EVAL-M1-IM06B50 user guide

Modular application design kit (MADK) of IM06B50GC1

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 Infineon's motor control evaluation platform kits. In combination with the control board equipped with the M1-20-pin interface connector such as KIT_PSC3M5_CC2, it features and demonstrates Infineon's CIPOS™ Mini IPM technology and advance motor control applications with the PSOC™ Arm® Cortex®-M33 based microcontroller 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 middle & high-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

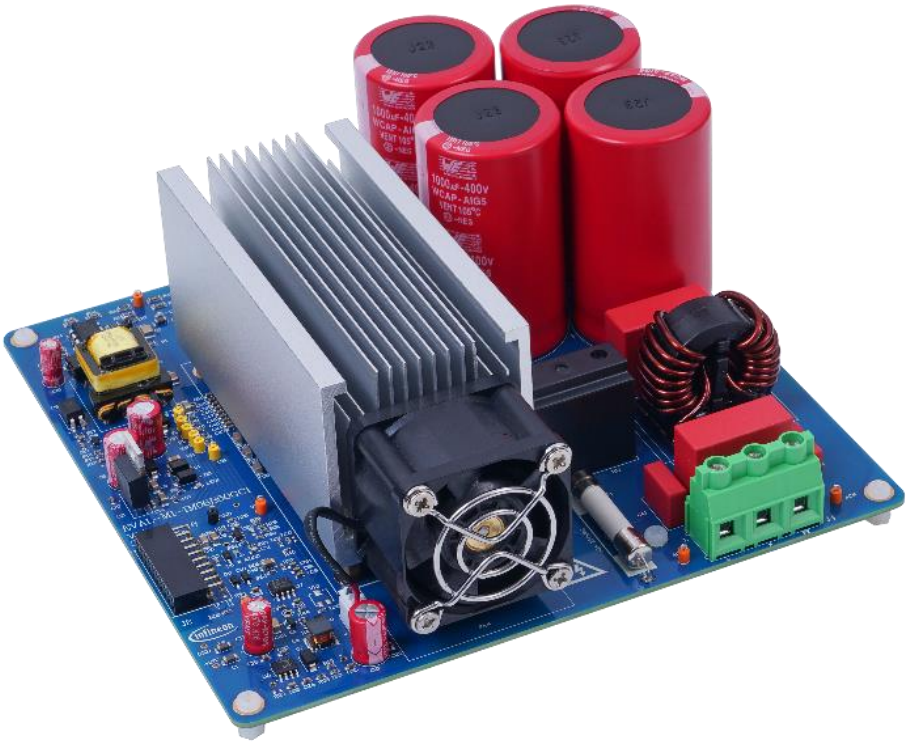
This user guide is intended for all technical specialists who know motor control, middle-power and high-power electronics converters. The board is intended to be used under laboratory conditions.

Evaluation board

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

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 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.*

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1 The board at a glance

The EVAL-M1-IM06B50 evaluation power board is a part of Infineon's motor control evaluation platform kits. 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 MADK M1 connector such as KIT_PSC3M5_CC2.

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 contents

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 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.

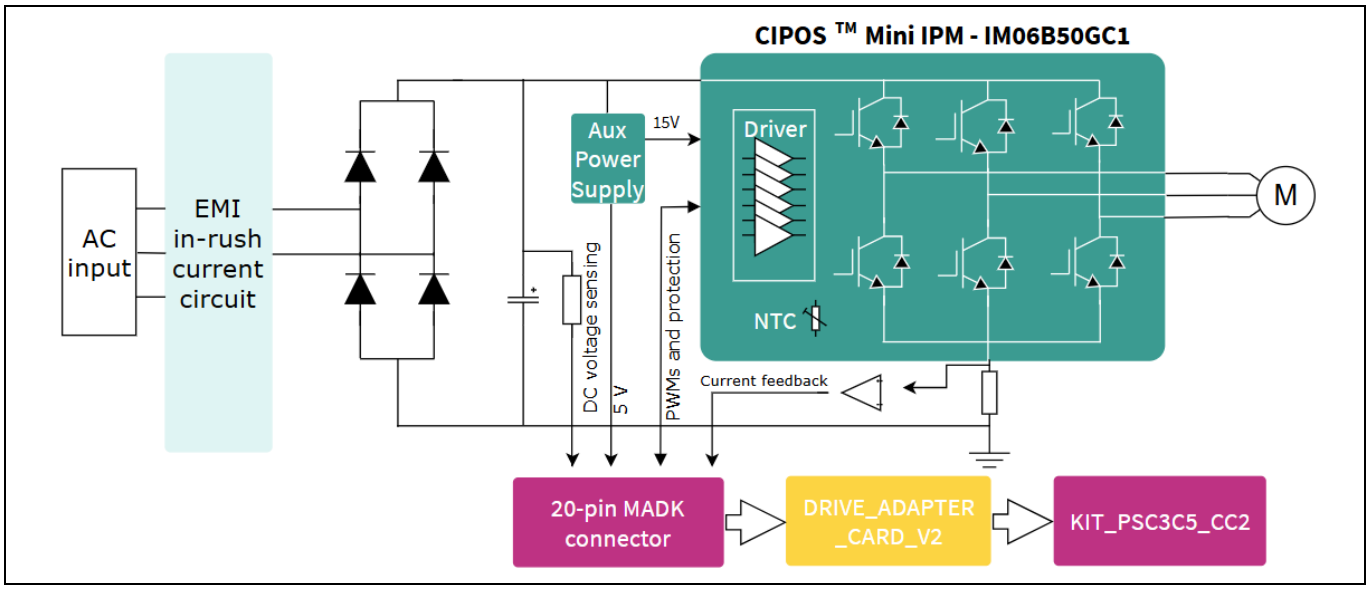
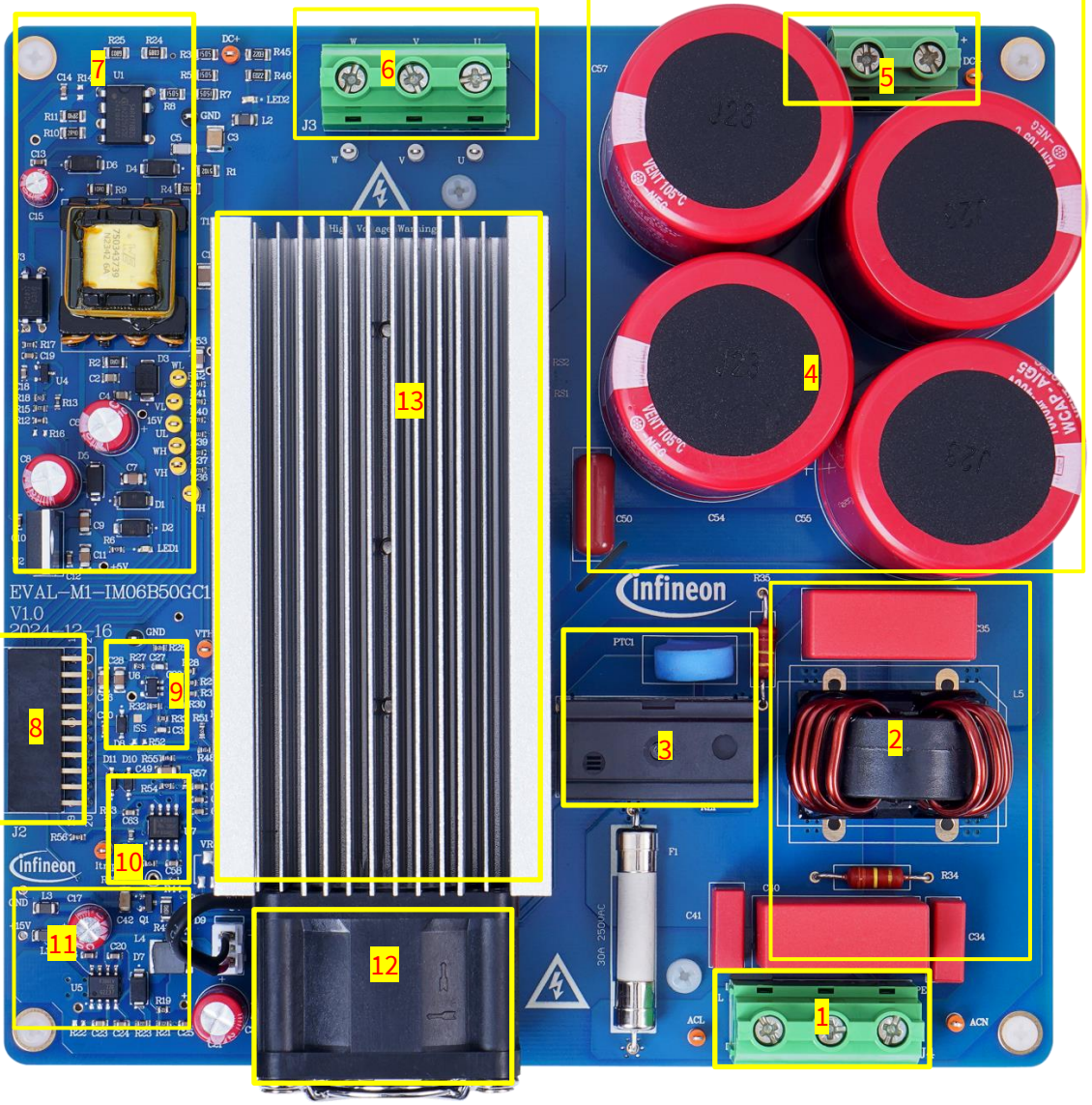


Figure 1 Block diagram of the board

Figure 2 points out the functional groups on the Top side of the EVAL-M1-IM06B50 design.



1. 220 V_{AC} & PE input connectors
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. MADK M1 connector (20-pin)
9. Current sensing OPA (SGM721XN5)
10. OCP & OTP comparator (LM393)
11. DCDC for cooling fan
12. BLDC cooling fan
13. Heat sink
    (IM06B50GC1 + input rectifier + shunt resistor)

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

1.3 Main features of the evaluation board

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	I_{trip}	Comparator source for OC trigger level, related to PSOC™ Controller internal comparator setup	Configured in Modus Toolbox™ Motor Suite GUI	A_{peak}
Motor current protection trigger level 2	I_{trip}	Gatekill-pin input source overcurrent protection, related to hardware setup	59	A_{peak}

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Parameter	Symbol	Conditions / comments	Value	Unit
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 MADK power board (EVAL-M1-IM06B50) and the matching PSOC™ Control C3 Motor Control Drive Kit (KIT_PSC3M5_CC2 or other control board) are required. This chapter provides more details on setting up the system and getting start with the PSOC™ Control C3M5 motor control card development platform.

Modification on DRIVE_ADAPTER_CARD_V2 board:

- Disconnect jumpers J13 and J17, connect jumpers J14 and J18 on the DRIVE_ADAPTER_CARD_V2 board for 1 shunt current measurement on AN_A3 pin of MCU.
- Disconnect J21 for NTC temperature measurement.
- Connect jumper J11 for VDC measurement.
- Connect jumper J10 on DRIVE_ADAPTER_CARD_V2 between PWR_5V_IN and U1.3V3.
- Keep J12, J15, J16, J19, J20, J22, J23 unconnected.
- Remove R422 and solder 0-ohm resistor on R421.
- Remove D1 to disconnect 15V from EVAL-M1-IM06B50.

Note: No current input offset is required due to an external amplifier with offset of 0.454 V already existed.

Modification on KIT_PSC3M5_CC2 board:

- Ensure that all the microswitches of SW3 on are on the right side (off state) for proper operation.
- Remove R39, R29, and R37 to adapt temperature sensing of NTC resistor in IM06B50GC1.

Modification on EVAL-M1-IM06B50 board:

- Change R55 from 16Kohm to 13.3 Kohm to adapt 0~3.3 V analog input of PSC3M5.
- Change R57 from 10Kohm to 2 Kohm to adapt 90 ℃ protection with new pull-up R55.
- Remove R56 and D10.

This guide is designed to familiarize you with this evaluation kit.

2.1.1 Hardware Connection

Figure 3 points out the system connection of the control board, adapter board and power board (MADK).

Note: Please do not power on 220V rms before configured software was downloaded because the default parameters in KIT_PSC3M5_CC2 will damage EVAL-M1-IM06B50.

Note: Please do not connect other power boards to terminal connector (J1) and (J2) on DRIVE_ADAPTER_CARD_V2 while power board EVAL-M1-IM06B50 is used.

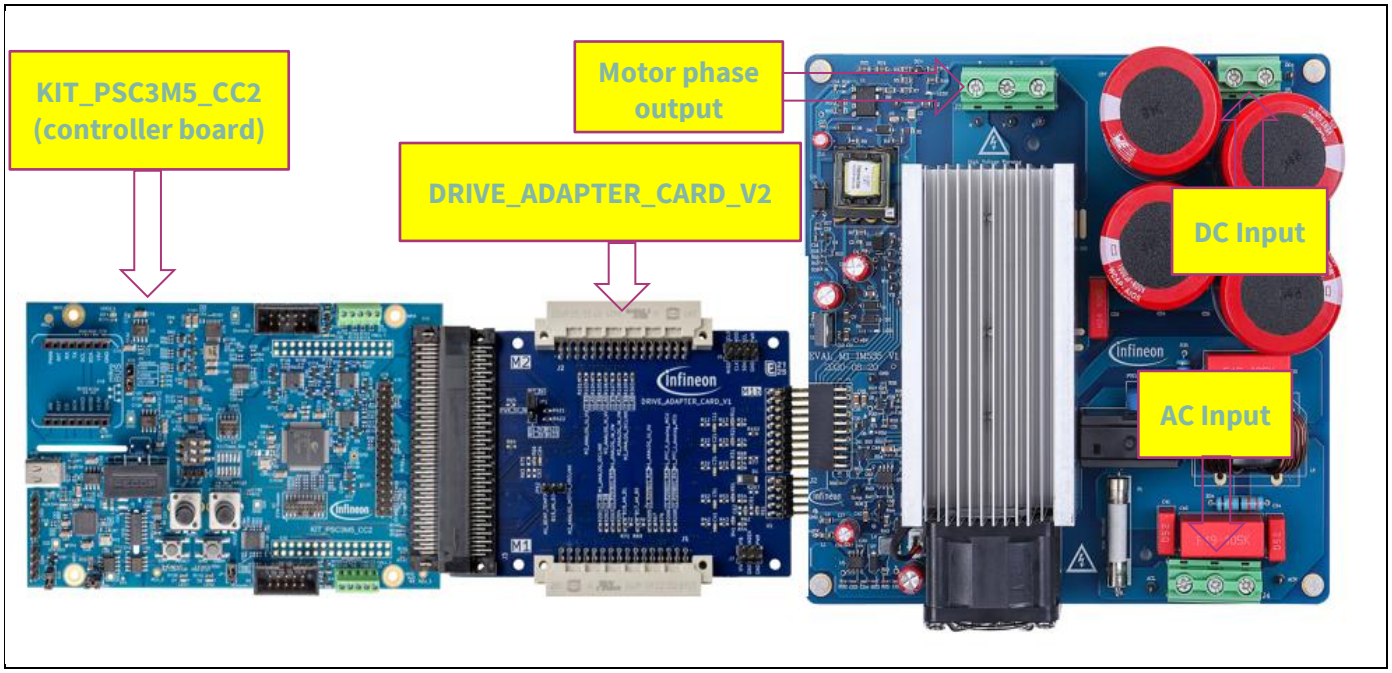


Figure 3 System connection example

2.1.2 Software Packages Installation

Please refer to ModusToolbox™ software installation guide to install all software packages necessary.

Access Infineon website to download ModusToolbox™ Setup program installer. If you do not have access, work with your IT department to download onto your machine or have the software placed on a local server or a thumb drive. Refer also to the "Installing with firewall or lack of web access" section in the Advanced ModusToolbox™ installation instructions.

Install all required software packages below:

- Eclipse IDE for ModusToolbox™
- Arm GUN Tool Chain (GCC)
- ModusToolbox™ Tools package
- ModusToolbox™ Programming tools
- ModusToolbox™ Motor Suite

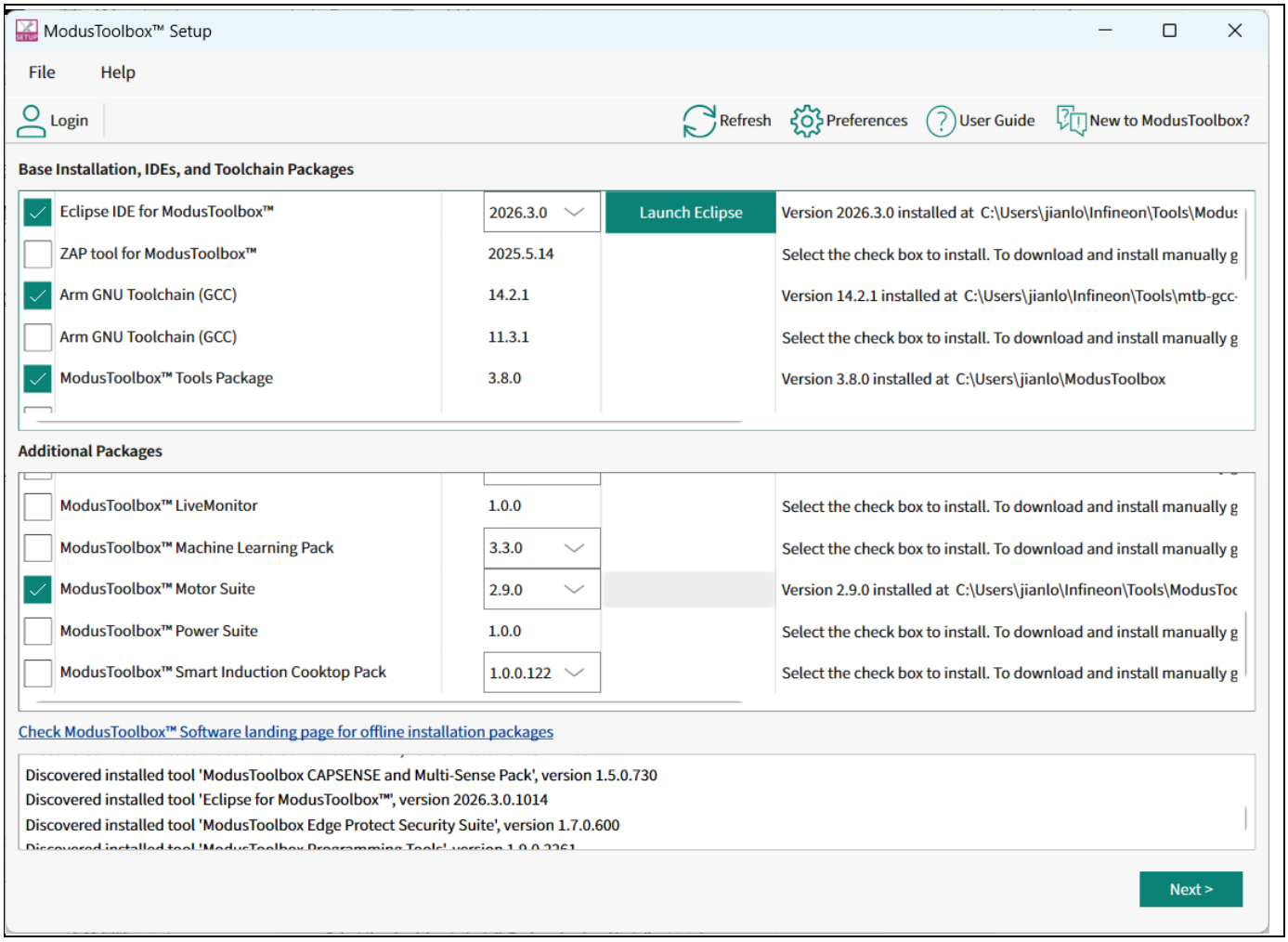


Figure 4 Install all software packages necessary

2.2 Motor tuning with EVAL-M1-IM06B50

2.2.1 Configure parameters in ModusToolbox™ Motor Suite

1. Connect input voltage selection jumper (X20) on KIT_PSC3M5_CC2 between VDD5 and 5V USB.
2. Connect USB cable to the PC and the control card KIT_PSC3M5_CC2 USB socket. Then the KIT_PSC3M5_CC2 will be powered by USB.
3. Open the ModusToolbox™ Motor Suite GUI.
4. Go to PSOC™ Control C3 Motor Drive Kit board KIT_PSC3M5_MC1, select **RFO** and latest motor-ctrl-lib version, click **New Project** to open the configurator view.

