Internal 2A, 42V Switch, Adjustable 2.5MHz Operating Frequency and 3mm × 3mm Package Allow Boost Regulator to Fit Numerous Applications

by Mathew Wich

Introduction

The world of switching DC/DC converters is awash with a dizzying array of product offerings. For a given application, much of the power supply design effort can be spent simply searching for the optimum combination of package size, switching frequency, input and output voltage range, and desirable features. In many cases, though, the LT3580 offers an optimal solution. It is the right choice for many diverse applications because of its smart combination of features, performance and ease of use.

The LT3580 is a current control switching regulator available in

The LT3580 supports a variety of converter configurations including boost, inverting, flyback, and SEPIC. Inputs can be from 2.5V–32V, and an integrated 2A, 42V NPN power switch allows the LT3580 to provide efficient power from a fraction of a watt up to more than several watts.

tiny 8-lead packages (MSOP and 3mm × 3mm DFN). Operating from 200kHz–2.5MHz, it supports numerous configurations including boost, inverting, flyback and SEPIC. Inputs can be from 2.5V–32V, and an integrated 2A, 42V NPN power switch allows the LT3580 to provide efficient power from a fraction of a watt up to more than several watts.

Be Picky—Choose the Ideal Clock Frequency up to 2.5MHz

Choosing a converter switching frequency is often a compromise between several performance parameters such as physical size, output ripple, efficiency and spectral noise issues. While most converter ICs operate at a single fixed frequency, the LT3580 operates at any frequency from 200kHz–2.5MHz allowing you to choose the ideal frequency for any application.

The high frequency capability (up to 2.5MHz) of the LT3580 helps to reduce the overall size of the converter by permitting the use of smaller inductors and output capacitors. Small inductors, with correspondingly small inductances, work best at higher frequencies because they store and release less energy in each switching cycle. This can be seen by looking at the energy storage relationship for an inductor,

$$E = \frac{1}{2}LI^2 ,$$

which shows that for a given peak inductor current (I), the stored energy is proportional to the inductance (L). Thus smaller inductances, storing less *energy* per cycle, switch at

C1: 2.2µF, 25V, X5R, 1206
C2: 10µF, 25V, X5R, 1206
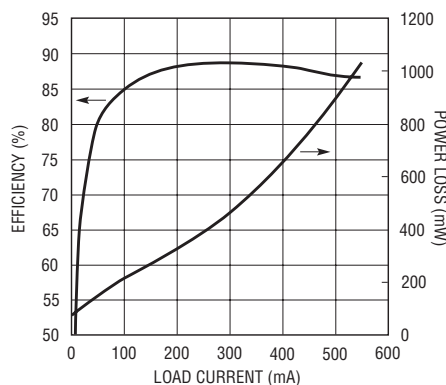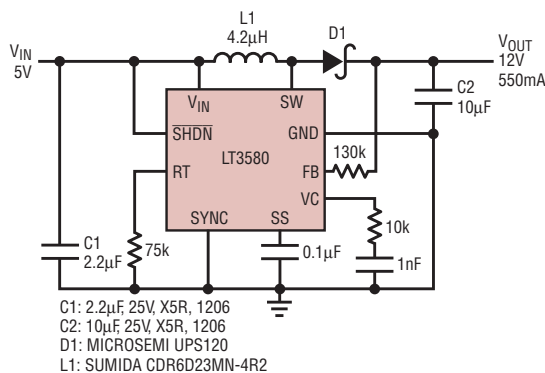D1: MICROSEMI UPS120
L1: SUMIDA CDR6D23MN-4R2

