A High Frequency Boost Converter with Air Core Inductor

Introduction

This paper presents an example of the potential for reduction in converter size and when employing NexGen's GaN power transistor technology. We will examine a 100W step up (boost) power stage with a with a 200V input and 800V output. We have pushed the switching frequency well beyond 1MHz up to 5MHz and higher, enabling the use of air core magnetics and eliminating typical ferrite core losses. A summary of design considerations and performance of a 200V to 800V, 100W boost converter, switching from 1 to 10MHz is presented.

The converter is a zero-voltage switching (ZVS) boost converter operating at the DCM/CCM border. The boost inductor is sized to guarantee ZVS while delivering full load current. At very high switching frequencies a significant portion of the time is spent during the switching transitions. Despite the ZVS switching, low transistor output capacitance is still very importing in that less energy will be required to achieve the resonant transitions, reducing the circulating currents and the associated RMS current losses.

Lower transistor Qoss correlates with faster resonant transactions, lower peak inductor current and a more efficient design. The Coss capacitance of the NexGen is sufficiently low to minimize the resonant transition durations and operate at switching frequency well above 1MHz and as high as 10MHz. Ultimately there will be an optimal balance between the very low Qoss and the Rdson of the transistor. The Rdson must be sufficiently low to efficiently deal with the circulating current that is required to achieve ZVS resonant switching.

Evaluation Board

A power stage evaluation board was developed to examine the 5 to 10MHz switching capabilities of the NexGen 1st generation 1200V depletion mode transistors in a cascode configuration. The board demonstrates a 50% reduction in PCB area when compared to NexGen's 1MHz ZVS Boost converter. Figure 1 shows the schematic of the board and figure 3 displays the board layout. The design includes and air core inductor

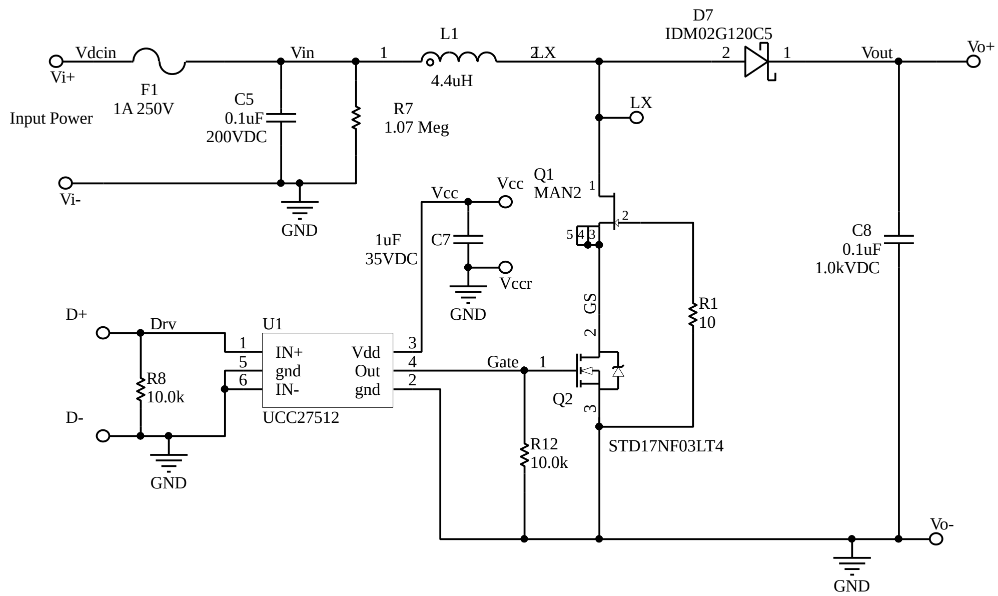


Figure 1. HF Boost Power Stage Schematic

Theory of Operation

Figure 2 breaks down the segments of the switching cycle with the transitions in the switching cycle detailed below.

