EVAL-M1-CMADK-S user guide

Modular application design kit (MADK) of AIM12SXXEB1

About this document

Scope and purpose

This user guide provides an overview of the evaluation board EVAL-M1-CMADK-S including its main features, key data, pin assignments and mechanical dimensions.

EVAL-M1-CMADK-S is a power evaluation board from the MADK including M1 connector and one CIPOS™ Maxi 1200 V three-phase module for motor drive applications. In combination with either EVAL-M1-101T or other control boards with compatible M1 connectors, it features and demonstrates Infineon's CIPOS™ Maxi IPM technology for motor drives.

The evaluation board EVAL-M1-CMADK-S was developed to support customers during their first steps designing applications with AIM12SXXEB1 CIPOS™ Maxi power modules.

Intended audience

This user guide is intended for all technical specialists who know motor control, middle- and low-power electronics converters. The board is intended to be used under laboratory conditions.

Evaluation board

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

Product family

Table 1 List of products in the AIM12SXXEB1 series

Part number	Voltage (V)	R_{dson} (m Ω)	Orderable Part number	Pmot @10kHz(W)
AIM12S25EB1	1200	25	AIM12S25EB1XKMA1	14100
AIM12S36EB1	1200	36	AIM12S36EB1XKMA1	10000
AIM12S54EB1	1200	54	AIM12S54EB1XKMA1	7600
AIM12S83EB1	1200	83	AIM12S83EB1XKMA1	4600
AIM12S112EB1	1200	112	AIM12S112EB1XKMA1	3600

Note: The AIM12S54EB1 is set as the default assembly for all test results presented in this document.

About this document

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

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

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Safety precautions

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

Table 2 Safety precautions

	**Warning:** *The DC link potential of this board is up to 800 V_{DC}. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning:** *The evaluation board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *The evaluation board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	**Caution:** *The evaluation board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	**Caution:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	**Caution:** *The evaluation board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

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1 The board at a glance

The EVAL-M1-CMADK-S evaluation board is a part of the iMOTION™ MADK for motor control (iMOTION™ MADK).

The MADK platform is intended for use in various power stages with different control boards. These boards can easily be interfaced through the 20-pin iMOTION™ MADK-M1 interface connector.

This evaluation board is designed to give comprehensible solution for the power section featuring by CIPOS™ IPM. It provides a AC/DC input and 3-phase output for power motor. It contains a leg shunt for current sensing and a voltage divider for DC-link voltage measurement.

The EVAL-M1-CMADK-S evaluation board is available from Infineon. The features of this board are described in the design feature chapter of this document (UG-2026-03), 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.

The 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.

1.1 Delivery contents

The EVAL-M1-CMADK-S evaluation board is designed to provide an ease-of-use power stage based on the Infineon's CIPOS™ Maxi intelligent power module (AIM12SXXEB1 IPM).

The delivery includes the finished board as shown in Figure 1 and Figure 2. It provides a 3-phase AC connector, an EMI filter and soft power-up circuit, input rectifier, DC bus capacitors and 3-phase output for connecting the motor.

It also contains quasi-resonant PWM controller and CoolSiC™ MOSFET based auxiliary power supply to provide 15 V & 18 V and 3.3 V, a leg shunt for current sensing and over-current protection, and a voltage divider for DC-link voltage measurement. The board shown here can be operated directly with the required power supply without the need for additional components.

1.2 Block diagram

The block diagram of the EVAL-M1-CMADK-S is depicted in Figure 1.

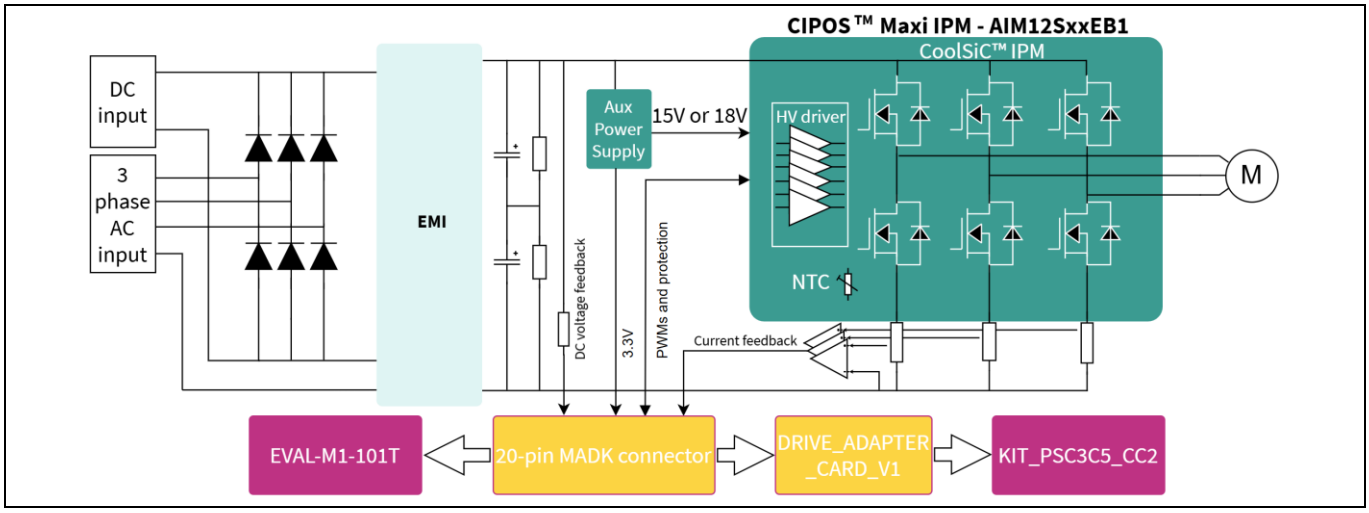
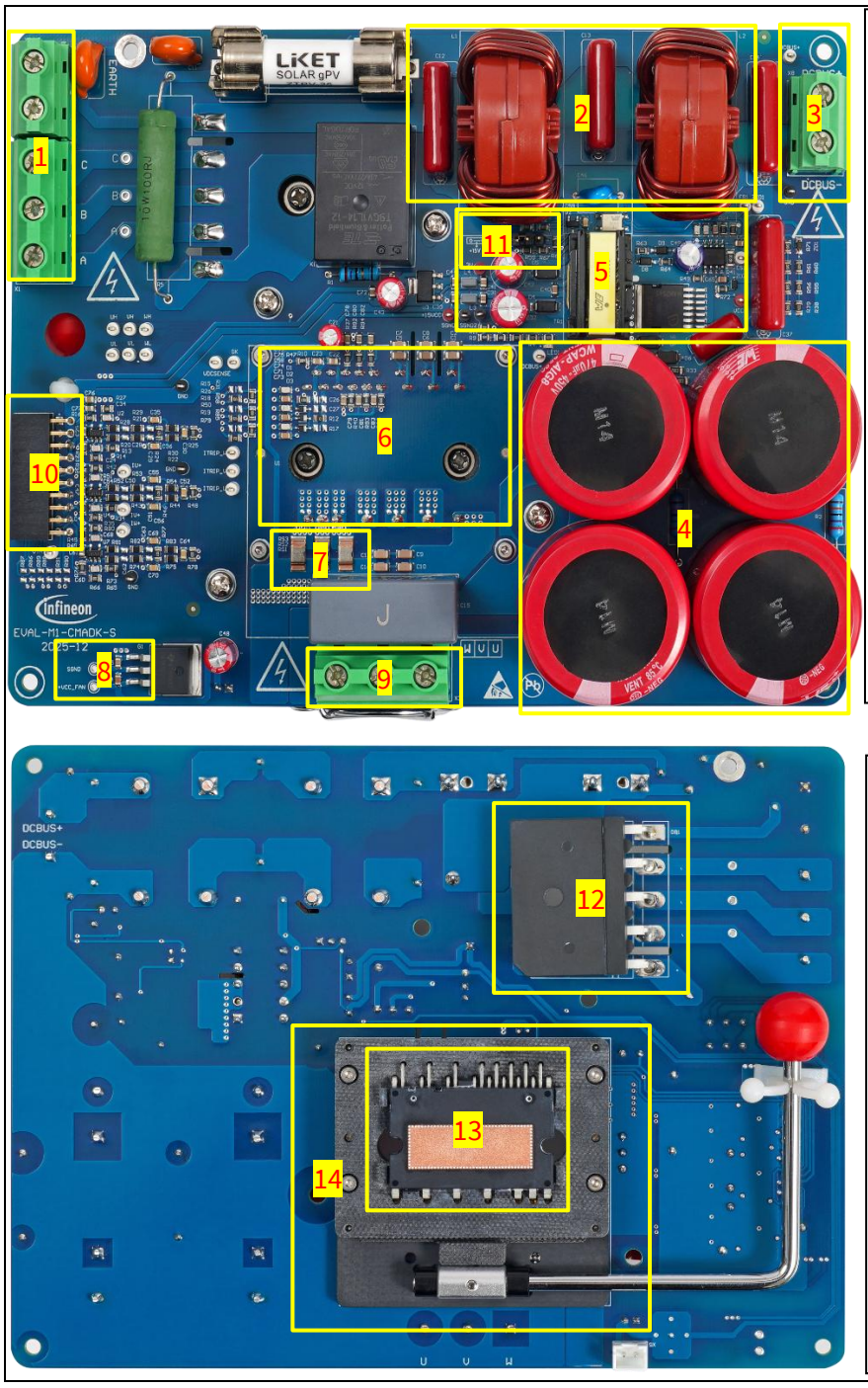


Figure 1 Block diagram of the EVAL-M1-CMADK-S board

Figure 2 points out the functional groups on the Top and Bottom side of the EVAL-M1-CMADK-S design.



1. 380V_{AC} & PE input connector
2. EMI filter
3. DC input connector
4. DC bus capacitors
5. Auxiliary power supply
6. CIPOS Maxi IPM
7. Current shunt resistor
8. Fan drive connector
9. U/V/W output connector
10. Control card connector
11. Jumper for 15V or 18V selection
12. 3phase Bridge rectifier
13. AIM12SXXEB1
14. Socket

Figure 2 Functional groups of the EVAL-M1-CAMDK-S reference design

1.3 Main features of the evaluation board

The evaluation board characteristics include:

- Provide a convenient replaceable method for IPM of different power rate
- Nominal input voltage 3-phase 380 V_{AC}
- Design for 3 kW motor power output
- On-board EMI filter

- Leg shunt for current sensing
- Sensing of DC-link voltage
- Measurement test points compatible with standard oscilloscope probes
- PCB size is 140 mm x 185 mm, four layers with 70 µm copper each
- RoHS compliant

1.4 Board parameters and technical data

Table 3 depicts the important specifications of the evaluation board EVAL-M1-CMADK-S.

Table 3 EVAL-M1-CMADK-S board specifications based on the AIM12S54EB1

Parameter	Symbol	Conditions / comments	Value	Unit
Input				
Input voltage	V_{AC}	Optimized design for 3-phase 380 V_{AC} or DC input. Lower AC input, less motor power output	320~480 V_{rms} AC /420~720 V DC	V
Input current	$I_{AC(max)}$	Input 3-phase AC 380 V_{rms}, 15VCC， 3.0 kW output, T_a=25°C	16.2	A_{rms}
Output				
Power (3 phases)	$P_{in(max)}$	Input AC 380 V, 15VCC, F_{PWM}=6 kHz, T_a=25°C, T_{case}= 100°C	3.0	W
Current per phase	$I_{mtr(max)}$	Input AC 380 V_{AC}, F_{PWM}=6 kHz, T_a=25°C, T_{case}= 100°C	16.2 A_{rms} [1]	A_{rms}
DC bus voltage				
Maximum DC bus voltage	$V_{DC(max)}$	DC bus capacitors are 450 V, 470µF X2 X2	780	V
Minimum DC bus voltage	$V_{DC(min)}$	Aux power supply's brown-in voltage	150	V
Current feedback				
Shunt resistance	R_{sh}	Three pieces of shunt resistors	2	mΩ
Protections				
Motor current protection trigger level 1	I_{trip1}	Wizard setup for OC trigger level, related to shunt resistor RS1， RS2， RS3 and current sensing bias	24 [2]	A_{peak}
Motor current protection trigger level 2	I_{trip2}	Hardware comparator over-current protection, related to shunt resistor and LMV793's setup	55	A_{peak}
Thermal protection level	$T_{protection}$	Users need to consider the temperature gap by NTC sensor; it is recommended to set temperature at 105°C or less	100	°C
Auxiliary power supply 1 – 15 V or 18 V				
Output voltage	V_{out1} V_{out2}	Used for IPM, 12 V fan and relay (K1) drive	15 ± 5% 18 ± 5%	V
Maximum output current	I_{out1}		300	mA
Auxiliary power supply 2 – 3.3 V				

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Parameter	Symbol	Conditions / comments	Value	Unit
Output voltage	V_{out2}	Used for IMC controller and protection circuits	3.3 ± 5%	V
Maximum output current	I_{out2}		150	mA
PCB characteristics				
Dimension		Length × width × height	140×185×82	mm
Material		FR4, 2.0 mm thickness, 2 oz. PCB		
System environment				
Ambient temperature	T_a	Non-condensing, maximum RH of 75%	0 ~ 50	°C

Note:

1. *As IPM and rectifier bridge are mounted on the same heat sink, IPM output capability is impacted by rectifier bridge's power loss.*
2. *For iMOTION™ IC IMCxxx, there are three types of Gatekill input source options in iMOTION™ Solution Designer setup: Gatekill-pin, Comparator and Both. If you select "comparator" mode, the external Gatekill signal will be not used, and the signal I_Shunt will be compared by the internal comparator with the "Device over-current trigger level setting" value set in iMOTION™ Solution Designer.*

2 System and functional description

2.1 Getting started with EVAL-M1-CMADK-S

In order to run the motor system, a combination of the iMOTION™ MADK power board (EVAL-M1-CMADK-S) and the matching MADK control board (EVAL-M1-101T or other control board) are required. This chapter provides more details on setting up the system and getting started with the iMOTION™ MADK development platform.

Note: ***If you are using an EVAL-M1-101T control board, please make the following changes to better match EVAL-M1-CMADK-S for op-amp current sensing, since EVAL-M1-101T's default configuration is directly ADC sample.***

a. *Remove R6 of EVAL-M1-101T (Since EVAL-M1-CMADK-S uses external OPA circuit, it has its own bias)*

b. *Change R7 of EVAL-M1-101T from 2 k Ω change to 0 ohm (To reduce total R & C delay for current sensing path)*

The EVAL-M1-CMADK-S reference designs are tested with EVAL-M1-101T controller boards.

The following steps have to do to achieve a usable motor controller IC from a blank IMC101T:

- Programming of the motion control engine (MCE) and parameter sets for system and motor.
- Programming of customer scripts (optional).

The iMOTION™ software tool, iMOTION™ Solution Designer, is required to initially set up the system, as well as to control and fine-tune the system performance to match the user's exact needs. This tool is available for download via the Infineon website link. Please visit this page periodically to check for updates.

- iMOTION Solution Designer

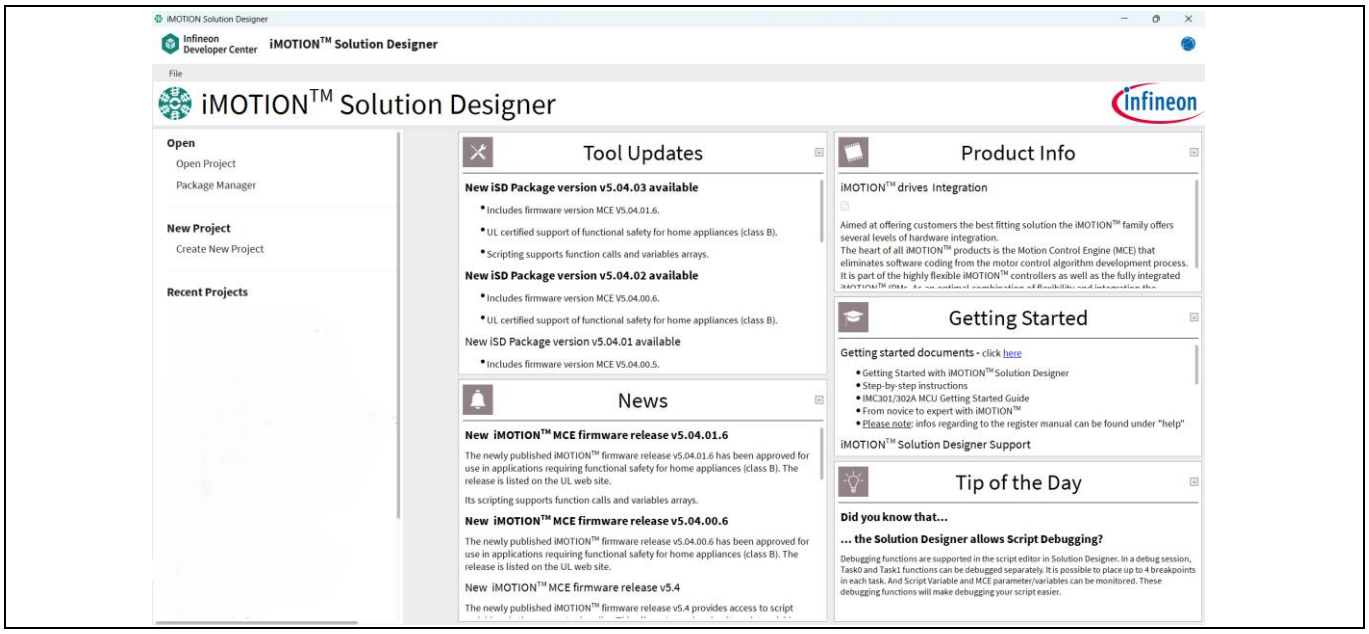

Figure 3 iMOTION™ Solution Designer

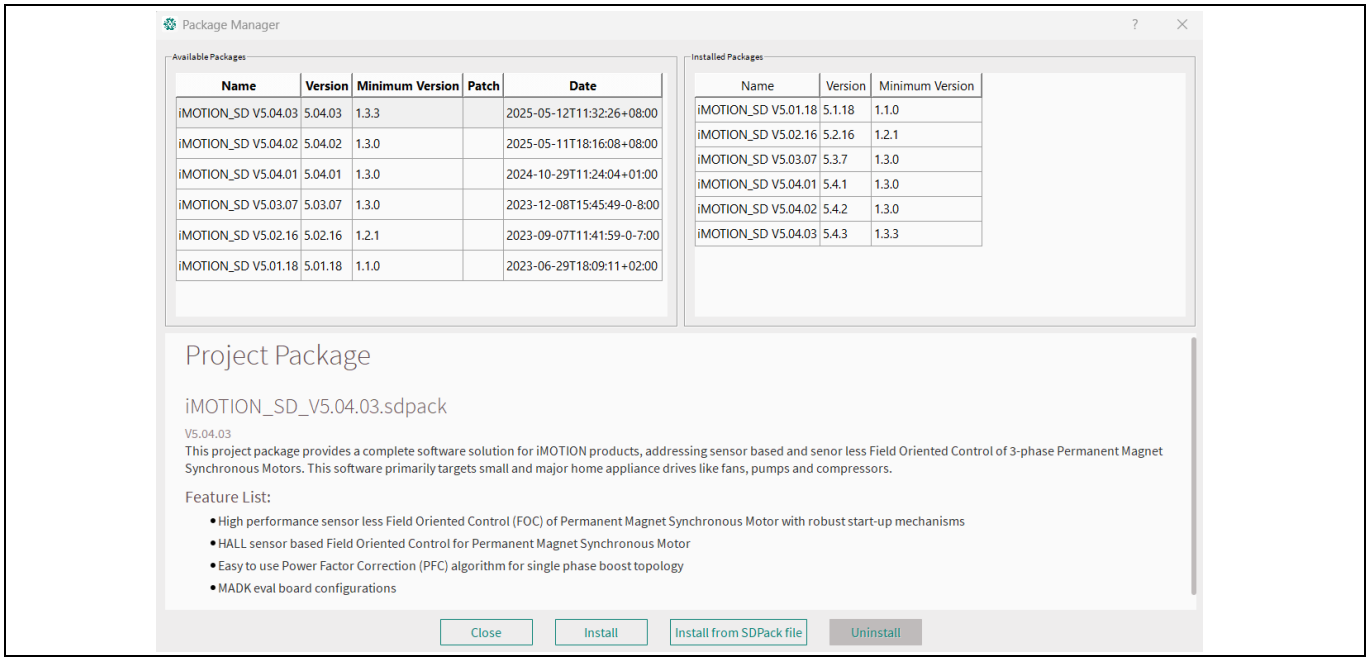

Figure 4 Sdpack installation

After installed iMOTION™ Solution Designer, need to install Sdpack by “Open->Package Management”. Select necessary version from left available list and click “Install”.

iMOTION™ Link or on board debugger is needed to bridge the PC/debugger side and motor drive system (the target iMOTION™ device, hot side) with 1 kV DC galvanic isolation.

This chapter provides more details on setting up the system and getting start with the iMOTION™ development platform.

After downloading and installing the iMOTION™ PC tool, iMOTION™ Solution Designer, the following steps need to be taken to run the motor. Refer to documentation *iMOTION™ Solution Designer* and *Getting Started with iMOTION Solution Designer* for more information.

Figure 5 shows the basic system connection using EVAL-M1-CMADK-S to run a 2.8 kW GK6105-8AC31 motor with iMOTION™ Solution Designer.