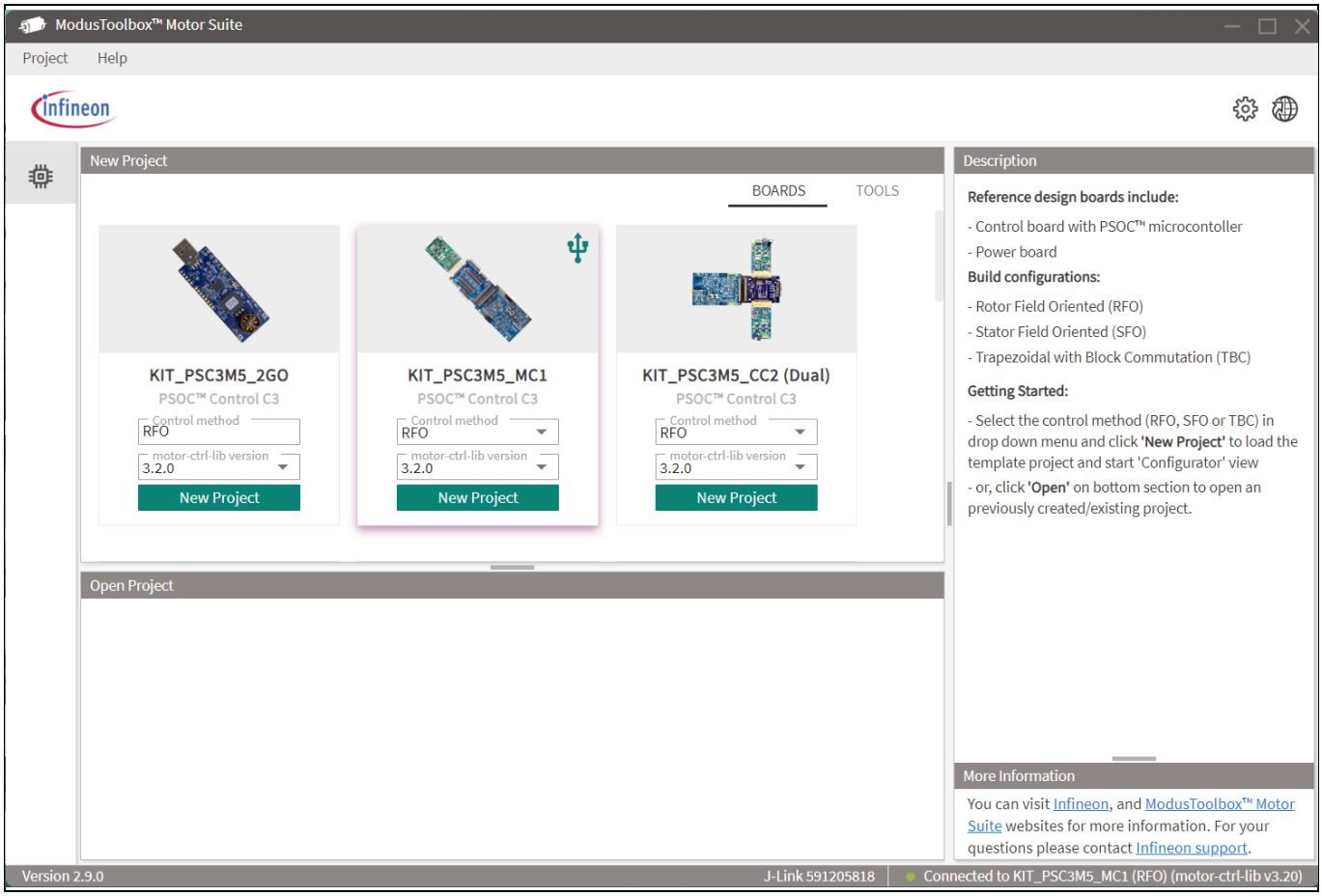


Figure 5 Modus Toolbox™ Motor Suite

5. Save this project in dedicated folder.
6. Enable “Display advanced parameters” in configuration window.

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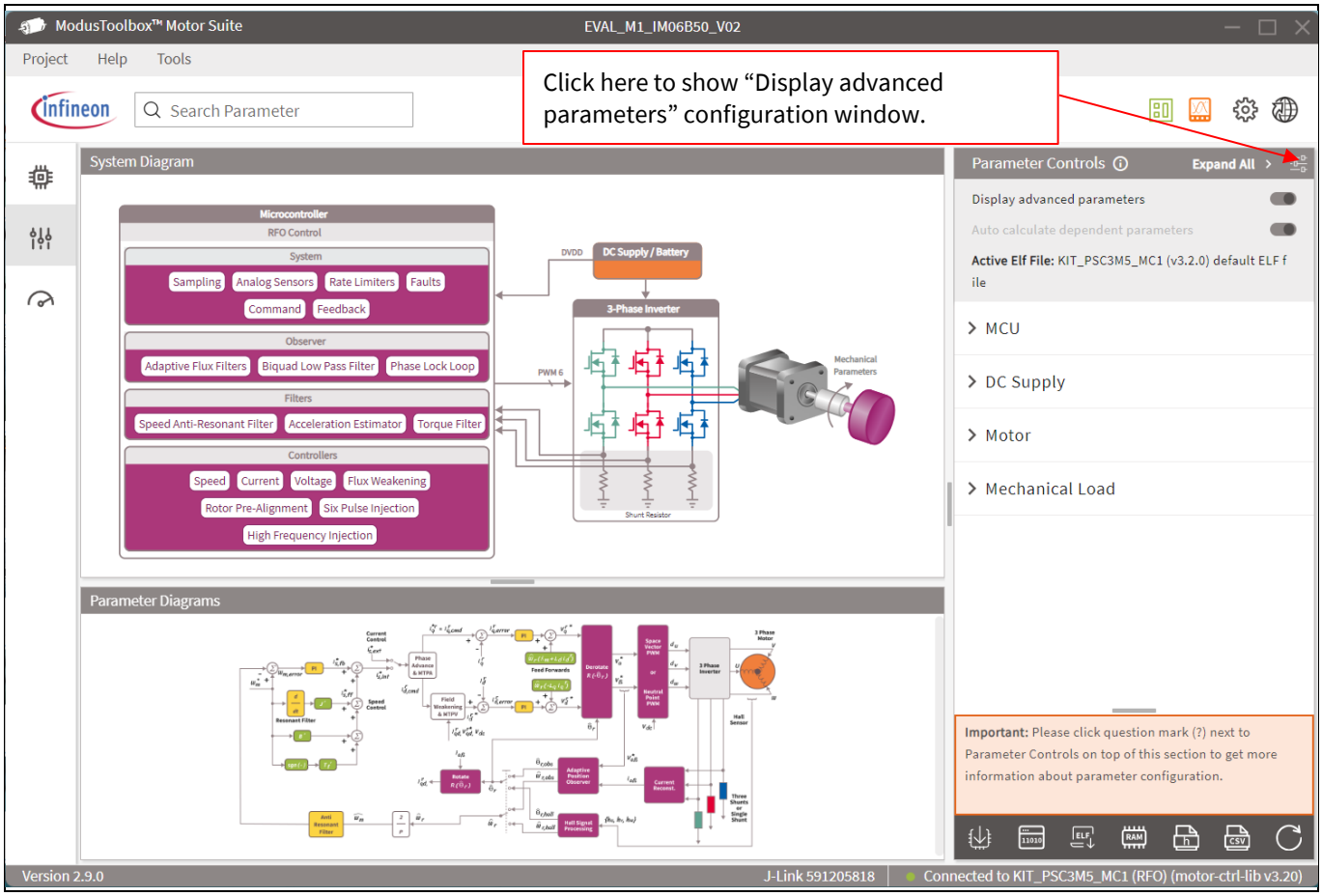


Figure 6 Enable “Display advanced parameters”

7. Configure hardware related parameters according to Table 3. All these parameters are related to EVAL-M1-IM06B50GC1, so they must be configured correctly. Regarding IPM NTC related parameters should be configured in code later.

Table 3 Hardware related parameters

Specification	Value	Path
PWM dead time	2.0 us	MCU→System→Sampling
Current Sensor Type	Shunt_Res	MCU→System→Analog Sensors→Shunts
Current Ploarity	LS_Current_Sense	MCU→System→Analog Sensors→Shunts
Type	Single_Shunt	MCU→System→Analog Sensors→Shunts
Single shunt measurement type	Phase_Shift	MCU→System→Analog Sensors→Shunts
Shunt resistance	0.0025 ohm	MCU→System→Analog Sensors→Shunts
Current Opamp Gain	30	MCU→System→Analog Sensors→Shunts
Min ADC conversion time	3.0 us	MCU→System→Analog Sensors→Shunts
Switch delay	2.0 us	MCU→System→Analog Sensors→Phase shift Modulation

VDC Scale	(15.0f)/(680.0f+680.0f+15.0f)	MCU→System→Analog Sensors→Voltage
VUVW Scale[1]	(15.0f)/(680.0f+680.0f+15.0f)	MCU→System→Analog Sensors→Voltage
Nomina dc voltage	310.0 V	DC Supply

1. *The VUVW sampling is not available for IM06B50GC1, but please configure its scale same as VDC scale here.*

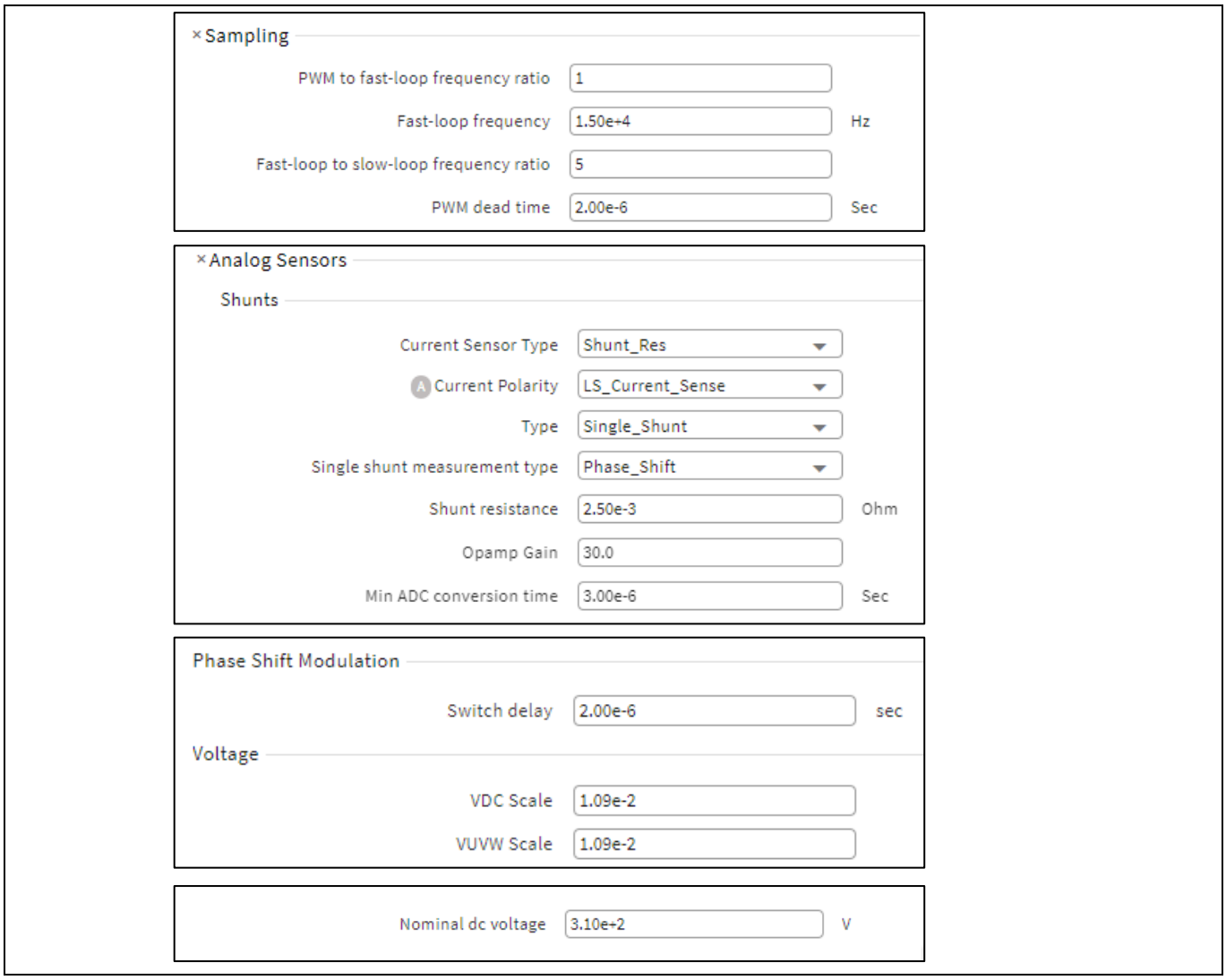


Figure 7 Hardware related parameters configuration

8. Motor parameters configuration. Please configure all motor parameters as shown in Figure 8. These parameters should match actual parameters of the motor used.

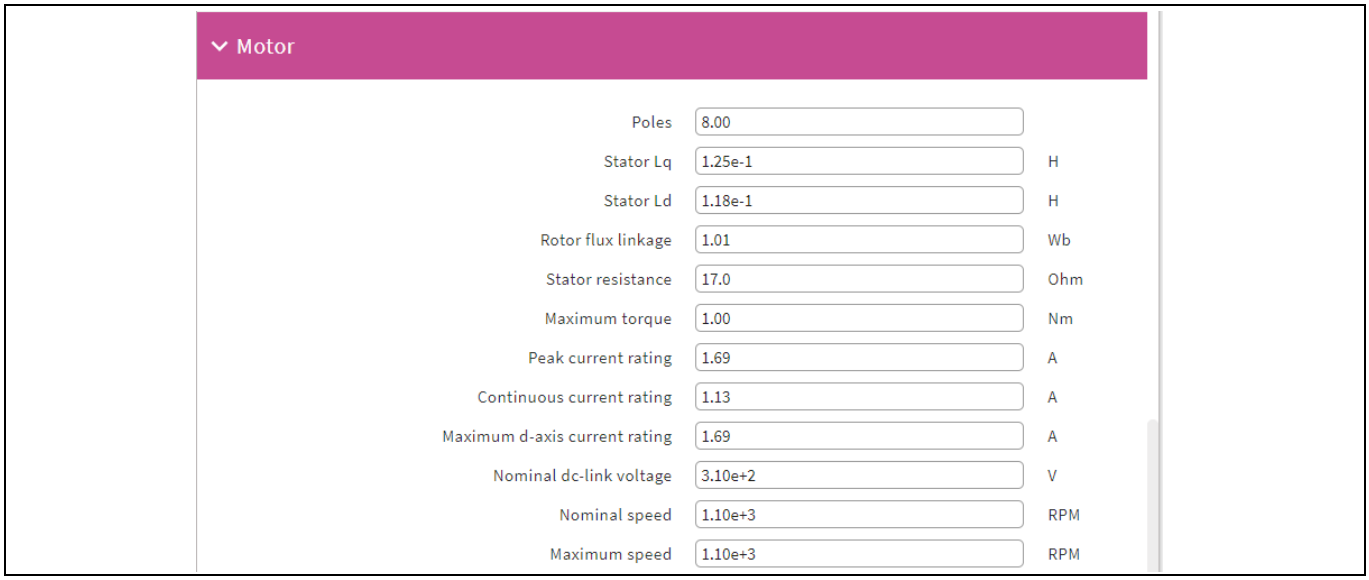


Figure 8 Motor parameters configuration

9. Other control parameters configuration.

Pleas select “Bootstrap charging mode” according to application request, there are “Boot_Only” and “Boot_and_Brake” options.

Please set “PWM to fast-loop frequency ratio”, “Fast-loop frequency” and “Fast-loop to slow frequency ratio” to set PWM frequency, fast-loop frequency and slow-loop frequency.

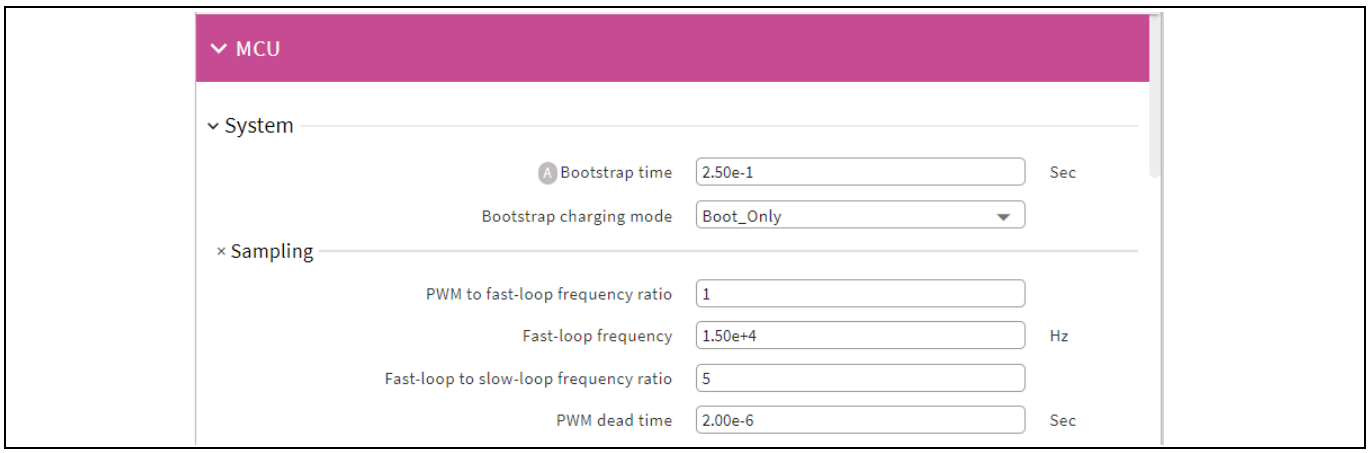


Figure 9 Control parameters 1

Please configure speed command rate, current command rate, speed command rate (open loop) and position command rate here if they are used by selected motor control mode.

