

# REF\_Fridge\_D111T\_MOS user guide

## Refrigerator compressor driver reference design kit

### About this document

#### Scope and purpose

This user guide provides an overview of the reference design board REF\_Fridge\_D111T\_MOS including its main features, key data, pin assignments and mechanical dimensions, and the guidance on how to run and design the motor with board.

The REF\_Fridge\_D111T\_MOS board is a complete reference design board designed for refrigerator compressors. It demonstrates the whole Infineon solution including digital motor control IC iMOTION™ Smart Driver IMD111T-6F040 and the 600 V CoolMOS™ PFD7 super junction MOSFET.

The REF\_Fridge\_D111T\_MOS board is developed to support customers in designing their refrigerator compressor drivers with Infineon products.

#### Intended audience

This user guide is intended for technical specialists working with the REF\_Fridge\_D111T\_MOS board and refrigerator compressor driver design.

#### Reference Board/Kit

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

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



**Important notice****Important notice**

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

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

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

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

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

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

**The customer is obliged to ensure that the use of the Evaluation Boards and Reference Boards does not cause any harm to persons or third party property.**

**The Evaluation Boards and Reference Boards and any information in this document is provided "as is" and Infineon Technologies disclaims any warranties, express or implied, including but not limited to warranties of non-infringement of third party rights and implied warranties of fitness for any purpose, or for merchantability.**

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

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

## Safety precautions

### Safety precautions

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

**Table 1 Safety precautions**

	<b>Warning:</b> The DC link potential of this board is up to 400 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.
	<b>Warning:</b> 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.
	<b>Warning:</b> 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.
	<b>Warning:</b> 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.
	<b>Caution:</b> 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.
	<b>Caution:</b> 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.
	<b>Caution:</b> 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.
	<b>Caution:</b> 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.
	<b>Caution:</b> The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.

Table of contents

**Table of contents**

<b>About this document</b> .....	<b>1</b>
<b>Important notice</b> .....	<b>2</b>
<b>Safety precautions</b> .....	<b>3</b>
<b>Table of contents</b> .....	<b>4</b>
<b>1 The reference board at a glance</b> .....	<b>5</b>
1.1 Delivery content .....	5
1.2 Block diagram.....	5
1.3 Main features.....	6
1.4 Board parameters and technical data.....	7
<b>2 System and functional description</b> .....	<b>8</b>
2.1 Commissioning.....	8
2.1.1 Hardware connection .....	9
2.1.2 Software/firmware preparation .....	9
2.1.3 Program firmware/parameters/script.....	10
2.1.4 Open-loop diagnostic .....	12
2.1.5 Closed-loop run.....	13
2.2 Description of the functional blocks.....	14
2.2.1 Inverter stage .....	14
2.2.2 DC bus sensing and MCEWizard configuration .....	15
2.2.3 Current sensing and over-current protection.....	16
2.2.3.1 Current sensing .....	16
2.2.3.2 Over-current protection.....	18
2.2.4 NTC sensing and thermal protection .....	18
2.3 Frequency-signal interface .....	20
<b>3 System design</b> .....	<b>22</b>
3.1 Schematics .....	22
3.2 Layout.....	22
3.3 Bill of material .....	23
3.4 Connector details .....	24
<b>4 System performance</b> .....	<b>26</b>
4.1 Thermal characterization test .....	26
4.2 MOSFET dV/dt test.....	27
<b>5 Reference and appendices</b> .....	<b>29</b>
5.1 Abbreviations and definitions.....	29
5.2 References .....	29
5.3 Additional information.....	29
<b>Revision history</b> .....	<b>30</b>

## 1 The reference board at a glance

The REF\_Fridge\_D111T\_MOS reference design kit is a part of the iMOTION™ reference design kit for motor drives, which is aimed at refrigerator-compressor driver applications. The kit is a ready-to-use solution in combination with full Infineon products such as 600 V CoolMOS™ PFD7 super-junction MOSFET in a small SOT223 package, and motor-control smart driver iMOTION™ IMD111T-F040. It can easily be switched to a final mass production application board, and has a fast time to market.

The REF\_Fridge\_D111T\_MOS reference board is available from Infineon. The features of this board are described in Chapter 1.3 of this document (UG-2020-19). The remaining sections provide information to enable customers to copy, modify and qualify the design for production according to their own specific requirements.

Environmental conditions have been considered in the design of the REF\_Fridge\_D111T\_MOS. The design was tested as described in this document, but not qualified in terms of safety requirements or manufacturing and operation over the whole operating temperature range or lifetime. The boards provided by Infineon are subject to functional testing only.

The boards are not subject to the same procedures as regular products in terms of returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD). Evaluation boards are intended to be used under laboratory conditions by specialists only.

### 1.1 Delivery content

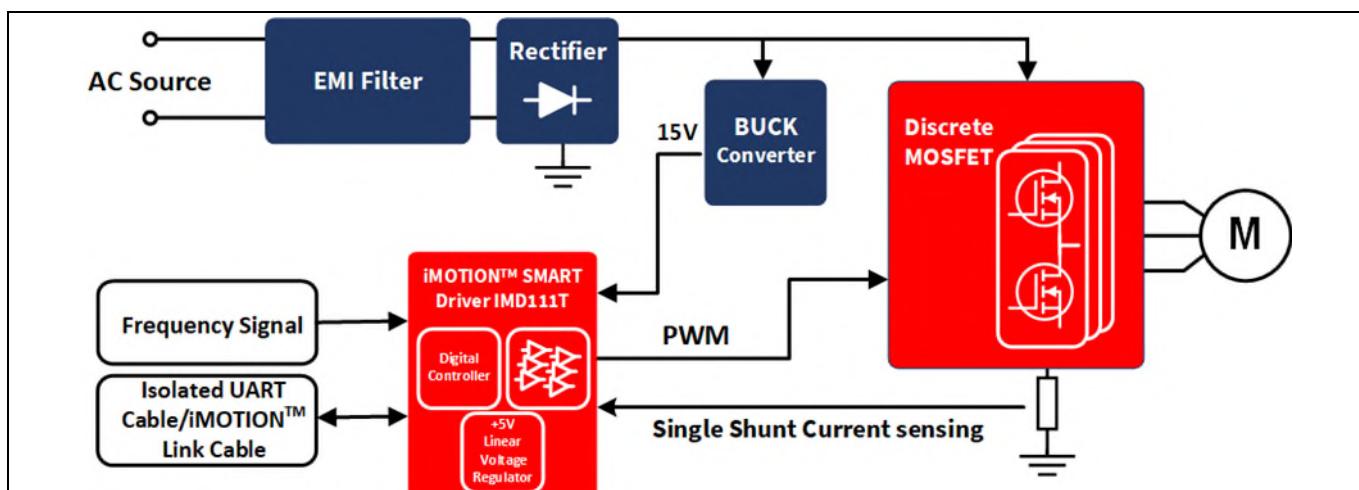
The delivery content only contains the board as Figure 2 shown, the detail ordering information is indicated in the Table 2.

The iMOTION™ Link cable shown in the Figure 4 is mandatory for the tuning, and it is not included in the delivery content, please order it if you do not have, ordering information can be found in the Section 5.3.

**Table 2 Delivery content**

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
<a href="#">REF_Fridge_D111T_MOS</a>		Boxed	1	REFFRIDGEDED111TMOSTOBO1

### 1.2 Block diagram

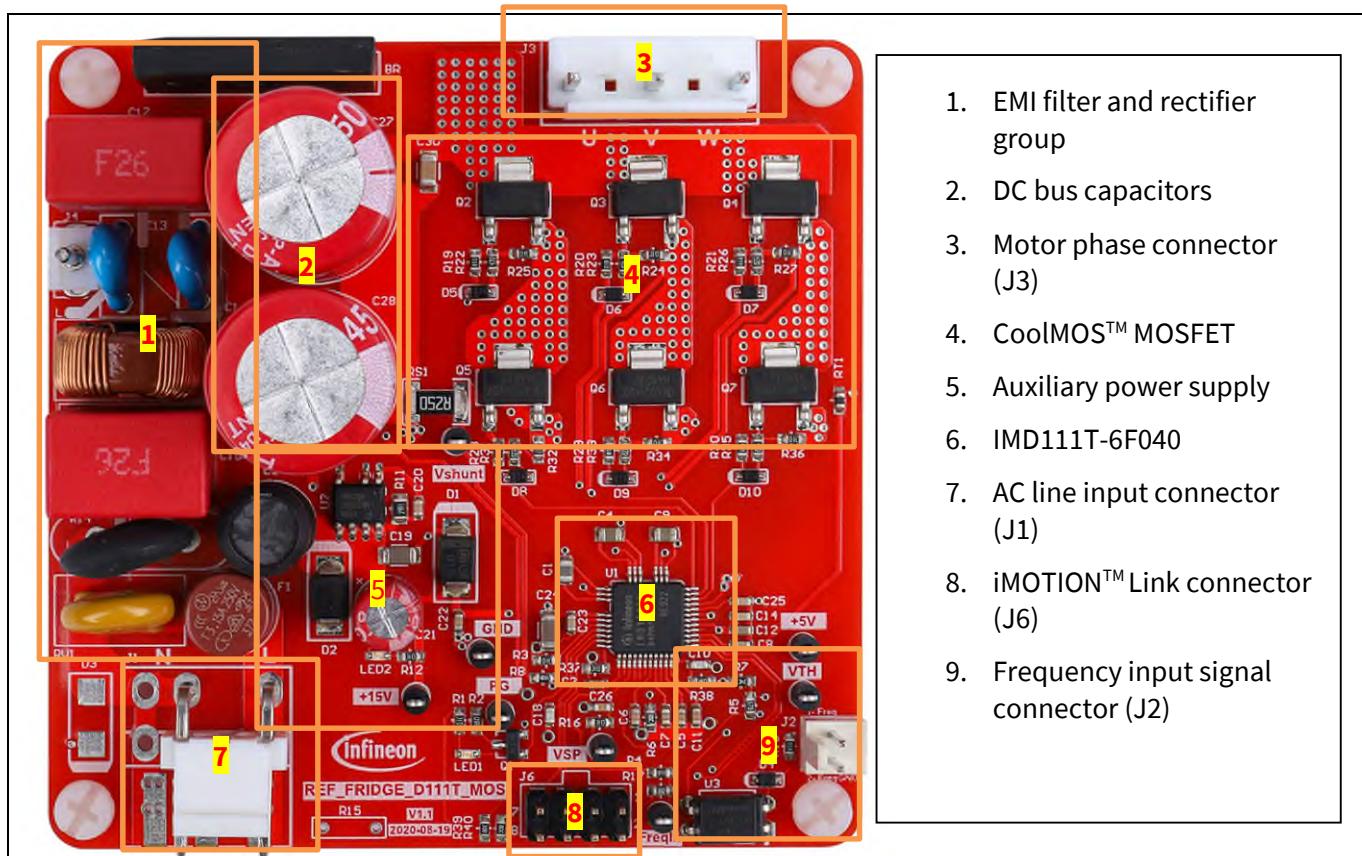


**Figure 1 Block diagram of the REF\_Fridge\_D111T\_MOS reference board**

### The reference board at a glance

Figure 1 shows the block diagram of reference design kit REF\_Fridge\_D111T\_MOS, and this document explains the features and details.

Figure 2 depicts the functional groups of the board. Connector definition details are described in section 3.4. Please see this section if you need more information.



**Figure 2 Functional groups on top side of board**

### 1.3 Main features

REF\_Fridge\_D111T\_MOS is a complete reference design board for refrigerator-compressor applications. Main features of the board include:

- iMOTION™ Smart Driver IMD111T-6F040
- Ready-to-use motion controller with scripting engine and 6-channel silicon on insulator (SOI) driver
- 600 V CoolMOS™ PFD7 – optimized technology with lowest Q<sub>rr</sub>, ESD protection and compact SOT223 surface mounted device (SMD) package
- System solution enables best light-load efficiency and compact design

Key features of iMOTION™ Smart Driver IMD111T-6F040 include:

- Motor controller with integrated high-voltage gate driver and voltage regulator
- Integrated 5 V low dropout regulator (LDO) allows single 15 V supply voltage
- Robust 600 V gate driver in thin-film SOI technology
- Gate driver integrated with ultra-fast bootstrap diodes
- Space saving LQFP 40-pin package with high-voltage creepage
- Motion control engine (MCE) as ready-to-use solution for variable speed drives

### The reference board at a glance

- Sensorless field-oriented control (FOC) for permanent magnet synchronous motor (PMSM)
- Flexible space vector PWM (3-phase PWM or 2-phase PWM)
- Motor-current sensing via single or leg shunt
- Optional analog or digital hall sensor interface
- Flexible host interface options for motor control commands: universal asynchronous receiver/transmitter (UART), frequency/duty cycle or analog VSP
- IEC60335-1/UL60730 Class B Safety Software certificate

For more information about the above-mentioned products, refer to the corresponding reference materials.

## 1.4 Board parameters and technical data

Table 3 depicts the important specifications of the reference design REF\_Fridge\_D111T\_MOS.

