UM11846

RD772BJBCANFDEVB battery junction box

Rev. 1.0 — 25 January 2023 User manual

Document information

Information	Content
Keywords	battery junction box measurement, isolation, current redundancy, pack, contactor, shunt, accuracy, temperature, precharge resistor, chassis, DCLINK, CAN, CANFD, CAN-FD
Abstract	This user manual targets the RD772BJBCANFDEVB board. The RD772BJBCANFDEVB is a typical battery junction box (BJB) solution that can be used in high-voltage battery management systems (BMS). The RD772BJBCANFDEVB is part of the high-voltage BMS reference design offered by NXP.

Revision history

Rev	Date	Description
1.0	20230125	Initial release

1 Important notice

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2 RD772BJBCANFDEVB

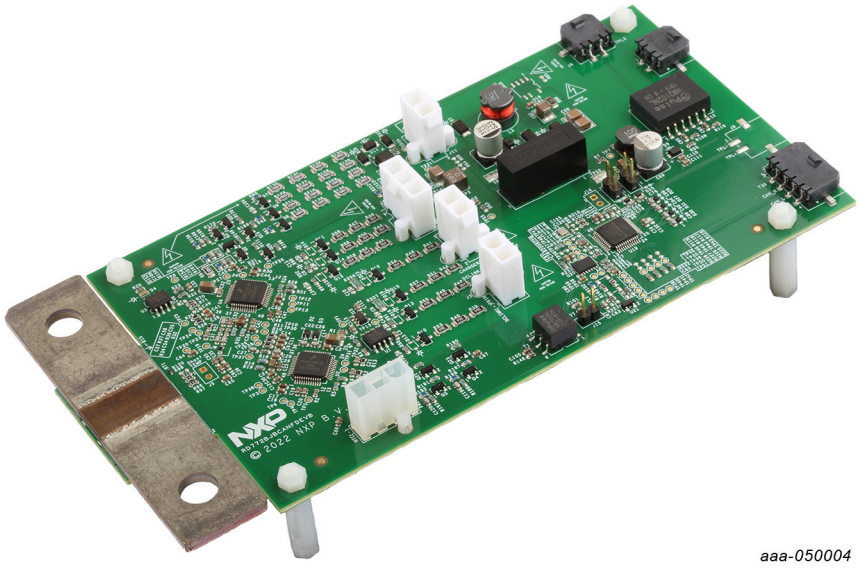

Figure 1. RD772BJBCANFDEVB

3 Introduction

The RD772BJBCANFDEVB is a BJB reference design for high-voltage battery management systems. The solution features high-voltage, current, and isolation-resistance measurements. The RD772BJBCANFDEVB has a communication port using CAN protocol.

Figure 2 shows a typical BJB with functions allocated to it and the context in a battery management system.

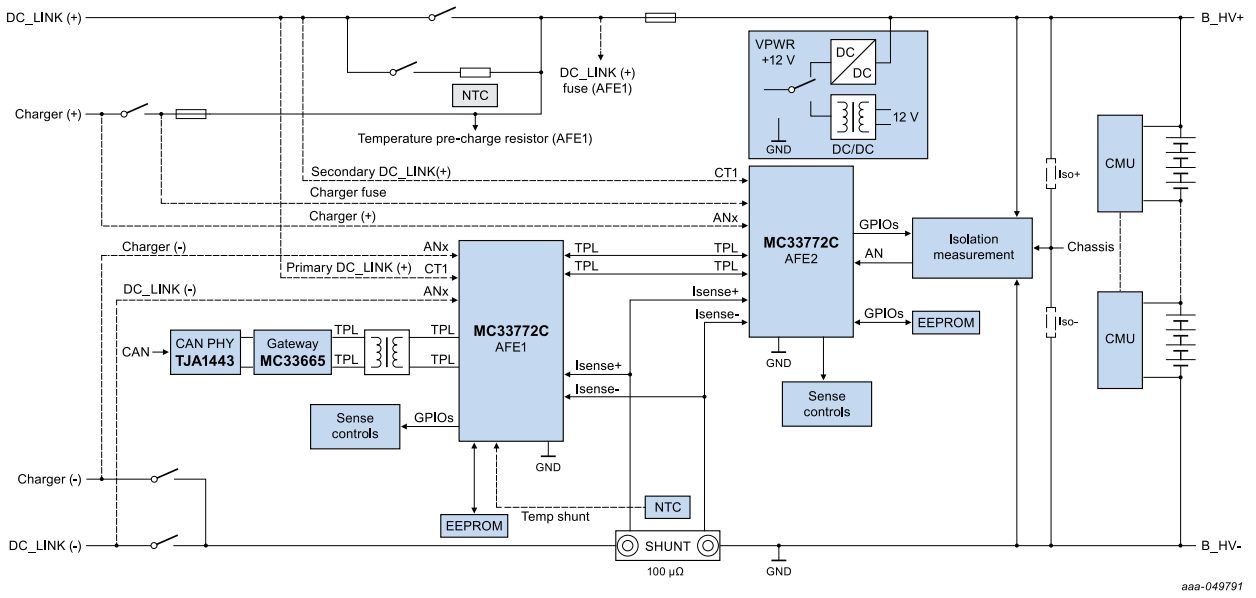

Figure 2. Typical high-voltage battery system

3.1 Kit contents/packing list

The kit includes:

- Assembled and tested board in antistatic bag
- High-voltage measurement cables
- External thermistor connection cable
- Power supply and CAN communication cable

4 Getting to know the hardware

4.1 Board overview

The RD772BJBCANFDEVB supports all typical functions of a BJB.

The RD772BJBCANFDEVB is supplied either with an isolated DC-DC from low-voltage domain (12 V) or directly from the high-voltage battery with a self-supply circuitry.

The RD772BJBCANFDEVB includes a galvanic isolation enabling communication between the high-voltage domain of the RD772BJBCANFDEVB and low-voltage domain of the controller.

4.2 Board features

Main features of the RD772BJBCANFDEVB:

- Five inputs high-voltage positive measurement up to 500 V
- Two inputs high-voltage negative measurement down to −500 V
- Single shunt for current measurement ±1500 A
- Shunt temperature measurement from −40 °C to +105 °C
- Connection to the precharge resistor for temperature measurement
- Passive isolation resistance measurement between high-voltage and low-voltage domains
- Two EEPROMs for data and calibration data storage
- Controller Area Network (CAN) line followed by an isolated gateway for communication with other systems
- Additional galvanically isolated electrical transport protocol link (ETPL) for communication with other systems

4.3 Block diagram

Figure 3 shows the main functions as well as the input and output of the battery junction box.

The voltage conditioning block is scaling down the high voltage from 0 V to 500 V to 0 V to 4.85 V range for analog-to-digital conversion by the MC33772C analog input.

Sense control function enables the voltage divider. A general-purpose input/output (GPIO) enables the switch in the voltage divider through a level shifter. This function prevents consumption of the voltage divider when the measurement is not performed (see Section 6.1 for an example of the sense control).

The resistance measurement function enables a connection to the chassis of the vehicle. Then several measurements are performed with different parallel resistor configurations. The isolation resistance between high-voltage domain and low-voltage domain is further computed in the main controller based on the voltage measurement (see Section 5).

The communication is based on a Controller Area Network (CAN) line. A MC33665 acts as a gateway and transfers the information to the MC33772C in TPL.

An additional communication line is based on the TPL working up to 2 Mbit/s. It is an NXP isolated communication protocol.

Two negative temperature coefficient resistors (NTCs) monitor the shunt temperature and the precharge resistor temperature. The analog inputs are configured as ratiometric analog inputs with reference to a voltage delivered by the MC33772C.

The battery junction box is supplied by a 12 V (typ.) either from the high-voltage battery with a buck converter or from a 12 V battery from low-voltage (LV) domain through an isolated DC-DC (see Section 4.11 for details).

The MC33772C performs analog-to-digital conversions of the sensed voltages and current, as well as battery coulomb counting.

The shunt is a 100 µΩ resistor with ±1500 A capability measurement. The resulting shunt voltage is redundantly measured by the two MC33772C.

