Switching regulator efficiently controls white-LED current

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A few years ago, manufacturers specified their white, but dim, LEDs for a maximum forward-current rating of 20 mA. Today's white LEDs deliver more light and thus must operate at ever-higher bias currents. Maintaining control of an LED's bias point while operating at high current near its maximum rating requires a new approach.

The simplest and most common method of biasing an LED involves connecting a resistor in series with the LED to limit the LED's maximum current, but this method directly impacts power efficiency, which you define as the ratio of power to the LED to the total input power. For a white LED operating at 350 mA, the corresponding forward-voltage drop across the diode is approximately 3.2V. A series resistor and LED connected to a 5V power source operates at 64% efficiency—that is, 3.2V for a 5V source. The power dissipates as heat, causing an average power loss in the series resistor of 36 mW at a forward current of 20 mA, which is acceptable, but this figure balloons to 630 mW at a forward current of 350 mA.

In addition, using a series resistor allows the diode's bias point and thus its brightness to fluctuate as the power-supply voltage and the ambient temperature vary. Based on National Semiconductor's (www.natsemi.com) LM2852 switched-mode bucking regulator, which features internal compensation and synchronous-MOSFET switches that can drive loads as large as 2A, the circuit efficiently provides constant-current drive to a high-current LED and minimizes the effects of supply-voltage and temperature variations on the LED's brightness (**Figure 1**).

In this circuit, the LM2852 operates at efficiency of approximately 93% and directly controls a step-down-regulator topology that maintains a constant current flow through LED_1, which potentiometer R_1 adjusts. Current-to-voltage conversion taking place within the circuit's control loop effectively regulates the circuit's output current. In operation, the LM2852 compares its internal reference voltage with the voltage from the divider formed by D_1, R_1, and R_2 and drives the control loop to maintain a constant 1.2V at its voltage-sense pin. Current through the voltage divider is proportional to the current through LED_1, and the ratio of the currents tracks over the circuit's operating-temperature range because D_1 and LED_1 exhibit approximately the same forward-voltage temperature coefficient of −2 mV/°C. Mounting D_1 and LED_1 next to each other on the pc board provides sufficiently close thermal coupling for temperature compensation.

With R_1's wiper fully clockwise, the

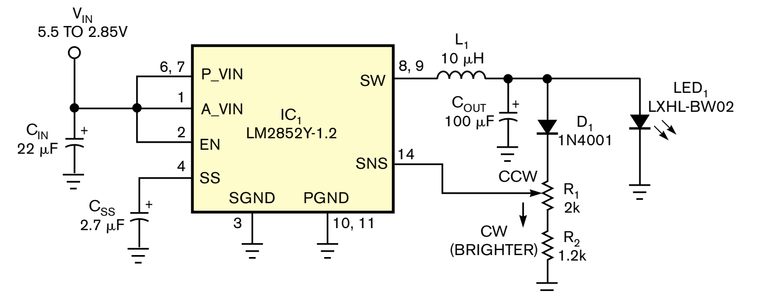

Figure 1 This circuit drives a high-current, white LED at 93% efficiency over input voltage and temperature. Potentiometer R_1 controls current through LED_1 and allows brightness adjustment. Diode D_1 provides temperature compensation for LED_1's forward-voltage drop.

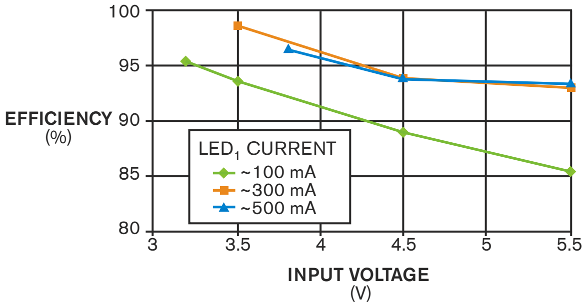

Figure 2 Circuit efficiency versus input voltage shows an increase in efficiency for increasing LED current and decreasing input voltage.

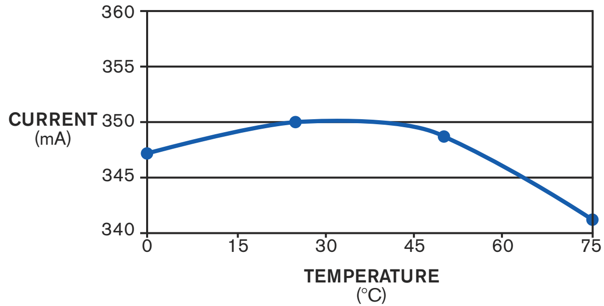

Figure 3 Current through the LED varies less than 3% over an operating-temperature range of 0 to 75°C.

current through D_1 approaches 1 mA, and the current through LED_1 averages approximately 500 mA. Adjusting R_1 counterclockwise reduces LED_1's forward current from 500 mA to 0A.

When scaling the values of R_1 and R_2 for a different current-loop gain, decreasing the gain impacts the circuit's conversion efficiency, and increasing the gain makes the loop more sensitive to component tolerances. To provide a remote brightness control, you can replace mechanical potentiometer R_1 with a digitally programmed potentiometer. Luxeon (www.luxeon.com), the manufacturer of LED_1, an LXHL-BW02, specifies limits of 350-mA continuous current and 500-mA peak-pulsed current. **Figure 2** shows the circuit's efficiency versus variations in input voltage. Note that the circuit's efficiency increases as input voltage decreases, which helps extend operating time in battery-powered-system applications.

As temperature fluctuates, the current through LED_1 varies less than 3% over the temperature range, a factor-of-three improvement over a series-resistor current-limiting circuit (**Figure 3**). Although more complex than a single resistor, the circuit in **Figure 1** requires only a few components. For L_1, this prototype uses Coilcraft's (www.coilcraft.com) MSS5131-103 surface-mount inductor rated for 10 μH.

National Semiconductor's data sheet for the LM2852 outlines criteria for selecting capacitors C_{IN}, C_{SS}, and C_{OUT}. For efficient heat removal, the circuit's pc board should include generous copper-mounting pads and traces for IC_1 and LED_1. At a forward current of 350 mA, LED_1 dissipates 1.1W, so consult the manufacturer's data sheet to review its thermal-design recommendations. EDN