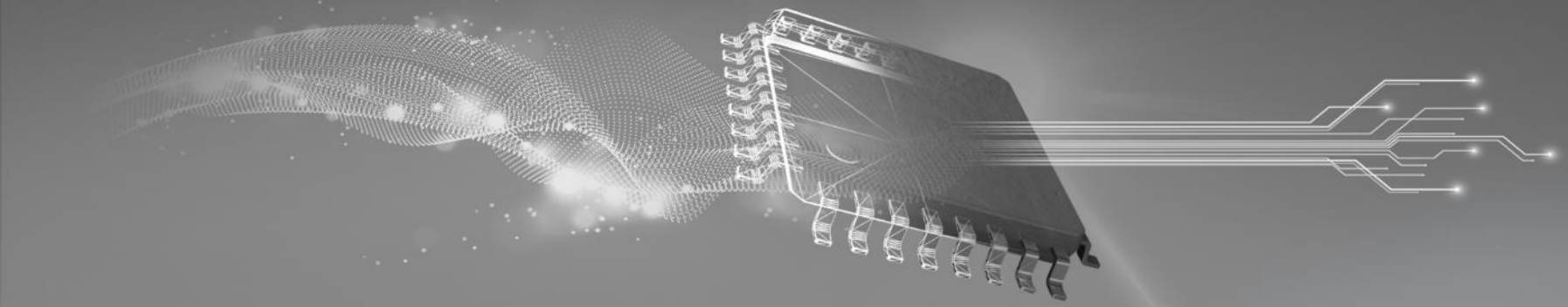
TI TECH DAYS



Comparing wired vs. wireless solutions in automotive battery management systems

Taylor Vogt

Battery management solutions

Texas Instruments

2020 Battery Management Deep Dive Technical Training

October 13-14, 2020
Virtual: wherever you are

Main Event Page:

ti.com/deepdive

Quick Links:

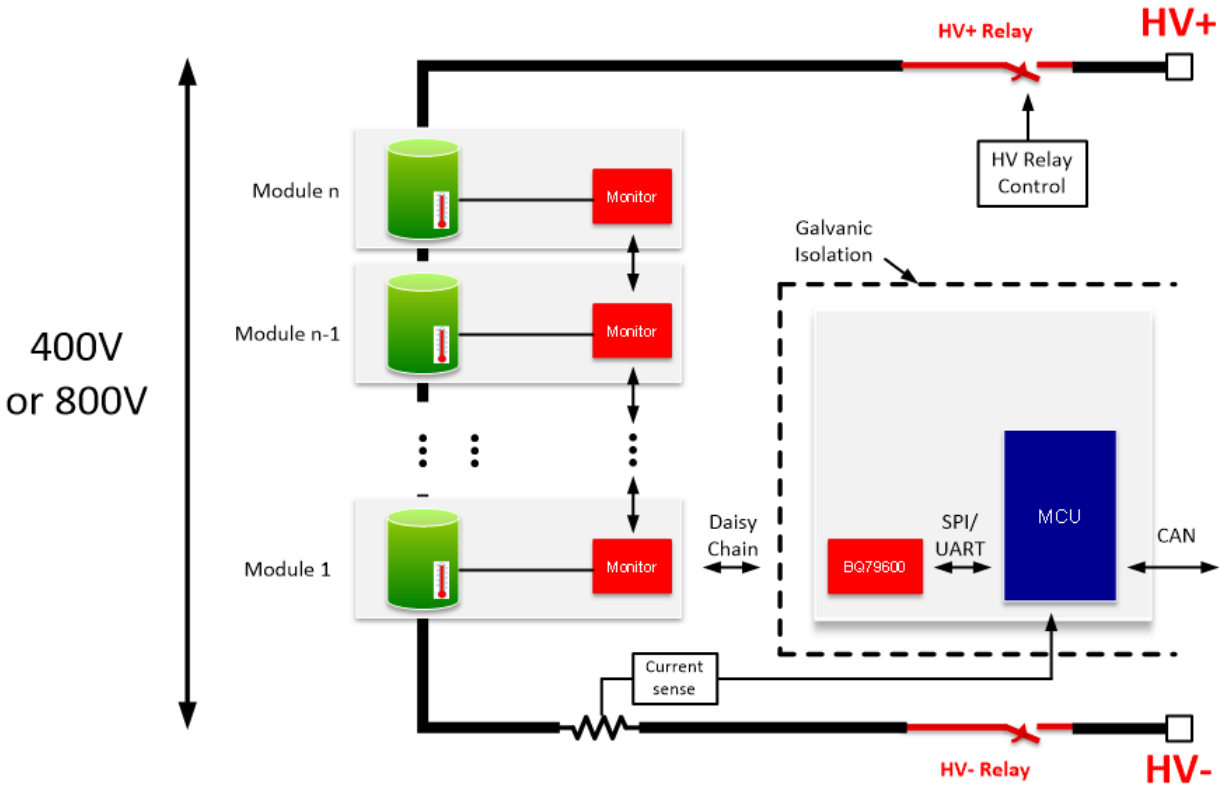
- Register Now
- Download the Agenda
- Presentation Abstracts

