

Primary-Side Sensing Takes Complexity out of Isolated Flyback Converter Design

by Tiger Zhou

Introduction

Flyback converters are widely used in isolated DC/DC applications, but they are not necessarily a designer's first choice. Power supply designers grudgingly choose a flyback out of necessity for electronic isolation; certainly not because they are an easy to design. A flyback converter requires that significant design time be devoted to transformer design, a task further complicated by limited off-the-shelf transformer selection and the necessity for customized magnetics. Moreover, the flyback converter has stability issues due to the well-known right-half-plane (RHP) zero in the control loop, which is further complicated by the propagation delay of an optocoupler.

The LT3573 isolated monolithic flyback converter solves many of the design difficulties commonly associ-

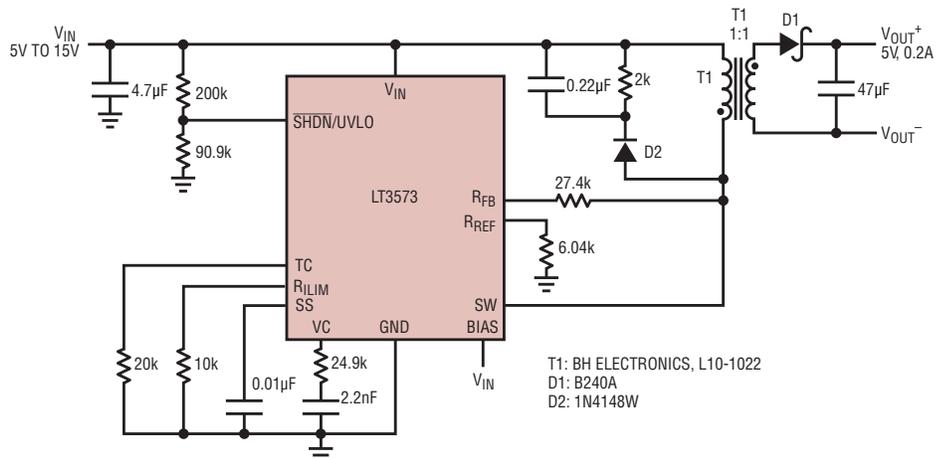


Figure 1. Amazingly simple flyback converter takes advantage of the primary side sensing scheme of the LT3573. Note the absence of an optocoupler. Also note the tiny coupling inductor available from many magnetics vendors.

ated with flyback converters by using a primary-side sensing scheme that is capable of detecting the output voltage through the flyback switching node waveform. During the switch off-period, the diode delivers the current to the output, and the output voltage is thus reflected to the primary-side of the flyback transformer (or the switch node). The magnitude of the switch node voltage is the summation of the input voltage and reflected output voltage. The flyback converter is able to reconstruct the output voltage from the measurement of the switching node voltage during the off period. This scheme has previously proven itself in Linear Technology's family of photoflash capacitor charger ICs. Design is simplified by getting rid of the optocoupler while maintaining the galvanic isolation between the primary-side and secondary-side of the transformer.

The LT3573's utilization of boundary mode operation further reduces converter size and simplifies system design. The flyback converter turns on the 1.25A, 60V internal switch right after the secondary diode current reduces to zero, while it turns

off when the switch current reaches the pre-defined current limit. Thus it always operates at the transition of continuous conduction mode (CCM) and discontinuous conduction mode (DCM), which is called boundary mode. Boundary mode operation also offers a superior load regulation.

Other features, such as soft-start, adjustable current limit, undervoltage lockout and temperature compensation further facilitate the flyback converter design. Figure 1 shows a simple flyback converter using LT3573.

Primary-Side Sensing Needs No Optocoupler

An optocoupler is essential for a traditional flyback converter. It transmits the output voltage feedback signal through an optical link while maintaining an isolation barrier. However, the optocoupler current transfer ratio (CTR) often changes with temperature, degrading accuracy. Also, the optocoupler causes a propagation delay, which impacts the dynamic response of the control loop.

The LT3573 eliminates the need for an optocoupler by sensing the output

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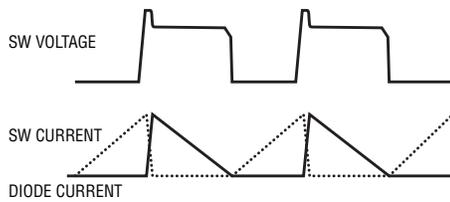


Figure 2. LT3573 flyback converter in boundary mode.

voltage on the primary-side. The output voltage is accurately measured at the primary-side switching node waveform during the off period. In addition to the obvious simplification and cost savings of this design, this scheme improves dynamic performance during load transients, which further simplifies the control loop design.

