LED Driver Yields 3000:1 True Color PWM Dimming with Any Buck, Boost or Buck-Boost Topology from a Wide 3V–40V Input Range

by Xin Qi

Introduction

High power LEDs are quickly expanding their reach as a light source for TV projection, scanners, and various automotive and avionic products. All require a constant LED current, whether in buck, boost, buck-boost or SEPIC configurations. Pulse Width Modulation (PWM) is the preferred dimming method for these LED systems to preserve LED color over a wide dynamic range of light intensities. The LT3518 is a highly integrated 2.3A full-featured LED driver capable of providing 3000:1 True Color PWM™ dimming ratio in a variety of topologies for high power LED driver applications.

The LT3518 features a 45V power switch, 100mV high side current sense and accurate open LED protection. It combines a traditional voltage feedback loop and a current feedback loop to operate as a constant current and/or constant voltage source. The programmable soft-start limits inrush current during startup, preventing input current spikes. The LT3518's wide operating input range of 3V to 40V makes it ideally suitable for automotive applications. The 10:1 analog dimming range further extends the total dimming range to 30,000:1. A PMOS disconnect switch driver is integrated to improve the transient response to the PWM control signal. The programmable operating frequency of 250kHz to 2.5MHz allows optimization of the external components for efficiency or component size. To reduce switching noise interference, the LT3518 is synchronizable to an external clock.

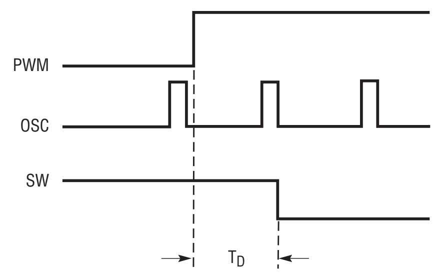


Figure 1. Regular LED driver timing diagram

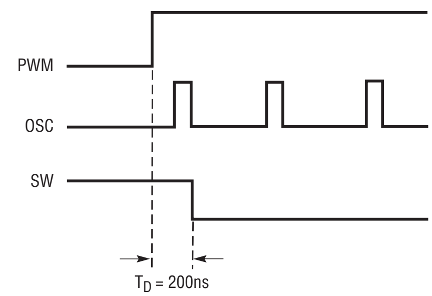


Figure 2. LT3518 timing diagram

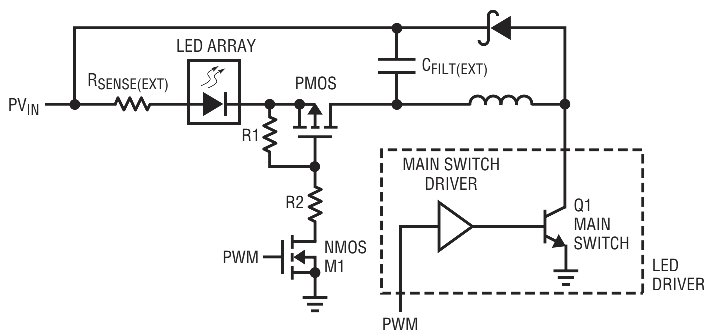


Figure 3. External PMOS disconnect switch driver for a conventional LED driver

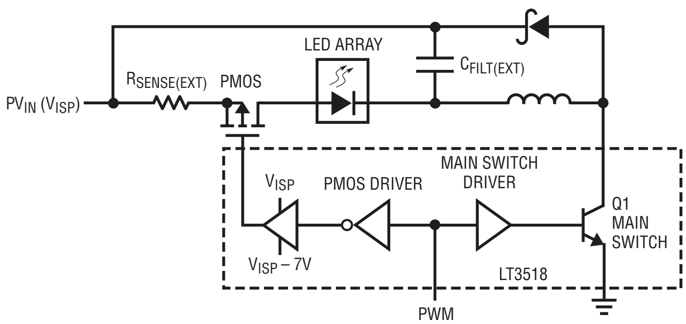


Figure 4. LT3518 internal PMOS driver

Highly Effective PWM Dimming Control

Alignment of Internal Clock and External PWM signal

Most LED drivers operate with an independent, free-running internal oscillator. Each switching cycle begins when the internal oscillator transitions from high to low. When PWM dimming, the switch is turned off when the PWM signal is low. After the PWM signal is driven high, the switch has to wait for the next oscillator high-low transition to turn on, as shown in Figure 1. The turn on delay varies from 0 to one full oscillator cycle, which limits