			Day 2: OCTOBER 14		
CST (Beijing)	CEST (Berlin)	CDT (Dallas)	Keynotes & Opening Sessions		
9:00 - 9:45 PM	3:00 - 3:45 PM	8:00 - 8:45 AM	Ivo Marocco and Ankush Gupta Industry trends driving high-accuracy battery monitors for HEV/EV		
Break					
			Chargers	Gauges	Automotive Monitors
9:50 - 10:35 PM	3:50 - 4:35 PM	8:50 - 9:35 AM	Sharafadeen Raheem Choosing the right battery charger topology for low-power applications	Dominik Hartl Gauge configuration featuring Impedance Track™ technology for applications with dynamic loads	Spencer Hu Design considerations for 48-V batteries in hybrid and electric vehicles
Break					
10:35 - 11:25 AM	4:40 - 5:25 PM	9:40 - 10:25 AM	Kedar Manishankar Achieving simple, safe and efficient charging	Shirish Kavoor Introduction to BQStudio and TI tool chain for gauge evaluation	Taylor Vogt Comparing wired vs. wireless solutions in automotive battery management systems

Overview

- Communications interface
  - Systems background
  - Which interface?
  - Communication options
- Why wired?
  - Proven industry method
  - Robust daisy chain communications
- Why wireless?
  - Cable/weight reduction
  - Naturally isolated
- How the BQ7x61x family enables both methods
- Demo

Auto battery monitor architecture: 400 V / 800 V (1)



Distributed

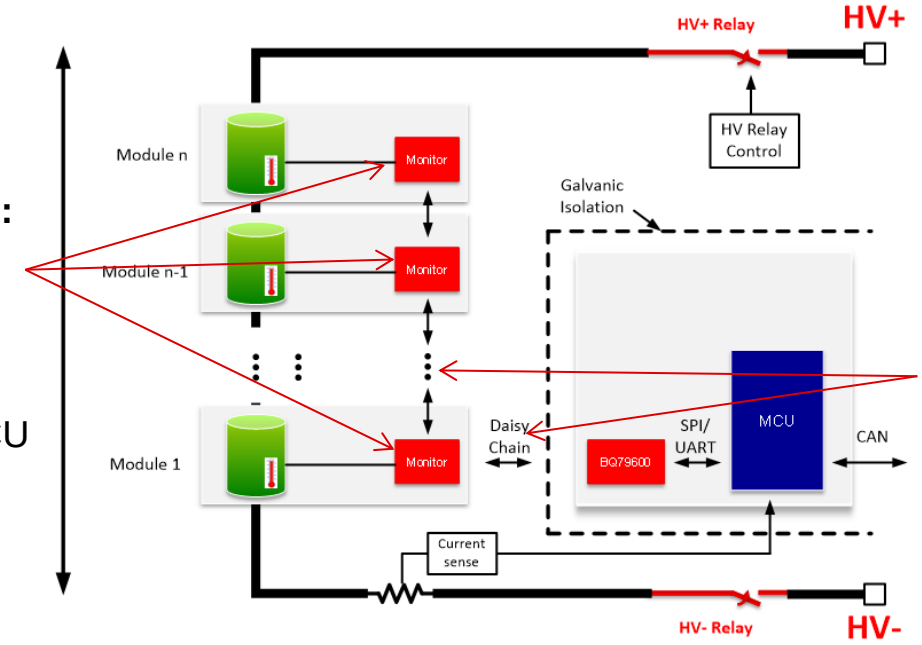
- Each module can be 3 – 20+ battery cells in series
- Each monitor IC on its own PCB
- Each monitor IC is connected by daisy chain cable
- Check out BQ79606A, BQ79616

Communications interface – Background

For automotive applications, the battery packs extend up to **800 V** and beyond. This means that there can be **100+ series** cells stacked inside the vehicle

Monitor Device (Bq796XX): connected directly to each battery module in the pack

- Reports voltage, temp, diagnostics back to host MCU via daisy chain propagation

