Designing a Synchronous Rectification Solution to Reduce Excessive Heat (Part I)

Introduction

Mobile devices — such as mobile phones and laptops — are integral to the modern world. The development of mobile devices has accompanied a demand for small, lightweight, and fast-to-charge adapters. Major manufacturers are rushing to introduce ultra-small, fast charge adapters (see Figure 1).

Figure 1: The Development of Ultra-Small Adapters

This article is the first part of a two-part series exploring how to design a side synchronous rectifier for ultra-small volume, fast charge adapters. Part I will introduce the basic topology of secondary-side synchronous rectification, as well as the requirements of its power supply. Part II will cover the opening and shutdown process of the side synchronous rectifier and quick shutdown technology.

Synchronous Rectification Topology

Fast charging typically requires more output current and heat, while a smaller solution often reduces a solution's cooling area. This tradeoff means that excessive heat is a challenge for ultra-small adapters.

Figure 2 shows a commonly used counter-inversion topology, assuming a system output of 5V/4A, where the average current flowing through the side diode is 4A. If there is a 0.7V due to pressure drop and 2.8W of power loss, the diode can become dangerously hot. In this scenario, the system's long-term operation can seriously affect reliability and user experience.

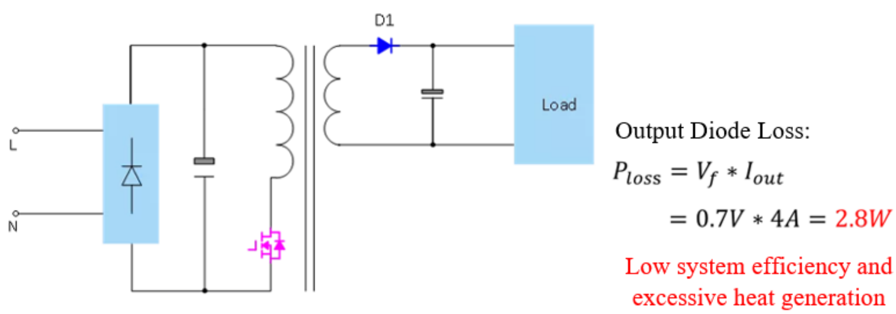

Figure 2: Excessive Heat on Counter-Inversion Topology

To address the challenge of excessive heat, the side output diode should be replaced with a MOS tube. The continuous flow of the X current through the MOS tube forces the system to operate in synchronous rectification mode (see Figure 3). Because the impedance of MOS tube is very small, the heat generated during the continuous flow is also very small. For a MOS with a 10mΩ impedance, the power loss is only 0.16W when the output current is 4A. This significantly reduces heat generation.

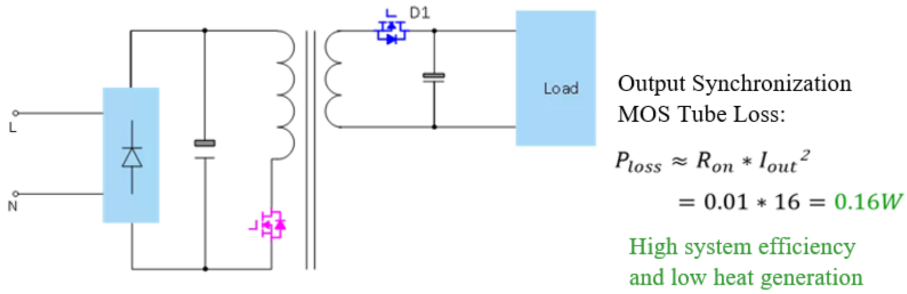

Figure 3: Significantly Reduced Heat with a MOS Tube

Synchronous Rectifier Power Supply

Figure 4 shows that for N-channel MOSFET, a voltage exceeding the source-to-gate (S-to-G) voltage must be provided to turn on the MOS tube during continuous flow, where the highest voltage is located at the source.

