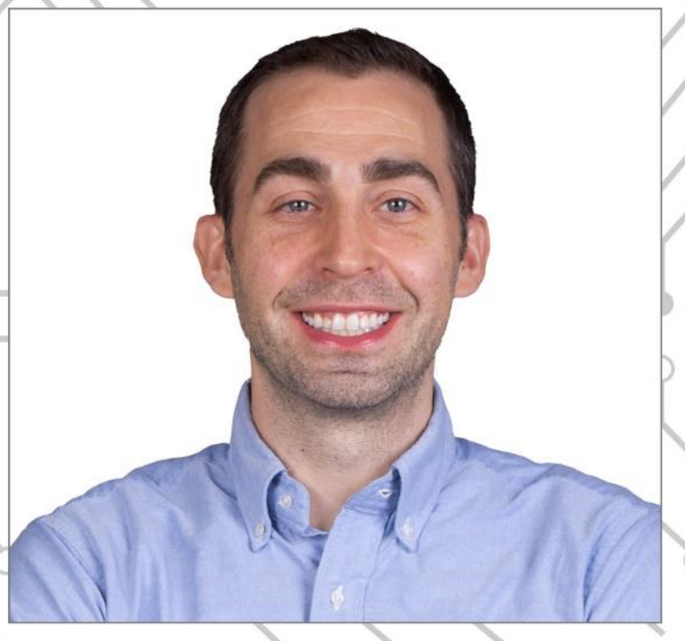
Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

MARK NG , JON NAFZIGER

MORE MILES, LESS WIRES: REVOLUTIONIZING AUTOMOTIVE BATTERY MANAGEMENT WITH TI WIRELESS BMS



Your partner in systems innovation

Passive safety systems

Reliable solutions to increase passenger safety

Infotainment and cluster

Immersive systems that keep drivers more informed and less distracted

Advanced driver assistance system

Advanced-assist and autonomous-driving capabilities for reducing human error

Body electronics and lighting

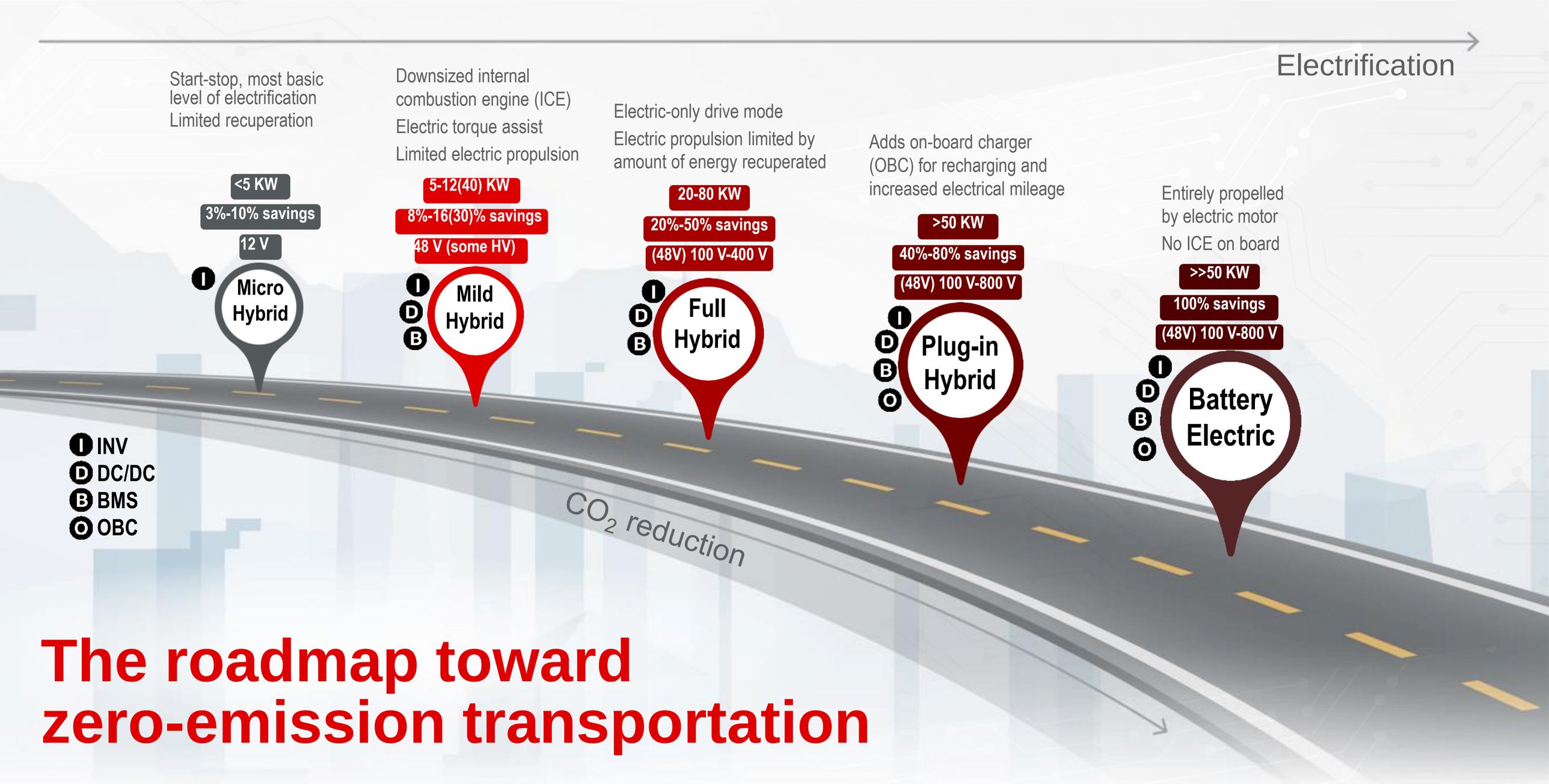
Innovative analog and embedded processors to optimize comfort and convenience

Hybrid and electric vehicles

Reducing emissions by electrifying systems from the car to the grid

Imagine a world where you can travel farther and more efficiently in an EV.

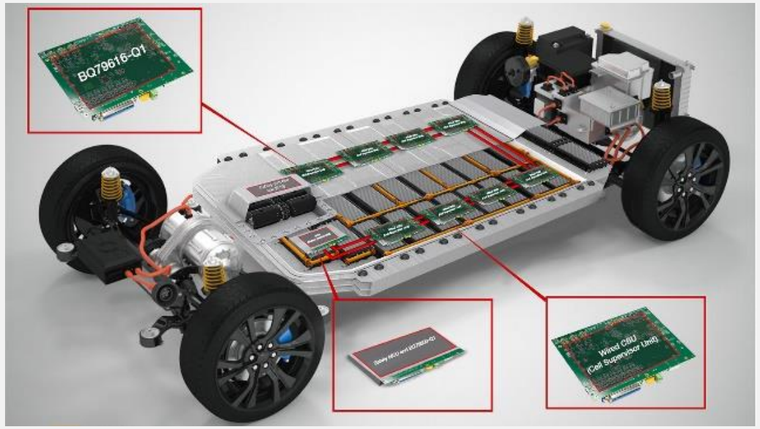
Wireless BMS can help make this a reality by enabling improved vehicle range, performance, maintenance and safety.



