eDisconnect Power Switch for battery-powered applications

REF_60100EDPS

About this document

Scope and purpose

Applications with lithium-ion batteries use battery management systems (BMS) to monitor the battery state and ensure safe operation. The battery protection unit (BPU), which is a subset of BMS, is typically equipped with electro-mechanical or electronic switches with control circuitry for precharge and (dis-)connect operations.

This user manual provides a brief overview about the concept and functions implemented as well as the use of the eDisconnect Power Switch (EDPS) reference board REF_60100EDPS. This reference board is targeted for battery-powered applications like EVs, servers, energy storage systems (ESS) and serves its purpose in safe disconnection of the battery to abnormal conditions and connection (auto-restart) of the system to normal conditions with the charger or load. The design offers an effective solution for the implementation of a smart BPU using electronic devices like MOSFETs, gate-drivers, and current sensor and is intended to provide reliable performance for such applications.

Intended audience

This document is intended for hardware developers and users of demonstrator boards.

About the reference board/kit

Product(s) embedded on a PCB with a focus on specific applications and defined use cases that may include software. PCB and auxiliary circuits are optimized for the requirements of the target application.

This reference board can also be used during the design-in process for evaluating performances of current sensors, Linear FETs, and TOLT MOSFETs.

Note: *Boards do not necessarily meet safety, EMI, quality standards (for example UL, CE) requirements.*

Note: *PCB and auxiliary circuits are NOT optimized for final customer design.*

Important notice

"Evaluation Boards and Reference Boards" shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as "Reference Board").

Environmental conditions have been considered in the design of the Evaluation Boards and Reference Boards provided by Infineon Technologies. The design of the Evaluation Boards and Reference Boards has been tested by Infineon Technologies only as described in this document. The design is not qualified in terms of safety requirements, manufacturing, and operation over the entire operating temperature range or lifetime.

The Evaluation Boards and Reference Boards provided by Infineon Technologies are subject to functional testing only under typical load conditions. Evaluation Boards and Reference Boards are not subject to the same procedures as regular products regarding returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD).

Evaluation Boards and Reference Boards are not commercialized products and are solely intended for evaluation and testing purposes. In particular, they shall not be used for reliability testing or production. The Evaluation Boards and Reference Boards may therefore not comply with CE or similar standards (including but not limited to the EMC Directive 2004/EC/108 and the EMC Act) and may not fulfill other requirements of the country in which they are operated by the customer. The customer shall ensure that all Evaluation Boards and Reference Boards will be handled in a way, which is compliant with the relevant requirements and standards of the country in which they are operated.

The Evaluation Boards and Reference Boards as well as the information provided in this document are addressed only to qualified and skilled technical staff, for laboratory usage, and shall be used and managed according to the terms and conditions set forth in this document and in other related documentation supplied with the respective Evaluation Board or Reference Board.

It is the responsibility of the customer's technical departments to evaluate the suitability of the Evaluation Boards and Reference Boards for the intended application, and to evaluate the completeness and correctness of the information provided in this document with respect to such application.

The customer is obliged to ensure that the use of the Evaluation Boards and Reference Boards does not cause any harm to persons or third-party property.
The Evaluation Boards and Reference Boards and any information in this document is provided "as is" and Infineon Technologies disclaims any warranties, express or implied, including but not limited to warranties of noninfringement of third-party rights and implied warranties of fitness for any purpose, or for merchantability.

Infineon Technologies shall not be responsible for any damages resulting from the use of the Evaluation Boards and Reference Boards and/or from any information provided in this document. The customer is obliged to defend, indemnify, and hold Infineon Technologies harmless from and against any claims or damages arising out of or resulting from any use thereof.

Infineon Technologies reserves the right to modify this document and/or any information provided herein at any time without further notice.

Safety precautions

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

Table 1 Safety precautions

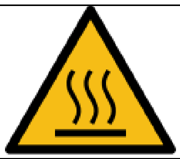
	**Warning:** *The DC link potential of this board is up to 100 VDC. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors, which 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.*

Table of contents

About this document ... **1**
Important notice ... **2**
Safety precautions ... **3**
Table of contents ... **4**
1 The board at a glance ... **6**
1.1 Scope of supply ... 6
1.2 Block diagram ... 7
1.3 Main features ... 7
1.4 Board parameters and technical data ... 8
2 System and functional description ... **9**
2.1 Power board (REF_60100EDPS_PB) ... 9
2.2 Control board (REF_60100EDPS_CB) ... 10
2.3 Hardware application setup ... 11
2.4 Description of the functional blocks ... 12
2.4.1 EiceDRIVER™ APD 2ED4820-EM (Protection switch controller) ... 12
2.4.2 Current sensor – TLE4972 ... 12
2.5 Basic operation ... 13
2.6 Special operation modes ... 14
3 System design ... **15**
3.1 Schematics ... 15
3.1.1 Power board schematics ... 15
3.1.2 Control board schematics ... 15
3.1.2.1 Gate driver schematics ... 15
3.1.2.2 MCU schematics ... 16
3.1.2.3 Auxiliary supply (V_{BAT} to 12 V) schematics ... 16
3.1.2.4 12 V external supply and LDO ... 16
3.2 Layout ... 17
3.2.1 Power board layout ... 17
3.2.2 Control board layout ... 19
3.3 Bill of materials ... 21
3.4 Connector details ... 22
4 Configuration tool ... **23**
4.1 Software setup ... 23
4.2 Getting started steps ... 23
4.3 User interface control ... 24
5 System performance ... **26**
5.1 Test parameters ... 26
5.2 Test results ... 26
5.2.1 Sleep-mode consumption ... 26
5.2.2 Precharge operation ... 26
5.2.3 Thermal performance ... 27
5.2.3.1 Without heatsink ... 27
5.2.3.2 With heatsink ... 29
5.2.4 Current sensor (TLE4972) performance ... 30
5.2.5 Smart gate-driver (2ED4820-EM) performance ... 31
5.2.6 LED indications ... 32

5.3 Test points 32
Appendices 34
A BOM of the power board 34
B BOM of the control board 35
References 40
Glossary 41
Revision history 43

1 The board at a glance

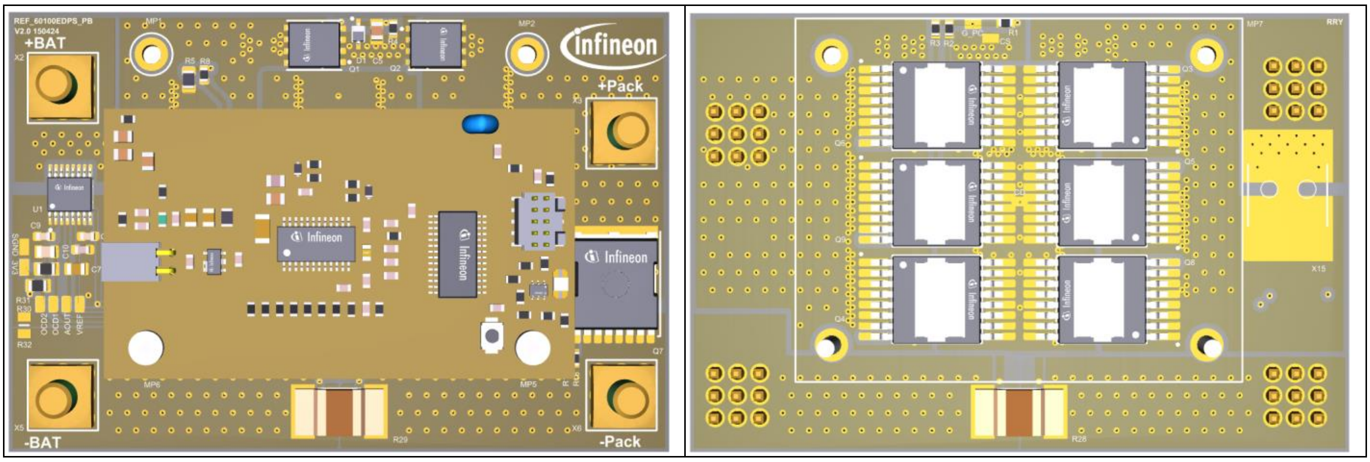


Figure 1 Board images of REF_60100EDPS, Left: Top view, Right: Bottom view

The eDisconnect Power Switch (EDPS) reference board named REF_60100EDPS, shown in Figure 1, offers a system solution of connecting or disconnecting the battery from the load across its pack terminals. The user can plug-in hardware in the battery-powered application to operate it using an isolated debug probe, using the Micro Inspector Pro GUI provided by Infineon within the standard PC setup.

REF_60100EDPS is a combination of a power board named REF_60100EDPS_PB and a control board named REF_60100EDPS_CB.

1.1 Scope of supply

The EDPS proof-of-concept system consists of:

- Power board (bidirectional protection switches, precharge switches, a free-wheeling switch, and a current sensor)
  - Six numbers of IPTC014N10NM5, 100 V TOLT MOSFETs in common-drain configuration
  - Two numbers of ISC035N10NM5LF2, 100 V SS08 (5x6) wide-SOA MOSFETs in common-source configuration
  - One IPT014N10N5, 100 V TOLL across pack terminals
  - One TLE4972-AE35D5 in the positive rail of the battery
- Control board (gate driver for protection switches, drive circuit for precharge MOSFETs, gate driver for free-wheeling MOSFET, MCU, and auxiliary supply circuits)
  - One 2ED4820-EM, two-channel high-side smart gate driver IC with SPI communication
  - One 1EDN8511B, one-channel low-side gate driver IC
  - One XMC1302-T028X0128 AB, 32-bit MCU with Arm® Cortex®-M0
  - One TLS202B1MBV33, linear regulator IC

1.2 Block diagram

Figure 2 shows a high-level schematic architecture of REF_60100EDPS which includes a protection switch unit, a current sensor, a microcontroller, a freewheeling MOSFET, a precharge drive circuit, an auxiliary supply, and voltage-sensing subsections. The block diagram provides a functional overview and illustrates how different subsections of the system interface based on the type of signal.

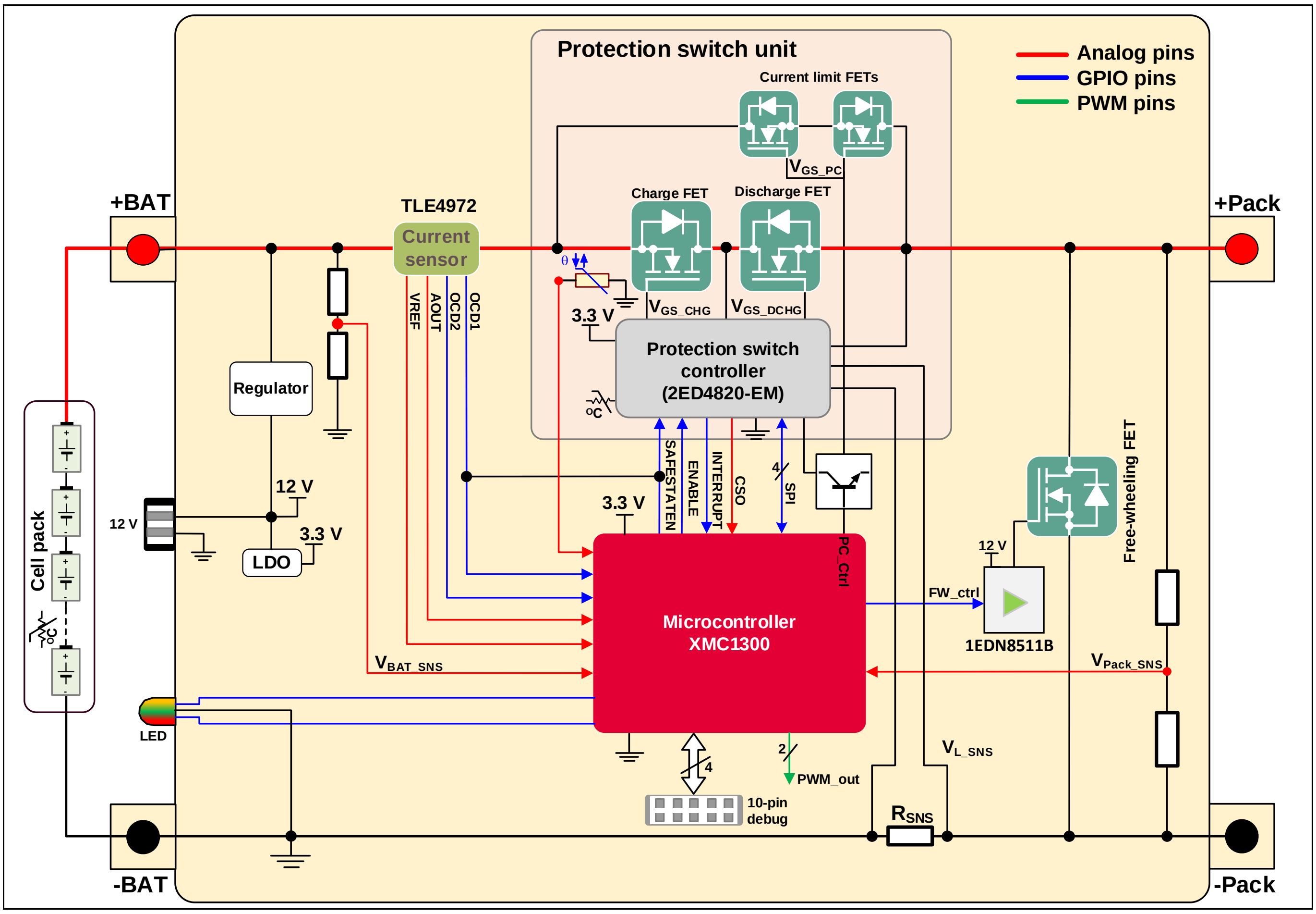


Figure 2 Block diagram of the eDisconnect power switch (REF_60100EDPS)

1.3 Main features

Protection can be implemented by connecting MOSFETs either on the positive rail or on the negative rail of the source (e.g., a battery). As shown in Figure 2, REF_60100EDPS is designed to implement protection on the high-side (HS) using bidirectional protection switches in common-drain configuration in the high-level block diagram of eDisconnect power switch reference board. Also, it shows MOSFETs connected in common-source configuration driven by a discrete circuit to precharge the load capacitance without a bulk-current-limiting resistor. The freewheeling MOSFET and its drive circuit across the pack terminals protects the reference board from short circuits. The current sensor in the positive rail is used to measure the battery current with integrated magnetic coreless hall technology and provides an analog signal proportional to the measured current. It also offers fast protection against overcurrents or short circuits with its dedicated digital outputs.

Typical low-side shunt mechanism is also provided on the negative rail to measure battery current with the help of an integrated current-sense amplifier in a smart gate-driver or a protection-switch controller. However, its use is limited to offering an autonomous, redundant short-circuit protection for this reference board.

A switching regulator is provided onboard to generate an auxiliary supply (12 V) to power the LED and the free-wheeling MOSFET's gate-drive circuit. Alternatively, the external connector (12 V) on the control board (REF_60100EDPS_CB) can also be used for these purposes. The linear regulator (LDO) generates 3.3 V from the 12 V input to further provide VDD supply for the MCU, the smart gate driver, and the current sensor. See Section 5.2.6 for the bicolor LED indications representing system status in the normal mode as well as fault modes.

1.4 Board parameters and technical data

Table 2 Board parameters

Parameter	Symbol	Value	Unit
Battery operating voltage	V_BAT	30 to 60	V
Continuous DC current (without heatsink)	I_BAT	0 to 80	A
Continuous DC current (with heatsink)	I_BAT	0 to 100	A
Overcurrent	OC	130	A
Operating temperature range	Temp	-15 to 100	°C
Response time	t_{OFF}	5	µs
Auxiliary supply voltage (Optional: External)	V_{AUX}	12	V
Control voltage	V_{DD}	3.3	V
Board size	L × W × H	75 × 50 × 20	mm

2 System and functional description

2.1 Power board (REF_60100EDPS_PB)

Figure 3 shows the REF_60100EDPS_PB reference board is a power board consisting of MOSFETs (TOLT) connected in drain-to-drain configuration, a current sensor [1] with a straight PCB-sensing structure, precharge MOSFETS (SSO8) in common-source configuration in the positive rail of the battery and a free-wheeling MOSFET (TOLL) across the pack terminals.

