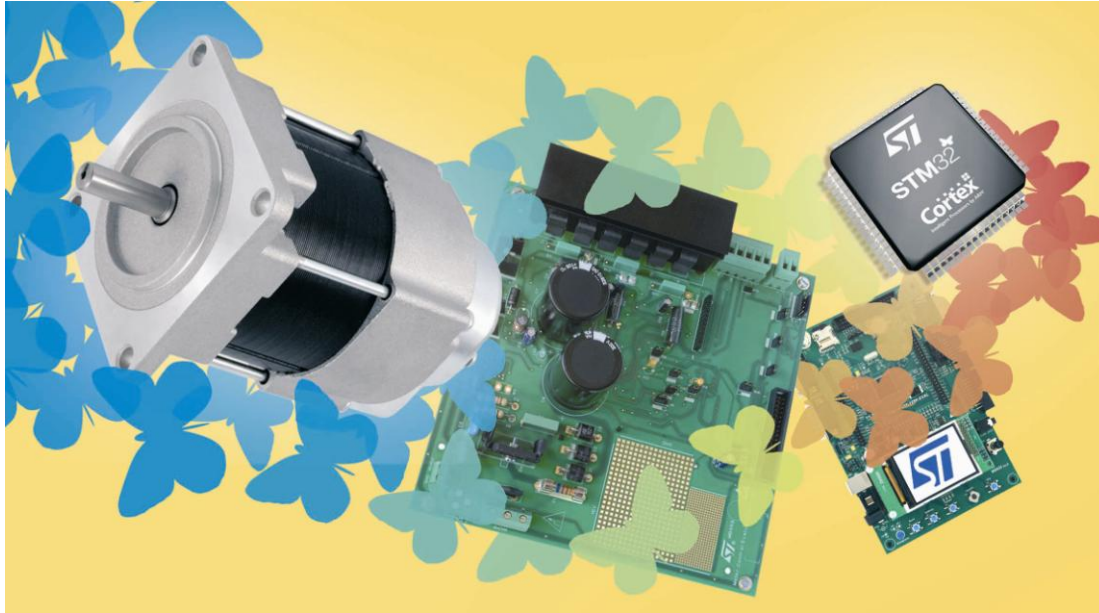# STM32 motor control firmware library

STM32 FOC PMSM SDK v3.0

Contents

- STM32 FOC PMSM SDK v3.0 overview
- The FOC (field oriented control) algorithm
- STM32 with FOC
- Motor control and electric motor offer
- FOC with STM32F100 and STM32F103
- Support tools for 3-phase motor control application

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Overview

STM32 FOC PMSM SDK v 3.0

Firmware library (free of charge)

- It implements the field oriented control (FOC) drive of 3-phase permanent magnet synchronous motors (PMSM), both surface mounted (SM-PMSM) and internal (I-PMSM)
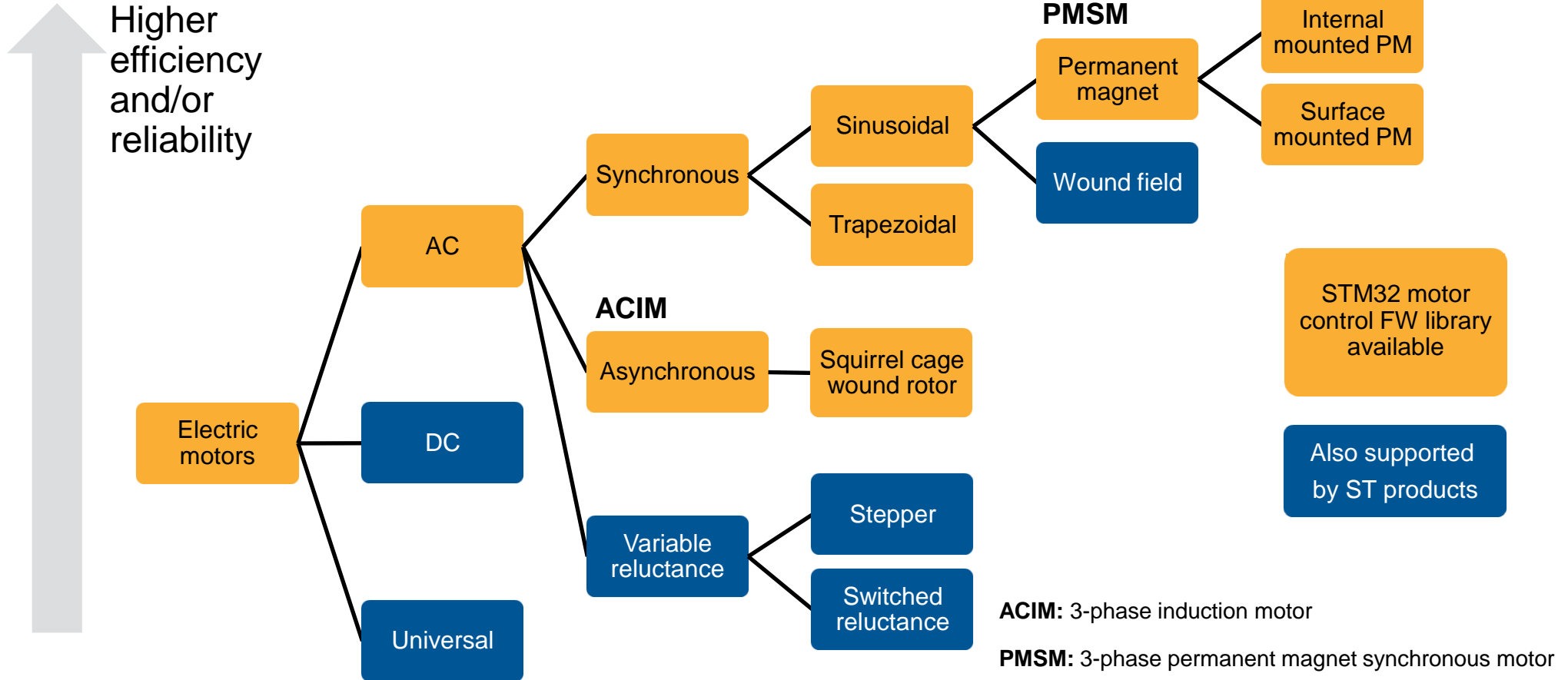
supporting

