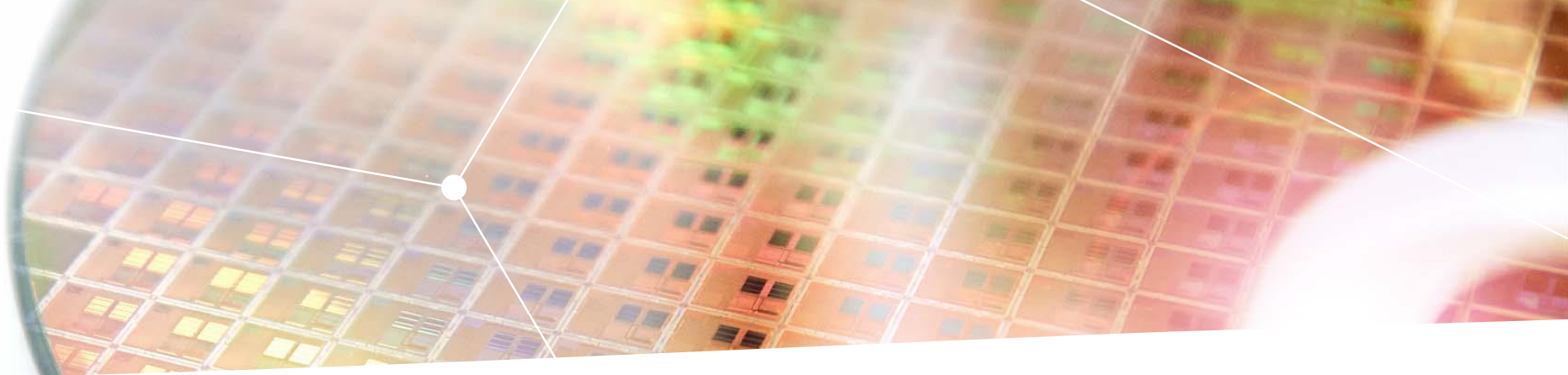




EVAL_FAN_XMC_PFD7

Information and user guide

www.infineon.com/eval-fan-xmc-pfd7



Agenda

1 Introduction to fan driver evaluation board

2 Hardware and software

3 Tools

4 Getting started

5 Resources

Agenda

1 Introduction to fan driver evaluation board

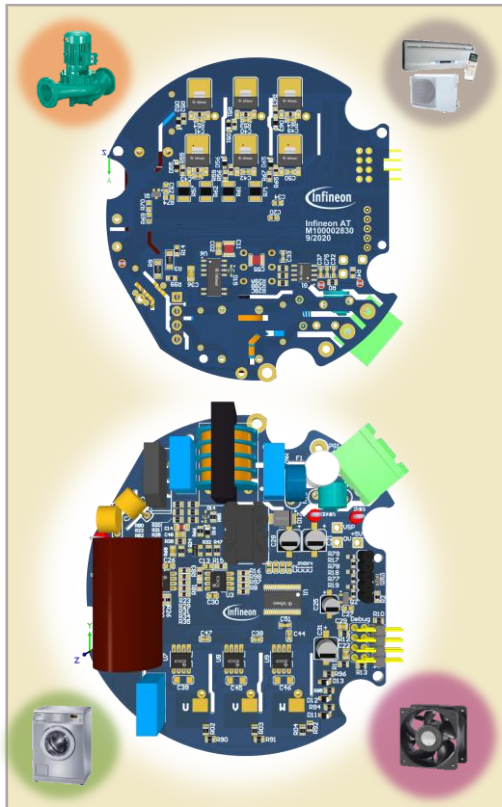
2 Hardware and software

3 Tools

4 Getting started

5 Resources

Introduction



Compact 3-phase motor drive system solution up to 100 W

Designed for **sensor less or sensored** motor control

Spin your motor with easy-to-use GUI for tuning of motor

The hardware board and motor control software provides:

- Sensorless speed controlled direct FOC startup
- 7-segment / 5-segment SVM
- Over-current protection by CTRAP
- Speed controlled using μ C/Probe™ GUI's slider

Agenda

1 Introduction to fan driver evaluation board

2 Hardware and software

3 Tools

4 Getting started

5 Resources

System overview

Components

- › **XMC1302 Microcontroller**
 - Based on XMC1302 ARM® Cortex®-M0 MCU enabling sensored and sensorless motor control
 - Supports HALL
 - Includes J-Link debug interface by Segger
 - µC/Probe™-based GUI for parametrization and tuning
- › **Half bridge gate driver EiceDRIVER™ 2ED28073J06F**
- › **CoolIMOS™ IPN60R2K0PFD7S**
- › **CoolSet™ ICE5QR4770AG**
- › **Software package** (downloadable from www.infineon.com/eva)
- › Micrium µC/Probe™ for XMC™
 - .zip file with DAVE™ 4 project for the EVAL_FAN_XMC_PFD7
 - kit (e.g. Eval-100W_FOC_XMC13_v1.zip)

System overview

For example the EVAL_FAN_XMC_PFD7 Kit consists of:

Hardware

- › EVAL_FAN_XMC_PFD7 board
- › XMC™ Link
- › Micro-B USB cable

Software

- › Micrium µC/Probe™ for XMC™
- › Eval-100W_FOC_XMC13.zip file
(downloadable from <https://www.infineon.com/cms/en/p>)

System overview

Software package content description:

› **Eval-100W_FOC_XMC13**

A DAVE™ 4 project for XMC1302-TO380200 device. The user can configure the motor parameter and startup mode in the source code. The compile firmware needs to be programed to EVAL_FAN_XMC_PFD7 board via DAVE™ 4 IDE and XMC Link

› **Eval-100W_FOC_XMC13.elf**

A debugging file used by µC/Probe™ GUI tool

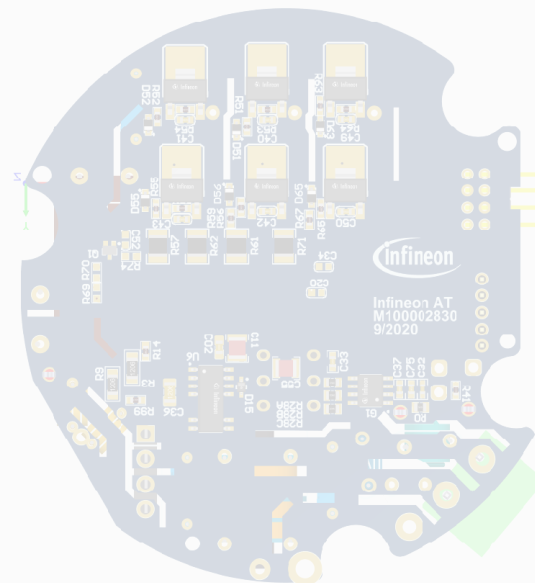
› **Eval-100W_FOC_XMC13.wspx**

A µC/Probe™ project file for predefined GUI used for system parametrization and tuning

Hardware overview

Hardware

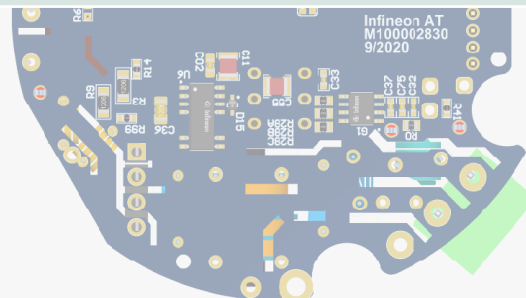
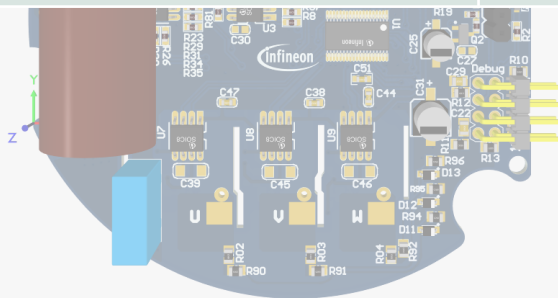
- › **Kit name**
 - EVAL_FAN_XMC_PFD7
- › **Kit description**
 - EVAL_FAN_XMC_PFD7 board
 - USB cable
 - XMC™ Link – Isolated Debug Probe
- › **Order number**
 - add
- › **Input voltage/output power**
 - 230 VAC/100 Watt max



Hardware overview

Infineon parts utilized on EVAL_FAN_XMC_PFD7 board:

Infineon Parts	Order Number
XMC1300 Microcontroller	XMC1302-T038F0200
600 V half bridge gate driver	2ED28073J06F
600 V CoolMOS™	IPN60R2K0PFD7S
Quasi-resonant CoolSET™	ICE5QR4770AG
5 V LDO regulator	IFX1763XEJV50



Hardware overview

To properly setup the board, follow these steps:

1
Connect 3-phase motor wiring to 'U V W' connector

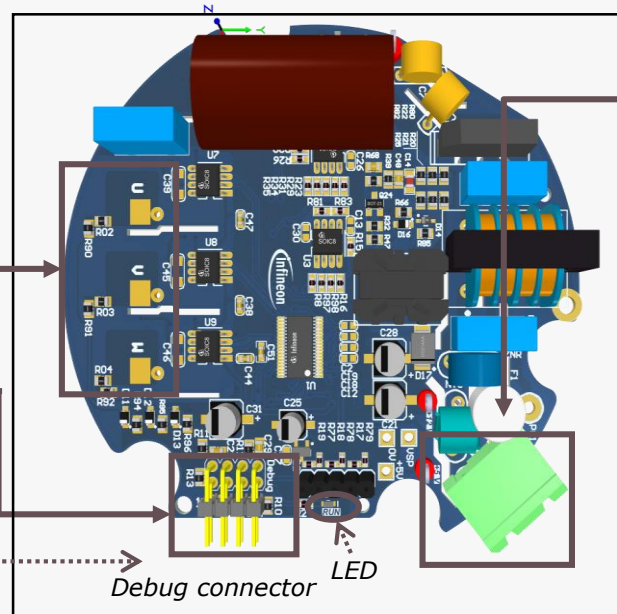
2a
Connect XMCT[™] Link's ribbon cable to pin 1 of Debug connector

XMCT[™] link for debugging the source code in DAVE[™] 4 IDE

3
Connect AC source to EVAL_FAN_XMC_PFD7 board

AC power input 230 VAC

2b
Connect to PC via micro-B USB cable



USB port of PC host

Agenda

1 Introduction to fan driver evaluation board

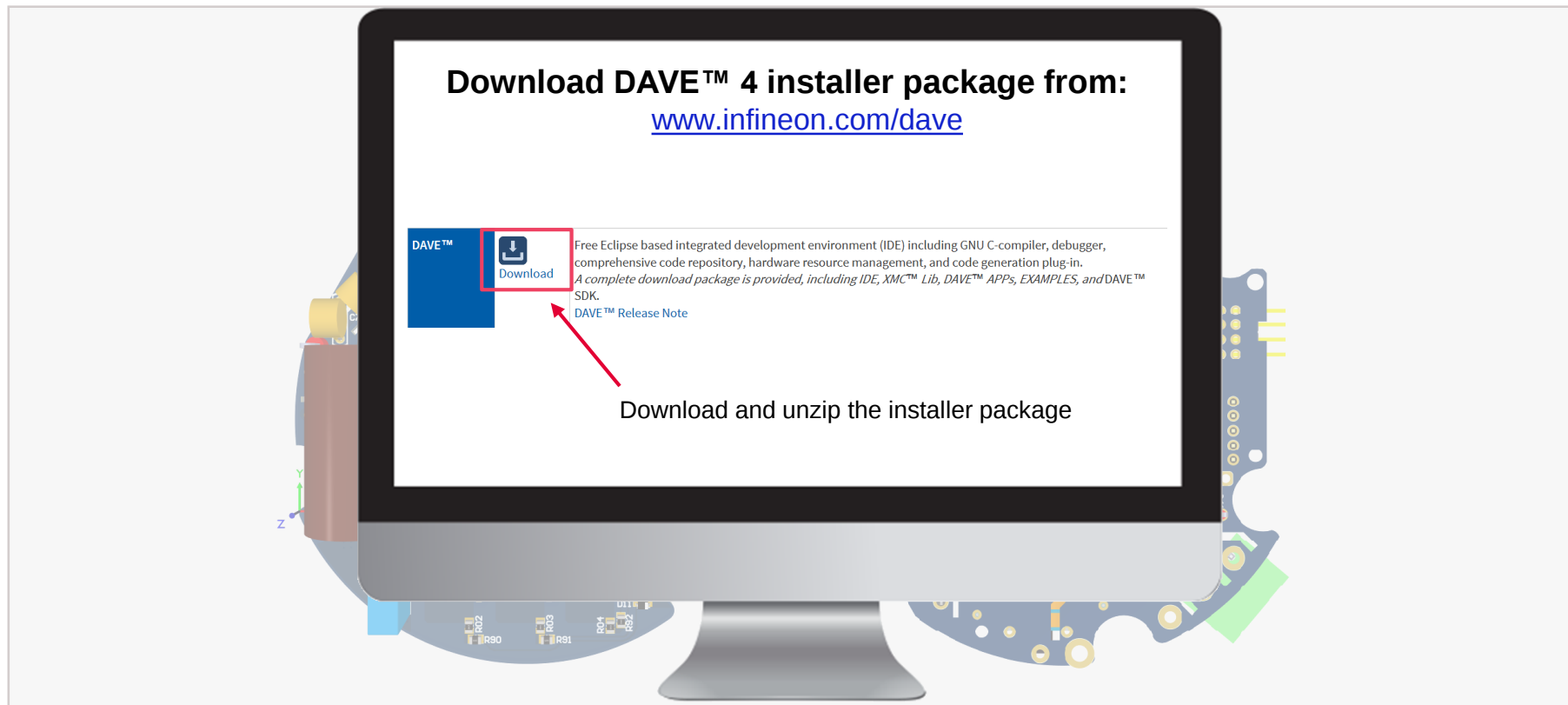
2 Hardware and software

3 Tools

4 Getting started

5 Resources

DAVE™ 4 setup



Download Micrium μ C/Probe™ for XMC™ installer package from:

www.infineon.com/ucprobexmc



Installation requirements:

- > PC with Windows Vista, Windows 7, Windows 8, Windows 10 – 32 bit & 64 bit
- > RAM – 3 GB or more

Agenda

1 Introduction to fan driver evaluation board

2 Hardware and software

3 Tools

4 **Getting started**

5 Resources

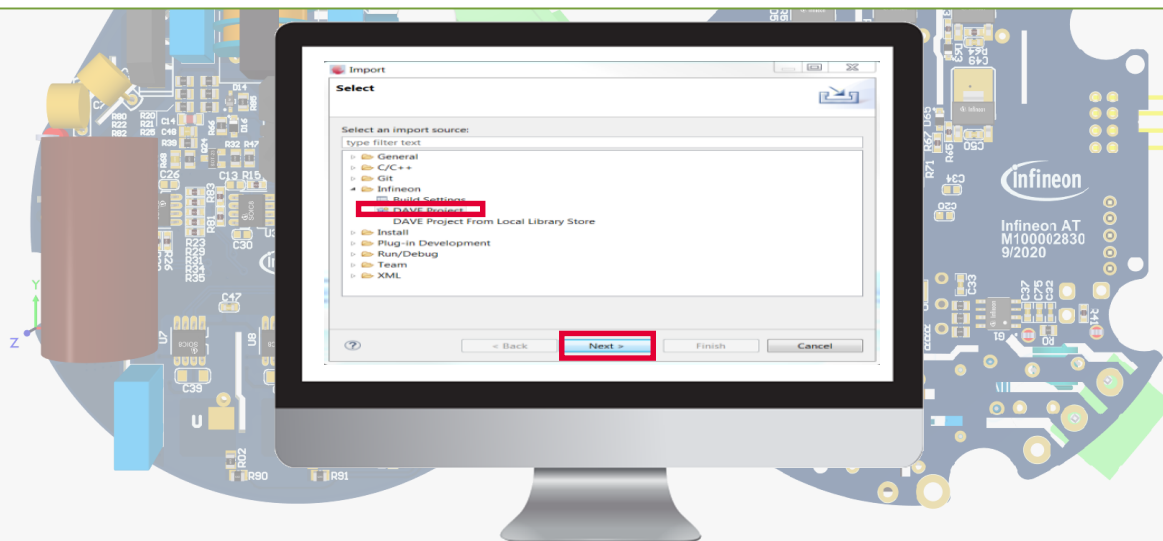
Import the *.zip project

1

Import the *.zip file into DAVE™ 4 IDE by clicking on **File > Import**

2

Select **Infineon > DAVE Project** and click the **Next** button



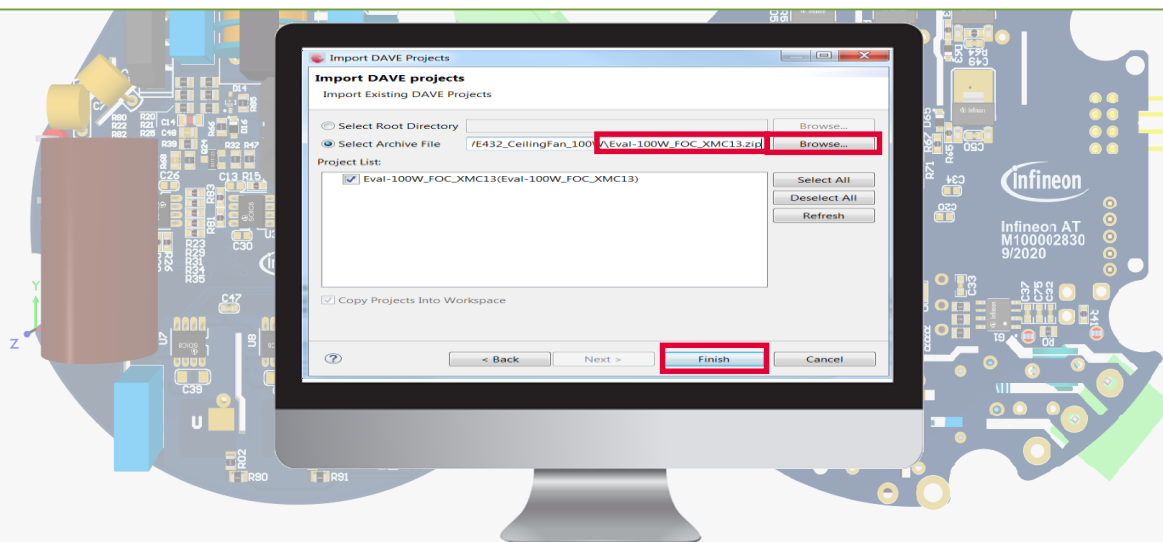
Import the *.zip project

3

Click **Browse** and navigate to the *.zip file location

4

Click the **Finish** button



1

Eval-100W_FOC_XMC13 [Active - Debug]

- Includes
- Libraries
- PMSM_FOC
 - Configuration
 - pmsm_foc_const_macro.h
 - pmsm_foc_invertercard_paramete
 - pmsm_foc_mcucard_parameters.h
 - pmsm_foc_motor_parameters.h**
 - pmsm_foc_uCProbe_parameters.c
 - pmsm_foc_user_config.h
 - pmsm_foc_variables_scaling.h
 - ControlModules

Input motor parameters

2

Scroll to **(MOTOR_TYPE == CUSTOM_MOTOR)** and update the parameters in the red box with your motor's data

```

204 /* ***** CUSTOM_MOTOR ***** */
205 #if(MOTOR_TYPE == CUSTOM_MOTOR)
206 /* ----- Motor Parameters ----- */
207 #define USER_MOTOR_R_PER_PHASE_OHM (23.0f) /* Motor Resistance per phase in Ohm */
208 #define USER_MOTOR_L_PER_PHASE_uH (55000.0f) /* Motor Inductance per phase in uH */
209 #define USER_MOTOR_POLE_PAIR (4.0f) /* Motor Pole Pairs */
210 /* ----- Constant Speed Control Mode (Used when Constant Speed Control is enabled) ----- */
211 /* POT ADC, or PWM to Adjust Speed --- */
212 #define USER_SPEED_HIGH_LIMIT_RPM (1050) /* Max Speed of User Motor */
213 #define USER_SPEED_LOW_LIMIT_RPM (wint32_t) (USER_SPEED_HIGH_LIMIT_RPM / 300)
214 #define USER_SPEED_RAMPUP_RPM_PER_S (300)
215 #define USER_SPEED_RAMPDOWN_RPM_PER_S (300)
216 #define USER_RATIO_S (10) /* Minimum ramp up and down ratio */
217 /* ----- V/F Start-Up Parameters ----- */
218 #define USER_STARTUP_SPEED_RPM (80)
219 #define USER_STARTUP_SPEED_THRESHOLD_RPM (150) /* threshold Speed to transit from Open loop to closed loop */
220 #define USER_STARTUP_VF_OFFSET_V (float) (USER_VDC_LINK_V * 0.05f-6) /* V/F offset */
221 #define USER_STARTUP_VF_SLEWRATE_V_PER_HZ (float) (USER_VDC_LINK_V / (ELECTRICAL_SPEED_FREQ_HZ * 2))
222 // #define USER_STARTUP_VF_OFFSET_V (0.4f) /* V/F startup offset in V */
223 // #define USER_STARTUP_VF_SLEWRATE_V_PER_HZ (0.07f) /* V/F start up slew rate in V/Hz */
224

```

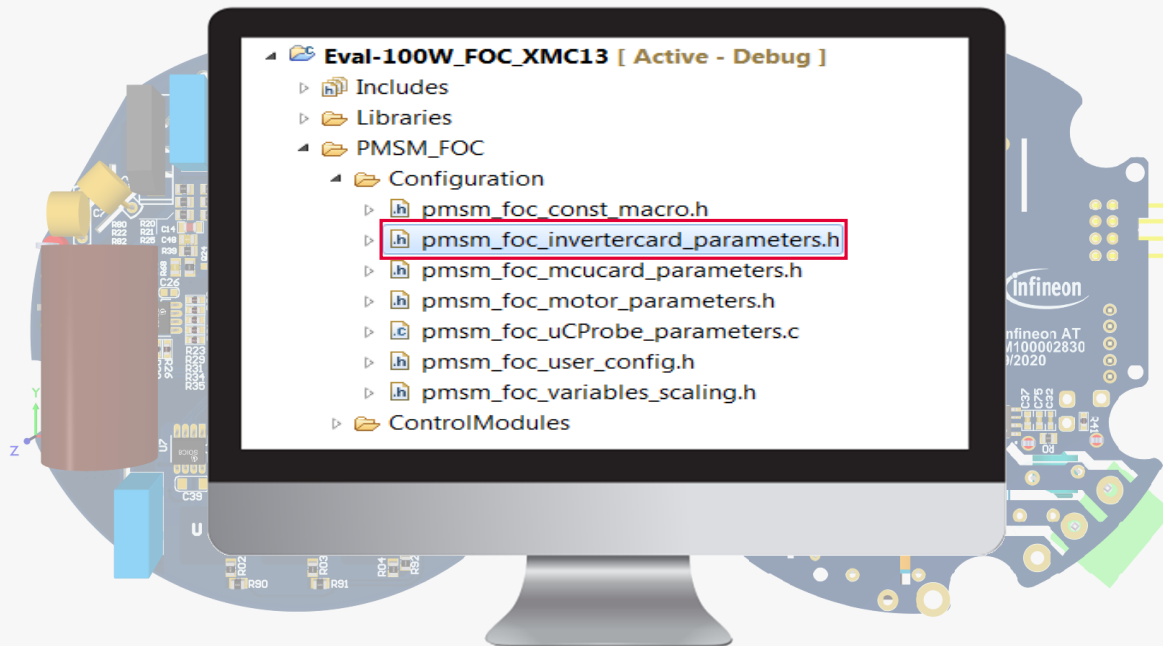
i

For more explanation of the parameter specified in the code, please refer to XMC1000 application note: 'AP32370-XMC1000-PMSM FOC motor control software using XMC™'

Input inverter circuitry parameters

1

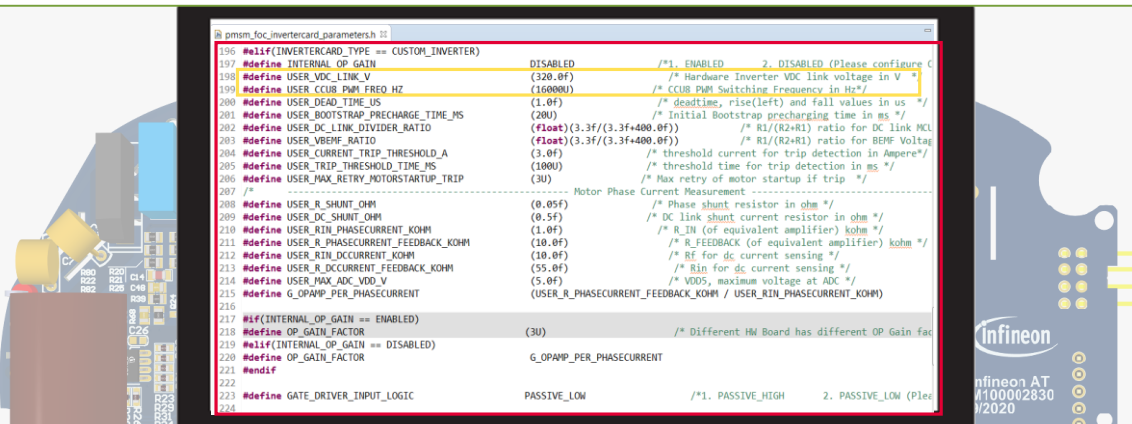
Double click on **pmsm_foc_invertercard_parameters.h**



