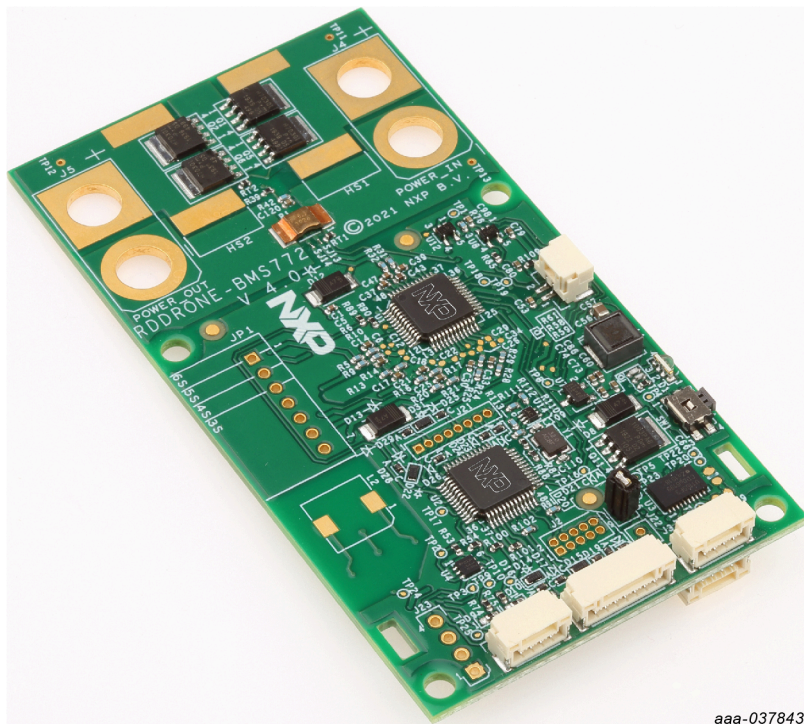


UM11421

RDDRONE-BMS772 reference design

Rev. 2 — 23 September 2021

User manual



aaa-037843

Figure 1. RDDRONE-BMS772 board



Important Notice

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This reference design is intended for use of ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY. It 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 reference design may be used with any development system or other source of I/O signals by simply 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.

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1 Introduction

This document is the user guide for the RDDRONE-BMS772 reference design. This document is intended for the engineers involved in the evaluation, design, implementation, and validation of MC33772B, 6-channel Li-Ion battery cell controller, S32K1 MCU, A1007 Secure element, and NTAG5 NFC interface.

The scope of this document is to provide the user with information that covers interfacing with the hardware, installing the GUI software, using other tools, and configuring the board for the application environment.

2 Finding kit resources and information on the NXP web site

NXP Semiconductors provides online resources for this reference design and its supported device(s) on <http://www.nxp.com>.

The information page for RDDRONE-BMS772 reference design is at <http://www.nxp.com/RDDRONE-BMS772>. 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 RDDRONE-BMS772 reference design, including the downloadable assets referenced in this document.

2.1 Collaborate in the NXP community

The NXP community is for sharing ideas and tips, ask and answer technical questions, and receive input on just about any embedded design topic.

The NXP community is at <http://community.nxp.com>.

The support for RDDRONE-BMS772 use with PX4 software is available in the opensource [PX4.io community](http://px4.io).

3 Getting ready

Working with the RDDRONE-BMS772 requires the kit contents, additional hardware and a Windows PC workstation with installed software.

3.1 Kit contents

- Assembled and tested RDDRONE-BMS772 in an anti-static bag
- CAN Bus Termination Resistor (DRONE-CAN-TERM)
- Unmounted cell balancing connectors for 3s, 4s and 6s
- 4-pin JST-GH to 4-pin JST-GH 300 mm cable
- Power input and power output connectors
- External thermistor with cable
- Small OLED display (soldered to the RDDRONE-BMS772 board)
- Quick start guide

3.2 Additional hardware

In addition to the kit contents, the following hardware is necessary or beneficial when working with this kit.

- Battery pack (3s to 6s with cell balancing connector), with a range of 6.0 V to 26 V and a current limit of 60 A DC
- Suitable charger for the battery
Note: The RDDRONE-BMS772 board allows to open the charge circuit when the battery is overcharging. Therefore, the charger does not need to have a BMS connector.
- Soldering iron to configure the board
- PEMicro universal multilink or SEGGER J-Link Mini debugger or other suitable debugger
Note: The DCD-LZ adapter and SEGGER J-Link Mini EDU are provided in the HoverGames Drone Kit (KIT-HGDRONEK66) and with the FMU (RDDRONE-FMUK66).

3.3 Software

Installing software is necessary to work with this reference design. All listed software is available on the reference design's information page at <http://www.nxp.com/RDDRONE-BMS772> and reference design's GitBook page at <https://nxp.gitbook.io/rddrone-bms772/>.

- S32 Design Studio for ARM-based MCUs (recommended)
- [PX4/NuttX board target example code](#) (optional)

4 Getting to know the hardware

4.1 RDDRONE-BMS772 overview

The RDDRONE-BMS772 is a standalone BMS reference design suitable for mobile robotics such as drones and rovers, supporting 3 to 6 cells batteries. Other portable electronics and equipment, such as scooters, power tools, portable medical devices could also benefit from referencing this design. If higher cell counts are required, this could be redesigned to daisy chain multiple BCC chips or switch to a larger cell count BCC such as MC33771B.

The device performs ADC conversion on the differential cell voltages and currents. It is capable of accurate battery charge coulomb counting and battery temperature measurements. Additionally, it communicates with a Flight Management Unit (FMU) through UAVCAN and/or an SMBus.

4.2 RDDRONE-BMS772 features

The RDDRONE-BMS772 integrates the following functions and features:

- Supports battery from 3s to 6s, with stack voltage ranging from 6.0 V to 26 V
- Supports ambient temperature range from $-20\text{ }^{\circ}\text{C}$ to $60\text{ }^{\circ}\text{C}$
- Measures battery stack and cell voltages with an accuracy of $\pm 5.0\text{ mV}$, battery charge or discharge current up to 200 A peak and 90 A DC¹

¹ This maximum current is obtained only when all MOSFETs and heat sinks are mounted. See [Section 5.5 "Power MOSFETs and heat sinks"](#).

