Gallium Nitride Transistors Drive Automotive Applications

Enhancement-mode gallium nitride transistors have been in production for over five years. As the technology has matured it has been adopted into a number of automotive applications such as cockpit wireless charging, LiDAR sensing, and EV charging with many more to follow. **Alex Lidow, CEO Efficient Power Conversion Corporation, USA**

Mobility has become a major theme for the consumer during this century. Smart phones allow us to take our music, games, movies, television shows, contacts, and our internet with us at all times. Applications such as Google Maps give us directions, tell us about traffic, and provide us with street and satellite images of our destination. Recently the automobile industry has caught on to this trend and has begun to show its vision of the future for the fully-mobile lifestyle. The dashboard is being taken over by the smartphone, the car is being taken over by sensors and computers to become semi, and eventually, fully autonomous. And, our cars are going semi, and eventually fully electric.

Power devices made with Gallium Nitride are an integral part of every aspect of this mobility trend. These new generation power devices have already carved out a significant position in the next generation automobile.

Electric drive

The automotive industry is evolving from vehicle propulsion that relies only on an internal combustion engine, to hybrid vehicles, plug-in hybrids, and, finally, fully electric cars. The demand for electricity grows in proportion to the amount of propulsion handled by the electric motor. For example, the Tesla S delivers 416 hp, or 310 kW of electrical power to the rear wheels. Delivering that much power requires higher voltages in order to keep the current levels flowing through the motor windings at a manageable level, with minimum conduction losses. Today the dominant transistor in electric or hybrid vehicle propulsion systems is the insulated gate bipolar transistor (IGBT) in voltages ranging from 500 V to 1200 V.

Wide bandgap (WBG) transistors made in either SiC or GaN technology hold great promise for this high power application because of their ability to block higher voltages with lower conduction losses compared with Silicon transistors and, potentially, their ability to operate at much higher temperatures. Motor drives operate at frequencies between 17 kHz and 100 kHz. The IGBT has a high saturation forward drop and stored charge, and the reverse conduction diode has a high stored charge. While the IGBT/ultrafast diode combination outperforms the silicon MOSFET, both GaN and SiC transistors have the capability to significantly increase the efficiency of these motor drives.

Figure 1 gives a conceptual graph showing the power levels and voltage levels that are best served by different types of transistors including IGBTs, GaN transistors, and SiC transistors. The requirements for electric drives sit right at the interface between GaN, SiC and IGBT technologies. Ultimately, the cost and reliability of the system will determine the winner of this application.

Wireless power transfer

Wireless power transfer was first demonstrated over 100 years ago. However, only in this century have we demonstrated safe, economic, convenient, and efficient wireless power transfer techniques. The latest techniques enable wireless charging of multiple objects within a distance of several centimeters from the power transmission unit (PTU) with efficiencies above 80 % (Figure 2). Wireless phone charging in a car is becoming more critical as the smartphone itself is becoming the information receiver and router for the dashboard infotainment center. Several automotive manufacturers are adopting operating system standards that enable seamless Android or iOS interfaces to dashboards that become slaves to the information and entertainment available in the smartphone. As a consequence, usage of wireless network data as well as the battery power will go up significantly.

Several automotive manufacturers are also planning to embed wireless charging stations in the center console of the vehicle so smartphone, as well as other mobile devices, can remain charged despite intense and continuous usage while the automobile is in operation. Given that the reference (Rezence) standard uses a 6.78 MHz standard frequency for power transmission, GaN is the heavy favorite for adoption over the slower and less efficient silicon power

Figure 1: Current and voltage ranges where various power semiconductor technologies are the most likely to be applied

