Light Up 12 LEDs from a Single-Cell Li-Ion Battery via Highly Integrated 3mm × 2mm Dual-LED-String Driver

by Ben Chan

Introduction

The LT3497 is a dual step-up converter capable of driving up to 12 white LEDs from a single-cell Li-Ion input. The device is capable of driving asymmetric LED strings with independent dimming and shutdown control, perfect for driving backlight circuits in battery-powered portable devices, such as cellular phones, MP3 players, PDAs, digital cameras, and portable GPS devices.

The LT3497 directly regulates LED current, providing consistent brightness for all LEDs regardless of variations in their forward voltage drop. Important features including internal compensation, open-LED protection, DC/PWM dimming control, a 35V power switch and a 35V Schottky diode are all integrated into the part, making the LT3497 LED driver an ideal solution for space-constrained portable devices. In addition, the 2.3MHz switching frequency allows the use of tiny inductors and capacitors. Figure 1 shows a typical 12-white-LED application. Figure 2 shows the efficiency of the circuit.

Features

High Side Sense

The LT3497 features a unique high side LED current sense that enables the part to function as a 1-wire current source—the cathode side of the bottom LED in the string can be returned to ground anywhere, allowing a simple 1-wire LED connection. Traditional LED drivers use a grounded resistor to sense LED current requiring a 2-wire connection to the LED string. High side sense moves the sense resistor to the top of the LED string. In addition, high side sense allows the LT3497 to operate in unique applications (Buck-Mode or Buck-Boost Mode) where traditional LED drivers cannot be used.

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Dimming & Shutdown Control

The LT3497 features single pin shutdown and dimming control for each converter. The LED current in the two drivers can be set independently by modulating the CTRL1 and CTRL2 pins. There are three different types of dimming methods: DC voltage dimming, filtered PWM signal dimming and direct PWM dimming.

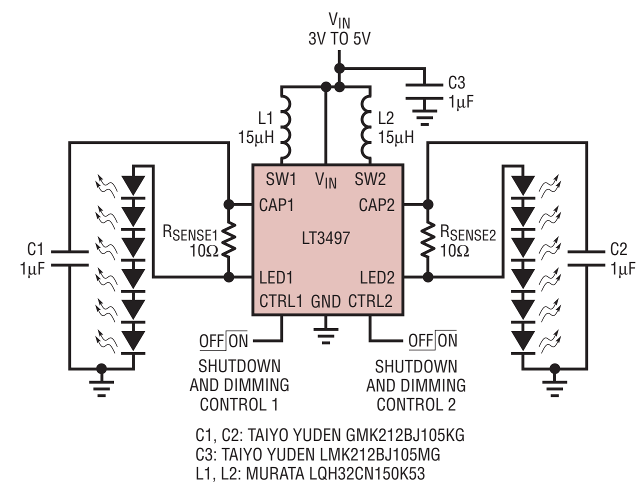

Figure 1. Li-Ion powered driver for twelve white LEDs

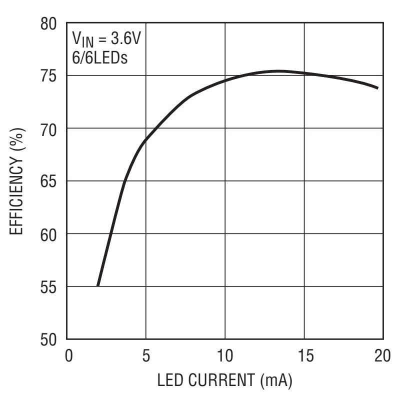

Figure 2. Efficiency of the circuit in Figure 1

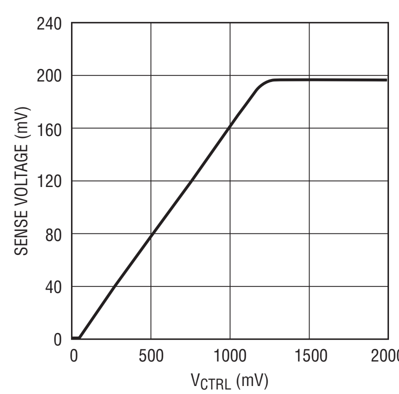

Figure 3. LED sense voltage versus CTRL pin voltage

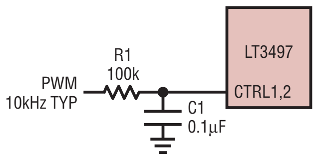

Figure 4. Filtered PWM Dimming

The LED currents are proportional to the DC voltages at the CTRL1 and CTRL2 pins, so DC voltage dimming is achieved by reducing the voltage on the CTRL pin. The dimming range of the part extends from 1.5V at the CTRL pin for full LED current down to 100mV. The CTRL pin directly controls the regulated sense voltage across the sense resistor that sets the LED current (see Figure 3).

Filtered PWM dimming works similarly to DC voltage dimming except that the DC voltage input to the CTRL pins comes from an RC-filtered PWM signal. The corner frequency of the R1 and C1 should be much lower than the frequency of the PWM signal for proper filtering. Filtered PWM dimming is shown in Figure 4.

