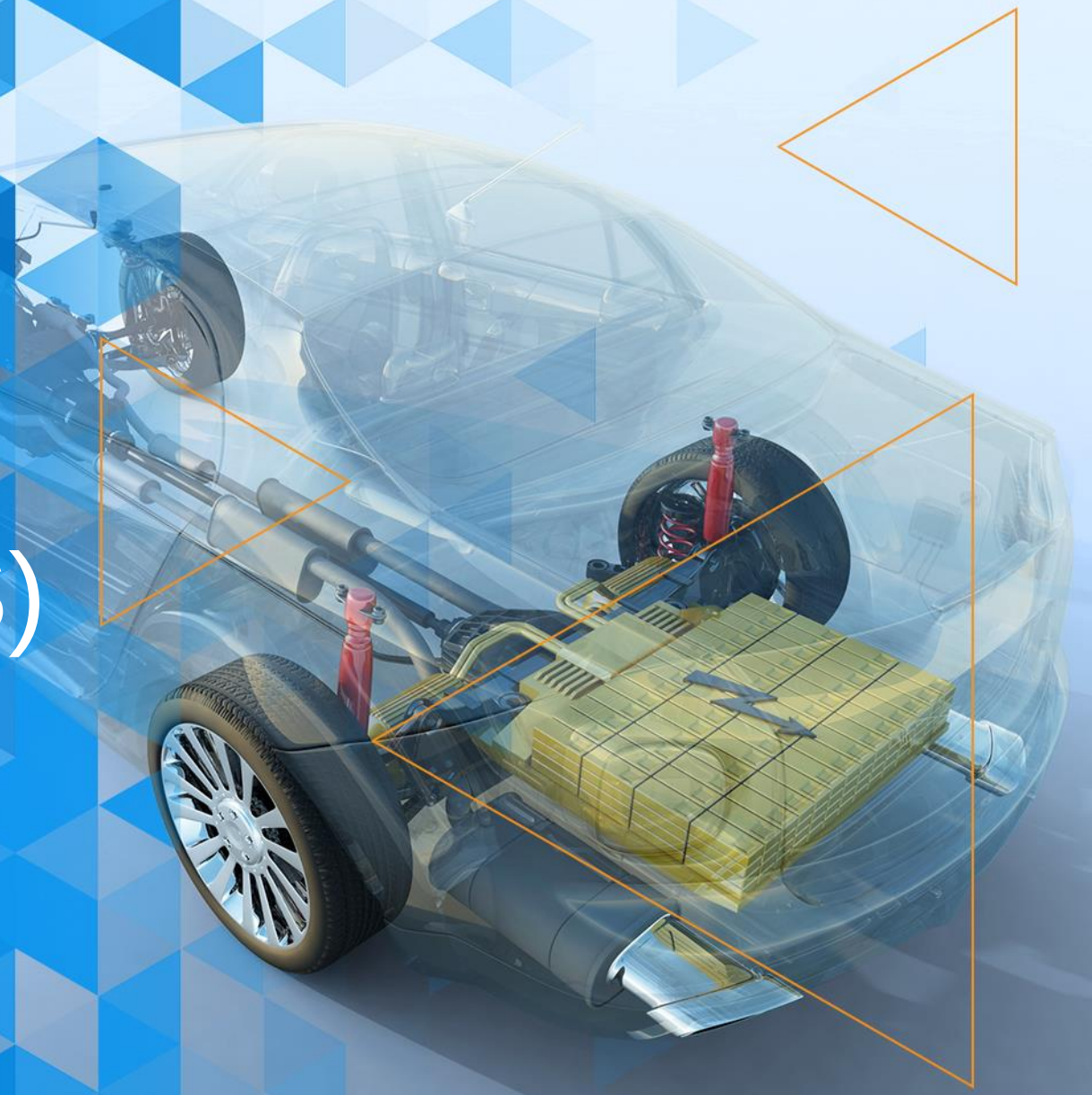
ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

ADI Battery Monitoring System Solutions(BMS) Introduction



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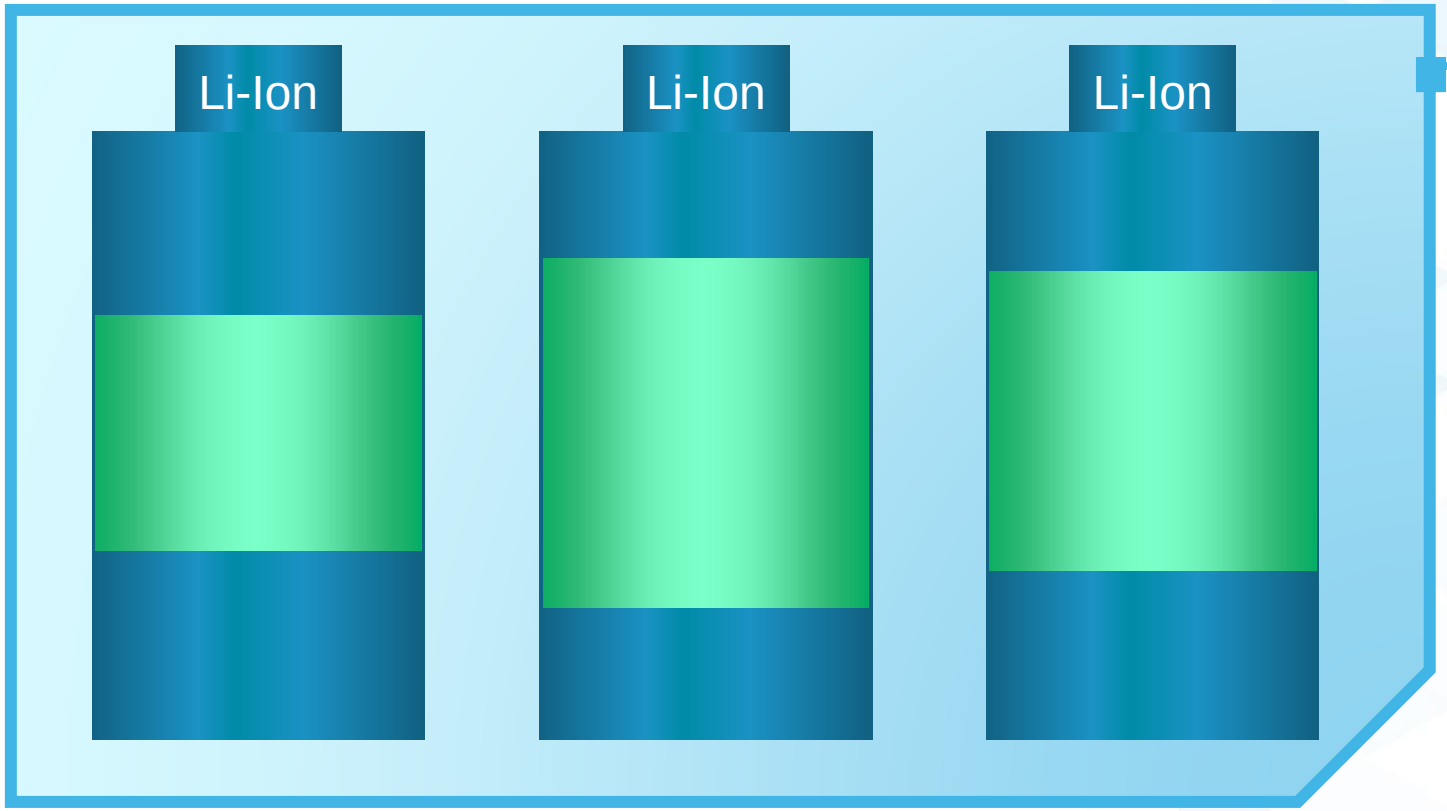
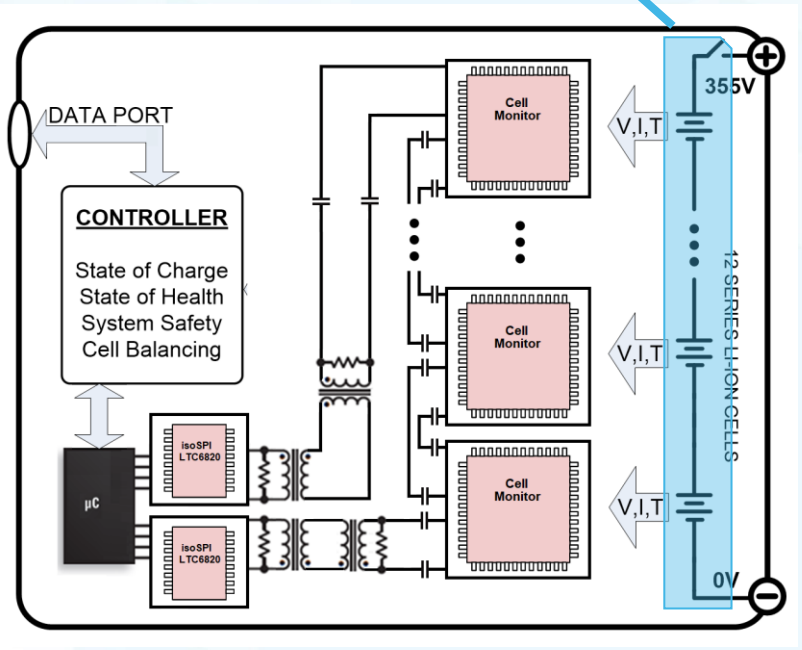
Outline

- What is a Battery Monitoring System (BMS) and General BMS system review
- Important design parameters for BMS
  - --Why High Accurate ADC are needed
  - --Communication in a noisy environment would be a trouble
- ADI BMS product introduction
- Summary

What Is a Battery Management System?

Animation





- The BMS safely and reliably maximizes capacity
  - State of charge (SOC) determination
  - State of health (SOH)
  - Safety: overvoltage detection
  - Cell balancing

