

# EVAL-M3-TS6-665PN User Manual

## iMOTION™ Modular Application Design Kit

### About this document

#### Scope and purpose

This application note provides an overview of the evaluation board EVAL-M3-TS6-665PN including its main features, key data, pin assignments and mechanical dimensions.

EVAL-M3-TS6-665PN is a complete evaluation board including PFC integration discrete IGBT and Gate driver for motor drives application. In combination with control-boards equipped with the M3 30pin interface connector, like [EVAL-M3-102T](#) and EVAL-M3-188. It features and demonstrates Infineon's discrete technology for motor drives.

The evaluation board [EVAL-M3-TS6-665PN](#) was developed to support customers during their first steps designing applications with discrete IGBTs and gate drivers.

#### Intended audience

This user manual is intended for all technical specialists working with the EVAL-M3-TS6-665PN board.

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**Safety precautions**









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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><i>Attention: The ground potential of the EVAL-M3-TS6-665PN 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. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.</i></p>
	<p><i>Attention: EVAL-M3-TS6-665PN system contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait three 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.</i></p>
	<p><i>Attention: 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><i>Attention: The surfaces of the drive may become hot, which may cause injury.</i></p>
	<p><i>Attention: EVAL-M3-TS6-665PN 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><i>Attention: 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 AC supply or excessive ambient temperatures may result in system malfunction.</i></p>
	<p><i>Attention: Remove and lock out power from the drive before you disconnect or reconnect wires or perform service. Wait three 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.</i></p>
	<p><i>Attention: EVAL-M3-TS6-665PN 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-TS6-665PN evaluation board is a part of the iMOTION™ Modular Application Design Kit for motor drive (iMOTION™ MADK).

The MADK platform is intended to use various power stages with different control boards. These boards can easily be interfaced through the iMOTION™ MADK-M3 30 pins interface connector to control board such as EVAL-M3-102T.

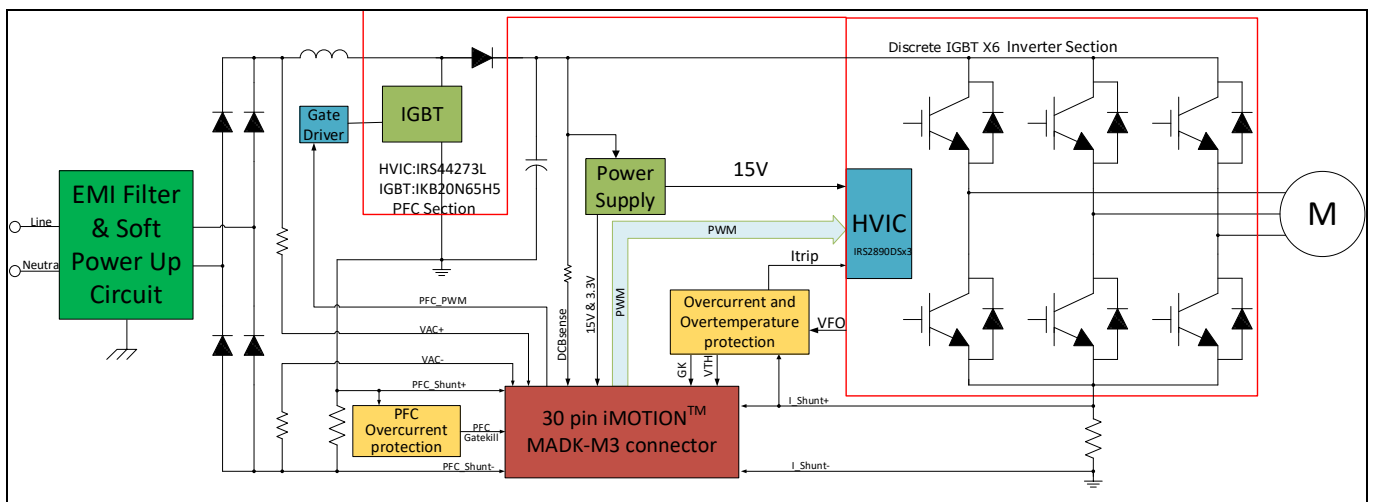
This evaluation board is designed to give Easy-to-use power stage based on the Infineon's discrete IGBT. The board is equipped with all assembly groups for sensorless field oriented control (FOC). It provides a single-phase AC-connector, rectifier, a PFC inductor, Boost PFC and 3-phase output for connecting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

The EVAL-M3-TS6-665PN 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 design feature 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-TS6-665PN. The design was tested as described in this document but 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.

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 and by trained specialists only.

The block diagram of the EVAL-M3-TS6-665PN 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 15 V and 3.3 V, PFC gate driver circuit and the discrete IGBT.



**Figure 1 The Block Diagram of the EVAL-M3-TS6-665PN**

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.

**Main features**

### **3 Main features**

EVAL-M3-TS6-665PN is an evaluation board for motor drives applications. It is integrating a single phase PFC and 3 phase inverter. It can be combined with one of the available MADK control board to demonstrate Infineon's motion control IC and discrete technology for motor drive.

Main features of [IKB20N65EH5](#) are:

- Best-in-Class efficiency in hard switching and resonant topologies
- Plug and play replacement of previous generation IGBTs
- 650 V breakdown voltage
- Low Qg
- IGBT copacked with RAPID 1 fast and soft antiparallel diode
- Maximum junction temperature 175° C

Main features of [IRS2890DS](#) are:

- Floating channel designed for bootstrap operation
- Fully operational to +600 V
- Tolerant to negative transient voltage, dV/dt immune
- Gate drive supply range from 10 V to 20 V
- Undervoltage lockout for both channels
- Matched propagation delay for both channels
- Integrated bootstrap functionality
- Overcurrent protection and fault reporting
- Integrated deadtime protection
- Shoot-through (cross-conduction) protection
- Adjustable fault clear timing

Main features of [IRS44273L](#) are:

- Low side gate driver
- Gate drive supply range from 10.2 V to 20 V
- Undervoltage lockout
- 1.5A output current capability

**Main features**

The evaluation board characteristics are:

- Input voltage 160~265 VAC
- Maximum 270 W (with heatsink) 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
- Sensing of DC-link voltage
- Thermistor output
- Measurement test-points compatible to standard oscilloscope probes
- PCB is 100 mm × 110 mm and has two layers with 35 µm copper each
- RoHS compliant

**Main features**

**3.1 EVAL-M3- TS6-665PN board specifications**

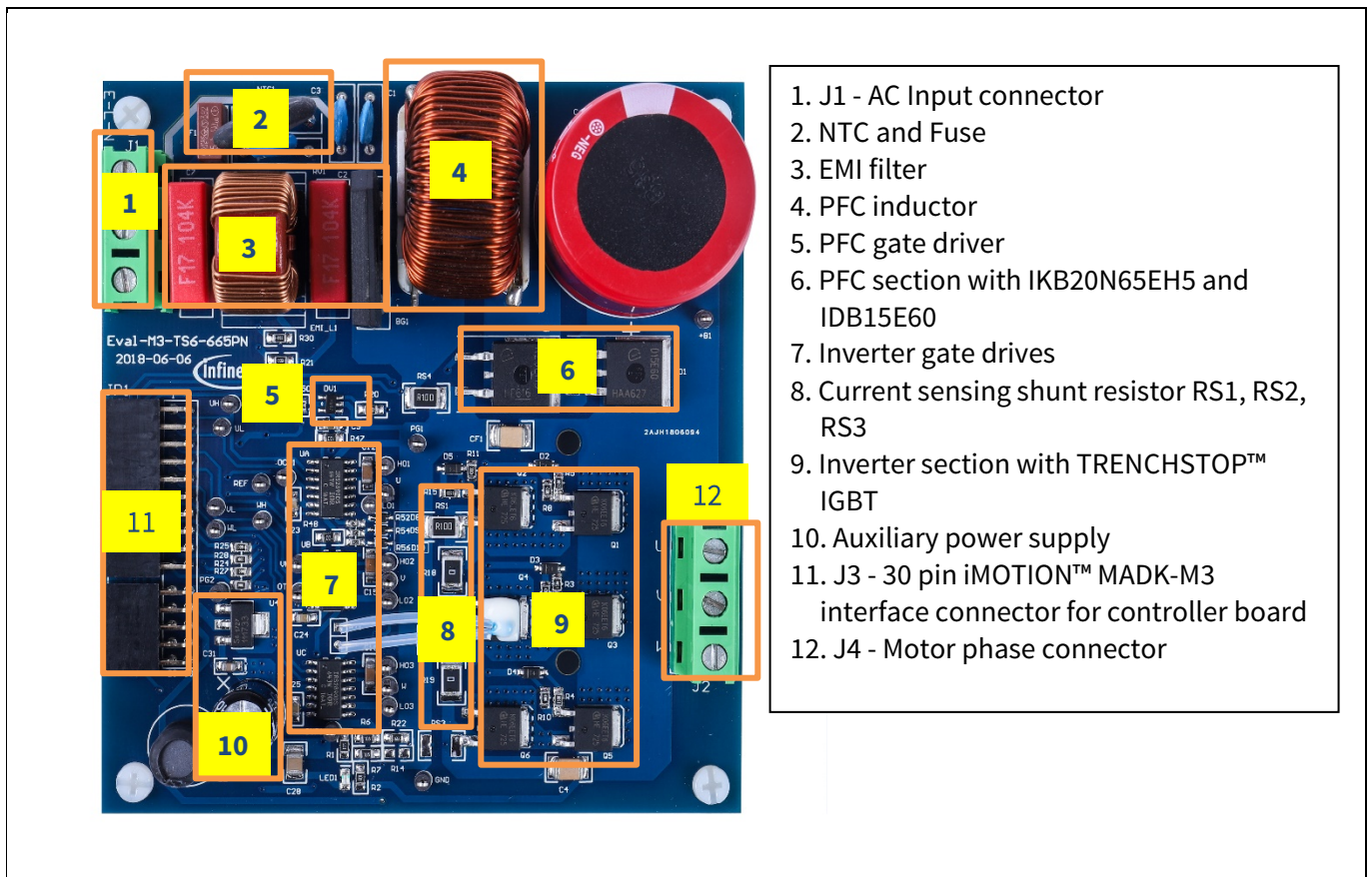
Table 2 depicts the important specifications of the evaluation board EVAL-M3-TS6-665PN.

**Table 2 EVAL-M3-TS6-665PN board specifications**

Parameters	Values	Conditions / comments
<b>Input</b>		
Voltage	165 - 265 V <sub>rms</sub>	lower AC input, less motor power output
Input current	1.2A <sub>rms</sub>	input 220 V <sub>AC</sub> , T <sub>a</sub> =25°C
<b>Output</b>		
Power (3phases)	270 W (with heatsink) 180W (without heatsink)	input 220V <sub>AC</sub> , f <sub>PWM</sub> =6 kHz, T <sub>a</sub> =25°C, T <sub>h</sub> =80°C
Current per leg	1.6 A <sub>rms</sub>	input 220V <sub>AC</sub> , f <sub>PWM</sub> =6 kHz, T <sub>a</sub> =25°C, T <sub>h</sub> =80°C
<b>DC Bus Voltage</b>		
Maximum DC bus voltage	400 V	
Minimum DC bus voltage	120 V	
<b>Switching Frequency</b>		
PFC switching frequency f <sub>PFC</sub>	60 kHz (max)	Limited by controller board (maximum 42 kHz for EVAL-M3-188)
Inverter switching frequency f <sub>PWM</sub>	20 kHz (max)	
<b>Current feedback</b>		
PFC current sensing resistor R1	100 mΩ	
Inverter current sensing resistor RS	100 mΩ	RS is the IPM inverter section's common emitter current sensing resistor.
<b>Protections</b>		
PFC Gatekill protection level	4 A <sub>peak</sub>	Configured by either PFC current sensing resistor R18, or adapting comparator threshold divider resistor R17.
Output current trip level	5.5A <sub>peak</sub>	Configured by changing shunt resistor R18.
Temperature trip level	100 °C	For controller board EVAL-M3-102T
<b>On board power supply</b>		
15 V	15 V ± 5 %, max. 50 mA	Used for gate driver and LDO
3.3 V	3.3 V ± 2 %, max. 20 mA	Supplying the 3.3V to the controller board and protection circuits
<b>PCB characteristics</b>		
Material	FR4, 1.6mm thickness, 2 layers. 35 μm copper thickness	
Dimension	100 mm x 110 mm	
<b>System environment</b>		
Ambient temperature	From 0 to 50°C	Non-condensing, maximum RH of 95 %

**Main features**

Figure 2 points out the functional groups on the top side of the EVAL-M3-TS6-665PN evaluation board.



**Figure 2 Functional groups of the EVAL-M3-TS6-665PN evaluation board's top side**



**Main features**

### **3.2 Pin assignments**

General information about the connectors of the EVAL-M3-TS6-665PN evaluation board is reported. Table 3 includes the details of the AC input connector J1.

**Table 3 J1- AC Line connector**

<b>S. No.</b>	<b>Pin</b>	<b>Details</b>
1	Line	AC line input
2	Neutral	AC neutral input
3	EARTH	Earth ground

Table 4 provides the details of the motor side connector J4.

**Table 4 J2- Motor side connector**

<b>S. No.</b>	<b>Pin</b>	<b>Details</b>
1	U	Connected to motor phase U
2	V	Connected to motor phase V
3	W	Connected to motor phase W

**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 JP1 - 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	Not used
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

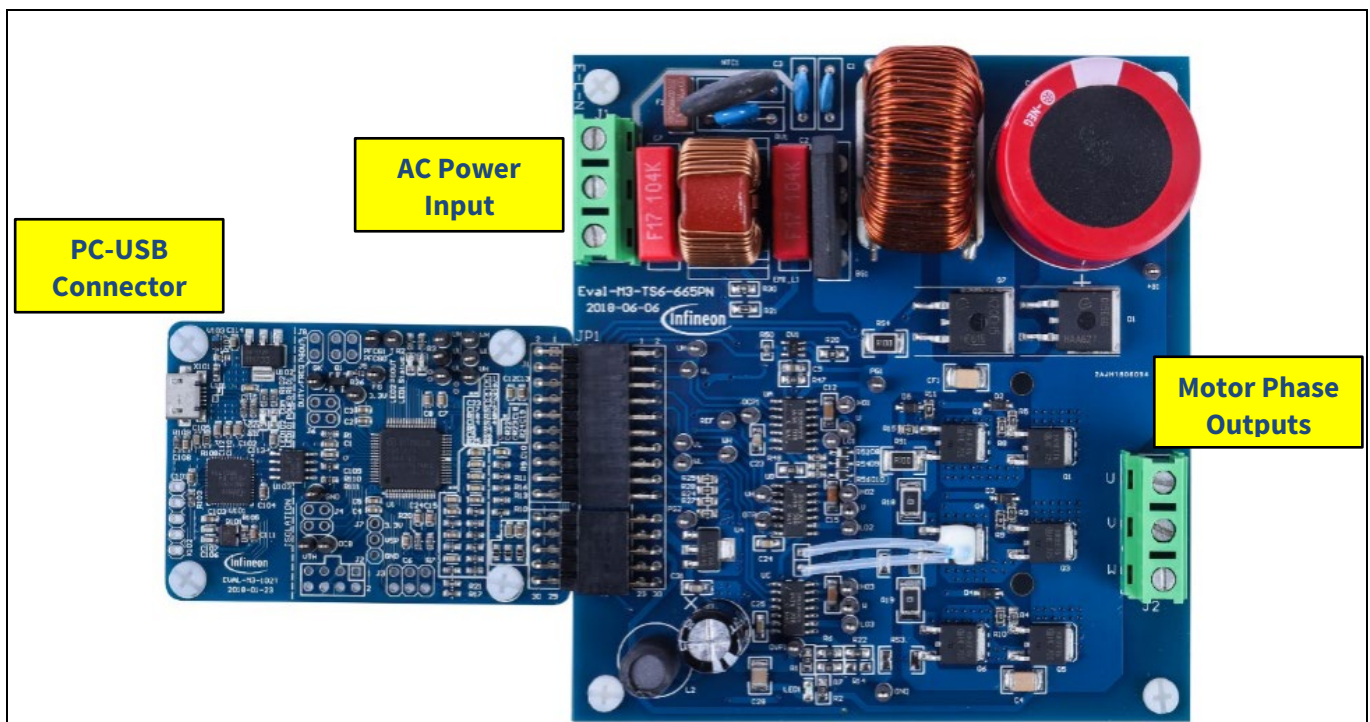
## 4 Getting Started with EVAL-M3-TS6-665PN

In order to run the motor system, a combination of the iMOTION™ MADK power board (EVAL-M3-TS6-665PN) 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 3 Shows the system connection using EVAL-M3-TS6-665PN and control board (used control board EVAL-M3-102T for example).