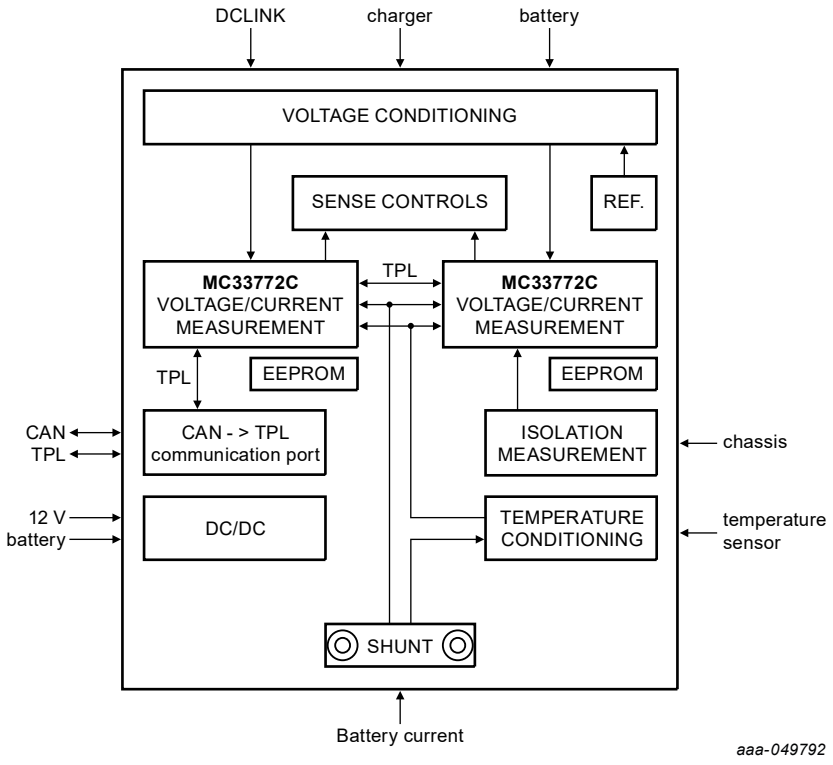

Figure 3. High-level block diagram

4.4 Board detailed features

The RD772BJBCANFDEVB embeds two MC33772C ICs. Table 1 and Table 2 show the measurement signal allocation per MC33772C:

Table 1. Battery junction box signal allocation to MC33772C AFE1

Signal	MC33772C AFE1
DCLINK(+) primary	CT1
DCLINK(−)	AN0 (GPIO0)
Charger(–)	AN1 (GPIO1)
DCLINK fuse	AN2 (GPIO2)
precharge resistor temperature	AN3 (GPIO3)

Table 2. Battery junction box signal allocation to MC33772C AFE2

Signal	MC33772C AFE2
DCLINK(+) secondary	CT1
Iso_R_mon	AN0 (GPIO0)
Charger(+)	AN1 (GPIO1)
Charger fuse	AN2 (GPIO2)
Shunt thermal sense	AN3 (GPIO3)

The GPIO4, GPIO5, and GPIO6 from AFE1 and AFE2 are selecting the signals for measurement. Table 3 shows the control signal allocation per MC33772C:

Table 3. GPIO control table

GPIO	AFE1	AFE2
GPIO4	DCLINK(+) primary DCLINK fuse DCLINK(–)	Charger(+) Charger(–) ISO_QL2
GPIO5	ISO_Opto	DCLINK(+) secondary
GPIO6	ISO_QL1	ISO_Q1

4.5 Board description

Figure 4 shows the location of functions over the board:

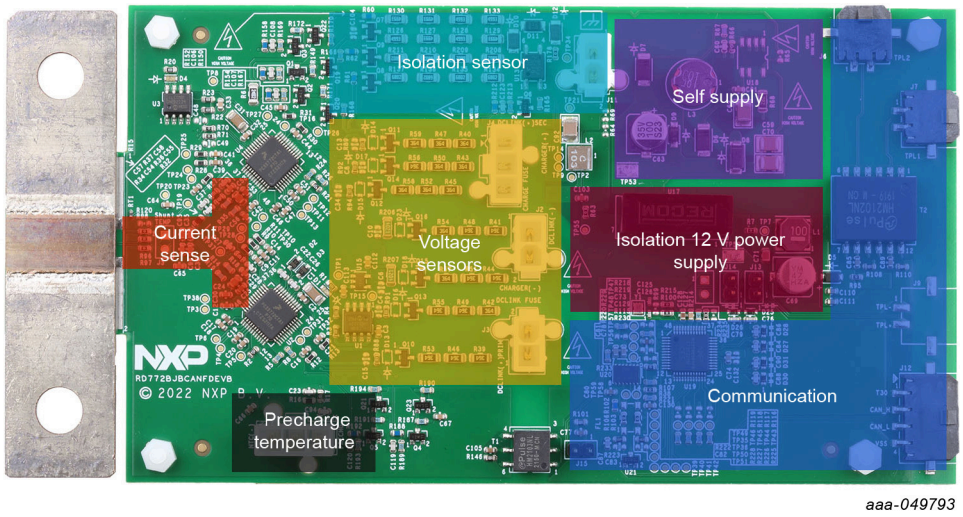

Figure 4. Location of functions over the board

Figure 5 shows the allocation of signals in different board connectors:

