EVAL-M7-HVMOS-INV user guide

Evaluation power board with M7 connector

About this document

Scope and purpose

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

EVAL-M7-HVMOS-INV is an evaluation power board with Infineon's latest CoolMOS™ PFD7 super-junction MOSFETs. This board features and demonstrates Infineon's CoolMOS™ PFD7 technology for inverter circuitry at hard switching conditions. The CoolMOS™ PFD7 optimizes switching and conduction losses to achieve high efficiency. The MOSFETs used on this board are in a SOT-223 package. This board is suitable for driving fans, pumps, and other smaller motors. The output power is up to 300 W with a heatsink at 16 kHz carrier frequency.

The evaluation board EVAL-M7-HVMOS-INV was developed to support users during their first steps in designing applications with running permanent magnet motors via sensorless 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. This board is intended to be used under laboratory conditions.

Evaluation board

This board will be used during the design-in phase, for evaluation and measurement of characteristics, and proof of data-sheet specifications.

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

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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 EVAL-M7-HVMOS-INV is an evaluation power board with an M7 connector. Please refer to Chapter 2.2.1 for details of the M7 connector pinout assignment. This evaluation power board was designed to be driven by a control board that is compatible with the M7 connector. Such a control board is the EVAL-M7-D111T smart-driver control board, however, other control boards that are M7 connector-compatible can also be used to drive this power board. The power board can handle up to 300 W output power when the carrier frequency is 16 kHz with an external heatsink.

The main device on the evaluation board is Infineon's 600 V CoolMOS™ PFD7 high-voltage MOSFET. The part number is IPN60R600PFD7S. This 600 V CoolMOS™ PFD7 high-voltage MOSFET series sets a new benchmark in 600 V super-junction (SJ) technologies, and combines best-in-class performance with state-of-the-art ease of use. It features an integrated fast body diode, ensuring a robust device, and hence reduced BOM for the user. CoolMOS™ PFD7 pushes the SJ MOSFET technology to new limits, leading to outstanding improvements such as lower conduction and charge/discharge losses, as well as reduced turn-off and gate-driving losses. The MOSFET has an integrated ESD protection of up to 2 kV that eliminates ESD-related yield loss.

The key features and functionality of this board are described in Chapter 1.3 with the main features of this document (UG-2021-24). The remaining 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 depicts the evaluation board EVAL-M7-HVMOS-INV.

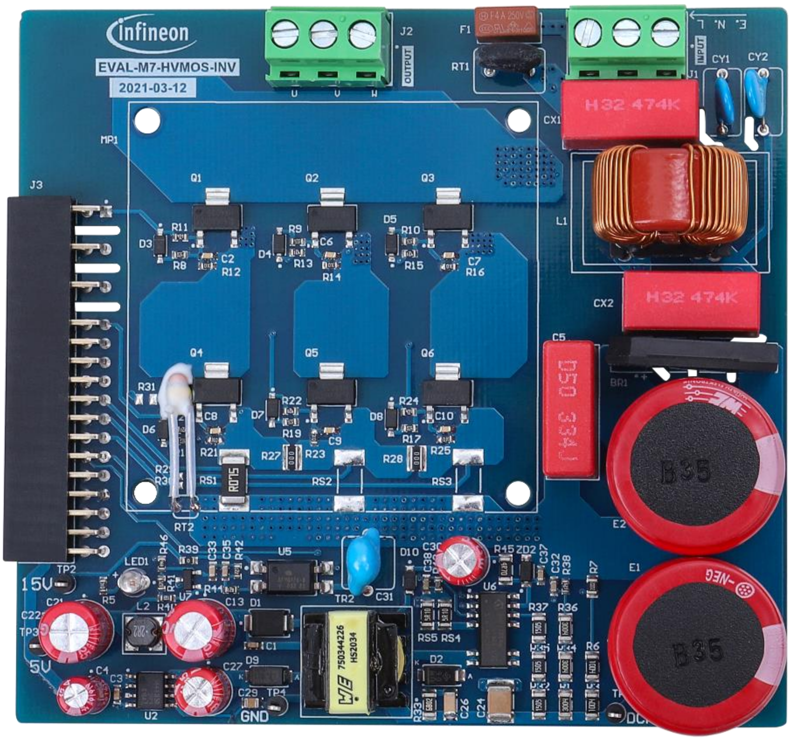


Figure 1 Evaluation board of EVAL-M7-HVMOS-INV

1.1 Scope of supply

The scope of supply comprises only the board, as shown in Figure 1. The detailed ordering information is indicated inTable 2.

If users do not have a control board, the Infineon smart-driver control board EVAL-M7-D111T can be used to evaluate the power board. Ordering information can be found in the following link.

Table 2 Ordering information

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
EVAL-M7-HVMOS-INV		Boxed	1	SP005555668
IPN60R600PFD7S	SOT-223	taped		

1.2 Block diagram

Figure 2 shows the block diagram of the EVAL-M7-HVMOS-INV and the connections with the control board. An example control board such as the EVAL-M7-D111T can be used for the motor drive with sensorless or rotor angle and speed feedback. The IMD111T has 5 V output capability with a maximum current of 20 mA. The 5 V power supply on the EVAL-M7-HVMOS-INV board is optional if the application needs more current output capability, or if the control board is without 5 V output power supply.

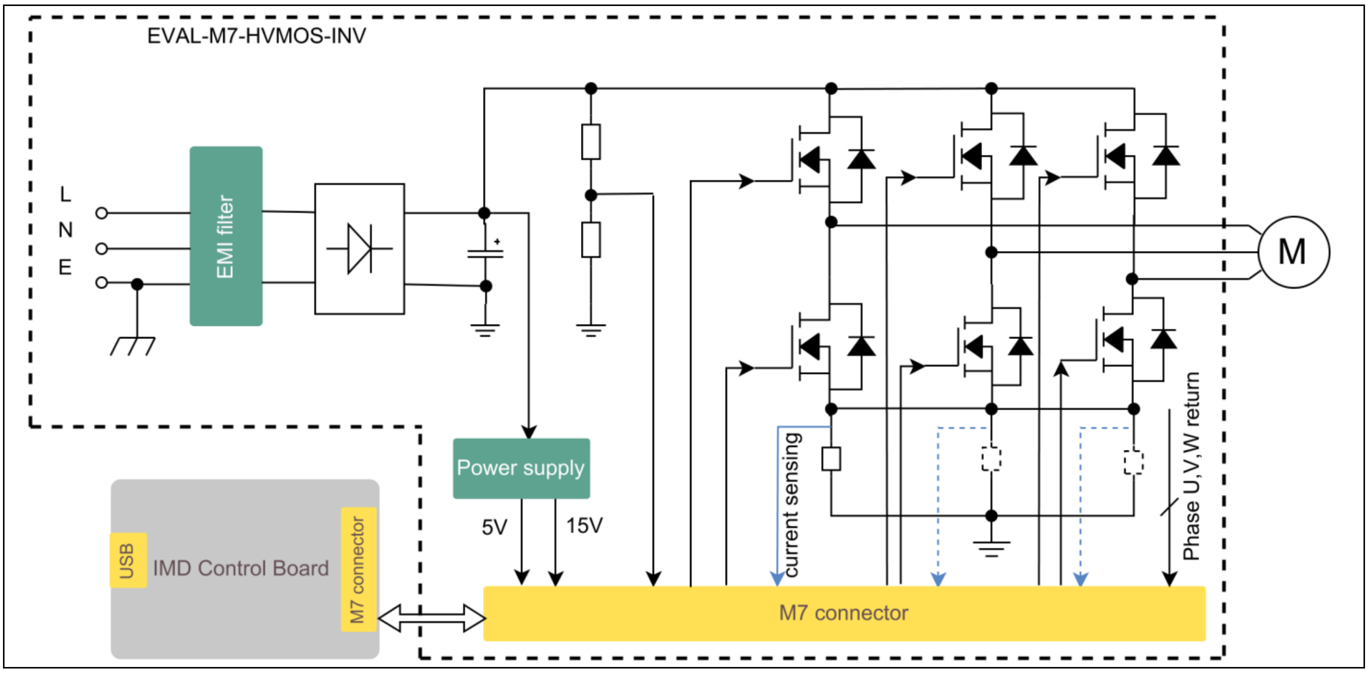


Figure 2 EVAL-M7-HVMOS-INV block diagram

1.3 Main features

EVAL-M7-HVMOS-INV is an evaluation board using Infineon's 600 V CoolMOS™ PFD7 high-voltage MOSFET. This board is suitable for permanent magnet synchronous motor or brushless direct current motor (PMSM or BLDC) control for home appliances, fans, pumps, etc.

The main features of the CoolMOS™ PFD7 IPN60R600PFD7S include:

- Extremely low losses
- Low switching losses E_{OSS}, excellent thermal behavior
- Fast body diode
- Wide-range portfolio of $R_{DS(on)}$ and package variations
- Integrated Zener diode
- Enables high-power density designs and small form factors
- Enables efficiency gains at higher switching frequencies
- Excellent commutation robustness
- Easy-to-select parts and optimize the design
- High ESD robustness

The main features of the EVAL-M7-HVMOS-INV evaluation board include:

- Best-in class performance CoolMOS™ PFD7 MOSFET used for the inverter section
- Single-shunt or leg-shunt current feedback configuration are alternatives
- 5 V and 15 V output power supply on the board
- PCB size is 96 mm x 103 mm, 2 layers, 1 oz copper
- RoHS-compliant

1.4 Board parameters and technical data

Table 3 depicts the evaluation board parameters and technical details.

