Electronic Design

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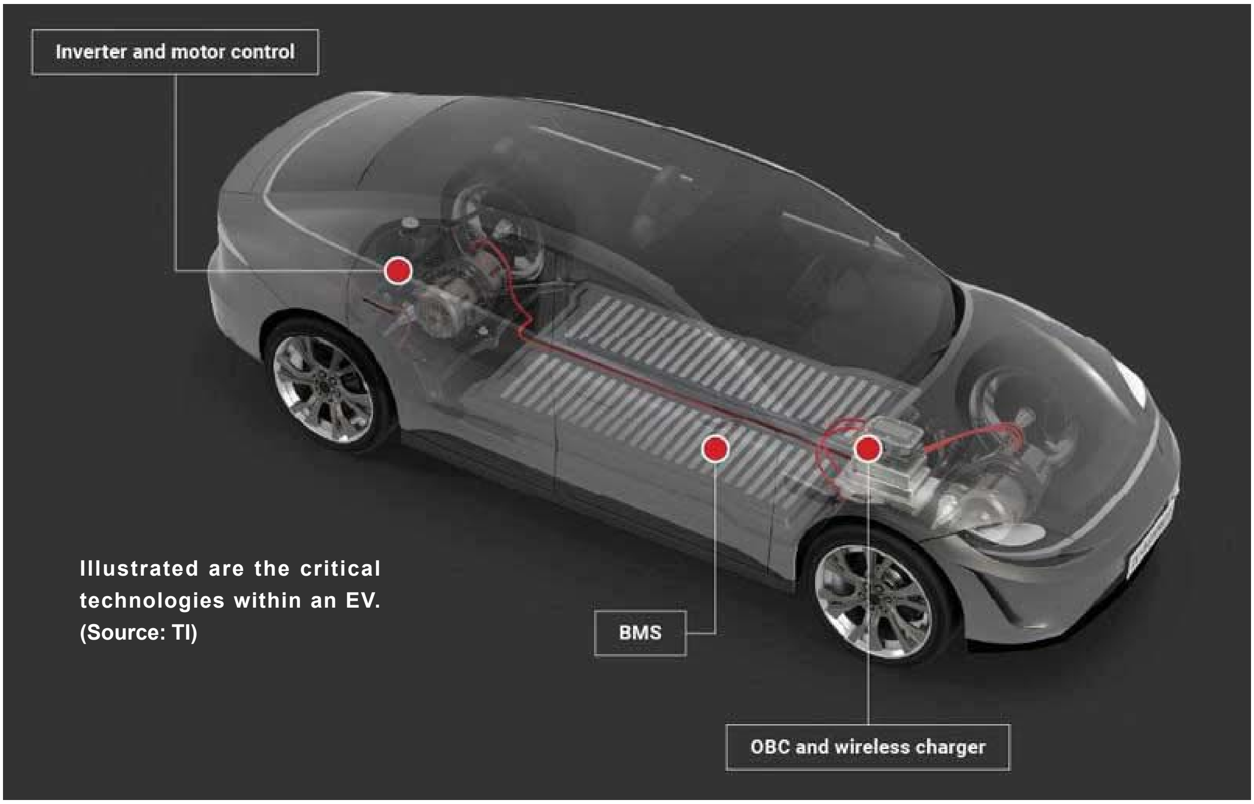
A High-Tech EV Strategy Built on 3 Key Technologies

Sponsored by Texas Instruments: Collaboration-driven semiconductor technologies are transforming electric vehicles into a practical, everyday option.

With the world steadily driving toward vehicle electrification, the scale of innovation in this space is unprecedented. Semiconductors enable automakers to optimize performance, accelerate development, and make electric vehicles (EVs) more affordable. Advances in EV design are propelled by the need to reduce emissions, decrease weight, and boost efficiency.

As EV/hybrid EV (HEV) adoption continues to grow, lowering vehicle cost by optimizing EV efficiency remains a key priority for automakers. [Semiconductor technologies can redefine the EV](#) by enabling faster charging, longer driving ranges, and smarter power management. Advanced chips are controlling every core function from the battery to the motor.



Illustrated are the critical technologies within an EV. (Source: TI)

Three Technologies Pave the Way

Texas Instruments' integrated circuits and reference designs help in the creation of battery-management unit designs that deliver high-accuracy monitoring of, and control over, the high-voltage battery stack. To further advance the adoption of EVs worldwide, TI is developing battery-management systems (BMS) solutions to support the requirements of safer, smarter vehicles. Importantly, the semiconductor technology in these systems is evolving *(see figure)*.

