UM12056

RDA777T2 battery junction box reference design

Rev. 1.0 — 21 March 2025 User manual

Document information

Information	Content
Keywords	battery junction box, high voltage, 800 V, measurement, isolation, current, contactor, shunt, accuracy, temperature
Abstract	This user manual targets the RDA777T2 board. It is a typical battery junction box (BJB) solution used in high-voltage battery management system (BMS).

IMPORTANT NOTICE

For engineering development or evaluation purposes only

NXP provides this evaluation product under the following conditions:

Evaluation kits or reference designs are intended solely for technically qualified professionals, specifically for use in research and development environments to facilitate evaluation purposes. This evaluation kit or reference design is not a finished product, nor is it intended to be a part of a finished product. Any software or software tools provided with an evaluation product are subject to the applicable terms that accompany such software or software tool.

The evaluation kit or reference design is provided as a sample IC pre-soldered to a printed circuit board to make it easier to access inputs, outputs, and supply terminals. This evaluation kit or reference design may be used with any development system or other source of I/O signals by connecting it to the host MCU or computer board via off-the-shelf cables. Final device in an application will be heavily dependent on proper printed circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality. This evaluation kit or reference design provided may not be complete in terms of required design, marketing, and or manufacturing related protective considerations, including product safety measures typically found in the end device incorporating the evaluation product. Due to the open construction of the evaluation product, it is the responsibility of the user to take all appropriate precautions for electric discharge. To minimize risks associated with the customers' applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards. For any safety concerns, contact NXP sales and technical support services.

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire. This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

1 Introduction

NXP provides a BJB reference design (RD) to showcase the MC33777A.

The reference design is used to quickly prototype the hardware and software of a high-voltage battery management system. The reference design showcases the latest generation of BJB controller IC.

This document describes the reference design features.

2 Getting to know the hardware

2.1 Board features

The reference design offers the following features:

- Four current measurement channels with external shunt (from −300 mV to +300 mV)
- Eight positive high-voltage measurement inputs (from 0 V to +1000 V)
- Two bipolar high-voltage measurement inputs (from −1000 V to +1000 V)
- Isolation monitoring between high-voltage domains and low-voltage domains
- Two temperature measurement channels with an external negative temperature coefficient (NTC) resistor
- One isolated crash signal monitoring input
- Two pyrotechnic switch control outputs with independent energy reservoir capacitor
- One EEPROM for calibration data storage
- Galvanically isolated electrical transport protocol link (ETPL) for communication
- Galvanically isolated DC-DC converter to supply the board from the low-voltage section
- Printed-circuit board (PCB) designed according to IEC 60664 (pollution degree 2, material group IIIa)

2.2 Connectors

Figure 1 shows the location of the connectors interfacing the reference design with a power supply, an emulator, or external instruments.

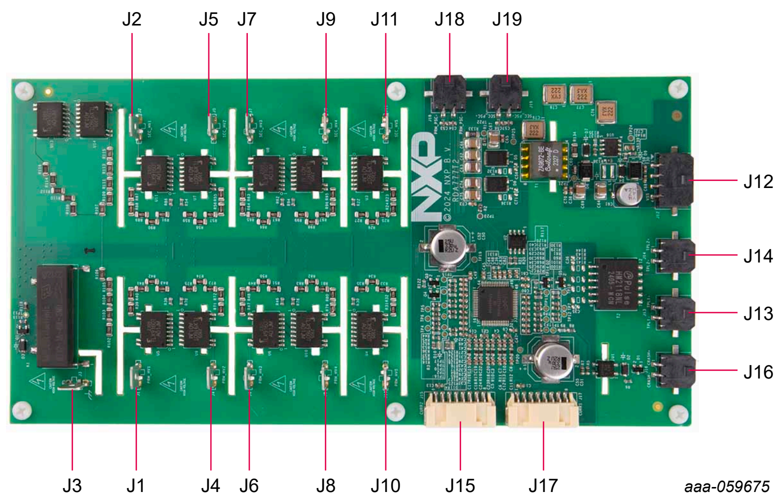

Figure 1. Connector location

Table 1. Connector description

Pin	Connection	Description
Power supply connector (J12)		
J12.1	+12 V	positive power supply terminal
J12.2	NC	not connected
J12.3	NC	not connected
J12.4	LV_GND	negative power supply terminal
ETPL communication (J13)		
J13.1	TPL1_P	ETPL positive input
J13.2	TPL1_N	ETPL negative input
ETPL communication (J14)		
J14.1	TPL2_P	ETPL positive input
J14.2	TPL2_N	ETPL negative input
Crash signal input (J16)		
J16.1	CRASH_P	crash signal positive input
J16.2	CRASH_N	crash signal reference ground
Primary pyrotechnic switch controller output (J18)		
J18.1	PRM_PSC_P	primary pyrotechnic switch controller high-side output
J18.2	PRM_PSC_N	primary pyrotechnic switch controller low-side output
Secondary pyrotechnic switch controller output (J19)		
J19.1	SEC_PSC_P	secondary pyrotechnic switch controller high-side output
J19.2	SEC_PSC_N	secondary pyrotechnic switch controller low-side output
High-voltage connections		
J1	PRM_HV_1	primary positive high-voltage input 1
J2	SEC_HV_1	secondary positive high-voltage input 1
J4	PRM_HV_2	primary positive high-voltage input 2
J5	SEC_HV_2	secondary positive high-voltage input 2
J6	PRM_HV_3	primary positive high-voltage input 3
J7	SEC_HV_3	secondary positive high-voltage input 3
J8	PRM_HV_4	primary positive high-voltage input 4
J9	SEC_HV_4	secondary positive high-voltage input 4
J10	PRM_HV_5	primary bipolar high-voltage input 5
J11	SEC_HV_5	secondary bipolar high-voltage input 5
J3	chassis	chassis input for isolation measurement
First current and temperature measurement connection (J15)		
J15.1	NTC_P	external NTC resistor positive input
J15.2	HV_GND	external NTC resistor negative input
J15.3	HV_GND	ground