Table 3 Board specification

Parameter	Symbol	Conditions	Value	Unit
Input AC voltage	V_{IN}	220 V_{AC} input	220±15%	V_{AC}
15 V output voltage	+15 V	Maximum 100 mA output current	15±5%	V
5 V output voltage	+5 V	Maximum 150 mA output current	5±5%	V
Maximum input power	P_{IN}	16 kHz carrier frequency with an external heatsink	300	W
Max. switching frequency	f_{SW}	V_{CC}=15 V	20	kHz
Max. output phase current	I_{phase_rms}	T_A=20℃, T_C=100℃, air cooling	1.3	A
Max. DC bus voltage	$V_{DC(max)}$	DC bus capacitor is 450 V rated voltage	400	V
PCB characteristics				
Material		1.6 mm thickness, 1 oz copper, 2 layers	FR4	
Dimensions		Length × width × height	103 × 96 × 42	mm
System environment				
Ambient temperature	T_{amb}	Non-condensing, maximum RH 95%	0 ~ 50	℃

2 System and functional description

2.1 Commissioning

The EVAL-M7-HVMOS-INV evaluation board is a power board and thus has no control function. Therefore, it should be used with an M7 connector-compatible control board. Figure 3 is an example of a system setup with Infineon iMOTION™ smart driver IMD111T control board EVAL-M7-D111T. The IMD111T is a motion control engine (MCE) 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-D111T control board can find more details in the Infineon user guide UG-2021-17. The IMD111T control board user guide describes how to use iMOTION™ tools to run the board.

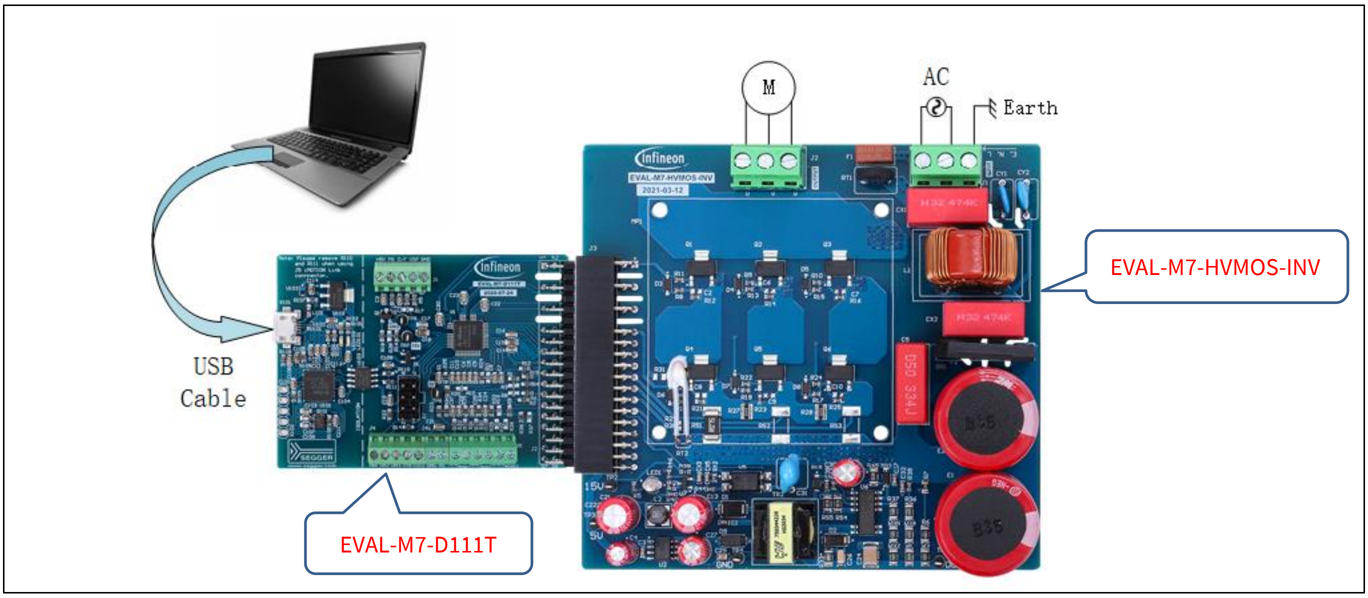


Figure 3 System setup example

2.2 Getting started with the IMD controller board EVAL-M7-D111T

Here is an explanation on how to set up the system and how to use the MCEWizard and MCEDesigner tools for creating and tuning users' motor parameter. The control board is the EVAL-M7-D111T. Figure 3 shows the system setup.

2.2.1 System set up

Before using the EVAL-M7-D111T IMD to evaluate this power board, users should install the iMOTION™ development tools (MCEWizard and MCEDesigner) on their computer. The iMOTION™ development tools can be downloaded from the Infineon website (link). The following steps must then be executed to run the motor. Refer to Chapters 2.2.1.1 and 2.2.1.2 as well as to the MCEWizard and MCEDesigner user guide for more information.

1. Get the latest "IMD111T Software Package" available on the www.infineon.com/imotion-software website.

2. Connect PC and evaluation board via USB cable or iMOTIONTM link.

3. Connect the AC source and target motor.

4. Use MCEWizard to calculate and create a parameter text file. See the MCEWizard setup overview in Chapter 2.2.1.1 for more details.

5. Power-on the system and start the MCEDesigner tool to open MCEDesigner default configuration file (.irc) for the IMD111T smart driver.

6. Program the firmware and calculated parameters into the flash. See the MCEDesigner setup overview in Chapter 2.2.1.2 for more details.

7. After programming successfully, click on the hammer icon to clear the fault signals if there is a red light at the bottom of MCEDesigner. When the system is ready, start the motor by clicking the green traffic light. Clicking the red traffic light stops the motor.

2.2.1.1 MCEWizard setup overview

MCEWizard defines control gains, limits and fault levels based on real number inputs, and converts gains and levels to parameter counts based on hardware and control limit settings. MCEWizard also exports parameters and variable scale factors to the MCEDesigner.

- Double-click the MCEWizard shortcut on Windows desktop; the MCEWizard welcome page is shown as in Figure 4.
- If users have the evaluation design kit MCEWizard configuration file, they only need to click the "Open System Configuration File" button and change the user's motor parameters under test.
- But if users do not have this evaluation design kit MCEWizard configuration file, they need to click the button "File" and select "Create System Configuration File." Then follow the pop-up window prompt to complete the configuration step by step.

For this system setup, if users do not have the MCEWizard configuration file, they should click "File" and select "Create System Configuration File," then select the IMD111T device in the pop-up window. Next, click OK and return to the welcome page, then select "Customized Design for Expert User." Click the "Next" button to answer all the questions concerning the hardware design and user test motor specification.

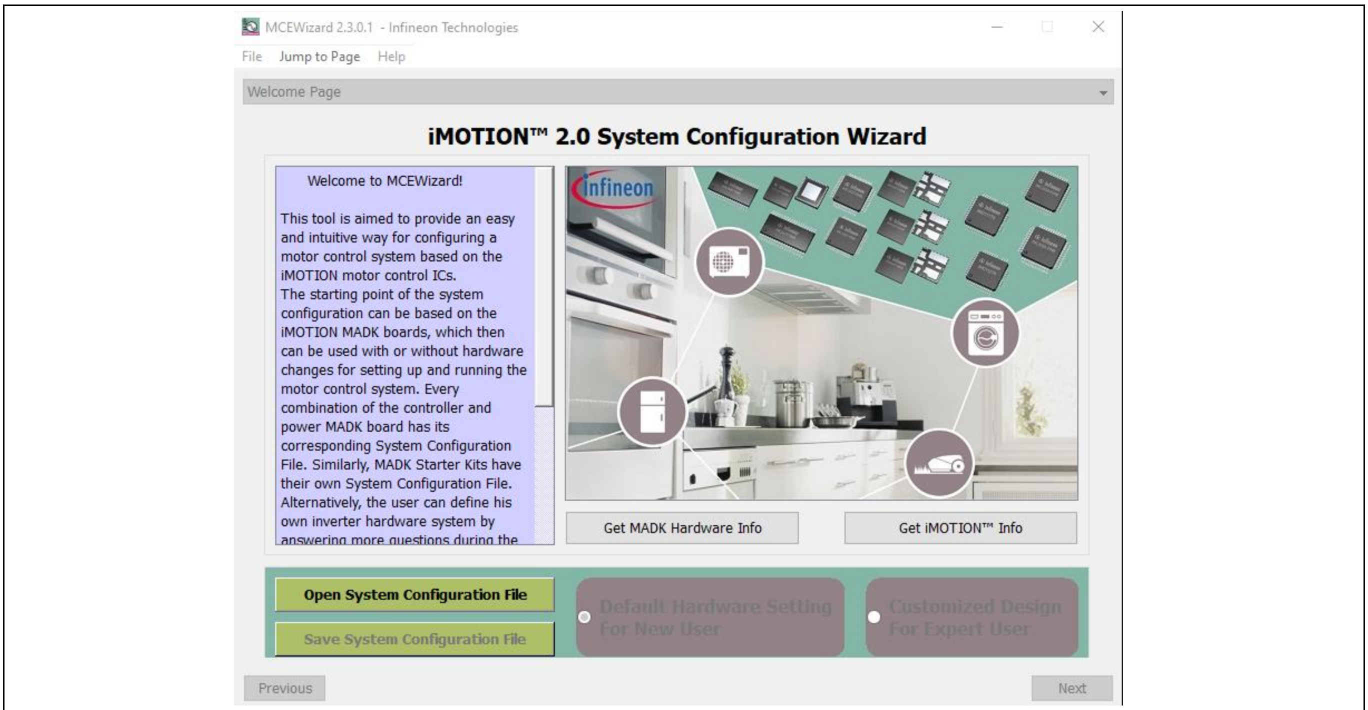


Figure 4 MCEWizard welcome page

Table 4 lists key questions to be answered in the MCEWizard in order to set up the system based on the evaluation board. The remaining set of questions also needs to be answered, including questions about OV/UV protection, fault conditions, startup setting, etc.

Table 4 MCEWizard setup overview table

Parameter	Value	Comment
Motor1 PWM frequency, current sensing configuration and control input on Option page	Fc<20 kHz, UART/VSP/duty/frequency Single/leg-shunt configuration	Key for selecting the IC working status
User motor parameters	Depends on the motor under test	Such as rated current, poles Lq, Ld, maximum RPM, etc.
DC bus sensing high resistor	2000 kΩ on board	These resistors are on the power board.
DC bus sensing low resistor	12.7 kΩ on board	The resistor is on the power board
Motor current input scaling	68.8 mV/A	Depends on the hardware design, single-shunt configuration
Current input to ADC offset voltage	415 mV	Depends on the hardware design
Overcurrent trip level	2.7 A	Depends on the rated current of the power board and motor
Catch spin	Enable/disable	

After answering all the questions, go to the "Verify & Save Page" (see Figure 5). On that page, click the "Calculate Parameters" button to create the parameters. Then click the "Export to MCEDesigner File" button to export and save the parameter text file.