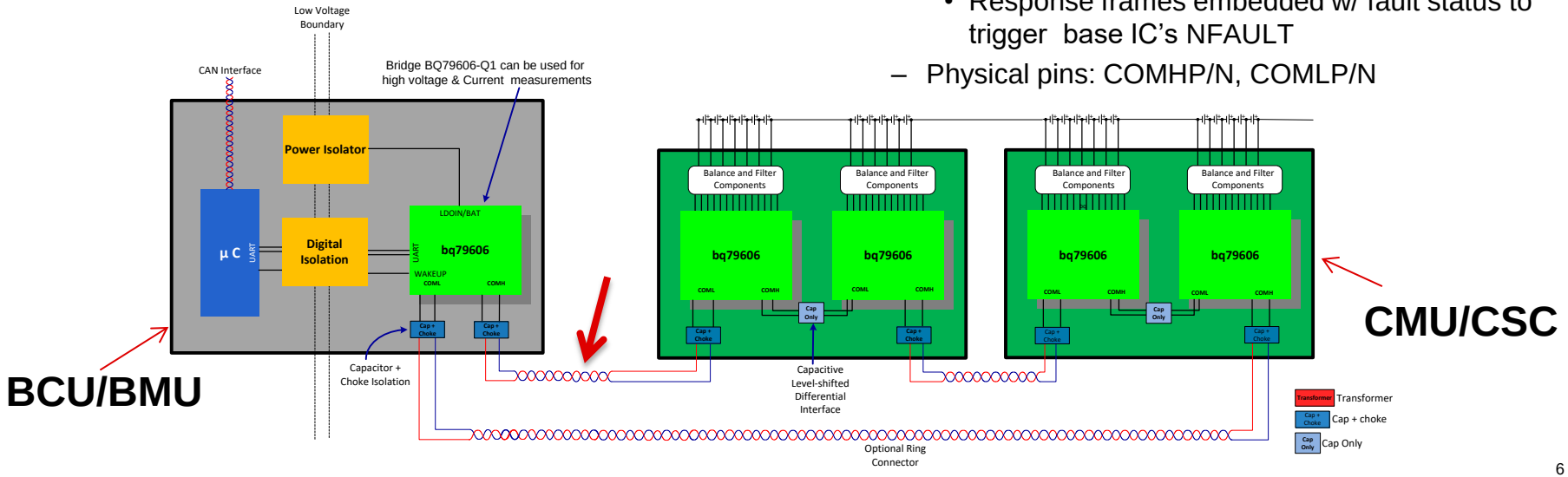


Communications: between each monitor device AND the bridge communication device (bq79600) to then relay info back to host MCU

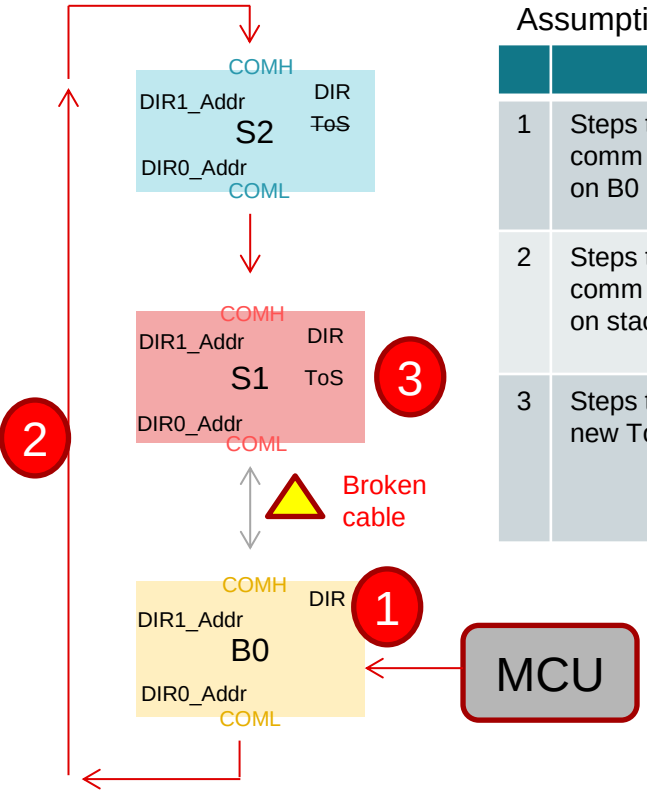
BQ79616 Communication

- **Serial interface**
  - **Communication between the base IC and the MCU**
    - UART, 1 MHz baud rate, half-duplex
    - Physical pins: RX and TX

- **Vertical interface (VIF) or daisy chain communication**
  - **Communication between stack and base ICs**
    - Differential bidirectional (command and response frames)
    - Response frames embedded w/ fault status to trigger base IC's NFAULT
  - Physical pins: COMHP/N, COMLP/N



Communication: Ring



Procedure for MCU to set up reverse communication in daisy chain (south to north)

Assumption: Daisy chain is already initialized in DIR = 0 (north to south comm) direction

