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Motor Control Basic with ST Motor Control SDK

Industrial Motor Control Competence Center
최현우 과장

Agenda

1 Introduction of Motor Control Competence Center

2 Motor Basic Theory

3 Control Method (Six-step / FOC)

4 ST Motor Control SDK

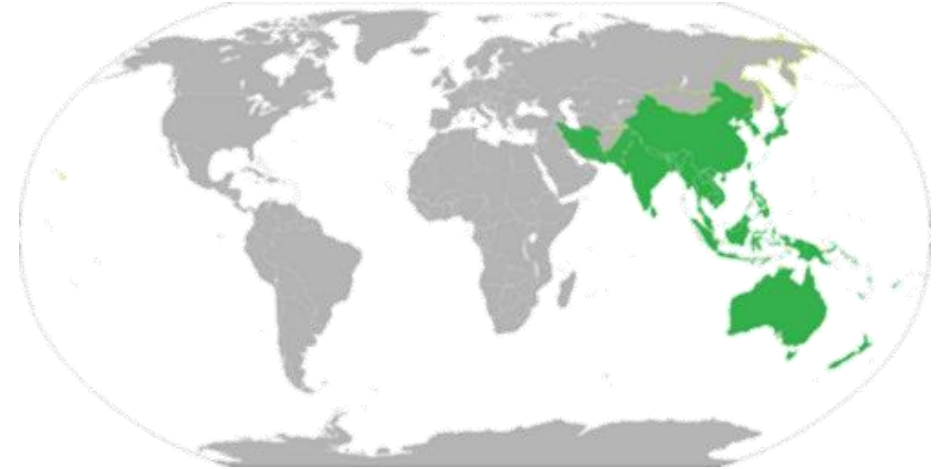
Introduction of Motor Control Competence Center





Motor Control Competence Center mission

Create and Promote innovative, convenient and mature
Motor Control System Solutions
to Design and **Partner** with our Regional Customers
in order to leverage on the **whole ST product portfolio**
for **Industrial Applications**
in order to boost **revenues growth** in the market segment



• SYSTEM R&D

- HW Reference Design, Application Boards
- FW Application Modules for the ST MC Library
- System Solutions

• CUSTOMER SUPPORT

- Evaluation & Training with ST Tools
- ST Kit Product Selection (in cooperation with TM)
- Schematics; Layout review; Tuning (in cooperation with FAE)

• PARTNERSHIP

- Overall Motor Control System expertise
- Partnership & new algorithms;
- Customer's IP porting to ST platforms

• NPP, NSP, GAP

- Products validation in-application: feedback to divisions
- New Product, New Solution Proposals: specification / roadmap
- Inter-divisional / strategic MKT / Joint Labs: information & technology



Motor Control Competence Center

Major focus sectors



Motor Control

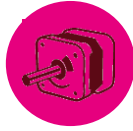


Home & Professional Appliances

Airconditioning
WM -fridge–DW -blenders
Ceiling Fan–Rangehood

Products

STM32 MCU / STSPIN32Fxxx
Family of SIP, IGBT, IPM,
MOSFET, Gate Drivers, STSPIN,
Sensors, Imaging, Connectivity



Automation

Servo – robot handler - fan
door – shutters - conveyors
Textile machine - pump

Products

STM32Fxxx Family of SIP, IGBT,
IPM, MOSFET Gate Drivers,
STSPIN, Sensors, Imaging



Industrial transportation

Scooter – forklift – golfcart
Elevator

Products

STM32Fxxx Family of SIP, IGBT,
IPM, MOSFET Gate Drivers,
STSPIN, Sensors

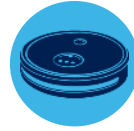


Tools

Power tools, garden tools

Products

ST32Fxxx Family, IGBT, IPM,
MOSFET
Gate Drivers,
STSPIN/MEMS/Sensors



Consumer

vacuum&robot cleaner,
balance board,ESC,
EduRobot,Fitness

Products

STM32Fxxx Family of SIP, IGBT,
IPM, MOSFET
Gate Drivers, STSPIN, ToF,
Sensors, connectivity

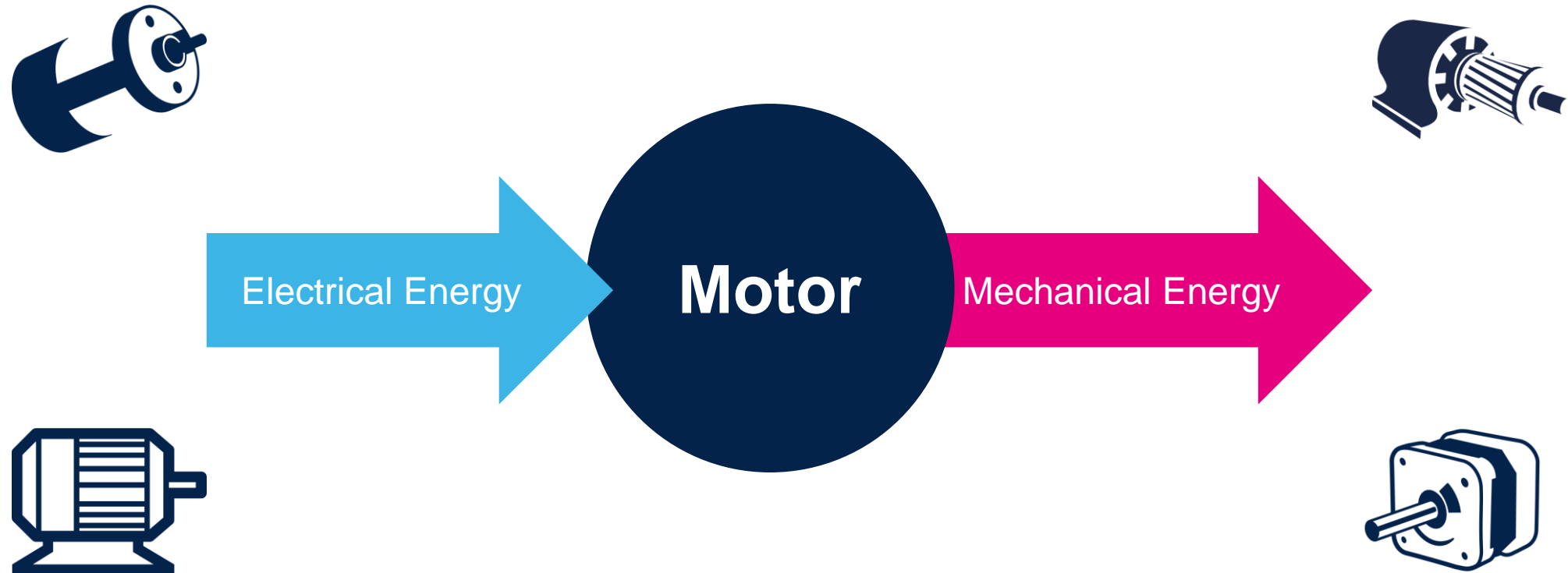
Motor Basic Theory



Motor Definition

An electric motor is a device converting electrical energy into mechanical energy

This conversion is usually obtained through the generation of a magnetic field by means of a current flow into one or more coils





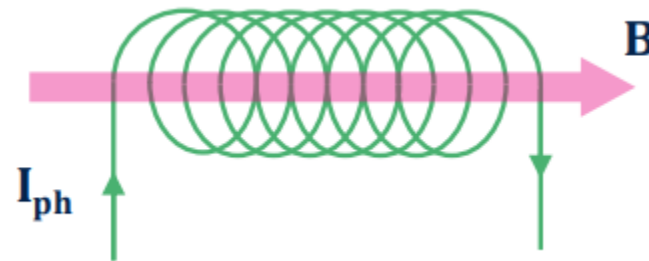
Magnetic Field Generation

The rotation is obtained thanks to the attractive force between two magnetic fields:

- One field is located on the rotor (the moving part)
- The second magnetic field is located on the stator (the body of the motor)

Usually, one of the two is generated by a permanent magnet while the other one is generated through an electromagnet (coil)

The relation between electrical energy (current) and magnetic field generated by a coil is obtained through the following formula:

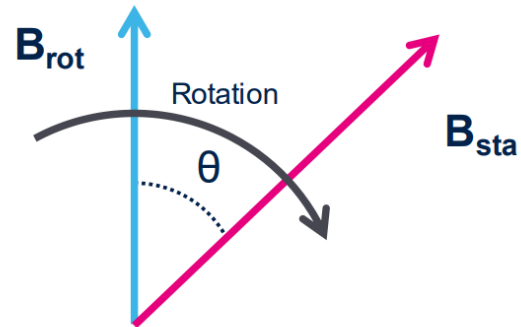


$$B = k \cdot I_{ph}$$



Torque and Angle

The **output torque** of an electrical motor depends on the intensity of the rotor and stator magnetic field and on their phase relation:



$$T_q \propto B_{rot} \cdot B_{sta} \cdot \sin \theta \propto I_{ph} \cdot \sin \theta$$

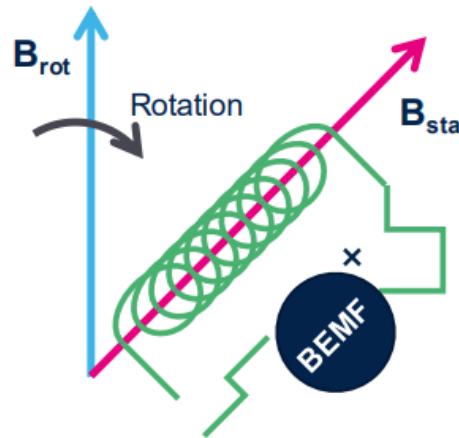
The angle θ between the two magnetic field is named **load angle**.

The **maximum output torque**, and then the **maximum efficiency**, is obtained when the **load angle is 90°**.



Back Electromotive Force

The rotation of the rotor magnetic field (B_{rot}) causes a variation of the magnetic flux in the solenoid.



Consequently, an electromotive force is generated that counteracts the magnetic flux change (Lenz's law).

This effect is named **back electromotive force** (a.k.a. **BEMF**) and it is proportional to the motor speed according to the formula:

$$V_{BEMF} = k_e \cdot Speed$$



The electric motor operation is based on following points:

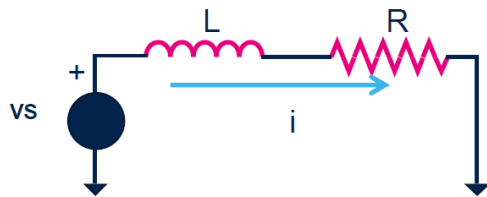
- At least one of the two **magnetic field** is generated by a coil carrying a current
- **Phase relation** between the rotor and stator magnetic field (i.e. the load angle) must be always greater than 0° in order to keep the motor in motion (negative angles reverse the rotation).
- Output **torque** depends to both coil **current** and **load angle**.
- Motor rotation causes a **back electromotive force (BEMF)** opposing the motion itself.



Motor expressed as inductive load

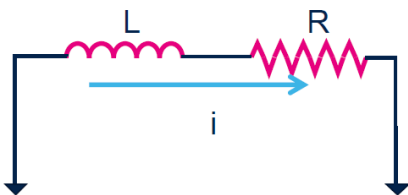
An inductive load can be represented as an LR series which stores energy in the form of current

Applying a voltage to the load, it is possible to change the amount of current stored into the inductance.



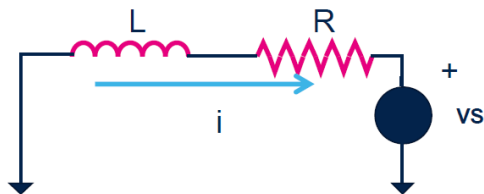
Scenario 1 (ON time)
Inductance is charged applying a voltage:

$$i(t) = \frac{V_S}{R} + \left(i(0) - \frac{V_S}{R} \right) \cdot e^{-t \cdot R/L}$$



Scenario 2 (slow decay)
Inductance is discharged shorting the leads:

$$i(t) = i(0) \cdot e^{-t \cdot R/L}$$



Scenario 2 (fast decay)
Inductance is discharged shorting the voltage:

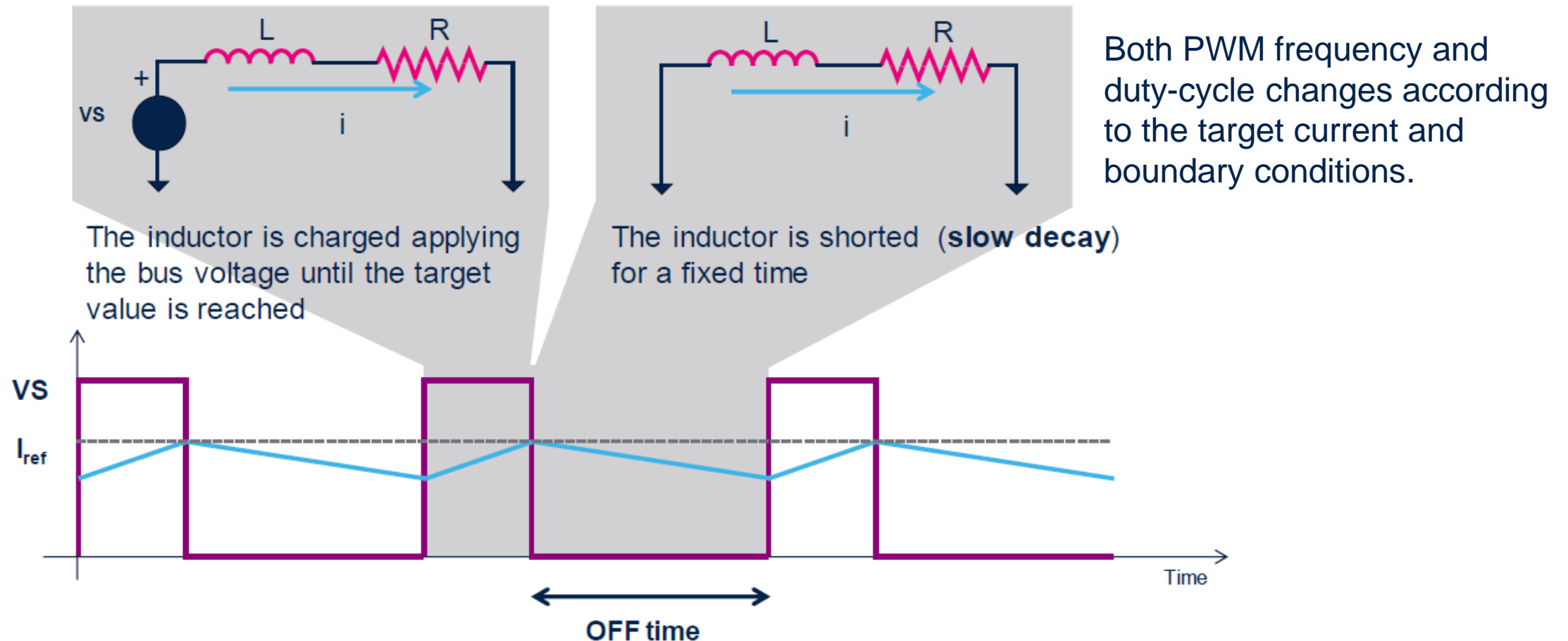
$$i(t) = -\frac{V_S}{R} + \left(i(0) + \frac{V_S}{R} \right) \cdot e^{-t \cdot R/L}$$



PWM current control basics

The most common method to control the current is the **fixed OFF time** method.

It is a **closed-loop** approach which implies the measurement of the controlled current.



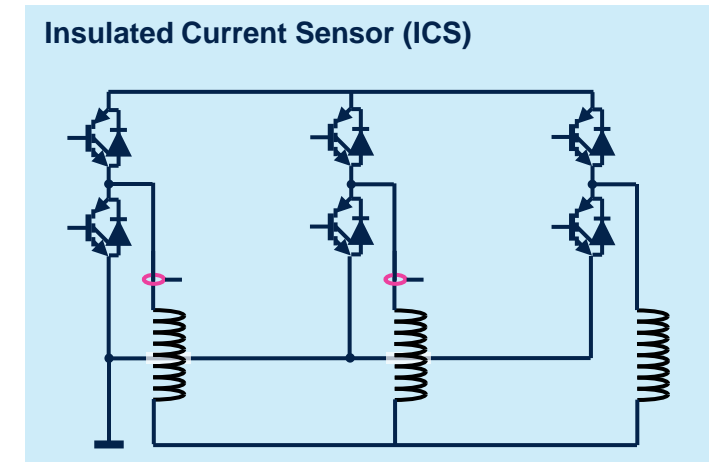
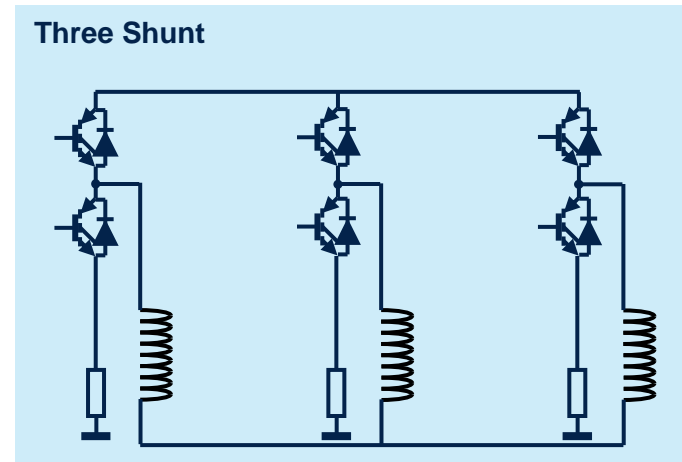
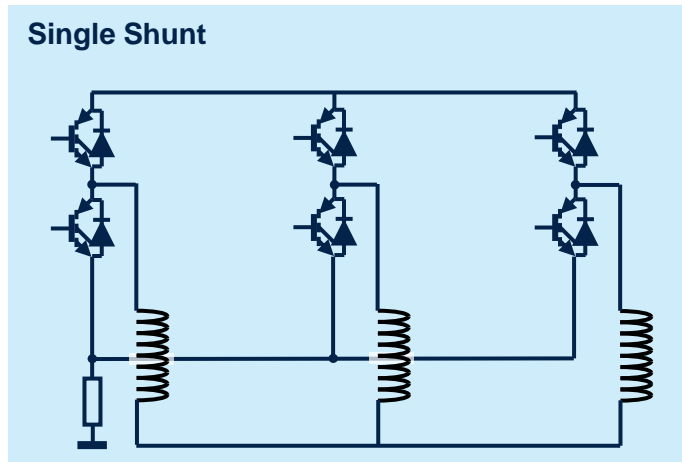


Current Sensing

To measure the motor phase currents a conditioning network is required.

The STM32 FOC SDK supports three current sensing network

- Insulated current sensor (ICS)
- Three shunts
- Single shunt



Cost Optimized

Best Quality

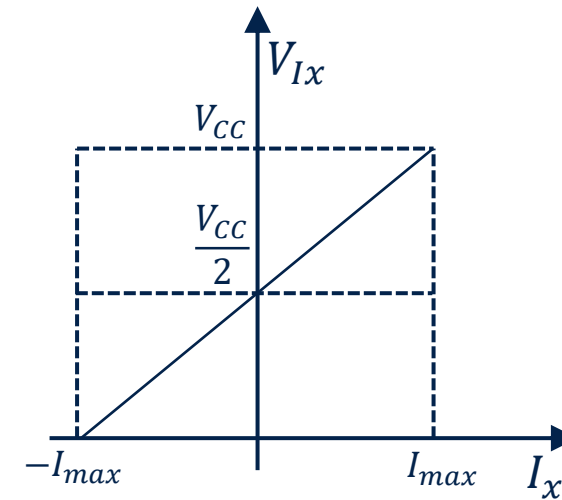
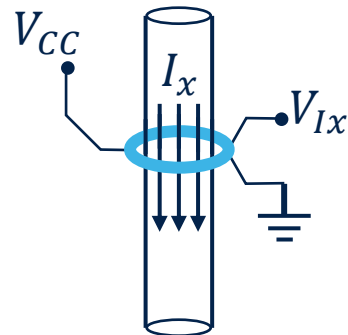


Insulated Current Sensing

Insulated current sensor is used to measure directly two of the motor phase currents.

Usually, ICS is provided with the adapting network.

It is important to choose the proper sensor according the range of current to be covered.



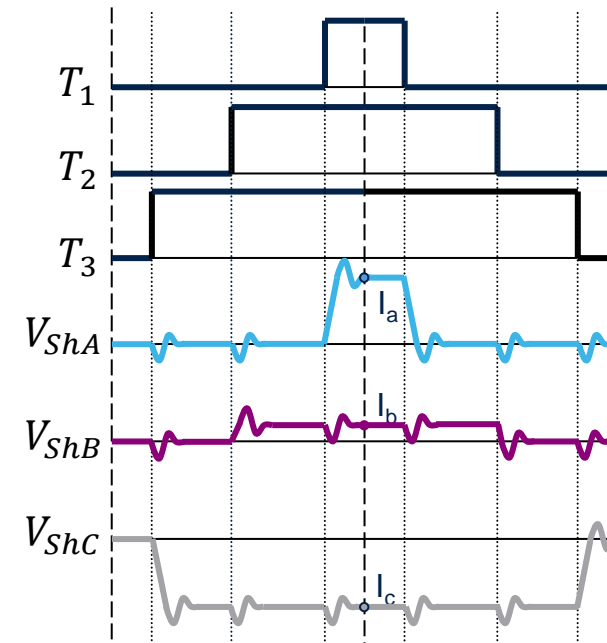
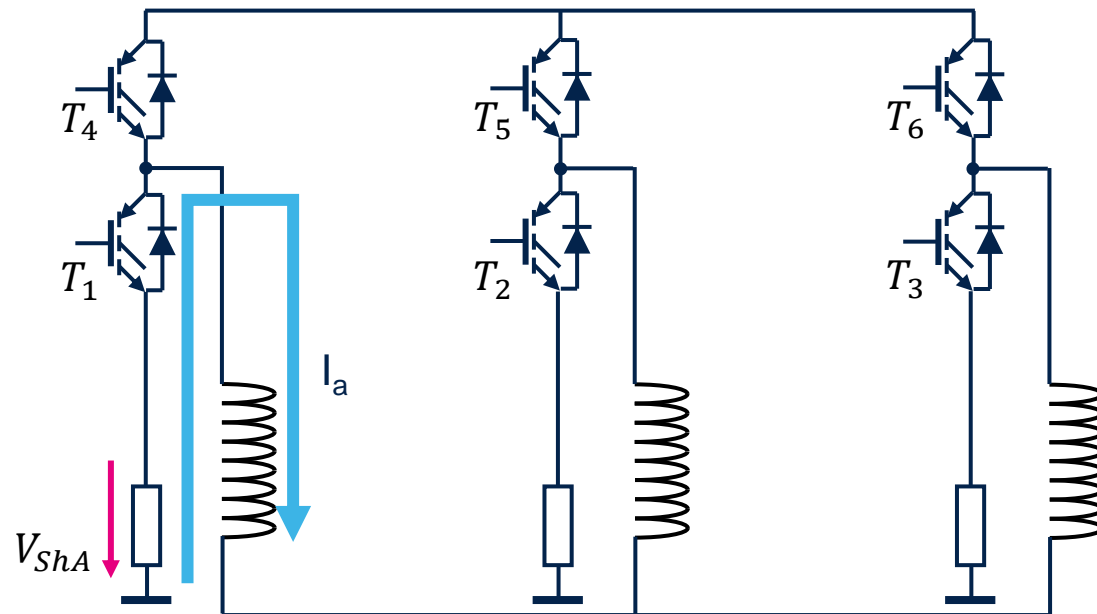


Three Shunt Current Sensing

Current flows into the shunt when the relative low side switches is closed.

According to the PWM duty cycles, the voltage on shunt resistor is proportional to the motor phase currents after a stabilization time.

