TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

SUDHIR NAGARAJ, MILOS ACANSKI

INTELLIGENT BATTERY JUNCTION BOX FOR VOLTAGE AND CURRENT SYNCHRONIZATION

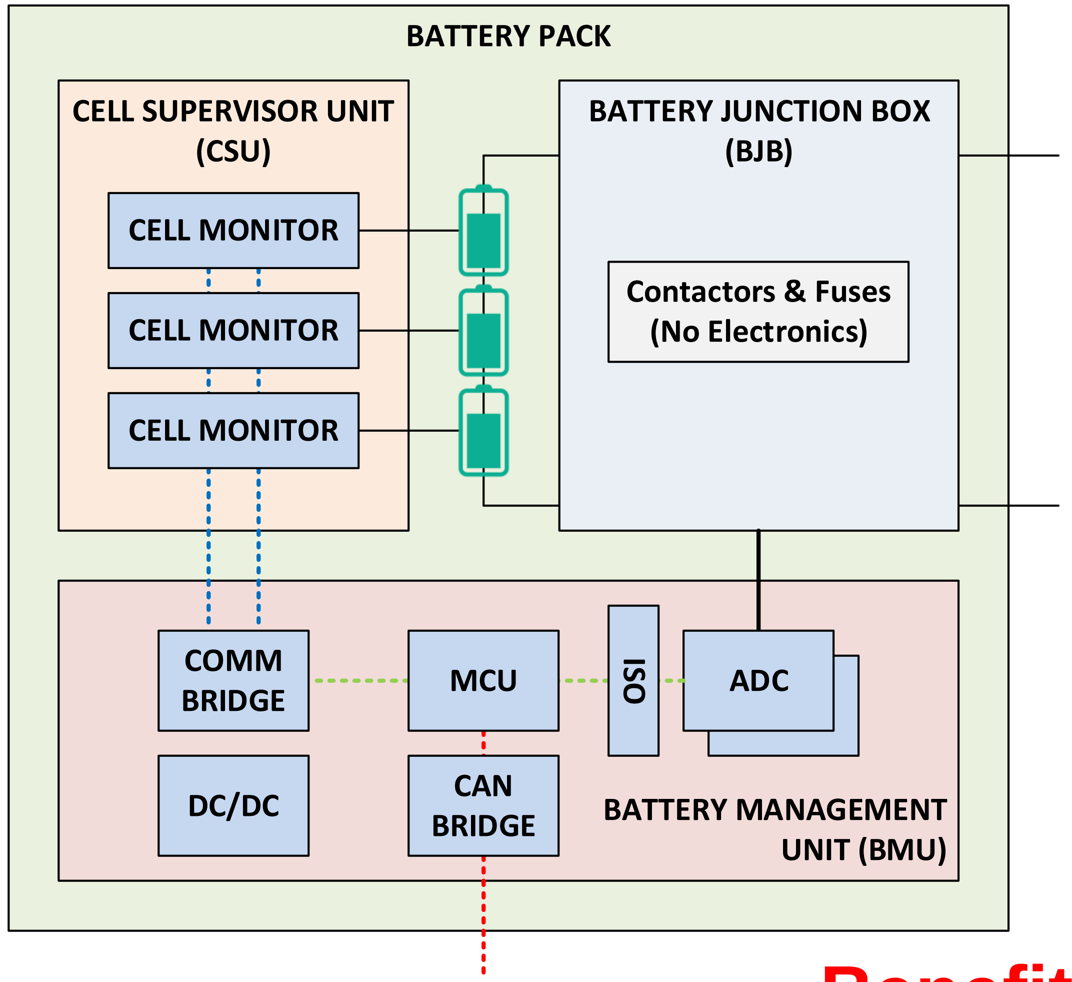
Agenda

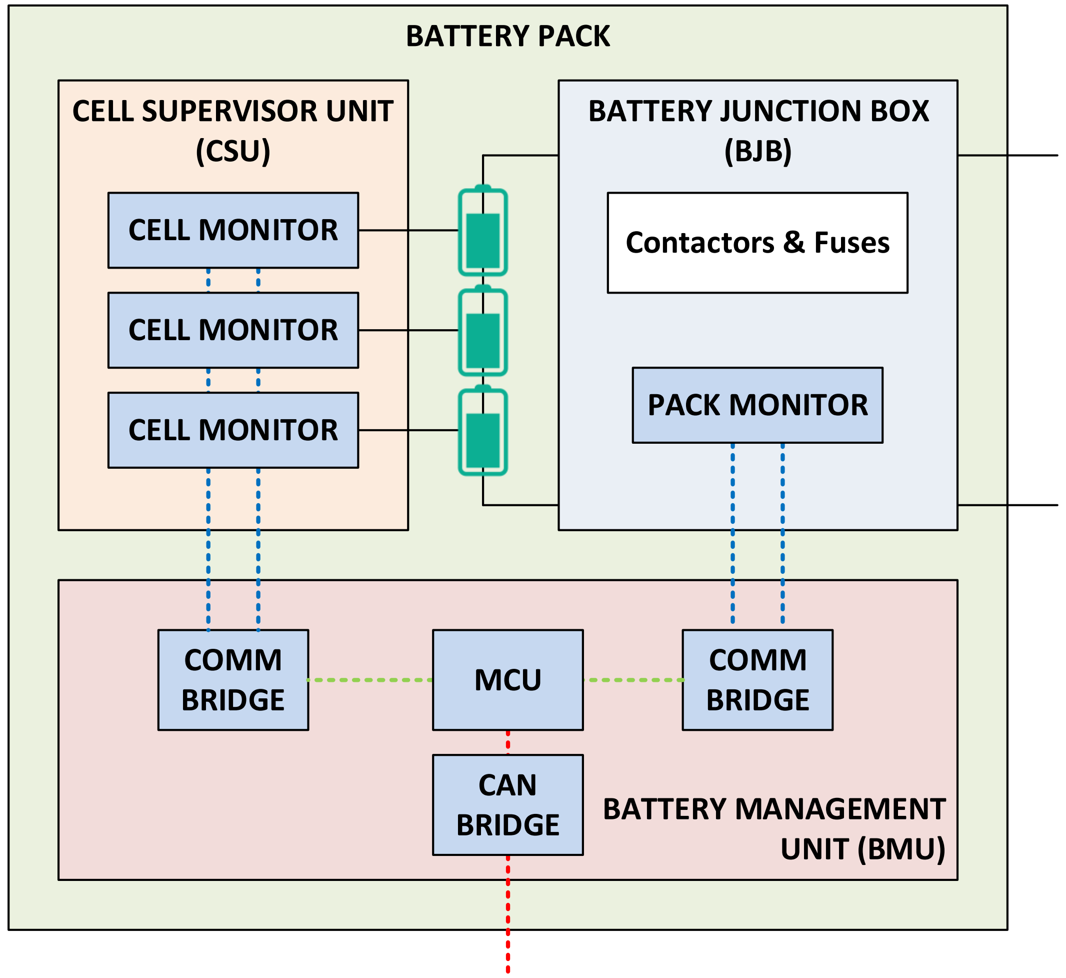
- Intelligent battery management system (BMS) introduction.
- Voltage (V), current (I) and insulation resistance (R) measurements.
- VI synchronization in BMSs.
- Summary.

Introduction – BMSs

- Main BMS function: monitor cell voltage (V_{CELL}), pack voltage (V_{PACK}) and pack current (I_{PACK}).