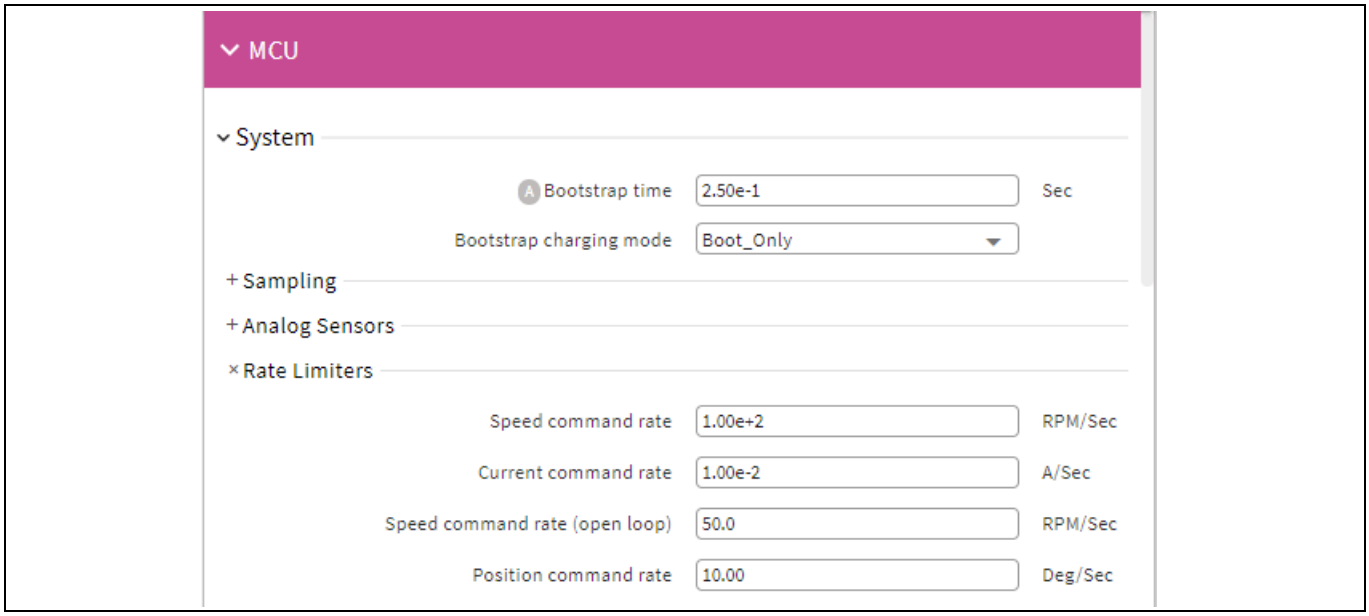


Figure 10 Control parameters 2

Please configure necessary faults and its threshold in the “Faults” page. If special fault definition is needed, it could be implemented in code later.

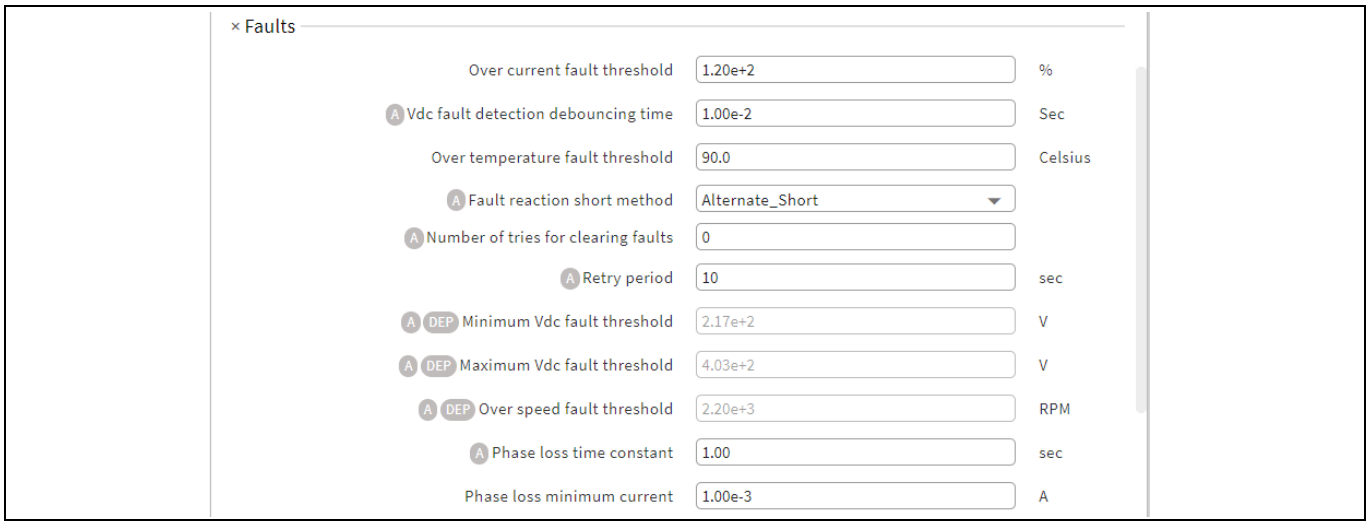


Figure 11 Control parameters 3

Please configure command source to “External”, then ModusToolbox™ Motor Suite GUI is used as command source. The max limitation of command also should be set here.

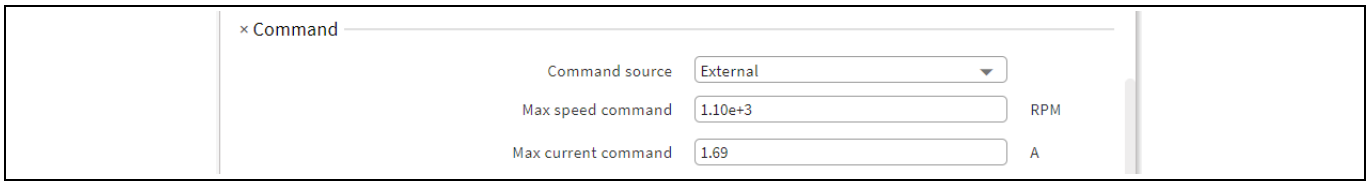


Figure 12 Control parameters 4

Feedback is to configure Hall or Encoder parameters, they should be configured if Hall or Encoder is used, otherwise, not needed.

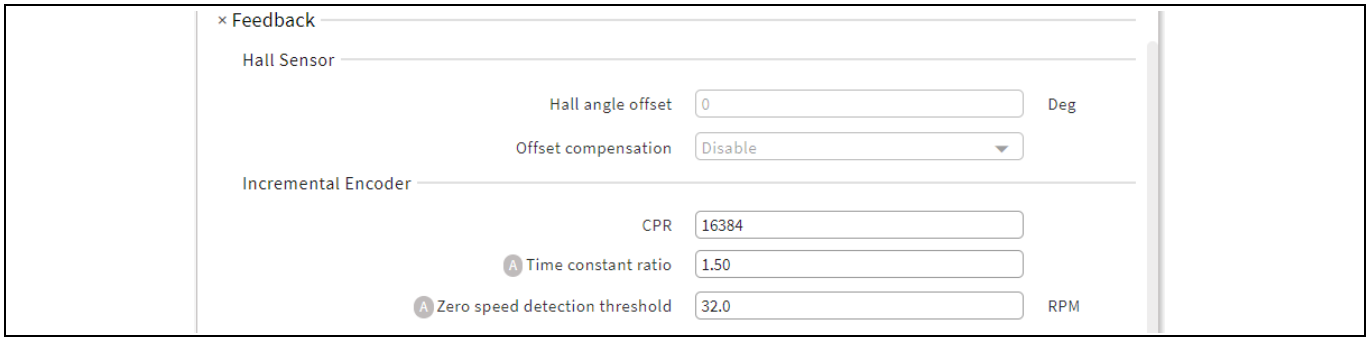


Figure 13 Control parameters 5

Please configure catch spin parameters here if it is needed for application.

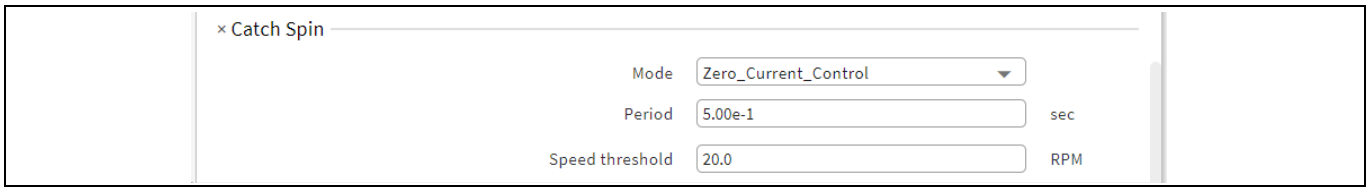


Figure 14 Control parameters 6

Please configure observer parameters according to motor characteristics.

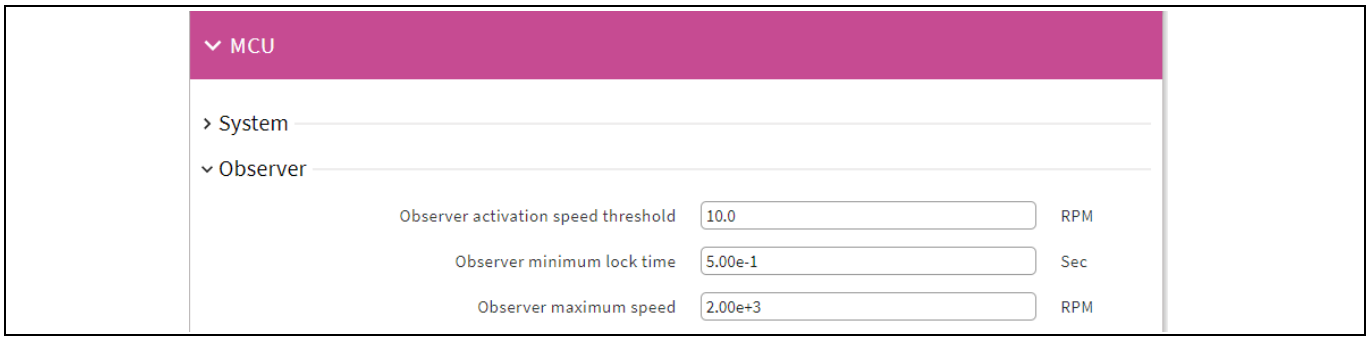


Figure 15 Control parameters 7

Please configure filter parameters according to motor characteristics.

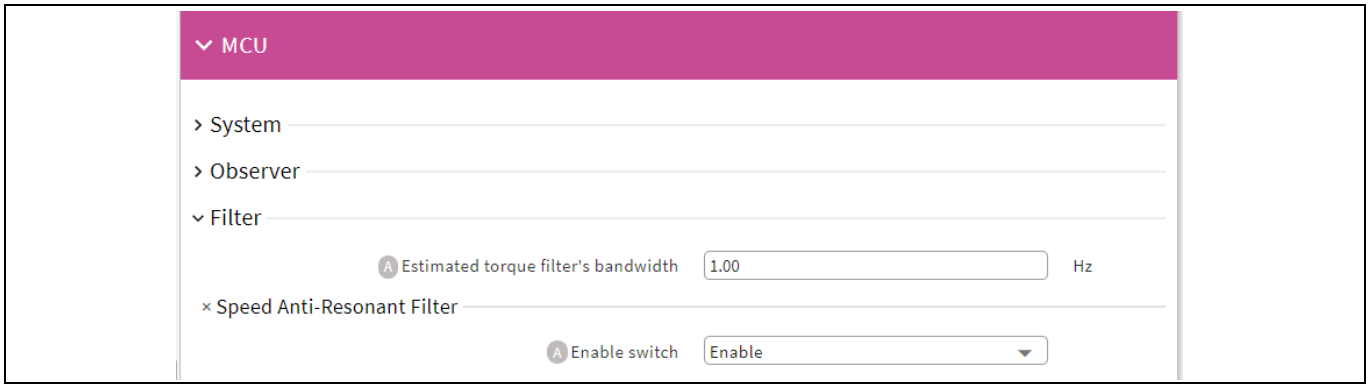


Figure 16 Control parameters 8

Please configure motor control mode and its corresponding parameter here. For example, speed controller, current controller and rotor pre-alignment parameters are needed when Speed_Mode_FOC_Sensorless_Align_Startup is selected.

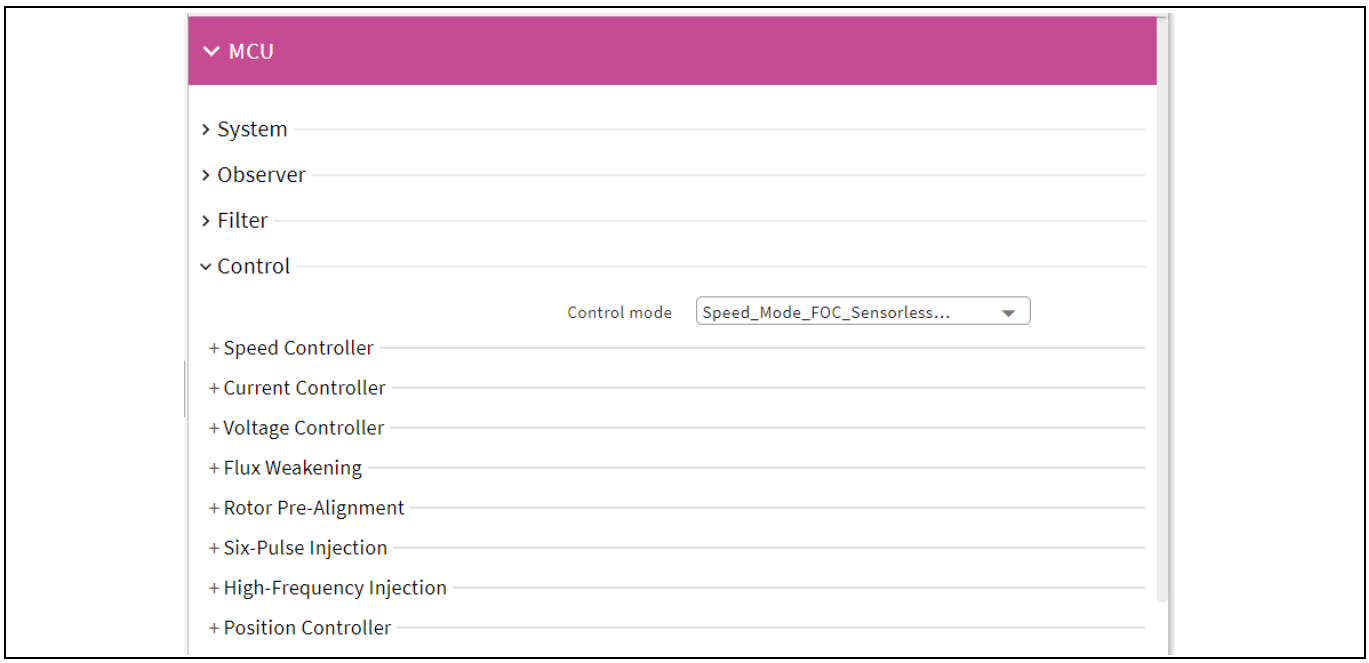


Figure 17 Control parameters 9

Please configure mechanical load parameters according to actual application here.

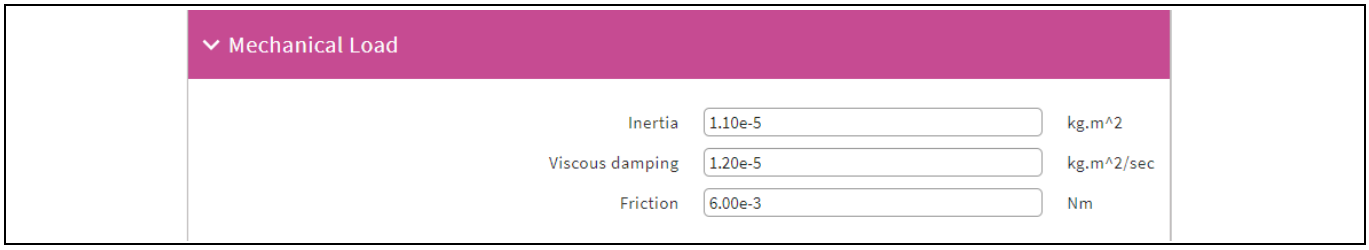


Figure 18 Control parameters 10

10. After parameters configuration, please save this project again and export parameters to “ParamConfig.h”.

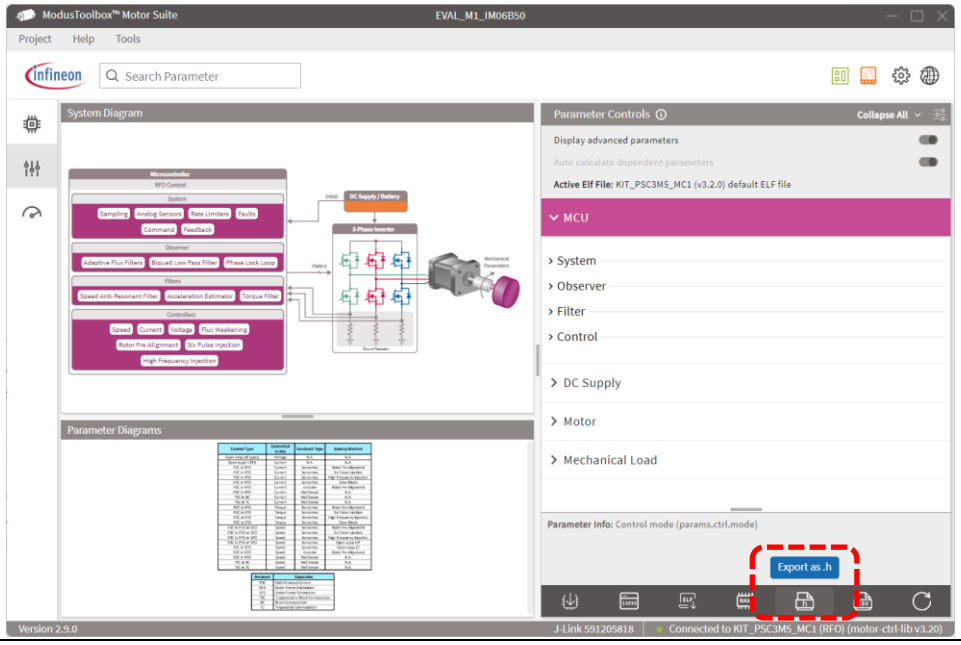


Figure 19 Export parameters to “ParamConfig.h”

2.2.2 Build code project in Eclipse for ModusToolbox™

In Eclipse for ModusToolbox™ a new code project needs to build, all code will be included in this project, therefore more flexible application can be implemented here.

