Infineon Mobile Robot (IMR) battery management system power

Using DEMO_IMR_BMSPWR_V1

About this document

Scope and purpose

This document describes the functions and the usage of the DEMO_IMR_BMSPWR_V1 kit used in the Infineon Mobile Robot (IMR) platform. The proposed design is intended to be used for mobile robotic application such as automated guided vehicles (AGV) or autonomous mobile robots (AMR). With its modular design approach, it can be utilized also in other battery powered applications. For the board to operate accordingly, a control board like DEMO_IMR_BMSCTRL_V1 is required and can be hooked up via pin headers. Furthermore 12 Li-ion batteries in the form factor 18650 are needed and should be inserted into the battery holders making sure the polarity is correct as shown and marked on the silkscreen.

The board offers several individual functions important in a battery powered application.

One of these is battery balancing and monitoring done with the TLE9012DQU Li-ion battery monitoring and balancing system IC. The TLE9012DQU is a multi-channel battery monitoring and balancing IC designed for Li-ion battery packs used in many applications on the automotive world (electric vehicles of any kind MHEV, HEV, PHEV, and BEV, etc.), industrial (energy storage systems) and consumer (i.e. e-bike BMS, home energy storage, etc.). TLE9012DQU fulfills four main functions: cell voltage measurement, temperature measurement, cell balancing, and isolated communication to main battery controller. Additionally, TLE9012DQU provides the necessary diagnostic tools to ensure proper function guaranteeing the safety of the persons around the controlled battery.

Furthermore, the battery can be disconnected from the load with the help of the EiceDRIVER™ 2ED4820-EM, a 48 V smart high-side MOSFET gate driver with SPI for automotive applications. The EiceDRIVER™ 2ED4820-EM is a smart high-side N-channel MOSFET Gate driver with two outputs controlled via SPI. The integrated powerful charge pump allows external MOSFETs to stay continuously on. Thanks to the enhanced turn-on and turn-off ability of the driver the number of MOSFETs could be easily scaled up to manage large currents in the order of several hundred amps while ensuring a fast switch on and off. The integrated current sense amplifier supports high-side and even low-side current measurement with a dedicated monitoring output. The 2ED4820-EM comes along with several latching failure detections, to implement protections for the external MOSFETs, the load, and the power source. Parameters can be adjusted by SPI; monitoring data, configuration, warning, and failure detection registers can be read.

The two selected IPT010N08NM5 single N-Channel OptiMOS™ 5 power MOSFET 80 V placed between battery and load are controlled in a back-to-back configuration in common source. Additionally, a pre-charge is done before the battery is connected the load which is achieved with an additional back-to-back common source configuration using two ISC035N10NM5LF2 single N-Channel OptiMOS™ 5 Linear FET 100 V operated in linear mode.

Intended audience

The document is intended for design engineers, technicians, and developers in the field of robotics and battery-powered applications who strive for highly integrated and efficient solutions.

Infineon components featured

- 2ED4820-EM Gate driver / charge pump / 48 V battery switch TSDSO-24
- IPT010N08NM5 OptiMOS™ 5 80 V/1.05 mΩ HSOF-8 (TOLL)
- ISC035N10NM5LF2 OptiMOS™ 5 100 V/3.55 mΩ TDSON-8 FL
- TLE9012DQU BMS IC TQFP-48
- TLI4971-A025T5-E0001 XENSIV™ current sensor IC TISON-8
- TLE9351BVSJ High speed CAN transceiver DSO-8
- ILD8150 80 V_{INPUT} buck converter DSO-8
- TLS208D1EJV LDO voltage regulator adjustable V_{OUT} and 0.8 A_{OUT} DSO-8
- TLS205B0EJV33 LDO voltage regulator 3.3 V_{OUT} 0.5 A_{OUT} DSO-8

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Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	Warning: *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	Warning*: The evaluation or reference board contains DC bus capacitors, which take time to discharge after removal of the main supply. Before working on the drive system, wait 5 minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by an oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	Caution: *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	Caution: *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	Caution: *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	Caution: *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	Caution: *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

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1 Introduction

1.1 Mobile robot general description

Mobile robots are now common in applications from logistics and warehouse centers and production sites to hospitals, restaurants, and schools, and as last-mile package delivery vehicles. On a high level, mobile robots are of two main types:

- **Automated guided vehicles (AGV):** “Fixed” vehicles that follow predefined paths using lasers, barcodes, radio waves, vision sensors, or magnetic tape for navigation.
- **Autonomous mobile robots (AMR):** Not “fixed”, and do not need external paths as these use autonomous mapping, localization, navigation, and obstacle avoidance by using sensors.

Usually, robots are battery-powered where the voltage level depends on the size and weight characteristics.

1.2 Infineon Mobile Robot (IMR)

The board described in this document is primarily targeted to be used in combination with the Infineon Mobile Robot (IMR). The IMR is a comprehensive robotic platform for use with a wide variety of boards such as sensors, motor controls, wireless communication, and battery management.

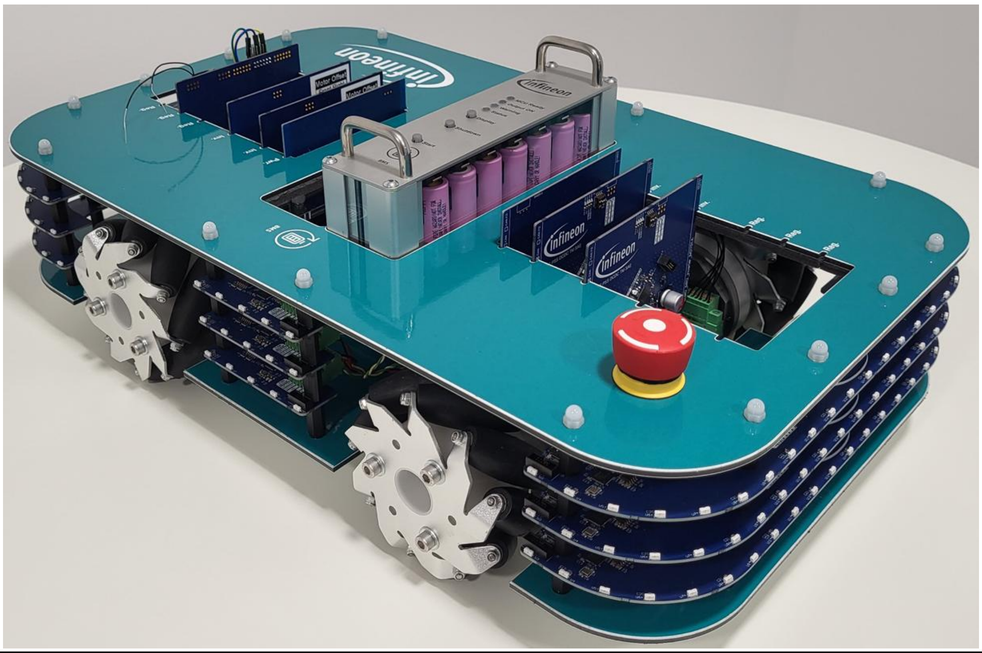

Figure 1 Infineon Mobile Robot (IMR): Isometric view

The IMR is intended to provide a demonstration platform for autonomous service robot functionalities by using Infineon components. This document describes the DEMO_IMR_BMSPWR_V1 board to provide the analog front-end of the battery management system (BMS) including the battery protection unit, to interface with the other BMS control board (DEMO_IMR_BMSCTRL_V1) to form the full BMS of the IMR.

To use the full BMS in the IMR, additional board DEMO_IMR_BMS_MOBO_V1 is needed to provide the slot connection. For more information, see Section 2 of IMR structural boards user guide.

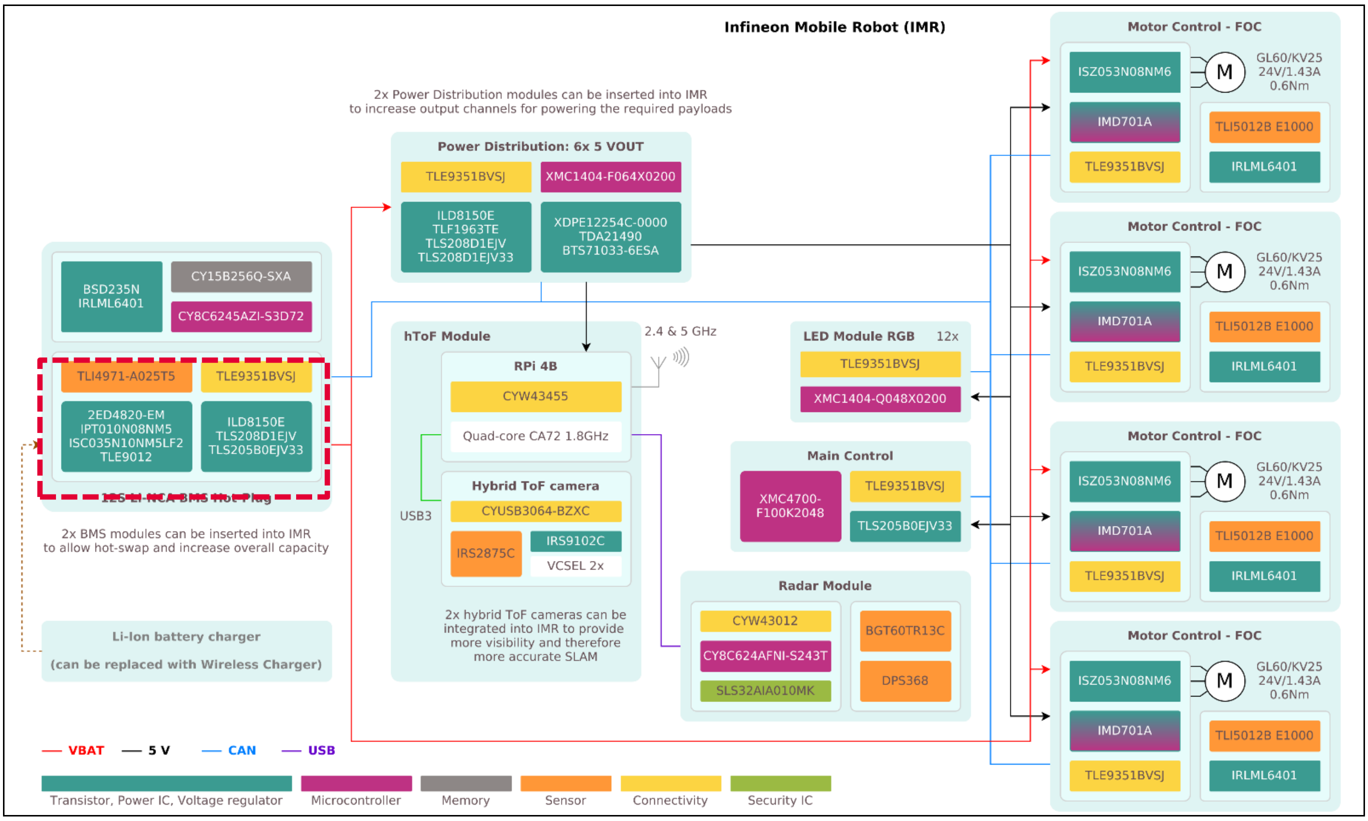

Figure 2 **IMR overview: DEMO_IMR_BMSCTRL_V1 board highlighted in red. Two BMS modules are installed in the IMR to facilitate hot swap**

1.3 Full battery management system

A full battery management system (BMS) in IMR consists of a DEMO_IMR_BMSPWR_V1 board, a DEMO_IMR_BMSCTRL_V1 board as well as the necessary mechanical components. There are two dedicated slots on the IMR where the full BMS can be plugged in to supply power to the whole IMR platform. This application note gives a detailed description of the DEMO_IMR_BMSPWR_V1 board, see Figure 3, for mobile robotic applications.

The whole system offers hot swapping hence allowing a change of the full BMS inside the IMR without interrupting the supply voltage to latter. The system can be interfaced via CAN over the card-edge connector. The user can also interface with the BMS via three buttons on top, where one can connect and disconnect the BMS as well as go through the different status screens on the E-paper display mounted on the DEMO_IMR_BMSCTRL_V1 board.