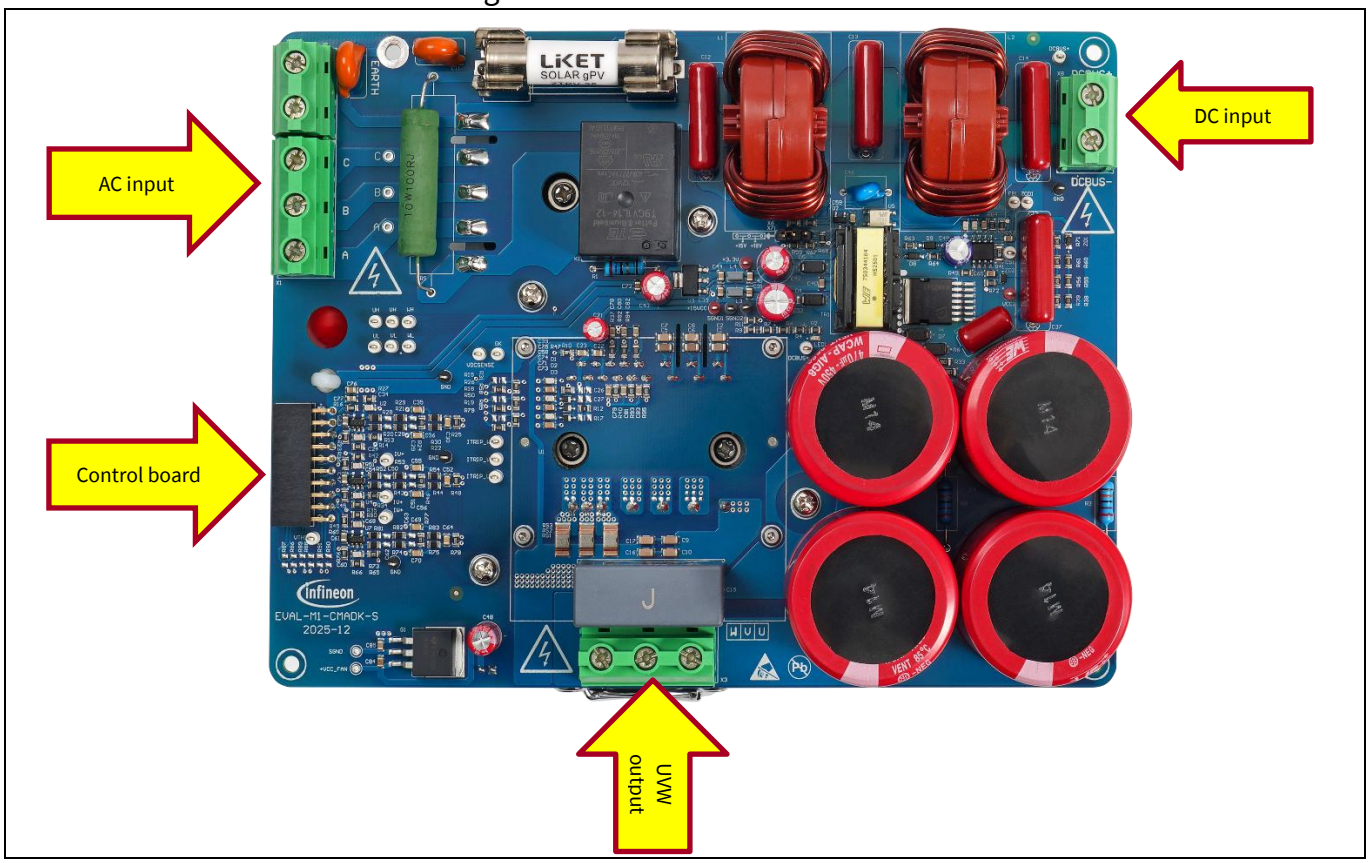

Figure 5 System connection example

Here are the steps needed to run the motor:

1. Connect EVAL-M1-101T control board to EVAL-M1-CMADK-S.
2. Connect PC-USB connector to EVAL-M1-101T J1 by iMOTION™ Link or X101 by pure USB cable.
    a. If iMOTION™ Link is used, please remove R110 and R111 on EVAL-M1-101T.
    b. If pure USB cable is used with on board debugger, please mount R110 and R111.
3. Connect 380 V AC power supply and UVW outputs to the motor.
4. Open iMOTION™ Solution Designer as shown in Figure 3, crease new project by “New project -> Create New Project” as shown in Figure 6.
    a. Select available sdpack version.
    b. Create file name.
    c. Select save location.
    d. Create project name.
    e. Check box “Create self contained project”.

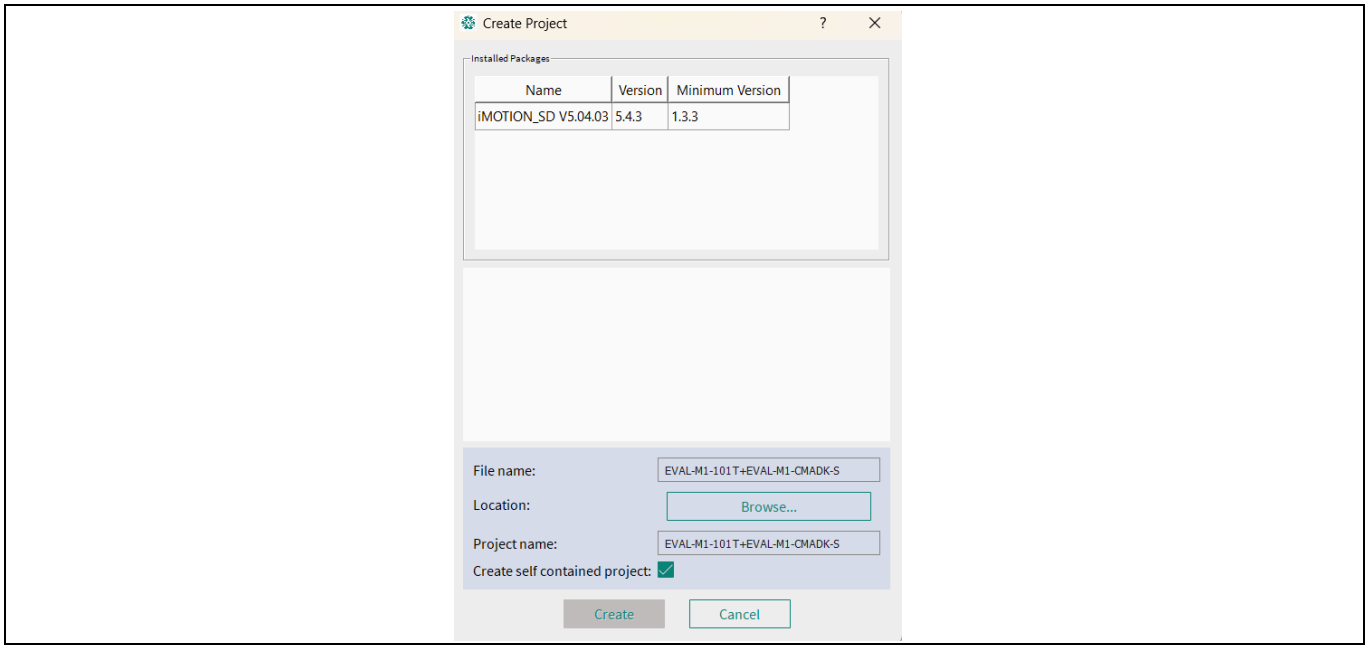

Figure 6 Create iMOTION™ Solution Designer project

5. Select iMOTION device matched the EVAL-M1-101T, here is IMC101T-T038.

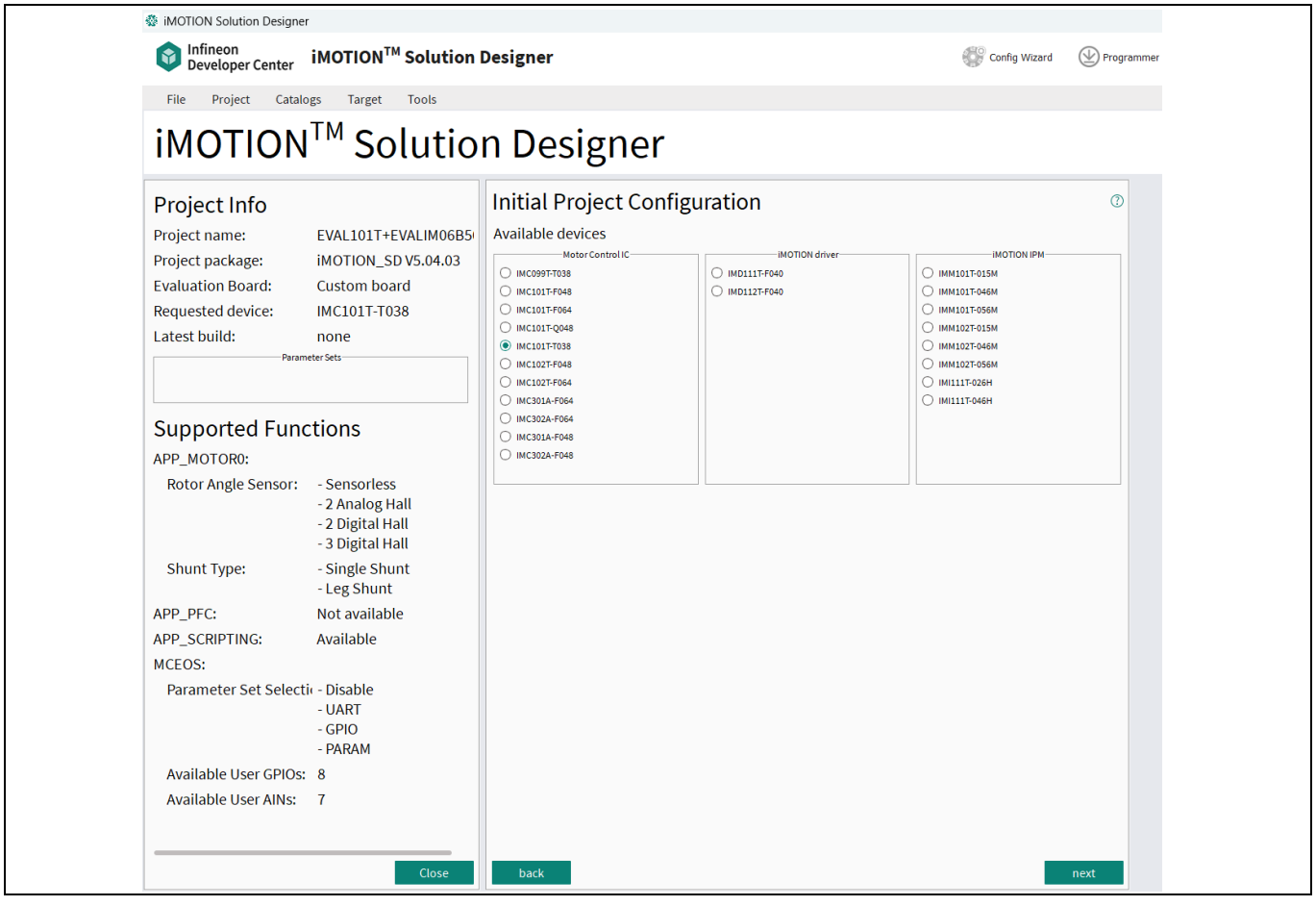

Figure 7 Select iMOTION device

6. Configure parameters in Config Wizard. Please open “Expert mode” by clicking right up icon  .
    a. For “IC configuration”, the default parameters are ok for this evaluation board.

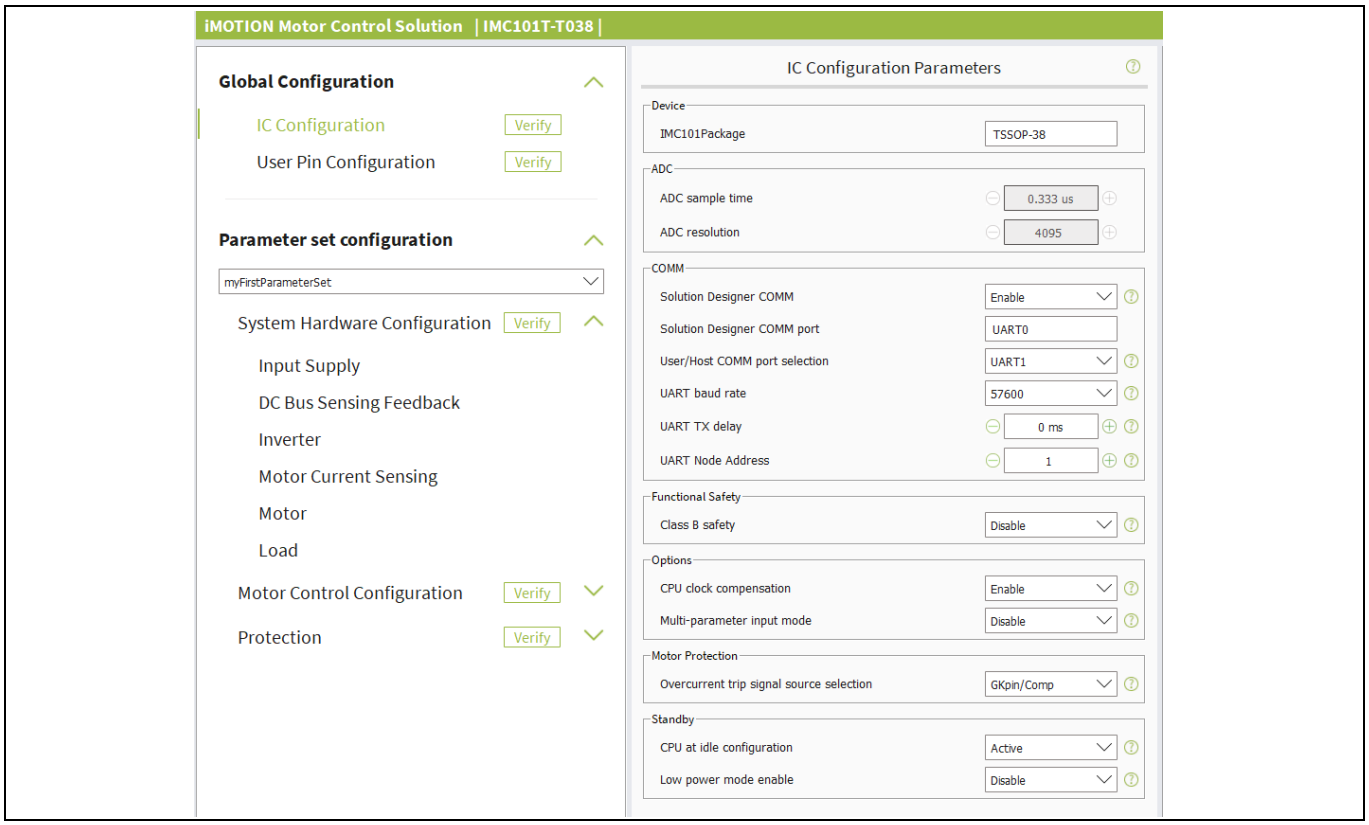

Figure 8 IC configuration

    b. For “User Pin Configuration”, the default parameters are ok for basic motor running. These configurations can achieve more further pin functions evaluation.

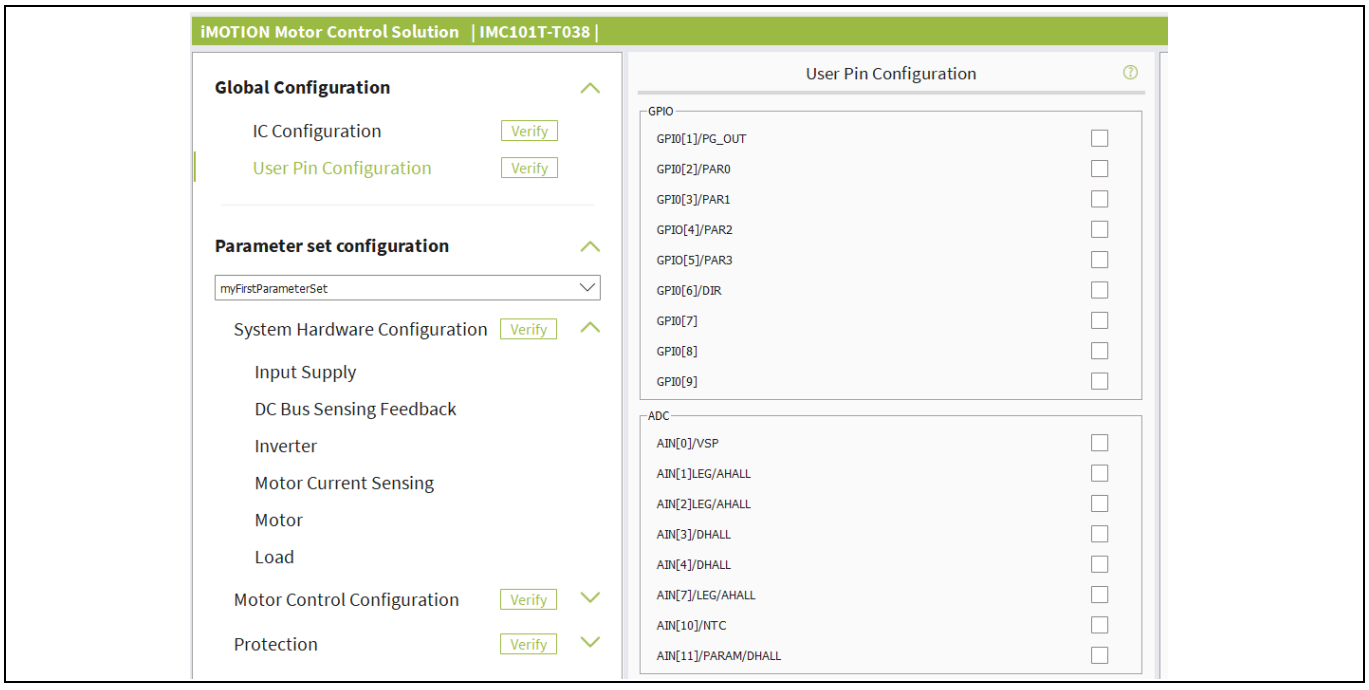

Figure 9 User Pin Configuration

c. For “Input Supply”, 3.3 V DC should be configured as control supply voltage of this evaluation board.

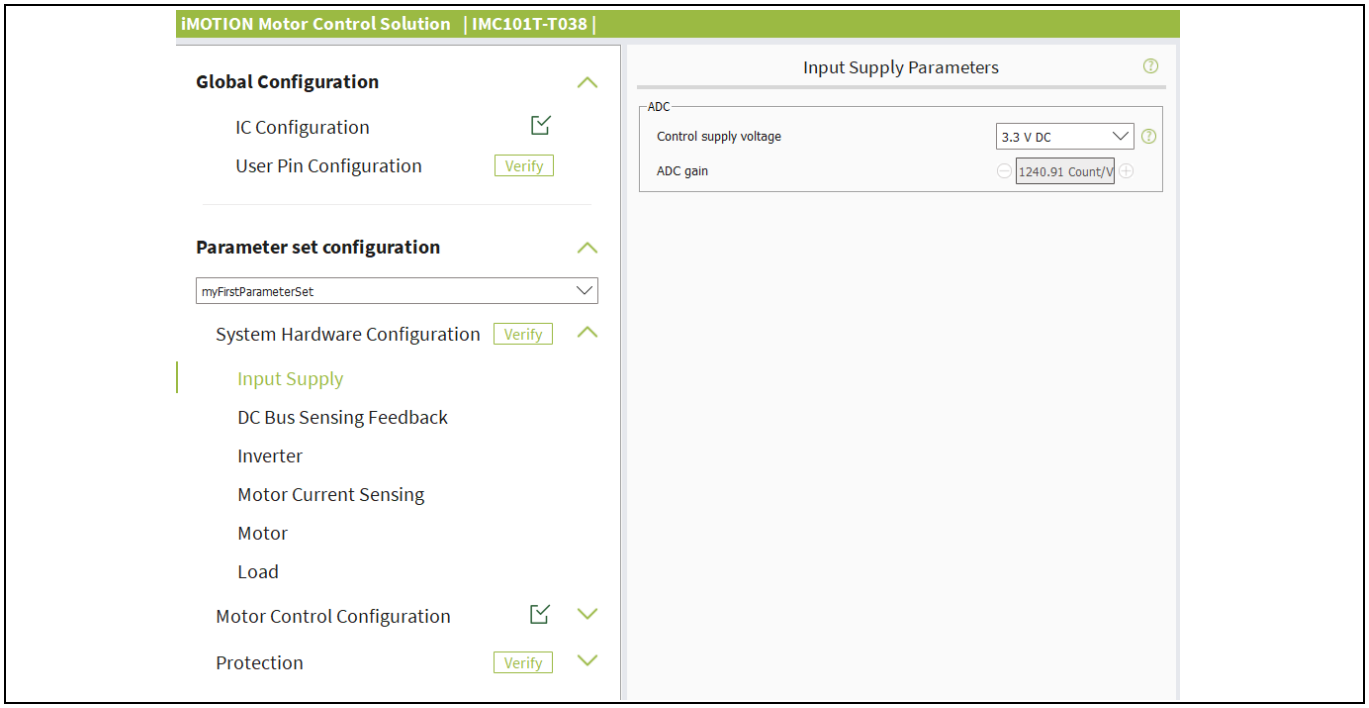

Figure 10 Input Supply

d. For “DC Bus Sensing Feedback”, The DC-BUS sensing low-side resistance is R11//R1(R1 is on EVAL-M1-101T) show in Figure 33. It is 13.13 kohm and upper resistor is 5 Mohm. Please refer to schematic of EVAL-M1-101T and EVAL-M1-CMADK-S for more information.

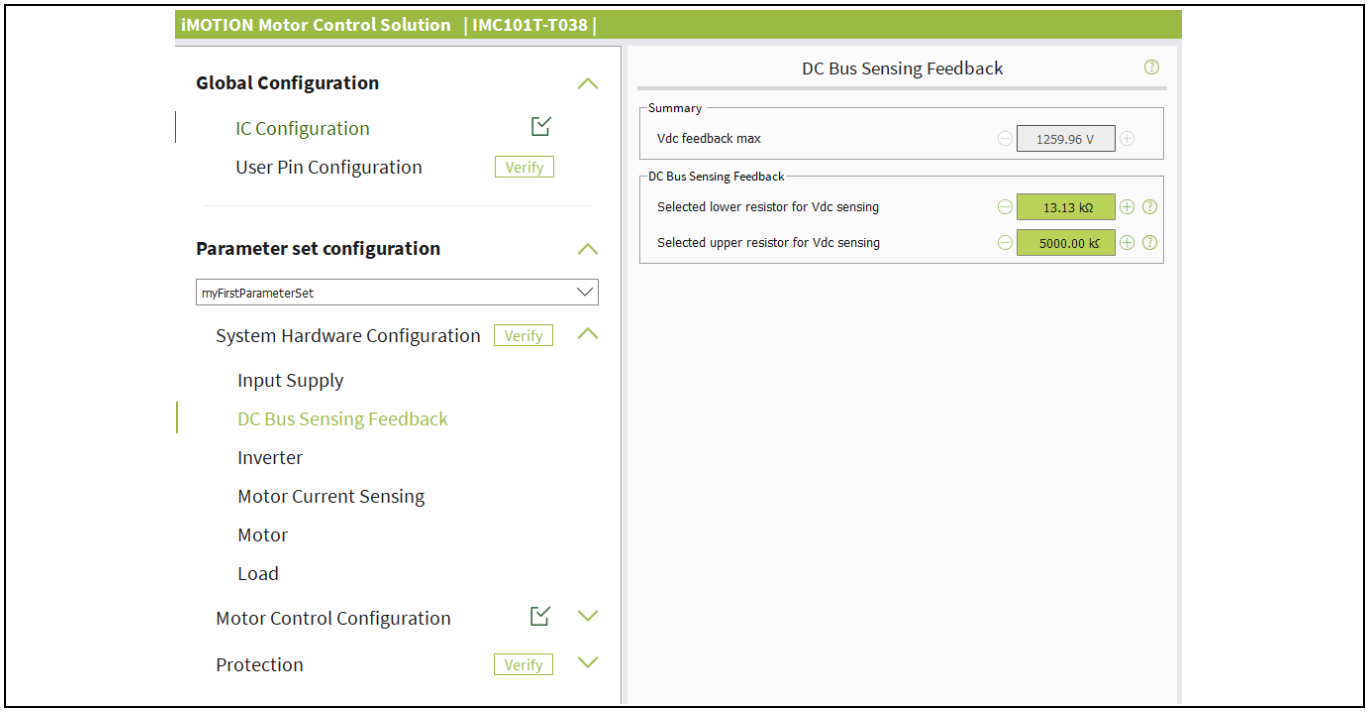

Figure 11 DC Bus Sensing Feedback

e. For “Inverter”, please refer to *AIM12S54EB1 datasheet* and board parameters and technical data section **Error! Reference source not found.** of this evaluation board to configure parameters here. T he configured parameters as shown in Figure 12. Please note that the maximum motor current of this evaluation board is 25 Arms. So here configured “Rated Inverter output current” to 25 Arms.

