

Powering a White LED Flashlight With the TPS61090

Steven R. Tom

Power Management Products/Portable Power DC-DC Applications

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	
$V_{in} = 2.5\text{ V} - 4.2\text{ V}$	Boost Converter	LED
$I_{out} = 750\text{ mA}$	TPS61090	LW W5SG
Target Efficiency = 90%	Texas Instruments	Osram Opto
$V(\text{sense resistor}) = V(\text{cs}) = 0.23\text{ V}$	$F(\text{sw}) = 600\text{ kHz typical, } 500\text{ kHz minimum}$	$V_f = 3.50\text{ V}$
	$I_{sw} (\text{switch current limit}) = 2.2\text{ A typical, } 2\text{ A minimum}$	

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 (V_{ref}) 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%.

$$R8 \equiv R6 \times \left(\frac{V_f}{V_{ref} - V_{cs}} - 1 \right) \quad (1)$$

Where V_f = forward voltage across the LED, V_{cs} = desired voltage across the current sense resistor at full LED current, V_{ref} = feedback voltage of the TPS61090

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

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

$$R1 \equiv \frac{V_{cs}}{I_{out}} - R_{dson} \quad (2)$$

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

The N-channel FET was chosen to have an R_{dson} of approximately 10 m Ω , yielding R1 = 0.3 Ω .

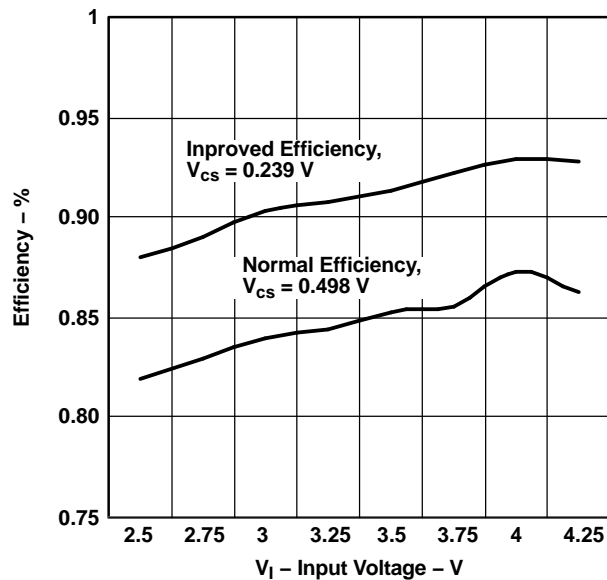


Figure 2. TPS61090 White LED Driver at 750 mA: Efficiency vs Input Voltage

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.

$$I_{sw_max} \equiv \frac{V_{out} \times I_{out}}{Eff \times V_{in_min}} + \frac{I_{ripple_ppk}}{2} \quad (3)$$

$$I_{sw_max} \equiv \frac{(V_f + V_{cs}) \times I_{out}}{Eff \times V_{in_min}} + \frac{V_{i_min}}{2 \times L_{min} \times F_{min}} \times \left(1 - \frac{V_{in_min}}{V_f + V_{cs}}\right) \quad (4)$$

Where V_{cs} = desired voltage across the current sense resistor at full LED current, V_f = forward voltage across LED, I_{out} = full LED current, Eff = target power supply efficiency, V_{in_min} = minimum input voltage, L_{min} = minimum inductance, F_{min} = minimum power supply switching frequency

A conservative estimate of 85% for converter efficiency and the recommended $10 \mu\text{H} \pm 20\%$ 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, $I_{sw_max} = 1.316 \text{ A} + 0.103 \text{ A} = 1.419 \text{ A}$.

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 $V_{in} = 2.5 \text{ V}$ is 15Ω . 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 $R_5 = 10 \text{ k}\Omega$. As C_7 charges, the FET turns on and the current sense resistor becomes R_5 ($10 \text{ k}\Omega$) in parallel with R_1 (0.3Ω). Transitioning the current sense resistor between $10 \text{ k}\Omega$ and 0.3Ω effectively soft-starts the LED current.

For this design, C_7 and R_7 were chosen as $1 \mu\text{F}$ and $1 \text{ k}\Omega$, respectively, to give the start-up circuit a 1-ms time constant. R_5 was chosen as $10 \text{ k}\Omega$ 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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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265