EVAL-M1-IM06B50 user guide

iMOTION™ modular application design kit

About this document

Scope and purpose

This user guide provides an overview of the evaluation board EVAL-M1-IM06B50 including its key features, data, pin assignments and mechanical dimensions.

The EVAL-M1-IM06B50 is an evaluation board for motor drive applications, as part of the iMOTION™ modular application design kit. In combination with the control board equipped with the M1 20-pin interface connector such as EVAL-M1-101T, it features and demonstrates Infineon's CIPOS™ Mini IPM technology and advanced motion control engine (MCE 2.0) technology for permanent magnet motors drive.

The IM06B50GC1 CIPOS™ Mini IPM has 600 V of voltage and 50 A of current rating. It is optimized for major home appliances like air conditioners, pumps, fans and other low & middle power motor drive applications.

This evaluation board EVAL-M1-IM06B50 is developed to support customers during their first steps designing applications with CIPOS™ Mini IPM IM06B50GC1 and running any permanent magnet motor via senseless sinusoidal control.

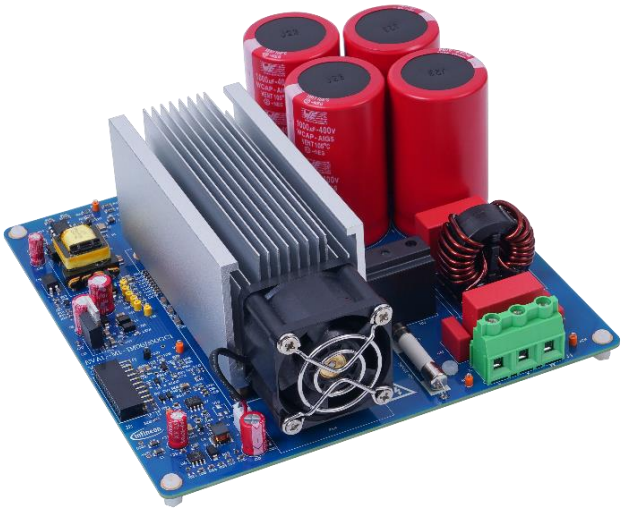
Intended audience

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.

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



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Safety precautions

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

Table 1 Safety precautions

	**Warning:** *The DC link potential of this board is up to 400 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.*

Table of contents

1 The board at a glance

The EVAL-M1-IM06B50 evaluation power board is a part of the iMOTION™ modular application design kit for motor drives (iMOTION™ MADK). The MADK platform is intended for use with various power stages and different control boards. The EVAL-M1-IM06B50 can easily be interfaced through the 20-pin iMOTION™ MADK M1 connector such as EVAL-M1-101T and is intended for single-motor control only.

The EVAL-M1-IM06B50 evaluation board is available through regular Infineon distribution partners as well as on Infineon's website. The features of this board are described in the main features chapter of this document, whereas the remaining paragraphs provide information to enable the customers to copy, modify and qualify the design for production according to their own specific requirements.

Environmental conditions were considered in the design of the EVAL-M1-IM06B50, but the board is not qualified in terms of safety requirements or manufacturing and operation over the entire operating temperature range or lifetime. The boards provided by Infineon are subject to functional testing only.

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 content

The EVAL-M1-IM06B50 evaluation board is designed to provide an easy-to-use power stage based on the Infineon's CIPOS™ Mini intelligent power module (IM06B50GC1 IPM).

The delivery includes the finished board as shown in Figure 1 and Figure 2. It provides a single-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 CoolSET™ based auxiliary power supply to provide 15 V & 5 V, emitter shunts for current sensing and overcurrent 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-IM06B50 is depicted in Figure 1.

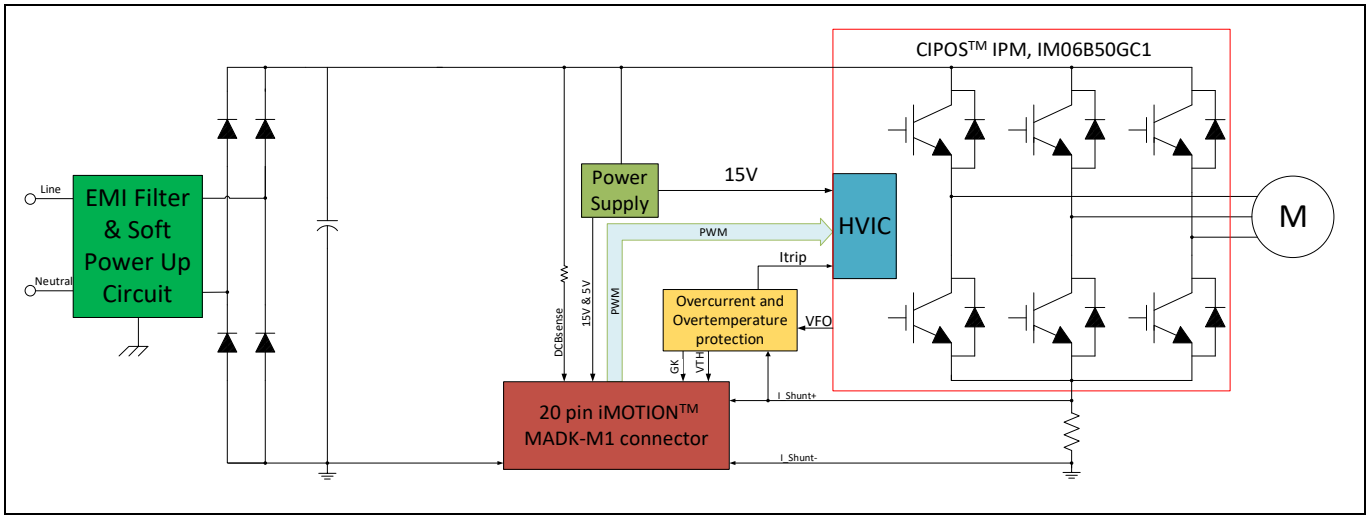
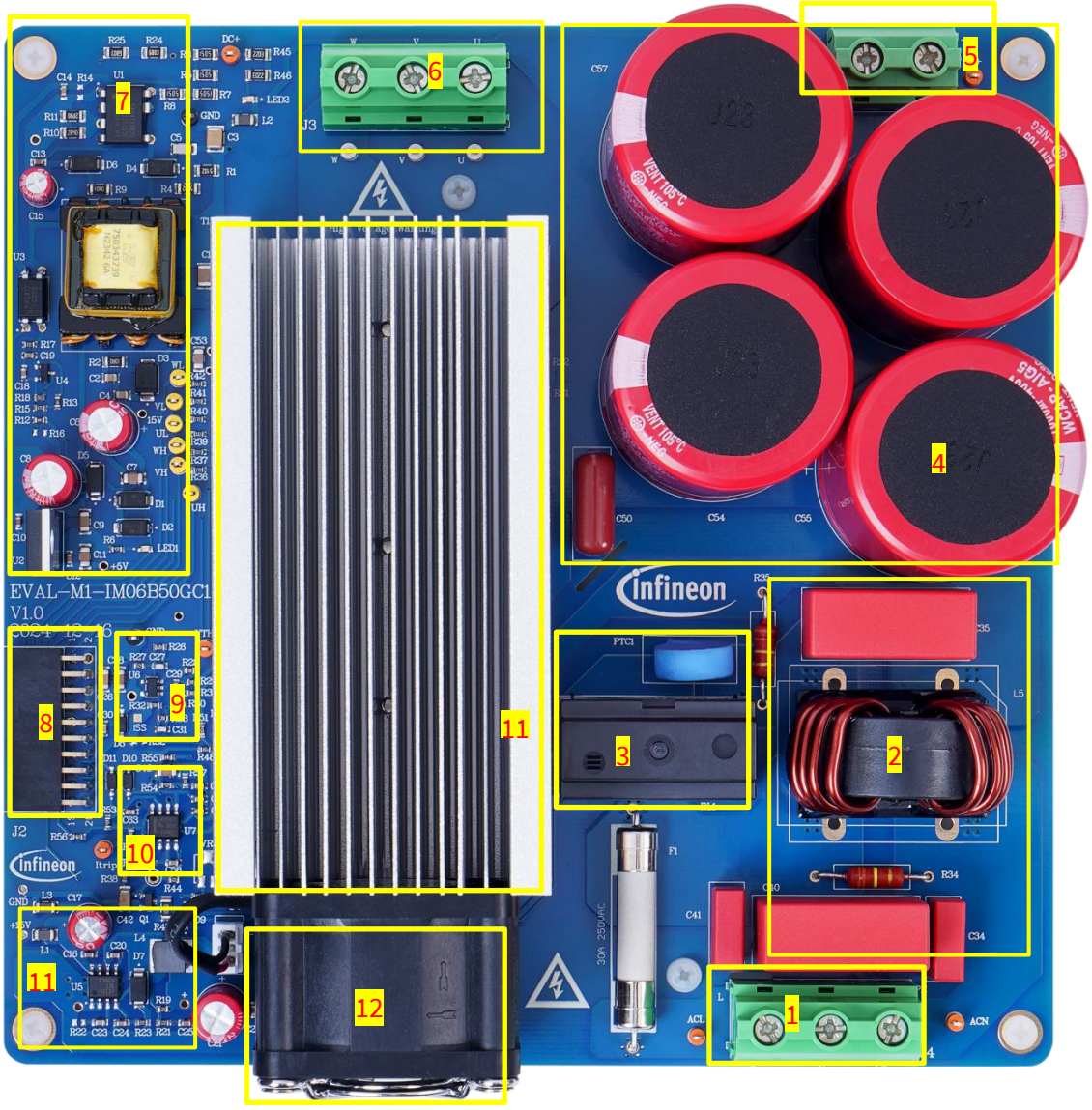


Figure 1 Block diagram of the EVAL-M1-IM06B50

Figure 2 points out the functional groups on the top side of the EVAL-M1-IM06B50 design:



1. 220 V_{AC} & PE input connector
2. EMI filter
3. In-rush relay control
4. DC bus capacitors
5. Connector for DC bus
   (For external PFC or DC source)
6. UVW motor phase connector
7. Auxiliary power supply

8. iMOTION™ MADK M1 connector (20-pin)
9. Current sensing OPA (SGM721XN5)
10. OCP & OCT comparator (LM393)
11. DCDC for cooling fan
12. BLDC cooling fan
13. Heat sink
    (IM06B50 + input rectifier + shunt resistor)

Figure 2 Functional groups of the EVAL-M1-IM06B50 reference design

1.3 Main features

The EVAL-M1-IM06B50 is an evaluation board for motor drive applications. Combined in a kit with one of the available MADK control board options, it demonstrates Infineon's motion control IC and IPM technology for motor drives.

The evaluation board characteristics include:

- Input voltage 85~265 V_{AC}
- Maximum 20 A input and output current
- Maximum 3000 W motor power output
- On board EMI filter
- Current sensing operational amplifier (OPA) with single shunt
- Auxiliary power supply with 15 V, 5 V
- Overcurrent hardware protection & over temperature protection
- Sensing of DC-link voltage
- Thermistor output
- PCB is 166 mm × 166 mm, two layers with 2 oz. copper
- RoHS compliant

1.4 Board parameters and technical data

Table 2 depicts the important specifications of the evaluation board EVAL-M1-IM06B50.

Table 2 EVAL-M1-IM06B50 board specifications

Parameter	Symbol	Conditions / comments	Value	Unit
Input voltage	V_{ac}	Optimized design for 220 V_{AC} application Lower AC input, less motor power output	85 ~ 265	V_{rms}
Maximum input current	$I_{ac(max)}$	Input 220 V_{AC}, T_a=25°C	20	A_{rms}
Maximum input power	$P_{in(max)}$	Input 220 V_{AC}, f_{PWM} = 6 kHz, T_a=25°C, T_{case}= 105°C Force cooling mode	3000	W
Maximum motor current	$I_{mtr(max)}$	Input 220 V_{AC}, f_{PWM}=5 kHz, T_a=25°C, T_{case}= 105°C Force cooling mode	30	A_{rms}
Maximum DC bus voltage	$V_{dc(max)}$	DC bus capacitors are 400 V, 820µFX4 (or 1000µF X4)	400	V
Minimum DC bus voltage	$V_{dc(min)}$	Aux power supply brown-in voltage	80	V
Shunt Resistance	R_{sh}	Two 5 mΩ in parallel, with external OPA gain 10	2.5	mΩ
Protections				
Motor current protection trigger level 1[1]	I_{trip}	Comparator source for OC trigger level, related to iMOTION™ internal comparator setup	Configured in iMOTION™	A_{peak}

[1] For iMOTION™ IC IMCxxx, there are three types of current protection setup: Gatekill-pin, Comparator and Both. If you select "comparator" mode, the external Gatekill-pin signal will be not used, and the signal ISS will be compared by the internal comparator with the "Overcurrent comparator current trip level (peak)" value set in iMOTION™ Solution Designer, it should be based on motor rated current to protect motor.

Parameter	Symbol	Conditions / comments	Value	Unit
			Solution Designer	
Motor current protection trigger level 2	I_{trip}	Gatekill-pin input source overcurrent protection, related to hardware setup	59	A_{peak}
Thermal protection level	$T_{protection}$	Temperature gap between junction and NTC (negative temperature coefficient) sensor needs to be considered; recommended is a setting of 105°C or less	105	°C
Auxiliary power supply 1 – 15 V				
Output voltage	V_{out1}	Used for IPM and cooling fan	15 ± 5%	V
Maximum output current	I_{out1}		450	mA
Auxiliary power supply 2 – 5 V				
Output voltage	V_{out2}	Used for IMC controller and protection circuits	5 ± 1%	V
Maximum output current	I_{out2}		150	mA
PCB characteristics				
Dimension		Length × width × height	166×166×62	mm
Material		FR4, 1.6 mm thickness, 2oz PCB		
System environment				
Ambient temperature	T_a	Non-condensing, maximum RH of 95%	0 ~ 50	°C

2 System and functional description

2.1 Getting started with EVAL-M1-IM06B50

In order to run the motor system, a combination of the iMOTION™ MADK power board (EVAL-M1-IM06B50) 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 start 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-IM06B50 for op-amp current sensing, since EVAL-M1-101T's default configuration is directly ADC sample.***

1. *Remove R6 of EVAL-M1-101T (Since EVAL-M1-IM06B50 uses external OPA circuit, it has its own bias)*
2. *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-IM06B50 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 Desinger, 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 below Infineon website link. Please visit this page periodically to check for updates.

- iMOTION Solution Designer

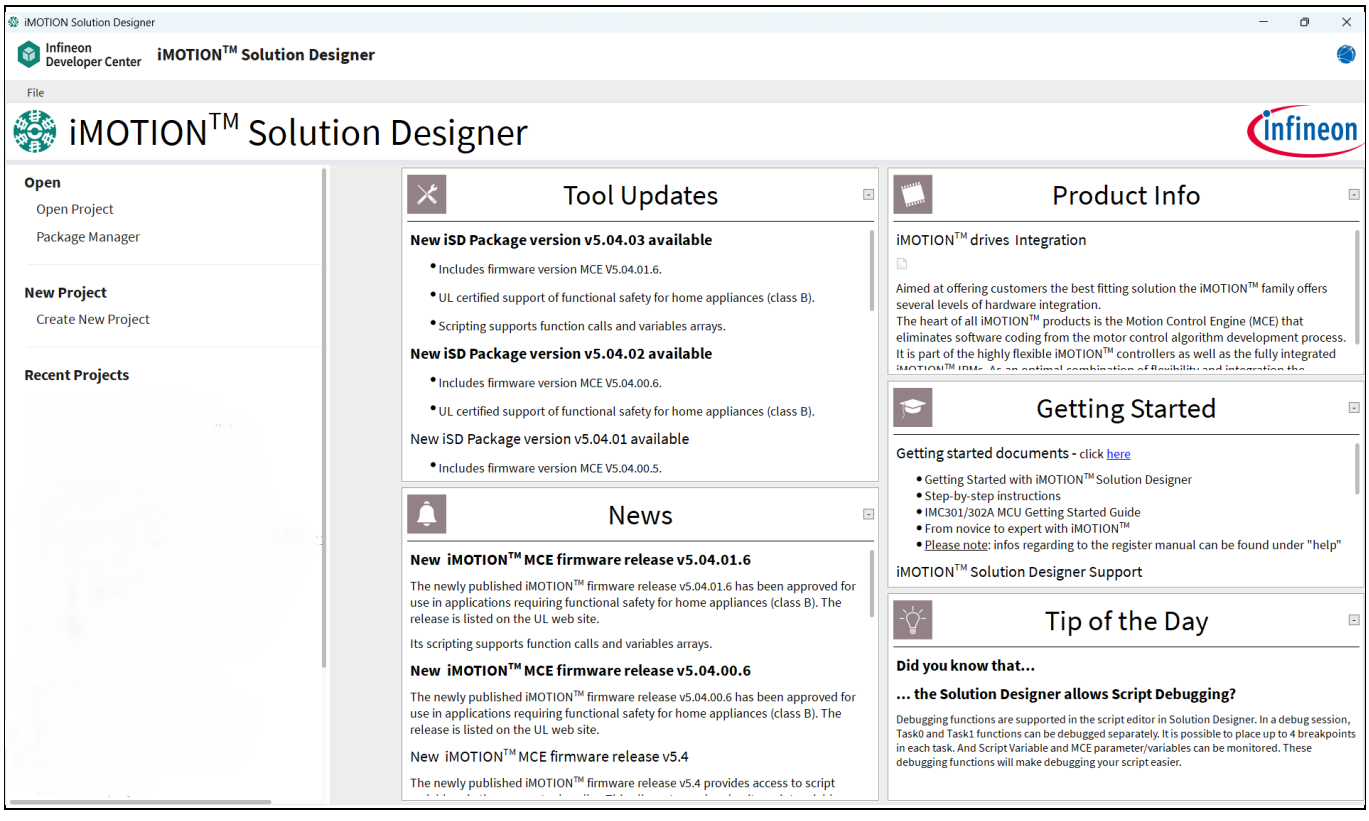


Figure 3 iMOTION™ Solution Designer

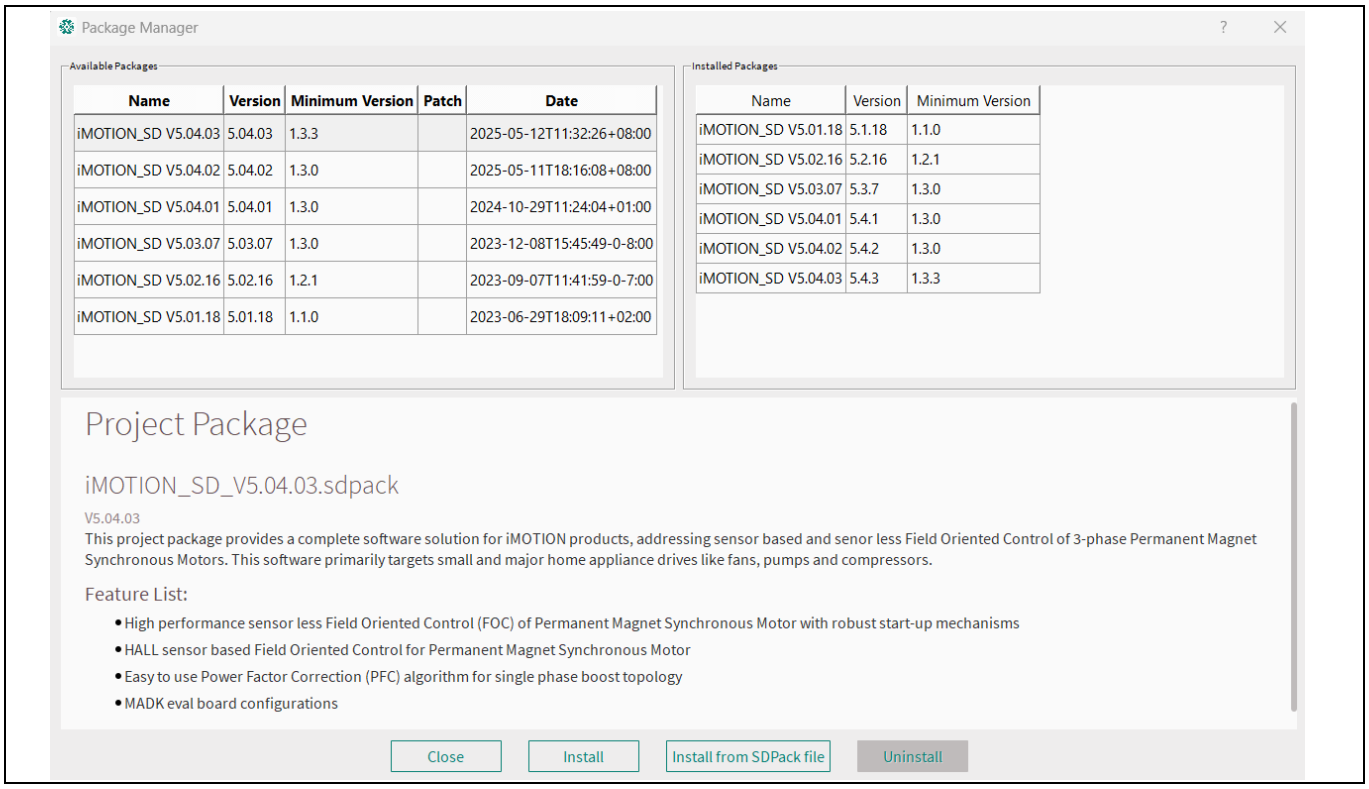


Figure 4 Sdpack installation

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-IM06B50 to run a 5KW GK6081-6AC31 motor with iMOTION™ Solution Designer.

