EVSPIN32G06Q2S1: 3-phase inverter based on STSPIN32G0602

Introduction

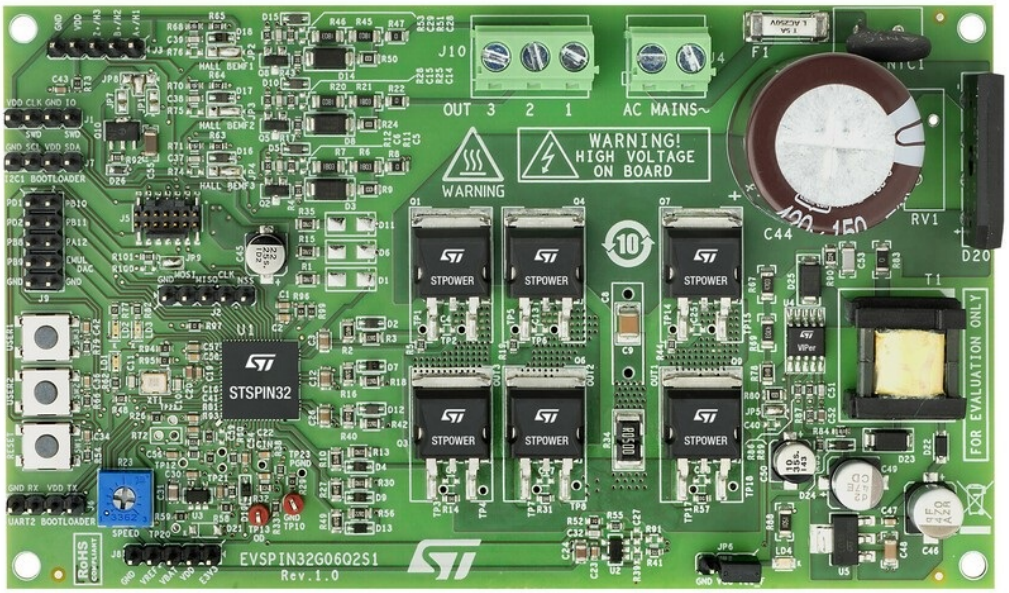
The EVSPIN32G06Q2S1 board is a three-phase complete inverter based on the STSPIN32G0602Q controller, which embeds a three-phase 600 V gate driver and a Cortex®-M0+ STM32 MCU. The power stage features STGB20M65DF2 IGBTs, but can be populated with any IGBT or power MOSFET in D^{2}PAK or PowerFLAT 8x8 HV package. The board has a single-shunt sensing topology, and both sensored/sensorless FOC and 6-step control algorithms can be implemented. This allows driving permanent magnet synchronous motors (PMSMs) and brushless DC (BLDC) motors.

It provides an easy-to-use solution for the evaluation of the device in different applications such as refrigerator compressors, dishwasher pumps, fans, and industrial appliances.

The evaluation board is compatible with a wide range of input voltages and includes a power supply stage with the VIPER06XS in flyback configuration to generate +15 V and +3.3 V supply voltages required by the application.

Debug and configuration of the FW can be performed with standard STM32 tools through the STLINK-V3SET debugger/ programmer. SWD and UART TX/RX connectors are also available.

Figure 1. EVSPIN32G06Q2S1 evaluation board



1 Main features

The EVSPIN32G06Q2S1 has the following features:

- Input voltage from 35 V_{AC} (50 V_{DC}) to 280 V_{AC} (400 V_{DC})
- Suitable for ~300 W applications, 1.2 A_{RMS} phase current
- STGB20M65DF2 IGBTs power stage featuring:
  - $V_{(BR)CES}$ = 650 V
  - $V_{CE(sat)}$ = 1.55 V @ I_C = 20 A
- Overcurrent threshold is set to 8.3 A_{peak} (value configurable by the user)
- Dual footprint for IGBT/MOSFET packages
  - D^2PAK or PowerFLAT 8x8 HV
- Single-shunt current sensing, suitable for:
  - Sensored or sensorless 6-step algorithm
  - Sensored or sensorless single-shunt vector (FOC) algorithm
- Smart shutdown overcurrent protection
- Digital Hall sensors and encoder input
- Bus voltage sensing
- 15 V VCC and 3.3 V VDD supplies
- External connection through STLINK-V3SET
- Easy user interface with buttons and trimmer
- RoHS compliant

