GaN-on-Si Based FETs Foster New Applications

by Ashok Bindra, Technology Writer, Technika

Although, for the last few years, there has been a lot of talk about gallium nitride (GaN) based power transistors displacing the entrenched silicon MOSFETs, it might take some time before the emerging gallium nitride on silicon (GaN-on-Si) based power FETs enter the mainstream power conversion space. However, in the meantime, a handful of emerging applications are poised to tap the benefits of this promising power technology. Besides commercial availability with high reliability, there are a number of unique GaN characteristics that are fostering these new applications.

Some of these emerging applications exploiting the attributes of GaN technology include wireless power transmission, RF envelope tracking, rad hard satellite and avionics power supplies, and light detection and ranging (LIDAR) among others. In addition, high-stepdown-ratio buck converters that must be operated in the megahertz range without compromising efficiency are also taking advantage of the technology.

Wireless power transmission and RF envelope tracking systems, for instance, are utilizing a distinctive blend of high-frequency operation with high-power and high-voltage capabilities. While power systems for satellite and avionics applications are making the most of GaN transistors' rad hard qualities, precision current sources are using GaN devices to generate high-current millisecond pulses to drive pulsed laser diodes. And, for mobile applications that require ultra-high power density and efficiency simultaneously, traditional dc-dc converters are incorporating GaN FETs operating at several megahertz in resonant mode.

While the concept has been around, the rapid adoption of wireless energy transfer in commodity products such as mobile phone chargers is relatively new. In such wireless charging applications, highly resonant converters operating in the lower ISM band at 6.78 MHz are used to power the magnetic coils on the transmitting side. The 6.78 MHz for wireless charging systems was recently standardized by the Consumer Electronics Association and Alliance for Wireless Power (A4WP). At such high frequencies, traditional MOSFET technology is approaching its limits. But, this high-frequency operation is ideal for enhancement-mode GaN (eGaN) FETs, according to Efficient Power Conversion (EPC) CEO Alex Lidow, the co-inventor of the HEXFET power MOSFET.

In fact, using WiTricity's magnetic coils, EPC has demonstrated an experimental high-efficiency resonant wireless power transfer system using eGaN FETs. The power converter implemented in this system is a class-D power amplifier operating at 6.78 MHz (Fig.1). It is believed that next year wireless charging systems utilizing eGaN-powered WiTricity technology will begin to enter the market.

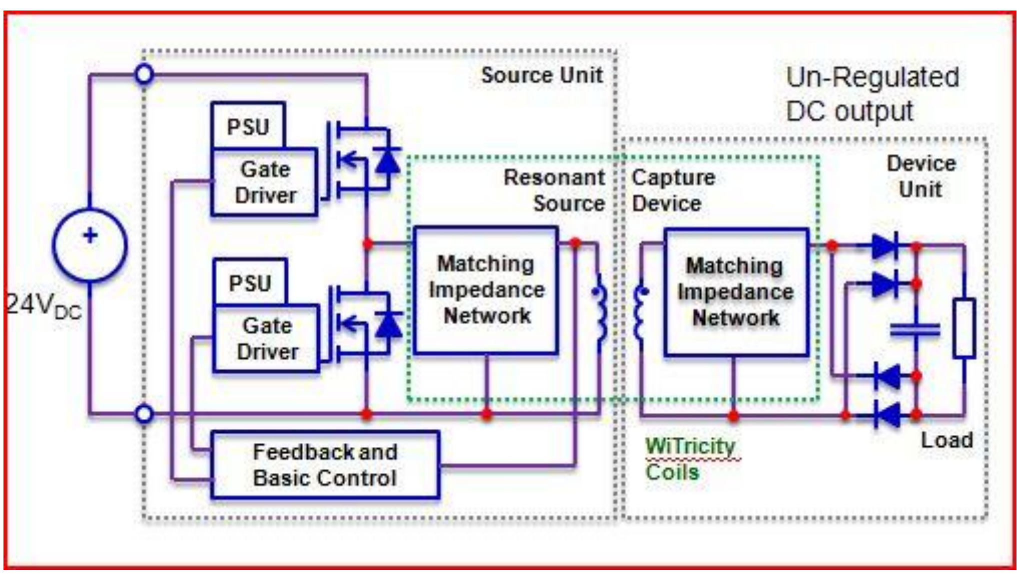

Fig. 1. Wireless power transfer system based on EPC's enhancement-mode gallium nitride (eGaN) FETs. The power converter implemented in this system is a class D power amplifier operating at 6.78 MHz.