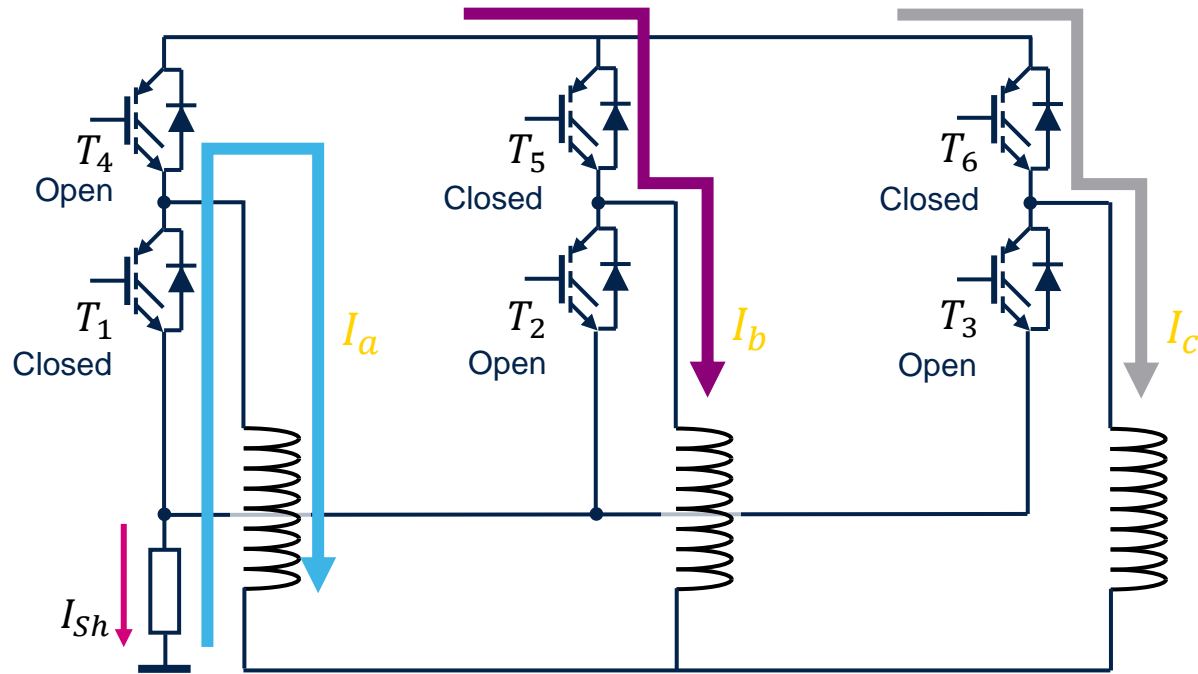
The third can be computed using: $I_a + I_b + I_c = 0$





Single Shunt Current Sensing

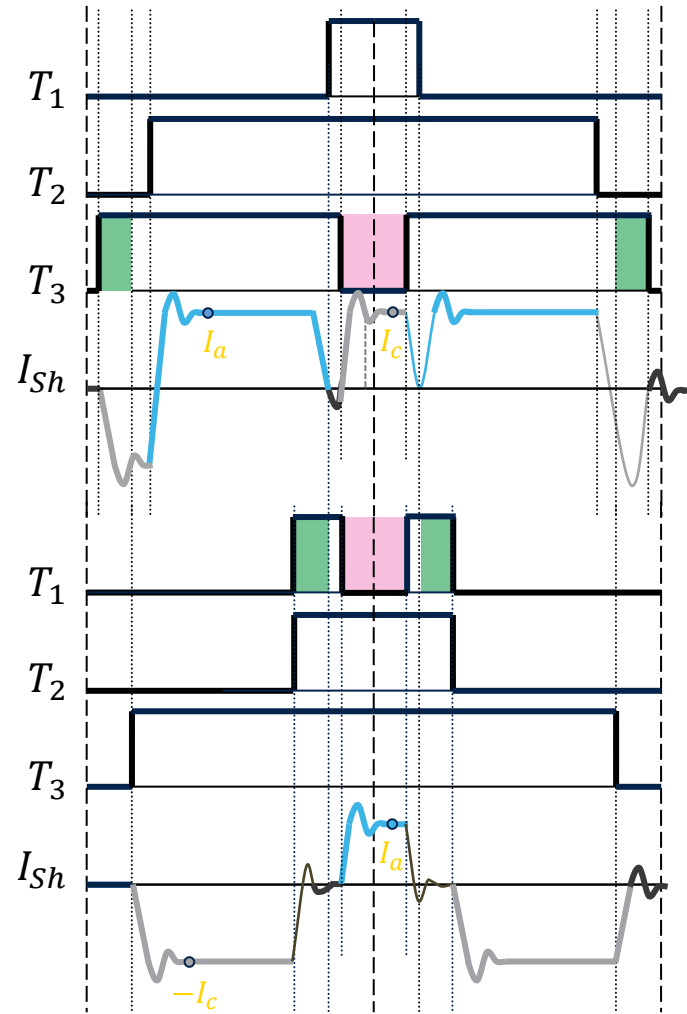
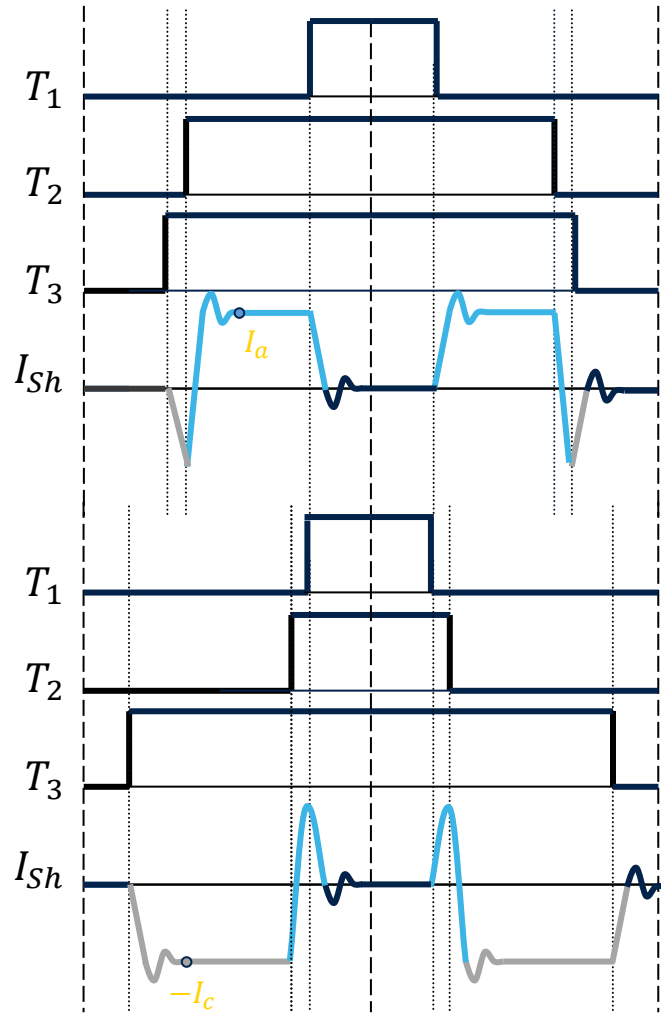
For each combination of the low side switches, the current that flows in the shunt resistor is indicated in the table



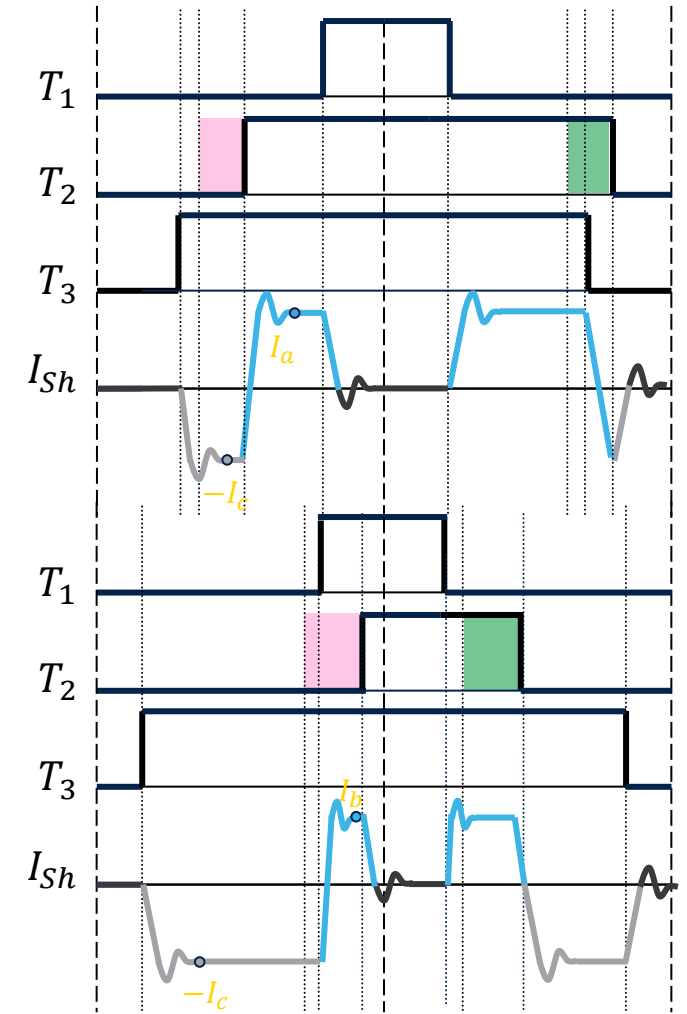
T_1	T_2	T_3	I_{Sh}
Open	Open	Open	0
Open	Close	Close	I_a
Open	Open	Close	$-I_c$
Close	Open	Close	I_b
Close	Open	Open	$-I_a$
Close	Close	Open	I_c
Open	Close	Open	$-I_b$
Close	Close	Close	0



Single Shunt Current Sensing



< MCSDK 5.4 >



< MCSDK 6 >

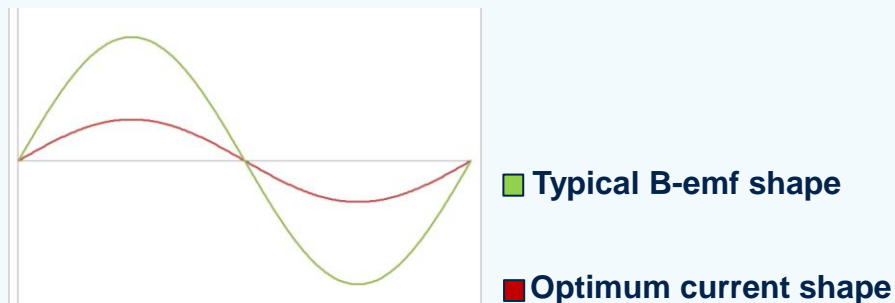
Control Method (Six-step / FOC)



PMSM vs BLDC

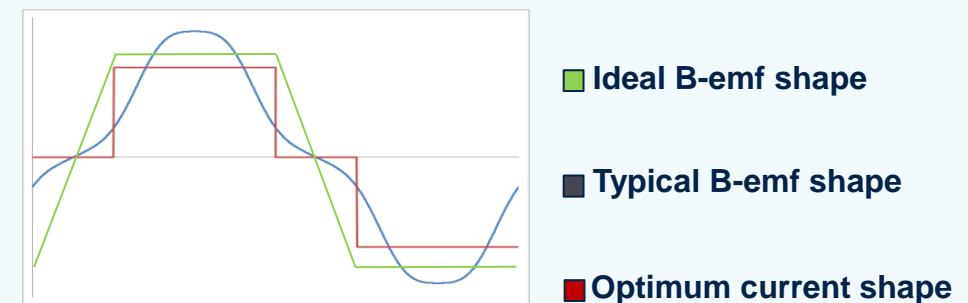
PMSM (Permanent Magnet Synchronous Motor)

- Rotor houses permanent magnets
 - On the surface → SPMSM (Surface Mounted PMSM)
 - Buried within the rotor → IPMSM (Interior PMSM)
- Stator excitation frequency must be synchronous with rotor electrical speed
- Rotation induces **sinusoidal** Back Electro-Motive Force (BEMF) in motor phases
- Gives best performances (torque steadiness) when driven by **sinusoidal** phase current



BLDC (Brushless DC Motor)

- Rotor houses permanent magnets
- Stator excitation frequency must be synchronous with rotor electrical speed
- Rotation induces **trapezoidal** Back Electro-Motive Force (BEMF) in motor phases
- Gives best performances (torque steadiness) when driven by **rectangular** phase current
- Generally, nowadays, BLDC magnetization is same as PMSM
- **No difference between BLDC and PMSM practically**



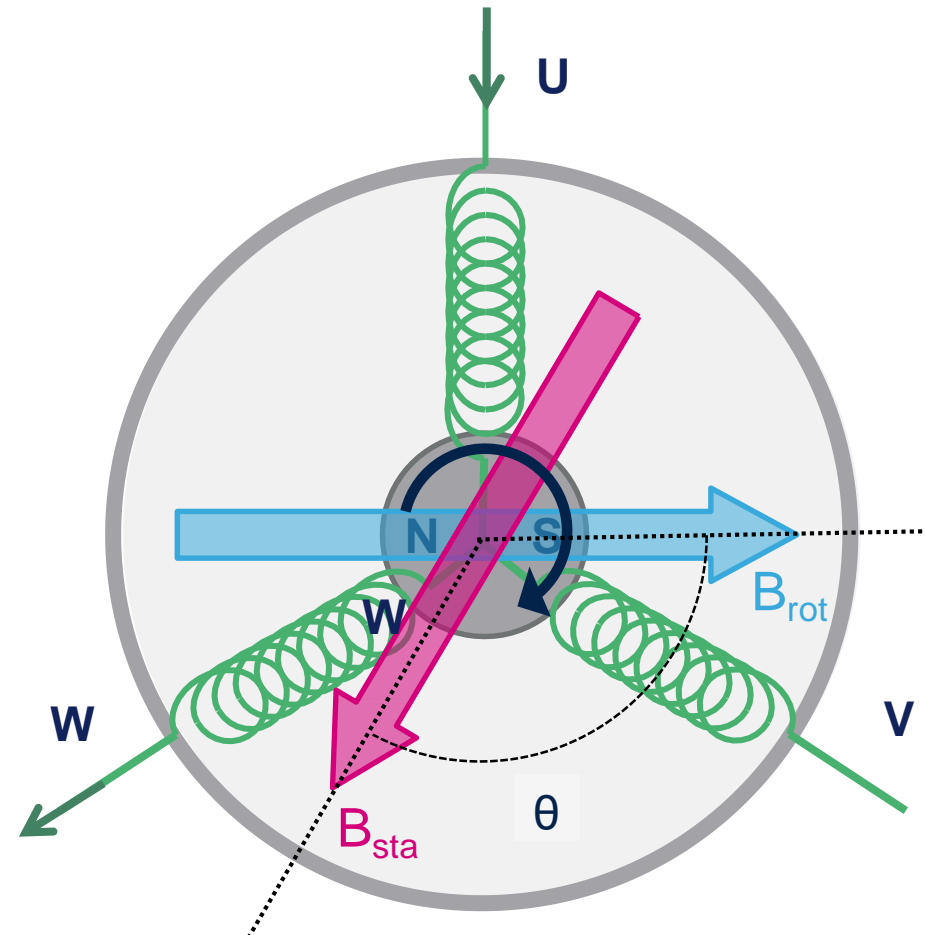


Three-phase BLDC/PMSM

Basics – load angle and rotation

The torque applied to the motor is proportional to the sine of the **load angle** (θ).

When the rotor magnetic field approaches the stator one, the torque is reduced.



In order to keep the motor in motion, it is necessary to change the direction of the stator magnetic field.

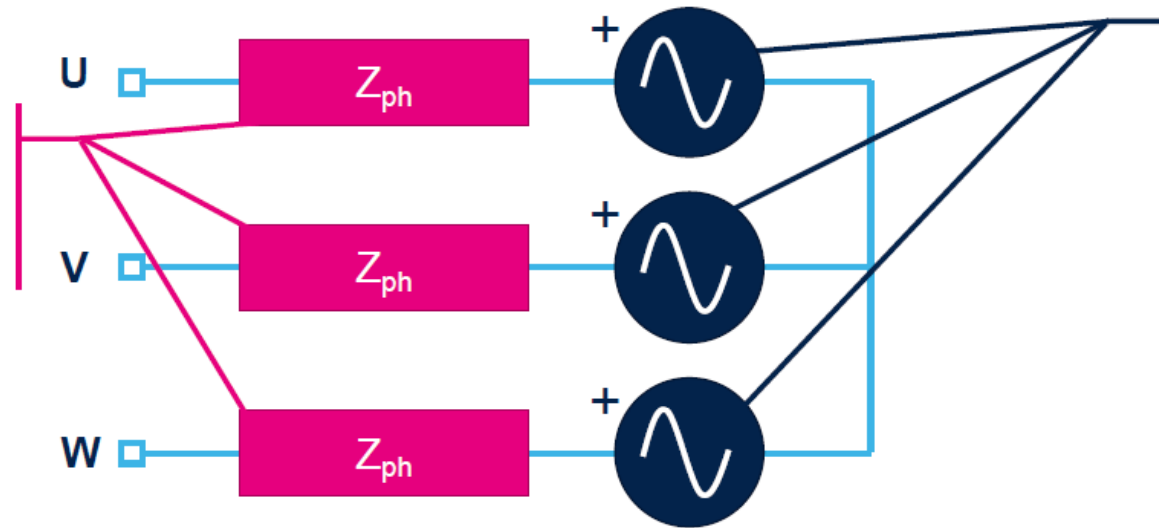


Three-phase BLDC/PMSM

Basics – electrical model

Phase impedance

$$Z_{ph} = R_{ph} + j\omega L_{ph}$$



Back electromotive force generators.

BEMFs are three sine wave voltages(*) delayed from each other by 120° .

The sinewave amplitude is proportional to the motor speed:

$$V_{BEMF} = k_e \cdot Speed$$



Three-phase BLDC/PMSM

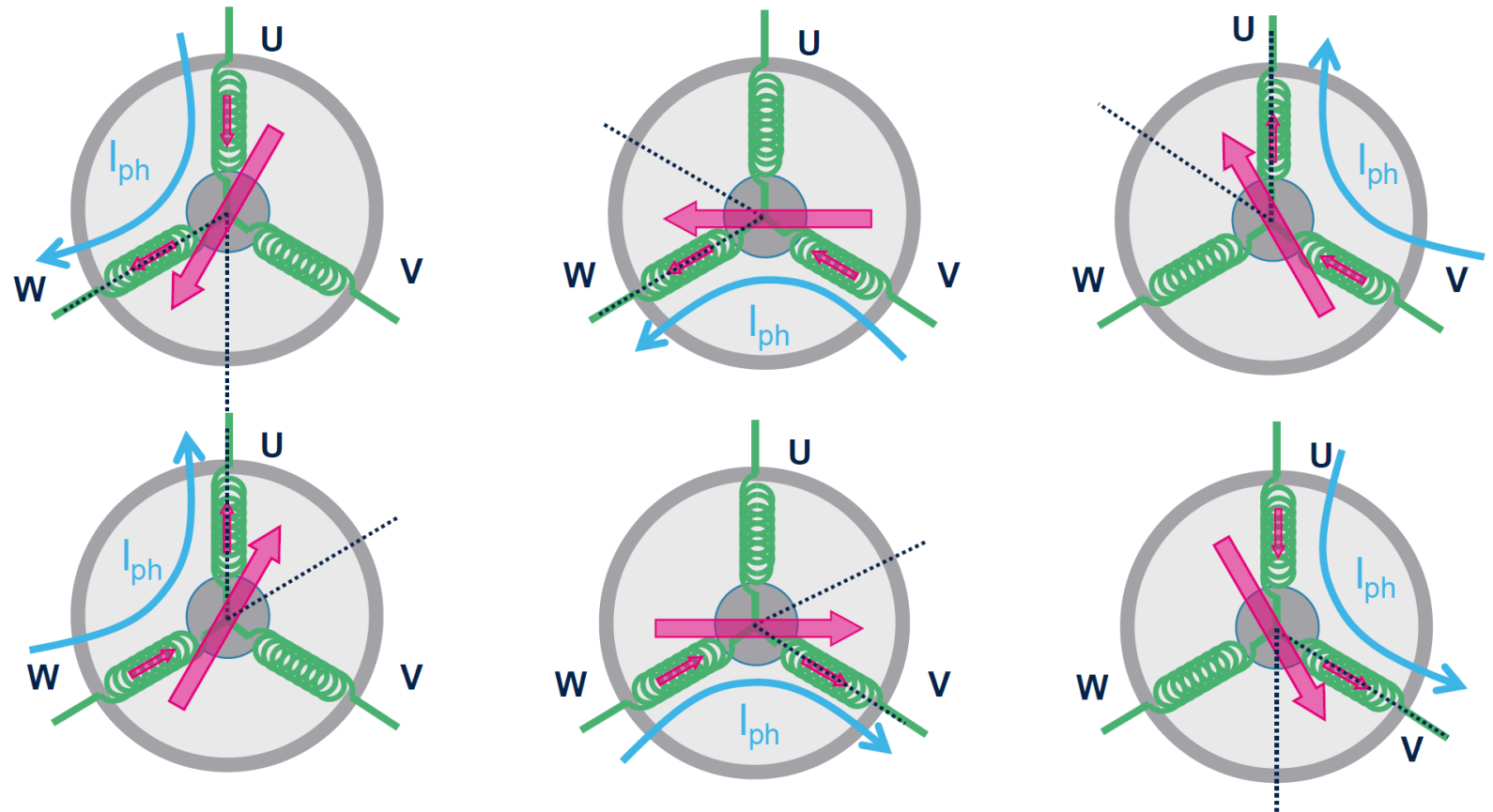
6-step driving – rotor position

The **6-step driving** imposes a current between two of the three phases leaving the third one floating.

In this way the stator magnetic field can be positioned in **6 discrete directions**.

The scanning of the 6 driving combinations of the six step is synchronized by the **rotor position**.

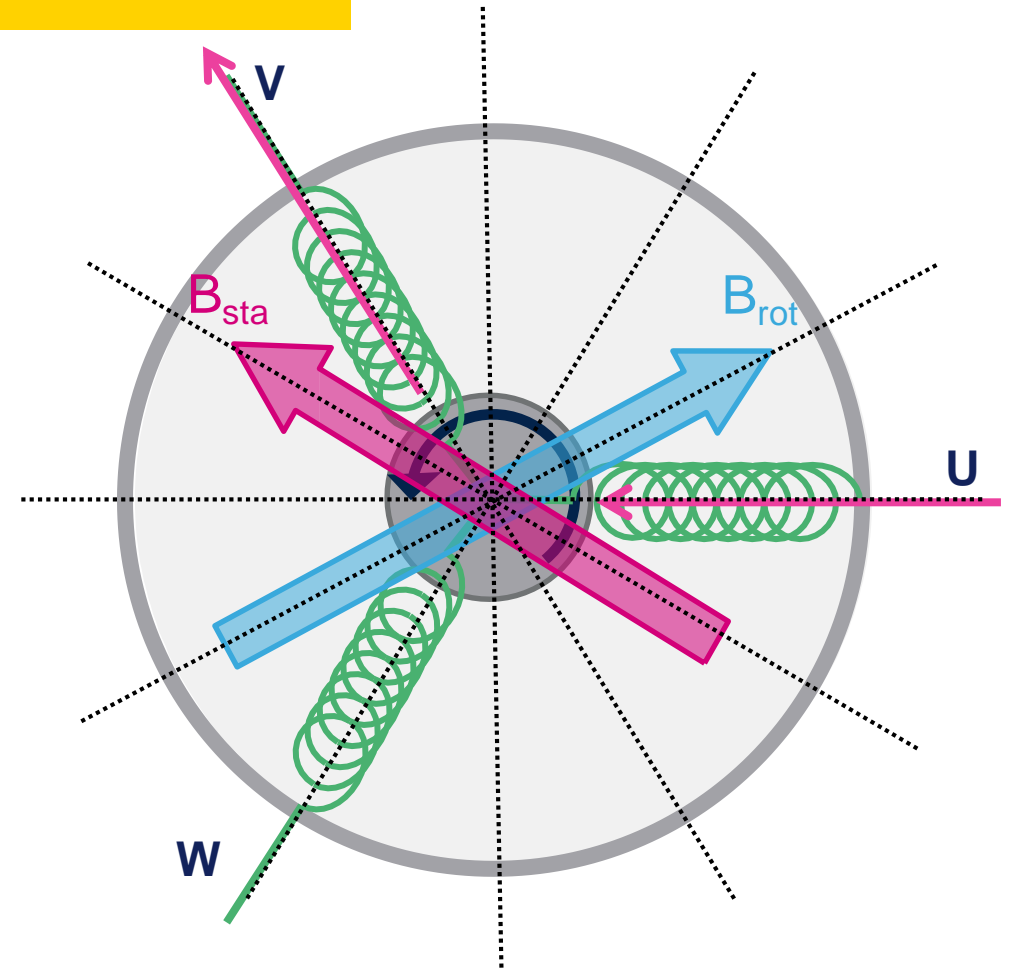
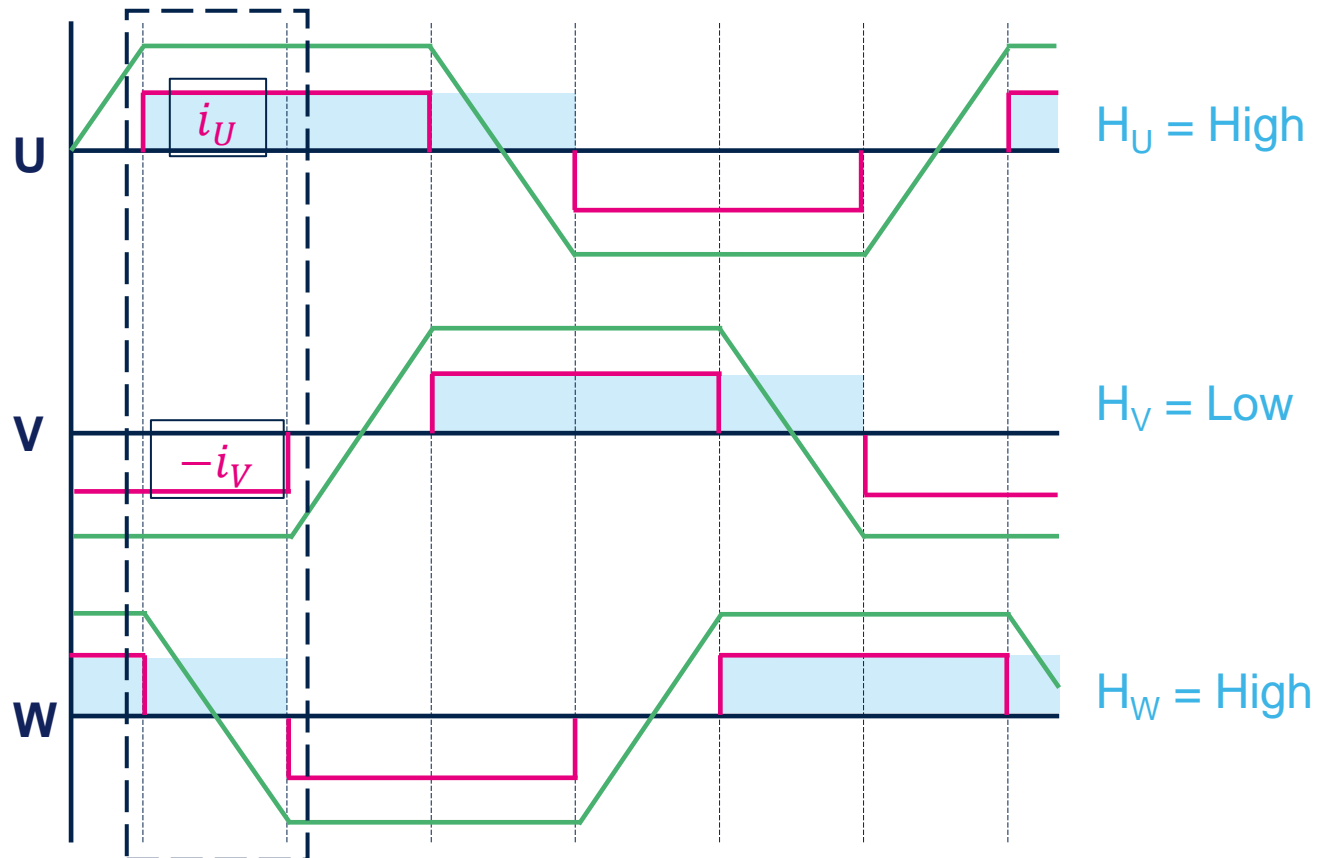
The rotor position can be monitored through Hall sensors or using a BEMF sensing technique (sensorless)





