

STM32 PMSM SDK 5.2 training

T.O.M.A.S. team





ST MC Timebase & Interrupt structure



NVIC Configuration 1/2

STM32 NVIC (Nested Vectored Interrupt Controller) priority group configuration is NVIC_PriorityGroup_3

Priorities used in MC Library:

A7)	IRQ	Pre-emption priority
4, N	TIM1 UPDATE	0
3, M	TIM8 UPDATE	0
K M3	DMA	0
rtex	RESERVED	1
Co	ADC	2
IS (USART (UI LIB)	3
32 Othe	TIMx (General, for speed sensor decoding, Hall, Encoder etc.)	3
TM	TIM1 BRK	4
0)	SYSTICK	4

10+)	IRQ	Pre-emption priority
X N	TIM1 UPDATE	0
orte	DMA	0
C (C	ADC	1
32F0xxx	TIMx (General, for speed sensor decoding, Hall, Encoder etc.)	2
TM3	SYSTICK	2
S	USART (UI Lib)	3



NVIC Configuration 2/2

, M4, M7)	COMPONENT	Pre-emption priority
ex M3,	MC LIBRARY	0,1,2,3,4
s (Cort	TIMEBASE (SYSTICK)	4
STM32 Others	USER	5,6,7

rtex M0+)	COMPONENT	Pre-emption priority
cx (Col	MC LIBRARY	0,1,2,3
32F0x)	TIMEBASE (SYSTICK)	2
STM:	USER	3



Timebase / clocks

A Timebase is needed to clock the MC Application The demo Timebase.c can be considered an example or used as it is

SysTick timer (main .c)



3/F4	Task name	Main role	Frequency (Period)
/F1/F2/F3	Safety task	Over voltage management Switch off PWM if fault occurs User ADC conversions	2kHz (500µs)
STM32F0	Medium frequency task	Execute the speed regulation loop State machine management	Speed Regulator Execution Rate (typical: 1 KHz) period must be a multiple of 500 µs

5

MC Application and user - Tasks

Safety task, medium frequency task, UI task and User task use Systick as time base. •

Scope	Name Main role		Priority	Frequency (Period)
	High frequency task	Execute the current regulation loop		PWM frequency FOC rate
tasks	Safety task	ty task Over voltage management Switch off PWM if fault occurs User ADC conversions		2kHz (500µs)
MC	Medium frequency task	Execute the speed regulation loop State machine management	SysTick	Speed Regulator Execution Rate (typical: 1 KHz) period must be a multiple of 500 µs
User tasks	User task code	User code	Main	Deepens on User code



MC FW library features list

available in Motor Control SDK v5.x (X-CUBE-MCSDK)

	STM32 series	F0	F1	F3	F4	F7 (v5.3)	L4 (V5.3)
•	1 Shunt	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	3 Shunt	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Hall sensors	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Encoder	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	ICS	×	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Flux weakening	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	MTPA	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Startup On the fly	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Sensorless (PLL / Cordic)	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Feed Forward	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark	\checkmark
•	Single FOC (max. FOC freq.*)	12 kHz	11/23 kHz	30 kHz	50 kHz	\checkmark	\checkmark
•	Dual FOC (max. FOC freq.*)	×	20 kHz / 🗴	23 kHz	45 kHz	√/x	×



