A Technology Conquers Power-Hungry Applications

Gallium nitride (GaN) power devices have opened many new applications since their commercial availability began in 2010. The superior switching speed of GaN devices and, as a result, their low switching losses, gave the starting signal for the development of new applications such as lidar (light detection and ranging) sensors and resonant wireless power. In the midst of a multitude of such innovative applications, a strong value chain with low production costs and extremely reliable products grew up. As a result, even more conservative, budget-conscious developers in cost-sensitive application areas, such as power supplies and the automotive industry, felt motivated to evaluate GaN power devices for their designs. **Tobias Herrmann, FAE and Jieyi Zhu, Line Manager EPC at Finepower, Ismaning, Germany**

For a new technology to establish itself on the market, it must meet four criteria: It must enable new applications, be easy to use, be lower cost, and be highly reliable.

Available GaN components today are 5 to 50 times better than state-of-the-art silicon solutions. This performance advantage has led to new applications that only became possible with GaN technology. One such application is lidar, a high-resolution sensing technology used for autonomous cars, augmented reality, industrial automation and drones. The second attribute that a new technology needs to establish itself is its ease of use. GaN-based power converters offer higher efficiency, higher power density and lower total system cost than Silicon-based alternatives. The ecosystem of supporting components such as gate drivers, controllers and passive components is growing continuously.

Cost is equally important for a new technology to displace an entrenched technology. GaN transistors and integrated circuits are produced using processes similar to silicon power MOSFETs, have many fewer processing steps than MOSFETs, and more devices are produced per manufacturing run because GaN devices are much smaller than their Silicon counterparts. In addition, lower voltage (<500 V) GaN transistors do not require the costly packaging needed to protect their Silicon predecessors. This packaging advantage alone can cut the cost to manufacture in half and, combined with high manufacturing yields and and smaller device size, has resulted in the cost of a GaN transistor from EPC to be lower in cost than a comparable (but lower performance) Silicon power MOSFET.

Finally, GaN components easily meet the reliability criterion: they not only pass the JEDEC standard tests for semiconductors, but in many cases also the more stringent qualification requirements of the automotive industry (AEC Q101). In addition, EPC's eGaN® transistors and ICs in chip-scale packaging are free from the typical failure mechanisms inherent in traditional MOSFET packaging techniques.

Entering conservative and cost-sensitive applications

These superior properties are increasingly prompting developers in more conservative and cost-sensitive applications such as power supplies and automotive to take a closer look at GaN devices. An example of such an application is 48 V DC/DC converters.

Such converters are used in many areas of the electronics industry. For example, the advent of 5G and the explosion of data for hyperscalers, cloud-based data centers, and artificial intelligence demand more power in much smaller form factors. Due to the significant improvements GaN offers in switching performance and size reduction, power supply designers are realizing that GaN FETs and ICs make higher power density and more efficient 48 V power supplies.

Likewise, in the automotive industry, GaN transistors are becoming the power technology of choice for the design of compact systems for 48 V supply in hybrid, mild hybrid, and plug-in hybrid vehicles. They enable the development of lighter and at the same time more cost-effective systems.

Why 48 V for cars?