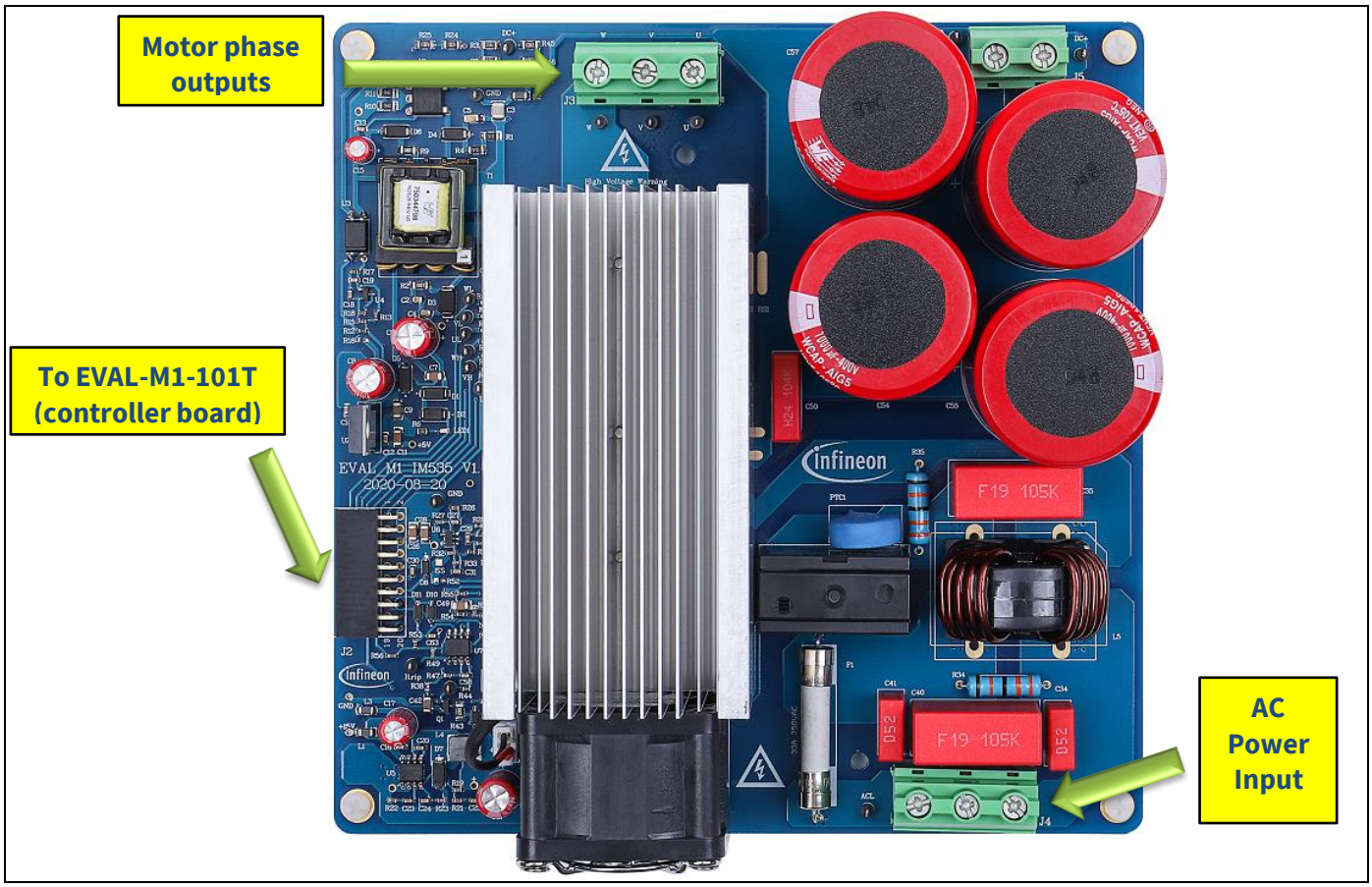


Figure 5 System connection example

Here are the steps needed to run the motor:

1. Connect EVAL-M1-101T control board to EVAL-M1-IM06B50
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 220 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”.

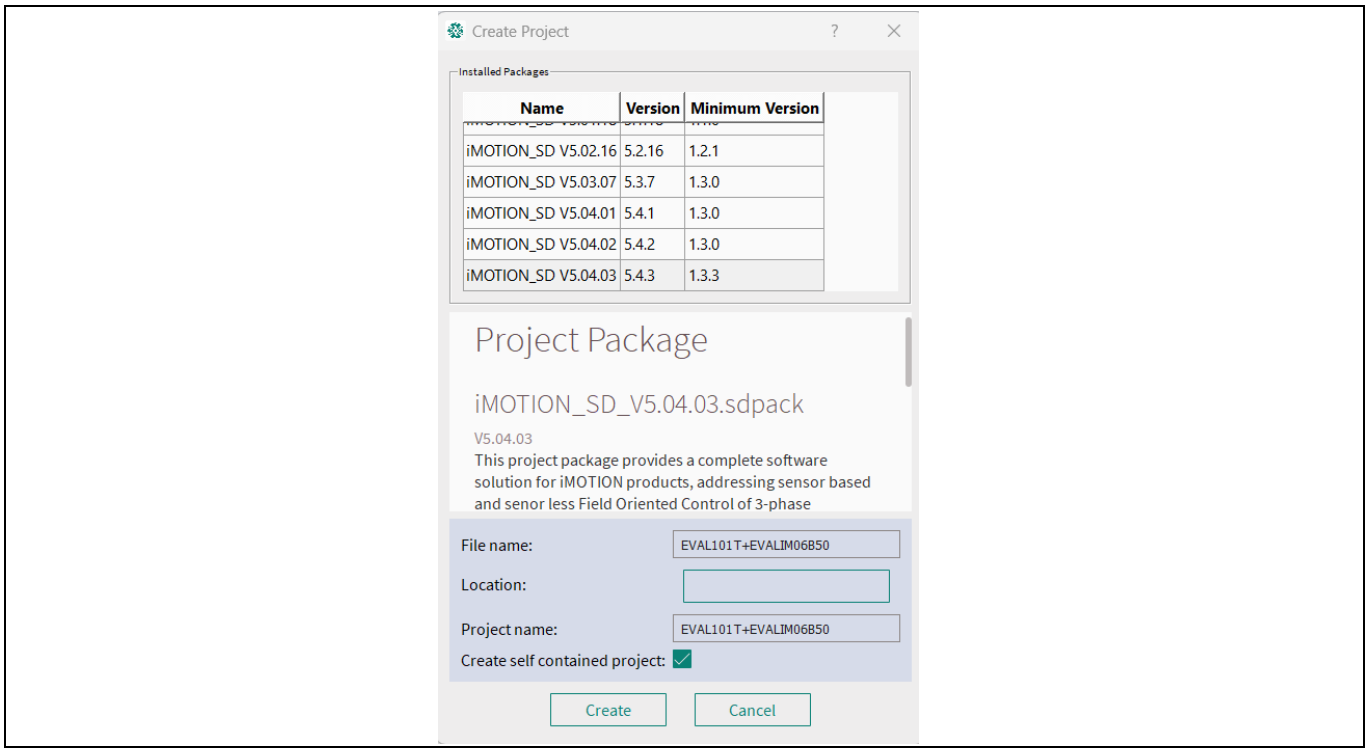


Figure 6 Create iMOTION™ Solution Designer project

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

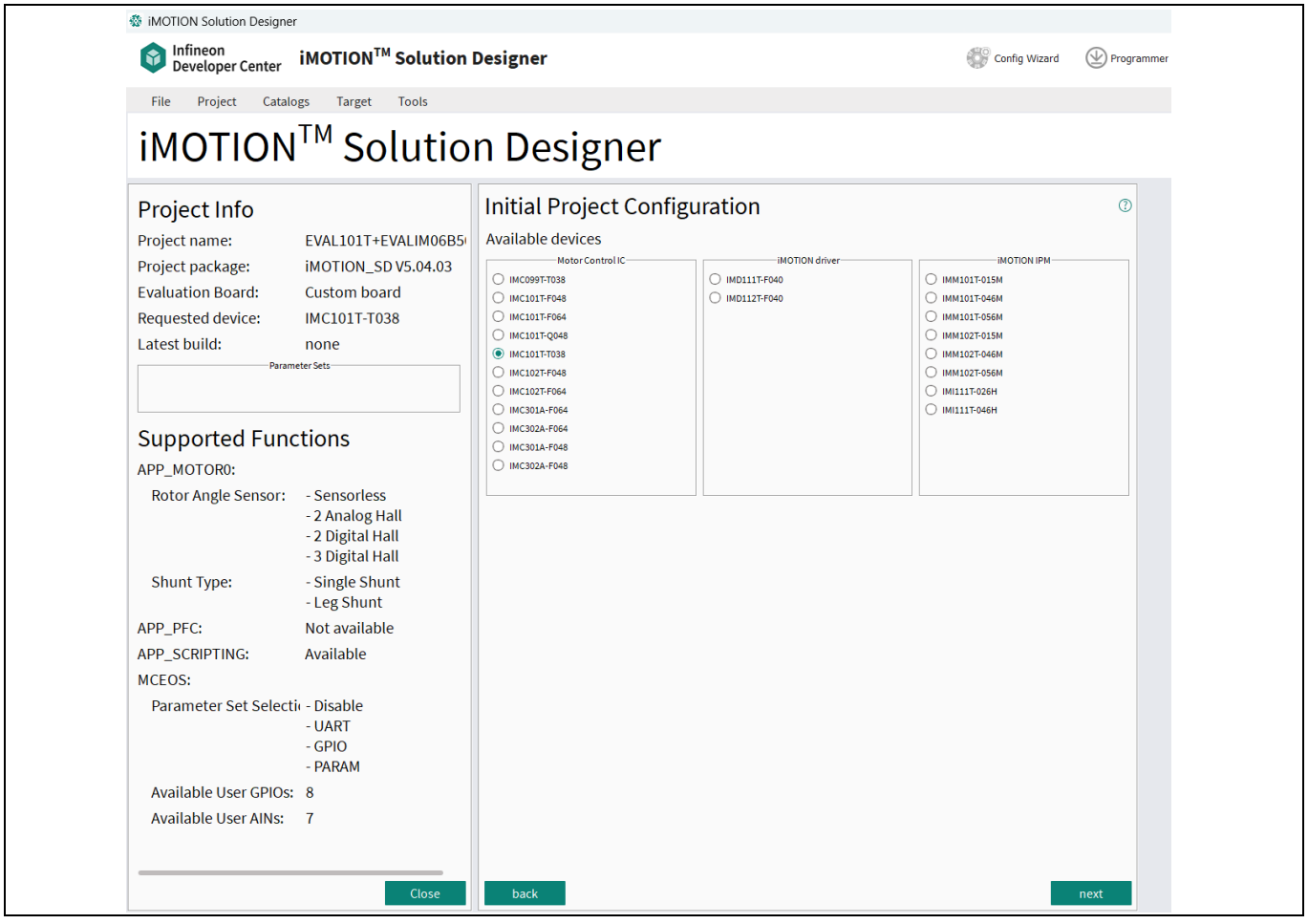


Figure 7 Select iMOTION™ device

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.

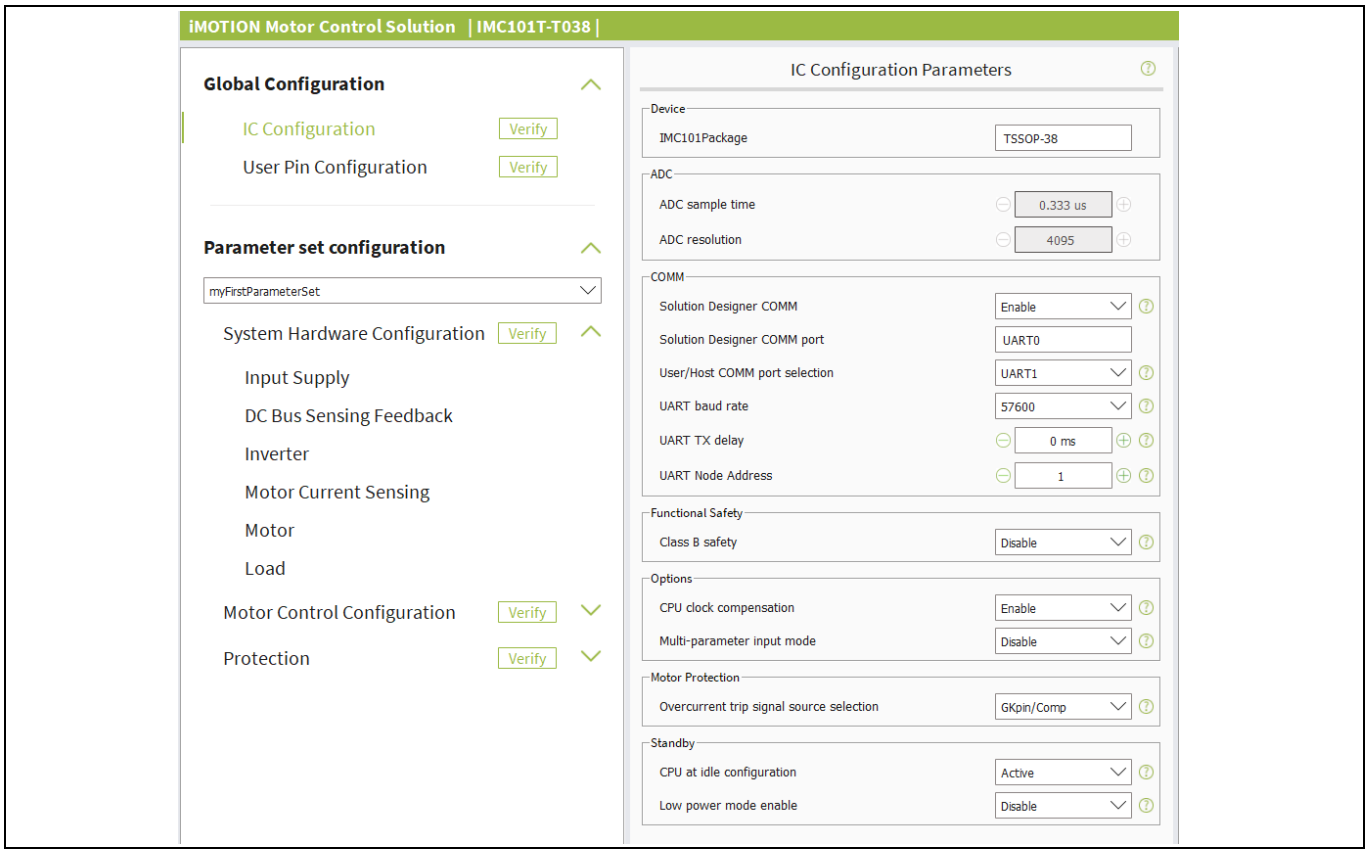


Figure 8 IC configuration

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

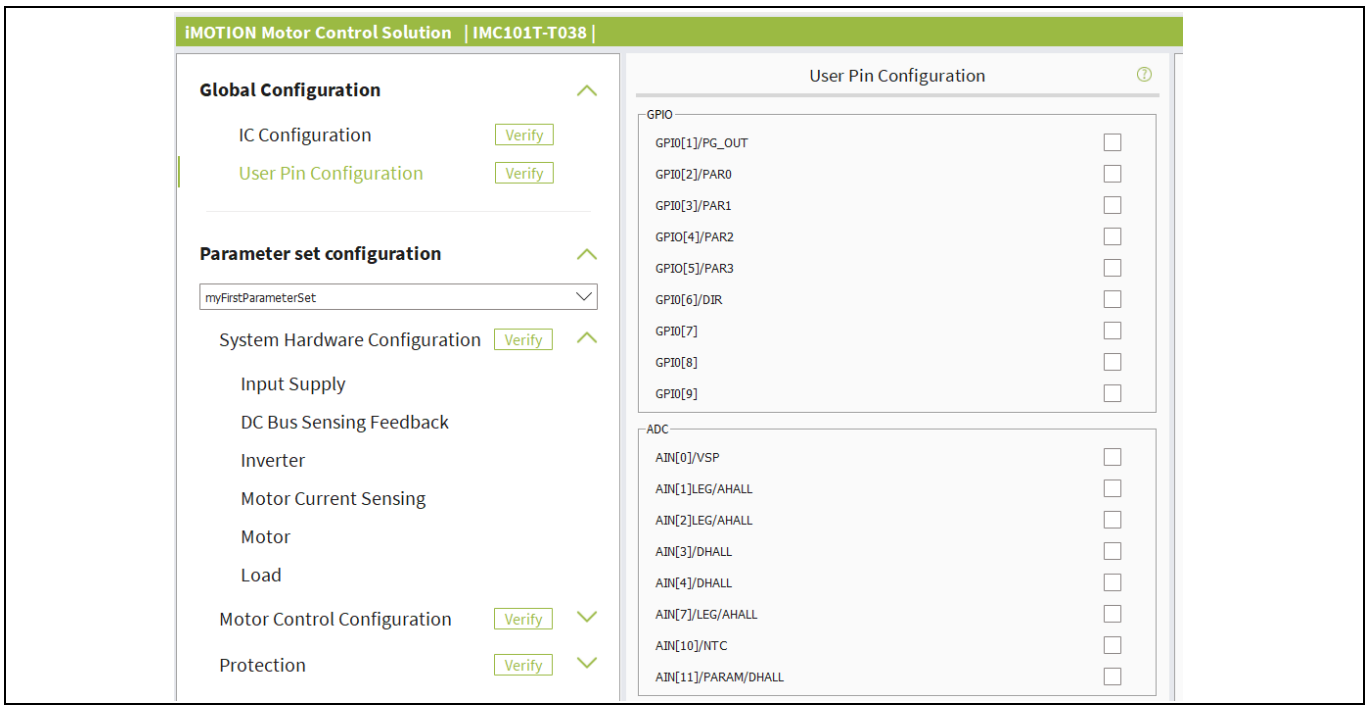


Figure 9 User Pin Configuration

c. For “Input Supply”, 5V DC should be configured as control supply voltage of this evaluation board.

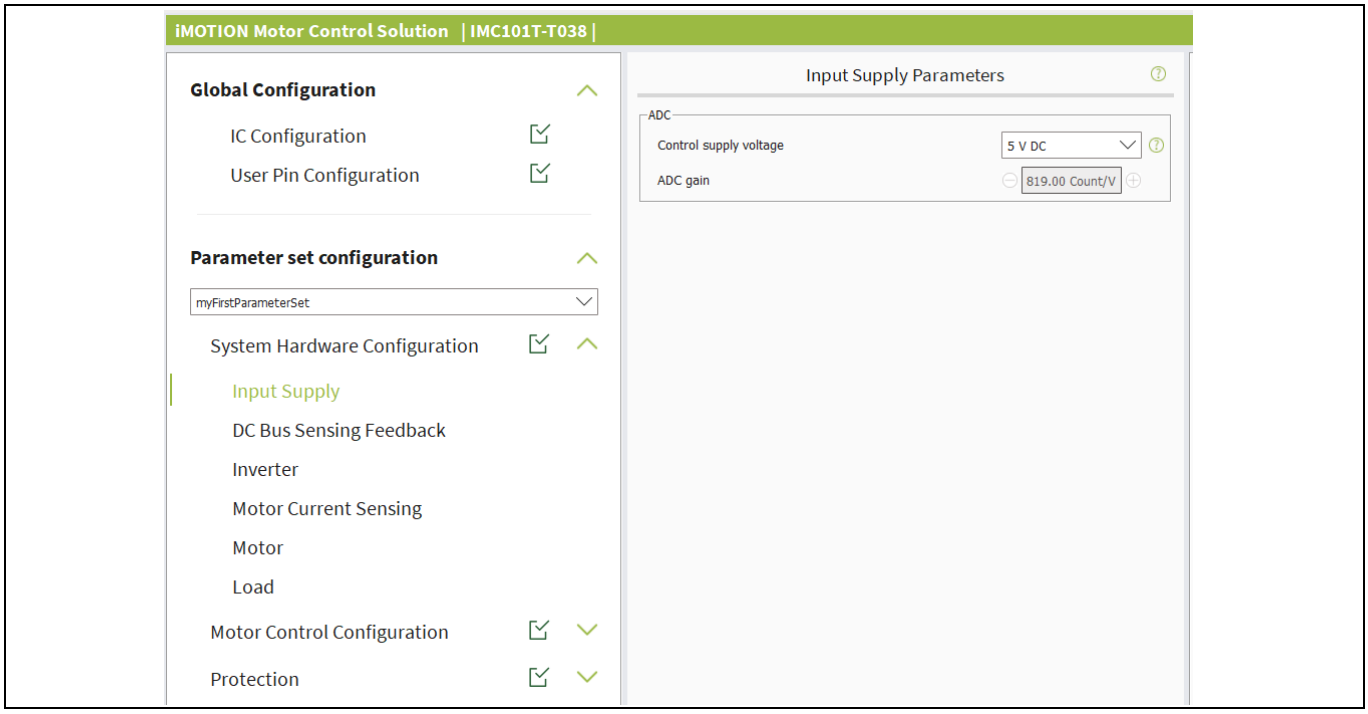


Figure 10 Input Supply

d. For “DC Bus Sensing Feedback”, lower resistor is 13.3 Khom and upper resistor is 1360 Khom, please refer to schematic of EVAL-M1-101T and EVAL-M1-IM06B50 for more information.

