Cascaded converter boosts LED-drive capability

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Powering 20 to 30 white LEDs from three alkaline cells presents an interesting problem for the conventional boost converter. The required boost ratio and duty factor are simply impractical. If you are determined to design with off-the-shelf components, cascading two stages of boost can yield reasonable results. This topology has been around for decades, but engineers often perceive it as too complicated. There are, however, certain inherent advantages in this approach's component requirements. The first-stage switch need not tolerate the total output voltage of the second switch, and the second switch does not have the current requirements of the first. If the duty factor were not a concern, the current/voltage requirements of a single-stage boost would require a larger, more expensive switch that might easily approach the cost of both switches in the cascaded boost. You can also realize similar advantages of the inductors, rectifiers, and filter capacitors.

This Design Idea powers 24 white or ultraviolet LEDs in series at approximately 20 mA. At a nominal 4.5V-dc input, the measured efficiency is 84.2%. This figure is reasonable for a 2 to 2.5W converter. At a 3V-dc input, the overall boost ratio for a noncascaded converter is potentially more than 30-to-1, requiring an on-time duty factor of approximately 97%. In a cascaded boost converter, this duty factor is a function of the square root of the total boost ratio. This ratio equates to

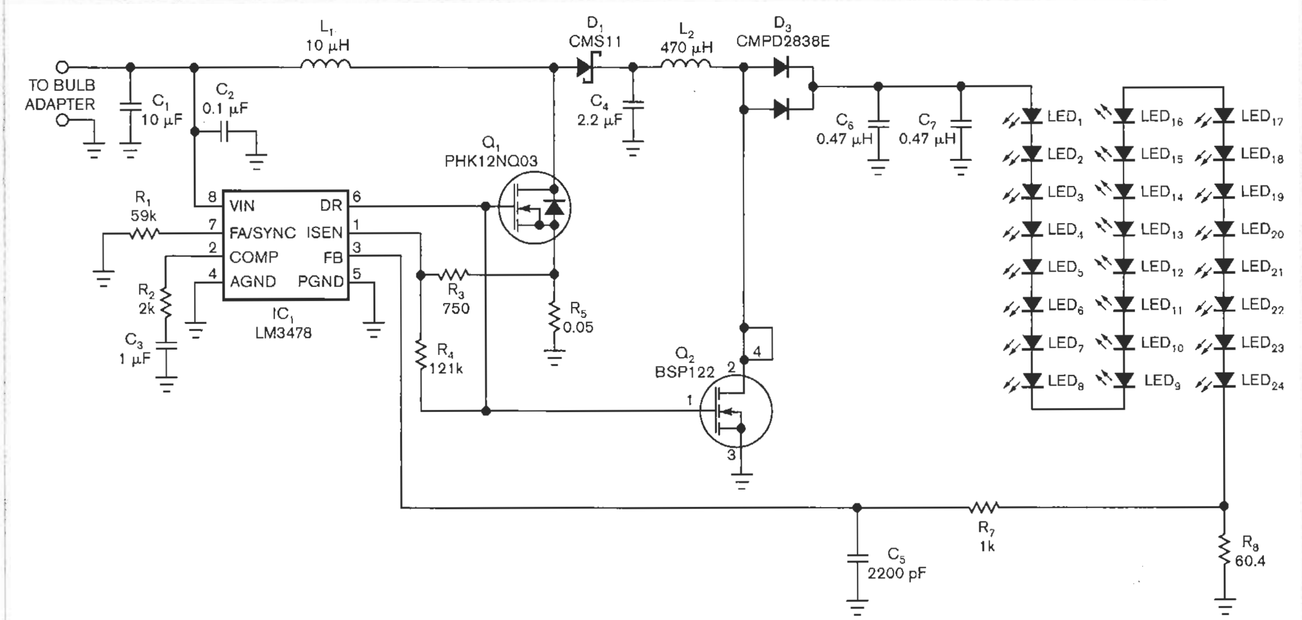

Figure 1 Comprising off-the-shelf components, this circuit cascades two stages of boost to drive a string of 20 to 30 LEDs.

a maximum of about 82% just before the occurrence of undervoltage shutdown. At a normal 4.5V-dc input, the duty factor should be slightly more than 77%.

The circuit in **Figure 1** implements a cascaded boost converter, which takes the place of the lens assembly in a popular heavy-duty flashlight. It includes 24 white or ultraviolet LEDs on one side of the circular PCB (printed-circuit board) and the active circuitry on the other. You can substitute red LEDs for three or four of the ultraviolet LEDs to offer an appropriate visible backlight. Although you may prefer to use a single high-powered white LED, high-powered ultraviolet LEDs appear to be unobtainable. This project uses 20 inexpensive LEDs offering 400 mW of optical power for 1.52W input at a more useful 30° viewing angle. Its directional nature also helps prevent accidental eye damage. Ultraviolet-light sources find use in many applications, including gem inspection, currency inspection, and scorpion detection.

The PWM controller, IC_1, an LM3478, operates at voltages as low as 3V dc, eliminating the need for a charge pump. The transistors are rated for less than 3V gate drive. IC_1 simultaneously drives Q_1 and Q_2. The circuit requires only one controller and uses off-the-shelf inductors. The first-stage inductor and filter capacitor can produce substantial ripple without adversely affecting the final output ripple. The first rectifier is an inexpensive, 40V Schottky unit, and the second is a simple signal diode rated for 120V.

IC_1 operates at a switching frequency of approximately 300 kHz, which R_1 sets. The design uses a current-mode-control scheme with slope compensation. A signal from current-sense resistor R_5 modulates slope compensation through R_3. In this case, the value of R_5 is small for enhanced efficiency. R_4 sums the signal with the gate-drive output to increase its apparent amplitude by the current-sense input at Pin 1. R_2 and C_3 are the usual compensation components. In this case, the response time of the converter is unimportant, so it is easy to choose the components.

It is easy to overlook the cascaded boost converter without sufficiently analyzing it. Mass-produced components that suit their function afford a more cost-effective and simple approach than you might realize at first. An integrated flyback regulator can easily require many components to provide this kind of solution without any real advantage. It is also likely to require custom magnetics.