TN0516
Technical note

Overview of the STM32F103xx/STM32F100xx PMSM single/dual FOC SDK V3.0

Introduction

This technical note provides an overview of the main features of the Motor Control Software Development Kit (generically called software library) designed for and to be used with STM32F103xx or STM32F100xx microcontrollers (STM32F103xx also called STM32 performance line, STM32F100xx also called STM32 value line). The software library implements the Field Oriented Control (FOC) drive of 3-phase Permanent Magnet Synchronous Motors (PMSM), both Surface Mounted (SM-PMSM) and Internal (I-PMSM).

The control of an AC induction motor equipped with encoder or tacho generator is described in the UM0483 user manual.

The STM32F family of 32-bit Flash microcontrollers is based on the breakthrough ARM Cortex™-M3 core, specifically developed for embedded applications. These microcontrollers combine high performance with first-class peripherals that make it suitable for performing both permanent-magnet and AC induction motor FOC.

The PMSM FOC library can be used to quickly evaluate ST microcontrollers and complete ST application platforms, as well as to save time when developing Motor Control algorithms to be run on ST microcontrollers. This PMSM FOC library is written in C language, and implements the core Motor Control algorithms (reference frame transformations, currents regulation, speed regulation, space-vector modulation, energy efficiency optimizations) as well as sensors reading/decoding algorithms (three shunts, ST-patented single DC link shunt, isolated current sensors, incremental encoder, hall sensors) and a sensorless algorithm for rotor position reconstruction.

When deployed with STM32F103xx High-Density / XL-Density devices (Flash memory density between 256 and 512 Kbytes / 768 Kbytes and 1 Mbyte) the PMSM FOC library allows simultaneous dual FOC of two different motors. The library can be customized to suit user application parameters (motor, sensors, power stage, control stage, pin-out assignment) and provides a ready-to-use Application Programming Interface (API).

A user project has been implemented to demonstrate how to interact with the Motor Control API. The project provides an LCD User Interface and a USART User Interface, represents a convenient real-time fine-tuning and remote control tool for the motor control application.

A PC Graphical User Interface (GUI), the ST Motor Control Workbench, allows complete and easy customization of the PMSM FOC library. In conjunction with the STM3210B-MCKIT motor control starter kit, a PMSM motor can be made to run in a very short time using default parameters.

Basic knowledge of C programming, C++ programming (for customizing the LCD User Interface), PM motor drives and power inverter hardware is necessary for using the software library. In-depth know-how of STM32F103xx or STM32F100x peripherals/functions is only required for customizing existing modules and for adding new ones for a complete application development.

1 Motor control library features

- Single or simultaneous Dual PMSM FOC sensorless / sensored (Dual PMSM FOC only when running on STM32F103xx High-Density, STM32F103xx XL-Density)
- Speed feedbacks:
  - Sensorless (B-EMF State Observer, PLL rotor speed/angle computation from B-EMF)
  - Sensorless (B-EMF State Observer, CORDIC rotor angle computation from B-EMF)
  - 60° or 120° displaced Hall sensors decoding, rising/falling edge responsiveness
  - Quadrature incremental encoder
  - For each motor, dual simultaneous speed feedback processing
  - On-the-fly speed sensor switching capability
- Current sampling methods:
  - Two ICS (only when running on STM32F103xx)
  - Single, common DC-link shunt resistor (ST patented)
  - Three shunt resistors placed on the bottom of the three inverter legs (only when running on STM32F103xx)
- Flux weakening algorithm to attain higher than rated motor speed (optional)
- Feed-Forward, high performance current regulation algorithm (optional)
- SVPWM generation:
  - Centered PWM pattern type
  - Adjustable PWM frequency
- Torque control mode, speed control mode; on-the-fly switching capability
- Brake strategies (optional):
  - Dissipative DC link brake resistor handling
  - Motor phases short-circuiting (with optional hardware over-current protection disabling)
- When running Dual FOC, any combination of the above-mentioned speed feedback, current sampling, control mode, optional algorithm
- Optimized I-PMSM and SM-PMSM drive
- Programmable speed ramps (parameters duration and final target)
- Programmable torque ramps (parameters duration and final target)
- Real-time fine tuning of:
  - PID regulators
  - Sensorless algorithm
  - Flux weakening algorithm
  - Start-up procedure (in case of sensorless)
- Fault conditions management:
  - Over-current
  - Over-voltage
  - Over-temperature
  - Speed feedback reliability error
  - FOC algorithm execution overrun

