EVAL-M7-HVIGBT-PFCINV user guide

Evaluation power board with M7 connector

About this document

This user guide provides an overview of the evaluation board EVAL-M7-HVIGBT-PFCINV, including its main features, key-technical data, pin assignments, and mechanical dimensions.

The board name, EVAL-M7-HVIGBT-PFCINV, contains two different boards — EVAL-M7-HVIGBT-PFCINV1 and EVAL-M7-HVIGBT-PFCINV4. The last number 1 in the board name represents a power factor control (PFC) frequency of 100 kHz, and the number 4 represents a PFC frequency of 40 kHz. Every mention of EVAL-M7-HVIGBT-PFCINV includes both EVAL-M7-HVIGBT-PFCINV1 and EVAL-M7-HVIGBT-PFCINV4 boards unless specified otherwise.

Scope and purpose

EVAL-M7-HVIGBT-PFCINV includes Infineon's TRENCHSTOP™ IGBTs. It features and demonstrates Infineon's TRENCHSTOP™ IGBT technology for PFC and inverter circuitry in hard-switching conditions. The TRENCHSTOP™ IGBT optimizes switching and conduction losses to reach a high efficiency. The IGBTs used on this board are in D^2PAK packages.

The evaluation board EVAL-M7-HVIGBT-PFCINV was developed to support users during their first steps in designing applications with running any permanent magnet motor via sensor-less sinusoidal field-oriented control.

Intended audience

This evaluation board is intended for all technical specialists who are familiar with motor control and power electronics converter systems.

Evaluation board

EVAL-M7-HVIGBT-PFCINV is meant to be used during the design-in process for evaluating and measuring the board characteristic curves, and checking datasheet specifications. It is intended only to be used under laboratory conditions.

Note: *The printed circuit board (PCB) and auxiliary circuits are NOT optimized for final customer design.*

Important notice

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

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Safety precautions

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

Table 1 **Safety precautions**

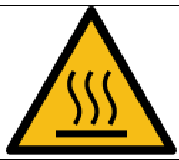
	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors which 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.*

Table of contents

1 The board at a glance

The evaluation power board described in this user guide includes two boards — EVAL-M7-HVIGBT-PFCINV1 and EVAL-M7-HVIGBT-PFCINV4. The EVAL-M7-HVIGBT-PFCINV1 has a 100 kHz PFC and EVAL-M7-HVIGBT-PFCINV4 has a 40 kHz PFC. These two evaluation power boards are designed with an M7 connector and can be driven only by control boards compatible with M7 connectors. Please refer to Chapter 2.2.1 for the details of the M7 connector pinout assignment. One such control board is the EVAL-M7-D112T smart-driver board. However, other M7 connector-compatible control boards can be used as well. The two power boards use the boost PFC topology and can handle up to 400 W of output power when the inverter carrier frequency is 10 kHz with fan cooling.

The high speed TRENCHSTOP™ 5 IGBT is used on the board as the PFC switch. TRENCHSTOP™ 5 is the highest efficiency discrete 650 V IGBT technology and is outstanding in terms of efficiency and power density. It trades off between switching losses and conduction losses to achieve better system performance. The part number of the PFC IGBT used on the board is IKB15N65ETH5. It can support a frequency of up to 100 kHz with lower switching losses. The inverter IGBT used on the board is IKB06N60T which is a 600 V TRENCHSTOP™ IGBT with a soft recovery, anti-paralleled diode to minimize turn-on losses. The compromised switching losses and conduction losses can achieve higher system efficiency. The key features and functionality of this board are described in Section 1.3 of this user guide. The other chapters provide information on how to set up and use this evaluation board, and how to copy and/or modify the design according to specific user requirements.

Figure 1 shows the EVAL-M7-HVIGBT-PFCINV4 evaluation board and Figure 2 shows the EVAL-M7-HVIGBT-PFCINV1 evaluation board.

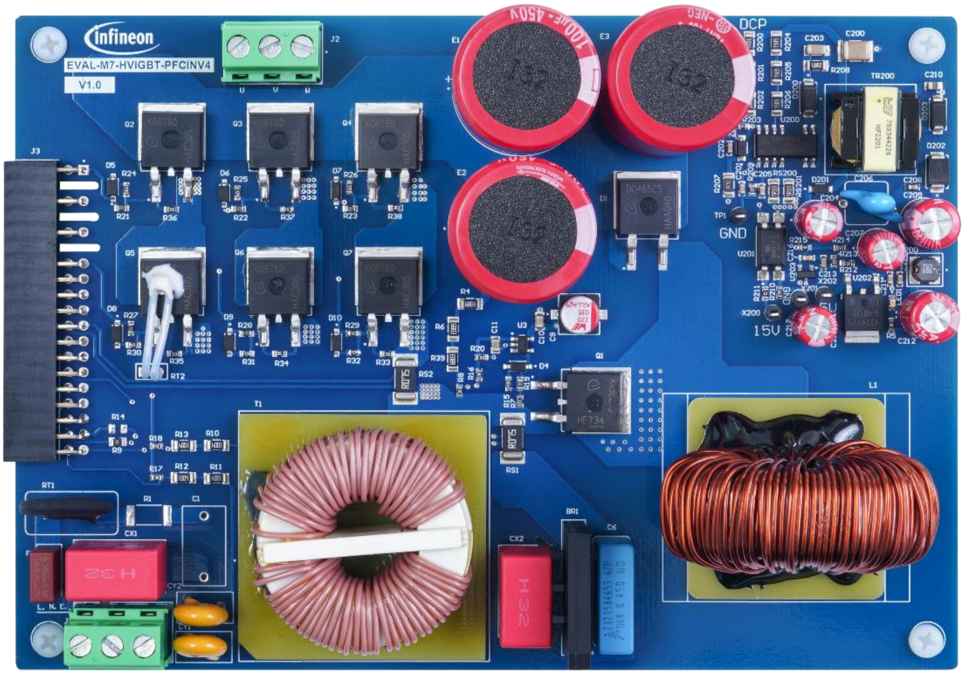


Figure 1 **EVAL-M7-HVIGBT-PFCINV4 evaluation board**

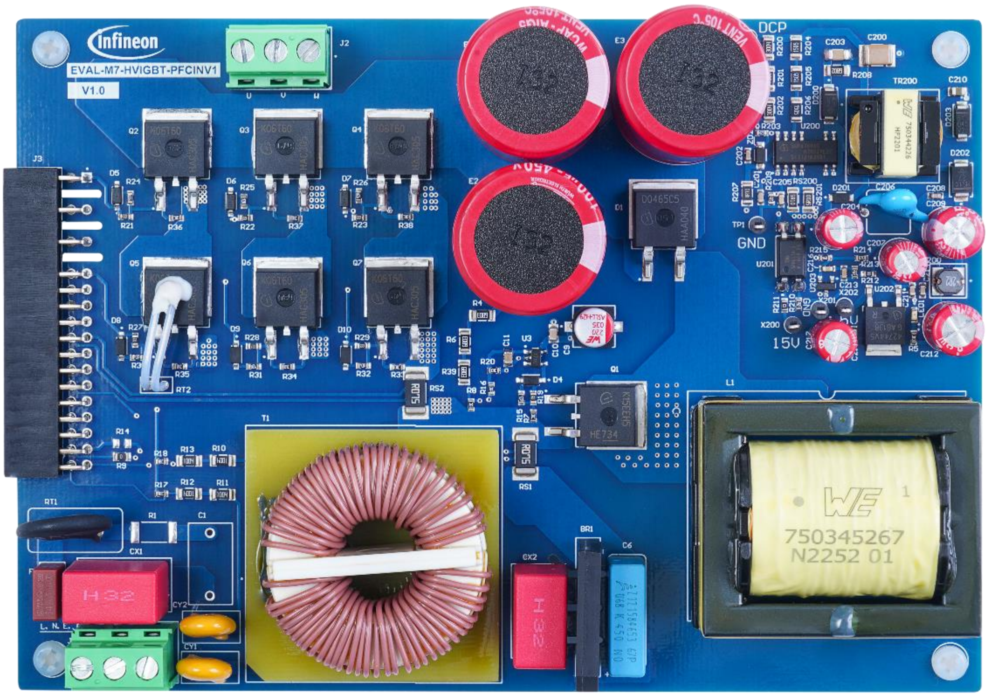


Figure 2 EVAL-M7-HVIGBT-PFCINV1 evaluation board

1.1 Scope of supply

The delivery box only contains the board as shown in Figure 1 (40 kHz PFC) or Figure 2 (100 kHz PFC). The detailed ordering information is listed in Table 1. Please select the right ordering part number based on the PFC frequency that is to be tested and verified.

The USB cable shown in Figure 4 is mandatory for tuning, but is not included with the delivery content. The iMOTION™ link connector on board is an optional tuning method in case users want to tune the board through the iMOTION™ link isolated debug probe. Please order it if you do not have it; the ordering information can be found here.

Table 1 Delivery content

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
EVAL-M7-HVIGBT-PFCINV4		Boxed	1	SP005555670
EVAL-M7-HVIGBT-PFCINV1		Boxed	1	SP005935281

1.2 Block diagram

Figure 3 shows the block diagram of the EVAL-M7-HVIGBT-PFCINV power board and the connections with the example control board, EVAL-M7-D112T. IMD112T has an output capability of 5 V with a maximum output current of 10 mA. The 5 V power supply on the EVAL-M7-HVIGBT-PFCINV board is optional depending on the application's needs for more current output capability, or if the control board used by the user is without a 5 V output power supply.

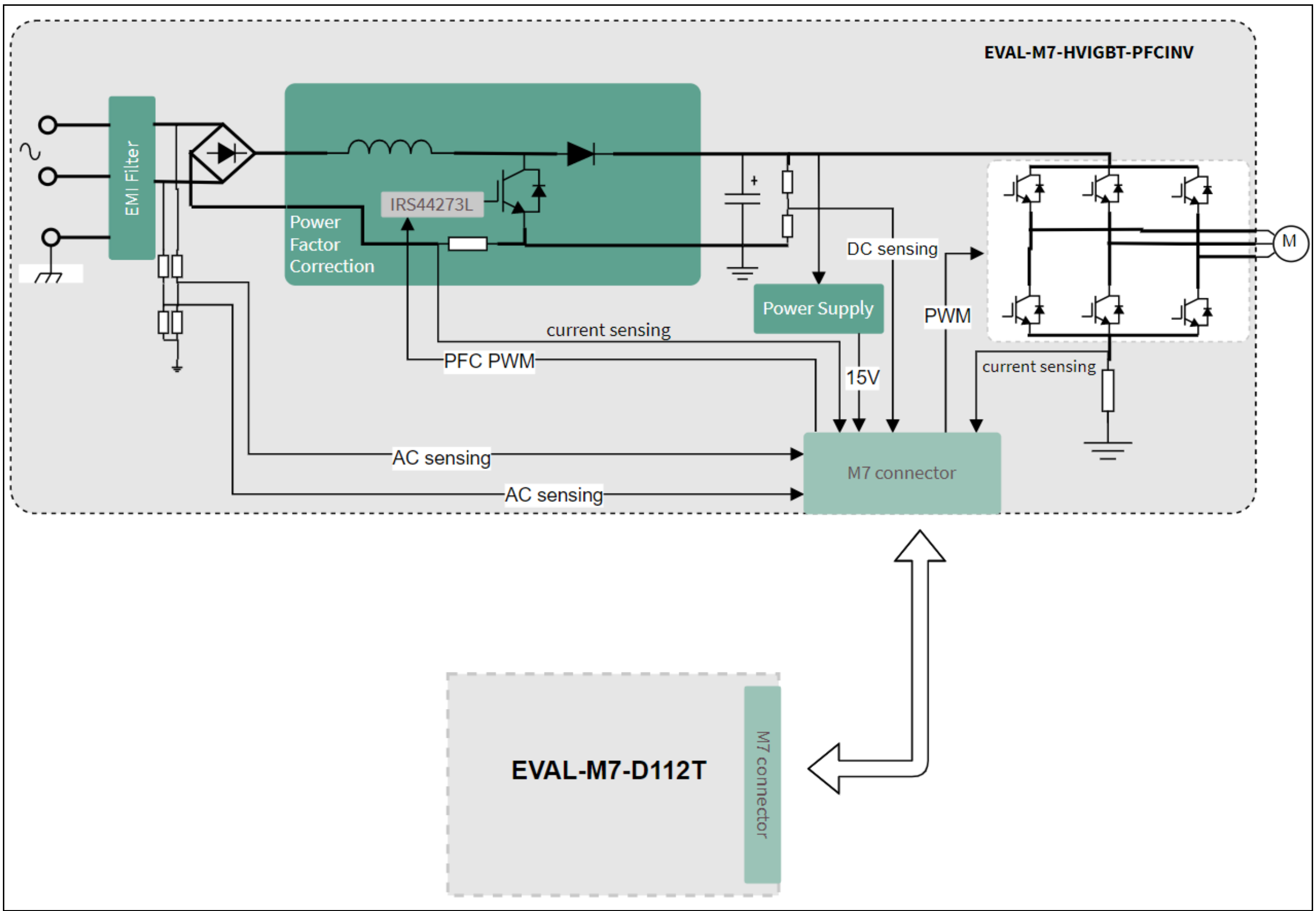


Figure 3 **Block diagram of EVAL-M7-HVIGBT-PFCINV**

1.3 Main features

EVAL-M7-HVIGBT-PFCINV uses Infineon's TRENCHSTOP™ IGBT. This board is suitable for both permanent magnet synchronous motor (PMSM) and brushless direct current motor (BLDC) control for applications such as refrigerators, pumps, fans, and smaller general purpose motors of up to 400 W output power.

