LINEAR TECHNOLOGY

DESIGN NOTES

# Step-Down Charge Pumps Are Tiny, Efficient and Very Low Noise – Design Note 310

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## Introduction

Inductorless charge pump DC/DC converters are popular in space-constrained applications with 10mA to 500mA load currents. Such converters are available in small packages, operate with very low quiescent current and require minimal external components. However, the downside for most charge pumps is noise. Noise that is generated at the power input can interfere with RF transmission and reception in wireless applications, and noise at the output can couple into sensitive circuits or even create audible noise. The new LTC®3250 and LTC3251 step-down charge pumps solve this problem with a new switching architecture that mitigates noise without sacrificing any of the space saving, high efficiency benefits typical of charge pump converters.

The LTC3250-1.5 is optimized for applications that require up to 250mA of current from a fixed 1.5V output, and where space is at an absolute premium. The LTC3251 provides more flexibility in a slightly larger footprint: it features an adjustable output voltage (0.9V to 1.6V), up to 500mA output, ultralow input and output noise and spread spectrum operation. Both ICs use 2-to-1 switched capacitor fractional conversion to improve efficiency by 50% over a linear regulator. Both parts require only 35µA of operating current.

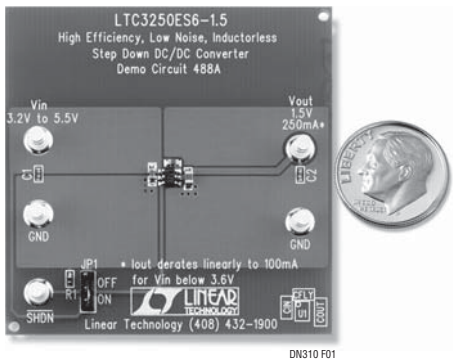


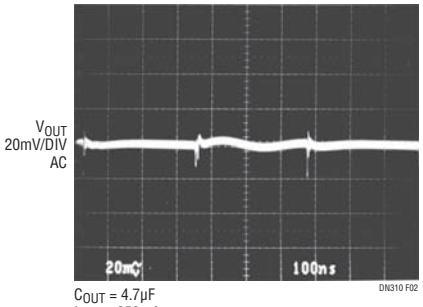

**Figure 1. The LTC3250 Is Available in a Tiny 6-Pin ThinSOT Package Making it Possible to Fit a Complete Converter in Less Than 0.04in²**

## Efficient Low Noise Fixed 1.5V Output Charge Pump with Ultrasmall Footprint

The LTC3250-1.5 switched capacitor step-down DC/DC converter squeezes into the tightest spaces while providing 1.5V at 250mA from a single 3.1V to 5.5V supply. To keep the converter footprint small, the LTC3250 operates at high frequency (1.5MHz) making it possible to use only three tiny low cost ceramic capacitors for operation. The LTC3250 is available in a 6-pin ThinSOT™ package making it possible to build a complete converter in an area of less than 0.04in² (see Figure 1).

The LTC3250's constant frequency architecture achieves regulation by sensing the output voltage and regulating the amount of charge transferred per cycle. This method of regulation provides much lower input and output voltage ripple than that of conventional switched capacitor charge pumps that regularly have 50mV or more of ripple. The constant, high frequency charge transfer of the LTC3250 makes filtering input and output noise less demanding than traditional switched capacitor charge pumps where switching frequencies depend on load current and can range over several orders of magnitude. Figure 2 shows the low output ripple for the LTC3250-1.5 with a 250mA load.






$C_{OUT}$ = 4.7µF
$I_{OUT}$ = 250mA
$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.5V

**Figure 2. Output Voltage Ripple**

## Ultralow Noise Adjustable Charge Pump with Spread Spectrum Operation

Switching regulators are commonly used to provide power conversion inside handheld devices such as cellular phones and PDAs. Such devices, particularly those which provide RF communication, tend to be very sensitive to noise and electromagnetic interference (EMI). Switching regulators operate on a cycle-by-cycle basis to transfer power to an output. For conventional step-down regulators, the first half cycle the input is supplying current to the output and charging the storage element (either capacitor or inductor), and the other half cycle the output current is supplied via the storage element from ground, and no current is supplied via the input. This rectangular wave of current at the input can cause a large ripple voltage with harmonics extending to very high frequencies (see Figure 3). Since the operating frequency of conventional step-down regulators is either fixed or variable, the output will still have a large component of noise at the frequency of operation and some harmonics (see Figure 4).