- Active cell balancing during charging
- Offers a deep sleep mode (for transportation and storage) with low leakage current, as well as an automatic sleep mode with low current consumption on the battery
- Allows authentication of the battery
- Allows diagnostics to verify the safe operation of the battery
- Allows CAN, I²C and NFC communication
- Implements SWD and JTAG debugging interfaces, works with standard J-Link and other debuggers
- Implements DCD-LZ combined debug console interface for use with PX4 DroneCode and HoverGames platforms

4.3 Block diagram

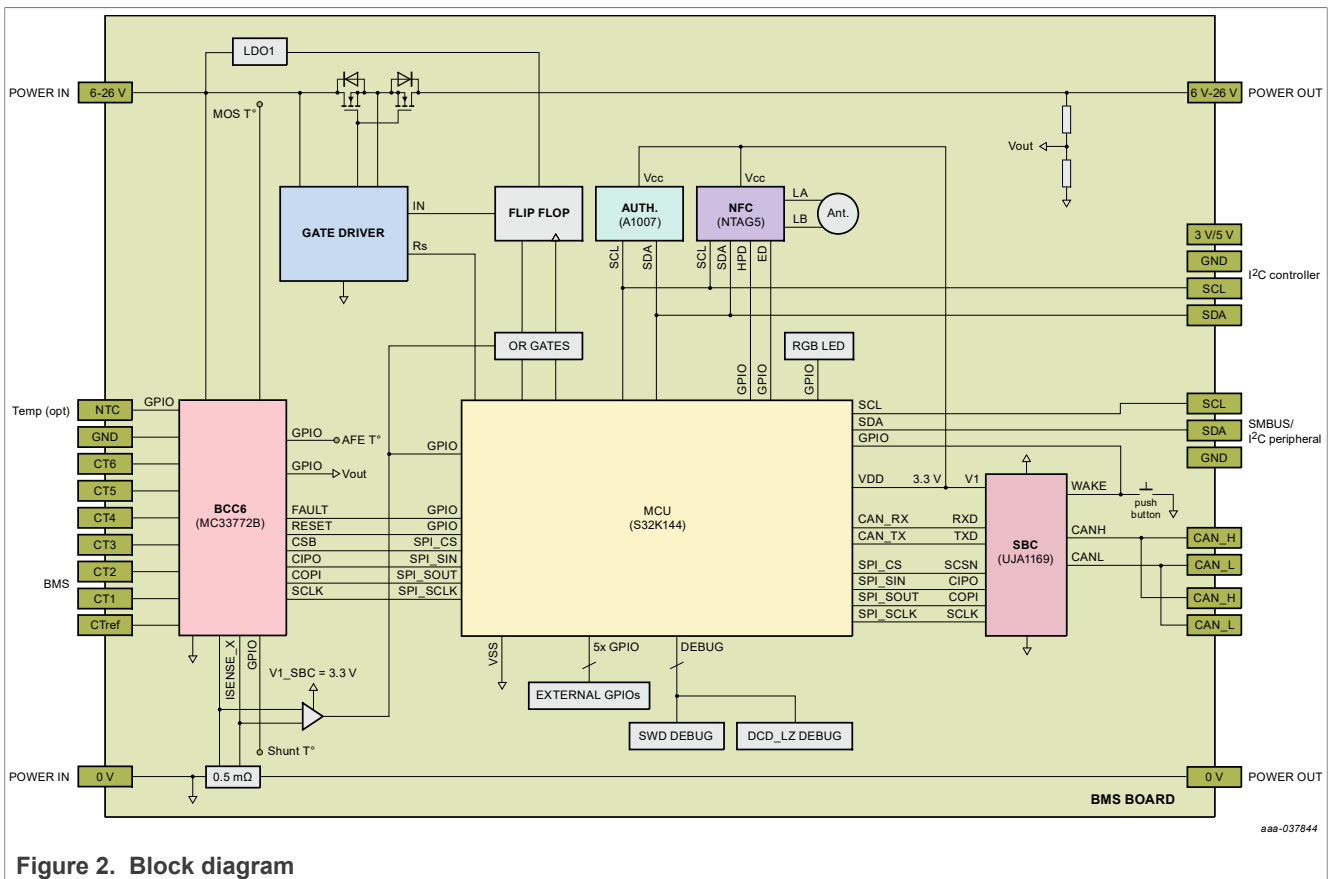


Figure 2. Block diagram

4.4 RDDRONE-BMS772 board characteristics

These boards have been designed and optimized for the operating conditions described in [Table 1](#). Usage of these boards beyond these conditions can lead to malfunction and damage.

Table 1. Maximum ratings

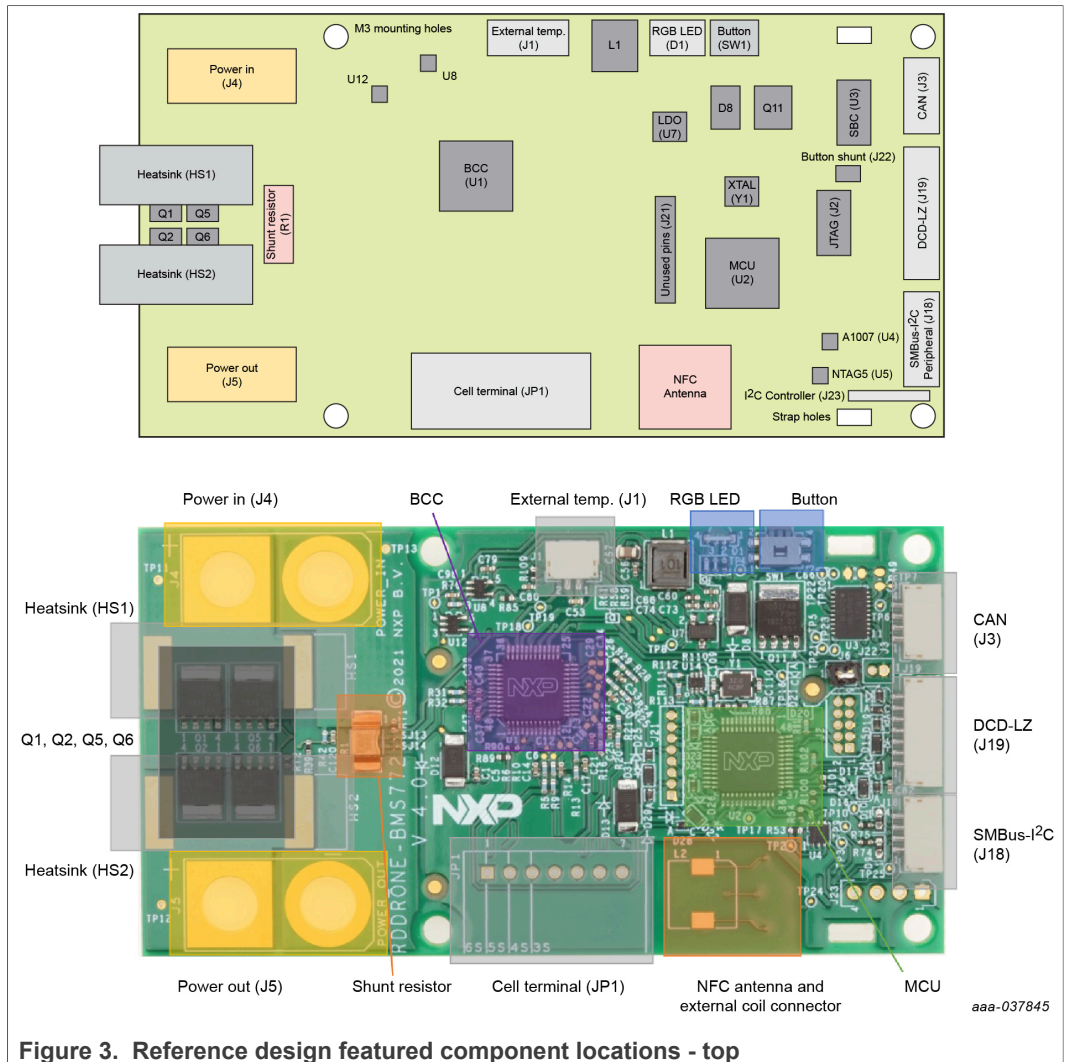
Description	Min	Max	Unit
Battery input voltage	6	26	V
Battery charge/discharge current (DC) ^[1]	—	90	A
Operating ambient temperature	-20	60	°C

[1] This value is valid for four pairs of power MOSFETs and four heat sinks configuration. See [Section 5.5](#) for more information.