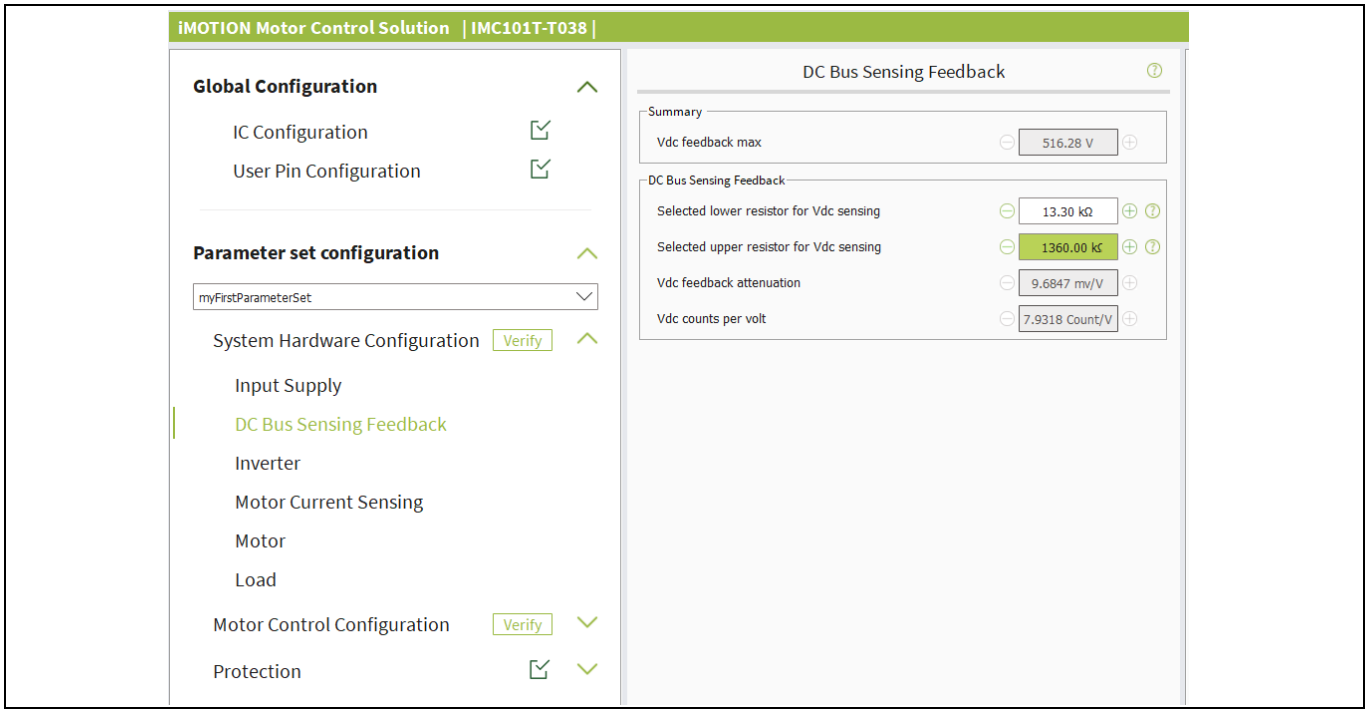


Figure 11 DC Bus Sensing Feedback

e. For “Inverter”, please refer to *IM06B50GC1 datasheet* and board parameters and technical data section 1.4 of this evaluation board to configure parameters here. The configured parameters as shown in Figure 12. Please note that the maximum motor current of this evaluation board is 30 Arms. So here configured “Rated Inverter output current” to 30 Arms.

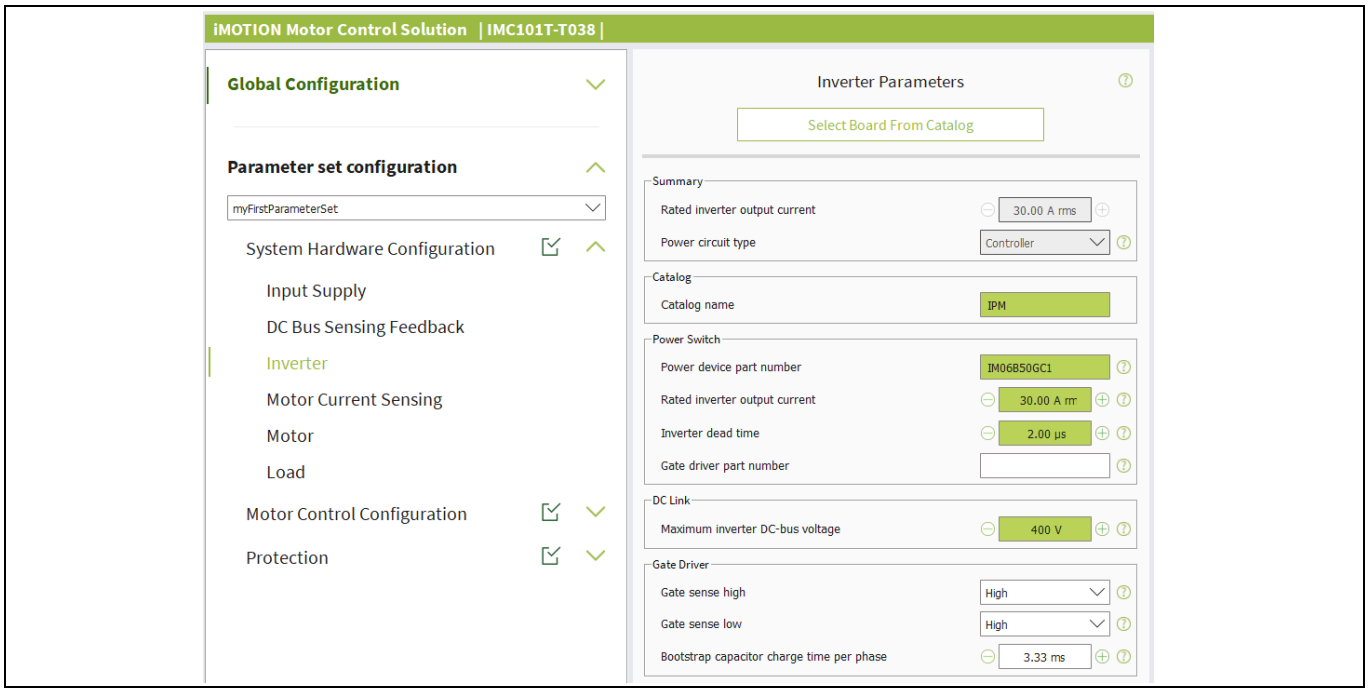


Figure 12 Inverter

f. For “Motor Current Sensing Feedback”, please refer to Section 2.2.3 of this document for detail calculation. Please configure all parameters as shown in Figure 13, all parameters here matched this evaluation board.

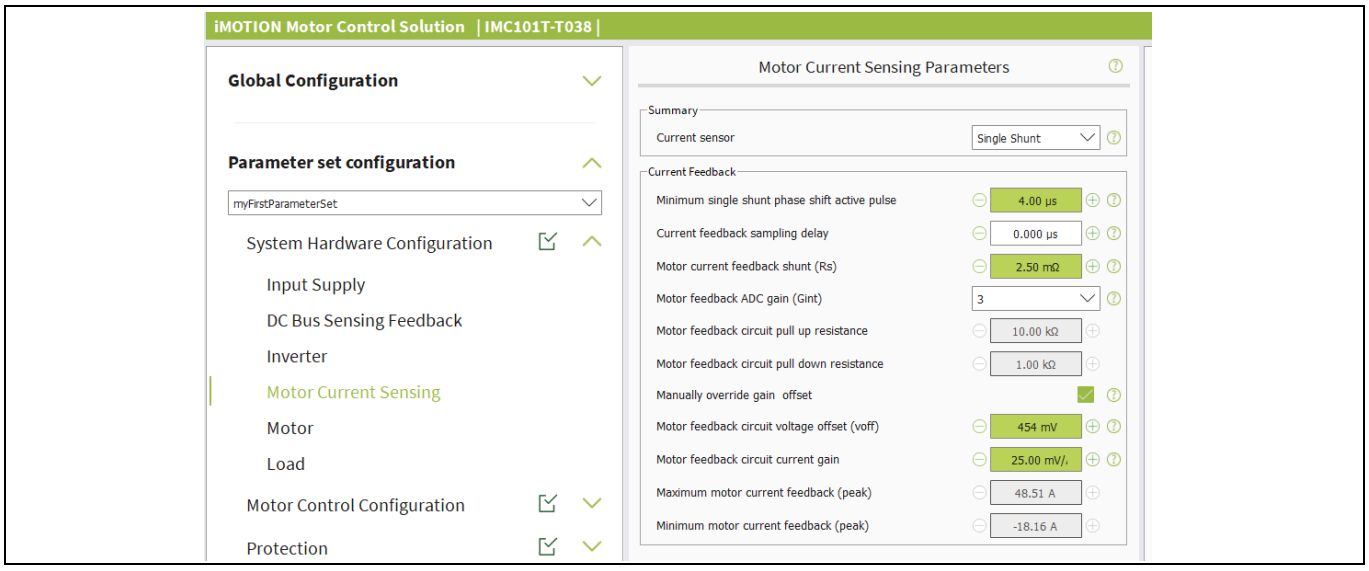


Figure 13 Motor Current Sensing Feedback

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*.

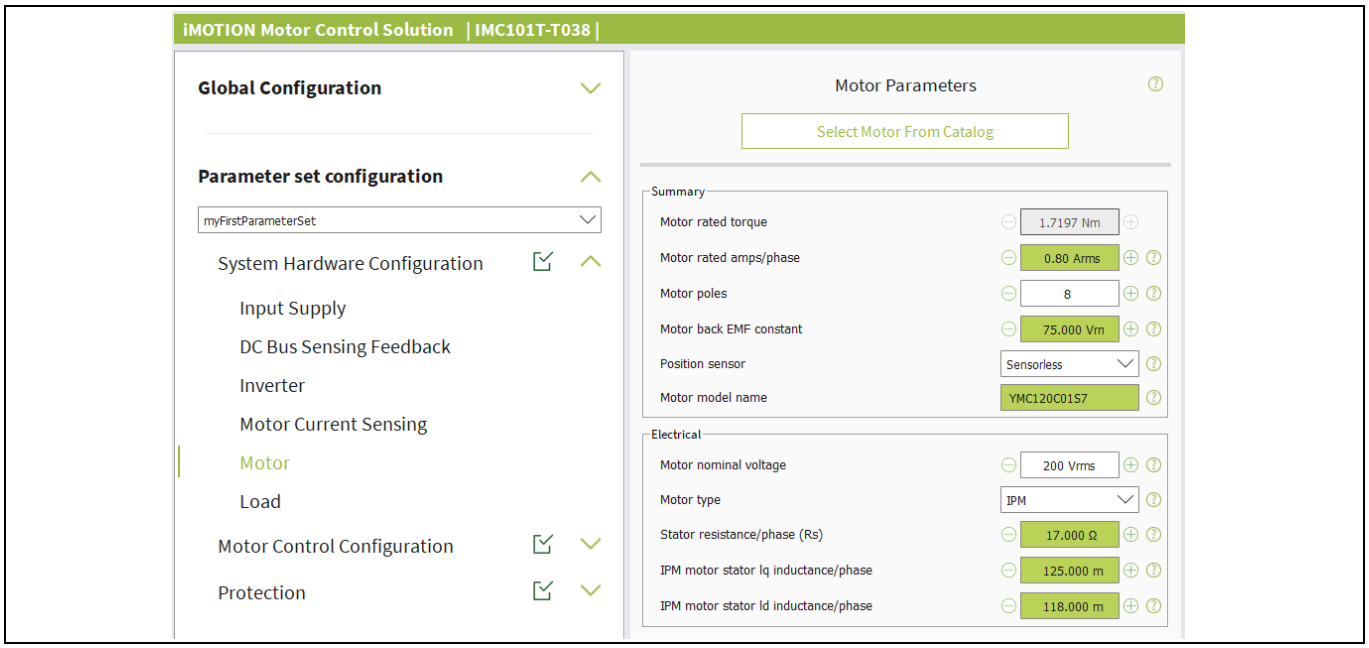


Figure 14 Motor

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.

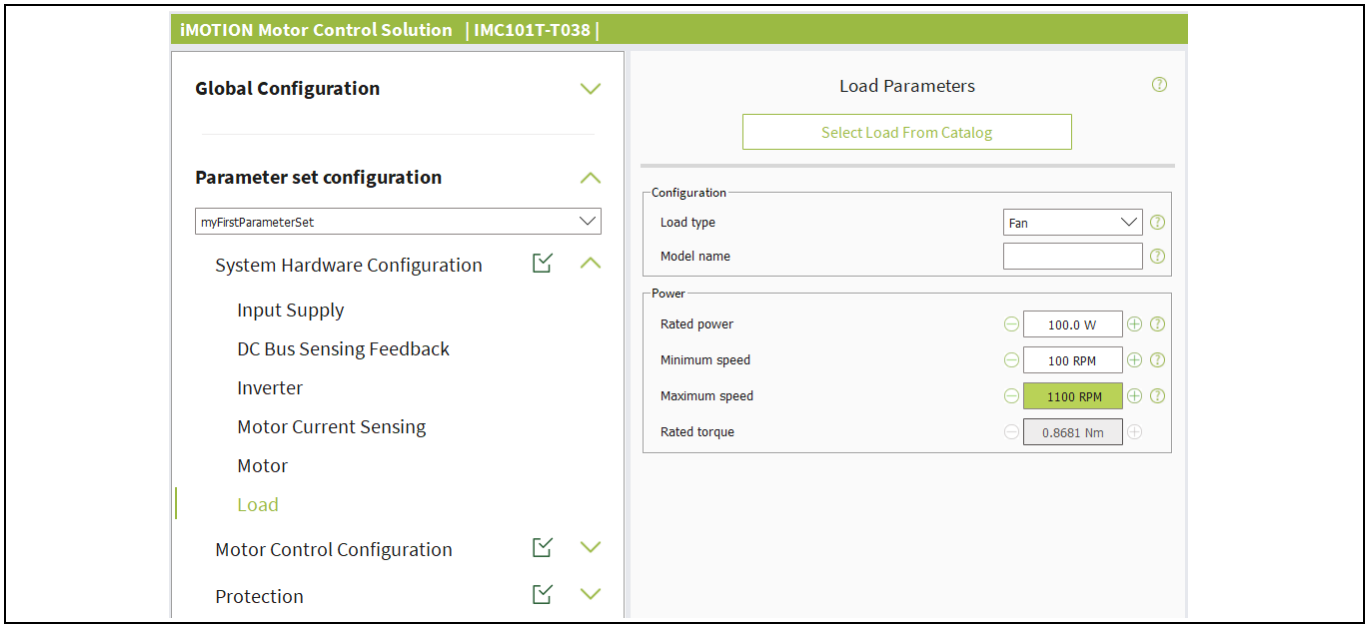


Figure 15 Load

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.

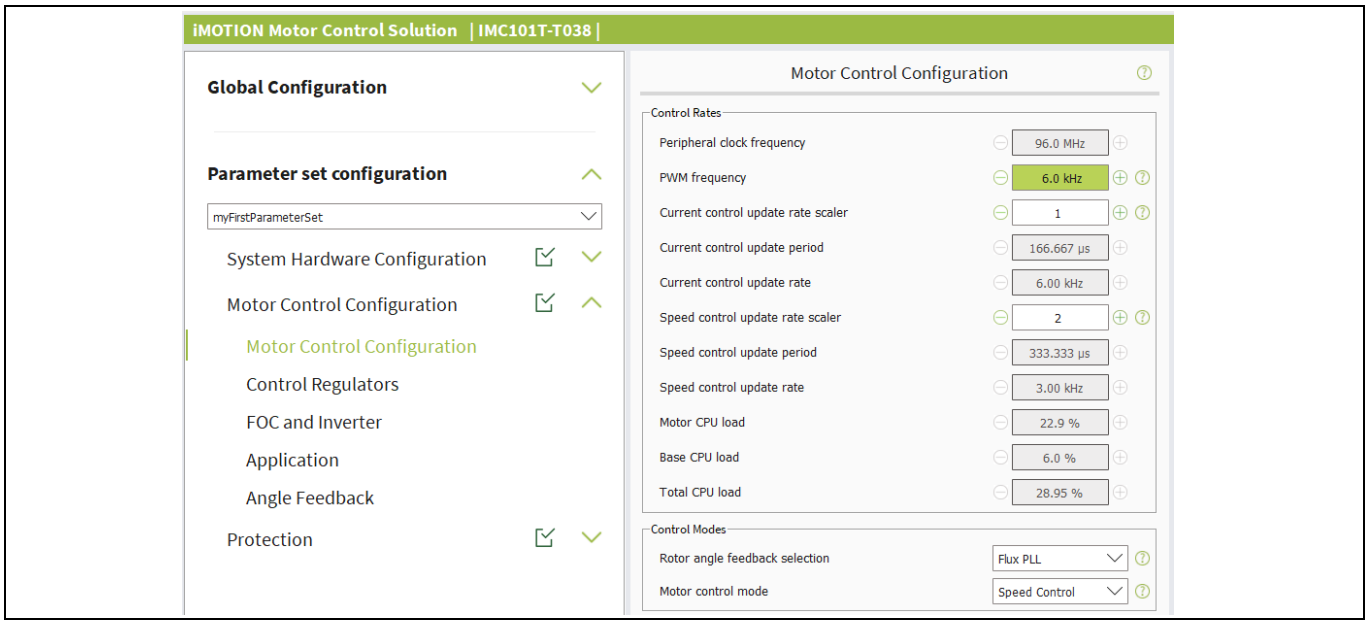


Figure 16 Motor Control Configuration

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.

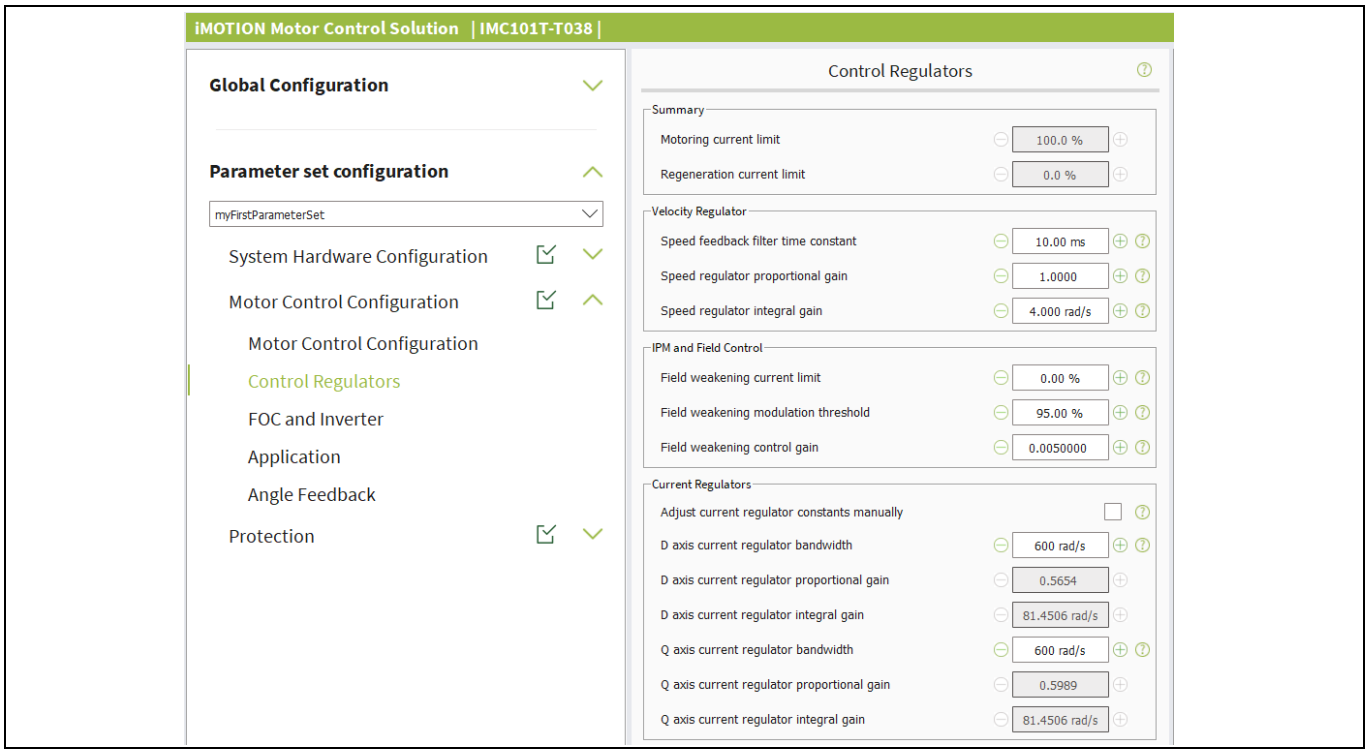


Figure 17 Control Regulators

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

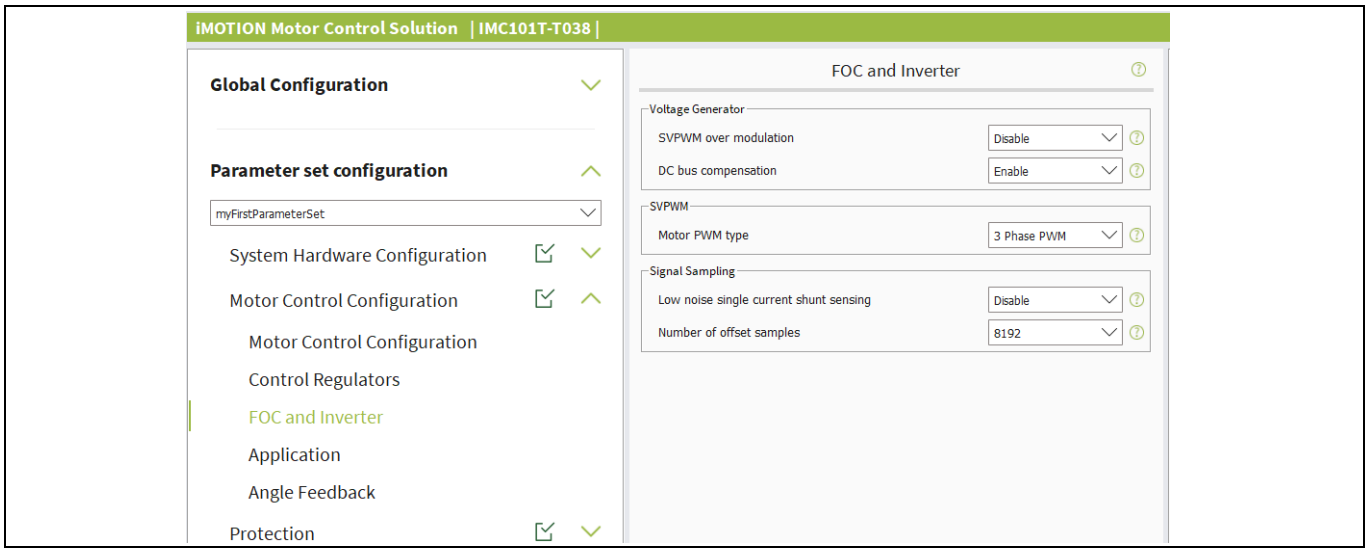


Figure 18 FOC and inverter

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.