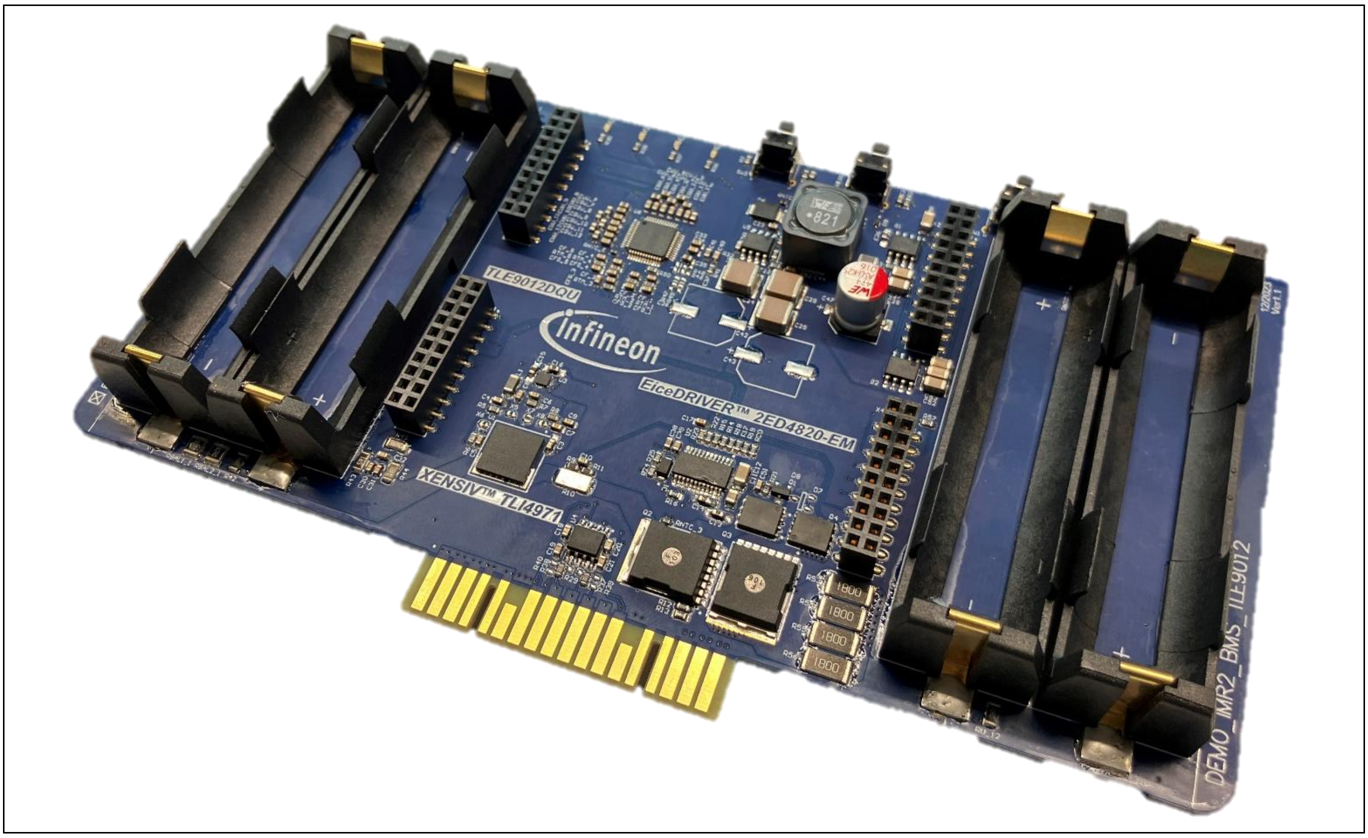

Figure 3 Top view: DEMO_IMR_BMSPWR_V1 board

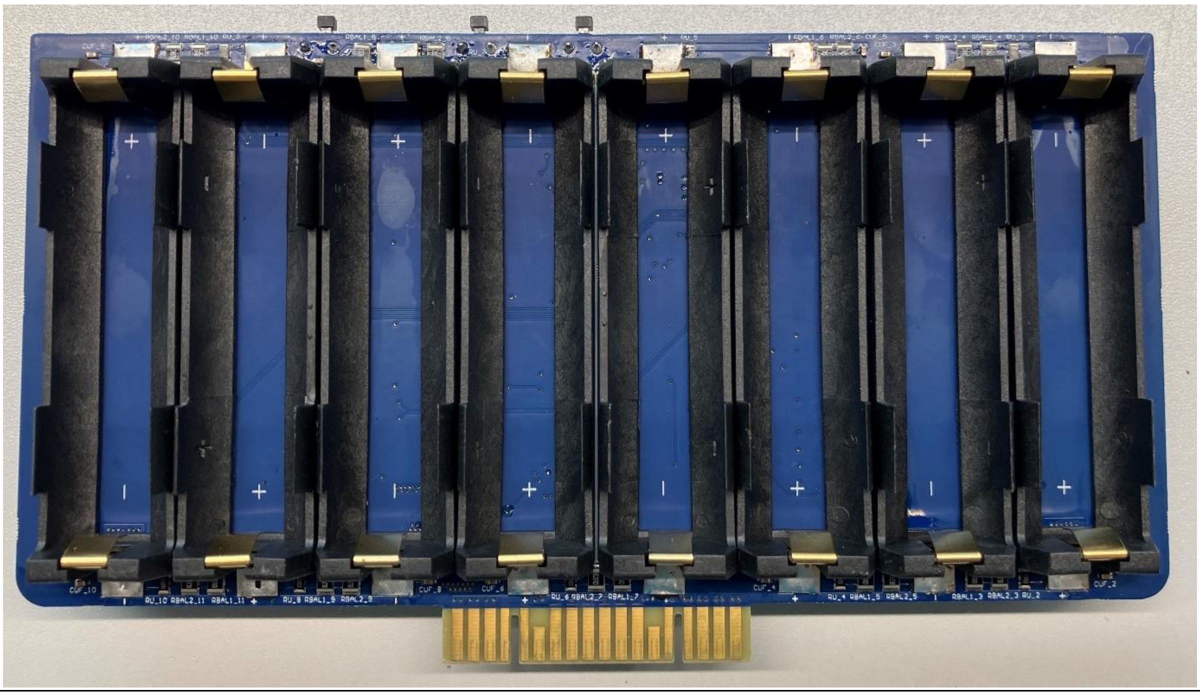

Figure 4 Bottom view: DEMO_IMR_BMSPWR_V1 board

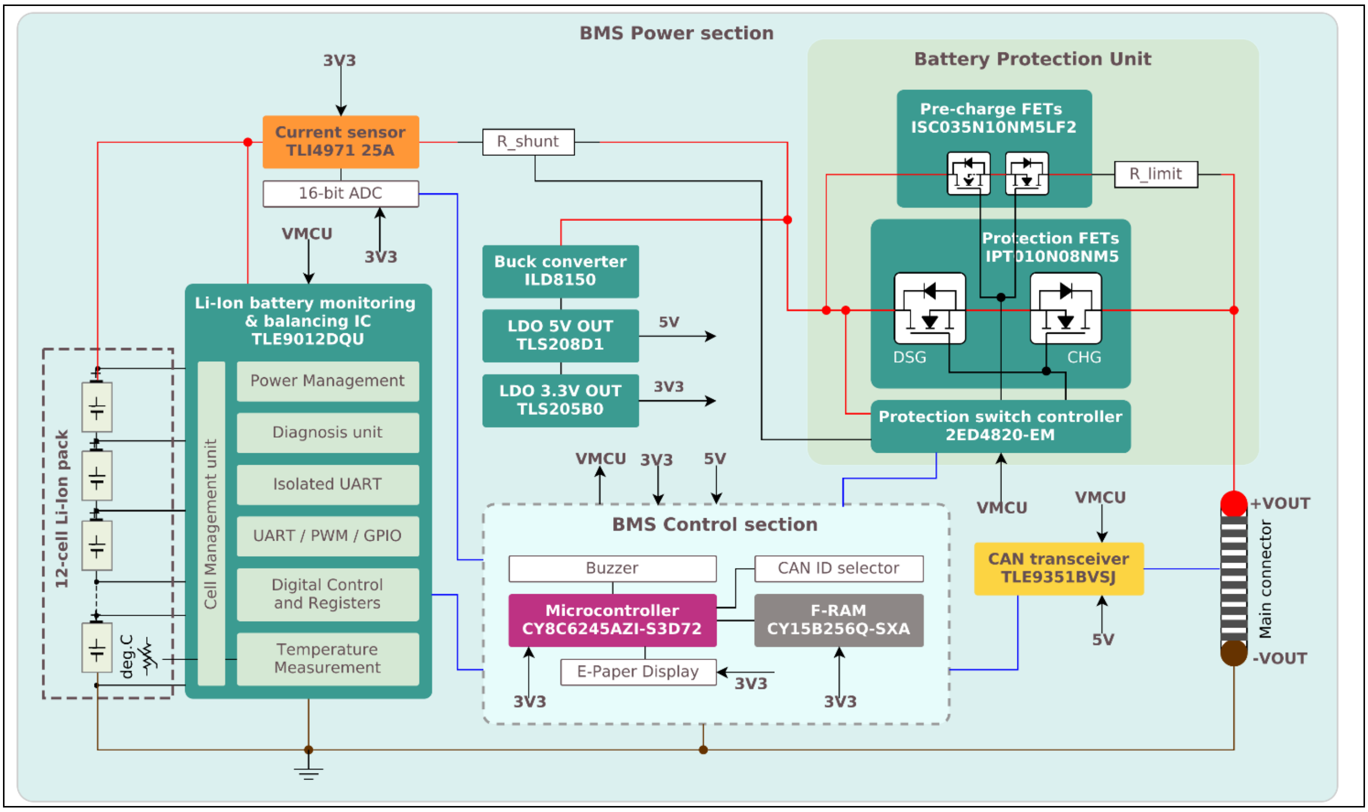

Figure 5 **Block diagram of the full BMS, showing both DEMO_IMR_BMSPWR_V1 and DEMO_IMR_BMSCTRL_V1 board**

2 Specifications

Input and output at normal operation

- DC charging input voltage 50.4 V
- DC output voltage 40.8 V – 50.4 V
- 12x Li-ion 18650 cell holders
- Maximum charging and discharging current depending on used cell

Protection features

- Voltage monitoring of all 12 battery cells connected in series
- Hot plugging support
- Dedicated 16-bit delta-sigma ADC for each cell with selectable measurement mode
- High-accuracy measurement for SoC and SoH calculation
- Five temperature measurements on various positions
- Integrated balancing switch allows up to 200 mA balancing current
- Internal round robin cycle routine triggers majority of diagnostics mechanisms
  - Automatic balancing over- and undercurrent detection scheme
  - Automatic open load and open wire detection scheme
  - Automatic NTC measurement unit monitoring scheme
- Configurable overcurrent or short circuit protection

Dimensions of the evaluation board

Width 180 mm, length 99.11 mm, height 31.9 mm without cells/38.9 mm with 18650 cells.

Note: *In order for this board to operate, the firmware on the piggyback board must be configured correctly for the specific cells being driven. This requires charge & discharge parameters as well as maximum charge and discharge voltage. Furthermore, one needs to ensure that the batteries plugged in are all the same type as well as model.*
Polarity markers need to be regarded at any time. Misuse and bypassing of safety features of the board can result in damaged cells, destroyed components as well as a potential fire hazard.
Before operation consultation of the battery datasheet is mandatory.

Attention: ***The board should be tested only by qualified engineers and technicians. All necessary safety precautions required when working with batteries need to be obliged. The board is designed to be used in combination with 12 Li-ion 18650 cells. One example for such a cell would provide the INR18650-35E. Although everything is tested vigorously and a variety of safety features are implemented, a misuse or a wrong handling of the cells can lead to a malfunction. Hence all necessary safety precautions and advice of the manufacturer of the cells should be obeyed under any circumstances. When inserting the batteries make sure to input them according to the polarity markings on the board. Depending on the software and the cells used, different cut-off voltages and capacity are in place. The status of the whole system is either represented by the status LEDs on this board or via other option like a screen on the piggyback board. In case the system shows any unexpected behavior remove the cells out of the board, store them in a dedicated battery pouch or other fire safe container and consult either this user guide or your Infineon representative for further advice.***

3 Schematics

3.1 TLE9012DQU

The main component on the board is the TLE9012DQU, which is a multi-channel battery monitoring and balancing IC designed for Li-ion battery packs used in many applications on the automotive world (electric vehicles of any kind MHEV, HEV, PHEV, and BEV, etc.), industrial (energy storage systems) and consumer (i.e., e-bike BMS, home energy storage, etc.). TLE9012DQU fulfills four main functions: cell voltage measurement, temperature measurement, cell balancing, and isolated communication to main battery controller. Additionally, TLE9012DQU provides the necessary diagnostic tools to ensure proper function guaranteeing the safety of the persons around the controlled battery.