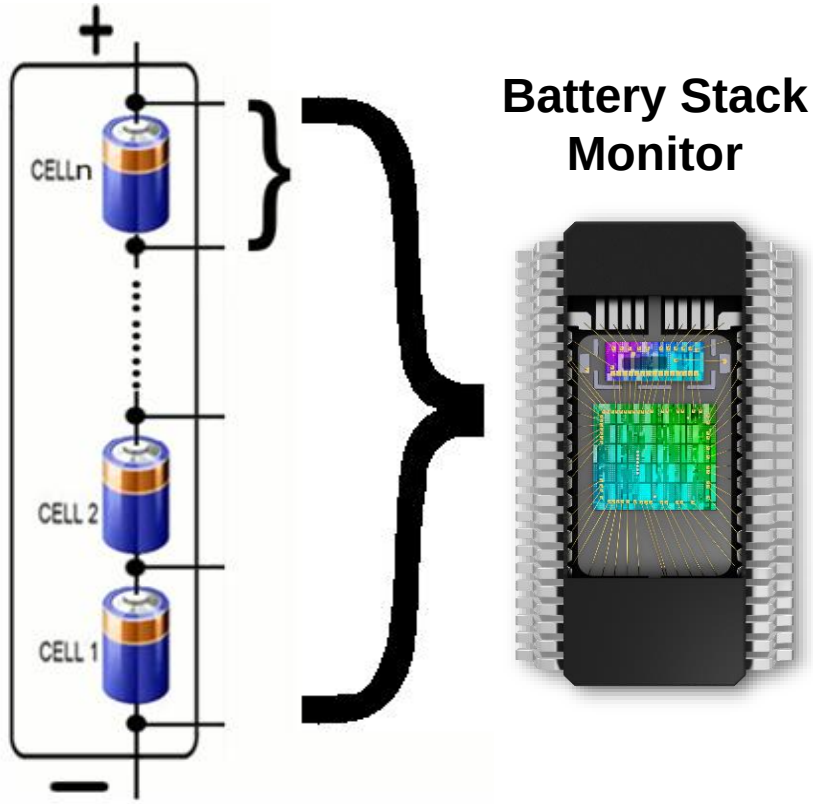
Purpose of a Battery Stack Monitor

ADI's Key Priorities

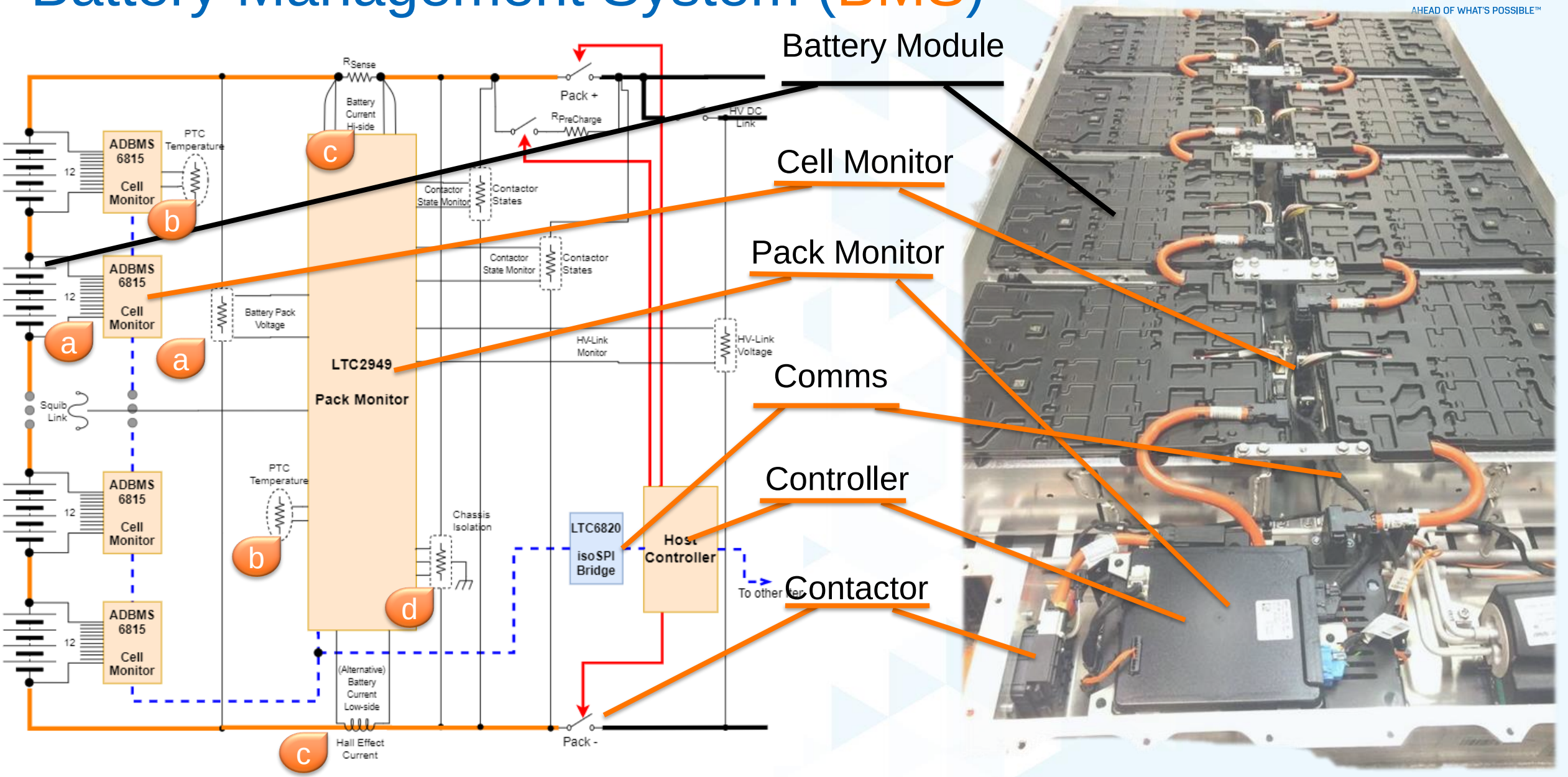
- Safety
- Reliability
- Accuracy

Values

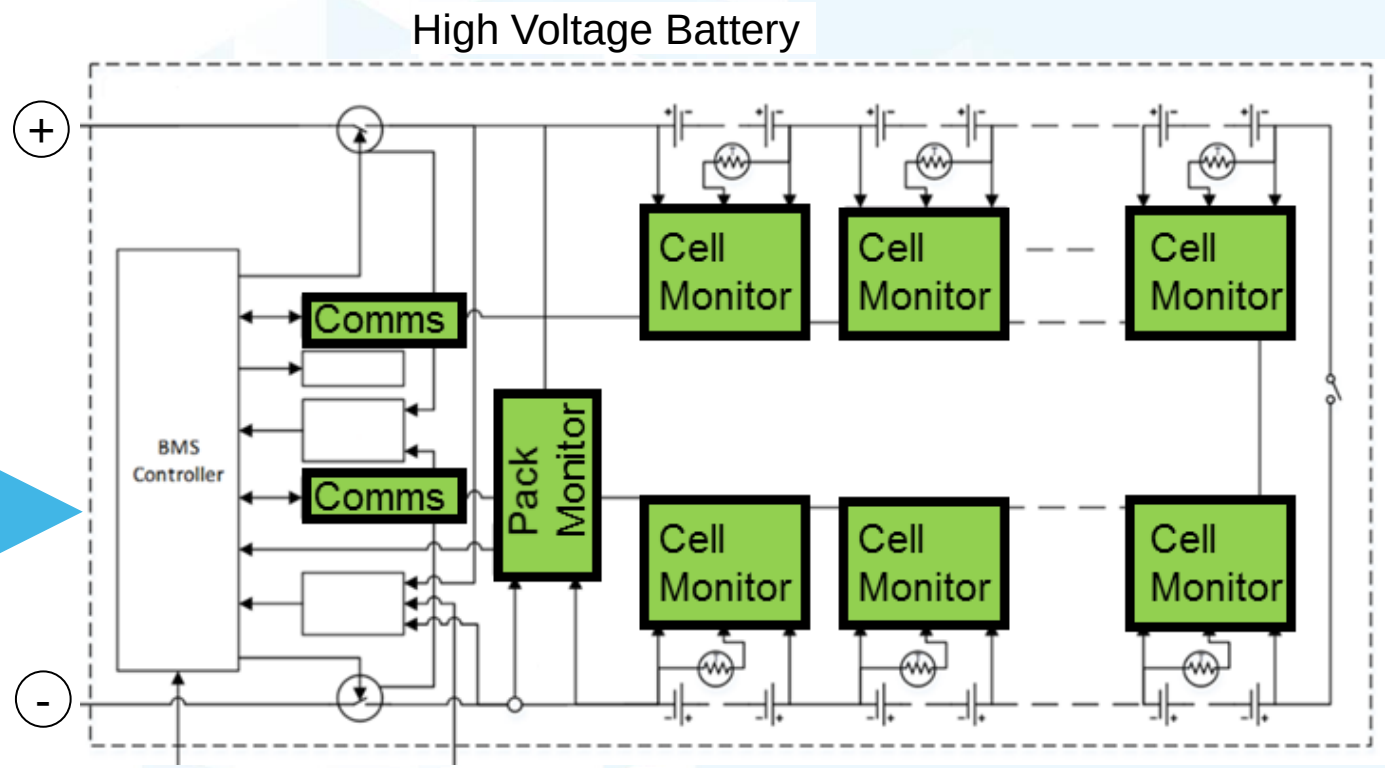
- Continuously confirm proper and safe operation with fault detection
  - Balance passive or active cells to manage the state of charge (SOC)
- Provide noise immune isolated communication
  - Enable HV battery stack monitoring
  - Enable modular pack designs
  - Ensure reliable communication
- Accurately measure cell voltages and other signals
  - Determine how much charge, SOC determination
  - Synchronize with current and temperature



Battery Management System (BMS)



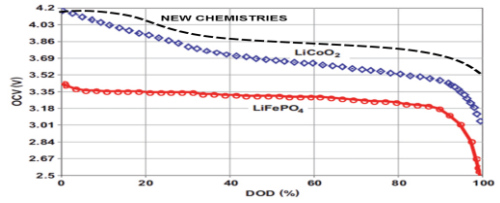
BMS Details and Analog Devices' Product Focus



- Cell monitors: measure voltage and temperature of battery cells, and balancing
- Pack monitors: measure entire pack voltage, pack current, ground faults, contactor positions
- Communication: communicates from monitors to system processor
- Software: high level software to control, coordinate all components and ensure safety

Trends in Battery Management

Advancing Technologies



New Battery Chemistries

New Cell/Pack Configurations

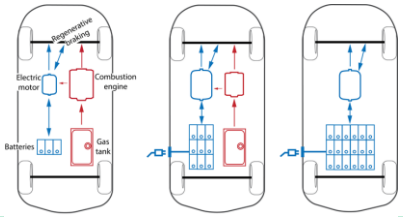
Higher Voltages

Fast Charging

Wireless BMS

PERFORMANCE, FLEXIBILITY, EXTENSIVE BMS PRODUCTS

Automotive Expectations



ASIL D with Single Device

>15-year life

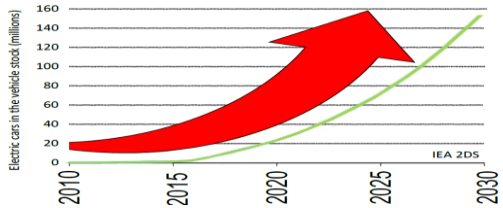
>200 mA BCI Performance

<1 ppm Failure Rates

Measurements with High Noise

ROAD-PROVEN EXPERIENCE AEC-Q100, ISO 26262 SUPPORT

Accelerating Growth



Increased Integration

Decreased BOM

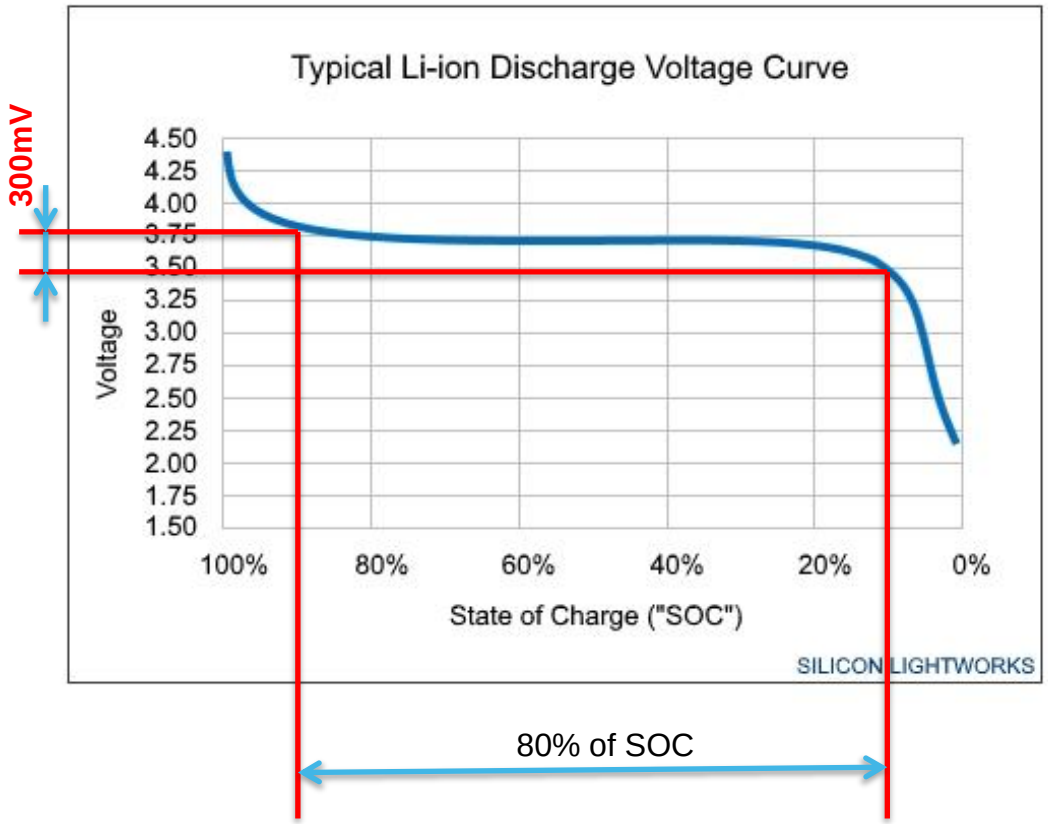
Simplest Implementation

Smallest Possible Footprint

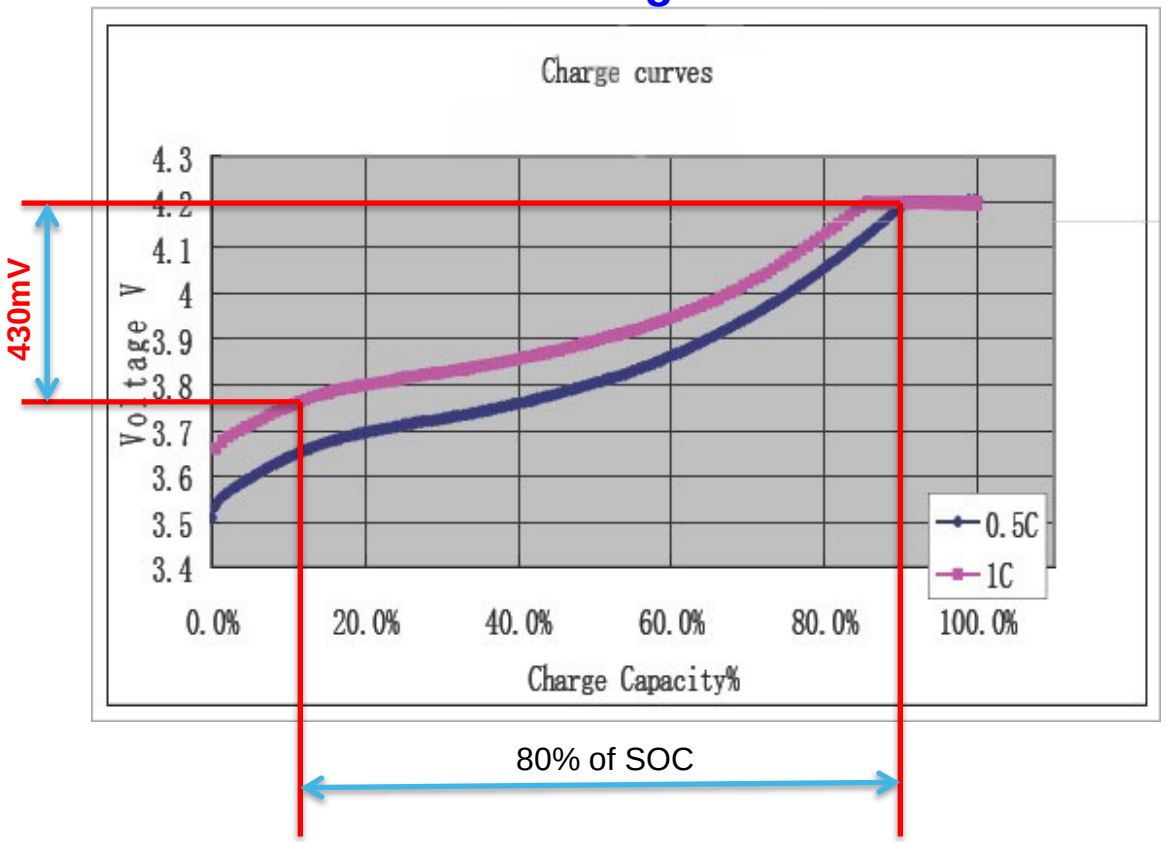
LOWEST TOTAL COST OF OWNERSHIP

Measurement: Why High Accuracy ADCs Are Needed

Li-Ion Discharge Curve



Li-Ion Charge Curve



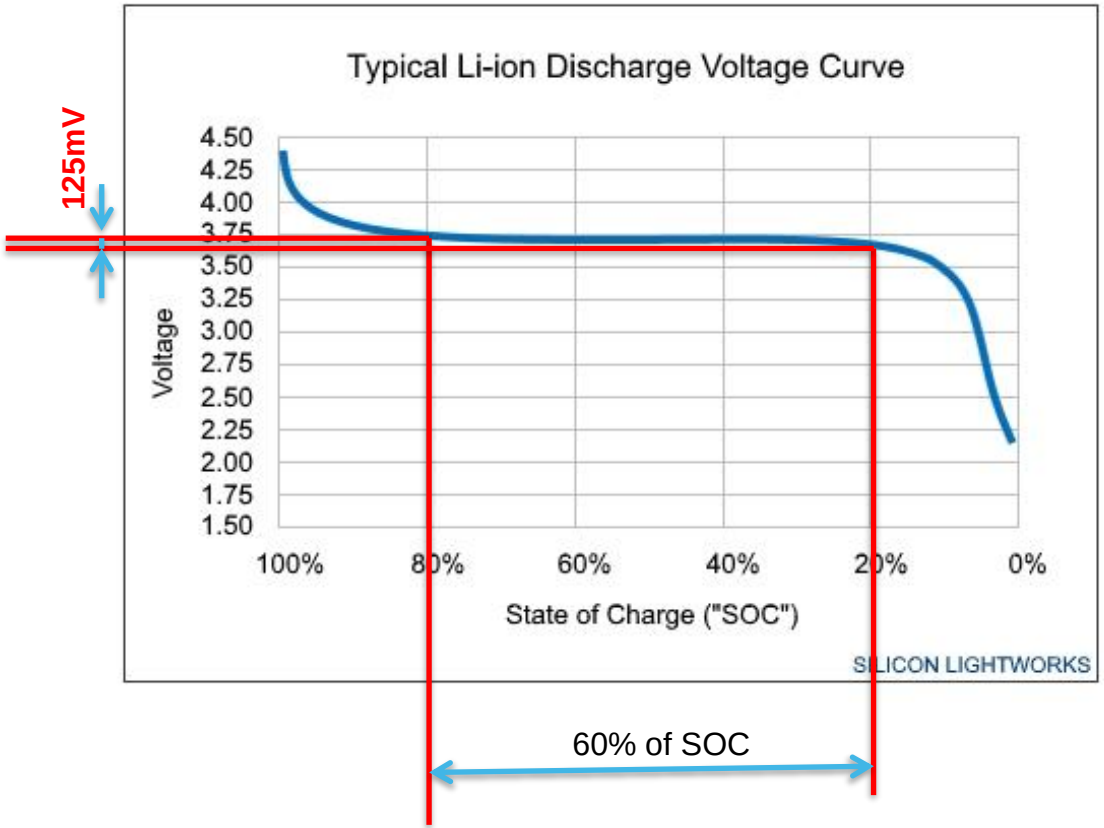
Accuracy of an ADC is very important to calculate the real SOC of the battery precisely.

