

STEVAL-SPIN3201: advanced BLDC controller with embedded STM32 MCU evaluation board

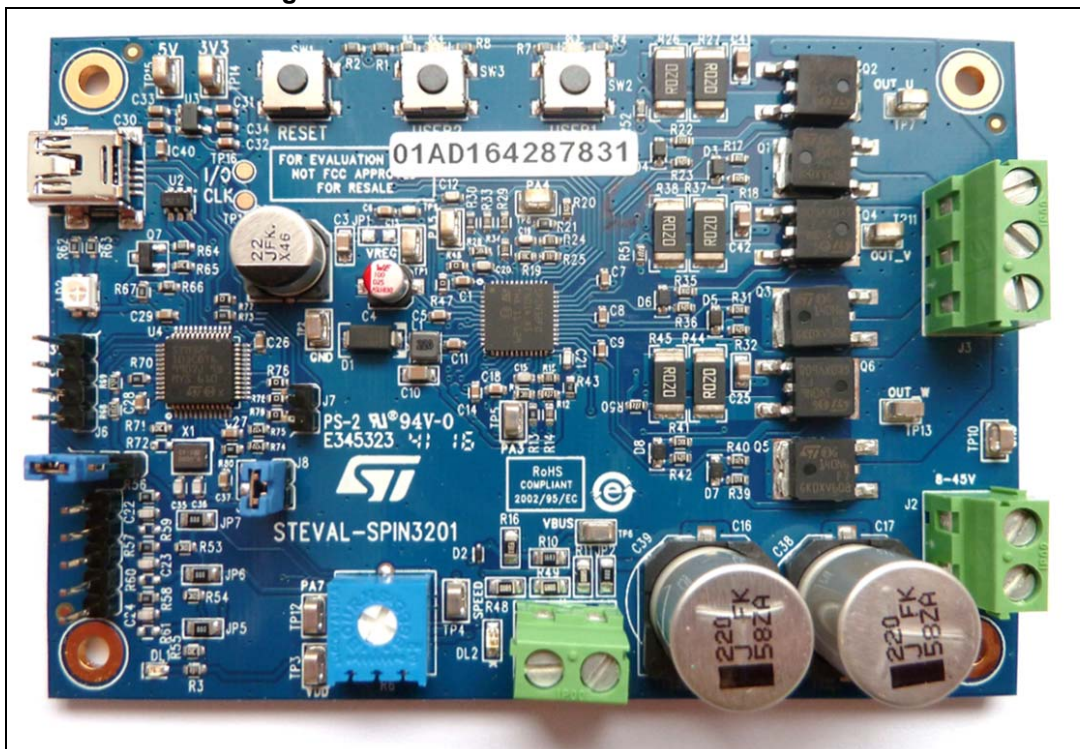
Introduction

The STEVAL-SPIN3201 board is a 3-phase brushless DC motor driver board based on the STSPIN32F0, a 3-phase controller with an integrated STM32 MCU, and implements 3-shunt resistors as current reading topology.

It provides an easy-to-use solution for the evaluation of the device in different applications such as the home appliance, fans, drones and power tools.

The board is designed for the sensed or sensorless field-oriented control algorithm with 3-shunt sensing.

Figure 1. STEVAL-SPIN3201 evaluation board



Contents

- 1 Hardware and software requirements 3**
- 2 Getting started 3**
- 3 Hardware description and configuration 4**
- 4 Circuit description 6**
 - 4.1 Hall/encoder motor speed sensor 6
 - 4.2 Current sensing 7
 - 4.3 Overcurrent detection 8
 - 4.4 Bus voltage circuit 9
 - 4.5 Hardware user interface 9
 - 4.6 Debug 9
- 5 Revision history 11**

1 Hardware and software requirements

Using the STEVAL-SPIN3201 evaluation board requires the following software and hardware:

- A Windows® PC (XP, Vista 7 , Windows 8, Windows 10) to install the software package
- A mini-B USB cable to connect the STEVAL-SPIN3201 board to the PC
- The STSW-SPIN3201 firmware example or the STM32 PMSM FOC Software Development Kit (both available on www.st.com)
- A 3-phase brushless DC motor with compatible voltage and current ratings
- An external DC power supply.

