LM5000

High-Voltage, Single-Chip DC/DC Regulator Optimized for Flyback, Boost, or Forward-Power Converter Applications

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Technology Edge

High-Voltage, Single-Chip DC/DC Regulator Optimized for Flyback, Boost, or Forward-Power Converter Applications

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Application Brief #126

Telecom and industrial applications such as local area networks (LAN), telephone interfaces (SLICs), ISDN, and xDSL terminals often require low-power multi-output, non-isolated power supplies operating from an unregulated 12-36V bus.

A flyback converter is the preferred solution because of its simplicity, size, low cost, and low parts count. National Semiconductor’s newest high-voltage, single-chip, DC/DC regulator (LM5000) is a monolithic integrated circuit designed for flyback, boost, or forward-power converter applications. Integrating a complete current-mode PWM controller and a high-voltage power switch (80V @ 2A), this highly efficient, low-cost regulator operates from an unregulated DC voltage source.

Consider the typical example shown in Fig. 1 of a converter delivering a 3.3V, 2A output from an unregulated 28V bus, which varies from 20V to 55V.

During the ON-time of the internal power switch, a fixed voltage is applied across the primary winding of the power transformer and the current ramps linearly at the rate of dI/dT = (VIN)/Lp, where Lp is the primary magnetizing inductance. Energy stored in the magnetic circuit (core and gap) is given by E = 0.5 * Lp * Ip 2 . When the power switch turns OFF, the current in the primary inductance forces a reversal of polarities on all windings, and energy stored in the magnetic circuit is given by the secondary winding. The peak secondary current is equal to Is(peak) = Ip(peak) * N, where N is the turns ratio between the primary and secondary (Np/Ns).

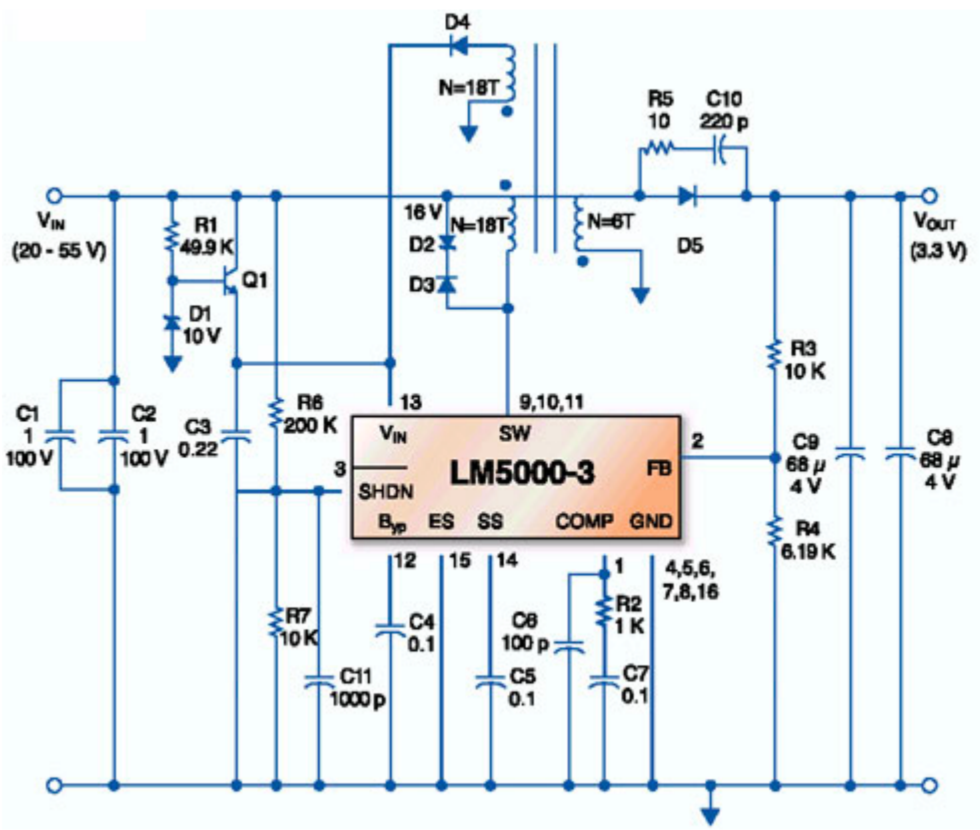

Figure 1. LM5000 Flyback Converter

The power delivered to the output is: P = E/T = [(VIN * TON)2]/2 * T * Lp where T is the period of the LM5000 oscillator. The feedback loop adjusts the volt * second product as required to maintain a constant output voltage.