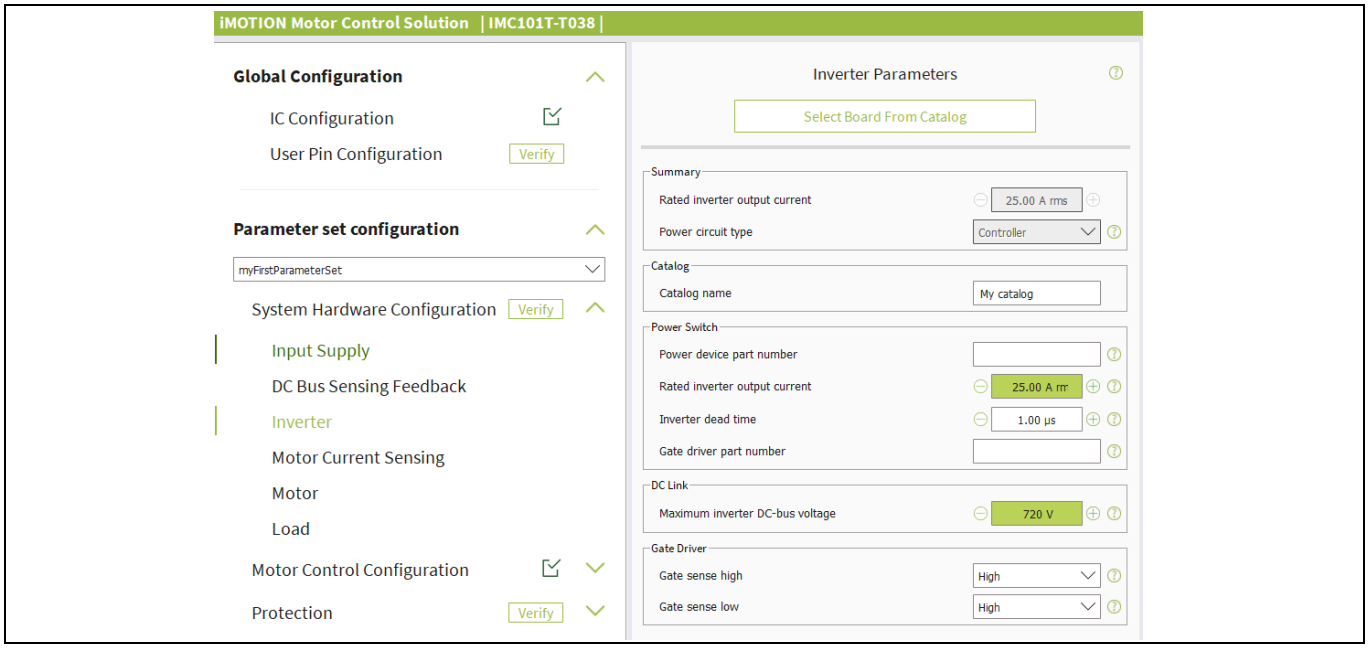

Figure 12 Inverter

f. For “Motor Current Sensing Feedback”, please refer to Section 3.5 of this document for detail calculation. Please configure all parameters as shown in Figure 13, all parameters here matched this evaluation board.

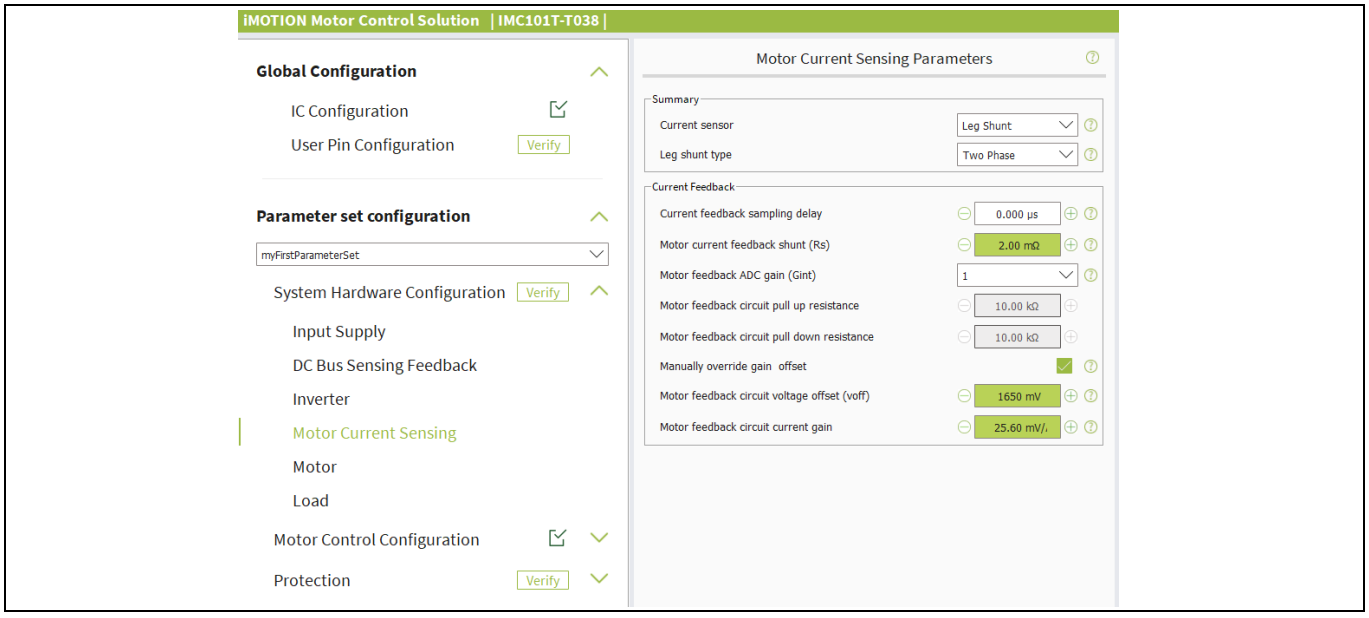

Figure 13 Motor Current Sensing

g. For “Motor”, please configure them based on actual motor used. Regarding how to measure motor parameters, please refer to document *Basic Motor Parameters and the Configuration*.

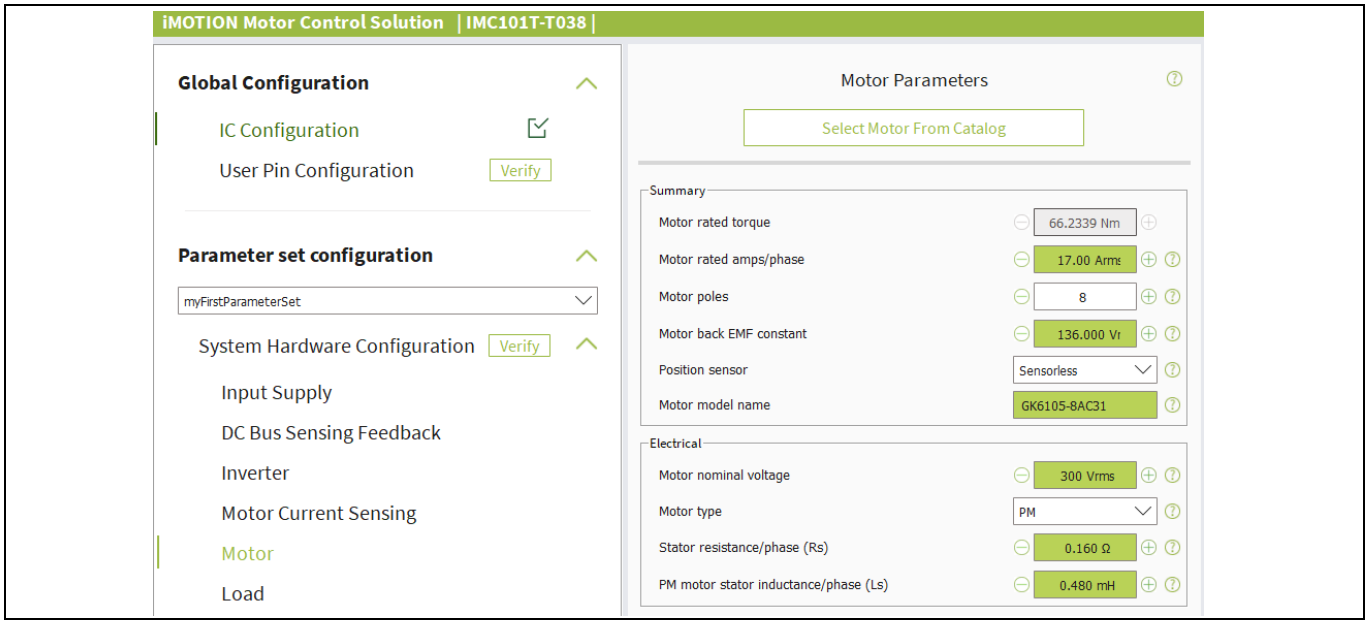

Figure 14 Motor

h. For “Load”, please configure them based on actual load used. They are related to “Rated power”, “Minimum speed”, “Maximum speed”. Please click question mark right input box for detail information.

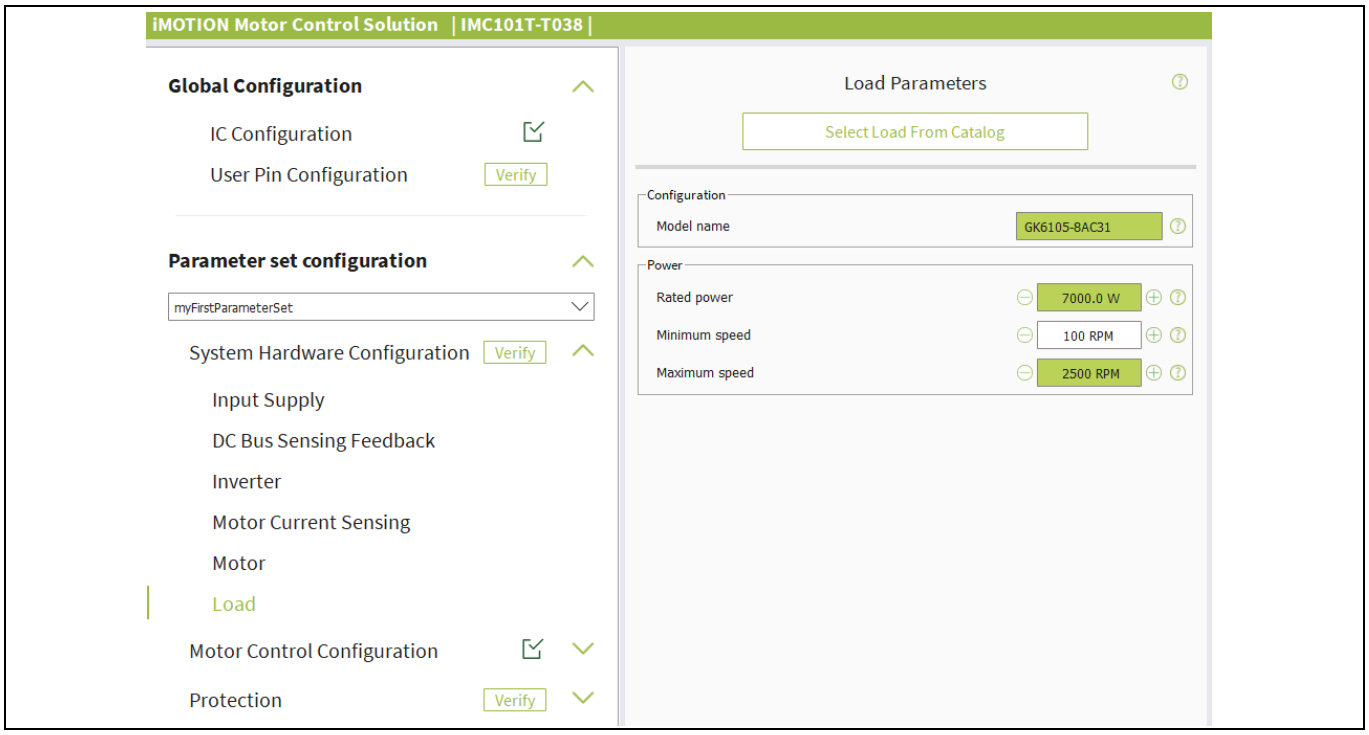

Figure 15 Load

i. For “Motor Control Configuration”, PWM frequency can be configured to evaluate performance of this IPM module. Meanwhile, “Current control update rate scale” and “Speed control update rate

scale" can be configured to improve CPU load. Please click question mark right input box for detail information.

Regarding "Rotor angle feedback selection" and "Motor control mode" please refer to *Functional Reference Manual iMOTION™ Motion Control Engine* for more information.

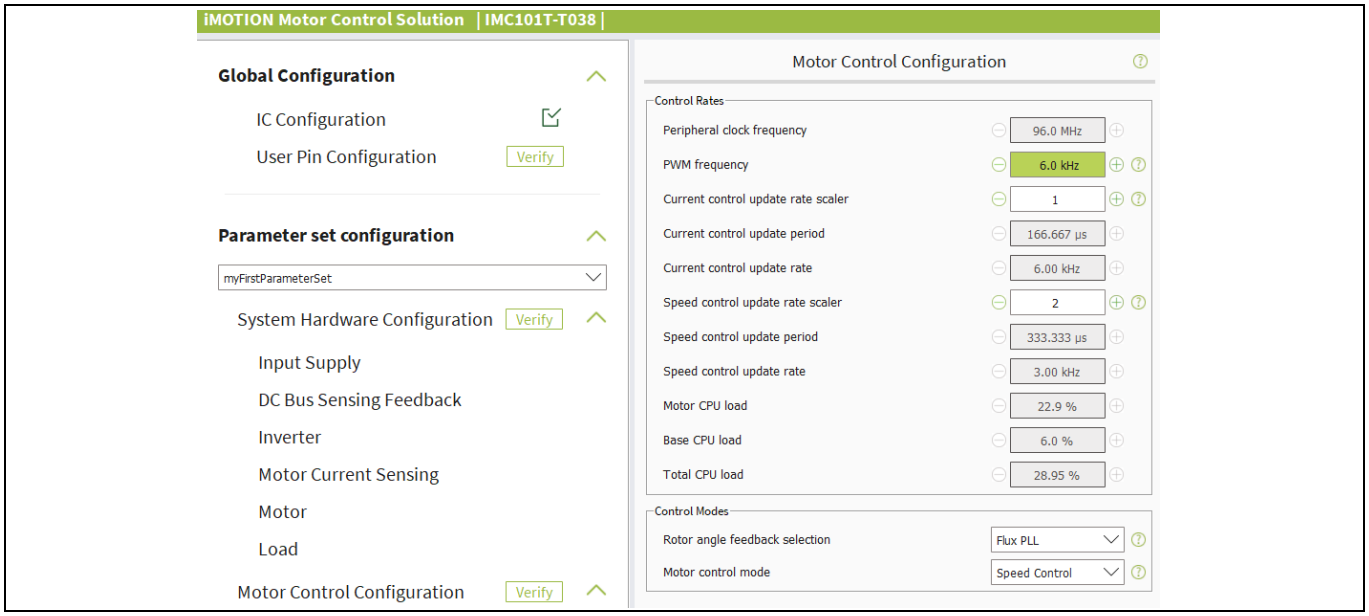

Figure 16 Motor Control Configuration

j. For "Control Regulators", velocity regulator and current regulator should be tuned at here. These parameters should be turned according to actual motor running performance. For general evaluation IPM and Filed Control is not need, please leave them as default value.

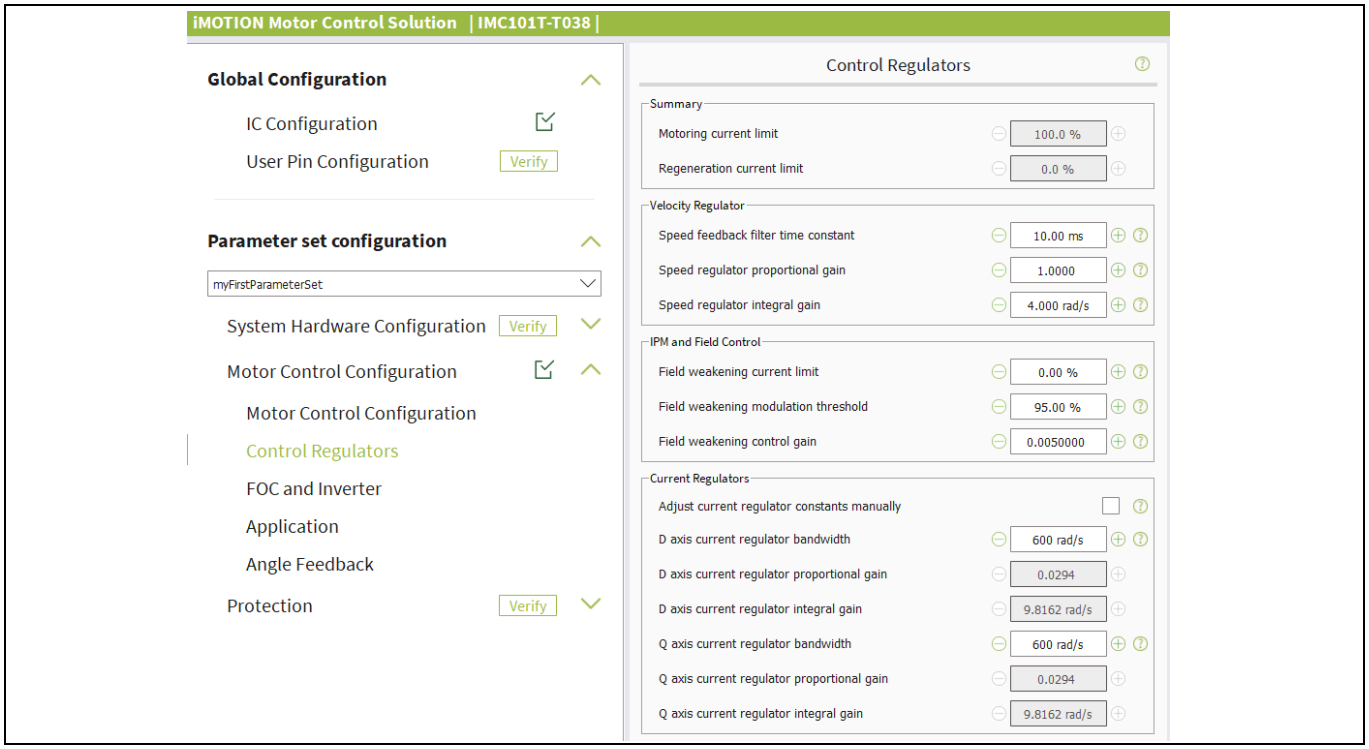

Figure 17 Control Regulators

k. For “FOC and inverter”, they are for high performance motor running, for general evaluation, please leave them as default value.

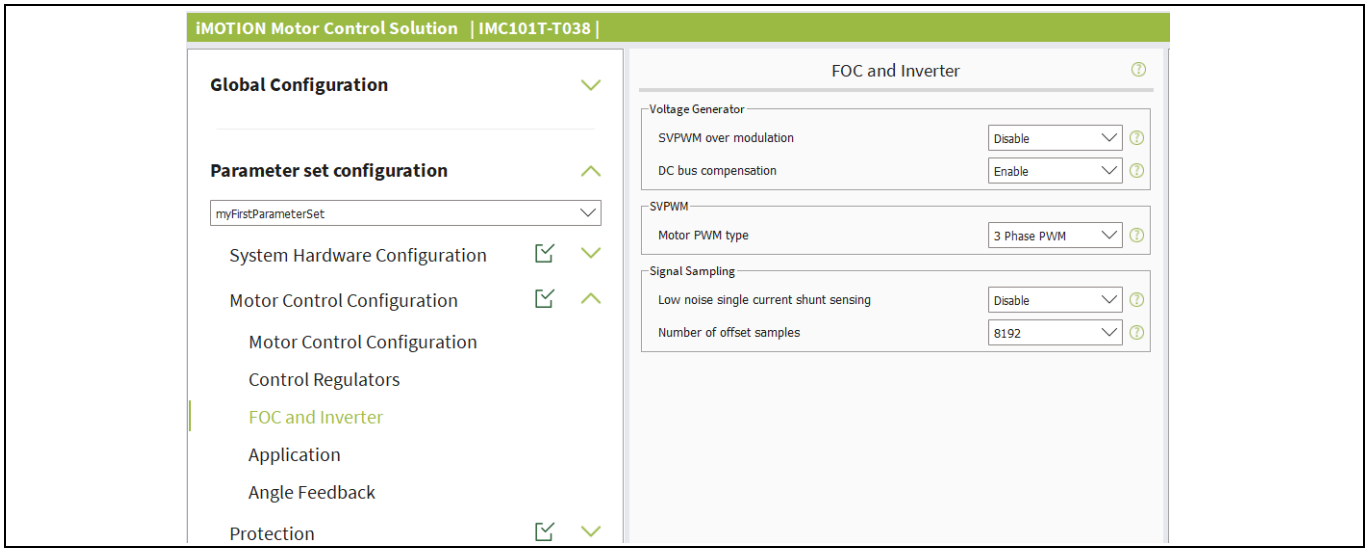

Figure 18 FOC and Inverter

l. For “Application”, it configures motor start-up performance. There are three start-up method: park + open loop ramp, initial angel sensing, and direct start. Please refer to *Functional Reference Manual iMOTION™ Motion Control Engine* for more information. The general start-up method is park + open loop. For this method, “Open loop ramp rate”, “Parking time”, “Low speed limit”, “Low speed threshold” and “Speed control ramp rate limit” are the key parameters for start-up performance.

