A BLDC Controller Based on Dedicated System-In-Package

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Abstract: - In this paper is presented the design and test of a controller based on a System-In-Package for a brushless DC motor used on a two wheel vehicle. This System-In-Package is STSPIN32F0 produced by ST Microelectronic announced in November 2016. The vehicle is an electric scooter for urban mobility equipped with a 250W BLDC motor powered by a 36V lithium-polymer battery. The goal is to evaluate this dedicated microcontroller for that type of application. The paper describes the microcontroller and the design of software package needed to drive the BLDC motor.

Key-Words: BLDC, microcontroller, Hall-effect sensors, e-vehicle.

1 Introduction

The brushless DC motors are similar with conventional DC motor, the differences between them being that the mechanical commutation is replaced by an electronically one. These motors are widely used in many applications from toys, air conditioning devices to electric vehicle. That fact increases the need for design of efficient control architectures and strategies for these noiseless motors.

The electronic controller requires rotor position information for commutation of currents in the stator windings. The rotor position can be sensed using embedded Hall Effect sensors or by back-EMF.

Because the reading of back-EMF increases the complexity of electronics and of algorithm, the Hall Effect sensors are preferred.

In present paper is considered a 250W BLDC motor with three phases in wye connection powered by a 36V lithium-polymer battery. The rotor position is provided by three Hall sensors disposed at 120 electrical degrees.

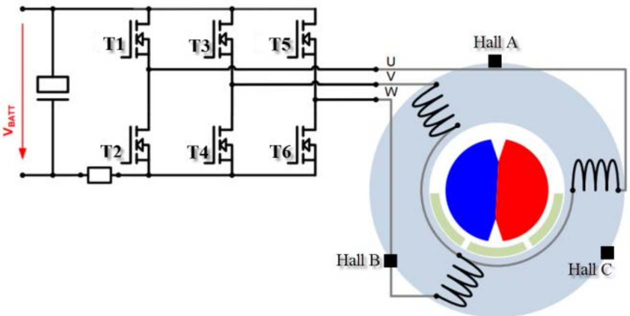


Fig.1 Three Phase Hex-bridge Inverter

The Hall sensors states and the corresponding drive signal are presented in figure 2.

HALL				REAR						FRONT					
A U	B V	C W		T1 U+	T2 U-	T3 V+	T4 V-	T5 W+	T6 W-	T1 U+	T2 U-	T3 V+	T4 V-	T5 W+	T6 W-
1	1	0	3	0	0	1	0	0	1	0	0	0	1	1	0
0	1	0	2	0	1	1	0	0	0	1	0	0	1	0	0
0	1	1	6	0	1	0	0	1	0	1	0	0	0	0	1
0	0	1	4	0	0	0	1	1	0	0	0	1	0	0	1
1	0	1	5	1	0	0	1	0	0	0	1	1	0	0	0
1	0	0	1	1	0	0	0	0	1	0	1	0	0	1	0

Fig.2 Hall Sensor Signals and Drive Signals

2 Hardware description

To control the BLDC motor was chosen a microcontroller produced by ST Microelectronics. This microcontroller is STSPIN32F0 which is a System-In-Package providing an integrated solution suitable for driving three-phase BLDC motors using different driving modes.

STSPIN32F0 embeds a triple half-bridge gate driver able to drive power MOSFETs or IGBTs with a current capability of 600 mA.

The high- and low-side switches of same half-bridge cannot be simultaneously driven high thanks to a very useful integrated interlocking function.

An internal DC/DC buck converter provides the 3.3V voltage suitable to power both the MCU and other external components. For gate drivers

STSPIN32F0 provides the supply voltage realized with an internal LDO linear regulator.
The integrated operational amplifiers are available for the signal conditioning of the analog Hall-effect sensors and the shunt resistor signal, but also permits sensor less control.
To perform the overcurrent protection this microcontroller integrates a comparator with a programmable threshold.