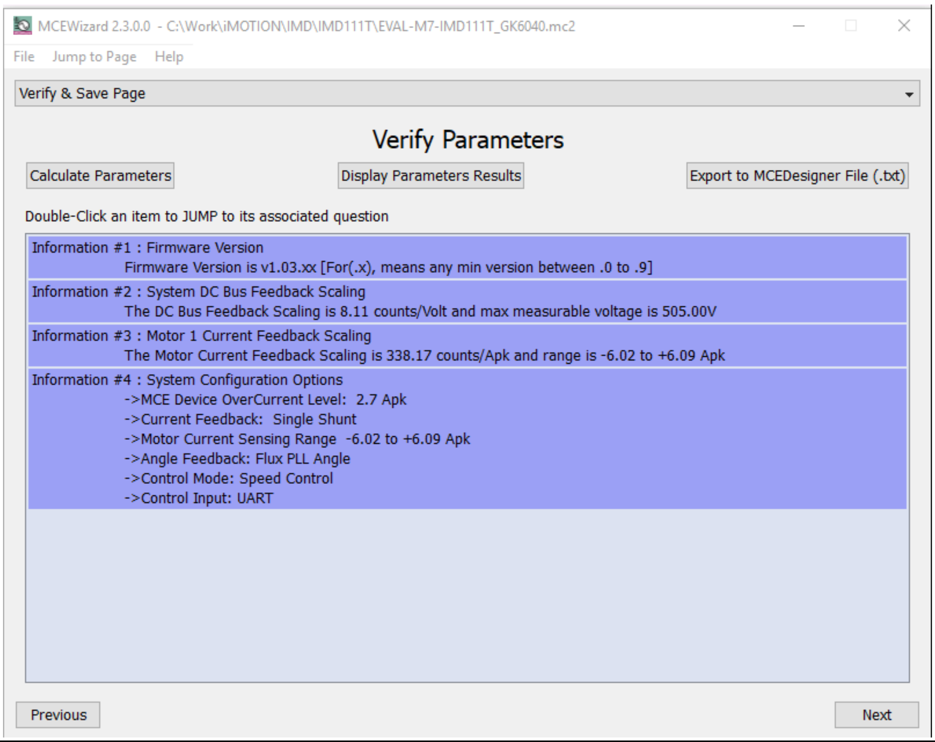


Figure 5 Verify & Save page of MCEWizard

2.2.1.2 MCEDesigner setup overview

The MCEDesigner is a tool used for programming code, and tuning the evaluation board. It also has the possibility to read from 16-bit MCE variable registers, and to read/write to MCE parameter registers. The MCEDesigner displays both real and counts value for all variable registers, and selects parameter registers. The count value means to convert the real value to digital number. The registers' value format can be selected from the "Performance > Tuning Value Format" pop-up window.

After installing the MCEDesigner installer, a shortcut for opening the tool will be available on the Windows desktop. Take the following steps to quick-start the MCEDesigner:

- Double-click the shortcut button to open MCEDesigner.
- Open the MCEDesigner default configuration file (.irc) for IMD111T smart driver (IMD111T_V1.03.01.irc included in the firmware zip folder downloaded from the Infineon website).
- Select the available COM port in "Performance > Connection" pop-up window

The MCEDesigner window appears as shown in Figure 6.

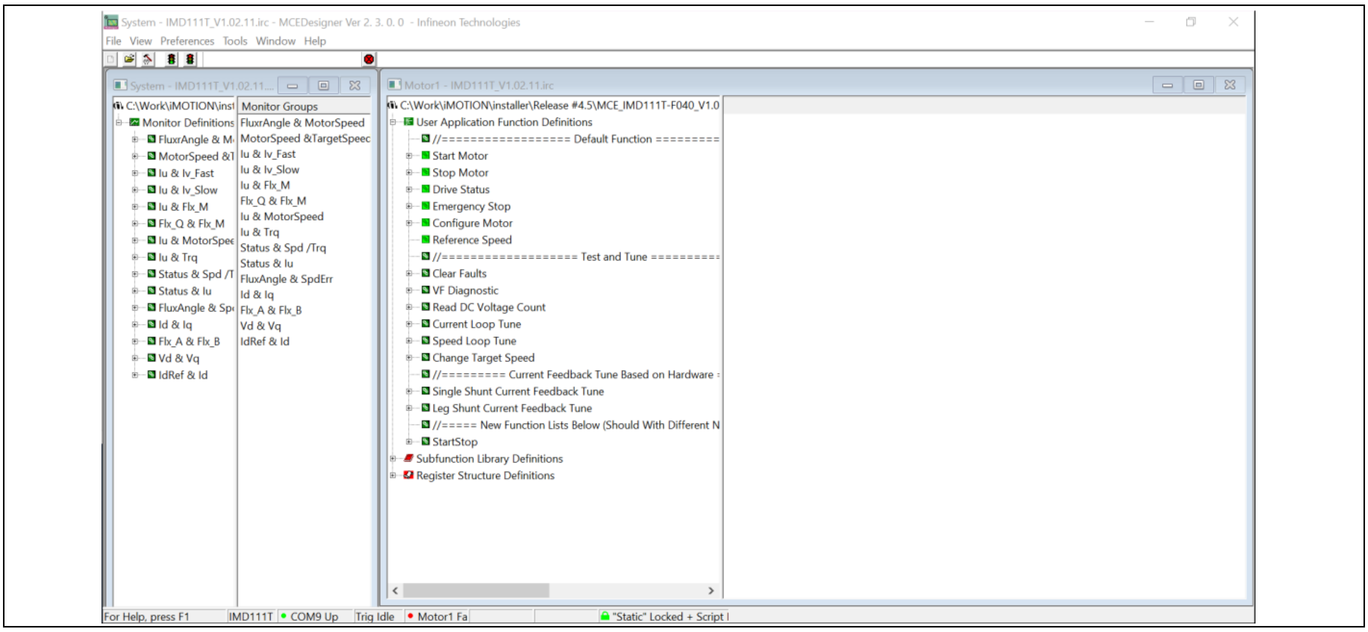


Figure 6 **MCEDeisgner window page**

For the next step, you need to program the firmware (.ldf file) and parameters (.txt file) into flash.

- Click on the "Tools" menu in the "System" window and select "Programmer" from the pull-down list.
- Choose the relevant ldf file and text file.
- Then click the Start button to program the ldf and text files.

The ldf file can be downloaded from the Infineon website. The txt file was created by the MCEWizard as described in Chapter 2.2.1.1. The programming window is shown in Figure 7 below.

After the firmware and parameters are programmed, the system will be ready to run the motor. You can click the green traffic light to start the motor or click the red traffic light to stop the motor. You can now check the waveform of phase current, Flx_M, motor speed, and other registers' values by double-clicking the monitor items in the system window.

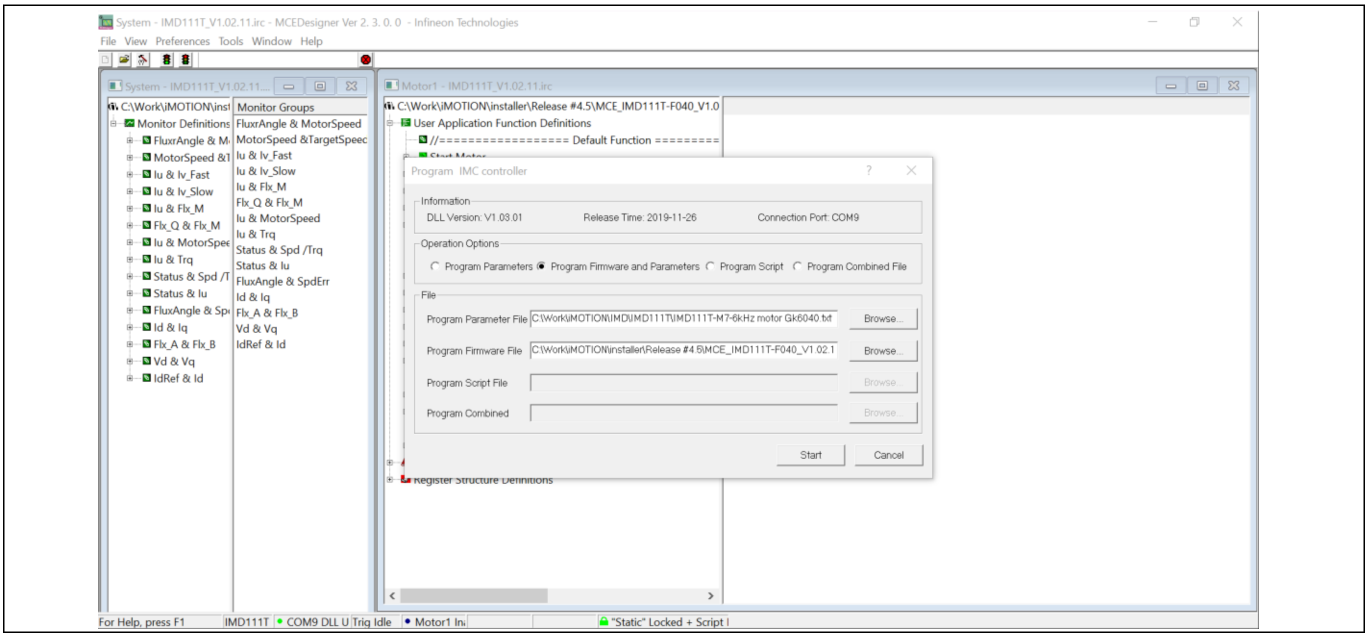


Figure 7 Programming window

2.3 Description of the functional blocks

This chapter covers the hardware design of the EVAL-M7-HVMOS-INV in more detail, so that users can understand the functional groups of this power board and use the board to easily evaluate the performance. And it is also helpful for users to develop their solution based on the evaluation board design.

