Constant Current from 3A DC/DC Converter with 2 Rail-to-Rail Current Sense Amplifiers

by Daniel Chen

Introduction

Traditional DC/DC converters use voltage feedback for constant output voltage regulation. There are many applications, however, that need to regulate a constant output current. Driving LEDs in series is one such application. The LT3477 combines a traditional voltage feedback loop and two unique current feedback loops to operate as a constant-current, constant-voltage source. It is a current mode, 3A DC/DC converter with dual rail-to-rail 100mV current sense amplifiers that can be configured as a buck mode or buck-boost mode LED driver. It is versatile enough to also be configured as an input-output current limited boost, SEPIC or inverting converter. Both current sense voltages can be adjusted independently using the I_{ADJ1} and I_{ADJ2} pins.

With two identical precision current sense amplifiers, the LT3477 can provide an accurate input current limit as well as an accurately regulated output current. With an input voltage range of 2.5V to 25V, the LT3477 works from a variety of input sources. The 42V switch rating allows an output voltage of up to 41V to be generated, easily driving up to ten white LEDs in series. The buck mode LED configuration is capable of driving multiple ten-LED strings in parallel if external current mirroring circuitry is added.

The unique feature of the three-feedback-loop topology (two current and one voltage) is that it can support constant voltage and/or constant current applications.

The switching fequency is adjustable from 200kHz to 3.5Mhz, set by a single resistor. The available high operating frequencies allow the use of low profile inductors and capacitors—important in applications where space is a premium. The wide available range makes it possible to optimize size and efficiency for your application.

How It Works

Figure 1 shows a block diagram of the LT3477. The voltage error amplifier has both FBP and FBN pins to allow a positive or negative output configuration. With the addition of two current feedback control loops, amplifier A3 becomes a summing point for three feedback loops. Depending on configuration, any of the loops can take over feedback control by sourcing or sinking current at the V_C node. The unique feature of the three-feedback-loop topology (two current and one voltage) is that it can support constant voltage and/or constant current applications.

