

# High Efficiency, Monolithic Synchronous Buck-Boost LED Driver Drives up to 1A Continuous Current

## Introduction

The LTC3454 is a synchronous buck-boost DC/DC converter, designed for driving a single high power LED with regulated currents up to 1A from a single Li-Ion battery. Switching converters are typically used to regulate a voltage, but LEDs require constant current to generate predictable light output. The LTC3454 uses an autozero transconductance error amplifier in its regulation loop to accurately control LED current. The LED current can be set to one of four levels, including shutdown, using two external resistors and dual enable pins. In shutdown no current is drawn.

The wide  $V_{IN}$  range of a Lithium-Ion battery (2.7V to 4.2V) requires that a converter be able to both step-up and step-down the input voltage when the LED forward voltage is within the range of the battery discharge profile. The LTC3454 LED driver efficiently performs step-up and step-down conversion via four internal switches. The regulator operates in synchronous buck, synchronous boost or buck-boost mode, depending on  $V_{IN}$  and the LED forward voltage. Transitions between modes are automatic and smooth.

The LTC3454 operates at a high fixed frequency of 1MHz, which re-

duces inductor size and eases output filtering.

## Application

Figure 1 shows the LTC3454 driving a high power LED in torch and flash modes. Only six external components are required in this application. Efficiency,  $P_{LED}/P_{IN}$ , greater than 90% is possible over the entire usable range of a Li-Ion battery (see Figure 2).

by Aspiyan Gazder

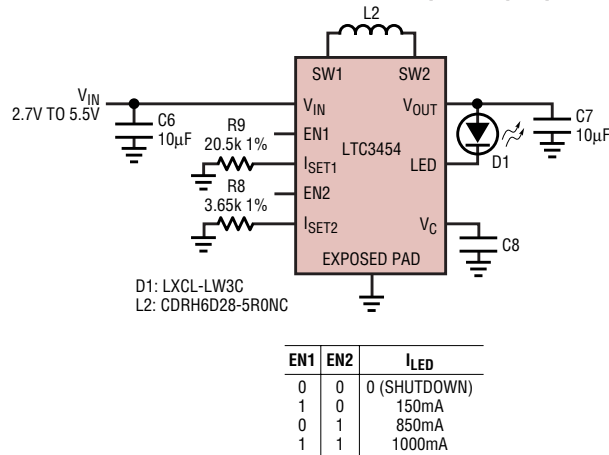


Figure 1. LTC3454 used in a typical application

The LTC3454 has two enable pins that control two current setting amplifiers. A resistor connected from an  $I_{SET}$  pin to GND programs the LED current to:

$$I_{LED} = 3850 \cdot \frac{0.8}{R_{ISET}}$$

when the current setting amplifier is enabled via its EN pin. When both enable pins are asserted, the net LED

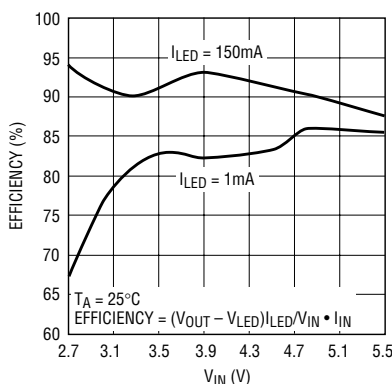


Figure 2. Efficiency for circuit of Figure 1

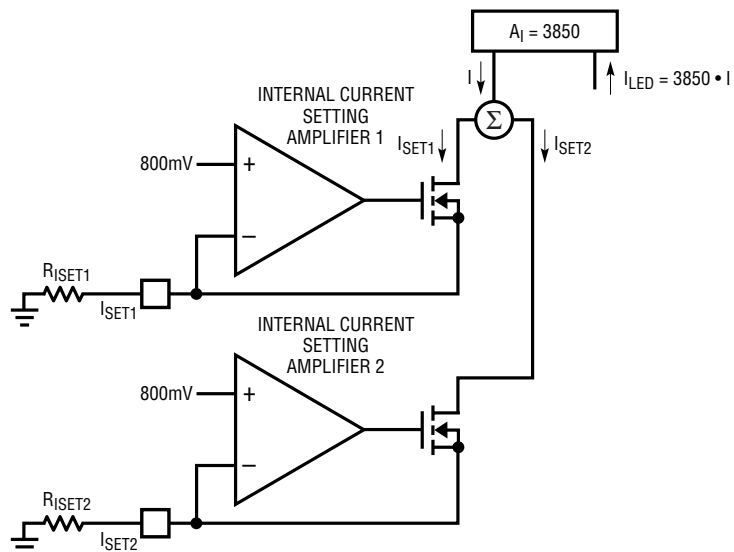
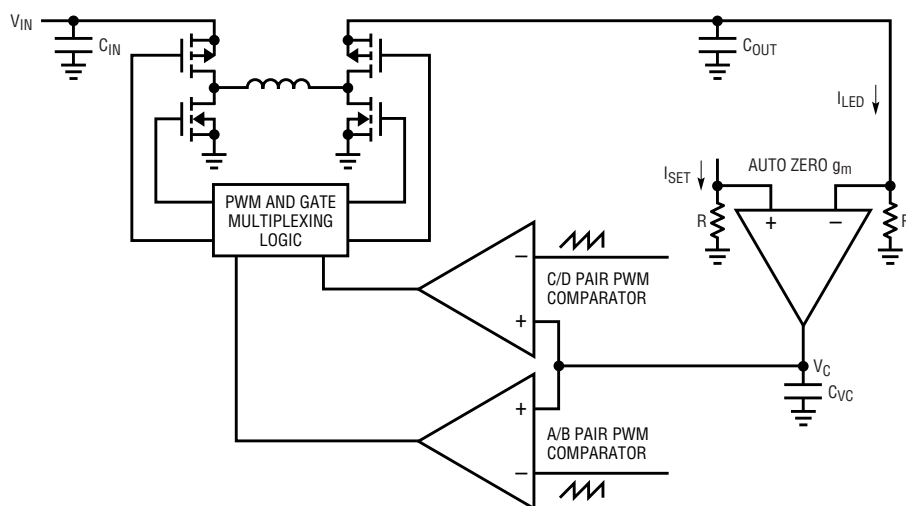