2 Getting started

The maximum ratings of the board are the following:

- Power stage supply voltage (VS) from 8 V to 45 V
- Motor phase current up to 15 A_{rms}.

To start your project with the board:

1. Check the jumper position according to the target configuration (see [Section 4.3 on page 8](#)).
2. Connect the motor to the connector J3 taking care of the motor phases sequence.
3. Supply the board through the input 1 and 2 of the connector J2. The DL1 (red) LED will turn on.
4. Develop your application using the code examples provided or the STM32 FOC MC Library. The STSW-SPIN3201 firmware example also provides pre-compiled binaries that are ready to be used. Please refer to the UM2152 user manual for details.

3 Hardware description and configuration

Figure 2 shows the position of the main components and connectors on the board.

Figure 2. Main components and connectors positions

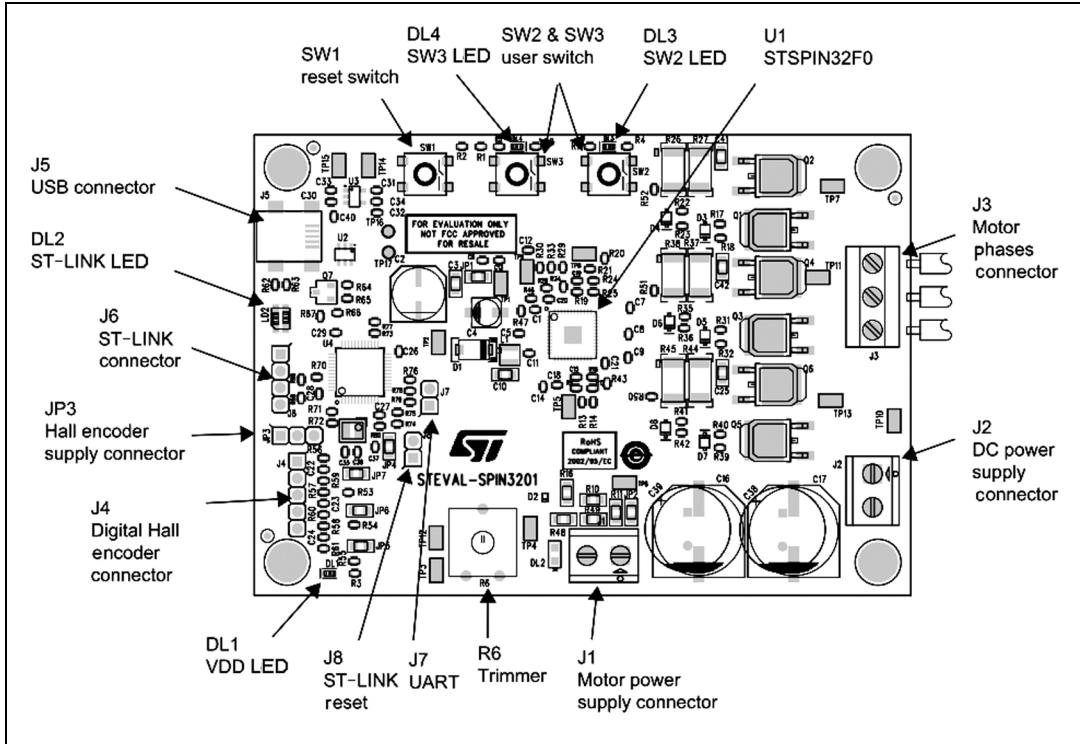


Table 1 provides the detailed pinout of the connectors.