1.1 Target applications

- Residential and industrial refrigerator compressors
- Industrial drives, pumps, and fans
- Air conditioning compressors and fans
- Corded power tools, garden tools
- Home appliances
- Industrial automation

2 Safety and operating instructions

2.1 General terms

Warning: *During assembly, testing, and operation, the evaluation board poses several inherent hazards, including bare wires, moving or rotating parts, and hot surfaces.*

Danger: *There is a danger of serious personal injury, property damage, or death due to electrical shock and burn hazards if the kit or components are improperly used or installed incorrectly.*

Attention: *The kit is not electrically isolated from the high-voltage supply AC/DC input. The evaluation board is directly linked to the mains voltage. No insulation is ensured between the accessible parts and the high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the demo, it must be isolated from the AC line. This prevents shock from occurring as a result of touching any single point in the circuit, but does NOT prevent shock when touching two or more points in the circuit.*

Important: *All operations involving transportation, installation and use, and maintenance must be performed by skilled technical personnel able to understand and implement national accident prevention regulations. For the purposes of these basic safety instructions, “skilled technical personnel” are suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.*

2.2 Intended use of evaluation board

The evaluation board is designed for demonstration purposes only, and must not be used for electrical installations or machinery. Technical data and information concerning the power supply conditions are detailed in the documentation and should be strictly observed.

2.3 Installing the evaluation board

- The installation and cooling of the evaluation board must be in accordance with the specifications and target application.
- The motor drive converters must be protected against excessive strain. In particular, components should not be bent nor should isolating distances be altered during transportation or handling.
- No contact must be made with other electronic components and contacts.
- The board contains electrostatically sensitive components that are prone to damage if used incorrectly. Do not mechanically damage or destroy the electrical components (potential health risks).

2.4 Operating the evaluation board

To properly operate the board, follow these safety rules:

1. Work area safety:
   - The work area must be clean and tidy.
   - Do not work alone when boards are energized.
   - Protect against inadvertent access to the area where the board is energized using suitable barriers and signs.
   - A system architecture that supplies power to the evaluation board must be equipped with additional control and protective devices in accordance with the applicable safety requirements (i.e., compliance with technical equipment and accident prevention rules).
   - Use a non-conductive and stable work surface.
   - Use adequately insulated clamps and wires to attach measurement probes and instruments.
2. Electrical safety:
   - Remove the power supply from the board and electrical loads before taking any electrical measurements.
   - Proceed with the arrangement of measurement setup, wiring, or configuration paying attention to high voltage sections.
   - Once the setup is complete, energize the board.

Danger: *Do not touch the evaluation board when it is energized or immediately after it has been disconnected from the voltage supply as several parts and power terminals containing potentially energized capacitors need time to discharge.*
Do not touch the boards after disconnection from the voltage supply as several parts, like heat sinks and transformers, may still be very hot.
The kit is not electrically isolated from the AC/DC input.

3. Personal safety:
   - Always wear suitable personal protective equipment such as, for example, insulating gloves and safety glasses.
   - Take adequate precautions and install the board in such a way to prevent accidental touch. Use protective shields such as, for example, an insulating box with interlocks, if necessary.

3 Hardware and software requirements

Using the EVSPIN32G06Q2S1 evaluation board requires the following software and hardware:

- A Windows PC (XP, Vista, Win 7, Win 8, Win 10, or Win 11) to install the software package.
- An STLINK-V3SET debugger/programmer to connect the EVSPIN32G06Q2S1 board to the PC.
- The STM32 Motor Control Software Development Kit (available on www.st.com).
- A 3-phase brushless PMSM/BLDC motor with compatible voltage and current ratings.
- AC mains power supply or external DC power supply.

Warning: *The kit is not electrically isolated from the AC/DC input.*

4 Getting started

The maximum ratings of the board are as follows:

- Power stage supply voltage between 35 V_{AC} (50 V_{DC}) and 280 V_{AC} (400 V_{DC}).
- Overcurrent protection set to 8. A_{peak} (value configurable by the user).

To start your project with the board:

1. Check the jumper position according to the target configuration (see Hardware description and configuration).
2. Connect the motor on the connector J10 keeping in mind the motor phase sequence.
3. Supply the board through AC mains connector J4. The LD4 LED (green) turns on.