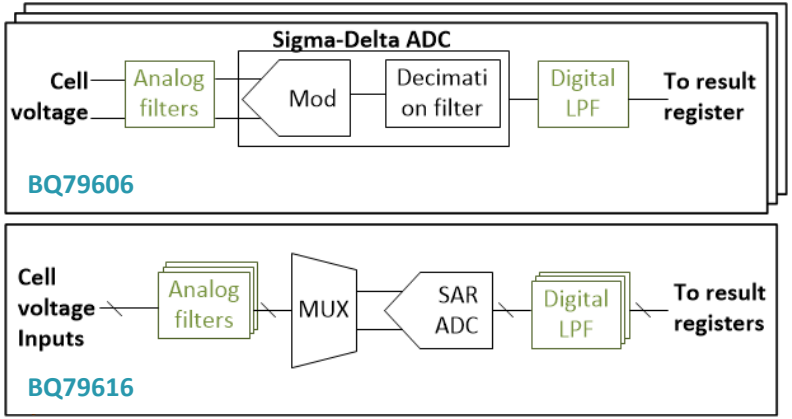
		BQ79606	BQ79616
1	Steps to change comm direction on B0	a. B0: enable COML TX/RX b. B0: disable COMH TX/RX c. B0: single device write to change DIR = 1	a. B0: single device write to change DIR = 1
2	Steps to change comm direction on stack devices	a. S2 to S1: reserve broadcast write to change DIR = 1 b. B0 to S2 to S1: auto-address	a. S2 to S1: reserve broadcast write to change DIR = 1 b. B0 to S2 to S1: auto-address
3	Steps to set up new ToS	a. S2: remove ToS b. S2: enable COML RX (if it's disabled) c. S1: set ToS d. S1: disable COML RX	a. S2: remove ToS b. S1: set ToS

Improvement on 616: **simplify host overhead**

- Add smartness to automatically configure the COML/H based on direction
- Separate device address registers (one for DIR = 0 direction and one for DIR = 1 direction)
  - Host auto-address daisy chain in north-south direction and auto-address in south-north direction once. No need to re-address every time comm direction is changed.

Time for all measurements to return to host

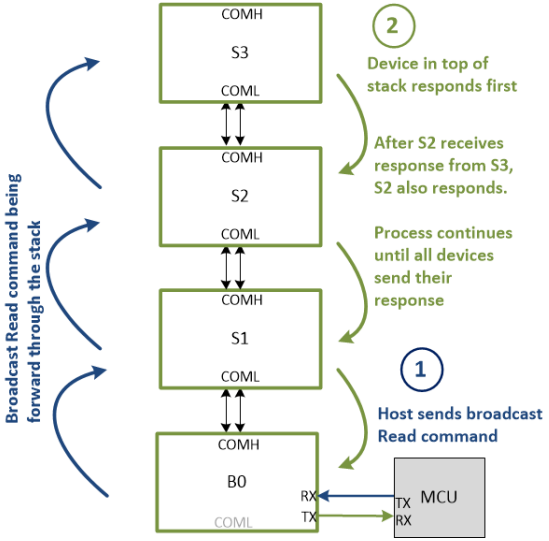
- **Measurement system architecture**



  - **BQ79606**: takes ~1 ms to finish all cell voltage measurements along the daisy chain
  - **BQ79616**: takes ~128 µs to finish all cell voltage measurements along the daisy chain

- **Reduce communication time to free up MCU for other operations**
- **Improve overall fault detection time tolerance**

