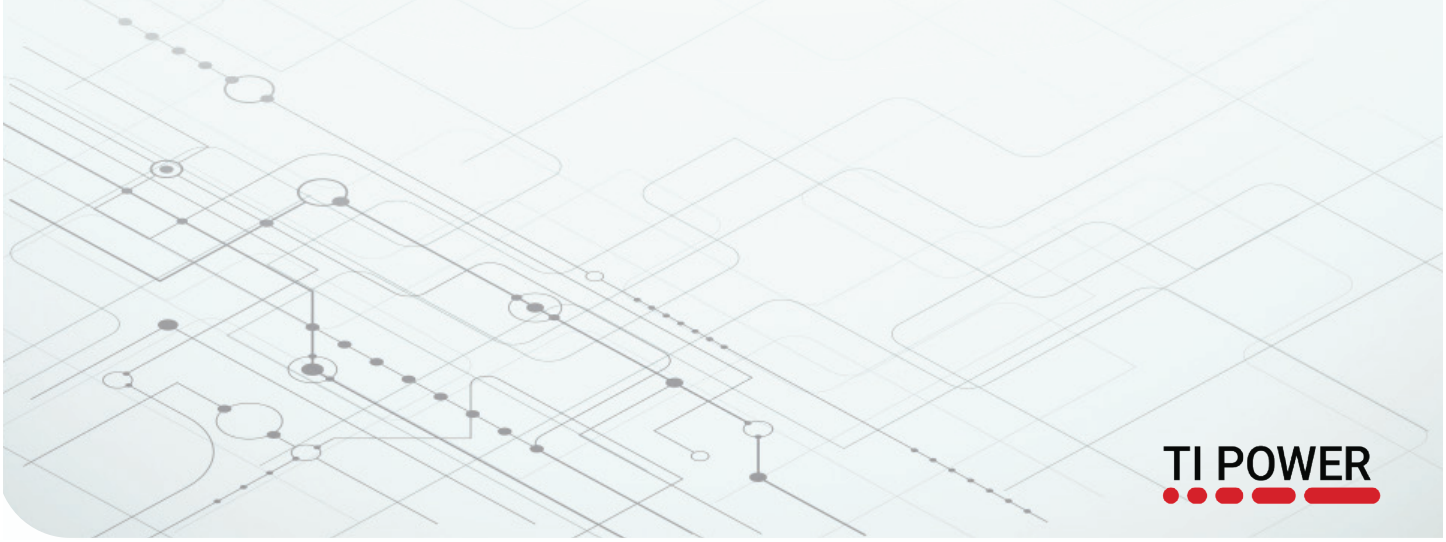
Wired vs. Wireless Communications in EV Battery Management

Taylor Vogt
Applications Engineer
Battery Management Systems
Texas Instruments



TI POWER

With electric vehicles (EVs) in high-demand, manufacturers are looking for ways to improve their performance in safe and cost-effective ways.

At a glance

This white paper examines design considerations for wired and wireless battery management systems in electric vehicles (EVs).

1 Distributed battery management systems in EVs

High-voltage EV battery packs require complex communication systems to relay cell voltages, temperature and other diagnostics.

2 Evaluating wired vs. wireless solutions

High-accuracy battery monitors can communicate via wired or wireless methods back to the host to deliver pertinent cell pack data. There are several design considerations and trade-offs for distributed battery systems.

3 Working with TI battery monitors in wired or wireless environments

TI's proprietary battery management system (BMS) protocols provide a reliable, high-throughput and low-latency communication method for both wired and wireless BMS configurations.

One particular area of interest is improving battery management systems, which work in real time to monitor the performance of individual battery cells within the EV. By effectively monitoring each battery cell, an EV's microcontroller (MCU) can ensure the proper operation of all battery cells and balance load sharing. This white paper examines the differences between wired and wireless BMS solutions to help you choose the best option for your EV design.

Distributed battery management systems in EVs

In electrified automotive applications, internal battery packs can extend up to 800 V and beyond to support the demanding loads of the AC motor. This translates into potentially 100 or more lithium-ion cells stacked together in series inside the vehicle chassis. These high-voltage packs are increasingly requiring more sophisticated technologies to report cell diagnostics in a safe, timely and reliable manner. One common design technique is to implement a distributed battery pack system, which supports high-cell-count packs by connecting multiple high-accuracy battery monitors on separate printed circuit boards (PCBs).

In a wired BMS solution, connecting these monitors in a daisy chain with twisted-pair cabling enables the propagation of data acquired for each module of battery cells. The difference between a wired and wireless BMS solution is that the latter uses a wireless communications interface rather than daisy-chain cabling. **Figure 1** displays a typical distributed battery pack system for 400-V to 800-V EVs.