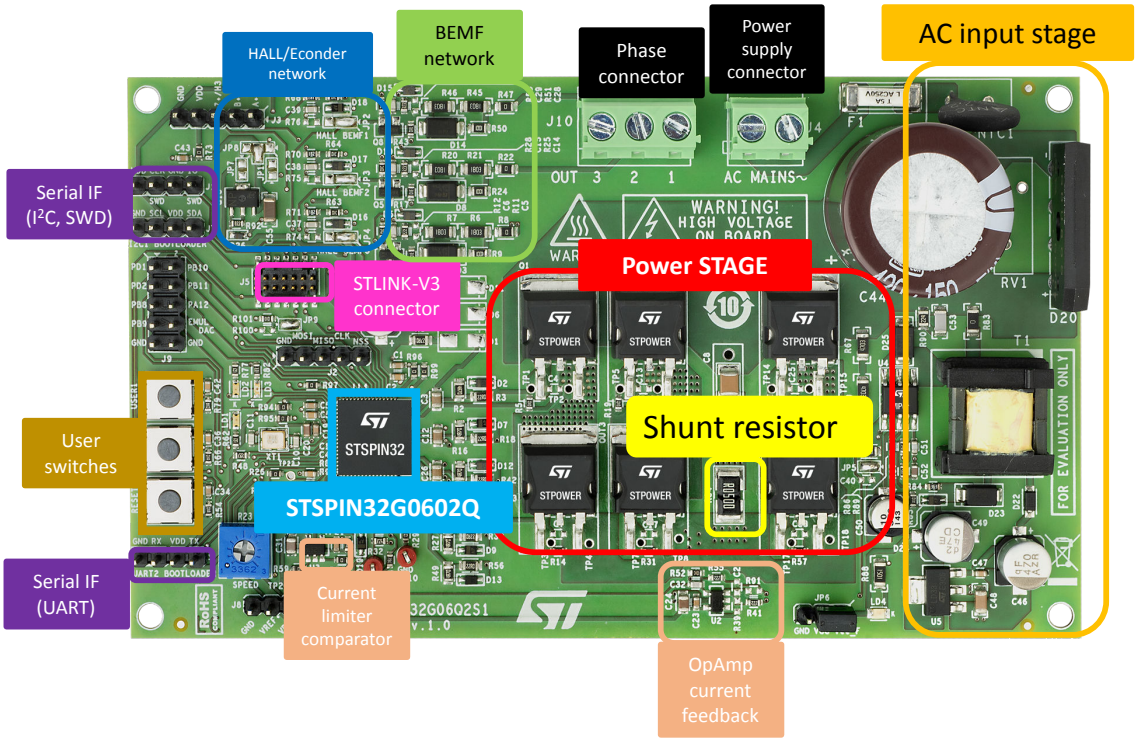
Develop the application using the code examples provided or the STM32 FOC MC library.

Refer to the relevant user manual for details.

5 Hardware description and configuration

The following figure shows the position of the main circuitry blocks of the board.

Figure 2. Board function blocks



The following figure shows the position of the connectors and jumpers of the board.

