Power GaN Can Revolutionize the Industrial World

Industry 4.0 brings rise to an era of smart factory floors that synergize mass production capabilities with automation, robotics, and M2M communication. Modern factories and industrial spaces must be increasingly intelligent and efficient with capital, costs, and energy, whether it's for pharmaceuticals, chemical, transportation, medical devices or fulfillment centers. However, power system design is reaching the theoretical limits of Silicon-based power devices. With its smaller, more energy-efficient and cost-effective capabilities, gallium nitride (GaN) plays a leading role in Industry 4.0. **Paul Wiener, VP Strategic Marketing, GaN Systems, Ottawa, Canada**

Two major application areas in the next industrial revolution are motors/motor drives and robotics/robots. GaN-based design and technical features in these areas keep factories competitive, flexible, efficient and optimized as we meet growing customer demands.

Motors and drives

Motors and the motor drives that harness and control industrial motion are the hidden workhorses of Industry 4.0. They are embedded in a variety of applications, including robotics, storage and retrieval shuttles, bulk conveying, packaging machines and fabrication systems. In robotics, servo motors in every joint of a robot are used to actuate movements, enabling precise angles in a robot arm. On conveyor belts, servo motors move, stop, and start products along various stages of an assembly line, such as for packaging and labeling. In fabrication, metal cutting, and metal forming machines, servo motors provide precise motion control for milling machines, lathes, grinding, centering, punching, pressing, and bending metal — from jar lids to automotive wheels.

With such a variety of applications, motor and motor drives are challenged with energy efficiency and design flexibility. The stakes are global: industrial markets account for 40-50 % of electricity used in the world, with motors using two-thirds of that. Today, there are 300 million motors in the industrial segment with 10 % annual growth. Insulated Gate Bipolar Transistor (IGBT) motors drives are not highly efficient when it comes to power conversion and use, with up to 30 % energy loss. GaN addresses this challenge.