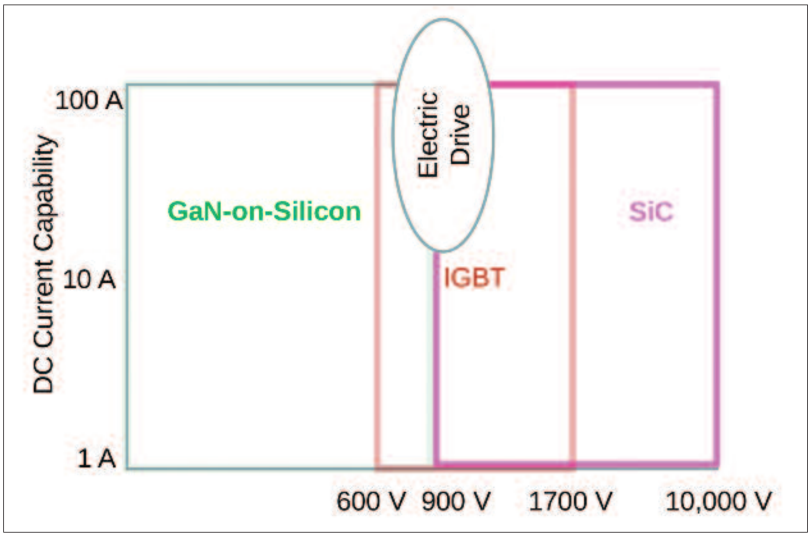

Figure 2: Wireless power transfer will be used in automobiles to keep smartphones charged despite continuous usage as part of the infotainment system

MOSFET in these applications.

Wireless charging for electric vehicles is also becoming more available as fully-electric cars become more prolific. Whereas there is no universal standard yet, loosely coupled magnetic energy transfer, similar to the method used in the Rezence standard is common to all implementations due to its ability to transfer power without precise alignment of transmitter and receiver units. GaN is certainly a good candidate technology for this application as well.

Autonomous control

It is critical that a car know what is around it at all times in order to prevent collisions. The higher the speed of the vehicle, the faster the system needs to sense, and the more precisely it needs to interpret the distance to the potential collision. Today automotive manufacturers use a variety of sensors in these functions, including ultrasonic sensing, microwave radar, short range radar, and video pattern recognition. Light Distancing and Ranging (LiDAR) sensors have only recently begun to emerge in automotive sensing applications. Initially LiDAR sensors were used to generate digital maps used for mapping and navigation software. Because LiDAR chases the speed of light for resolution, eGaN FETs, with about a 10 times advantage in switching speed over Silicon, have been used almost exclusively in these mobile applications.

The imaging speed and depth resolution has become so good with eGaN FETs that manufacturers experimenting with autonomous vehicles are using these same types of LiDAR sensors used for mapping for their driverless navigation systems. In addition, several automakers are incorporating eGaN FET-based LiDAR sensors in their vehicles for general collision avoidance and blind spot detection.

Conclusions

The around 70 million annually manufactured cars presents a huge potential market for any technology that can improve the customers' automotive experience. Infotainment mobility through wireless charging and autonomous vehicles enabled by LiDAR sensors are two areas that will infiltrate the automotive world over the next few years. Both of these applications rely on the higher speed and low cost of GaN transistors. In the future, as electric vehicles become more ubiquitous, motor controls might also become an enormous market for GaN transistors, depending upon the cost structure of higher voltage GaN transistors compared with today's IGBTs or tomorrow's SiC transistors.

Literature

Lidow, A: "Enhancement-Mode Gallium Nitride Transistors in Automotive Applications", PCIM Europe 2015, Special Session "Power GaN in Automotive Applications"

Monolithic Gallium Nitride Half Bridge

EPC has designed the EPC2105, a 80-V enhancement-mode monolithic GaN transistor half bridge. By integrating two eGaN power FETs into a single device, interconnect inductances and the interstitial space needed on the PCB are eliminated. This increases both efficiency (especially at higher frequencies) and power density, while reducing assembly costs to the end user's power conversion system. The EPC2105 is intended for high frequency DC/DC conversion and enables efficient single stage conversion from 48 V directly to 1 V system loads.

Each device within the EPC2105 half-bridge component has a voltage rating of 80 V. The upper FET has a typical $R_{DS(on)}$ of 10 mΩ, and the lower FET has a typical $R_{DS(on)}$ of 2.3 mΩ. The high-side FET is approximately one-fourth the size of the low-side device to optimize efficient DC/DC conversion in buck converters with a high V_{IN}/V_{OUT} ratio. The EPC2105 comes in a chip-scale package for improved switching speed and thermal performance, and is only 6.05 mm x 2.3 mm for increased power density.

The EPC9041 development board (2" x 1.5") contains one integrated half-bridge component using the TI LM5113 gate driver, supply and bypass capacitors. The board has been laid out for optimal switching performance and there are various probe points to facilitate simple waveform measurement and efficiency calculation.

First EPC 80-V enhancement-mode monolithic GaN transistor half bridge