Technical Article

Enabling the next phase of battery intelligence

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- Why deeper insights into what happens inside each cell enable safer, longer-lasting batteries.
- New battery monitor with an integrated EIS engine supports earlier thermal runaway detection in 400V and 800V battery systems.

Whether supporting the grid or powering an electric vehicle (EV), today's battery systems are expected to deliver energy safely and predictably. A grid-scale energy storage system (ESS) may have a 20-year life span, but still must charge and discharge as grid conditions change. An EV pack must deliver reliability across years of driving, charging and changing temperatures.

From the outside, both systems may appear stable. But inside each cell, electrochemical changes can begin long before voltage, current or temperature measurements show that anything has changed.

That visibility gap is becoming more important as batteries take on larger roles in EVs and energy storage. Beyond monitoring a pack from the outside, battery management systems must now detect what is happening inside each cell. Understanding that shift requires recognizing the limits of surface-level measurements.

Why voltage and temperature monitoring fall short

Every battery management system relies on voltage, current and temperature. These measurements are essential, but they primarily read the cell from the outside. They cannot fully reveal the electrochemical changes that affect safety, aging and performance inside the cell.

Additionally, external sensors can only be reactive, not proactive. Only after a change inside the cell develops and reaches the surface will the sensor register a voltage, current or temperature measurement. By then, the system is reacting to a condition already in progress.

This gap matters most in safety-critical events such as thermal runaway, a self-heating chain reaction in which a cell generates heat faster than it can dissipate it. Thermal runaway may begin as an internal electrochemical event, generating heat before external sensors respond. By the time the system triggers an alert, the condition may be close to irreversible.

Regulators are responding. An update to China's Guobiao (GB) 38031 national EV battery standard, effective July 2026, requires battery packs to prevent fire or explosion for at least two hours after thermal runaway begins. Many designers are anxious about what this standard and future requirements will demand. The answer is not to replace traditional sensing, but to add a deeper layer of visibility into the cell itself.

How EIS sees inside every cell

Electrochemical impedance spectroscopy (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. Detecting these warning signs early is the difference between a manageable maintenance event and a critical failure – one that can compromise safety, halt operations, or cause irreversible damage to the system.

For decades, this kind of measurement largely required specialized lab equipment. But today, it is possible to build that capability into every cell without additional sensors or costly redesigns.

While voltage, current and temperature remain fundamental, EIS adds a complementary proactive layer, detecting changes that may not yet appear at the surface.

What cell-level intelligence means for EV and ESS designs

Once you understand the internal state of individual cells, battery management becomes part of a broader ecosystem that connects cell-level insight to the actions needed to improve safety, reliability and performance.

For automotive original equipment manufacturers and tier-1 suppliers, cell-level insights matter as EV platforms move to higher voltages and cell counts. TI's battery EIS chipset, featuring TI's 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 400V and 800V architectures. Figure 1 illustrates how the battery monitor integrates within the full battery management system (BMS) architecture, including its relationship to cells, communication buses and pack monitor.