**Table 3** REF\_Fridge\_D111T\_MOS board specifications

Parameter	Symbol	Conditions / comments	Value	Unit
Operation input voltage	$V_{ac}$	Lower AC input, less motor power output	165 ~ 265	$V_{rms}$
Maximum input current	$I_{ac(max)}$	Input 220 $V_{AC}$ , $T_a=25^\circ C$	1.7	$A_{rms}$
Maximum input power	$P_{in(max)}$	Input 220 $V_{AC}$ , $f_{PWM}=5$ kHz, $T_a=25^\circ C$ , $T_{case}=100^\circ C$ without heat sink	250	W
Maximum motor current	$I_{mtr(max)}$	Input 220 $V_{AC}$ , $f_{PWM}=5$ kHz, $T_a=25^\circ C$ , $T_{case}=100^\circ C$ without heat sink	0.69	$A_{rms}$
Maximum DC bus voltage	$V_{dc(max)}$		400	V
Shunt Resistance	$R_{sh}$		250	$m\Omega$

### Protection

Current protection trigger level	$I_{trip}$	Set in the MCEWizard	-	$A_{peak}$
Thermal protection level	$T_{protection}$	Temperature gap between MOSFET's case and NTC (negative temperature coefficient) sensor needs to be considered; recommended is a setting of maximum 105°C for the case temperature, considering the gap, set 75°C in the MCEWizard.	75	°C

### Auxiliary power supply 1 - 15V

Output voltage	$V_{out1}$	Used for IMD111T-6F040, integrate 5 V LDO in the IMD111T-6F040	$15 \pm 5\%$	V
Maximum output current	$I_{out1}$		100	mA

### PCB characteristics

Dimension		Length × width × height	78×78×46	mm
Material		1.6 mm thickness, 1 oz. copper	FR4	

### System environment

Ambient temperature	$T_a$	Non-condensing, maximum RH of 95%	0 ~ 50	°C
---------------------	-------	-----------------------------------	--------	----

## 2 System and functional description

### 2.1 Commissioning

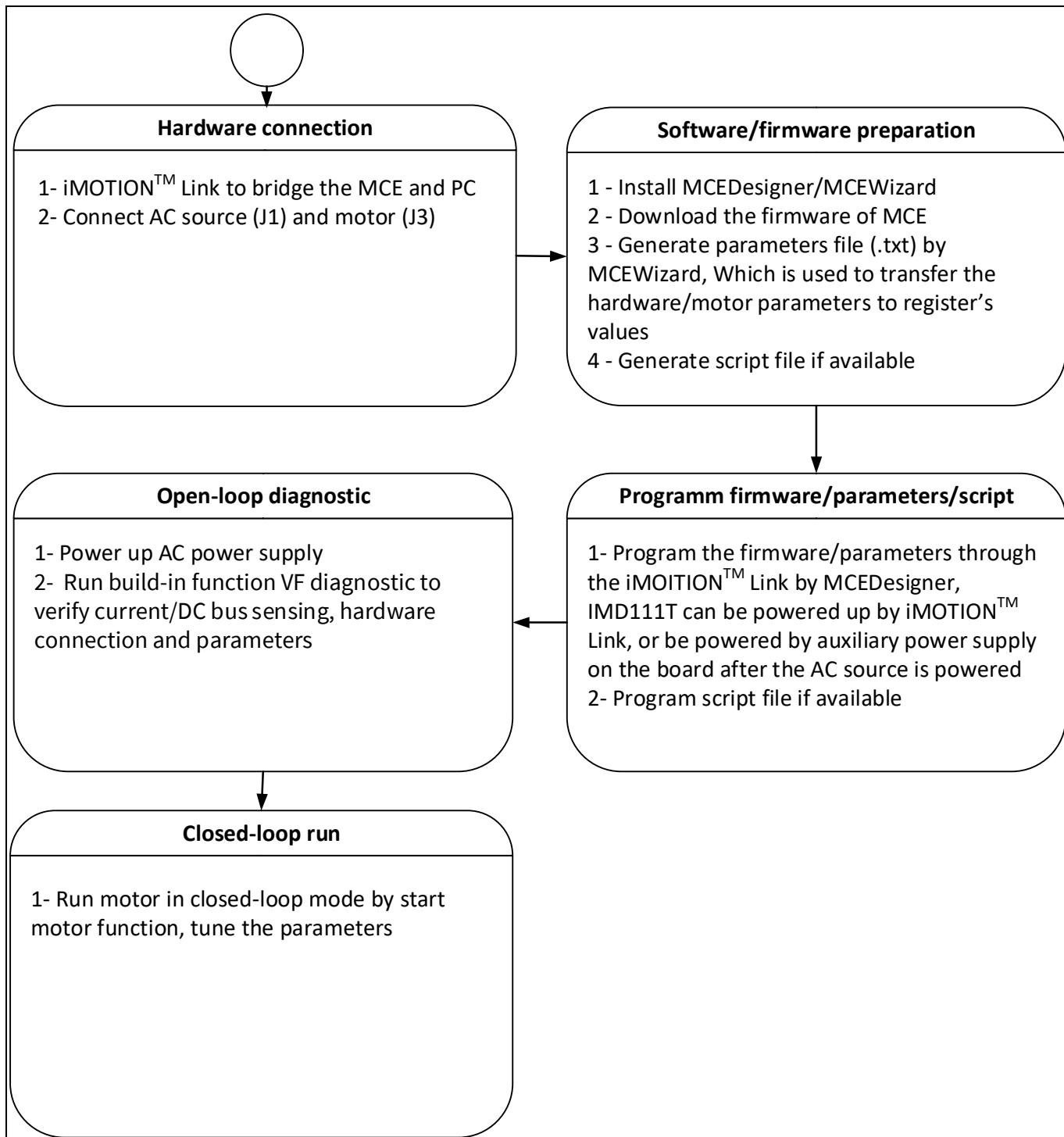


Figure 3 Basic process for running the motor the first time

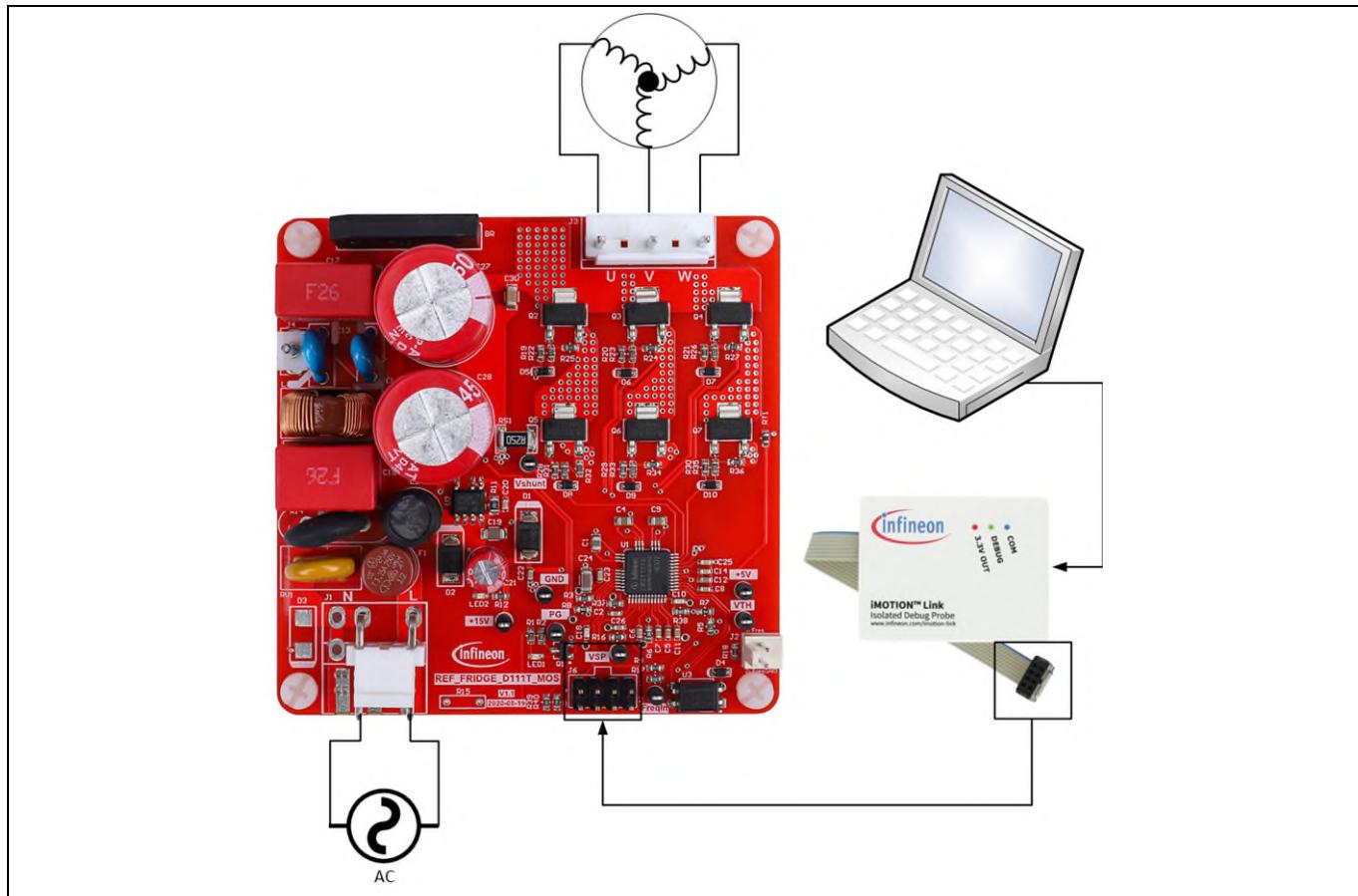
This section describes how to get the system working when user first installs the board (refer to Figure 3 for general steps). The following items detail these steps. For those who are already familiar with the system, or have already run the board, unnecessary steps can be skipped depending on user's actual situation. For more in-depth commissioning process requirements, please refer to the MCE reference manual or the corresponding reference material <sup>[4][5][6]</sup>.

### 2.1.1 Hardware connection

Figure 4 shows the hardware connection details for the reference design board.

[iMOTION™ Link](#) cable is needed to bridge the PC/debugger side and motor drive system (the target iMOTION™ device, hot side) with 1 kV DC galvanic isolation. Users can go to Section 5.3 for more information about iMOTION™ Link.

1. Connect iMOTION™ Link's 8-pin cable to J6 with default pin order, and connect PC and iMOTION™ Link with the USB wire.
2. Then connect AC power supply (J1) and the motor (J3).



**Figure 4      Hardware connection details**

### 2.1.2 Software/firmware preparation

1. The iMOTION™ software tools MCEDesigner and MCEWizard are required to set up the system, as well as to control and fine-tune the system performance to match users' exact needs. These tools are available for download via the Infineon website (<http://www.infineon.com/imotion-software>). Please check this page periodically for tool/software updates.
2. The MCE firmware then has to be downloaded on our website; select the proper version of the firmware based on your requirements. Included in the package are the firmware ('.ldf'), default parameters ('.txt'), default map file ('.map'), the file for the MCEDesigner ('.irc') and other documents.
3. Generate your parameters' file.
  - Use MCEWizard to enter the target motor's system and operating parameters, as well as reference board's hardware parameters, which will then be used to calculate the controller's digital parameter set representing the complete motor drive system.

## System and functional description

- After system and operating parameters are set, go to the “Verify & Save Page” and click on “Calculate” button. If no errors are reported, then save the drive parameter set in your project directory by clicking “Export to Designer file (.txt)” (Figure 7); if some errors are detected, double-click on the error message (highlighted in RED) and adjust the related parameters. Saved Drive System Parameter File will be later used for programmers.

**Note:** *After you log-in on myInfineon, you could download the default MCEwizard file (.mc2) for this board, you only need to modify the parameters related to your motor to make things easier and save time*

- Generate the script if available. For users who are running the board for the first time, it is recommended not to use this function first, but to add the script function after the motor performance commissioning is completed.

### 2.1.3 Program firmware/parameters/script

The REF\_Fridge\_D111T\_MOS reference design kit is shipped with pre-programmed firmware and default parameters, since the functional tests were done before the shipment. Users need to program their parameters, as the motor is different from the one under test.

The following steps have to be performed in order to make a blank IMD111T working:

- Program the firmware of the MCE
- Program parameter sets for system and motor
- Program customer script file (optional)

Or

- Program the combined file, which is combined by MCEWizard containing all three items above. Customer script file is optional depending on whether it is available. The combined file is usually used for production, since it only needs to be programmed once.

The programming process is as follows:

- Start the MCEDesigner tool and open MCEDesigner default configuration file (‘.irc’) for IMD111T device (IMD111T\_Vxxx.irc) by clicking “File” > “Open.”

**Note:** *The IMD111T\_Vxxx.irc file is included in the downloaded firmware package “IMD111T MCE Software Package.”*

- Power the iMOTION™ control IC with 3.3 V. It is recommended to program the IC with the 3.3 V isolated power supply that comes from the iMOTION™ Link; there is a switch on the iMOTION™ Link to enable the 3.3 V output. The iMOTION™ control IC will also be powered by the on-board auxiliary power supply after the AC source is powered, but caution due to high voltage.