- STM32F103 microcontroller (STM32 performance line)
  - Medium-density devices (up to 256 Kbytes of Flash) or high-density devices (from 256 Kbytes to 1 Mbyte of Flash)
- STM32F100 microcontroller (STM32 value line)

in order to

- Quickly evaluate ST microcontrollers on 3-phase PMSM motor control applications
- Save time when developing motor control solutions to be run on ST microcontrollers

Electric motor control at ST

Higher efficiency and/or reliability

PMSM

- Electric motors
  - AC
    - Synchronous
      - Sinusoidal
        - Permanent magnet
          - Internal mounted PM
          - Surface mounted PM
        - Wound field
      - Trapezoidal
    - **ACIM**
      - Asynchronous
        - Squirrel cage wound rotor
    - Variable reluctance
      - Stepper
      - Switched reluctance
  - DC
  - Universal

STM32 motor control FW library available

Also supported by ST products

ACIM: 3-phase induction motor

PMSM: 3-phase permanent magnet synchronous motor
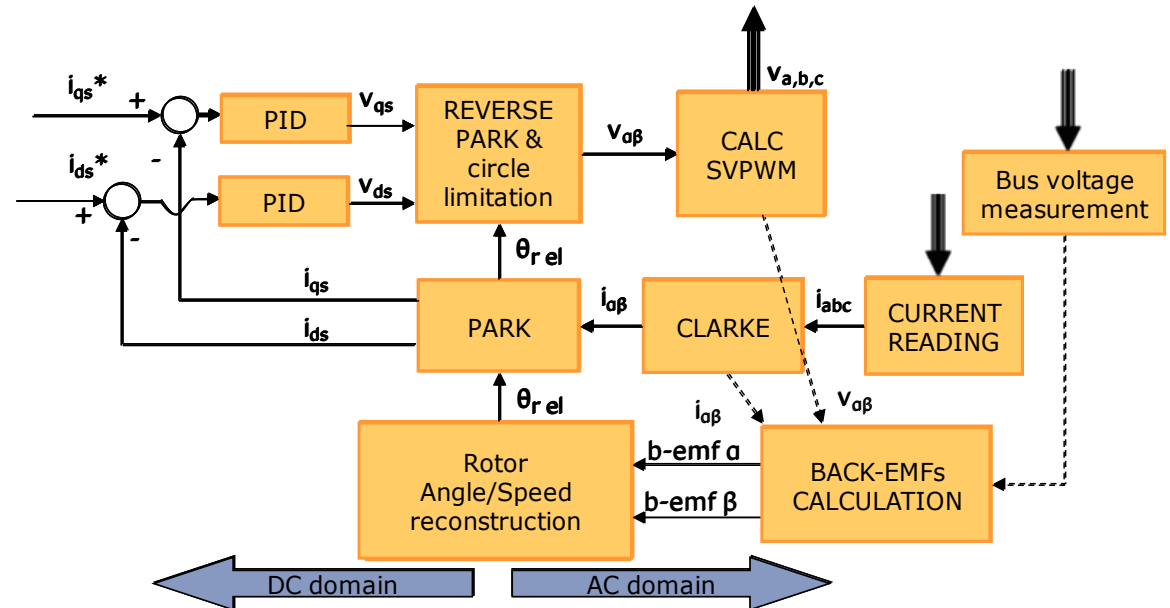
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Field oriented control (FOC)