**Figure 3 System connection example using EVAL-M3-TS6-665PN and EVAL-M3-102T**

1. Connect PC-USB connector on the on-board-debugger to the PC via USB cable.
2. Connect EVAL-M3-TS6-665PN's MADK M3 30-pin interface connector (J3) to control board (see Figure 3).
3. Get the latest "IMC102T-F064 MCE Software Package" available on [www.infineon.com/imotion-software](http://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 and power on system.
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.

**Getting Started with EVAL-M3-TS6-665PN**

8. Import system drive parameters file (generated in step 5) into MCEDesigner by clicking “File” > “Import DriveParameters”. 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

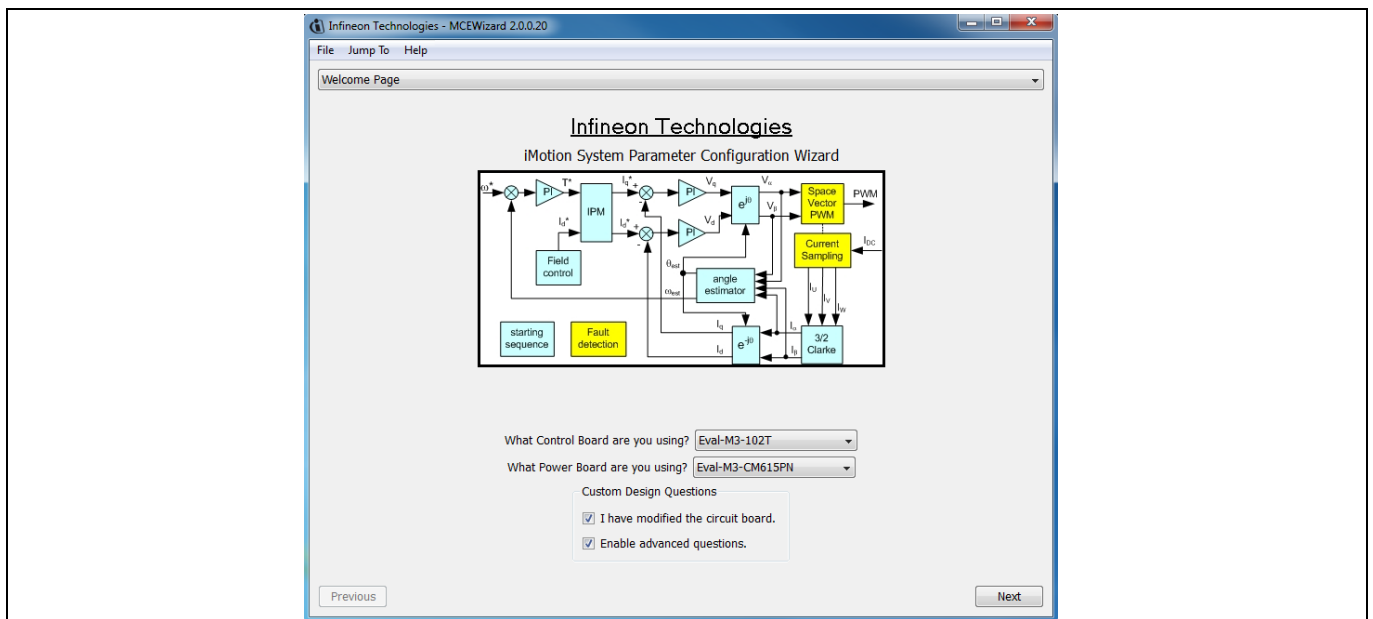
The iMOTION™ Development Tool installers for MCEDesigner and MCEWizard are available for download via Infineon iMOTION™ website (<http://www.infineon.com/imotion-software>). All the available tools and software variants are listed there.

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 5 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 4.



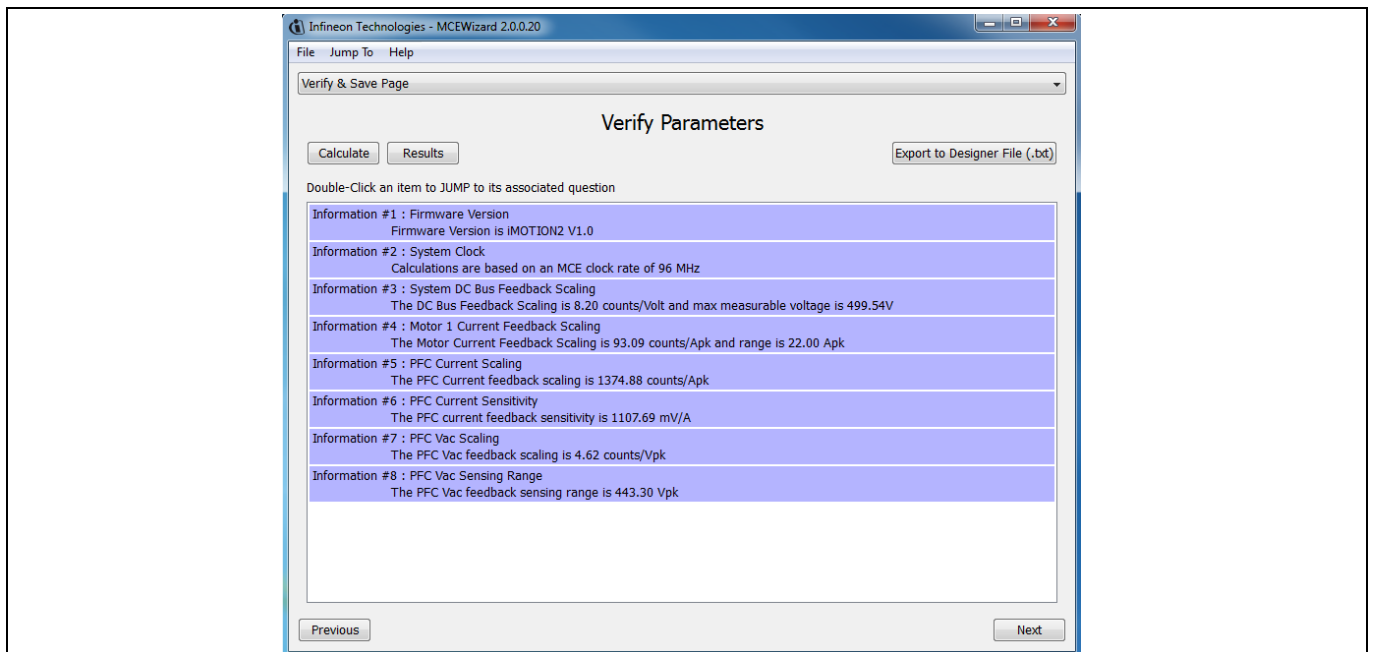
**Figure 4** Welcome Page of MCEWizard

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 power board’s User Manual. Combination of this table and the corresponding table of the power 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	100mΩ	
Question 3	Controller Supply Voltage	Refer to control board user manual	
Question 19	Max DC Bus Voltage	420V	
Question 23	DC Bus Sensing High Resistor	2MΩ	
Question 24	DC Bus Sensing Low Resistor	Refer to control board user manual	13.3kΩ by default
Question 54	NTC Temperature Shutdown value	No need to set (hardware protection in power board)	Refer to the the Section 5.2.4
Question 63	GateSense Low-Side Devices	High is true	
Question 64	GateSense High-Side Devices	High is true	
Question 69	Motor 1 Current Input	Calculated as the Section 5.2.2	
Question 83	PFC Topology	Boost PFC	
Question 85	PFC Current Input	Calculated as the Section 5.1.3	
Question 90	AC Voltage Sensing High Resistor	2000kΩ	
Question 91	AC Voltage Sensing low Resistor	Refer to control board user manual	
Question 92	PFC Gate Driver Polarity High Side	High is active	
Question 93	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 5



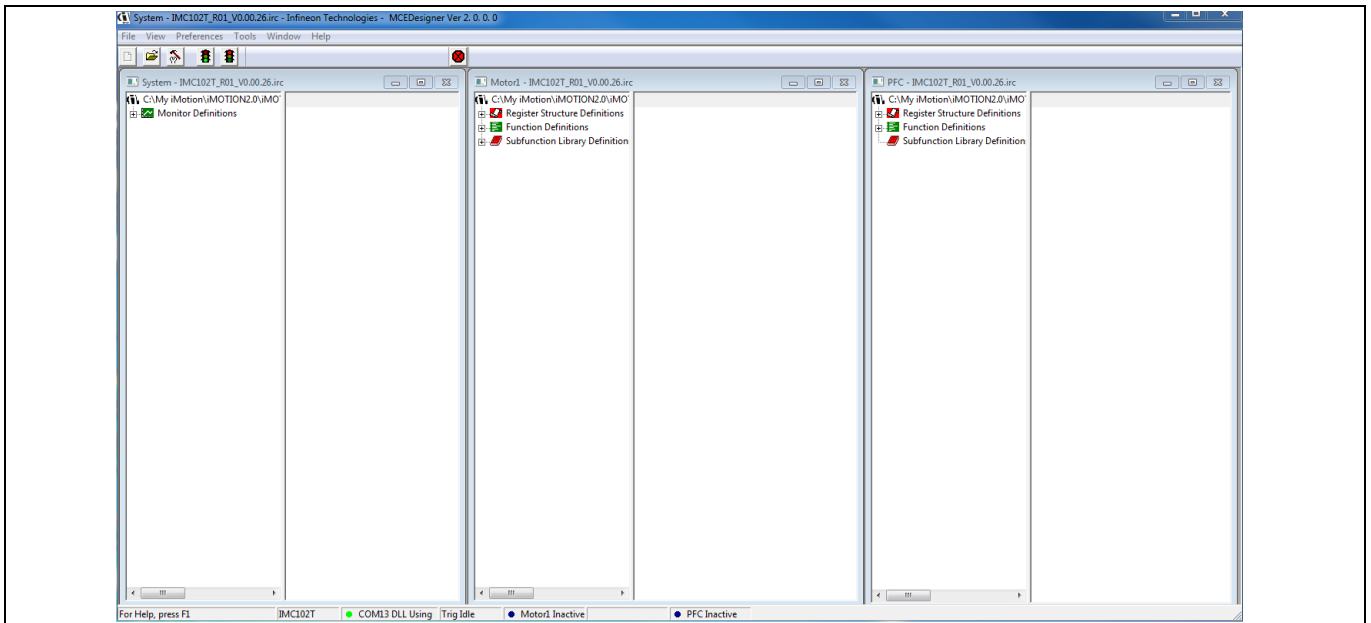
**Figure 5** Verify and Save page for MCEWizard

**Getting Started with EVAL-M3-TS6-665PN**

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.

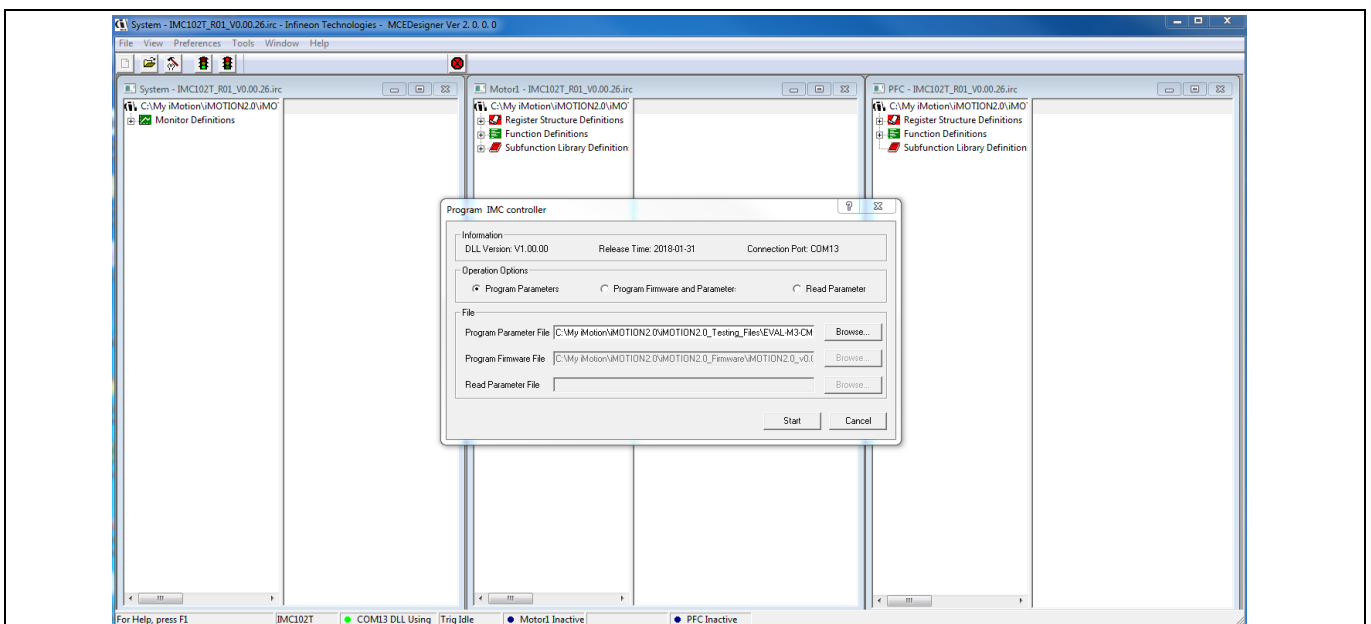
### 4.2.2 MCEDesigner setup overview

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 6 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 7. 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.



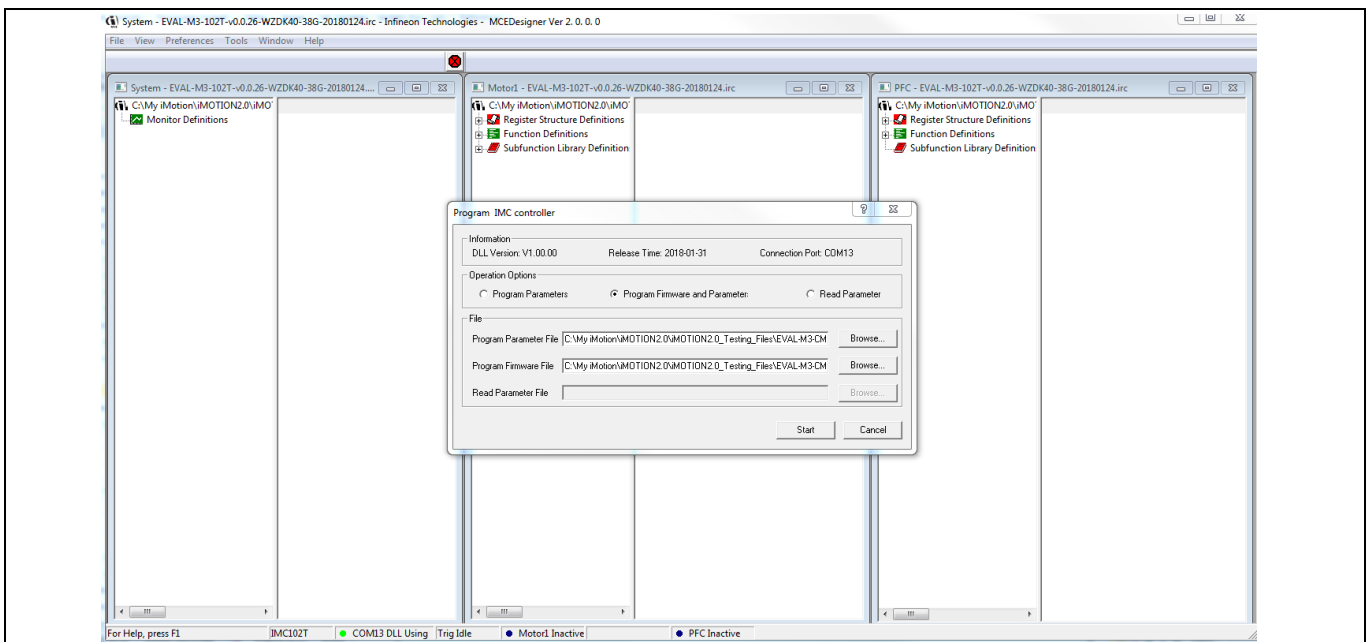
**Figure 7 “Program IMC Controller” pop-up window**

**Getting Started with EVAL-M3-TS6-665PN**

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 8. 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 8 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>).

