Current Mode Flyback DC/DC Controller Provides Tremendous Design Flexibility

by Arthur Kelley

Introduction

By its nature, a flyback DC/DC converter is one of the most versatile power converter topologies. Because it uses a transformer, it can step up or step down voltages and provide DC isolation if needed. Applications include power supplies for networking equipment, Power-over-Ethernet (PoE), automotive, consumer and general system house keeping. The LTC3805 has been designed to enhance the flexibility of the basic flyback converter, making it possible to optimize a single design for diverse applications. The converter input and output voltage is limited only by the rating of external components such as the power MOSFET and the transformer. The LTC3805 can be programmed for frequency, slope compensation, soft-start, input voltage RUN/STOP thresholds (including programmable hysteresis), synchronization to an external frequency source, and overcurrent protection to protect the converter from faults.

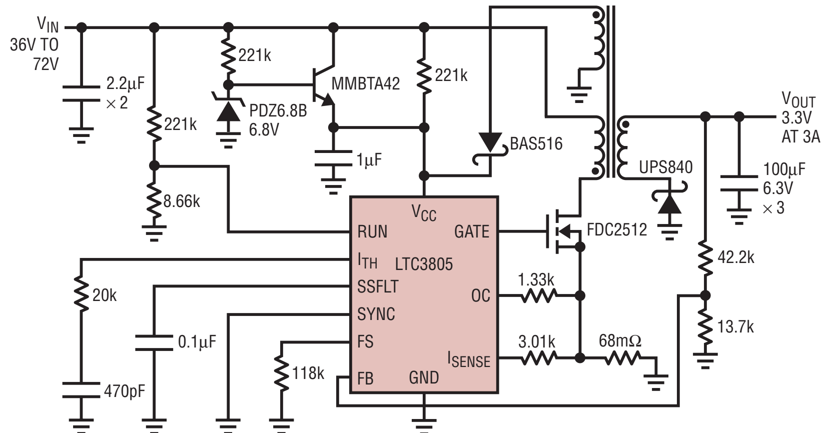

Figure 1. Non-isolated 36V to 72V to 3.3V 3A flyback converter

36V–72V to 3.3V at 3A Non-Isolated Flyback

Figure 1 shows the LTC3805 in a non-isolated flyback converter with an input voltage range of 36V to 72V and an output voltage of 3.3V at 3A. The remainder of this section details the design decisions made in creating this converter and describes methods for altering the design for various applications. An isolated version of the converter is described in the next section.

V_{CC} Power and Start-Up

In this design, start-up V_{CC} power for the LTC3805 is provided by an external pre-regulator using an NPN transistor, a zener diode and two resistors. Once the converter begins operation, a winding on the transformer provides a bias supply which turns off the NPN transistor to save power and increase efficiency. Alternately, since the LTC3805 has an ultralow shutdown current of 40µA, a simple trickle charger could be used to eliminate the NPN pre-regulator. The LTC3805 has a V_{CC} rising threshold of 8.5V and a falling threshold of 4V so there is plenty of hysteresis to implement a trickle charger. In either case, note that V_{CC} is not connected to V_{IN} so that almost any input supply above 8.5V can be accommodated by proper selection of external components and that, once started, the LTC3805 can run with input supplies down to 4V.

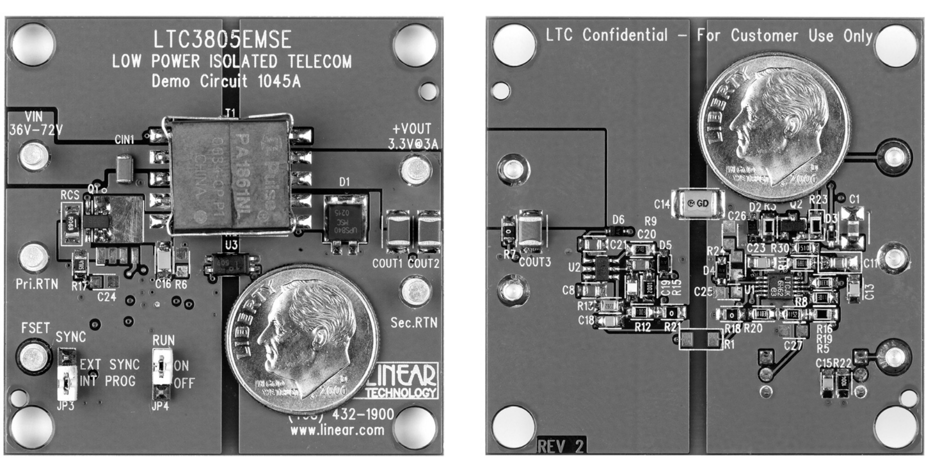

Figure 2. Isolated 36V to 72V to 3.3V 3A flyback converter

Programming V_{OUT}

The FB pin monitors the output voltage by comparing it—via a resistive divider—to the 0.8V internal reference of the LTC3805. Since the FB pin is not connected directly to the output, the LTC3805 can accommodate any output voltage down to 0.8V simply by adjustment of the resistor values.