Traditional BMS → Intelligent battery junction box (BJB)



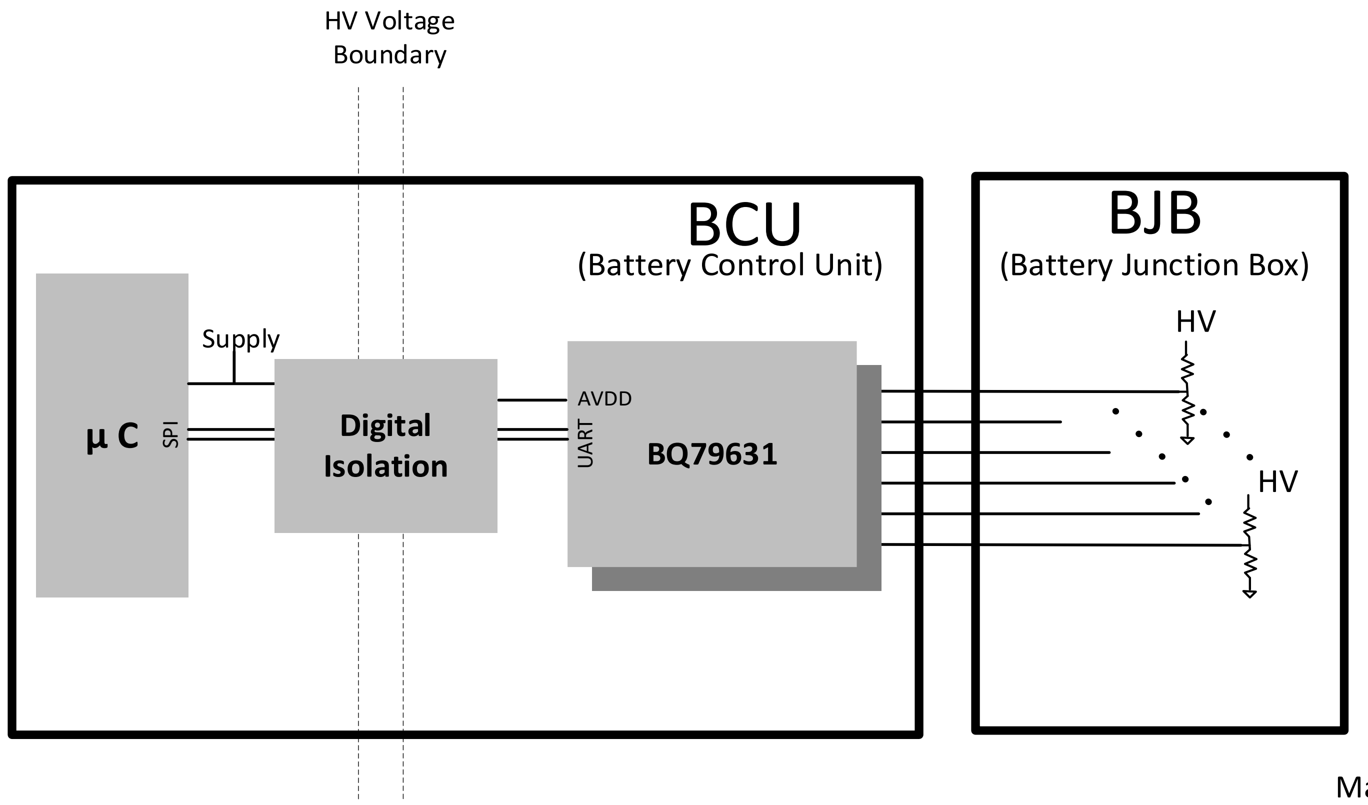


Legend:
- Wire harness
- CAN
- SPI/UART
- Daisy-chain

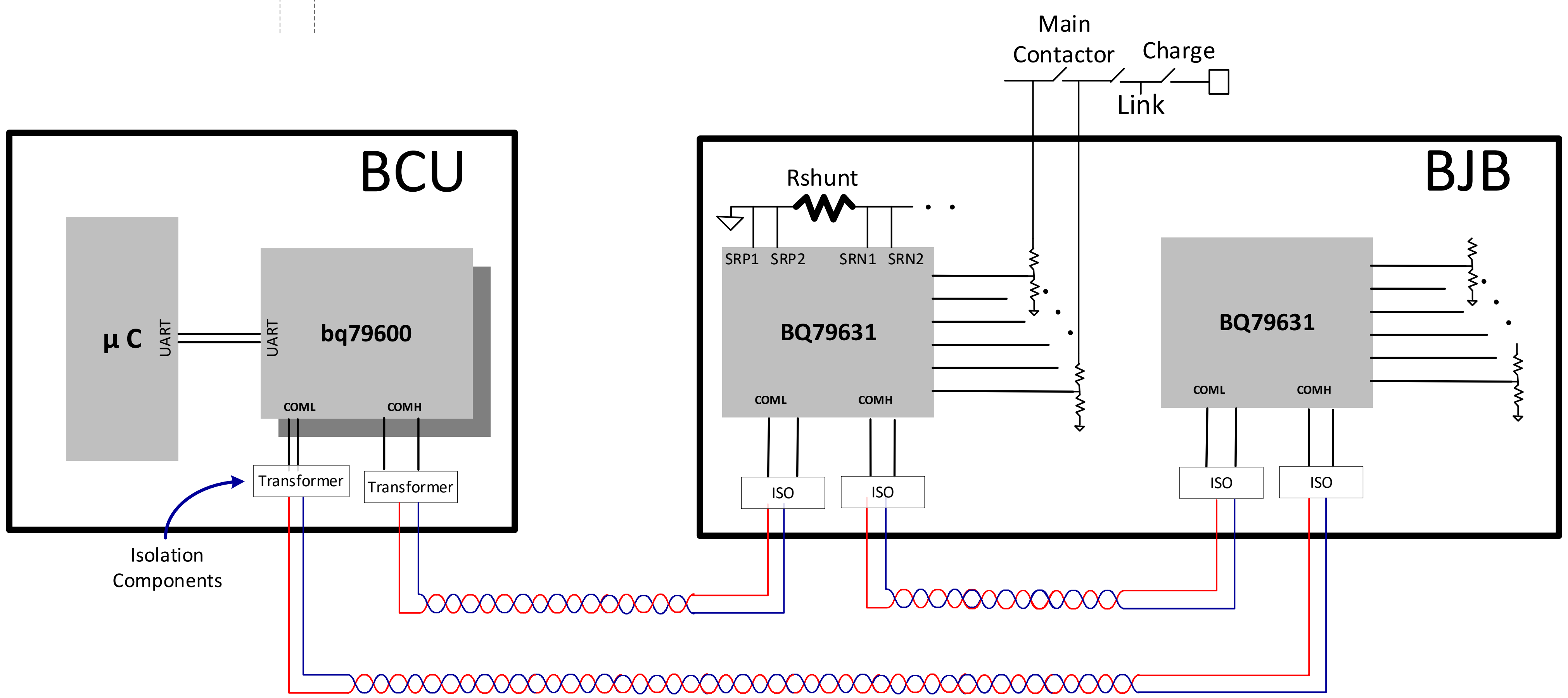
Benefits

- Eliminates numerous connections in BMU and BJB interface.
- Simplifies hardware and MCU software development.
- Synchronized VI measurements.

