A 100W 800V to 14V 1MHz Dc-DC converter Design using High Voltage NexGen Vertical GaN Transistors

The trend for increasing the EV battery voltage from 400V to 800V for faster charging, reduced weight, cooler operation and better packaging creates new opportunities for NexGen's high voltage GaN transistors.

Electric Vehicles using 800 Volts include Fisker's Emotion launched in 2019, the planned Chevrolet Camaro race car, Porsche Taycan, an Audi supercar prototype, the Aston Martin Rapide E GT-supersaloon, and the Genovation Corvette (Harrop, 2019).

With the vehicle power operating from an 800V battery all vehicle power must be converted from this high voltage with power capability up to 3kW. To demonstrate NexGen transistors high voltage and fast switching capability for this type of application we have developed a low power (100W), high switching frequency 800V to 14V buck converter.

For this low power level, a cost-effective half bridge isolated buck converter was chosen. For higher power levels a similar approach using a full bridge converter is used.

This paper summarizes the design of a 100W 800V to 14V buck converter using NexGen's first generation depletion mode Vertical GaN on GaN devices in a cascode configuration. The devices have a 1200V rating with a Rdson of 1 to 2 Ohms.

Design Summary

To achieve the high voltage conversion ratio of 800V to 14V, a step-down transformer with a NexGen 1200V GaN totem pole switching network in a half bridge configuration is used. The half bridge configuration cuts the voltage applied to the transformer primary in half and allows for a more optimum steady state duty cycle. The schematic for the design is shown in figure 1. The half bridge converter has a 500kHz primary, 1MHz secondary switching frequency and uses voltage mode control with the addition of a small amount of current feedback to simplify compensation network required (Nielsen, 2012). The UC2825 high frequency PWM controller is primary referenced with a secondary side TL431 error amplifier and additional isolation using the Silicon labs isolated gate drive IC (SI8273). Isolated +15V and -5V drive bias rails for both the high side and low side of the totem pole network are supplied by Murata's MGJ1 DC-DC bias supply converter. The secondary side synchronous rectifiers are driven directly form windings on the power transformer.

The high voltage primary, relatively low primary current, and high switching frequency of this design created some interesting challenges for sensing the primary current. The Pulse PA0368 current sense transformer with a 500 Vrms isolation rating, a 50:1 turns ratio, and a 4A current rating ultimately was found to meet the requirements for accurate current sense.

The printed circuit board show in figure 2 has been designed to handle both TO247 and TO220 power transistors.

