Efficient, Flexible Boost Converter Fits into Charge-Pump Footprint

by Eddy Wells

Introduction

Handheld devices often use low power step-up DC/DC converters to power displays, LEDs and I/O circuitry, or to charge alternate power sources. Capacitive charge-pumps or inductor-based boost converters are the two most common solutions to step-up conversion, and each has certain advantages and trade-offs. A charge-pump converter offers a simple, compact solution, but it has a limited range of V_{IN} to V_{OUT} ratios, such as 3.3V to 5V. A traditional boost converter offers more efficient operation and a greater range of step-up ratios, but boost solutions typically take more space, and systems issues such as inrush current and short circuit protection are often solved with added external circuitry.

The LTC3459 is a small, synchronous boost converter that addresses many issues found in a traditional boost converter. The LTC3459 offers Burst Mode operation for high efficiency at light loads and a simple design (no compensation network). The internal MOSFET switches save space, protect circuitry by controlling inrush current during start-up, and are robust enough to survive a continuous short-circuit at the output. When the LTC3459 is shutdown the output is disconnected from the input, removing voltage from the load and reducing the drain on the battery.

Tiny Solution Size

A demonstration board with a complete LTC3459 ThinSOT solution is shown in Figure 1. The input and output capacitors, used to minimize voltage ripple on the supply rails, are 0603 X5R ceramics. Since the converter operates with a low peak current of approximately 75mA, a 0805 miniature inductor from Murata is chosen to maintain a footprint similar to a charge-pump. External feedback resistors and pads for an optional feed-forward capacitor complete the design. The resulting solution size is approximately 30mm^2.

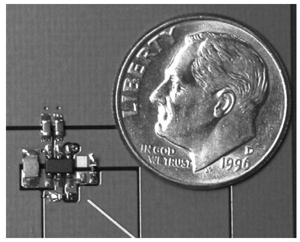

Figure 1. Typical solution size with LTC3459 ThinSOT™ boost converter

Efficiency and Operating Range

The LTC3459 has an input voltage range from 1.5V to 5.5V and an output that is programmable up to 10V. V_{OUT} can be regulated below V_{IN} with this IC, an important consideration for battery-powered devices. The converter is designed to maintain good efficiency over the Li-Ion battery range (2.7V to 4.2V) or a 2-cell alkaline input (2.0V to 3.3V).

Figure 2 shows an application where the LTC3459 is used to provide a 7V, 50mW bias for an organic LED display (OLED). V_{OUT} ripple (AC coupled) and inductor current waveforms are shown in Figure 3, where Figure 4 shows efficiencies of this application with a 2V–5.5V input. Efficiency was taken with two 22µH Murata inductors: one from the LQH2MC series (shown in Figure 1) and a slightly larger inductor from the LQH32CN series. The larger inductor gives about 5% better efficiency, due to lower DC resistance and losses in the core. Since the LTC3459 uses Burst Mode operation with only 10µA of quiescent current, the efficiencies shown in Figure 4 are relatively constant with load current down to 100µA. If the minimum input voltage is increased to 3V, a 100mW load can be supported in this application.

Charging a SuperCap

The output disconnect function in the LTC3459 allows peak current to be controlled during startup or when V_{OUT} is less than V_{IN}. This makes the LTC3459 an ideal candidate for charging a backup source such as a SuperCap®. Figure 5 shows an application where the LTC3459 is used to charge a 2F, 5V ultracap from a 3.3V or battery input. Once the SuperCap is charged to 5V, it can be used to backup the 3.3V supply rail (through an LTC1844-3.3 VLDO in this example) if the primary power source is removed.