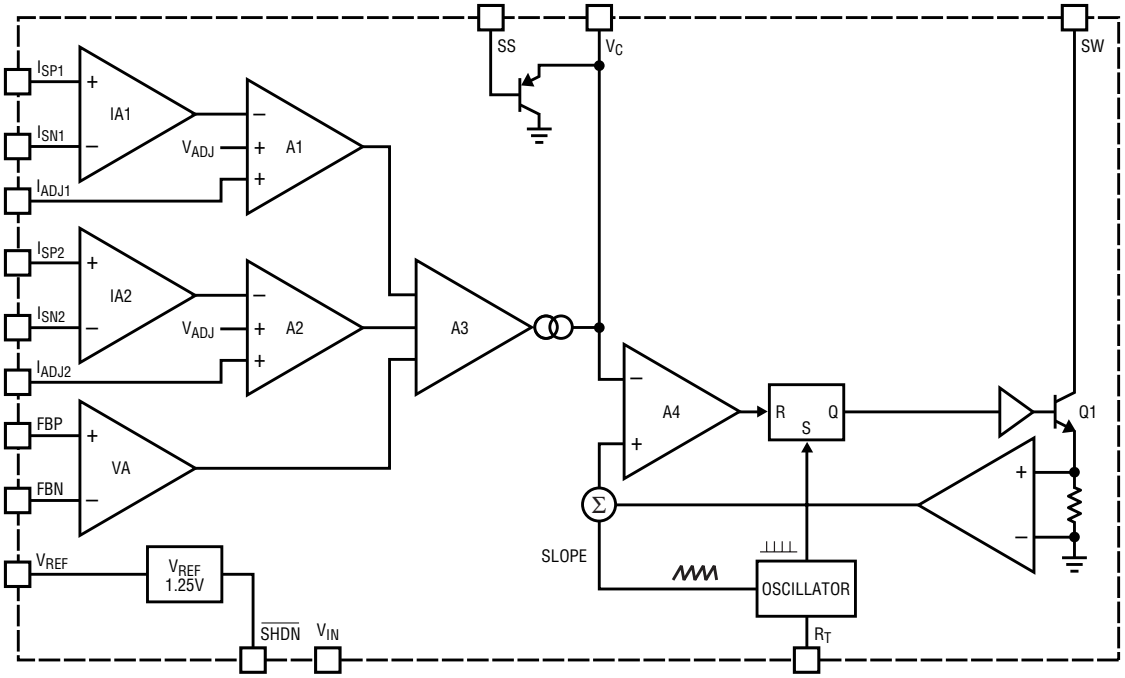

Figure 1. LT3477 block diagram

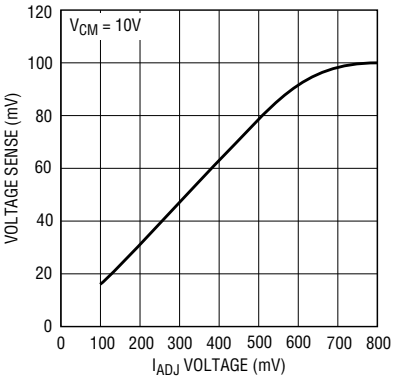

Figure 2. Current sense amplifier voltage sense level vs I_{ADJ} pin voltage

Current sense levels are adjustable via sense resistors at the I_{ADJ1} and I_{ADJ2} pins. The default sense voltage is 100mV for each current sense amplifier if the I_{ADJ1} and I_{ADJ2} pins are tied to a potential higher than 650mV. If the potentials at the I_{ADJ1} and I_{ADJ2} pins are lower than 625mV, the LT3477 linearly adjusts the current sense level. Figure 2 shows the voltage sense level vs the I_{ADJ} pin voltage. For LED drivers, I_{ADJ1} and I_{ADJ2} pins can be used to adjust LED current levels. Rail-to-rail current sense amplifiers allow flexible current sense schemes.

Applications

Buck Mode
High Current LED Driver

Figure 3 shows a typical application to drive high current LEDs. Traditionally, LED drivers use a grounded current sense resistor to regulate current, but the LT3477 current sense amplifiers work in a high side sense scheme, so the sensed voltage for current feedback no longer needs to be ground referred. In buck mode configuration, the sense resistor is placed right at the input supply. The LEDs are placed between the sense resistor and the inductor and the Schottky diode is connected between the SW and PV_{IN} nodes. With high side current sense, the boost converter is effectively converted into a buck LED converter, which increases the part's power handling capability. In addition, the V_{IN} pin, which provides the chip operating current, can be tied to a lower voltage level such as 3.3V. As a result, the power consumption on the chip itself is also reduced, thus improving overall efficiency. Over 90% efficiency can be readily achieved with a wide range of inductor and frequency selections.