The TLE9012DQU supports balancing of each cell in the cell stack individually in any combination including all channels in parallel with a balancing current per cell. The IC can balance each cell for an individual period of time, without necessary periodic watchdog communication. The maximum internal balancing current is 200 mA, but the IC can also be equipped with external balancing N-channel MOSFETS hence increasing the balancing current to higher values. On this board only the internal balancing switches are used hence greatly decreasing system complexity. The communication with the TLE9012DQU is happening via UART. The isoUART interface is not used due to the required cell count of 12 cells which one IC can handle on its own. If higher cell counts are required, the ICs can be stacked in series to one another and the isoUART interface in between the stacked chips can be used. VIO can be tied to the corresponding communication voltage of the connected microcontroller.

In this low voltage application without the need for galvanic isolation a regular UART interface can be used where only one pin, either UART_HS or UART_LS is used for communication. In case higher safety is required both pins can be used to form a ring communication on system level. Note that a resistor connecting RX and TX UART lines is needed in any case. For more information, see Figure 17.

The error pin is connected to the pin headers leading to the piggyback controller board. This pin is triggered depending on the configuration in the ERR pin / EMM mask register, which can be:

- Overvoltage or undervoltage of a cell
- External NTC resistance measurement fault
- Open load diagnostics error for any voltage sensing and balancing pin
- Balancing overcurrent and undercurrent error
- ADC cross-check error
- Internal overtemperature detected
- Register CRC check fault detected
- Internal IC error

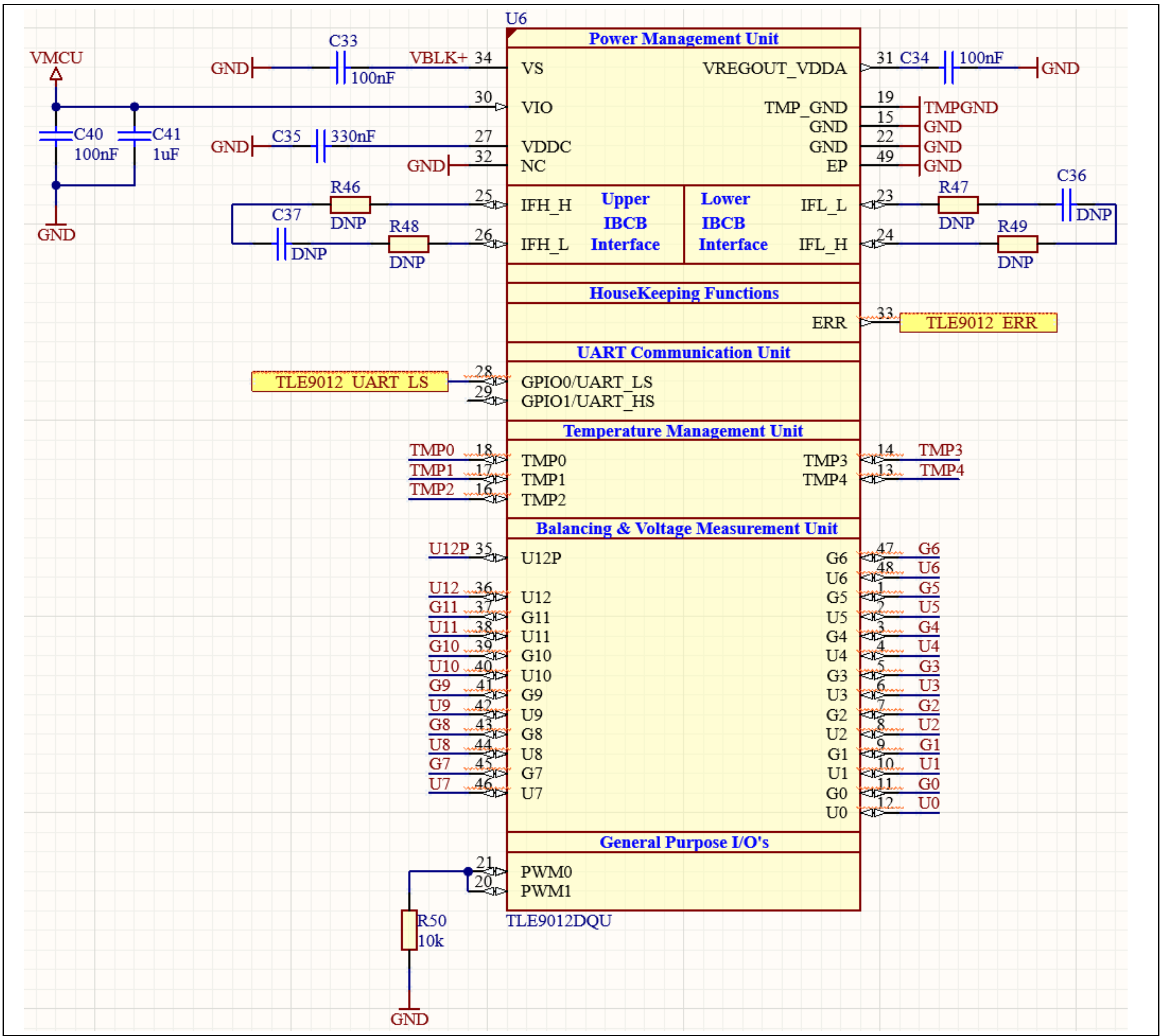

Figure 6 Schematic around the TLE9012DQU

The battery holders are connected in series to each other. As the holders are not polarized, the user needs to ensure that the polarity of the battery is inserted correct as depicted on the silkscreen layer. When removing the batteries out of the holder make sure when lifting the cell to not damage the plastic wrapping of the cell.

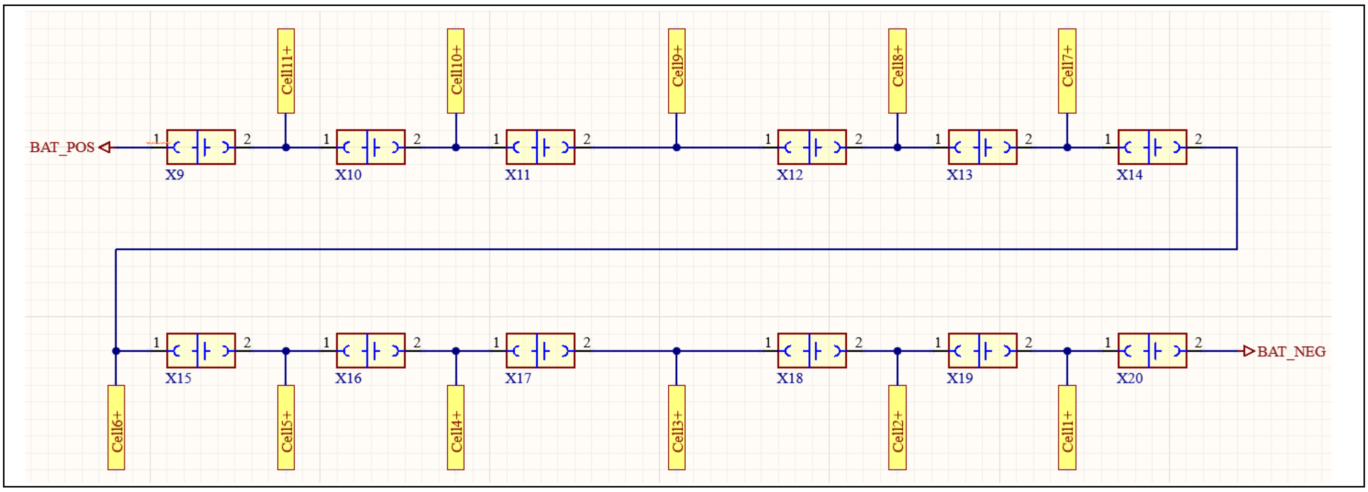

Figure 7 **Schematic of the 12 battery holders**

There are five temperature measurement pins on the TLE9012DQU. All of them are in used and connected to a circuit containing one NTC resistor. They are located at:

- RNTC_1 – Below cell 1
- RNTC_2 – Next to freewheeling diode of ILD8150
- RNTC_3 – At drain terminal of disconnect switch Q2
- RNTC_4 – Below cell 12
- RNTC_5 – Close to TLE9012DQU

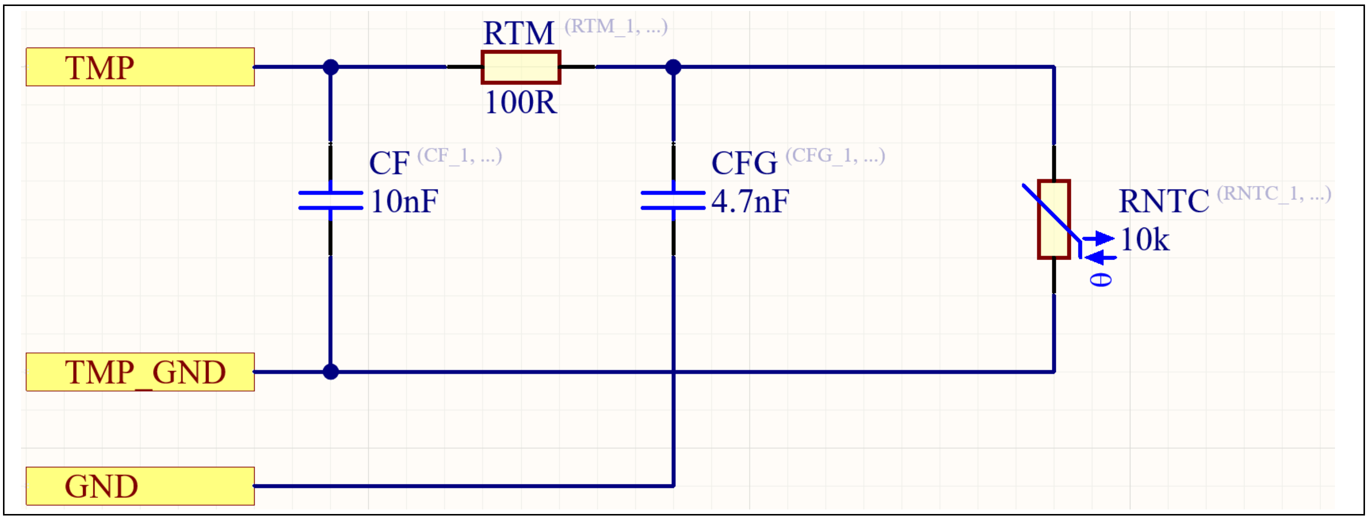

Figure 8 **NTC and corresponding filter circuit**

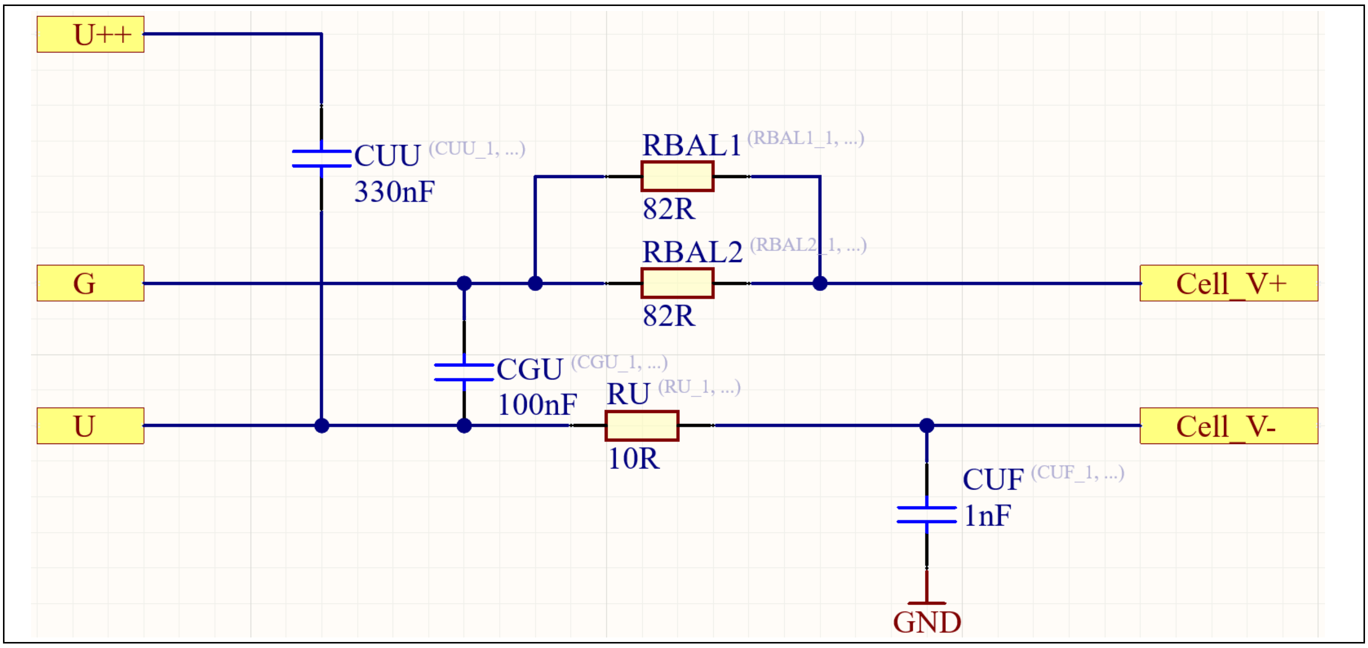

Figure 9 **Balancing resistor network and corresponding filter circuit**

All cells are connected via balancing and filter resistors to the TLE9012DQU additionally filter capacitors are placed. The balancing resistors are of size 1210 so that the temperature even at long balancing operation stays low. The value can be reduced further to reach the maximum internal balancing current of 200 mA if required.