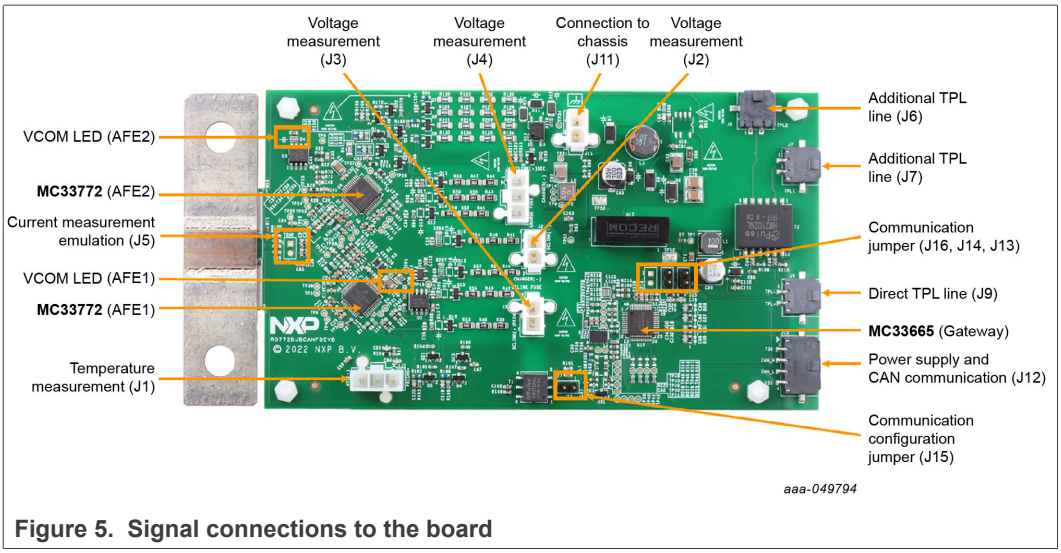

Figure 5. Signal connections to the board

4.6 VCOM LED

The VCOM LED is on the board, as shown in Figure 5. The VCOM LED indicates when the device is in normal mode. Upon reset, the MC33772C enters into normal mode (VCOM turns on). If there is no activity on the bus after a timeout period of 60 s, the device enters low-power idle mode (VCOM turns off). Once the device is initialized, if no communication occurs on the TPL bus after 1 s, the device resets and the LED turns off (VCOM off). Depending on the device settings, the VCOM LED may flash with 8 s interval during cyclic acquisition.

4.7 Connectors

Figure 5 shows the location of connectors on the board. Table 4 to Table 8 list the pinouts for each connector.

Table 4. Precharge resistor temperature connector (J1)

Pin	Connection	Description
1	PRECHARGE_TEMP	NTC connection (+)
2	n.c.	not connected
3	GND	NTC connection (−)

Table 5. Negative signal connector (J2)

Pin	Connection	Description
1	HV_DCLINK_NEG	DCLINK(−), negative voltage node
2	HV_CHARGER_NEG	charger (−), negative voltage node

Table 6. High-voltage DCLINK(+) connector (J3)

Pin	Connection	Description
1	HV_DCLINK_POS_PRM	DCLINK(+) primary, positive voltage node
2	HV_DCLINK_FUSE	DCLINK fuse, positive voltage node

Table 7. High-voltage charger connector (J4)

Pin	Connection	Description
1	HV_DCLINK_POS_SEC	DCLINK(+) secondary, positive voltage node
2	HV_CHARGER_POS	charger(+), positive voltage node
3	HV_CHARGER_FUSE	charger fuse, positive voltage node

Table 8. Shunt voltage connector (J5)

Pin	Connection	Description
1	Sense_p	differential voltage to simulate shunt voltage
2	Sense_n	differential voltage to simulate shunt voltage

Table 9. Additional TPL line connector (J6)

Pin	Connection	Description
1	TPL_P	positive signal of the TPL communication
2	TPL_N	negative signal of the TPL communication

Table 10. Additional TPL line connector (J7)

Pin	Connection	Description
1	TPL_P	positive signal of the TPL communication
2	TPL_N	negative signal of the TPL communication

Table 11. Direct TPL line connector (J9)

Pin	Connection	Description
1	TPL_P	positive signal of the TPL communication
2	TPL_N	negative signal of the TPL communication

Table 12. Chassis connector (J11)

Pin	Connection	Description
1	chassis	connection to chassis for resistance measurement
2	n.c.	not connected

4.8 Temperature measurement

The RD772BJBCANFDEVB offers two temperature measurements: one temperature measurement of the shunt and one temperature measurement of the precharge resistor. The NTC used is B57232V5103F360. The voltage divider is supplied by VCOM from MC33772C.

4.9 Cell terminal voltage measurement

CT1 of each MC33772C is used for voltage measurement. The other CT pins are unused. To comply with the maximum differential rating between pins, the unused CTx and CBx pins are externally biased with a voltage divider. The resistor values for the CTx/CBx biasing have been calculated to comply with maximum ratings and to comply with the supply voltage range specified in Section 4.11.

4.10 Bus terminal communication

The 1:1 transformer galvanically isolates the superior control unit on LV domain to the MC33772C AFE1 on High-Voltage (HV) domain. The TPL bus has a direct connection between AFE1 and AFE2. Isolation is not required, as both devices share GND and supply. For additional information about the TPL protocol and external components, refer to MC33772C data sheet[1].

