UM12145

RDBESS772BJBEVB battery junction box

Rev. 1.0 — 20 September 2024 — User manual

Document information

Information	Content
Keywords	RDBESS772BJBEVB, battery junction box, high voltage, 1500 V, measurement, isolation, current, contactor, shunt, accuracy, temperature
Abstract	This user manual targets the RDBESS772BJBEVB board. It is a typical battery junction box (BJB) solution used in battery energy storage system (BESS). The RDBESS772BJBEVB is part of the BESS reference design offered by NXP.

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1 Introduction

The RDBESS772BJBEVB is a BJB reference design around two NXP MC33772Cs. The board is ideal to quickly prototype the hardware and the software of a high-voltage BMS.

This document describes the RDBESS772BJBEVB features.

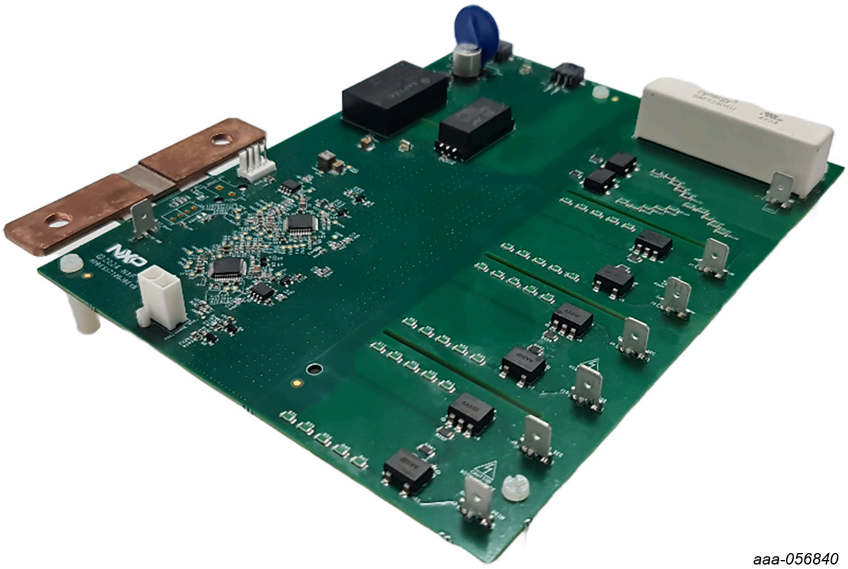

Figure 1. RDBESS772BJBEVB

2 Finding the kit resources and information on the NXP web site

NXP Semiconductors provides online resources for this evaluation board and its supported device(s) on http://www.nxp.com.

The information page for the RD-BESS1500BUN (1500 V battery energy storage reference design) evaluation board is at https://www.nxp.com/design/design-center/development-boards-and-designs/1500-v-battery-energy-storage-reference-design-:RD-BESS1500BUN. The information page provides overview information, documentation, software and tools, parametrics, ordering information and a Getting Started tab. The Getting Started tab provides quick-reference information applicable to using the RD-BESS1500BUN (1500 V battery energy storage reference design) evaluation board, including the downloadable assets referenced in this document.

3 Getting ready

3.1 Kit contents

- Battery junction box (BJB)

- One RDBESS772BJBEVB board
- One power cord
- Six high-voltage measurement cables
- Two thermal sensor cables
- One chassis cable
- One GND cable
- Two Hall sensor cables
- One electrical transport protocol link (ETPL) cable
- One plexiglass cover

4 Getting to know the hardware

4.1 Board overview

The RDBESS772BJBEVB supports battery current measurement, contactor and fuse monitoring, isolation monitoring, and temperature measurement.

The battery management unit (BMU) communicates and controls the two MC33772CTC1AEs. These ICs provide the necessary features to fulfill the various measurements.

Figure 2 presents the block diagram of the board and its interaction with the rest of the system.

