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3MHz Synchronous Boost Regulators Save Critical Board Space in Portable Applications

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Introduction

The proliferation of portable devices with ever increasing functionality has imposed a higher demand on power conversion circuitry, with a continued emphasis on maximizing battery life while reducing board real estate. Linear Technology's new LTC3401 and LTC3402 synchronous boost converters operate at high frequency, facilitating the use of a small low cost inductor and tiny ceramic capacitors. Both the LTC3401 and LTC3402 come in a thermally enhanced MSOP-10 package, with the lead frame of the IC connected to ground (pin 5).

With the converter housed in a small MSOP-10 package, the area of a complete 300mW converter is less than 0.08in^2, with a low 1.2mm profile. For a 2W converter, the board area is less than 0.18in^2. Efficiencies of up to 97% are achieved through internal features such as lossless current sensing, low gate charge, low $R_{DS(ON)}$ synchronous power switches and fast switching transitions to minimize power loss. An external Schottky diode is not required, but may be used to maximize efficiency.

The LTC3401 is optimized for applications requiring less than 1 amp of input current, whereas the LTC3402 is optimized for applications requiring up to 2 amps of input current. The operating frequency is programmable from 100kHz to 3MHz, which allows these products to fit nicely in various applications where size and efficiency considerations can be traded off. The ICs start up with an input voltage below 1V and, once started, operate with an input below 0.5V. Proper operation below 0.5V protects against worst-case voltage droops in the battery during high current load transients. The output voltage is adjustable from 2.6V to 5.5V with a simple resistor voltage divider.

The current mode control architecture, along with OPTI-LOOP™ compensation and adaptive slope compensation, allows the transient response to be optimized over a wide range of loads, input voltages, and output capacitors. At light loads, the user can choose to enter high efficiency Burst Mode™ operation. The IC consumes only 38µA of quiescent current in this mode. The part can also be commanded to shut down, drawing less than 1µA of quiescent current.

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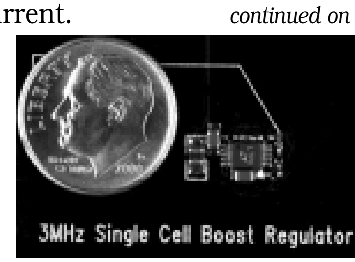