MC SDK v5.x – Perf. Measurements

PWM set at 20KHz / 10KHz FOC

			MCSDK4.3 MCSDK5.1.1									
MCU	Nb Motor	Config	CPU Workload (%)	Total Code size (Kb)	MC Lib (Kb)	STD Lib (Kb)	CPU Workload (%)	Grand Total Code Size (+ HAL) (Kb)	Grand Total Code Size (+ LL) (Kb)	MC Lib (Kb)	HAL (Kb)	LL (Kb)
F072RB	Single	1x Shunt	52.0	19.3	17.3	2.0	46.4	18.0	16.9	13.1	5.2	3.2
F072RB	Single	3x Shunt	49.0	19.6	17.7	2.0	42.6	17.1	16.3	12.5	4.6	3.2
F303RE	Single	1x Shunt	20.0	21.2	18.2	3.0	20.4	22.4	19.9	14.9	8.1	4.4
F303RE	Single	3x Shunt	18.5	23.0	20.6	2.4	17.8	23.4	19.3	16.1	7.7	2.6
F446RE	Single	1x Shunt	10.5	20.1	17.7	2.4	10.2	20.1	19.0	14.7	5.5	3.3
F446RE	Single	3x Shunt	8.9	17.8	15.8	2.0	8.2	18.2	15.7	13.2	4.8	2.0
F303VE	DUAL	3x Shunt	38.9	25.2	17.4	2.4	38.2	25.5	21.8	18.6	7.9	2.6
F415ZG	DUAL	3x Shunt	23.1	19.9	17.9	2.0	18.3	19.6	17.7	15.2	4.8	2.0





Braking & overvoltage handling



Brake strategies

- Unless you are using a power system with regenerative capabilities, your inverter bulk capacitors will be charged if:
 - The six inverter switches are opened and the motor is running at a speed higher than the nominal one
 - The control tries to brake
- Different ways can be utilized to dissipate the motor kinetic energy, in particular:
 - Shorting motor windings
 - Brake resisitor
 - HFI active control at zero speed
 - DC vector



Shorting motor windings

- Not supported by the library, it could be implemented with STM32 (TIM1 configured so that low side switches are turned on when the MOE bit is reset)
- Shorting the motor winding, the motor current path does not go through the bulk capacitor and flow only inside the motor phases
- Steady state ISC is limited by motor inductance:

$$I_{SC} = \left| \frac{K_e \cdot \omega_r}{R_s + j \omega_r L_S} \right| = \frac{K_e}{\sqrt{\frac{R_s^2}{\omega_r^2} + L_s^2}}$$

 Warning: during transient a higher current can flow. L6386 overcurrent must be properly sized to avoid forcing the low side switches turn-off from gate drivers



Brake resistor

- Acts by sinking current from DC bus
- Additional hardware to be soldered when using MB459



MANDATORY TO BE USED IN FIELD WEAKENING OPERATIONS AT HIGH VOLTAGE



Over voltage management



No over voltage FAULT is generated when BRAKE is defined



FAULT definitions

- Over-voltage, acts above OV_VOLTAGE_THRESHOLD_V (drive_parameters.h) only if BRAKE is not defined
- Under-voltage, acts below UD_VOLTAGE_THRESHOLD_V (drive_parameters.h)
- Over-temperature, acts below OV_TEMPERATURE_THRESHOLD_C, hysteresis is specified by OV_TEMPERATURE_HYSTERESIS_C (drive_parameters.h)
- **Start-up failure**, used only in sensorless and HFI, acts when speed ramp is finished and observer did not pass the start-up validity tests
- Speed feedback, occurs when too many errors have been observed in speed measurement (variance threshold, b-emf size, Hall time-out or invalid input) – can be caused by noise in current measurement and b-emf reconstruction, speed PID oscillations, too high cut-off frequency
- Over-current, detected by BKIN, BKIN2 input





Advanced function



Open Loop mode

- Activated by defining the macro OPEN_LOOP_FOC in "drive_params.h" together with other parameters
- In Open Loop mode the library generates rotating field, useful i.e. for ACIM motor testing
- Beware of initial voltage, the current at the beginning may be very high: Vol/(2 * Rs)