The roadmap toward zero-emission transportation

Battery management system today and tomorrow

Wired is today's industry standard

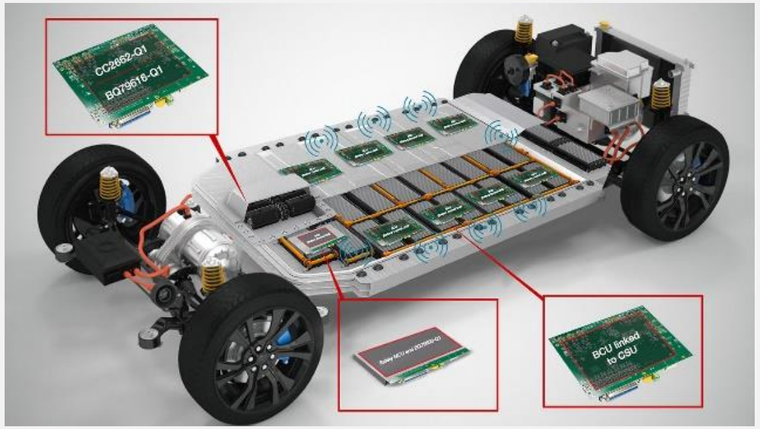


- Today's choice for implementing our parts with wired daisy chain communications interface
- Widely perceived to be a safe standard

Robust daisy chain communications

- ASIL D-capable communications support a single twisted-pair interface that can be connected in ring architecture for reliable communications in the event of a cable break

Wireless reduces cost and weight

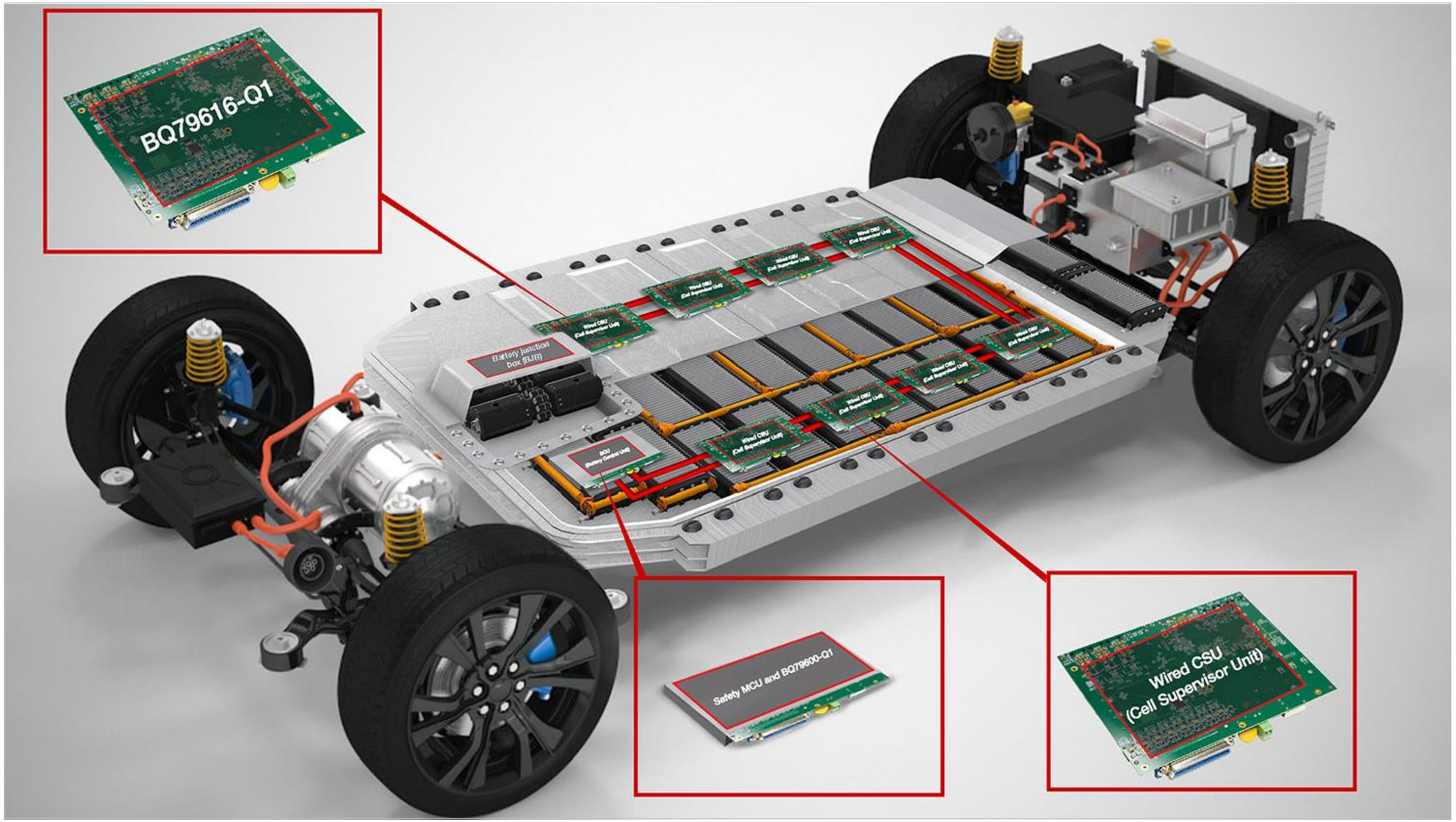


- Cable failures are costly. Warranty repairs and replacing the battery cell are expensive
  - The leading failures occur with the wiring harness and connectors
  - Eliminates lengthy cabling, significantly reducing weight

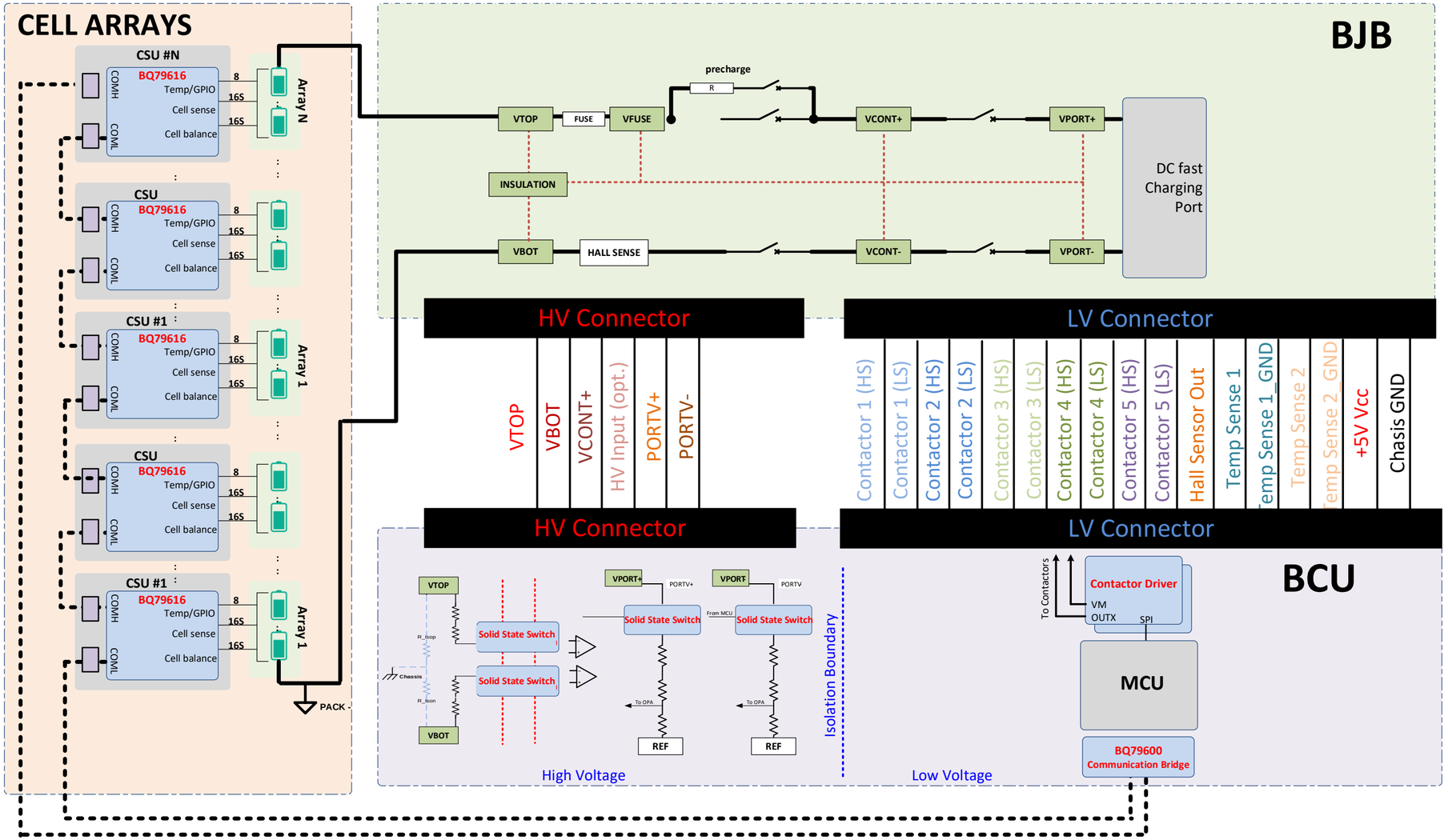
Inherently isolated

- Each cell-monitoring unit would naturally be isolated from one another to avoid noisy communications lines
- No need for daisy chain isolation components on external BOM