Comm supports both traditional and intelligent BMSs

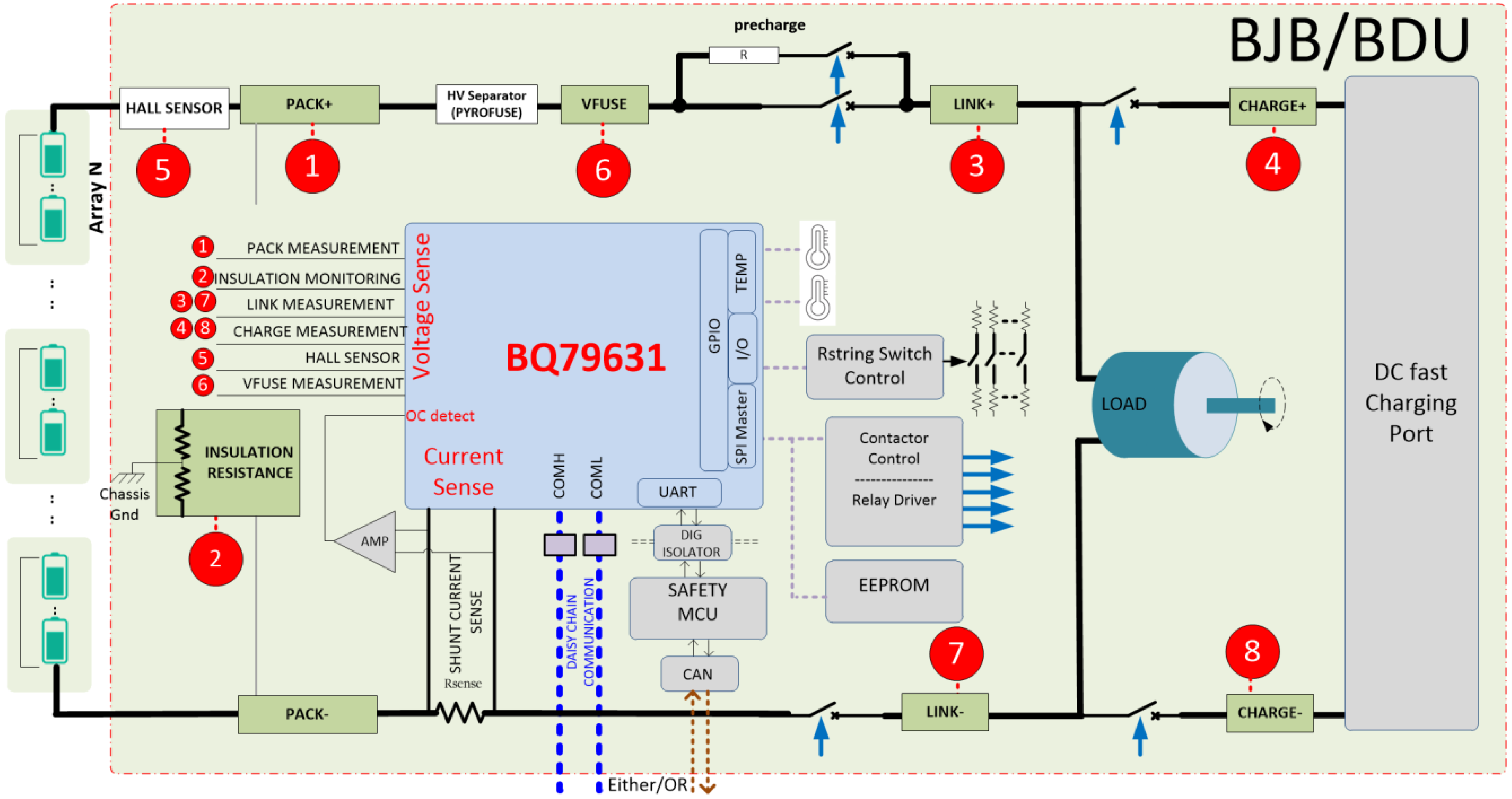


- Traditional UART-based communication.



- Intelligent BMS: communication over daisy chain.
- Can also be connected in same daisy chain as cell monitors.

Voltage measurements



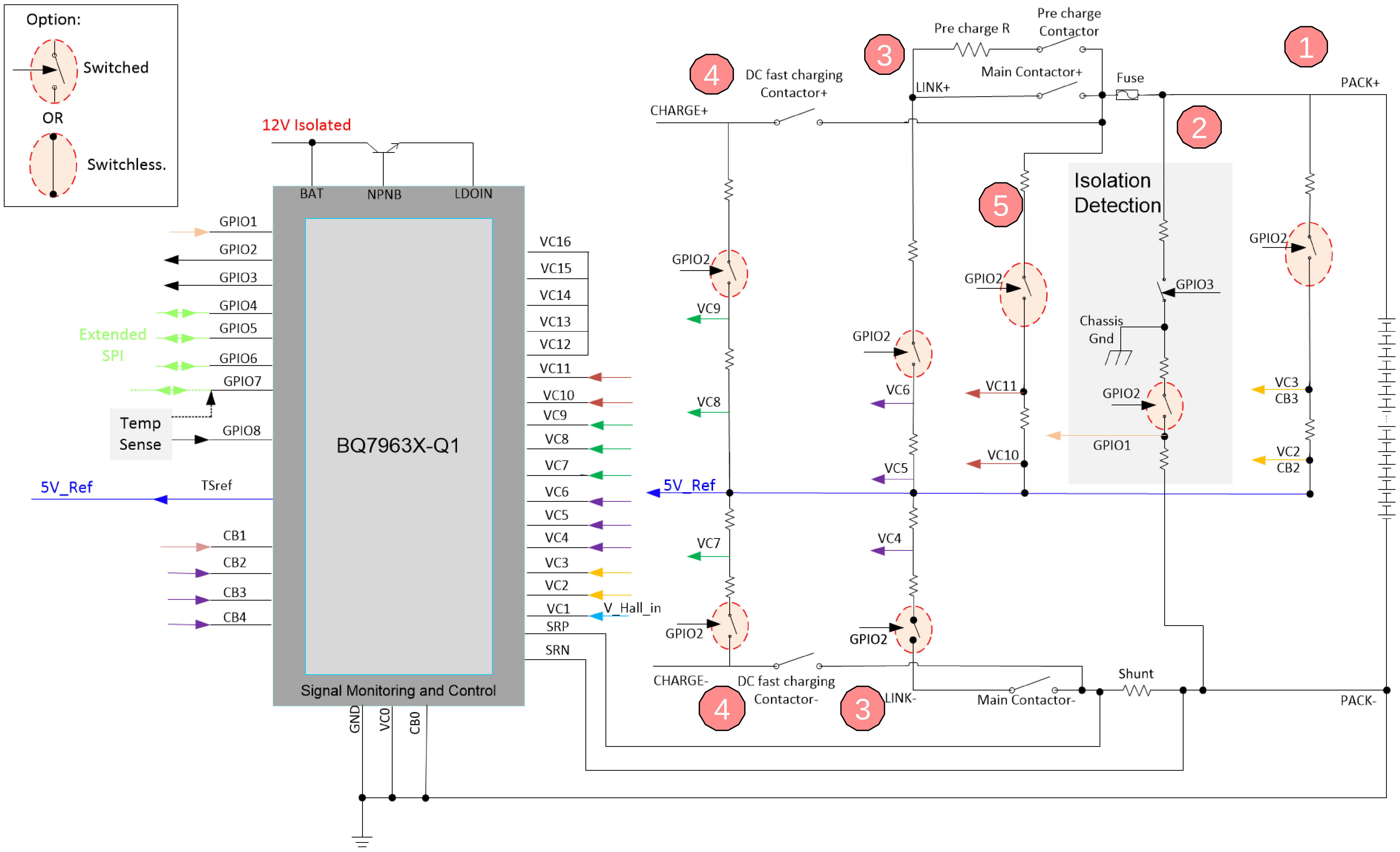
Voltage measurements:

- Indicate the status of contactors and fuses.
- Power calculations.
- Temperature measurements.
- Measure the DCFC voltage.

Key measurement properties:

- Accuracy to support <1% error in high-voltage estimations.
- All high voltages are divided down using resistor strings.
- Voltage measurement inputs need to have extremely low leakage to avoid affecting measurements.

