

# No Space? No Problem for these Tiny, Inductorless, Efficient, Low Noise, 1.8V and 1.5V, Step-Down DC/DC Converters

by Bill Walter

## 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. The new LTC1911 Step-Down DC/DC converter helps designers make extremely small conversion circuits while maintaining the high efficiencies needed to extend battery life. The LTC1911 saves space by operating at high frequency, allowing the use of tiny low cost ceramic capacitors—no inductors required. The LTC1911 also comes in a low profile (1.1mm) MSOP-8 package. Figure 1 shows just how small the conversion circuit can be—a complete converter takes less than 0.08in<sup>2</sup> of board space. Its small size and efficiency make it well suited for single cell Li-Ion as well as 3-cell NiMH/NiCd battery powered applications.

The LTC1911-1.8 and LTC1911-1.5 are switched capacitor step-down DC/DC converters that provide 250mA of output current at 1.8V and 1.5V, respectively, with a tolerance of  $\pm 4\%$ , from a single 2.7V to 5.5V supply. To achieve high efficiency over the entire input range, the LTC1911 uses three possible switched capacitor fractional conversion modes: 2-to-1, 3-to-2 or 1-to-1 step-down mode. Internal circuitry selects the step-down conversion mode to optimize efficiency and ensure output regulation as the input supply voltage and output load conditions vary. A single input and output capacitor, as well as two external flying capacitors are all that is needed to operate in all three modes. The typical LTC1911 efficiency is over 25% higher than that of a linear regulator.

The LTC1911 also has a Burst Mode function that delivers a minimum amount of charge for one cycle then goes into a low current state until the output drops enough to require another burst of charge. Burst Mode<sup>®</sup> operation allows the LTC1911 to achieve high efficiency even at light loads. An output current sense circuit is used to detect when the required output current drops below about 30mA. When this occurs, the oscillator shuts down and the part goes into a low current operating state. The LTC1911 will remain in the low current operating state until the output has dropped enough to require another burst of current.

In the case of traditional charge pumps the amount of current delivered during a burst cycle is a function of many factors such as supply voltage, switch strength and capacitor selection. For this reason the output ripple voltage of a traditional charge pump can vary widely under light loads and it is not uncommon to have a couple hundred millivolts of output ripple under worst case conditions. In contrast, the amount of current delivered during the burst cycle of the LTC1911 is a function of burst thresh-

old, which is essentially constant over all conditions. Therefore the peak-to-peak output ripple voltage of the LTC1911 will also remain essentially constant, and is only about 5mV<sub>P-P</sub> for a 10 $\mu$ F output capacitor.

## Low Noise

The LTC1911's constant frequency architecture (patent pending) not only provides a low noise regulated output, but also has lower input noise than conventional switched capacitor charge pump regulators. Regulation is achieved by sensing the output voltage and regulating the amount of charge transferred per cycle. This method of regulation provides much lower input and output ripple than that of conventional switched capacitor charge pumps. Charge transfer in the LTC1911 is at a constant, high frequency making it easy to filter input and output noise. Conventional switched capacitor charge pumps, like those used in most other regulators with burst operation, are much more difficult to filter because they operate over a range of frequencies that covers several orders of magnitude. Figure 2 shows the ripple voltage of the LTC1911 output for all 3 switching

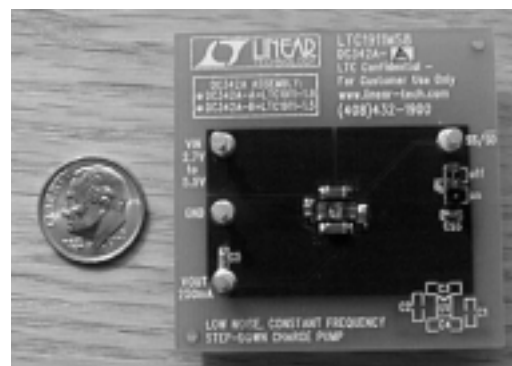
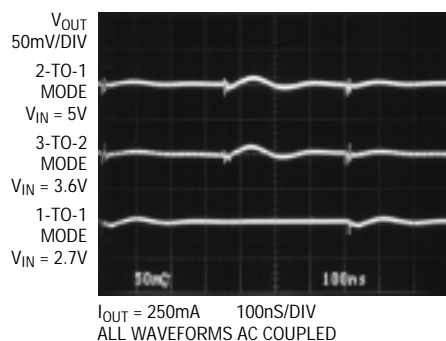
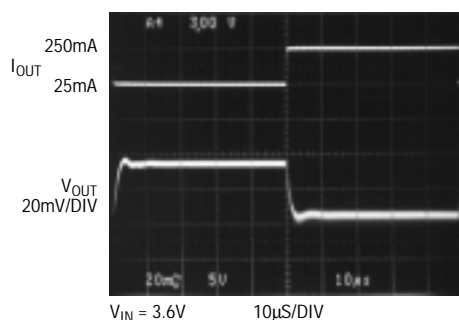