- Mathematical technique used to achieve decoupled control of the flux and torque in a 3-phase motors
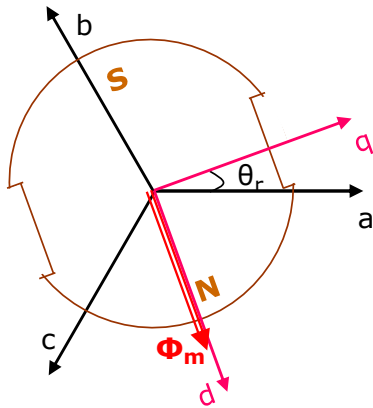
Block diagram of FOC algorithm example
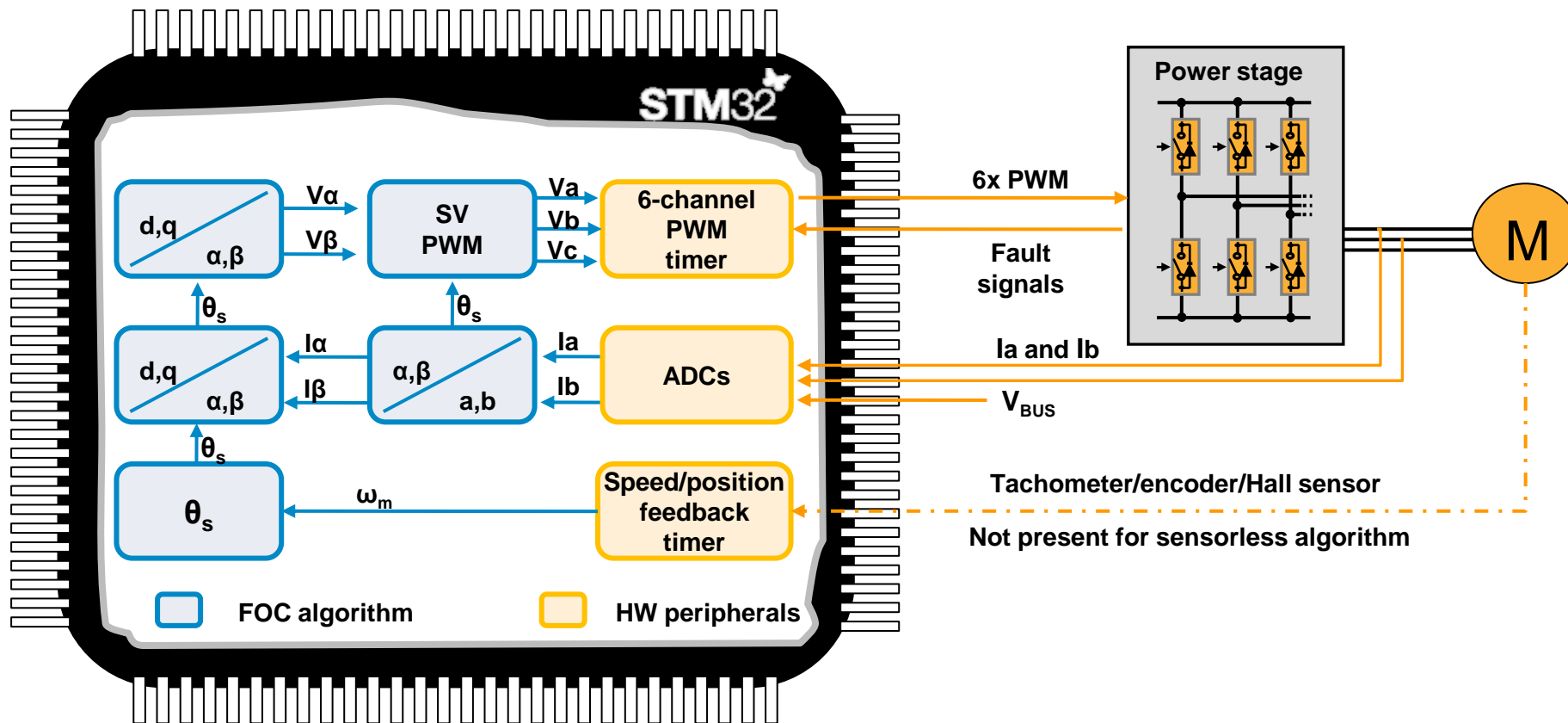
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Benefits of FOC

- Optimized efficiency even during transient operation
- Precise and responsive speed control to load variations
- Precise position control (through instantaneous torque control)
- Acoustical noise reduction due to precise control technique

FOC with STM32

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STM32 FOC PMSM SDK v3.0 key features

Single/dual simultaneous vector control (FOC)
Any combination of current-reading topologies and speed
or position sensors is supported

