STMICROELECTRONICS' MOTOR CONTROL ECOSYSTEM FEATURING STM32F30X AND L6230

Antonino Bruno, Dino Costanzo, Gianluigi Forte

ST MOTOR CONTROL ECOSYSTEM OVERVIEW

STMicroelectronics' Ecosystem, leveraging a deep knowledge and system expertise accrued in digital and power system solutions, is able to support all kinds of motors because of its broad portfolio of innovative products ranging from Power Discretes to intelligent power modules, Motor driver ICs, and to the latest digital microcontrollers that combine high computational performances with a unique set of dedicated peripherals. Since 2002, ST has focused on three-phase motor controls and developed dedicated HW and SW solutions such as its field oriented control software development kit (STM32 PMSM FOC SDK and ST MC Workbench) in order to speed up the time to market of motion control applications. The upcoming releases of STM32 PMSM FOC SDK and ST Workbench will also support the STM32F30x MCU series. These microcontrollers combine a 32-bit ARM Cortex-M4 core with a DSP and FPU instructions running at 72 MHz with advanced analog peripherals for more flexibility.

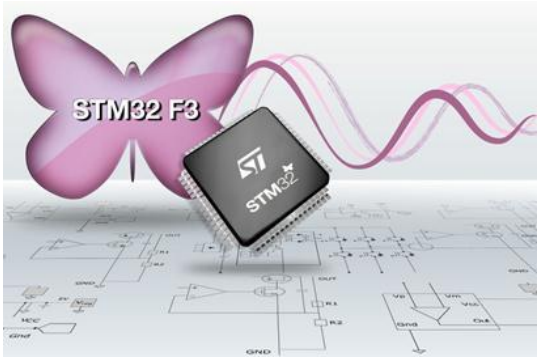

Figure 1: STM32F3 series

STM32F3 and FOC advantages

Field Oriented Control (FOC) is the mathematical technique that optimizes many aspects of Variable Speed Drives of three-phase motors: the finest electromagnetic torque response as in DC motors during transients, the best energy-efficiency, and silent operations due to smooth torque production and sinusoidal current waveforms.

Basic hardware requirements are a microcontroller, a 3 phase inverter, a means to measure phase currents (shunt resistors, insulated current transducers) and rotor angle (encoder, Hall effect sensor, resolver, an algorithm). Applications range from factory automation (robots, PLC, CNC) to home appliances (washing machines, air conditioners) to industrial (pumps, fans) and many more (medical and fitness equipment, for instance) with – of course – great shifts of power size.

ST's STM32F30 microcontroller has been conceived to become the "FOC master", focusing the established experience of STM32 families in the Motor Control arena; each feature performs at the utmost: the Cortex-M4 core with Floating Point Unit, Core-Coupled Memory (CCM) RAM, embedded fast analog, and improved digital peripherals.

Floating Point Unit (FPU)

The single precision floating point unit, IEEE 754 compliant, is a key asset for fast development of innovative applications: in fact, integer or fixed point numbers require slow and careful design that often discourages engineers to bring to light new feasible concepts, to the point that even small modifications of existing designs are sometimes considered risky tasks – and justly so.

On the other hand, working with FPU reassures programmers: hurdles can be overcome with a more relaxed use of math; modifications – and hence prototyping and testing - are fast, the result being that the task is implemented to schedule. In addition, the ready-to-use ARM CMSIS DSP software library provides a suite of common signal processing functions, among them digital filters (IIR, FIR, LMS, convolution), transformations, and complex math.

Furthermore, the FPU unit enables an easy exploitation of tools for automatic generation of embedded code, such as Mathworks' "Embedded Coder". Here, the experienced motor control engineer might mumble, 'This is out of my sphere,' where peripherals are configured and synchronized at the bit level as intricate as a watch collector's timepieces, and we definitely agree. Instead, 'Embedded Coder' is a translation of algorithm blocks, whose boundaries - in terms of input/output variables - are traced so that the code generated (and optimized for F3's core) plugs inside a "manually designed" firmware frame. The consequences of this approach are clear: algorithms can be deeply tested in worst-case conditions in Processor-In-the-Loop (PIL) simulations, so that firmware reliability is greatly enhanced and time to market accelerated.

CCM-RAM and Dual FOC

The STM32F30x architecture features the ultimate resource for achieving full computational power out of its Cortex-M4 core, regardless of both wait states (for flash memory to get along with CPU frequency) or task repetition frequency (for relevant code to be statistically resident inside buffer accelerators). An 8 Kbyte Core-Coupled Memory (CCM) RAM is linked to the Cortex-M4 Instruction bus (see figure1): instructions placed in CCM area are fetched with no wait states, while data is accessed on the separate D-bus from SRAM, therefore the processor's three stage pipelines can run at its full capability.