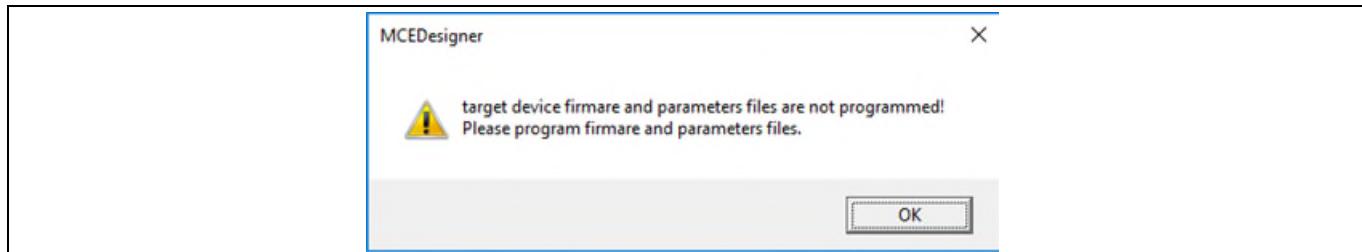
**Note:** *The output voltage of LDO combined in the IMD111T-6F040 is 5 V, i.e. the controller of IMD111T-6F040 is powered by 5 V. However, it is also possible to use the 3.3 V power supply in the iMOTION™ Link to power the IMD111T-6F040 (for programmers).*

- MCEDesigner should automatically connect to the board using default COM port (Indicated by green circle next to “COMx Up” status in the bottom frame of the MCEDesigner GUI) when iMOTION™ control IC is powered. If it cannot establish the connection due to an incorrect COM port, change COM port by doing the

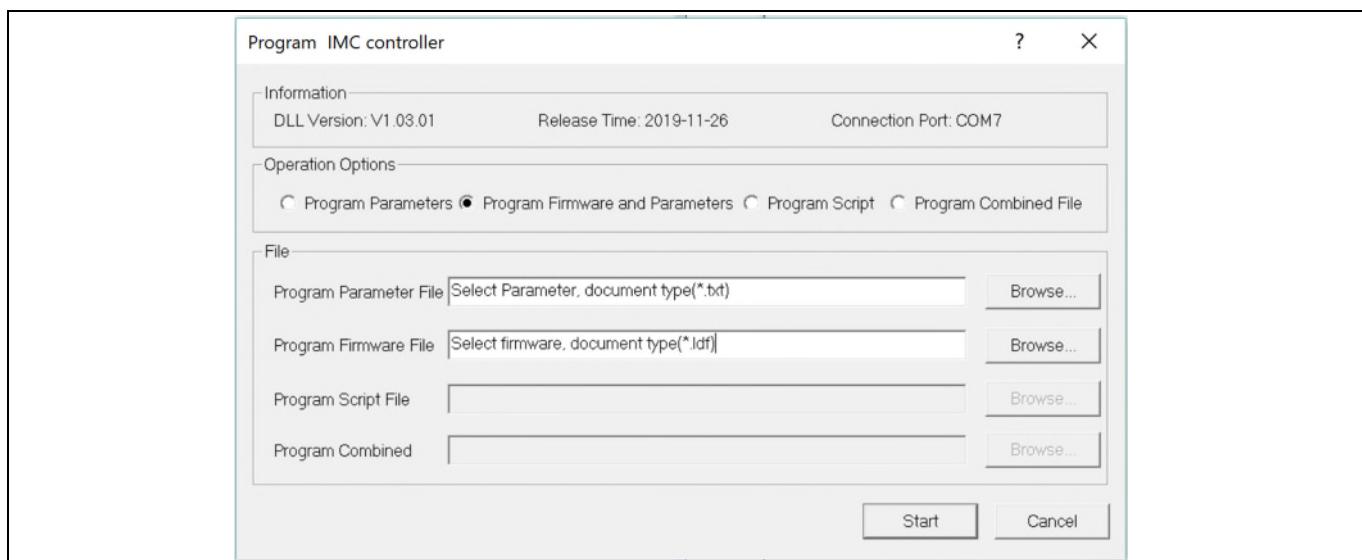
**System and functional description**

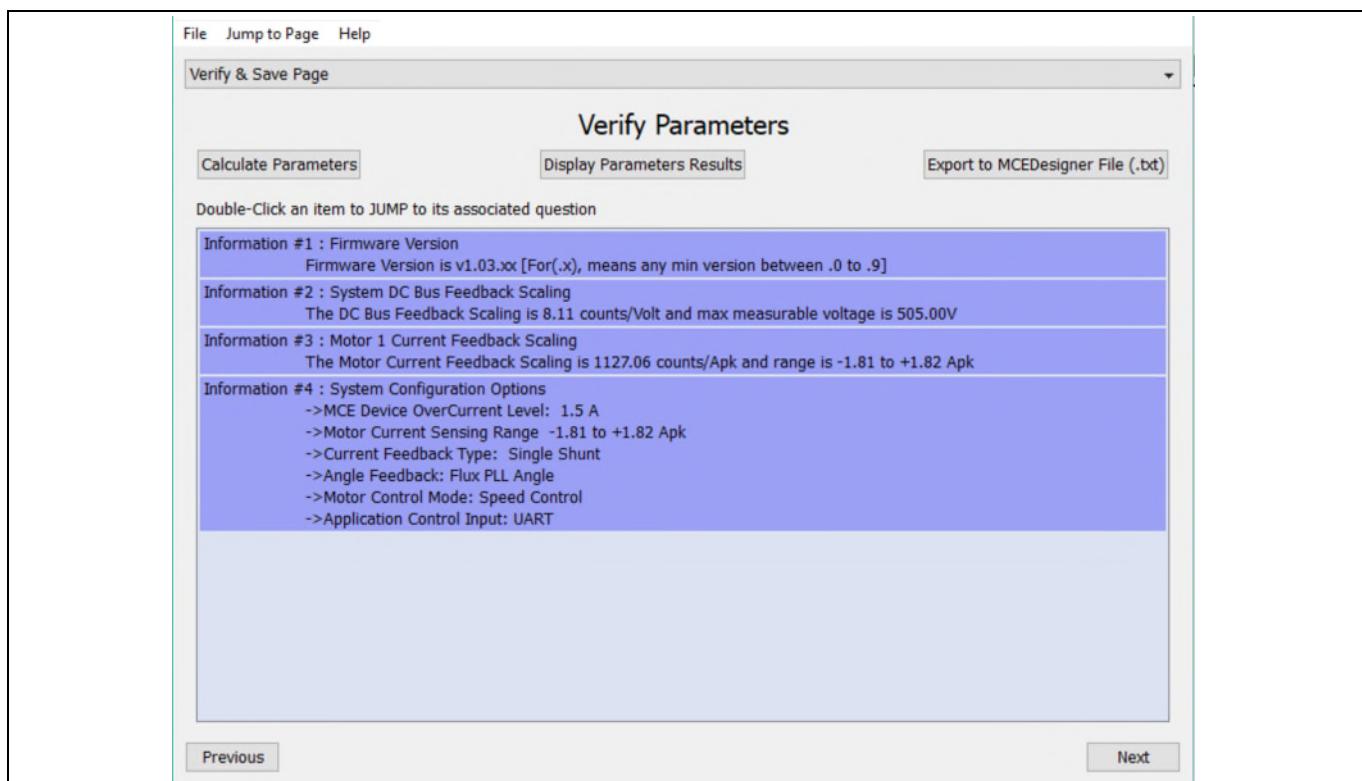
following: click on the “System Page” window and then click on “Preferences > Connection > Connect using,” and choose one of the other available COM ports from the drop-down list.

4. (In case blank IC) If the firmware has been erased from the IMD111T, the following warning message will pop up “Target device firmware and parameters file are not programmed! Please program firmware and parameters file” as Figure 5. Then you can program the firmware and parameters as described in the Step 5. If it is not the blank IC, no such message will be indicated.

**Figure 5 MCEDesigner warning message**

5. Use the following steps to program the firmware and the parameters’ file into the internal Flash memory of iMOTION™ Control IC: click on system page, click “Tools” > “Programmer” and select “Program Firmware and Parameters.” Shown as Figure 6 below. The encrypted firmware is available at “IMD111T MCE Software Package;” regarding the parameters file, browse and select the’.txt’ file in the section 2.1.2.

**Figure 6 Program the parameters and firmware**



**Figure 7 MCEWizard verify and save page**

#### **2.1.4 Open-loop diagnostic**

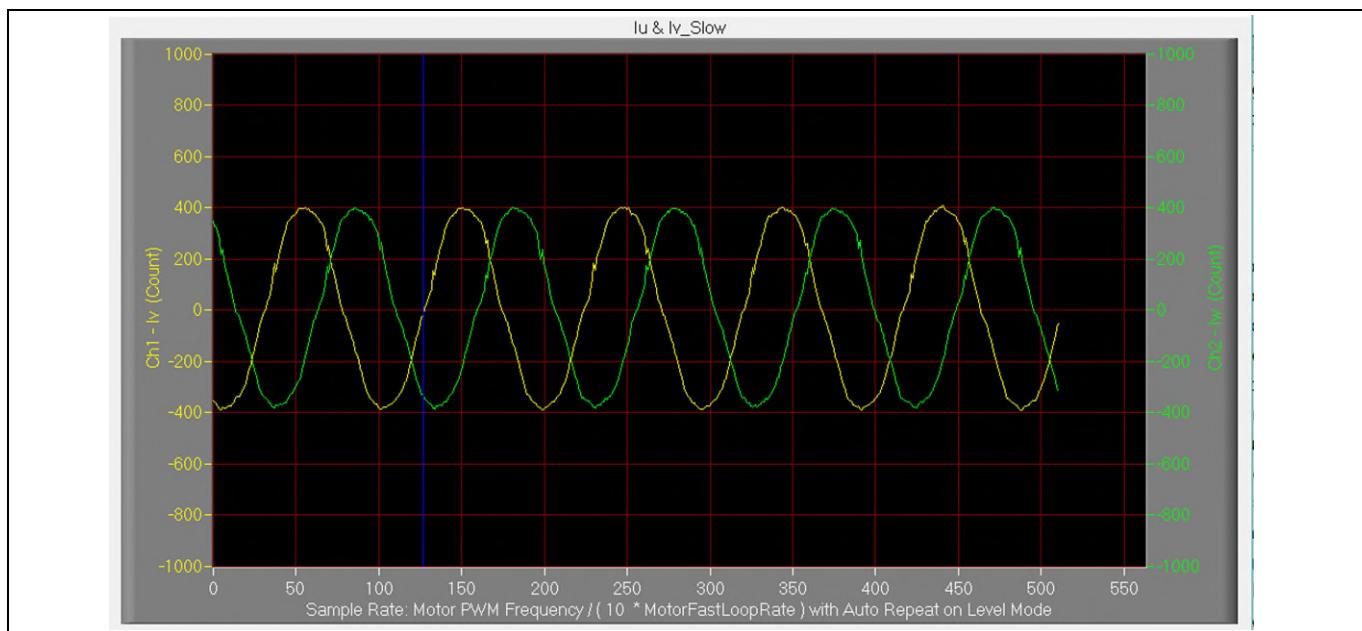
Double-click the “VF Diagnostic” function in the window of motor1, and monitor motor current with oscilloscope. If motor current is not sinusoidal, change register TargetSpeed and Vd\_Ext in VF Diagnostic sub-function, then double-click “VF Diagnostic” until the oscilloscope shows a steady sinusoidal current with an amplitude of 30~50% motor rate current.

Double-click “Iu & Iv\_Slow” in System page > Monitor Definitions, the motor current feedback should be very clean and sinusoidal, as shown in Figure 8; otherwise please tune “Gating Propagation Delay & Phase Shift Window Size” in MCEWizard.

“VF Diagnostic” sub-function can verify:

- If motor is connected correctly
- If IGBT(or MOSFET ) and gate driver work as expected
- If current-sensing related parameters are correctly configured
- If PCB layout and DC bus decoupling have been done correctly

After “VF Diagnostic” is done, click STOP button (the red traffic light button) or run “stop motor” function to stop the motor.



**Figure 8 Trace waveform for Iu & Iv open loop diagnostic**

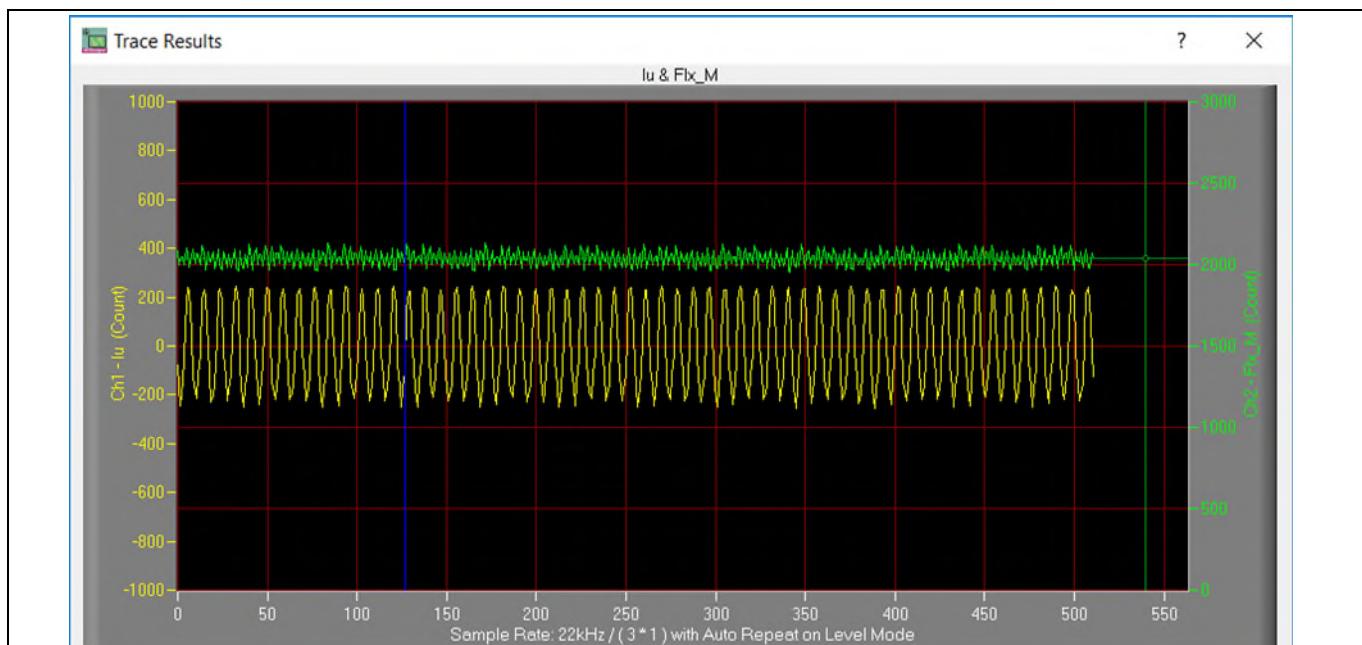
### 2.1.5 Closed-loop run

If the VF Diagnostic works correctly, the hardware circuit and signal sampling will work normally, at which point we can try to run the motor in a closed-loop mode. The steps are listed below.