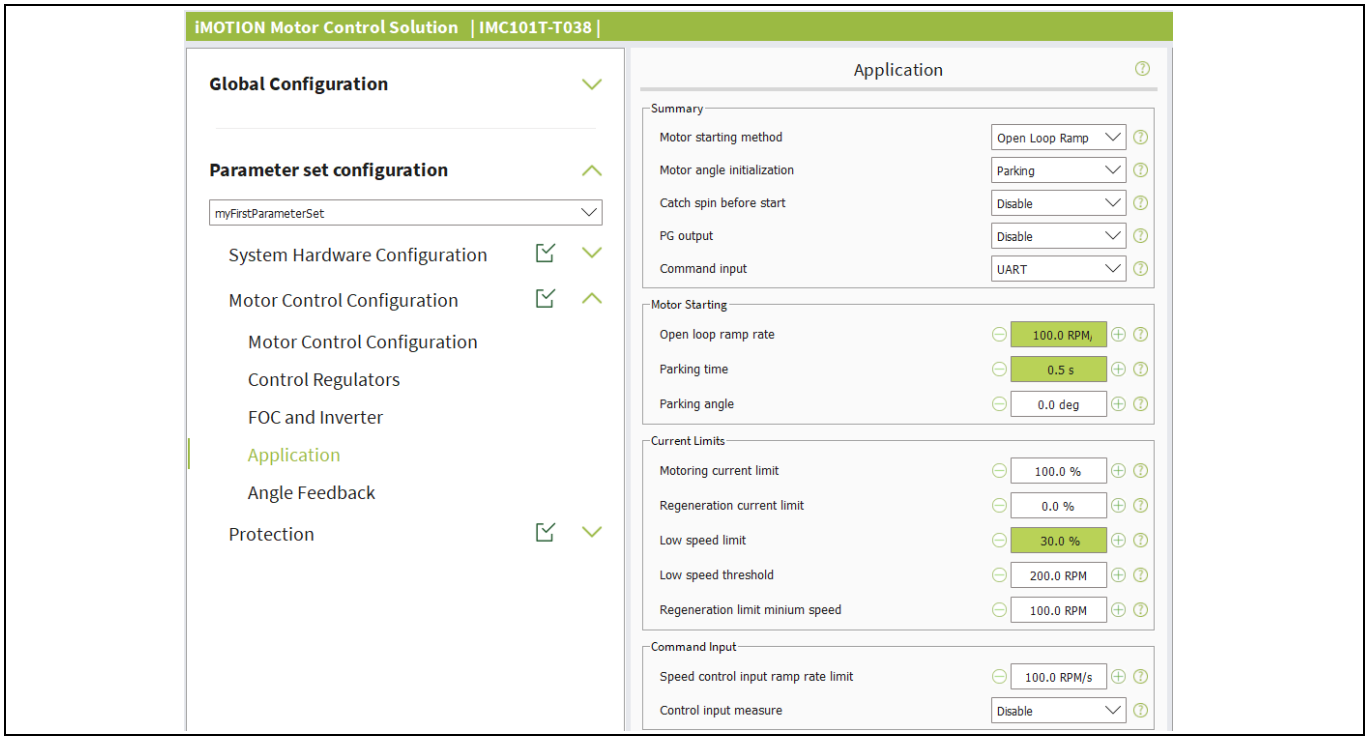


Figure 19 Application

m. For “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.

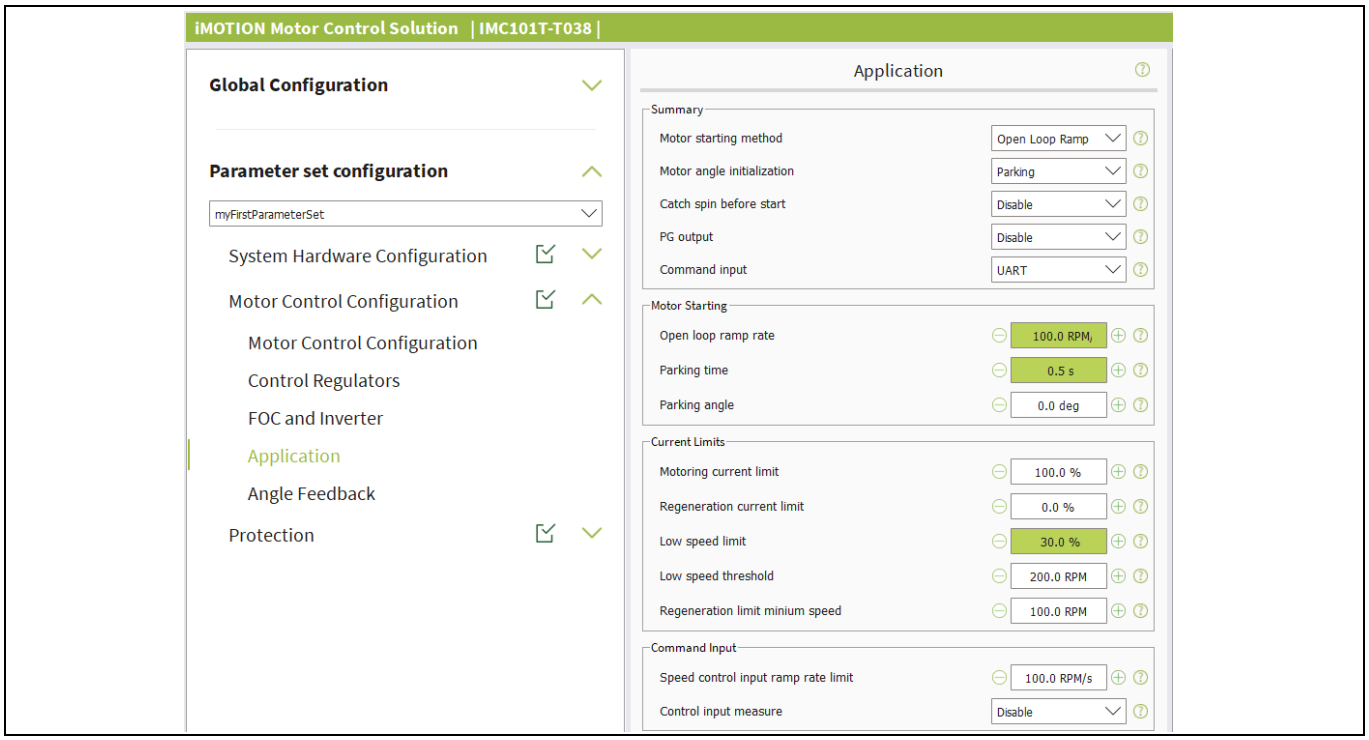


Figure 20 Application

n. 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.”

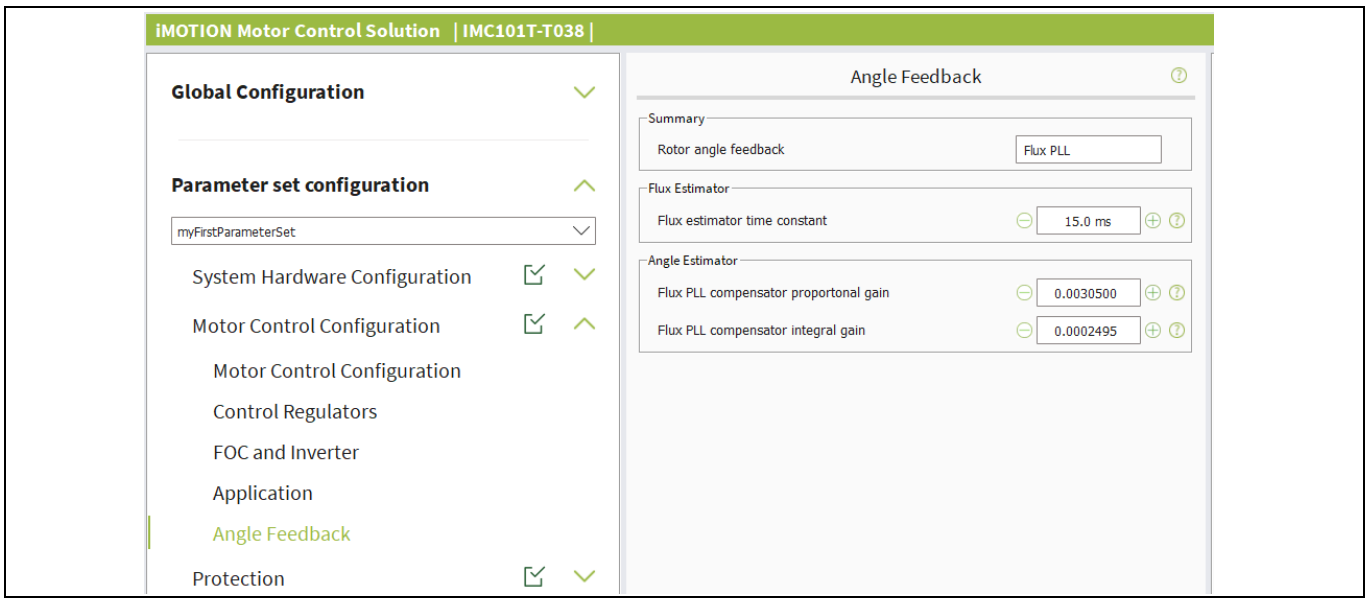


Figure 21 Application

o. 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 22.
- Please refer section 4.5 of this document for “NTC voltage threshold for an over-tempture fault” configuration.
- All other configurations please use value shown in Figure 22.

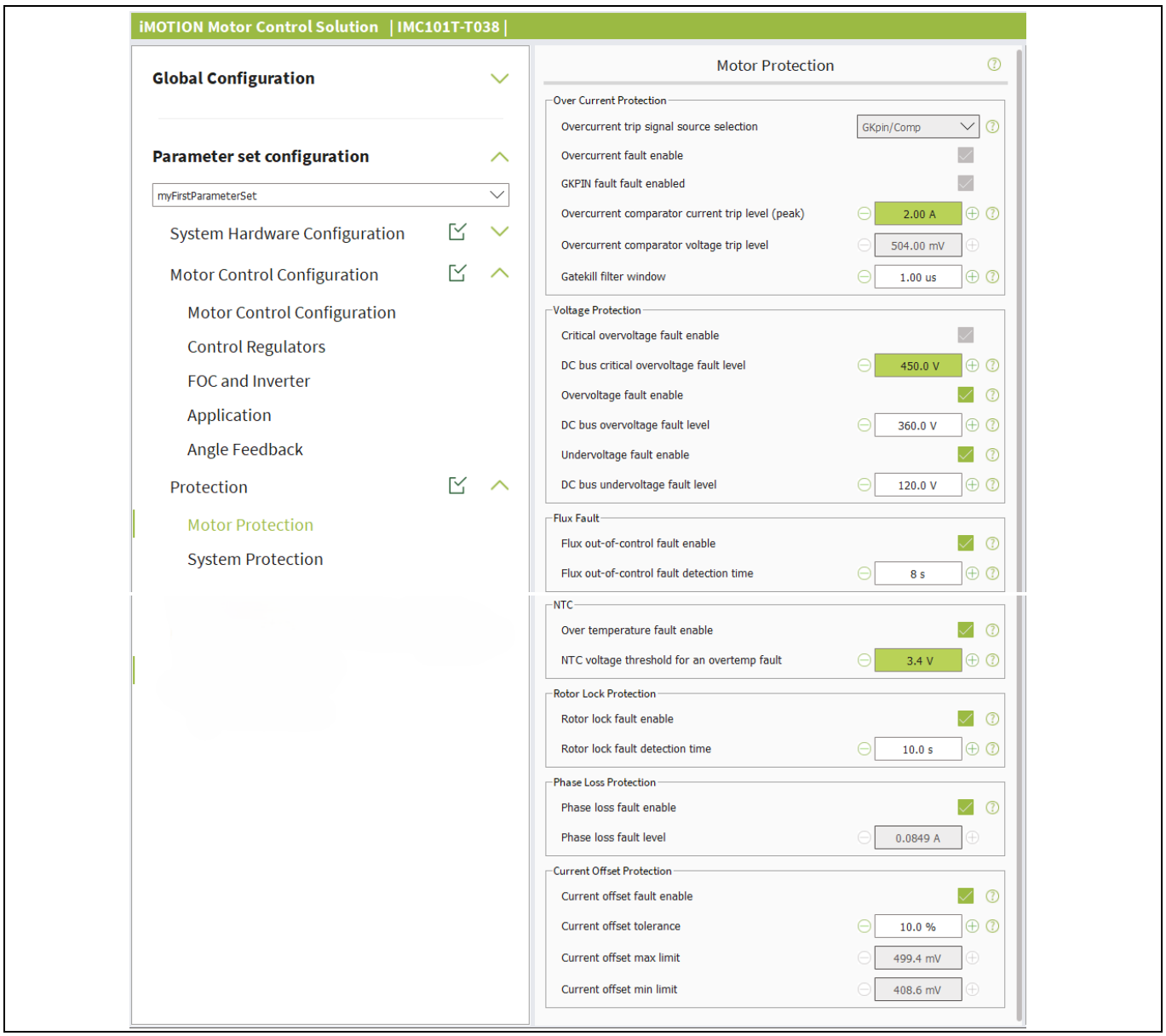


Figure 22 Motor Protection

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

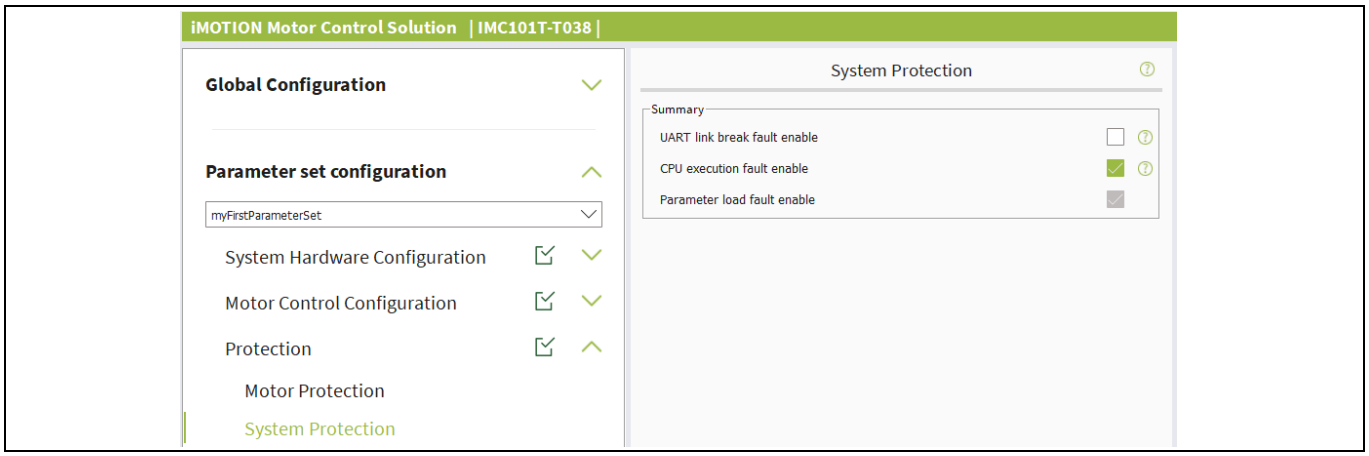


Figure 23 System Protection

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).

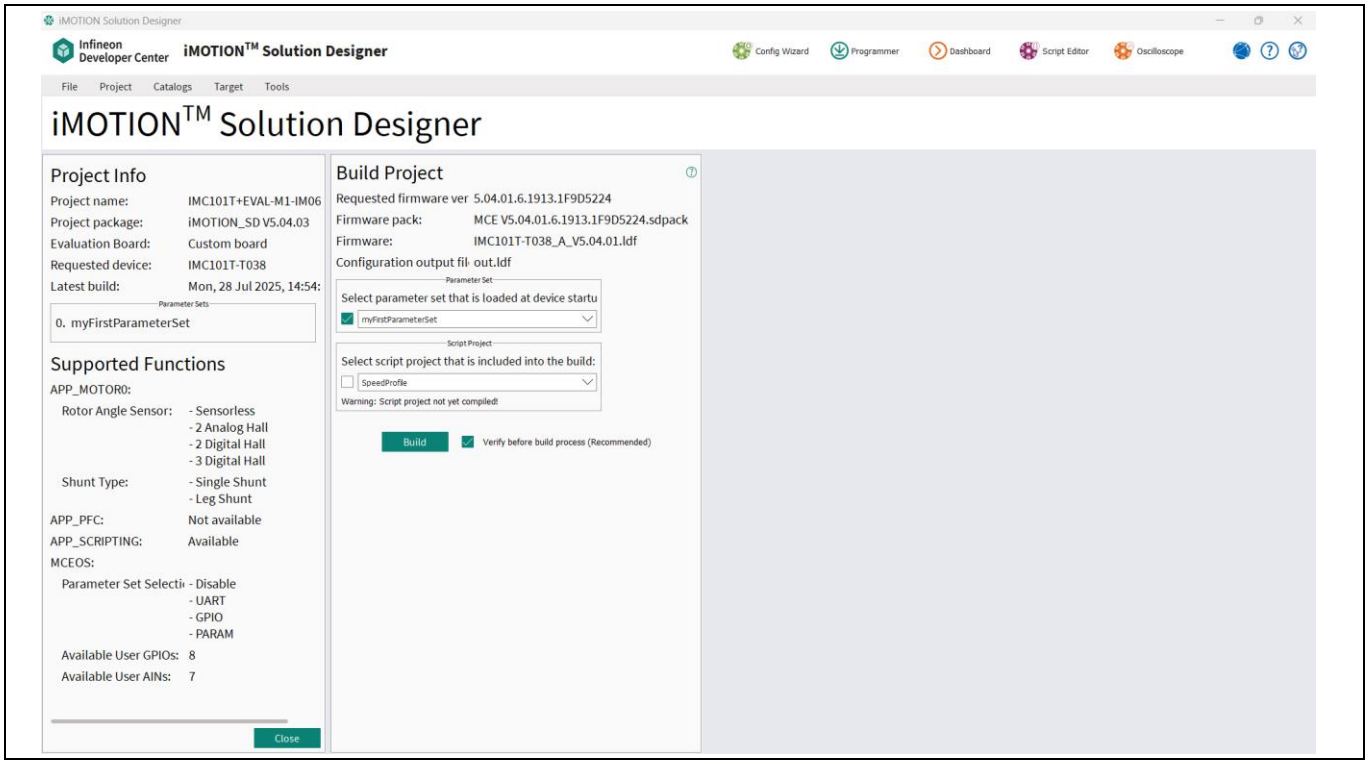


Figure 24 Build Project

8. Power on 220 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 26 and power on EVAL-M1-101 in 2~10 seconds. Please try again if fails.

