LED Controller with Dual Current Regulation Loops Detects Faulty LEDs, Provides 100:1 Analog Dimming

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The LT3796-1 is a switching controller designed to regulate a constant current or constant voltage at the output—necessary requirements for driving LEDs. It uniquely features two independent current sense amplifiers, and its high side PMOS disconnect switch driver, which can be operated either in combination with the switching regulator using the PWM pin or independently using the TGEN pin.

These features allow the LT3796-1 to satisfy the needs of some specific LED applications. For instance, in high reliability lighting, the controller can be configured to drive two LED strings in parallel so that it is possible to detect a single faulty LED in either string using the other as a reference. Or, for applications requiring accurate analog dimming, the two current sense amplifiers can be scaled to regulate the LED current at two ranges, high and low, thereby extending the analog dimming capability of a high power LED driver to 100:1, a tenfold improvement over what is typically available using a single current control loop.

DRIVING TWO IDENTICAL PARALLEL LED STRINGS WITH FAULTY LED DETECTION CAPABILITY

Detection of a single degraded or shorted LED in a string is challenging because the forward voltage can vary so much over load, temperature and manufacturing tolerances. One way to eliminate these variables is to use two matched strings in parallel, so that any relative difference in forward voltage between the two strings can indicate a fault. In such a solution, the strings are initially built from binned parts selected to match in total forward voltage drop.

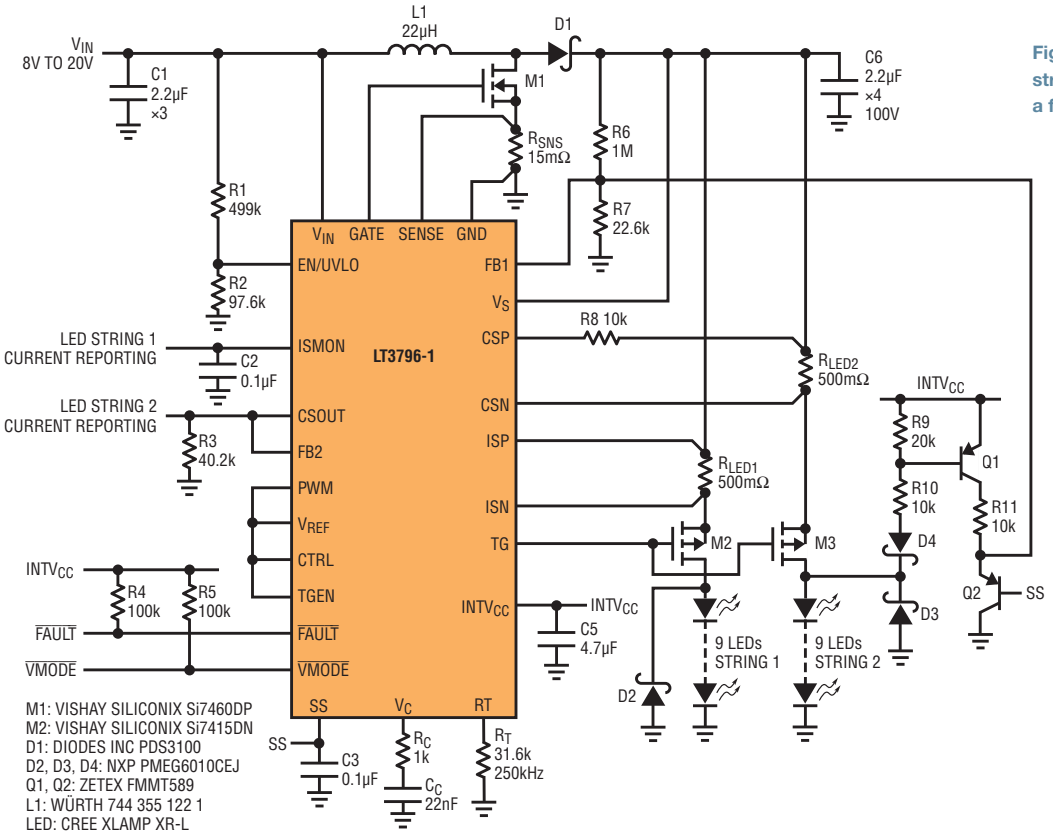

Figure 1. Boost LED driver for twin LED strings with detection and protection for a faulty LED in either string

One potential problem of driving two parallel strings from a single output is that twice the current could run in one of the strings if the other string becomes open or nonconducting. The dual current regulation loops in the LT3796-1 can be used to prevent this current hogging situation.