Table 1. Connector description*...continued*

Pin	Connection	Description
J15.4	PRM_ISENSE_P	primary ISENSE positive input
J15.5	PRM_ISENSE_N	primary ISENSE negative input
J15.6	HV_GND	ground
J15.7	SEC_ISENSE_P	secondary ISENSE positive input
J15.8	SEC_ISENSE_N	secondary ISENSE negative input
Second current and temperature measurement connection (J17)		
J17.1	NTC_P	external NTC resistor positive input
J17.2	HV_GND	external NTC resistor negative input
J17.3	HV_GND	ground
J17.4	PRM_VISENSE_P	primary VISENSE positive input
J17.5	PRM_VISENSE_N	primary VISENSE negative input
J17.6	HV_GND	ground
J17.7	SEC_VISENSE_P	secondary VISENSE positive input
J17.8	SEC_VISENSE_N	secondary VISENSE negative input

Table 2 lists the reference of the connectors and their mating part number.

Table 2. Connector part number

Connector	Manufacturer	Part number	Mating connector
J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11	TE Connectivity	63824-1	2-520405-2
J13, J14, J16, J18, J19	Molex	436500213	436450200
J12	Molex	0436500413	436450400
J15, J17	Molex	5023520800	5023510800

2.3 LEDs

The battery junction box embeds two LEDs: D10 and D11. They are switched on when the MC33777A is in active mode.

2.4 Kit contents

Table 3 lists the components included in the kit.

Table 3. Kit contents

Description	Quantity
ETPL communication cable	1
Power supply cable	1
High-voltage measurement cable (orange)	10
Chassis connection cable (black)	1
Two-point general-purpose cable (pyrotechnic switch connection, crash signal connection)	4
Current measurement and temperature measurement cable	2

2.5 Extra hardware

The RDA777T2 requires an external +12 V power supply (see Section 3.1).

The following equipment can also ease the evaluation:

- ETPL communication board (KIT-PC2TPLEVB)
- Battery junction box emulator to emulate the high voltages, the battery current, and the pyrotechnic switch controllers (PACK-BJBEMUL)
- High-voltage source
- High-current source coupled with a shunt resistor

2.6 Configure the hardware

This section describes the typical setup to configure the RDA777T2 and to evaluate the MC33777A key features.

It uses a PACK-BJBEMUL to emulate the voltages, the battery current, and the pyrotechnic switches. Any other external equipment can replace the optional board.

The setup shows a KIT-PC2TPLEVB board to interface the MC33777A with the computer via NXP software tools (for example, BMS ScriptGUI).