The main features of the IGBTs used on the board include:

PFC IGBT

- Best-in-class efficiency in hard switching and resonant topologies
- 650 V breakdown voltage
- Low gate charge Q_G
- The IGBT is co-packed with a full rated current RAPID 1 fast anti-parallel diode
- Maximum junction temperature of 175°C
- RoHS compliant, Pb-free plating

Inverter IGBT

- Very low $V_{CE(sat)}$ 1.5 V (typical)
- Maximum junction temperature of 175°C
- Short circuit withstand time of 5 µs
- TRENCHSTOP™ and FieldStop technologies for 600 V applications offer:
  - Very tight parameter distribution
  - High ruggedness, temperature stable behavior
  - Very high switching speed
- Low EMI
- Pb-free plating

Main features of the EVAL-M7-HVIGBT-PFCINV evaluation power board are:

- Boost PFC topology
- Supports 40 kHz and 100 kHz PFC depending on the power board
- Direct current feedback for the both PFC and inverter
- Single-shunt current feedback configuration for the inverter
- 5 V and 15 V output power supply on the board. 5 V output is optional depending on the application's need
- PCB size of 153 mm x 107 mm, two layers, 1 oz copper

1.4 Board parameters and technical data

Table 2 lists the evaluation board's parameters and technical details.

Table 2 Parameter

Parameter	Symbol	Conditions	Value	Unit
Input AC voltage	V_{IN}	220 V_{AC} input typical（50 Hz default in test iSD）	165~260	V_{AC}
15 V output voltage	+15V	Maximum 100 mA output current	15 ±5%	V
5 V output voltage	+5V	Maximum 150 mA output current	5 ±2%	V
Maximum input power	P_{IN}	10 kHz inverter carrier frequency without any external heat sink, up to 100 kHz PFC	200	W
		10 kHz inverter carrier frequency with force cooling, up to 100 kHz PFC	400	
Low line maximum input power	$V_{IN(Low)}$	40 kHz PFC (PFC IGBT T_{ca} = 100℃)	170	V_{AC}
		100 kHz PFC (PFC IGBT T_{ca} = 100℃)	180	
Max. output phase current	I_{phase_rms}	T_A = 20℃, T_C = 100℃, force cooling	2.3	A
DC bus voltage	V_{DC}	DC bus capacitor has 450 V rated voltage	380	V
PFC frequency	f_{PFC}	EVAL-M7-HVIGBT-PFCINV4	40	kHz
		EVAL-M7-HVIGBT-PFCINV1	100	
Max. switching inverter frequency	f_{SW}	V_{CC} = 15 V, the maximum switching frequency is limited by the inverter IGBT's junction temperature	20	kHz
PCB characteristics				
Material		1.6 mm thickness, 1 oz copper, 2 layers	FR4	
Dimensions		Length × width × height	153 × 107 × 45	mm

2 System and functional description

2.1 Getting started

The EVAL-M7-HVIGBT-PFCINV evaluation board is only a power board with boost PFC and has no control function. Therefore, it should be used with an M7 connector-compatible control board. Figure 4 is an example of the system setup with Infineon iMOTION™ smart driver IMD112T control board EVAL-M7-D112T. IMD112T is a motion control engine (MCE) with PFC control that can be implemented as a ready-to-use solution for variable speed drives. Users who would like to drive the power board with the EVAL-M7-D112T control board can find more details in Infineon user guide, UG-2023-04 [4].

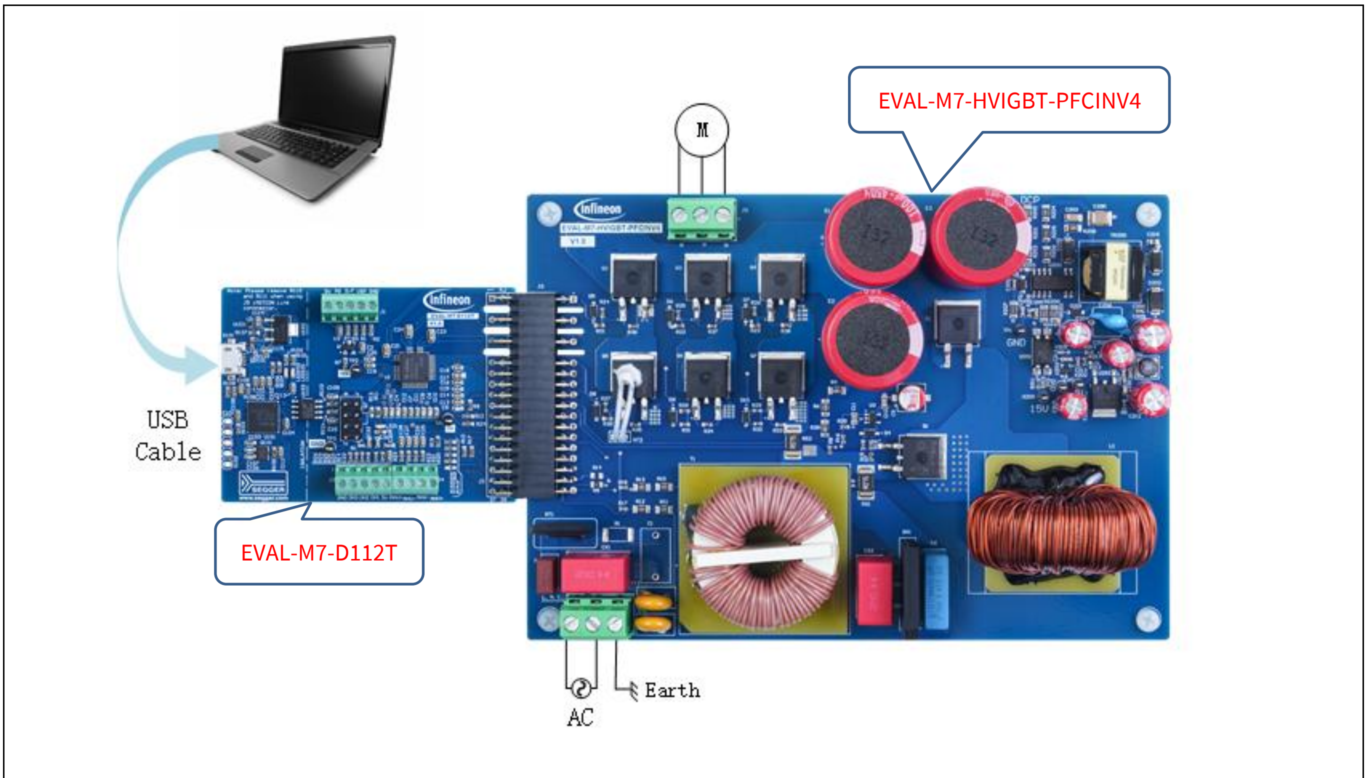


Figure 4 **System setup example**

2.2 Description of the functional blocks

This chapter covers the hardware design of EVAL-M7-HVIGBT-PFCINV in more detail to help users understand the functional groups of this power board and use it to easily evaluate the board performance. It also helps users develop their solutions based on the evaluation board's design.

2.2.1 Functional groups of EVAL-M7-HVIGBT-PFCINV

The functional groups of EVAL-M7-HVIGBT-PFCINV1 are shown in Figure 5. The design of EVAL-M7-HVIGBT-PFCINV4 is very similar to that of EVAL-M7-HVIGBT-PFCINV1.

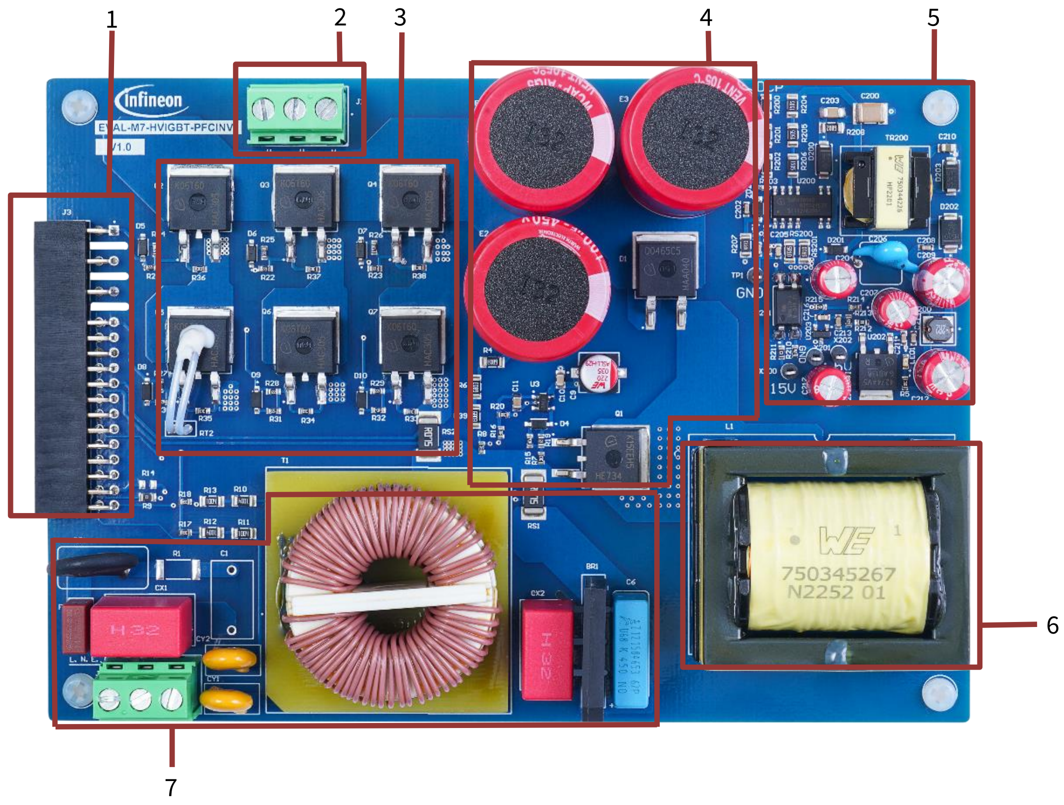


Figure 5 Functional groups

1. M7 connector
2. Inverter output
3. Inverter switches
4. PFC IGBT switch, driver, diode, and bus capacitors
5. Auxiliary power supply
6. PFC inductor
7. AC input connector, EMI filter, and rectifier bridge

There are three connectors on the EVAL-M7-HVIGBT-PFCINV board. All connector pin assignments are listed in Table 3 to Table 5.