Three-phase BLDC/PMSM

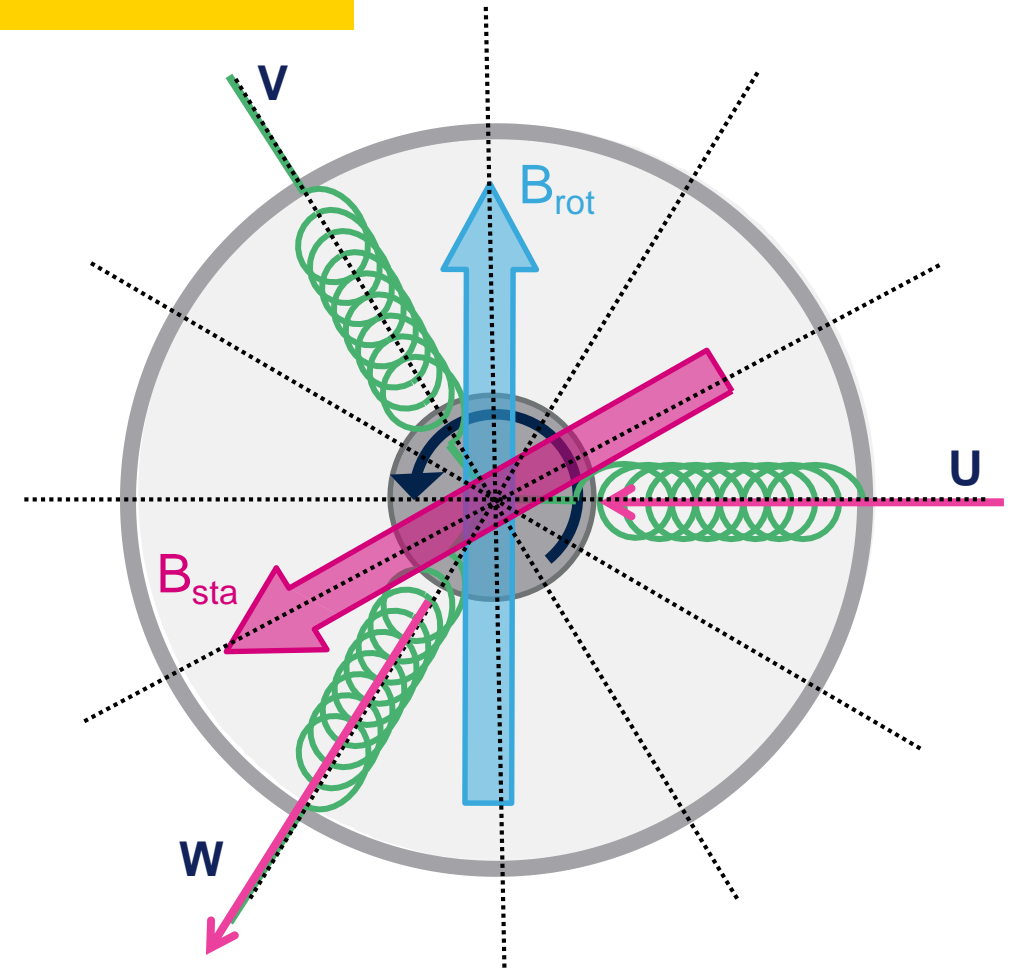
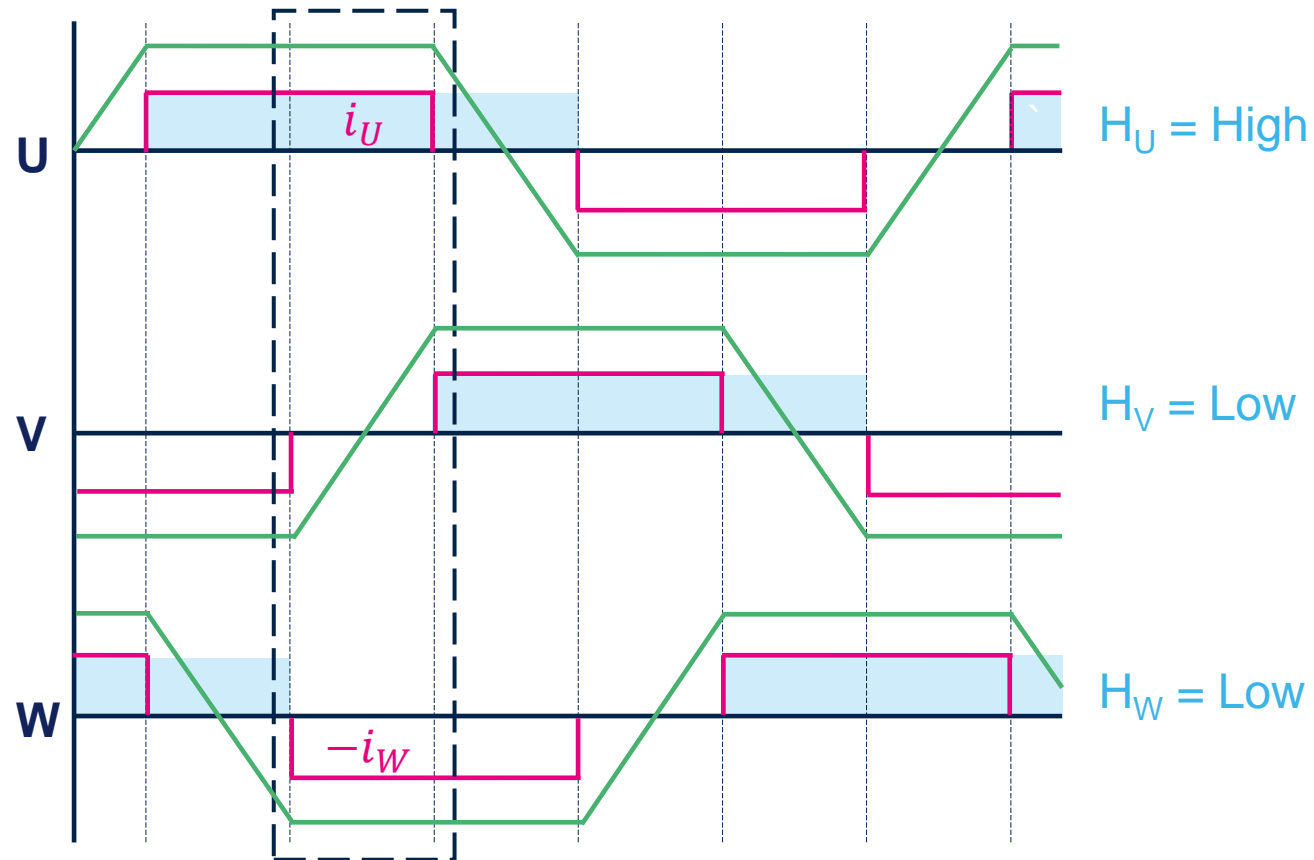
6-step driving – Hall sensors feedback (30° - 90°)





Three-phase BLDC/PMSM

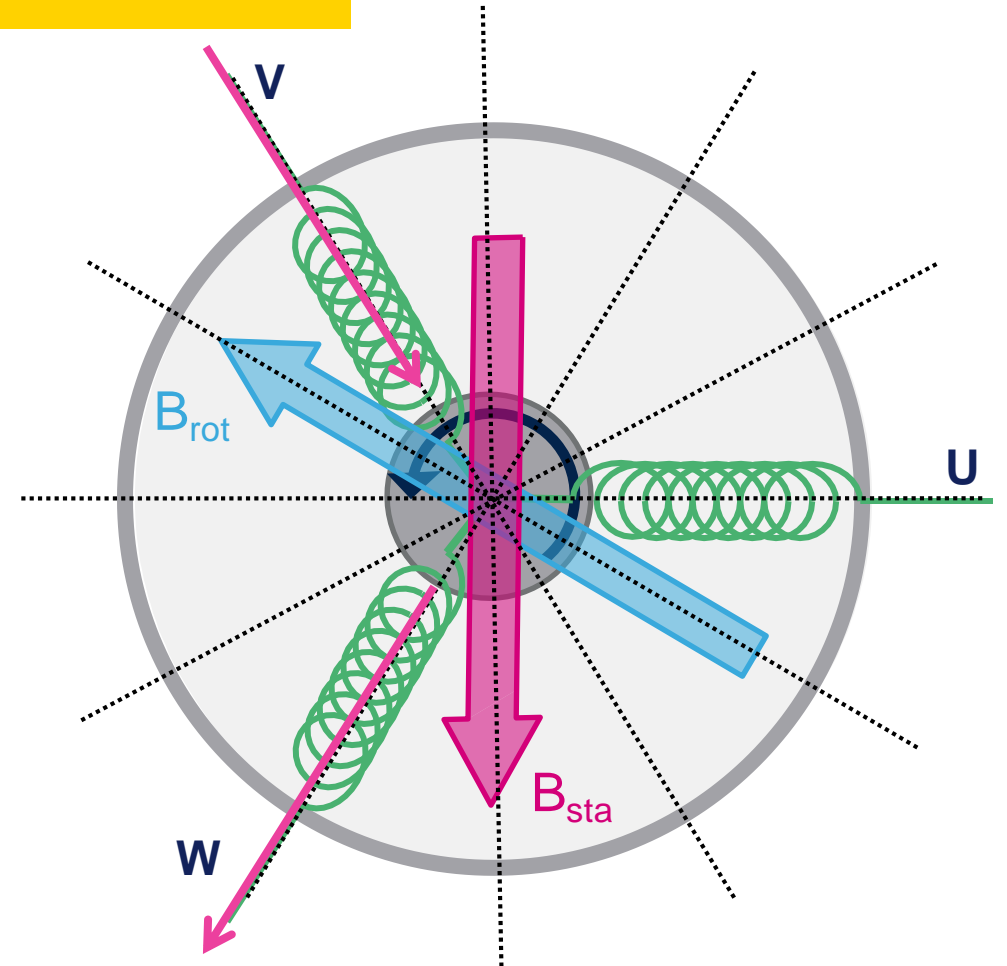
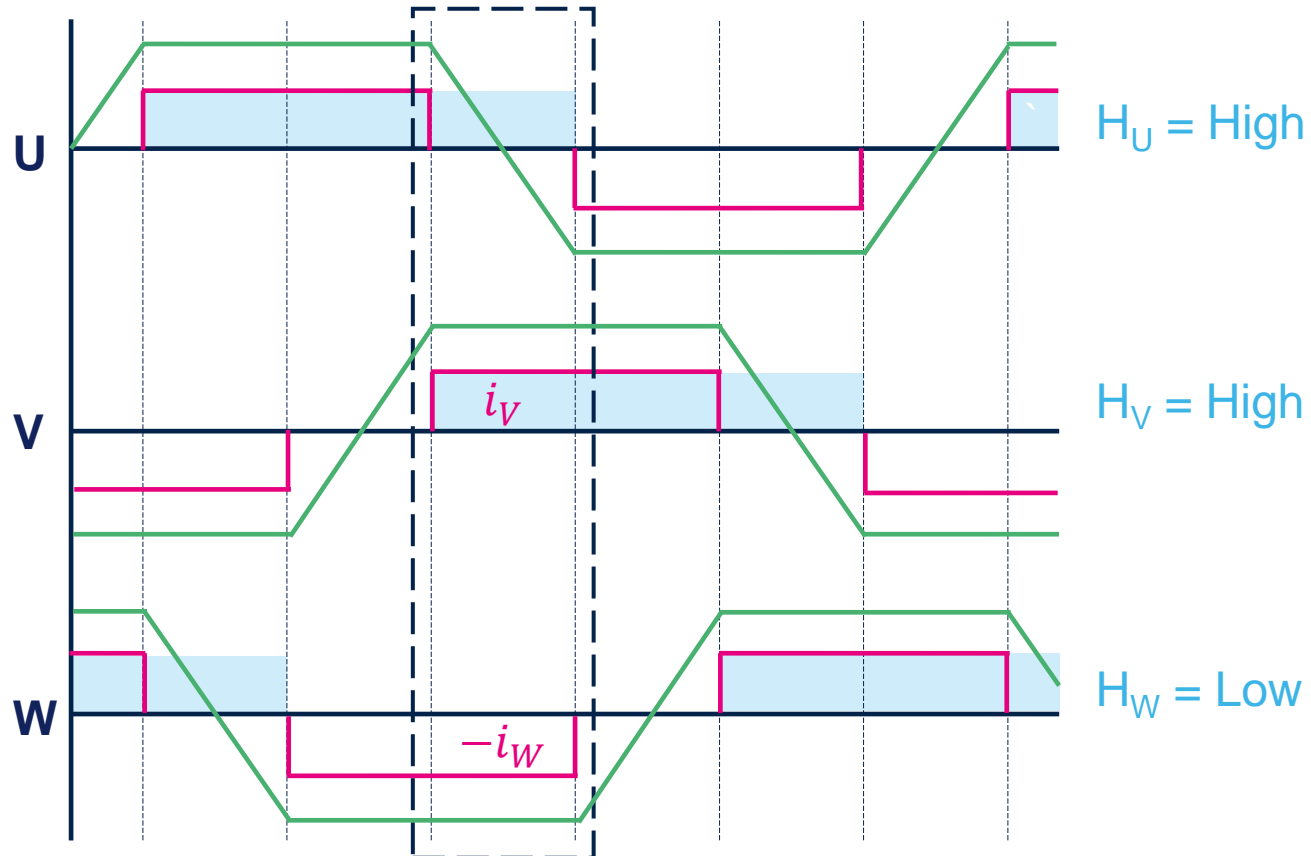
6-step driving – Hall sensors feedback (90° - 150 °)





Three-phase BLDC/PMSM

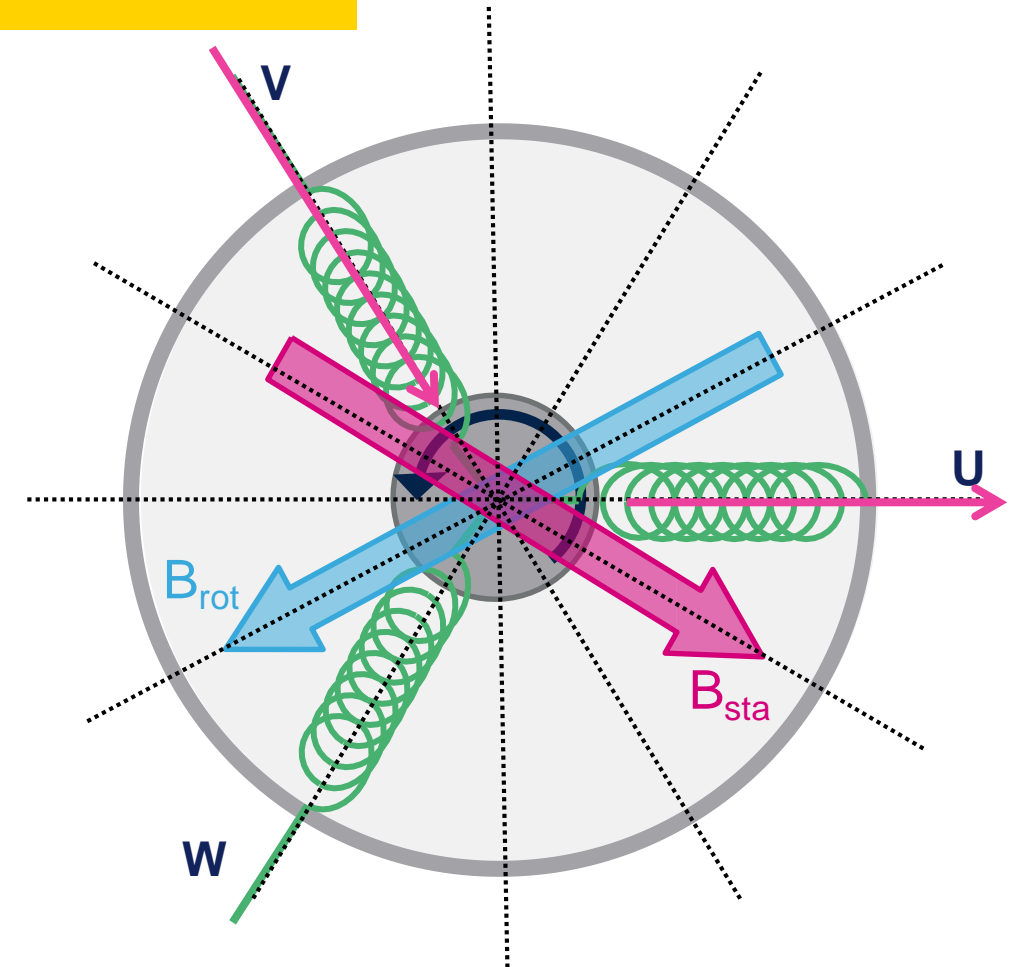
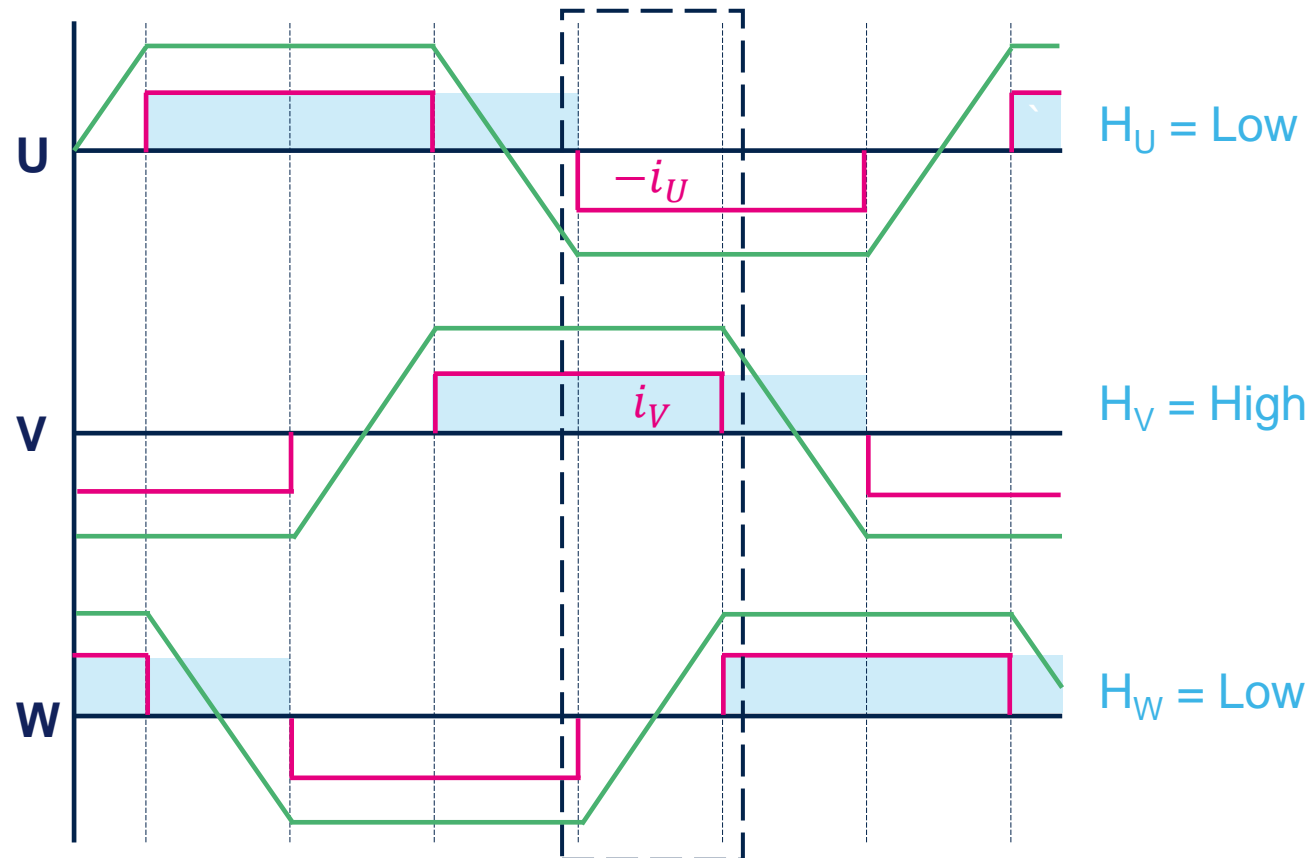
6-step driving – Hall sensors feedback (150° - 210°)





Three-phase BLDC/PMSM

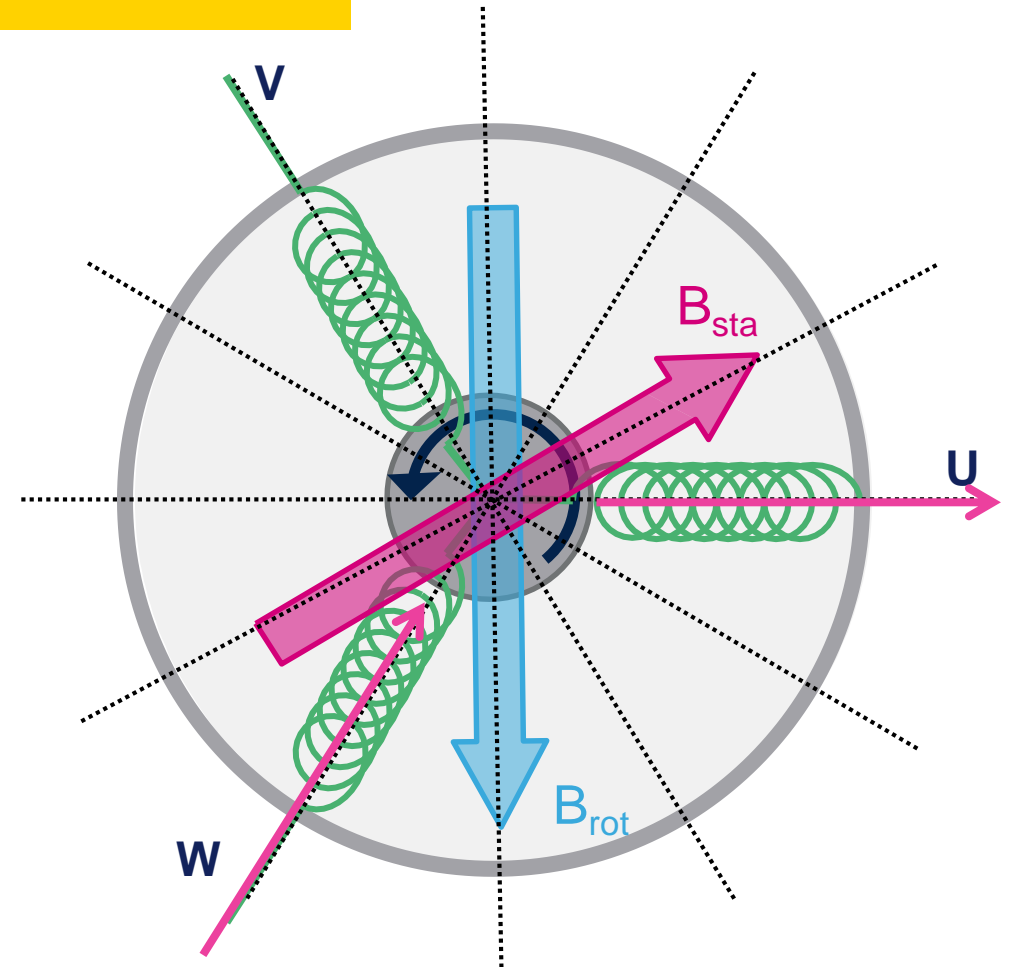
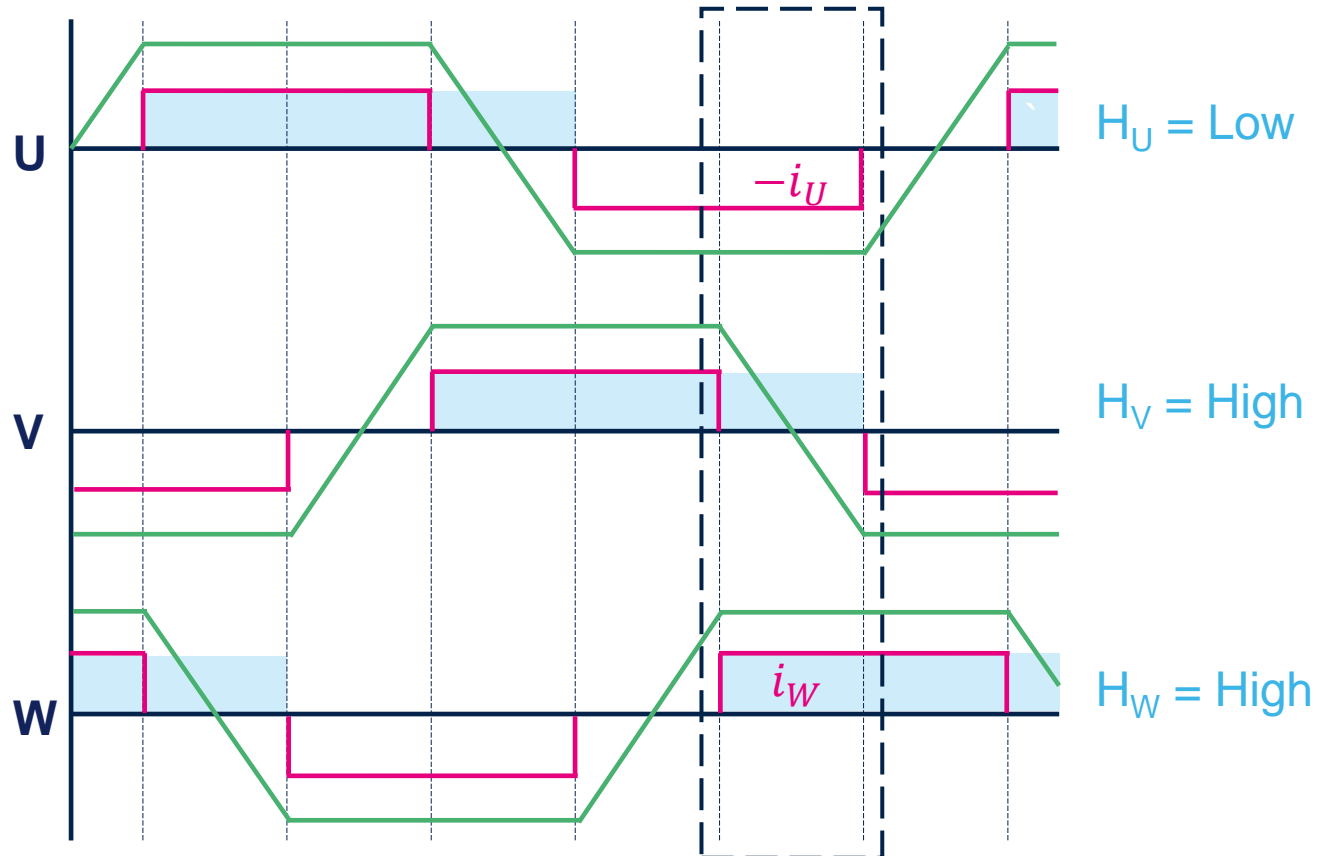
6-step driving – Hall sensors feedback (210° - 270°)





