ST solutions for efficient motor control

Technical Marketing Team
Systems Lab and Technical Marketing
Industrial and Multi Segment sector

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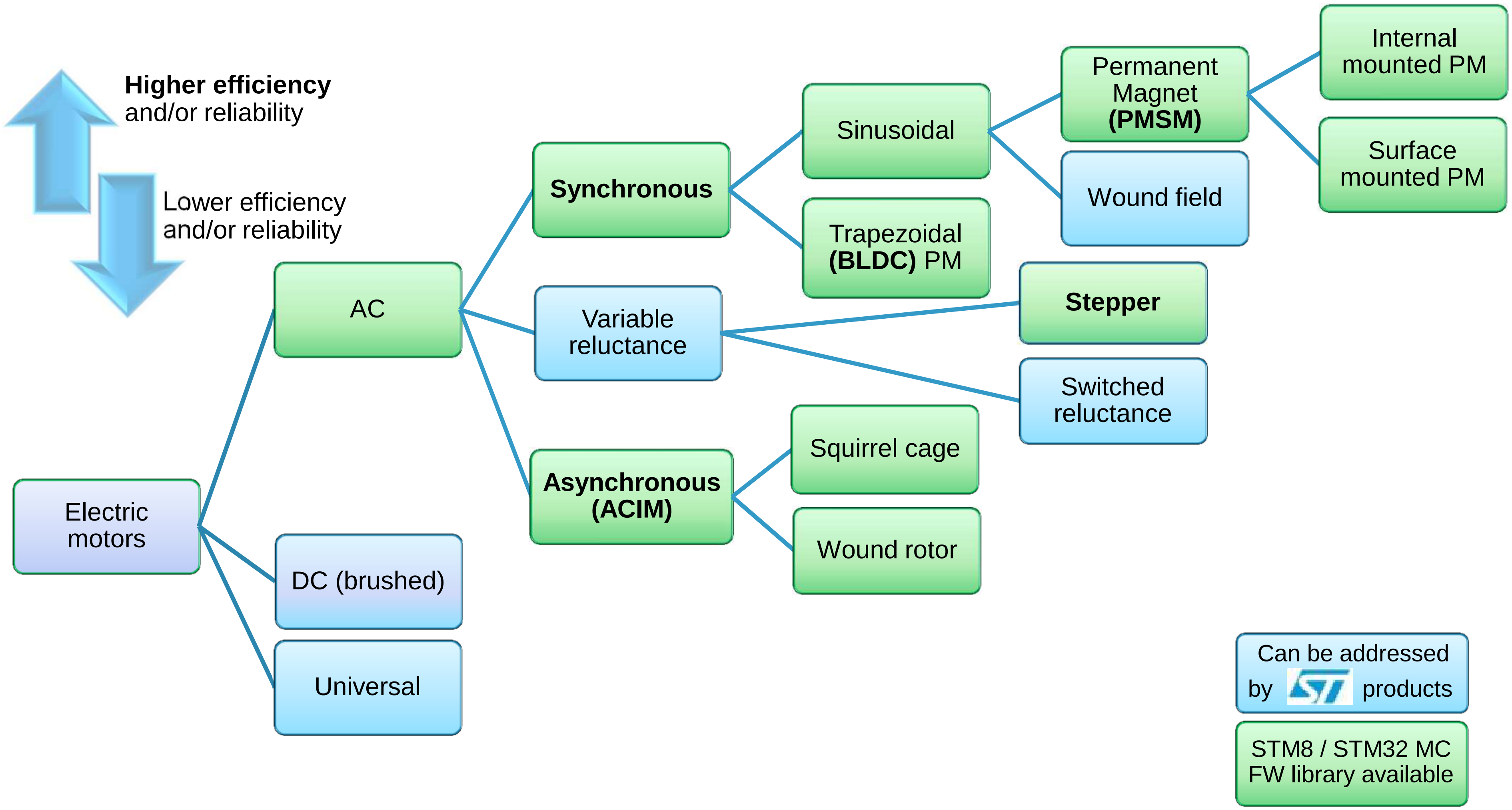
Agenda

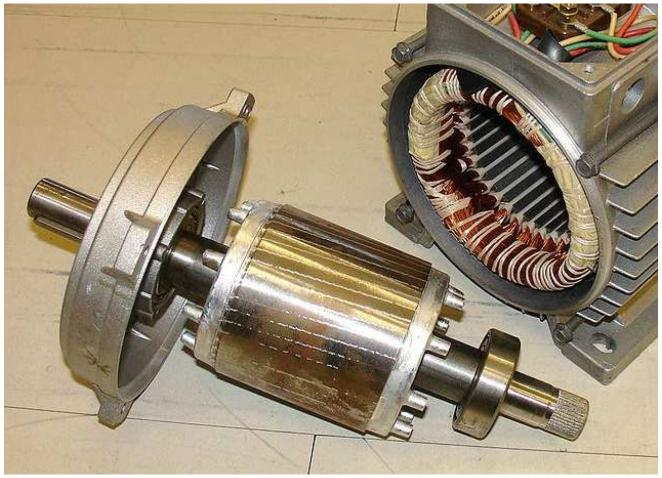
- Electric motors classification
- Nomenclature
- Scalar and vector drives
- ST motor control 'Ecosystem'
- Focus on vector control
  - STM32 Software Development Kit (SDK)
  - Software Tools
  - HW evaluation boards

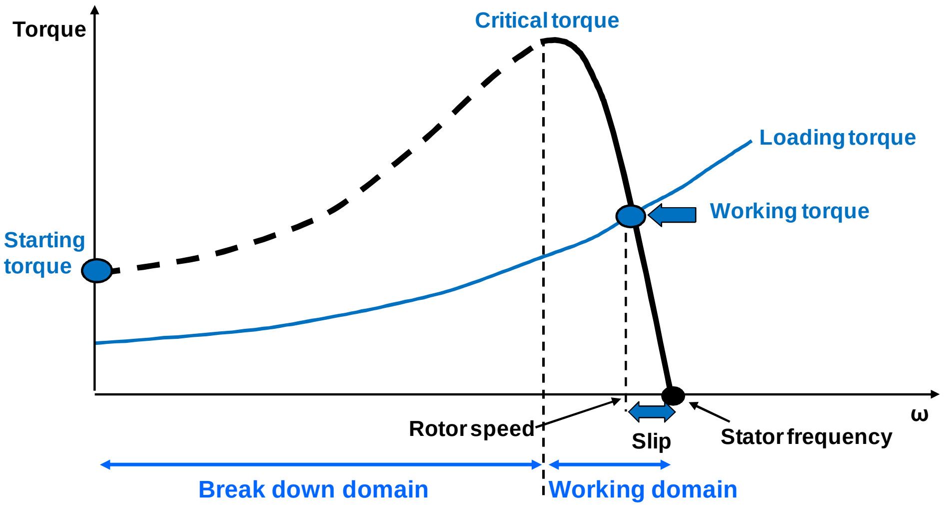
Electric motors classification



Focus on 3Φ motors: Asynchronous motor

- **Asynchronous motor or Induction Motor (AC IM)**
  - Rotor is powered through electromagnetic induction (Brush-less motor);
  - Stator excitation frequency and rotor electrical speed differ by a quantity called *slip*
  - Rotor often consists of laminated cylindrical iron cores with slots for receiving some aluminum bars (squirrel cage)