Wired battery management system



A traditional wired battery management system



- Daisy chain communication used today
- One of the main issues is the wire harnessing and the complexity, cost and manufacturing time required. Manual production and installation needed!
- Connector, cable and isolation (cap choke, transformer)
- Additional components for isolation

BJB = Battery junction box
BCU = Battery control unit
CSU = Cell supervisor unit

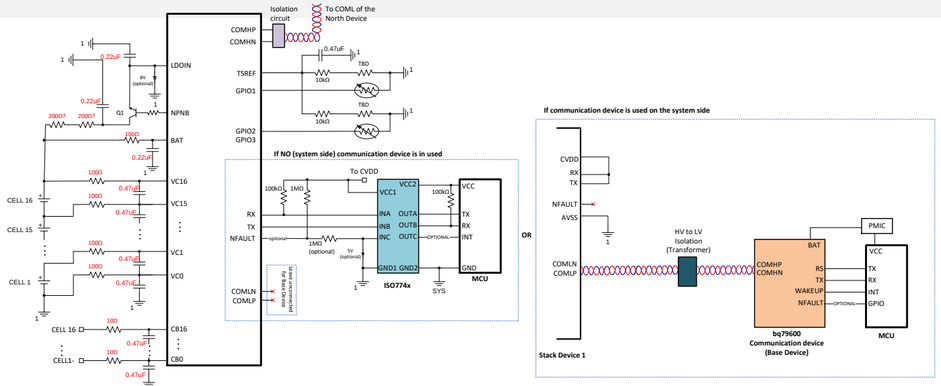
BQ79616-Q1 high-accuracy precision monitor and balancer

Target features

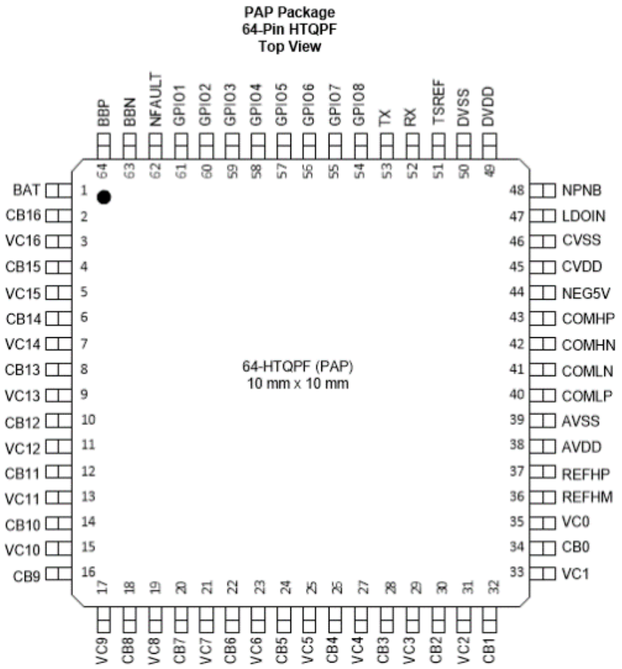
- **ASIL D voltage/temperature** measurement and **communication**
- **Cell count of 16S/stack up to 63 ICs**
- **Dedicated busbar measurement**
- **Voltage accuracy +/-2 mV**
  - All 16 cell voltage measurements complete in <128 us
  - Integrated front-end RC filters on voltage measurement path
  - Integrated post-ADC digital low pass filters w/ as low as 6 Hz f_{cutoff} option
- **Built-in second-level protector** for OV/UV/OT/UT and embedded differential fault signal through vertical communication interface
- **Robust daisy chain communication** with data re-clocking and ring architecture
  - Support capacitive, choke and transformer comm. isolation
- **UART communication** to system MCU; **SPI Main**
- **Hardware reset:** POR-like event without battery removal
- **Internal cell balancing** with 2.5 Ω Rdson at 240 mA/80ºC (8-channel balancing)
  - Or effective 120 mA/ 80º C on concurrent balancing all channel
  - Optional device controlled odd/even duty cycle w/out constant host system monitoring, or manual control to turn on adjacent CBFET
  - Independent configurable balancing timer range from 10 s to 10 hrs
  - Thermal management to pause/resume CB progress with internal CBFET temperature and external NTC measurement
- Optional **module balancing** with built-in timer and stack voltage cut-off setting
- **100 ms FDTI mode**
- Package: 64-pin QFP

Benefits

- **IC level ASIL D.** No special software requirement
- **Learn one, learn all applies to multiple platforms**
  - Part of the ASIL D family with 16S, 14S,12S monitor for HV system and 48V system
  - All devices sharing same package/pinout, functional control and register map
  - Dedicated busbar measurement allow same schematic on various module size design
- **Minimal BOM count and voltage measurement accuracy and integrity for SOC calculation**
  - Simple differentiate front-end RC filters (no voltage clap, no single ended cap)
  - Integrated post ADC low pass filters provides high integrity level of DC voltage measurement by filtering out system noise (e.g. invertor, charger, heater, motor rotation, etc.) for SOC calculation
- **Robust daisy chain communication**
  - Strong voltage drive strength (20 mA) with +/-20 V tolerant on receiver and data re-clocking
  - Hardware reset can be initiated by MCU to create POR-like reset
- **Additional features allow flexibility system design and system robustness**
  - Embedded fault function via communication line without extra fault cable or isolation need
  - Ring architecture on vertical communication like to support reverse communication direction in case of broken cable
  - Built-in second level protector with user programmable OV/UV/OT/UT threshold independent of ADC measurement, allowing critical cell monitoring in sleep mode



What is BQ79616-Q1?

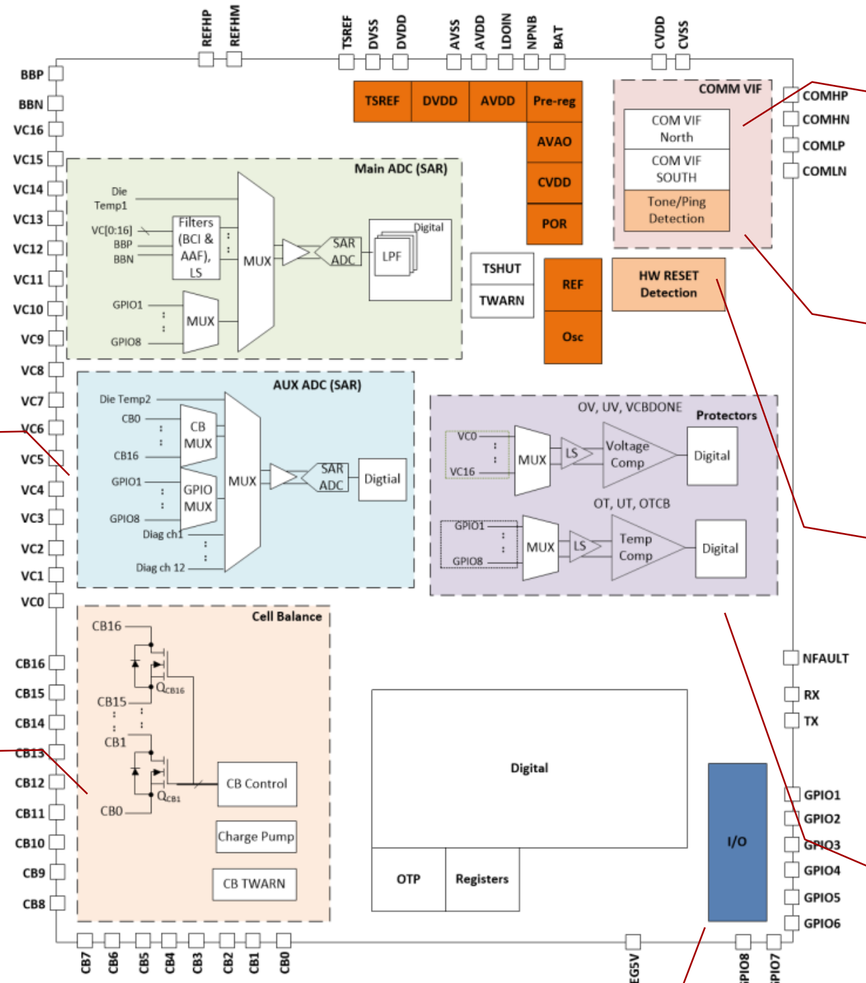


- **16S stackable battery monitor**
- **Same package/pinout on its 12S/14S variants**
- **Support min of 6S (9V) operation**