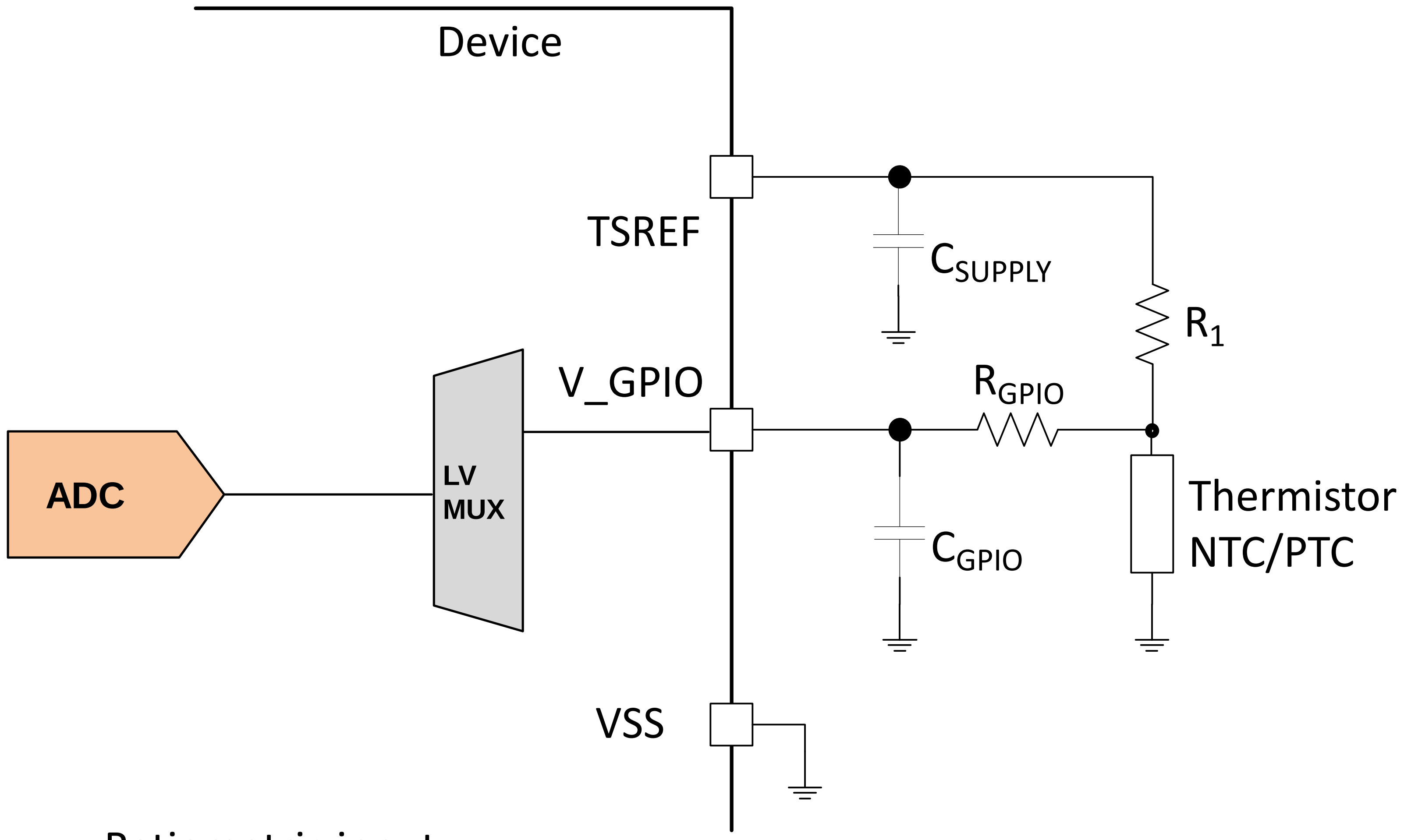
Voltage measurement resource assignment



Measurements:

1. Pack+
2. Insulation
3. Link +/-
4. Charge +/-
5. Fuse +

Temperature measurements



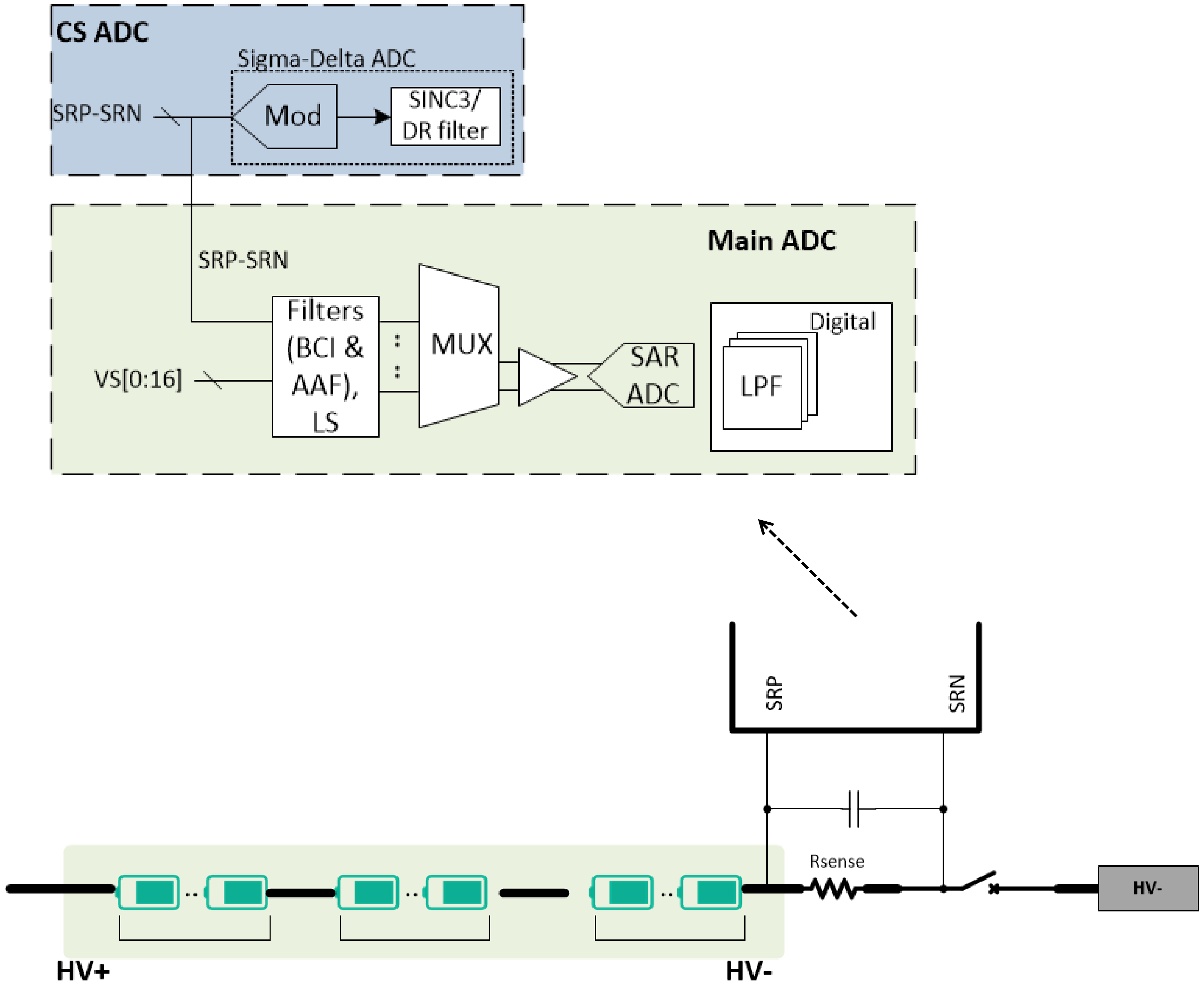
Ratiometric input measurement on GPIO

R1 = 10 kΩ

- Simply use a pullup resistor to TSREF to form an **NTC thermistor** connection.
- Device supports ratiometric measurement through the ADC.