4.11 Power supply

The battery junction box offers two options for the supply:

- 12 V from a DC-DC converter from low-voltage domain
- 12 V from the high-voltage domain with a step-down converter

Table 13. Power supply

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{CC}	supply voltage	high-voltage domain	9	12	13.5	V
I_{CC}	supply current	normal mode; ADC active; TPL communication active; 12 V supplied without DC-DC	—	21	—	mA
		sleep mode	—	430	—	µA
		normal mode; ADC active; TPL communication active; 12 V supplied from DC-DC	—	37	—	mA

The default supply is from the DC-DC converter. On RD772BJBCANFDEVB, an industrial integrated DC-DC converter is used. If the BJB is used in an automotive environment, an automotive-qualified, isolated DC-DC is recommended. Four resistors connect or disconnect the power supply options. Table 14 details the resistor connections for the supply selection source.

Table 14. Power supply selection

Power source	R65	R95	R63	R64
12 V from DC-DC converter from low-voltage domain	Do Not Place (DNP)	0 Ω	0 Ω	DNP
12 V from high-voltage battery	0 Ω	DNP	DNP	0 Ω

5 Isolation measurement

The BJB features a passive isolation resistance measurement circuit. A dedicated circuitry connects the chassis to specific resistor networks. This connection unbalances the network as a function of the resistance between the chassis and the battery. Figure 6 shows the resistor networks and chassis connections.

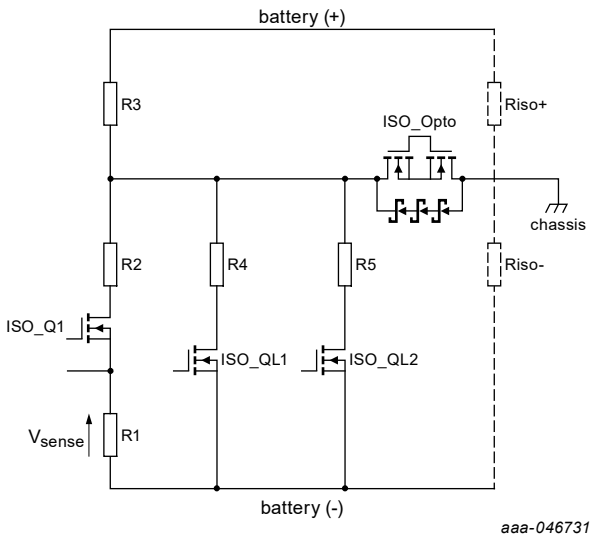

Figure 6. Isolation measurement circuitry

The ISO_Q1, ISO_QL1, and ISO_QL2 prevent continuous current leakage between the battery rails. ISO_Opto connects or disconnects the chassis to the isolation resistance measurement circuit. The principle of operation is to close ISO_Q1 then to measure V_{sense}. This measurement is called *V1*. Then, ISO_QL1 closes and V_{sense} is measured again. This second measurement is called *V2*. After the second measurement, the two voltages, V1 and V2, are used in the formulas Equation 1 and Equation 2, assumed to be implemented in the battery management unit (BMU), to compute Riso+ and Riso–. To ease the computation, the Y1 to Y4 conductances of the R1 to R4 resistances are considered. V_{bat} is the battery voltage. The last low branch, that includes R5 and is enabled by ISO_QL2, is a redundant branch of the one enabled by ISO_QL1. This last branch can be used instead of ISO_QL1 one or to make a third measurement.

$$Y_{iso+} = -\frac{V_1}{V_{bat}} \times \frac{V_2}{V_2 - V_1} \times \frac{Y_1 + Y_2}{Y_2} \times Y_4 - Y_3 \quad (1)$$

$$Y_{iso-} = -Y_3 - \frac{Y_1 Y_2}{Y_1 + Y_2} - Y_4 \times \frac{V_2}{V_2 - V_1} - Y_{iso+} \quad (2)$$

6 High-voltage measurement

The high-voltage nodes are sensed through a voltage divider to scale the voltage down to a range suitable for the input of the MC33772C. Figure 7 represents the DCLINK(+) and DCLINK(−) measurements. The capacitor represents the total traction inverter load capacitance.

A reference is in the negative measurement path to allow negative voltage measurement.

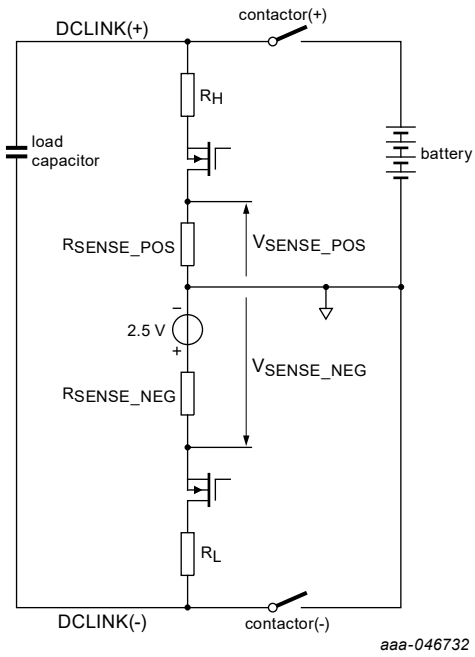

Figure 7. High-voltage measurement schematic

Sense voltages are computed in the BMU with Equation 3 and Equation 4:

$$V_{SENSE\_POS} = DCLINK(+) \times \frac{R_{SENSE\_POS}}{R_{SENSE\_POS} + R_H} \quad (3)$$

$$V_{SENSE\_NEG} = V_{REF} \times \frac{R_L}{R_{SENSE\_NEG} + R_L} + DCLINK(-) \times \frac{R_{SENSE\_NEG}}{R_{SENSE\_NEG} + R_L} \quad (4)$$

