ABSTRACT

This application report explains how to build a white LED (WLED) driver circuit using the TPS61200 Boost Converter from Texas Instruments. It also explains an analog dimming scheme for the LED drivers.

The TPS61200 integrated circuit (IC) is a low-input voltage synchronous boost converter with down-conversion mode when \( V_{IN} > V_{OUT} \). This device provides output currents up to 600 mA with a 5-V output and 3.6-V input voltage. The boost converter is based on a fixed-frequency, pulse-width-modulation (PWM) controller using synchronous rectification to obtain maximum efficiency.

The WLED driver circuit is based on a basic circuit (see Figure 1) where the WLED is connected between the OUT pin and the FB (feedback) pin of the switcher. The current through the WLED is given by Equation 1.

\[
I_{LED} = \frac{V_{FB}}{R_{sense}}
\]  

Figure 1. Basic WLED Driving Using a Switcher

The WLED driver circuit using TPS61200 is shown in Figure 2. The analog dimming function is implemented using variable voltage \( V_{ANALOG} \).

Figure 2. TPS61200 Used as WLED Driver
Being internally compensated, the TPS61200 requires a 1.5-µH inductor and two 10-µF ceramic outputs for small-signal loop stability when configured as a single WLED driver. Other configurations may be stable but it is the responsibility of the user to carefully test the loop stability of such configurations.

The following paragraph explains how to implement dimming with any adjustable dc/dc converter configured as a WLED driver. When a variable analog voltage source is available as shown in Figure 3(a), or can be filtered from a PWM signal with duty cycle D as shown in Figure 3(b), analog dimming can be implemented using two resistors connected between the FB pin and the junction of the cathode of the WLED and sense resistor. Equation 2 gives the maximum value for R3. Once R3 is selected, Equation 3 computes the value for R2. With R2 and R3, Equation 4 computes the value for R1. Equation 5 computes LED current.

\[
\begin{align*}
R3 & \leq \frac{V_{\text{ANALOG MAX}} - V_{\text{FB}}}{10 \times I_{\text{FB}}} \\
R1 &= \frac{V_{\text{FB}} \times R3 + V_{\text{FB}} \times R2 - V_{\text{ANALOG MAX}} \times R2}{I_{\text{LED MIN}} \times R3 - V_{\text{FB}} + V_{\text{ANALOG MAX}}} \\
R2 &= V_{\text{FB}} \times \left( \frac{I_{\text{LED MIN}} \times R3 + V_{\text{ANALOG MAX}} - I_{\text{LED MAX}} \times R3 - V_{\text{ANALOG MIN}}}{V_{\text{FB}} \times I_{\text{LED MAX}} - V_{\text{ANALOG MAX}} \times I_{\text{LED MAX}} - V_{\text{FB}} \times I_{\text{LED MIN}} + V_{\text{ANALOG MIN}} \times I_{\text{LED MIN}}} \right) \\
I_{\text{LED}} &= \frac{V_{\text{FB}}}{R1} \times \frac{R2}{R1 \times R3} \times (V_{\text{ANALOG}} - V_{\text{FB}})
\end{align*}
\]

This method provides maximum current through WLED when \(V_{\text{ANALOG}}\) is at its minimum value and minimum value of current through WLED when \(V_{\text{ANALOG}}\) is at its maximum value.

![Figure 3. Analog Dimming Using (a) Variable DC voltage (b) PWM Signal](image)

If the PWM signal is filtered to produce the analog drive voltage, it is recommended that the low-pass filter (LPF) corner frequency be 10x below the PWM frequency.

\[V_{\text{ANALOG}} = D \times V_{\text{PWM MAX}}\]

The TPS61200 configured as a WLED driver has the following advantages over other similarly configured converters:

1. The circuit can work for a wide input voltage from 0.9 V to 5 V.
2. For \(V_{\text{IN}} \geq 2\) V, the current flowing through WLED can be as high as 500 mA.
3. For \(V_{\text{IN}} = 0.9\) V, the current though WLED can go greater than 150 mA.

The efficiency graphs for different values of input voltages are shown in Figure 4.
The efficiency graphs show that the circuit works most efficiently for the input voltages less than 3.5 V, which is approximately the output voltage set by the LED. This is because the TPS61200 is optimized for use in boost mode. For input voltages greater than 3.5 V, the device enters down-conversion mode and has higher power dissipation. Note that if the sense resistor is selected properly per Equation 2, then the device can provide current $I_{LED}$ up to 680 mA. Table 1 shows the typical battery voltages and corresponding currents flowing through the WLED. (Note that the value of sense resistor in each case is different and is selected to get the maximum amount of current flowing through the WLED and achieve stability. All the measurements are taken at room temperature of $T_A = 25°C$).

Table 1. Typical Battery Voltages and Corresponding Currents Through WLED

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Vin (V)</th>
<th>$I_{LED}$ (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-ion</td>
<td>4.2</td>
<td>680</td>
</tr>
<tr>
<td>Li-ion Polymer</td>
<td>3.7</td>
<td>680</td>
</tr>
<tr>
<td>Li-ion</td>
<td>3.6</td>
<td>680</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>2.1</td>
<td>550</td>
</tr>
<tr>
<td>Zinc Carbon D-type cell</td>
<td>1.5</td>
<td>370</td>
</tr>
<tr>
<td>NiCD and NiMH battery</td>
<td>1.2</td>
<td>280</td>
</tr>
</tbody>
</table>
The following figures show the start-up waveforms, loop gain measurement, and load transients (from 0 mA to 500 mA) with the circuit in Figure 2 configured to provide 500 mA from $V_{IN} = V_{EN} = 3.6\, \text{V}$.

**Figure 5. Start-Up Waveforms**

Legends for Figure 5 are as follows. (Time scale is 200 $\mu$s/div for all the three channels.)

1. Channel 2 (red) : Switch-node waveform (Vertical scale is 10 V/div.)
2. Channel 3 (blue) : Input voltage waveform (Vertical scale is 5 V/div.)
3. Channel 4 (green) : ILED waveform (Vertical scale is 100 mA/div.)

**Figure 6. Loop Gain Measurements (PM = 71.26 deg, Fco = 71.26 kHz)**
Legends for Figure 7 are as follows. (Time scale is 50 µs/div for all the three channels.)

1. Channel 1 (yellow) : Switch-node waveform (Vertical scale is 5 V/div.)
2. Channel 3 (blue) : Output voltage waveform (Vertical scale is 2-V/div.)
3. Channel 4 (green) : ILED waveform (Vertical scale is 200 mA/div.)

Testing at Vin = 0.9 V and Vin = 5 V resulted in similar results as those shown in Figure 7

**Conclusion**

The TPS61200 boost converter can be used as a WLED driver and can provide a current flowing through the WLED greater than 500 mA.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to test only TI components. It is the responsibility of the customer to ensure the functionality and safety of the solution based on their applications. Further, TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI products are neither designed nor intended for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or “enhanced plastic.” Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>Audio</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Automotive</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Broadband</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Control</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Medical</td>
</tr>
<tr>
<td>Interface</td>
<td>Military</td>
</tr>
<tr>
<td>Logic</td>
<td>Optical Networking</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Security</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Telephony</td>
</tr>
<tr>
<td>RFID</td>
<td>Video &amp; Imaging</td>
</tr>
<tr>
<td>RF/IF and ZigBee® Solutions</td>
<td>Wireless</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2009, Texas Instruments Incorporated