Note: For more information about maximum ratings and electrical characteristics, see [RDDRONE-BMS772 gitbook](#).

4.5 Featured components

[Figure 3](#) identifies important components on the board.



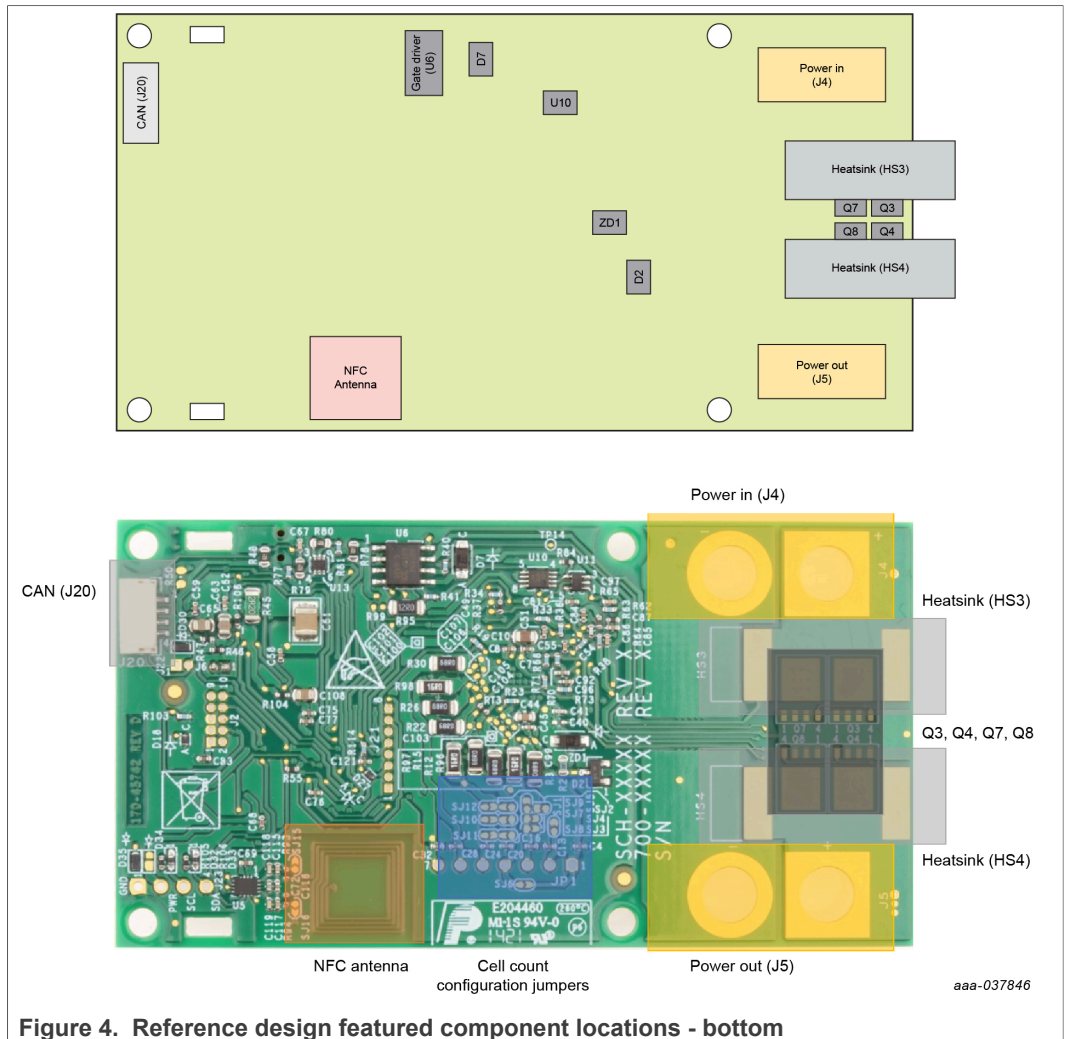


Figure 4. Reference design featured component locations - bottom

The main featured devices are listed in the following table:

Table 2. Featured devices

Label	Description	Reference
U1	Battery Cell Controller (BCC)	MC33772BSP1AE
U2	Micro-Controller Unit (MCU)	FS32K144HAT0MLFT
U3	System Basis Chip (SBC)	UJA1169TK/F3
U4	Authentication	A1007
U5	Near-Field Communication (NFC)	NTA53321G10FHK

4.5.1 MC33772B: 6-Channel Li-Ion battery cell controller

4.5.1.1 General description

The MC33772B is a Li-Ion battery cell controller IC designed for automotive applications, such as hybrid electric (HEV) and electric vehicles (EV) along with industrial applications, such as energy storage systems (ESS) and uninterruptible power supply (UPS) systems.

The device performs ADC conversions of the differential cell voltages and current, as well as battery coulomb counting and battery temperature measurements. The information is digitally transmitted through the Serial Peripheral Interface (SPI) or Transformer Isolation (TPL) to a microcontroller for processing.

4.5.1.2 Features

- 5.0 V ≤ VPWR ≤ 30 V operation, 40 V transient
- 3 to 6 cells management
- 0.8 mV total cell voltage measurement error
- Isolated 2.0 Mbps differential communication or 4.0 Mbps SPI
- Synchronized cell voltage/current measurement with coulomb count
- Total stack voltage measurement
- Seven GPIO/temperature sensor inputs
- Automatic over/undervoltage and temperature detection routable to fault pin
- Integrated sleep mode over/undervoltage and temperature monitoring
- Onboard 300 mA passive cell balancing with diagnostics
- Detection of internal and external faults, as open lines, shorts, and leakages
- Designed to support ISO 26262 up to ASIL D safety system
- Qualified in compliance with AEC-Q100

4.5.1.3 Upgrading to MC33772C

A new version of the MC33772 battery cell controller is available. For more information, go to <http://www.nxp.com/MC33772C>.