Input inverter circuitry parameters

2

Scroll to **(INVERTERCARD_TYPE == CUSTOM_INVERTER)**



The inverter parameters is already preset to the EVAL_FAN_XMC_PFD7 board's value, e.g. USER_VDC_LINK_V is 320 V ($\sqrt{2} \times 230$ V) with the assumption that AC input voltage is 230 V

The PWM frequency driving the power MOSFET is set to 16 kHz

The minimum PWM frequency can be set is 6.6 kHz

The user does NOT need to change the value here if AC input voltage to EVAL_FAN_XMC_PFD7 board is 230 V

1

▲ **Eval-100W_FOC_XMC13 [Active - Debug]**

- ▶ Includes
- ▶ Libraries
- ▲ PMSM_FOC
 - ▲ Configuration
 - ▶ pmsm_foc_const_macro.h
 - ▶ pmsm_foc_invertercard_parameters.h
 - ▶ **pmsm_foc_mcucard_parameters.h**
 - ▶ pmsm_foc_motor_parameters.h
 - ▶ pmsm_foc_uCProbe_parameters.c
 - ▶ pmsm_foc_user_config.h
 - ▶ pmsm_foc_variables_scaling.h
 - ▶ ControlModules

Input XMC1302 pin setting

2

Scroll to (MCUCARD_TYPE == CUSTOM_MCU)

```

770 #elif(MCUCARD_TYPE == CUSTOM_MCU)
771 /*****
772  * CUSTOM_MCU
773  * GPIO Resources Configuration
774 *****/
775 #define TRAP_PIN P0_12
776 #define INVERTER_EN_PIN P0_11
777 #define USE_INVERTER_EN_PIN 0
778
779 #define PHASE_U_HS_PIN P0_0
780 #define PHASE_U_HS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT5
781
782 #define PHASE_U_LS_PIN P0_1
783 #define PHASE_U_LS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT5
784
785 #define PHASE_V_HS_PIN P0_2
786 #define PHASE_V_HS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT7
787
788 #define PHASE_V_LS_PIN P0_3
789 #define PHASE_V_LS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT7
790
791 #define PHASE_W_HS_PIN P0_8
792 #define PHASE_W_HS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT5
793
794 #define PHASE_W_LS_PIN P0_9
795 #define PHASE_W_LS_ALT_SELECT XMC_GPIO_MODE_OUTPUT_PUSH_PULL_ALT5
796
797 #define TEST_PIN P0_4
    
```



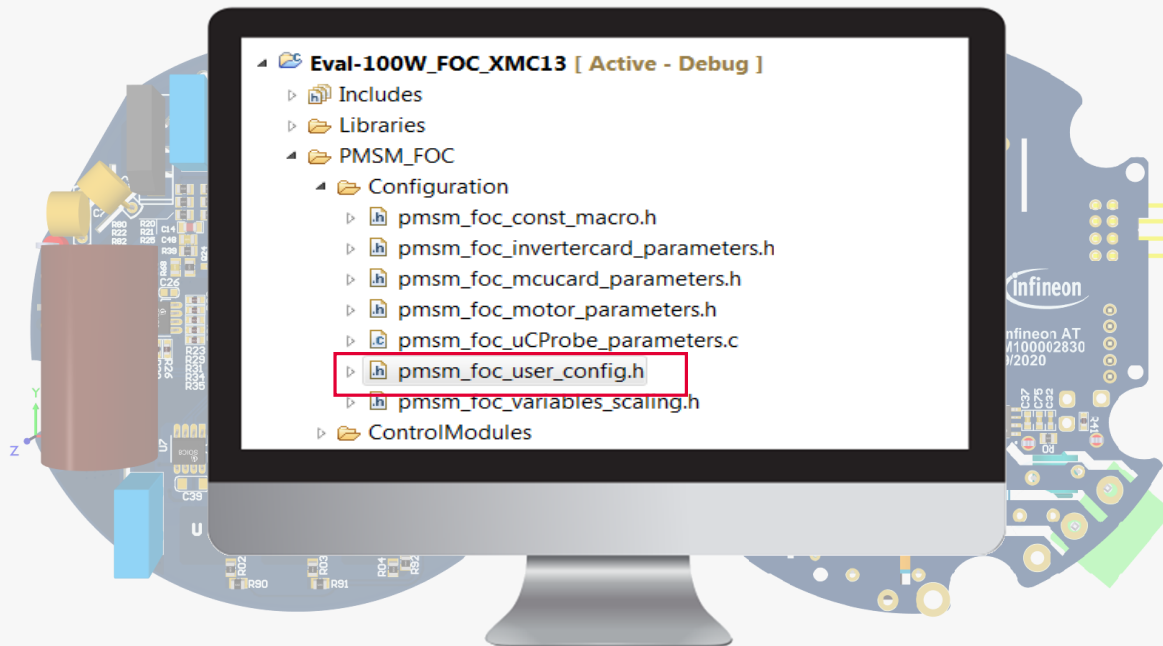
INVERTER_EN_PIN is not available on this board. Hence, the USE_INVERTER_EN_PIN is 0

*The MCU pinout setting is already set according to the EVAL_FAN_XMC_PFD7 board.
The user does NOT need to change it!*

Input motor startup: current sensing setting

1

Double click on **pmsm_foc_user_config.h**



Input motor startup: current sensing setting

2

Scroll to (MCUCARD_TYPE == CUSTOM_MCU)



```

78
79=====
80 * MACROS
81 =====
82 #define PMSM_FOC_HARDWARE_BOARD      CUSTOM_KIT          /*1. KIT_XMC1X_AK_MOTOR_001
83                                     2. KIT_XMC750WATT_MC_AK_V1
84                                     3. CUSTOM_KIT*/
85
86 /*----- Current feedback Sensing Mechanism -----
87 #define CURRENT_SENSING              USER_THREE_SHUNT_SYNC_CONV /*1. USER_SINGLE_SHUNT_CONV
88                                     2. USER_THREE_SHUNT_ASYNC_CONV
89                                     3. USER_THREE_SHUNT_SYNC_CONV*/
90
91 /*----- FOC Control and Startup Scheme (Only Select 1 Scheme at one time)
92 #define MY_FOC_CONTROL_SCHEME        SPEED_CONTROLLED_DIRECT_FOC /*1. SPEED_CONTROLLED_VF_ONLY,
93                                     2. SPEED_CONTROLLED_VF_MET_FOC
94                                     3. SPEED_CONTROLLED_DIRECT_FOC
95                                     4. TORQUE_CONTROLLED_DIRECT_FOC
96                                     5. VQ_CONTROLLED_DIRECT_FOC */
96
97 /*----- Micrium uC Probe Enable/Disable
98 #define UC_PROBE_GUI                 ENABLED                /*1. ENABLED 2. DISABLED
99
100 /*----- Reference Speed Adjustment Method
101 #define SETTING_TARGET_SPEED         MICRIUM_UC_ONLY        /*1. MICRIUM_UC_ONLY
102                                     2. BY_POT_ONLY */
  
```

The user can select 3 types of current sensing methods (as shown in green comment lines)

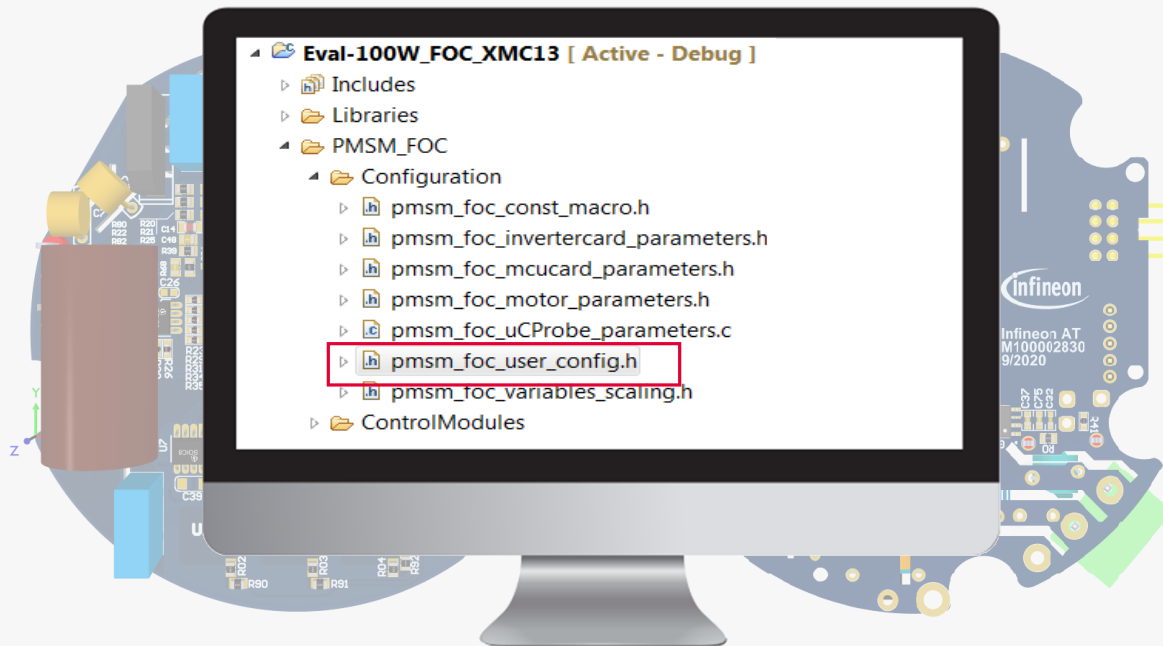
The user can select 5 types of motor control schemes (as shown in green comment lines)

3 shunt synchronous current sensing and speed controlled direct FOC startups have been selected by default. The user does NOT need to change these!

Input SVM scheme

1

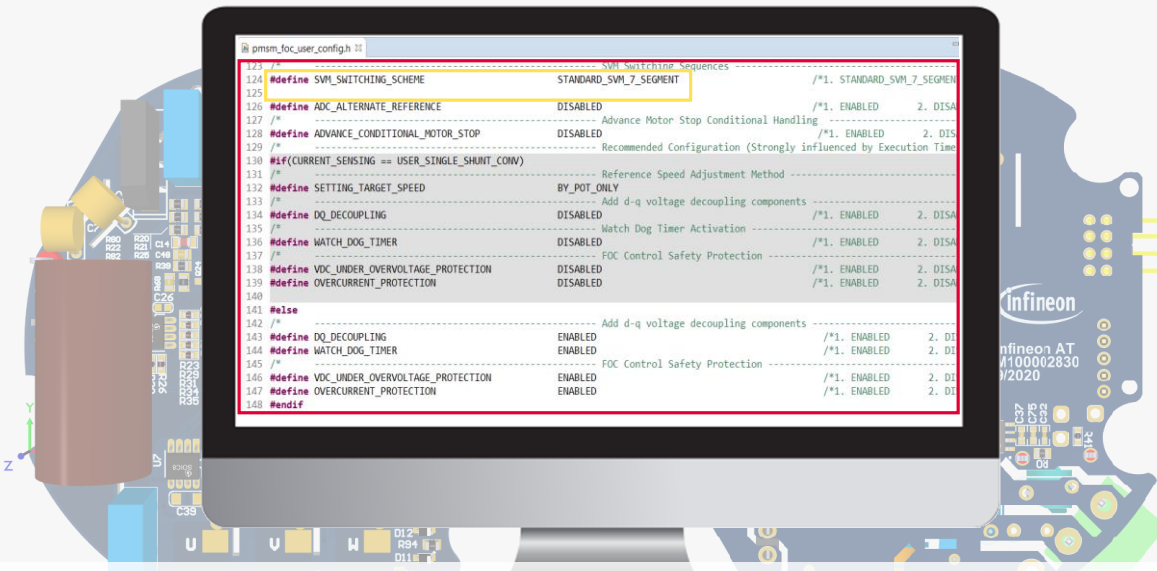
Double click on **pmsm_foc_user_config.h**



Input SVM scheme

2

The user can select 2 types of SVM scheme: 7-segment or 5-segment SVM (as shown in green comment lines)