Table 1. Hardware setting jumpers

Jumper	Permitted configurations	Default condition
JP1	Selection of VREG connected to V motor	OPEN
JP2	Selection motor power supply connected to DC power supply	CLOSED
JP3	Selection Hall encoder supply to USB (1) / VDD (3) power supply	1 - 2 CLOSED
JP4	Selection reset of ST-LINK (U4)	OPEN
JP5	Selection PA2 connected to Hall 3	CLOSED
JP6	Selection PA1 connected to Hall 2	CLOSED
JP7	Selection PA0 connected to Hall 1	CLOSED

Table 2. Other connectors, jumper and test points description

Name	Pin	Label	Description
J1	1 - 2	J1	Motor power supply
J2	1 - 2	J2	Device main power supply (VM)
J3	1 - 2 - 3	U, V, W	3-phase BLDC motor phases connection
J4	1 - 2 - 3	J4	Hall/encoder sensors connector
	4 - 5	J4	Hall sensors/encoder supply
J5	-	J5	USB input ST-LINK
J6	1	3V3	ST-LINK power supply
	2	CLK	SWCLK of ST-LINK
	3	GND	GND
	4	DIO	SWDIO of ST-LINK
J7	1 - 2	J7	UART
J8	1 - 2	J8	ST-LINK reset
TP1	-	VREG	12 V voltage regulator output
TP2	-	GND	GND
TP3	-	VDD	VDD
TP4	-	SPEED	Speed potentiometer output
TP5	-	PA3	PA3 GPIO (output op amp sense 1)
TP6	-	VBUS	VBus feedback
TP7	-	OUT_U	Output U
TP8	-	PA4	PA4 GPIO (output op amp sense 2)
TP9	-	PA5	PA5 GPIO (output op amp sense 3)
TP10	-	GND	GND
TP11	-	OUT_V	Output V
TP12	-	PA7	PA7_3FG
TP13	-	OUT_W	Output W
TP14	-	3V3	3V3 ST-LINK
TP15	-	5V	USB voltage
TP16	-	I/O	SWD_IO
TP17	-	CLK	SWD_CLK

4 Circuit description

The STEVAL-SPIN3201 provides a complete 3-shunt FOC solution composed by an STSPIN32F0 - advanced BLDC controller with an embedded STM32 MCU - and a triple half-bridge power stage with the NMOS STD140N6F7.

The STSPIN32F0 autonomously generates all the required supply voltages: the internal DC/DC buck converter provides 3V3 and an internal linear regulator provides 12 V for the gate drivers.

The current feedback signal conditioning is performed through three of the operational amplifiers embedded into the device and an internal comparator performs overcurrent protection from shunt resistors.

Two user buttons, two LEDs and a trimmer are available to implement simple user interfaces (e.g. starting/stopping the motor and set target speed).

The STEVAL-SPIN3201 board supports the quadrature encoder and digital Hall sensors as motor position feedback.

The board includes an ST-LINK-V2 allowing the user to debug and download firmware without any extra hardware tool.

4.1 Hall/encoder motor speed sensor

The STEVAL-SPIN3201 evaluation board supports the digital Hall and quadrature encoder sensors as motor position feedback.

The sensors can be connected to the STSPIN32F0 through the J4 connector as listed in [Table 3](#).

Table 3. Hall/encoder connector (J4)

Name	Pin	Description
Hall1/A+	1	Hall sensor 1/encoder out A+
Hall2/B+	2	Hall sensor 2/encoder out B+
Hall3/Z+	3	Hall sensor 3/encoder zero feedback
VDD sensor	4	Sensor supply voltage
GND	5	Ground

A protection series resistor of 1 k Ω is mounted in series with sensor outputs.

For sensors requiring an external pull-up, three 10 k Ω resistors are already mounted on the output lines and connected to the VDD voltage. On the same lines, a footprint for pull-down resistors is also available.

The jumper JP3 selects the power supply for the sensor supply voltage:

- Jumper between the pin 1 - pin 2: Hall sensors powered by VUSB (5 V)
- Jumper between the pin 1 - pin 2: Hall sensors powered by VDD (3.3 V)