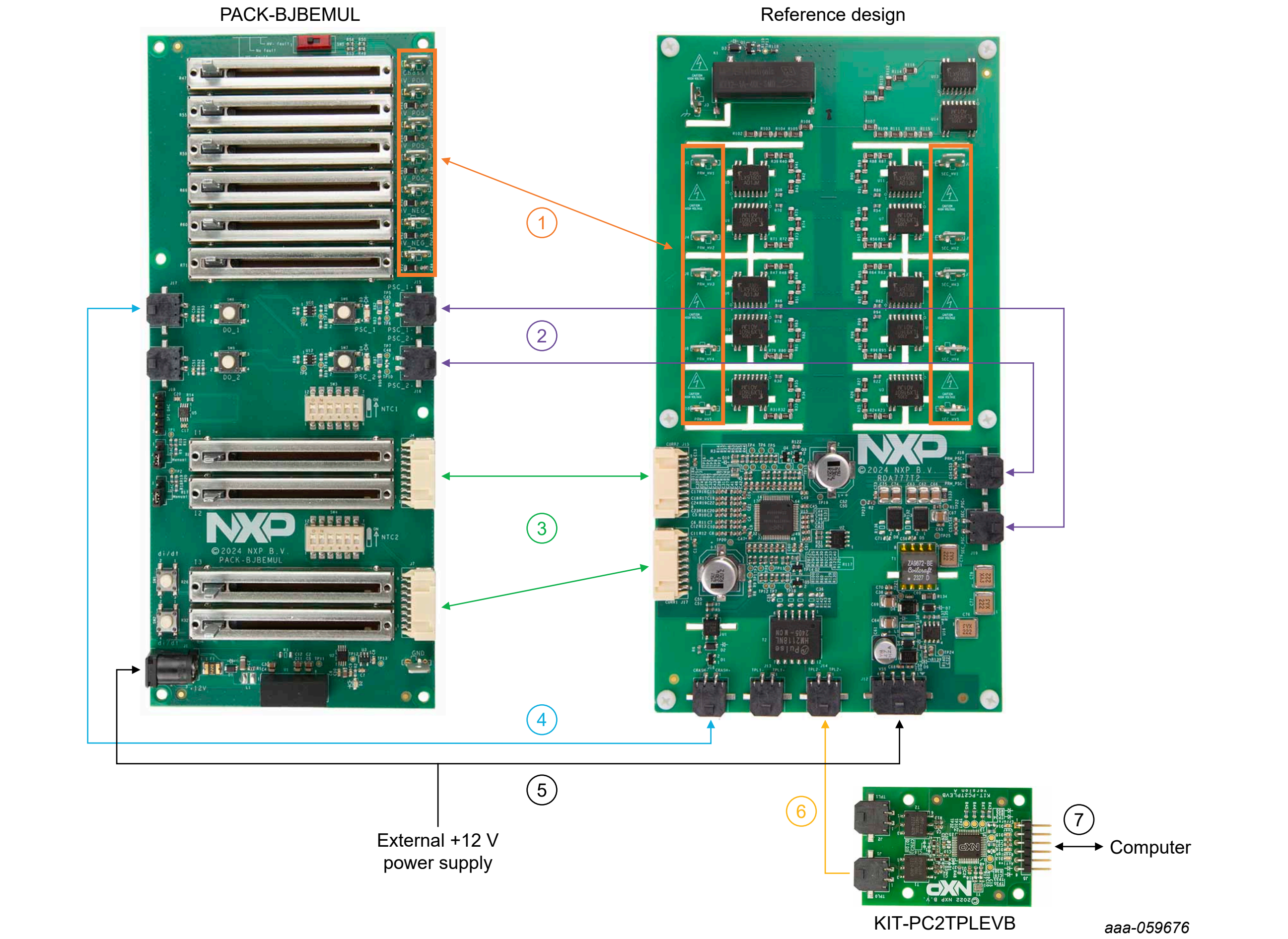

Figure 2. Hardware setup

Table 4 lists the material required to set up the test.

Table 4. Bill of materials

Identifier	Description	Comment
RDA777T2	battery junction box reference design	
PACK-BJBEMUL	battery junction box emulator	
KIT-PC2TPLEVB	communication board	
1	voltage measurement cable	included in the kit
2	pyrotechnic switch cable	included in the kit
3	current and temperature measurement cable	included in the kit
4	crash signal cable	included in the kit
5	power supply cable	included in the kit
6	ETPL communication cable	included in the kit
7	USB to universal asynchronous receiver/transmitter (UART) cable	included in the KIT-PC2TPLEVB kit

3 Feature description

3.1 Power supply

The reference design usually receives power from the battery management unit (BMU) on the connector J12. The power supply must follow the characteristics described in Table 5.

Table 5. Power supply characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{CC}	supply voltage		6	12	35	V
I_{CC}	supply current	12 V output voltage, RDA777T2 in active mode	500	-	-	mA

The BMU is in the low-voltage domain, whereas the BJB is in the high-voltage domain. Therefore, the RDA777T2 embeds an isolated DC-DC converter to power the MC33777A and the external circuitry. The converter provides a 1.5 kV isolation.

3.2 Current measurement

The RDA777T2 measures up to four currents.

For typical use cases, two channels are sufficient to measure redundantly the battery current to meet ASIL D safety goals.

For more complex systems (for example, switched battery packs with two separate current measurements), the reference design offers two extra current measurement channels.

3.2.1 Current measurement characteristics

The user can connect to current measurement inputs to:

- A shunt resistor to measure the current flowing in it
- An external voltage source emulating the shunt resistor voltage drop

Table 6 lists the current measurement input characteristics.

Table 6. Current measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{pin}	pin voltage	voltage from P pin or N pin relatively to GND	−300	-	+300	mV
V_{dif}	differential voltage	voltage from P pin relatively to N pin	−300	-	+300	mV

The board follows the MC33777A data sheet regarding the required external components.

3.2.2 Current measurement connection

The RDA777T2 measures the current on the following MC33777A inputs:

Table 7. Current measurement channel allocation

Current measurement	MC33777A measurement lines
Primary ISENSE inputs	PRM_ISENSEP and PRM_ISENSEN
Primary VISENSE inputs	PRM_VISENSEP and PRM_VISENSEN
Secondary ISENSE inputs	SEC_ISENSEP and SEC_ISENSEN
Secondary VISENSE inputs	SEC_VISENSEP and SEC_VISENSEN

The current measurement connector also offers MC33777A ground connections. The ground lines are separated from the measurement lines. It removes the current in the positive/negative lines and improves the accuracy.

The user can evaluate the current measurement with two methods:

- Applying a current in a shunt resistor
- Using an external voltage source

Figure 3 shows an example of a connection on a shunt resistor.

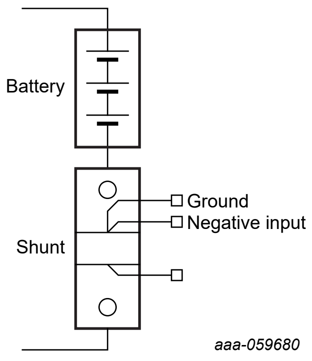

Figure 3. Current measurement with a shunt resistor

The positive and negative lines are connected on both sides of the shunt sensing element. Inverting the orientation of the lines simply inverts the polarity of the current measurement.

In the given example, a battery discharge current gives a positive measurement. A battery charge current gives a negative measurement.

