9 kW 2–level boost converter reference design

REF 9KW2LBOOST

About this document

Scope and purpose

This user guide describes the REF-9KW2LBOOST boost converter reference design for solar photovoltaic solutions and its main features, key data, pin assignments, mechanical dimensions, and electrical interfaces. This power conversion reference design is modular so that the hardware can be reused for various power converter applications and use cases, with a special focus on solar photovoltaic solutions.

This reference design is not a qualified and certified commercial product. Its hardware does not necessarily meet any safety, EMI, or quality standard (for example, UL, and CE) requirements.

Intended audience

This user guide is meant for engineers and technical specialists working on solar photovoltaic solutions and similar domains.

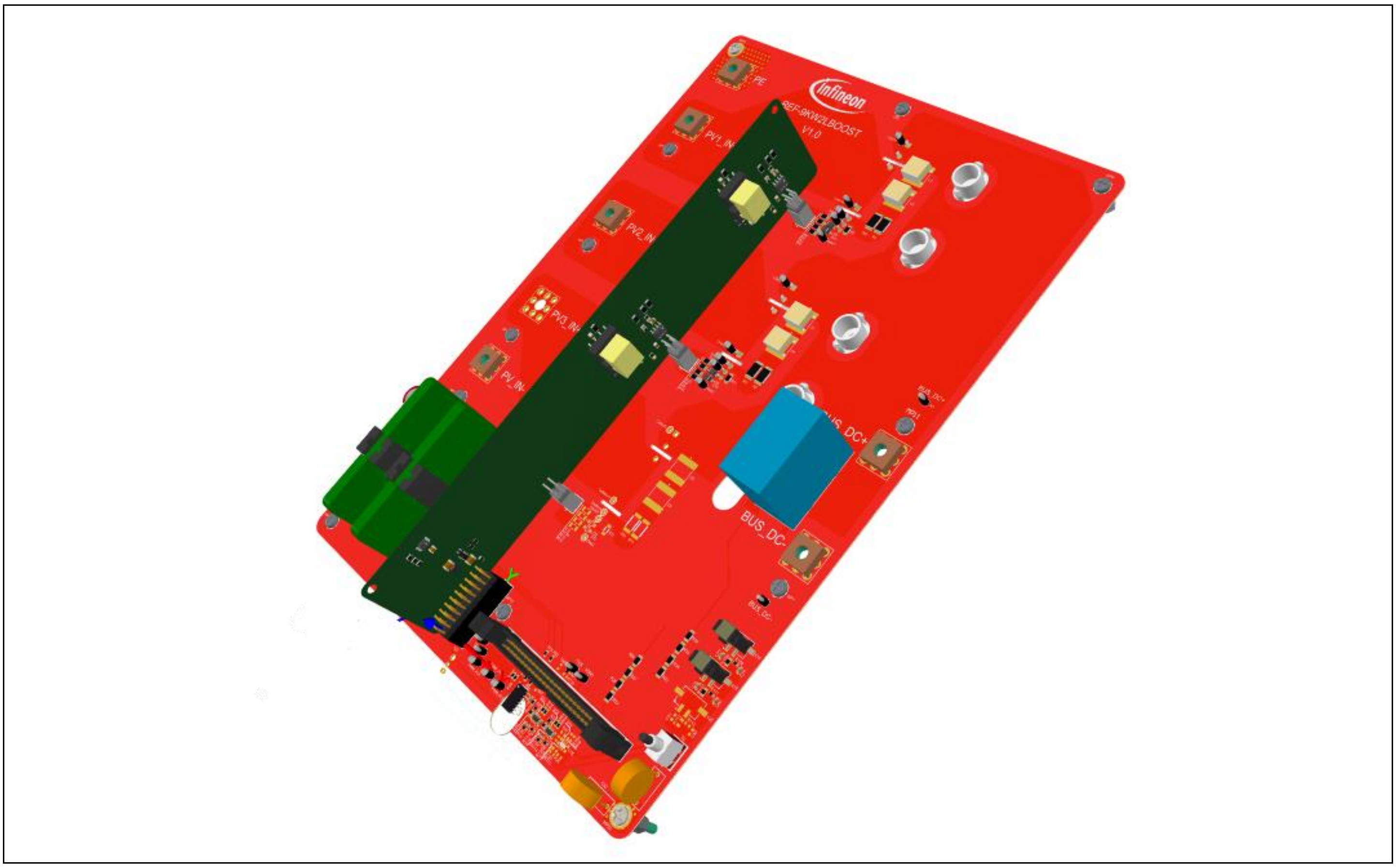


Figure 1 **Power conversion board REF-9KW2LBOOST**

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 non-infringement 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**

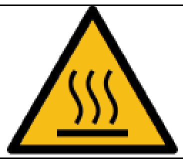
	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five 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 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

Table of contents

1 Power conversion reference design at a glance

1.1 Introduction

REF-9KW2LBOOST comes as a kit and includes different boards that can help to build and operate a 2-channel boost converter:

- REF-9KW2LBOOST: 2-channel boost DC-DC converter main board
- ISODRV-8275C3P12N00-1: 2-channel gate driver daughter card
- PB-APS-24V-5V ISO: 24 V–5 V isolated auxiliary power supply
- Filter-REF-9KW2LBOOST: Boost inductor and EMI filter board
- PB-CAPTANK-1.1KV: Output DC-link capacitor board

The REF-9KW2LBOOST main board contains two basic boost DC-DC converters and carries power semiconductors, gate drivers and an auxiliary power supply. Additionally, the PCB offers all traces for a third channel. It also offers connectors that you can use to connect your own passives.

You can also get a separate REF-CLBXMC7PEC control board based on XMC7200 MCU, which comes with all the signal conditioning circuits, power conversion software and a GUI that can help to operate the 9 kW boost converter as a 2-channel interleaved boost in open-loop configuration.

Figure 1 shows the completely assembled 9 kW boost converter reference design.

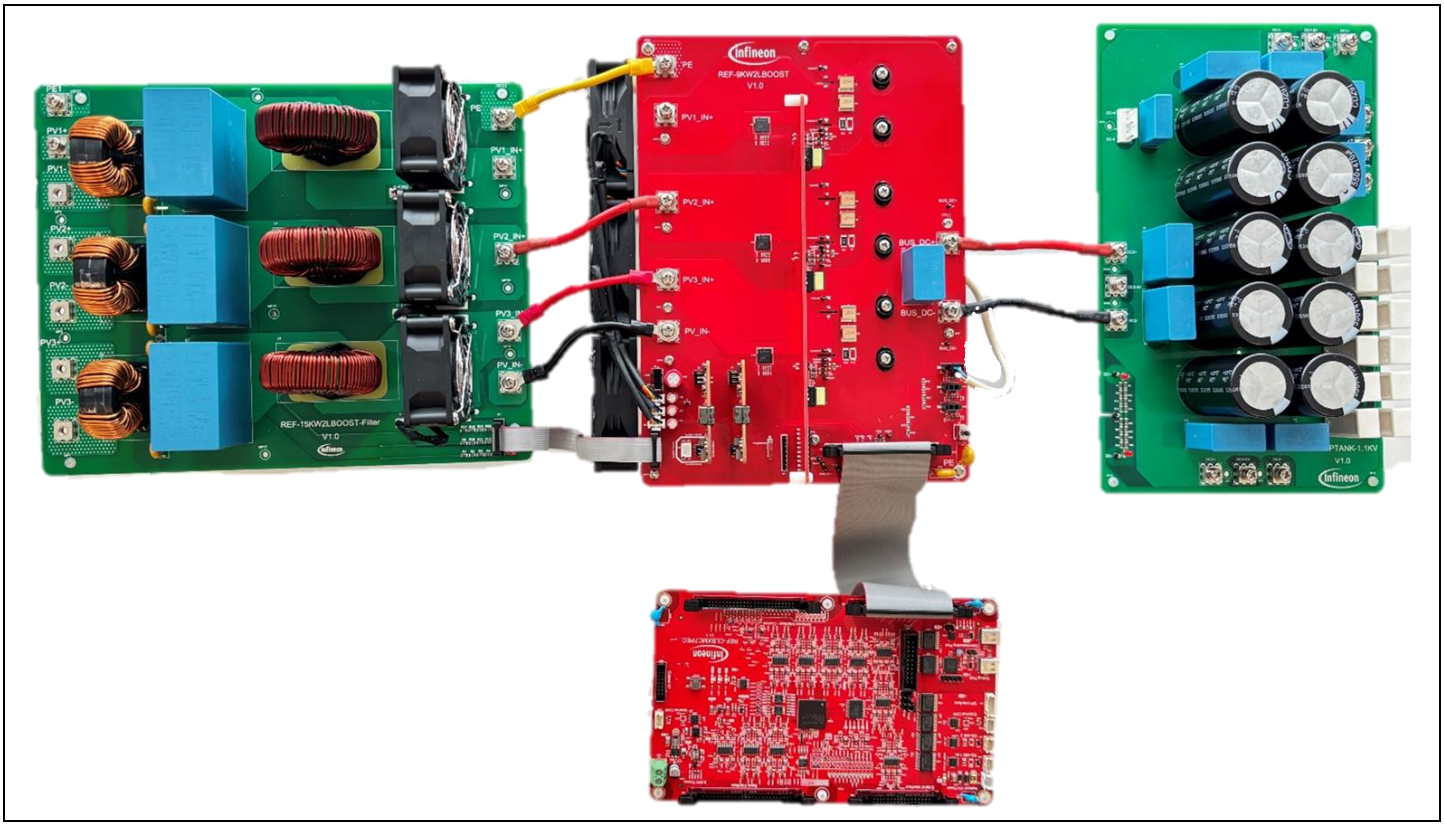


Figure 2 Power conversion reference design REF-9KW2LBOOST

1.2 Top-level specifications

Table 2 Specifications

Parameter	Typical	Maximum	Unit
Input voltage	–	550	V_{dc}
Output voltage	380	550	V_{dc}
Output power per channel	–	4.5	kW
Output power	–	9	kW
Switching frequency	24	24	kHz

1.3 Key design building blocks

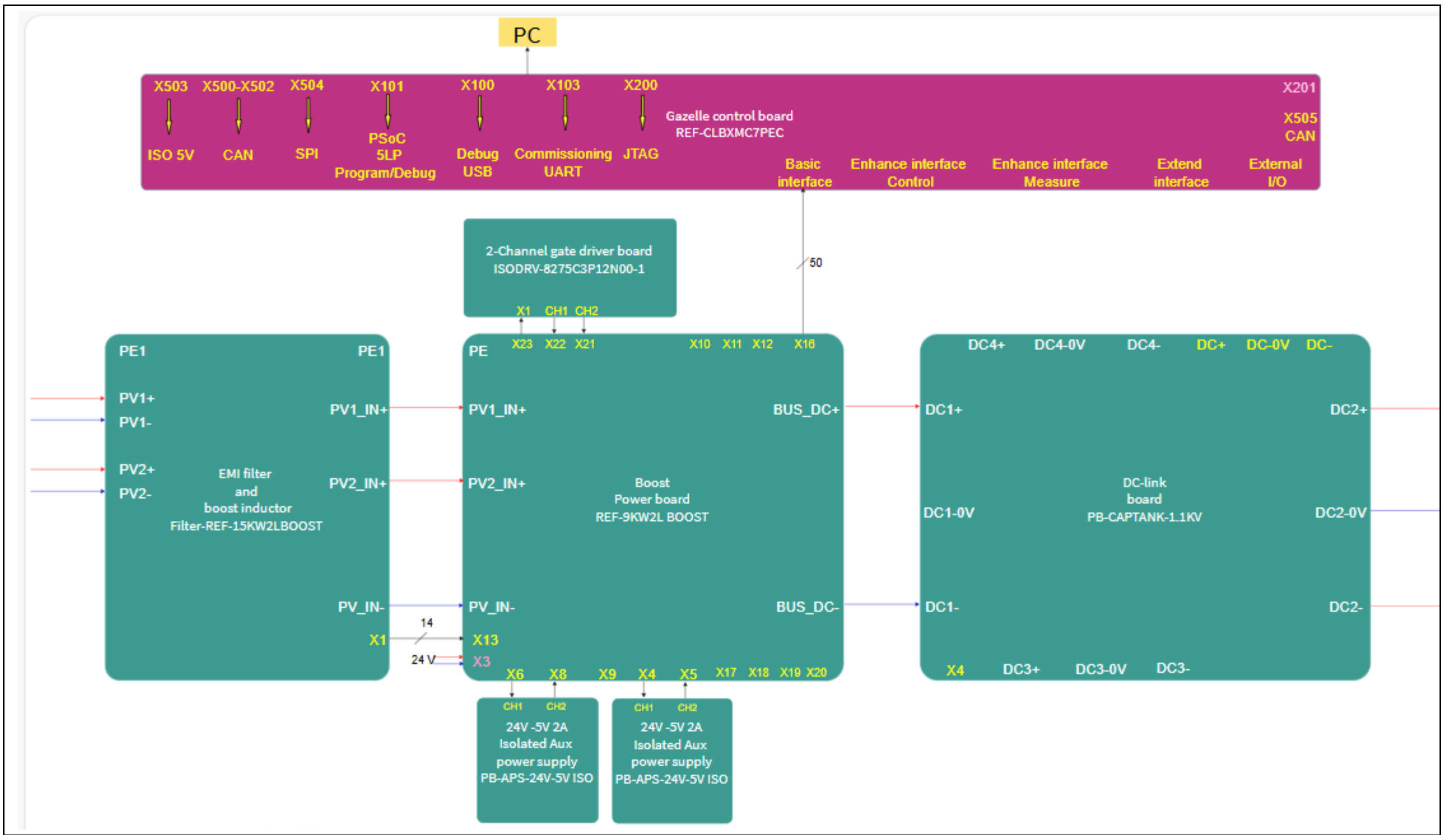


Figure 3 Assembly diagram

Figure 2 shows how the different boards are connected to construct the 2-channel boost DC-DC converter.

Starting from the left, the EMI filter board consists of the EMI filter and the boost inductor for the two channels. The filter board is connected to the boost power conversion board. The negative terminals of the two boost converters are connected internally. The boost power conversion board also contains a gate driver daughter card and two auxiliary power supply daughter cards (only one is delivered for current system setup; the other one is intended for powering the communication card in future). Finally, the boost power conversion board is connected to the output DC-link board.

Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7 show the standalone REF-9KW2LBOOST, ISODRV-8275C3P12N00-1, PB-APS-24V-5V ISO, Filter-REF-9KW2LBOOST, and PB-CAPTANK-1.1KV respectively.

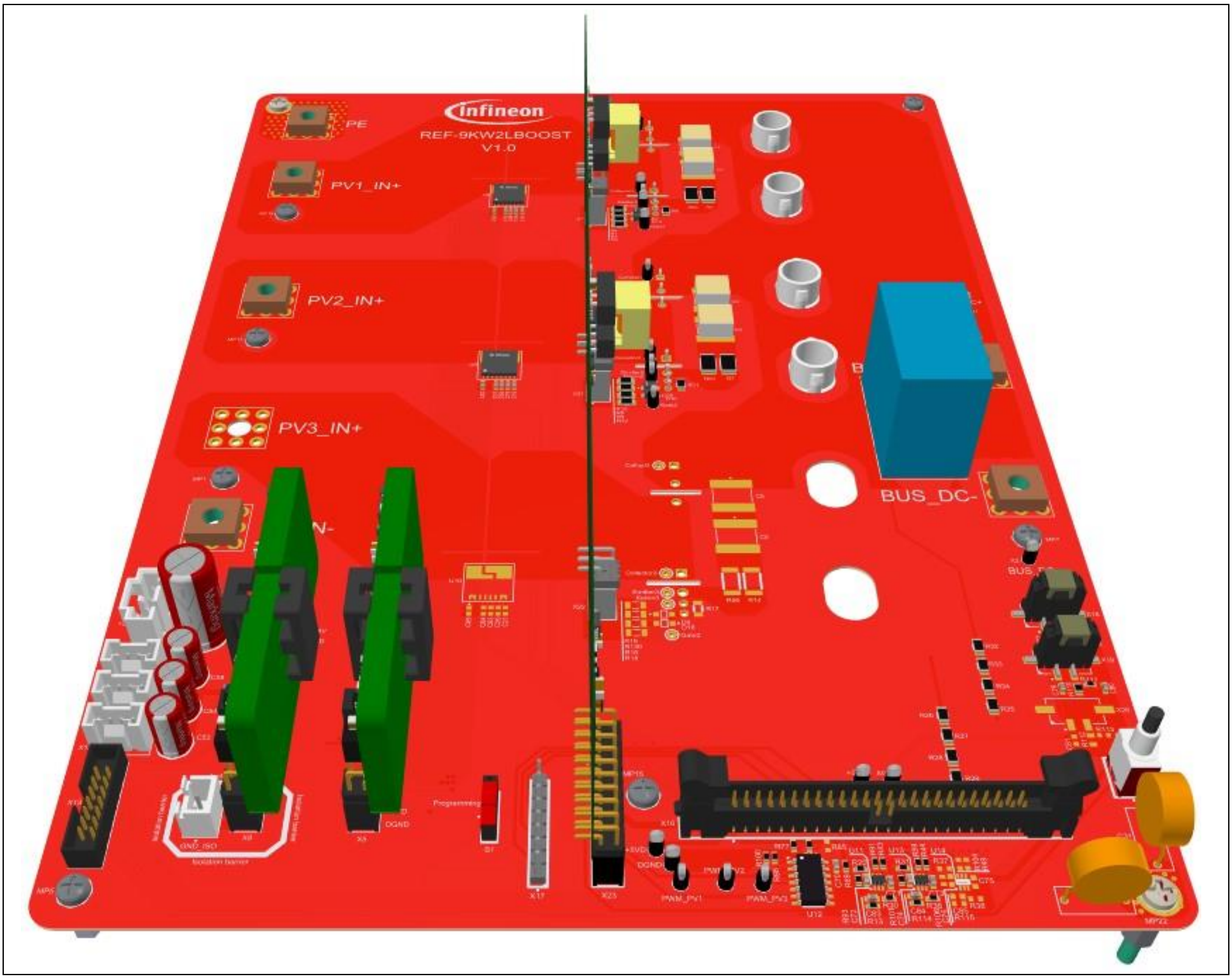


Figure 4 REF-9KW2LBOOST (Note: PCB is populated with two channels only)

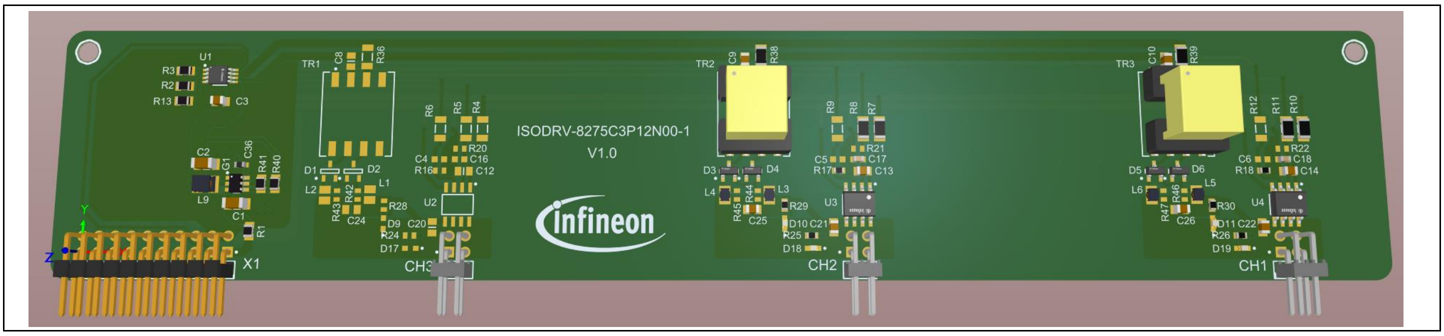


Figure 5 ISODRV-8275C3P12N00-1 (note: PCB is populated with 2 channels only)

