Powering Multiple WLED Strings Using the TPS61150/50A

Jeff Falin
HPA Portable Power

ABSTRACT

This application report describes how to regulate more than two white light-emitting diodes (WLED) using the TPS61150/50A high-frequency boost converter with two regulated current outputs for driving WLEDs.

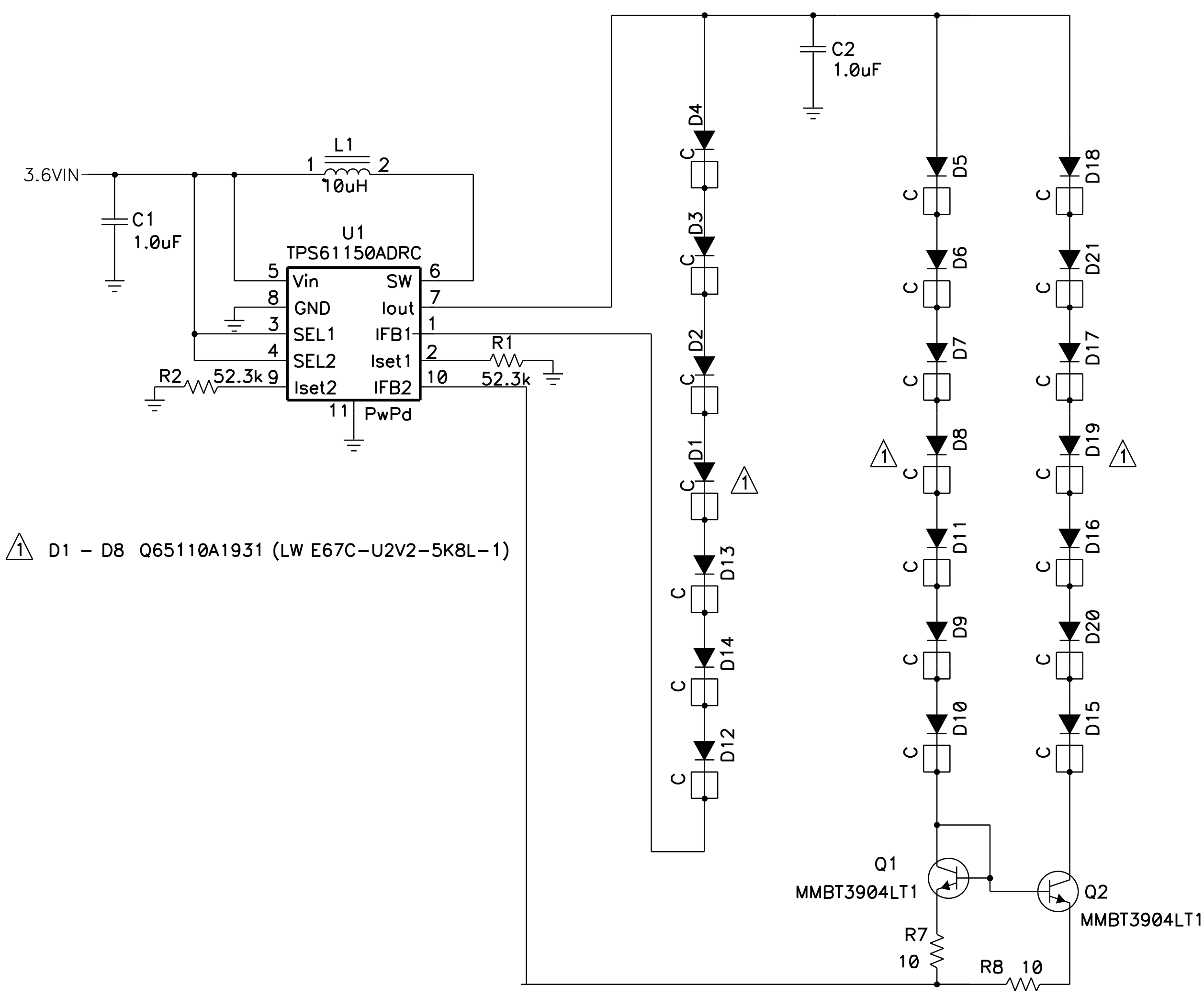

Figure 1. Schematic of TPS61150A With Current Mirror

Although designed to independently regulate two strings of WLEDs, the TPS61150/50A can be configured to regulate additional WLED strings at the same current level with the addition of an inexpensive, discrete current mirror circuit. The current mirror consists of two or more bipolar transistors, one diode configured, and both with emitter resistors to improve matching. Figure 1 shows such a configuration.

The current mirror consists of two or more npn bipolar transistors. Equation 1 models the collector current through a bipolar transistor.

$$I_C = I_S * e^{\frac{V_{BE}}{0.026mV}} * (1 + \frac{V_{CE}}{V_A}) \tag{1}$$

Where

- I_S is the transistor's unique saturation current
- V_{BE} is the voltage applied across the transistor's base-emitter
- V_{CE} is the voltage across the transistor's collector and emitter
- V_A is the transistor's unique Early voltage

In Figure 1, transistor Q1 has its base and collector tied together and is referred to as being diode connected. Because the base of transistor Q2 is connected to the base of Q1, Q1 and Q2 have the same base-emitter voltages and so, per Equation 1, the current through Q2's collector closely matches the current through Q1. Two factors cause the currents not to match exactly: variations in each transistor's I_S, V_A, and current gain (β) and differences in their V_{CE} voltages. Differences in the V_{CE} voltages cannot be avoided due to the diode-connected transistor having a fixed $V_{CE} = V_{BE}$. V_{CE2} is determined by the difference between the sum of the forward voltages of the LEDs [$\Sigma V_{(WLEDs)2}$] and resistor R7. By keeping the $\Sigma V_{(WLED1s)}$ slightly greater than or equal to $\Sigma V_{(WLED2s)}$, either by having more of the same WLEDs in string 1 than in string 2 or LEDs with larger forward voltages in string 1 than in string 2, V_{CE2} remains large enough to keep transistor Q2 in forward active mode. However, if $\Sigma V_{(WLED1s)} >> \Sigma V_{(WLED2s)}$, V_{CE2} could become quite large, on the order of the transistor's Early voltage (typically around 20 V) and therefore affect Q2's collector current.

Matched transistors, built on the same die and therefore having nearly identical I_S, V_A, and β specifications, are available and improve current matching, but their relatively high cost makes them impractical. By adding large-enough resistors R7 and R8, the current mismatch is dominated by the resistor mismatch instead of the transistor parameter mismatch(1). These resistors should be at least 10 Ω, in order to improve matching, but smaller than 100 Ω in order to prevent reducing V_{CE2}. Table 1 shows current, matching, and efficiency data for the circuit in Figure 1 with no R7 or R8, R7 = R8 = 10 Ω and R7 = R8 = 49.9 Ω.

(1) Analysis and Design of Analog Integrated Circuits, 3rd Edition, Paul R. Gray and Robert G. Meyer, Appendix A.4.1

Table 1. Measured Data

R7=R8	I1	IQ1	IQ2	Match Q2 to Q1 (%)	Efficiency (%)
0	21.1	10.15	10.7	4.9	72
10	21.1	10.38	10.44	0.58	72
49.9	21.1	10.42	10.39	–0.29	72

Where the matching % was computed as (IQ2 - Q1)/[(IQ1 + IQ2)/2] × 100 and P_{OUT} for the efficiency calculation includes only WLED power.