

EVAL-M3-IM564 User Manual

iMOTION™ Modular Application Design Kit

About this document

Scope and purpose

This user manual provides an overview of the Evaluation board EVAL-M3-IM564 including its main features, key data, pin assignments and mechanical dimensions.

EVAL-M3-IM564 is an Evaluation board as part of the iMOTION™ Modular Application Design Kit. This power board includes a PFC integrated 3-phase CIPOS™ Mini Intelligent Power Module (IPM) for motor drive application. In combination with the control board equipped with the M3 30pin interface connector such as EVAL-M3-102T, it features and demonstrates Infineon's CIPOS™ Mini IPM technology and Advanced Motion Control Engine (MCE 2.0) technology for permanent magnet motors drive over the full speed range.

The inverter section has 600V of voltage and 20A of current rating, and the PFC section has 600V of voltage and 20A of current rating. It is optimized to major home appliances like air conditioners and low power motor drive application with high frequency switching operation of power factor correction.

This Evaluation board EVAL-M3-IM564 was developed to support customers during their first steps designing application with CIPOS™ Mini PFC integrated IPM IM564-X6D/IM564-X6DS and running any permanent magnet motor via sensorless sinusoidal control.

Intended audience

This user manual is intended for all technical specialists who know motor control and high power electronics converter and this board is intended to be used under laboratory conditions.

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Safety precautions

1 Safety precautions

In addition to the precautions listed throughout this manual, please read and understand the following statements regarding hazards associated with development systems.

Table 1 **Precautions**

| | |
|---|---|
|  | <p>Attention: <i>The ground potential of the EVAL-M3-IM564 system is biased to a negative DC bus voltage potential. When measuring voltage waveform by oscilloscope, the scope's ground needs to be isolated. Failure to do so may result in personal injury or death and equipment damage.</i></p> |
|  | <p>Attention: <i>Only personnel familiar with the drive and associated machinery should plan or implement the installation, start-up and subsequent maintenance of the system. Failure to comply may result in personal injury and/or equipment damage.</i></p> |
|  | <p>Attention: <i>The surfaces of the drive may become hot, which may cause injury.</i></p> |
|  | <p>Attention: <i>EVAL-M3-IM564 system contains parts and assemblies sensitive to Electrostatic Discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing this assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.</i></p> |
|  | <p>Attention: <i>A drive, incorrectly applied or installed, can result in component damage or reduction in product lifetime. Wiring or application errors such as under sizing the motor, supplying an incorrect or inadequate DC supply or excessive ambient temperatures may result in system malfunction.</i></p> |
|  | <p>Attention: <i>Remove or connect the control board from or to the power drive. Wait three minutes after removing power from the power drive 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.</i></p> |
|  | <p>Attention: <i>EVAL-M3-IM564 system is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials which are unnecessary for system installation may result in overheating or abnormal operating condition.</i></p> |

Introduction

2 Introduction

The EVAL-M3-IM564 Evaluation power board is a part of the iMOTION™ Modular Application Design Kit for motor drives (iMOTION™ MADK). In order to run a motor, the matching control board is required to interface this power board.

The MADK platform is intended to use various power stages with different control boards. These boards can easily be interfaced through the 30-pin iMOTION™ MADK M3 such as EVAL-M3-102T, or the 20-pin iMOTION™ MADK M1 interface connector to control board. This board is equipped with 30-pin M3 connector and is intended for single motor control only.

This Evaluation board is designed to give Easy-to-use power stage based on the Infineon's CIPOS™ Mini Intelligent Power Module (IPM). The board is equipped with all assembly groups for sensorless field oriented control (FOC). It provides a single-phase AC-connector, rectifier, Boost PFC and 3-phase output for connecting the motor. The power stage also contains emitter shunts for current sensing and a voltage divider for DC-link voltage measurement.

The EVAL-M3-IM564 Evaluation board is available through regular Infineon distribution partners as well as on Infineon's website. The features of this board are described in the main features chapter of this document, whereas the remaining paragraphs provide information to enable the customers to copy, modify and qualify the design for production according to their own specific requirements.

Environmental conditions were considered in the design of the EVAL-M3-IM564, but it is not qualified regarding 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 block diagram of the EVAL-M3-IM564 is depicted in Figure 1. This Evaluation board includes an EMI filter and soft power up circuit, 30 pins iMOTION™ MADK-M3 interface connector, auxiliary power supply to provide 15V and 3.3V, PFC gate drive circuit and the CIPOS™ Mini IPM IM564-X6D/IM564-X6DS.

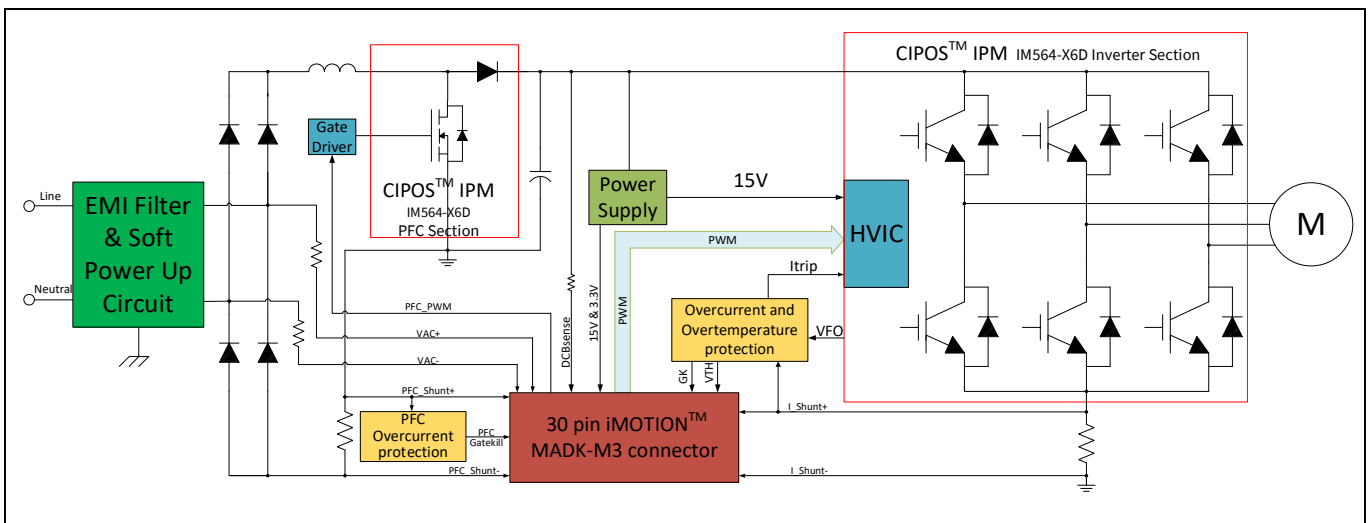


Figure 1 The Block Diagram of the EVAL-M3-IM564

The hardware circuit regarding overtemperature and overcurrent protection is also included in this power board. The sense connection to common emitter shunt resistor is connected to the 30 pins iMOTION™ MADK-M3 interface connector. This power board is compatible with PFC integrated CIPOS™ Mini IPMs that feature 3 phase common emitter and built-in NTC considering motor power rating and IPM's current rating.

Introduction

Evaluation 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 are intended to be used under laboratory conditions by technical specialists only.

3 EVAL-M3-IM564 main features

EVAL-M3-IM564 is an Evaluation board for motor drive applications with single phase PFC integrated 3 phase IPM. Combined in a kit with one of the available MADK control board options, it demonstrates Infineon's motion control IC and IPM technology for motor drives with single phase PFC.

Main features of CIPOS™ Mini IPM IM564-X6D/IM564-X6DS are:

- 3 half bridges with TRENCHSTOP™ 20 A/600 V and antiparallel diodes for inverter section
- 20 A/600 V CoolMOS™ Power MOSFET and rapid switching emitter controlled diode for PFC section
- Lead-free terminal plating; RoHS compliant
- Very low thermal resistance due to DCB
- Rugged SOI gate driver technology with stability against transient and negative voltage
- Negative potential allowed up to $V_S = -11$ V for single transmission at $V_{BS} = 15$ V
- Integrated bootstrap functionality
- Overcurrent shutdown
- Temperature monitor
- Undervoltage lockout at all channels
- Low side common emitter
- Cross conduction prevention
- All six switches turn off during protection

The Evaluation board characteristics are:

- Input voltage 160~265 VAC
- Maximum 2800 W motor power output
- Power Factor Correction
- On board EMI filter
- Current sensing with single shunt
- Auxiliary power supply with 15 V, 3.3 V
- Overcurrent protection
- Overtemperature hardware protection
- Sensing of DC-link voltage
- Thermistor output
- Fault diagnostic output
- Measurement test-points compatible to standard oscilloscope probes
- PCB is 148 mm × 165 mm and has two layers with 35µm copper each
- RoHS compliant

EVAL-M3-IM564 main features

3.1 EVAL-M3- IM564 board specifications

Table 2 depicts the important specifications of the Evaluation board EVAL-M3-IM564.

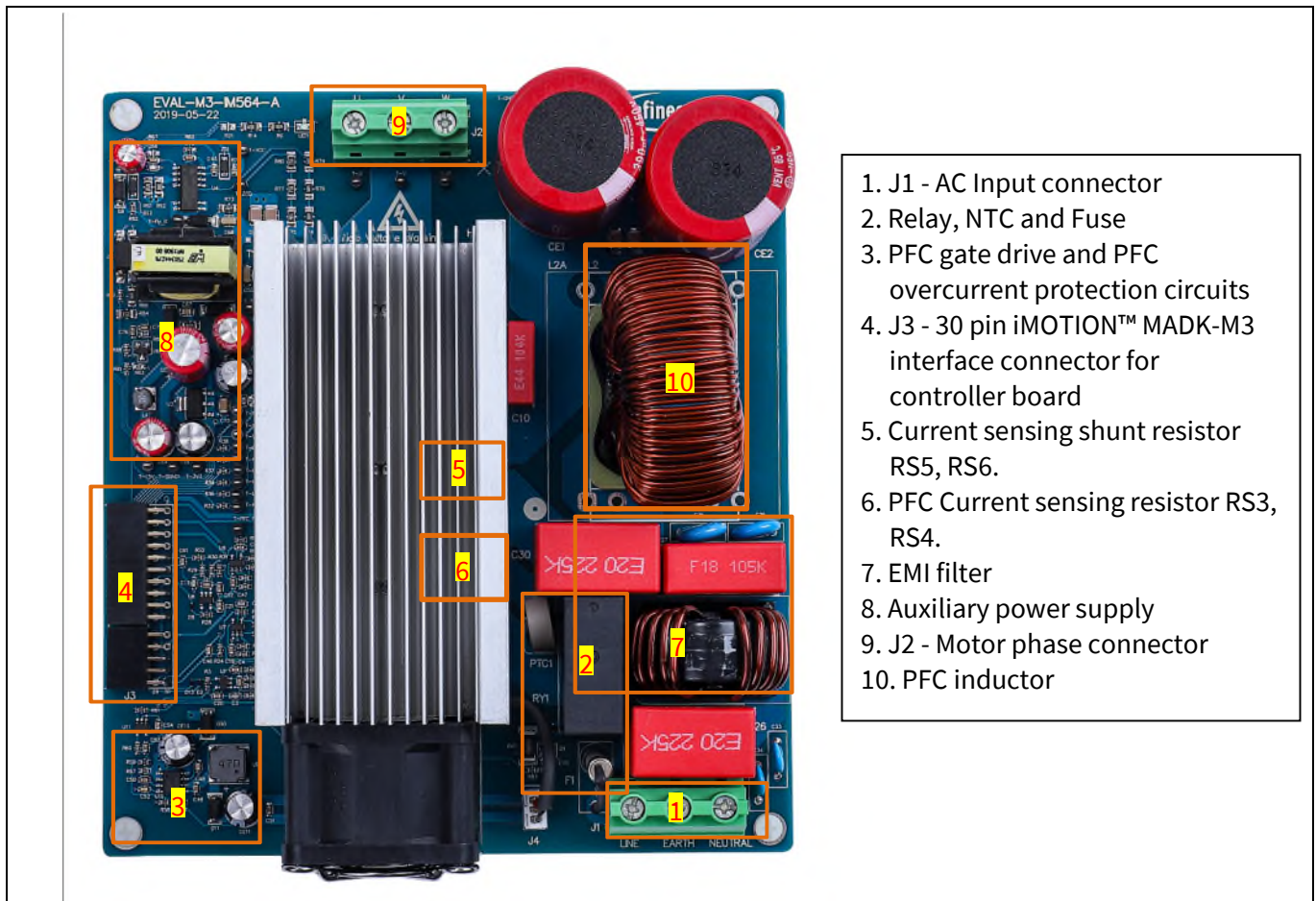
Table 2 EVAL-M3-IM564 board specifications

| Parameters | Values | Conditions / comments |
|---|---|--|
| Input | | |
| Voltage | 165 - 265 V _{rms} | lower AC input, less motor power output |
| Input current | 9.6 A _{rms} | input 220 V _{AC} , T _a =25°C, IM564-X6D/IM564-X6DS |
| Output | | |
| Power (3phases) | 2000 W | input 220V _{AC} , f _{PWM} = 8 kHz, T _a =25°C, T _h =80°C |
| Current per leg | 7.8 A _{rms} | input 220V _{AC} , f _{PWM} = 8 kHz, T _a =25°C, T _h =80°C |
| DC Bus Voltage | | |
| Maximum DC bus voltage | 420 V | |
| Minimum DC bus voltage | 120 V | |
| Switching Frequency | | |
| PFC switching frequency f _{PFC} | 50 kHz (max) | Limited by controller board EVAL-M3-102T |
| Inverter switching frequency f _{PWM} | 20 kHz (max) | |
| Current feedback | | |
| PFC current sensing resistor | 5 mΩ | RS3 is fit, RS4 is for optional. |
| Inverter current sensing resistor | 5 mΩ | RS6 is fit, RS5 is for optional. |
| Protections | | |
| PFC Gatekill protection level | 36.67 A _{peak} | Configured by either PFC current sensing resistor RS3/RS4, or adapting comparator threshold divider resistor R4. |
| Output current trip level | ¹ 25 A _{peak} | Configured by changing shunt resistor RS5/RS6, ITRIP positive going threshold is about 470mV. Or comparator R30/R31. |
| Temperature trip level | 100 °C | For controller board EVAL-M3-102T |
| On board power supply | | |
| 15 V | 15 V ± 5 %, max. 1A | Used for CIPOS™ IPM gate driver & cooling fan |
| 3.3 V | 3.3 V ± 2 %, max. 20 mA | Supplying the 3.3V to the controller board and protection circuits |
| PCB characteristics | | |
| Material | FR4, 1.6mm thickness, 2 layers. 35 μm copper thickness | |
| Dimension | 148 mm × 165 mm | |
| System environment | | |
| Ambient temperature | From 0 to 50°C | Non-condensing, maximum RH of 95 % |

¹ For iMOTION™ IC IMC1xx, there are three types of Gatekill Input Source (Refer to section 5.2.3 or control board user manual for detail). Please note that, if select comparator for Gatekill Input Source, the external Gatekill signal will be not used. And the signal I_Shunt will be compared by the internal comparator with the “Gatekill Comparator Reference” value set in MCEWizard only.

EVAL-M3-IM564 main features

Figure 2 points out the functional groups on the top side of the EVAL-M3-IM564 Evaluation board.



- 1. J1 - AC Input connector
- 2. Relay, NTC and Fuse
- 3. PFC gate drive and PFC overcurrent protection circuits
- 4. J3 - 30 pin iMOTION™ MADK-M3 interface connector for controller board
- 5. Current sensing shunt resistor RS5, RS6.
- 6. PFC Current sensing resistor RS3, RS4.
- 7. EMI filter
- 8. Auxiliary power supply
- 9. J2 - Motor phase connector
- 10. PFC inductor

Figure 2 Functional groups of the EVAL-M3-IM564 Evaluation board's top side

Figure 3 points out the functional groups on the bottom side of the EVAL-M3-IM564 Evaluation board.

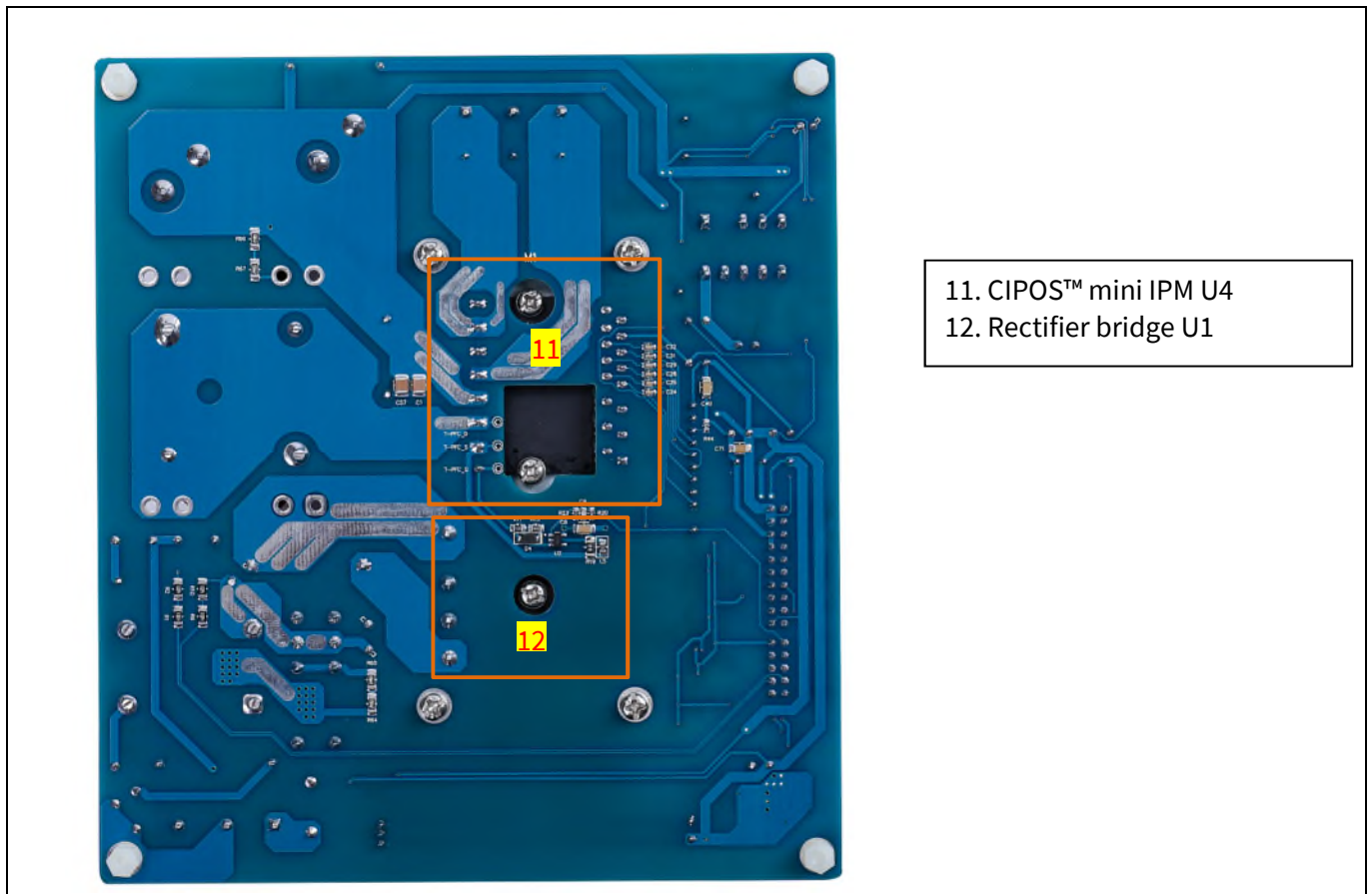


Figure 3 Functional groups of the EVAL-M3-IM564 Evaluation board's bottom side

3.2 Pin assignment

General information about the connectors of the EVAL-M3-IM564 Evaluation board is reported. Table 3 includes the details of the AC input connector J1.