Figure 1. LTC3401, 3MHz single cell to 3V evaluation circuit

LTC3401/02, continued from page 1

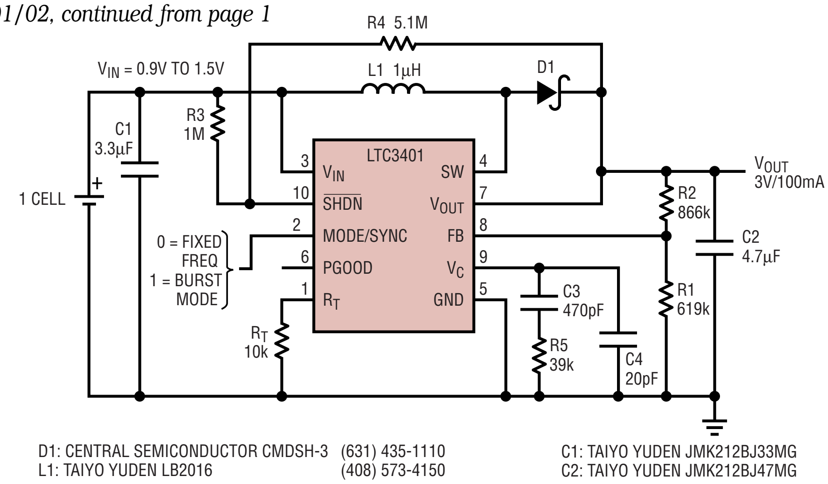

Figure 2. 1.2mm high, ultracompact single cell to 3V converter

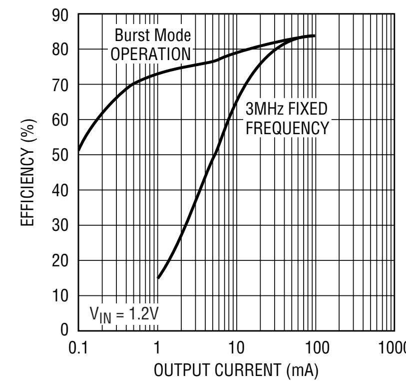

Figure 3. Efficiency of the circuit in Figure 2

1V to 3V, 300mW Converter in less than 0.08 in^2

In applications where the physical size is the most critical design factor, the high switching frequency of the LTC3401 allows the use of small ceramic capacitors and a tiny chip inductor, as shown in the evaluation circuit photo in Figure 1. The circuit schematic is shown in Figure 2. This compact, 1.2mm high converter switches at a fixed frequency of 3MHz and can step up a single-cell alkaline battery to 3V with an output load up to 100mA. The efficiency peaks at 83% at 100mA output current, as shown in Figure 3, with the efficiency loss being primarily due to the series resistance of the chip inductor and the ICs switching losses. Using an inductor with lower series resistance, reducing the operating frequency and increasing the size of the filter capacitor result in efficiencies over 90% for this application, although the improved efficiency comes at the expense of added board area.

The Burst Mode efficiency of the converter of Figure 2 is 70% at 500µA load, making it ideal for applications such as pagers, which power down for extended periods of time.

The switching waveform of the SW pin at 3MHz is shown in Figure 4. The fast rise and fall times of less than 5ns along with short break-before-make times between the synchronous switches of 20ns contribute to the high efficiency of the converter.

High Efficiency 1.6W, 2 Cell to 3.3V Converter

Many 2-cell applications require higher output power, but efficiency considerations are as important as board area. The circuit of Figure 5 operates at 1MHz and uses a 0.16in diameter Sumida power inductor along with all ceramic capacitors. The efficiency is 95% at 300mW output power, as shown in Figure 6. Removing the Schottky diode will reduce board area by approximately 5%, but at the cost of 4% less efficiency.

The LTC3402 for Higher Power Applications

The LTC3402 is ideal for applications requiring higher power, such as a 4W Li-Ion to 5V converter shown in Figure 7. To minimize conduction losses at these higher currents, it is imperative to choose low ESR power components. Inductor saturation at high current is also a factor in the selection process. The efficiency of the circuit in Figure 7, with the Li-Ion battery at the nominal 3.6V, peaks at 94%, as shown in Figure 8.