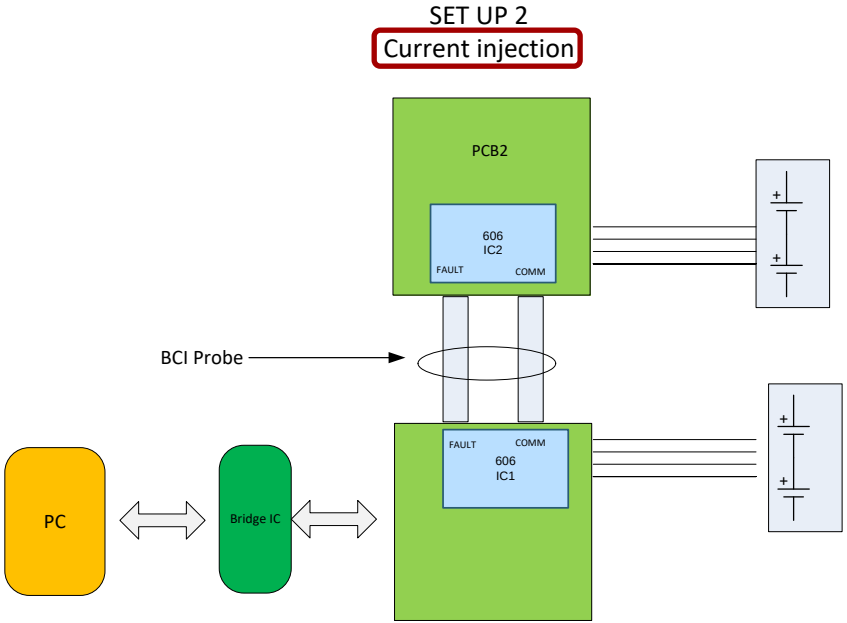
- **Communication protocol**



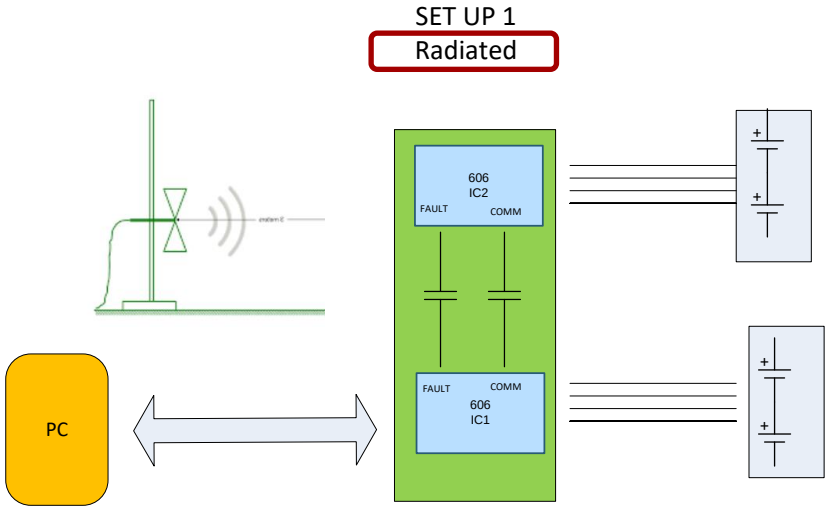
  - **BQ79606** (6s module x 16 ICs)
    - Takes ~3 ms to read 96 cell voltages
  - **BQ79616:** (16s module x 6 ICs)
    - Takes ~2.4 ms to read 96 cell voltages

EMC testing

Communication cables between ICs in different PCBs

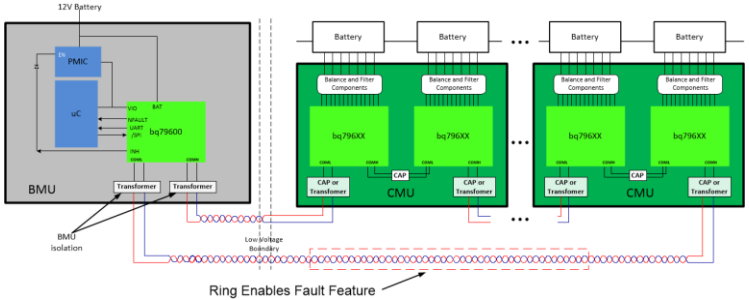


Communication traces between ICs in the same PCB

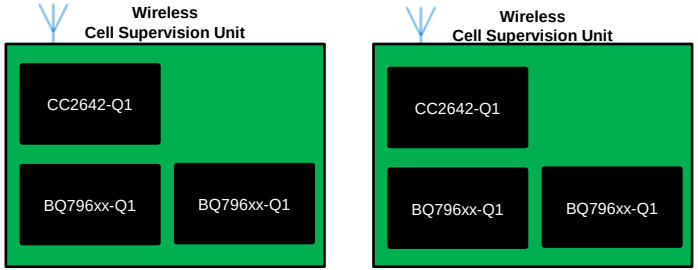


Communications interface – Options

- Option 1: (**Wired**) The BQ7961X family includes integrated daisy chain communications which require twisted pair cabling between each module