The user must connect the ground line to any side of the shunt resistors. It ensures that the shunt common mode voltage meets the MC33777A input range.

Figure 4 shows an example of a connection with a voltage source.

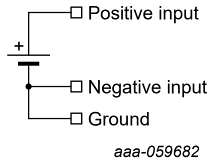

Figure 4. Current measurement with a voltage source

To evaluate the current measurement, the user can also connect a voltage source to the inputs. Then, there is no need for a high-voltage battery or a high-current source.

The positive and negative lines are connected on both sides of the voltage source. Inverting the orientation of the lines simply inverts the polarity of the current measurement.

The user must connect the ground line to any side of the voltage source. It ensures that the common mode voltage meets the MC33777A input range.

3.2.3 Current measurement conversion

The MC33777A automatically converts the input voltage measurement to a current value (more information is available in the device reference manual).

The user must configure the sensor current to voltage ratio in a register (for example, the external shunt conductance).

3.3 Temperature measurement

The RDA777T2 measures two temperatures with external NTC resistors. The user has the possibility to place the NTC resistor close to the shunt resistor to measure its temperature.

3.3.1 Temperature measurement characteristics

Table 8 describes the characteristics of the temperature measurement feature.

Table 8. Temperature measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VREF5V0	biasing voltage		-	5	-	V
R_{pu}	pull-up resistance		-	10	-	kΩ
$R_{NTC(ext)}$	external NTC resistance	T_{amb} = 25 °C	-	10	-	kΩ

3.3.2 Temperature measurement circuit description

The user can directly connect the external NTC resistor between the two dedicated pins on the current measurement connector.

The temperature measurement circuitry follows the MC33777A data sheet recommendations.

The RDA777T2 measures the temperature on the following inputs:

Table 9. Temperature measurement channel allocation

Temperature measurement	MC33777A input
Primary temperature measurement	PRM_IO6
Secondary temperature measurement	SEC_IO6

The MC33777A outputs a 5 V source to bias the NTC resistor. To improve the accuracy of the measurement, the user must configure the analog input for ratiometric measurements.

3.3.3 Temperature measurement conversion

With the analog input configured for ratiometric measurements, the MC33777A returns a ratio of the biasing voltage.

The system controller can calculate the NTC value using the following equation:

$$R_{NTC} = R_{TC} \times \frac{RESULT \times \Delta_{res(ratio\text{-}io)}}{1\text{-}RESULT \times \Delta_{res(ratio\text{-}io)}}$$

Where:

- R_{NTC} is the result of the NTC calculation in Ω
- R_{TC} is the pullup resistor in Ω
- RESULT is the result of the analog-to-digital converter (ADC) measurement (16-bit value)
- $\Delta_{res(ratio\text{-}io)}$ is the ratiometric measurement resolution (see MC33777A data sheet)

Then, the controller can compute the temperature by using the NTC resistor data sheet (for example: calculation with β coefficient, or with look-up table).

3.4 High-voltage measurement

The RDA777T2 measures several high voltages in the system. The BMU can compute the result and proceed, for instance, to contactor monitoring.

3.4.1 High-voltage measurement characteristic

Table 10 describes the high-voltage measurement characteristics.

Table 10. High-voltage measurement characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_D	off-state voltage	high-voltage switch disabled	−1500	-	+1500	V
V_{hv+}	positive voltage measurement range	high-voltage switch enabled	0	-	1000	V
V_{hv-}	bipolar voltage measurement range	high-voltage switch enabled	−1000	-	+1000	V
f_{-3dB}	cut-off frequency		-	340	-	Hz
t_s	settling time		-	3	-	ms

3.4.2 High-voltage measurement circuit description

The RDA777T2 measures up to ten high voltages in the system.

The eight positive inputs typically monitor the voltage across the high-side contactors and high-side fuses (for example, a contactor between the battery positive terminal and the inverter positive terminal). These inputs accept high voltages meeting V_{hv+}. Two inputs (one primary and another secondary) can monitor the same point to provide redundancy and increase the overall safety integrity level.

The two bipolar inputs typically monitor the voltage across the low-side contactors (for example, a contactor between the battery negative terminal and the charger negative terminal). These inputs accept high voltages meeting V_{hv-}.

Figure 5 describes the circuitry of positive and bipolar high-voltage measurement paths.