Table 3 J1- AC Line connector

| S. No. | Pin | Details |
|--------|---------|------------------|
| 1 | Line | AC line input |
| 2 | Earth | Earth ground |
| 3 | Neutral | AC neutral input |

Table 4 provides the details of the motor side connector J2.

Table 4 J2- Motor side connector

| S. No. | Pin | Details |
|--------|-----|----------------------------|
| 1 | W | Connected to motor phase W |
| 2 | V | Connected to motor phase V |
| 3 | U | Connected to motor phase U |

EVAL-M3-IM564 main features

Table 5 provides the pin assignments of the 30 pins iMOTION™ MADK-M3 interface connector J3. This connector is the interface to the controller board.

Table 5 J3 - iMOTION™ MADK-M3 30 pin interface connector for controller board

| Pin | Name | Pin Name Connectors |
|-----|----------|---|
| 1 | PWMUH | 3.3 V compatible logic input for high side gate driver-Phase U |
| 2 | GND | Ground |
| 3 | PWMUL | 3.3 V compatible logic input for low side gate driver-Phase U |
| 4 | GND | 4 GND Ground |
| 5 | PWMVH | 3.3 V compatible logic input for high side gate driver-Phase V |
| 6 | +3.3V | On board 3.3 V supply |
| 7 | PWMVL | 3.3 V compatible logic input for low side gate driver-Phase V |
| 8 | +3.3V | On board 3.3 V supply |
| 9 | PWMWH | 3.3 V compatible logic input for high side gate driver-Phase W |
| 10 | I_U | Positive Current sense output |
| 11 | PWMWL | 3.3 V compatible logic input for low side gate driver-Phase W |
| 12 | I_U- | Negative current sense output or Ground |
| 13 | GK | Gate kill signal – active low when overcurrent is detected |
| 14 | DCBSense | DC bus positive voltage, scaled in 0-3.3 V range by a voltage divider |
| 15 | VTH | Thermistor Output |
| 16 | I_V | Not used |
| 17 | I_V- | Not used |
| 18 | I_W | Not used |
| 19 | I_W- | Not used |
| 20 | VCC | 15 V Power Supply |
| 21 | PFCG0 | 3.3 V compatible logic input for PFC gate driver IC |
| 22 | GND | Ground |
| 23 | PFCG1 | Not used |
| 24 | +3.3V | On board 3.3 V supply |
| 25 | PFCGK | PFC Gate kill signal – active low when PFC overcurrent is detected |
| 26 | DCBSense | DC bus positive voltage, scaled in 0-3.3 V range by a voltage divider |
| 27 | VAC+ | AC voltage sensing positive cycle |
| 28 | VAC- | AC voltage sensing negative cycle |
| 29 | IPFC+ | PFC current sensing positive |
| 30 | IPFC- | PFC current sensing negative |

4 Getting Started with EVAL-M3-IM564

In order to run the motor system, a combination of the iMOTION™ MADK power board (EVAL-M3-IM564) and the matching MADK control board is required. The iMOTION™ Software Tools MCEDesigner and MCEWizard are also required in order to initially setup the system, as well as to control and fine-tune the system performance to match users exact needs. This chapter provides more details on setting up the system and getting started with iMOTION™ MADK development platform.

4.1 Setting up the system

After downloading and installing the iMOTION™ PC Tools (MCEWizard and MCEDesigner), following steps needs to be executed in order to run the motor. Refer to user manual for iMOTION™ MADK control board such as (EVAL-M3-102T), MCEWizard and MCEDesigner documentation for more information.

Figure 4 shows the system connection using EVAL-M3-IM564 and control board (used control board EVAL-M3-102T for example).

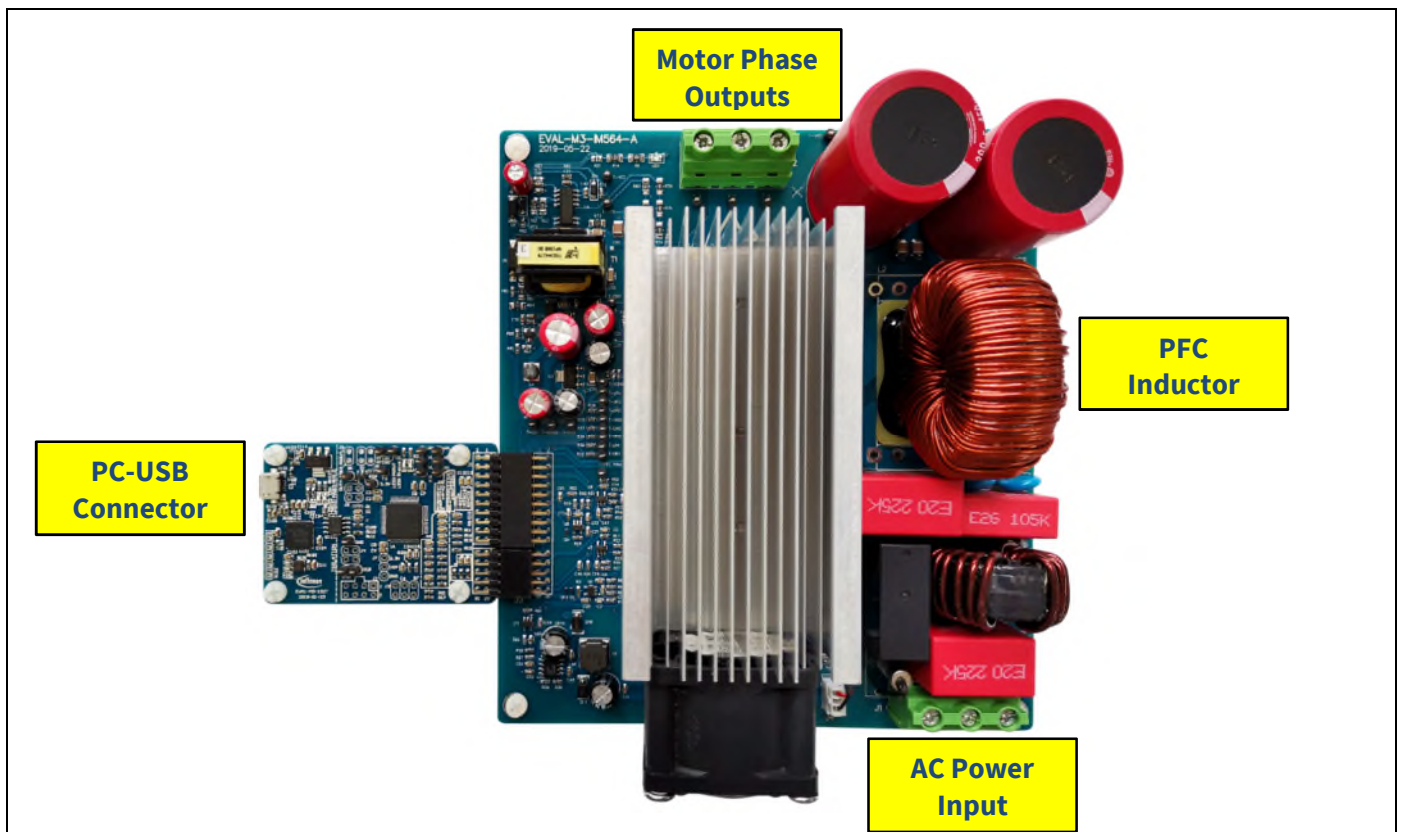


Figure 4 **System connection example using EVAL-M3-IM564**

1. Connect PC-USB connector on the on-board-debugger to the PC via USB cable.
2. Connect EVAL-M3-IM564's MADK M3 30-pin interface connector (J3) to control board (see Figure 4).
3. Get the latest "IMC102T-F064 MCE Software Package" available on www.infineon.com/imotion-software web page. (Infineon iMOTION™ control IC IMC102T-F064 is used for control board EVAL-M3-102T).
4. Connect motor phase outputs to the motor.
5. Use MCEWizard to enter the motor and Evaluation board hardware parameters and click button "Export to Designer file (.txt)" to system drive parameters file which will be used by MCEDesigner.
6. Connect AC power to power input connector (J1) and power on system.

Getting Started with EVAL-M3-IM564

7. Open MCEDesigner and open MCEDesigner default configuration file (.irc) for IMC102T devices (IMC102T_xx.irc) by clicking “File” menu and select “Open” in the pull down list.
8. Import system drive parameters file (generated in step 5) into MCEDesigner by clicking “File” > “Import Drive Parameters”. Select “Update All” radio button.
9. Program the MCE Firmware and system parameters into the internal Flash memory of iMOTION™ IC by clicking “Tools > Programmer” in the pull down menu, and then clicking on the “Program Firmware and Parameter” radio button. See chapter MCEDesigner setup overview section 4.2.2 for more details. If the latest version of MCE firmware is already programmed into the IMC102T-F064 IC, then programming firmware can be skipped by selecting “Program Parameters” radio button option. Finally click “Start” button to program firmware and parameter (or parameters only when programming firmware was skipped).
10. Start the motor by clicking the green traffic light button in the control bar.

4.2 iMOTION™ development tools and software

The iMOTION™ Development Tool installers for MCEDesigner and MCEWizard are available for download via Infineon iMOTION™ website (<http://www.infineon.com/imotion-software>). All the available tools and software variants are listed there.

On-board debugger uses the SEGGER J-Link’s driver for UART communication with IMC102T-F064. J-Link driver will be installed during the MCEDesigner installation. In case the driver is not installed properly, please go to [SEGGER J-Link website](#) to download and install the latest J-Link “Software and Documentation pack for Windows”.

4.2.1 MCEWizard setup overview

After installing the MCEWizard, the shortcut for MCEWizard appears on the Windows desktop. Double click the shortcut to open the MCEWizard and configure the parameters for Evaluation boards or motor. Figure 6 shows the “Welcome Page” for MCEWizard, where the MADK control board or power board can be selected through the pull-down list. Infineon keeps releasing new MADK controller and power boards. Therefore, it could happen that some of the newest power boards are not pre-configured in the MCEWizard tool and cannot be selected through the pull-down menu. In that case, the user should select any other power board (as similar as possible) and follow the MCEWizard setup steps by entering the parameter values which are specific to the chosen board. Make sure both “I have modified the circuit board” and “Enable advanced question” checkmarks are selected. Please refer to the User Manual of the corresponding power board for additional information.

After selecting the MADK control and the power board, start the MCEWizard system setup procedure by clicking the “Next” button in the right bottom corner as shown in Figure 6.

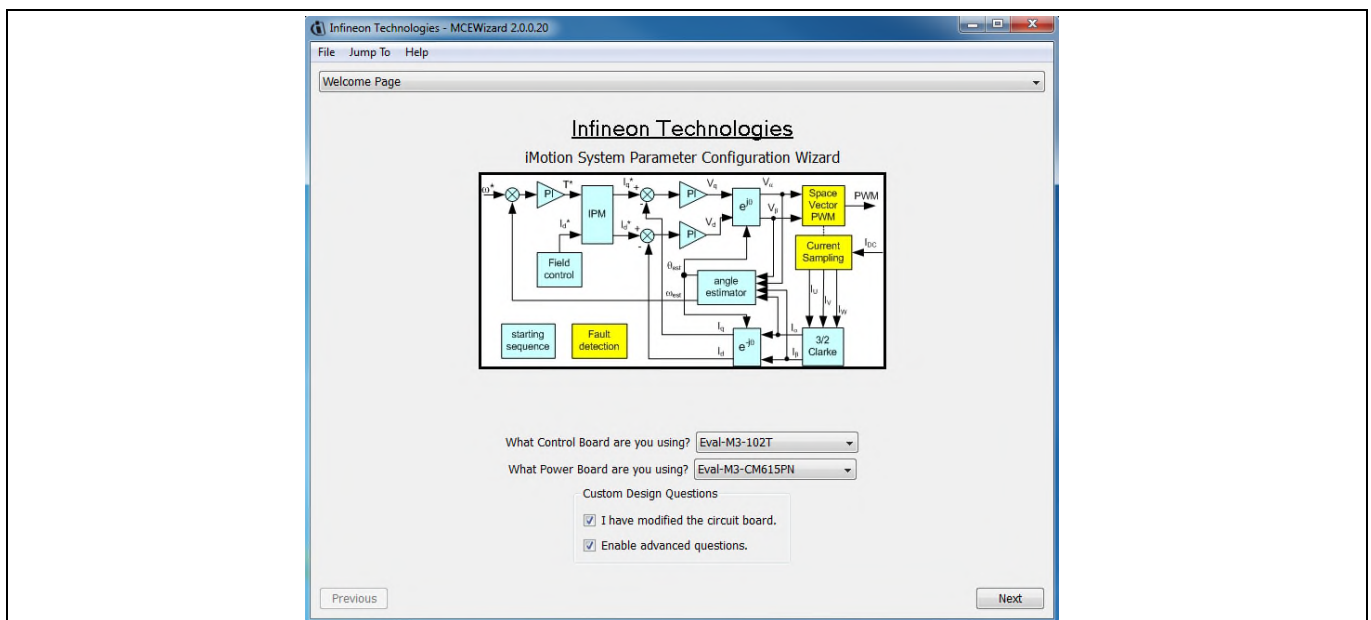


Figure 5 Welcome Page of MCEWizard

iMOTION™ MADK system enables users to easily test different combination of control and power board with their motors. User should be familiar with the system level parameters which are related to the motor used. There are very limited numbers of parameters which are specific to the control board or power board hardware. Table 6 provides the MCEWizard setup overview for hardware related parameters. Similar tables will be available in each control board’s User Manual. Combination of this table and the corresponding table of the control board provides enough information to setup the MADK-based motor drive system in shortest time.

Table 6 MCEWizard setup overview table

| Page | Parameter | Value | Comment |
|--------------|------------------------------------|------------------------------------|---|
| Welcome Page | Power Board selecting | MADK power board name | If no, select similar power board to modify |
| Options Page | Motor 1 Shunt Configuration | Single Shunt | |
| Question 5 | Controller Supply Voltage | Refer to control board user manual | |
| Question 21 | Max DC Bus Voltage | 420V | |
| Question 25 | DC Bus Sensing High Resistor | 2000KΩ | |
| Question 26 | DC Bus Sensing Low Resistor | Refer to control board user manual | 13.3kΩ by default |
| Question 56 | NTC Temperature Shutdown value | Calculated as the Section 5.3.3 | Refer to the control board user manual |
| Question 65 | GateSense Low-Side Devices | High is true | |
| Question 66 | GateSense High-Side Devices | High is true | |
| Question 71 | Motor 1 Current Input | Calculated as the Section 5.2.2 | |
| Question 79 | PFC Topology | Boost PFC | |
| Question 81 | PFC Current Input | Calculated as the Section 5.1.2 | |
| Question 86 | AC Voltage Sensing High Resistor | 2000kΩ | |
| Question 87 | AC Voltage Sensing low Resistor | Refer to control board user manual | 15kΩ by default for EVAL-M3-102T |
| Question 88 | PFC Gate Driver Polarity High Side | High is active | no high side, just compatibility |
| Question 89 | PFC Gate Driver Polarity Low Side | High is active | |

After all the MCEWizard questions are answered, the “Verify & Save Page” will be shown as in Figure 6

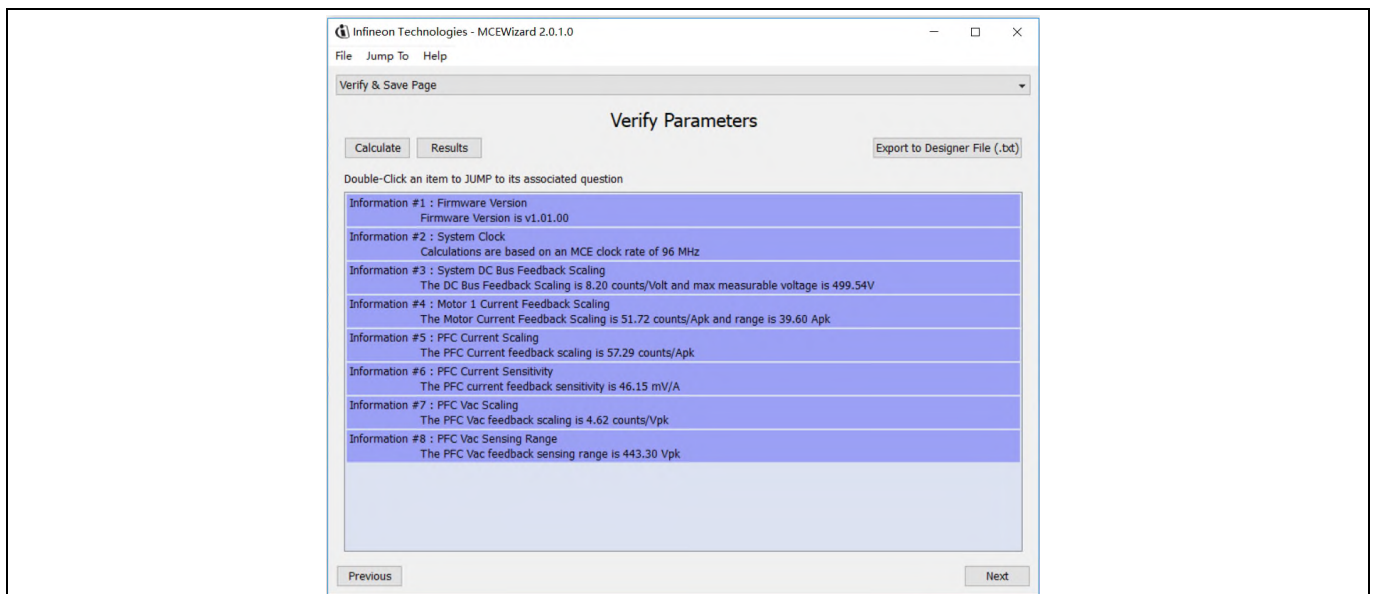


Figure 6 Verify and Save page for MCEWizard

Getting Started with EVAL-M3-IM564

Click “Calculate” button and “Export to Designer File (.txt)” button to save the parameter file which will be used by the MCEDesigner in the next steps.

