TEXAS INSTRUMENTS

Application Report
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Powering a White LED Flashlight With the TPS61090

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ABSTRACT

This application report details how to drive a 3-W white LED from a single lithium-ion battery using the Texas Instruments TPS61090 low-power dc-dc boost converter to achieve efficiencies >90%. Design considerations and equations needed for driving a single, multiple-watt white LED are covered including efficiency improvements, peak switch current calculations, and soft-start considerations.

High-power LEDs are becoming popular in portable handheld end equipment. Because multiple-watt LEDs have forward voltage drops in the order of 3.5 V, a boost converter is necessary when powering from a single lithium-ion battery (2.7 V – 4.2 V) to maintain a constant current. The Texas Instruments TPS61xxx boost converter family offers a wide range of flexibility for this application.

A regulated current source drives the white LEDs by monitoring the voltage drop across a current sense resistor. General information regarding white LED drivers is provided in the TPS61040EVM-002 User's Guide (SLVU068). When driving a single, multiple-watt LED, three additional factors should be considered:

1. Increasing efficiency by injecting voltage into the feedback pin
2. Staying under the peak switch current limit of the internal FET
3. Maintaining start-up conditions necessary for correct soft-start operation

The following paragraphs explain how to design a single 3-W LED at 750 mA using the TPS61090 synchronous boost converter with a 2-A switch.

Table 1. General Design Parameters

Design Requirements	Part Requirements	
Vin = 2.5 V – 4.2 V	Boost Converter	LED
Iout = 750 mA	TPS61090	LW W5SG
Target Efficiency = 90%	Texas Instruments	Osram Opto
V(sense resistor) = V(cs) = 0.23 V	F(sw) = 600 kHz typical, 500 kHz minimum	Vf = 3.50 V
	Isw (switch current limit) = 2.2 A typical, 2 A minimum	

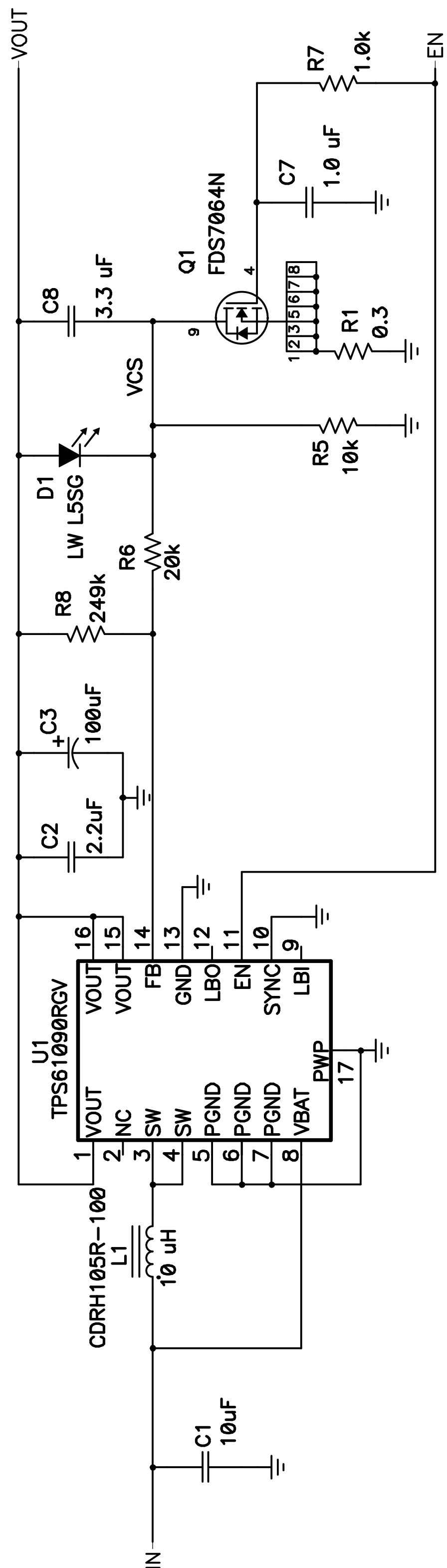

Figure 1. Schematic of a 3-W White LED Driver Using the TPS61090

1. Increasing efficiency by injecting voltage into the feedback pin

Minimizing power dissipation in the current sense resistor increases efficiency and thus lengthens battery life. The application report *Extending Battery Life with the TPS61040 White Light LED Driver* (SLEA004) explains how to inject voltage into the feedback pin of the integrated circuit (IC) under no-load conditions to reduce the voltage (and thus power dissipation) across the current sense resistor. Sizing resistors R8 and R6 sets the appropriate voltages at the feedback pin of the IC and across the sense resistor. The reference voltage (Vref) is 0.5 V for the TPS61090, and the voltage at the current sense node, V_{CS}, is set to 0.23 V. Figure 2 shows that this method improves efficiency (LED Power/Input Power) by an average of 6%.

$$R8 \equiv R6 \times \left(\frac{Vf}{Vref - Vcs} - 1 \right) \qquad (1)$$

Where Vf = forward voltage across the LED, Vcs = desired voltage across the current sense resistor at full LED current, Vref = feedback voltage of the TPS61090

For this design, R6 was chosen at 20 kΩ yielding R8 = 249 kΩ.