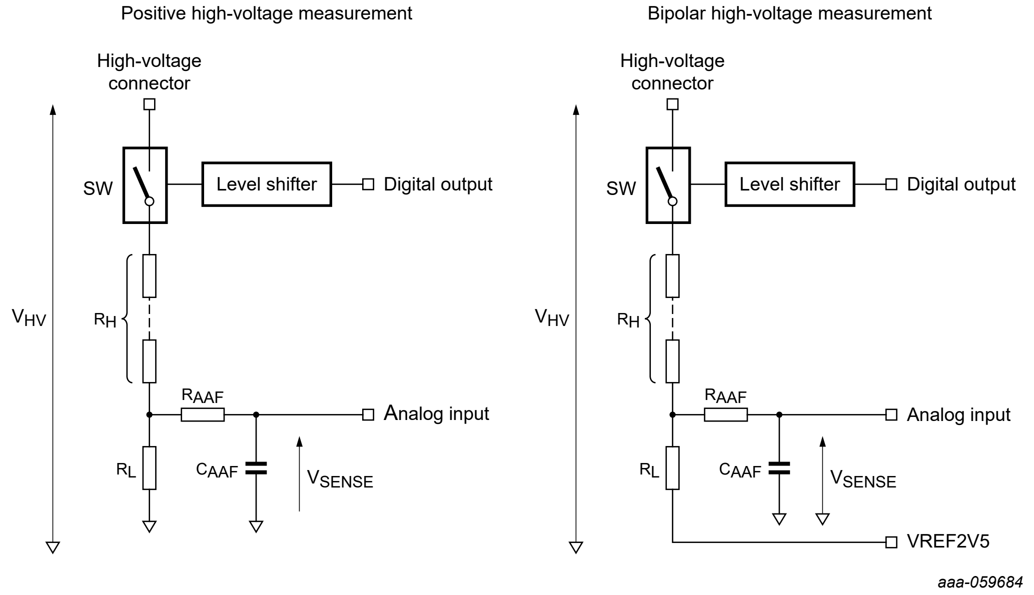

Figure 5. High-voltage measurement circuitry

To reduce the leakage current in the resistors when there is no measurement, a high-voltage switch can disconnect the bridge. An MC33777A digital output controls this switch.

A voltage divider divides the high voltage down to the device input voltage range. The resistors forming R_H must withstand the high voltage.

To avoid leakages due to the high voltage, the board has to ensure a big enough creepage distance between the different nodes. The cuttings in the PCB increase the creepage distance. The cuttings are optional when using coating or with lower voltages.

For bipolar voltage measurement, the MC33777A outputs a 2.5 V reference. It shifts the output of the resistor bridge to half of the MC33777A input voltage range. The device can do a differential measurement between the output of the divider and the reference.

An analog anti-aliasing filter improves the noise performance. Due to the filter and the switch circuitry response time, the controller must wait t_s before starting a voltage measurement.

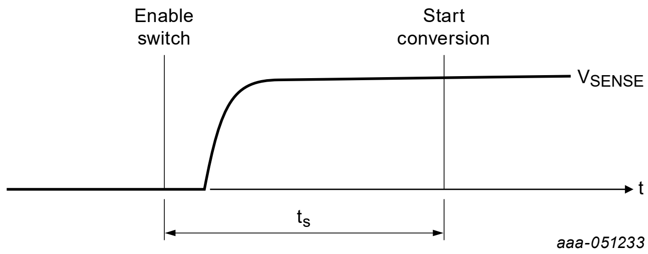

Figure 6. High-voltage measurement settling time

The MC33777A measures the divided voltage. To improve the accuracy, the user must configure the analog input as:

- Absolute mode (for positive measurements)
- Differential mode versus 2.5 V reference (for bipolar measurements)

3.4.3 High-voltage measurement channel allocation

Table 11 describes the RDA777T2 high-voltage measurement channel allocation.

Table 11. Channel allocation

High-voltage measurement	MC33777A measurement input	High-voltage switch control signal
Primary positive high-voltage input 1	PRM_IO1	PRM_IO0
Primary positive high-voltage input 2	PRM_IO2	
Primary positive high-voltage input 3	PRM_IO3	
Primary positive high-voltage input 4	PRM_IO4	
Primary bipolar high-voltage input 5	PRM_IO5	
Secondary positive high-voltage input 1	SEC_IO1	SEC_IO0
Secondary positive high-voltage input 2	SEC_IO2	
Secondary positive high-voltage input 3	SEC_IO3	
Secondary positive high-voltage input 4	SEC_IO4	
Secondary bipolar high-voltage input 5	SEC_IO5	

3.4.4 Positive-voltage measurement conversion

For positive-voltage measurements, the voltage divider is referenced to the MC33777A ground.

The device directly measures the output voltage of the divider as:

$$V_{SENSE} = V_{ADC} = V_{HV} \times \frac{R_L}{R_L+R_H}$$

Then, the controller can compute the high-voltage measurement as:

$$V_{HV} = V_{ADC} \times \frac{R_L}{R_L+R_H} = RESULT \times V_{res(abs\text{-}io)} \times \frac{R_L}{R_L+R_H}$$

With:

- V_{HV} is the high voltage to measure in V
- V_{SENSE} is the output of the voltage divider in V
- V_{ADC} is the device measurement in V
- R_L is the low-side divider resistor equal to 10 kΩ
- R_H is the high-side divider resistor equal to 2.1 MΩ
- RESULT is the device measurement result (16-bit number)
- $V_{res(abs\text{-}io)}$ is the device measurement resolution equal to 154 µV/LSB

3.4.5 Bipolar-voltage measurement conversion

For bipolar-voltage measurements, the voltage divider is referenced to the MC33777A 2.5 V reference.

The output voltage of the divider is:

$$V_{SENSE} = V_{HV} \times \frac{R_L}{R_L+R_H} + V_{REF} \times \frac{R_H}{R_L+R_H}$$

The device runs a differential measurement between the output of the divider and the 2.5 V reference:

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

Then, the controller can calculate the high-voltage measurement as:

$$V_{HV} = V_{ADC} \times \frac{R_L + R_H}{R_L} + V_{REF} = RESULT \times V_{res(v2v5\text{-}io)} \times \frac{R_L + R_H}{R_L} + V_{REF}$$

With:

- V_{HV} is the high voltage to measure in V
- V_{SENSE} is the output of the voltage divider in V
- V_{ADC} is the device measurement in V
- R_L is the low-side divider resistor equal to 4.7 kΩ
- R_H is the high-side divider resistor equal to 2.1 MΩ
- RESULT is the device measurement result (16-bit number)
- $V_{res(v2v5\text{-}io)}$ is the device measurement resolution equal to 154 μV/LSB

3.4.6 Adapting circuitry for low-voltage measurements

Using a low-voltage source can ease the RDA777T2 evaluation. However, as the board typically measures high voltages, the user can adapt the circuitry.