4.2.2 MCEDesigner setup overview

After installing MCEDesigner installer, there is a shortcut for MCEDesigner on Windows desktop. Double click the shortcut to open MCEDesigner and then open “IMC102T_xx.irc” file as shown in Table 6.

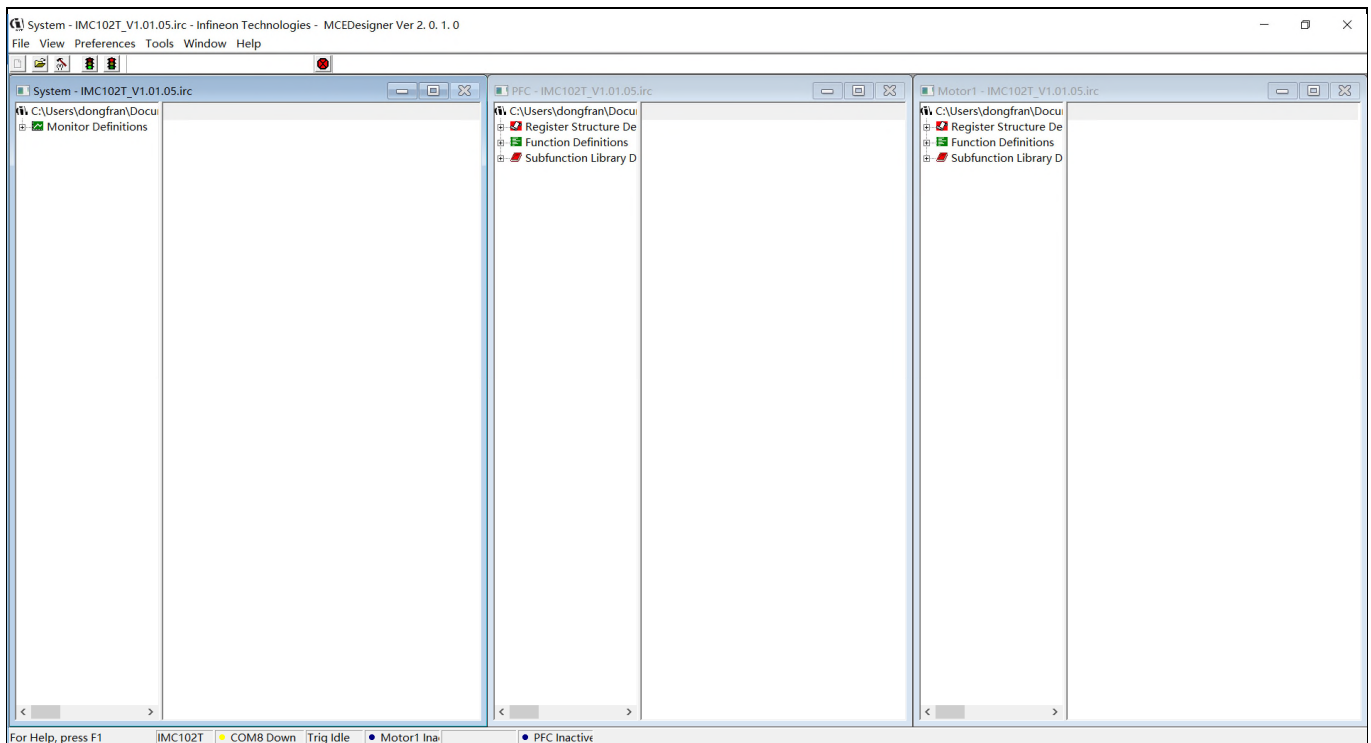


Figure 7 MCEDesigner’s Main Display for EVAL-M3-102T

To program system drive parameters into IMC102T-F064, please click “Tools” menu and select “Programmer” in the pull down list. The pop-up window “Program IMC controller” will show up as in Figure 8. Click on the “Program Parameters” radio button (this is the default option), and then select the Drive System Parameter file created using MCEWizard by clicking on “Browse”. Finally, click on the “Start” button to program the parameter file into the IMC102T-F064 IC.

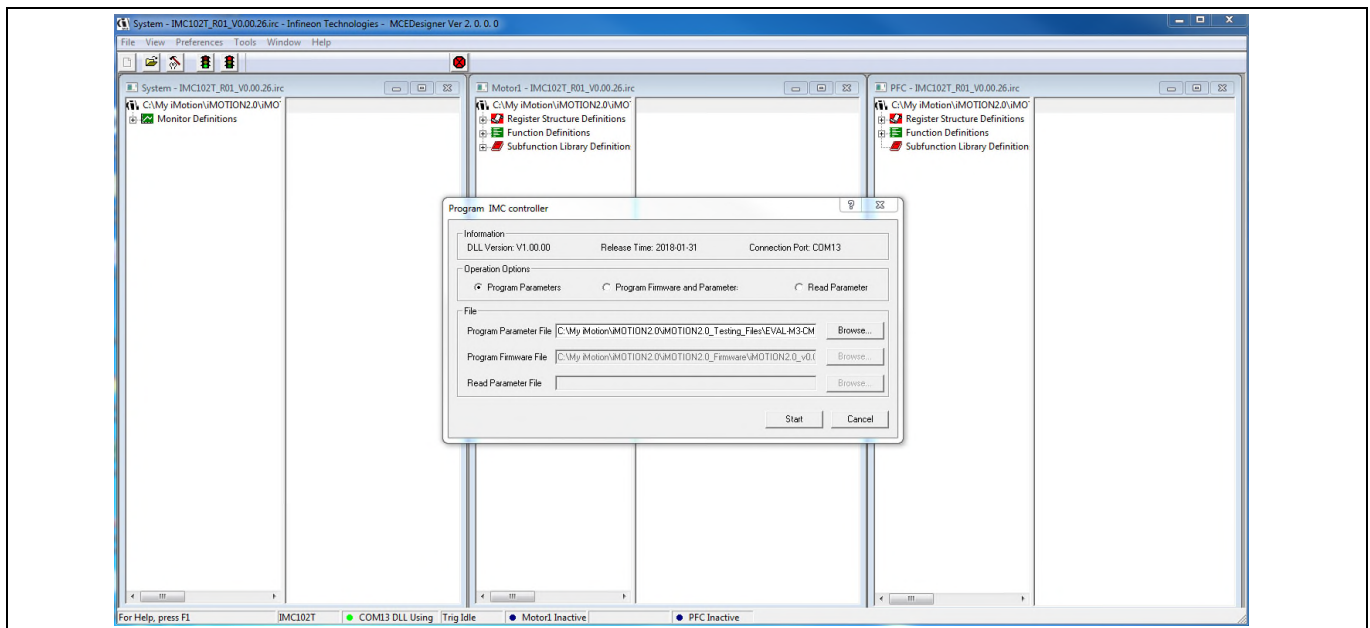


Figure 8 “Program IMC Controller” pop-up window

After Drive System Parameter file has been programmed into IMC102 controller, and the motor drive system is powered, the MCEDesigner can be used to start/stop the motor, display motor current traces, change the motor speeds, modify drive parameters and many other functions. Please refer to the MCEDesigner documentation for more details.

Note: On-board Debugger portion of EVAL-M3-102T is galvanically isolated from the controller portion and the attached power board. In order to program the parameters or firmware to the IMC102T-F064 controller, the 3.3V DC voltage needs to be supplied to the controller portion of the EVAL-M3-102T. This voltage can either be supplied by the power board (MADK power boards are designed to supply the 3.3V to the control board through M3 connector) or by feeding the 3.3V DC voltage to the control board through some of the available 3.3V access/test points if the power board is not attached to the EVAL-M3-102T control board.

To program new firmware and Drive System Parameter into IMC102T-F064, please click “Tools” menu and select “Programmer” in the pull down list. The pop-up window “Program IMC controller” will show up as in Figure 9. Click on the “Program Firmware and Parameter” radio button, and select the Drive System Parameter file created using MCEWizard by clicking on the “Browse” button on the row of “Program Parameter File”, and then select the firmware file by clicking on the “Browse” button on the row of “Program Firmware File”. Finally, click on the “Start” button to program the parameter file into the IMC102T-F064 IC.

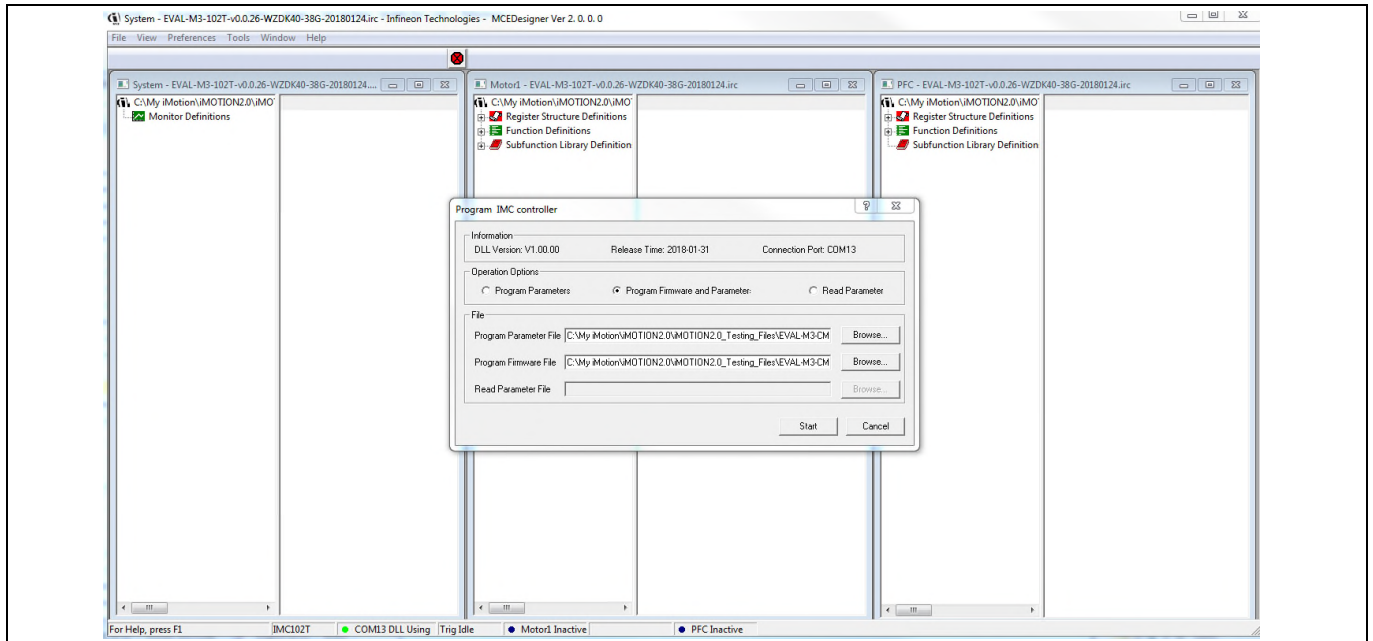


Figure 9 Program Firmware and Parameter in “Program IMC Controller” pop-up window

All latest firmware file for different type of iMOTION™ control ICs are available for download via Infineon iMOTION™ website (<http://www.infineon.com/imotion-software>).

5 Hardware description of EVAL-M3-IM564

To meet individual customer requirements and make the EVAL-M3-IM564 Evaluation board a basis for development or modification, all necessary technical data like schematics, layout and components are included in this chapter.

5.1 Boost PFC section using CIPOS™ mini IPM

Figure 10 depicts the schematic from the AC input connector J1 to the rectified DC bus voltage DCBUS. This circuitry includes a passive EMI filter consisting of elements X2, Y2 capacitors and common mode inductor, a 25 A/1200 V rectifier bridge D1, a fuse F1 for circuit protection, a PTC resistor PTC1 and a relay RY1 for soft powering up and reducing conduction losses in steady state. The PFC section is implemented using the CIPOS™ mini IPM as sketched in Figure 10. The IRS44273L is used to drive MOSFET for PFC section.

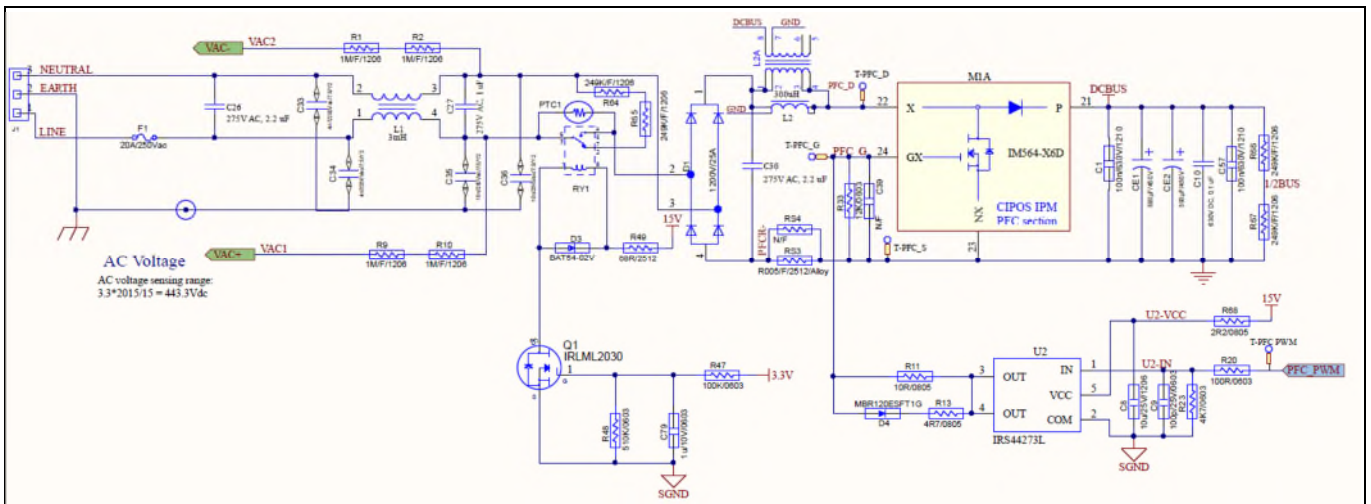


Figure 10 Schematic for EMI filter and PFC section of the EVAL-M3-IM564 Evaluation board

The PFC section of CIPOS™ IPM IM564-X6D/IM564-X6DS contains a CoolMOS™ power MOSFET and a rapid switching emitter controlled diode. Two electrolytic capacitors CE1 and CE2 are used for buffering the rectified DC bus voltage DCBUS.

5.1.1 AC Voltage sensing and MCEWizard configuration

AC voltage sensing is in the front of rectifier bridge D1 by default as shown in Figure 10. To drive the boost PFC circuitry for EVAL-M3-IM564, the default matching MADK control board is EVAL-M3-102T. Figure 11 shows the VAC sensing schematic of EVAL-M3-102T Evaluation board.

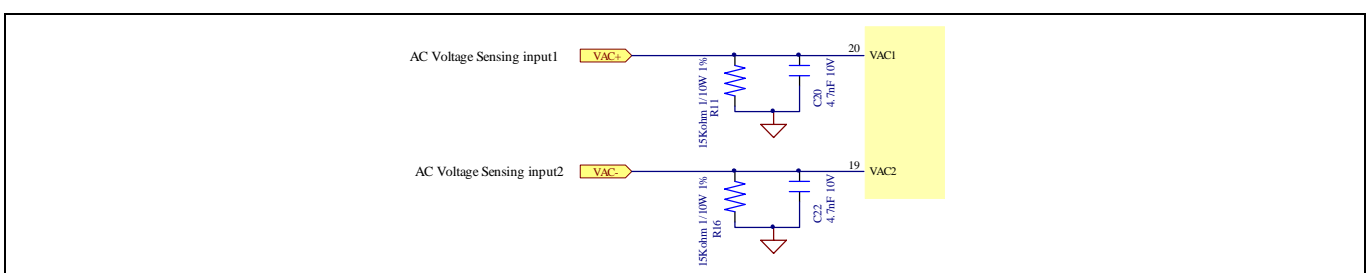


Figure 11 The AC Voltage sensing schematic of EVAL-M3-102T

There are two AC voltage sensing modes in MCEWizard, differential mode and single-ended as shown in Figure 12. Please select differential mode for the combination between EVAL-M3-IM564 and EVAL-M3-102T.

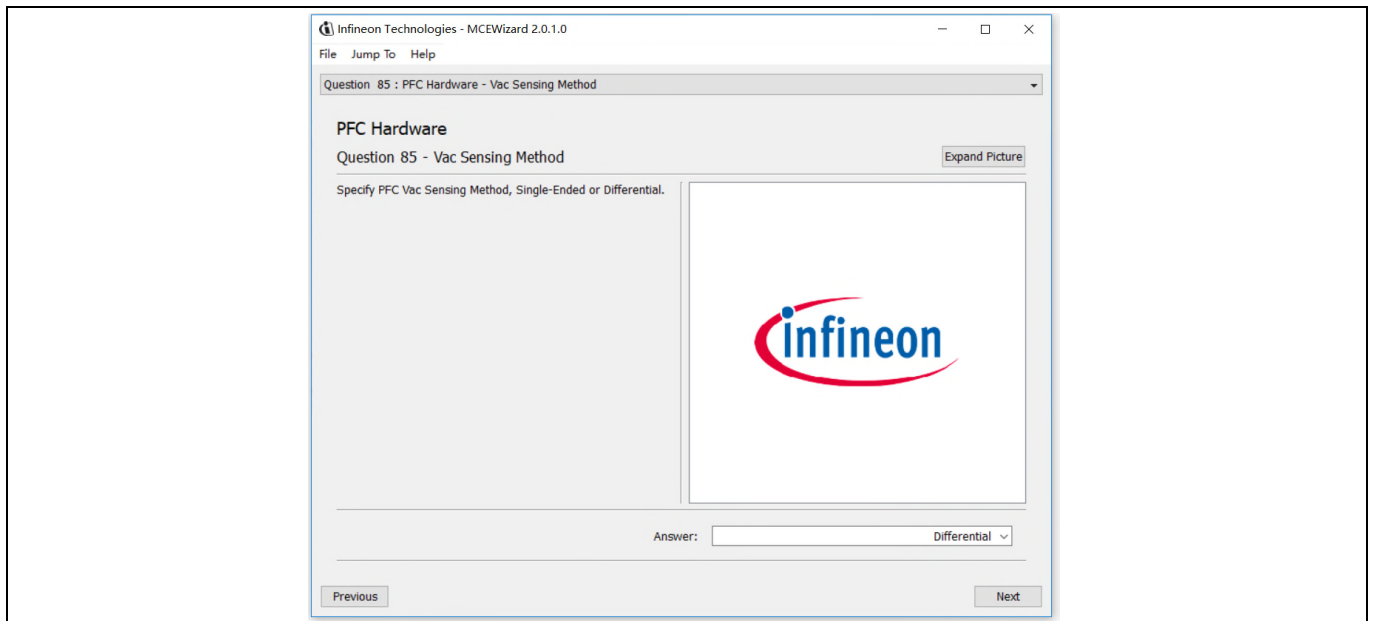


Figure 12 Vac Sensing Method configuration for EVAL-M3-102T and EVAL-M3-IM564

The high side resistors R1 and R2 or R9 and R10 for the AC voltage sensing resistor divider on the power board EVAL-M3-IM564 is 2000k Ω , and should be configured in MCEWizard as shown in Figure 13. For the low side resistor value, please refer to the User Manual of the corresponding control board.