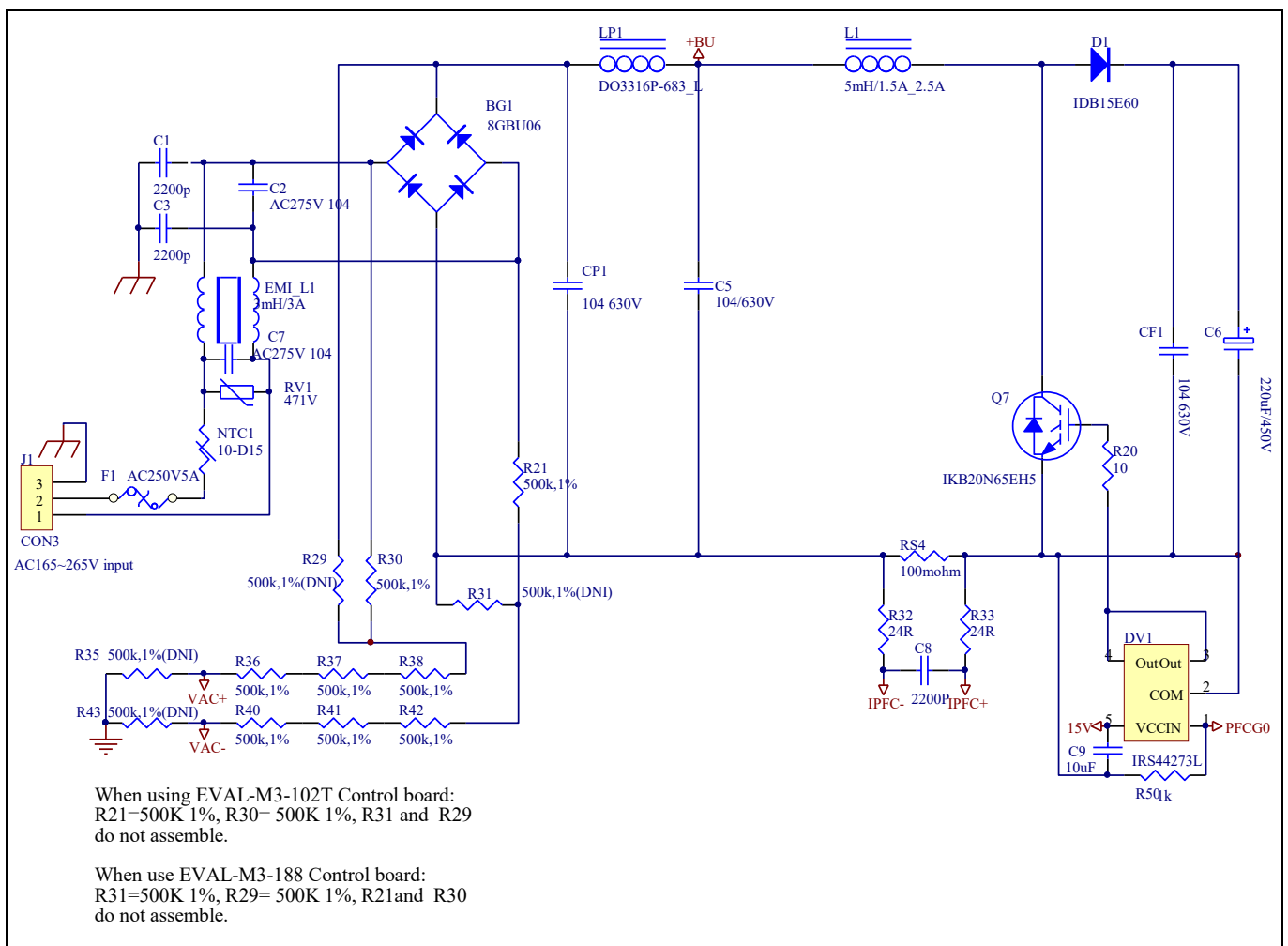


## 5 Hardware description of EVAL-M3-TS6-665PN

In order to meet individual customer requirements and make the EVAL-M3-TS6-665PN 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 IGBT and diode

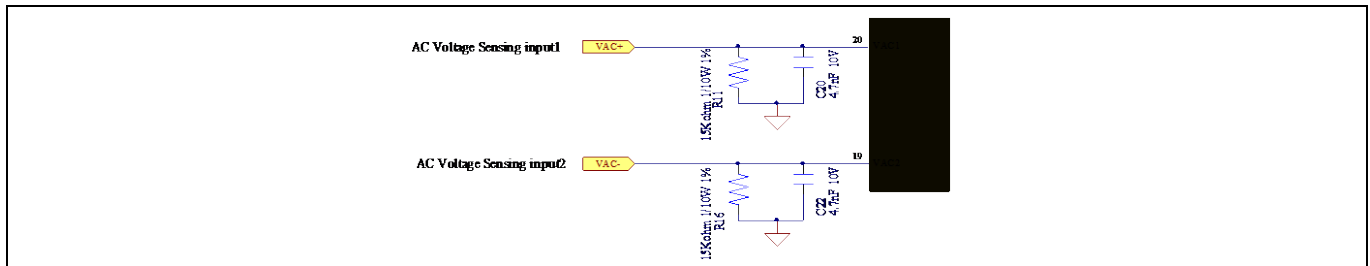
Figure 9 depicts the schematic from the AC input connector J1 to the rectified DC bus voltage DCP. This circuitry includes a passive EMI filter consisting of elements C2, C7, EMI\_L1, C1 and C3, a 8 A/600 V rectifier bridge BG1, a fuse F1 for inrush current protection, a NTC resistor reducing conduction losses in steady state. A PFC inductor L1. The PFC section is implemented using IGBT and diode as sketched in Figure 9. The IRS44273L is used to drive IGBT for PFC section.



**Figure 9 Schematic for EMI filter and PFC section of the Eval-M3-TS6-665PN evaluation board**

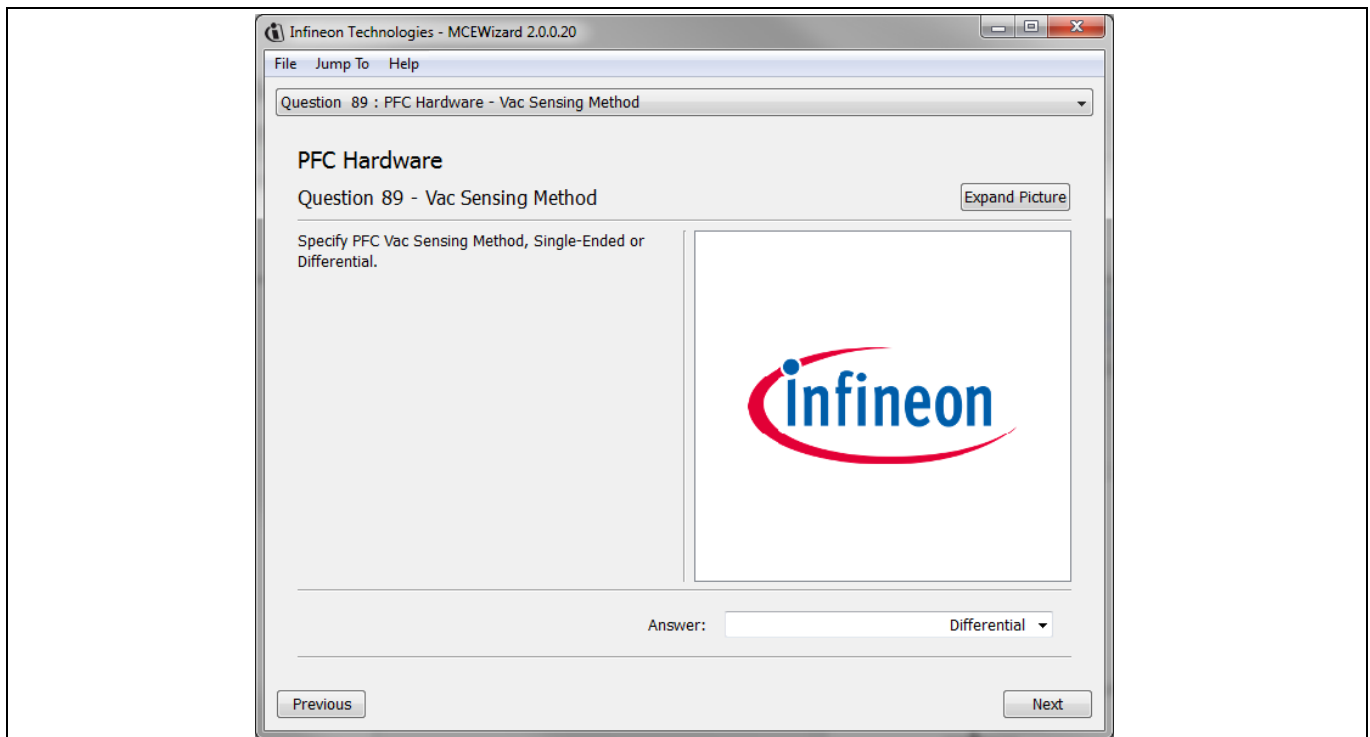
### 5.1.1 AC Voltage sensing and MCEWizard configuration

AC voltage sensing is in the front of rectifier bridge U1 by default as shown in Figure 10. To dive the boost PFC circuitry for EVAL-M3-TS6-665PN, the default matching MADK control board is EVAL-M3-102T. Figure 10 shows the VAC sensing schematic of EVAL-M3-102T evaluation board.



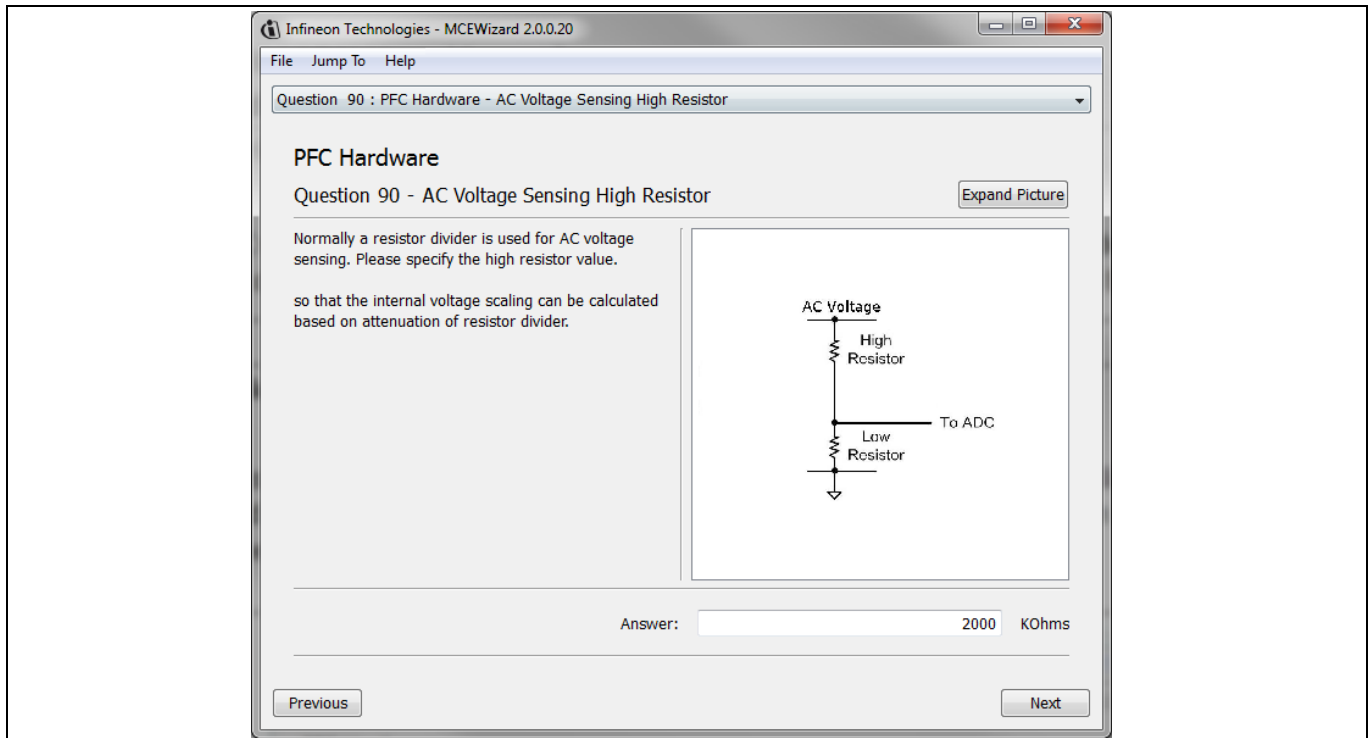
**Figure 10 The AC Voltage sensing schematic of EVAL-M3-102T**

There are two AC voltage sensing modes in MCEWizard, differential mode and single-ended as shown in Figure 11. Please select differential mode for the combination between EVAL-M3-TS6-665PN and EVAL-M3-102T.



**Figure 11 Vac Sensing Method configuration for EVAL-M3-102T and EVAL-M3-TS6-665PN**

The high side resistors R30 and R38 or R21 and R42 for the AC voltage sensing resistor divider on the power board EVAL-M3-TS6-665PN is 2000kΩ, and should be configured in MCEWizard as shown in Figure 12. For the low side resistor value, please refer to the User Manual of the corresponding control board.



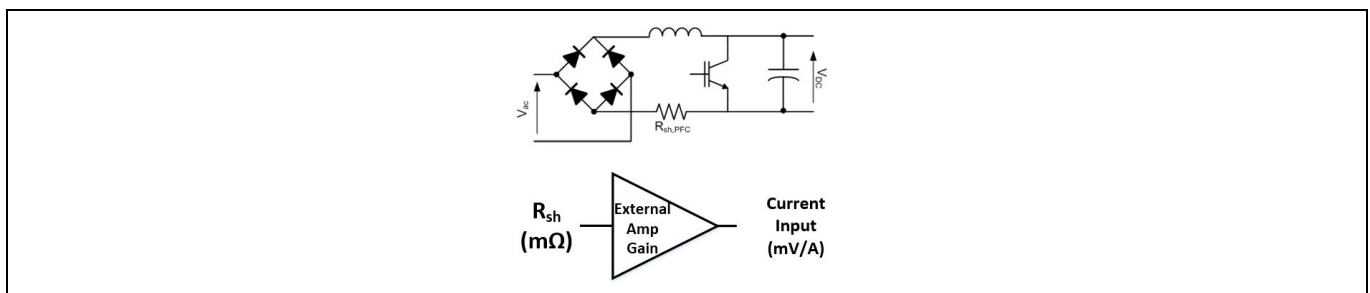
**Figure 12 AC Voltage sensing configuration in MCEWizard**

### 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 BG1 by default for this power board EVAL-M3-TS6-665PN as shown in Figure 9. But for control board EVAL-M3-188 with controller IC IRMCF188, AC Voltage sensing should be behind the rectifier bridge BG1. To work with control board EVAL-M3-188 or IRMCF188, power board EVAL-M3-TS6-665PN should be modified by assembling 500kΩ AC Voltage sensing resistors R31 and R29 and removing the resistors R21 and R30.