Figure 1. This 1.2MHz, 5V to 12V boost converter achieves over 88% efficiency.
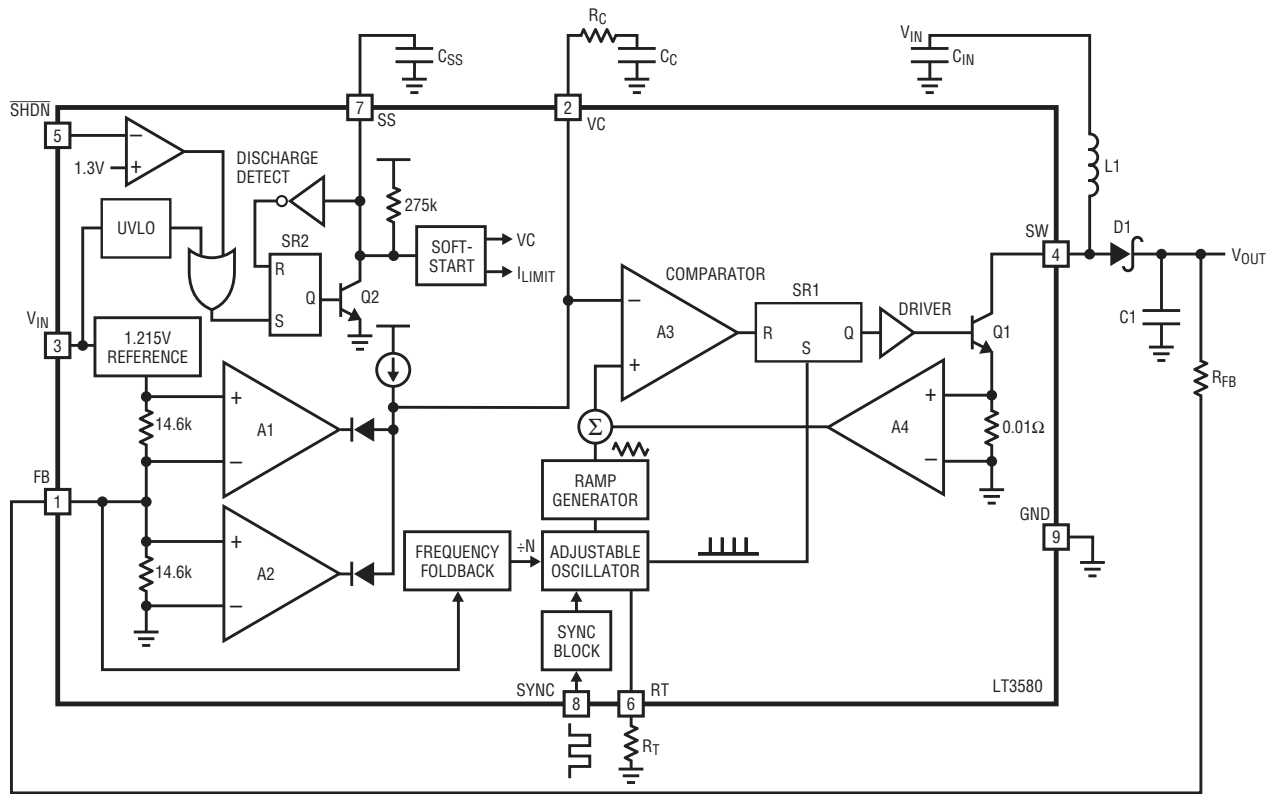
Figure 2. Block diagram of the LT3580 in a boost converter configuration

higher frequencies to deliver the same *power* as larger inductances. Also, smaller inductances reach their peak current (or energy) faster than large inductances as seen by rearranging the relationship

$$V = L\frac{di}{dt} \Rightarrow L\frac{\Delta I}{\Delta T}$$

and solving for ΔT.

$$\Delta T = \frac{L \cdot \Delta I}{V}$$

This shows that, for a given inductor voltage (V), a smaller inductor (L) will ramp to its peak current (I) in less

time (T) than a larger inductance, again leading to higher frequency operation to make best use of the inductor.

Depending on the load requirements, high frequency operation also facilitates smaller output capacitors. Since charge is delivered to the output in smaller but more frequent packets, the voltage ripple is reduced for a given capacitance.

