UM2154 STEVAL-SPIN3201 Advanced BLDC Controller with Embedded STM32 MCU Evaluation Board User Manual

Home » ST » UM2154 STEVAL-SPIN3201 Advanced BLDC Controller with Embedded STM32 MCU Evaluation Board User Manual

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User manual

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

Contents hide

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 sensored or sensorless field-oriented control algorithm with 3-shunt sensing.

Figure 1. STEVE-SPIN3201 evaluation board

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 STM32 Motor Control Software Development Kit Rev Y (X-CUBE-MCSDK-Y)
- A 3-phase brushless DC motor with a compatible voltage and current ratings
- An external DC power supply.

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 Arms

To start your project with the board:

Step 1. Check the jumper position according to the target configuration **(see Section 4.3 Overcurrent detection**
Step 2. Connect the motor to the connector J3 taking care of the sequence of the motor phases.
Step 3. Supply the board through the input 1 and 2 of the connector J2. The DL1 (red) LED will turn on.
Step 4. Develop your application using the STM32 Motor Control Software Development Kit Rev Y **(X-CUBEMCSDK-Y).**

Hardware description and configuration

Figure 2. Main components and connectors' positions show the position of the main components and connectors on the board.
Figure 2. Main components and connectors positions

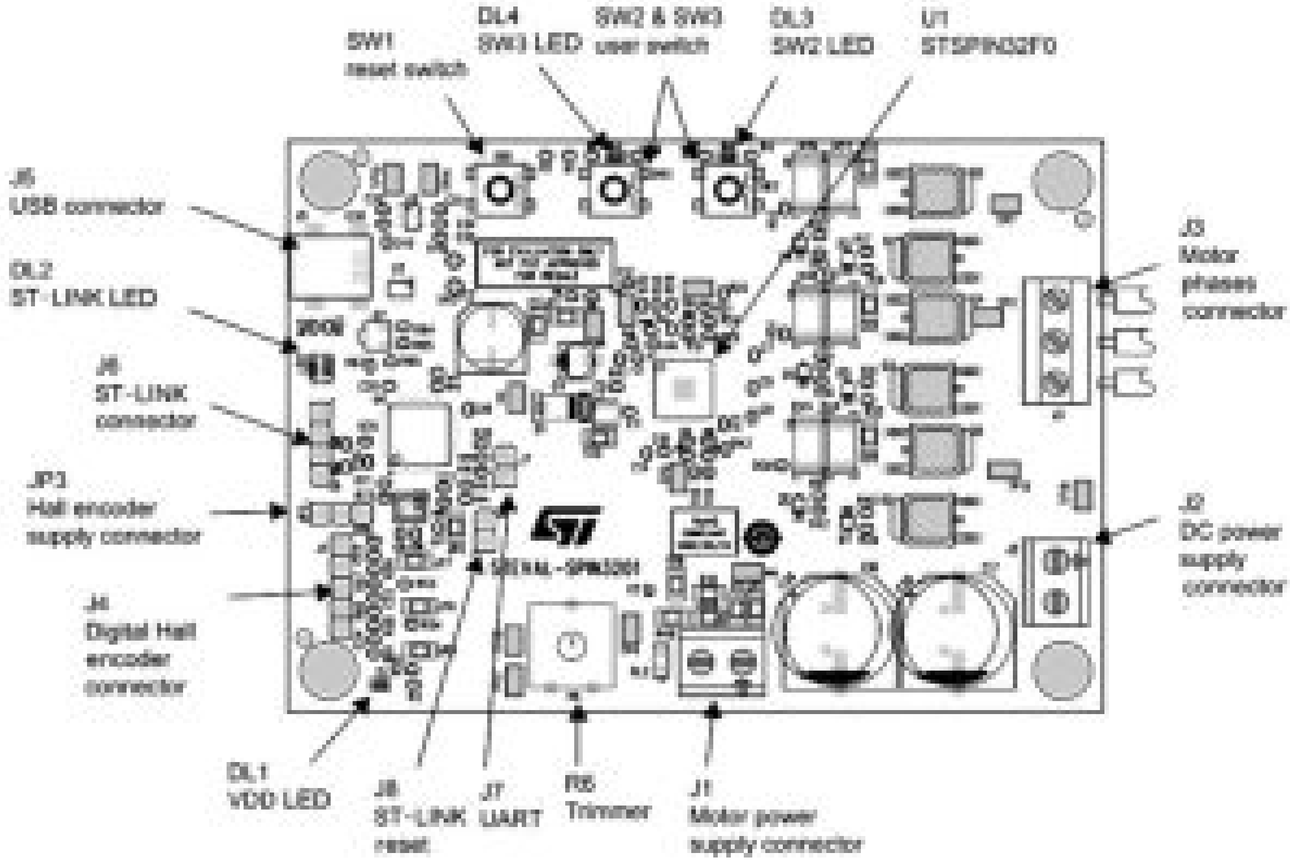


Table 1. Hardware setting jumpers provide the detailed pinout of the connectors.