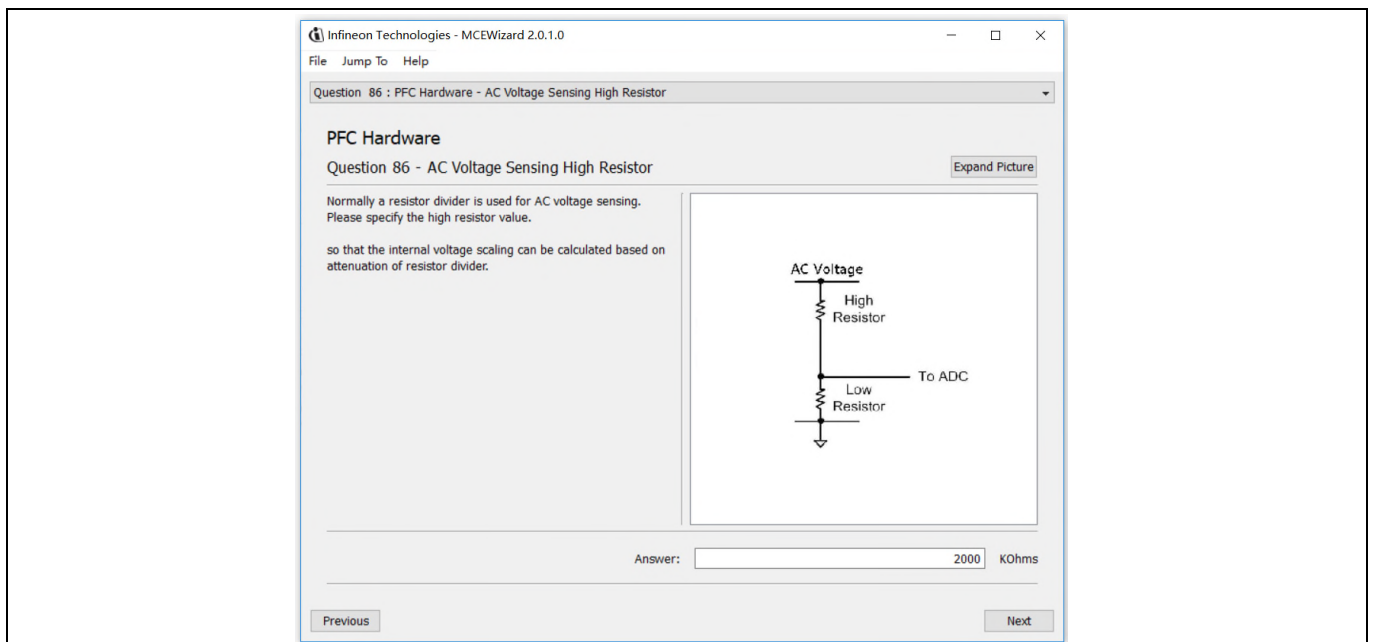


Figure 13 AC Voltage sensing configuration in MCEWizard

5.1.2 Hardware Modification for AC Voltage sensing to work with IRMCF188

As mentioned in the previous section, AC voltage sensing is in the front of rectifier bridge D1 by default for this power board EVAL-M3-IM564 as shown in Figure 10. But for control board EVAL-M3-188 with controller IC

IRMCF188, AC Voltage sensing should be behind the rectifier bridge D1. To work with control board EVAL-M3-188 or IRMCF188, power board EVAL-M3-IM564 should be modified by assembling 1MΩ AC Voltage sensing resistors R2A and R10A and removing the resistors R2 and R10.

5.1.3 PFC External Current feedback configuration and calculation

The PFC shunt resistor RS3 is 5mΩ for EVAL-M3-IM564. But for control board EVAL-M3-102T, the current input value is product of the shunt resistance in milliohms and gain of External current sense amplifier as shown in Figure 14.

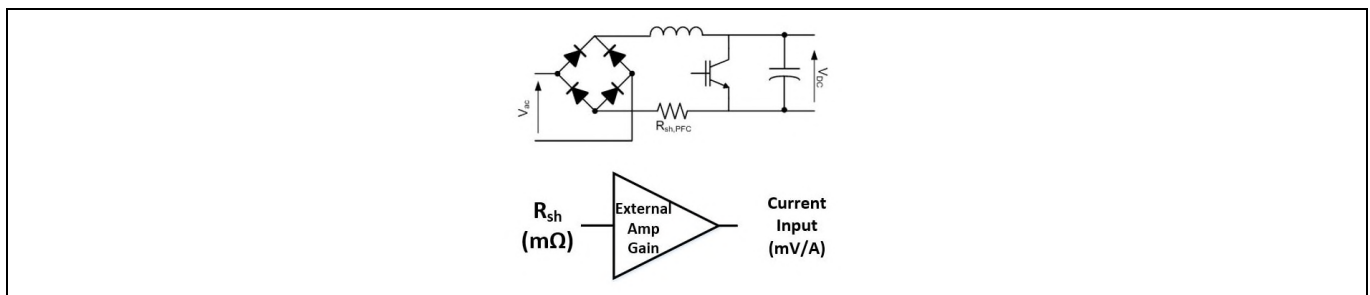


Figure 14 PFC Current shunt feedback and sample timing

Figure 15 depicts IPFC- current feedback sensing circuitry on EVAL-M3-102T Evaluation board. Please note that the default external amplification gain is less than 1 for current sense in this Evaluation board.

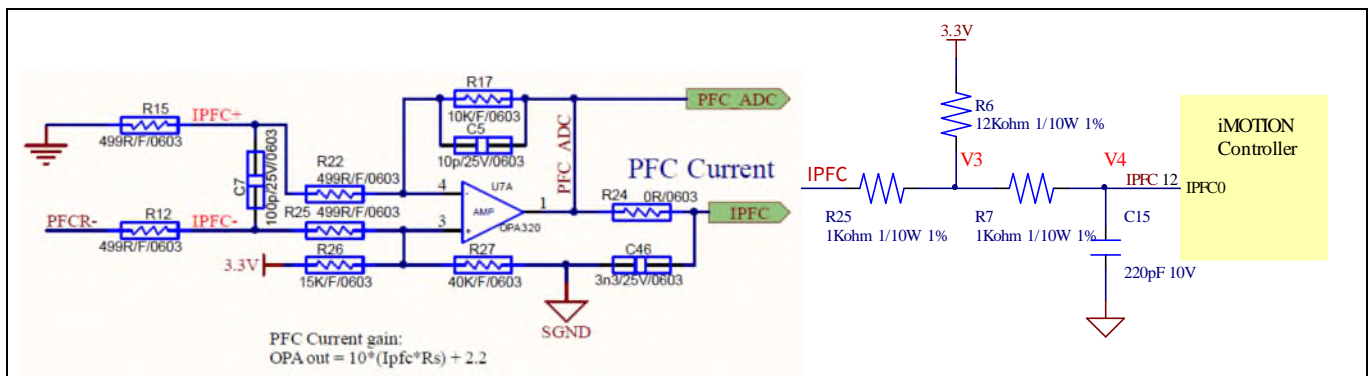


Figure 15 The PFC Current feedback circuit for EVAL-M3-102T Evaluation board

Based on the principle of Kirchoff's voltage law,

$$V_4 \approx V_3 \approx (V_{DD} - V_{IPFC}) * \frac{R_{25}}{R_6 + R_{25}} + V_{IPFC} = \frac{R_{25}}{R_6 + R_{25}} V_{DD} + \frac{R_6}{R_6 + R_{25}} V_{IPFC}$$

$$\text{Current input} = \frac{R_6}{R_6 + R_{25}} V_{IPFC} = \frac{12}{13} V_{IPFC}$$

Based on this calculation, and included the power board amplifier gain as well, the current input for the MADK combination of EVAL-M3-102T and EVAL-M3-IM564 is 46.154 mV/A. Please use same procedure to calculate the current input for other combinations of MADK boards and enter it into MCEWizard.

5.1.4 PFC Overcurrent protection circuit and PFC Gatekill configuration

PFC protection circuit for EVAL-M3-IM564 as shown in Figure 16, but the left side of RS3 is negative. If the bus current I_{bus} is larger than the setting value, the output VFO of U1 will be trigger low and be active.

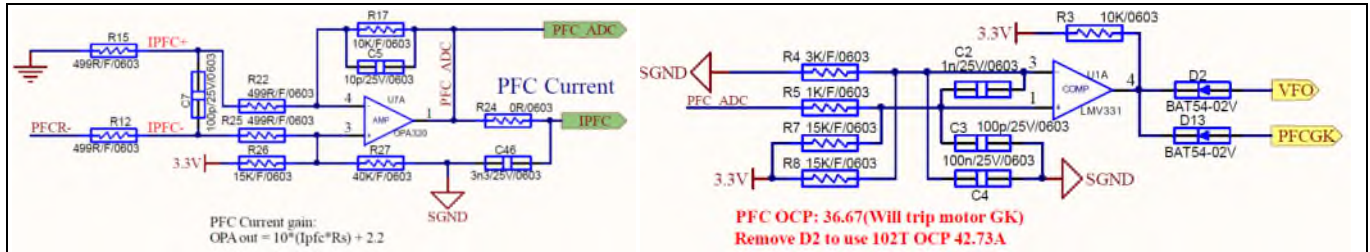


Figure 16 PFC protection Circuit on the EVAL-M3-IM564 Evaluation board

The PFCGK active setting current is 36.67A for EVAL-M3-IM564 Evaluation board. And the calculation formula is as follows,

$$I_{PFCGK} = \frac{V_{IPFC} - V_{os}}{\frac{R_{17}}{R_{15} + R_{22}} R_s}$$

Where,

$$V_{IPFC} = V_{comp+} - \frac{(V_{DD} - V_{comp+}) * R_5}{R_7}$$

$$V_{comp+} = V_{comp-} = \frac{V_{DD} * R_4}{R_4 + R_8}$$

Please attention that for control board EVAL-M3-102T, it doesn't use the external PFC gatekill signal PFCGK. This MADK board connects the PFCGK to the motor GK temporarily for PFC overcurrent protection when using control board EVAL-M3-102T.

Note: PFC Overcurrent protection circuit just generates the signal of PFCGK, and there is no more action for EVAL-M3-IM564. The power board will not turn off the PFC gate driver IC if the control board doesn't do anything when PFCGK is active.

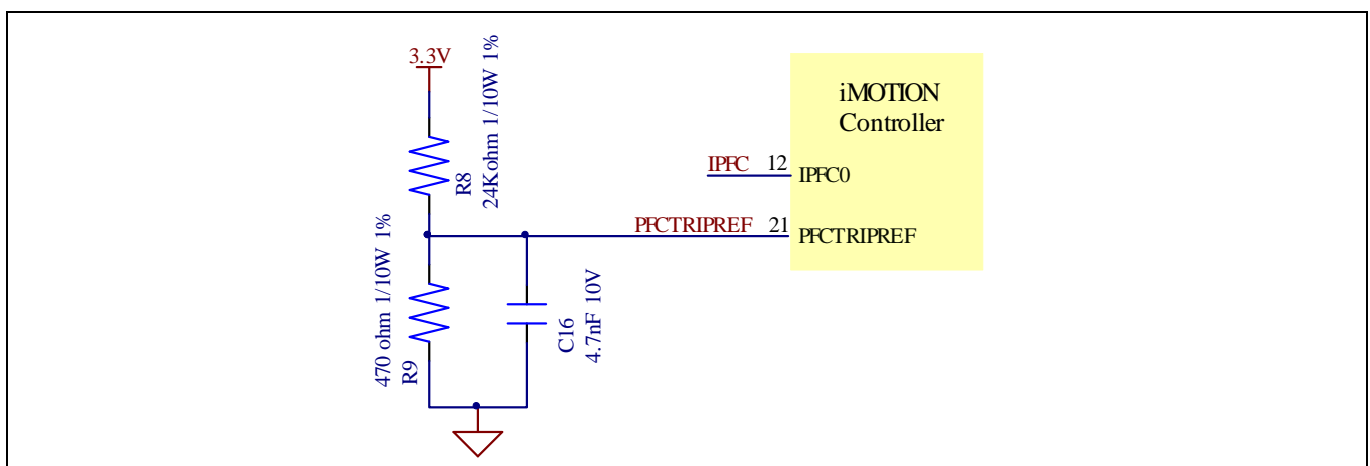


Figure 17 The PFCTRIREF Circuit on the EVAL-M3-102T Evaluation board

The PFC’s overcurrent protection circuit on the control board EVAL-M3-102T is shown in Figure 15 and Figure 17. The $I_{PFCTRIP_Peak}$ equal to 42.73A for the combination between EVAL-M3-102T and EVAL-M3-IM564 only.

The calculation formula is as follows,

$$I_{PFCTRIP_Peak} = \frac{\frac{V_{DD}}{R_8 + R_9} R_9 - V_{Os}}{\frac{R_{17}}{R_{15} + R_{22}} R_s}$$

If larger PFC current protection setting value needed, please use smaller resistance of PFC shunt resistor RS3, or modify the control board EVAL-M3-102T following the previous formula. Please refer to the control board’s user manual for more details.

5.2 Inverter section using CIPOS™ mini IPM

The inverter section is also implemented using the CIPOS™ mini IPM as sketched in Figure 18. The inverter section of IPM module includes an optimized SOI gate driver and a three-phase inverter consisting of TRENCHSTOP™ IGBTs and anti parallel diodes.

The three pairs of capacitors C14 and C15, C16 and C17, C22 and C23 are used as bootstrap capacitors to provide the necessary floating supply voltages V_{BS1} , V_{BS2} and V_{BS3} respectively.

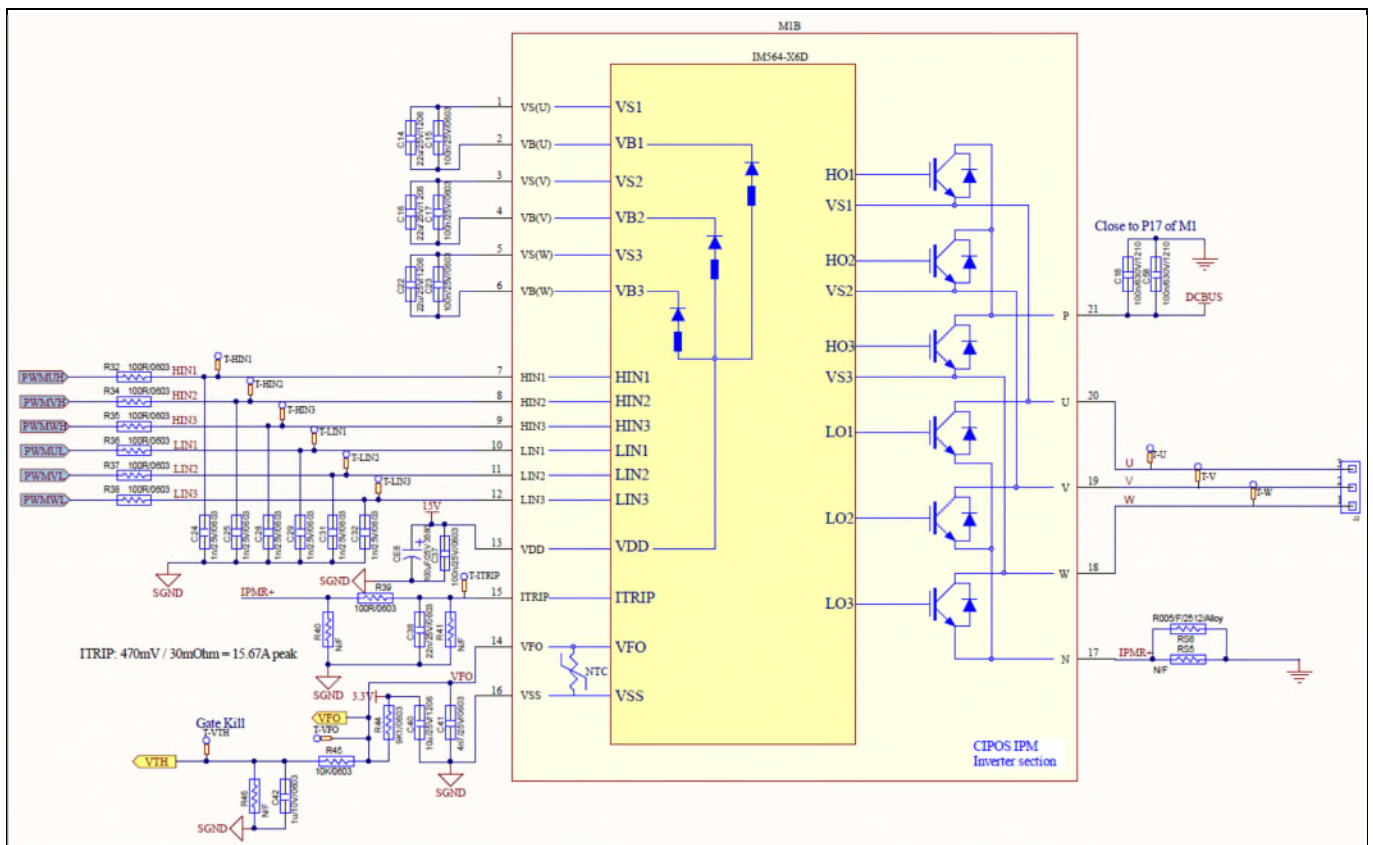


Figure 18 Schematic of the 3-phase inverter section using CIPOS™ mini IPM on EVAL-M3-IM564

5.2.1 DC bus sensing and MCEWizard configuration

Pin 14 and pin 26 of connector J3 provide access to the DC-link voltage DCBSense. Three possible feedback cases are associated with these pins. Figure 19 provides the DC bus sense resistor details. By default, the resistor R21 is not mounted on EVAL-M3-IM564. There must be a pull-down resistor mounted on the corresponding controller board.