Three-phase BLDC/PMSM

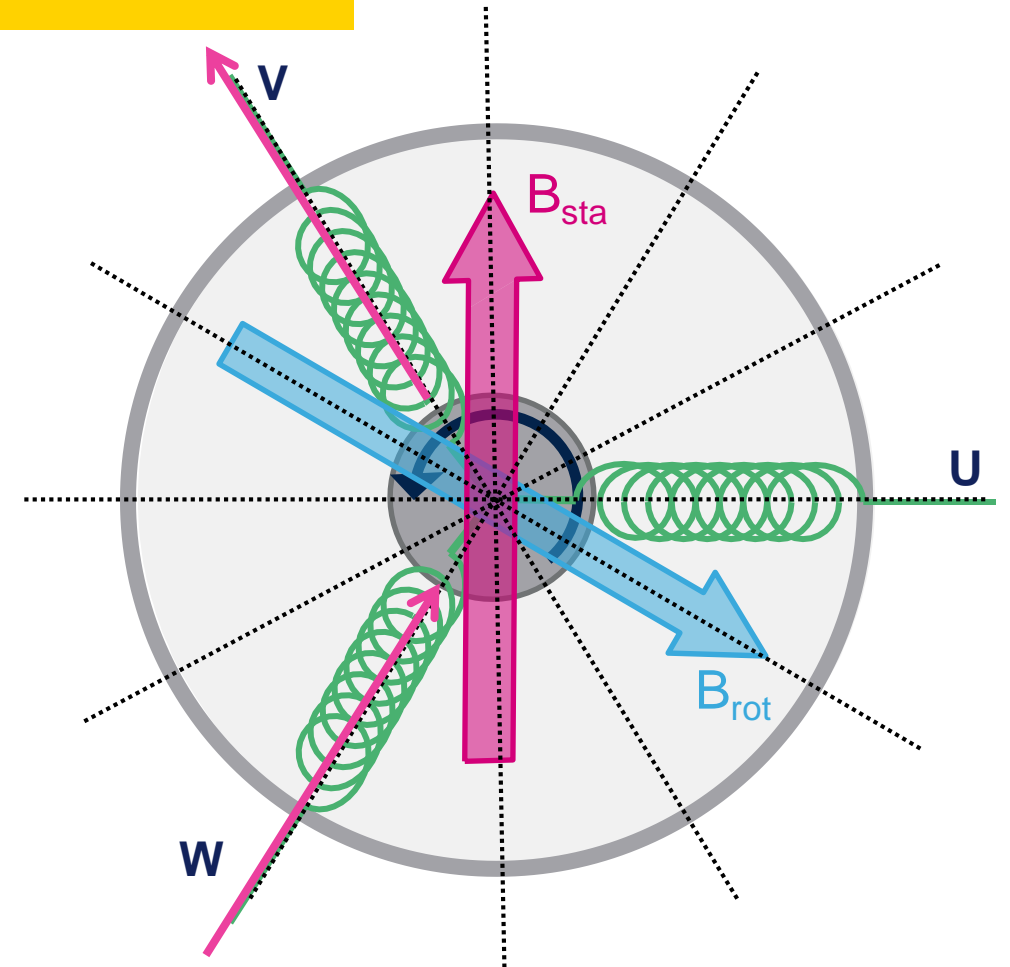
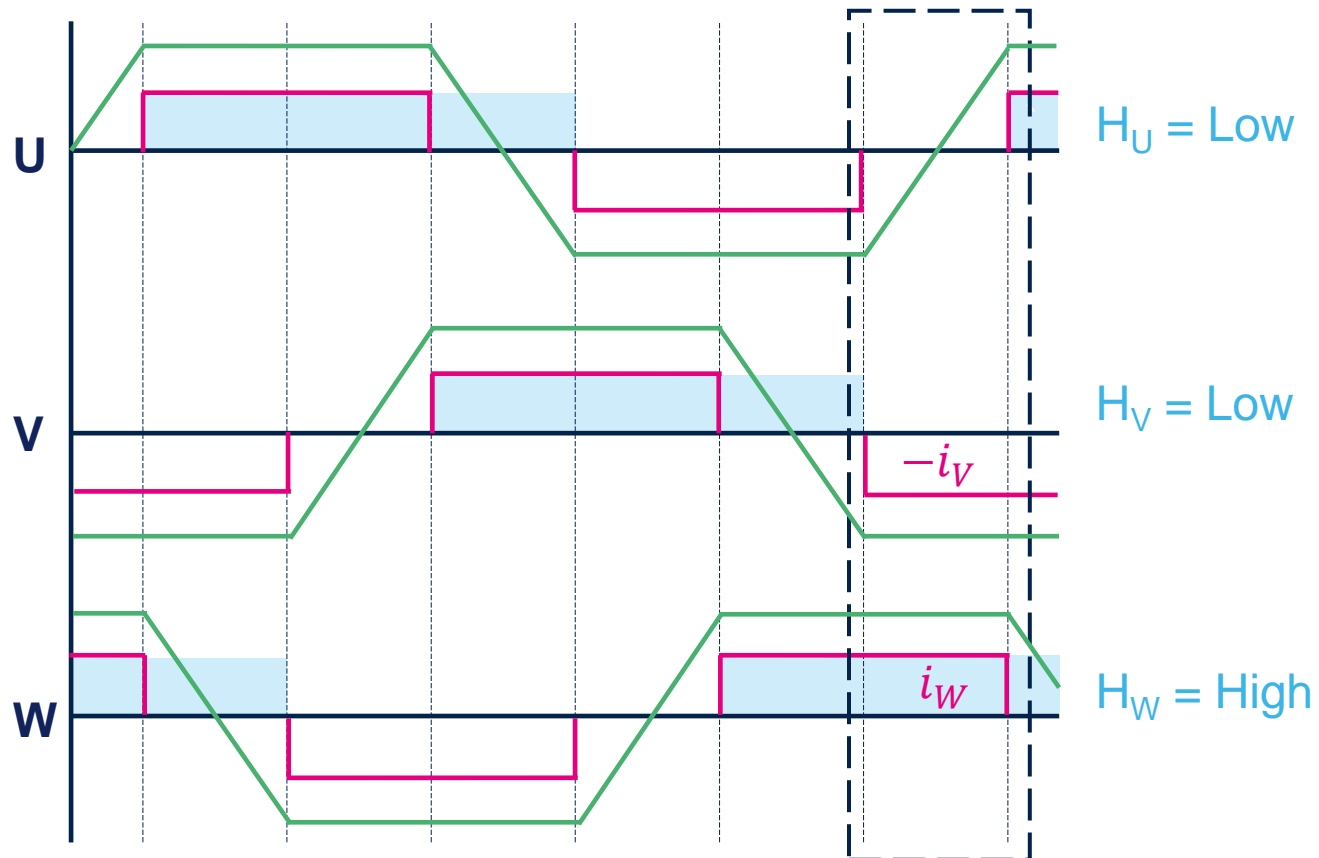
6-step driving – Hall sensors feedback (270° - 330°)





Three-phase BLDC/PMSM

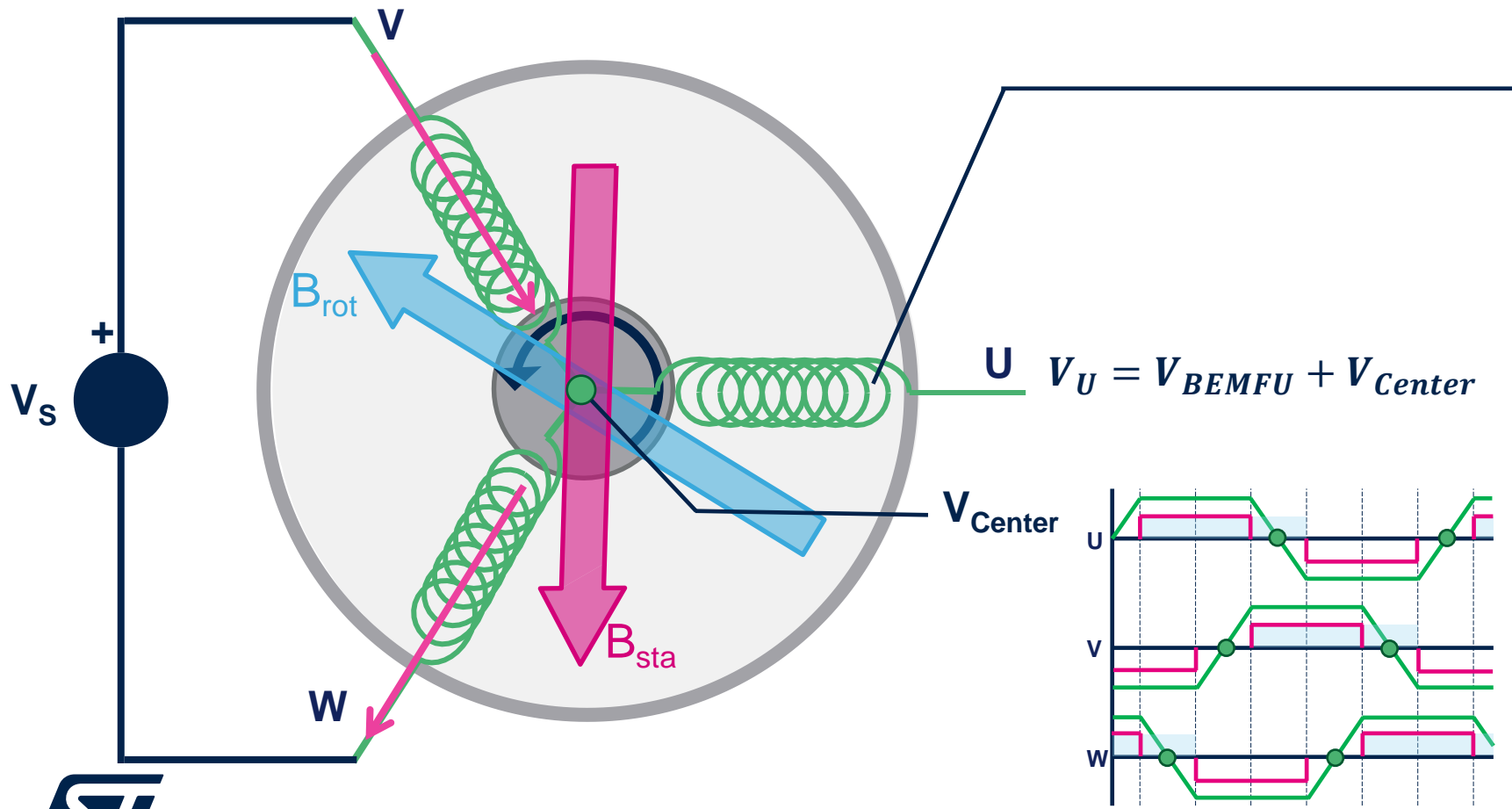
6-step driving – Hall sensors feedback ($330^\circ - 30^\circ$)





Three-phase BLDC/PMSM

6-step driving – sensorless driving



When the magnetic field of the rotor crosses the unloaded phase, the respective BEMF voltage changes polarity (zero-crossing)

The sensorless driving detects the BEMF zero-crossing measuring the voltage on the floating phase

In order to detect the zero-crossing of the BEMF the center-tap voltage must be known.

Some motors makes the center tap available. In other cases, it can be reconstructed through the phase voltages.



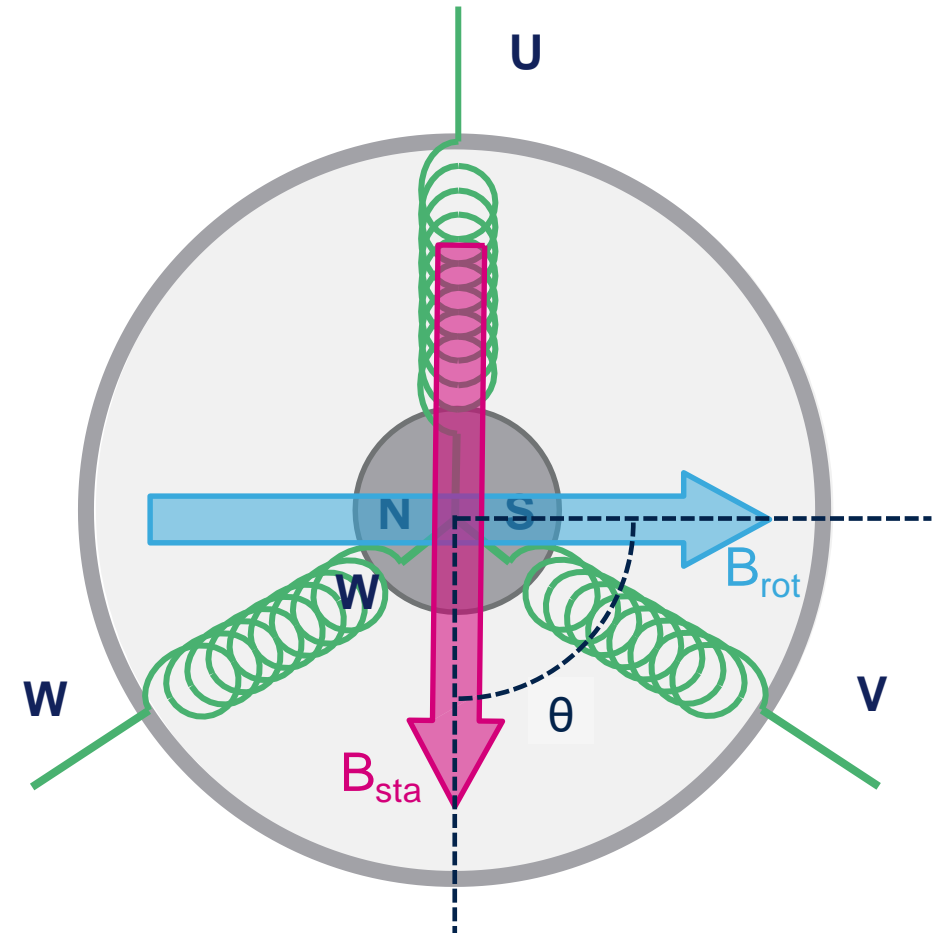
Three-phase BLDC/PMSM

Field Oriented Control

The **Field Oriented Control (FOC)** algorithm allows to obtain the maximum performance from a BLDC/PMSM motor.

The objective of the algorithm is to control the vector components of the stator magnetic field (i.e. the phase currents) in order to obtain the target **intensity** and **phase relation** with the rotor magnetic field.

$$T_q \propto B_{rot} \cdot B_{sta} \cdot \sin \theta \propto I_{ph} \cdot \sin \theta$$





Three-phase BLDC/PMSM

Field Oriented Control

D-Q rotation reference frame

d-q reference frame is a projection of a, b, c variables.
Control factors can be reduced from three to two.
($a - b - c$ to $d - q$)

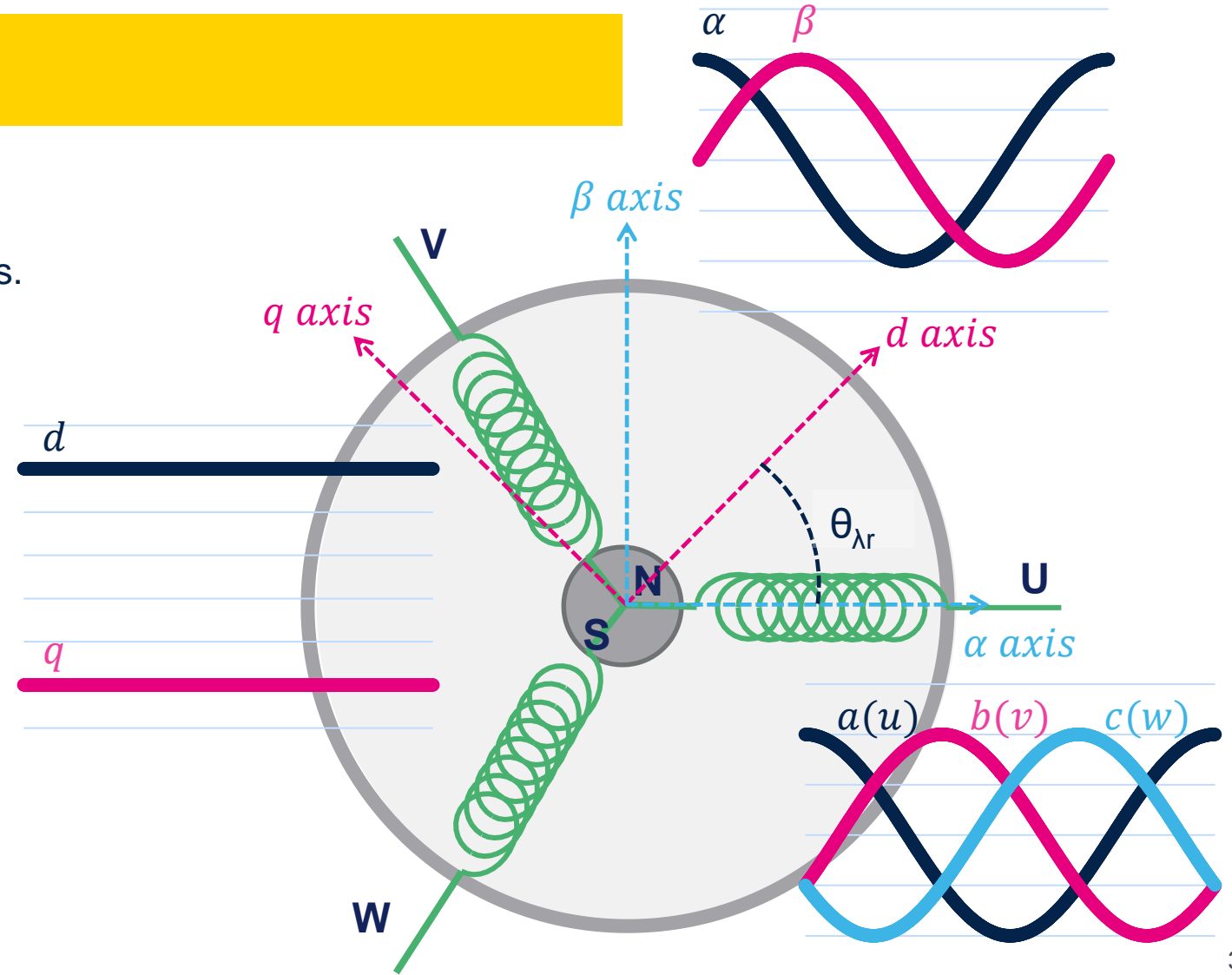
The d-axis and q-axis have independence
by being orthogonal.

D-axis (Direct Axis)

Aligned with rotor flux vector.
Control **flux density** (i.e. Flux(field) Weakening)

Q-axis (Quadrature Axis)

Aligned perpendicularly to the d-axis
Control **torque** directly



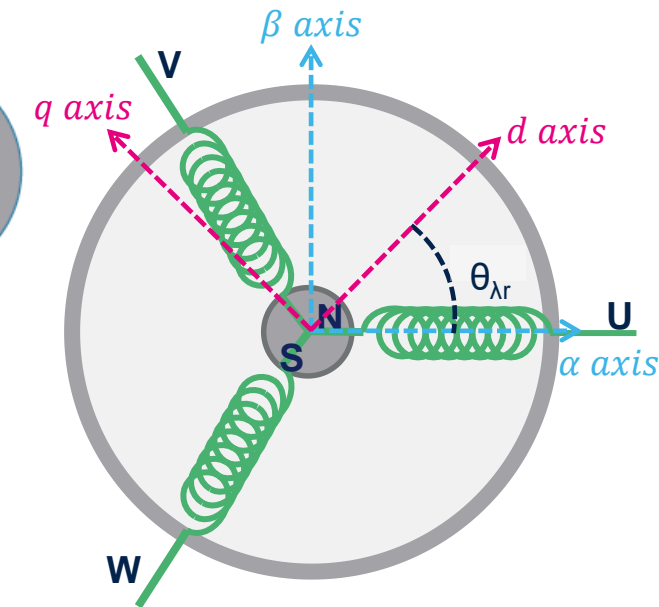
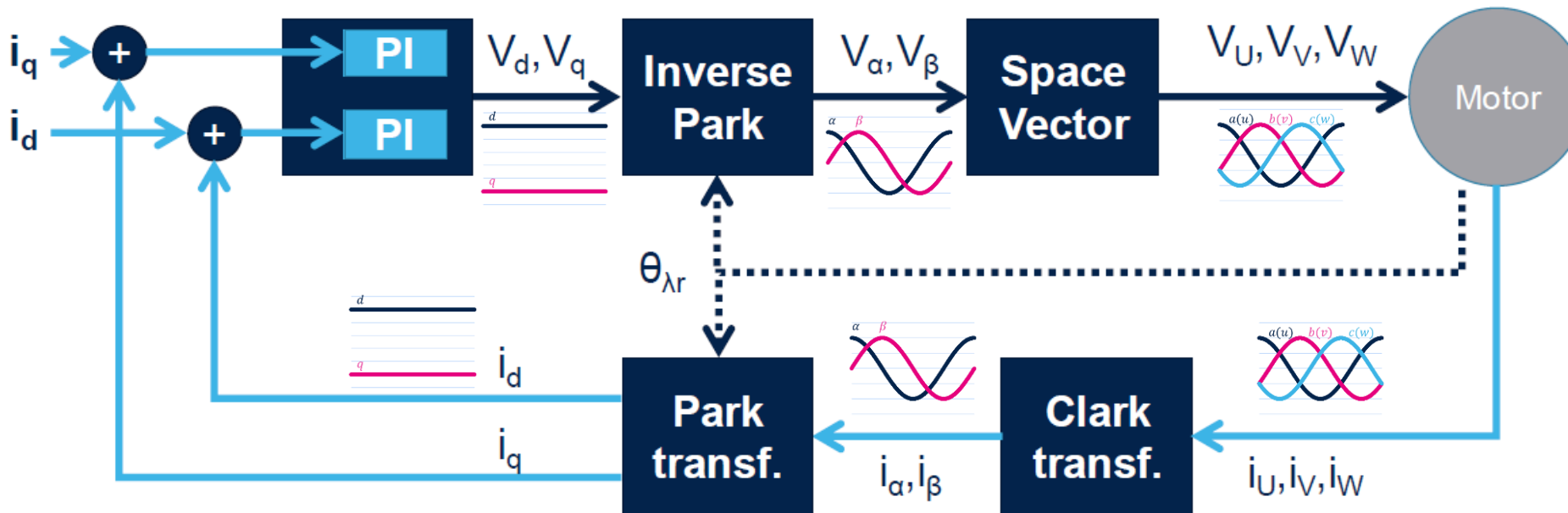


Three-phase BLDC/PMSM

Field Oriented Control

$$V_{\alpha ref} = V_{dref} \cos(\theta_{\lambda r}) - V_{qref} \sin(\theta_{\lambda r})$$

$$V_{\beta ref} = V_{dref} \sin(\theta_{\lambda r} + \frac{\pi}{2}) - V_{qref} \cos(\theta_{\lambda r} + \frac{\pi}{2})$$



$$i_{ds} = i_{\alpha s} \cos(\theta_{\lambda r}) + i_{\beta s} \sin(\theta_{\lambda r})$$

$$i_{qs} = -i_{\alpha s} \sin(\theta_{\lambda r}) + i_{\beta s} \cos(\theta_{\lambda r})$$

$$i_{\alpha s} = i_U$$

$$i_{\beta s} = \frac{1}{\sqrt{3}} i_U + \frac{2}{\sqrt{3}} i_V$$



Three-phase BLDC/PMSM

Field Oriented Control – pros & cons

Pros

- Can control the **efficiency** of the system imposing a **load angle** (direct component of the current)
- **Smooth operation** thanks to the sinusoidal driving

Cons

- Implies **complex calculations** which cannot be performed by low level microcontrollers
- Needs the **information** of the rotor flux (i.e. expensive sensors or more complex calculations)

ST Motor Control SDK

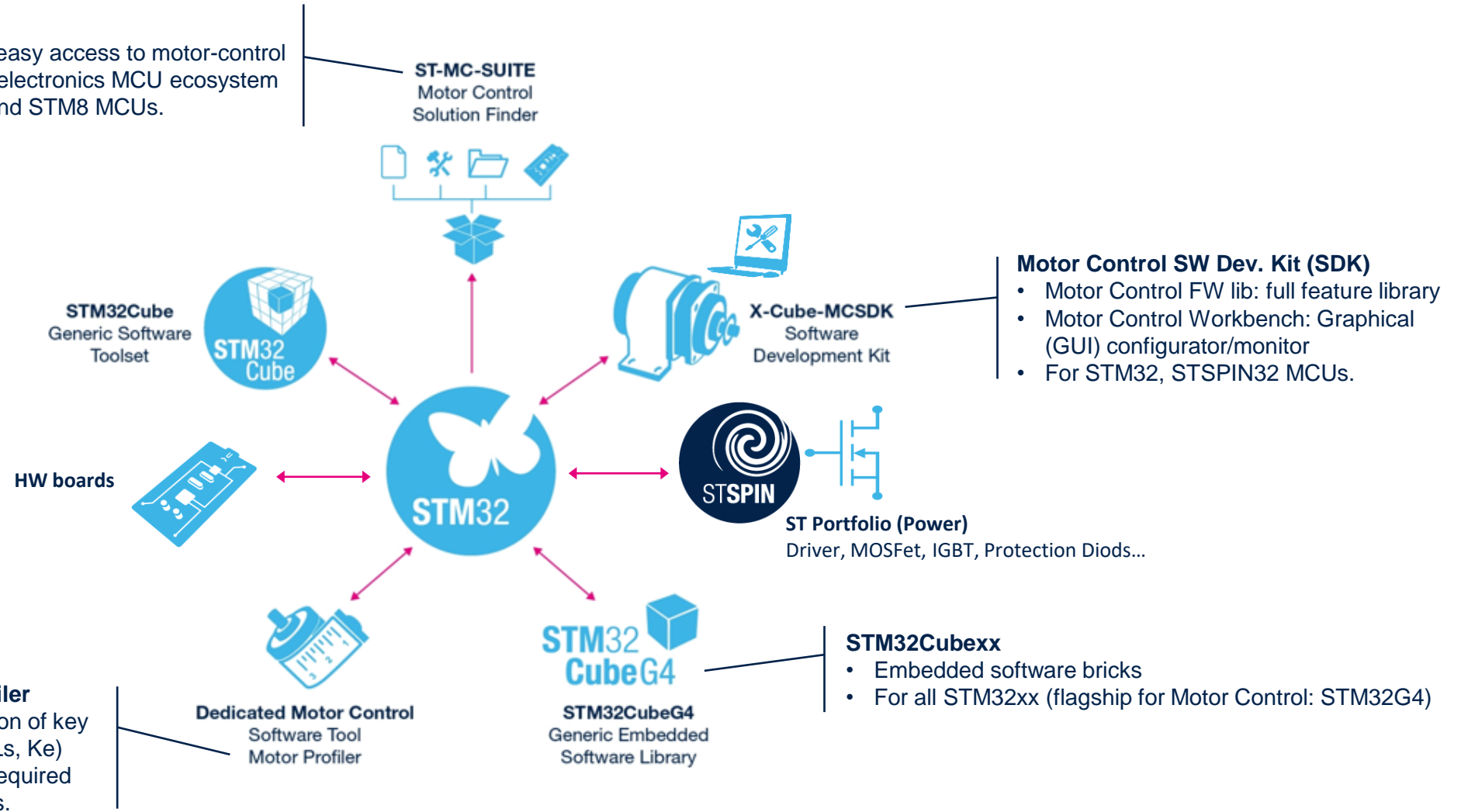


STM32 for Motion Control – Ecosystem

Motor Control Suite

- Online tool that provides easy access to motor-control resources in the STMicroelectronics MCU ecosystem
- For STM32, STSPIN32 and STM8 MCUs.