3.2 Board edge header

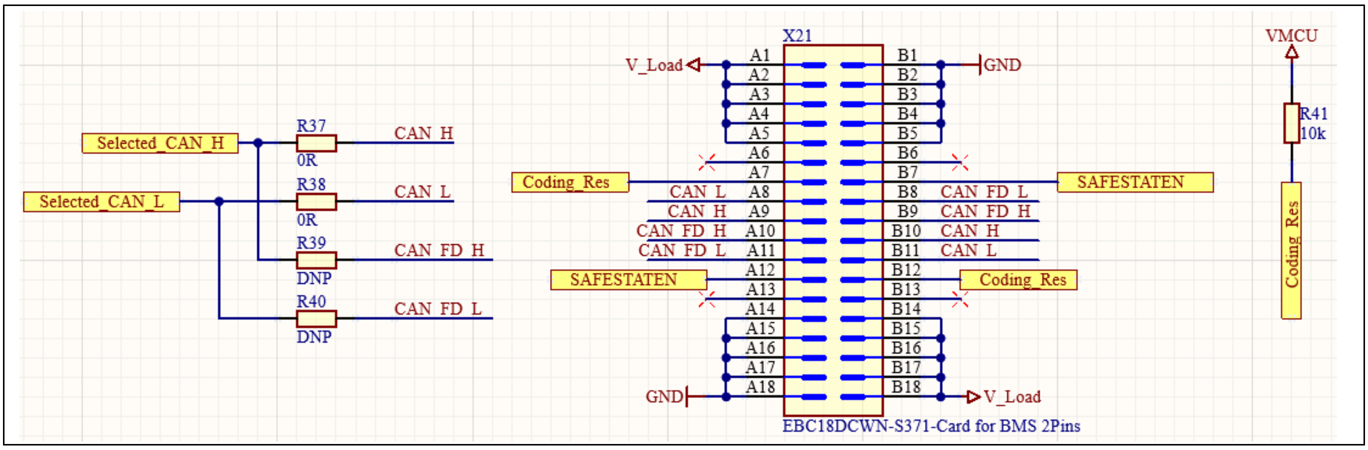

Figure 10 **Card edge header, coding resistor pull up and CAN resistors**

The board offers a board edge header which can be plugged directly into the IMR platform on the BMS motherboard. The interface is symmetrical hence the system itself cannot be connected in the wrong orientation. Next to voltage connection, the CAN and CAN FD interfaces are also connected to the card edge header. Depending on the population of R37-R40, either CAN FD or regular CAN is forwarded to the piggyback board (e.g. DEMO_IMR_BMSCTRL_V1). Additionally, the card edge header features the SAFESTATEN and Coding_res pin. The SAFESTATEN is a safety related function, which is connected to an emergency stop and to the 2ED4820 IC that will open the connection from the battery to the robot when the emergency stop is pushed.

The Coding_res pin is used to distinguish between different possible mounting options of the BMS. In total three possible options are considered:

- Not plugged in (Coding_res --> VMCU)
- Plugged into charger (Coding_res --> GND)
- Plugged into robot/load (Coding_res --> VMCU/2)

Depending on the option selected, the Coding_res pin has a different voltage potential due to the voltage divider where the upper half is situated on the board itself and the lower half on the BMS motherboard. This information can then be processed by the controller on the piggyback board and then decide on the behavior at turn on.

The card edge itself has two notches which are used for polarization. This is to make sure that each board can only be inserted into the corresponding slot. The BMS card edge has as only board the unique property to be symmetric so the BMS system can be plugged in into both orientations.

Table 2 Pin out of BMS power board slot on IMR motherboard with thick row lines marking polarizing key positions

PIN	Function	PIN	Function
A1	Load supply	B1	GND
A2	Load supply	B2	GND
A3	Load supply	B3	GND
A4	Load supply	B4	GND
A5	Load supply	B5	GND
A6	N.C.	B6	N.C.
A7	Coding resistor	B7	SAFESTATEN
A8	CAN L	B8	CAN FD L
A9	CAN H	B9	CAN FD H
A10	CAN FD H	B10	CAN H
A11	CAN FD L	B11	CAN L
A12	SAFESTATEN	B12	Coding resistor
A13	N.C.	B13	N.C.
A14	GND	B14	Load supply
A15	GND	B15	Load supply
A16	GND	B16	Load supply
A17	GND	B17	Load supply
A18	GND	B18	Load supply

3.3 Logic voltage supply

To supply all ICs with their respective logic voltage the battery voltage is converted in three steps down to 3.3 V. As first step the ILD8150 steps down the voltage to just over 5 V to have enough margin for the connected 5 V LDO. The ILD8150 is activated via a button press on SW1 by pulling the SD_N pin high. As soon as the MCU on the piggyback board is supplied and operating, it will hold the SD_N_MCU high on its own. The following TLS208D1EJV and TLS208D1EJV33 are then creating the 5 V and 3.3 V logic supply. Depending on the controller of the piggyback board, both voltages can be used for as supply.

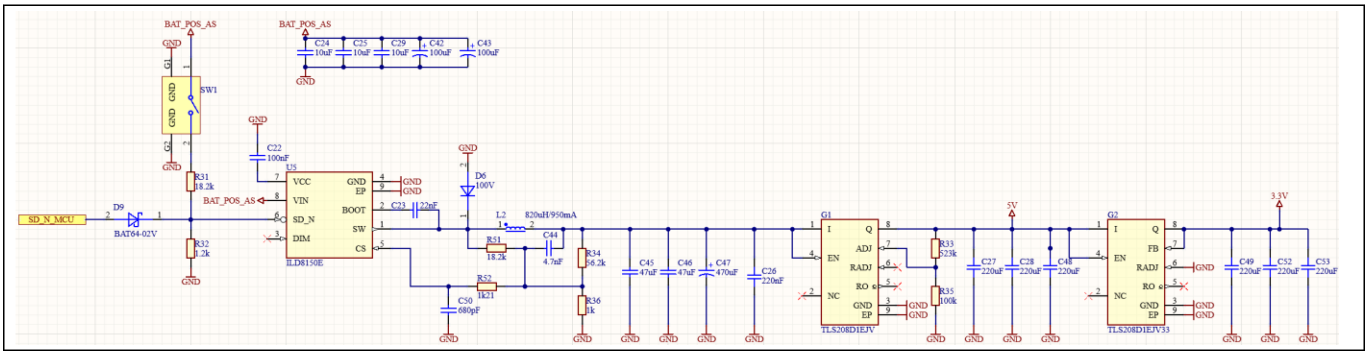

Figure 11 **Auxiliary power ICs consisting of 3 stages**

3.4 Current measurement

Depending on the application, the requirements on the current measurement can differ. On this board two methods are implemented serving different needs, where in principle only one would be required. The first methods use the Infineon XENSIV™ TLI4971-A025T5-E0001 which is a sensor, pre-programmed to the 25 A measurement range. It offers high precision current measurement in applications with lower currents. This coreless magnetic current sensor solution is usable for AC and DC measurements. It consists of an analog interface and dual fast over-current detection outputs. Infineon's well-established and robust Hall technology enables accurate and highly linear measurement of currents with a full measurement range up to ±25 A full scale range. All negative effects (saturation, hysteresis) commonly known from sensors using flux concentration techniques are avoided.

The digitally assisted analog concept of TLI4971 offers superior stability over temperature and lifetime thanks to the proprietary digital stress and temperature compensation. The differential measurement principle allows great stray field suppression for operation in harsh environments.

Due to these properties, the sensor enables a high level of accuracy when calculating State of Charge (SoC) and State of Health (SoH). As the distance to the microcontroller is quite large and the resolution of the integrated ADCs is usually around 12-bit, an external ADC is mounted on the board to increase the resolution to 16-bit and provide a digital interface to the microcontroller.

The solder bridges X5-X8 are in place to disconnect the programming pins of the TLI4971 from the rest of the board. This is necessary due to the high programming voltage required for flashing the EEPROM. By programming the TLI4971 parameters such as OCD thresholds, blanking times and output configuration modes can be set.

The TLI4971 also possesses two overcurrent detection pins (OCD1 and OCD2) which go high once certain current levels are reached. This allows the connected controller to act accordingly. This method is used to proactively engage certain measures, however, for extremely fast reaction time in the sub microsecond area, the shunt-based current measurement of the 2ED4820-EM should be used.

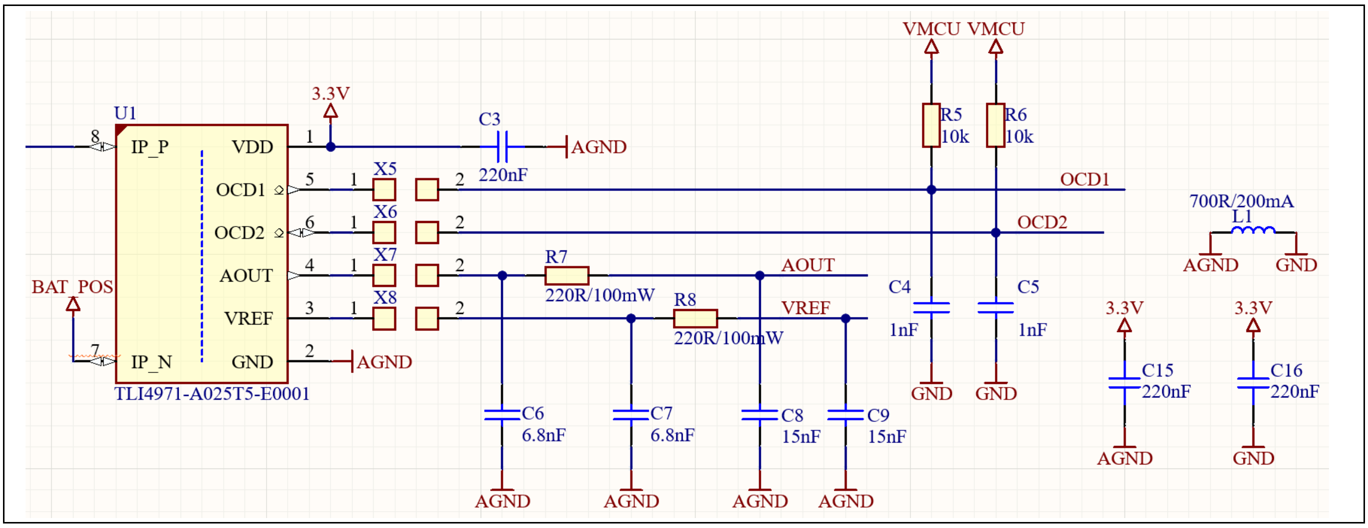

Figure 12 **Current sensor for SoC and SoH estimation**

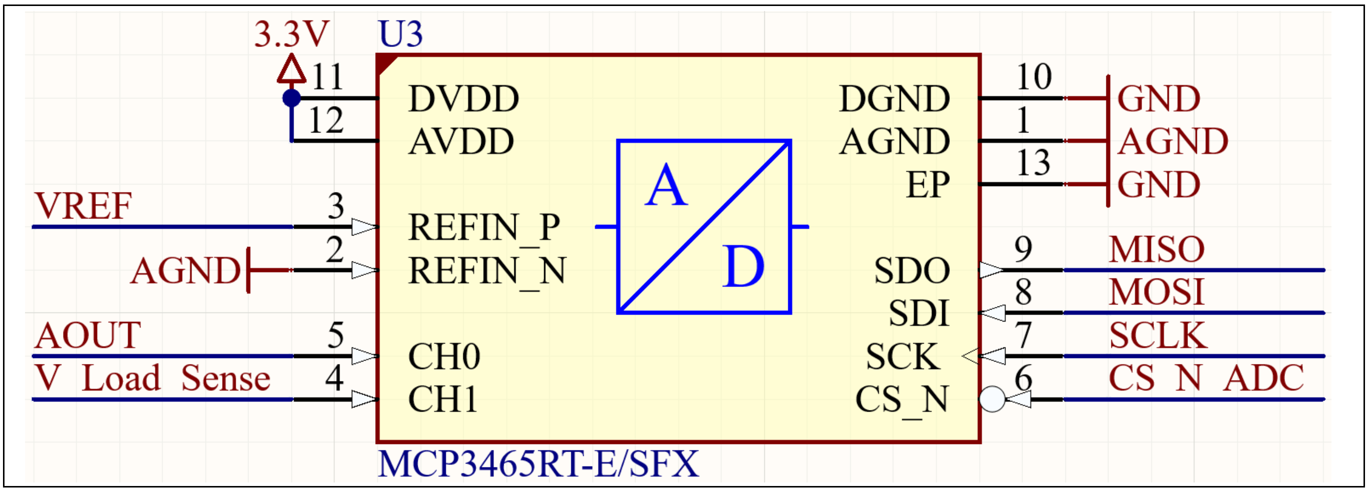

Figure 13 **16-bit ADC for accurate SoC and SoH estimation**

Therefore, 2ED4820 can act autonomously in a high current event. This allows the whole BMS to quickly cut off the batteries from the load in a failure event.