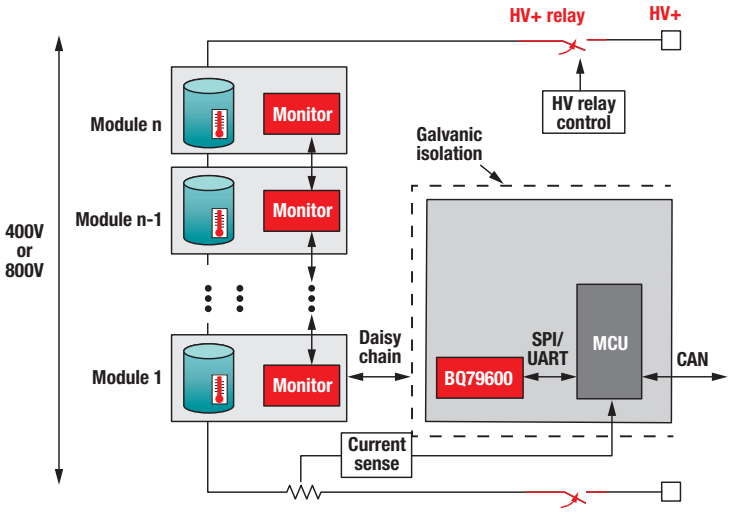


Figure 1. *Distributed BMS example.*

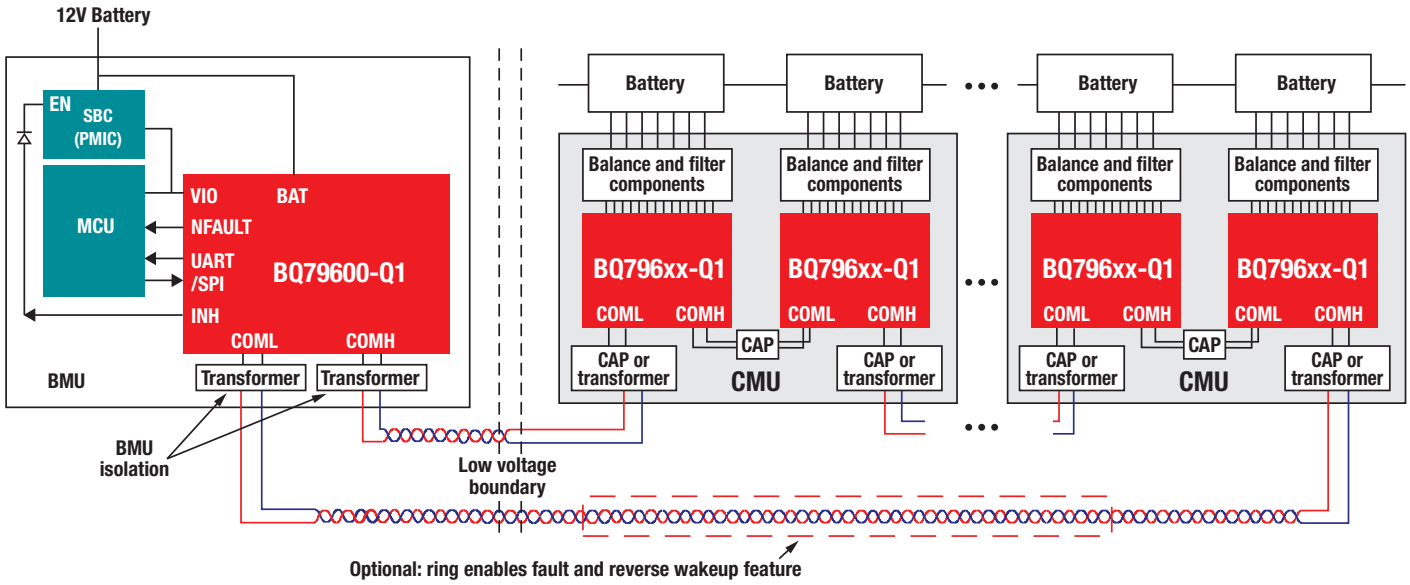


Figure 2. *Wired BMS example.*

In Figure 1, there is a subsystem containing the host MCU, which interfaces with the control unit of the vehicle through a Controller Area Network bus. Then the MCU processor drives the battery monitor devices connected out to the battery modules to sense voltage and temperature. Depending on how many channels the battery monitors support, there can be any number of devices stacked to support high-voltage packs, which all need to communicate back to the host MCU quickly. Other common aspects of the system requiring monitoring and communications include high-voltage relay controls to ensure safe disconnection of the high voltage when the vehicle is not in use, and current sensing to calculate the state of charge and state of health of the battery pack.

