Automotive High-Voltage BMS Reference Design: 18S Wired or Wireless Cell Supervisor Unit

Description

This reference design implements a cell supervision unit for up to 18 cells. The unit can be daisy-chained to cover typical high-voltage battery ranges used in passenger cars, commercial vehicles, and two- and three-wheelers operating at voltages higher than 72V. The reference design features both wired and wireless interfacing options to enable side-by-side comparison of wired and wireless battery management system (BMS) performance.

Resources

TIDA-020076	Design Folder
BQ79718B-Q1, TPS3436-Q1, TPS715-Q1	Product Folder
TPD6E004, LM5168-Q1, CC2662R-Q1	Product Folder
TXU0204-Q1, ISO7741-Q1, ESD2CAN24-Q1	Product Folder

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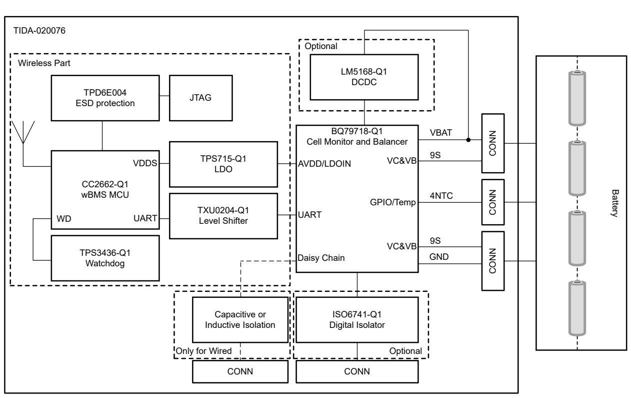
Features

- Cell Supervision Unit (CSU) for 6 to 18 cells, stackable for high-voltage BMS. Optional bus-bar support
- High-accuracy cell voltage measurement and integrated cell-balancing
- Wired: Isolated differential daisy chain with optional ring architecture, capacitive and inductive isolation
- Wireless: wireless state of charge (SoC), ISO26262 and IEC61508 certified on system-level Automotive Safety Integrity Level D (ASIL D) capability
- Various additional interfacing options for communication and environmental sensor integration: universal asynchronous receiver-transmitter (UART), serial peripheral interface (SPI), general purpose IO (GPIO), I2C
- Optional DCDC for increased system efficiency during key-off and active states

Applications

- HEV, EV battery-management system (BMS)
- Wired cell monitor unit
- Wireless cell monitor unit
- Wired high-voltage battery system
- Wireless high-voltage battery system



1 System Description

The reference design demonstrates both wired and wireless BMS for evaluation purposes. The design embeds two ways of powering the system: LDO and DCDC. For mass production, the design can be reduced to the desired interface and supply method.

1.1 Wired System Description

This Battery Management System (BMS) design provides an evaluation board for the BQ79718B-Q1 family of devices. The board supports large format lithium-ion battery pack applications and delivers monitoring, protection, balancing, and communications functions.

Each reference design manages up to 18 cells (100Vmax) for Li-ion battery applications. Up to 35 reference design modules stack together for packs up to 560 series cells.

Each system delivers fast cell balancing, diagnostics, and module-to-controller communication. The design also includes independent protection circuitry.

Each design features precision measurement and synchronous communication that enables a main controller to perform State of Charge (SOC) and State of Health (SOH) estimation. Highly accurate cell voltages and fast sampling time for the entire battery pack enable more efficient operation of battery modules and more accurate SOC and SOH calculations. Communication with stacked reference design devices occurs through an isolated daisy-chain differential bus.

Control a single reference design or multiple stacked reference design devices using a PC-hosted GUI. Communication between the PC and the base device occurs through a USB2ANY UART interface. For a stack of reference design devices, communication between all other devices in the stack occurs through the isolated, daisy-chain differential communication bus. The PC GUI enables configuration of the reference design to monitor cells and other analog data channels, control balancing, and monitor fault details.

Table 1-1. Key System Specifications

ITEM	DESCRIPTION	TYP	UNIT
VBATP_Max	Maximum operating voltage	100	V
VBATP_Min	Minimum operating voltage	9	V
V_{VC_RANGE}	$VC_n – VC_{n – 1}$, where n = 1 to 18	1 to 5	V
V_{CB_RANGE}	$CB_n – CB_{n – 1}$, where n = 1 to 18	1 to 5	V
T_A	Operation temperature	–40°C to 125°C	°C

1.2 Wireless System Description

This design integrates the BQ79718B-Q1, a precise 18-cell automotive-grade battery monitor, with the CC2662-Q1 wireless BMS MCU.

This combination of TI ICs enables engineers to create a network of devices that transmit battery monitoring data through the 2.4GHz Wireless Battery Monitoring System (WBMS) communications protocol. Exploring the functionality of this design shows how to streamline operations and significantly reduce the need for extensive wiring harnesses in Electric Vehicles (EVs).

A WBMS represents technology that enables monitoring and control of multiple batteries in a distributed system without the need for physical wires or cables. The system achieves this through wireless communication protocols, such as radio frequency (RF), Bluetooth®, or cellular connectivity.

The benefits of a WBMS include:

- Reduced cabling complexity and weight
- Increased flexibility and scalability for system upgrades or modifications
- Lower maintenance costs through reduced manual intervention and automated system control

1.3 Power Supply Options

For the wireless part, the CC2662-Q1 power supply uses an LDO that delivers a 3.3Voutput. The LDO input uses either LDOIN or AVDD, both supplied from BQ79718B-Q1.

For BQ79718B-Q1 power, both LDO and DCDC designs support different usage requirements. The LDO setup integrates within BQ79718B-Q1 and requires only a transistor. The LDO advantage includes lower cost through simple design and fewer components needed.

The DCDC offers higher efficiency and lower quiescent current. When customers require lower current consumption, the DCDC design works with LM5168-Q1. This component outputs power to LDOIN for BQ79718B-Q1.

Besides LDOIN, the device provides other voltage outputs for different modes as shown in Table 1-2.

Table 1-2. BQ79718B-Q1 Power In Different Mode

POWER NAME	ACTIVE	SLEEP	SHUTDOWN
LDOIN	6V	6V	6V
AVDD	5V	5V	5V(If EN)[1]
DVDD	1.5V	1.5V	0V
TSREF	4V(If EN)[1]	4V(Configurable)	0V
REF_CAP	4V	4V	4V(If AVDD EN)[1]

(1) Enabled (EN)

For more details as to the normal operating voltage for each of the voltage references, see the BQ79718B-Q1 data sheet.

2 System Overview

2.1 Block Diagram

Figure 2-1 shows the system level functional block diagram.

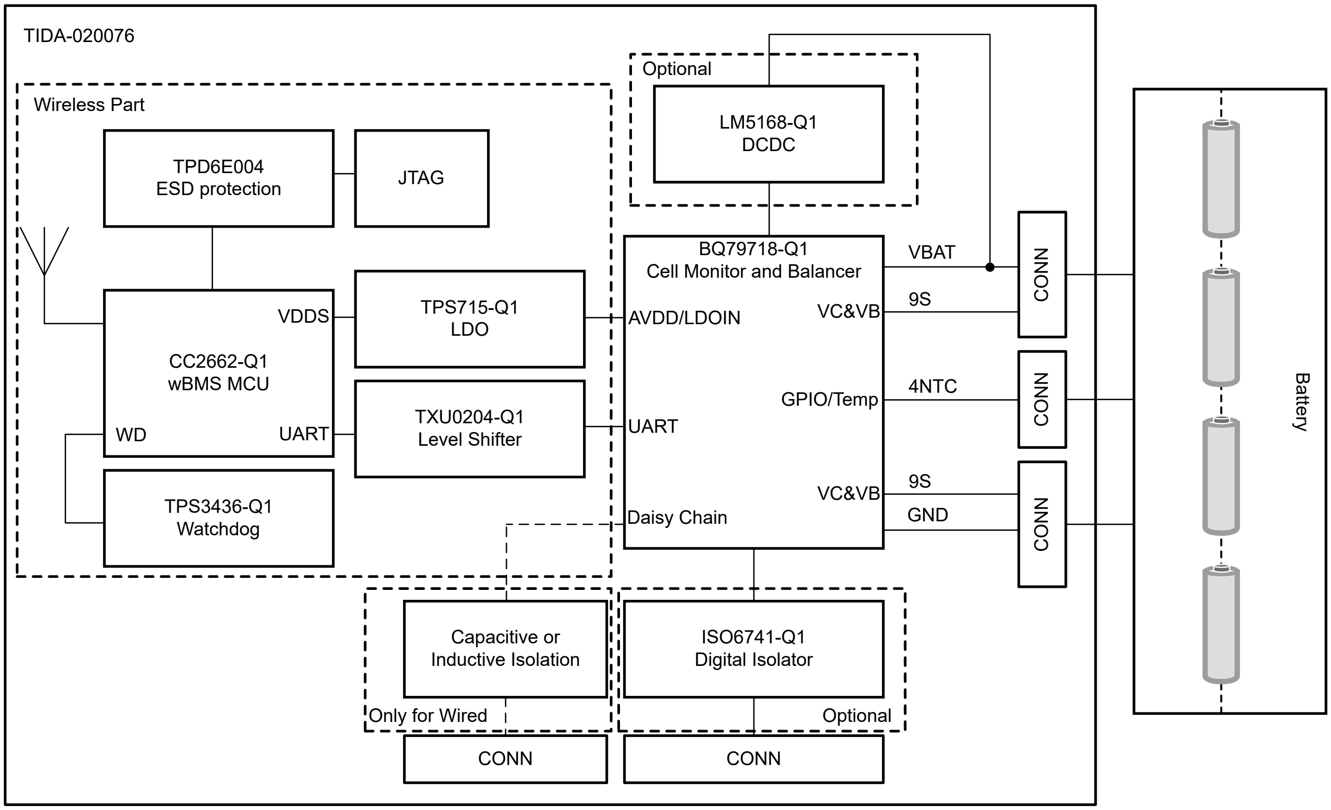


Figure 2-1. TIDA-020076 Functional Block Diagram

2.2 Design Considerations

This design features a close-to-mass-production automotive CSU while providing flexibility for evaluation of both TI wired and wireless interface designs. The design is part of a complete automotive BMS evaluation platform to equip interested customers with a fast way to evaluate and later industrialize.

2.3 Highlighted Products

2.3.1 BQ79718B-Q1

The BQ79718V-Q1 (wired and wireless operation) provides high-accuracy cell voltage measurements for up to 18S battery modules in high-voltage battery management systems in xEV and EV. The family of monitors offers different channel options in the same package type, providing pin to-pin compatibility and supporting high reuse of the established software and hardware across any platform. With the daisy chain isolated by transformer and capacitor, the device supports centralized and distributed architectures in xEV powertrain applications.

Key features of the BQ79718V-Q1 include:

- AECQ100 qualified with the following results:
  - Device temperature grade 1: –40°C to +125°C ambient operating temperature range
  - Device human body model (HBM) electrostatic discharge (ESD) classification level 2
  - Device CDM ESD classification level C1
- Functional safety-compliant:
  - Documentation to aid ISO 26262 system design
  - Systematic capability up to ASIL D
  - Hardware capability up to ASIL D

- Measure 9 to 18 batteries in series per device, stackable up to 64 devices
- Dedicated ADC with typical ±1mV accuracy
- Cell voltage and battery pack current measurement synchronized to 64µs
- Support limp-home mode with full redundancy
- Integrated post-ADC configurable digital low-pass filters
- Supports bus bar without affecting measurement accuracy
- 12 GPIOs for temperature sensor, analog, digital, I2C controller, and SPI controller
- Internal cell balancing:
  - Balancing at 300mA
  - User-controlled PWM adjustment cell balancing current
  - Built-in balancing thermal management with automatic pause and resume control
- Robust daisy chain communication and support ring architecture
- Hardware reset by host simulates POR-like event without battery removal
- Support transformer and capacitive isolation
- On-chip memory for one-time custom programming
- Low-power mode current < 6µA
- Compatible with BQ79600-Q1 with SPI and UART interface

2.3.2 TPS3436-Q1

The TPS3436-Q1 (wireless operation) features ultra-low power consumption (250nA typical) and offers a programmable window watchdog timer. The TPS3436-Q1 offers a high accuracy window watchdog timer with host of features for a wide variety of applications. The close window timer can be factory programmed and user programmed using an external capacitor. The open window to close window ratio can be changed on-the-fly using a combination of logic pins. The watchdog also offers advanced features such as enable-disable, start-up delay. The watchdog output (WDO) delay can be set by factory-programmed default delay settings and programmed by an external capacitor. The device also offers a latched output operation where the output remains latched until the watchdog fault clears. The TPS3436-Q1 provides a performance upgrade alternative to TPS3430-Q1 device family. The TPS3436-Q1 comes in a small 8-pin SOT-23 package.