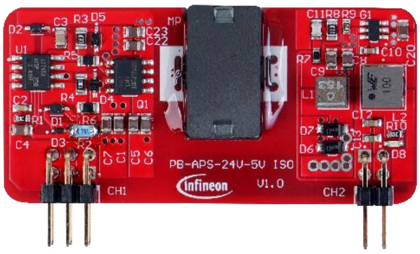


Figure 6 PB-APS-24V-5V ISO

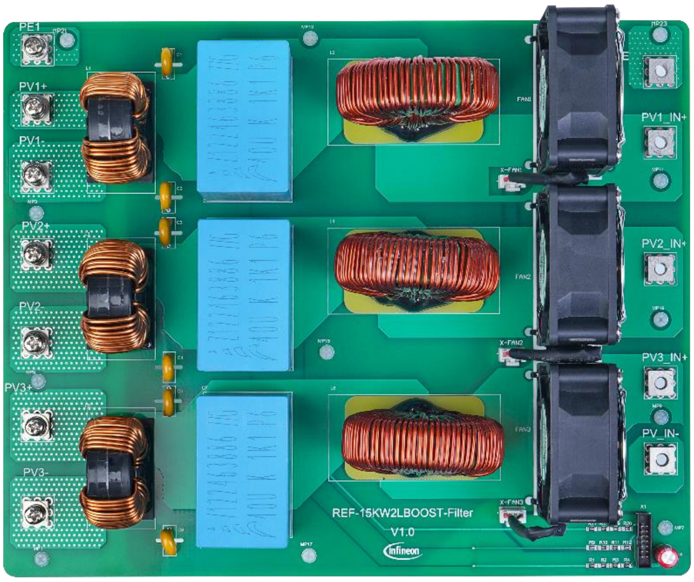


Figure 7 Filter-REF-9KW2LBOOST

Figure 8 PB-CAPTANK-1.1KV

1.4 Preferred components

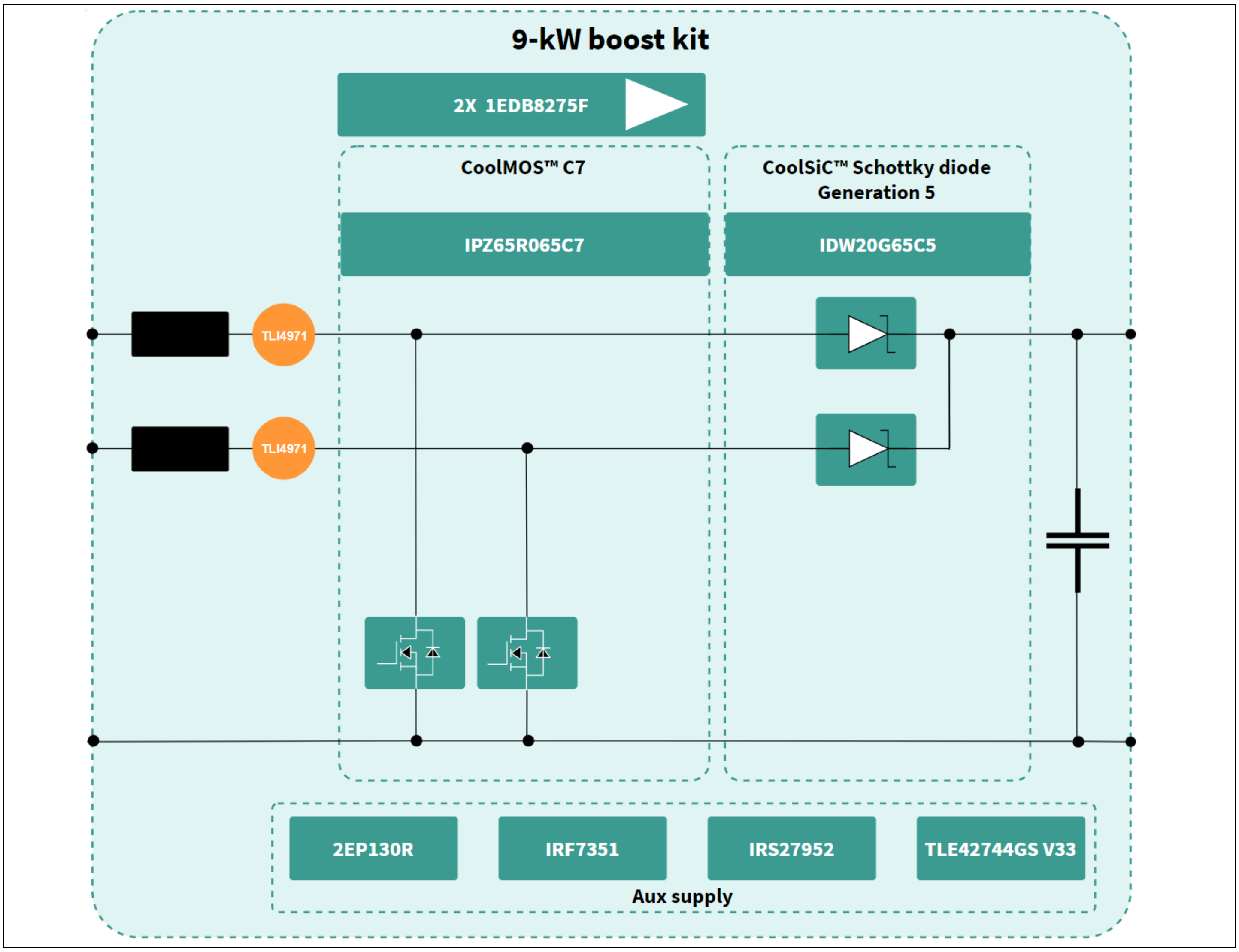


Figure 9 Power conversion board block diagram

Figure 9 shows the main semiconductors offered in the 9 kW boost converter reference design.

- Power semiconductors:
  - CoolMOS™ C7 IPZ65R065C7 superjunction MOSFET
  - CoolSiC™ IDW20G65C5 Schottky diode MOSFET generation 5
- Gate driver:
  - EiceDRIVER™ 1EDB8275F Single-channel isolated gate driver with 2-level slew rate control:
- Current sensor:
  - XENSIV™ TLI4971 magnetic current sensor:
- Auxiliary power supply:
  - 2EP130R full-bridge transformer driver
  - IRS27952 half-bridge controller IC
  - HEXFET™ IRF7351 60 V dual N-channel power MOSFET

2 Board functional description

This chapter lists the features available for the 9 kW boost converter reference design.

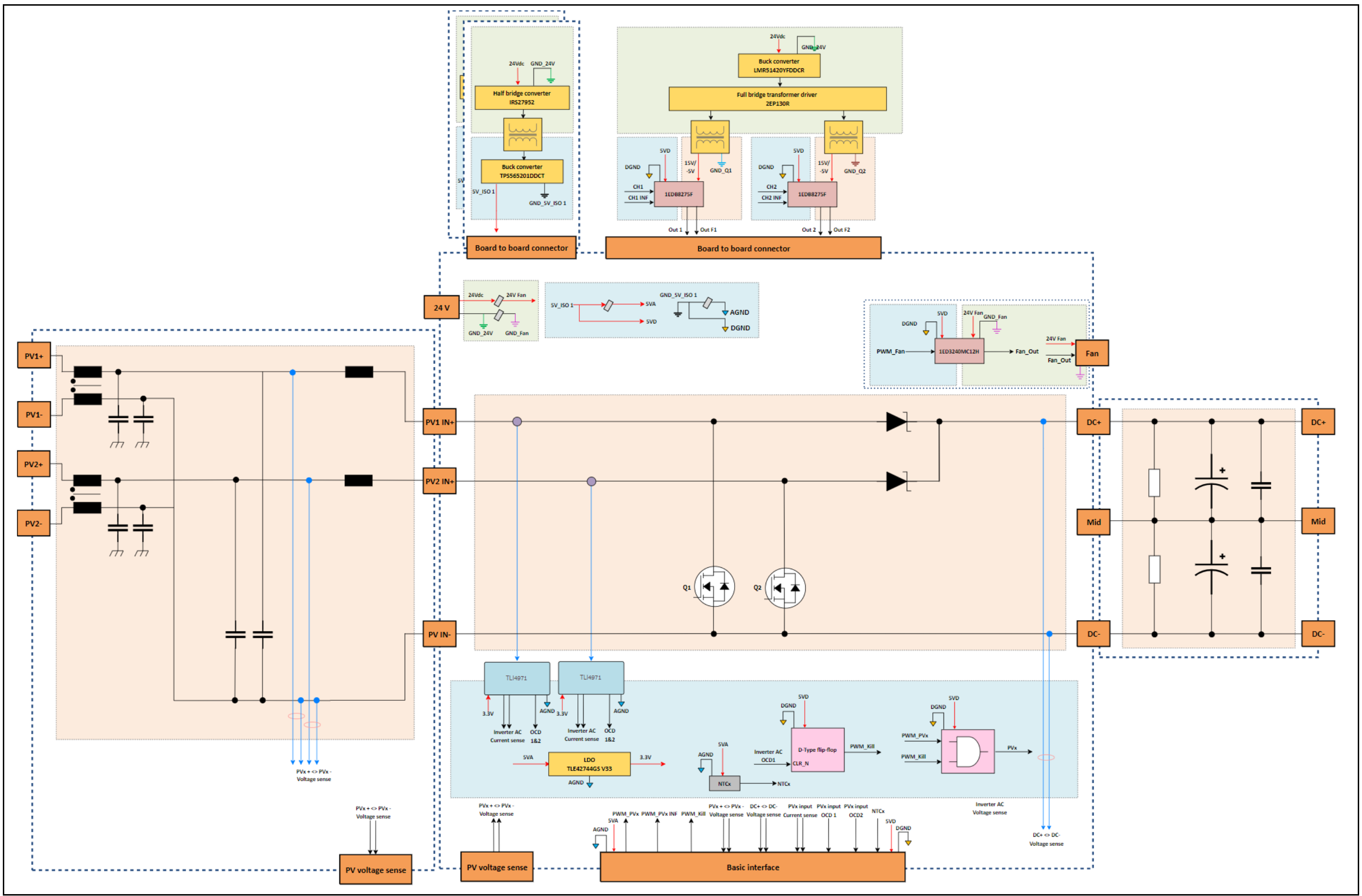


Figure 10 Block diagram of REF-9KW2LBOOST

2.1 Functional blocks

2.1.1 Switching devices

The boost power stage is realized using the CoolMOS™ C7 IPZ65R065C7 and the CoolSiC™ IDW20G65C5 Schottky diode.

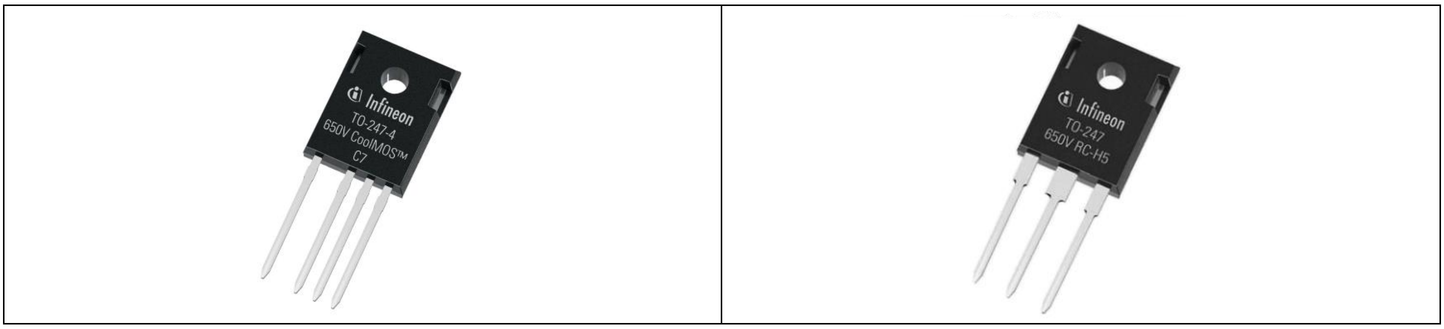


Figure 11 IPZ65R065C7 and IDW20G65C5

CoolMOS™ C7 IPZ65R065C7 is a discrete TO-247 4-pin package technology that has been developed to fulfill the demand in applications focusing on decarbonization such as solar photovoltaic, uninterruptible power supplies and battery chargers.

CoolSiC™ IDW20G65C5 is a part of the Schottky diodes thinQ!™ Generation 5, 650 V, 20 A in a TO-247 3-pin package. ThinQ!™ Generation 5 represents Infineon’s leading edge technology for the SiC Schottky barrier diodes. Due to the more compact design and thin-wafer technology, the new family of products shows improved efficiency over all load conditions, resulting from both the improved thermal characteristics and a lower figure of merit (Qc x Vf).

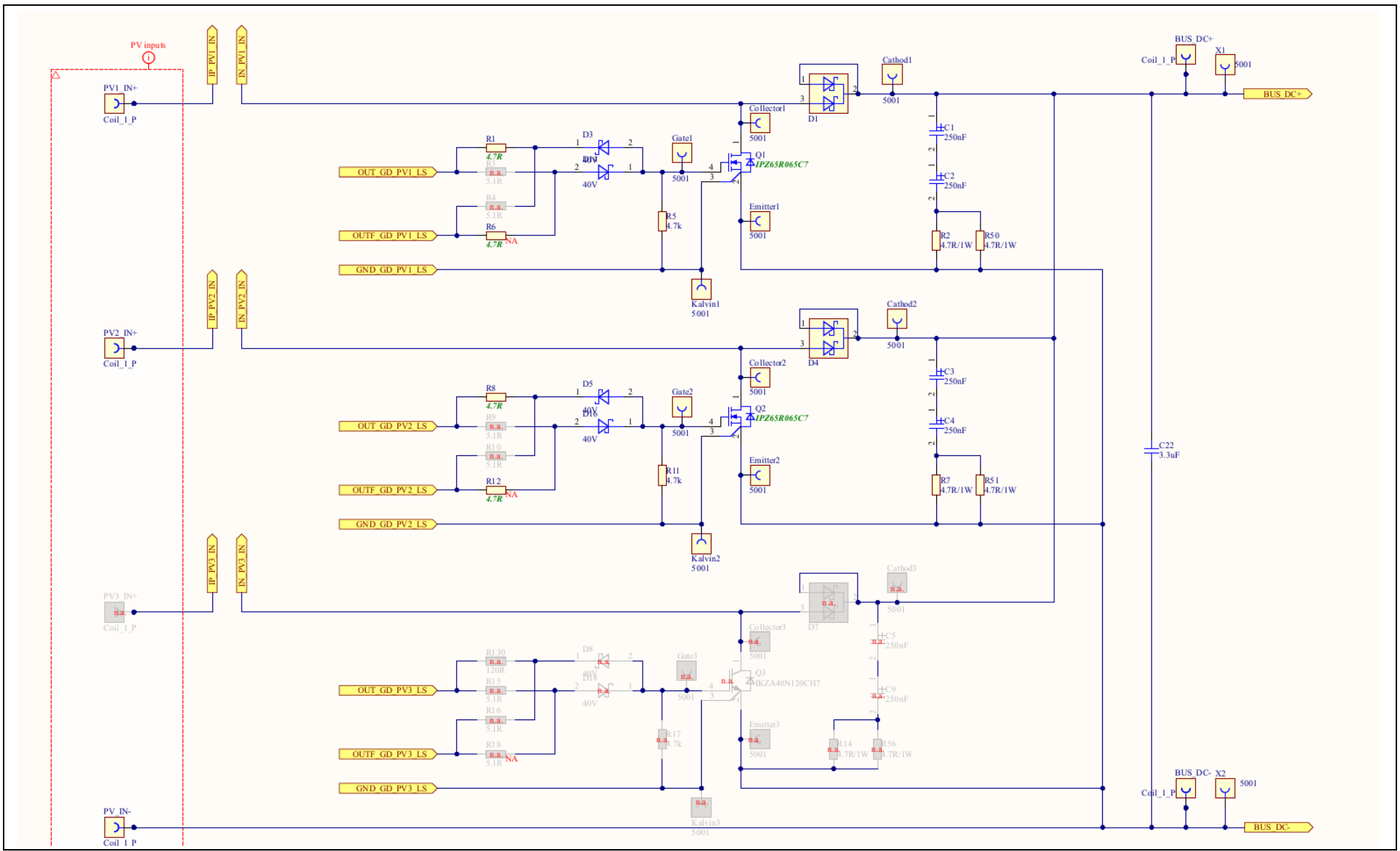


Figure 12 Power stage

2.1.2 Gate driver

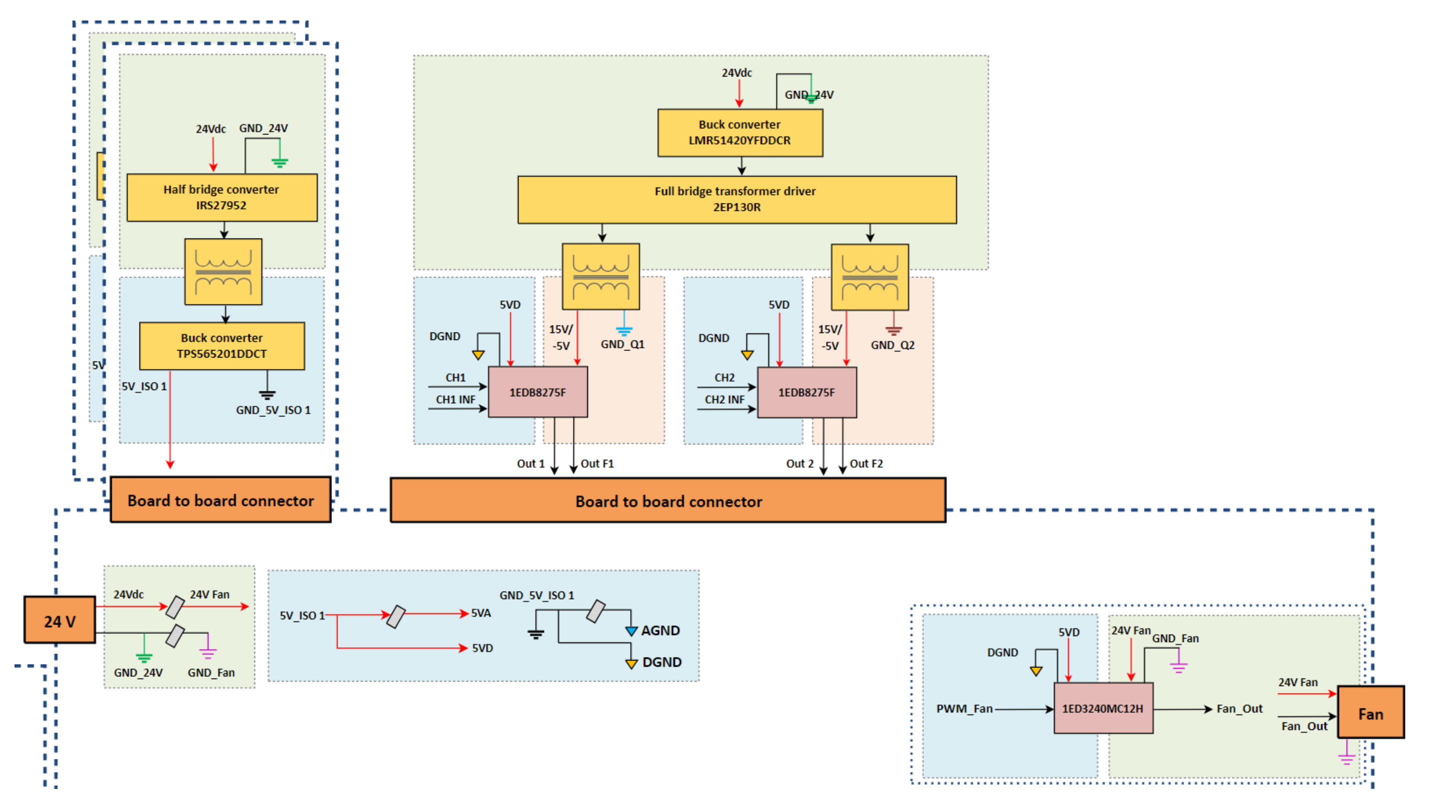


Figure 13 Gate driver daughter card functional block diagram

Two single-channel isolated gate drivers are used to drive the two CoolMOS™ devices. The gate driver used is 1EDB8275F.

Figure 14 1EDB8275F

1EDB8275F belongs to the EiceDRIVER™ Compact 1EDBx275F family and is a single-channel isolated gate driver with 5 A/9 A peak source/sink output current in DSO-8 wide-body package with 4 mm input-to-output creepage distance, designed to drive Si, SiC, and GaN power switches. It provides isolation by means of on-chip coreless transformer (CT) technology.

With tight timing specifications, 1EDB8275F is designed for fast-switching medium-to-high power systems. Excellent common-mode rejection, low part-to-part skew, fast signal propagation and small package size make 1EDB8275F a superior alternative to high-side driving solutions using optocouplers or pulse transformers.

1EDB8275F offers separate low-impedance source and sink outputs to control two independent gate resistances for both turn-on and turn-off.

