6 kW HERIC reference design user guide

REF-6KW HERIC design for solar photovoltaic solutions

About this document

Scope and purpose

This document describes a highly efficient reliable inverter concept (HERIC) reference design REF-6KWHERIC and its main features, key data, pin assignments, mechanical dimensions, and electrical interfaces. This power conversion reference design is modular and the hardware can be reused for various power converter applications and use cases, with a special focus on solar photovoltaic solutions.

Intended audience

This document is meant to demonstrate the advantages of Infineon products to engineers and technical specialists working on solar photovoltaic solutions and similar domains.

Reference design

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

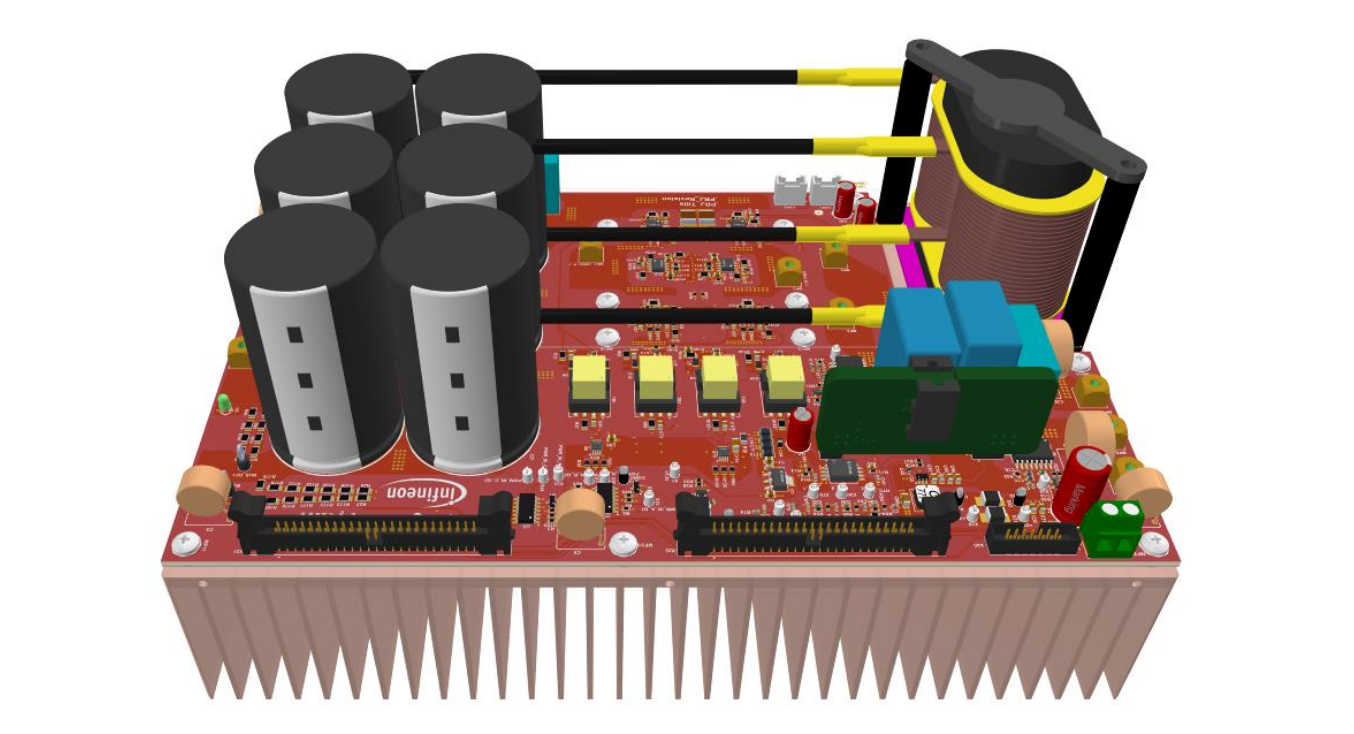

Figure 1 Power conversion board REF-6KWHERIC

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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.*

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1 Introduction

1.1 Power conversion board

The REF-6KWHERIC reference design is available as a kit and includes different boards that can help you build and operate an inverter power stage:

- REF-6KWHERIC: Inverter power stage main board
- PB-APS-24V-5V ISO: Isolated auxiliary power supply

The REF-6KWHERIC main board consists of a single-phase power stage based on HERIC topology and carries power semiconductors, gate drivers, auxiliary power supply, filter elements like DC link capacitors, output inductors, and output capacitors. This topology is efficient as the additional MOSFETs is used to manage the freewheeling current when the time that the H-bridge MOSFETs are off.

Additionally, you must procure an XMC7200-based control board (REF-CLBXMC7PEC) separately. It comes with all the signal conditioning circuits, power conversion software, and a GUI that allows you to operate and control the inverter in an off-grid operating mode.

Figure 2 shows the completely assembled 6 kW HERIC reference design.

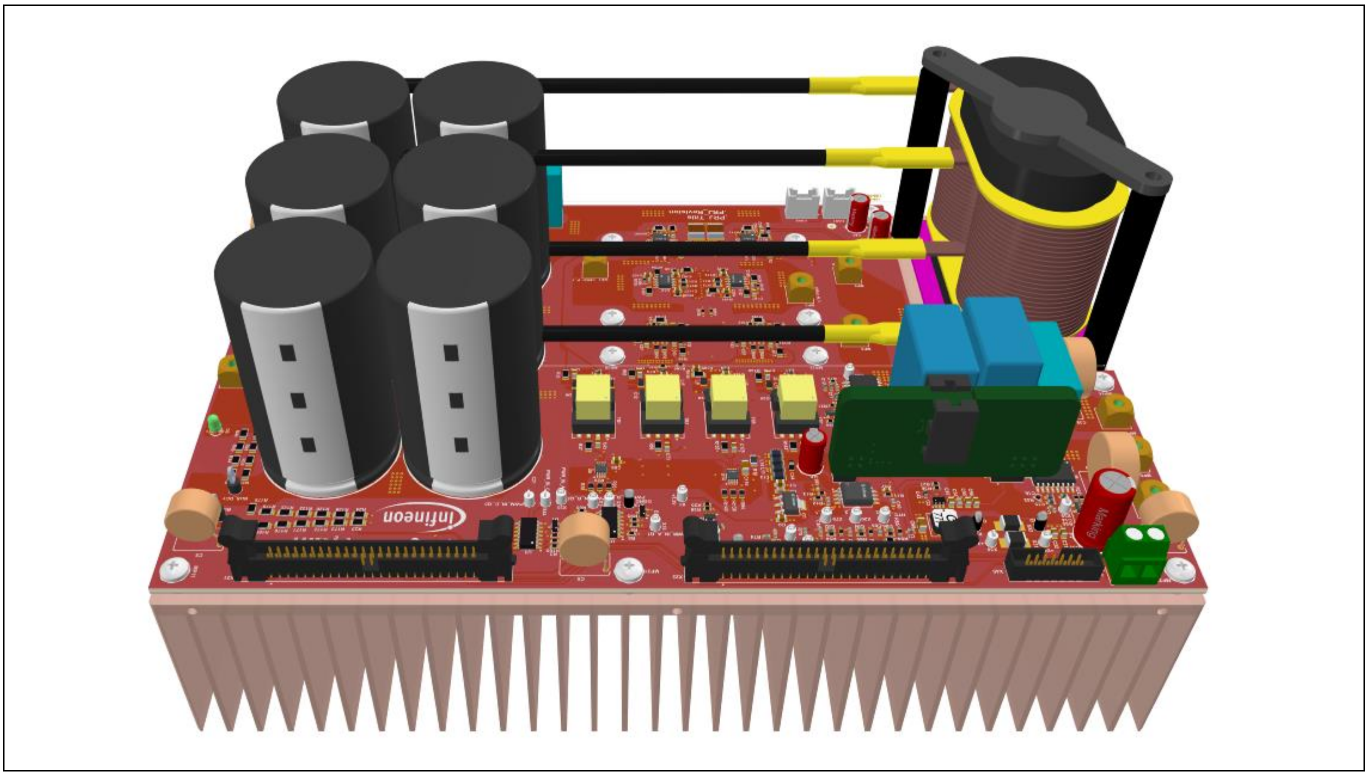


Figure 2 Power conversion reference design REF-6KWHERIC

1.2 Top-level specifications

Table 2 Specifications

Parameter	Typical	Maximum	Unit
Input voltage	380	510	V_{dc}
Output voltage	230	–	V_{rms}
Output current	27	–	A
Output power	–	6	kW
Switching frequency	50	–	kHz
Output frequency	50/60	–	Hz

1.3 HERIC inverter design blocks

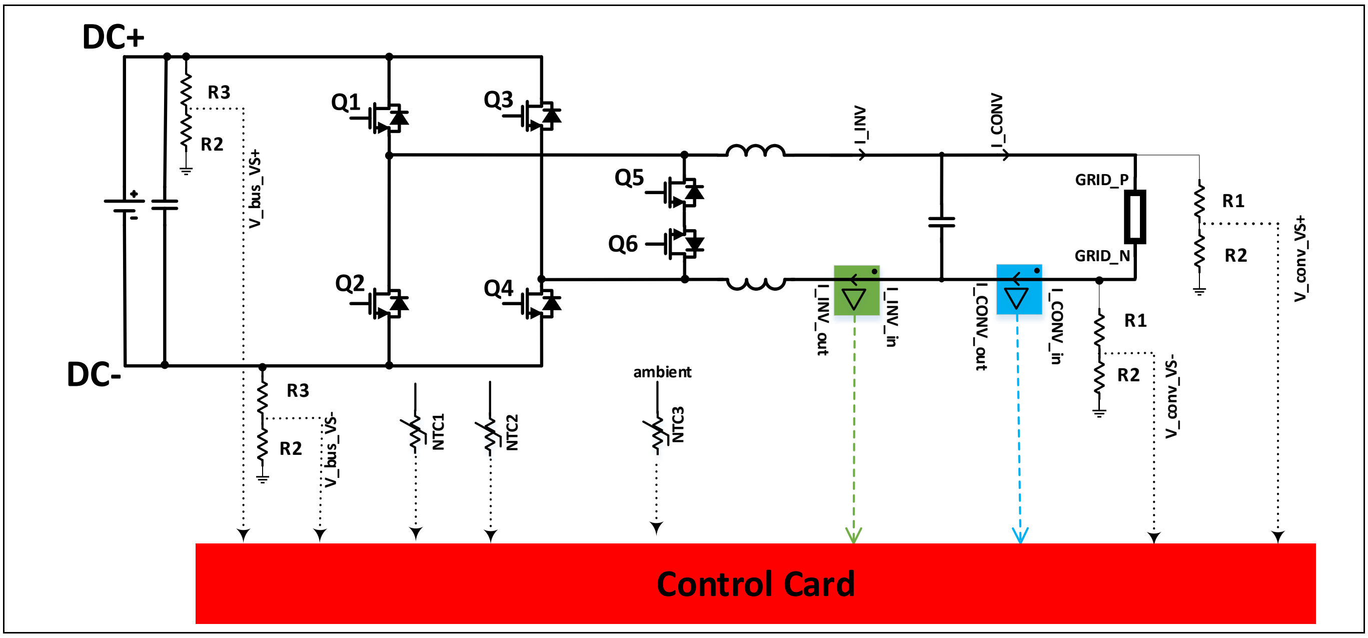


Figure 3 Assembly diagram

Figure 3 shows how the different boards are connected to construct the HERIC inverter. This HERIC reference design consists of the following boards:

- Main HERIC power board
- 24 VDC – 5 VDC isolated aux power supply board
- MCU control board

The DC input power supply and the AC output load are connected to the main board. You must provide an external 24 VDC supply to power all the auxiliary circuits on the main board as well as to power the MCU control board. This auxiliary power board plugged into the main board, provides the 5 V isolated supply to the power the auxiliary loads on the main board. The control MCU board is connected to the main board via two cables. The MCU board can be connected to a PC to flash the firmware or control the inverter through the GUI.

The following figures (Figures 4 and 5) show the stand-alone REF-6KWHERIC and PB-APS-24V-5V ISO boards.

Figure 4 REF-6KWHERIC

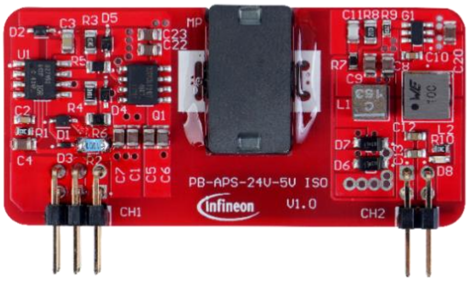


Figure 5 PB-APS-24V-5V ISO

1.4 Preferred components

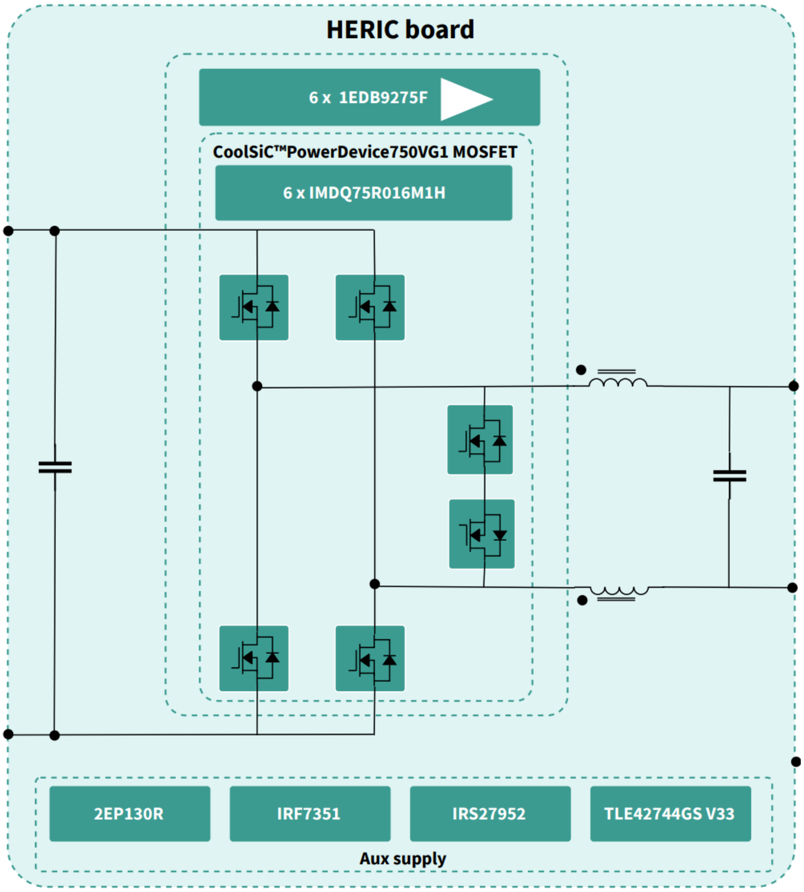


Figure 6 Preferred Infineon components

Figure 6 shows the main semiconductors offered in the 6 kW HERIC inverter reference design.

- Power semiconductors:
  - CoolSiC™ Power Device 750 V G1 MOSFET with top-side cooling package (QDPAK): IMDQ75R016M1H
- Gate driver:
  - Single-channel isolated gate driver IC EiceDRIVER™: 1EDB9275F
- Auxiliary power supply:
  - 2EP130R: Full-bridge transformer driver
  - IRS27952: Half Bridge controller IC
  - IRF7351: 60 V dual N-channel HEXFET power MOSFET
  - TLE42744GS V33: Monolithic integrated low dropout voltage regulator for load currents up to 400 mA

2 Board functional description and schematics

This section lists the features available for the 6 kW HERIC inverter reference design.

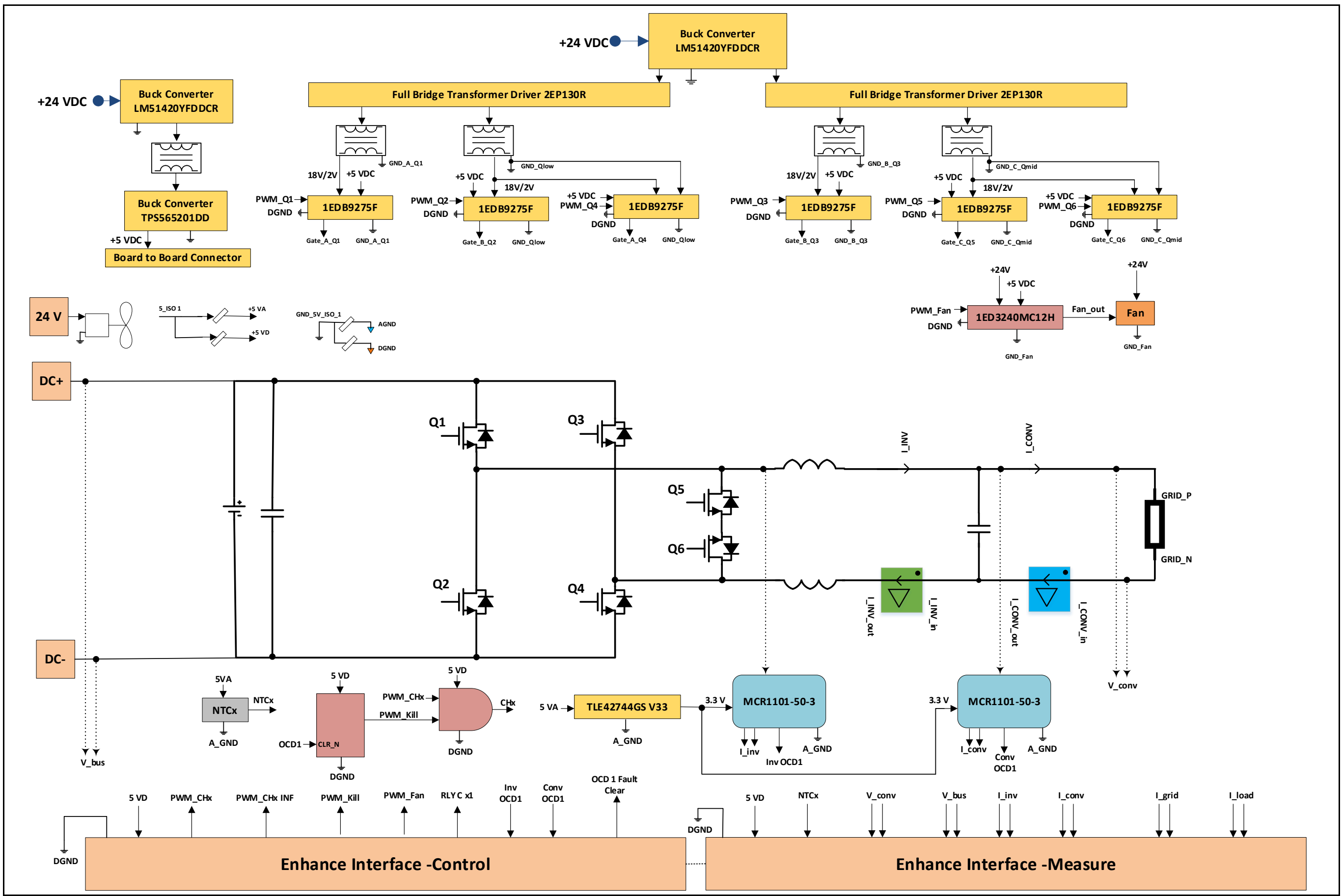


Figure 7 **Block diagram of REF-6KWHERIC reference design**

2.1 Description of the functional blocks

2.1.1 Switching devices

The inverter stage is designed with the CoolSiC™ Power Device G1 MOSFET products IMDQ75R016M1H.

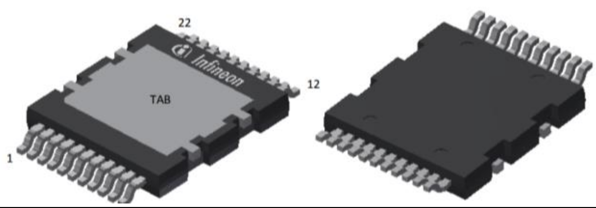


Figure 8 **IMDQ75R016M1H**

IMDQ75R016M1H belongs to the CoolSiC™ Power Device 750 V G1 family. The 750 V CoolSiC™ MOSFET offers excellent performance in this design due to its low switching losses, stable conduction loss overtemperature, and ease of thermal management. It is an ideal part for hybrid inverter applications which are typically passive cooled and sealed from the environment.

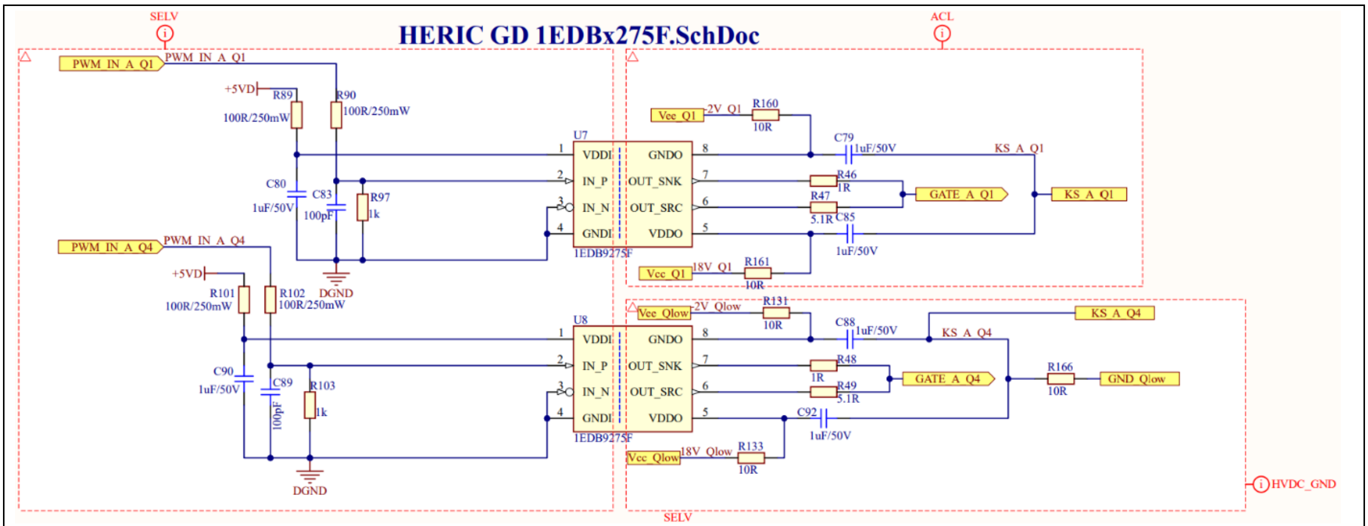
2.1.2 Gate driver

Six single-channel isolated gate drivers (1EDB9275F) are used to drive the six MOSFETs.

Figure 9 **1EDB9275F**

1EDB9275F belongs to the EiceDRIVER™ 1EDBx275F family of single-channel isolated gate driver ICs. It is specifically targeted to drive the SiC power switches due to its high source and sink current and optimized UVLO thresholds. It is available in an 8-pin DSO package with 4 mm input-to-output creepage distance. It provides isolation by means of on-chip coreless transformer (CT) technology meeting UL 1577 requirements of 3000 VRMS clearance. A low propagation delay of 45 ns enables the use of this single channel driver to drive inverter topologies where diagonal switches have to be turned on simultaneously. It can be used to drive fast SiC power devices with kelvin source with its separate low impedance source and sink outputs. Its high common-mode transient immunity (CMTI) allows robust driving of wide bandgap SiC power switches with high dv/dt values.

The externally supplied 24 V power is 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 +18 V/-2 V voltage rails for the six gate drivers driving the SiC MOSFETs. The PWM signals coming from the MCU control board are routed to the gate driver.



