White LED Driver with Output Disconnect and 1-Wire Current Programming

by Ahmed Hashim

Introduction

The LT3593 is designed to drive up to ten white LEDs in series from a single lithium-ion cell, ensuring matched LED current and eliminating the need for ballast resistors. The LT3593 internally compensated step-up DC/DC converter switches at 1MHz so that it can be used with tiny, low profile external components.

The LT3593 features an internal 5-bit DAC, allowing the LED current to be programmed using only one pin. The device features true output disconnect in shutdown as well as a unique high side current sense allowing it to function as a "1-wire" current source where the low side of the LEDs can be returned to ground anywhere. A typical application schematic along with expected efficiency can be seen in Figure 1. The functionality and feature set available in the LT3593 make it ideal for portable electronics display back-lighting applications. The LT3593 is available in a 6-lead (2mm × 2mm) DFN as well as 6-lead SOT-23.

1-Wire Current Programming

The LED current can be programmed linearly to 32 unique values by strobing the CTRL pin. A 5-bit internal counter is decremented on each rising edge on the CTRL pin, reducing the programmed current by 625µA from the full-scale current of 20mA with each step. The programmed LED current can be calculated using the following equation:

$$I_{LED} = 20mA - (N - 1) \bullet 625\mu A$$

where N is the number of rising edges on the CTRL pin. Strobing the CTRL pin more than 32 times results in the minimum current of 625µA. The CTRL pin must stay high after the last CTRL strobe and 128µs later the part will turn on and start to regulate the programmed current. To shut down the part, the CTRL pin is held low; 128µs after the falling edge of CTRL, the part shuts down. Figure 2 shows current programming and shutdown timing.

If the LED current needs to be reprogrammed, there is no need to shutdown and then reprogram. The LT3593 can be reprogrammed from one LED current to another by simply strobing the CTRL pin and, 128µs after the last rising edge, the part starts regulating the newly programmed current (also shown in Figure 2).

Buck-Boost Mode

If a low number of LEDs is needed, there could be a case where the required output voltage is lower than the input voltage. In this case, the LT3593 can be used in buck-boost mode where the LED string is returned to the input supply instead of ground. Figure 3

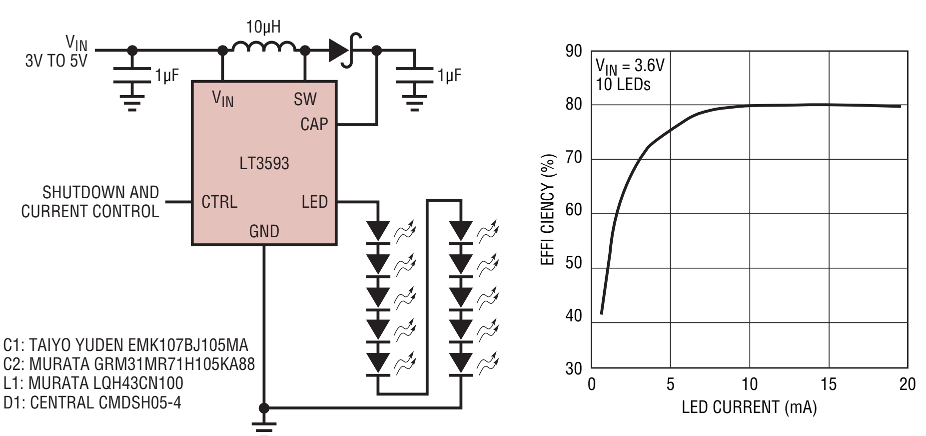

Figure 1. LED driver for ten white LEDs

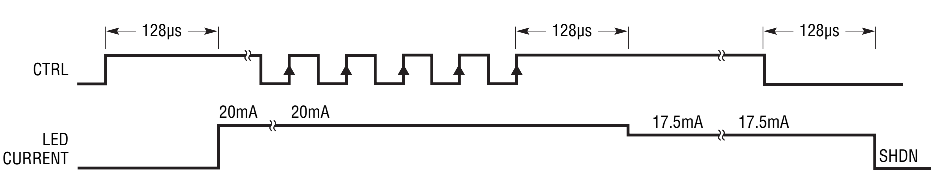

Figure 2. Current programming and shutdown timing

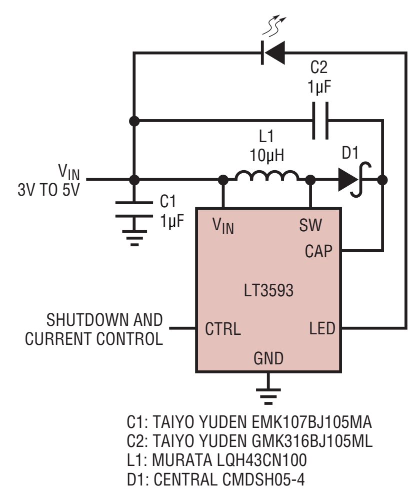

Figure 3. LED driver in Buck-Boost mode driving one LED

shows an application where a single LED is driven from a 5V supply.

Output Disconnect

The LT3593 has an internal disconnect switch that is used to sense the LED current during normal operation. This internal switch also serves to provide output disconnect during shutdown so that the LEDs are truly disconnected from the output of the regulator.