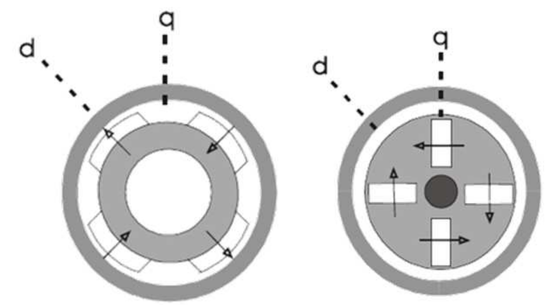


3-phase motors and nomenclature

- **Asynchronous motor or Induction Motor (AC IM)**
- **Permanent Magnet Synchronous Motor (PMSM)**
  - Stator can be the same as AC IM
  - Rotor houses permanent magnets
    - Glued on the surface → Surface Mounted (SM) PMSM
    - Buried within the rotor (different topologies possible) →Internal (I) PMSM
  - Sinusoidal-Bemf
- **Permanent Magnet Brushless DC motors (BLDC)**

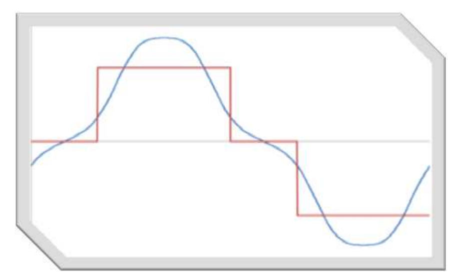
Focus on 3Φ motors: PMSM/BLDC

- **Permanent Magnet Synchronous Motor (PMSM) / Brushless DC (BLDC)**
  - Stator can be the same as AC IM
  - Rotor houses permanent magnets
  - Glued on the surface → Surface Mounted (SM) PMSM
    - Buried within the rotor (different topologies possible) →Internal (I) PMSM
  - Stator excitation frequency matches rotor electrical speed
  - Rotor spinning induced sinusoidal (PMSM) or trapezoidal (BLDC) shaped Back Electro-Motive Force in motor phases
  - Gives best performances (torque steadiness) when driven by sinusoidal phase current



SM-PMSM Example of I-PMSM

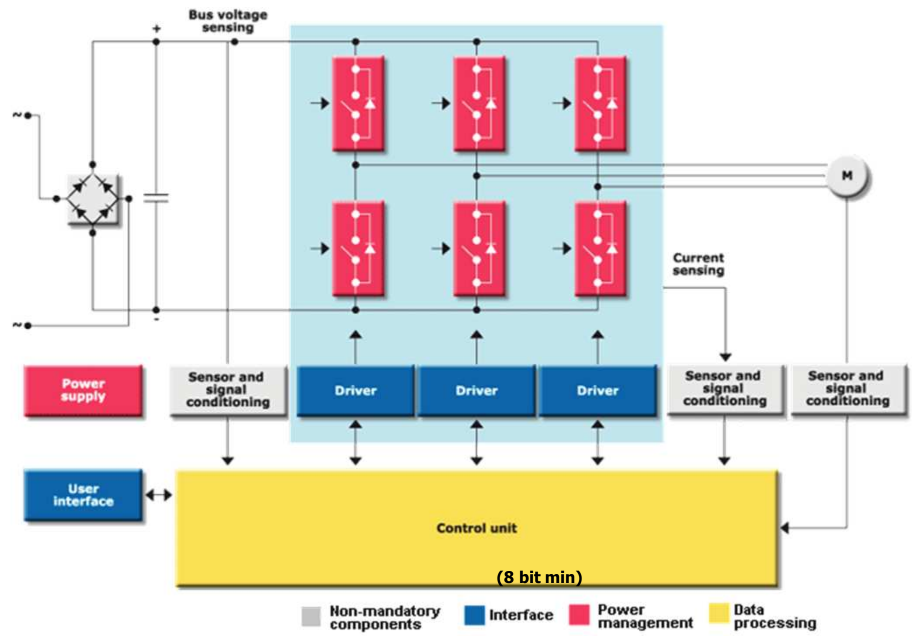
Typical B-emf shape Optimum current shape

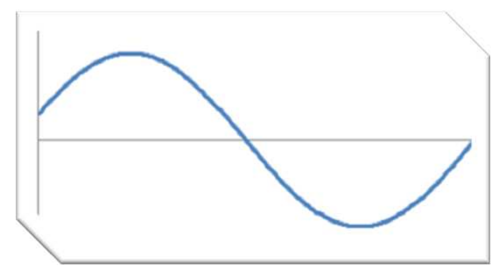


Typical B-emf shape Optimum current shape

Scalar drives of 3Φ motors for AC IM

- Work often without any feedback devices (open-loop control)
- Low cost and easy-to-implement solution (8-bit MCU)
- On the other side
  - Developed torque is not controlled directly (depends on load)
  - Transient response is not fast due to the predefined switching pattern of the inverter
- Adding a speed sensor (tachometer) and slightly increasing control scheme complexity, transients responses can be made faster and torque estimation possible

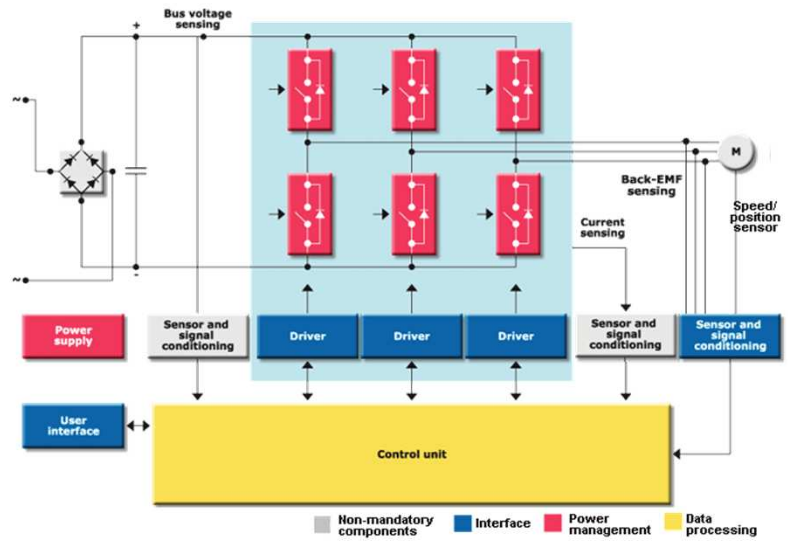


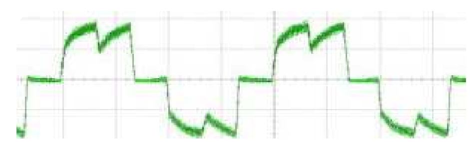


ACIM scalar drive motor phase current

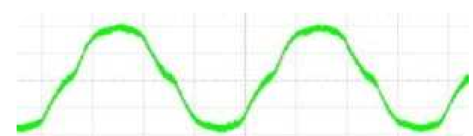
Scalar drives of 3Φ motors for PMSM

- Dislike AC IM, always requires speed/position information
  - Hall sensors
  - Drawn from electrical quantities (e.g. phase voltage) feedback (sensor-less)
- Two families of drives available
  - Six-step
    - Sensor-less solution is low cost (8 bit MCU): advanced ADC and timer peripherals are mandatory
    - Torque steadiness is not excellent → noisy compared to other methods
  - Sinusoidal
    - Sensor-ed can be handled by 8 bit MCUs → low cost MCU
    - Sensor-less solution for sinusoidal would require hard computation (not manageable by 8 bit MCUs) → scalar sensor-less wouldn't be low cost;
    - Torque steadiness is better compared to six step→ more quiet
  - In both cases developed torque is not accurately controlled