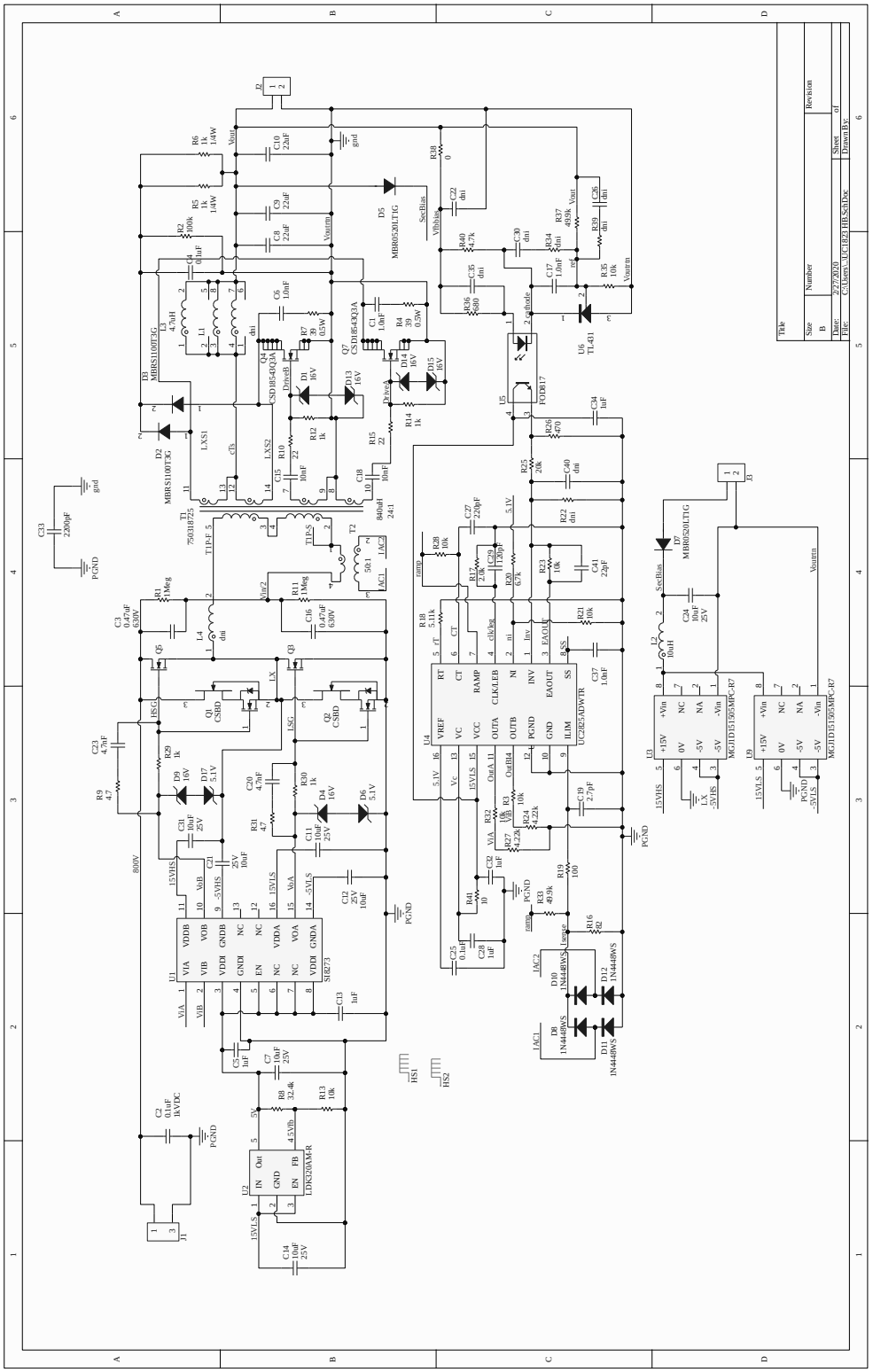

Figure 1. 800V to 14V Half Bridge Converter Schematic

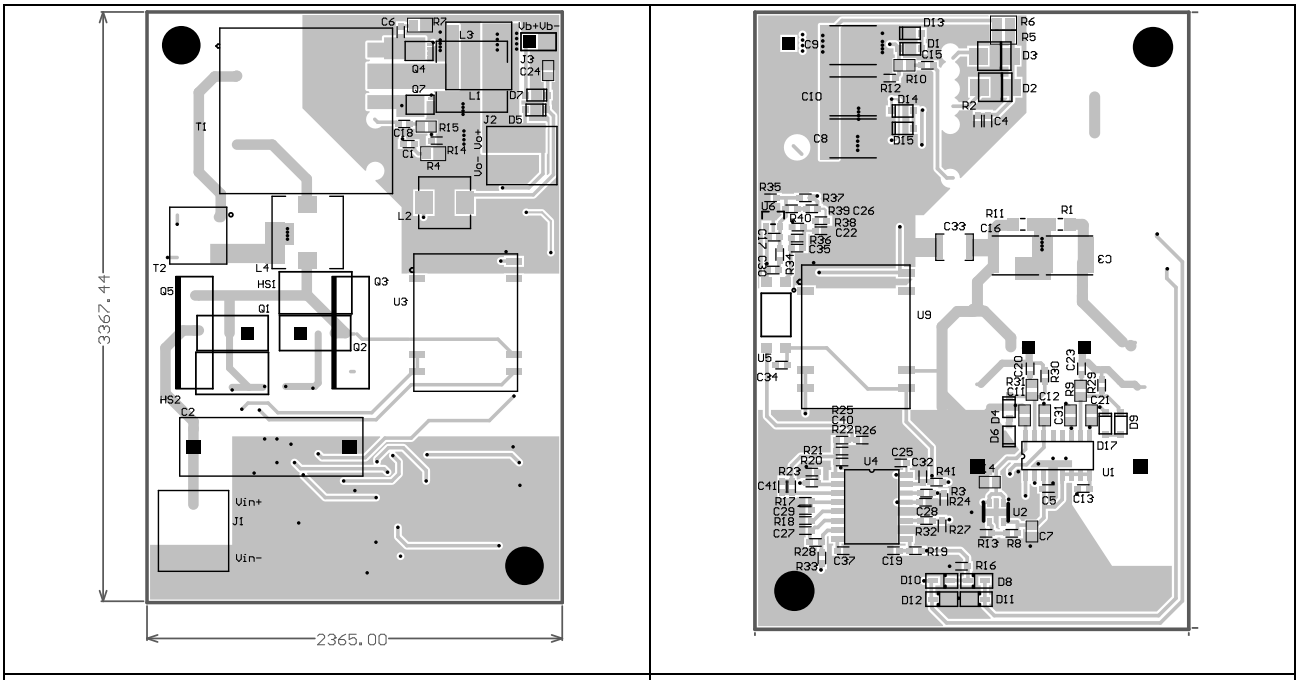

Figure 3. 100W 800V to 12V Buck Converter PCB

Results

Only a cursory evaluation of the current revision of the design has been completed with the main goal of demonstrating the high voltage/high frequency capability of NexGen's transistors. Typical waveforms are shown in figure 3 and a measured efficiency/regulation curve is shown in figure 4.

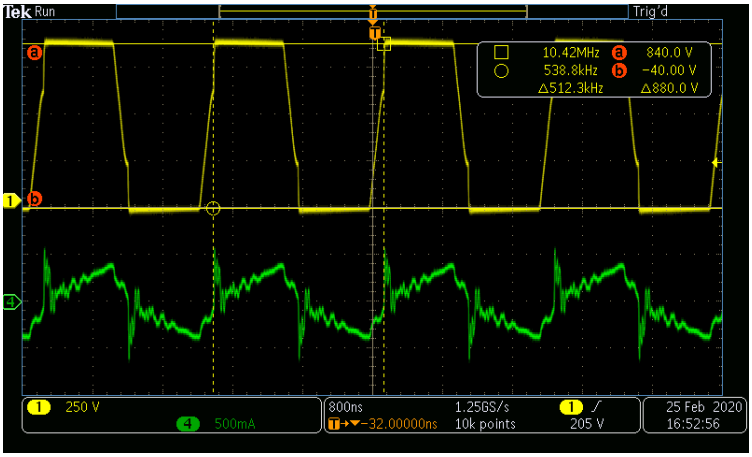

Figure 3. Typical Switching Waveforms. Top yellow (Primary transformer switch node), Bottom Green Primary transformer current.