2.3.1 E VAL-M7-HVMOS-INV functional groups

Figure 8 depicts the evaluation board of EVAL-M7-HVMOS-INV functional group.

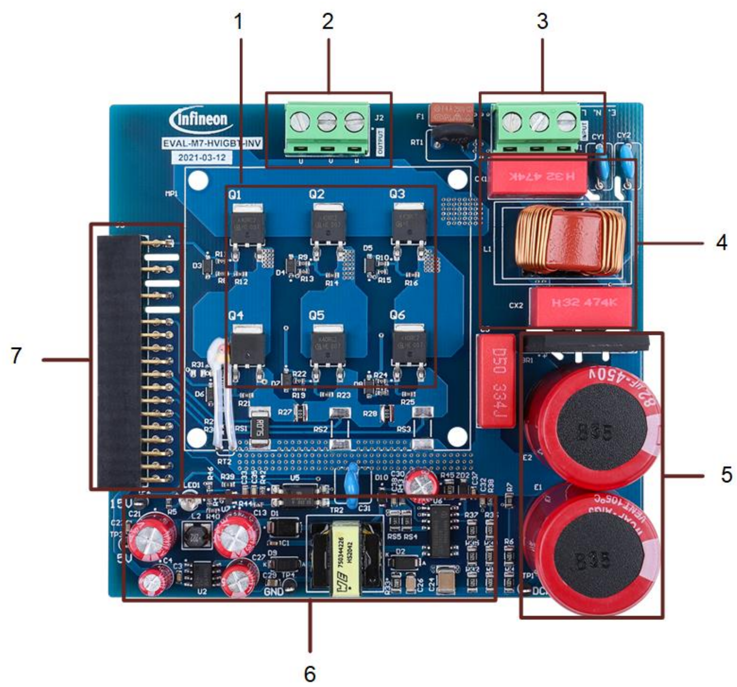


Figure 8 Functional groups

1. Inverter function (Q1~Q6)
2. Inverter output connector (J2)
3. 220 VAC input connector (J1)
4. EMI filter (CX1, CX2, L1)
5. Rectifier bridge & bus capacitors (E1, E2, BR1)
6. Auxiliary power supply (U2, U6, TR2)
7. M7 connector (J2)

There are 3 connectors on the EVAL-M7-HVMOS-INV board. All connector pin assignments are described in Table 5 to Table 7.

Table 5 $220V_{AC}$ input connector-J1

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

Table 6 Inverter output connector-J2

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

Table 7 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 LDO output
20	VDD1	External VDD supply voltage
21	IU+	U phase current-sensing signal positive

Pin Number	Symbol	Assignment
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)

2.3.2 Bus voltage feedback

The EVAL-M7-HVMOS-INV evaluation board includes a bus voltage feedback circuitry. It is a voltage divider. The high-side resistor is composed of two 1 MΩ resistors (R3, R6) in series, and the low-side resistor (R7) is composed of one 20 kΩ. Figure 9 shows the bus voltage feedback on the board. Make sure the low-side resistor is on this power board, which is different from some other power boards that have the low-side resistor on the control board. The control board EVAL-M7-D111T has no low-side resistor, but only a decoupling capacitor, which is located near the input pin of the IMD111T bus voltage feedback. So if users use a different control board, they should keep in mind the location of the low-side resistor, and make sure to get the correct feedback voltage.

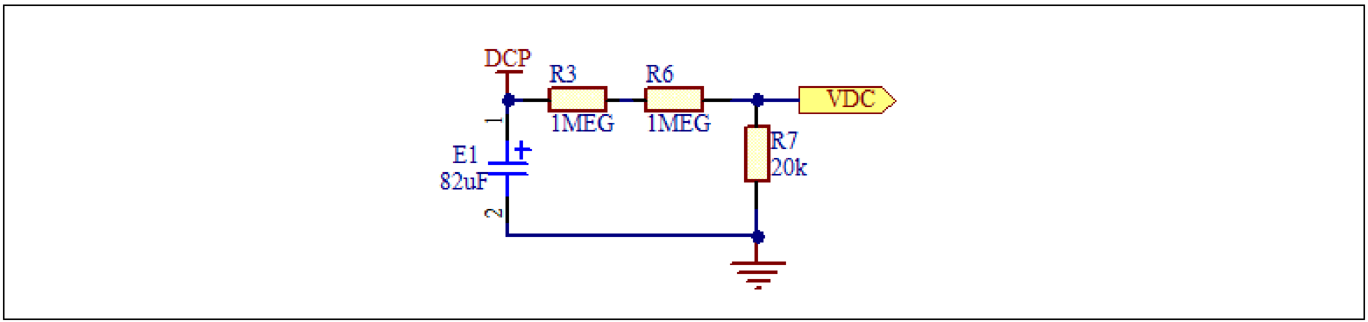


Figure 9 **Bus voltage feedback**

2.3.3 Current feedback configuration

There are two current feedback configurations on this EVAL-M7-HVMOS-INV power board. One is a single-shunt current feedback configuration. The other is a leg-shunt current feedback configuration. The single shunt configuration is the default setting on the board. If users want to use a leg-shunt configuration, they should remove the resistors R26, R27, and R27 first. Then they should solder the resistors R29, R30, R31, RS2, and RS3. The value is 0 Ω for R29, R30, and R30. RS2 and RS3 are 75 mΩ. Please refer to the schematics for more details in Chapter 3.

Figure 10 shows the single-shunt current-sensing circuit. According to the explanation in MCEWizard for Question 83, the current input scaling can be calculated as:

$$Current\ input\ scaling = G_{ext} \times Rs = \frac{R12}{R15 + R12} \times RS2 = \frac{22.1}{2 + 22.1} \times 75 = 68.8\ mA/V$$

And the offset voltage calculated is:

$$Voff = \frac{\mathrm{R15}}{\mathrm{R15 + R12}} \times VDD = \frac{2}{2 + 22.1} \times 5 = 0.415\ V = 415\ mV$$

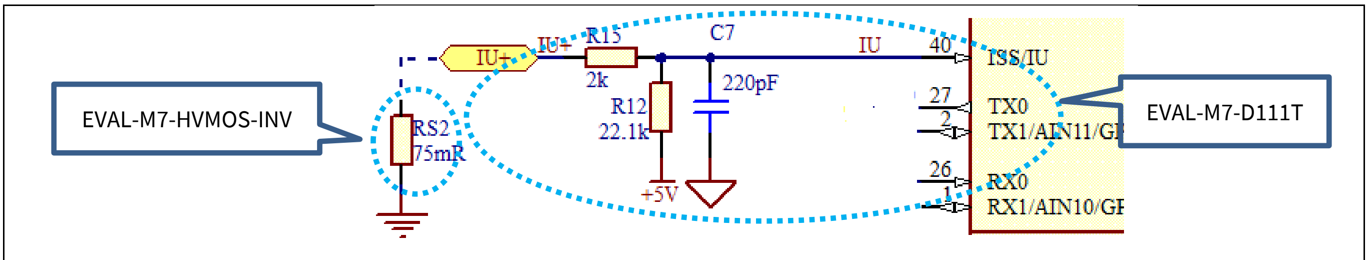


Figure 10 **Current sensing – single shunt**

2.3.4 Temperature measured with NTC on board

In order to measure the case temperature of the MOSFET switch, an NTC was assembled on the board near the U-phase, low-side MOSFET. The NTC was placed on the board as shown in Figure 11. It is very close to MOSFET with glue. But there is a little gap between the NTC and MOSFET case. So there will be a difference between the measured case temperature and real MOSFET case temperature. The pull-up resistor on the EVAL-M7-D111T control board is 4.87 kΩ. The connection between the NTC and control board is shown in Figure 11. According to the NTC datasheet, Table 8 gives the NTC resistance values at intermediate temperature in case users want to calculate the divider voltage.

According to the connection shown in Figure 11, the NTC character on the board has been tested to observe the relationship between the dropped voltage of the NTC resistor and the maximum MOSFET case temperature. In this way, users can get the hottest MOSFET temperature by measuring the NTC dropped voltage. And they can also set the over-temperature threshold that they want to protect the system. Figure 12 shows the test results for the NTC dropped voltage and case temperature.

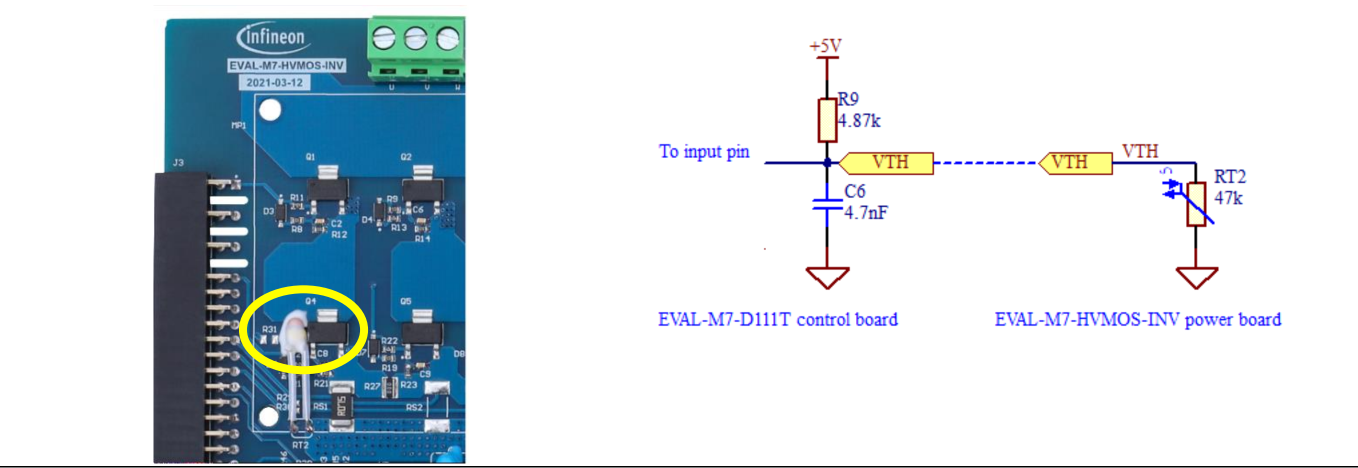


Figure 11 NTC placed on the board and voltage divider circuit

Table 8 NTC resistance values at intermediate temperature

T_{OPER} (℃)	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} (℃)	**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

