100V Controller in 3mm × 3mm QFN or MSE Drives High Power LED Strings from Just About Any Input

by Keith Szolusha

Introduction

Strings of high power solid-state LEDs are replacing traditional lighting technologies in large area and high lumens light sources because of their high quality light output, unmatched durability, relatively low lifetime cost, constant-color dimming and energy efficiency. The list of applications grows daily, including LCD television backlights and projection system bulbs, industrial and architectural lighting systems, automotive headlamps, taillights and indicator lights, computer monitors, street lights, billboards and even stadium lights.

As the number of applications expands, so does the complexity of input requirements for the LED drivers. LED drivers must be able to handle wide ranging inputs, including the harsh transient voltage environment presented by automotive batteries, the wide voltage range of the Li-ion cells and wallwart voltages. For LED lighting manufacturers and designers, applying a different LED driver for each application means stocking, testing and designing with a wide variety of LED controllers. This can be an expensive and time-consuming proposition. It would be far better to use a controller that can be applied to many solutions.

The LT3756 high voltage LED driver features a unique topological versatility that allows it to be used in boost, buck-boost mode, buck mode, SEPIC, flyback and other topologies. Its high power capability provides potentially hundreds of watts of steady-state LED power over a very wide input voltage range. Its 100V floating LED current sense inputs allow the LED string to float above ground, as shown in the buck mode and buck-boost mode topologies in this article. Excellent PWM dimming architecture produces high dimming ratios, up to 3000:1.

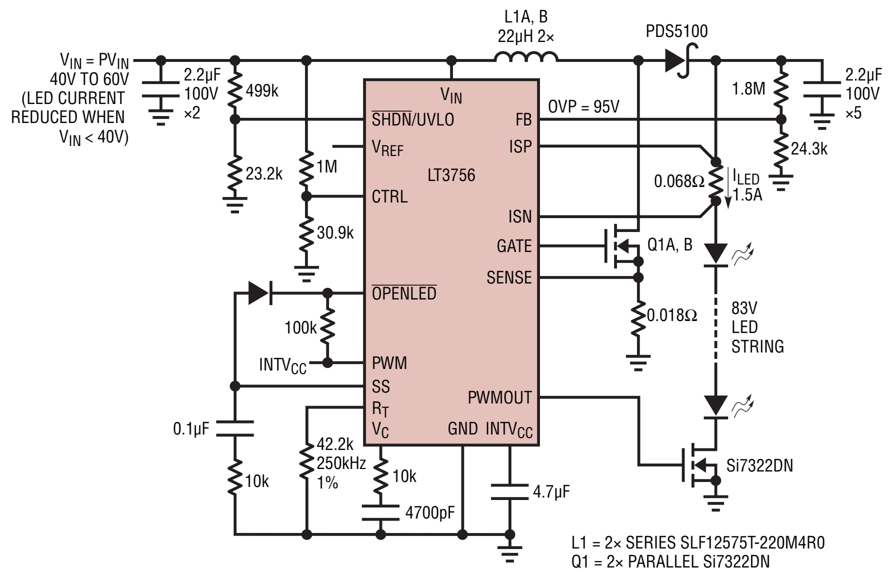

Figure 1. A 125W, 83V at 1.5A, 97% efficient boost LED driver for stadium lighting

A number of features protect the LEDs and surrounding components. Shutdown and undervoltage lockout, when combined with analog dimming derived from the input, provide the standard ON/OFF feature as well as a reduced LED current should the battery voltage drop to unacceptably low levels. Analog dimming is accurate and can be combined with PWM dimming for an extremely wide range of brightness control. The soft-start feature prevents spiking inrush currents during start-up. The $\overline{\text{OPENLED}}$ pin informs of open or missing LEDs and the SYNC (LT3756-1) pin can be used to sync switching to an external clock.

The 16-pin IC is available in a tiny QFN (3mm × 3mm) and an MSE package, both thermally enhanced. For applications with lower input voltage requirements, the $40V_{IN}$, $75V_{OUT}$ LT3755 LED controller is a similar option to the LT3756.