Six step drive - motor phase current



Sinusoidal drive - motor phase current

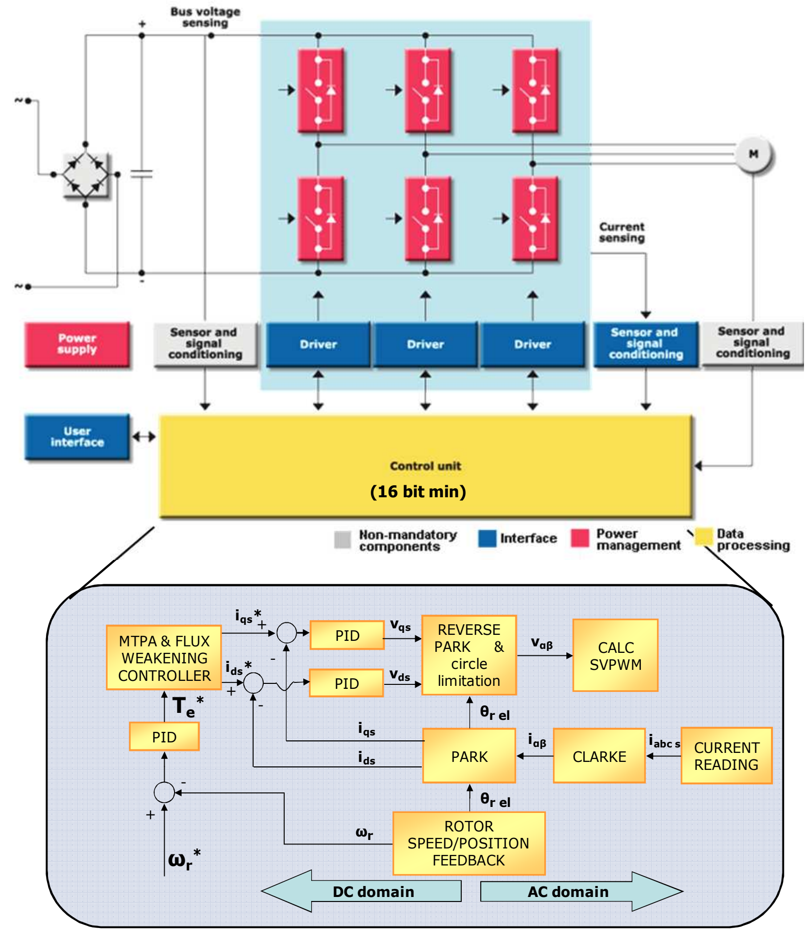
Field Oriented Control drive

- FOC drive is also called *vector control* drive as the algorithm is based on a vector representation of the stator current, voltage and magnetic flux

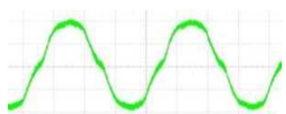
- The method always requires rotor speed/position information
  - Measured through real sensors: Hall sensors, quadrature encoder, tachometer, …
  - Computed indirectly from electrical quantities feedback (sensor-less)

- FOC scheme and rotor position estimation algorithm (where needed) must be executed at a rate comparable with PWM frequency
  - Higher computational power required compared to scalar drives → higher cost vs scalar
  - At least 16bit MCU

- FOC drive ensures:
  - The torque steadiness typical of a sinusoidal control
  - Excellent performance in terms of accurate static and dynamic speed regulation and rapid response to sudden changes in load torque
  - Provide torque control as an alternative to speed control



Application web pages



Sinusoidal drive - motor phase current

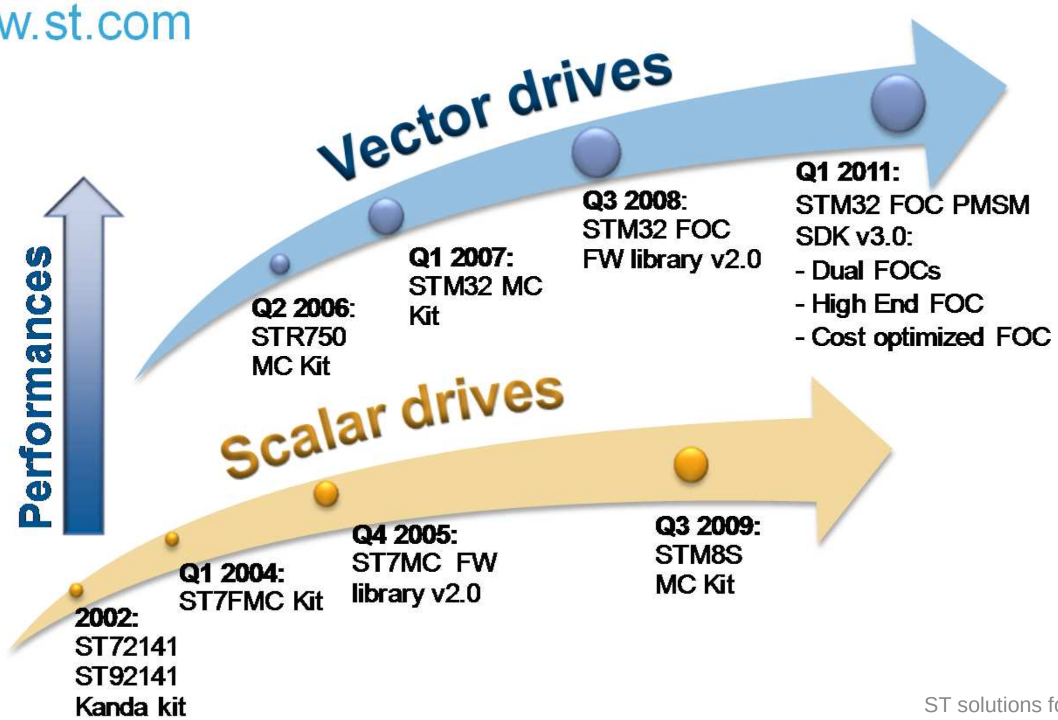
Scalar drives vs Field Oriented Control drive

- Both of them are Variable Frequency Drives (VFD)

Scalar drive	Field Oriented Control drive
Only the frequency and the magnitude of the voltage fed to the motor are controlled	The applied voltage is computed each PWM cycle so as to make current follow a precise profile
Don’t require motor current feedback to the control unit	Requires motor current feedback to control unit
Do not allow to fully control the torque of the electric motor	Allow to control fully and quickly the torque of the electric motor (e.g reducing the ripple)
Does not require high computational power	Require computational power (30MIPS for 32bit micro)

ST and efficient motor control: 10 years of 3-phase motor drives

- ST is focusing on 3-phase motor control since 2002
  - **10 years** experience in scalar drives of AC IM and Permanent Magnet Synchronous Motors (PMSM)
  - **6 years** experience in vector drives of ACIM and PMSM
  - a lot of product and system motor control evaluation boards are available today on www.st.com



STM32's Motor control 'Ecosystem'

- The STM32's MC 'Ecosystem' is the right answer to 3-phase FOC PMSM developers to quickly start & complete their design keeping flexibility on their platform strategy (low, mid, hi –end)

- The 'STM32 MC Ecosystem' is made of *(major items):*
  - MCU: STM32 large portfolio (Cortex-M based)
  - SW lib: 3-phase FOC PMSM SDK (SW lib) + WorkBench to generate code
  - HW: Motor Control kit (based on STM32 eval board + MC SW lib & all other 'power' component from ST)
  - Tools: among others: STM Studio, to monitor any variable selected in the code to optimize application performance

- The STM8's MC 'Ecosystem' complete by the STM32's one with
  - AC Induction Motors (scalar) and BLDC (6-step) supported in the STM8s MC FW lib