Part of file "Drive parameters.h" /************************************	*****	***/
#define BUS_VOLTAGE_READING	ENABLE	
#define TEMPERATURE_READING	DISABLE	
#define OPEN LOOP FOC	ENABLE	/*!< ENABLE for open loop */
#define OPEN_LOOP_VOLTAGE_d	8000	/ *!< Three Phase voltage amplitude in s16 format */
#define OPEN_LOOP_SPEED_RPM	100	/*!< Final forced speed in rpm */
#define OPEN_LOOP_SPEED_RAMP_DURATION_MS	1000	/*!< 0-to-Final speed ramp duration */
#define OPEN_LOOP_VF	ENABLE	/ *!< TRUE to enable V/F mode */
#define OPEN_LOOP_K	44	/*! Slope of V/F curve expressed in s16 Voltage for each 0.1Hz of ecchanical frequency increment. */
#define OPEN_LOOP_OFF	4400	/*! Offset of V/F curve expressed in s16 Voltage applied when frequency is zero. */



Inrush current limiter 17

- Blocks power stage overcurrent when charging bulk capacitors
- Defined in MCWB, Power stage
- Activated at start-up, deactivated and re-activated on voltage thresholds from Vbus measurement





When? & How?

- Allows start of FOC in sensor-less while motor already turns (e.g. air-con fans, pumps)
- Implies zero amplitude on Iq, Id and waits for observer lock.
- If such start-up fails, then normal alignment and start-up are required



Why is it needed in some applications?

- When freewheeling, the outdoor unit fan is exposed to wind, thus it can rotate – even very fastly – in both directions.
- Should the direction be positive (the one that is applied to maximize heat exchange) or negative, in any case the motor drive
 - in sensorless mode (open-loop startup)
 - can't be started efficiently:





The New Algorithm

- ST's "on-the-fly" startup algorithm allows a smooth drive insertion in direct and reverse speed.
- A null 3phase current is forced: according to rotor speed, 3 different behaviors are implemented:
 - Negative or very low (< ω_L) positive speed: \rightarrow braking with low sides
 - $\omega_{L,}$ < positive speed < ω_{H} :
 - positive speed > ω_{H} :

 \rightarrow profiled acceleration before going in RUN mode

20

→ straight in RUN mode





Live Capture: rotor speed > ω H

- drive locks and runs in about 15 ms
- no perturbation on rotor speed
- Minimal perturbation on phase currents





Motor Startup "on-the-fly" motor with big inertia





22

Digital PFC 23

DEC

- Digital PFC is embedded from the version v4.3
- Digital PFC FW is available (v5.2) for the
 - STM32F103 line (STM32F103xC, STM32F103xD, STM32F103xE)

orkbench [Noname]*		
Documentation	Hardware Settings	PFC Enable
x 🐟 🕴 🙆 🕢 🕣	Hardware Settings	PFC Disable
Control Board: STM3210E-EVAL - custom 🔺 - Powe	Nominal power 1000 W Nominal current 6.149 Apk Shunt resistor value 0.220 ohm Image: Open power stage PFC Parameters	PFC Fault Ack
AC Input Info	Image: Second secon	⑦ P 令 1
Control Unit	Toff propagation delay 2550 ms Driving signal polarity Active low Voltage regulation frequency 100 Hz Overcurrent signal polarity Active low AC Mains synch signal polarity Active low voltage regulation frequency 100 Hz Soft Start Duration 300 ms	
Firmware Drive Management	Phase W	Done



STM32 FOC SDK 5.2 - user experience



STM32 FOC SDK 5.2 - user experience 25

- HALL/LL Based & STM32CubeMX compatible
- Ready for most common IDEs (IAR, Keil, TrueSTUDIO)
- Software examples
- MC Application (State machine, Tasks)
- Fast Unidirectional/Bidirectional communication
- Workbench features (Startup sensorless, examples, doc link, PFC)
- Motor profiler / Self tuning algorithm
- HFI sensor-less algorithm



Workspaces and projects 26

- Each motor control workspace is composed of two projects:
 - the MC Library project and
 - the User project
- Both are required to build the executable
- In the WEB distribution the MC Library is provided already compiled for each • configuration and for each supported IDE