1. Start the motor by clicking the green traffic light button in the control bar (or double click Start Motor sub-function in the window of motor1, which is in the group of User Application Function Definitions), the motor will run if above step works well.
2. Check the motor spin direction, adjust the connection order of the motor's winding, or set negative TargetSpeed in MCEDesigner if the direction is wrong.
3. Set TargetSpeed to about 50% of maximum speed, start “Iu & Flx\_M” trace with “Auto Repeat On Level,” see Figure 9. Flx\_M is good within the range of 2000~2500 (rated value is 2048), and must be steady and DC-like.

Here are some key tips for better motor performance tuning:

- If Flx\_M is not steady (swing or oscillation), motor parameters, speed loop PI gain, flux estimator time constant and PLL PI bandwidth (parameters PLLKp and PLLKi) and related setup need to be checked.
- If Flx\_M is very noisy, current feedback and  $V_{dc}$ -related hardware and parameters need to be checked.
- If Flx\_M does not come close to 2048, “Motor Back EMF Constant ( $K_e$ )” needs to be adjusted in MCEWizard.



**Figure 9** Trace waveform for Iu & Flx-M at 50% speed

4. Once the firmware has been programmed, and a new parameters' file has to be programmed, follow the same instructions given in Section 2.1.3. In this case, the firmware programming is no longer needed, and you can select the first option "Program Parameters."

**Note:** For detailed information on controller programming, refer to AN2018-33 *iMOTION™ 2.0 Device Programming, MCEDesigner documentation and MCEWizard documentation*.

## 2.2 Description of the functional blocks

### 2.2.1 Inverter stage

The inverter section is implemented with the 600 V CoolMOS™ PFD7 super-junction MOSFET in a small SOT223 package. The PFD7 high-voltage, n-channel MOSFET series combines best-in-class performance with state-of-the-art ease of use, shaped by Infineon's experience of more than 20 years as a pioneer in super-junction technology innovation. The products come with an integrated fast body diode ensuring a robust device, and in turn, a reduced BOM for the customer. Figure 10 shows the diagram of the inverter and peripheral circuit.

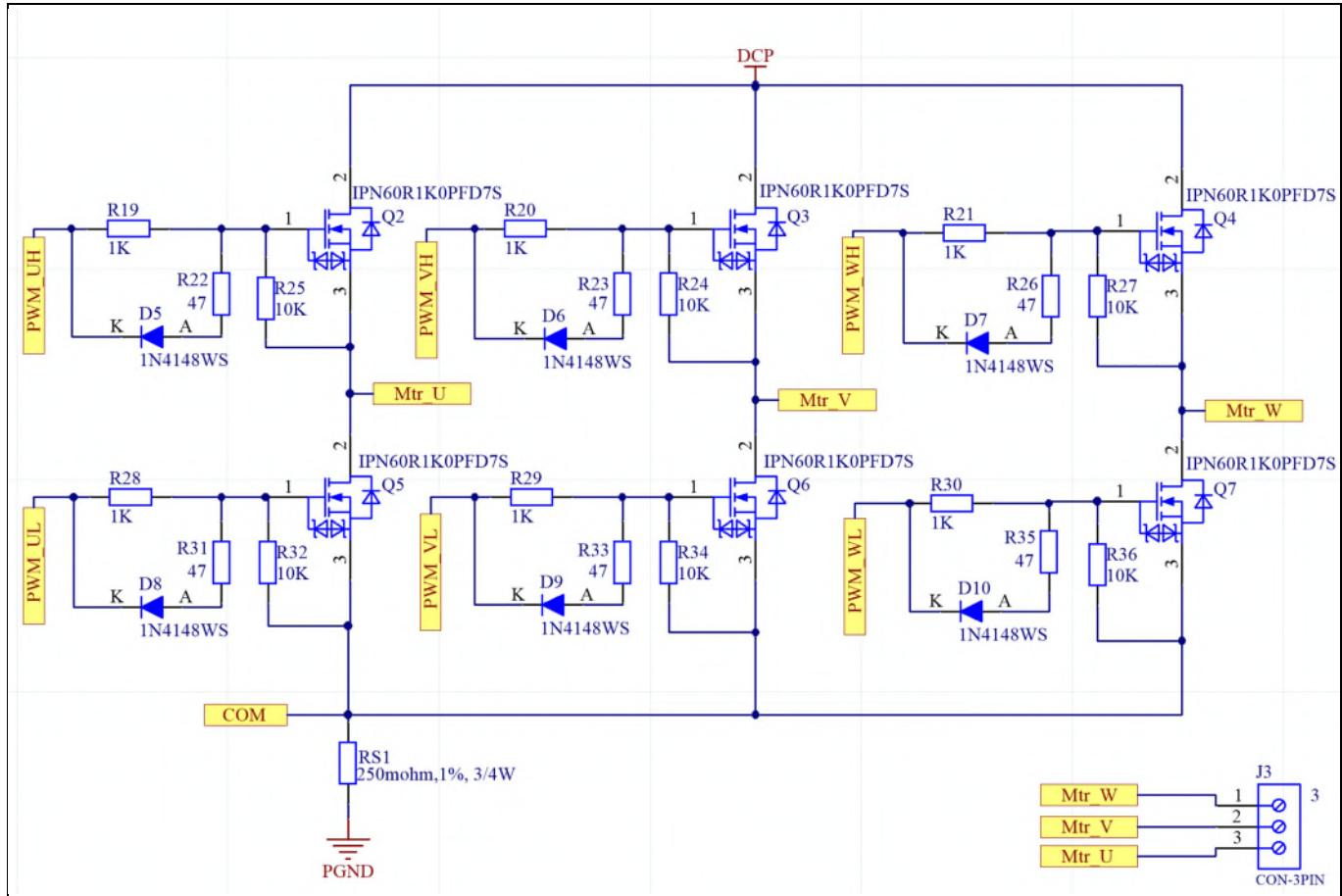


Figure 10 Inverter and peripheral circuit

## 2.2.2 DC bus sensing and MCEWizard configuration

Figure 11 provides the DC bus sensing resistor details on the reference design.

The high-side resistors are  $2\text{ M}\Omega$  and the low-side resistor is  $20\text{ k}\Omega$ , the default DC bus sensing voltage results in a range of 0 to 5 V on the ADC input, reflecting a range of 0 to 505 V.

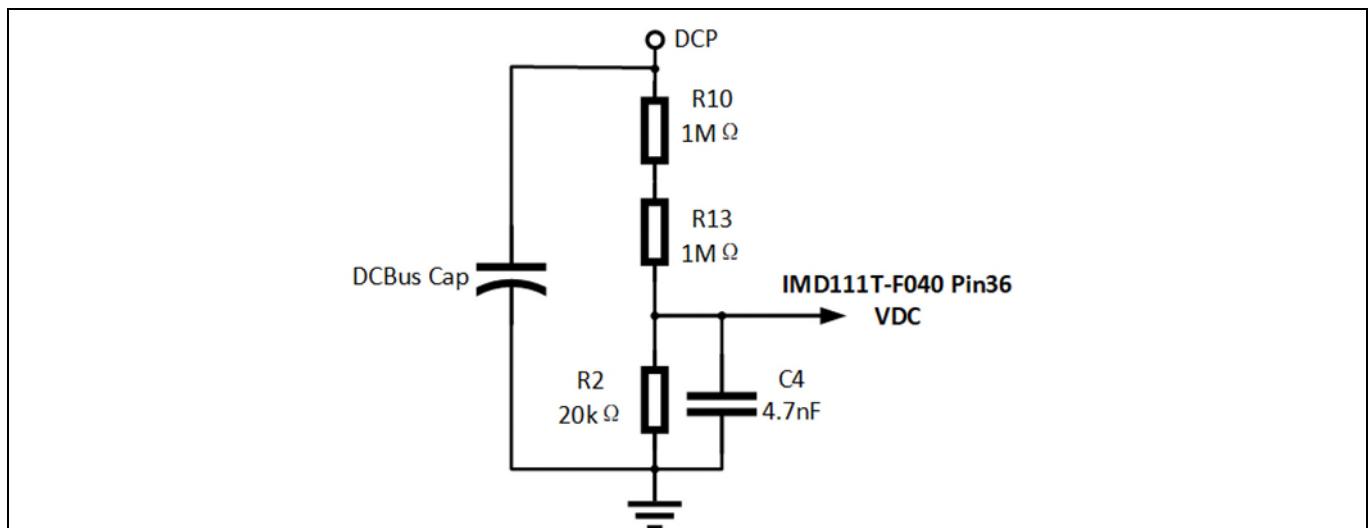
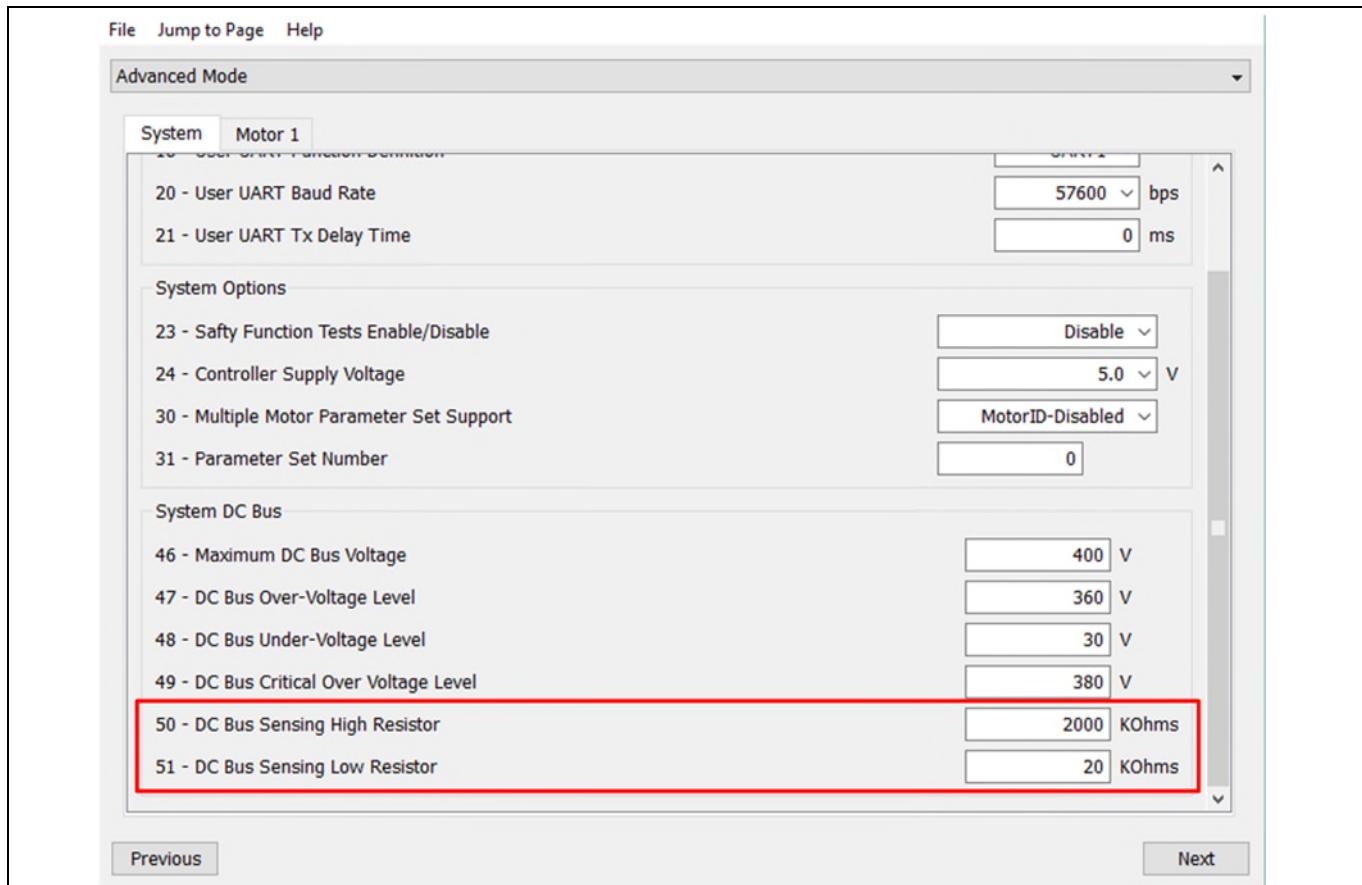


Figure 11 DC bus sensing

The hardware parameters need to be configured in MCEWizard as shown in Figure 12.