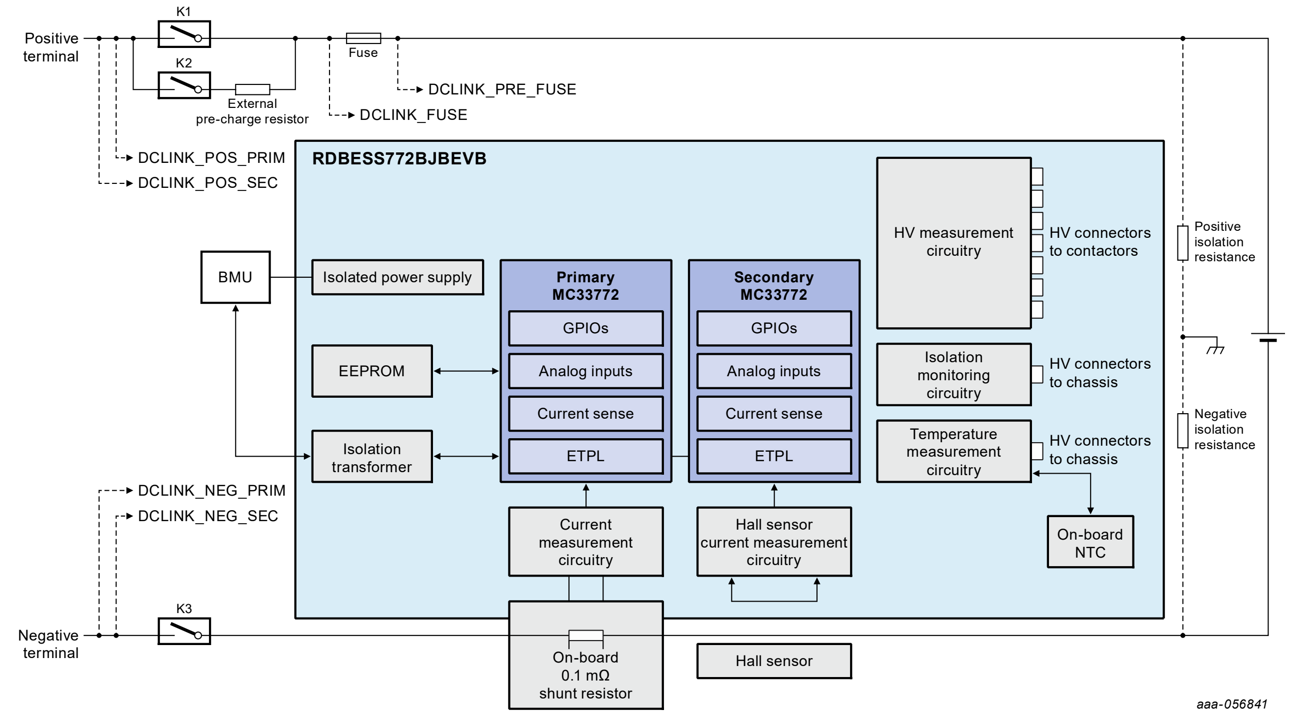

Figure 2. RDBESS772BJBEVBblock diagram

4.2 Board features

The RDBESS772BJBEVB offers the following features:

- Four positive high-voltage measurement inputs (up to 1800 V)
- Two bipolar high-voltage measurement inputs (from −1800 V to 1800 V)
- Isolation monitoring between high-voltage and low-voltage domains
- Current measurement with a 100 µΩ shunt resistor (from −500 A to 500 A) with the option for redundancy using two shunt resistors
- Shunt resistor temperature estimation
- The option to have onboard shunt resistors or external shunt resistors
- One Hall sensor for current measurement (from 0 A to 500 A) with the option to have another Hall sensor
- Precharge resistor temperature measurement with an external sensor
- Two EEPROMs for calibration data storage
- Galvanically isolated ETPL for communication
- Printed-circuit board designed according to IEC 60664 (pollution degree 3, material group III[b])

4.3 Kit featured components

Figure 3 shows the connectors and the LEDs available on the RDBESS772BJBEVB.

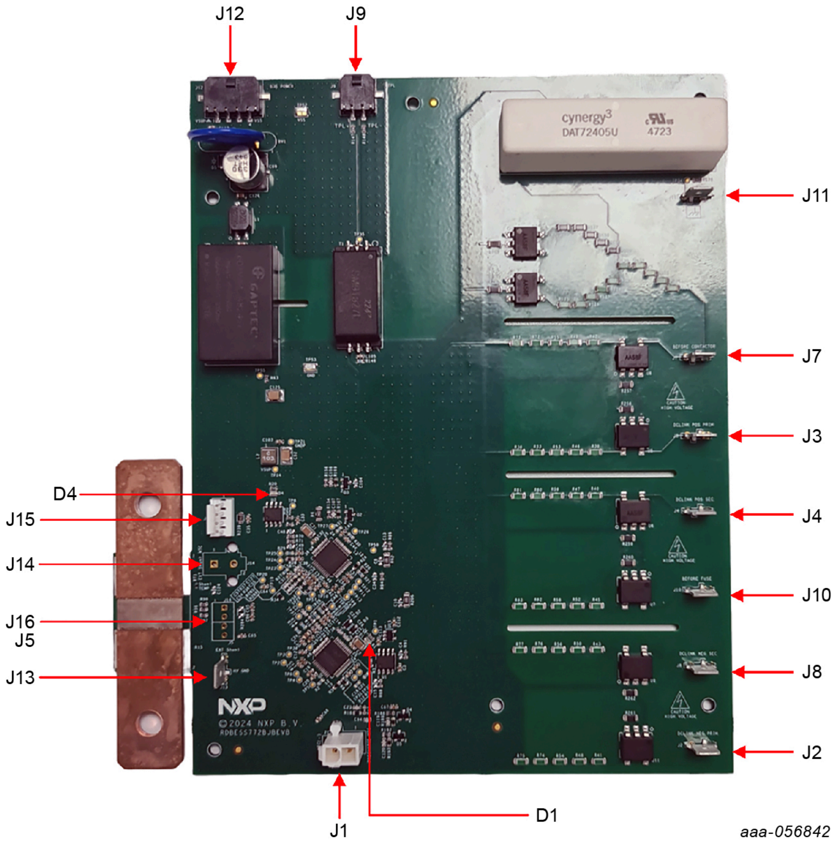

Figure 3. Connectors and LEDs location

4.3.1 Connectors

Table 1 lists the high-voltage connectors used for high-voltage measurement or isolation monitoring. Section 6 describes the associated cables.

Table 1. High-voltage connectors

Connector name	Description
J11	Chassis connection for isolation monitoring
J7	DCLINK_FUSE input for voltage measurement
J3	Primary DCLINK_POS input for voltage measurement
J4	Secondary DCLINK_POS input for voltage measurement
J10	DCLINK_PRE_FUSE input for voltage measurement
J8	Secondary DCLINK_NEG input for voltage measurement
J2	Primary DCLINK_NEG input for voltage measurement

Table 2 through Table 8 describe the remaining connectors and their pinout.

Table 2. Power supply connector

Connector name	Pin	Description
J12	1	Power supply positive input (BJB_PWR_IN)
	2	Do not connect
	3	Do not connect
	4	Power supply negative input (VSS)

Table 3. Communication connector

Connector name	Pin	Description
J9	1	Positive ETPL input
	2	Negative ETPL input

Table 4. Hall sensor connector

Connector name	Pin	Description
J15	1	Hall sensor supply positive input (VSUP)
	2	Hall sensor supply negative input (GND)
	3	Analog output signal
	4	Power supply negative input (GND)

Table 5. External shunt resistor temperature sensor connector

Connector name	Pin	Description
J14	1	Temperature sensor positive input
	2	Temperature sensor negative input

Table 6. Optional Hall sensor connector

Connector name	Pin	Description
J16	1	Hall sensor supply positive input (VSUP)
	2	Hall sensor supply negative input (GND)
	3	Analog output signal
	4	Power supply negative input (GND)

Table 7. Current emulation connector

Connector name	Pin	Description
J5	1	Current measurement positive input
	2	Current measurement negative input

Table 8. Precharge resistor temperature sensor connector

Connector name	Pin	Description
J1	1	Temperature sensor positive input
	2	Temperature sensor negative input

4.3.2 LEDs

Figure 3 highlights two LEDs:

- D1 (powered by the V_{COM} of the primary MC33772C)
- D4 (powered by the V_{COM} of the secondary MC33772C)

These components give information on the MC33772C operation mode. If an LED is on, the associated MC33772C is in Active mode. If an LED is off, the integrated circuit is either unpowered, in reset, or in sleep.