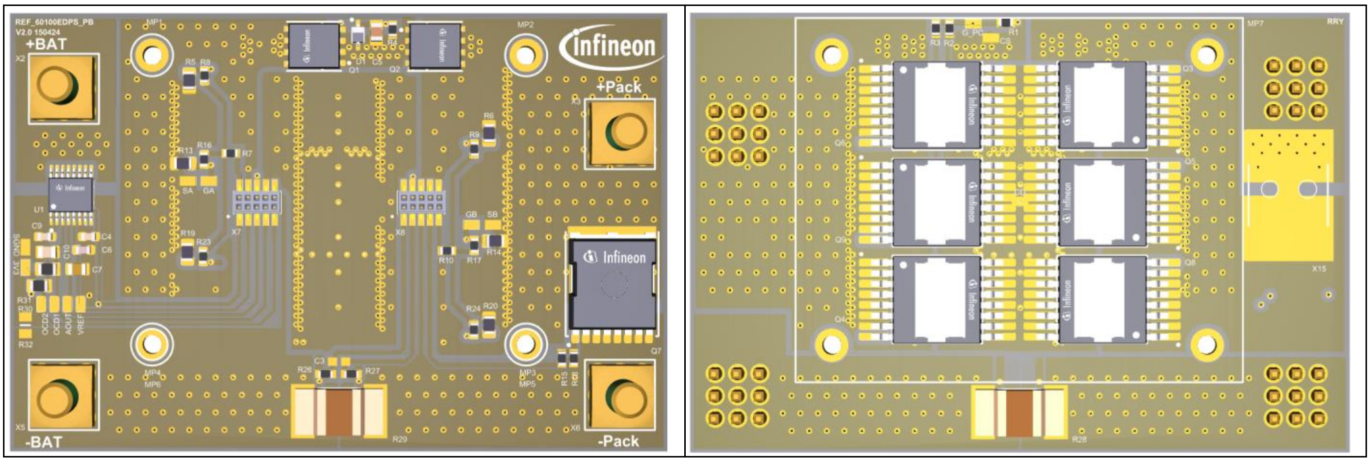


Figure 3 REF_60100EDPS_PB images, Left: Top view, Right: Bottom view

The reference board is designed to handle the charging and discharging operations with the following specifications.

Table 3 REF_60100EDPS_PB specifications

Parameter	Value/SPN
Maximum peak voltage on the board	100 V
Maximum continuous DC current (without heatsink)	80 A
Maximum continuous DC current (with heatsink)	100 A
Maximum temperature on PCB	125°C
MOSFETs	IPTC014N10NM5 ISC035N10NM5LF2 IPT014N10N5
Current sensor	TLE4972-AE35D5
Board size	75 mm × 50 mm

2.2 Control board (REF_60100EDPS_CB)

Figure 4 shows the REF_60100EDPS_CB reference board which is a power management control board consisting of the 2ED4820-EM smart gate driver [2], 1EDN8511B non-isolated one-channel gate-driver, and a 32-bit MCU, XMC1302-T028X0200 AB.

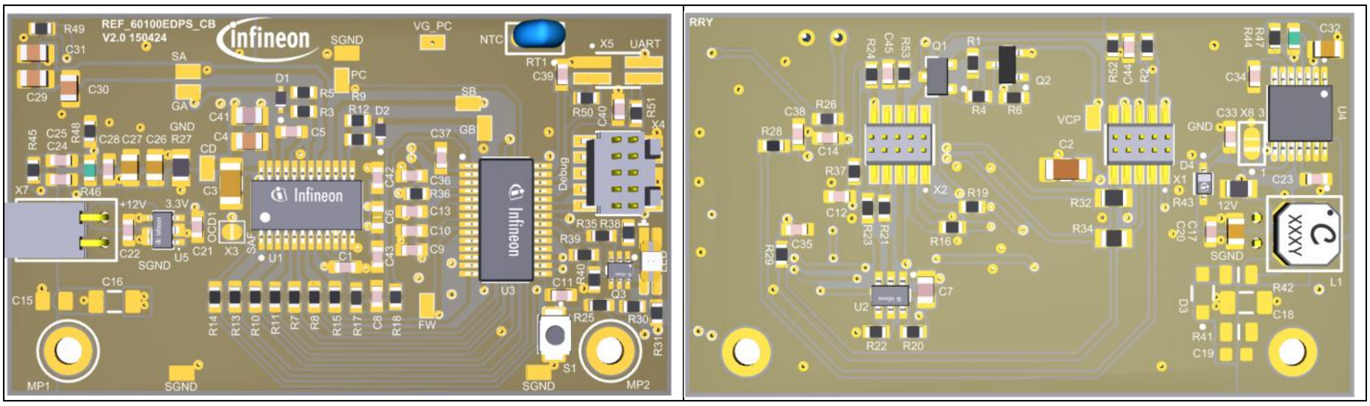


Figure 4 REF_60100EDPS_CB images. Left: Top view. Right: Bottom view.

A two-channel non-isolated high-side smart gate driver 2ED4820-EM on the REF_60100EDPS_CB board drives the protection (TOLT) MOSFETs in addition to powering the precharge gate drive circuit with its integrated charge pump on the REF_60100EDPS_PB board. Both output channels are individually driven through a strong, integrated charge pump which supplies the outputs. Each channel can drive three TOLT MOSFETs in parallel on REF_60100EDPS_PB with 0.3 A source and 1 A sink currents. The 1EDN8511B gate-driver drives the freewheeling MOSFET across the pack terminals if a short circuit fault occurs.

The controller board is to be supplied 12 V externally through the X7 connector for flashing the firmware in the MCU's memory, as well as for debugging the hardware without the onboard voltage regulator IC. The reference board comes with shorted pads on the X3 solder bridge to activate the SAFESTATEN pin of the 2ED4820-EM gate-driver along with OCD1 pin of TLE4972. Due to this, CHA and CHB gate outputs safely switch both MOSFET channels OFF in case of an overload on the power board. Also, the X8 solder bridge at the bottom of the control board is open between pads 1 and 2 to operate the voltage regulator IC in the discontinuous mode of operation for a tightly regulated output of 12 V.

The reference board REF_60100EDPS_CB is designed with the specifications given in the following table.

Table 4 REF_60100EDPS_CB specifications

Parameter	Value/SPN
Switching regulator operational voltage range	12 V to 60 V
Switching regulator output (or) external supply voltage	12 V
LDO output voltage (V_{DD})	3.3 V
Gate-driver ICs	2ED4820-EM 1EDN8511B
Microcontroller	XMC1302-T028X0200 AB
LDO	TLS202B1MBV33
Board size	52.3 mm × 30 mm

The control board REF_60100EDPS_CB must be interfaced with the power board REF_60100EDPS_PB to drive MOSFETs. The X1 and X2 male connectors on the control board are to be interfaced with X7 and X8 on the power board respectively.

2.3 Hardware application setup

The battery/source and load/charger interface with REF_60100EDPS is shown in Figure 5.

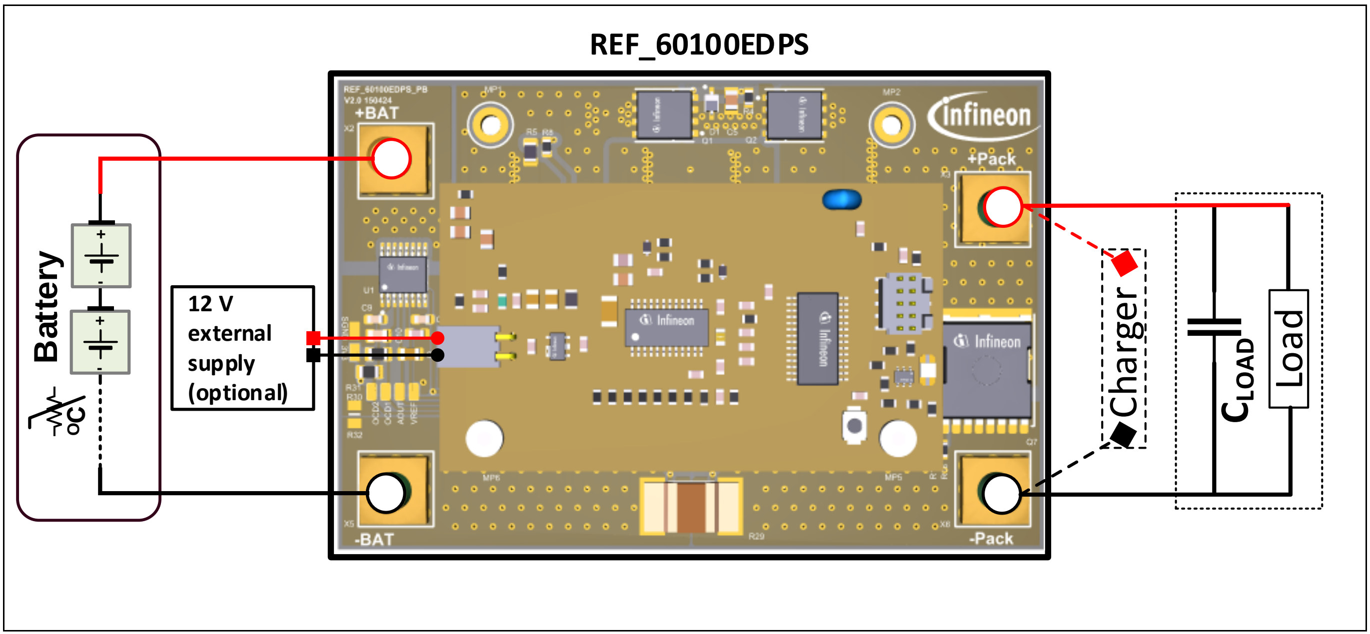


Figure 5 REF_EDPS setup in the application

The X2 and X5 power terminals on the power board are used to connect REF_60100EDPS with the battery positive (+BAT) and negative (-BAT) terminals; X3 and X6 power terminals to the load positive (+Pack) and negative (-Pack) terminals respectively. MP5 and MP6 are spacers used to provide the required spacing between REF_60100EDPS_CB and REF_60100EDPS_PB. MP1, MP2, MP3, and MP4 are M2 screws to mount the heatsink at the bottom of the power board. MP3 and MP4 are also used to mount the control board on top of the power board.

Note: Terminals X2 and X5 as well as X3 and X6 on REF_60100EDPS are not interchangeable.

The control board REF_60100EDPS_CB can be powered in two ways:

Battery or source: As shown in Figure 5, interfacing X1 and X2 connectors on the control board with X7 and X8 on the power board will power the control board directly from the battery voltage. The switching regulator IC onboard the control board regulates the input battery voltage to 12 V. The 12 V to 3.3 V LDO provides a 3.3 V supply for the control board logic functionalities.

12 V external supply (optional): As shown in Figure 5, an external supply voltage of 12 V can also be used. Connector X7 for 12 V external supply is provided to flash the MCU with software updates and debugging the hardware without using the onboard switching regulator IC. Connect pin 1 of the X7 connector on the control board to the positive terminal and pin 2 to the ground of the external power supply. The 12 V external supply ground is connected to the battery's negative terminal (-BAT) on the control board through the resistor jumper R27.

A GUI running on a PC enables reading, controlling, configuring, and diagnosing the eDisconnect power switch operation for various battery-powered application requirements.

2.4 Description of the functional blocks

2.4.1 EiceDRIVER™ APD 2ED4820-EM (Protection switch controller)

EiceDRIVER™ 2ED4820-EM is a high-side N-channel MOSFET gate-driver with two outputs controlled via SPI for industrial and automotive applications. The driver IC's ability of enhanced fast turn-on and turn-off due to the integrated charge pump allows driving several MOSFETs in parallel for high discharge-current requirements.

On this reference board, a total of six TOLT MOSFETs in three parallel paths are connected in a common-drain configuration to share a maximum of 80 A of load current without heatsink. Although the reference board's operational voltage is set between 30 V and 60 V, the driver IC can be used for supply voltages from 20 V to 70 V.

The integrated current-sense amplifier with a dedicated monitoring output current sense output (CSO) supported by low-side current measurement is used to measure load current. Configurable overcurrent threshold together with current-sense gain selection allows current measurements as well as overcurrent protection. In addition, the driver comes with several failure detection features. The device control, configuration, and diagnostics are performed via the SPI interface.

An interrupt pin informs the MCU whenever one of the protection mechanisms offered by the driver is triggered. As the MCU has no access to the internally defined parameters $V_{REFBIDIR}$ and G_{DIFF} of its differential amplifier structure, it always computes the load-current based on the typical values of these two parameters.

2.4.2 Current sensor – TLE4972

Current Sensor Simulation Tool: The current-sensing structure for the defined external-rail PCB structure is simulated using the XENSIV™ Current Sensor Simulation Tool [3] provided by Infineon Technologies. The user can enter the geometries of the PCB sensing structure as well as the layer stack to calculate the key performance parameters such as the magnetic field transfer factor, electric resistance, and power dissipation. Additionally, the tool allows the user to study the impact of mounting tolerance due to the displacement of the current sensor (x, y, and z translations) with respect to the sensing structure.

For the REF_60100EDPS_PB design which is supported by a straight sensing structure [4] on the PCB current rail, the sensing structure parameters are given below:

Length = 38.0 mm, width = 12.0 mm, slit_x = 1.5 mm, slit_dy = 4.3 mm

The layer stack manufactured on REF_60100EDPS_PB is shown in Figure 6.

Solder Resist Top	25 µm		Layer Position w.r.t. top of PCB
Layer1	70 µm	☐ Contains Current Rail	layer_1_position: 25µm
Dielectric 1	203 µm		
Layer 2	70 µm	☑ Contains Current Rail	layer_2_position: 298µm
Core	800 µm		
Layer 3	70 µm	☑ Contains Current Rail	layer_3_position: 1168µm
Dielectric 2	203 µm		
Layer 4	70 µm	☑ Contains Current Rail	layer_4_position: 1441µm
Solder Resist Bottom	25 µm		

Figure 6 REF_60100EDPS_PB layer stack

The differential field transfer factor for the layer stack as shown in Figure 6 calculates to 52 µT/A. The programmable sensitivity corresponding to the calculated transfer factor is set to the S6 measurement range code. In this case, S = 23 mV/A, which is double the normal sensitivity as the current sensor is operated in a fully differential output mode [5].

Current sensor programmer: To guide the user in programming, calibration, and evaluation of the TLE4972 current sensor on the REF_60100EDPS_PB power board, Infineon provides a programmer GUI along with the current sensor programmer. GUI installation procedure, application setup, EEPROM programming, internal signals readout, and calibration procedure are explained in the current sensor programmer user guide [6].

To enable the current sensor's programming/test mode, you must connect the programmer board through the USB connection and open the GUI software **XENSIV™ TLx4971 - TLE4972 Current Sensor Programmer app** in the Infineon Developer Center launcher. After the programmer board is recognized by the GUI, the user can initiate communication with the TLE4972 by selecting it from the list of devices in the current toolbox section. The user must enter the expected sensitivity in mV/A so that the tool uses the value to convert the V reading into A reading in the continuous readout mode. The user can also view AOUT and VREF readings in the continuous readout mode, and OCD1 detections and current readings in the oscilloscope-like window.

Additionally, the user can change the measurement range code (S1…S6) and the respective OCD1 and OCD2 thresholds along with deglitch filter values (OCD calculation tool available in the current toolbox) corresponding to full-scale currents by selecting the basic configuration mode. Clicking the Burn EEPROM button, programs the internal EEPROM of the current sensor for the application requirements.

Note: REF_60100EDPS_PB must be disconnected from REF_60100EDPS_CB before the current sensor is activated in test mode.