Figure 3 shows an example of reduced solution size at a higher switching frequency. The 5V to 12V boost converter operates at 2.5MHz and uses a smaller inductor and less output capacitance than the 1.2MHz

solution in Figure 1. The tradeoff is slightly reduced efficiency due to the increased switching losses incurred at the higher switching frequency.
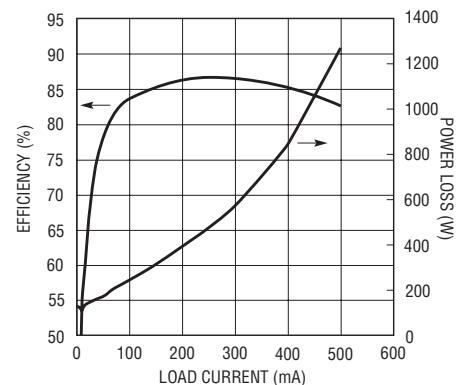
For large voltage gains, the LT3580's low frequency capability (down to 200kHz) is very useful. Figure 5 shows a direct conversion from 5V to 40V running at 750kHz. Figure 6 shows a 5V to 350V flyback converter running at 200kHz.
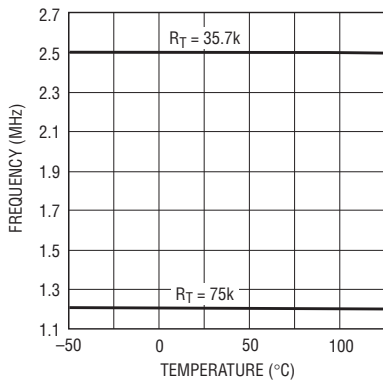
Finally, the LT3580's wide frequency range makes it easy to avoid sensitive frequency bands that can't tolerate spectral noise. For example radio power supplies may operate
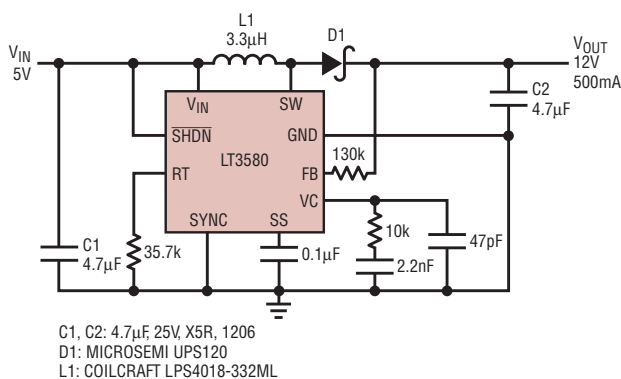
Figure 3. The high 2.5MHz switching frequency of this 5V to 12V boost converter allows the use of a tiny 4mm × 4mm × 1.7mm inductor.

Figure 4. Typical internal oscillator frequency at $V_{IN} = 5V$

C1, C2: 2.2µF, 25V, X5R, 1206
D1: MICROSEMI UPS140
L1: SUMIDA CDRH105R-470

Figure 5. A 750kHz, 5V to 40V, 150mA boost converter

at 2MHz or above to avoid the AM broadcast band. Also, some RF communications products are sensitive to noise at 455kHz, therefore switching above 600kHz is desired.
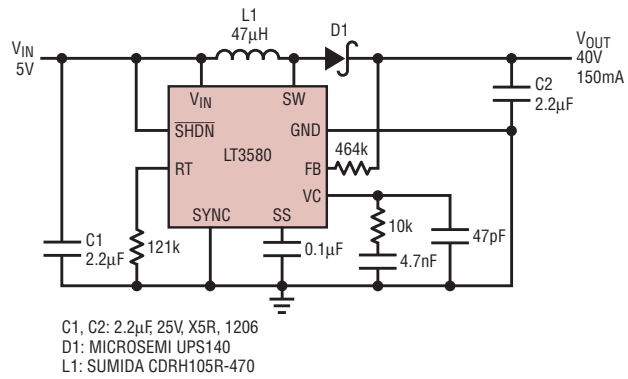
Accurate Clocking Options

