Space-Saving, Dual Output DC/DC Converter Yields Plus/Minus Voltage Outputs with (Optional) I²C Programming

by Mathew Wich

Introduction

There are many applications that require both positive and negative DC voltages generated from a single input supply. The LT3582 is a highly integrated dual switching regulator that produces positive and negative voltages for AMOLEDs, CCDs, op amps, and general ±5V and ±12V supplies. The LT3582 uses a novel control scheme resulting in low output voltage ripple and high conversion efficiency over a wide load current range. The total solution size is very small due to the tiny 3mm × 3mm 16-pin QFN package, integrated feedback resistors, integrated loop compensation networks and the single-inductor negative output topology (see Figure 1).

The LT3582-5 and LT3582-12 are factory configured for accurate ±5V and ±12V outputs respectively, making it easy to squeeze a high performance solution into a small space. For other voltage combinations, the LT3582 offers I²C digitally programmable outputs of 3.2V to 12.775V and –1.2V to –13.95V that can be made permanent with on-chip OTP (One-Time-Programming) memory. The input supply range is 2.55V to 5.5V and switch current limits are 350mA and 600mA for the boost and inverting switches, respectively. In addition, the LT3582 features power up sequencing with ramping from ground to regulation, power down discharging, positive output disconnect and soft-start.

Accurate Output Voltages without External Feedback Resistors

The LT3582 series uses integrated feedback resistors to select the output voltages. The LT3582-5 and LT3582-12 are pre-configured at the factory for ±5V and ±12V outputs with ±1.5% accuracy or better. The LT3582 allows other output voltages to be configured using the I²C interface. There are nine bits to configure the positive output voltage from 3.2V to 12.775V in 25mV steps and another eight bits to configure the negative output voltage from –1.2V to –13.95V in 50mV steps. Default settings can be stored

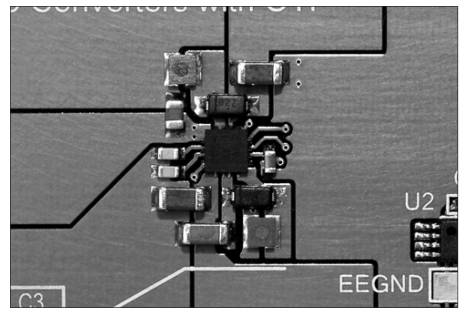
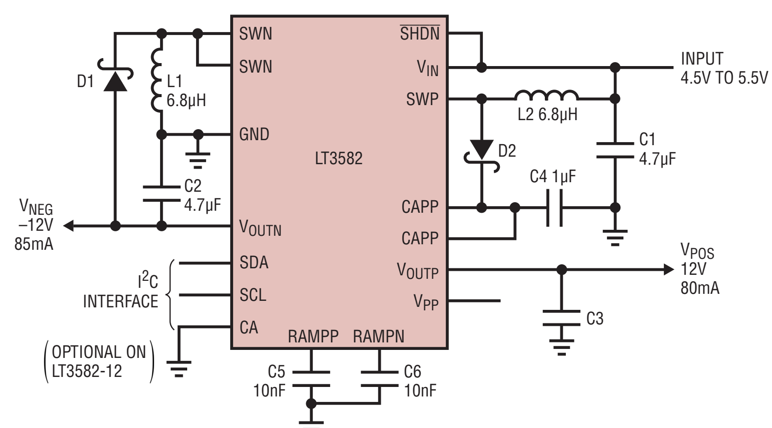


Figure 1. Dual output supplies in a small board footprint

in One-Time-Programmable memory and, if left unlocked, the voltages can be subsequently changed on the fly using the I²C interface.

Great Performance Includes Low Ripple and High Efficiency Across the Load Range

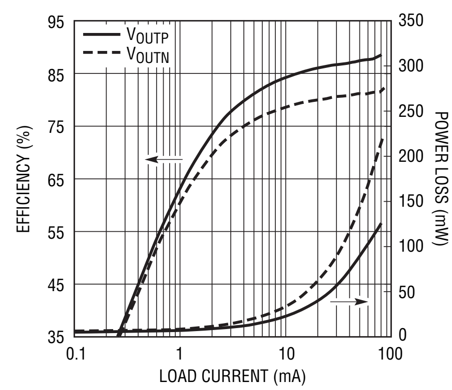
The LT3582 is among several novel parts from Linear Technology that modulate peak switch current and switch off time to reduce ripple and improve light load efficiency (also see the LT3494, LT3495, LT8410 and