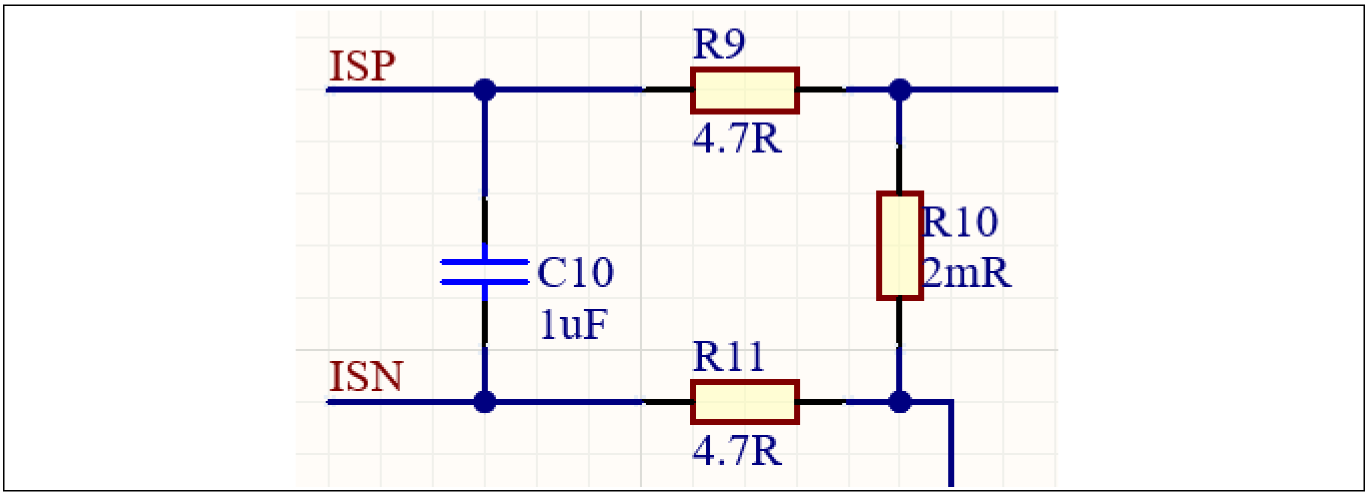

Figure 14 **Shunt resistor for 2ED4820-EM**

3.5 2ED4820-EM

The 2ED4820-EM is a gate driver designed for high current 48 V automotive applications, with powerful gate outputs to drive many MOSFETs in parallel to minimize the conduction losses. It supports the back-to-back configuration, both common source and common drain structures, thanks to its two gate outputs. In common source configuration, one gate output can be used to pre-charge highly capacitive loads. 2ED4820-EM generates the supply for the gate outputs based on an integrated one-stage charge pump with external pump and tank capacitors. 2ED4820-EM comes with an SPI interface, for easy configuration, diagnosis, and control. several protection mechanisms are provided:

- Supply under-and overvoltage detection with configurable restart timer
- Charge pump undervoltage detection
- Gate to source undervoltage detection with immediate lock-out to prevent linear mode conduction of the MOSFETs
- Configurable drain to source overvoltage detection, which can also be deactivated
- Configurable overcurrent protection based on an analog current sense amplifier compatible for high-side or low-side shunt topologies
- Internal overtemperature warning and protection

An interrupt pin informs the MCU whenever one of these protections is triggered. Status registers can then be read by the MCU to understand what the trigger for the notification was. The output of the current sense amplifier can be monitored by the MCU to implement additional protections, such as wire overtemperature. In addition, 2ED4820-EM enables to implement an open load detection mechanism, checking the source voltage of the MOSFETs with respect to ground in the OFF state.

On this board the 2ED4820-EM is used in common source configuration enabling the direct usage of a pre-charge path. Later is populated with the 100 V OptiMOS™ 5 ISC035N10NM5LF2 Linear FET. Depending on the load the maximum initial current flowing can vary greatly. To limit this current either hardware changes or software changes are required. Here only hardware changes are discussed. Depending on R16 the maximum current flowing into the gate can be influenced hence the switch on characteristic can be altered. Same hold true for the capacitance C51 which can be increased so that the time constant for charging the gate will increase yielding to a slower turn on of the pre-charge MOSFETs. Also, R21 can be reduced to act as a voltage divider and further limit the maximum gate voltage.

Furthermore, there is the possibility to add an additional Zener Diode to limit the gate voltage and ensure that these MOSFETs are only operated in their linear region. For the application inside the IMR a configuration of R21=2.6 kOhm, C51=10 nF and a 4.3 V Zener at D7 provides a robust and gentle pre-charge without software changes. For other applications this configuration might be too conservative to fully pre charge the load. In this case also the pre-charge resistor value should be decreased. In the instance of a low capacitive load, the pre-charge resistors may even be removed entirely once the gate charge components are well tuned. Once the pre-charge is done (V_Load =~BAT_POS_AS) the main current path with two single 80 V N-Channel OptiMOS™ 5 power MOSFETs is turned on.

As stated in Section 3.2 the SAFESTATEN is routed to the board edge connector enabling the use of an emergency stop. Once this button or any other protection is triggered the 2ED4820-EM will turn of the main path as quickly as possible.

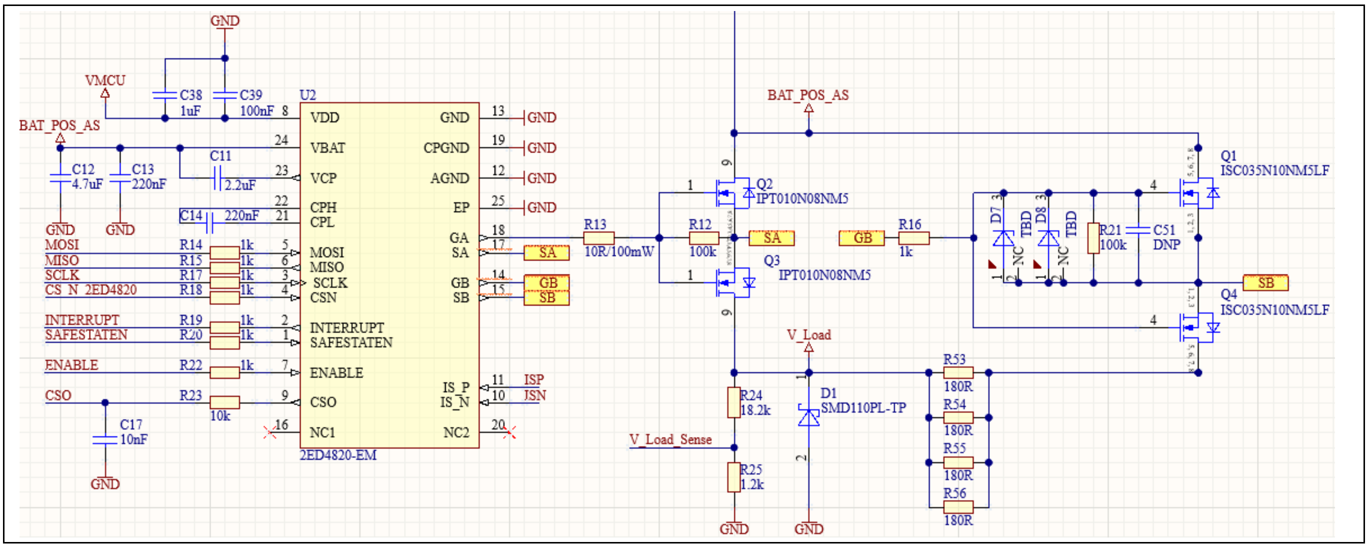

Figure 15 2ED4820-EM including pre-charge and main path

3.6 CAN interface

To communicate with the other subsystems of the robot a CAN interface is used. The TLE9351BVSJ is a high-speed CAN transceiver, used in HS CAN systems for automotive applications as well as for industrial applications. It is designed to fulfill the requirements of ISO 11898-2:2016 physical layer specification as well as SAE J1939 and SAE J2284. The TLE9351BVSJ is available in a RoHS compliant, halogen free PG-DSO-8 package.

As an interface between the physical bus layer and the HS CAN protocol controller, the TLE9351BVSJ is designed to protect the microcontroller against interferences generated inside the network. A very high ESD robustness and the optimized RF immunity allows the use in automotive applications without additional protection devices, such as suppressor diodes or common mode chokes. Based on the high symmetry of the CANH and CANL output signals, the TLE9351BVSJ provides a very low level of electromagnetic emission (EME) within a wide frequency range. The TLE9351BVSJ fulfills even stringent EMC test limits without an additional external circuit, such as a common mode choke.

The optimized transmitter symmetry combined with the optimized delay symmetry of the receiver enables the TLE9351BVSJ to support CAN FD data frames. The device supports data transmission rates up to 5 Mbit/s, depending on the size of the network and the inherent parasitic effects. Dedicated low-power modes, such as standby mode, provide very low quiescent current during power-up of the device. In standby mode the typical quiescent current on VIO is less than 10 µA while the device can still wake up by a bus signal on the HS CAN bus. Fail-safe features, such as overtemperature protection, output current limitation or the TxD timeout feature are designed to protect the TLE9351BVSJ and the external circuitry from irreparable damage.

The CAN/CAN FD messages are routed to the piggyback board where they are processed. A termination resistor R29 footprint is included on the board, and it can be populated in case the BMS is in the end of the CAN line.

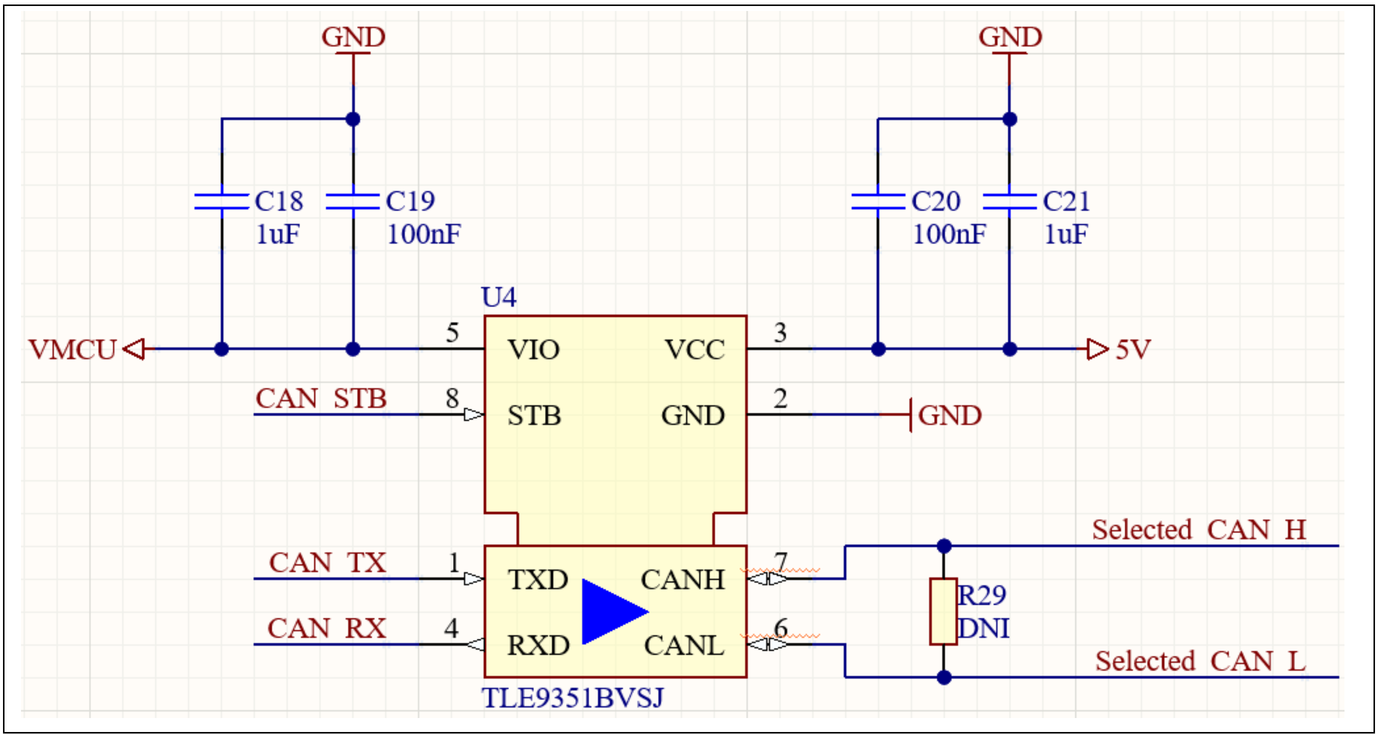

Figure 16 **TLE9351BVSJ CAN transceiver**

3.7 Piggyback board interface

All necessary interfaces are passed onto the piggyback board (e.g. DEMO_IMR_BMSCTRL_V1) via four 20-pin headers. These include the SPI for ADC and 2ED4820-EM, the CAN interface, the coding resistor pin, the overcurrent pins of the TLI4971, the UART interface of the TLE9012 as well as the LED and buttons which are situated on the board. Furthermore, depending on the piggyback board, the 3.3 V or 5 V respectively are passed back again and acts as a supply logic voltage for all interfaces like on the 2ED4820 or TLE9012. This is to make sure that the whole board can operate with a controller using either 5 V or 3.3 V logic.