The LT3580 provides two options for generating the clock. First, the integrated oscillator can be accurately set between 200kHz–2.5MHz by connecting a single resistor from the R_T pin to ground, where

$$R_T(k\Omega) = \frac{91.9}{f_{OSC}(MHz)} - 1$$

The boost converter in Figure 3, for example, uses a 35.7k R_T resistor to set the switching frequency to 2.5MHz. The internal oscillator's frequency is accurate to ±10% with little temperature variation as shown in Figure 4. The excellent frequency tolerance maximizes system performance by reducing necessary design margin.

The switching frequency can also be synchronized to an external clock source. The SYNC pin overrides the internal oscillator when toggled at frequencies greater than 75% of the internal oscillator's set frequency. Simply connect a digital clock signal to the SYNC pin using V_{IH} levels from 1.3V to 5.5V, V_{IL} levels below 0.4V and any frequency between 200kHz and 2.5MHz. Using an external clock source is often helpful for several reasons, including...

❑ Synchronization of several switching regulators, often out of phase, to reduce switching current spikes

❑ Additional frequency precision yielding higher performance
❑ Precisely targeting the frequency out of sensitive bands for EMI benefits.

The LTC6908 resistor set oscillator is a nice choice for generating the SYNC clock due to its high precision, dual phase outputs, spread spectrum capabilities, small size and simple operation.

Single-Pin Feedback and Support for Multiple Configurations

The novel single-pin feedback of the LT3580 reduces external component count and allows it to be used in many different converter topologies. The output voltage is set by simply connecting a single external resistor from V_{OUT} to the FB pin. The FB pin automatically servos to the correct reference voltage for a given topology (1.215V for positive V_{OUT} and 5mV for negative V_{OUT}).
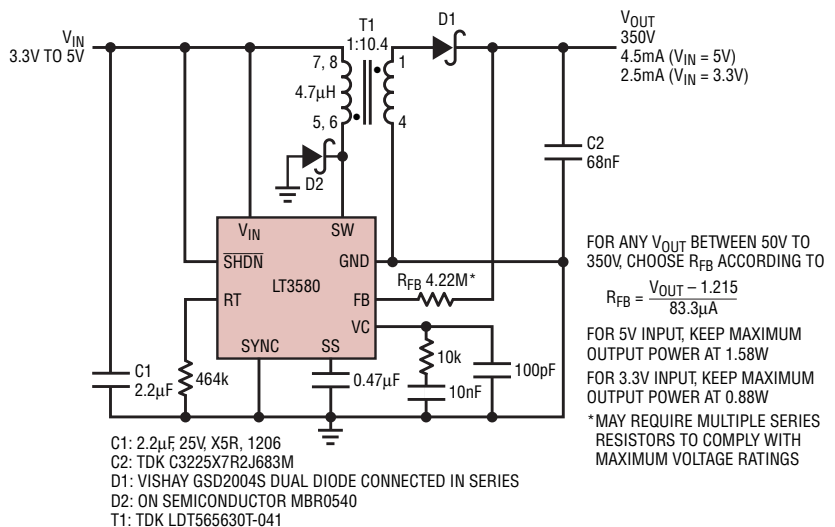
Supported configurations include boost, SEPIC (Figure 10), and other topologies such as the flyback (Figure 6) and inverting (Figure 7).

Finally, to improve V_{OUT} accuracy, the FB pin is factory trimmed to an accurate *current*, instead of trimming the *resistance*, which is typical of other parts. This eliminates multiplication of reference voltage errors to V_{OUT}.