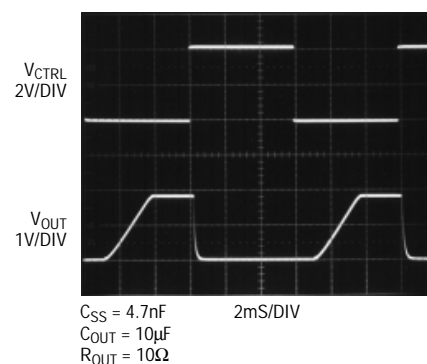
Figure 1: Space is no problem for this complete DC/DC converter.



**Figure 2. Output voltage ripple**



**Figure 3. Output current transient response**



**Figure 4. Soft-start operation**

modes of operation with a 250mA output load.

## Fast Transient Response

In addition to low output noise, the LTC1911 provides exceptional transient recovery. Figure 3 shows the LTC1911 recovery from a fast (<1μs) near full-scale (25mA to 250mA) load transient. The LTC1911 recovers in only 5μs, with very little overshoot, or undershoot.

## Short-Circuit and Thermal Protection

The LTC1911 has built-in short-circuit current limiting as well as over temperature protection. During a short-circuit condition the part automatically limits the output current to approximately 600mA. The LTC1911 shuts down and stops all charge transfer when the IC temperature exceeds approximately 160°C. Under normal operating conditions, the part should not go into thermal shutdown but the function is included to protect the IC in cases of excessively high ambient temperatures, or in cases of excessive power dissipation inside the IC (i.e., overcurrent or short circuit). The charge transfer will reactivate once the junction temperature drops back

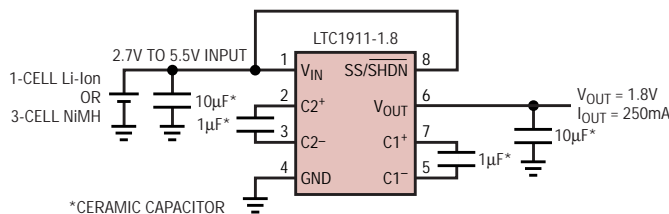
to approximately 150°C. The LTC1911 can cycle in and out of thermal shutdown indefinitely without latch-up or damage until the fault condition is removed. To keep the LTC1911 running cool, the IC is housed in a thermally enhanced MSOP-8 package, with the lead frame of the IC connected to ground (pin 4).

## Soft-Start and Shutdown Operation

The SS/SHDN pin is used to implement both low current shutdown and soft-start. Forcing a voltage lower than 0.6V on the SS/SHDN pin will put the LTC1911 into shutdown mode. Shutdown mode disables all control circuitry and forces the output into a high impedance state. A 2μA pull-up current on the SS/SHDN pin will force the part into active mode if the pin is left floating or is driven with an open-drain output that is in a high impedance state. If the pin is not driven with an open-drain device or floating, it must be forced to a logic high voltage of 2.2V (min) to ensure proper output regulation.

A known issue with conventional charge pumps is that the initial inrush of current required to charge the output capacitor to regulation can

cause undesirable transients on the input supply during power on. The soft-start feature limits inrush currents required to charge the output capacitor, thereby minimizing input supply transients caused by the power on phase of the IC. To implement soft-start, a capacitor is connected to the SS/SHDN pin. An open-drain device can also be connected from the SS/SHDN pin to GND to implement shutdown. Once the open-drain device is turned off, the 2μA pull-up current will begin charging the external soft-start capacitor and force the voltage on the pin to ramp towards  $V_{IN}$ . As soon as the shutdown threshold is reached (0.6V typical), the internal reference voltage that controls the output regulation point will follow the ramp voltage on the SS/SHDN pin until the reference reaches its final band gap voltage. This occurs when the voltage on the SS/SHDN pin reaches approximately 1.9V. Since the ramp rate on the SS/SHDN pin controls the ramp rate on the output, the average inrush current can be controlled through the selection of soft-start capacitor ( $C_{SS}$ ) and the output capacitor. For example, a 4.7nF capacitor on SS/SHDN results in a 3ms ramp time from 0.6V to 1.9V on the pin. If the output capacitor is 10μF, the 3ms output ramp time results in an average output capacitor current of only 6mA which translates directly into 6mA of input current. Figure 4 shows a scope photo of the output ramping up following an open drain device going into high impedance.



**Figure 5. Single cell Li-Ion to 1.8V DC/DC converter**

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