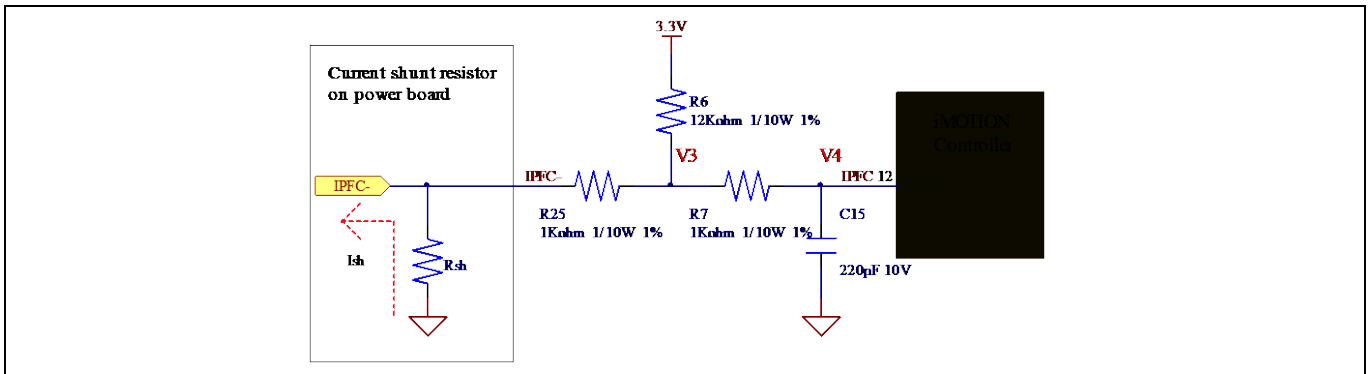
### 5.1.3 PFC External Current feedback configuration and calculation

The PFC shunt resistor RS4 is 100mΩ for EVAL-M3-TS6-665PN. 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 13.



**Figure 13 PFC Current shunt feedback and sample timing**

Figure 14 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 14 The PFC Current feedback circuit for EVAL-M3-102T evaluation board**

Based on the principle of Kirchhoff's voltage law,

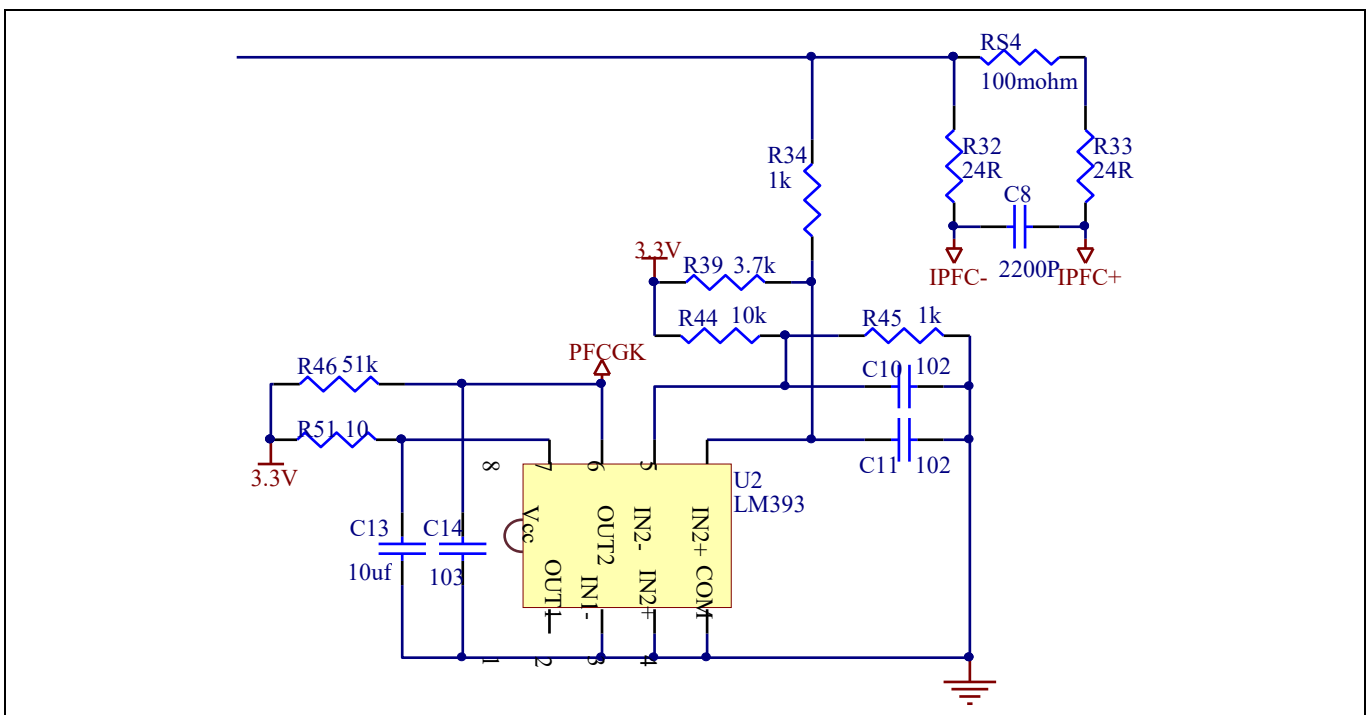
$$V_4 \approx V_3 \approx (V_{DD} + I_{sh} * R_{sh}) * \frac{R_{25}}{R_6 + R_{25}} - I_{sh} * R_{sh} = \frac{R_{25}}{R_6 + R_{25}} V_{DD} - \frac{R_6}{R_6 + R_{25}} R_{sh} * I_{sh}$$

$$Current\ input = \frac{R_6}{R_6 + R_{25}} R_{sh} = \frac{12}{13} R_{sh}$$

Based on this calculation, the current input for the MADK combination of EVAL-M3-102T and EVAL-M3-TS6-665PN is 92.3 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-TS6-665PN as shown in Figure 15, but the left side of RS4 is negative. If the bus current Ibus is larger than the setting value, the output PFCGK of U2 will be trigger low and be active.



**Figure 15 PFC protection Circuit on the EVAL-M3-TS6-665PN evaluation board**

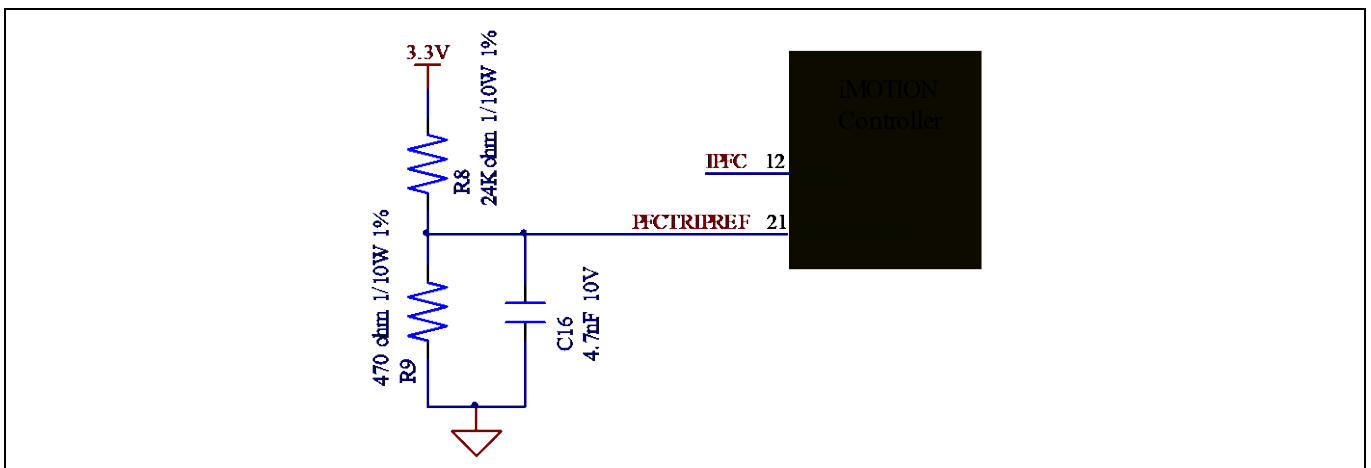
**Hardware description of EVAL-M3-TS6-665PN**

The PFCGK active setting current is 15.5A for EVAL-M3-TS6-665PN evaluation board. And the calculation formula is as follows,

$$I_{PFCGK} = \frac{\left( \frac{R_{34}}{R_{34} + R_{39}} - \frac{R_{45}}{R_{45} + R_{44}} \right) * V_{DD}}{\frac{R_{34}}{R_{34} + R_{39}} * R_{S4}} = \frac{\left( \frac{R_{34}}{R_{39}} - \frac{(R_{34} + R_{39}) * R_{45}}{(R_{45} + R_{44}) * R_{39}} \right) * V_{DD}}{R_{S4}}$$

Please attention that for control board EVAL-M3-102T, it doesn't use the external PFC gatekill signal PFCGK.

*Note: PFC Overcurrent protection circuit just generates the signal of PFCGK, and there is no more action for EVAL-M3-TS6-665PN. 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 16 The PFCTRIPREF 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 14 and Figure 16. The  $I_{PFCTRIP\_Peak}$  equal to 6.347A for the combination between EVAL-M3-102T and EVAL-M3-TS6-665PN only.

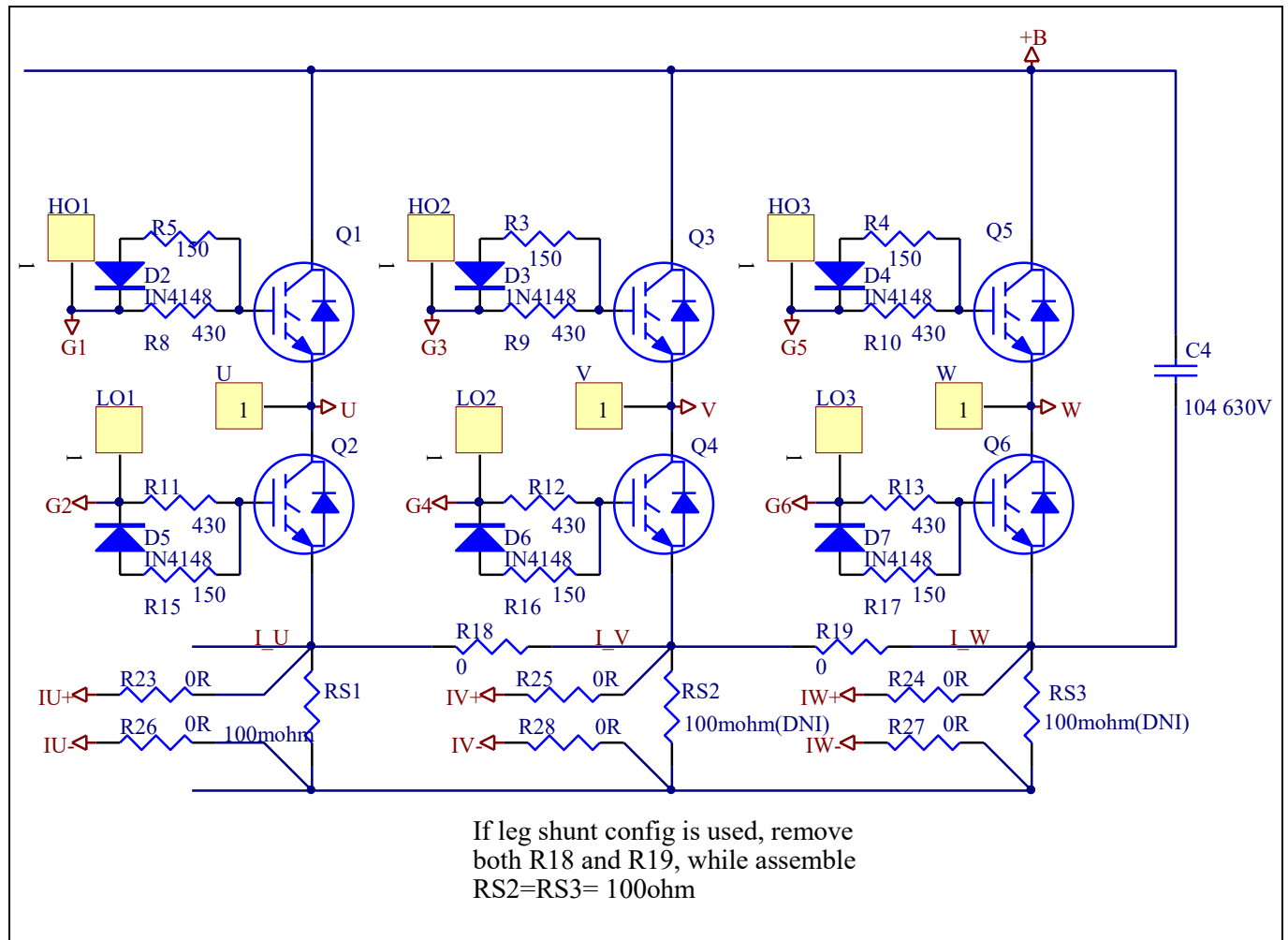
The calculation formula is as follows,

$$I_{PFCTRIP\_Peak} = \frac{(R_{25} * R_8 - R_6 * R_9) * V_{DD}}{(R_8 + R_9) * R_6 * R_{S4}}$$

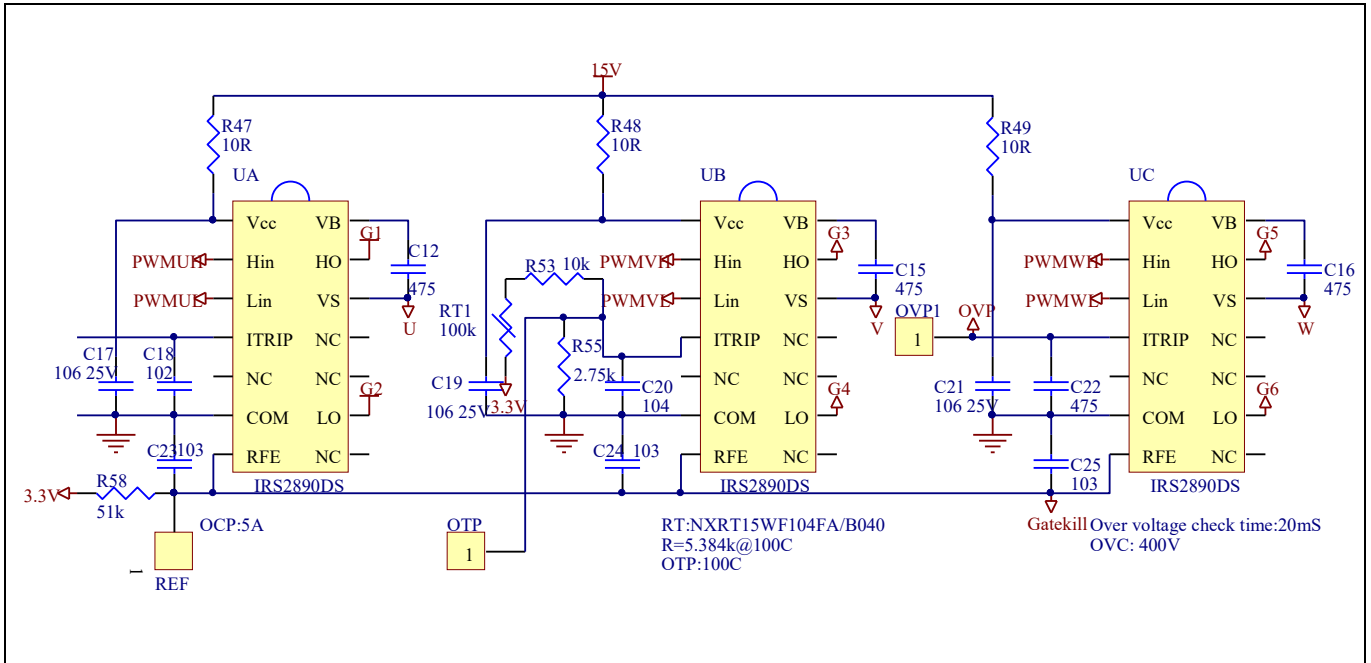
If larger PFC current protection setting value needed, please use smaller resistance of PFC shunt resistor RS4, or modify the control board EVAL-M3-102T following the previous formula. Please refer to the control board's user manual for more details.

## 5.2 Inverter section using six discrete IGBTs and three gate drivers

The inverter section is also implemented using six discrete IGBTs and three gate drivers as sketched in Figure 17.