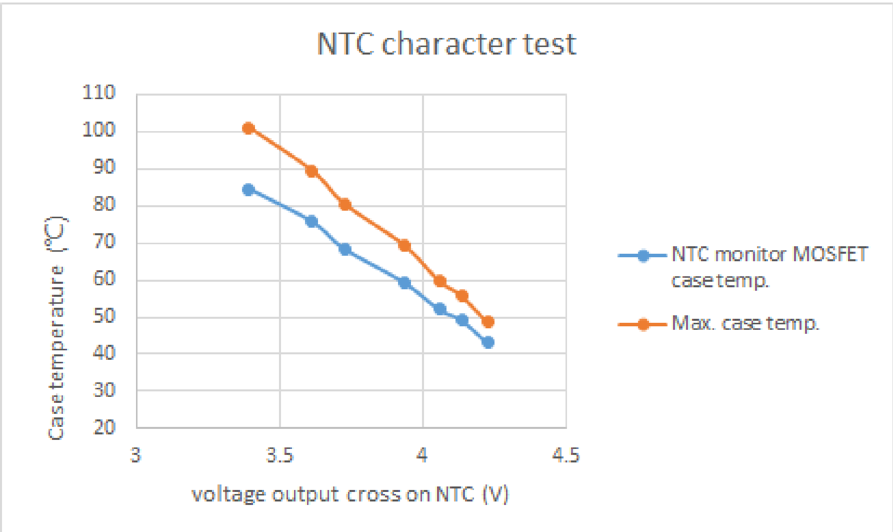


Figure 12 NTC character test on the board

2.3.5 DC power supply

This evaluation board EVAL-M7-HVMOS-INV is dedicated to motor applications under 300 W at 220 V_{AC} input. It is designed using two 82 µF bus capacitors. If this board is being used to evaluate higher power over 300 W, users should consider the effect of the higher bus voltage ripple at heavy load.

Figure 13 shows the measured bus voltage ripple is 14.8% at 300 W load and 220 VAC input condition (45 V/304 V = 14.8%).

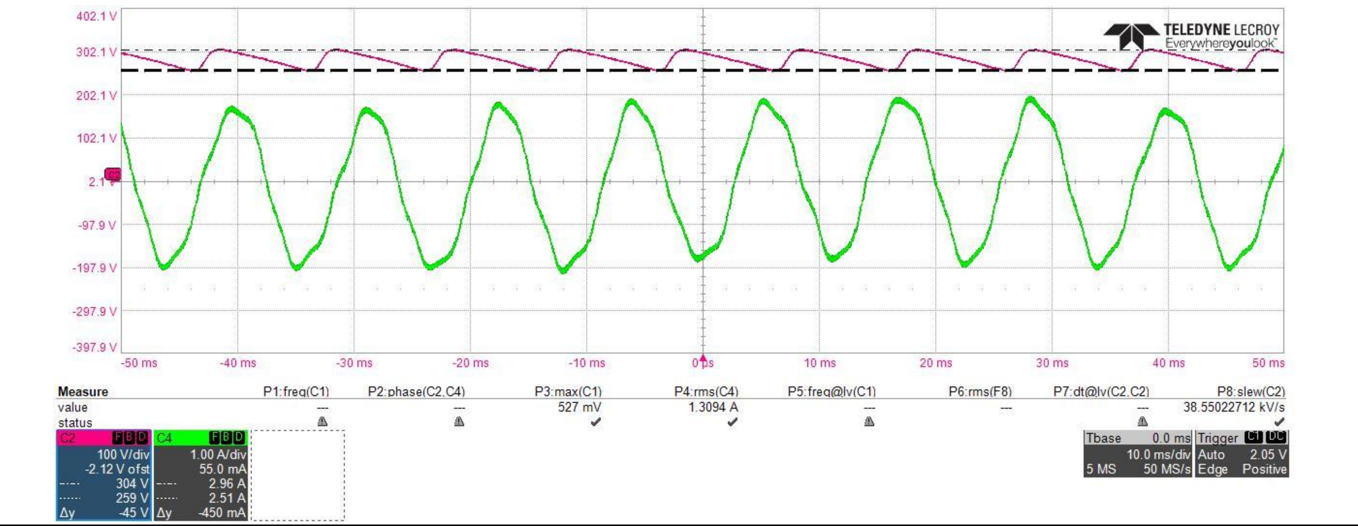


Figure 13 Bus voltage ripple test

2.3.6 Protection function

For this power board EVAL-M7-HVMOS-INV, there is no external hardware protection function on the board. Protection functions such as overcurrent, over-/undervoltage, phase loss, and rotor lock are all carried out by the control board when using the EVAL-M7-D111T control board for evaluation. The overcurrent and over-/undervoltage protection threshold can be set in the MCEWizard. Users can also enable/disable the protection functions such as phase loss, rotor lock, etc. All the protection functions that are included in the IMD111T can be set in the MCEWizard. Figure 14 shows the overcurrent trip level setting page in MCEWizard.

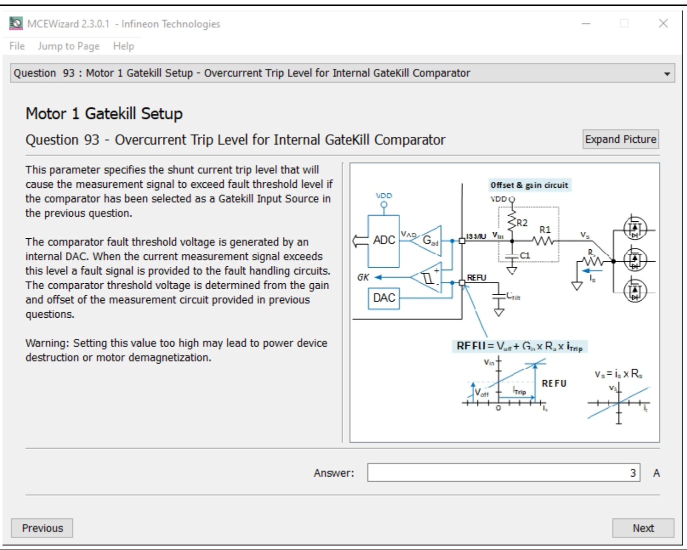


Figure 14 Overcurrent trip level setting in MCEWizard

3 System design

3.1 Schematics

The schematics of EVAL-M7-HVMOS-INV power board include EMI filter, rectifier-bridge, inverter section, and auxiliary power supply. Figure 15 shows the inverter section schematics of the EVAL-M7-HVMOS-INV. Figure 16 depicts the auxiliary power supply schematics. The power supply has two outputs: 15 V and 5 V.

The complete schematic diagrams are available on the download section of the Infineon homepage. A log-in is required to download this material.