Table 3 220 VAC input connector-J1

Pin number	Symbol	Assignment
1	L	Line
2	N	Neutral
3	E	Earth

Table 4 Inverter output connector-J2

Pin number	Symbol	Assignment
1	W	W phase output
2	V	V phase output
3	U	U phase output

Table 5 M7 connector -J3

Pin number	Symbol	Assignment
1	GUH	U phase, high-side gate PWM
2	VSV	U phase, high-side floating return
3, 4, 7, 8, 11, 12	-	Not used
5	GVH	V phase, high-side gate PWM
6	VSV	V phase, high-side floating return
9	GWH	W phase, high-side gate PWM
10	VSW	W phase, high-side floating return
13	GUL	U phase, low-side gate PWM
14	GVL	V phase, low-side gate PWM
15	GWL	W phase, low-side gate PWM
16	COM	Gate driver, low-side return
17, 18, 32	GND	Ground
19	VDD	Internal low dropout regulator (LDO) output
20	VDD1	External VDD supply voltage
21	IU+	U phase, current-sensing signal positive
22	IU-	U phase, current-sensing signal negative
23	IV+	V phase, current-sensing signal positive
24	IV-	V phase, current-sensing signal negative
25	IW+	W phase, current-sensing signal positive
26	IW-	W phase, current-sensing signal negative
27	VTH	Negative temperature coefficient (NTC) resistor output voltage
28	VDC	V_{bus} voltage sensing
29	GK	Inverter gate kill signal
30	VCC	Gate driver supply voltage

31	PFCG0	PFC gate driving PWM 0 (not used for this board)
33	PFCG1	PFC gate driving PWM 1 (not used for this board)
34	PFCGK	PFC gate kill signal (not used for this board)
35	IPFC+	PFC current-sensing positive (not used for this board)
36	IPFC-	PFC current-sensing negative (not used for this board)
37	VAC1	AC voltage-sensing input 1 (not used for this board)
38	VAC2	AC voltage-sensing input 2 (not used for this board)

2.2.2 Voltage feedback

The EVAL-M7-HVIGBT-PFCINV evaluation board includes AC line voltage and DC bus voltage feedback circuits. They both are voltage dividers. The DC bus voltage feedback high-side resistor is composed of three 680 kΩ resistors (R4, R6, R39) in series, and the low-side resistor (R8) is a single 13.3 kΩ resistor. AC line voltage feedback is composed of two high-side resistors (1 MΩ) and one low-side resistor (15 kΩ). Figure 6 shows the AC line and DC bus voltage feedback on the board. Please ensure that a the low-side resistor is available on this power board because unlike some other boards that have the low-side resistor on the control board, the tested control board, EVAL-M7-D112T, has no low-side resistor but only a decoupling capacitor that is located near the input pin of the IMD112T voltage feedback. Users using a different control board should remember the location of the low-side resistor and make sure they get the correct feedback voltage gain.

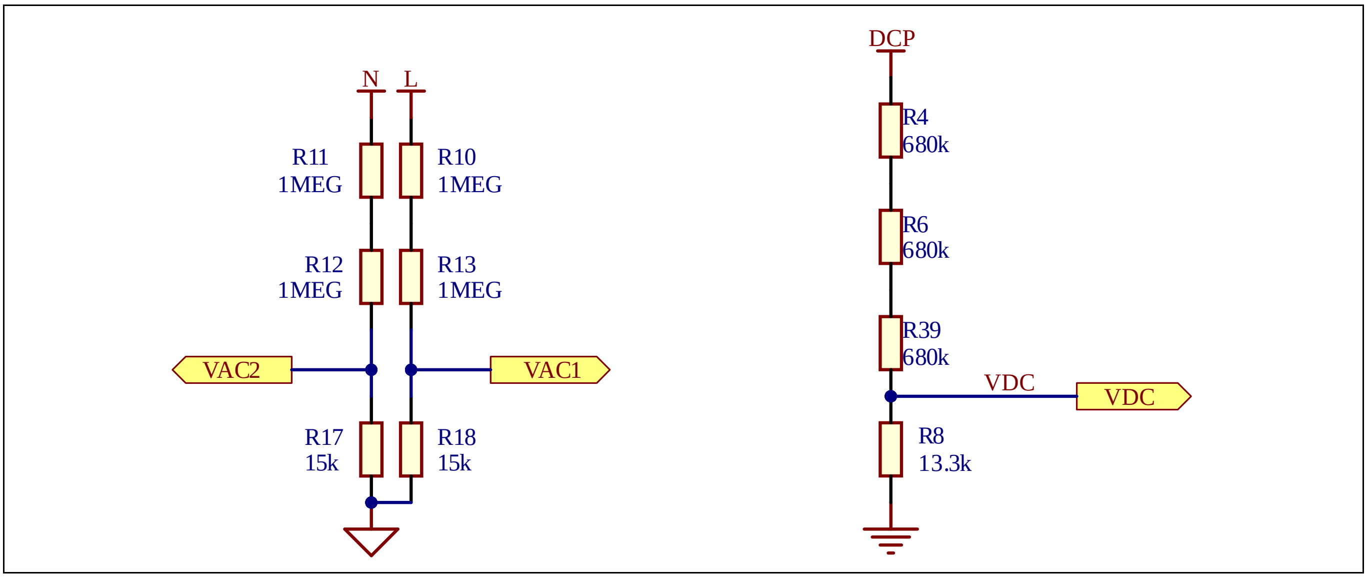


Figure 6 Voltage feedback circuitry

2.2.3 Temperature measured with NTC on board

To measure the case temperature of the IGBT switch, a negative temperature coefficient (NTC) resistor is located on the surface of the U phase, low-side IGBT on the board. NTC's placement on the board is as shown in Figure 7. The highest inverter IGBT case temperature versus the voltage output on the NTC resistor curve is shown in Figure 8. This case temperature is probably not the highest case temperature of all six inverter IGBTs, but it shows the relationship between NTC voltage and the highest case temperature. This can help users set the over-temperature threshold required to protect the system.

The pull-up resistor on the EVAL-M7-D112T control board is 4.87 kΩ. The connection between the NTC and control board is shown in Figure 7. Based on the NTC datasheet, Table 6 lists the NTC resistance values at intermediate temperatures. This will help users calculate the divider voltage (if required).

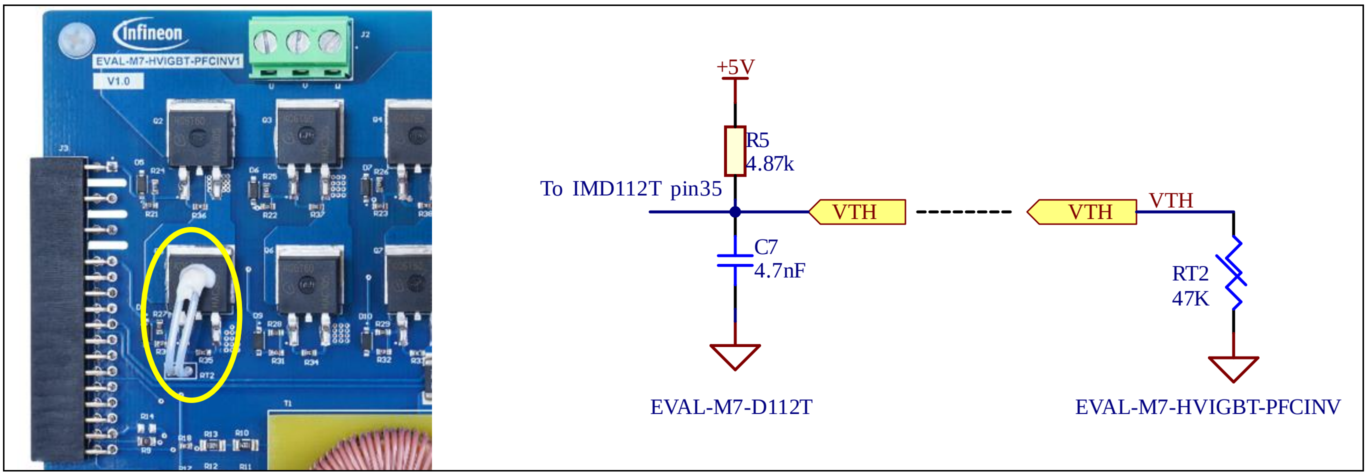


Figure 7 NTC location and voltage divider circuitry

Table 6 NTC resistance values at intermediate temperatures

T_{OPER} (°C)	15	20	25	30	35	40	45	50	55	60
R_T (kΩ)	74.4	58.95	47.00	37.71	30.43	24.70	20.15	16.53	13.63	11.30
T_{OPER} (°C)	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**
R_T (kΩ)	9.404	7.865	6.607	5.573	4.721	4.015	3.427	2.936	2.525	2.179

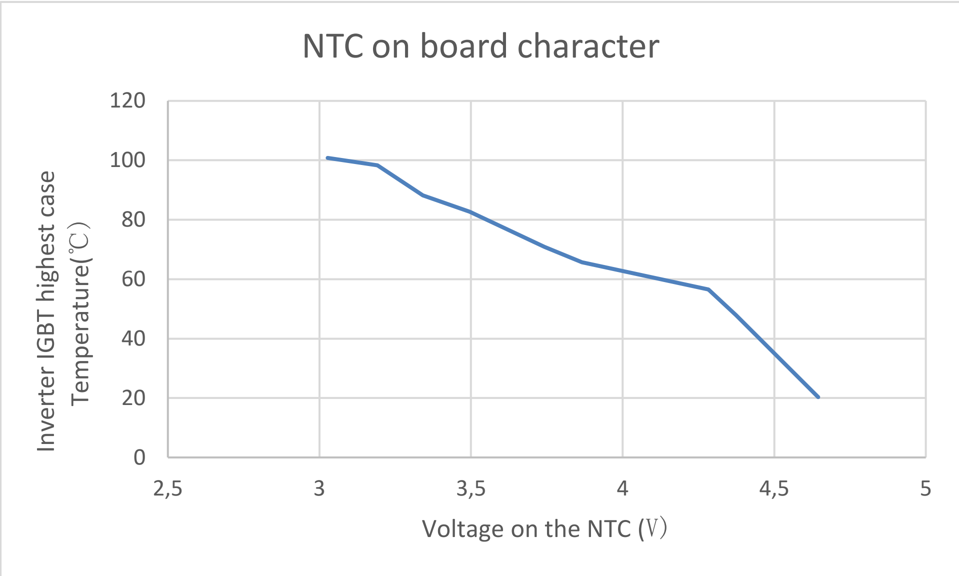


Figure 8 **NTC character test on the board**

2.2.4 Protection function

There is no external hardware protection function onboard for EVAL-M7-HVIGBT-PFCINV. Protection functions such as overcurrent, over and undervoltage, phase loss, and rotor lock are all carried out by the control board when EVAL-M7-D112T control board is used for evaluation. Overcurrent and overvoltage/undervoltage protection thresholds can be set using a wizard. Users can also enable or disable the protection functions such as phase loss, rotor lock, etc. All protection functions that are included in IMD112T can be set in the configuration wizard of the iSD tool. For details, please refer to the EVAL-M7-D112T control board user guide (UG-2023-04) [4] and the Getting Started with iMOTION™ Solution Designer guide [3].

3 System design

3.1 Schematics

The schematics of EVAL-M7-HVIGBT-PFCINV power board include an EMI filter, a rectifier bridge, boost PFC, inverter section, and an auxiliary power supply. Figure 9 shows the boost PFC schematics of EVAL-M7-HVIGBT-PFCINV4. Figure 10 shows the inverter section schematics and Figure 11 shows the auxiliary power supply schematics. The power supply has two outputs — 15 V and 5 V. 5 V output is optional depending on the application's need.

In the EVAL-M7-HVIGBT-PFCINV1 evaluation board schematics, the PFC inductor value is 1.5 mH with ferrite core and R19 resistor value is 120 Ω. These are the only two differences between EVAL-M7-HVIGBT-PFCINV1 and EVAL-M7-HVIGBT-PFCINV4.

The complete schematic diagrams are available on Infineon's website in the download section. Login credentials are required to download this material.