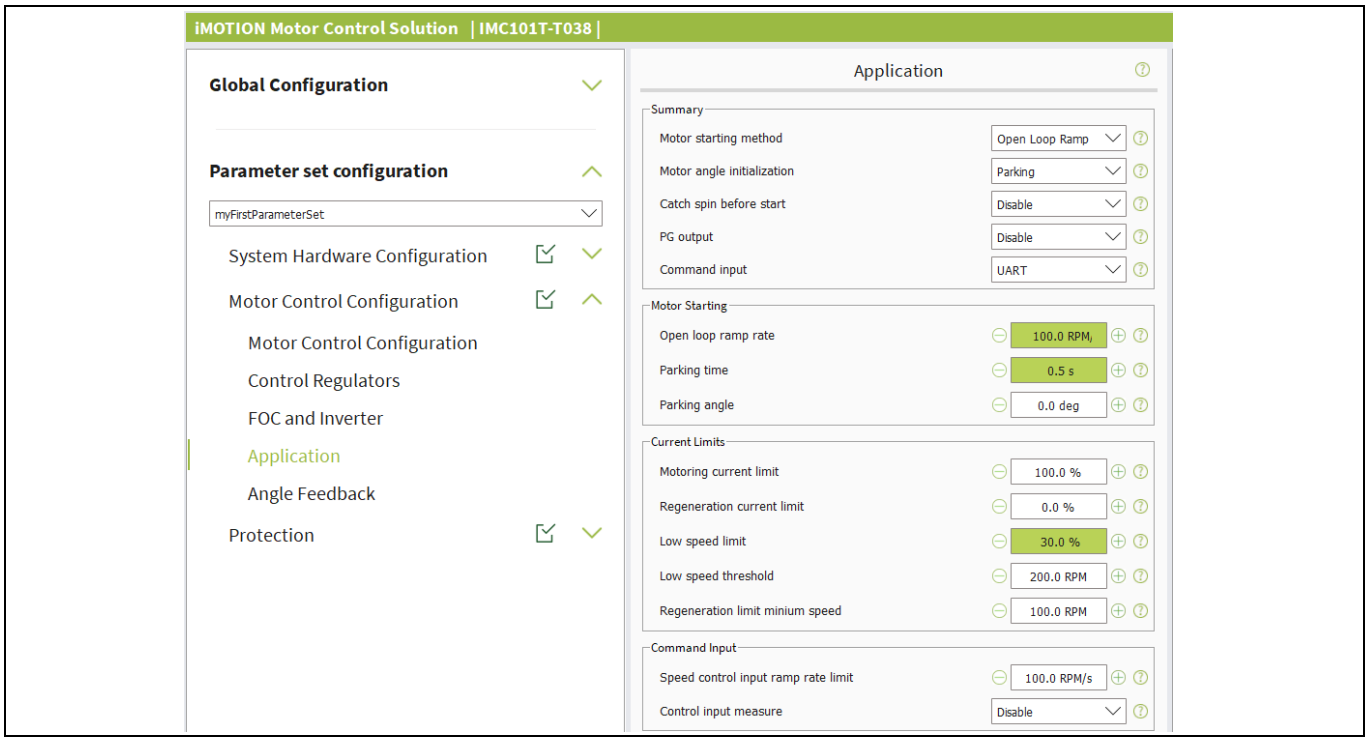

Figure 19 Application

m. For “Angle Feedback”, generally only “Flux estimator time constant” needs to be configured. If Flux PLL is configured as rotor angle feedback, then “Flux estimator time constant” is very important for flux angle estimation. The recommended flux estimator time constant is between 4 and 5 times the motor winding time constant (L/R). Generally, “Flux PLL compensator proportional gain” and “Flux PLL compensator integral gain are left to default value.”

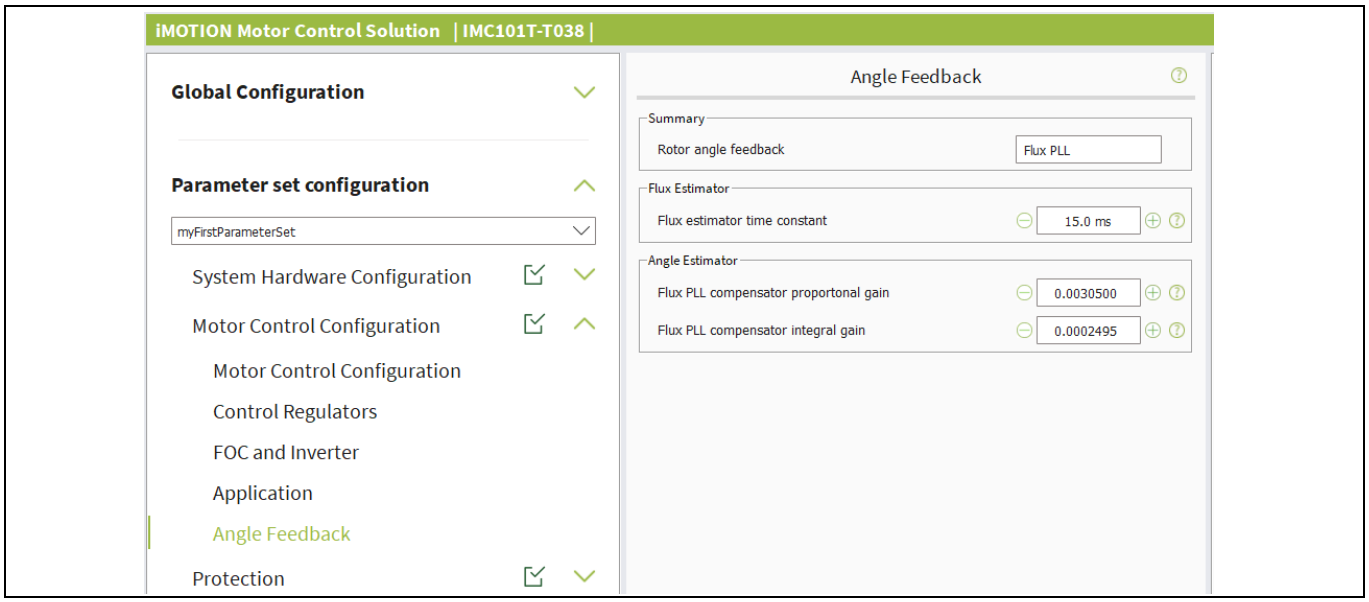

Figure 20 Angle Feedback

n. For “Motor protection”, please enabled all protection items to protect evaluation system well.
   - Over current protection has two sources: Gate kill pin and internal comparison. Here two sources are selected. The threshold of Gate kill pin is designed by hardware of evaluation board, please refer to schematic for more detail information. The threshold of internal comparison is configured by “Overcurrent comparator current trip level (peak)”. Recommend configuring “Overcurrent comparator current trip level (peak)” only a little bigger than motor rated current to protect motor avoid damage.
   - Voltage protection please configure them as shown in Figure 21.
   - Please refer section 0 of this document for “NTC voltage threshold for an overtemp fault” configuration.
   - All other configurations please use value shown in Figure 21.

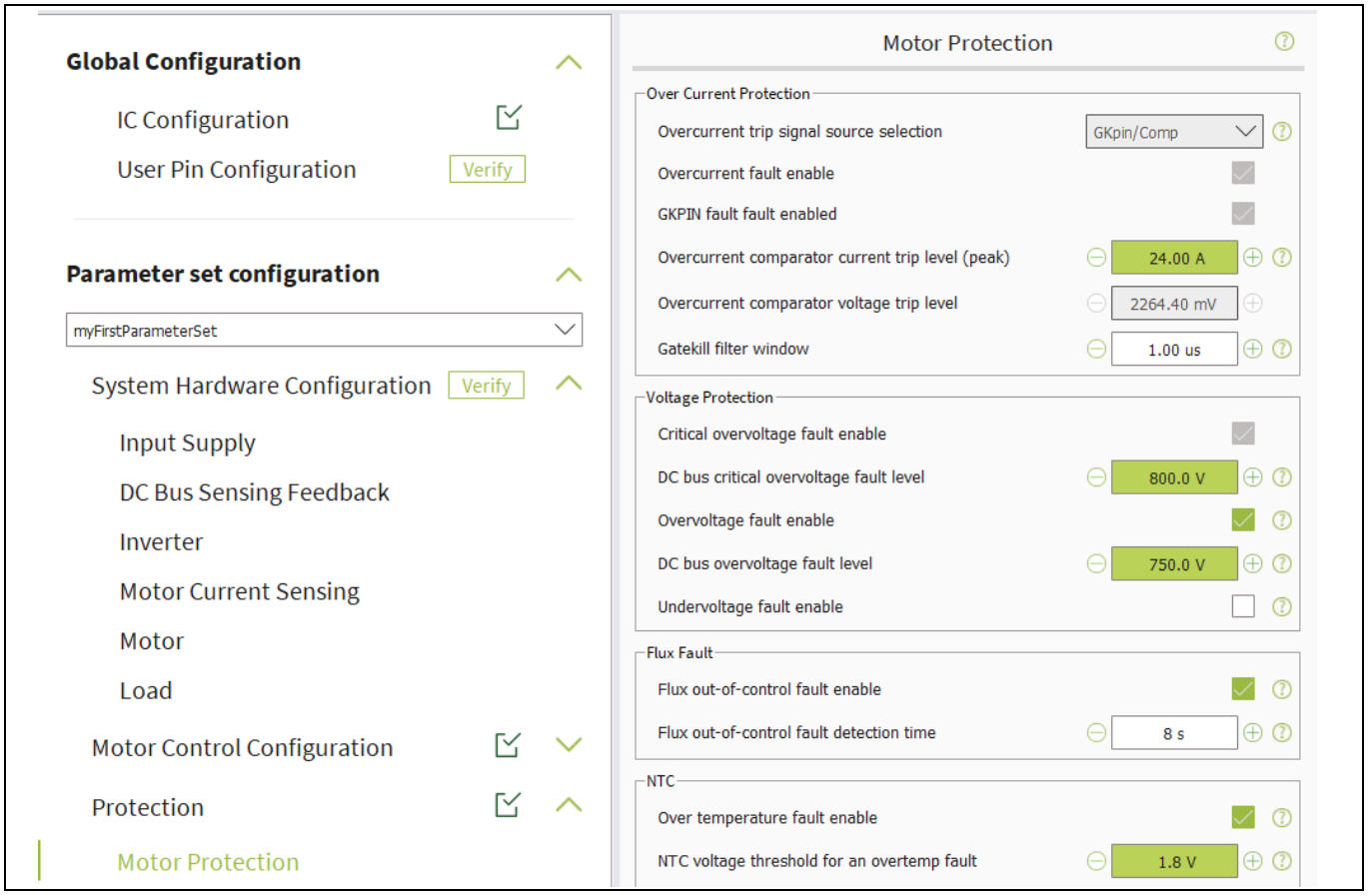

Figure 21 Motor Protection

o. For “System Protection”, the default configuration is well.

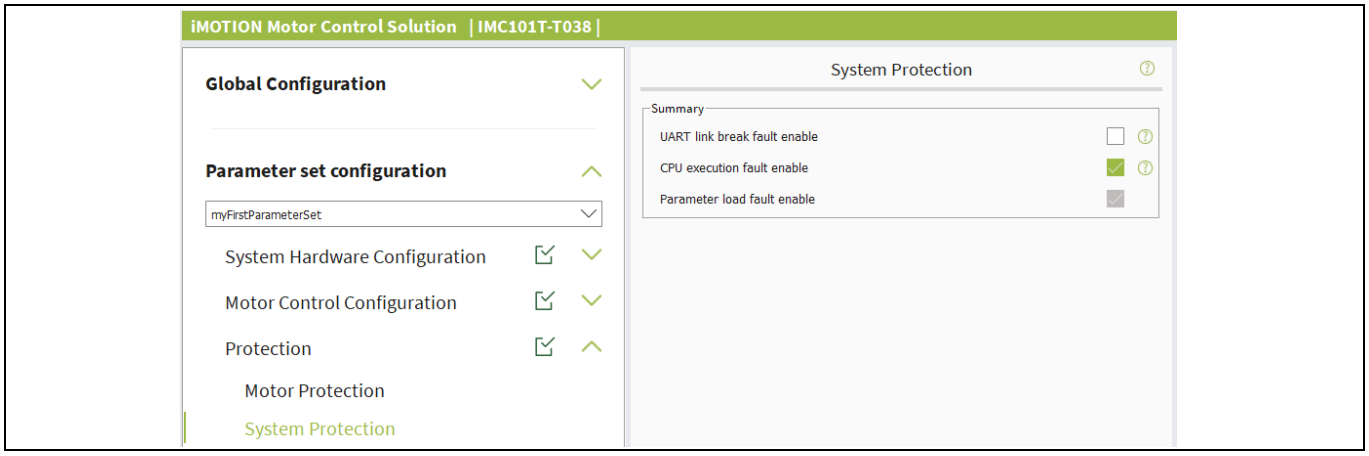

Figure 22 System Protection

7. After parameters configuration in Config Wizard, please click menu “Project->Build Project” enter build window to build project to generate parameters file and script file (optional).

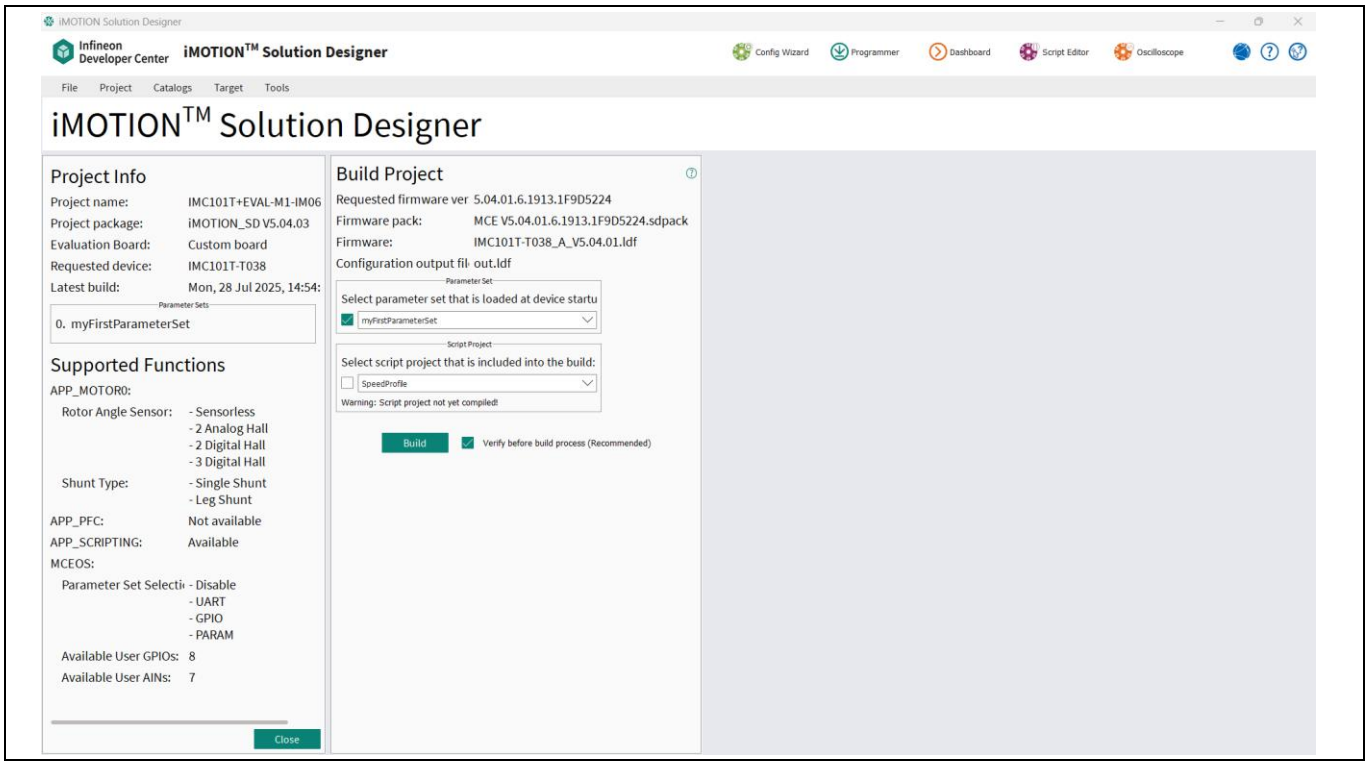

Figure 23 Build Project

8. Power on 380 V AC.
9. Click menu “Tools -> Programmer-> Connect”, select available COM port to connect EVAL-M1-101T.

Notes: if you encounter connection issue after clicking “Connect” button, please power off EVAL-M1-101T first, then click “Connect” button in Figure 25 and power on EVAL-M1-101 in 2~10 seconds. Please try again if fails.

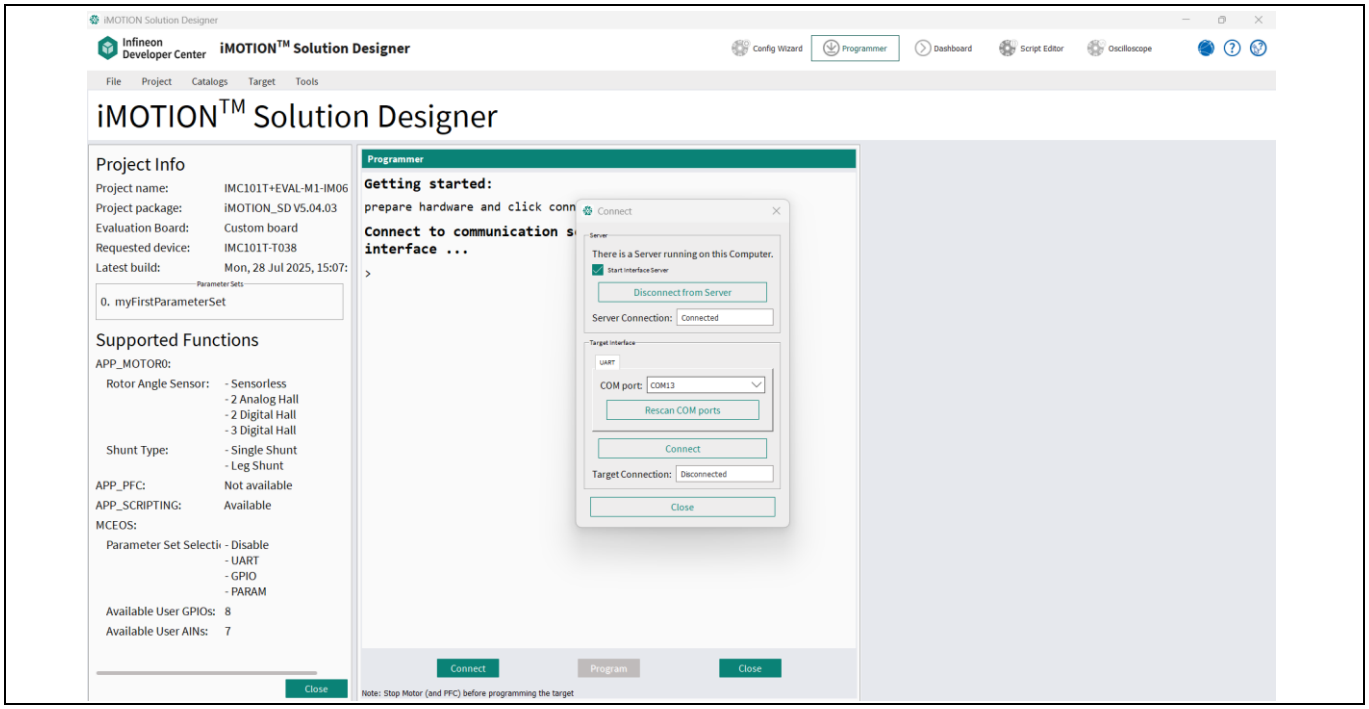

Figure 24 Connect target board

10. Click button “Program” to download parameter and firmware. Script code will also be downloaded if it was selected in build project window.

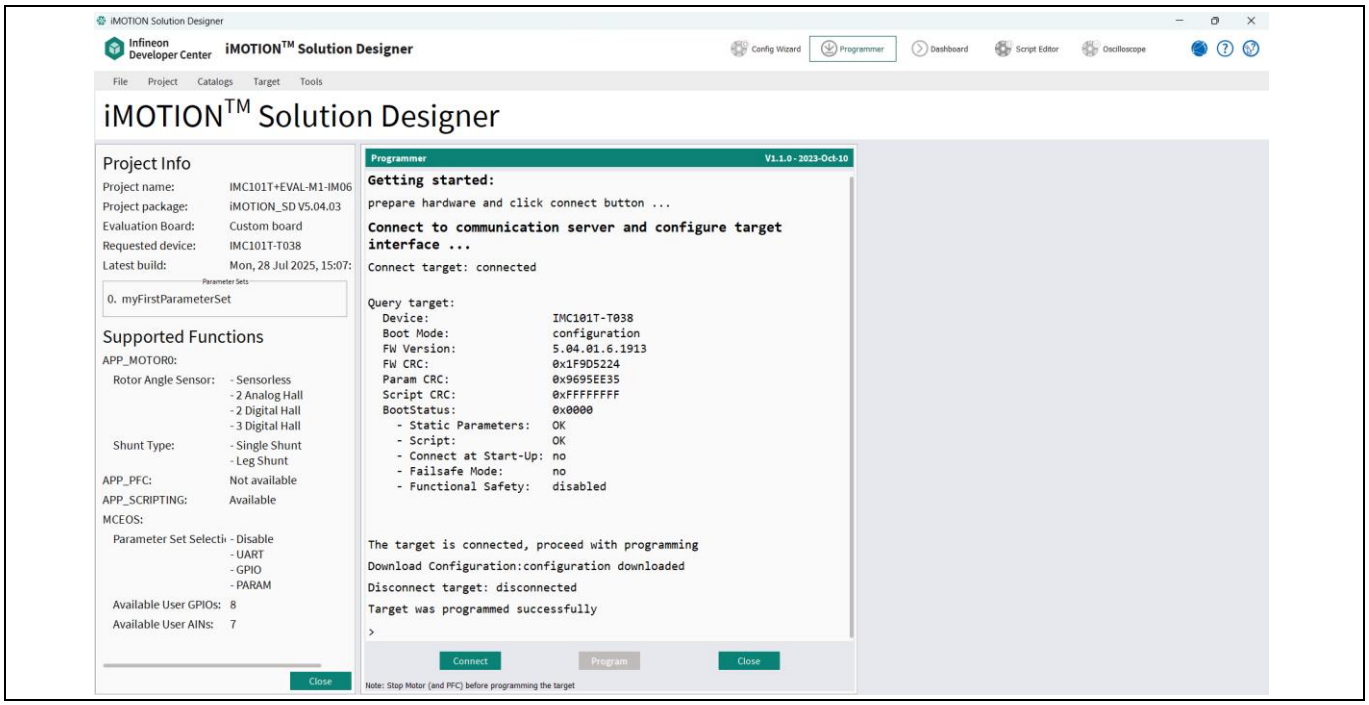

Figure 25 Programming

11. Close programming window in Figure 26. Click “Tools -> Dashboard” and click “no” on popup window “Download Parameter to target before switching to Dashboard” to enter dashboard window. Then you can change “Target speed” and click “Start Motor” to run a motor for evaluation test.

