

Boost-then-Buck LED Drivers Enable Wide PWM Dimming Range with Wide-Ranging Input Voltages

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Multichannel LED drivers are primarily designed to power multiple LEDs or multiple LED strings, sometimes of different colors or lengths, from a single IC. These drivers, however, include a number of features that allow for other compelling uses. The LT3797 3-channel LED driver, for instance, can be configured to produce boost-then-buck capability with one channel as a boost voltage preregulator while the other two channels are configured as buck mode LED drivers.

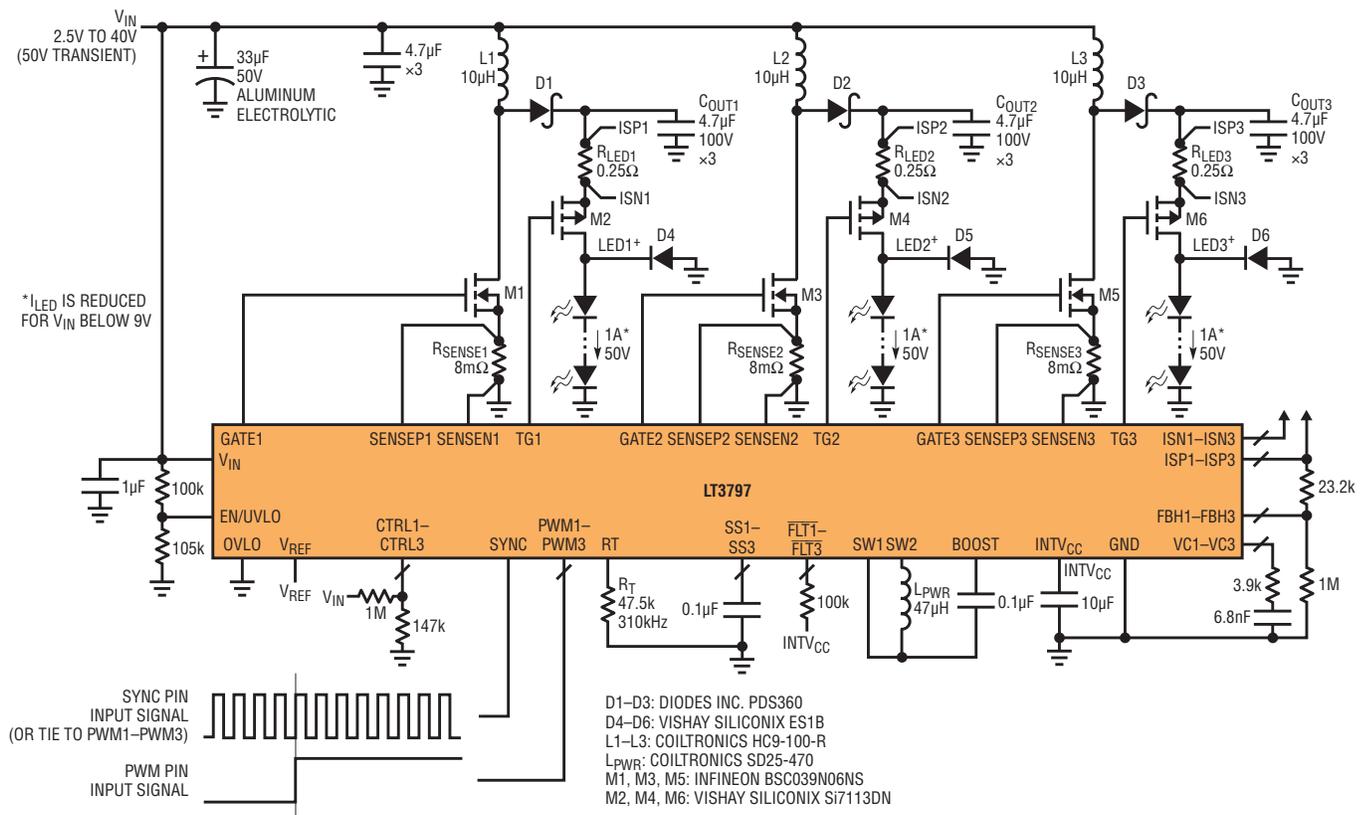
When the input voltage source is wide-ranging and can be both above and below the LED string rating, a buck-boost or SEPIC topology is commonly used. These