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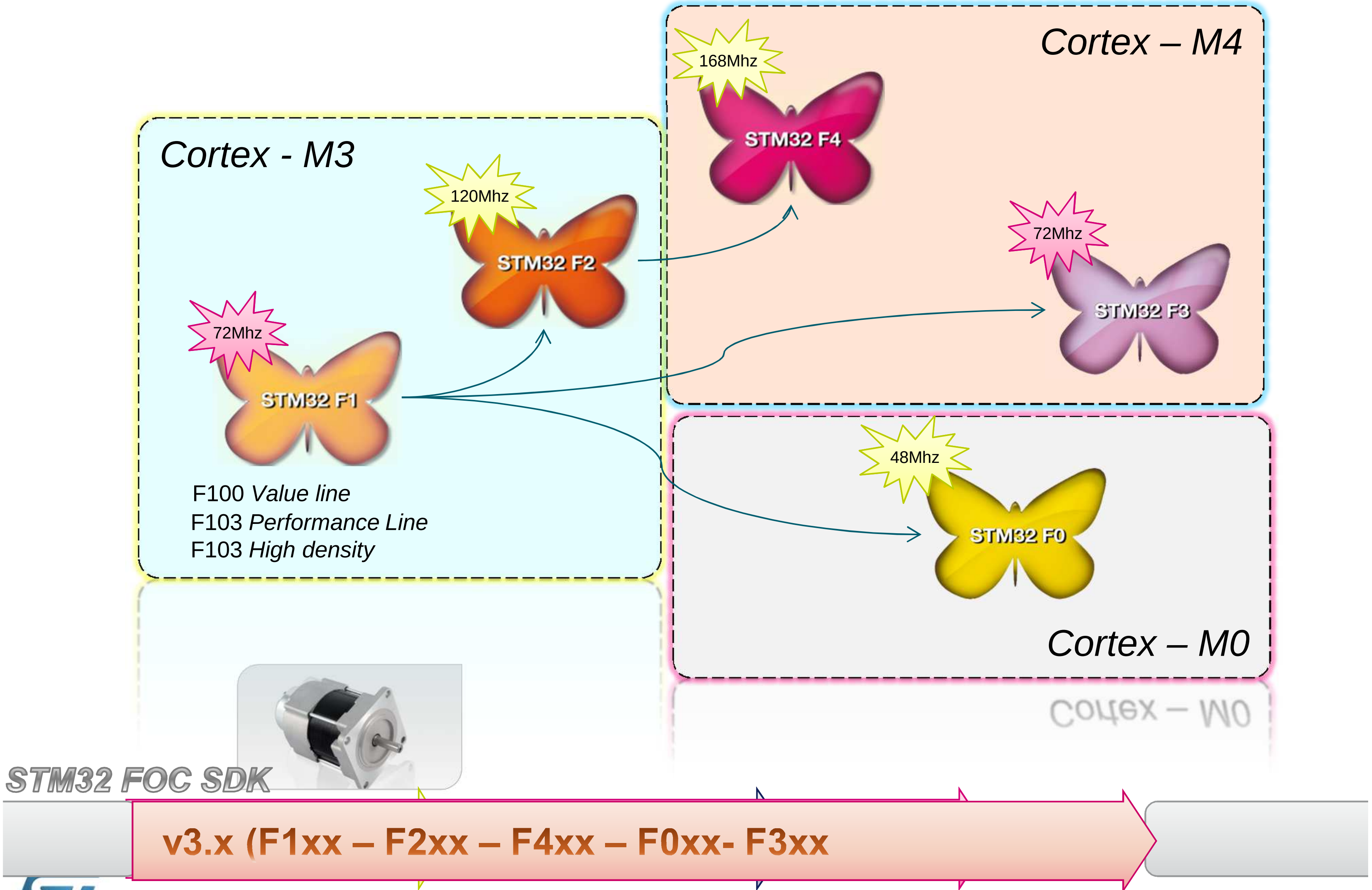
Field oriented control

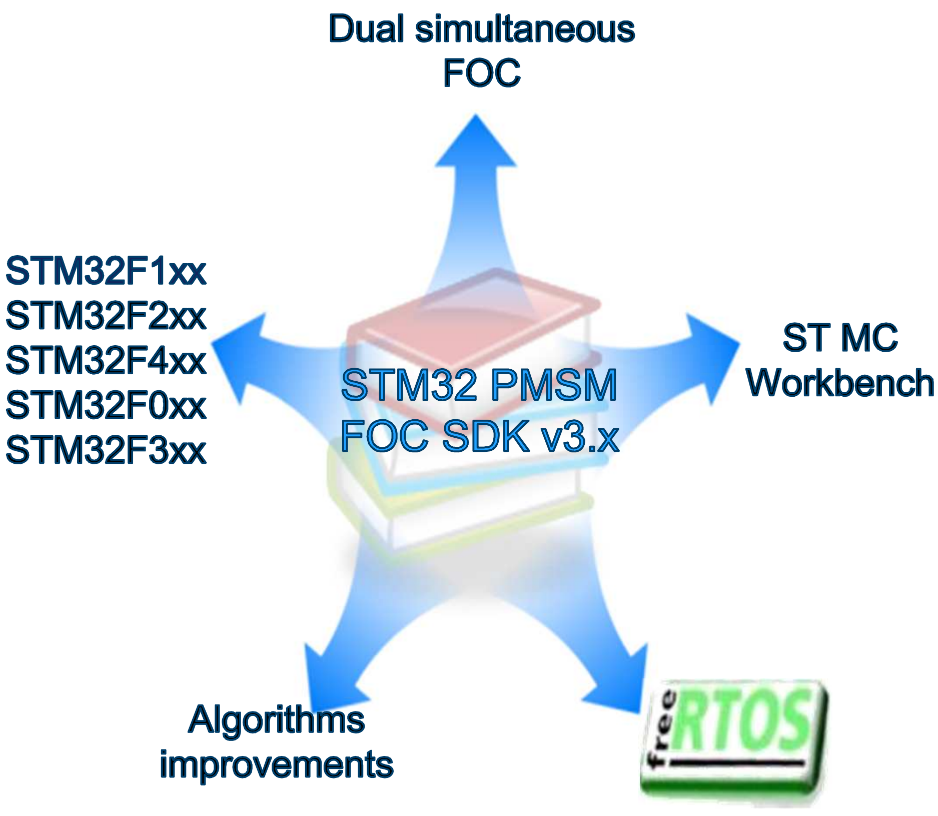
STM32 Family & FOC SDK roadmap



FOC SDK v3.x

- STM32 PMSM FOC SDK v3.x:
  is a Motor Control Software Development Kit
  for 3-phase Permanent Magnet Synchronous Motors
  (PMSM) based on Field Oriented Control (FOC)
  supporting STM32F103, STM32F100, STM32F2xx,
  STM32F4xx, STM32F0xx, *STM32F3xx.*

- Key features:
  - Single/Dual simultaneous vector control (FOC)
  - Any combination of current reading topologies and/or speed/position sensors is supported
  - Wide range of STM32 microcontrollers families supported
  - Full customization and real time communication through PC software ST MC Workbench
  - Wide range of motor control algorithms implemented for specific applications
  - Application example based on FreeRTOS
  - Increase code safety through
    - MISRA C rules 2004 compliancy
    - Strict ANSI C compliancy
    - New object oriented FW architecture (better code encapsulation, abstraction and modularity)



FOC SDK distributions and policy

Distributions

- **Web distribution** is available on internet
  - Contains compiled ‘MC library’ layer
  - Can be configured using ST MC Workbench enabling all the possible customizations

- **Confidential distribution** is not available on internet.
  - Source files of motor ‘MC library’ are provided with the only exception of ST protected IPs (not mandatorily to be used) which are furnished as compiled object files.