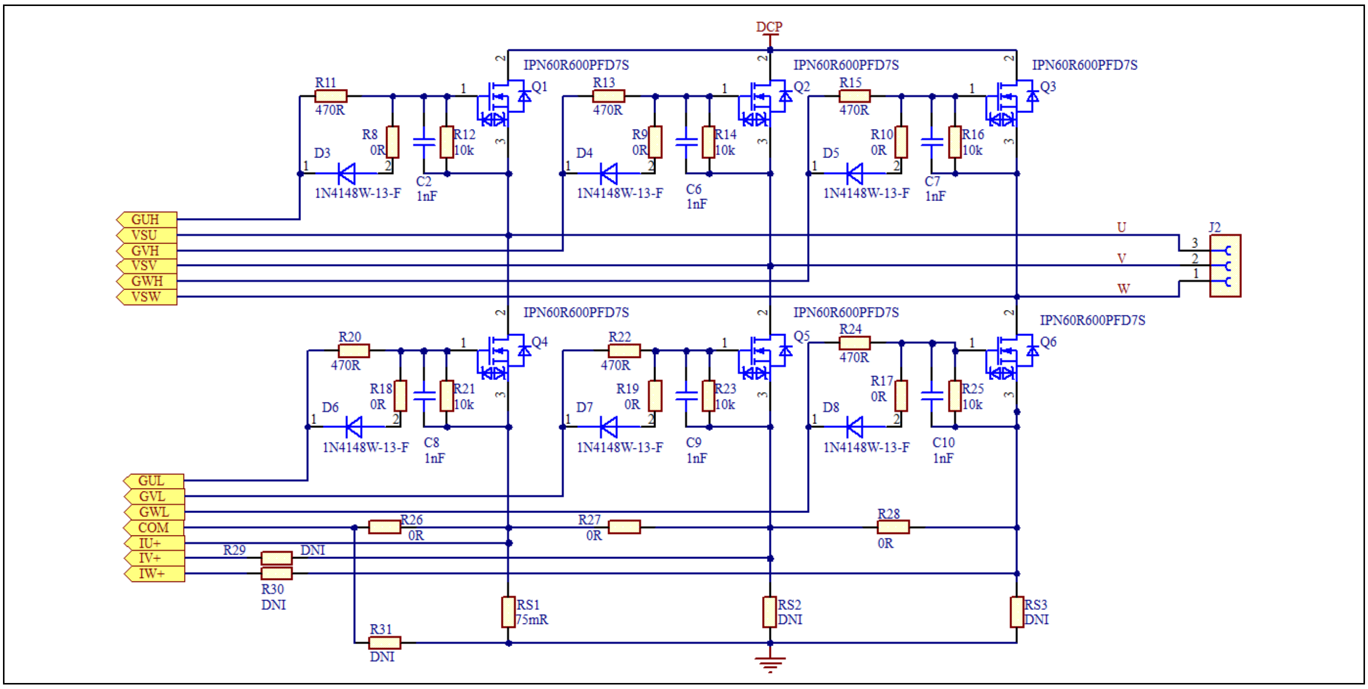


Figure 15 Inverter section schematics

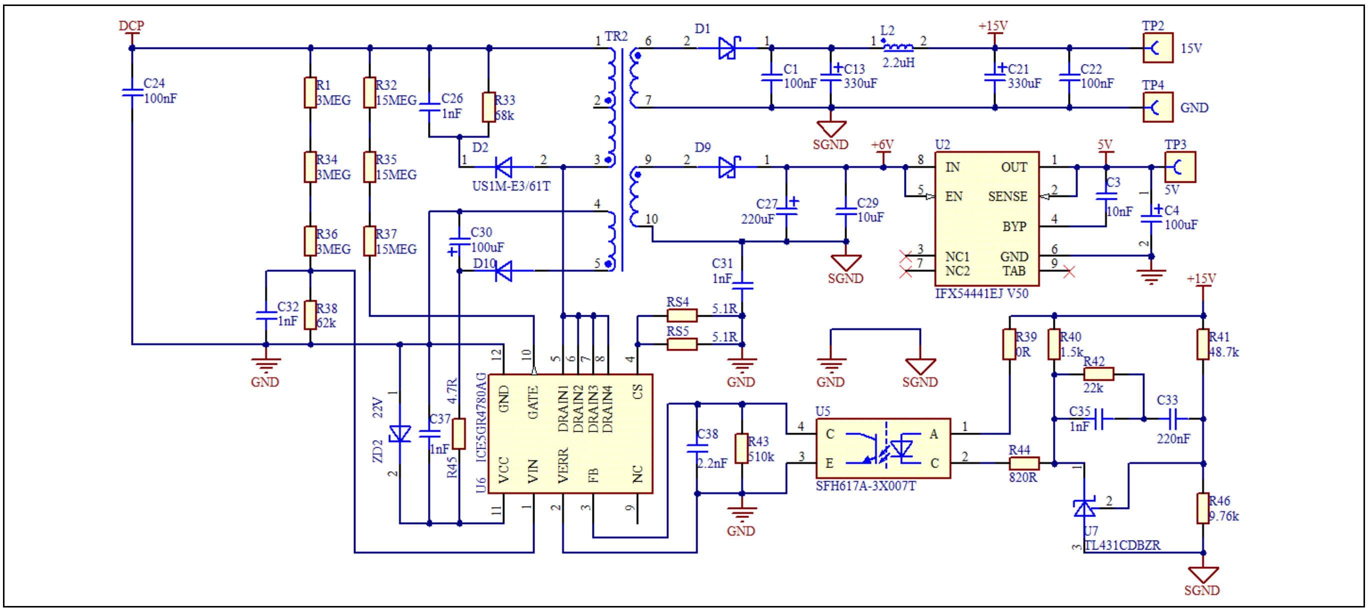


Figure 16 Auxiliary power supply

3.2 Layout

The EVAL-M7-HVMOS-INV board consists of two copper PCB layers. The copper thickness is 35 µm and the board size is 103 mm x 96 mm. The board material is FR4 grade with 1.6 mm thickness. Check Infineon's website or contact Infineon's technical support team for more detailed information. The Gerber files are available on the download section of the Infineon homepage. A log-in is required to download this material.

The top layer and bottom layer PCB layout are shown in Figure 17 and Figure 18. For the power board PCB layout, users should connect the signal ground and power ground at one single point to keep low noise for the current-feedback sensing. The current-feedback trace should be short and close to ground copper. This can ensure that less noise is introduced into the current feedback loop. Lower current feedback noise is beneficial to motor control performance.

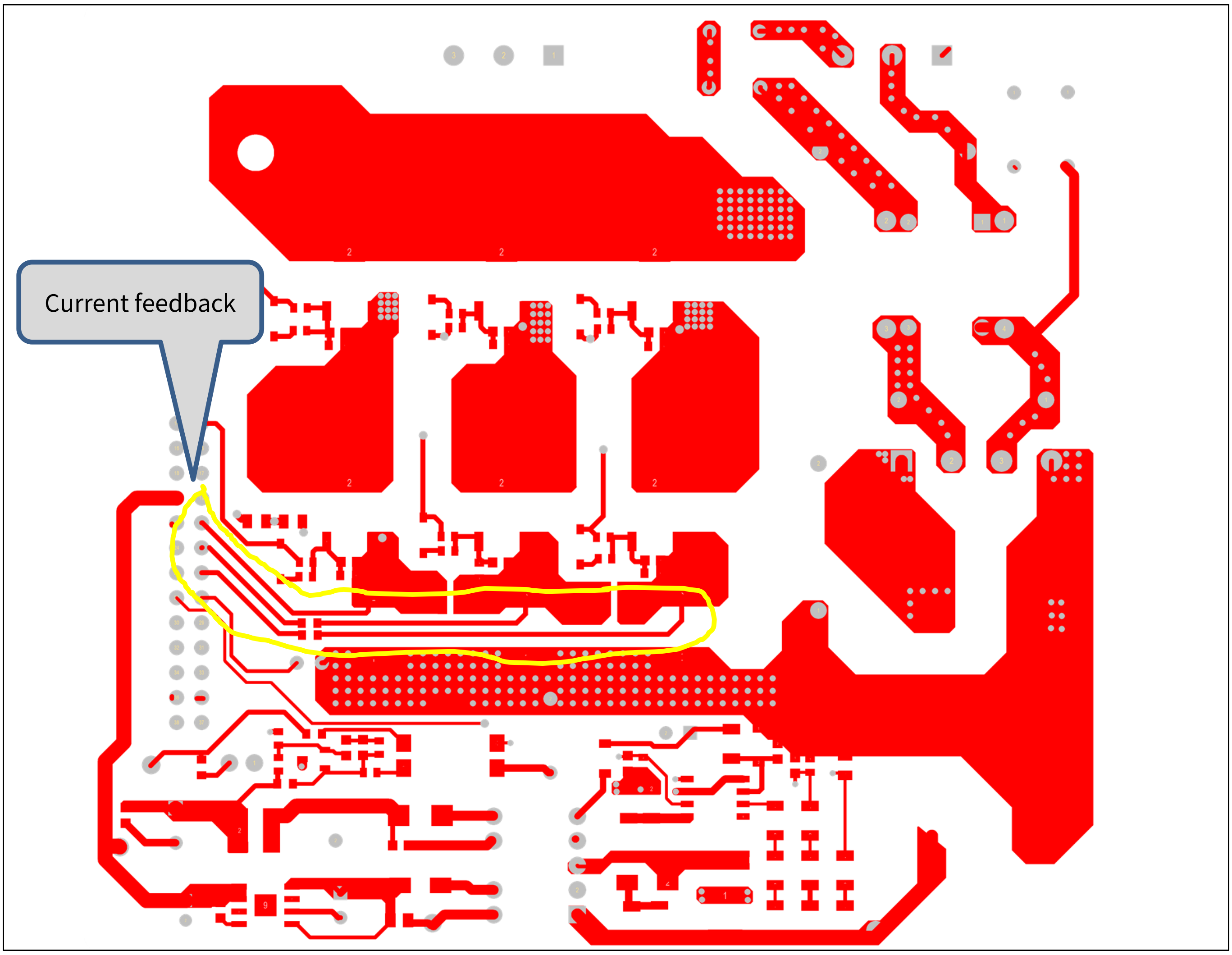


Figure 17 Top layer

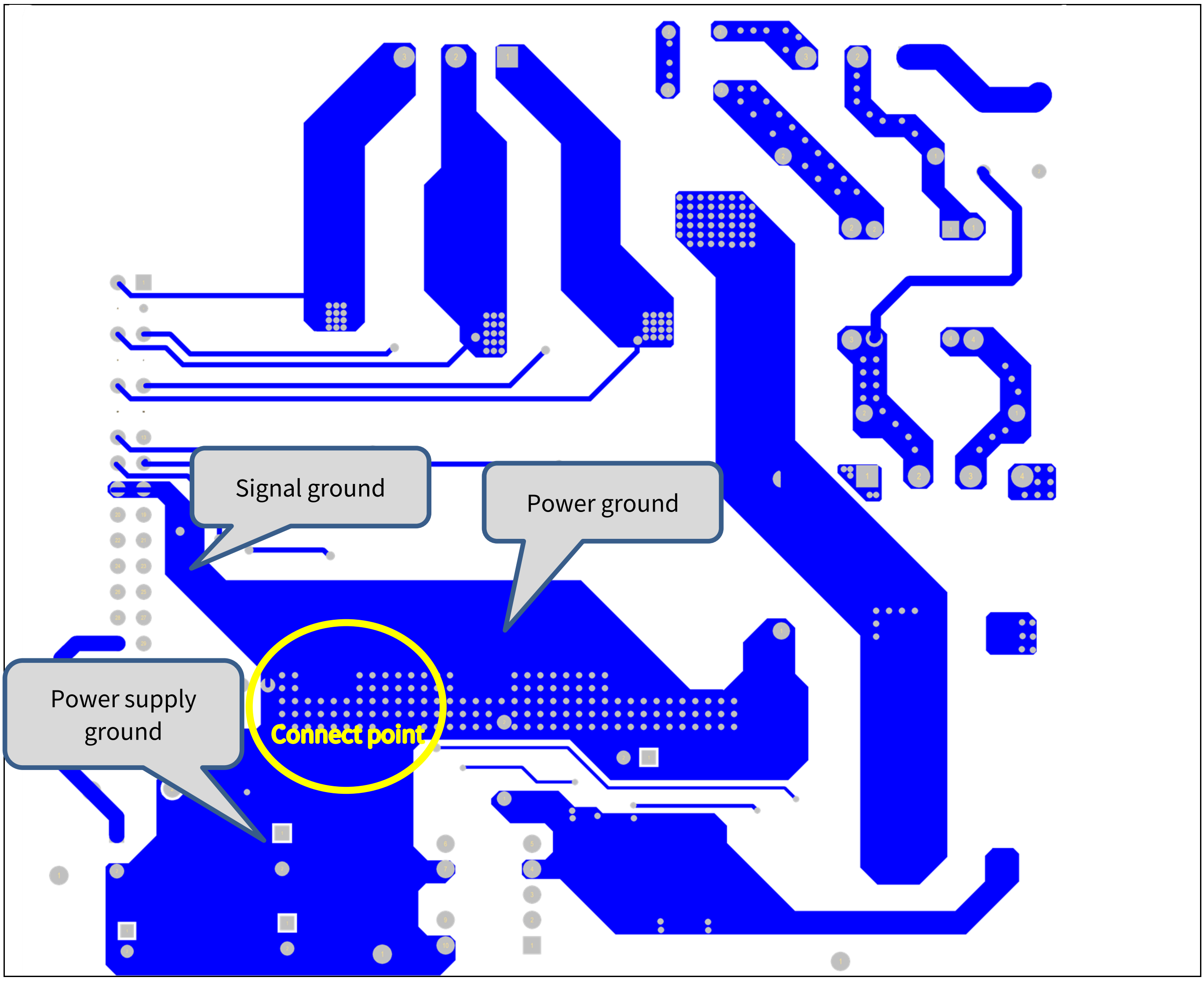


Figure 18 **Bottom layer**

3.3 Bill of material

The complete bill of material is available on the download section of the Infineon homepage. A log-in is required to download this material. Table 9 is the BOM of EVAL-M7-HVMOS-INV board.