4.5.2 Connectors

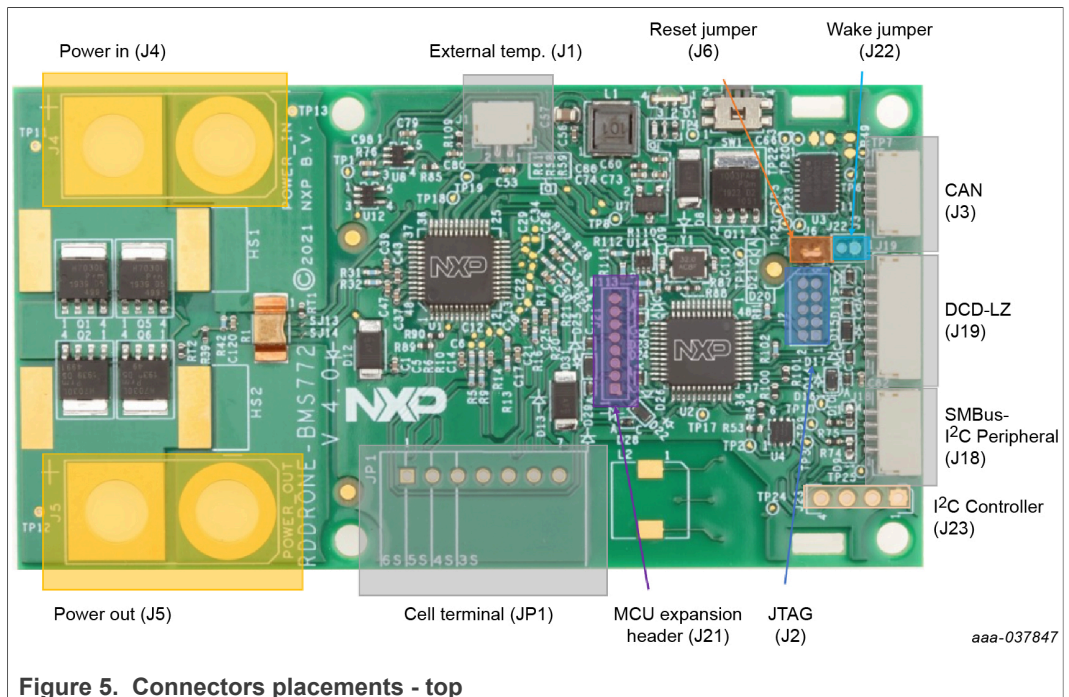


Figure 5. Connectors placements - top

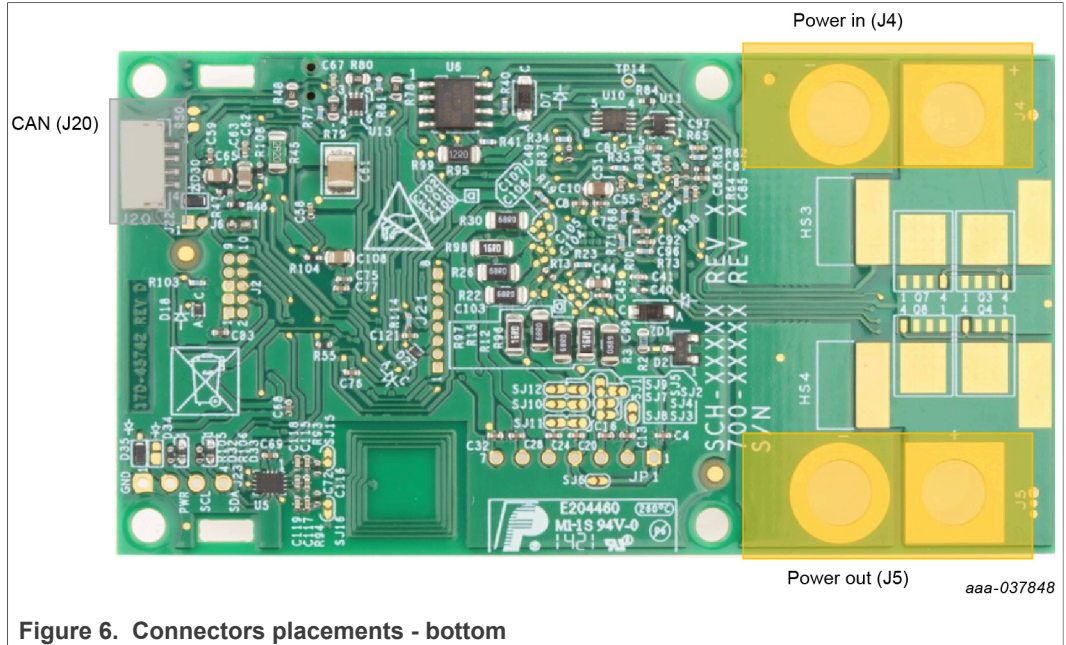


Figure 6. Connectors placements - bottom

Table 3. Reference design connector description

Label	Description	Manufacturer	Reference	Populated or DNP [1]
JP1	Cell terminal connector	JST MFG. CO	SxB-XH-A(LF)(SN)	DNP
J1	External temperature sensor	JST MFG. CO	SM02B-GHS-TB(LF)(SN)	Populated
J2	JTAG debugger	SMD header 10 position 0.050"/1.27mm (several manufacturers, for example, FTS-105-01-F-D by SAMTEC)		Populated
J3	CAN-bus	JST MFG. CO	SM04B-GHS-TB(LF)(SN)	Populated
J4	Battery power input	XT-90 connectors (several manufacturers, for example, FIT0588 by DFRobot)		DNP
J5	Battery power output	XT-90 connectors (several manufacturers, for example, FIT0588 by DFRobot)		DNP
J6	Reset jumper	FCI	68000-202HLF	Populated with jumper attached
J18	SMBus (I ² C peripheral bus)	JST MFG. CO	SM04B-GHS-TB(LF)(SN)	Populated
J19	DCD-LZ debugger	JST MFG. CO	SM07B-GHS-TB(LF)(SN)	Populated
J20	Additional CAN-bus	JST MFG. CO	SM04B-GHS-TB(LF)(SN)	Populated
J21	MCU expansion header	HARWIN INC	M50-3530842	DNP
J22	Wake jumper	FCI	68000-202HLF	DNP
J23	I ² C controller bus	FCI	68000-204HLF	DNP

[1] DNP: Do not populate

Note: Hardware configuration of the board is done via 16 jumpers to solder (SJ1 to SJ16). See [Section 5.2 "Cell terminal connection"](#), [Section 5.3 "Shunt resistor"](#), and [Section 5.4 "External NFC antenna"](#) for more details.

4.5.3 Communication with Flight Management Unit (FMU)

The RDDDRONE-BMS772 board can communicate with a host device such as a PX4 Flight Management Unit (FMU) using the SMBus bus (can also be used as a simple I²C bus, connector J18) or the UAVCAN bus (can also be used as a simple CAN-bus, connectors; J3 and J20).

Note: For more information about UAVCAN, see enablement in PX4.io software and <https://uavcan.org>.

4.5.4 Programming and debug

There are two ways to program and debug the RDDDRONE-BMS772 board:

- through the DCD-LZ connector (J19)
- through the JTAG connector (J2)

Note: The DCD-LZ combines a debug interface with a debug serial console. It is used on RDDDRONE-FMUK66 (HoverGames). For more information, see [HoverGames gitbook](#).

4.5.5 LED

The RDDDRONE-BMS772 implements a programmable RGB LED. Various color combinations and blink patterns are used to indicate the state of the battery and system.

