be 35 lm/W. Category B will cover the efficient SSL devices that will have emerged within three years. At that time, SSL will rival today's most efficient lighting systems using traditional light sources. For example, the best commonly available, high-performance T8 fluorescent-lamp and electronic-ballast systems currently produce approximately 100 lm/W. High-quality fixtures for these lamp-ballast systems are approximately 70% efficient, yielding 70-lm/W luminaire efficacy. Based on today's commercially available SSL technology, HB-LED luminaires cannot achieve the Category B level of minimum luminaire efficacy. However, LED technology is advancing rapidly and likely will meet Energy Star's Category B requirements. But LEDs have strengths in addition to efficiency and longevity, which make SSL worth pursuing even before further efficiencies are available. For example, dimming is difficult with fluorescent lighting, whereas it involves only a straightforward drop in current for LEDs. In addition, you can dynamically change the color of a room with LEDs by having arrays of cool- and warm-white LEDs. Expect that SSL will become a significant technology in home and industrial lighting in the next five years (**Reference 3**).

Most HB LEDs available today require dc voltage and current, so most of an SSL system comprises the conversion circuitry to convert from ac power to regulated dc power. However, Seoul Semiconductor recently introduced its Acriche HB LED, which runs directly off ac power (**Figure 1**). You use a single surface-mount resistor to set the input voltage, which can range from 100 to 110V ac and 220 to 230V ac. At the die level, the LED consists of layers of LED-semiconductor junctions. The diode junctions build up until the total forward voltage is relatively close to the ac voltage of 110 or 220V. The devices have two series of opposing LEDs. The first turns on and conducts over the positive-voltage half of the cycle, and the second conducts over the second half of the cycle, so that the LED emits light over the entire ac-voltage cycle. Running directly off the ac and simplifying the power-conversion circuitry increase system reliability and decrease design time. The Acriche HB LEDs come in two models: the AW3200 for 100/1110V and the AW3220 for 220/230V. Both versions provide 59 lm/W, which is lower than but comparable with the light that dc-powered HB LEDs produce.

Figure 1 The Acriche series of HB LEDs from Seoul Semiconductor runs directly off ac-line voltage with no power conversion or regulation. It provides 59 lm/W of light.

As energy costs continue to rise, lighting efficiency increases in importance. The US DOE estimates that lighting uses 20% of a building's electricity. However, in developing countries, which often lack reliable grid power, individuals can procure reliable nighttime lighting using solar-panel-based SSL to power batteries. The only other option is often kerosene lanterns, which are both dangerous and expensive (see **sidebar** "Solid-state lighting offers efficient relief for light-starved countries").

In addition to HB LEDs' obvious advantages of efficiency and lifetime, they have other strong points that make them attractive for nontraditional lighting applications. For example, their narrow light spectrum makes them well-suited for applications such as bilirubin lights. Bilirubin is a reddish-yellow organic compound derived from hemoglobin during the normal destruction of erythrocytes. An excess of bilirubin can cause hyperbilirubinemia, with symptoms including jaundice—yellowish discoloration of tissues, including the sclera, or "white of the eye," and bodily fluids. Although low levels of bilirubin are not usually a concern, large amounts can circulate to tissues in the brain and may cause seizures and brain damage in newborns. Fortunately, the condition usually responds to a phototherapeutic treatment because bilirubin absorbs blue light and breaks down into a water-soluble form that passes out of the body (**Figure 2**). The light is most effective in the narrow blue range of 458 to 462 nm. In the past, therapeutic bilirubin lights have comprised custom-made blue fluorescent tubes and color filters. However, fluorescent lights have a relatively wide optical spectrum. Although the distribution centers on the desired wavelength, the spectral distribution has lobes on both sides, indicating light energy that is less effective at breaking down the bilirubin and resulting in a longer treatment period. Blue-LED bilirubin lights, in contrast, can target the correct frequency with almost no wasted light energy. In addition, LED-based bilirubin lights are mechanically stable, have greater longevity, and are cheaper than fluorescent devices. In the future, phototherapy will deliver light through

SOLID-STATE LIGHTING OFFERS EFFICIENT RELIEF FOR LIGHT-STARVED COUNTRIES

By Alan Li, Intersil

Some 1.6 billion people live in areas with abundant sunlight but little electricity. These people often must use expensive, heavily polluting, or hazardous methods for basic lighting. Now, the rapid evolution of LED (light-emitting-diode) technology promises to bring inexpensive, ubiquitous, off-grid solar lighting one step closer to reality.

One new-product concept comprises a laptop-sized, rooftop-mounted solar panel; heavy-gauge indoor wiring; and a lead-acid gel battery that powers eight 700-mA, highly efficient, 3.75V LEDs connected in series (Figure A). The Intersil ISL97801 HPLED (high-power-LED) driver powers this circuit. This driver has an integrated 3A switch, I/O short-circuit protection, and a configurable buck- or boost-driving architecture. In addition to PWM dimming, the ISL97801 can work with analog control that allows a rotary switch or an up/down-interface digital potentiometer to provide manual dimming, which further conserves energy.

Intersil has verified the circuit in the laboratory, where the circuit drives eight HPLEDs at 700 mA and 12V for 18W of lighting. Efficiency reaches 91 and 88% at 700- and 100-mA output current, respectively. In general, LED brightness can degrade by 20% from 25 to 100°C; therefore, thermal management is crucial. To alleviate thermal problems, you must mount the LEDs on a metal-clad PCB (printed-circuit board) and use adequate heat sinking. If cost allows, you can parallel multiple strings of LEDs with some logic design to cycle the individual PWM signals, thereby reducing the LEDs' power dissipation and keeping the LEDs' MTBF (mean time between failures) in check. Assuming that the application runs on a small-form-factor, 12V battery that you charge from the solar panels, this 18W LED light can operate for as long as a few hours, which is adequately bright with reasonable operating time for the people who need it most.