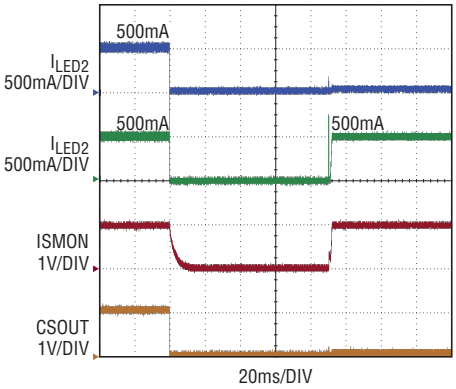

Figure 2. Shorting one LED in string 1 in Figure 1

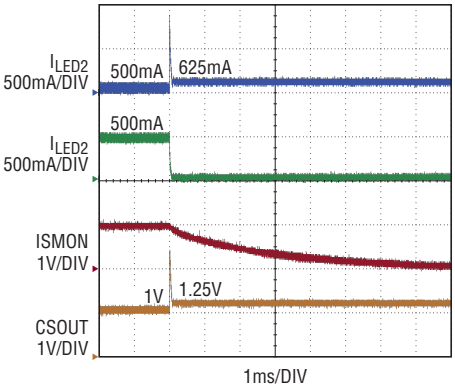

Figure 3. Shorting one LED in string 2 in Figure 1

One potential problem of driving two parallel strings from a single output is that twice the current could run in one of the strings if the other string becomes open or nonconducting. The dual current regulation loops in the LT3796-1 can be used to prevent this current hogging situation.

Figure 1 shows how to configure the ISP/ISN and CSP/CSN current sense amplifiers in a boost LED driver. In normal operation, the ISP/ISN current loop dominates and sets the LED current. The current through LED string 1 is reported at ISMON. The CSP/CSN current loop normally provides monitoring at CSOUT, since it is set 25% below the regulation point of FB2. The CSOUT pin reports the current of LED string 2 as

$$V_{CSOUT} = 1V \bullet \frac{I_{LED2}}{500mA}$$

If the two strings become unbalanced, the reporting pins, ISMON and CSOUT, will show the relative LED current difference in voltage. By externally comparing the two analog signals, a fault signal can be triggered by an external controller.

Figure 2 shows the oscilloscope waveform when one LED from string 1 is shorted. The ISP/ISN current sense amplifier instantly senses the overcurrent event, and disconnects both PMOS switches. After one soft-start cycle, the ISP/ISN current loop starts to regulate the LED string at a new output voltage, which corresponds to the forward voltage drop of eight LEDs. Since the new output voltage can't drive nine LEDs, LED string 2 stops conducting current and CSOUT reports 0V. Similarly, if one LED is shorted in string 2, the CSP/CSN current loop takes control and regulates the output current to 625mA through the FB2 pin, as shown in Figure 3. LED string 1 now stops conducting current and ISMON reports 0V.

This converter also provides high performance PWM dimming and robust short-circuit protection for both strings through the high side PMOS disconnect switch driver pin TG. The built-in overcurrent comparator inside ISP/ISN current sense amplifier protects from a short circuit of string 1, whereas the circuit formed by D4, Q1 and R9–R11 detects the short circuit of string 2, drives FB1 pin high and turns off PMOS switches, M2 and M3.

LED DRIVER WITH 100:1 ANALOG DIMMING RATIO

Many high power LED applications require a high analog dimming ratio, which is difficult to achieve with a single current sense path. The problem is dynamic range: at high currents, a low differential voltage is needed to limit power dissipation in the sense resistor, typically 250mV or less, but with so little signal to work with, the several mV accuracy of the current sense amplifier becomes an appreciable contribution to error in the sense voltage even at 10% analog dimming.

The two current sense loops of the LT3796-1 enable it to produce a high analog dimming ratio by dividing the job of current regulation between two loops. One loop features a low value sense resistor to limit power dissipation in the high current path, while the other loop uses a higher sense signal in the low current path to elevate accuracy, when power dissipation is less of a concern. Figure 4 shows the LT3796-1 configured to produce 100:1 analog dimming ratio in SEPIC mode by using the LTC1541 (a precision reference, op amp and a comparator in single package).