Note: The interface cable to enable the connection and communication between the programmer board and the REF_60100EDPS_PB board is not provided. Hence, users are required to use jumper cables as per the pinout of the DUT board connector and interface with labeled test pads or the X7 connector on the REF_60100EDPS_PB board to establish the connections.

2.5 Basic operation

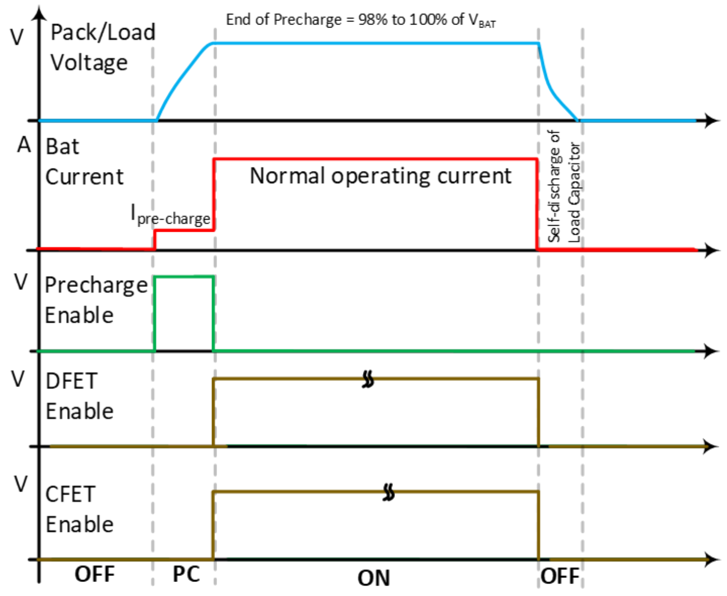


Figure 7 Normal operation of REF_60100EDPS

Figure 7 shows the ideal waveforms during normal operation of the REF_60100EDPS board. During normal operation, the system start-up is initially handled by the precharge operation of the load capacitance connected across the pack terminals followed by turn-on of the main switches. The precharge pulse duration in the system is decided by the threshold setting of voltage sensing across pack terminals. After the precharge operation is completed, gate signals of charge MOSFETs (CFET) and discharge MOSFETs (DFET) are enabled for battery charge/discharge rate requirements. In the event of a fault during normal operation, the battery is disconnected from the load by disabling gate signals of the main switches after which the load/pack voltage gradually drops to zero due to the discharge of load capacitance.

2.6 Special operation modes

Figure 8 describes the state-flow for various operation modes of the eDisconnect power switch solution.

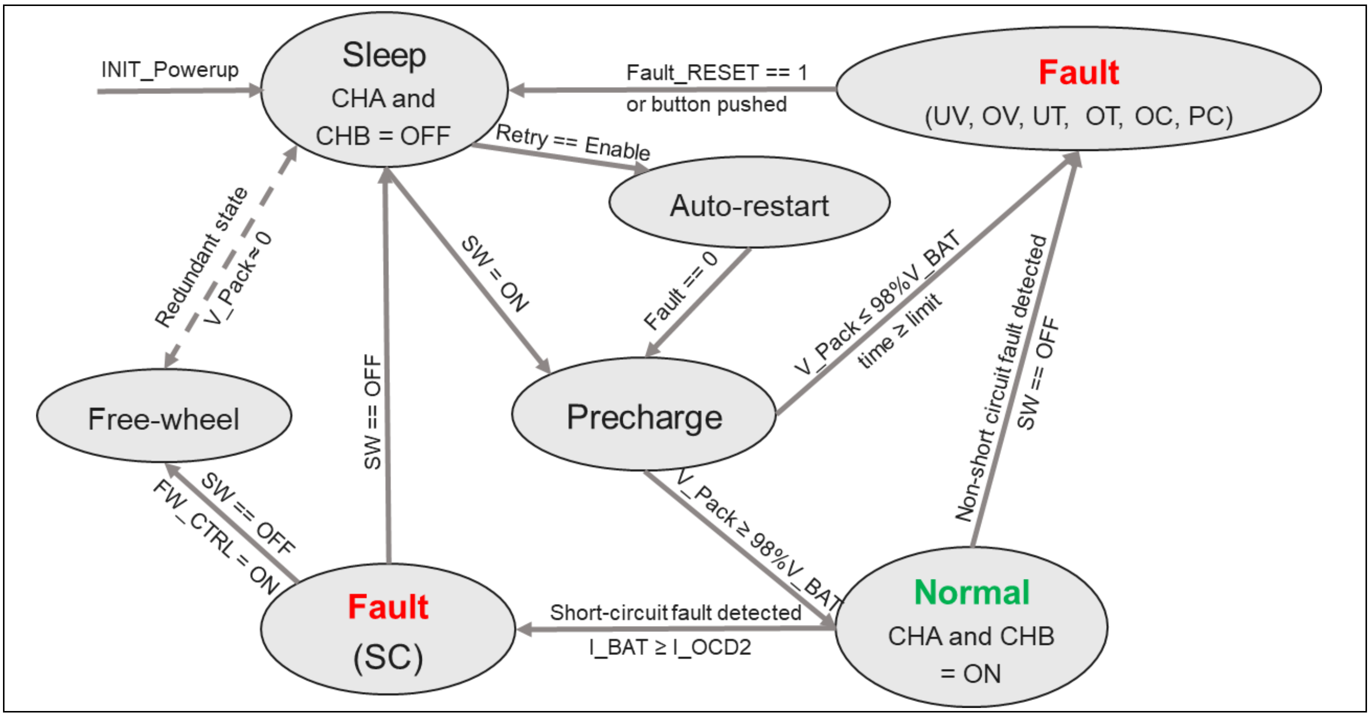


Figure 8 State diagram of EDPS

The state in which the protection MOSFETs are not in conduction with channels in the OFF condition corresponds to sleep-mode. The system state goes into the precharge state before the normal mode of operation after the main switch turns on. In the event of a precharge failure, the system recognizes the state as a fault and the channels are turned off to go to sleep-mode. If any abnormal condition occurs when the system is in the normal mode, the system goes into a fault state where the channels are disabled immediately. After the fault events are cleared, the system auto-restarts to enable the precharge function followed by the main-switch-ON operation. The free-wheeling event will remain redundant following a short-circuit fault, which is the active- or the passive-mode operation of the MOSFET across the pack terminals, and the system state goes into sleep-mode.