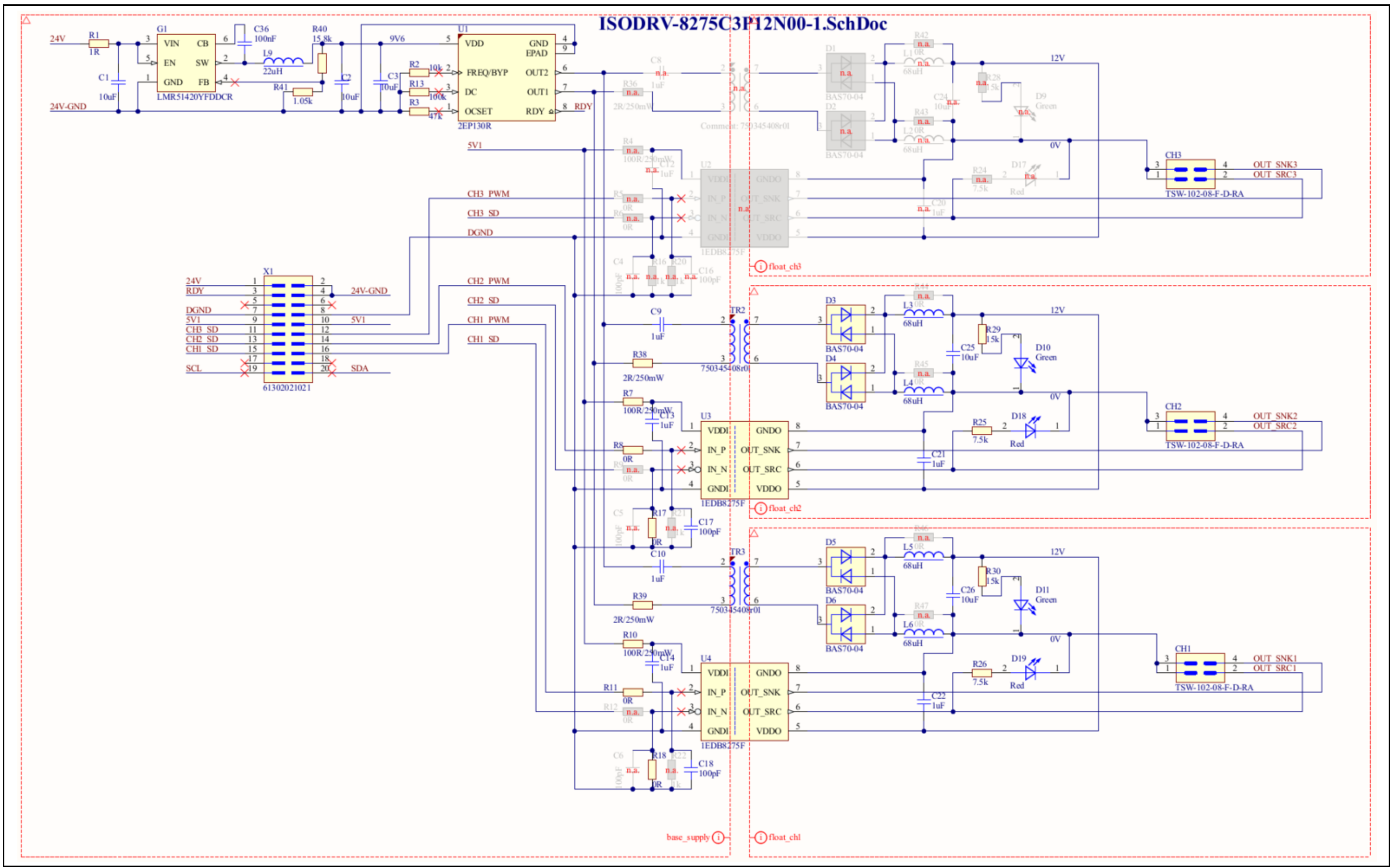


Figure 15 Gate driver daughter card

The 24 V and the PWM signals are connected to the power board and used as an input to the gate drive daughter card. The 24 V supply is then stepped down and used as an input to the 2EP130R full-bridge transformer driver. A transformer is then used to provide functional isolation, and the voltage of 12 V is then generated on the rectifier side to be used as the supply voltage for driving the CoolMOS™ devices on the power board. The gate resistors are located on the power board.

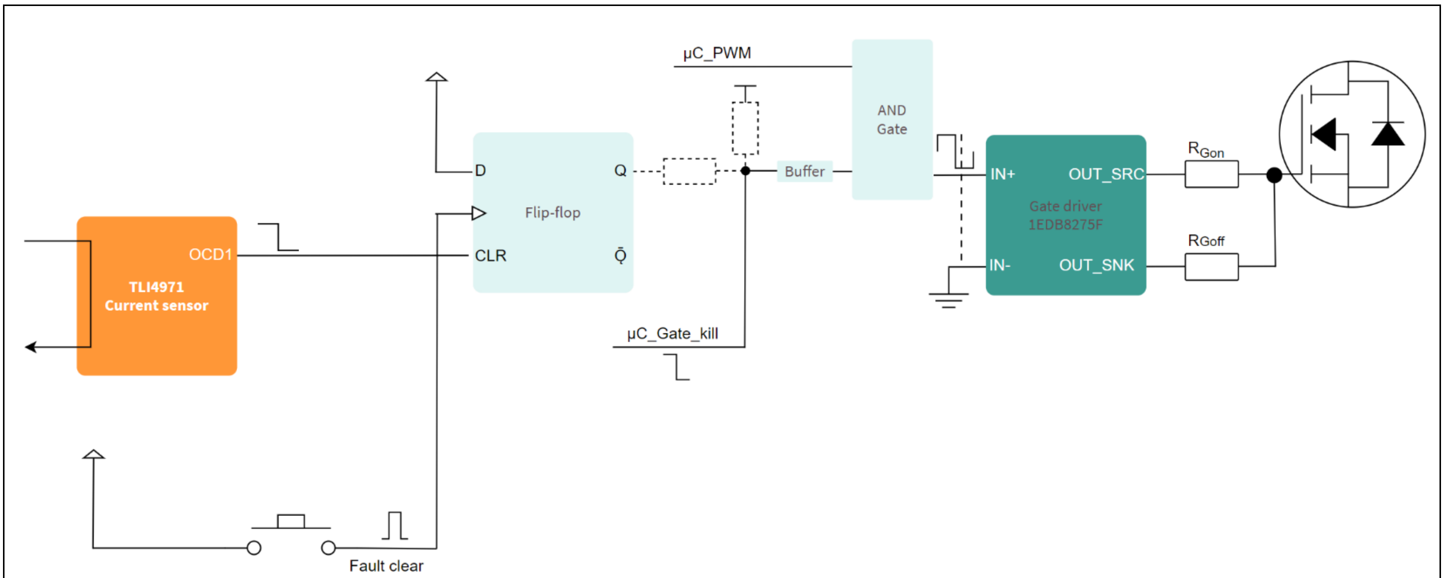


Figure 16 Overcurrent protection (OCP) concept

In this design, two possibilities to turn off the switch during abnormal conditions are implemented:

- The microcontroller board can disable the switches by setting the µC_Gate_kill signal to LOW
- An OCD1 fault from the TLI4971 current sense device leads to a clear of a D-FF

Both signals are used to block the PWM signal from the microcontroller board via an AND gate. As shown in Figure 15, the resistor to connect the D-FF with the AND-gate is not assembled by default. It can be assembled to use the D-FF protection structure if a different controller board is used that does not provide a kill functionality. If the D-FF structure is used, you need to press the power switch S1 to clear a fault and for startup.

Figure 15 shows also the two gate resistors, R_{Gon}, and R_{Goff}. The 1EDB8275F gate driver provides two outputs: one source and one sink to offer use of different gate resistors for the CoolMOS™ devices to switch on and off.

2.1.3 Internal power supplies

You need to supply 24 V externally to the power board. The 24 V supply is then fed to a power supply daughter card which generates an isolated 5 V. The 24 V supply and the isolated 5 V supply are both then fed to the gate driver daughter card which generates the isolated 12 V needed to drive the CoolMOS™ devices.

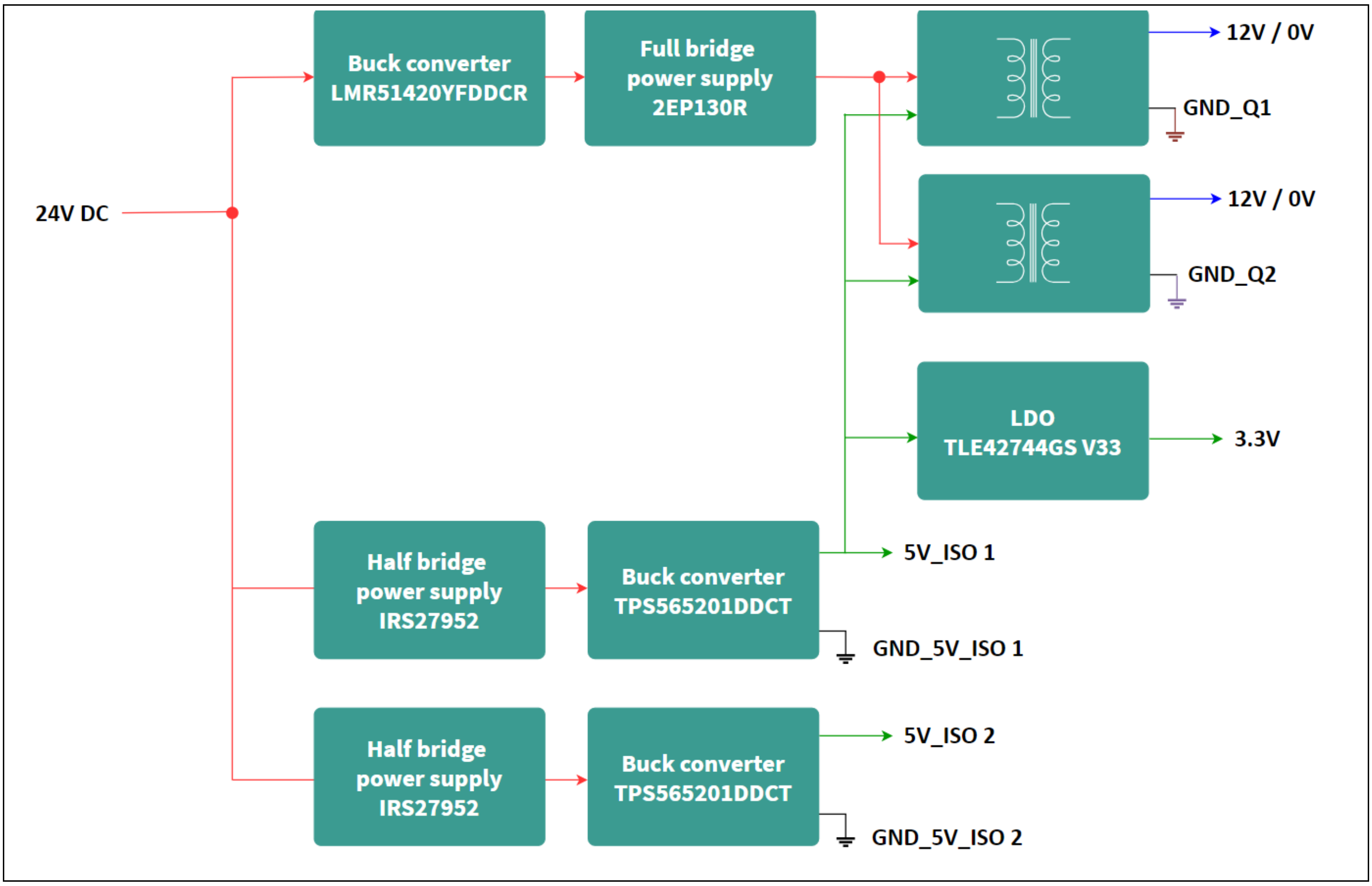


Figure 17 Auxiliary power supply tree

The specifications of the power supply daughter card are as follows:

Table 3 Specifications of the power supply daughter card

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	21.6	24	26.4	V_{dc}
Input current	–	–	0.5	A
Output voltage	4.75	5	5.25	V_{dc}
Output current	0		2	A
Switching frequency	–	226	–	kHz
Half-bridge IC used	IRS27952			–
Isolation	Reinforced isolation			–

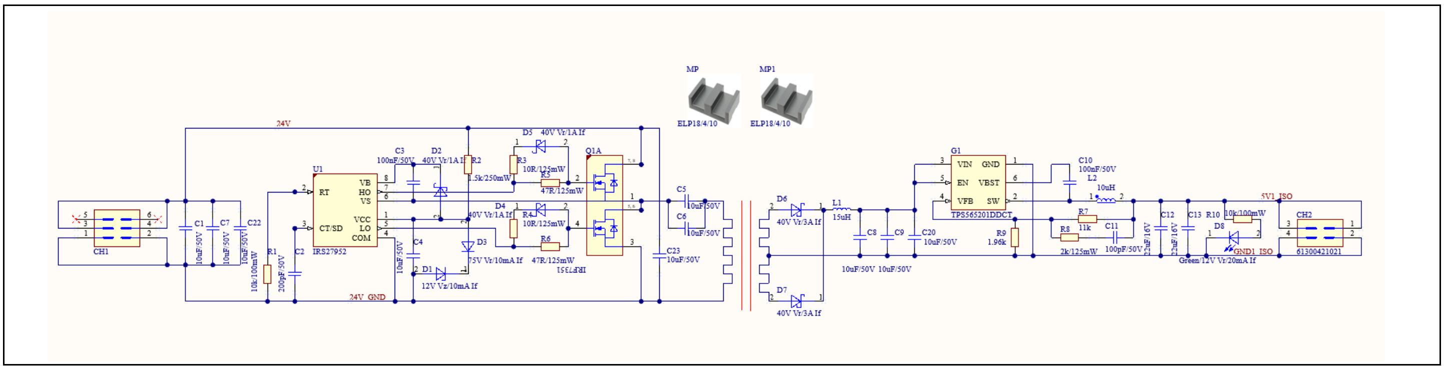


Figure 18 Power supply daughtercard schematics

2.1.4 Sensing and protection

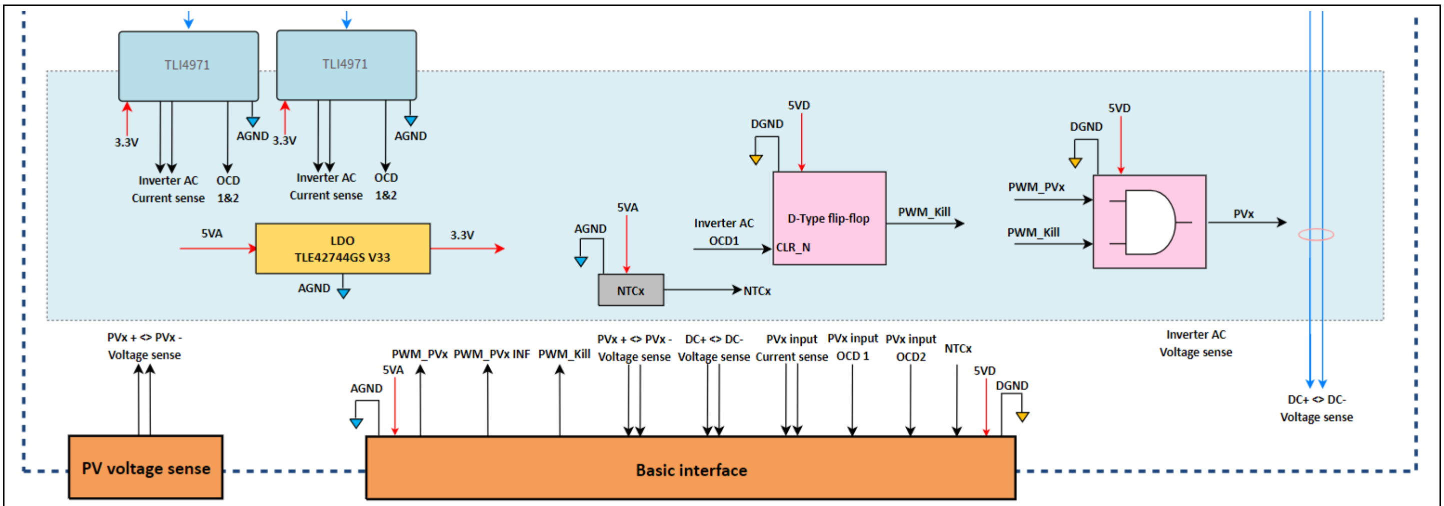


Figure 19 Functional block diagram of the measurement signals

2.1.4.1 Current sense

The inductor currents are sensed using the TLI4971 current sensor.

XENSIV™ TLI4971-A120T5-U-E0001 is an Infineon high-precision miniature coreless magnetic current sensor for AC and DC measurements with analog interface and dual fast overcurrent detection outputs. The two overcurrent detection (OCD) pins are used to implement protection on hardware and software levels.

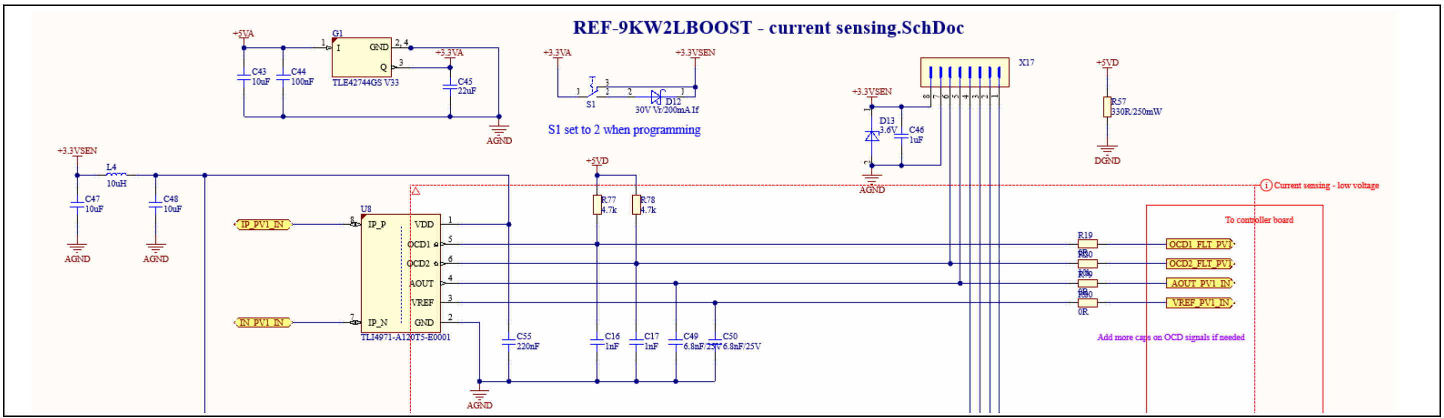


Figure 20 Current sense circuit

One way to reprogram the current sensor is by using the XENSIV™ - TLI4971, TLE4972 current sensor programmer board. See the user guide for details.

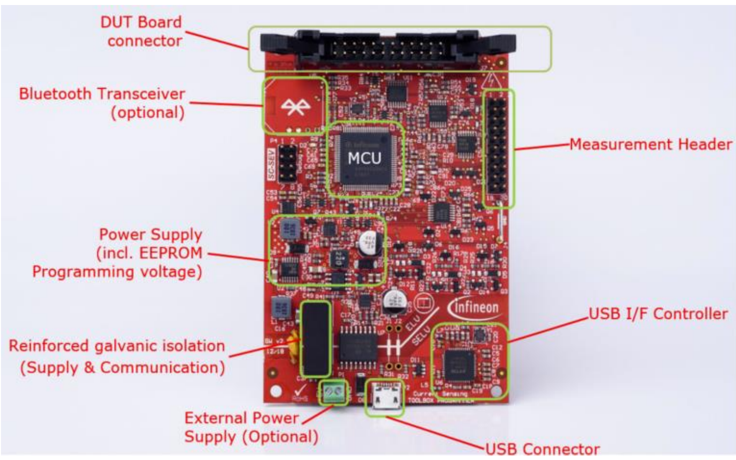


Figure 21 Current sensor programmer board

Connect the board to a PC. Interface the DUT board connector with the power board.