Main ADC
Measure VCELL, busbar (if used) and temperatures

AUX ADC
Redundancy for Main measurement. Mainly use for diagnostic. Also measure VBAT

Cell balancing
Internal CB with typ 2.5 Ω Rdson.
Support Icb 240 mA with thermal management



Vertical interface
Bi-directional daisy chain communication requires 1 twisted cable pair. Also support RING communication

Tone/ ping detection
Handle critical power transition signal (e.g. wake, shutdown, etc). Implemented in pure analog. Operates in all power modes

Hardware reset
Independent hardware reset detection block implemented in pure analog. Operates in all power modes

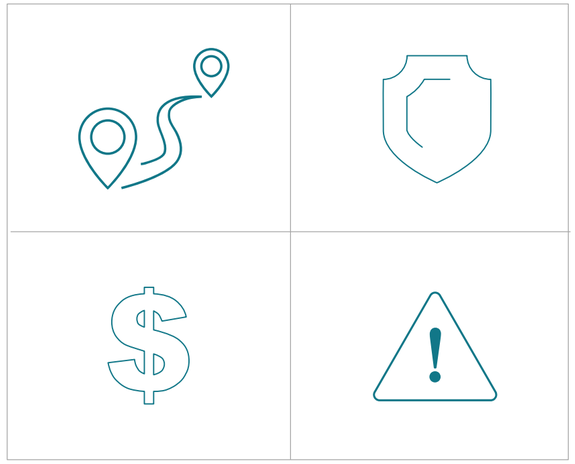
Integrated hardware protectors
Hardware comparators, independent of ADC operation, for OV, UV, OT, UT detection

Can operate in sleep mode. These are also used for CB voltage/thermal detection

GPIOs
8 GPIOs: can be use for NTC thermistor or auxiliary voltage input measurement. Can also be use for SPI main

Current challenges with BMS in EVs

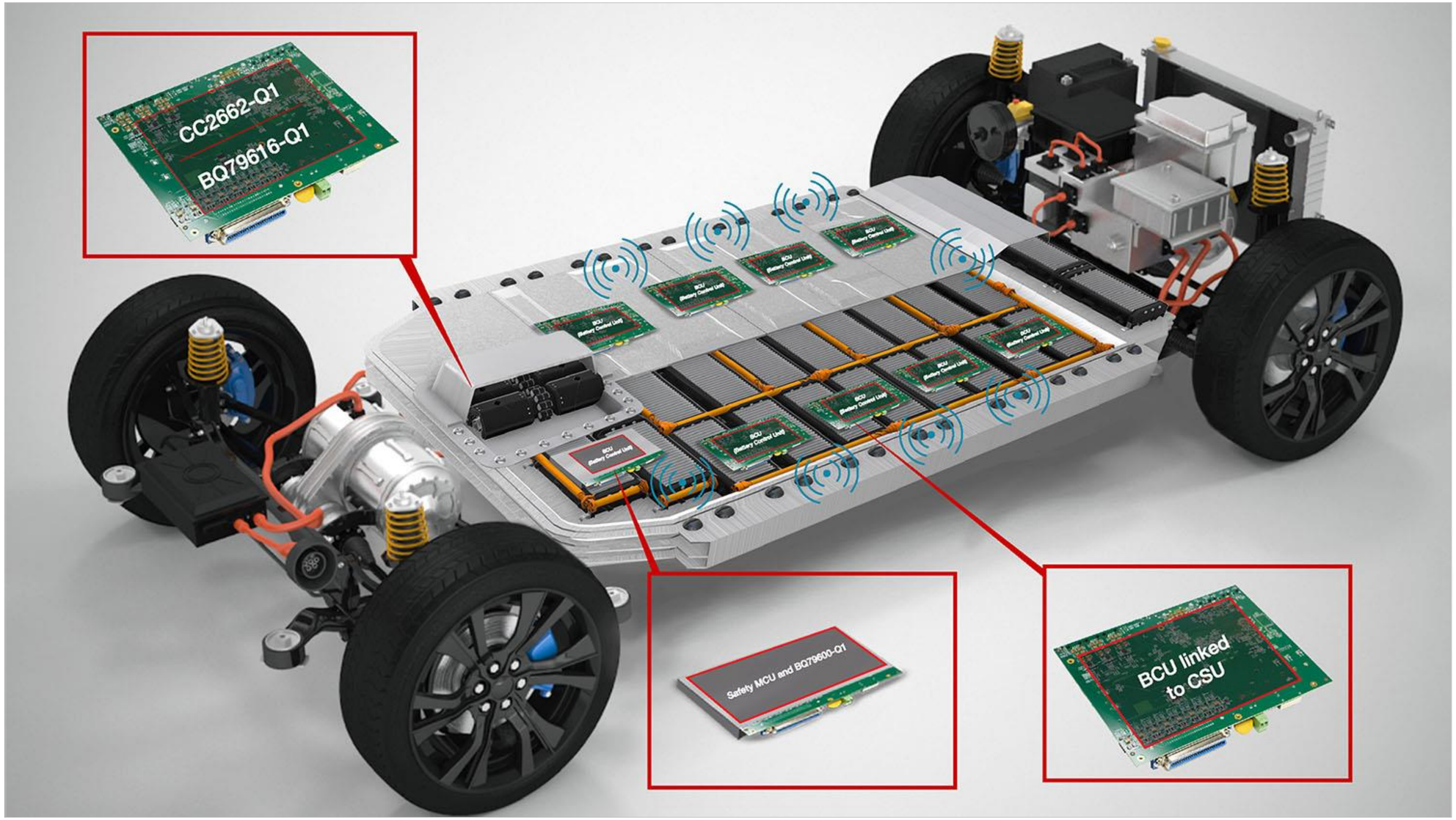
Pounds of wire are a drag on distance, reliability, price and safety



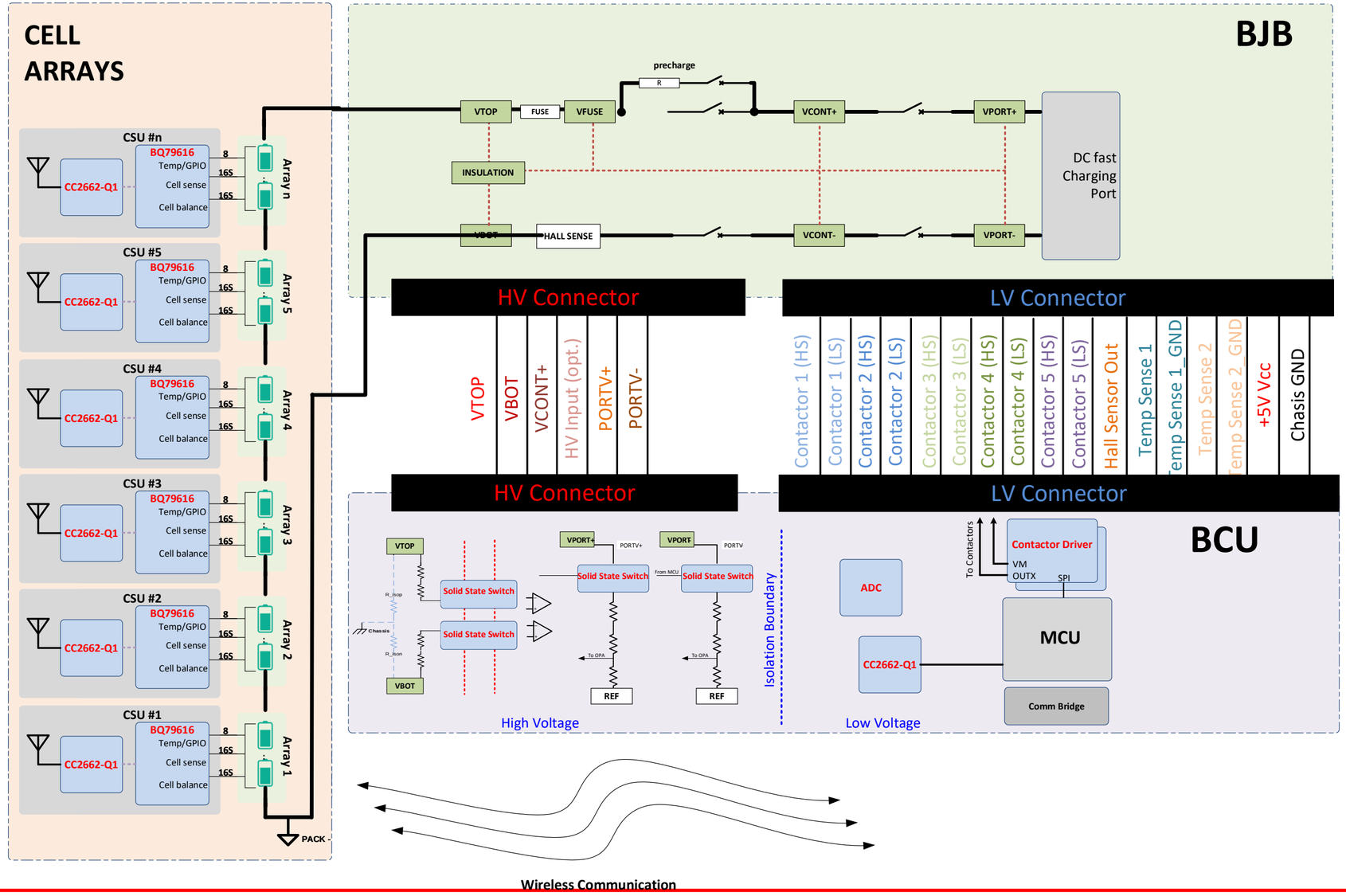
- Every battery cell must be connected by cable to a monitor, which regulates energy performance
- Warranty repairs due to cable failures are costly, and replacing the battery cell is expensive
- The wiring harness and connectors are a common source of cable failures
- The heavy-duty copper wire required to make the cabling more reliable, produces a bulky labyrinth of battery-management cabling