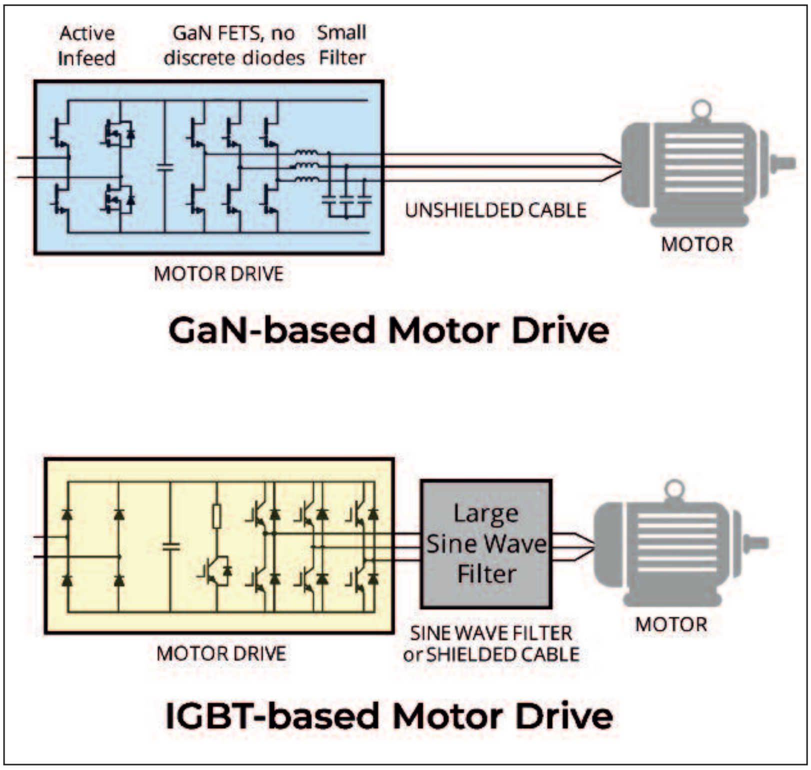


Figure 1: GaN-based and IGBT-based motor drive schematics

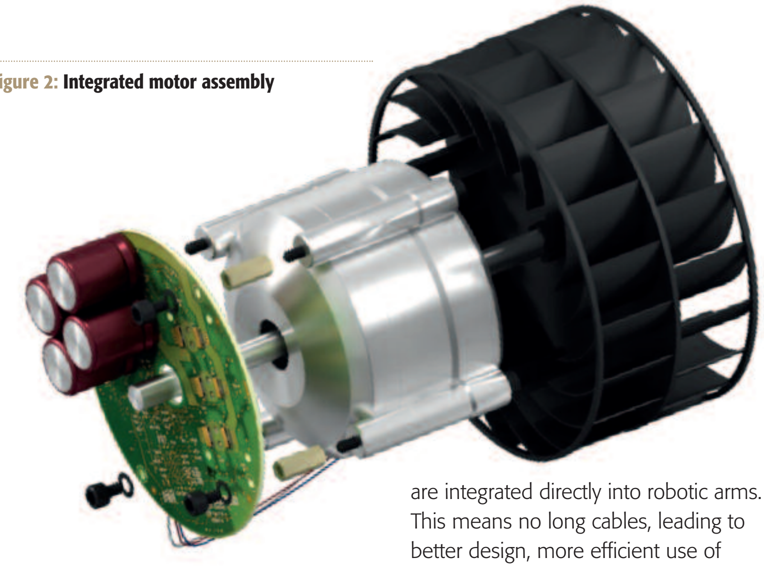
GaN-based versus IGBT-based motor drives

One of the advantages GaN has over IGBTs in this applications is that the motor drive can be up to two times smaller because of lower losses. Efficient higher switching frequency offers savings in costs and cabinet space. These features mean the drive module can fit an active infeed and LC filters, as highlighted in Figure 1a. The active infeed allows for smaller, cheaper filters and no braking chopper while meeting harmonics requirements with regeneration. There are also the advantages of no acoustic noise, built-in sinusoidal output filter, and increased system efficiency of 98 % (versus 92 % with IGBTs). These features lead to quieter operating environments, smaller size, lower operating costs, and the ability to use long, unshielded cables. These cables offer more flexibility and lower costs while increasing the motor lifetime and having an easy-to-use inverter.

Drive size is further reduced because GaN does not require additional SiC freewheeling diodes, as shown in Figure 1b. GaN drives have heatsinks that are 40-70 % smaller – or there is no heatsink at all – with two times more power density. Altogether, GaN offers 40-60 % smaller devices and 10-20 % lower costs.

An example of design flexibility in practice is demonstrated in an integrated motor assembly design (Figure 2). This

Figure 2: **Integrated motor assembly**



assembly has voltage and current feedback for each of the three-motor phase control half bridges, up to 1.5 kW at 300 V, and five times the power density of existing 12 V BLDC motor controllers. The elegance of this design lies in a motor assembly that creates one motor controller for all voltages and a simple interface of power, communication, and ground. This is a low-cost universal design that is part of the future of motor drives.

Robots and robotics

GaN power transistors advance robot and robotic performance in three important areas: size, precision, and autonomy. Today, power conversion and motor drive components of robotic arms can be so large that they are located in separate cabinets distant from the arm on the assembly line. This requires expensive cables and sub-optimal layout. GaN's size and power conversion efficiency enables motor drives and power conversion that are integrated directly into robotic arms. This means no long cables, leading to better design, more efficient use of facilities, and, ultimately, lower operating costs.

With Industry 4.0, there is a growing need for more complex robotics with multiple motors working simultaneously in an orchestrated and controlled manner. In all industrial applications, precision, flexibility, dexterity, and speed are critical; whether it's for small parts assembly, part transfer, part presentation, dispensing, or packaging. GaN-based power systems address these next generation requirements. Multiple motors working simultaneously require improvements in motor drive control. GaN-powered semiconductors in robotics increases the motor control precision by reducing or eliminating mechanical vibration. Furthermore, GaN enables hardware switching with a figure of merit (FOM) that is 10-13 times better than today's Silicon MOSFETs. Motor drives operating at higher frequencies and efficiencies deliver increased control bandwidth for the motor.