The equivalent resistance from the cathode of the LED to ground determines the LED current. R5 was chosen at 10 kΩ and thus has negligible effect on LED current. It is used for start-up as described later in this application report.

$$R1 \equiv \frac{Vcs}{Iout} - Rdson \qquad (2)$$

Where V_{CS} = desired voltage across the current sense resistor at full LED current, Iout = full LED current, Rdson = the drain-to-source resistance of Q1

The N-channel FET was chosen to have an Rdson of approximately 10 mΩ, yielding R1 = 0.3 Ω.

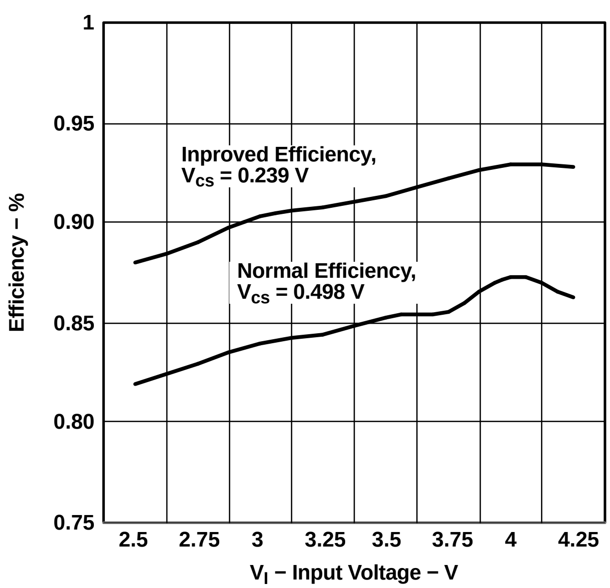

Figure 2. TPS61090 White LED Driver at 750 mA: Efficiency vs Input Voltage

2. Staying under the peak switch current limit of the internal FET

The TPS61xxx family of dc-dc boost converters has integrated FETs to increase ease of use while decreasing component count and necessary board space. Care must be taken not to exceed the peak switch current limit of the internal FETs. In a boost converter, a direct-current component depends on the LED current and an alternating-current component depends on input and output voltages, switching frequency, and inductance.

$$Isw\_max \equiv \frac{Vout \times Iout}{Eff \times Vin\_min} + \frac{Iripple\_ppk}{2} \quad (3)$$

$$Isw\_max \equiv \frac{(Vf + Vcs) \times Iout}{Eff \times Vin\_min} + \frac{Vi\_min}{2 \times Lmin \times Fmin} \times \left(1 - \frac{Vin\_min}{Vf + Vcs}\right) \quad (4)$$

Where Vcs = desired voltage across the current sense resistor at full LED current, Vf = forward voltage across LED, Iout = full LED current, Eff = target power supply efficiency, Vin_min = minimum input voltage, Lmin = minimum inductance, Fmin = minimum power supply switching frequency

A conservative estimate of 85% for converter efficiency and the recommended 10 µH ± 20% inductor are reasonable values used for the above calculations. The calculated peak switch current must be less than 2000 mA for the TPS61090; for this design, Isw max = 1.316 A+ 0.103 A = 1.419 A.

3. Maintaining start-up conditions necessary for correct soft-start sequencing

The TPS61090 undergoes multiple discrete soft-start stages at initial turnon and requires a minimum equivalent load resistance to start up properly. The minimum load needed is highest at low input voltages; for this design, the minimum load required at Vin = 2.5 V is 15 Ω. This is achieved by adding an N-channel FET in series with the current sense resistor. When the part is initially enabled, the FET is high impedance, so the current sense resistance is R5 = 10 kΩ. As C7 charges, the FET turns on and the current sense resistor becomes R5 (10 kΩ) in parallel with R1 (0.3 Ω). Transitioning the current sense resistor between 10 kΩ and 0.3 Ω effectively soft-starts the LED current.

For this design, C7 and R7 were chosen as 1 µF and 1 kΩ, respectively, to give the start-up circuit a 1-ms time constant. R5 was chosen as 10 kΩ to minimize excess power dissipation during start-up.

References

1. *Extending Battery Life With the TPS61040* White Light LED Driver application report (SLEA004)
2. *TPS61090, TPS61091, TPS61092, Synchronous Boost Converter with 2A Switch data sheet* (SLVS484)
3. *TPS61040EVM-002 White Light LED Bias Supply Evaluation Module User's Guide* (SLVU068)

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