Safety is a critical consideration overall.
Meeting the necessary safety requirements for BMS are rigorous.

Wireless BMS



A wireless BMS system



- Nodes communicate in wirelessly
  - Failure of one node does not cause failure of complete communication chain
- Simpler HV/LV isolation concept
  - No need of galvanic isolation BCU/CSU

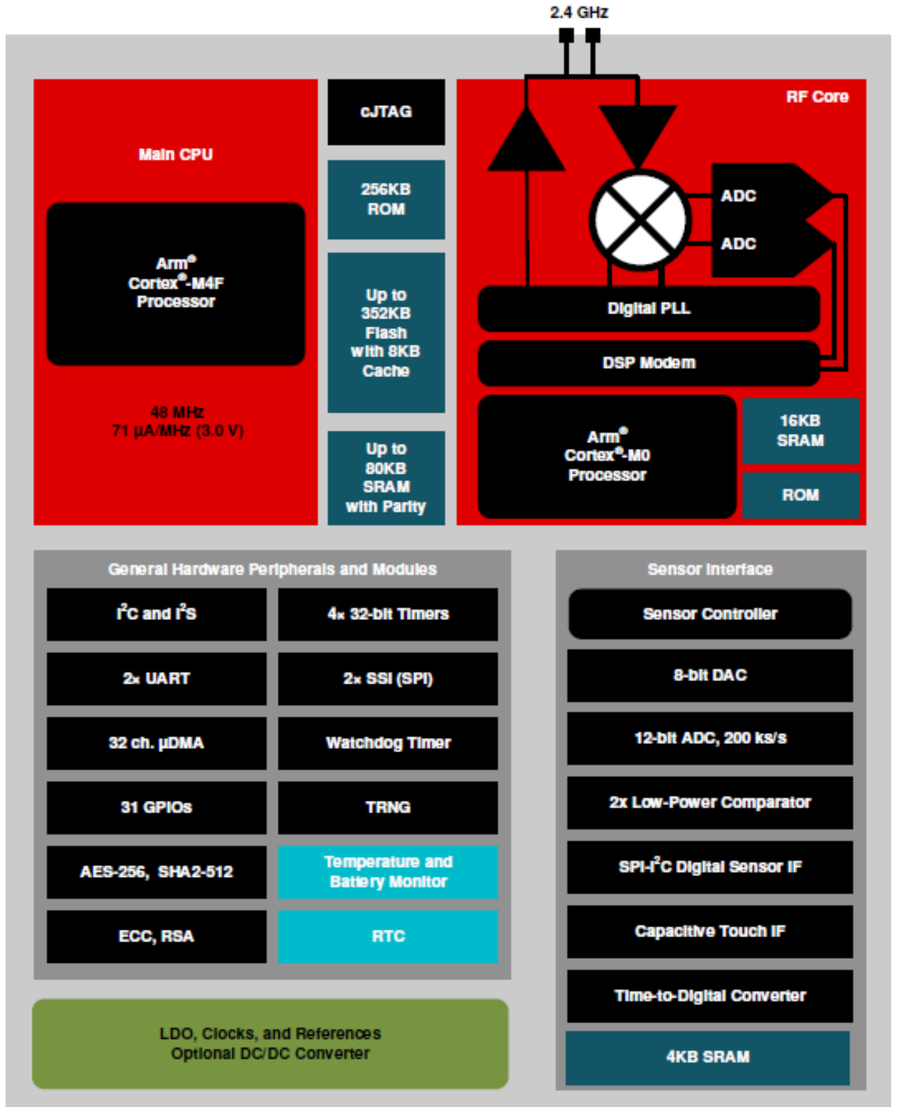
CC2662R-Q1 device overview

Identity

- Arm® Cortex®-M4 wireless MCU targeting wireless BMS and cable replacement applications
- AEC-Q100 compliant device optimized for low-power wireless automotive applications

Key Features

- TI wireless BMS protocol
- 2.4 GHz
- Functional Safety Quality-Managed device
- AEC-Q100-Qualified at the Grade 2 temperature range (-40ºC to +105ºC)
- Extended temperature for automotive applications (TA = 105ºC)
- Low Power:
  - Wide voltage range: 1.8 V to 3.63 V
  - Active-mode RX: 6.9 mA
  - Active-mode TX: 0 dBm: 7.3 mA
  - Active mode: 71 uA/MHz
  - Standby: 0.94 µA (CPU retention, 80 KB RAM)



Key Device Specification

- Arm® Cortex®-M4
- 352 kB of flash, 88-kB total SRAM, 256 kB of system ROM
- 2 UART, 2 SPI, I2C and I2S
- Sensor controller
- Enhanced security (hardware acceleration, AES-128/256, SHA-2, TRNG, ECC, RSA-2048)