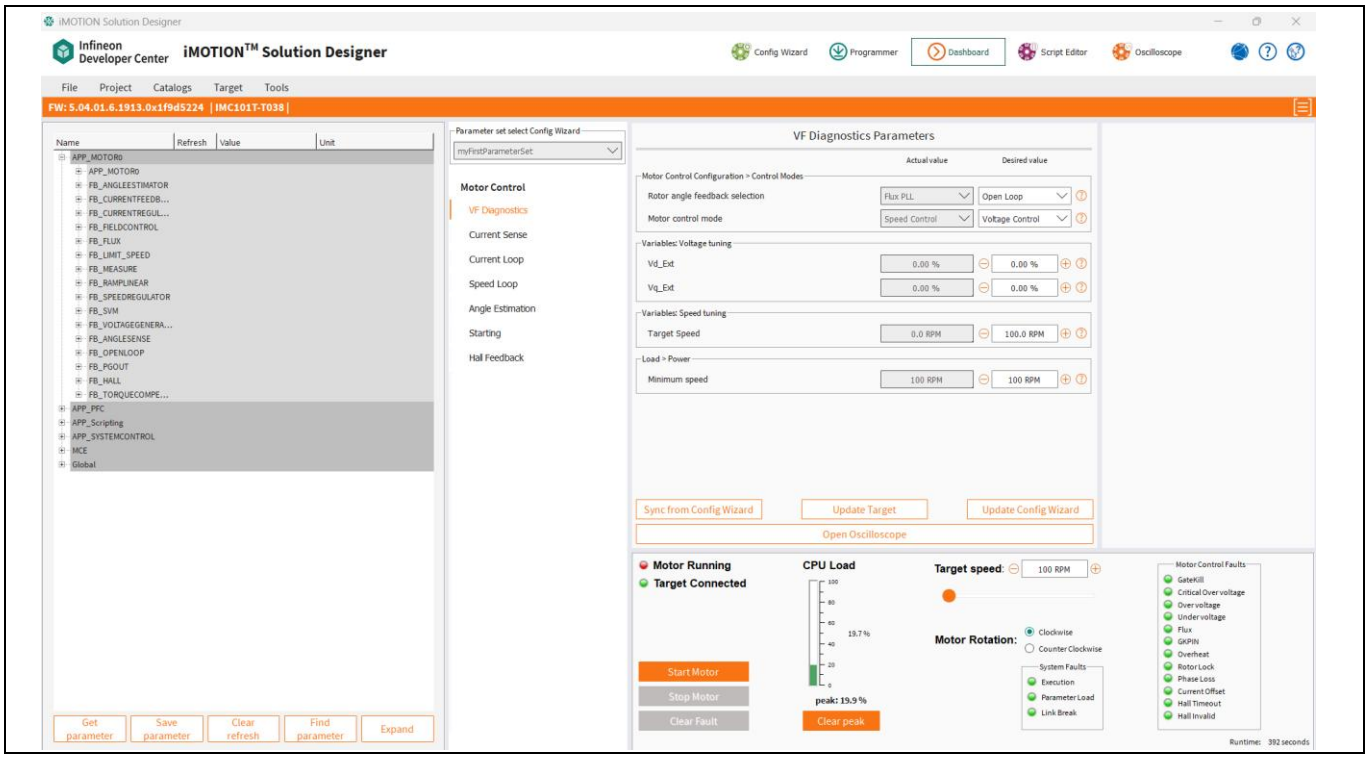

Figure 26 Dashboard

2.2 Description of the functional blocks

The motor inverter of EVAL-M1-CMADK-S reference design is implemented by the AIM12SXXEB1 module, and the auxiliary power supply is based on quasi-resonant controller: ICE5QSAG and CoolSiC™ MOSFET IMBF170R1K0M1.

2.2.1 Overview of AIM12SXXEB1

Figure 27 provides the overview of the AIM12SXXEB1 internal electrical schematics. For further information regarding these CIPOS™ SiC IPMs such as static and dynamic electrical behavior, as well as thermal and mechanical characteristics, please refer to the datasheet of the AIM12SXXEB1.

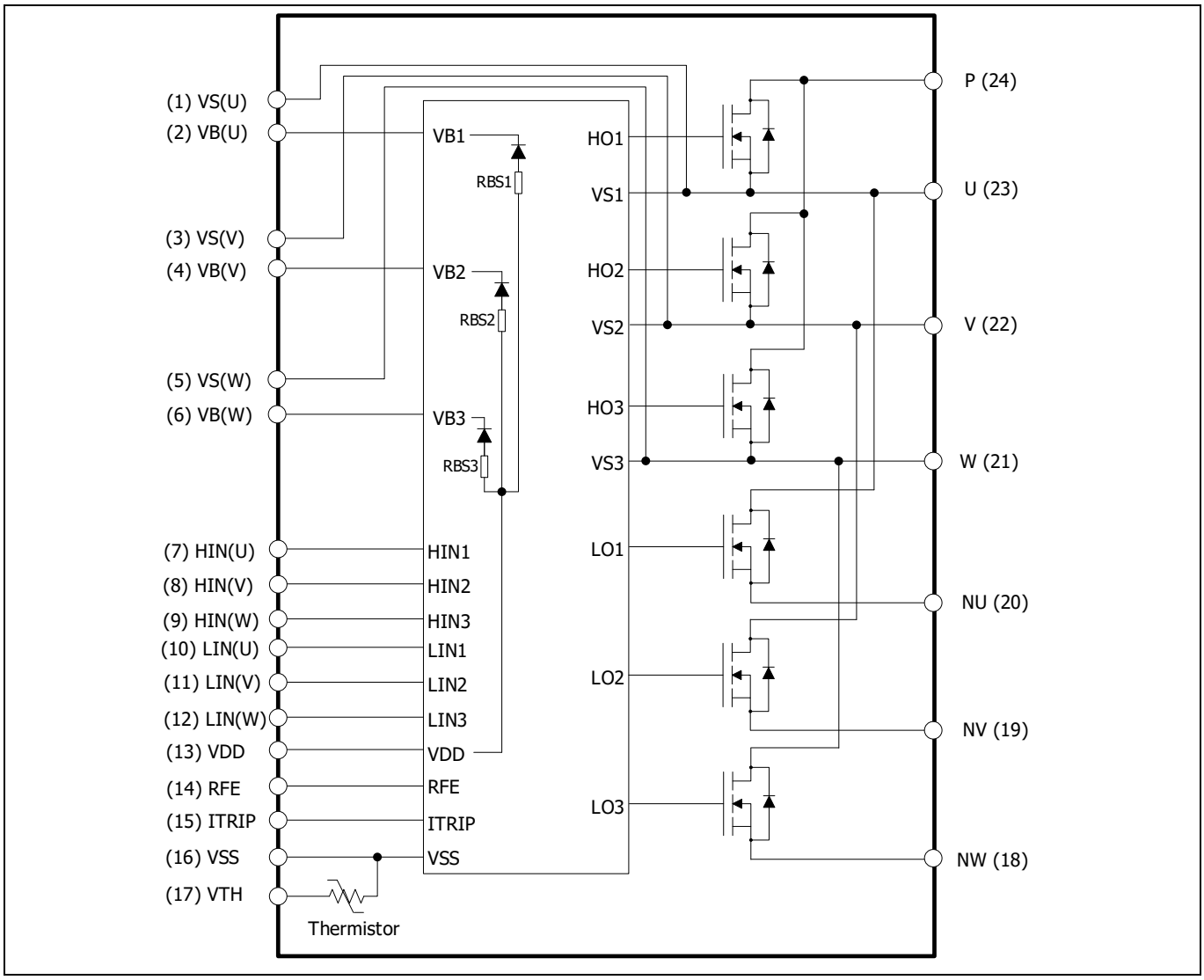

Figure 27 AIM12SXXEB1 internal electrical schematic

The main features of CIPOS™ Maxi IPM AIM12SXXEB1 include:

- Qualified AEC-Q & AQG324 molded IPM
- Fully isolated Dual In-Line molded module with AlN DCB substrate
- 1200 V CoolSiC MOSFETs technology with turn off stability thanks to higher VGS(th)
- 1200 V C5SOI gate driver technology with stability against transient and negative voltage
- Allowable negative VS potential up to -11 V for signal transmission at VBS = 15 V
- Integrated bootstrap functionality
- Over current shutdown and under-voltage lockout at all channels
- Built-in NTC thermistor for temperature monitor

- Low side source pins accessible for phase current monitoring (open source)
- Anti-cross conduction functionality
- All of 6 switches turn off during protection
- Fault reporting, programmable fault clear timing and enable input
- Lead-free terminal plating; RoHS compliant

Table 4 Absolute maximum ratings of AIM12S54EB1

Symbol	Description		Min	Max	Unit
V_{DS}	MOSFET drain-to-source voltage		--	1200	V
I_D	DC drain current	T_C = 25°C, T_J < 150°C	--	25	A
		T_C = 80°C, T_J < 150°C	--	20	A
P_d	Maximum power dissipation per MOSFET		--	86	W
T_J (MOSFET & IC)	Operating junction temperature		-40	150	°C
T_S	Storage temperature range		-40	125	°C
V_{BS}	High side floating supply voltage		-1	20	V
V_S	High side floating supply offset voltage		--	1200	V
V_{DD}	Module control supply voltage		-1	20	V
V_{IN}	Input voltage (LIN, HIN, REF)		-1	V_{DD} + 0.3	V
V_{RRM}	Repetitive peak reverse voltage of bootstrap diode		--	1200	V

2.2.2 Overview of IMBF170R1K0M1

The IMBF170R1K0M1 is Infineon's CoolSiC™ 1700V SiC Trench MOSFET, offers high performance, high efficiency and easy to use with DC 120~1000 V full voltage range safe industrial auxiliary power supply for fly-back topology.

This is the MOSFET package and definition:

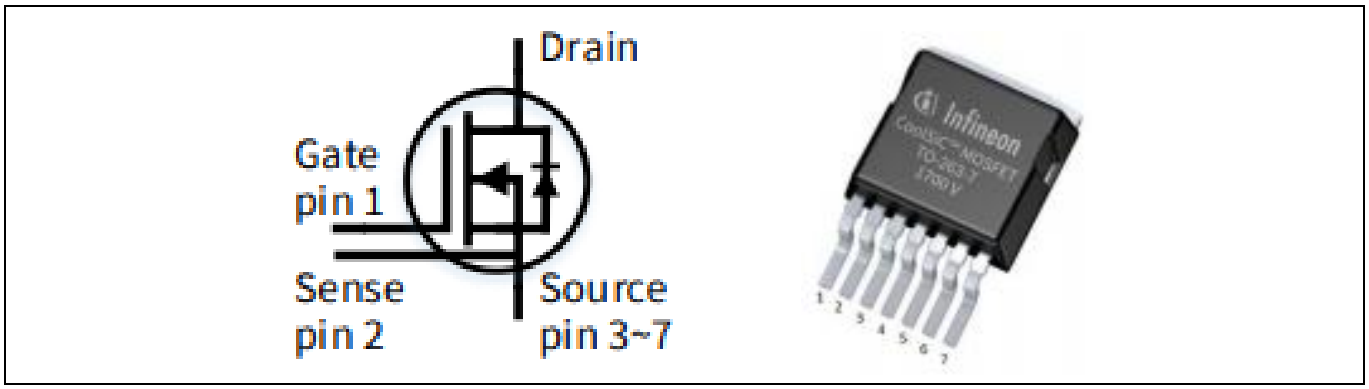

Figure 28 IMBF170R1K0M1 package: PG-TO263-7 and pin definition

The main features of CoolSiC™ MOSFET IMBF170R1K0M1 include:

- 1700 V CoolSiC™ MOSFET
- Revolutionary semiconductor material - Silicon Carbide

- Optimized for fly-back topologies
- 12 V/0 V gate-source voltage compatible with most fly-back controllers
- Very low switching losses
- Benchmark gate threshold voltage, $V_{GS(th)}$ = 4.5V
- Fully controllable dV/dt for EMI optimization

Table 5 Absolute maximum ratings of IMBF170R1K0M1

Symbol	Description		Value	Unit
V_{DS}	MOSFET drain-to-source voltage		1700	V
I_D	DC drain current	T_C = 25°C	5.2	A
		T_C = 100°C	3.7	A
P_{tot}	Power dissipation, limited by T_{vjmax}	T_C = 25°C	68	W
		T_C = 100°C	34	W
$I_{D.pulse}$	Pulsed drain current, t_p limited by T_{vjmax}, V_{GS} = 12 V		13.3	A
T_{vj}	Virtual junction temperature		-55 ~ 175	°C

3 System design

The EVAL-M1-CMADK-S board is an optimized design for 3-phase AC 380V major home and industry appliances. To meet individual customer's requirements and to make the EVAL-M1-CMADK-S reference design a basis for development or modification, all board design data such as schematics, Gerber and Altium design data can be found on the Infineon homepage and log in your account to download them.

3.1 Inverter section using CIPOS™ Maxi

The inverter section is implemented using the CIPOS™ Maxi as sketched in Figure 29. This is 3-phase inverter bridge section with Infineon CoolSiC™ SiC MOSFET and driver inside. RS1, RS2 and RS3 are three shunts for current sensing. The three capacitors C1, C2 and C6, C8 and C5, C7 are used as bootstrap capacitors to provide the necessary floating supply voltages VBU, VBV and VBW respectively. C15 is a DC bus snubber for IPM.

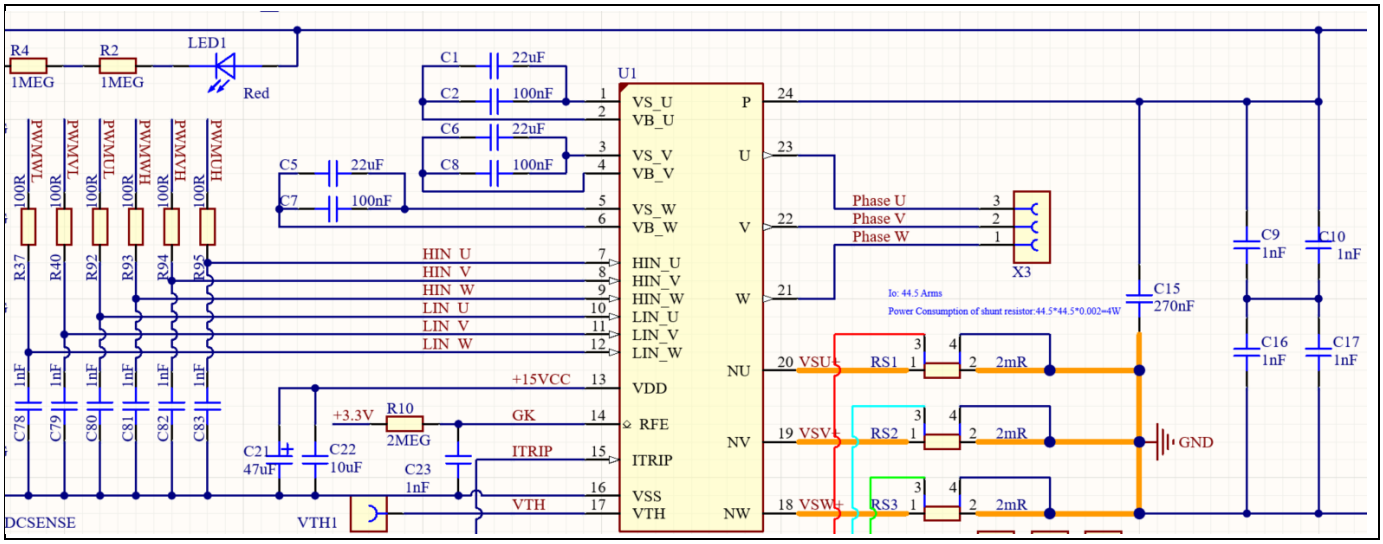

Figure 29 The diagram of the inverter section

3.2 DC/DC

Figure 30 depicts the schematic of the power supply available on the EVAL-M1-CMADK-S board. The circuit is ZVS fly-back topology; the input voltage range is 150~780 V DC bus, and the discharge DC bus is go to lower than 60 V in 180 seconds (by K1 and fan) when power is turned off. It includes the ICE5QSAG and CoolSiC™ 1700 V SiC trench MOSFET used to generate 15 V and 6 V directly from the DC bus. 15 V is connected to the gate drivers inside the CIPOS™ Maxi IPM, which generates 12 V for K1 and fan. 3.3 V power supply is from DC6 V by linear regulator IFX_TLE4274GS V33. The 3.3 V power supply is used in the over-current comparator circuit. Both 15 V and 3.3 V are also present on the 20-pin interface connector X4.

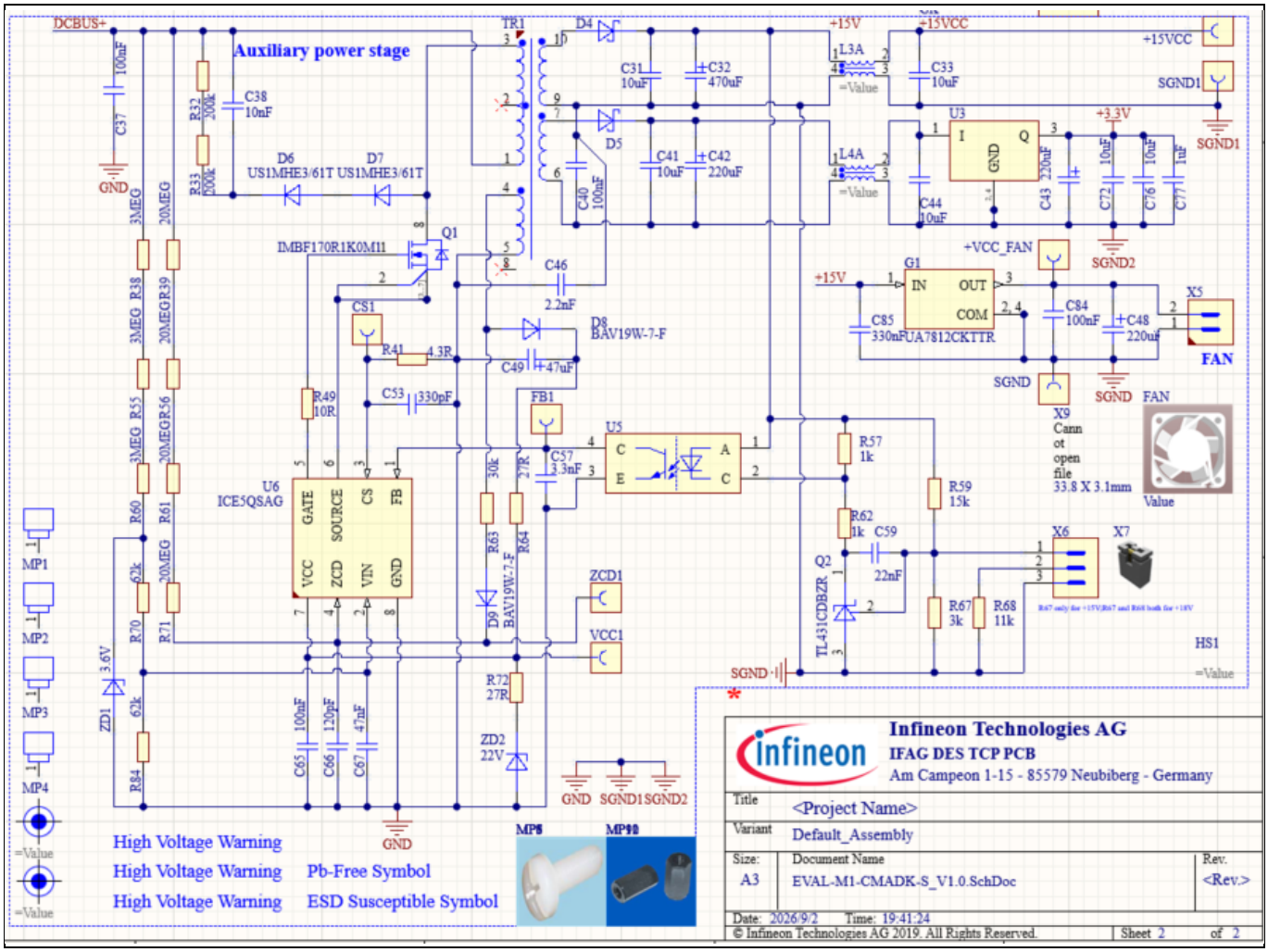

Figure 30 DC/DC power supply

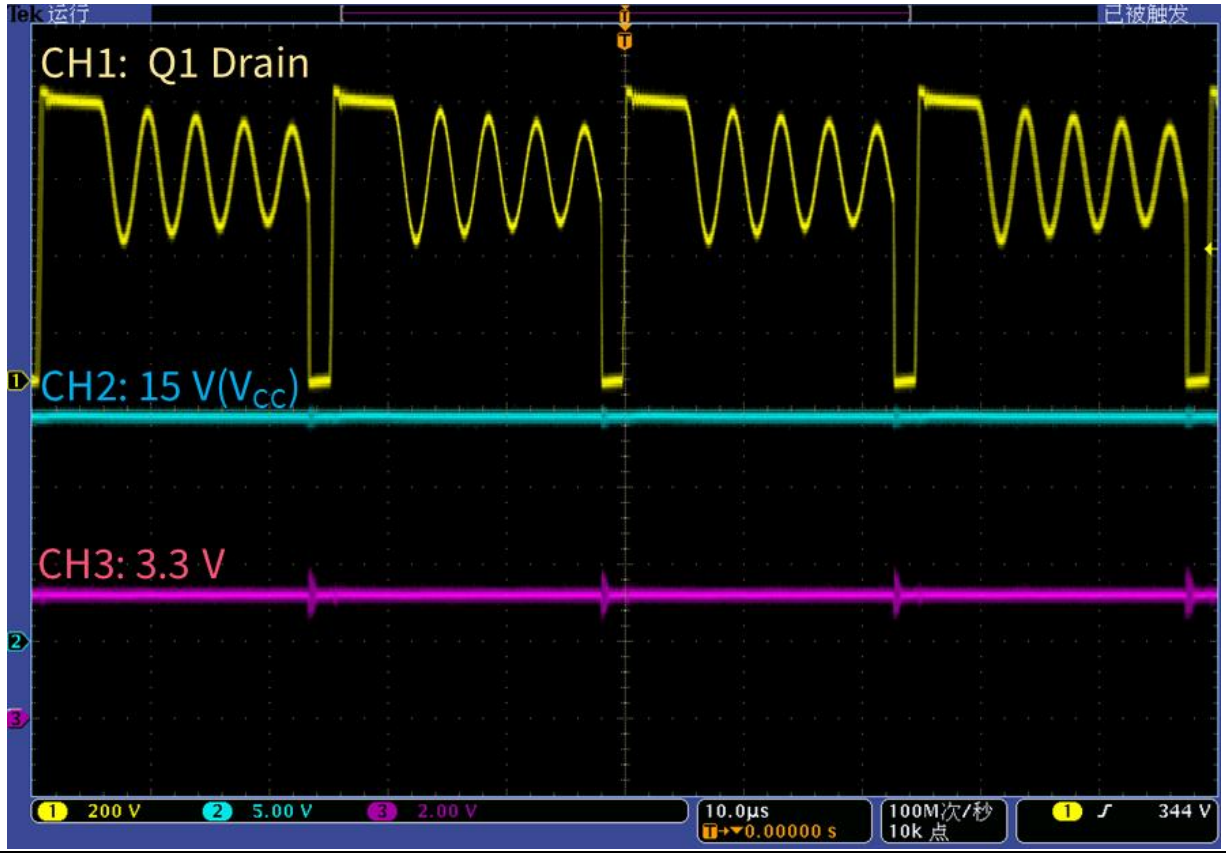

Figure 31 Q1 ZVS switching and 15 V/3.3 V output at 430 VAC input

3.3 AC/DC input and soft start

Figure 32 depicts the schematic of the AC/DC input section. It includes the connector X1, the rectifier (DB1), soft start (R5, K1), a passive EMI filter (C11, C12, C13, C14, C20, L1, L2), a fuse F1 for over-current protection, and DC bus capacitors (C3, C4, C18, C19).