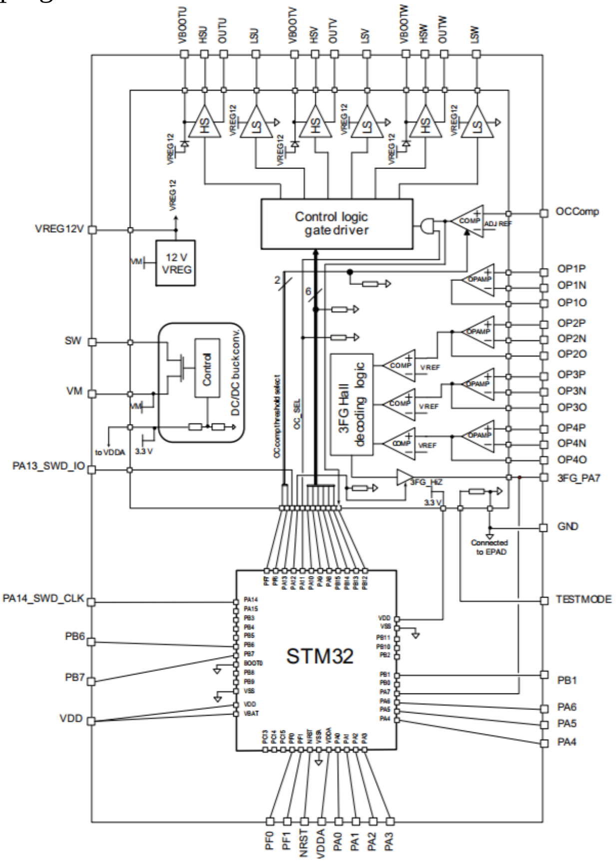


Fig.3 STSPIN32F0 System-In-Package block diagram

STSPIN32F0 integrates STM32F031C6 controller. This incorporates the high-performance ARM Cortex M0 32-bit RISC core operating at up to 48 MHz frequency making possible the complex control algorithm implementation.
The evaluation of STSPIN32F0 was made on STEVAL-SPIN3201 board provided by ST Microelectronics.
That board provides a complete 3-shunt for field orientation control solution composed by an STSPIN32F0 and a triple half-bridge power stage. Also, there are available a port for Hall Effect sensors, two user buttons, two LEDs and a potentiometer connected on an analog-to-digital input.
Also, the board has an embedded in-circuit debugger and programmer ST-LINK/V2 which together with the STM Studio software helps debug and diagnose STM32 applications while they are running by reading and displaying their variables in real-time.

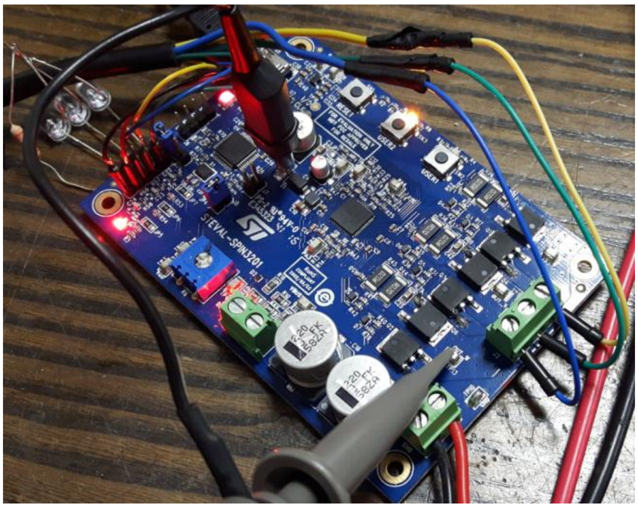


Fig.4 The STSPIN32F0 evaluation board

The STEVAL-SPIN3201 board requires a power supply voltage from 8 V to 45 V.

3 The software implementation

The software package for STSPIN32F0 implements the control algorithm for a BLDC motor used on a two wheels vehicle. It includes two routines: one for initialization and one that implements the main program.
The initialization is very important otherwise the MCU does not start. For this sequence was used STM32Cube MX software from ST.

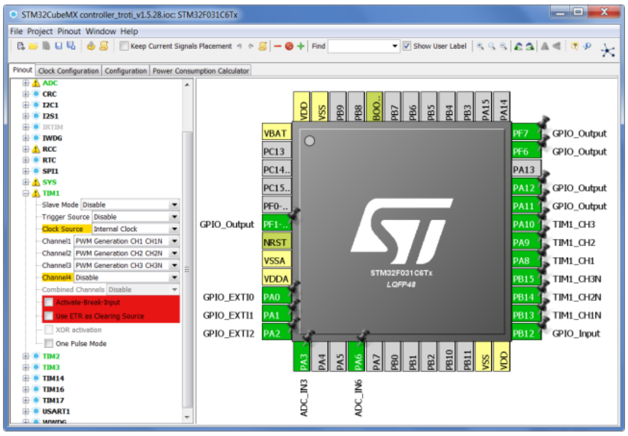


Fig.5 STM32Cube MX

This program makes developers' lives easier by reducing development effort.
In this stage, it must be initialized the GPIO, Analog-to-Digital converters, the timers used to

generate a 15 kHz signal applied to MOSFET's block.
After that, the initialization continues with the settings of the pins PF6 and PF7. These outputs sets the overcurrent protection value and their status was selected according datasheet for a current of 20A.
Also, the pin OC_SEL (PA11) will be set to 1 and 3FG_HIZ (PA12) to 0. Now, the core of STSPIN32F0 is running.
The main program reads two analogic inputs for acceleration and electric break, the information's from Hall sensors and generates the PWM signal for power MOSFETs.
All Hall sensors are read on three external interrupts on both edges. Every time an interrupt routine is launched. In that routine the Hall Effect sensors inside the motor are evaluated and are generated the next drive signals for MOSFET's.