Supports both
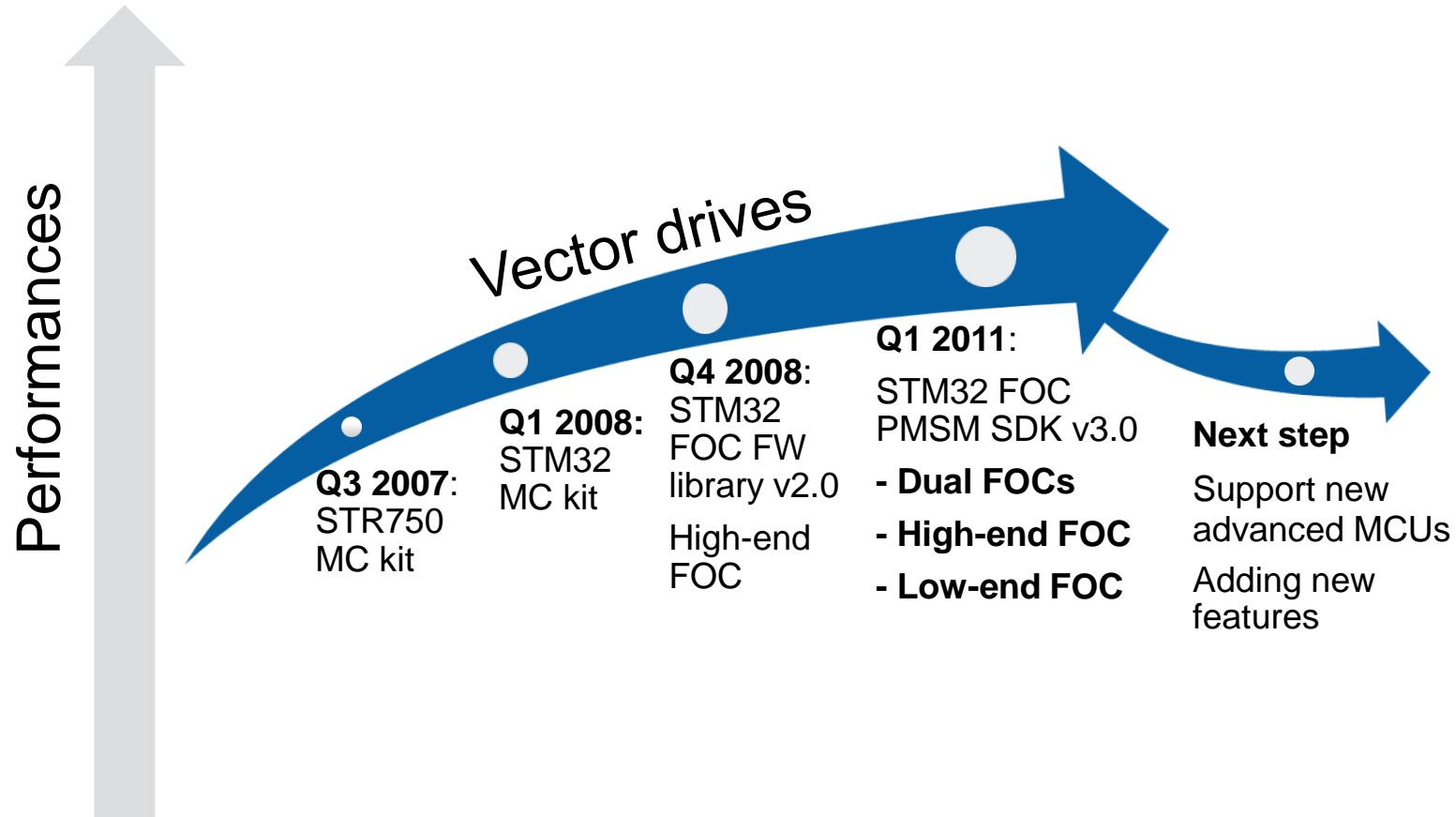STM32F100x and
STM32F103x families

STM32 FOC
PMSM SDK
v 3.0

Full customization
through ST MC
workbench (GUI)

Algorithm improvements
compared to v2.0

Application example
based on FreeRTOS

3-phase brushless motor control evolution

Performances

Vector drives

Q3 2007: STR750 MC kit

Q1 2008: STM32 MC kit

Q4 2008: STM32 FOC FW library v2.0

High-end FOC

Q1 2011: STM32 FOC PMSM SDK v3.0
- **Dual FOCs**
- **High-end FOC**
- **Low-end FOC**

Next step

Support new advanced MCUs

Adding new features

STM32F100 Value line

- 32-bit ARM® Cortex™-M3 core
  - Up to 30 DMIPS at 24 MHz max
- 2.0 to 3.6 V operation
- -40 to +105 °C
- Enhanced control
  - 1x 16-bit advanced timer
  - 6x 16-bit PWM timers
- Advanced analog
  - 1x fast 12-bit 1.2 µs ADC
  - Dual-channel 12-bit DAC
- System integration
  - Internal 8 MHz RC oscillator
  - Built-in safe reset system
- Datasheets

System
- Power supply 1.8 V regulator POR/PDR/PVD
- Xtal oscillator 32 kHz + 4-24 MHz
- Internal RC oscillators 40 kHz + 8 MHz
- PLL
- Clock control
- RTC/AWU
- Systick timer
- 2x watchdogs (independent and window)
- 37/51/80 I/Os
- Cyclic redundancy check (CRC)