4.4 Schematic, board layout, and bill of materials

The schematic, board layout, and bill of materials for the RDBESS772BJBEVB are available at http://www.nxp.com/RDBESS772BJBEVB.

5 Configuring the hardware

5.1 Power supply

The RDBESS772BJBEVB usually receives power from the BMU on the connector J12. The power supply must follow the characteristics described in Table 9.

Table 9. Power supply characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{BJB\_PWR\_IN}$	Supply voltage		18	24	30	V
$I_{BJB\_PWR\_IN}$	Supply current	RDBESS772BJBEVB in Normal mode; TPL communication active; all high-voltage switches enabled	-	160	200	mA
		RDBESS772BJBEVB not active	-	20	-	mA

The BMU is in the low-voltage domain, whereas the BJB is in the high-voltage domain. Therefore, the RDBESS772BJBEVB embeds an isolated DC-DC converter to power the MC33772C and the measurement circuitry. This converter is by default an industrial component.

5.2 Current measurement

The RDBESS772BJBEVB redundantly measures the battery current with either two shunt resistors, two Hall sensors, or a combination from the two of them.

5.2.1 Current measurement characteristics

Table 10 describes the characteristics of the current measurement feature.

Table 10. Current measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{shunt}	Shunt resistor value		-	100	-	μΩ
I_{BAT}	Battery current under measurement	Measurement with shunt resistor	−500	-	500	A
V_{ISENSE}	Voltage on ISENSE inputs measurement	Measurement with shunt resistor or with voltage across J5	−150	-	150	mV
$f_{ISENSE\text{-}DIFF}$	Current measurement filter cut-off frequency	Differential voltage; −3 dB attenuation	-	600	-	Hz
$f_{ISENSE\text{-}COMM}$	Current measurement filter cut-off frequency	Common mode voltage; −3 dB attenuation	-	26.7	-	kHz

5.2.2 Current measurement circuit description

The RDBESS772BJBEVB provides a shunt resistor to measure the battery current (from the battery to the inverter). Typically, the shunt resistor is on the high-voltage battery negative terminal. It serves as a ground for the high-voltage section of the RDBESS772BJBEVB (MC33772C, measurement circuitry ...).

The primary MC33772C chip measures the voltage drop across the shunt resistor (R15). As the current measurement is bipolar, the user can link the ISENSE+ and ISENSE− measurement pins to any side of the shunt resistor.

To ease the evaluation of the RDBESS772BJBEVB, a connector (J5) is available in parallel to the shunt resistor. Then, a voltage source can replace a high-current source to validate the current measurement feature. The connector (J5) can also be used to connect the RDBESS772BJBEVB board with an external shunt resistor.

To give the user the flexibility to either use a shunt resistor or a Hall sensor to be connected to the primary MC33772C chip, a connector (J16) is available in parallel to the shunt resistor. The connector (J13) should be connected to the battery pack GND reference.

Figure 4 describes the current measurement circuitry.