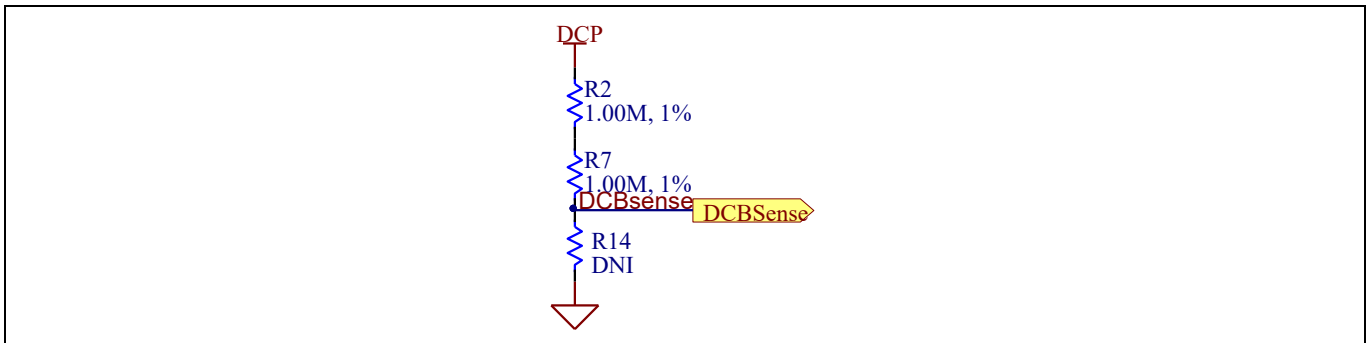
**Figure 17 Schematic of the 3-phase inverter section using six discrete IGBTs on EVAL-M3-TS6-665PN**



**Figure 18 Schematic of the 3-phase inverter section using three gate drivers on EVAL-M3-TS6-665PN**

### 5.2.1 DC-Link Voltage Measurement

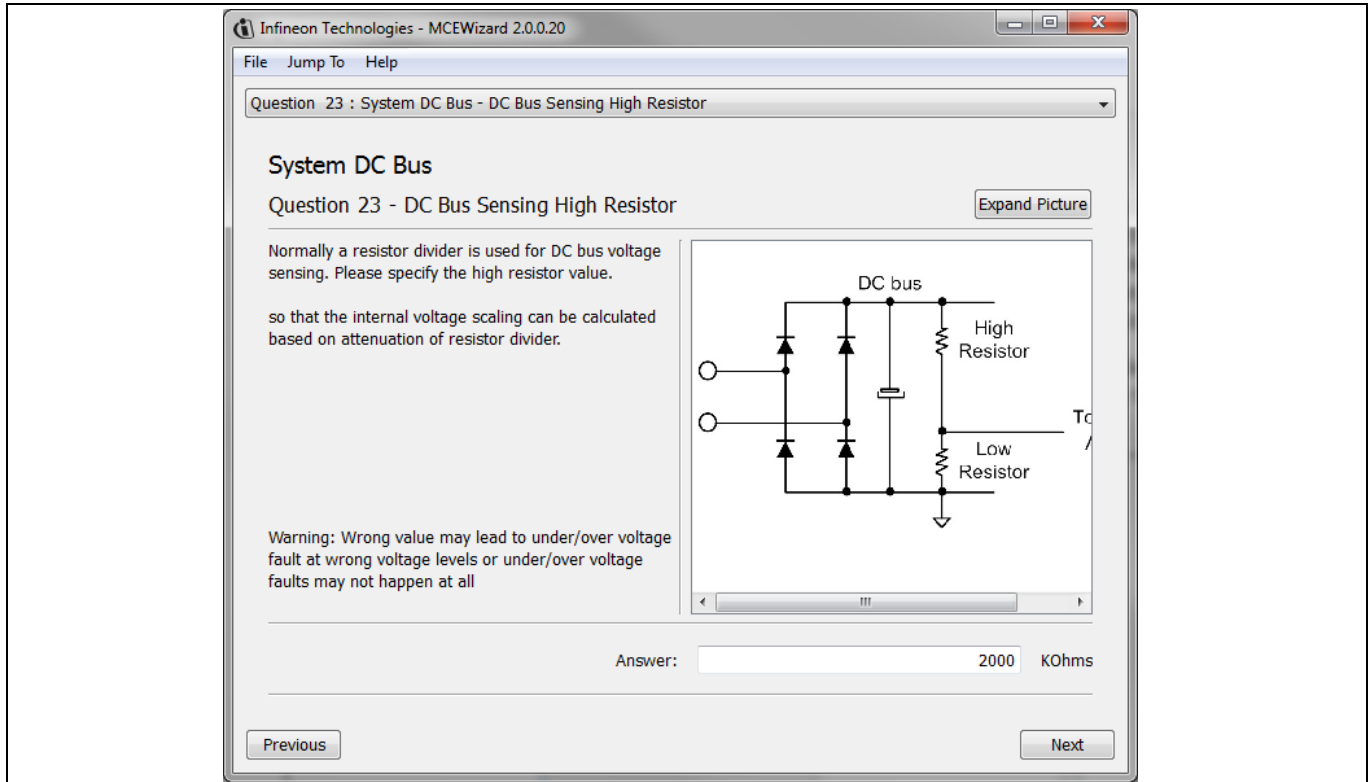
Pin 14 and pin 26 of connector JP1 provide access to the DC-link voltage. Three possible feedback cases are associated with this pin. Figure 19 provides the DC bus sense resistor details. By default, the resistor R14 is not mounted on Eval-M3-TS6-665PN. There must be a pull-down resistor mounted on the corresponding controller board.



**Figure 19 DC bus sense resistor on Eval-M3-TS6-665PN evaluation board**

If a pull down resistor of 13.3 kΩ referred to ground is inserted either on the Eval-M3-TS6-665PN 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-TS6-665PN 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, R2 or R7 should be removed to avoid high voltage on the connector.

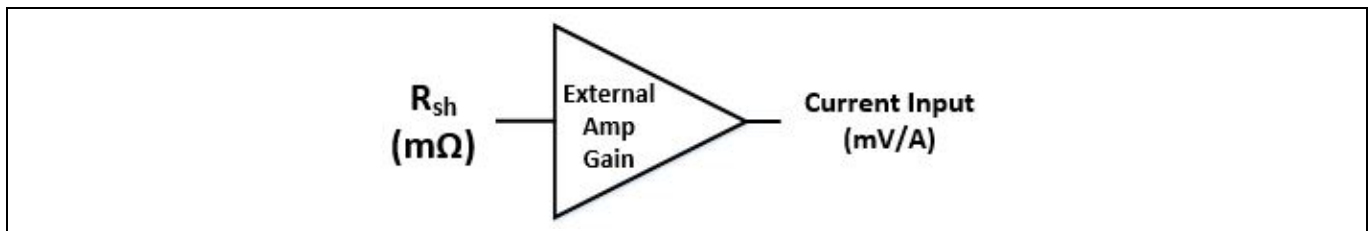
The high side resistors R2 and R7 for the DC bus sensing resistor divider on the controller board EVAL-M3-TS6-665PN are 2000kΩ, and should be configured in MCEWizard as shown in Figure 20. For the low side resistor value, please refer to the User Manual of the corresponding control board.



**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.

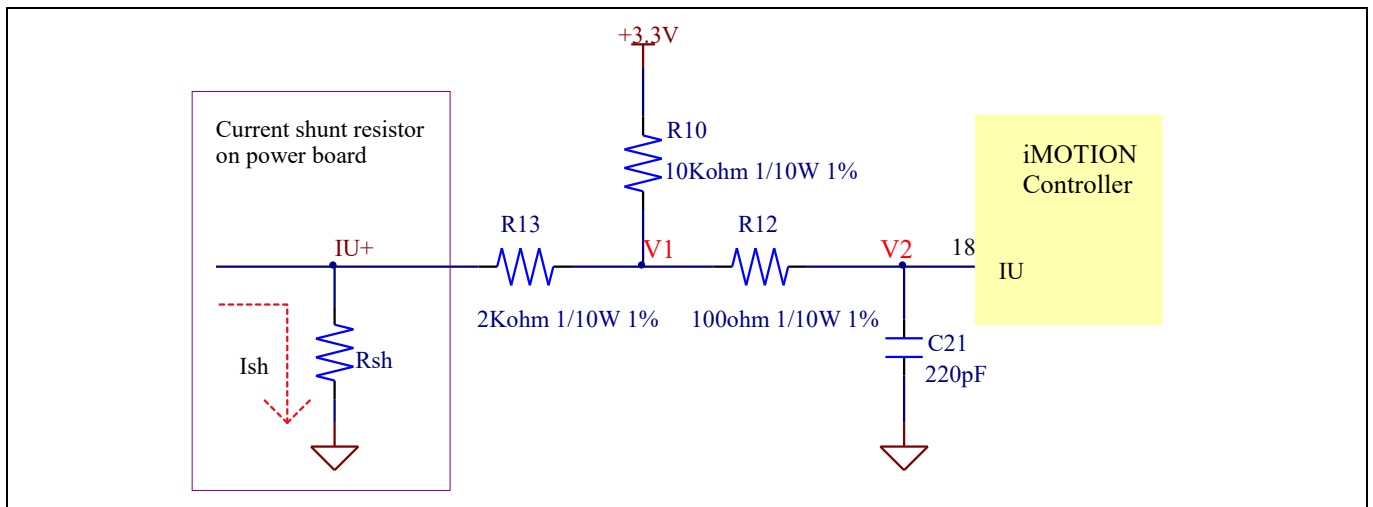


**Figure 21 Current shunt feedback and sample timing for EVAL-M3-102T**

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**

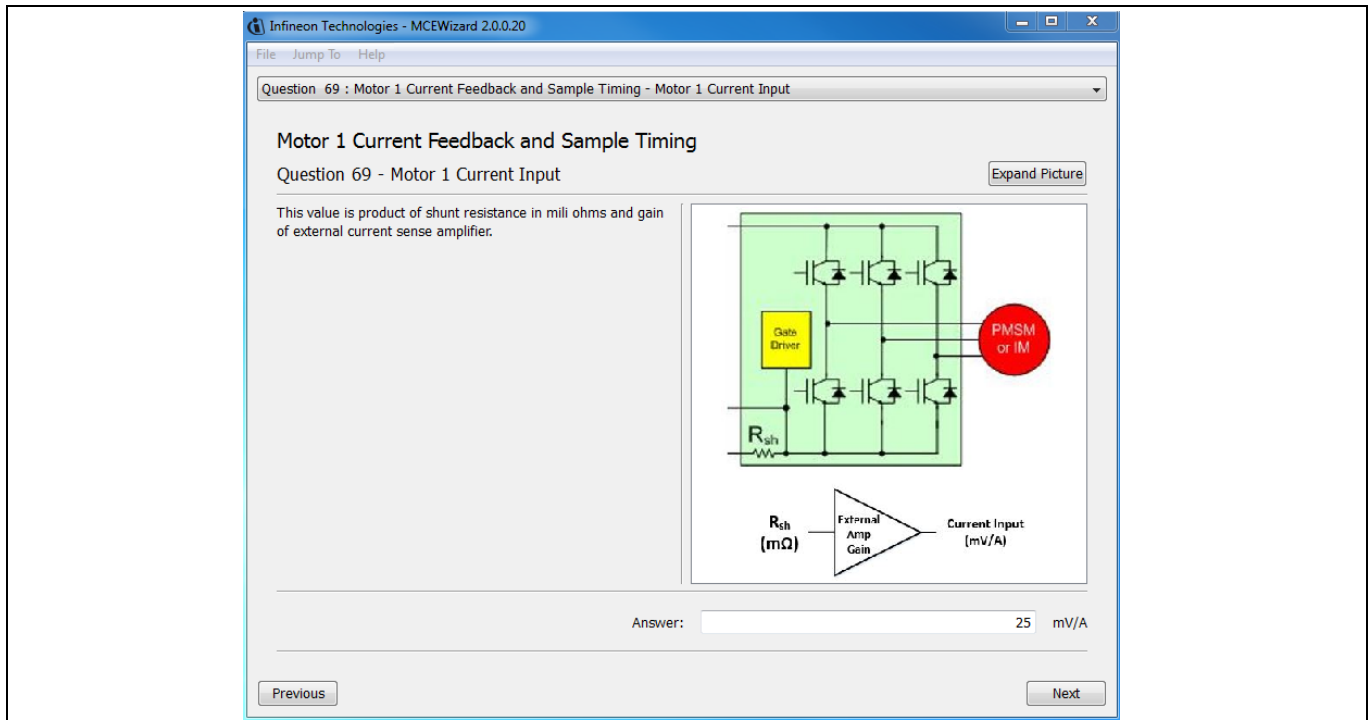
Based on the principle of Kirchhoff's voltage law,

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

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

Based on this calculation, the current input for the MADK combination of EVAL-M3-102T and EVAL-M3-TS6-665PN is 25 mV/A.

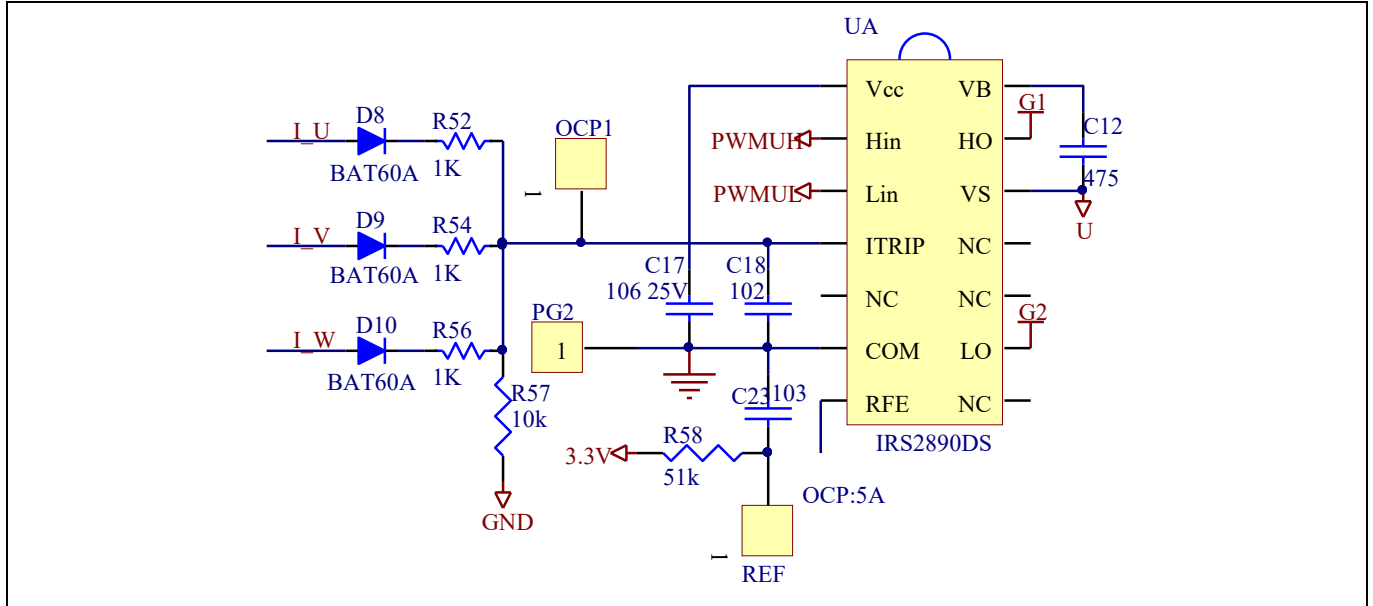
Please use same procedure to calculate the current input for other combinations of MADK boards and enter it into MCEWizard as shown in Figure 23.



**Figure 23** Current feedback configuration in MCEWizard for EVAL-M3-102T and EVAL-M3-TS6-665PN

### 5.2.3 Inverter Overcurrent protection and Motor Gatekill configuration

Figure 24 displays the inverter overcurrent protection circuitry implemented using IRS2890DS. The current sensing signal is connected to ITRIP via the resistor R57, and ITRIP is filtered through capacitor C18.



