

Developing next-generation electrified propulsion systems



John Martin, Founder and director, EMPEL Systems

When implementing electronic propulsion systems, one approach when designing for vehicles with vastly different design requirements and goals is to create a modular motor system that can scale.

These motor systems need to have high power density, be extremely compact, and deliver high performance. At [EMPEL Systems](#), we aim to integrate the traction inverter as much as possible with the motor and to have all components be as small as possible. From a wide range in motor diameters to the phase-current requirement and number of phases for the inverter, designing modular motor systems as shown in [Figure 1](#) unlocks flexibility for vehicle manufacturers and saves cost while reducing time to market.

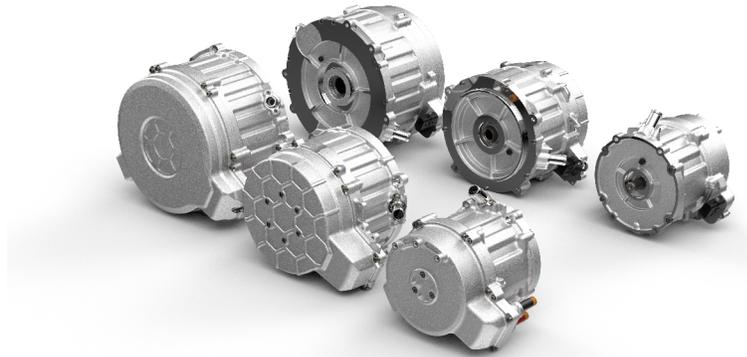


Figure 1. A modular automotive xEV propulsion system

Evolving semiconductor technology

The next generation of traction inverters will require more control, more performance, and more sophisticated sensing capabilities – partly to enable higher performance with greater control over the motor torque and electrical characteristics, and partly to support deeper levels of system monitoring and diagnostics. Beyond great performance, inverters like that shown in [Figure 2](#) should be able to deliver torque even when a significant subsystem is facing issues.



Figure 2. EM250x75 500kW eModule with integrated EMPEL Lightning inverter

Achieving these goals necessitates a power electronic system – including a gate driver, power supply and microcontroller (MCU) – that can scale depending on the phase and kilowatts that the vehicle requires, while providing intelligence and resilience for functional safety. Semiconductor technology has evolved such that it's possible to modify the power supplies within an inverter to the requirements of a single motor phase. These technologies now enable you to change the number of phases and rating of the system, whether it's running on insulated-gate bipolar transistors, silicon carbide (SiC), or more than one semiconductor technology.

Achieving control and precision with semiconductors

The next generation of motors will also need to run faster. While it's possible to achieve higher power with larger, higher-torque machines, their implementation requires copper, electrical steel, aluminum and power electronic devices, which have a significant environmental impact. A bigger motor also makes vehicles heavier and requires more space.

High-speed, high-performance electric machines achieve their power and compactness by delivering performance at higher rpms (and thus a typically higher electrical frequency), “pumping” energy in and out of the motor's stator coils faster than traditional motors. But again, there are demanding requirements on the semiconductors driving these motors – the MCU, power supply and gate drivers.

MCUs in next-generation systems need control switching at 40kHz with >25,000 rpm support, as well as multiple three-phase machines, while spending a substantial portion of their processing capacity monitoring system health diagnostics, performance refinement algorithms and sensor optimization. TI's [AM263P4 Arm® Cortex®-R MCU](#) is capable of completing an inverter control loop running at 20kHz in less than 4μs. The integrated resolver-to-digital converter enables high angle accuracy within .05 degrees, which reduces traction inverter back-electromotive force to improve system efficiency, and the trigonometric math accelerator increases computing performance as much as 5 times.

The bias supply helps achieve high efficiency by minimizing the conduction power losses of SiC power modules within the motor. TI's [UCC14141-Q1 isolated DC/DC power module](#) integrates the controller, power stage, transformer, rectifier and feedback monitoring logic, enabling the small modular approach that EMPEL solutions demonstrate. The UCC14141-Q1 module can adjust both positive and negative gate-drive voltages for SiC field-effect transistors (FET), while its 1% voltage accuracy helps keep SiC FET conduction power losses low, extending battery run times and thus driving ranges. The small, low weight and low center of gravity of the UCC14141-Q1 help reduce mechanical stresses over the lifetime of the vehicle, improving vibration tolerance compared to solutions using traditional discrete transformers.