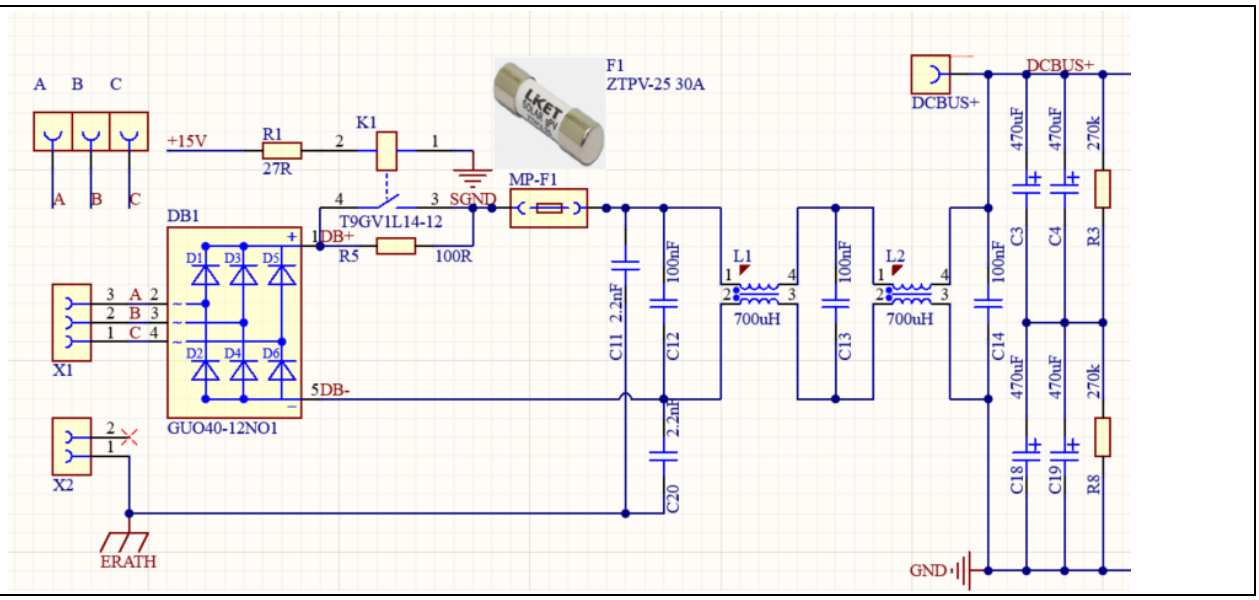

Figure 32 The schematic of AC/DC section and soft start circuit

3.4 DC-link voltage measurement

Pin 14 of connector X4 provides access to the DC-link voltage.

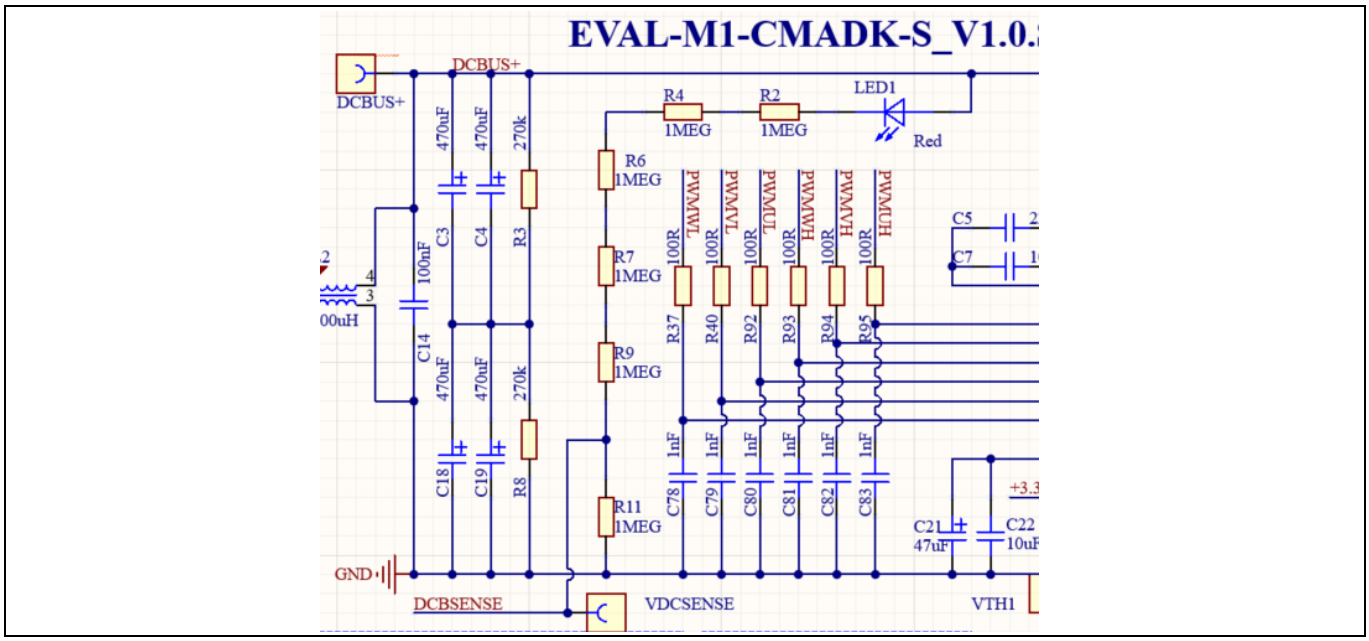

Figure 33 DC bus sensing

R11 is the safety resistor on the connection port when the connector is open. The DC-bus sensing low-side resistance is R11 // R1 (R1 is on EVAL-M1-101T). It is 1 MΩ // 13.3 kΩ = 13.13 kΩ.

3.5 Current sensing and amplifier

EVAL-M1-CMADK-S has three shunt sensing by RS1, RS2 and RS3. The final value of shunt resistance is 2 mΩ. The current output IU+ goes to X4.

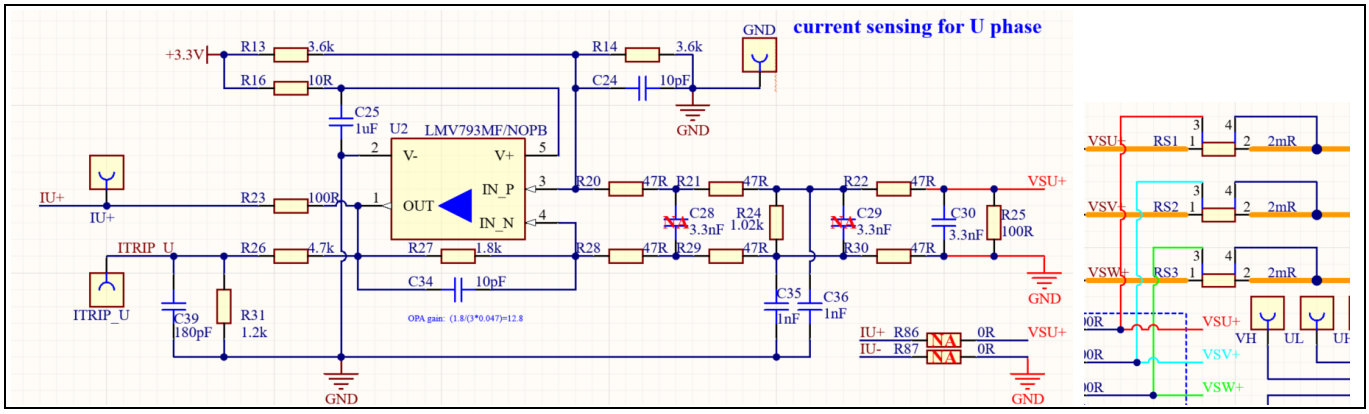

Figure 34 Current sensing and signal amplification

R21 / R22 / R29 / R30 / C28 / C29 / C30 are for low-pass filter (LPF) for EMC noise from shunt resistor. R20 / R28 / R27 / C34 and U2 consist of a low-noise proportional amplifier. The gain of the amplifier is:

$$\text{Gain} = \frac{\text{R27}}{\text{R28} + \text{R29} + \text{R30}} \approx 12.8$$

The current scaling is:

$$V_{shunt} = RS1 \times Gain = 25.6\ mV/A$$

Static status @ I_{shunt}=0 A:

$$V_{offset} = \frac{R14}{R13 + R14} \times 3.3V = 1.65\ V$$

The response time:

$$T_o \approx \frac{1}{\frac{GBW}{Gain - 1}} = 0.145\ \mu S$$

R23 is U2 output transmission matching resistor. GBW is the gain bandwidth of U2.

The circuit below shows the feedback current signal to the control board. The offset circuit consists of R6 and 3.3 V on the EVAL-M1-101T. Please remove R6 and chang R27 from 2 kohm to 0 ohm.

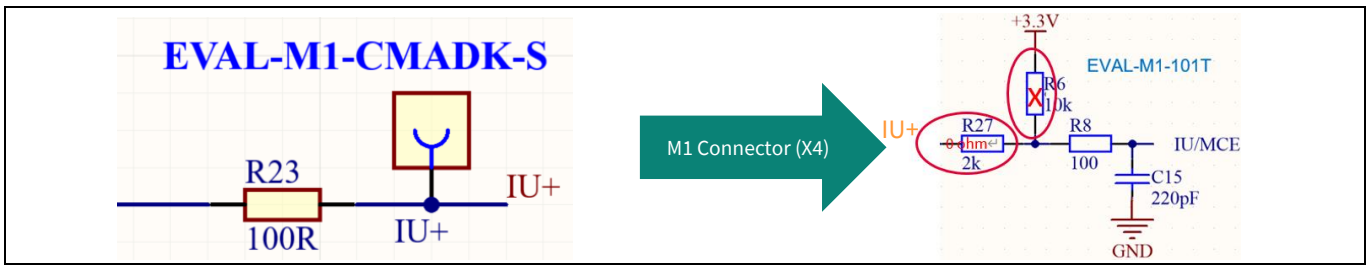

Figure 35 Current signal transmission between EVAL-M1-CMADK-S and EVAL-M1-101T

The attenuation of the current signal from IU+ to X4 (Pin 10 IU+).

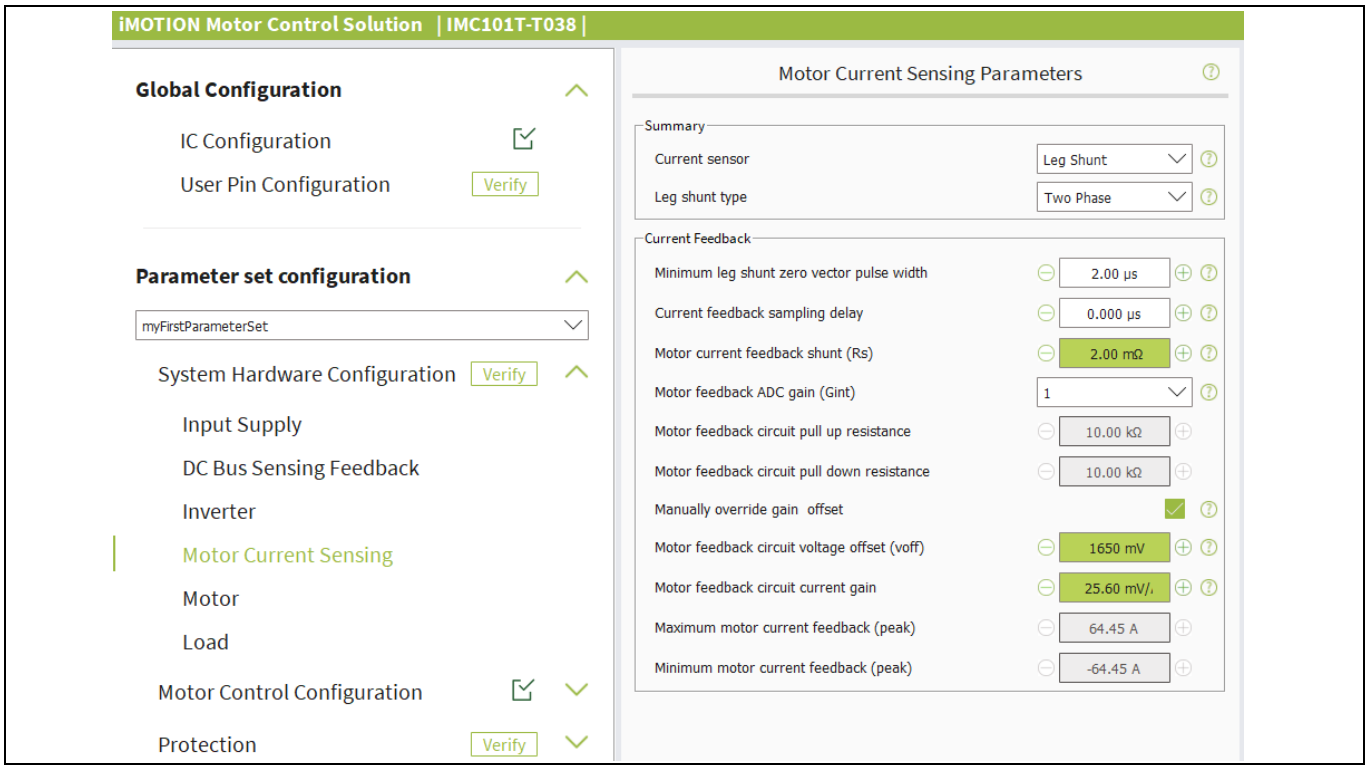

Figure 36 Current input scaling setup

The current feedback range:

$$I_{range} = \frac{(3.3V - 1.65V)}{Gain \times G\_int \times RS1} = \pm 64.5\ A$$

Since control board ADC range is 3.3 V, we have to select the internal gain of control board to “1”.

3.6 ITRIP and GK setup

3.6.1 ITRIP setup

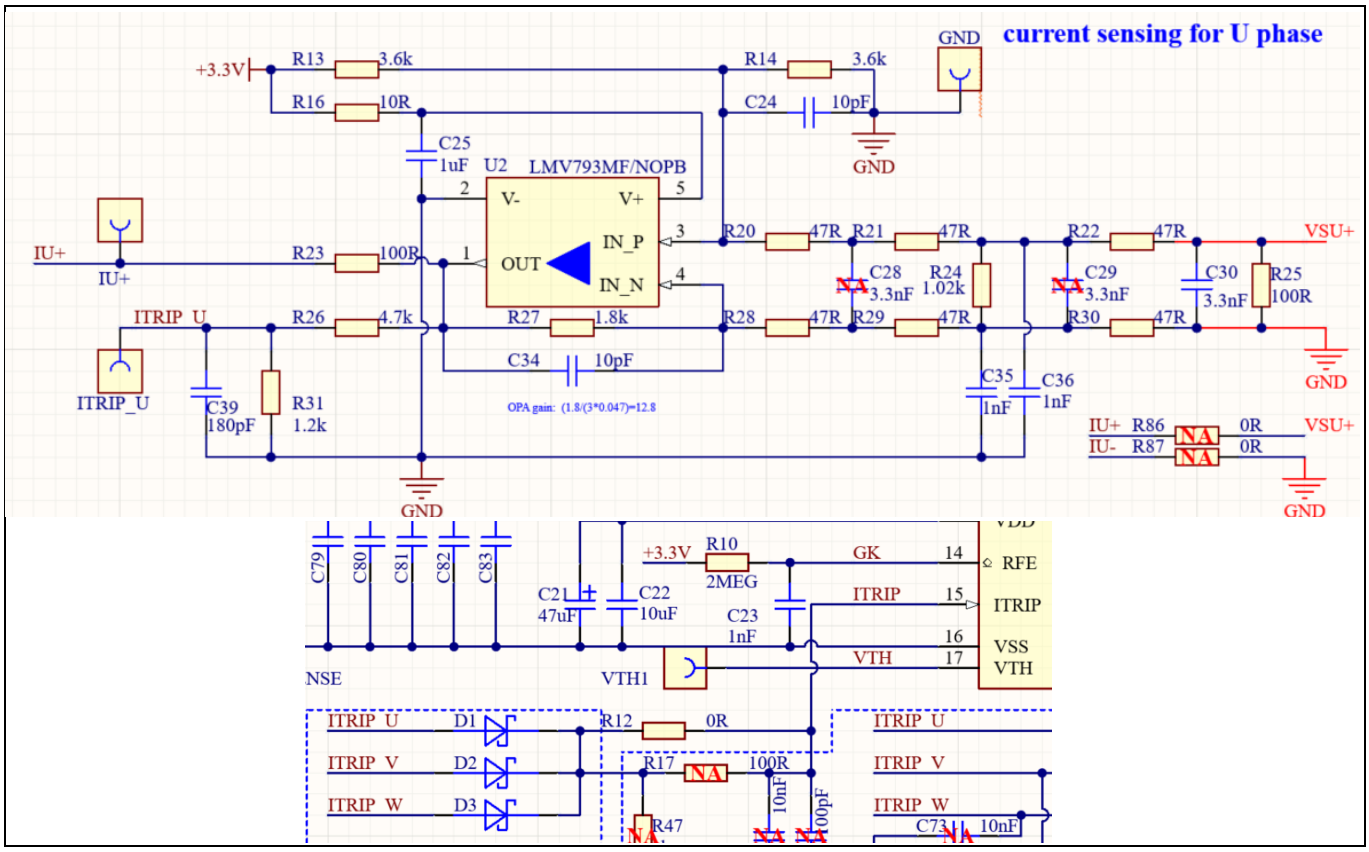

Figure 37 Over-current protection circuit and ITRIP signal

AIM12SXXEB1 provides an over-current detection function by connecting the ITRIP input with the MOSFET drain current feedback. The ITRIP comparator threshold (typ. 0.5 V) is referenced to VSS ground.

The typical over-current threshold (IOCP) is:

$$IOCP = \frac{(0.5 + 0.12)\ V \times (R26 + R31)}{R31} - \frac{V_{offset}}{V_{shunt1}} = 55\ A$$

When the current is higher than 55 A, it will generate a shutdown for all outputs of the gate driver. The shutdown propagation delay is typically 1 µs.

3.6.2 PWM shut down and GK output

When over-current is detected, the ITRIP voltage is over the threshold value, then C23 will be discharged (GK is open drain), and GK drops to “0”. This GK sends signal to control board via X4. GK “0” status is continuous for

about 150 µs. After 150 µs, GK becomes open drain and charges C23 via R10. The R10 and C23 time constant is about 2 ms. Figure 38 shows the ITRIP and GK circuit. Figure 39 shows the over-current protection waveform.