3 System design

3.1 Schematics

3.1.1 Power board schematics

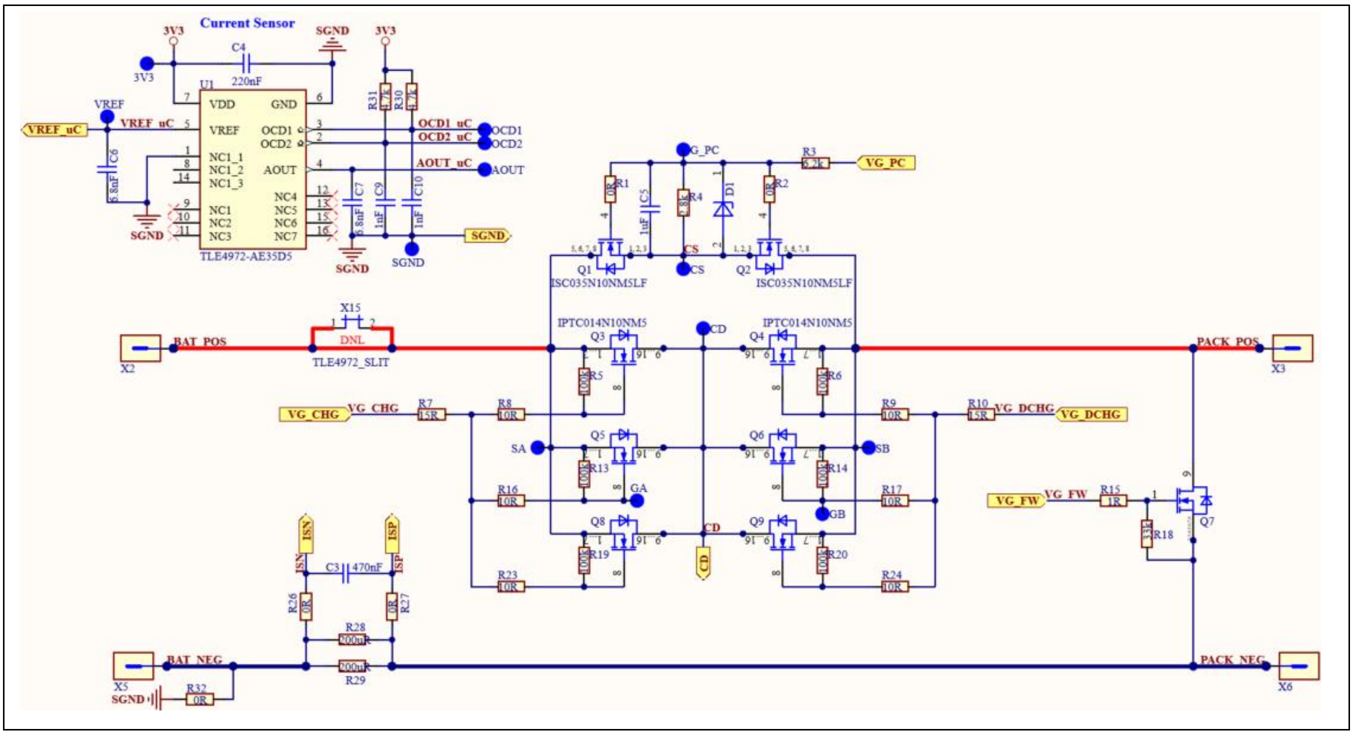


Figure 9 Power board schematic

3.1.2 Control board schematics

3.1.2.1 Gate driver schematics

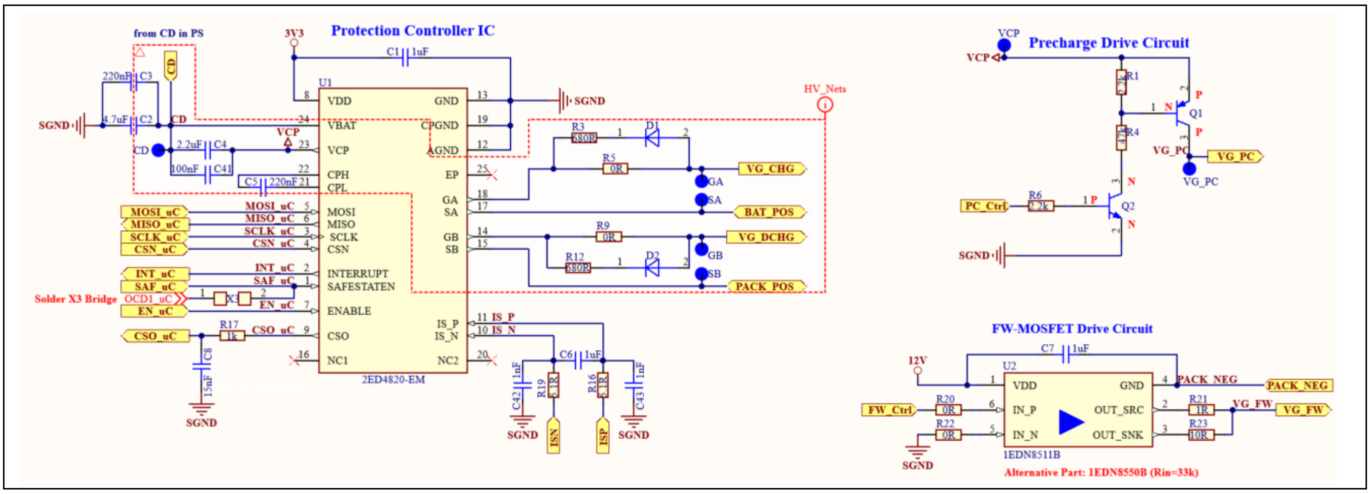


Figure 10 Schematics of the gate-driver

3.1.2.2 MCU schematics

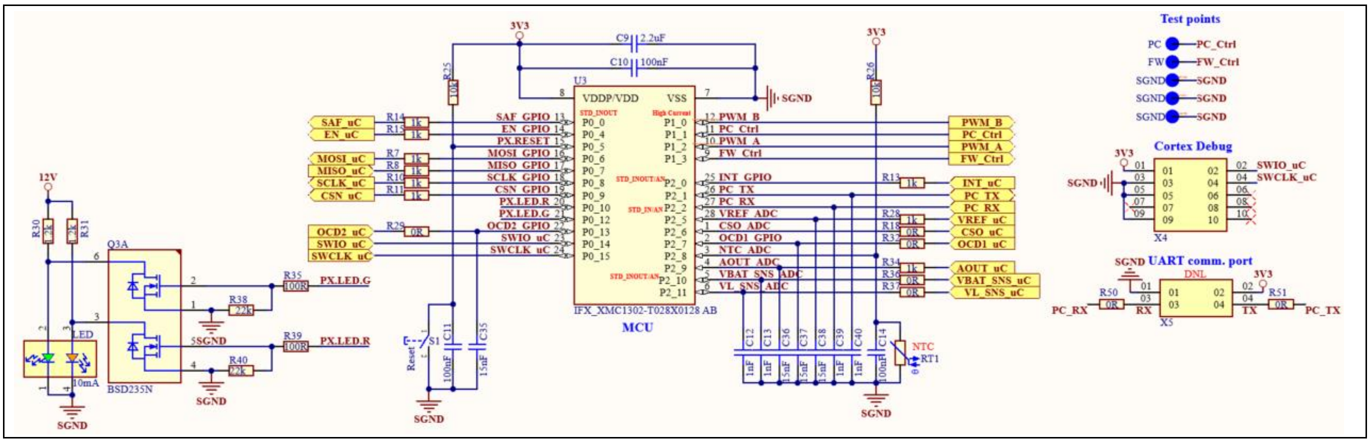


Figure 11 Schematic of MCU

3.1.2.3 Auxiliary supply (V_{BAT} to 12 V) schematics

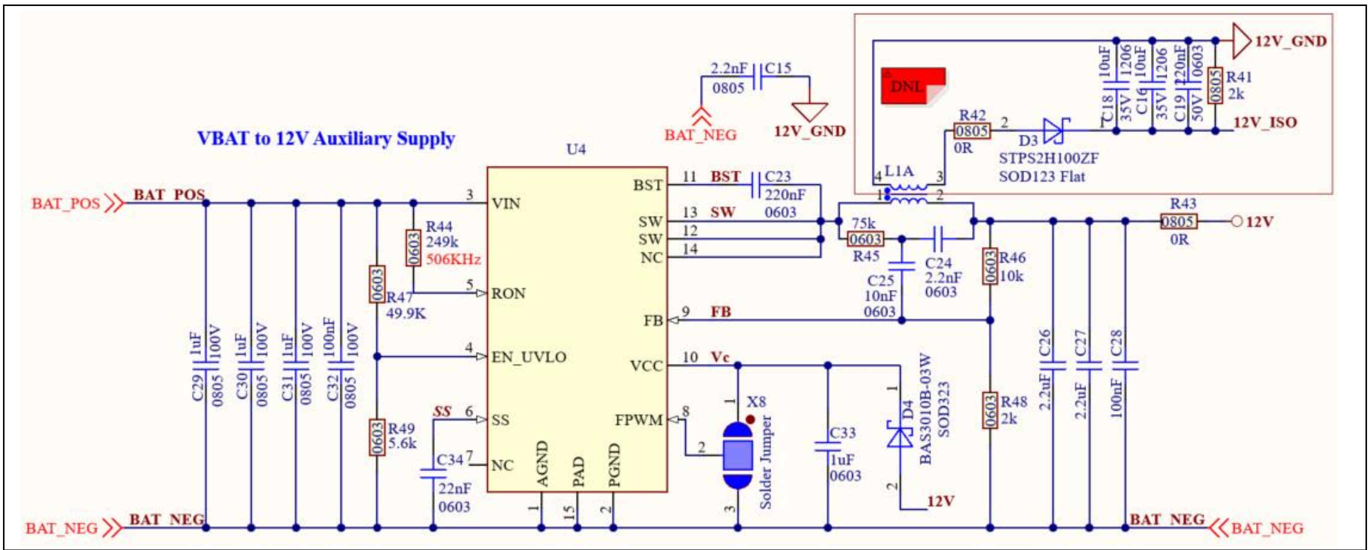


Figure 12 Schematic of the switching regulator

3.1.2.4 12 V external supply and LDO

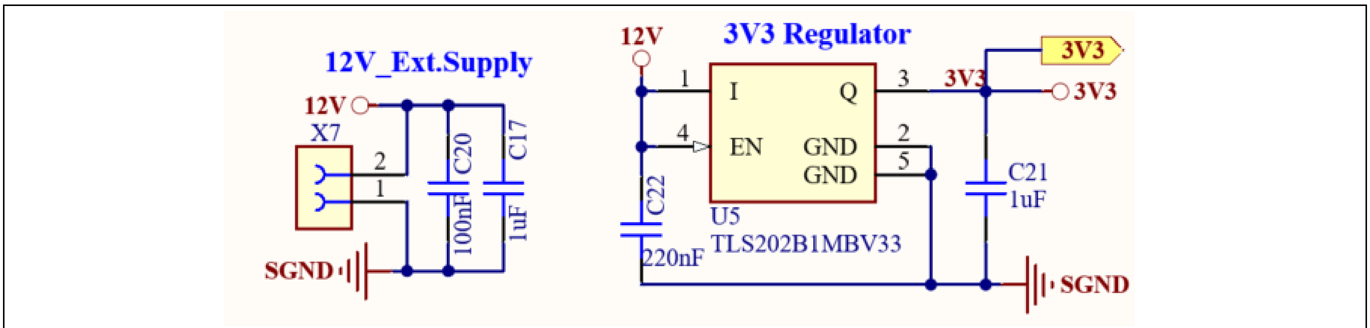


Figure 13 Schematics of the 12 V to 3.3 V supply

3.2 Layout

3.2.1 Power board layout

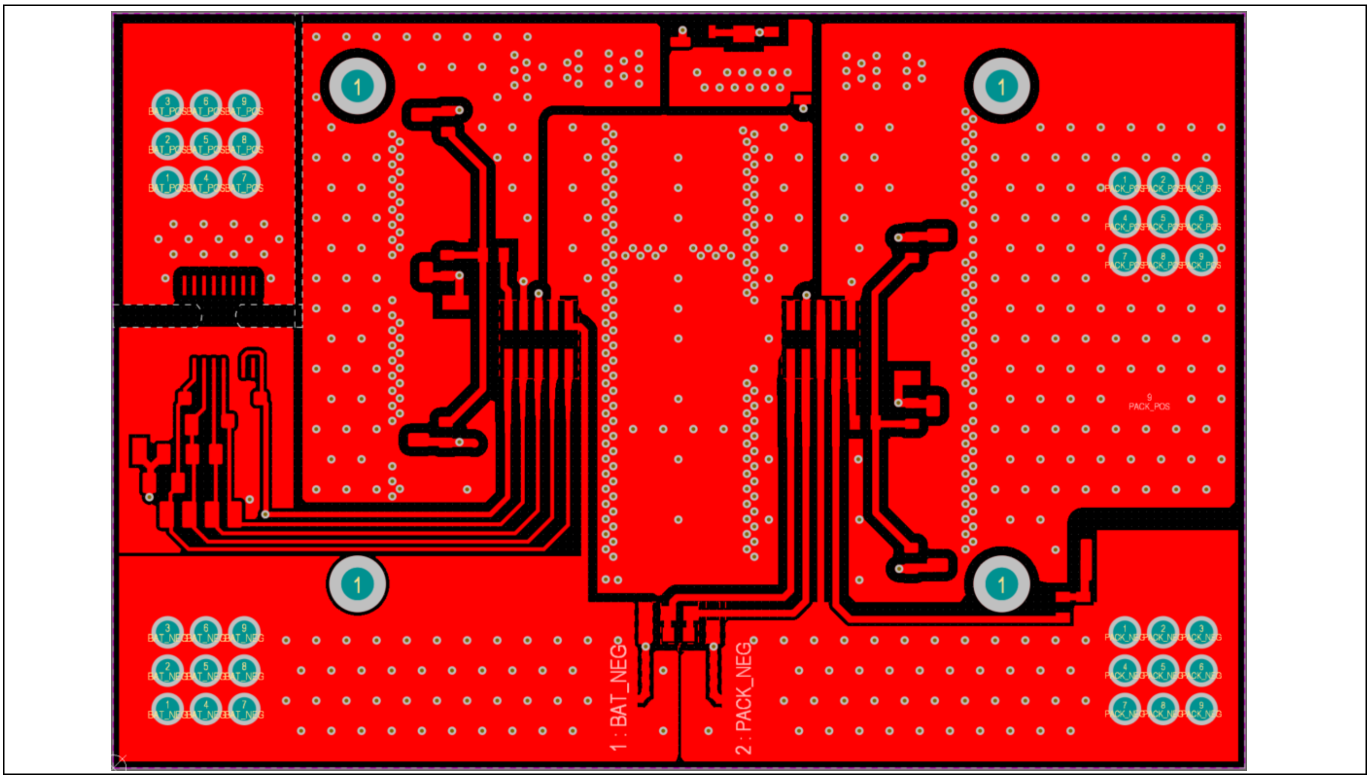


Figure 14 REF_60100EDPS_PB top layer

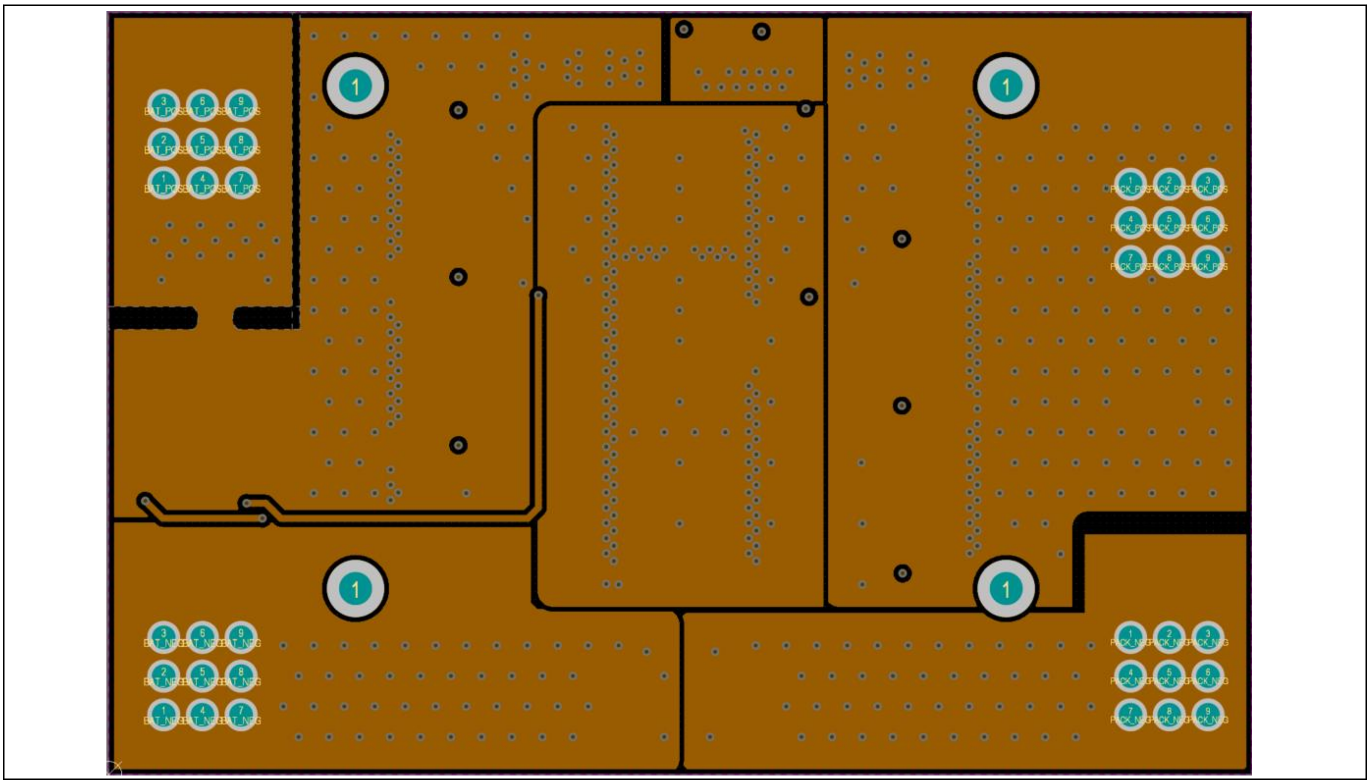


Figure 15 REF_60100EDPS_PB layer 2

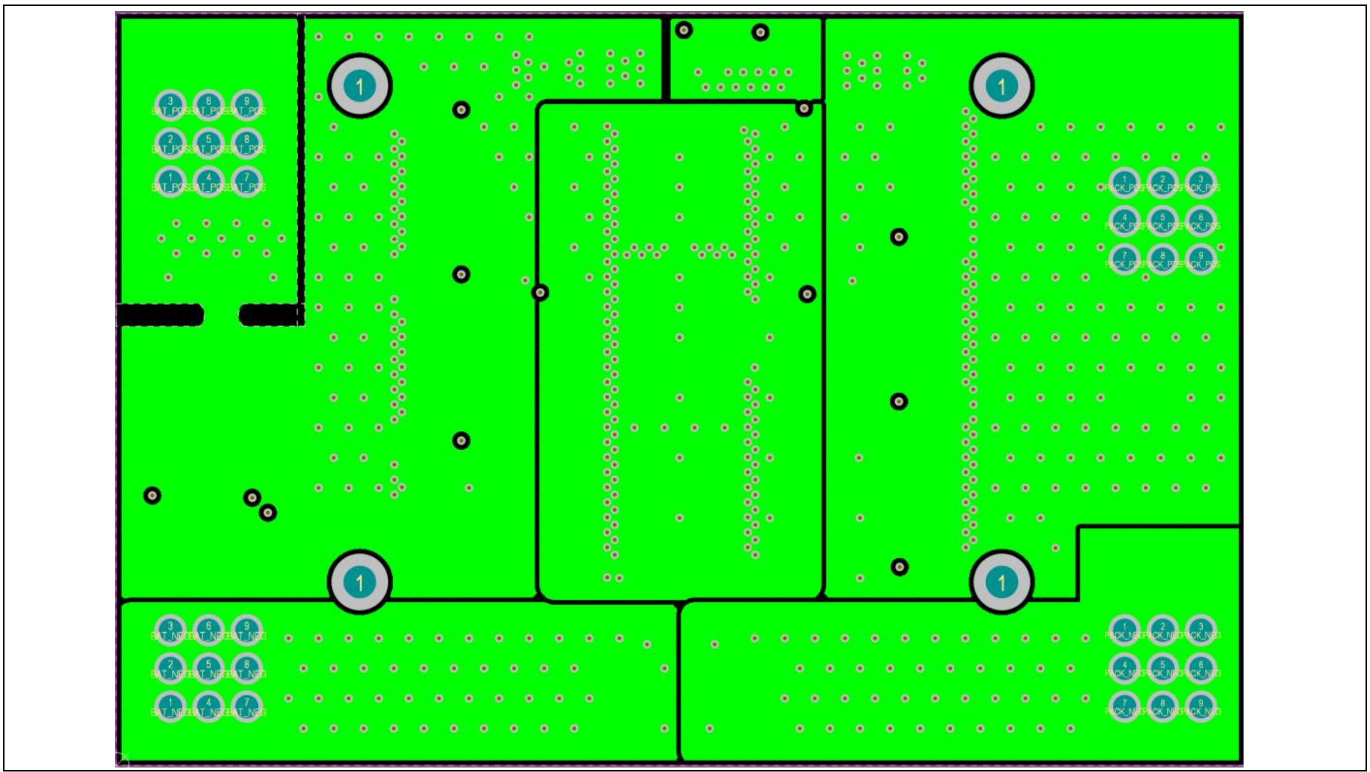


Figure 16 REF_60100EDPS_PB layer 3

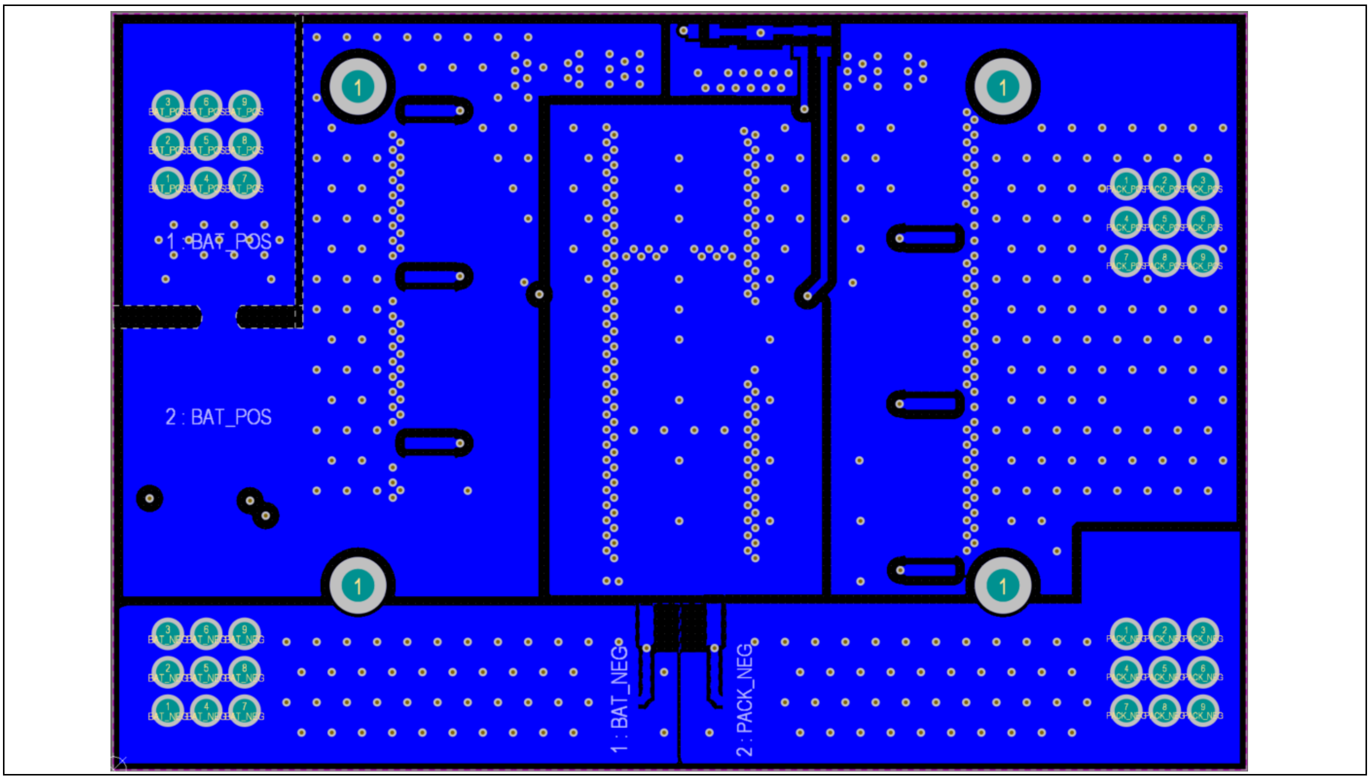


Figure 17 REF_60100EDPS_PB bottom layer

3.2.2 Control board layout

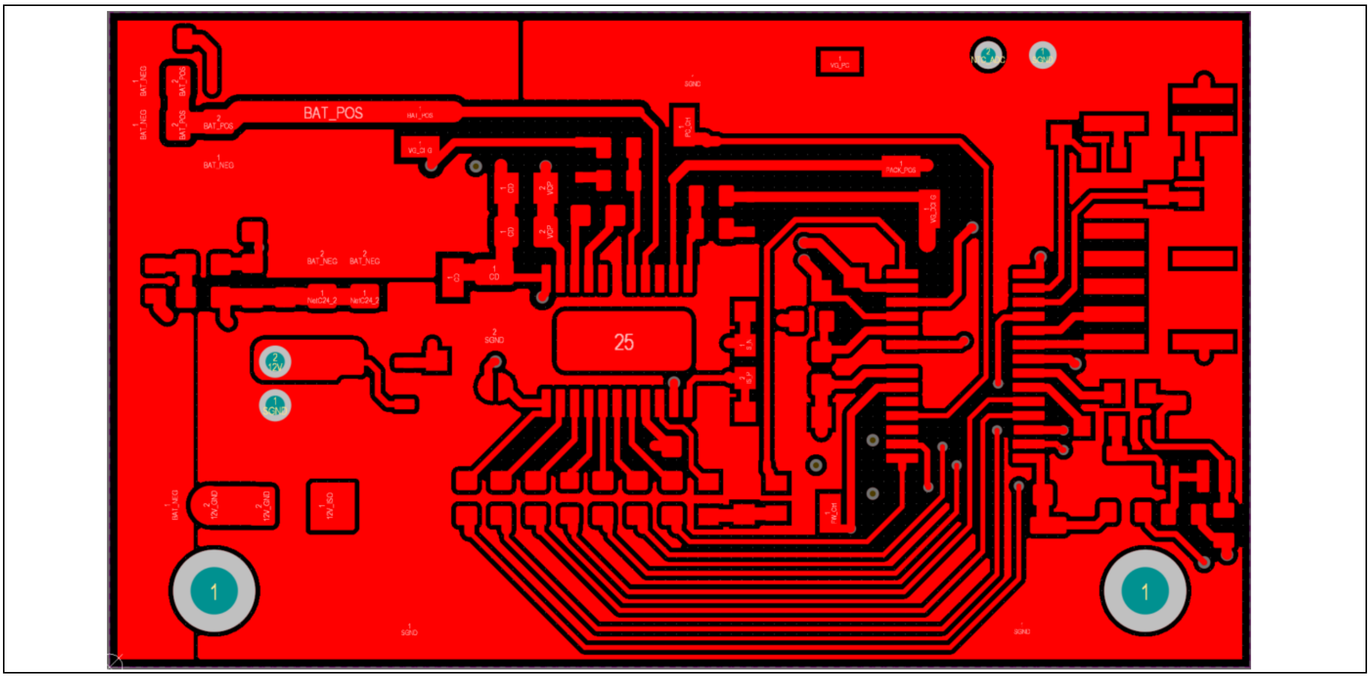


Figure 18 REF_60100EDPS_CB top layer

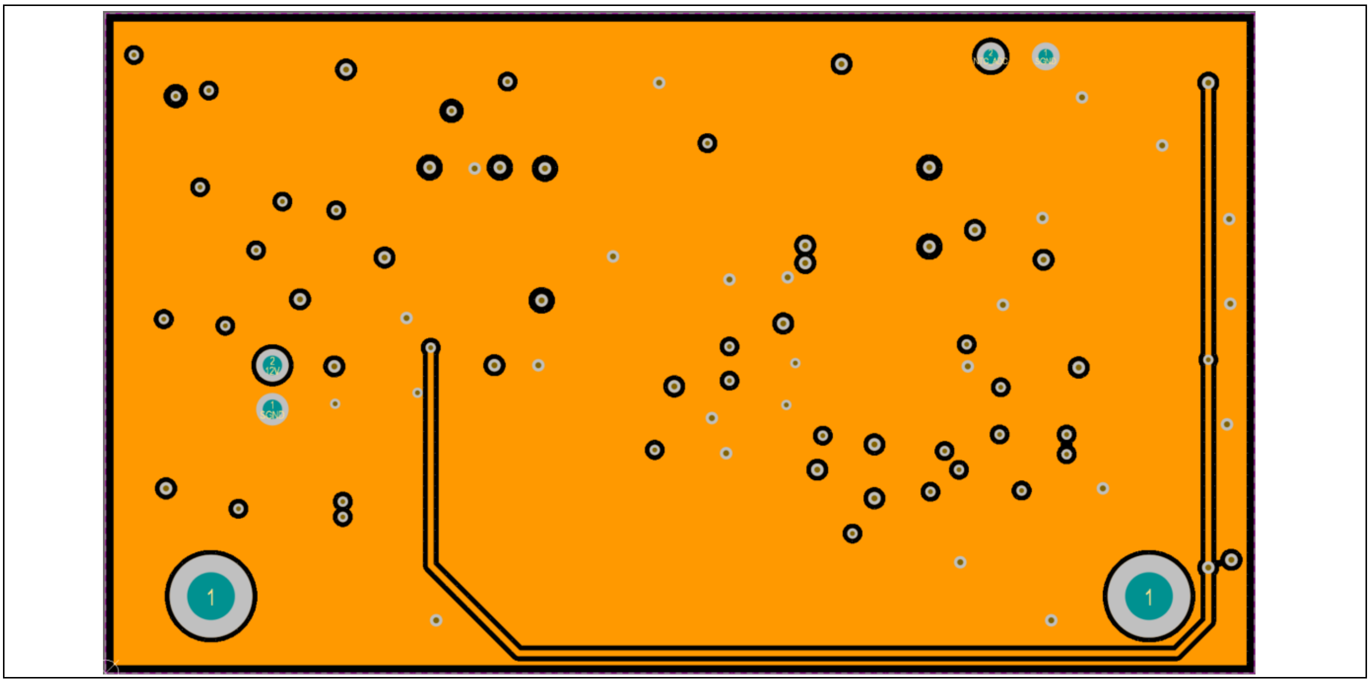


Figure 19 REF_60100EDPS_CB layer 2

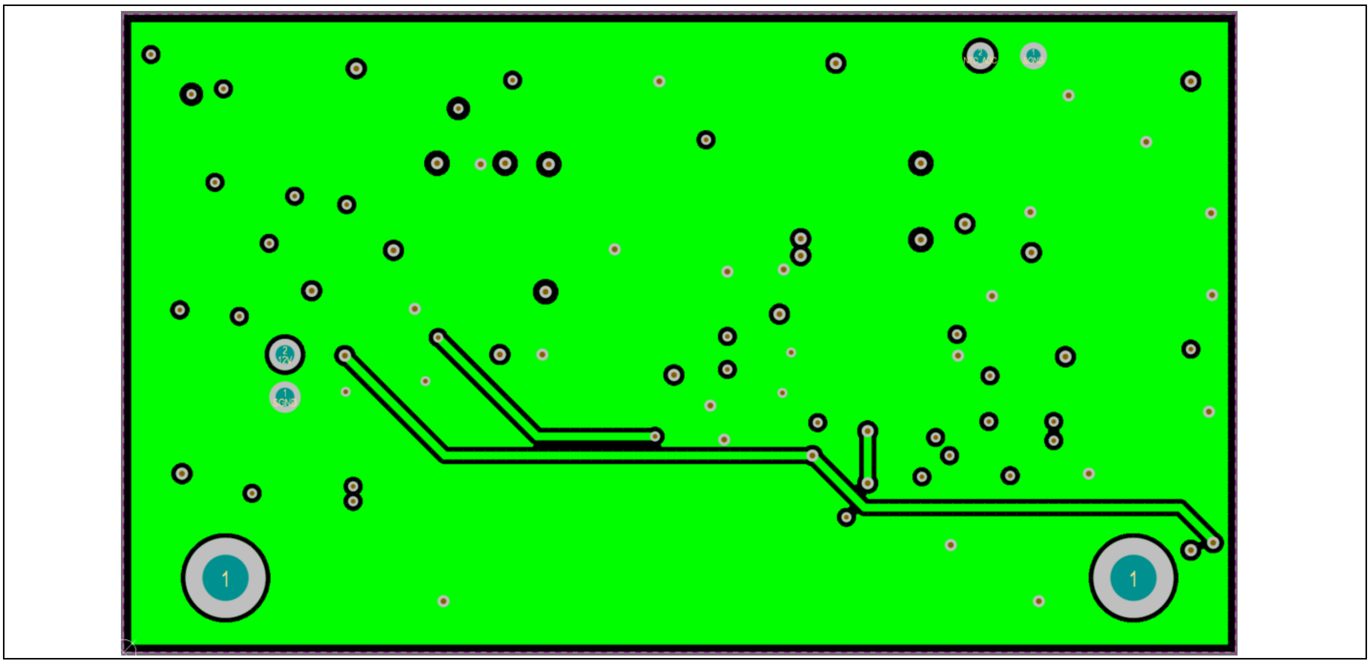


Figure 20 REF_60100EDPS_CB layer 3

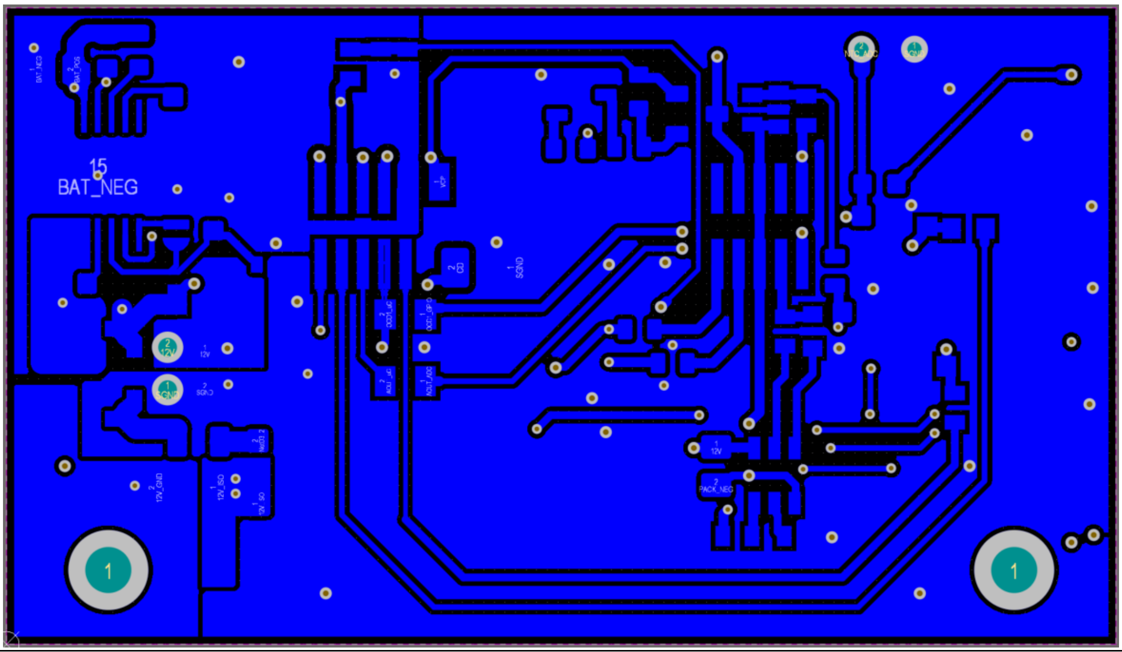


Figure 21 REF_60100EDPS_CB bottom layer

3.3 Bill of materials

Table 5 BOM of REF_60100EDPS_PB

Qty	Designator	Description	Manufacturer	Manufacturer P/N
2	Q1, Q2	OptiMOS™ 5 Single N-Channel Linear FET 100 V	Infineon	ISC035N10NM5LF2
6	Q3, Q4, Q5, Q6, Q8, Q9	OptiMOS™ 5 power MOSFET in TOLT	Infineon	IPTC014N10NM5
1	Q7	OptiMOS™ 5 power MOSFET 100 V in TOLL	Infineon	IPT014N10N5
1	U1	XENSIV™ - magnetic coreless current sensor in a leaded TDSO-16 package	Infineon	TLE4972-AE35D5

Table 6 BOM of the most important parts of REF_60100EDPS_CB

Qty	Designator	Description	Manufacturer	Manufacturer P/N
1	U1	48 V smart high-side MOSFET gate driver with SPI	Infineon	2ED4820-EM
1	U2	EiceDRIVER™, fast single channel 4 A/8 A low-side gate driver, UVLO – 8 V	Infineon	1EDN8511B
1	U3	32-bit microcontrollers with Arm® Cortex®-M0, 200 KB flash	Infineon	XMC1302-T028X0200 AB
1	U5	Fixed linear voltage post regulator, 3.3 V	Infineon	TLS202B1MBV33
1	Q3	N-Channel Small Signal MOSFET 20 V in SOT363 package	Infineon	BSD235N

Qty	Designator	Description	Manufacturer	Manufacturer P/N
1	U1	48 V smart high-side MOSFET gate driver with SPI	Infineon	2ED4820-EM