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
	1	3V3	ST-LINK power supply

J6	2	CLK	SWCLK of ST-LINK
	3	GND	GND
	4	DIO	SWDIO of ST-LINK
J7	1 – 2	J7	CART
J8	1 – 2	J8	ST-LINK reset
TP1	–	GREG	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

Circuit description

The STEVAL-SPIN3201 provides a complete 3-shunt FOC solution composed of a 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 setting 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 is listed in

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 a series with sensor outputs.
For sensors requiring an external pull-up, three 10 kΩ 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.

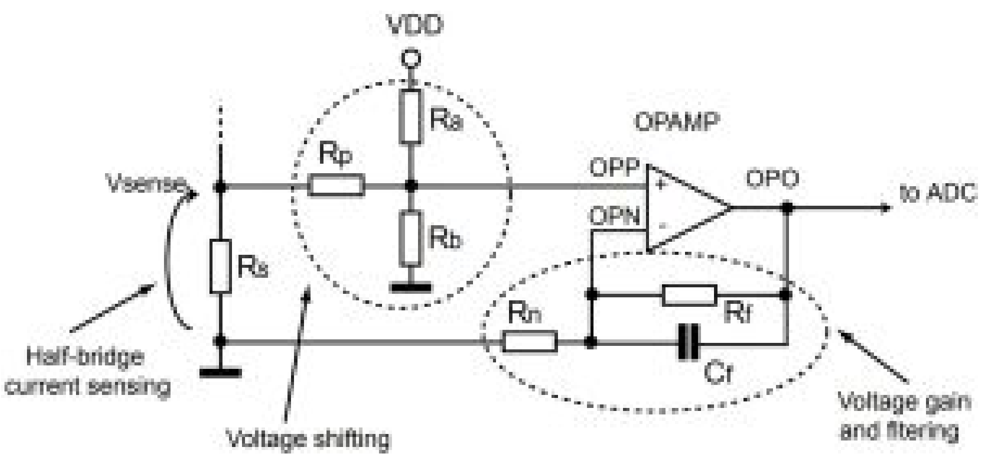
The jumper JP3 selects the power supply for the sensor supply voltage:

- 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. Current sensing scheme example).

Figure 3. Current sensing scheme example



The sense signals have to be shifted and centered on VDD/2 voltage (about 1.65 V) and amplified again 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/Gp) of the feedback signal which, together with the gain of the non-inverting configuration (Gn, fixed by Rn and Rf), contributes to the overall gain (G). As already mentioned, 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 (ISmax peak value of motor rated current) fits the range of voltages readable by the ADC.

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

Note that, once G is fixed, it is better to configure it by lowering the initial attenuation 1/Gp as much as possible and, therefore the gain Gn. 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 Gn).

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

The gain and the polarization voltage (VOPout, pol) determine the operative range of the current sensing circuitry:

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

Where:

- IS- = maximum sourced current
- IS+ = maximum sunk current that can be sensed by the circuitry.

Table 4. STEVE-SPIN3201 op-amps polarization network

Parameter	Part reference	Rev. 1	Rev. 3
Rp	R14, R24, R33	560 Ω	1.78 kΩ
Ra	R12, R20, R29	8.2 kΩ	27.4 kΩ
Rb	R15, R25, R34	560 Ω	27.4 kΩ
Rn	R13, R21, R30	1 kΩ	1.78 kΩ
Rf	R9, R19, R28	15 kΩ	13.7 kΩ
Cf	C15, C19, C20	100 pF	N. M.
G	–	7.74	7.70
VOPout, pol	–	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 with 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. 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 by 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:

$$R_{43} = \frac{V_{DD} \cdot 2.2k\Omega}{3 \cdot OC\_COMP_{th} - I_{OC} \cdot 0.01\Omega} - \frac{2.2k\Omega}{3}$$

where OC_COMPth is the voltage threshold of the internal comparator (selected by the PF6 and PF7), and VDD 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:

$$I_{OC} = \frac{3 \cdot OC\_COMP_{th}}{0.01\Omega}$$

4.4 Bus voltage circuit

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

4.5 Hardware user interface

The board includes the following hardware user interface items:

- Potentiometer R6: sets the target speed, for example
- Switch SW1: resets STSPIN32F0 MCU and ST-LINK V2
- Switch SW2: user button 1
- Switch SW3: user button 2
- LED DL3: user LED 1 (also turns on when user 1 button is pressed)
- LED DL4: user LED 2 (also turns on when user 2 buttons are pressed)

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 the target
- Green ON: communication finished and successful
  The reset function is disconnected from the ST-LINK by removing the jumper J8.

Revision history

Table 6. Document revision history

Date	Revision	Changes
12-Dec-20161	1	Initial release.
23-Nov-2017	2	Added Section 4.2: Current sensing on page 7.
27-Feb-2018	3	Minor modifications throughout the document.
18-Aug-2021	4	Minor template correction.

Documents / Resources

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UM2154, STEVAL-SPIN3201 Advanced BLDC Controller with Embedded STM32 MCU Evaluation Board