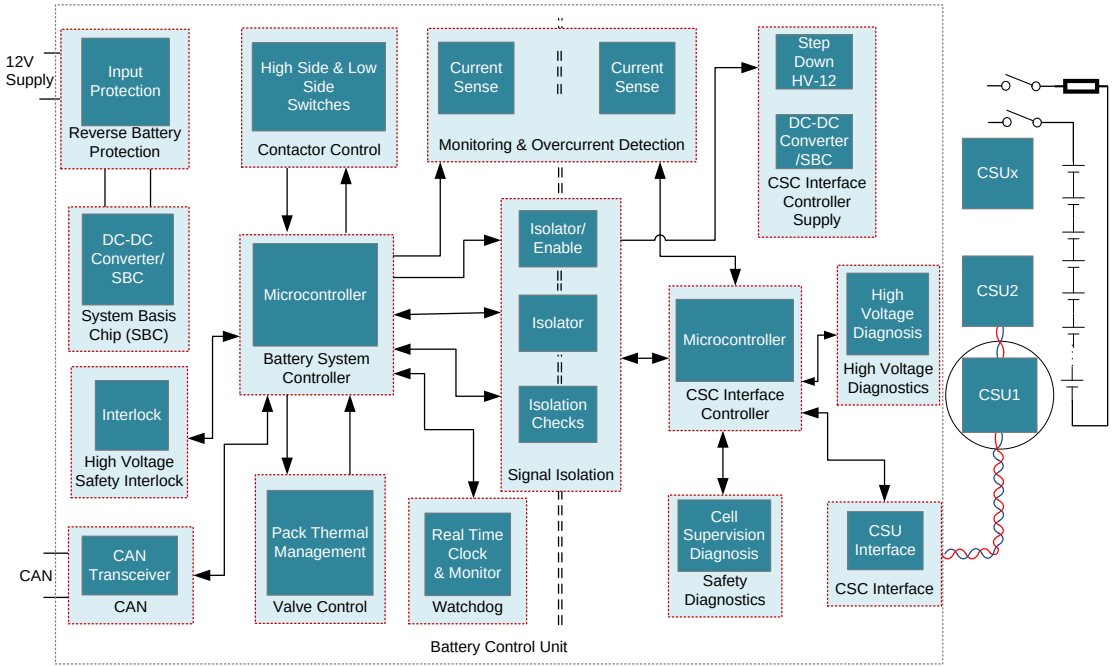


- Option 2: (**Wireless**) Using a wireless interface to transmit UART data to the host MCU and a slave transceiver attached to each battery monitor device



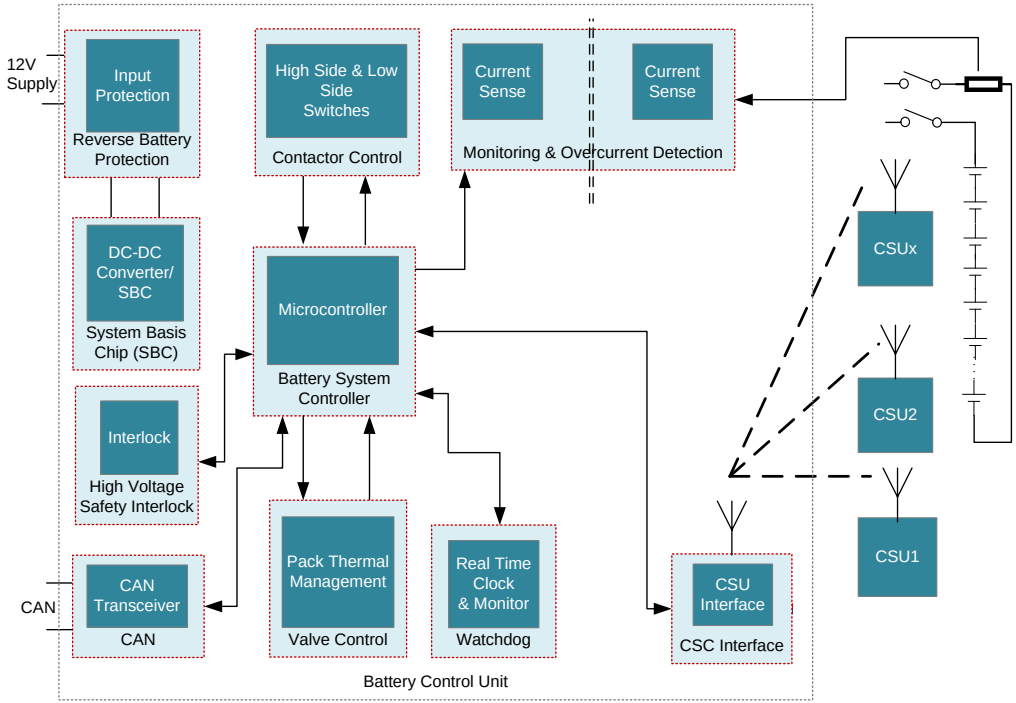
Why wired?

- **Proven industry method**
  - We see many larger tier 1/OEMs designing in our parts with wired daisy chain communications interface today
  - Wired is still considered the ‘safer’ standard and customers are more familiar with this interface historically in automotive
- **Robust daisy chain communications**
  - Huge R&D effort to test and ensure our daisy chain communications are robust in extremely noisy environments (over temperature, BCI, EMC/EMI, using various components)
  - ASIL-D capable communications that supports use of a single twisted pair interface that can be connected in ring architecture to ensure communications are not lost in the event of a cable break



Why wireless?