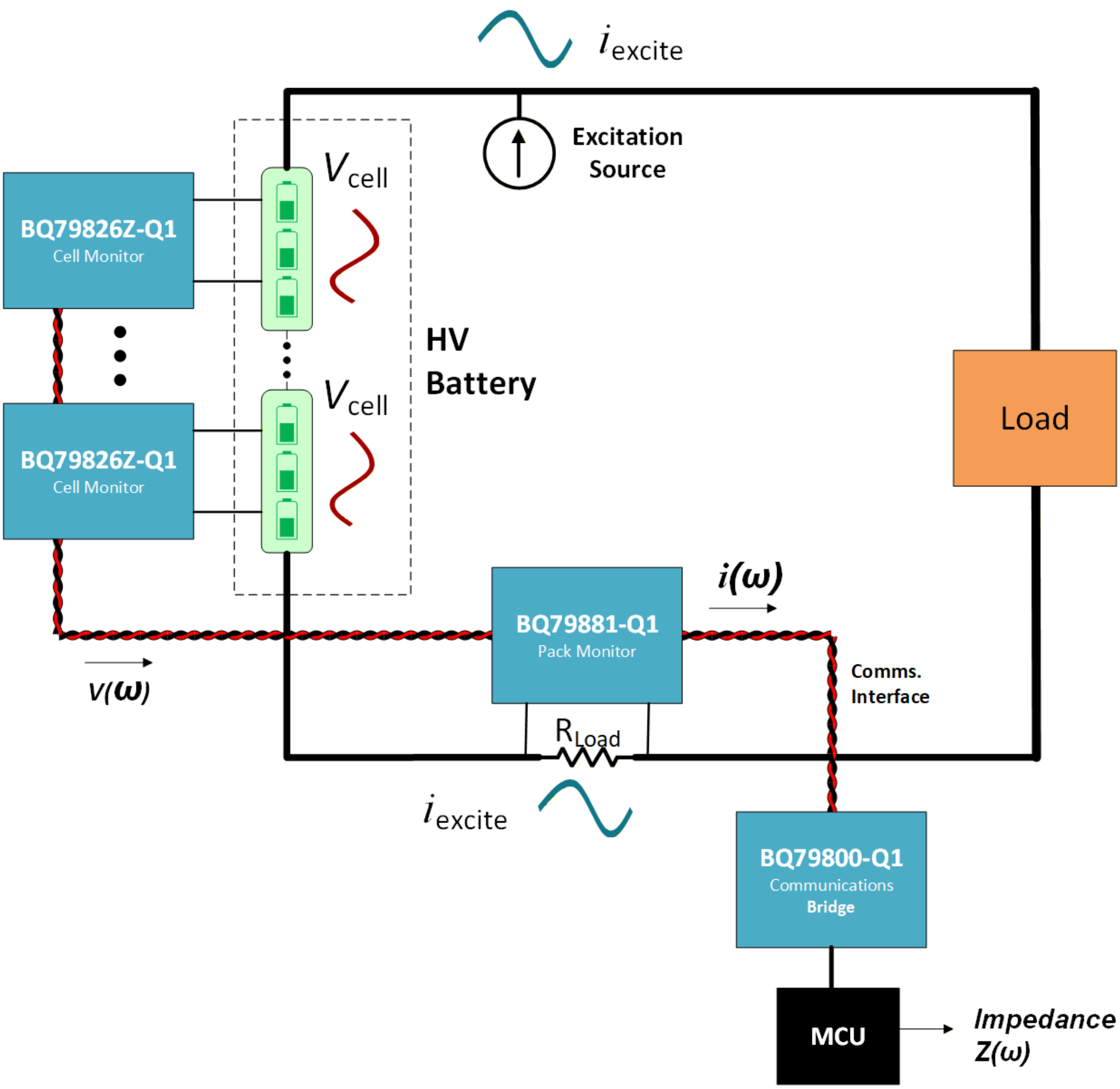

Figure 1: TI's battery EIS chipset, featuring the BQ79826Z-Q1 battery monitor with integrated EIS engine, within the full BMS architecture.

An ESS may be expected to last 15 to 20 years. Real-time insight into cell health helps operators identify degradation earlier, plan maintenance more effectively, and keep the system operating and performing as expected. When paired with active cell balancing, EIS-derived data helps redistribute energy across large cell populations in real time, improving efficiency and performance.

The path toward predictive battery management

Traditional battery management systems respond to a malfunction after it occurs. By the time the system triggers an alert, the condition may be close to irreversible. This shift from reactive monitoring to predictive battery management is becoming one of the most important changes in battery system design.

EIS generates internal electrochemical data that the system can track over time. Machine learning models trained on that data can recognize impedance patterns that precede battery capacity fade or thermal risk, giving battery management systems the ability to predict changes rather than passively detect them. That data builds more complete battery profiles, helping systems detect degradation before it affects performance, and thus extending system life.

Over time, these battery profiles can help artificial intelligence-enhanced battery systems move beyond isolated measurements toward a more complete understanding of the battery. The priority then becomes turning that data into better decisions, faster action, and safer, more reliable systems.

The future of battery management

As battery use expands, deeper cell-level intelligence will become increasingly important across high-voltage EVs, energy storage systems, and industrial and consumer devices. The industry will need battery management built on an understanding of what happens inside the cell, before problems arise.

The organizations that make such insights practical, scalable and affordable – with the goal to anticipate battery conditions that lead to malfunction or critical failure before they occur – will help define the next generation of safer, more reliable battery systems.

Additional resources

- To learn more about EIS-based battery monitoring, read the technical white paper, "Next-Generation Battery Monitoring with Electrochemical Impedance Spectroscopy."
- Order the BQ79826Q1EVM-086 evaluation module to get started on your EIS design.

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