1. Open Eclipse for ModusToolbox™ and click “New Application”.

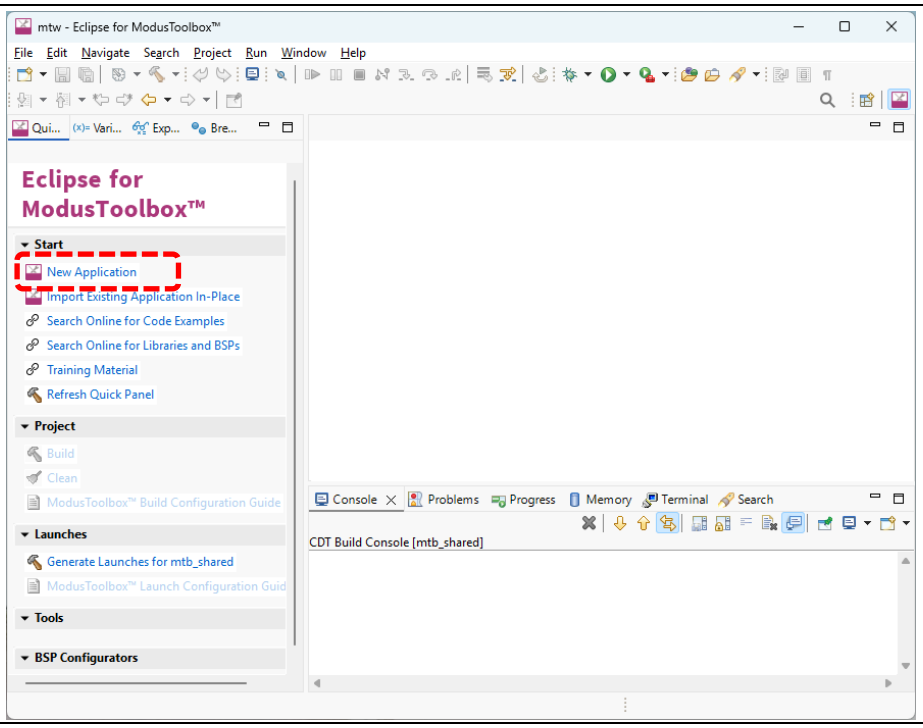


Figure 20 Click “New Application”

2. In the next page, select KIT_PSC3M5_CC2.

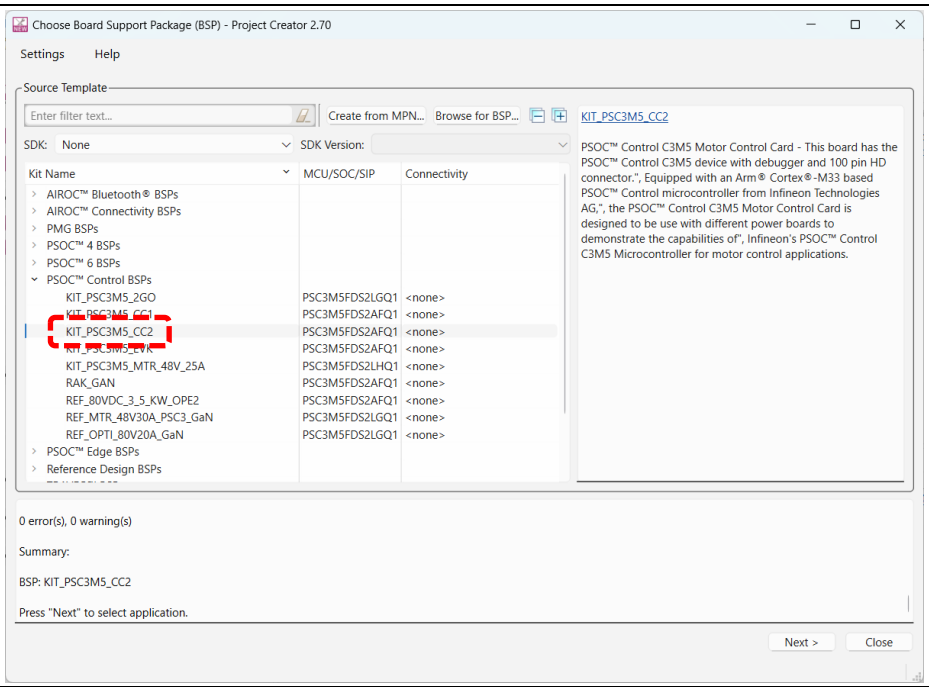


Figure 21 Select “KIT_PSC3M5_CC2”

3. In the next page, select Motor control -> MOTOR DEMO and click “Create”

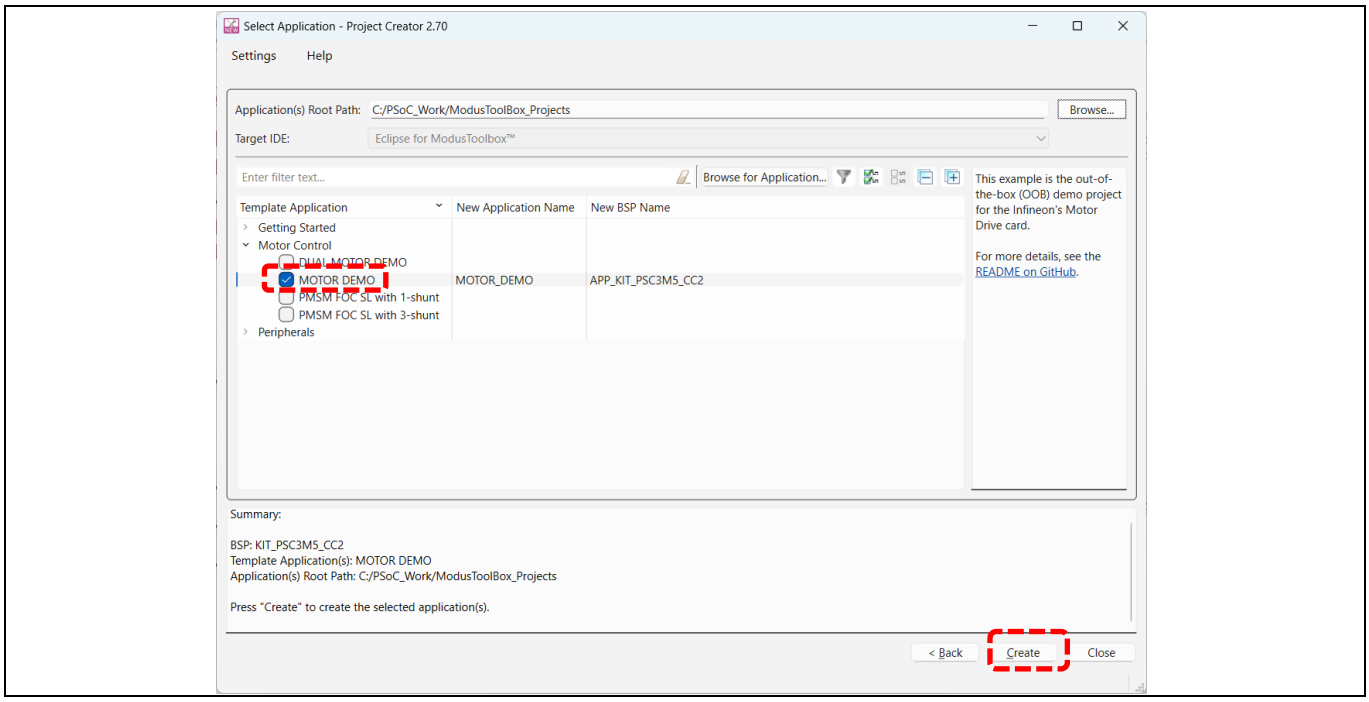


Figure 22 Create project

4. Find parameter file “ParamConfig.h” in the project storage folder “MOTOR_DEMO\bsps\TARGET_APP_KIT_PSC3M5_CC2\configuration\motor-ctrl-lib-config”, use the previous exported “ParamConfig.h” from Modus Toolbox™ Motor Suite to replace it.

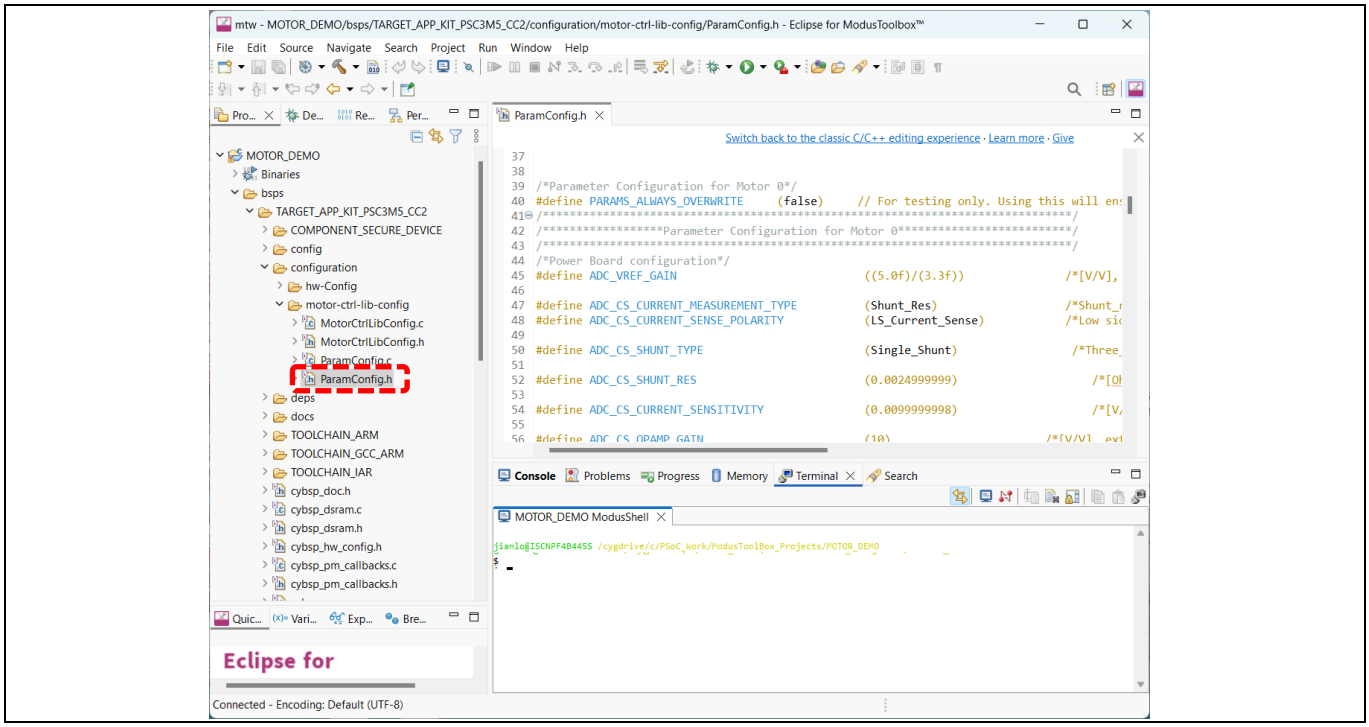


Figure 23 Replace “ParamConfig.h”

5. Configure current sensing internal gain ADC_INTERNAL_GAIN to 3.

Table of contents

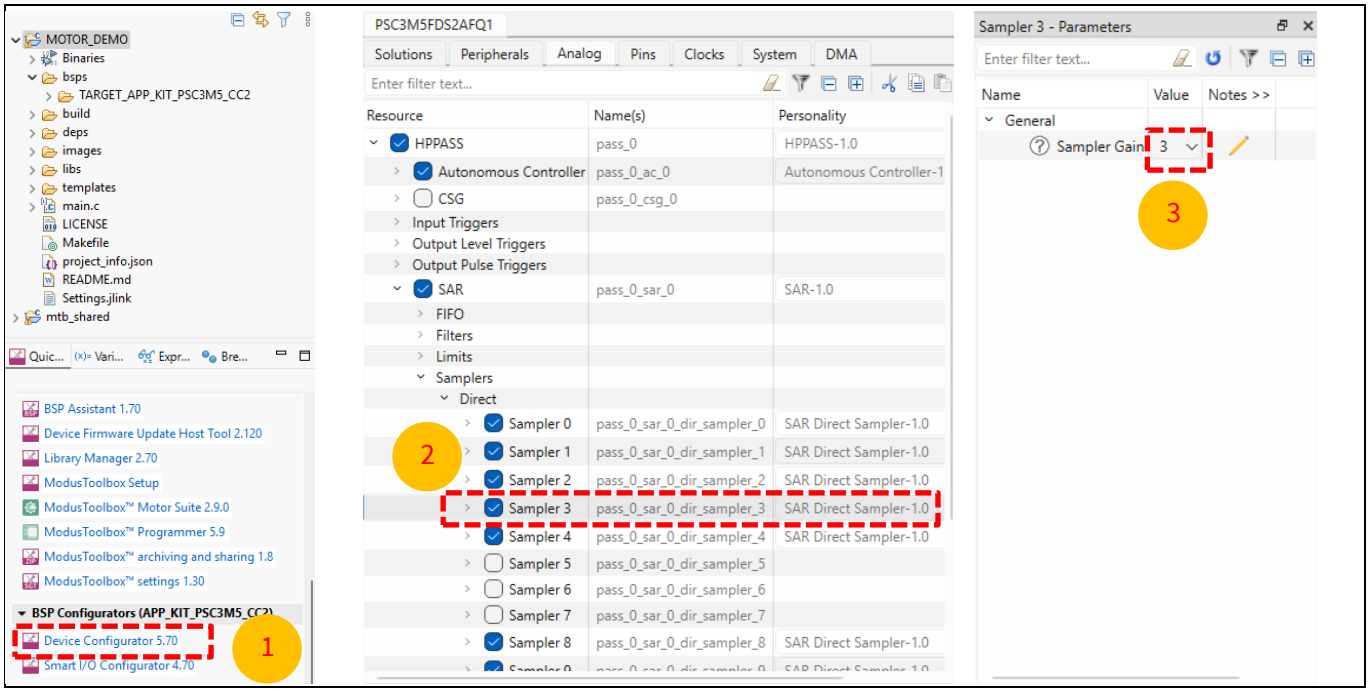


Figure 24 Configure current sensing internal gain to 3x

6. Open file “MotorCtrlHWConfig.c” in the project storage folder “MOTOR_DEMO\bsps\TARGET_APP_KIT_PSC3M5_CC2\configuration\hw-Config”, modify temperature curve coefficients according to thermistor resistance of NTC in IM06B50GC1.

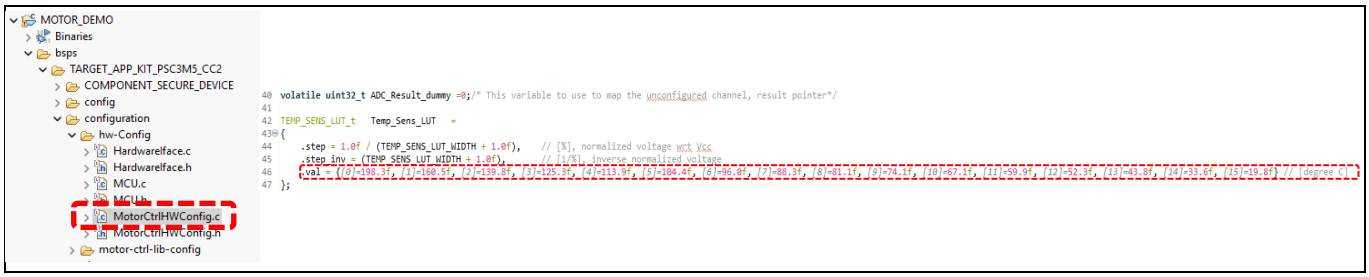


Figure 25 Modify temperature curve coefficients

The temperature sense lookup table size is 16. The mapping of voltage to temperature is defined in this table, where each step corresponds to “Vadcref(3.3 V)/17”. The temperature mapping for EVAL-M1-IM06B50 is mentioned in Figure 26.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
STEP	0.0588	0.1176	0.1765	0.2353	0.2941	0.3529	0.4118	0.4706	0.5294	0.5882	0.6471	0.7059	0.7647	0.8235	0.8824	0.9412
Voltage (V)	0.1941	0.3882	0.5824	0.7765	0.9706	1.1647	1.3588	1.5529	1.7471	1.9412	2.1353	2.3294	2.5235	2.7176	2.9118	3.1059
Temperature (°C)	198.3	160.5	139.8	125.3	113.9	104.4	96.0	88.3	81.1	74.1	67.1	59.9	52.3	43.8	33.6	19.8

Figure 26 Temperature mapping for EVAL-M1-IM06B50

7. After all codes are changed, select “MOTOR_DEMO” and click “Build Project” to build it.

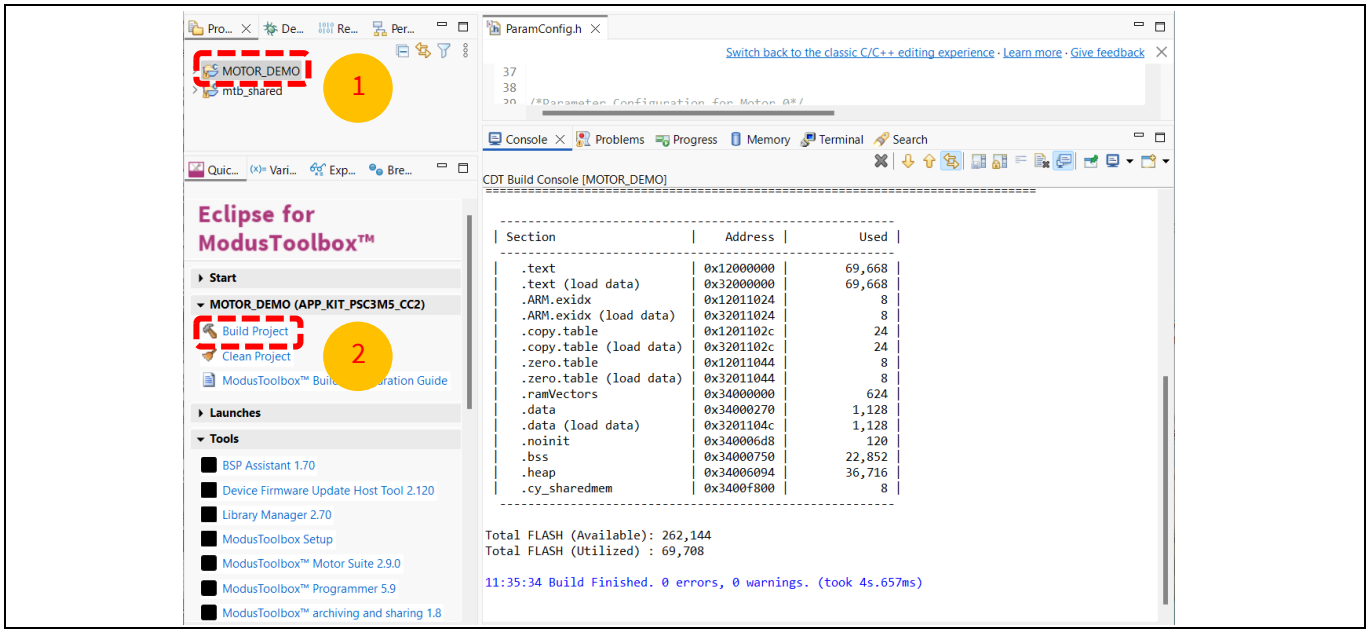


Figure 27 Build project

2.2.3 Tuning motor in ModusToolbox™ Motor Suite

1. Connect input voltage selection jumper (X20) on KIT_PSC3M5_CC2 between VDD5 and 5V USB.
2. Connect USB cable to the PC and the control card KIT_PSC3M5_CC2 USB socket. Then the KIT_PSC3M5_CC2 will be powered by USB. Please do not power on EVAL-M1-IM06B50 with 220V rms.
3. Select project “MOTOR_DEMO” in Eclipse for ModusToolbox™, then open ModusToolbox™ Motor Suite from Eclipse for ModusToolbox™.