1	D4	Medium Power AF Schottky Diode, 30 V, 1 A	Infineon	BAS3010B-03W

3.4 Connector details

Table 7 Connectors

PIN	Label	Function
+BAT	X2	Battery positive terminal
-BAT	X5	Battery negative terminal
+Pack	X3	Pack positive terminal
-Pack	X6	Pack negative terminal
Signals	X1, X2, X7, X8	Interfacing signals of REF_60100EDPS_PB and REF_60100EDPS_CB
+12V	X7	12 V external supply (optional)
Debug	X4	10-pin Cortex™ debug connector
UART	X5	UART comm. port (Not used)

Note: The UART module is not provided in the software. The user has the flexibility to enable communication via the hardware interface.

4 Configuration tool

The board should be connected to the PC through XMC™ Link and operated from the Micro Inspector Pro software available in Infineon Toolbox Developer Center Launcher. X4 and X5 connectors on the control board serve the purpose of debugging the firmware with an external card KIT_XMC_LINK_SEGGER_V1 which is an isolated debug probe shown in Figure 22. It is based on SEGGER J-Link [7] which enables usage with DAVE™ and all common third-party compilers/IDEs known from the wide Arm® ecosystem. The 10-pin XMC™ MCU Debug connector supports communication between a PC/laptop and the target XMC™ device using Serial Wire Debug (SWD) protocol. The virtual COM port (UART) is also provided on the control board to connect the UART pins of the target XMC™ device to the TX/RX pins of the debug connector.

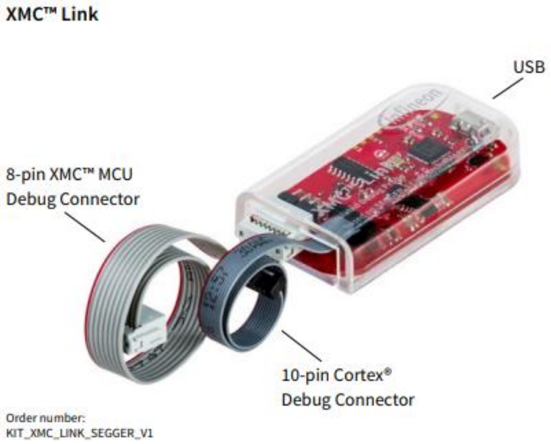


Figure 22 XMC™ Link functional isolated debug probe

4.1 Software setup

The following software tools are to be installed on the Windows operating system to interface with the hardware.

- Segger J-Link software
- XMCFlasher installation via Infineon Developer Center Launcher
- Micro Inspector Pro installation via Infineon Developer Center Launcher

4.2 Getting started steps

1. Connect the XMC™ Link USB port to the PC and the 10-pin connector to the X4 connector on REF_60100EDPS_CB.
2. Power the reference board REF_60100EDPS using battery or source from the application setup.
3. Load the eDisconnect_GUI_G2M.wspx file in Micro Inspector Pro launched via Infineon Developer Center.
4. Choose the corresponding hardware target MCU as XMC1000 in Micro Inspector Pro Settings [8].
5. Click **Run** to run the dashboard of Micro Inspector Pro.
6. Click **Stop** to terminate the execution after the switch is manually turned off in the dashboard.