Although it is typically used as an LED driver, the LT3756's voltage FB pin provides a well-regulated output voltage if the constant current sense voltage is not used. This is a side benefit of the LT3756's overvoltage protection feature, in which the current control loop is superceded by the FB voltage loop in the case of an open LED string, thus preventing the controller from a running up the voltage in an effort to maintain current.

125W Boost LED Driver for Stadium Lights or Billboards

Lighting systems for stadiums, spotlights and billboards require huge strings of LEDs running at high power. The LT3756 controller can drive up to 100V LED strings with its floating sense resistor inputs ISP and ISN. The 125W LED driver in Figure 1 accepts a wide-range 40V–60V input taken from the output of a high power transformer.

The LT3756's high power GATE driver switches two 100V MOSFETs at 250kHz. This switching frequency minimizes the size of the discrete components while maintaining high 97% efficiency, thus producing a less-than-

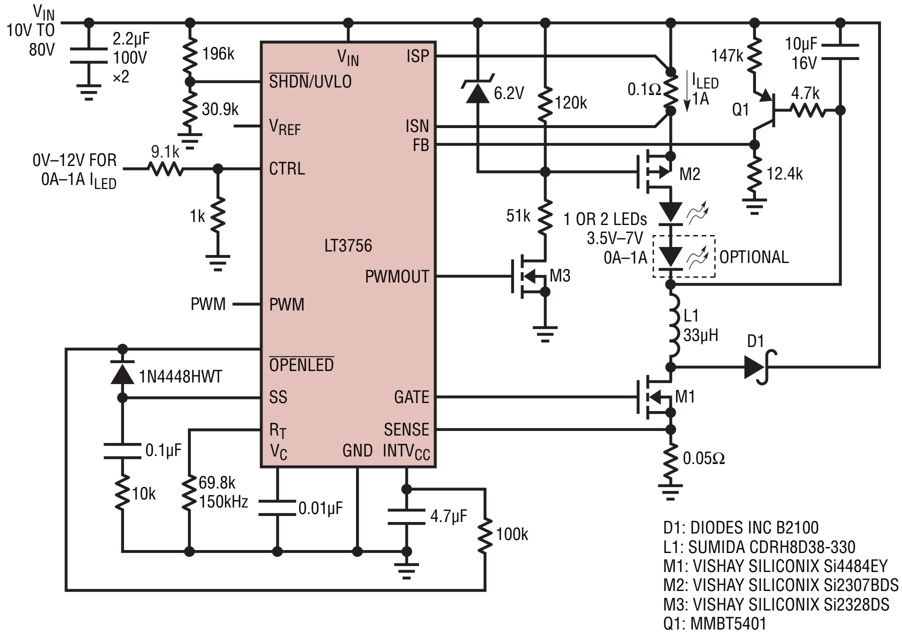

Figure 2. An $80V_{IN}$ buck mode LED driver with PWM dimming for single or double LEDs

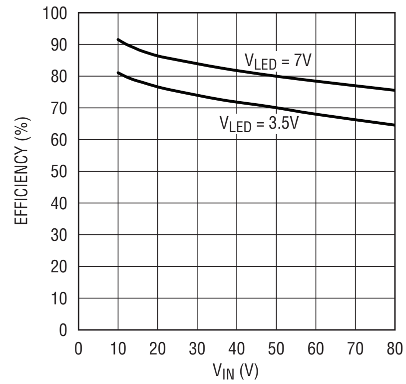

Figure 3. Efficiency for the buck mode converter in Figure 2

50°C discrete component temperature rise—far more manageable than the potential heat produced by the 83V string of 1.5A LEDs.

Even if PWM dimming is not required, the PWMOUT dimming MOSFET is useful for LED disconnect during shutdown. This prevents current from running through the string of ground-connected LEDs—possible under certain input conditions.

If an LED fails open or if the LED string is removed from the high power driver, the FB constant voltage loop takes over and regulates the output at 95V until a proper string is attached between LED⁺ and LED⁻. Without overvoltage protection, the LED sense resistor would see zero LED current and the control loop would work hard to increase its output. Eventually, the output capacitor voltage would go over 100V, exceeding the maximum rating of several components. While in OVP the $\overline{\text{OPENLED}}$ status flag goes low.