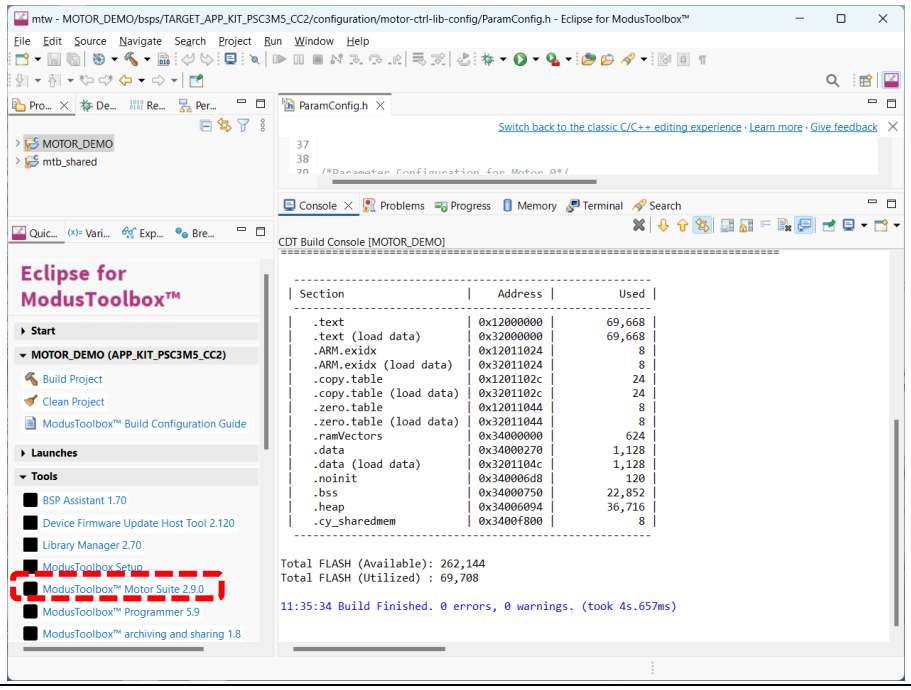


Figure 28 Open ModusToolbox™ Motor Suite from Eclipse for ModusToolbox™

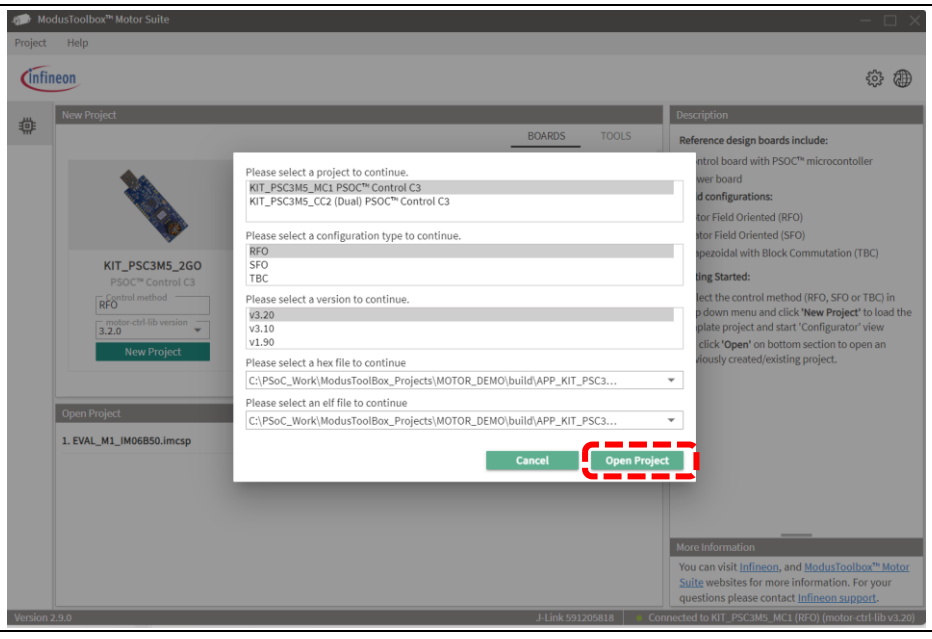


Figure 29 Configuration in ModusToolbox™ Motor Suite

4. In the pop-up window of ModusToolbox™ Motor Suite please complete below options, then click “Open Project” as shown in Figure 29.

   - Select project “KIT_PSC3M5_MC1 PSOC™ Control C3” to continue.
   - Select “RFO” for a configuration type to continue.
   - Select latest lib version to continue.
   - Select hex file “MOTOR_DEMO\build\APP_KIT_PSC3M5_CC2\Release\mtb-example-ce240614-motor-control-solutions.hex”

Select elf file “MOTOR_DEMO\build\APP_KIT_PSC3M5_CC2\Release\ mtb-example-ce240614-motor-control-solutions.elf”

5. Download firmware and elf file to device, then from device by clicking “Read Device”. After that, please store this ModusToolbox™ Motor Suite project for tuning, this project has been corelated to the project build in Eclipse for ModusToolbox™.

   - Please tune parameters in this ModusToolbox™ Motor Suite project.
   - After all parameters are tuned well and fixed, then export them to Eclipse for ModusToolbox™ project.

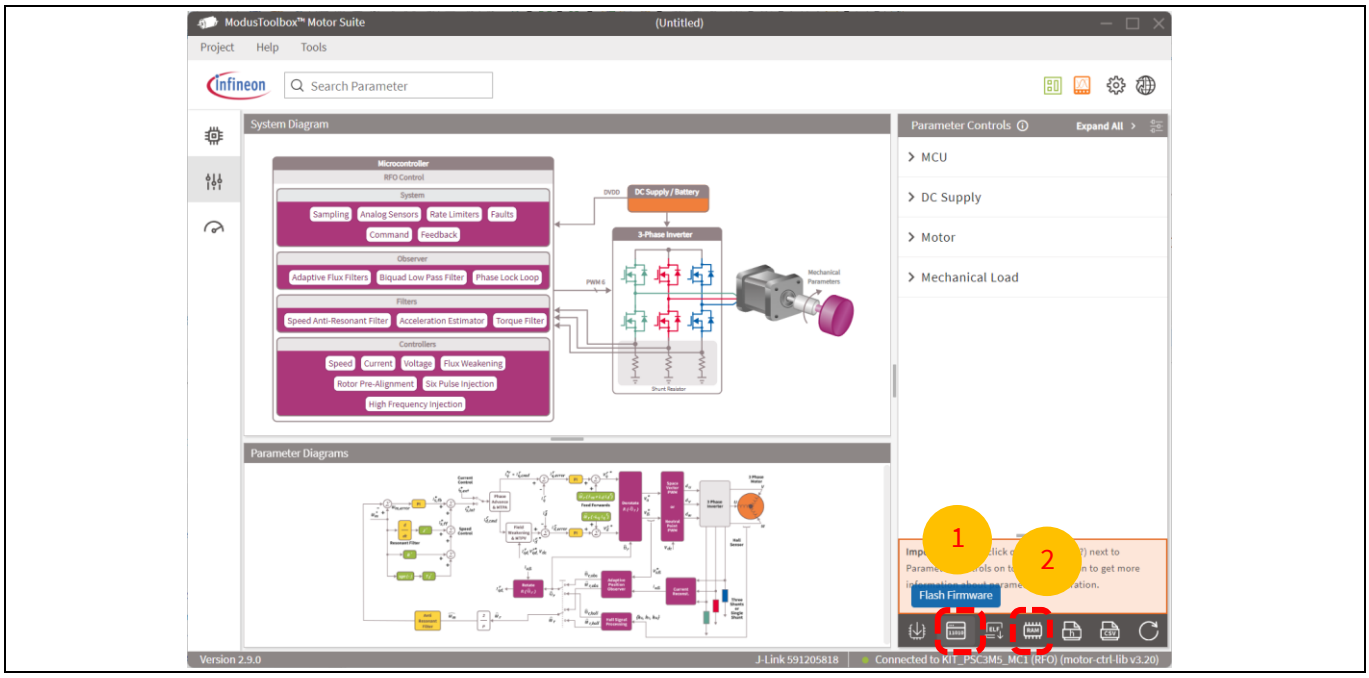


Figure 30 Download firmware to device

6. Move voltage selection jumper (X20) on KIT_PSC3M5_CC2 to VDD5 and V5V, to use EVAL-M1-IM06B50 to power it.
7. Connect motor to EVAL-M1-IM06B50.
8. Power on EVAL-M1-IM06B50 with 220 Vrms.
9. Click “Test Bench” to open tuning interface.

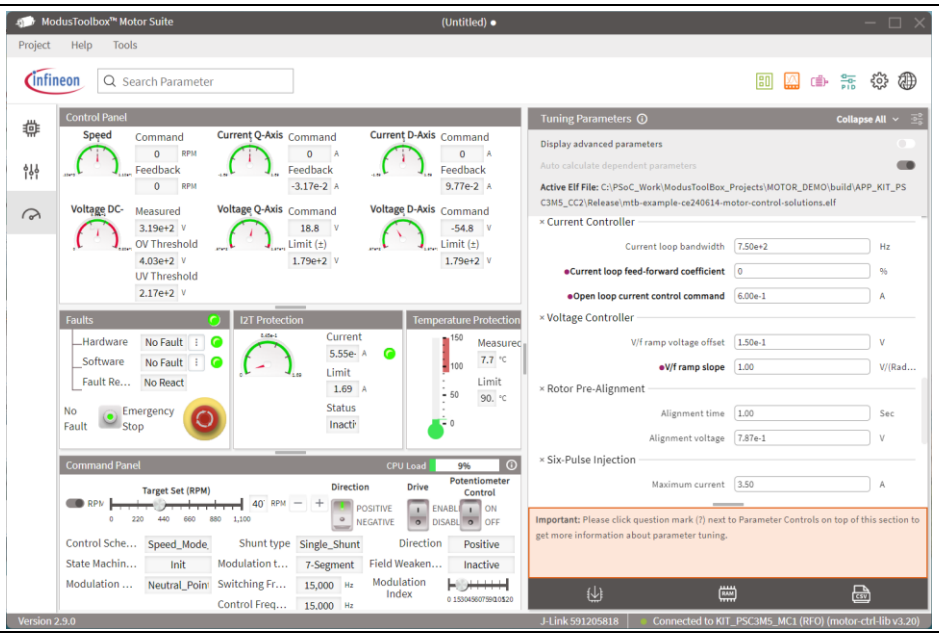


Figure 31 Tuning interface

10. Check motor current sensing performance.

- Change control mode to “**Volt_Mode_Open_Loop**”.
- Download it to Flash.
- Configure Target Set to 4% ~ 10% make appropriate current flowing through motor.
- Enable drive.
- Click “Lauch Oscilloscope” to view motor current sensed.

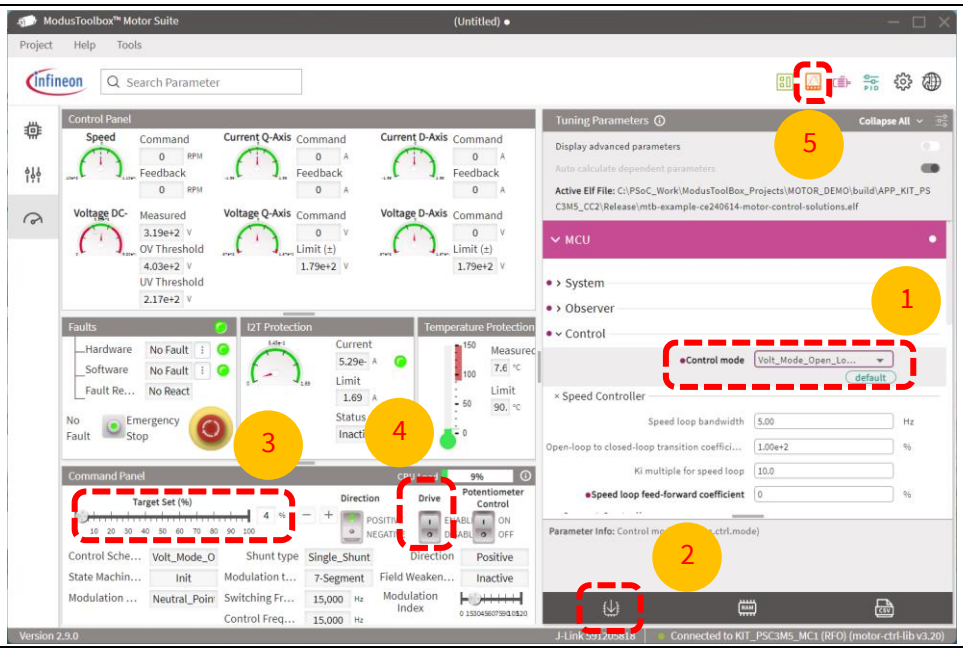


Figure 32 Check current sensing performance

If the sensed current is not good, please change “Switch delay” or “Min ADC conversion time” in Configurator page and download them to Flash, continue to tune until sensed current is good.



Figure 33 Sensed current view

11. When current sensing is good, then control mode can be switched back to **Speed_Mode_FOC_Sensorless_Align_Startup** to tune close loop performance.

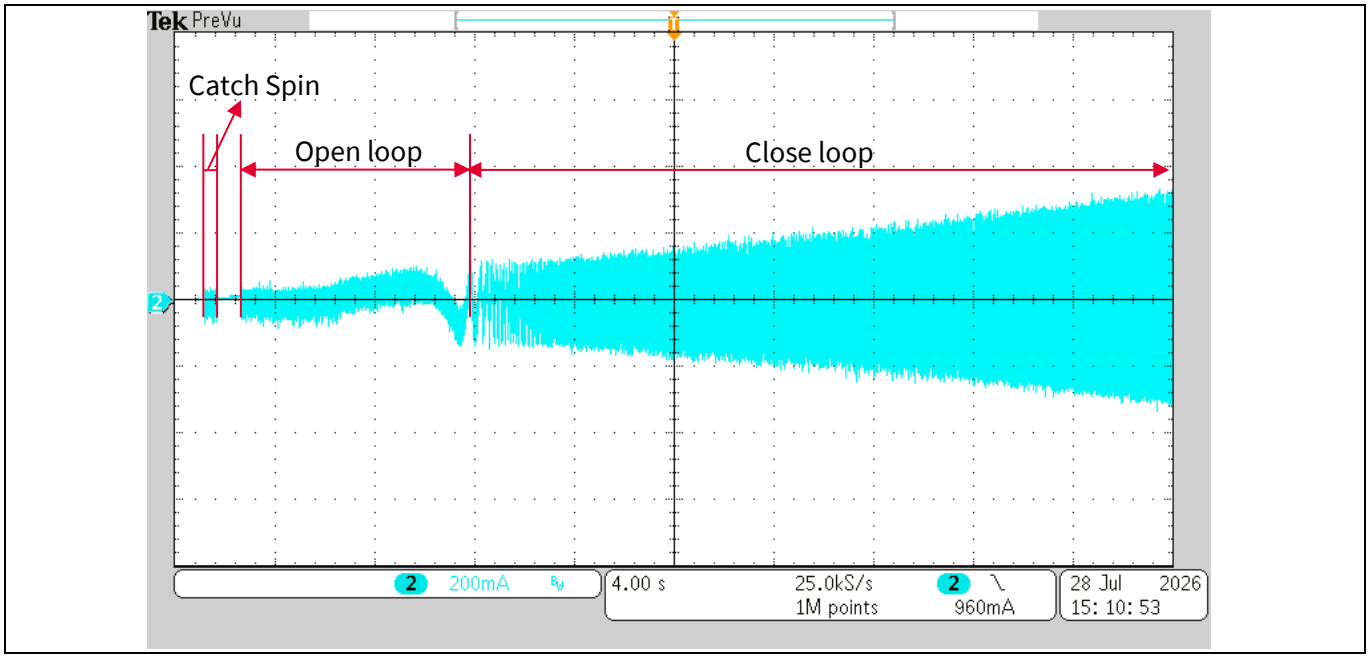


Figure 34 Close loop tuning

12. After all parameters are tuned well, then export new “ParamConfig.h” as shown in Figure 19, and integrate this file into project built in Eclipse for ModusToolbox™ as shown in Figure 23 to build it again.

2.3 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.

2.3.1 Overview of IM06B50GC1

Figure 35 illustrates the internal block diagram of the CIPOS™ Mini IPM IM06B50GC1.

Main features include:

- 3 half bridges with TRENCHSTOP™ 50 A / 650 V IGBT 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 V_S = -11 V for single transmission at V_{BS} = 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

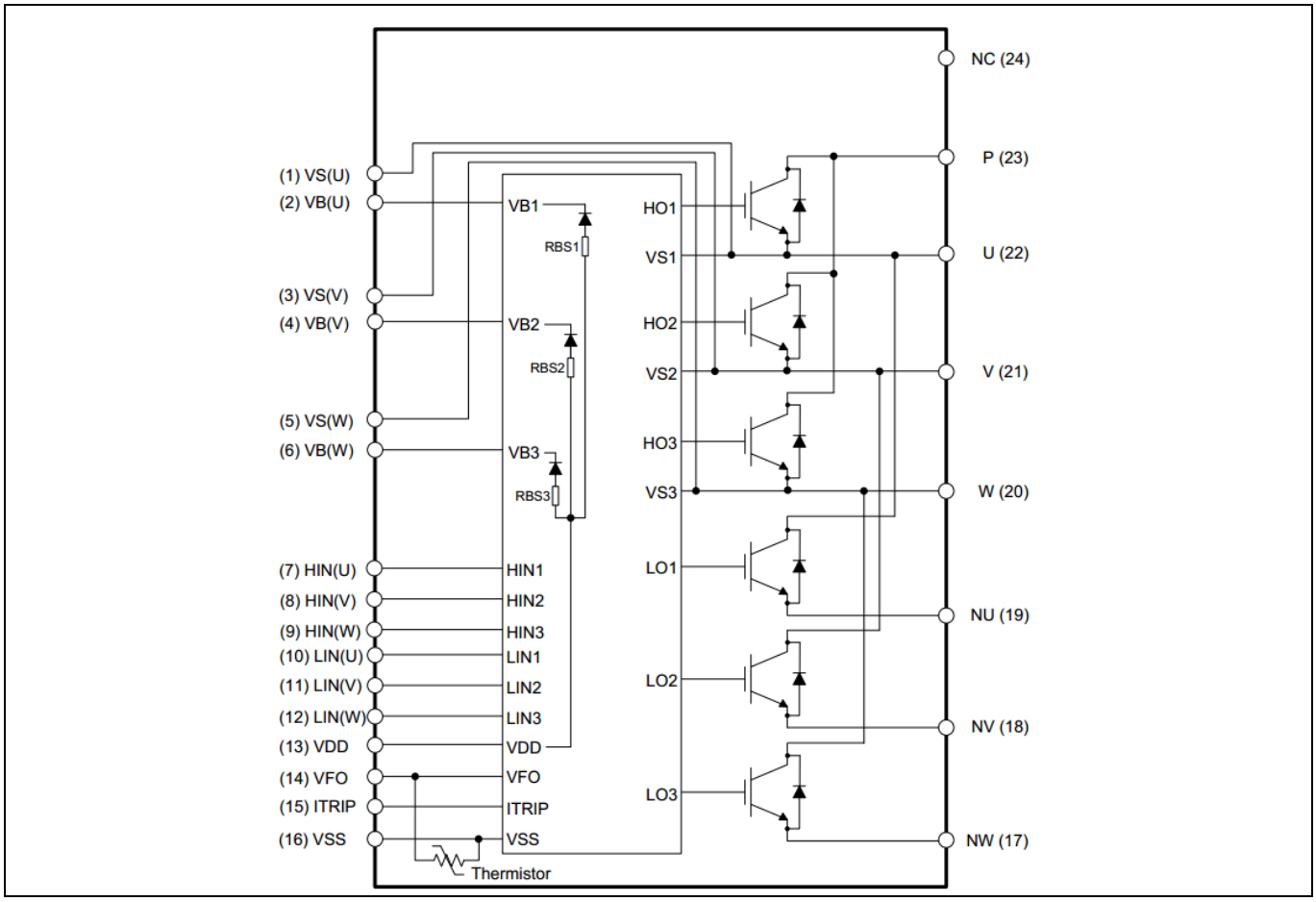


Figure 35 IM06B50GC1 internal block

2.3.2 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™ superjunction MOSFETs in DIP-7 package.

Figure 36 illustrates the internal block diagram and typical isolated flyback application.