topologies have some disadvantages when compared to buck-only or boost-only regulators: namely, lower efficiency and bandwidth (reduced PWM dimming capability)

compared to buck-only converters, and lower efficiency and higher conducted EMI compared to boost-only regulators.

One way to avoid these problems is to boost a wide-ranging input with a voltage preregulator and use that as the input to a buck-only LED driver. This has the advantages of step-up and step-down, high PWM dimming bandwidth, and lower conducted EMI. Since the LT3797 has three channels that can be used for either voltage regulation or driving LEDs, one channel can be used to boost the input voltage to a higher voltage,

Figure 1. LT3797 triple LED driver configured as 3 × 50V 1A boost LED drive



Higher PWM dimming ratios can be achieved by a buck LED driver than by a boost mode driver. To achieve high LED dimming ratios from a wide-ranging input, low input voltages can be boosted to an intermediate voltage with a preregulator. The intermediate, boosted output serves as input to buck-mode LED drivers. Figure 2 shows a boost-then-buck scheme achieved using a single LT3797.

which can then be used to power two high bandwidth buck mode LED drivers produced using the other two channels.

TRIPLE LED DRIVER (MULTI-TOPOLOGY, HIGH EFFICIENCY)

The LT3797 is a triple LED driver controller IC that can be used to power three strings of LED current in several topologies, including boost, buck mode, buck-boost mode, and SEPIC. Each channel runs

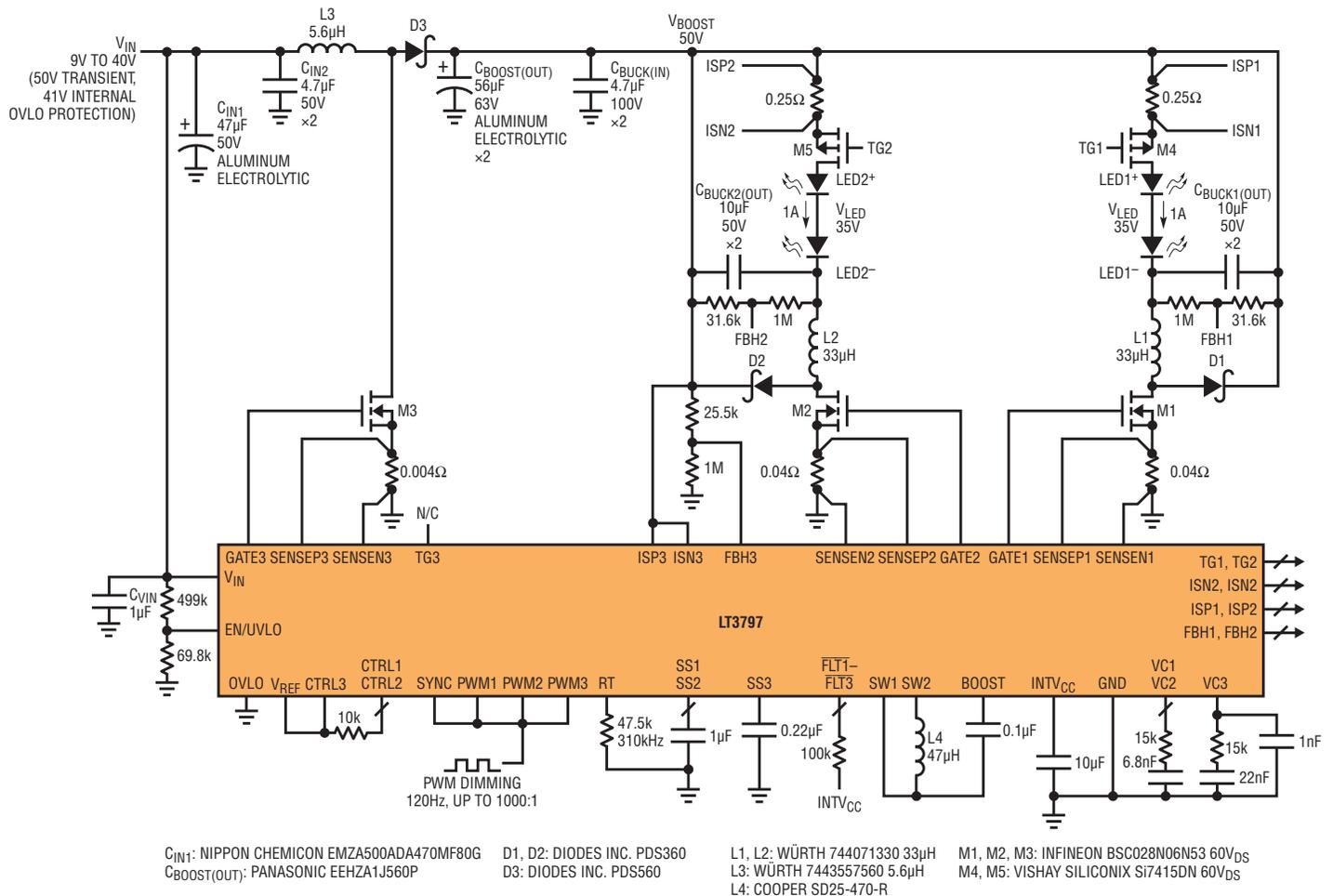
independently of the other channels, but they share clock phase. LED current, open LED protection, analog and PWM dimming control can be controlled independently.