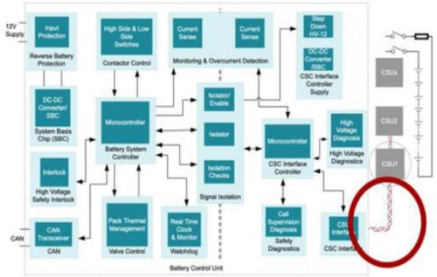
- **Cable/weight reduction**
  - Warranties cost due to cable failures and high cost to replace a battery cell
    - #1 failure reason in automotive is the wiring harness and connectors (according to OEM/tier1)
  - More than 3 miles of wiring adding weight
- **Naturally isolated**
  - Each cell monitoring unit would naturally be isolated from one another to avoid noisy communications lines
  - No need for daisy chain isolation components on external BOM



What is wireless BMS (WBMS)

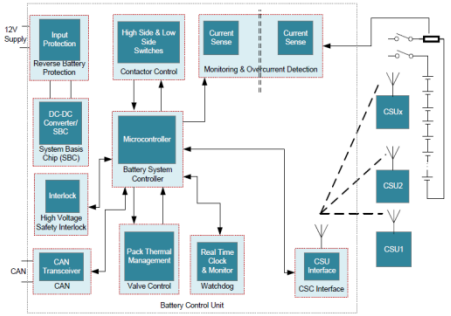
- **WBMS aims to provide a wireless connection between the between the battery management system and the battery packs, thereby replacing traditional wired (daisy chain) connections**
- **WBMS has the potential to provide significant breakthroughs:**
  - Improved reliability with the elimination of wiring harness and connectors
  - Lower system cost and weight
  - Reduced wiring complexity for large multi-cell battery stacks
  - Flexible (and therefore improved) placement of battery modules in an HEV/EV
  - Time synchronized measurements across each battery individual node
- **However, WBMS must address and resolve:**
  - Safety
  - Quality
  - Reliability
  - Availability
  - Security

Wired BMS



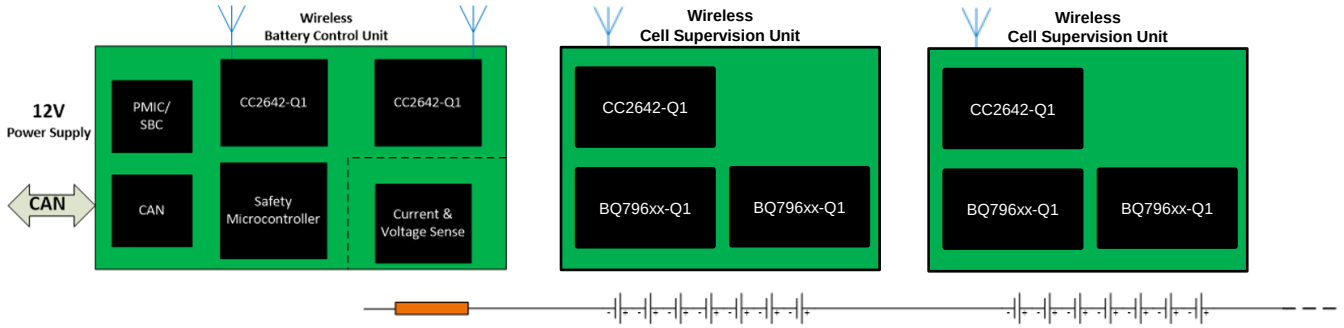
- Daisy Chain communication used today
- One of the main issues is the wire harnessing and the complexity, cost and manufacturing time required. Manual production and installation needed!
- Connector, cable & isolation (cap choke, transformer) ~0.80$ per connection (OEM information)
- Additional components for isolation

Wireless BMS



- 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

WBMS – Cable replacement use case



Safe state:
Disconnect battery
Cool down battery

Battery control unit

- Battery disconnect
- Thermal control

- Safety critical
- Black channel
- Timestamp needed
- Data every 100 ms

Cell supervision unit

- Cell voltage
- Cell temperature

Safety risk:
Cell UV/OV
String/cell OC
Thermal runaway

- System can maintain SAFETY in the event of a lost connection
- Compromise on the AVAILABILTY of the system – the car is not working

TI WBMS protocol – Performance summary

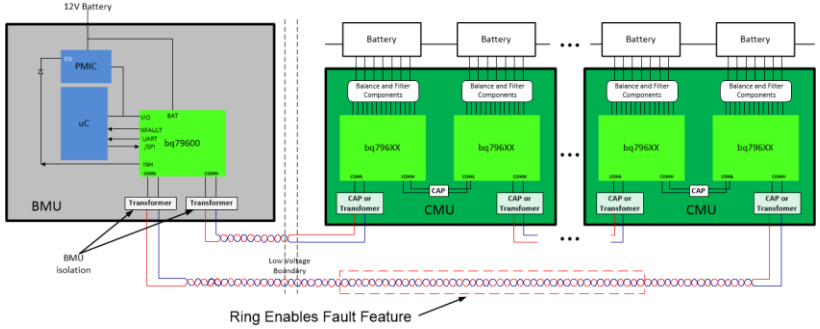
Topology	Star network Up to 32 nodes per 1 master
Reliability	Network PER 10^{-7} 97 dB link budget: 5 dB TX & -92 dB RX @ 2 Mbps PHY
Safety	TUV certified concept based on black channel principle ISO-26262 certifiable protocol with SW FMEA and ASPICE Level 2 compliance CC26x2R-Q1 with safety manual, FMEDA & FIT rate
Data integrity mechanisms	Timestamp, CRC, ACK, unique ID, sequence number Multiple retransmissions per FTTI (100 ms)
Throughput	1.2 Mbps
Latency	16 ms network (1M:8S)
Network formation	300 msec
Power consumption	300 µW
Security	Shared network key: pre-shared key to start & key refreshment Packets are authenticated & encrypted (AES-128)