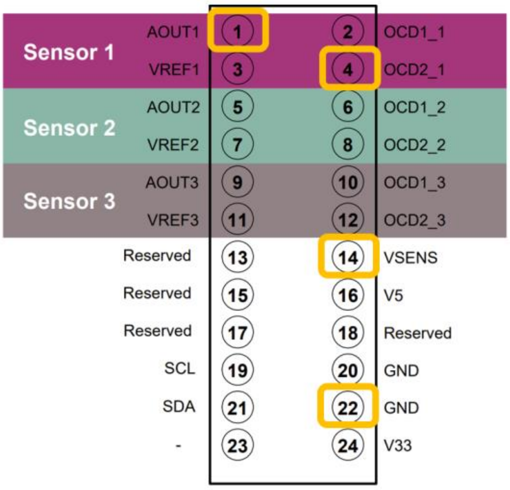


Figure 22 DUT board connector on the programmer board

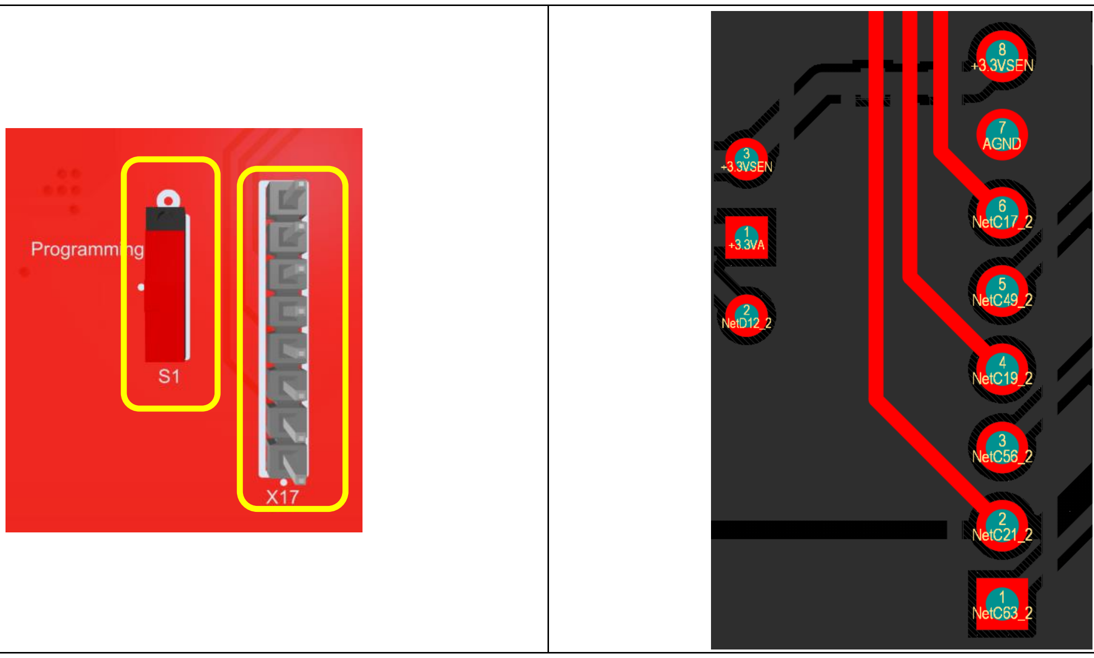


Figure 23 Current sensor programming connector on the power board

The previous two figures show the two connectors that need to be interfaced together on the programming board and the power board. Make the following connections:

- Connect X17 pin 7 to GND of the DUT board connector
- Connect pin 8 to VSENS
- Connect X17 pin 1 to pin 6 to provide the pins AOUT and OCD2 of all three devices according to the schematic in Figure 20

2.1.4.2 Reprogram the current sensor

1. Connect the programmer board with X17 on the power board and with USB cable to the PC
2. Place switch S1 in programming mode
3. Start the TLI4971 programming software

4. In the GUI, go to **Memory** and then **Basic configuration**
5. Set all the data, and click **Burn EEPROM**
6. Repeat the previous steps to program other current sensors
7. Remove all connections
8. Place the switch S1 back in default mode

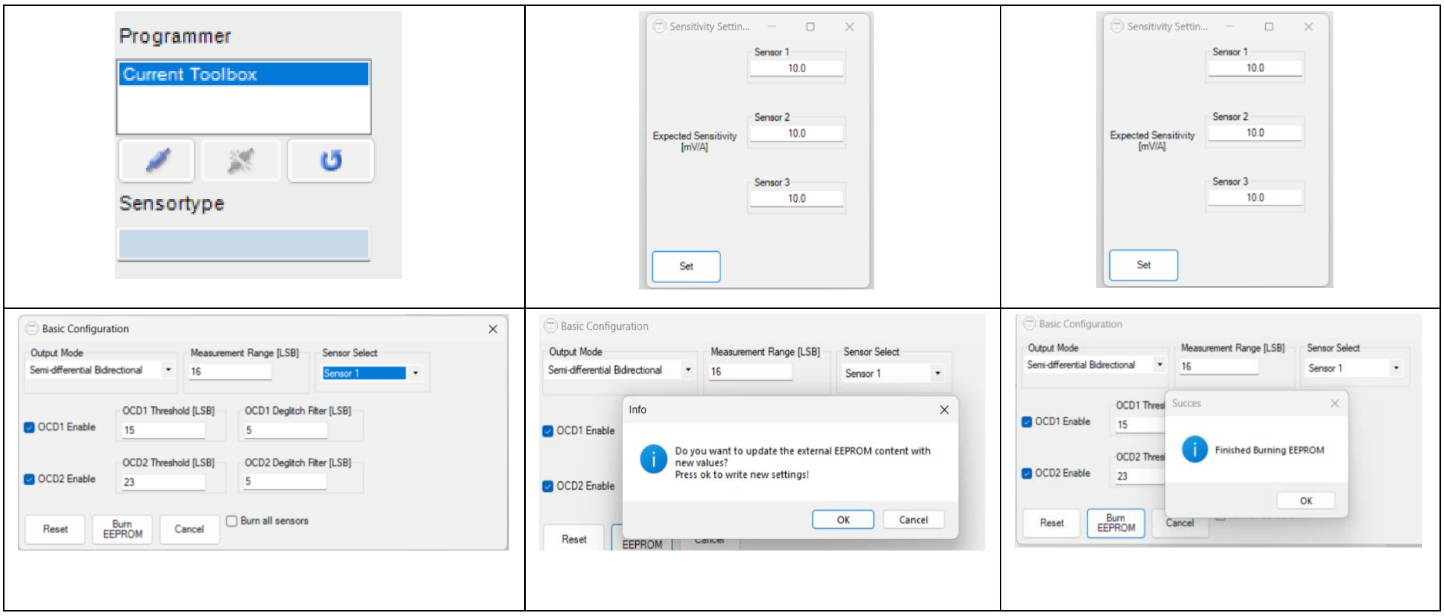


Figure 24 GUI

2.1.4.3 Voltage sense

Voltage measurements are taken for the DC link voltage on the power board. The voltage at the input of each boost channel is also measured on the filter board. Both measurements are done using voltage dividers.

Attention: ***The controller board must be connected with the main power board before powering the DC bus. Failure to do so can lead to a hazardous situation.***

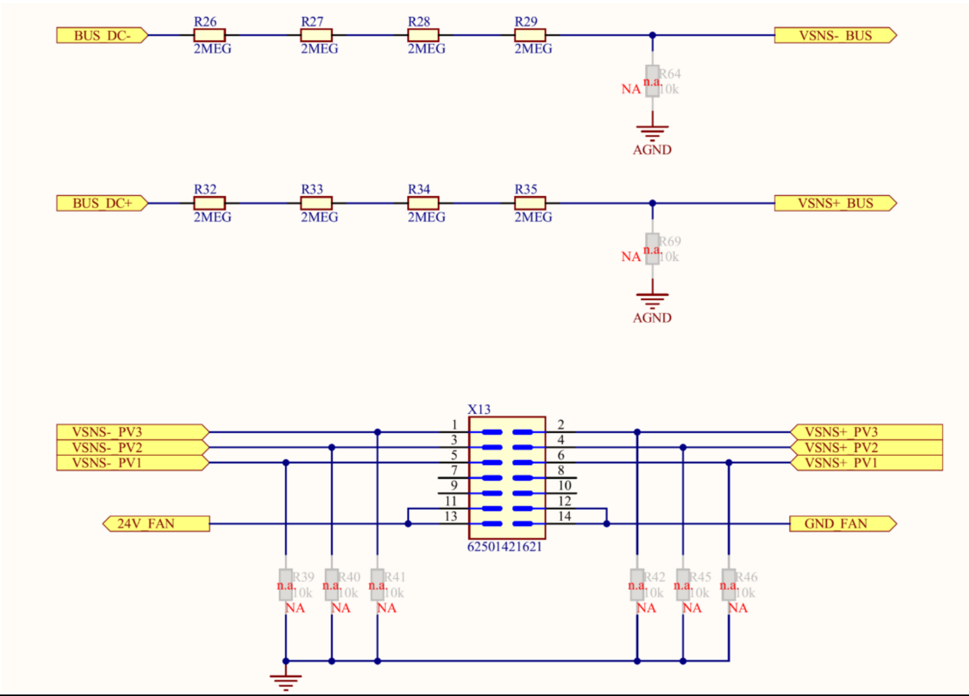


Figure 25 Voltage sense circuits

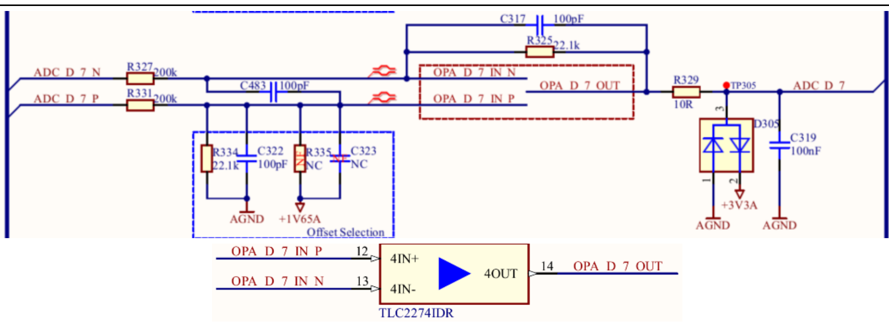


Figure 26 Signal conditioning circuit used on the control board

2.1.4.4 Temperature sense

Three temperature measurements are provided on the board using B57703M0502A006 NTCs.

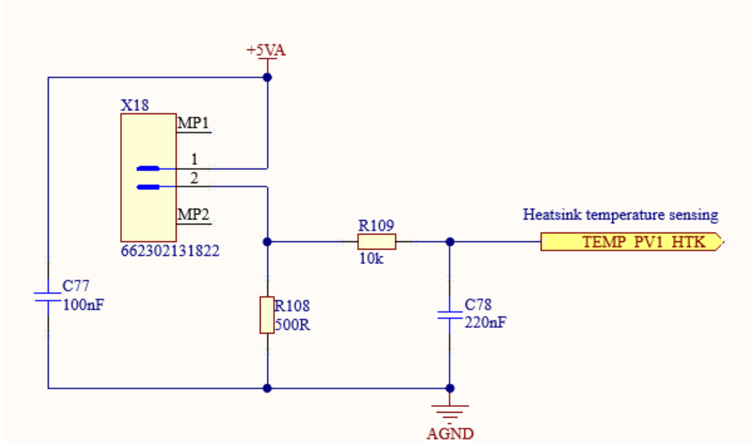


Figure 27 Temperature sense circuit

Table 4 shows the voltage vs. temperature for the previous circuit.

Table 4 Voltage vs. temperature

T (℃)	R (Ω)	Interface voltage (V)
–40	169157	0.014735614
–35	121795	0.020442373
–30	88766	0.028006184
–25	65333	0.037974876
–20	48614	0.050901983
–15	36503	0.06756209
–10	27680	0.088715401
–5	21166	0.115388166
0	16330	0.148544266
5	12696	0.189451349
10	9951	0.239211559
15	7855	0.299222023
20	6246	0.370589979
25	5000	0.454545455
30	4029	0.551998234
35	3266	0.663834307
40	2665	0.789889415
45	2186	0.930752048
50	1803	1.085540599
55	1495	1.253132832
60	1247	1.431024614
65	1044	1.619170984
70	878.9	1.813039379
75	743.1	2.011101279
80	631	2.210433245
85	538.2	2.40801387
90	460.8	2.601998335
95	396.1	2.789867202
100	341.8	2.969826562
105	296.2	3.139914594

2.1.4.5 Fault and latch circuit

Fault and latch circuits are provided to disable the PWMs in the case of a fault which can be seen in Figure 28.

The TLI4971 sensor has two levels of overcurrent threshold setting: OCD2 for lower threshold and OCD1 for higher threshold. OCD1 is usually used for protection from short-circuit condition. When OCD1 is triggered, the output of the SN74LVC1G175DCKT D-type flip-flop turns to LOW state to shut down the PWM signal permanently.

The same OCD1 protection circuit is also placed in the controller board. Therefore, the same function on the main power board is not used by not assembling R43, R44, and R49 by default. If a different controller board that does not provide this functionality is used, the resistors can be placed to enable the OCD1 protection circuit.

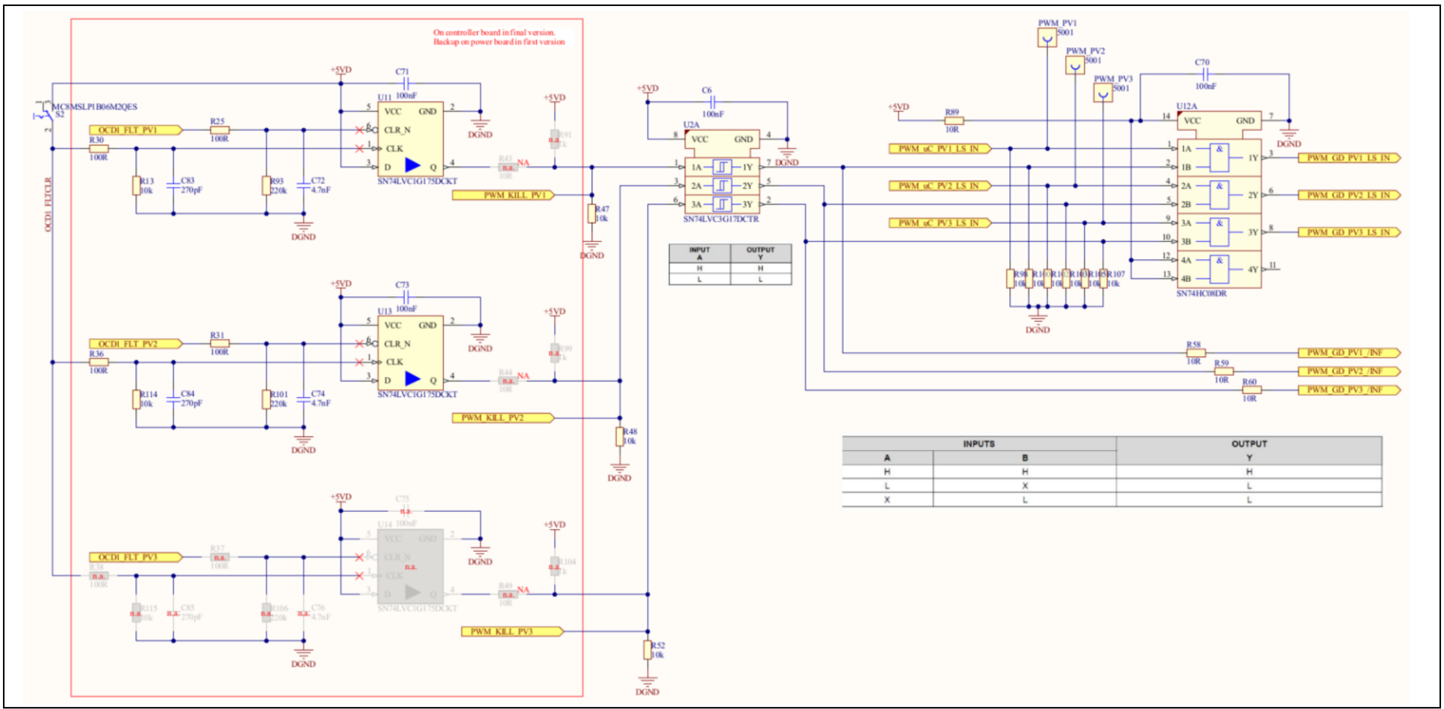


Figure 28 Fault and latch circuit

2.1.5 Fan control

Additional fan control circuits are also provided if you need to add fans to the design.

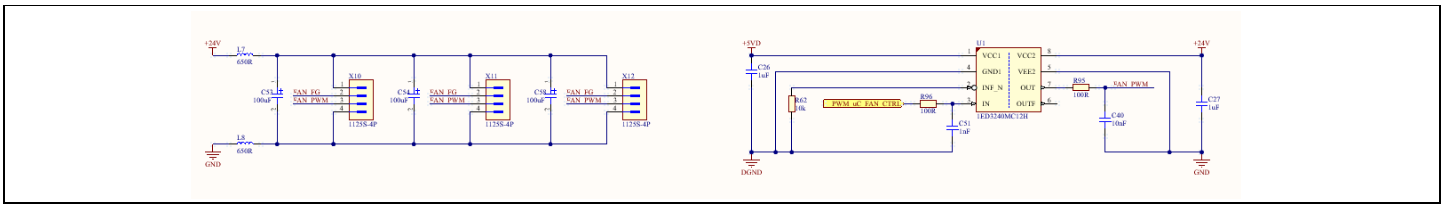


Figure 29 Fan control circuits

2.1.6 Connectors

2.1.6.1 Signal connectors

2.1.6.1.1 Input voltage sense interface

The input voltage measurement is located on the filter board and is transferred to the power board through connector X13. The signals are given below:

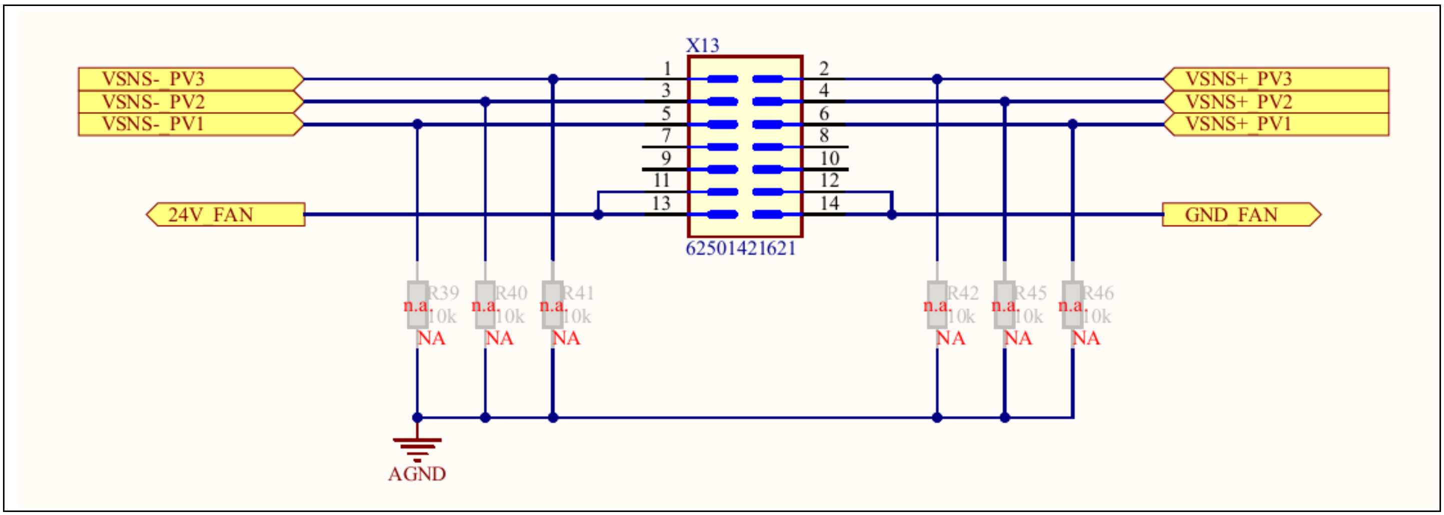


Figure 30 Input voltage sense interface

Note: The filter board must be connected to the power board before applying voltage on the input.

Table 5 Input voltage sense interface

Pin	Signal	Description
1	VSNS- PV3	PV3 voltage N
2	VSNS+ PV3	PV3 voltage P
3	VSNS- PV2	PV2 voltage N
4	VSNS+ PV2	PV2 voltage P
5	VSNS- PV1	PV1 voltage N
6	VSNS+ PV1	PV1 voltage P
7	NC	NC
8	NC	NC
9	NC	NC
10	NC	NC
11	24V FAN	24 V used to power up the fans on the filter board
12	GND FAN	24 V ground
13	24V FAN	24 V used to power up the fans on the filter board
14	GND FAN	24 V ground

2.1.6.1.2 Basic interface

The connector X16 contains all the signals that are needed to control the Photovoltaic boost. It can also be interfaced with the REF-CLBXMC7PEC kitkit which has the same connector under the name ‘Basic interface’. The signals of the basic interface are given below:

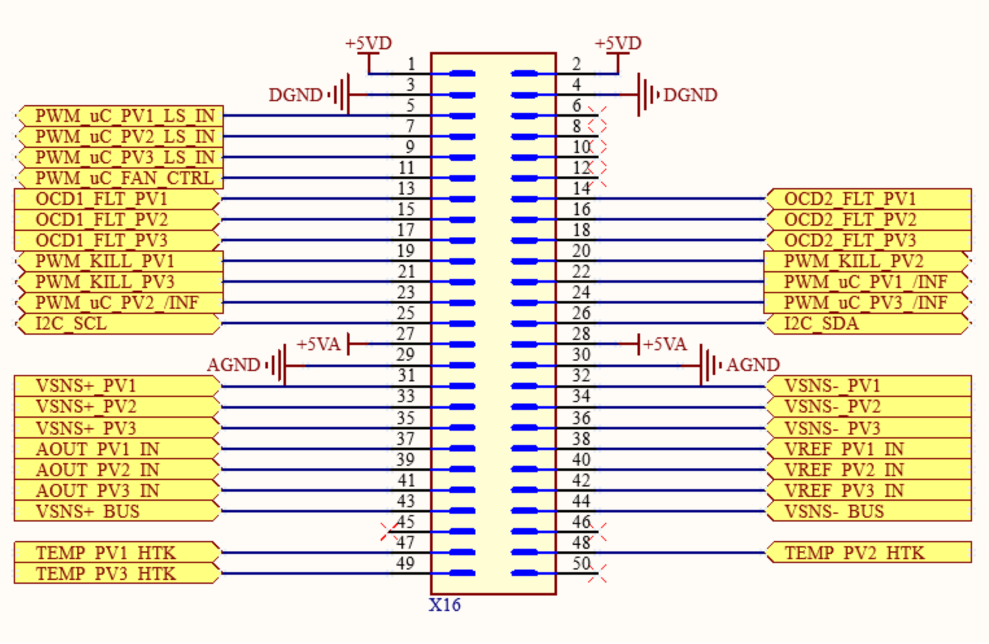


Figure 31 Basic control interface

Table 6 Basic interface signals

Pin	Signal	Description
1	+5VD	Digital power
2	+5VD	Digital power
3	DGND	Digital power
4	DGND	Digital power
5	PWM_uC_PV1_LS_IN	PV 1 PWM
6	NC	NC
7	PWM_uC_PV2_LS_IN	PV 2 PWM
8	NC	NC
9	PWM_uC_PV3_LS_IN	PV 3 PWM
10	NC	NC
11	PWM_uC_FAN_CTRL	PV fan control
12	NC	
13	OCD1_FLT_PV1	PV1 current sensor ODC1
14	OCD2_FLT_PV1	PV1 current sensor ODC2
15	OCD1_FLT_PV2	PV2 current sensor ODC1
16	OCD2_FLT_PV2	PV2 current sensor ODC2
17	OCD1_FLT_PV3	PV3 current sensor ODC1
18	OCD2_FLT_PV3	PV3 current sensor ODC2
19	PWM_KILL_PV1	PV 1 PWM Kill
20	PWM_KILL_PV2	PV 2 PWM Kill
21	PWM_KILL_PV3	PV 3 PWM Kill

Pin	Signal	Description
22	PWM_uC_PV1_/INF	PV1 gate driver control
23	PWM_uC_PV2_/INF	PV2 gate driver control
24	PWM_uC_PV3_/INF	PV3 gate driver control
25	I2C_SCL	Gate driver config (If required)
26	I2C_SDA	Gate driver config (If required)
27	+5 VA	Analog power
28	+5 VA	Analog power
29	AGND	Analog power
30	AGND	Analog power
31	VSNS+_PV1	PV1 voltage P
32	VSNS-_PV1	PV1 voltage N
33	VSNS+_PV2	PV2 voltage P
34	VSNS-_PV2	PV2 voltage N
35	VSNS+_PV3	PV3 voltage P
36	VSNS-_PV3	PV3 voltage N
37	AOUT PV1 IN	PV1 current P
38	VREF PV1 IN	PV1 current N
39	AOUT PV2 IN	PV2 current P
40	VREF PV2 IN	PV2 current N
41	AOUT PV3 IN	PV3 current P
42	VREF PV3 IN	PV3 current N
43	VSNS+ BUS	Bus voltage P
44	VSNS- BUS	Bus voltage N
45	NC	NC
46	NC	NC
47	TEMP PV1 HTK	PV1 temperature
48	TEMP PV2 HTK	PV2 temperature
49	TEMP PV3 HTK	PV3 temperature
50	NC	NC

3 Testing

The testing of the 9 kW boost converter was done using the REF-CLBXMC7PEC XMC7200-based power control board reference design that can be purchased separately. It was operated in an open loop and tested using a resistive load.