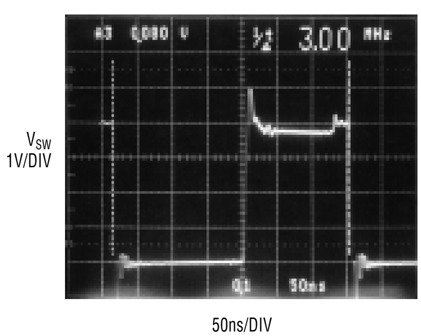

Figure 4. 3MHz switching waveform on the SW pin

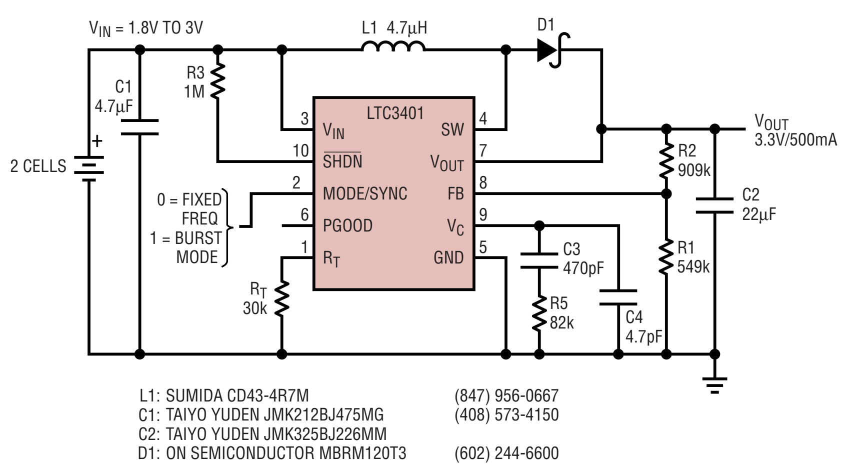

Figure 5. All-ceramic-capacitor 2-cell converter delivers 3.3V at 500mA

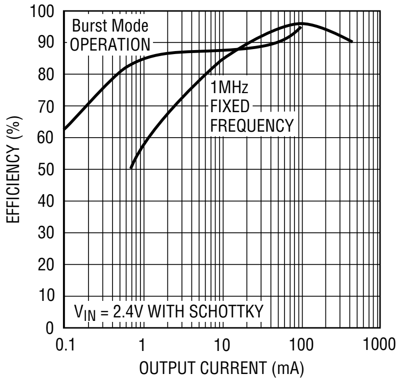

Figure 6. Efficiency of the circuit in Figure 5

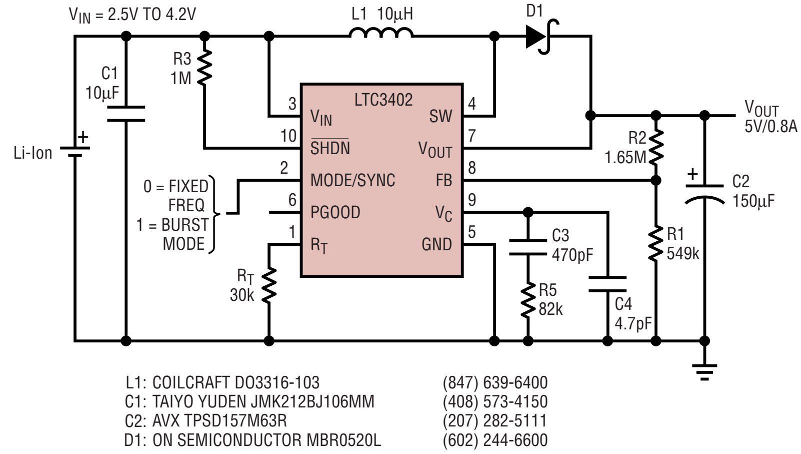

Figure 7. Single Li-Ion cell to 5V application at 800mA

High Efficiency Li-Ion CCFL Backlight Application

Small portable applications with a CCFL backlight, such as a PDA, require a highly efficient backlight converter solution to maximize operating time before recharging. A high efficiency Li-Ion CCFL supply is shown in Figure 9. The LTC3401 provides the tail current to the self-oscillating resonant Royer circuit, which generates the high voltage sinusoidal wave to the lamp. The lamp dimming is provided by means of a control voltage, but alternate dimming techniques can be used.

Flexible Boost Converters

Today's portable electronics environment requires power conversion that is adaptable to varying conditions. The LTC3401 and LTC3402 allow the user to modify output voltage, operating frequency, Burst Mode operation and loop compensation with simple modifications to external components.

The IC remains in fixed frequency mode until the user allows the IC to enter Burst Mode operation. When the MODE/SYNC pin is driven high, full-time power saving Burst Mode operation is enabled. In Burst Mode operation, the converter delivers energy to the output until the regulation voltage is reached. At that point the IC ceases to switch and goes to "sleep" until the output voltage has drooped to typically 1% of the regulated value. The IC then wakes up and delivers energy again and the cycle repeats itself. The efficiency at light loads is improved in Burst Mode operation due to the dramatic reduction in switching and quiescent current losses.