REG0/OTP0 = B0h
REG1/OTP1 = D8h
REG2/OTP2 = 03h

D1-D2: DIODES INC. B0540WS-7
L1-L2: COILCRAFT XPL2010-682
C1: 4.7µF, 6.3V, X5R, 0805
C2: 4.7µF, 16V, X5R, 0805
C3: 1× 4.7µF OR 2× 4.7µF OR 10µF 16V, X5R, 0805
C4: 1µF, 16V, X5R, 0603
C5-C6: 10nF, 0603

Figure 2. ±12V supplies from a single 5V input



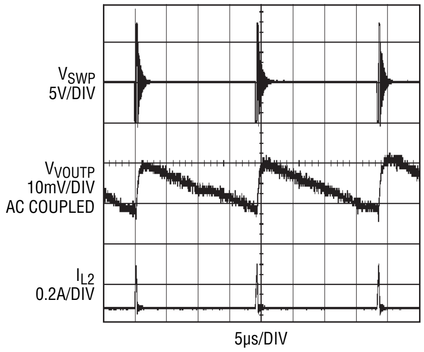


Figure 3. Switching waveforms at 1mA load for the boost application shown in Figure 2

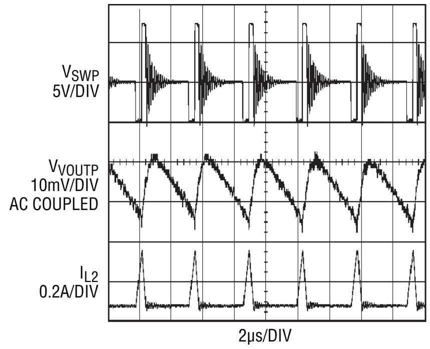


Figure 4. Switching waveforms at 10mA load for the boost application shown in Figure 2

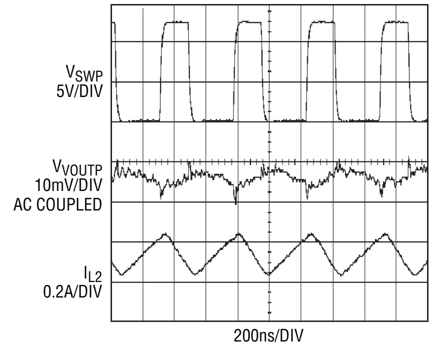


Figure 5. Switching waveforms at 100mA load for the boost application shown in Figure 2

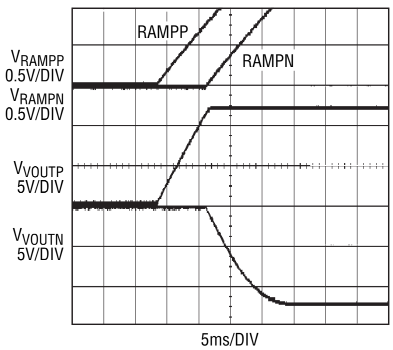


Figure 6. Power-Up Sequencing (V_{OUTP} followed by V_{OUTN})

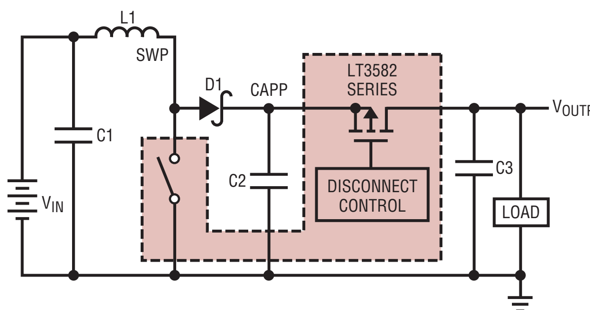


Figure 7. Output disconnect PMOS

LT8415). Under light load conditions, the LT3582 chooses an optimum combination of frequency and peak switch current to improve efficiency while moderating the output ripple. Figures 3–5 show how the frequency and peak inductor current vary from light to heavy loads. At very light loads (typically < 1mA), peak switching currents are dramatically reduced to further reduce ripple when frequencies are in the audio band.