4.3 User interface control

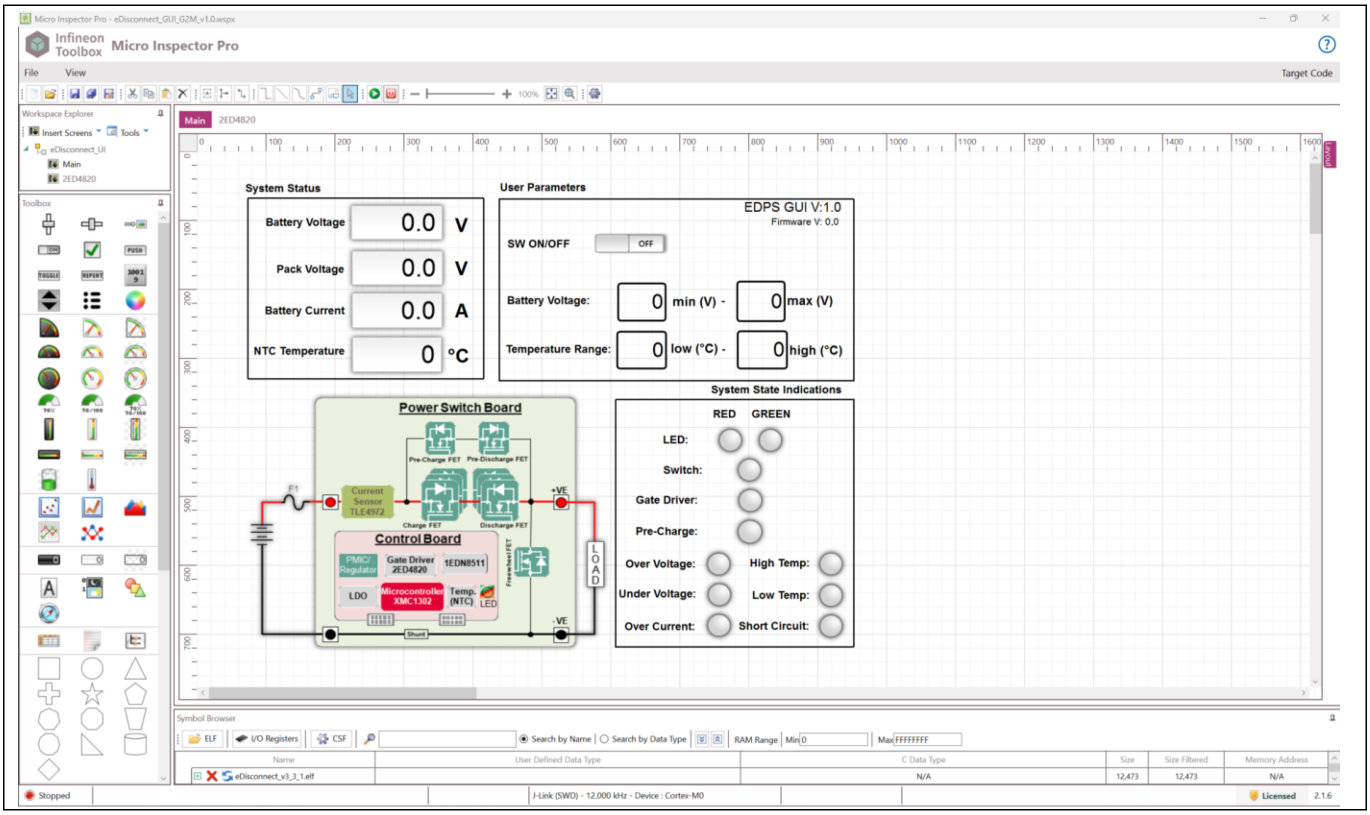


Figure 23 User interface control design in Micro Inspector Pro

Figure 23 shows the user interface control design which has three main sections together with the simplified block diagram of REF_60100EDPS.

- **System Status**: Displays the telemetry information of the board
  - Battery Voltage - displays the battery/supply voltage at the input terminals (+BAT and -BAT)
  - Pack Voltage - displays the pack/load voltage at the output terminals (+Pack and -Pack)
  - Battery Current - displays the battery's positive rail current measurement from the current sensor
  - NTC Temperature - displays the temperature of the probe connected to the board/battery
- **User Parameters**: Allows the user to input key parameters and turn on/off the system
  - SW ON/OFF - toggle button to switch between on and off in manual and auto-restart modes
  - Battery Voltage Range - values of the undervoltage and overvoltage limits of the battery
  - Temperature Range - values of the operational limits of the board/battery
- **System State Indications**: Indicator lights (red and green) of the board operation state
  - LED - red and green indications correspond to the PCB LED indications
  - Switch - displays the operation status of the main switches. Green corresponds to on, grey corresponds to off, and red corresponds to fault.
  - Gate Driver - displays the normal/fault status of 2ED4820-EM. Grey (default) corresponds to normal and red corresponds to fault mode operation of the smart gate driver.
  - Pre-Charge - displays the success or failure status of the precharge operation. Green corresponds to precharge successful and red indicates precharge failure.
  - Over Voltage - displays red on overvoltage (Default: Grey)

- Under Voltage - displays red on undervoltage (Default: Grey)
- Over Current - displays red on overcurrent (Default: Grey)
- High Temp - displays red on over-temperature (Default: Grey)
- Low Temp - displays red on under-temperature (Default: Grey)
- Short Circuit - displays red on short-circuit (Default: Grey)

Clicking **Run** executes the project dashboard which is shown in Figure 24. The user can enter the parameters of the system's operational range in the User Parameters section before toggling the SW ON/OFF button to on.

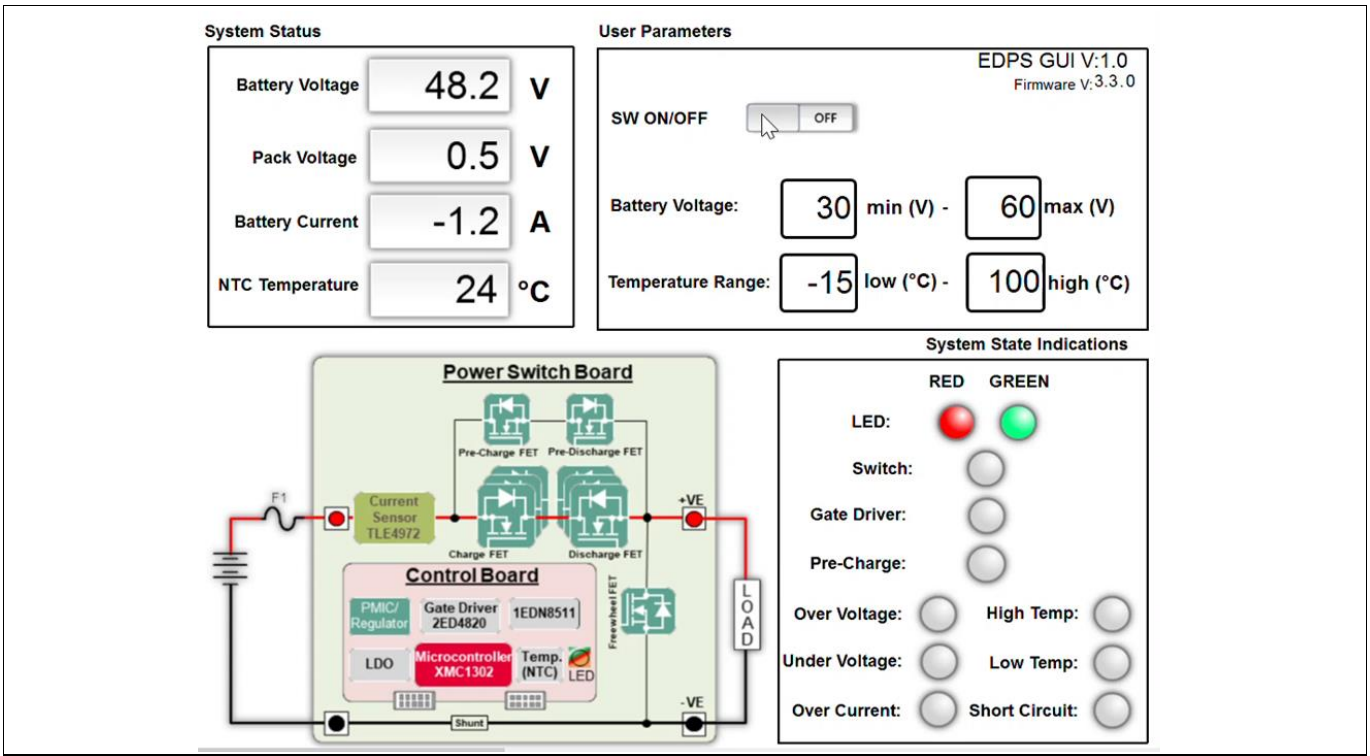


Figure 24 **GUI dashboard of REF_60100EDPS**

Note:

1. *The software package offers a discharge mode of operation of a battery connected to a load setup that includes a DC-bus capacitor.*
2. *The user takes full responsibility for the safety of the reference board or the battery if operated outside of the specified test setup and conditions.*
3. *Contact Infineon for any further technical support on hardware and software functionalities of the system.*

5 System performance

5.1 Test parameters

Table 8 lists the parameters for which REF_60100EDPS is tested to show the performance of the system.

Table 8 Test parameters of REF_60100EDPS

Specification	Variable	Value
Battery voltage	V_{BAT}	48 V
Cable inductance	L_{loop}	1.5 µH
Maximum load capacitance	C_{LOAD}	4.5 mF
Maximum temperature on MOSFETs	T_{max}	100 °C
Overload (Discharge) current	I_{OC}	130 A
Short circuit current limit - 1	I_{SC_1}	250 A
Short circuit current limit - 2	I_{SC_2}	420 A

5.2 Test results

5.2.1 Sleep-mode consumption

Sleep-mode consumption of the REF_60100EDPS solution with a switching regulator onboard is measured at <1 W. This power consumption accounts for all quiescent-mode power consumption of the current sensor, the MCU, the switching regulator, and the LDO as well as the internal supply of the smart gate driver and the LED indication.

Note: When the system is in sleep-mode, there is a leakage current flowing out of Sx pins of the smart gate driver from BAT terminals to Pack terminals, which charges the load capacitance up to 3.5 V.

5.2.2 Precharge operation

The LinearFETs in the precharge path are activated until the pack voltage reaches up to 98 percent of the battery voltage to avoid overcurrent detection by the current sensor due to the inrush current drawn by the capacitive load at the output. Figure 25 shows the pack voltage with a maximum load capacitance of 4.5 mF across the pack terminals charged in a 60 ms time duration. The precharge current is limited by the linear-mode operation of the MOSFETs. After the precharge operation, the remaining capacitance gets charged by turn-on of the main switches.

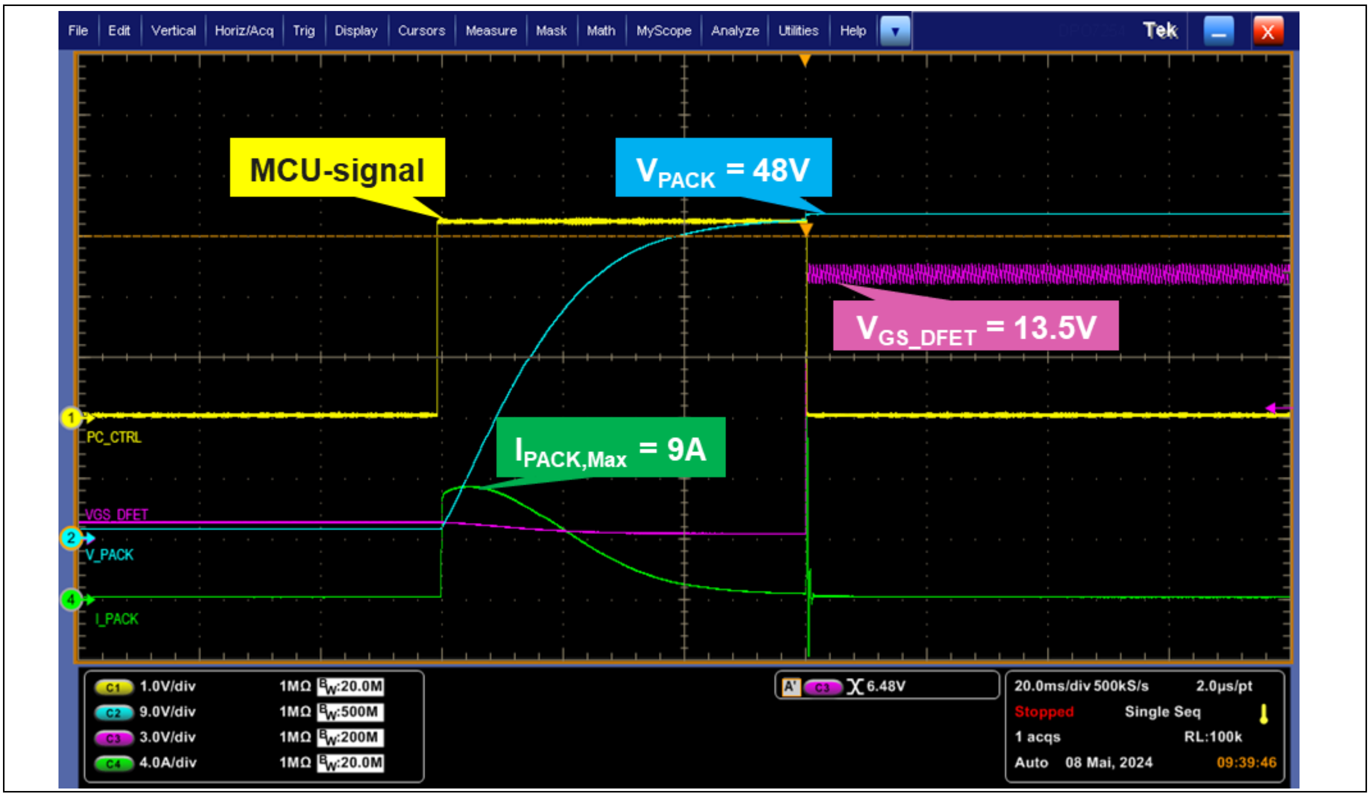


Figure 25 **Precharge operation with LinearFETs: V_{BAT} = 48 V, C_{Load} = 4.5 mF**

5.2.3 Thermal performance

5.2.3.1 Without heatsink

The power board is configured in the application setup without connecting the heatsink for measuring the maximum continuous DC current that can be drawn from the board, at a maximum case temperature of 100°C, on bidirectional protection MOSFETs at an ambient temperature of 25 °C. The maximum DC current measured in this case is 80 A. Figure 26 and Figure 27 show the temperature distribution across the board, the case temperature of the MOSFETs, and the temperature rise on the current sense.

