LINEAR TECHNOLOGY

DESIGN NOTES

Switching Regulator Generates Both Positive and Negative Supply with a Single Inductor – Design Note 47

Brian Huffman

Many systems require ±12V from a 5V input. Analog or RS-232 driver power supplies are obvious candidates. This requirement is usually solved by using a switcher with a multiple-secondary transformer or multiple switchers. These solutions can be complicated, requiring either transformer design or two inductors. An alternative approach, shown in Figure 1, uses a single inductor and charge pump to obtain the dual outputs. This solution is particularly noteworthy because is uses off-the-shelf components.

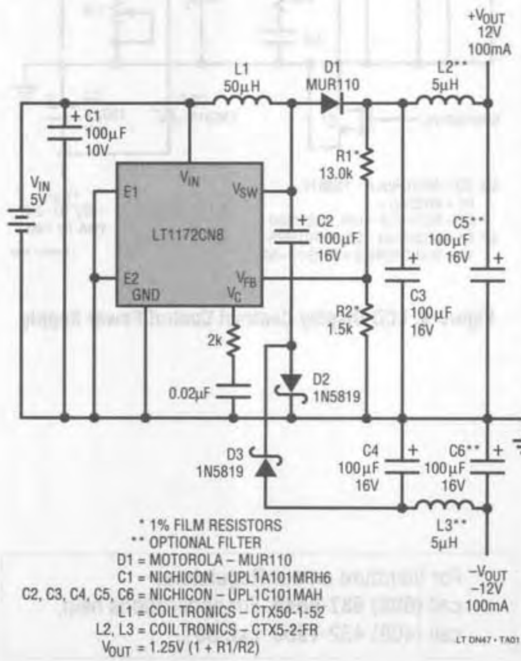

Figure 1. Inductor and Switch Capacitor Techniques Provide Bipolar Output

Figure 1 uses an LT1172 to generate both the positive and negative supply. The LT1172 is configured as a step-up converter to obtain the positive output. To generate the negative output a charge pump is used. The pump capacitor, C2, is charged up by the inductor when D2 is forward biased and discharges into C4 when the LT1172's power switch pulls the positive side of C2 to ground. The output capacitor provides current to the load during the charging cycle.

Figure 2 shows the regulator's operating waveforms. Since the LT1172 has a ground referred power switch, the inductor has the input voltage applied across it when the switch is on. Trace A is the V_{SW} pin voltage and trace B is its current. The inductor current, trace C, rises slowly as the magnetic field builds up. The current rate of change is determined by the voltage applied across the inductor and its inductance. During this interval, energy is being stored in the inductor and no power is transferred to the +12V output. When the switch is turned off, energy is no longer transferred to the inductor, which causes the magnetic field to collapse. The collapsing magnetic field induces a change in voltage across the inductor causing the V_{SW} pin to rise until output diode D1 forward biases.

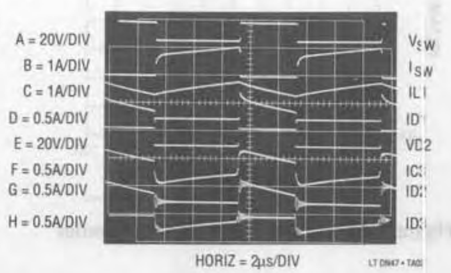

Figure 2. Switching Waveforms for ±12V Output Converter

output capacitor provides the load current. The LT1172's error amplifier compares the feedback pin voltage, from the 13kΩ–1.5kΩ divider, to its internal 1.24V reference and controls duty cycle. The output voltage can be varied by changing the R1–R2 divider ratio (see Equation 1). An RC network at the V_C pin provides loop compensation.

A charge pump is used to invert the +12V output to a –12V output. When the LT1172's power switch turns off, the voltage on C2's positive side rises until D1 is forward biased. The inductor charges C2 when the voltage on C2's negative side rises enough to forward bias D2. Trace F shows C2's current waveform, trace E is D2's voltage waveform and trace G is its current. The voltage across C2 will be equal to a diode drop above $+V_{OUT}$ minus a Schottky diode drop. When the LT1172's power transistor turns on, the positive side of C2 is pulled to ground. During this period diode D3 is forward biased (trace H is its current waveform), and C4 is charged by C2. An optional LC filter is added to each output to attenuated output voltage ripple. Efficiency for this circuit generally exceeds 70%.

Diode junction losses (D2 and D3) preclude ideal results, but performance is quite good. This circuit will convert $+V_{OUT}$ to $-V_{OUT}$ with losses as shown in Figure 3. Negative output load current should not exceed the positive output load by more than a factor of 5, otherwise the imbalance will cause the –12V transient response to suffer.

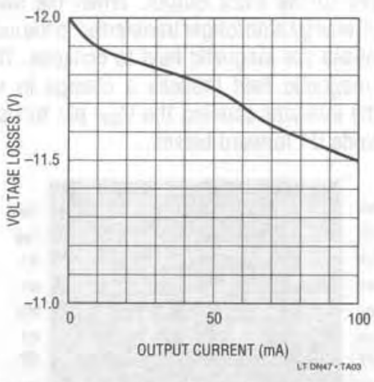

Figure 3. Losses for Charge Pump Converter

quickly reflected to the positive output. Resistor R3 adjusts output voltage between –12V to –21V.

The LT1172 provides an elegant solution to power shutdown problems by integrating a shutdown feature; eliminating the need to place a power MOSFET in series with the input voltage. When the voltage of the V_C pin is pulled below 150mV, the IC shuts down pulling only 150µA. This is implemented by turning on Q1, reducing the circuit's quiescent current from 6mA to 150µA.

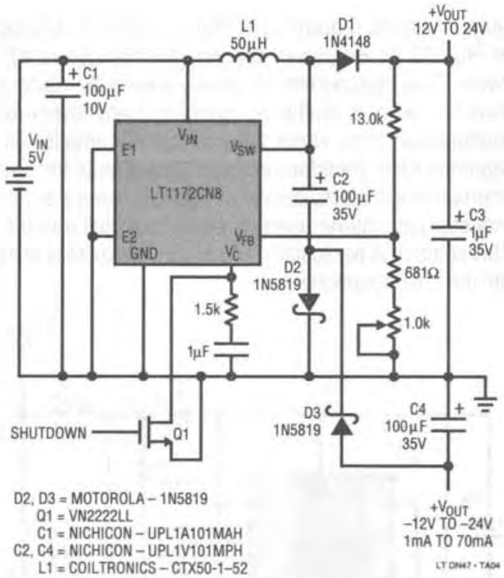

Figure 4. LCD Display Contrast Control Power Supply

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