Current-mode control circuitry is integrated in the LM5000 regulator giving it tight regulation of output voltage, cycle-by-cycle current limiting and good rejection of input line transients. Pulse-width-modulation (PWM) of the duty cycle and ON-time of the power transistor corrects for input line voltage variation and variations in the primary switch current. The output does not vary with line or load in this type of converter where the error signal is compared with the sawtooth waveform represent-ing the primary inductor current. This comparison affects feedforward of the input voltage and feedback of the output voltage in one stage. The power switch is turned ON, allowing the current to ramp in the primary until the instantaneous ramp voltage equals the error voltage, at which point it switches OFF and dis-charges the energy stored in the magnetic circuit to the output. This current-mode control scheme is preferred over voltage-mode control because it provides superior bandwidth and line-transient rejection as well as overload protection to prevent electrical and thermal overstress.

The LM5000 can operate at four different selectable switching frequencies: 300 kHz/700 kHz (LM5000-3) and 600 kHz/1.25 MHz (LM5000-6). These four switching frequency options allow the system to be “tuned” to a preferred operating frequency to optimize efficiency or eliminate interference with other sensitive circuitry. Higher switching frequencies can reduce the size of output capacitance and the inductance of the primary and secondary windings, which reduces the total volume of the trans-former and the cost of the power supply. However, higher switching frequencies increase transformer core losses and total AC switching losses. A frequency of 300 kHz may be selected to keep core and switching losses of the flyback converter to a minimum.

Flyback converters can operate in both discontinuous and continuous modes. In the discontinuous mode, all of the energy stored in the magnetic circuit during the ON-time is delivered to the secondary and the load before the next cycle. In the continuous mode of operation, some energy is stored in the core at the beginning of the next cycle.

In the typical LM5000 application of Fig. 1, a continuous mode of operation with maximum duty cycle of 33% was used to reduce the peak AC output current, thereby reducing the output voltage ripple. A 3:1 turns ratio between primary and secondary windings limits the maximum stress voltage below the breakdown voltage of the integrated 80V FET: VSWoff = [VIN max + (VOUT+VDIODE)]* Npri/Nsec.

To reduce voltage spikes at the leading edge of the voltage waveform across the FET caused by transformer leakage inductance and output rectifier recovery time, a transient voltage suppressor (clamp) in series with a diode is inserted across the transformer primary.

Particular attention must to be paid to the principle magnetic component, the power transformer, to achieve maximum performance in a high switching frequency design. Flyback transformers are coupled inductors rather than power transformers. Other topologies store minimal energy in the magnetic circuit and transfer energy through transformer action during the ON-time of the power transistor. Conversely, flyback converters store energy during the ON-time and deliver it to the secondary during the OFF-time. In this way, currents never flow in the primary and secondary winding at the same time.

Flyback transformers are designed for minimal leakage inductance, minimal winding and core losses and have an air gap to avoid saturation. High-frequency operation causes current to concentrate in the outermost region of the wire (known as a “skin effect”), increasing the AC resistance and power dissipation in the transformer. High-frequency transformers are sometimes designed using multiple strand windings (or Litz wire) to reduce the AC power losses.

The winding window of the power transformer core should be broad and shallow to minimize the number of layers, AC winding losses and the leakage inductance.

To assist in the design of flyback power supplies, a Mathcad file containing equations needed to calculate all external components can be found on the National Semiconductor Web site: http://power.national.com

Additional Information http://www.national.com/appinfo/power/hv.html

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