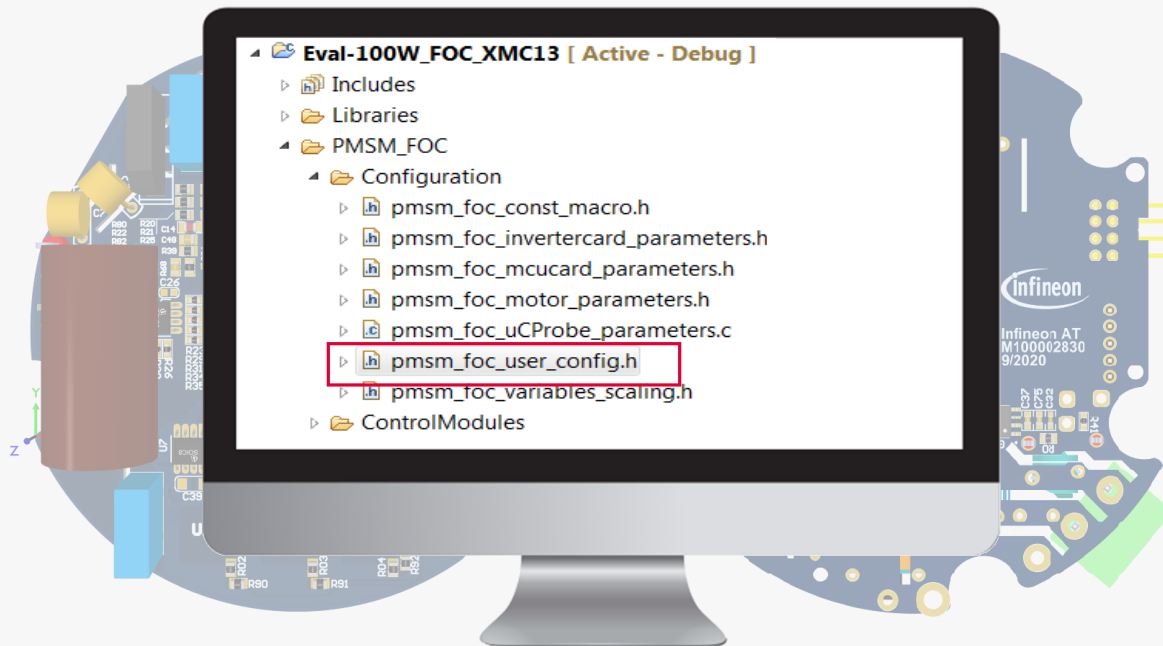


Standard 7-segment SVM is selected by default. The user does NOT need to change this!

Input current and voltage protection setting

1

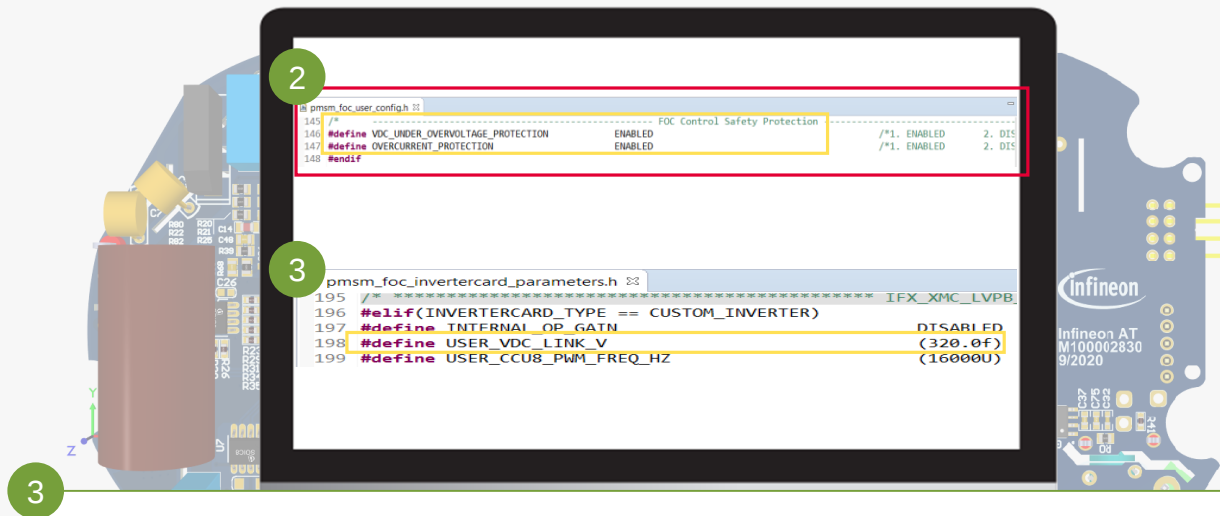
Double click on **pmsm_foc_user_config.h**



Input current and voltage protection setting

2

User can enable over-current and under-voltage protection (as shown in the green comment lines)



If the DC link voltage is <0.8 or >1.2 of `USER_VDC_LINK_V`, the PWM signal input to gate driver will go into high impedance and the motor will slowly stop

Input current and voltage protection setting

4

If the average current flow through the DC link shunt resistor R57 is $> \text{USER_IDC_MAXCURRENT_A}$, the reference speed will reduce until the current is $< \text{USER_IDC_MAXCURRENT_A}$

i

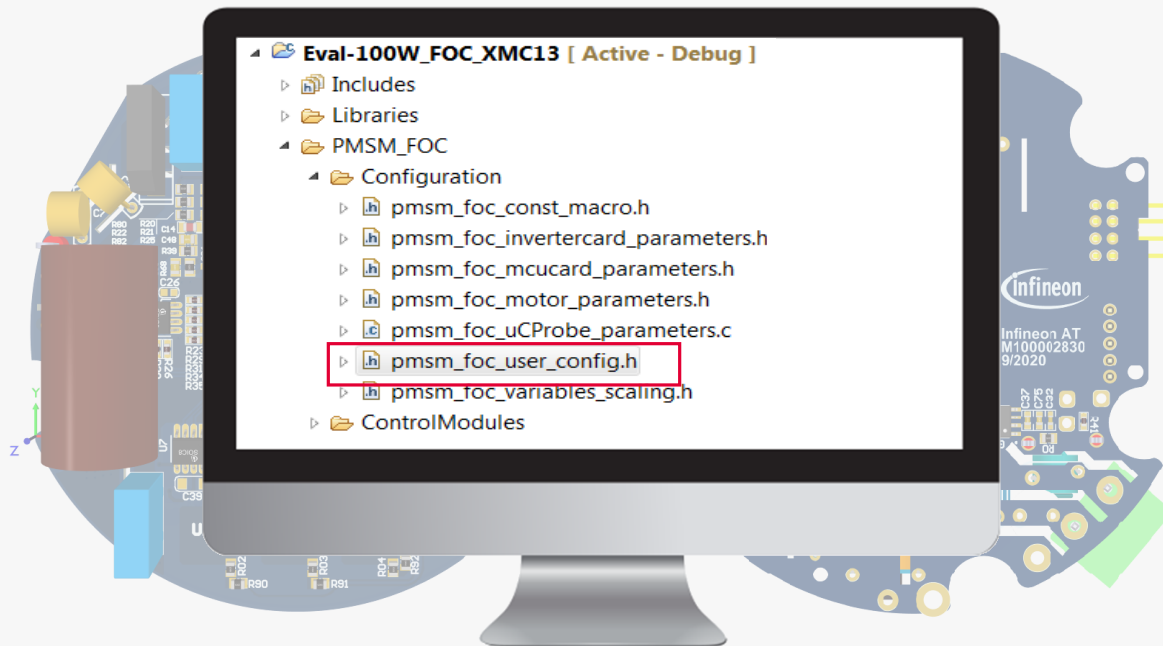
*Under-voltage and over-current protection have been selected by default.
The user does NOT need to change this!*

USER_VDC_LINK_V and USER_IDC_MAXCURRENT_A values might need to change depending on user motor setting

Input speed control setting

1

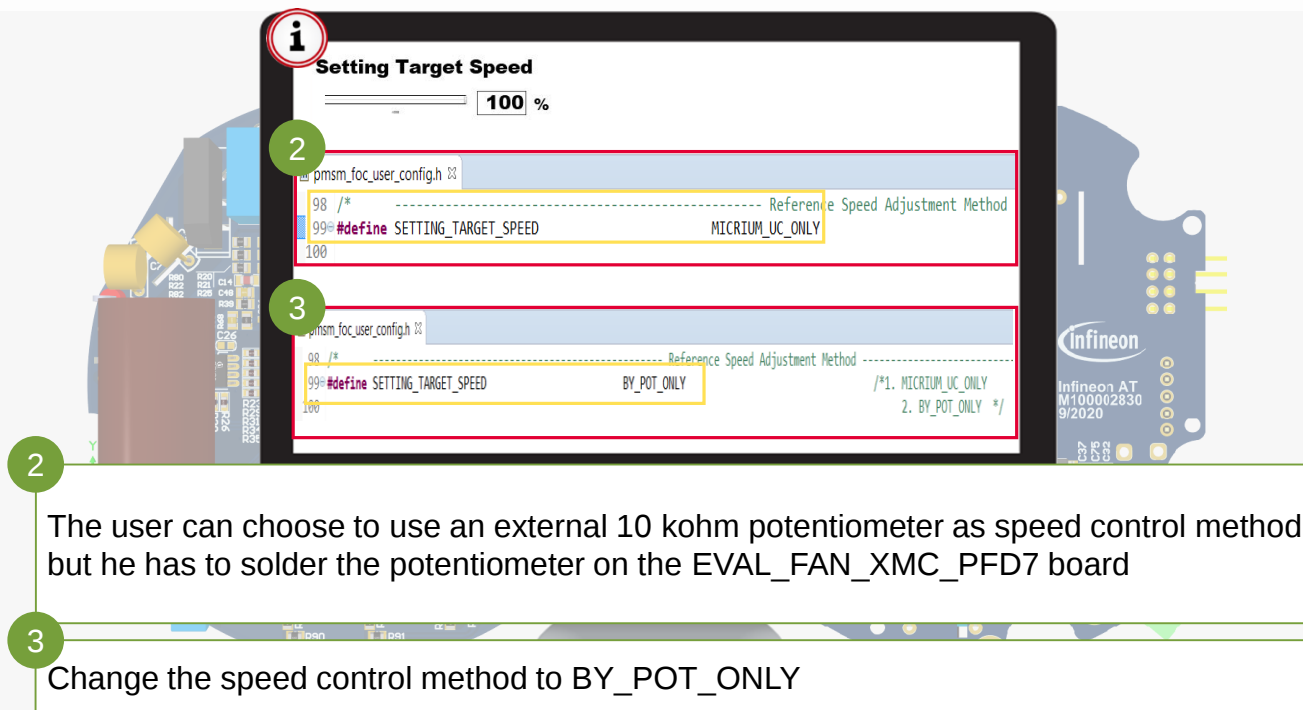
Double click on **pmsm_foc_user_config.h**



Input speed control setting



By default, the speed control method is using μ C/Probe™ GUI's speed slider



Setting Target Speed

100 %

2

```

pmsm_foc_user_config.h
98 /* ----- Reference Speed Adjustment Method -----
99 #define SETTING_TARGET_SPEED MICRUM_UC_ONLY
100

```

3

```

pmsm_foc_user_config.h
98 /* ----- Reference Speed Adjustment Method -----
99 #define SETTING_TARGET_SPEED BY_POT_ONLY /*1. MICRUM_UC_ONLY
100 2. BY_POT_ONLY */

```

2

The user can choose to use an external 10 kohm potentiometer as speed control method but he has to solder the potentiometer on the EVAL_FAN_XMC_PFD7 board