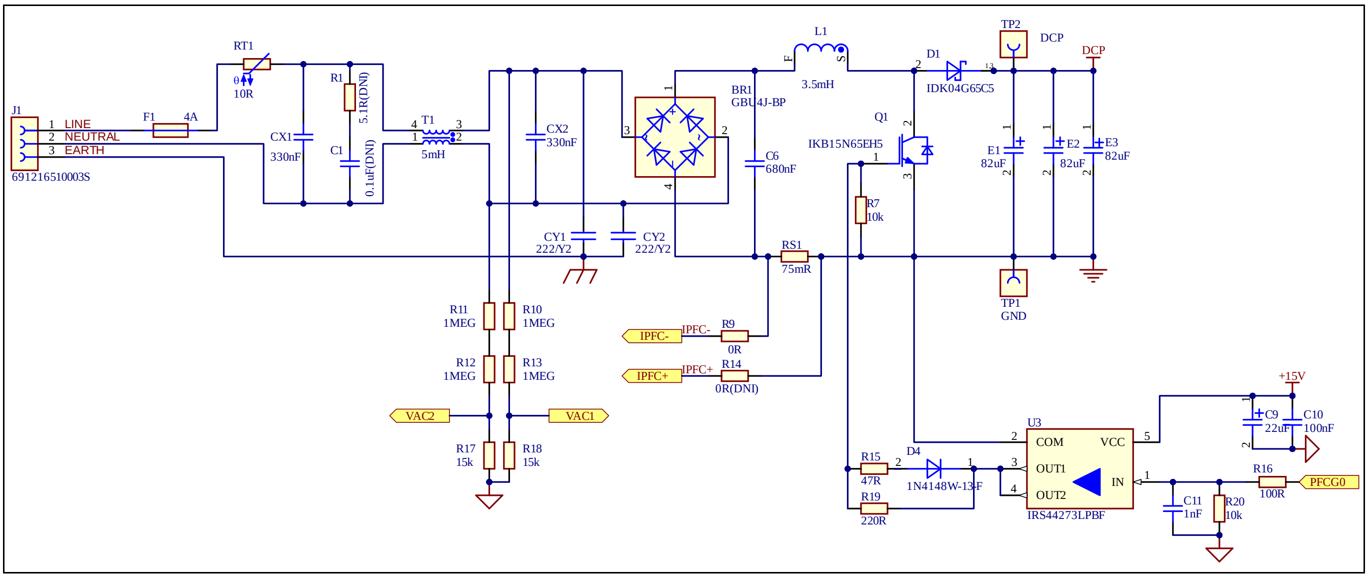


Figure 9 Boost PFC schematics of EVAL-M7-HVIGBT-PFCINV4

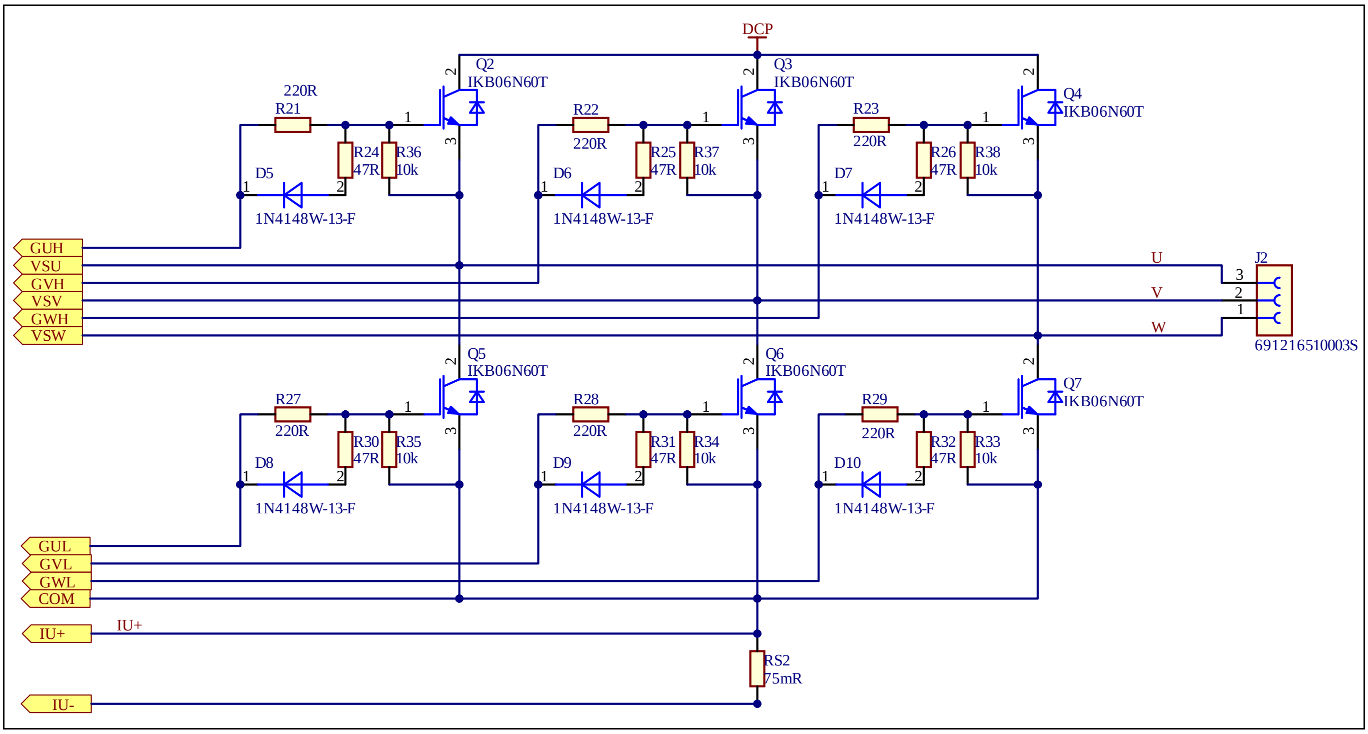


Figure 10 Inverter schematics of EVAL-M7-HVIGBT-PFCINV4

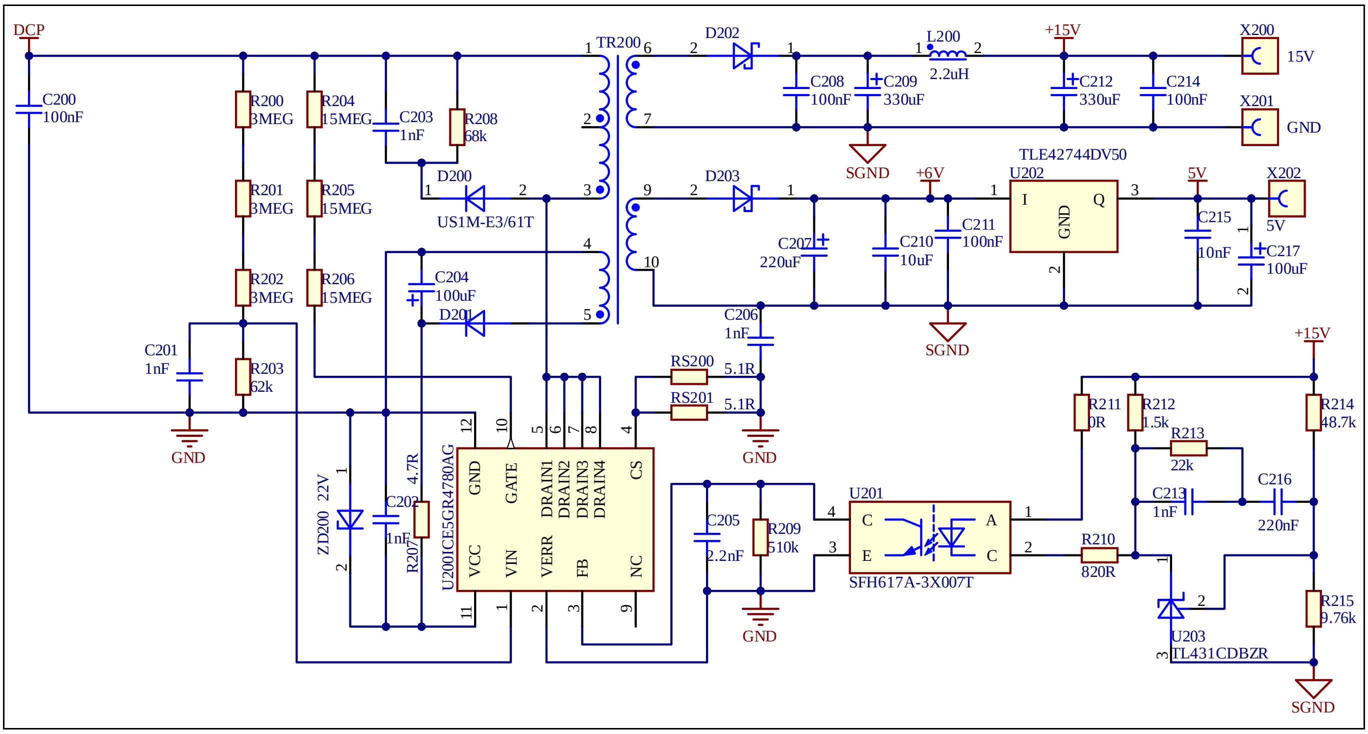


Figure 11 Auxiliary supply schematics

3.2 Layout

The EVAL-M7-HVIGBT-PFCINV board consists of two copper PCB layers. The copper thickness is 35 µm and the board size is 153 mm x 107 mm. The board material is of FR4 grade with 1.6 mm thickness. Check Infineon's website or contact Infineon's technical support team for detailed information. Gerber files are available on Infineon's website in the download section. Login credentials are required to download these files.

The layout of the top and bottom layers of the PCB are shown in Figure 12 and Figure 13. For the power board's PCB layout, users should connect the signal ground and power ground at a single common point to keep the noise low for current-feedback sensing. The PFC and inverter shunt resistor ground terminals should be connected to the common ground point, as close as possible. The current-feedback trace should be short and close to ground copper. This will ensure that less noise is introduced into the current feedback loop. Lower current-feedback noise is beneficial for PFC and motor control performance, especially for direct current-sensing control.