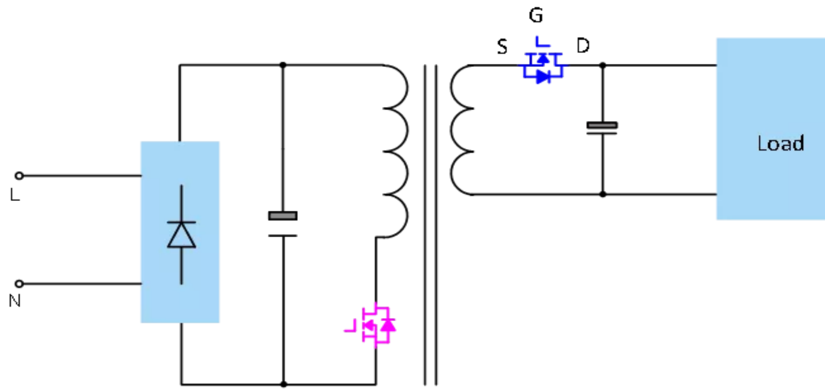

Figure 4: Required Voltage to Turn On the MOS Tube during Continuous Flow

Auxiliary windings can also be used to provide a voltage that exceeds the source voltage. Figure 5 shows additional windings that power the side MOSFET's drive. However, this approach requires a transformer winding and drive circuit, which increases system cost and complexity.

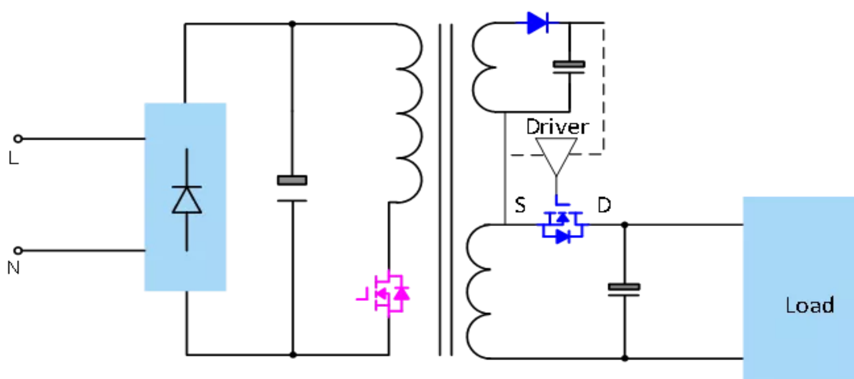

Figure 5: Auxiliary Windings Provide a Voltage Exceeding S

For a solution that does not require auxiliary windings, place the MOS tube at the lower end of the side output (see Figure 6). The output voltage subsequently powers the MOS tube. At the same time, placing the MOS on the low side can result in worse EMI performance. In addition, placing the MOS tube on the low side is not applicable for systems with an output voltage that is too low to power the MOSFET driver.

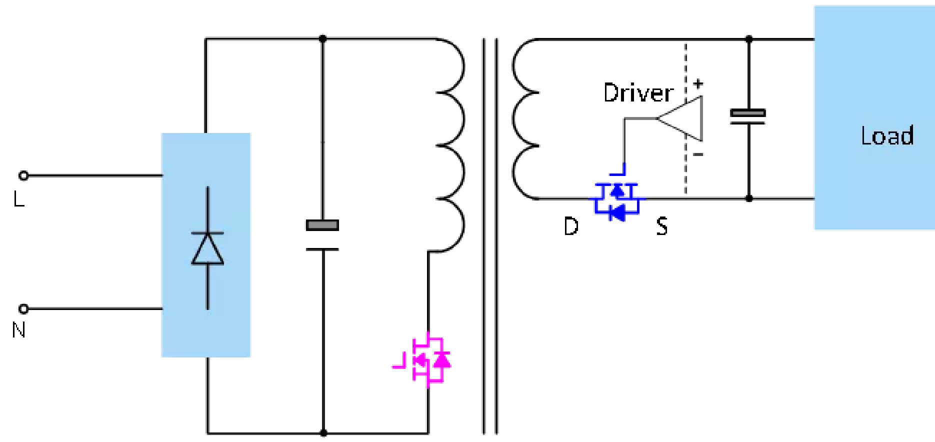

Figure 6: Output Voltage Powers the MOS Tube at the Side Output's Lower End

The critical design question is how to select a scheme that improves EMI performance without requiring either auxiliary windings or adaptability for different output voltage applications. The MP9989, a continuous conduction mode (CCM) and discontinuous conduction mode (DCM) flyback diode, can mitigate these issues (see Figure 7).