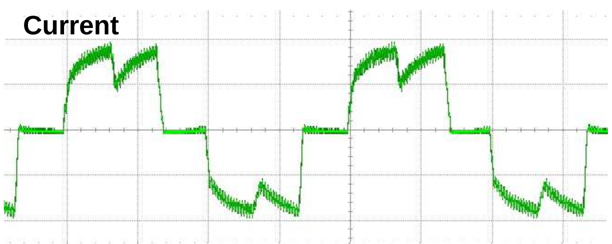
- **Protected IPs source files**.
  - Only provided to customers under NDA where there is high confidence and trust.

FOC single motor for budgetary applications

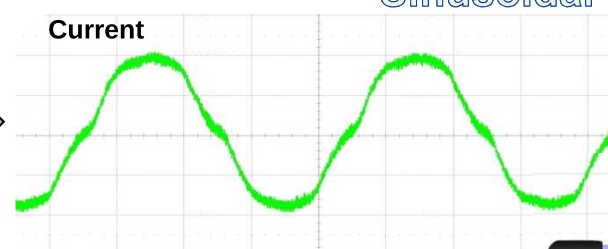
STM32F100x
STM32F05x

- **Target applications:**
  - All those applications where:
    - Requirements for dynamic performances are moderate
    - Quietness of sinusoidal current control (vs six steps drive) is valuable
    - Extended speed range is required
  - Particularly suitable for **pumps, fans and compressors**

Sinusoidal control



Six-steps drive



DW Spray & drain pumps

WM Drain pump

Fridge compressor

- More silent
- Lower torque ripple
- Extended speed range easier to be achieved

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FOC single or **dual motor** for higher performance

- **Target applications:**
  - Wide range from home appliances to robotics, where:
    - Accurate and quick regulation of motor speed and/or torque is required (e.g. in torque load transient or target speed abrupt variations)
    - CPU load granted to motor control must be low due to other duties

STM32F103 → STM32F3xx → STM32F2xx → STM32F4xx

Games

Industrial motor drives

Fitness, wellness and healthcare

Home appliances

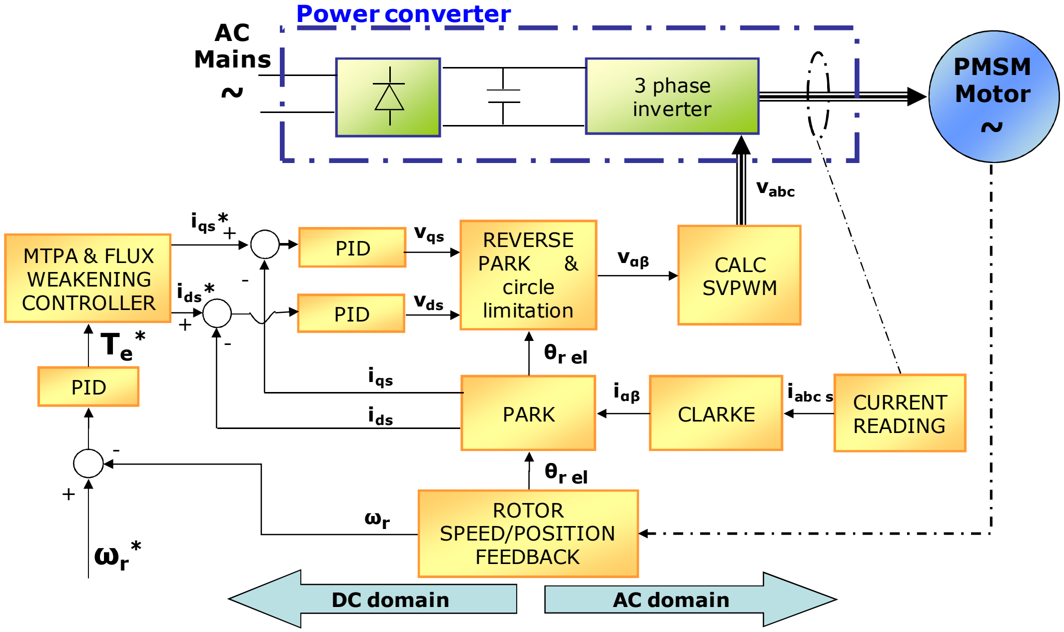
Power tools

And much much more…

Escalators and elevators

FOC block diagram and possible configurations 1/2

- Speed position feedback is mandatory
- Three speed/position sensors are supported:
  - Quadrature encoder
    - Expensive sensor, usually only in robotics applications
  - Hall sensors
    - Cheaper sensors, usually for application requiring full torque at zero speed
  - Sensor-less
    - Use electrical quantities (mainly current feedback) to estimate rotor position
    - Used for many applications not requiring full torque at zero speed or very low speed operations (< 3-5% of nominal speed)
- Current feedback is mandatory



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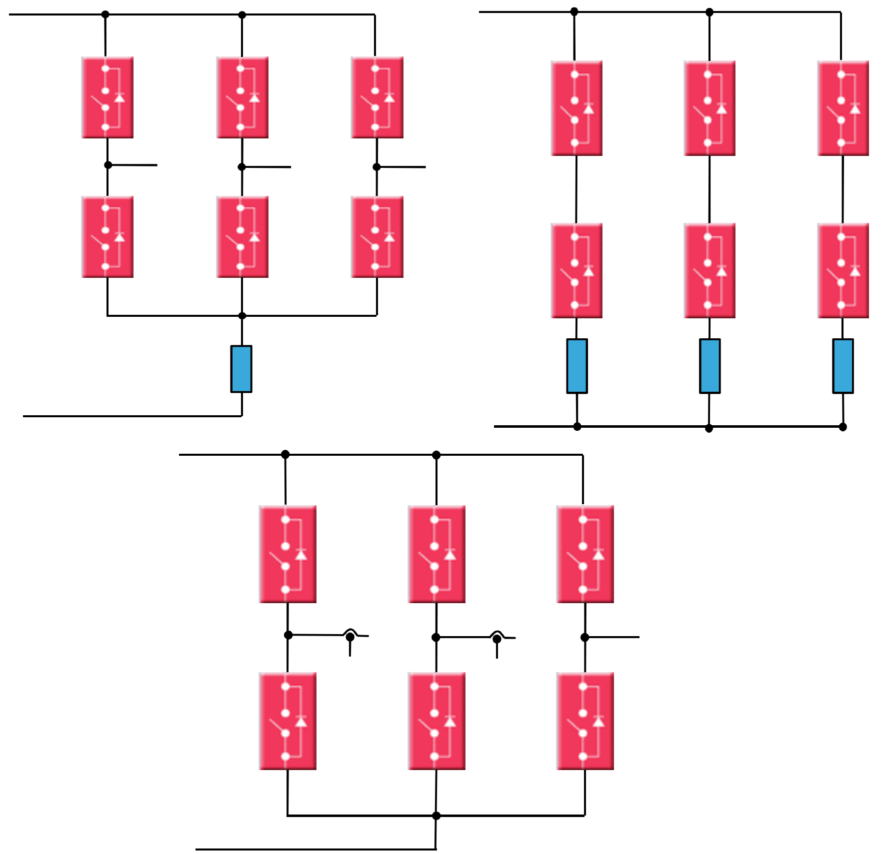
FOC block diagram and possible configurations 2/2