The gate driver has to combine intelligence; gate-drive strength control at every pulse-width modulation cycle; configurability through Serial Peripheral Interface; high switching speeds to take advantage of SiC technology; fast overcurrent protection; and an array of fault-management features to ensure system-level safety up to Automotive Safety Integrity Level D. The [UCC5880-Q1 functional safety-compliant isolated gate driver](#) addresses these exact design challenges and comes with design support tools that enable fast prototyping for system validation. [Figure 3](#) shows the UCC14141-Q1 bias module and UCC5880-Q1 gate driver on the power module.

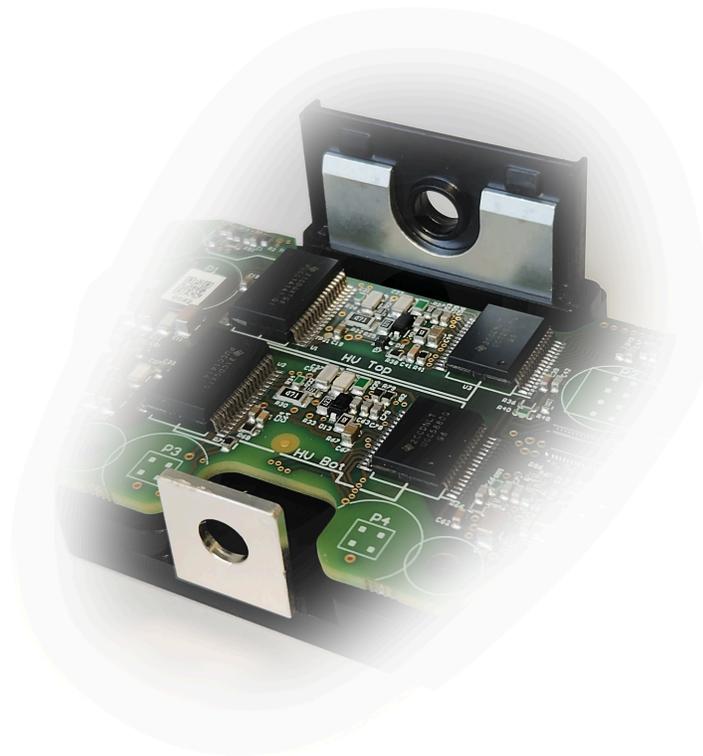


Figure 3. Gate-driver printed circuit board with both the UCC5880-Q1 and UCC14141-Q1 mounted on the power module

Withstanding harsh environments

In some testing environments, systems can experience 30G to 50G in cyclic vibration and localized temperatures over 300°F. In plug-in hybrid EVs, a high-power engine may add additional vibration and heat sources. Such systems need to meet Ingress Protection (IP) 67 standards and be completely sealed, yet endure internal pressure variations at altitudes as high as 6,000m. Packaging electronics in the motor inside of a box with antivibration mounts requires significant space, and increases the complexity and costs of interfacing and integrating electronics with the motor.

To deliver a tightly integrated traction inverter system, the goal is to make the inverter as small as possible with as low a mass as possible. The compact and solid-state nature of the inverter helps eliminate vibration and environmental weak points compared to conventional transformers. However, this also means that the energy losses will be acting on an even smaller thermal mass. The electronics and the components around them may get hotter in such a space, while still needing to meet requirements for high-voltage creepage and clearance. System designers will need to create the most reliable systems possible to withstand these conditions while minimizing part count and assembly complexity. It's an exciting propulsion system problem, every bit as rewarding as the combustion engines that preceded them.

Conclusion

Vehicle manufacturers will always focus on a primary goal to provide drivers with an attractive, competitive product that fundamentally provides more space in their vehicle. If we think about looking at the modern electric vehicles on sale today, we typically see a big aluminum box that has all the electronics in it and is typically the size of a substantial piece of luggage in the car. Fundamentally, vehicles give people the ability to have a personal space that moves physically throughout the world, so giving drivers and passengers more space for their money is important, while meeting all the other performance and refinement goals we've touched on.

Technological breakthroughs such as very compact, reliable power electronics and functional enhancements are crucial in enabling designers to simplify electronic propulsion systems and save vehicle space and cost. There's a bright future for the automotive industry, with further breakthroughs expected in the next generation of intelligent traction propulsion systems.

Additional resources

- Learn more about [EMPEL Systems](#).
- See how TI components are helping [create high-performance traction inverters](#).

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