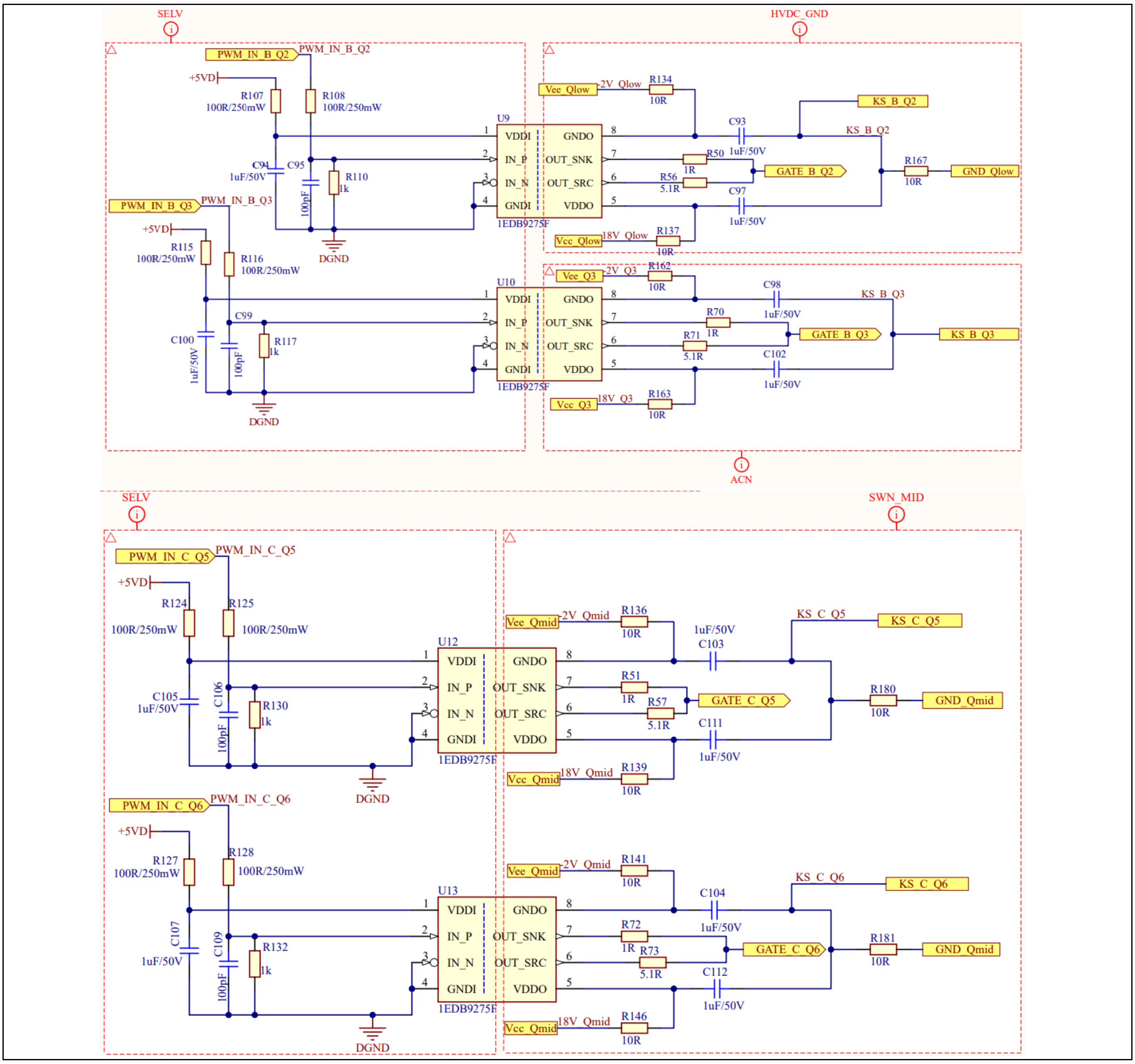


Figure 10 Gate driver (GD) circuitry

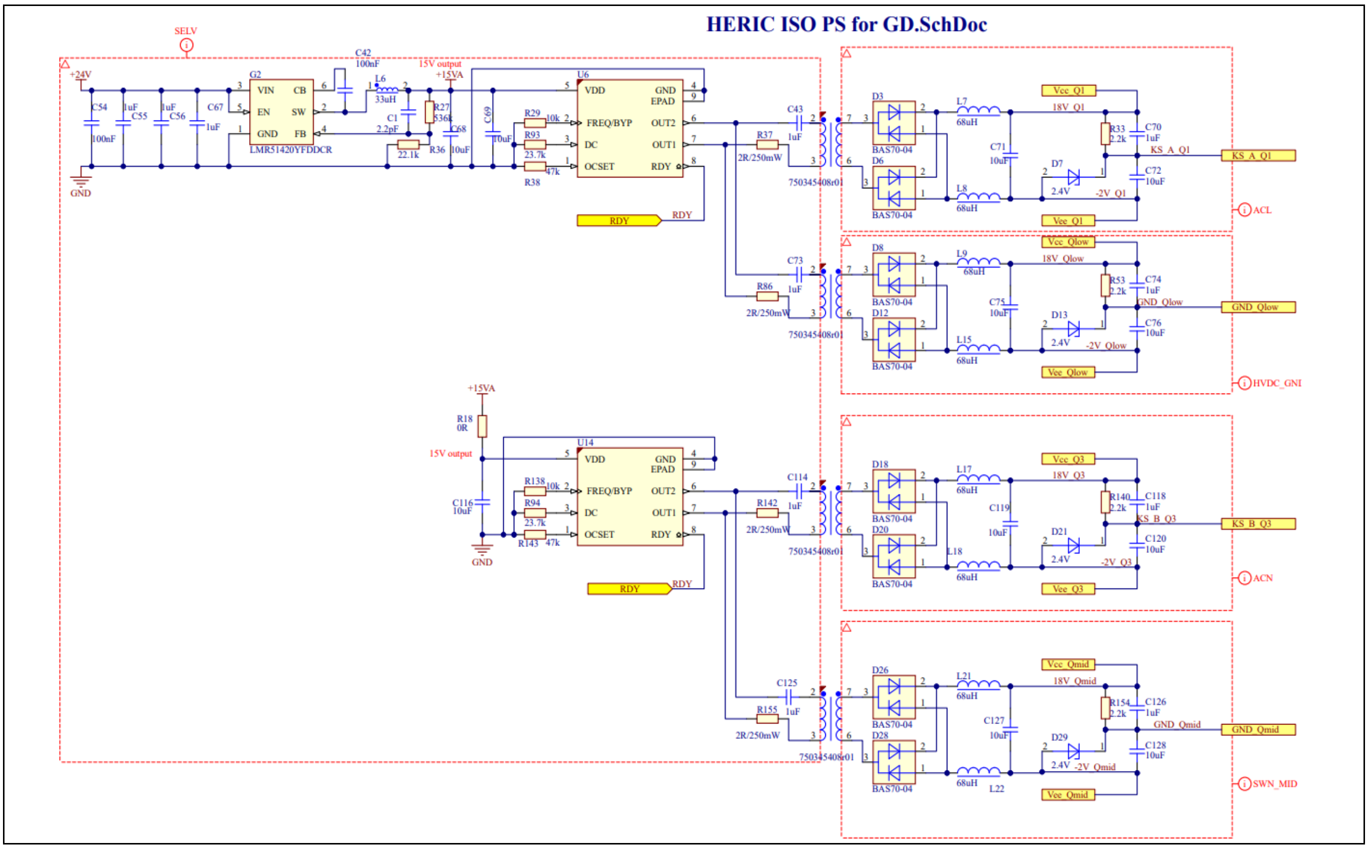


Figure 11 **Isolated Power Supplies (ISO PS) for HERIC Gate Drivers**

2.1.3 Input and power stage

The input stage consists of a DC capacitor link. The capacitor link has six electrolytic capacitors rated at 470 µF/550 V and connected to the Bus voltage.

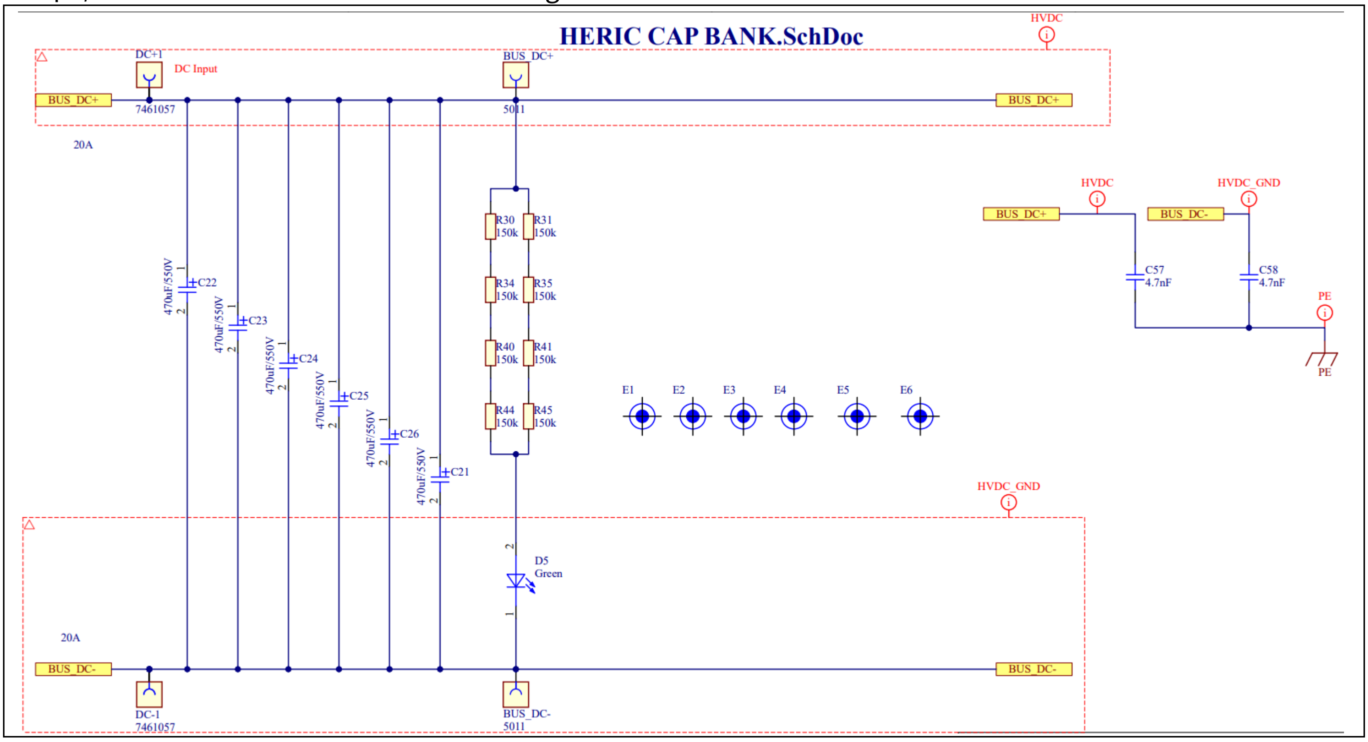


Figure 12 Capacitor bank

The power stage has a total of six SiC MOSFETs rated at 750 V. Four of the MOSFEETs make an H-bridge switch at high frequency and the two external ones (freewheeling switches) switch at the same high switching frequency or switch at grid frequency. The two external (freewheeling) switches can pass freewheel current through the shortest route during the period when the output voltage of the H-bridge inverter is zero. Using SiC MOSFETs enable switching at a higher frequency resulting in a significant reduction in magnetic size, capacitor filter, and heatsink size.

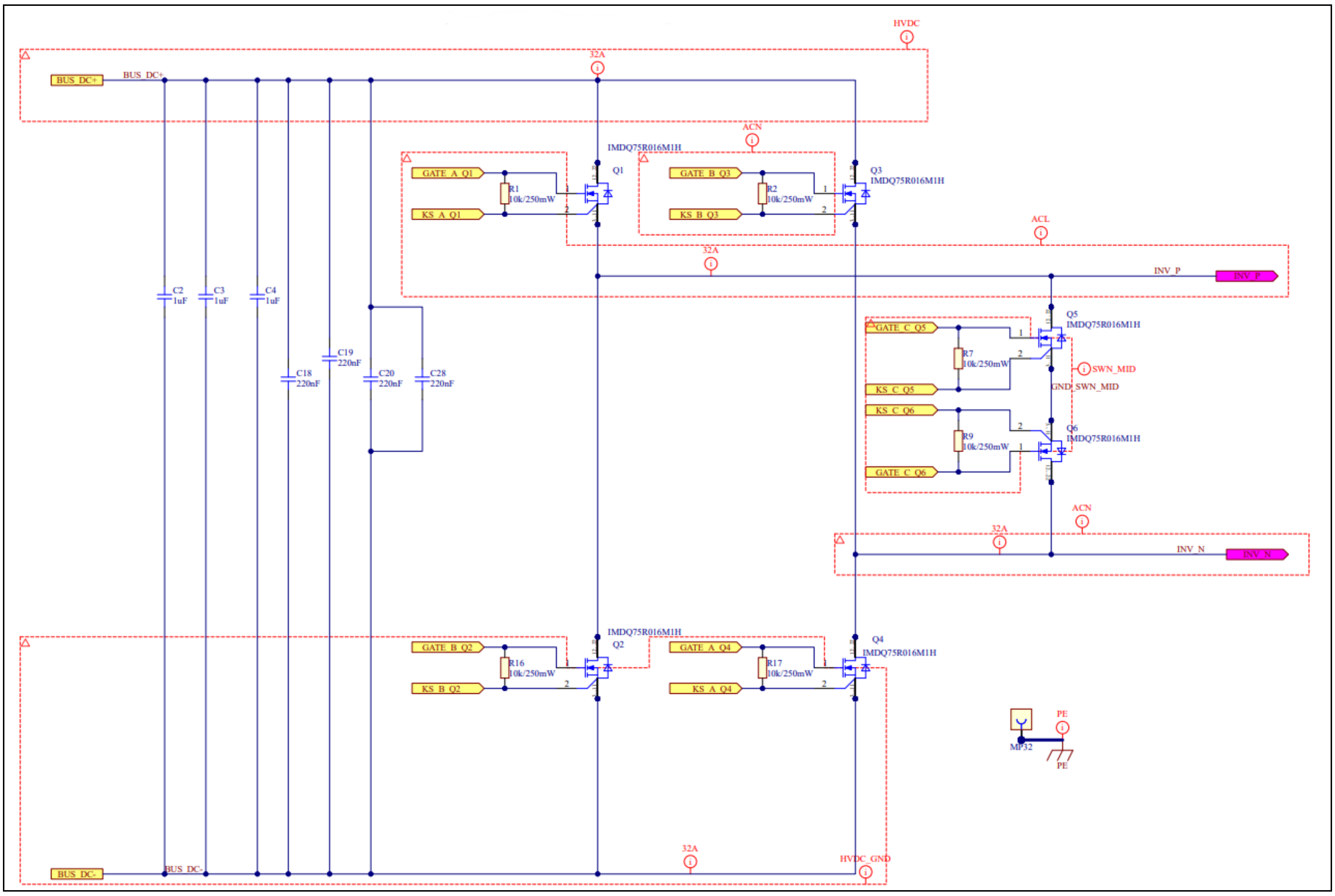


Figure 13 Power stage

2.1.4 Sensing and filter

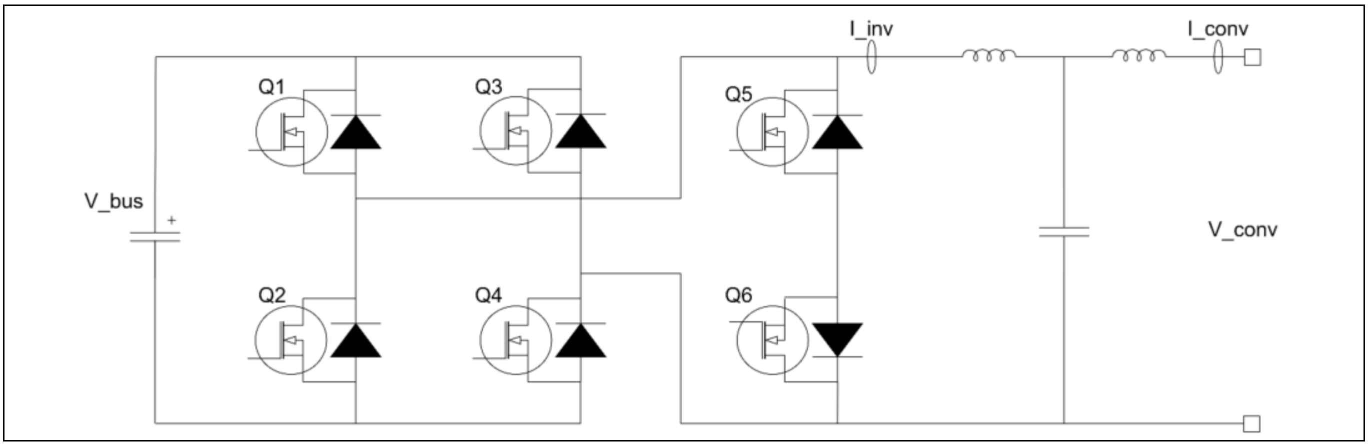


Figure 14 Sensing locations on the HERIC inverter

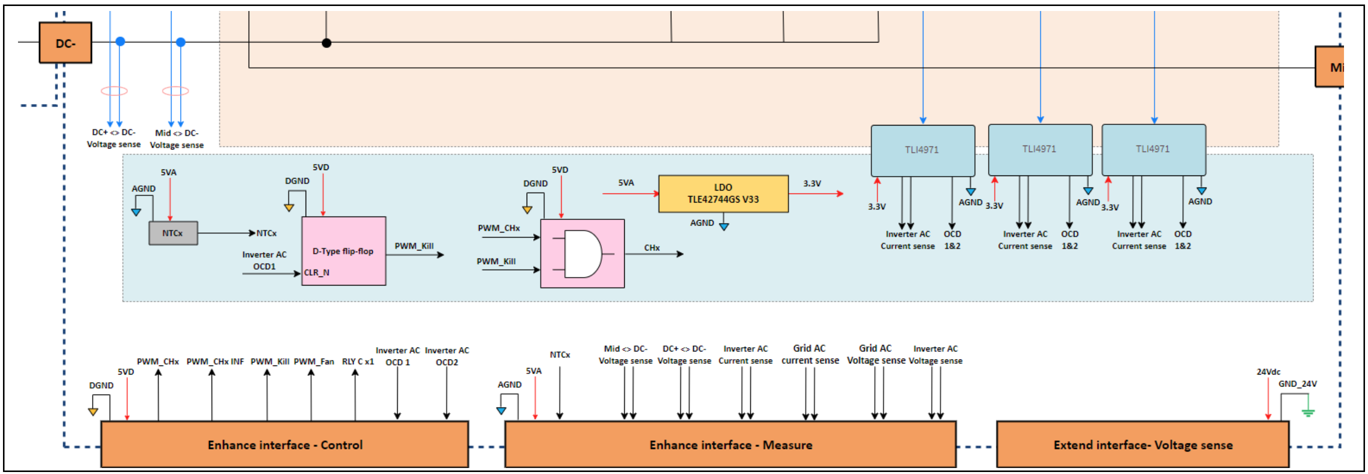


Figure 15 Functional block diagram of the measurement signals on the power board

2.1.4.1 Voltage sense

The DC-link voltage (V_bus) and the AC output voltage (V_conv) are measured on the power board.

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

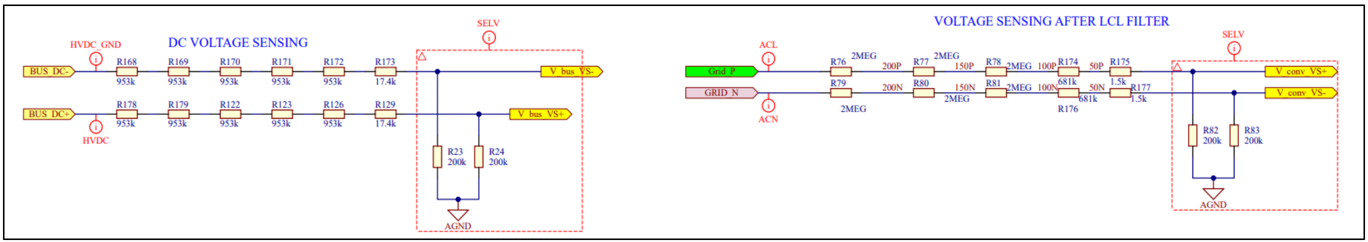


Figure 16 Voltage sense circuit

2.1.4.2 Current sense

The inductor current (I_inv) and AC output current (I_conv) are sensed using MCR1101-50-3 current sensors.

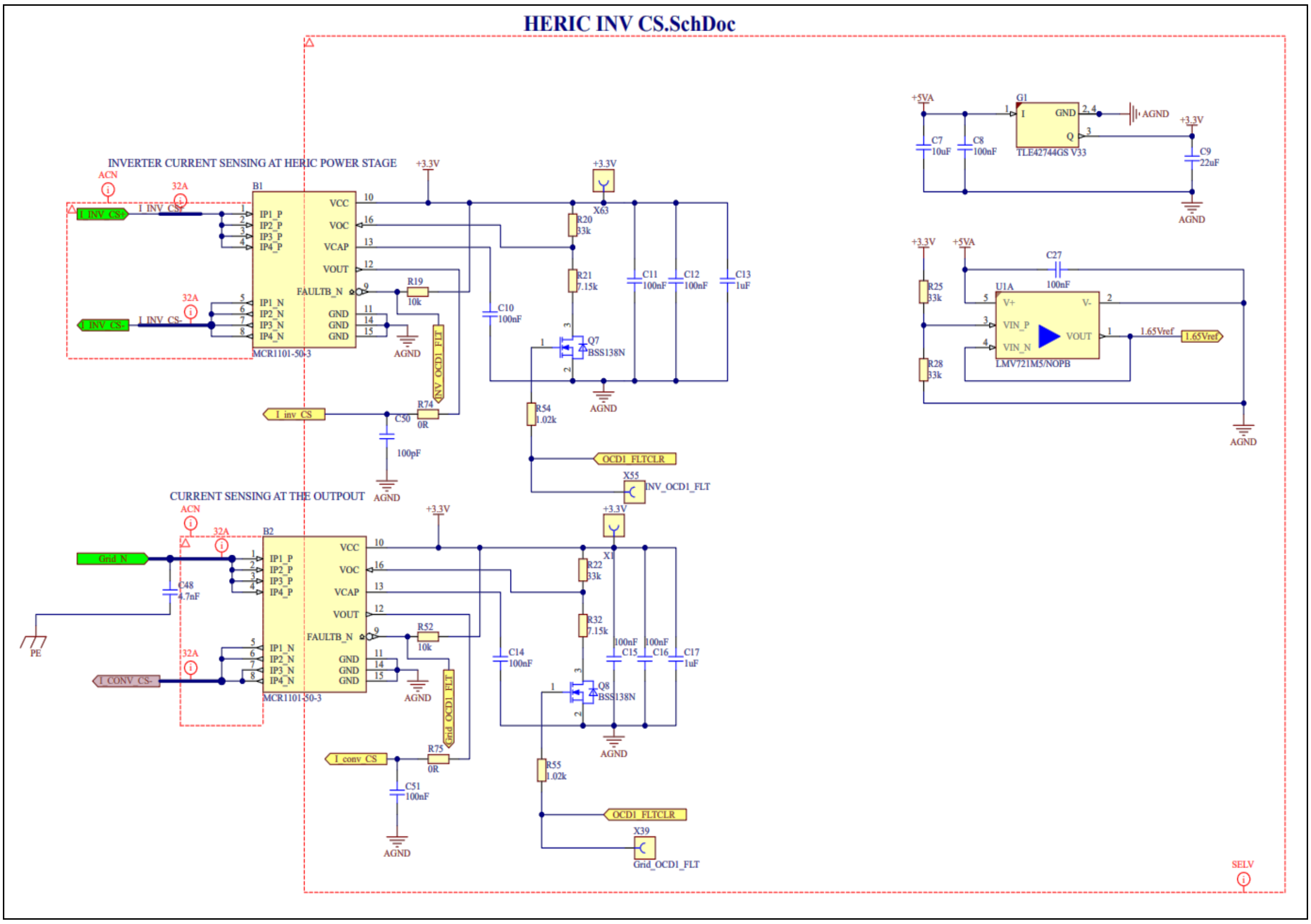


Figure 17 Current sense circuit

2.1.4.3 Temperature sense

Three temperature measurements are provided on the power board using NTCs. The NTCs can be connected to the heat sink to measure the temperature and feed it back to the connector which can be connected to a control board.

