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ZXGD3103 Boosts Set Top Box Power Supply Efficiency, Reduces Heat Dissipation

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Introduction

This design note describes the benefits of using the ZXGD3103 for secondary side synchronous rectification of a single-output Flyback converter. The ZXGD3103, which integrates a high voltage detector and a high current gate driver in one device, is purposefully designed to drive a MOSFET to emulate an ideal diode. When the IC is used to drive a low $R_{DS(on)}$ MOSFET it reduces output rectifier loss, ultimately improving power efficiency. The electrical and thermal performance benefits of synchronous rectification are illustrated through comparison with a 60V Schottky in a 40W Flyback converter suitable for use as a set top box power supply.

Power loss considerations for a set top box Flyback converter

The Flyback converter with multiple transformer secondary windings is the most popular topology for set top box power supply. This is due to its low component count and simpler control scheme compared with other converter topologies.

Most recently the functionality of the set top box has become increasingly sophisticated, placing ever more stringent demands on power density and dissipation of the power supply within them. Designers are now migrating from multiple-, to single-output, Flyback converters to achieve the required performance. The Flyback converter will provide a 12V output which is then stepped down to lower voltages, required by different internal peripherals, using Point-of-Load converters.

Now, the primary building blocks of the Flyback converter are, as shown in Figure 1: the primary side MOSFET (Q1); output rectifier diode; power transformer (T1) and PWM controller (U1). The PWM controller was chosen because it can supply sufficient current to drive the MOSFET at typically 66kHz. It also provides simple, single feedback loop, voltage mode control with fast transient response. At sub 60W power, Q1 and U1 are often integrated in one single package as shown in Figure 1 to simplify design. Q1 in the integrated device is a $R_{DS(on)} = 1.2\Omega$, 725V rated MOSFET.

The majority of the power loss in the converter cumulates from:

- Conduction loss in output Schottky rectifier
- Transformer loss (T1)
- Switching and conduction losses in the primary side MOSFET (Q1)
- Snubber circuit loss

The efficiency of a Flyback converter can be improved if these losses can be reduced. As the output voltage of the set top box power supply is low then the forward conduction loss of output Schottky rectifier could be as high as 25% of the total loss. Therefore the biggest improvement in Flyback performance will be achieved by replacing the diode with a synchronous MOSFET with low $R_{DS(on)}$ as shown in Figure 1. It is recognized as a clear means of drastically improving efficiency to 1) meet the voluntary energy standards 2) remove the need for heat sink and 3) reduce the size and weight of the power supply.

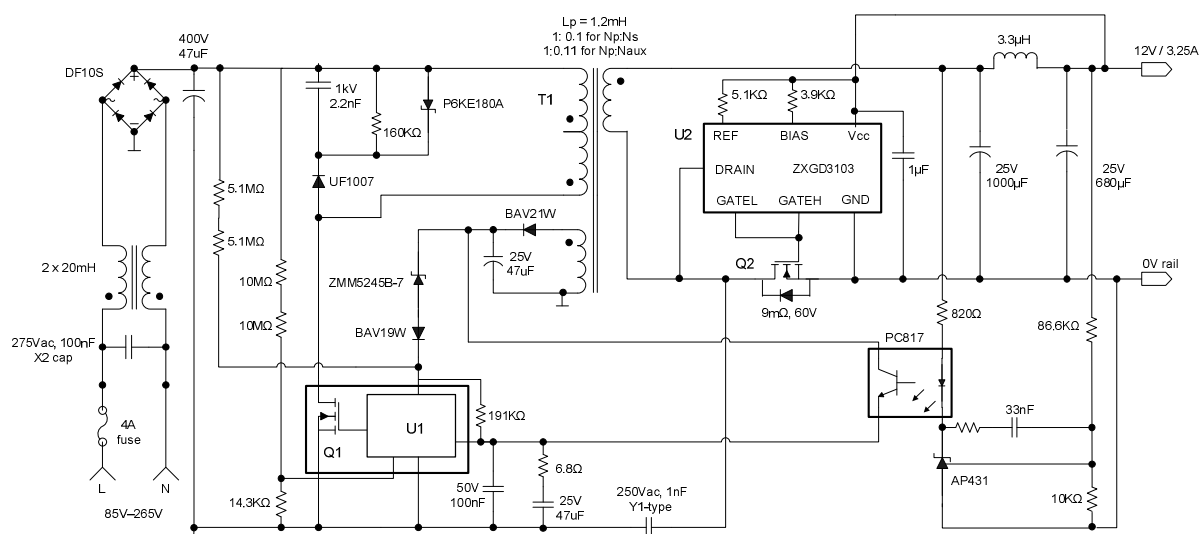


Figure 1. Single output Flyback converter with synchronous rectification.