Boundary Mode Operation Reduces Converter Size and Simplifies System Design

Since the flyback converter operates in boundary mode, the switch is always turned on at zero current and the diode has no reverse recovery loss. Reducing power losses allows the flyback converter to operate at a relatively high switching frequency, which in turn reduces the transformer size when compared to lower frequency operation. Figure 1 shows an isolated flyback using a small coupling inductor with 19µH primary inductance.

Another benefit of boundary mode operation is a simplified control loop.

The LT3573 simplifies the design of flyback converters by using a primary-side sensing scheme that detects the output voltage through the flyback switching node waveform.

Figure 2 shows the LT3573 flyback converter voltage and current waveform in boundary mode. Assuming a 1:1 transformer is used; the control-to-output transfer function is:

$$G_{VC} = \frac{1-D}{2} \cdot \frac{R \left(R_C + \frac{1}{s \cdot C} \right)}{R + R_C + \frac{1}{s \cdot C}}$$

Where R is the load resistor, C is the output capacitor, R_C is the ESR of the output capacitor and D is the duty cycle. From this, a load pole at

$$s_p = \frac{1}{RC}$$

and ESR zero at

$$s_z = \frac{1}{R_C C}$$

are observed. This reduced-order transfer function can be easily compensated by an external V_C network.

The simplified control loop network also eases transformer design. The control-to-output transfer function has no inductance component, which means the flyback converter easily tolerates transformer variations. The transformer inductance only affects the converter switching frequency; it does not affect the converter output capability and stability. The data sheet includes a detailed design example, which outlines converter design guidelines.

Boundary Mode Operation for Superior Load Regulation

Since the diode voltage drop is included in the reflected output voltage, it can affect load regulation in primary-side sensing flyback converters that operate in CCM. The reason is the diode has nonlinear I-V characteristics. Other methods such as load regulation compensation must be used if a tight load regulation is required. However, the load regulation is much improved in boundary mode operation because the reflected output voltage is always sampled at the diode current zero-crossing. The LT3573 flyback converter has a typical 1% load regulation.

Figure 3 shows a 5V, 1A flyback converter that accepts a 9V to 30V input. The BIAS winding is used to improve the system efficiency. The T_C resistor compensates the output voltage at all temperatures, the UVLO resistors set the intended input range, and the current limit resistor programs the output current.

Conclusion

The LT3573 simplifies the design of isolated flyback converters with a primary-side sensing scheme and boundary mode operation. Its wide 3V to 40V input range, and its ability to deliver 7W output power make it suitable for industrial, automotive and medical applications. It also includes undervoltage lockout, soft-start, temperature compensation, adjustable current limit and external compensation. 

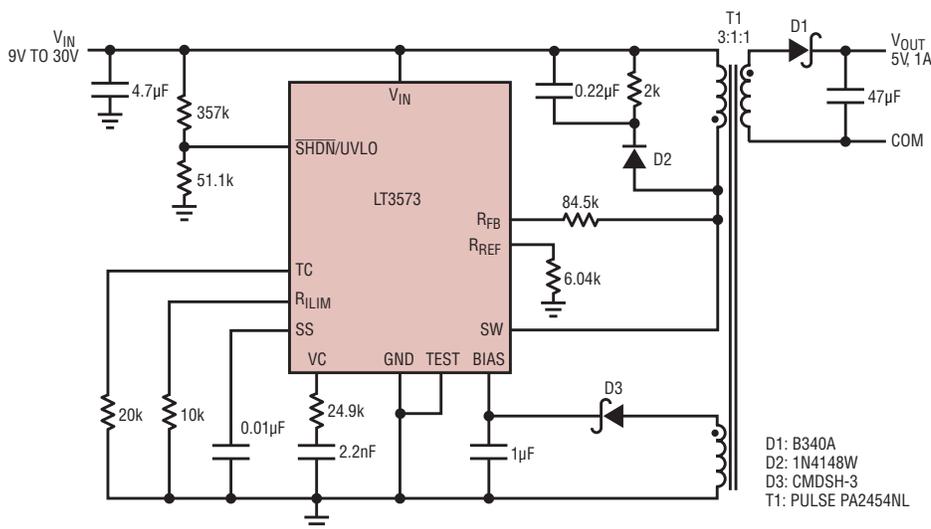


Figure 3. A 9V-30V input, 5V/1A flyback converter with a BIAS winding to maximize the system efficiency.