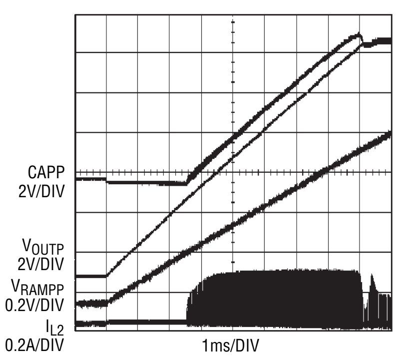


Figure 8. V_{OUTP} soft-start ramping from ground

Adjustable Power-Up Sequencing and Soft-Start Options

The LT3582 has digitally configurable power-up sequencing that forces the outputs to power up in one of four ways:

- ❑ V_{OUTP} ramps up first, followed by V_{OUTN} (shown in figure 6)
- ❑ V_{OUTN} ramps up first, followed by V_{OUTP}
- ❑ both outputs ramp up simultaneously
- ❑ both outputs are disabled

The LT3582-5 and LT3582-12 are factory configured for both outputs to ramp up simultaneously.

The power-up ramp rates of the output voltages are also adjustable. Slowly ramping the outputs (also known as soft-start) reduces what would otherwise be high peak switching currents during start-up. Without soft-start, high start-up current is inherent in switching regulators 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 output voltage ramp rates are proportional to the ramp rates of the RAMPP and RAMPN pin voltages. Upon chip enable, a programmable current (1μA, 2μA, 4μA or 8μA) linearly charges capacitors (typically about 10nF) connected to the RAMPP and RAMPN pins. By varying the capacitor sizes or charging currents, a wide range of output voltage ramp rates can be accommodated.