Note. In general, the cycle lifetime of Li-Ion is 500 cycles, but if using the range of SOC like **20% to 80%,** then the lifetime will be increased so that 10 years guarantee for cars would be achieved.

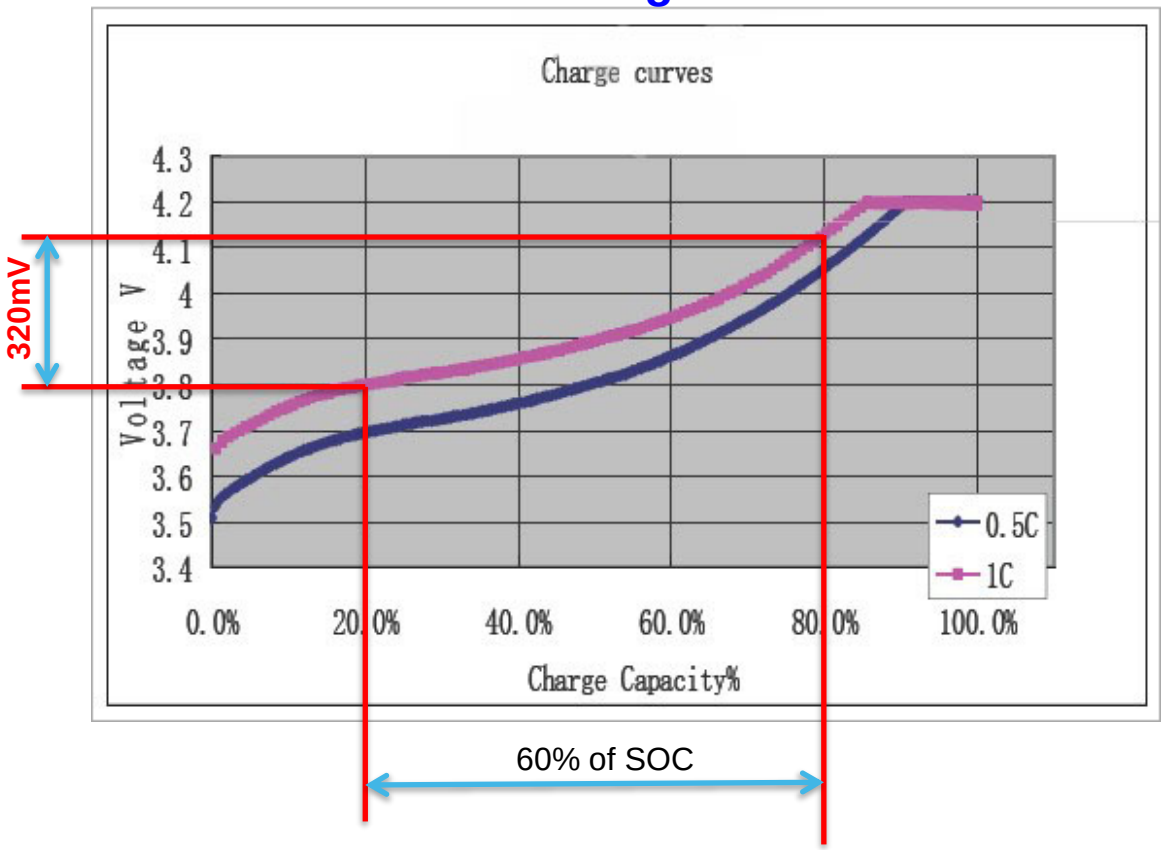
* SOC: State of Charge

Measurement: Why High Accuracy ADCs Are Needed

Li-Ion Discharge Curve



Li-Ion Charge Curve



Accuracy of an ADC is very important to calculate the real SOC of the battery precisely.

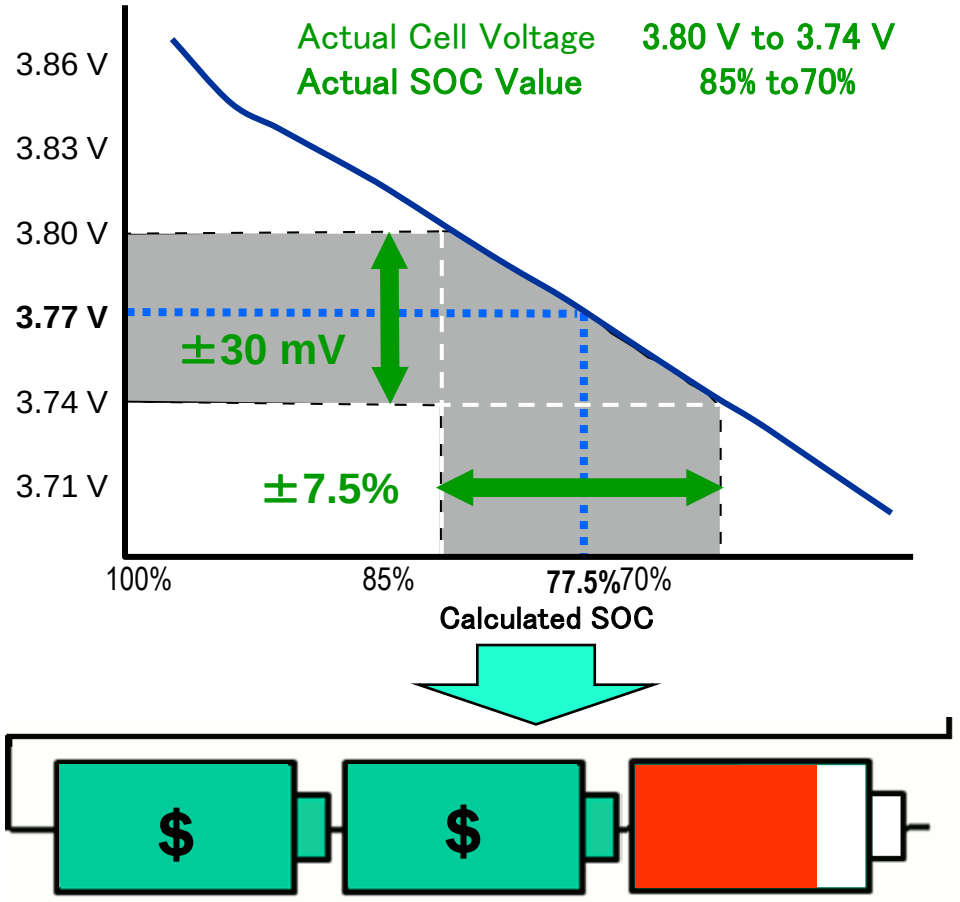
Needs more accuracy measurement.

* SOC: State of Charge

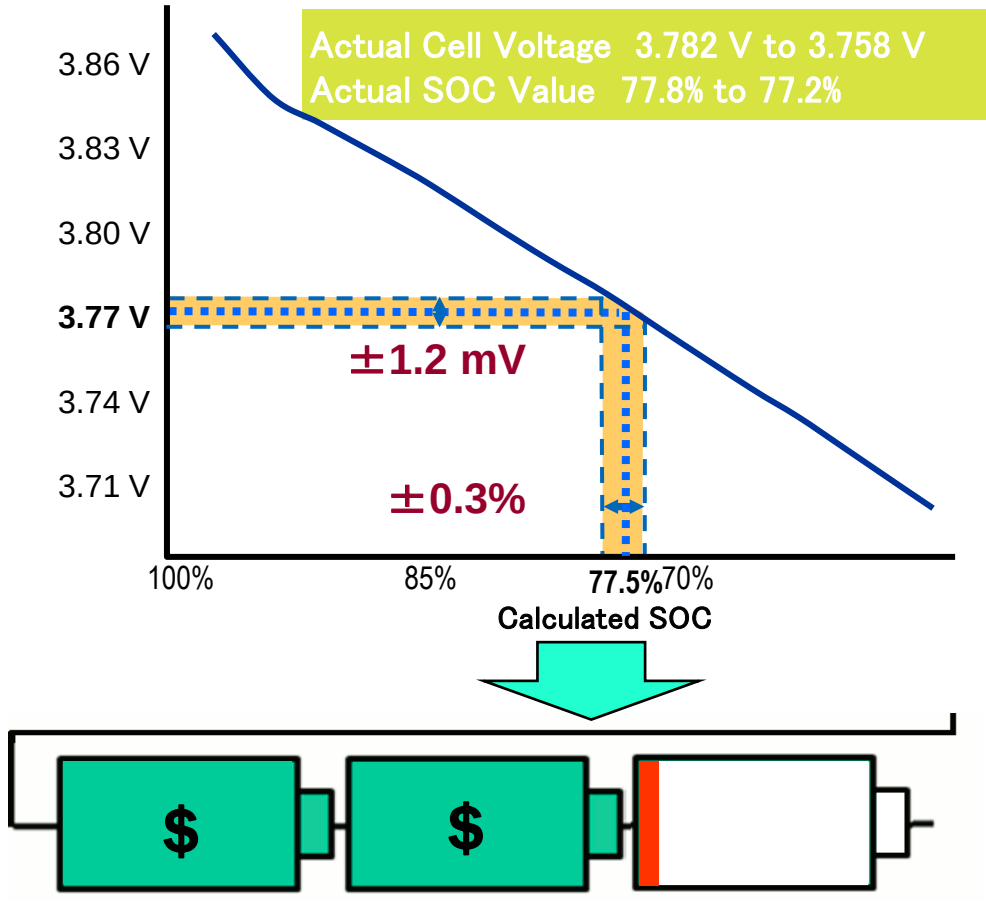
Measurement: Why High Accuracy ADCs Are Needed

Example: Measured Value of Cell Voltage = 3.77 V Measured Value of SOC = 77.5%

If the measurement error is ±30 mV (± 7.5%)



Measuring with LTC6804



Battery cost, weight reduction, mileage improvement

ADI Battery Stack Monitors Feature Set Review

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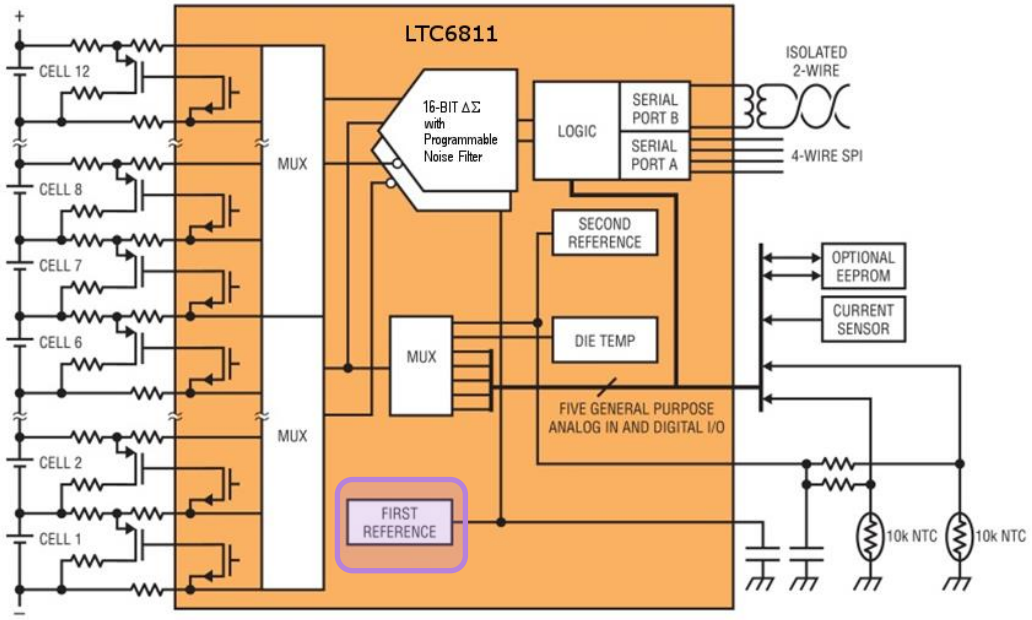
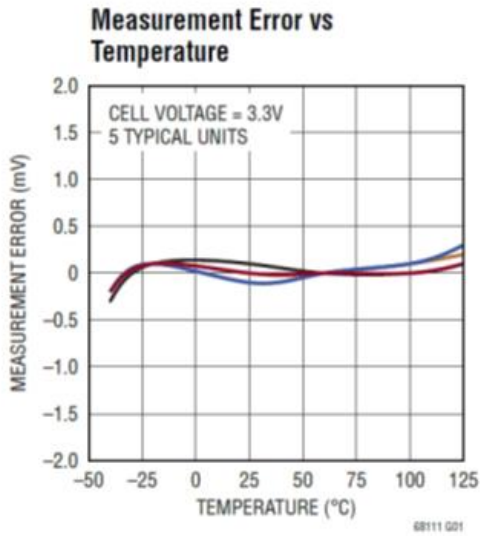
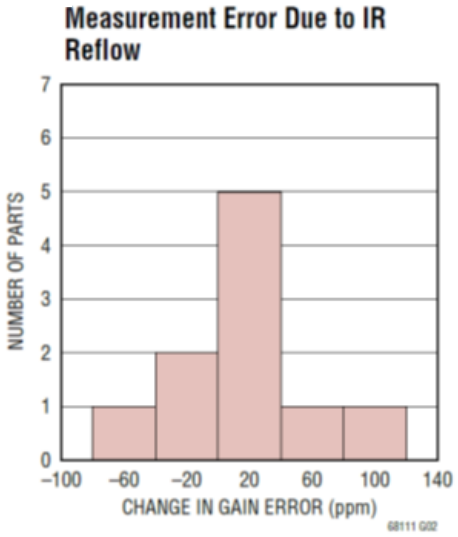
Measurement Accuracy

