1.5MHz Monolithic Synchronous Step-Down Regulator Brings High Efficiency to WCDMA Cellular Telephone Applications

by Theo Phillips

Introduction

To extend talk time and save battery power, new 3rd generation WCDMA cellular telephones are expected to adjust their power levels to the requirements of each transmission. The highest power levels are reserved for data transmission far from the base station; the lowest for voice transmission near the station. Power amplifiers in these phones require a DC power supply which can slew quickly from one voltage to another. To perform this function, the LTC3403 and LTC3408 provide DC/DC conversion from single lithium-ion cell voltages down to a dynamically adjustable 0.3V–3.5V, which can be easily modulated with an external DAC.

These monolithic, synchronous step-down regulators are offered in a tiny, low profile 8-lead (3mm square, 0.8mm high) plastic DFN package. Their 1.5MHz switching frequency allows the use of tiny inductors and capacitors. With power switches located on-chip, the minimal number of required external components permits an entire regulator to occupy less than $8mm^2$ of board space. The power switches' low 0.4Ω of on-resistance increases efficiency when delivering as much as 600mA of current; efficiency as high as 96% can be achieved in buck mode. Further efficiency gains are possible in bypass mode where V_{OUT} connects directly to V_{IN} through the internal bypass P-Channel MOSFET, which has an on-state resistance of 0.08Ω for the LTC3408 and 0.20Ω for the LTC3403. The LTC3403 includes a gate driver for controlling an external bypass MOSFET, providing even higher efficiency in this mode.

The regulators employ a constant frequency, current mode architecture. In forced continuous mode, they switch at 1.5MHz, permitting the use of low inductor values. Because smaller case sizes are usually offered for lower inductor values, the overall solution size is reduced. Minimal output voltage ripple is generated, since output voltage ripple is inversely proportional to the high switching frequency. Below output voltages of 0.6V, the frequency decreases linearly to 700KHz, allowing the output to reach 0.3V. In practice, the output ripple voltage is just 10mV–15mV throughout the range of output voltages.

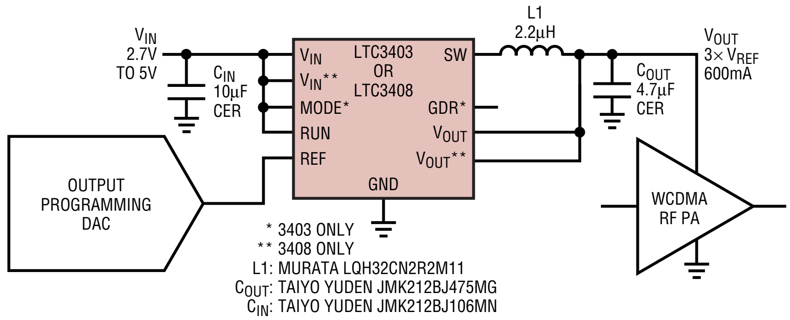

Figure 1. WCDMA transmitter power supply

The LTC3403 can be configured for either Burst Mode® operation or forced continuous mode. Burst Mode operation provides high efficiency and extends battery life by reducing gate charge loss at light loads. Forced continuous mode is not as efficient at light loads but it offers lower output voltage ripple in noise-sensitive applications. With no load, the LTC3403 consumes as little as 20µA in Burst Mode; both the LTC3403 and the LTC3408 draw less than 1µA in shutdown.

Because the LTC3408 uses only an internal bypass PFET and runs only in forced continuous mode, two extra terminals are available to halve the I^2R losses associated with the V_{IN} and V_{OUT} bonding wires leading to this PFET. With all power switches contained within the device, current comparators are available to provide short-circuit protection to the main and bypass PFETs. In the presence of a short from V_{OUT} to ground, the bypass PFET will immediately turn off,

continued on page 35

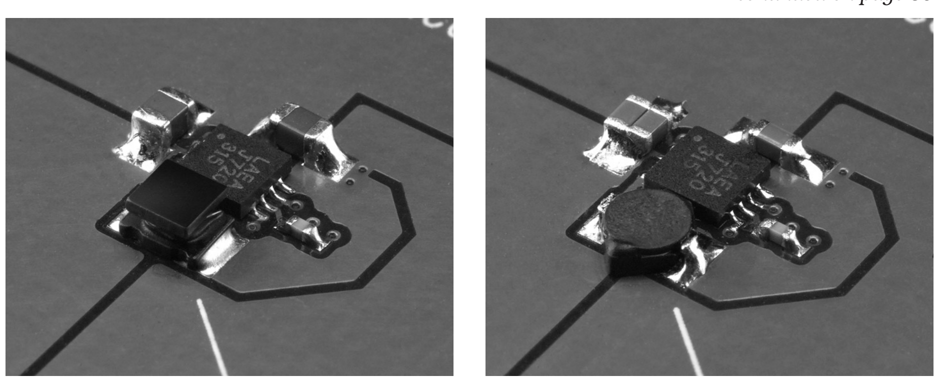

Figure 2. The circuit in Figure 1 (left) and an equivalent low profile version (right), which uses components with a maximum height of 1.1mm

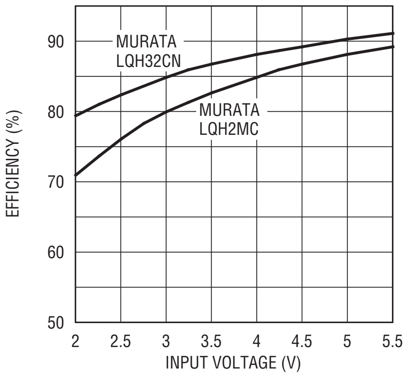

Figure 4. OLED efficiency comparison for two inductor types with a 7V, 50mW load

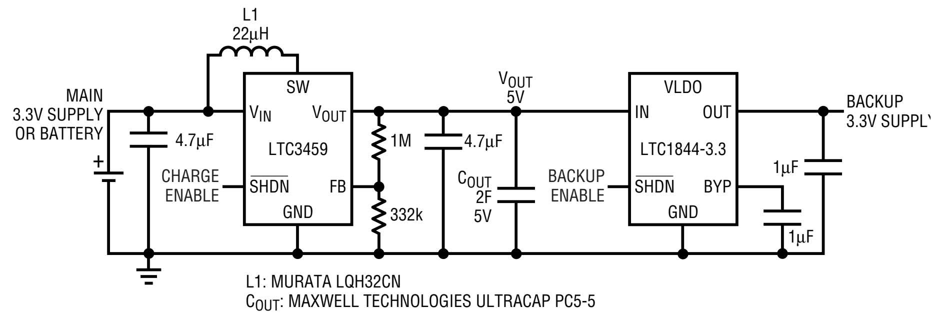

Figure 5. SuperCap-based backup supply using the LTC3459 and LTC1844

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

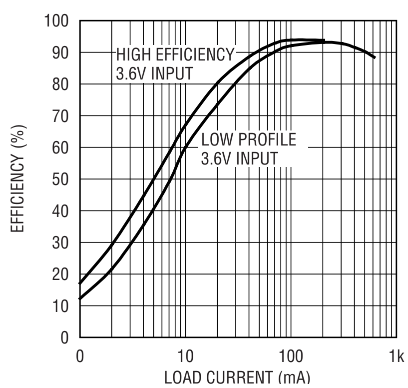

Figure 3. Efficiencies of the circuit shown in Figure 1 and the low profile version

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.

Low Profile Alternative

Figure 2 shows the same circuit, next to a version modified to include components with a maximum height of 1.1 mm[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