Visit the STM32 Motor control dedicated web page:
www.st.com/content/st_com/en/stm32-motor-control-ecosystem.html



Motor Control Profiler

- Automatic detection of key parameters (Rs, Ls, Ke)
- Zero equipment required
- For STM32 MCUs.

Dedicated Motor Control
Software Tool
Motor Profiler

STM32Cubexx

- Embedded software bricks
- For all STM32xx (flagship for Motor Control: STM32G4)

STM32CubeG4
Generic Embedded
Software Library

Motor Control SW Dev. Kit (SDK)

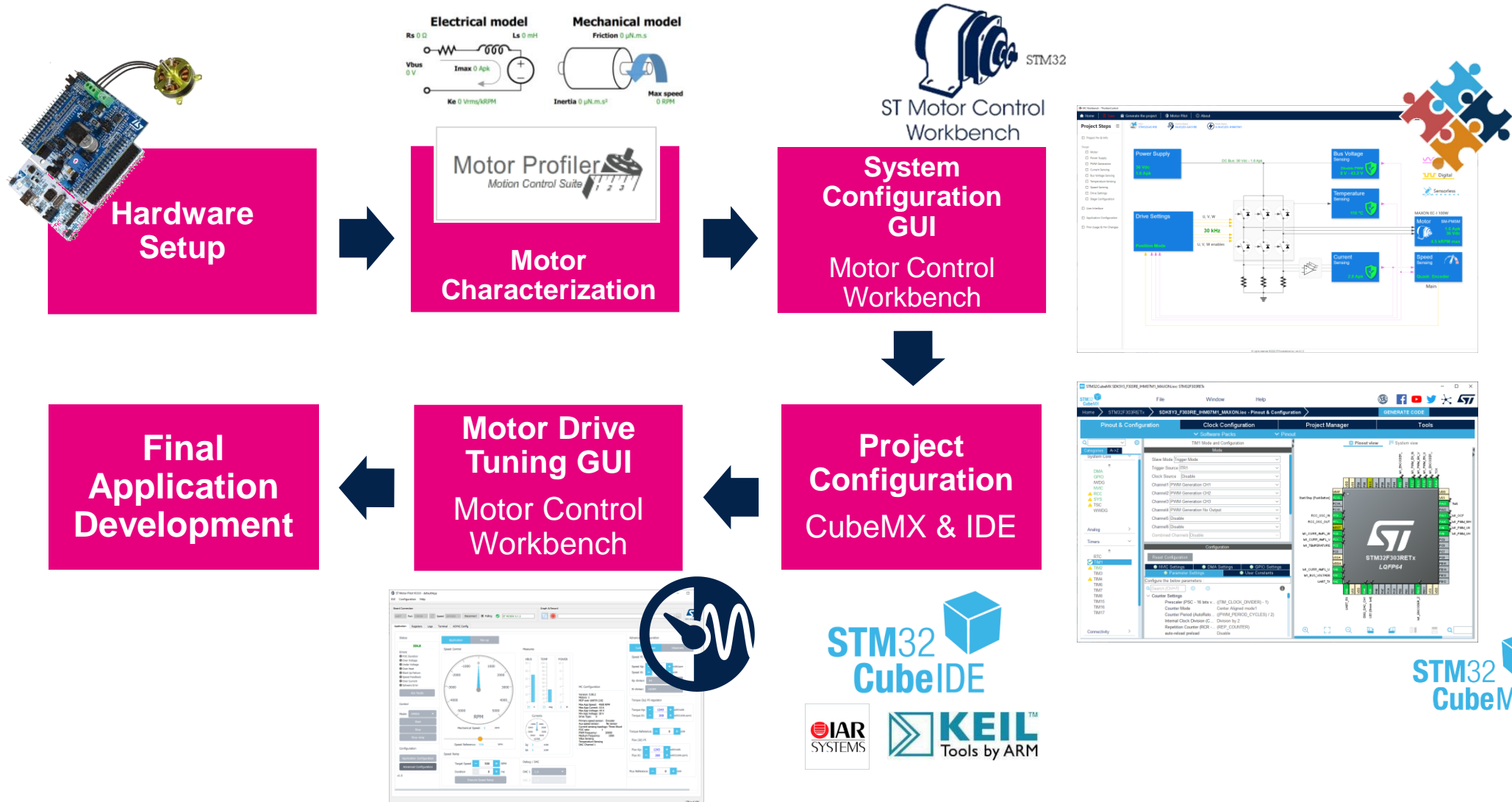
- Motor Control FW lib: full feature library
- Motor Control Workbench: Graphical (GUI) configurator/monitor
- For STM32, STSPIN32 MCUs.

X-Cube-MCSDK
Software
Development Kit

ST Portfolio (Power)
Driver, MOSFet, IGBT, Protection Diodes...



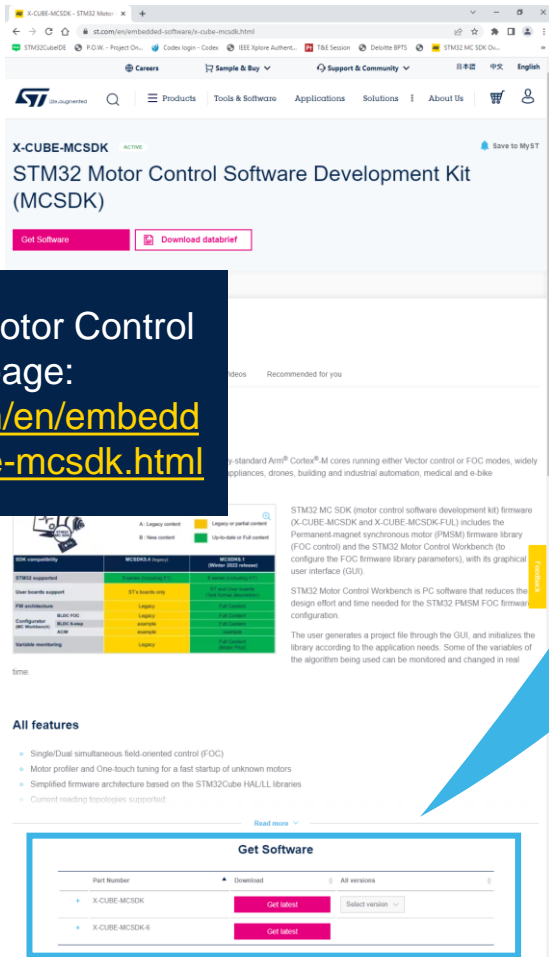
MCSDK work-flow





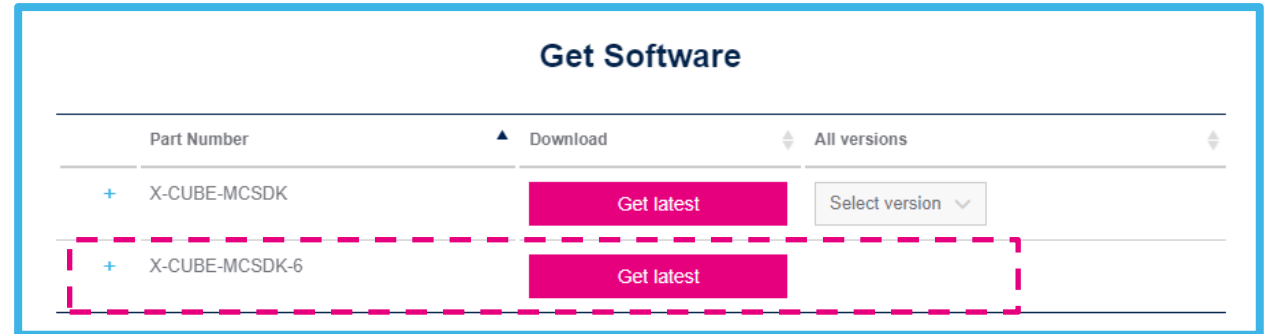
ST Motor Control SDK

Install MCSDK 6.1.0



Visit the STM32 Motor Control SDK web page:

<https://www.st.com/en/embedded-software/x-cube-mcsdk.html>



MotorControl
Workbench 6.1.0



Motor Pilot 6.1.0



Motor Profiler




Motor Pilot 6.1.0





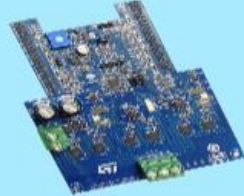
Motor Profiler

NUCLEO-G431RB
STM32G431RB




**One Motor Control connector
ST-LINK/V2 Embedded**
[Product Web Page](#)

X-NUCLEO-IHM08M1 3Sh
STL220N6F7




**Bus voltage : 10 - 48 Vdc
DC input voltage : 10 - 48 Vdc
Output peak current : 3 - 30 A**
[Product Web Page](#)

NUCLEO-G431RB
STM32G431RB



**One Motor Control connector
ST-LINK/V2 Embedded**

X-NUCLEO-IHM08M1 3Sh
STL220N6F7



**Bus voltage: 10 - 48 Vdc
DC Input voltage: 10 - 48 Vdc
Output peak current: 3 - 30 A**

Pole pairs: [Detect pole pairs](#)

Max speed: RPM

Max current: Apk

Magnetic: SM-PMSM I-PMSM



Motor Profiler

ST Motor Pilot V1.1.3 - profiler

GUI Configuration Help

Graph & Record

Application Registers Logs

NUCLEO-G431RB STM32G431RB

X-NUCLEO-IHM08M1 3Sh STL220N6F7

One Motor Control connector ST-LINK/V2 Embedded

Bus voltage: 10 - 48 Vdc
DC Input voltage: 10 - 48 Vdc
Output peak current: 3 - 30 A

Pole pairs: Detect pole pairs

Max speed: 16000 RPM

Max current: 30 Apk

Magnetic: SM-PMSM I-PMSM

Disconnect

Start profile

Start Hall profil...

Save

Electrical model

Rs 0.32 Ω Ls 0.44 mH

Vbus 23.6 V

Imax 2 Apk

Ke 4.57 Vrms/kRPM

Mechanical model

Friction 13.01 μ N.m.s

Inertia 8.33 μ N.m.s²

Max speed 3714 RPM

Errors

- FOC Duration
- Over Voltage
- Under Voltage
- Over Heat
- Start Up Failure
- Speed Feedback
- Over Current
- Software Error

Ack Faults

Profiler Hall profiler

Profiling % 100

Pole pairs detection

You don't know the number of pole pairs?
Click on start to begin the detection process.

Close

Start



Motor Profiler

Pole pairs detection x

Before launching the detection, please check that your 3 phases are connected to the power board and set the current to 10% of the maximum current supported by the motor.

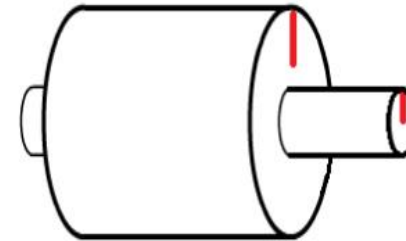
Current: Apk

Back

Next

Pole pairs detection x

Apply a mark to the fixed part and the rotating part



Back

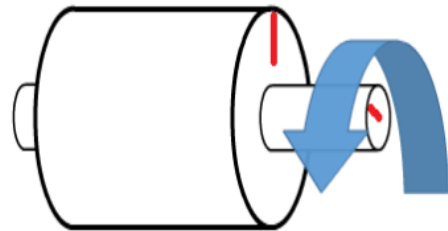
Begin



Motor Profiler

Pole pairs detection X

Spin your motor manually, the number of pole pairs is the number of notches you will feel during a complete mechanical rotation of the motor.

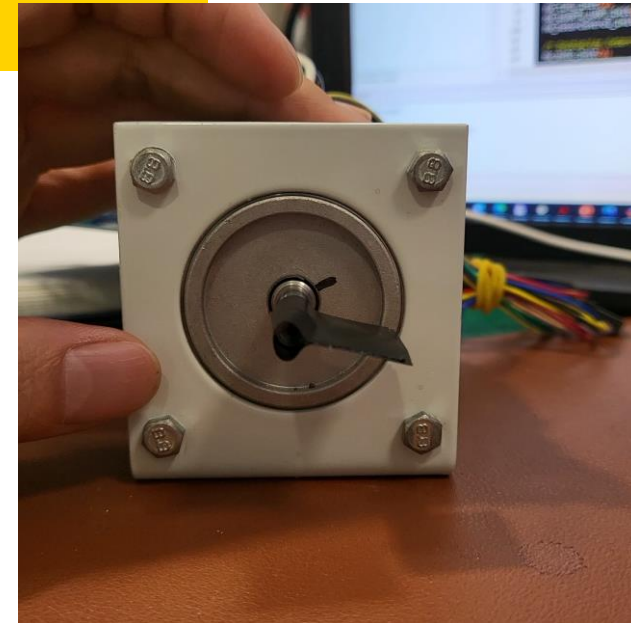


Need Help ?



Stop

Finish



Pole pairs:

2

Detect pole pairs

Max speed:

16000

RPM

Max current:

30

Apk

Magnetic:

SM-PMSM

I-PMSM

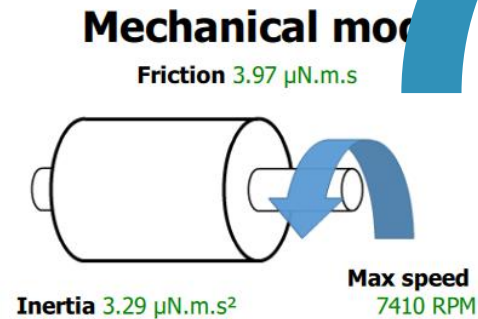
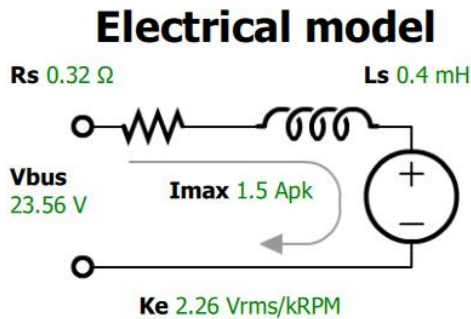


ST Motor Control SDK

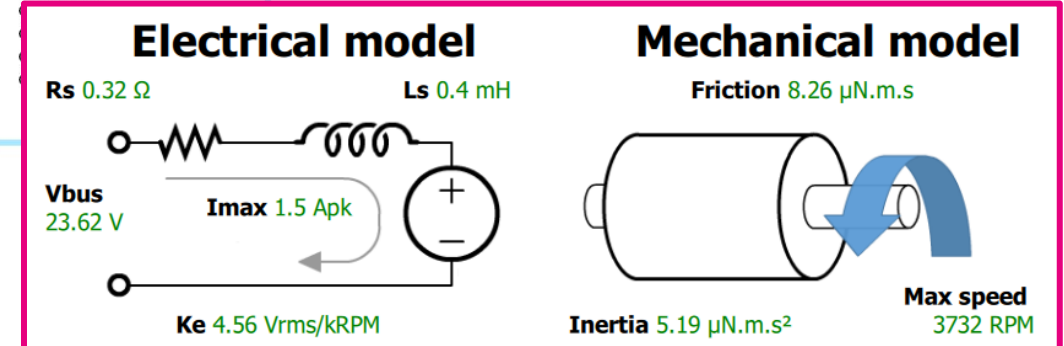
Motor Profiler

- Motor turns automatically
- After 30-40 seconds, Motor parameters are updated.

- Disconnect
- Start profile
- Start Hall profil...
- Save




- ### Errors
- FOC Duration
 - Over Voltage
 - Under Voltage
 - Over Heat





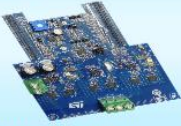
Motor Profiler

NUCLEO-G431RB
STM32G431RB



One Motor Control connector
ST-LINK/V2 Embedded

X-NUCLEO-IHM08M1 3Sh
STL220N6F7



Bus voltage: 10 - 48 Vdc
DC Input voltage: 10 - 48 Vdc
Output peak current: 3 - 30 A

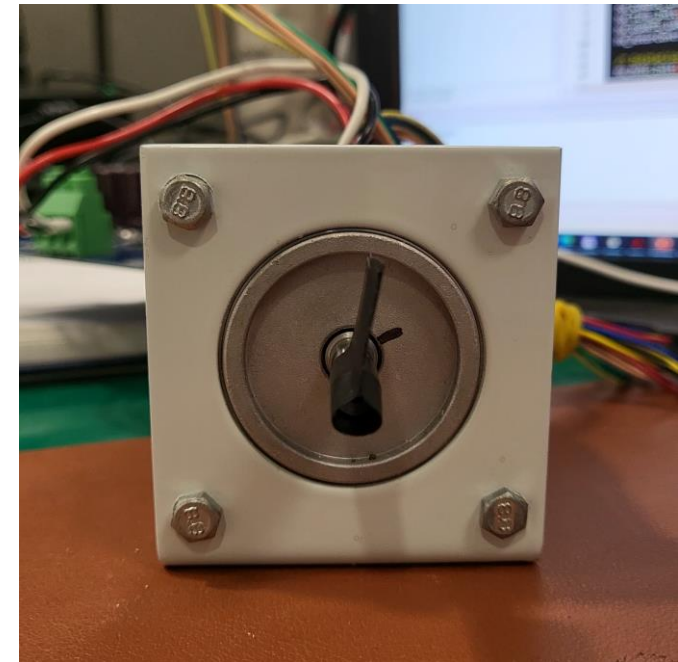
Pole pairs: [Detect pole pairs](#)

Max speed: RPM

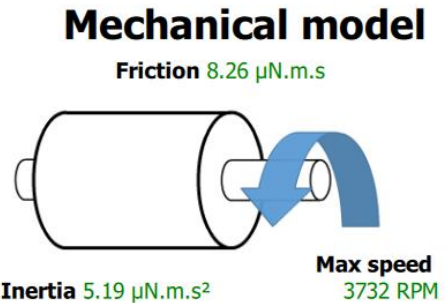
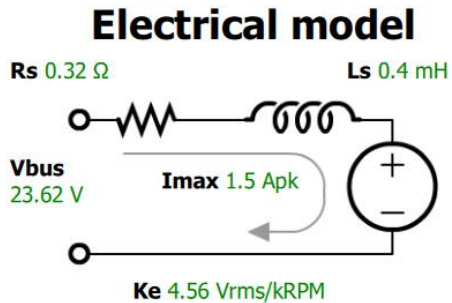
Max current: Apk

Magnetic: SM-PMSM I-PMSM

Please, can you confirm that the motor is spinning in the wanted positive direction.



- Disconnect
- Start profile
- Start Hall profil...
- Save



- #### Errors
- FOC Duration
 - Over Voltage
 - Under Voltage
 - Over Heat
 - Start Up Failure
 - Speed Feedback
 - Over Current
 - Software Error
-



Motor Profiler


Save profiling results

Motor name:

Description:


Save

NUCLEO-G431RB
STM32G431RB



One Motor Control connector
ST-LINK/V2 Embedded

X-NUCLEO-IHM08M1 3Sh
STL220NGF7



Bus voltage: 10 - 48 Vdc
DC Input voltage: 10 - 48 Vdc
Output peak current: 3 - 30 A

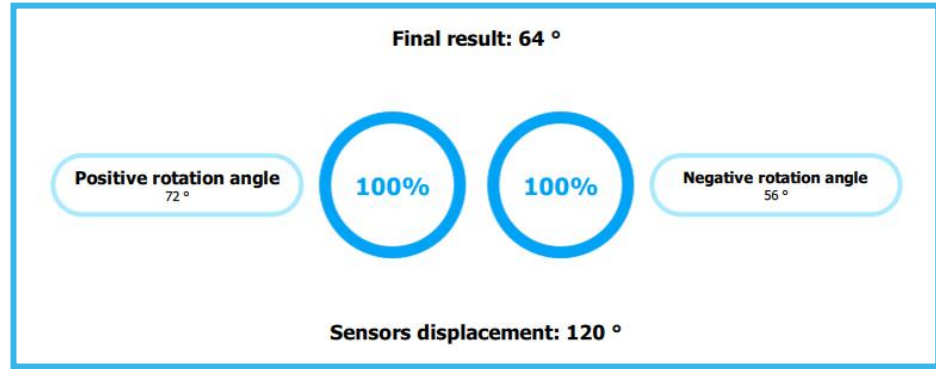
Pole pairs: Detect

Max speed: RPM

Max current: Apk

Magnetic: SM-PMSM I-PMSM

- Disconnect**
- Start profile**
- Start Hall profil...**
- Save**



- Errors**
- FOC Duration
 - Over Voltage
 - Under Voltage
 - Over Heat
 - Start Up Failure
 - Speed Feedback
 - Over Current
 - Software Error
- Ack Faults**

```
{
  "BEmfConstant": 4.5612945556640625,
  "compatibility": [
    "FOC",
    "sixStep"
  ],
  "description": "shinano_webinar",
  "friction": 8.26,
  "hallSensor": {
    "placementElectricalAngle": 64,
    "sensorsDisplacement": 120
  },
  "hardwareFamily": "MOTOR",
  "hasHallSensor": true,
  "id": "shinano_webinar",
  "inertia": 5.19,
  "label": "shinano_webinar",
  "ls": 0.4,
  "magneticStructure": {
    "ld_lq_ratio": "",
    "type": "SM-EMSM"
  },
  "maxRatedSpeed": 3732,
  "nominalCurrent": 1.5,
  "nominalDCVoltage": 23.622116088867188,
  "polePairs": 2,
  "rs": 0.32255738973617554
}
```



MC Workbench



MotorControl
Workbench 6.1.0





MC Workbench

General Info

Motors

Power

Control

Motor

Search Motors (23 / 23)

Shinano LA052-080E3NL1

General Info

Motors

Power

Control

MAXON EC-I 100W
brushless DC motor with encoder and Z I...

Magnetic Struct: SM-PMSM
Pole Pairs: 7
Max Speed: 4.5 krpm
Nominal Voltage: 36 V
Nominal Current: 1.6 Apk

Shinano LAC

Inner rotor type

Magnetic Str
Pole P
Max Sp
Nominal Volt
Nominal Cur

SM-PMSM 320V motor
Motor high voltage

Magnetic Struct: SM-PMSM
Pole Pairs: 4
Max Speed: 4 krpm

I-PMSM 24V
Motor low volta

Magnetic Str
Pole P
Max Sp

< Prev

Power

Search Powers (17 / 17)

X-NUCLEO-IHM08M1


General Info

Motors

Power


Control

X-NUCLEO-IHM07M1
Three-phase brushless DC motor driver e...



Motor Drive
Rated Voltage: [8 - 48] V
Rated Current: 2.8 A

X-NUCLEO-IH...
Low-Voltage BLDI...



Motor Drive
Rated Voltage
Rated Current

< Prev

Control

Search Controls (16 / 16)

NUCLEO-G431RB


General Info

Motors

Power


Control

NUCLEO-G431RB
STM32 Nucleo-64 development board wi...



MCU: STM32G431RBTx
Clock Frequency: 170 MHz
Clock Source: 24_crystal

NUCLEO-G474RE
STM32 Nucleo-64 development board wi...