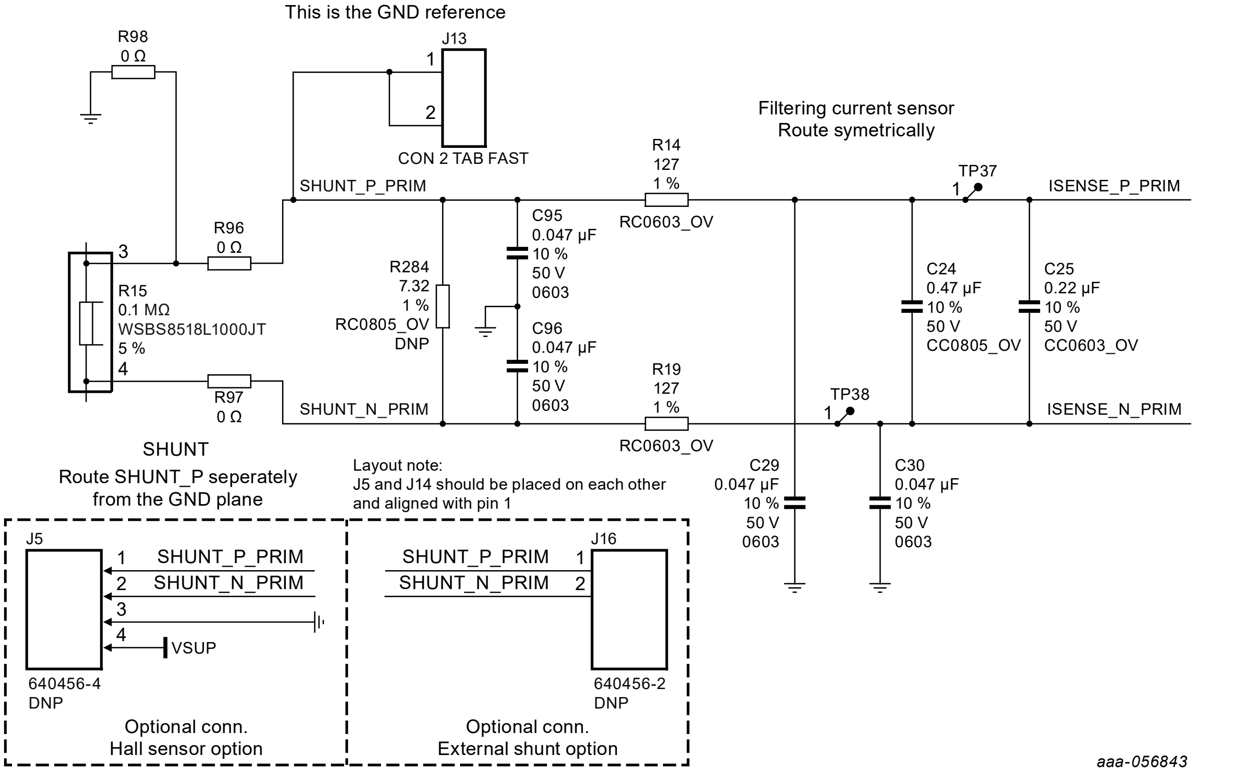

Figure 4. Shunt resistor current measurement circuitry

The placement of the resistors defines whether the two MC33772Cs measure the voltage drop across the shunt resistor or across the connector, as explained in Table 11.

Table 11. Resistor placement for current measurement

Resistor	Placement when using shunt resistor	Placement when using a voltage source on J5/Hall sensor on J16
R98	0 Ω	Do not place
R96	0 Ω	Do not place
R97	0 Ω	Do not place

The secondary MC33772C chip measures the voltage drop across the Hall sensor shunt resistor (R239). To ease the evaluation of the RDBESS772BJBEVB, a connector (J15) is available in parallel to the Hall sensor shunt resistor. Then, a voltage source can replace a high-current source to validate the current measurement feature.

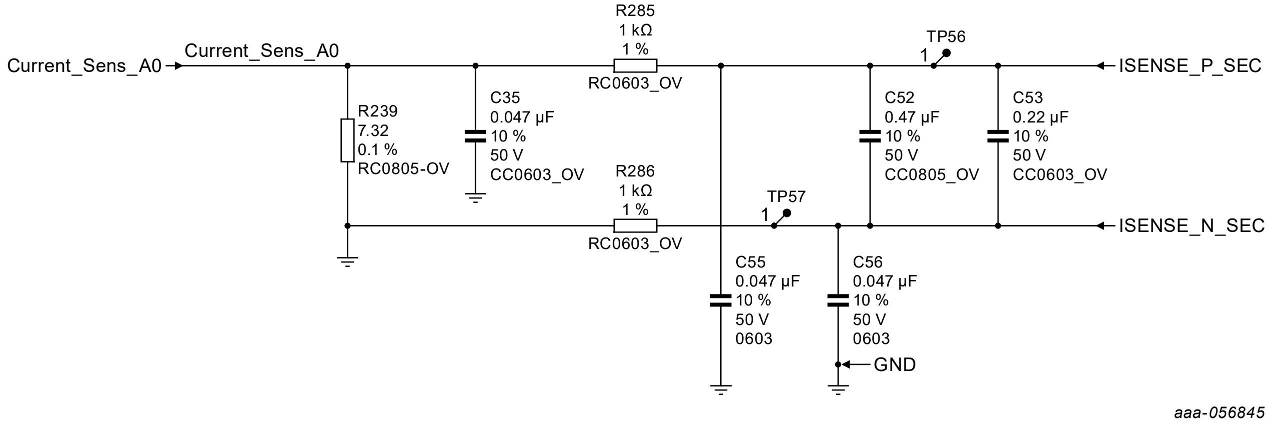

Figure 5. Hall sensor current measurement circuitry

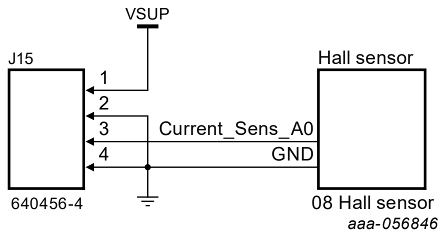

Figure 6. Hall sensor connector

The part number of the Hall sensor used as a reference is ATO-AHKC-EKCA. It is an open-loop current sensor with split-core structure, 1 ms fast response time, 1.0 % FS accuracy, 4 mA-20 mA output signal, 24 V power supply.

https://www.ato.com/dc-current-sensor-50a-to-1500a

Figure 7. ATO-AHKC-EKCA Hall sensor

At no load, the sensor output signal is 4 mA, and at maximum load, the output signal is 20 mA. The output current from the Hall sensor creates a voltage drop across the Hall sensor shunt resistor (R239), which is measured by the secondary MC33772C chip.

5.2.3 Current measurement layout guideline

The layout of the current measurement path of the shunt resistor is compatible with the use of an external voltage source.

The current measurement paths for both the shunt resistor and the Hall effect sensor are independent, as shown in Figure 8.