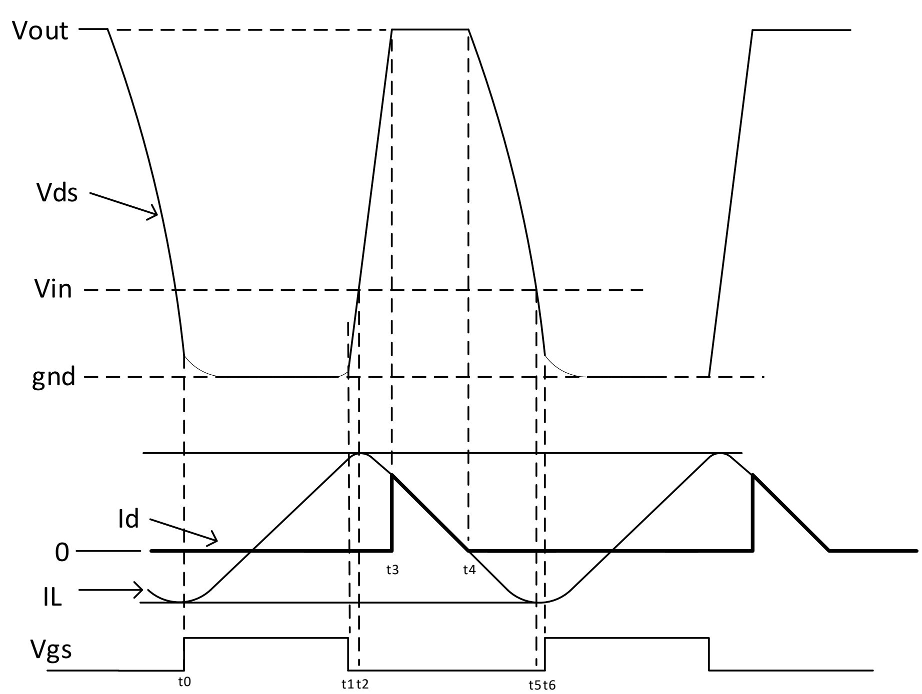
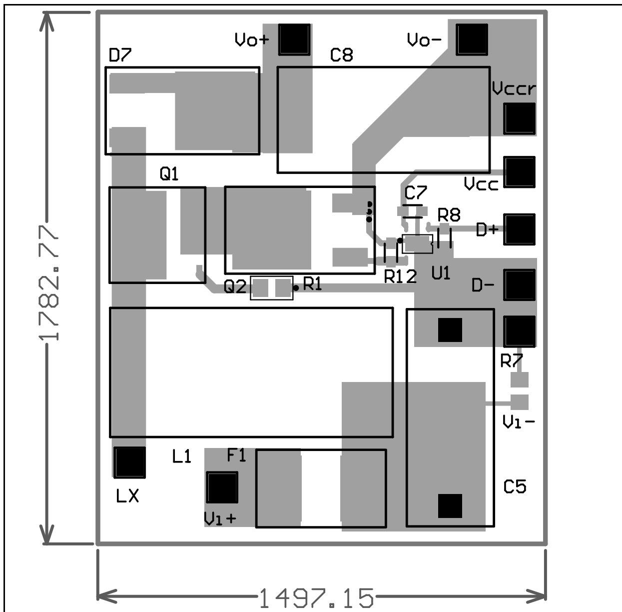


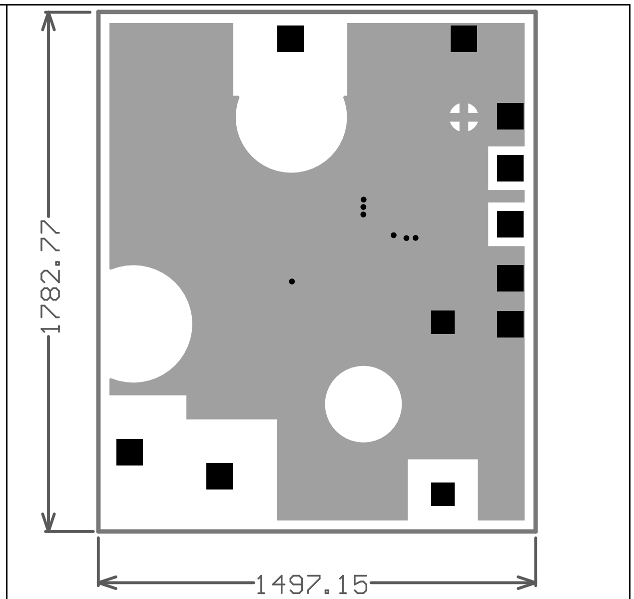
Figure 2. Switching Cycle of High Frequency ZVS Boost

1. **t0 to t1**. Power Switch turn on and the inductor current builds from the negative value to a value enough to deliver full power to the load as well as charge the LX node capacitance to Vout plus the diode forward voltage.

2. **t1 to t2**. The power switch has turned off and current is delivered from the source through the inductor to charge the LX node capacitance to the input voltage.
3. **t2 to t3**. Her the energy stored in the inductor is transferred to the LX node capacitance in till the boost diode begins conduction.
4. **t3 to t4**. During this portion of the switching cycle inductor current is delivered to the load. The average of this current is roughly equal to the load current.
5. **t4 to t5.** During this segment of the switching cycle the Coss energy drives the inductor current negative until the LX node voltage has decreased to the input voltage.
6. **t5 to t6.** During this portion of the switching cycle the polarity of the voltage across the inductor reverses and its current reverses direction, continuing to discharge the SW node voltage until it approaches zero, at which time the gate drive is applied, and the power switch enabled.



Top Side



Bottom Side

Figure 3. HF Boost Power Stage with Air Core Inductor PCB Layout

Performance and Evaluation

In theory the ZVS converter does not have any switching losses. Bench testing has not confirmed this, and we are still working to accurately account for transistor losses under these typical high frequency operating condition. Transistor temperatures were recorded at switching frequencies above 5MHz and compared to the same temperature rise with dc losses only. The results show that transistor RMS current during the on time alone does not account for the power loss and temperature rise seen during the very high switching frequency conditions. Further testing and study of the transistor performance is required to determine the limits of the converter and transistor performance required to reach the goal of a 10MHz 100W 200V to 800V ZVS boost converter.