Table 9 **BOM of the evaluation board EVAL-M7-HVMOS-INV**

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	Q1, Q2, Q3, Q4, Q5, Q6	600V CoolMOS PFD7 SJ Power Device	Infineon	IPN60R600PFD7S
2	U6	Fixed frequency 700 V/800 V CoolSET, lowest standby power <100 mW	Infineon	ICE5GR4780AG
3	U2	Wide input range low noise 300 mA 5V LDO	Infineon	IFX54441EJ V50
4	TR2	Flyback Transformer, Offline aux SMPS for server, PC power applications	Wurth Elektronik	750344226

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
5	E1, E2	CAP / ELCO / 82 uF / 450 V / 20% / - / - 25℃ to 105℃ /	Wurth Elektronik	861021483005
6	J1, J2	Horizontal Cable Entry With Rising Cage Clamp - WR-TBL, 3Pins	Wurth Elektronik	691216510003S
7	CX1, CX2	CAP / FILM / 470nF / 630V / 10% / MKP (Metallized Polypropylene)	Wurth Elektronik	890324025039CS
8	BR1	4 Amp Single Phase Glass Passivated Bridge Rectifier, 600V	Micro Commercial Components	GBU4J-BP
9	C1, C22	CAP / CERA / 100nF / 50V / 10% / X7R (EIA) / -55℃ to 125℃ / 603(1608) / SMD / -	AVX	06035C104K4Z2A
10	C3	CAP / CERA / 10nF / 50V / 10% / X7R (EIA) / -55℃ to 125℃ / 0603 / SMD / -	AVX	06035C103K4Z2A
11	C4	CAP / ELCO / 100uF / 16V / 20% / Aluminiumelectrolytic / -40℃ to 85℃ / 2.00mm C X 0.50mm W 5.00mm Dia X 12.50mm H / THT / -	Wurth Elektronik	‘860010473007
12	C5	CAP / FILM / 330nF / 400V / 5% / - / -40 ℃ to 105℃ / 15.00mm C X 0.80mm W 18.00mm L X 7.00mm T X 14.00mm H / THT / -	Wurth Elektronik	890283325008CS
13	C13, C21	CAP / ELCO / 330uF / 25V / 20% / Aluminiumelectrolytic / -40℃ to 85℃ / 3.50mm C X 0.60mm W 8.00mm Dia X 13.00mm H / THT / -	Wurth Elektronik	’ 860010474012
14	C24	CAP / CERA / 100nF / 630V / 10% / X7R (EIA) / -55℃ to 125℃ / 1812 / SMD / -	Wurth Elektronik	8.85E+11
15	C26	CAP / CERA / 1nF / 630V / 10% / X7R (EIA) / -55℃ to 125℃ / 1206(3216) / SMD / -	MuRata	GRM31BR72J102KW01
16	C27	CAP / ELCO / 220uF / 16V / 20% / Aluminiumelectrolytic / -40℃ to 85℃ / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / THT / -	Wurth Elektronik	‘860010373010
17	C29	CAP / CERA / 10uF / 16V / 10% / X5R (EIA) / -55℃ to 85℃ / 0805(2012) / SMD / -	MuRata	GRM219R61C106KA73
18	C30	CAP / ELCO / 100uF / 35V / 20% / Aluminiumelectrolytic / -40℃ to 85℃ / 2.50mm C X 0.50mm W 6.30mm Dia X 12.50mm H / - / -	Wurth Elektronik	’ 860010573007
19	C31	CAP / CERA / 1nF / / 20% / E (JIS) / -40 ℃ to 125℃ / 7.50mm C X 0.60mm W	MuRata	DE6E3KJ102MN3A

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
		7.00mm L X 7.00mm T X 10.00mm H / THT / -		
20	C2, C6, C7, C8,C9, C10, C32	CAP / CERA / 1nF / 50V / 1% / C0G (EIA) / NP0 / -55℃ to 125℃ / 0603(1608) / SMD / -, CAP / CERA / 1nF / 16V / 10% / X7R (EIA) / -55℃ to 125℃ / 0603(1608) / SMD / -	Kemet	C0603C102F5GAC, C0603C102K4RACTU
21	ZD2	Zener Diode with Surge Current Specification	Vishay	BZD27C22P-HE3-08
22	C33	CAP / CERA / 220nF / 25V / 10% / X5R (EIA) / -55℃ to 85℃ / 0603(1608) / SMD / -	MuRata	GRM188R61E224KA88
23	C35, C37	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
24	C38	CAP / CERA / 2.2nF / 50V / 10% / X5R (EIA) / -55℃ to 85℃ / 0603(1608) / SMD / -	MuRata	GRM188R61H222KA01
25	CY1, CY2	CAP / CERA / 2.2nF / 1kV / 20% / Y5U (EIA) / -40℃ to 125℃ / 7.50mm C X 0.60mm W 9.00mm L X 5.00mm T X 13.00mm H / - / -	Vishay	VY2222M35Y5US6TL7
26	D1	High Voltage Surface-Mount Schottky Rectifier, VRRM 100V	Vishay	SS2H10-E3/52T
27	D2	Surface Mount Ultrafast Rectifier 1.0A/1000V	Vishay	US1M-E3/61T
28	D3, D4, D5, D6, D7, D8	Surface Mount Fast Switching Diode	Diodes Incorporated	1N4148W-13-F
29	D9	Surface-Mount Schottky Barrier Rectifier, VRRM 45V	Vishay	BYS10-45-E3/TR3
30	D10	Super Fast Recovery Diode, VR 200 V, IF 1 A	ROHM Semiconductor s	RF071MM2STR
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	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
33	L1	IND / STD / 5mH / 2.5A / 30% / -40℃ to 125℃ / 95mR / THT / Inductor, THT, 4	Wurth Elektronik	7.45E+08

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
		pin, 13.80 mm L X 23.00 mm W X 25.50 mm H body / THT / -		
34	L2	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	7.45E+08
35	LED1	LED 3mm Red Through Hole Lamp	LiteOn Optoelectronics	LTL-1CHEE
36	MP1	Customized Heat sink - 4 pins	Infineon Technologies	HS-55-55-25
37	R1, R34, R36	RES / STD / 3MEG / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12063M00FK
38	R3, R6	RES / STD / 1MEG / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12061M00FK
39	R5, R12, R14, R16, R21, R23, R25	RES / STD / 10k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-0710KL
40	R7	RES / STD / 20k / 125mW / 1% / 100ppm/K / -55℃ to 155℃ / 0805 / SMD / -	Vishay	CRCW080520K0FK
41	R8, R9, R10, R17, R18, R19	RES / STD / 0R / - / 0R / - / -55℃ to 155 ℃ / 0603 / SMD / -	Vishay	CRCW06030000Z0
42	R11, R13, R15, R20, R22, R24	RES / STD / 470R / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603470RFK
43	R31	RES / STD / 0R / 125mW / 0R / 0ppm/K / -55℃ to 155℃ / 0805 / SMD / -	Yageo	RC0805JR-070RL
44	R39	RES / STD / 0R / 100mW / 0R / 0ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603JR-070RL
45	R26	RES / STD / 0R / 125mW / 0R / 0ppm/K / -55℃ to 155℃ / 0805 / SMD / -	Yageo	RC0805JR-070RL
46	R27, R28	RES / - / 0R / 500mW / - / - / - / 0612 / SMD / -	Vishay	RCL06120000Z0EA
47	R29, R30	RES / STD / 0R / 100mW / 0R / 0ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603JR-070RL
48	R32, R35, R37	RES / STD / 15MEG / 250mW / 5% / 200ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Yageo	RC1206JR-0715ML
49	R33	RES / STD / 68k / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW120668K0FK

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
50	R38	RES / STD / 62k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060362K0FK
51	R40	RES / STD / 1.5k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Yageo	RC0603FR-071K5L
52	R41	RES / STD / 48.7k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060348K7FK
53	R42	RES / STD / 22k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW060322K0FK
54	R43	RES / STD / 510k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603510KFK
55	R44	RES / STD / 820R / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW0603820RFK
56	R45	RES / STD / 4.7R / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12064R70FK
57	R46	RES / STD / 9.76k / 100mW / 1% / 100ppm/K / -55℃ to 155℃ / 0603 / SMD / -	Vishay	CRCW06039K76FK
58	RS1	RES / STD / 75mR / 3W / 1% / 50ppm/K / -55℃ to 170℃ / 2512 / SMD / -	Bourns	CRA2512-FZ-R075ELF
59	RS2, RS3	RES / STD / 75mR / 3W / 1% / 50ppm/K / -55℃ to 170℃ / 2512 / SMD / -	Bourns	CRA2512-FZ-R075ELF
60	RS4, RS5	RES / STD / 5.1R / 250mW / 1% / 100ppm/K / -55℃ to 155℃ / 1206 / SMD / -	Vishay	CRCW12065R10FK
61	RT1	RES / NTC / 10R / 1.8W / 20% / - / -55℃ to 170℃ / 5.25mm C X 0.60mm W 9.50mm L X 4.5mm T X 14mm H / - / -	TDK Corporation	B57235S0100M000
62	RT2	RES / NTC / 47k / 500mW / - / - / -40℃ to 125℃ / 2.54mm C X 0.60mm W 3.30mm L X 3.00mm T X 9.00mm H / THT / -， 3%	Vishay	NTCLE100E3473HB0
63	TP1, TP2, TP3, TP4	Test Point THT, Black	Keystone Electronics Corp.	5001
64	U2	Wide Input Range Low Noise 300mA 5V LDO	Infineon Technologies	IFX54441EJ V50

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
65	U5	Optocoupler, Phototransistor Output, High Reliability, 5300 VRMS, 110 ℃ Rated	Vishay	SFH617A-3X007T
66	U7	Precision Programmable Reference	Texas Instruments	TL431CDBZR

4 System performance

4.1 dv/dt test

The dv/dt is important for the motor control system. The motor application requires the switching dv/dt below 5 V/ns. This can improve motor-control reliability. But please note that lower dv/dt will increase the MOSFET switching losses. The turn-on dv/dt of the EVAL-M7-HVMOS board is measured at 4.85 V/ns. Figure 19 depicts the dv/dt test waveform.