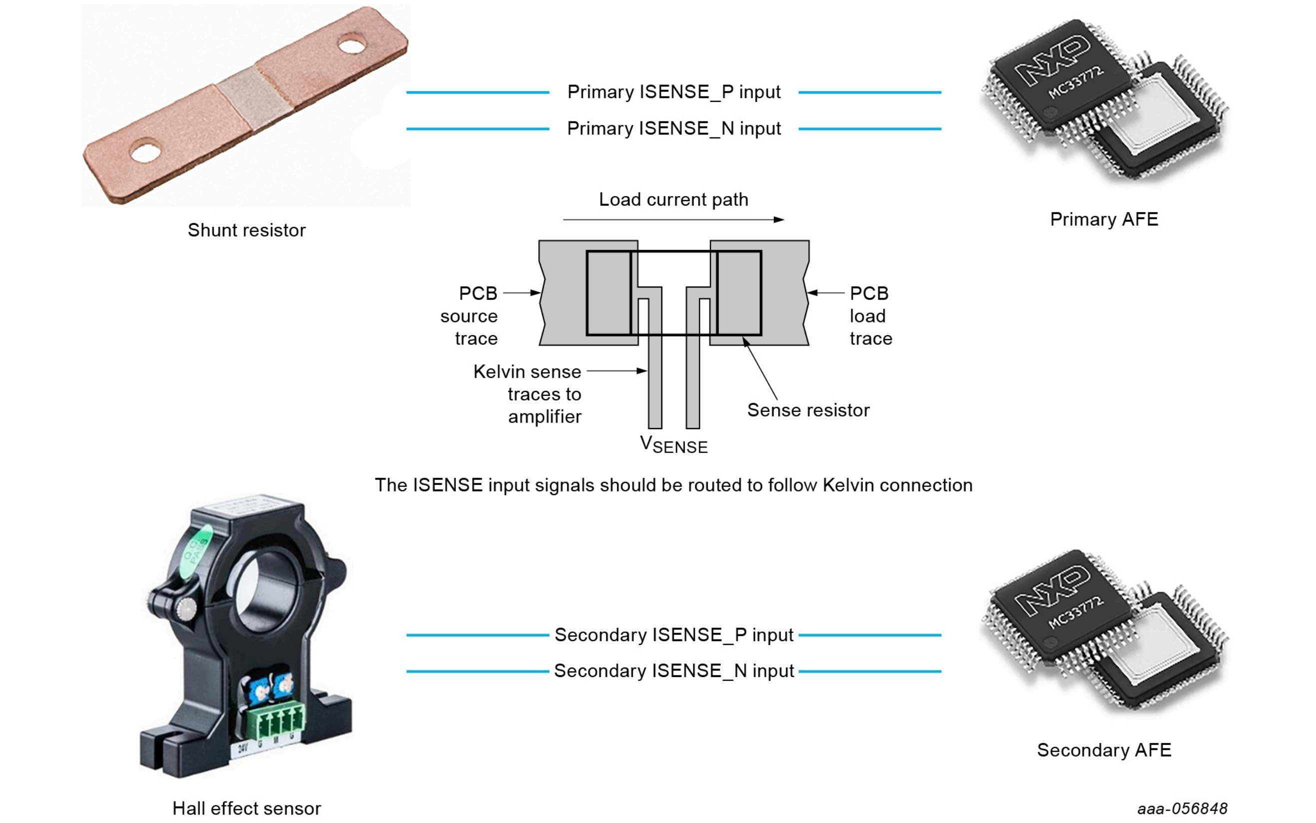

Figure 8. Current measurement layout guideline

5.2.4 Current measurement conversion

After a current measurement, both AFEs (MC33772C) return a 19-bit, signed value available in the registers MEAS_ISENSE1 and MEAS_ISENSE2. The microcontroller in the BMU computes the result using the following equation:

$$I_{MEAS} = \frac{MEAS\_ISENSE \times V_{2RES}}{R_{SHUNT}}$$

Where:

- I_{MEAS} is the result of the current measurement in A.
- MEAS_ISENSE is the result of the analog-to-digital converter (ADC) of the MC33772C (19-bit two's complement signed value, status bit removed).
- V_{2RES} is the resolution of the current measurement ADC in V/LSB (see MC33772C data sheet).
- R_{SHUNT} is the value of the shunt resistor in Ω.
  - If the current measurement uses the shunt, R_{SHUNT} = 100 μΩ.
  - If the current measurement uses the connector J5, R_{SHUNT} = 1 and the result unit is V.
  - If the current measurement uses the Hall sensor, R_{SHUNT} = 7.32 Ω.

5.3 High-voltage measurement

The RDBESS772BJBEVB measures several high voltages in the system. The BMU can compute the result and proceed, for instance, to contactor monitoring.

5.3.1 High-voltage measurement characteristics

Table 12 describes the characteristics of the high-voltage measurement feature.

Table 12. High-voltage measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{HV\text{-}MAX}$	Maximum off-state voltage	High-voltage switch disabled	−1800	-	1800	V
V_{HV+}	Positive voltage measurement range	High-voltage switch enabled	0	-	1800	V
$V_{HV+/-}$	Bipolar voltage measurement range	High-voltage switch enabled	−1800	-	1800	V
t_s	Voltage measurement settling time		-	5	-	ms
f_{HV+}	Positive voltage measurement cut-off frequency	−3 dB attenuation	-	600	-	Hz
f_{HV-}	Bipolar voltage measurement cut-off frequency	−3 dB attenuation	-	500	-	Hz

5.3.2 High-voltage measurement circuit description

The RDBESS772BJBEVB measures up to six high voltages in the system.

The four positive inputs typically monitor the voltage across the high-side contactors and fuses (for example, contactor between battery positive terminal and inverter positive terminal). These inputs accept high-voltages meeting V_{HV+} (see Section 5.3.1). Two inputs can monitor the same point in order to provide redundancy and increase the diagnostic coverage.

The two bipolar inputs typically monitor the voltage across the low-side contactors (for example, contactor between battery negative terminal and inverter negative terminal). These inputs accept high-voltages meeting $V_{HV+/-}$ (see Section 5.3.1). Two inputs can monitor the same point in order to provide redundancy and increase the diagnostic coverage.

Figure 10 describes the circuitry of positive and bipolar high-voltage measurement paths.