Wired vs. wireless BMS considerations

The focus in this paper will be on the communications interface between each battery monitor device connected in the pack and the host MCU. Both examples will use the BQ796xx family of monitors. The typical wired solution connects battery monitors in a daisy-chain cable with twisted-pair cabling between battery modules. The wireless communication method uses the CC2642R-Q1 wireless MCU for transmitting data.

In **Figure 2**, the wired solution displays a battery management or monitor unit (BMU) board on the left, which holds the host MCU and BQ79600-Q1 communications bridge device. This BMU acts as an interface between the MCU and other BQ796xx monitoring devices on the cell monitoring unit (CMU), which connects to the actual battery cells. These CMUs are interconnected through a twisted-pair daisy-chain cable on both the high and low sides of each battery monitor device, and there is an optional ring cable that provides the ability to transmit in either direction in the event of a cable break. The wired solution does require isolation components on either side of the daisy-chain cabling to ensure robust communication in noisy environments that can withstand strict automotive electromagnetic interference (EMI) and electromagnetic compatibility (EMC) limits.

The wireless solution uses a wireless interface to transmit universal asynchronous receiver-transmitter (UART) data from the battery monitor to the host MCU via a wireless transceiver device.

Figure 3 uses a more simplified representation of a CMU than Figure 1, but adds a wireless receiver node to show that the CMU has an additional device to transmit cell data wirelessly back to the host. This enables the two CMUs shown in Figure 2 to be naturally isolated from one another.

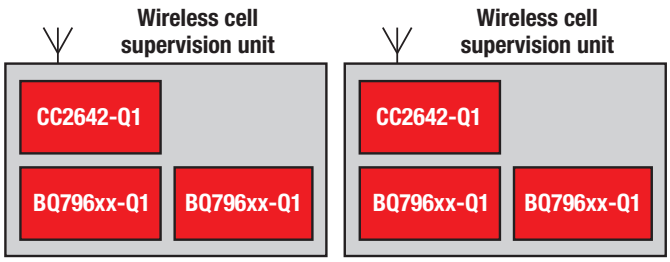


Figure 3. *Wireless BMS example.*

The significant difference between both solutions comes down to the replacement of the twisted-pair cabling in the wired solution with a CC2642R-Q1 device on each BMU in the wireless solution.

It may appear that adding an extra device may create more complexity and cost more than cabling, but consider the cost and weight of the cabling and the need to place high-performance isolation components on either side of the twisted-pair interface to ensure communication robustness. **Table 1** outlines further considerations for wired vs. wireless battery manangement solutions.

TI's wired vs. wireless BMS protocol

Going deeper into the TI protocols used in both solutions, the wired solution uses a differential, bidirectional and half-duplex interface, and therefore has a transmitter (TX) and receiver (RX) on both the high- and low-side communication interfaces to propagate information from low to high by default. These TX and RX functions are controlled automatically by the hardware based on the device's base or stack detection, and the data is re-clocked as it propagates to each module. The RX topology of the BQ796xx devices is similar to RS-485 but with added design mechanisms to attenuate high common-mode voltages caused by the noisy conditions typical in vehicle environments. Each byte transmits at 2 MHz (250 ns per pulse or 500 ns per couplet). As shown in **Figure 4**, the time between each byte depends on the UART baud rate (1 Mbps in normal operation), but the byte time is always the same.

Considerations	Wired BMS	Wireless BMS
Weight	• Typical reliability standard • Increases overall vehicle weight and complexity	• Decreases overall vehicle weight and complexity
Design flexibility and serviceability	• Less flexibility with a larger overall footprint • More difficult to service • Modular once cables are disconnected	• Smaller footprint enables design flexibility and more flexible placement within the vehicle • Easier to service
Measurement	• Time-synchronized measurements of voltage and current must propagate all the way up and down, causing delay between readings • Delayed measurement feature can improve performance	• Wireless system naturally enables time-synchronized measurements • Offers the ability to add more synchronized sensing capabilities
Reliability	• Wiring is reliable and meets functional safety standards but can break over time • Ring Architecture features built-in redundant cables in both directions • Can be more complex to repair	• No wires to maintain • Design must overcome harsh automotive radio-frequency environments and non-line-of-sight challenges
Security	• Contained and fully secure system communication	• Possible to breach poorly designed systems that lack security protocols