Assuming M2's $R_{DS(ON)}$ is negligible, in the high current range between

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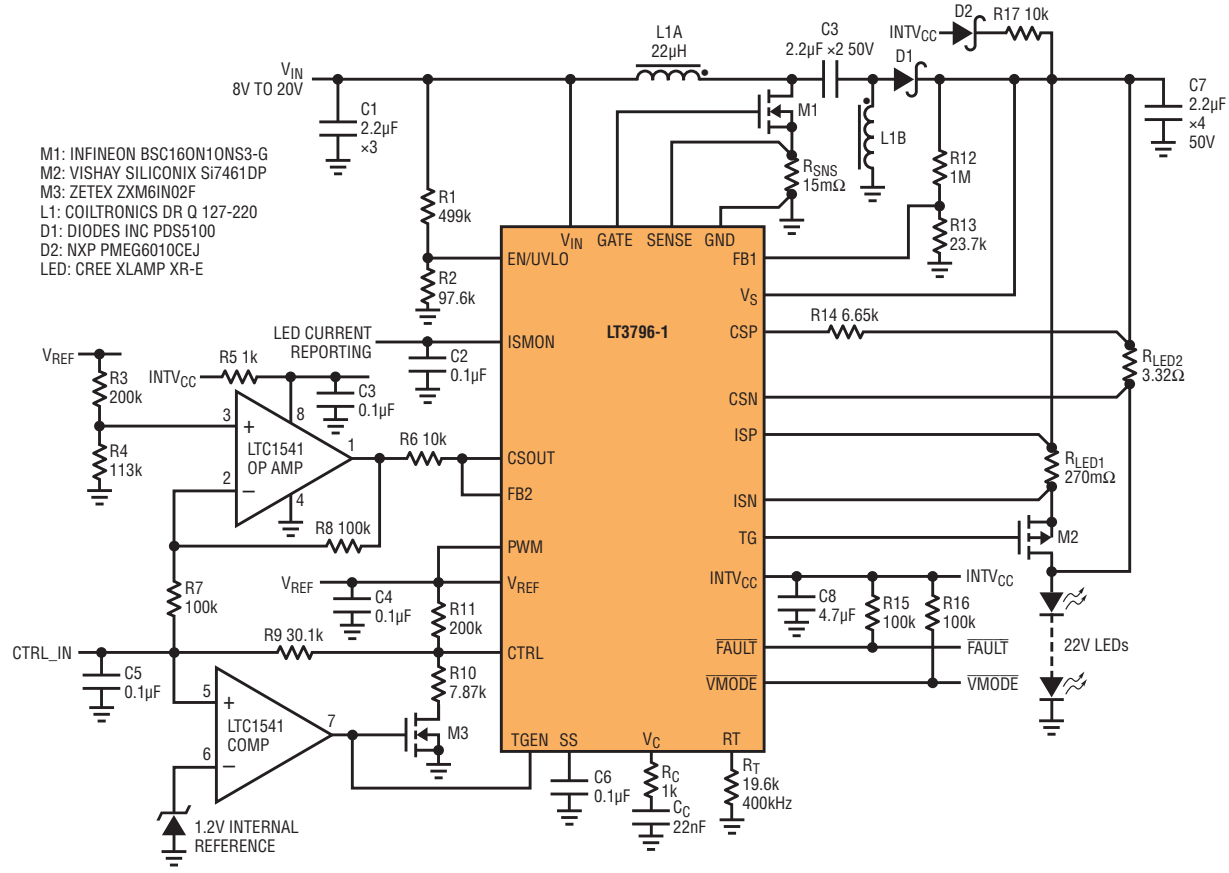
Figure 4. A SEPIC mode LED driver with 100:1 analog dimming ratio

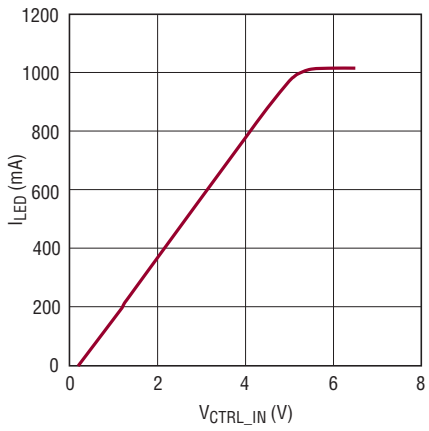


200mA and 1A, the ISP/ISN current loop regulates the output current at

$$I_{LED} = \frac{V_{CTRL\_IN} - 0.2V}{20 \bullet (R_{LED1} \,||\, R_{LED2})}$$

When V_{CTRL} drops below 1.2V, the LTC1541's comparator forces the TGEN pin low and disconnects M2. Thus the LED string is only sensed and regulated by CSP/CSN loop. When the CSP/CSN loop takes control, the FB2 pin voltage is regulated at 1.25V and the CTRL_IN input sets the CSP/CSN threshold by pulling current out of CSOUT pin through R6. The CSP/CSN dimming range is from 668mV to 33.4mV, sensing low LED currents between 200mA to 10mA while maintaining accuracy. Overall, the combined two current loops provide 100:1 analog dimming range as shown in Figure 5.

Figure 5. ILED vs CTRL for the solution in Figure 4



CONCLUSION

The LT3796-1 is a LED controller that features two independent current sense amplifiers with reporting, two FB pins and a high side disconnect switch driver. It also features robust fault protection and a versatile toolset to address challenging LED applications such as high reliability and high performance analog dimming. ■