AUTHOR'S BIOGRAPHY

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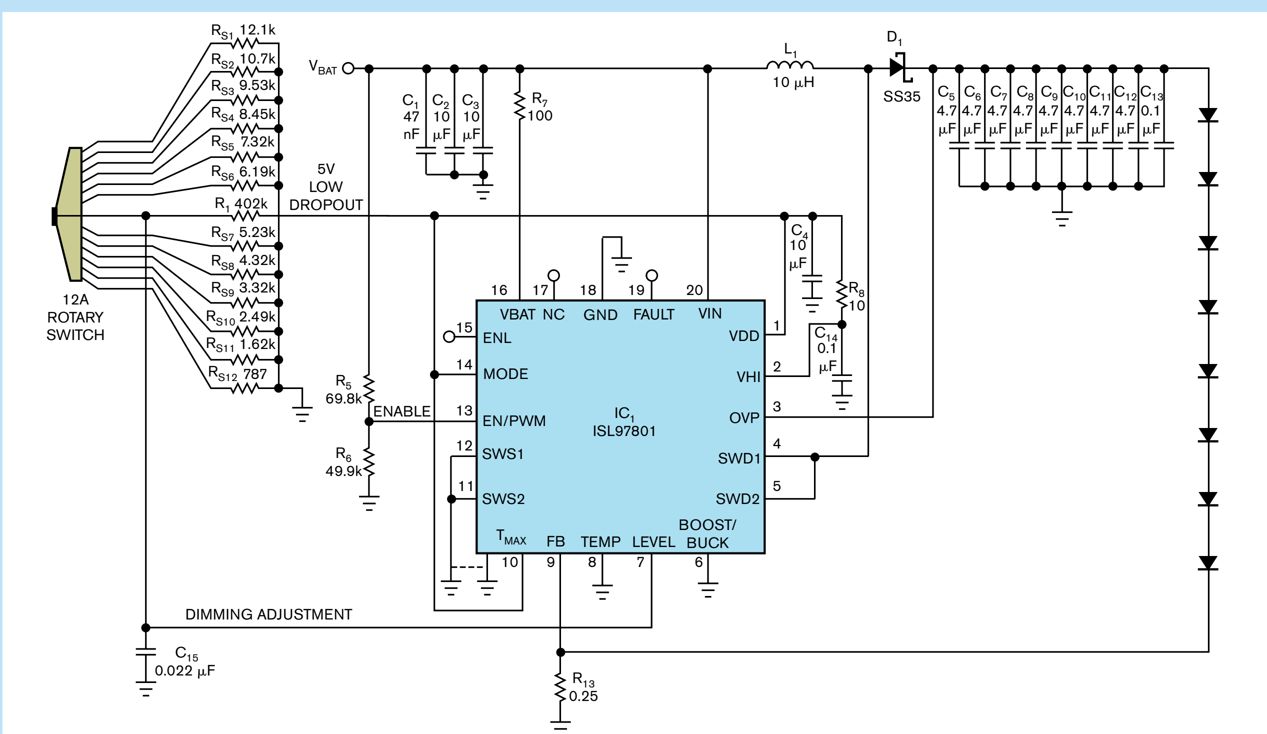

Figure A In areas lacking a reliable power grid, a solar panel charging a battery may be the only safe, cost-effective alternative to a kerosene lamp. This circuit allows for manual dimming to further conserve the battery power.

"light cloths," which can even more efficiently deliver the treatment than a light box can.

A significant difference between HB LEDs and traditional incandescent or fluorescent lighting is that HB LEDs come in a greater variety of packages. Given this fact, you might expect standards in packaging to be on the way, but that scenario won't happen for at least another five years, predicts Mark McClear, director of business development at Cree. "Every time we make [HB LEDs] brighter, cheaper, and more efficient, we enable more applications. We're on a steep curve, doing all three at once, and an important component is the package. We have one type of package; our competitor might have another … not to confound the customer but because [one type of package] gets more light out, and light is valuable," he says.

The rapid advancements in HB LEDs bring up a concern for eye safety, which these devices' designers often overlook, according to Cary Eskow, director of Avnet's LightSpeed SSL and LED business unit. "The rapid advancement of HB LEDs may have outpaced safe and careful design," he says. The most obvious hazard to the eye is from the intensity of the light: Some HB LEDs can deliver as much as 150 lm from a small die. In some circumstances, this amount of light can damage the eye through either photothermal or photochemical processes.

Figure 2 Blue LEDs, like those in this bassinet system from Natus Medical, target the most effective blue-light spectrum of 458 to 462 nm for the treatment of hyperbilirubinemia in infants.

Our human blink response offers little protection to these kinds of damage because the response doesn't occur at the ends of the visual spectrum where the damage occurs.

Photothermal injury occurs when the temperature of the retina increases by approximately 10°C. Because of the way heat flows in the retina, this damage directly relates to spot size; it increases as the size of the focused spot decreases, much as the pressure of a pinpoint on your skin is more painful than the same pressure applied with a finger tip. This type of damage tends to dominate as the wavelength lengthens from approximately 550 nm (green) through yellow, orange, and red to IR (infrared).

Intense violet and blue light, on the other hand, can cause photochemical injury to the eye. Blue light and short wavelengths can be 1000 times more dangerous than IR radiation. Again, the blink response is of no help in this situation. Eskow strongly suggests that designers keep safety as a primary design consideration for HB LEDs as the devices make their way into an ever-increasing variety of applications, from lighting to medical and even to toys.EDN

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