	Min		Max
GPIO ratiometric accuracy	–0.2%		+0.2%

Current measurements using a shunt resistor



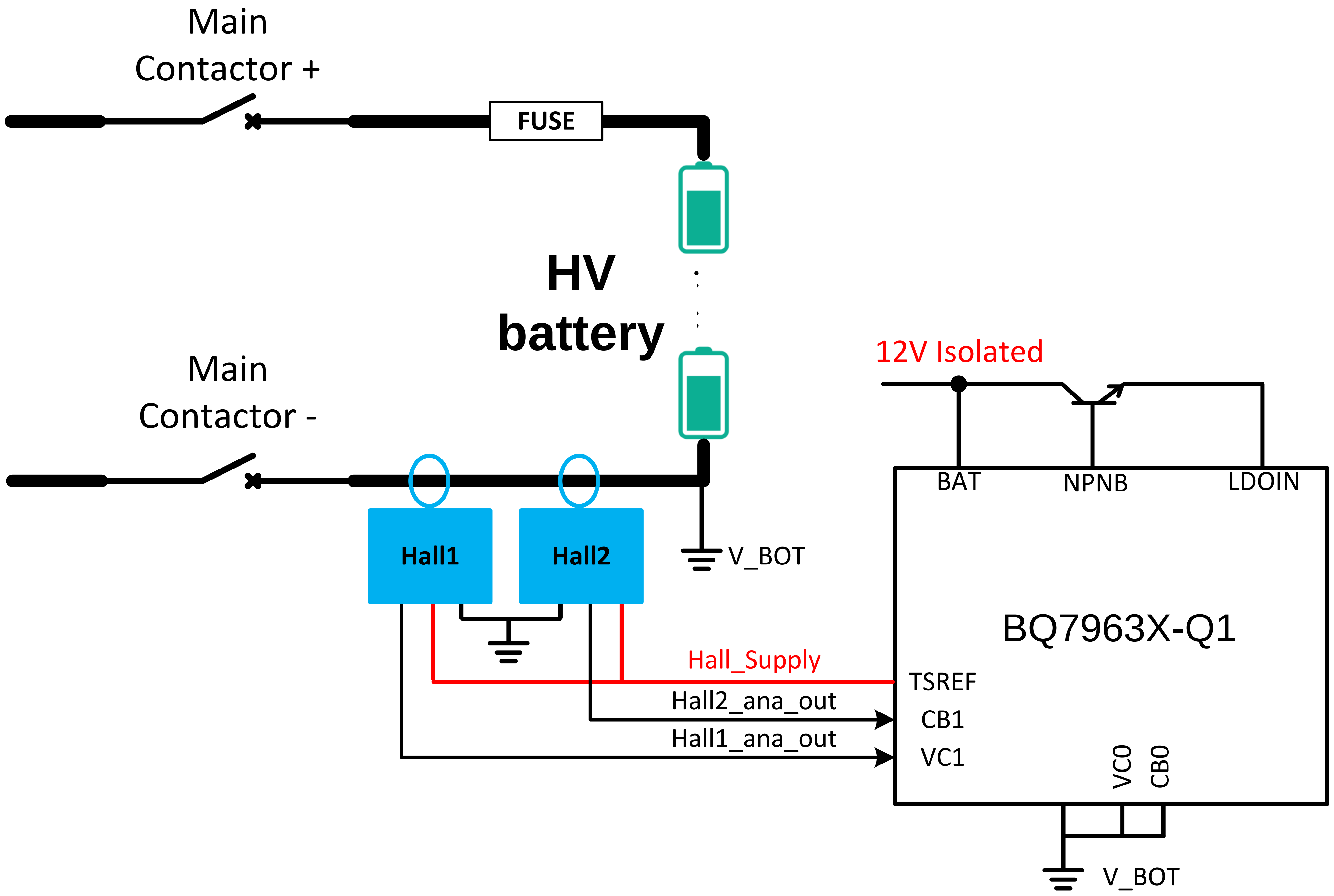
Current measurements:

- Measure load currents such as current in the drive motor.
- Measure the charging current.
- Battery power calculations.
- Cell impedance calculations.

Key measurement properties:

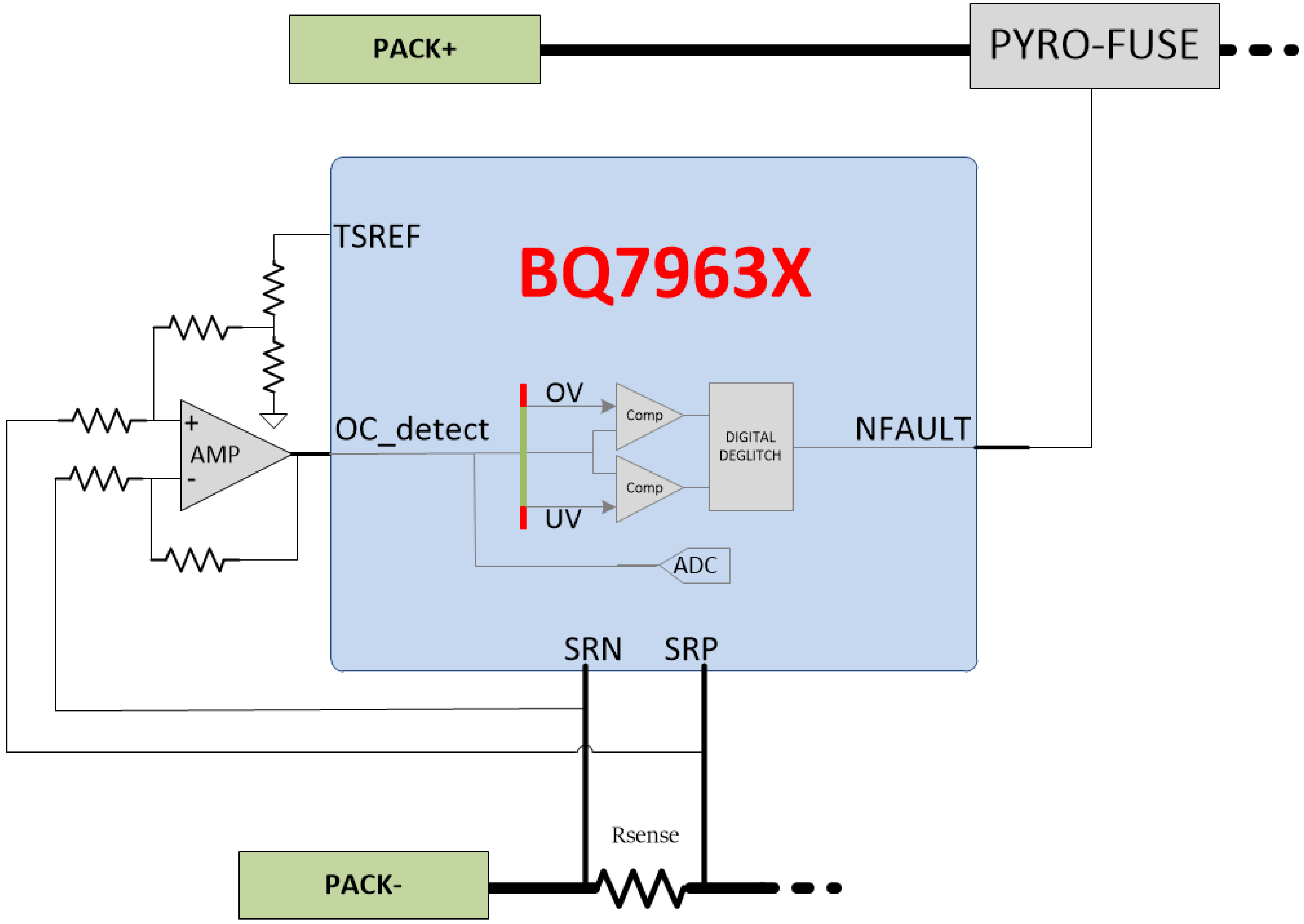
- Very high accuracy (typically <0.3% error from measurement).
- Conversion rates and characteristics to match cell voltage measurement properties (cycle time, filter, etc.). This helps achieve good VI sync between cell voltage and current, which helps in accurate power, cell impedance, and state-of-charge and state-of-health calculations.