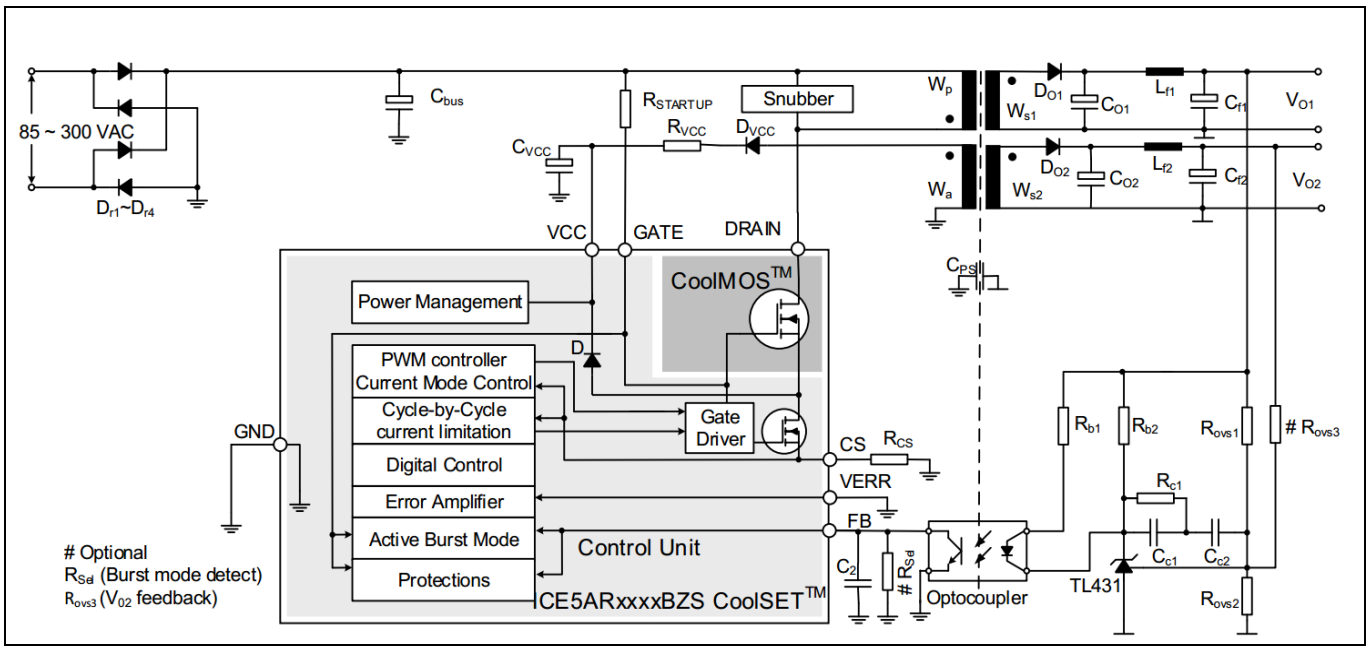


Figure 36 ICE5AR4770BZS internal block and typical application in isolated flyback mode

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 VAC) 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 softstart.
- 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 VCC pin short to ground.
- Comprehensive protection with VCC over voltage, VCC undervoltage, overload/open loop, over-temperature protection.
- Auto-restart for all protection features.

2.3.3 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 ADC_CS_OPAMP_GAIN equal to ADC_INTERNAL_GAIN× EXTERNAL_GAIN (Gain total=3×10=30).

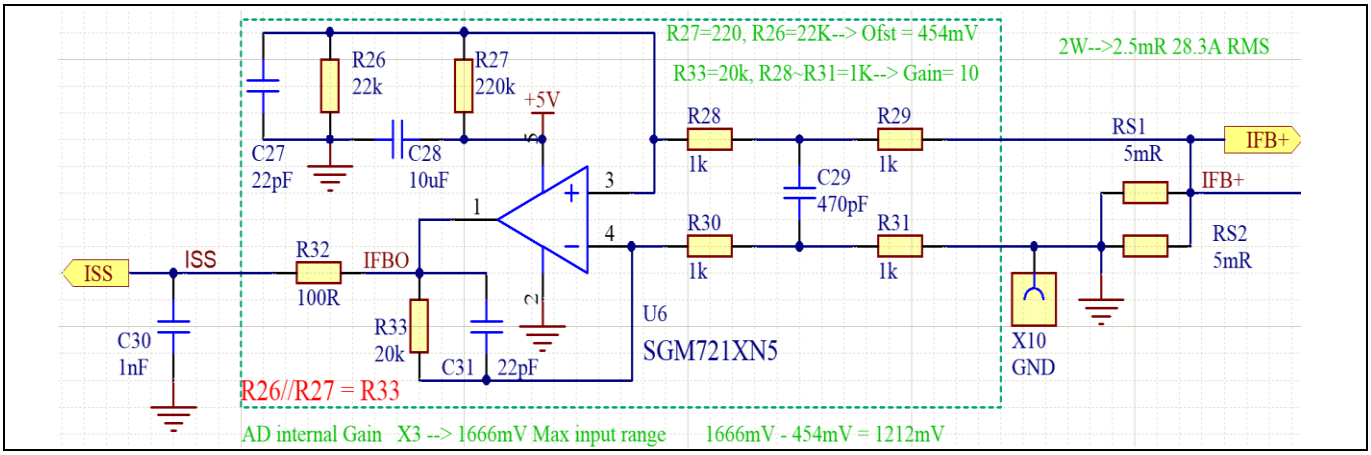


Figure 37 Current feedback with external 10X op-amp

Figure 37 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 constant 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 provides 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 kΩ & R27 = 220 kΩ, 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. The actual motor current 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. The actual motor current should be below this maximum allowable range.
- For applications that never work in 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.

Configure ADC_CS_OPAMP_GAIN to 30 in ModusToolbox™ Motor Suite as shown in Figure 7.

Configure ADC_INTERNAL_GAIN to 3 in project built in Eclipse for ModusToolbox™ as shown in Figure 24.

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 38 and Figure 39.

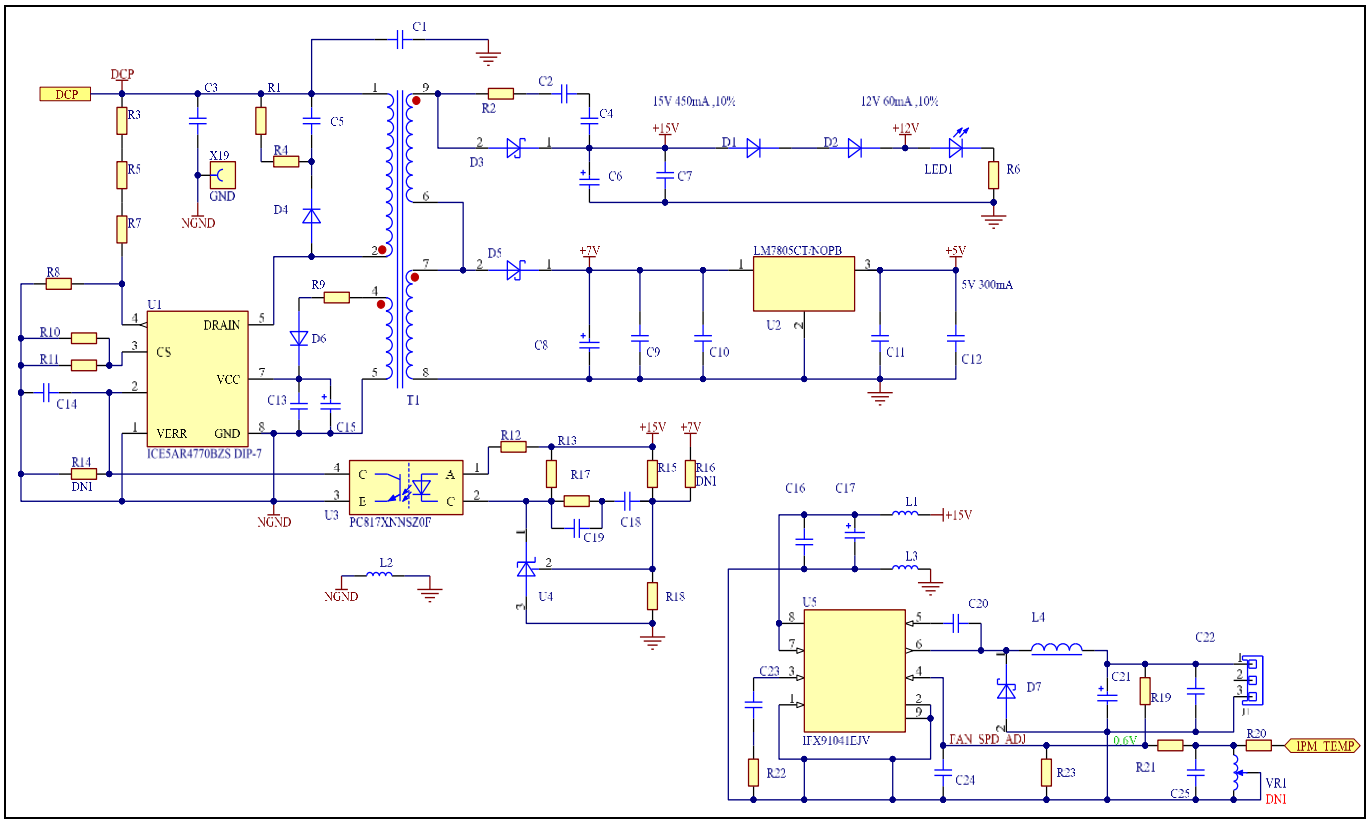


Figure 38 Aux power supply for EVAL-M1-IM06B50

Figure 38 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 are 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 39 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.

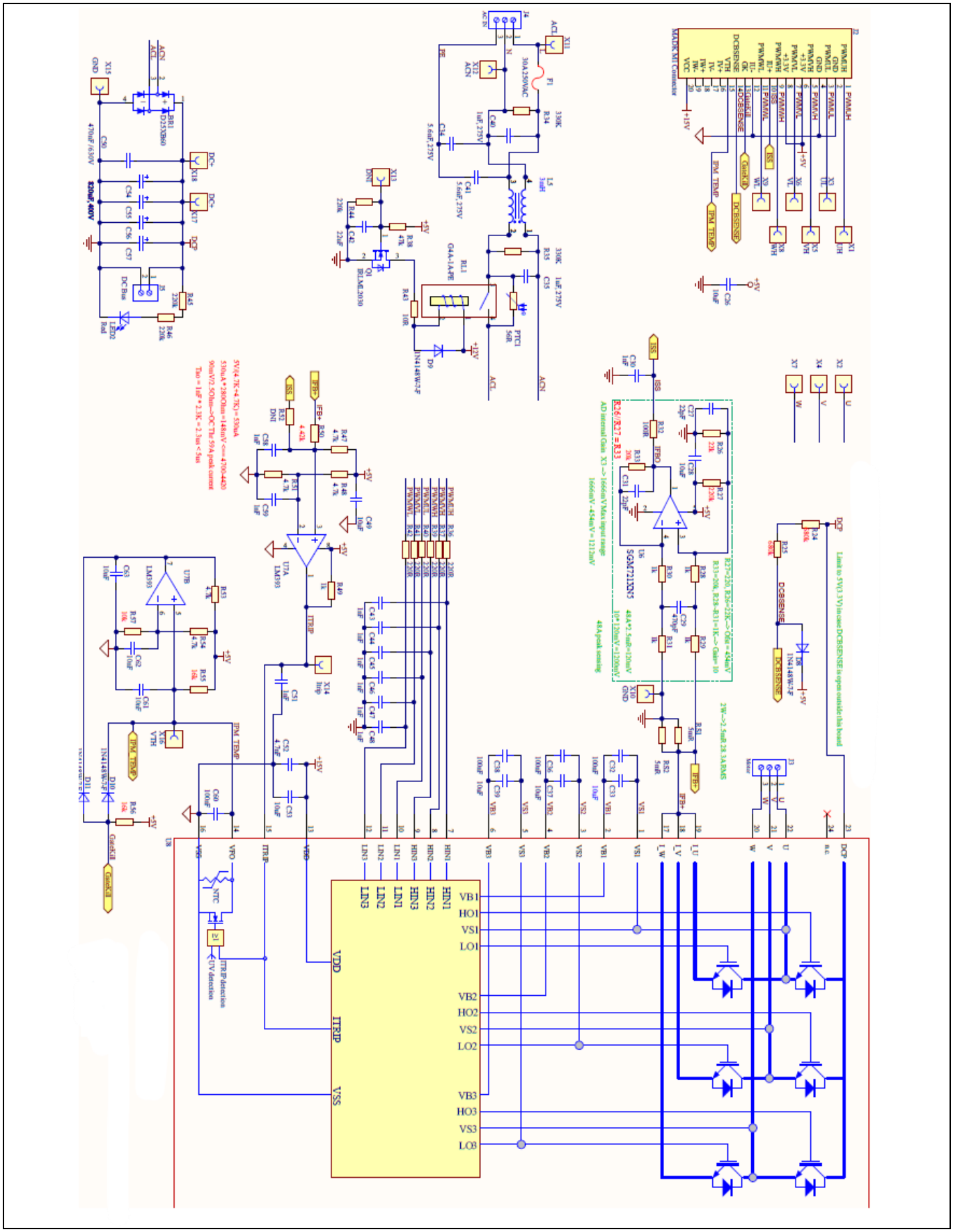


Figure 39 Schematics for IM06B50 IPM and peripheral circuit

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 40 illustrates the top assembly print of the reference design.

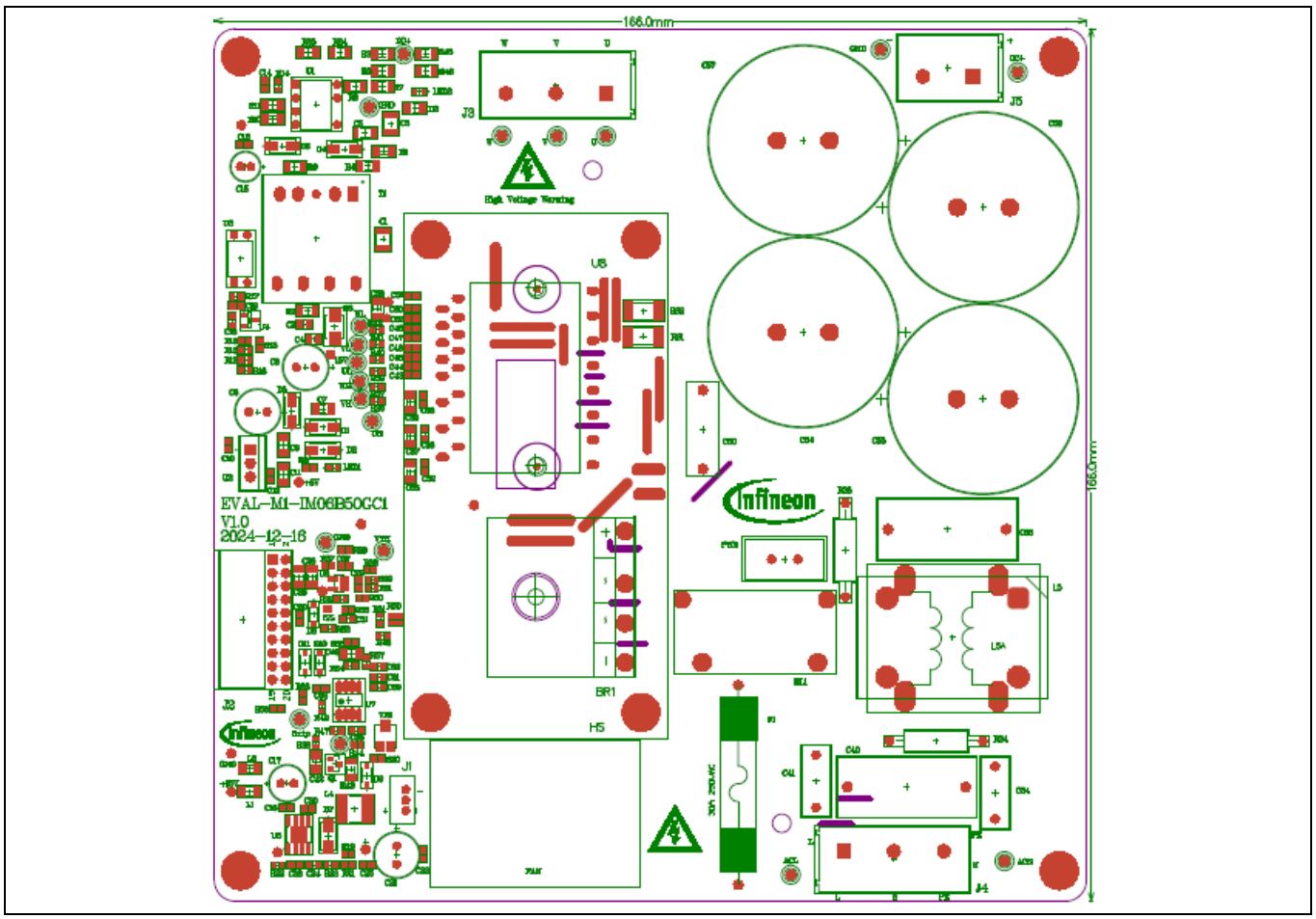


Figure 40 Top assembly print of the EVAL-M1-IM06B50 reference design

The top layer and bottom layer routing of the PCB are provided in Figure 41 and Figure 42.