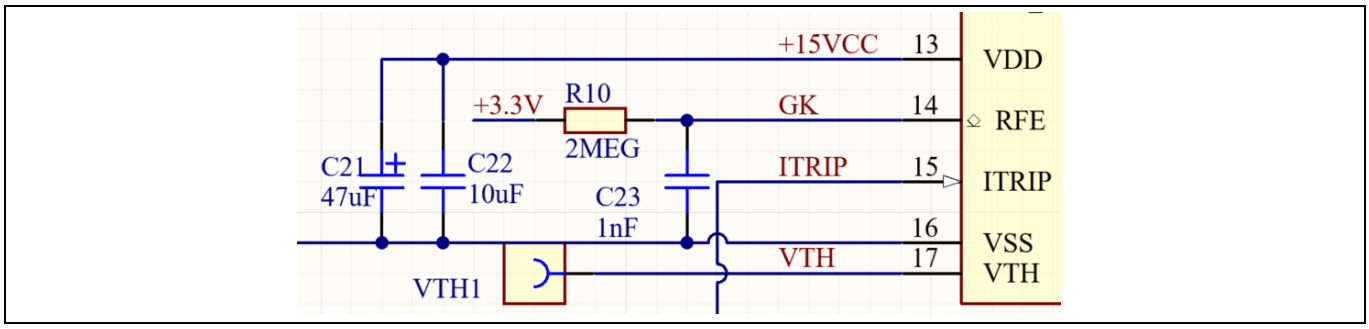

Figure 38 ITRIP / GK and fault-clear

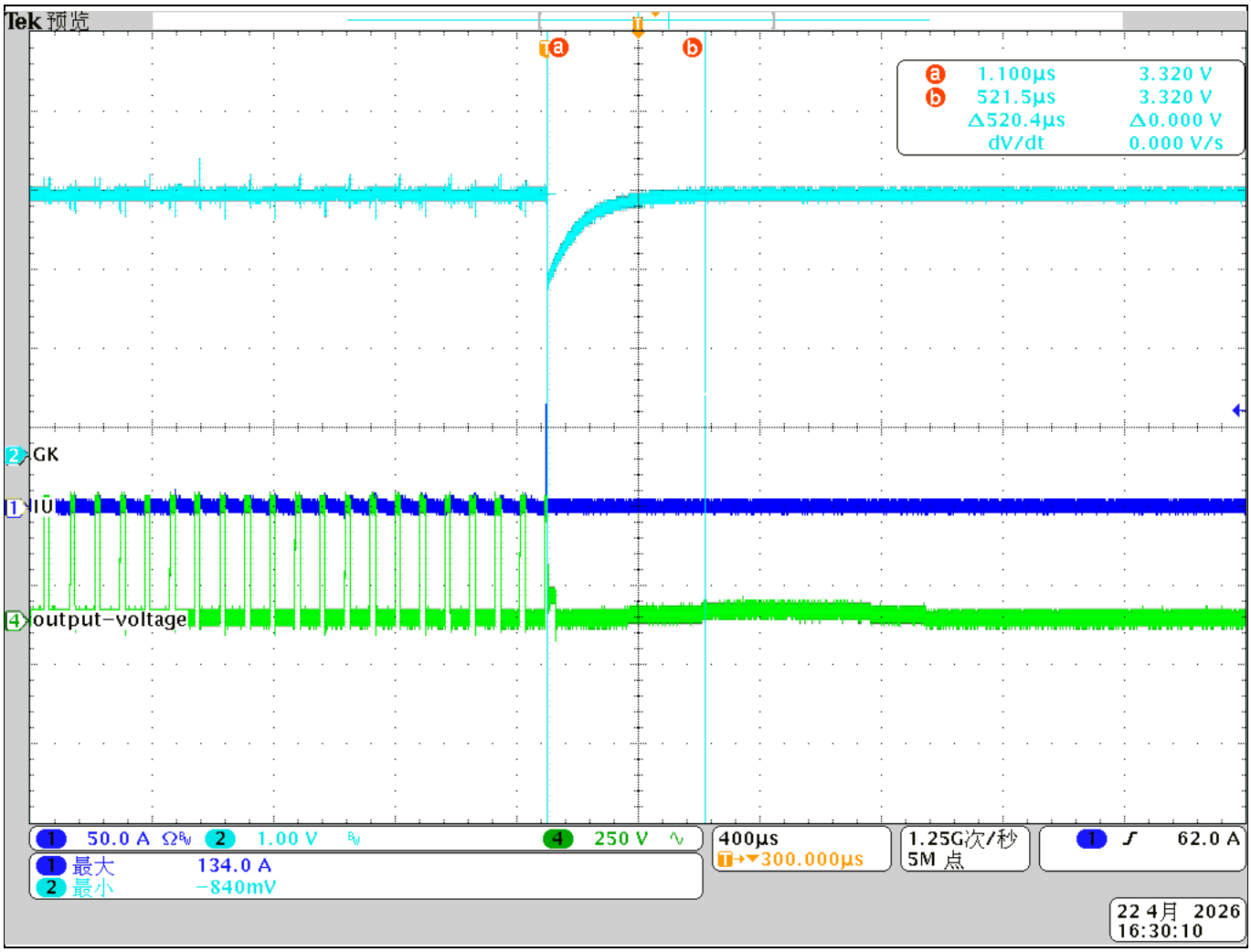

Figure 39 GK and U phase current and voltage waveform in short output on J2

3.7 NTC thermistor characteristics and over-heat protection calculation

Figure 40 shows the NTC measurement circuit.

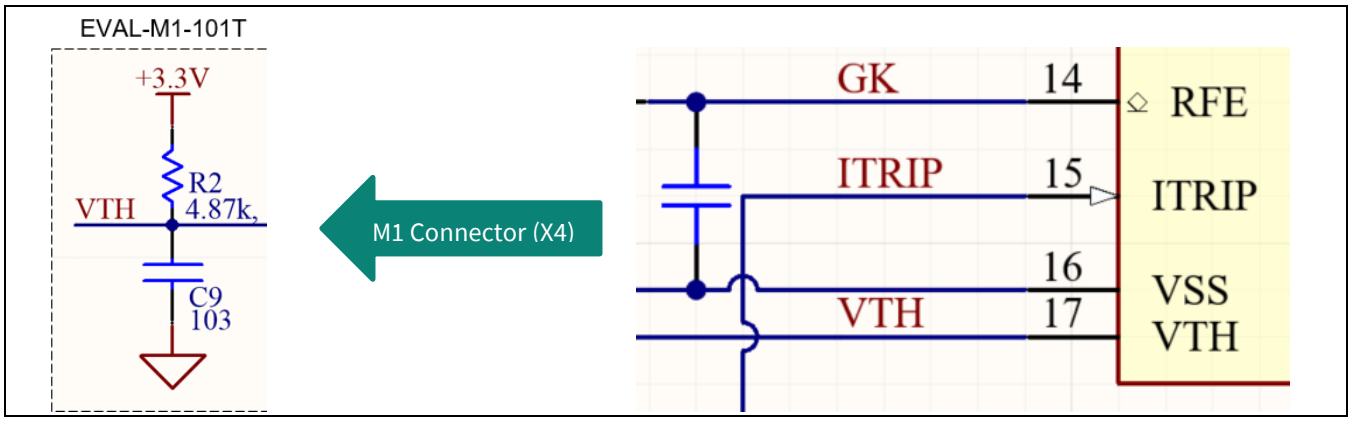

Figure 40 NTC (inside AIM12SXXEB1) connect to EVAL-M1-101T via X4

The NTC is 85 kΩ @ T_{NTC} = 25°C, B-constant = 4092 K:

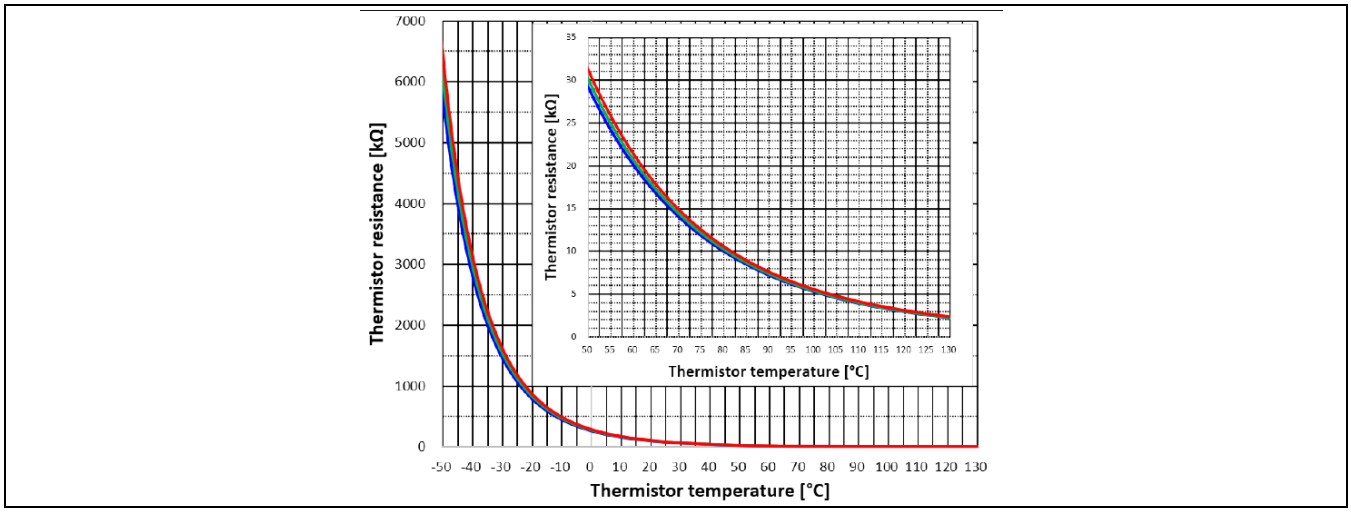

Figure 41 NTC temperature curve and table

Table 6 VTH output vs NTC to EVAL-M1-101T:

Temperature (°C)	NTC (kΩ)	VTH (V)
50	30.157	2.841
60	20.669	2.671
70	14.424	2.467
80	10.234	2.236
90	7.373	1.987
100	5.388	1.733
110	3.99	1.486
120	2.991	1.256
125	2.601	1.149

Figure 42 shows curve of VTH vs NTC

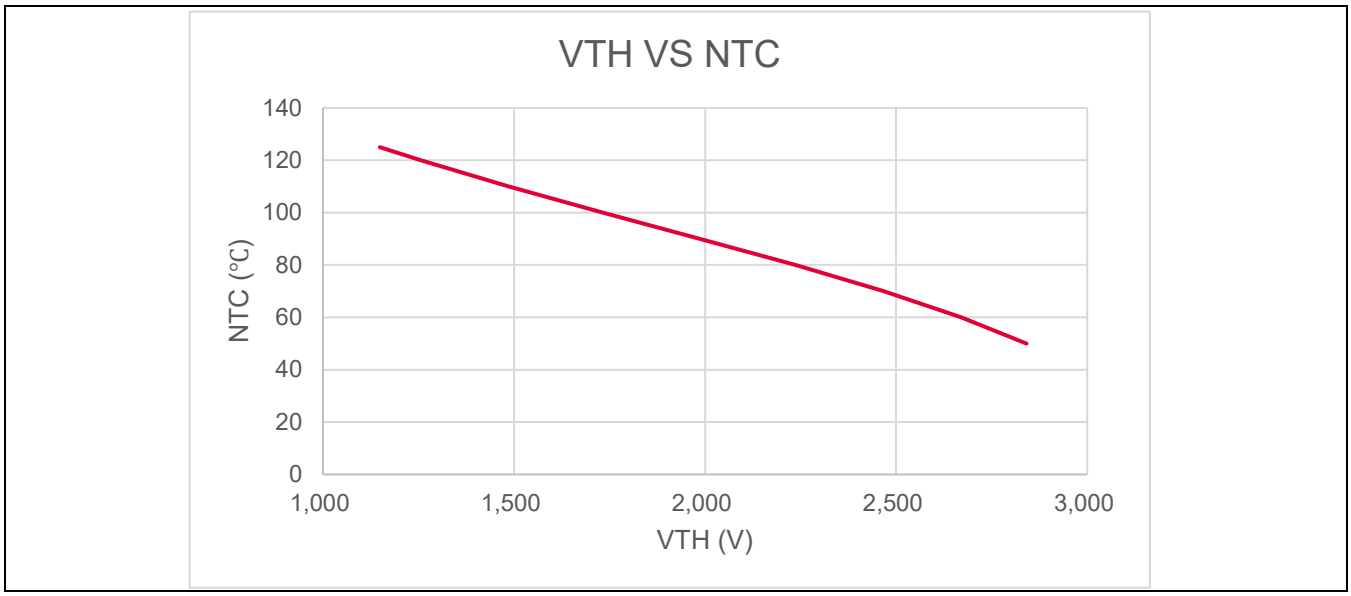

Figure 42 VTH output

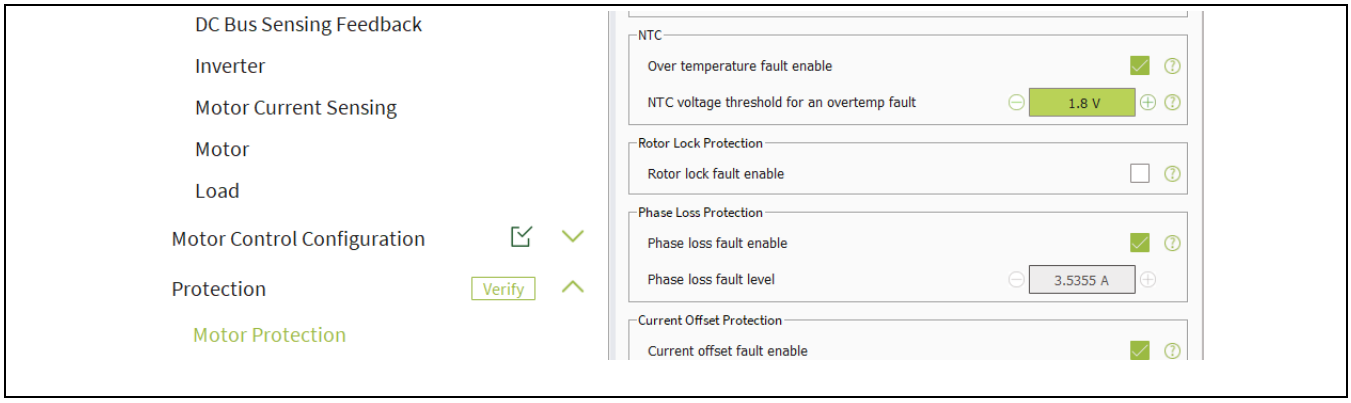

Figure 43 IPM temperature shutdown set to 100°C in iMOTION Designer

3.8 Layout

This board has four electrical layers with 70 µm copper (2 oz. copper) and dimensions are 140 mm × 185 mm. The thickness of the PCB board is 2.0 mm. Figure 44 and Figure 47 illustrate the top and bottom layers of the reference design. As well as Figure 45 and Figure 46 illustrate the layer 2 and layer 3 of the inter layer reference design.