Current sensing using a Hall sensor



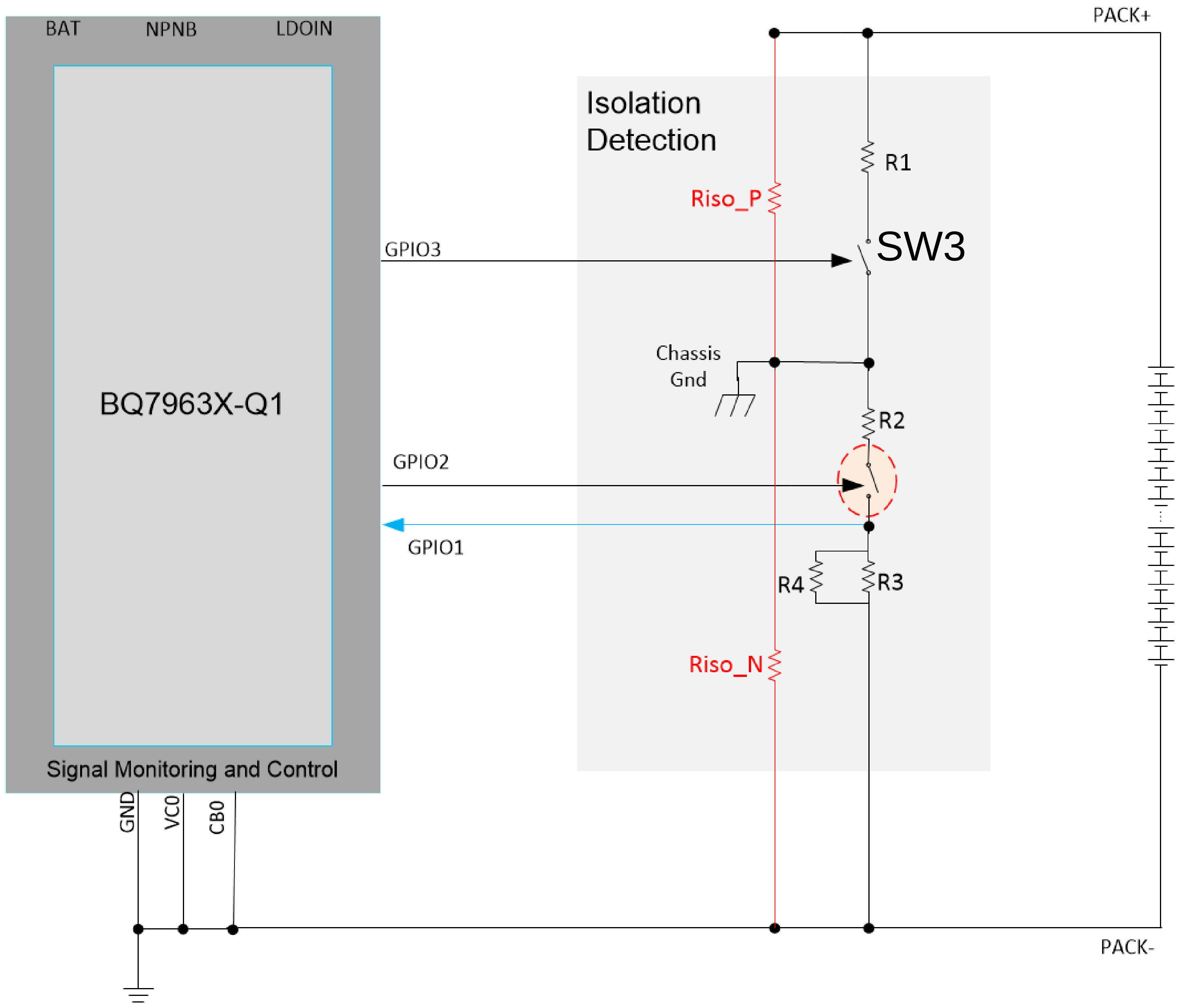
- A shunt achieves higher accuracy across the range (mA to kA). It is also more immune to EMI noise compared to Hall sensors.
- A Hall sensor offers flexibility of placement and inherent voltage isolation from magnetic sensing.
- The BQ's voltage input channels can also measure the analog outputs from typical Hall-based current sensors.

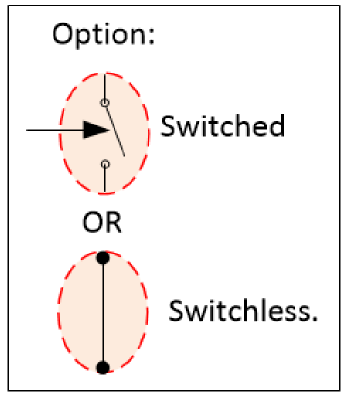
Overcurrent detection



- Bidirectional detection.
- Programmable thresholds.
- Fault signal on pin, which can trigger a pyro-fuse to provide the fastest response to overcurrent events. A pyro-fuse is a one-time trigger chemical fuse where once triggered, the fuse is permanently open.
- Fault response in 500 µS.
- Deglitch of 100 µS.

Insulation resistance measurements





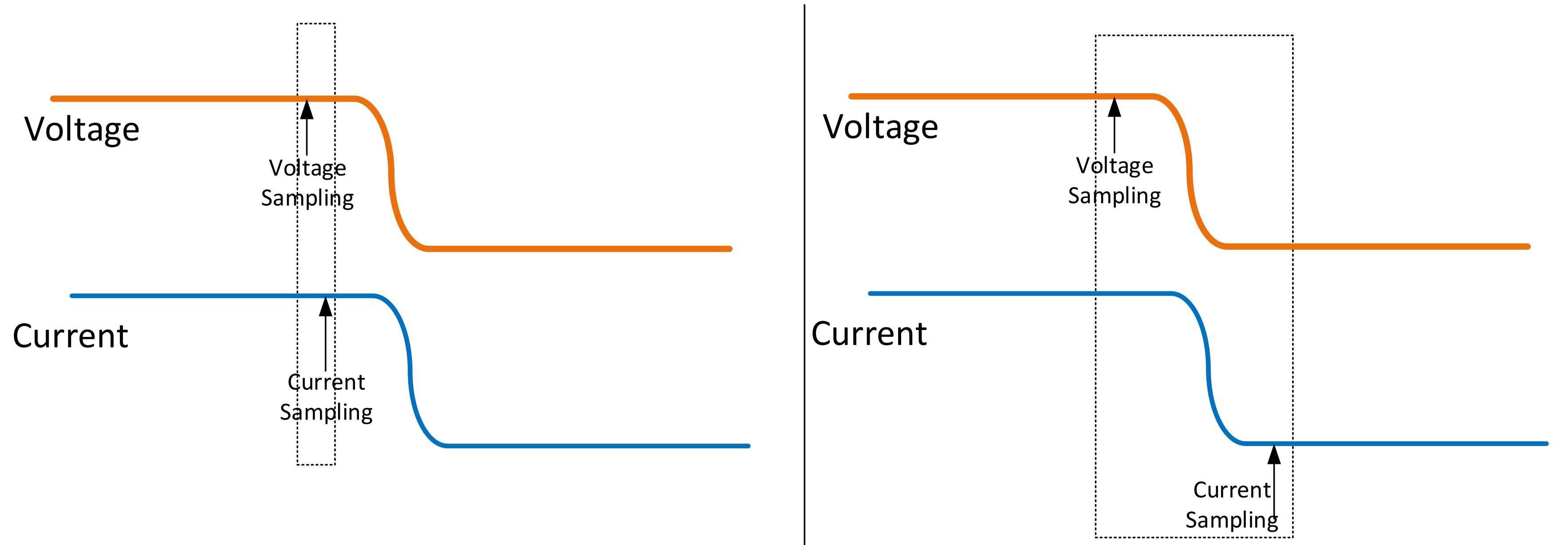
A GPIO2 switch prevents leakage current from flowing between chassis ground and PACK– during a key-off state.

- The insulation resistance is the resistance of all insulation materials used to isolate the high-voltage battery +/- from the low-voltage chassis ground.
- Represented by Riso_P and Riso_N .
- Determine their values by following these steps:
  1. SW3 open, measure voltage on GPIO1. Use this voltage in the circuit/network equation for the SW3 open circuit.
  2. SW3 closed, measure voltage on GPIO1. Use this voltage in the circuit/network equation for the SW3 closed circuit.
  3. Combine equations from steps 1 and 2 to solve Riso_P and Riso_N.

VI synchronization in BMSs

VI synchronization in BMSs

- V_{CELL}, V_{PACK} and I_{PACK} are used for:
  - Battery monitoring.
  - Calculations (state of charge, state of health, electrical impedance spectroscopy).
  - Diagnostics (for example, comparing the pack voltage and the sum of cell voltages).
  - BMS without a pack monitor → pack voltage calculated by summing all cell voltages.
- V_{CELL}, V_{PACK} and I_{PACK} need correlation in time to provide the most accurate power and impedance estimates. Samples taken within a certain time interval → synchronization interval or VI sync time.
- Nonsynchronized data can lead to errors (1% state-of-charge error → 1% shorter vehicle range).



Example 1: Small VI sync time
More accurate SOC, Impedance and Power calculations.

Example 2: Large VI sync time
Less accurate SOC, Impedance and Power calculations.