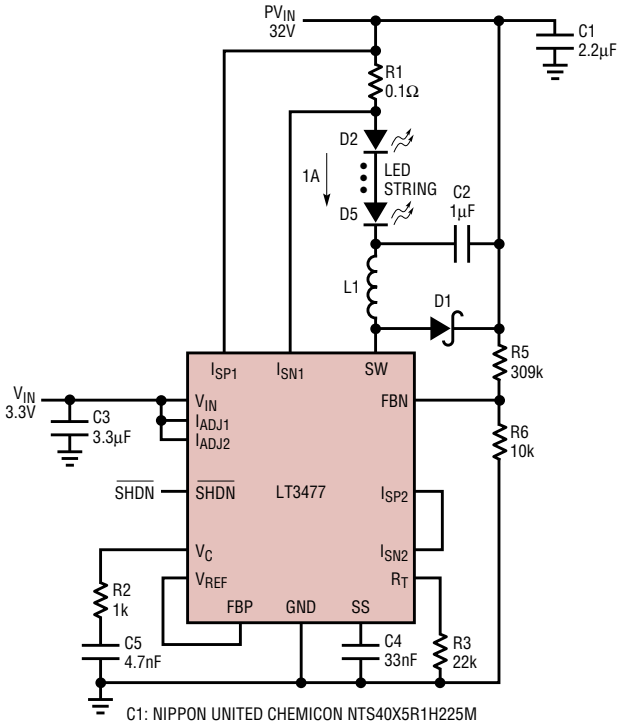

Figure 3. Buck mode high current LED driver

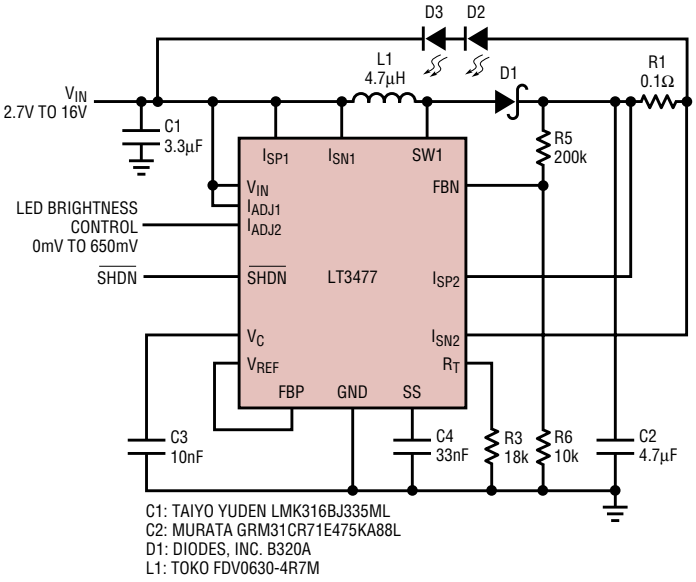

Figure 4. Buck-boost LED driver

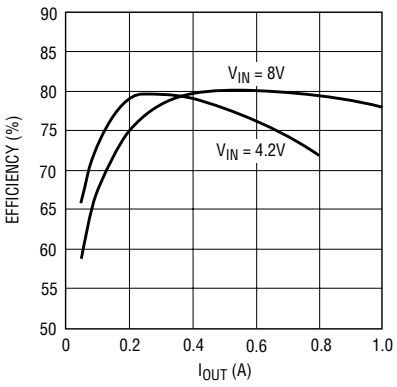

Figure 5. Buck-boost LED driver efficiency

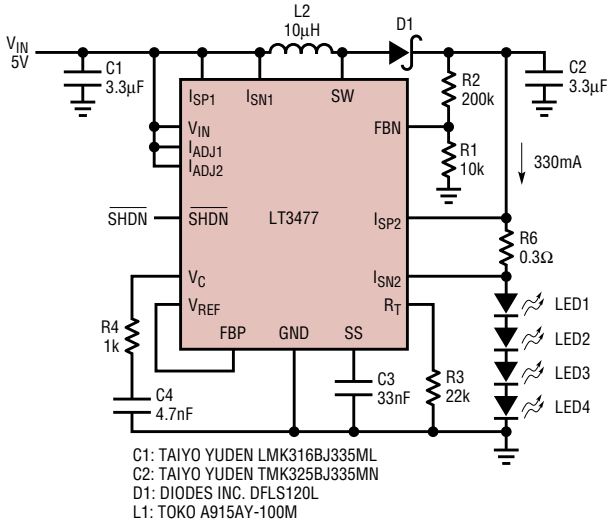

Figure 6. 4W LED driver

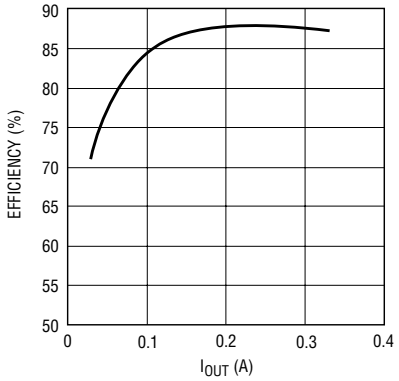

Figure 7. 4W LED driver efficiency

Buck-Boost LED Driver

In some applications, the input voltage might be comparable to the total LED voltage drop or the input voltage might fluctuate to higher or lower than the total LED voltage drop. A buck-boost LED driver works well in this type of application. Figure 4 shows the LT3477 buck-boost LED driver. The cathode end of the LED string is tied back to the input voltage, which allows it to operate from a wide input voltage range. R5 and R6 in Figure 4 are used for open LED protection. Figure 5 is the efficiency measured for this circuit.

330mA LED Driver with Open LED Protection

LT3477 can also be used for LED driver applications using a conventional boost topology with the current sense amplifier for current regulation. Figure 6 shows a typical application circuit, and Figure 7 shows the efficiency. Figure 6 uses a high side current sense configuration for feedback control. The current sense amplifier could also be used for a grounded current sense for this application, if desired, so the output can be tied to the LED string directly. I_{SP2} would be tied to the cathode side of the LEDs, and I_{SN2} is tied to ground. Voltage feedback is used for open LED protection.