- Three current sensing HW topologies:
  - 1 shunt resistor placed on the DC link
    - ST patented algorithm
    - Only one op-amp /shunt resistor is needed → lowest cost
    - Current reading algorithm may result in not accurate torque regulation (worsening with ratio V/L)
  - 3 shunt resistors placed in the three legs
    - Current reading accuracy: high
    - Best compromise cost / performances
  - 2 Isolated Current Sensors (ICS)
    - Not dissipative current sensing topology → mandatory when current exceed some tens Ampere
    - Expensive
  - Any possible configuration (2 motors x 3 current sensing x 3 speed sensors type) is supported by FW library



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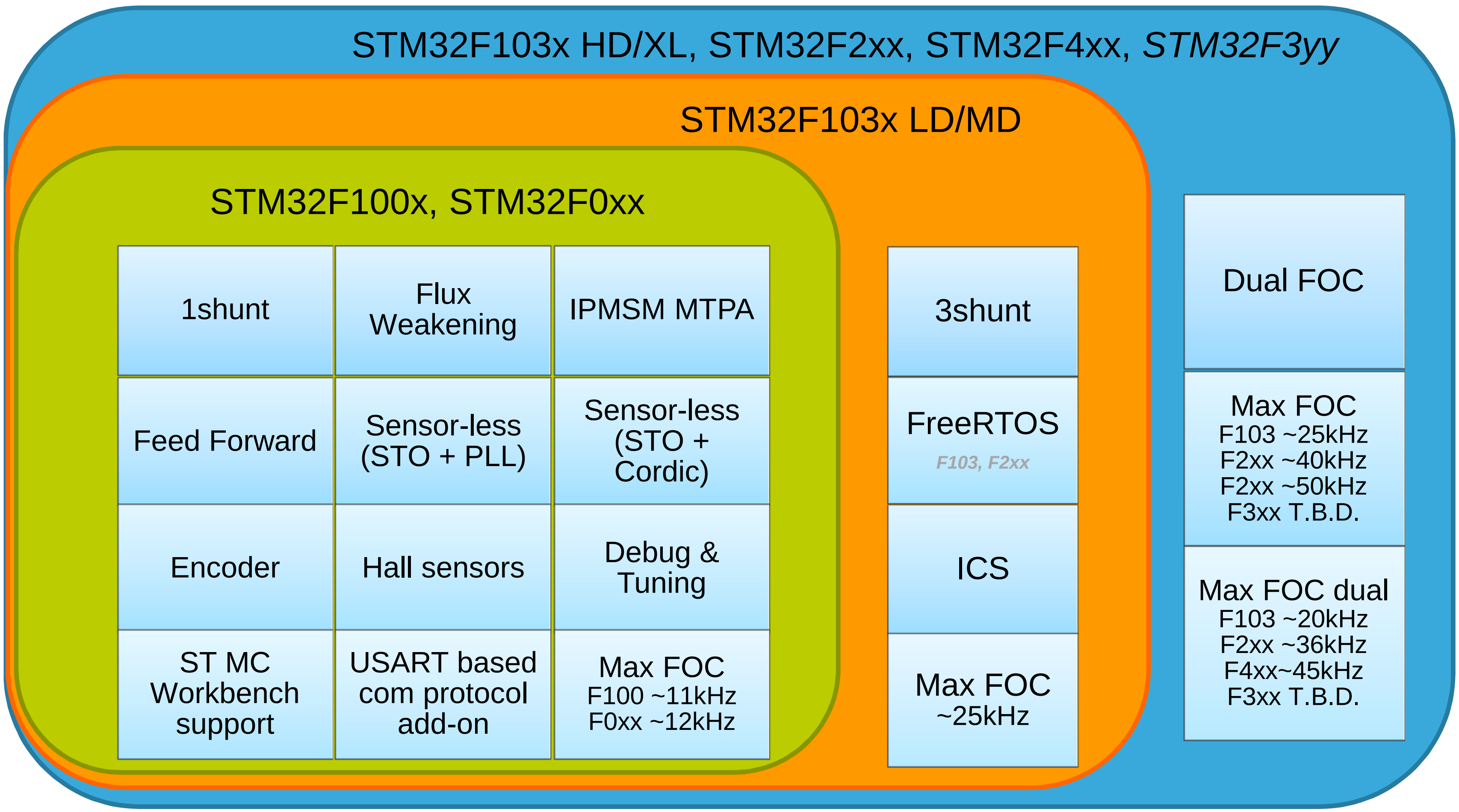
Features set, MCU support



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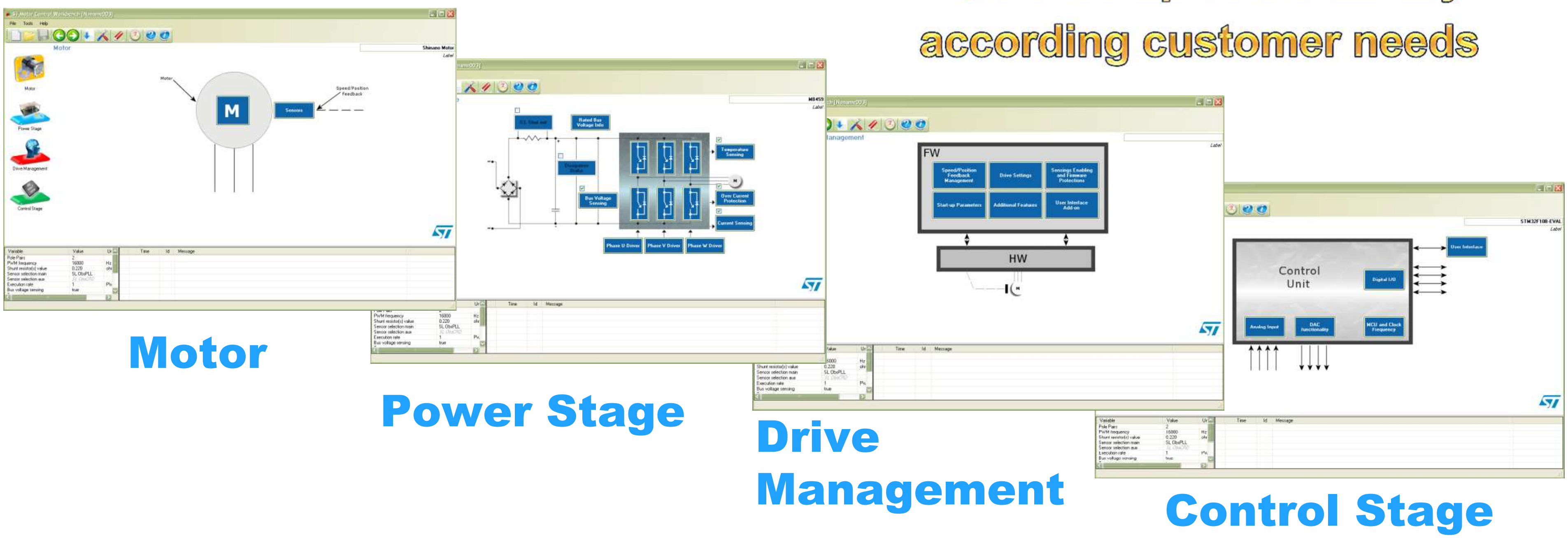
Drives / MCU FW availability matrix