Synchronous rectification addresses efficiency challenge of Flyback: output rectifier loss

The ZXGD3103 is a synchronous MOSFET control IC that addresses these circuit requirements. It features a high voltage Drain detect pin, to enable direct connection to the MOSFET Drain terminal, and a high current gate driver that drives a MOSFET to emulate the performance of an ideal diode. Therefore, a MOSFET driven by ZXGD3103 removes the need for a heat sink, simplifying circuit design.

The ZXGD3103 senses the forward voltage drop of the intrinsic body diode within the MOSFET. When the body diode conducts, the IC applies a voltage to the MOSFET gate, turning it on after a small delay. The magnitude of the gate drive voltage is then proportional to the sensed voltage. As the Flyback current through the synchronous MOSFET decreases, the gate drive voltage is reduced, thereby minimizing turn OFF time.

Performance evaluation

The performance of synchronous rectification was evaluated against that of a 20A, 60V Schottky in the 40W Flyback converter shown in Figure 1. In the test, the ZXGD3103 was used to drive Q2 which is a 60V N-channel MOSFET with $R_{DS(on)} = 9.3m\Omega$. Q2, was connected on the 0V rail allowing the control IC to be operated directly from the output of the Flyback converter.

The efficiency of the 12V output was measured whilst the converter's load was varied from 25% to 100%. The power supply's full load output current was 3.25A. These measurements were taken under two input voltage conditions: 110Vac and 230Vac. The results of these efficiency measurements are shown in Figure 2.

Figure 2 highlights that the Flyback converter with synchronous rectification is 0.5 to 1.5% more efficient than that with Schottky, at output loading >35%. Similarly, an increase in efficiency is observed when the Flyback converter operates from 110Vac input. It is clear that substantial power savings are possible by implementing circuits that can be designed with little trouble by following the application guidelines. Synchronous rectification also enables the converter to exceed Energy Star V2.0 requirement.

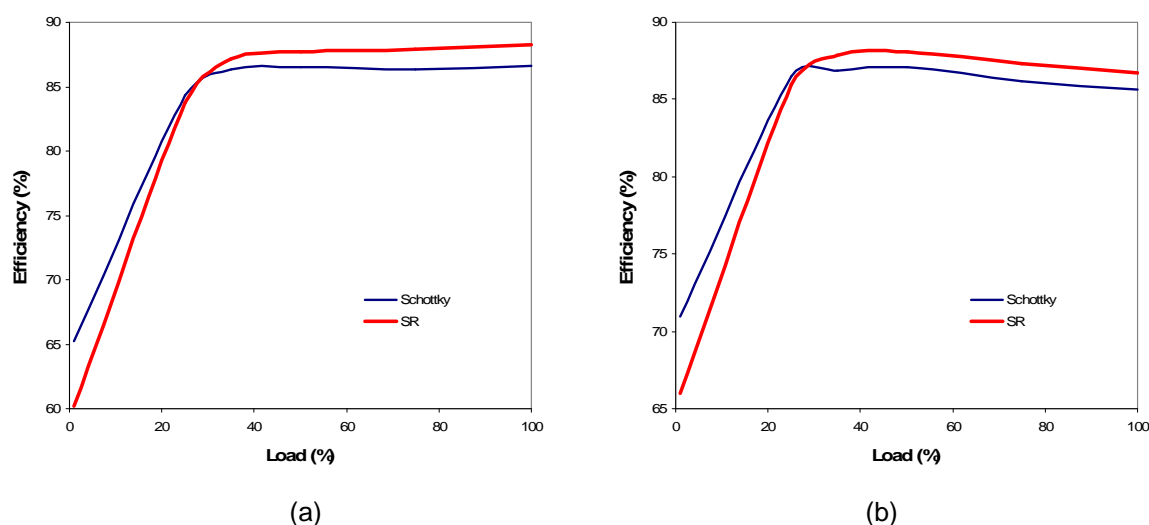


Figure 2. Efficiency data at: (a) 230Vac and (b) 110Vac.

Figure 3a shows the oscilloscope waveforms of the ZXGD3101 driving Q2 in the circuit. At full load, the gate drive voltage reduces as the Flyback current starts reducing. Gate voltage oscillation occurs momentarily just after Q2 is switched ON. This is due to noise generated on the Drain terminal through the parasitic inductance of the circuit and the DPAK package.