The simplest solution is to change the low-side divider resistor (R_L). By choosing a higher value resistor, the divider ratio increases.

The time constant of the anti-aliasing filter depends on the divider impedance. To keep the same cut-off frequency, the user can adapt the capacitor of the filter (C_{AAF}) along with R_L.

Table 12 presents typical values for R_L and C_{AAF} to measure low voltage. Following these values ensures meeting the MC33777A measurement range.

Table 12. Component value to measure low voltage

Low voltage to measure	Positive measurement channel		Bipolar measurement channel	
	R_L	C_{AAF}	R_L	C_{AAF}
12 V	1.3 MΩ	680 pF	470 kΩ	1.5 nF
24 V	470 kΩ	1.5 nF	220 kΩ	2.2 nF
48 V	220 kΩ	2.2 nF	100 kΩ	4.7 nF

The user must clearly identify the modified boards. Applying high voltage to a modified board can lead to injuries and permanent damage to the board.

3.5 Isolation monitoring

The RDA777T2 is in between the low-voltage section (car chassis, +12 V battery) and the high-voltage section (high-voltage battery, inverter) of the car.

The board embeds the circuitry to monitor the isolation between the two sections. It helps to detect any isolation failure that could put the car user in danger.

Note: *The RDA777T2 provides the isolation monitoring circuitry as an example to demonstrate the usage. The example has not undergone extensive testing in production. NXP advises the user to evaluate its suitability for their specific use cases.*

3.5.1 Isolation monitoring characteristics

Table 13 describes the characteristics of the isolation monitoring feature.

Table 13. Isolation monitoring characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{D(chassis)(max)}$	maximum chassis off-state voltage	high-voltage switch disabled	−3000	-	+3000	V
t_s	settling time	excluding external capacitors	-	10	-	ms

3.5.2 Isolation monitoring circuit description

Figure 7 describes the isolation monitoring circuitry.

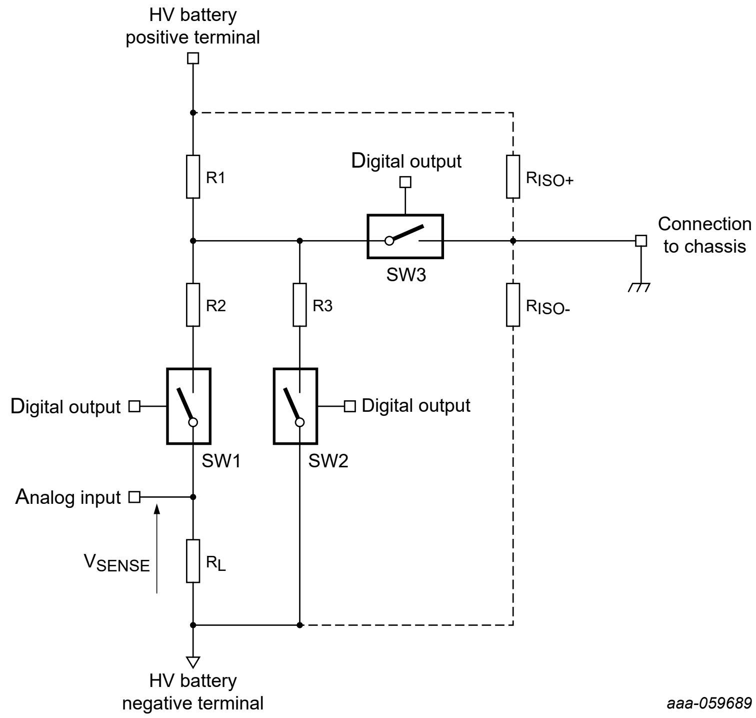

Figure 7. Isolation monitoring circuitry

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 before measuring. As the measurement resistors are high enough, closing SW3 does not lead to an isolation failure and does not put the car 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 3.5.3 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 MC33777A measures this voltage. To improve the accuracy, the user must configure the analog input for absolute measurements.

Table 14 describes the allocation of the MC33777A inputs and outputs for isolation monitoring.

Table 14. Isolation monitoring channel allocation

Function	Channel
SW1 control	PRM_IO0
SW2 control	GPIO1
SW3 control	GPIO0
V_{SENSE} measurement	PRM_IO7

Due to the switch circuitry response time, the BMU must wait t_s before starting each voltage measurement.

After running the sequence, the BMU computes the voltage measurements to determine the isolation resistors as explained in Section 3.5.4.

3.5.3 Isolation monitoring sequence

Table 15 describes the steps of the isolation monitoring sequence.