3

Change the speed control method to BY_POT_ONLY

Compile and download the code

1

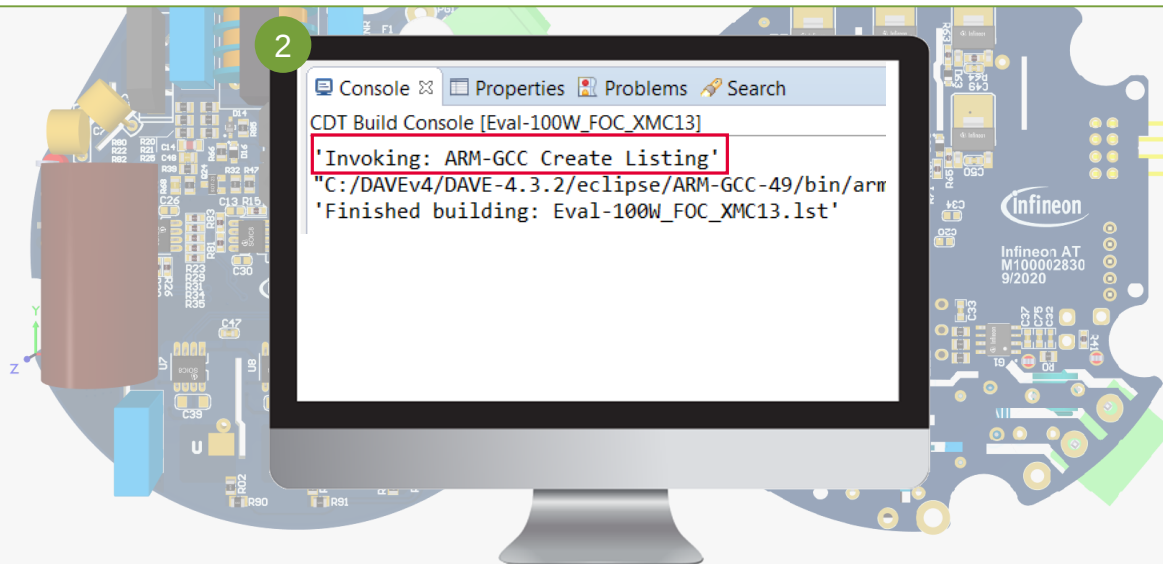
Click **Build Active Project**



2

Check **Eval-100W_FOC_XMC13.lst** created

2



Compile and download the code

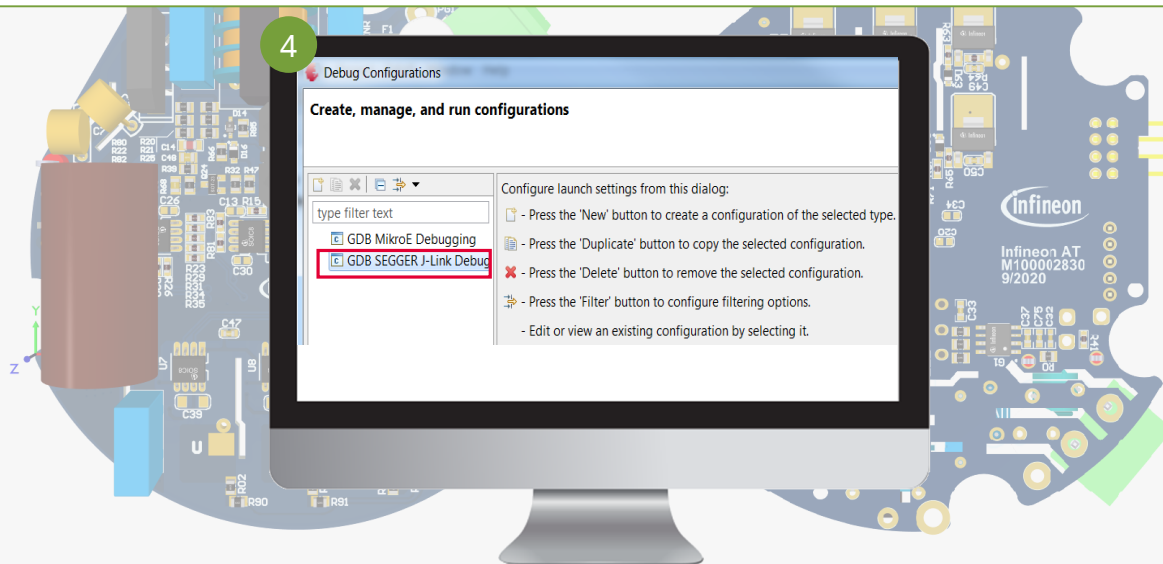
3

Click **Debug Configuration**



4

Select **GDB SEGGER J-Link Debugging**



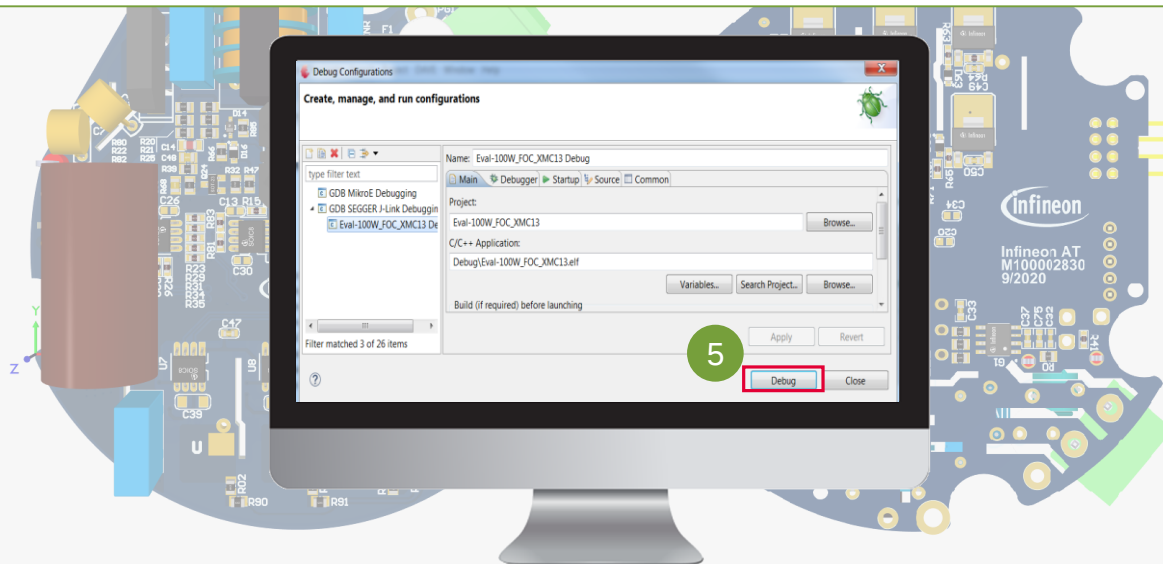
Compile and download the code

5

Click the **Debug** button to download the code

6

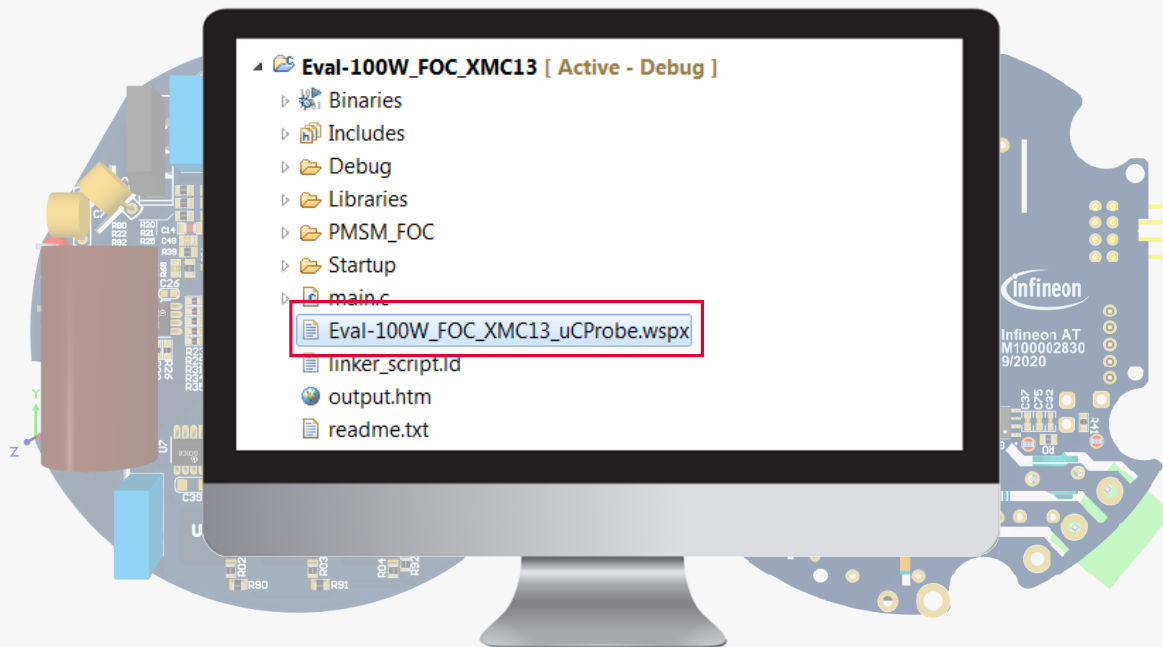
Click the **Resume** button to start the application



Using μ C/Probe™ GUI

1

Open the *.wspx μ C/Probe™ project by double click on the *.wspx file



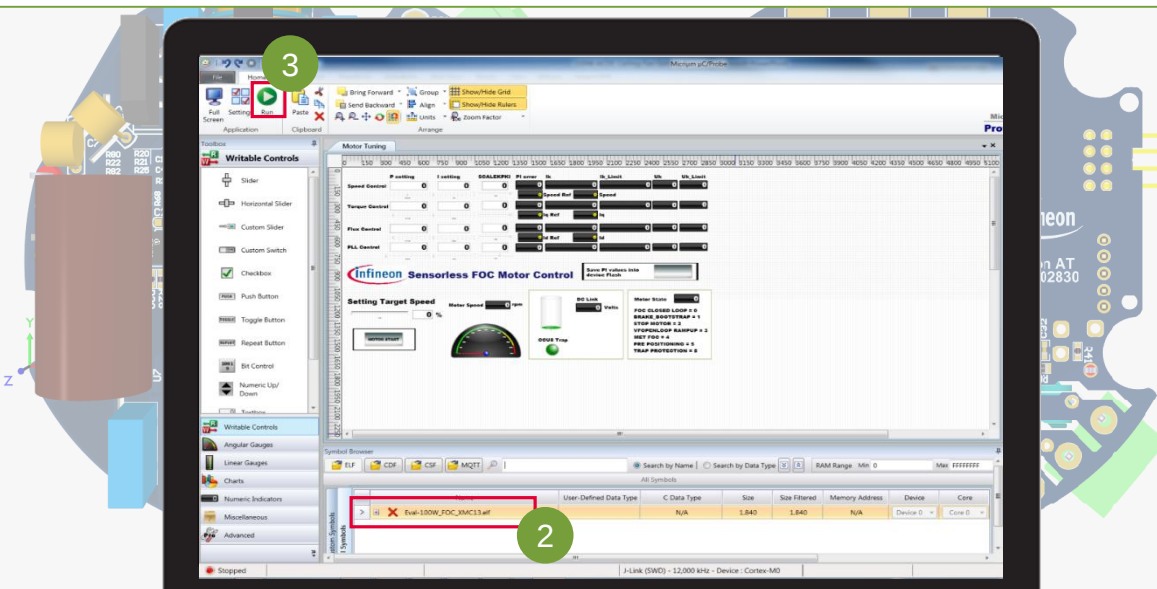
Using μ C/Probe™ GUI

2

Check the *.elf file is attached to μ C/Probe™ project

3

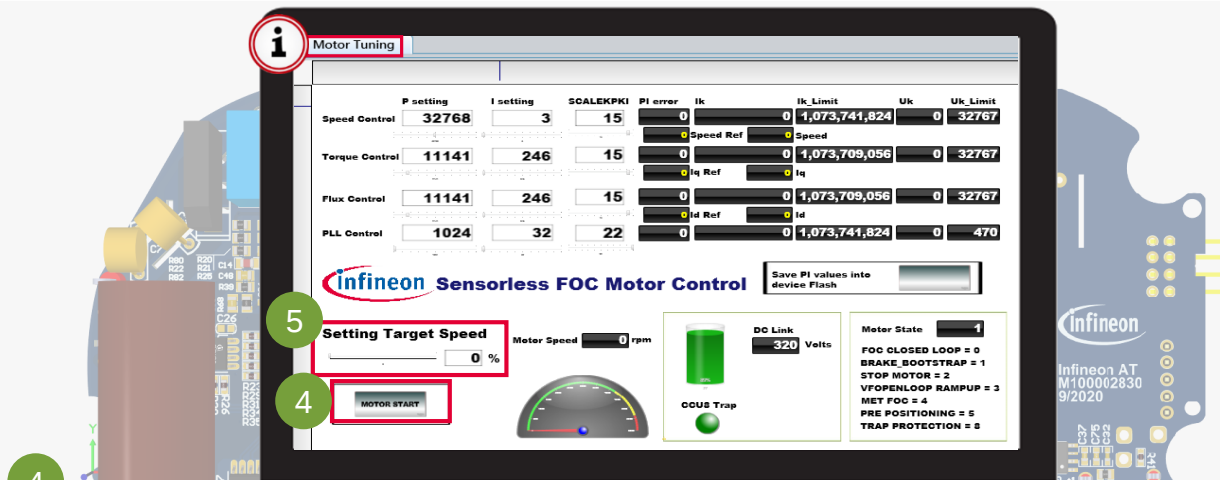
Click the **Run** button



Using μ C/Probe™ GUI



The default K_p , K_i values from the `pmsm_foc_motor_parameters.h` file are automatically displayed in the Motor Tuning page