	STM8S	STM32F0x	STM32F100	STM32F103	STM32F2xx	STM32F4xx	STM32F3xx	Notes
AC IM Scalar	Available now	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Open & closed speed loop
AC IM FOC drive	Not feasible	Expected Q2/2013	Expected Q1/2013	Available now	Not planned yet	Not planned yet	Not planned yet	Sensored, Sensor-less to be planned
BLDC/PMSM Scalar 6-steps	Available now	planned	Not planned yet	FW example available	Not planned yet	Not planned yet	Not planned yet	
BLDC/PMSM scalar sinus	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Not planned yet	Only sensored
BLDC/PMSM FOC drive	Not feasible	Available now	Available now	Available now	Available now	Available now	Q2/2013	Sensored & Sensor-less
BLDC/PMSM 2x FOC drive	Not feasible	Not feasible	Not feasible	Available now	Available now	Available now	Q2/2013	Sensored & Sensor-less

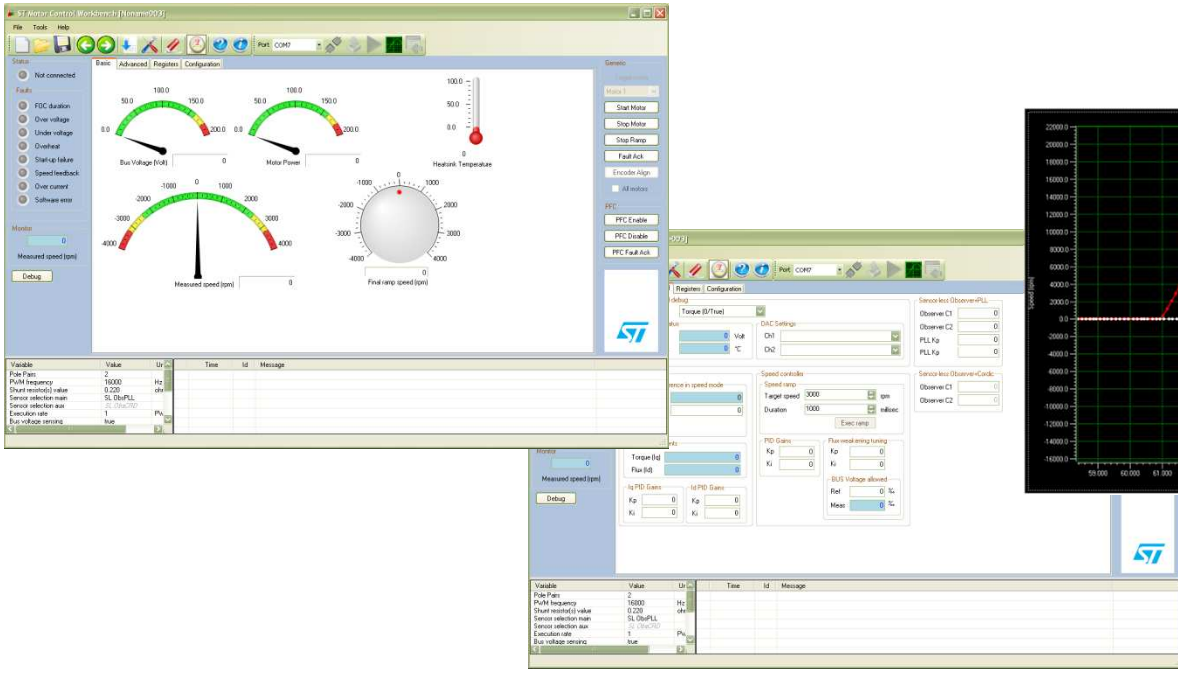
MC Workbench

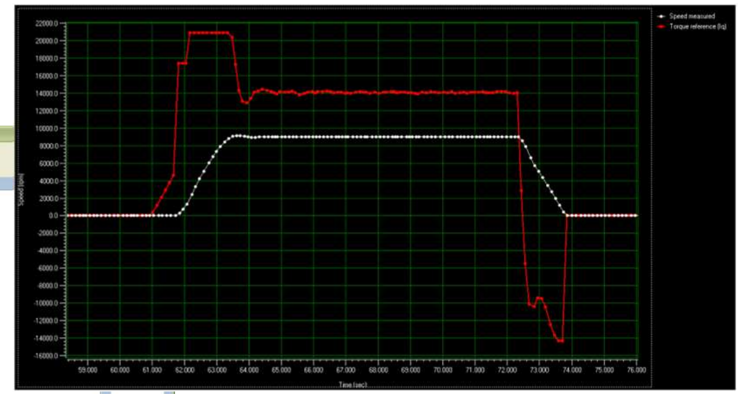
Quick setup of the library according customer needs



- ST Motor Control Workbench
  - PC software that reduces the design effort and time in the STM32 PMSM FOC firmware library configuration. The user through a graphical user interface (GUI) generate all parameter header files which configures the library according the application needs.

Serial communication





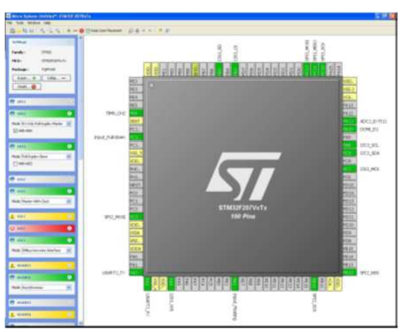
- RS232 (Available)
- SPI (T.B.I.)
- I2C (T.B.I.)

- Real time communication
  - Using the ST MC workbench is possible to instantiate a “real time communication” to send start/stop commands or to set a speed ramp.
  - Debug or fine tuning motor control variables (like speed PI parameters) can be assessed using the advanced tab.
  - Plotting significant motor control variables (virtual oscilloscope) like target or measured motor speed.

Making life easier with ST tools

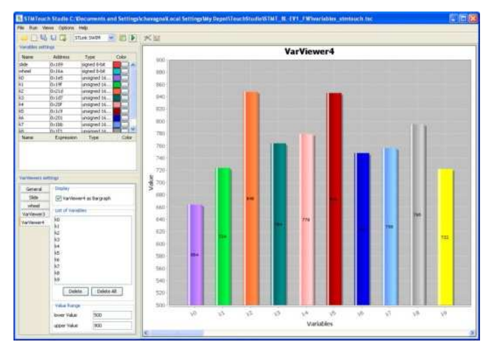
Start with the right STM32 and get the optimum pinout configuration

- **MicroXplorer tools**
  - MCU product selector
    - Identify the best STM32 to fit your application needs (performance, memory, peripherals, I/Os, etc.)
  - MCU configuration tool
    - Configure the STM32 pinout to fit your application needs



Optimize application performance

- **STM Studio tool**
  - Monitor any variable selected in your code to optimize application performance (motor control, touch sense, etc.)
    - Several display modes
    - On-the-fly acquisition modes
    - Log to/replay from file
    - Variables read/write capability



For further info about STM32 PMSM FOC SDK v3.2, please visit:

http://www.st.com/stm32

Downloads:

STM32 PMSM FOC SDK v3.2:

http://www.st.com/internet/com/SOFTWARE_RESOURCES/SW_COMPONENT/FIRMWARE/stm32_pmsm_foc_motorcontrol_fwlib.zip

ST MC Workbenchv2.0.0:

http://www.st.com/internet/com/SOFTWARE_RESOURCES/TOOL/CONFIGURATION_UTILITY/motorcontrol_workbench.zip