The high side feedback pin, FBH, provides versatile overvoltage protection in both buck mode and buck-boost mode when the LED string does not return to GND, eliminating the need for a level-shifting feedback transistor. The

2.5V–40V V_{IN} range and 100V output range give the LED driver high voltage and power capability. It can be used in automotive and industrial applications as well as battery-powered devices.

Figure 1 shows a 93%-efficient triple boost LED driver powering three 50W (50V, 1A) LED strings from an automotive input. It features 250:1 PWM dimming at 120Hz and short-circuit protection. An internal

Figure 2. LT3797 double boost-then-buck LED driver with 1000:1 PWM dimming ratio



An extra benefit of the boost-then-buck mode driver is the reduced conducted EMI versus a similarly rated buck-boost regulator. Boost converters typically have lower conducted EMI around the AM band than buck converters due to the location of the main inductor in series with the input. In a boost-then-buck scheme, the inductor is in series with the input, versus a buck-boost single inductor between the buck and boost stages.

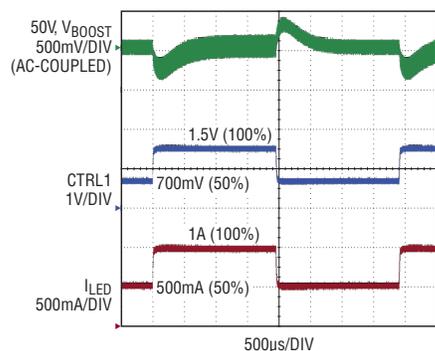


Figure 3. Analog dimming transient from 50% (500mA) to 100% (1A) full-scale current shows high bandwidth of buck mode, even as the boost stage recovers at its own, regular speed.

buck-boost $INTV_{CC}$ supply delivers 7.8V of gate charge to the power switches, even when V_{IN} drops down to 2.5V, making this a very wide input range converter.

DUAL BOOST-THEN-BUCK MODE LED DRIVER

The highest PWM dimming ratios can be achieved by a buck LED driver, which offers the highest operating bandwidth. To achieve high LED dimming ratios from a wide-ranging automotive input voltage, the automotive voltage must first be boosted with a preregulator. The boosted output voltage can then be applied as input to buck-mode LED drivers. Figure 2 shows how this can be achieved with a single IC by using one of the channels of the LT3797 as the boost preregulator with the other two channels acting as buck mode LED drivers.