- Easy customization of options, pin-out assignments, CPU clock frequency through ST MC Workbench GUI
- C language code:
  - Compliant with MISRA-C 2004 rules
  - Conforms strictly with ISO/ANSI
  - Object-oriented programming architecture

1.1 User project and interface features

There are two available options:

- FreeRTOS-based user project (for STM32 performance line only)
- SysTick-timer-easy-scheduler-based user project

Available User Interface options (and combinations of them):

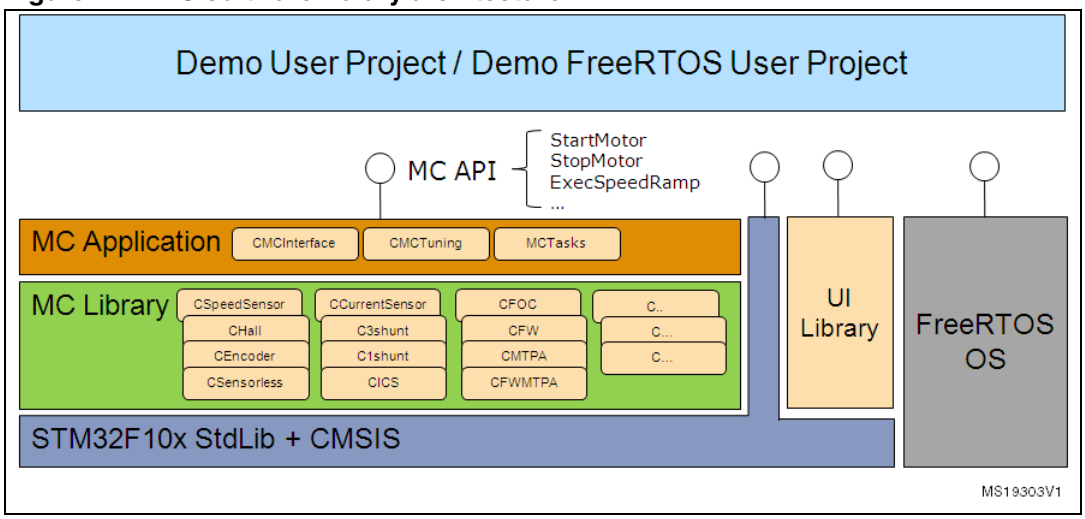
- LCD (C++ programmed) plus joystick
- Serial communication protocol
- Drive system variables logging/displaying via:
  - SPI
  - DAC (DAC peripheral available only on STM32F100xx or STM32F103xx High-Density and XL-Density; RC-filtered PWM signal option where not available)

2 MC software development kit architecture

Figure 1 shows the system architecture. The Motor Control SDK has a four-layer structure:

- STM32F10x standard peripherals library and CMSIS library
- Motor Control Library
- Motor Control Application
- Demonstration user project

Figure 1. MC software library architecture



From the bottom layer upwards:

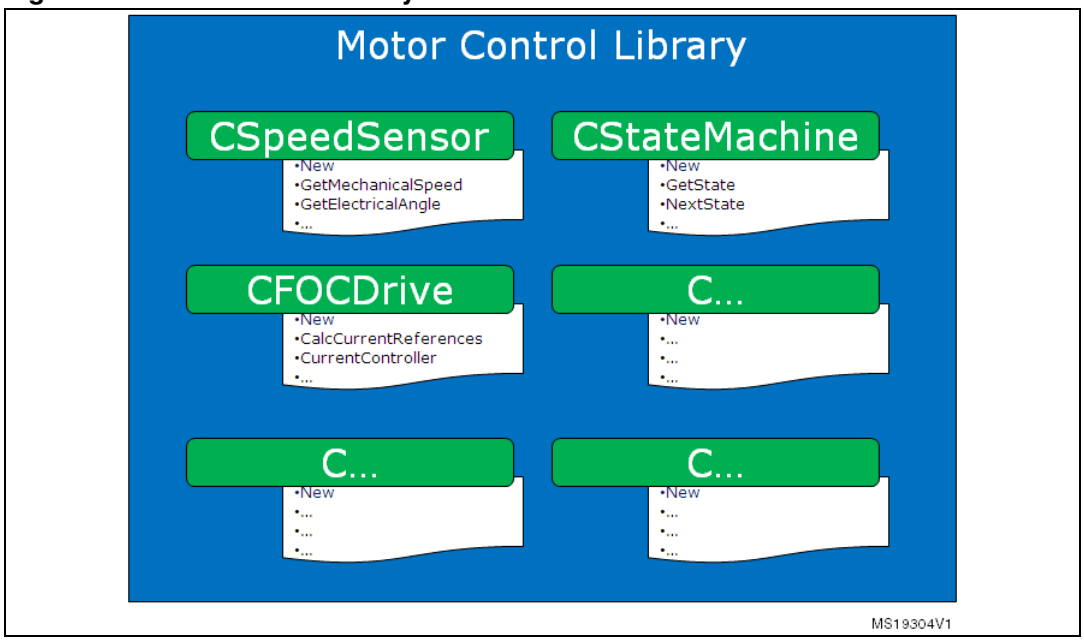
The STM32F10x Standard Peripherals Library is an independent firmware package that contains a collection of routines, data structures and macros that cover the features of the STM32 peripherals. Version 3.3.0 is included in the MC SDK. The STM32F10x Standard Peripherals Library is CMSIS and MISRA-C compliant. Visit www.st.com/stm32 for complete documentation.