Table 15. Isolation monitoring sequence

Step	Description
1	measure the battery voltage as explained in Section 3.4
2	convert the high-voltage measurement (as explained in Section 3.4.4); name the result V_{BAT}
3	close SW3
4	close SW1
5	wait t_s
6	measure V_{SENSE}
7	convert the voltage measurement (as explained in Section 3.5.4); name the result V_1
8	close SW2
9	wait t_s
10	measure V_{SENSE}
11	convert the voltage measurement (as explained in Section 3.5.4); name the result V_2
12	open SW1, SW2, and SW3
13	to calculate the isolation resistors, compute the V_{BAT}, V_1, and V_2 (as explained in Section 3.5.4)

3.5.4 Isolation monitoring conversion

During the isolation monitoring sequence, the MC33777A proceeds to voltage measurements. The IC returns a 16-bit. The controller computes the result in V following below equation:

$$V_{\text{meas}} = RESULT \times V_{res(abs\text{-}io)}$$

Where:

- V_{meas} is the MC33777A input voltage, measured by the ADC, in V
- RESULT is the result of the ADC conversion
- $V_{res(abs\text{-}io)}$ is the device measurement resolution equal to 154 µV/LSB

Once the sequence is over, the controller computes the measurements to calculate the isolation resistors. To ease the calculation, the formula uses the conductance instead of the resistance.

The 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:

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

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 16 describes the conversion parameters of the RDA777T2.

Table 16. Isolation measurement conversion parameters

Parameter	Value
R_L	24 kΩ
R_1	4.03 MΩ
R_2	4.03 MΩ
R_3	685 kΩ

3.6 Crash signal monitoring

The RDA777T2 monitors an isolated digital signal. It can be a crash signal coming from the low-voltage section. Then, the MC33777A can trigger a reaction (for example, pyrotechnic switch controller) based on the signal state.

3.6.1 Crash signal monitoring characteristics

Table 17 describes the crash signal monitoring characteristics.

Table 17. Crash signal monitoring characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{i(range)}$	input voltage range		0	-	12	V
V_{th}	threshold voltage	input signal low/high or high/low	-	2.5	-	V
V_{HV}	high voltage	RMS value; primary to secondary isolation; ensured by VOMA617A-4X001T	-	3750	-	V

3.6.2 Crash signal monitoring circuitry

Figure 8 describes the crash signal monitoring circuitry.

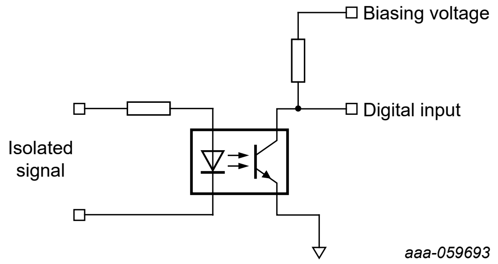

Figure 8. Crash signal monitoring circuitry

The circuitry accepts any voltage meeting V_{in}. An optocoupler isolates the signal and forwards the information to the MC33777A. The device outputs a 5 V biasing voltage and monitors the signal on a digital input.

The circuitry inverts the signal:

- An input signal lower than V_{th} results in a high-level reading
- An input signal higher than V_{th} results in a low-level reading

Table 18 describes the channel allocation.

Table 18. Crash signal monitoring channel allocation

Function	Channel
Biasing voltage	SEC_VREF5V0
Digital input	SEC_IO7

3.7 Pyrotechnic switch control

The RDA777T2 supports the driving of two pyrotechnic switches, with the MC33777A independent pyrotechnic switch controllers.

3.7.1 Pyrotechnic switch control characteristics

Table 19 describes the pyrotechnic switch control characteristics.

Table 19. Pyrotechnic switch control characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
CER	energy reservoir capacitance	primary capacitor and secondary capacitor	-	1000	-	µF
V_{CER}	energy reservoir capacitor voltage	see MC33777A data sheet	-	18	-	V
I_{ch}	charge current	R_{PSC_CFG} = 200 kΩ	-	86	-	mA
t_{ch}	charge time	R_{PSC_CFG} = 200 kΩ	-	210	-	ms

3.7.2 Pyrotechnic switch control circuitry

The two MC33777A pyrotechnic switch controllers are available on two connectors. The user can connect:

- Both controllers to a single pyrotechnic switch (redundant driving)
- Each controller to a different pyrotechnic switch (independent driving)

Both pyrotechnic switch controllers have an independent energy reservoir capacitor (CER). If there is a power supply loss, the capacitors store the energy for the firing and keep the device active.

By default, the resistors connected on the pin PSC_CFG configures the capacitor charge current to I_{charge}.

3.8 Communication

The RDA777T2 communicates with the BMU with ETPL. A transformer galvanically isolates both boards. The MC33777A data sheet describes the required circuitry for the communication.

4 References

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

The information page for the MC33777A is http://nxp.com/mc33777. The page provides overview information, documentation, software and tools, parametrics, ordering information and a getting started tab.

5 Revision history

Revision history

Document ID	Release date	Description
UM12056 v.1.0	21 March 2025	initial version

Legal information

Definitions

Draft — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Terms and conditions of commercial sale — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at https://www.nxp.com/profile/terms, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

Suitability for use in automotive applications — This NXP product has been qualified for use in automotive applications. If this product is used by customer in the development of, or for incorporation into, products or services (a) used in safety critical applications or (b) in which failure could lead to death, personal injury, or severe physical or environmental damage (such products and services hereinafter referred to as "Critical Applications"), then customer makes the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, safety, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP. As such, customer assumes all risk related to use of any products in Critical Applications and NXP and its suppliers shall not be liable for any such use by customer. Accordingly, customer will indemnify and hold NXP harmless from any claims, liabilities, damages and associated costs and expenses (including attorneys' fees) that NXP may incur related to customer's incorporation of any product in a Critical Application.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Evaluation products — This evaluation product is intended solely for technically qualified professionals, specifically for use in research and development environments to facilitate evaluation purposes. It is not a finished product, nor is it intended to be a part of a finished product. Any software or software tools provided with an evaluation product are subject to the applicable license terms that accompany such software or software tools.