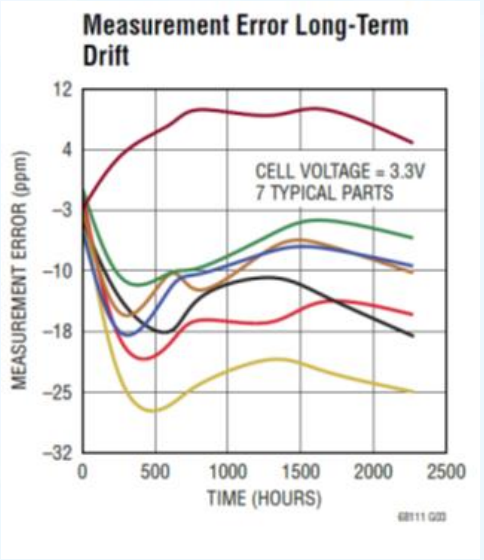


Precision Zener Reference

- Industry-leading guaranteed total measurement error
- No factory calibration after PCB assembly
- Best-in-class long-term drift, tempco, and hysteresis







Long term ref drift
Bandgap Voltage Vs Buried Diode

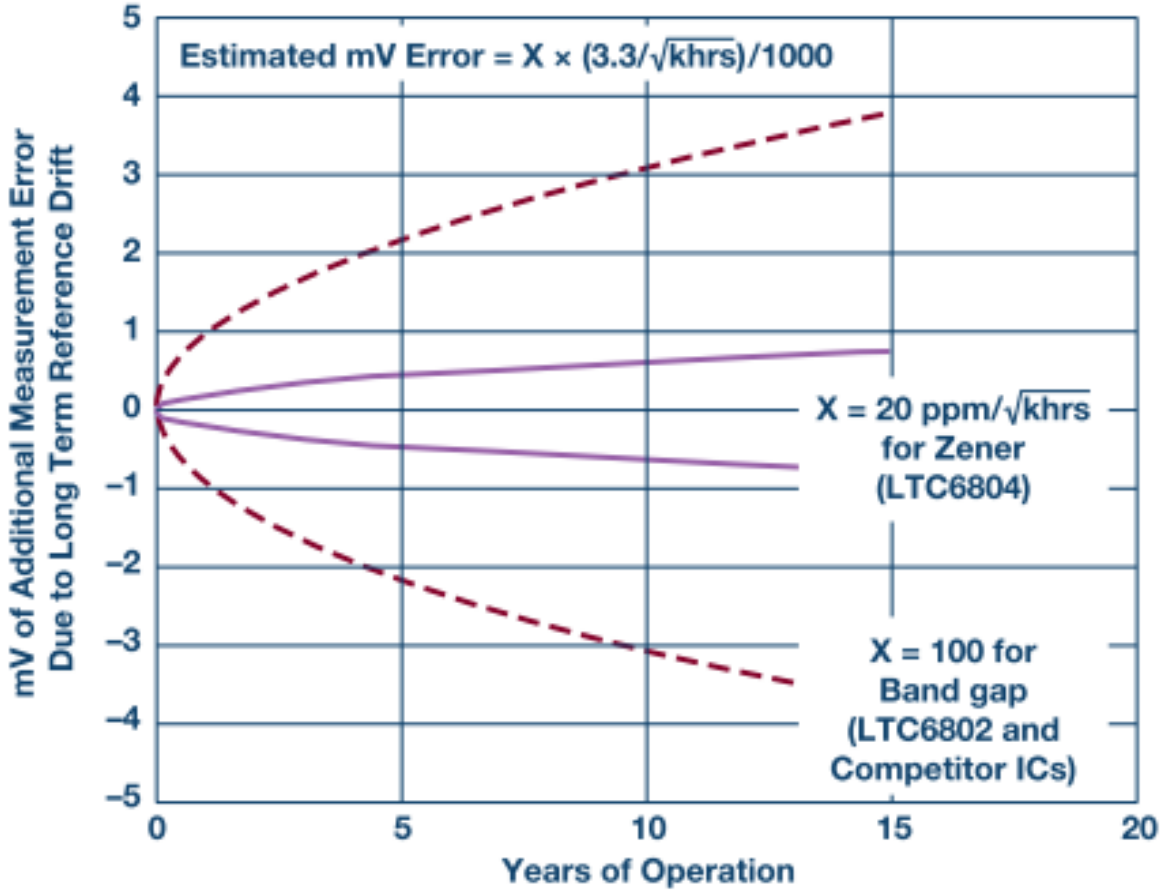
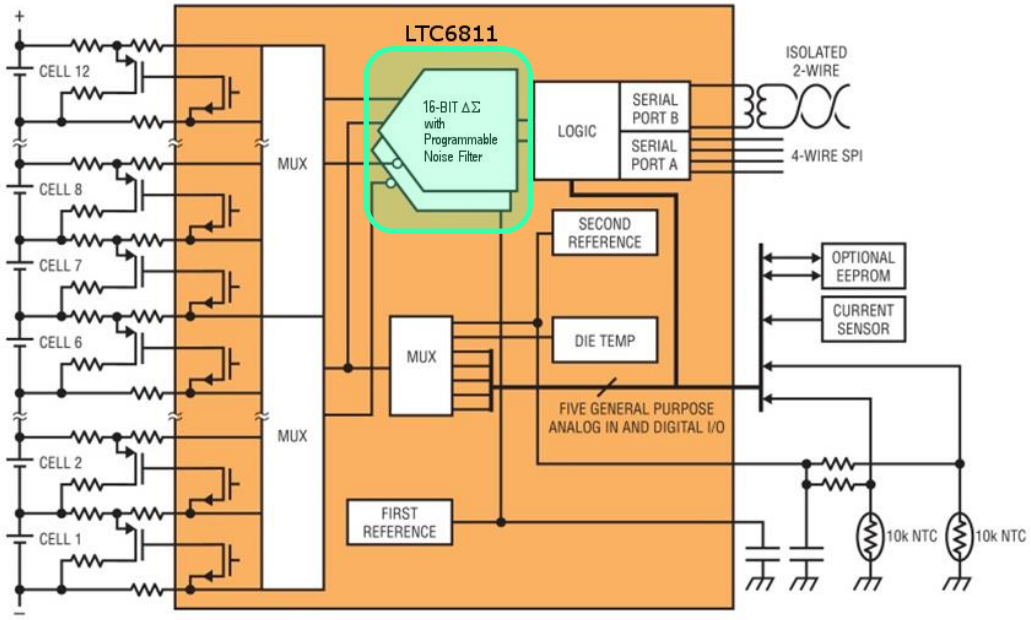


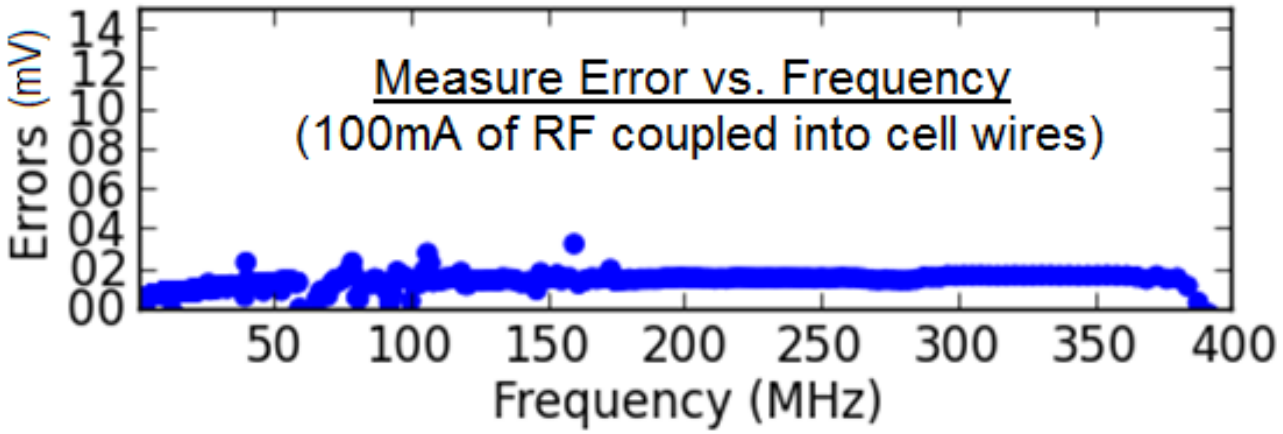
Figure 7. Long-term drift comparison between buried Zener diode and bandgap voltage references.

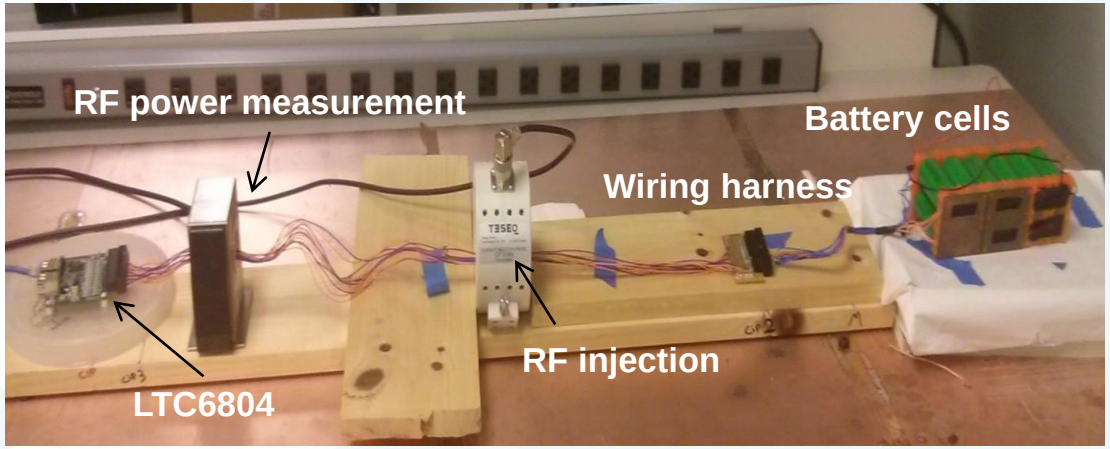
Measurement Accuracy



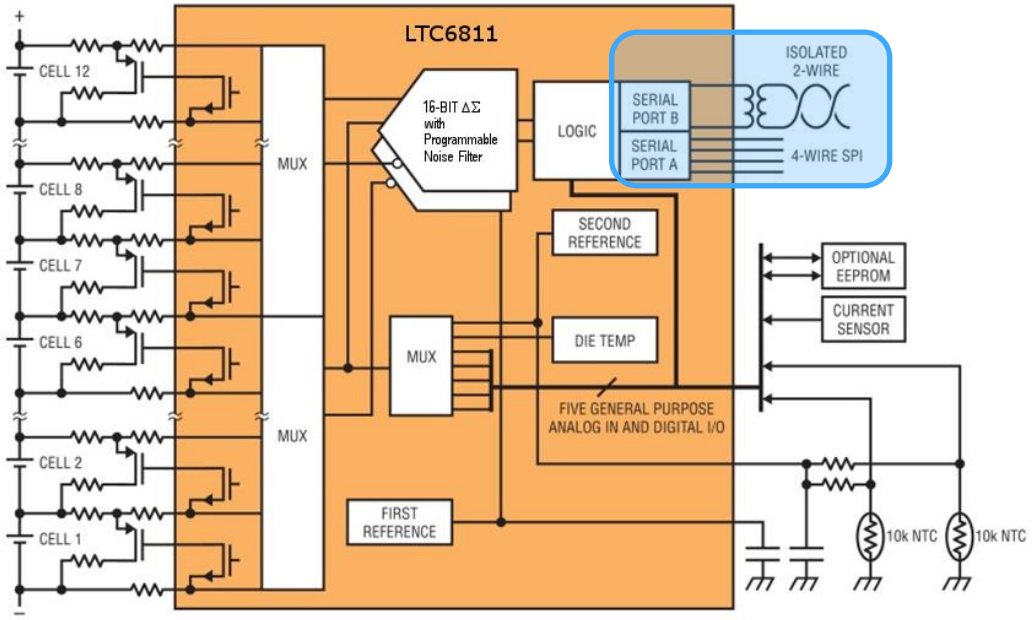
Patented ADC Topology

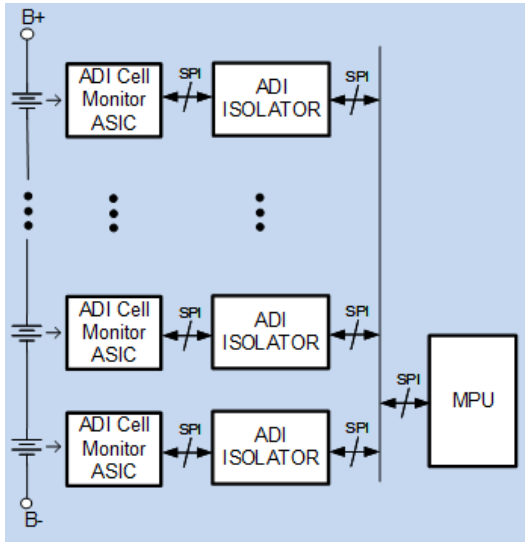
- 16-bit sigma-delta ADC
- Programmable oversample ratios for noise filtering
- Averaging characteristics of Σ-Δ converter offer immunity to RF interference