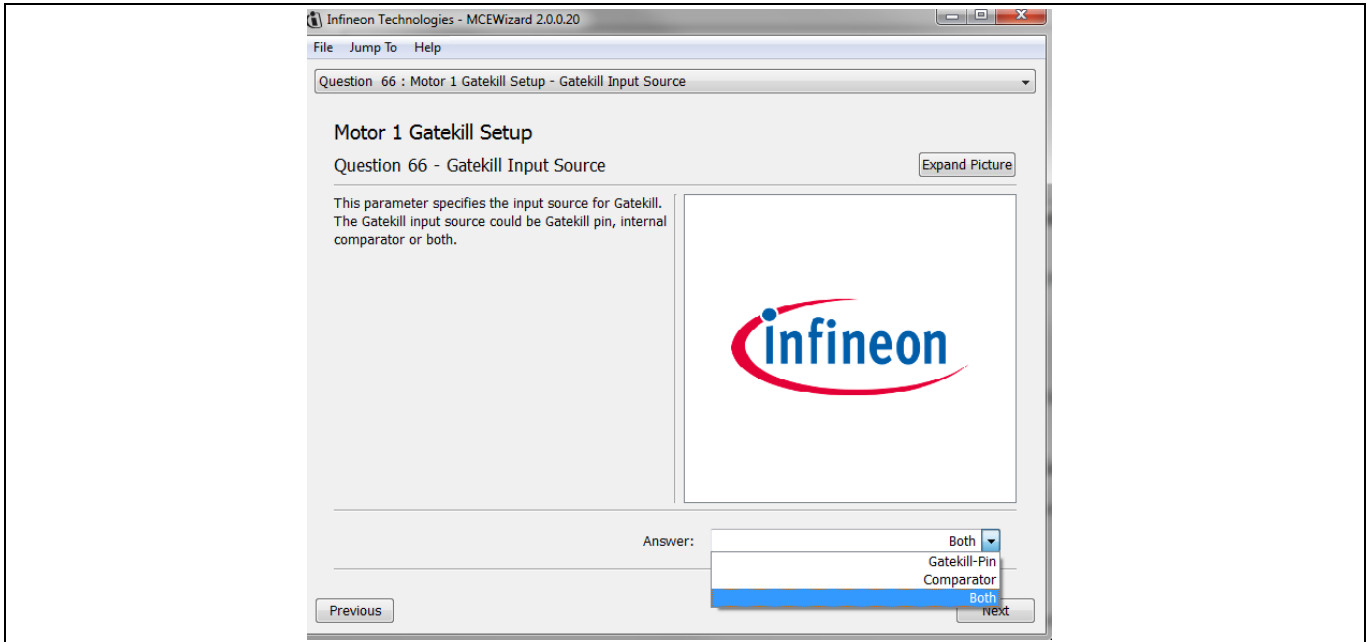
**Figure 24 Overcurrent protection circuit on the Eval-M3-TS6-665PN evaluation board**

The typical value of ITRIP positive going threshold  $V_{IT,TH+}$  is 550mV. So the inverter output peak current is about 5.5A.

$$I_{trip} = \frac{V_{IT,TH+}}{R_{shunt}} = \frac{550mV}{100m\Omega} = 5.5A$$

If the motor peak current larger than the setting value  $I_{trip}$  for more than ITRIP input filter time, RFE will be trigger low which means 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.

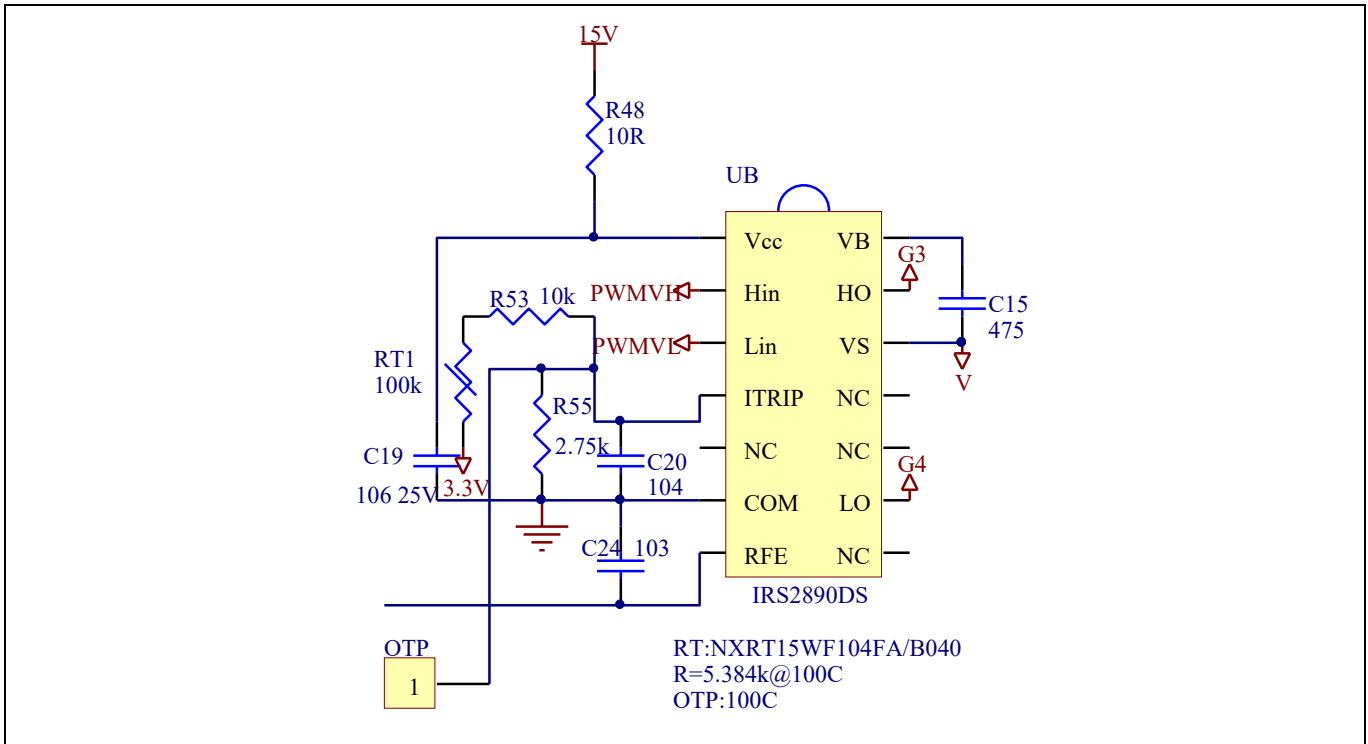
But please note that, if select “comparator” for gatekill input source, the external gatekill signal will be not used. And the current sensing signal  $I_{Shunt}$  will be compared by the internal comparator with the “Gatekill Comparator Reference” value set in MCEWizard only.



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

### 5.2.4 Overtemperature Hardware Protection Circuit

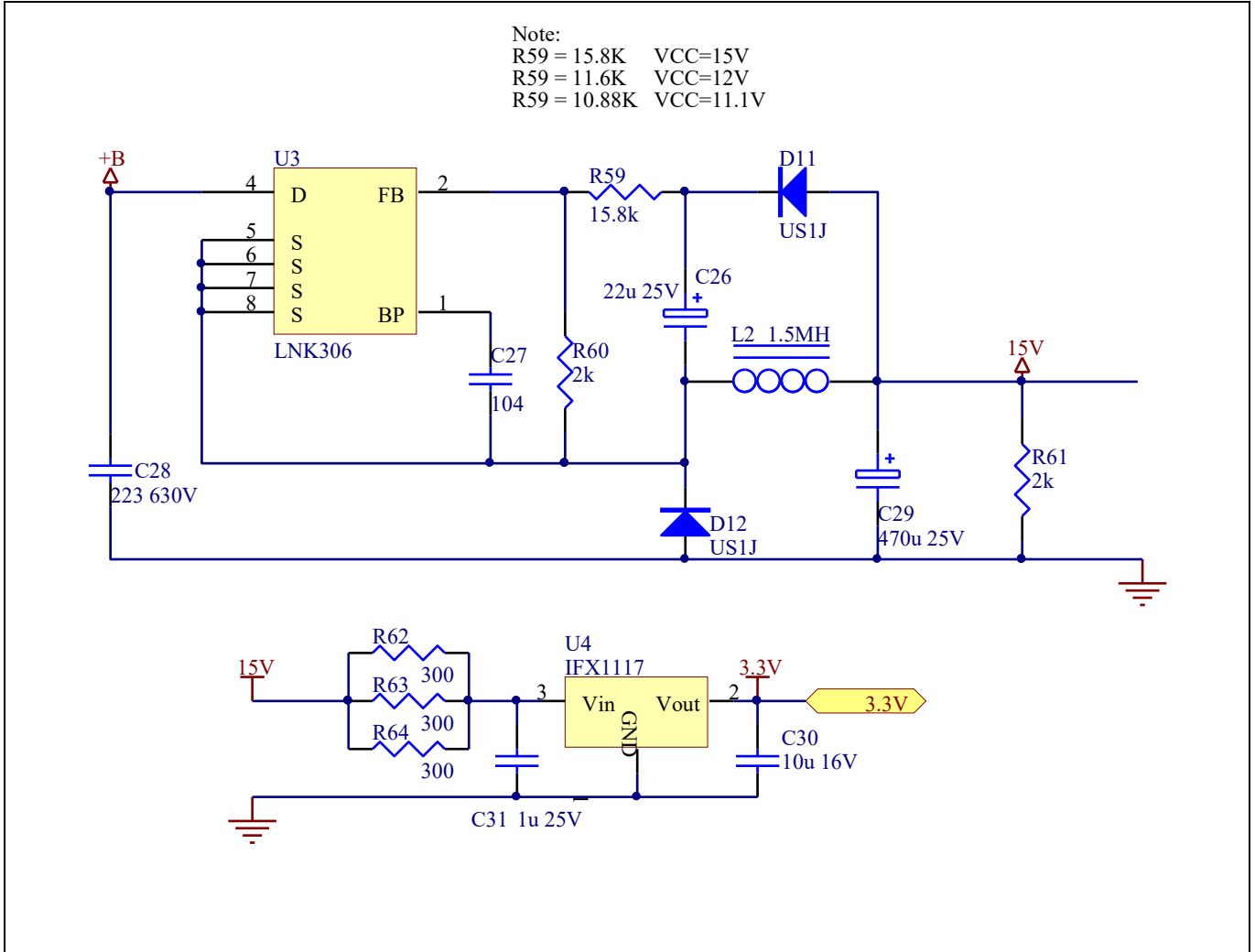
A temperature protection circuit is implemented for IGBT Q4, as shown in Figure 26, connecting NTC to ITRIP pin through a resistor divider. The default temperature threshold is setting is 100°C. When the IGBT Q4 case temperature is higher than 100°C, the OTP1 value will be higher than the ITRIP positive going threshold value, and then the gate driver will be turn off issuing a fault signal through RFE pin. The fault signal will be read by the other two inverter gate drivers causing the turn off of all inverter stage.



**Figure 26 External temperature sense input configuration**

### 5.2.5 Auxiliary power supply

Figure 27 depicts the schematic of the auxiliary power supply for the Eval-M3-TS6-665PN board. The circuit includes a LNK306 that is used to generate 15 V directly from the DC bus.  $V_{CC}$  is connected to the gate drivers.

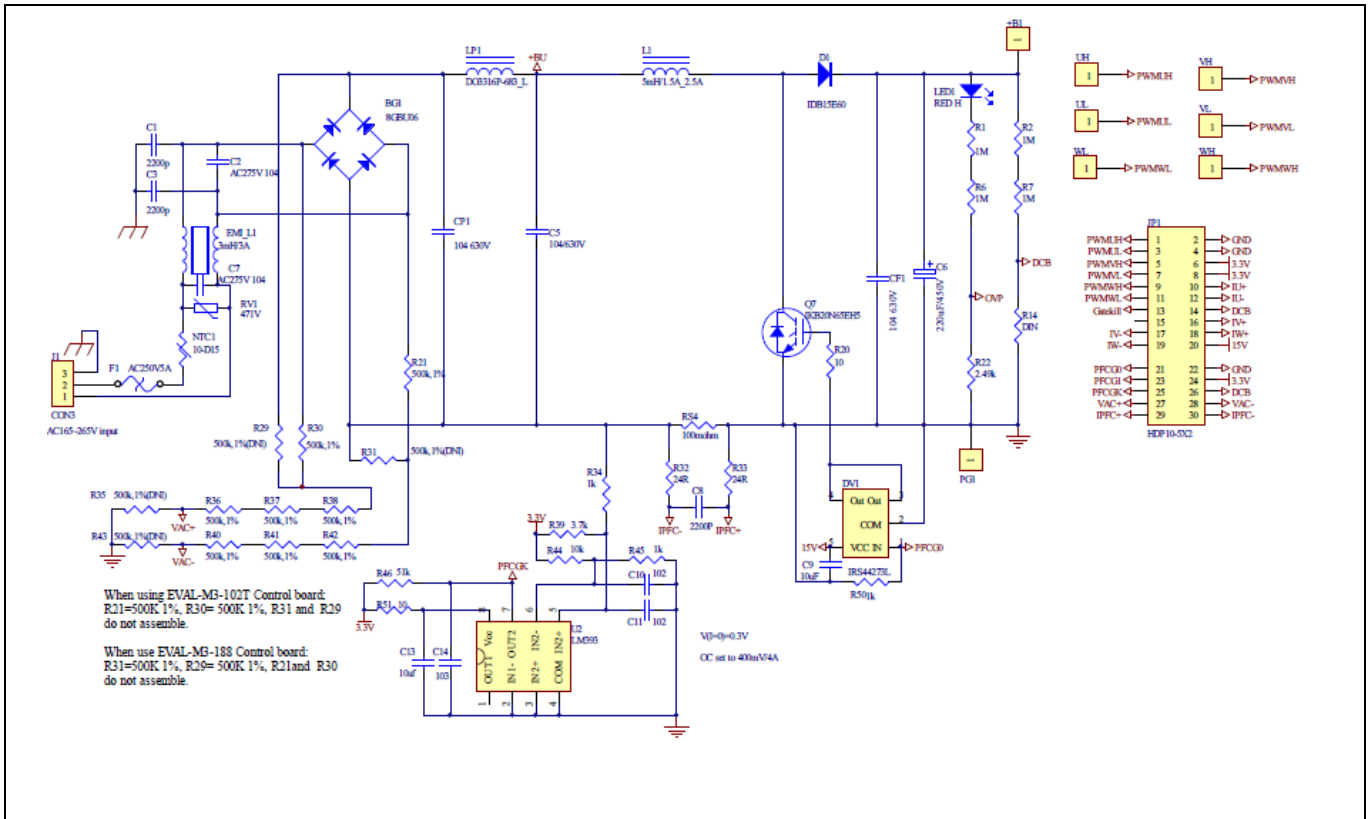


**Figure 27 Power supply section of the Eval-M3-TS6-665PN evaluation board**

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

### 5.2.6 PFC stage schematic

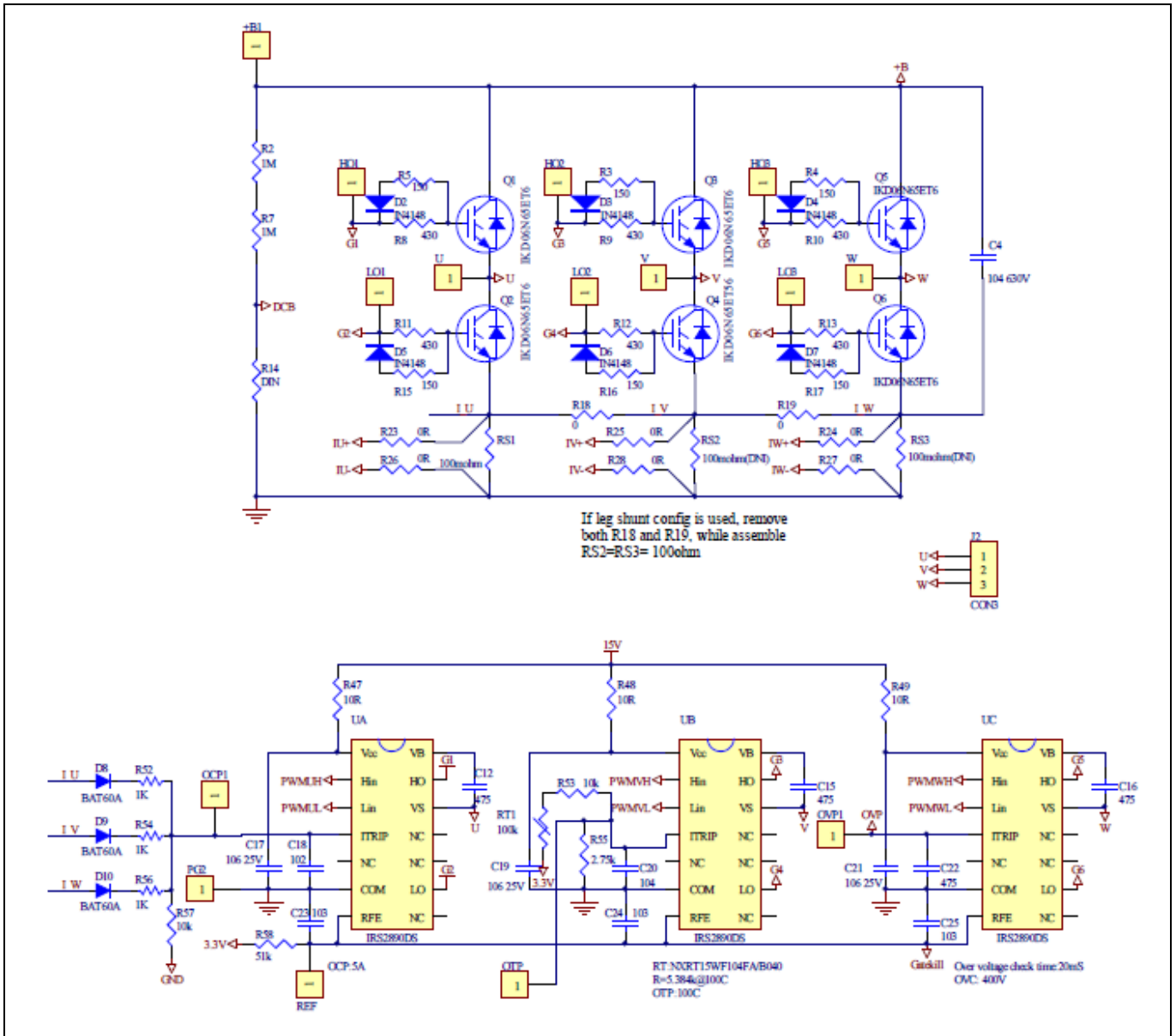
The PFC section schematic for EVAL-M3-TS6-665PN is provided in Figure 28.