Soft-Start Feature Limits Start-Up Current

The LT3580 contains a soft-start circuit to limit peak switch currents during start-up. High start-up current is inherent in switching regulators since the feedback loop is saturated

Danger High Voltage! Operation by High Voltage Trained Personnel Only

C1: 2.2µF, 25V, X5R, 1206
C2: TDK C3225X7R2J683M
D1: VISHAY GSD2004S DUAL DIODE CONNECTED IN SERIES
D2: ON SEMICONDUCTOR MBR0540
T1: TDK LDT565630T-041

FOR ANY V_{OUT} BETWEEN 50V TO 350V, CHOOSE R_{FB} ACCORDING TO

$$R_{FB} = \frac{V_{OUT} - 1.215}{83.3\mu A}$$

FOR 5V INPUT, KEEP MAXIMUM OUTPUT POWER AT 1.58W
FOR 3.3V INPUT, KEEP MAXIMUM OUTPUT POWER AT 0.88W
*MAY REQUIRE MULTIPLE SERIES RESISTORS TO COMPLY WITH MAXIMUM VOLTAGE RATINGS

Figure 6. This 350V power supply features a tiny 5.8mm × 5.8mm × 3mm transformer switching at 200kHz.

due to V_{OUT} being far from its final value. The regulator tries to charge the output capacitors as quickly as possible, which results in large peak currents.

The start-up current can be limited by connecting an external capacitor (typically 100nF to 1µF) to the SS pin. This capacitor is slowly charged to ~2.2V by an internal 275k resistor once the part is activated. SS voltages below ~1.1V reduce the internal current limit. Thus, the gradual ramping of SS also gradually increases the current limit as the capacitor charges. This, in turn, allows the V_{OUT} capacitor to charge gradually toward its final value while limiting the start-up current (see Figure 9).

Innovative $\overline{SHDN}$ Pin Resets Soft-Start and Serves as Undervoltage Lockout (UVLO)

The $\overline{SHDN}$ pin has threshold hysteresis to resist noise and tolerate slowly varying input voltages. Driving the $\overline{SHDN}$ pin to ground shuts down the LT3580 and reduces input current to less than 1µA. Driving $\overline{SHDN}$ above 1.38V enables the part and begins the soft-start sequence. A built in safety feature ensures that the SS capacitor is actively discharged before start-up begins. This allows for proper soft-start even in the event of short $\overline{SHDN}$ pulses or thermal lockout.

The LT3580 also features an integrated UVLO that shuts down the chip when the input voltage falls below ~2.3V. However, the $\overline{SHDN}$ pin can also be configured to disable the chip below even higher voltages as shown in Figure 8.