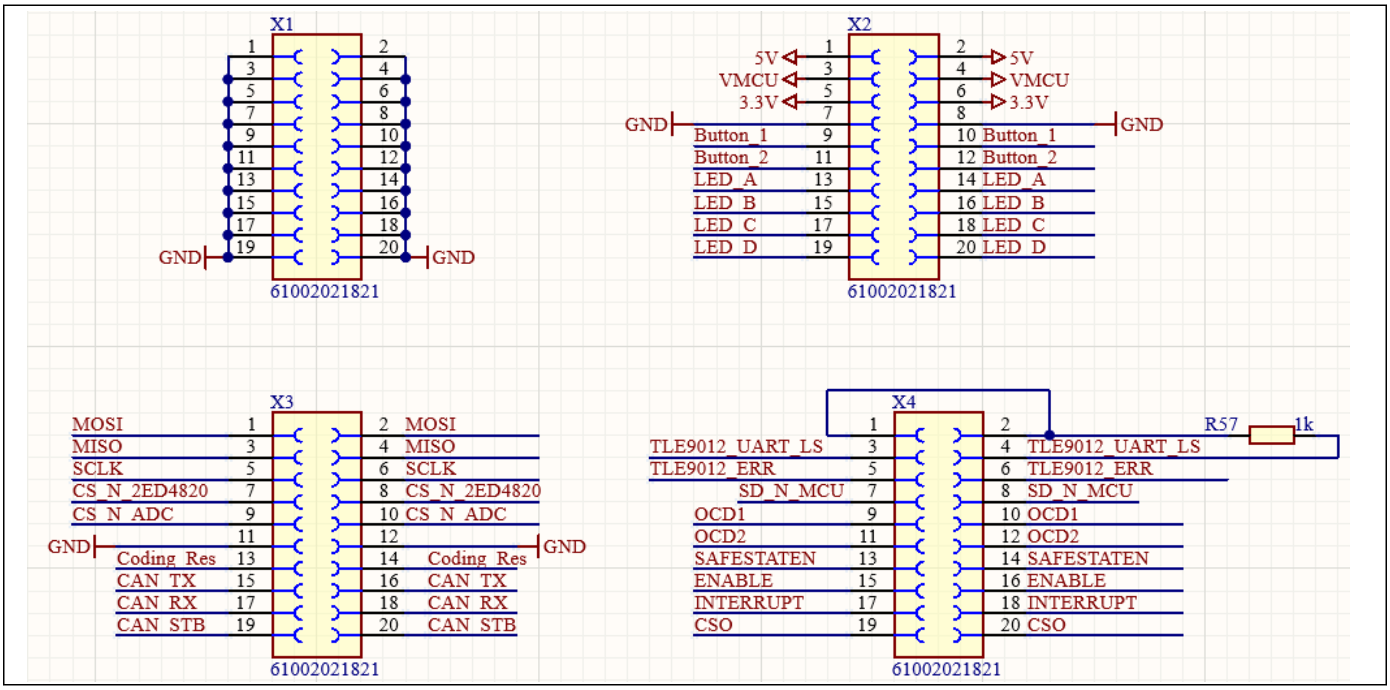

Figure 17 Interface to the piggyback board

3.8 LEDs and buttons

The board has four LEDs on it which are controlled by the piggyback board. With this LEDs the status of the BMS system can be indicated. Furthermore, two buttons are situated on the board which are also forwarded to the controller board. Depending on the software of the controller board, these LEDs and buttons may have various functions attached to them.

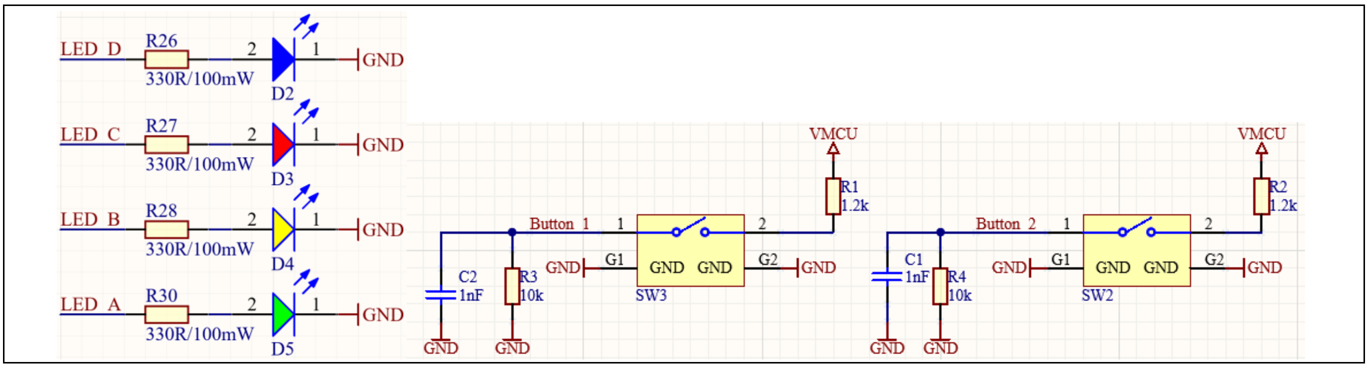

Figure 18 Status LEDs and buttons for the BMS

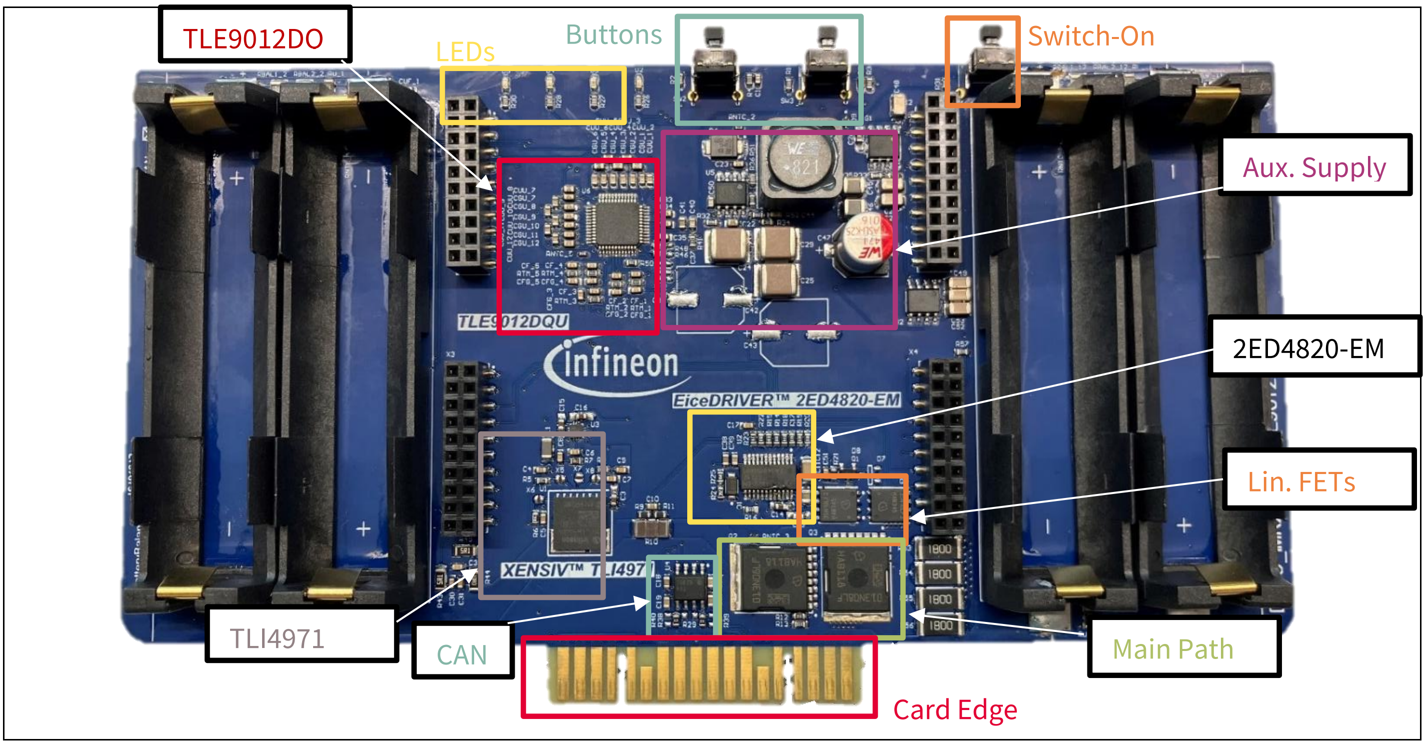

Figure 19 DEMO_IMR_BMSPWR_V1 board with all function blocks highlighted

4 PCB

The DEMO_IMR_BMSPWR_V1 evaluation board utilizes a four-layer PCB with 1 oz. copper on the top and bottom layers and 1 oz. copper on the internal layers. Components are mounted on the top and bottom sides. The width is 180 mm and the length is 99.11 mm.