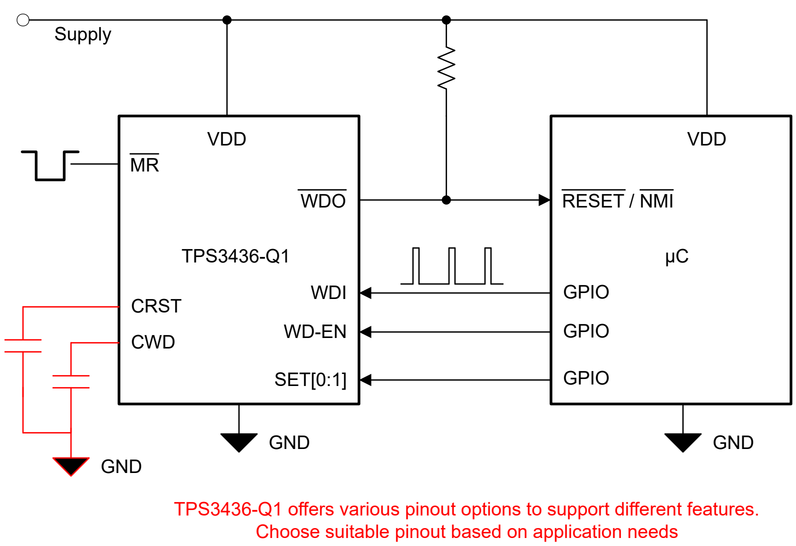


Figure 2-2. TPS3436-Q1 Block Diagram

Key features of the TPS3436-Q1 include:

- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: –40°C to 125°C ambient operating temperature range
- Factory programmed or user-programmable watchdog timeout:
  - ±10% accurate timer (maximum)
  - Factory-programmed close window: 1ms to 100s
- Factory programmed or user-programmable reset delay:
  - ±10% accurate timer (maximum)

- Factory programmed option: 2ms to 10s

- Input voltage range: V_{DD} = 1.04V to 6.0V
- Ultra low supply current: I_{DD} = 250nA (typical)
- Open-drain, push-pull; active-low outputs
- Various programmability options:
  - Watchdog enable-disable
  - Watchdog start-up delay: no delay to 10s
  - Open window to close window ratio option: 1 × to 511 ×
  - Latched output option
- MR functionality support

2.3.3 TPS715-Q1

The TPS715-Q1 (wireless operation) low-dropout (LDO) linear voltage regulator features low quiescent current and offers wide input voltage range and low-power operation in miniaturized packaging. The TPS715-Q1 supports battery-powered applications and serves as a power-management attachment to low-power microcontrollers. The TPS715-Q1 comes in both fixed and adjustable versions. For more flexibility and higher output voltages, the adjustable version uses feedback resistors to set the output voltage from 1.2V to 15V. The TPS715-Q1 LDO supports low dropout of typically 415mV at 50mA of load current. The low quiescent current (3.2µA typically) remains stable over the entire range of output load current (0mA to 50mA). The TPS715-Q1 also features internal soft-start to lower the inrush current. The built-in overcurrent limit helps protect the regulator during load short and fault conditions. The TPS715-Q1 comes in a 2.00mm × 1.25mm, 5-pin SC-70 (DCK) package for fixed and adjustable outputs.

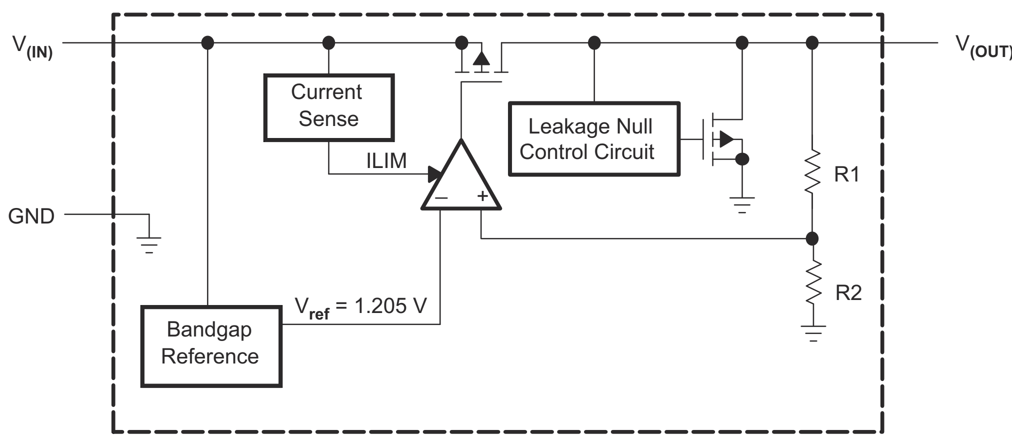


Figure 2-3. TPS715-Q1 Block Diagram

Key features of the TPS715-Q1 include:

- AEC-Q100 qualified for automotive applications:
  - Temperature grade 1: –40°C to +125°C, T_A
  - Device HBM ESD classification level H2
  - Device CDM ESD classification level C4B for legacy chip and C5 for new chip
- Input voltage range: 2.5V to 24V
- Available output voltage options:
  - Fixed: 1.8V to 5V
  - Adjustable: 1.2V to 15V
- Output current: Up to 50mA
- Very low IQ: 3.2µA at 50mA load current
- Stable with output capacitor ≥ 0.47µF
- Overcurrent protection
- Package: 5-pin SC70 (DCK)

2.3.4 TPD6E004

The TPD6E004 (wireless operation) device features low-capacitance, ±15kV ESD protection diode array designed to protect sensitive electronics attached to communication lines. Each channel consists of a pair of diodes that steers ESD current pulses to V_{CC} and GND. The TPD6E004 protects against ESD pulses up to ±15kV human-body model (HBM), ±8kV contact ESD, and ±12kV air-gap ESD as specified in IEC 61000-4-2. This device has typical 1.6pF capacitance per channel, making the device an appropriate choice for use in high-speed data I/O interfaces. The TPD6E004 device comes in the RSE package and operates from –40°C to +85°C. The TPD6E004 device features a six-channel ESD structure designed for USB, Ethernet, and FireWire applications.

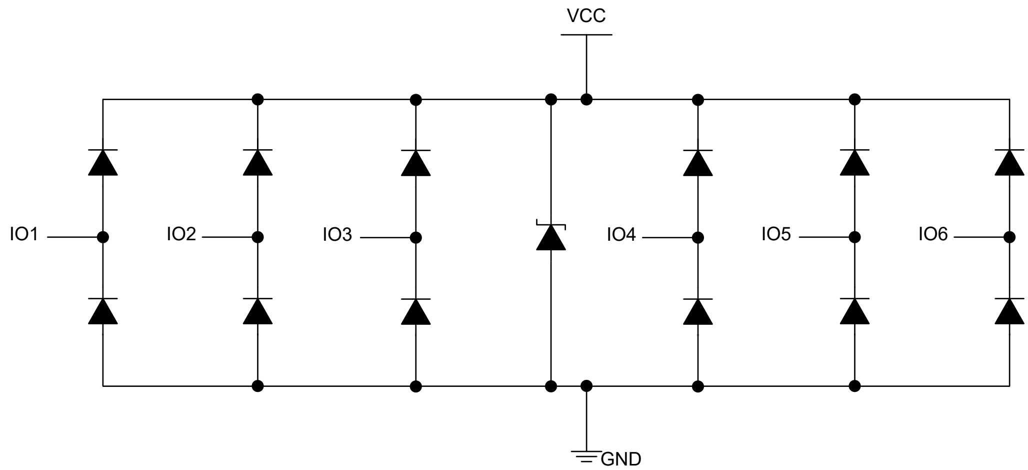


Figure 2-4. TPD6E004 Block Diagram

Key features of the TPD6E004 include:

- ESD protection exceeds JESD:
  - ±15kV human-body model (HBM)
  - ±8kV IEC 61000-4-2 contact discharge
  - ±12kV IEC 61000-4-2 air-gap discharge
- Low 1.6pF I/O capacitance
- 0.9V to 5.5V supply-voltage range
- Six-channel device
- Space-saving UQFN (RSE) package

2.3.5 CC2662R-Q1

The SimpleLink™ 2.4GHz CC2662R-Q1 (wireless operation) device features AEC-Q100 compliant wireless microcontroller (MCU) targeting wireless automotive applications. The device supports low-power wireless communication in applications such as battery management systems (BMS) and cable replacement. The highlighted features of this device include:

- Support for TI's SimpleLink wireless BMS (WBMS) protocol for robust, low latency and high throughput communication.
- Functional Safety Quality-Managed classification including TI quality-managed development process and forthcoming functional safety FIT rate calculation, FMEDA and functional safety documentation.
- AEC-Q100 qualified for Grade 2 temperature range (–40 °C to +105 °C) and is offered in a 7mm x 7mm VQFN package with wettable flanks.
- Low standby current of 0.94μA with full RAM retention.
- Excellent radio link budget of 97dBm.

The CC2662R-Q1 device is part of the SimpleLink™ MCU platform, which consists of Wi-Fi®, Bluetooth Low Energy, Thread, Zigbee®, Sub-1GHz MCUs, and host MCUs that all share a common, easy-to-use development environment and rich tool set.

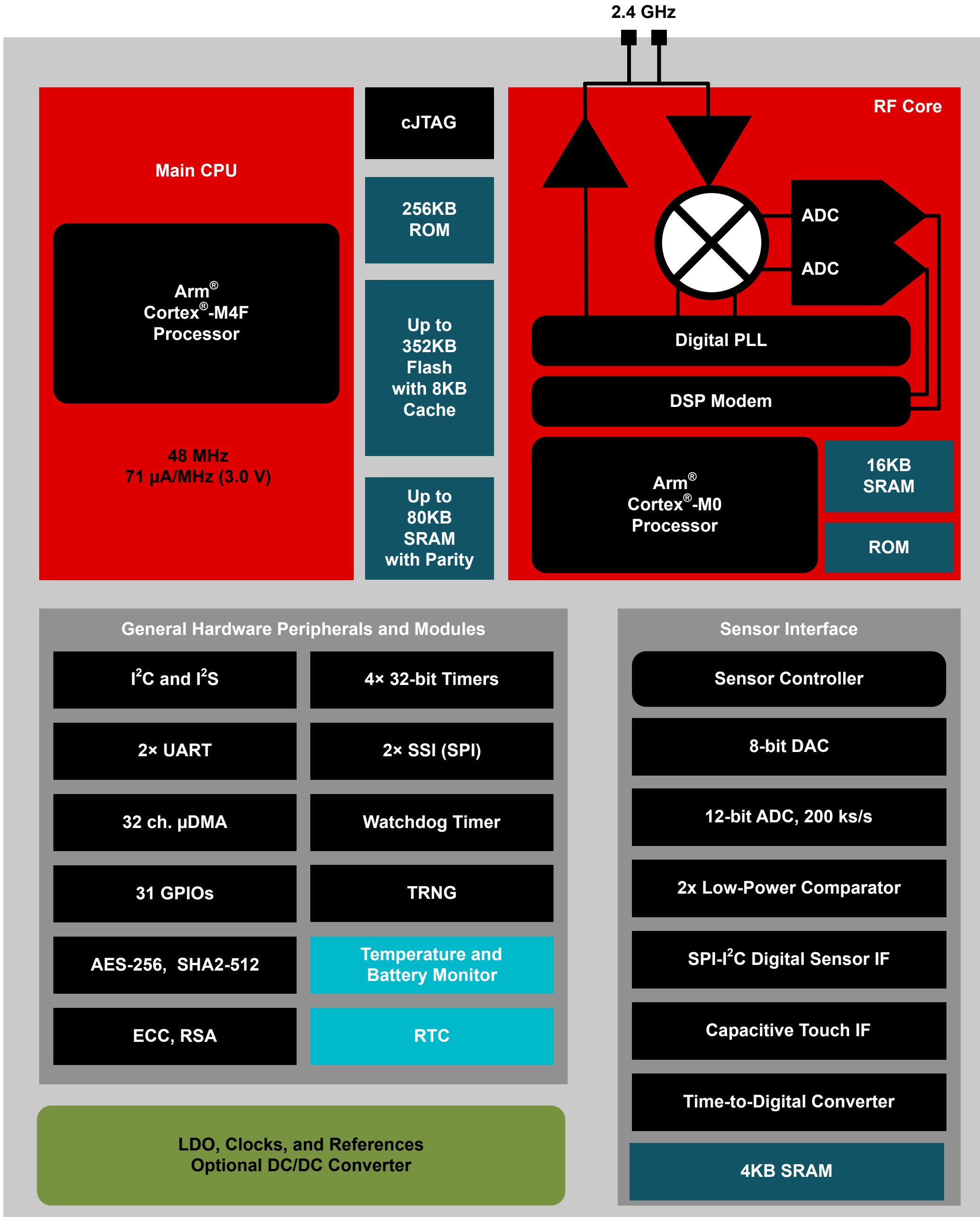


Figure 2-5. CC2662R-Q1 Block Diagram

Key features of the CC2662R-Q1 include:

Wireless microcontroller:

- Powerful 48MHz Arm® Cortex®-M4F processor
- EEMBC CoreMark score: 148
- 352KB flash program memory
- 256KB of ROM for protocols and library functions
- 8KB of cache SRAM
- 80KB of ultra-low leakage SRAM with parity for high-reliability operation
- Two-pin cJTAG and JTAG debugging
- Supports over-the-air upgrade (OTA)
- Programmable radio supporting SimpleLink™ WBMS

Ultra-low power sensor controller:

- Autonomous MCU with 4KB of SRAM
- Sample, store, and process sensor data
- Fast wake-up for low-power operation
- Software defined peripherals; capacitive touch, flow meter, LCD

2.3.6 TXU0204-Q1

TXU0204-Q1 (wireless operation) features a 4-bit, dual-supply non-inverting fixed direction voltage level translation device. Ax pins reference V_{CCA} logic level, OE pin can reference V_{CCA} and V_{CCB} logic levels, and Bx pins reference V_{CCB} logic levels. The A port accepts input voltages ranging from 1.1V to 5.5V, while the B port accepts input voltages from 1.1V to 5.5V. Fixed direction data transmission occurs from A to B and B to A when OE sets to high in reference to either supply. When OE is set to low, all output pins are in the high-impedance state.

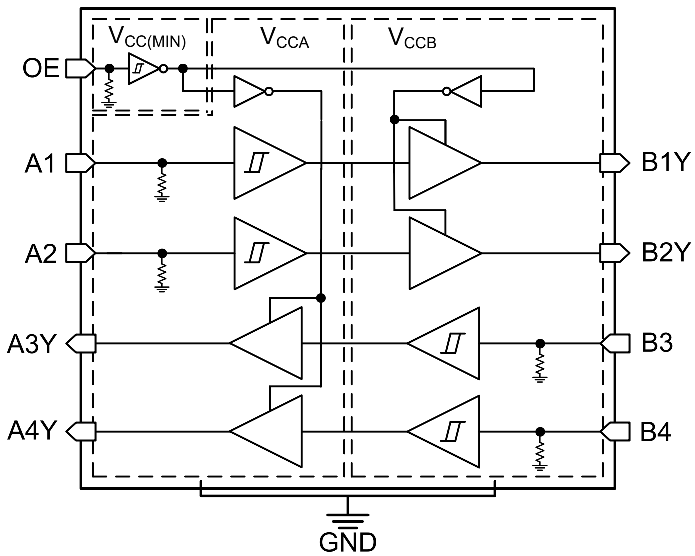


Figure 2-6. TXU0204-Q1 Block Diagram

Key features of the TXU0204-Q1 include:

- AEC-Q100 qualified for automotive applications
- Available in wettable flank QFN (WBQA) package
- Fully configurable dual-rail design allows each port to operate from 1.1V to 5.5V
- Up to 200Mbps support for 3.3V to 5.0V
- Schmitt-trigger inputs allows for slow and noisy inputs
- Inputs with integrated static pulldown resistors prevent channels from floating
- High drive strength (up to 12mA at 5V)
- Low power consumption:
  - 3μA maximum (25°C)
  - 6μA maximum (–40°C to 125°C)
- V_{CC} isolation and V_{CC} disconnect ($I_{off\text{-}float}$) feature:
  - If either V_{CC} input is < 100mV or disconnected, all outputs are disabled and become high-impedance
- I_{off} supports partial-power-down mode operation
- Control logic (OE) with $V_{CC(MIN)}$ circuitry allows for control from either A or B port
- Pinout compatible with TXB family level shifters
- Available in other variants that support common applications: TXU0104-Q1, TXU0304-Q1
- Operating temperature from –40°C to +125°C
- Latch-up performance exceeds 100mA per JESD 78, class II
- ESD protection exceeds JESD 22:
  - 2500V human-body model

– 1500V charged-device model

2.3.7 ISO7741-Q1

The ISO774x-Q1 (wired and wireless operation) automotive devices feature high-performance, quad-channel digital isolators with 5700V_{RMS} (DWW package), 5000V_{RMS} (DW package), and 3000V_{RMS} (DBQ package) isolation ratings per UL1577. This family of devices provides reinforced insulation ratings according to VDE, CSA, TUV and CQC.

The ISO774x-Q1 devices provide high electromagnetic immunity and low emissions at low power consumption, while isolating CMOS and LVCMOS digital I/Os. Each isolation channel features a logic input and output buffer separated by a double capacitive silicon dioxide (SiO2) insulation barrier. These devices include enable pins which can be used to put the respective outputs in high impedance for multi-controller driving applications and to reduce power consumption. The ISO7740-Q1 device features all four channels in the same direction, the ISO7741-Q1 device features three forward and one reverse-direction channels, and the ISO7742-Q1 device features two forward and two reverse-direction channels. If the input power and signal are lost, default output remains high for devices without suffix F and low for devices with suffix F.

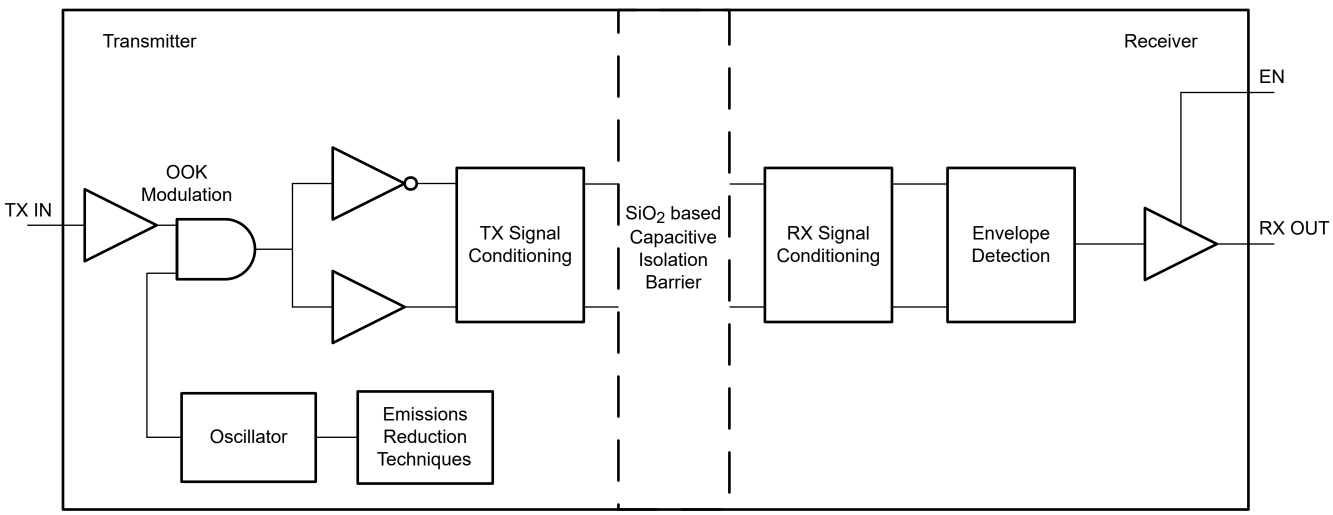


Figure 2-7. ISO7741-Q1 Block Diagram

Key features of the ISO7741-Q1 include:

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  – Device temperature grade 1: –40°C to 125°C ambient operating temperature
- Functional safety-capable:
  – Documentation available to aid functional safety system design: ISO7740-Q1, ISO7741-Q1, ISO7742-Q1
- 100Mbps data rate
- Robust isolation barrier:
  – > 30year projected lifetime at 1500V_{RMS} working voltage
  – Up to 5700V_{RMS} isolation rating
  – Up to 12.8kV surge capability
  – ±100kV/μs typical CMTI
- Wide supply range: 2.2V to 5.5V
- 2.25V to 5.5V level translation
- Default output high (ISO774x) and low (ISO774xF) options
- Low power consumption, typical 1.5mA per channel at 1Mbps
- Low propagation delay: 10.7ns typical (5V Supplies)
- Robust electromagnetic compatibility (EMC):
  – System-level ESD, EFT, and surge immunity
  – ±8kV IEC 61000-4-2 contact discharge protection across isolation barrier
  – Low emissions

- Extra-wide SOIC (DWW-16), wide-SOIC (DW-16) and QSOP (DBQ-16) package options
- Safety-related certifications:
  - DIN EN IEC 60747-17 (VDE 0884-17)
  - UL 1577 component recognition program
  - IEC 61010-1, IEC 62368-1, IEC 60601-1, and GB 4943.1 certifications

2.3.8 ESD2CAN24-Q1

The ESD2CANxx24-Q1 (wired operation) features a bidirectional ESD protection diode for Controller Area Network (CAN) interface protection. The ESD2CANxx24-Q1 dissipates contact ESD strikes beyond the maximum level specified in the ISO 10605 automotive standard (±30kV contact, ±30kV air gap). The low dynamic resistance and low clamping voltage enable system level protection against transient events. This protection provides essential capability as automotive systems require high levels of robustness and reliability for safety applications.

This device features low I/O capacitance per channel and a pinout designed to protect two automotive CAN bus lines (CANH and CANL) from damage caused by electrostatic discharge (ESD) and other transients. Additionally, the 3pF (typical) and less line capacitance of the ESD2CANxx24-Q1 supports CAN, CANFD, CAN SiC, and CAN-XL applications that can achieve data rates up to 10Mbps.

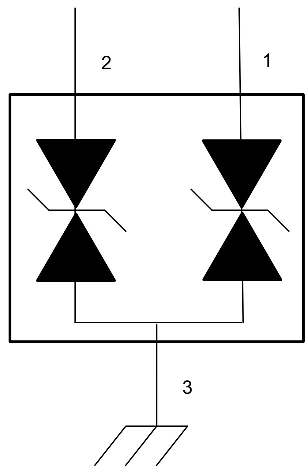


Figure 2-8. ESD2CAN24-Q1 Block Diagram

Key features of the ESD2CAN24-Q1 include:

- IEC 61000-4-2 level 4 ESD protection:
  - ±30kV, ±25kV or ±20kV contact discharge
  - ±30kV, ±25kV or ±20kV air-gap discharge
- ISO 10605 (330pF, 330Ω) ESD protection:
  - ±30kV, ±25kV or ±20kV contact discharge
  - ±30kV, ±25kV or ±20kV air-gap discharge
- Tested in compliance to IEC 61000-4-5
- 24V working voltage
- Bidirectional ESD protection
- 2-channel device provides complete ESD protection with single component
- Low clamping voltage protects downstream components
- AEC-Q101 qualified
- I/O capacitance = 3pF, 2.5pF, or 1.7pF (typical)
- SOT-23 (DBZ) small, standard, common footprint
- SOT-323, SC-70 (DCK) very small, standard, space saving, common footprint
- Leaded packages used for automatic optical inspection (AOI)

2.3.9 LM5168-Q1

The LM5169-Q1 and LM5168-Q1 (wired and wireless operation) synchronous buck converters regulate over a wide input voltage range, minimizing the need for external surge suppression components. A minimum controllable on time of 50ns facilitates large step-down conversion ratios, enabling direct step-down from a 48V nominal input to low-voltage rails for reduced system complexity and design cost. The LM516x-Q1 operates during input voltage dips as low as 6V, at nearly 100% duty cycle, if needed, making the LM516x-Q1 an appropriate choice for wide input supply range industrial and high cell count battery pack applications.

