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

**by Mark Jordan**

**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 0.08in², with a low 1.2mm profile. For a 2W converter, the board area is less than 0.18in². 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.

Figure 1. LTC3401, 3MHz single cell to 3V evaluation circuit
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1V to 3V, 300mW Converter in less than 0.08 in²

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 500mA 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 2. 1.2mm high, ultracompact single cell to 3V converter

Figure 3. Efficiency of the circuit in Figure 2

Figure 4. 3MHz switching waveform on the SW pin

Figure 5. All-ceramic-capacitor 2-cell converter delivers 3.3V at 500mA
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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 continued on page 8

**Figure 6. Efficiency of the circuit in Figure 5**

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

**Figure 8. Efficiency of the circuit in Figure 7**

**Figure 9. High efficiency, compact CCFL supply with remote dimming**
high, in which case the recovery time will rise and the output pulse width will increase. The higher capacitance BPV22NF shows this effect more than does the SFH213. This circuit is not suited to pulse width modulation schemes unless physical transmitter motion will be below the frequency of interest and the steady-state pulse width is noncritical.

### Convert Your Favorite Op Amp to a Rail-to-Rail Output

Many of the world’s greatest op amps were not originally intended for operation on reduced supply voltages, the ultralow noise LT1028 being a good example. The LT1797 can help remedy this situation by converting the output stage of one of these amplifiers to a rail-to-rail output stage. Figure 8 shows the method. The LT1028 output drives the noninverting input of the LT1797, which is placed in a gain of three by R1 and R2. The feedback resistors R3 and R4 put the entire loop in a gain of 500, forcing the LT1028 to provide a gain of 167. This combination of the two amplifiers takes advantage of the ultralow noise, precision front end of the LT1028 and the rail-to-rail output of the LT1797. The circuit is stable from a gain-phase point of view without compensation components R5 and C1. However, when the input receives a transient or the output hits a rail, the two op amps begin a usually unrecoverable slew-rate contest. R5 and C1 fix this by slowing down the LT1028.

### Conclusion

The LT1797 is a compelling choice where minimal footprint or rail-to-rail 10MHz gain bandwidth are essential. The efficient nature of the LT1797 design also makes it suitable for applications where power is at a premium and wide bandwidth and output drive are also required.

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**Notes:**

1. To cut to the chase, results will be given with sixteen feet of transmitter-receiver separation.
2. Some of the photodiodes tested had more capacitance than this, and some had less. Although it is tempting to place a trimpot at R1, the parasitic capacitance of a bulky trimpot would quickly complicate the matter.
3. Cascading the two 100kHz –3dB bandwidths results in a net bandwidth of 65kHz. However, the –3dB that is due to the photodiode capacitance and R1 will be more or less dependent on the photodiode used, and this will have an effect on the net bandwidth.
4. The bandwidth is chosen at about 80kHz because the low capacitance photodiode will not reduce the 100kHz bandwidth as much as would the design value of 16pF. For additional complexity, the bandwidth reduction due to input capacitance has effect on current noise and Johnson noise but not voltage noise. Also, the fact that measurements are made over a finite period of time introduces an inherent highpass characteristic. The skirt factor is next to impossible to determine because of the complexity of the various roll-off mechanisms. The value of 1.3 is a compromise.
5. Taking 100 measurements using a 50μs window, the average peak-to-peak noise was 7.7mVp-p with a standard deviation of 1.2mVp-p. Note that a 50μs window has a highpass effect above 15kHz.

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