4

Click the **MOTOR START** button

5

Then use the target speed slider or key in directly to set the percentage of maximum speed desired. The motor will start to spin

Using μ C/Probe™ GUI

6

Modify the K_p , K_i and **SCALEKPKI** values of the **Speed Control** and **PLL Control** loops to get optimum motor behaviour.
The default K_p , K_i and **SCALEKPKI** values for Torque Control and Flux Control normally do not need change

7

Type in the desired values and hit **Enter**

8

Increasing the **SCALEKPKI** by 1 will reduce the gain by half

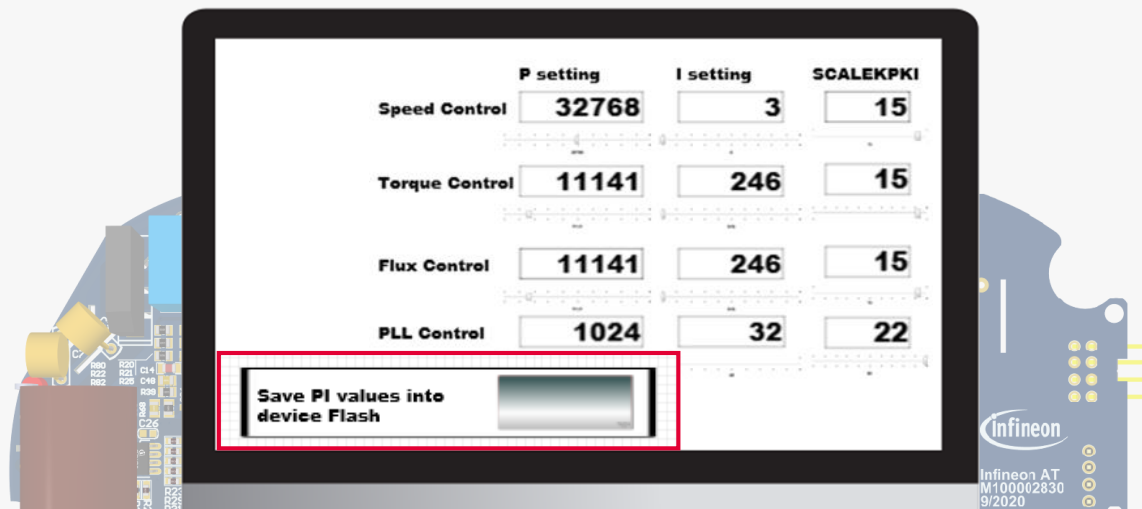


Under the **P setting** column are the K_p value for the 4 control loops

Under the **I setting** column are the K_i value for the 4 control loops

	P setting	I setting	SCALEKPKI
Speed Control	32768	3	15
Torque Control	11141	246	15
Flux Control	11141	246	15
PLL Control	1024	32	22

Using μ C/Probe™ GUI



9

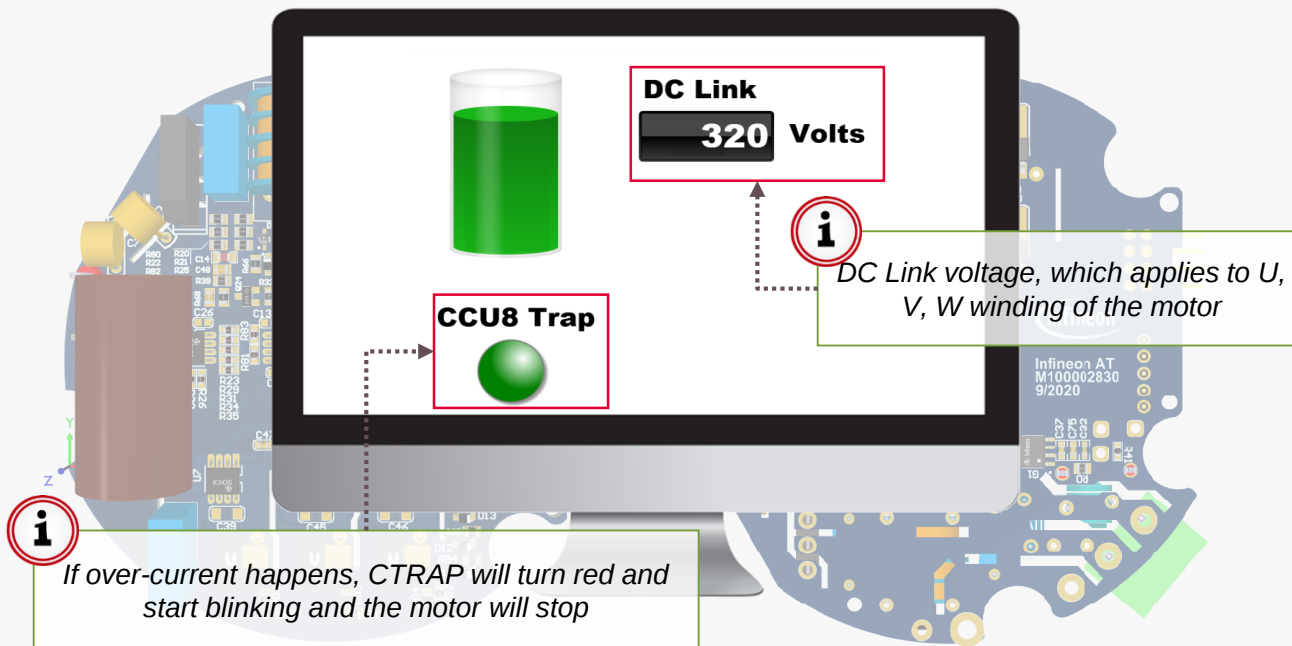
Click this button to save K_p , K_i , SCALEKPKI values to Flash.
The motor will stop



This saving function only works if the motor is rotating normally

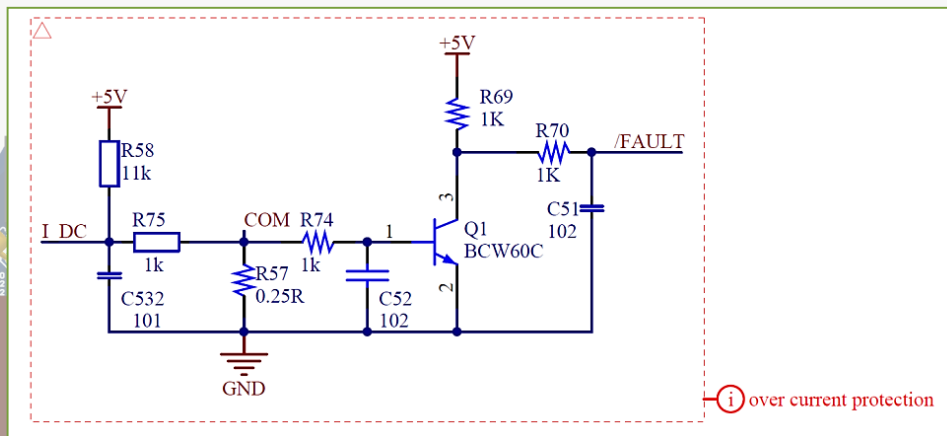
Using μ C/Probe™ GUI

Over-current and under-voltage protections



Using $\mu\text{C}/\text{Probe}^{\text{TM}}$ GUI

Over-current and under-voltage protections



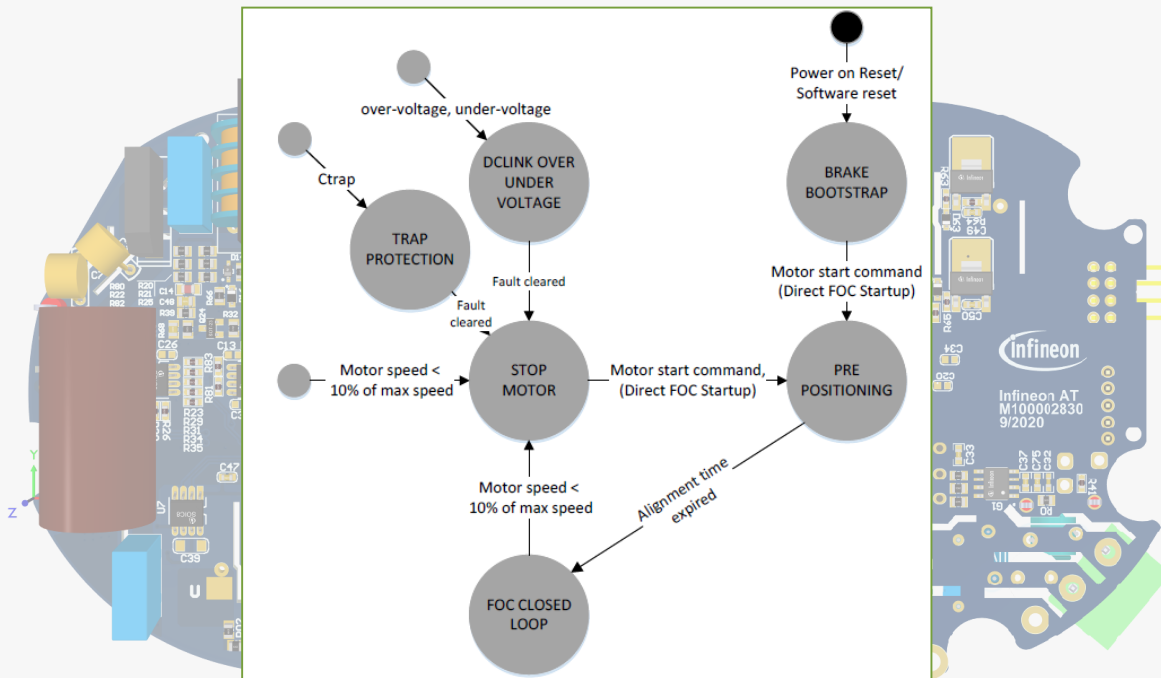
On the Eval-100W_FOC board, the $V_{BE(th)}$ of BCW60C is 0.7 V

The trip current I_{trip} is $0.7/0.25=2.8$ A

When the 3-phase motor currents exceed its trip current, the CTRAP signal is activated and over-current detected