3.1 Flashing the firmware

1. Connect 24 V to the control board
2. Add three jumper headers as shown in Figure 32
3. Connect the debug port of the control board to a PC using a USB cable

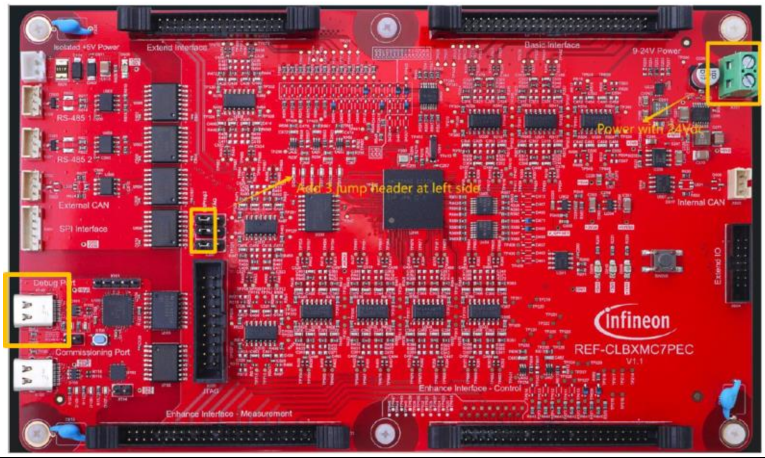


Figure 32 REF–CLBXMC7PEC debug configuration

4. Install ModusToolbox™ software
5. Start the GUI

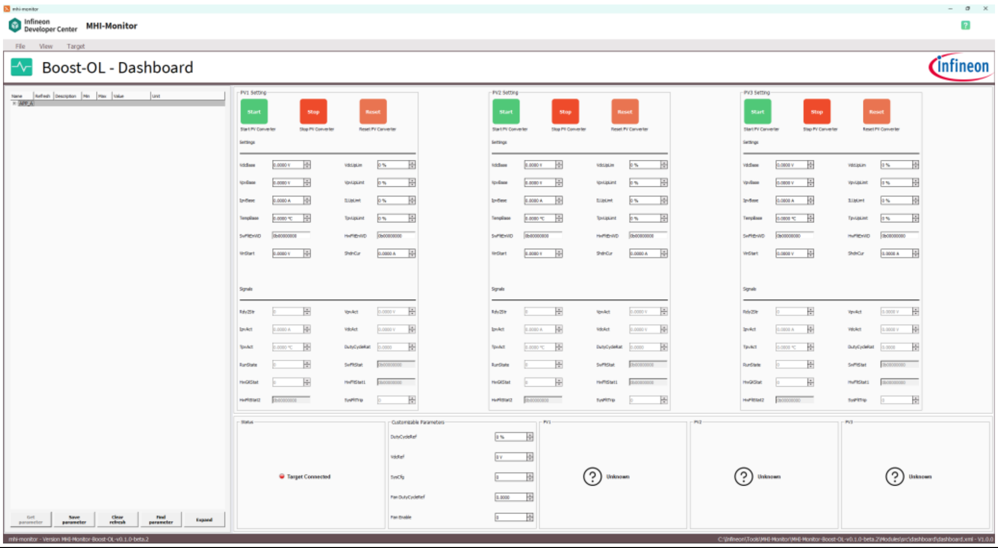


Figure 33 GUI

6. Click **Flash Firmware to Target** and wait until to tool flashes the firmware to the target. You will be notified after the operation is done. Note that this operation needs to be done only once

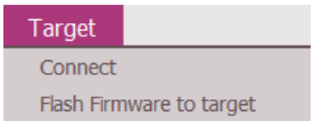


Figure 34 Flashing the firmware

7. Click **Connect**, and then click **Connect to Server**
8. Choose the COM port (defined in Device Manager) and then click **Connect and Close**

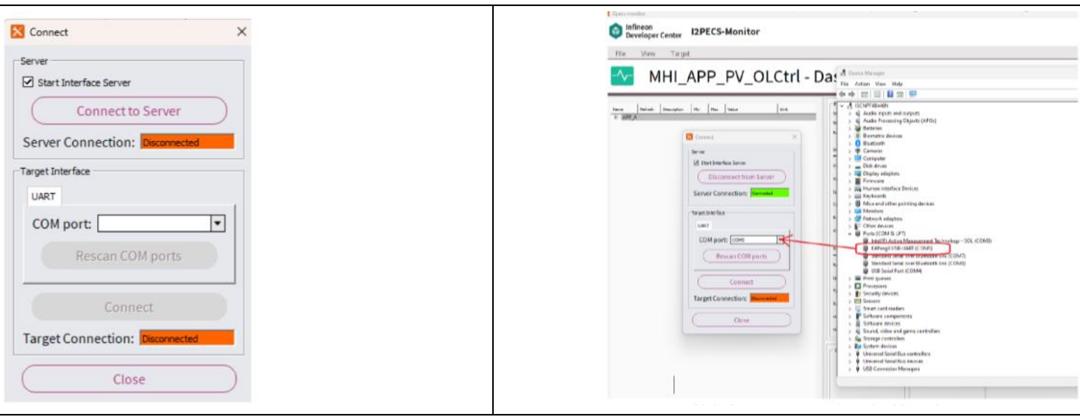


Figure 35 Connecting to target

9. Disconnect the external 24 V power supply

3.2 Control

The firmware allows you to control the channels independently or together. The firmware gives flexibility over the duty cycle, fan enablement, and software protection thresholds.

3.3 GUI

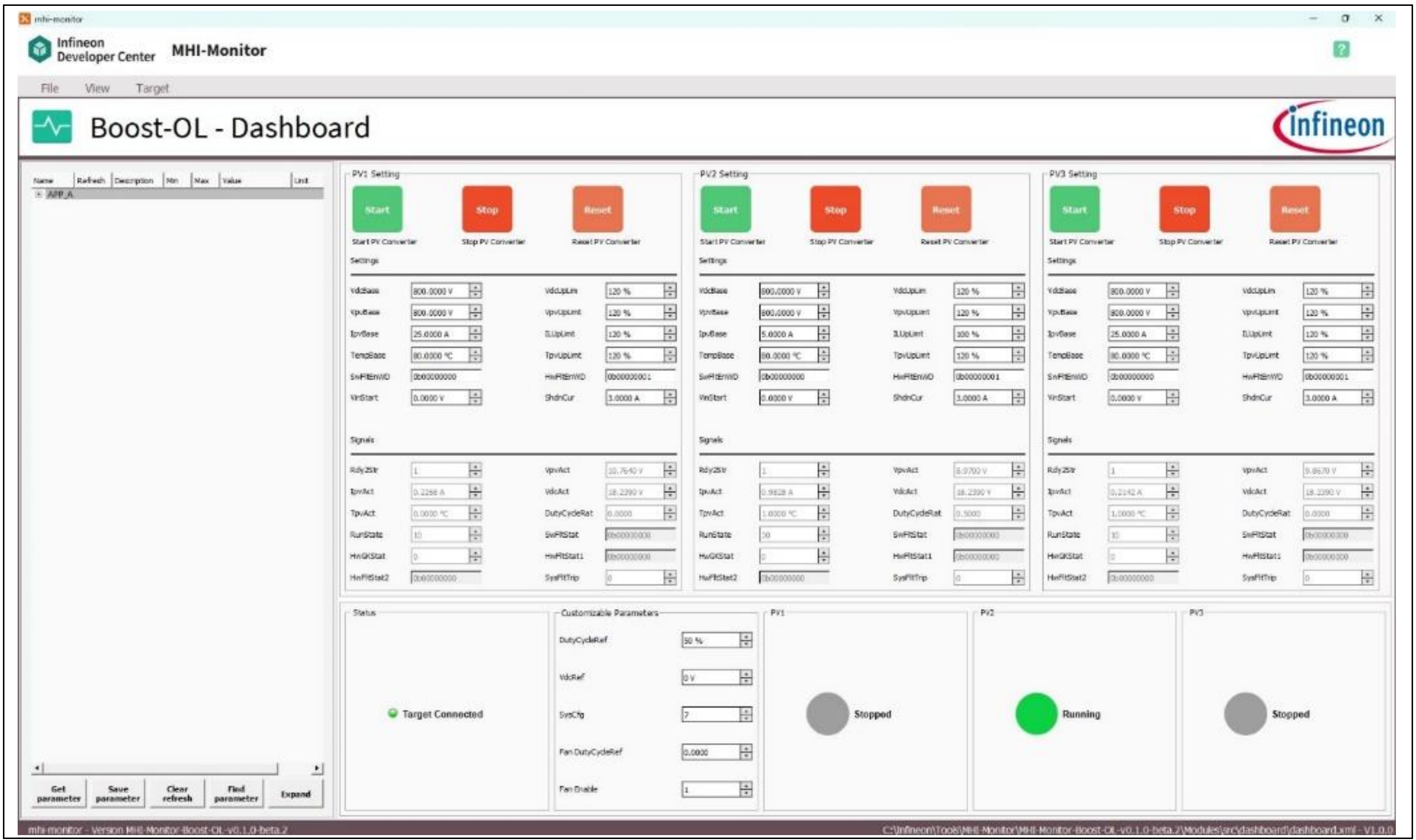


Figure 36 Boost GUI

The GUI has some sections that have different functionalities:

1. Start, stop, and reset:
   Use this part to start and the individual channels. Use the reset button after a fault is cleared. At the beginning of the evaluation, you must click **Reset**.

Figure 37 Control section

2. Converter status:
   This section shows the current status of the individual channels.

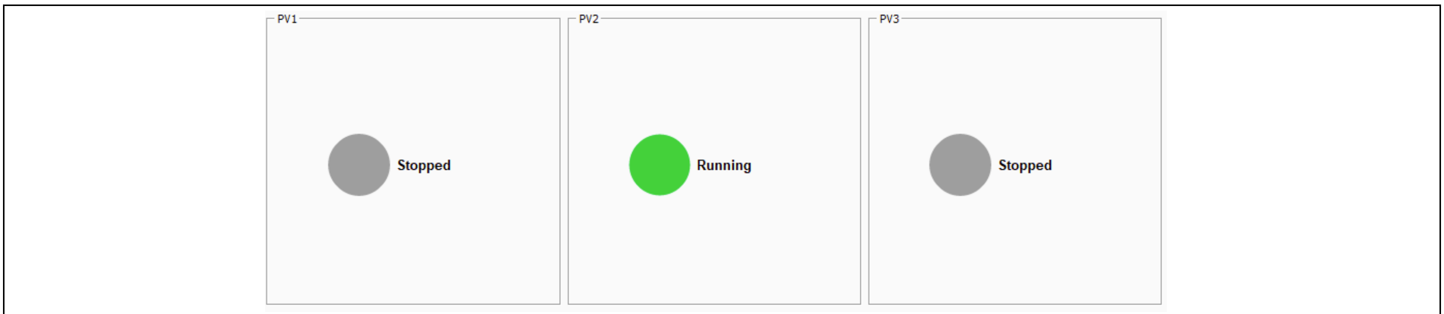


Figure 38 Status section

3. Customizable parameters:
   Use this section to set the parameters of the individual channels including the duty cycle and fan enablement. Both duty cycle and vdcRef (reference output voltage) can be used to control the duty cycle. When using one parameter, the other parameter must be set to zero.

The parameter SysCfg can have four values:

- SysCfg = 1: Changes only apply to channel 1
- SysCfg = 2: Changes only apply to channel 2
- SysCfg = 4: Changes only apply to channel 3
- SysCfg = 7: Changes only apply to the 3 channels

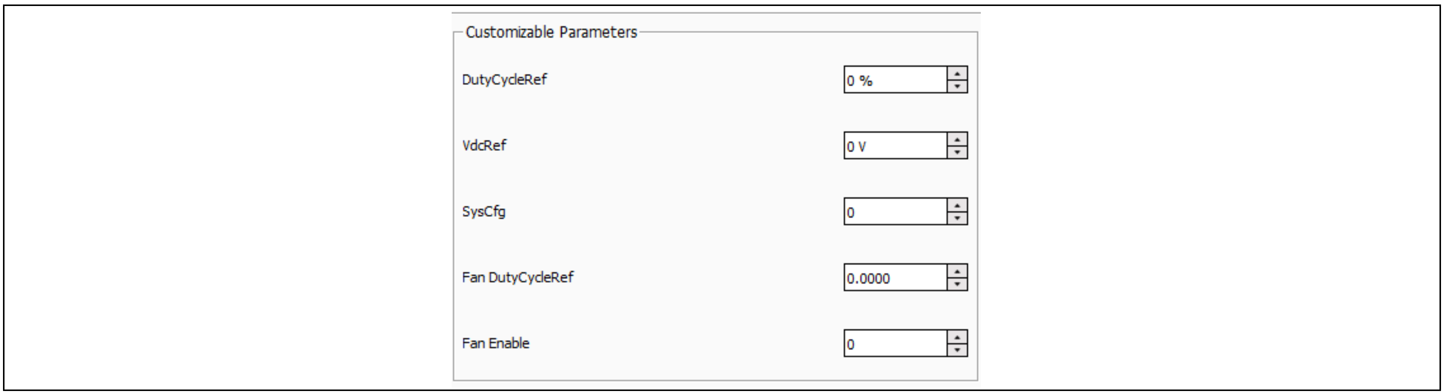


Figure 39 Customizable parameters

4. Protection thresholds:
   Use this section to set the software protection thresholds for the individual channels.

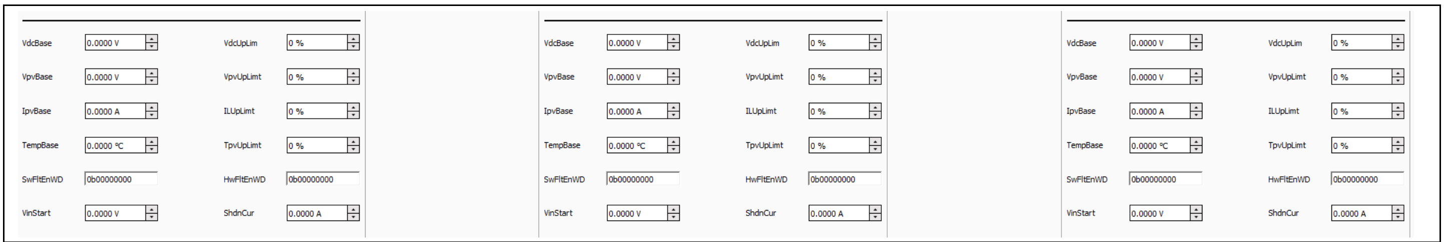


Figure 40 Protection thresholds

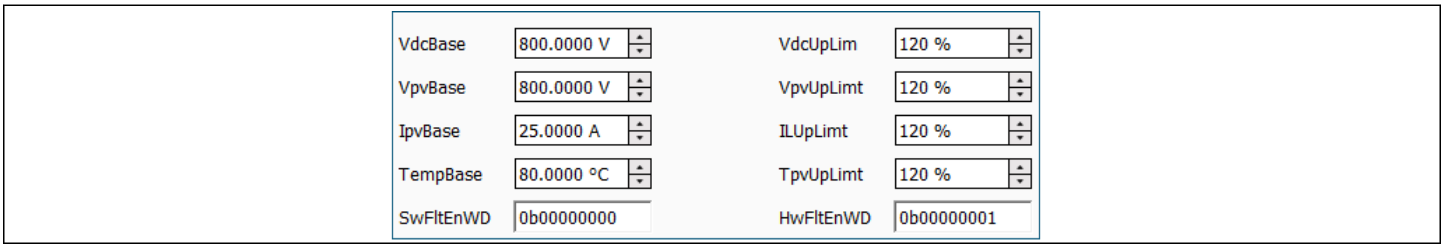


Figure 41 Protection thresholds used during testing

Table 7 GUI parameters

No.	Name	Min.	Max.	Step	Unit	Description	Comment
Settings (setpoints)							
1	Start	N/A	N/A	N/A	N/A	Start the converter	
2	Stop	N/A	N/A	N/A	N/A	Stop the converter	
3	Reset	N/A	N/A	N/A	N/A	Reset faults	
4	VdcBase	1	1100	0.0001	V	The base value of the output voltage of the converter	
5	VpvBase	1	1100	0.0001	V	The base value of the input voltage of the converter	
6	IpvBase	1	100	0.0001	A	The base value of the current	
7	TempBase	1	150	0.0001	℃	The base value of the temperature of NTC	
8	VdcUplimt	0	120	1	%	Vdc OV threshold (%) based on VdcBase	
9	VpvUplimt	0	120	1	%	Vpv OV threshold (%) based on VpvBase	
10	IpvUplimt	0	120	1	%	Ipv OC threshold (%) based on IpvBase	
11	TempUplimt	0	120	1	%	IGBT OT threshold (%) based on TempBase	
12	SwFltEnWD	N/A	N/A	N/A	N/A	Software fault enable Bit0: Vdc_OV Bit1: Tpv_OT Bit2: Vpv_OV Bit3: Ipv_OC Bit4~Bit7: Rsd	
13	HwFltEnWD	N/A	N/A	N/A	N/A	Hardware fault enable Bit0: PV_OC2 Bit1~Bit7: Rsd	
14	VinStart	0	500	0.0001	V	Start voltage of the PV converter	If Vin is more than this value, the converter can start
15	ShdnCur	0	10	0.0001	A	Shut down current	When you stop the converter: • If the current is more than the value of ShdnCur, the converter will switch to ShutDown state to reduce the current. • If the current is less than the value of ShdnCur, the converter will disable PWM and switch to Stopped state.

No.	Name	Min.	Max.	Step	Unit	Description	Comment
16	Rdy2Str	0	1	N/A	N/A	Converter is ready for start	
Signals (actual value)							
1	VpvAct	0	1500	N/A	V	Input voltage display value	
2	VdcAct	0	1500	N/A	V	Output voltage display value	
3	IpvAct	0	500	N/A	A	Average current value of inductance	
4	TpvAct	0	200	N/A	°C	The temperature of the MOSFET	Only positive temperature values are displayed
5	DutyCyclRat	0	1	N/A	N/A	The output duty cycle	
6	RunState	N/A	N/A	N/A	N/A	The states of the converter 10: Stopped State 30: Running State 50: Shut Down State 70: Fault State	
7	SwFltStat	N/A	N/A	N/A	N/A	Software fault state 1: fault; 0: normal Bit0: Vdc_OV Bit1: Tpv_OT Bit2: Vpv_OV Bit3: Ipv_OC Bit4~Bit7: Rsd	This hardware fault can be enabled /disabled by the parameter: SwFltEnWD.
8	HwGKStat	N/A	N/A	N/A	N/A	Gate kill fault state 1: fault; 0: normal	No
9	HwFltStat1	N/A	N/A	N/A	N/A	Hardware fault state 1: fault; 0: normal Bit0: PV_OC1 Bit1: PV_OV Bit2: Vdc_OV Bit3~Bit7: Rsd	This fault signal comes from the gate kill pin of the MCU which cannot be disabled
10	HwFltStat2	N/A	N/A	N/A	N/A	Hardware fault state 1: fault; 0: normal Bit0: PV_OC2 Bit1~Bit7: Rsd	This hardware fault can be enabled/disabled by the HwFltEnWD parameter
11	SysFltTrip	0	1	N/A	N/A	Fault Flag 1: fault; 0: normal	In the case of a hardware fault or a software fault, the parameter will be set to 1
Customization parameters (setpoints)							

No.	Name	Min.	Max.	Step	Unit	Description	Comment
1	DutyCycleRef	0	100	0.0001		Reference value of duty cycle (%)	If the input signal of DutycycleRef is not equal to zero, the duty cycle reference (DutycycleRef) becomes the input command If the input signal of DutycycleRef is equal to zero, VoutRef is not equal to zero, the duty cycle reference (VoutRef) becomes the input command
2	VdcRef	0	1100	0.0001	V	Reference value of output voltage	
3	SysCfg	0	7	N/A	N/A	Hardware Configuration word Bit 0=1: PV1 is active Bit 1=1: PV2 is active Bit 2=1: PV3 is active Bit 3~Bit 7: Rsd	From master control to define which channel is active
4	Fan DutyCycleRef	0	1	0.0001	N/A	Reference value for Fan duty cycle	No
5	Fan Enable	0	1	N/A	N/A	Enable/disenable word for fan control 1: enable 0: disable	No

3.3.1.1 Establish connection between PC and control board

1. Make sure that the boost board and the control board are connected as shown in the upcoming Bench setup section. The signal cables from the power board provide the control board with power. Do not connect an external power supply to the control board
2. Connect the 24 V supply to the power board

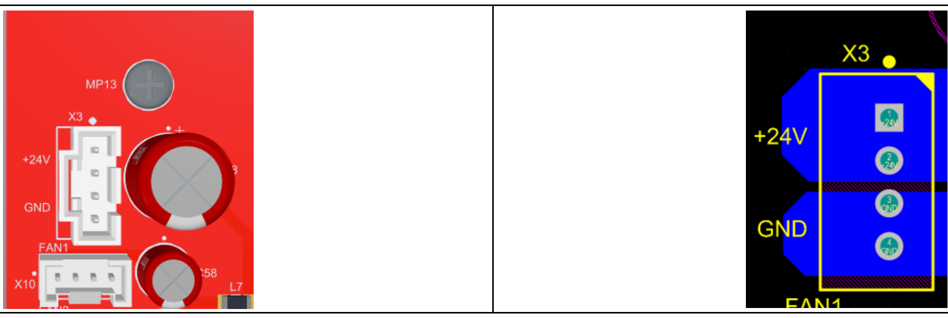


Figure 42 24 V connector

3. In the COM port setting in the GUI, choose the COM port the control board is connected to. You can determine the COM port in Windows Device Manager
4. Click **Open COM.** If the settings in the Measurement section are correct, the GUI starts displaying the values
5. After the bench setup is set, click **Start** to start evaluating the hardware

3.4 Open-loop test results

3.4.1 Bench setup

The converter is operated in open-loop mode. Exercise caution to avoid accidently operating the converter outside the voltages, currents, and frequencies specified. The inverter was tested only for the specifications shown in Table 2 with a resistive load. If you operate the board outside these specifications, performance is not guaranteed.