4.5.6 External display

An external display could be used to display important battery information. This display can be connected to J23. This header could be supplied with 3.3 V (D34) or 5.0 V (D35, populated by default). By switching the diode, 3.3 V or 5 V could be used.

A SSD1306 OLED display is provided with the RDDDRONE-BMS772 rev. 4.0 board kit. It is directly soldered to the board for easier operation.

4.5.7 External and additional components

4.5.7.1 External components

An optional external temperature sensor can be added onto the RDDDRONE-BMS772 board using connector J1. An example of application for this external sensor is used to monitor the cells temperature inside the battery pack.

4.5.7.2 Additional components

Some components are included in the design but are not mounted on the RDDDRONE-BMS772 original board. They are marked "DNP" on the schematics and the BOM.

The following table provides the list of additional components that can be implemented in the design as well as their use:

Table 4. Additional features

Feature	Description	Label
Additional MOSFETs	If the application requires more power, two pairs of back to back MOSFETs can be added on the bottom side of the board. Corresponding part is PSMNR70-30YLH. See Section 5.5 "Power MOSFETs and heat sinks"	Q3, Q4, Q7, Q8

Table 4. Additional features...continued

Feature	Description	Label
Heat sinks	In order to dissipate more power, four additional heat sinks can be mounted: two on the top side and two on the bottom side of the board. Recommended part is FK 244 08 D2 PAK	HS1, HS2, HS3, HS4
Optional termination resistor network on CAN-bus	One 60.4 Ω resistor on each CAN line connected to a 4700 pF capacitor wired to the ground	R49, R50, C66
Capacitors on cell measurements connections	A filter can be added to the cell voltage measurements connections, according to the number of cells in use	C6, C12, C18, C22, C26, C29, C34
Capacitors on external temperature sensor	If the external temperature sensor is implemented, two capacitors can be added on the external temperature sensor low pass filter for more EMC demanding applications	C49, C54
Capacitor on cell balancing connections	Capacitors can be added on the cell balancing circuit for EMC, according to the number of cells in use	C99, C100, C101, C102, C103, C104, C105, C106, C107
External NFC antenna	Coil as an alternative option for the PCB NFC antenna for extended range operations	L2
Resistor on gate driver RS pin	Resistor to link RS pin on gate driver to MCU	R99
MCU expansion header	Additional MCU pins are wired to a 1x8 header slot. Possible uses: additional battery level LEDs, emergency button, etc.	J21
Wake jumper	Jumper for SBC wake-up (in parallel to the button)	J22

4.5.8 Test points definition

[Figure 7](#) shows the location of the test points on the board.

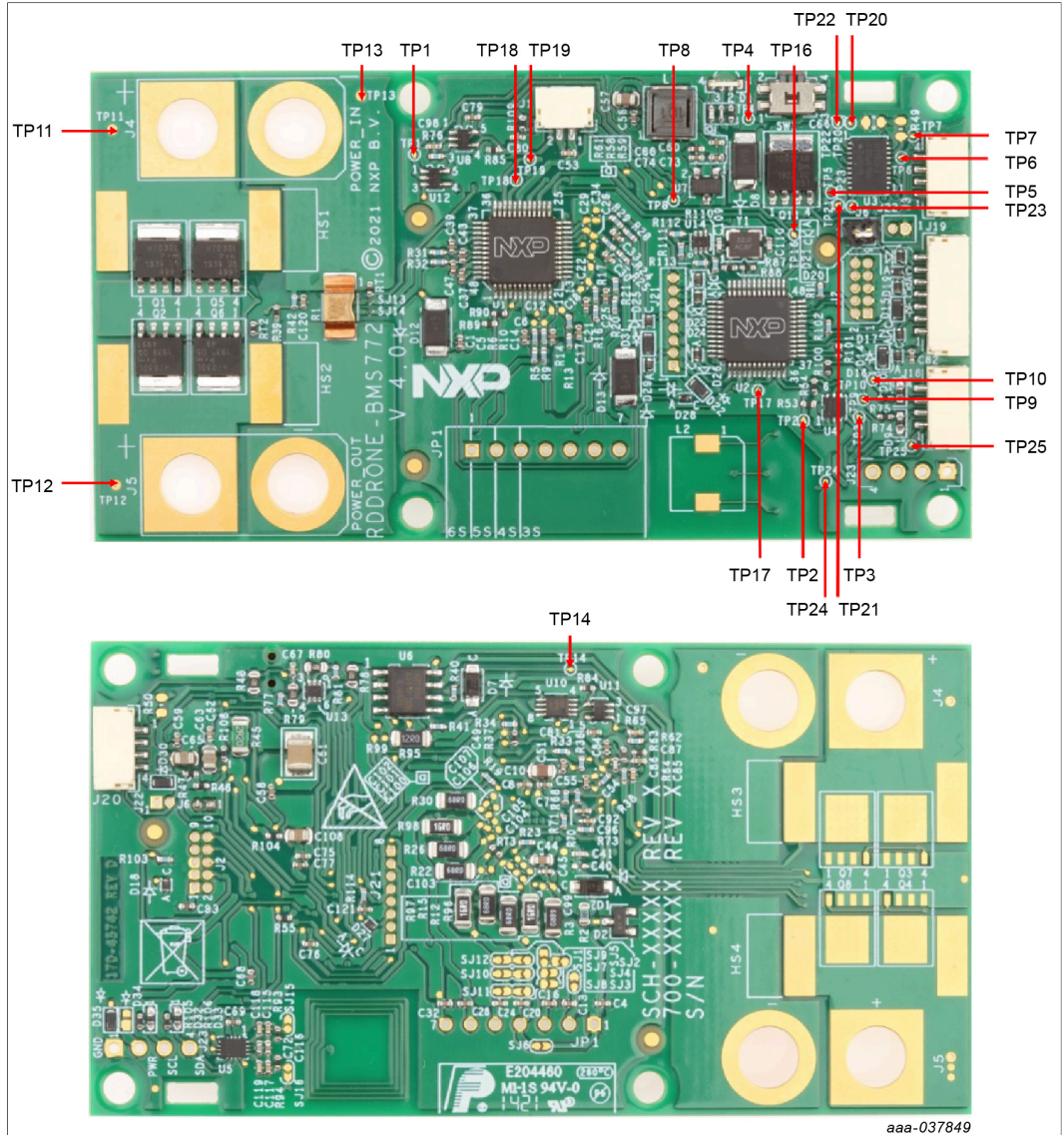


Figure 7. Test points

Table 5. Test points

Test point name	Signal name	Description
TP1	OVERCURRENT	Overcurrent signal
TP2	AUTH_NFC_SCL	Authentication and NFC I ² C bus clock signal
TP3	AUTH_NFC_SDA	Authentication and NFC I ² C bus data signal
TP4	VCC_3V3_SBC	SBC 3.3 V regulator output
TP5	RST_N	Reset signal (active low)
TP6	CAN_LO	CAN Low signal
TP7	CAN_HI	CAN High signal
TP8	VCC_3V3_LDO1	LDO 3.3 V regulator output

