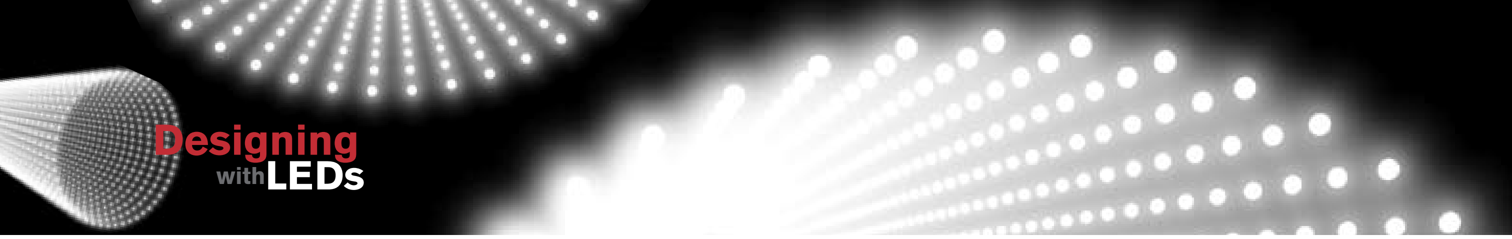

BY JOHN BETTEN, TEXAS INSTRUMENTS

Inverting buck-boost converter regulates LED current

When input- and output-voltage ranges overlap and are "dirty" to boot, consider biasing on LEDs with a negative voltage.

Controlling the brightness of LEDs requires a driver that provides a constant, regulated current. To achieve this goal, the driver topology must be able to generate a large enough output voltage to forward bias the LEDs. So, what are your choices when the input- and output-voltage ranges overlap? In one case, the converter may need to step down the input voltage, and, in another, it may need to boost up the output voltage. These situations often arise in applications with wide-ranging "dirty" input-power sources, such as automotive systems. Several topologies work well in this buck or boost roll, such as the SEPIC (single-ended-primary-inductor converter) or a four-switch buck-boost converter. These topologies generally require a large number of components, increasing the materials cost of the design. Although most experts consider these choices acceptable, the converters provide positive output voltages. A negative-output voltage converter, however, can provide an alternative that you should not overlook.

Figure 1 shows the schematic of an inverting buck-boost circuit driving three LEDs in a constant-current configuration. This circuit has several positive attributes. First, it uses a standard buck controller, minimizing cost and facilitating possible system-level reuse. You can easily adapt this circuit to use an integrated FET buck controller or a synchronous-buck topology for improved efficiency. This topology uses the same number of power-stage components as a simple buck converter, thereby realizing the fewest components for a switching regulator and the lowest overall cost compared with other topologies. Because the LED output is light, it may not matter from a system level that the LEDs are biased on with negative rather than positive voltage.

The system regulates LED current by

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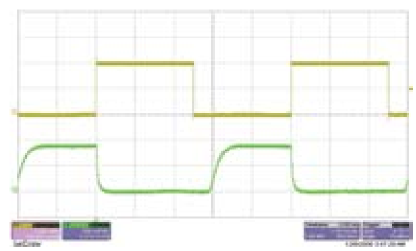

FIGURE 2 Shorting the soft-start capacitor to ground allows the PWM drive (top) to dim the LED by decreasing its current (bottom). For applications that don't require high-speed response or 100% PWM dimming, this method may suffice.

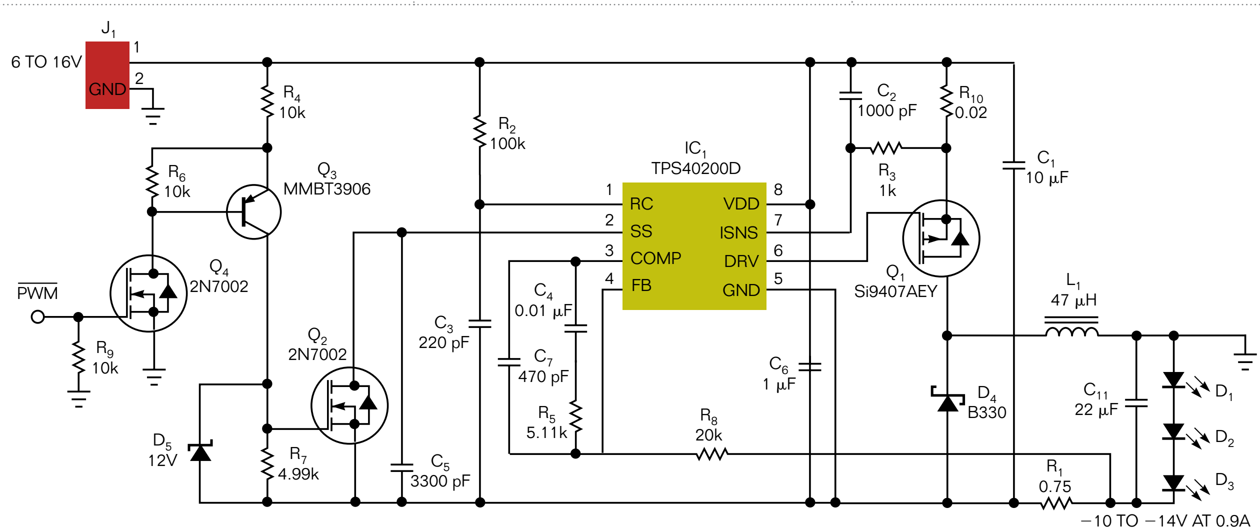

FIGURE 1 This buck-boost circuit regulates a constant LED current with a negative output voltage.

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sensing the voltage across sense resistor R_1 and using it as feedback to the control circuit. For this direct feedback to work properly, you must reference the controller's ground pin to the negative output voltage. Referencing the controller to system ground would require a level-shifting circuit. This "negative ground" places several restrictions on the circuit. The power MOSFET, diode, and controller must have a higher voltage rating than the sum of the input and the output voltage.

Second, external interfacing with the controller, such as enable, requires level-shifting the signal from system ground to controller ground, resulting in additional components. For this reason alone, it is best to eliminate or minimize the use of unnecessary external controls.

Finally, an inverting buck-boost converter places additional voltage and current stresses on the power devices compared with a four-switch buck-boost circuit, reducing relative efficiency. But the stresses are comparable to that of the SEPIC. Even so, this circuit achieved 89% efficiency. You can achieve additional improvements of 2 to 3% by making the circuit fully synchronous.

A simple way to dim the intensity of the LEDs is by rapidly turning the converter on and off via shorting out soft-start capacitor C_5. **Figure 2** shows the PWM input signal and the actual LED current. This PWM-dimming technique is efficient because the converter is off and consumes little power when the SS pin is shorted. But this method is also relatively slow because the converter must ramp the output current up in a controlled fashion each time it goes on, introducing a nonlinear, finite dead time before the output current rises. This action also reduces the minimum on-time duty cycle to 10 to 20%. In LED applications that do not require high-speed and 100% PWM dimming, this method may suffice.

This inverting buck-boost circuit provides an additional option for driving LEDs. Using a low-cost buck controller and a few parts makes this alternative suitable for more complex topologies.

John Betten is an application engineer and senior member of the technical staff at Texas Instruments and has more than 23 years' worth of ac/dc- and dc/dc-power-conversion-design experience. Betten received his bachelor's degree in electrical engineering from the University of Pittsburgh and is a member of IEEE.