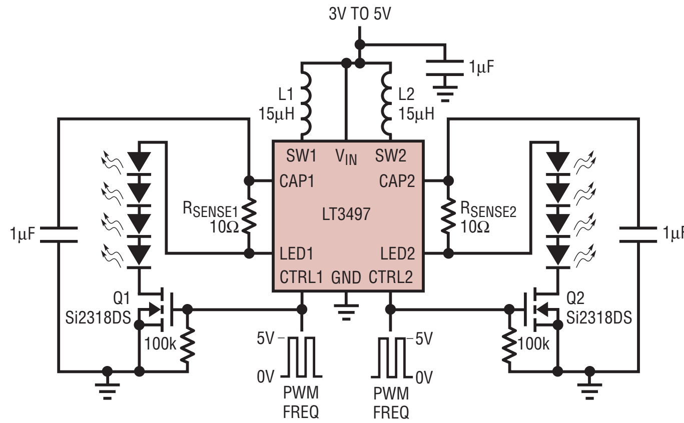

Figure 5. Li-Ion to eight white LEDs with direct PWM dimming.

Direct PWM dimming is typically used because it achieves a much wider dimming range compared to using a filtered PWM or a DC voltage. Direct PWM dimming uses a MOSFET in series with the LED string to quickly connect and disconnect the LED string. Figure 5 displays direct PWM dimming in a Li-Ion to a 4-and-4 white LED application. A PWM signal is applied to the CTRL pin and MOSFET where the PWM signal controls both the turn-on and turn-off of the part. Figure 6 shows the linearity of PWM dimming. The available dimming range depends on the settling time of the application and the PWM frequency used. The application in Figure 5 achieves a dimming range of 250:1 using a 100Hz PWM frequency. Figure 7 shows the available dimming ranges for different PWM frequencies.

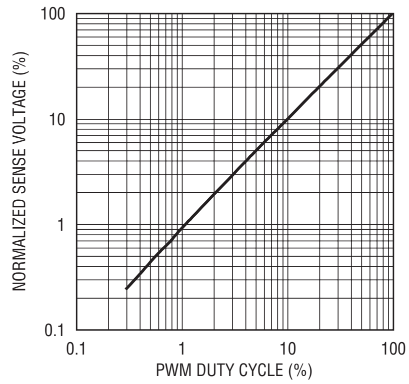

Figure 6. Linearity of PWM Dimming of Figure 5 at 100Hz

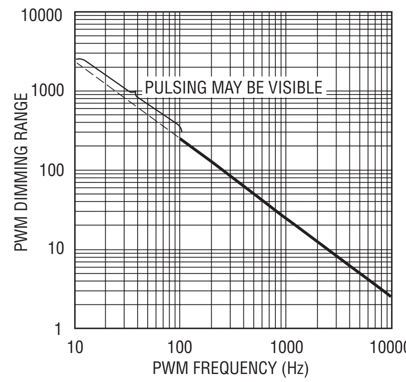

Figure 7. Dimming Ratio Range vs Frequency

Applications

Li-Ion Powered Driver for 12 White LEDs

Figure 1 highlights the LT3497's impressive input and output voltage range. This circuit is capable of driving two strings of six LEDs each with 20mA of constant current. As shown

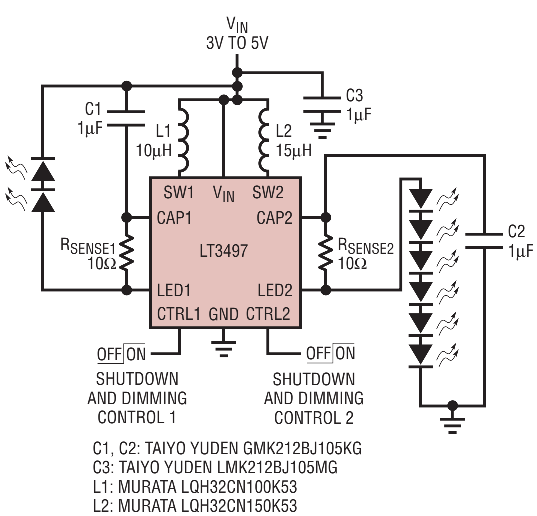

Figure 8. Li-Ion to a 2-LED and 6-LED Display

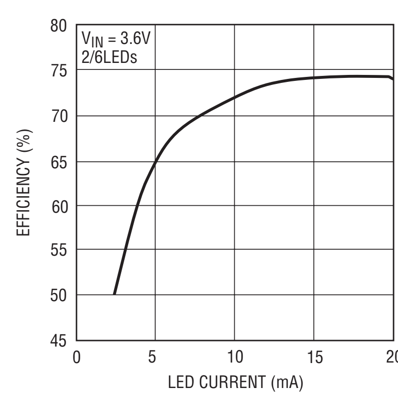

Figure 9. Efficiency of the circuit in Figure 8

in Figure 1, the circuit works from a single Li-Ion (3V) battery or 5V wall adapter. Figure 2 shows efficiency with a 3.6V input.