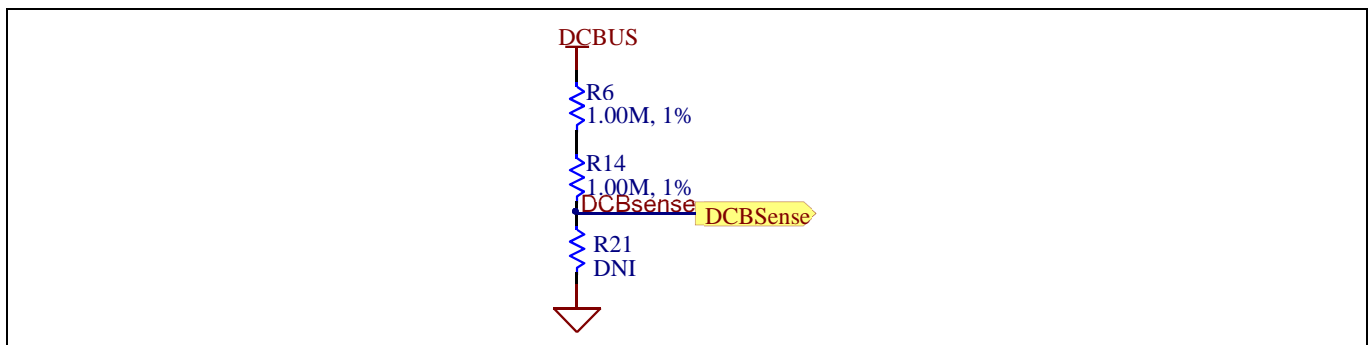


Figure 19 DC bus sense resistor on EVAL-M3-IM564 Evaluation board

If a pull down resistor of 13.3 kΩ referred to ground is inserted either on the EVAL-M3-IM564 Evaluation board or on the control board, the DCBSense voltage results in the range of 0 to 3.3 V on the pin reflecting a DC bus voltage range of 0 to 420 V. If a pull down resistor of 13.3 kΩ is inserted on both, EVAL-M3-IM564 Evaluation board and on the control card, the DCBSense results scale to 0-1.65 V. No safety issue occurs. If no feedback is desired on the DCBSense pin, R6 or R14 should be removed to avoid high voltage on the connector.

The high side resistors R6 and R14 for the DC bus sensing resistor divider on the controller board EVAL-M3-IM564 are 2000kΩ, and should be configured in MCEWizard as shown in Figure 20. For the low side resistor value, please refer to the User Manual of the corresponding control board.

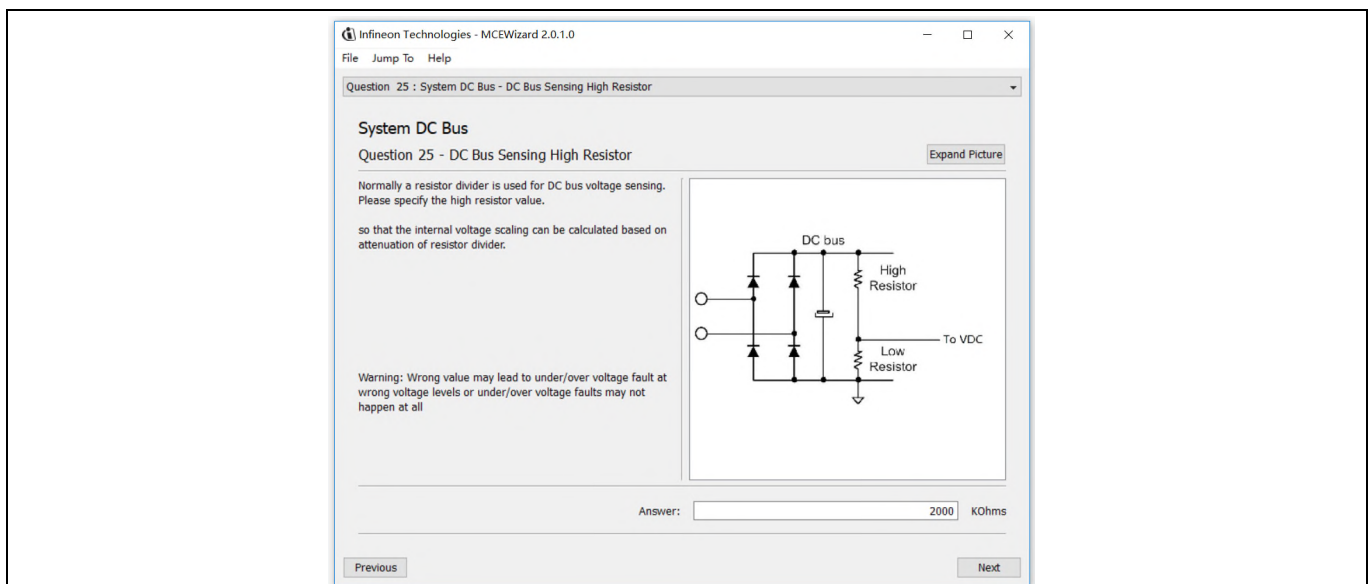


Figure 20 DC bus sensing configuration in MCEWizard

5.2.2 Motor External Current feedback configuration and calculation

The current input value is product of the shunt resistance in milliohms and gain of External current sense amplifier for EVAL-M3-102T as shown in Figure 21.

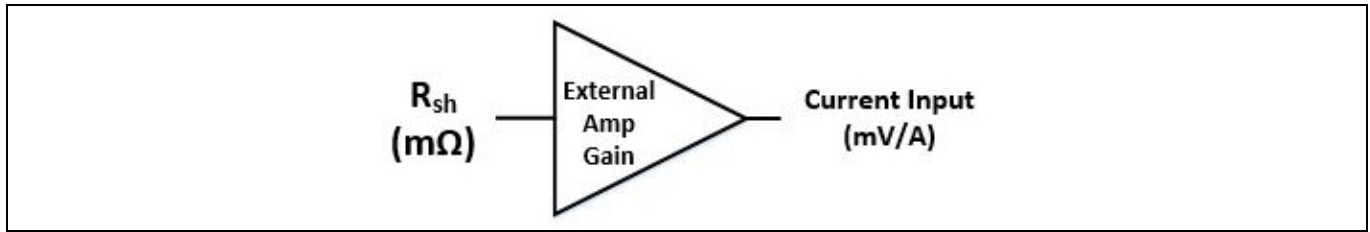


Figure 21 Current shunt feedback and sample timing for EVAL-M3-102T

The External Amplifier Gain circuit can be found in the schematics or User Manual for the control board (For example, EVAL-M3-102T see Figure 22).

Figure 22 depicts IU+ current feedback sensing circuitry on EVAL-M3-102T Evaluation board. Please note that the default external amplification gain is less than 1 for current sense in this Evaluation board.

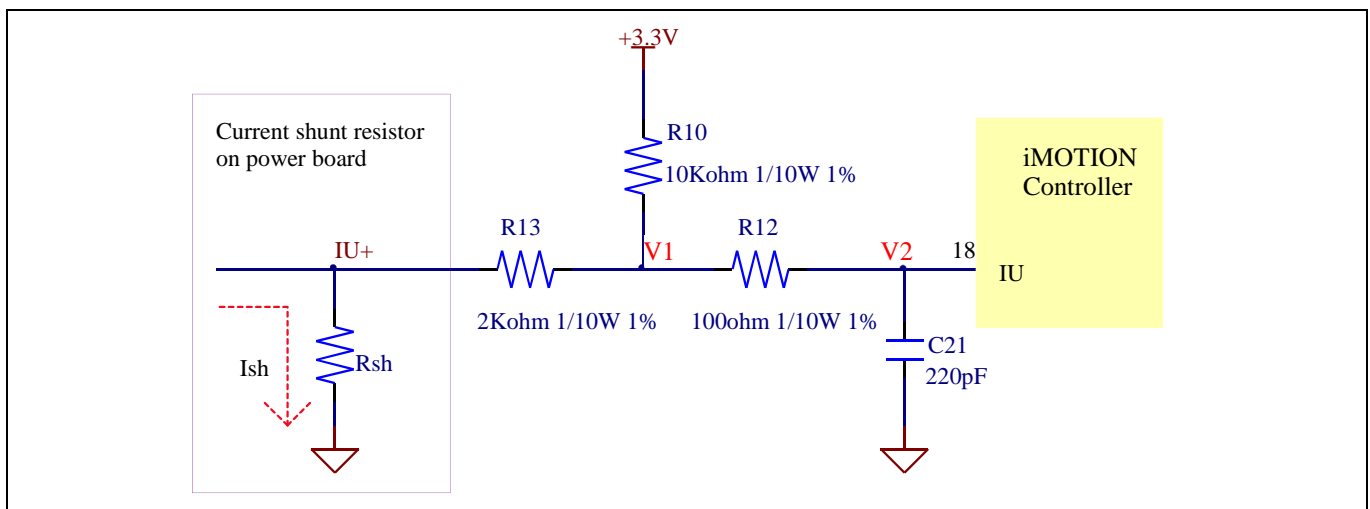


Figure 22 The part of Current feedback on the EVAL-M3-102T Evaluation board

Based on the principle of Kirchhoff's voltage law,

$$V_2 \approx V_1 \approx (V_{DD} - I_{sh} * R_{sh}) * \frac{R_{13}}{R_{10} + R_{13}} + I_{sh} * R_{sh} = \frac{R_{13}}{R_{10} + R_{13}} V_{DD} + \frac{R_{10}}{R_{10} + R_{13}} R_{sh} * I_{sh}$$

$$Current\ input = \frac{R_{10}}{R_{10} + R_{13}} R_{sh} = \frac{5}{6} R_{sh}$$

Based on this calculation, and included the power board amplifier gain as well, the current input for the MADK combination of EVAL-M3-102T and EVAL-M3-IM564 is 41.667 mV/A.

Please use same procedure to calculate the current input for other combinations of MADK boards and enter it into MCEWizard as shown in Figure 23.

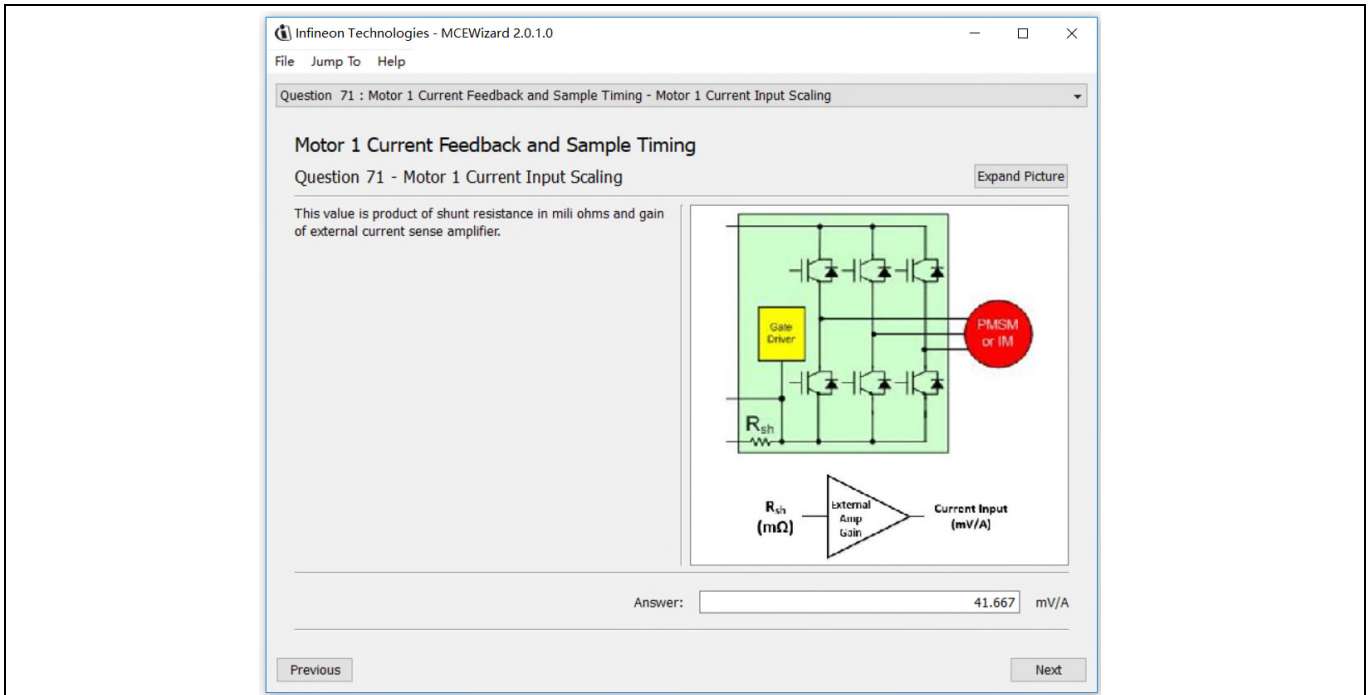


Figure 23 Current feedback configuration in MCEWizard for EVAL-M3-102T and EVAL-M3-IM564

5.2.3 Inverter Overcurrent protection and Motor Gatekill configuration

Figure 24 displays the overcurrent protection circuitry. The current sensing signal I_Shunt is connected to ITRIP via the resistor R39, and ITRIP is filtered through capacitor C38.

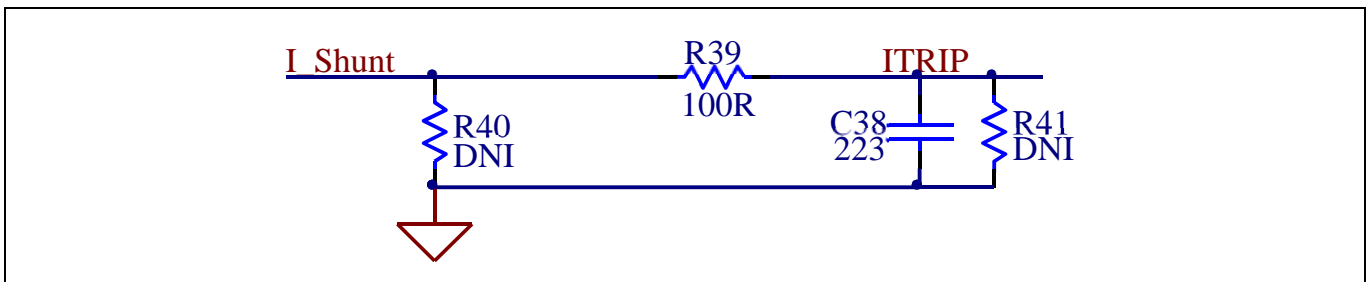


Figure 24 Overcurrent protection circuit on the EVAL-M3-IM564 Evaluation board

The typical value of ITRIP positive going threshold $V_{IT,TH+}$ is 470mV. So the inverter output peak current is calculated by

$$I_{trip} = \frac{V_{IT,TH+}}{R_{shunt}}$$

If the motor peak current larger than the setting value I_{trip} for more than ITRIP Input filter time, VFO will be trigger low which is mean that the signal Gatekill is active. For iMOTION™ IMC1xx control IC, there are three types of Gatekill Input Source (as shown in Figure 25). For Gatekill Input Source configured Gatekill-Pin or Both, iMOTION™ control IC will stop the Motor when the signal GateKill is active.

In order to get high power output for this MADK board, the board uses a very low resistance R_{shunt} with 5 mΩ, the inverter overcurrent protection signal (Gatekill) comes from an external comparator (U8). The ITRIP of IPM doesn't used any more.

But please note that, if select comparator for Gatekill Input Source, the external Gatekill signal will be not used. And the current sensing signal I_Shunt will be compared by the internal comparator with the “Gatekill Comparator Reference” value set in MCEWizard only.

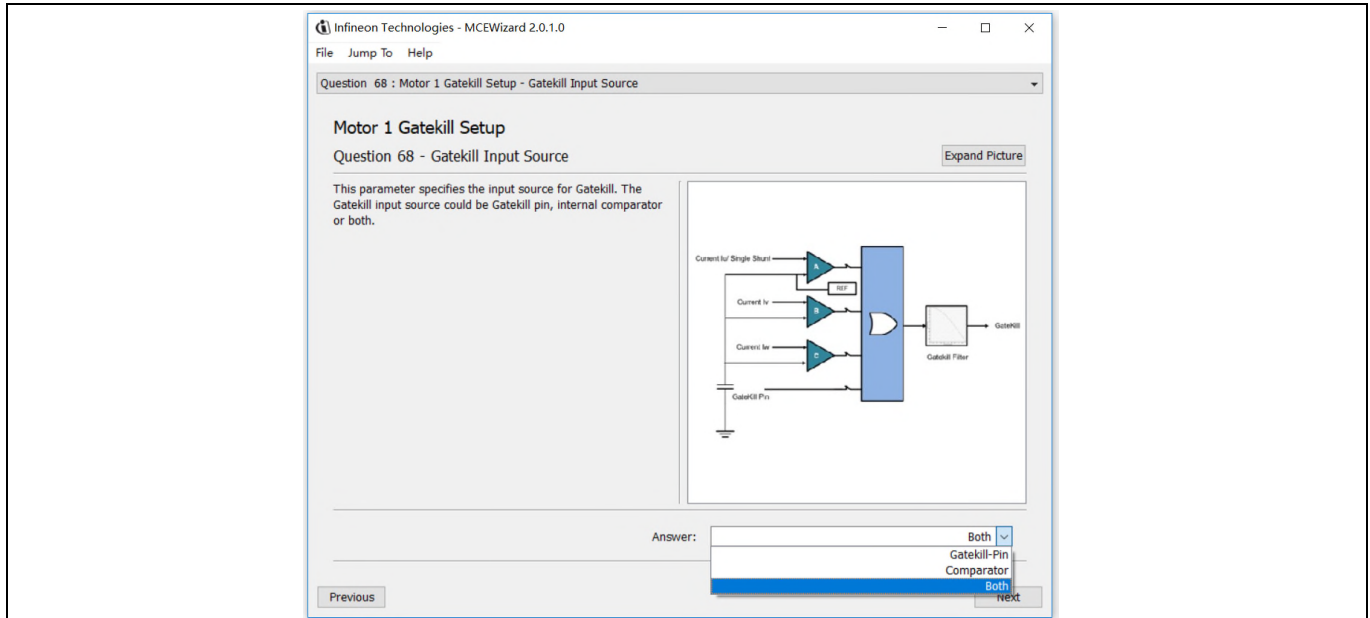


Figure 25 Gatekill configuration in MCEWizard for EVAL-M3-102T

5.3 Thermistor/NTC Characteristics and protection calculation

This board provides Thermistor/NTC output on pin 15 of the 30 pins connector J3. Temperatures can be calculated by resistor measurement.