With the emergence of autonomous cars

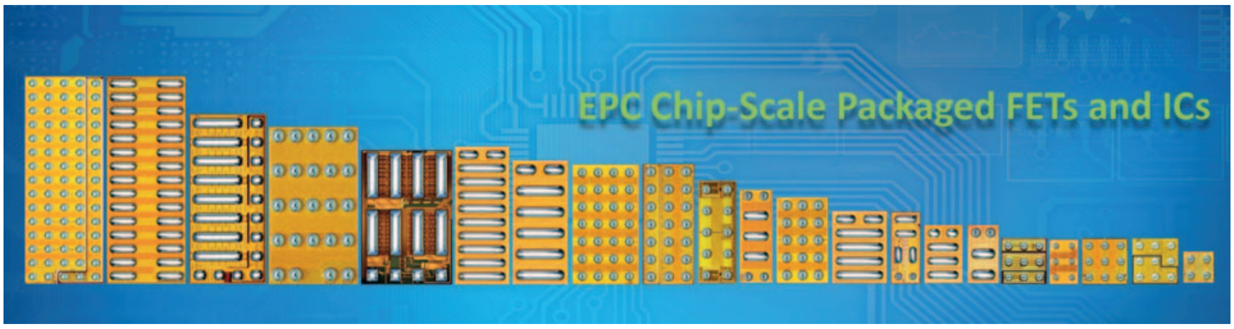

Figure 1: **Line-up of EPC's chip-scale GaN power FETs and ICs**

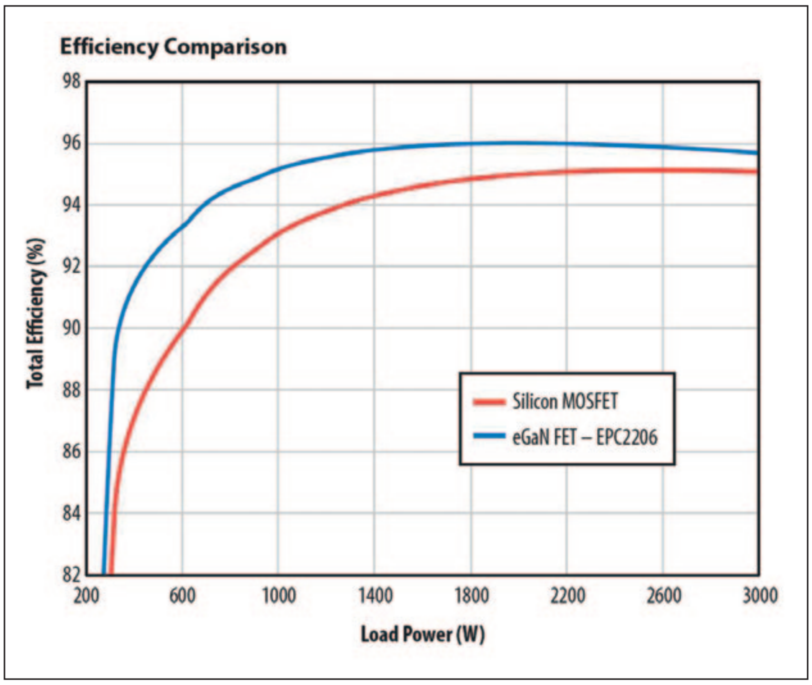

Figure 2: Efficiency comparison of eGaN FET vs. Silicon MOSFET in a 48 V to 12 V, 3 kW system

and electric propulsion, the automotive industry is facing a massive transformation. IHS Markit estimates that 12 million cars will drive autonomously by 2035. According to Bloomberg New Energy, 32 million cars are expected to have electric drives by that year. Both trends will significantly increase the demand for power semiconductors.

In the car, it is the innovative but power-hungry electronically controlled functions and features that require a 48 V power supply. These include start/stop systems, electric steering, and turbochargers, electronic chassis controls, and electronically controlled air conditioning, to name just a few examples. The intelligent control systems of (partially) autonomous vehicles also require sophisticated sensor technology such as lidar, radar, and cameras, as well as powerful graphics processors. All these systems increase the power consumption in the car. In particular GPUs are very energy-hungry and represent a major additional load on the car's traditional 12 V power supplies. For 48 V automotive power systems, GaN technology increases the efficiency, shrinks the size, and reduces system cost (Figure 2).

For applications in autonomous and assisted driving, where lidar systems serve as the "eyes" of the vehicles, very short laser pulses of the order of a few nanoseconds are used to achieve the required distance resolution. These pulses are typically generated by a laser diode. To achieve a sufficient range, the optical peak power must be high, i. e. current peaks of a few 10 A up to a few 100 A are involved. Until now, this has required complex circuits and exotic, expensive semiconductors.

A typical lidar pulsed laser driver uses a semiconductor switch in series with the laser source and a power supply. Limiting factors for system performance are stray inductances and the speed of the semiconductor power switch. In recent years, low-cost GaN power FETs and ICs have come on the market that offer significantly lower inductance while providing switching frequencies up to 10 times higher than comparable Silicon MOSFETs.

The advent of GaN FETs and ICs makes it possible to achieve the desired performance with simple, space-saving circuits at low cost. The greatly improved performance of GaN FETs compared to Silicon MOSFET technology results in much faster switching for a given peak current capability, enabling currents >100 A and pulse widths <2 ns with one laser load.

Automotive electronics can now take full advantage of the improved efficiency, speed, smaller size, and lower cost of eGaN devices. EPC has a growing line of products that have achieved AEC Q101 qualification. To complete AEC-Q101 testing, these eGaN FETs had to undergo rigorous environmental and bias-stress testing. Of particular note is the fact that these wafer level chip-scale devices passed all the same testing standards created for convention packaged parts.