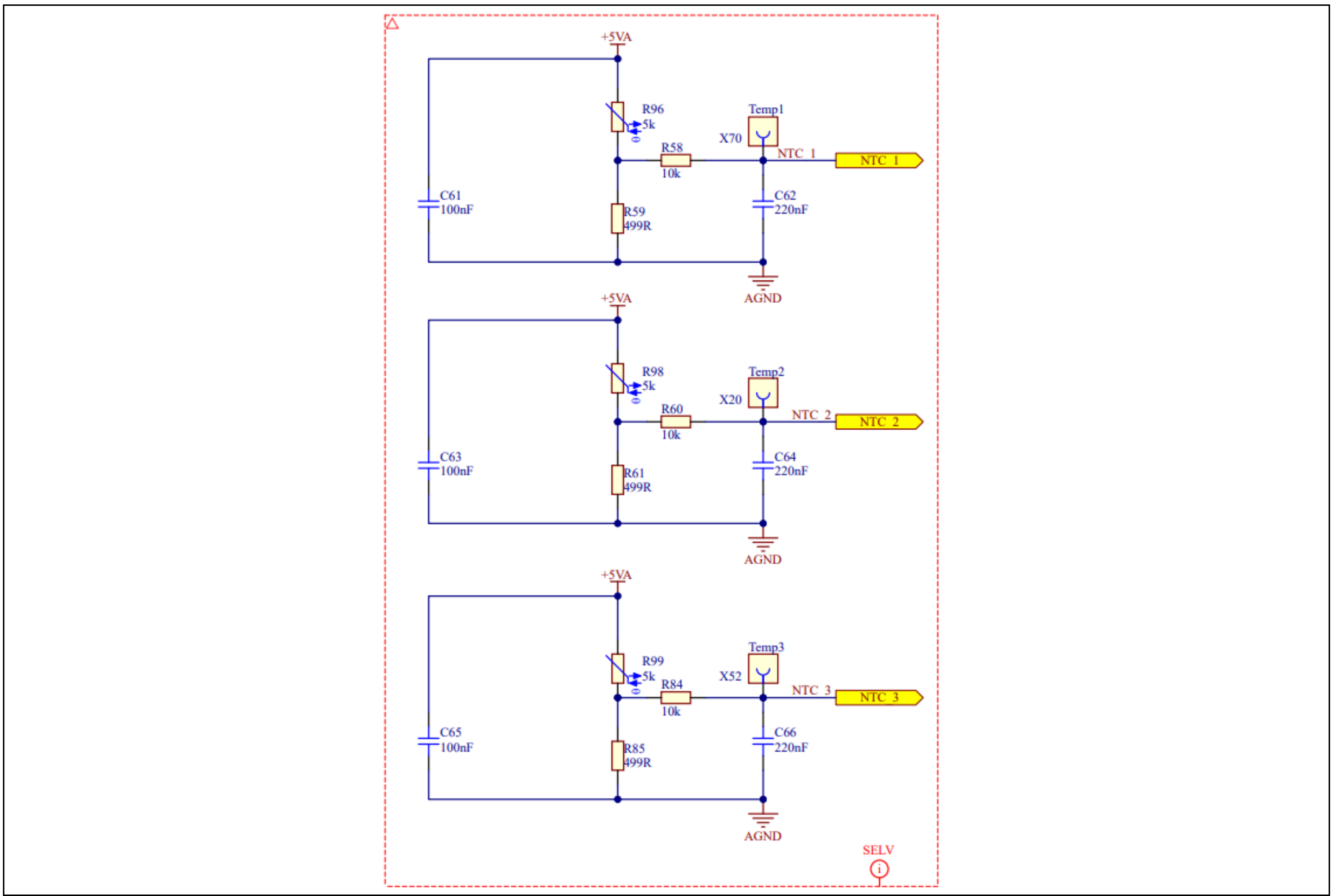


Figure 18 Temperature sense circuit

An LCL filter is located in between the power stage and current sensing circuitry. The inductor that is being used is rated at 110 µH/45.3A.

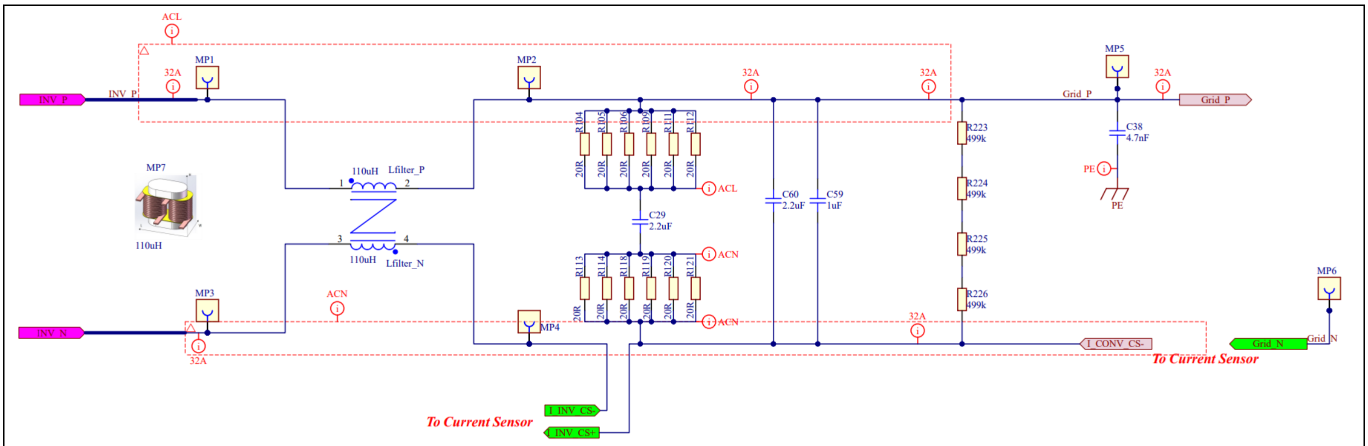


Figure 19 Temperature sense circuit

2.1.4.4 Gate drive logic

Fault and latch circuits latch the PWMs to the off state in case of a fault. The PWM_KILL or INV_OCD1_FLT signal can hold the logic gates low, latching the gate driver input to a low state. A fault clear signal can then be provided from the MCU to reset the latch.

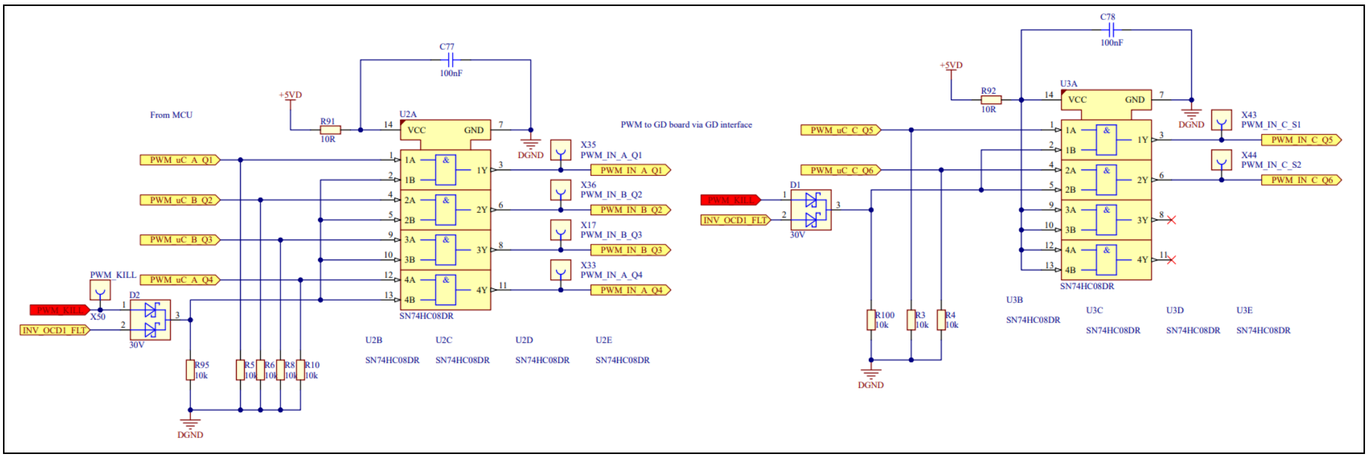


Figure 20 Fault and latch circuit

2.1.5 Internal power supplies

You must provide a 24 V supply to the main HERIC board. The 24 V is then fed to a power supply card which generates an isolated 5 V. This 5 V is split into the 5VA rail which is used for sensing and analog circuits and the 5VD one which is used for digital circuits like the power for the primary side of the gate driver. The 24 V is fed to the isolated power stage which generates the isolated 18 V/-2 V needed to power the secondary side of the gate driver and drive the SiC MOSFETs.

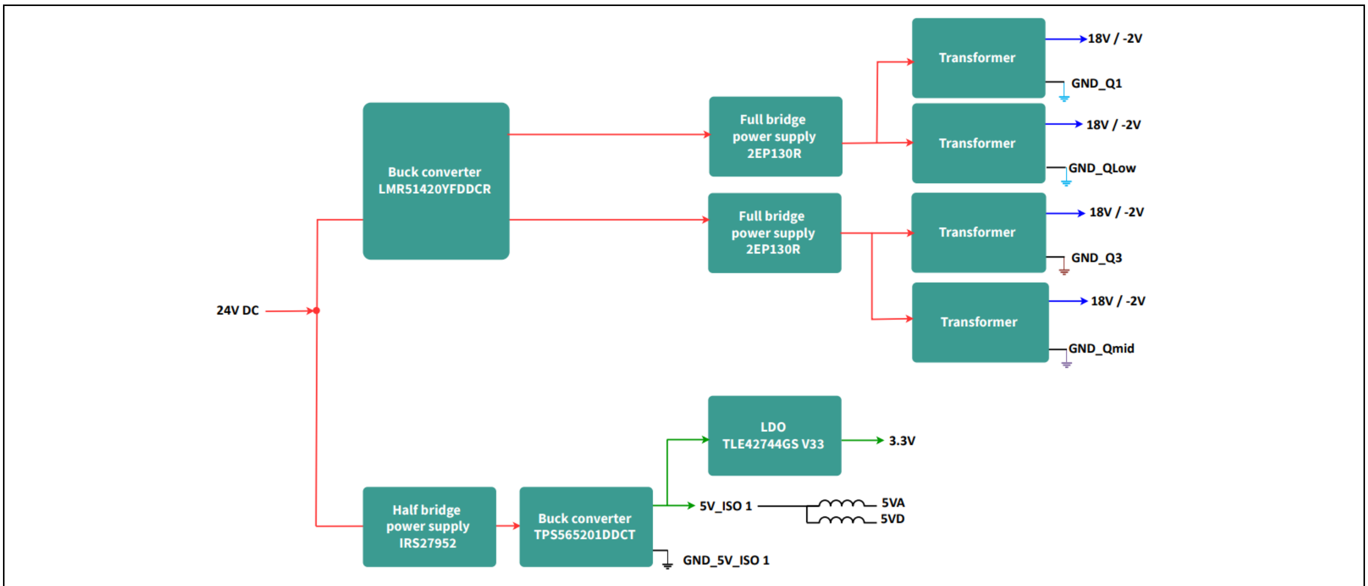


Figure 21 Auxiliary power supply tree

The specifications of the power supply card are as given in the following table.

Table 3 Specifications of the power supply 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	–	–	2	A
Switching frequency	–	226	–	kHz
Half bridge IC used	IRS27952			–

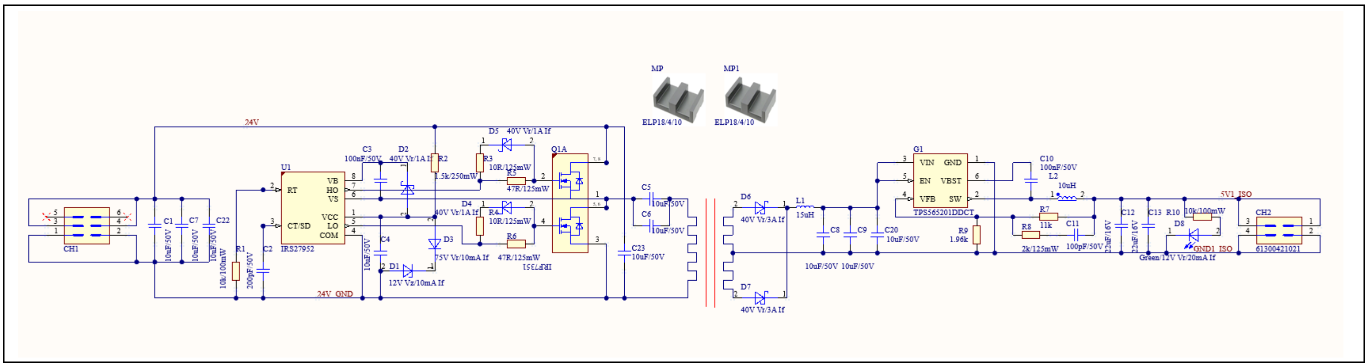


Figure 22 Power supply card schematics

2.1.6 Connectors

Additional fan control circuits are also provided if you need to use forced air-cooling during evaluation.

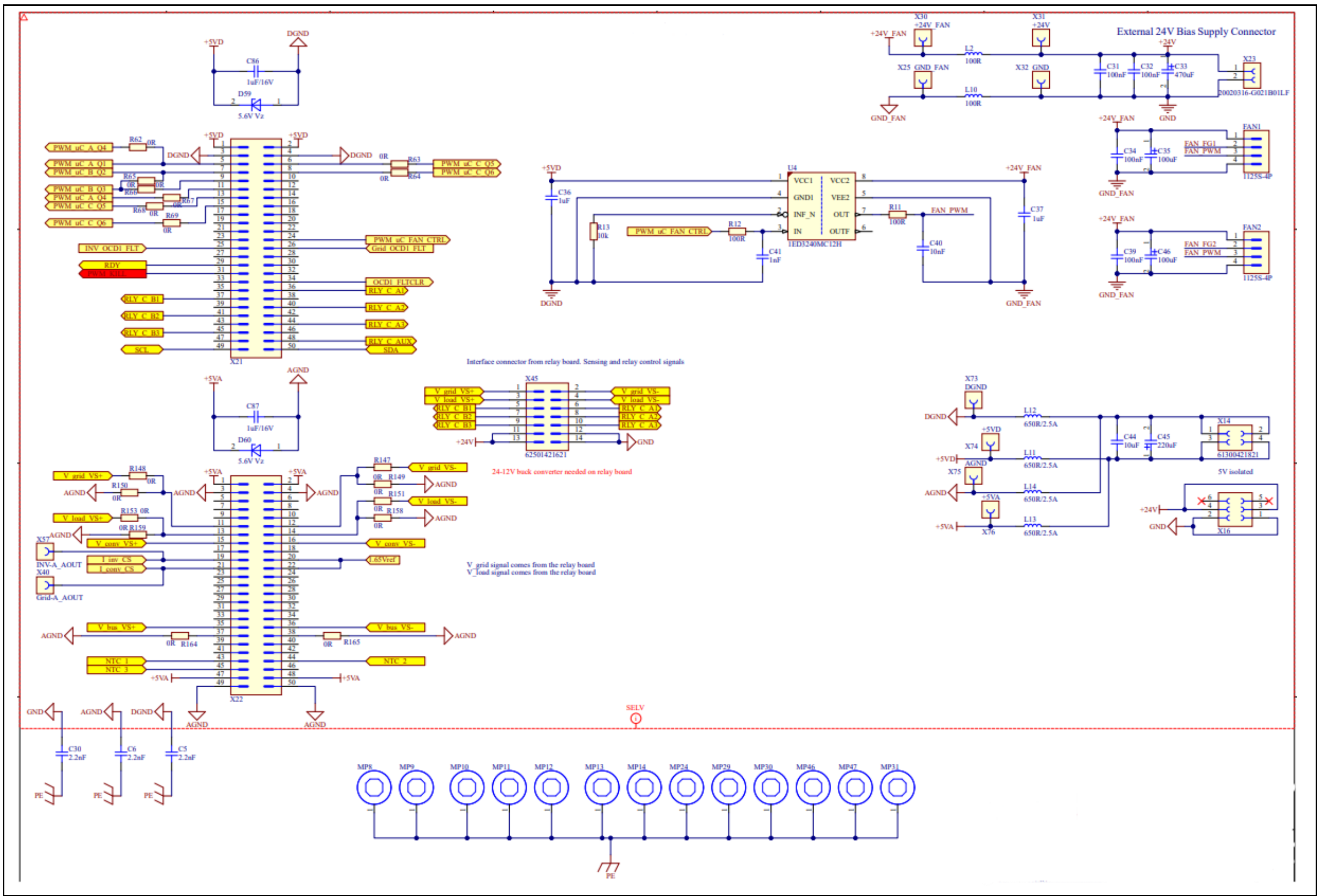


Figure 23 HERIC onnections

2.1.6.1 Enhanced interface - Measure

All the measurement signals are fed to the control board using the X22 connector located on the power board.

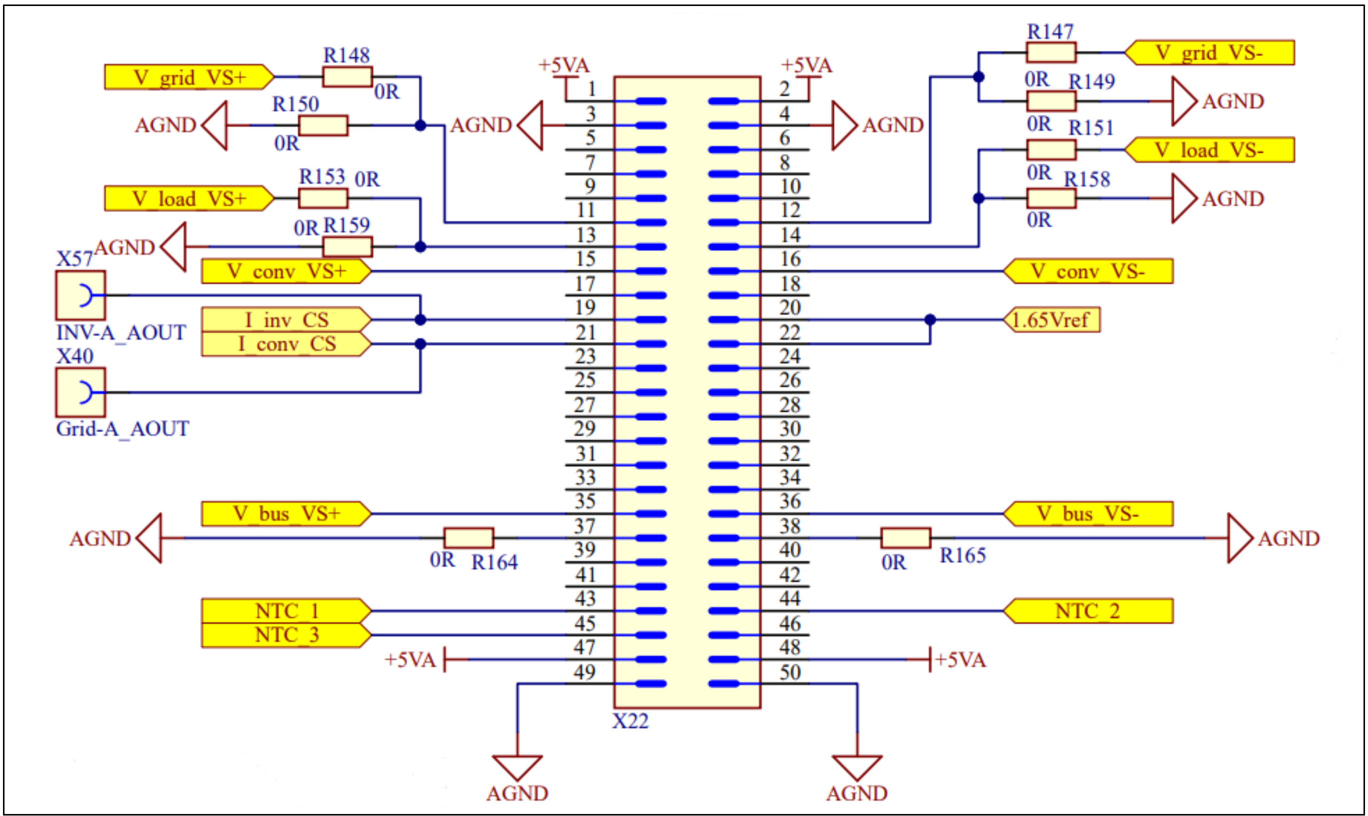


Figure 24 Enhanced interface - Measure

Table 4 Enhanced interface - Measure

Basic interface		
Pin	**Signal**	**Description**
1	+5VA	Analog power
2	+5VA	Analog power
3	AGND	Analog power ground
4	AGND	Analog power ground
5	NC	NC
6	NC	NC
7	NC	NC
8	NC	NC
9	NC	NC
10	NC	NC
11	V_grid_VS+	Not used
12	V_grid_VS-	Not used
13	V_load_VS+	Not used
14	V_load_VS-	Not used

Basic interface		
Pin	**Signal**	**Description**
15	V_conv_VS+	AC voltage P
16	V_conv_VS-	AC Voltage N
17	NC	NC
18	NC	NC
19	I_inv_CS	Inductor current
20	1.65Vref	1.65 V reference voltage
21	I_conv_CS	AC output current
22	1.65Vref	1.65 V reference voltage
23	NC	NC
24	NC	NC
25	NC	NC
26	NC	NC
27	NC	NC
28	NC	NC
29	NC	NC
30	NC	NC
31	NC	NC
32	NC	NC
33	NC	NC
34	NC	NC
35	V_bus_VS+	Bus Voltage P
36	V_bus_VS-	Bus Voltage N
37	NC	NC
38	NC	NC
39	NC	NC
40	NC	NC
41	NC	NC
42	NC	NC
43	NTC1	Temperature Sensor 1
44	NTC2	Temperature Sensor 2
45	NTC3	Temperature Sensor 3
46	NC	NC
47	+5VA	Analog Power
48	+5VA	Analog Power
49	AGND	Analog Power Ground
50	AGND	Analog Power Ground

2.1.6.2 Enhanced interface - control

Connector X21 contains all the signals related to the PWMs, faults, and relay control.

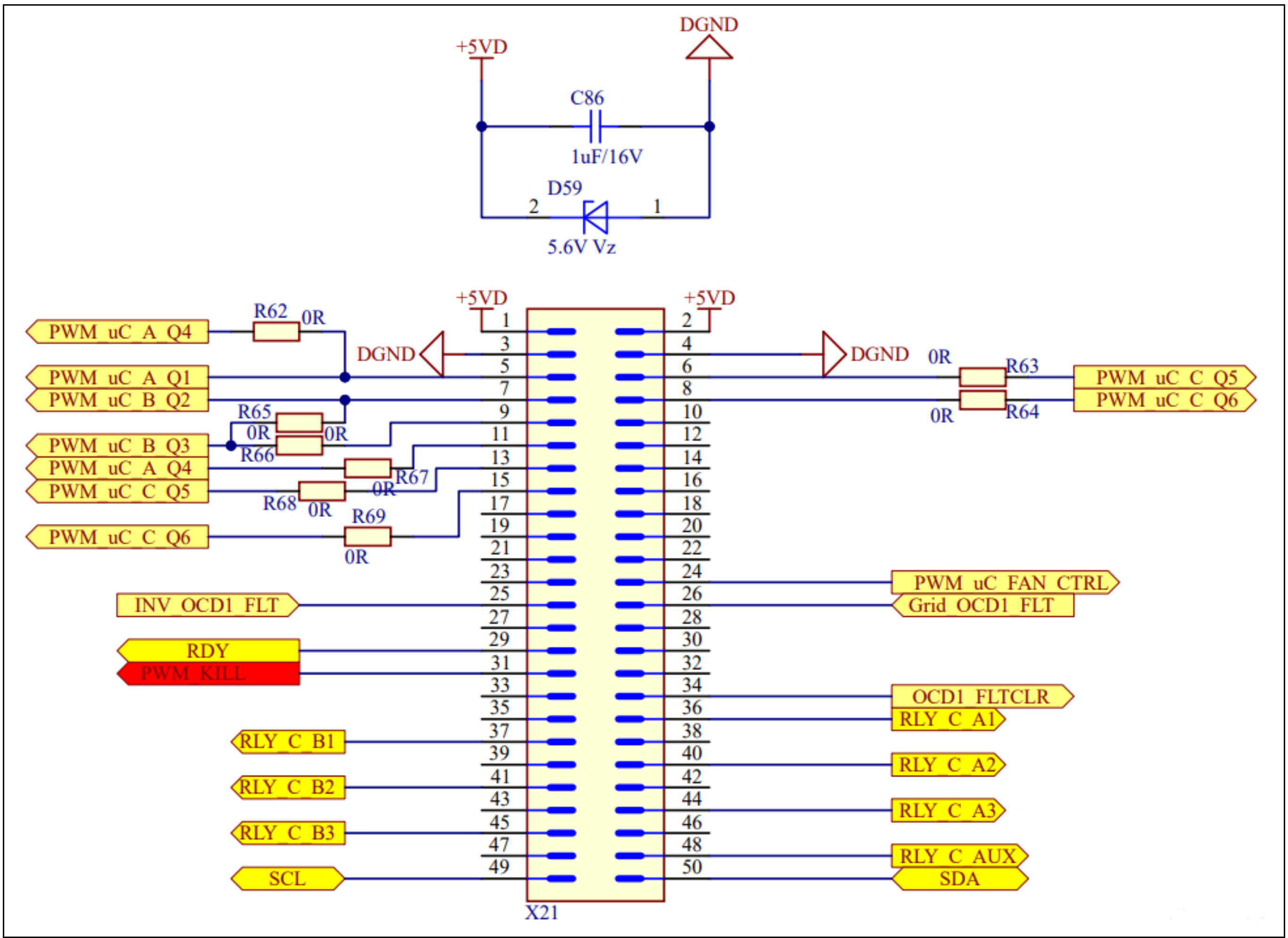


Figure 25 Enhanced interface - control

Table 5 Enhanced interface - control

Basic interface

Pin	Signal	Description
1	+5VD	Digital Power
2	+5VD	Digital Power
3	DGND	Digital Power Ground
4	DGND	Digital Power Ground
5	PWM_uC_A_Q1/ PWM_uC_A_Q4	MOSFET Q1 and Q4 PWM
6	PWM_uC_A_Q5	MOSFET Q5 PWM
7	PWM_uC_A_Q2/ PWM_uC_A_Q3	MOSFET Q2 and Q3 PWM
8	PWM_uC_A_Q6	MOSFET Q6 PWM
9	PWM_uC_A_Q3	NC
10	NC	NC

Basic interface		
Pin	**Signal**	**Description**
11	PWM_uC_A_Q4	NC
12	NC	NC
13	PWM_uC_A_Q5	NC
14	NC	NC
15	PWM_uC_A_Q6	NC
16	NC	NC
17	NC	NC
18	NC	NC
19	NC	NC
20	NC	NC
21	NC	NC
22	NC	NC
23	NC	NC
24	PWM_uC_FAN_CTRL	FAN Control PWM
25	INV_OCD1_FLT	Inductor Over Current Fault Signal
26	Grid_OCD1_FLT	AC Output Over Current Fault Signal
27	NC	NC
28	NC	NC
29	RDY	Not used
30	NC	NC
31	PWM_KILL	PWM shut down signal
32	NC	NC
33	PWM_uC_INF	Not used
34	OCD1_FLTCLR	Overcurrent fault clear signal from MCU
35	NC	NC
36	RLY_C_A1	Not used
37	RLY_C_B1	Not used
38	NC	NC
39	NC	NC
40	RLY_C_A2	Not used
41	RLY_C_B2	Not used
42	NC	NC
43	NC	NC
44	RLY_C_A3	Not used
45	RLY_C_B3	Not used
46	NC	NC
47	NC	NC
48	NC	NC

Basic interface		
Pin	**Signal**	**Description**
49	I2C2_SCL	Not used
50	I2C2_SDA	Not used

2.7 Isolation coordination

The 6 kW HERIC reference design follows a cold-side control structure where all the measurements and the gate-drive power supply offer functional isolation. IEC 62109-1 was used for clearance and creepage requirements.