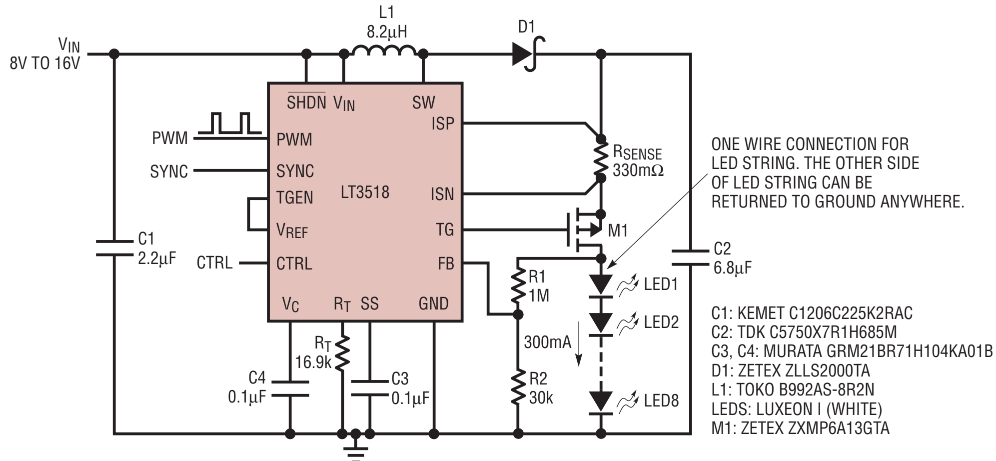


Figure 5. ***1-wire*** **boost 300mA LED driver with LED open protection**

the achievable PWM dimming ratio. This extra cycle becomes an obstacle when high PWM dimming ratios are required.

The LT3518 adopts a new timing scheme, illustrated in Figure 2, to run the converter. Instead of using a free-running oscillator, the LT3518 aligns the internal oscillator to the external PWM signal. When the PWM signal is low, the internal clock is disabled. The PWM rising edge wakes up the internal oscillator with a fixed 200ns delay. In this manner, the LT3518 has a fast response to the PWM input signal, thus improving the achievable PWM dimming ratio.

PMOS Disconnect Switch Driver

Recent LED driver designs disable all internal loads to the V_C pin during the PWM low period, which preserves the charge state of the V_C pin on the external compensation capacitor. This feature reduces the transient recovery time, further increasing the achievable PWM dimming ratio. However, to achieve the best PWM dimming ratio for a buck/buck-boost mode LED driver, other ICs still rely on several additional external components to drive a PMOS disconnect switch. As shown in Figure 3, a typical PMOS disconnect switch driver consists of an NMOS transistor and a level shift resistor network formed by R1 and R2. This kind of PMOS driver must juggle the tradeoffs between fast transient response and high power consumption. The diverse input voltage and LED voltage combinations also make the level shifter design difficult.

The LT3518's wide operating input range of 3V to 40V makes it ideally suitable for automotive applications.