MCU: STM32G474RETx
Clock Frequency: 170 MHz
Clock Source: 24_crystal

< Prev Next > >> OK X Cancel



MC Workbench

MC Workbench

Motor Control WorkBench

English

New project Load Project Tools About

Recent Projects:

- SDK6_G474RE_IHM08M1_FOC
- webinar_project
- SDK6_Slx2FOC
- 6_Step_CM

Example Projects:

Project name	MCU	Type	Control	Powers	Motors	Description
ACIM FOC	STM32G431RB	ACIM / FOC	NUCLEO-G431RB	STEVAL-IHM023V3	ACIM SELNI AHV 242 N06	Sensorless Field Ori...
ACIM V/F Open Loop	STM32G431RB	ACIM / V/F	NUCLEO-G431RB	STEVAL-IHM023V3	ACIM SELNI AHV 242 N06	Open Loop Control ...
FOC STM32H745ZI with IHM08 example	STM32H745ZI	FOC / short_topology_3-SHUNT	NUCLEO-H745ZI	X-NUCLEO-IHM08M1	SHINANO	FOC example with c...

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General Info

Motors

Power

Control

Project Name & Description

Project name: MC_Webinar

Description: Project for Motor Control Basic Webinar

Select Motor Control Algorithm & Hardware

Num. Motors: 1

Algorithm: FOC 6-Step

Hardware: Modular Pack Inverter

Modular : Control Board + Power Board + Motor
(i.e. NUCLEO + X-NUCLEO + Motor)

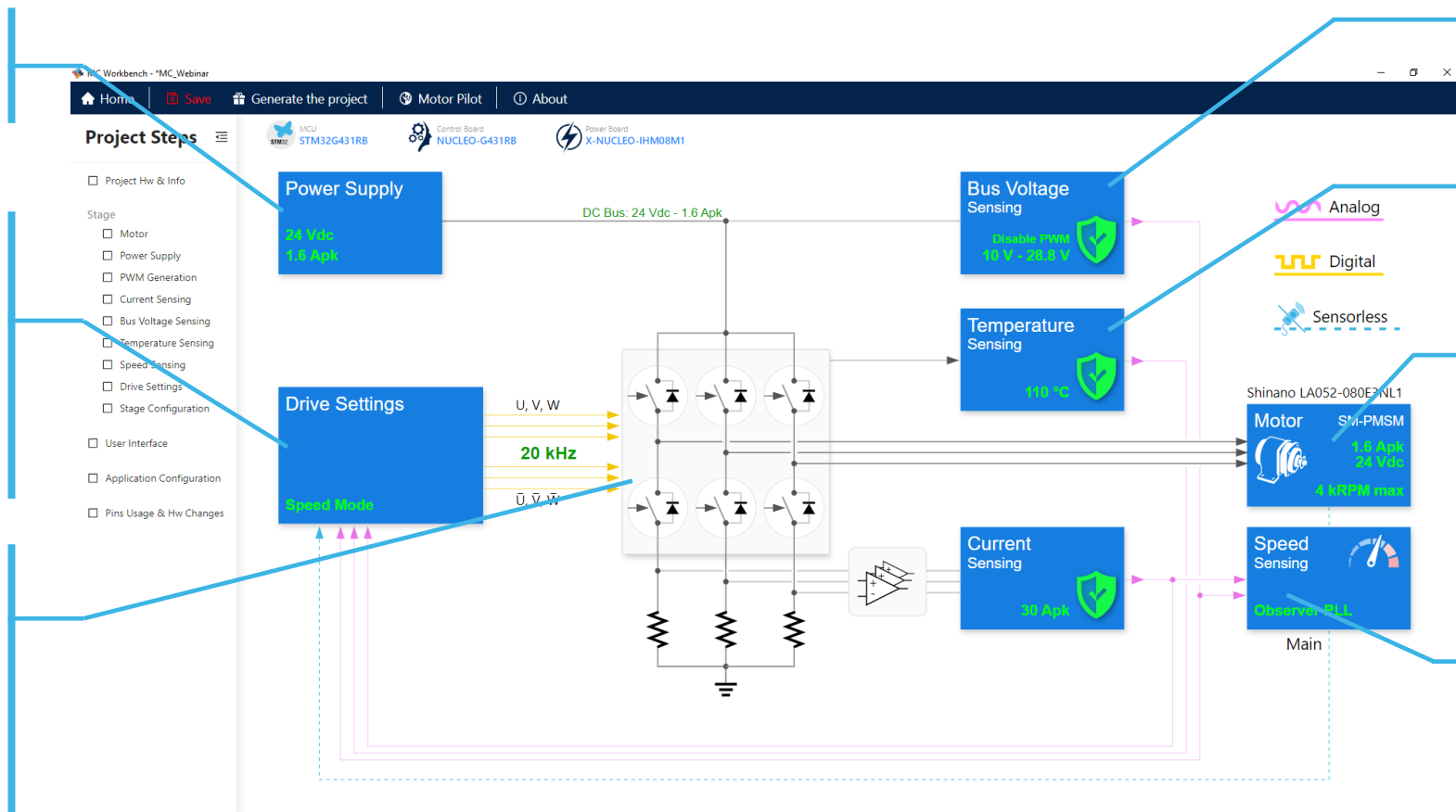
Pack : ST Modular Kit Product
(i.e. P-NUCLEO_IHM002/03)

Inverter : ST Inverter Product
(i.e. EVSPIN32G4, EVSPIN32F0601Q1)



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
- Torque, Speed
- (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM



- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
- Hall sensor
- Encoder

- Position sensing type
- Sensorless(PLL/Cordic)
- Hall sensor
- Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage

- Control Mode
- Torque, Speed
- (Position)
- Control Gain
- Feed forward
- Flux weakening

- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

MC Workbench - MC_Webinar

Home Save Generate the project Motor Pilot About

FOC Wizard

Project Hw & Info

Provide here below the Max Current and the Bus Voltage levels that will be used by this application.
Please note that these values have to be provided by your Power Supply and they have to be compatible with both PowerBoard and Motor

Stage

Motor

Power Supply

PWM Generation

Current Sensing

Bus Voltage Sensing

Temperature Sensing

Speed Sensing

Drive Settings

Stage Configuration

User Interface

Application Configuration

Pins Usage & Hw Changes

Max. application Current: 1.6 A Up to 1.6 A

Bus Voltage: 24 V from 10 V to 24 V

Power board Info:

- ✓ Maximum rated current: 30 Apk
- ✓ Supported voltage range: (10 - 48) Vdc

Motor Info:

- ✓ Max current: 1.6 Apk
- ✓ Max DC Voltage: 24 Vdc

< Prev Next > OK Cancel

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- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
- Hall sensor
- Encoder

- Position sensing type
- Sensorless(PLL/Cordic)
- Hall sensor
- Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
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MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

The screenshot shows the 'FOC Wizard' interface in MC Workbench. The 'Temperature Sensing' section is highlighted with a red dashed box and includes:

- Temperature Sensing:** A toggle switch is turned 'On'.
- NTC thermistor info:**
 - V @ 25 °C: 1.06 V
 - dV/dT: 22.7 mV/°C
 - Max working temp.: 110 °C
- MCU pin mapping:**
 - ADC: ADC1_IN8 (PC2)
 - Sampling time: 1 μs (47.5 adc. clk)
 - Diagram: A box labeled 'ADC1' has an input 'IN8' connected to a pin 'C2'.
- Over temperature protection:** A toggle switch is turned 'On'.
 - Threshold: 110 °C (1 - 110 °C)
 - Hysteresis: 10 °C (1 - 10 °C)

Navigation buttons at the bottom include '< Prev', 'Next >', '>> OK', and 'X Cancel'.

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

FOC Wizard

Project Hw & Info

Stage

Motor

Power Supply

PWM Generation

Current Sensing

Bus Voltage Sensing

Temperature Sensing

Speed Sensing

Drive Settings

Stage Configuration

User Interface

Application Configuration

Pins Usage & Hw Changes

General Info

Motor name: Shinano LA052-080E3NL1

Description: Inner rotor type - 2 poles pairs - brushless DC motor with encoder

Motor parameters

Motor magnetic structure: SM-PMSM

Pole Pairs: 2

Electrical parameters

Max current: 1.6 Apk

Max DC Voltage: 24 V

Rs: 0.35 Ω

Ls: 0.6 mH

B-Emf constant: 4 Vrms/kRPM

Mechanical parameters

Inertia: 5 μN-m-s²

Friction: 14 μN-m-s

Max. Application Speed: 4000 rpm

```
{
  "BEmfConstant": 4.5612945556640625,
  "compatibility": [
    "FOC",
    "sixStep"
  ],
  "description": "shinano_webinar",
  "friction": 8.26,
  "hallSensor": {
    "placementElectricalAngle": 64,
    "sensorsDisplacement": 120
  },
  "hardwareFamily": "MOTOR",
  "hasHallSensor": true,
  "id": "shinano_webinar",
  "inertia": 5.19,
  "label": "shinano_webinar",
  "ls": 0.4,
  "magneticStructure": {
    "ld_lq_ratio": "",
    "type": "SM-PMSM"
  },
  "maxRatedSpeed": 3732,
  "nominalCurrent": 1.5,
  "nominalDCVoltage": 23.622116088867188,
  "polePairs": 2,
  "rs": 0.32255738973617554
}
```

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

The screenshot displays the 'FOC Wizard' interface in MC Workbench. It is divided into several sections:

- Project Steps:** A sidebar on the left lists various configuration stages like Project Hw & Info, Motor, Power Supply, etc.
- Electrical parameters:** Fields for Max current (1.6 Apk), Max DC Voltage (24 V), Rs (0.35 Ω), Ls (0.6 mH), and B-Emf constant (4 Vrms/kRPM). Green checkmarks indicate power board compatibility.
- Mechanical parameters:** Fields for Inertia (5 μN·m·s²), Friction (14 μN·m·s), and Max. Application Speed (4000 rpm).
- Position sensor config. (highlighted):** Includes 'Hall Effect' and 'Quadrature Encoder' options, 'Sensors displacement' (120), 'Placement electrical angle' (300), and 'Pulses per mechanical revolution' (400).

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
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- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

The screenshot shows the 'FOC Wizard' configuration window in MC Workbench. The 'Auxiliary Sensor' section is highlighted with a red dashed box. It includes a toggle for 'Auxiliary Sensor' (set to 'On'), a dropdown for 'Speed Sensor Mode' (set to 'Quadrature Encoder'), and a field for 'Max Num. Errors before fault' (set to 3). Below this, the 'Quadrature Encoder' section is expanded, showing parameters like 'Average speed FIFO depth' (16), 'Input capture filter duration' (0.7 µsec), and 'Pulse per mechanical revolution' (400). The 'Start-up parameters' section shows 'Duration' (700 ms), 'Alignment electrical angle of Id' (90 deg), and 'Final current ramp value' (1.6 A). The 'MCU pin mapping' section shows 'Timer: TIM2'. Navigation buttons for '< Prev', 'Next >', '>> OK', and 'X Cancel' are at the bottom.

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder

- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

The screenshot shows the 'FOC Wizard' interface in MC Workbench. The 'Sensorless start-up parameters' tab is active, displaying a 'Start-up profile' table and a corresponding graph. The table defines the duration, speed target, and current target for five phases. The graph plots these targets over time, showing a step increase in speed and current targets.

Phase	Duration (ms)	Speed target (rpm)	Current target (A)
Phase 1	100	0	1
Phase 2	200	300	1
Phase 3	200	800	1
Phase 4	500	1200	1
Phase 5	500	1300	1

Initial electrical angle of Iq: 0 deg
On-the-fly start-up: Off

Graph Data (Approximate):

Time (ms)	Speed target (rpm)	Current target (A)
0	0	0
100	0	1
200	300	1
400	800	1
1000	1200	1
1600	1300	1

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

MC Workbench - MC_Webinar

FOC Wizard

Project Hw & Info

Stage

Motor

Power Supply

PWM Generation

Current Sensing

Bus Voltage Sensing

Temperature Sensing

Speed Sensing

Drive Settings

Stage Configuration

User Interface

Application Configuration

Pins Usage & Hw Changes

Execute sensor-less algorithm starting from phase: 2

Speed target (rpm)

Current target (A)

Time (ms)

Start-up exit condition

Start-up speed threshold: 1300 rpm

Consecutive correct measures: 2

Estimated limits for the speed band tolerance

Lower limit: 93.75 %

Upper limit: 106.25 %

Rev-up to FOC switch-over

Duration: 25 ms

< Prev Next > >> OK X Cancel

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- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening
- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

The screenshot shows the 'FOC Wizard' interface in MC Workbench. It features a 'Project Hw & Info' sidebar with various configuration options like Motor, Power Supply, PWM Generation, Current Sensing, Bus Voltage Sensing, Temperature Sensing, Speed Sensing, Drive Settings, Stage Configuration, User Interface, Application Configuration, and Pins Usage & Hw Changes. The main area displays a graph of 'Speed target (rpm)' and 'Current target (A)' over 'Time (ms)'. The speed target (red line) starts at 0 and reaches 1125 rpm by 1000ms. The current target (blue line) starts at 0 and reaches 1A by 1000ms. Below the graph, there is a dropdown menu for 'Execute sensor-less algorithm starting from phase: 2'. A red dashed box highlights the 'Start-up exit condition' section, which includes:

- Start-up speed threshold: 1300 rpm
- Consecutive correct measures: 2
- Estimated limits for the speed band tolerance:
 - Lower limit: 93.75 %
 - Upper limit: 106.25 %
- A checked radio button for 'Rev-up to FOC switch-over' with a duration of 25 ms.

 At the bottom, there are navigation buttons: '< Prev', 'Next >', '>> OK', and 'X Cancel'.

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters

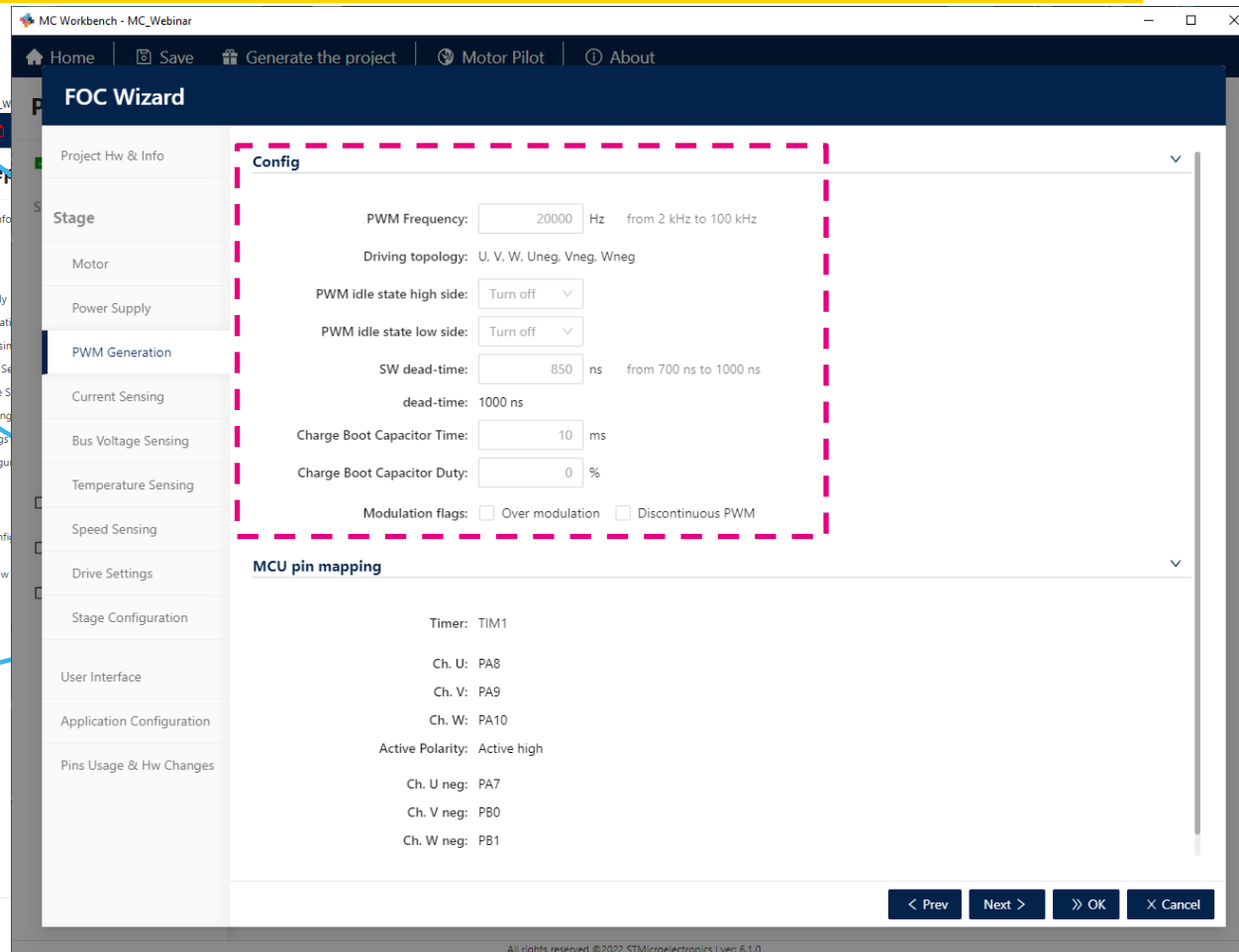




MC Workbench

- Max. Current
- Bus Voltage
- Control Mode
 - Torque, Speed
 - (Position)
- Control Gain
- Feed forward
- Flux weakening

- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM



- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
 - Hall sensor
 - Encoder

- Position sensing type
 - Sensorless(PLL/Cordic)
 - Hall sensor
 - Encoder
- Auxiliary sensor
- Sensorless start-up parameters



MC Workbench

- Max. Current
- Bus Voltage

- Control Mode
- Torque, Speed
- (Position)
- Control Gain
- Feed forward
- Flux weakening

- PWM frequency
- Idle state
- Dead-time
- Bootcap config.
- Over modulation
- Discontinuous PWM

- Bus voltage sensing
- OVP/UVP
- Recovery action

- Temperature sensing
- OTP (Hysteresis)

- Motor type
- Motor parameters
- Position sensor config.
- Hall sensor
- Encoder

- Position sensing type
- Sensorless(PLL/Cordic)
- Hall sensor
- Encoder
- Auxiliary sensor
- Sensorless start-up parameters



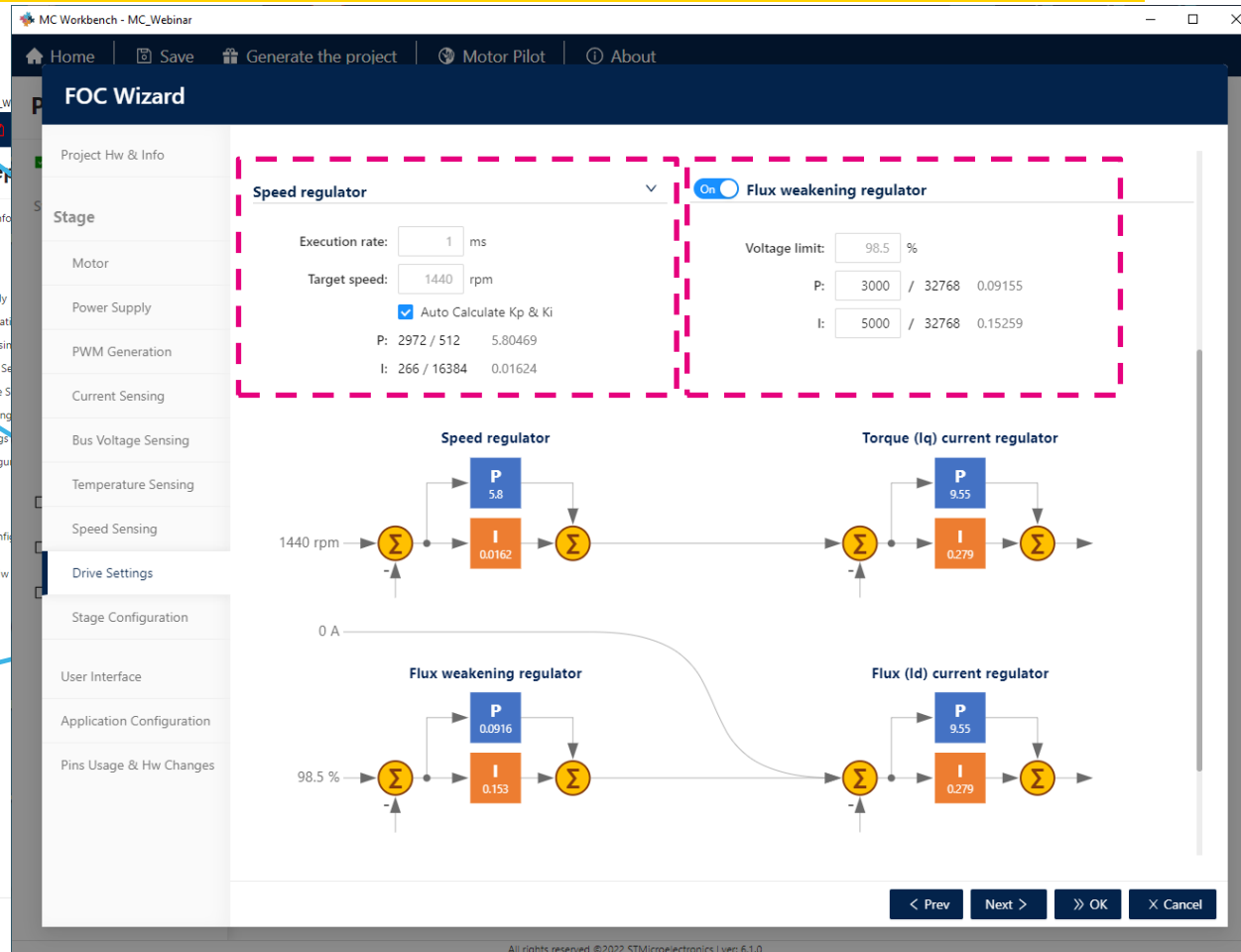


MC Workbench

- Max. Current
- Bus Voltage

- Control Mode
- Torque, Speed
- (Position)
- Control Gain
- Feed forward
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- Encoder
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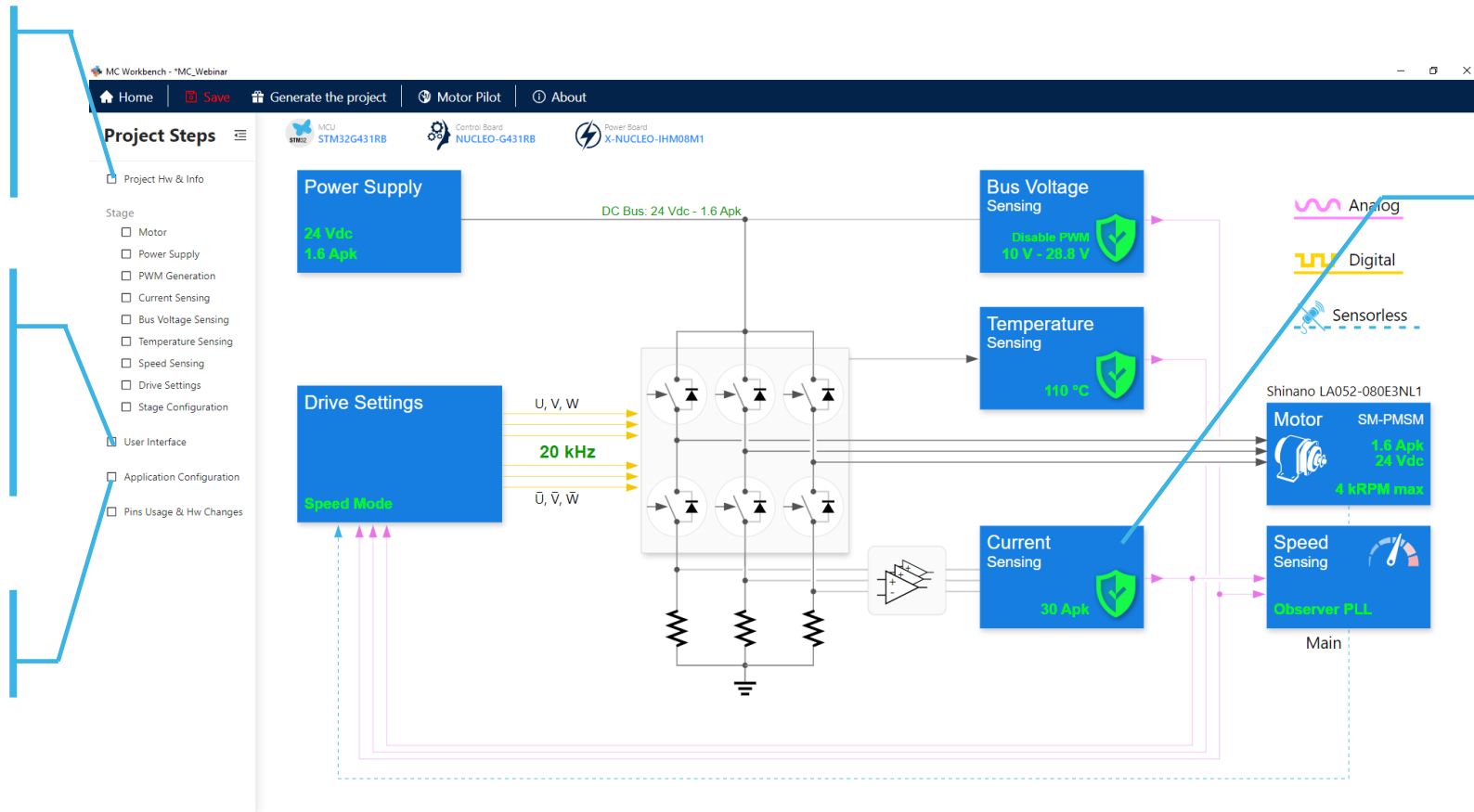


MC Workbench

- Project info.
- Open projects
 - output folder
 - CubeMX

- Start/Stop button
- USART Protocol
 - MCU Pin-map
 - Baudrate
 - Buffer size

- FreeRTOS
- DAC



- FOC execution time
- Current sensing topology
 - Three shunt resistors
 - Single shunt resistors
- Switching characteristic
 - T-rise
 - T-noise
- Sampling time
- OVP



MC Workbench

FOC Wizard

Project: MC_Webinar

Home | Save | Generate the project | Motor Pilot | About

Current Sensing

- Regulator execution time: 50 μ s (1 PWM)
- Current reading topology: Three Shunt Resistors
- Amplification: External OpAmps
- Shunt Resistor: 10 mOhm
- Gain: 5.181
- T-rise: 1000 ns
- T-noise: 1000 ns
- Readable current range: [-33 A, 30.69 A] \pm 30.69 A

MCU pin mapping

- ADC: ADC1 / ADC2
- Channel U: ADC1_IN1 (PA0)
- Channel V: ADC1_IN7 / ADC2_IN7 (PC1)
- Channel W: ADC2_IN6 (PC0)
- Sampling time: 153 ns (6.5 adc clk)
- Max Modulation: 100 %

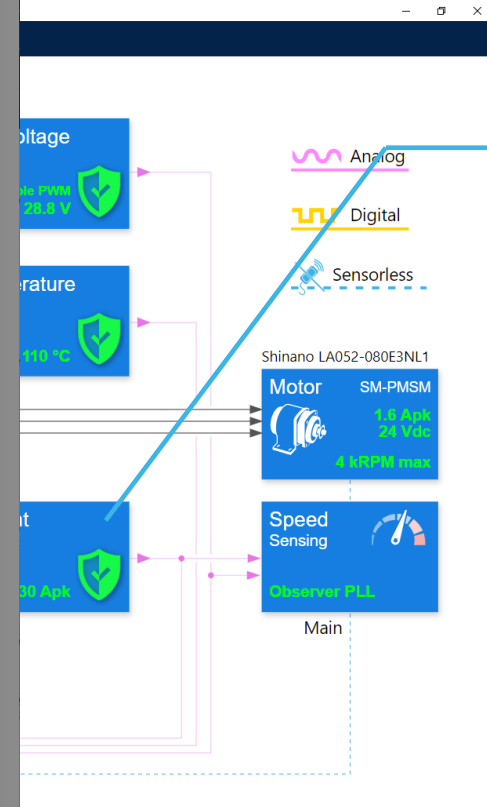
Waveform Diagrams:

- Top: PWM signals for phases T₁, T₂, T₃.
- Middle: Shunt voltage signals V_{ShA}, V_{ShB}, V_{ShC} with current I_a, I_b, I_c overlaid.
- Bottom: Detailed view of current I_b showing T-rise and T-noise.