Using μ C/Probe™ GUI

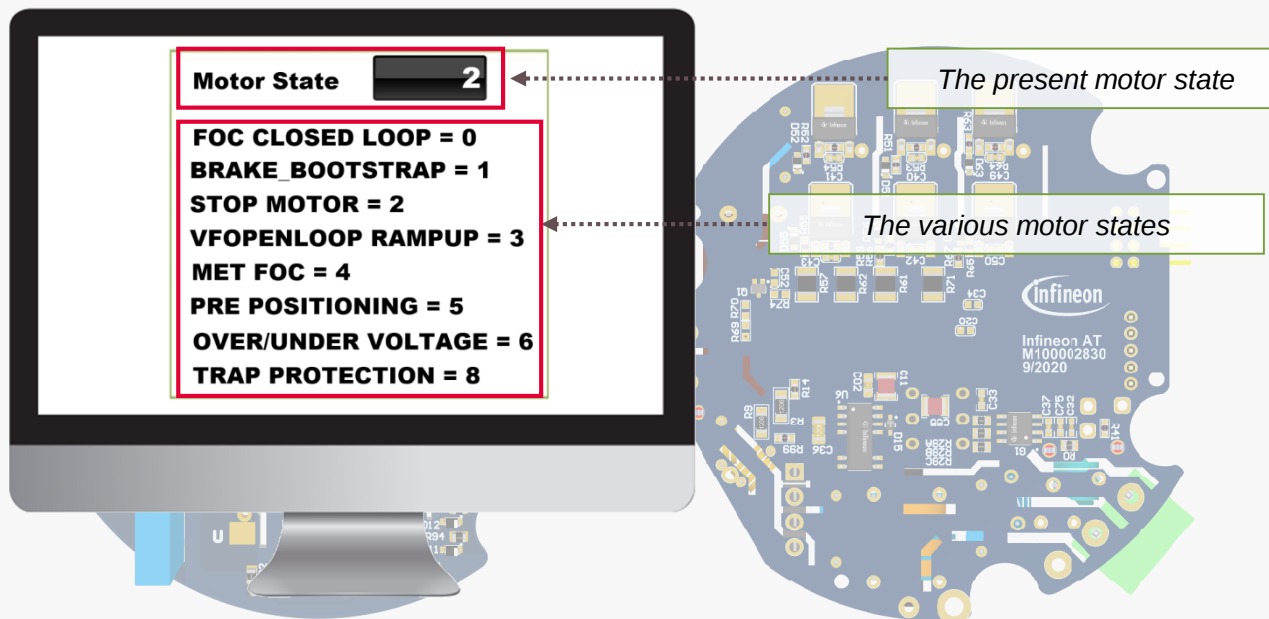
PMSM FOC state machine panel



Direct FOC startup state machine diagram

Using μ C/Probe™ GUI

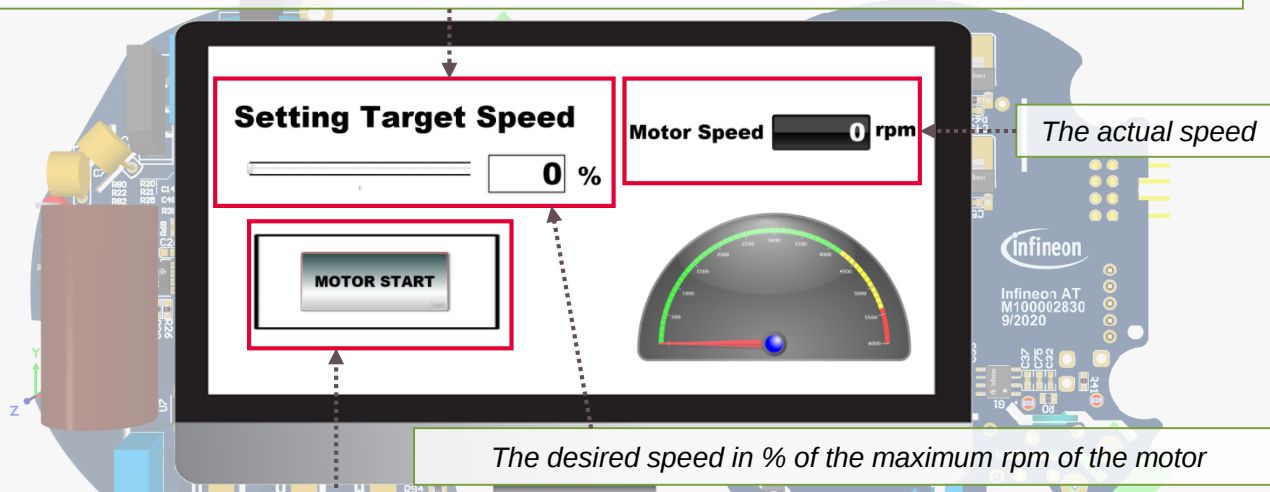
PMSM FOC state machine panel



Using μ C/Probe™ GUI

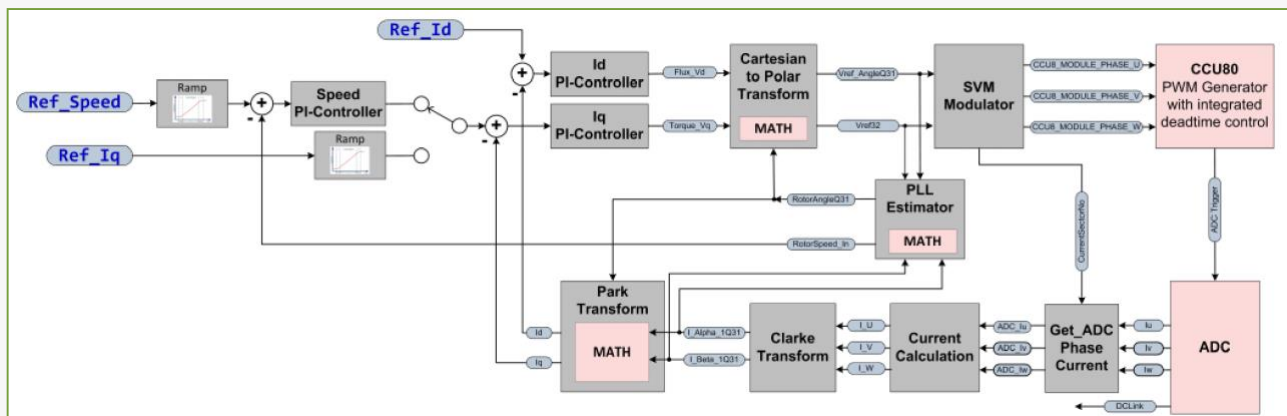
Motor speed, motor start/stop control panel

Use the slider to set the desired speed (% of motor maximum speed in rpm).
The motor should start to run if **MOTOR START** is clicked



1) Click this **MOTOR START** button. 2) Then, set the desired speed for the motor to start. The wording on the button will change to **MOTOR STOP**. 3) Click this button to stop the motor

Tuning of K_P , K_I value using the $\mu\text{C}/\text{Probe}^{\text{TM}}$

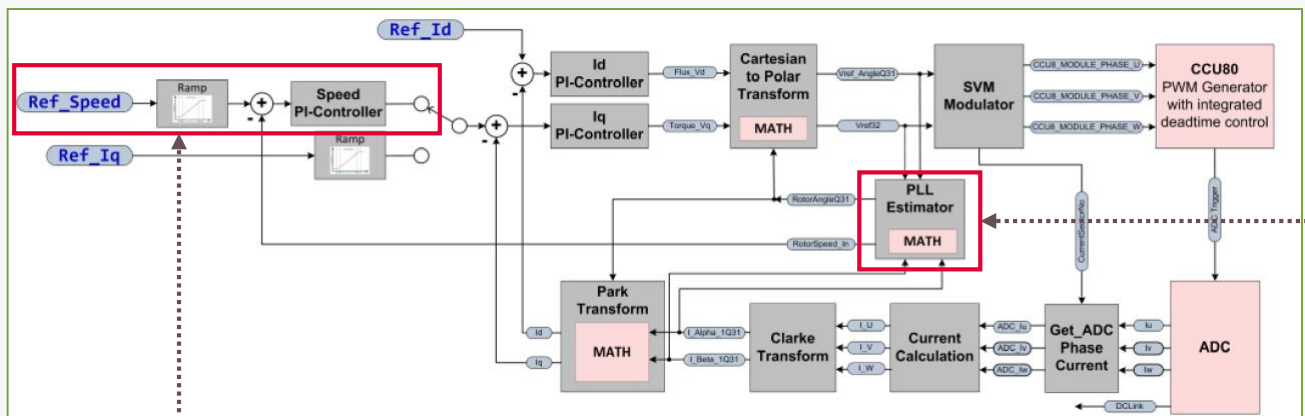


PMSM FOC block diagram



The FOC software starts the motor directly with **Speed Control Direct FOC control** scheme (by default setting)

Tuning of K_P , K_I value using the μ C/Probe™



PMSM FOC block diagram



Remove the Speed control here if using
TORQUE_CONTROLLED_DIRECT_FOC scheme

Tune the PLL control loop here

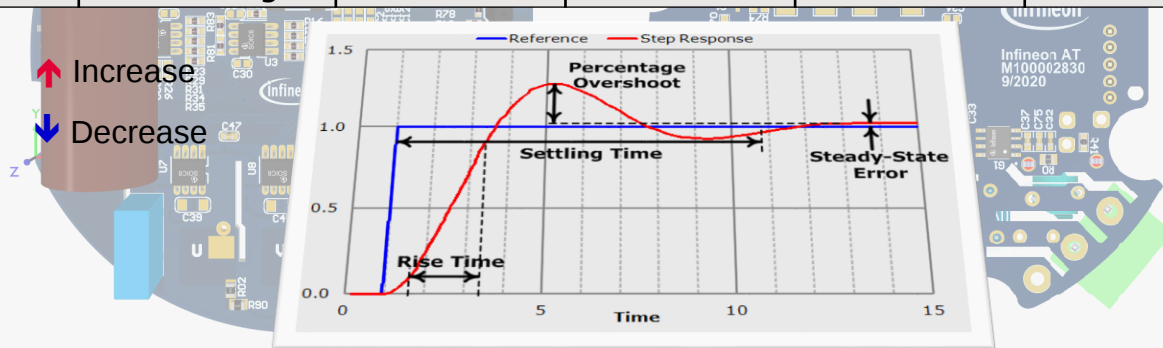
If the **MOTOR START** button was clicked and the motor does not spin after the desired speed slider is set to 30%, for example, the user should change the **My_FOC_CONTROL_SCHEME** in `pmsm_foc_user_config.h` to **TORQUE_CONTROLLED_DIRECT_FOC**, re-compile and reload

So that the user can tune the K_P , K_I and SCALEKPKI of PLL, control loop first

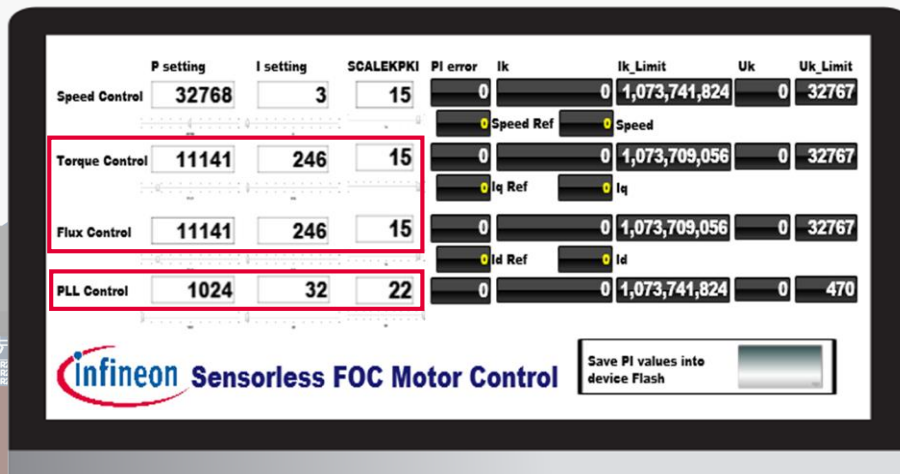
Tuning of K_P , K_I value using the $\mu C/Probe^{\text{TM}}$

Effects of increasing proportional gain K_P or integral gain K_I of PI controller independently

	Gain change	Effects on step response characteristics			
		Rise time	Overshoot	Settling time	Steady-state error
1	$K_P \uparrow$ K_I unchanged	$\downarrow$ 😊	$\uparrow$ ☹️	Minor Change 😊	$\downarrow$ 😊
2	$K_I \uparrow$ K_P unchanged	$\downarrow$ 😊	$\uparrow$ ☹️	$\uparrow$ ☹️	Eliminate 😊



Tuning of K_P , K_I value using the $\mu C/Probe^TM$



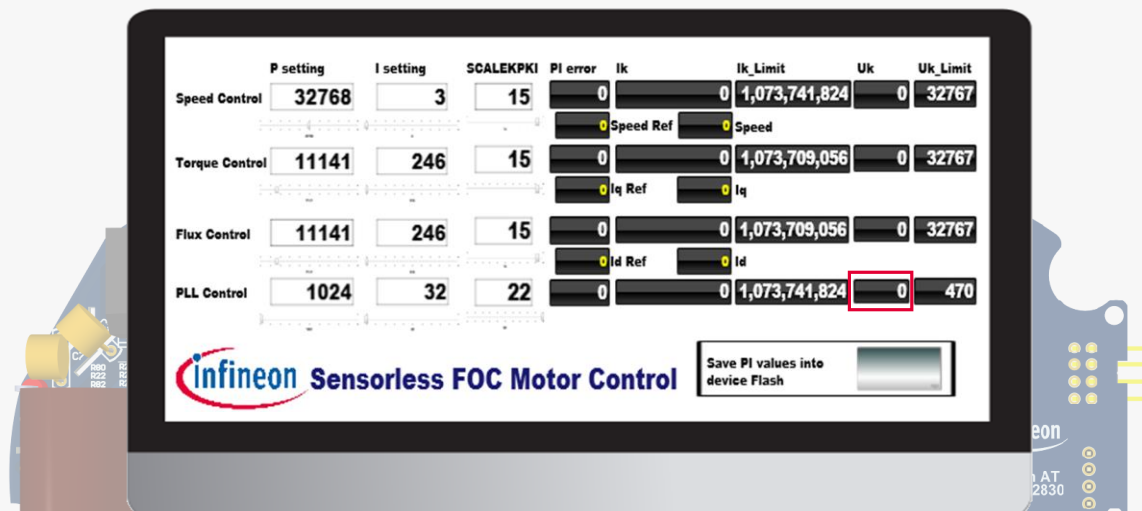
1

The P setting, I setting and SCALEKPKI values for Torque and Flux PI Controllers are calculated from the physical motor and system parameters, and typically don't need to be tuned in the first iteration

2

The PLL Control parameters K_P , K_I , SCALEKPKI should start to be modified if the motor cannot startup in FOC closed-loop smoothly