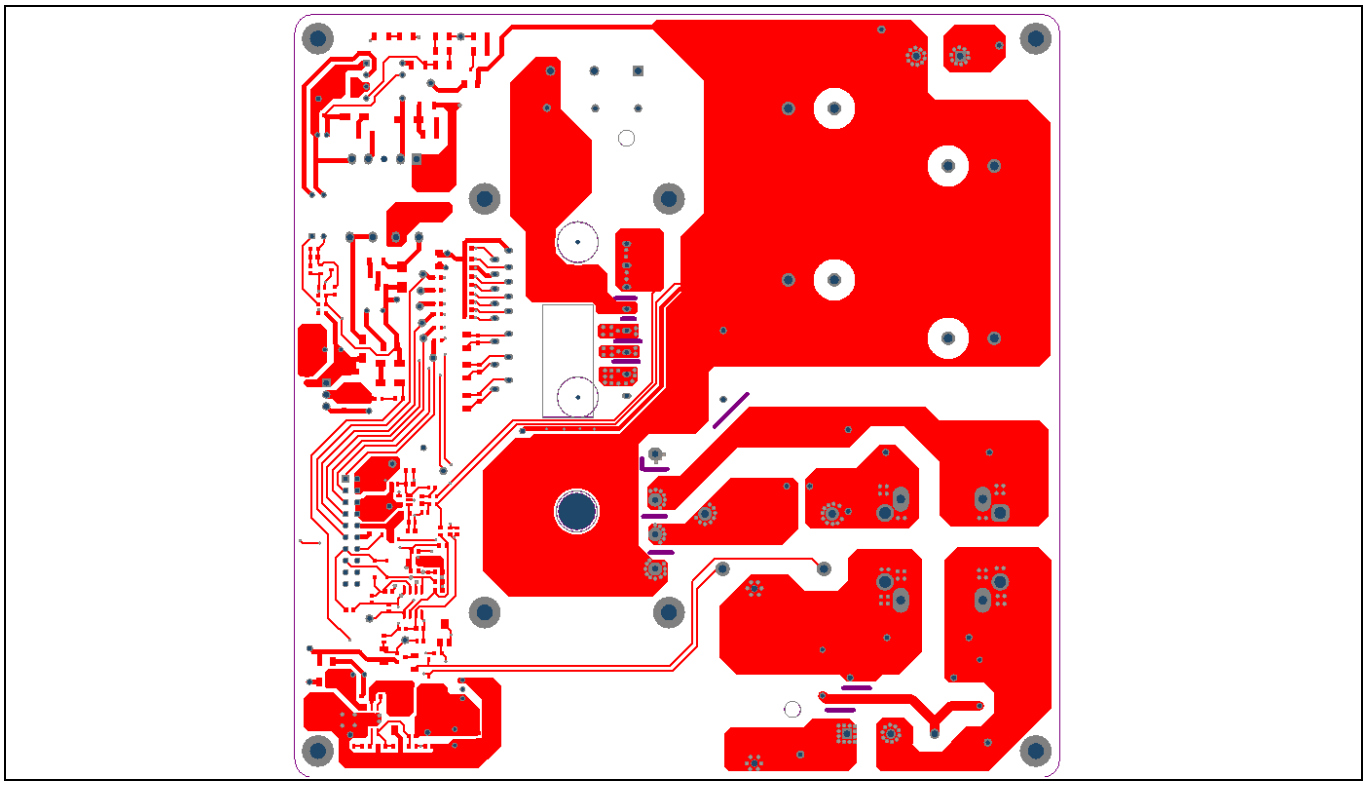


Figure 41 Top layer routing of the EVAL-M1-IM06B50

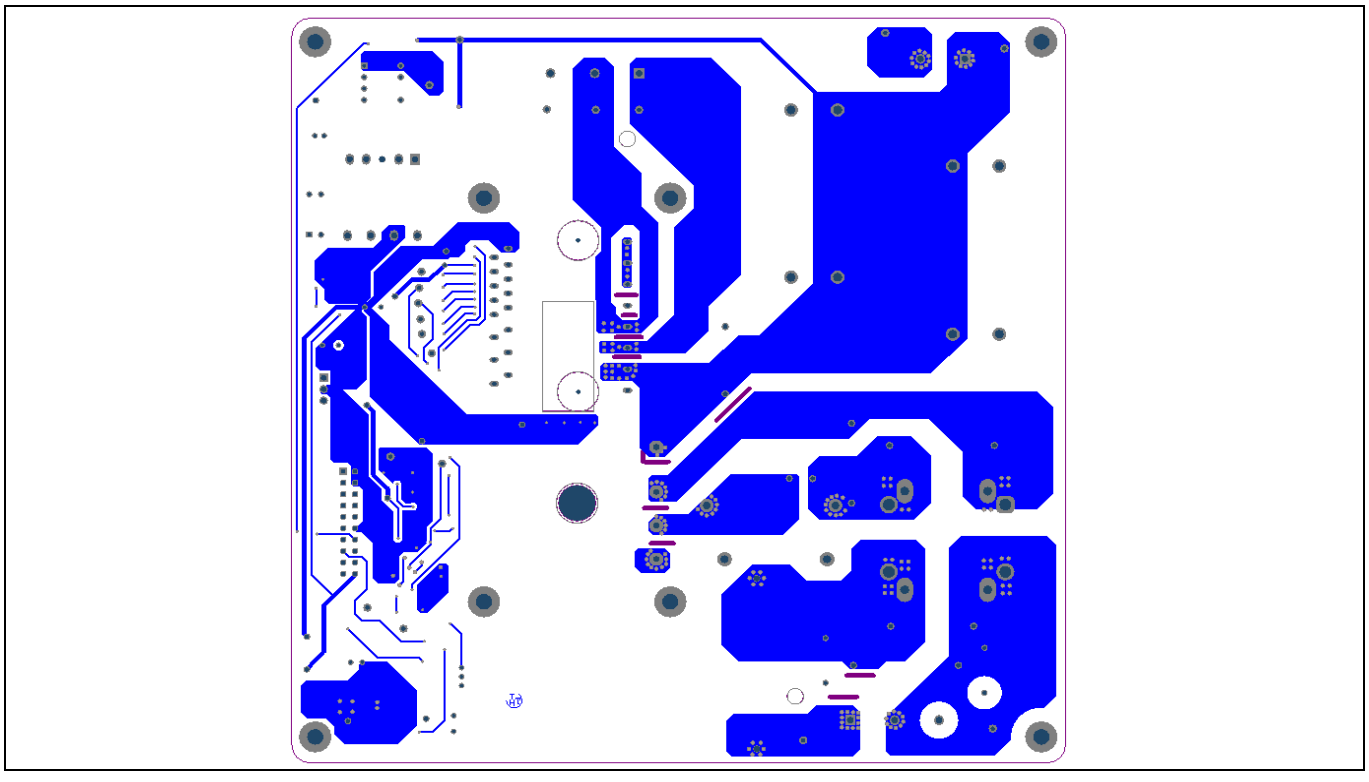


Figure 42 Bottom layer routing of the EVAL-M1-IM06B50

3.3 Bill of material

Table 4 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 4 BOM of the most important/critical parts of the evaluation 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, 275 V	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 5 includes the details of the AC input connector.

Table 5 AC input connector (J4)

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

Table 6 provides the details of the motor UVW output connector J3.

Table 6 Motor side connector (J3)

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

Table 7 provides the details of the DC bus output connector J5, for external PFC or DC source connection.

Table 7 DC bus connector (J5)

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

Table 8 provides the pin assignments of the 20-pin iMOTION™ MADK-M1 interface connector J2. This connector is the interface to the controller board.

Table 8 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
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

Pin	Name	Pin name connectors
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 9 provides the assignments of the on-board test points.

Table 9 Key test points

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

In order 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 43. 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.

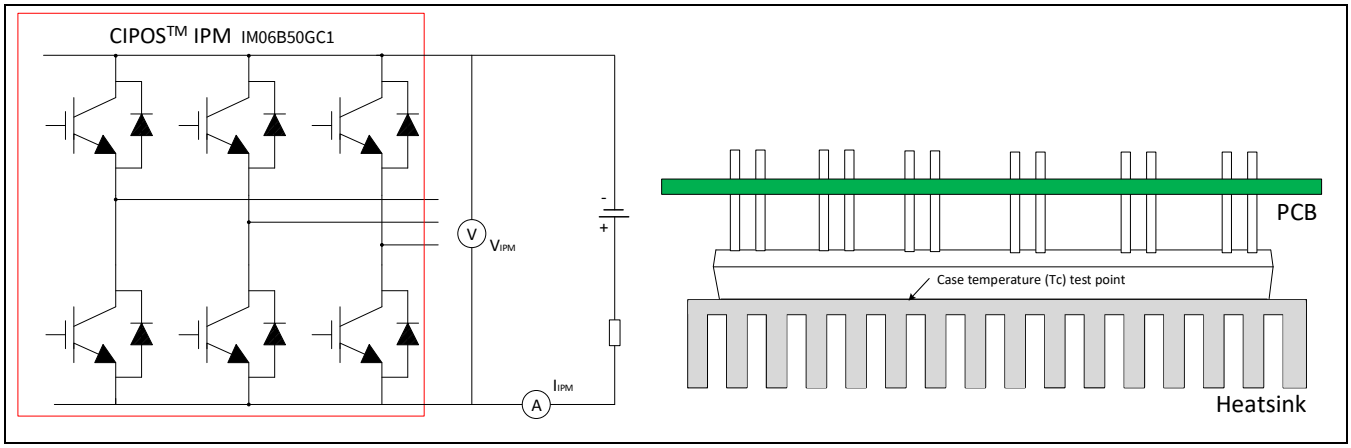


Figure 43 Heatsink thermal testing set-up

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 44 below. The IPM case temperature is detected for about one hour until the temperature is stable.

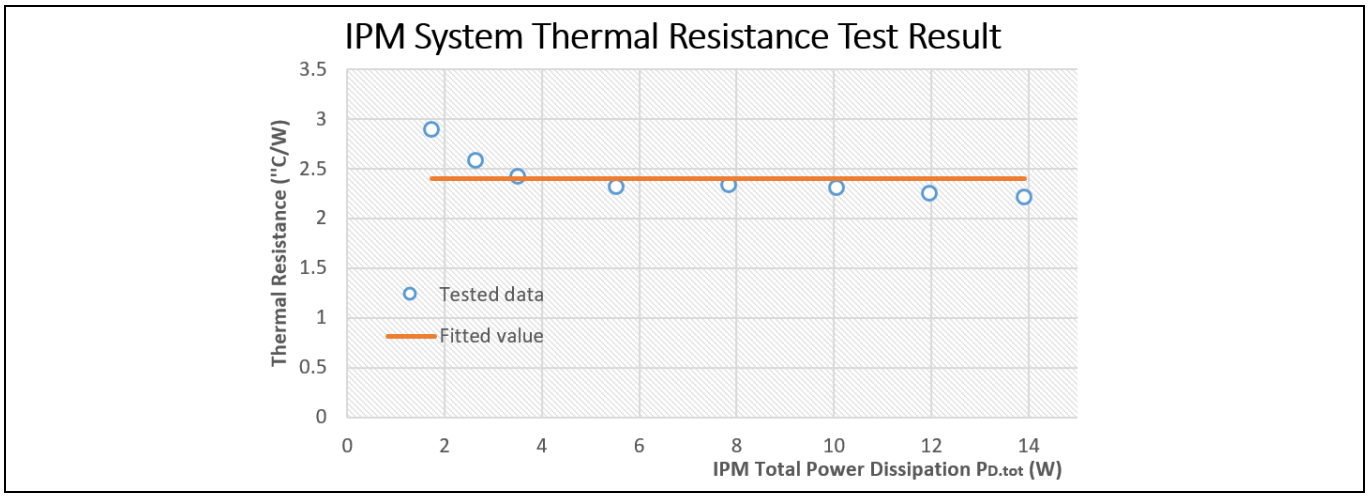


Figure 44 Heatsink thermal testing result

*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:

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

Please note that:

- 2.4 °C/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°C.
- Cooling fan's rate voltage is 12 V corresponding to 110°C 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°C
- Cooling fan voltage is 14.3 V, 8 m/s air flow after heatsink (5 mm distance center of heatsink fins)
- AC input is V_{AC} = 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 45 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°C (temperature rise reaches 80°C), get the curve for temperature rise and input power as shown in Figure 46.

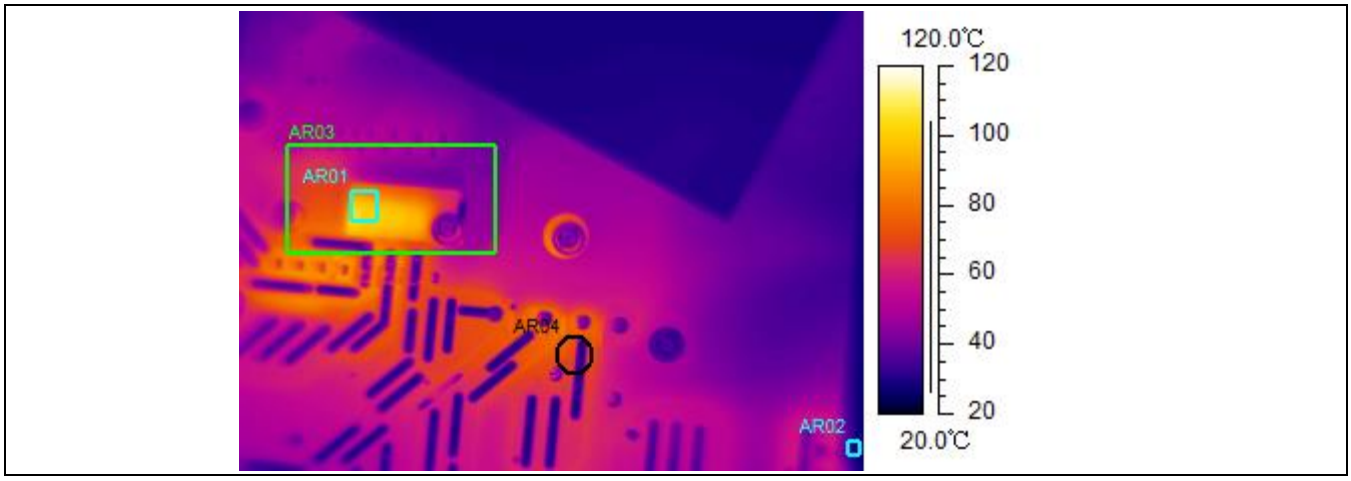
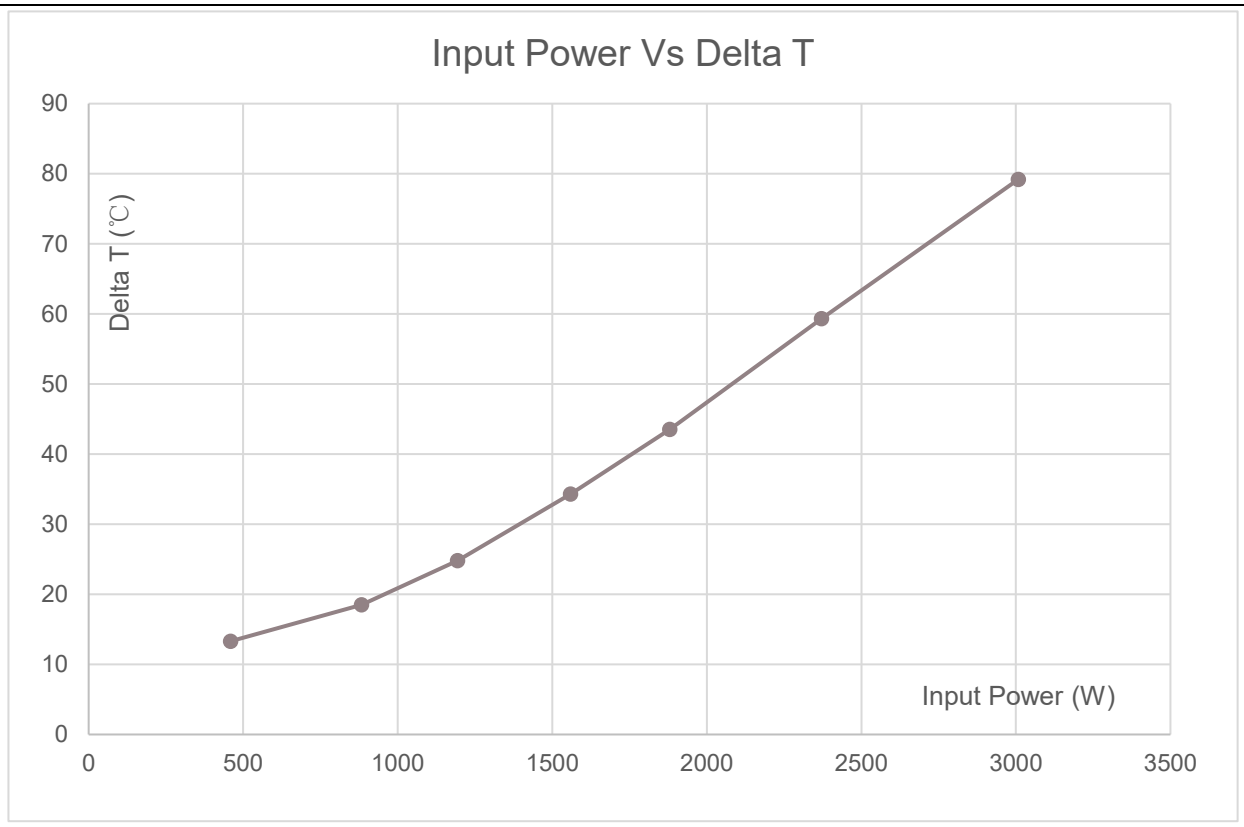


Figure 45 Infrared camera image for IPM temperature test



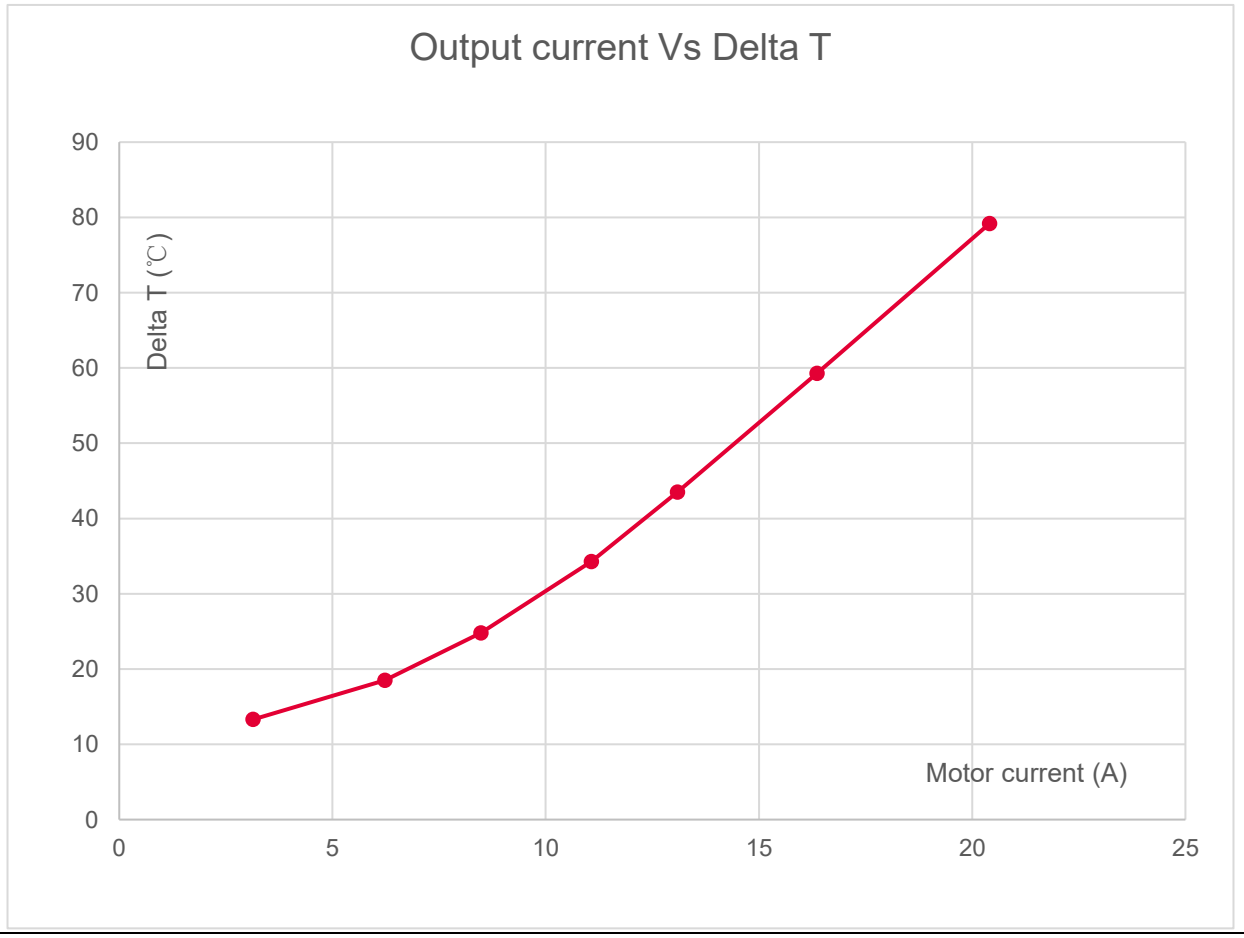


Figure 46 EVAL-M1-IM06B50 output power capability test result

4.3 Test results for PWM range

Figure 47 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°C
- Cooling fan voltage is 14.3 V, 8 m/s air flow after heatsinking (5 mm distance, center of heatsink fins)
- AC input is V_{AC} = 220 V/50 Hz (V_{DC} bus is 290 V ~ 310 V)