The Motor Control Library is a wide collection of classes that describe the functionality of elements involved in motor control (such as speed sensors, current sensors, algorithms). Each class has an interface, which is a list of methods applicable to objects of that class. *Figure 2* is a conceptual representation of the library.

Two distributions of the Motor Control Library are available:

- Web distribution, available free of charge at www.st.com, where the Motor Control Library is provided as a compiled .lib file.
- Confidential distribution, available free of charge on demand by contacting your nearest ST sales office or support team. Source files of classes are provided, with the exception of ST protected IPs, which are furnished as compiled object files. Source files of protected IPs can also be provided free of charge to ST partners upon request. Contact your nearest ST office or support team for further information.

Figure 2. Motor control library



The Motor Control Library uses the lower STM32F10x Standard Peripheral Library layer extensively for initializations and settings on peripherals. Direct access to STM32 peripheral registers is preferred when optimizations (in terms of execution speed or code size) are required. More information about the Motor Control Library, its classes and object oriented programming, can be found in the *Advanced developers guide for STM32F103xx/STM32F100xx PMSM single/dual FOC library (*UM1053).

The Motor Control Application (MCA) is an application that uses the Motor Control Library in order to accomplish commands received from the user level. This set of commands is specified in its Application Programming Interface (API).

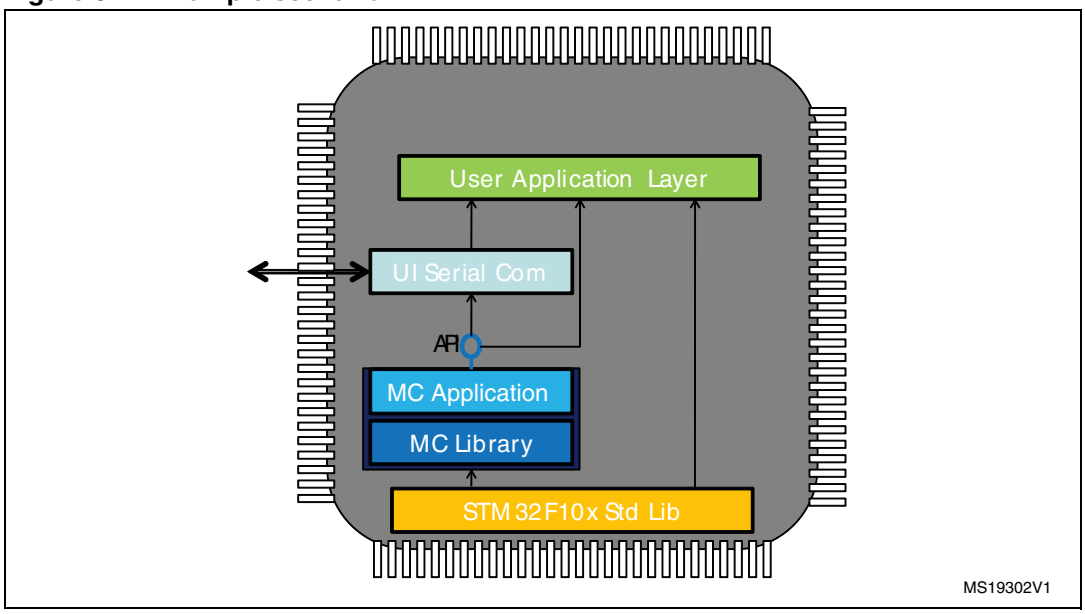
During its boot stage, the MCA creates the required controls in accordance with actual system parameters, defined in specific .h files that are generated by the ST MC Workbench GUI (or manually edited). It coordinates them continuously for the purpose of accomplishing received commands, by means of tasks of proper priority and periodicity. More information about the MCA can be found in *User manual STM32F103xx or STM32F100xx PMSM single/dual FOC SDK v3.0* (UM1052), and details on tasks and implemented algorithms in the *Advanced developers guide for STM32F103xx/STM32F100xx PMSM single/dual FOC library (*UM1053).