Selecting Frequency

The 200kHz operating frequency is programmed by the 118kΩ resistor on the FS pin. By changing this resistor, the operating frequency can be set anywhere between 70kHz and 700kHz. High power designs tend to use lower frequencies while low power designs tend to use higher frequencies. The frequency programmability of the LTC3805 allows selection of the optimum frequency for any given design.

Programming the V_{IN} Thresholds

The rising threshold on V_{IN}, which is independent of the thresholds on V_{CC}, is set by the 221kΩ and 8.86kΩ resistors connected to the RUN pin. The rising threshold on the RUN pin is 1.2V while its absolute maximum voltage is 18V—a 15:1 ratio. Therefore the RUN pin accommodates designs with a wide range of input voltages and still has a high enough voltage rating to survive a transient overvoltage on V_{IN}. Once started, the LTC3805 sources a 5µA current from the RUN pin. Multiplied by the 221kΩ resistor, this current sets the hysteresis on V_{IN} to 1.1V. A different hysteresis, with the same rising threshold, can be selected by changing the values of the 221kΩ and 8.86kΩ resistors while keeping their ratio constant.

Setting the Soft-Start

The rate of change of V_{OUT} at start-up is programmed by the capacitor on the SSFLT pin—0.1µF in this case. A major consideration in the selection of the SSFLT capacitor is the filter capacitor used to bypass V_{OUT}. Generally, a larger output filter capacitor requires a slower soft-start to limit the inrush current caused by the charging filter capacitor. Conversely, if the converter has a small output filter capacitor, the SSFLT capacitor can be omitted and the LTC3805 internal soft-start ramps up the output voltage in 1.8ms.

Programming Slope Compensation and Overcurrent Operation

The 68mΩ resistor monitors the current through the main NMOS switch and implements both current mode control and overcurrent protection via the I_{SENSE} and OC pins, respectively. The I_{SENSE} pin monitors the current through the main switch and turns it off when the current exceeds a level set by the voltage on the I_{TH} pin. The 3.01kΩ resistor sets the amount of slope compensation using a ramp of current that is sourced by the LTC3805.

The overcurrent protection level is set by the 1.33kΩ resistor in series with the OC pin using a constant 10µA current sourced by the OC pin. Several behaviors can be programmed using this resistor. This particular design is set to regulate output voltage up to 3A and then overcurrent trip just above that. An alternate strategy, using a smaller resistor, would be to allow the output voltage to sag as the converter goes into current limiting and then trip on overcurrent only to prevent damage. In either case, once there is an overcurrent trip the LTC3805 shuts down, waits for a time out interval determined by discharging the capacitor on the SSFLT pin and then restarts if the overcurrent fault has been removed. If the fault is not removed, the LTC3805 enters a hiccup mode in which it periodically tries to restart with the period determined by the capacitor on the SSFLT pin. Thusly, the LTC3805 completely protects a flyback converter from short circuits on the output.

Frequency Synchronization to an External Source

Although shown grounded in Figure 1, the SYNC pin is used to synchronize the frequency of operation of the LTC3805 to an external source. The synchronization signal can be applied and removed without any particular sequencing requirement—it can be present before the LTC3805 begins operation or it can be applied after the LTC3805 has begun operation using the frequency programmed by the resistor on the FS pin. When the synchronization signal is applied, the LTC3805 locks on to the signal within two cycles of operation. When the synchronization signal is removed, the LTC3805 takes no more than two cycles to jump back to the frequency programmed by the FS pin.

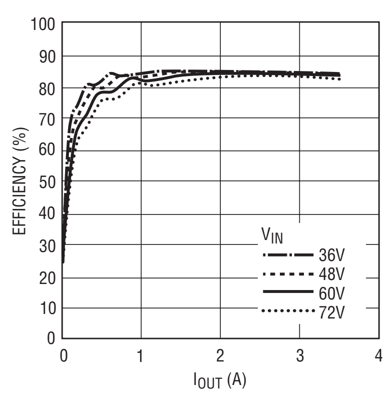

Figure 3. Efficiency for isolated and non-isolated 36V–72V to 3.3V 3A flyback converter

Isolated Converter Design

The basic design shown in Figure 1 can be modified to provide DC isolation between the input and output by the addition of a reference, such as the LT4430, on the secondary side of the transformer and an optoisolator to provide feedback from the isolated secondary to the LTC3805. Figure 2 shows a photo of the DC1045 demonstration circuit, which is an isolated converter with the same basic design and performance as the converter in Figure 1, and is representative of the size of both the isolated and non-isolated designs. Figure 3 shows the efficiency of the isolated converter and is also representative of the non-isolated converter.

Modifications for Different Input or Output Voltages

The two applications described above represent typical non-isolated and isolated 10W flyback converters. It is fairly easy to take this basic design and change the input or output voltage by scaling the external components in direct proportion to the change in voltage. These changes are transparent to the LTC3805 and can be accomplished with a circuit no more complex than that of Figure 1 and a board no bigger than that shown in Figure 2.