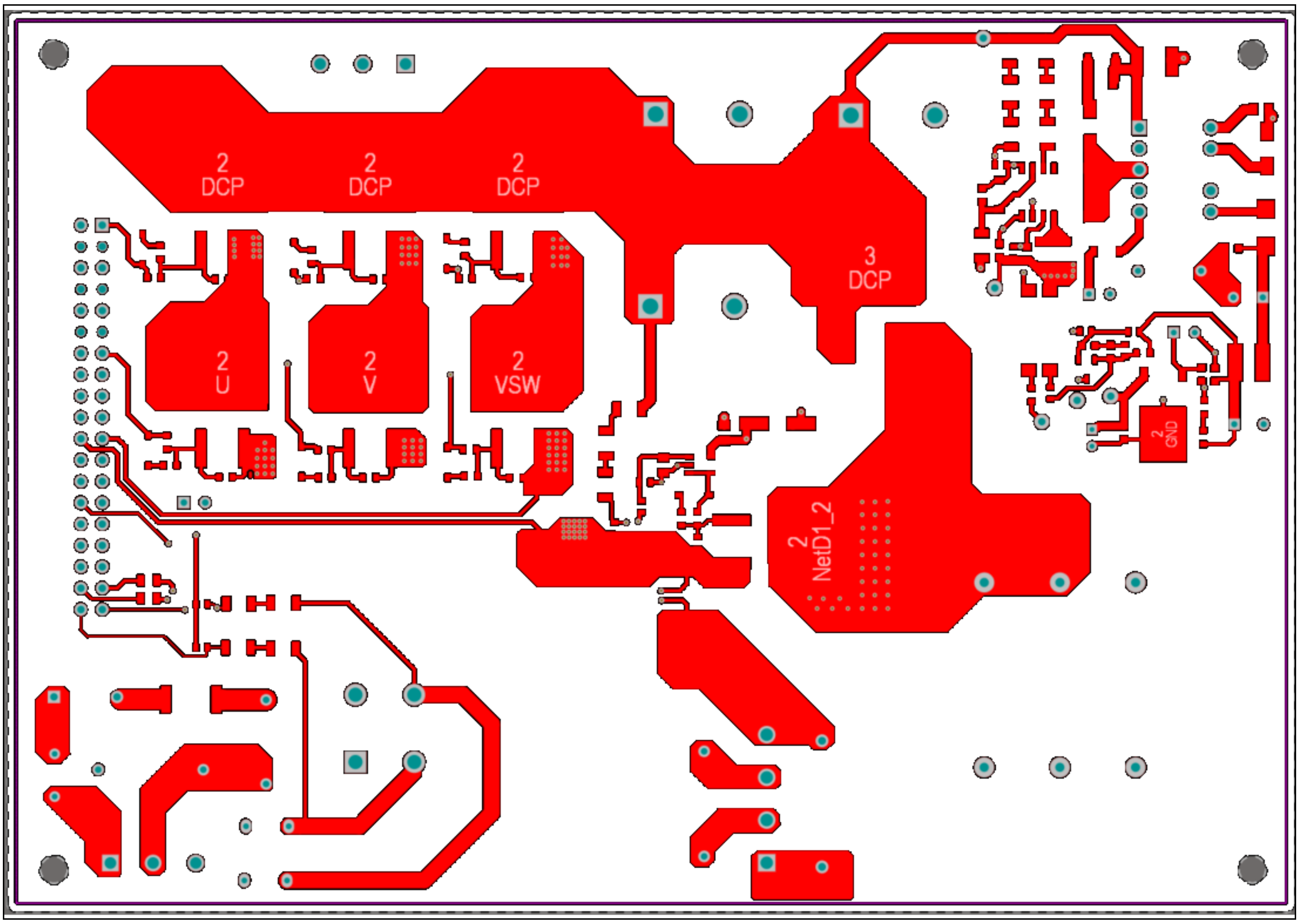


Figure 12 **Top layer**

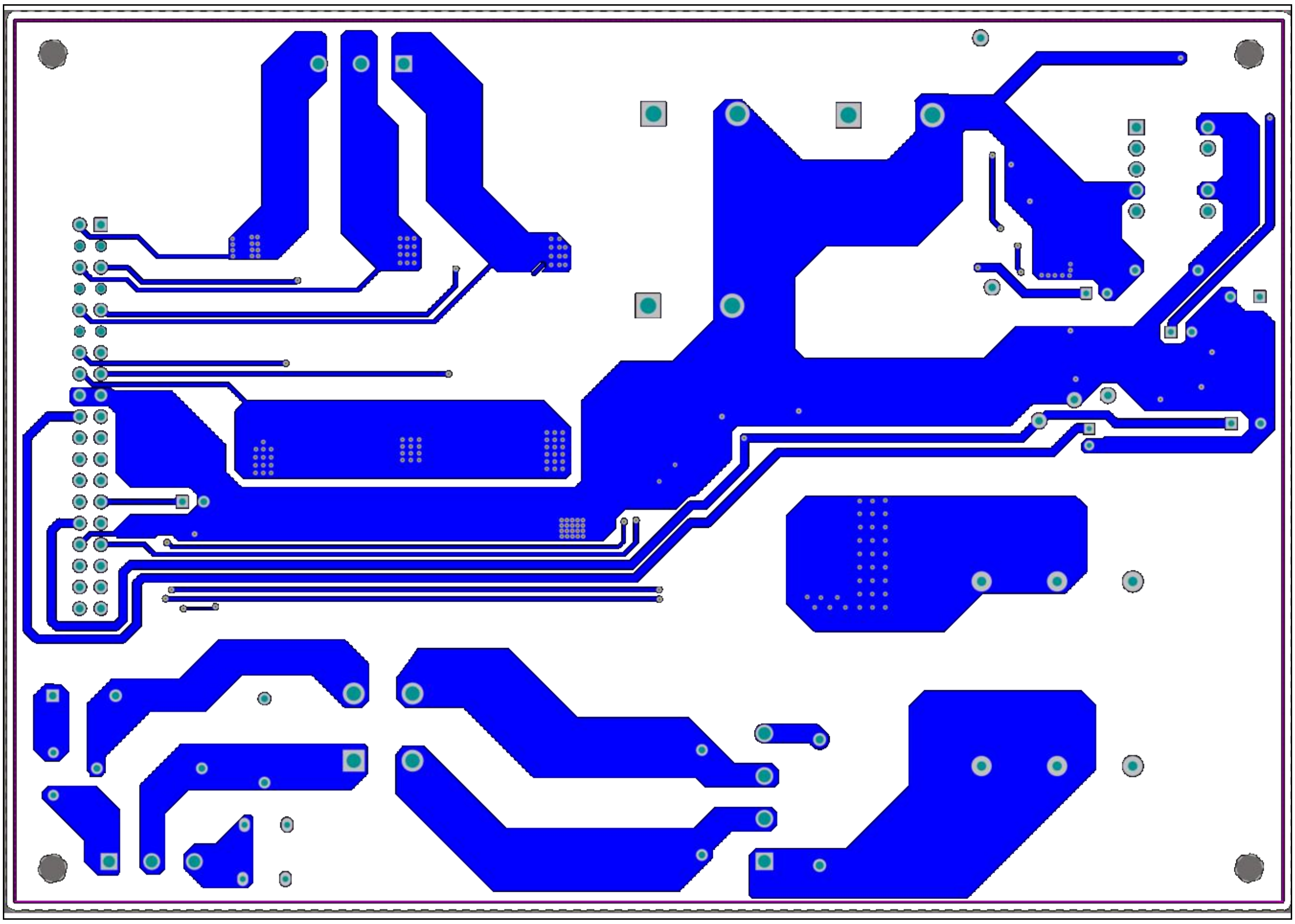


Figure 13 Bottom layer

3.3 Bill of material

The bill of material is available on Infineon's website in the download section. Login credentials are required to download this material. Table 7 lists the combined BOMs of the two power boards. The differences are listed in line items 34 and 51.

Table 7 BOM of the EVAL-M7-HVIGBT-PFCINV evaluation board

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	BR1	4 Amp Single Phase Glass Passivated Bridge Rectifier, 600V	Micro Commercial Components	GBU4J-BP
2	C1	CAP / FILM / 100nF / 630V / 10% / - / -40℃ to 105 ℃ / 10.00mm C X 0.60mm W 13.00mm L X 7.00mm T X 13.50mm H / THT / -	Wurth Elektronik	890334023023CS
3	C6	CAP / FILM / 680nF / 450V / 10% / - / -55℃ to 125 ℃ / 15.00mm C X 0.80mm W 18.00mm L X 6.00mm T X 12.00mm H / THT / -	TDK Corporation	B32672P4684K000
4	C9	CAP / ELCO / 22uF / 35V / 20% / Aluminum electrolytic / -55℃ to 105℃ / 6.60mm L X 6.60mm W X 5.50mm H body / SMD / -	Wurth Elektronik	865060543003

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
5	C10	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55 ℃ to 125℃ / 0805(2012) / SMD / -	TDK Corporation	C2012X7R1H104K085A A
6	C11	CAP / CERA / 1nF / 50V / 5% / X7R (EIA) / -55℃ to 125℃ / 0805(2012) / SMD / -	MuRata	GRM216R71H102JA01
7	C200	CAP / CERA / 100nF / 630V / 10% / X7R (EIA) / -55 ℃ to 125℃ / 1812 / SMD / -	Wurth Elektronik	885342211006
8	C201	CAP / CERA / 1nF / 16V / 10% / X7R (EIA) / -55℃ to 125℃ / 0603(1608) / SMD / -	Kemet	C0603C102K4RACTU
9	C202, C213	CAP / CERA / 1nF / 25V / 5% / C0G (EIA) / NP0 / -55℃ to 125℃ / 0603(1608) / SMD / -, CAP / CERA / 1nF / 25V / 5% / C0G (EIA) / NP0 / -55℃ to 125 ℃ / 0603(1608) / SMD / -	MuRata	GRM1885C1E102JA01
10	C203	CAP / CERA / 1nF / 630V / 10% / X7R (EIA) / -55℃ to 125℃ / 1206(3216) / SMD / -	MuRata	GRM31BR72J102KW01
11	C204	CAP / ELCO / 100uF / 35V / 20% / Aluminum electrolytic / -40℃ to 85℃ / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / - / -	Wurth Elektronik	860010573007
12	C205	CAP / CERA / 2.2nF / 50V / 10% / X5R (EIA) / -55 ℃ to 85℃ / 0603(1608) / SMD / -	MuRata	GRM188R61H222KA01
13	C206	CAP / CERA / 1nF / / 20% / E (JIS) / -40℃ to 125 ℃ / 7.50mm C X 0.60mm W 7.00mm L X 7.00mm T X 10.00mm H / THT / -	MuRata	DE6E3KJ102MN3A
14	C207	CAP / ELCO / 220uF / 16V / 20% / Aluminum electrolytic / -40℃ to 85℃ / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / THT / -	Wurth Elektronik	860010373010
15	C208, C214	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55 ℃ to 125℃ / 603(1608) / SMD / -	AVX	06035C104K4Z2A
16	C209, C212	CAP / ELCO / 330uF / 25V / 20% / Aluminum electrolytic / -40℃ to 85℃ / 3.50mm C X 0.60mm W 8.00mm Dia X 13.00mm H / THT / -	Wurth Elektronik	860010474012
17	C210	CAP / CERA / 10uF / 16V / 10% / X5R (EIA) / -55℃ to 85℃ / 0805(2012) / SMD / -	MuRata	GRM219R61C106KA73
18	C211	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55 ℃ to 125℃ / 0603 / SMD / -	AVX	06035C104KAT2A
19	C215	CAP / CERA / 10nF / 50V / 10% / X7R (EIA) / -55℃ to 125℃ / 0603 / SMD / -	AVX	06035C103K4Z2A
20	C216	CAP / CERA / 220nF / 25V / 10% / X5R (EIA) / -55 ℃ to 85℃ / 0603(1608) / SMD / -	MuRata	GRM188R61E224KA88
21	C217	CAP / ELCO / 100uF / 16V / 20% / Aluminum electrolytic / -40℃ to 85℃ / 2.00mm C X 0.50mm W 5.00mm Dia X 12.50mm H / THT / -	Wurth Elektronik	860010473007
22	CX1, CX2	CAP / FILM / 330nF / 630V / 10% / MKT (Metallized Polyester) / -40℃ to 105℃ / 12.50mm C X 0.60mm W 15.00mm L X 8.50mm T X 14.50mm H / THT / -	Wurth Elektronik	890324024003CS
23	CY1, CY2	CAP CER 2.2nF 300VAC Y2 RADIAL	Vishay	VY2222M35Y5US6TV5

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
24	D1	Schottky Diode, 5th Generation ThinQ SiC	Infineon Technologies	IDK04G65C5
25	D4, D5, D6, D7, D8, D9, D10	Surface Mount Fast Switching Diode	Diodes Incorporated	1N4148W-13-F
26	D200	Surface Mount Ultrafast Rectifier 1.0A/1000V	Vishay	US1M-E3/61T
27	D201	Super-fast Recovery Diode, VR 200 V, IF 1 A	ROHM Semiconductor s	RF071MM2STR
28	D202	High Voltage Surface-Mount Schottky Rectifier, VRRM 100V	Vishay	SS2H10-E3/52T
29	D203	Surface-Mount Schottky Barrier Rectifier, VRRM 45V	Vishay	BYS10-45-E3/TR3
30	E1, E2, E3	CAP / ELCO / 82uF / 450V / 20% / - / -25℃ to 105 ℃ / 10.00mm C X 1.50mm W 22.00mm Dia X 38.00mm H body / THT / -	Wurth Elektronik	861021483005
31	F1	RES / STD / - / - / - / - / -55℃ to 125℃ / 5.08mm C X 0.60mm W 8.50mm L X 4.00mm T X 7.90mm H / - / -	Hollyland (China) Electronics Technology Corp., Ltd	5EF-040H
32	J1, J2	Horizontal Cable Entry with Rising Cage Clamp - WR-TBL, 3Pins	Wurth Elektronik	691216510003S
33	J3	The part can be named as M7-38-F, Connector, 38 pins, 2.54 mm pitch, Board to Board, Right Angle	Sullins	PPTC192LJBN-RC
34	L1	IND / STD / 3.5m mH / 4 A, (40 kHz PFC)	Poco	PI221435V1
		IND/STD/1.5 mH/4 A, (100 kHz PFC)	Wurth Elektronik	750345267
35	L200	IND / STD / 2.2uH / 2.5A / 20% / -40℃ to 125℃ / 71mR / SMD / Inductor, SMD; 2-Leads, 4.50 mm L X 4 mm W X 3.50 mm H body / SMD / -	Wurth Elektronik	744773022
36	LED1	Standard 0603 SMD LED, 2.1V Red, Luminous Intensity 63 mcd	Vishay	TLMS1100-GS08
37	Q1	TRENCHSTOP 5highspeedswitchingIGBTcopackedwithfullrated currentRAPID1antiparalleldiode	Infineon Technologies	IKB15N65EH5
38	Q2, Q3, Q4, Q5, Q6, Q7	Low Loss DuoPack: IGBT in TRENCHSTOP™ and FieldStop technology with soft, fast recovery anti-parallel Emitter Controlled HE diode	Infineon Technologies	IKB06N60T
39	R1	RES / STD / 5.1R / 1W / 1% / 100ppm/K / -55℃ to 155℃ / 2512(6332) / SMD / -	Vishay	CRCW25125R10FK
40	R4, R6, R39	RES / STD / 680k / 250mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 1206(3216) / SMD / -	Vishay	CRCW1206680KFK
41	R5, R33, R34, R35,	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-0710KL