The MODE/SYNC pin serves an additional function of oscillator synchronization. The internal oscillator can be synchronized to an external clock at a higher frequency than the free-running frequency, with

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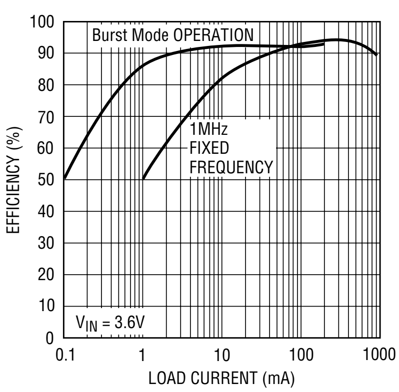

Figure 8. Efficiency of the circuit in Figure 7

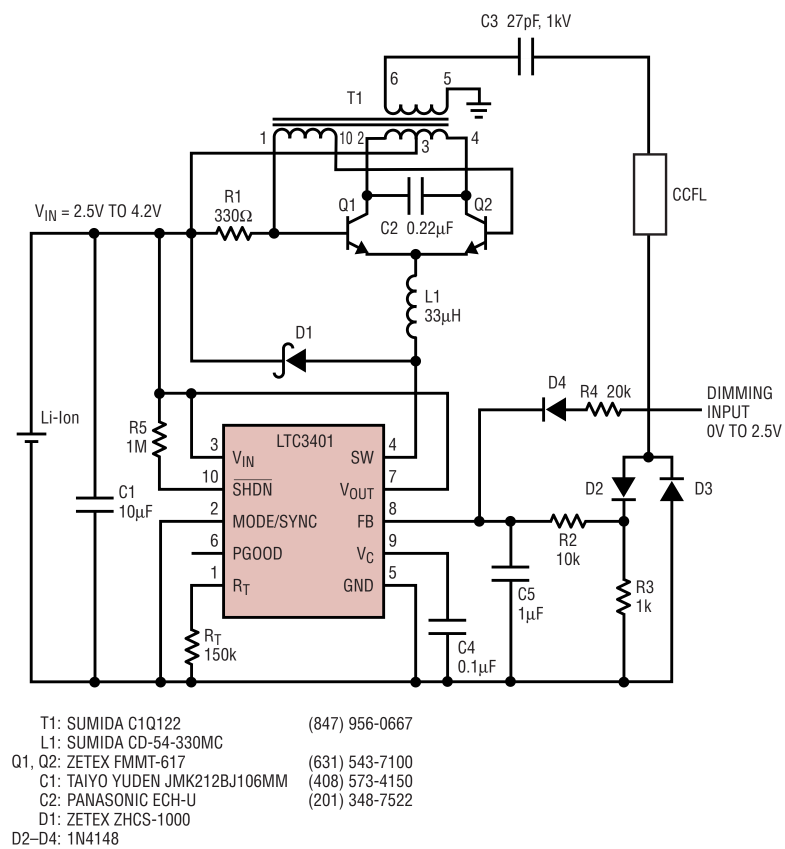

Figure 9. High efficiency, compact CCFL supply with remote dimming

LTC3401/02, continued from page 4

a pulse width of less than 2µs. The state of the Mode condition remains unchanged because of internal filtering. For applications requiring a flag to indicate the condition of the output voltage, the PGOOD pin provides an open drain output, which pulls low when the output voltage is more than 9% below the regulation voltage.

Conclusion

With Linear Technology's family of high performance synchronous boost converters, the designer of handheld electronics can easily extend operation time while saving critical board real estate. The high frequency operation of the LTC3401 and LTC3402 allows the use of all ceramic capacitors and a small inductor. The low voltage start-up makes these products ideal for single-cell alkaline portable applications, and the ability to program the operating frequency, output voltage, loop compensation and Burst Mode operation allows the designer to make the necessary decisions to optimize the power conversion for the given portable application. Low R_{ON} (0.16Ω NMOS, 0.18Ω PMOS) synchronous switches optimize efficiencies for all applications. All of this functionality is packed into a small MSOP-10 package.