5.3.1 CIPOS™ Internal NTC – Thermistor Characteristics

The thermistor characteristics for CIPOS™ mini IPM with build in NTC are listed as summarized in Table 7.

Table 7 CIPOS™ Internal NTC – Thermistor Characteristics

| Description | Condition | Symbol | Value | | | Unit |
|-------------------|--------------------------|------------------|--------|--------|--------|------|
| | | | min | typ | max | |
| Resistor | T _{NTC} = 25°C | R _{NTC} | 79.638 | 85.000 | 90.362 | kΩ |
| Resistor | T _{NTC} = 50°C | R _{NTC} | 28.400 | 29.972 | 31.545 | kΩ |
| Resistor | T _{NTC} = 60°C | R _{NTC} | 19.517 | 20.515 | 21.514 | kΩ |
| Resistor | T _{NTC} = 70°C | R _{NTC} | 13.670 | 14.315 | 14.960 | kΩ |
| Resistor | T _{NTC} = 80°C | R _{NTC} | 9.745 | 10.169 | 10.593 | kΩ |
| Resistor | T _{NTC} = 90°C | R _{NTC} | 7.062 | 7.345 | 7.628 | kΩ |
| Resistor | T _{NTC} = 100°C | R _{NTC} | 5.199 | 5.388 | 5.576 | kΩ |
| Resistor | T _{NTC} = 110°C | R _{NTC} | 3.856 | 4.009 | 4.163 | kΩ |
| Resistor | T _{NTC} = 120°C | R _{NTC} | 2.900 | 3.024 | 3.149 | kΩ |
| Resistor | T _{NTC} = 125°C | R _{NTC} | 2.527 | 2.639 | 2.751 | kΩ |
| B-constant of NTC | | B(25/100) | | 4092 | | K |

The VFO pin of CIPOS™-Modules provides direct access to the NTC, which is referenced to VSS. An external pull-up resistor connected to +3.3V ensures that the resulting voltage can be directly connected to the microcontroller.

Figure 26 depicts the CIPOS™ internal circuit at pin VFO. An external pull-up resistor is required to bias the NTC.

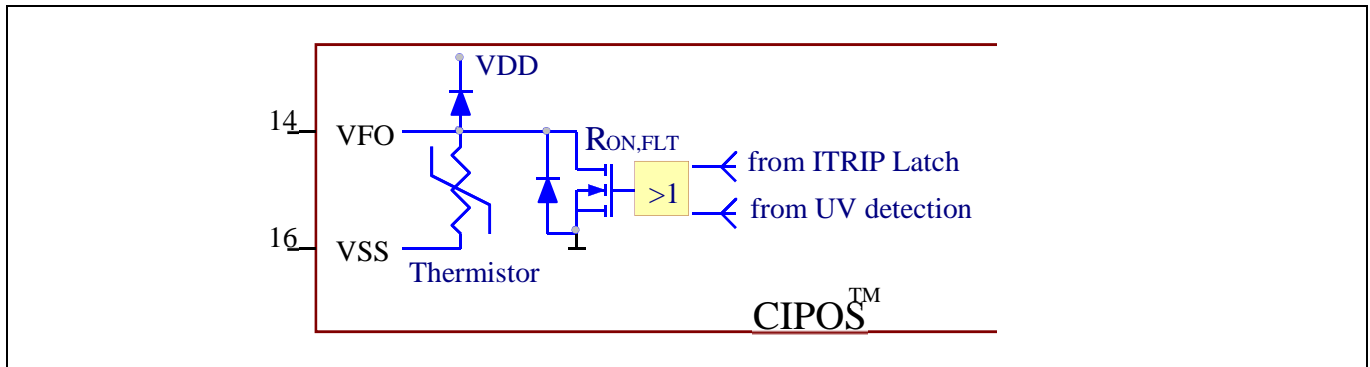


Figure 26 Internal circuit at pin VFO for CIPOS™ IPM IM564-X6D/IM564-X6DS

5.3.2 Overtemperature Hardware Protection Circuit

The VFO pin not only provides direct access to the NTC, but also indicates a module failure in case of under voltage at pin VDD or in case of triggered overcurrent detection at ITRIP. In this Evaluation design kits EVAL-M3-IM564 and EVAL-M3-102T, the VFO pin is directly connected to the Gatekill pin for controller IC IMC102T.

But for iMOTION™ 100series control board, the maximum input low voltage of Gatekill for IRMCF1xx is 0.8V. And NTC thermal resistor is about 3.0 kΩ at 120°C. The resistors R44 and R45 for the power board EVAL-M3-IM564 are chosen properly to make sure the voltage of VFO is 0.8V at 120°C. And then the Gatekill will ask the microcontroller to stop generating PWM pulses if the temperature of NTC continues to rise.

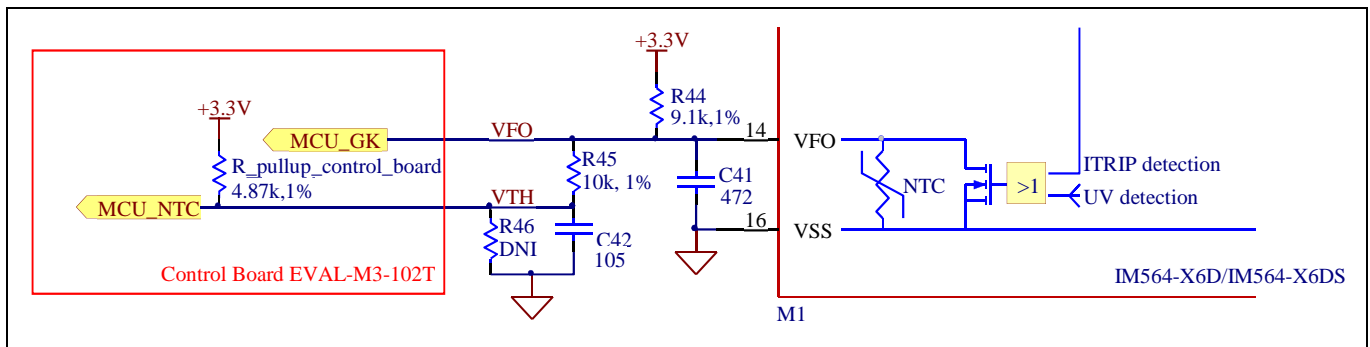


Figure 27 Overtemperature protection circuit schematic for EVAL-M3-IM564 and EVAL-M3-102T

5.3.3 NTC shutdown value calculation and configuration

External NTC Temperature shutdown value can be calculated as shown below and configured in MCEWizard as shown in Figure 28. For pull-up resistor on Evaluation control board, please refer to the control board's User Manual. For example, for EVAL-M3-102T, the pull-up resistor on the control board is 4.87kΩ. The value of resistors R44 and R45 on EVAL-M3-IM564 are 9.1 kΩ and 10 kΩ (see Figure 27). The typical value of R_{NTC} at 100°C is 5.388kΩ for IPM IM564-X6D/IM564-X6DS which is used in EVAL-M3-IM564.

$$V_{FO} = \frac{R_{NTC@setting\ temperature}}{R_{NTC@setting\ temperature} + \frac{R_{44} * (R_{45} + R_{pull-up\ on\ Control\ board})}{R_{44} + R_{45} + R_{pull-up\ on\ Control\ board}}} V_{DD}$$

$$V_{shut\ down} = \frac{R_{45} * V_{DD} + R_{pull-up\ on\ Control\ board} * V_{FO}}{R_{45} + R_{pull-up\ on\ Control\ board}}$$

If the setting temperature is 100°C, the shutdown value should be 2.75V. If the setting temperature is 85°C, the shutdown value should be 2.87V.

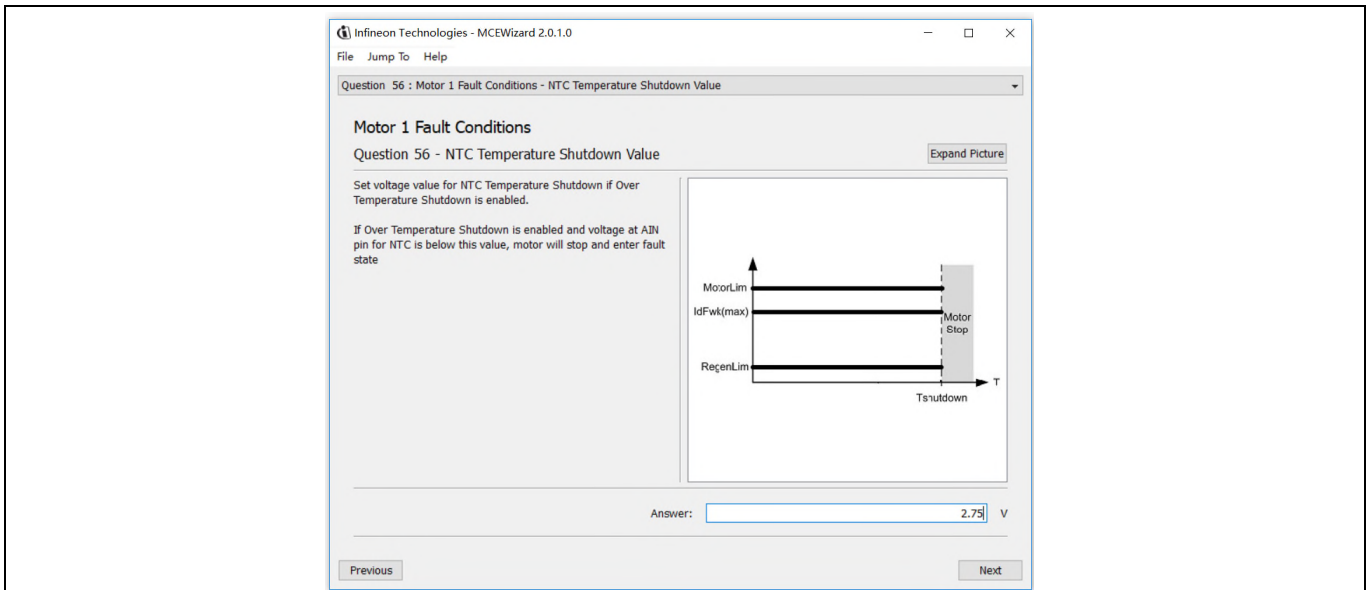


Figure 28 External temperature sense input configuration in MCEWizard

5.4 System thermal resistance testing

5.4.1 Heatsink thermal resistance

In order to test the thermal impedance of heatsink to ambient R_{thCA} , DC source is used to conduct the IPM internal diodes as the shown in Figure 29. With the DC source voltage increasing, current through IPM I_{IPM} and voltage on IPM V_{IPM} are monitored by current and voltage meter, IPM case temperature test point is between IPM and heatsink as shown in Figure 29 below, the same as T_c point of inverter IGBT of the IPM datasheet [1].

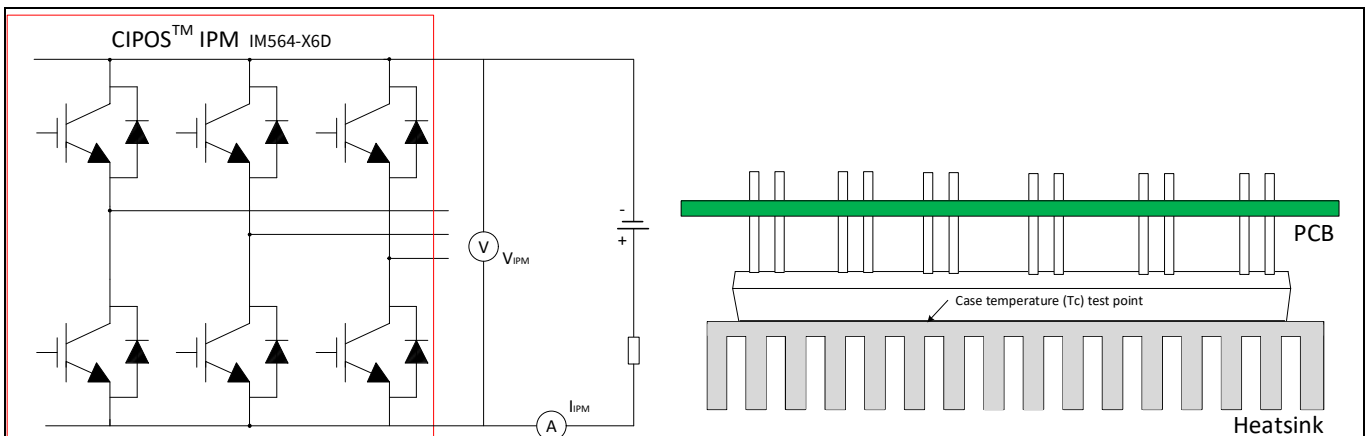


Figure 29 Heatsink thermal testing set-up

Thermal resistance between junction to ambient R_{thJA} is divided into 2 parts as following formular, thermal resistance between junction to case R_{thJC} and thermal resistance between case to ambient R_{thCA} .

$$R_{thJA} = R_{thJC} + R_{thCA}$$

And then we could get the formular as follows.

$$R_{thCA} = \frac{\Delta T_{CA}}{P_{D.tot}} = \frac{T_C - T_A}{V_{IPM} \times I_{IPM}}$$

According to the test set up, test result is shown in the Figure 30 below. The IPM case temperature is detected about 1 hours until the temperature is stable.

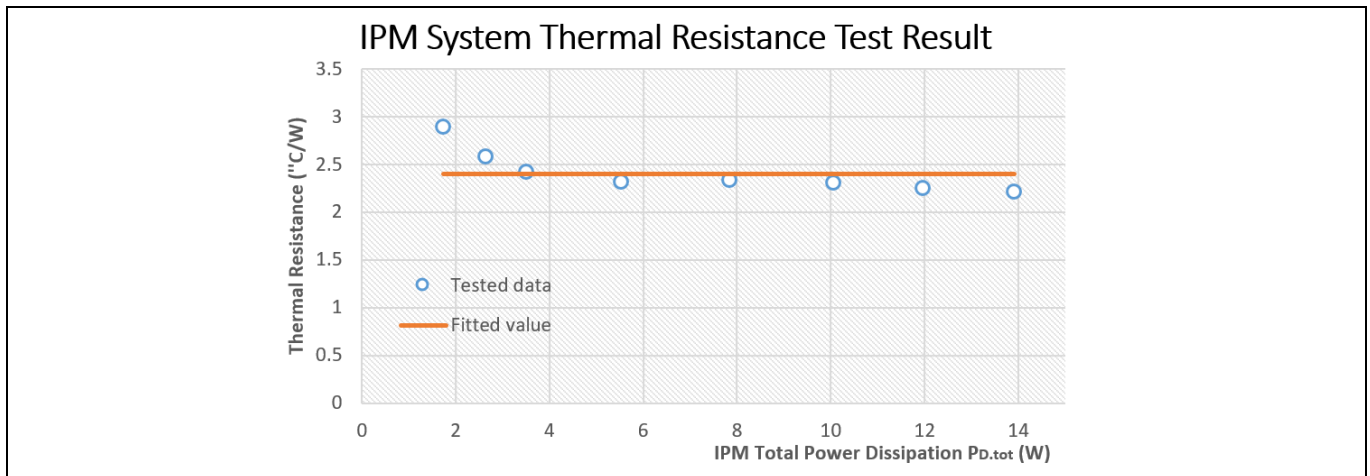


Figure 30 Heatsink thermal testing result

So, we could roughly get the final case to ambient resistance value as:

$$R_{thCA} = 2.4^{\circ}\text{C}/\text{W}$$

5.4.2 System power output capability

In order to test the total output power capability of the MADK system as Figure 2, DCB case temperature is tested with different MADK output power.

Test conditions are: Ambient temperature $T_a=25^{\circ}\text{C}$, AC input voltage is $V_{AC}=220\text{V}/50\text{Hz}$, Bus voltage is $V_{DC}=380\text{V}$, PFC PWM frequency is 50 KHz and inverter frequency is 6 KHz.

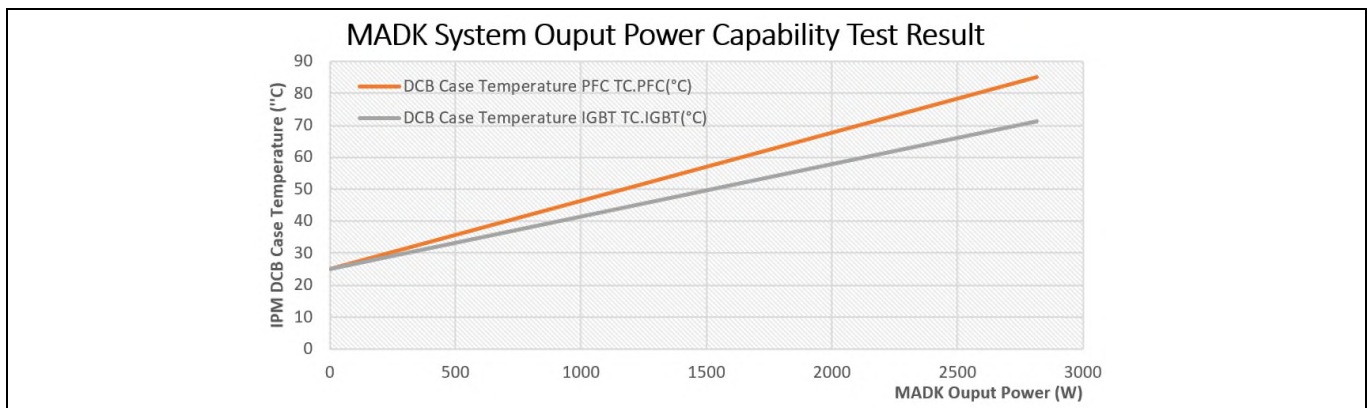


Figure 31 MADK Output Power Capability Test Result

With the MADK output power increasing, IPM DCB PFC test point and IGBT test point temperature are monitored, final test result are shown as Figure 31.

5.5 Auxiliary power supply

Figure 32 depicts the schematic of the auxiliary power supply for the EVAL-M3-IM564 board. The circuit includes an ICE5QR4770AG that is used to generate 15 V and 6V through QR flyback topology from the DC bus.