16- to 128-Kbyte Flash memory
4- to 8-Kbyte SRAM
20-byte backup data

ARM Cortex-M3 CPU 24 MHz
- ARM
- Nested vector interrupt controller (NVIC)
- JTAG/ SW debug

- AHB bus matrix
- 7-channel DMA

Connectivity
- Consumer electronics control (CEC)
- 3x USART
- 2x SPI
- 2x I²C

Control
- 16-bit motor control PWM Synchronized AC timer
- 6x16-bit timer

Analog
- 2 -channel 12-bit DAC
- 12-bit ADC 16 channels
- Temperature sensor

# FOC single motor drive with STM32F100

Target application characteristics

- Requirements for dynamic performances are moderate
- Quietness of sinusoidal current control (versus 6-step drive) is valuable
- Extended speed range is required
- Particularly suitable for pumps, fans and compressors

Advantages

- Cost optimized
- More silent
- Lower torque ripple
- Extended speed range more easily achieved

Current

Six-step drive

Current
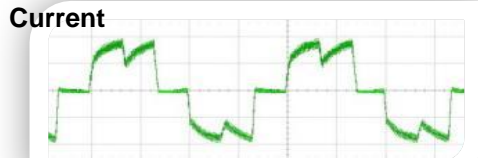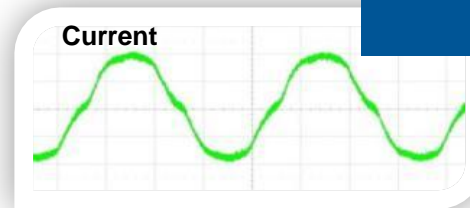
FOC control

Performances of FOC with STM32F100

Configuration: 1 shunt/sensorless at 20 kHz PWM,10 kHz FOC

- Motor control code size is 15.82 Kbytes
- Motor control RAM usage is 2.77 Kbytes
- FOC total execution time is 65.22 µs (ADC ISR + TIM1 update ISR)
- FOC introduced CPU load is 65.2%
- Total CPU load is ~70% (~60% at 8 kHz FOC)

ISR: interrupt service routine

STM32F103 Performance line

- 32-bit ARM® Cortex™-M3 core
  - 1.25 DMIPS/MHz (Dhrystone 2.1)
- 2 to 3.6 V supply
- -40 to + 105°C
- From 16-Kbytes to 1-Mbyte Flash memory
- Enhanced control
  - Up to 2x 16-bit advanced timer
  - Up to 4x 16-bit PWM timers
- Advanced analog
  - Up to 3x fast 12-bit 1.2 µs ADC
- System integration
  - Internal 8 MHz RC oscillator
  - Built-in safe reset system
- Datasheets

System
- Power supply 1.8 V regulator POR/PDR/PVD
- Xtal oscillator 32 kHz + 3-25 MHz
- Internal RC oscillators 40 kHz + 8 MHz
- PLL
- Clock control
- RTC/AWU
- Systick timer
- 2x watchdogs (independent and window)
- 37/51/80/112 I/Os
- Cyclic redundancy check (CRC)

ARM Cortex-M CPU 24 to 72 MHz
- ARM
- Nested vector interrupt controller (NVIC)
- JTAG/SW debug/ ETM

- AHB bus matrix
- 12-channel DMA

- Up to 1-Mbyte Flash memory
- Up to 96-Kbyte SRAM
- FSMC/ SRAM/NOR/NAND/CF/L CD parallel interface
- 84-byte backup data

Connectivity
- Consumer electronics control (CEC)
- 2x I²S
- 2x I²C
- 2x CAN 2.0B
- USB 2.0 FS/OTG
- Ethernet MAC 10/100 with IEEE 1588
- 3x SPI
- SDIO
- 5x USART LIN, smartcard, IrDA, modem control

Control
- 2x16-bit motor control PWM Synchronized AC timer
- 10x16-bit timer

Analog
- 2 -channel 12-bit DAC
- 3x12-bit ADC 21 channels 1 Ms/second
- Temperature sensor

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FOC single motor drive with STM32F103

Target applications

- Wide application range from home appliances to robotics, where:
  - Accurate and quick regulation of motor speed and torque is required (such as in torque load transient or abrupt target speed variations)
  - CPU load granted to motor control must be low due to other duties

Power tools

Industrial motor drives

Home appliances

Games

Escalators and elevators

Fitness, wellness and healthcare

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Performances of FOC with STM32F103

Configuration: 1 shunt/sensorless at 10 kHz FOC sampling time

- Motor control code size is 16.2 Kbytes
- Motor control RAM usage is <2.5 Kbytes
- FOC total execution time is 26.1 µs (ADC ISR + TIM1 update ISR)
- FOC introduced CPU load is 30%

ISR: interrupt service routine

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FOC dual motor drive with STM32F103

Target applications

- Wide application range from home appliances to robotics, where:
    - Up to two FOC drives have to run at the same time
    - Accurate and quick regulation of motor speed and torque is required (such as in torque load transient or abrupt target speed variations)

