High Voltage Gallium Nitride Devices for Inverters

Gallium Nitride (GaN) devices now demonstrate higher efficiency in inverter circuits for both solar and motor drive systems and in power supply building blocks such as the DC/DC LLC and the PFC. The article investigates how GaN is making such rapid performance progress and uses test results to illustrate what is now possible using GaN compared to recent SiC transistor performance. It then predicts future improvements that will continue to make GaN a more attractive alternative to either Si or SiC for high efficiency systems. **Umesh Mishra and Yifeng Wu, Transphorm Inc., Goleta, USA**

For the past four decades, the Silicon MOSFET designers have accomplished great results in density by converting from planar designs to trench and then decreasing the size of the trenches which reduces the specific on-resistance while increasing the capacitance.

At high voltage the super junction devices were created to reduce the EPI portion of the conduction losses of high voltage devices while again increasing the capacitance and changing its characteristics in the circuit. Subsequent generations of super junction devices minimized this capacitance problem in hard switched applications. Subsequent generations focused on either hard switched or soft switched in order to optimize the performance trade-offs specifically for that application. While recent improvements in super junction silicon devices reduce the output capacitance by 20 % and the reverse recovery charge Q_{rr} of the intrinsic body diode by 25 %, that is a far distance behind the effective Q_{rr} of the new GaN transistors which reduce Q_{rr} by 95 %. While GaN was behind SiC for power devices, its pace of progress has been rapid, overtaking that of SiC in many applications and thereby capturing the interest of systems manufacturers.

Rejecting some of the myths

When discussing the latest trends in HV GaN products is best to begin by rejecting some of the myths. First, dynamic on-resistance or current collapse has been eliminated for 600 V products back in 2009. Second there were many people who believed that it was not possible to make and qualify 600 V GaN on Silicon. With the recent JEDEC qualification of Transphorm's first generation of GaN-on-Si devices, we believe that has also been laid to rest as well as the issue that dislocations would prevent such an accomplishment.

The initial 600 V products include both diodes and GaN high electron mobility transistors (HEMT). The TPH3006PS HEMT combines low switching and conduction losses to reduce energy loss by 50 percent compared to conventional Silicon-based power conversion designs. The TO-220-packaged GaN transistor features low on-state resistance of 150 mΩ, low reverse-recovery charge of 54 nC and thus high-frequency switching capability. As illustrated in Figure 1, the HEMT is capable of switching 400 V in 3.5 ns. It is this fast switching that makes the higher performance achievable. While fast switching is expected with GaN devices, the low capacitance of the GaN HEMT improves the performance in resonant switching more than expected.