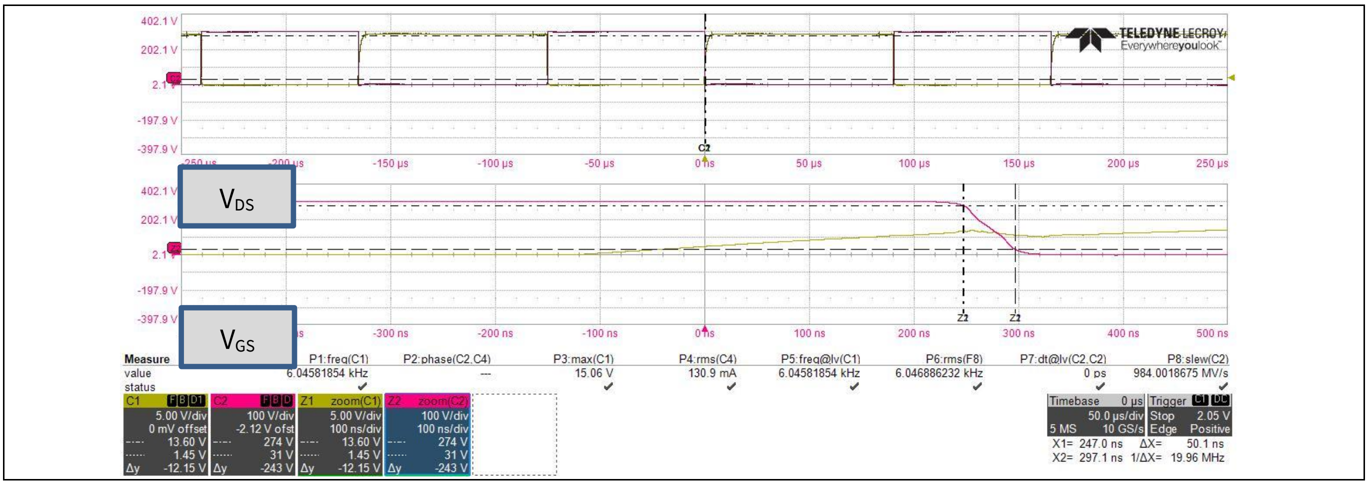
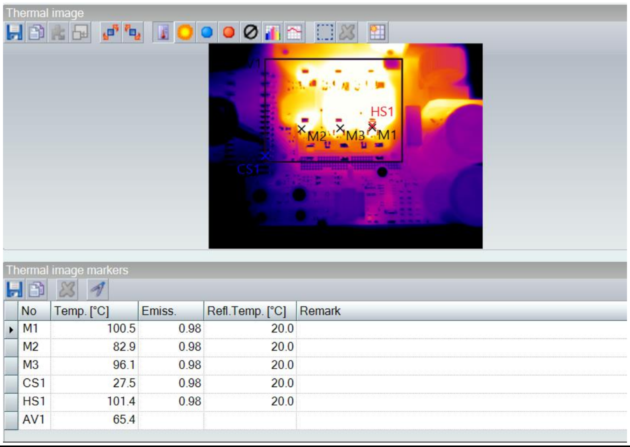


Figure 19 **EVAL-M7-HVMOS-INV dv/dt test waveform**

4.2 Thermal performance test

For the EVAL-M7-HVMOS-INV power board thermal performance test, the input power and motor-phase current were measured when the MOSFET case temperature was increased to 100℃. The power board was tested in different carrier frequencies. The PWM frequency range is from 4 kHz to 16 kHz under testing conditions. Keep in mind, however, that this power board can be run up to 20 kHz; the output power capability will drop down accordingly. Figure 20 shows a thermal test snapshot at 220 V_{AC} input, 8 kHz carrier frequency, and 200 W input power. The hot point of the power board is 101.4℃ when the room temperature is 23℃. Users can add a heatsink or cooling fan to increase the board ouput power. Space for a heatsink has been reserved on the board. If a heatsink is added, exercise caution when using a thermal pad.



No	Temp. [°C]	Emiss.	Refl.Temp. [°C]	Remark
M1	100.5	0.98	20.0	
M2	82.9	0.98	20.0	
M3	96.1	0.98	20.0	
CS1	27.5	0.98	20.0	
HS1	101.4	0.98	20.0	
AV1	65.4			

Figure 20 **Thermal test**

4.3 Test results

The output power capability of the EVAL-M7-HVMOS-INV power board was tested at different carrier frequencies. The MOSFET case temperature is up to 100℃ under test conditions. All the tests take place at room temperature and without heatsink or cooling fan. Figure 21 shows the increase of MOSFET case temperature in relation to input power at different PWM frequencies. Figure 22 shows the motor-phase current at different PWM frequencies.

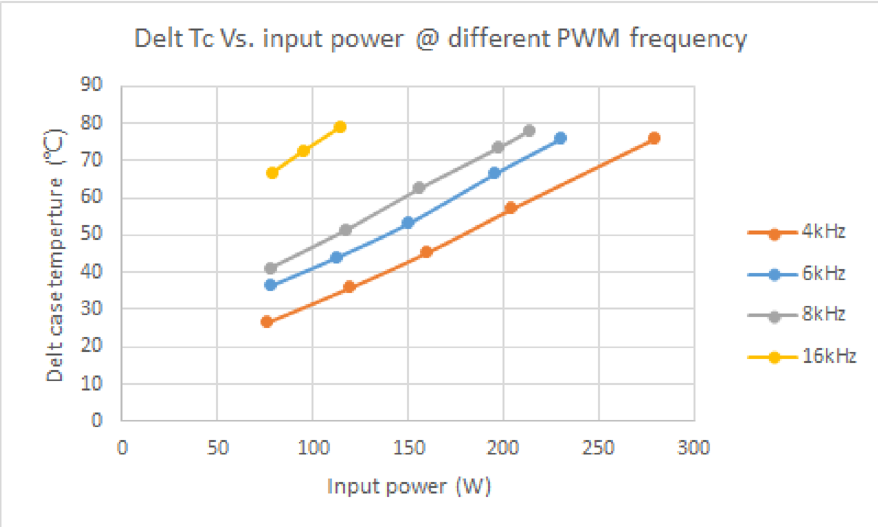


Figure 21 MOSFET Δ T_C Vs. input power

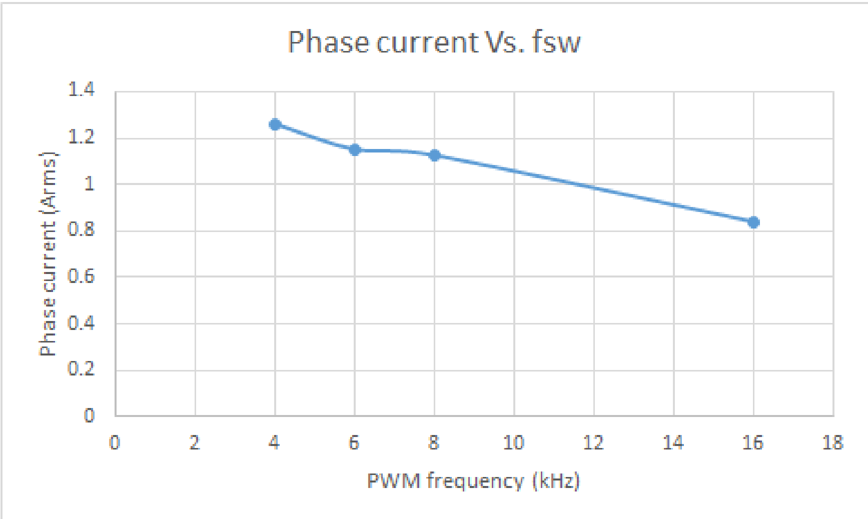


Figure 22 Phase current Vs. carrier frequency

5 References and appendices

References

[1] Infineon Technologies AG. Datasheet (2019): IPN60R600PFD7S - 600V CoolMOSª PFD7 SJ Power Device. V2.0 www.infineon.com

[2] Infineon Technologies AG. Datasheet (2018): ICE5GR4780AG - Fixed frequency 700 V/800 V CoolSET™ - in DSO-12 Package. V2.2 WWW.infineon.com

[3] Vishay. Datasheet (2020): NTCLE100E3, NTC thermistors. V 18-Sep-2020. www.vishay.com

[4] Infineon Technologies AG. User guide (2020): MCEWizard V2.3 user guide. V2.3 www.infineon.com

[5] Infineon Technologies AG. AppNote (2020): MCEDesigner application guide. V2.3 www.infineon.com

5.1 Ordering details and other additional information

The board is now available for customers in small order quantities. Design data are available in the download section of the Infineon homepage. A log-in is required to download the material.

In order to initiate the testing, customers are advised to order this board from the link below:

Buy online: link, or https://www.infineon.com/madk

Revision history

Document version	Date of release	Description of changes
V1.0	2021-06-28	First release

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Edition 2021-06-28

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference
UG-2021-24

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