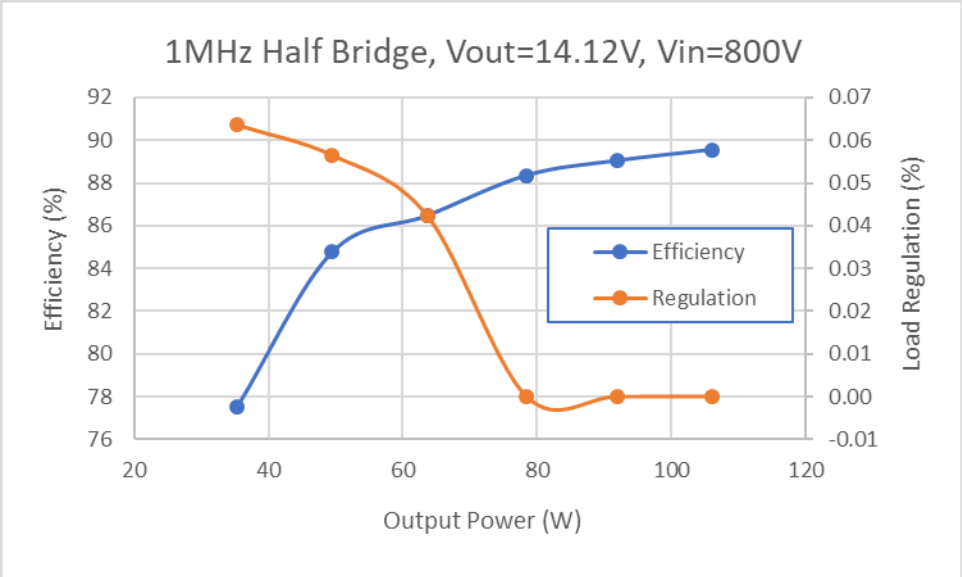

Figure 4. Converter Efficiency and Load Regulation

Further work will be done is detailed below.

1. Fully evaluate converter performance.
2. Optimize and fully characterize stability.
3. Retrofit for next generation of NexGen devices.
4. Examine converting to a secondary side synchronous controller for improved efficiency.
5. Examine potential for Improved ZVS with primary shim inductor and optimized dead time.
6. Cost reduction examination.
7. Use results to design high power version.

References

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