Typically, UVLO is needed in situations where the input supply is current-limited, has a relatively high source resistance, or ramps up/down slowly. A switching regulator draws constant power from the source, so source current increases as source voltage drops. This looks like a negative resistance load to the source and can cause the source to current-limit or latch low under low voltage conditions. The configurable UVLO prevents the regulator from operating at source
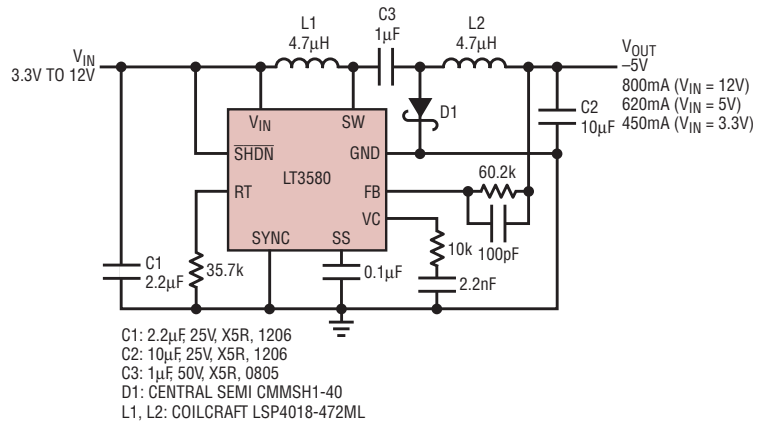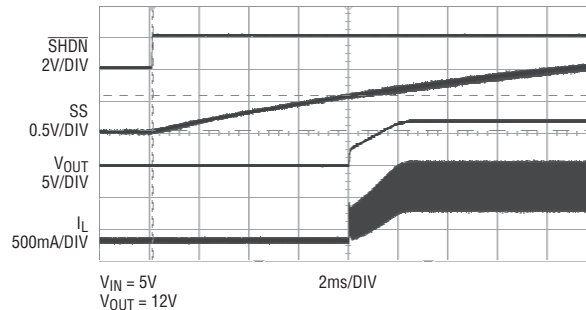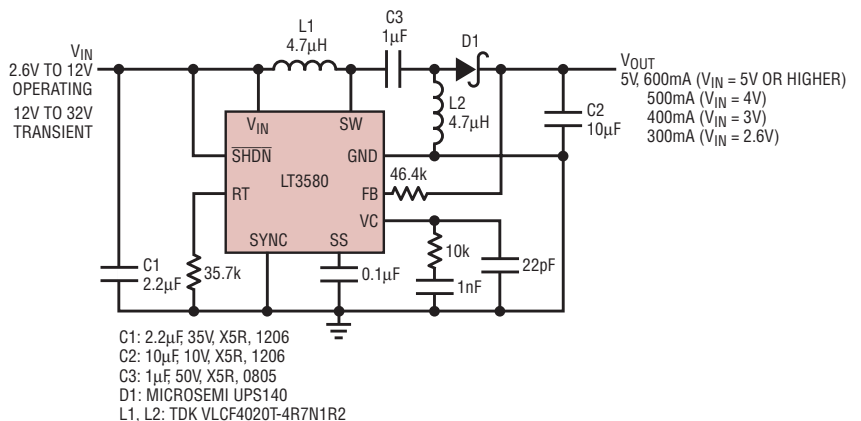
Figure 7. This –5V output inverting converter switches at 2.5MHz and accepts inputs between 3.3V and 12V
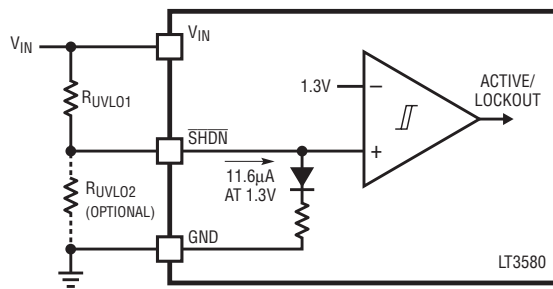
Figure 8. Configurable undervoltage lockout

Figure 9. Soft-start of a 5V to 12V boost topology

Figure 10. Wide input range SEPIC converter with 5V output switches at 2.5MHz

with the flexibility to program both the upper and lower battery temperature points that are considered safe for charging the battery. In this example, the NTC hot and cold trip points are set for approximately 55°C and 0°C, respectively.

One of the buck regulators is programmed for 3.3V at its output. When the BAT pin voltage approaches 3.3V, the buck regulator operates in dropout. An LED at the $\overline{CHRG}$ pin gives a visual indication of the battery charge status.

Figure 2 shows an actual circuit similar to that shown in Figure 1, illustrating how little board space is required to build a full featured LTC3559 application. Figure 3 shows how much more efficient Burst Mode operation is at light loads as compared to pulse skipping mode.

A basic sequencer function can be built for the buck regulator outputs by driving the enable pin on one buck
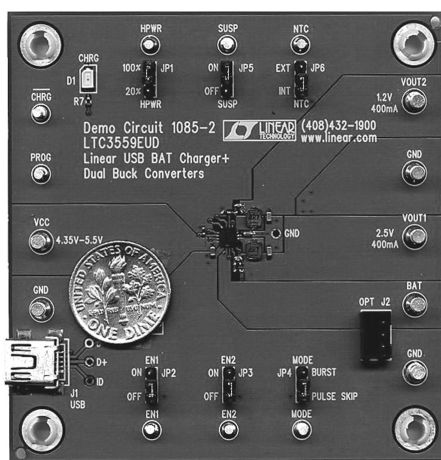

Figure 2. A USB battery charger and two buck regulators small enough to fit in the latest cell phones, PDAs and MP3 players

regulator with the output of the other buck regulator. For proper operation, the BAT and PV$_{IN}$ pins must be tied together. If a buck regulator is enabled while the battery is charging, the net current charging the battery will be lower than the actual programmed value.