**Figure 12 DC bus sensing configuration in MCEWizard**

The  $V_{dc}$ -sensing, low-pass-filter time constant is  $((R10 + R13) // R15) * C4 = (2 M\Omega // 20 k\Omega) * 4.7 nF = 93.1 \mu s$ , C17 can be adjusted to higher capacitance for clean  $V_{dc}$  sensing.

## 2.2.3 Current sensing and over-current protection

### 2.2.3.1 Current sensing

The current sensing on this board uses only the RC network for operational bias and low-pass filter to minimize the cost. No additional operational amplifier is needed.

Based on the principle of Kirchhoff's voltage law, and assuming the AD port input impedance is infinite, you obtain the equation below.

$$V_{ADC} = \frac{(V_{cc} - V_{shunt})}{R_1 + R_2} * R_1 + V_{shunt}$$

The equation can be transformed to two parts as shown here:

$$V_{ADC} = \frac{R_2 * V_{shunt}}{R_1 + R_2} + \frac{R_1 * V_{cc}}{R_1 + R_2}$$

The impedance of the RC network is much larger than the  $R_{shunt}$ , so it can be assumed that:

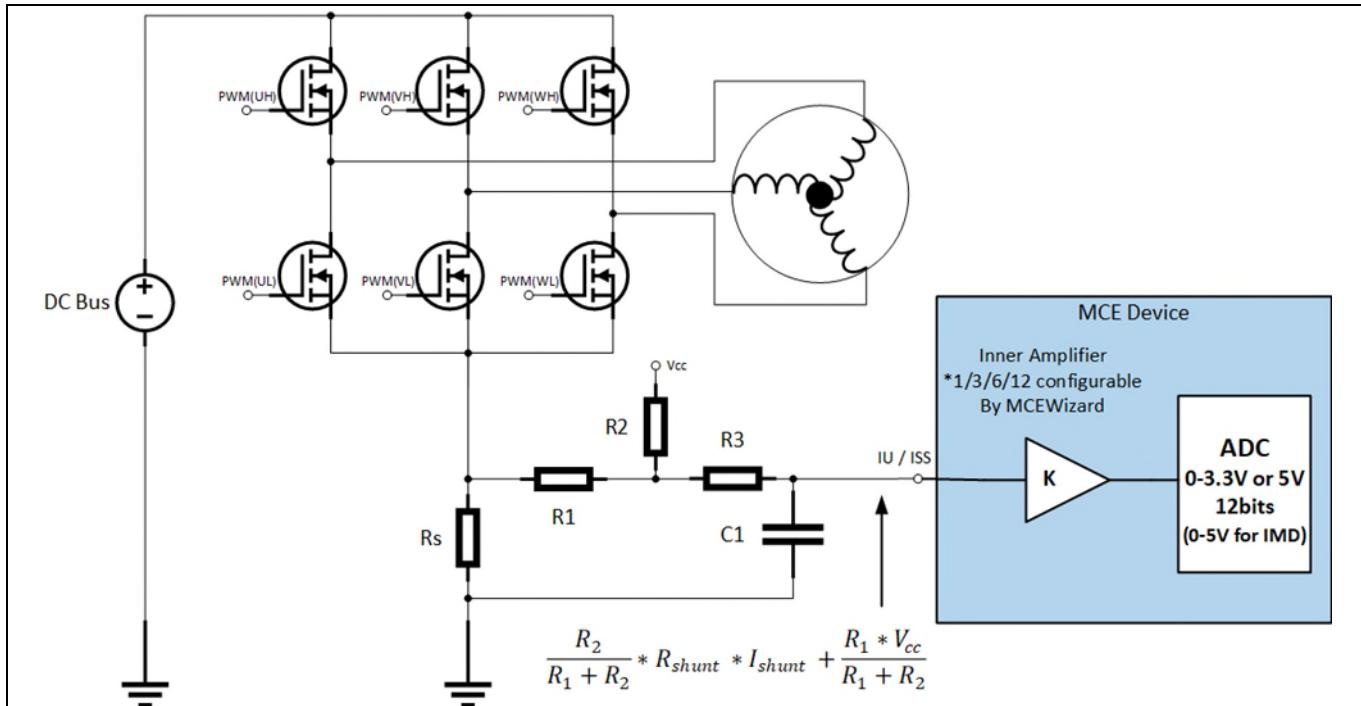
$$V_{shunt} = I_{shunt} * R_{shunt}$$

### System and functional description

$V_{ADC}$  can then be written as:

$$V_{ADC} = \frac{R_2}{R_1 + R_2} * R_{shunt} * I_{shunt} + \frac{R_1 * V_{cc}}{R_1 + R_2}$$

Where  $\frac{R_1 * V_{cc}}{R_1 + R_2}$  is the offset, and  $\frac{R_2}{R_1 + R_2} * R_{shunt}$  is the gain of the shunt current.



**Figure 13 Current-sensing topology**

Use this board with, for example,  $R1 = R20 = 2 \text{ k}\Omega$ ,  $R2 = R8 = 22.1 \text{ k}\Omega$ ,  $V_{cc} = 5 \text{ V}$ , offset = 0.415V, gain =  $\frac{R_2}{R_1 + R_2} * R_{shunt} = 229.3 \text{ mV/A}$ .

Note the following points concerning current sampling:

- R8 & R20 also determine ADC operational bias for current sensing, which corresponds to the motor regeneration operation range. For those applications that do not work at regenerative brake mode, the bias can be as low as possible to reserve enough ADC range for the drive mode, since negative current to DC bus does not occur.
- Since the gain of the external RC circuit is less than 1, internal signal amplification is required to increase the ADC input voltage range with lower shunt value. If a larger shunt is chosen, the power loss and size are both larger. MCE provides an inner current sampling amplifier with \*1, \*3, \*6 and \*12 gain selections, which can be configured in the MCEWizard.
- There is no common mode noise-rejection ability without an outer operational amplifier, so the GND network of the PCB needs to be dealt with very carefully, since any voltage difference between IMD111T's ADC ground and shunt resistor ground will be considered as an "input signal," and will deteriorate control performance or increase audible noise.

## System and functional description

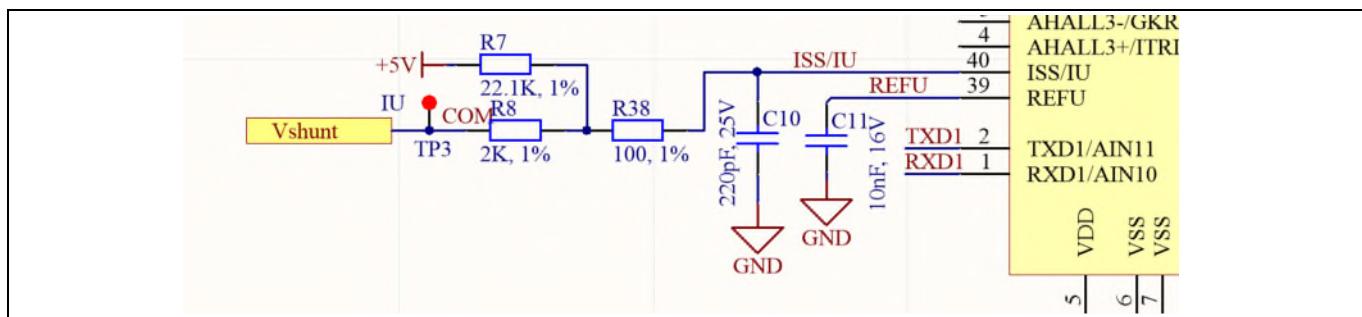


Figure 14 Current-sensing circuit on the board

### 2.2.3.2 Over-current protection

The over-current condition can be detected by IMD111T-6F040 by the input sources as shown in Figure 15.

- Internal comparator in the IMD111T-6F040

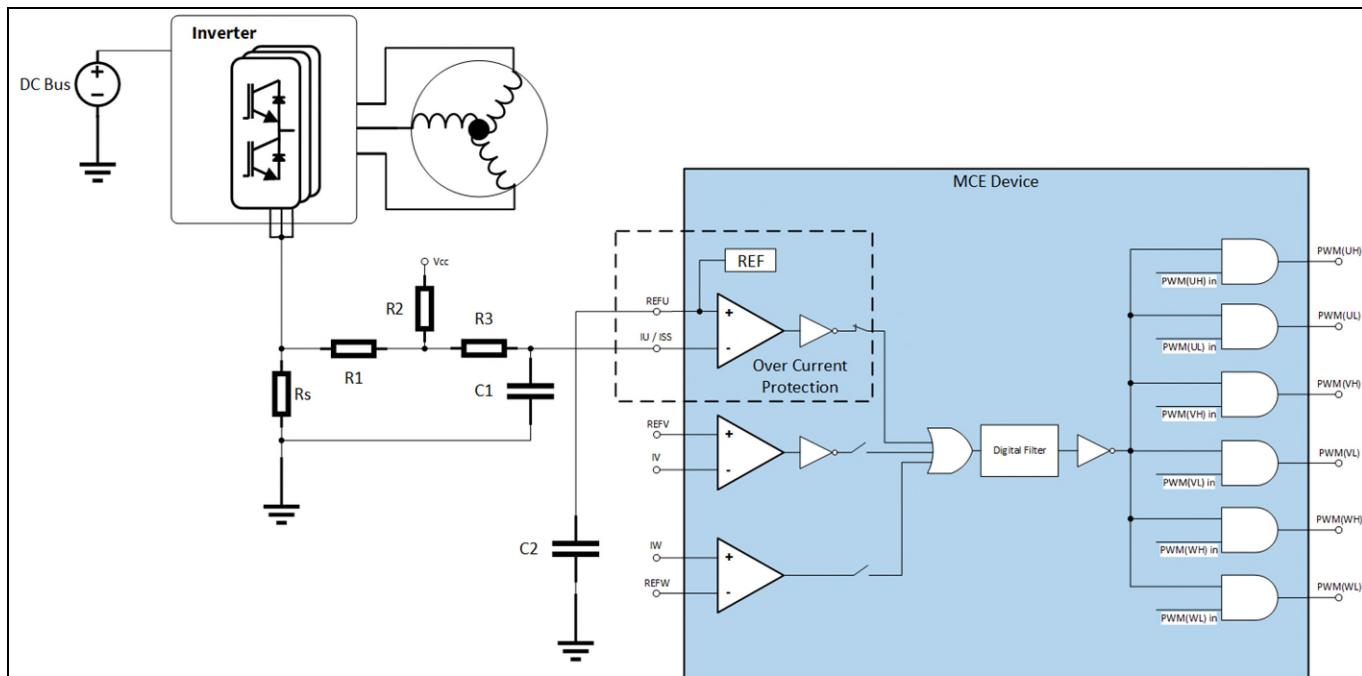


Figure 15 Over-current protection on the board

For more details about the over-current protection (OCP) in the IMD111T, refer to chapter on motor over-current protection in the reference material <sup>[6]</sup>.

The internal comparator's reference level is set by the internal DAC, the level can be set in the MCEWizard by "Device over-current trigger level setting for comparator" and "Motor1 current input to ADC offset voltage." The DAC output pin REFU needs to be connected to a capacitor; 10 nF/16 V is used on the board.

### 2.2.4 NTC sensing and thermal protection

Pin 35 of IMD111T-6F040 is the ADC port dedicated to NTC temperature sampling. On the board, an NTC is connected to the ADC channel by the circuit shown in Figure 16. The position of the NTC on the board is shown in the Figure 17