Table 5. Test points...continued

Test point name	Signal name	Description
TP9	SMBUS_SCL	SMBus I ² C bus clock signal
TP10	SMBUS_SDA	SMBus I ² C bus data signal
TP11	VBAT_IN	Voltage input
TP12	VBAT_OUT	Voltage output
TP13	GND	Ground reference of the device
TP14	N/A	Power switches gate command
TP16	BCC_CIPO	BCC SPI bus CIPO signal
TP17	BCC_CS	BCC SPI bus chip select signal
TP18	BCC_SCLK	BCC SPI bus clock signal
TP19	BCC_COPI	BCC SPI bus COPI signal
TP20	SBC_CS	SBC SPI bus chip select signal
TP21	SBC_CIPO	SBC SPI bus CIPO signal
TP22	SBC_COPI	SBC SPI bus COPI signal
TP23	SBC_SCK	SBC SPI bus clock signal
TP24	VCC_HARVEST	Antenna energy harvesting output
TP25	N/A	SMBus I ² C bus ground

4.6 CAN Bus termination resistor

The RDDRONE-BMS772 boards need a termination resistor network (DRONE-CAN-TERM) to provide termination on any CAN bus in PX4/DroneCode systems. It is used on the last CAN device on the daisy chain, providing a termination at both ends of a CAN bus.

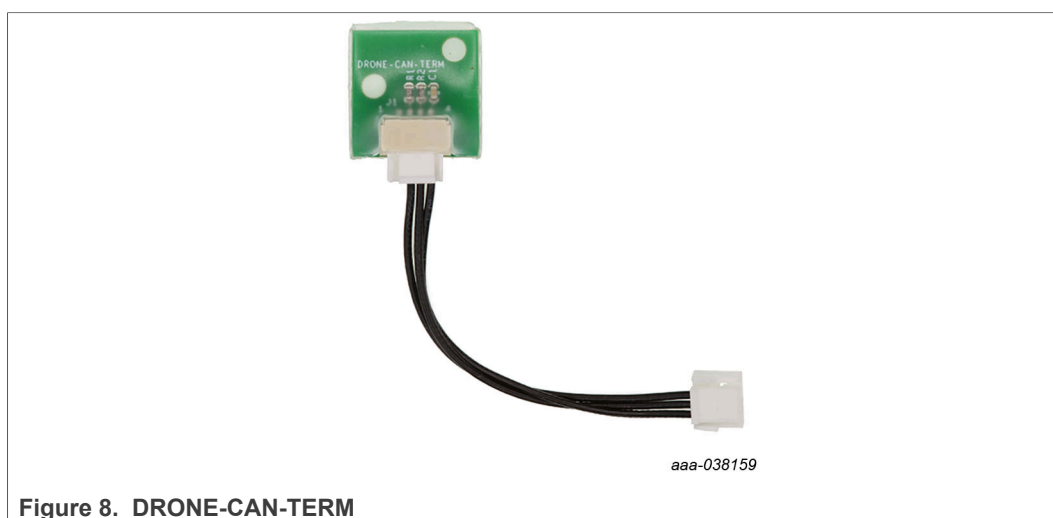


Figure 8. DRONE-CAN-TERM

Note: If using a CAN device with the RDDRONE-FMUK66, it should be considered one of the two end CAN devices, as there are termination resistors built into the FMUK66 board.

4.7 Schematic, board layout and bill of materials

The schematic, board layout and bill of materials for the RDDRONE-BMS772 board are available at <http://www.nxp.com/RDDRONE-BMS772>.

5 Configuring the hardware

5.1 Power connectors

As the RDDRONE-BMS772 board aims to be adaptable for every battery setup, power and battery cell termination connectors are not mounted on the PCB. This allows the user to configure the board with the connector.

The power connectors footprints on the design correspond to the DFRobot FIT0588 connector. They are also used for soldering typical silicone insulation heavy gage power wires. TE connectivity provides a line "UMP" connectors specifically for professional high-power mobile systems.

5.2 Cell terminal connection

The RDDRONE-BMS772 board is configurable to fit 3s to 6s battery packs.

Depending on the desired configuration, some adjustments should be done on the board:

- The correct cell terminal connector should be soldered as JP1 on the top side (3s, 4s, and 6s connectors are provided in the kit).
- The connection to the cell terminal circuit should be done by soldering the correct solder jumpers (see [Table 6](#)). All jumpers are open by default.

Table 6. Cell balancing circuit jumpers

Configuration	Jumpers connected	Associated connector	Connector placement on JP1 footprint
3s	SJ6, SJ10, SJ11, and SJ12	S4B-XH-A(LF)(SN)	Pin 4 to 7
4s	SJ3, SJ7, SJ11, and SJ12	S5B-XH-A(LF)(SN)	Pin 3 to 7
5s	SJ1, SJ4, SJ8, and SJ12	S6B-XH-A(LF)(SN)	Pin 2 to 7
6s	SJ2, SJ5, and SJ9	S7B-XH-A(LF)(SN)	Pin 1 to 7

Note: *SJ13, SJ14, SJ15 and SJ16 are not used for cell terminal connection. See [Section 5.3 "Shunt resistor"](#) and [Section 5.4 "External NFC antenna"](#).*

The cell terminal configuration depending on the battery type are shown in the following figures.