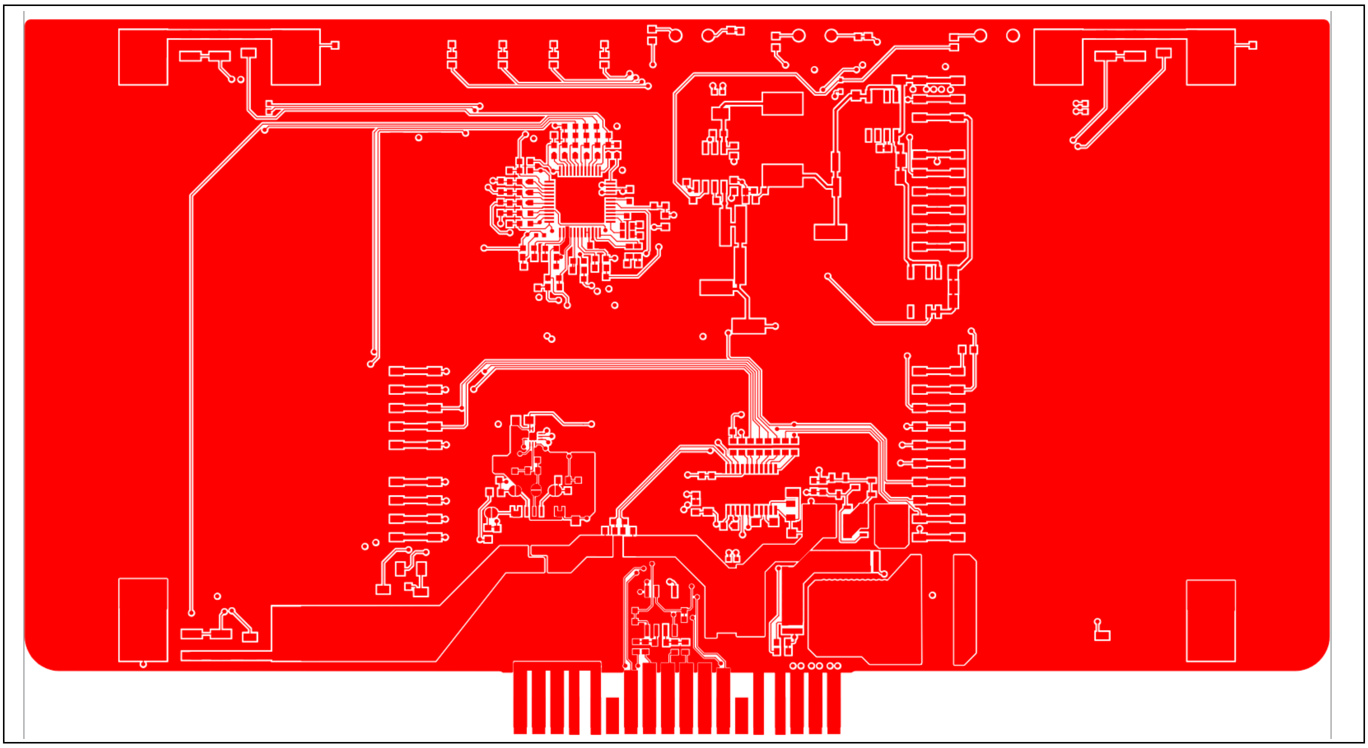

Figure 20 DEMO_IMR_BMSPWR_V1 PCB top layer

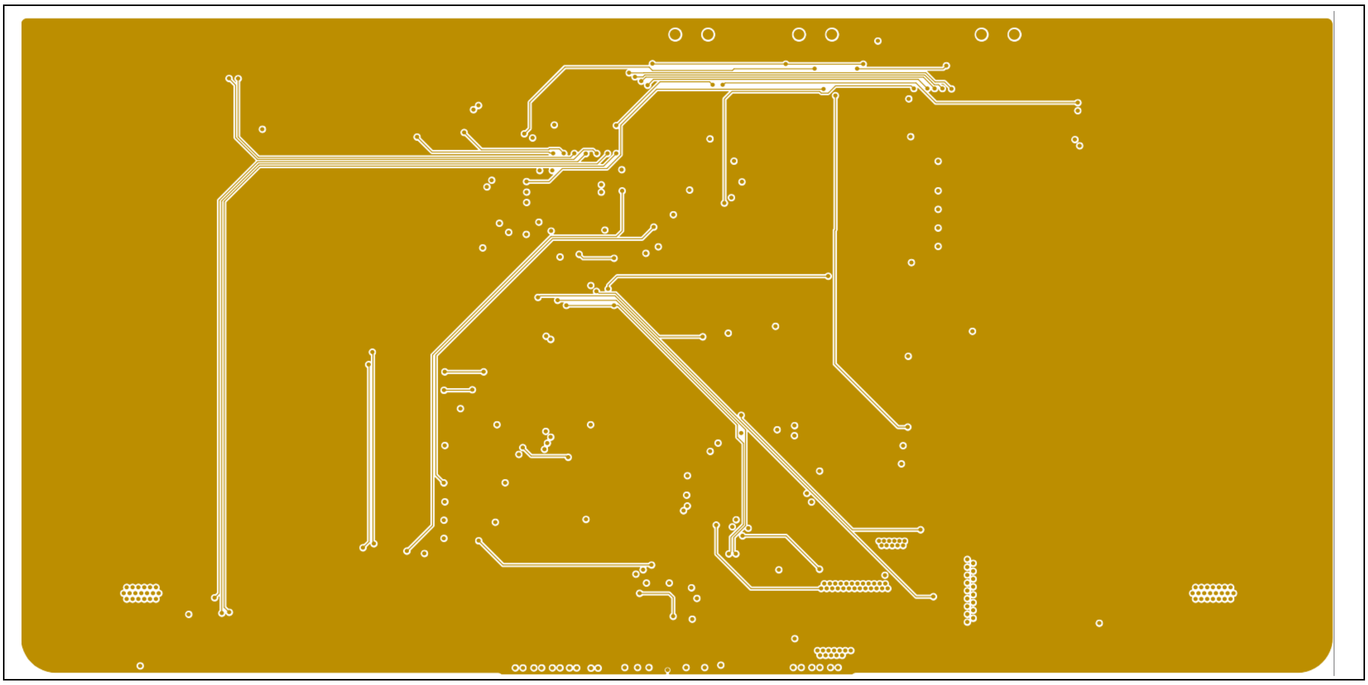

Figure 21 DEMO_IMR_BMSPWR_V1 PCB mid layer 1

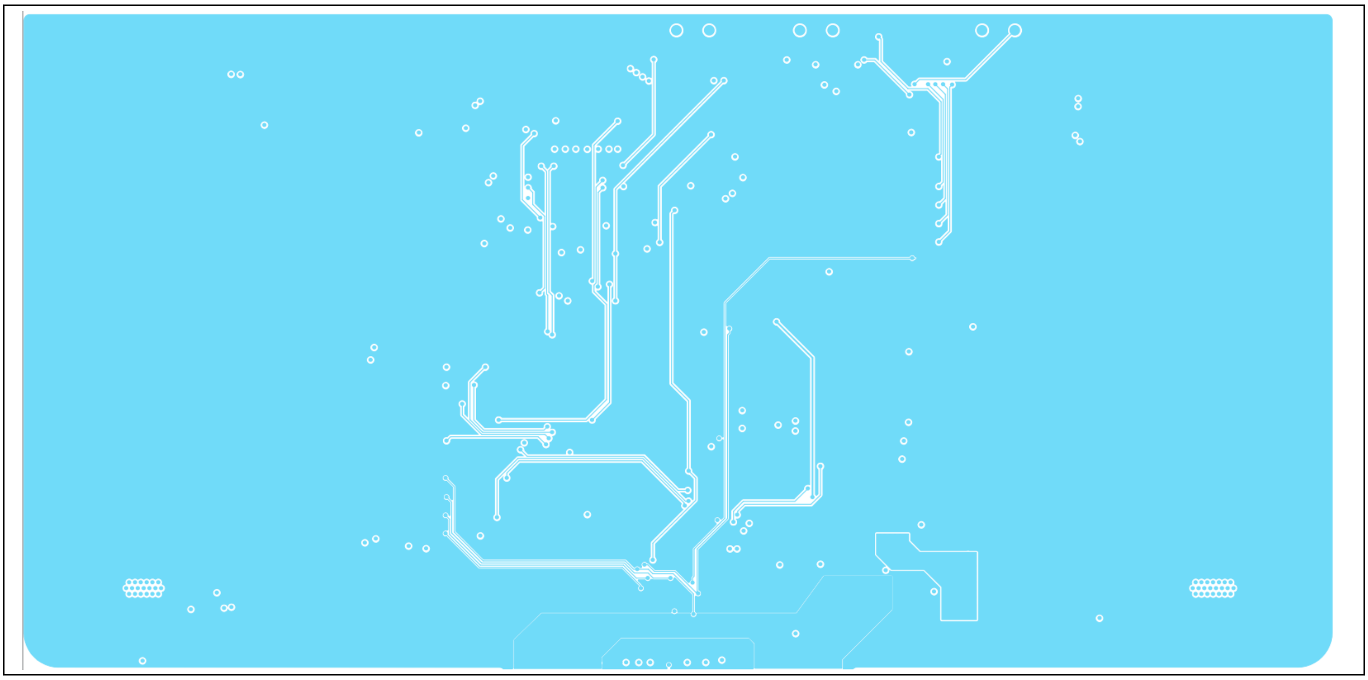

Figure 22 DEMO_IMR_BMSPWR_V1 PCB mid layer 2

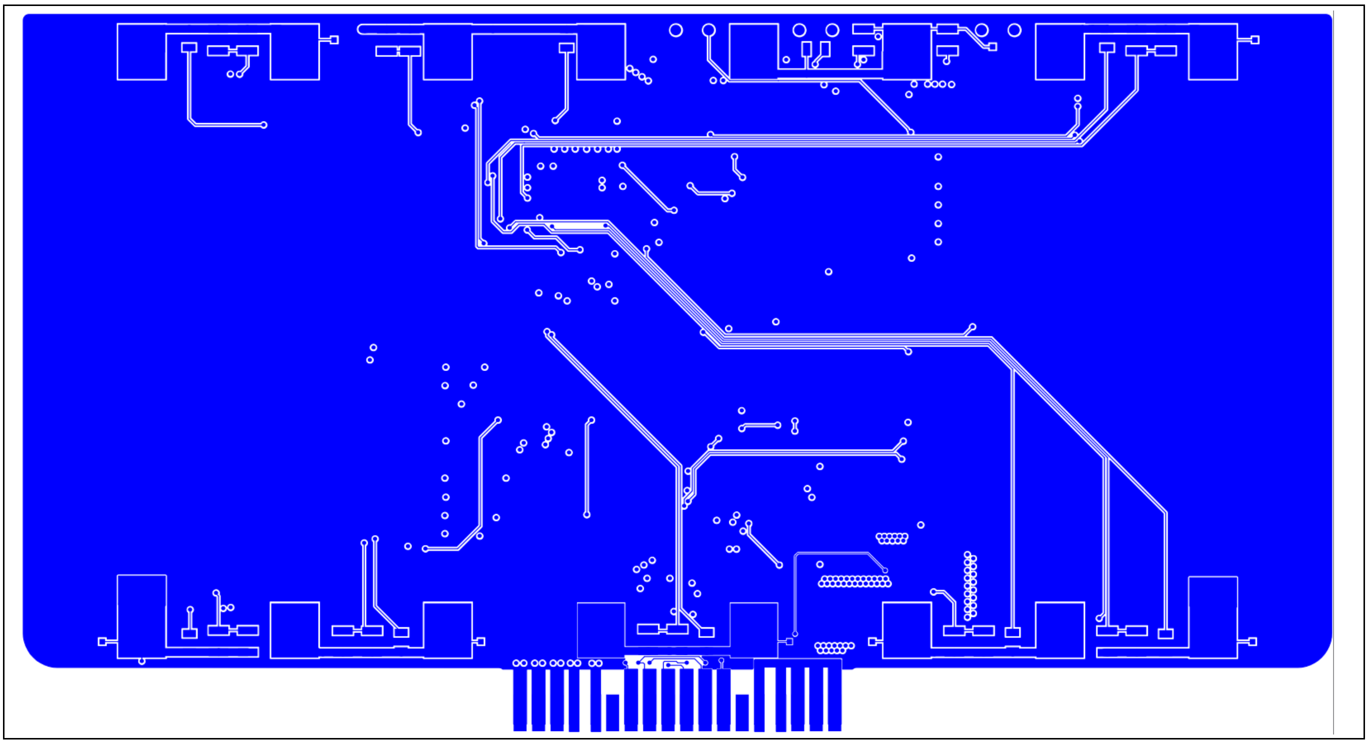

Figure 23 DEMO_IMR_BMSPWR_V1 bottom layer

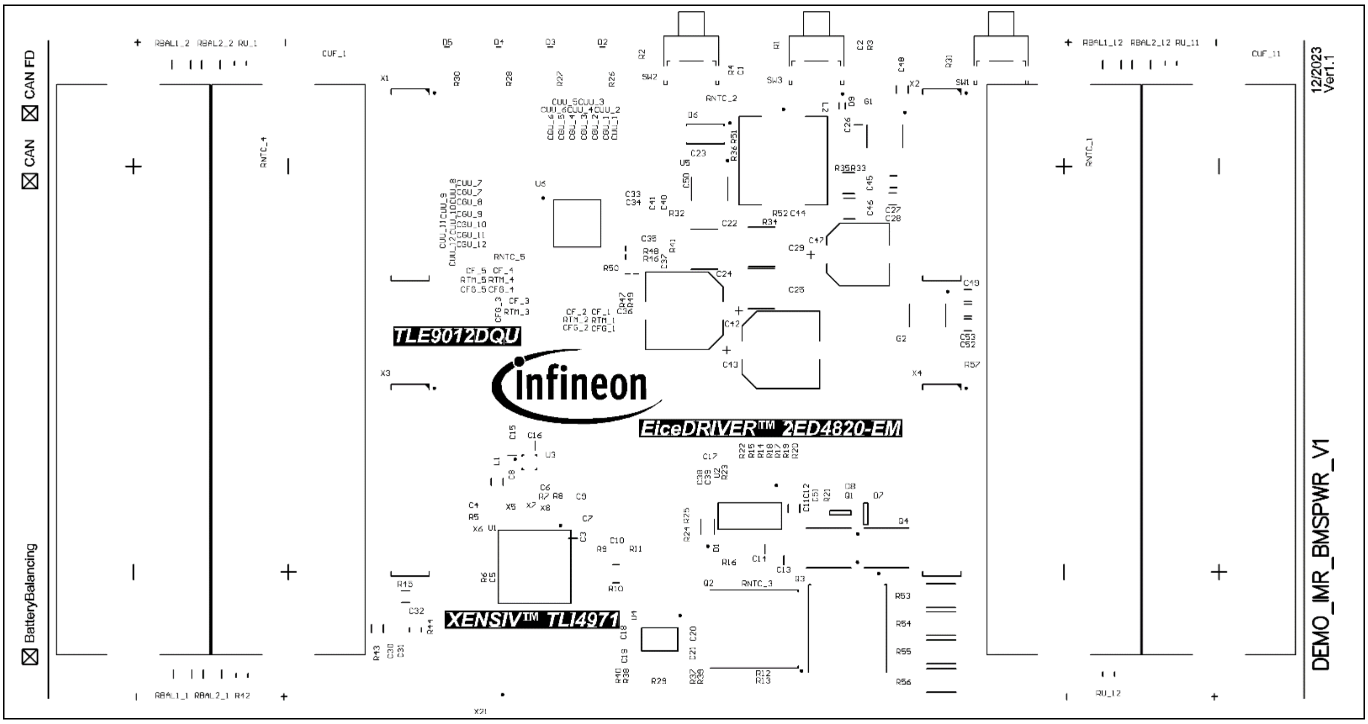

Figure 24 DEMO_IMR_BMSPWR_V1 PCB top silkscreen layer

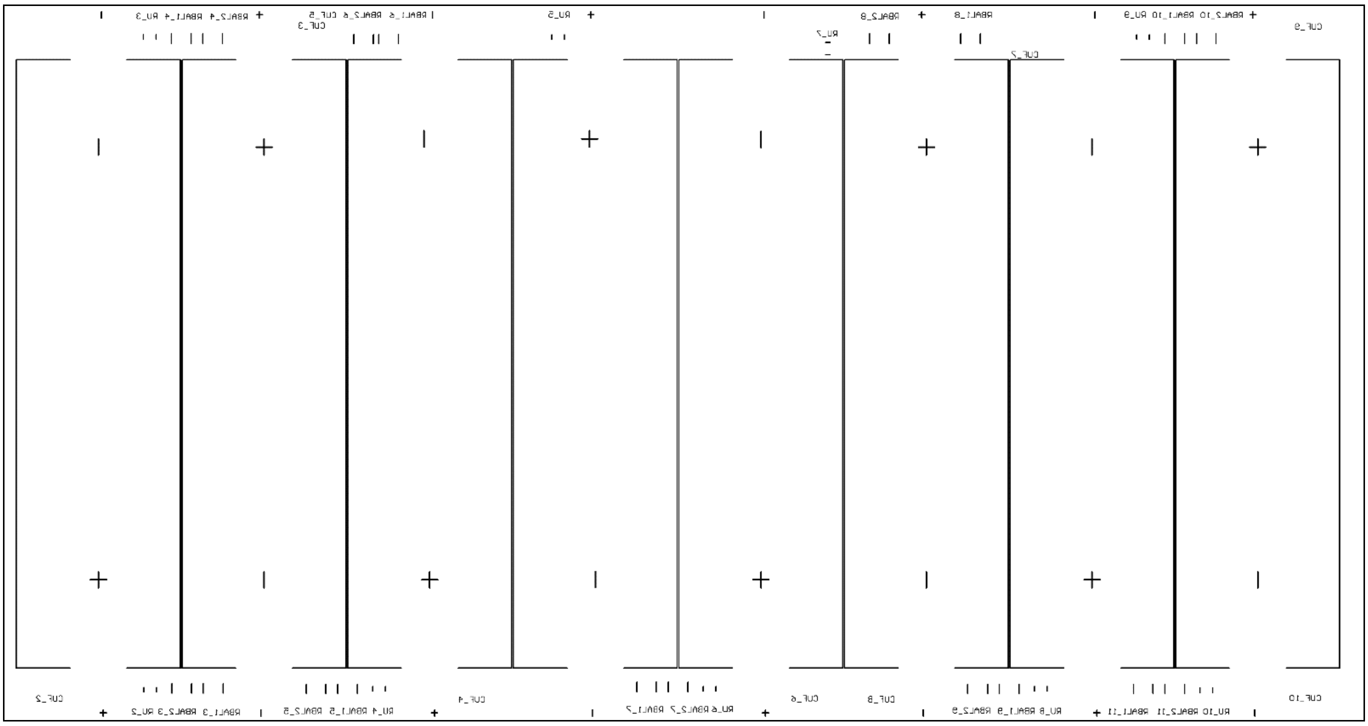

Figure 25 DEMO_IMR_BMSPWR_V1 PCB bottom silkscreen layer

5 Bill of materials

Table 1 Bill of materials

Reference	Qty	Type	Value/Rating	Manufacturer	Part number
C1, C2, C4, C5, C30, C31, CUF_1, CUF_2, CUF_3, CUF_4, CUF_5, CUF_6, CUF_7, CUF_8, CUF_9, CUF_10, CUF_11, CUF_12	18	Capacitor	1 nF/100 V/0603	Würth Elektronik	885012006085
C3, C13, C14, C15, C16, C26	6	Capacitor	220 nF/100 V/0805	TDK	CGA4F3X7S2A224K085AE
C6, C7	2	Capacitor	6.8 nF/50 V/0603	Würth Elektronik	885012206088
C8, C9	2	Capacitor	15 nF/50 V/0603	Würth Elektronik	885012206090
C10, C18, C21, C38, C41	5	Capacitor	1 uF/16 V/0603	Würth Elektronik	885012206052
C11	1	Capacitor	2.2 uF/25 V/0805	Würth Elektronik	885012107016
C12	1	Capacitor	4.7 uF/100 V/1206	Kyocera	12061Z475KAT2A
C17, CF_1, CF_2, CF_3, CF_4, CF_5	6	Capacitor	10 nF/50 V/0603	Würth Elektronik	885012206089
C19, C20, C22, C32, C33, C34, C39, C40, CGU_1, CGU_2, CGU_3, CGU_4, CGU_5, CGU_6, CGU_7, CGU_8, CGU_9, CGU_10, CGU_11, CGU_12	20	Capacitor	100 nF/100 V/0603	Würth Elektronik	885012206120
C23	1	Capacitor	22 nF/50 V/0603	Würth Elektronik	885012206091
C24, C25, C29	3	Capacitor	10 uF/100 V/2220	Würth Elektronik	885012214001
C27, C28, C48, C49, C52, C53	6	Capacitor	220 uF /6.3 V/1206	Murata	GRM31CR60J227ME11L
C35, CUU_1, CUU_2, CUU_3, CUU_4, CUU_5, CUU_6, CUU_7, CUU_8, CUU_9, CUU_10, CUU_11, CUU_12	13	Capacitor	330 nF/16 V/0603	Würth Elektronik	885012106014
C36, C37, C42, C43, C51	5	Capacitor	DNP	-	-
C44, CFG_1, CFG_2, CFG_3, CFG_4, CFG_5	6	Capacitor	4.7 nF/50 V/0603	Würth Elektronik	885012206087
C45, C46	2	Capacitor	47 uF/16 V/1210	Würth Elektronik	885012109011

Reference	Qty	Type	Value/Rating	Manufacturer	Part number
C47	1	Capacitor	470 uF/16 V	Würth Elektronik	865080353015
C50	1	Capacitor	680 pF/100 V/0603	Würth Elektronik	885012006085
D1	1	Diode	SMD110PL-TP	Micro C. C.	SMD110PL-TP
D2	1	LED	Blue, 3.2 V, 140°	Würth Elektronik	150060BS75000
D3	1	LED	Red, 2 V, 140°	Würth Elektronik	150060RS75000
D4	1	LED	Yellow, 2 V, 140°	Würth Elektronik	150060YS75000
D5	1	LED	Green, 3.2 V, 140°	Würth Elektronik	150060GS75000
D6	1	Diode	100 V/ \DO-214AC	Vishay	US1B-E3/61T
D7, D8	2	Diode	TBD / SOT-23	–	-
D9	1	Diode	40 V/SC79	Infineon	BAT64-02V
G1	1	IC	Adjustable LDO	Infineon	TLS208D1EJV
G2	1	IC	Fixed 3.3 V LDO	Infineon	TLS208D1EJV33
