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 Vertical GaN™ eJFET 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 basic operation principles and design considerations for a 200V to 800V, 100W boost converter with a switching frequency 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, a low transistor output capacitance - as provided by NexGen's Vertical GaN™ eJFETs - is very important in that less energy will be required to achieve the resonant transitions, reducing the circulating currents and the associated RMS current losses.

Lower transistor Coss correlates with faster resonant transactions, lower peak inductor current and a more efficient design. The Coss capacitance of NexGen Vertical GaN™ eJFETs 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 a optimal balance between the very low Coss 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 has been developed as high frequency test platform for NexGen's 2nd generation eMode Verical GaN™ JFET. To validate the baseline design decisions and ready the HW for testing with the 2nd generation eMode JFETS, initial tests have been performed with 1st generation depletion mode devices. 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 an air core inductor.

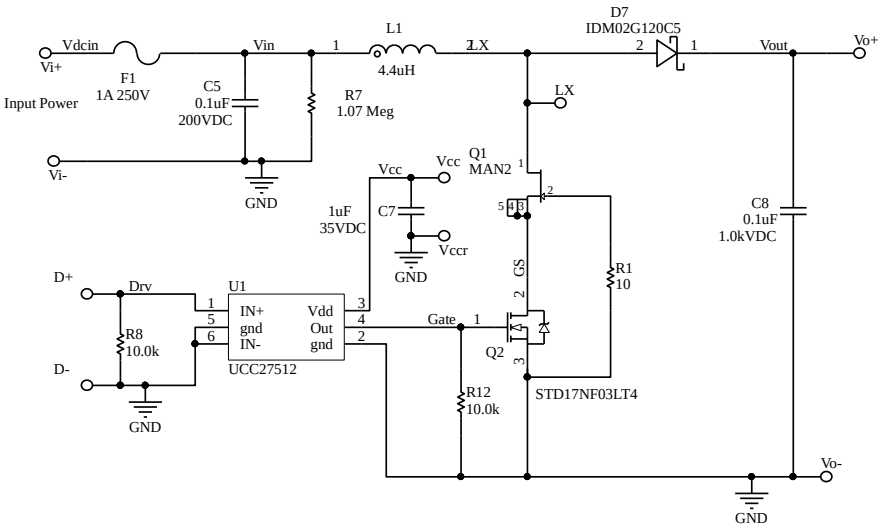

Figure 1. HF Boost Power Stage Schematic

Theory of Operation

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

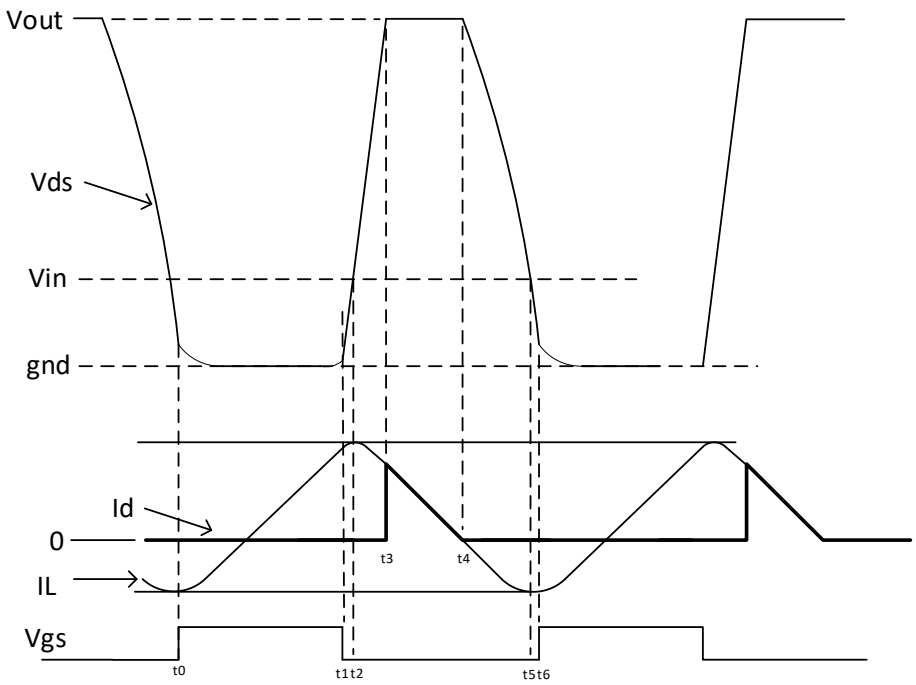

Figure 2. Switching Cycle of High Frequency ZVS Boost

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.

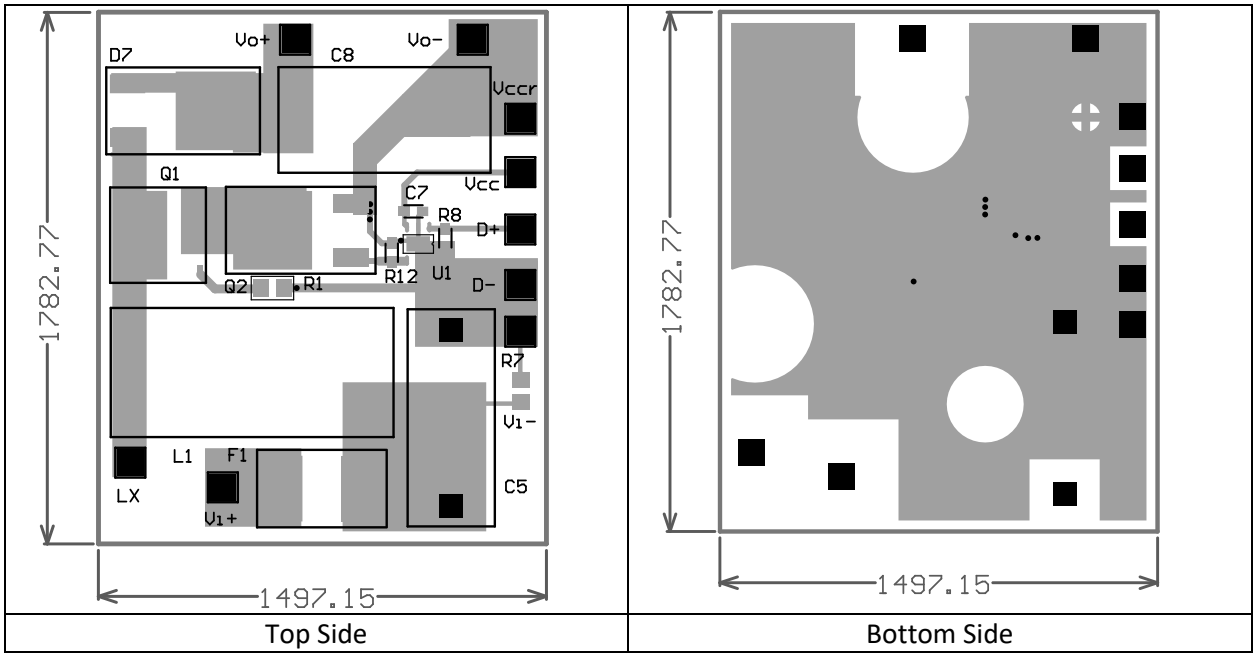

Figure 3. HF Boost Power Stage with Air Core Inductor PCB Layout

Initial Evaluation and Next Steps

Initial testing of the design using NexGen 1st generation depletion mode Vertical GaN™ devices confirms the baseline design decisions and the capability of the test platform to operate well beyond 1MHz switching frequency. The design is validated and prepared for testing with the 2nd generation eMode Vertical GaN™ JFETs (see also https://nexgenpowersystems.com/datasheets/)

Once available, the application note will be updated accordingly with the most recent test results