3 Bills of materials

Table 6 BOM of the power conversion board and Auxiliary power supply

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
1	1	U4	1ED3240MC12H	SOIC127P1030X265-8N-1-V	Single-channel 5.7kV (rms) isolated gate driver IC with 2L-SRC	Infineon Technologies	1ED3240MC12H
2	6	U7, U8, U9, U10, U12, U13	1EDB9275F	SOIC127P600X175-8N-10	Single-channel isolated gate-driver ICs	Infineon Technologies	1EDB9275F
3	2	U6, U14		SOP65P490X104-9N-V2	Full-bridge transformer driver for IGBT and SiC MOSFET gate driver supply	Infineon Technologies	2EP130R
4	2	FAN1, FAN2	1125S-4P	CON-M-THT-1125S-4P	DIP Grove Female Header-White;4P-2.0, Straight	Shenzhen NS-Tech Co. Ltd	1125S-4P
5	4	X25, X32, X73, X75	GND_FAN, GND, DGND, AGND	CON-THT-TP-5001	Test Point THT, Black	Keystone Electronics Corp.	5001
6	20		+3.3V, PWM_IN_B_Q3, Temp2, +24V_FAN, +24V, PWM_IN_A_Q4, PWM_IN_A_Q1, PWM_IN_B_Q2, Grid_OCD1_FLT, Grid-A_AOUT, PWM_IN_C_S1, PWM_IN_C_S2, PWM_KILL, Temp3, INV_OCD1_FLT, INV-A_AOUT, Temp1, +5VD, +5VA	CON-THT-TP-5002	Test Point THT, White	Keystone Electronics Corp.	5002
7	2	BUS_DC-, BUS_DC+	5011	CON-THT-TP-5011	PC Test Point-Multipurpose THT, Black	Keystone Electronics Corp.	5011
8	2	C8, C54	100 nF	CAPC2013X94N	CAP / CERA / 100nF / 25V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 0805(2012) / SMD / -	AVX	08053C104K4Z2A

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
9	9	DC-1, DC+1, MP1, MP2, MP3, MP4, MP5, MP6, MP32	7461057	CON-TER-THT-7461057	WP-BUTR REDCUBE PRESS-FIT, 100A	Würth Elektronik	7461057
10	1	X23	20020316-G021B01LF	CON-TER-THT-20020316-G021B01LF	Conn Terminal Block 2 POS 5mm Solder ST Thru-Hole 16A/Contact Box	Amphenol	20020316-G021B01LF
11	4	L11, L12, L13, L14	650R/2.5 A	INDC3216X130N	IND / FERR / 650R/2.5A / 2.5A / 25% / -55¡ãC to 125¡ãC / 70mR / 1206(3216) / Inductor,Chip;3.20mm L X 1.60mm W X 1.30mm H / SMD / -	Würth Elektronik	742792118
12	4	TR1, TR2, TR3, TR5	750345408r01	TR-SMD-750345408r00	Transformer, 170¦ÌH, Turns Ratio 1.4:1	Würth Elektronik	750345408r00
13	1	X14	61300421821	CON-F-THT-61300421821	WR PHD Dual Socket Header, 4Pins, 2.54mm Pitch, 3A, 250VAC	Würth Elektronik	61300421821
14	1	X16	61300621821	CON-F-THT-61300621821	WR-PHD Dual Socket Header, 6 Position, 3A, 250VAC	Würth Elektronik	61300621821
15	1	X45	62501421621	CON-M-THT-62501421621	WR-BHD Male Box Header, 2.00 mm Pitch, 14 Pins	Würth Elektronik	62501421621
16	2	X21, X22	62505022021	CON-M-THT-62505022021	WR-BHD Male Box Header, 2.00 mm Pitch, 50 Pins, Dual Row, 2A, 250VAC	Würth Elektronik	62505022021
17	2	L2, L10	100R	INDC4532X345N	IND / FERR / 100R / 8A / 25% / -55¡ãC to 125¡ãC / 6mR / 1812(4532) / Inductor,Chip;4.50mm L X 3.20mm W X 2.55mm H / SMD / -	Würth Elektronik	74279226101
18	1	C45	220 uF	CAPPRD250W50D630H1250B	CAP / ELCO / 220uF / 16V / 20% / Aluminiumelectrolytic / -40¡ãC to 85¡ãC / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / THT / -	Würth Elektronik	8.60E+11
19	2	C35, C46	100 uF	CAPPRD250W50D630H1250B	CAP / ELCO / 100uF / 35V / 20% / Aluminiumelectrolytic / -40¡ãC to 85¡ãC / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / THT / -	Würth Elektronik	8.60E+11

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
20	1	C33	470 uF	CAPPRD500W60D1000H2150B	CAP / ELCO / 470uF / 35V / 20% / - / -55°C to 105°C / 5.00mm C X 0.60mm W 10.00mm Dia X 21.50mm H / THT / -	Würth Elektronik	8.60E+11
21	6	C83, C89, C95, C99, C106, C109	100 pF	CAPC1608X87N-1	CAP / CERA / 100pF / 50V / 5% / C0G (EIA) / NP0 / -55¡ãC to 125¡ãC / 0603(1608) / SMD / -	Würth Elektronik	8.85E+11
22	2	C86, C87	1 uF/16 V	CAPC1608X87N-1	CAP / CERA / 1uF/16V / 16V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 0603(1608) / SMD / -	Würth Elektronik	8.85E+11
23	1	C42	100 nF	CAPC1608X95N-4	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 0603(1608) / SMD / -	Würth Elektronik	8.85E+11
24	1	C44	10 uF	CAPC2012X135N	CAP / CERA / 10uF / 10V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 0805(2012) / SMD / -	Würth Elektronik	8.85E+11
25	11	C43, C55, C56, C67, C70, C73, C74, C114, C118, C125, C126	1 uF	CAPC2013X135N	CAP / CERA / 1uF / 50V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 0805(2012) / SMD / -	Würth Elektronik	8.85E+11
26	3	C5, C6, C30	2.2 nF	CAPRR1000W60L1200T700H1500B	CAP / CERA / 2.2nF / / 20% / - / -55¡ãC to 125¡ãC / 10.00mm C X 0.60mm W 12.00mm L X 7.00mm T X 15.00mm H / THT / -	Vishay	AY1222M47Y5UC63L0
27	4	C38, C48, C57, C58	4.7 nF	CAPRR1000W60L1650T700H1950B	CAP / CERA / 4.7nF / / 20% / - / -55¡ãC to 125¡ãC / 10.00mm C X 0.60mm W 16.50mm L X 7.00mm T X 19.50mm H / THT / -	Vishay	AY1472M65Y5UC63L0
28	4	C2, C3, C4, C59	1 uF	CAPRR2250W80L2650T1100H2050B	CAP / FILM / 1uF / 630V / 10% / MKP (Metallized Polypropylene) / -40°C to 110°C / 22.50mm C X 0.80mm W 26.50mm L X 11.00mm T X 20.50mm H / THT / -	TDK Corporation	B32923C3105K289
29	2	C29, C60	2.2 uF	CAPRR2250W80L2650T1450H2950B	CAP / FILM / 2.2uF / 630V / 20% / MKP (Metallized Polypropylene) / - / 22.50mm C X 0.80mm W 26.50mm L X 14.50mm T X 29.50mm H / THT / -	TDK Corporation	B32923H3225M000

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
30	8	D3, D6, D8, D12, D18, D20, D26, D28	BAS70-04	SOT95P240X110-3N-1	Silicon Schottky diode	Infineon Technologies	BAS70-04
31	2	D1, D2	30 V	SOT95P237X111-3N	Dual Common Cathode Schottky Barrier Diodes	ON Semiconductor	BAT54CLT1G
32	2	Q7, Q8	BSS138N	SOT95P240X110-3N-1-V1	N-Channel Small Signal Transistor	Infineon Technologies	BSS138N
33	2	D59, D60	5.6V Vz	SODFL1608X70N-1	Small Signal Zener Diodes, 5.6V	Vishay	BZX584C5V6-V-G
34	8	C10, C11, C12, C14, C15, C16, C27, C51	100 nF	CAPC1608X87N	CAP / CERA / 100nF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Kemet	C0603X104K4RACTU
35	2	C13, C17	1 uF	CAPC1608X90N-4	CAP / CERA / 1uF / 16V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	TDK Corporation	CGA3E1X7R1C105K080AC
36	1	C1	2.2 pF	CAPC1608X90N-4	CAP / CERA / 2.2pF / 50V / 250fF / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608) / SMD / -	TDK Corporation	CGA3E2C0G1H2R2C080AA
37	6	R97, R103, R110, R117, R130, R132	1k	RESC1609X50N	RES / STD / 1k / 100mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 0603(1608) / SMD / -	Vishay	CRCW06031K00FK
38	2	R54, R55	1.02k	RESC1609X50N	RES / STD / 1.02k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW06031K02FK
39	4	R160, R161, R162, R163	4.99R	RESC1609X50N	RES / STD / 4.99R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW06034R99FK
40	2	R21, R32	7.15k	RESC1609X50N	RES / STD / 7.15k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW06037K15FK
41	6	R46, R48, R50, R51, R70, R72	1R	RESC2013X60N-3	RES / STD / 1R / 500mW / 1% / 100ppm/K / - / 0805(2012) / SMD / -	Vishay	CRCW08051R00FKEAHP
42	2	R175, R177	1.5k	RESC3216X60N	RES / STD / 1.5k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay	CRCW12061K50FK

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
43	4	R33, R53, R140, R154	2.2k	RESC3216X60N	RES / STD / 2.2k / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW12062K20FK
44	6	R76, R77, R78, R79, R80, R81	2MEG	RESC3216X60N	RES / STD / 2MEG / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW12062M00FK
45	4	R37, R86, R142, R155	2R/250mW	RESC3216X60N	RES / STD / 2R/250mW / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW12062R00FK
46	1	R13	10k	RESC1609X50N	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW060310K0FKEA
47	1	R36	22.1k	RESC1609X50N	RES / STD / 22.1k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW060322K1FK
48	4	R20, R22, R25, R28	33k	RESC1609X50N	RES / STD / 33k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW060333K0FK
49	2	R29, R138	10k	RESC2113X50N	RES / STD / 10k / 125mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 0805(2012) / SMD / -	Vishay	CRCW080510K0FK
50	2	R93, R94	23.7k	RESC2113X50N	RES / STD / 23.7k / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Vishay	CRCW080523K7FK
51	2	R38, R143	47k	RESC2113X50N	RES / STD / 47k / 125mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 0805(2012) / SMD / -	Vishay	CRCW080547K0FK
52	2	R129, R173	17.4k	RESC3216X60N	RES / STD / 17.4k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay	CRCW120617K4FK
53	12	R104, R105, R106, R109, R111, R112, R113, R114, R118, R119, R120, R121	20R	RESC6332X70N	RES / STD / 20R / 1W / 1% / 100ppm/K / -55°C to 155°C / 2512(6432) / SMD / -	Vishay	CRCW251220R0FK

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
54	3	R59, R61, R85	499R	RESC1609X50N	RES / STD / 499R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW0603499RFK
55	1	R27	536k	RESC1609X50N	RES / STD / 536k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	CRCW0603536KFK
56	12	R89, R90, R101, R102, R107, R108, R115, R116, R124, R125, R127, R128	100R/250 mW	RESC3216X60N	RES / STD / 100R/250mW / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW1206100RFK
57	8	R30, R31, R34, R35, R40, R41, R44, R45	150k	RESC3216X60N	RES / STD / 150k / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW1206150KFK
58	4	R23, R24, R82, R83	200k	RESC3216X60N	RES / STD / 200k / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Vishay	CRCW1206200KFK
59	4	R223, R224, R225, R226	499k	RESC3216X60N	RES / STD / 499k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay	CRCW1206499KFK
60	2	R174, R176	681k	RESC3216X60N	RES / STD / 681k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay	CRCW1206681KFK
61	10	R122, R123, R126, R168, R169, R170, R171, R172, R178, R179	953k	RESC3216X60N	RES / STD / 953k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay	CRCW1206953KFK
62	6	C21, C22, C23, C24, C25, C26	470 uF/550 V	CAP-THT-ECS2HBB471M350060	CAP / ELCO / 470uF/550V / 550V / 20% / Aluminiumelectrolytic / -25¡ãC to 105¡ãC / 10.00mm Pitch X 36.00mm Dia X 62.00mm H / THT / -	Jianghai	ECS2HBB471M350060
63	6	R47, R49, R56, R57, R71, R73	5.1R	RESC2013X70N-1	RES / STD / 5.1R / 500mW / 5% / 600ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Panasonic	ERJP06J5R1V

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
64	2	R19, R52	10k	RESC1608X55N-1	RES / STD / 10k / 250mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Panasonic	ERJUP3F1002V
65	1	C9	22 uF	CAPC2013X145N-0	CAP / CERA / 22uF / 25V / 20% / X5R (EIA) / -55¡ãC to 85¡ãC / 805(2012) / SMD / -	Murata	GRM21BR61E226ME44L
66	5	C69, C71, C75, C119, C127	10 uF	CAPC2013X145N-0	CAP / CERA / 10uF / 50V / 10% / X5R (EIA) / -55¡ãC to 85¡ãC / 805(2012) / SMD / -	Murata	GRM21BR61H106KE43K
67	4	C31, C32, C34, C39	100 nF	CAPC2013X135N	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55°C to 125°C / 0805(2012) / SMD / -	Murata	GRM21BR71H104KA01
68	1	C7	10 uF	CAPC2013X145N-0	CAP / CERA / 10uF / 25V / 10% / X7R (EIA) / -55¡ãC to 125¡ãC / 805(2012) / SMD / -	Murata	GRM21BZ71E106KE15L
69	2	C68, C116	10 uF	CAPC3216X180N	CAP / CERA / 10uF / 50V / 10% / X5R (EIA) / -55¡ãC to 85¡ãC / 1206(3216) / SMD / -	Murata	GRM31CR61H106KA12
70	4	C18, C19, C20, C28	220 nF	CAPC5750X200N	CAP / CERA / 220nF / 630V / 10% / X7R (EIA) / -55°C to 125°C / 2220(5750) / SMD / -	Murata	GRM55DR72J224KW01L
71	2	C36, C37	1 uF	CAPC1608X50N	CAP / CERA / 1uF / 25V / 10% / X5R (EIA) / -55°C to 85°C / 0603(1608) / SMD / -	Murata	GRM185R61E105KA12
72	2	C77, C78	100 nF	CAPC1608X90N	CAP / CERA / 100nF / 16V / 10% / X5R (EIA) / -55¡ãC to 85¡ãC / 0603(1608) / SMD / -	Murata	GRM188R61C104KA01
73	1	C41	1 nF	CAPC1608X90N	CAP / CERA / 1nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Murata	GRM188R71E102KA01
74	1	C40	10 nF	CAPC1608X90N	CAP / CERA / 10nF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Murata	GRM188R71E103KA01
75	3	C62, C64, C66	220 nF	CAPC1608X90N	CAP / CERA / 220nF / 25V / 5% / X7R (EIA) / -55¡ãC to 125¡ãC / 0603(1608) / SMD / -	Murata	GRM188R71E224JA88
76	3	C61, C63, C65	100 nF	CAPC1608X90N	CAP / CERA / 100nF / 50V / 5% / X7R (EIA) / -55¡ãC to 125¡ãC / 0603(1608) / SMD / -	Murata	GRM188R71H104JA93

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
77	4	C72, C76, C120, C128	10 uF	CAPC2013X95N	CAP / CERA / 10uF / 25V / 20% / X5R (EIA) / -55¡ãC to 85¡ãC / 0805(2012) / SMD / -	Murata	GRM219R61E106MA12
78	18	C79, C80, C85, C88, C90, C92, C93, C94, C97, C98, C100, C102, C103, C104, C105, C107, C111, C112	1 uF/50 V	CAPC2013X95N	CAP / CERA / 1uF/50V / 50V / 10% / X5R (EIA) / -55°C to 85°C / 0805(2012) / SMD / -	Murata	GRM219R61H105KA73
79	6	Q1, Q2, Q3, Q4, Q5, Q6	IMDQ75R016M1H	SOP114P2095X250-22N-V	CoolSiC Power Device, 750V, 98A	Infineon Technologies	IMDQ75R016M1H
80	1	G2	LMR51420YFDDCR	SOT95P280X110-6N-1	Simple Switcher Power Converter, Synchronous Buck Converter	Texas Instruments	LMR51420YFDDCR
81	1	U1	LMV721M5/NOPB	SOT95P280X145-5N-2	Low Noise, Low Voltage, and Low Power Operational Amplifier	Texas Instruments	LMV721M5/NOPB
82	1	L6	33 uH	IND-SMD-LPS6225	IND / STD / 33uH / 1.2A / 20% / -40°C to 85°C / 260mR / SMD / Inductor, SMD; 2 pins, 6.00 mm L X 6.00 mm WX 2.50 mm H body / SMD / -	Coilcraft	LPS6225-333MRB
83	8	L7, L8, L9, L15, L17, L18, L21, L22	68 uH	INDC2016X95N_LQH2MC_02	IND / STD / 68uH / 100mA / 10% / -40¡ãC to 85¡ãC / 8.58R / 0805(2012) / Inductor,Chip;2.00mm L X 1.60mm W X 0.95mm H / SMD / -	Murata	LQH2MCN680K02
84	1	D5	Green	LED-THT-LTL-4232N	LED, High Intensity, General Purpose Lead,	LiteOn Optoelectronics	LTL-4232N
85	2	B1, B2	MCR1101-50-3	SOIC127P1031X264-16N-1	High Accuracy Magnetic Current Sensor IC with 1.5MHz 3dB Bandwidth and Isolation 50A	ACEINNA	MCR1101-50-3
86	2	R74, R75	0R	RESC1609X55N-5	RES / STD / 0R / 125mW / - / - / -55°C to 155°C / 0603(1608) / SMD / -	Vishay	MCT06030Z0000ZP500
87	4	D7, D13, D21, D29	2.4 V	SODFL1608X70N	Zener Voltage Regulator, 2.4V, 10mA	ON Semiconductor	MM5Z2V4T1G
88	3	R96, R98, R99	5k	NTCC2013X95N	RES / NTC / 5k / 210mW / 3% / - / -55°C to 150°C / 0805(2012) / SMD / -	Vishay	NTCS0805E3502HLT

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
89	1	MP7	110 uH	IND-PI240866V1	IND / STD / 110uH / 45.3A / - / - / 7.16mR / THT / IND, 79.50 mm L X 233.122 mm W X 66.82 mm H body / THT / -	POCO Holding Co., Ltd	PI240866V1
90	11	R3, R4, R5, R6, R8, R10, R58, R60, R84, R95, R100	10k	RESC1608X55N-1	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 0603(1608) / SMD / -	Yageo	RC0603FR-0710KL
91	14	R91, R92, R131, R133, R134, R136, R137, R139, R141, R146, R166, R167, R180, R181	10R	RESC1608X55N-1	RES / STD / 10R / 100mW / 1% / 200ppm/K / -55¡ãC to 155¡ãC / 0603(1608) / SMD / -, RES / STD / 10R / 100mW / 1% / 200ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Yageo	RC0603FR-0710RL
92	2	R11, R12	100R	RESC1608X55N-1	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Yageo	RC0603FR-07100RL
93	14	R62, R63, R64, R65, R147, R148, R149, R150, R151, R153, R158, R159, R164, R165	0R	RESC1608X55N-1	RES / STD / 0R / 100mW / 0R / 0ppm/K / -55¡ãC to 155¡ãC / 0603(1608) / SMD / -	Yageo	RC0603JR-070RL
94	6	R1, R2, R7, R9, R16, R17	10k/250 mW	RESC3116X65N	RES / STD / 10k/250mW / 250mW / 1% / 100ppm/K / -55¡ãC to 155¡ãC / 1206(3216) / SMD / -	Yageo	RC1206FR-0710KL
95	1	R18	0R	RESC3116X65N-6	RES / STD / 0R / 250mW / 5% / - / -55°C to 155°C / 1206(3216) / SMD / -	Yageo	RC1206JR-070RL
96	13	MP8, MP9, MP10, MP11, MP12, MP13, MP14, MP24, MP29, MP30, MP31, MP46, MP47	RM3X10MM 2701	SCREW_M3X10_RM3X10MM 2701	Pan Head Screw, M3X10 mm	APM Hexseal	RM3X10MM 2701
97	2	U2, U3	SN74HC08DR	SOIC127P600X175-14N-1	Quadruple 2-Input Positive-AND Gate	Texas Instruments	SN74HC08DR

#	Qty	Designator	Value	Footprint	Description	Manufacturer	Manufacturer order number
98	1	G1	TLE42744GS V33	SOT230P700X180-4N-3	Monolithic integrated low dropout voltage regulator, device is designed for the harsh environment of automotive applications, Very Low Current Consumption, Output Current Limitation, Reverse Polarity Protection	Infineon Technologies	TLE42744GS V33
99	1	HS	N/A	N/A	Anodized Copper/MP00001425	Custom Made	Contact Infineon Support
100	.125	TP	N/A	N/A	GAP PAD, 8inx16in Sheet	Bergquist Company	951-GPVOUS-060-00
101	1	IB	N/A	N/A	LHS/RHS	Custom Made	Contact Infineon Support
102	2	ST	N/A	N/A	Alum/Hex/.24in/2-.5in	Lyn-tron	AA6980-2.500-00
103	2	STS	N/A	N/A	MACH SCREW TRUSS PHIL M2.5X0.45	Kanebridge	4753-MJ2.58MPTA2-ND

4 Testing the design

The 6 kW HERIC reference design is tested using the XMC7200-based power control board reference design REF-CLBXMC7PEC that can be purchased separately. It is operated in an off-grid mode and tested using a resistive and reactive load.