This evaluation product is provided on an "as is" and "with all faults" basis for evaluation purposes only and is not to be used for product qualification or production. If you choose to use these evaluation products, you do so at your risk and hereby agree to release, defend and indemnify NXP (and all of its affiliates) for any claims or damages resulting from your use. NXP, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this evaluation product remains with user.

In no event shall NXP, its affiliates or their suppliers be liable to user for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the evaluation product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that user might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP, its affiliates and their suppliers and user's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by user based on reasonable reliance up to the greater of the amount actually paid by user for the evaluation product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose and shall not apply in case of willful misconduct.

HTML publications — An HTML version, if available, of this document is provided as a courtesy. Definitive information is contained in the applicable document in PDF format. If there is a discrepancy between the HTML document and the PDF document, the PDF document has priority.

Translations — A non-English (translated) version of a document, including the legal information in that document, is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

Security — Customer understands that all NXP products may be subject to unidentified vulnerabilities or may support established security standards or specifications with known limitations. Customer is responsible for the design and operation of its applications and products throughout their lifecycles to reduce the effect of these vulnerabilities on customer's applications and products. Customer's responsibility also extends to other open and/or proprietary technologies supported by NXP products for use in customer's applications. NXP accepts no liability for any vulnerability. Customer should regularly check security updates from NXP and follow up appropriately.

Customer shall select products with security features that best meet rules, regulations, and standards of the intended application and make the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP.

NXP has a Product Security Incident Response Team (PSIRT) (reachable at PSIRT@nxp.com) that manages the investigation, reporting, and solution release to security vulnerabilities of NXP products.

NXP B.V. — NXP B.V. is not an operating company and it does not distribute or sell products.

Trademarks

Notice: All referenced brands, product names, service names, and trademarks are the property of their respective owners.

NXP — wordmark and logo are trademarks of NXP B.V.

Tables

Tab. 1. Connector description 4
Tab. 2. Connector part number 5
Tab. 3. Kit contents 5
Tab. 4. Bill of materials 7
Tab. 5. Power supply characteristics 7
Tab. 6. Current measurement characteristics 8
Tab. 7. Current measurement channel allocation 8
Tab. 8. Temperature measurement characteristics 9
Tab. 9. Temperature measurement channel allocation 9
Tab. 10. High-voltage measurement characteristics 10
Tab. 11. Channel allocation 12
Tab. 12. Component value to measure low voltage 13
Tab. 13. Isolation monitoring characteristics 14
Tab. 14. Isolation monitoring channel allocation 15
Tab. 15. Isolation monitoring sequence 15
Tab. 16. Isolation measurement conversion parameters 16
Tab. 17. Crash signal monitoring characteristics 16
Tab. 18. Crash signal monitoring channel allocation 17
Tab. 19. Pyrotechnic switch control characteristics 17

Figures

Fig. 1. Connector location 3
Fig. 2. Hardware setup 6
Fig. 3. Current measurement with a shunt resistor 8
Fig. 4. Current measurement with a voltage source 9
Fig. 5. High-voltage measurement circuitry 11
Fig. 6. High-voltage measurement settling time 11
Fig. 7. Isolation monitoring circuitry 14
Fig. 8. Crash signal monitoring circuitry 17

Contents

1 **Introduction** 3
2 **Getting to know the hardware** 3
2.1 Board features 3
2.2 Connectors 3
2.3 LEDs 5
2.4 Kit contents 5
2.5 Extra hardware 6
2.6 Configure the hardware 6
3 **Feature description** 7
3.1 Power supply 7
3.2 Current measurement 7
3.2.1 Current measurement characteristics 7
3.2.2 Current measurement connection 8
3.2.3 Current measurement conversion 9
3.3 Temperature measurement 9
3.3.1 Temperature measurement characteristics 9
3.3.2 Temperature measurement circuit description 9
3.3.3 Temperature measurement conversion 10
3.4 High-voltage measurement 10
3.4.1 High-voltage measurement characteristic 10
3.4.2 High-voltage measurement circuit description 10
3.4.3 High-voltage measurement channel allocation 12
3.4.4 Positive-voltage measurement conversion 12
3.4.5 Bipolar-voltage measurement conversion 12
3.4.6 Adapting circuitry for low-voltage measurements 13
3.5 Isolation monitoring 13
3.5.1 Isolation monitoring characteristics 13
3.5.2 Isolation monitoring circuit description 14
3.5.3 Isolation monitoring sequence 15
3.5.4 Isolation monitoring conversion 15
3.6 Crash signal monitoring 16
3.6.1 Crash signal monitoring characteristics 16
3.6.2 Crash signal monitoring circuitry 17
3.7 Pyrotechnic switch control 17
3.7.1 Pyrotechnic switch control characteristics 17
3.7.2 Pyrotechnic switch control circuitry 17
3.8 Communication 18
4 **References** 18
5 **Revision history** 18
Legal information 19

Date of release: 21 March 2025
Document identifier: UM12056