With integrated high-side and low-side power MOSFETs, the LM5169-Q1 delivers up to 0.65A of output current and the LM5168-Q1 delivers up to 0.3A of output current. A constant on-time (COT) control architecture provides nearly constant switching frequency with effective load and line transient response. The LM516x-Q1 comes in forced pulse width modulation (FPWM) and auto mode versions. FPWM mode provides forced CCM operation across the entire load range supporting isolated fly-buck converter applications. Auto mode enables ultra-low I_Q and diode emulation mode operation for high light-load efficiency.

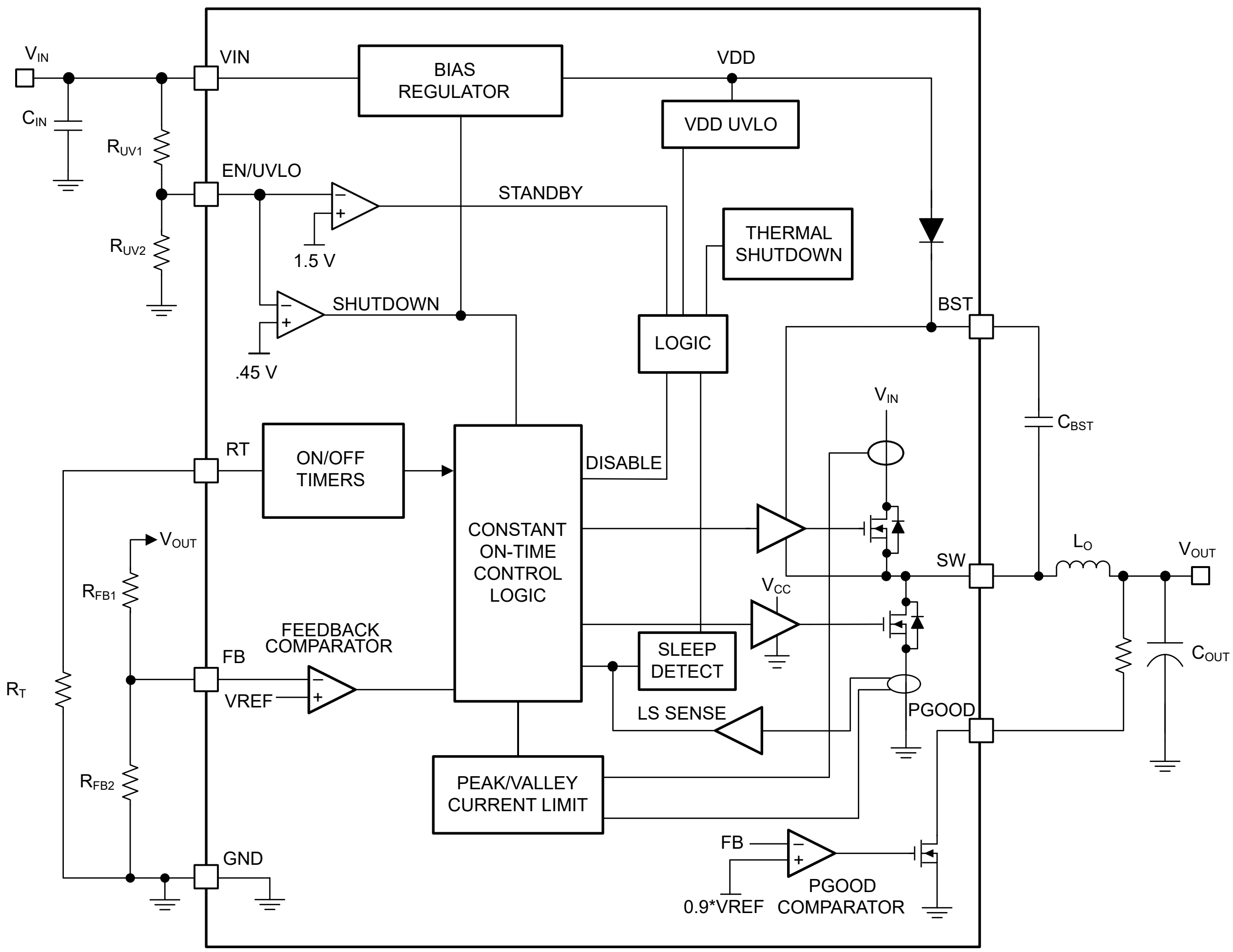


Figure 2-9. LM5168-Q1 Block Diagram

Key features of the LM5168-Q1 include:

- AEC-Q100-qualified for automotive applications:
  - Device temperature grade 1: –40°C to +125°C, ambient temperature range
- Designed for reliability in rugged applications:
  - Wide input voltage range of 6V to 120V
  - Junction temperature range: –40°C to +150°C
  - Fixed 3ms internal soft-start timer
  - Peak and valley current-limit protection
  - Input UVLO and thermal shutdown protection
- Designed for scalable automotive HEV and EV power supplies:
  - Low minimum on and off times of 50ns
  - Adjustable switching frequency up to 1MHz
  - Diode emulation for high light-load efficiency
  - Auto mode with low-quiescent current (< 10µA)
  - FPWM for fly-buck converter capability
  - 3µA shutdown quiescent current
  - Pin-to-pin compatible with LM5164-Q1, LM5163-Q1, LM5017, LM5013-Q1, and LM34927
- Integration reduces design size and cost:
  - COT mode control architecture
  - Integrated 1.9Ω NFET buck switch
  - Integrated 0.71Ω NFET synchronous rectifier
  - 1.2V internal voltage reference
  - No loop compensation components
  - Internal V_{CC} bias regulator and boot diode
  - Open-drain power-good indicator
  - SOIC PowerPAD™ integrated circuit package

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

The reference design is categorized into five sections to explain the design in terms of the application:

- DCDC power
- Cell monitor, NTC, and digital isolator
- Connectors
- Daisy chain
- Wireless

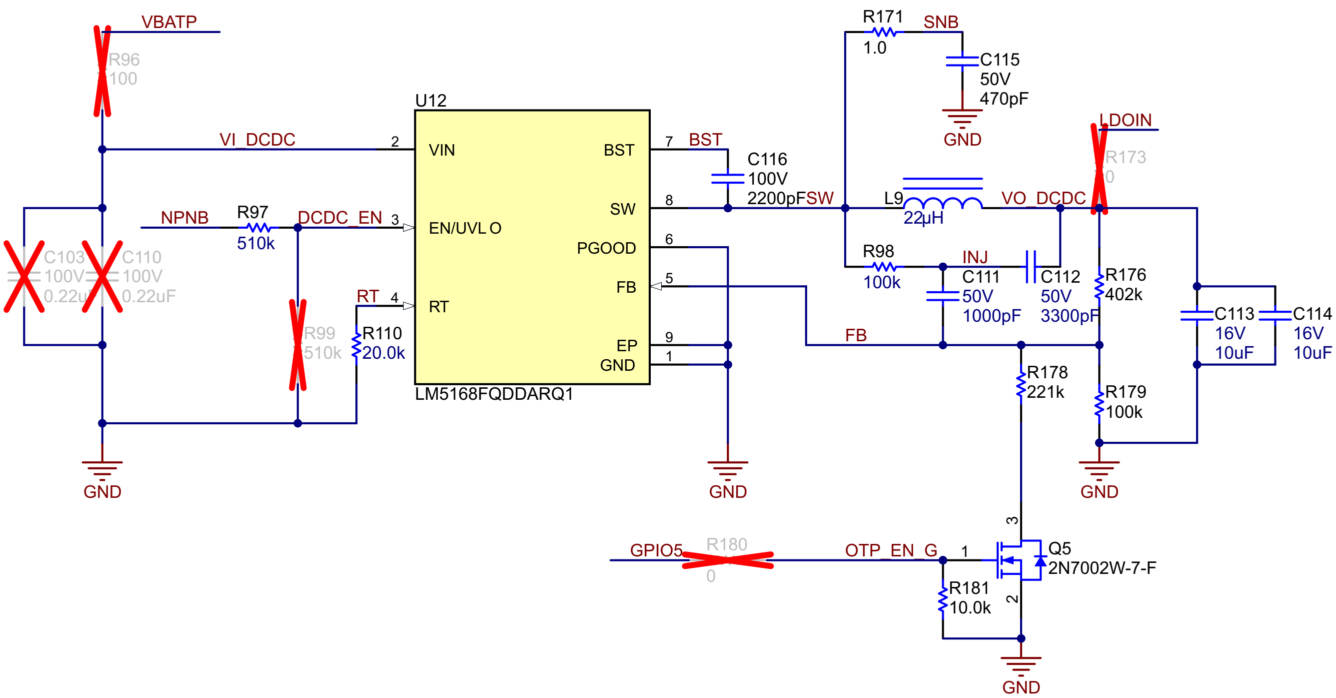


Figure 3-1. TIDA-020076 Schematic: DCDC Power

Two methods can power the BQ79718B-Q1: DCDC power and LDO power. This reference design includes both methods, but only one method can be selected. DCDC power provides more efficiency and LDO power has lower cost.

DCDC power is needed when the customer requires lower current consumption.

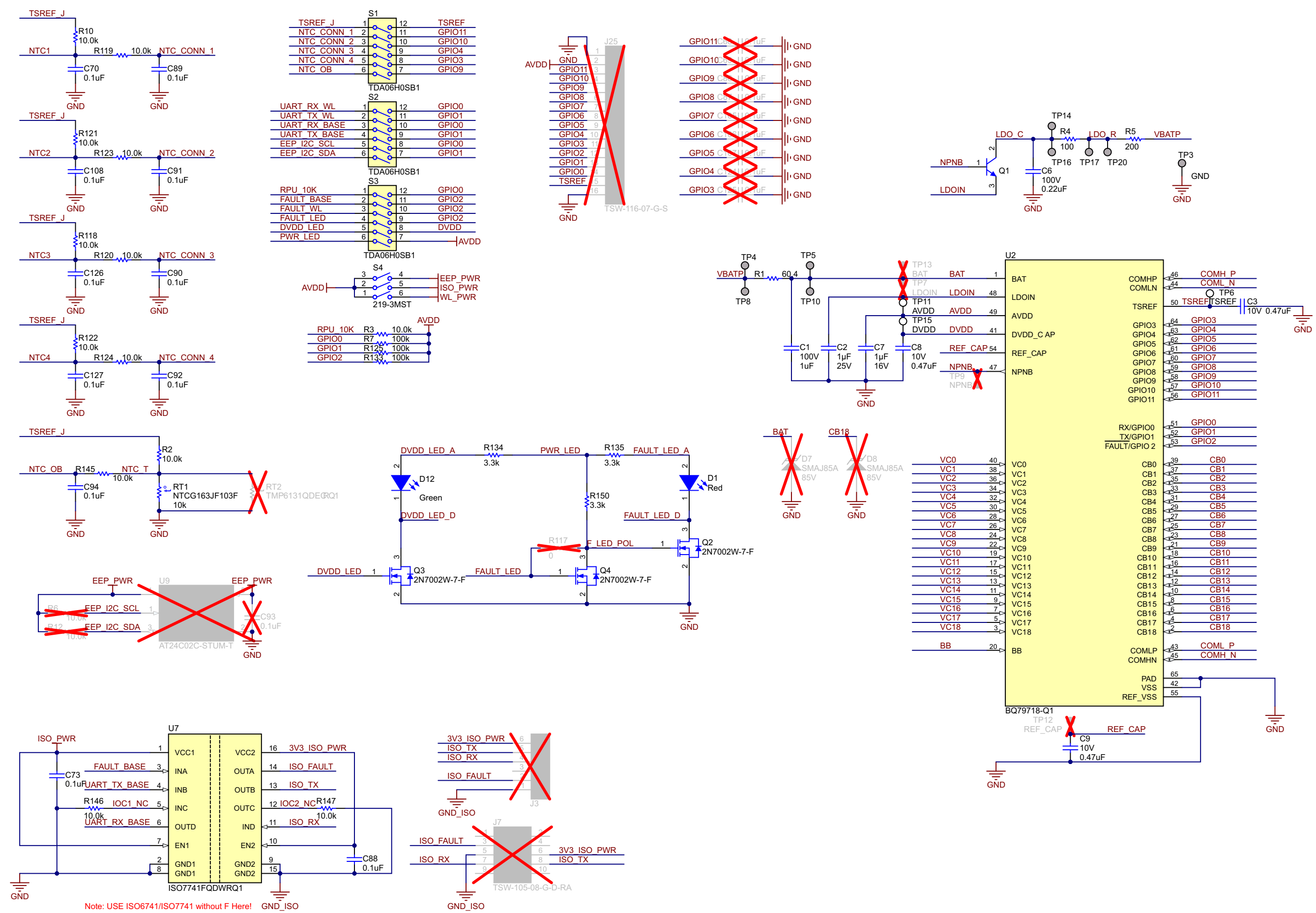


Figure 3-2. TIDA-020076 Schematic: Cell Monitor

For the main cell monitor design, an LDO power on the top right corner is needed when the DCDC power is not populated.