Dishwashers:
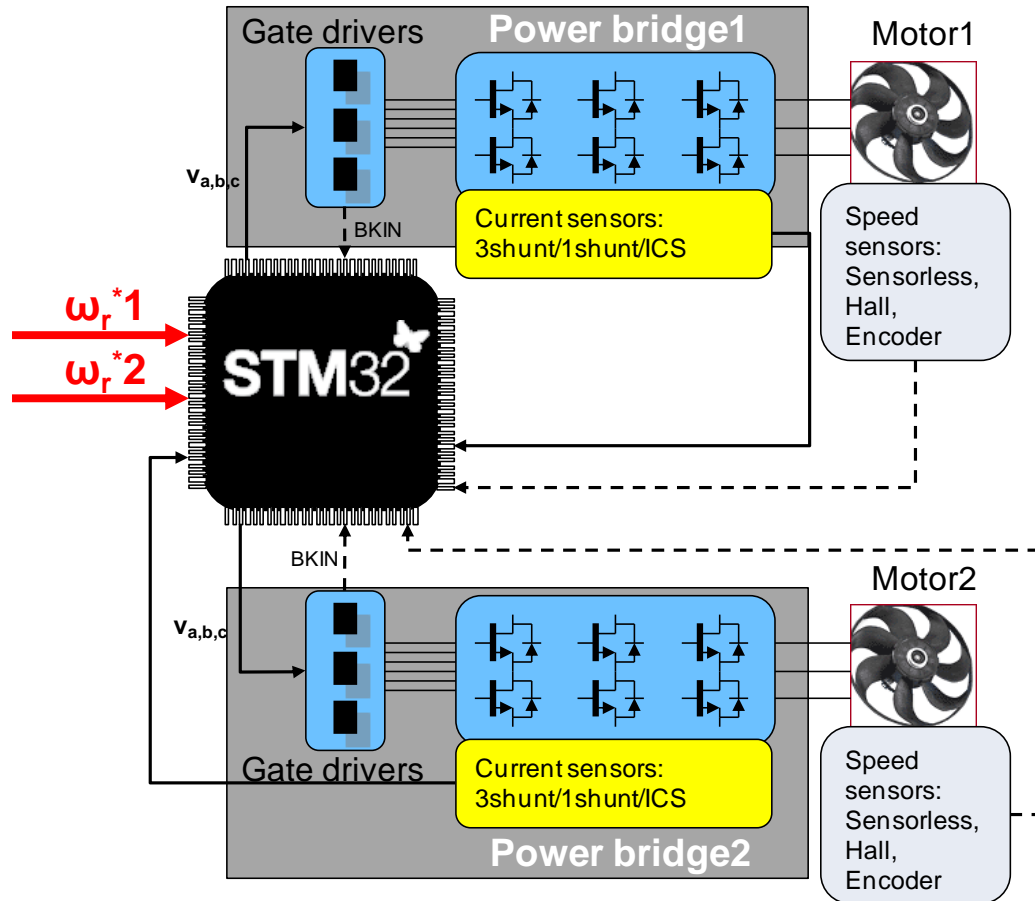**spray + drain pumps**

Washing machines:
drum + drain pumps

Air conditioners:
compressors + outdoor fans

Industrial motor drives

Dual FOC PMSM – block diagram

With STM32 FOC PMSM SDK v3.0, STM32F103 high-density devices with their extended set of peripherals (2 advanced timers, 3 fast ADCs, and more) can drive 2 motors in diverse configurations

ICS: isolated current sensors

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Performances of dual FOC with STM32F103

Example of configuration No. 1:

- Motor 1, 1 shunt/sensorless @ 8 kHz PWM/FOC – flux weakening enabled
- Motor 2, 1 shunt/sensorless @ 16 kHz PWM, 8 kHz FOC

- Motor control code size is 22.3 Kbytes (1.5 times below single motor case)
- Motor control RAM usage is 4.01 Kbytes
- FOC introduced CPU load (including TIMx update ISRs) is 44%
- Total CPU load ~50%

ISR: interrupt service routine

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Performances of dual FOCs with STM32F103

Example of configuration No. 2:

- Motor 1, 3 shunts/sensorless @ 16 kHz PWM/FOC – MTPA and flux weakening enabled
- Motor 2, 1 shunt/sensorless @ 16 kHz PWM, 8 kHz FOC

- Motor control code size is 25.5 Kbytes
- Motor control RAM usage is 4.14 Kbytes
- FOCs introduced CPU load (including TIMx update ISRs) is 62.6%
- Total CPU load <70%

ISR: interrupt service routine

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Summary table: features set – MCU support

STM32F103 (Performance line) HD

STM32F103 (Performance line) MD and HD

STM32F100 (Value line) and STM32F103

1-shunt	Flux weakening	IPMSM MTPA
Feed forward	Sensorless (STO + PLL)	Sensorless (STO + Cordic)
Encoder	Hall sensors	Debug and tuning
ST MC workbench support	USART-based com protocol add-on	Max FOC ~ 11 kHz