3.4.1.1 Equipment required for testing

- 9 kW boost kit
- REF-CLBXMC7PEC kit with the boost firmware
- GUI
- Resistive load
- DC power source

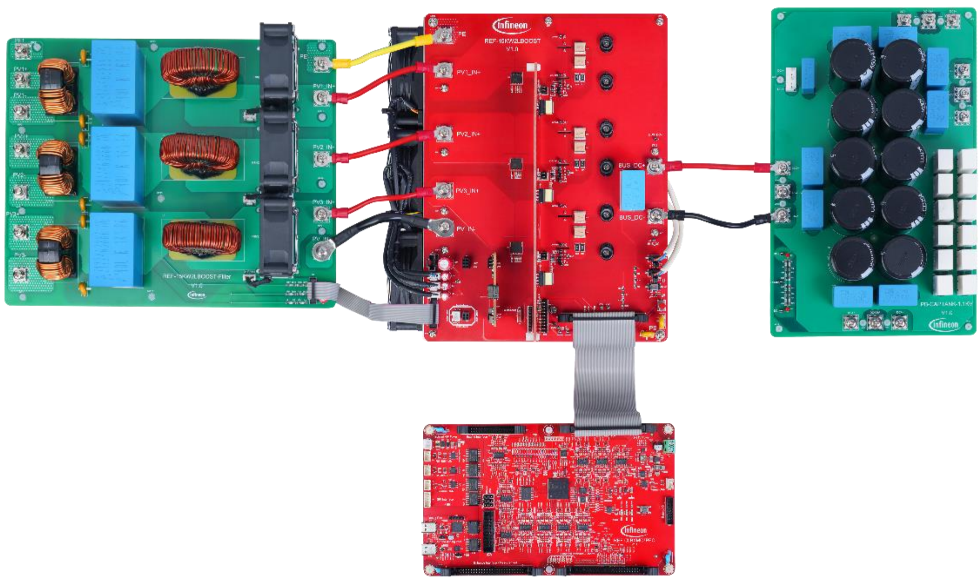


Figure 43 Test setup

3.5 Test Results

To evaluate the performance of REF-9KW2LBOOST kit, tests at different voltage and power ratings were conducted. Table 8 shows the test specification with high output voltage. Output waveforms are shown in Figure 44. **It is important to note that testing was done up to 3 kW and no higher output power setup was tested.**

Table 8 Test specification for High output voltage test

Input voltage	350 V
Output voltage	520 V
Frequency	24 kHz
Output power	1.65 kW
Legend	Ch1: Inductor current 1, Ch2: MOSFET V_{ds}, Ch3: Input voltage, Ch4: Output voltage

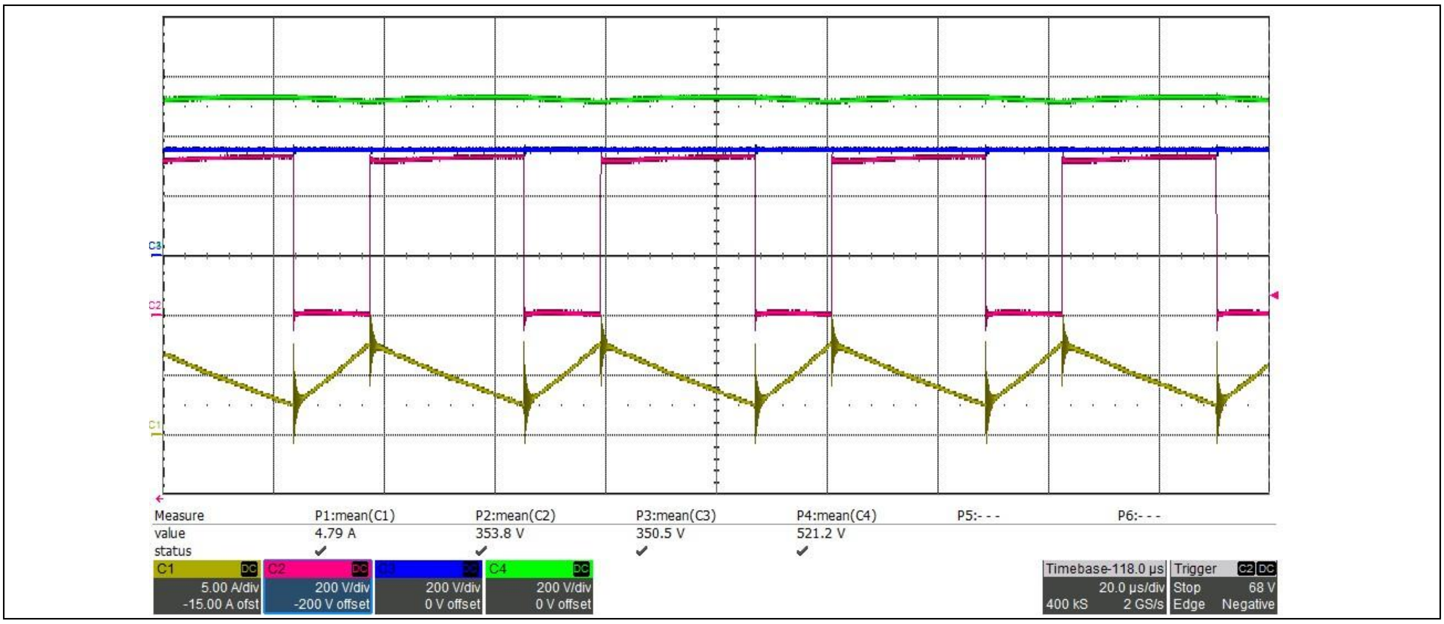


Figure 44 Ch1: Inductor current, Ch2: MOSFET V_{ds}, Ch3: Input voltage, Ch4: Output voltage

Table 9 shows the test specification that was conducted to monitor the gate to source voltage of the MOSFET. Output waveforms are shown in Figure 45.

Table 9 Test specification to evaluate MOSFET Gate voltage

TAB	350 V
Output voltage	505 V
Frequency	24 kHz
Output power	1.6 kW
Legend	Ch1: Inductor current, Ch2: MOSFET V_{gs}, Ch3: Output current, Ch4: Output voltage

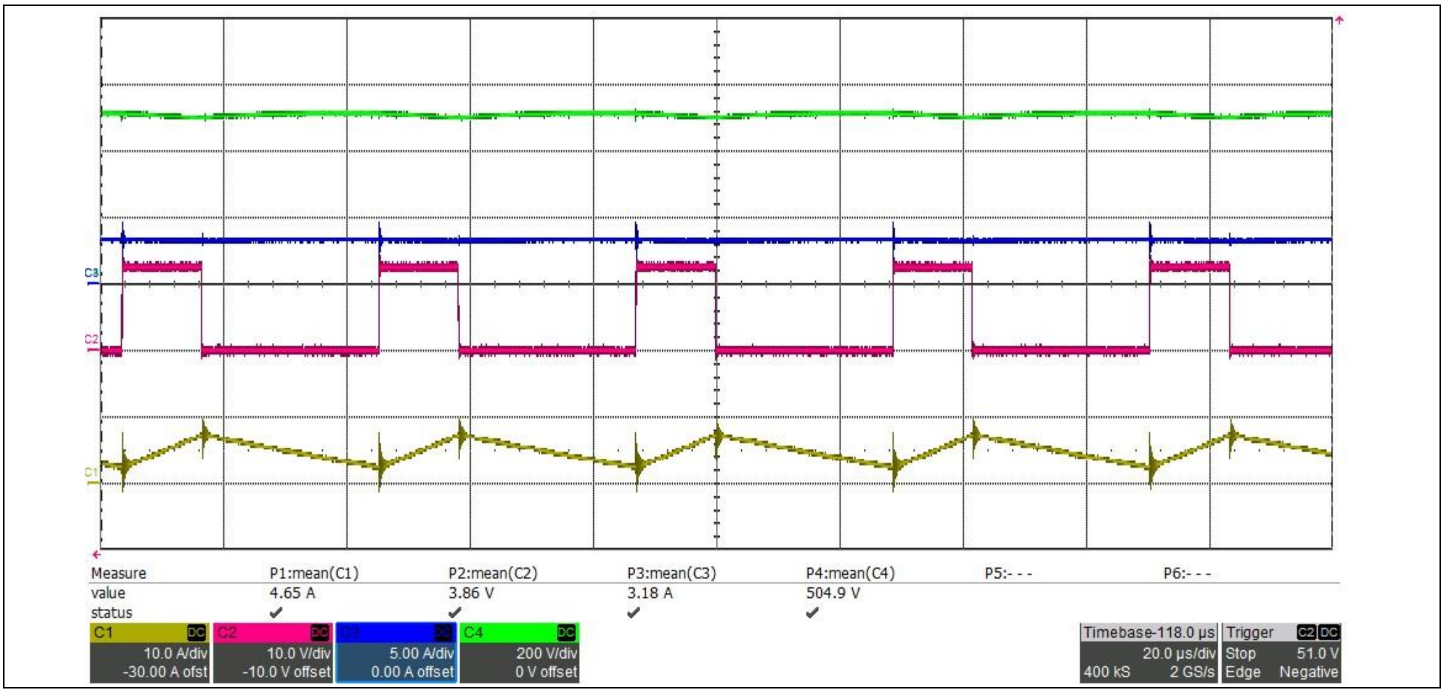


Figure 45 Ch1: Inductor current, Ch2: MOSFET V_{gs}, Ch3: Output current, Ch4: Output voltage

Table 10 shows the test specification with high power output. Output waveforms are shown in Figure 46. Both output current and voltage are monitored, which shows the power rating of approximately 3100 W.

Table 10 Test specification with high output power

Input voltage	290 V
Output voltage	318 V
Frequency	24 kHz
Output power	3.1 kW
Legend	Ch1: Inductor current, Ch2: MOSFET V_{ds}, Ch3: Output current, Ch4: Output voltage

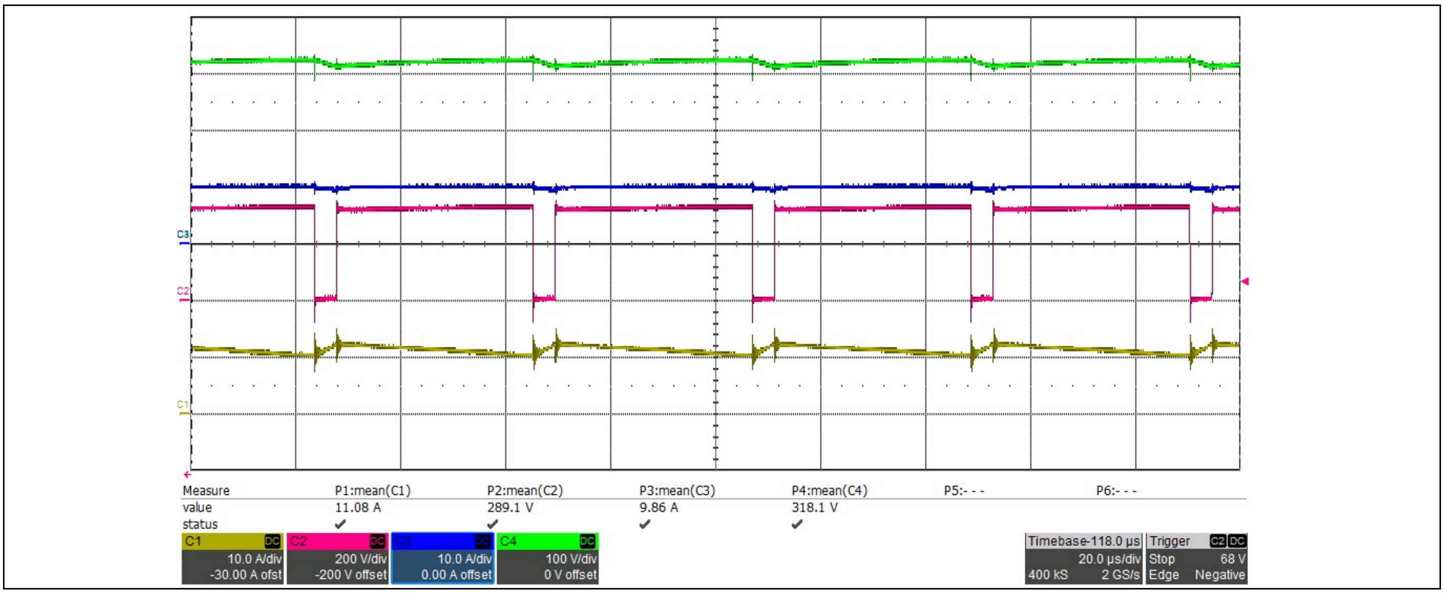


Figure 46 Ch1: Inductor current, Ch2: MOSFET V_{ds}, Ch3: Output current, Ch4: Output voltage

3.5.1 Inductor overcurrent protection

Table 11 Test specification

Specification	OCD1 programmed to 52 A
Input voltage	10 V
Duty cycle	0.9
Conclusion	Soft turn-off is activated when OCP occurs (due to the large duty cycle, soft turn-off can be easily triggered)
Legend	Ch2: Inductor current, Ch3: V_{gk}, Ch4: V_{ce}

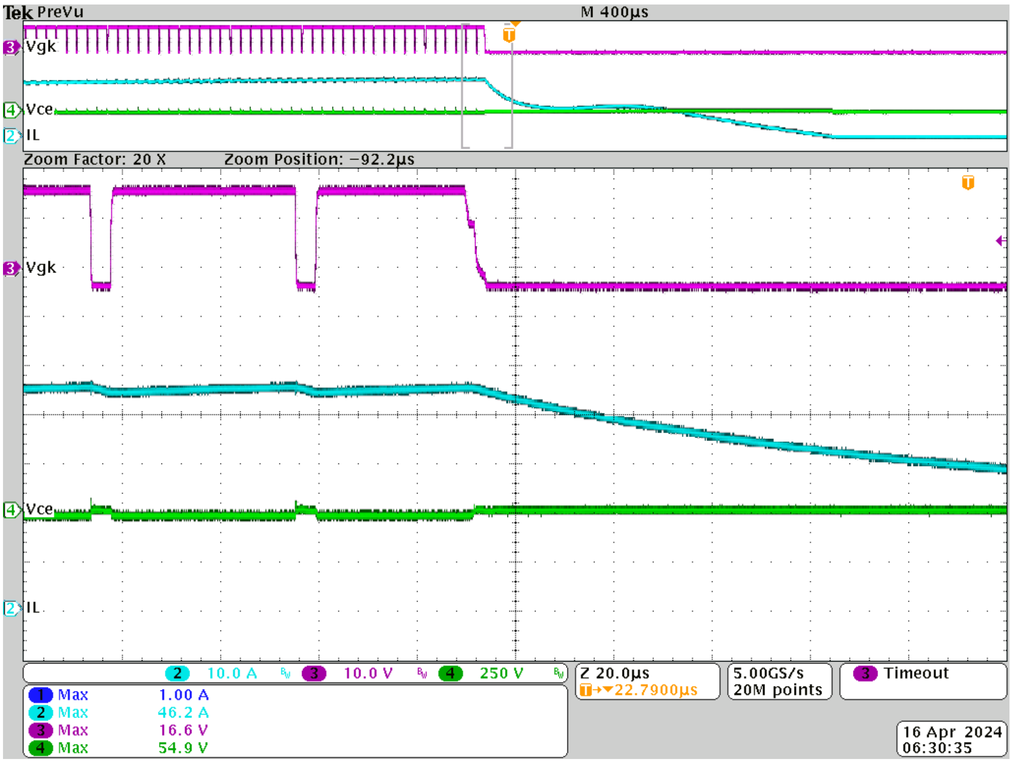


Figure 47 OCP protection triggers

3.5.2 Input overvoltage protection

Table 12 Test specification

Specification	Input OVP threshold is set to 883 V
Input voltage	890 V
Duty cycle	0.05
Output resistance	1000 V/5 A
Conclusion	OVP for channel 1: 875 V (due to the small duty cycle, soft turn-off may not be easily triggered)
Legend	Ch2: Inductor current, Ch3: V_{gk}, Ch4: V_{in}

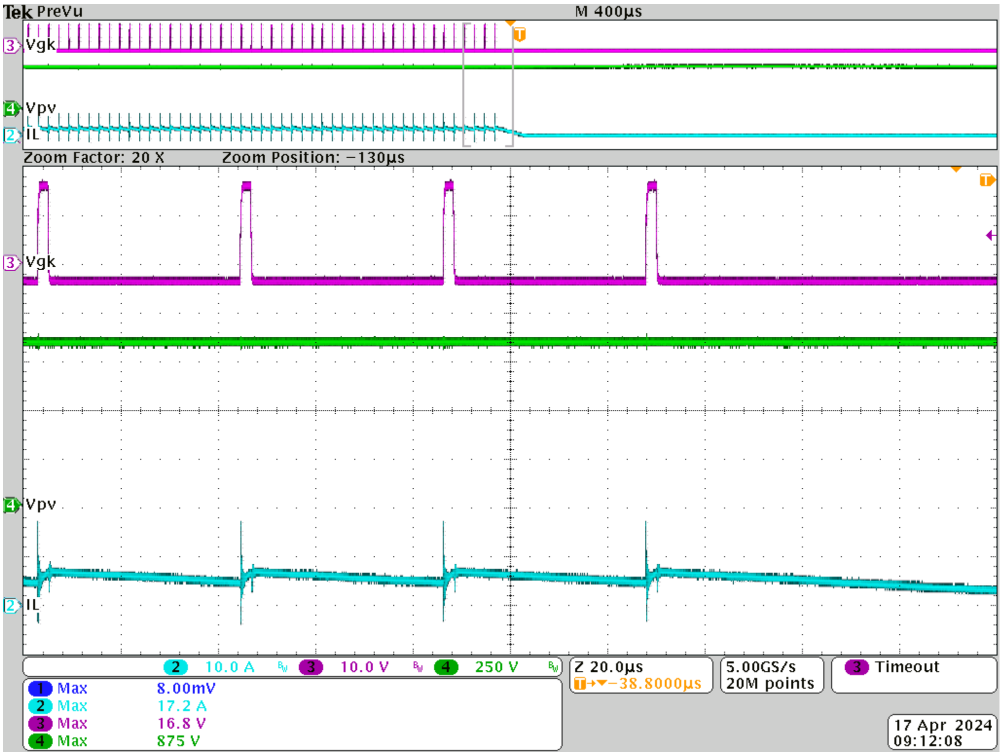


Figure 48 OVP triggers

3.6 DC-link overvoltage protection

Table 13 Test specification

Specification	DC-link OVP threshold is set to 992 V
Input voltage	890 V
Duty cycle	0.1
Output resistance	1000 V/5 A
Conclusion	OVP for channel 1: 985 V
Legend	Ch2: Inductor current, Ch3: V_{gk}, Ch4: $V_{DC\text{-}link}$