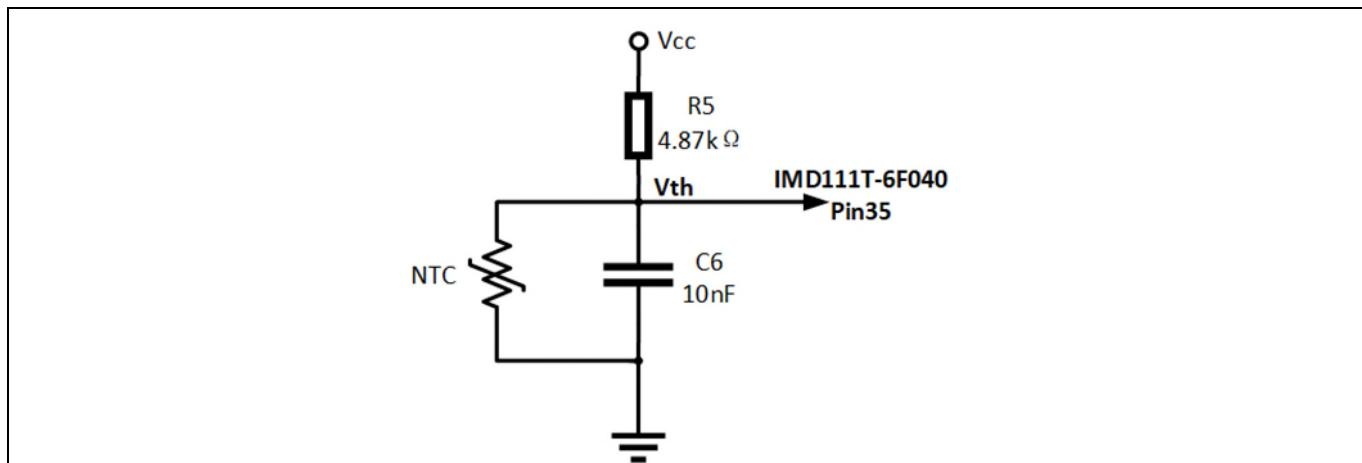


Figure 16 NTC sensing circuit

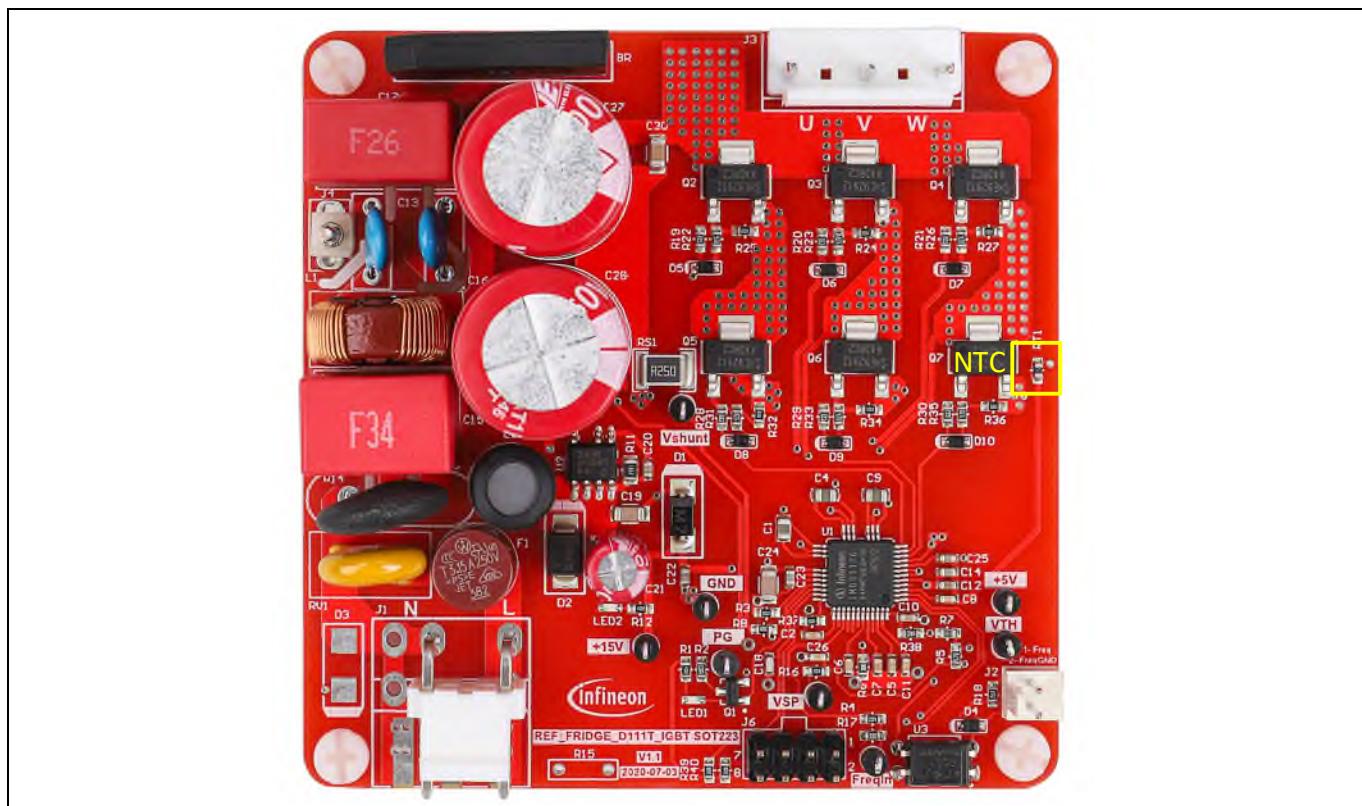


Figure 17 NTC position on the board

The parameters of the NTC are: B-constant =  $4050\text{ K} \pm 1\%$ ,  $R_{25} = 47\text{ k}\Omega \pm 1\%$ . Based on the typical value of the thermistor resistance, voltage of the  $V_{th}$  can be obtained in Table 4.

The firmware inside the IMD111T integrates the over-temperature protection device, which will be triggered by the voltage  $V_{th}$ . Simply set the proper trigger level in the MCEWizard. More information can be found in the over-temperature protection section of the reference material [6].

**Table 4 Thermistor characteristics with V = 5 V, R5=4.87 kΩ**

Temperature (°C)	Resistance typ. (kΩ)	V <sub>th</sub> (V)	V <sub>th</sub> register value
15.00	75.31	4.70	3846
20.00	59.25	4.62	3784
25.00	47.00	4.53	3711
30.00	37.57	4.43	3625
35.00	30.25	4.31	3527
40.00	24.52	4.17	3416
45.00	20.01	4.02	3293
50.00	16.43	3.86	3159
55.00	13.58	3.68	3014
60.00	11.28	3.49	2860
65.00	9.42	3.30	2700
70.00	7.92	3.10	2535
75.00	6.68	2.89	2369
80.00	5.67	2.69	2202
85.00	4.83	2.49	2039
90.00	4.13	2.30	1880
95.00	3.55	2.11	1727
100.00	3.06	1.93	1582
105.00	2.65	1.76	1445
110.00	2.31	1.61	1317
115.00	2.01	1.46	1198

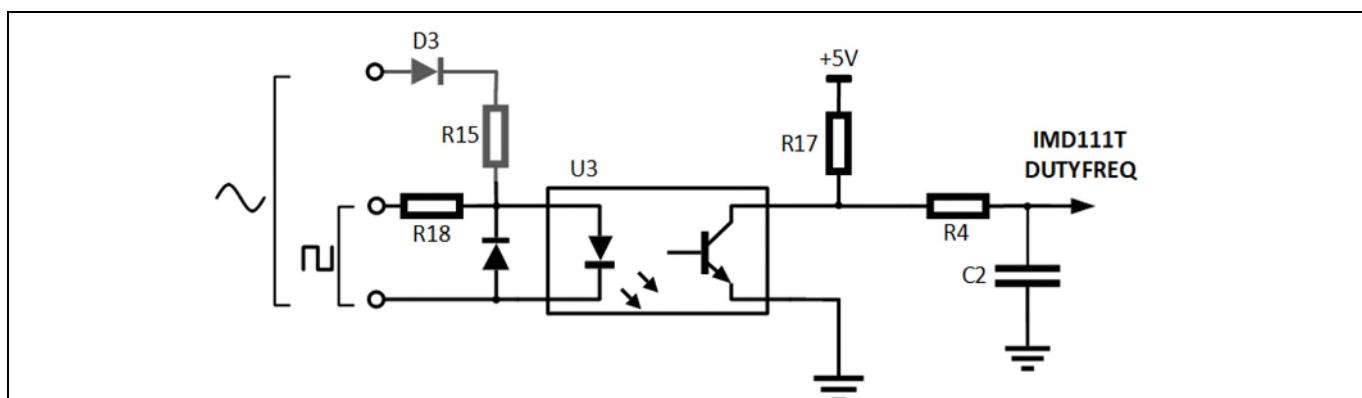
## 2.3 Frequency-signal interface

Since current refrigerator applications mainly use frequency signals to control the compressor speed, the board is designed with a frequency-signal interface. Figure 18 shows the interface circuit. The input signal is isolated from the control and power parts on the board.

The board has two types of input interface:

1. Square-wave interface (default, remove the D3, R15)
2. AC 220 V as the control input (you need to remove R18, and install D3, R15)

Type 1 is a more common signal type, while type two is used less, leaving only the interface for customers who need it.

**Figure 18 Frequency-interface circuit**

**System and functional description**

A typical square wave input signal for refrigerator applications is shown in Table 5 for reference.

**Table 5      Typical frequency/speed characteristic**

<b>Signal frequency <math>f_n</math> (Hz)</b>	<b>Motor speed <math>n</math> (RPM)</b>
$f_n < 30$	Stop
$30 \leq f_n < 40$	Minimum speed
$40 \leq f_n < 150$	$30 * f_n$
$150 \leq f_n < 200$	Maximum speed
$f_n \geq 200$	Stop

## System design

### 3 System design

This section provides the complete details of the schematics, layout and connectors. Please note that the schematics, routing and Gerber generation are done in Altium Designer. Customers who are interested in the original Altium format files or pdf files for better clarity can visit [www.Infineon.com](http://www.Infineon.com).

#### 3.1 Schematics

The major function blocks are introduced in Section 2.2. Customers who are interested in further details can download the design files after logging in your account on infineon webpage.

#### 3.2 Layout

The board is designed in two layers, and its dimensions are 78 mm × 78 mm, manufactured with 1 oz. (35 µm) copper thickness. The project is designed with Altium Designer, and all design files can be downloaded after logging in your account on Infineon webpage.

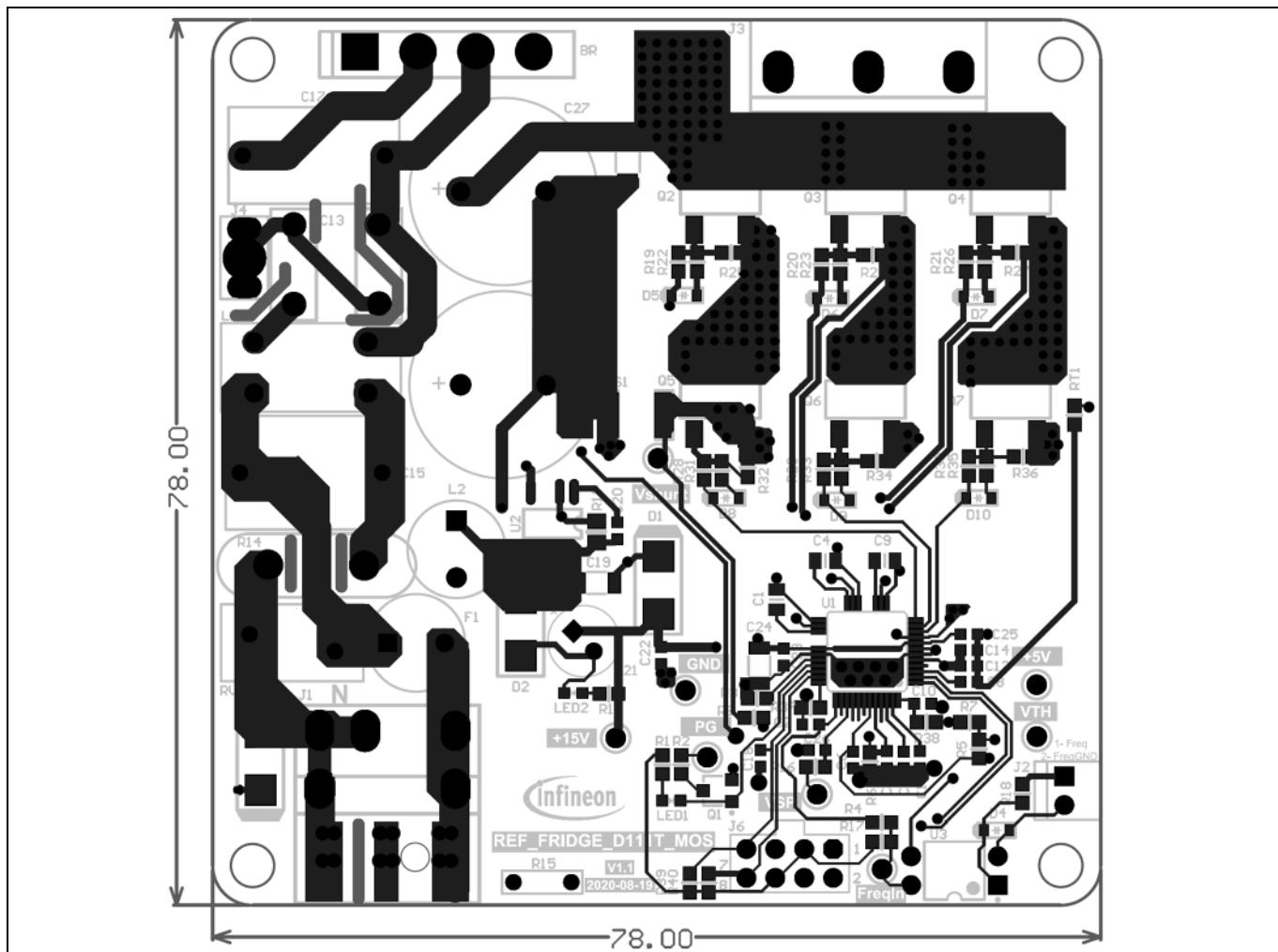
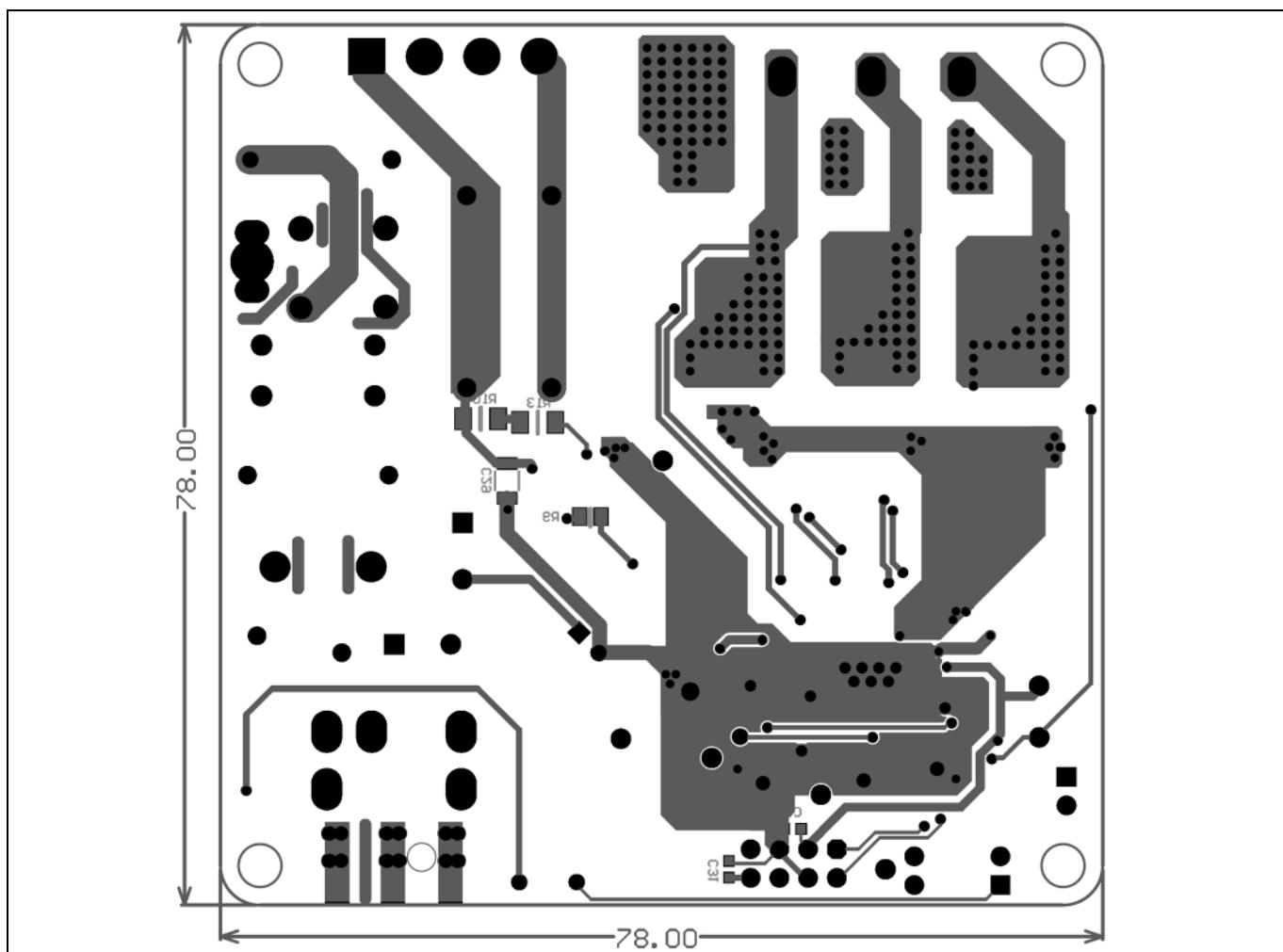