Also available in industry-standard TO-

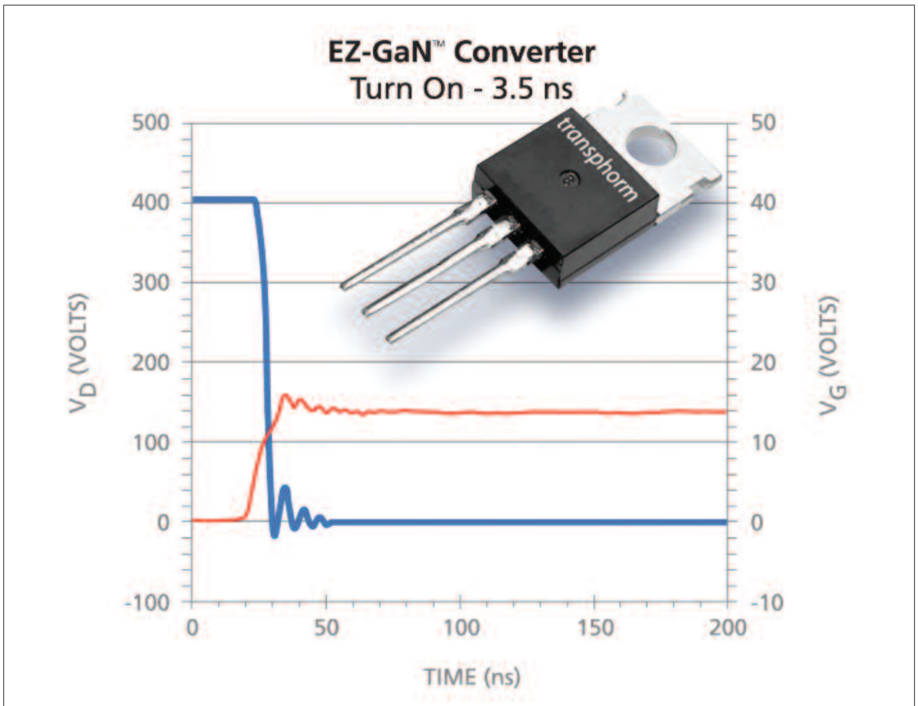

Figure 1: Switching characteristics of the TPH3006PS HEMT

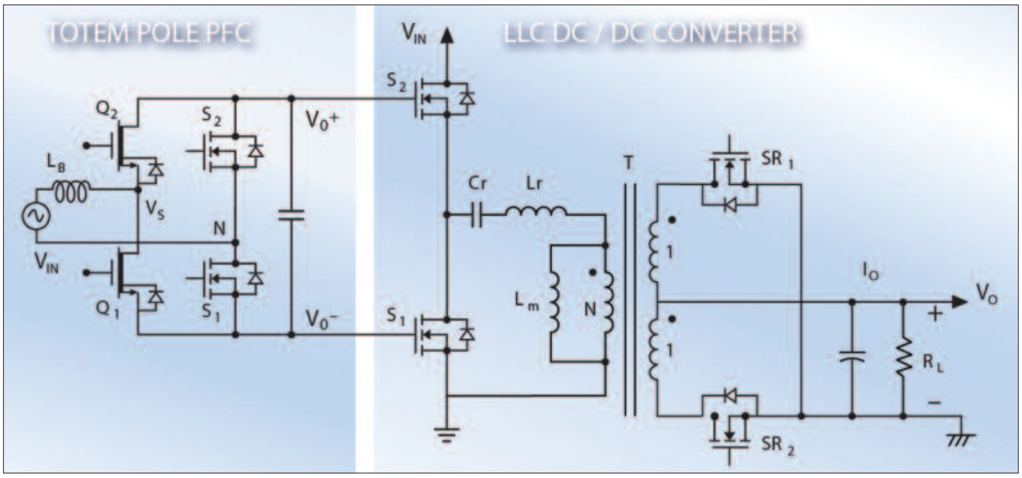

Figure 2: Off-line 1 kW 48 V power supply reaches a peak efficiency of 97.5 percent utilizing GaN devices

220 packages, the TPS3410PK and TPS3411PK GaN diodes offer 6 A and 4 A operating currents, respectively, with a forward voltage of 1.3 V. In addition, three application kits – PFC (TDPS400E1A7), Daughter Board (TDPS500E0A) and Motor Drive (TDMC4000E0I) – are available for rapidly benchmarking the in-circuit performance.

High-efficiency applications

With the implementation of a high efficiency off-line 1 kW 48 V power supply a peak efficiency of 97.5 percent has been demonstrated . The power supply design utilizes a 99 % efficient totem pole power factor correction (PFC) front end, combined with a 98.6 % efficiency LLC converter (Figure 2). A prototype circuit has been displayed at the PCIM Europe Conference and Exhibition.

Conclusion

GaN devices for high voltage have now moved out of the lab and into systems providing designers new tools with which to continue enabling greater systems performance. The completion of qualification of GaN at 600 volts clearly dispels several myths that were previously repeated in order to predict a very limited opportunity for GaN.

Literature

"Latest High Voltage GaN Devices for Inverters", PEE Special Session Power GaN for Highly Efficient Converters, PCIM Europe 2013, Nuremberg