Technical Article

The importance of hardware emulation when developing a next-generation automotive BMS

TEXAS INSTRUMENTS

In the competitive landscape of vehicle electrification, one thing that original equipment manufacturers (OEMs) cannot compromise on is safety and reliability in hybrid and electric vehicles.

The vehicle's battery management system (BMS) is indispensable for achieving safety and reliability by:

- Avoiding cell failures.
- Detecting and reacting to failures quickly through cell and environmental sensor supervision.
- Continuously monitoring isolation within the vehicle's high-voltage system.
- Estimating the vehicle range.
- Assessing the maximum power for charging or driving.
- Extending the driving range based on battery pack capacity.
- Increasing the amount of battery cycles before a battery pack needs to be replaced or recycled.

While demands for higher levels of BMS reliability have increased, so has the need for faster development cycles. Given the complexity of these types of systems, OEMs are seeking closer collaboration with system developers, semiconductor companies and their third-party partners to streamline development. Figure 1 shows an example of an electric vehicle (EV) BMS.

Figure 1. Typical BMS and battery in an EV

This collaboration is evident in the software-based simulation capabilities used during BMS development, during which components and systems are tested in both normal and excessive conditions early in the development cycle without physical hardware or an expensive testing space. Tools such as hardware-in-the-loop simulators can emulate a battery module or pack, enabling accelerated development, compact test setups, virtual prototyping, automatic testing, and the ability to develop software for the BMS without a physical battery pack.

By simplifying the testing process, emulators can play an important role in accelerating innovation in the BMS field.

The advantages of using emulators when developing an automotive BMS

Hardware-in-the-loop solutions provide a safe way to simulate the two-pole behavior of battery cells, modules or packs. The output of real, high-precision voltages for all cells is referred to as voltage-level hardware-in-the-loop testing.

It is also possible to test the BMS main controller at the signal level and simulate the battery cells and cell supervision units (CSUs). The focus in this approach is to test the functions of the BMS controller and its interaction with the vehicle network (or any other environment) without using actual high voltages. This provides a deeper representation toward the final hardware and is referred to as an emulator.

Emulation of both the entire battery pack (or module) and the cell and pack monitors allows for deep and repetitive testing. For example, you could test in the very early development stages using a simulated integrated circuit like the BQ79616-Q1 battery monitor. Another potential use case for testing the BMS controller at the signal level is integration testing with other control units, such as motor controllers or onboard chargers.

The functionality of a BMS emulator

The dSPACE Cell Controller Virtualization (CCV) can perform comprehensive signal-level BMS testing of cell controller functions without the need for complete hardware, and without high-voltage safety equipment (as shown in Figure 2).

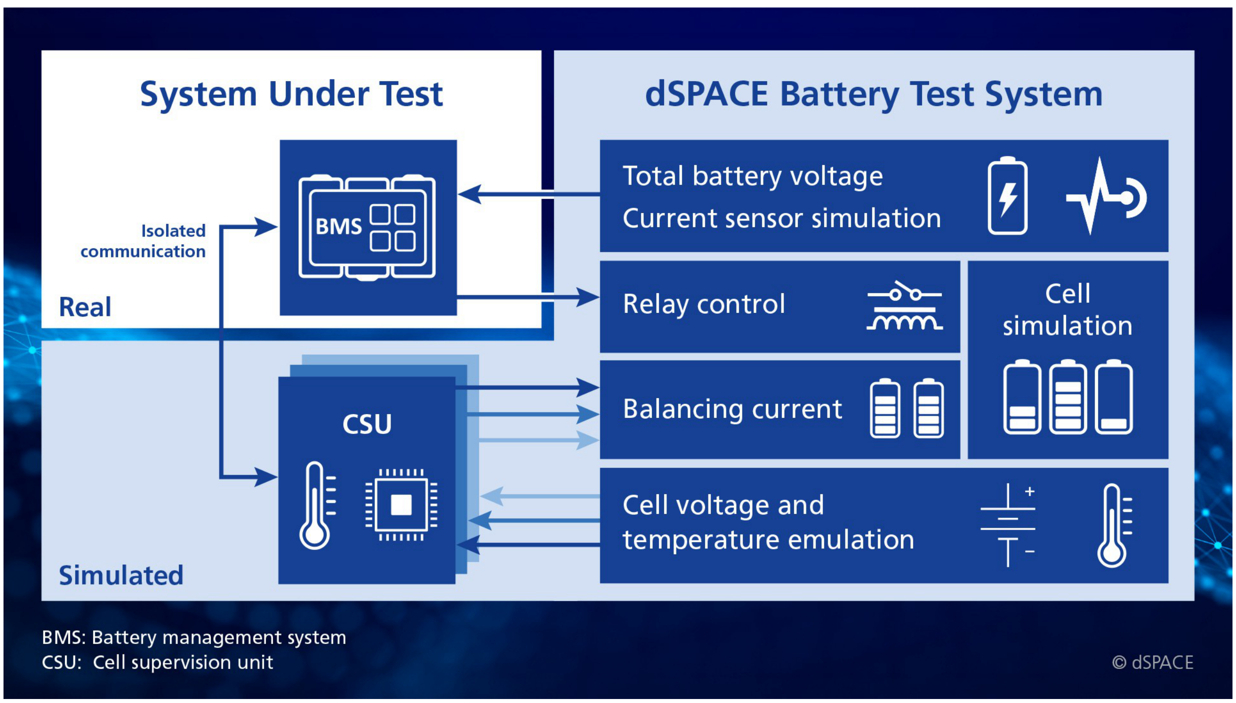

Figure 2. Diagram of battery cell, CSU and communication with the main BMS controller simulation when using the dSPACE solution for signal-level BMS testing