5.5V SEPIC Converter with Short-Circuit Protection

Certain applications demand a converter output that is DC-isolated from the input. SEPICs (single-ended primary inductance converters) provide the solution. Figure 8 is an implementation which provides a 5.5V output with complete short-circuit protection. The current sense amplifier used for current sense not only provides excellent short-circuit protection, but also helps soft start the output. The accurate output current limit ensures the maximum current is set at 670mA. When the load demands more, the output voltage will droop while the 670mA output current is maintained. Efficiency is shown in Figure 9.

Cuk Converter

The LT3477 provides pins for both inputs to the voltage error amplifier, which enables negative output voltages. Figure 10 is an implementation

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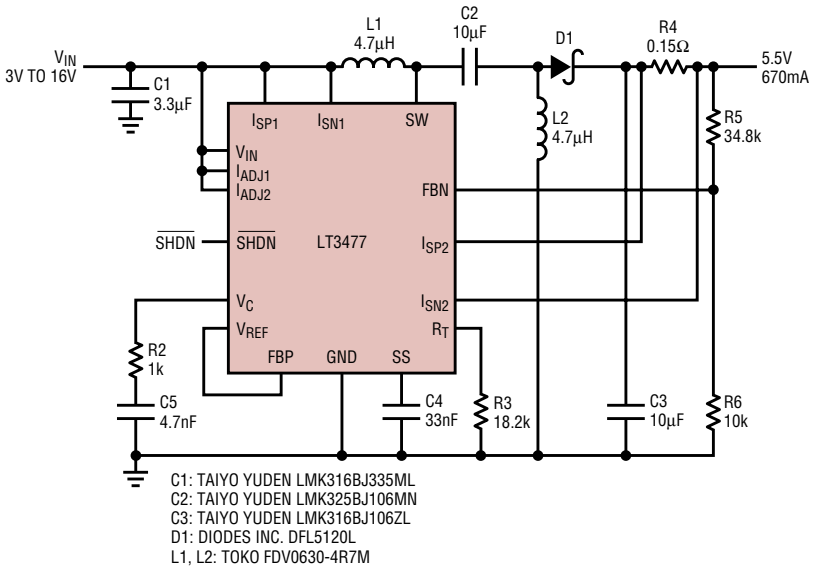

Figure 8. 5.5V SEPIC converter with short-circuit protection

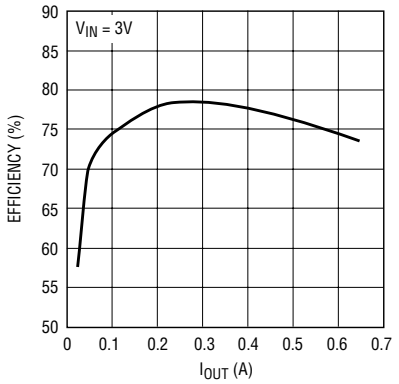

Figure 9. 5.5V SEPIC converter with short-circuit protection efficiency

Dual Display Power Supply for Cell Phones

A typical application for the LT3466-1 is as a driver for dual displays in cell phones. Present day, clam-shell cell phones typically use a color TFT-LCD main display and a secondary OLED display. Figure 1 shows the LT3466-1 powering the main LCD backlight and the secondary OLED display. The LT3466-1 drives 6 white LEDs at 20mA for backlighting the main LCD panel and generates 16V output for powering the OLED. The LT3466-1 allows for independent dimming control of the main and secondary displays via the respective CTRL1 and CTRL2 pins. Figure 2 shows the efficiency versus output current for both the LED driver and the boost converter. The typical efficiency at 3.6V input supply is 84% with the white LEDs and the OLED driven at 20mA.

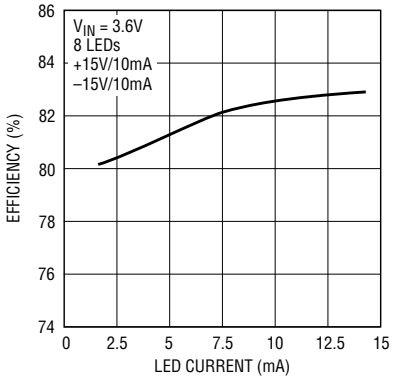

Figure 4. Efficiency versus LED current for the circuit in Figure 3. The circuit achieves greater than 83% efficiency driving eight LEDs at 15mA from 3.6V input.