High Voltage Buck Mode LED Driver with High PWM Dimming Ratio

When the input voltage is higher than the LED string voltage, the LT3756 can serve equally well as a constant current buck mode converter. For example, an automotive battery's voltage can present a wildly moving target, from drooping voltages to dizzyingly high voltage spikes, The buck mode LED driver in Figure 2 is perfect for such harsh environments. It operates with a wide 10V-to-80V input range to drive one or two 3.5V LEDs (7V) at 1A. In this case, both the V_{IN} pin and ISP and ISN current sense inputs can go as high as 80V.

PWM dimming requires a level-shift from the PWMOUT pin to the high side LED string as shown in Figure 2. The maximum PWM dimming ratio increases with higher switching frequency, lower PWM dimming frequency, higher input voltage and lower LED power. In this case, a 100:1 dimming ratio is possible with a 100Hz dimming frequency, a 48V input, a 3.5V or 7V LED at 1A, and a 150kHz switching frequency. Although higher switching frequency is possible with the LT3756, the duty cycle eventually has its limits. Generous minimum on-time and minimum off-time restrictions require a frequency on the lower end of its range (150kHz) to meet both the harsh high-V_{IN}-to-low-V_{LED} ($80V_{IN}$ to one 3.5V LED) and low-V_{IN}-dropout requirements ($10V_{IN}$ to $7V_{LED}$) of this particular converter.

The overvoltage protection of the buck mode LED driver has a level shift as well. Q1, a pnp transistor, helps regulate the maximum allowable output capacitor voltage to a level just beyond that of the LED string. Without the level-shifted OVP network tied to FB, an open LED string would result in the output capacitor charging up to the input voltage. Although the buck mode components will survive this scenario, the LEDs may not survive being plugged back into a potential equal to the input voltage. That is, a single 3.5V LED might not survive being connected directly to 80V.

Single Inductor Buck-Boost Mode LED Driver

One increasingly common LED driver requirement is that the ranges of both the LED string voltage and the input voltage are wide and overlapping. In fact, some designers prefer to use the same LED driver circuit for several different battery sources and several different LED string types. Such a versatile configuration trades some efficiency, component cost, and board space for design simplicity, but the tradeoffs are usually mitigated by the significantly reduced time-to-market by producing an essentially off-the-shelf multipurpose LED driver.

The buck-boost mode topology shown in Figure 4 uses a single inductor and can both step-up and step-down the input voltage to the LED string voltage. It accepts inputs from 6V to 36V to drive 10V–50V LED strings at up to 400mA. The PWM dimming and OVP are level-shifted in a manner similar to the buck mode for optimal performance of these features.