3-shunt
FreeRTOS
ICS
Max FOC ~25 kHz

Dual FOC
Max dual FOC ~20 kHz
Max FOC ~25 kHz

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ICS: isolated current sensors

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ST Motor Control Workbench v1.0.2 (STMCWB)

STMCWB is a PC code generator tool developed to reduce the firmware development time for STM32 FOC PMSM SDK v3.0. A graphical user interface (GUI) allows you to generate all parameter header files that configure the library, according to application needs.
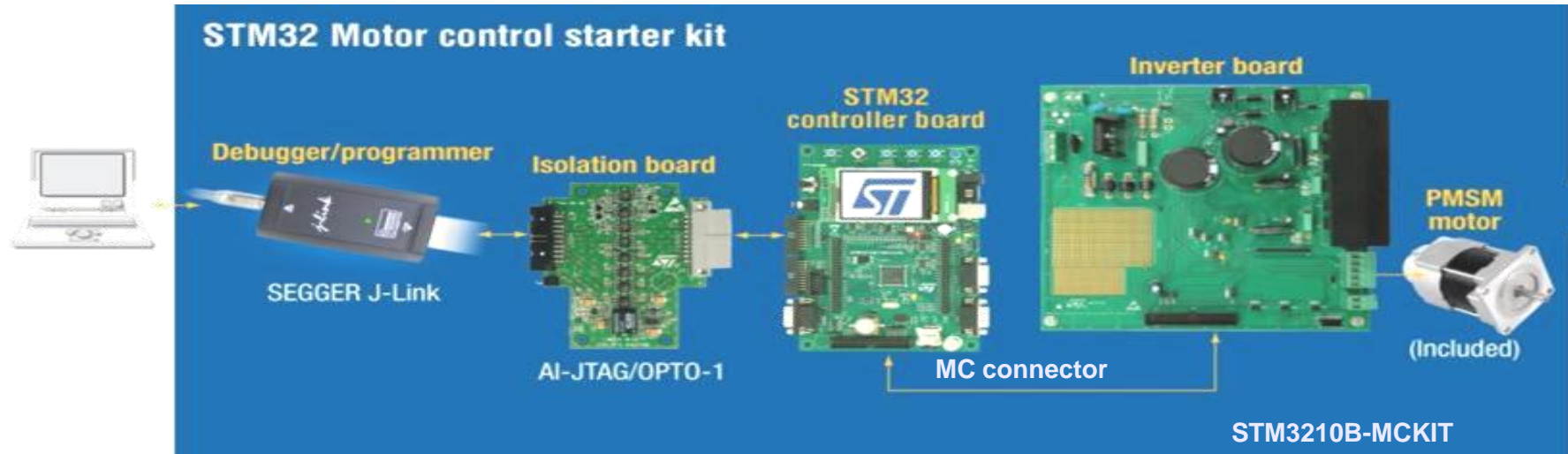

Motor   **Power stage**   **Drive management**   **Control stage**

STM3210B-MCKIT starter kit

STM3210B-MCKIT starter kit

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STM3210B-MCKIT starter kit

Main features

- Driving strategy: vector control
  - AC induction motors, sensored
  - PMSM motors, sensored and sensorless
- 34-pin dedicated motor control connector
- Encoder, Hall sensor, tachometer sensor inputs
- Current sensing mode:
 - 3 shunt resistors
  - Single shunt

ST complete offer

- STM32F103 (32-bit MCU with dedicated motor control timer)
- L6386DE (gate driver)
- VIPer12AS (power supply downconverter)
- L7815CP, L7805CP, LD1117S33TR (voltage regulators)
- STGF7NC60H (IGBT)
- TSV994, TS374ID, TS372ID (op-amps)
- M74HC09RM13TR, M74HCT7007RM13TR (logic)

STM32 evaluation boards (control board)

STM32 FOC PMSM SDK v3.0

FOC — Optimized for STM32F100x

FOC — High performance

FOC | Dual FOC — High performance
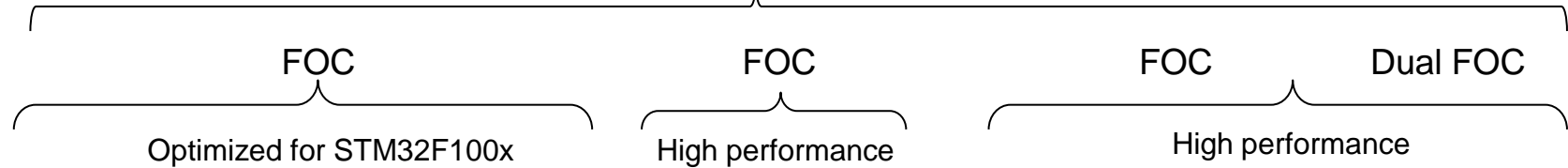
STM32100B-EVAL   **STEVAL-IHM032V1**   **STM3210B-EVAL**   **STM3210E-EVAL**   **STEVAL-IHM022V1**
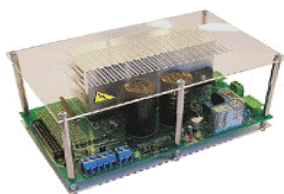
http://www.st.com/evalboards