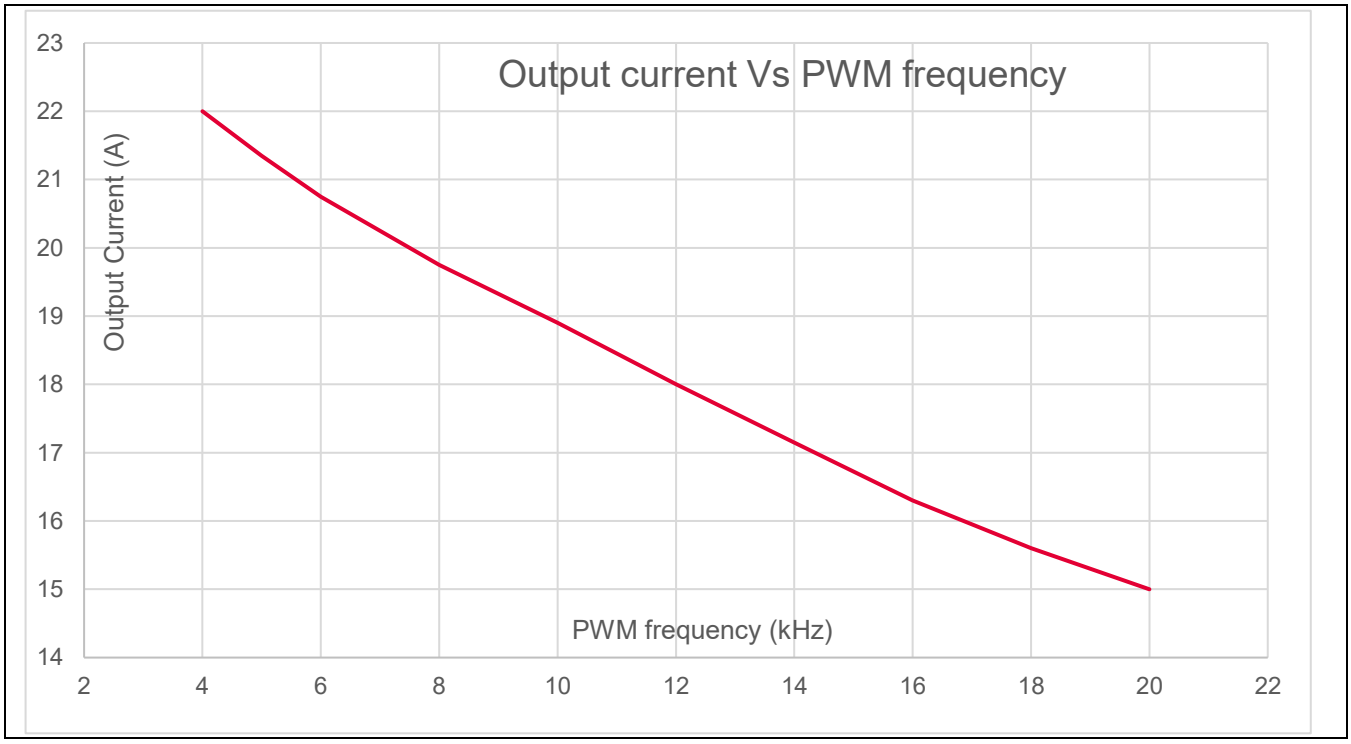


Figure 47 Output ability at different PWM frequency

4.4 Test results for overcurrent protection

The IM06B50GC1 product provides an overcurrent detection function by connecting the I_{TRIP} 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 I_{TRIP} pin input is over 525 mV and lasts longer than 300 ns.

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 mΩ shunt resisters.

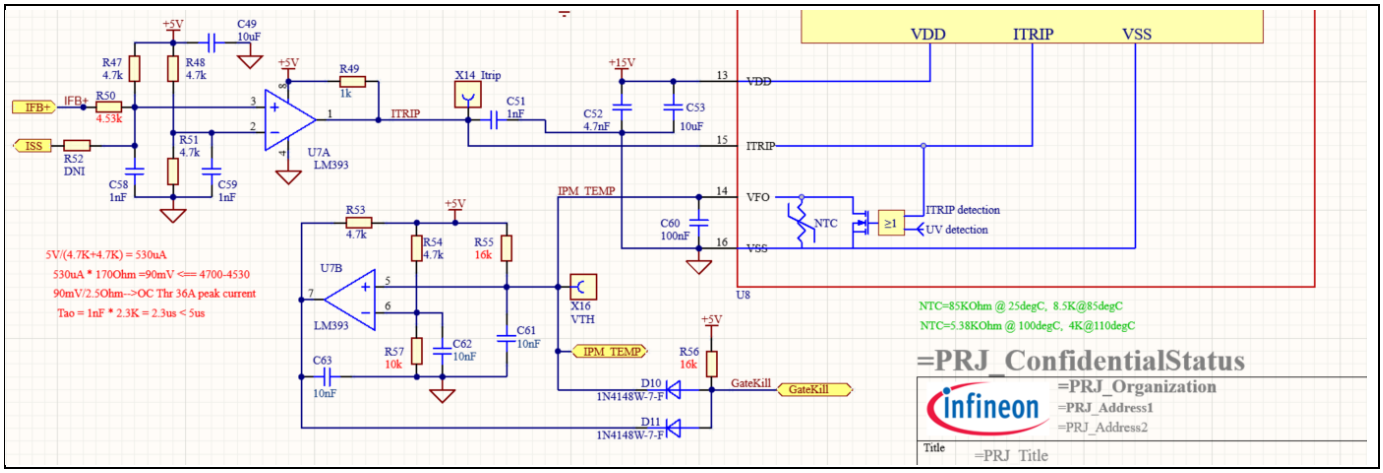


Figure 48 IPM overcurrent protection and over-temperature protection circuit

The small and big signal response of this overcurrent protection circuit is shown in Figure 48

- 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.

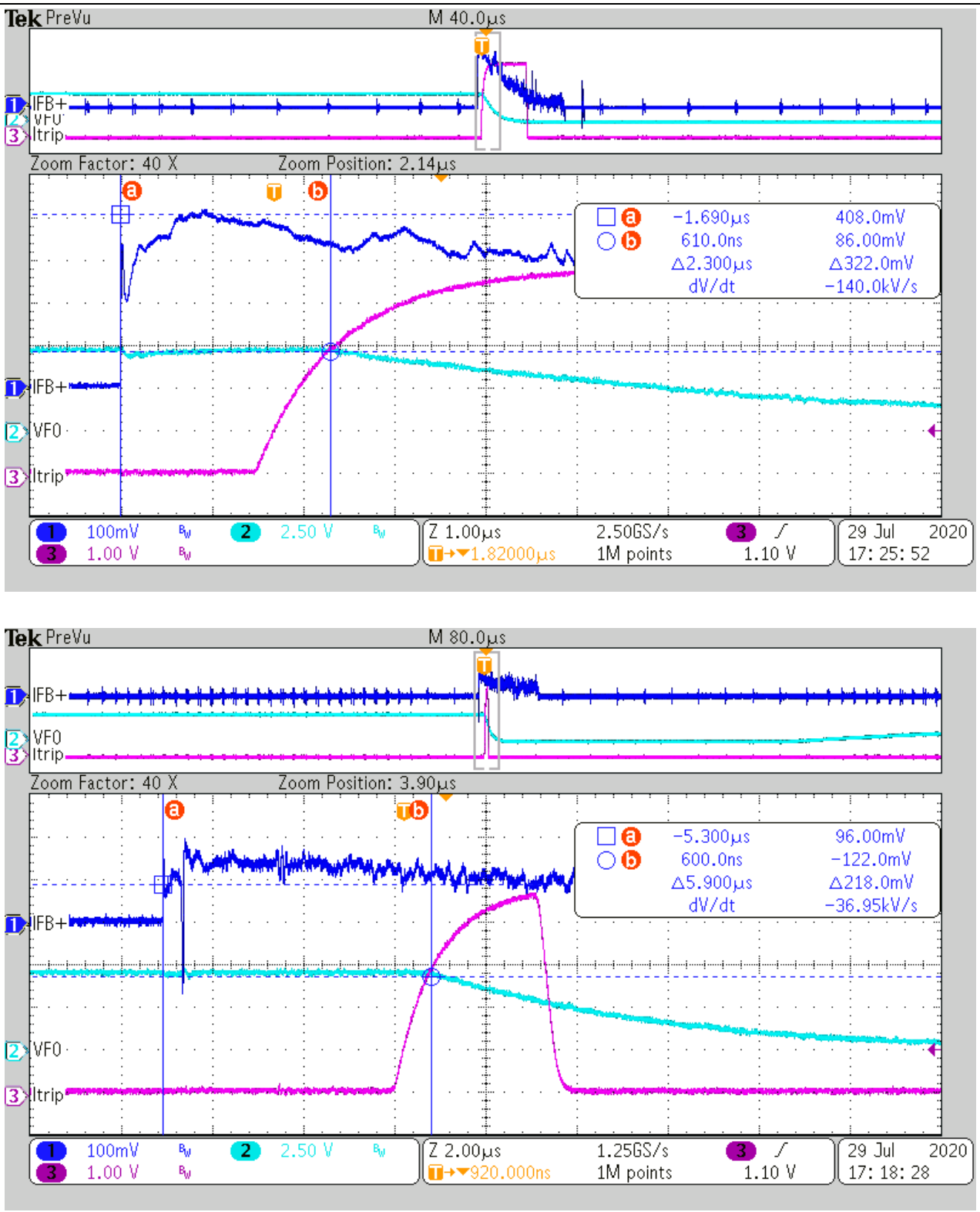


Figure 49 Overcurrent protection response waveform (CH1: IFB+, CH2: VFO, CH3: Itrip)

4.5 Test results for over-temperature protection

The IM06B50GC1 IPM has an internal NTC resistor, which connects to V_{FO} multifunction pin, as shown in Figure 50.

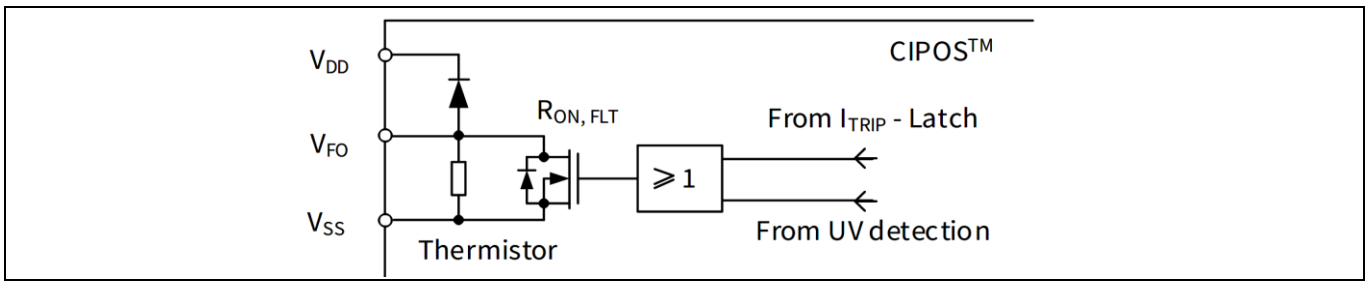


Figure 50 Temperature sensing for IM06B50GC1

The IM06B50GC1 IPM built-in NTC thermistor is 85 kΩ at 25°C and its B-constant is 4092, typical resistance and output of temperature-sensing voltage are listed in Table 10.

Table 10 NTC – Thermistor Characteristics

Temperature (°C)	Resistance (kΩ)	V_{out} (mV)
50	30.157	2593
60	20.669	2347
70	14.424	2075
80	10.234	1794
90	7.373	1519
100	5.388	1264
110	3.990	1037
120	2.991	843
125	2.601	758

Set voltage for NTC voltage threshold for an over temperature fault threshold in ModusToolbox™ Motor Suite. is shown in Figure 51.

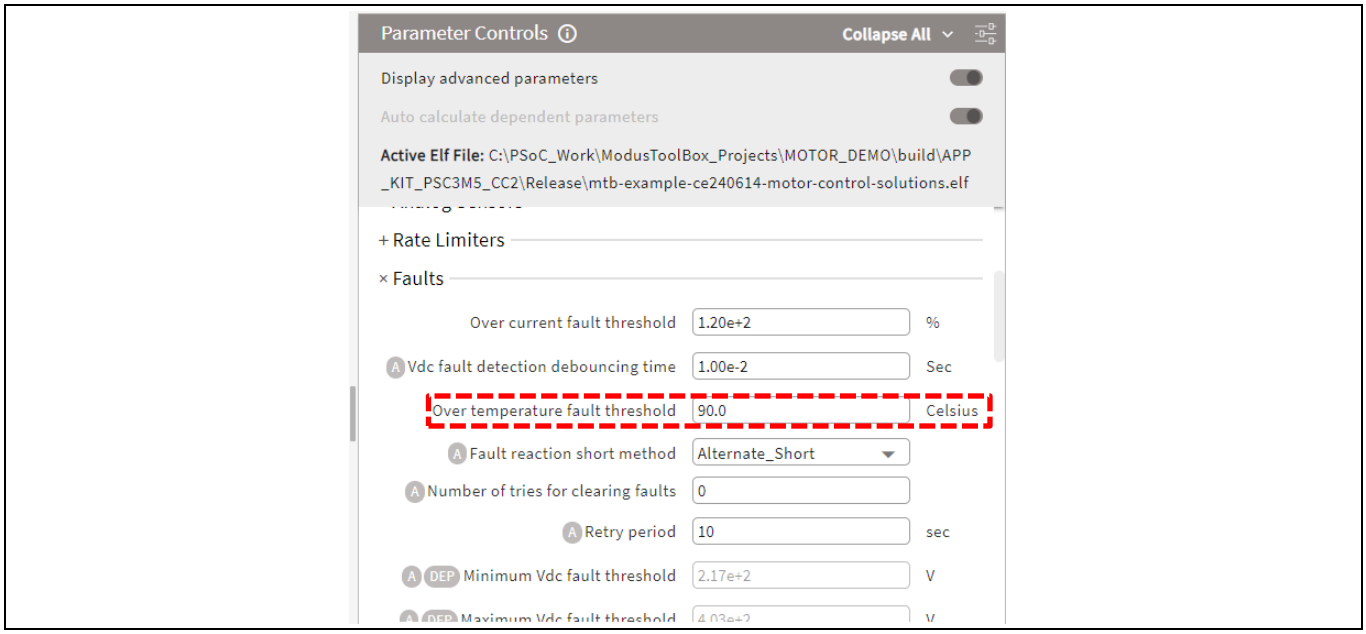


Figure 51 Over temperature protection configuration in ModusToolbox™ Motor Suite.

4.6 Test result for DC bus voltage ripples

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

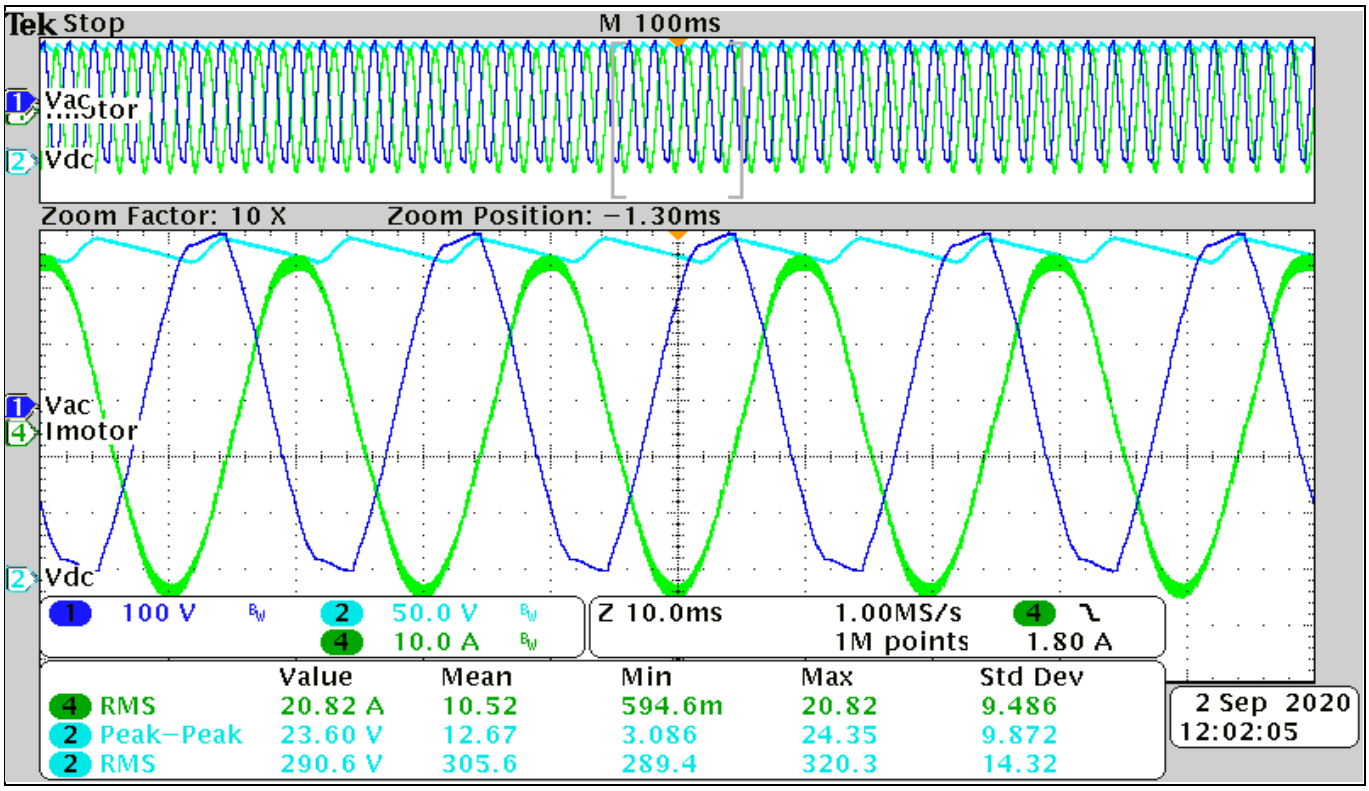


Figure 52 DC bus voltage ripple at 3000 W input power

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] Datasheet of Infineon IM06B50GC1

[2] KIT_PSC3M5_MC1 user guide

[3] ModusToolbox™ Motor Suite Motor Control Library tuning guide

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:

Table 12 Ordering information

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	IM06B50GC1XKMA1

5.3.1 Software Tools

Segger Jlink -Windows J-link drive: Install latest J-Link driver (version V8.10i or latest)

- https://www.segger.com/downloads/jlink/?utm_source=www&utm_medium=top_menu

ModusToolboxMotor Suite GUI: Downlaod and Install Motor control Suite GUI 2.6.1 version or latest of GUI

- https://softwaretools.infineon.com/tools/com.ifx.tb.tool.ifxmotorsolutions

5.3.2 Hardware Details

PSOC™ Control C3M5 Motor Drive Control Card

- KIT_PSC3M5_CC2

MADK Evaluation board for CIPOS™ Mini IPM

- EVAL-M1-IM06B50

Revision history

Document revision	Date	Description of changes
V1.0	2025-06-30	First release
V1.1	2025-07-29	Update to iMOTION™ Solution Designer
V1.2	2026-10-29	Change to PSOC™ Platform from iMOTION™ Solution Designer

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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.