Besides reduced component count and cost, the advantage of this single-IC scheme

over adding a separate boost IC as a pre-regulator, is that the PWM pin of the boost regulator can be used to both disable switching and freeze the state of the control loop during PWM off-time. This allows the boost converter to quickly return to its previous PWM on state without its output collapsing when the buck mode LED drivers are turned back on. If PWM of the boost is not turned off during PWM off-time, or if a separate boost IC is used, then the bandwidth of the boost converter can limit the maximum PWM dimming ratio.

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often required to reduce conducted EMI in high-powered LED driver applications.

The LT3797 dual boost-then-buck LED driver shown in Figure 2 powers two 35W (35V, 1A) LED strings directly from an automotive input. It features 1000:1 PWM dimming ratio at 120Hz. It also includes short-circuit protection and open LED protection. All three PWM dimming input pins are tied to the same PWM dimming input in order to maximize the PWM dimming ratio and freeze the state of the control loops of all three channels when PWM is off. The output of the boost channel is a regulated 50V. A higher boost output voltage would yield even higher PWM dimming ratios, but at the cost of requiring higher-voltage-rated power components and reduced efficiency. The two buck mode LED driver channels power the two 1A, 35V LED strings from 50V input with high efficiency. Total converter efficiency is 87%.

HIGH PWM DIMMING RATIO

As mentioned above, buck and buck mode LED drivers offer higher bandwidth than boost topology drivers (including

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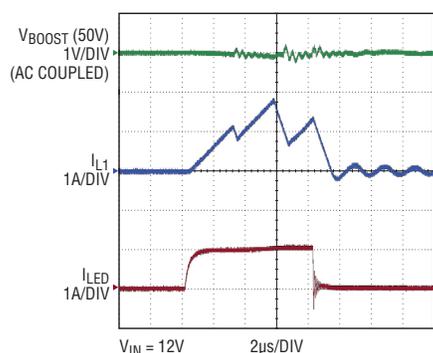


Figure 4. Dual boost-then-buck mode LED driver PWM dimming waveform. 1000:1 dimming at 120Hz.

buck-boost and SEPIC converters), and therefore a higher possible PWM dimming ratio. Unlike boost topologies, where the output temporarily receives less energy as duty cycle is increased in order to raise inductor current during a transient, buck topologies continue to deliver increased energy to the output when duty cycle is increased. The control loop of the buck converter can be optimized at a higher bandwidth for this reason, separate from the boost.

Additionally, during PWM dimming, at the beginning of each cycle, inductor current in a buck regulator does not need to ramp up as far as it must for a boost regulator, since its current is approximately equal to the LED current and not higher. This gives buck converters an advantage over boost converters in both transient response and PWM dimming ratio. As long as the boost preregulator does not lose its output charge during transients, a boost-then-buck mode converter can mimic the high bandwidth of the buck converter.

SHORT AND OPEN LED PROTECTION

The LT3797 LED drivers shown in Figures 1 and 2 are short-circuit proof. The high-side PMOS disconnects are not only used for PWM dimming, but also for short-circuit protection when an LED+ terminal is shorted to ground. Unique internal circuitry monitors when the output current is too high, and turns off the disconnect PMOS on that channel and reports a fault. Similarly, if an LED string is removed or opened, the IC limits its maximum output voltage on that channel and reports a fault.

CONCLUSION

The LT3797 is a 2.5V–40V input and up to 100V output triple LED driver that can be used in many topologies. When step-up and step-down is needed, for the highest PWM dimming ratio of 1000:1 or higher, one channel can be used as a voltage boost preregulator and the other two channels can be used as buck mode LED drivers. Short-circuit protection is available in all topologies, making this IC a robust and powerful solution for driving LEDs in many applications. ■