Fault Protection

The LT3593 protects against both open and shorted LED faults. In the case of an open LED fault, the output voltage V_{CAP} continues to rise. Once V_{CAP} reaches 38V, an open fault is triggered and the part goes into a low frequency mode clamping the output to 38V and minimizing input current. A waveform showing the LT3593's response to an open LED fault can be seen in Figure 4.

In a shorted LED fault, the LED pin can be shorted to ground, running excessive current from V_{CAP}. To protect from such a fault, the LT3593 limits the maximum current out of the LED pin to approximately 45mA.

Conclusion

The LT3593 is a step-up LED driver that can drive up to ten white LEDs from a single lithium-ion cell. It can easily be programmed through a single pin interface and combines many desirable features as well as fault protection against open or shorted LEDs.

The feature-rich LT3593 is available in the 6-lead (2mm × 2mm) DFN as well as the 6-lead SOT-23. These two small, low profile packages, together with internal compensation and an output disconnect device, are ideal for a complete small board area LED driver solution, especially in portable device display backlighting applications.

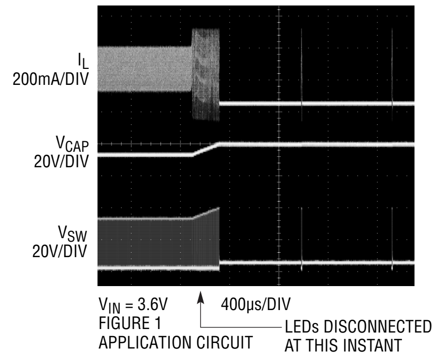

Figure 4. Open LED fault protection

LTC3100, continued from page 32

power while maximizing battery life. The diode on the USB input prevents any reverse current from the 3.3V output (while operating on batteries) back to the USB input when it is open or grounded. Figure 2 shows the converter efficiency versus load with various input sources, illustrating the high efficiency over a wide load range. The LDO in the LTC3100 (with its input internally tied to the Boost output) provides a second regulated output, in this case programmed to 1.8V.

Because the buck converter input can come from the boost output, the LTC3100 can function as an ultra-low voltage buck-boost converter, providing a regulated 1.2V output from a single alkaline or NiMH cell. This is shown in Figure 3, where the LTC3100 generates two regulated outputs from a single cell input (whose voltage may be above or below 1.2V) by boosting V_{IN} up to 3.5V and then regulating down to 1.2V and 3.3V using the buck and the LDO. In this example, the Power Good outputs and the LDO are used to provide voltage sequencing, so that the 1.2V core supply comes up before the 3.3V I/O supply, as shown in the scope photo of Figure 4. The LDO also provides additional noise filtering and ripple rejection for the 3.3V output, guaranteeing a low noise output for sensitive analog circuitry, even when the converters are in Burst Mode operation.

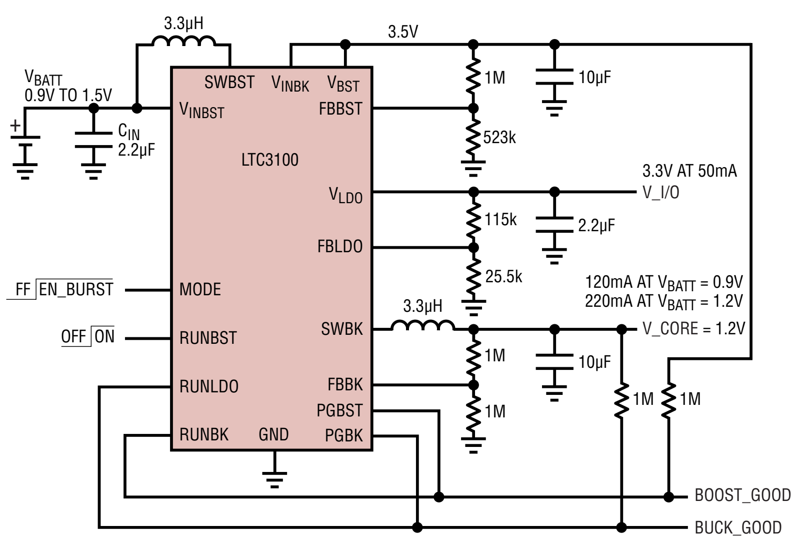

Figure 3. Single-cell dual output converter with voltage sequencing

Conclusion

The LTC3100 is a high efficiency, multichannel converter that can operate from a wide range of voltage sources. Independent input voltages for each converter, Power Good outputs and an LDO make the LTC3100 a small, highly integrated and flexible solution for many demanding applications.

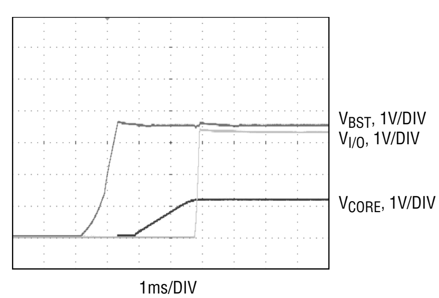

Figure 4. Voltage sequencing of the output voltages for the circuit of Figure 3