L1	1	Inductor	700R/200 mA	Würth Elektronik	74279219
L2	1	Inductor	820 uH/950 mA	Würth Elektronik	7447709821
Q1, Q4	2	MOSFET	OptiMOS™ 5 100 V/3.5 mΩ TDSON-8 FL	Infineon	ISC035N10NM5LF2
Q2, Q3	2	MOSFET	IPT010N08NM5 OptiMOS™ 5 80 V/1.05 mΩ TO-Leadless	Infineon	62701021621
R1, R2, R25, R32	4	Resistor	1.2k/0603	Yageo	RC0603FR-071K2L
R3, R4, R5, R6, R23, R41, R50	7	Resistor	10k/0603	Yageo	RC0603FR-0710KL
RNTC_1, RNTC_2, RNTC_3, RNTC_4, RNTC_5	5	NTC Resistor	10k/0402	TDK	B57232V5103F360
R7, R8	2	Resistor	220R/0603	Vishay	CRCW0603220RFK
R9, R11	2	Resistor	4.7R/0603	Vishay	CRCW06034R70FK
R10	1	Resistor	2 mR/2010	KOA Speer	TLR2HWDTE2L00F50
R12, R21, R35	3	Resistor	100k/0603	Yageo	RC0603FR-07100KL
R13	1	Resistor	10R/0603	Yageo	RC0603FR-0710RL
R14, R15, R16, R17, R18, R19, R20, R22, R36, R57	10	Resistor	1k/0603	Yageo	RC0603FR-071KL

Reference	Qty	Type	Value/Rating	Manufacturer	Part number
R24, R31, R51	3	Resistor	18.2k/0603	Vishay	CRCW060318K2FK
R26, R27, R28, R30	4	Resistor	330R/0603	Vishay	CRCW0603330RFK
R29	1	Resistor	DNI	Yageo	RC0603FR-07120RL
R33	1	Resistor	523k/0603	Bourns	CR0603-FX-5233ELF
R34	1	Resistor	56.2k/0603	Vishay	CRCW060356K2FK
R37, R38	2	Resistor	0R/0603	Vishay	CRCW06030000Z0EA
R39, R40, R46, R47, R48, R49	6	Resistor	DNP	-	-
R42, R44, RU_1, RU_2, RU_3, RU_4, RU_5, RU_6, RU_7, RU_8, RU_9, RU_10, RU_11, RU_12	14	Resistor	10R/1206	Vishay	RCS120610R0FKEA
R43, R45	2	Resistor	5.1R/1206	Panasonic	ERJP08F5R1V
R52	1	Resistor	1k21/0603	Yageo	AC0603FR-072KL
R53, R54, R55, R56	4	Resistor	180R/2512	Vishay	CRCW2512180RFK
RBAL1_1, RBAL1_2, RBAL1_3, RBAL1_4, RBAL1_5, RBAL1_6, RBAL1_7, RBAL1_8, RBAL1_9, RBAL1_10, RBAL1_11, RBAL1_12, RBAL2_1, RBAL2_2, RBAL2_3, RBAL2_4, RBAL2_5, RBAL2_6, RBAL2_7, RBAL2_8, RBAL2_9, RBAL2_10, RBAL2_11, RBAL2_12	24	Resistor	82R/1210	Vishay	CRCW121082R0FK
RTM_1, RTM_2, RTM_3, RTM_4, RTM_5	5	Resistor	100R/0603	Yageo	RC0603FR-07100RL
SW1, SW2, SW3	3	Button	160 g	Würth Elektronik	431256058716
U1	1	IC	Current Sensor	Infineon	TLI4971-A025T5-E0001
U2	1	IC	Smart High-side Gate Driver	Infineon	2ED4820-EM
U3	1	IC	16-bit ADC	Microchip	MCP3465RT-E/SFX
U4	1	IC	CAN Transceiver	Infineon	TLE9351BVSJ
U5	1	IC	DC-DC buck LED driver IC	Infineon	ILD8150E
U6	1	IC	Li-ion battery monitoring and balancing system IC	Infineon	TLE9012DQU
X1, X2, X3, X4	4	Connector	2.54 mm SMT Dual Socket Header	Würth Elektronik	61002021821
X5, X6, X7, X8	4	Jumper	Solder Jumper 2 Pins	-	-

Reference	Qty	Type	Value/Rating	Manufacturer	Part number
X9, X10, X11, X12, X13, X14, X15, X16, X17, X18, X19, X20	12	Connector	Battery Holder for 18650	Keystone	KEYSTONE 1042
X21	1	Header	Card-edge header	N/A	N/A

Revision history

Document revision	Date	Description of changes
1.0	2024-04-08	Initial release
2.0	2025-04-25	Updated Figure 5

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