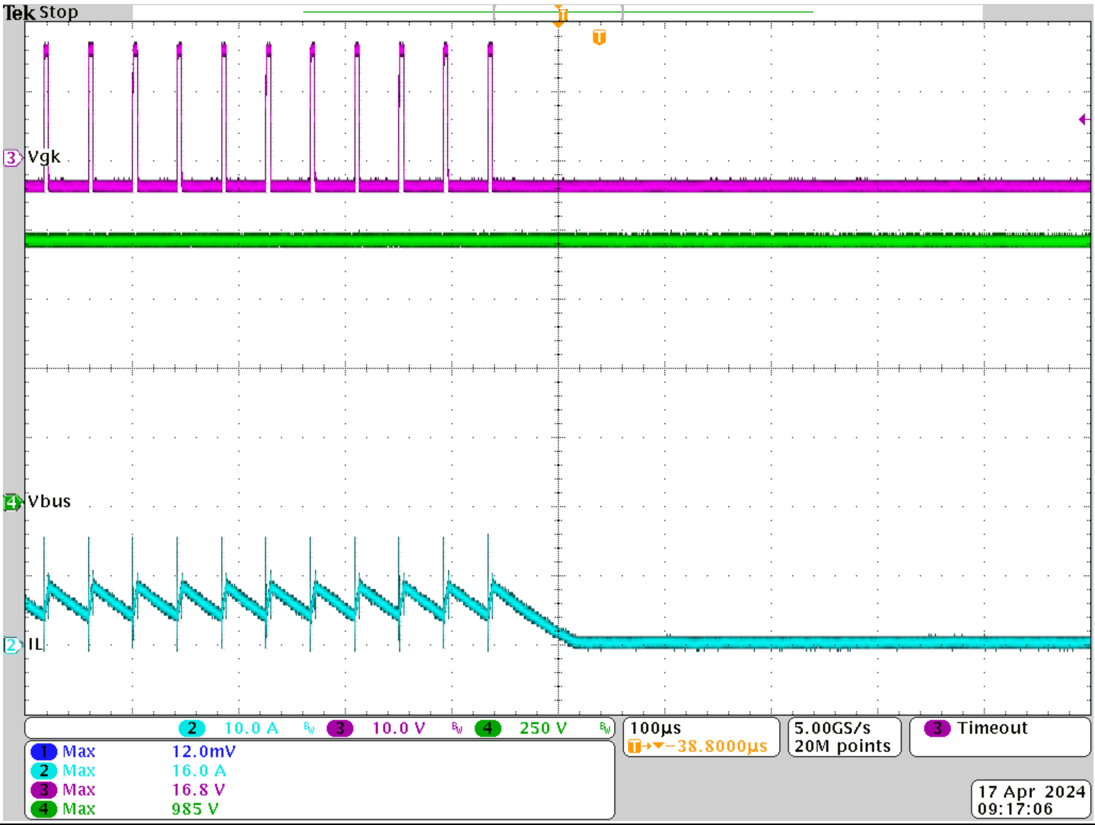


Figure 49 DC-link OVP triggers

3.6.1 Efficiency measurement

Table 14 Power semiconductors efficiency measurement

Specification	Efficiency measurement
Condition	Duty cycle = 0.3, V_o = 500 V, Vin = 350 V Measurements are taken after the boost inductor (Power semiconductor losses) for only one channel
Loading	**Efficiency**
1600 W	98.6%

3.6.2 24 V–5 V auxiliary power supply

Table 15 Test specification

Specification	Output voltage, ripple, and current measurement
Input voltage for Aux power supply	24 V
Input voltage	350 V
Output voltage	500 V
Output power	9 kW
Legend	Ch1: I_o, Ch2: V_o

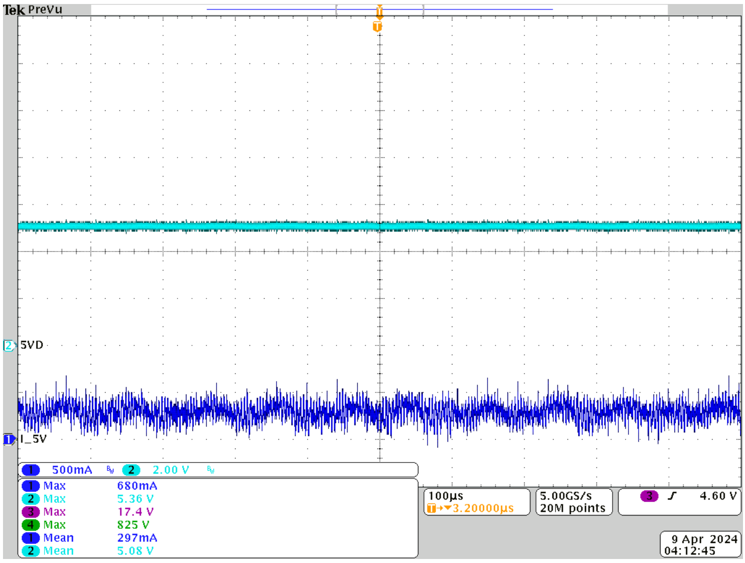


Figure 50 Output voltage and current of the auxiliary power supply

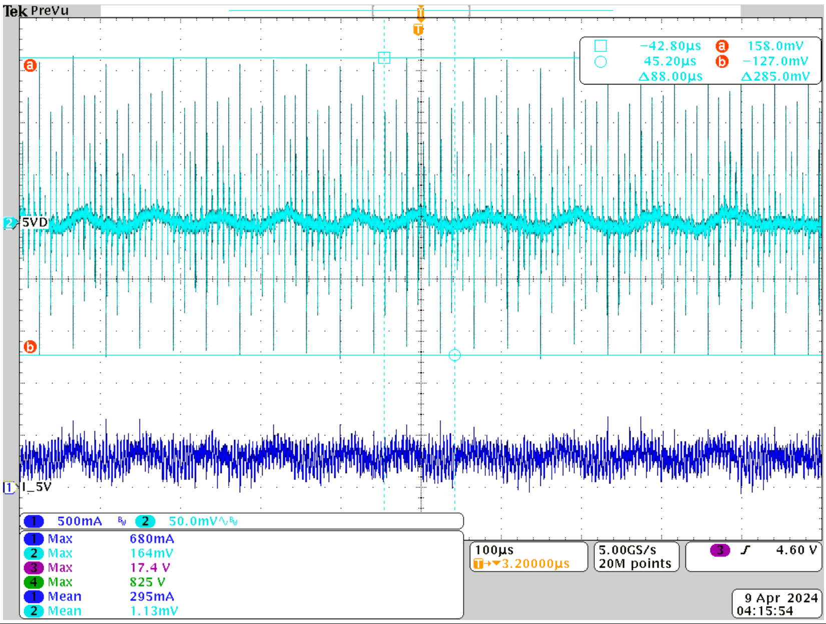


Figure 51 Voltage ripple and noise of the auxiliary power supply

4 Board layout

4.1 REF-9KW2LBOOST

Table 16 Mechanical data

Dimensions	260.01 mm x 190 mm
Number of layers	4
Copper thickness	70 µm
Weight	4.4 kg