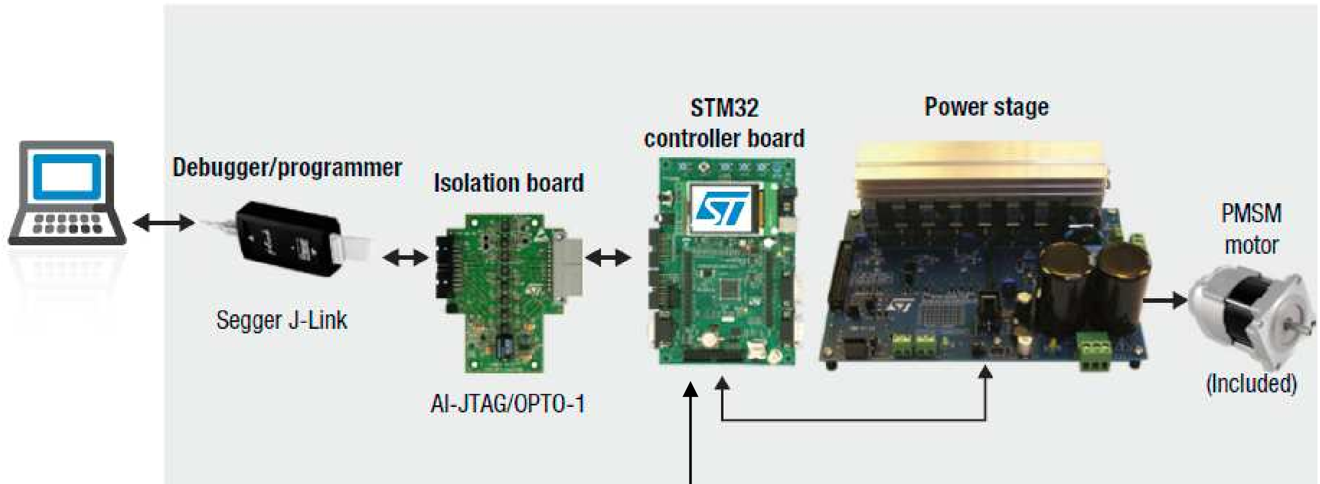
UM1052**:** STM32F103xx/ STM32F100xx/STM32F2xx/STM32F4xx PMSM single/dual FOC SDK v3.2

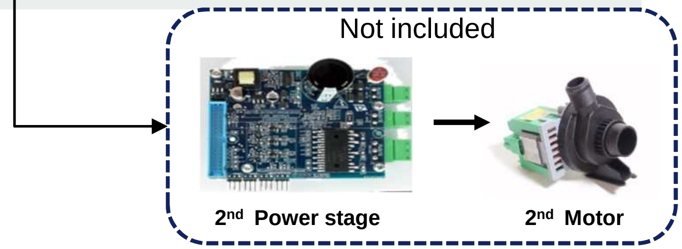
UM1053**:** Advanced developers guide for STM32F100x/103x/2x/40x/41x MCUs PMSM single/dual FOC library

www.st.com

Hardware tools

STM32Fxx MC kit





- Main Features
  - Driving Strategy: Vector Control
  - PMSM motor sensored and sensorless
  - Two (34-pin) dedicated motor control connectors
  - Encoder sensor input
  - Hall sensor input
  - Tachometer sensor input
  - Current sensing mode:
    - 3 shunt resistors
    - Single shunt

- Key Component
  - L6390D (Gate Drivers)
  - VIPer16LD (Power Supply down converter)
  - L7815ABV, L78M05CDT, LD1117S33TR (Voltage regulators)
  - STGP10NC60KD (IGBT)
  - TS391ILT, (Comparator)
  - M74HC14TTR (Logic)

Complementing MC starter kits

STM8/32 Evaluation boards

STM8 MC library v1.0

Scalar Control

STM8/128-EVAL

STM32 PMSM FOC SDK v3.0

FOC

STM32F100x

STM32100B-EVAL

STEVAL-IHM033V1

FOC | **Dual FOC**

STM32F103

STM3210E-EVAL

STEVAL-IHM022V1

MC connector

Power Stages

Thanks configurable tools it is possible to have diverse motor drive solutions

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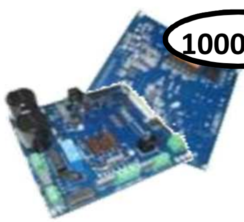
Please visit http://www.st.com/evalboards or contact a [local ST office](#)

Complementing MC starter kits

STM8/32 Evaluation boards

STEVAL-IHM025V1

- 1 x IGBT SLLIMM™ **STGIPL14K60**
- 1 converter based on **Viper16**
- 1 x IGBT **STGP10NC60KD**



STEVAL-IHM027V1

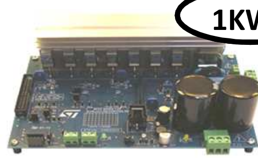
- 1 x IGBT SLLIMM™ **STGIPS10K60A**
- 1 converter based on **Viper16**
- 1 x IGBT **STGP10NC60KD**

STEVAL-IHM028V1

- 1 x IGBT SLLIMM™ **STGIPS20K60**
- 1 x PWM SMPS **VIPer26LD**
- 1 x IGBT **STGW35NB60SD**

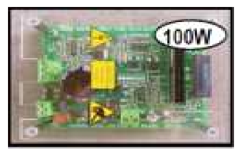
STEVAL-IHM035V1

- 1 x IGBT SLLIMM™ **STGIPN3H60**
- 1 x PWM SMPS **VIPer16L**



STEVAL-IHM023V2

- 3 x PWM smart driver **L6390**
- 1 converter based on **Viper16**
- 7 x IGBT power switch **STGP10NC60KD**



STEVAL-IHM021V2

- 3 x PWM smart driver **L6390**
- 1 converter based on **Viper12**
- 6 x MOSFET power switch **STD5N52U**

STEVAL-IHM032V1

- 3 x PWM smart driver:
  2xL6392D and **1x L6391D**
- 1 converter based on **Viper12**
- 6 x IGBT power switch: **STGD3HF60HD**

SLLIMM™ (ST IPMs) based

Gate drivers & Power Transistors based

Please visit : System evaulation boards or contact a local ST office

Complementing MC starter kits
Low Voltage Power Stages

120W

STEVAL-IHM031V1

Power stage up to 12/24V

- 3 x dual PowerMOSFETs **STS8dnh3l**
- 2 x PWM smart driver **L6387E**
- 1x step down converter **L4976D**

2000W

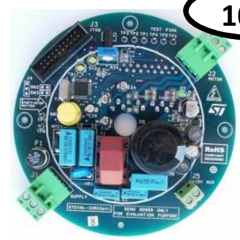
STEVAL-IEM003V1

Power stage up to 48V

- 3 x PWM smart driver **L6388**
- 6x LV Power MOSFET **STV250N55F3**
- 1x step down converter **L4978D**

Please visit System evaluation board or contact a local ST office

Complete 3ph motor drive solutions



100w

STEVAL-IHM036V1

PMSM FOC Motor Drive

- 1 x 32bit Micro **STM32F100C6**
- 1 x IGBT SLLIMM™ **STGIPN3H60**
- 1 converter based on **Viper16**

45w

STEVAL-IFN003V1

PMSM FOC Motor Drive

- 1 x 32bit Micro **STM32F103C**
- 1 x Motor Drive Ic **L6230PD**

1300W

STEVAL-IHM034V1

Coming soon

Dual motor drive + digital PFC

- 1 x 32bit Micro **STM32F103C8T6**
- 1 x IGBT SLLIMM™ **STGIPS20K60**
- 1 converter based on **Viper16L**

35W

STEVAL-IFN004V1

BLDC Six-Steps Motor Drive

- 1 x 8bit-Micro **STM8S**
- 1 x Motor Drive Ic **L6230Q**

40W

STEVAL-IHM038V1

Coming soon

FAN Drive + PFC + IrDA

- 1 x 32bit Micro **STM32100**
- 1 x IGBT SLLIMM™ **STGIPN3H60**
- 1 PFC controller **L6562A**

Low voltage drives

High voltage drives

Thanks for your attention