Figure 3. Two current setting amplifiers give the user the flexibility to choose more than one non-zero current level.



**Figure 4. An auto-zeroing transconductance amplifier maintains loop regulation.**

current is the sum of each individually programmed current. Figure 3 shows schematically how the LED current is programmed.

## Autozeroing Transconductance-Amplifier-Based Current Regulation

The LTC3454 employs an auto-zeroing transconductance amplifier in its regulation loop, as shown in Figure 4. The autozero amplifier topology nullifies any offset at its input, allowing an accurate LED current to be achieved with very low common mode input voltage levels, resulting in high  $P_{LED}/P_{IN}$  efficiency. The regulation voltage present at the LED pin can be as low as 100mV at 100mA of LED current.

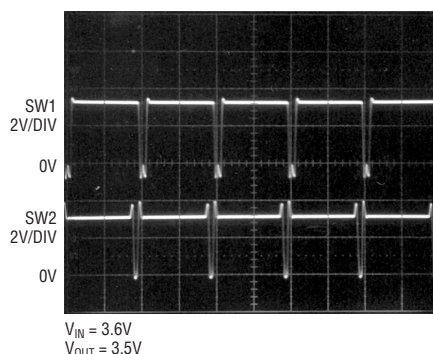
## Synchronous Buck-Boost DC/DC Converter

The LTC3454 can drive an LED at up to 1A continuous current. LEDs that can be driven with such high current typically have forward voltage drops of 3.3V – 3.6V. When powered from a single Li-Ion battery (2.7V to 4.2V), as in the case of handheld battery powered applications, neither a pure buck nor a pure boost solution can efficiently regulate the LED current. A pure buck would dropout at lower battery voltages, causing a lower than programmed LED current to flow. At high battery voltages, a pure boost converter would regulate a higher output voltage than necessary, result-

ing in low efficiency. The buck-boost converter can efficiently regulate LED current over the entire Li-Ion battery range.

The autozero amplifier topology nullifies any offset at its input, allowing an accurate LED current to be achieved with very low common mode input voltage levels, resulting in high  $P_{LED}/P_{IN}$  efficiency.

The control voltage,  $V_C$ , determines the region of operation of the buck-boost converter. The gate drives of the internal power switches A, B, C and D are controlled by the logic block (Figure 4). A patented gate drive multiplexing scheme enables smooth



**Figure 5. Switching waveforms in buck-boost mode**

transition between buck and boost modes and through the four-switch region. In buck mode, the duty cycles on gate drives of switches A and B are controlled while switch D is turned on continuously. In boost mode, duty cycles of switches C and D are controlled, while switch A is on continuously.

Using synchronous rectifier switches B and D instead of catch diodes helps improve efficiency. This scheme requires that the synchronous rectifier switch and the main switch are not turned on simultaneously. A cross conduction delay prevents this condition from occurring. The LTC3454 has a break before make time of approximately 30ns. During this time the current conduction path is completed through the body diodes of the switches. In the case of forward current flow from the SW1 pin to the SW2 pin through the inductor, the body diode of NMOS switch B conducts in buck mode. The SW1 node is pulled a diode drop below ground. Likewise, in boost mode, the body diode of PMOS switch D conducts during the switch C and switch D switching, but node SW2 now flies above  $V_{OUT}$  by a diode drop. Body diodes of the main switches A and C conduct during reverse current flow. Figure 5 shows the switch waveforms in the buck-boost mode.

The LTC3454 has both forward and reverse current limiting—requiring no external sense resistors. If the peak input current exceeds approximately 3.4A, forward current limit is tripped and switches B and D are turned on for the rest of the cycle. The reverse current limit is tripped when current flowing from switch D through the inductor to the SW1 node exceeds approximately 250mA and switches A and C are turned on for the rest of the cycle.