Figure 3. Main components and connector positions

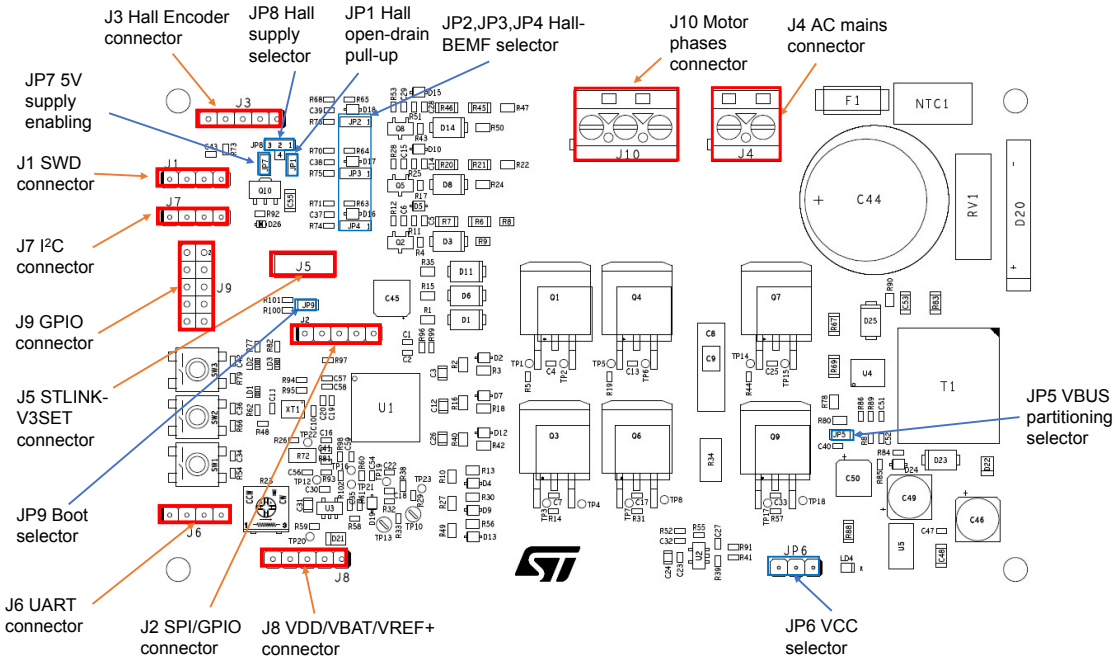


Table 1. Hardware jumper settings

Jumper	Permitted configurations	Default condition
JP1	Selection Hall encoder power supply to VDD	OPEN
JP2	Selection PA0 connected to BEMF1 (1-2 CLOSED) or Hall 1 (2-3 CLOSED)	1-2 CLOSED
JP3	Selection PA1 connected to BEMF2 (1-2 CLOSED) or Hall 2 (2-3 CLOSED)	1-2 CLOSED
JP4	Selection PA2 connected to BEMF3 (1-2 CLOSED) or Hall 3 (2-3 CLOSED)	1-2 CLOSED
JP5	Selection VBUS feedback partition value	CLOSED
JP6	Selection VCC connected to power supply (1-2 CLOSED) or external supply (VCC = pin 2 GND = pin 3, jumper removed)	1-2 CLOSED
JP7	Auxiliary +5 V supply for Hall sensors	OPEN
JP8	Selection Encoder sensor power to VDD (1-2 CLOSED), VCC (2-3 CLOSED) or +5 V (2-4 CLOSED)	2-4 CLOSED
JP9	Selection of Boot from Flash or System/SRAM if nBOOT_SEL = 0 (flash option bit, legacy mode)	OPEN

Table 2. Connectors

Name	Pin	Label	Description
J1	1	VDD	Auxiliary connector for SWD mode debugging/programming
	2	SWD CLK	
	3	GND	
	4	SWD IO	
J2	1	GND	SPI interface or customizable GPIOs
	2	SPI1_MOSI	
	3	SPI1_MISO	
	4	SPI1_CLK	
	5	SPI1_NSS	
J3	1	A+/H1	Hall/encoder sensors connector
	2	B+/H2	
	3	Z+/H3	
	4	VDD	Hall sensors/encoder supply
	5	GND	
J4	1 - 2	J4 - AC MAINS ~	AC mains power supply
J5	3	VDD	ST-LINKV3SET connector
	4	SWD_IO	
	5 - 7 - 11	GND	
	6	SWD_CLK	
	12	NRST	
	13	UART1_RX	
	14	UART1_TX	
J6	1	GND	UART2
	2	RX	
	4	VDD	
	4	TX	

Name	Pin	Label	Description
J7	1	GND	I2C1 / UART1
	2	I2C1_SCL/UART1_TX	
	3	VDD	
	4	I2C1_SDA/UART1_RX	
J8	1	E3V3 (onboard regulator output)	VDD/VBAT/VREF+ power supply connector Connect E3V3 to VDD with a jumper if no external supply is available
	2	VDD (digital power supply)	
	3	VBAT	
	4	VREF+	
	5	GND	
J9	1	PD1	GPIO connector
	2	PB10	
	3	PD2	
	4	PB11	
	5	PB8	
	6	PB2	
	7	PB9	
	8	EMUL_DAC	
	9	GND	
	10		
J10	1	OUT3	3-phase BLDC motor phase connector
	2	OUT2	
	3	OUT1	

Table 3. Test points

Name	Description
TP1	High side gate 3
TP2	OUT 3
TP3	Low side gate 3
TP4, TP8, TP18	SENSE
TP5	High side gate 2
TP6	OUT 2
TP7	Low side gate 2
TP10	GND – signal ground
TP12	EMUL_DAC (emulated DAC)
TP13	OD – SmartSD timing Open Drain output, unlatch, and restart input
TP14	High side gate 1
TP15	OUT 1
TP16	Current feedback
TP17	Low side gate 1
TP19	CIN – comparator positive input
TP20	Comparator output/ETR

Name	Description
TP21	Current reference
TP22	PA4 GPIO (SPEED)
TP23	PGND – power ground