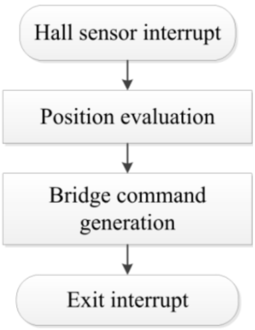


Fig.6 Interrupt routine

At every 20ms a timer generates a software interrupt. In that interrupt the microcontroller evaluates three ADC channels: the acceleration and brake inputs as well as the value of current. All these information are used in control algorithm to decide the PWM duty cycle.

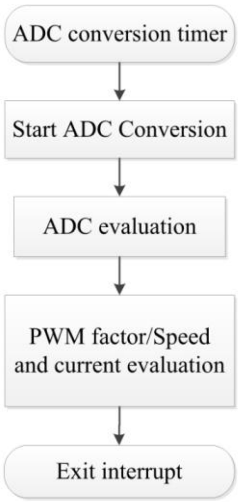


Fig.7 Software interrupt

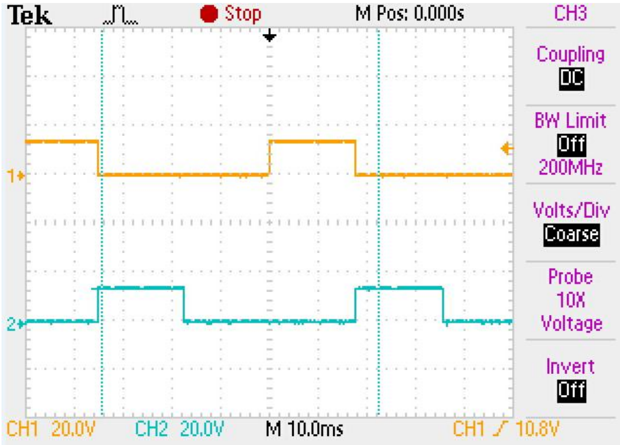
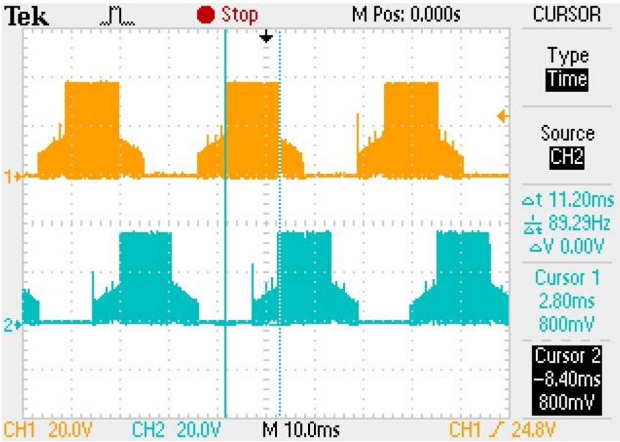


Fig.8 The signal for two MOSFETs from negative side

If brake is applied the controller use two algorithms: a regenerative brake in which the kinetic energy is recovered as electric power into bateries, and a dynamic brake implemented by disconnecting the power supply to windings and short circuiting them using the MOSFET's from low side o bridge.



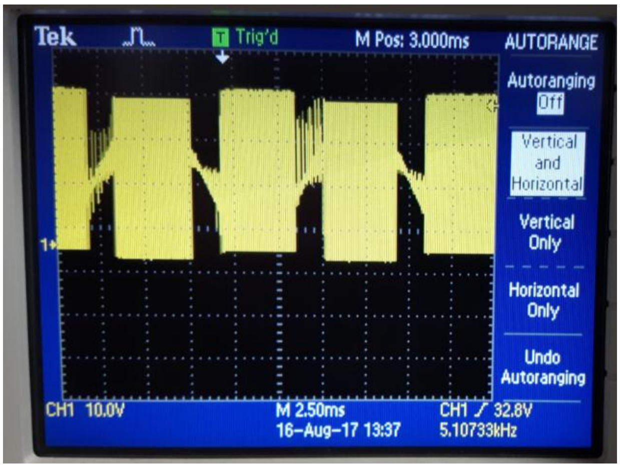


Fig.9 Terminal voltages

The system was tested on a two wheel vehicle driven by a person with 90kg weight with a current limitation at 16A by software and a the top speed around 32km/h. The microcontroller was very fast and stable.

Fig.10 The E-Twow scooter

All software were developed in C language using System Workbench for STM32 IDE using HAL drivers.

4 Conclusions

In this paper, was presented a comprehensive guide of design of a BLDC drive system using STSPIN32F0 product. The software tools made available by ST Microelectronic together with this System-In-Package offers the conditions to create a very good controller for BLDC motors.

The results have been obtained for various load conditions. In all situations the designed system has behaved very well with great performance. In future, it is desired the development of a controller based on this system-in-package by implementing software algorithms that lead to outstanding dynamic performance with increased autonomy.

Acknowledgement

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