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
	R36, R37, R38			
42	R7, R20	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060310K0FK
43	R8	RES / STD / 13.3k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603(1608) / SMD / -	Vishay	CRCW060313K3FK
44	R9	RES / STD / 0R / 125mW / 0R / 0ppm/K / -55℃ to 155℃ / 0805 / SMD / -	Yageo	RC0805JR-070RL
45	R14	RES / STD / 0R / 125mW / 0R / 0ppm/K / -55℃ to 155℃ / 0805 / SMD / -	Yageo	RC0805JR-070RL
46	R10, R11, R12, R13	RES / STD / 1MEG / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12061M00FK
47	R15, R24, R25, R26, R30, R31, R32	RES / STD / 47R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-0747RL
48	R16	RES / STD / 100R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603100RFK
49	R17, R18	RES / STD / 15k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603(1608) / SMD / -	Vishay	CRCW060315K0FK
50	R21, R22, R23, R27, R28, R29	RES / STD / 220R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-07220RL
51	R19	RES / STD / 220R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / - (40 kHz PFC only)	Yageo	RC0603FR-07220RL
		RES / STD / 120R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603(1608) / SMD / - (100 kHz PFC only)	Yageo	RC0603FR-07120RL
52	R200, R201, R202	RES / STD / 3MEG / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12063M00FK
53	R203	RES / STD / 62k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060362K0FK
54	R204, R205, R206	RES / STD / 15MEG / 250mW / 5% / 200ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Yageo	RC1206JR-0715ML
55	R207	RES / STD / 4.7R / 250mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12064R70FK
56	R208	RES / STD / 68k / 250mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW120668K0FK
57	R209	RES / STD / 510k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603510KFK
58	R210	RES / STD / 820R / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603820RFK
59	R211	RES / STD / 0R / 100mW / 0R / 0ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603JR-070RL
60	R212	RES / STD / 1.5k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-071K5L

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
61	R213	RES / STD / 22k / 100mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060322K0FK
62	R214	RES / STD / 48.7k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060348K7FK
63	R215	RES / STD / 9.76k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW06039K76FK
64	RS1, RS2	RES / STD / 75mR / 3W / 1% / 50ppm/K / -55℃ to 170℃ / 2512 / SMD / -	Bourns	CRA2512-FZ-R075ELF
65	RS200, RS201	RES / STD / 5.1R / 250mW / 1% / 100ppm/K / -55 ℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12065R10FK
66	RT1	RES / NTC / 10R / 3.1W / 20% / - / - / - / THT / -	Epcos	B57237S0100M000
67	RT2	NTC Thermistors, Radial Leaded, Standard Precision	Vishay	NTCLE100E3
68	T1	IND / STD / 5mH / - / - / -40℃ to 125℃ / 100mR / T40 / Inductor, THT, 7.00 mm pitch, 4 pin, 40.64 mm L X 40.64 mm W X 25 mm H body / - / -	Wurth Elektronik	750345266
69	TP1, TP2, X200, X201, X202	Test Point THT, Black	Keystone Electronics Corp.	5001
70	TR200	Flyback Transformer, Offline aux SMPS for server, PC power applications	Wurth Elektronik	750344226
71	U3	Single Low-Side Driver IC, Application General Purpose Gate Driver, DC-DC converters, Plasma display panel (PDP)applications	Infineon Technologies	IRS44273LPBF
72	U200	Fixed Frequency 700 V/800 V CoolSET, lowest standby power <100 mW	Infineon Technologies	ICE5GR4780AG
73	U201	Optocoupler, Phototransistor Output, High Reliability, 5300 VRMS, 110 ℃ Rated	Vishay	SFH617A-3X007T
74	U202	Low Dropout Linear Voltage Regulator, 5.0 V Output	Infineon Technologies	TLE42744DV50
75	U203	Precision Programmable Reference	Texas Instruments	TL431CDBZR
76	ZD200	Zener Diode with Surge Current Specification	Vishay	BZD27C22P-HE3-08

4 System performance

4.1 dv/dt test

For motor control systems, dv/dt is important. The motor application requires the switching dv/dt to be below 5 V/ns. This can improve motor-control reliability, but lower dv/dt will also increase the IGBT’s switching losses. This is a trade-off between switching losses and dv/dt. For the PFC turn-on dv/dt, there is a different gate resistor to balance the dv/dt and switching losses for EVAL-M7-HVIGBT-PFCONV4 and EVAL-M7-HVIGBT-PFCINV1. The inverter turn-on dv/dt of the EVAL-M7-HVIGBT-PFCINV board is measured at 1.58 V/ns. Figure 14 shows the inverter dv/dt test waveform.

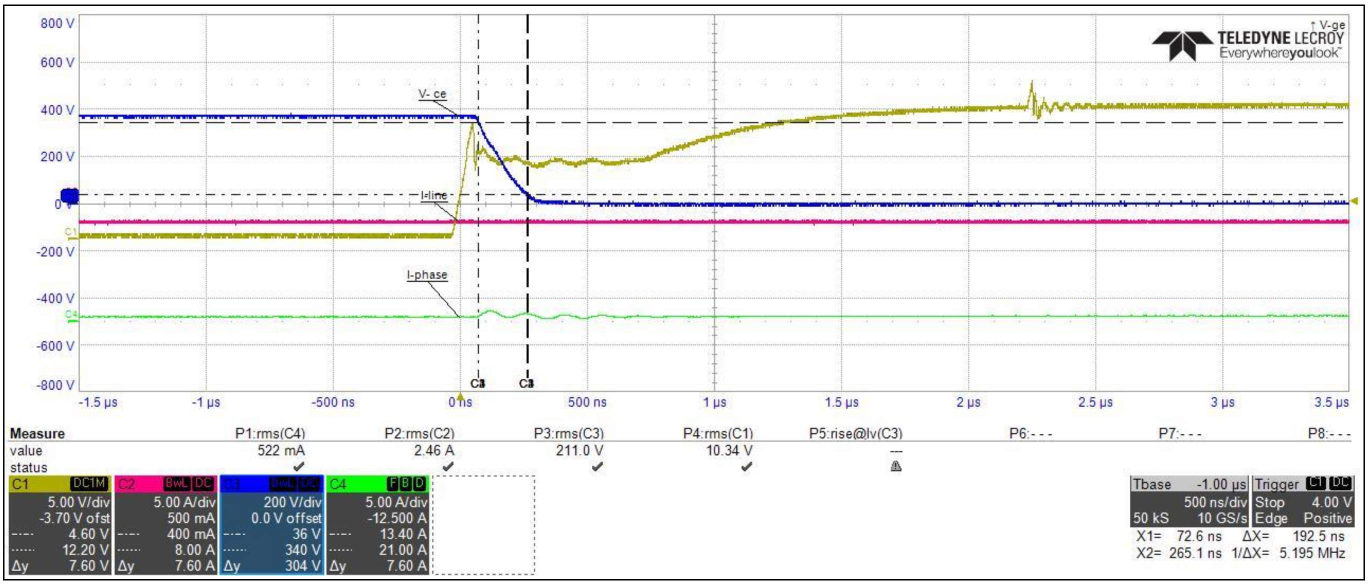


Figure 14 Inverter turn-on dv/dt

4.2 Thermal performance test

For thermal performance test of the EVAL-M7-HVIGBT-PFCINV power board, the input power and motor-phase current were measured when the IGBT case temperature of either PFC IGBT or Inverter IGBT reached 100°C. The power board was tested at different carrier frequencies. The inverter PWM’s frequency range was from 6 kHz to 15 kHz under testing conditions. Note that this power board can be run for up to 20 kHz, but the output power capability will drop down accordingly. Figure 16 shows a thermal test snapshot at 220 VAC input, 6 kHz carrier frequency of inverter, and 400 W input power with force cooling. At this test condition, the hot point of the IGBT on the power board was 72.5℃ for 40 kHz PFC and 87.3℃ for 100 kHz PFC at 23℃room temperature.

The force cooling fan, SJ4020HD2, with 24 VDC input and 0.18 A current was placed as shown in Figure 15. The wind speed over the PFC IGBT was about 1.00 m/s.