The inductor current is the sum of the input current and the LED string

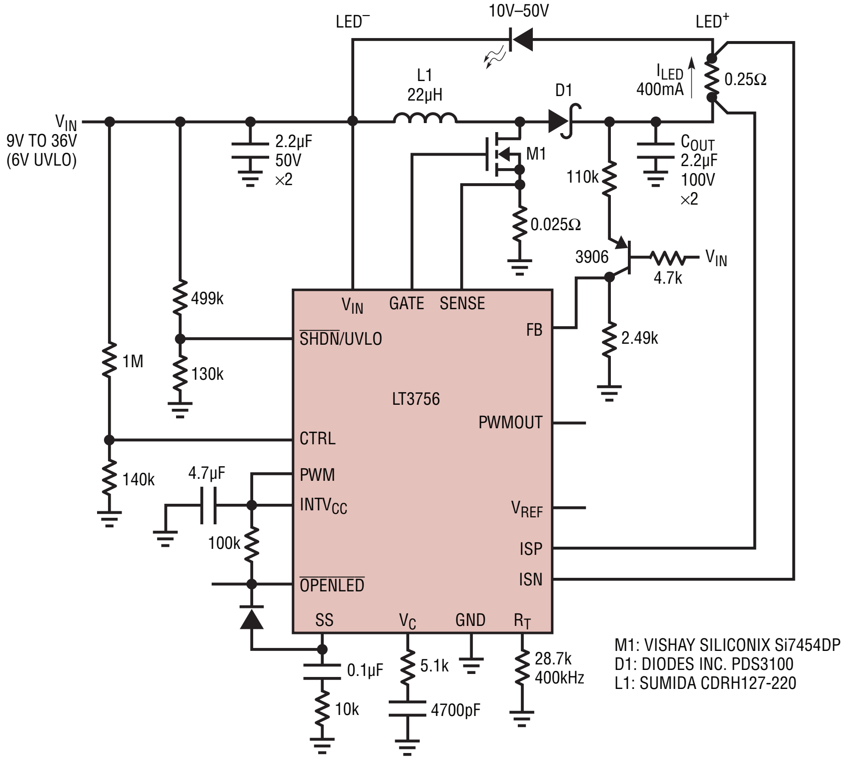

Figure 4. A buck-boost mode LED driver with wide-ranging V_{IN} and V_{LED}

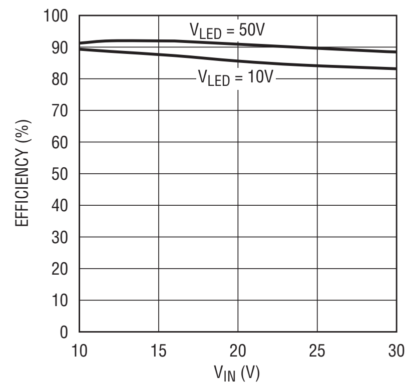

Figure 5. Efficiency for the buck-boost mode converter in Figure 4

current; the peak inductor current is also equal to the peak switching current—higher than either a buck mode or boost topology LED driver with similar specs due to the nature of the hookup. The 4A peak switch current and inductor rating reflects the worst-case 9V input to 50V LED string at 400mA.

Below 9V input, the CTRL analog dimming input pin is used to scale back the LED current to keep the inductor current under control if the battery voltage drops too low. The LEDs turn off below 6V input due to undervoltage lockout and will not turn back on until the input rises above 7V, to prevent flickering. In buck-boost mode, the output voltage is the sum of the input voltage and the LED string voltage. The output capacitor, the catch diode, and the power MOSFET can see voltages as high as 90V for this design.

Conclusion

The 100V LT3756 controller is ostensibly a high power LED driver, but its architecture is so versatile, it can be used in any number of high voltage input applications. Of course, it has all the features required for large (and small) strings of high power LEDs. It can be used in boost, buck-boost mode, buck mode, SEPIC and flyback topologies. Its high voltage rating, optimized LED driver architecture, high performance PWM dimming, host of protection features and accurate high side current sensing make the LT3756 a single-IC choice for a variety of high voltage input and high power lighting systems.

LT3782A, continued from page 36

other out, thus reducing the total output ripple by 50%, which in turn reduces output capacitance requirements. The input current ripple is also halved, which reduces the required input capacitance and reduces EMI. Finally, the power dissipated as heat is spread out over two phases, reducing the size of heat sinks or eliminating them altogether.

24V at 8A from a 10V–15V Input

Figure 1 shows a high power boost application that efficiently produces a 24V/8A output from a 10V–15V input. The LTC4440 high side driver is used to level shift the SGATE signals and drive the synchronous MOSFETs. The 250kHz switching frequency optimizes efficiency and component size/board area. Figure 2 shows the layout. Proper routing and filtering of the sense pins, placement of the power components and isolation using ground and supply planes ensure an almost jitter free operation, even at 50% duty cycle.

Figure 3 shows the efficiency of the circuit in Figure 1 with synchronous MOSFETs (measured to 8A) and the efficiency of an equivalent non-synchronous circuit using boost diodes (measured to 6A). The 1% improvement in peak efficiency may not seem significant, but take a look at the difference in heat dissipation shown in Figure 4, which shows thermal images of both circuits under equivalent operating conditions. The thermal advantages of using synchronous switches are clear.

Conclusion

The 2-phase synchronous boost topology possible with the LT3782A offers several advantages over a non-synchronous or a single-phase boost topology. Its combination of high efficiency, small footprint, heat sink-free thermal characteristics and low input/output capacitance requirements make it an easy fit in automotive and industrial applications.