Packages

- QFN48 WF 7 mm x 7 mm

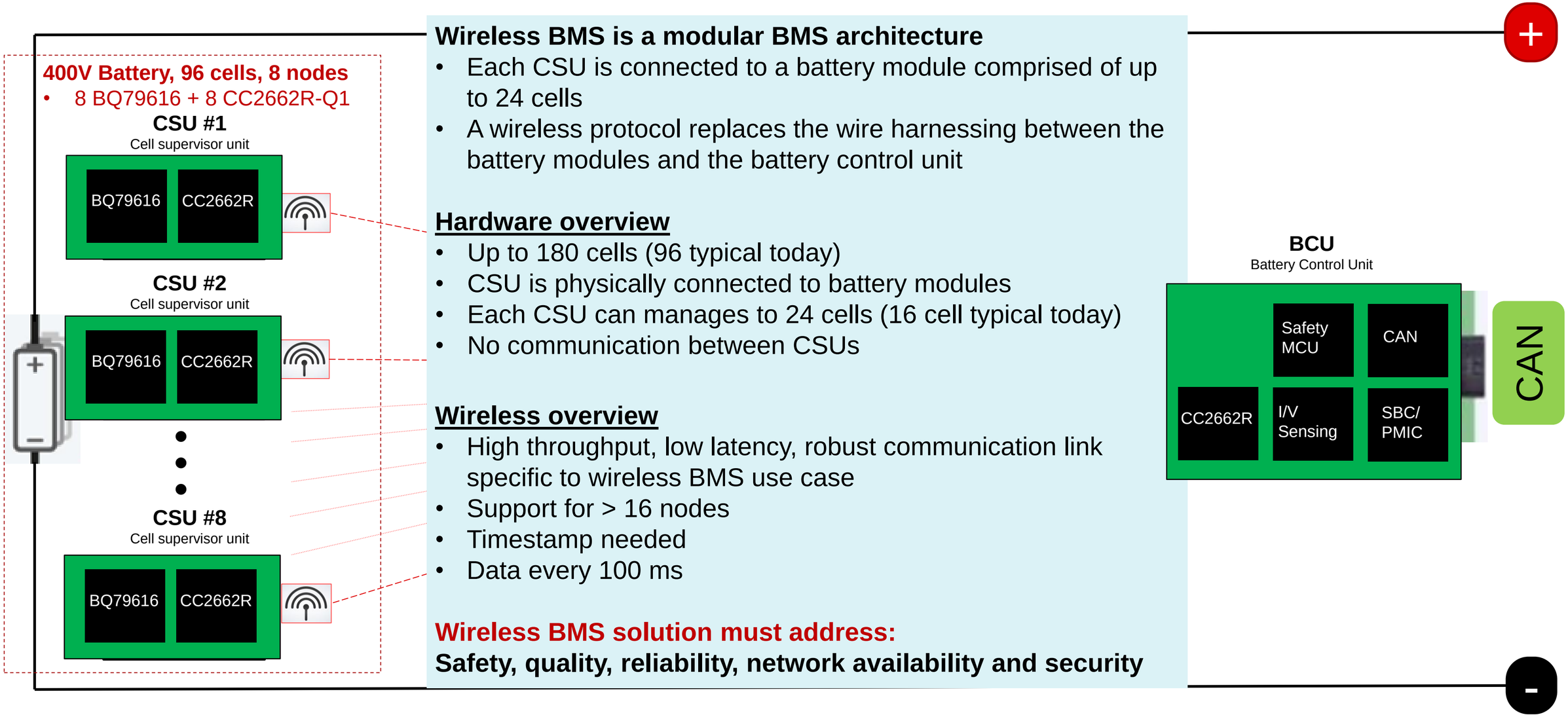
Key applications

- Automotive – wireless battery management system
- Cable replacement

Availability

- Samples available today

Wireless BMS overview



Wireless BMS is a modular BMS architecture

- Each CSU is connected to a battery module comprised of up to 24 cells
- A wireless protocol replaces the wire harnessing between the battery modules and the battery control unit

Hardware overview

- Up to 180 cells (96 typical today)
- CSU is physically connected to battery modules
- Each CSU can manages to 24 cells (16 cell typical today)
- No communication between CSUs

Wireless overview

- High throughput, low latency, robust communication link specific to wireless BMS use case
- Support for > 16 nodes
- Timestamp needed
- Data every 100 ms

Wireless BMS solution must address:
Safety, quality, reliability, network availability and security

TI’s new advancements in wireless BMS improve range, reliability and safety

- ✓ The industry’s first wireless BMS TÜV SÜD assessed for enabling ASIL D functional safety systems
- ✓ A wireless protocol that securely enables the industry’s best network availability
- ✓ Provides freedom to develop reliable, system-level designs across multiple platforms

WBMS Quality | Functional Safety And Cyber Security

- Process Level:
  - TI have completed ISO21434 process certification
  - WBMS development is following TI approved Cyber Security process.
  - Cyber Security TARA was completed

- Component Level:
  - BQ79x1x-Q1 is an ASIL D Compliant Battery/Pack Monitor
  - CC2662R-Q1 is an FS-QM Wireless Microcontroller
  - TI WBMS protocol is systematically compliant to ASIL D

- System Level:
  - TI Technical Concept is unique among competitors
  - TÜV SÜD assessed concept of safety layer to support communication up to ASIL D / SIL 3

CERTIFICATE

No. Q4B 088989 0027 Rev. 00

Holder of Certificate: Texas Instruments
12500 TI Boulevard
Dallas TX 75243
USA

Factory(ies): Texas Instruments
12500 TI Boulevard, Dallas TX 75243, USA

Certification Mark:

Scope of Certificate: Automotive Cybersecurity process

Cybersecurity Management System according to ISO/SAE21434 - Road Vehicles - Cybersecurity engineering. This process framework applies to Texas Instruments products globally

Applied Standard(s): ISO/SAE 21434:2021

The Certification Body of TÜV SÜD Product Service GmbH certifies that the company mentioned above has established and is maintaining a management system which meets the requirements of the listed standards. The results are documented in a report. For details see: www.tuvsud.com/ps-cert

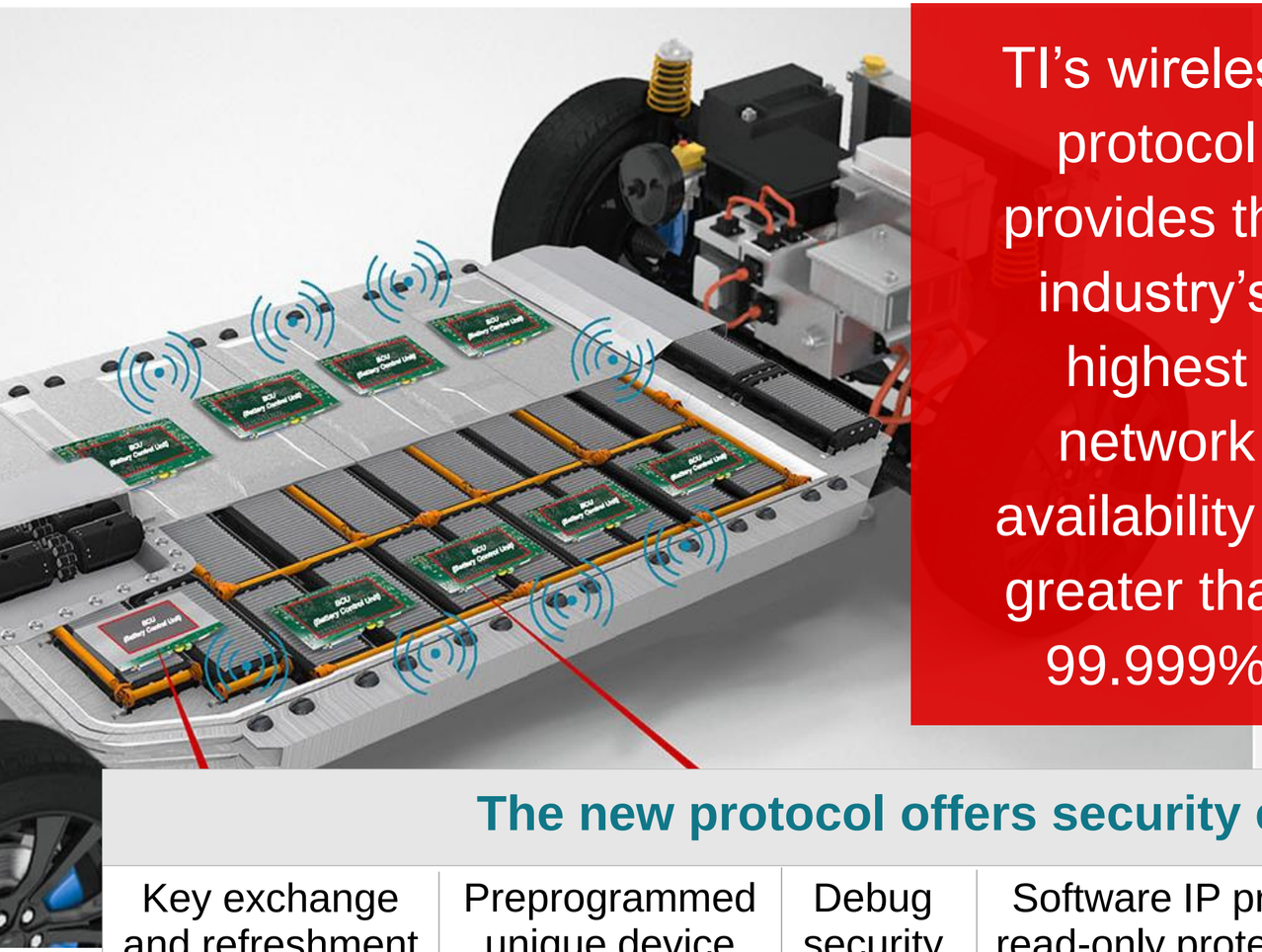
Report No.: TD99838T

Valid until: 2025-12-13

Date, 2022-12-15

(Christian Dirmeier)

TI’s wireless BMS securely supports the industry’s best network availability



TI’s wireless protocol provides the industry’s highest network availability of greater than 99.999%

Network restart of 300 mSec maximum availability

Dedicated time slots providing high throughput and low latency to further protect data from loss or corruption

Enables multiple battery cells to send voltage and temperature data to the main MCU with ±2- mV accuracy and a network packet error rate of less than 10^{-7}

The new protocol offers security enablers to help mitigate threats

Key exchange and refreshment	Preprogrammed unique device serial ID	Debug security	Software IP protection with read-only protection for flash sectors	Secure firmware update	Cryptographic accelerators (AES, ECC, SHA), TRNG App Note