Supported families 27

STM32F0xxFamily	STM32F1xx Family :	STM32F3xx Family:
NUCLEO-F030R8 NUCLEO-F072RB STM32072B-EVAL	NUCLEO-F103RB STM3210E-Eval	NUCLEO-F302R8 NUCLEO-F303RE STM32303E-EVAL
STM32F4xx Family:	STM32F7xx Family:	STM32L4xx Family:
NUCLEO-F446RE NUCLEO-F401RE STM3240G-EVAL STM3241G-EVAL STM32446E-EVAL	NUCLEO-F746ZG STM32F769I-EVAL	NUCLEO-L452RE NUCLEO-L476RG STM32L476G-EVAL



Software examples

28

- Software examples can be used as staring point for new design or guideline to understand the MC API.
- You can found in installed path MC_SDK_5.x.x/Projects





MC Application – State machine 29



Is not supported by v5.2

Light/Full LCD 30

Light LCD allows to customize the GUI itself adding extra interactions with the firmware



	Туре	Customizable	Feature
Full LCD	External project to be flashed separately	Hard	Full
Light LCD	Inside MC project	Easy	Partial



Light LCD



Full LCD



Fast unidirectional/Bidirectional communication

• With fast unidirectional communication the data is send from the firmware to the PC at the maximum speed rate without control bytes

Drive Management - User Inte	rface Add-on	×
Joystick, LCD	Start / Stop button	
Enable		
Full		
Clight		
Serial communication		
V Enable		
Bidirectional		
Fast unidirectional		
CH1 M1	Observer BEMF alpha (PLL)	_
CH2 📃	la	
		Done

Bidirectional + Workbench



Fast unidirectional + Excel





Workbench sensorless startup 32

- Graphical representation of the imposed current and acceleration.
- Will be fully presented in another session.

Include alignment before ramp-up Read ramp value Consecutive succesful start up output tests Read used to for the succesful start up output tests Consecutive succesful start up output tests Estimated speed Band tolerance lower limit Totalion	ensor-less rev-up settings										
Advanced customized Seed ramp duration 1500 100	Profile Resic										
Speed ramp duration 1500 mms Speed ramp duration 1500 mms Quent ramp final value 0.60 mms Current ramp initial value 0.70 mms Duration 350 mms Include alignment before ramp up 100 mms Duration 90 mms Alignment electrical angle 90 mms Seed ramp value 0.60 mms Consecutive succesful start up output tests 100 mms Estimated speed Band tolerance upper limit 106 25 mms Seed ramped and tolerance lower limit 100 0 mms	 Advanced customized 										
Speed ramp final value 2700 mm Current ramp initial value 0.60 mm Current ramp initial value 0.70 mm Include alignment before ramp up II Duration 700 mm Alignment electrical angle 90 mm Alignment angle 10.60 mm Consecutive succesful start up output tests 10 mm Estimated speed Band tolerance upper limit 106 25 mm X Estimated speed Band tolerance lower limit 100 mm X Estimated speed Band tolerance lower limit 100 mm X Include alignment before ramp up II Consecutive succesful start up output tests 10 mm Include alignment before ramp up III Consecutive succesful start up output tests 10 mm Estimated speed Band tolerance upper limit 100 mm Include alignment before ramp up IIII 100 mm Include alignment before ramp up IIII 100 mm Include alignment before ramp up IIII 100 mm Include alignment before ramp up IIIII 100 mm Include alignment before ramp up IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Speed ramp duration	1500	÷ ms			_				_ 10	
Current ramp initial value 0.60	Speed ramp final value	2700	rpm		2500	1				1	
Current ramp final value 0.70	Current ramp initial value	0.60	A		2000	4					
Current ramp duration 350	Current ramp final value	0.70	A	E.	1500	4				- 0.6	-
Include alignment before ramp-up Duration 700	Current ramp duration	350	🔹 ms	Speed	1000	д,				- 0.4	the Associate
Duration 700 ms Alignment electrical angle 90 deg Final current ramp value 0.60 Alignment electrical angle Consecutive succesful start-up output tests p Estimated speed Band tolerance upper limit 106.25 % Estimated speed Band tolerance lower limit 100.00 %	Include alignment before ramp-up	V			500					- 0.2	
Alignment electrical angle 90 m Alignment electrical angle 90 m Final current ramp value 0.60 m A 0 500 1000 1500 2000 Duration (ms) Per-up to FOC switch-over Enable Image: Consecutive speed 580 m Estimated speed Band tolerance upper limit 106.25 2000 1000 2000 Duration	Duration	700	<u>▲</u> ms							E	
Final current ramp value 0.60 A Duration (ms) Consecutive succesful start-up output tests P C Enable Minimum start-up output speed 580 mmm Enable Estimated speed Band tolerance upper limit 106.25 % Estimated speed Band tolerance lower limit 100.00 %	Alignment electrical angle	90	≑ deg		0	0	500 1	000 1500	2000	-; 0.0	
Consecutive succesful start-up output tests Minimum start-up output speed Estimated speed Band tolerance upper limit. Estimated speed Band tolerance lower limit. 100 00 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Final current ramp value	0.60	A				Dur	ation (ms)			
Minimum start-up output speed 580 mmm Enable Image: Constraint of the speed	Consecutive succesful start-up output	tests	þ	-	F	Rev-up to FO	C switch-ove	er			
Estimated speed Band tolerance upper limit 106 25 1 1 100 1 100 1 100 1 100 1 100 100 10	Minimum start-up output speed		580	in in	1	Enable					
Estimated speed Band tolerance lower limit	Estimated speed Band tolerance uppe	er limit	106.25	÷ %		Duration		100	÷ m	5	
	Estimated speed Band tolerance lowe	r limit	100.00	÷ %							