For example, the MCU has two primary roles within the BMS: Connecting to sensors to receive data and communicating that information back to the vehicle network. And expanding the size of the battery means that more individual cells need measuring.

Furthermore, higher voltage levels and higher overall power are now stored within the battery. As a result, more signals are coming in than ever before, requiring both an increase in MCU package size as well as the number of input/outputs as vehicle architectures transition from domain to zone control.

Traditional MCUs may have been able to operate in a BMS, taking simple current and voltage measurements and temperature measurements with 100 MHz on a single core. But now there are multi-core devices running up to 1 GHz that can compute and then act within the system.

In addition, predictive battery management enables BMS to detect changes such as state of charge, temperature, aging, or charge imbalance in the cells of a battery pack using model-based algorithms or edge artificial intelligence. Careful monitoring of cell behavior in turn allows OEMs to implement protective features. Sensing and data analysis in real time make it possible to detect and address risks earlier, improving battery safety and performance and extending pack life. A longer battery life lowers overall ownership costs as well. Charging becomes faster and more predictable for drivers. And for OEMs, more efficient charging designs can reduce system weight and cost, lowering the cost of bringing EVs to market.

Another key technology in the battery-management ecosystem, specifically for battery cell health, is electrochemical impedance spectroscopy (EIS). Integrated chip-level EIS functions as a real-time internal sensor for battery cells, tracking impedance to detect early thermal runaway, measure aging, and improve state-of-charge accuracy (especially important for lithium-iron-phosphate, or LFP, battery chemistries).

Traditional BMS respond to a malfunction after it occurs. By the time the system triggers an alert, the condition may be close to irreversible. EIS is a measurement technique that analyzes how a battery cell responds to a small electrical signal across multiple frequencies.

By applying that electrical signal and analyzing the cell's impedance response, EIS provides deeper insight into the cell's state of charge, state of health, temperature, and early indicators of thermal runaway risk. It detects changes that may not yet appear at the surface. Machine-learning models trained on EIS data can recognize impedance patterns preceding battery capacity fade or thermal risk, giving BMS the ability to predict changes rather than passively detect them.

For automotive OEMs and tier-1 suppliers, cell-level insights matter as EV platforms move to higher voltages and cell counts. TI's battery EIS chipset, featuring the BQ79826Z-Q1 battery monitor, addresses this need by integrating an EIS measurement engine directly into the battery monitor, supporting high-cell-count systems across both 400- and 800-V architectures.

Optimal Pulse Positioning

The traction inverter offers the best case for optimization. Advanced motion control and optimal-pulse-pattern (OPP) algorithms minimize energy loss in traction inverters, helping EVs extend driving range on a single charge while improving acceleration smoothness.

Current traction inverter systems use variations of the space-vector pulse-width-modulation (SVPWM) technique. This algorithm controls three-phase voltage-source inverters. While SVPWM is simple, effective, and well-understood, synchronous OPP-based modulation promises increased efficiency.

OPP is the process of creating an AC waveform from a DC battery by precisely turning switches on and off. Faster switching enables a cleaner sine waveform, but it increases switching losses, as there's loss in the FET every time it's switched. Slower switching introduces motor harmonic losses due to a distorted sine waveform.

OPP can deliver meaningful system-level benefits, including reduced battery size and/or longer drive range. For automotive OEMs and Tier-1 suppliers seeking to maximize EV efficiency, OPP finds the sweet spot in minimizing both switching and motor harmonic losses, resulting in optimized traction system efficiency. Thus, it's a compelling next step in traction inverter innovation.

Applying OPP modulation to EV traction systems, however, provides fundamental challenges that existing MCUs struggle to overcome. TI addresses these issues via the processing power of its F29x MCUs, which are 64-bit real-time microcontrollers featuring up to three 200-MHz C29 CPU cores. Preliminary high-power test results show a 0.8% improvement in traction system efficiency, enabling more than $100 in savings per battery pack for EV makers.

Conclusion

TI is engineering the future of electric vehicles with cutting-edge technologies that overcome today's most critical challenges in battery safety, fast charging, vehicle range, and affordability. Through early collaboration with OEMs in the design process, it's advancing EV design with breakthrough semiconductor technologies that improve traction inverter efficiency, motor control, and high-voltage power distribution.