In contrast, the LT3518 incorporates a PMOS driver inside, which can transition a 1nF gate capacitance PMOS switch in 200ns with a small holding current, typically 600µA. In this way, the LT3518 simplifies board layout, reduces the bill of material, and avoids the dilemma of trading off the power consumption for a fast transient response. Additionally, the LT3518 includes an internal level shifter to ensure the that the TG pin

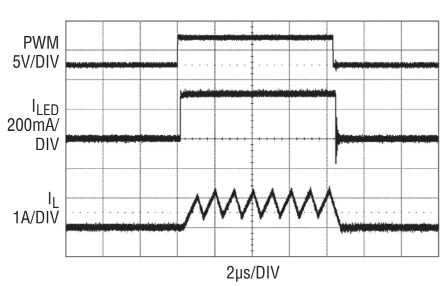


Figure 6. PWM dimming waveform for Figure 5 at 120Hz PWM frequency and V_{IN} = 10V

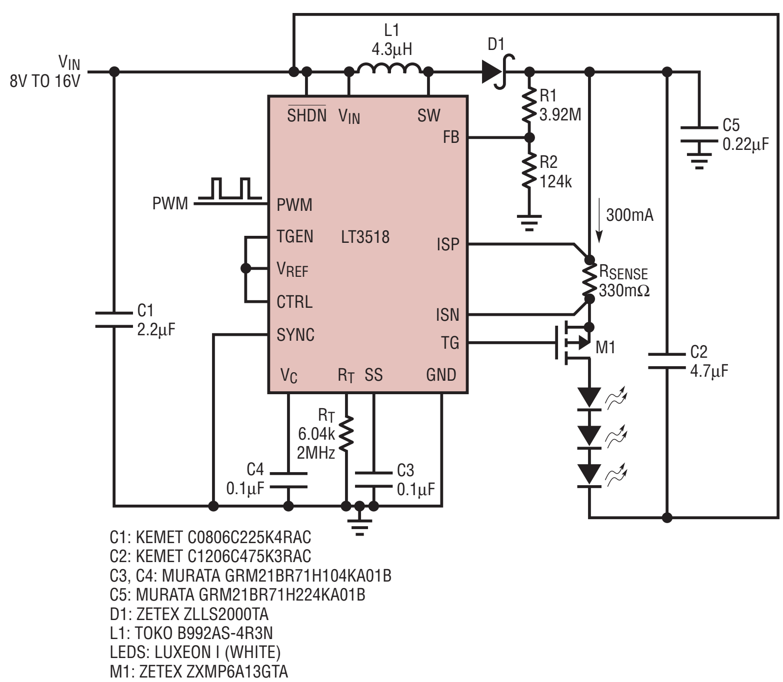


Figure 7. Buck-boost LED driver for automotive applications

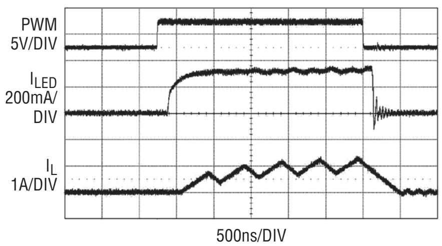
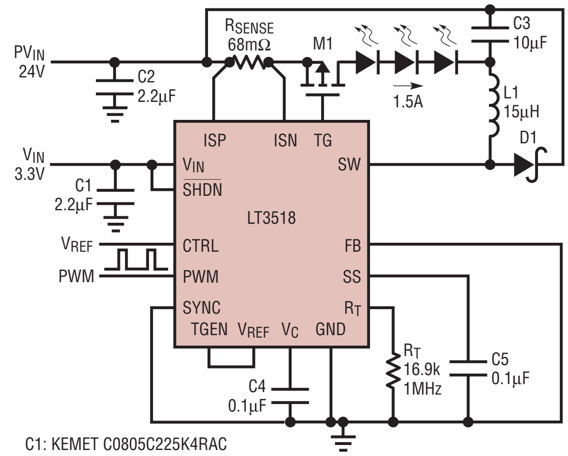


Figure 8. 3000:1 PWM dimming waveform of application circuit of Figure 7 at 120Hz PWM frequency and V_{IN} = 12V.

is 7V or less below ISP pin. The internal PMOS driver can also be used to implement fault protection. When a fault is detected (e.g., an input surge), the LED array will be disconnected and protected by pulling down the PWM input.