On the top left corner, these components provide the design for sensing the NTC outside and on the board. RT1 is the NTC on the board and RT2 is PTC on the board. Select one of these components.

S1, S2, S3, and S4 are the switches to select the function needed. To test NTC outside, put S1 PIN1, PIN2, PIN3, PIN4, and PIN5 on. Put S1 PIN6 on to test the NTC value on the board.

GPIO0 and RX default to UART RX at reset until I2C is enabled. When unused (for example, for stack devices), short RX to AVDD or use with pullup resistor less than 20kΩ (turn S3 PIN 1 on). When used as UART RX, pull up to AVDD with larger than 70kΩ (turn off S1 PIN1).

AVDD remains on during SHUTDOWN mode when a large resistor (greater than 70kΩ) is connected between GPIO0 and RX and AVDD. AVDD allows an external device such as wireless RX and TX to be powered in SHUTDOWN.

AVDD turns off when the device is in SHUTDOWN mode when GPIO0 pullup resistor is less than 20kΩ.

To test wireless, the power supply for WBMS LDO is LDOIN or WL_PWR. Turn S4 PIN1 or keep R8 populated.

J25 is not needed to perform any test or measurement outside. The caps from GPIO to GND are needed for ESD protection.

In the middle of this page, D1 and D12 are the LEDs for FAULT and DVDD. D7 and D8 are needed when the customer requires more strict EMC test conditions.

On the bottom left, U7 is the digital isolator when there is a need for isolated UART communication requirement. J3 and J7 are the output connectors for these isolated signals.

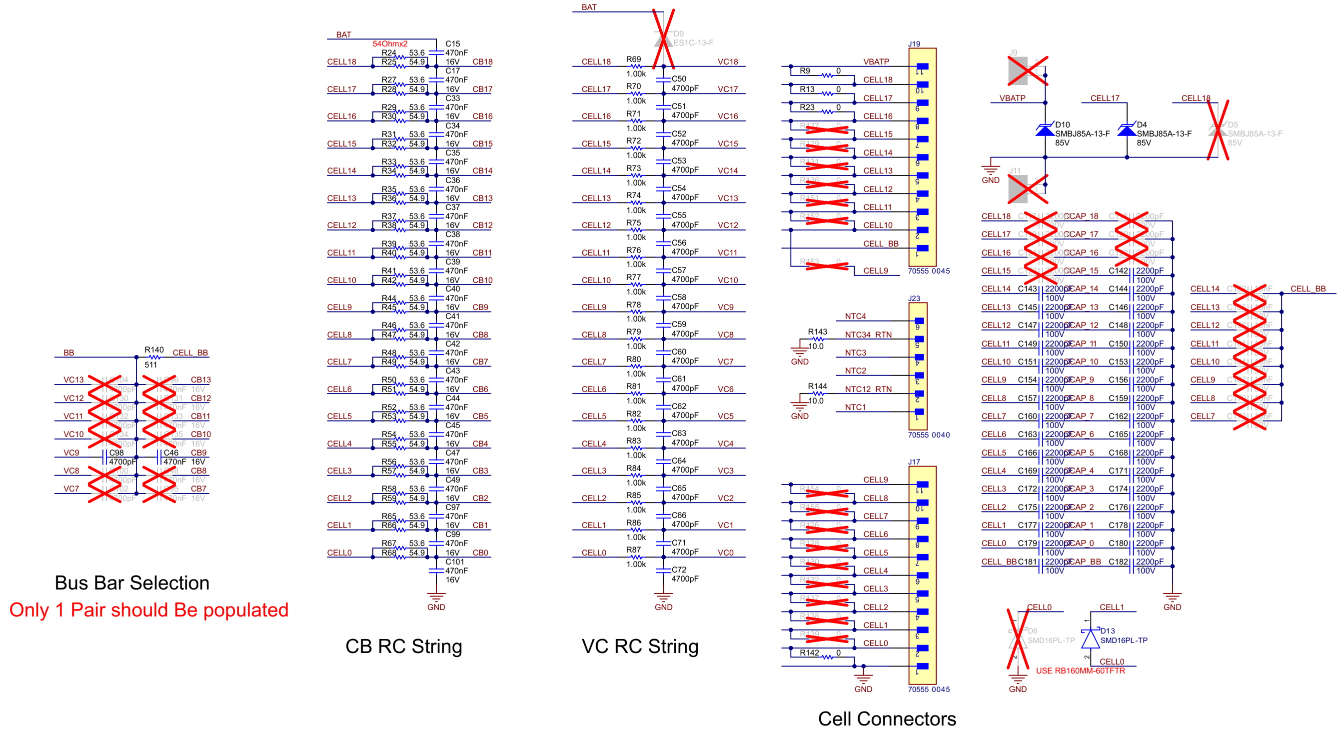


Figure 3-3. TIDA-020076 Schematic: Connectors

On the left of the connector page, this section shows the design of the BB pin. The BB pin is used to bypass or to sense the voltage of the bus bar. When the BB pin is used, populate only 1 pair of capacitors; otherwise, keep all the capacitors and resistances unpopulated.

The balance resistance value in CB RC string is decided by the balance current requirement and the VC RC string can be adjusted based on the EMC test result. D9, D10, D4, D5, D6, and D13 need to be populated when the EMC test cannot pass.

The 0Ω resistances between each channel, VBATP and GND are only populated when the channels are not used. Change the 0Ω resistances to 10kΩ, then 0Ω can be used as the resistor ladder to divide the input voltage to each channel.

J9 and J11 are used as the input voltage connector when the 0Ω resistances are changed to 10kΩ resistor ladder.

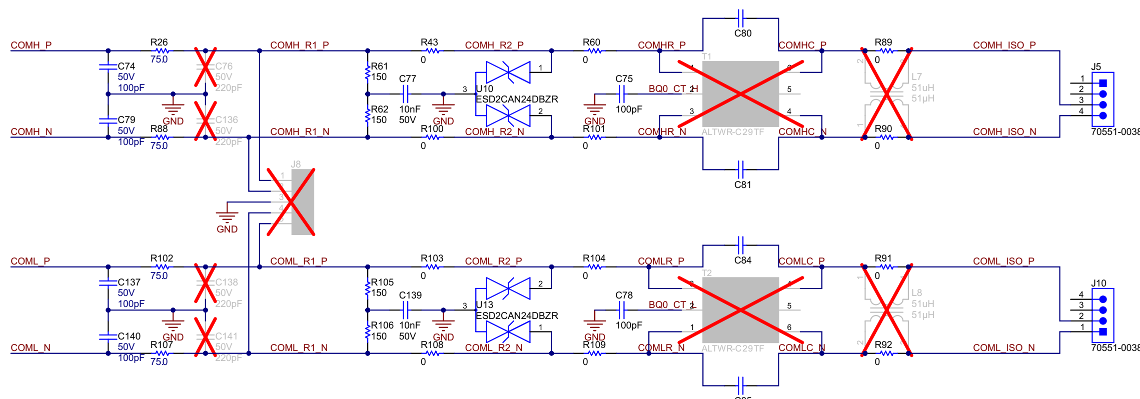


Figure 3-4. TIDA-020076 Schematic: Daisy Chain

Two different daisy chain setups exist: transformer isolation and capacitor isolation. Select different populated devices to select different isolation types.

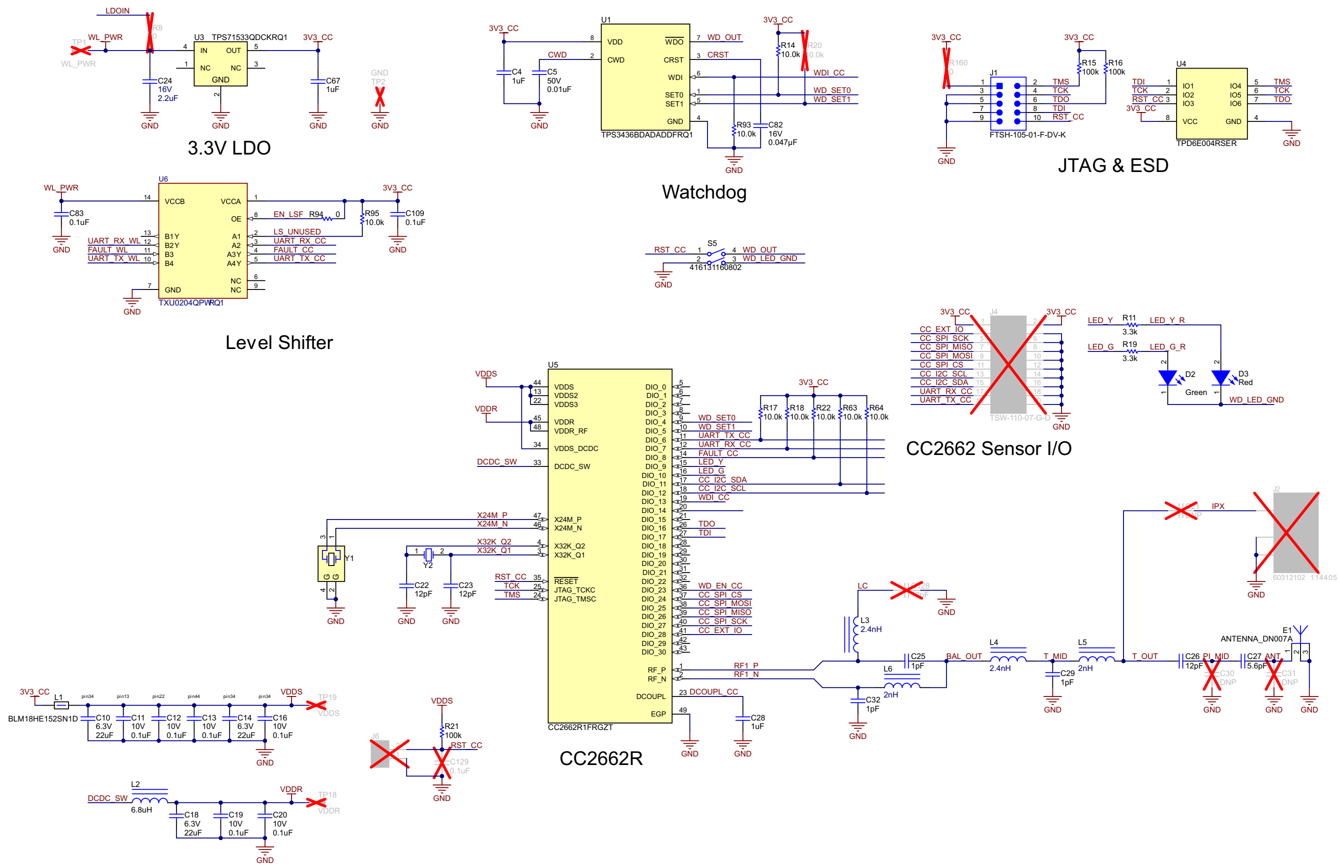


Figure 3-5. TIDA-020076 Schematic: Wireless

The core device of the wireless part is CC2662. The power supply of this device is 3.3V, so a 3.3V LDO is needed. Also, a 5V to 3.3V level shifter is needed for the UART communication. The watchdog is used for functional safety requirements. JTAG connector J1 is used to download the software to CC2662.

J4 and J6 are used only when performing the measurement. J2 is used to measure the wireless signal.