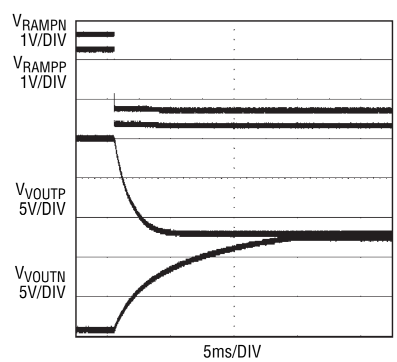


Figure 9. Power-down discharge waveforms

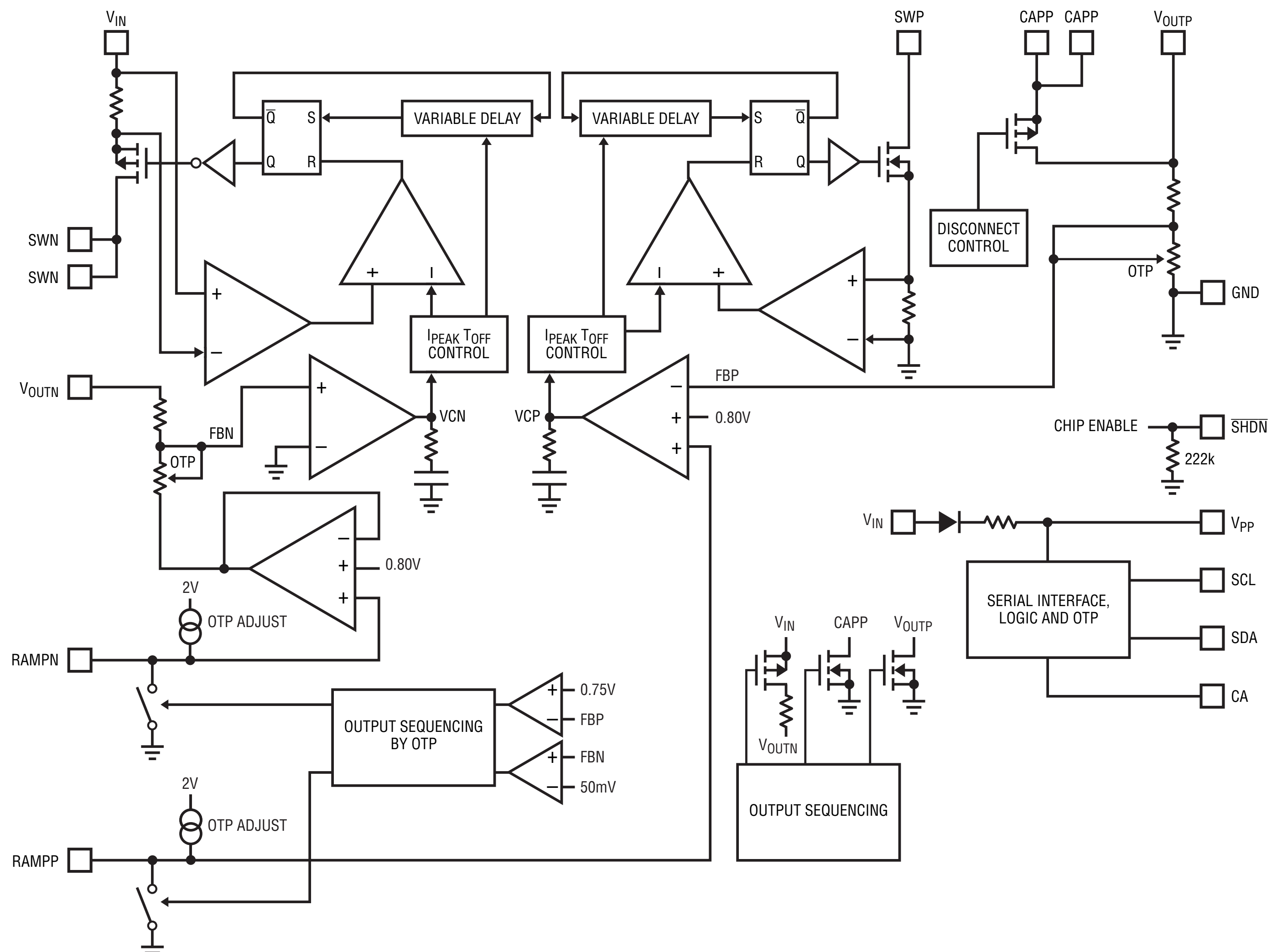


Figure 10. LT3582 block diagram

Output Disconnect and Improved Efficiency

The LT3582 series has a PMOS output disconnect switch connected between CAPP and V_{OUTP} (see Figure 7). During normal operation the switch is closed and current is limited to about 155mA to help protect against output shorts. During shutdown, the PMOS switch is open providing up to 5V–5.5V of isolation between CAPP and V_{OUTP}. In most cases this allows V_{OUTP} to discharge to ground.

In normal operation, the output disconnect switch represents ~1.4Ω of resistance in series with the output leading to a 1%–2% efficiency loss under heavy load conditions. The CAPP pin can be externally shorted to the V_{OUTP} pin to eliminate the power loss in the switch and improve efficiency.

Unique Ability to Ramp Output Up From Ground

Smart control of the output disconnect PMOS also gives the LT3582 the unique ability to generate a smooth V_{OUTP} voltage ramp starting from ground and continuing all the way up to regulation (see Figures 6 and 8). This ability is not possible with typical boost converters because the current path from V_{IN} through the inductor (L1) and Schottky diode (D1) to the output prevents it from starting at 0V (see Figure 7).

The disconnect control circuitry in the LT3582 allows V_{OUTP} to discharge to ground when disabled. Once enabled, the gate of the output disconnect PMOS is precisely controlled such that V_{OUTP} rises smoothly from ground up to regulation where the PMOS is fully turned on to reduce power losses.

Power Down Discharge Assist

The power down discharge feature assists in discharging the outputs after shutdown (see Figure 9). This option is factory enabled on the LT3582-5 and LT3582-12 and can be enabled through the I²C interface in conjunction with the “both together” power-up setting on the LT3582.

Upon $\overline{SHDN}$ falling and when power-down discharge is enabled, internal transistors activate to assist in discharging the outputs toward ground. After both outputs are within ~0.5V to ~1.5V of ground, the chip powers down.

Digital Control and One-Time Programming

The LT3582 series supports the Standard Mode I²C interface. Although using this interface is not required for the LT3582-5 or LT3582-12, it does permit reading of the chip's configuration and the ability to disable the power switches through the interface.

Additional I^2C functionality is available with the LT3582 including re-programmability of the output voltages, and setting the power up sequencing and power down discharge.

A default power-up configuration can be made permanent in the LT3582 through the One-Time-Programmable memory. The chip will always use the default configuration from OTP memory upon power-up. Unless locked by programming a specific OTP memory bit, the chip configuration can be changed after power-up by writing new settings through the I^2C interface.

Conclusion

The LT3582 is an easy-to-use compact solution for DC/DC converter applications where positive and negative outputs are required. It is accurate, efficient and includes an outsized number of features for its diminutive 3mm × 3mm 16-pin QFN package. It is offered in ±5V (LT3582-5), ±12V (LT3582-12) and I^2C-programmable (LT3582) output versions.