Figure 19 Top view of the board

## System design



**Figure 20 Bottom view of the board**

Here are a few design tips to note for your reference:

- Thermal performance

Maximizing the copper area of the collector could effectively reduce the IGBT junction temperature, so the board can deliver more power.

- Ground layout

Since current sampling is non-differential and without op-amp, the ground area should be carefully laid out; the digital ground should refer to the shunt ground to ensure the sampling noise is correct.

### 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 6 BOM of the most important/critical parts of the reference board**

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	U1	IC iMOTION SMART DRIVER	Infineon Technologies	IMD111T-6F040
2	Q2, Q3, Q4, Q5, Q6, Q7	600 V CoolMOS PFD7 SJ Power Device	Infineon Technologies	IPN60R1K0PFD7S
3	Q1	MOSFET N-CH 30 V 2.7 A SOT-23-3	Infineon Technologies	IRLML2030TRPBF
4	C19, C24	WCAP-CSGP General Purpose Ceramic Capacitors, size 1206, 10 uF, +/-10%, 25 VDC	Wurth Elektronik	885012208069
5	C21	WCAP-ATG8 Aluminum Electrolytic Capacitors, 6.3x11 mm, 25 Vdc, 220 uF	Wurth Elektronik	860010473011
6	C27, C28	WCAP-AT1H THT Aluminum Electrolytic Capacitors, D16mm x L35.5 mm, 100 uF, +/-20%, 450 VDC	Wurth Elektronik	860241480001
7	C29, C30	WCAP-CSST Soft Termination Ceramic Capacitors, size 1206, 22 nF, +/-10%, 500 VDC	Wurth Elektronik	885382208010
8	J2	WR-WTB 2.54 mm Male Locking Header, 2p	Wurth Elektronik	61900211121
9	J6	CONN HEADER VERT 8POS 2.54 mm	Wurth Elektronik	61300821121
10	L1	WE-CMB Common Mode Power Line Choke, Type XS, 4 mH, 1.5 A, 250 V	Wurth Elektronik	744821240
11	RV1	WE-VD Disk Varistor, size 10 mm, 300 Vrms, 385 Vdc	Wurth Elektronik	820513011
12	RS1	RES 0.25 OHM 1% 3/4 W 2010		

### 3.4 Connector details

**Table 7 J1- AC line connector**

PIN	Label	Function
1	L	AC line input
2	N	AC neutral input
3	N	AC neutral input

**Table 8 J2- Frequency input signal connector**

PIN	Label	Function
1	Frequency input	Frequency input signal, isolated by optocoupler
2	Frequency ground	Frequency input signal ground, isolated by optocoupler

**Table 9 J3- Motor side connector**

<b>PIN</b>	<b>Label</b>	<b>Function</b>
1	W	Connected to motor phase W
2	V	Connected to motor phase V
3	U	Connected to motor phase U

**Table 10 J4- Earth connector**

<b>PIN</b>	<b>Label</b>	<b>Function</b>
1	Earth	

**Table 11 J6- iMOTION™ link connector**

<b>PIN</b>	<b>Label</b>	<b>Function</b>
1	TXD1	User UART for script communication
2	RXD1	User UART for script communication
3 & 6	+3.3V	On board 3.3 V supply
4 & 5	GND	Ground
7	RXD0	MCEDesigner & firmware download
8	TXD0	MCEDesigner & firmware download

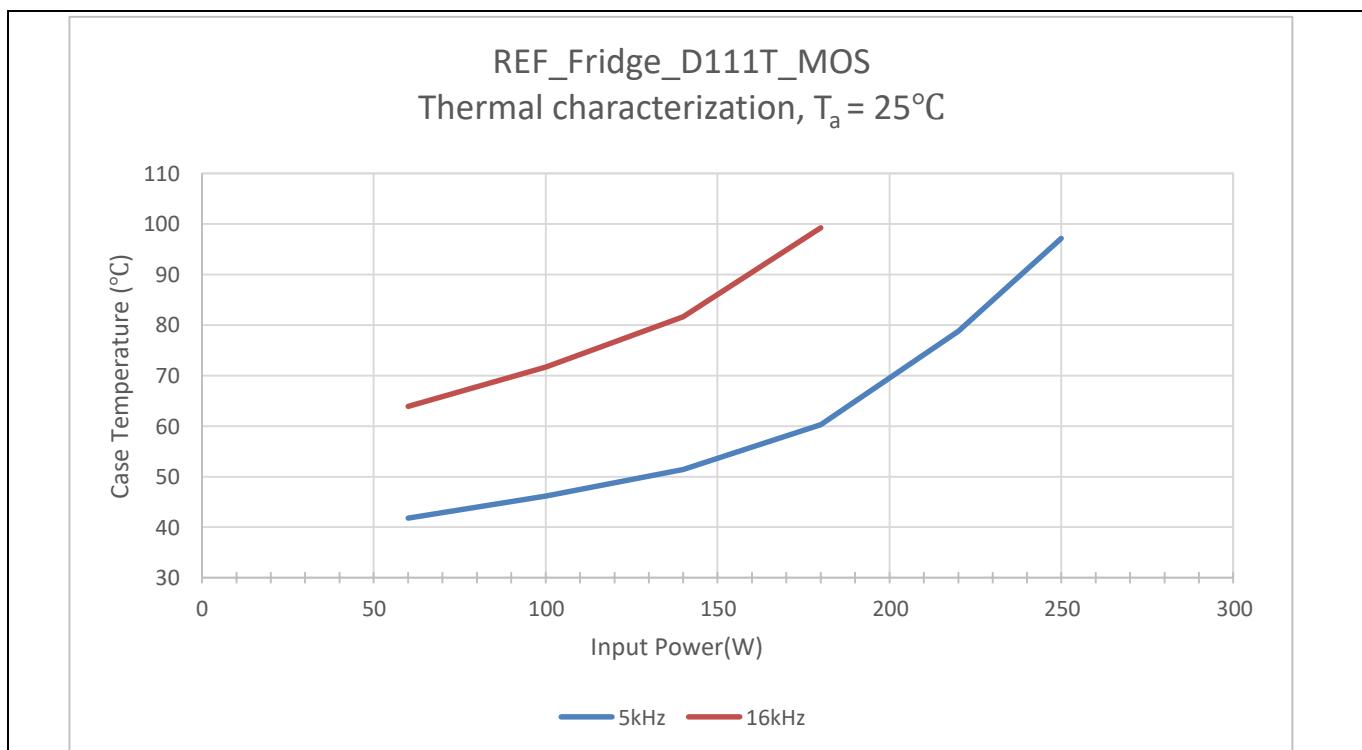
**System performance**

## 4 System performance

### 4.1 Thermal characterization test

Figure 21 and Figure 22 show the thermal characterizations of REF\_Fridge\_D111T\_MOS, based on 2 layers FR4 PCB with 1 oz. copper.

The tests reported on were performed under the following conditions:  $t_{amb}=25^{\circ}\text{C}$ ,  $V_{ac} = 220 \text{ V}$  with different input power until the MOSFET case reaches  $100^{\circ}\text{C}$ . There are two PWM frequencies (5 kHz and 16 kHz), and 3-phase modulation mode only.



**Figure 21** REF\_Fridge\_D111T\_MOS thermal characterization case temperature – input power,  $t_a = 25^{\circ}\text{C}$

**Table 12** Input power and current characterization

Input power (W)	30	60	100	140	180	220	260
Input current (A)	0.24	0.45	0.72	1.03	1.32	1.6	1.81

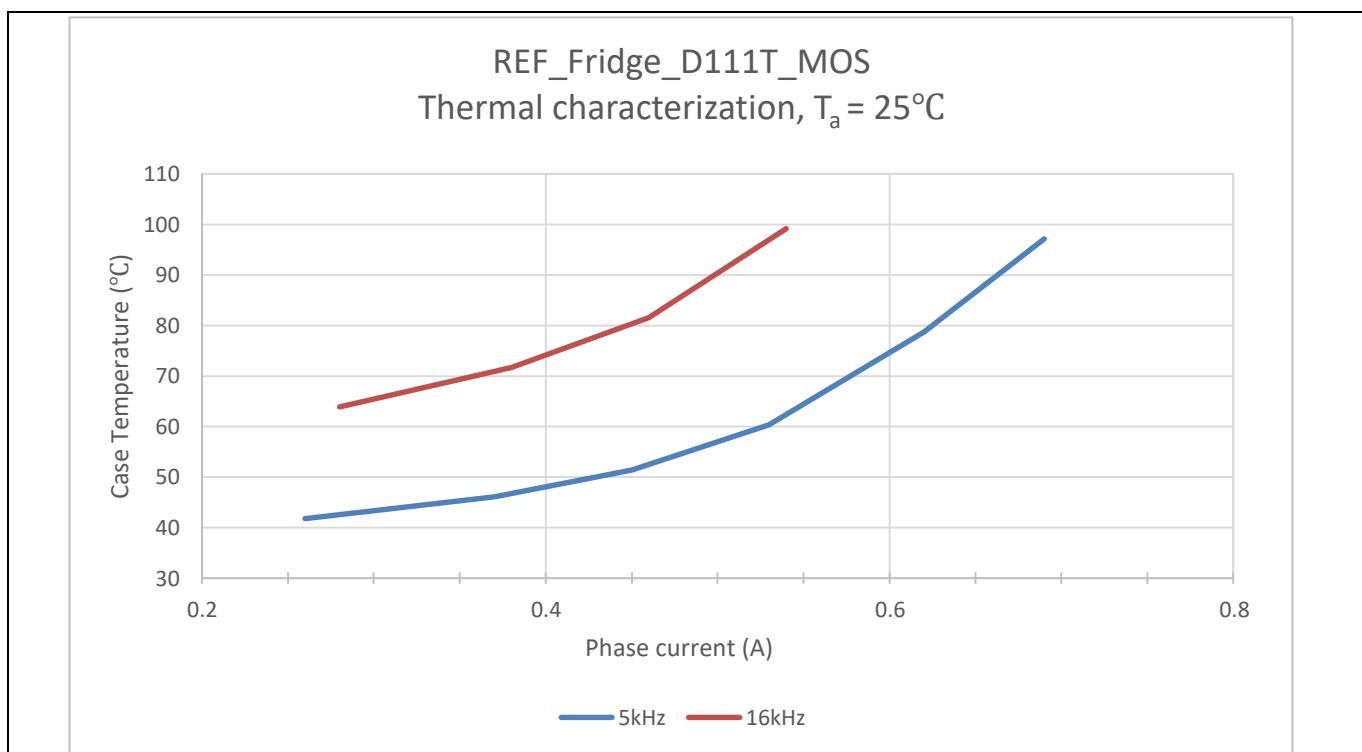


Figure 22 REF\_Fridge\_D111T\_MOS thermal characterization, case temperature - motor phase current,  $t_a = 25^\circ\text{C}$

## 4.2 MOSFET dV/dt test

This section indicates the MOSFET turn-on and turn-off waveform, the oscilloscope probe is connected as shown in Figure 23. On the board,  $R_{g(on)} = 1 \text{ k}\Omega$ , and  $R_{g(off)} = 47 \Omega$ . The dV/dt is calculated by the voltage varying from 10% to 90%.

