Electronic Design

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BMS and Traction-Inverter Innovations Propel Vehicle Electrification

Sponsored by Texas Instruments: High-precision battery monitors improve driving-range estimation for multiple battery chemistries while real-time MCUs and advanced gate drivers power traction-inverter upgrades and facilitate powertrain integration.

Electric vehicles (EVs) are rolling toward the future, but the path isn't without obstacles. Range anxiety persists—no driver wants to experience an unexpected dead battery when miles from the nearest charging station. And initial EV costs remain high in contrast to conventional internal-combustion-engine (ICE) vehicles. Fortunately, advanced semiconductors are arriving on the scene to help overcome these obstacles.

EVs are Here to Stay

Mark Ng, who leads Texas Instruments' hybrid-EV (HEV) and EV powertrain business, sees EVs not as cars with batteries and electric motors, but rather as big electronic devices climbing the same innovation curve that has transformed communications, computing, and personal-electronics markets. Ng cites several specific innovations:

- Advanced battery-management systems (BMSs) help drivers overcome concerns about range, safety, and reliability.
- Onboard chargers deliver optimal voltages and currents to each battery cell while avoiding the overcharging or undercharging that can limit battery life.
- Gate drivers with adjustable gate-drive strength enable traction inverters to optimize energy usage based on road conditions and driving style.
- Power-management technologies provide high levels of functional safety, while sensors and microcontrollers help drivers cope with sudden hazards.

Ng adds that new technologies make EVs more affordable as manufacturers move toward zone-control architectures, integrated powertrains, wireless BMSs, and intelligent battery junction boxes.

Multiple Chemistries

New battery chemistries offer a key opportunity for EVs. Most have employed lithium-ion batteries, which require cobalt, an expensive rare-earth element. Consequently, manufacturers are investigating cobalt-free alternative chemistries, including lithium ferro (iron) phosphate (LFP).

LFP batteries, however, have a significant drawback. Unlike lithium-ion batteries, whose voltage drops steadily as they discharge, LFP batteries exhibit a minuscule voltage drop even as they approach full depletion. That characteristic makes it difficult to predict remaining driving range.

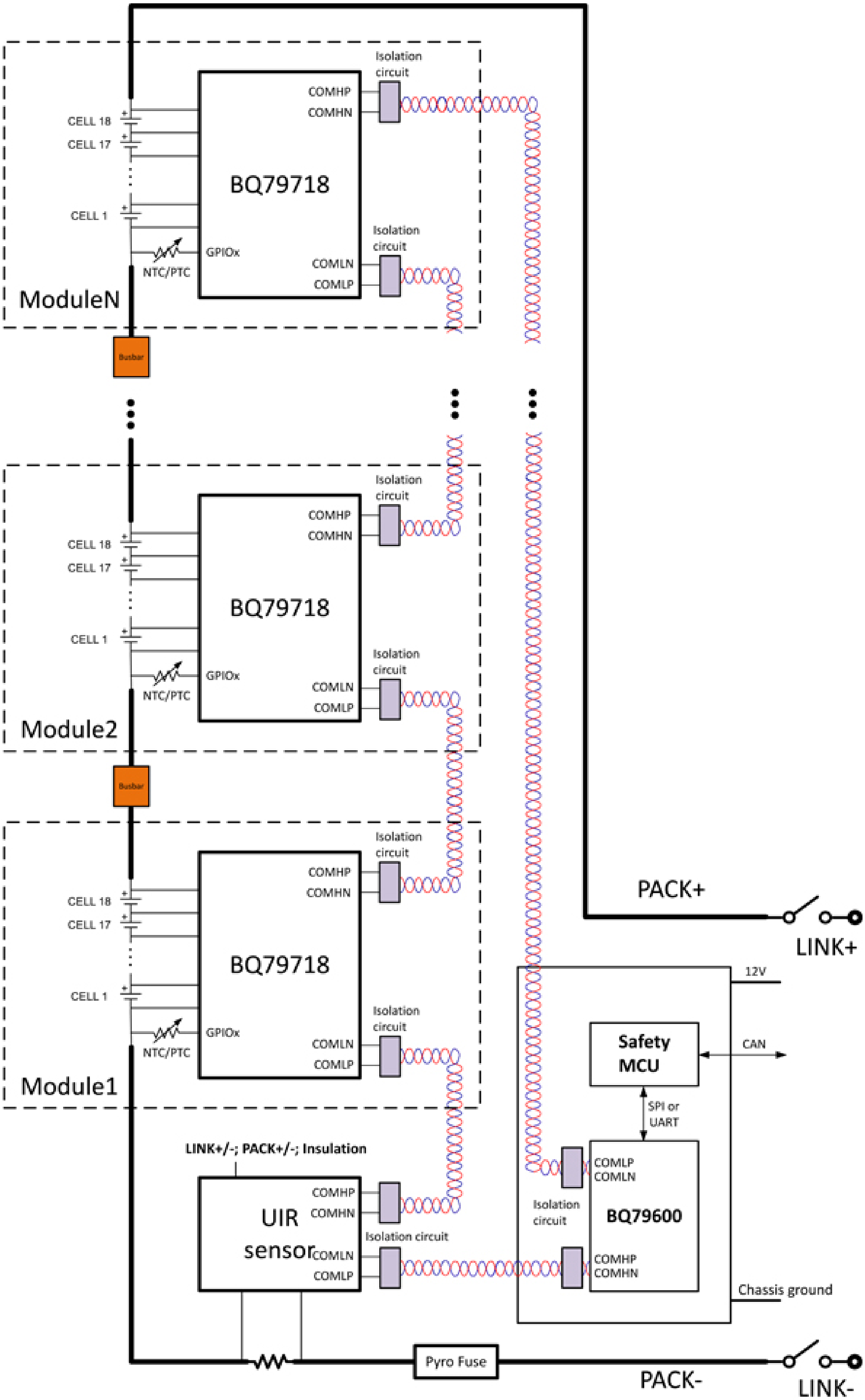
"LFP's flat discharge rate requires a voltage measurement accuracy that's right at the limit of what modern semiconductor technology can deliver," said Ng.