Low Cost, Complete LCD Bias and White LED Backlighting Solution for Small TFT Displays

Small, active-matrix, TFT-LCD displays, used in cell phones, PDAs and other handheld devices generally require four to ten white LEDs for providing the backlight and fixed +15V and –15V supply voltages to bias the LCD. Figure 3 shows LT3466-1 powered complete TFT-LCD supply with minimal external components and high efficiency. The LT3466-1 drives eight white LEDs at 15mA and generates 15V boost output powered from a single Li-Ion supply. A discrete charge pump produces the secondary output of –15V. As seen in Figure 4, the circuit achieves greater than 83% efficiency driving eight LEDs at 15mA from 3.6V input.

Conclusion

The LT3466-1 integrates a full featured white LED driver and a boost converter in a space saving 3mm × 3mm DFN package. Integrated power switches and Schottky diodes reduce the overall system cost and size making it an excellent fit for handheld applications. Features like internal compensation, soft-start, Open LED protection enables LT3466-1 to provide complete TFT-LCD supply (bias and white LED backlight) for handheld devices with minimal external components and high efficiency.

LT3477, continued from page 27

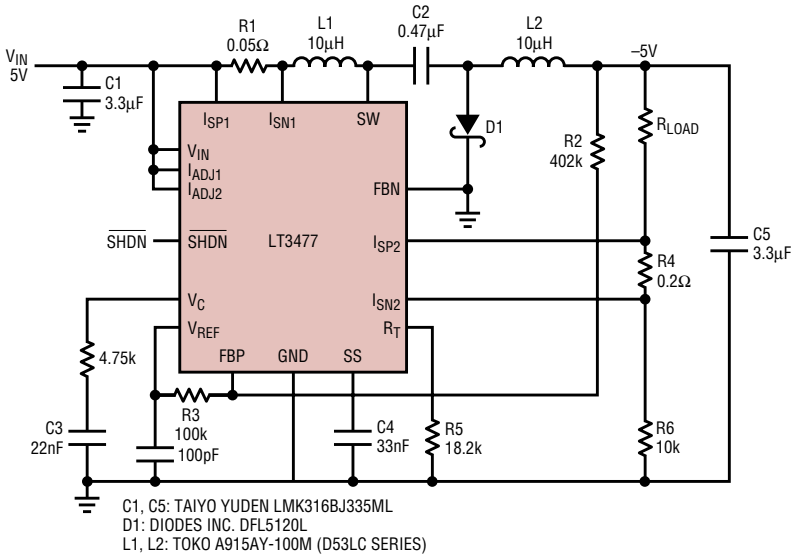

Figure 10. Negative output voltage Cuk converter.

using a Cuk topology for 5V to –5V conversion. The first current sense amplifier is used for input current limit, and the second current sense amplifier is used for ground rail current sense to accurately limit the load current at 500mA. Even though the two current sense amplifiers are used, efficiency up to 81% at 500mA output load can still be achieved. Figure 11 shows the efficiency.

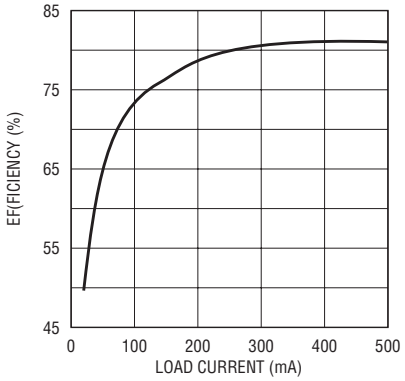

Figure 11. Efficiency of the Cuk converter.

Conclusion

The rail-to-rail constant-current/constant-voltage operation of the LT3477 makes the device an ideal choice for a variety of constant-current designs, including negative outputs. The dual current-sense amplifiers allow flexible configuration for input current limit, constant output current and fail-safe protection, along with excellent output voltage regulation. A wide input voltage range and the ability to produce outputs up to 42V make the LT3477 extremely versatile.

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