3.2 Test Setup

3.2.1 Hardware Setup

Use the following steps and reference Figure 3-6 to set up the hardware:

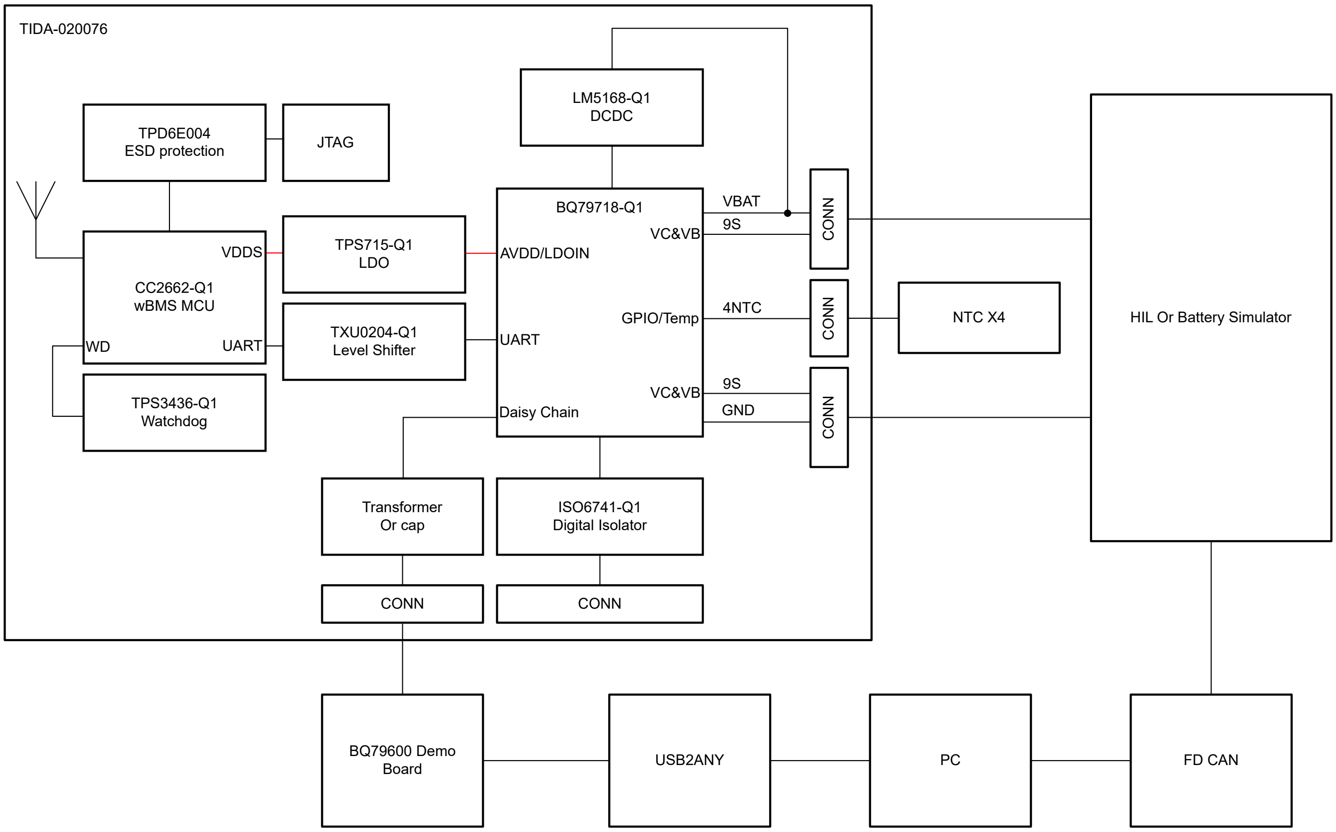


Figure 3-6. TIDA-020076 Hardware Test Setup

1. J17 and J19 are the VB and CB connectors. J23 is the NTC connector. First, the reference design needs a power input. Connect J17 and J19 to the Hardware-in-the-Loop (HIL) or battery simulator or change the 0Ω resistances (R13, R23, R127...R129) to 10kΩ resistor ladder and connect the power between J9 and J11. Balance is not functional when the resistor ladder is chosen as the power and cell input.
2. Connect 4 real NTC or resistance to J23 as the NTC input
3. J5 and J10 are the daisy chain output of the reference design. J5 is COMH and J10 is COML. Also, there are two connectors on the BQ79600 demonstration board. Connect COMH (COML) on this reference design to the COML (COMH) on the BQ79600 demonstration board.
4. A USB2ANY interface adapter is needed to connect between the BQ79600 demonstration board and the PC, so that the GUI on the PC can work. To test wireless part function, replace the BQ79600 demonstration board and USB2ANY adapter with the main CC2662 wireless demonstration board.
5. FD CAN is used to set up the HIL. FA CAN is not needed when using battery simulator or resistor ladder as the power and cell input.

3.2.2 Software Setup

Three software programs are needed here for the reference design:

- BQ797XX device GUI
- PCAN View
- WBMS GUI

For the BQ797XX device GUI:

1. Make sure the USB2ANY and BQ79600 demonstration board are connect in the right way, and the BQ79600 demonstration board is powered with 5V input from UAB2ANY(or a power supply)
2. Connect to a PC and open the BQ797XX device GUI, select bridge device, default is UART mode:

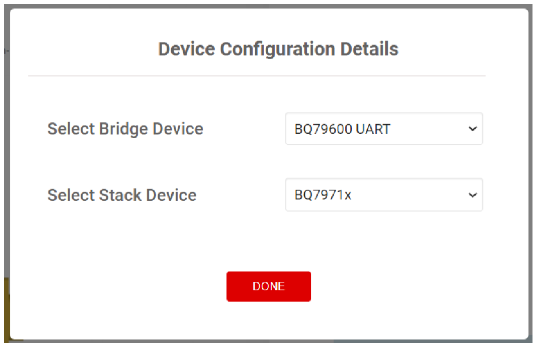


Figure 3-7. TIDA-020076 Software Test Setup: BQ797XX Device GUI Connect

3. The bottom left corner displays *USB2ANY/OneDemo device Hardware Connected*.
4. Click the battery pattern button on the left and then click the button on the top one by one: *POWER DOWN*, *WAKE UP DEVICE*, and *AUTO ADDRESS*:

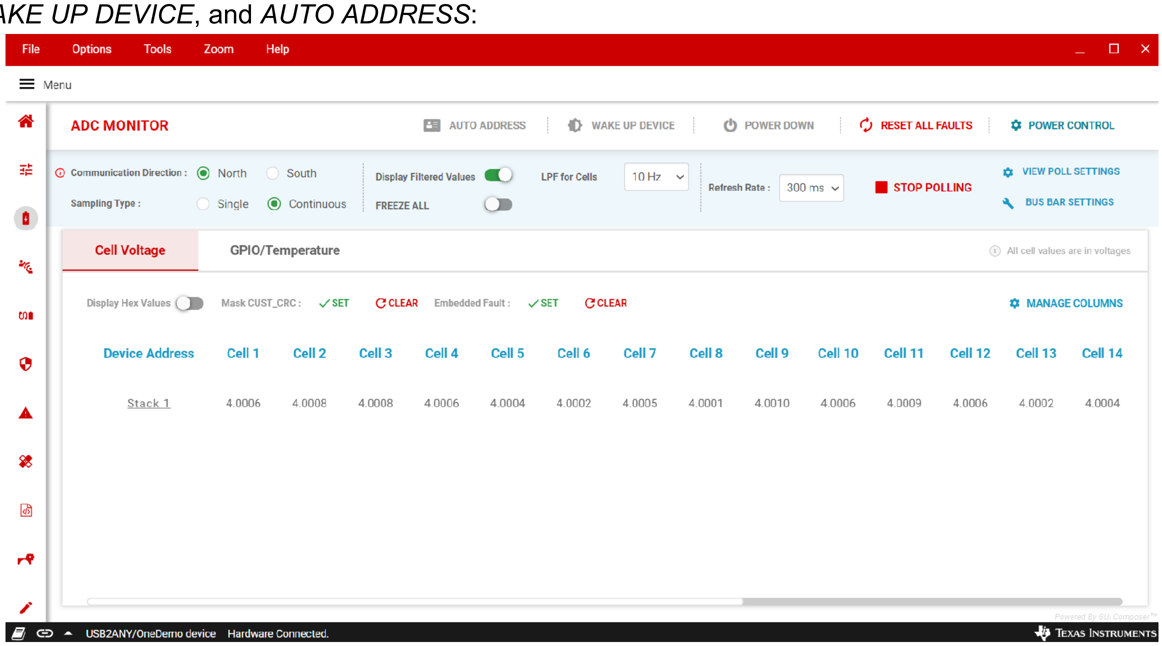


Figure 3-8. TIDA-020076 Software Test Setup: BQ797XX Device GUI Auto Address

5. For the balancing setup, click the cell balancing pattern button on the left, select *Auto* mode, and set the balancing time on the top, click *RUN* on the top left corner to start the balancing, click *PAUSE BALANCING* to pause and set the balancing time to 0s to stop.

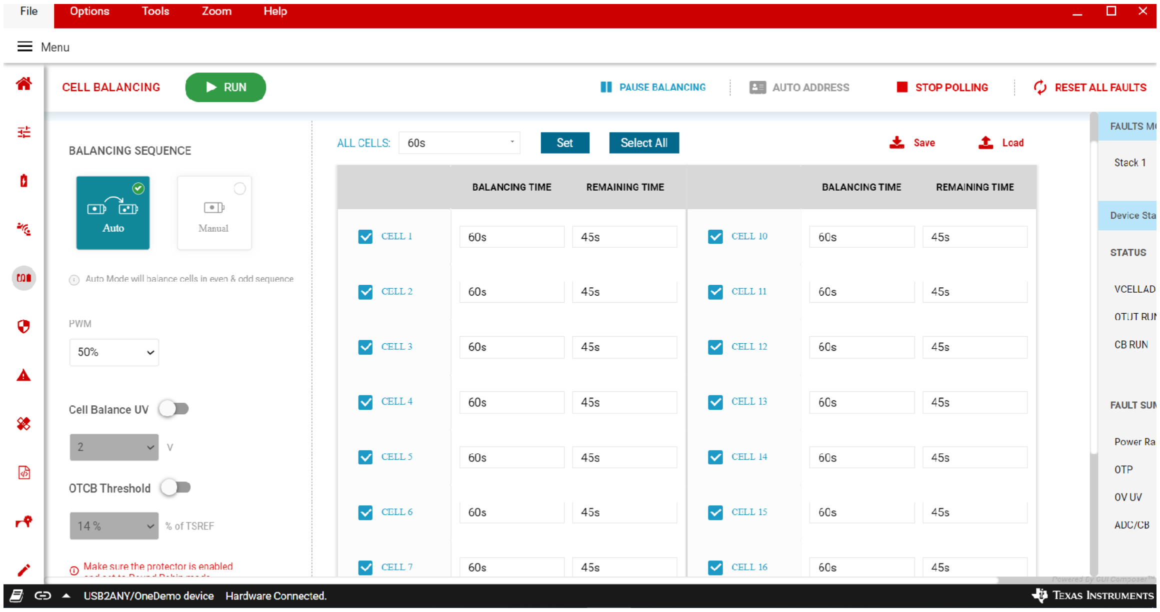


Figure 3-9. TIDA-020076 Software Test Setup: BQ797XX Device GUI Cell Balancing

For the PCAN View, see Figure 3-10 and the following list:

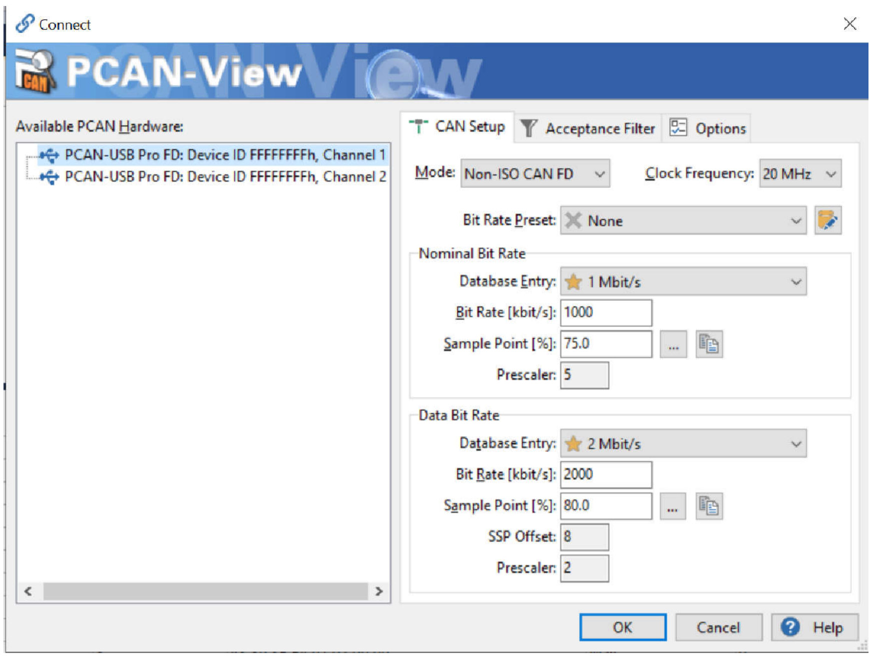


Figure 3-10. TIDA-020076 Software Test Setup: PCAN View

1. Connect the PCAN between HIL and the PC
2. Select Channel 1, keep the default setup as Figure 3-10 shows
3. Set the channel voltage to 4V as shown in the following:

```
501h 0 8 D 13h 80h 3Eh F4h 01h 01h 00h 00h
501h 0 8 D 23h 80h 3Eh F4h 01h 01h 00h 00h
501h 0 8 D 83h 80h 3Eh F4h 01h 01h 00h 00h
501h 0 8 D 43h 80h 3Eh F4h 01h 01h 00h 00h
502h 0 8 D 13h 80h 3Eh F4h 01h 01h 00h 00h
502h 0 8 D 23h 80h 3Eh F4h 01h 01h 00h 00h
502h 0 8 D 83h 80h 3Eh F4h 01h 01h 00h 00h
502h 0 8 D 43h 80h 3Eh F4h 01h 01h 00h 00h
```

```
503h 0 8 D 13h 80h 3Eh F4h 01h 01h 00h 00h
503h 0 8 D 23h 80h 3Eh F4h 01h 01h 00h 00h
503h 0 8 D 83h 80h 3Eh F4h 01h 01h 00h 00h
503h 0 8 D 43h 80h 3Eh F4h 01h 01h 00h 00h
504h 0 8 D 13h 80h 3Eh F4h 01h 01h 00h 00h
504h 0 8 D 23h 80h 3Eh F4h 01h 01h 00h 00h
504h 0 8 D 83h 80h 3Eh F4h 01h 01h 00h 00h
504h 0 8 D 43h 80h 3Eh F4h 01h 01h 00h 00h
505h 0 8 D 13h 80h 3Eh F4h 01h 01h 00h 00h
505h 0 8 D 23h 80h 3Eh F4h 01h 01h 00h 00h
```

4. Close the cell voltage input:

```
501h 0 8 D 13h 80h 3Eh F4h 01h 02h 00h 00h
501h 0 8 D 23h 80h 3Eh F4h 01h 02h 00h 00h
501h 0 8 D 83h 80h 3Eh F4h 01h 02h 00h 00h
501h 0 8 D 43h 80h 3Eh F4h 01h 02h 00h 00h
502h 0 8 D 13h 80h 3Eh F4h 01h 02h 00h 00h
502h 0 8 D 23h 80h 3Eh F4h 01h 02h 00h 00h
502h 0 8 D 83h 80h 3Eh F4h 01h 02h 00h 00h
502h 0 8 D 43h 80h 3Eh F4h 01h 02h 00h 00h
503h 0 8 D 13h 80h 3Eh F4h 01h 02h 00h 00h
503h 0 8 D 23h 80h 3Eh F4h 01h 02h 00h 00h
503h 0 8 D 83h 80h 3Eh F4h 01h 02h 00h 00h
503h 0 8 D 43h 80h 3Eh F4h 01h 02h 00h 00h
504h 0 8 D 13h 80h 3Eh F4h 01h 02h 00h 00h
504h 0 8 D 23h 80h 3Eh F4h 01h 02h 00h 00h
504h 0 8 D 83h 80h 3Eh F4h 01h 02h 00h 00h
504h 0 8 D 43h 80h 3Eh F4h 01h 02h 00h 00h
505h 0 8 D 13h 80h 3Eh F4h 01h 02h 00h 00h
505h 0 8 D 23h 80h 3Eh F4h 01h 02h 00h 00h
```

5. Set the channel voltage to 3V:

```
501h 0 8 D 13h E0h 2Eh F4h 01h 01h 00h 00h
501h 0 8 D 23h E0h 2Eh F4h 01h 01h 00h 00h
501h 0 8 D 83h E0h 2Eh F4h 01h 01h 00h 00h
501h 0 8 D 43h E0h 2Eh F4h 01h 01h 00h 00h
502h 0 8 D 13h E0h 2Eh F4h 01h 01h 00h 00h
502h 0 8 D 23h E0h 2Eh F4h 01h 01h 00h 00h
502h 0 8 D 83h E0h 2Eh F4h 01h 01h 00h 00h
502h 0 8 D 43h E0h 2Eh F4h 01h 01h 00h 00h
503h 0 8 D 13h E0h 2Eh F4h 01h 01h 00h 00h
503h 0 8 D 23h E0h 2Eh F4h 01h 01h 00h 00h
503h 0 8 D 83h E0h 2Eh F4h 01h 01h 00h 00h
503h 0 8 D 43h E0h 2Eh F4h 01h 01h 00h 00h
504h 0 8 D 13h E0h 2Eh F4h 01h 01h 00h 00h
504h 0 8 D 23h E0h 2Eh F4h 01h 01h 00h 00h
504h 0 8 D 83h E0h 2Eh F4h 01h 01h 00h 00h
504h 0 8 D 43h E0h 2Eh F4h 01h 01h 00h 00h
505h 0 8 D 13h E0h 2Eh F4h 01h 01h 00h 00h
505h 0 8 D 23h E0h 2Eh F4h 01h 01h 00h 00h
```

6. Close the cell voltage input:

```
501h 0 8 D 13h E0h 2Eh F4h 01h 02h 00h 00h
501h 0 8 D 23h E0h 2Eh F4h 01h 02h 00h 00h
501h 0 8 D 83h E0h 2Eh F4h 01h 02h 00h 00h
501h 0 8 D 43h E0h 2Eh F4h 01h 02h 00h 00h
502h 0 8 D 13h E0h 2Eh F4h 01h 02h 00h 00h
502h 0 8 D 23h E0h 2Eh F4h 01h 02h 00h 00h
502h 0 8 D 83h E0h 2Eh F4h 01h 02h 00h 00h
502h 0 8 D 43h E0h 2Eh F4h 01h 02h 00h 00h
503h 0 8 D 13h E0h 2Eh F4h 01h 02h 00h 00h
503h 0 8 D 23h E0h 2Eh F4h 01h 02h 00h 00h
503h 0 8 D 83h E0h 2Eh F4h 01h 02h 00h 00h
503h 0 8 D 43h E0h 2Eh F4h 01h 02h 00h 00h
504h 0 8 D 13h E0h 2Eh F4h 01h 02h 00h 00h
504h 0 8 D 23h E0h 2Eh F4h 01h 02h 00h 00h
504h 0 8 D 83h E0h 2Eh F4h 01h 02h 00h 00h
504h 0 8 D 43h E0h 2Eh F4h 01h 02h 00h 00h
505h 0 8 D 13h E0h 2Eh F4h 01h 02h 00h 00h
505h 0 8 D 23h E0h 2Eh F4h 01h 02h 00h 00h
```

Select the SIMPLELINK-WBMS-SDK GUI link to download the SDK setup.

3.3 Test Results

To measure the test result, prepare a digital multimeter to measure the resistance of the input NTC. When the HIL cell input is set to 4V with PCAN, connect all the parts shown in the test setup, then step one by one. Figure 3-11 shows the test result.

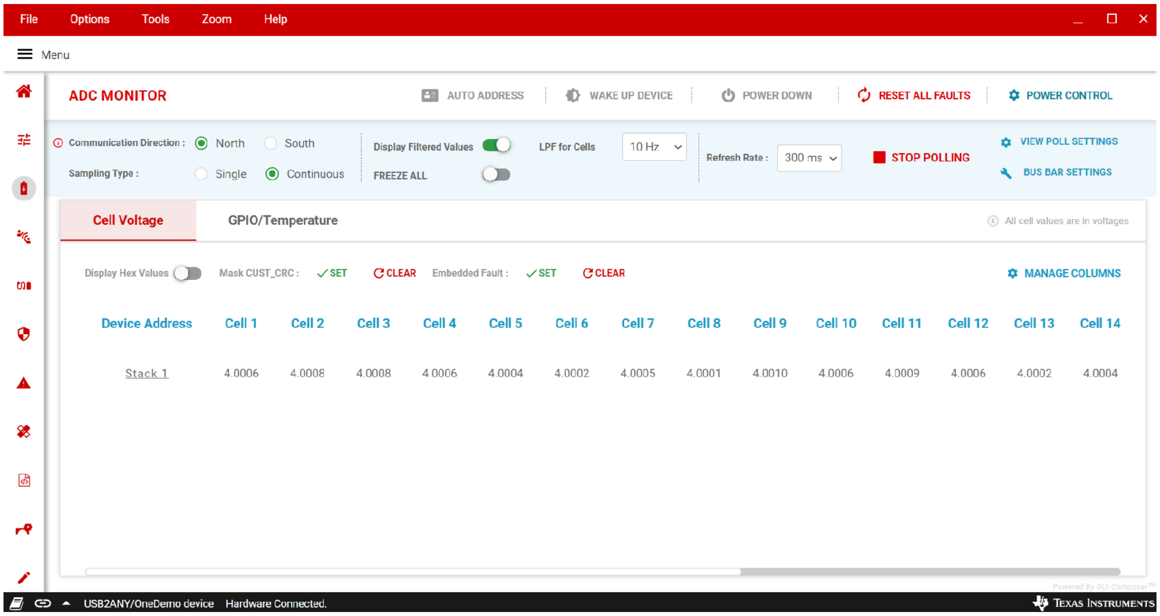


Figure 3-11. TIDA-020076 Test Result: 4V Cell Input

All channel cell voltage values can be read by the BQ797XX device GUI.

Set the cell voltage input to 3V with PCAN. Figure 3-12 shows the test results.

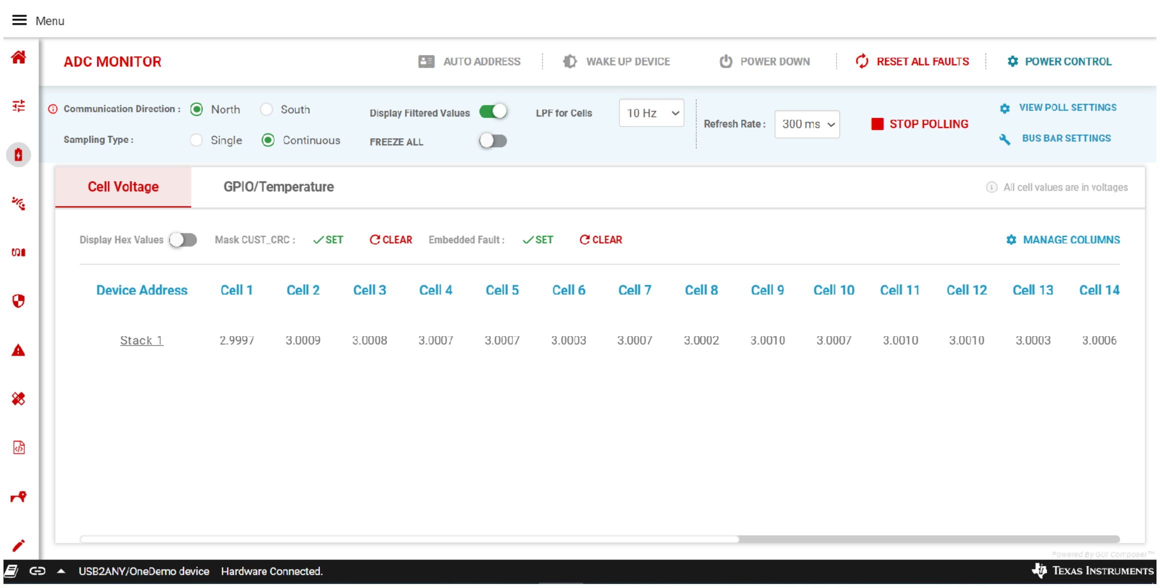


Figure 3-12. TIDA-020076 Test Result: 3V Cell Input

Record all the values to Table 3-1.