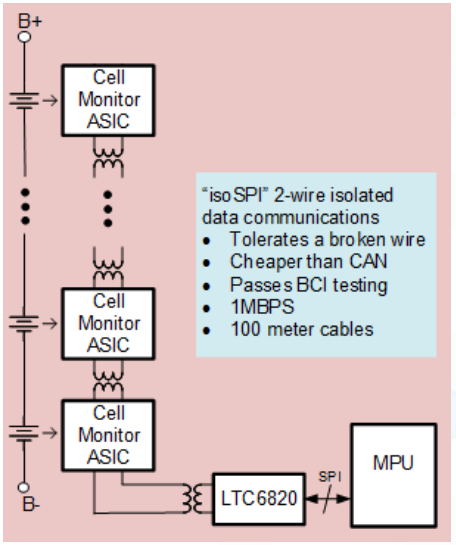




Communication Reliability







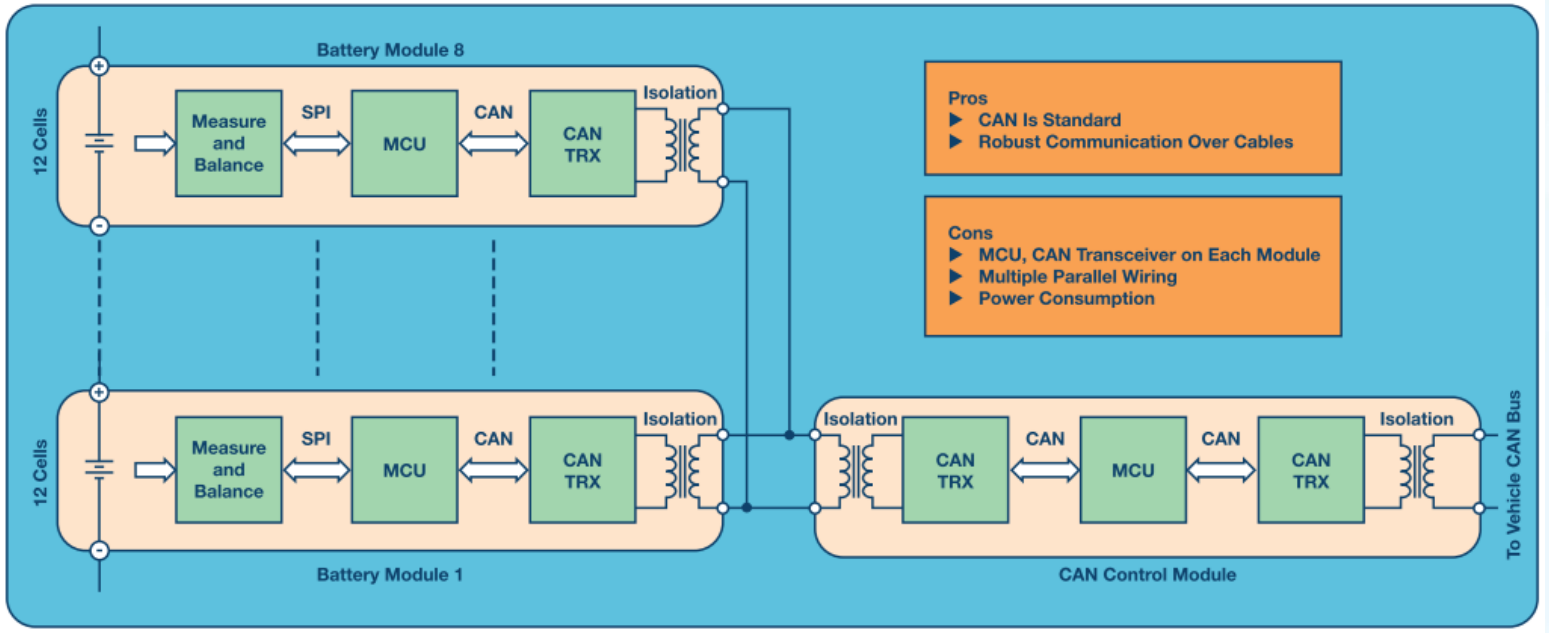
Built-In isoSPI™ Interface

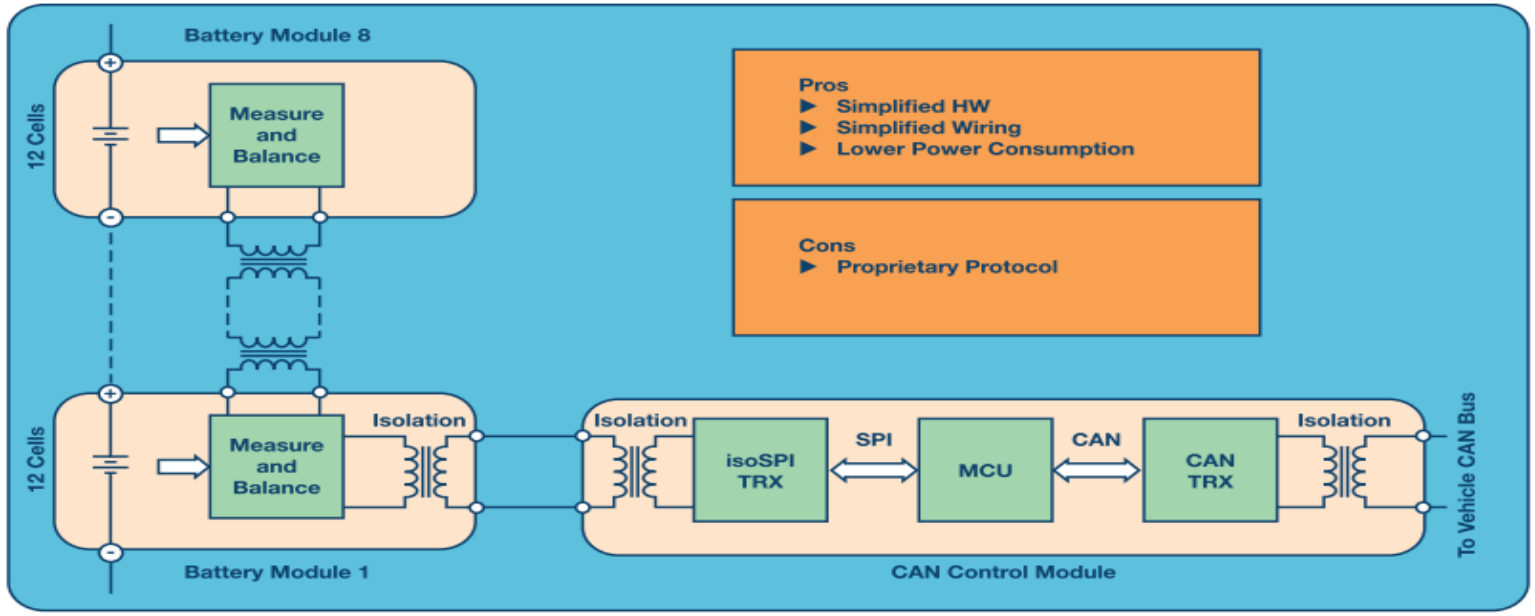
- Single twisted pair
  - Simple alternative to CAN
- 1 Mb isolated serial communications
- Passes 200 mA BCI testing
- Supports random stackability
- Supports ring architecture

Local SPI Interface

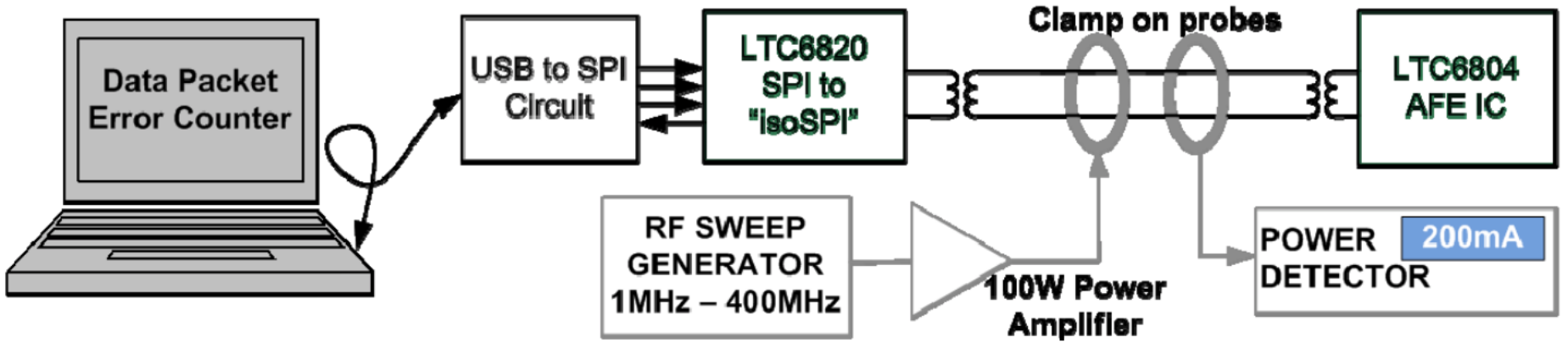
- Direct microprocessor connection
- Digital isolators for single board designs

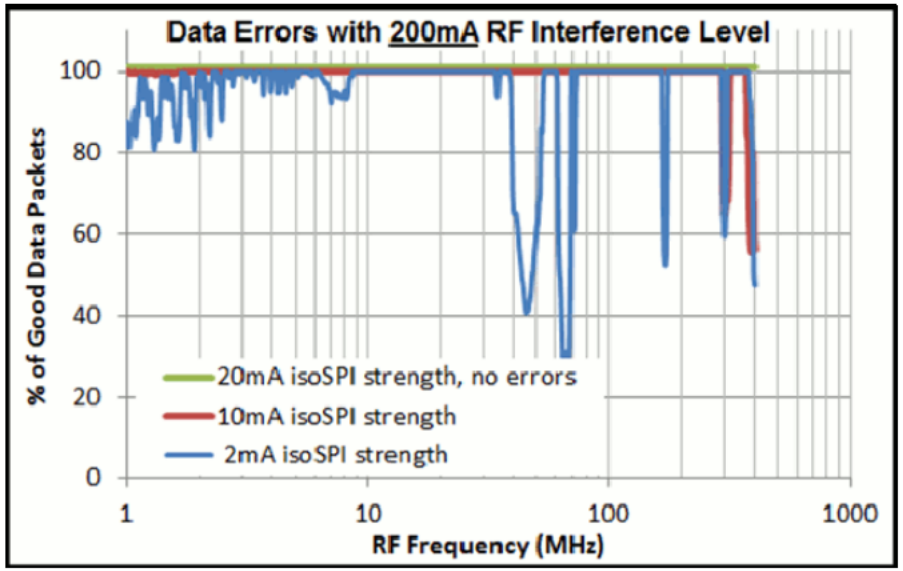
Canbus vs ISOspi





BCI testing for ISOSPI

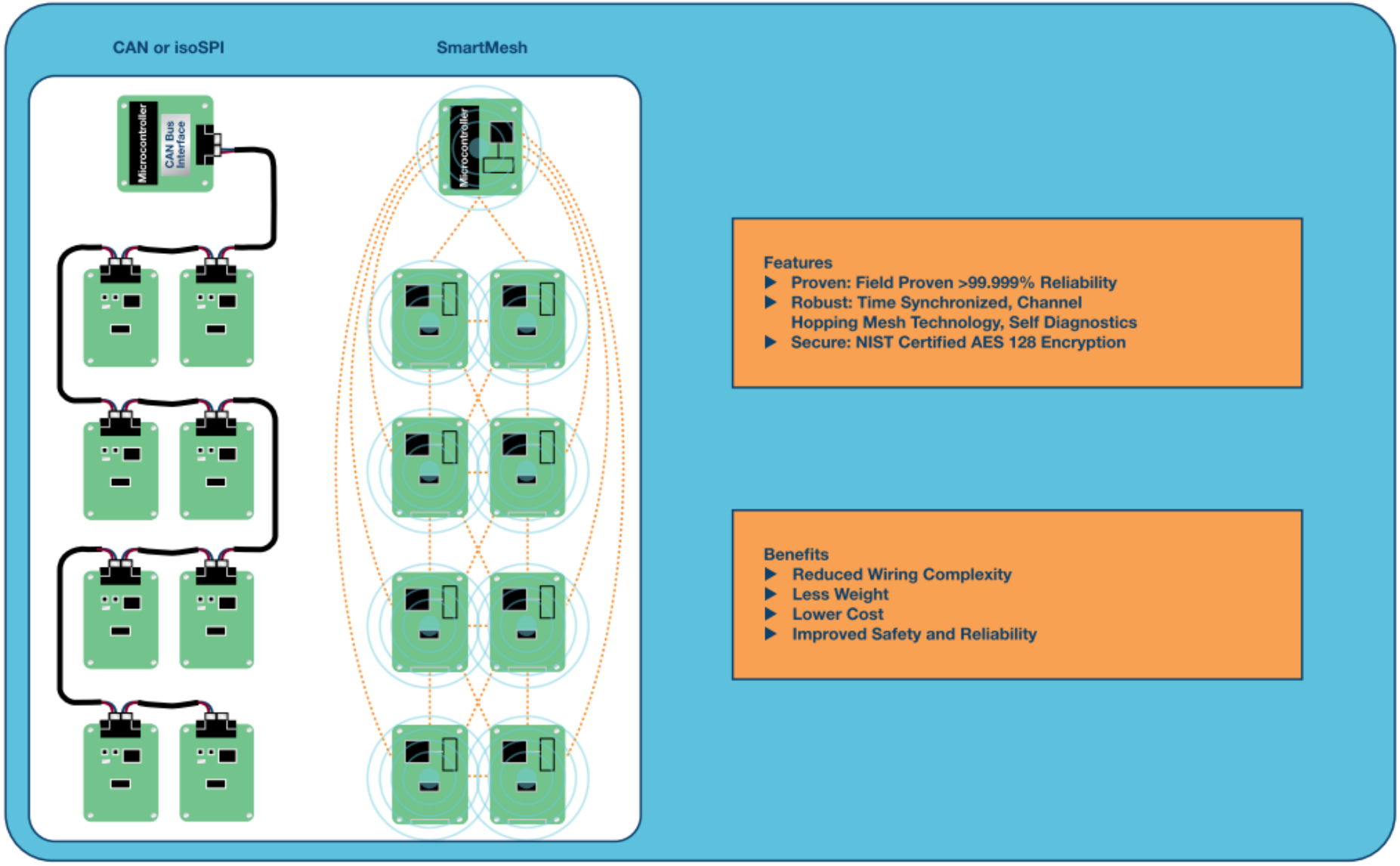




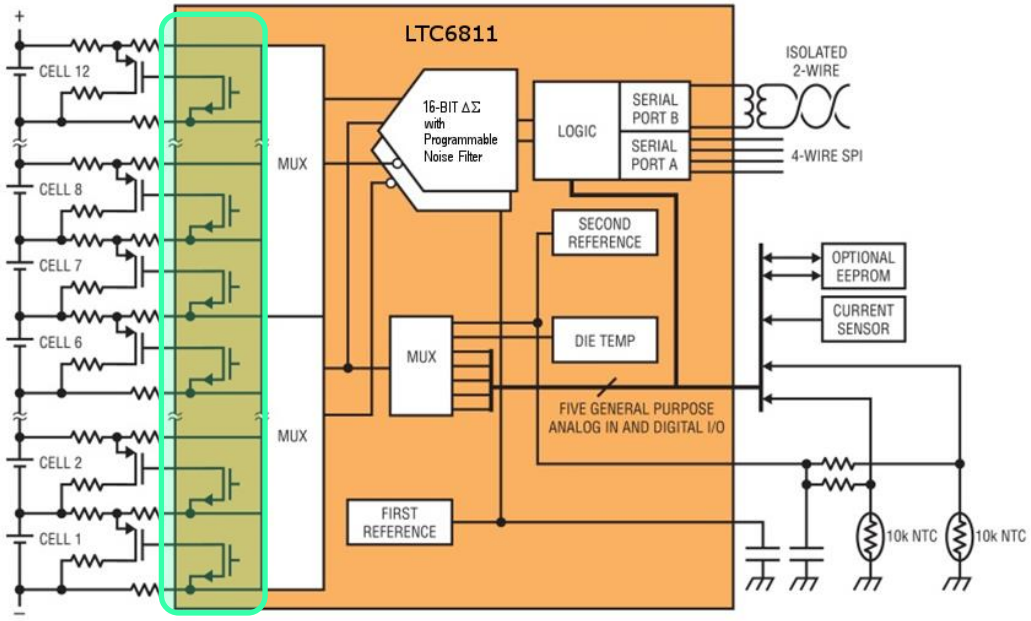
BCI Test Results

BCI testing was conducted on an isoSPI link, using signal strength of 2mA, 10mA, and 20mA. This graph shows that when the isoSPI link was operating with 20mA signal strength, there were no transmitted errors under a 200mA BCI test.