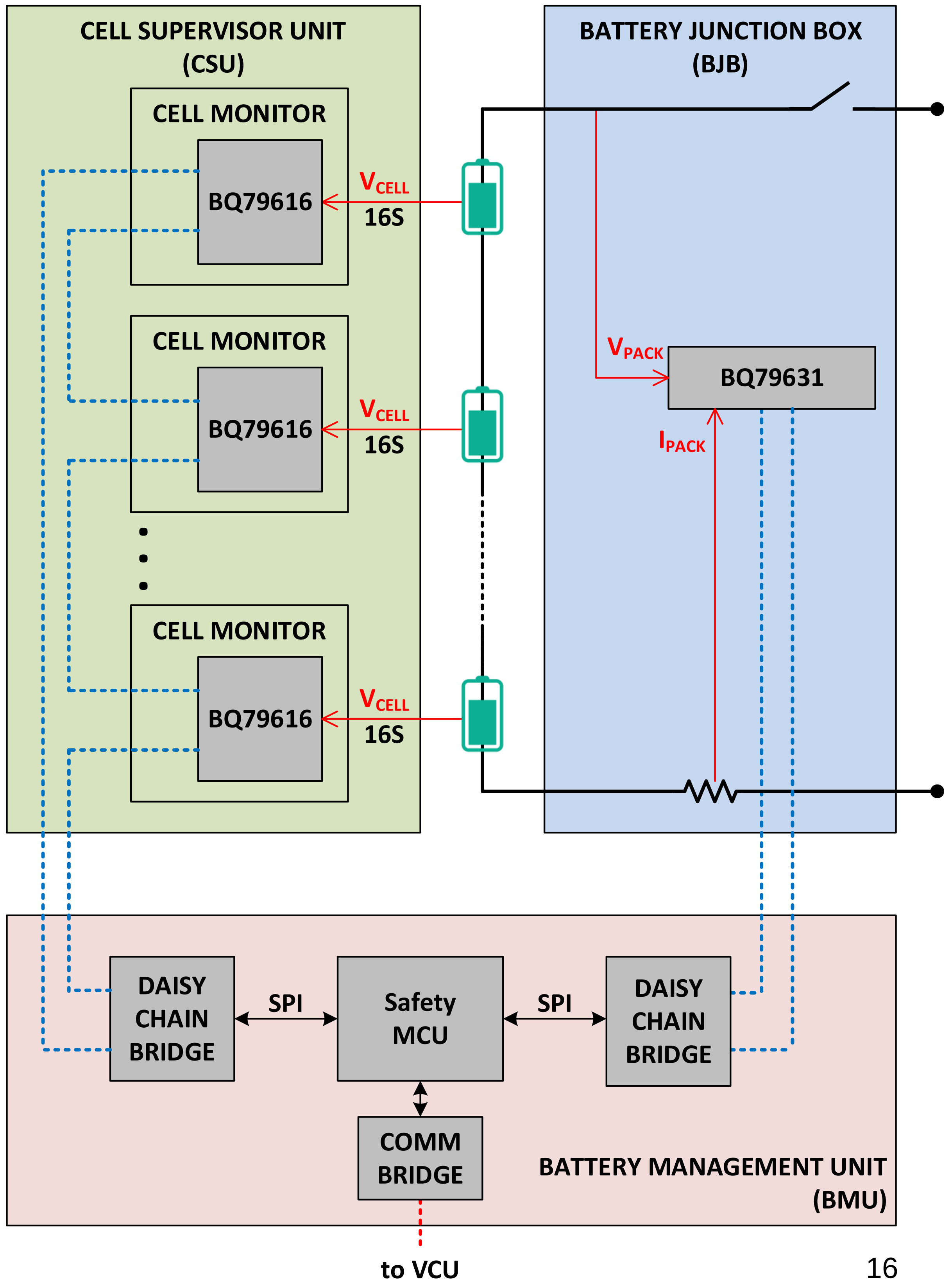
Challenges in synchronization

- Increasingly demanding timing requirements:
  - VI synchronization below 1 ms for more accurate state-of-charge, impedance and power calculations.
  - Sample intervals down to 10 ms and below.
- Challenges/considerations:
  - Nonsynchronized cell monitors.
  - Measurement readout/buffering.
  - Influence of the filter.
  - Synchronizing cell and pack measurements.
  - Command propagation delay.
  - Bandwidth of the communication interface.
  - Wired vs. wireless (protocol).

VI synchronization with BQ7961x battery monitors

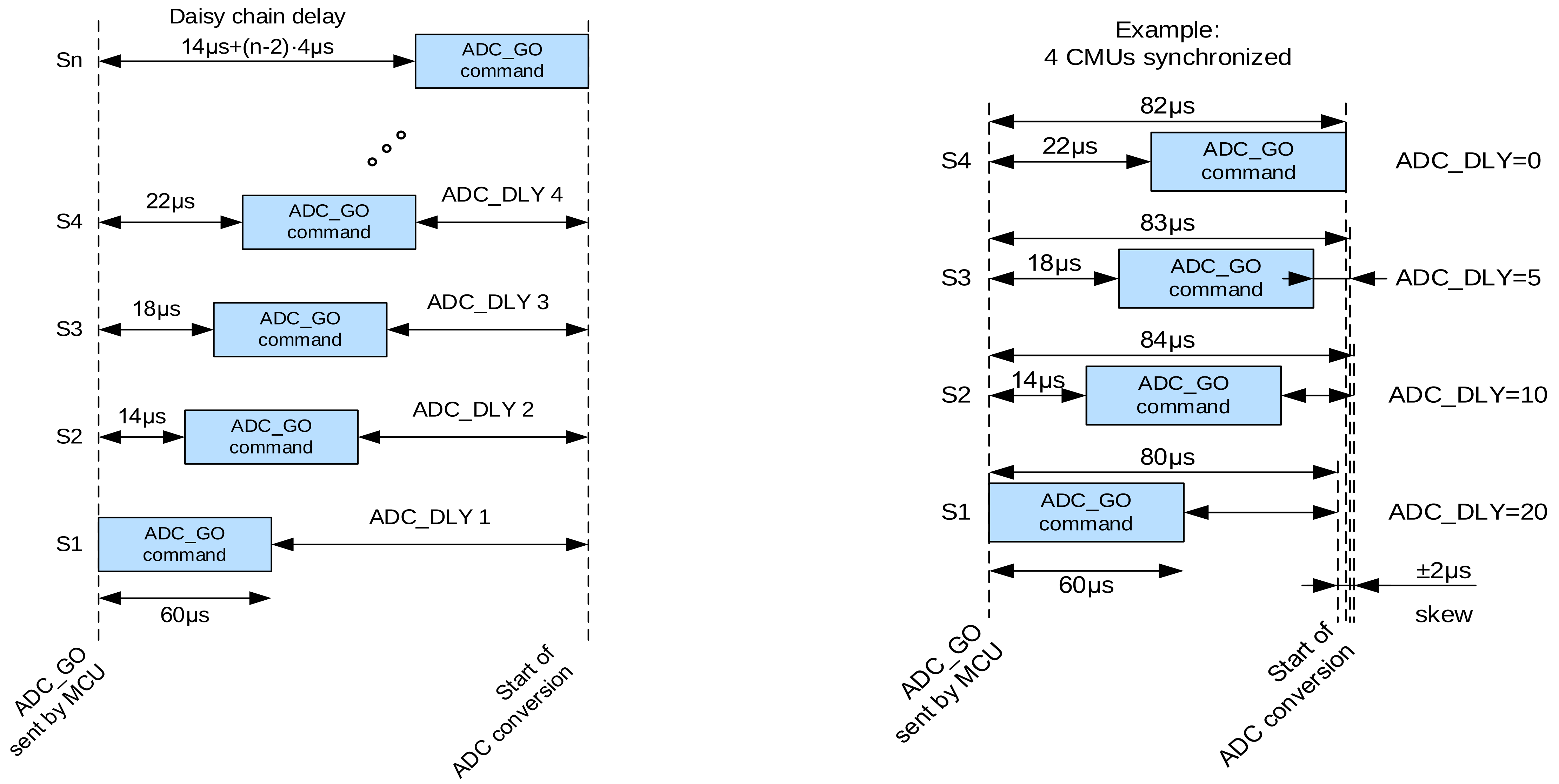
VI synchronization in wired BMSs

- Wired BMS → all monitors connect to the BMU through a wired communication interface.
- BQ796xx family considered here:
  - Daisy-chain communication.
- Two separate daisy chains → MCU is in charge of synchronizing cell and pack daisy chains.
- Example – 400-V BMS:
  - 96 cells (six BQ79616s): V_{CELL1} … V_{CELL96}.
  - Single-pack monitor (BQ79631): V_{PACK}, I_{PACK}.