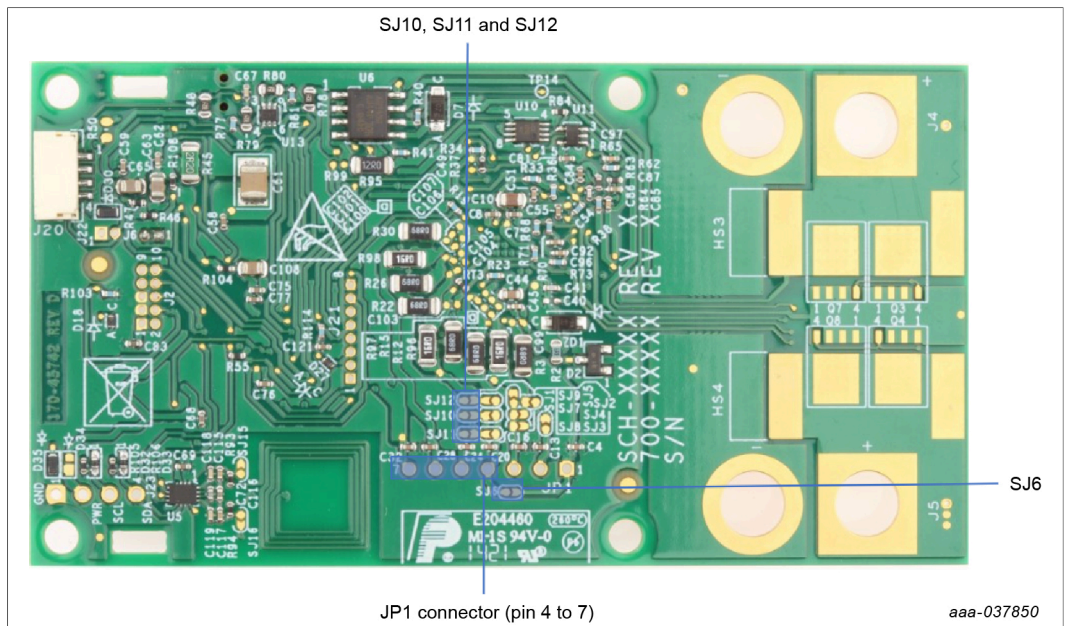


Figure 9. RDDRONE-BMS772 configuration for 3s

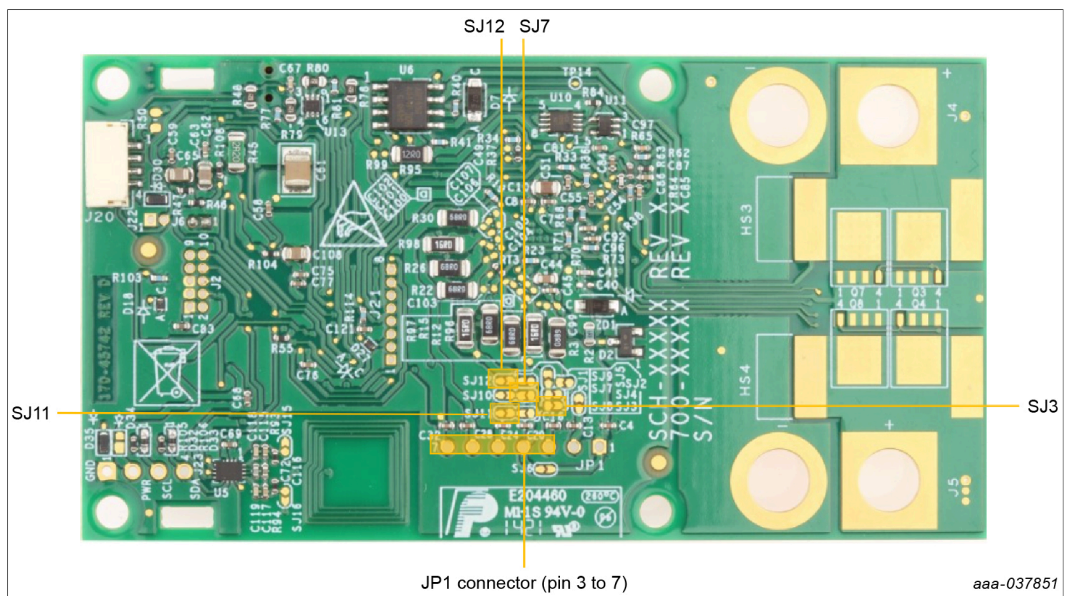


Figure 10. RDDRONE-BMS772 configuration for 4s

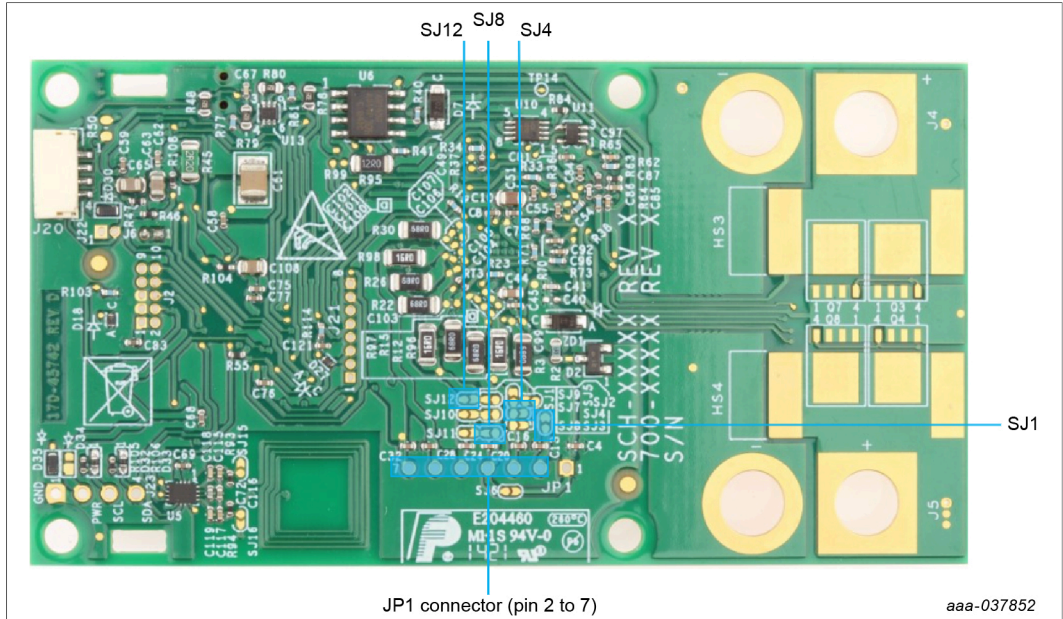


Figure 11. RDDRONE-BMS772 configuration for 5s

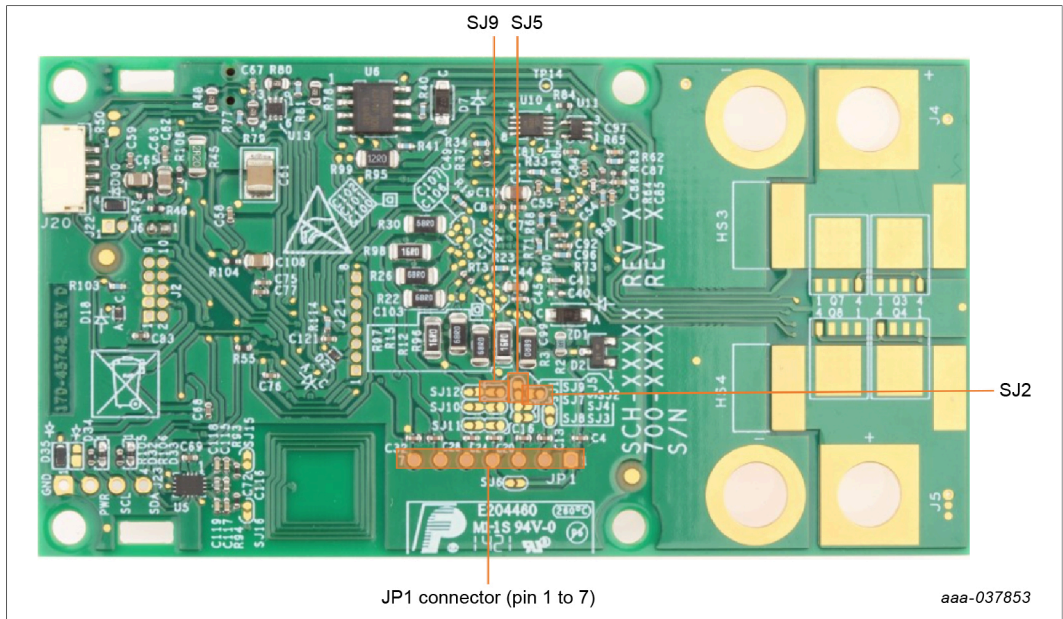


Figure 12. RDDRONE-BMS772 configuration for 6s

Note: The JP1 connector should be soldered on the top side of the board.