Another application that GaN is enabling is envelope tracking (ET) in wideband RF power amplifiers. ET promises to deliver high efficiency across the frequency range of the wideband RF power amplifiers that are being used in modern multi-mode and multi-band cell phones and base stations. For that, it needs a high-efficiency power supply that can respond quickly to the voltage requirements of the broadband PA whose peak-to-average power ratio (PAPR) can be as high as 10.

With a fixed supply, a typical broadband PA can achieve efficiency as high as 65%, but with PAPRs as high as 10, the average efficiency is likely to drop below 25%. Through modulation of the PA supply voltage, this can be improved to over 50%—essentially doubling the efficiency and reducing PA losses by two thirds, which lowers the cost of operation and cooling requirements tremendously.

EPC has demonstrated that an eGaN FET-based multiphase buck converter can efficiently meet the fast-changing voltage requirements of ET functions deployed in multi-band base stations. EPC engineers have shown that such modulated multiphase buck converters offer over 97% efficiency at 1 MHz and over 94% at 4 MHz (Fig.2.)

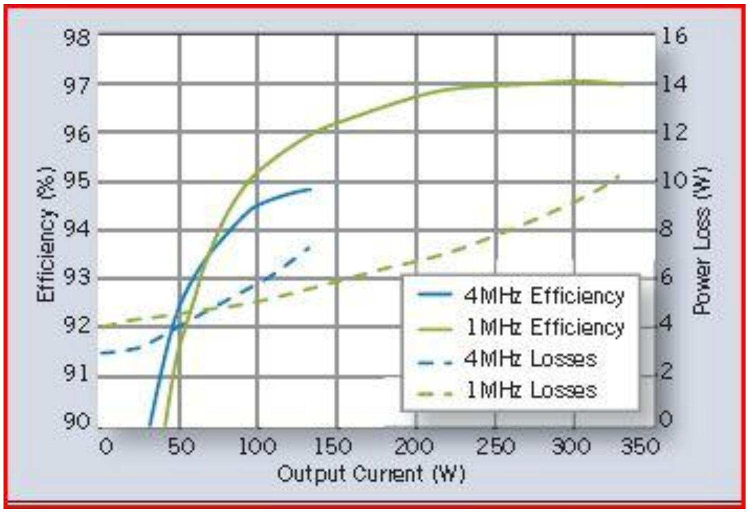

Fig. 2. EPC engineers have shown that eGaN-based modulated multiphase buck converters can efficiently meet the fast-changing voltage requirements of envelope tracking deployed in broadband RF power amplifiers.

Applications such as satellite communications and avionics require power supplies that must work under harsh conditions and in high-radiation environments. Because GaN transistors are inherently more radiation tolerant than silicon, they lend themselves very well to these applications. EPC engineers have characterized the stability of eGaN FETs under radiation exposure. In so doing, they have shown that second-generation eGaN FETs have much higher tolerance to single event effects (SEE) and can withstand a total ionizing dose up to 1 MRad.

According to tests conducted at Texas A&M's K500 Superconducting Cyclotron, three EPC eGaN types (EPC1005, EPC1014 and EPC1015) proved capable of withstanding the maximum un-degraded Linear Energy Transfer. In essence, studies have shown that eGaN is an order of magnitude better than silicon MOSFETs in terms of radiation tolerance, asserts Lidow.

Comparing the measured efficiency of rad hard eGaN FETs versus rad hard silicon MOSFETs in a 12-V input to 3.3-V output point-of-load (POL) converter switching at 500 kHz, EPC designers have demonstrated nearly 9 percentage points of improvement in efficiency for a rad hard POL converter using eGaN devices (Fig.3).