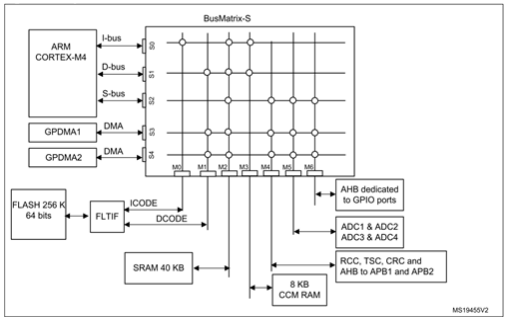

Figure 2: system architecture

Eight Kbyte has been estimated to be an optimum tailoring to hold – for instance - the computation intensive sections of the STM32F3 MC library, such as the sensorless algorithm, currents measurement, Space Vector Modulation, PI(D) regulators, transformations and filtering.

Selective placement of functions in the CCM area is easily achieved thanks to #pragma directives or __attribute keywords made available by toolchains such as EWARM, MDK-ARM and GNU.

Preliminary tests done with the upcoming version of the STM32 PMSM FOC SDK v3.4 show the FOC execution duration – comprising the sensorless algorithm – shrinks by 29% on the same machine running at 72MHz.

Therefore, dual and simultaneous FOC on the STM32F30x is absolutely viable for the richness of peripherals (as shown in the introduction), the patented HW acceleration, the affordable CPU load, and the long standing firmware implementation of STM32 PMSM FOC SDK.

Embedded and improved peripherals

The new STM32F30x microcontroller family has been conceived and designed to take advantage of more than ten year of experience and expertise in the motor control field, expanding the, already strong offering of products dedicated to this specific application.

On top of the computational power achieved by the improved core, new analog peripherals have been added to reduce the workload of the CPU and to reduce the number of external components required by the application.

Into the product have been embedded four PGA (programmable gain amplifiers) directly connected with the analog to digital converters. These amplifiers have been designed with bandwidth and slew rate characteristics, respectively 8.2 MHz and 4.7V/µs typical, properly sized to exploit the "state of the art" motor current sensing techniques. If this kind of flexibility is required by the control technique, the PGA gains can be changed internally by the software among four different values x2-x16, or it can be fixed with an external network.

Up to seven fast comparators, up to 90ns of propagation delay typical, have been embedded in the microcontroller. Each one can be directly connected to one of the two emergency inputs of each PWM peripherals present in the product to manage safety features such as over-current and over-voltage faults. Managing those faults usually represents a critical aspect of motor drives.

The advanced timer peripherals used to generate the six PWM outputs (two of them are present in the STM32F30x version) have been improved with two extra channels that, in combination with the ability to trigger the analog to digital conversions, allow the performance of complex functions without the intervention of the core, lowering the total CPU workload.

Finally the analog to digital peripherals (up to four have been embedded in the microcontroller) have been improved with an ST patented architecture that makes use of a "queue of synchronized injected conversions" to realize a hardware acceleration of the motor current measurements, specifically design for the dual drive.

Dual motor control board, based on STM32F303 MCU and L6230 monolithic motor driver

STMicroelectronics' Motor Control Ecosystem offers a lot of solutions power and control stages addressing diverse power rates, diverse motors. The upcoming STEVAL-IHM042V1 is a complete drive that shows how STM32F303 performs a dual FOC motor drive in combination with two DMOS fully integrated L6230 3-phase motor driver ICs with 2.8 A output peak current.

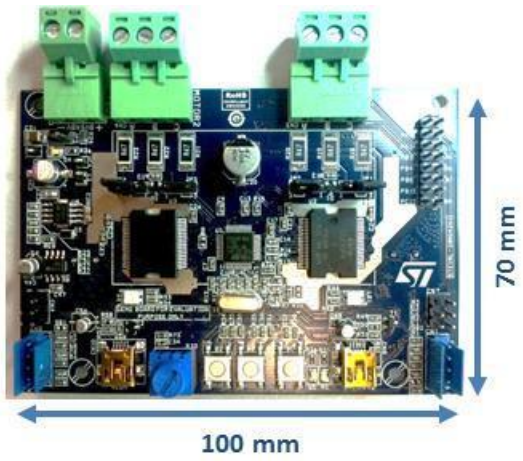

Figure 4: STEVAL-IHM042V1, Dual motor control board

Main features:

- Simultaneous field oriented control (FOC) of two PMSM motors
- On board ST Link in-circuit debugger and programmer with SWD support (based on STM32F103)
- On Board-to-serial interface for real time control via ST MC Workbench
- 3-shunts or 1-shunt current sensing topology for each drive easily selectable through jumpers
- DC voltage range from 8 V to 48 V (extendable up to 52 V)
- Maximum load current of 1.4 Arms (2.8 A peak) for each output
- Integrated DC-DC regulator (3.3 V)
- Two Hall sensors/encoders inputs

STMicroelectronics' products used in the STEVAL-IHM042V1 are reported in the Table 1.

Table 1: STEVAL-IHM042V1 Key products.

2 x L6230	Monolithic power stage in PowerSO package
STM32F303CCT6	32-bit Microcontroller
ST1S14PHR	DC DC switching conveter
LD1117D33TR	LDO Voltage Regulator

CONCLUSIONS

In this article news about the STMicroelectronics' Motor Control Ecosystem is presented. Every year ST enriches the Ecosystem with new technologies and products, and adds value through a system approach to meet new trends in motion control in terms of efficiency, integration, precision, and reliability.