4.1 Flashing the firmware

To flash the firmware, perform the following steps:

1. Connect the 24 V power supply to the control board
2. Add three jumper headers as shown in Figure 26
3. Connect the debug port of the control board to the PC using a USB cable

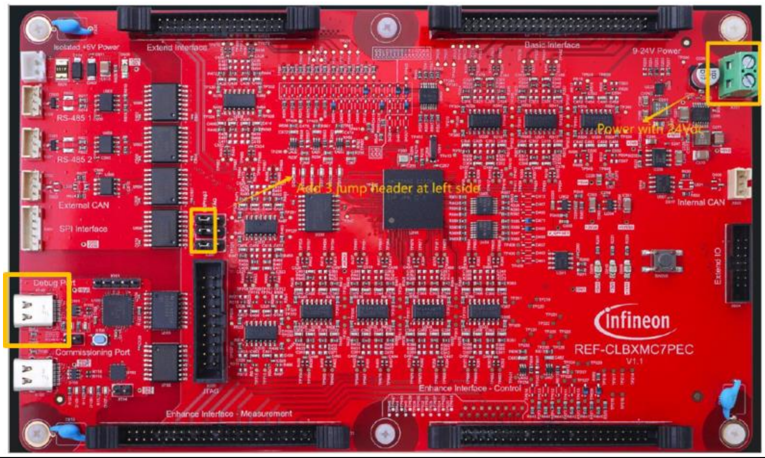


Figure 26 REF-CLBXMC7PEC debug configuration

4. Install the ModusToolbox™ on your PC
5. Open View advanced system setting in the Control panel of your PC
6. In the Advanced tab of system properties, select **Environment Variables** and then under system variables, select Path (Figure 27)

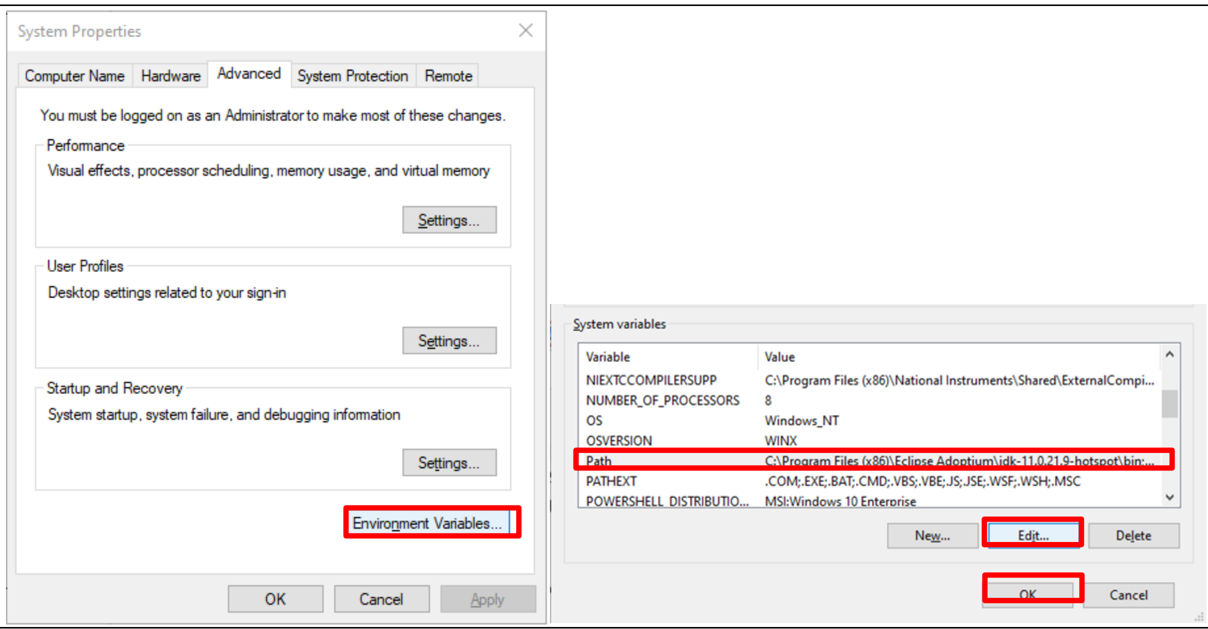


Figure 27 Adding environment variable

7. Select **Delete** and then select **OK** (Figure 28)

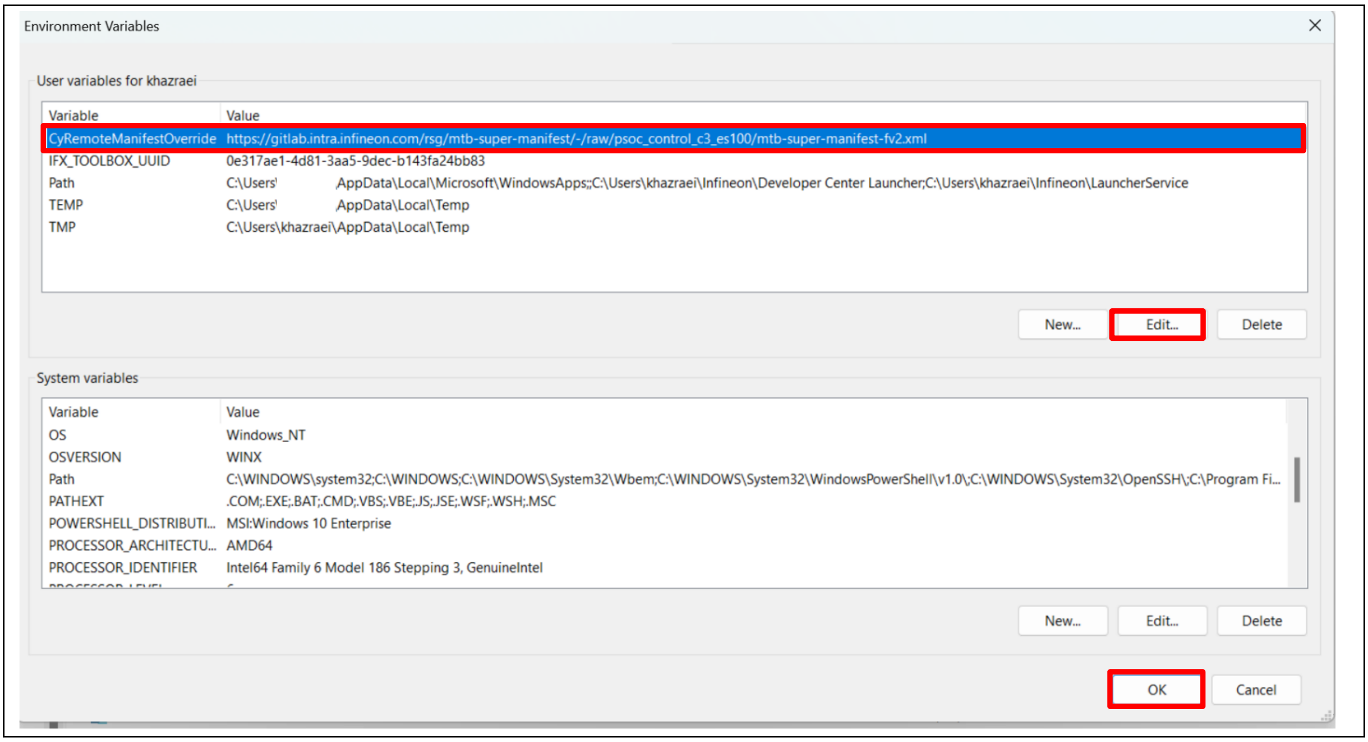


Figure 28 Editing variable

8. In the **User Variables** section, select **Edit**
9. Copy and paste the following link for CyRemoteManifestOverride as seen in Figure 28 and then select **OK** *https://gitlab.intra.infineon.com/rsg/mtb-super-manifest/raw/pext/mtb-super-manifest-fv2.xml*
10. Start the command prompt on your PC and type `openocd` to verify that the previous steps were completed correctly
11. Type the following using the address of the location where the firmware is located on your PC:
```
openocd -s ../scripts -f interface/kitprog3.cfg -f target/cat1c.cfg -c "program
C:/*/AN/Desktop/Firmware/app_combined.hex verify exit"
```

Note: You must change this path (/AN/Desktop/Firmware/app_combined.hex verify exit) to the path used in your installation.*

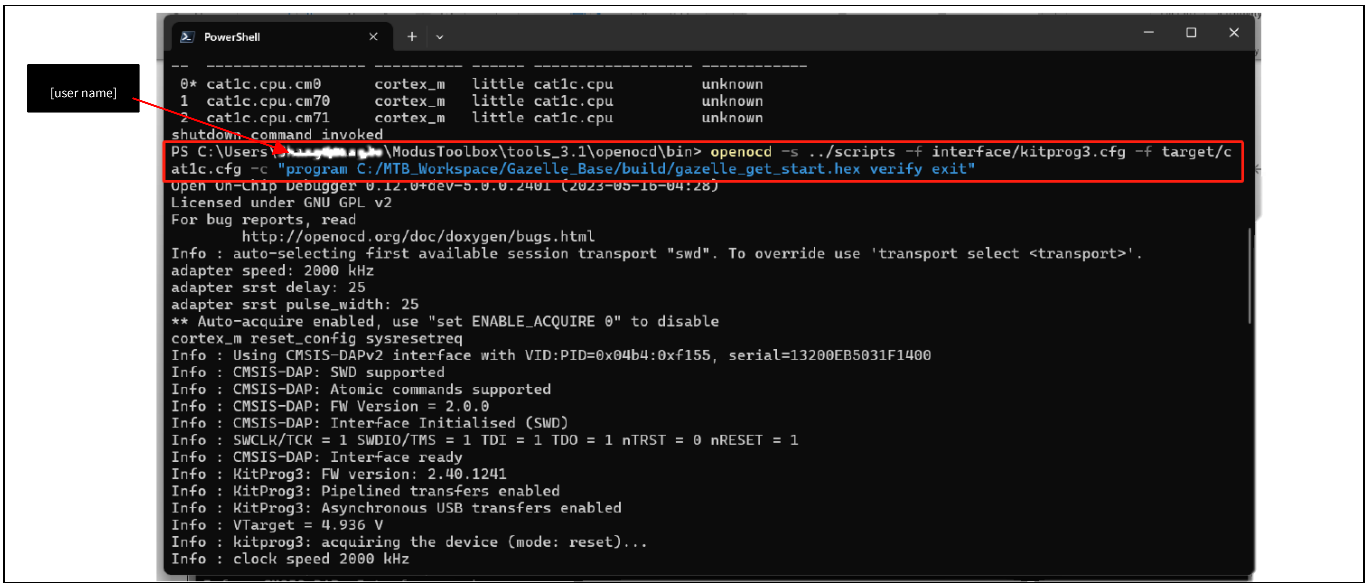


Figure 29 Flashing the firmware

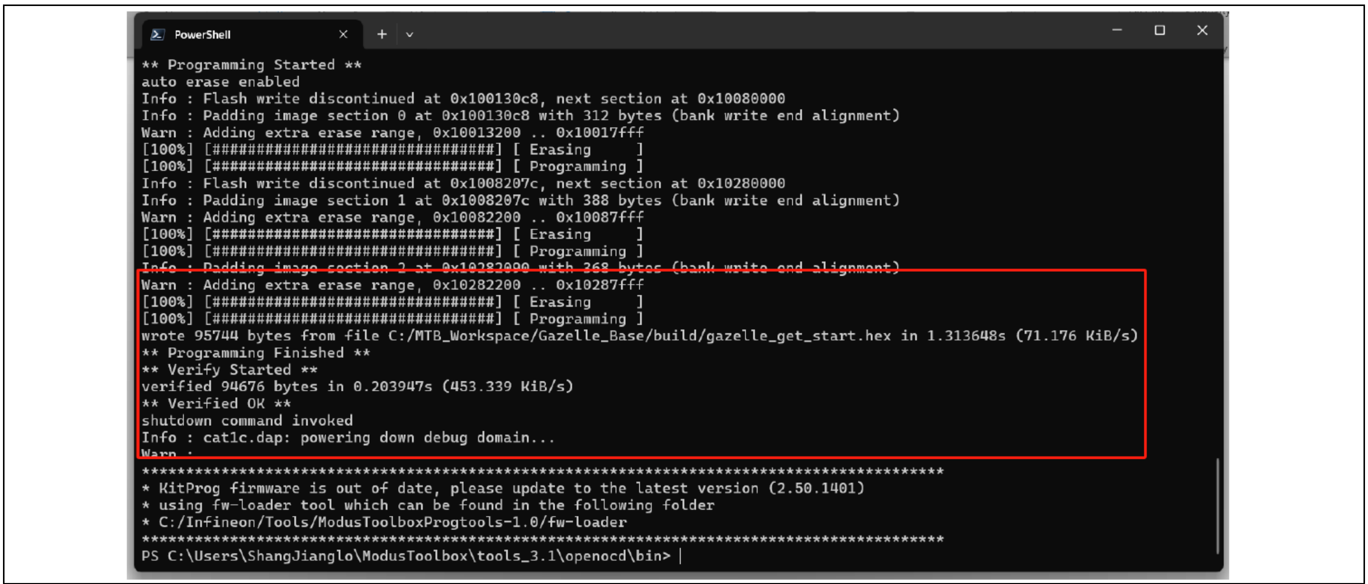


Figure 30 Firmware successfully flashed

12. Remove the jumpers present on the control board
13. Disconnect the external 24 V power supply
14. Connect the USB cable to the commissioning port instead of the debug port

4.1.1 Flashing the firmware using ModusToolbox™ (alternative flashing method)

You must add the environment variable as described in Section 4.1 before flashing the firmware using ModusToolbox™.

1. Open ModusToolbox™ and select Launch Eclipse IDE for Modus Toolbox (Figure 31)

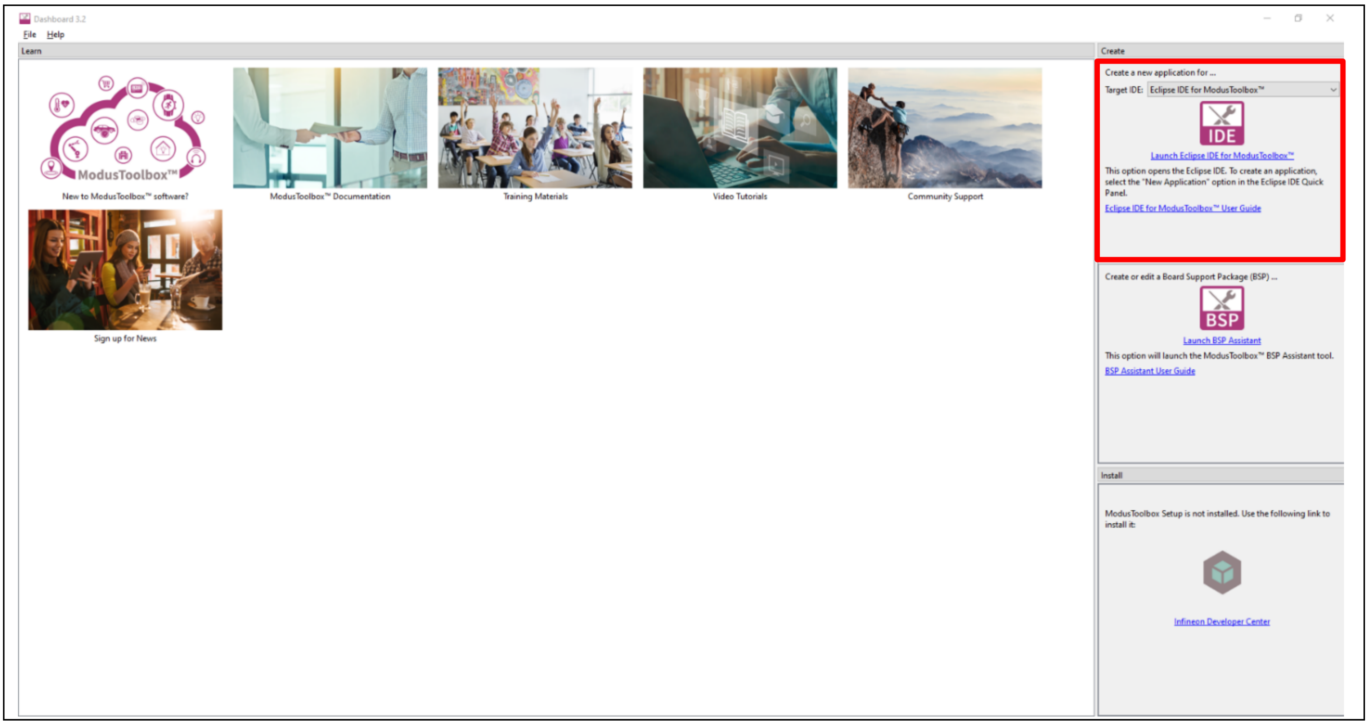


Figure 31 ModusToolbox™ - Launch Eclipse IDE

2. In the left navigation menu, under **Quick Panel** select **New Application**
3. Select **XMC™ BSPs** and then select **KIT_REF_CLBXMC7PEC** and select **Next >** (Figure 32)

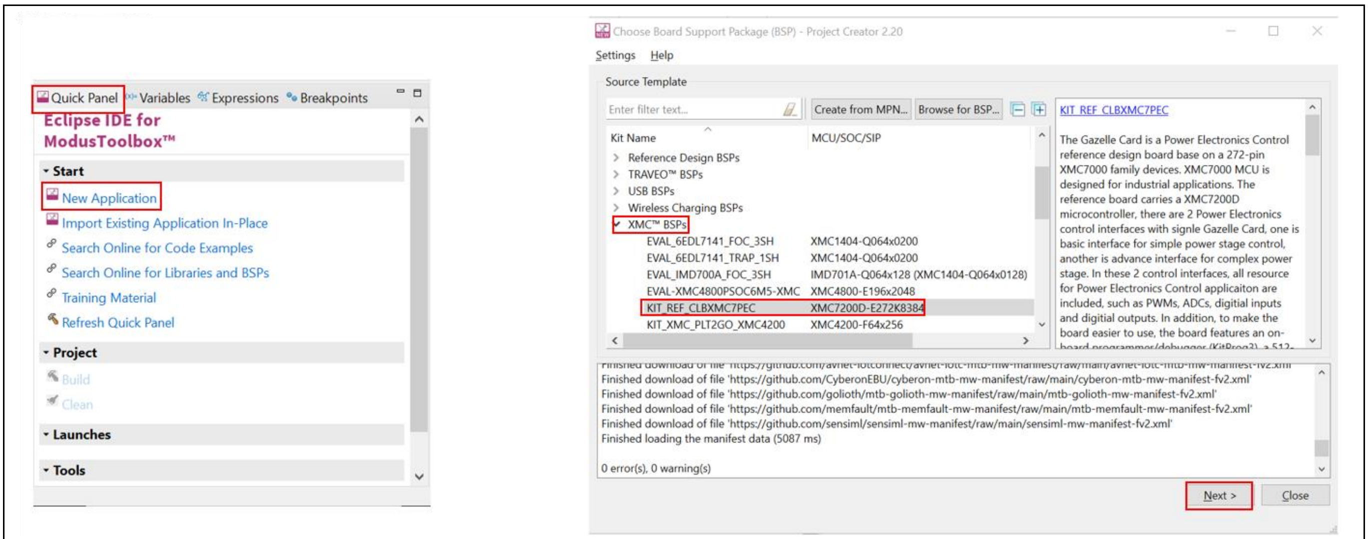


Figure 32 Select application

4. Navigate to where you previously cloned the repository (firmware), select the folder and repository, and click **Create** (Figure 33)

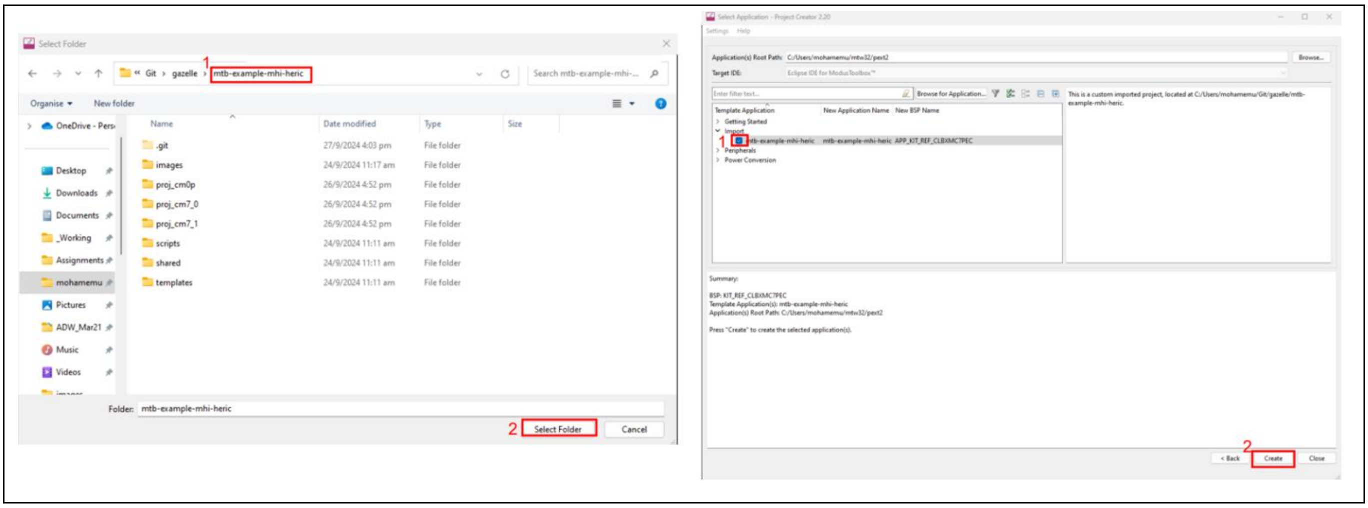


Figure 33 Create a new project

5. Select **Library Manager** under **Tools** in the left navigation **menu** and select **Update** in the Library Manager window (Figure 34)

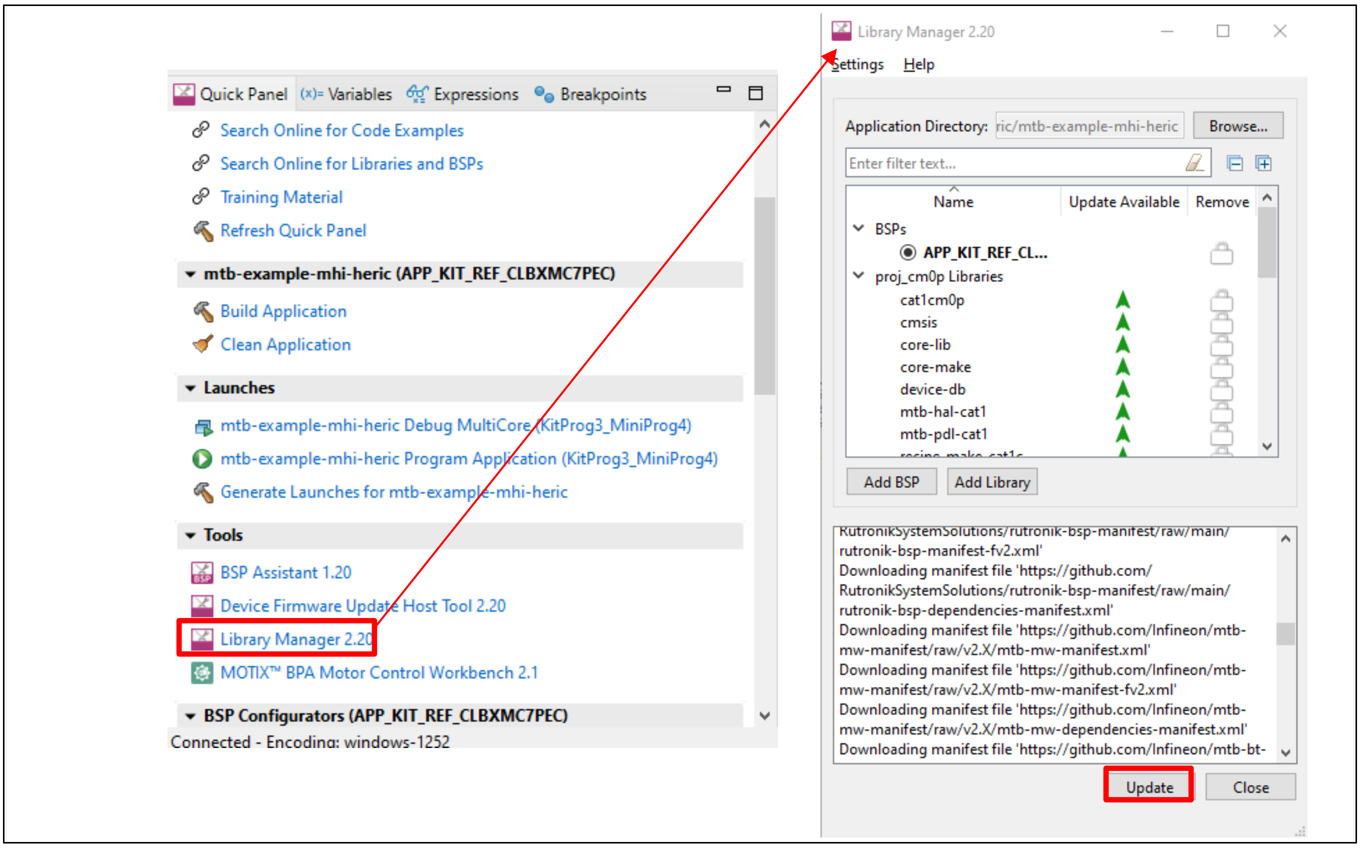


Figure 34 ModusToolbox™ - Library Manager 2.20

6. Select **Build Application** and click **Play** to launch the program (Figure 35).
   D205 and D203 (heartbeat LEDs) will start flashing indicating the firmware has been successfully flashed
7. Remove the jumper on X202 and disable the 24 V supply to proceed to the main board setup

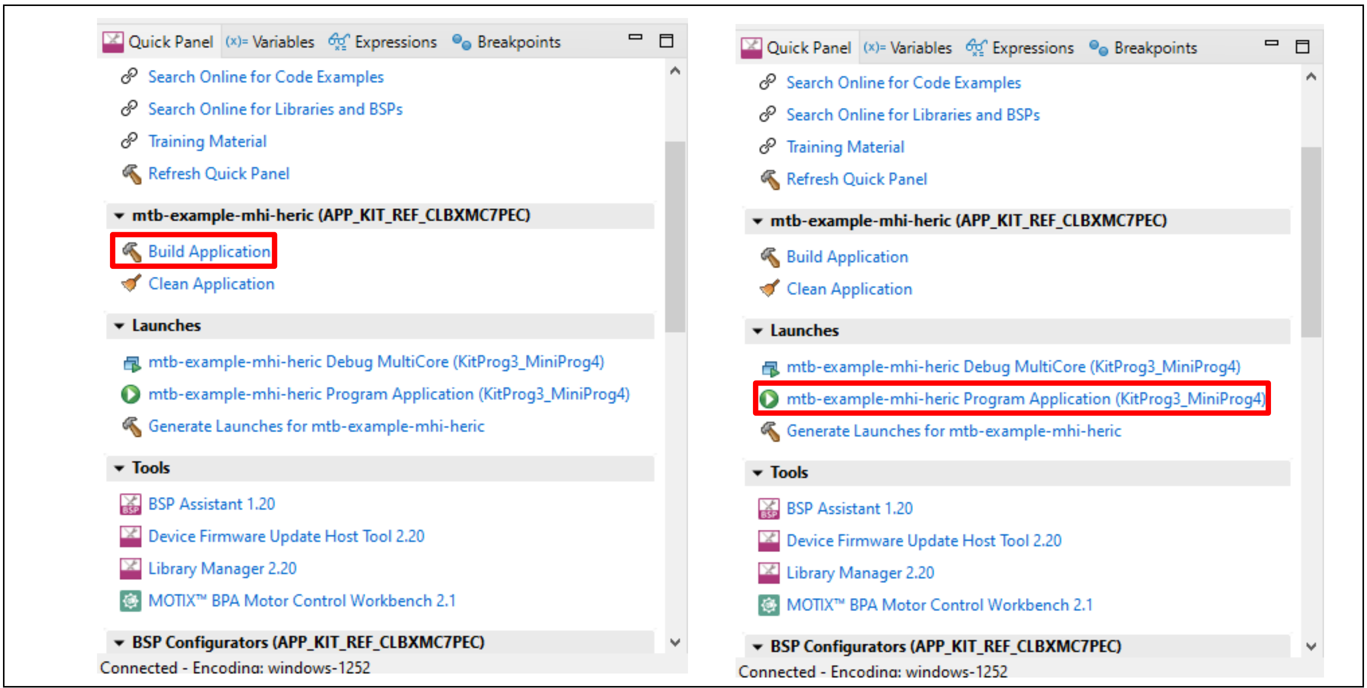


Figure 35 ModusToolbox™ - Build Application

4.2 Control

The firmware allows you to operate the HERIC in an open/close loop using the SPWM scheme. The firmware also allows you to change the modulation index.