6.1 Blanking time

Before doing any measurement with the MC33772C, a blanking time is required to secure that the voltage is stabilized before the analog-to-digital conversion. Figure 8 shows the complete path from GPIO output enable to ANx input. Figure 9 shows the time needed before measurement. This blanking time is 2 ms minimum.

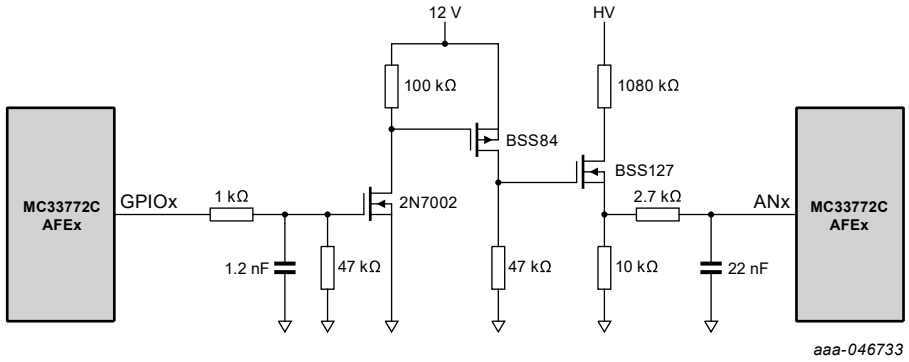

Figure 8. Schematic from GPIO enable to ANx input

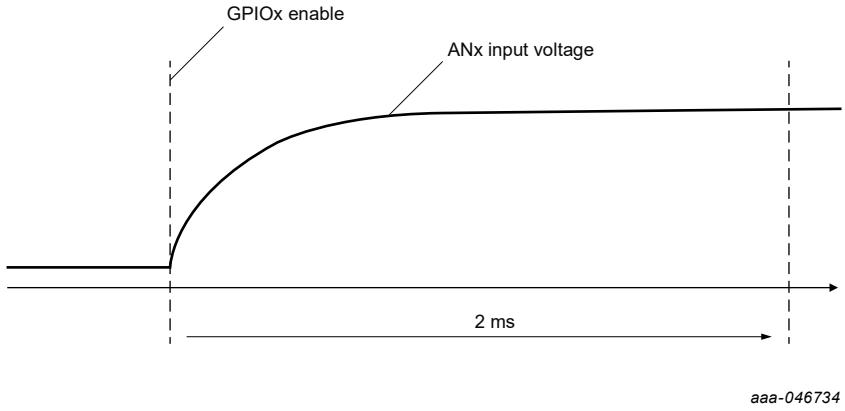

Figure 9. Delay from GPIO enable to voltage ready at ANx input

6.2 Low-voltage input signals emulation

All high-voltage nodes are sensed with a voltage divider to lower the voltage in a range suitable for the MC33772C analog input (4.85 V max). If the solution must be tested with lower voltage (5 V, 12 V, or 15 V), the voltage divider ratio has to be adapted. In Figure 10, the resistor has been chosen for 3.75 V at MC33772C inputs.

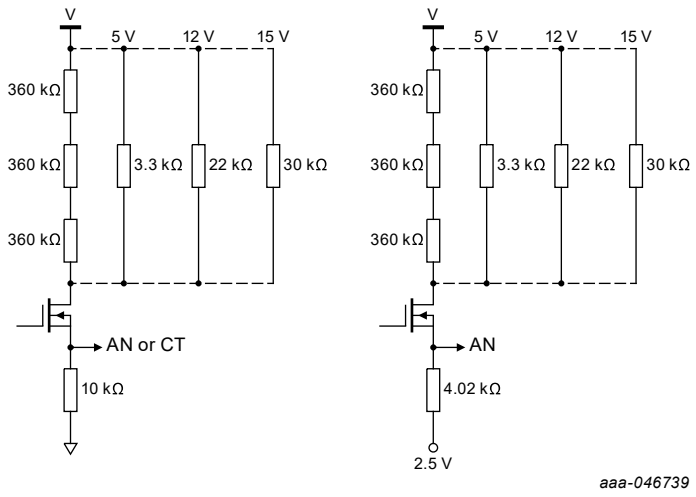

Figure 10. Resistor bridge adapted for 5 V, 12 V, and 15 V

7 Current measurement

7.1 Current sense input selection

The battery junction box board allows the customer to apply an external voltage to simulate the current across the shunt. The maximum differential voltage is ±150 mV at MC33772C current sense inputs.