Basic

Advanced





Workbench examples

The number of example configuration is growing





Workbench examples & new project 34

New face in Workbench - STM32 FOC SDK 5.2.0

	New Project			
🐝 ST Motor Control Workt File Tools Help [Application type	▼ System ③ Single l	Motor 🔘 Dual Motors	
Sew Project	Select Boards: O Inverter	O MC Kit O Power & Control		
Recent Projects	custom board	 Control board where the control s parameters have to customized b 	tage custom board	
Filename			custom board	
User_Project.stmcx F446 IHM23V3.stmcx			STM32072B-EVAL	
test52.stmcx	Power		STM3210E-EVAL	
LAB_3.stmcx E303_IHM16_stmcx	custom board	 Power board where the power sta parameters have to customized b 	age STM32303E-EVAL	
F030_IHM07.stmcx		custom board	STM3240G-EVAL	
		custom board	STM32446E-EVAL	
		STEVAL-IHM023V3 3Sh Less 35 STEVAL IHM022V2 1Sh Less 25	STEVAL-IHM039V1	
Example Projects		STEVAL-IHM023V3 3Sh High Vo	NUCLEO-F302R8	
Filename		STEVAL-IHM023V3 1Sh High Vo STEVAL-IHM028V2-3Sh	NUCLEO-F303RE	
NUCLEO_L452RE_IHM07M1_		STEVAL-IHM028V2-1Sh	NUCLEO-F446RE	
NUCLEO_L452RE_IHM07M1_		STEVAL-IHM025V1-3Sh	NUCLEO-F072RB	
NUCLEO_F746ZG IHM07M1		STEVAL-IHM025VI-ISh STEVAL-IHM045VI-3Sh	NUCLEO-E030B8	
STM32F476_IHM07M1_1S_S		STEVAL-IHM045V1-1Sh	NUCLEO-E103BB	
NUCLEO-F303RE-X-NUCLEO		X-NUCLEO-IHM07M1 3Sh X-NUCLEO-IHM07M1 1Sh	STM32L476G_EV/AL	
NUCLEO-F446RE_HM07M1_		X-NUCLEO-IHM08M1-3Sh		
NUCLEO-F446RE_IHM07M1_	Motor	X-NUCLEO-IHM08M1-1Sh	NUCLEO-L478RG	
NUCLEO_F103RB_LD_IHM07		STEVAL-IPM05F 3Sh	- NUCLEO-L452RE	
NUCLEO_F103RB_MD_IHM07	Generic Low voltage <= 50V	STEVAL-IPM05F 1Sh	NUCLEO-F746ZG	
STM3210E-EVAL_HM07M1_	Motor low voltage	STEVAL-IPM07F 3Sh STEVAL-IPM07F 1Sh	STM32F769I-EVAL	
STM3210E-EVAL_IHM07M1_		STEVAL-IPM10B 3Sh	NUCLEO-F401RE	
STM3210E-EVAL_IHM07M1_		STEVAL-IPM10B 1Sh		
NUCLEO-F303RE-X-NUCLEO		STEVAL-IPM10F 350 STEVAL-IPM10F 1Sh	-	
		STEVAL-IPM15B 3Sh	life	augmented
		STEVAL-IPM15B 1Sh STEVAL-IPM08B-1Sh		
		STEVAL-IPM08B-3Sh		
		STEVAL-IPMNG3Q-1Sh		
		STEVAL-IPMNG3Q-3Sh	OK Cancel	