A Novel Concept for Communication



Measurement Accuracy



Internal FETs

- Direct passive balancing
- Operable in sleep mode with timer and undervoltage thresholds
- Able to control external FETs for off-board balancing

LTC681x Overview

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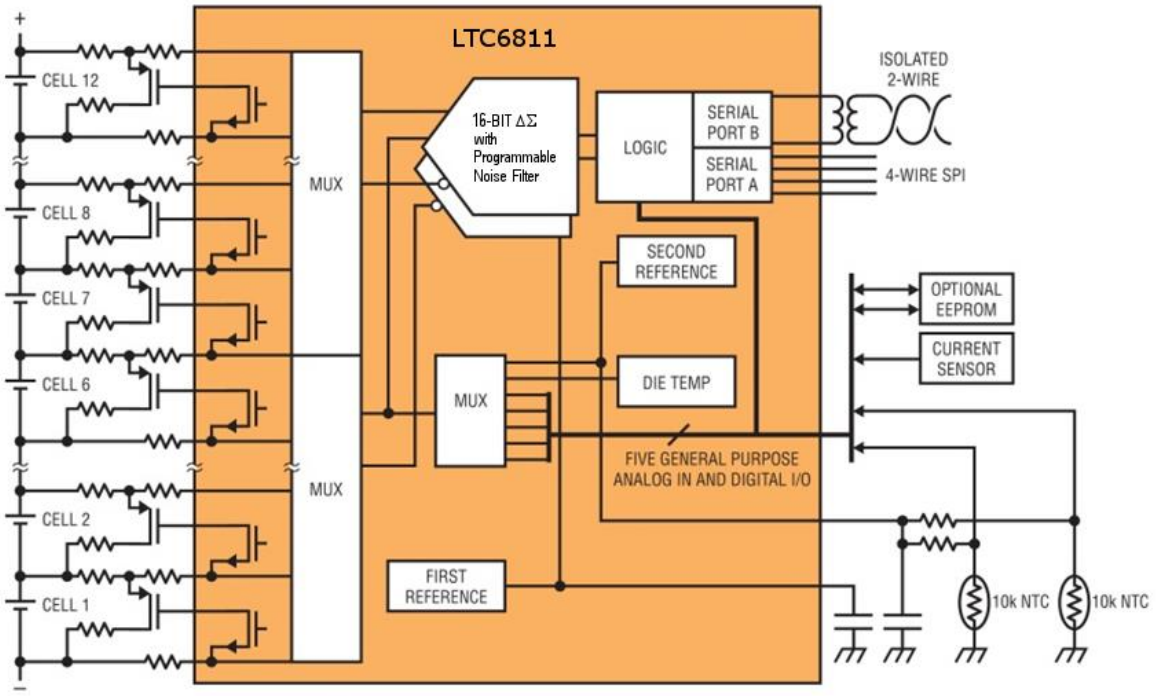
LTC6811: 12-Cell Battery Stack Monitor

Value Proposition

- <2.2 mV total measurement error –40°C to +125°C
- Connect multiple devices in series or in parallel
- Built-in isoSPI™ interface
- Includes comprehensive self-tests
- Engineered for ISO 26262 systems



Key Benefits

- Maximizes the range of your EV battery design
- Create unique high voltage battery strings
- High speed communication with low EMI susceptibility and emissions
- Monitors the devices to always ensure proper operation
- Ensures functionally safe solution design

LTC6811: 12-Cell Battery Stack Monitor

Features and Specifications

- Measures 12 series connected battery cells
- Industry-leading accuracy:
  - <1.2 mV total measurement error at 25°C
  - <2.2 mV total measurement error –40°C to +125°C
- 16-bit sigma-delta ADC
  - Eight programmable oversampling ratios/noise filter settings
  - (26 Hz to 27 kHz)
- Built-in isoSPI™ interface:
  - Uses a single twisted pair
  - 1 Mb isolated serial communications
  - Passes 200 mA BCI testing
  - Supports random stackability
- Active and passive cell balancing control
- Five general use digital I/O or analog inputs
- Synchronized voltage and current measurement
- 4 µA sleep mode supply current

Portfolio Positioning

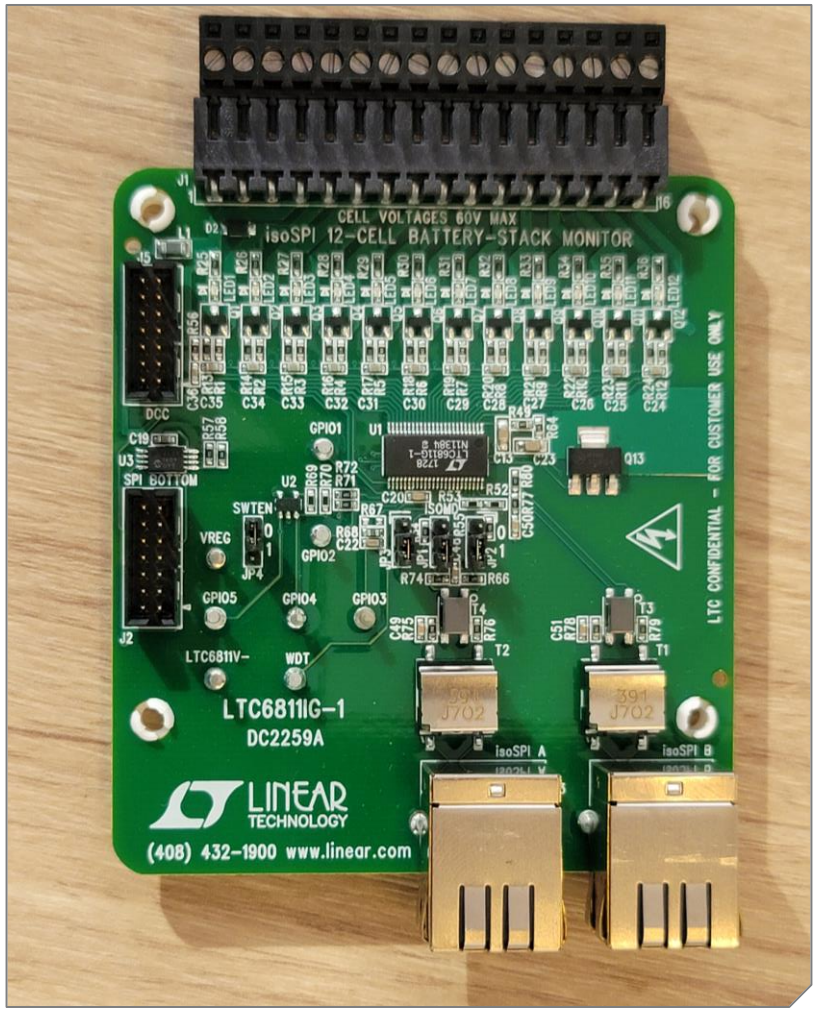
- A family of voltage measurement products (LTC6810/LTC6811/LTC6812/LTC6813) providing flexible cell configurations to create unique, EMI robust, high voltage battery solutions that can balance cells both internally and externally to the devices

Competitive Positioning

- Standard 12-channel configuration
- Active and passive cell balancing capabilities
- Passive cell balancing up to 60 mA using internal switches
- Nine general-purpose analog in and digital I/O
- Includes open-wire detection between ADCs and external cells
- LQFP 64-pin package

LTC6811: Design Resources and Release

- Data Sheet: Available
- Samples: Available
- Evaluation Kit: Available
- Reference Designs: Available
- Companion Parts
  - LTC6820—bidirectional SPI interface between two isolated devices through a single twisted pair



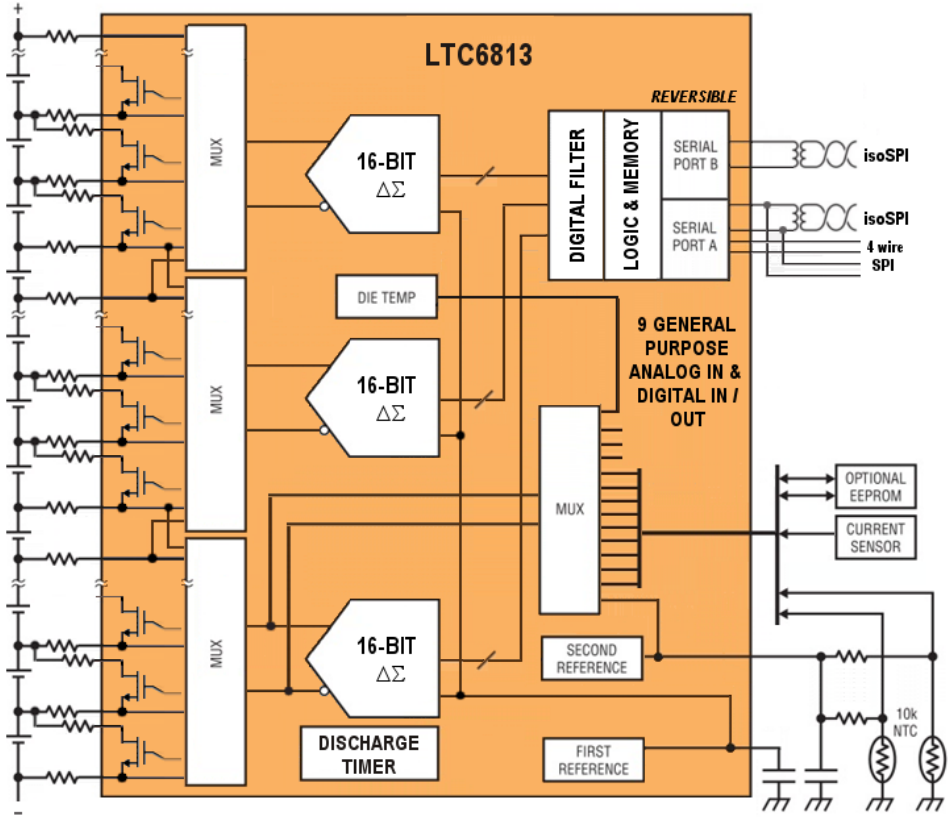
LTC6812/LTC6813: 15- and 18-Cell Battery Monitor

Value Proposition

- <2.2 mV total measurement error –40°C to +125°C
- Connect multiple devices in series or in parallel
- Reversible isoSPI™ interface
- Includes comprehensive self-tests
- Engineered for ISO 26262 systems

Key Benefits

- Maximizes the range of your EV battery design
- Create unique high voltage battery strings
- Bidirectional communication for broken wire protection
- Monitors the devices to always ensure proper operation
- Ensures functionally safe solution design



LTC6812/LTC6813: 15- and 18-Cell Battery Monitor

Features and Specifications

- Measures up to 15 (LTC6812) and 18 (LTC6813) battery cells in series
- 2.2 mV maximum total measurement error
- Stackable architecture for high voltage systems
- Reversible isoSPI™ interface
  - 1 Mb isolated serial communications
  - Uses a single twisted pair, up to 100 meters
  - Low EMI susceptibility and emissions
  - Bidirectional for broken wire protection
- 245 µs to measure all cells in a system (for LTC6812)
  - 290 µs for the LTC6813
- Synchronized voltage and current measurement
- 16-bit sigma-delta ADC with programmable 3rd order noise filter
- Engineered for ISO 26262-compliant systems
- Passive cell balancing up to 200 mA (max) with programmable pulse-width modulation
- Nine general-purpose digital I/O or analog inputs
  - Temperature or other sensor inputs
  - Configurable as an I^2C or SPI master
- 6 µA sleep mode supply current

Portfolio Positioning

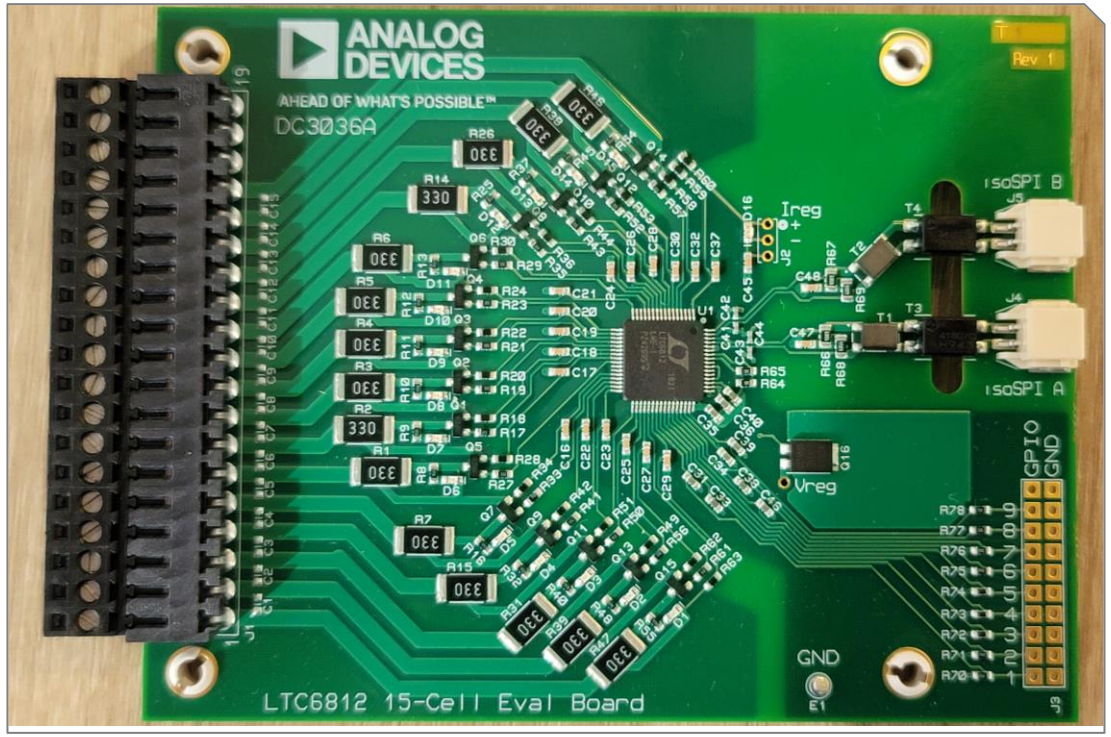
- A family of voltage measurement products (LTC6810/LTC6811/LTC6812/LTC6813) providing flexible cell configurations to create unique, EMI robust, high voltage battery solutions that can balance cells both internally and externally to the devices