5.3 Shunt resistor

The shunt resistor (R1) can be disconnected from the overcurrent protection circuit and the BCC by opening the SJ13 and SJ14 jumpers. Both jumpers are closed by default.

5.4 External NFC antenna

The onboard NTAG 5 chip is designed to provide active antenna matching and amplification and gives enhanced performance when the battery is present and providing power. However, for extended range operation, the PCB antenna can be replaced by an SMD coil (L2). The coil is not mounted by default but the recommended part is SDR7045-2R2M. It is possible to solder wires and attach a remote NFC antenna to the same pads used for L2.

To use the SMD coil, the user must reconfigure the board using the following steps:

- remove both 0.75 Ω resistors R93 and R94
- solder SJ15 and SJ16
- replace 82 pF and 680 pF capacitors C72 and C116 by a single 56 pF capacitor

5.5 Power MOSFETs and heat sinks

The RDDRONE-BMS772 board allows placement of four pairs of power MOSFETs (PSMNR70-30YLH) and four heat sinks (FK 244 08 D2 PAK). Half is on the top side of the board and the other half is on the bottom side. By default, only the two pairs of MOSFETs of the top side are mounted.

The user can place additional MOSFETs and/or optional heat sinks to their board. This helps to widen the maximum DC current limit as described in the following table.

Table 7. Cell balancing circuit jumpers

Configuration	Maximum DC current
Four pairs of MOSFETs and four heat sinks	90 A
Two pairs of MOSFETs and two heat sinks	70 A
Two pairs of MOSFETs and no heat sink	60 A

Note: Exceeding the given current limit can permanently damage the board.

5.6 Optional components

Depending on the application, the user can add some optional components onto the RDDRONE-BMS772 board.

External and additional components and their use are detailed in [Section 4.5.7 "External and additional components"](#).

6 Start-up checklist

6.1 First start-up

[Figure 13](#) presents a typical hardware configuration.

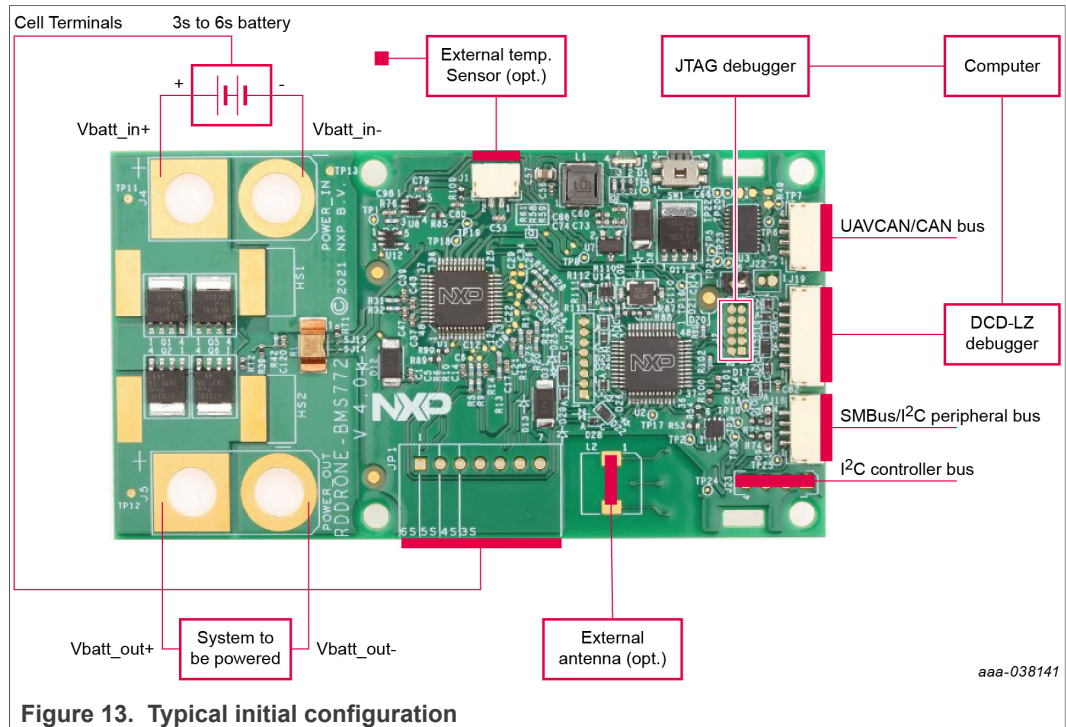


Figure 13. Typical initial configuration

Before first start-up, make sure that the board is configured properly:

1. Solder your power in and power out connectors or wires on the J4 and J5 footprints.
2. Solder the correct cell terminal connector at the JP1 location. Ensure it is correctly positioned and aligned.
3. Configure the board for your application by soldering the corresponding SJxx connectors.
4. Configure the board with additional and/or optional components as described in [Section 5 "Configuring the hardware"](#) to fit the application requirements.

6.2 Powering the RDDRONE-BMS772 board

Once the board is configured properly (see [Section 5 "Configuring the hardware"](#) for more details about configuration), connect the board.

To power On the RDDRONE-BMS772 board, connect the battery to the power input connector (J4) first and then the cell terminal connector (JP1). This protects the boards form internal damage due to hot plugging.

Similarly, to disconnect the battery from the board, the cell terminal connector (JP1) should be disconnected first. The power input (J4) can then be disconnected.

7 References

- [1] **RDDRONE-BMS772** — detailed information on this board, including documentation, downloads, and software and tools
<http://www.nxp.com/RDDRONE-BMS772>
- [2] **MC33772B** — product information on MC33772B, 6-Channel Li-ion Battery Cell Controller IC
<http://www.nxp.com/MC33772B>

- [3] **UJA1169** — product information on UJA1169TK, Mini High-Speed CAN System Basis Chip
<https://www.nxp.com/UJA1169TK>
- [4] **S32K** — product information on S32K1 microcontrollers for general purpose
<https://www.nxp.com/S32K>
- [5] **NTAG** — product information on NTAG® 5 boost, NFC Forum-compliant I²C bridge for tiny devices
<http://www.nxp.com/NTAG5-BOOST>

8 Revision history

Revision history

Rev	Date	Description
v.2	20210923	Global: updated images and description to align with rev. 4 of the board <ul style="list-style-type: none"> • Section 3.1: updated kit content list • Section 4.3: updated Figure 2 • Section 4.5: added Section 4.5.1.3 and Section 4.5.6 • Figure 3: replaced "master" by "controller" and "slave" by "peripheral" • Section 4.5.2: updated Figure 5 • Table 3: replaced "master" by "controller" and "slave" by "peripheral" • Section 4.5.8: updated signal names, added additional items to the list in Table 5 and updated Figure 7 • Section 5.2: updated Figure 12 • Section 6.1: updated Figure 13
v.1	20200612	Initial version

9 Legal information

9.1 Definitions

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