Figure 4 helps to explain this scenario. The current being delivered at the BAT pin is 500mA. Both buck regulators are enabled. The sum of the average input currents being drawn by both buck regulators is 200mA. This makes the effective battery charging current only 300mA. If the HPWR pin were tied low, the BAT pin current would be only 100mA. With the buck regulator conditions unchanged, this would cause the battery to discharge at 100mA.

Conclusion

The LTC3559 is ideally suited for space-constrained applications that are powered from a single Li-Ion cell and that need multiple voltage supply rails. The high switching frequency allows the use of small low profile external inductors. The high efficiency buck regulators and Burst Mode operation combine to maximize battery life, extending battery operation time between charge cycles. *LT*
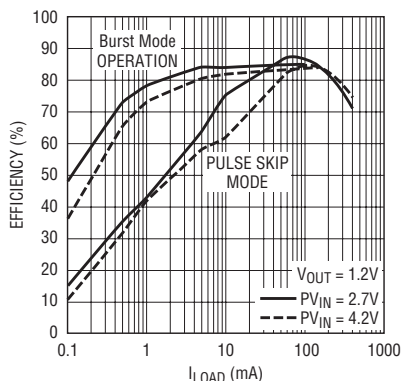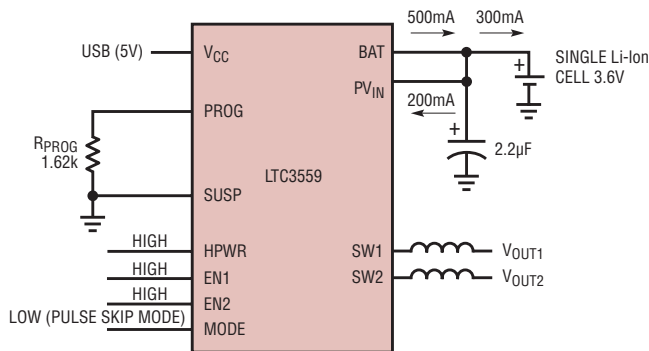

Figure 3. Buck regulator efficiency

Figure 4. The net current charging the battery depends on the operating mode of the buck regulators.

LT3580, continued from page 10
voltages where these problems might occur.

The shutdown pin comparator has voltage hysteresis with typical thresholds of 1.32V (rising) and 1.29V (falling). Resistor R$_{UVLO2}$ is optional but can be included to reduce overall UVLO voltage variation caused by variations in $\overline{SHDN}$ pin current. A good choice for R$_{UVLO2}$ is 10k ±1%. After choosing a value for R$_{UVLO2}$, R$_{UVLO1}$ can be determined from either of the following:

$$R_{UVLO1} = \frac{V_{IN}^+ - 1.32V}{\left(\dfrac{1.32V}{R_{UVLO2}}\right) + 11.6\mu A}$$

or

$$R_{UVLO1} = \frac{V_{IN}^- - 1.29V}{\left(\dfrac{1.29V}{R_{UVLO2}}\right) + 11.6\mu A}$$

where V$_{IN}$+ and V$_{IN}$- are the V$_{IN}$ voltages when rising or falling respectively.

Conclusion

The LT3580 is a smart choice for many DC/DC converter applications. It's packed with features without compromising performance or ease of use and is available in tiny 8-lead packages. The accurate and adjustable clock, 2A/42V power switch, wide input voltage range, integrated soft-start and a configurable $\overline{SHDN}$ pin make the LT3580 an ideal choice for many DC power supply needs. For additional information and a complete data sheet visit www.linear.com. *LT*