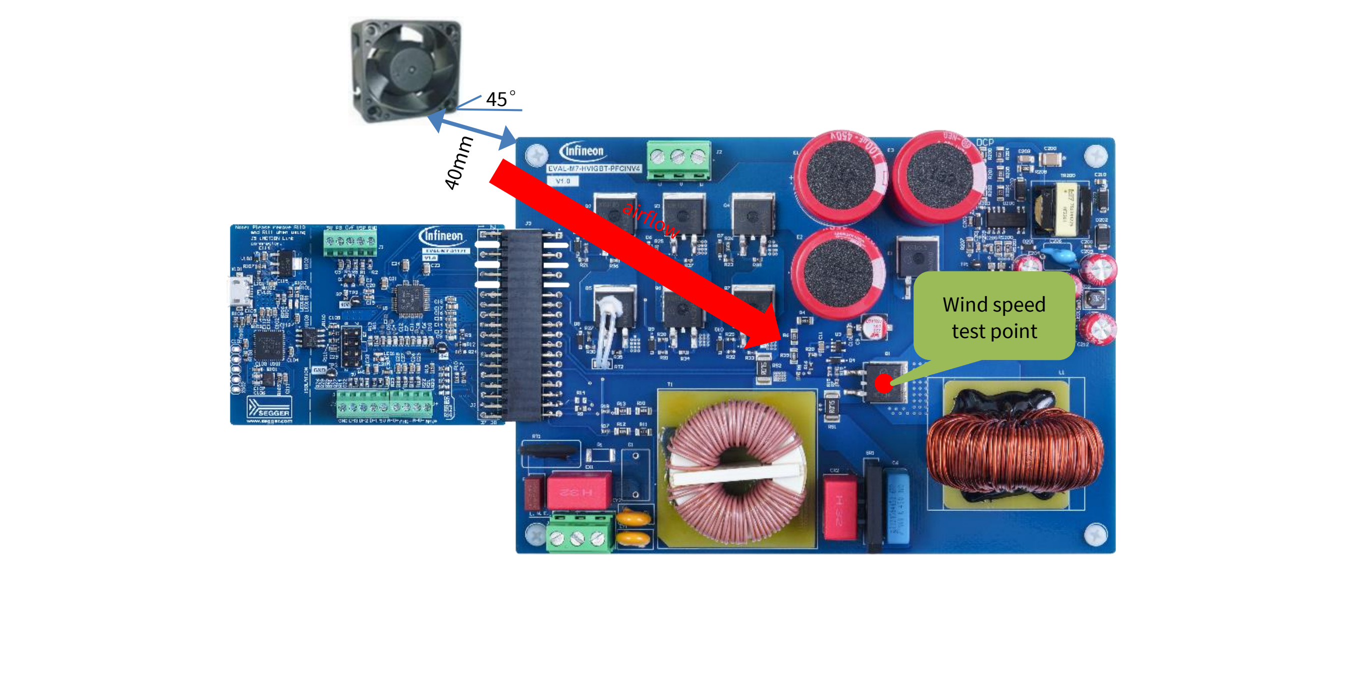


Figure 15 Cooling fan location for the test

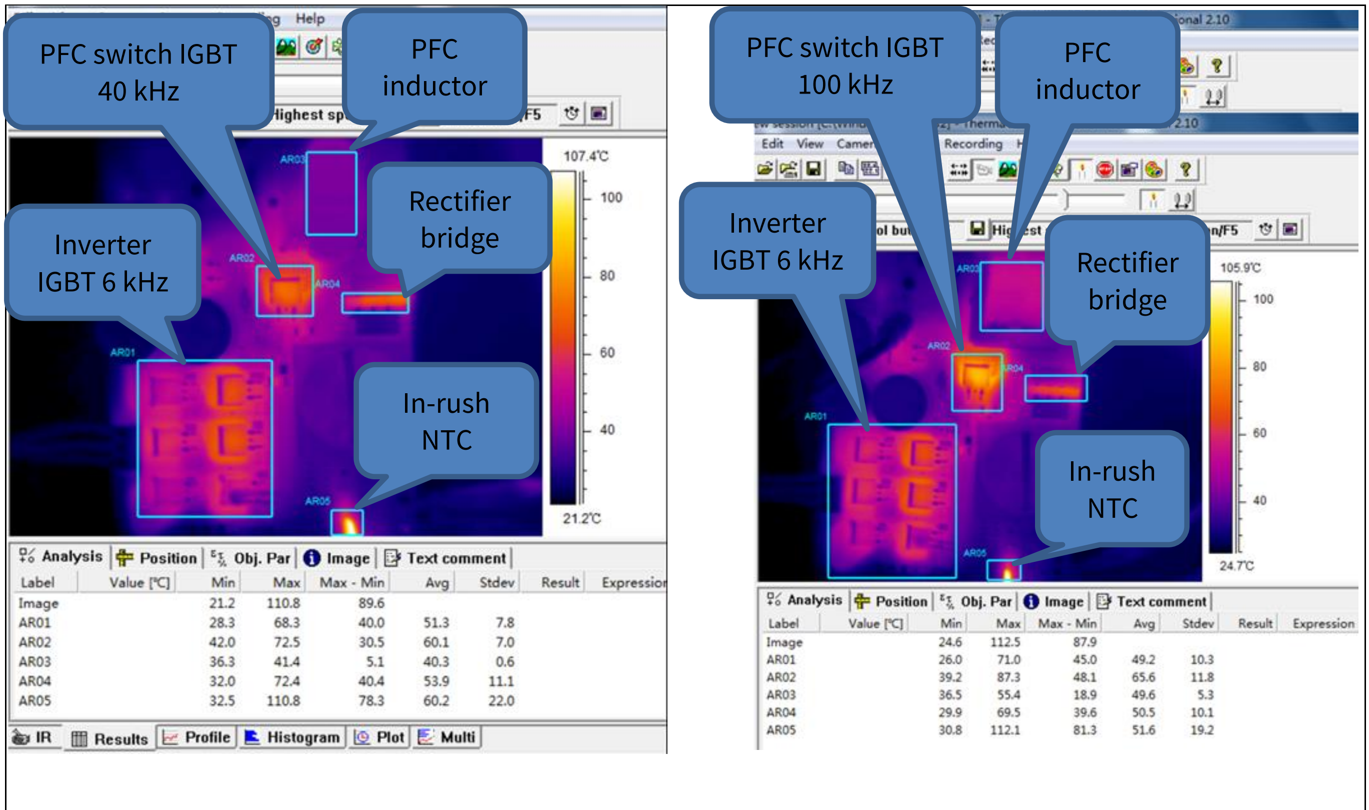


Figure 16 Thermal test snapshot with cooling fan at 220 Vac input, 40 kHz & 100 kHz PFC, and 400 W output

4.3 PFC test results

The two power boards, EVAL-M7-HVIGBT-PFCINV4 and EVAL-M7-HVIGBT-PFCINV1, were tested with the IMD112T control board, EVAL-M7-D112T. Please refer to the EVAL-M7-D112T control board's user guide, UG-2023-04, for more details [4].The EVAL-M7-HVIGBT-PFCINV power board can support up to 200 W output power with natural cooling and 400 W output power with force cooling (24 V_{DC}/0.18 A cooling fan). The EVAL-M7-D112T can, of course, drive higher power output when matched with a higher rated power board compatible with M7 connector.

Table 8 lists the PFC test results with 40 kHz and 100 kHz PWM frequency. The line current total harmonic distortion (THD) is as low as 1.031% at 220 Vac input, 40 kHz PFC, and 400 W load.

Table 8 PFC test results

Test conditions	PFC inductor: 3.5 mH for 40 kHz; 1.5 mH for 100 kHz PFC frequency: 40 kHz; 100 kHz DC Bus voltage: 380 V AC input: AC power source (50 Hz selected for test)				
Input voltage (Vac)	**Input power (W)**	**PF**	**I_{THD} (%)**	**PFC frequency (kHz)**	**Condition**
170	205	0.9974	1.352	40	Natural cooling
	405	0.9996	1.175	40	Fan cooling
220	202	0.9932	1.821	40	Natural cooling
	411	0.9986	1.031	40	Fan cooling
260	207	0.9853	3.817	40	Natural cooling
	409	0.9966	1.972	40	Fan cooling
170	201	0.9962	3.642	100	Natural cooling
	373	0.9994	2.166	100	Fan cooling
220	207	0.9896	4.330	100	Natural cooling
	404	0.9971	2.656	100	Fan cooling
260	203	0.9773	6.777	100	Natural cooling
	405	0.9949	1.988	100	Fan cooling

4.4 Test results

The output power capability of the EVAL-M7-HVIGBT-PFCINV power board was tested at different carrier frequencies. The IGBT case temperature of both boards was tested for up to 100℃ under test conditions. All the tests were conducted at room temperature. The tests began with natural cooling; the cooling fan was started when the case temperature of either the PFC IGBT or the inverter IGBT reached 100℃. The test was stopped when the input power reached 400 W.

Typically, I_{THD} is as low as 1.031% at 220 Vac input voltage and 410 W input power for 40 kHz PFC PWM and I_{THD} is 2.656% for 100 kHz PFC PWM under same conditions: 220 Vac input voltage, 410 W input power.

Figure 17 and Figure 18 show the increment in PFC IGBT case temperature in relation to input power for 40 kHz and 100 kHz PFC frequency. Figure 19 shows the inverter IGBT's highest case temperature increment versus the motor-phase current at different PWM frequencies. Figure 20, Figure 21, and Figure 22 depicts the scope waveforms for input line voltage and current, DC bus voltage, PFC inductor current, and inverter phase current at 400 W input power.