6 Board description

6.1 Sensorless

By default the evaluation board is configured in sensorless mode. This enables the BEMF zero crossing detection network. Jumpers are set in the following way:

- JP2 pins 1-2 closed, PA0 connected to BEMF1
- JP3 pins 1-2 closed, PA1 connected to BEMF2
- JP4 pins 1-2 closed, PA2 connected to BEMF3

6.2 Hall/encoder motor speed sensor

The EVSPIN32G06Q2S1 evaluation board supports the digital Hall and quadrature encoder sensors for motor position feedback. The sensors can be connected to the STSPIN32G0602Q through the J3 connector as listed in the following table.

Table 4. Hall/encoder connector (J3)

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 1.8 kΩ is mounted in series with sensor outputs.

For sensors requiring external pull-up, three 10 kΩ resistors are already mounted on the output lines and connected to VDD voltage when JP1 is closed.

The jumper JP8 selects the power supply for sensor supply voltage:

- JP8 pins 1-2 closed: Hall sensors powered by VDD (3.3 V)
- JP8 pins 2-3 closed: Hall sensors powered by VCC (15 V)
- JP8 pins 2-4 closed: Hall sensors powered by +5 V supply

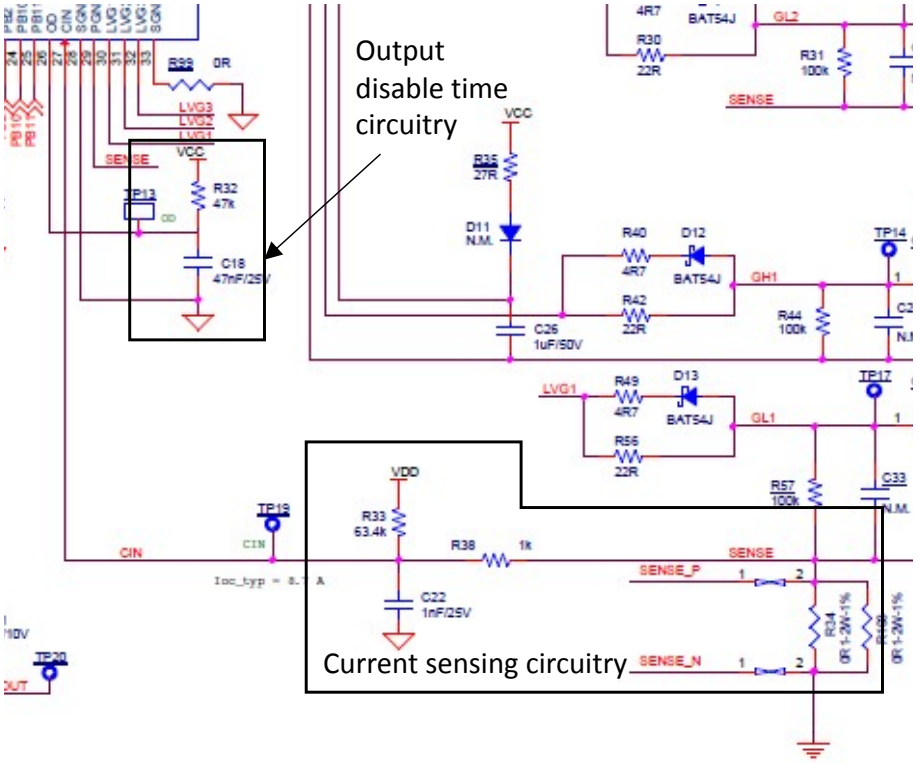
The MCU of STSPIN32G0602Q can decode Hall/encoder sensor outputs configuring jumpers as follows:

- JP2 pins 2-3 closed, PA0 connected to Hall 1
- JP3 pins 2-3 closed, PA1 connected to Hall 2
- JP4 pins 2-3 closed, PA2 connected to Hall 3

6.3 Overcurrent detection and current sensing measurement

The EVSPIN32G06Q2S1 evaluation board implements overcurrent protection based on the STSPIN32G0602Q integrated comparator. The single-shunt resistor measures the load current bringing the voltage signal associated to the load current to the CIN pin (TP19). When the peak current in the phases exceeds the selected threshold, the integrated comparator is triggered and all the power switches are disabled. Power switches are enabled again when the current falls below the threshold and the *output disable time* expires, thus implementing a current limitation control.