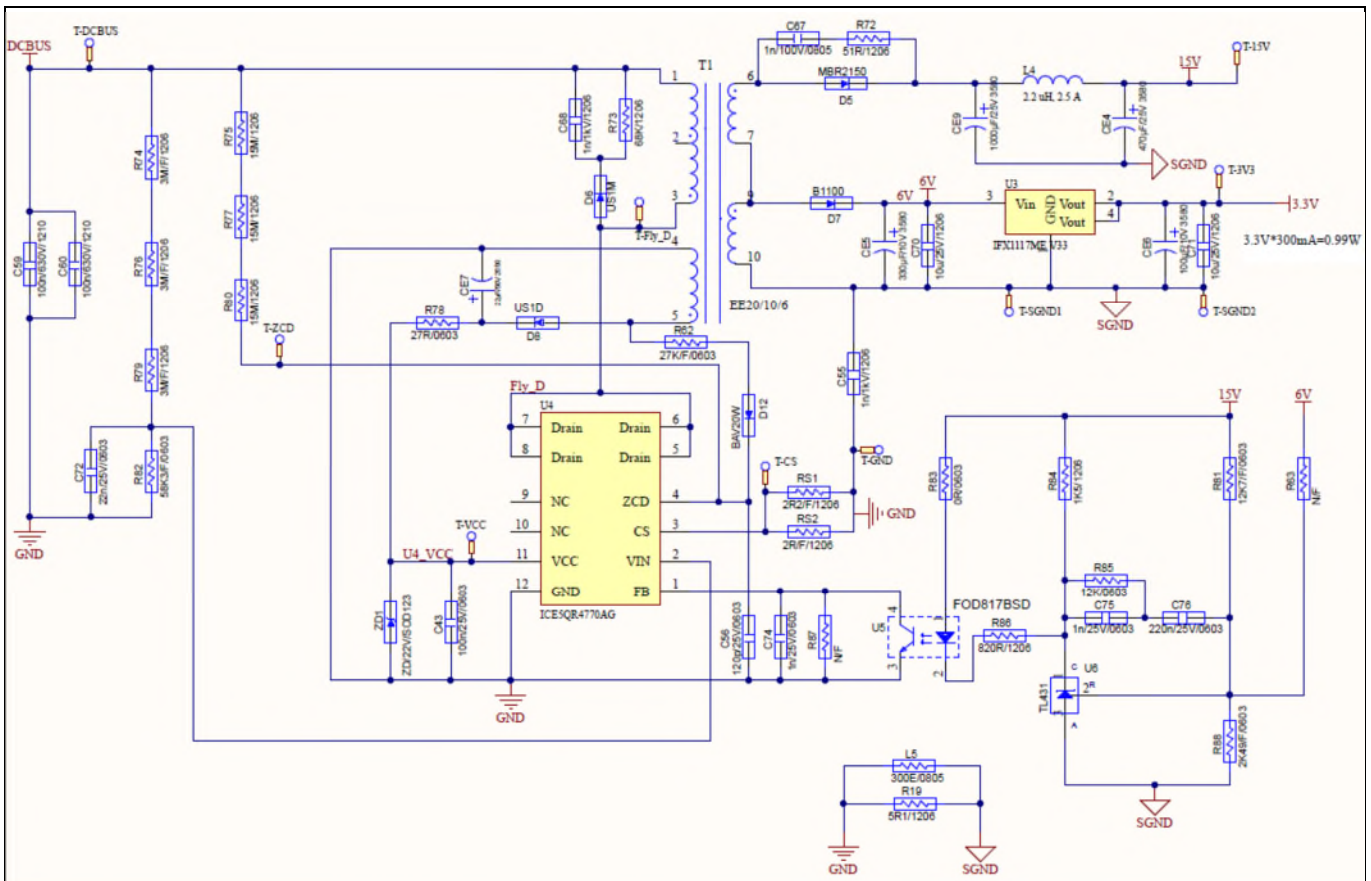


Figure 32 Power supply section of the EVAL-M3-IM564 Evaluation board

The linear voltage regulator IFX1117ME V33 generates 3.3 V from 6V power supply. The 3.3 V power supply is used in the PFC overcurrent comparator circuit and overtemperature hardware protection circuit. Both 15V and 3.3 V are also present on the 30 pins iMOTION™ MADK-M3 interface connector J3 to power circuitry on the control board.

5.6 Schematics for EVAL-M3- IM564

The PFC setion schematic for EVAL-M3- IM564 is provided in Figure 33.

The Inverter section schematic for EVAL-M3- IM564 is provided in Figure 34.

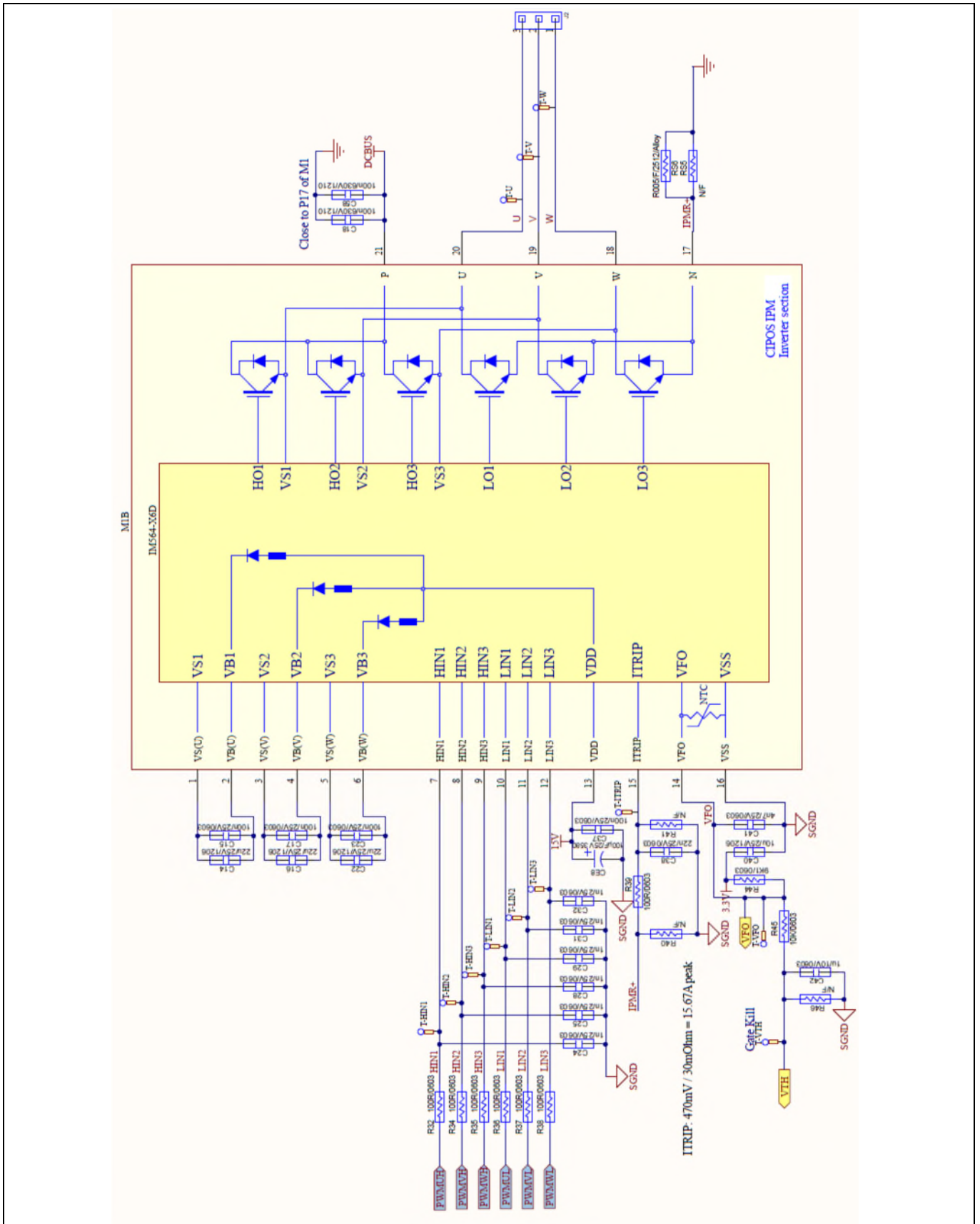


Figure 34 Inverter Section Schematics for EVAL-M3- IM564

5.7 PCB Layout for EVAL-M3- IM564

The layout of this board can be used for different voltage or power classes. The PCB has two electrical layers with 35µm copper by default and its size is 148 mm × 165 mm. The PCB board thickness is 1.6mm. Get in contact with our technical support team to get more detailed information and the latest Gerber-files.

Figure 36 illustrates the top assembly print of the Evaluation board.

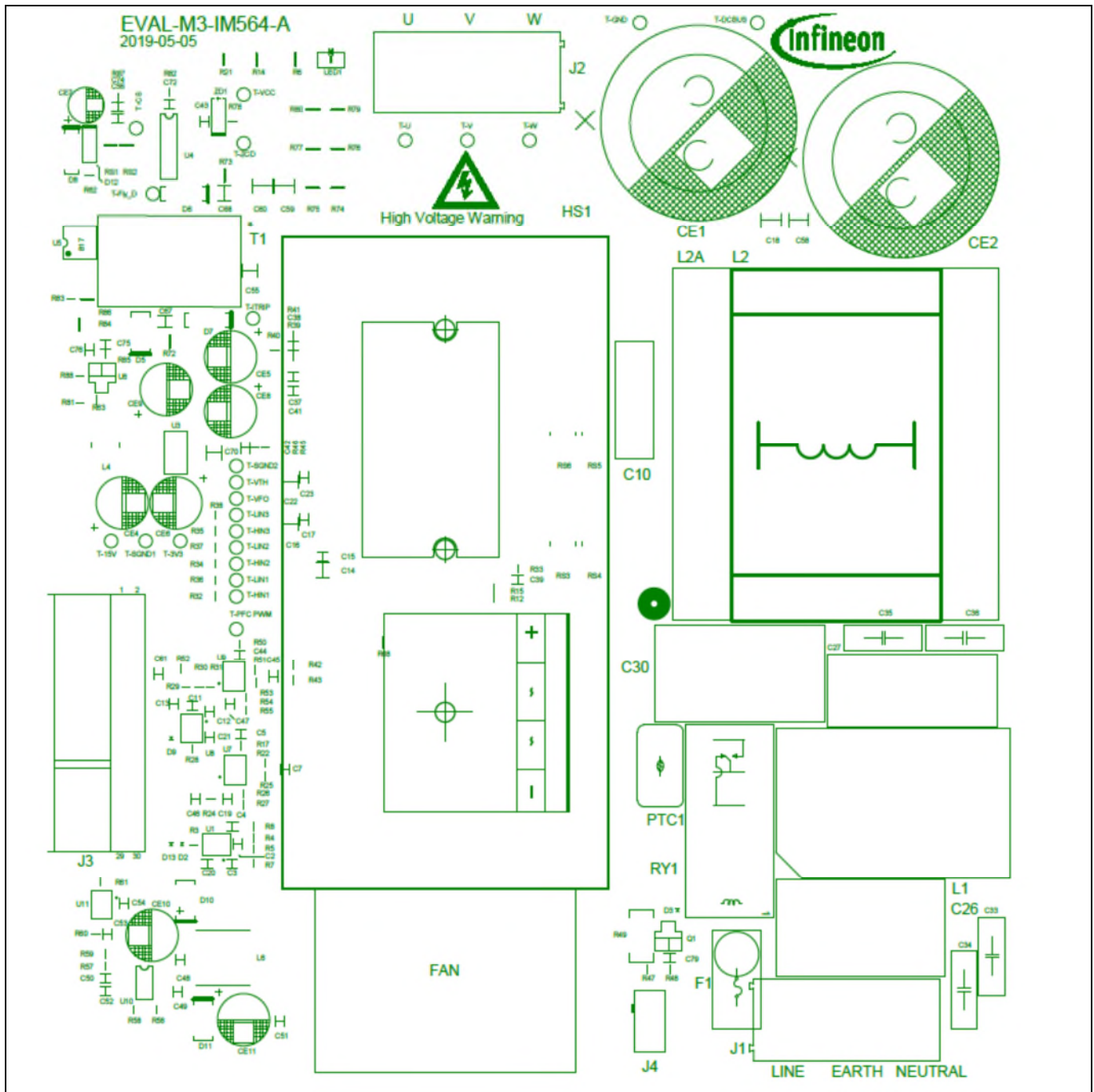


Figure 36 Top assembly print of the EVAL-M3-IM564 Evaluation board

Figure 37 depicts the bottom assembly print of the Evaluation board.



Figure 37 Bottom assembly print of the EVAL-M3-IM564 Evaluation board

The top layer routing of the PCB is provided in Figure 38.

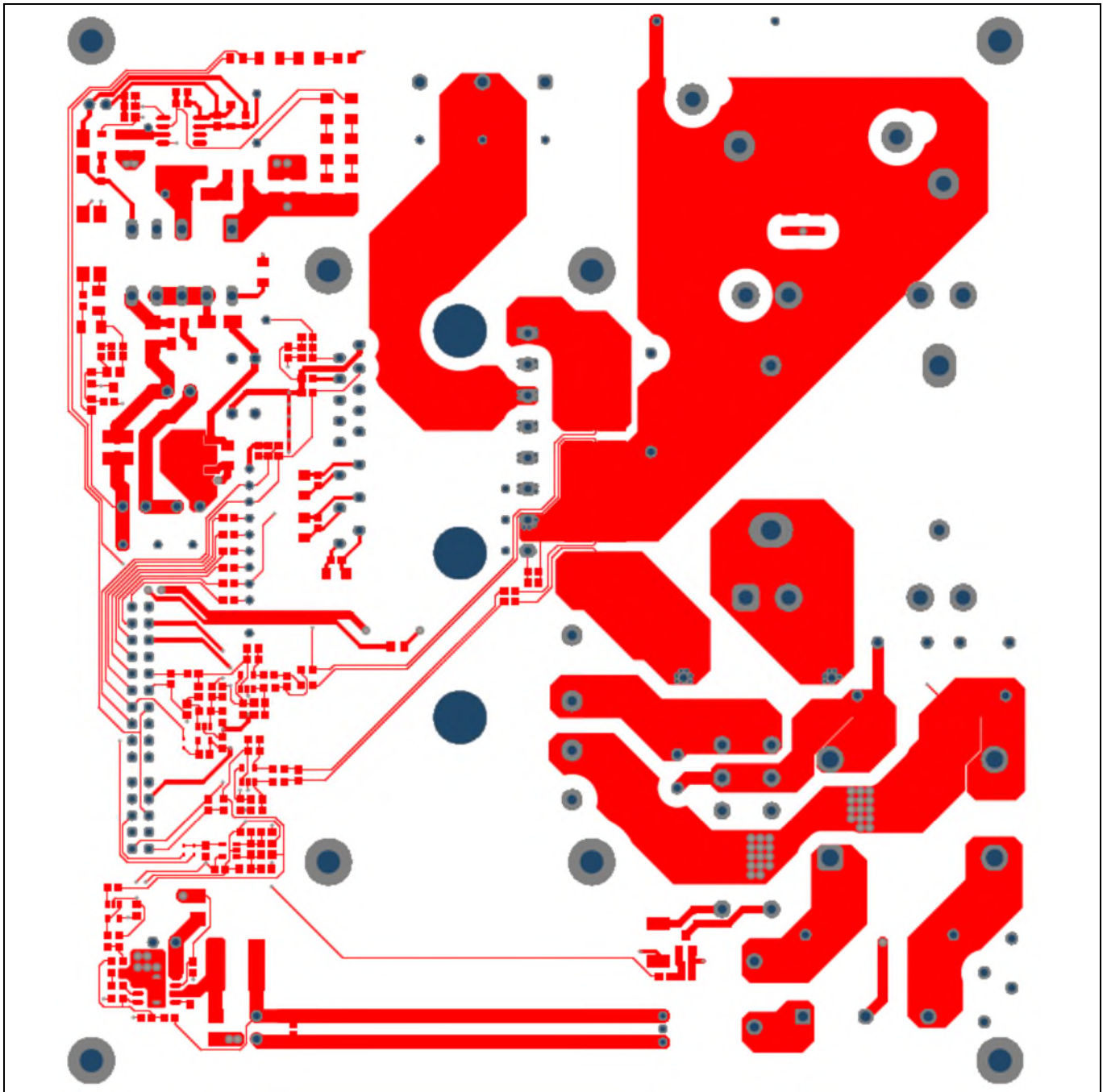


Figure 38 Top layer routing of the EVAL-M3-IM564

Figure 39 illustrates the bottom layer routing of the PCB.

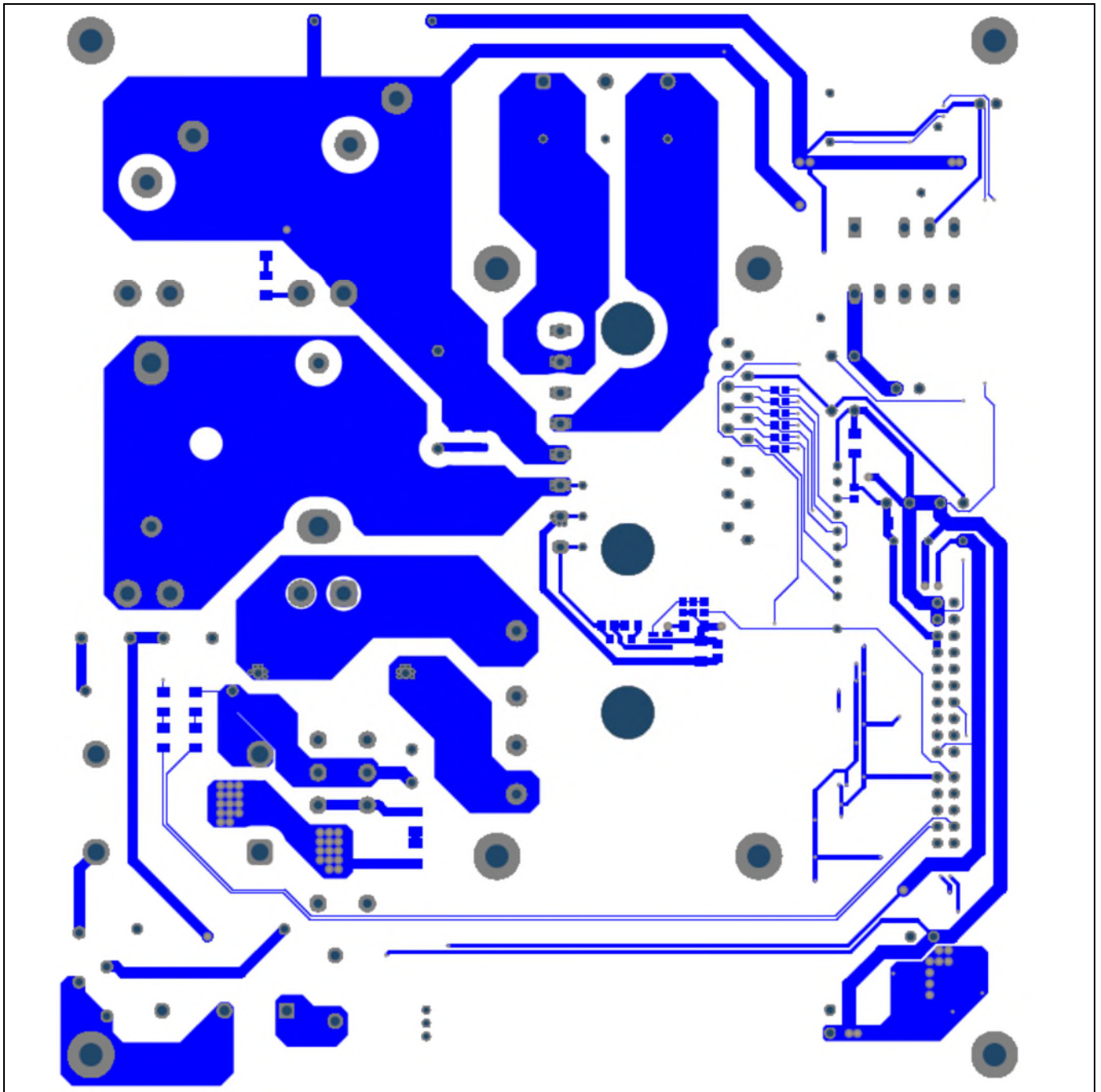


Figure 39 Bottom layer routing of the EVAL-M3-IM564

Bill of material

6 Bill of material

Table 8 provides the complete bill of materials for the EVAL-M3-IM564.