**Figure 28 PFC Section Schematic on the Eval-M3-TS6-665PN evaluation board**

### 5.2.7 Inverter stage schematic

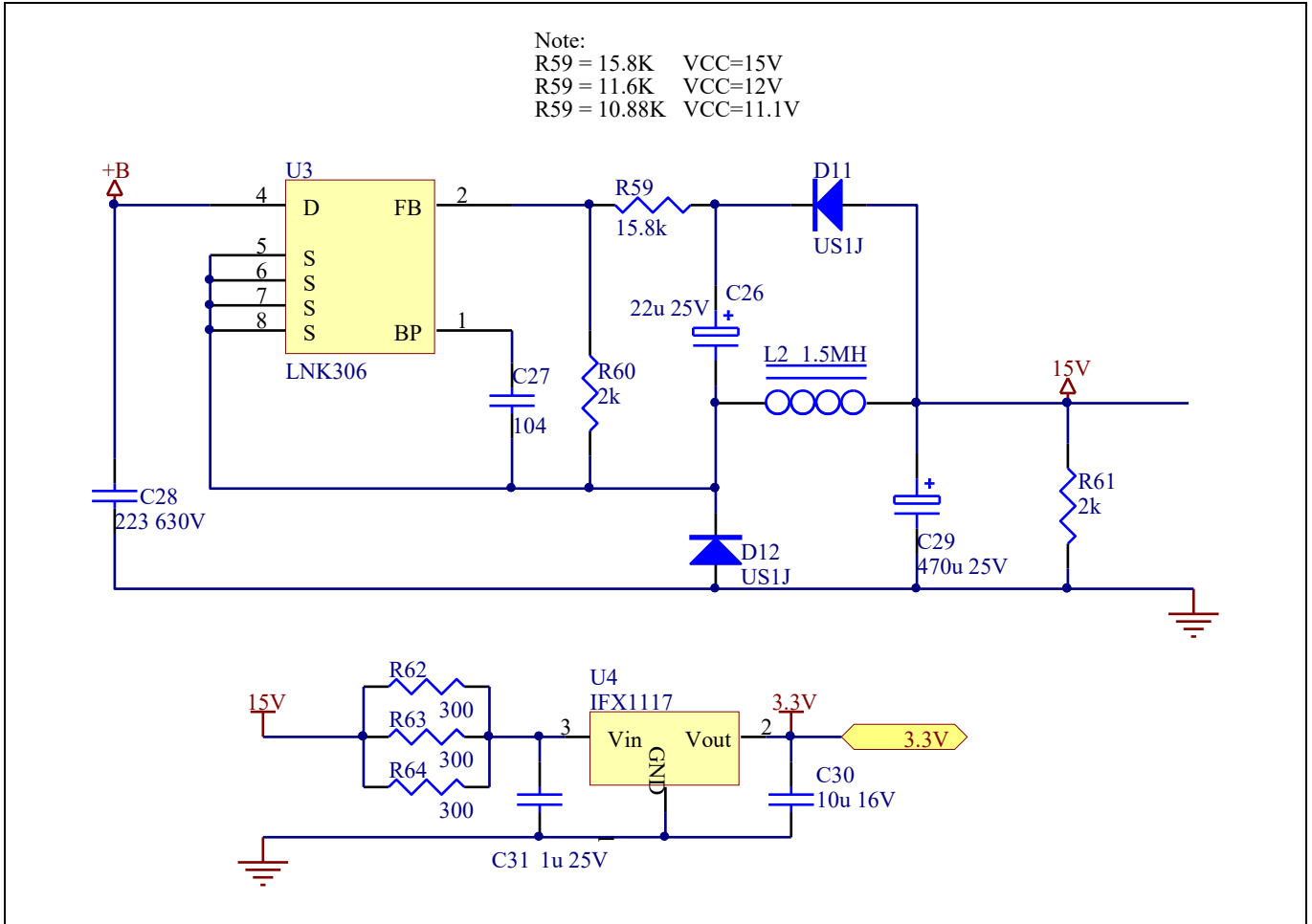
The Inverter section schematic for EVAL-M3-TS6-665PN is provided in Figure 29.



**Figure 29 Inverter Section Schematics for the Eval-M3-TS6-665PN evaluation board**

### 5.2.8 Auxiliary stage schematic

The Auxiliary Power Supply section schematic for EVAL-M3-TS6-665PN is provided in Figure 30.



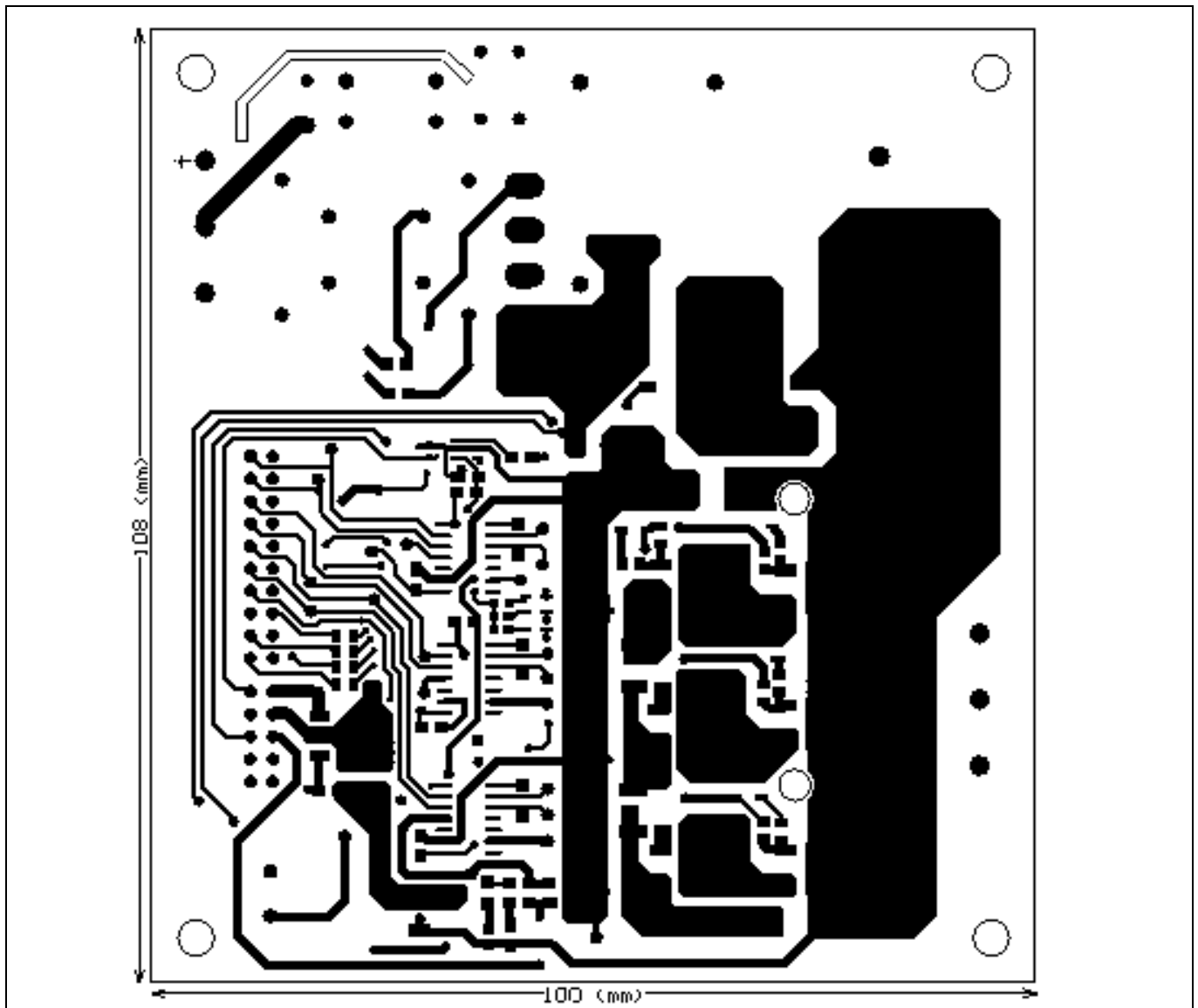
**Figure 30 Auxiliary Power Supply Section Schematics for the Eval-M3-TS6-665PN evaluation board**



### 5.3 PCB Layout

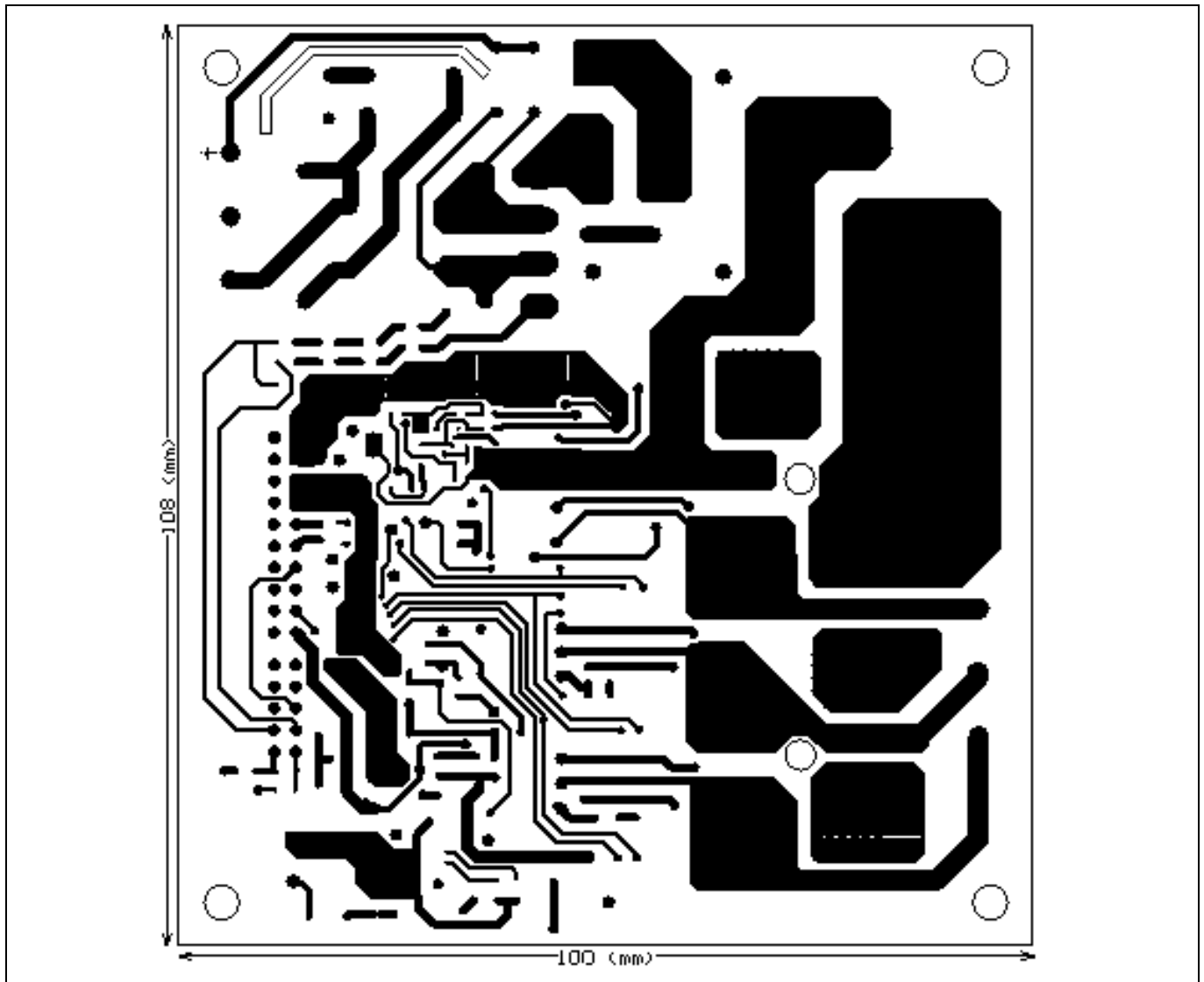
The layout of this board can be used for different voltage or power classes. The PCB has two electrical layers with 35µm copper by default and its size is 100 mm × 110 mm. The PCB board thickness is 1.6mm. Get in contact with our technical support team to get more detailed information and the latest Gerber-files.

Figure 31 illustrates the top assembly print of the evaluation board.