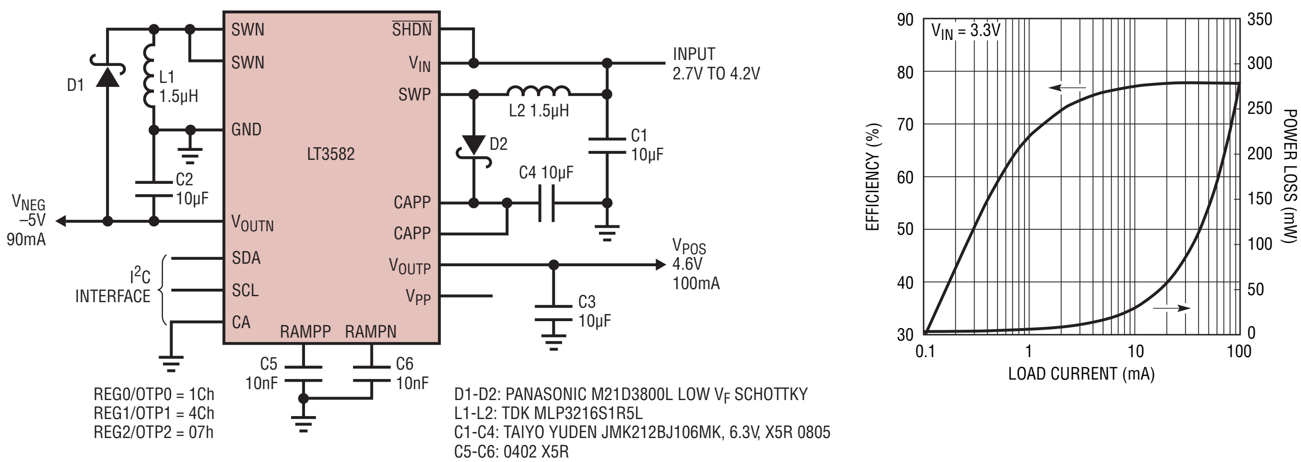


Figure 11. Tiny AMOLED power supply is 0.8mm (max) thin

LTC4217, continued from page 17

This example places a 20k resistor on the I_{MON} pin to set the gain of the current monitor output to 1V per amp of MOSFET current.

Instead of tying the TIMER pin to the $INTV_{CC}$ pin for a default 2ms overcurrent timeout, an external 0.47µF capacitor is used to set a 5.7ms timeout. During an overcurrent event the external timing capacitor is charged with a 100µA pull-up current. If the voltage on the capacitor reaches the 1.2V threshold, the MOSFET turns off. The equation for setting timing capacitor's value is as follows:

$$C_T = T_{CB} \bullet 0.083(\mu F/ms)$$

While the MOSFET is cooling off, the LTC4217 discharges the timing capacitor. When the capacitor voltage reaches 0.2V an internal 100ms timer is started. Following this cool down period the fault is cleared (when using auto-retry) and the MOSFET is allowed to turn on again.

It is important to consider the safe operating area of the MOSFET when extending the circuit breaker timeout beyond 2ms. The SOA graph for the MOSFET used in LTC4217 is shown in Figure 7. The worse case power dissipation occurs when the voltage versus current profile of the foldback current limit is at maximum. This occurs when the current is 1A and the voltage is one half of the 12V or 6V (see Figure 4, FB pin at 0.7V). In this case the power is 6W, which dictates a maximum time of 100ms (Figure 7, at 6V and 1A).

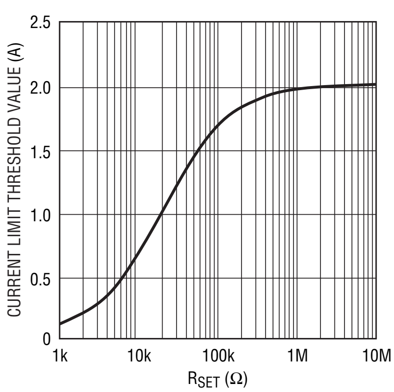


Figure 6. Current limit adjustment

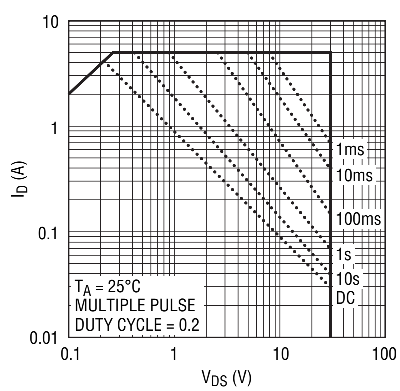


Figure 7. MOSFET SOA curve

Conclusion

The primary role of the LTC4217 is to control hot insertion and provide the electronic circuit breaker function. Additionally the part includes protection of the MOSFET with focus on SOA compliance, thermal protection and precise 2A current limit. It is also adaptable over a large range of applications due to adjustable inrush current, overcurrent fault timer and current limit threshold. A high level of integration makes the LTC4217 easy to use yet versatile.