

# Simple, Efficient, High-Brightness-LED Control

*LEDs are also less vulnerable to moisture ingress*

*A variety of lighting applications are adopting HBLEDs (high-brightness light-emitting diodes), making them the fastest growing light source worldwide. Today's advanced devices boast luminous efficacies in the 35-to-50-lm/W (lumens-per-Watt) range. Prototype devices emit more than 100 lm/W.*

*By Peter Green, International Rectifier*

Current trends suggest that ongoing improvements in LED technology can produce devices with greater luminous efficacy than fluorescent lamps and eventually, will match HID lamp outputs. HBLEDs already surpass incandescent and halogen lamps' and provide longer life, greater reliability, smaller size, and superior low-temperature characteristics. Additionally, LEDs are solid-state devices containing neither toxic gases nor filaments.

Designers are increasingly using HBLEDs in architectural lighting, street lighting, decora-

tive lighting, signage, and backlighting for high-end televisions and monitors. These applications must derive a regulated DC current from the AC line or DC-voltage supply.

International Rectifier's IRS2540 control IC implements a constant-current source for non-isolated applications. These include, for example, where a low-voltage isolated power supply already exists or where a class-2 fixture houses the LEDs in an inaccessible location, as is the case with traffic lights. This arrangement is similar to electronic ballasts for fluorescent or HID lamps, which typically do not provide galvanic isolation.

Buck converters are suitable for applications where the input voltage is greater than the output voltage, which includes most signage, decorative, and architectural lighting. Typical arrays use series-connected LED stacks to ensure equal current through all devices (Figure 1).

The series connection avoids the additional circuitry that would otherwise be necessary to maintain equal currents in parallel strings. Nonetheless, large arrays require parallel strings when the forward voltage across a single series stack would exceed either the available compliance voltage or the converter's maximum operating voltage.

The most common LED failure mode is a short circuit. When an LED fails in a series string, the others will all continue to operate normally. A failure of LEDs in parallel, however, prevents the remaining LEDs from operating. The combined forward voltage drop for series LEDs varies with temperature and with LED color. The forward voltage also has a wide tolerance in production.

Many applications require dimming. Combinations of primary-color LEDs can create any color in the spectrum by adjusting the intensities of each color, allowing many possibilities for display lighting, signage, and mood lighting. A buck regulator system based on the IRS2540 can dim over the full range from a logic-level PWM control signal.

The low-frequency PWM signal switches the average LED current by driving the converter in burst mode, changing the light intensity (Figure 2).

Unlike current modulation, PWM accomplishes the dimming without changing the LED's color. The PWM frequency is sufficient to prevent visible flicker.

HBLEDs enable architects, designers, specifiers, and manufacturers to create never-before-possible lighting effects and design luminaires for theaters, studios, nightclubs, restaurants, and other high-visibility venues. Digital scene controls and protocols such as DMX512 provide means for dramatic and dynamic lighting displays. The IRS2540 suits these applications allowing simple interfacing with microcontroller-based dimming circuitry.

LED light sources also naturally lend themselves to landscape and outdoor lighting, offering longer life correspondingly lower maintenance costs than incandescent and fluorescent lamps. LEDs are also less vulnerable to moisture ingress. Unlike conventional bulbs, LEDs have no fragile components to break, even when roughly handled. Flexible digital-control systems can produce dramatic lighting effects as they do in interior applications. Lighting schemes can change without rewiring or installing new systems.

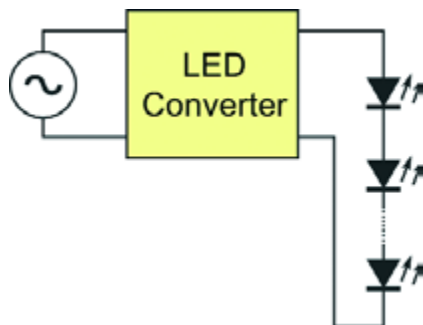


Figure 1: A basic LED converter provides constant current to series strings of LEDs.

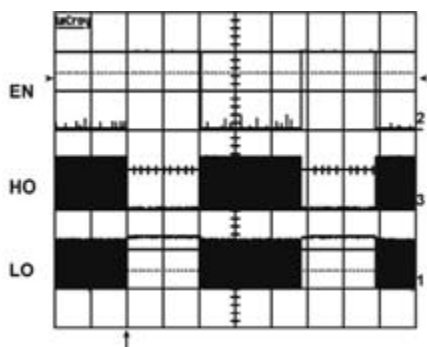


Figure 2: Burst-mode dimming provides excellent control of the LED string's light output while maintaining excellent color fidelity.