One of the advantages of a BMS testing emulator like the dSPACE CCV is that it enables you to conduct tests outside of an expensive, often-booked high-voltage lab environment. Compared to high-voltage BMS testing, a signal-level approach provides benefits in terms of price efficiency and a more compact test system footprint. Since signal-level testing doesn't require any real cell voltages, the test systems are less complex and require fewer safety installations.

Signal-level testing also offers design flexibility. Testing system functions early allows designers to focus on optimization even before the real battery or battery pack monitoring hardware (like the CSU) becomes available. And beyond just simulating the cell controllers, the dSPACE solution can also emulate communication with the main BMS controller, the vehicle electronic control unit, real-time test computers, or vehicle hardware.

Typical use cases of the dSPACE cell controller virtualization solution include running integration tests on the main BMS controller to validate its communication with other vehicle control units, such as the e-motor controller (inverter) or the onboard charger in hybrid and electric vehicles. You can also test state-of-charge and state-of-health algorithms for fault detection and reaction, and conduct integration tests on a system or on a full vehicle hardware-in-the-loop simulator.

These emulators are based on powerful field-programmable gate arrays (as shown in Figure 3) and are able to meet demanding timing requirements. They support a wide range of communication protocols, for fast, safe and isolated communication. This enables more flexible testing capabilities, such as connecting the emulated battery pack to the battery management unit in a hybrid emulated/real hardware environment.

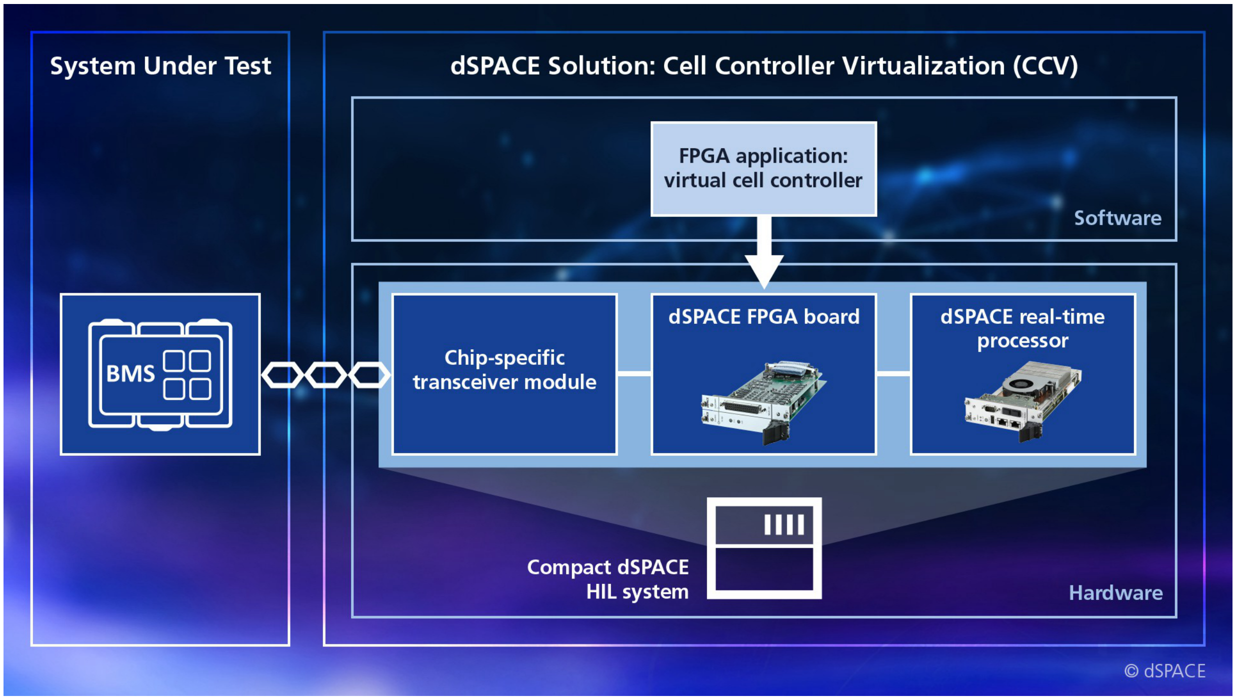

Figure 3. Overview of dSPACE CCV solution for testing BMS at the signal level

Conclusion

After two decades of automotive BMS innovations, it's exciting to see corresponding advancement in emulation solutions. By emulating TI battery management ICs, the dSPACE cell controller virtualization solution helps facilitate system development earlier in the design process. An expedited process enables software to progress before hardware is available and tests real-life or extreme conditions to help enhance system safety and reliability.

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