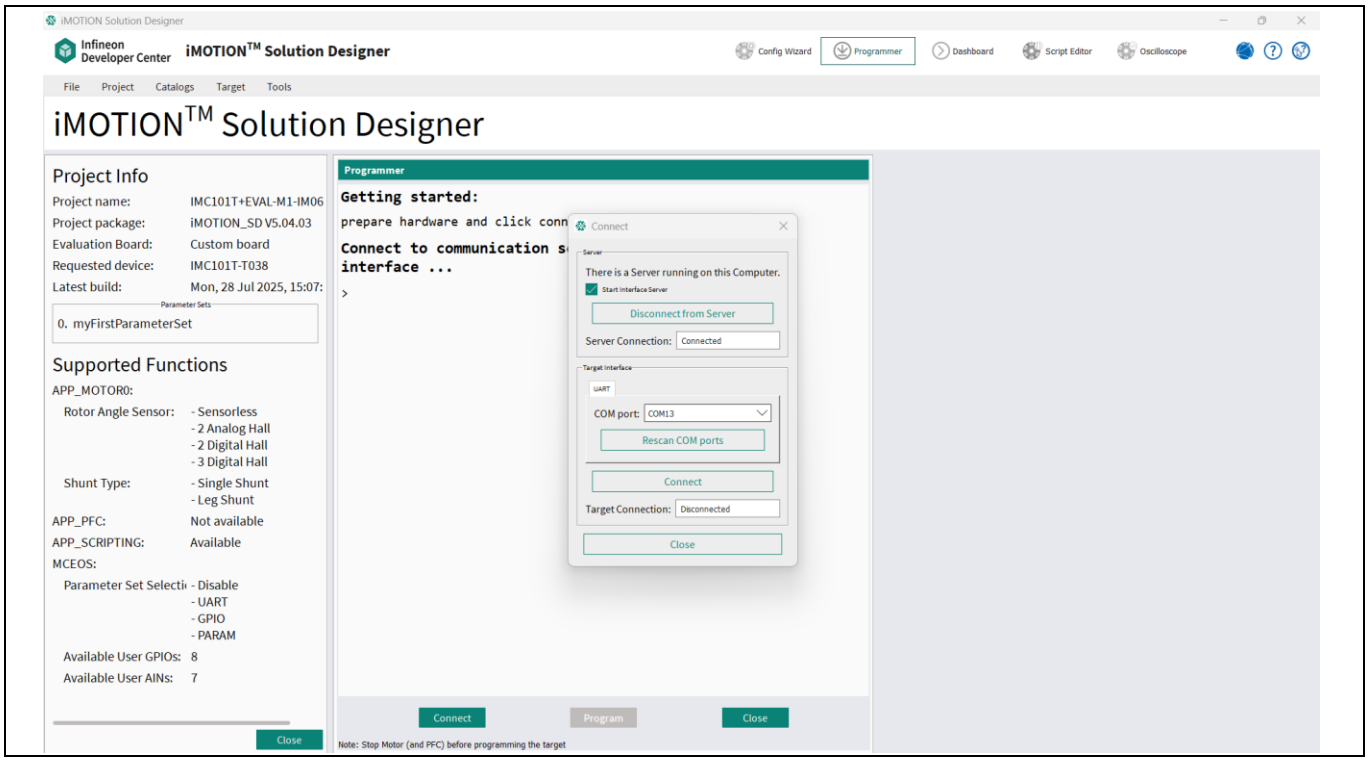


Figure 25 Connect target board

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

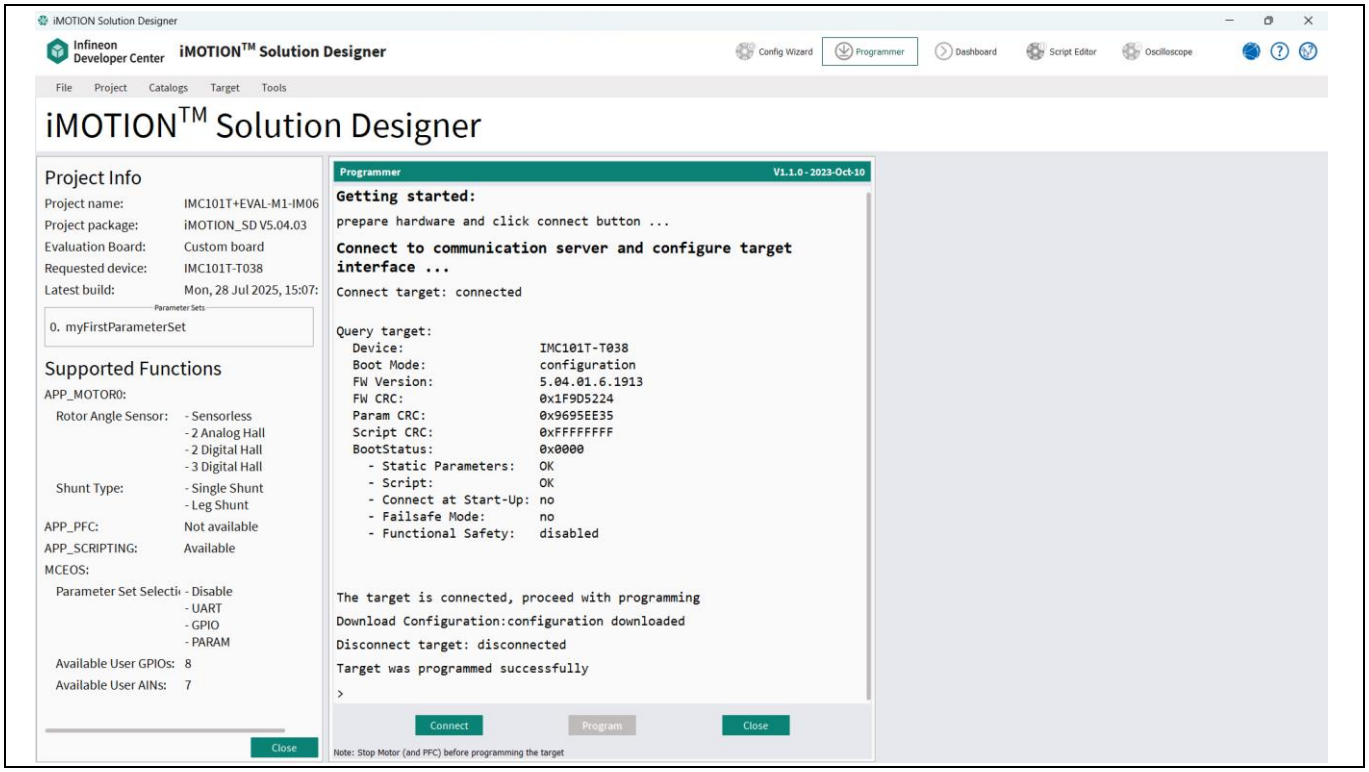


Figure 26 Programming

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.

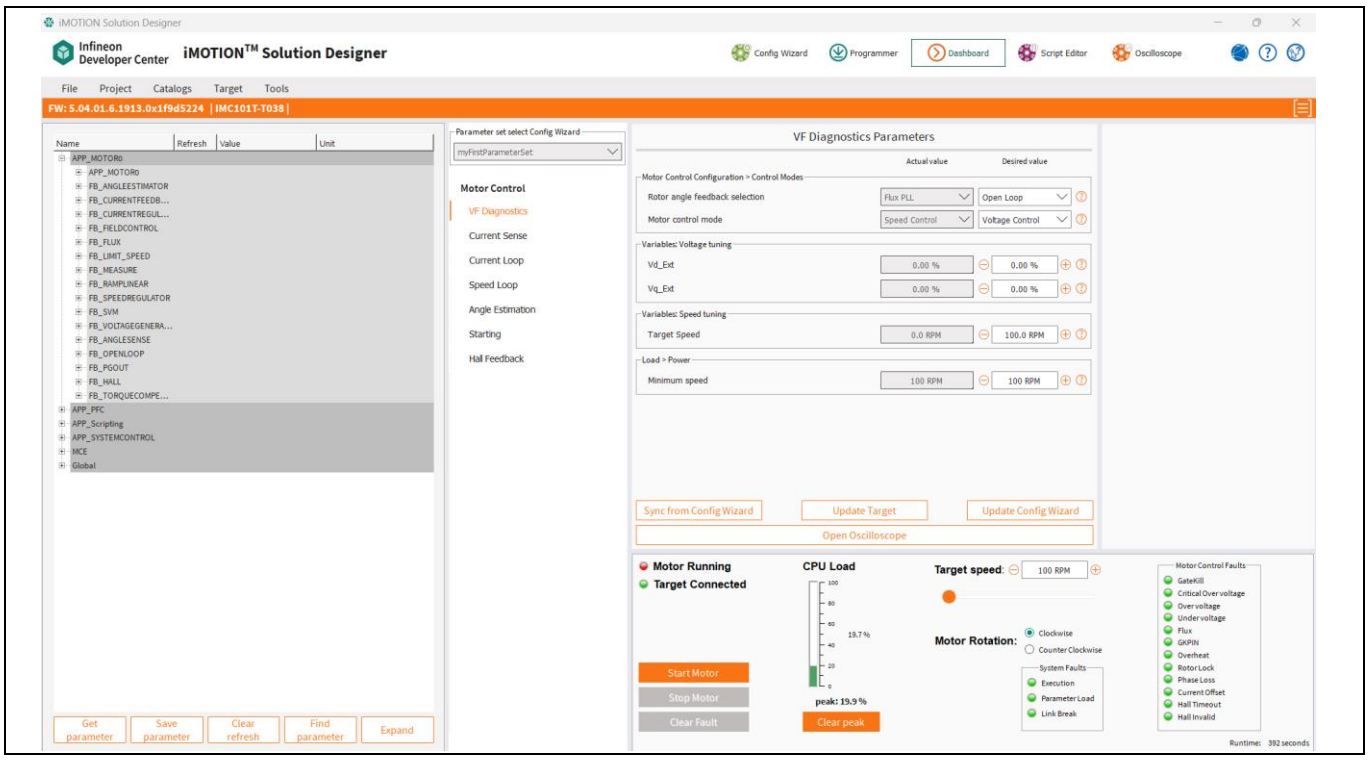


Figure 27 Dashboard

2.2 Description of the functional blocks

The motor inverter of EVAL-M1-IM06B50 reference design is implemented by the IM06B50 module, and the auxiliary power supply is based on fixed frequency CoolSET™ ICE5AR4770BZS.

Motor current sensing is single shunt mode, with an external OPA SGM721XN5 for 10 X gain.

2.2.1 Overview of IM06B50GC1

Figure 28 illustrates the internal block diagram of the CIPOS™ Mini IPM IM06B50GC1.

Main features include:

- 3 half bridges with TRENCHSTOP™ 50 A / 600 V and antiparallel diodes for inverter section
- Very low thermal resistance due to DCB
- Rugged SOI gate driver technology with stability against transient and negative voltage
- Negative potential allowed up to VS = -11 V for single transmission at VBS = 15 V
- Integrated bootstrap functionality
- Overcurrent shutdown, and build-in temperature monitor
- Undervoltage lockout and all six switches turn off during protection
- Low-side emitter pins accessible for phase current monitoring (open emitter)
- Cross conduction prevention and sleep function

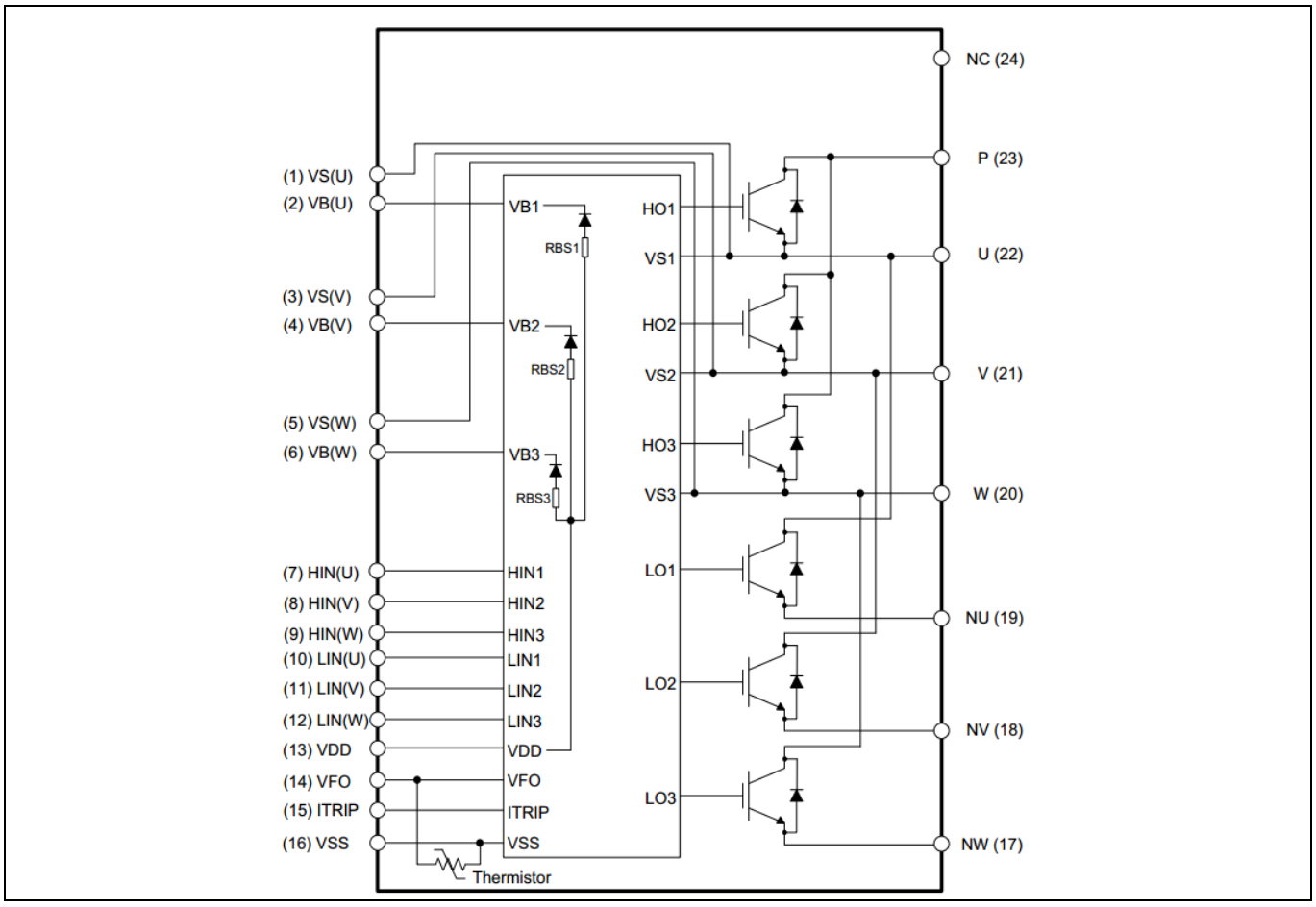


Figure 28 IM06B50GC1 internal block

2.2.2 Overview of ICE5AR4770BZS

The ICE5AR4770BZS is Infineon's latest 5th generation fixed frequency CoolSET™, offers high performance and integration of latest generation of 700 V CoolMOS™ super junction MOSFETs in DIP-7 package.

Figure 29 illustrates the internal block diagram and typical isolated flyback application.

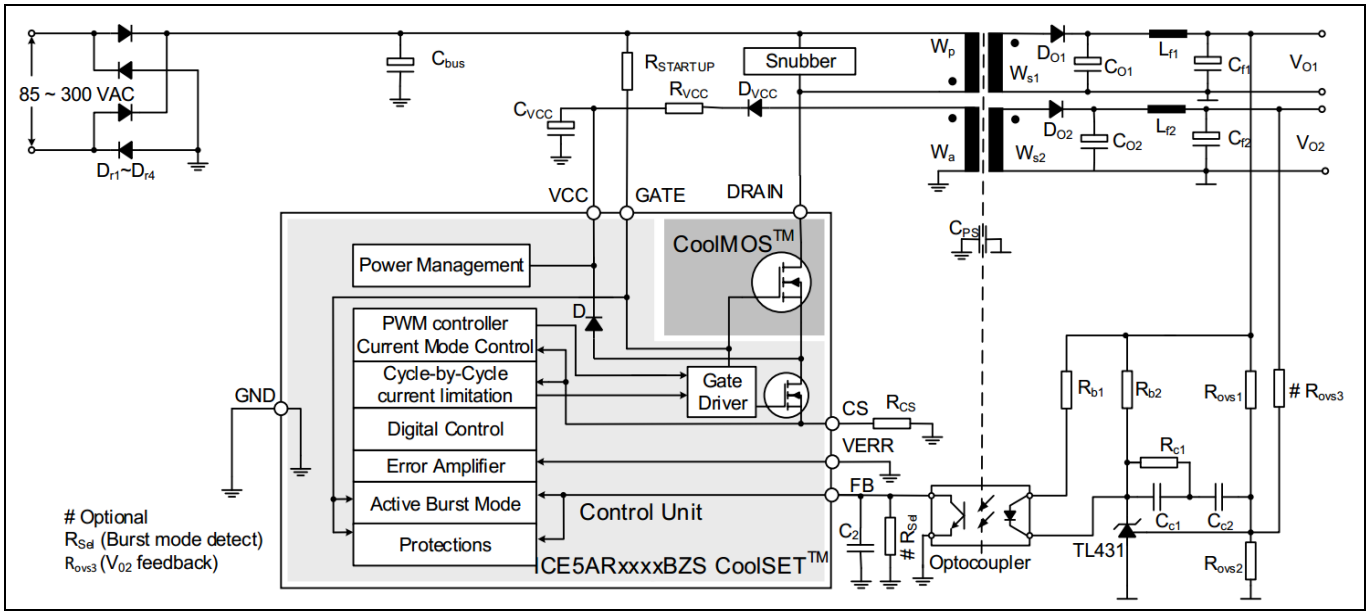


Figure 29 ICE5AR4770BZS internal block and typical application in isolated flyback mode

Main features of ICE5AR4770BZS include:

- 100 kHz maximum switching frequency with 700 V integrated MOSFET
- Power delivery of up to 15 W with universal wide input range (85~300 V_{AC}) DCM design
- Brown-in protection, fast and robust start-up operation with cascode configuration
- 3-level selectable entry/exit active-burst mode profile (optional)
- Built-in digital soft start
- Cycle by cycle peak current limitation
- Support both DCM and CCM operation with slope compensation
- Integrated error amplifier to support direct feedback typical with non-isolated flyback topology
- Digital frequency reduction with decreasing load for higher efficiency
- Frequency jitter and soft gate driving for low EMI
- Limited charging current for V_{CC} pin short to ground
- Comprehensive protection with V_{CC} over voltage, V_{CC} undervoltage, overload/open loop, over-temperature protection
- Auto-restart for all protection features

2.2.3 Motor current sensing op-amp configuration and calculation

To suppress common mode noise between this power board and the MADK control board, an 11 MHz rail-to rail I/O CMOS OPA SGM721XN5 is used for motor current sensing.

Two 5 mΩ 2.5 W (2512 package) shunt resistor and 10X external-gain OPA is the default configuration for the EVAL-M1-IM06B50 evaluation design, which means 1 A motor current produces 25 mV voltage to ADC input, the "Motor feedback circuit current gain" in iMOTION™ Solution Designer Config Wizard needs to input of 25 mV/A.

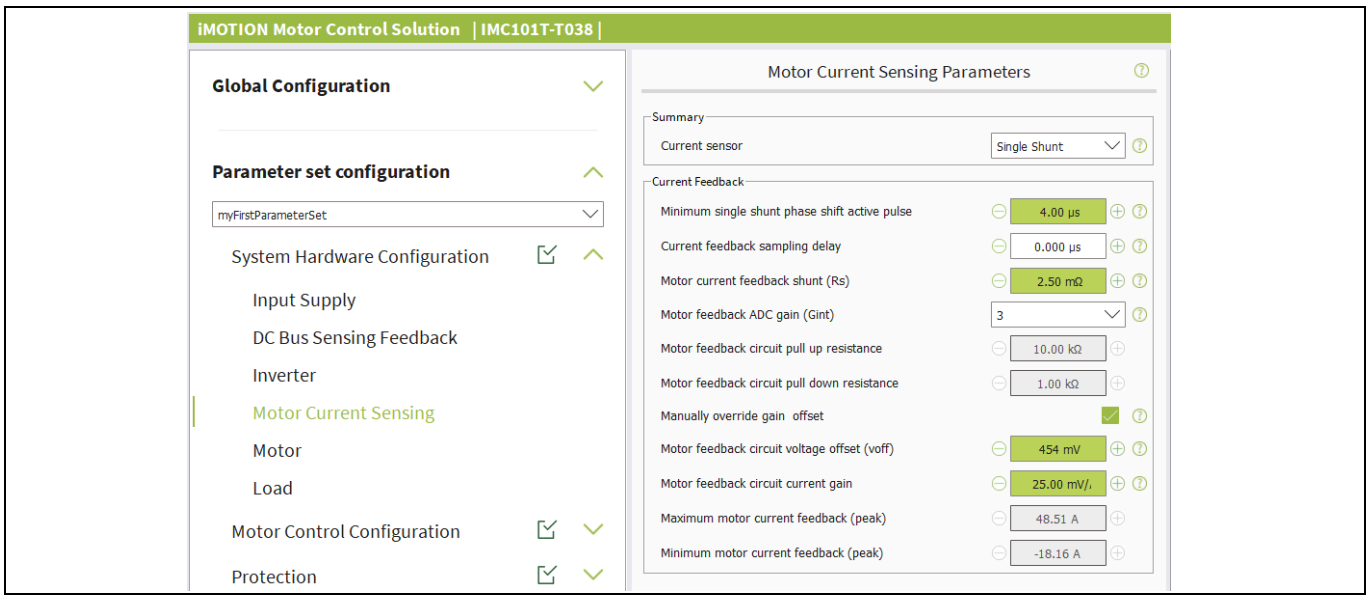


Figure 30 Motor Current Sensing configuration in iMOTION™ Solution Designer

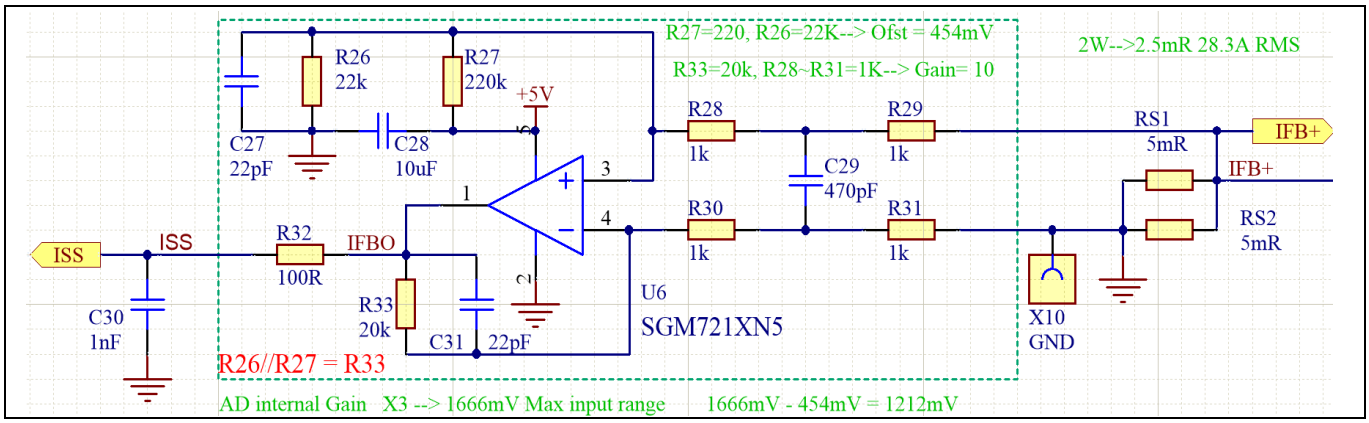


Figure 31 Current feedback with external 10X op-amp

Figure 31 shows the external amplifier gain circuit in EVAL-M1-IM06B50 evaluation design, which is a typical differential amplifier based on SGM721XN5, with input low-pass filter (LPF) and operational bias. C29, R28, R29, R30 and R31 build the input differential mode LPF, which can damp parts of PWM switching noise. The default LPF time constants is 2*RC = 2*(R28//R29) *C29 = 470 ns. The typical setup time is 0.1~0.5 µs, which depends on PCB layout, DC bus decouples capacitor and IGBT / MOS gate driver configuration.