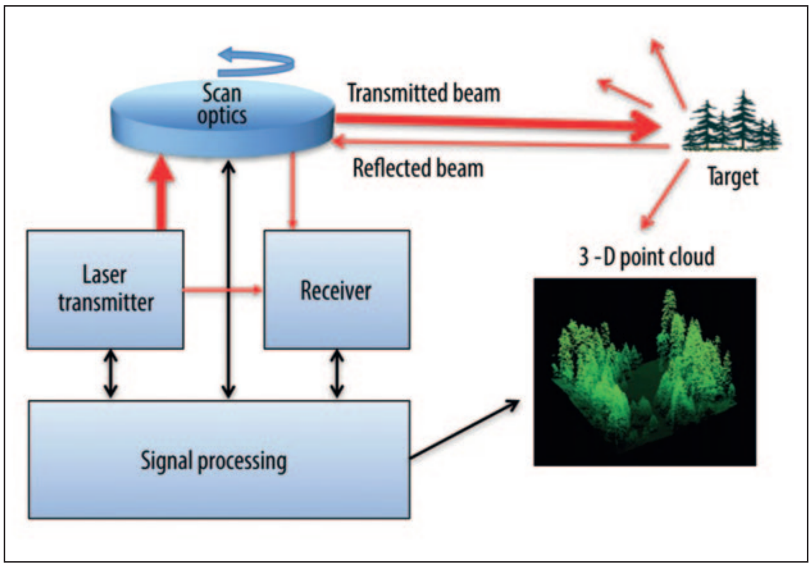

Figure 3: Overview of a typical lidar system

GaN in precision motor drives

Low cost, high-precision motor drives are finding expanding use in applications such as industrial automation, robotics, drones, and emobility such as scooters and ebikes. The brushless direct current (BLDC) motor offers these applications a lot of power in a small installation space, precise control, and a high electromechanical efficiency while generating only minimal vibrations.

BLDC motors are driven by inverter circuits, most of which are multiphase and traditionally use MOSFETs. The higher switching speed of GaN FETs and ICs compared to Silicon MOSFETs allows the construction of converters with a much higher switching frequencies. This not only benefits efficiency, but also

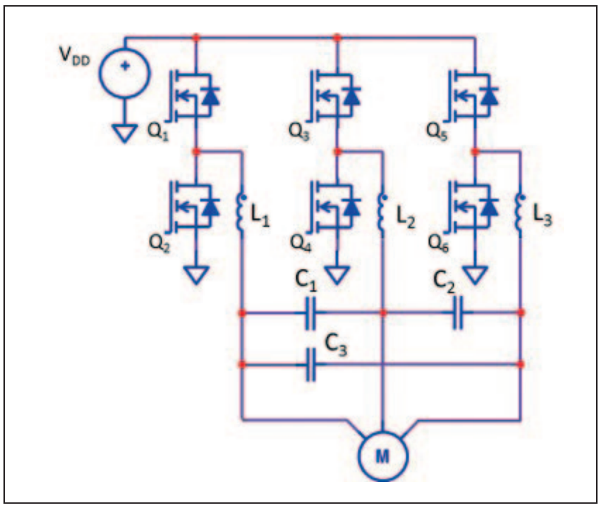

Figure 4: Typical 3-phase motor drive with filter

enables higher positioning accuracy. The advantages of GaN for high precision motor drives include the ability to get higher output in a smaller sized solution, faster response time, lower torque ripple, lower EMI generation, and lighter weight motors.

GaN integration

The greatest opportunity for GaN to impact the performance of power conversion systems comes from the intrinsic ability to integrate both power-level and signal-level devices on the same substrate. EPC has been been developing GaN technology from the original discrete devices to monolithic half-bride deivces to power FETs that include their own monolithically integrated driver.

Additionally, EPC has been developing customer specific GaN ICs for the past several years. The general release of more complex monolithic GaN solutions will offer in-circuit performance beyond the capabilities of Silicon solutions and enhance the ease of design for power systems engineers.

Conclusion

All in all, GaN components serve a wide range of technically challenging applications with very high growth potential. Today's GaN FETs are improving rapidly in performance and the current benchmark devices are still 300 times away from their theoretical performance limits. EPC has been shipping GaN transistors for a decade with over 100 billion hours of field experience with fewer failures than the mature power MOSFET.

Finepower supports developers in technical questions regarding EPC components as well as logistical issues with an appropriate stock level and demand-oriented delivery for series production.