Table 3-1. All Channel Cell Voltage

CHANNEL	VALVE_4V	ACCURACY_4V	VALVE_3V	ACCURACY_3V	UNIT
CELL1	4000.6	0.6	2999.7	–0.3	mV
CELL2	4000.8	0.8	3000.9	0.9	mV
CELL3	4000.8	0.8	3000.8	0.8	mV
CELL4	4000.6	0.6	3000.7	0.7	mV
CELL5	4000.4	0.4	3000.7	0.7	mV
CELL6	4000.2	0.2	3000.3	0.3	mV
CELL7	4000.5	0.5	3000.7	0.7	mV
CELL8	4000.1	0.1	3000.2	0.2	mV
CELL9	4001.0	1.0	3001.0	1.0	mV
CELL10	4000.6	0.6	3000.7	0.7	mV
CELL11	4000.9	0.9	3001.0	1.0	mV
CELL12	4000.6	0.6	3001.0	1.0	mV
CELL13	4000.2	0.2	3000.3	0.3	mV
CELL14	4000.4	0.4	3000.6	0.6	mV
CELL15	4000.4	0.4	3000.6	0.6	mV
CELL16	4000.3	0.3	3000.2	0.2	mV
CELL17	4000.6	0.6	3000.8	0.8	mV
CELL18	4000.8	0.8	3001.0	1.0	mV

The first column lists all 18 channels. The second and fourth columns show cell values read by the BQ797XX device GUI when the HIL output sets to 4V and 3V. The third and fifth columns show accuracy values. All values and accuracy measurements fall within the specification.

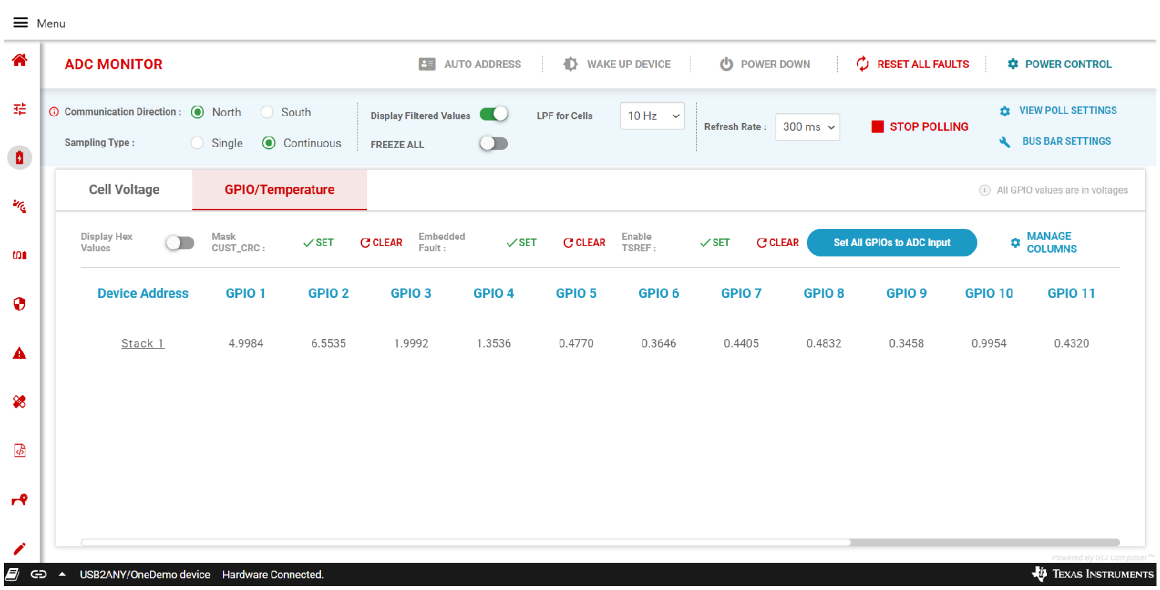


Figure 3-13. TIDA-020076 Test Result: NTC

This design includes four NTC outputs. Select four resistors with different values and connect them as shown in the test setup. Follow the test setup step by step, choose *GPIO/Temperature* view. Table 3-2 shows all the values.

Table 3-2. NTC Measurement

ITEM	TYP	MEASURE	CALCULATION	ACCURACY	UNIT
TSREF	4	3.9998			V
R_Pullup	10			1%	kΩ
R_Pulldo	10			1%	Ω
R_NTC1		1.2083			kΩ
V_NTC1		432	430.8	1.2	mV
R_NTC2		3.3086			kΩ
V_NTC2		995.4	993.6	1.8	mV
R_NTC3		5.1101			kΩ
V_NTC3		1353.6	1351.8	1.8	mV
R_NTC4		9.98			kΩ
V_NTC4		1999.2	1996.9	2.3	mV

In Table 3-2, *TYP* represents the typical value of all items. *MEASURE* represents the value measured or read by the BQ797XX device GUI or digital multimeter. Table 3-2 shows all values and accuracy measurements fall within the specification.

For the wireless test, replace the BQ79600 and USB2ANY with the main CC2662 wireless demonstration board. This wireless setup allows placement of the reference design on another desk, away from the battery module, with WBMS GUI and the test setup. When all hardware components are ready, click *Start* to display values in the WBMS GUI.

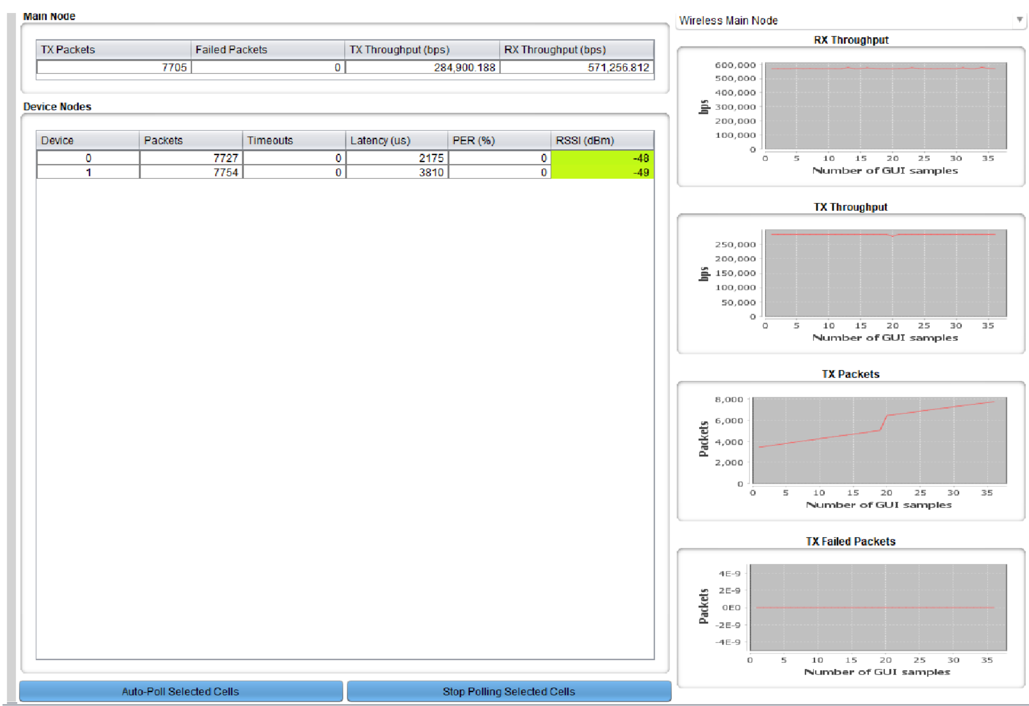


Figure 3-14. TIDA-020076 Test Result: WBMS GUI

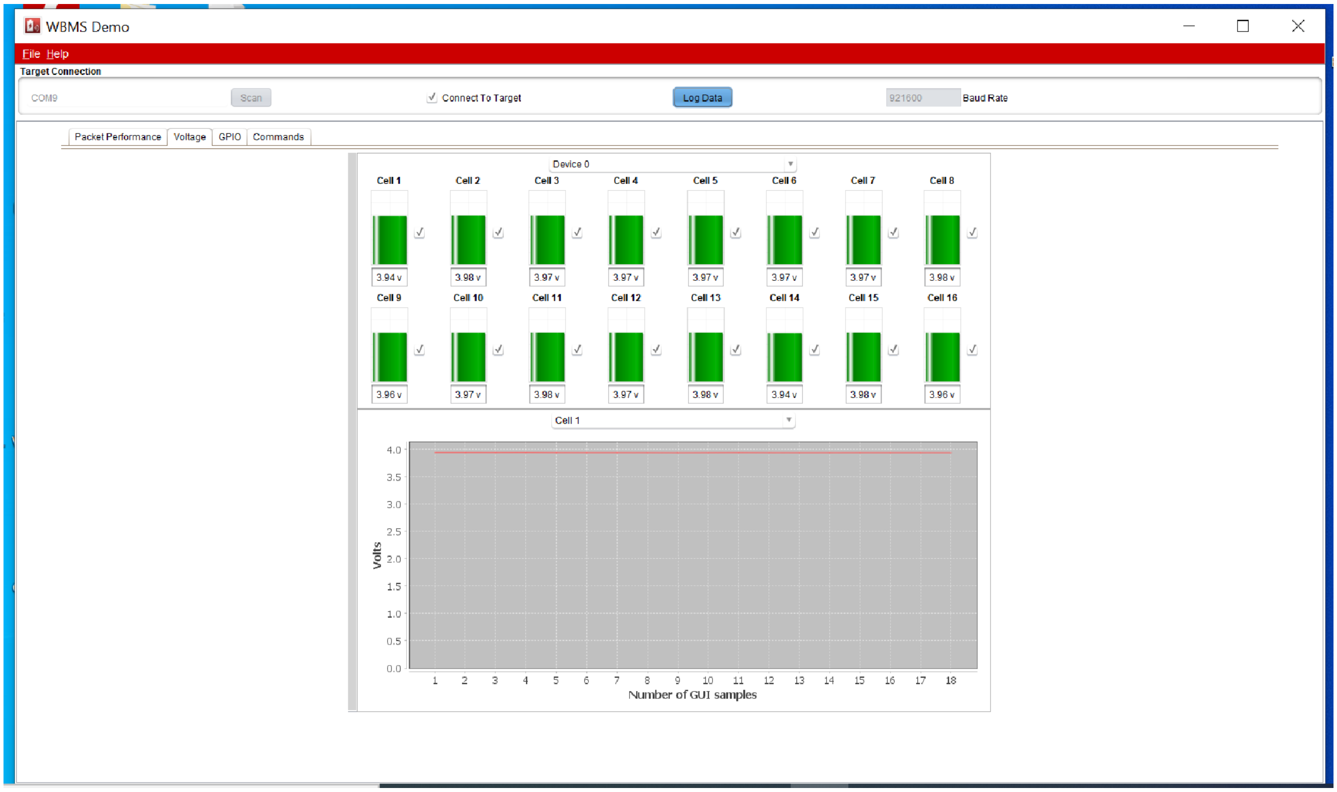


Figure 3-15. TIDA-020076 Test Result: Wireless Cell Value

Table 3-3. Wireless Cell Voltage

CHANNEL	READ	MEASURE	ACCURACY	UNIT
CELL1	3941.2	3940.4	0.8	mV
CELL2	3980.1	3979.1	1.0	mV
CELL3	3970.2	3968.6	1.6	mV
CELL4	3970.2	3969.2	1.0	mV
CELL5	3970.4	3969.2	1.2	mV
CELL6	3970.6	3969.4	1.2	mV
CELL7	3970.4	3969.4	1.0	mV
CELL8	3980.2	3979.6	0.6	mV
CELL9	3962.8	3962.2	0.6	mV
CELL10	3970.6	3969.4	1.2	mV
CELL11	3980.4	3979.4	1.0	mV
CELL12	3970.6	3969.6	1.0	mV
CELL13	3981.0	3980.2	0.8	mV
CELL14	3942.2	3941.4	0.8	mV
CELL15	3980.8	3980.2	0.6	mV
CELL16	3962.2	3961.6	0.6	mV
CELL17	3970.2	3969.4	0.8	mV
CELL18	3981.4	3980.2	1.2	mV

The images and table show RSSI values and cell voltages fall within the specification.

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-020076.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-020076.

4.2 Tools and Software

Tools

USB2ANY	USB2ANY interface adapter
BQ79600EVM	Functional Safety-Compliant SPI/UART to daisy chain bridge interface with automatic host wake-up
CC2662RQ1-EVM	CC26x2R LaunchPad™ development kit for multistandard SimpleLink™ wireless MCU

Software

SLVC695	USB2ANY Explorer Software
BQ797XX GUI	BQ797XX device GUI
PCAN View	PCAN View
SIMPLELINK-WBMS-SDK	SimpleLink™ wireless battery management system (BMS) software development kit (SDK)

4.3 Documentation Support

1. Texas Instruments, Wired vs. Wireless Communications in EV Battery Management
2. Texas Instruments, BQ79616-Q1 Software Design Reference

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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