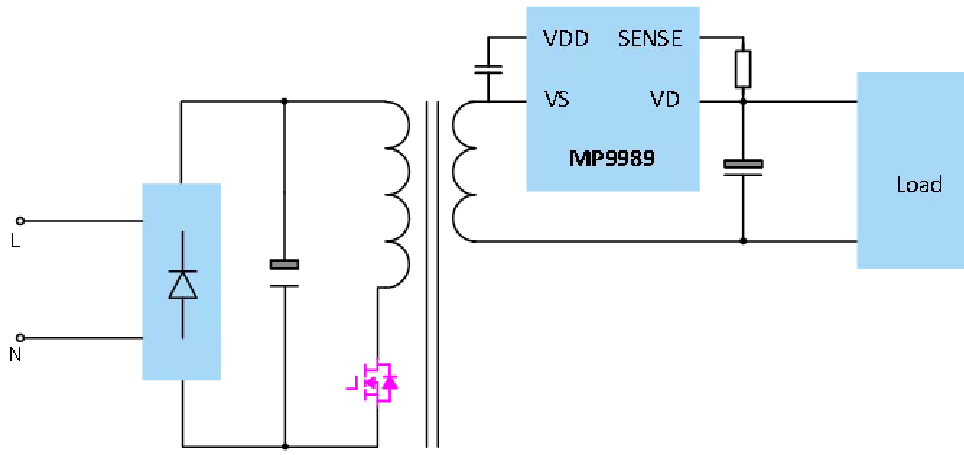

Figure 7: The MP9989 Improves System EMI Performance

The MP9989 can be placed directly at the output's high end. It also supports low output voltages and features a simple peripheral circuit, which is considered the ideal diode. The main advantage of the MP9989 is its internal, self-powered circuit.

Figure 8 shows that when the primary-side MOSFET is turned on, the MP9989's MOS tube reverses, and the drain-to-source voltage (V_{DS}) is positively pressurized. This allows the internal, self-powered circuit to charge the VDD capacitator. When the primary-side MOSFET is switched off, VDD can supply power to the drive circuits using the charged VDD capacitor. This ensures the smooth opening of the primary-side MOSFET.

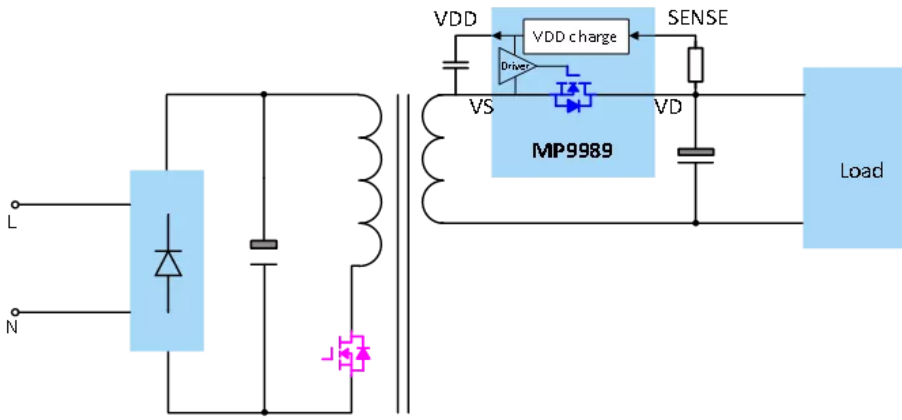

Figure 8: An Internal, Self-Powered Circuit Charges the VDD Capacitor

As USB powered devices (PDs) becomes more common, the output voltage range is increasing. Higher output voltages can challenge the chip's voltage resistance. To counteract this, the MP9989 has a built-in, 100V MOSFET that provides a sufficient margin for a wide range of designs.

Conclusion

In this article, we reviewed a side synchronous rectifier design scheme with the MP9989 to successfully turn on the MOS tube and reduce excessive heat. Part II will dive into the opening and shutdown process of the synchronous rectifier, while also discussing the advantages of quick shutdown technology.