Circuit Diagram:

Shunt resistor connected to phase U, amplified by x5.181, and connected to ADC1 (IN1 and IN7).

Navigation: < Prev | Next > | >> OK | X Cancel



- FOC execution time
- Current sensing topology
 - Three shunt resistors
 - Single shunt resistors
- Switching characteristic
 - T-rise
 - T-noise
- Sampling time
- OVP



MC Workbench

MC Workbench - MC_Webinar

Home | Save | Generate the project | Motor Pilot | About

FOC Wizard

Project Hw & Info

Stage

- Motor
- Power Supply
- PWM Generation
- Current Sensing**
- Bus Voltage Sensing
- Temperature Sensing
- Speed Sensing
- Drive Settings
- Stage Configuration
- User Interface
- Application Configuration
- Pins Usage & Hw Changes

Current Sensing

Over Current Protection

OCP Mode: External Comparators

Digital Filter Duration: 47.06 ns

Threshold: 30 A

Signal polarity: Active low

Timer: TIM1_BKIN2 (PA11)

Cur. Threshold: 30 A

shunt

U

V

W

shunt

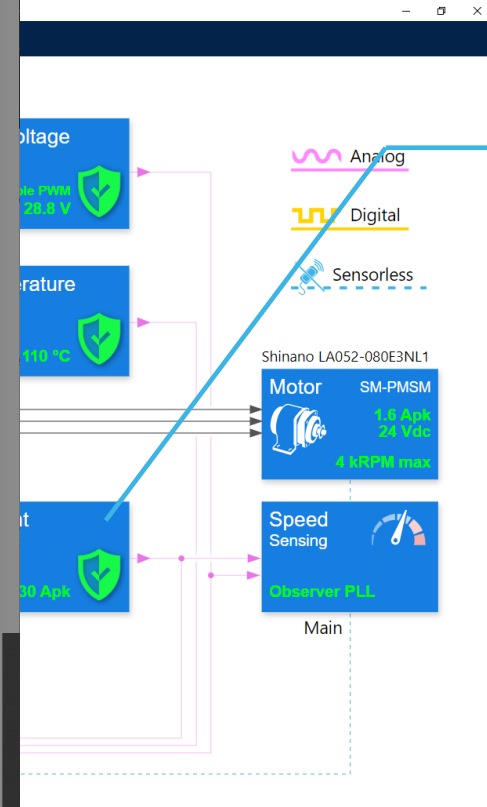
shunt

A11

TIM1

BKIN2

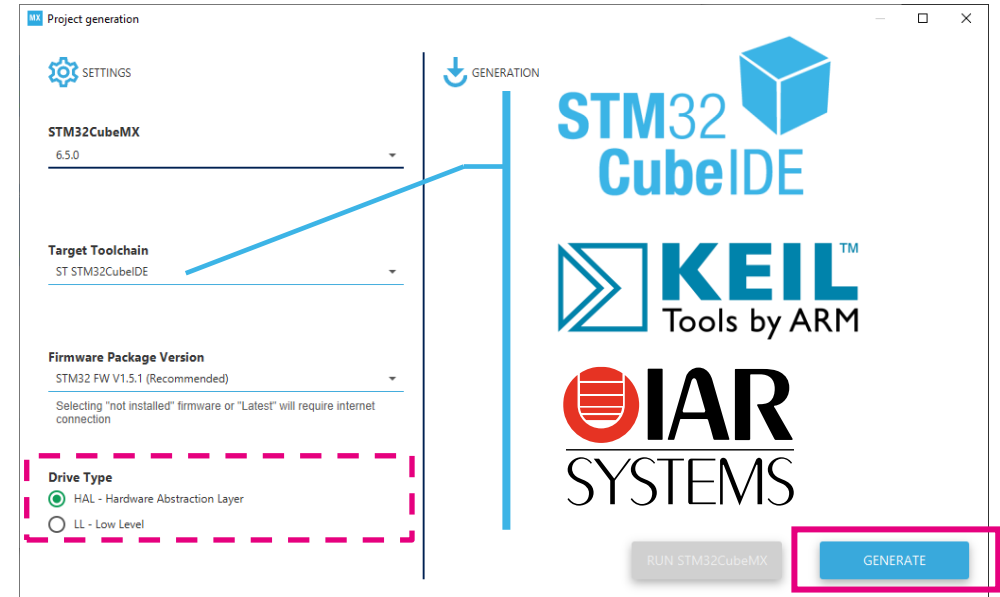
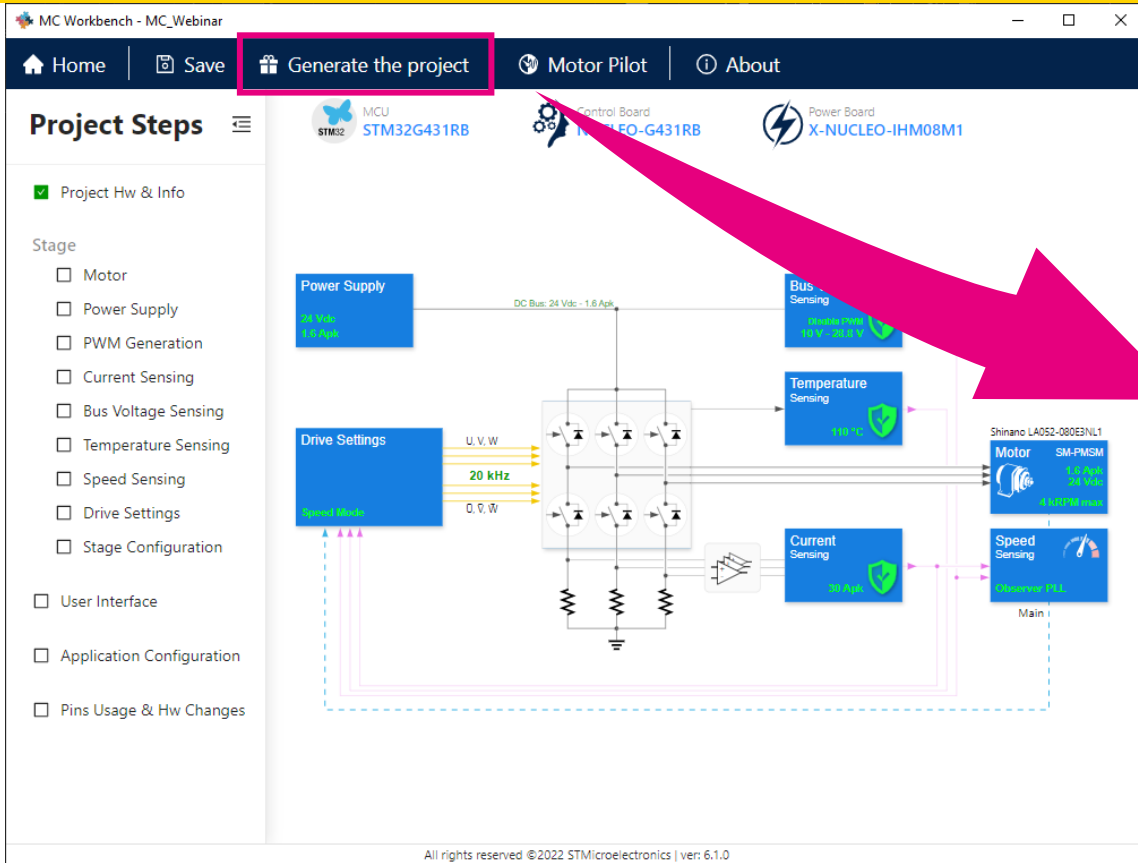
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- FOC execution time
- Current sensing topology
 - Three shunt resistors
 - Single shunt resistors
- Switching characteristic
 - T-rise
 - T-noise
- **Sampling time**
- **OVP**



MC Workbench



HAL (Hardware Abstraction Layer)

- High-level and feature-oriented API

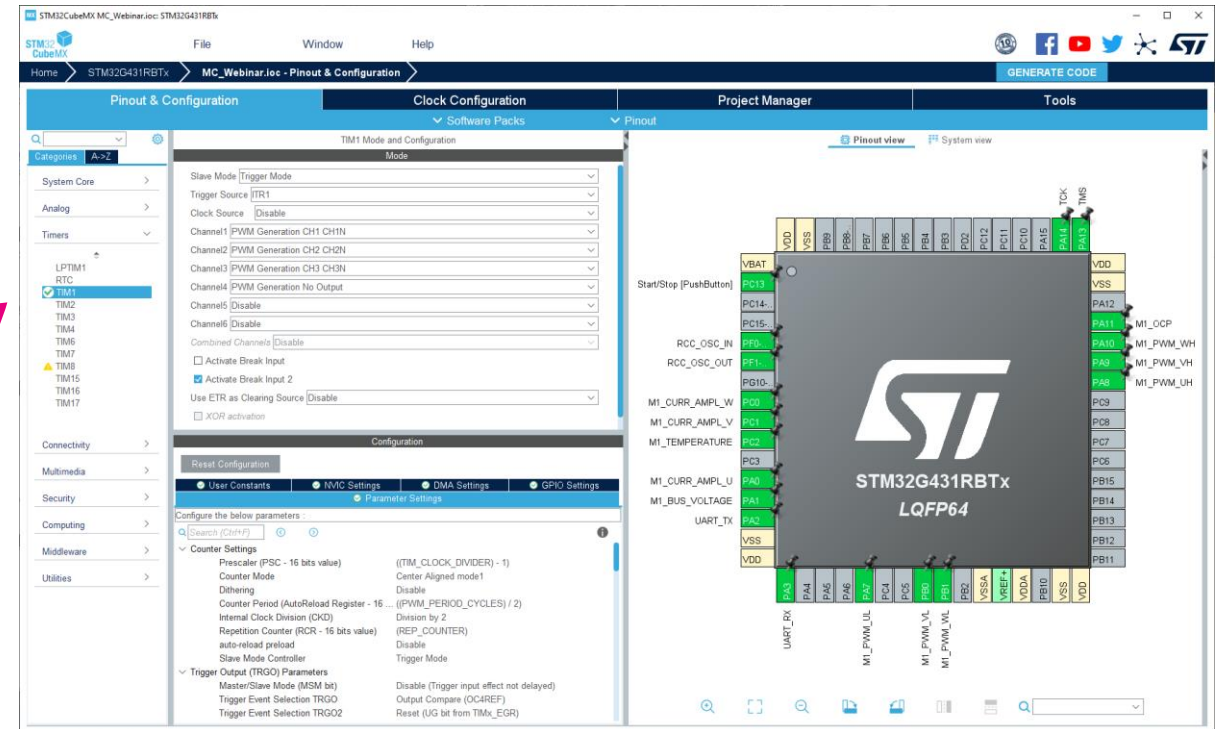
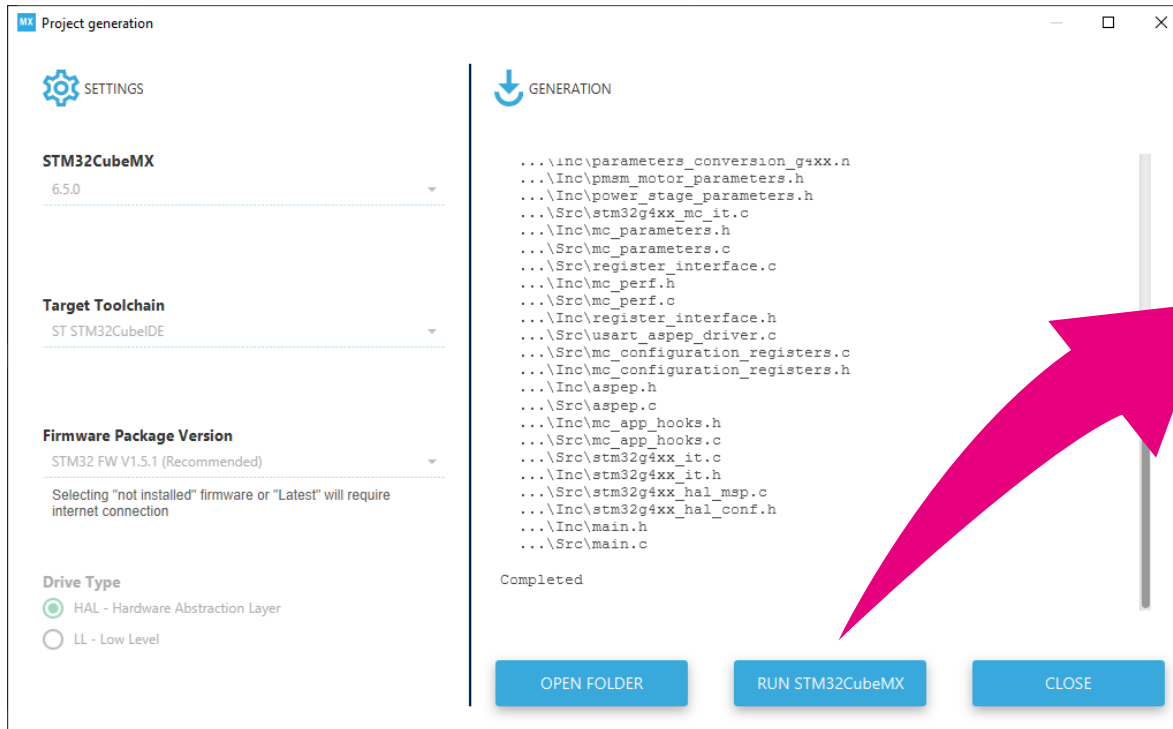
LL (Low Level)

- low-level APIs at registers level



MC Workbench

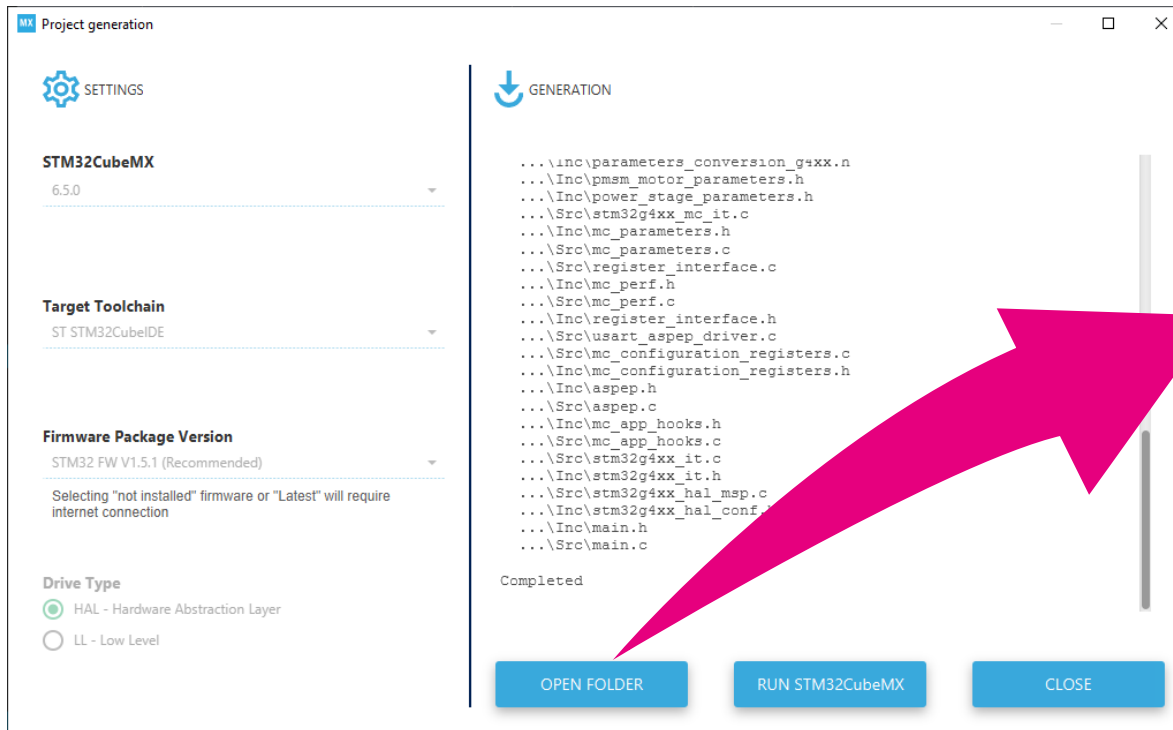
Open **STM32CubeMX** to see how the firmware settings for motor drives are made.





MC Workbench

Generated folder consists of motor control **source code**, **STM32CubeMX** project and **IDE** project.



nar_Training\Webinar\MC_Webinar

HueyCHOI > 03_Seminar_Training > Webinar > MC_Webinar >

Search MC_Webinar

Name

- Drivers
- Inc
- MCSDK_v6.1.0-Full
- Src
- STM32CubeIDE
- .extSettings
- .mxproject
- MC_Webinar.ioc
- MC_Webinar.ioc.bak
- MC_Webinar.ioc.wb
- MC_Webinar.log
- MC_Webinar.settings
- MC_Webinar.wbdef

Source code

STM32CubeIDE Project

STM32CubeMX Project

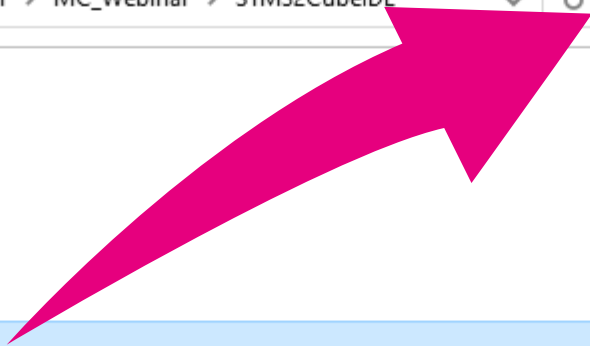


MC Workbench

03_Seminar_Training > Webinar > MC_Webinar > STM32CubeIDE

Name

- .settings
- Application
- Debug
- Drivers
- Middlewares
- .project
- .project
- MC_Webinar.launch
- STM32G431RBTX_FLASH.ld



The screenshot shows the STM32CubeIDE IDE interface. The Project Explorer on the left displays the project structure, with the 'User' folder expanded to show 'main.c'. A pink dashed box highlights the 'main.c' file. The Editor window shows the code for 'main.c', which includes a header section, a license notice, and a main function. The Build Console at the bottom shows the output of the build process, including the path to the binary and the memory regions for RAM and FLASH.

```

1 /* USER CODE BEGIN Header */
2 /**
3  * @file
4  * @brief : Main program body
5  * @attention
6  *
7  * Copyright (c) 2023 STMicroelectronics.
8  * All rights reserved.
9  *
10  * This software is licensed under terms that can be found in the LICENSE file
11  * in the root directory of this software component.
12  * If no LICENSE file comes with this software, it is provided AS-IS.
13  */
14
15
16
17
18 /* USER CODE END Header */
19
20 #include "main.h"
21
22
23 /* Private includes -----*/
24
25 /* USER CODE END Includes */
26
27
28 /* Private typedef -----*/
29
30 /* USER CODE BEGIN PTD */
31
32 /* USER CODE END PTD */
33
34
35 /* Private define -----*/
36
37 /* USER CODE BEGIN PD */
38
39 /* USER CODE END PD */
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```



MC Workbench

```

99
100 /* USER CODE BEGIN SysInit */
101
102 /* USER CODE END SysInit */
103
104 /* Initialize all configured peripherals */
105 MX_GPIO_Init();
106 MX_DMA_Init();
107 MX_ADC1_Init();
108 MX_ADC2_Init();
109 MX_CORDIC_Init();
110 MX_TIM1_Init();
111 MX_TIM2_Init();
112 MX_USART2_UART_Init();
113 MX_MotorControl_Init();
114
115 /* Initialize interrupts */
116 MX_NVIC_Init();
117 /* USER CODE BEGIN 2 */
118
119 /* USER CODE END 2 */
120
121 /* Infinite loop */
122 /* USER CODE BEGIN WHILE */
123 while (1)
124 {
125 /* USER CODE END WHILE */
126
127 /* USER CODE BEGIN 3 */
128 }
129 /* USER CODE END 3 */
130 }
131
132 /**
133  * @brief System Clock Configuration
134  * @retval None
135  */
136 void SystemClock_Config(void)
137 {
138   RCC_OscInitTypeDef RCC_OscInitStruct = {0};
139   RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
140
141   /** Configure the main internal regulator output voltage
142   */

```

User code initialization

```

59 /* USER CODE END PRIVATE */
60
61 /* Public prototypes of IRQ handlers called from assembly code -----*/
62 void ADC1_2_IRQHandler(void);
63 void TIMx_UP_M1_IRQHandler(void);
64 void TIMx_BRK_M1_IRQHandler(void);
65
66 void SPD_TIM_M1_IRQHandler(void);
67 void HardFault_Handler(void);
68 void SysTick_Handler(void);
69 void EXTI15_10_IRQHandler(void);
70
71 #if defined (CCMRAM)
72 #if defined (__ICCMRAM__)
73 #pragma location = ".ccmram"
74 #elif defined (__CC_ARM) || defined(__GNUC__)
75 __attribute__((section(".ccmram")))
76 #endif
77 #endif
78 /**
79  * @brief This function handles ADC1/ADC2 interrupt request.
80  * @param None
81  * @retval None
82  */
83 void ADC1_2_IRQHandler(void)
84 {
85 /* USER CODE BEGIN ADC1_2_IRQn 0 */
86
87 /* USER CODE END ADC1_2_IRQn 0 */
88
89 // Clear Flags M1
90 LL_ADC_ClearFlag_JEOS( ADC1 );
91
92 (void)TSK_HighFrequencyTask();
93
94 /* USER CODE BEGIN HighFreq */
95
96 /* USER CODE END HighFreq */
97
98 /* USER CODE BEGIN ADC1_2_IRQn 1 */
99
100 /* USER CODE END ADC1_2_IRQn 1 */
101
102