Table 1. *Wired vs. wireless BMS considerations.*

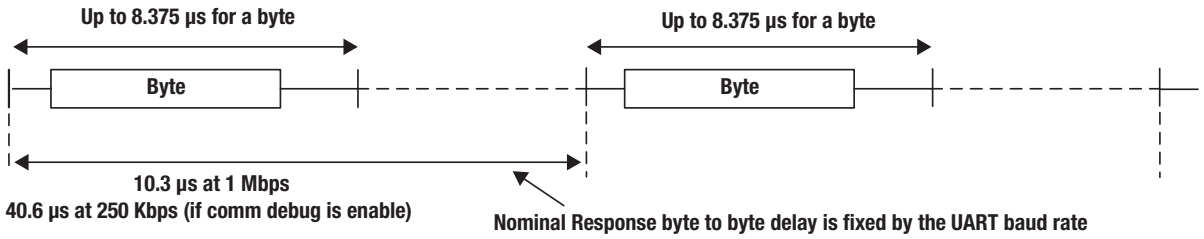


Figure 4. *BQ796xx byte-level communications.*

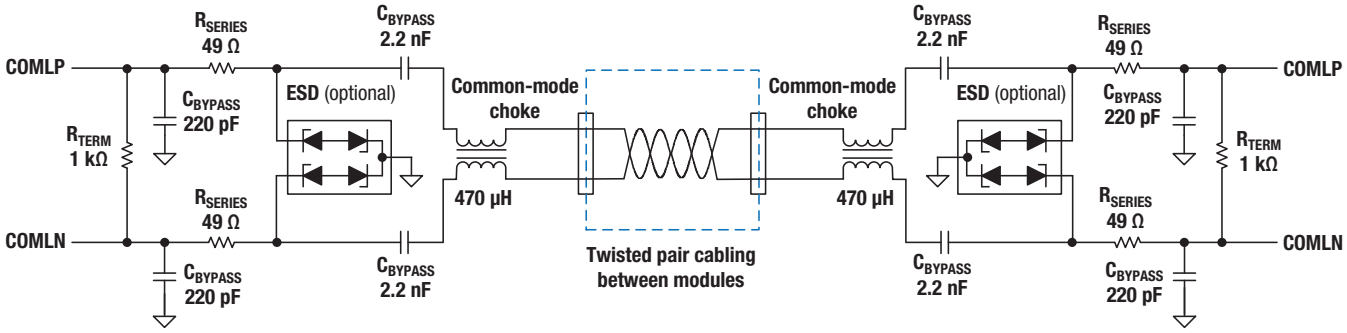


Figure 5. *Wired isolated circuit example.*

The wired interface is designed to support capacitive or inductive isolation for robustness amid stringent automotive EMC/EMI specification limits. **Figure 5** shows an example using capacitors and chokes. You would design the circuit between each battery monitor PCB, with as many as 64 devices all in one stack, to support varying sizes of vehicle battery modules.

To meet the requirements of tier-1 and original equipment manufacturers developing next-generation EVs, TI developed a proprietary wireless BMS protocol based on Bluetooth® Low Energy technology operating in the 2.4-GHz frequency band. **Table 2** lists features for the TI wireless BMS protocol, including the star network configuration to support as many as 32 nodes per central unit; the ability to provide high-throughput, low-latency data transmission; and the use of a functional safety-rated protocol.

Function	Target
Safety-critical reaction time (latency)	Max. 100 ms (safety)
Data throughput	Up to 400 bytes per wireless device
Link reliability	99.9999%
Security	Secured and encrypted messages
Scalability	Up to 32 wireless devices and more
Multi-cluster support	Yes
Functional safety	ASIL-D / ASIL-C at the system level
Power consumption	<1 mA (avg) at primary nodes, <1 mA (avg) at secondary nodes
Link budget	>95 dB
Time for forming network	<600 ms

Table 2. *TI's wireless BMS system targets.*

The key difference between the two protocols is the daisy-chain twisted pair wiring propagating the signal from the MCU all the way to the top monitor and back down; in a wireless star network configuration, each individual module can communicate independently back to the host processor. Both solutions do provide specifications that are highly important for automotive systems to deliver large amounts of pertinent battery pack data quickly, safely and reliably.

Conclusion

Safe, reliable, low-cost solutions for high-voltage battery packs in EVs require high-quality communications protocols to withstand noisy environments and allow system flexibility for varying cell module placement in the pack. The BQ7961x-Q1 family of products provides a path to support a system desiring wired or wireless communications.

Streamline your wired or wireless BMS design with these additional resources:

- Functional Safety Considerations in Battery Management Vehicle Electrification white paper
- BQ7961x-Q1 data sheet

Important Notice: The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

All trademarks are the property of their respective owners.

© 2020 Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated