Keywords: LED drive, high-efficiency, low-loss, green, current-sense amplifier, CSA, forced pulse-width modulation, FPWM, extend battery life, boost converter

APPLICATION NOTE 4328

Low-Loss LED Driver Improves a System's Green Footprint by Boosting Efficiency and Extending Battery Life

By: Keith Welsh, Senior Member of the Technical Staff
Fons Janssen, Senior Member of the Technical Staff
Jun 28, 2010

Abstract: Providing power to drive high-brightness LEDs (HB LEDs) can be achieved by a number of different schemes. Because many systems are battery powered, energy efficiency is key to maximizing each battery charge and the system's operating time. By improving battery efficiency you also improve the system's "green" footprint. Over the life of the battery for the same number of charge cycles, longer times between charges translate into potentially hundreds of hours of additional use from the batteries. Thus fewer batteries may end up in landfills or hazardous waste-disposal sites.

This article was also featured in Maxim's Engineering Journal, vol. 65 (PDF, 756kB).

The usual approach for low-power lighting is a simple linear regulator configured to operate in a constant-current mode (**Figure 1a**). This linear regulator offers the benefit of simple design. Its main disadvantage, however, is its high power loss, since the surplus headroom voltage is dissipated as heat in the current-measuring resistor and the regulator itself. This heat could also have a negative effect on the system's "green" footprint. More heat might require more cooling (a fan or large metal heatsink) which could consume still more energy, space, and weight while adding to materials cost and manufacturing time.

An alternative method employs a switch-mode-regulation scheme such as a buck regulator (**Figure 1b**). This type of regulator often requires a feedback voltage between 0.8V and 1.3V to regulate the current to the LED. The current-measurement scheme to set that voltage typically employs a low-value resistor in series with the LED. The voltage developed across this resistor provides the feedback voltage that maintains the constant-current power supply to the LED. The losses in the regulator can thus be reduced, but there are still losses in the system due to the power dissipated by the current-measuring resistor.

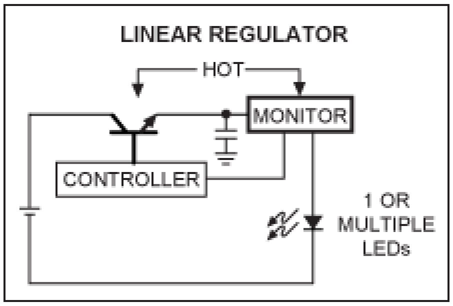

Figure 1a. A simple linear regulation scheme experiences power losses due to both the regulator and the current-setting resistor. The advantages of this circuit are its simplicity and the fact that it generates no EMI. The circuit can, however, only lower voltage and it does generate some heat.

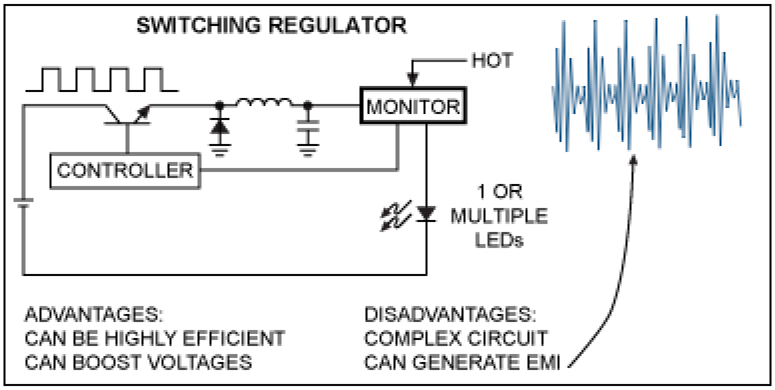

Figure 1b. In a basic switch-mode-regulation approach the main source of power loss comes from the energy dissipated by the current-sensing resistor. This design is highly efficient and can be reconfigured to boost voltages. It is, however, a more complex circuit and can generate EMI.

To reduce the power loss due to the current in the resistor, a low-loss current-measuring scheme such as a resistor/amplifier combination can be incorporated to provide the required feedback voltage to the switching converter. One such approach employs a dedicated, precision current-sense amplifier such as the MAX9938T, which generates 25V/V sensed across the series current-measuring resistor. This approach reduces the losses in the feedback portion of the circuit to only a few tens of milliwatts.