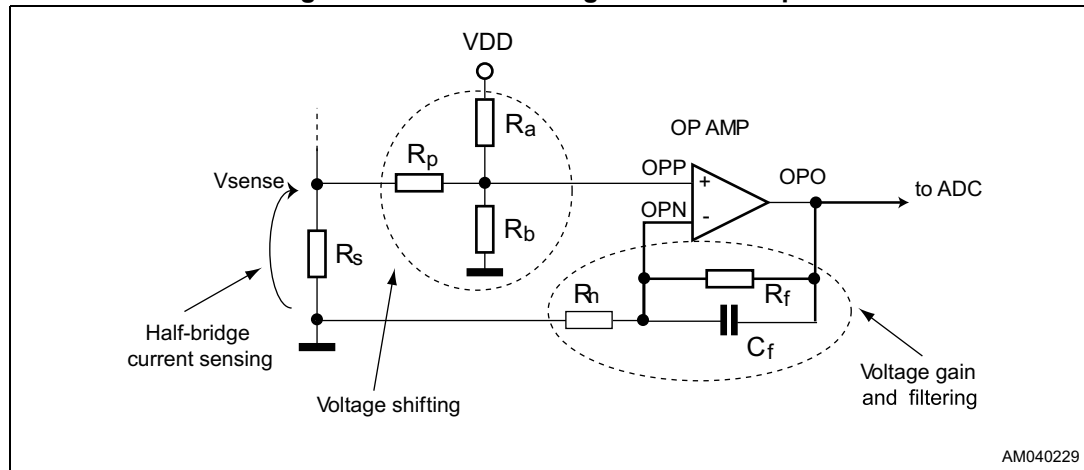
The user can disconnect sensor outputs from the MCU GPIO opening jumpers JP5, JP6 and JP7.

4.2 Current sensing

In the STEVAL-SPIN3201 board the current sensing signal conditioning is performed through three of the operational amplifiers embedded into the STSPIN32F0 device.

In a typical FOC application the currents in the three half-bridges are sensed using a shunt resistor on the source of each low side power switch. The sense voltage signals are provided to an analog-to-digital converter in order to perform the matrix calculation related to a certain control technique. Those sense signals are usually shifted and amplified by dedicated op amps in order to exploit the full range of the ADC (refer to [Figure 3](#)).

Figure 3. Current sensing scheme example



The sense signals have to be shifted and centered on $V_{DD}/2$ voltage (about 1.65 V) and amplified with a gain which provides the matching between the maximum value of the sensed signal and the full scale range of the ADC.

The voltage shifting stage introduces attenuation ($1/G_p$) of the feedback signal which, together with the gain of the non-inverting configuration (G_n , fixed by R_n and R_f), contributes to the overall gain (G). As mentioned above, the goal is to establish the overall amplification network gain (G) so that the voltage on the shunt resistor corresponding to the maximum motor allowed current (I_{Smax} peak value of motor rated current) fits the range of voltages readable by the ADC.

Equation 1

$$G = G_p \times G_n = \frac{(R_a // R_b)}{R_p + (R_a // R_b)} \times \left(1 + \frac{R_f}{R_n}\right)$$

Note that, once G is fixed, it is better to compose it by lowering the initial attenuation $1/G_p$ as much as possible and, therefore the gain G_n . This is important not only to maximize the signal by the noise ratio but also to reduce the effect of the op amp intrinsic offset on the output (proportional to G_n).

Equation 2

$$V_{OPout,poi} = \frac{(R_p // R_b)}{R_a + (R_p // R_b)} \times \left(1 + \frac{R_f}{R_n}\right) \times V_{DD}$$

The gain and the polarization voltage ($V_{OPout,poi}$) determine the operative range of the current sensing circuitry:

Equation 3

$$\begin{cases} I_{S-} = \frac{V_{OPout,poi}}{R_S \cdot G} \\ I_{S+} = \frac{V_{DD} - V_{OPout,poi}}{R_S \cdot G} \end{cases}$$

where I_{S-} is the maximum sourced current and I_{S+} is the maximum sinked current that can be sensed by the circuitry.