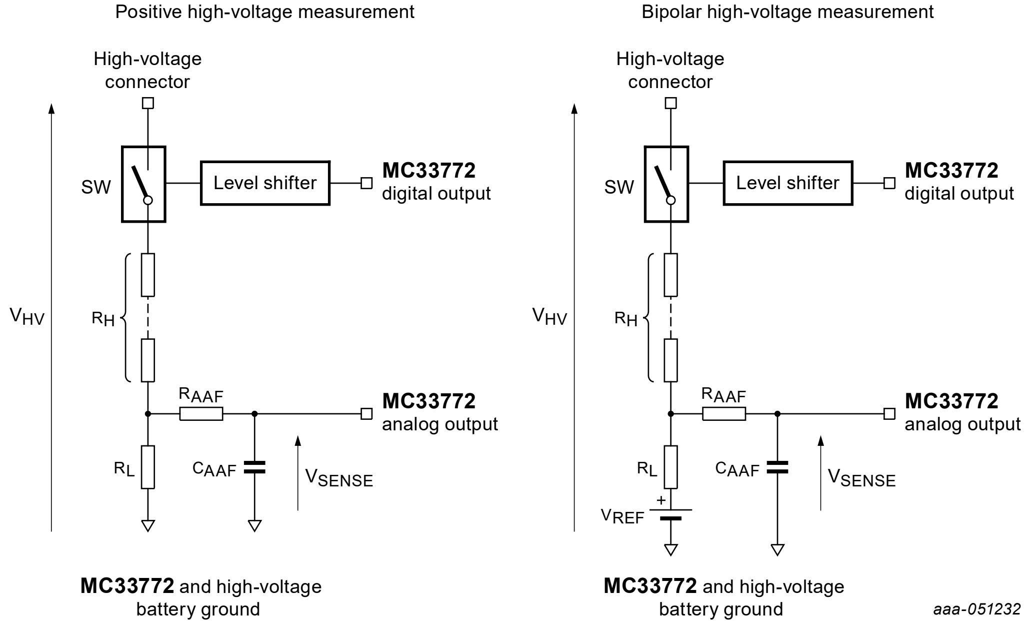

Figure 9. High-voltage measurement circuitry

In order to reduce the leakage current in the resistors when there is no measurement, a high-voltage switch can disconnect the bridge. A MC33772C digital output and a level-shifter control this switch.

A resistor bridge divides the high voltage down to the MC33772C input voltage range. The resistors forming R_H must withstand the high voltage.

For bipolar voltage measurement, a voltage reference shifts the output of the resistor bridge to half of the MC33772C input voltage range.

An analog antialiasing filter improves the noise performance. Due to the filter and the switch circuitry response time, the BMU must wait t_s before starting a voltage measurement (see Section 5.3.1).

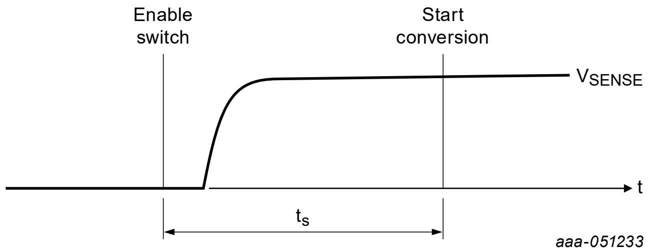

Figure 10. High-voltage measurement settling time

The MC33772C measures the divided voltage. To improve the accuracy, the user should configure the analog input as a single-ended input.

Table 13 describes the allocation of the MC33772C inputs and outputs for high-voltage measurement.

Table 13. High-voltage measurement channel allocation

High-voltage switch control signal	High-voltage measurement	MC33772C measurement input
Primary GPIO4	Primary DCLINK_POS	Primary CT1
	DCLINK_FUSE	Primary GPIO2
	Primary DCLINK_NEG	Primary GPIO0
Secondary GPIO5	Secondary DCLINK_POS	Secondary CT1

Table 13. High-voltage measurement channel allocation*...continued*

High-voltage switch control signal	High-voltage measurement	MC33772C measurement input
	DCLINK_PRE_FUSE	Secondary GPIO2
	Secondary DCLINK_NEG	Secondary GPIO1

5.3.3 High-voltage measurement conversion

After a voltage measurement, the MC33772C returns a 15-bit signed value available in the register MEAS_ANx or MEAS_CT1 depending on the channel (see Table 11). The microcontroller in the BMU computes the result using the following equations:

$$V_{HV} = \frac{R_L+R_H}{R_L} \times \left(V_{MEAS} - \frac{R_H}{R_L+R_H} \times V_{REF} \right)$$

$$V_{MEAS} = MEAS\_xxx \times V_{CT\_ANx\_RES}$$

Where:

- V_{HV} is the result of the high-voltage measurement in V
- R_L is the low-side resistor of the voltage divider in Ω (see Table 14)
- R_H is the high-side resistor of the voltage divider in Ω (see Table 14)
- V_{REF} is the voltage to which the voltage divider is referenced in V (see Table 14)
- V_{MEAS} is the MC33772C input voltage, measured by the ADC, in V
- MEAS_XXX is the result of the ADC conversion (15-bit unsigned value, status bit removed)
- $V_{CT\_ANx\_RES}$ is the resolution of the ADC in V/LSB (see MC33772C data sheet) Table 14 describes the conversion parameters depending on the type of measurement.

Table 14. Voltage conversion parameters

Parameter	Positive voltage measurement channel	Bipolar measurement channel
R_L	10 kΩ	1.0 MΩ
R_H	3.75 MΩ	3.75 MΩ
V_{REF}	0 V	2.5 V

5.3.4 Adapting circuitry for low-voltage measurements

Using a low-voltage source can ease the RDBESS772BJBEVB evaluation. However, as the board typically measures high voltages, the user should adapt the circuitry.

The simplest solution is to change the low-side resistor of the voltage divider (R_L in Figure 9). By choosing a bigger resistor, the divider ratio increases, allowing to measure smaller voltages.

The time constant of the antialiasing filter depends on the divider impedance. In order to keep the same cut-off frequency, the user should adapt the capacitor of the filter (C_{AAF} in Figure 9) along with R_L.

Table 15 presents typical values for R_L and C_{AAF} to measure low voltage. Following these values ensures meeting the MC33772C measurement range.

Table 15. Component values to measure low voltage

Low voltage to measure	Positive measurement channel		Bipolar measurement channel	
	R_L	C_{AAF}	R_L	C_{AAF}
12 V	2.32 MΩ	200 pF	1 MΩ	470 pF
24 V	887 kΩ	390 pF	420 kΩ	910 pF
48 V	397 kΩ	820 pF	180 kΩ	2 nF

The user must clearly identify the modified RDBESS772BJBEVB.