Competitive Positioning

- High channel count gives better cost per channel
- Reversible isoSPI
- Passive cell balancing capability up to 200 mA using internal switches
- Nine general-purpose analog in and digital I/O
- Includes open-wire detection between ADCs and external cells
- LQFP 64-pin package

LTC6812/LTC6813: Design Resources and Release

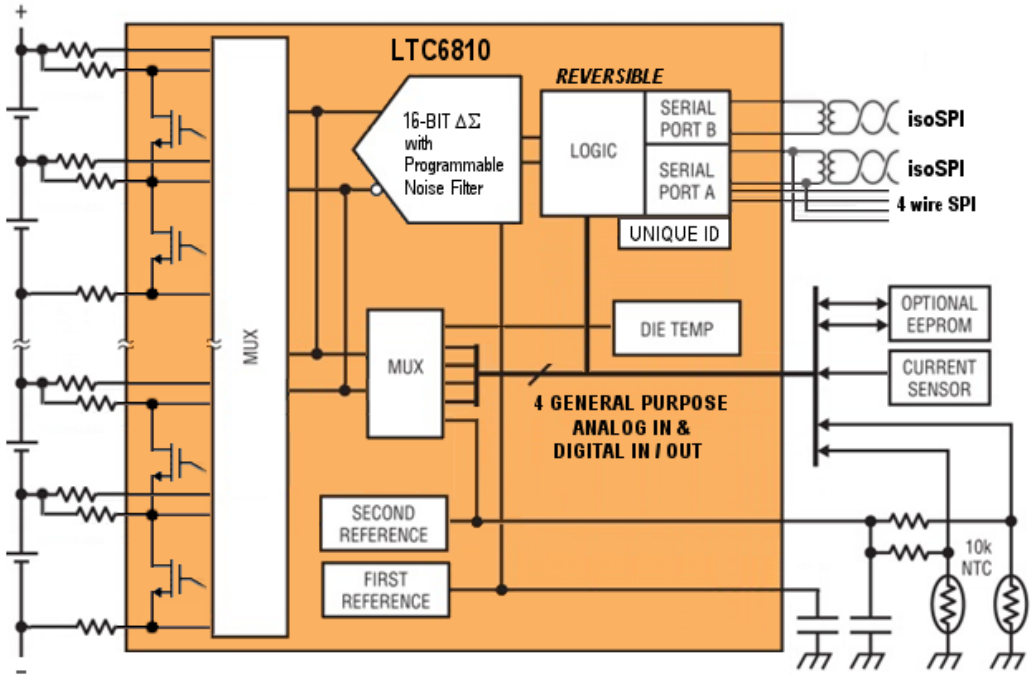
- Data Sheet: Available
- Samples: Available
- Evaluation Kit: Available
- Reference Designs: Available
- Companion Parts
  - LTC6820—bidirectional SPI interface between two isolated devices through a single twisted pair



LTC6810: 6-Cell Battery Monitor

Value Proposition

- <2.2 mV total measurement error –40°C to +125°C
- Connect multiple devices in series or in parallel
- Reversible isoSPI™ interface
- Includes comprehensive self-tests
- Engineered for ISO 26262 systems



Key Benefits

- Maximizes the range of your EV battery design
- Create unique high voltage battery strings
- High speed long-distance communication that's immune to RF
- Monitors the devices to always ensure proper operation
- Ensures functionally safe solution design

LTC6810: 6-Cell Battery Monitor

Features and Specifications

- Measures up to six battery cells in series
- 1.8 mV maximum total measurement error
- Stackable architecture for high voltage systems
- 290 µs to measure all cells in a system
- Reversible isoSPI™ interface
  - 1 Mb isolated serial communications
  - Uses single twisted pair, up to 100 meters
  - Low EMI susceptibility and emissions
  - Bidirectional for broken wire protection
- Guaranteed performance down to 5 V
- Performs redundant cell measurements
- Engineered for ISO 26262 compliant systems
- Passive cell balancing with programmable PWM
- Four general-purpose digital I/O or analog inputs
  - Temperature or other sensor inputs
  - Configurable as an I^2C or SPI master
- 4 µA sleep mode supply current

Portfolio Positioning

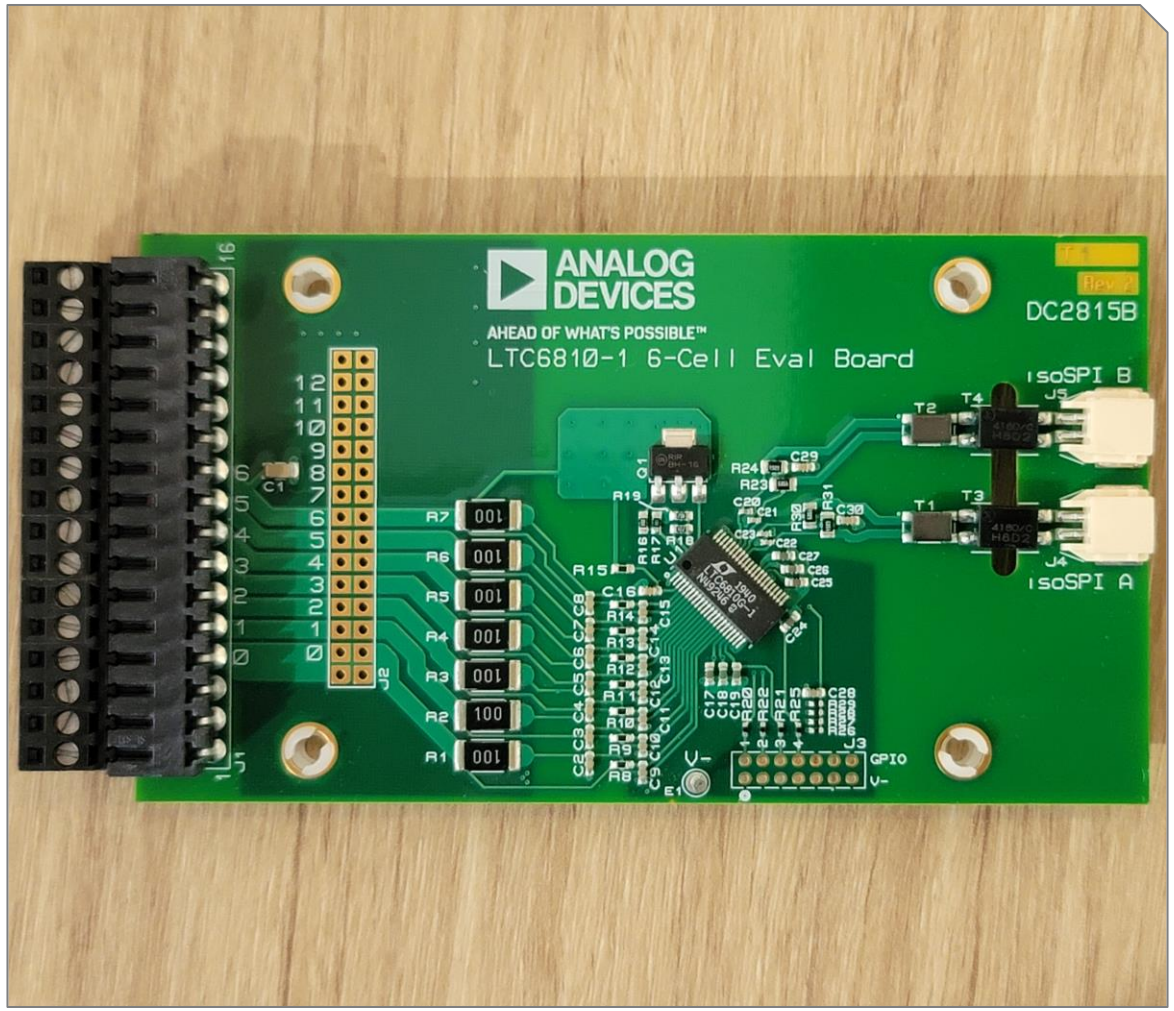
- A family of voltage measurement products (LTC6810/LTC6811/LTC6812/LTC6813) providing flexible cell configurations to create unique, EMI robust, high voltage battery solutions that can balance cells both internally and externally to the devices

Competitive Positioning

- Includes dual cell measurement capability (fault coverage)
- Includes reversible isoSPI
- Up to 150 mA passive cell balancing capability using internal switches
- Includes open-wire detection between ADCs and external cells
- Ability to operate in 7-cell mode
- Operates with stack voltages down to 4.8 V
- Unique ID and authentication feature

LTC6810: Design Resources and Release

- Data Sheet: Available
- Samples: Available
- Evaluation Kit: Available
- Reference Designs: Available
- Companion Parts
  - LTC6820—bidirectional SPI interface between two isolated devices through a single twisted pair



LTC681x Feature Matrix

Feature	LTC6810	LTC6811	LTC6812	LTC6813
Cell Measurement Channels	6	12	15	18
Reversible isoSPI™	Yes	No	Yes	Yes
Dual Port Measurements (Leakage Detect)	Yes	No	No	No
Internal Max Discharge Current (per Channel)	150 mA	50 mA	200 mA	200 mA
Discharge Path Bypasses R_{FILTER}	Yes	No	No	No
PWM Discharge Timer	Yes (LP mode)	Yes (LP mode)	Yes (LP mode)	Yes (LP mode)
UV Detection on Each Cell During Sleep Mode PWM Discharge	Yes	No	No	No
Open-Wire Detection on GPIO	Yes	No	Yes	Yes
Unique ID	Yes	No	No	No
Authentication Feature	Yes	No	No	No

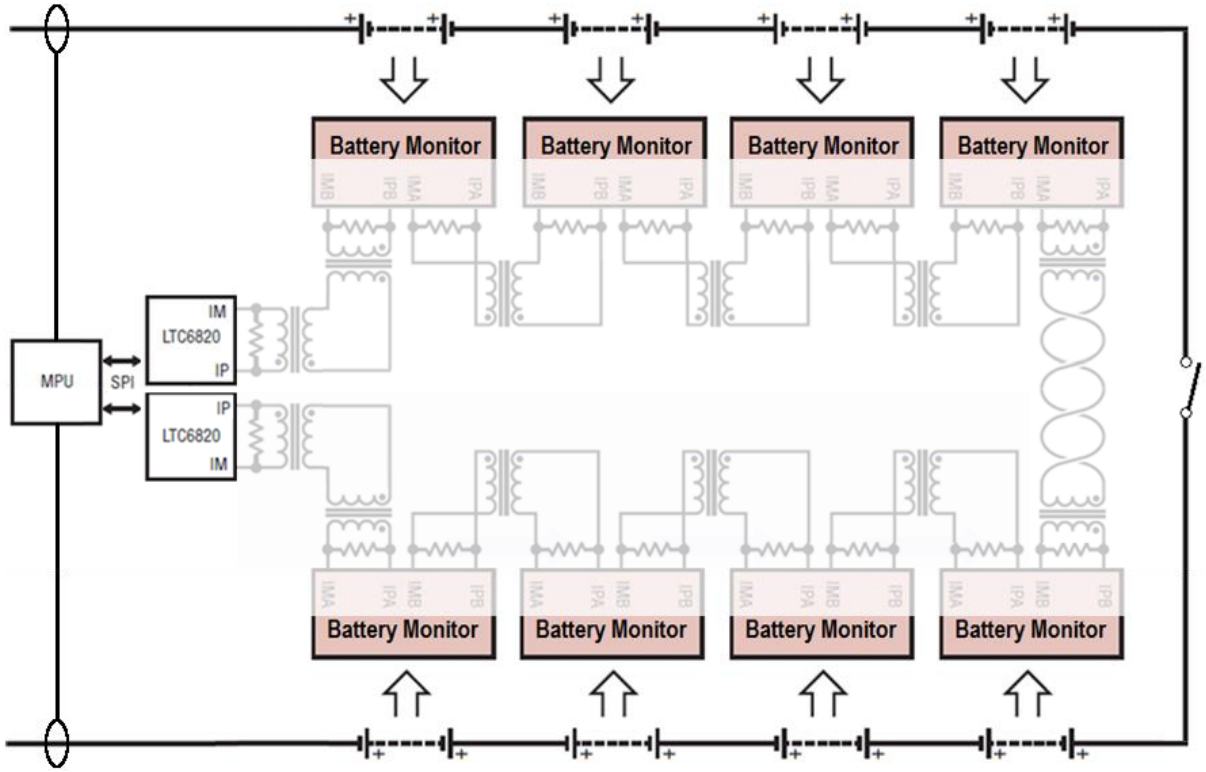
What is Reversible isoSPI

Reversible isoSPI:

- Addresses Potential Breaks in the Daisy Chain
- Automatic Operation; No Configuration Required
- Every Port Accepts Commands

Reversible Communication Mode:

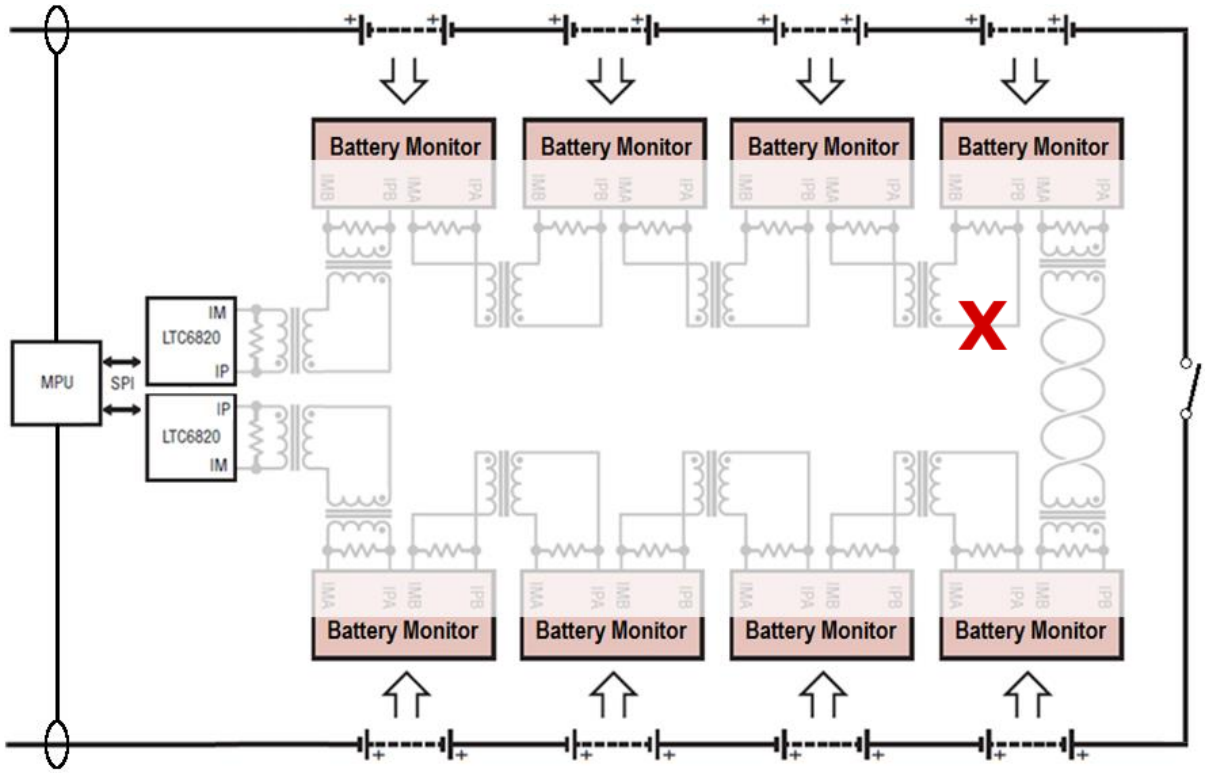
- Alternating Ports can Monitor Signal Integrity
- Signal Breaks Quickly Located