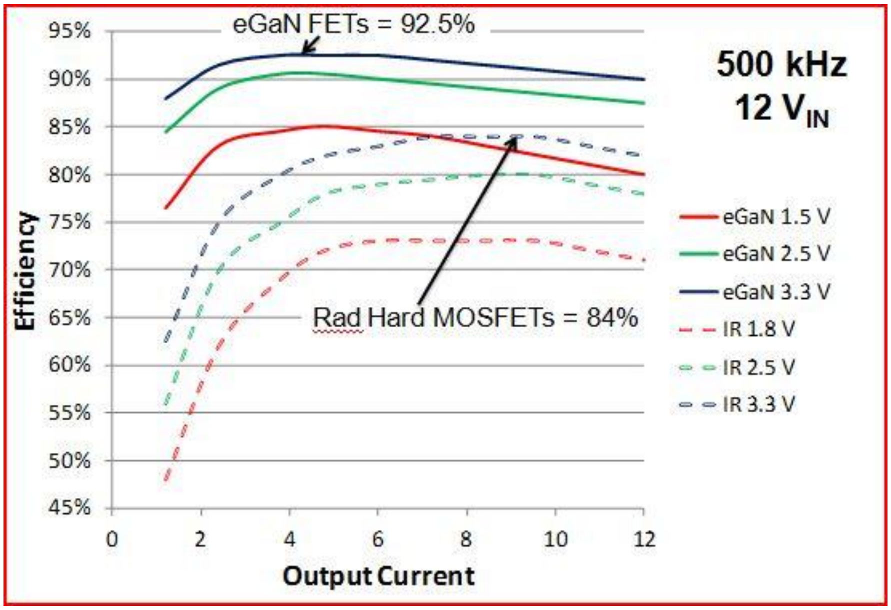

Fig. 3. Buck converters using radiation hardened eGaN FETs offer much higher efficiency compared to rad hard silicon MOSFETs.

Likewise, on the LIDAR front, Omnipulse Technology which specializes in ultra compact, precision current sources for driving pulsed laser diodes is exploiting the properties of the eGaN transistor to generate millisecond pulses up to 1,000 A into a very low impedance load (a few milliohms.)

According to Jay Philippbar, vice president of R&D at Omnipulse Technology, "eGaN devices are much simpler to drive compared to silicon MOSFETs. With good layout techniques we easily achieve a switching time of less than two nanoseconds. eGaN devices are easy to parallel and their small package size is ideal for miniaturization. Our latest product uses four eGaN devices which allow us to switch 300 A at 5 MHz on a time-limited basis. Our products have superior waveform quality due to the eGaN's much lower interelectrode capacitance," adds Philippbar.

Another area where GaN technology is making inroads is in telecom power. Although the intermediate bus architecture is popular in telecom systems, it is coming under pressure as system designers seek solutions to simplify power supply design while maintaining high system efficiency. They are looking for single-stage, high stepdown ratio point-of-load (POL) buck converters that can convert +48 V system bus directly to the POL voltages.

Until now, the technical limitations of the current silicon MOSFET technology and cost concerns have made it impractical to design such a POL and produce it commercially. However, recently introduced GaN power devices have overcome these hurdles, making it feasible to build POLs with the high stepdown ratios needed to generate 1 V or less directly from a 48 V bus.

About The Author

Ashok Bindra is a veteran writer and editor with more than 25 years of editorial experience covering RF/wireless technologies, semiconductors and power electronics. He has written, both for print and the web, for leading electronics trade publications in the U.S, including Electronics, EETimes, Electronic Design and RF Design. Presently, he has his own technical writing company called Technika through which he does writing projects for different trade publications and vendors. Prior to becoming an editor, Bindra worked in industry as an electronics engineer. He holds an M.S. degree from the Department of Electrical and Computer Engineering, Clarkson College of Technology (now Clarkson University) in Potsdam, NY, and an M.Sc (Physics) from the University of Bombay, India. He can be reached by email at bindra1[at]verizon.net.