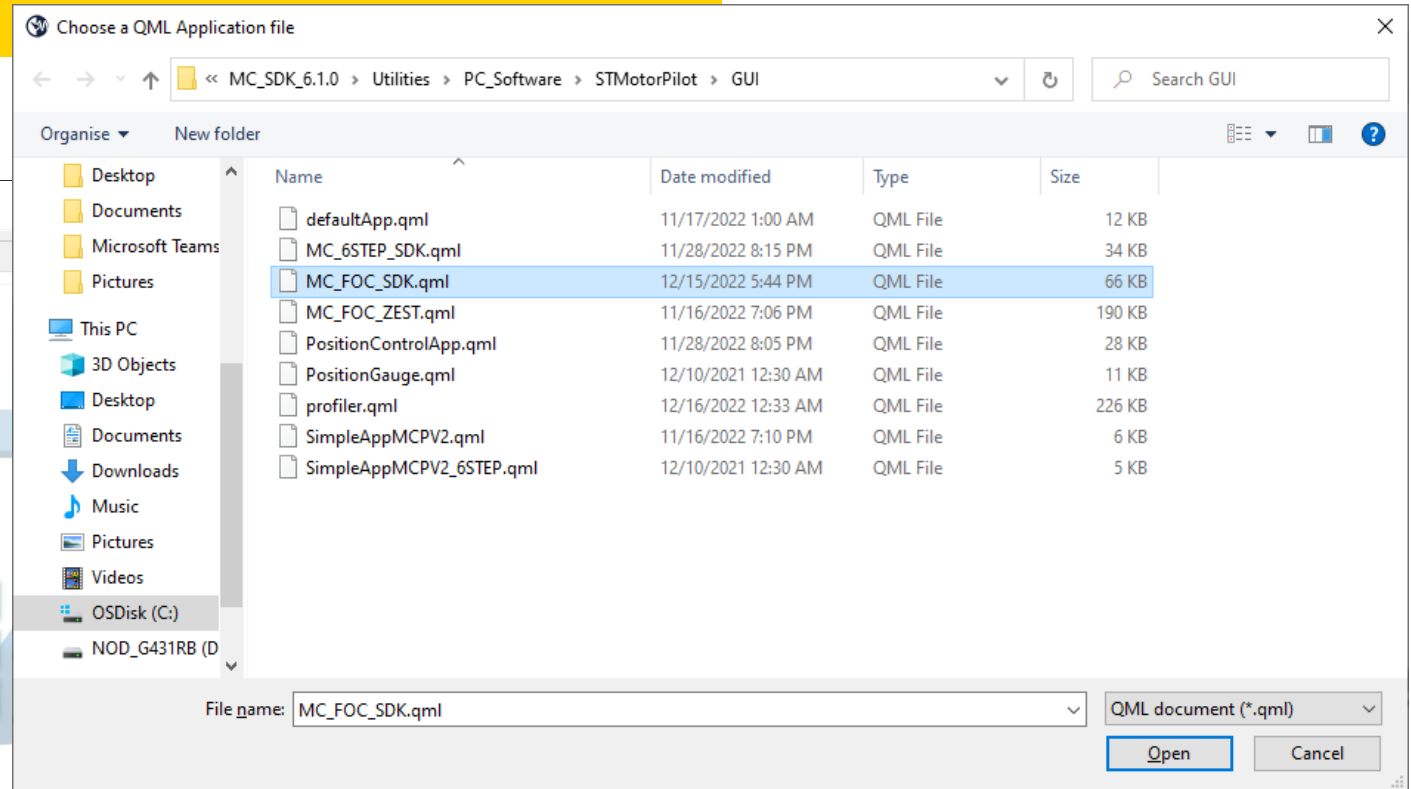
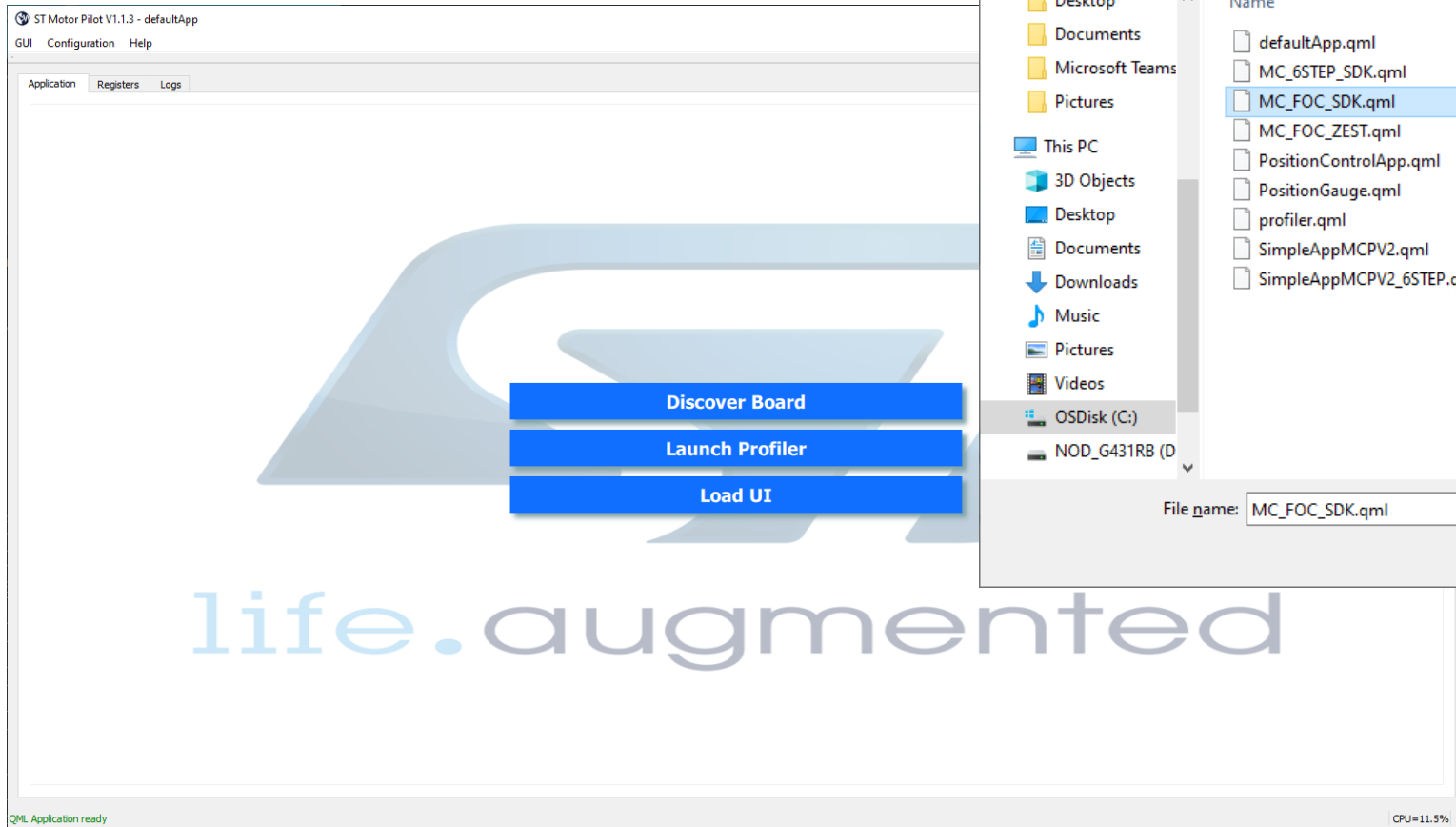
```

Motor control interrupt functions

Written user code between
/* USER CODE BEGIN xxxxx */
and /* USER CODE END xxxxx */,
would not be removed after regeneration



Motor Pilot





Motor Pilot

- Baudrate
- COM port
- Connection
- Version Info.

- Motor control status
- Clear fault

- Control mode
 - Current
 - Speed
- Start/Stop
- Stop speed ramp

- Speed reference
- Set speed ramp

The screenshot displays the ST Motor Pilot V1.1.3 - MC_FOC_SDK GUI. The interface is divided into several functional areas:

- Board Connection:** Shows UART port (COM4), speed (1843200), and connection status (Polling).
- Status:** Displays 'IDLE' and a list of error types (FOC Duration, Over Voltage, Under Voltage, Over Heat, Start Up Failure, Speed Feedback, Over Current, Software Error) with an 'Ack Faults' button.
- Control:** Includes a 'SPEED' dropdown menu and buttons for 'Start', 'Stop', and 'Stop ramp'.
- Configuration:** Features an 'Advanced Configuration' button and 'Perf Measurements'.
- Speed Control:** A large circular gauge shows 'Mechanical Speed: 996 RPM'. Below it, 'Speed Reference: 996 RPM' and 'Speed Ramp' settings (Target Speed: 1000 RPM, Duration: 500 ms) are visible.
- Measures:** Three vertical bar charts show 'VBUS' (23 V), 'TEMP' (28 deg), and 'POWER' (0 W). A smaller speed gauge shows 'Speed: 996 RPM' and 'Id: 0 s16A'.
- MC Configuration:** Lists motor details: Control Stage: NUCLEO-G431RB, Power Stage: X-NUCLEO-IHM08M1, Motors: 1, MCP over UARTA [10], Max App Speed: 4000 RPM, Max Readable Current: 31.853 A, Nominal Current: 1.600 A, Nominal Voltage: 24 V, Control Type: FOC, Primary speed sensor: STO+PLL, Aux speed sensor: No sensor, Current sensing topology: 3 Shunt, FOC rate: 1, PWM frequency: 20000 Hz, Medium frequency: 1000 Hz, VBus Sensing: Enable, Temperature Sensing: Enable.
- Advanced Configuration:** Contains 'Currents_Speed' and 'Observers' tabs. It includes 'Speed PI regulator' (Speed Kp: 2972, Speed Ki: 266), 'Torque (Iq) PI regulator' (Torque Kp: 4000, Torque Ki: 1000), 'Flux (Id) PI' (Flux Kp: 1000, Flux Ki: 1000), and 'Flux Reference' (0 s16A).
- Debug / DAC:** Shows DAC 1 and DAC 2 outputs (LA).
- Graph & Record:** A dashed box highlights the top right area, indicating high resolution plotting and record log data capabilities.

- High resolution plotting
- Record log data

- Monitoring
 - Motor speed
 - Bus voltage
 - PCB temperature
 - Motor power
 - Speed/Current
 - DAC Signal

- Motor control information
 - Board
 - Control Type
 - Sensor
 - Current sensing topology



Motor Pilot

The screenshot shows the ST Motor Pilot V1.1.3 - MC_FOC_SDK GUI. The interface includes a status panel on the left with an 'IDLE' indicator and a list of error types. The main area is divided into several sections: 'Speed Control' with a large RPM gauge and a speed reference slider; 'Measures' with smaller gauges for VBUS, TEMP, and POWER; 'MC Configuration' showing control stage and power stage details; and 'Advanced Configuration' on the right, which is further divided into 'Currents_Speed' and 'Observers' sub-sections. The 'Currents_Speed' section contains parameters for Speed PI and Torque (Iq) PI regulators, as well as Flux (Id) PI and Flux Reference. The 'Observers' section contains parameters for State Observer with PLL and State Observer with CORDIC. A large blue arrow points from the 'Advanced Configuration' section towards the 'Observers' sub-section.

- Speed control gain
- Current(Torque) control gain
- Torque reference(I_q^{ref})
- for Speed Control
- Flux weakening gain
- Flux weakening reference

- State observer gain
- Change G2 value
(/2, /4, /8,...)
if tuning is required
- PLL gain



Motor Pilot

Project folder

ST Motor Pilot V1.1.3 - MC_FOC_SDK

GUI Configuration Help

Board Connection: UART Port COM4 Speed 1843200 Disconnect Polling STMCSDK 6.1.0

Graph & Record

Application Registers Logs

Status: **IDLE**

Errors:

- FOC Duration
- Over Voltage
- Under Voltage
- Over Heat
- Start Up Failure
- Speed Feedback
- Over Current
- Software Error

Ack Faults

Control:

SPEED

Start

Stop

Stop ramp

Configuration

Advanced Configuration

CPU Perf Measurements

CPU Load: 0 %

Min: 0 Max: 0

v1.6

Advanced Configuration

Currents_Speed Observers

Speed PI regulator

Speed Kp: 2972 s16A/ppm

Speed Ki: 266 s16A

Kp divisor: 256

Ki divisor: 16384

Torque (Iq) PI regulator

Torque Kp: 4000 s16V/s16A

Torque Ki: 1000 s16V/(s16A.ppm)

Torque Reference: 0 s16A

Flux (Id) PI

Flux Kp: 4000 s16V/s16A

Flux Ki: 1000 s16V/(s16A.ppm)

Flux Reference: 0 s16A

MC Configuration

Control Stage: **NUCLEO-G431RB**

Power Stage: **X-NUCLEO-IHM08M1**

Motors: **1**

MCP over UARTA [10]

Max App Speed: **4000 RPM**

Max Readable Current: **31.853 A**

Nominal Current: **1.600 A**

Nominal Voltage: **24 V**

Control Type: **FOC**

Primary speed sensor: **STO+PLL**

Aux speed sensor: **No sensor**

Current sensing topology: **3 Shunt**

FOC rate: **1**

PWM frequency: **20000 Hz**

Medium frequency: **1000 Hz**

VBus Sensing: **Enable**

Temperature Sensing: **Enable**

Speed Control

Speed Reference: 996 RPM

Measures

VBUS: 23 V

TEMP: 28 deg

POWER: 0 W

Speed

Mechanical Speed: 996 RPM

Speed: 996 RPM

Id: 0 s16A

Speed Ramp

Target Speed: 1000 RPM

Duration: 500 ms

Execute Speed Ramp

Debug / DAC

DAC 1: LA

DAC 2: LA

CPU=15.2%



Motor Pilot

The screenshot displays the ST Motor Pilot V1.1.3 - MC_FOC_SDK GUI. The interface is divided into several sections:

- Board Connection:** Shows UART Port COM4, Speed 1843200, and ST MCSDK 6.1.0.
- Status:** Shows the motor is in a **RUN** state. A list of errors is visible, including FOC Duration, Over Voltage, Under Voltage, Over Heat, Start Up Failure, Speed Feedback, Over Current, and Software Error.
- Control:** Includes buttons for Start, Stop, and Stop ramp, along with a speed reference slider set to 1440 RPM.
- Measures:** Displays real-time data for VBUS (23 V), TEMP (28 deg), and POWER (0.5 W). A speed gauge shows the current mechanical speed at 1416 RPM.
- MC Configuration:** Lists motor details such as Control Stage (NUCLEO-G431RB), Power Stage (X-NUCLEO-IHM08M1), Motors (1), and MCP over UARTA (10). It also specifies Max App Speed (4000 RPM), Max Readable Current (31.853 A), Nominal Current (1.600 A), Nominal Voltage (24 V), and Control Type (FOC).
- High_Frequency_Plot_0:** A graph showing the electrical signals for STOPLL_EL_ANGLE (blue), HALL_EL_ANGLE (green), and Trigger (red) over time. The plot shows a periodic, high-frequency waveform.

At the bottom of the GUI, the CPU load is shown as 9.8%.



Motor Pilot

ST Motor Pilot V1.1.3 - MC_FOC_SDK

GUI Configuration Help

Board Connection: UART Port COM4 Speed 1843200 Disconnect Polling ST MSDK 6.1.0

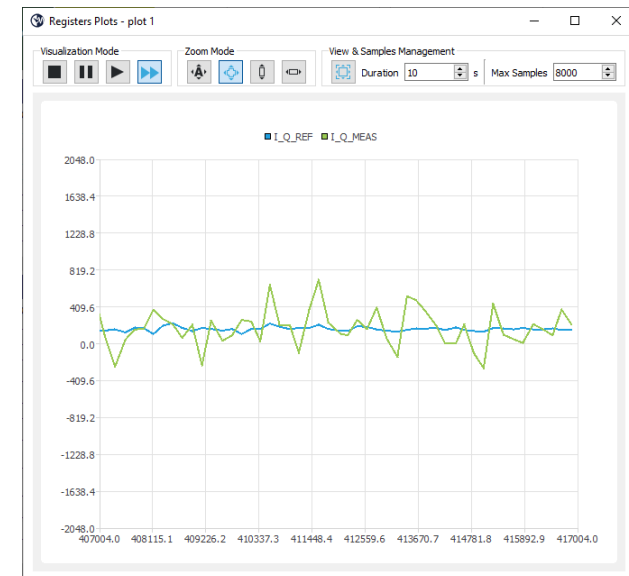
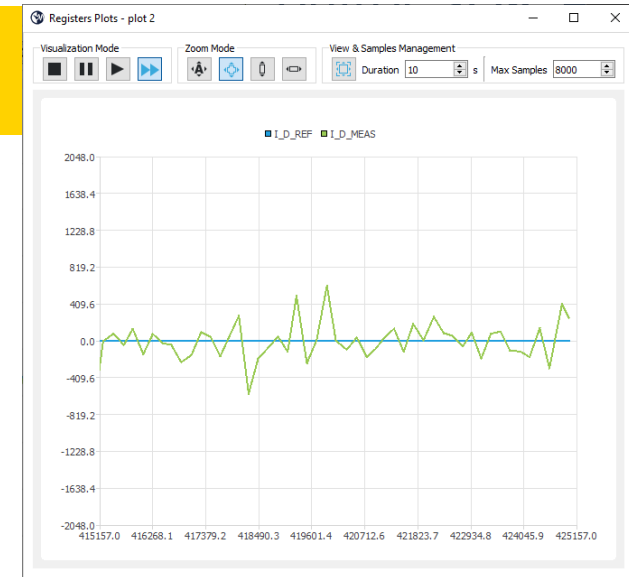
Graph & Record: C:/Users/choihuey/Documents/dfadsf

Application Registers Logs

C:/Program Files (x86)/STMicroelectronics/MC_SDK_6.1.0/Utilities/PC_Software/STMotorPilot/RegisterList/RegListSTMV2.json 1.1

Poll	Id	Name	Value	Access	Unit	Type	Plot	status
<input checked="" type="checkbox"/>	1105	STOPLL_KI	8	R	dpp/s16V	S16	Configure	OK PLL PID regulator K_I par
<input checked="" type="checkbox"/>	1169	STOPLL_KP	213	R	dpp/s16V	S16	Configure	OK PLL PID regulator K_P par
<input type="checkbox"/>	1233	FLUXWK_KP	0	NONE	s16A/(s16V2)	S16		Init Flux weakening PID regul
<input type="checkbox"/>	1297	FLUXWK_KI	0	NONE	s16A/(s16V2)	S16		Init Flux weakening PID regul
<input type="checkbox"/>	1361	FLUXWK_BUS	0	NONE	%	U16		Init Flux weakening BUS Volt
<input checked="" type="checkbox"/>	1425	BUS_VOLTAGE	23	R	V	U16	Configure	OK Bus Voltage measuremen
<input checked="" type="checkbox"/>	1489	HEATS_TEMP	30	R	deg	U16	Configure	OK Heatsink temperature
<input type="checkbox"/>	1616	DAC_OUT1	2001	NONE	N/A	U16		Init DAC Out 1
<input type="checkbox"/>	1680	DAC_OUT2	2001	NONE	N/A	U16		Init DAC Out 2
<input type="checkbox"/>	1937	FLUXWK_BUS_MEAS	0	NONE	%	U16		Init Flux weakening BUS Volt
<input type="checkbox"/>	2001	I_A	0	R	s16A	S16	Configure	Init I_a phase current measur
<input type="checkbox"/>	2065	I_B	0	R	s16A	S16	Configure	Init I_b phase current measur
<input type="checkbox"/>	2129	I_ALPHA_MEAS	0	R	s16A	S16	Configure	Init I α current measurement
<input type="checkbox"/>	2393	I_BETA_MEAS	0	R	s16A	S16	Configure	Init I β current measurement
<input checked="" type="checkbox"/>	2257	I_Q_MEAS	0	R	s16A	S16	plot 1	OK I_q current measurement
<input checked="" type="checkbox"/>	2321	I_D_MEAS	0	R	s16A	S16	plot 2	OK I_d current measurement
<input checked="" type="checkbox"/>	2385	I_Q_REF	0	RW	s16A	S16	plot 1	OK I_q current reference (syn
<input checked="" type="checkbox"/>	2449	I_D_REF	0	RW	s16A	S16	plot 2	OK I_d current reference (syn
<input type="checkbox"/>	6865	V_D_REF	0	NONE	%	U16		Init voltage reference (open I
<input type="checkbox"/>	2513	V_Q	0	R	s16V	S16	Configure	Init V_q voltage
<input type="checkbox"/>	2577	V_D	0	R	s16V	S16	Configure	Init V_d voltage
<input type="checkbox"/>	2641	V_ALPHA	0	R	s16V	S16	Configure	Init V α voltage
<input type="checkbox"/>	2705	V_BETA	0	R	s16V	S16	Configure	Init V β voltage
<input type="checkbox"/>	2769	ENCODER_EL_ANGLE	0	NONE	s16degree	S16		Init Measured electrical angle
<input type="checkbox"/>	2833	ENCODER_SPEED	0	NONE	s16speed	S16		Init Measured mechanical rot
<input checked="" type="checkbox"/>	2897	STOPLL_EL_ANGLE	-17579	R	s16degree	S16	Configure	OK Observed electrical angle

ReadAll Load Use Register list from QML file CPU=13.9%





ST Motor Control Solutions

Solutions



STEVAL-ETH001V1

Reference design for servo drive solution with Ethernet



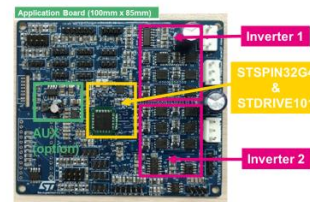
- Based on STM32F767ZI (Cortex-M7)
- Three-phase motor drive inverter based on STDRIVE101 and STH270N8F7-2
- On-board DC-DC converter and linear regulator
- Max. power dissipation up to 700W
- NetX90 network controller
- RS485 interface for digital encoder and host interface
- Real-time communication via EtherCAT protocol
- Support firmware example inc. EtherCAT protocol



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Dual Motor Control Platform with STSPIN32G4

Dual Motor Control Solution with STSPIN32G4 + STDRIVE101



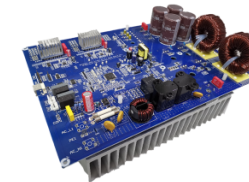
- Integrated STM32G431 (Cortex-M4)
- Operating Range : 5 – 75V; 200W
- FW & HW support for
 - Dual BLDC motor FOC control
 - Sensored/Sensorless Algorithms
- Sensor feedback is supported
 - Hall/Encoder sensor for both motor
 - Compatible for both single and three shunt
- CAN, RS485 Protocols



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Commercial Air Conditioning 7kW

Triple motors, Interleaved dPFC with Single STM32G4 MCU



- STM32G4 based full platform control
 - Three BLDC motor FOC control
 - 1 Compressor + 2 Fans
 - Digital interleaved PCF, 2-stage, CCM
- SLLIMM® for IPM inverter power
- Trench Gate Field Stop IGBT
ST proprietary technology
- VIPER31 Aux Power Supply section
- SJ MOSFET and STM32G4 HiRes timer for PFC High switching frequency 60 – 80 kHz



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EVALKIT-ROBOT-1

Reference design for Robot



- Max operating ratings: 36V, 6A_{PK}
- Based on STSPIN32F0A (Cortex-M0)
- Position control loop based on Field Oriented Control
- MODBUS communication is supported
- Maxon 100W 3-phase BLDC motor with 1024 pulse incremental encoder
- Extremely compact footprint (40mm x 40mm)
- Firmware example is provided from MCSDK



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Switched Reluctance Motor(SRM)

Reference design for 3-phase vacuum cleaner SR motor



- MCU : STM32F303CBT
- Auxiliary power supplies
 - Flyback and linear converters : Viper26L, LD1117S50, SD1117S33C
- Gate Drivers : L6395D
- Asymmetric H-Bridge : STTH15RQ06, STGB30H65FB
- Sensorless with sliding mode observer(SMO)



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STEVAL-IHM023V3

Reference design for induction motor



- Operating Range: 125-400 VDC or 90-285 VAC
- Maximum output power for motors: up to 1 kW
- Regenerative brake control
- Tachometer/Hall/Encoder inputs
- Possibility to connect BEMF daughterboard for sensorless six-step control of BLDC motors
- Total dimensions of board: 127 mm x 180 mm
- SDK is supported with NUCLEO-G431RB



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Recent Projects:

MC_Webinar
STM32G431RB

Type: FOC / Three Shunt Resistors
Control: NUCLEO-G431RB
Powers: X-NUCLEO-IHM08M1
Motors: Shinano LA052-080E3NL1

SDK6_G474RE_IHM08M1_FOC
STM32G474RE

Type: FOC / Three Shunt Resistors
Control: NUCLEO-G474RE
Powers: X-NUCLEO-IHM08M1
Motors: Shinano LA052-080E3NL1

webinar_project
STM32G431RB

Type: FOC / Three Shunt Resistors
Control: NUCLEO-G431RB
Powers: X-NUCLEO-IHM08M1
Motors: MAXON_1

SDK6_B-G431B-ESC1
STM32G431CB

Type: FOC / Three Shunt Resistors
Control: B-G431B-ESC1
Powers: B-G431B-ESC1
Motors: Shinano LA052-080E3NL1

SDK6_Six2FOC
STM32G431RB

Type: FOC / Three Shunt Resistors
Control: NUCLEO-G431RB
Powers: X-NUCLEO-IHM08M1
Motors: Shinano LA052-080E3NL1

Example Projects:

Project name	MCU	Type	Control	Powers	Motors	Description
ACIM FOC	STM32G431RB	ACIM / FOC	NUCLEO-G431RB	STEVAl-IHM023V3	ACIM SELNI AHV 242 N06	Sensorless Field Oriented Control of an...
ACIM V/F Open Loop	STM32G431RB	ACIM / V/F	NUCLEO-G431RB	STEVAl-IHM023V3	ACIM SELNI AHV 242 N06	Open Loop Control of an AC Induction ...
FOC STM32H745ZI with IHM08 example	STM32H745ZI	FOC / short_topology_3-SHUNT	NUCLEO-H745ZI	X-NUCLEO-IHM08M1	SHINANO	FOC example with control board STM3...
Electronic speed control on B-G431B-ESC1 kit	STM32G431CB	FOC / short_topology_3-SHUNT	B-G431B-ESC1	B-G431B-ESC1	SHINANO	Electronic speed control on B-G431B-E...
EVSPIN32G4 example	STSPIN32G4	FOC / short_topology_3-SHUNT	EVSPIN32G4	EVSPIN32G4	GIMBALL	EVSPIN32G4 example and PMSM SHIN...
Speed ramp with Potentiometer on P-NUCLEO-IHM003 kit	STM32G431RB	FOC / short_topology_3-SHUNT	NUCLEO-G431RB	X-NUCLEO-IHM16M1	GIMBAL GBM2804H-100T	Speed ramp with Potentiometer on P-...
Position Control feature example on NUCLEO-G431RB and MAXON Motor	STM32G431RB	FOC / short_topology_3-SHUNT	NUCLEO-G431RB	X-NUCLEO-IHM07M1	MAXON EC-I 100W	Example for Position control on NUCLE...
6-Step example on IHM03 pack and nominal bus voltage	STM32G431RB	hardware.AlgorithmType.6STEP / short_topology_	NUCLEO-G431RB	X-NUCLEO-IHM16M1	GimBal GBM2804H-100T	6-Step example on IHM03 pack and no...
6-Step example on NUCLEOG431+IHM07 in sensorless current mode	STM32G431RB	hardware.AlgorithmType.6STEP / short_topology_1-SHUNT	NUCLEO-G431RB	X-NUCLEO-IHM07M1	GimBal GBM2804H-100T	6-Step example on Gimbal motor nucle...
STSPIN32F0A FOC example on STEVAL-SPIN3201	STSPIN32F0A	FOC / short_topology_3-SHUNT	STEVAl-SPIN3201	STEVAl-SPIN3201	Bull Running BR2804-1700kv	STSPIN32F0A project with 3 shunts inv...

Solution



Reference design for ser



STM32F767Z
32bit, Cortex-M7, 216 M



Reference design for Ro



tions

conditioning 7kW

AC control
 DC control
 18
 F, 2-stage, CCM
 power
 BT
 ly section
 4 HiRes timer
 frequency 60 – 80 kHz

AL-IHM023V3

5-400 VDC or 90-285 VAC
 er for motors: up to 1 kW
 control
 order inputs
 BEFMF daughterboard for
 control of BLDC motors
 board: 127 mm x 180 mm
 h NUCLEO-G431RB

Our technology starts with You



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