What is Reversible isoSPI

Managing Physical Breaks in Communication

- Valid Data Received for Devices before Break Point (confirmed by PEC)
- Host Receives Invalid Data for Devices after Break Point
- Host MPU Continues to Receive and Monitor all Devices by Alternating Communication Ports



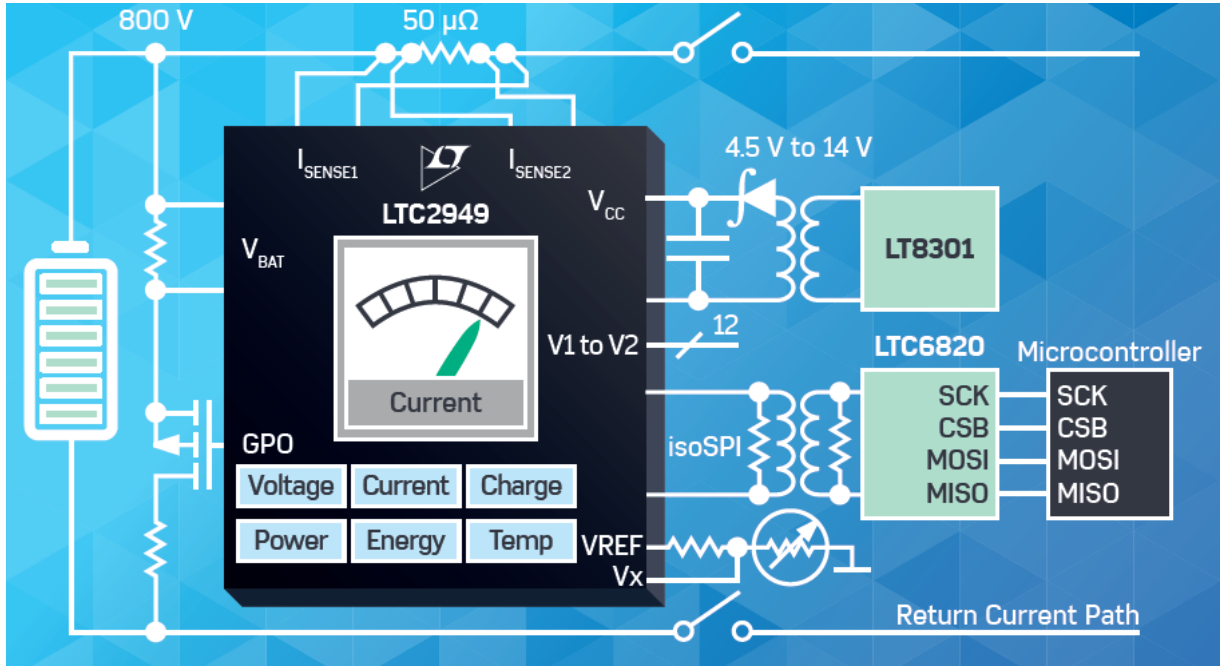
Pack Monitoring

AHEAD OF WHAT'S POSSIBLE™

LTC2949 Pack Monitor

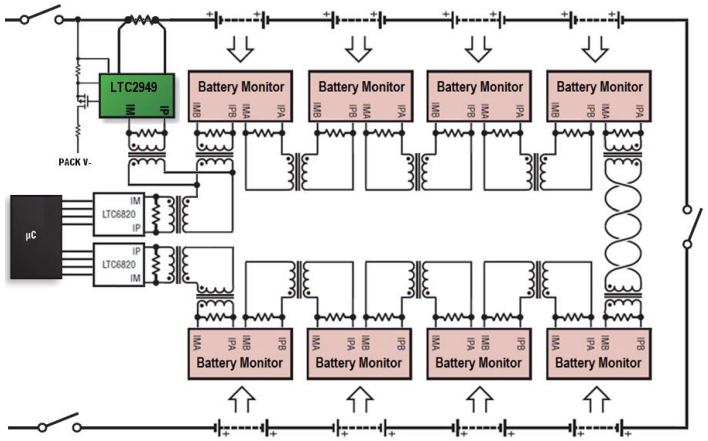
Value Proposition

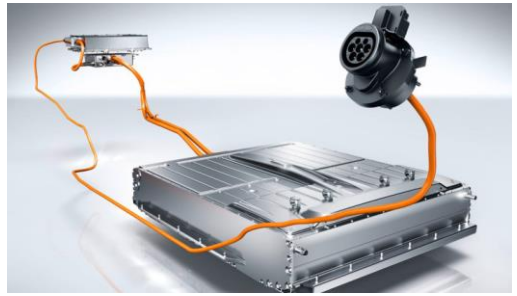
- On-device processing
- High-side and low-side implementation
- Built-in isoSPI™ interface
- 2nd order programmable temperature compensation
- Accurately measure and monitor battery power and energy



Key Benefits

- Real-time measurement and monitoring for improved SOC/SOH
- Flexibility in battery design architecture
- High speed communication with low EMI susceptibility and emissions
- Accurately compensate for sense resistor errors for improved performance across temperature
- Enhance the driving experience with being able to drive longer





*** Bidirectional ring topology supported with LTC6810/LTC6812/LTC6813**

LTC2949 Pack Monitor

Features and Specifications

- Dual current measurements
  - Configurable for high-side or low-side operation
  - ±124 mV range, 237.5 nV resolution (20-bit Σ-Δ)
  - 3 µV offset max (–40°C to +125°C)
  - Built-in 2nd order shunt tempco correction factor
  - Fast overcurrent detection with deglitch
  - Max/min values stored on-board
- Voltage measurements
  - ±5.5 V range, 46 µV resolution (18-bit Σ-Δ)
  - Dedicated stack measurement
  - Seven dedicated buffered voltage inputs
  - Five additional buffered voltage inputs or digital outputs (configurable as heartbeat monitors)
- Real-time on-board processing
  - 1% accuracy power, energy, and charge measurements
  - Lossless tracking of charge and energy
  - Built-in tolerance and tempco correction factors
  - True average ADCs
  - Threshold registers for all measured quantities

Portfolio Positioning

- The LTC2949 is the first device in a family of products being developed for pack monitoring to precisely and quickly measure the total stack parameters of the entire battery

Competitive Positioning

- Simultaneous monitoring of voltage drop across two sense resistors and the battery pack voltage
- Synchronous measurements for improved SOC and SOH accuracy
- Low-side or high-side connection for flexibility of design
- Programmable thresholds and tracking
- Programmable temperature compensation relative to sense resistor

LTC2949: Design Resources and Release

- Data Sheet: Available
- Samples: Available
- Evaluation Kit: Available
- Reference Designs: Available
- Companion Parts
  - LTC6820—bidirectional SPI interface between two isolated devices through a single twisted pair
  - LT8301—micropower no-opto isolated flyback converter
  - LT8302—monolithic micropower isolated flyback converter
  - LT8315—560 V_{IN} micropower no-opto isolated flyback converter
  - LT8316—600 V_{IN} micropower no-opto isolated flyback controller

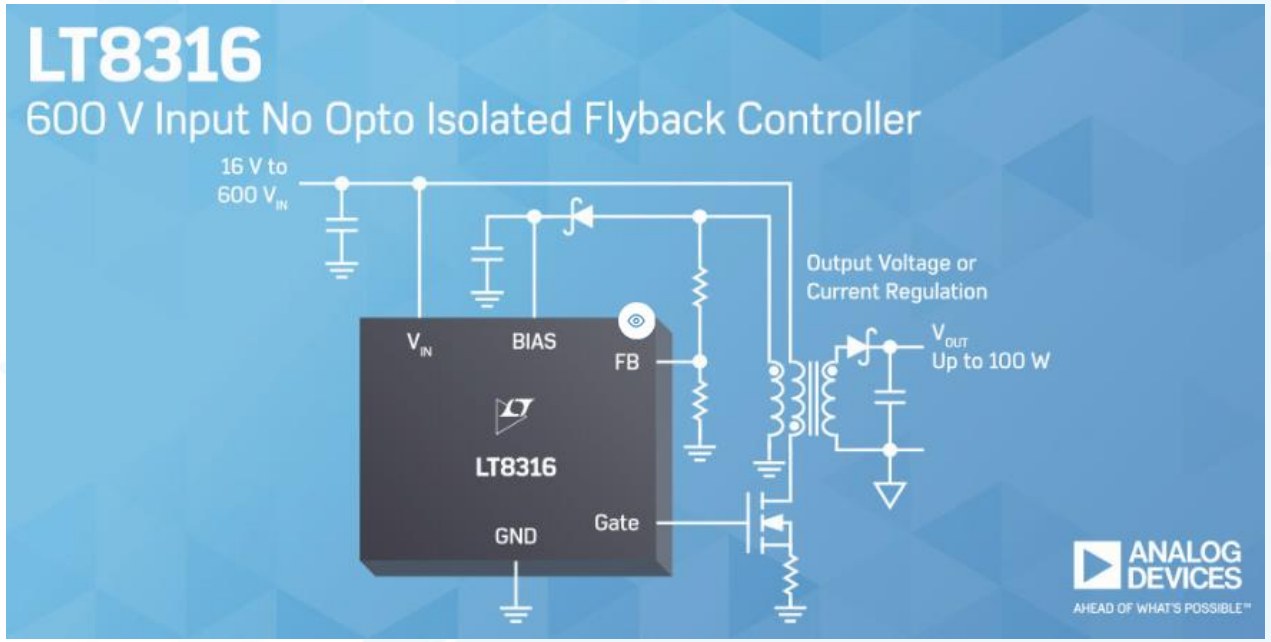
LT8316: 600 V_{IN} Micropower No-Opto Flyback

Value Proposition

- Greatly simplifies isolated power circuit design for up to 100 W systems
- Fast startup and low idle current draw allow permanent connection to battery stacks
- No optocoupler required for voltage feedback information
- Quasi-resonant boundary mode improves load regulation and reduces transformer size

Key Benefits

- Converts high input voltages up to 600 V in one step
- Simplified application circuit provides compact solution
- Well-controlled constant current and constant voltage regulation



Summary

ANALOG DEVICES

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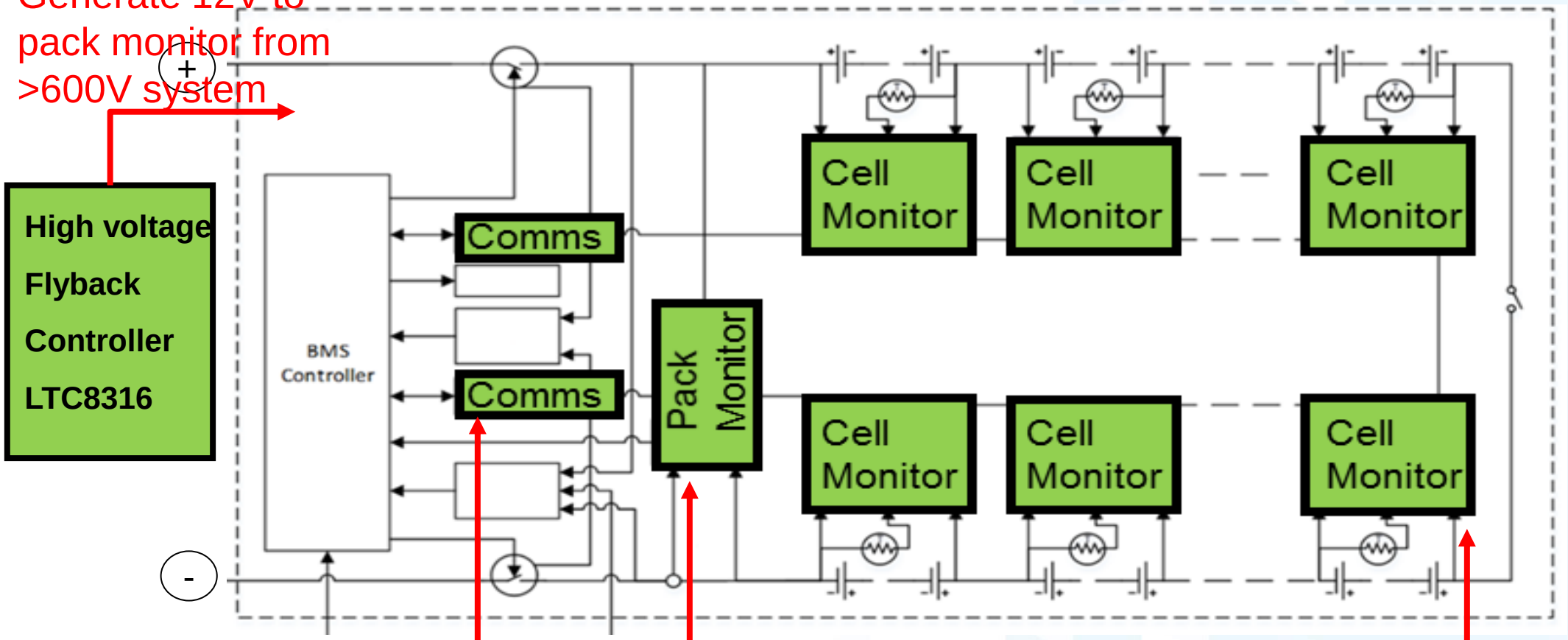
Total solutions for BMS application



Advantages of Choosing ADI as a Partner

- Experience
  - The broadest range of BMS ICs supporting 6 to 18 battery cells
  - Leadership with more than a decade of road-proven BMS experience
  - Success across the globe
- Capability
  - Designed for performance and accuracy: OEM RFQ requirements are more easily achievable, resulting in more production margin and/or more pack capacity (higher $ value for our customers)
  - Designed for automotive reliability and safety: AEC-Q100 qualified and full ISO 26262 ASIL D compliance
  - Designed for robustness: high temperature (125°C), high EMI, hot plug, long life
  - Designed to meet industry standards, such as new China, EU, and U.S. requirements
- Support
  - ADI designers, application experts, and field support available for functional safety, EMC debug, software, etc.
  - More than 100 BMS engineers worldwide

Thank you

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