Workbench documentation link 35

Direct link to documentation in ST Motor Control Workbench





Or in ST website X-CUBE-MCSDK

Technical Documentation

Product S	pecifications		
	Description	Version	Size
	DB3548: STM32 MC SDK software expansion for STM32Cube	1.0	159 KB
Applicatio	n Notes		
	Description	Version	Size
	AN5166. Guidelines for control and customization of power boards with STM32 MC SDK v5.0	1.0	322 KB
	AN5143: How to migrate motor control application software from SDK v4.3 to SDK v5.x	3.0	660 KB
User Man	uals		
	Description	Version	Size
	UM2312: Development checklist for STM32Cube Expansion Packages	1.0	283 KB
	UM2285: Development guidelines for STM32Cube Expansion Packages	1.0	485 KB

1.0

2 MB

UM2374: Getting started with STM32 motor control SDK v5.0



Workbench digital PFC support 36

Complete support for the digital PFC plug-in*



life.augmented



HFI sensorless algorithm

- HFI sensor-less algorithm for I-PMSM is able to detect rotor angular position at *zero speed* exploiting the peculiar anisotropy of their magnetic structure.
- Will be fully presented in another session.





a)SM-PMSM: Surface mounted permanent magnets -> $L_d=L_q$ b) & c)I-PMSM: Internal permanent magnets -> $L_d<L_q$ In particular: b) inset magnets; c) radial buried magnets.





Motor Control Workbench 38

New face in Workbench - STM32 FOC SDK 5.2.0

T Motor Control Workbench [Noname]*
e Tools Help Documentation
otor: Shinano LA052-080E3NL1 - Control Board: Custom - Power Board: Custom
AC Input Info
Control Unit Firmware Drive Management Phase V Phase V Phase V Phase V Current Current
MCU and Clock Freq. Digital VO
DAC functionality Analog Input and Protection Sensoriess Main Speed Sensing
able Motor Uni Time Motor Id Message
M frequency 16000 Hz = 🚯 10:08:24 The 'Sensor-less (HFI+Observer)' is not supported in the FW for SDK5x. All parameters will be disabled.
sor selection main Sensor-less (U) 10:08:24 F2 mcus are not supported in the FW for SDK5 x
evention rate in the FW for SDK5x = 10:08:24 F103 High Density in dual Motor mcus are not supported in the FW for SDK5x =
voltage sensing true +
III III III III III III III III III II
ICWorkshop18Q3\Examples\02_LAB3\LAB_3.stmcx .



Thank you