4.3 HERIC Debugger graphical user interface

The HERIC Debugger provides a GUI which can control and monitor the application in run-time (Figure 36).

Figure 36 HERIC Debugger GUI

4.3.1 GUI parameters

Table 7 describes the list of parameters within the HERIC Debugger GUI.

Table 7 GUI Parameters

Parameter	Type	Description	Unit	Min. value	Max. value
COM Port	COM Port settings	COM port number for the Commissioning Port	N/A	N/A	N/A
Baud Rate	COM Port settings	The data transfer rate (only 19200 supported)	baud	19200	N/A
Parity Bit	COM Port settings	Error checking bit (only None supported)	N/A	None	N/A
Data Bit	COM Port settings	Number of bits in data packet (only 8-bits supported)	bit	8	N/A
Stop Bit	COM Port settings	Number of stop bits in transfer packet (only 1 stop bit supported)	bit	1	N/A
Open COM	Control Button	To connect GUI to COM port	N/A	N/A	N/A
Close COM	Control Button	To disconnect GUI from COM port	N/A	N/A	N/A
Ctrl Mode	Configurable Input	Converter control mode: Detail is given on UI	N/A	1: Open loop 2: V/F control (off grid)	
Modulation Index	Configurable Input	Modulation index for Open Loop and V/F Control modes	N/A	0.000	1.000
AC Frequency	Configurable Input	AC frequency	Hz	45	65
Fan Duty Cycle	Configurable Input	Fan speed	N/A	0.000	1.000
VAC Set	Configurable Input	AC voltage	V	185	240
Vconv	Application output	Converter RMS voltage	Vrms	N/A	–
Iinv	Application output	Inverter current	Arms	N/A	–
Iconv	Application output	Converter current	Arms	N/A	–
Sconv	Application output	Converter power	VA	N/A	–
Vbus	Application output	Bus voltage	V	N/A	–
Tambient	Application output	Ambient temperature	°C	N/A	–

Parameter	Type	Description	Unit	Min. value	Max. value
HW FaultWord	Application output	HW fault representation	N/A	Bit 0: Iinv overcurrent Bit 1: Iconv overcurrent Bit 6: Vconv overvoltage Bit 7: Vconv undervoltage Bit 8: Vbus overvoltage Bit 9: Watchdog timer no service	–
SW FaultWord1	Application output	SW fault representation (level 1)	n.a.	Bit 0: Iinv overcurrent Bit 1: Iinv undercurrent Bit 2: Iconv overcurrent Bit 3: Iconv undercurrent Bit 6: V_BUS overvoltage Bit 15: V_BUS undervoltage	–
SW Faultword2	Application output	SW fault representation (Level 2)	N/A	Bit 14: AC over-frequency Bit 15 over-frequency	–
State	Application output	HERIC application state representation	N/A	0: Default 10: Standby 30: Run 50: Stop 70: Fault	–
Fault	Application output	Fault state indication	N/A	Green: No fault Red: Fault	–

4.3.2 Connecting to the board with the GUI

This section provides a guide for using the GUI with the control board.

1. Connect the HERIC board and control board as shown in Section 4.4.1.

Note: The signal cables from the power board provide the necessary power to the control board. No external power supply is required for the control board.

2. Connect an external 24 V power supply to the HERIC board via X23 (Figure 37).

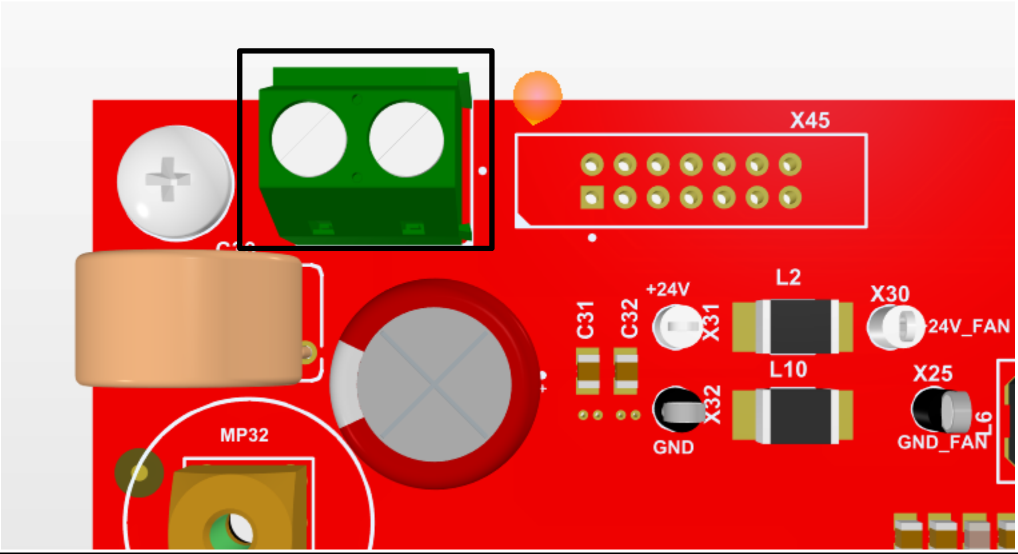


Figure 37 X31 and X32 for connection to external 24 V

3. Connect a USB cable via the commissioning port of the control board to the PC (Figure 38)

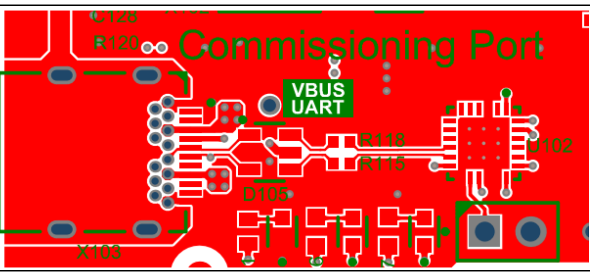


Figure 38 Commissioning port on Control board

4. Launch the HERIC Debugger GUI on PC. A login window will appear (Figure 39). Select Normal mode and key in 123456 as the password.

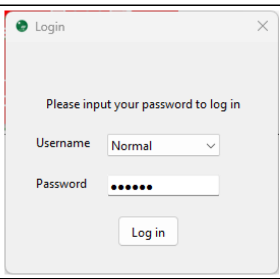


Figure 39 Login window for HERIC Debugger GUI

5. In the COM port setting in the GUI, select the **COM Port** number for the control board. If unsure about the number, check in the PC's **Device Manager** (Figure 40). Then, click **Open COM**.

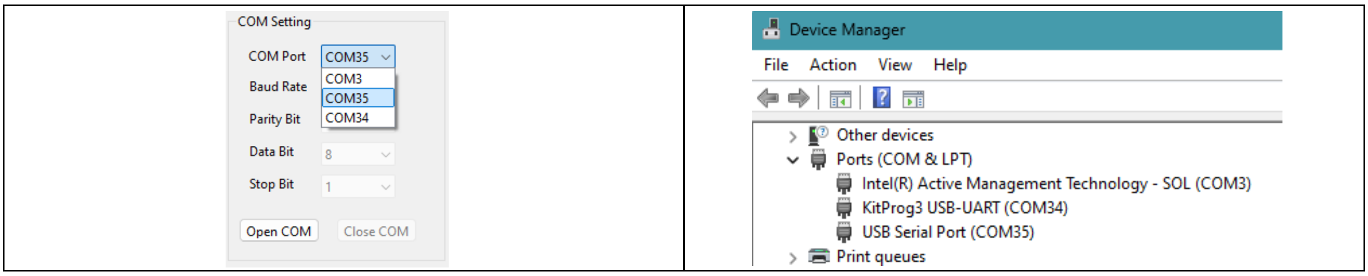


Figure 40 COM Port number selection

6. Switch on the input **Vbus** supply. The Vbus value should be reflected on the GUI (Figure 41) to show that the connection is successful.

Figure 41 GUI connection successful

4.3.3 Using the converter in the open loop mode

Prerequisite

The setup is successfully up and running and the GUI shows the connection to the board as per the guide in Section 4.3.2 Connecting to the board with the GUI.

1. Select **Open Loop** from the dropdown options under **Ctrl Mode**
2. Set the **Modulation Index** value
3. Set the **AC Frequency** value
4. Click **Start**

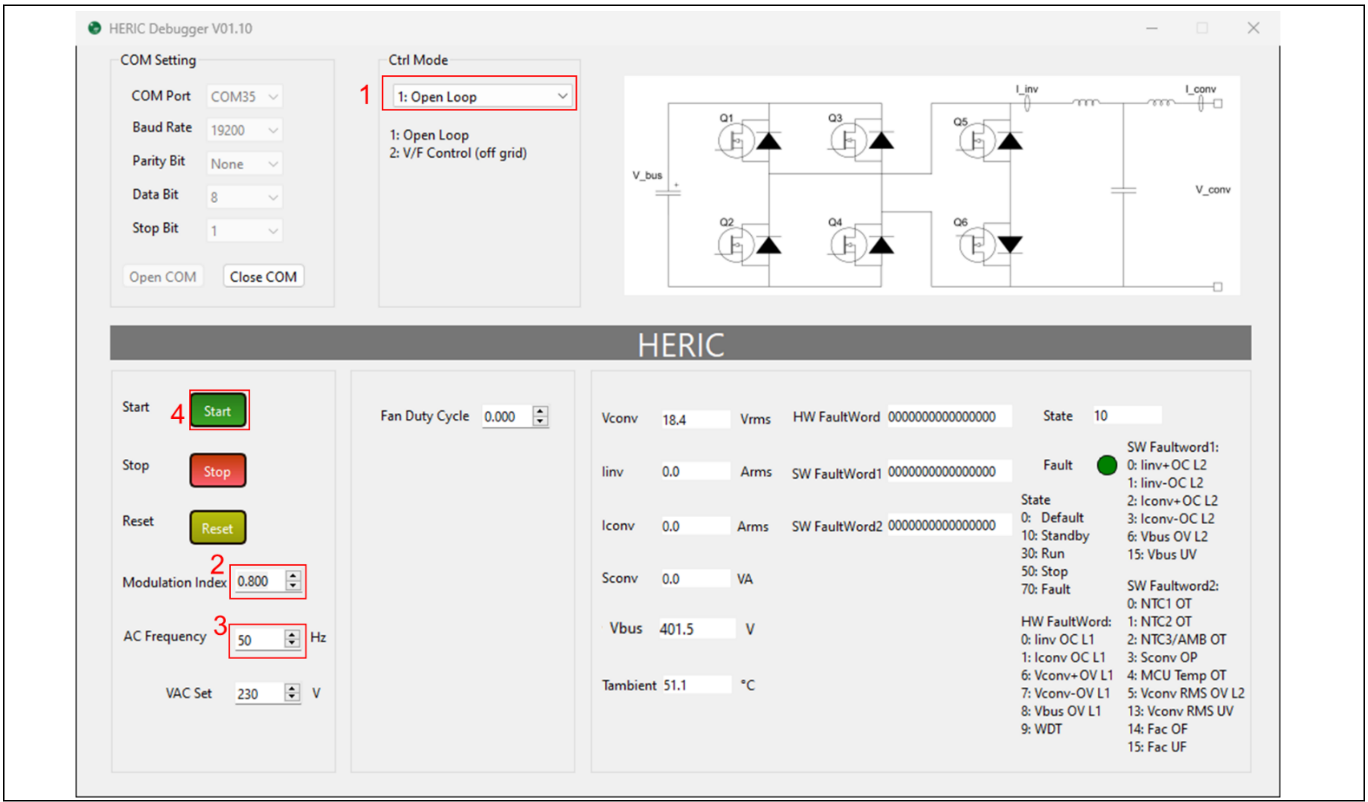


Figure 42 **Using the converter in the Open Loop mode**

Note: *The modified parameters in the GUI (e.g. Modulation Index, AC Frequency) will only be in effect after the Start button is pressed.*

4.3.4 Using the converter in V/F Control Mode

Once the setup is successfully up and running as per the guide in Chapter 4.3.2 Connecting to the board with the GUI, follow the steps below to start the converter in V/F Control mode (Figure 43):

1. Select **V/F Control** from the dropdown options under **Ctrl Mode**
2. Set the **VAC Set** value
3. Set the **AC Frequency** value and click **Start**

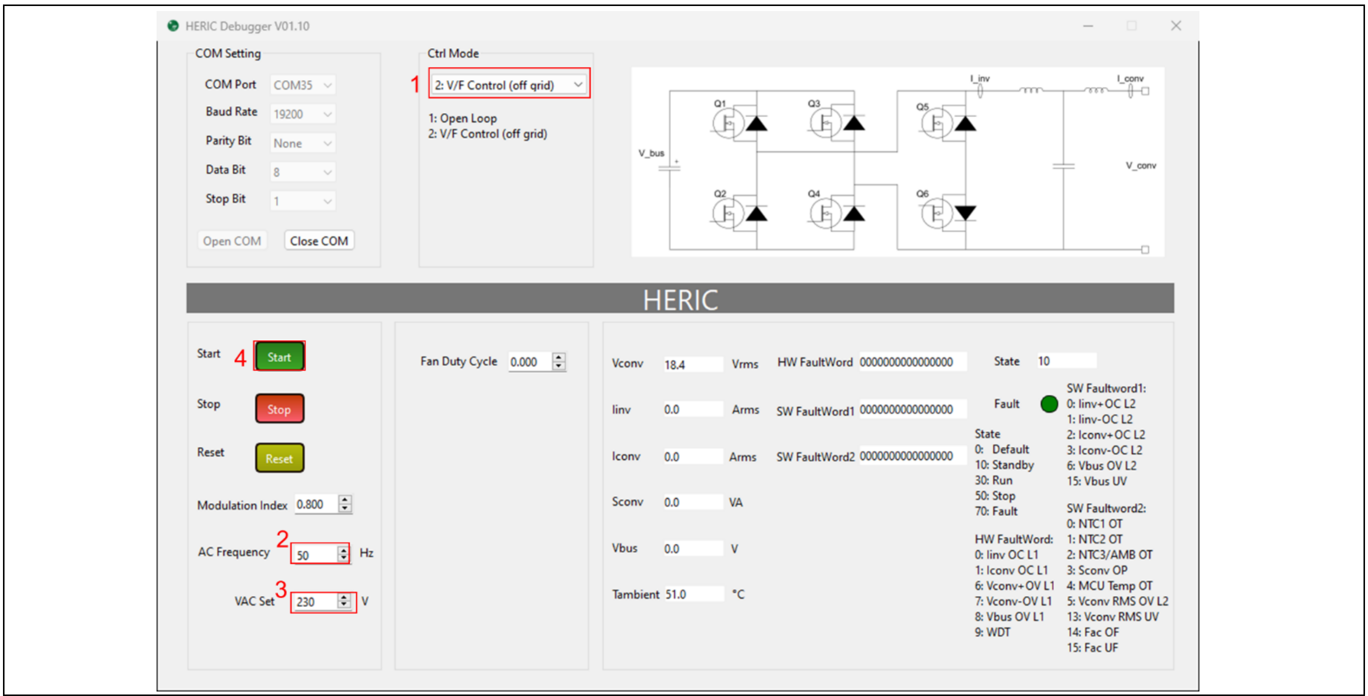


Figure 43 Using the converter in V/F control mode

Note: The modified parameters in the GUI (for example, AC Frequency, VAC Set) will only be in effect after the Start button is pressed.

4.3.5 Rectifying a fault

If there are any faults, the **State** field indicates 70 and the **Fault** indicator will turn red (Figure 44). The fault can then be checked from the fault words (i.e., HW FaultWord, SW FaultWord1, and SW FaultWord2). The fault word bit representation is given in Figure 44.

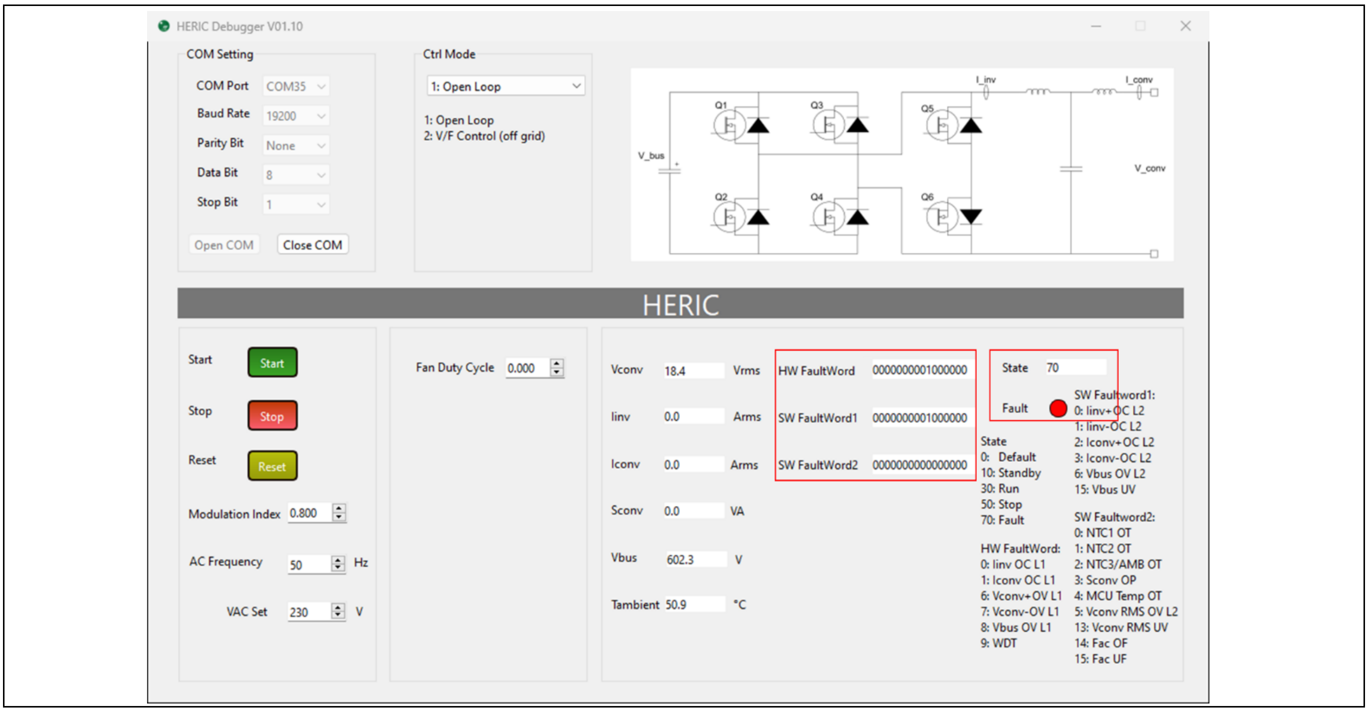


Figure 44 Fault indication in the GUI

Once the fault is investigated and alleviated, you can reset the application. To reset the application, click **Reset**.

4.3.6 Stopping the converter

To stop the converter, click **Stop** on the GUI as shown in the following figure.

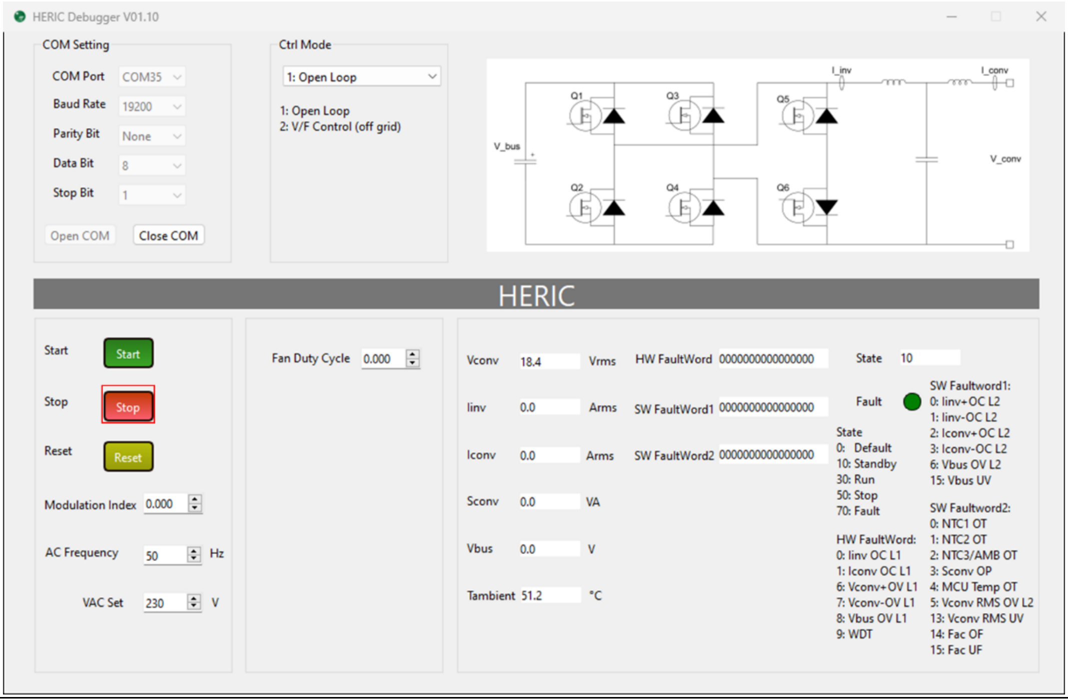


Figure 45 **Stopping the converter**

4.4 Test results

4.4.1 Bench setup

The inverter is operated in a closed loop off-grid mode where the output voltage is regulated.

Note: Do not accidently operate the inverter outside the voltages, currents, and frequencies specified.

The inverter was tested only for the specifications shown in Table 7 with an AC load in the Constant Power mode. If you decide to operate outside these specifications, performance is not guaranteed.

The following equipment is needed to start testing:

- 6 kW HERIC reference design
- REF-CLBXMC7PEC kit with the HERIC firmware
- GUI
- AC load with constant power mode capability (Resistive load could be used alternatively but some results may vary)
- DC power source

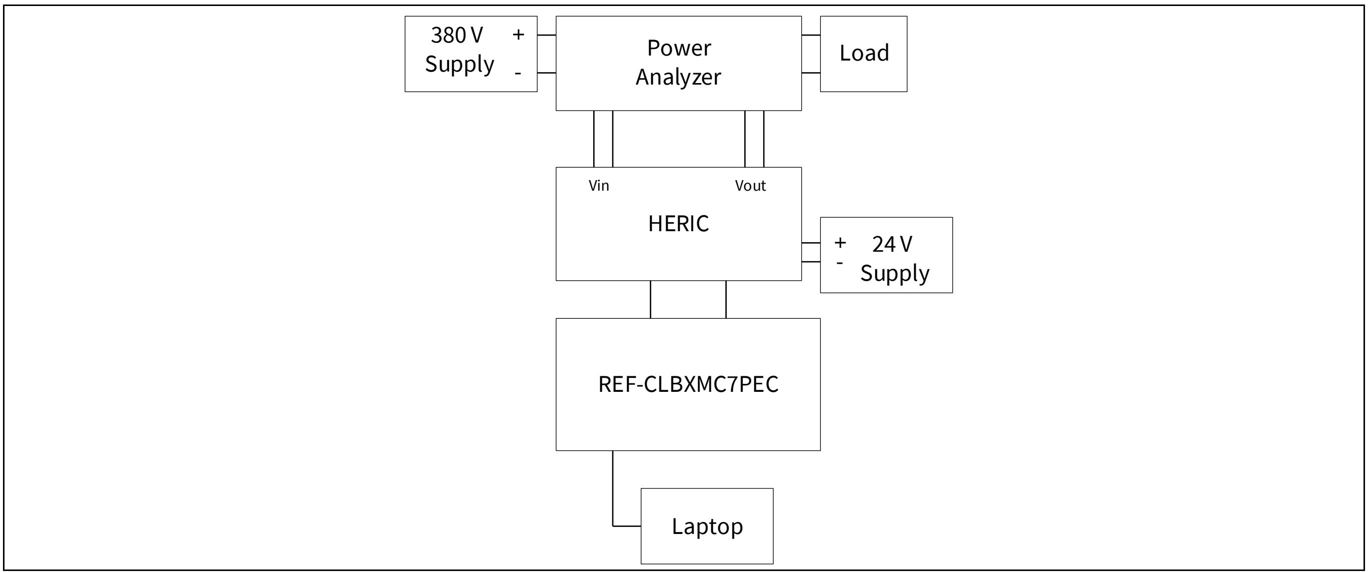


Figure 46 Test setup

4.4.2 Output AC voltage against different DC input voltages

The design was tested with input DC voltages 380 V, 445 V, and 510 V. The output RMS voltage was regulated close to 230 V at a power of 6 kW.