Table 8 Bill of materials

| No. | Qty | Part description | Designator | Part number | Manufacturer |
|-----|-----|---------------------------------------|--|------------------------|---------------------------------|
| 1 | 6 | CAP CER 0.1UF 630V X7R 1210 | C1, C18, C57, C58, C59, C60 | C1210C104KBRAC78 00 | KEMET |
| 2 | 10 | CAP CER 1000PF 25V X7R 0603 | C2, C11, C24, C25, C28, C29, C31, C32, C74, C75 | 885012206059 | Wurth Electronics Inc. |
| 3 | 5 | CAP CER 100PF 25V X7R 0603 | C3, C7, C9, C13, C45 | 885012206053 | Wurth Electronics Inc. |
| 4 | 12 | CAP CER 0.1µF 25V X7R 0603 | C4, C12, C15, C17, C19, C20, C21, C23, C37, C43, C47, C54 | 885012206071 | Wurth Electronics Inc. |
| 5 | 2 | CAP CER 10PF 25V C0G/NP0 0603 | C5, C44 | 885012006032 | Wurth Electronics Inc. |
| 6 | 4 | CAP CER 10UF 25V X5R 1206 | C8, C40, C70, C71 | 885012108021 | Wurth Electronics Inc. |
| 7 | 1 | 0.1µF Film Capacitor 630V Polyester | C10 | 890303425004CS | TDK Corporation |
| 8 | 3 | CAP CER 22UF 25V X5R 1206 | C14, C16, C22 | TMK316BBJ226ML-T | Taiyo Yuden |
| 9 | 2 | CAP FILM 2.2UF 10% 275VAC RADIAL | C26, C30 | 890324026034CS | Wurth Electronics Inc. |
| 10 | 1 | 1µF Film Capacitor 275V Polypropylene | C27 | 890324026027CS | Wurth Electronics Inc. |
| 11 | 2 | CAP CER 4700PF 250VAC Y5U RADIAL | C33, C34 | ECK-DNA472ME | Panasonic Electronic Components |
| 12 | 2 | CAP CER 10000PF 440VAC Y5V RDL | C35, C36 | ECK-ATS103MF6 | Panasonic Electronic Components |
| 13 | 3 | CAP CER 0.022UF 25V X7R 0603 | C38, C50, C72 | 885012206067 | Wurth Electronics Inc. |
| 14 | 1 | CAP CER 4700PF 25V X7R 0603 | C41 | 885012206063 | Wurth Electronics Inc. |
| 15 | 3 | CAP CER 1UF 10V X5R 0603 | C42, C53, C79 | 885012106010 | Wurth Electronics Inc. |
| 16 | 2 | CAP CER 3300PF 25V X7R 0603 | C46, C61 | 885012206062 | Wurth Electronics Inc. |
| 17 | 1 | CAP CER 10000PF 25V X7R 0603 | C48 | 885012206065 | Wurth Electronics Inc. |
| 18 | 3 | CAP CER 0.22UF 25V X5R 0603 | C49, C51, C76 | 885012106019 | Wurth Electronics Inc. |
| 19 | 1 | CAP CER 470PF 25V X7R 0603 | C52 | 885012206057 | Wurth Electronics Inc. |

Bill of material

| No. | Qty | Part description | Designator | Part number | Manufacturer |
|-----|-----|---|--------------------------------|--------------------------------|-----------------------------|
| 20 | 2 | CAP CER 1000PF 1000V X7R 1210 | C55, C68 | 885342209006 | Würth Electronics Inc. |
| 21 | 1 | CAP CER 120PF 50V NPO 0805 | C56 | CC0805GRNPO9BN1 21 | Yageo |
| 22 | 1 | CAP CER 1000PF 100V X7R 0805 | C67 | 885012207116 | Würth Electronics Inc. |
| 23 | 2 | CAP ALUM 390UF 20% 450V SNAP | CE1, CE2 | 861011485019 | Würth Electronics Inc. |
| 24 | 1 | CAP ALUM 470UF 20% 25V | CE4 | 860020474014 | Würth Electronics Inc. |
| 25 | 1 | CAP ALUM 330UF 20% 10V | CE5 | 860020273010 | Würth Electronics Inc. |
| 26 | 1 | CAP ALUM 100UF 20% 10V | CE6 | 860020272005 | Würth Electronics Inc. |
| 27 | 1 | CAP 22 UF 20% 50 V | CE7 | 860240673003 | Würth Electronics Inc. |
| 28 | 3 | CAP ALUM POLY 100UF 20% 25V T/H | CE8, CE10, CE11 | 870025574005 | Würth Electronics Inc. |
| 29 | 1 | CAP ALUM 1000UF 20% 25V RADIAL | CE9 | 860020475018 | Würth Electronics Inc. |
| 30 | 1 | BRIDGE RECT 1PHASE 1200V 25A GBJ | D1 | GBJ2512 | Diodes Incorporated |
| 31 | 4 | DIODE SCHOTTKY 30V 200MA SC79- 2 | D2, D3, D9, D13 | BAT5402VH6327XTS A1 | Infineon Technologies |
| 32 | 1 | DIODE SCHOTTKY 20V 1A SOD123L | D4 | MBR120ESFT1G | ON Semiconductor |
| 33 | 1 | DIODE SCHOTTKY 150V 2A DO15 | D5 | MBR2150VGTR-E1 | Diodes Incorporated |
| 34 | 1 | DIODE GEN PURP 1KV 1A SMA | D6 | US1M-13-F | Diodes Incorporated |
| 35 | 1 | DIODE SCHOTTKY 100V 1A SMA | D7 | B1100LB-13-F | Diodes Incorporated |
| 36 | 1 | DIODE GEN PURP 200V 1A SMA | D8 | US1D-13-F | Diodes Incorporated |
| 37 | 2 | DIODE SCHOTTKY 20V 2A SMB | D10, D11 | SS22T3G | ON Semiconductor |
| 38 | 1 | DIODE GEN PURP 150V 200MA SOD323 | D12 | BAV20WS-TP | Micro Commercial Co |
| 39 | 1 | FAN 40X28MM 12VDC TACH,PWM | FAN | 9GA0412P3J01 | Sanyo Denki America Inc. |
| 40 | 2 | CONN TERM BLOCK 3POS 9.52MM PCB | J1, J2 | 691 250 910 003 | Würth Electronics Inc. |
| 41 | 1 | HEADER 20POS SCKT R/A DL 2.54 MM & HEADER 10POS SCKT R/A DL 2.54 MM | J3 | 613020243121 & 613010243121 | Würth Electronics Inc. |
| 42 | 1 | Connector | J4 | XH 2P 2.54MM | |
| 43 | 1 | COMMON MODE CHOKE 3MH 23A 2LN TH | L1 | 7448052303 | Würth Electronics Inc. |
| 44 | 1 | FIXED 2.2uH 2.5A SMD | L4 | 744773022 | Würth Electronics Inc. |
| 45 | 1 | FERRITE BEAD 300 OHM 0805 1LN | L5 | 742792035 | Würth Electronics Inc. |
| 46 | 1 | FIXED IND 47UH 1.55A 136 MOHM | L6 | 74404084470 | Würth Electronics Inc. |
| 47 | 1 | LED RED CLEAR 0805 SMD | LED1 | 150080RS75000 | Würth Electronics Inc. |
| 48 | 6 | RES SMD 1MΩ 1% 1/4W 1206 | R1, R2, R6, R9, R10, R14 | RC1206FR-071ML | Yageo |

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| No. | Qty | Part description | Designator | Part number | Manufacturer |
|-----|-----|---------------------------------|---|-------------------|--------------|
| 49 | 6 | RES SMD 10kΩ 1% 1/10W 0603 | R3, R28, R45, R17, R50, R59 | RC0603FR-0710KL | Yageo |
| 50 | 1 | RES SMD 3K OHM 0.1% 1/10W 0603 | R4 | RT0603BRD073KL | Yageo |
| 51 | 3 | RES SMD 1K OHM 0.5% 1/10W 0603 | R5, R29, R60 | RT0603DRD071KL | Yageo |
| 52 | 3 | RES SMD 15K OHM 0.5% 1/10W 0603 | R7, R8, R26 | RT0603DRD0715KL | Yageo |
| 53 | 1 | RES SMD 10 OHM 1% 1/8W 0805 | R11 | RC0805FR-0710RL | Yageo |
| 54 | 8 | RES SMD 499 OHM 0.5% 1/10W 0603 | R12, R15, R22, R25, R42, R43, R51, R53 | RT0603DRD07499RL | Yageo |
| 55 | 1 | RES SMD 4.7 OHM 5% 1/8W 0805 | R13 | RC0805JR-074R7L | Yageo |
| 56 | 1 | RES SMD 5.1 OHM 5% 1/4W 1206 | R19 | RC1206JR-075R1L | Yageo |
| 57 | 8 | RES SMD 100 OHM 0.5% 1/10W 0603 | R20, R32, R34, R35, R36, R37, R38, R39 | RT0603DRD07100RL | Yageo |
| 58 | 1 | RES SMD 4.7K OHM 5% 1/10W 0603 | R23 | RC0603JR-074K7L | Yageo |
| 59 | 3 | RES SMD 0 OHM JUMPER 1/10W 0603 | R24, R52, R83 | RC0603JR-070RL | Yageo |
| 60 | 2 | RES SMD 40K OHM 1% 1/10W 0603 | R27, R55 | 9C06031A4002FKHFT | Yageo |
| 61 | 1 | RES SMD 20K OHM 1% 1/10W 0603 | R30 | RC0603FR-0720KL | Yageo |
| 62 | 1 | RES SMD 7.5K OHM 5% 1/10W 0603 | R31 | RC0603JR-077K5L | Yageo |
| 63 | 2 | RES SMD 12K OHM 5% 1/10W 0603 | R33, R85 | RC0603JR-0712KL | Yageo |
| 64 | 1 | RES SMD 9.1K OHM 5% 1/10W 0603 | R44 | RC0603JR-079K1L | Yageo |
| 65 | 1 | RES SMD 100K OHM 5% 1/10W 0603 | R47 | RC0603JR-07100KL | Yageo |
| 66 | 1 | RES SMD 510K OHM 5% 1/10W 0603 | R48 | RC0603JR-07510KL | Yageo |
| 67 | 1 | RES 68 OHM 1% 2W 2512 | R49 | SR2512FK-7W68RL | Yageo |
| 68 | 1 | RES SMD 30K OHM 5% 1/10W 0603 | R54 | RC0603JR-0730KL | Yageo |
| 69 | 1 | RES SMD 56K OHM 5% 1/10W 0603 | R56 | RC0603JR-0756KL | Yageo |
| 70 | 1 | RES SMD 22K OHM 5% 1/10W 0603 | R57 | RC0603JR-0722KL | Yageo |
| 71 | 8 | RES SMD 2K OHM 1% 1/10W 0603 | R20, R32, R34, R35, R36, R37, R38, R39 | RC0603FR-072KL | Yageo |
| 72 | 1 | RES SMD 27K OHM 5% 1/10W 0603 | R21 | RC0603JR-0727KL | Yageo |
| 73 | 3 | RES SMD 249 OHM 1% 1/4W 1206 | R23 | RC1206FR-07249RL | Yageo |

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| No. | Qty | Part description | Designator | Part number | Manufacturer |
|-----|-----|--------------------------------------|---|------------------------|--------------------------------|
| 74 | 3 | RES SMD 2.2 OHM 5% 1/8W 0805 | R24, R52, R83 | RC0805JR-072R2L | Yageo |
| 75 | 2 | RES SMD 51 OHM 5% 1/4W 1206 | R27, R55 | RC1206JR-0751RL | Yageo |
| 76 | 1 | RES SMD 68K OHM 5% 1/4W 1206 | R30 | RC1206JR-0768KL | Yageo |
| 77 | 1 | RES SMD 3M OHM 1% 1/4W 1206 | R31 | RC1206FR-073ML | Yageo |
| 78 | 2 | RES SMD 15M OHM 5% 1/4W 1206 | R33, R85 | RV1206JR-0715ML | Yageo |
| 79 | 5 | RES SMD 27 OHM 5% 1/10W 0603 | R40, R41, R46, R63, R87 | RC0603JR-0727RL | Yageo |
| 80 | 1 | RES SMD 12.7K OHM 1% 1/10W 0603 | R44 | RC0603FR-0712K7L | Yageo |
| 81 | 1 | RES 58.3K OHM 1% 1/10W 0603 | R82 | RN73R1JTTD5832F1 00 | KOA Speer Electronics, Inc. |
| 82 | 1 | RES SMD 1.5K OHM 5% 1/4W 1206 | R84 | RC1206JR-071K5L | Yageo |
| 83 | 1 | RES SMD 820 OHM 5% 1/4W 1206 | R86 | RC1206JR-07820RL | Yageo |
| 84 | 1 | RES SMD 2.49K OHM 1% 1/10W 0603 | R88 | RC0603FR-072K49L | Yageo |
| 85 | 1 | RES SMD 2.2 OHM 5% 1/4W 1206 | RS1 | RC1206JR-072R2L | Yageo |
| 86 | 1 | RES SMD 2 OHM 1% 1/4W 1206 | RS2 | RC1206FR-072RL | Yageo |
| 87 | 2 | RS3, RS6 RES 0.005 OHM 1% 1W 2512 | RS3, RS6 | PA2512FKF070R005E | Yageo |
| 88 | 1 | 24VDC 16A 8pin | RY1 | HF14FW-024-ZT | Hongfa relay |
| 89 | 1 | 998Uh 100kHz, 100mV, Ls | EE20/10/6 | 750344279 | Würth Electronics Inc. |
| 90 | 25 | PC TEST POINT MINIATURE BLACK | T-3V3, T- 15V, T- DCBUS, T- Fly_D, T- GND, T- HIN1, T- HIN2, T- HIN3, T- ITRIP, T- LIN1, T- LIN2, T- LIN3, T- PFC PWM, T-PFC_D, T-PFC_G, T-PFC_S, T-SGND1, T-SGND2, T-U, T-V, T-VCC, T- VFO, T- VTH, T-W, T-ZCD | 5001 | Keystone Electronics |

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| No. | Qty | Part description | Designator | Part number | Manufacturer |
|-----|-----|-------------------------------------|----------------|-------------------------------|-----------------------|
| 91 | 2 | IC GP LV COMPARATOR SOT-23-5 | U1, U8 | LMV331IDBV | Texas Instruments |
| 92 | 1 | IC DRIVER LOW SIDE 1.5A SOT23-5 | U2 | IRS44273LTRPBF | Diodes Incorporated |
| 93 | 1 | IC REG LINEAR 3.3V 1A SOT223-4 | U3 | IFX1117MEV33HTMA 1 | Infineon Technologies |
| 94 | 1 | IC CTRLR QUASI-RES 12SOIC | U4 | ICE5QR4770AGXUMA 1 | Infineon Technologies |
| 95 | 1 | OPTOISOLATOR 5KV TRANSISTOR 4SMD | U5 | FOD817BSD | ON Semiconductor |
| 96 | 1 | IC VREF SHUNT ADJ SOT23-3 | U6 | TL431BSA-7 | Diodes Incorporated |
| 97 | 3 | IC OPAMP GP 1 CIRCUIT SOT23-5 | U7, U9, U11 | OPA320AIDBVR | Texas Instruments |
| 98 | 1 | IC REG BUCK 5V 1.8A 8DSO-27 | U10 | IFX91041EJV50XUMA 1 | Infineon Technologies |
| 99 | 1 | DIODE ZENER 22V 500MW SOD123 | ZD1 | BZT52C22-7-F | Diodes Incorporated |
| 100 | 1 | IFPS MODULES 24MDIP | M1 | IM564-X6D/IM564- X6DSXKMA1 | Infineon Technologies |
| 101 | 1 | MOSFET N-CH 30V 2.7A SOT-23-3 | Q1 | IRLML2030TRPbF | Infineon Technologies |
| 102 | 1 | T184 NPH-L 300uH | L2 | PI190103V1 | POCO |

7 Reference

- [1] Datasheet of Infineon CIPOS™ mini IPM IM564-X6D/IM564-X6DS
- [2] Application Note AN2016-10 CIPOS Mini Technical Description
- [3] AN2018-02 EVAL-M3-102T User manual
- [4] MCEWizard User Guide
- [5] MCEDesigner User Guide

Note: All listed reference materials are available for download on Infineon's website www.infineon.com/. All the iMOTION MADK Evaluation board's User Manuals are available at www.infineon.com/MADK. All the CIPOS™ IPM's Datasheets and documents are available at www.infineon.com/IPM.

Revision history

| Document version | Date of release | Description of changes |
|-------------------------|------------------------|-------------------------------|
| 1.0 | 2019-09-17 | First release |
| | | |
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Edition 2019-09-1

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference

AN2019-04

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