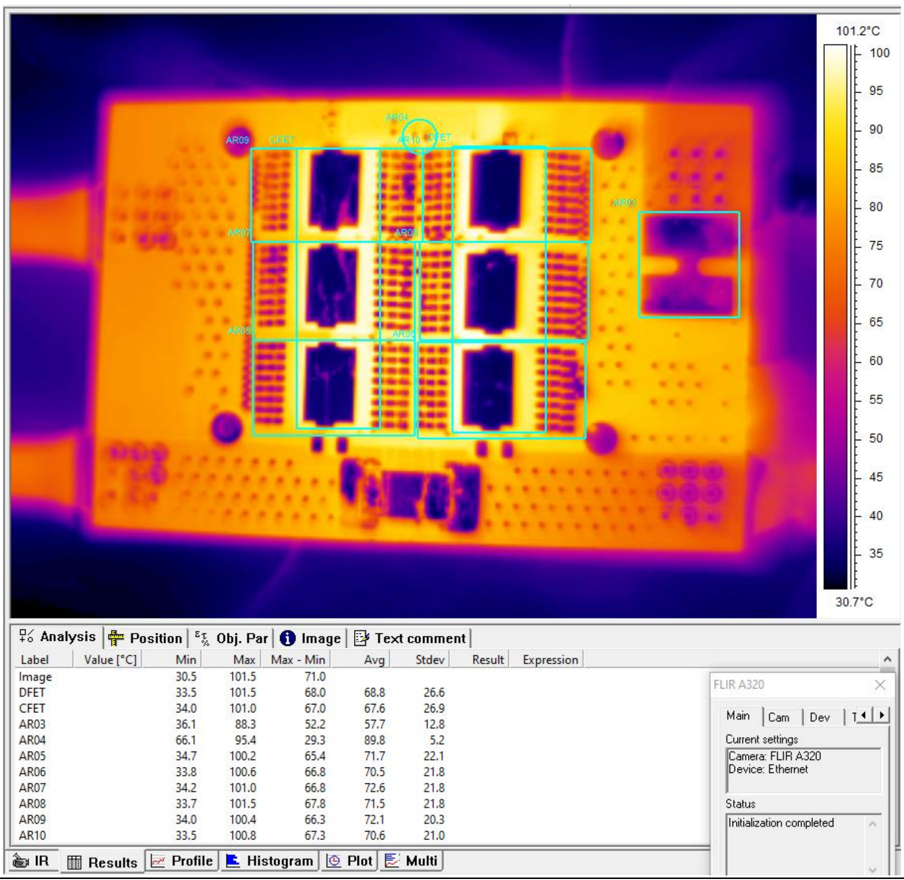


Figure 26 Temperature distribution at 80 A after a ramp-up time of 90 seconds

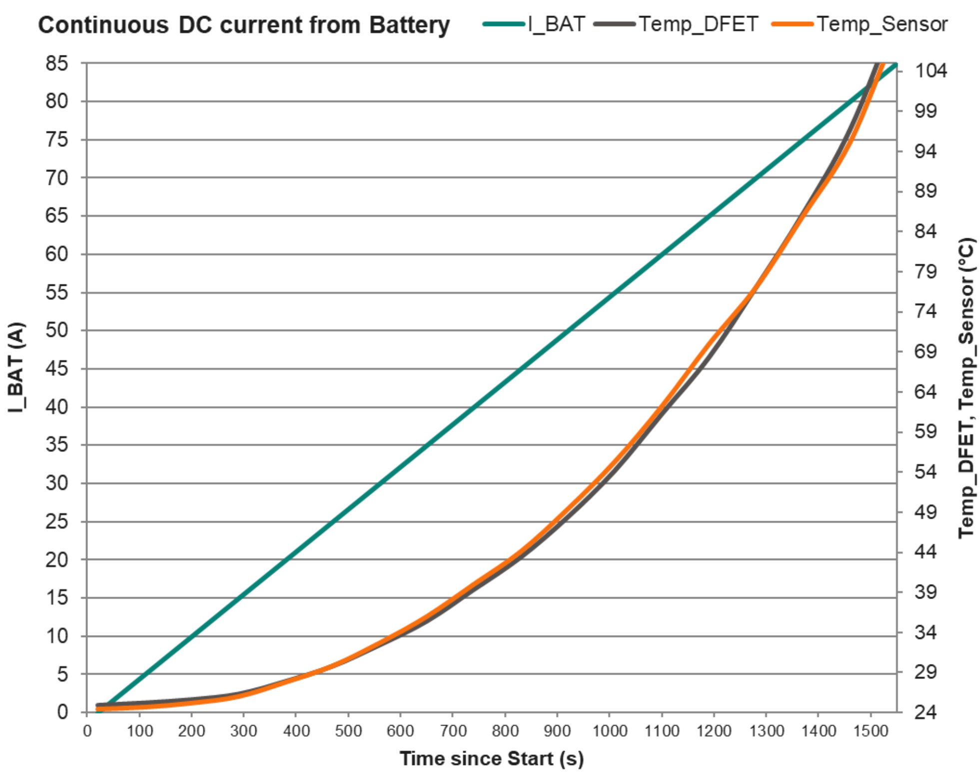


Figure 27 Thermal performance without heatsink

5.2.3.2 With heatsink

To utilize the performance of Infineon TOLT devices with the top-side cooling package for superior thermal performance, the reference board REF_60100EDPS_PB is connected to an aluminum plate heatsink having a thermal resistance ($R_{TH,HS}$) of 4 K/W for enhancing heat transfer in natural air convection. With top-side cooling, the drain is exposed at the surface of the package allowing for most of the heat to be dissipated directly to the heatsink, allowing the handling of high currents for a given maximum temperature rise on the device. The thermal interface material (TIM) used between the exposed pads and heat sink is a thermal pad with a thermal conductivity of 12.5 W/mK. Figure 28 shows the temperature rise on the case temperature of the MOSFETs with respect to the current steps, with the heatsink included.

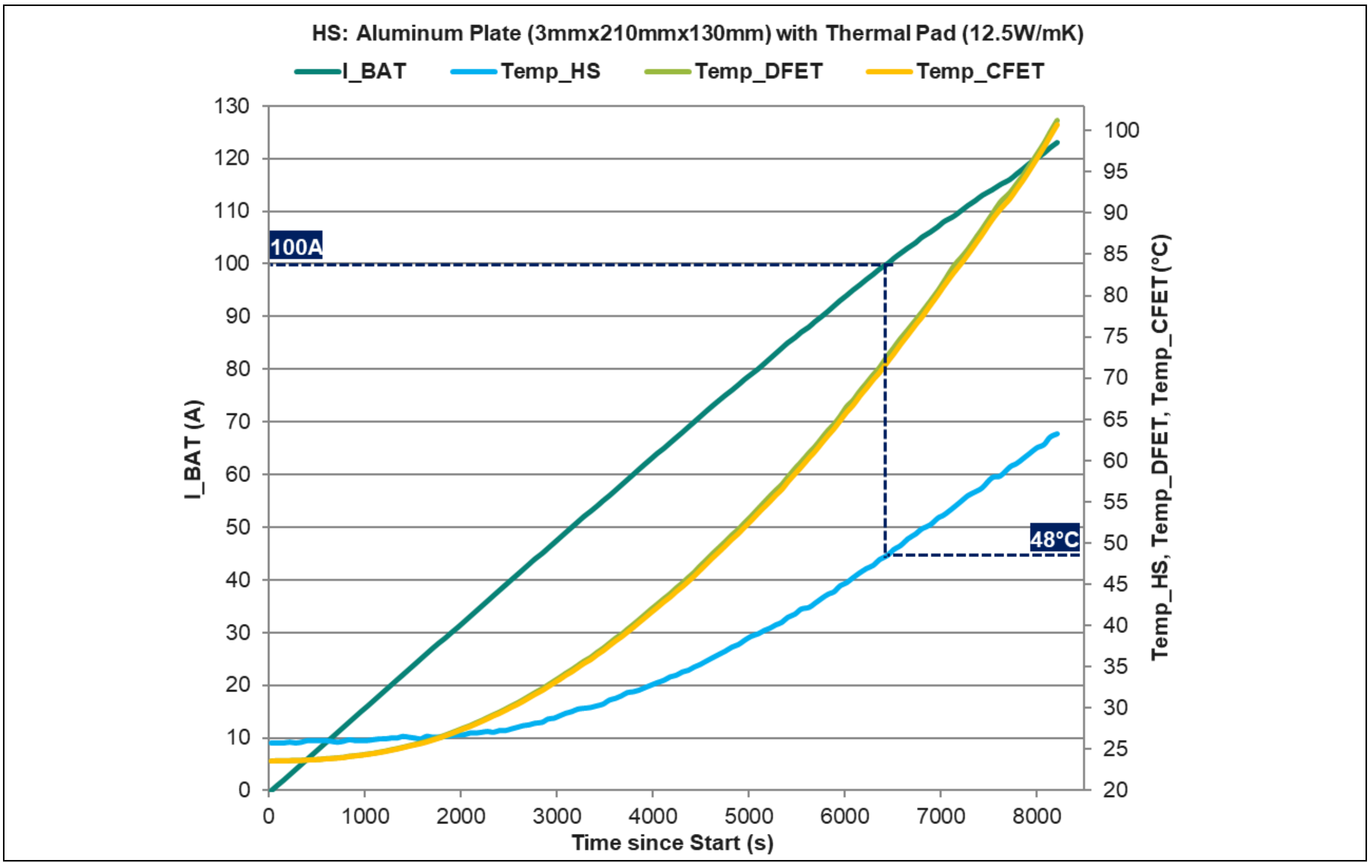


Figure 28 Thermal performance with heatsink

5.2.4 Current sensor (TLE4972) performance

Figure 29 Sensor current deviation against Instrument current

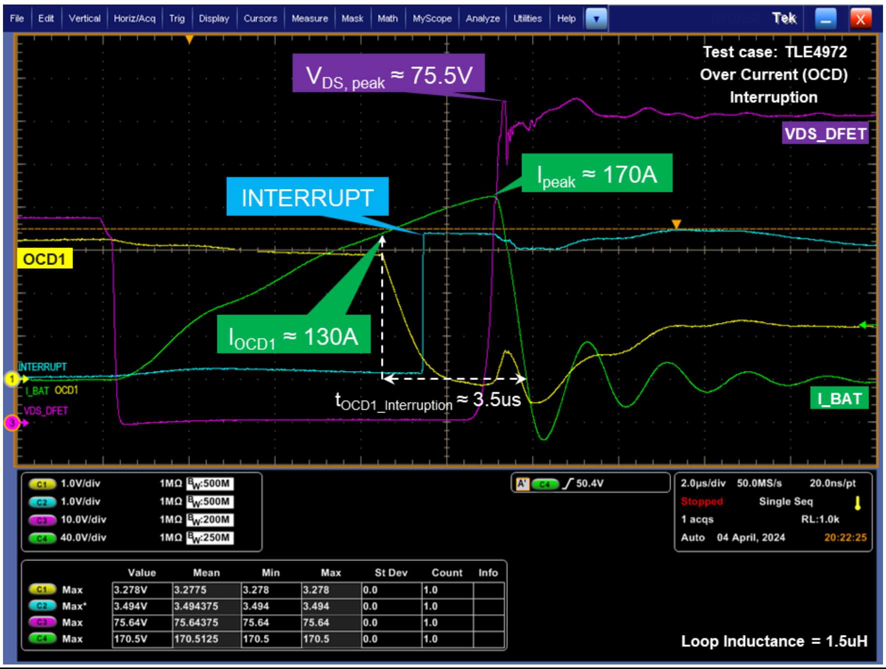


Figure 30 Overcurrent protection by TLE4972

Figure 29 and Figure 30 show current sense measurements and overcurrent protection by the current sensor TLE4972-AE35D5 with its analog pins and a fast over-current detection output. The OCD1 pin of the current sensor is connected to the SAFESTATEN pin of the gate-driver 2ED4820-EM on the control board for a fast protection mechanism. The overcurrent test is performed in pulse mode after disconnecting the precharge path in the setup.

5.2.5 Smart gate-driver (2ED4820-EM) performance

Figure 31 shows the waveform for a short-circuit applied across the pack terminals using the test parameters given in Table 9. The interrupt associated with the ITRIP register bit is generated for a short-circuit event and the peak current is detected at 420 A for the defined default settings of overcurrent protection. The overall response time, which comprises detection time and interrupting time, to the short circuit event is roughly 5 µs. The short circuit test is performed in pulse mode after disconnecting the precharge path in the setup. The green curve in the scope shows that the short-circuit current rises linearly with a di/dt of 19 A/µs. After the disconnect operation of the MOSFETs, the energy stored in the cable inductance is dissipated by the passive free-wheeling operation through MOSFET (TOLL) Q7.

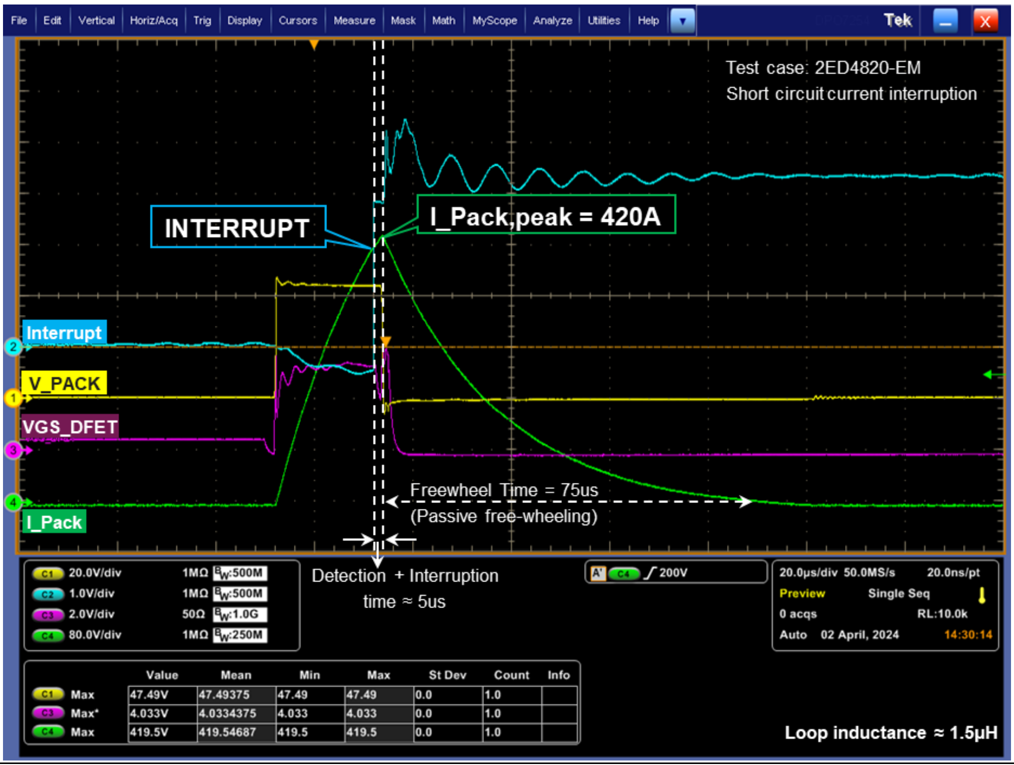


Figure 31 Short-circuit current interruption by 2ED4820-EM

The default settings of the smart gate-driver 2ED4820-EM on REF_60100EDPS_CB are listed in Table 9.

Table 9 2ED4820-EM default settings on REF_60100EDPS_CB

Parameter	Variable	Value
VBAT overvoltage auto-restart time	$t_{OV\_RESTART}$	1 ms
VBAT undervoltage auto-restart time	$t_{UV\_RESTART}$	1 ms
Current-sense amplifier gain (CSAG)	G_{DIFF}	10 V/V
Overcurrent-detection threshold	$\Delta V_{OCTHxH/L}$	0.5 V_{DD} ± 0.3 V_{DD} (x = 4)
Drain-to-source overvoltage threshold	V_{DSTHx}	±600 mV

Parameter	Variable	Value
MOSFET voltage blank time	t_{MOS_BLKx}	10 µs
MOSFET voltage filter time	t_{MOS_FLTx}	5 µs

The user can request the device settings depending on application requirements.

The protection mechanisms for overcurrent and short-circuit faults on REF_60100EDPS are adopted in the order shown in Table 10.

Table 10 Order of overcurrent and short-circuit protection on REF_60100EDPS

Function	Value	Pin description
Overcurrent limit	130 A	OCD1 of TLE4972
Short-circuit current limit - 1	250 A	OCD2 of TLE4972
Short-circuit current limit - 2	420 A	INTERRUPT (ITRIP register bit) of 2ED4820-EM

To handle over/short circuit currents other than the specified default limits, see the application notes of the OCD calculation tool (TLE4972 only) in XENSIV™-TLE4972 current sensor programmer [6] and current sense and overcurrent accuracy with EiceDRIVER™ APD 2ED4820-EM [9].