Table 8 DC input voltage range

Input voltages	380 V_{DC}, 445 V_{DC}, and 510 V_{DC}
PWM	50 kHz
Output power	6 kW, V_{out}=230 V_{rms}/ 50 Hz

Table 9 Test data

Input voltage (V_{dc})	**Input Current (A_{dc})**	**Input Power (kW)**	**Output Voltage ($V_{l\text{-}l\ rms}$)**	**Output Power (kW)**	**Output Current (A_{rms})**	**PF**	**iTHD**	**Efficiency**
380	16.13	6.09	231.6	6.0	25.94	0.9993	1.62	98.65
445	13.79	6.1	230	6.0	26.14	0.9994	1.766	98.5
510	12.02	6.1	230	6.01	26.14	0.9992	1.764	98.45

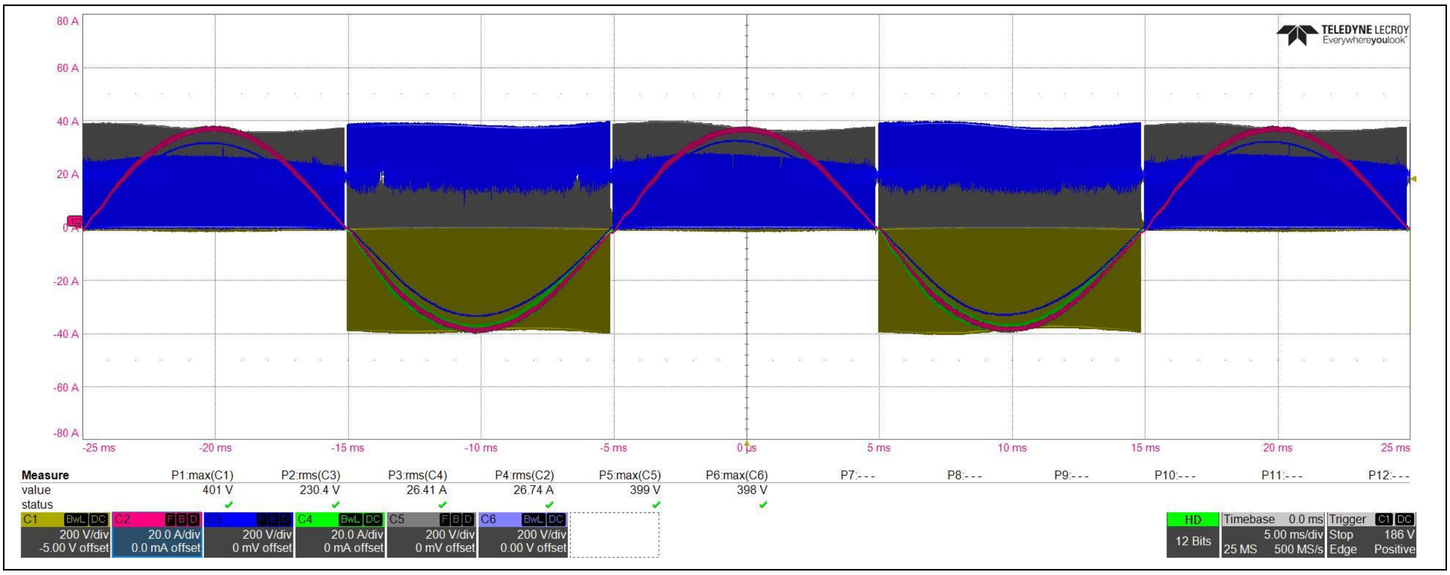


Figure 47 **Input DC voltage = 380 V at 6 kW: CH1: V_{AB}, CH2: LOUT, CH3: Q1 V_{DS}, CH4: I_{RMS}, CH5: Q2 V_{DS}, CH6: V_{OUT}**

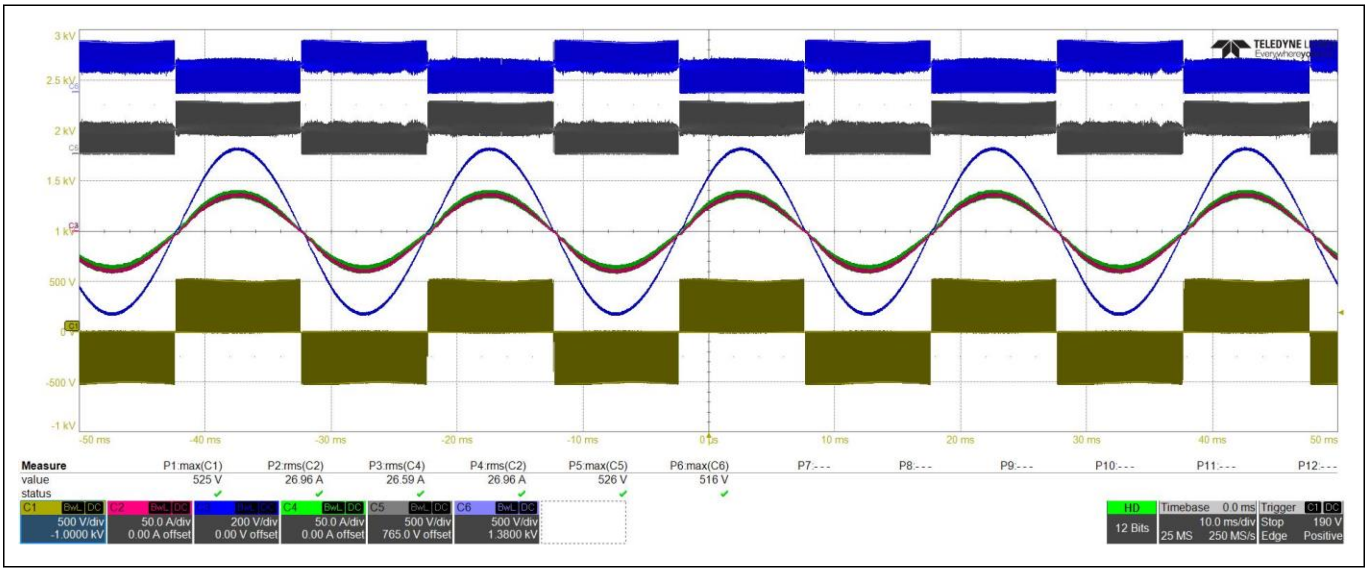


Figure 48 **Input DC voltage = 510 V at 6 kW: CH1: V_{AB}, CH2: L_{OUT}, CH3: Q1 V_{DS}, CH4: I_{RMS}, CH5: Q2 V_{DS}, CH6: V_{OUT}**

4.4.3 Reactive load testing

The inverter is tested with reactive loads at 0.8 leading and lagging power factor. It can be seen from the following images that this inverter can support this wide range of power factor.

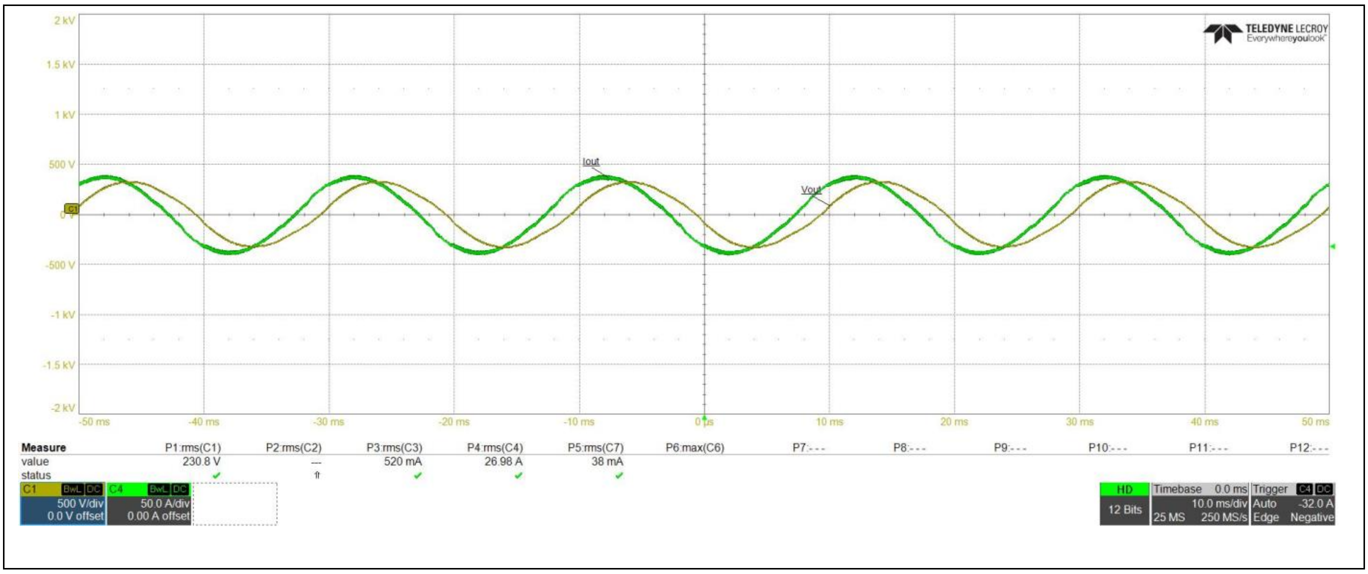


Figure 49 0.8 pF leading CH1: V_{OUT} (230 V_{RMS}), CH2: I_{OUT} (27 A_{RMS})

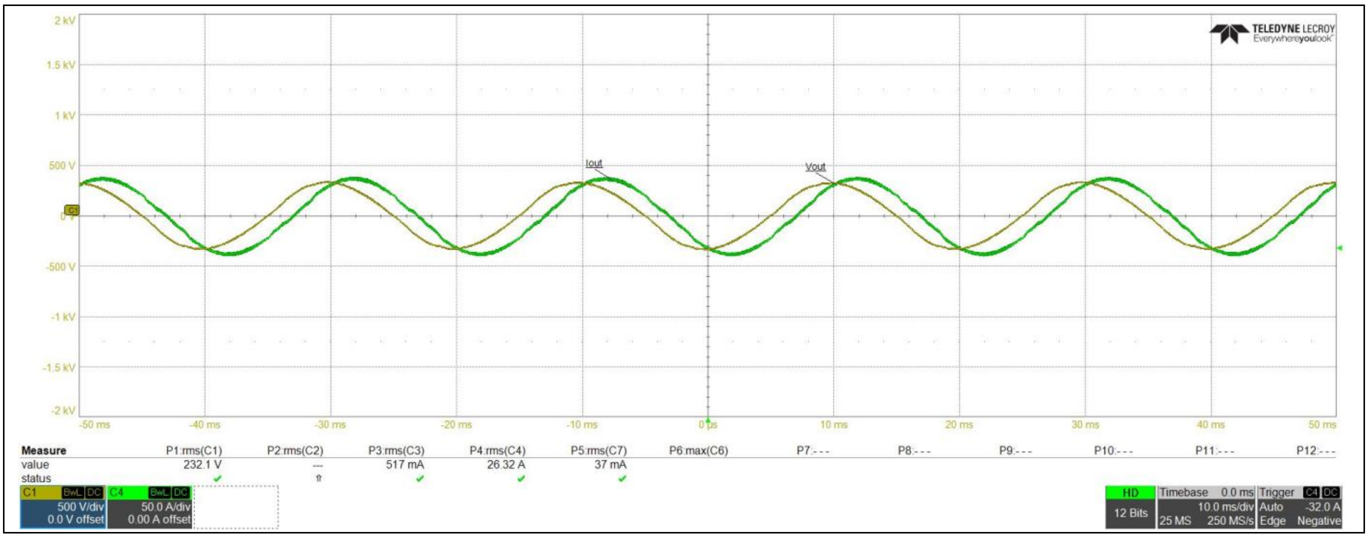


Figure 50 0.8 pF lagging CH1: V_{OUT} (230 V_{RMS}), CH2: I_{OUT} (27 A_{RMS})

4.4.4 Overcurrent protection

The output current is increased until the overcurrent protection reacts. OCD trips when the peak current is 39.6 A.

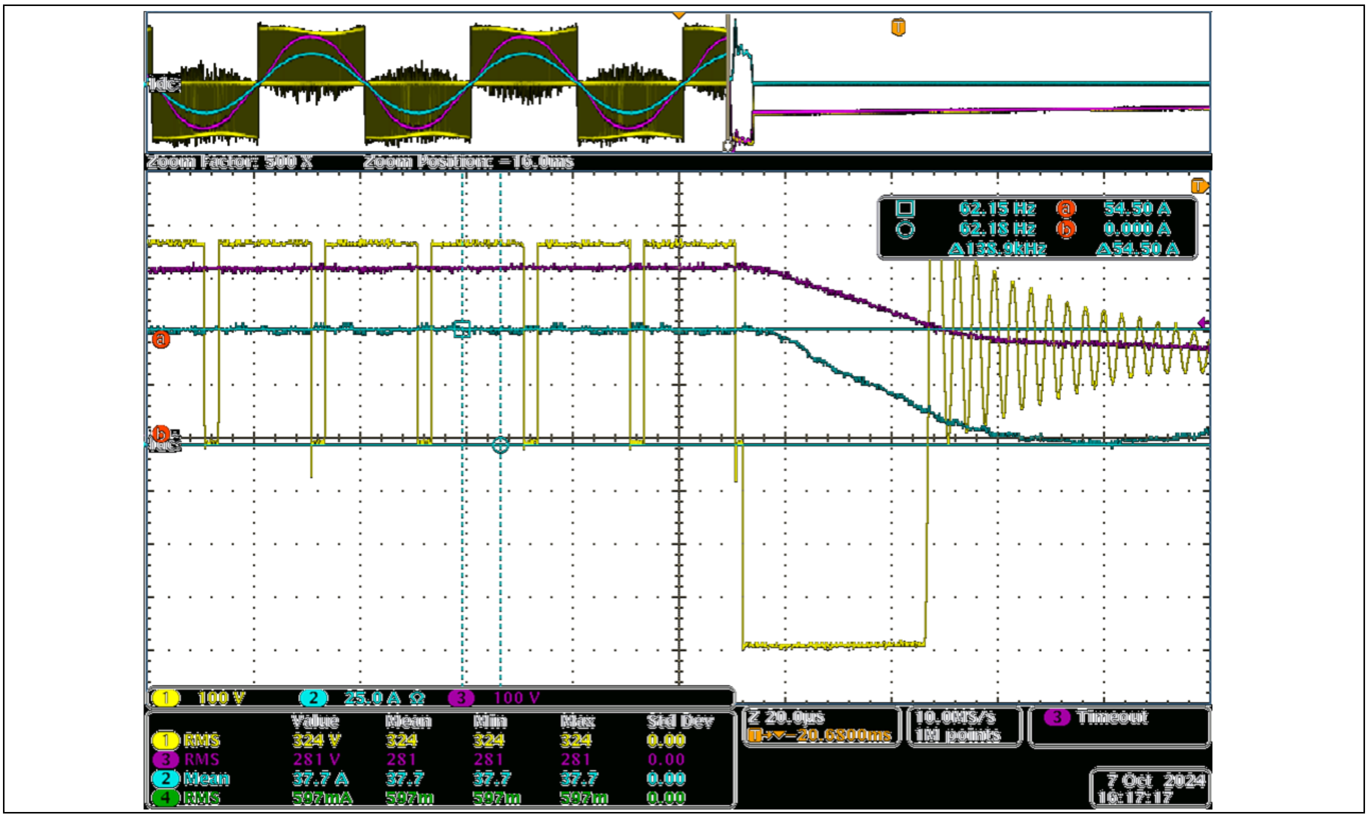


Figure 51 **Overcurrent protection, CH1: Switch node, CH2: I_{AC}, CH3: V_{AC}**

4.4.5 Efficiency and temperature measurements

Table 10 Power semiconductors efficiency measurement

Specification	Efficiency measurement using Tektronix PA3000 power analyzer		
Condition	V_{in} = 380 V, V_{rms}= 230 V, Loading = 5, 10, 20, 30, 40, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, and 100% HERIC Power Stage Efficiency only to demonstrate high efficiency benefits of CoolSiC™		
Operation	**Efficiency at V_{in} = 380 V**	**Efficiency at V_{in} = 445 V**	**Efficiency at V_{in} = 510 V**
5% load	92.87	91.18	89.26
10% load	95.99	95.27	94.10
20% load	97.98	97.36	96.66
30% load	98.48	98.05	97.54
40% load	98.67	98.38	97.95
50% load	98.77	98.51	98.08
55% load	98.75	98.50	98.11
60% load	98.73	98.47	98.14
65% load	98.72	98.46	98.14
70% load	98.69	98.43	98.17
75% load	98.65	98.40	98.14
80% load	98.60	98.39	98.14
85% load	98.57	98.37	98.13
90% load	98.56	98.32	98.13
95% load	98.51	98.28	98.11
100% load	98.46	98.26	98.10
CEC efficiency	98.51	98.2	97.82

Efficiency at 380 V is highest since switching loss is low. At 380 V, 50% load 98.8% efficiency is achieved (max. efficiency). At 510 V, the efficiency is the least due to the higher switching loss.

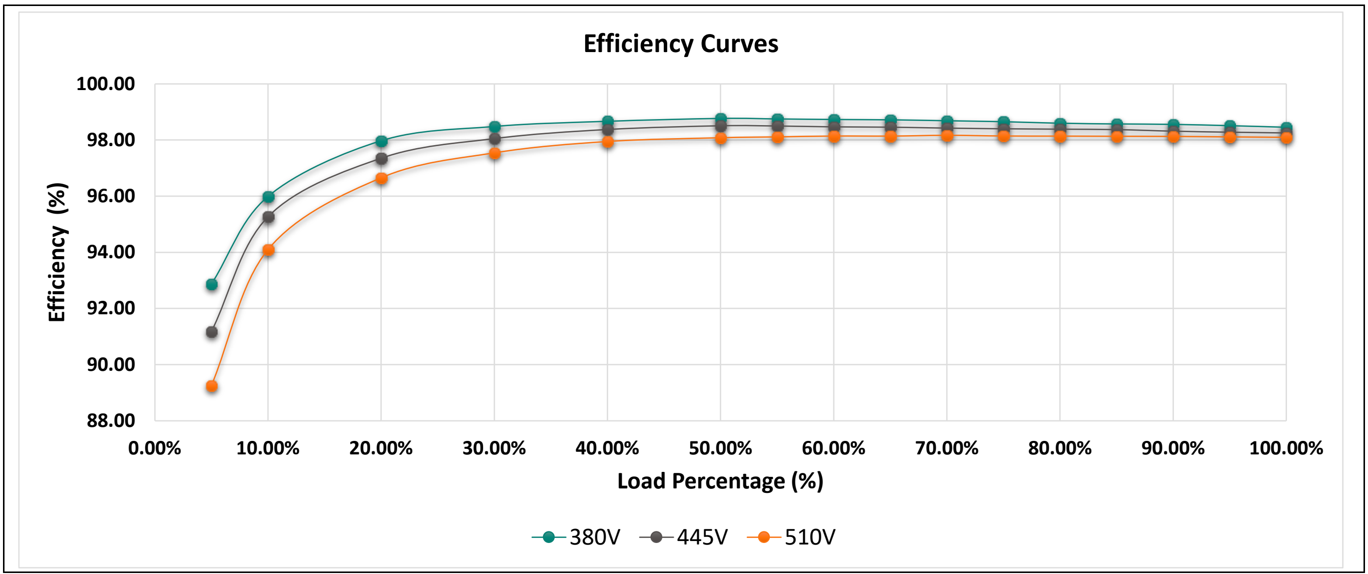


Figure 52 Efficiency of the inverter power stage

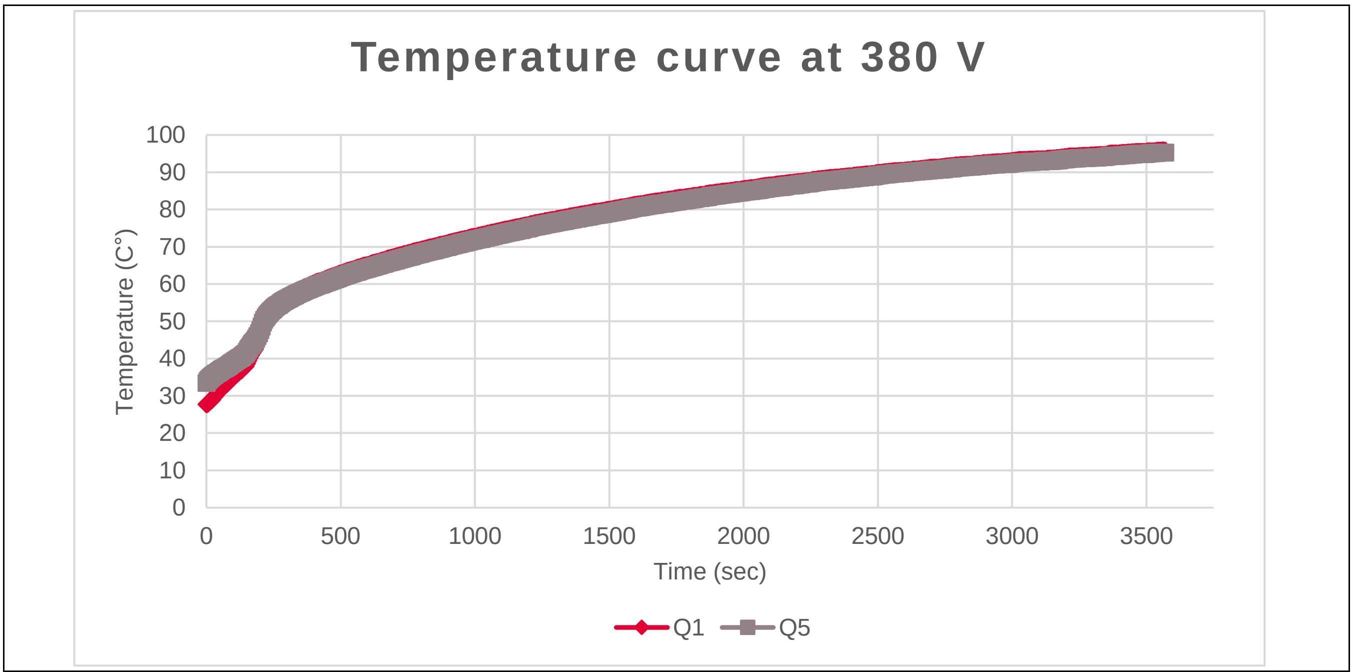


Figure 53 Temperature curves at 380 V

The MOSFETs' temperature increases slowly but stabilizes after an hour. While Q5 (freewheeling MOSFET) conducts more time, the temperature of both MOSFETs are almost the same. This is due to the large duty cycle of Q1 at a lower voltage of 380 V.