For better common-mode noise-rejection ability, a balanced differential amplifier is highly recommended, which means R33 is equal to the value of R26 & R27 in parallel.

The divider of R26 & R27 provide operational bias for the amplifier, which affects the maximum motoring current and regeneration current range. With the default configuration of EVAL-M1-IM06B50, R26=22 k & R27=220 k, the op-amp operational bias is 5000 mV * 22 / (22+220) = 454 mV, which means:

- Op-amp outputs 454 mV at zero motor current (motor stopped), 454 mV/op-amp gain/RS1 is the maximum allowable regeneration current.
- If 1X ADC internal gain is selected, 4546 mV range for motor current sensing (5000 mV – 454 mV = 4546 mV). And 4546 mV/op-amp gain/RS1 is the maximum allowable motor current. “Motor Rated Amps * Motoring Current Limit” should be below this maximum allowable range.
- If 3X ADC internal gain is selected, 1212 mV range for motor current sensing (5000/3 – 454 mV = 1666 - 454 mV = 1212 mV). And “1212 mV/op-amp gain/RS1” is the maximum allowable motor current. “Motor Rated Amps * Motoring Current Limit” should be below this maximum allowable range.
- For applications that never work at regeneration mode (e.g. air conditioner), the OPA output bias wastes the available range of ADC and reduces the available ADC range.
- For applications that need more current range for regeneration (e.g. fan application), the amplifier bias needs an increase based on the regeneration requirement. For example, R26 = R27 = 2 * R33 for a bias of 2.5 V (50% of AD range) so that they have the same range for motoring current and regeneration current.

Please note that EVAL-M1-101T default configuration is in direct current sensing mode, R6 & R7 on EVAL-M1-101T are not needed for EVAL-M1-IM06B50’s motor current sensing. We **need to remove R6, and short R7 on EVAL-M1-101T control board**, as shown in Figure 32.

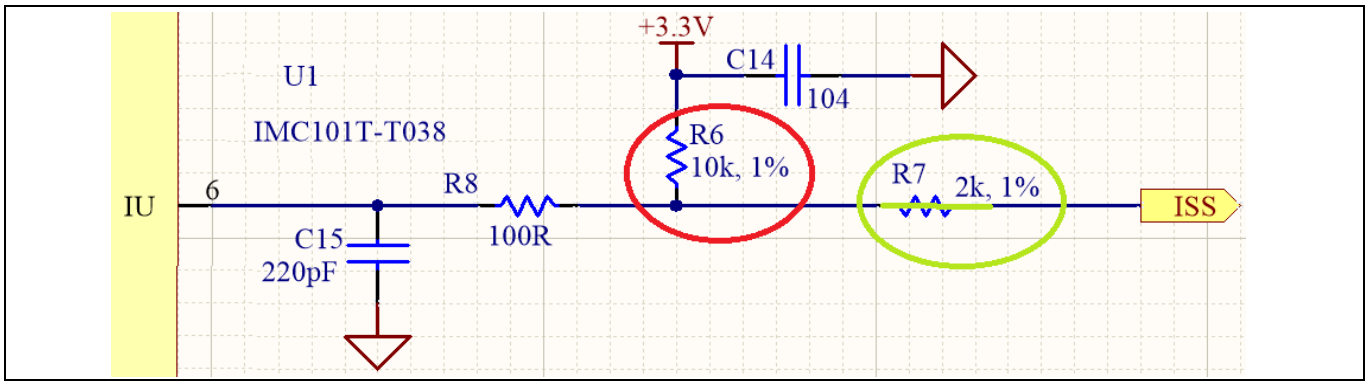


Figure 32 Modification on EVAL-M1-101T (remove R6 and short R7)

3 System design

The EVAL-M1-IM06B50 board is an optimized design for 220 V major home appliances like air conditioners applications. To meet individual customer requirements and to make the EVAL-M1-IM06B50 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.

3.1 Schematics

The overall schematic diagram for EVAL-M1-IM06B50 is provided in Figure 33 and Figure 34.

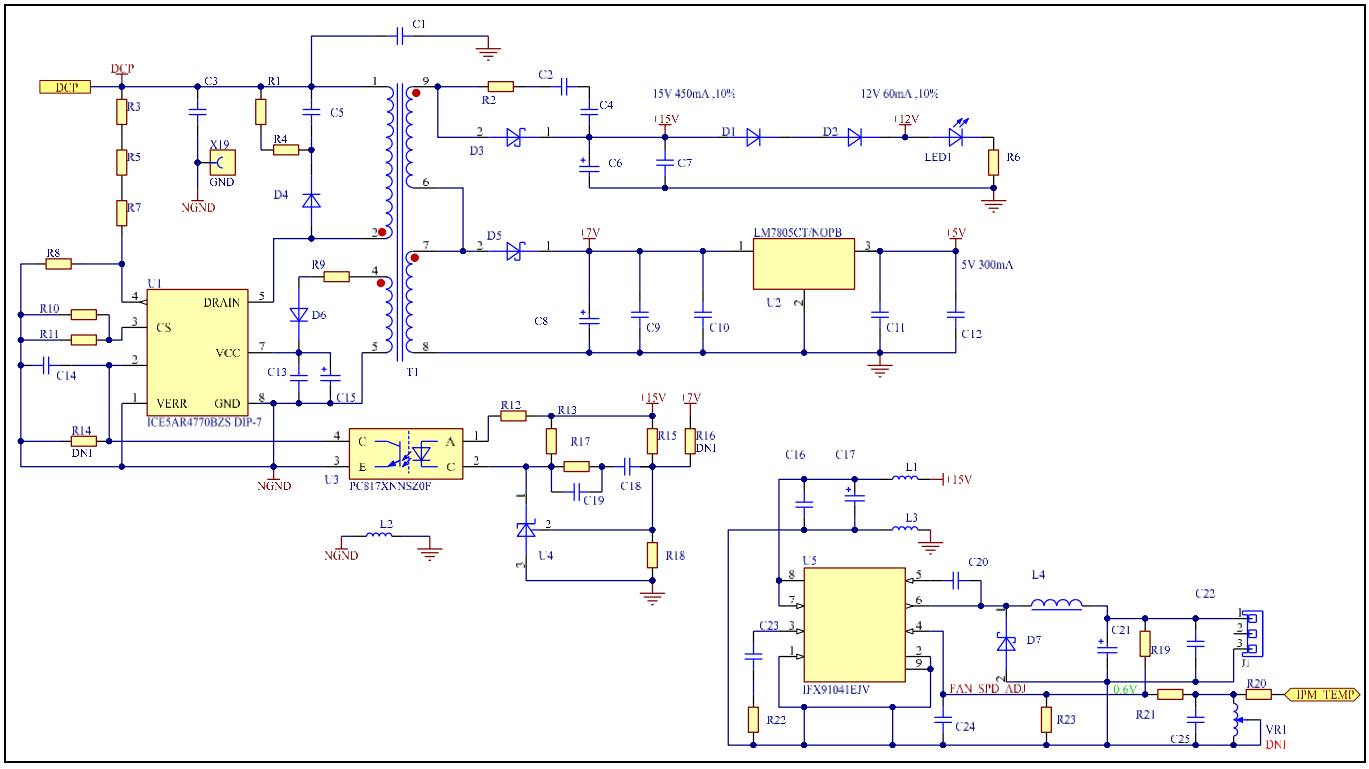


Figure 33 Aux power supply for EVAL-M1-IM06B50

Figure 33 shows the 8 W isolated flyback power supply based on ICE5AR4770BZS, +15 V and +5 V output for IPM and controller board, the major function information are listed as below:

- Transformer T1 is based on EE16 core, and the rated power is 8 W, which is suitable for most air conditioner applications.
- R3, R5, R7 and R8 decide the brown-in and brown-out voltage for power-on and power-off, which means ICE5AR4770BZS start work when DC bus voltage is over 82 V and stop work when DC bus below 40 V.
- R10 and R11 sensing the maximal peak current, related to cycle-by cycle current limitation.
- R15, R16 and R18 decide the output voltage for +15 V and +7 V.
- U5 is the DC-DC controller for cooling fan speed, R19, R23 and R21 can be adjusted to tune initial fan speed and adjustment based on IPM temperature. VR1 is reserved for manual fan speed adjustment (by removing R20).
- 12 V power supply for relay control is from +15 V via D1 and D2, which is not very accurate.

- PC817 used for primary isolation of flyback power supply, is not for real isolation, but for easier PCB layout for signal ground and power ground connections. This can reduce common-mode noise for controller board and achieve higher SNR for motor current sensing.

Figure 34 shows the invertor section of EVAL-M1-IM06B50, which contains IM06B50GC1 and its peripheral circuits, the major function information is listed below:

- U6 (SGM721) is a typical balanced difference amplifier for 10 X gain, the OPA bias decided by divider of R26 & R27; C29, C27 and C31 effect the total LPF bandwidth.
- U7A (LM393) for overcurrent protection; R50 is the major resistor for overcurrent threshold adjustment.
- U7B (LM393) for over-temperature protection; the pull-up resistor for IPM internal NTC is not a unique device, which is a combination of R55, R56, D10 and circuit in “Gatekill” and “IPM_TEMP” networks on control board, it is not recommended to change the hardware setup of U7B.
- J5 is reserved for Vdc bus voltage test or applications that use external DC source or PFC circuits.
- C54 ~ C57 are DC bus capacitors; default value is 400 V, 820 µF or 1000 µF. Please replace them by 450 V capacitors if there are external 380 V PFC or over 265 V_{AC} inputs.
- L5 is common-mode choker, which is the key component for EMI performance. Two packages placed on the PCB for convenient EMI performance testing and evaluation, suitable for 3 ~ 9 mH and 18~23 A common mode inductor.
- J2 is 20-pin interface for MADK control boards; only pin 10 & pin 12 (IU+ & IU-) are used for single-shunt current sensing (ISS from OPA output).

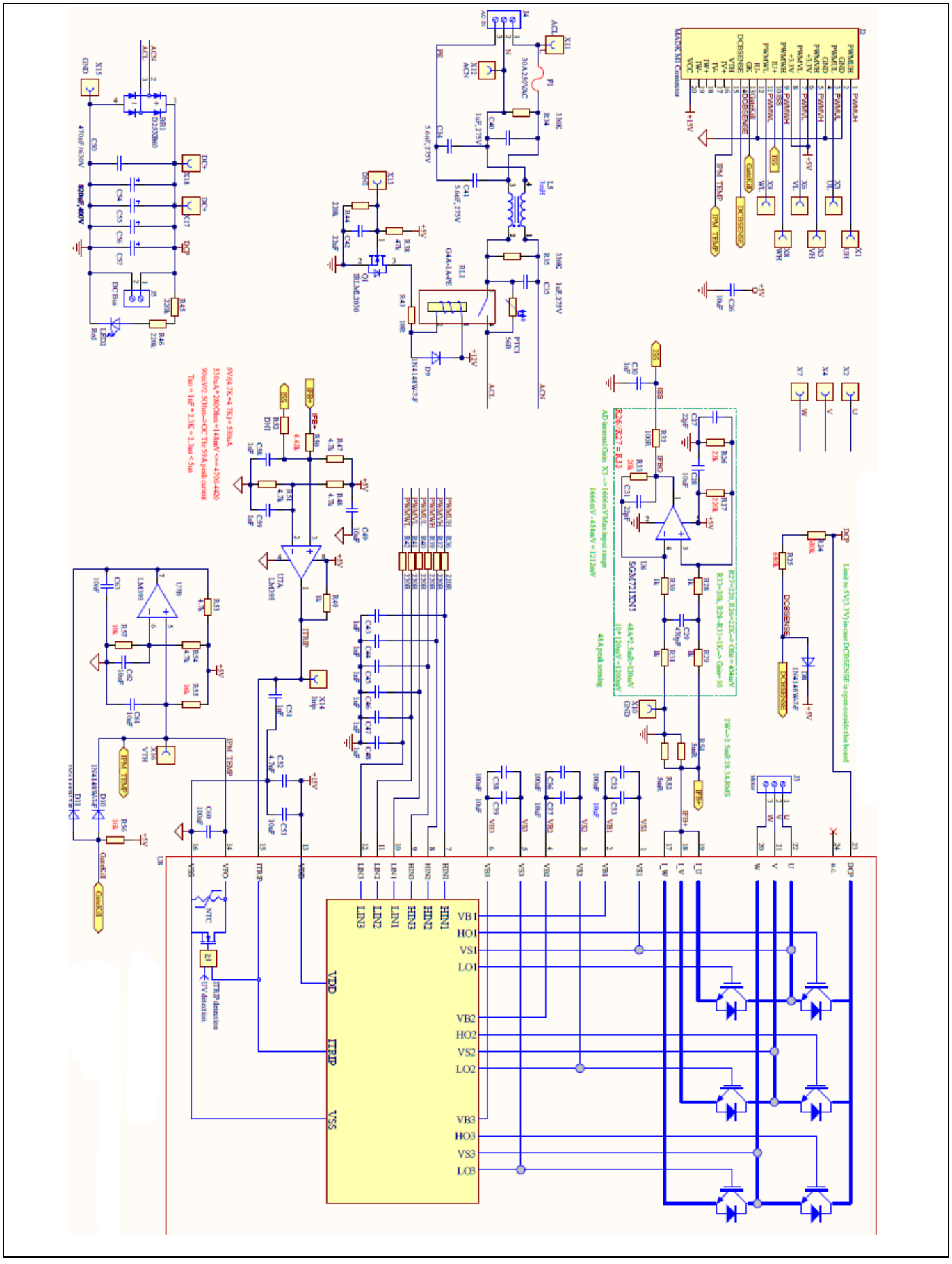


Figure 34 Schematics for IM06B50 IPM and peripheral circuit

3.2 Layout

This board has two electrical layers with 70 µm copper (2 oz. copper) and dimensions of 166 mm × 166 mm. The thickness of the PCB board is 1.6 mm. Figure 35 illustrates the top assembly print of the reference design.

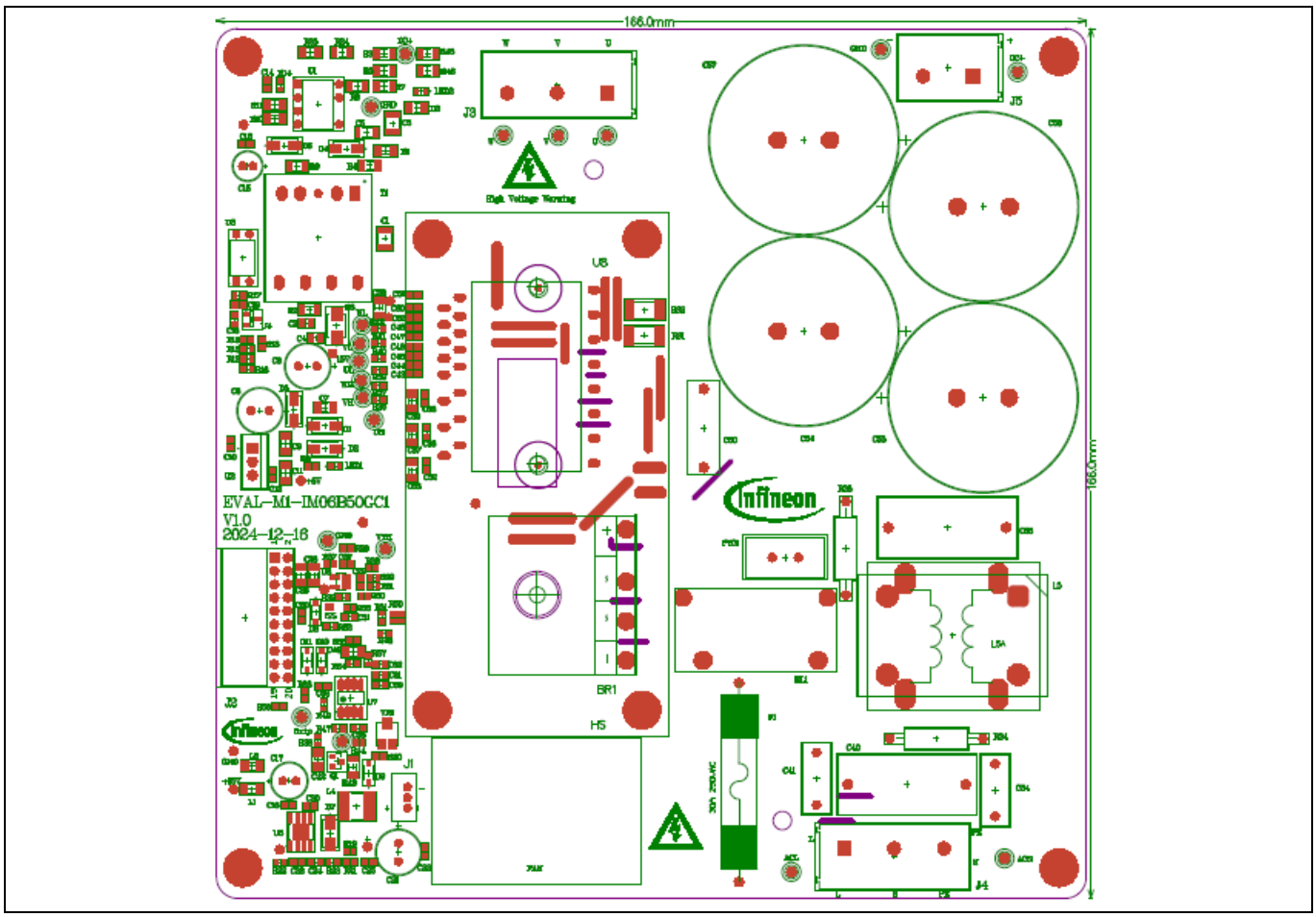


Figure 35 Top assembly print of the EVAL-M1-IM06B50 reference design

The top layer and bottom layer routing of the PCB are provided in Figure 36 and Figure 37.