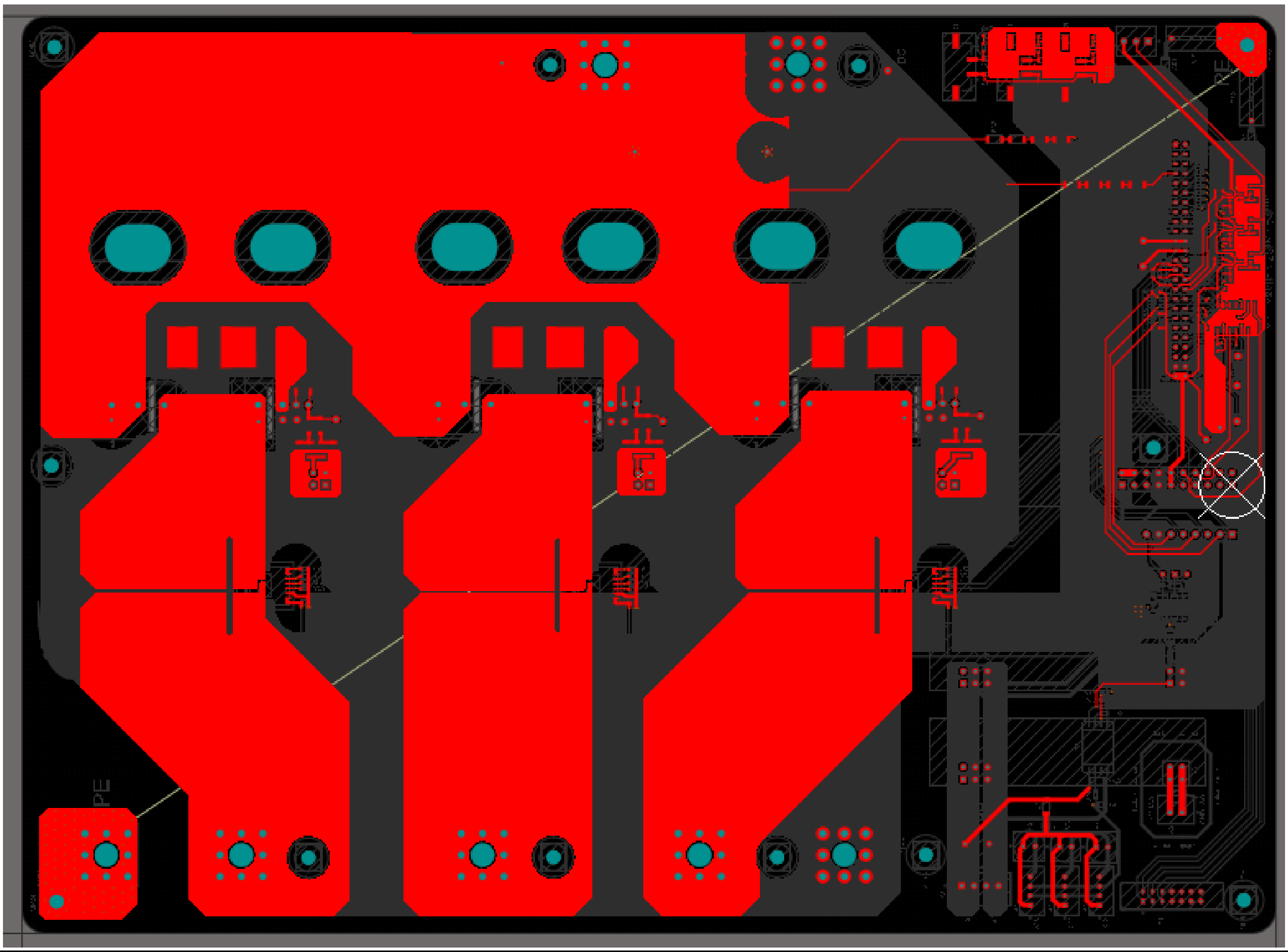


Figure 52 Layer 1

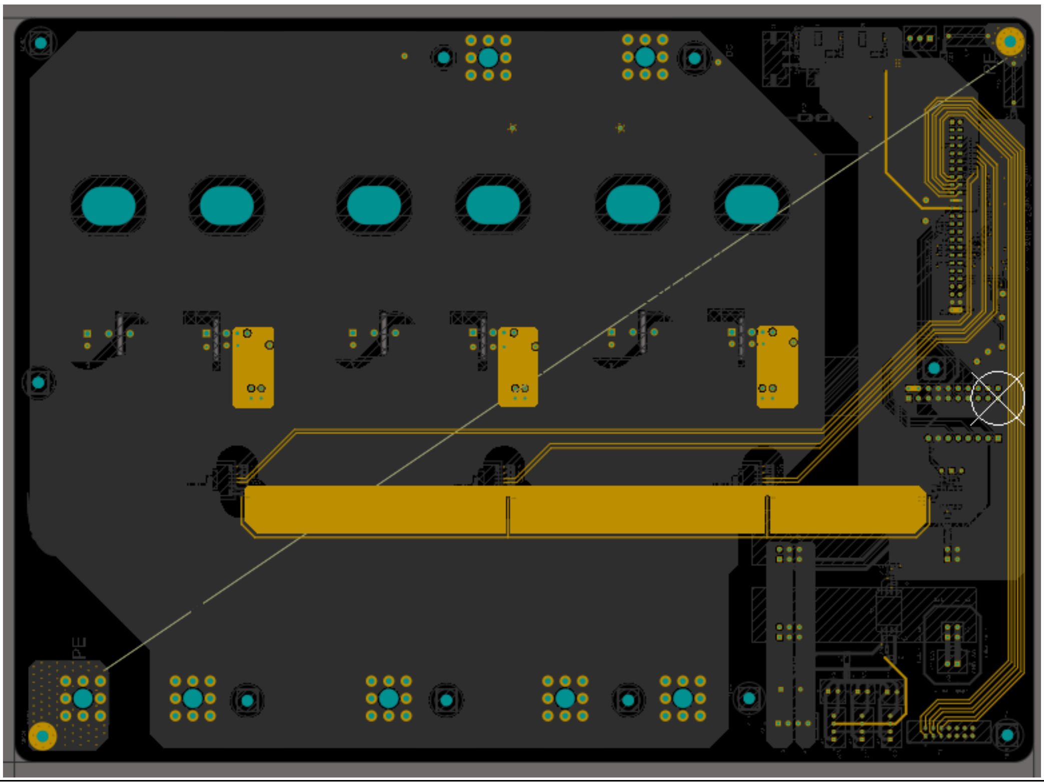


Figure 53 Layer 2

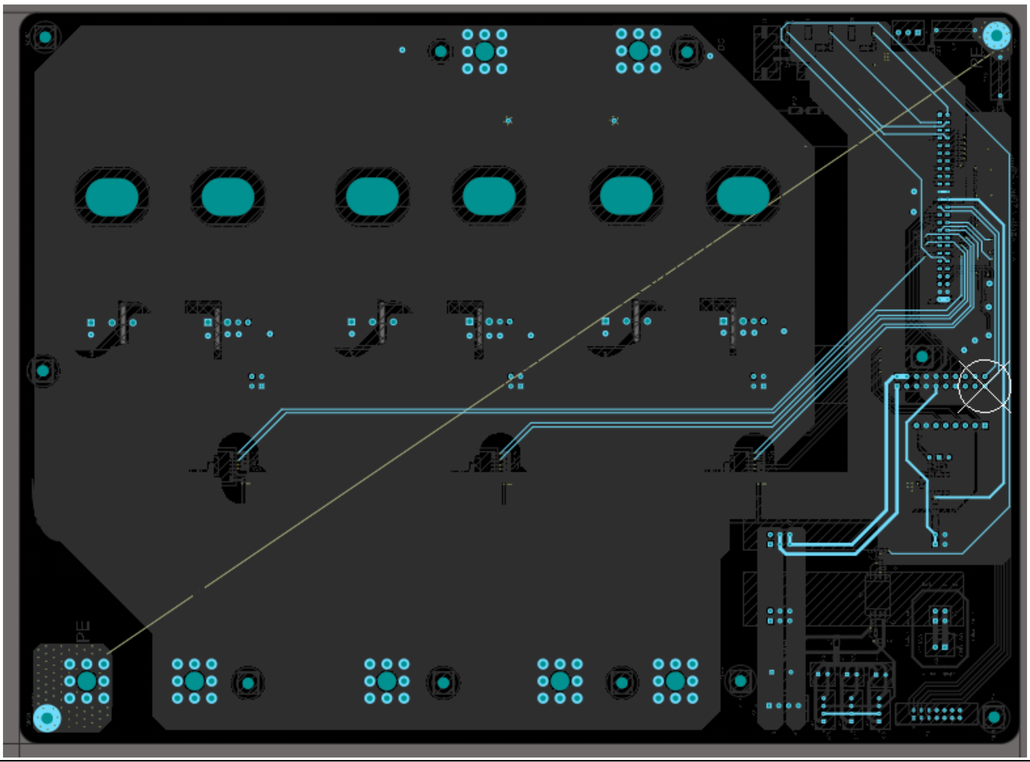


Figure 54 Layer 3

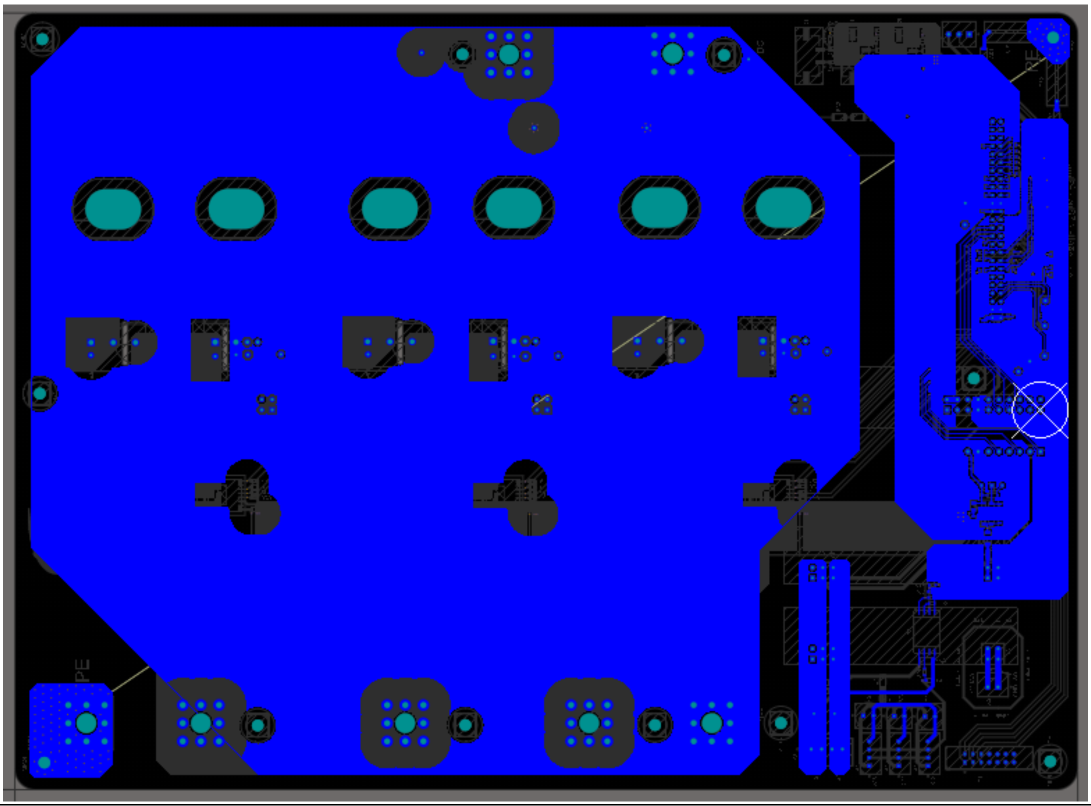


Figure 55 Layer 4

4.2 PB-GD-1EDB8275F-3CH

Table 17 Mechanical data

Dimensions	210 mm x 40 mm
Number of layers	2
Copper thickness	35 µm
Weight	45 g

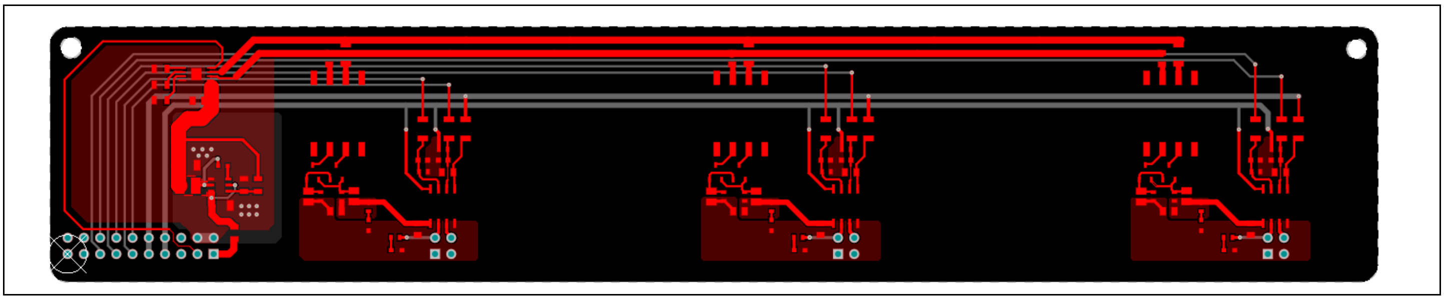


Figure 56 Layer 1

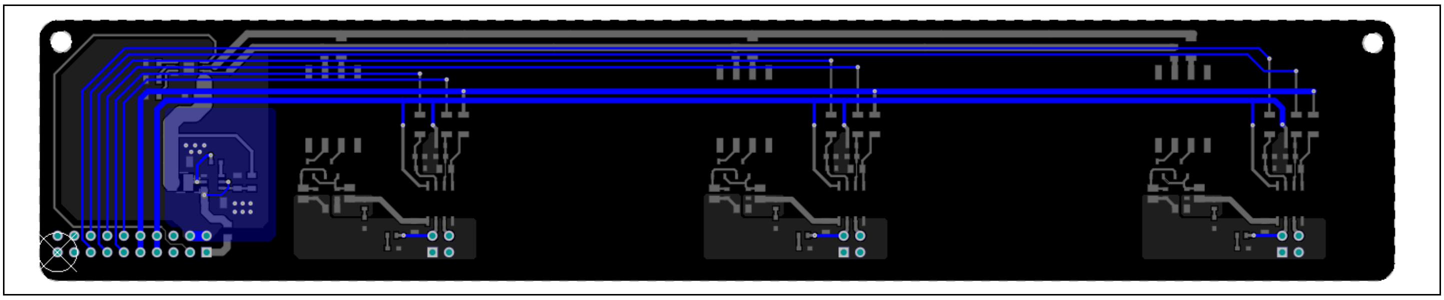


Figure 57 Layer 2

4.3 PB-APS-24V-5V ISO

Table 18 Mechanical data

Dimensions	57.1 mm x 27.1 mm
Number of layers	8
Copper thickness	105 µm

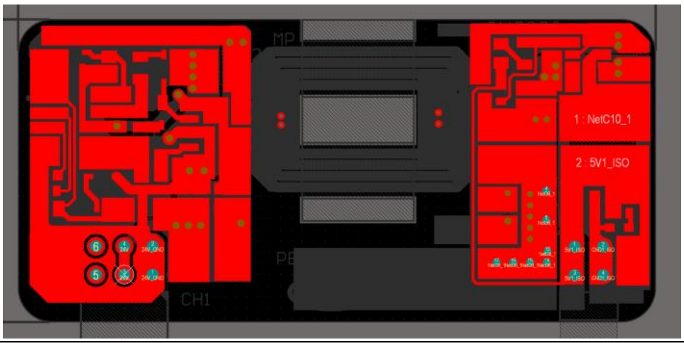


Figure 58 Layer 1

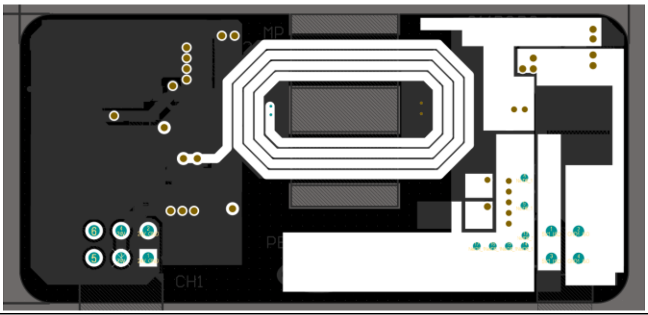


Figure 59 Layer 2

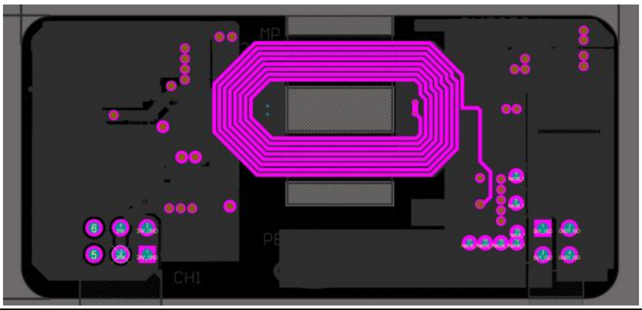


Figure 60 Layer 3

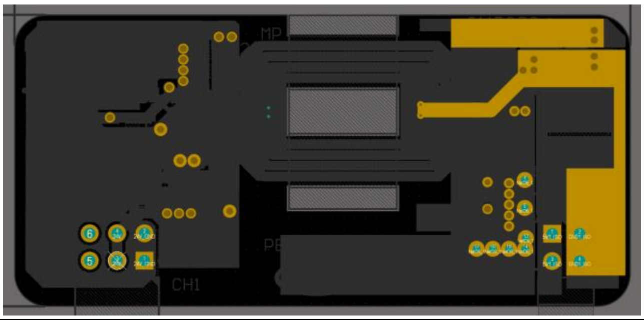


Figure 61 Layer 4

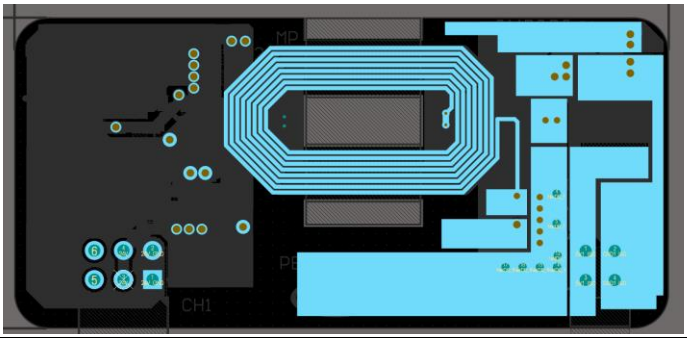


Figure 62 Layer 5

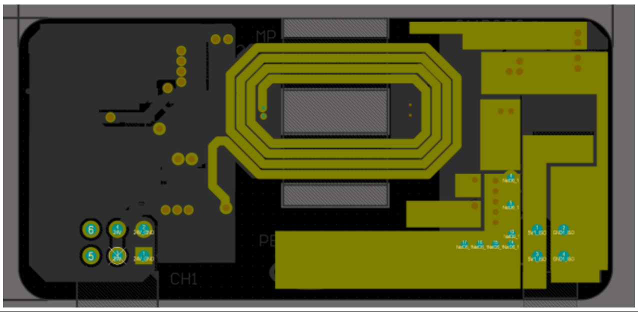


Figure 63 Layer 6

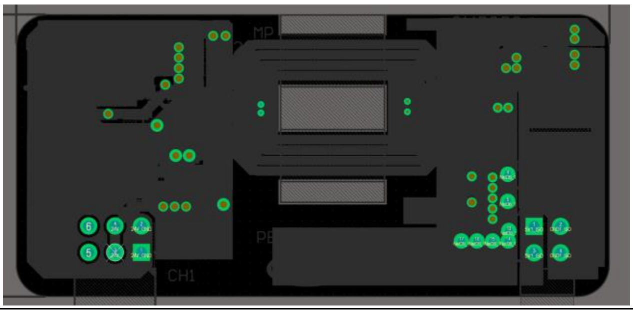


Figure 64 Layer 7

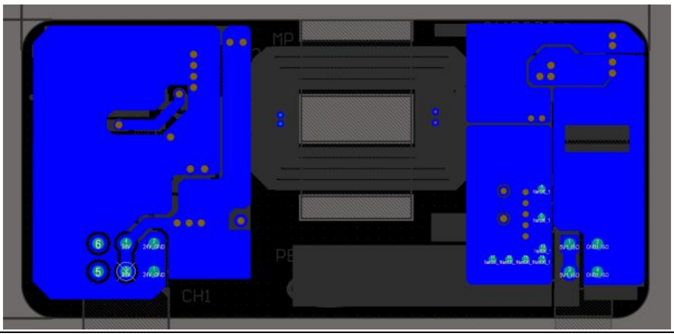


Figure 65 Layer 8

4.4 REF-9KW2LBOOST-Filter

Table 19 Mechanical data

Dimensions	230 mm x 220 mm
Number of layers	4
Copper thickness	35 µm
Weight	2.5 kg

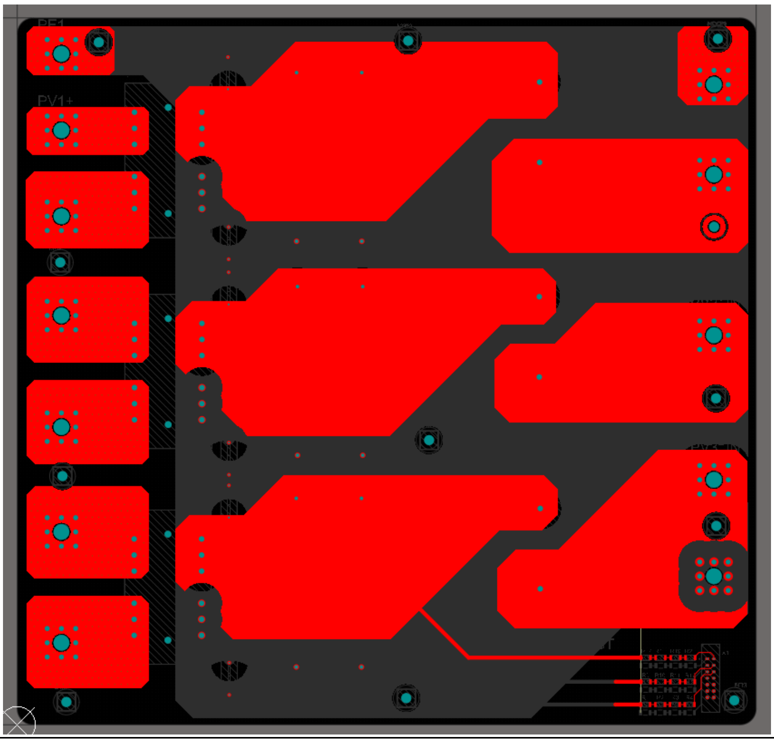


Figure 66 Layer 1

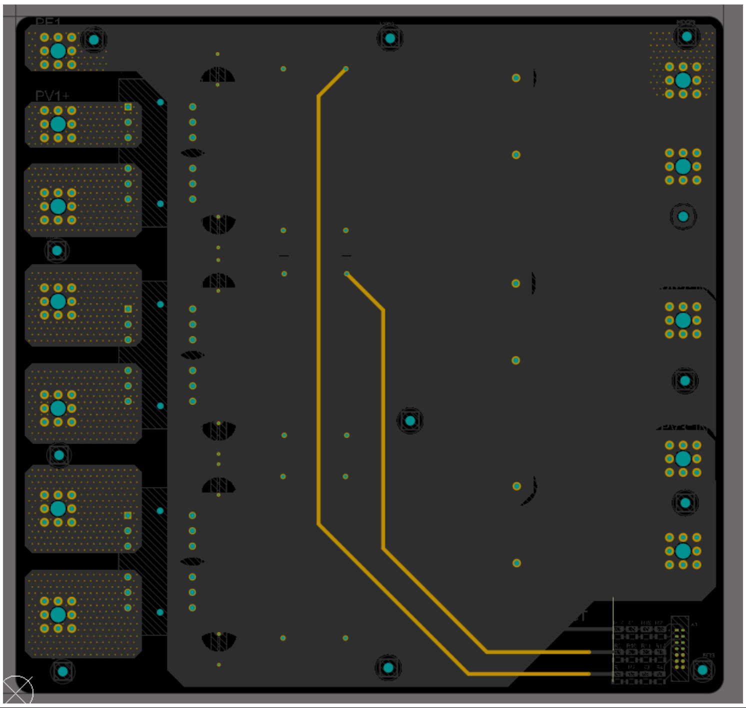


Figure 67 Layer 2

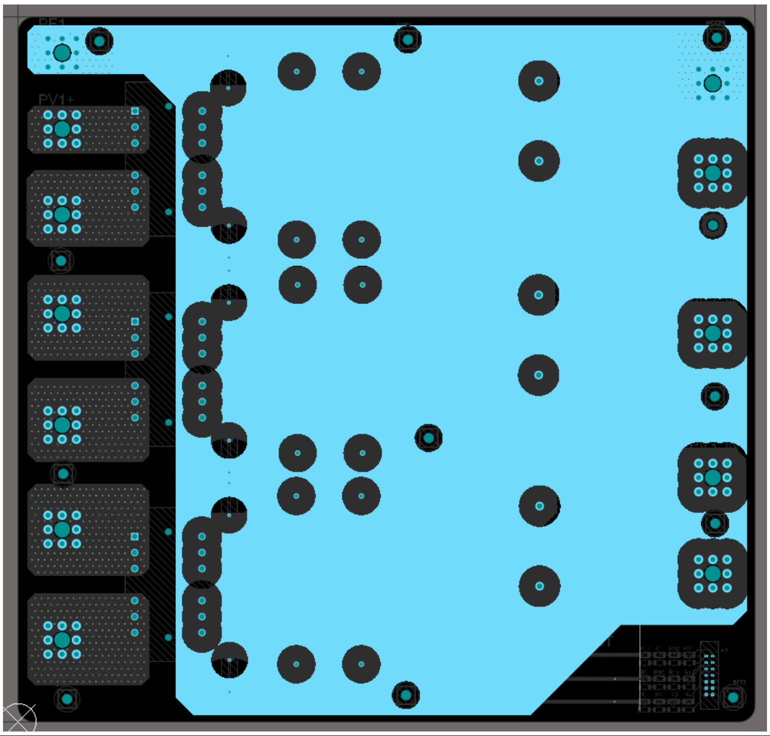


Figure 68 Layer 3

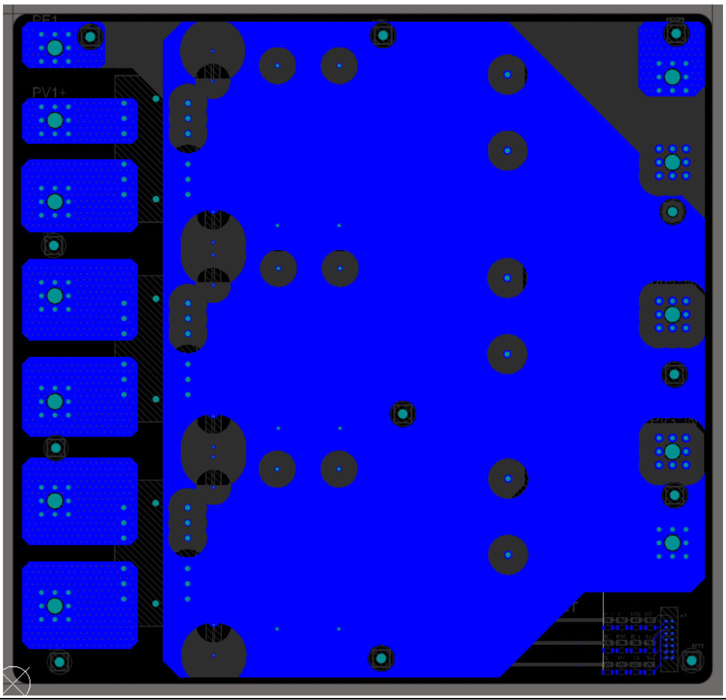


Figure 69 Layer 4

4.5 PB-CAPTANK-1.1KV

Table 20 Mechanical data

Dimensions	280 mm x 170 mm
Number of layers	4
Copper thickness	35 µm
Weight	1.7 kg

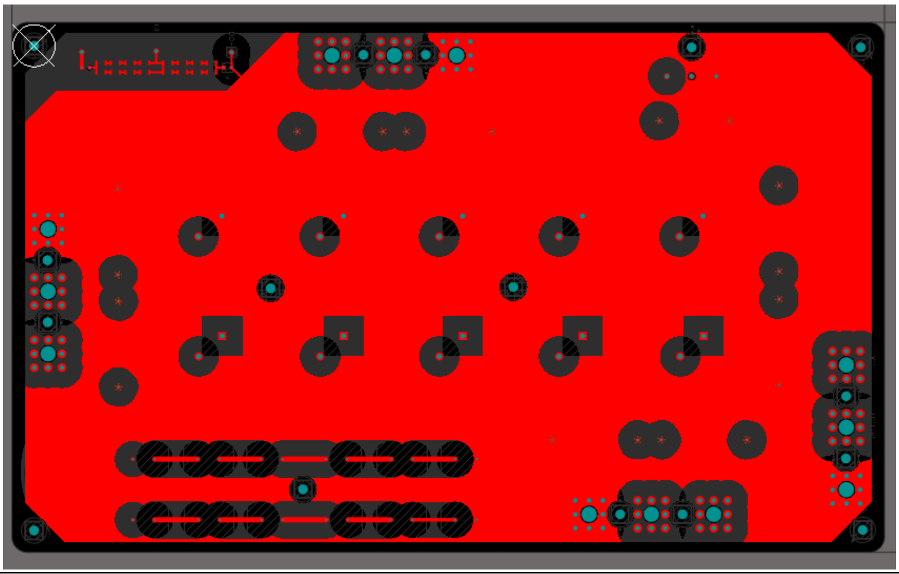


Figure 70 Layer 1

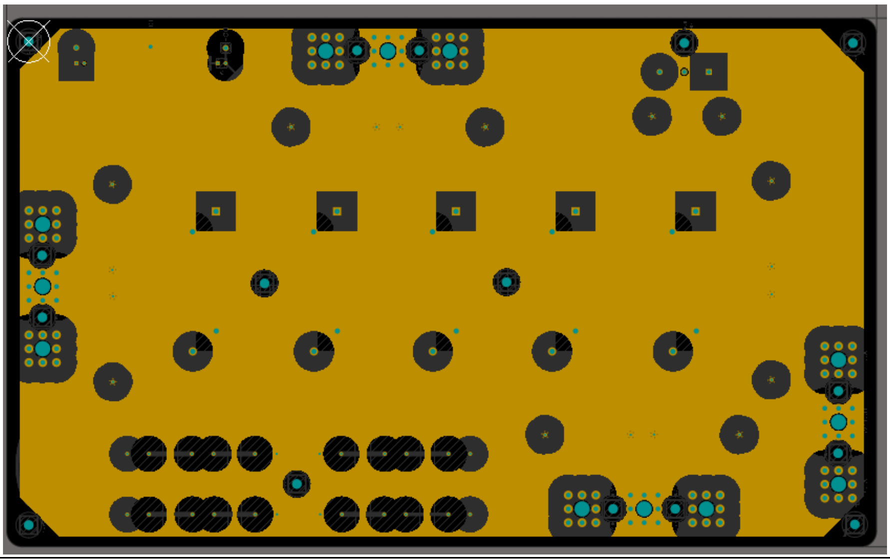


Figure 71 Layer 2

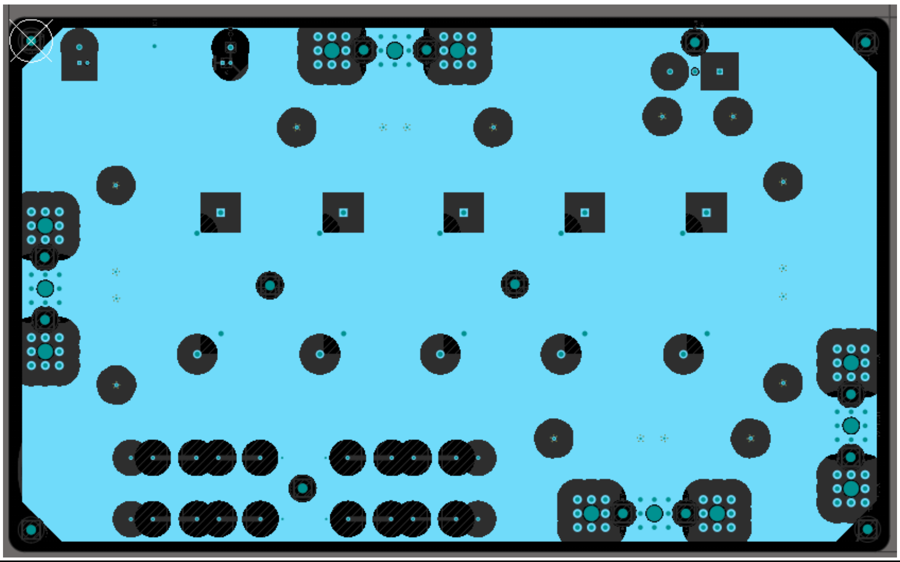


Figure 72 Layer 3

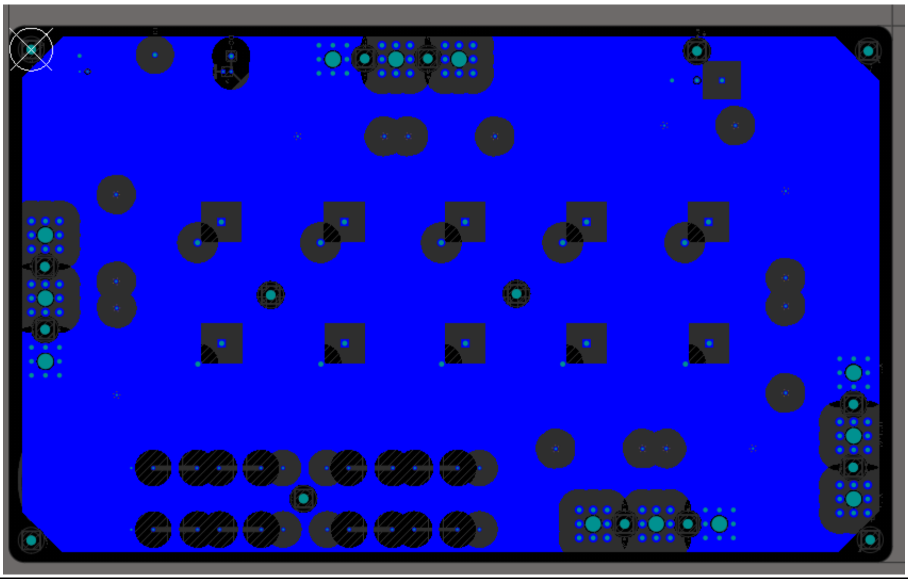


Figure 73 Layer 4

5 Infineon featured products

Table 21 Bill of materials

Part	Description
IPZ65R065C7	650 V, 33 A CoolMOS™ MOSFET in TO-247 4 pin package
IDW20G65C5	650 V, 20 A silicon carbide Schottky diode in TO-247 2 pin package
1ED3240MC12H	Single-channel 5.7kV (rms) isolated gate driver IC with 2L-SRC
TLI4971-A120T5-U-E0001	High-precision coreless current sensor for industrial applications
BAT54-03W	30 V, 200 mA Silicon Schottky Diode
TLE42744GS V33	3.3 V, 400 mA LDO

References

[1] Infineon Technologies AG: *Modular Hybrid Inverter Design Platform*; Available online

Revision history

Document revision	Date	Description of changes
V.1.0	2025-06-27	Initial release

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

Edition 2025-06-27
Published by

Infineon Technologies AG
81726 Munich, Germany

Do you have a question about this document?
Email: erratum@infineon.com

Document reference
UG192329

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.