At the user level, a user project has been implemented to demonstrate how to interact with the MC API to successfully achieve the execution of commands. Depending on definable options, the user project can act as a Human Interface Device (using a joystick, buttons and LCD screens), as a command launcher through a serial communication protocol, as a data logging/displaying utility, or as a tuning tool.

Two versions of this user project are available. One is based on FreeRTOS, the other is not. The demonstration user project can be dismantled and replaced by the user application layer, or quite easily integrated, as shown in *Figure 3*: the user application layer uses the STM32F10x Standard Library for its own purposes, sends commands directly to the MC API, while the serial communication interface provided in the demonstration user project dispatches commands received from the outer world to the MC API.

More information about the modules integrated with the demonstration user project, such as serial communication protocol, drive variables monitoring through DAC / SPI, HID (generically called 'UI library') and a description of LCD screens can be found in *User manual STM32F103xx or STM32F100xx PMSM single/dual FOC SDK v3.0* (UM1052).

Figure 3. Example scenario



Please contact your nearest ST sales office or support team to obtain the STM32F103xx/STM32F100xx PMSM single/dual FOC SDK v3.0 installation file. For a complete list of ST offices and distributors, refer to the ST website http://www.st.com.

3 Documentation architecture

3.1 Where to find the information you need

Technical information about the MC SDK is distinguished and organized by topic. The following is a list of the documents that are available and the subjects they cover:

- *STM32F103xx/STM32F100xx permanent-magnet synchronous motor single/dual FOC software library V3.0* (UM1052), provides the following:
  - Features
  - Architecture
  - Workspace
  - Customization processes
  - Overview of algorithms implemented (FOC, current sensors, speed sensors)
  - MC API
  - Demonstrative user project
  - Demonstrative LCD user interface
  - Demonstrative serial communication protocol
- *Advanced developers guide for STM32F103xx/STM32F100xx PMSM single/dual FOC library* (UM1053). This provides the following:
  - Object oriented programming style used for developing the MC library
  - Description of classes that belong to the MC library
  - Interactions between classes
  - Description of tasks of the MCA
- MC library source documentation (Doxygen-compiled HTML file). This provides a full description of the public interface of each class of the MC library (methods, parameters required for object creation).
- MC Application source documentation (Doxygen-compiled HTML file). This provides a full description of the classes that make up the MC API.
- User Interface source documentation (Doxygen-compiled HTML file). This provides a full description of the classes that make up the UI Library.
- STM32F10x Standard Peripherals Library source documentation (Doxygen-compiled HTML file).
- ST MC Workbench GUI documentation. This is a field guide that describes the steps and parameters required to customize the library, as shown in the GUI.
- In-depth documentation about particular algorithms (sensorless position/speed detection, flux weakening, MTPA, feed-forward current regulation).

Please contact your nearest ST sales office or support team to obtain the documentation you are interested in if it was not already included in the software package you received or available on the ST web site (*www.st.com*).

3.2 Related documents

Available from www.arm.com

- Cortex™-M3 Technical Reference Manual, available from: *http://infocenter.arm.com/help/topic/com.arm.doc.ddi0337e/DDI0337E_cortex_m3_r1p1_trm.pdf*

Available from www.st.com or your STMicroelectronics sales office

- *STM32F103xx datasheet*
- *STM32F100xx datasheet*
- *STM32F103xx user manual (RM0008)*
- *STM32F100xx user manual (RM0041)*
- *STM32F103xx AC induction motor IFOC software library V2.0 (UM0483)*
- *STM32 and STM8 Flash Loader demonstrator (UM0462)*

4 Revision history

Table 1. Document revision history

Date	Revision	Changes
19-Apr-2011	1	Initial release.
24-May-2011	2	Added references for web and confidential distributions of STM32 FOC PMSM SDK v3.0