SuperCap is a registered trademark of Baknor Industries

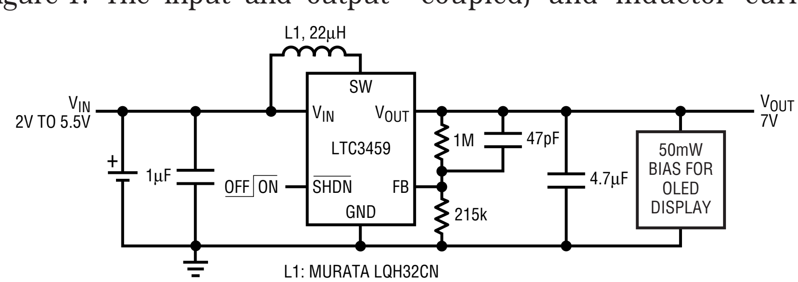

Figure 2. Powering a 7V, 50mW OLED from a 2V–5.5V input

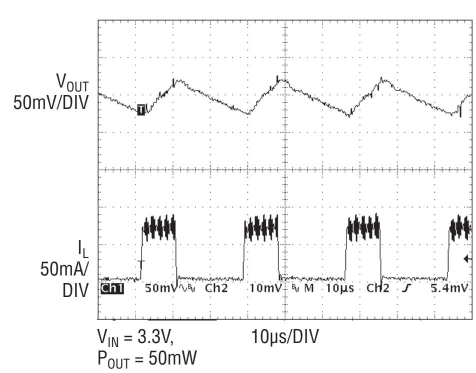

Figure 3. V_{OUT} ripple and inductor current for the OLED application

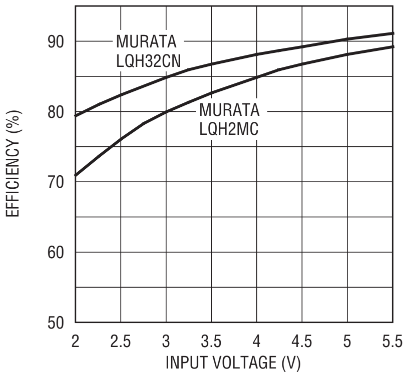

Figure 4. OLED efficiency comparison for two inductor types with a 7V, 50mW load

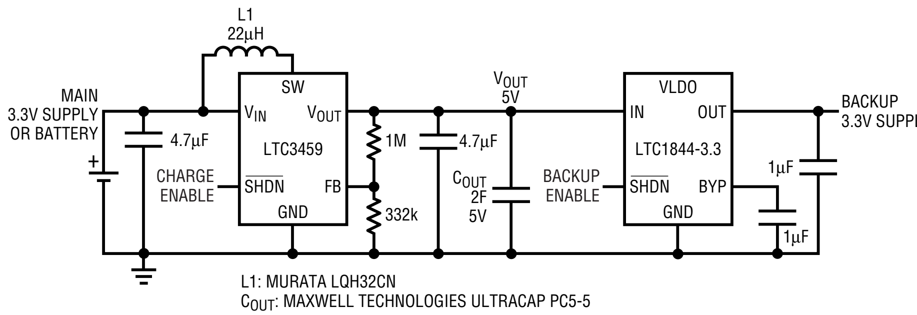

Figure 5. SuperCap-based backup supply using the LTC3459 and LTC1844

The LTC3459's operation in this application depends on the levels of V_{IN} and V_{OUT}. When V_{OUT} is less than approximately 3.5V, the body of the internal synchronous P-channel MOSFET rectifier is connected to V_{IN} (forming a PNP transistor) and the SW pin rises a V_{be} above V_{IN} when current is delivered to the load. While efficiency is lower in this mode of operation, current to the SuperCap is controlled, preventing any damaging effects of inrush current. When V_{OUT} is greater than 3.5V, normal boost mode operation and efficiency begin, with the P-channel MOSFET acting as a synchronous switch. Average input current is approximately 50mA during charging, while the current delivered to the SuperCap varies somewhat with duty cycle. Once the SuperCap is charged to 5V, the LTC3459 begins to regulate and the input current is reduced to the amount required to support the load and/or self discharge of the SuperCap.

Conclusion

The LTC3459 simplifies and shrinks the traditional boost converter without compromising flexibility and efficiency. The device itself takes care of typically challenging boost converter design issues such as output disconnect, inrush current limiting, and short circuit protection. The LTC3459's wide input voltage range makes it compatible with many different battery sources, and its output voltage can be programmed to satisfy the requirements of a wide variety of applications.

LTC3403 and LTC3408, continued from page 32

then iteratively attempt to turn on at about 2/3 of its normal current limit. The buck regulator will not change its current limit, but will lower its oscillator frequency to avoid inductor current runaway.

All Ceramic Capacitor, 2.5W, Dynamically Controlled Power Converter for WCDMA Power Amplifiers

Figure 1 shows a WCDMA transmitter power supply that is capable of providing output voltages from 0.3V to V_{IN} at up to 600mA of output current.

Efficiency for the circuit is as high as 99% when operated in bypass mode, and above 90% for much of its useful range. The input and output capacitors are ceramic, which are desirable because of their small size, low cost, and low ESR. Many switching regulators are unstable using ceramic capacitors because they rely on the ESR of tantalum capacitors. But the LTC3403 and LTC3408 feature internal compensation specifically designed to work with ceramic capacitors, eliminating the cost, complexity, and circuit board space associated with external compensation networks. Even with small ceramic input and output capacitors, the LTC3403 and LTC3408 maintain stable output voltage with minimal voltage ripple.

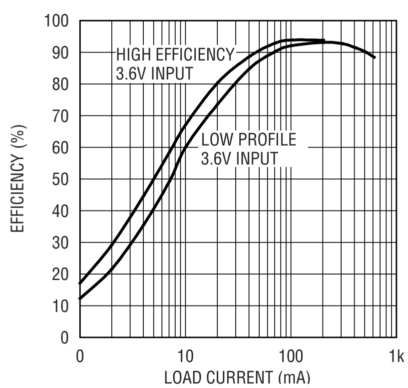

Figure 3. Efficiencies of the circuit shown in Figure 1 and the low profile version

Low Profile Alternative

Figure 2 shows the same circuit, next to a version modified to include components with a maximum height of 1.1mm[1]. The inductor is shielded, but occupies a larger footprint. Switching losses in the inductor cause nearly a 10% drop in efficiency at low currents (Figure 3). At higher currents, DC resistance predominates, allowing the low profile inductor to match the efficiency of the unshielded inductor.

Conclusion

The LTC3403 and the LTC3408 are high performance monolithic, synchronous step-down DC/DC converters well suited for applications requiring up to 600mA of output current while dynamically adjusting output voltage from 0.3V–3.5V to prolong battery life. Their internal low $R_{DS(ON)}$ power switches and bypass switches, their high switching frequency, and the small number of ancillary components allow these regulators to offer compact, high efficiency power supply solutions for WCDMA power amplifiers.

Notes

[1] L = Sumida CDRH2D11 2.2µH
C_{IN} = 2× TDK C1608X5ROJ475M
C_{OUT} = TDK C1608X5ROJ475M