TI’s wireless BMS solution is the most scalable in the industry

Automakers can create a battery module using a single CC266C2R-Q1 wireless system-on-chip

- Each cell-monitoring unit is isolated to avoid noisy communication lines
- Eliminates the need for and cost of daisy-chain isolation components

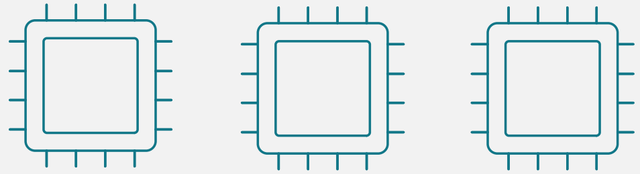
CONNECTED TO

Supports up to 100 nodes

Industry’s lowest latency of less than 2 mS per node

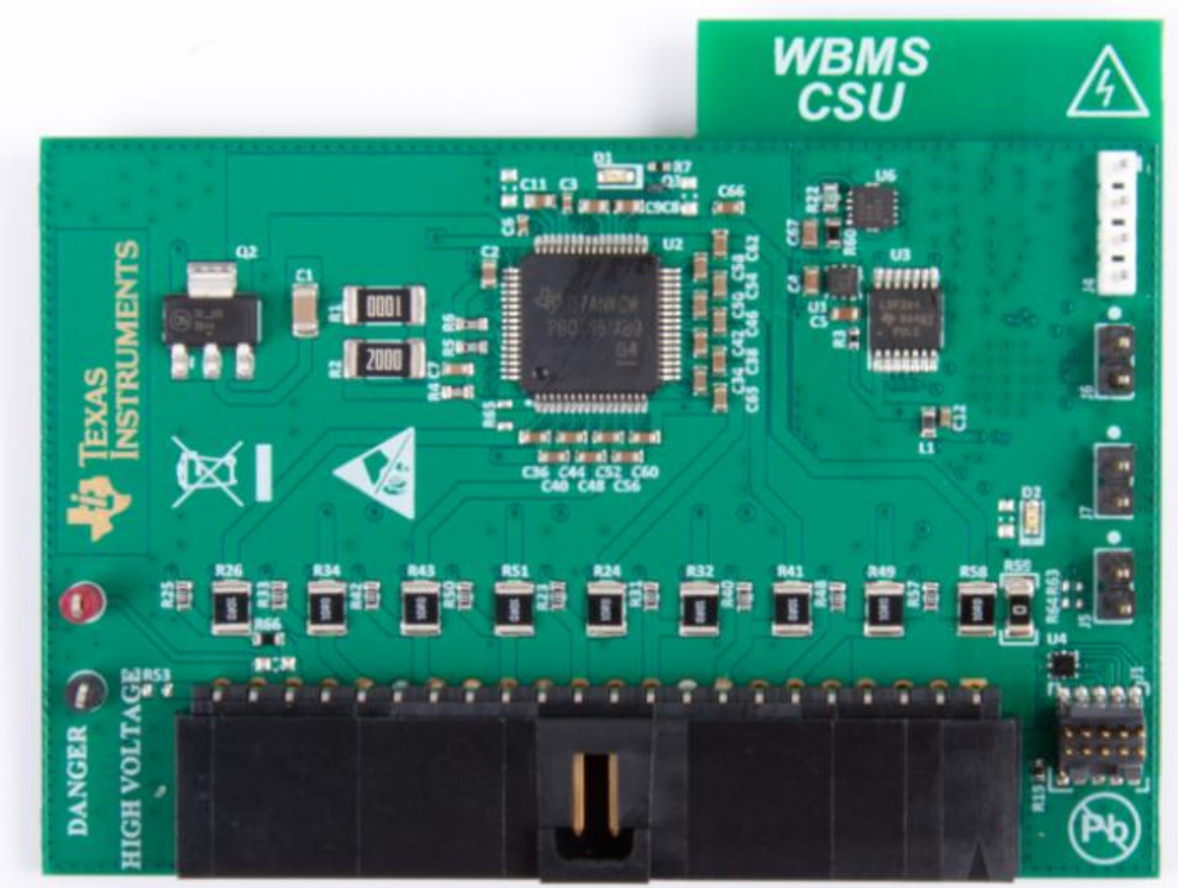
Time-synchronized measurements across every node

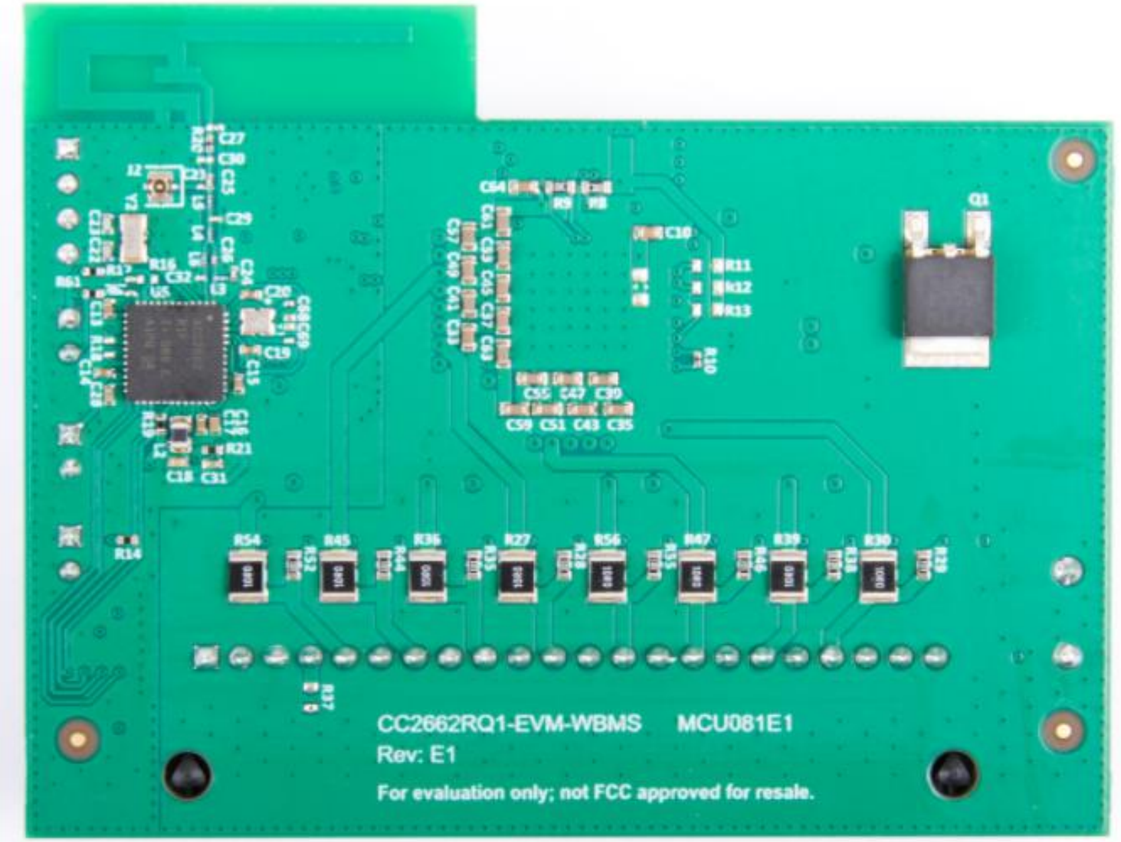
Multiple BQ79616-Q1 battery monitors for different configurations such as 16-, 32- and 64-cell systems



- Different channel options in the same package type
- Pin-to-pin compatibility
- Supports reuse of the established software and hardware