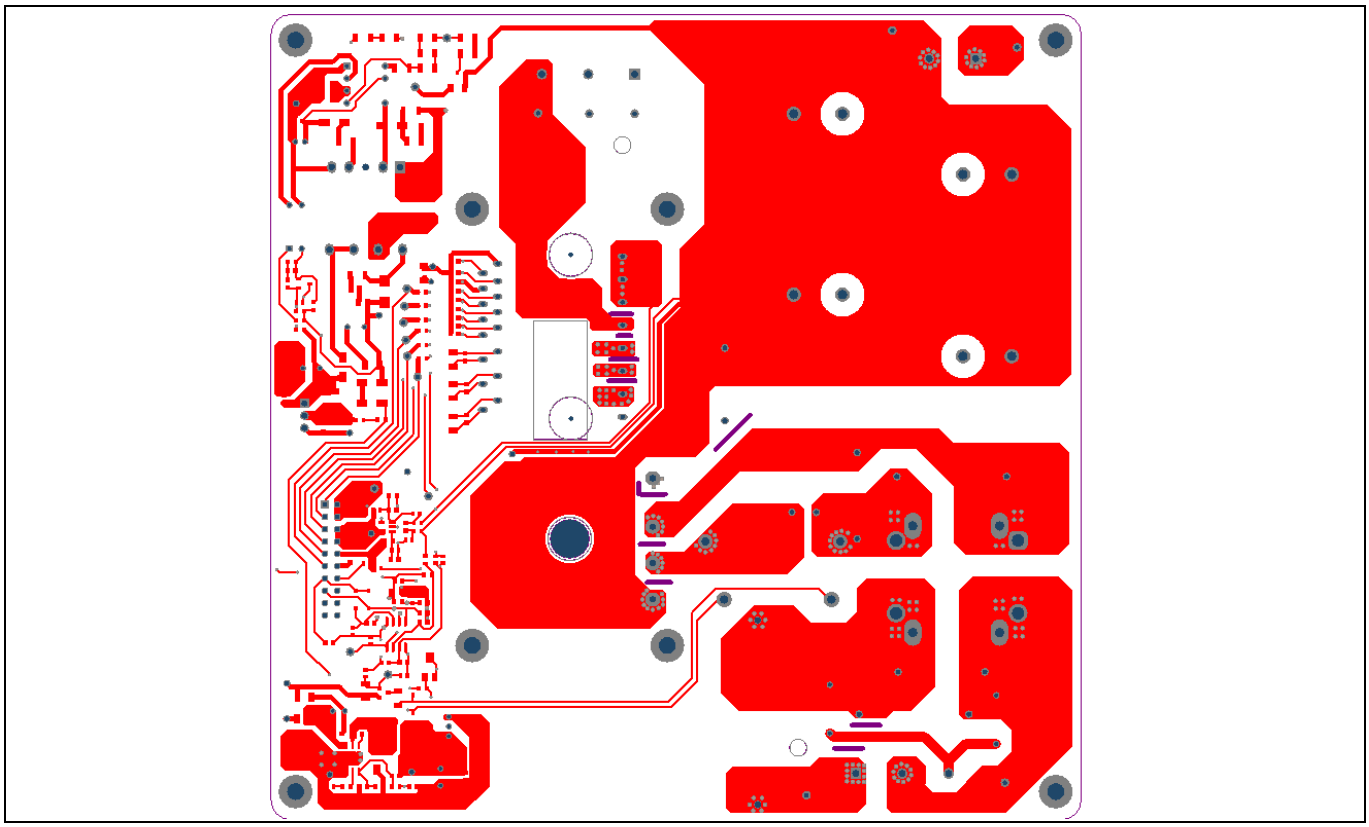


Figure 36 Top layer routing of the EVAL-M1-IM06B50

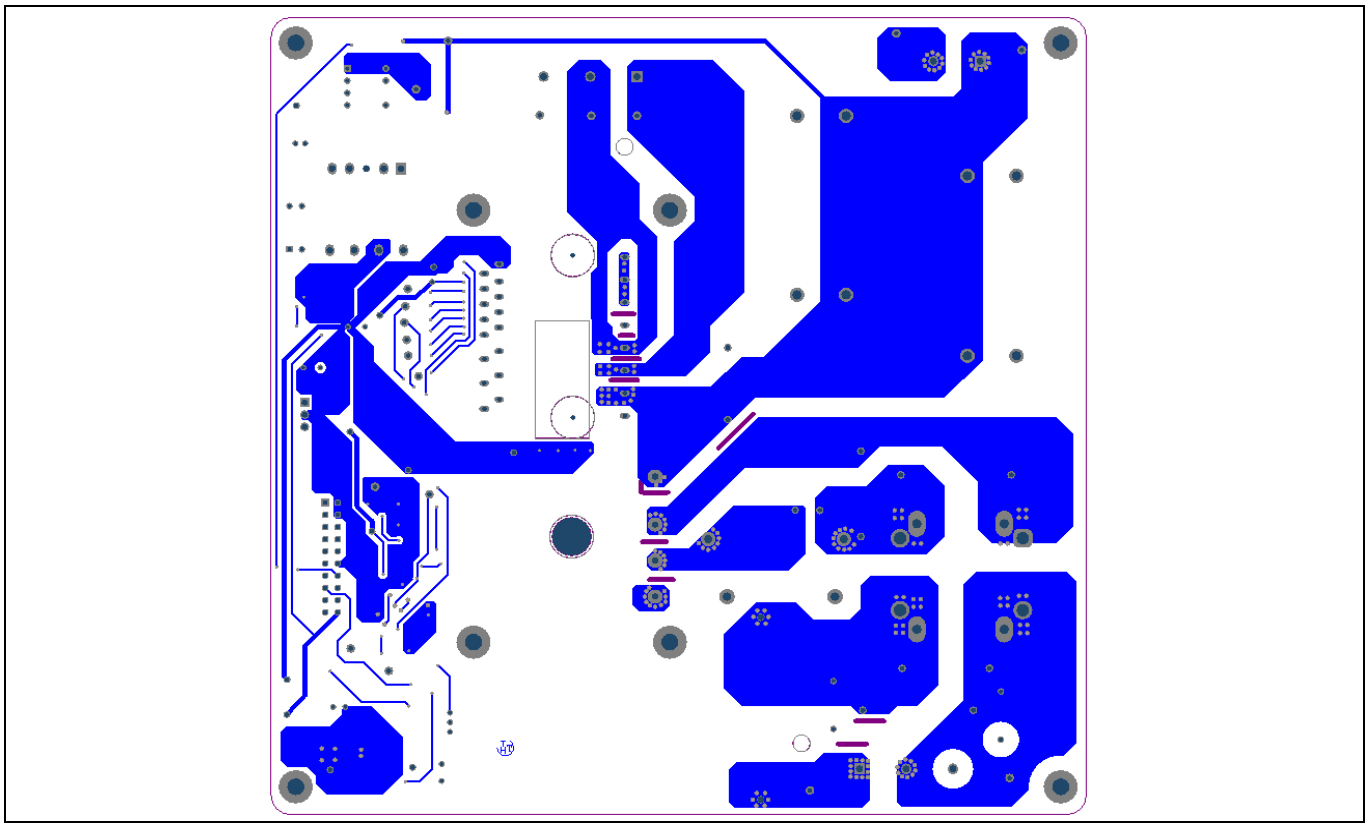


Figure 37 Bottom layer routing of the EVAL-M1-IM06B50

3.3 Bill of material

Table 3 shows the major parts of EVAL-M1-IM06B50 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 3 BOM of the most important/critical parts of the evaluation or reference board

S. No.	Ref Designator	Description	Manufacturer	Manufacturer P/N
U6	SGM721XN5	11MHz, 8.5V/µS, Rail-to-Rail OPA	SG Micro	SGM721XN5/TR
U7	LM393	Dual comparator		
Q1	IRLML2030	30V 154mOhm@4.5V MOSFET	Infineon Technologies	IRLML2030
U8	IM06B50GC1	CIPOS™ MINI	Infineon Technologies	IM06B50GC1
U5	IFX91041EJV	1.8A DC/DC Step-Down Voltage Regulator, Adjustable	Infineon Technologies	IFX91041EJV
U1	ICE5AR4770	Fixed Frequency 700 V CoolSET™	Infineon Technologies	ICE5AR4770BZS DIP-7
RL1	G4A-1A-PE	20A Relay		
FAN	FAN4028	FAN4028 12V 3.36W, 14500rpm, 19.1CFM;	SANYO	9GA0412P3H01
BR1	D25XB60	25A 600V Diode Bridge		
C54~C57	820uF, 400V	Diameter 35mm, Height 45mm~60mm, 820uF~1000uF, 400V	Wurth Elektronik	861021386035
T1	710uH/EE16	Wurth Electronics Midcom (750343739), Core: 150-2182 (EE16/8/5), bobbin: 070-5280 (9-pin EXT, THT, horizontal version)	Wurth Electronics	750343739
R24, R25	680k	1206 Thick Film Chip Resistor		
L1, L2, L3	650R	WE-CBF SMD EMI Suppression Ferrite Bead	Wurth Elektronik	INDC3216X130N
C50	470nF / 630V	CBB22 Film Capacitors		
F1	30A 250VAC	30A 250VAC fuse		
C34, C41	5.6nF, 275V	Film Capacitor, THT, L13W5H10, 5.6nF, 275V	Wurth Elektronik	890324023002CS
RS1, RS2	5mR	Current Sense Precision Resistor	Isabellenhuette	BVT-I-R005
L5	3mH	WE-CMBNC Common Mode Power Line Choke, Type XL, 3mH, 23A, 250V	Wurth Elektronik	7448052303
C35, C40	1uF, 275V	WCAP-FTX2 Film Capacitor, THT, L26W11H20, 1uF, 275V	Wurth Elektronik	890324026027CS

3.4 Connector details

General information about the connectors of the EVAL-M1-IM06B50 reference design is provided in this section. Table 4 includes the details of the AC input connector.

Table 4 AC input connector (J4)

PIN	Label	Function
1	L	AC line
2	N	AC neutral
3	PE	Protection earth

Table 5 provides the details of the motor UVW output connector J3.

Table 5 Motor side connector (J3)

PIN	Label	Function
1	U	Connected to motor phase U
2	V	Connected to motor phase V
3	W	Connected to motor phase W

Table 6 provides the details of the DC bus output connector J5, for external PFC or DC source connection.

Table 6 DC bus connector (J5)

PIN	Label	Function
1	DCP	Connected to DC+
2	GND	Connected to DC-

Table 7 provides the pin assignments of the 20-pin iMOTION™ MADK-M1 interface connector J2. This connector is the interface to the controller board.

Table 7 J2 - iMOTION™ MADK-M1 20-pin interface connector for controller board

Pin	Name	Pin name connectors
1	PWMUH	5 V compatible logic input for high side gate driver-Phase U
2	GND	Ground
3	PWMUL	5 V compatible logic input for low side gate driver-Phase U
4	GND	4 GND ground
5	PWMVH	5 V compatible logic input for high side gate driver-Phase V
6	+5 V	On board 5 V supply
7	PWMVL	5 V compatible logic input for low side gate driver-Phase V
8	+5 V	On board 5 V supply
9	PWMWH	5 V compatible logic input for high side gate driver-Phase W

Pin	Name	Pin name connectors
10	I_U	Positive current sense output
11	PWMWL	5 V compatible logic input for low side gate driver-Phase W
12	I_U-	Negative current sense output or ground
13	GK	Gatekill signal – active low when overcurrent is detected
14	DCBSense	DC bus positive voltage, scaled in 0-5 V range by a voltage divider
15	VTH	Thermistor output
16	I_V	Not used
17	I_V-	Not used
18	I_W	Not used
19	I_W-	Not used
20	VCC	15 V power supply

3.5 Test points

Table 8 provides the assignments of the on-board test points.

Table 8

Pin	Name	Functions & net label describe
X1	UH	High side gate driver PWM-Phase U
X2	U	Invertor output, motor phase U
X3	UL	Low side gate driver PWM-Phase U
X4	V	Invertor output, motor phase V
X5	VH	High side gate driver PWM-Phase V
X6	VL	Low side gate driver PWM-Phase V
X7	W	Inverter output, motor phase W
X8	WH	High side gate driver PWM-Phase W
X9	WL	Low side gate driver PWM-Phase W
X10	GND	Ground test point for controller board (signals ground)
X11	ACL	AC voltage measure point (L)
X12	ACN	AC voltage measure point (N)
X13	*DNI*	
X14	Itrip	Output of over current protection circuit (Pin 1 for LM393)
X15	GND	Power GND test point (DC-)
X16	VTH	Test point for temperature sensing (Pin 15 of IM06B50)
X17, X18	DC+	DC+ test point
X19	GND	Ground test point for primary side of fly-back power supply

4 System performance*

4.1 Heatsink thermal resistance test result

To test the thermal impedance of heatsink to ambient R_{thCA}, the DC source is used to conduct the IPM internal diodes, as shown in Figure 38. With the DC source voltage increasing, current through IPM I_{IPM} and voltage on IPM V_{IPM} are monitored by current and voltage meter, the IPM case-temperature test point is between IPM and heatsink, the same as Tc point of inverter IGBT of the IPM datasheet.

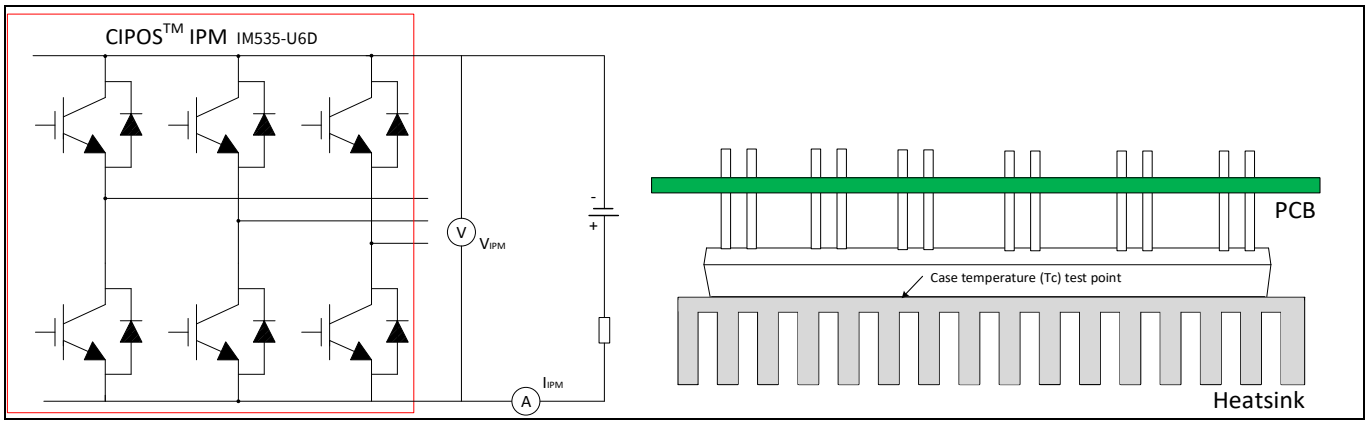


Figure 38 Heatsink thermal testing set-up

Thermal resistance between junction to ambient R_{thJA} is divided into 2 parts as in the following formula: thermal resistance between junction to case R_{thJC} and thermal resistance between case to ambient R_{thCA}.

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

Thus, we get the following formula:

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

According to the test set-up, the test results are shown in Figure 39 below. The IPM case temperature is detected for about one hour until the temperature is stable.

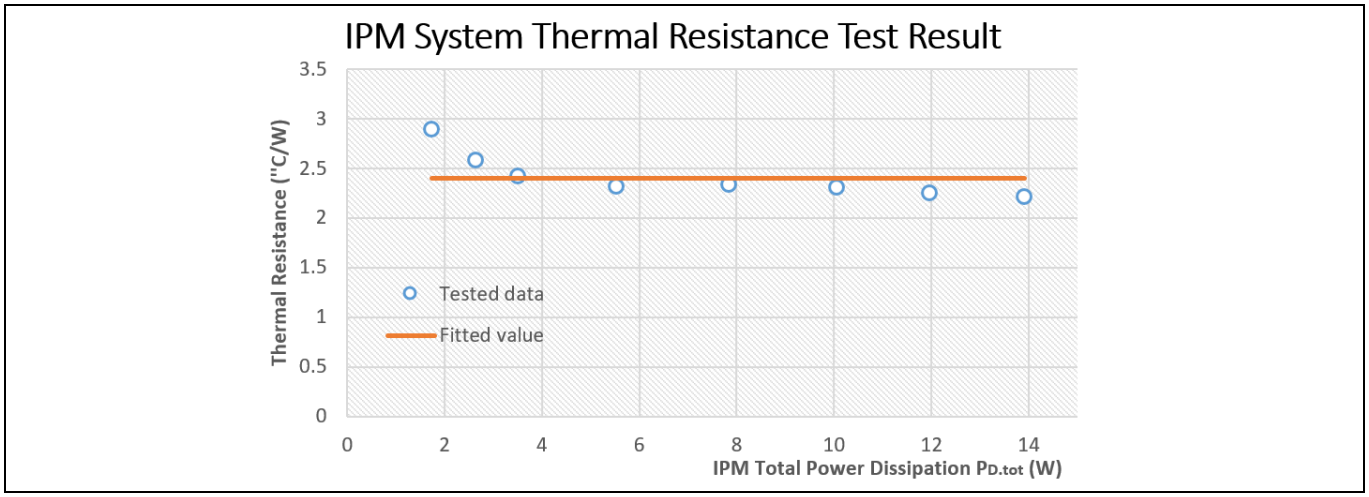


Figure 39 Heatsink thermal testing result

*Note: All test results are used the IM535-U6D because IM60B50GC1 are almost similar IM535-U6D.

Therefore, the final case-to-ambient resistance value is roughly:

$$R_{thCA} = 2.4\ ℃/W$$

Please note that:

- 2.4 $℃/W$ thermal resistance is calculated with a fan voltage of 10 V.
- DC-DC output voltage for EVAL-M1-IM06B50's cooling fan is 7~14.3 V in default hardware configuration, which is adjusted by IPM temperature from 25 ~ 125℃.
- Cooling fan's rate voltage is 12 V corresponding to 110℃ IPM surface temperature.
- Tuning R19, R23 and R21 can change the relationship between fan speed (voltage) and IPM temperature.

4.2 Test results for output ability

In order to test the total output power capability of EVAL-M1-IM06B50 design, the IPM case temperature is tested with different MADK input power and motor output current.

The test conditions are:

- Ambient temperature Ta=25℃
- Cooling fan voltage is 14.3 V, 8m/s air flow after heatsink (5 mm distance center of heatsink fins)
- AC input is VAC=220 V/50 Hz (V_{DC} bus is 290 V~310 V)
- PWM frequency 6 kHz, three-phase modulation, about 40% V_{DQ} modulation (1000 RPM)

Figure 40 shows how to monitor IPM case temperature by infrared camera from the window on PCB bottom. Run motor at 1000 RPM and adjust motor load until the hottest point in the center of IM06B50GC1 reaches 105℃ (temperature rise reaches 80℃), get the curve for temperature rise and input power as shown in Figure 41.

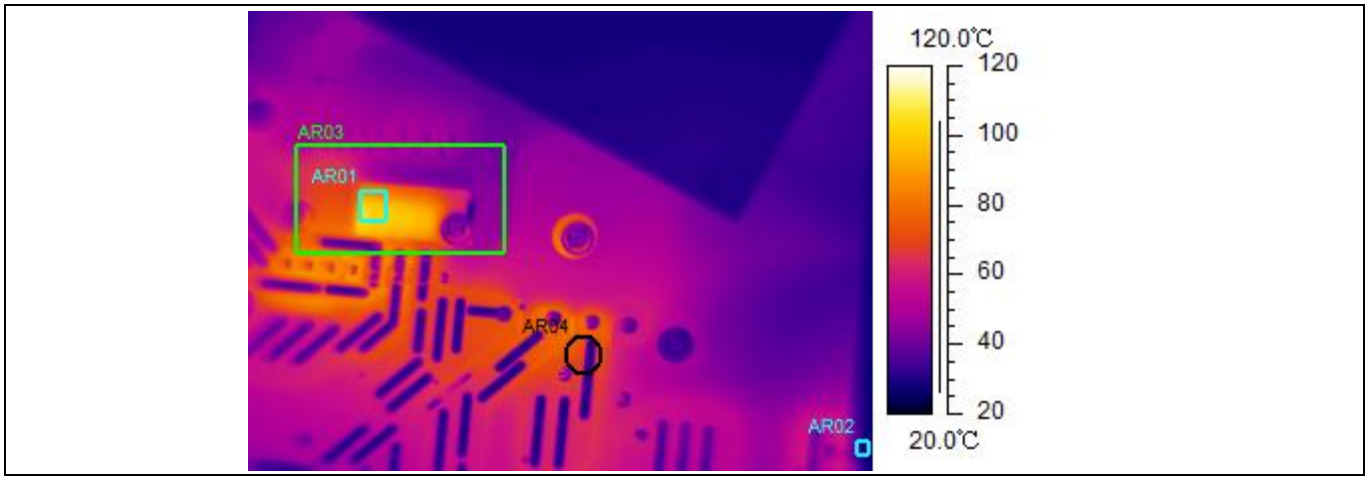


Figure 40 Infrared camera image for IPM temperature test

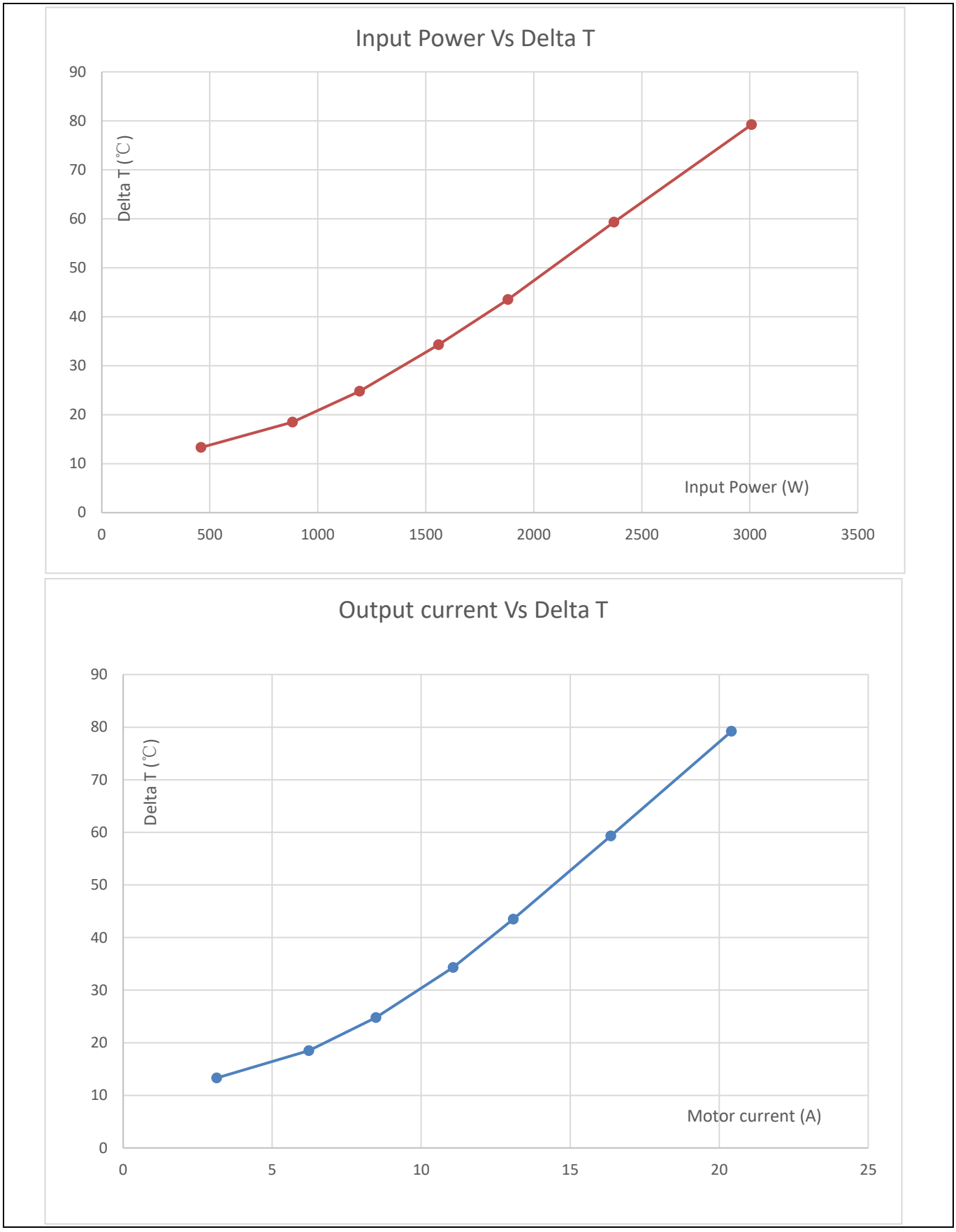


Figure 41 EVAL-M1-IM06B50 output power capability test result

4.3 Test results for PWM range

Figure 42 shows the output ability at different PWM frequencies, which are performed under the following conditions:

- 4~20 kHz PWM, three-phase modulation
- Run GK6081 motor at 1000RPM (about 40% V_{DQ} modulation) and increase motor load at given PWM frequency, till the hottest case temperature of IM06B50GC1 reaches 105℃
- Ambient temperature Ta=25℃
- Cooling fan voltage is 14.3 V , 8m/s air flow after heatsink (5 mm distance, center of heatsink fins)
- AC input is VAC=220 V/50 Hz (V_{DC} bus is 290 V~310 V)

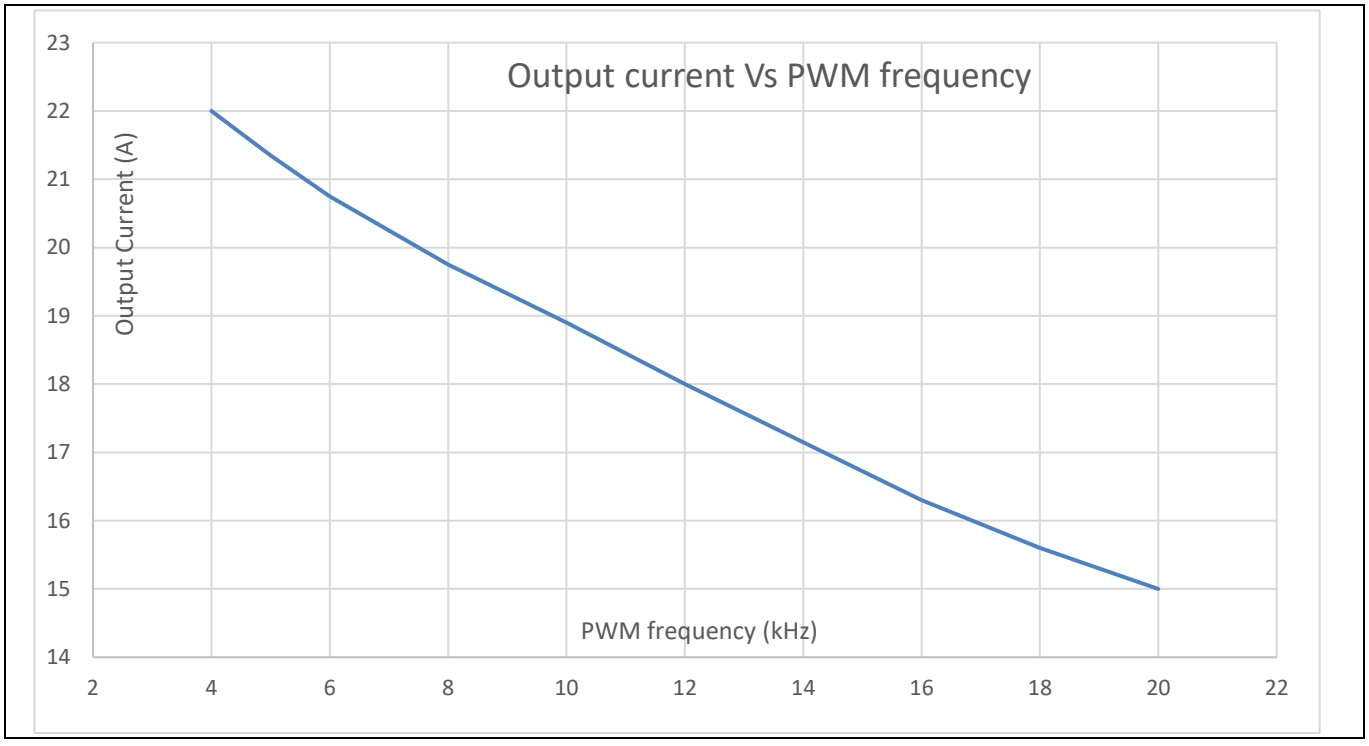


Figure 42 Output ability at different PWM frequency

4.4 Test results for overcurrent protection

The IM06B50GC1 product provides an overcurrent detection function by connecting the ITRIP input with the IGBT current feedback, and IGBT short-circuit withstand time is 5 µs. Overcurrent detection generates a shutdown of outputs of the gate driver if ITRIP pin input is over 525 mV and lasts longer than 300ns.

An external LM393 comparator is used for overcurrent protection in EVAL-M1-IM06B50 design to lower the request of shunt resisters voltage to 90 mV, since 525 mV means too much current for 2.5 mOhm shunt resisters.

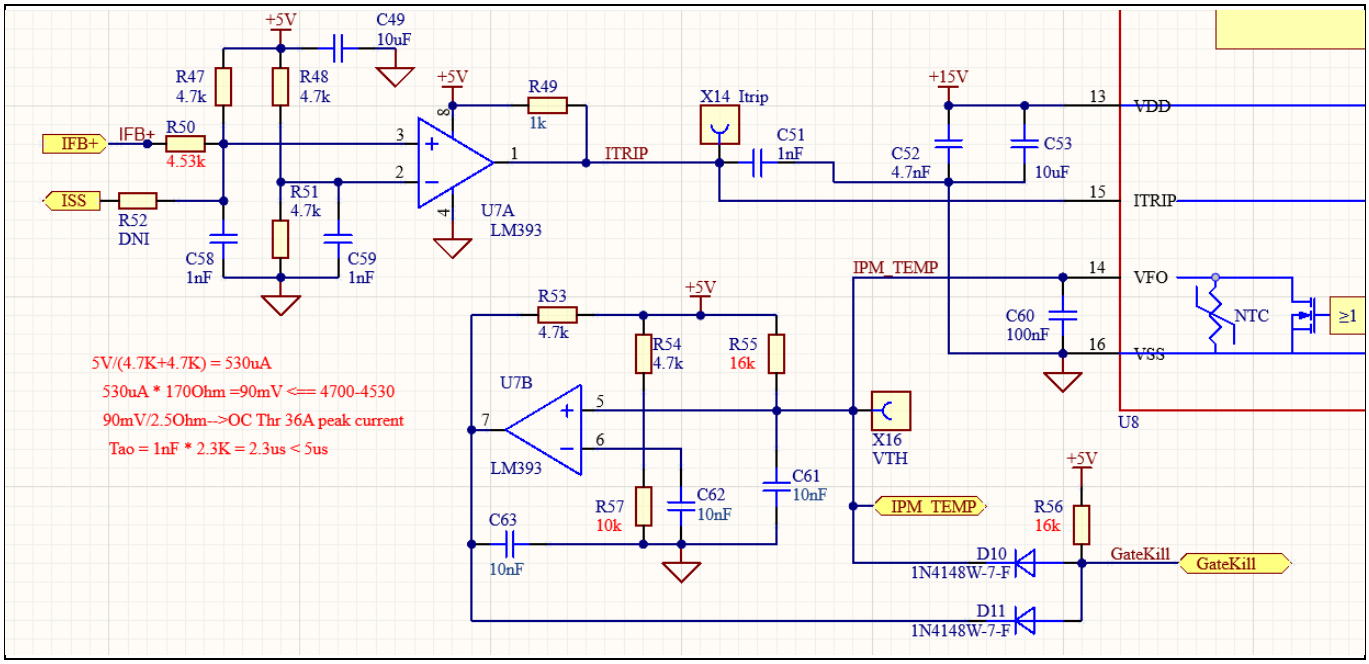


Figure 43 IPM overcurrent protection and over-temperature protection circuit

The small signal and big signal response of this overcurrent protection circuit is shown in Figure 44:

- 2.3 µs for 300 ~ 400 mV shunt resistor voltage, which means 120 ~ 160 A short-circuit condition.
- 5.9 µs for 100~150 mV shunt resistor voltage, which means 40 ~ 60 A overcurrent circuit condition.

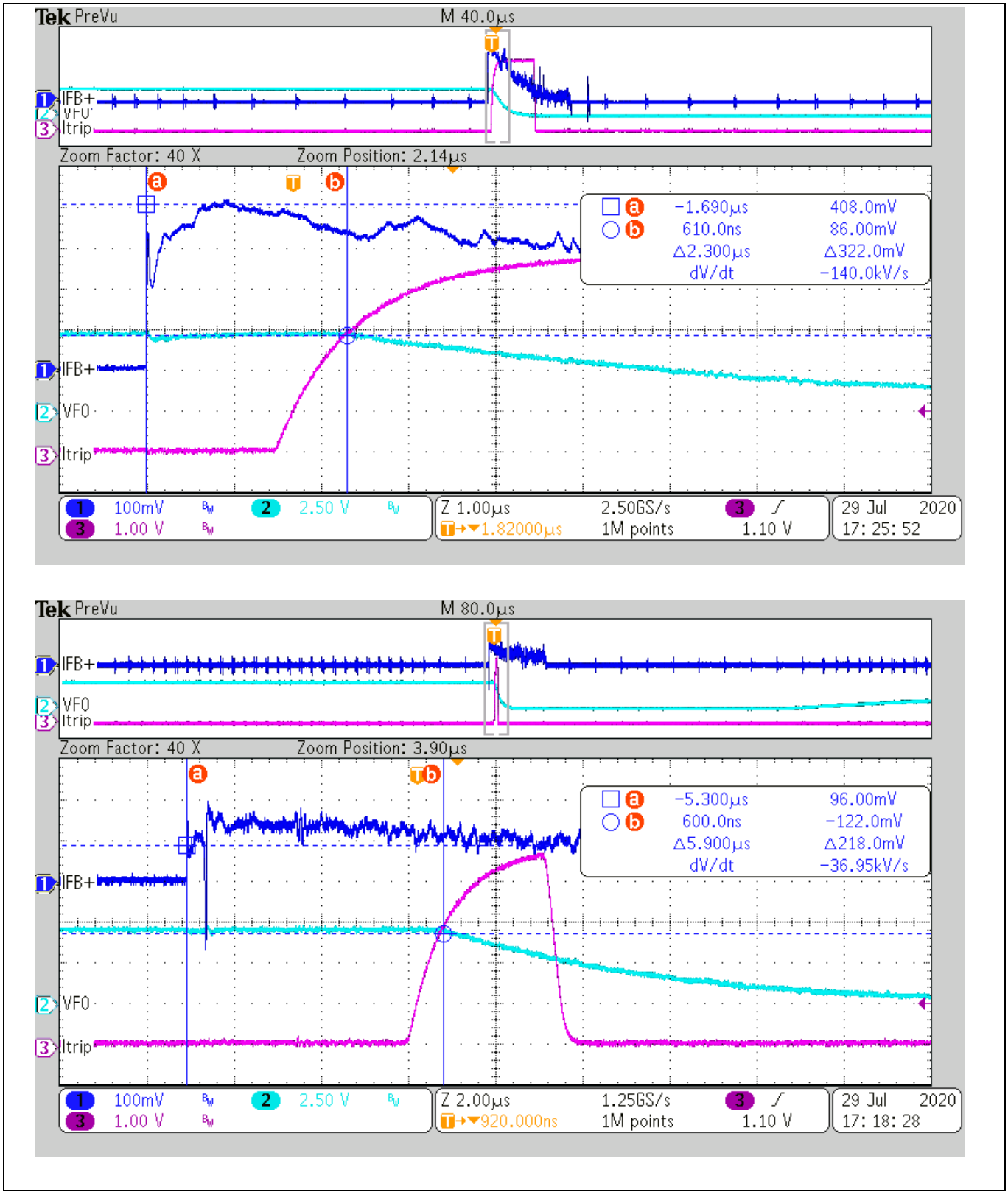


Figure 44 Overcurrent protection response waveform (CH1: IFB+, CH2: VFO, CH3: Itrip)

4.5 Test results for over-temperature protection

The IM06B50 IPM has an internal NTC resistor, which connects to VFO multifunction pin, as shown in Figure 45:

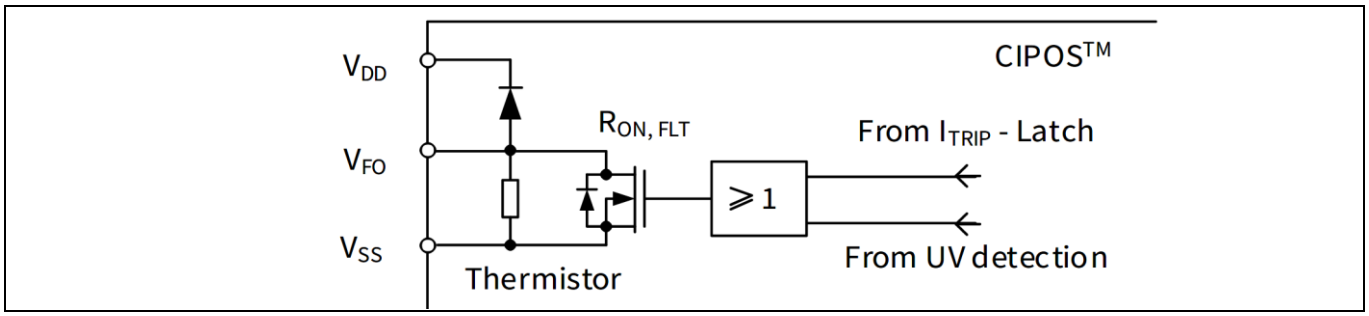


Figure 45 Temperature sensing for IM06B50GC1

The IM06B50GC1 IPM built-in NTC thermistor is 85 kOhm at 25℃ and its B-constant is 4092, typical resistance and output of temperature-sensing voltage are listed in Table 9.

Table 9 NTC – Thermistor Characteristics

Temperature (℃)	Resistance (kOhm)	V_{out} (mV)
50	29.972	4220
60	20.515	4160
70	14.315	4080
80	10.169	4000
90	7.345	3920
100	5.388	3830
110	4.009	3720
120	3.024	3600
125	2.639	3520

Given that the VFO pin is fault-output compatible pin (LOW true at IPM fault status), the temperature sensing pull-up resistor needs to keep the temperature detection output as far away from the digital IO's low level threshold as possible, which means the available range should be beyond 3.5 V (0.7 x V_{DD}) to make sure IMC101T in EVAL-M1-101T considers this input as HIGH.

The pull-up resistor NTC is a complex network (R55, R56, D10 and circuit in EVAL-M1-101T), the final temperature protection (OTP) circuit output voltage to IMC101T's temperature-related AD input is shown in Figure 46.

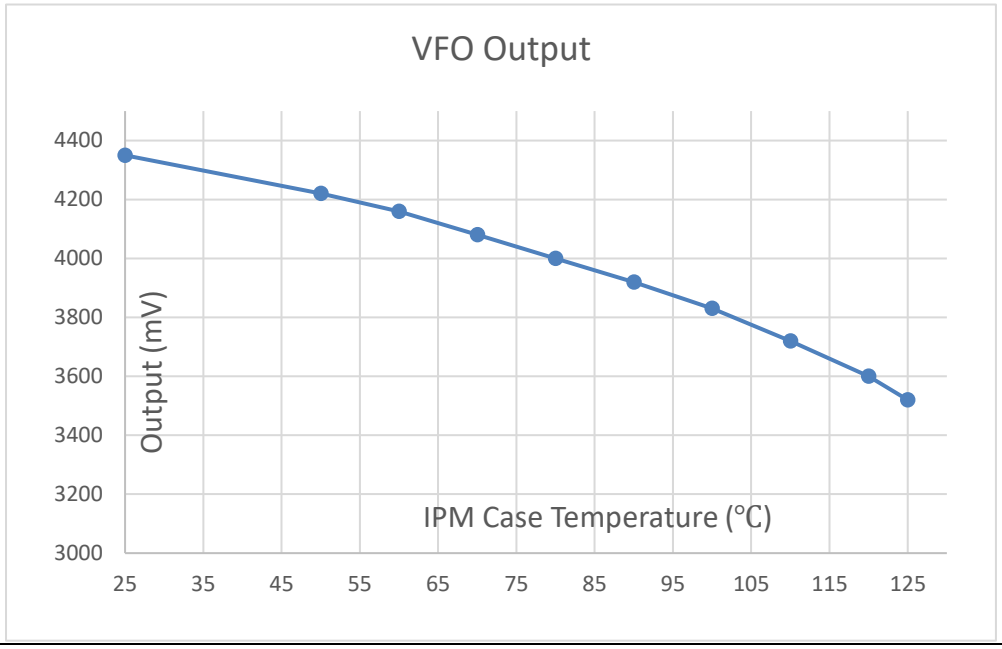


Figure 46 OTP (NTC circuit) and output voltage curve

Please note that output of VFO pin is very noisy; EVAL-M1-101T's OTP function might be triggered by noise. Normally the iMOTION™ Solution Designer setup needs to consider a margin for the input noise, for example, setup 3.3 ~ 3.4 V in iMOTION™ Solution Designer corresponding to the real shutdown temperature of 110 ~ 120°C.

To activate over-temperature protection, 2 setups in iMOTION™ Solution Designer are needed, as shown in Figure 47 :

- Enable over temperature fault
- Set voltage for NTC voltage threshold for an over temperature fault

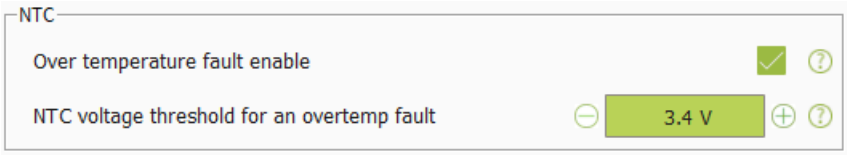


Figure 47 Over-temperature protection setup in iMOTION™ Solution Designer

4.6 Test result for DC bus voltage ripple

The EVAL-M1-IM06B50 design does not equip PFC function, which means the DC bus voltage is determined by the AC input voltage and the load of motor; the DC bus voltage ripple is the function of IPM inverter load and grid input.

Figure 48 shows the DC bus ripple waveform with 4 x 1000µF capacitors, 220 V_{AC}, 3000 W input power, which is 7.5% (23.6 V / 311 V = 7.5%).

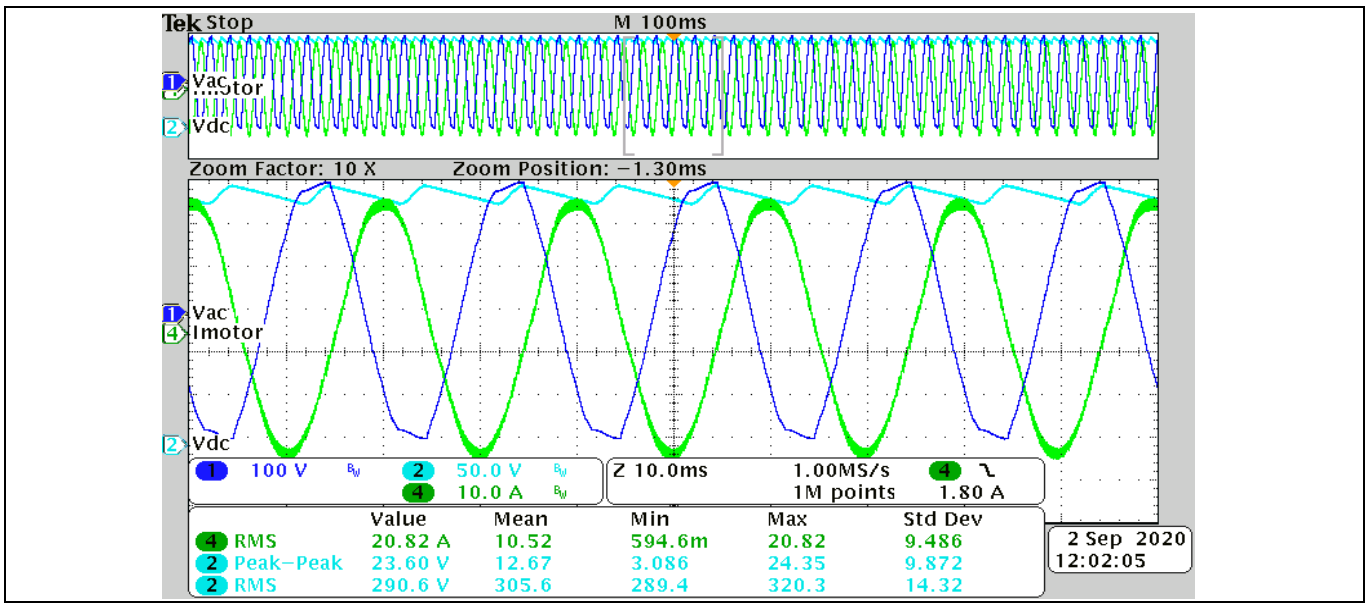


Figure 48 V_{dc} ripple test at 3 kW input power

5 References and appendices

5.1 Abbreviations and definitions

Table 10 Abbreviations

Abbreviation	Meaning
CE	Conformité Européenne
EMI	Electromagnetic interference
UL	Underwriters Laboratories
OPA	Operational amplifier
LPF	Low-pass filter

5.2 References

[1] Datasheet of Infineon IM06B50GC1

[2] Datasheet of Infineon IMC101T

[3] iMOTION™ Solution Designer

[4] Getting Started with iMOTION™ Solution Designer

[5] Basic Motor Parameters and the Configuration

[6] Functional Reference Manual iMOTION™ Motion Control Engine

5.3 Ordering details and other 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:

Base Part Number	Package	Standard Pack		Orderable Part Number
		Form	Quantity	
EVAL-M1-IM06B50	EVAL	Boxed	1	EVALM1IM06B50TOBO1
ICE5AR4770BZS DIP-7	PG-DIP-7	TUBE	2000	ICE5AR4770BZSXKLA1
IM06B50GC1	DIP 36x21D	TUBE	280	IM06B50U6DXKMA1

Revision history

Document version	Date of release	Description of changes
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