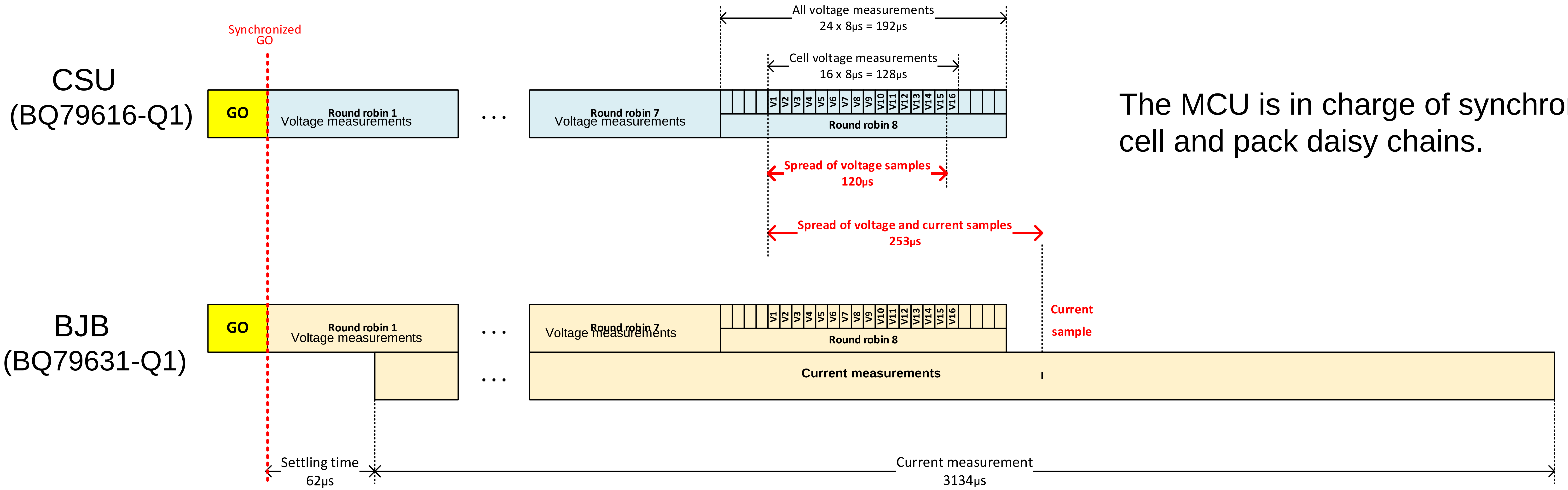
Cell voltage measurement (BQ7961x) timing

- Voltage synchronization within multiple cell monitors:
  - Using single conversion mode, all cell supervisor units (CSUs) can synchronously measure the cell voltages.
  - The BQ7961x supports delayed ADC sampling in order to compensate for the CSU-to-CSU propagation delay when transmitting the ADC_GO command down the daisy-chain interface.



Pack VI measurement (BQ79631) timing

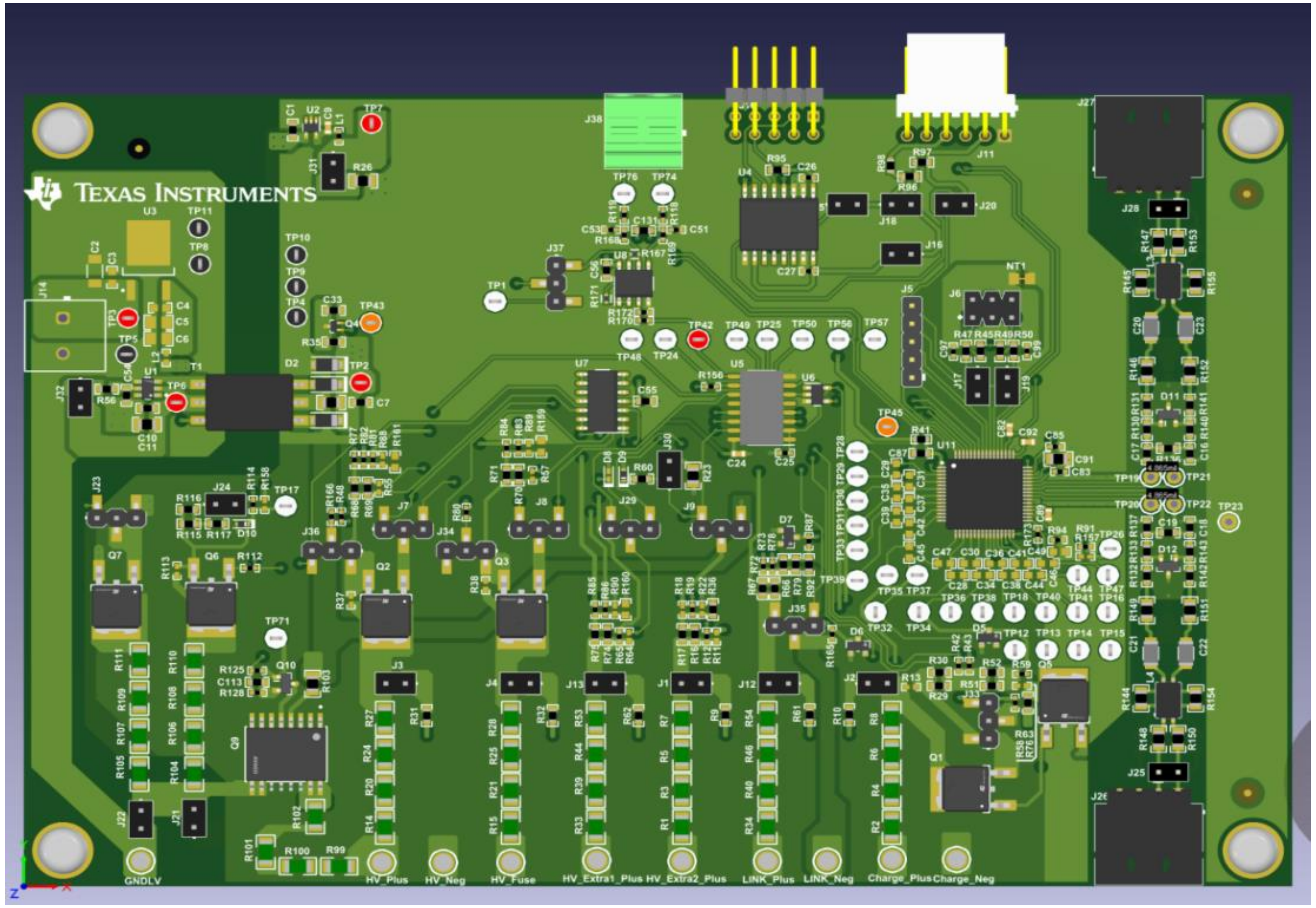
- With the appropriate settings (a 1-mS conversion in this case), for current measurement in the BQ79631, it is possible to synchronize current sampling to cell and pack voltage sampling **within approximately 250 µs**.
- Owing to the delay compensation, all cell and pack voltage measurements are synchronized **within approximately 120 µs**.



The MCU is in charge of synchronizing cell and pack daisy chains.

BQ79631 reference board and contact

- Available since 3Q 2020.
- Contact Sudhir Nagaraj (BMS-BGM).



Features

- Stackable BMS system with **voltage** and **current** sensing and **insulation resistance** monitoring.
- Daisy chain to interface with other sensors and cell monitors in the BQ796xx family.
- Ambient temperature range: –40°C to 85°C.

Target applications

- High-voltage battery-management control.
- Charge monitor for high-voltage battery packs.
- Current sensor for high-voltage battery packs.

Tools and resources

- Design file, board, user guide.
- Software configuration tool.
- Insulation resistance calculation tool.

Benefits

- Integrated ASIL D-based IC benefits.
- Lower bill-of-materials costs.
- Enables quick evaluation.
- Flexible printed circuit board provided with jumpers to play with different configurations.

Summary

- Conclusions on VIR measurements:
  - Voltage and current measurement accuracy improvements will result in optimal utilization of the battery.
  - Overcurrent detection and local autonomous triggering of the pyro-fuse enhance safety in vehicles.
  - Integrated insulation detection capability provides enhanced safety for operators and sensitive electronics in vehicles.
- Conclusions on VI synchronization:
  - Effective VI synchronization enables precise state-of-charge, state-of-health and electrical impedance spectroscopy calculations that will result in optimal utilization of the battery.