## Robust Design: Can Tolerate Open and Shorted LED Conditions

If the LED faults as an open circuit, the regulation loop drives  $V_C$  higher, which has the effect of raising the output voltage. A safety amplifier—a

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## Performance of 50µA CMOS Amplifier Rivals Best Bipolar Op Amps with 0.7µV/°C Drift

The LTC6078/LTC6079 are dual/quad, low offset, low noise operational amplifiers with low power consumption and rail-to-rail input/output swing.

Input offset voltage is trimmed to less than 25µV and the CMOS inputs draw less than 50pA of bias current. The low offset drift, excellent CMRR, and high voltage gain make it a good choice for precision signal conditioning.


Each amp draws only 54µA current on a 3V supply. The micropower, rail-to-rail operation of the LTC6078/LTC6079 is well suited for portable instruments and single supply applications.

The LTC6078/LTC6079 are specified on power supply voltages of 3V and 5V from -40°C to 125°C. The dual amplifier LTC6078 is available in 8-lead MSOP and 10-lead DFN packages. The quad amplifier LTC6079 is available in 16-lead SSOP and DFN packages.

## Dual and Quad, 1.8V, 13µA Precision Rail-to-Rail Op Amps

The LT6001 and LT6002 are dual and quad precision rail-to-rail input and output operational amplifiers. Designed to maximize battery life in always-on applications, the devices operate on supplies down to 1.8V while drawing only 13µA quiescent current. The low supply current and low voltage operation is combined with precision

specifications—for instance, input offset is guaranteed less than 500µV. The performance on 1.8V supplies is fully specified and guaranteed over temperature. A shutdown feature in the 10-lead dual version can be used to extend battery life by allowing the amplifiers to be switched off during periods of inactivity.

The LT6001 is available in the 8-lead MSOP package and a 10-lead version with the shutdown feature in a tiny, dual fine pitch leadless package (DFN). The quad LT6002 is available in a 16-lead SSOP package and a 16-lead DFN package. These devices are specified over the commercial and industrial temperature range. 

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Figure 5 shows an actual ESD event. Note the arc onto the  $\overline{\text{PB}}$  pin. The ESD strike fed directly onto the pin; there were no series resistors or parallel capacitors. This strike did not damage the pin, nor did it generate any leakage.

## LTC2950-1 and LTC2950-2 Versions

The LTC2950-1 (high true EN) and LTC2950-2 (low true  $\overline{\text{EN}}$ ) differ only by the polarity of the EN/ $\overline{\text{EN}}$  pin. Both versions allow the user to extend the amount of time that the  $\overline{\text{PB}}$  must be held low in order to begin a valid power on/off sequence. An external capacitor placed on the ONT pin adds additional time to the turn-on time. An external capacitor placed on the


OFFT pin adds additional time to the turn-off time. If no capacitor is placed on the ONT (OFFT) pin, then the turn on (off) duration is given by an internally fixed 32ms timer. The LTC2950 fixes the  $\overline{\text{KILL}}$  turn off delay time ( $t_{\text{KILL(OFF DELAY)}}$ ) at 1024ms (the amount of time from interrupting the µP to turning off power).

## LTC2951-1 and LTC2951-2 Versions

The LTC2951 fixes the turn on debounce time at 128ms. The turn off debounce time is the same as the LTC2950: 32ms internal plus the optional additional external when a capacitor is placed on the OFFT pin. The  $\overline{\text{KILLT}}$  pin in the LTC2951-1 and LTC2951-2 provides extendable  $\overline{\text{KILL}}$

turn off timer,  $t_{\text{KILL(OFF DELAY, ADDITIONAL)}}$ , by connecting an optional external capacitor on the  $\overline{\text{KILLT}}$  pin. The default power down delay time is 128ms,  $t_{\text{KILL(OFF DELAY)}}$ .

## Conclusion


The LTC2950/LTC2951 is a family of micro-power (6µA), wide input voltage range (2.7V to 26.4V) push button controllers. The parts lower system cost and preserve battery life by integrating flexible push button timing, a high voltage LDO, and a simple µP interface that provides intelligent power up and power down. The device is available in space saving 8-lead 3mm × 2mm DFN and ThinSOT™ packages. 

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transconductance amplifier with sink only capability—takes control of the regulation loop and prevents  $V_{\text{OUT}}$  runaway. The  $V_{\text{OUT}}$  threshold at which this happens is approximately 5V.

If the LED faults as a short circuit, the regulation loop continues to regulate the output current to its programmed current level.

## Conclusion

The LTC3454 adds to Linear Technology's family of LED drivers. High efficiencies can be achieved over the entire Li-Ion range with a minimal number of external components. Additionally, it draws zero current when in shutdown, helping conserve battery life in hand held battery powered applications. The LTC3454 is available in a low profile small footprint 3mm × 3mm DFN package. 

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