In the circuit shown in **Figure 2**, the boost converter configuration features the MAX9938T current-sense amplifier and uses a MAX8815A step-up converter to get its power from two NiMH series-connected cells. The MAX8815A operates at switching frequencies up to 2MHz with efficiencies up to 97%. That high-switching frequency minimizes the size of external components; internal compensation further reduces the external component count for cost- and space-sensitive applications. The converter can generate any output voltage from 3.3V to 5V from a two-cell NiMH.

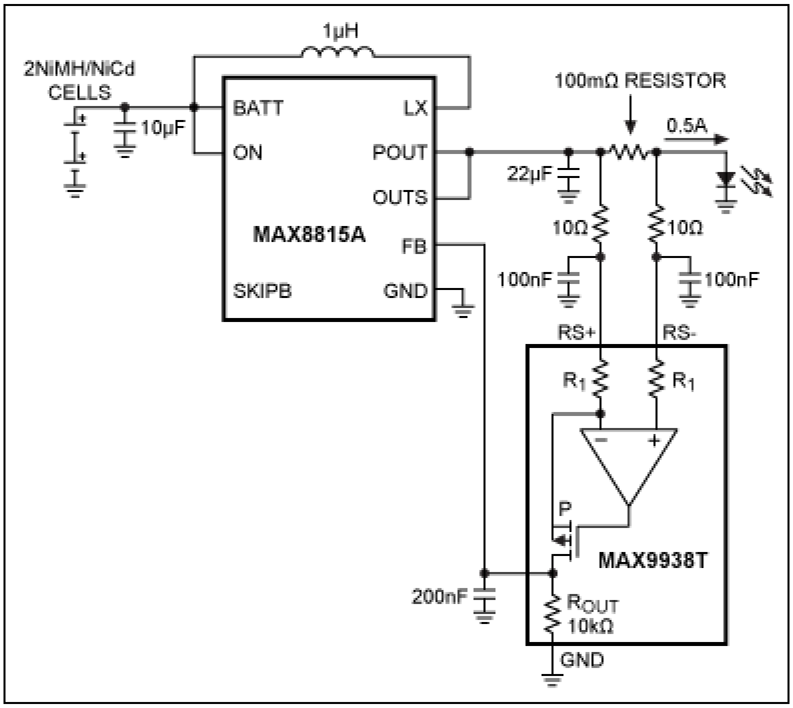

Figure 2. Working from Figure 1b, a current-sense amplifier such as the MAX9938T reduces the power losses in the current-sensing resistor to just a few tens of milliwatts vs. hundreds of milliwatts, or more, for the previous schemes in Figure 1.

The MAX9938T current-sense amplifier controls the current flowing into the LED. This amplifier integrates the gain-setting resistors on its inputs for a gain of 25V/V. Additionally, it offers precision accuracy specifications with a V_{OS} of less than 500µV (max) and a gain error of less than ±0.5% (max). Since the feedback voltage of the MAX8815A is 1.265V, a 100mΩ sense resistor yields (1.265V/25)/0.1Ω ≈ 0.5A of LED current.

The input common-mode filter, built up with the two 10Ω/100nF combinations, is needed to prevent common-mode voltages on the input of the MAX9938T. These are caused by the high-frequency ripple on the output of the MAX8815A. The 200nF capacitor on the MAX9938T's output reduces the bandwidth of the amplifier to prevent oscillations.

This design approach presents a low-component-count solution and the battery's operational life is maximized since the power losses are minimized in both the regulator and the control loop.

Related Parts		
MAX8815A	1A, 97% Efficiency, 30µA Quiescent Current, Step-Up Converter with True Shutdown	Free Samples
MAX9938	1µA, 4-Bump UCSP/SOT23, Precision Current-Sense Amplifier	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support

For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

---

Application Note 4328: http://www.maximintegrated.com/an4328
APPLICATION NOTE 4328, AN4328, AN 4328, APP4328, Appnote4328, Appnote 4328