WBMS evaluation board





TI WBMS reference design and demo

Design Features

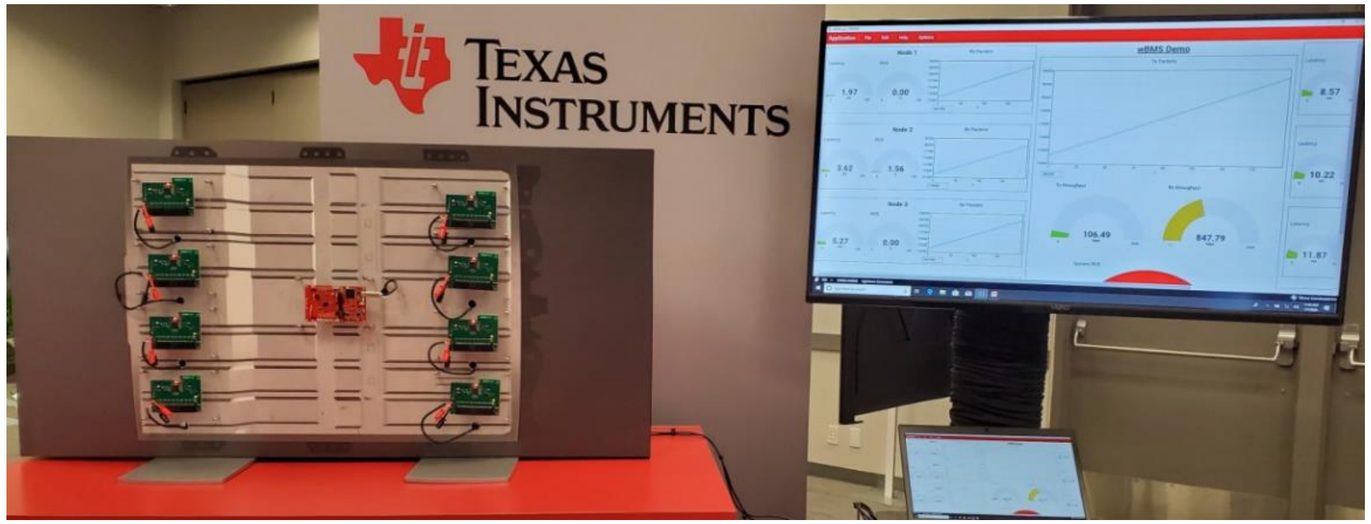
- Wireless BMS evaluation board featuring BQ7961x-Q1 Functional Safety-Compliant and SimpleLink™ CC2662R-Q1 wireless MCU
- High throughput, low latency and robust 2.4-GHz wireless protocol operating with “black channel” principle per IEC 61784-3
- Guaranteed data transmission from each node every 100 ms
- Supports battery stacks up to 1 kV
- 2-Mbps data rate

Design Benefits

- High throughput, low latency wireless protocol optimized for the wireless BMS use case.
- Per “black channel” principle: all safety-oriented mechanisms are exclusively implemented on the application level, which enables total independence from the underlying transport layer.
- The TI WBMS protocol will provide measures for all defined failure modes and will handle additional overhead needed to fulfill ASIL D (per ISO 26262) error failure rates in harsh RF environments.

Tools & Resources

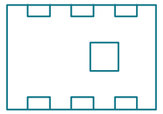
WBMS evaluation board - CSU



TI wireless BMS technology resources, product availability and pricing

Automakers can jump-start their designs by downloading:

The SimpleLink™ wireless BMS software development kit (SDK), **available at no cost**



The SimpleLink wireless WBMS development kit is available via request through your local TI sales assosciate.

SimpleLink 2.4-GHz CC2662R-Q1 wireless MCU

- 7-mm-by-7-mm
- 48-pin quad-flat no-lead (QFN) wettable flank (WF) packages

US$3.20 in 1,000-unit quantities

16-channel BQ79616-Q1 battery monitor and balancer

- 10-mm-by-10-mm
- 64-pin thermally enhanced thin quad flat package (HTQFP)

US$6.90 in 1,000-unit quantities

All products featured in the wireless BMS solution are immediately available for purchase on TI.com

2.4-GHz wireless battery management system

Wireless connection between battery packs and battery management system to replace traditional, wired connections

Why wireless BMS?

Increases EV range	• Reduces overall vehicle weight by replacing heavy battery-management wiring with high-reliable, secure wireless connections
Improves time to market	• Eliminates development costs & complexity associated with routing a labyrinth of battery-management cabling
Enhances vehicle scalability	• Manufacturers can address multiple EV vehicle and market segments with a single modular wBMS platform
Reduces warranty expense	• Removes the need for costly repairs due to common cable breaks and harness failures in traditional wired systems

Getting started

1. Request SDK download
2. Request wBMS development kit
3. Download documentation
4. Request functional safety assessmen

Three questions to ask about wireless BM for hybrid and electric vehicles

Why wireless for battery management systems (BMS)?

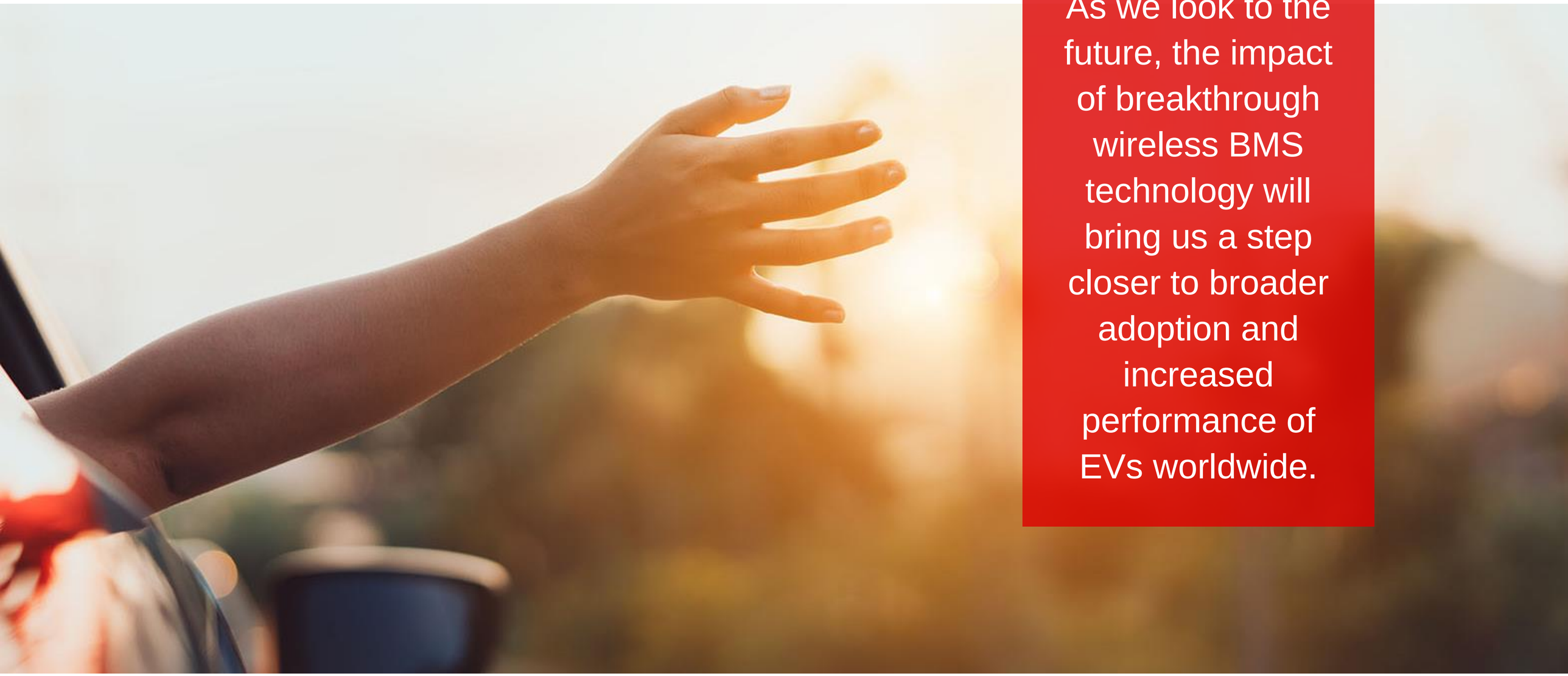
CC2662R-Q1 Automotive qualified SimpleLink™ wireless MCU for use in wireless battery management systems

BQ79616-Q1 Automotive ASIL D compliant battery monitor for use in wireless battery management systems

Fixed-low-latency protocol with high throughput and high reliability for ultra-low packet error rate

Why TI?

Best network availability	• TI's wireless protocol for BMS via the CC2662R-Q1 MCU offers the industry's highest network availability greater than 99.999%
System-level functional safety compliance	• Industry's first TÜV SÜD assessed safety concept for wBMS • System-level ASIL D compliance • AEC-Q100 functional safety Quality-Managed wireless MCU • AEC-Q100 functional safety compliant battery monitor
Flexible battery architecture	• Industry-best scalable solution with support for up to 100 nodes
Low power	• Up to 10X lower power consumption than competition



As we look to the future, the impact of breakthrough wireless BMS technology will bring us a step closer to broader adoption and increased performance of EVs worldwide.

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