C1: KEMET C0805C225K4RAC
C2: MURATA GRM31MR71E225KA93
C3: MURATA GRM32DR71E106KA12B
C4, C5: MURATA GRM21BR71H104KA01B
D1: ZETEX ZLLS2000TA
L1: TOKO B992AS-150M
LEDS: LUXEON K2 (WHITE)
M1: ZETEX ZXMP6A13GTA

Figure 9. Buck mode 1.5A LED driver

Applications

1-Wire High PWM Dimming Boost LED Driver

Many LED drivers feature high side current sensing that enables the parts to function as a 1-wire current source. To improve PWM dimming ratio in boost configuration, those LED drivers typically rely on a low side NMOS disconnect switch, unfortunately limiting the 1-wire operation. On the contrary, the unique internal PMOS driver of the LT3518 makes 1-wire operation feasible in boost configuration while keeping a high PWM dimming ratio. Figure 5 shows the LT3518 driving eight 300mA LEDs in boost configuration. This setup only needs to provide 1-wire for the top side of the LED string, while the other side of the LED string can be returned to ground anywhere. Figure 6 shows a 1000:1 PWM dimming waveform captured by using this setup.

Buck-Boost PWM LED Driver

For an application in which the V_{IN} and V_{OUT} ranges overlap, a buck-boost topology is preferred. To make the LT3518 with a low side switch function as a buck-boost converter, the LED current should be returned to V_{IN}. Thus, the LEDs see a voltage of V_{OUT}-V_{IN}. Figure 7 depicts a buck-boost PWM LED driver for automotive applications. In this setup, the single battery input voltage is able to vary from 8V to 16V. The 6.04kΩ R_T resistor sets the system up for 2MHz switching, which permits a higher PWM dimming ratio than the standard 1MHz switching frequency. The 3000:1 PWM dimming ratio shown in Figure 8 is achieved at 120Hz PWM frequency.

High Current Buck PWM LED Driver

The LT3518 features a 2.3A switch, which makes it capable of driving 1.5A LEDs in buck configuration. Special attention should be paid to the internal power consumption when driving high current LEDs. Both high switching frequency and high power input voltage (PV_{IN}) tend to cause high power consumption and heat up the silicon. With 1MHz switching frequency and 24V PV_{IN}, the circuit shown in Figure 9 can provide 1000:1 PWM dimming ratio as shown in the waveforms in Figure 10.

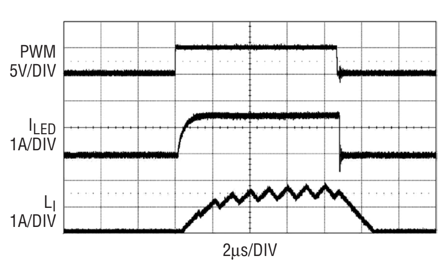


Figure 10. 1000:1 PWM dimming waveform of the application circuit of Figure 9 at 120Hz PWM frequency.

When a high power input voltage drives a few LEDs in buck configuration, open LED protection should be considered. Unlike the boost configuration, the output voltage needs to be level-shifted to a signal with respect to ground as illustrated in Figure 11. In this manner, the unique constant voltage loop of the LT3518 can regulate the output voltage of the buck configuration at the predefined value, thus protect LEDs.

Conclusion

The LT3518 is a high current, high voltage and high accuracy LED driver offering high PWM dimming ratios a variety of topologies. Its versatility, simplicity and reliability make it very attractive in most LED applications. The LT3518 is available in the tiny footprint QFN UF16 package and leaded FE16 package. It provides a complete solution for both constant-voltage and constant-current applications.

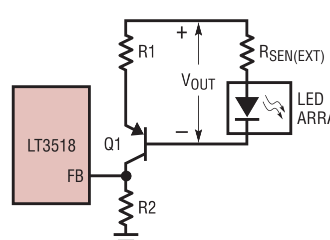


Figure 11. Open LED protection setup for buck configuration