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Complementary high-voltage power stages

SLLIMM™ (ST IPMs) based

STEVAL-IHM025V1

- 1000 W
- 1x IGBT SLLIMM™: **STGIPL14K60**
- 1x converter based on **VIPer16**
- 1x IGBT: **STGP10NC60KD**

STEVAL-IHM027V1

- 1000 W
- 1x IGBT SLLIMM™: **STGIPS10K60A**
- 1x converter based on **VIPer16**
- 1x IGBT: **STGP10NC60KD**

STEVAL-IHM028V1

- 2000 W
- 1x IGBT SLLIMM™: **STGIPS20K60**
- 1x PWM SMPS: **VIPer26LD**
- 1x IGBT: **STGW35NB60SD**

(*) Available in Q4/2011

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Gate-driver and power-transistor based

STEVAL-IHM023V2

- 1000 W
- 3x PWM smart drivers: **L6390**
- 1x converter based on **VIPer16**
- 7x IGBT power switches: **STGP10NC60KD**

STEVAL-IHM021V1

- 3x PWM smart drivers: **L6390**
- 1x converter based on **VIPer12**
- 6x MOSFET power switches: **STD5N52U**

STEVAL-IHM024V1

- 3x PWM smart drivers: **L6390**
- 1x converter based on **VIPer12**
- 6x IGBT power switches: **STGDL35NC60DI**

STEVAL-IHM032V1 (*)

- 150 W
- 3x PWM smart drivers: **2xL6392D** and **1x L6391D**
- 1x converter based on **VIPer12**
- 6x IGBT power switches: **STGD3HF60HD**

Low voltage power stages and drive solutions

Low-voltage power stages

STEVAL-IHM031V1

- 120 W
- 3x dual power MOSFETs: **STS8DNH3L**
- 2x PWM smart drivers: **L6387E**
- 1x step-down converter: **L4976D**

STEVAL-IEM003V1

- Power stage up to 48 V
- 2000 W
- 3x PWM smart drivers: **L6388**
- 6x LV power MOSFETs: **STV250N55F3**
- 1x step-down converter: **L4978D**

Complete motor drive solutions

STEVAL-IFN003V1 (*)

- FOC PMSM motor drive
- 80 W
- 1x 32-bit microcontroller: **STM32F103C**
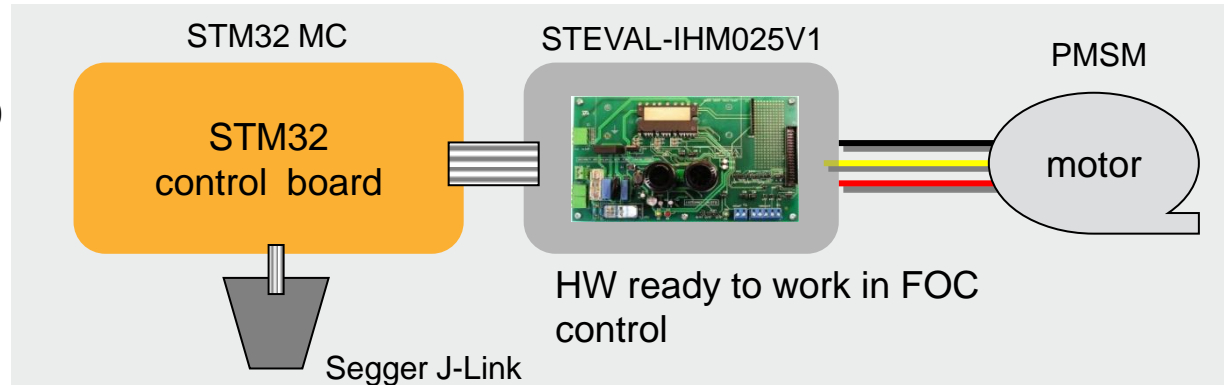- 1x motor drive IC: **L6230PD**

(*) Available in Q4/2011

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Example: STEVAL-IHM025V1 configurations

Field oriented control (FOC)

STM32 FOC PMSM SDK v3.0 configuration through the PC GUI: STMCWB v1.0.2

STM32 MC

STM32 control board

STEVAL-IHM025V1

HW ready to work in FOC control

PMSM

motor

Segger J-Link

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More information

Download:

STM32 FOC PMSM SDK v 3.0 firmware library zip file

ST MC Workbenchv1.0.2 zip file

Consult:

Technical note TN0516 Overview of the STM32F103/STM32F100 PMSM single/dual FOC SDK V3.0

User manual UM1052 STM32F103 or STM32F100 PMSM single/dual FOC SDK V3.0

User manual UM1053 Advanced dev. guide for STM32F103/STM32F100 PMSM single/dual FOC library

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Thank you