A decrease of the input voltage, and increase of the input current, mainly involves selecting a NMOS power switch with a lower voltage and higher current rating and selecting a transformer primary winding with a reduced number of turns and a proportionally larger wire size. For the input filter capacitor, the voltage rating can be

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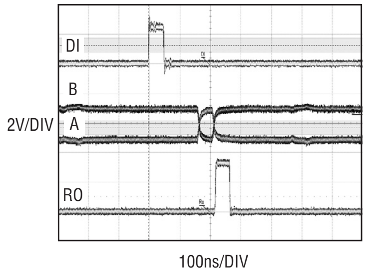

Figure 8. The LTC2854 driver delivering a single 50ns pulse through 100ft of Cat 5 cable, which is received by another LTC2854. Both parts have their on-chip termination enabled. Top trace is the input to the transmitting device and the middle and bottom traces are observed at the receiving part.

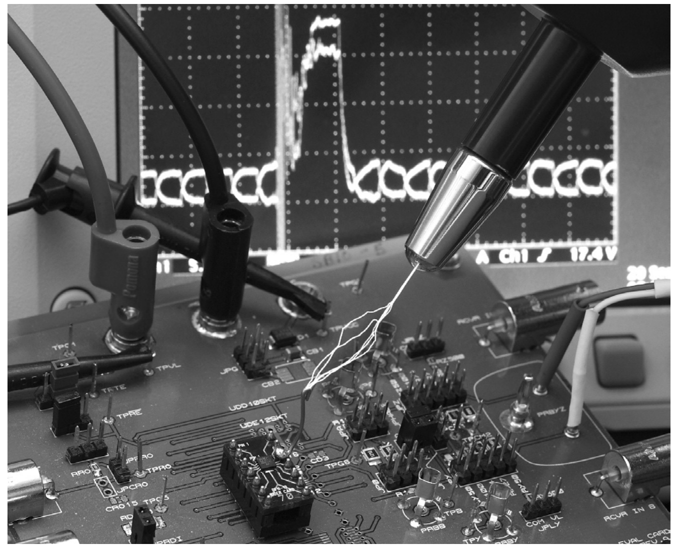

Figure 9. The LTC2854 sending data (see scope traces in background) while hit with multiple 30kV ESD strikes on the 'A' pin.

to +15V, with typical peak current not exceeding 180mA. Additionally, thermal shutdown protection disables the driver, receiver, and terminator if excessive power dissipation causes the device to heat to temperatures above 160°C. When the temperature drops below 140°C, normal operation resumes.

Extreme ESD Protection

The driver output pins and receiver input pins on the LTC2854 are protected to ESD levels of ±25kV HBM with respect to ground or V_{CC}. The full-duplex LTC2855 withstands ±15kV ESD. These protection levels exist for all modes of device operation including power-down, standby, receive, transmit, termination and all combinations of these. Furthermore, the protection level is valid whether V_{CC} is on, shorted to ground, or disconnected.

When a line I/O pin on the LTC2854/LTC2855 is hit with an ESD strike during operation, the part undergoes a short disturbance of duration similar to the ESD event and then fully recovers. The device does not latch up and there is no need to toggle states or cycle the supply to recover. This is true whether the part is in a static state or sending/receiving data and for the full range of ground common mode voltages called out in the RS485 standard. The photo in Figure 9 shows the LTC2854 absorbing the energy from an ESD gun (configured for IEC air discharge) delivering repeated 30kV strikes to the 'A' pin while transmitting data. The oscilloscope traces in the background show data toggling happily on the A and B pins before and after a strike, with a positive glitch only during the ESD event. This device can handle many such strikes without damage.

Conclusion

The LTC2854 and LTC2855 break new ground in the world of 3.3V RS485/RS422 transceivers. The inclusion of a selectable termination resistor provides a complete solution to RS485 networking with the ability to remotely configure the network for optimal data transfer. Unparalleled ESD performance provides outstanding ruggedness while a balanced-threshold receiver with full failsafe capability makes this family of small-footprint devices a natural choice for modern RS485/RS422 systems.

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reduced and the capacitance increased in proportion. Also, the resistor divider connected to the RUN pin must be adjusted for the new input voltage. Finally, the 68mΩ current sense resistor should be reduced in value to account for the higher input current. For an increase in input voltage, everything is changed proportionally in the opposite direction.

Similarly, a change in the output voltage involves a change in the diode, the number of turns in the secondary winding of the transformer and the voltage rating and value of the output filter capacitor along with the appropriate change to the voltage divider that senses the output voltage. If the output voltage is between 4V and 9V, the design of non-isolated converters is very simple because V_{CC} can be provided by a diode connected directly to the output instead of the third winding on the transformer.

Conclusion

Because of its flexibility, the flyback converter is the most widely used transformer-based converter. The LTC3805 maximizes the flexibility of the flyback converter by making it possible to use the same basic circuit for a wide range of converter input and output voltages. Simply scale component values to match voltage and current conditions, greatly simplifying board design and updates.