5.2.6 LED indications

LED indications on the REF_60100EDPS hardware are shown in Table 11.

Table 11 LED indications on REF_60100EDPS

LED Status	Color	Functional description
	Amber (solid)	Sleep mode (CHA and CHB - OFF)
	Green (solid)	Normal mode (CHA and CHB - ON)
	Red (blinking)	Under/Overvoltage (UV/OV, CHA, and CHB = OFF)
	Red (blinking)	High/Low-temperature (UT/OT, CHA, and CHB = OFF)
	Red (solid)	Overcurrent/Short-circuit fault (OC/SC, CHA, and CHB = OFF)
	Green (blinking)	Firmware upgrade/controller operation

5.3 Test points

The boards REF_60100EDPS_PB and REF_60100EDPS_CB are provided with test pads as shown in Table 12 and Table 13 to easily probe the main signals on an oscilloscope.

Table 12 Test pads on REF_60100EDPS_PB

Label	Function
SGND	Signal ground
3V3	Connection for current-sensor supply voltage
OCD1	Overcurrent detection channel 1 of the current-sensor (open drain)

Label	Function
OCD2	Overcurrent detection channel 2 of the current-sensor (open drain)
AOUT	Analog output voltage of the current sensor
VREF	Analog output voltage of the current sensor
GA	Gate connection of charge MOSFETs
SA	Source connection of charge MOSFETs
GB	Gate connection of discharge MOSFETs
SB	Source connection of discharge MOSFETs
CD	Common-drain connection of charge and discharge MOSFETs
G_PC	Gate connection of precharge MOSFETs
CS	Common-source connection of precharge MOSFETs

Table 13 Test pads on REF_60100EDPS_CB

Label	Function
SGND	Signal ground
GA	Gate connection of charge MOSFETs
SA	Source connection of charge MOSFETs
GB	Gate connection of discharge MOSFETs
SB	Source connection of discharge MOSFETs
CD	Common-drain connection of charge and discharge MOSFETs
PC	Precharge control signal from the MCU
FW	Freewheeling control signal from the MCU
VG_PC	Gate connection to precharge MOSFETs
VCP	Charge-pump (internal) output of 2ED4820-EM

Appendices

A BOM of the power board

Table 14 Total BOM of REF_60100EDPS_PB

Qty	Designator	Description	Manufacturer	Manufacturer P/N
2	Q1, Q2	OptiMOS™ 5 Single N-Channel Linear FET 100 V	Infineon	ISC035N10NM5LF2
6	Q3, Q4, Q5, Q6, Q8, Q9	OptiMOS™ 5 power MOSFET in TOLT	Infineon	IPTC014N10NM5
1	Q7	OptiMOS™ 5 power MOSFET 100 V in TOLL	Infineon	IPT014N10N5
1	U1	XENSIV™ - magnetic coreless current sensor in a leaded TDSO-16 package	Infineon	TLE4972-AE35D5
1	D1	DIODE ZENER 4.7V 200mW SOD323	Diodes Incorporated	BZT52C4V7S-7-F
4	X2, X3, X5, X6	Terminals WP-SHFU Pin-Plate 9Pin M4 Shank 130A	Wurth Elektronik	7461096
2	X7, X8	Low Profile Dual-Wipe Socket, 1.00mm Pitch	Samtec	CLM-105-02-F-D
1	C4	CAP / CERA / 220nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 603 / SMD / -	Wurth Elektronik	885012206073
1	C5	CAP / CERA / 1uF / 100V / 10% / X7S (EIA) / -55°C to 125°C / 0805 / SMD / -	TDK Corporation	CGA4J3X7S2A105K125AB
1	C6	CAP / CERA / 6.8nF / 25V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM1885C1E682JA01
1	C7	CAP / CERA / 6.8nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	MuRata	GRM216R71E682KA01
1	C9	CAP / CERA / 1nF / 50V / 5% / - / -55°C to 125°C / 603 / SMD / -	Wurth Elektronik	885012006063
1	C10	CAP / CERA / 1nF / 25V / 5% / - / -55°C to 125°C / 0805 (2012) / SMD / -	Wurth Elektronik	885012007040
1	D1	DIODE ZENER 4.7V 200MW SOD323 Vz=4.7V 4.4V~5V Izt=5mA P=200mW	Diodes Incorporated	BZT52C4V7S-7-F
2	R1, R2	RES / STD / 0R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06030000Z0EB
1	R15	RES / STD / 1R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06031R00FK
1	R3	RES / STD / 6.2k / 100mW / 1% /	Vishay	CRCW06036K20FKEA

Qty	Designator	Description	Manufacturer	Manufacturer P/N
		100ppm/K / -55°C to 155°C / 0603 / SMD / -		
1	R4	RES / STD / 2.8k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06032K80FKEA
6	R5, R6, R13, R14, R19, R20	RES / STD / 100k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay	CRCW0805100KFKEA
2	R7, R10	RES / STD / 15R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW060315R0FK
6	R8, R9, R16, R17, R23, R24	RES / STD / 10R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW060310R0FKEA
1	R18	RES / STD / 33k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW060333K0FK
2	R26, R27	RES / STD / 0R / 100mW / 0R / 0ppm/K / -55°C to 155°C / 0603 / SMD / -	Yageo	RC0603JR-070RL
2	R28, R29	RES / STD / 200uR / 12W / 1% / 50ppm/K / -55°C to 170°C / 3920 (1052) / SMD / -	Bourns	CSS2H-3920R-L200F
2	R30, R31	RES / STD / 4.7k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Yageo	RC0805FR-074K7L

B BOM of the control board

Table 15 Total BOM of REF_60100EDPS_CB

Qty	Designator	Description	Manufacturer	Manufacturer P/N
1	U1	48 V smart high-side MOSFET gate driver with SPI	Infineon	2ED4820-EM
1	U2	EiceDRIVER, Fast Single Channel 4A/8A Low-Side Gate Driver, UVLO - 8V	Infineon	1EDN8511B
1	U3	32-bit Microcontrollers with ARM® Cortex®-M0, 200 KB Flash	Infineon	XMC1302-T028X0200 AB
1	U5	Fixed Linear Voltage Post Regulator, 3.3V	Infineon	TLS202B1MBV33
1	Q3	N-Channel Small Signal MOSFET 20V in SOT363 package	Infineon	BSD235N
1	D4	Medium Power AF Schottky Diode, 30V, 1A	Infineon	BAS3010B-03W

Qty	Designator	Description	Manufacturer	Manufacturer P/N
1	Q1	Bipolar Transistors - BJT PNP 100V Transistor	Diodes Incorporated	ZXTP19100CFFTA
1	Q2	Bipolar Transistors - BJT NPN 100V Transistor	Diodes Incorporated	ZXTN25100BFHTA
2	D1, D2	Diodes - General Purpose, Power, Switching 100V Io/150mA T/R	Diodes Incorporated	1N4148WT-7
1	LED	Standard LEDs - SMD SMD LED Bi-Color Green/Red Clear	Lite-On	LTST-C235KGKRKT
2	X1, X2	1.00 mm Flex Stack, Flexible Micro Board Stacker, Surface Mount	Samtec	MW-05-03-G-D-095-085
1	X4	High Reliability Header Strips, .050" pitch	Samtec	FTSH-105-01-L-DV-K-TR
1	X7	Headers & Wire Housings Cost Effective Rugged PCB Sockets, 2.00mm pitch	Samtec	SQT-102-01-F-S-RA
1	S1	Ultra-small Tactile Switch (SMT)	Omron	B3U-1000P
1	RT1	NTC (Negative Temperature Coefficient) Thermistors 10k 3988 1%	EPCOS/TDK	B57861S0103J040
1	L1	Coupled Inductors for SEPIC Applications	Coilcraft	LPD5030V-103MRC
1	C1	CAP / CERA / 1uF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Yageo	GRM188R71C105KE15
1	C2	CAP / CERA / 4.7uF / 100V / 10% / X7S (EIA) / -55°C to 125°C / 1206 / SMD / -	MuRata	GRM31CC72A475KE11L
1	C3	CAP / CERA / 220nF / 100V / 5% / X7R (EIA) / -55°C to 125°C / 1206(3216) / SMD / -	MuRata	C1206C224J1RAC7800
1	C4	CAP / CERA / 2.2uF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0805 / SMD / -	TDK	CGA4J3X7R1H225K125AB
1	C5	CAP / CERA / 220nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GCM188R71H224KA64
1	C7	CAP / CERA / 1uF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0805 / SMD / -	AVX	08053C105K4Z2A
1	C8	CAP / CERA / 15nF / 25V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R71E153JA01
1	C9	CAP / CERA / 2.2uF / 6.3V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GCM188R70J225KE22
3	C10, C11, C14	CAP / CERA / 100nF / 6.3V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R70J104KA01

Qty	Designator	Description	Manufacturer	Manufacturer P/N
4	C12, C13, C39, C40	CAP / CERA / 1nF / 10V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GCM188R72A102JA37
1	C17	CAP / CERA / 1uF / 25V / 10% / X5R (EIA) / -55°C to 85°C / 0805(2012) / SMD / -	MuRata	GRM21BR61E105KA99
1	C20	CAP / CERA / 100nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0603 (1608) / SMD / -	MuRata	GCJ188R71E104KA12D
1	C21	CAP / CERA / 1uF / 6.3V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R70J105KA01
1	C22	CAP / CERA / 220nF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R71C224KA01
1	C23	CAP / - / 220nF / 16V / 10% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	Vishay	VJ0603Y223JXACW1BC
1	C24	CAP / - / 2.2nF / 50V / 20% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	AVX	KGM15AR71H222JT
1	C25	CAP / - / 10nF / 50V / 5% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	MuRata	AC0603JRX7R9BB103
2	C26, C27	CAP / CERA / 2.2uF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0805 / SMD / -	Kemet	C0805C225K4RAC7800
1	C28	CAP / CERA / 100nF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R71C104KA01
3	C29, C30, C31	CAP / - / 1uF / 100V / 10% / X7S (EIA) / -55Â°C to 125Â°C / 0805 / SMD / -	TDK Corporation	CGA4J3X7S2A105K125AB
1	C32	CAP / - / 100nF / 100V / 10% / X7R (EIA) / -55Â°C to 125Â°C / 0805(2012) / SMD / -	Kemet	C0805C224J1RECTU
1	C33	CAP / - / 1uF / 25V / 10% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	MuRata	GCJ188R71E105KA01D
1	C34	CAP / - / 22nF / 25V / 20% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	Yageo	CC0603JRX7R9BB223
4	C35, C36, C37, C38	CAP / CERA / 15nF / 25V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	MuRata	GRM188R71E153JA01
1	C41	CAP / CERA / 100nF / 100V / 5% / X7R (EIA) / -55°C to 125°C / 0805 (2012) / SMD / -	AVX	KGM21AR72A104JU
4	C42, C43, C44, C45	CAP / CERA / 1nF / 25V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Yageo	CC0603KRX7R9BB102
2	R1, R6	RES / STD / 2.2k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Yageo	RC0603FR-072K2L

Qty	Designator	Description	Manufacturer	Manufacturer P/N
2	R2, R24	RES / STD / 51k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW060351K0FKEAC
2	R3, R12	RES / STD / 680R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW0603680RFKEAHP
3	R4, R38, R40	RES / STD / 22k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW060322K0FKEAC
9	R5, R9, R28, R29, R36, R37, R43, R50, R51	RES / STD / 0R / - / 0% / - / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06030000Z0EA
8	R7, R8, R10, R11, R13, R14, R15, R17, R18	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Panasonic	ERJ-3EKF1001V
2	R16, R19	RES / STD / 5.1R / 100mW / 0ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06035R10FKEA
2	R20, R22	RES / STD / 33k / 100mW / 0.1% / 25ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Yageo	RT0603BRD0733KL
1	R21	RES / STD / 1R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06031R00FKEAHP
1	R23	RES / STD / 10R / 100mW / 1% / 200ppm/K / -55°C to 155°C / 0603 / SMD / -	Yageo	RC0603FR-0710RL
1	R25	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Yageo	RC0603FR-0710KL
1	R26	RES / - / 10k / 100mW / 1% / 100ppm/K / - / 0603 / SMD / -	Yageo	AC0603FR-0710KL
2	R30, R31	RES / STD / 1.2k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06031K20FKEA
2	R32, R34	RES / - / 0R / 125mW / - / - / - / 0805 / SMD / -	Panasonic	ERJ-6GEY0R00V
2	R35, R39	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Yageo	RC0603FR-07100RL
1	R44	RES / STD / 249k / 100mW / 0.1% /	Vishay	CRCW0603249KFKEA

Qty	Designator	Description	Manufacturer	Manufacturer P/N
		25ppm/K / -55Â°C to 155Â°C / 0603(1608) / SMD / -		
1	R45	RES / STD / 75k / 100mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 0603 / SMD / -	Vishay	AC0603FR-0775KL
1	R46	RES / STD / 10k / 100mW / 0.1% / 50ppm/K / -55Â°C to 125Â°C / 0603 / SMD / -	Vishay	CRCW060310K0FKEA
1	R47	RES / STD / 50k / 100mW / 0.02% / 5ppm/K / -55Â°C to 125Â°C / 1608 (0603) / SMD / -	Vishay	CRCW060349K9FKEB
1	R48	RES / STD / 2k / 63mW / 0.1% / 10ppm/K / -55Â°C to 125Â°C / 0603 / SMD / -	Vishay	CRCW06032K00DHEAP
1	R49	RES / STD / 5.6k / 100mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 0603 / SMD / -	Vishay	CRCW06035K60FKEAHP
2	R52, R53	RES / STD / 2.7k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay	CRCW06032K70FKEAHP
1	X3	Solder bridge		
2	X8	Solder bridge		

References

[1] Infineon Technologies AG, 2021: TLE4972 high precision coreless current sensor for automotive applications; Available online

[2] Infineon Technologies AG, 2022: 48V Smart high-side MOSFET gate driver with SPI for automotive applications; Available online

[3] Infineon Technologies AG: Current Sensor Simulation Tool; Available online

[4] Infineon Technologies AG: Application note; Available online

[5] Infineon Technologies AG: User manual Rev1.01; Available online

[6] Infineon Technologies AG: TLE4972/TLx4971 Current sensor programmer user guide. Rev 1.01; Available online

[7] Infineon Technologies AG: XMC™ Link Functional Isolated Debug Probe, Based on SEGGER J-Link Technology; Available online

[8] Infineon Technologies AG: Getting Started with Micro Inspector Pro; Available online

[9] Infineon Technologies AG: Current sense and overcurrent accuracy with EiceDRIVER™ APD 2ED4820-EM. Rev 1.0; Available online

Glossary

BOM
Bill of Materials

CB
Control Board

CFET
Charge MOSFET

CSAG
Current sense amplification gain of smart gate driver

CSO
Current sense output of smart gate driver

DFET
Discharge MOSFET

EDPS
eDisconnect Power Switch

EEPROM
Electrically Erasable Programmable Read-Only Memory of TLE492 current sensor

GPIO
General Purpose Input Output pin

GUI
Graphical user interface

LDO
Linear dropout regulator IC

MCU
Microcontroller unit

OC
Over current from battery

OCD
Over current detection of TLE492 current sensor

OCTHxH/L
Over current threshold High/Low limit of smart gate driver

OT
Overtemperature inside battery

OV
Overvoltage of battery

PB
Power Board

PWM
Pulse width modulation

REF
Reference Board

SOA
Safe operating area

SC
Short circuit in the system

SPI
Serial Peripheral Interface communication

SWD
Serial Wire Debug protocol

TIM
Thermal interface material

TOLL
TO-Leadless package

TOLT
TO-Leaded top-side cooling package

UART
Universal Asynchronous Receiver/ Transmitter hardware communication protocol

UT
Under temperature inside battery

UV
Under voltage of battery

Revision history

Document revision	Date	Description of changes
V 1.0	2024-06-28	Initial revision

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2024-06-28

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

UM103815

Warnings
Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.