The LTC3251 significantly reduces input noise through the use of a dual phase spread spectrum charge pump. The dual phase architecture works by supplying current on both clock phases, thus drawing a constant input current that is half the output current. Additionally, with spread spectrum operation the internal oscillator of the LTC3251 produces a clock pulse whose period is random on a cycle-by-cycle basis, but fixed between 1MHz and 1.6MHz. This has the benefit of spreading the switching noise over a range of frequencies, thus significantly reducing harmonic noise. This architecture achieves extremely low output and input noise. Figure 5 shows the virtual elimination of input harmonics using only a tenth of the input capacitance of a conventional step-down regulator, and Figure 6 shows the significant reduction in peak output noise using only half of the output capacitance.

### Versatility

The LTC3251 has four modes of operation which are selected by the mode pins MD0 and MD1. The modes are: Continuous Spread Spectrum for low noise at all operating currents; Burst Mode® operation for high efficiency at light loads; Super Burst™ mode for ultralow operating current at very light loads (9µA typical at no load); and shutdown.

### Conclusion

The LTC3251 is available in a 10-pin thermally enhanced MSOP package; the LTC3250 is available in a tiny ThinSOT package. Their small size, relatively high current outputs, and low noise make them ideally suited for space-constrained battery-powered applications.

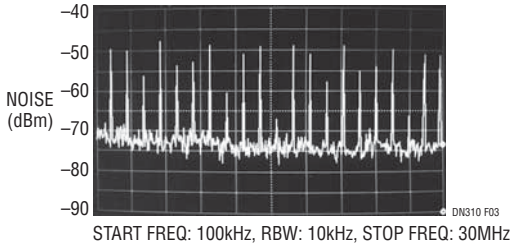



**Figure 3. Conventional Step-Down Regulator Input Noise Spectrum with 10µF Input Capacitor ($I_O$ = 500mA)**

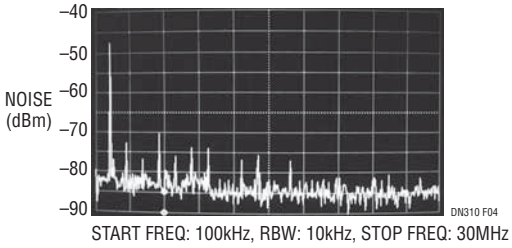



**Figure 4. Conventional Step-Down Regulator Output Noise Spectrum with 22µF Output Capacitor ($I_O$ = 500mA)**

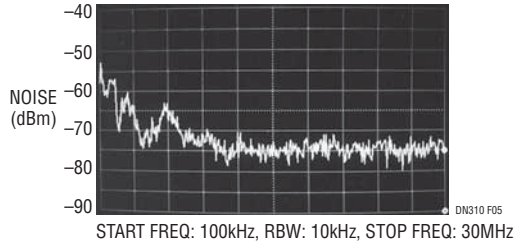



**Figure 5. LTC3251 Input Noise Spectrum with 1µF Input Capacitor ($I_O$ = 500mA)**

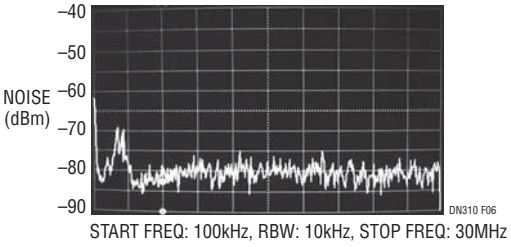



**Figure 6. LTC3251 Output Noise Spectrum with 10µF Output Capacitor ($I_O$ = 500mA)**

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