Li-Ion to a 2-LED and 6-LED Display

Figure 8 (Buck-Boost/Boost configuration) shows a white LED driver used to backlight two displays: a 6-LED main and a 2-LED sub display. This design generates a constant 20mA in each white LED string from a Li-Ion (3V~4.2V) or 5V adapter input. Two independent dimming and shutdown controls (CTRL1 and CTRL2) simplify power management and extend battery life. Figure 9 shows the efficiency of the circuit.

Conclusion

The LT3497 is a dual channel white LED driver capable of driving up to 12 white LEDs from a single cell Li-Ion input. The device features 35V internal power switches, internal Schottky diodes, DC or PWM dimming control, open LED protection and optimized internal compensation. The LT3497 is an ideal solution for a wide range of applications including multipanel LCD backlighting, camera flash or space constrained portable applications such as cellular phones, MP3 players, PDAs and digital cameras.

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pin serving as ballast to equalize the currents. PC trace resistance in milliohms/inch is shown in Table 3. Only a tiny area is needed for ballasting.

Figure 6 shows two devices with a small 10mΩ ballast resistor, which at full output current gives better than 80% equalized sharing of the current. The external resistance of 10mΩ (5mΩ for the two devices in parallel) only adds about 10mV of output regulation drop at an output of 2A. Even with the 1V output, this only adds 1% to the regulation.

Thermal Performance

Two LT3080 3mm × 3mm QFN devices are mounted on a double sided PC board. They are placed approximately 1.5 inches apart and the board is mounted vertically for convection cooling. Two tests were set up to measure the cooling performance and current sharing of these devices.

The first test was done with approximately 0.7V input-to-output differential and a 1A load per device. This setup produced 700mW dissipation in each device and a 2A output current. The temperature rise above ambient is approximately 28°C and both devices were within ±1°C of each other. Both the thermal and electrical sharing of these devices is excellent. The thermograph in Figure 7 shows the temperature distribution between these devices, where the PC board reaches ambient within about 0.5in from the devices.

Figure 8 shows what happens when the power is increased to 1.7V across each device. This produces 1.7W dissipation in each device and a device temperature of about 90°C, about 65°C above ambient. Again, the temperature matching between the devices is within 2°C, showing excellent tracking between the devices. The board temperature drops to about 40°C within 0.75 inches of each device.

While 95°C is an acceptable operating temperature for these devices, this rise is in a 25°C ambient environment. For higher ambient temperatures, the temperature rise must be controlled to prevent the device temperature from exceeding 125°C. A 3-meter-per-second airflow across the devices decreases the device temperature by about 20°C, providing a margin for higher operating ambient temperatures. Also, this example is for a 2-layer board. A 4-layer board would provide better power dissipation.

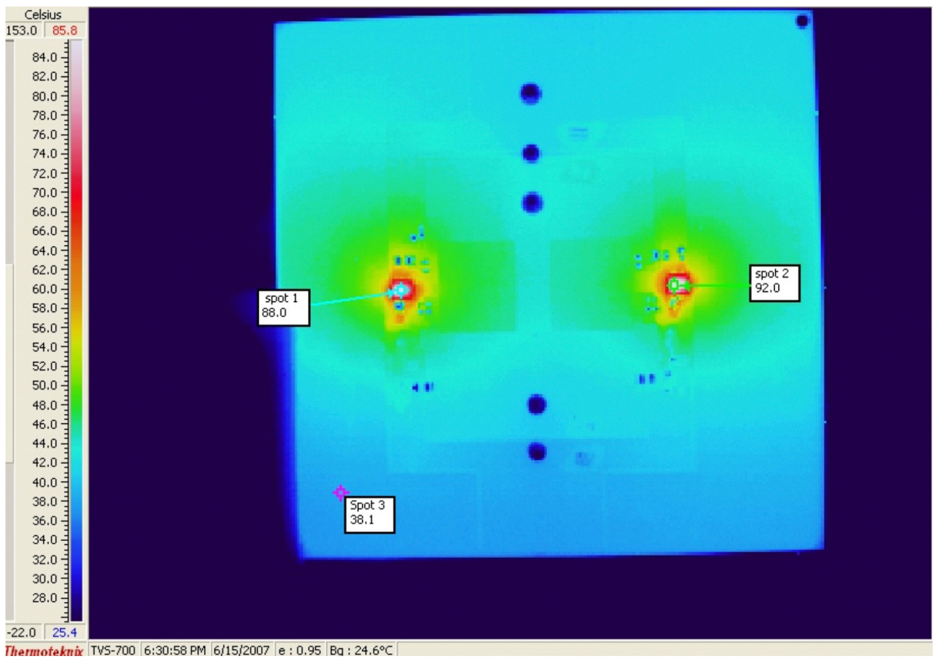

Figure 8. Thermograph shows a 65°C rise for two regulators, each dissipating 1.7W from a 1.7V input-to-output differential at 2A load.

Conclusion

The LT3080's breakthrough design and high performance DC characteristics allows it to be paralleled for high current all-surface-mount applications. It is also adjustable to zero output, an impossible feat with a traditional 3-terminal adjustable linear regulator. It is optimized for new circuit applications and all-surface-mount system assembly techniques—especially high performance, high density circuit boards.