Improved layout can be achieved by 1) placing the control IC closer to Q2 and 2) increasing the PC board track width that connects the Drain input of ZXGD3103 with Q2. This resolves the issue as shown in Figure 3b. Finally, it is noteworthy that Q2 is turned off precisely when the Flyback current goes to zero, with little or no reverse current.

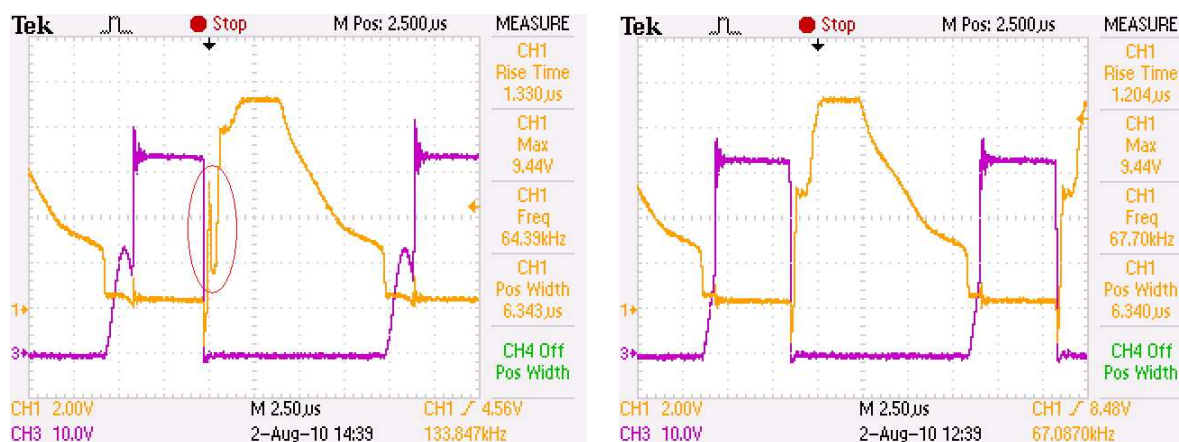


Figure 3. Secondary side driver operating waveforms: a) Gate voltage oscillation due to circuit inductance and b) Gate voltage with improved layout (Orange: Gate voltage; Purple: Drain voltage).

A type-K thermal coupler was then used to assess the thermal performance of the two solutions. At full load the Schottky warms up to 98°C in a 25°C ambient. A heat sink will be required for continuous operation above 25°C ambient. By contrast, Q2 operated at 67.3 °C so it can be operated at full load without a heat sink. This leads to the possibility of a cost saving to be made from the elimination of the heat sink. Lower operating temperature also reduces conduction loss in the surrounding components and increases reliability.

Another important consideration when implementing synchronous rectification is the IC power consumption. The ZXGD3103 operating current varies over the power supply load range. The IC current consumption peaks at full load as the IC provides a high gate current to switch ON the MOSFET. At very high switching frequencies there is a risk that control IC over-heating could happen.

The phenomenon is more probable when the secondary side controller is driving a very high Q_G MOSFET. This causes excessive power dissipation in the IC, and could ultimately lead to device failure.

The risk of over-heating can be minimized by optimization of the PC board layout. The majority of the heat from the synchronous control IC will be dissipated through its 'VCC' and 'GND' pin. The board layout should provide ample copper area for the 'VCC' and 'GND' pin to reduce the package thermal resistance R_{thj-a} .

In the test, a digital multi-meter was used to measure the IC operating current at full load. The IC consumed 12.5mA when it was driving Q2, which has $Q_G = 47nC$, at 66kHz switching frequency. The associated power dissipation within the control IC is 150mW. The temperature of ZXGD3103 at full load was recorded at 65.9°C. The IC current reduces at power supply low-load condition as the switching period increases. At no-load, the IC current drops to 5.5mA when the Flyback converter enters pulse skipping mode. This enables the standby power consumption of the Flyback converter to stay below 300mW.

Conclusion

It has been demonstrated that the efficiency of a 40W Flyback converter can be increased by up to 1.5% when a low $R_{DS(ON)}$ MOSFET driven by ZXGD3103 is used to replace a low V_F Schottky. Furthermore, synchronous rectification provides this increase in performance whilst operating at a lower temperature and improving the reliability of the Flyback converter. This makes the design suitable for use as set top box power supply.

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