Fast-Charging Electric Vehicles: SiC Delivers the Most Power from the Smallest Charger

Fast-charging infrastructure continues to be a critical variable in the emergence and widespread adoption of electric vehicles (EVs).

The expectation from drivers is that they should be able to embark on a road trip in their EV, rather than be limited to local commuting. This range anxiety remains a consumer obstacle. Charging stations must be readily available and able to charge the vehicle battery quickly, just like filling up a tank of gas.

EV charging infrastructure must not only be fast and ubiquitous, but it must be powerful, efficient, smaller, and cost-effective. Silicon carbide (SiC) is the technology best equipped to meet these requirements, while also preparing fast-charging infrastructure for future requirements such as bidirectional charger design.

The SiC differential for EV driving

SiC is a semiconductor base material typically found in power products. Wolfspeed SiC-based power products include bare die, discrete Schottky diodes and MOSFETs, and power modules.

The benefits of Wolfspeed SiC over silicon in similar devices include higher power conversion capabilities, faster switching speeds, and improved thermal performance. SiC products offer a material advantage compared to silicon, enhancing the performance of power systems and providing the differentiation necessary to enable an EV fast-charging infrastructure that will overcome any consumer hesitation.

SiC runs cooler and faster at higher switching frequencies, which allows for smaller and lighter power electronics with much higher energy efficiencies. But SiC devices also offer a level of ruggedness and reliability at the system device level required for EV faster-charging infrastructure capable of emulating the availability and ubiquity of gas stations. The limitation of having to charge a car overnight needs to be eliminated if consumers are to have confidence that they can do a long-haul trip in their EV.

While there is some supercharging infrastructure in parts of the world — including the U.S., Europe, and China — availability is limited. Not only do charger power levels need to increase to better accommodate fast charging, but also equipment must be practical enough to be implemented everywhere. Even the infrastructure that’s already in place needs an upgrade to SiC-based power if it’s to be truly fast-charging, rugged, reliable, and cost-efficient.

EV users today probably have a low power residential AC charger that can be used to charge the vehicle battery overnight. And while fast DC chargers for commercial vehicles are emerging, there’s a long way to go to get the market saturation required. Cost is a big challenge to produce the volume necessary for a widely available fast-charging infrastructure.

A lot of the emerging infrastructure today is still between 80 and 160 kW, so it means the minimum charge time is a half hour and often as long as an hour. It must also accommodate a lot of different types of vehicles, power levels, user models, and stakeholders, including municipalities, business owners, and EV owners, which means compatibility issues are putting a lot of pressure on system designers to bring flexibility to their equipment. A lot of the charging stations you see at residential or commercial properties are small and simple. Use of these stations assumes you’ll be charging over a 30- to 60-minute window while at home, working, grocery shopping, or running other errands.
The desired recharge is as quick as 15 minutes so the EV can travel as far as 400 km. For this to happen, battery voltage must increase to 800 V to keep currents down while maintaining thin, light cables inside the car and on the charging station. However, higher voltages and higher currents must not increase the volume and weight of chargers — density is critical. Bidirectionality must also be accommodated in the topologies as to support the anticipated demand for vehicle-to-grid (V2G) applications. This would allow the plugged in EVs to be a backup for utilities during a power outage.

SiC becomes even more advantageous, as it can support bidirectionality while also enabling higher charging voltage, higher power, and higher efficiency in smaller, lighter, and less costly chargers.

**Simplicity is where SiC shines**

The immediate design challenge for a fast charger is one that can support EV off-board battery charging in the 80- to 350-kW range through a DC charge from station to car. A high-power, modular design is critical for building a cost-effective, fast-charging system architecture.

Today’s designs are typically constructed from multiple 15- to 30-kW power blocks, although some new high-power designs are built with 50- to 60-kW power blocks. Regardless, the aim is to minimize the size and weight of the charging station while maintaining a 30-minute-or-less charge time. This is where SiC shines, because it can deliver on those goals with a 65% increase in power density with up to 30% lower losses. The overall system cost is lower because 30% fewer components are required.

Not only is it possible to hit the magic number of 15 minutes to charge a battery at 350 kW to drive 400 km with confidence, it can be done with a simpler design that results in lower costs and better efficiency. Service providers appreciate this capability based on their want of more power in smaller, lighter, and easier-to-manage devices. Energy efficiency, of course, contributes in all directions, not the least of which is how much energy it costs to charge the battery. It can also translate into simpler systems that are lighter, more reliable, and ultimately last a lot longer, all of which are enabled by a SiC-based approach.

**Building bigger blocks with SiC**

In most cases today, block sizes are hitting 30 kW. Wolfspeed has already developed SiC-based reference designs that enable higher efficiency, faster switching for smaller sizes and lower weights, and higher power densities at 20 kW. Wolfspeed is also expanding its evaluation platforms to include hardware that supports full bidirectionality.

One of Wolfspeed’s latest reference designs features a 20 kW SiC AC/DC converter building block. The three-phase converter targets high-efficiency and high-power-density off-board charging applications. For simplicity, the reference design employs a two-level topology rather than a complicated multi-level silicon MOSFET topology or traditional silicon IGBT solution.

Component-wise, the reference design uses Wolfspeed 1,000 V, 65-mΩ C3M SiC MOSFETs that deliver higher efficiency and higher power density than a silicon solution and operate at a higher frequency to significantly reduce the magnetics, size, and weight. The design includes all the necessary schematics, board layouts, bill of materials, connection and user guides, and waveforms and efficiency charts.

**Conclusion**

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