Overall wireless system requirements

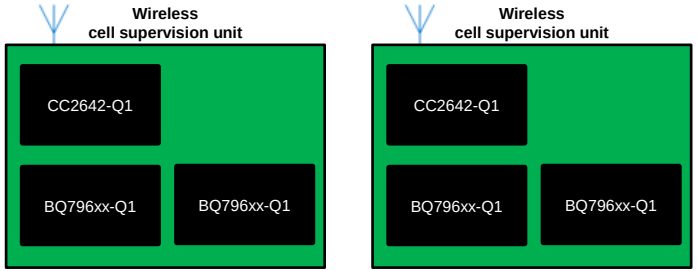
Function	Target
Safety critical reaction time (latency)	Max. 100 ms (safety)
Data throughput	Up to 400 bytes per wireless device
Link reliability	99.9999%
Security	Secured and encrypted messages
Scalability	Up to 32 wireless devices and more
Multi-cluster support	Yes
Functional safety	ASIL-D / ASIL-C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

How the BQ7961X family enables both methods

- The daisy chain vertical interface protocol is naturally integrated with all devices in the BQ7961X family. We provide several documents to support customers designing with this interface in either distributed or centralized systems.



- We've designed a custom TI proprietary protocol specifically to interface with the BQ7961X family. A demo board and software have been designed to provide example solutions.



Comparing aspects of wired and wireless BMS

Considerations	Wired BMS	Wireless BMS
Weight	Wiring increases overall vehicle weight	A wireless system decreases vehicle weight
Design flexibility and serviceability	Less flexibility with a larger footprint overall; more difficult to service Larger overall footprint; less flexible system design due to cumbersome wires, difficult to service	Smaller footprint enables more flexibility with a simpler design and placement within the vehicle Easier to service
Measurement	Time-synchronized measurements of voltage and current can be a difficult design challenge	Wireless systems naturally enable time-synchronized measurements and provide the ability to add more synchronized sensing capabilities
Reliability	Wiring harnesses tend to break over time; they are difficult to repair and require rewiring of battery packs	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

TI WBMS reference design and demo

Design features

- Wireless BMS evaluation board featuring **BQ7961x-Q1** FuSa compliant and SimpleLink™ **CC26x2R-Q1** wireless MCU
- High throughput, low latency, robust 2.4 GHz frequency hopping wireless protocol operating with “black channel” principle per ISO-26262
- Guaranteed data transmission from each node every 100 ms
- Supports battery stacks up to 1 kV

Design benefits

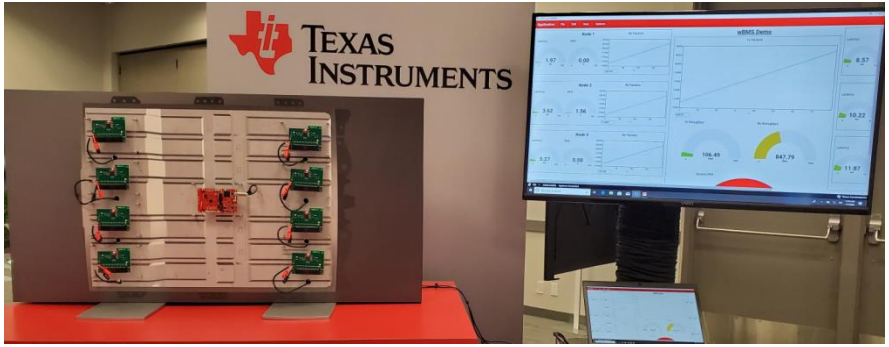
- High throughput, low latency wireless protocol optimized for the wireless BMS use case
- ISO-26262 compliant components (BQ79616-Q1) together with CC26x2R-Q1
- Per “black channel” principle: all safety-oriented mechanisms are exclusively implemented on the application level, which enables total independence from the underlying transport layer
- The TI WBMS protocol provides measures for all defined failure modes and handles additional overhead needed to fulfill ASIL-D (per ISO-26262) error failure rates at system level in harsh RF

Tools & resources

- **WBMS rev B hardware**

- Hardware design files available now
- WBMS blog and Video

CES2020 demo



WBMS video demo

- https://training.ti.com/wireless-battery-management-system-bms-demo

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