Figure 11 shows the resistor configuration for shunt usage and Figure 12 shows the configuration for external voltage usage.

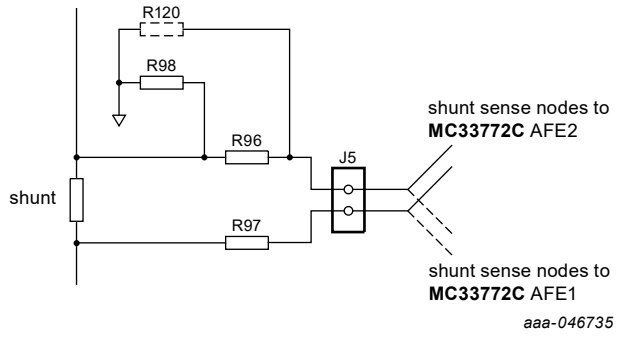

Figure 11. Resistor configuration for shunt usage

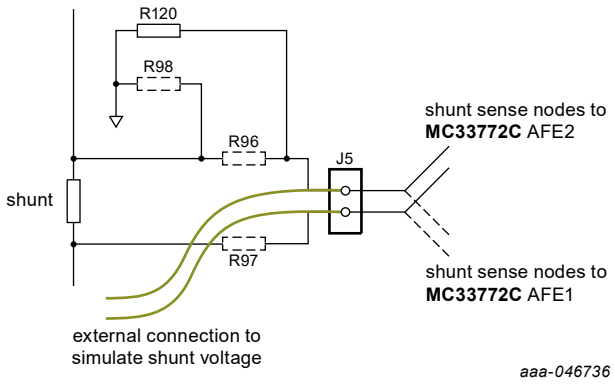

Figure 12. Resistor configuration for external voltage usage to simulate shunt voltage drop

7.2 Layout note

The layout of the current sense has been designed to connect an external voltage source to simulate the battery current. The connection to the shunt is not redundant, as it should be. Figure 13 shows the layout on the BJB reference board and Figure 14 shows the layout to be implemented on the final application to secure the redundant connection to the shunt.

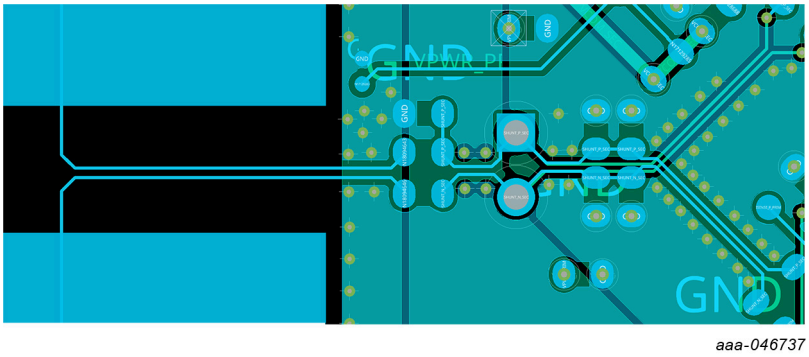

Figure 13. Layout on the reference battery junction box

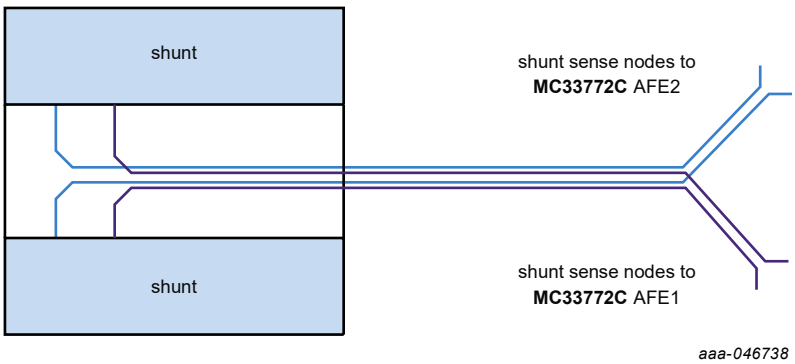

Figure 14. Layout to be implemented for redundant connection to the shunt

8 Battery junction box filters

A low-pass filter is implemented on each measurement input. Table 15 summarizes the cutoff frequencies of all input signals.