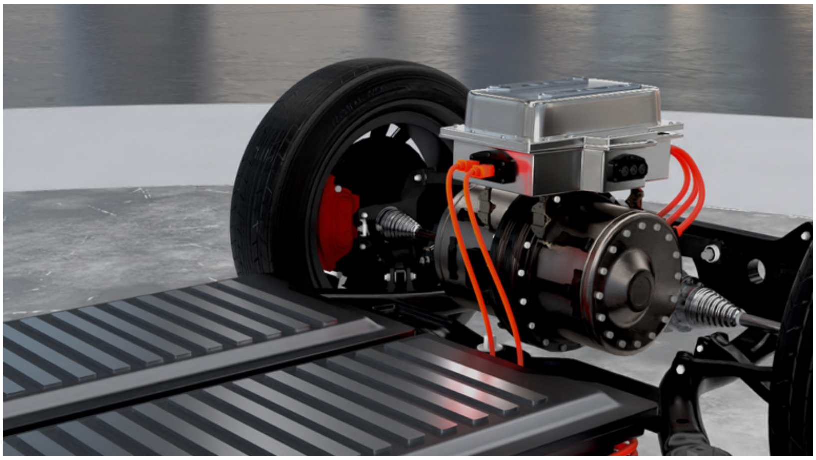
To cite a specific number, a conventional BMS device offers a 25% uncertainty in remaining driving-range estimation for an LFP battery. Consequently, an LFP-battery-powered EV must underreport remaining range by 25% to minimize the chance of a battery dying in the middle of a journey. TI offers a BMS portfolio that includes chargers, gauges, monitors, and protection ICs that provide the precision necessary to alleviate this problem.

Ng elaborated, "Instead of telling you there are 200 miles left when you actually have 250 miles, with our chip the car might tell you that you have 230 miles left. The BMS has essentially extended your range by 30 miles, with the same charge on the same batteries."

Accurate battery monitors find use beyond remaining driving-range indication. They're also critical for maintaining the safety and reliability of the nearly 200 cells that typically go into an EV's battery pack. During normal operation, a monitor can determine whether one cell is discharging

1. The BQ79718-Q1 battery monitor provides precise monitoring of nine to 18 cells in series.





2. The traction inverter turns stored energy into propulsion.

faster than others, and during charging, it can tell if a cell is reaching capacity more quickly than others.

In either case, the abnormally performing cell can be switched out as necessary to prevent damage to the cell as well as maintain a suitable balance among all of the cells. In addition, monitors can look for overtemperature conditions.

"The BMS provides an elaborate monitoring network to sense the voltage, current, and temperature of each cell," said Sam Wong, who leads a battery-monitor team at TI. "That way, we can cut a battery off from the system, or adjust the current going in or out of it."

A specific member of TI's BMS IC portfolio is the BQ79718-Q1 battery monitor, which complies with ISO-26262 ASIL-D functional-safety requirements and provides precise monitoring of nine to 18 cells in series *(Fig. 1)*.

Traction Inverters Drive EV Performance

While battery-monitor devices are critical for keeping EVs safe and reliable and the driver informed, it's the multikilowatt traction inverter *(Fig. 2)* that turns stored energy into propulsion. Advanced microcontroller units (MCUs) with real-time control capabilities along with isolated gate drivers are leading to traction-inverter reliability, performance, weight, and power-density improvements.

"Innovation in power electronics is actually overtaking the constraints on the mechanical side," said Xun Gong, a systems manager for EV and HEV traction inverters at TI. "We're getting close to the mechanical limits."

A key factor in traction-inverter improvements is the transition from insulated-gate bipolar transistors (IGBTs) to silicon-carbide (SiC) switches. SiC devices switch very fast, making them more efficient than IGBTs, turning more stored energy into usable motor output.

However, SiC devices are more susceptible to damage from short circuits, a limitation that TI addresses with its advanced gate-driver technology. "Our gate driver quickly detects a short and turns that switch off in less than one-millionth of a second to protect it from damage," said Audrey Dearien, an applications manager for isolated gate drivers at TI.

In addition to upgrading traction inverters, automakers are looking to integrate powertrains to improve overall power density. Advances in analog and embedded-processing technologies enable the combination of individual systems like the onboard charger, traction inverter, and dc-dc converters into a single compact mechanical enclosure operating under a single domain controller. Such integration holds the promise of cutting costs while improving reliability and efficiency.

Looking Ahead

The EV industry is continually evolving as battery-system manufacturers investigate additional battery chemistries and different cell configurations, and as traction inverters incorporating SiC devices move to higher voltage and power levels. TI offers semiconductor products that will propel the industry into the future.

For example, the company's MCUs for real-time control and its isolated gate drivers will speed the transition from 400- to 800-V battery voltages. In addition, TI's monitoring options can help automakers bring new EVs to market quickly.

"There are probably another hundred different battery chemistries that are being looked at in the industry," said Gong. "We want to make sure our BMS products can offer the flexibility to get the most out of any of them."