Warning!! Applying high voltage to a modified board can lead to injuries and permanent damage to the board. Any misuse will lead automatically to a loss of warranty.

5.4 Isolation monitoring

The RDBESS772BJBEVB is in between the low-voltage section (BESS chassis, 24 V battery) and the high-voltage section (high-voltage battery, inverter) of the BESS. The board embeds the circuitry to monitor the isolation between the two sections. It helps detect any isolation failure that could put the BESS user in danger.

5.4.1 Isolation monitoring characteristics

Table 16 describes the characteristics of the isolation monitoring feature.

Table 16. Isolation measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{Chassis\text{-}MAX}$	Maximum chassis off-state voltage	High-voltage switch disabled	−3000	-	3000	V
t_s	Voltage measurement settling time		-	10	-	ms

5.4.2 Isolation monitoring circuit description

Figure 11 describes the isolation monitoring circuitry.

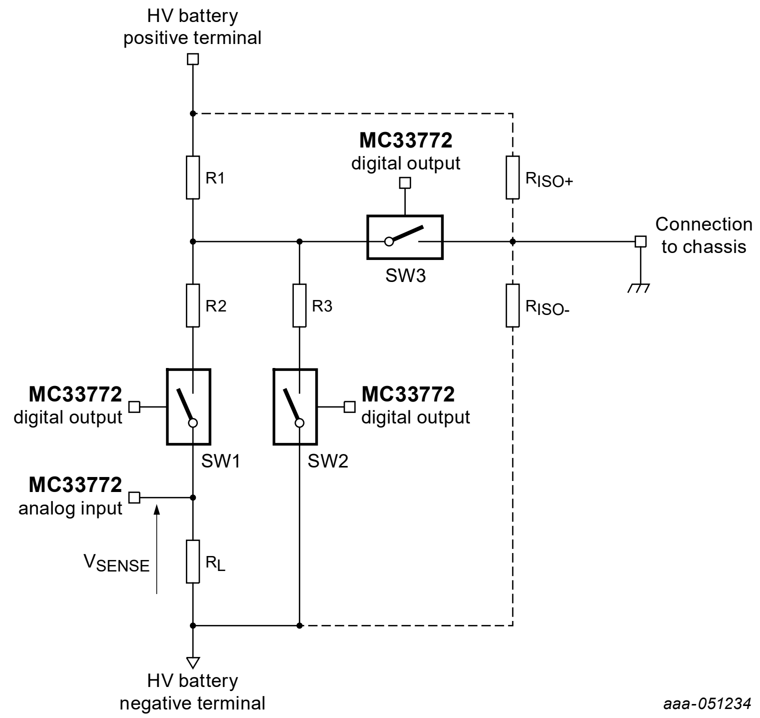

Figure 11. Isolation monitoring

This feature aims to evaluate the value of the equivalent resistance between:

- The battery positive terminal and the chassis (R_{ISO+})
- The battery negative terminal and the chassis (R_{ISO-})

A high-voltage switch (SW3) connects the chassis to the circuit prior doing the measurement. As the measurement resistors are high enough, closing SW3 does not lead to an isolation failure and does not put the BESS user in danger.

Another high-voltage switch (SW1) disconnects the resistor bridge to reduce the leakage current on the high-voltage battery when there is no measurement.

The circuit has to measure two resistors (R_{ISO+} and R_{ISO-}). Two voltage measurements are necessary to solve this two-unknown equation. The first measurement involves R1, R2, and R_L. Enabling R3 (with SW2) allows getting a second voltage measurement. Section 5.4.3 describes the measurement sequence.

The output voltage (V_{SENSE}) depends on the measurement circuitry (R1, R2, R_L, and R3 if enabled), the battery voltage, and the isolation resistors. The MC33772C measures this voltage. To improve the accuracy, the user should configure the analog input as a single-ended input. The output voltage (V_{SENSE}) is measured redundantly on both analog front-ends (AFEs) MC33772C to achieve safe operation of the BESS.

Table 17 describes the allocation of the MC33772C inputs and outputs for isolation monitoring.

Table 17. Isolation monitoring channel allocation

Function	Channel
SW1 control	Secondary GPIO6
SW2 control	Primary GPIO6
SW3 control	Primary GPIO5
V_{SENSE} primary measurement	Primary GPIO1
V_{SENSE} secondary measurement	Secondary GPIO0

Because of the switch circuitry response time, the BMU must wait t_s before starting each voltage measurement (see Section 5.4.1).

After running the sequence, the BMU computes the voltage measurements to determine the isolation resistors as explained in Section 5.4.4.

5.4.3 Isolation monitoring sequence

Table 17 describes the steps of the isolation monitoring sequence.

Table 17. Isolation monitoring sequence

Table 18.

Step	Description
1	Measure the battery voltage (ex: DCLINK_FUSE), as explained in Section 4.3
2	Convert the high-voltage measurement (as explained in Section 4.3.3); name the result V_{BAT}
3	Close SW3
4	Close SW1
5	Wait t_s (see Section 4.4.1)
6	Measure V_{SENSE}
7	Convert the voltage measurement (as explained in Section 4.4.4); name the result V_1
8	Close SW2
9	Wait t_s (see Section 4.4.1)
10	Measure V_{SENSE}
11	Convert the voltage measurement (as explained in Section 4.4.4); name the result V_2
12	Open SW1, SW2, and SW3

Table 18. *...continued*

Step	Description
13	To calculate the isolation resistors, compute the V_{BAT}, V_1, and V_2 (as explained in Section 4.4.4)

5.4.4 Isolation monitoring conversion

During the isolation monitoring sequence, the MC33772C proceeds to voltage measurements. The IC returns a 15-bit signed value available in the register MEAS_ANx. The microcontroller in the BMU computes the result in V following below equation:

$$V_{MEAS} = MEAS\_XXX \times V_{CT\_ANX\_RES}$$

Where:

- V_{MEAS} is the MC33772C input voltage, measured by the ADC, in V
- MEAS_XXX is the result of the ADC conversion (15-bit unsigned value, status bit removed)
- $V_{CT\_ANx\_RES}$ is the resolution of the ADC in V/LSB (see MC33772C data sheet)

Once the sequence is over, the BMU computes the measurements to calculate the isolation resistors. To ease the calculation, the formula uses the conductance instead of the resistance. Below equation describes the relationship between resistance and conductance.

$$Y_x = \frac{1}{R_x}$$

Where:

- Y_X is the conductance in S
- R_X is the resistance in Ω

The formula expressing the isolation resistances in function of the measurements is as follows:

$$\begin{cases} Y_{ISO+} = \frac{V_1 \times V_2}{V_{BAT} \times (V_2 - V_1)} \times \frac{Y_3(Y_L + Y_2)}{Y_2} - Y_1 \\ Y_{ISO-} = Y_{ISO+} - Y_1 - \frac{Y_L \times Y_2}{Y_L \times Y_2} - Y_3 \times \frac{V_2}{V_2 - V_1} \end{cases}$$

Where:

- Y_{ISO+} is the conductance of the positive isolation resistance in S
- Y_{ISO-} is the conductance of the negative isolation resistance in S
- V_{BAT} is the converted high-voltage measurement of the battery in V
- V_1 is the first converted voltage measurement of the sequence in V
- V_2 is the second converted voltage measurement of the sequence in V
- Y_L, Y_1, Y_2, and Y_3 are the conductances of the measurement resistors in S Table 19 describes the conversion parameters of the RDBESS772BJBEVB.

Table 19. Isolation measurement conversion parameters

Parameter	Value
R_L	24 kΩ
R_1	7.5 MΩ
R_2	7.5 MΩ
R_3	1.275 MΩ

5.5 Temperature measurement

The RDBESS772BJBEVB measures up to two temperatures with negative temperature coefficient (NTC) resistors.

The board embeds one sensor close to the shunt resistor. It allows estimation of the shunt resistor temperature in order to proceed to temperature compensation of the current measurement. The board embeds a connector in case of using an external shunt resistor.

The board offers the possibility to use an external NTC. This sensor could measure, for instance, the precharge resistor temperature.

5.5.1 Temperature measurement characteristics

Table 20 describes the characteristics of the temperature measurement feature.

Table 20. Temperature measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
RNTC-board	Onboard NTC resistor	Value at 25 °C (B57232V5103F360, TDK)	-	10	-	kΩ
RNTC-ext	External NTC resistor	Value at 25 °C	-	10	-	kΩ

5.5.2 Temperature measurement circuit description

Figure 12 describes the temperature measurement circuitry.

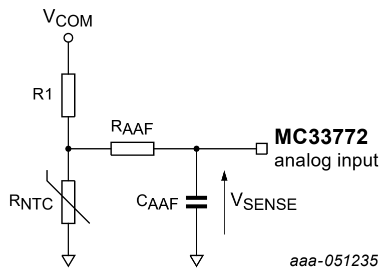

Figure 12. Temperature measurement circuitry

The regulated output voltage of the MC33772C (V_{COM}) powers the voltage divider with the NTC resistor. To improve the accuracy of the measurement, the user should configure the analog input as ratiometric input.

Table 21 describes the allocation of the MC33772C inputs for temperature measurement.

Table 21. Temperature measurement channel allocation

Function	Channel
Temperature measurement with external NTC	Primary GPIO3
Temperature measurement with onboard NTC	Secondary GPIO3

5.5.3 Temperature measurement conversion

After a temperature measurement, the MC33772C returns a 15-bit signed value available in the register MEAS_ANx. The microcontroller in the BMU computes the NTC resistor value using the following equation:

$$R_{NTC} = \frac{R_1}{\frac{2^{15}}{MEAS\_ANx} - 1}$$

Where:

- R_{NTC} is the result of the NTC resistor measurement in Ω
- R_1 is the pullup resistor, R_1 = 6.8 kΩ in the RDBESS772BJBEVB
-

$$T = \frac{\beta \times T_0}{T_0 \times ln\left(\frac{R_{NTC}}{R_0}\right) + \beta}$$

MEAS_ANx is the result of the ADC measurement (15-bit unsigned value, status bit removed) After computing the NTC resistor value, the BMU can calculate the temperature with the following equation:

Where:

- T is the result of the temperature measurement in K
- R_{NTC} is the NTC resistor measurement in Ω
- β in K, T_0 in K, and R_0 in Ω are the NTC parameters available in the NTC data sheet

5.6 Communication

The RDBESS772BJBEVB communicates with the BMU with ETPL. A transformer galvanically isolates both boards. The ETPL lines between the two MC33772C do not require isolation as the two ICs share the isolated ground. The MC33772C data sheet describes the required circuitry for the communication.

5.7 PCB design for insulation coordination

The RDBESS772BJBEVB PCB is designed according to the IEC60664-1 standard.

- The RD-BESS1500BUN specified as pollution degree 3 and material group III_b
- Based on **Table A.1** of the IEC60664-1 standard, minimum clearance distance is 10 mm
- Based on **Table F.5** of the IEC60664-1 standard, minimum creepage distance is 20 mm

6 Kit accessories

Table 22 lists the available kit accessories.

Table 22. Available kit accessories

Part number	Description
600-77624	ETPL cable, two positions, 450 mm
600-10041	Power supply cable, two positions, 300 mm
600-77763	High-voltage measurement cable, 3 kV isolation, one position, 300 mm
600-77776	External NTC resistor cable, 1 kV isolation, two positions, 300 mm
600-77765	Chassis cable, one position, 20 kV isolation, 300 mm
To be defined	Hall sensor cable, four positions, 300mm

7 References

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

8 Revision history

Table 23. Revision history

Document ID	Release date	Description
UM12145 v.1.0	20 September 2024	Initial version

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Tables

Figures

Contents

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