Table 15. Cutoff frequencies

Parameter	Cutoff frequency (−3 dB)
DCLINK(+)	600 Hz
DCLINK(−)	600 Hz
DCLINK fuse	600 Hz
Charger(+)	600 Hz
Charger(−)	600 Hz
Charger fuse	600 Hz
Isolation to chassis	530 Hz
Shunt temperature	600 Hz
precharge resistor temperature	600 Hz
Current sense differential voltage	600 Hz
Current sense common-mode voltage	26.7 kHz

Note: *The safety mechanism SM05 (OT/UT diagnostic on ANx) shall not be used with the capacitor computed for above cutoff frequencies. If SM05 is used, then the capacitor shall be below 10 nF. This limitation applies to pins set as analog inputs. For SM05 safety mechanism details, refer to the MC33772C safety manual.*

9 Communication

By default, the reference design communicates with the Battery Management Unit (BMU) with a Controller Area Network protocol (CAN), as detailed in Figure 15.

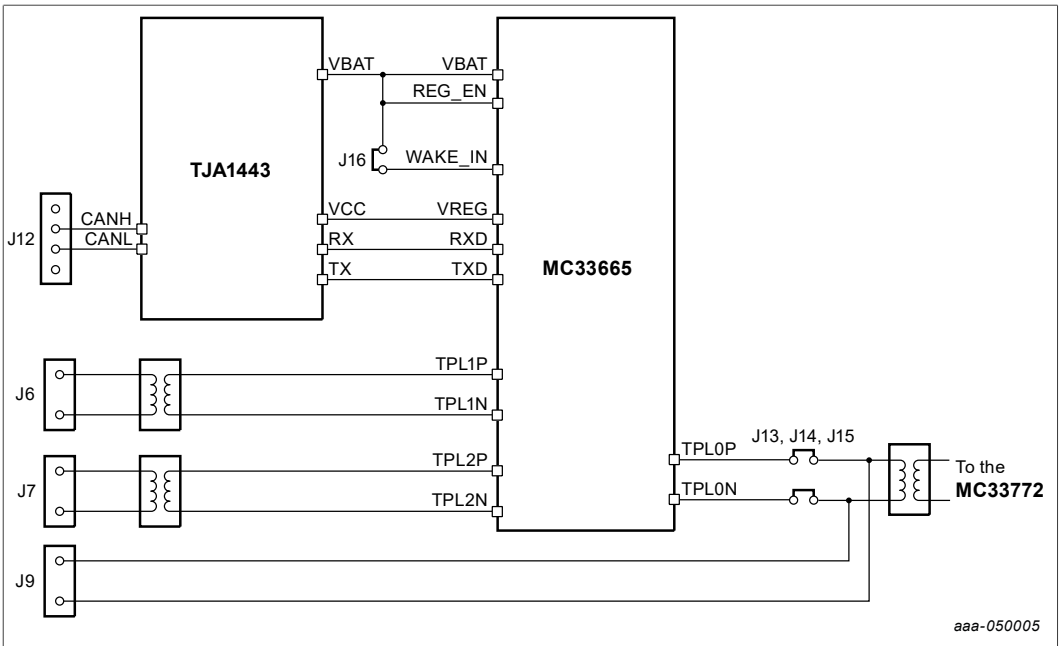

Figure 15. Communication diagram

9.1 CAN communication

The CAN lines coming from the BMU are connected to J12. The TJA1443 acts as a transceiver and interfaces the CAN lines with the MC33665. The MC33665 is a gateway that can be configured to forward all the messages between the BMU (CAN) and the MC33772 (TPL).

The user must put jumpers on J13, J14 and J15 to communicate in CAN with the RD772BJBCANFDEVB.

The jumper J16 keeps the MC33665 awake. This feature is useful when using a software tool with a delay between messages longer than the MC33665 timeout. If the MC33665 sleep feature is necessary, the jumper can be removed.

9.2 TPL communication

The RD772BJBCANFDEVB can be converted to a TPL Battery Junction Box by removing J14, J14, and J15. Then, the TPL line connected to J9 bypasses the MC33665 and is connected to the MC33772.

Two additional TPL lines are available on J6 and J9. These lines are directly connected to the MC33665 and could be used to interface the RD772BJBCANFDEVB with other TPL boards. The MC33665 could then distribute the messages from the BMU to any TPL line.

10 Available accessories

Table 16. Bill of materials

Part number	Description
600-77571	 Figure 16. Cable for high-voltage connections, two positions, 500 mm
600-77659	 Figure 17. Cable for high-voltage connections, three positions, 500 mm

Table 16. Bill of materials...*continued*

Part number	Description
600-77573	***Note:*** *The connector has three positions to prevent misconnection to a high-voltage plug on the BJB board*  aaa-046741 **Figure 18. Cable for precharge resistor temperature sensor, three positions, 500 mm**
600-77576	 aaa-049795 **Figure 19. Cable for power supply and CAN communication, four positions, 500 mm**

11 References

[1] Data sheet MC33772C http://www.nxp.com/MC33772C

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