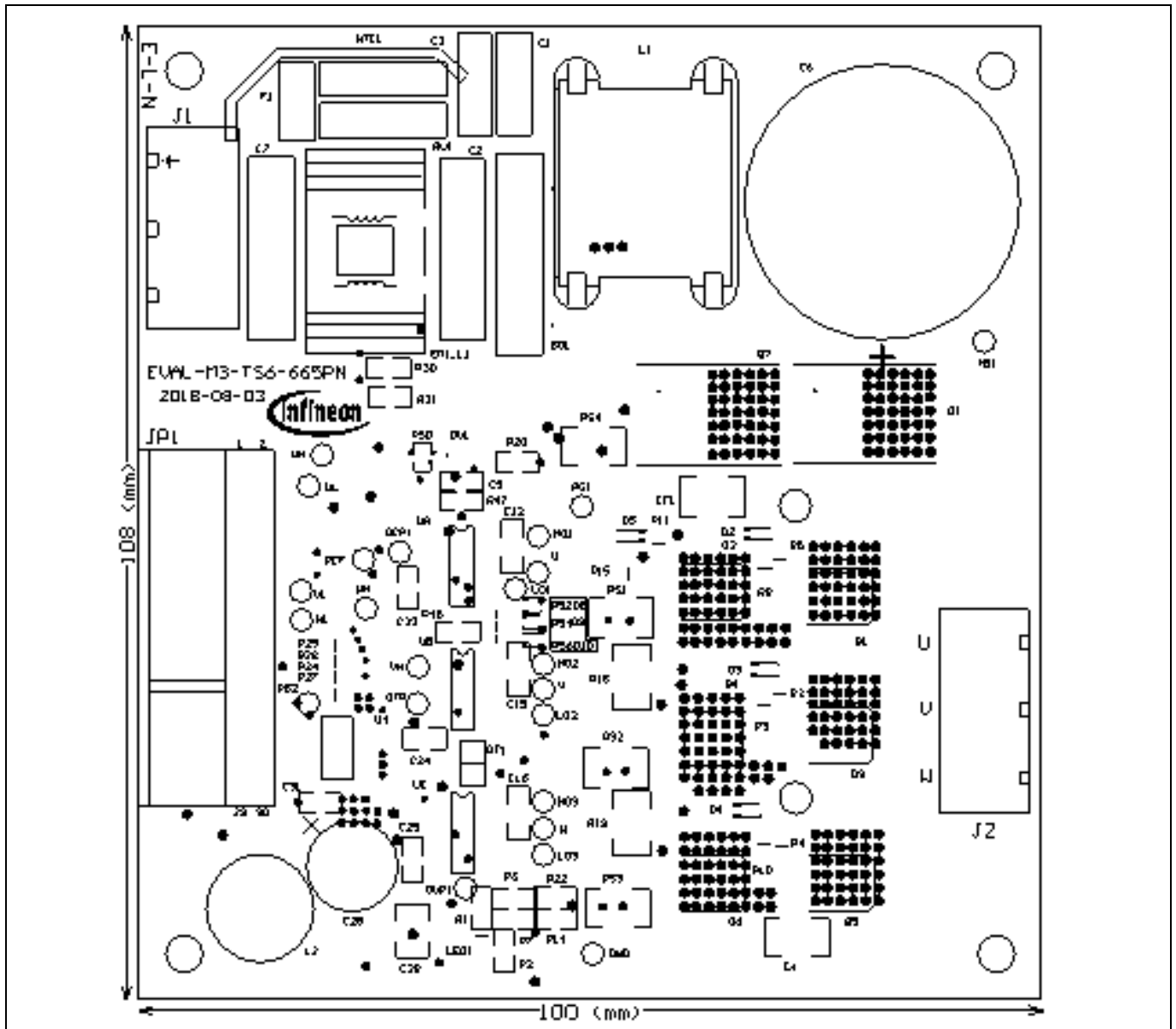
**Figure 31 Top assembly print of the Eval-M3-TS6-665PN evaluation board**

Figure 32 depicts the bottom assembly print of the evaluation board.



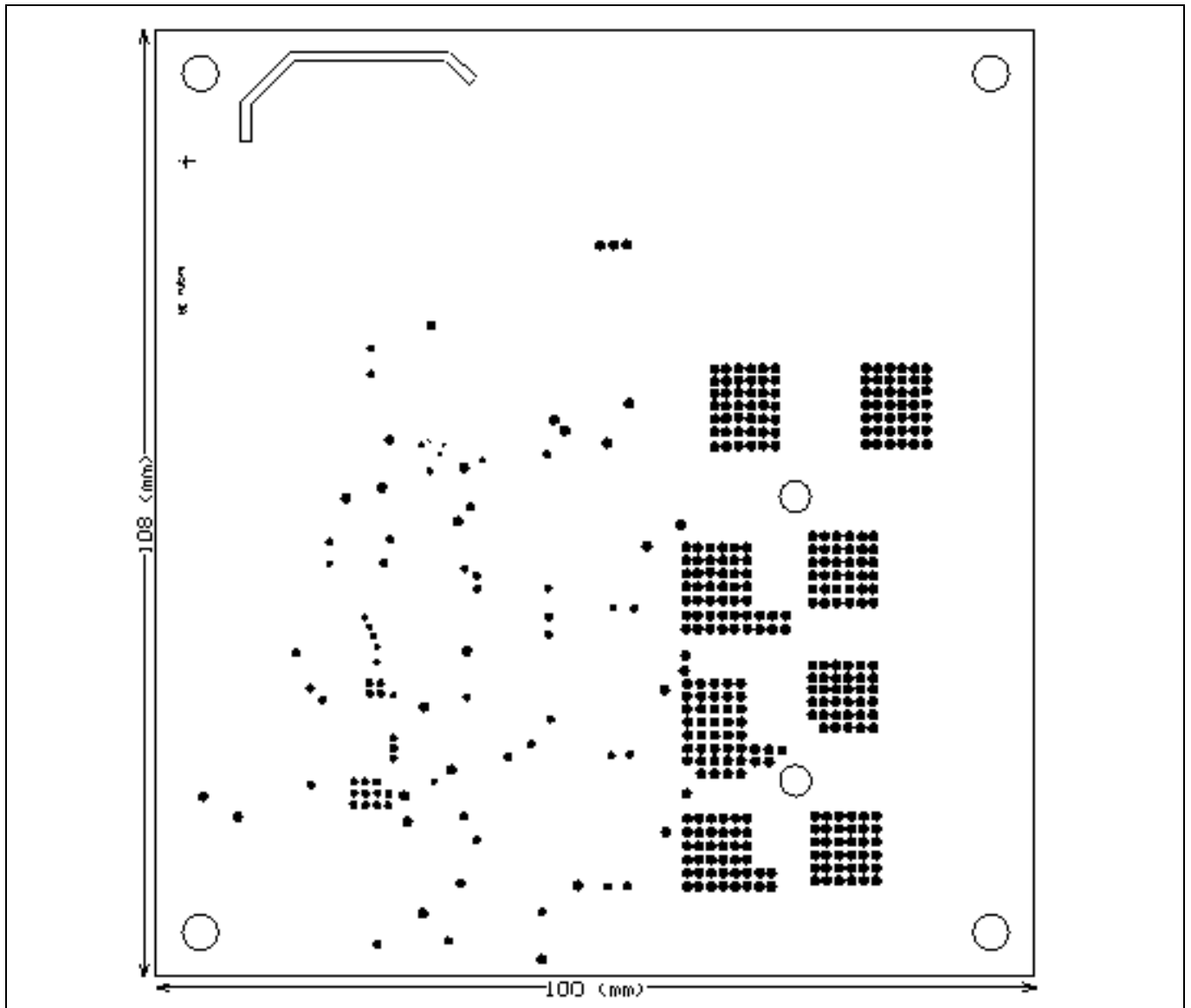
**Figure 32 Bottom assembly print of the Eval-M3-TS6-665PN evaluation board**

The top layer routing of the PCB is provided in Figure 30.



**Figure 33 Top layer routing of the Eval-M3-TS6-665PN**

Figure 34 illustrates the bottom layer routing of the PCB.



**Figure 34** Bottom layer routing of the Eval-M3-TS6-665PN

## 6 Bill of Materials of Eval-M3-TS6-665PN

Table 7 provides the complete bill of materials of the evaluation board.

**Table 7 Bill of materials**

No.	Qty	Part description	Designator	Part number	Manufacturer
01	1	RECT BRIDGE GPP 8A 600V GBU	BG1	GBU806	DIODES INCORPORATED
02	2	CAP CER 2200pF 250VAC RADIAL	C1, C3	DE2E3KY222MN3AM02F	MURATA ELECTRONICS
03	4	CAP CER 0.1UF630V X7R 1812	C4, C5, CF1, CP1	885342211006	Würth Electronics Inc.
04	5	CAP CER 10µF 25V X5R 0805	C9, C17, C19, C21, C30	C2012X5R1E106M125AB	TDK Corporation
05	3	CAP CER 10000PF 50V X7R 0805	C23, C24, C25	885012207092	Würth Electronics Inc.
06	1	CAP CER 10UF 6.3V X7R 0603	C13	885012107004	Würth Electronics Inc.
07	2	CAP FILM 0.1µF 20% 275VAC RADIAL	C2, C7	890324025017CS	Würth Electronics Inc.
08	2	CAP CER 1000PF 50V X7R 0603	C10, C11	885012206008	Würth Electronics Inc.
09	1	CAP ALUM 220UF 20% 450V SNAP	C6	861011485016	Würth Electronics Inc.
10	3	CAP CER 4.7UF 25V X5R 1206	C12, C15, C16	885012208068	Würth Electronics Inc.
11	1	CAP CER 1000PF 50V X7R 0805	C18	885012007063	Würth Electronics Inc.
12	2	CAP CER 0.1µF 50V X7R 0805	C20, C27	885012207098	Würth Electronics Inc.
13	1	CAP CER 1µF 25V X7R 0805	C31	885012207078	Würth Electronics Inc.
14	1	CAP CER 22UF 25V X5R 1206	C26	TMK316BBJ226ML-T	Taiyo Yuden
15	1	CAP ALUM 470UF 20% 25V RADIAL	C29	860020474014	Würth Electronics Inc.
16	1	CAP CER 0.022UF 630V X7R 1210	C28	C1210V223KBRAC7800	kemet
17	1	CAP CER 10000PF 50V X7R 0603	C14	885012206089	Würth Electronics Inc.
18	1	CAP CER 0.022UF 1000V X7R 1210	C28	885342209007	Würth Electronics Inc.
19	1	CAP CER 2200PF 50V C0G/NP0 0805	C8	885012007065	Würth Electronics Inc.
20	6	Diode GEN PURP 100V 300mA SOD123	D2, D4, D5, D6, D7, D3	1N4148W-7-F	Diodes Incorporated
21	2	Diode Standard 600V 1A Surface Mount SMA	D11, D12	US1J-13-F	Diodes Incorporated
22	1	WE-CMB Power Choke 5mH 2.5A 95m	EMI_L1	744823305	Würth Electronics Inc.
23	1	FUSE CERAMIC 5A 250VAC	F1	5HF-5	Bel Fuse Inc.
24	2	TERMINAL BLOCK 7.50MM 3POS PCB	J1, J2	691216910003	Würth Electronics Inc.

**Bill of Materials of Eval-M3-TS6-665PN**

No.	Qty	Part description	Designator	Part number	Manufacturer
25	1	HEADER 20POS SCKT R/A DL 2.54 MM & HEADER 10POS SCKT R/A DL 2.54 MM	JP1	613020243121 & 613010243121	Würth Electronics Inc.
26	1	Inductor 5mH/2A	L1	NPH107060	Pocomagnetic
27	1	RFS1113 1500uH 10% 1.36Ohms Radial Shld	L2	RFS1317-155KL	Coilcraft
28	1	LED RED CLEAR 0805 SMD	LED1	150080RS75000	Würth Electronics Inc.
29	1	FIXED IND 68UH 1.6A 240 MOHM SMD	LP1	74456168	Würth Electronics Inc.
30	1	NTC thermistors for inrush	NTC1	NTC10D-15	Veteng Electronic
31	4	RES SMD 1MΩ 1% 1/8W0805	R1, R2, R6, R7	RC0805FR-071ML	Yageo
32	6	RES SMD 150 OHM 0.1% 1/8W 0805	R3, R4, R5, R15, R16, R17	RT0805BRB07150RL	Yageo
33	6	RES SMD 430 OHM 1% 1/8W 0805	R8, R9, R10, R11, R12, R13	RC0805FR-07430RL	Vishay Beyschlag
34	1	DIN	R14	DIN	DIN
35	2	RES SMD 0 OHM JUMPER 3/4W 1812	R18, R19	ERJ-12Y0R00U	Panasonic Electronic Components
36	1	RES SMD 10 OHM 1% 1/8W 0805	R20	RC0805FR-0710RL	Yageo
37	10	RES SMD 500K OHM 0.1% 0.06W 0805	R21, R30, R36, R37, R38, R40, R41, R42 R29(DNI), R31(DNI),	PHT0805Y5003BGTB	Vishay Dale
38	2	RES 500K OHM 1% 300MW 1206	R35(DNI), R43(DNI)	CRMA1206AF500KFK EF	Vishay Dale
39	1	RES SMD 2.49K OHM 0.1% 1/8W 0805	R22	RT0805BRD072K49L	Yageo
40	6	RES SMD 0 OHM JUMPER 1/8W 0805	R23, R24, R25, R26, R27, R28	AC0805JR-070RL	Yageo
41	2	RES SMD 24 OHM 1% 1/8W 0805	R32, R33,	RC0805FR-0724RL	Yageo
42	3	RES SMD 1kΩ 1% 1/10W0603	R34, R45, R50	RC0603FR-071KL	Yageo
43	1	RES 3.7K OHM 0.1% 1/8W 0603	R39	TNPW06033K70BEE A	Yageo
44	1	RES SMD 10kΩ 1% 1/10W0603	R44	RC0603FR-0710KL	Yageo
45	1	RES SMD 51K OHM 0.1% 1/10W 0603	R46	RT0603BRD0751KL	Yageo
46	3	RES SMD 10 OHM 1% 1/8W 0805	R47,R48,R49	RC0805FR-0710RL	Yageo
47	1	RES SMD 10 Ω 5% 1/10W0603	R51	RC0603JR-0710RL	Yageo

**Bill of Materials of Eval-M3-TS6-665PN**

No.	Qty	Part description	Designator	Part number	Manufacturer
48	3	RES SMD 1kΩ 1% 1/10W0603	R52, R54, R56	RC0603FR-071KL	Yageo
49	2	RES SMD 10kΩ 5% 1/8W0805	R53,R57	RC0805JR-0710KL	Yageo
50	1	RES SMD 2.7K OHM 0.1% 1/8W 0805	R55	RT0805BRD072K7L	Yageo
51	1	RES SMD 51K OHM 0.1% 1/8W 0805	R58	RT0805BRD0751KL	Yageo
52	1	RES SMD 15.8kΩ 1% 1/8W0805	R59	RC0805FR-0715K8L	Yageo
53	1	RES SMD 2kΩ 1% 1/8W0805	R60	RC0805FR-072KL	Yageo
54	1	RES SMD 2K OHM 1% 1/4W 1206	R61	RC1206FR-072KL	Yageo
55	3	RES SMD 300 OHM 5% 1/4W 1206	R62,R63,R64	RC1206JR-07300RL	Yageo
56	1	RES 0.1 OHM 1% 1/2W 1812	RS1	ERJ-L12KF10CU	Panasonic Electronic Components
57	2	RES 0.1 OHM 1% 1/2W 1812 (DNI)	RS2,RS3	ERJ-L12KF10CU	Panasonic Electronic Components
58	1	RES 0.1 OHM 1% 1/2W 1812	RS4	ERJ-L12KF10CU	Panasonic Electronic Components
59	1	NTC THERMISTOR 100K OHM 1% BEAD	RT1	NXRT15WF104FA1B 040	Murata Electronics North America
60	1	105pF 470volts 10%	RV1	MOV-07D471KTR	Bourns
61	1	IC OFFLINE SWIT OCP 8SOIC	U3	LNK306DN	Power Integrations
62	1	IC DUAL DIFF COMPARATOR 8-SOIC	U2	LM393MF/NOPB	Texas Instruments
63	1	IC REG LINEAR 3.3V 1A SOT223-4	U4	IFX1117MEV33HTMA 1	Infineon Technologies
64	3	IC DRIVER HALF-BRIDGE 14SOIC	UA, UB, UC	IRS2890DSTRPBF	Infineon Technologies
65	1	DIODE GEN PURP 600V 29.2A TO263	D1	IDB15E60ATMA1	Infineon Technologies
66	3	DIODE SCHOTTKY 10V 3A SOD323-2	D8, D9, D10	BAT60AE6327HTSA1	Infineon Technologies
67	1	IC DRIVER LOW SIDE 1.5A SOT23-5	DV1	IRS44273LTRPBF	Infineon Technologies
68	6	IGBT 600V 6A DPAK	Q1, Q2, Q3, Q4, Q5, Q6	IKD06N60-RF	Infineon Technologies
69	1	IGBT 650V 8A D <sup>2</sup> PAK	Q7	IKP08N65H5XKSA1	Infineon Technologies

**Reference**

**7 Reference**

- [1] AN2017-15\_EVAL-M3-CM615PN User Manual\_V1.2 EN
- [2] AN2018-02 EVAL-M3-102T User manual
- [3] MCEWizard User Guide
- [4] MCEDesigner User Guide
- [5] Infineon-IKP08N65H5-DS-v02\_01-en
- [6] Infineon-IDB15E60-DS-v02\_04-en
- [7] Infineon-IRS2890DS-DS-v01\_00-EN
- [8] Infineon-IRS44273L DS-v01\_00-EN
- [9] AN2018-17 IRS2890DS Technical Description-AN-v1.0-en.

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



**Revision History**

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**Major changes since the last revision**

<b>Version number</b>	<b>Revision Date</b>	<b>Revision description</b>
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**Email: [erratum@infineon.com](mailto:erratum@infineon.com)**

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