

Drive Farther and Charge Faster with These New GaN Transistors

Sponsored by Texas Instruments: Limitations in range and charging options continue to suppress electric-vehicle adoption. The latest semiconductor technology could very well change that tune.

Gallium-nitride (GaN) transistors have been around for a while, with their main application being RF power amplification. Now, with recent developments, special GaN devices are beginning to bring real improvements to the evolving electric vehicle (EV). Major electronic subsystems in the modern EV include the onboard battery charger (OBC), multiple dc-dc converters, inverters, and some form of power management.

Due to the high power involved in most EV circuits, a discrete component design is often required. That translates into the need for some special discrete transistors which can survive and deliver with high voltages and currents. New examples of these devices are the LMG3522R030-Q1 and LMG3525R030-Q1 GaN field-effect transistors (FETs) developed by Texas Instruments.

Features

Here's a short list of the TI GaN FETs' key features:

- Operates from a 12-V unregulated power supply
- Made with GaN-on-silicon
- Integrated gate driver
- Up to 2.2-MHz switching rate
- High-voltage capability up to 600/650 V
- Internal monitoring of temperature as well as undervoltage and overvoltage conditions
 - Slew-rate adaptability from 30 to 150 V/ns lets you control electromagnetic interference (EMI)
 - Low 30-mΩ on-resistance
 - Up to 4-kW power maximum in a half-bridge configuration

Benefits

Here are a few of the good things that derive from adopting these devices:

- Ability to achieve at least two times the power density of equivalent designs
- 99% efficiency
- Higher efficiency in power-factor-correction (PFC) applications.
- Reduction in the use of power magnetics up to 59%
- Smaller capacitors for filtering, all leading to...
- Much smaller PCBs and resulting weight reduction

The Need for Speed While Going the Distance

After all these years of hype and discussion, EVs only represent a small percentage of overall U.S. auto sales—about 5% depending on who you ask. So why aren't consumers buying these machines with all of their potential advantages? Three big problems stand in the way:

- Range anxiety
- Charging time
- High cost

The average internal-combustion-engine (ICE) gasoline vehicle can go 300 to 400 miles after a fill-up. And if your gasoline gets low, there are dozens, maybe even hundreds of gas stations where you can conveniently fill up and go another 300 or 400 miles. Not so with even the best EV today. The maximum for even the newest EV today on a full charge is approximately around 250 miles, which freaks people out.

But that's not all. If there were lots of charging stations to readily access, buyers could get comfortable knowing there was a place to plug in just around the corner. That's not yet the case, though. And what few do exist are usually occupied by some other desperate driver. If you're just commuting over

a short distance each day, then you're probably okay in an EV. An overnight charge is all you probably need. Otherwise, potential buyers are staying away due to range anxiety.

The second problem is the long charging times. It takes many hours to bring an EV battery up to full charge. Times range from about 15 to 30 hours for a full charge using a typical home charger. The newer higher-power direct dc chargers are much faster, but they do require a 240-V hook-up at the house. A full charge overnight is possible. However, that would take many hours of wasted time at some charging station that was available when you need it.

It only takes five to 10 minutes to fill up with gasoline. We need to get to that point or close to it with an EV. New battery types will probably be better, but they haven't been discovered yet. So, faster chargers and many more charging stations are the answer. But when?

And, finally, high price. Have you priced a full electric like a Tesla or equivalent lately? Few can afford their \$40K to over \$100K price tags. Will cost come down? It may not, given the state of our government overreach. But better design and electronic subsystems can help.

The rallying cry is definitely "drive farther, charge faster."

Designing the Future EV

One of the major requirements of electronic systems for new EVs is to reduce size and weight. The new high-power equipment must often fit into tight places occupied by older hardware. And there must be a significant weight reduction.

The prime target of such requirements is the [onboard charger](#). With larger batteries and challenging charge times, extra power is needed. Current power levels in the 3- to 4-kW range must go to the 20-kW level to noticeably decrease charge time. And, oh by the way, make that OBC half the size and weight.

The solution has been the move to wide-bandgap (WBG) semiconductors such as improved silicon MOSFETs and special devices like SiC. But now, the automotive industry has discovered [GaN and its benefits](#). GaN devices can switch faster at 2 MHz+, making it possible to use smaller, lighter transformers and inductors. That goes for capacitors, too.

Smaller values and sizes save space. The resulting new designs are much smaller and lighter. Add to that the super-low on-resistance and you not only achieve major power savings, but less heat and smaller heat sinks allow for even smaller packaging.

Switching speed is also a factor. With 10-ns rise and fall times for some of these new GaN transistors, power savings is possible. But controlling rise/fall time is the secret to minimizing EMI. As mentioned, TI's new GaN devices can achieve a 30- to 150-V/ns rise/fall time range that enables the designer to fine-tune the EMI. In addition, fast switching means less power consumption. The outcome is higher efficiency, up to 99%, in the finished product.

The on-chip gate driver is a major factor in the performance of these transistors. As it has been discovered, the design of a good gate driver for an HEMT GaN transistor takes considerable effort and is a time issue. Without that need, designers can concentrate on other more critical parts of the design.

An interesting factor that emerges when using GaN devices is the lack of a so-called body diode. Most MOSFETs inherently have a diode between the source and drain that manifests itself because of the device geometry and physical structure. This feature puts certain limits on the circuit when designing with traditional MOSFETs.

Eliminating the virtual diode allows GaN devices to have zero reverse recovery, making them more viable than competitive devices in high-power switch-mode power supplies. Add to that the smaller gate charge and smaller input and output capacitances that improve efficiency.

In contrast, the [ideal diode mode](#) enables an adaptive dead time. It automatically realizes a fast, synchronous FET operation with no external circuitry or control.