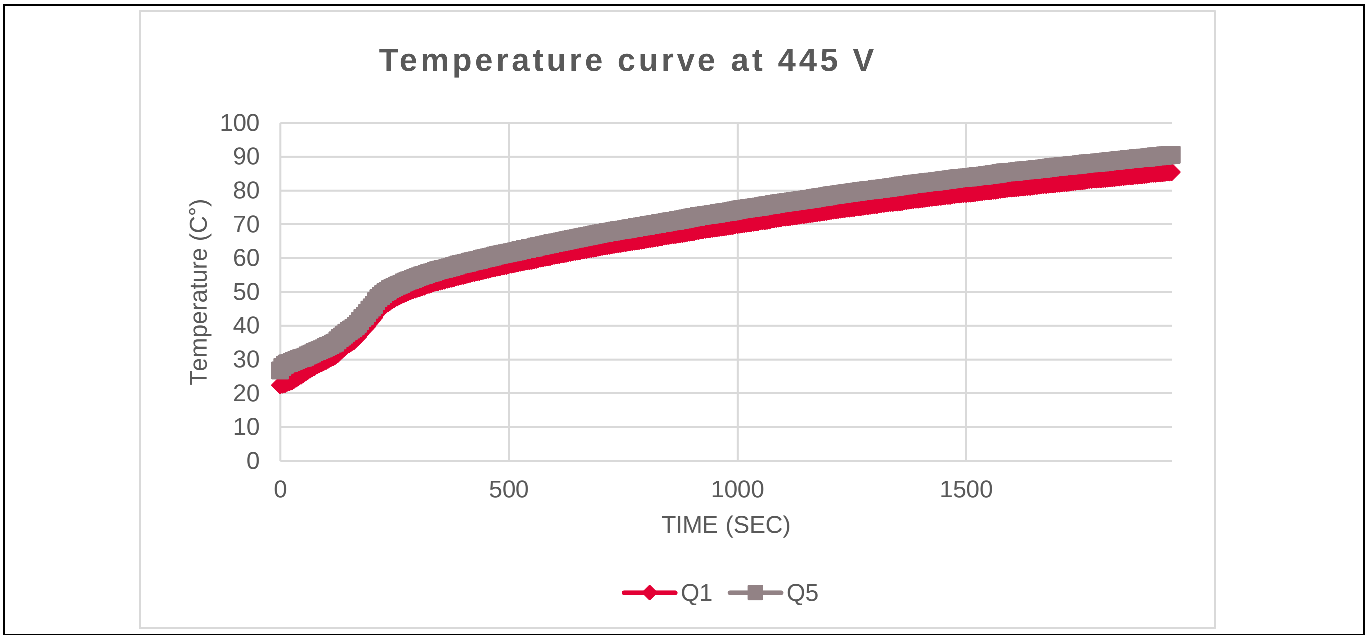


Figure 54 Temperature curves at 445 V

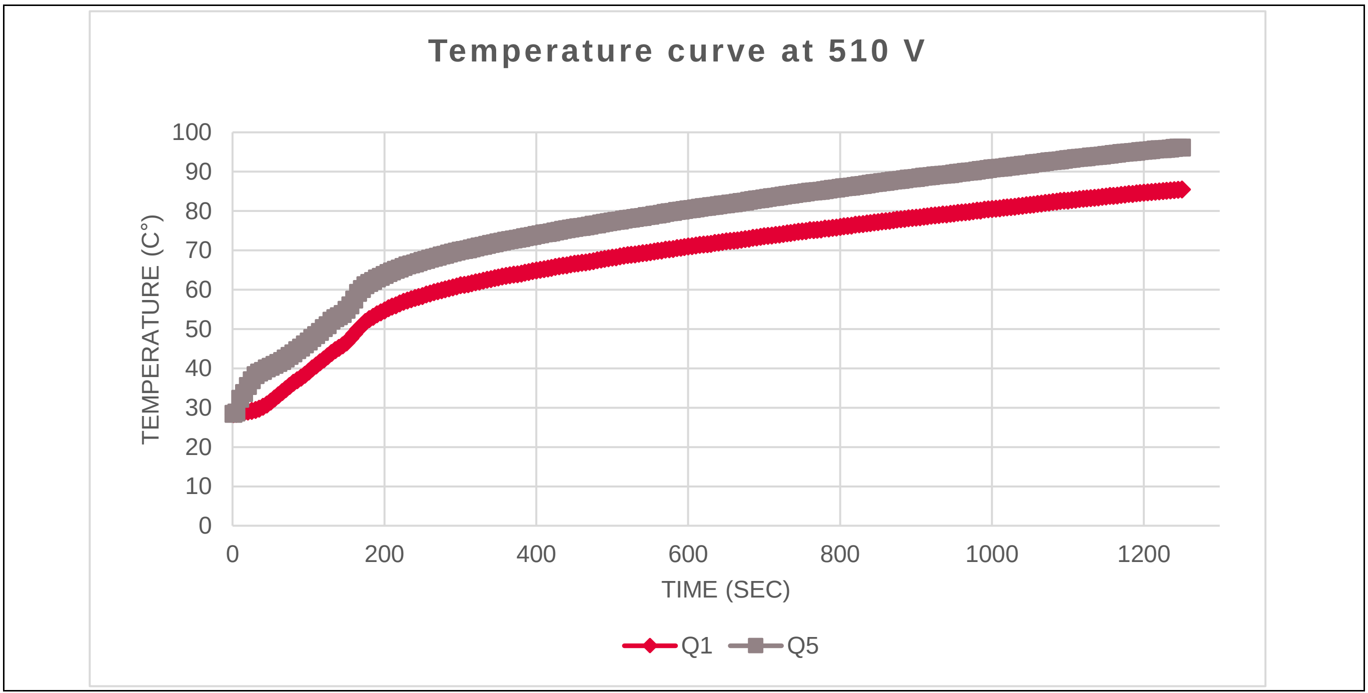


Figure 55 Temperature curves at 510 V

At 510 V input, the duty cycle of top MOSFET (Q1) is less compared to the lower input voltage of 380 V. The increased delta between Q5 and Q1 MOSFET is due to Q5 conducting more.

5 Board layout

5.1 REF-6KWHERIC

Table 11 Mechanical data

Dimensions	250 mm x 155 mm
No. of layers	6
Copper thickness	77.36 mil
Weight	9.02 kg

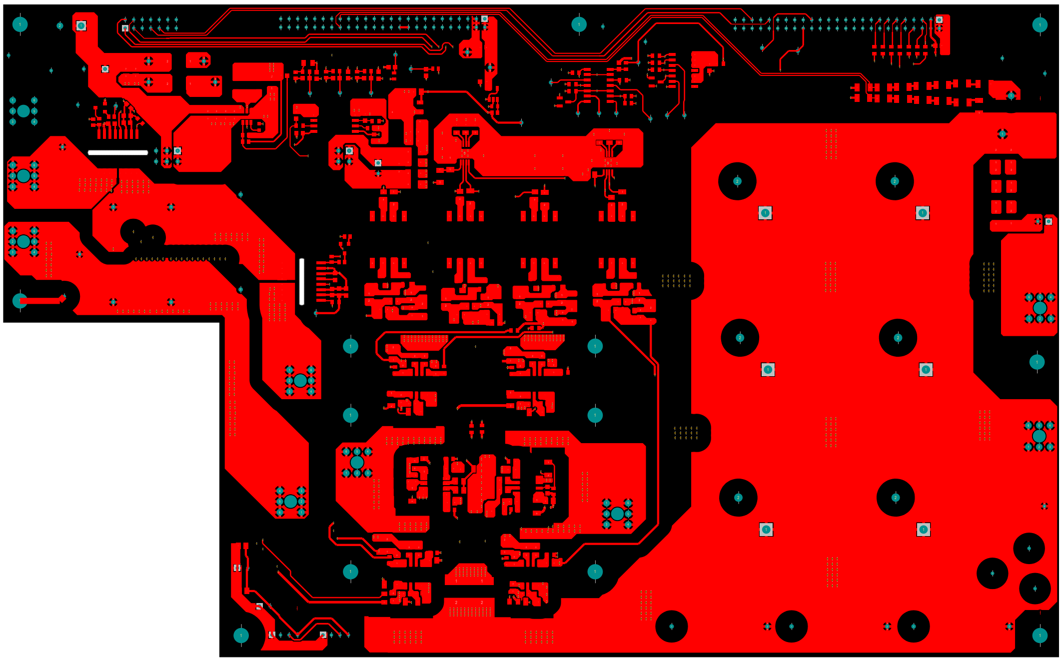


Figure 56 Layer 1 top layer

The top layer contains the traces for high current including MOSFETs current, input BUS_DC+, and AC output. Also, some thin traces have been used for control-related task on the low voltage side.

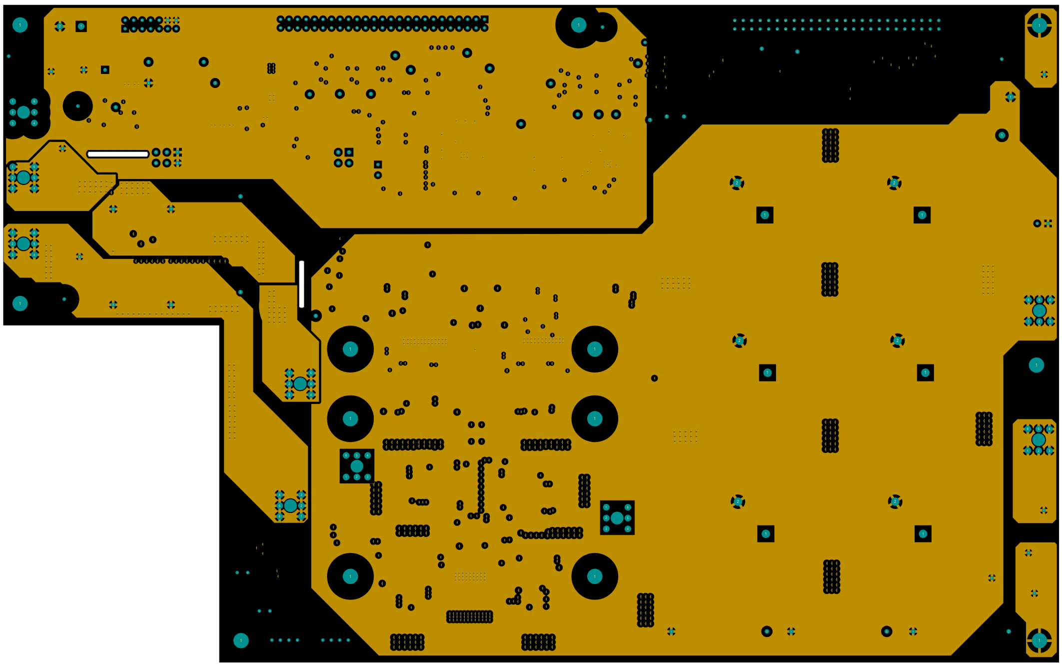


Figure 57 **Layer 2 inner layer 1**

The second layer has been dedicated to different ground layers including negative DC bus and low voltage ground.

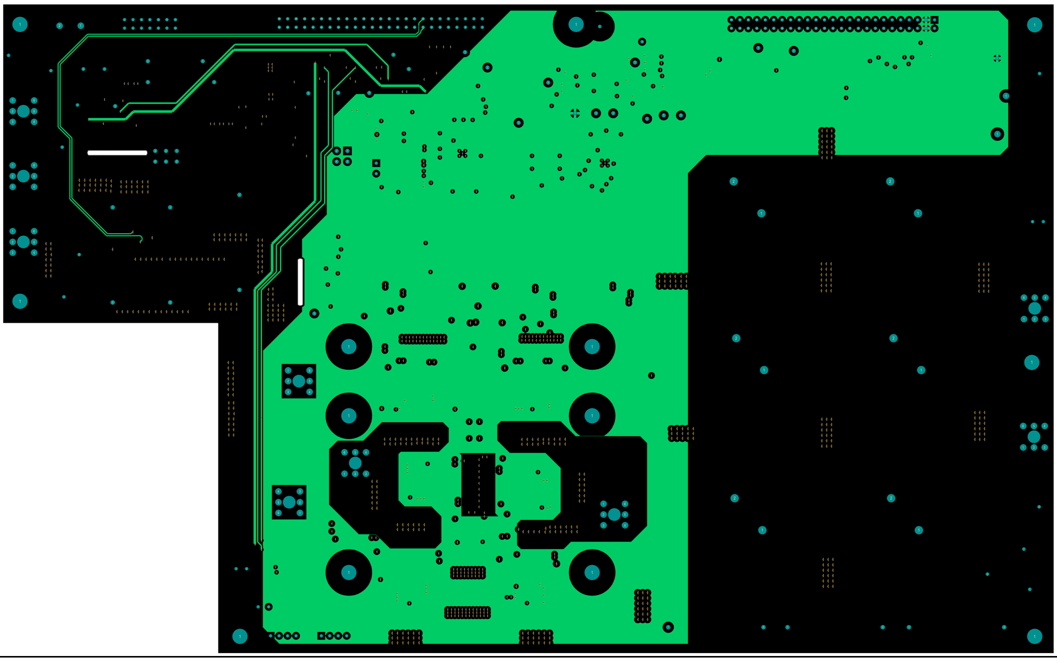


Figure 58 **Layer 3 inner layer 2**

The third layer is dedicated to the low voltage ground digital section. This is to cover the PWM signals that go to the gate drivers.

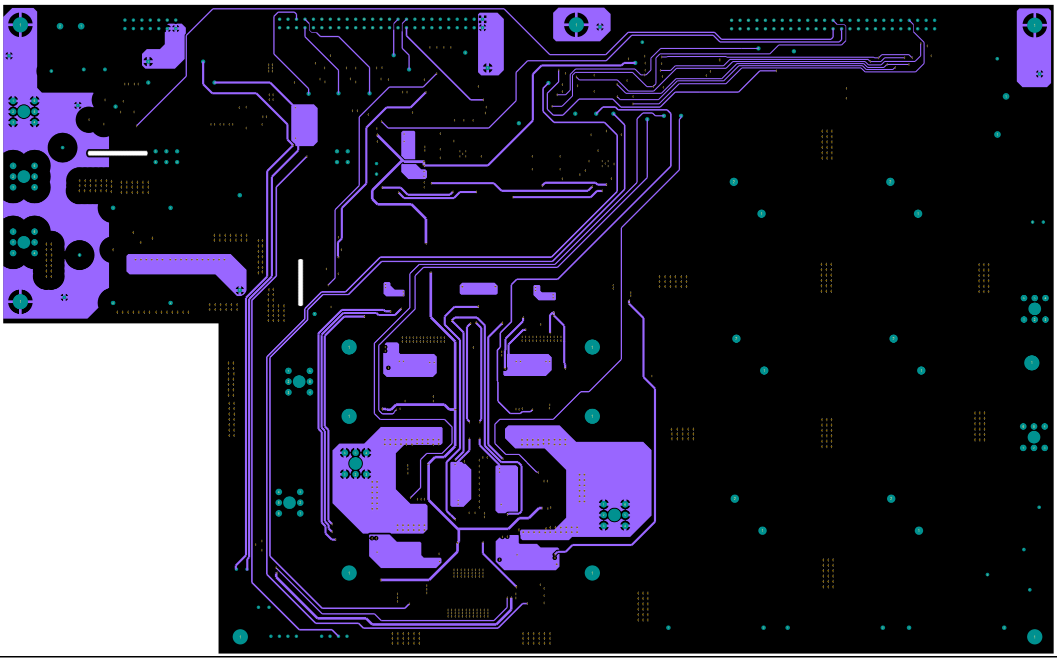


Figure 59 Layer 4 inner layer 3

The fourth layer is mainly dedicated to PWM traces and is also used to add copper and improve current conduction around the switching node.

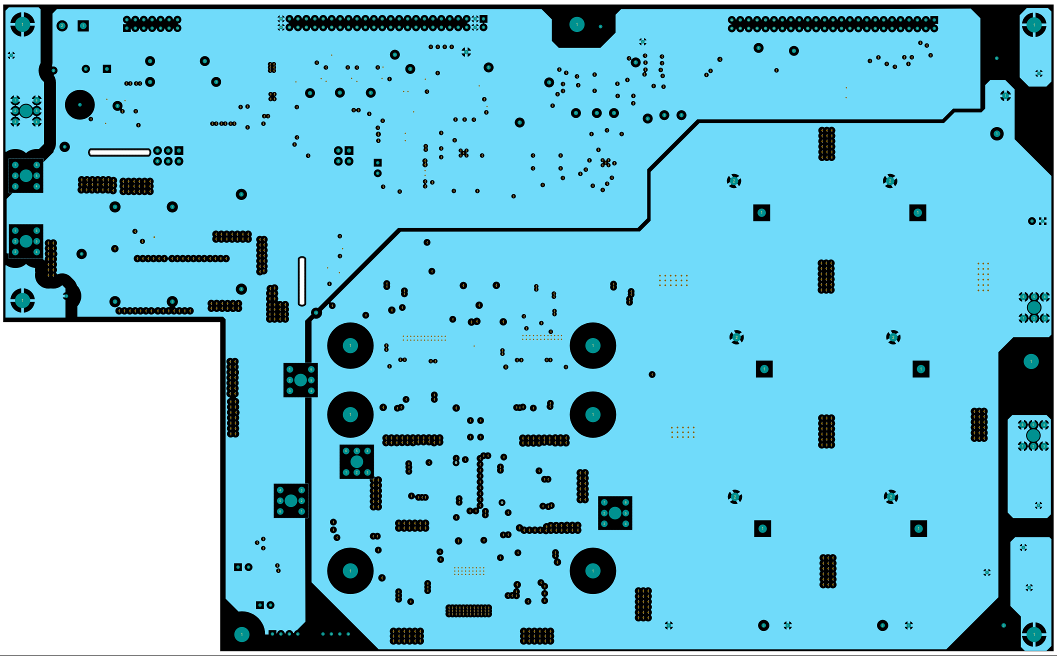


Figure 60 Layer 5 inner layer 4

The fifth layer has been dedicated to different ground layers including negative DC bus and low voltage ground.

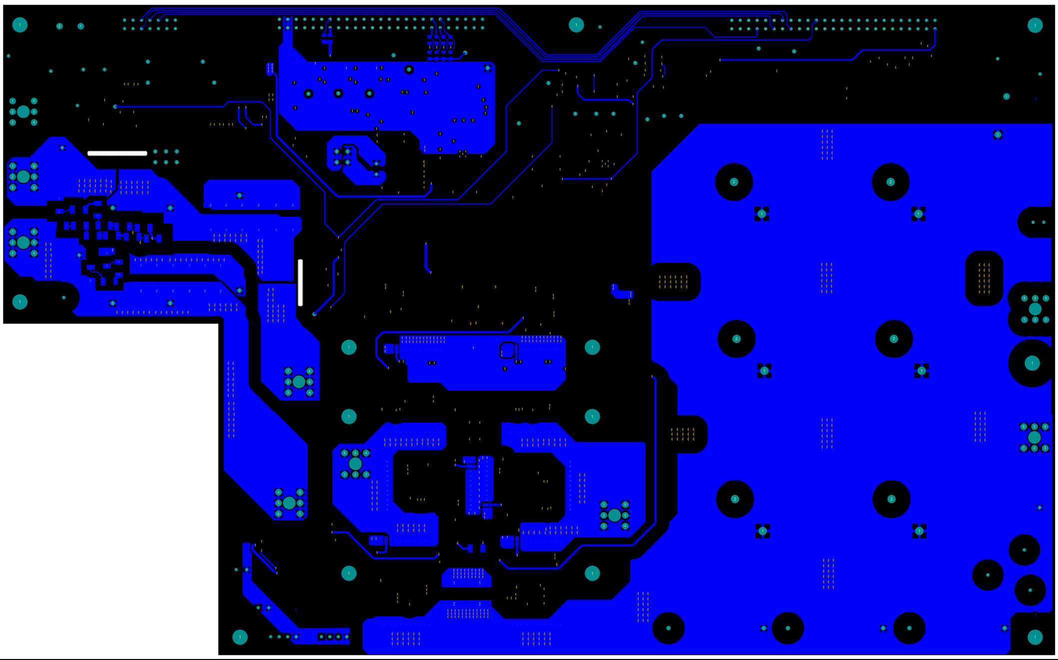


Figure 61 Layer 6 – Bottom layer

The bottom layer contains the traces for high current including MOSFETs current, input BUS_DC+, and AC output. Also, some thin traces have been used for control-related task on the low voltage side.

5.2 PB-APS-24V-5V ISO

Table 12 Mechanical data

Dimensions	57.1 mm x 27.1 mm
No. of layers	8
Copper thickness	4.13 mil

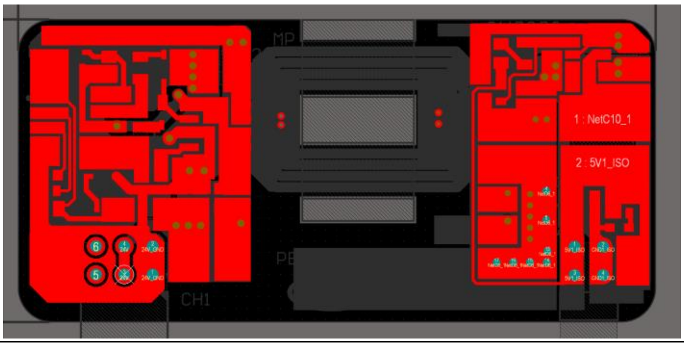


Figure 62 Layer 1

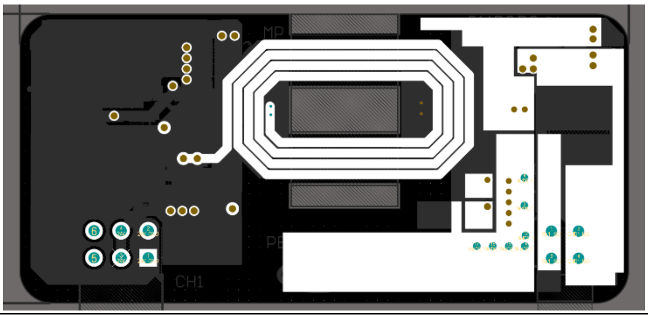


Figure 63 Layer 2

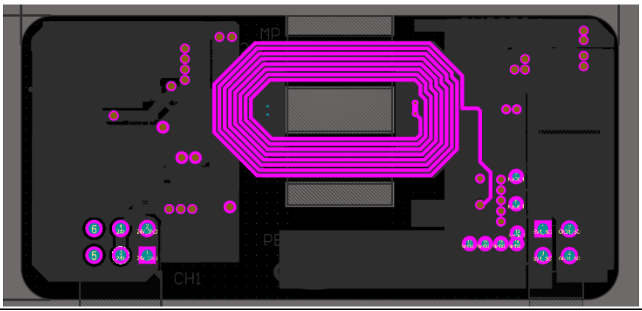


Figure 64 Layer 3

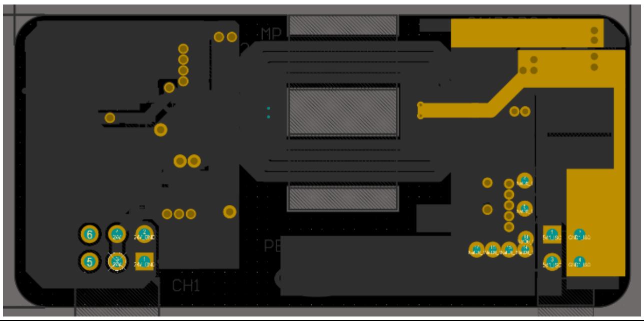


Figure 65 Layer 4

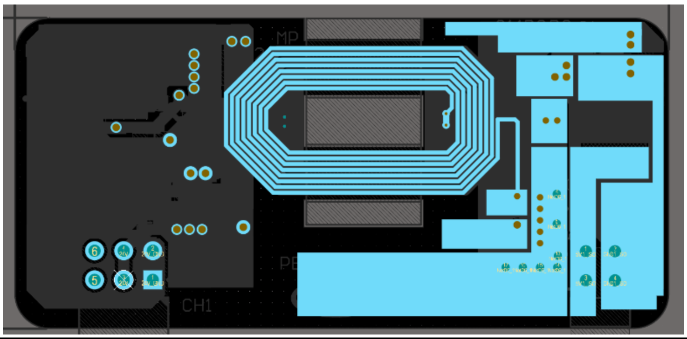


Figure 66 Layer 5

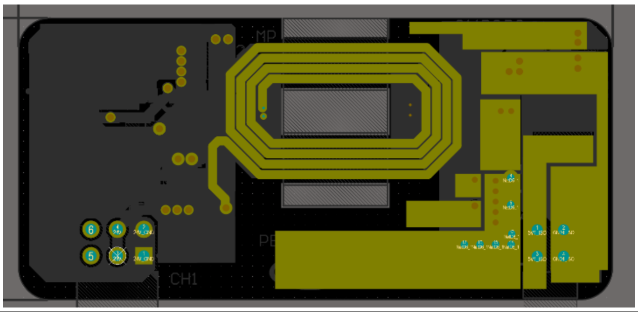


Figure 67 Layer 6

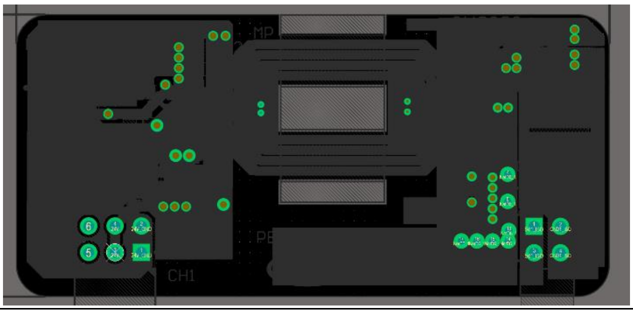


Figure 68 Layer 7

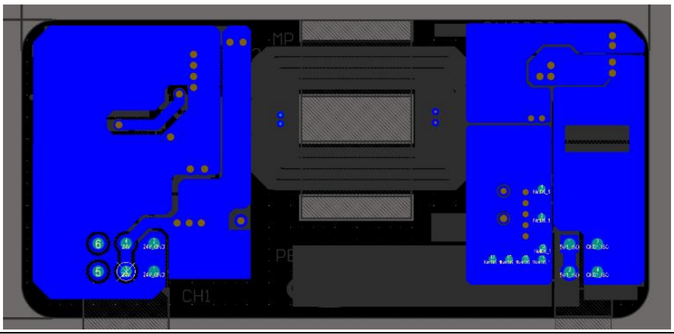


Figure 69 Layer 8

Revision history

Document revision	Date	Description of changes
V 1.0	2025-04-21	Initial release

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