Table 4. STEVAL-SPIN3201 op amps polarization network

Parameter	Part reference	Rev. 1	Rev. 3
R_p	R ₁₄ , R ₂₄ , R ₃₃	560 Ω	1.78 k Ω
R_a	R ₁₂ , R ₂₀ , R ₂₉	8.2 k Ω	27.4 k Ω
R_b	R ₁₅ , R ₂₅ , R ₃₄	560 Ω	27.4 k Ω
R_n	R ₁₃ , R ₂₁ , R ₃₀	1 k Ω	1.78 k Ω
R_f	R ₉ , R ₁₉ , R ₂₈	15 k Ω	13.7 k Ω
C_f	C ₁₅ , C ₁₉ , C ₂₀	100 pF	N. M.
G	-	7.74	7.70
$V_{OPout,poi}$	-	1.74 V	1.65 V

4.3 Overcurrent detection

The STEVAL-SPIN3201 evaluation board implements overcurrent protection based on the STSPIN32F0 integrated OC comparator. Shunt resistors measure the load current of each phase. The resistors R50, R51, and R52 bring the voltage signals associated to each load current to the OC_COMP pin. When the peak current flowing in one of the three phases exceeds the selected threshold, the integrated comparator is triggered and all the high side power switches are disabled. High side power switches are enabled again when the current falls below the threshold, thus implementing overcurrent protection. Current thresholds for the STEVAL-SPIN3201 evaluation board are listed in [Table 5](#).

Table 5. Overcurrent thresholds

PF6	PF7	Internal comp. threshold	OC threshold
0	1	100 mV	20 A
1	0	250 mV	65 A
1	1	500 mV	140 A

These thresholds can be modified changing the R43 bias resistor. It is recommended to choose R43 higher than 30 kΩ. In order to calculate the value of the R43 for a target current limit IOC, the following formula can be used:

Equation 4

$$R43 = \frac{V_{DD} \cdot 2.2k\Omega}{3 \cdot OC_{COMP_{th}} - I_{oc} \cdot 0.01\Omega} - \frac{2.2k\Omega}{3}$$

where $OC_{COMP_{th}}$ is the voltage threshold of the internal comparator (selected by the PF6 and PF7), and V_{DD} is the 3.3 V digital supply voltage provided by the internal DCDC buck converter.

Removing the R43, the current threshold formula is simplified as follows:

Equation 5

$$I_{oc} = \frac{3 \cdot OC_{COMP_{th}}}{0.01\Omega}$$

4.4 Bus voltage circuit

The STEVAL-SPIN3201 evaluation board provides the bus voltage sensing. This signal is set through a voltage divider from the motor supply voltage (VBUS) (R10 and R16), and sent to the PB1 GPIO (the channel 9 of the ADC) of the embedded MCU. The signal is also available on the TP6.

4.5 Hardware user interface

The board provides a hardware user interface as following:

- Potentiometer R6 setting, for example, the target speed
- Switch SW1 reset STSPIN32F0 MCU and ST-LINK V2
- Switch SW2: user button 1
- Switch SW3: user button 2
- LED DL3: user LED 1 (turned on when user 1 button is pressed too)
- LED DL4: user LED 2 (turned on when user 2 button is pressed too).

4.6 Debug

The STEVAL-SPIN3201 evaluation board embeds an ST-LINK/V2-1 debugger/programmer. The features supported on the ST-LINK are:

- USB software re-enumeration
- Virtual com port interface on USB connected to PB6/PB7 pins of the STSPIN32F0 (UART1)
- Mass storage interface on USB

The power supply for the ST-LINK is provided by the host PC through the USB cable connected to the J5.

The LED LD2 provides ST-LINK communication status information:

- Red LED flashing slowly: at power-on before USB initialization
- Red LED flashing quickly: following first correct communication between the PC and ST-LINK/V2-1 (enumeration)
- Red LED ON: initialization between the PC and ST-LINK/V2-1 is complete
- Green LED ON: successful target communication initialization
- Red/green LED flashing: during communication with target
- Green ON: communication finished and successful

The reset function is disconnected from the ST-LINK by removing the jumper J8.

5 Revision history

Table 6. Document revision history

Date	Revision	Changes
12-Dec-2016	1	Initial release.
23-Nov-2017	2	Added Section 4.2: Current sensing on page 7 . Minor modifications throughout document.
27-Feb-2018	3	Minor template correction.

IMPORTANT NOTICE – PLEASE READ CAREFULLY

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2018 STMicroelectronics – All rights reserved