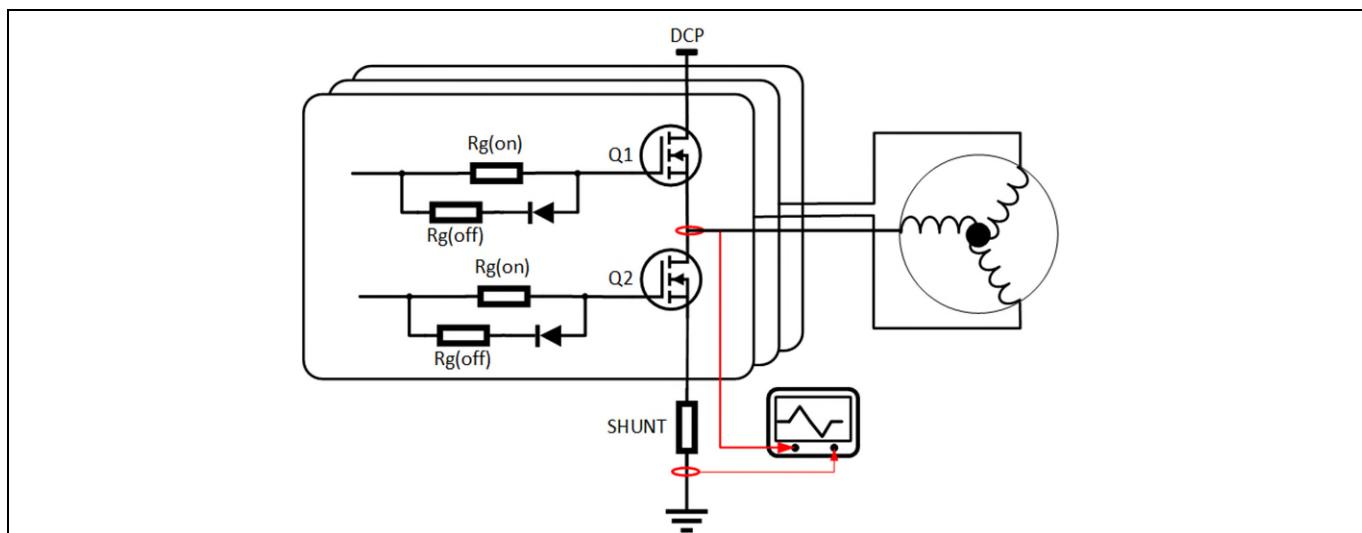


Figure 23 Drain-to-source voltage test - dV/dt control

As shown in Figure 24 and Figure 25, when the low-side MOSFET turns on, the  $V_{ds} \text{ dV/dt} = 245 \text{ V}/28.1 \text{ ns} = 8.7 \text{ V/ns}$ . When the low-side MOSFET turns off, the  $\text{dV/dt} = 247.9 \text{ V}/29.8 \text{ ns} = 8.3 \text{ V/ns}$ . Users may further adapt the  $R_g$  value to control MOSFET dv/dt if needed.

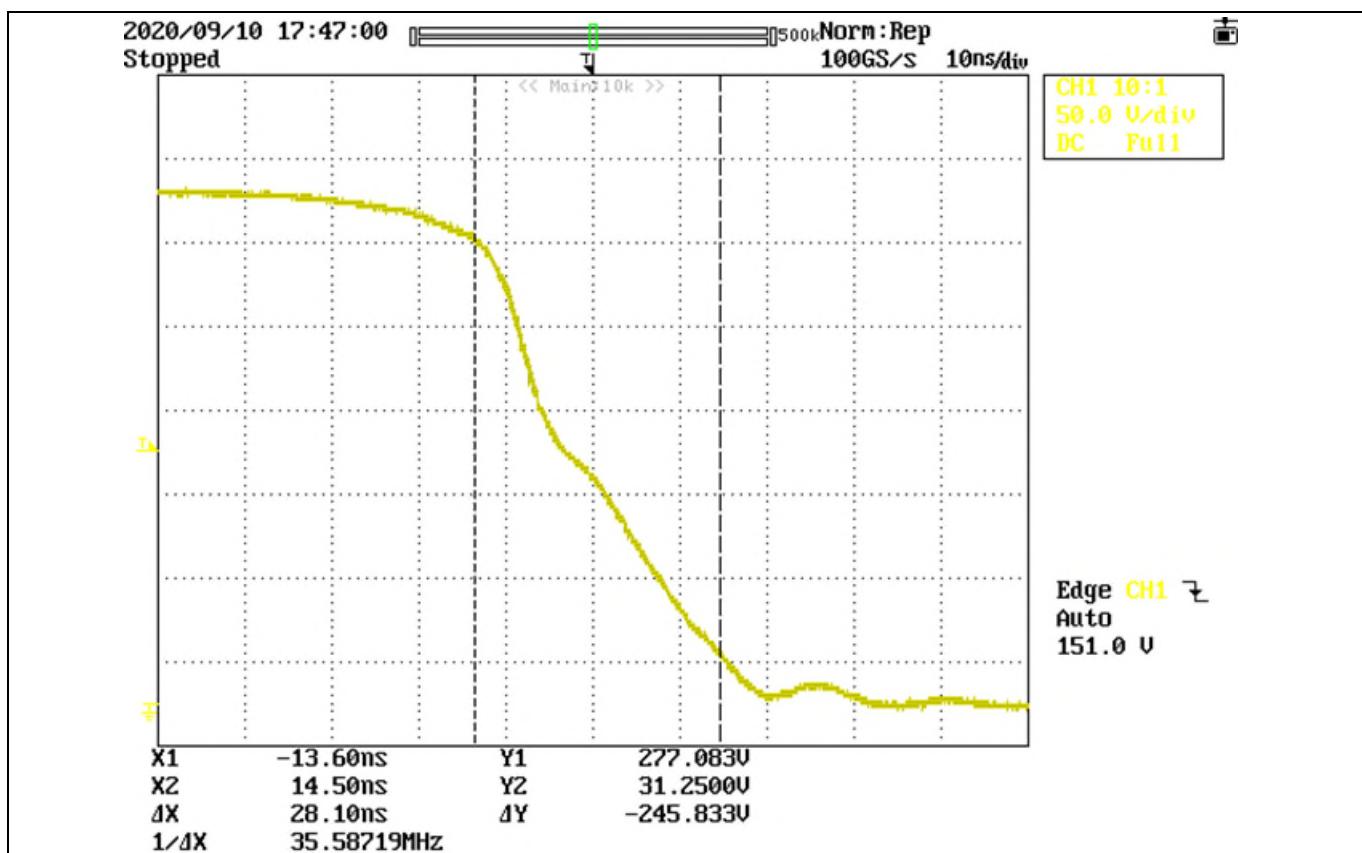


Figure 24 MOSFET turn-on waveform

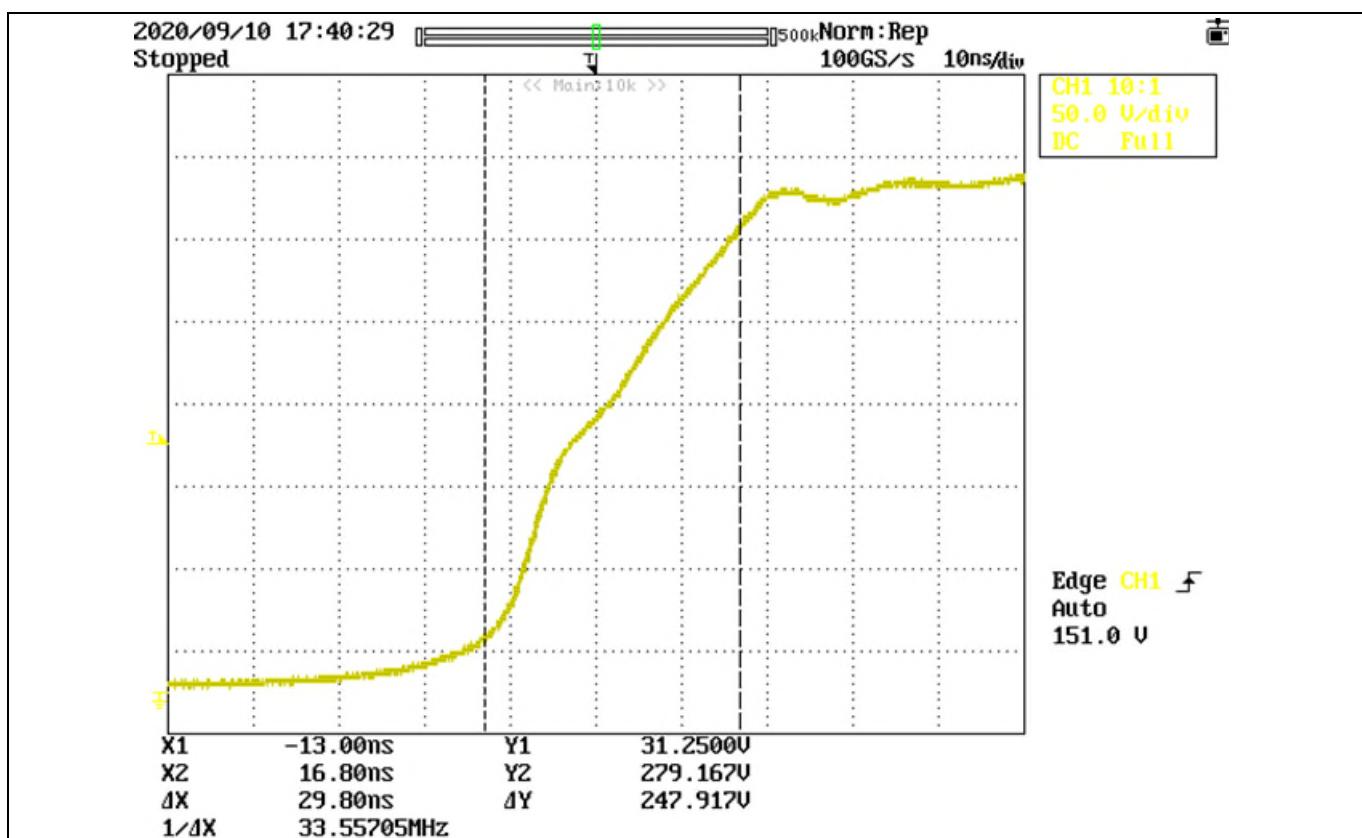


Figure 25 MOSFET turn-off waveform

## 5 Reference and appendices

### 5.1 Abbreviations and definitions

**Table 13 Abbreviations**

Abbreviation	Meaning
CE	Conformité Européenne
EMI	Electromagnetic interference
UL	Underwriters Laboratories

### 5.2 References

- [1] Infineon Technologies AG. Datasheet of IPN60R1K0PFD7S (2019) V2.0 [www.infineon.com](http://www.infineon.com)
- [2] Infineon Technologies AG. Datasheet of IMD111T-6F040 (2020) V1.0 [www.infineon.com](http://www.infineon.com)
- [3] Infineon Technologies AG. Datasheet of IRLM2030TRPbF (2009) [www.infineon.com](http://www.infineon.com)
- [4] Infineon Technologies AG. MCEWizard\_V2.3.0.0 User Guide (2019) [www.infineon.com](http://www.infineon.com)
- [5] Infineon Technologies AG. MCEDesigner\_V2.3.0.0 Application Guide (2019) [www.infineon.com](http://www.infineon.com)
- [6] Infineon Technologies AG. iMOTION™ Motion Control Engine Software Reference Manual (2020) V1.3 [www.infineon.com](http://www.infineon.com)

### 5.3 Additional information

In order to initiate testing, customers are advised to order the iMOTION™ Link, the information is listed in the Table 14.

The Infineon's components on the board are listed in the Table 14 as well, the customers can visit the corresponding webpage for more information.

**Table 14 Additional information of tools and infineon's components**

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
<a href="#">iMOTION™ Link</a>		Container	1	IMOTIONLINK
<a href="#">IMD111T-6F040</a>	PG-LQFP-40	Tape and reel	1500	IMD111T6F040XUMA1
<a href="#">IPN60R1K0PFD7S</a>	PG-SOT223-3	Tape and reel	3000	IPN60R1K0PFD7SATMA1
<a href="#">IRLML2030TRPBF</a>	SOT-23	Tape and reel	3000	IRLML2030TRPBF

**Revision history**

**Revision history**

<b>Document version</b>	<b>Date of release</b>	<b>Description of changes</b>
1.0	2020/10/16	Initial version

## Trademarks

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

**Edition 2020-10-16**

**Published by**

**Infineon Technologies AG**

**81726 Munich, Germany**

**© 2021 Infineon Technologies AG.  
All Rights Reserved.**

**Do you have a question about this  
document?**

**Email:** [erratum@infineon.com](mailto:erratum@infineon.com)

**Document reference  
UG-2020-19**

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office ([www.infineon.com](http://www.infineon.com)).

## WARNINGS

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

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