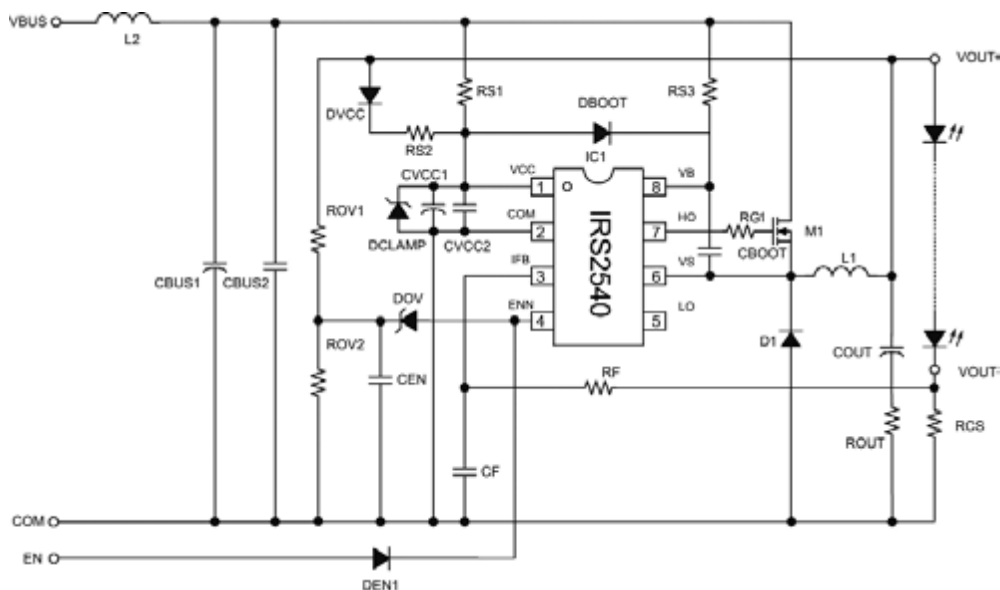


Figure 3: The IRS2540 provides conversion continuous-time current monitoring for true average current control.

Lighting designers are increasingly turning to high-power LEDs for their long life, ruggedness, flexibility, small size, and energy efficiency. They now have access to larger LEDs than those available just a few years ago—1, 3, and 5 W/package—that operate on currents up to 1.5 A.

By integrating a floating high-side driver, IRS2540 is able to use a current-sensing scheme that continuously monitors LED current (Figure 3).

Other controllers are limited to monitoring the current only during the time when the buck-converter switch is on. This allows the IRS2540 to realize average-current control as opposed to peak-current control and pro-

vides an inherently stable regulation that operates over a wider line and load range without running into design limitations.

The converter IC accurately regulates the current by means of its patented time-delayed hysteretic-control method. The overall system is simple, flexible, and able to power LEDs from a DC bus or directly from a rectified AC line. Controlling current accurately is a challenge when the forward voltage of each LED has a large manufacturing tolerance. For example, in the case of Lumiled's popular Luxeon III emitter, the forward voltage,  $V_F$ , varies around a nominal of 3.70V from 3.03 to 4.47V for white, green, or blue, per the manufacturer's datasheet. This slightly asymmetrical tolerance allows a -18%, +20% variation in the device's forward voltage at 700 mA. The  $V_F$  also varies over temperature, with a negative temperature coefficient of -2mV/C. At 100C, this is another 0.15V voltage change. Typical strings of multiple LEDs further magnify these variations, requiring medium to high bus voltages.

The IRS2540 achieves accurate current control with a simple design that is inherently stable and requires no complex circuit analysis. Because this method uses continuous-current mode, the design must limit stress during hard switching. It achieves this simply by controlling the control-circuits' delays. The design's peak currents are far smaller than in a peak-current control-mode topology. As a result, the LED converter can use smaller, more efficient MOSFET switches and a smaller inductor.

The control-circuit delays do cause a current ripple in the inductor, but an output capacitor

in parallel with the load reduces the ripple current. The output capacitor also reduces the frequency by adding delays to the current feedback, which improves the system's efficiency by reducing switching losses. Overload and short-circuit protection are inherent to this configuration. Implementing open-load protection and PWM dimming is also easy.

Two variations of the high-voltage LED-converter IC drive LED strings with forward voltages as great as 200 V (IRS2540) and 600 V (IRS2541). The design achieves efficiencies greater than 85% at 175 kHz (Figure 4). The converter operates at PWM duty cycles to 100% with no stability issues above 50% as can occur in peak-current-controlled systems.

Manufacturers of LCD Televisions, monitors, laptop displays, and various custom-sized panels are now replacing CCFL (cold-cathode fluorescent lamp) with LED backlighting sources, which offer substantial advantages. The LED-based backlighting system expands the palette of reproducible hues by as much as 45 percent. LED-based systems have already achieved 105% reproduction of the NTSC color space compared with the best CCFL lit LCD TVs, which only reproduce 65-75%. Not even a CRT (cathode-ray tube) display can match the color reproduction and brightness of an LED-based system. An LED-based system also has the potential for dynamic tuning to reproduce images with even greater accuracy.

PCIM 12/202

[www.irf.com](http://www.irf.com)



Figure 4: The IRS2540 and its sibling, the IRS2541, support bus voltages as large as 200 and 600 V, respectively.