The business operating results are 1) faster response times from incident detection to action and 2) higher real-time precision positioning and control with extensive degrees of freedom and dexterity, as illustrated in Figure 3.

Autonomy and wireless charging

In current industrial environments, humans work with robots to control the processes and optimize decision-making. However, robots are becoming increasingly autonomous and mobile. When we consider how we get to true robotic autonomy, wireless charging is a significant part of the answer, as depicted in Figure 4.

For wireless power transfer (WPT), GaN again has an significantly advantage over Silicon-based solutions. GaN-based power systems result in higher power transfer capabilities of up to 1 kW versus 15 W with Silicon, and device spatial freedom in X, Y and Z axes that enables air gaps up to 200 mm between power transmitter and receiver. This means that devices can operate in harsh conditions with enhanced durability and maximum robot uptime. The problem with contact-based charging is that exposure to dust, moisture, and other debris negatively impacts performance and requires expensive maintenance. Wired power equipment is prone to failure and physical wear-and-tear, causing expensive robot downtime. With no power connectors to worry about, wireless charging systems can be sealed against dirty and corrosive environments. This makes operations possible in environments where wires are not possible or are unsafe, such as in mining or underwater operations. Having reliable power to wireless robots with high power levels and high degrees of positional flexibility optimizes productivity on a continuous self-charging cycle that never wears out.

Automated Guided Vehicle Systems

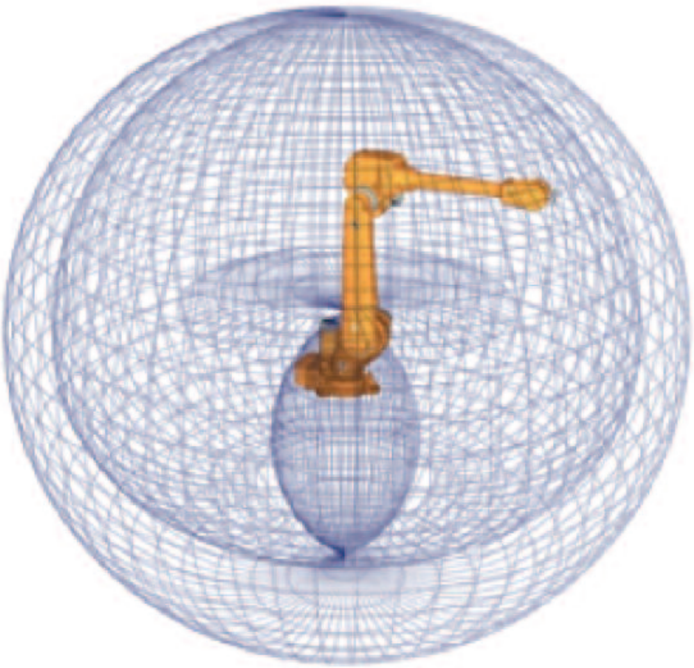


Figure 3: **Precision and performance are significantly enhanced with GaN-based drives**

Figure 4: Wireless power transfer in robotics enables high autonomy

(AGVS) are an example. AGVS's follow guided paths and have robotic arms that perform repetitive and precise tasks on assembly lines. To charge the vehicle in a wired environment, a human operator makes a physical connection with a docking mechanism. In a wireless environment, the vehicle parks itself over a charging pad, eliminating human intervention. Inefficiencies are mitigated further with no docking mechanisms, no failure-prone wiring and connectors, and no labor-intensive manual recharging. Finally, with such a low profile, wireless charging stations can be placed throughout a facility to provide "opportunity charging" for maximum robot uptime. Wireless charging allows mobile robots/AGVS to work efficiently and without interruption.

Conclusion

Industrial, governmental, and environmental pressures are changing how we make, move and package products. We operate in a world with hundreds of millions of motors, motor drives, robotics and robots that continuously require innovation to improve performance. With GaN, system designers have the ability to change motor drive design to be smaller and more energy efficient, robotics to have high precision, and enable true autonomy for robots. All of these actions will have an exponential impact on the revenue and environmental metrics of Industry 4.0.