Figure 4. Current sensing and disable time circuitry



By default, the evaluation board has an overcurrent threshold set to I_{OC_typ}= 8.3 A and a restart time after fault detection of ~590 µs.

The overcurrent threshold can be modified by changing the R33 bias resistor, R38 loop resistor, R34 and R103 shunt resistors according to the following formulas:

- V_{REF_typ} = 460 mV
- VDD = 3.3 V
- R_{SHUNT} = R34 // R103 = 50 mΩ
- R_{PU} = R33 = 63.4 kΩ
- R_{LOOP} = R38 = 1 kΩ

$$I_{OC\_typ} = V_{REF\_typ} \cdot \frac{(R_{PU} + R_{LOOP})}{R_{SHUNT} \cdot R_{PU}} - VDD \cdot \frac{(R_{PU} + R_{LOOP}) \cdot (R_{LOOP} + R_{SHUNT})}{R_{SHUNT} \cdot R_{PU} \cdot (R_{LOOP} + R_{SHUNT} + R_{PU})}$$

The *output disable time* can be monitored on the OD pin (TP13) and is determined mainly by the time required to recharge the C18 capacitor up to the V_{SSDh} threshold, according to the following formulas:

- V_{SSDh} = 4 V
- V_{SSDl} = 0.56 V
- V_{OD} = VCC = 15 V

$$t_2 \cong C18 \cdot R32 \cdot \ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right)$$

Taking into account also the contribution of the OD internal current source I_{OD} (typical value 5 µA) the previous equation becomes:

$$t_2 \cong C_{OD} \cdot R_{OD\_ext} \cdot \ln\left(\frac{V_{SSDl} - V_{OD} - I_{OD} \cdot R_{OD\_ext}}{V_{SSDh} - V_{OD} - I_{OD} \cdot R_{OD\_ext}}\right)$$

6.4 Bus voltage circuit

The EVSPIN32G06Q2S1 evaluation board provides the bus voltage sensing. This signal is set through a voltage divider from the motor supply voltage (VBUS) (R67, R69 and R78, R80), and sent to PB0 GPIO (channel 8 of the ADC) of the embedded MCU.

- JP5 closed (by default) allows the bus voltage divider to be set to 146.
- JP5 open allows the bus voltage divider to be set to 126.

6.5 Hardware user interface

The board provides a hardware user interface as follows:

- A potentiometer R23 setting, for example, the target speed
- Switch SW1: reset STSPIN32G0602Q MCU
- Switch SW2: user button 2
- Switch SW3: user button 1
- LED LD1: turned on when user 2 button is pressed
- LED LD2: turned on when user 1 button is pressed
- LED LD3: turned on when VDD is on (MCU stage powered)
- LED LD4: turned on when VCC supply from flyback is on (gate driver stage powered)

6.6 Debug

The EVSPIN32G06Q2S1 evaluation board embeds an STLINK-V3SET debugger/programmer. Some of the features supported by STLINK are:

- USB 2.0 high-speed compatible interface
- Direct firmware update support (DFU)
- Virtual com port interface on USB connected to PB6/PB7 pins of the STSPIN32G0602Q (UART1)
- SWD and serial wire viewer (SWV) communication support

Just plug the provided flat cable on the J5 connector (STDC14 STM32 JTAG/SWD and VCP) to start programming/debugging the board through the preferred IDE.

The firmware can be generated using the STM32 Motor Control Software Development Kit.

6.7 Using an external DC power supply

The EVSPIN32G06Q2S1 evaluation board generates VDD = 3.3 V and VCC = 15 V through a flyback converter by default.

Optionally, it can be configured to provide VDD and VCC through an external power supply:

- VCC is provided by removing the jumper JP6 between VCC & Vcc_F and connecting pin2 to a suitable supply (i.e. 15 V or 12 V) and pin3 to GND.
- VDD can be provided by removing the jumper between E3V3 & VDD of connector J8 and connecting pin2 to 3.3 V and pin5 to GND.

7 References

This user manual provides information on the hardware features and use of the EVSPIN32G06Q2S1 evaluation board. For additional information refer to:

- EVSPIN32G06Q2S1 data brief (schematics, bill of materials, layouts)
- STSPIN32G0602Q datasheet
- STGB20M65DF2 datasheet
- UM2448 STLINK-V3SET debugger/programmer for STM8 and STM32 user manual
- STM32 Motor Control Software Development Kit (MCSDK)

Revision history

Table 5. **Document revision history**

Date	Version	Changes
05-Aug-2024	1	Initial release.

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