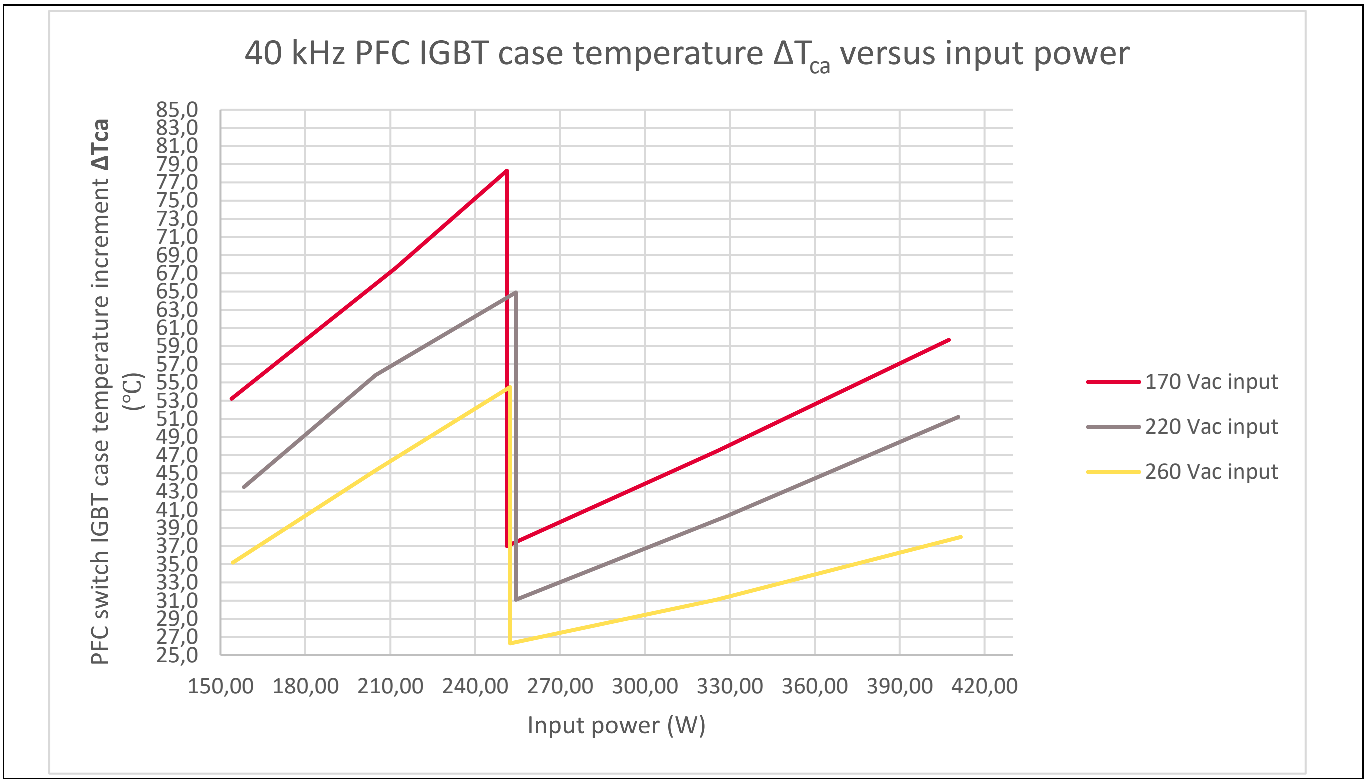


Figure 17 PFC switch IGBT ΔT_{ca} versus input power at 40 kHz PFC frequency

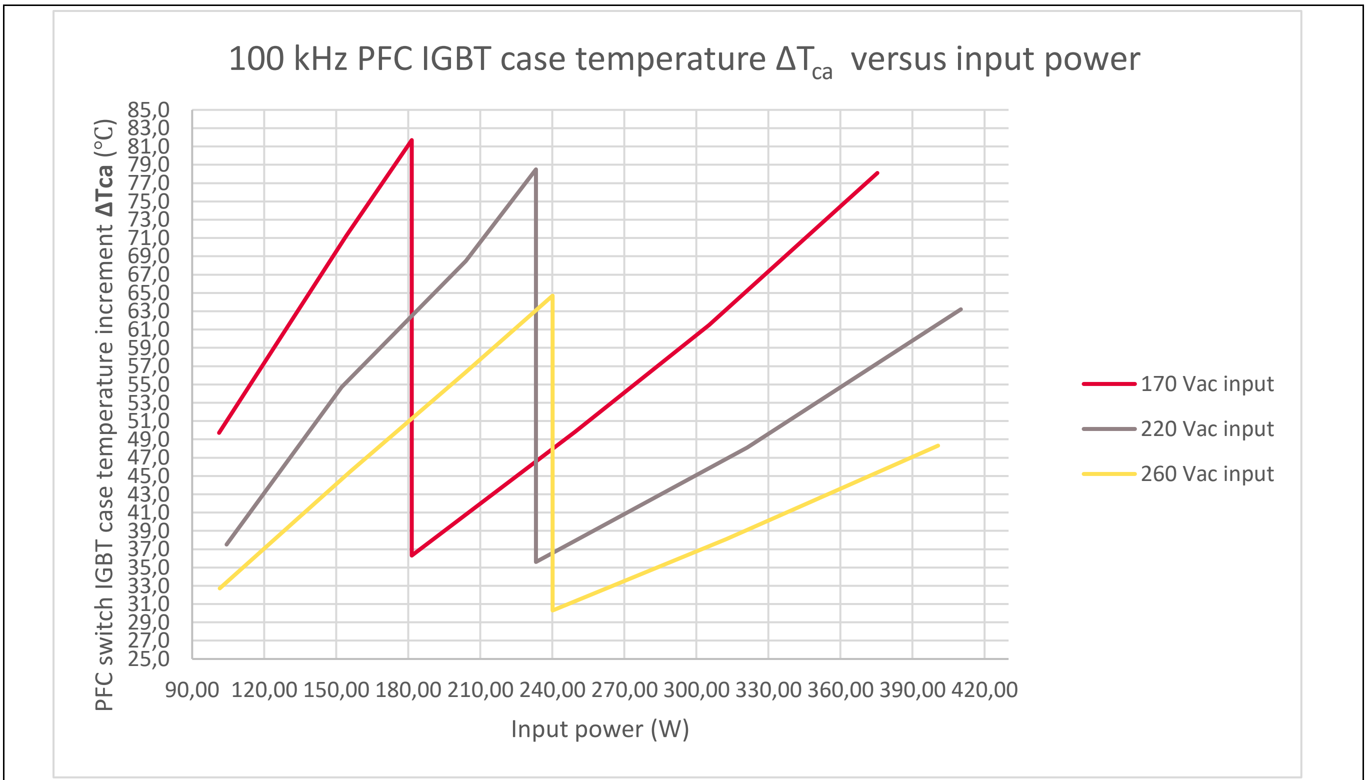


Figure 18 PFC switch IGBT ΔT_{ca} versus input power at 100 kHz PFC frequency

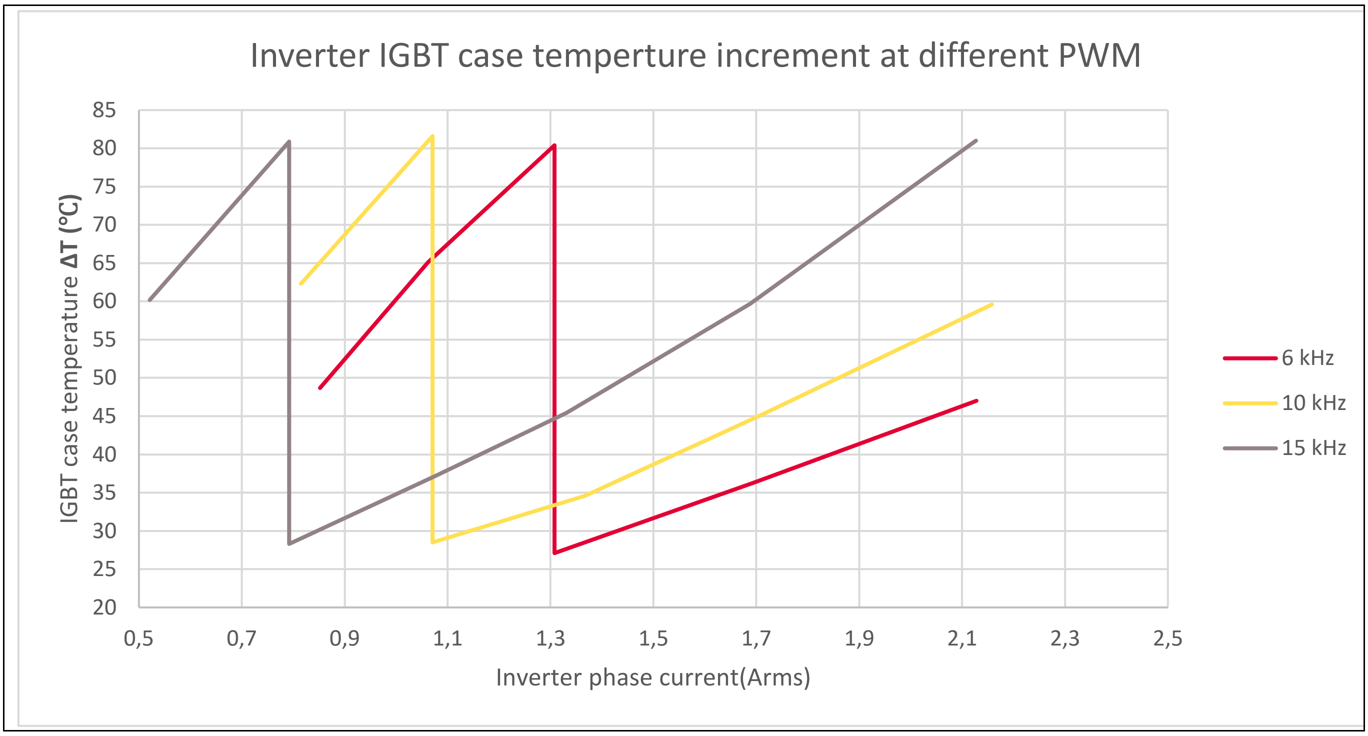


Figure 19 **Inverter IGBT case temperature ΔT_{ca} versus output phase current at different carrier frequencies**

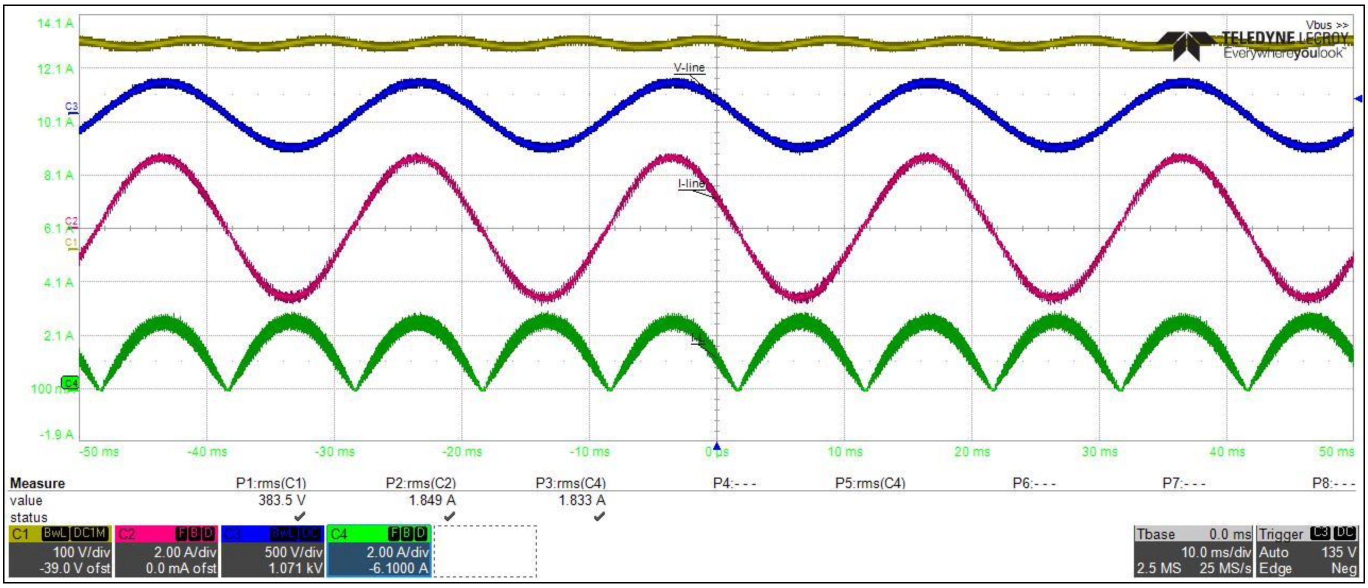


Figure 20 **Line voltage (blue), line current (red), DC bus voltage (yellow), PFC inductor current (green) at 40 kHz PFC PWM, 220 Vac input, 400 W output (2.1 Arms phase current)**

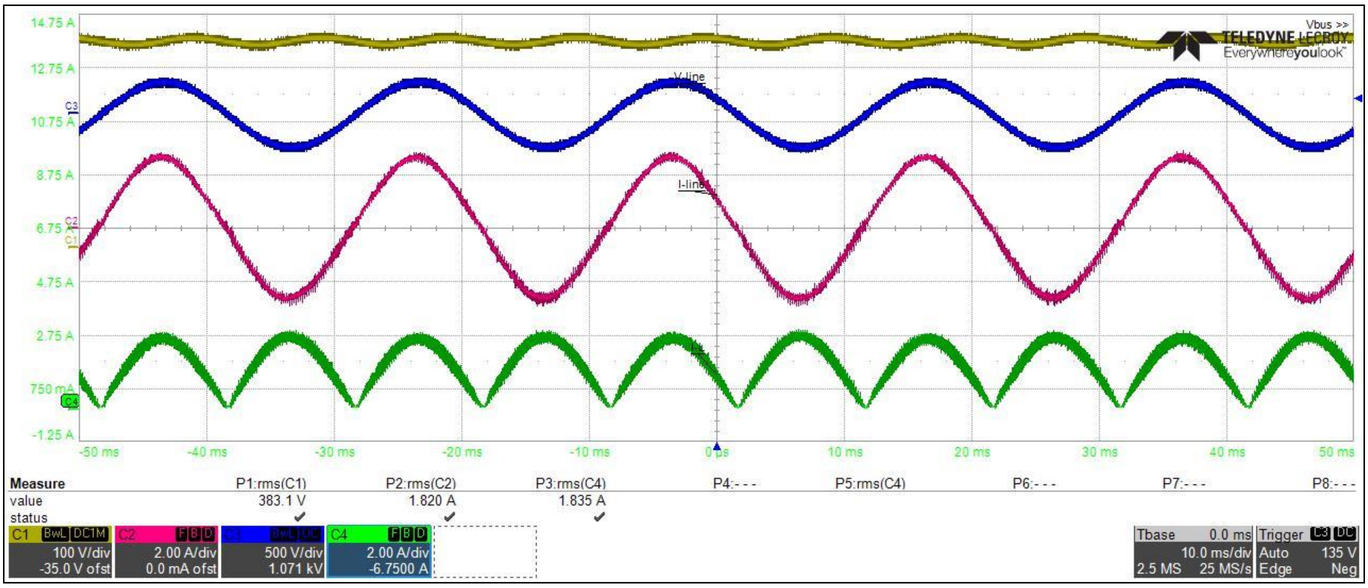


Figure 21 Line voltage (blue), line current (red), DC bus voltage (yellow), PFC inductor current (green) at 100 kHz PFC PWM, 220 Vac input, 400 W output (2.1 Arms phase current)

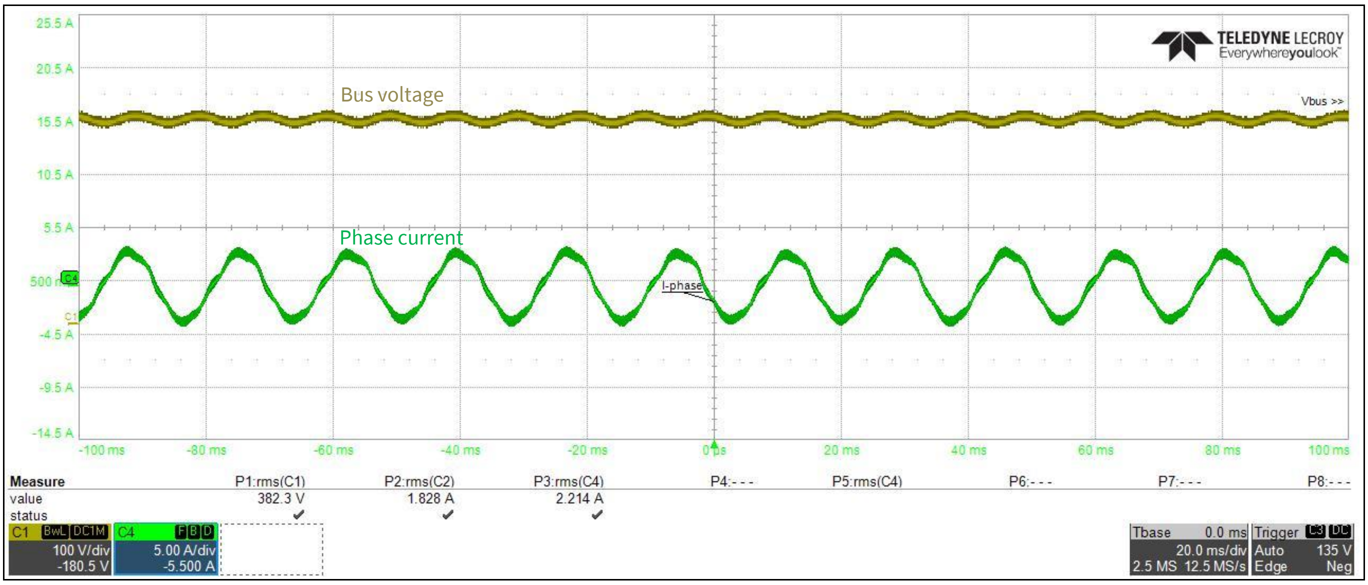


Figure 22 DC bus voltage (yellow) and inverter phase current (green) waveforms at 400 W input power and 6 kHz inverter PWM

5 Appendices

5.1 Abbreviations and definitions

Table 9 Abbreviations

Abbreviation	Meaning
THD	Total harmonic distortion
EMI	Electromagnetic interference
PFC	Power factor correction
PF	Power factor
iSD	iMOTION™ Solution Designer
FOC	Field oriented control

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[1] Infineon Technologies AG. Datasheet (2018): IKB15N65EH5 – TRENCHSTOP™ 5 high speed switching IGBT with full rated current RAPID 1 anti paralled diode. V2.1 www.infineon.com

[2] Infineon Technologies AG. Datasheet (2013): IKB06N60T – TRENCHSTOP™ and FieldStop technology with soft, fast recovery anti-paralled Emitter Controlled HE diode. V2.5 www.infineon.com

[3] Infineon Technologies AG. User manual (2022): Getting Started with iMOTION™ Solution Designer. www.infineon.com

[4] Infineon Technologies AG. User guide (2023): EVAL-M7-D112T user guide. www.infineon.com

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