Tuning of K_P , K_I value using the $\mu C/Probe^TM$



3

The target speed slider becomes the target torque slider under TORQUE_CONTROLLED_DIRECT_FOC mode

4

Make sure the Uk value of PLL control does not hit its Uk_Limit while tuning the PLL control parameters

Tuning of K_P , K_I value using the $\mu\text{C}/\text{Probe}^{\text{TM}}$

	P setting	I setting	SCALEKPKI
Speed Control	32768	3	15
Torque Control	11141	246	15
Flux Control	11141	246	15
PLL Control	1024	32	22

↑ this value by 1 will ↓ gain of Speed controller by half

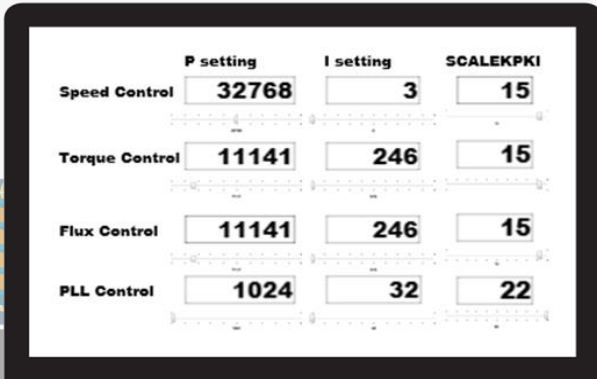
PI gains: $K_p = \frac{P \text{ setting}}{2 \text{SCALEKPKI}}$, $K_i = \frac{I \text{ setting}}{2 \text{SCALEKPKI}}$

↑ this value by 1 will ↓ gain of PLL estimator controller by half

3

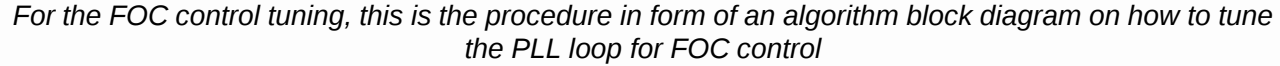
If the motor does not spin in FOC close loop, ↑ the SCALEKPKI of PLL Control and check the motor behavior. If the motor starts to move slowly, ↑ the SCALEKPKI further. Else, ↓ the SCALEKPKI.

Tuning of K_P , K_I value using the $\mu C/Probe^TM$



	P setting	I setting	SCALE KPI
Speed Control	32768	3	15
Torque Control	11141	246	15
Flux Control	11141	246	15
PLL Control	1024	32	22

- 4 After the motor is able to rotate smoothly under TORQUE_CONTROLLED_DIRECT_FOC, remember to save the parameters by clicking the **Save PI** button
- 5 Change the My_FOC_CONTROL_SCHEME in pmsm_foc_user_config.h to SPEED_CONTROLLED_DIRECT_FOC, re-compile and reload the code
- 6 Use the same tactic to tune the Speed Control parameters. No need to modify the PLL control parameters

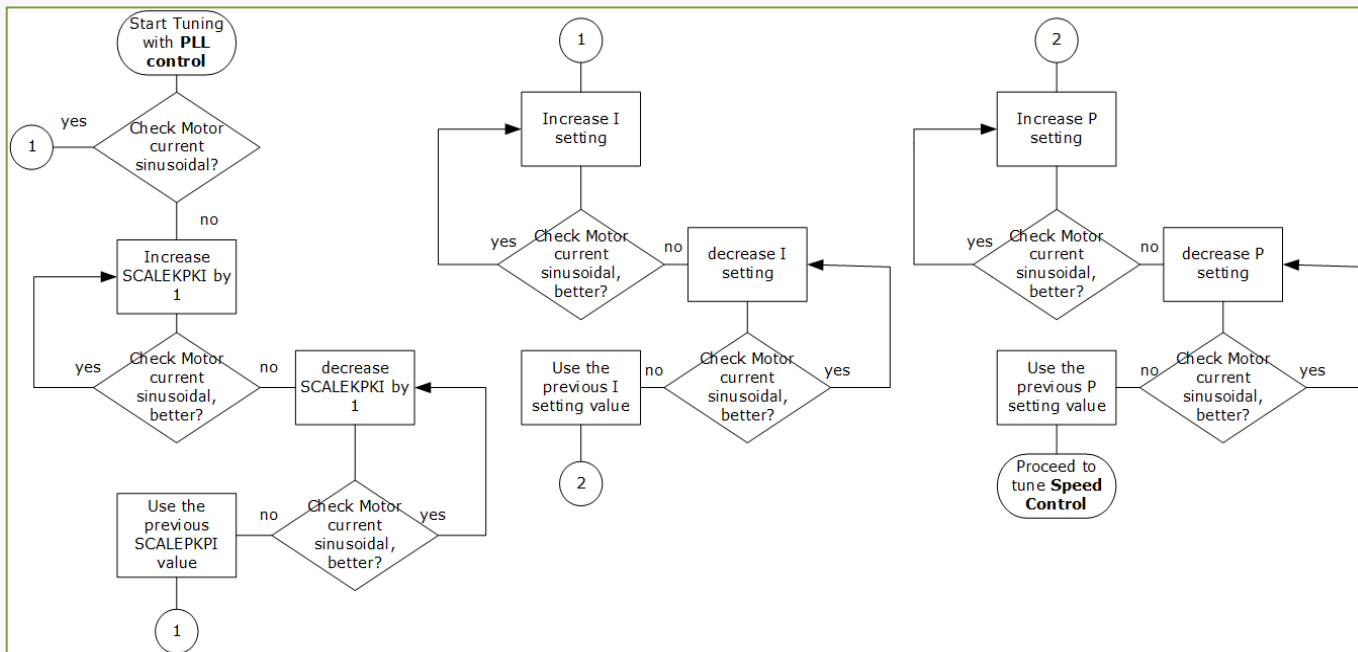


General hints on tuning of SCALEPKPI, P, I value using the μ C/Probe™



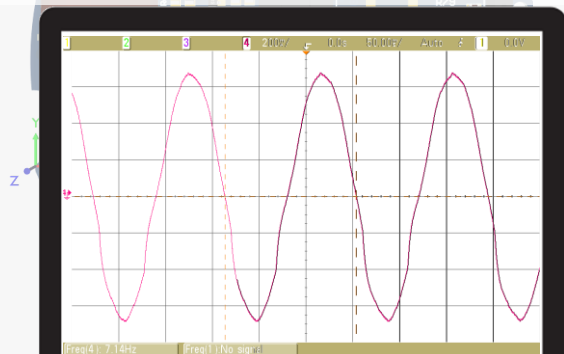
For Speed Control tuning the user should follow the same flow

Typically, only these 2 PI control loops need to be tuned with the FOC software for EVAL_FAN_XMC_PFD7 kit

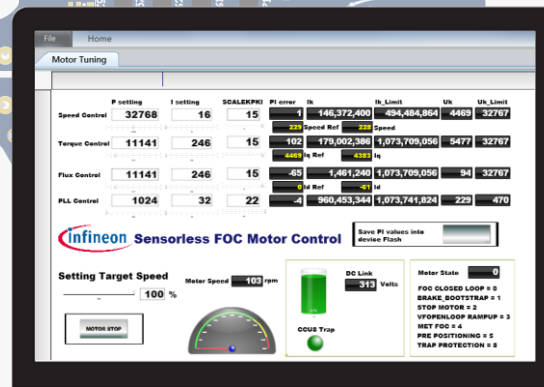


Testing result with a ceiling fan

- › AC input: 230 V/50 Hz
- › Ceiling Fan motor specification:
 - Resistance/phase: 23 ohms
 - Inductance/phase: 65 mH
 - Pole pairs: 4
 - Max. speed: 105 rpm
- › Power consumption: 35 W @ 105 rpm



The current waveform of phase U at max. speed



Agenda

1 Introduction to fan driver evaluation board

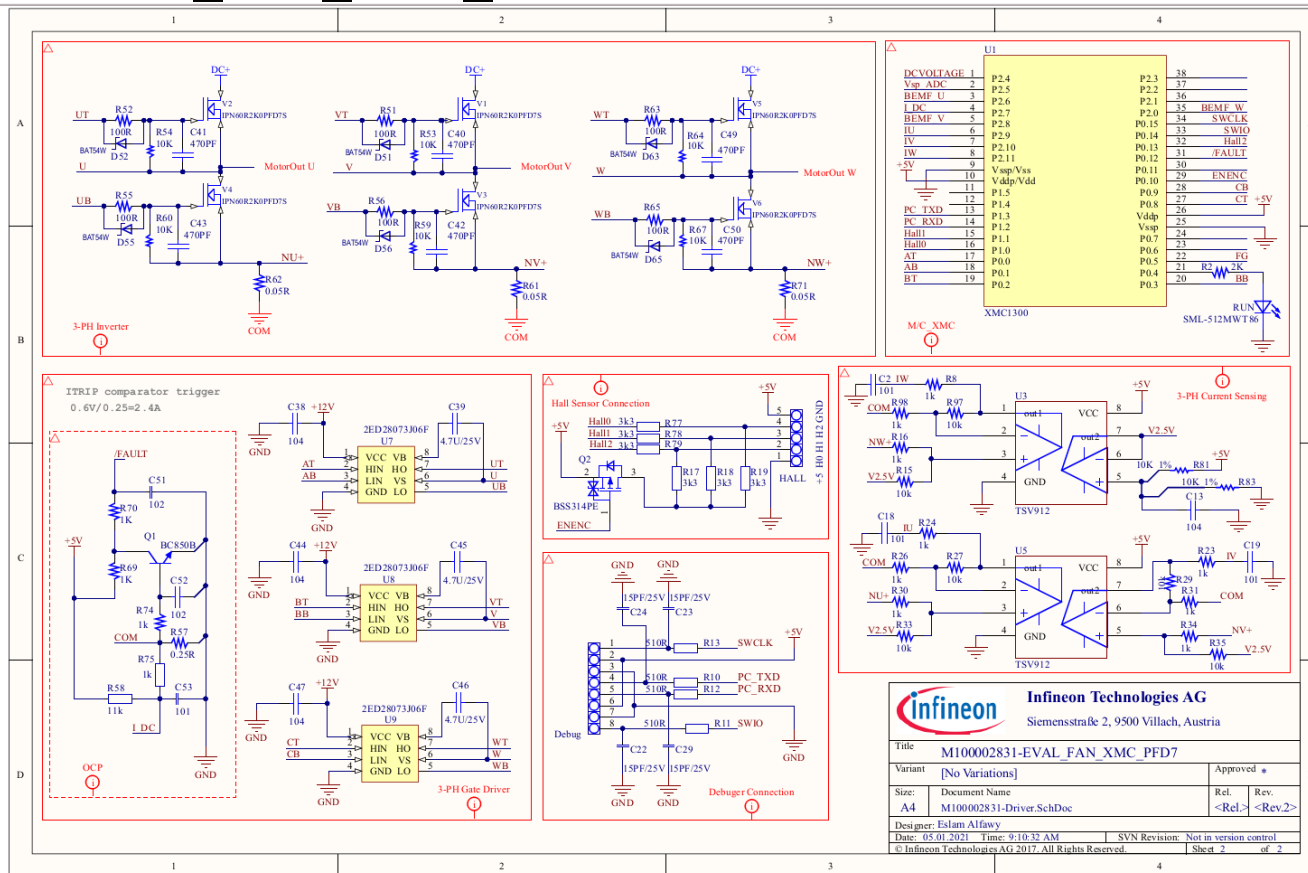
2 Hardware and software

3 Tools

4 Getting started

5 Resources

Schematic of EVAL_FAN_XMC_PFD7 board





Support material:

Collaterals and brochures Document Info	› Product briefs › Selection guides › Application brochures › Presentations › Press releases, ads	› www.infineon.com/XMC › www.infineon.com/PFD7 › www.infineon.com/COOLSET › www.infineon.com/motorcontrol
Technical material Tools Evaluation Board	› Application notes › Technical articles › Simulation models › Datasheet, MCDS files › PCB design data	› www.infineon.com/XMC › Kits and Boards › DAVE™ › Software and Tool Ecosystem
Videos Play	› Technical videos › Product information Videos	› Infineon Media Center › XMC Mediathek › How to measure motor parameters
Contact Support	› Forums › Product support	› Infineon Forums › Technical Assistance Center (TAC)

Glossary abbreviations

Abbreviation	Full name
ADC	Analog-to-Digital Converter
FOC	Field-Oriented Control
PI Controller	Proportional–Integral Controller
PMSM	Permanent Magnet Synchronous Motor
PWM	Pulse Width Modulation
SVM	Space Vector Modulation
XMC™	Cross-Market Microcontrollers

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