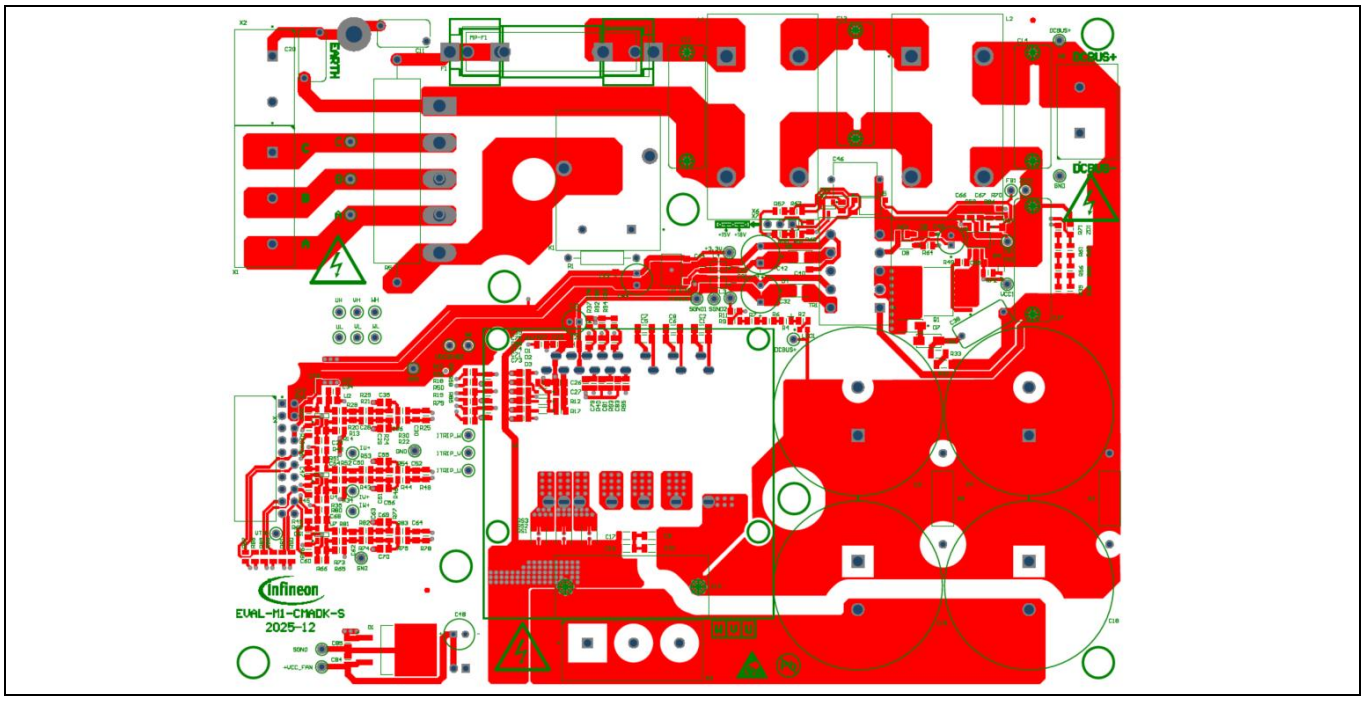

Figure 44 Top layer

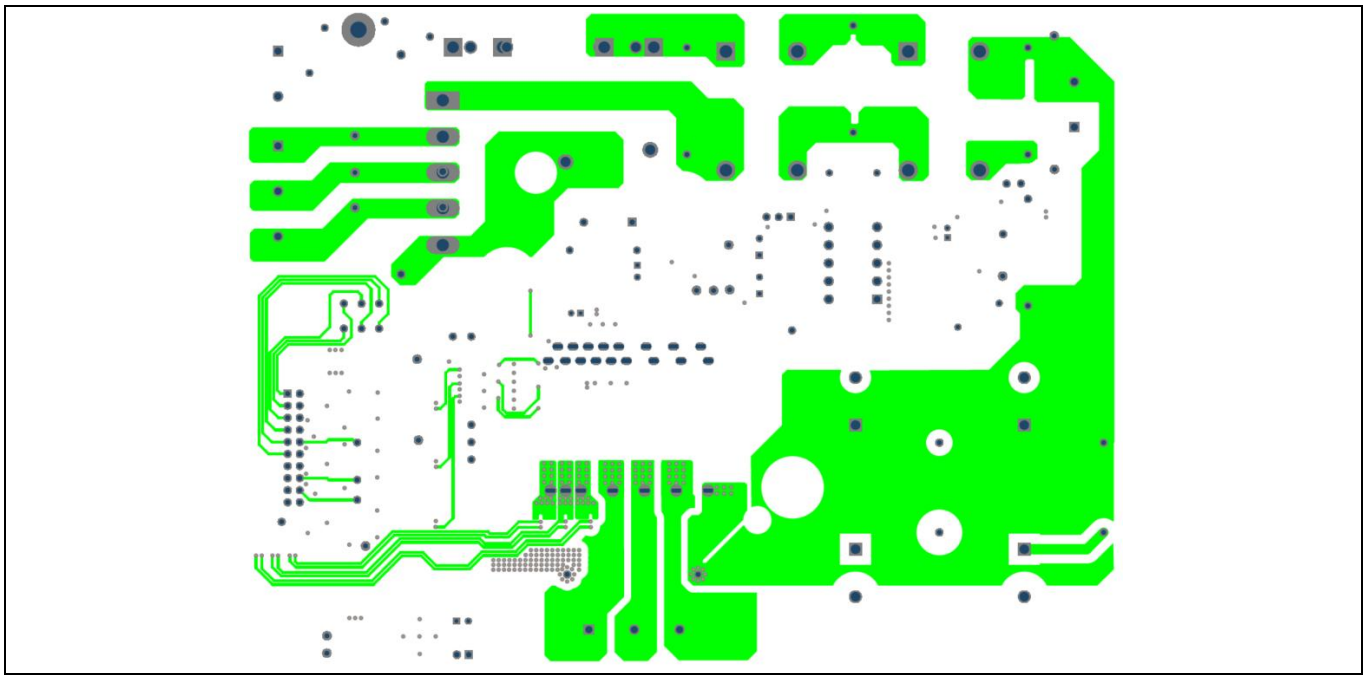

Figure 45 Layer 2

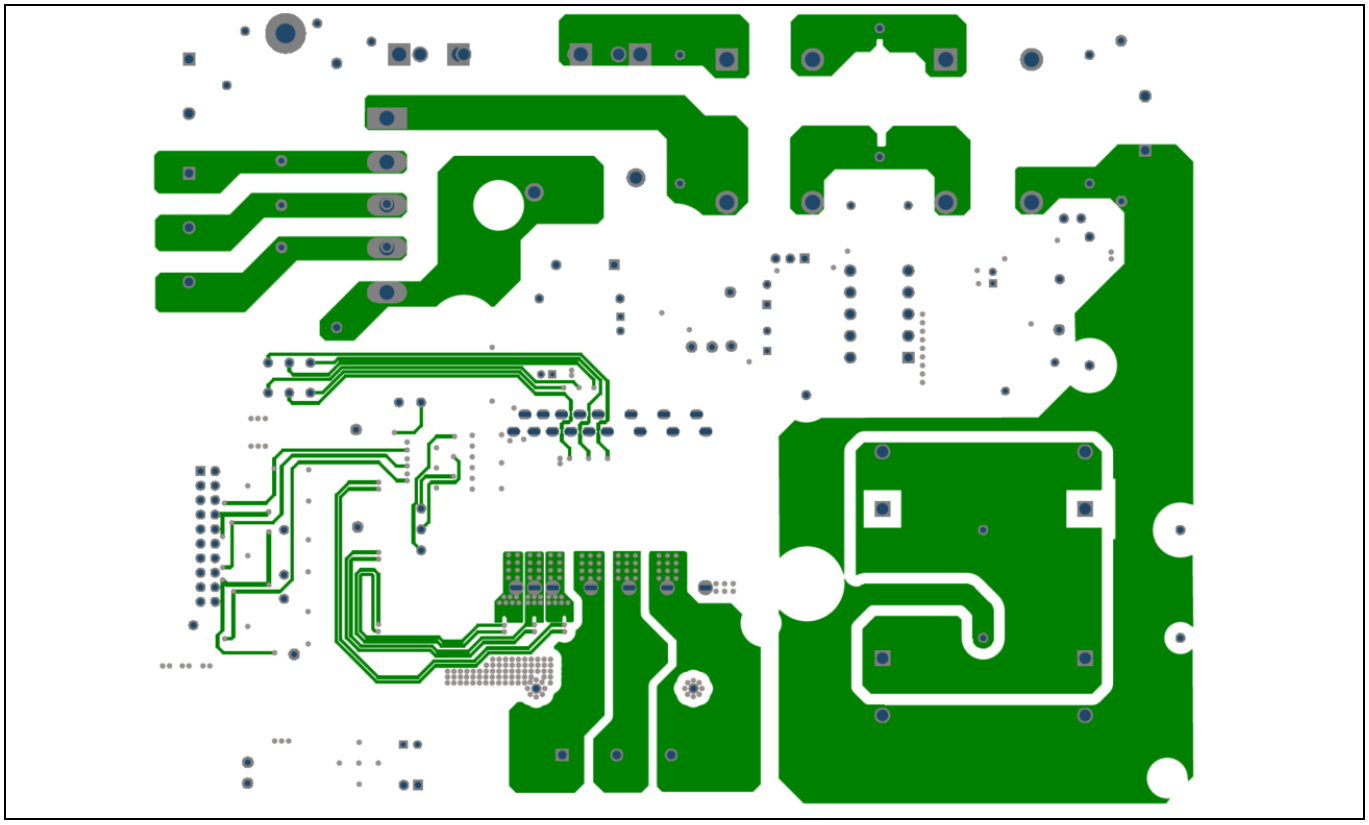

Figure 46 Layer 3

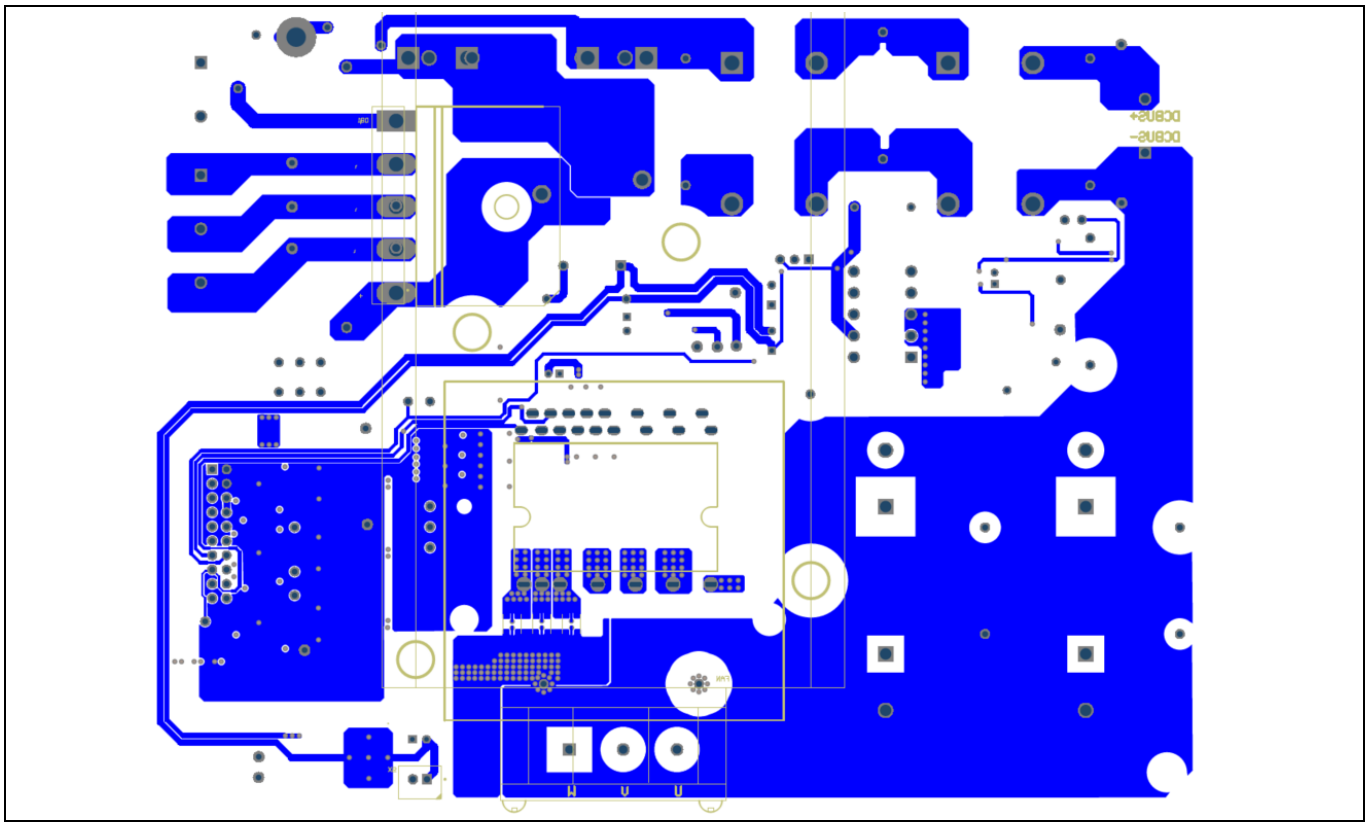

Figure 47 Bottom layer

3.9 Bill of material

Table 7 shows the major parts of EVAL-M1-CMADK-S design.

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

Table 7 BOM of the most important/critical parts of the evaluation board

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
1	U1	CoolSiC™ IPM	Infineon Technologies	AMI12SXXEB1
2	Q1	CoolSiC™ SiC MOSFET 1700 V	Infineon Technologies	IMBF170R1K0M1
3	U6	Quasi-resonant PWM controller	Infineon Technologies	ICE5QSAG
4	U3	Low dropout voltage regulator, 3.3 V output	Infineon Technologies	TLE4274GS V33
5	C3, C4, C18, C19	Electrolytic capacitor	Wurth Elektronik	861011486024
6	X3	Connector	Wurth Elektronik	613020243121
7	L1, L2	WE-CMB HV common mode	Wurth Elektronik /Sunlord	744830007215/ARCD C432340A701N2B
8	L3A, L4A	WE-CMB HV common mode	Wurth Elektronik	744232261
9	TR1	EE20 / 10 / 6	Wurth Elektronik	750344164

3.10 Connector details

General information about the connectors of the EVAL-M1-CAMDK-S evaluation board is provided in the tables below. Table 8 includes the details of the 3-phase AC X1 and X2. Table 9 provides the details of the motor side connector X3. Table 10 provides the pin assignments of the iMOTION™ MADK M1 20-pin interface connector X4. This connector is the interface to the control board.

Table 8 X1- 2-phase AC input connector

Pin #	Pin name	Description
1	EARTH	Earth
2	NC	No connection
3	A	AC input
4	B	AC input
5	C	AC input

Table 9 X3- Motor side connector

Pin #	Pin name	Description
1	W	Connected to motor phase W
2	V	Connected to motor phase V

Pin #	Pin name	Description
3	U	Connected to motor phase U

Table 10 X4- iMOTION™ MADK M1 20-pin interface connector for power board

Pin #	Pin name	Description
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	Ground
5	PWMVH	3.3 V compatible logic input for high-side gate driver-Phase V
6	+3.3 V	3.3 V power supply
7	PWMVL	3.3 V compatible logic input for low-side gate driver-Phase V
8	+3.3 V	3.3 V power supply
9	PWMWH	3.3 V compatible logic input for high-side gate driver-Phase W
10	IU+	Shunt voltage+
11	PWMWL	3.3 V compatible logic input for low-side gate driver-Phase W
12	IU-	Ground
13	GK	Gatekill
14	DCBSENSE	Input, DC bus voltage to AIN1 after 2000 kΩ registers
15	VTH	Input, voltage input of power module’s temperature sense
16	IV+	Open
17	IV-	Open
18	IW+	Open
19	IW-	Open
20	VCC	Defined for 15 V power supply

4 System performance

4.1 Type output waveform at 3-phase AC380 V input

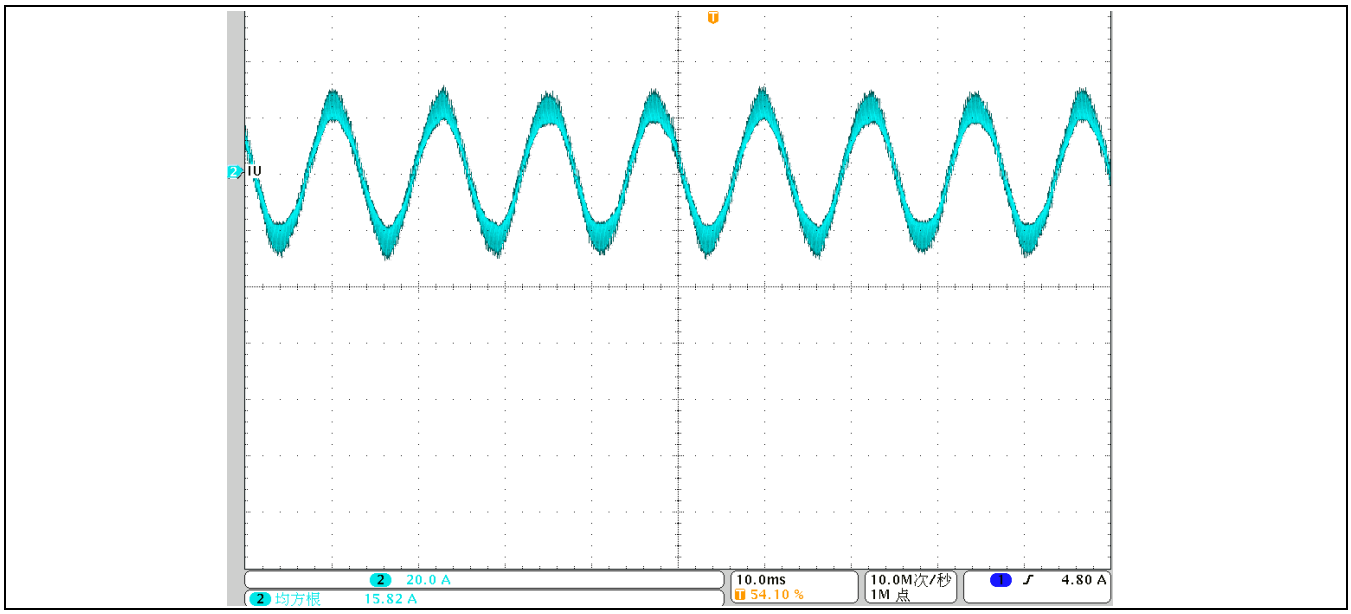

Figure 48 I_U Output 15.8 A at PWM=6 kHz waveform by DPO4104(oscilloscope) + TCP0030(probe)

4.2 Test results for over-current protection

Figure 49 is the EVAL-M1-CMADK-S over-current detection function by connecting the ITRIP input with the AIM12S54EB1 current feedback, and CoolSiC™ MOSFET short-circuit withstand time is about 1.8 µs. Over current detection generates a shutdown of outputs of the gate driver if ITRIP pin input is over 525 mV and lasts longer than 500 ns.

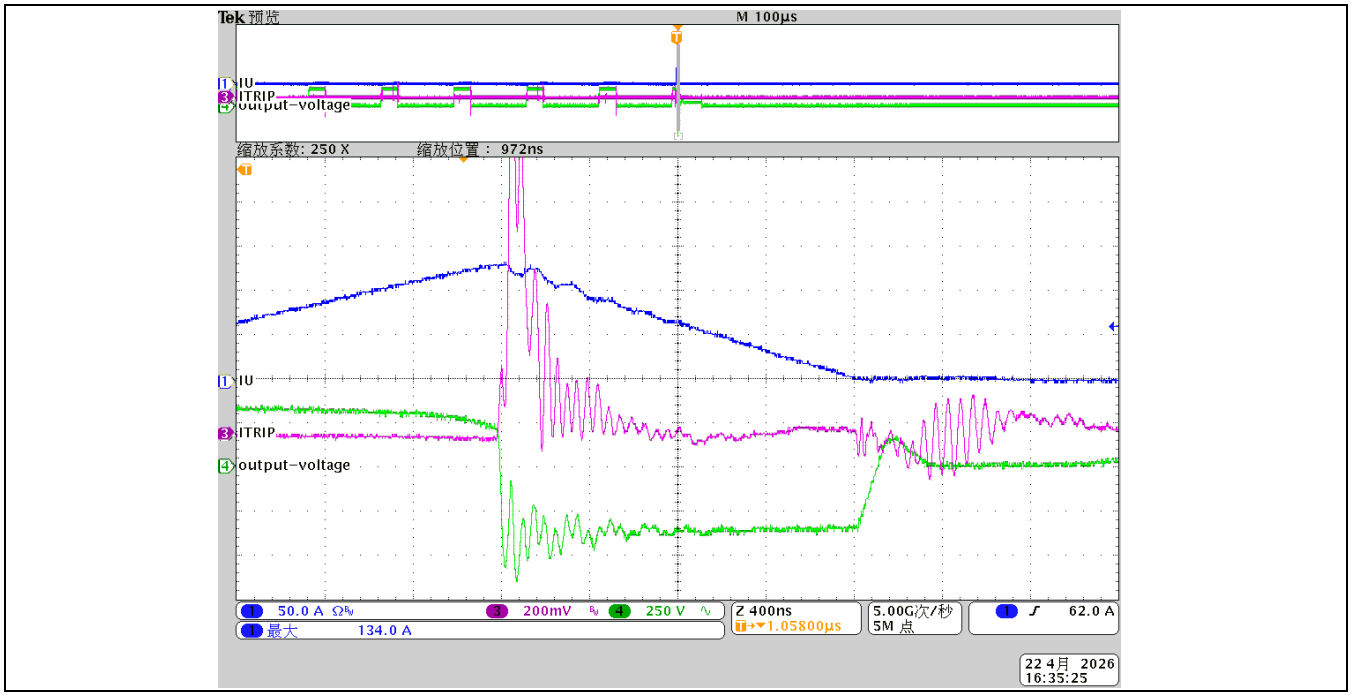

Figure 49 Over-current protection response waveform

4.3 T_{cmaxi} vs I_{out} at different PWM frequencies

Figure 50 shows the IPM case temperature vs output current with difference PWM carrier frequencies based on the specific heatsink dissipation conditions of the EVAL-M1-CMADK-S board.

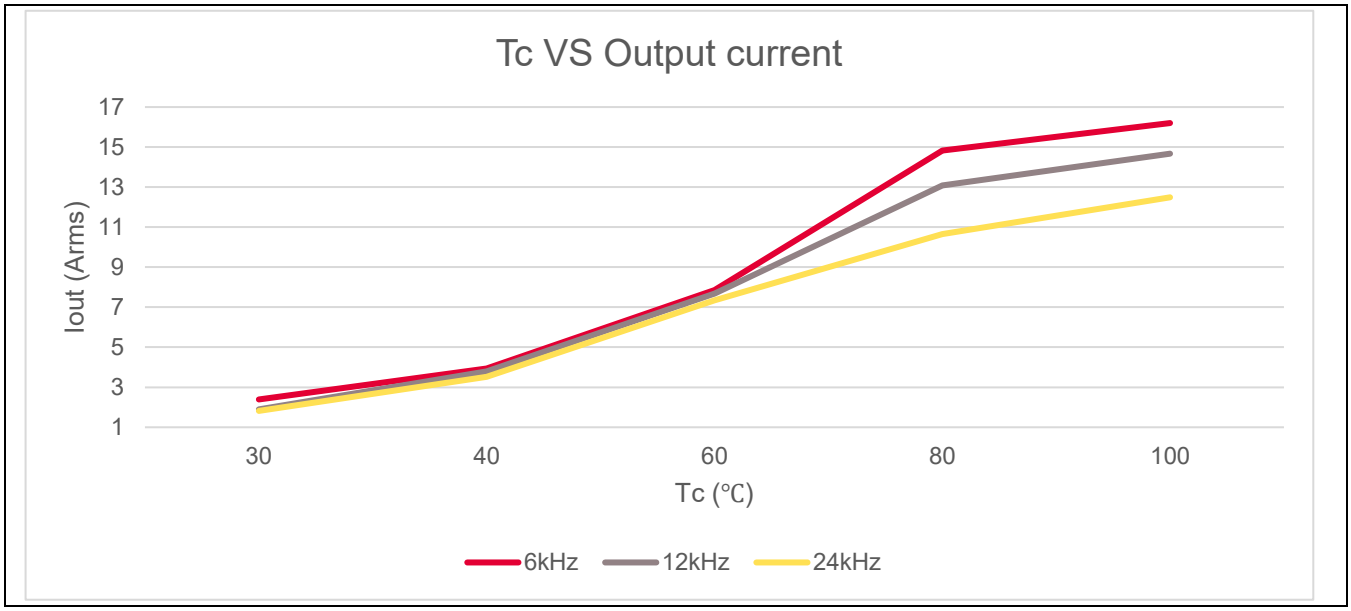

Figure 50 AIM12S54EB1 case temperature vs output current at different PWM frequencies @380 V AC input, T_a=25℃

4.4 AIM12S54EB1's efficiency

Figure 51 shows the IPM efficiency vs output current at 380 V AC input and 6 kHz carrier frequency

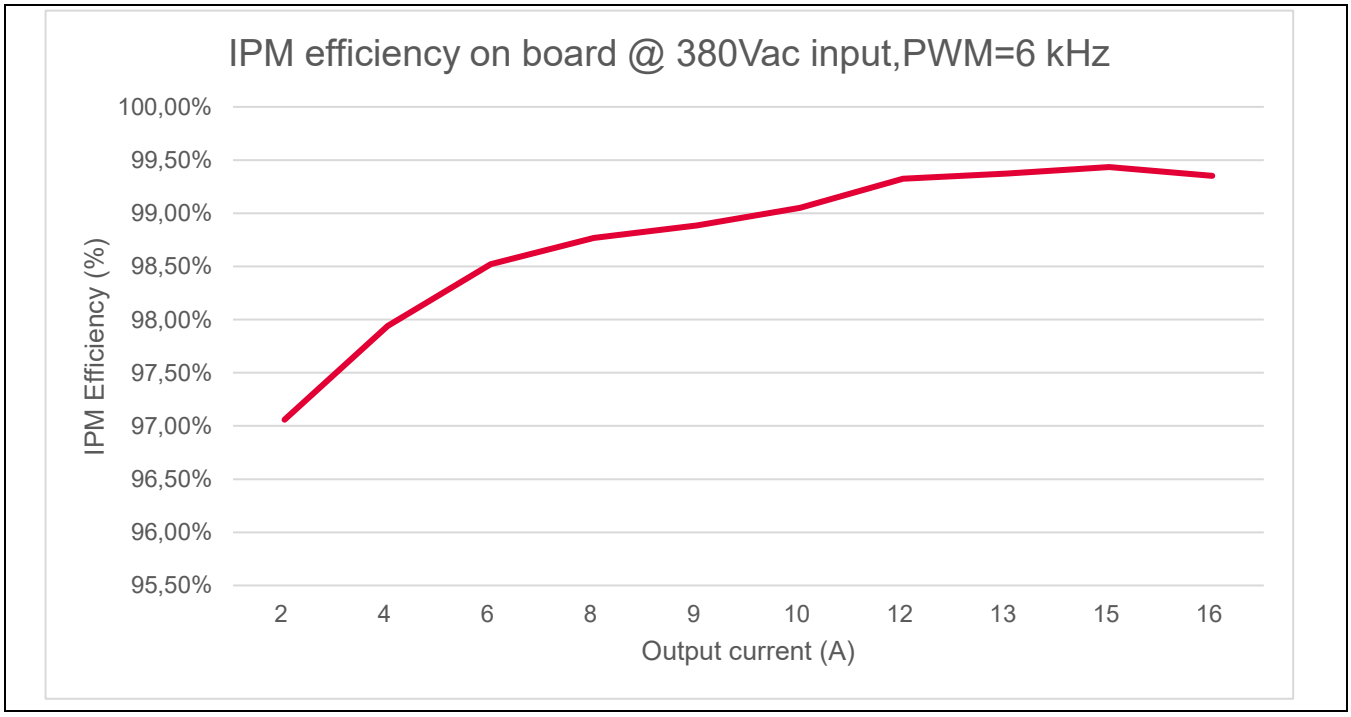

Figure 51 AIM12S54EB1 efficiency vs output current @ 380 V AC input, 18VCC, 6 kHz

5 References and appendices

5.1 Abbreviations and definitions

Table 11 Abbreviations

Abbreviation	Meaning
MADK	Modular application design kit
CE	Conformité européenne
EMI	Electromagnetic interference
UL	Underwriters laboratories
OPA	Operational amplifier
LPF	Low-pass filter

5.2 References

[1] Infineon Technologies AG. Datasheet of Infineon AIM12SXXEB1 Datasheet www.infineon.com

[2] Infineon Technologies AG. Datasheet of Infineon IMC101T Datasheet (2020). V1.6 https://infineon.com

5.3 Additional information

The power board is now available for customers in small order quantities. In order to initiate the testing, customers are advised to order the following items:

Table 12 Ordering information

Part number	Symbol	Package	Quantity
EVAL-M1-CMADK-S		Boxed	1
AIM12SXXEB1	U1	DIP 36x23D	1
ICE5QSAG	U6	PG-DSO-8	1
IMBF170R1K0M1	Q1	PG-TO263-7	1

Revision history

Document revision	Date	Description of changes
V1.0	2026.04.15	First version

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Edition 2026-04-22
Published by

Infineon Technologies AG
Am Campeon 1-15
85579 Neubiberg
Germany

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UG-2026-03

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Safety & Operating Instructions:
Customer shall check the Evaluation Board for any physical damage which may have occurred during transport. If customer detects any damages or defects in the Evaluation Board, customer shall not connect the Evaluation Board to a power source. Customer shall contact Infineon for further support. If customer observes unusual operating behavior during the evaluation process, customer shall immediately shut off the power supply to the Evaluation Board and consult Infineon for support.
Customer shall not touch the Evaluation Board during operation and keep a safe distance.
Customer shall not touch the Evaluation Board after disconnecting the power supply, several components may still store electrical voltage and can discharge through physical contact. Several parts, like heat sinks and transformers, may still be very hot. Allow the components to cool before touching or servicing.
The electrical installation must be completed in accordance with the appropriate safety requirements.