EVSPIN32F06Q1S1: 3-phase inverter based on STSPIN32F0601

Introduction

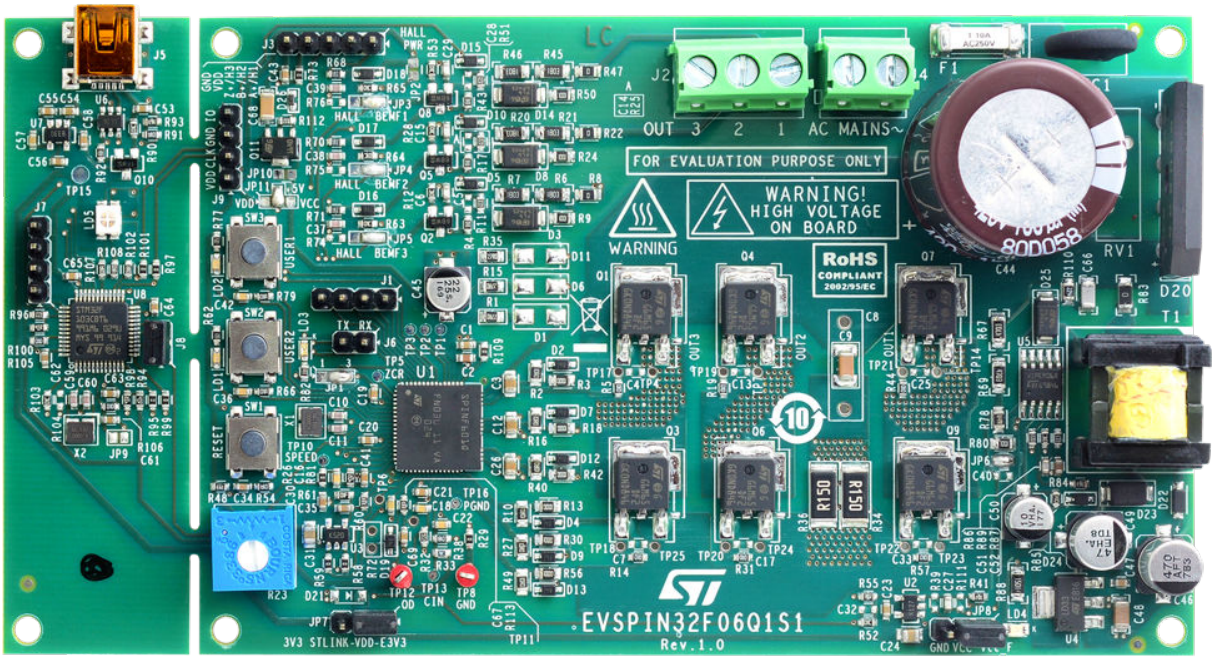
The EVSPIN32F06Q1S1 board is a 3-phase complete inverter based on the STSPIN32F0601Q controller, which embeds a 3-phase 600 V gate driver and a Cortex®-M0 STM32 MCU. The power stage features STGD6M65DF2 IGBTs, but can be populated with any IGBT or power MOSFET in DPAK or power FLAT 8x8 HV package. The 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, pumps, fans and industrial appliances.

The evaluation board is compatible with a wide range of input voltage 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 FW can be performed with standard STM32 tools through the detachable STLINK debugger. SWD and UART TX RX connectors are also available.

Figure 1. EVSPIN32F06Q1S1 evaluation board



1 Main features

The EVSPIN32F06Q1S1 has the following features:

- Input voltage from 35 V_{AC} (50 V_{DC}) to 280 V_{AC} (400 V_{DC})
- Suitable for applications up to 300 W
- High voltage rail up to 600 V
- STGD6M65DF2 IGBTs power stage featuring:
  - $V_{(BR)CES}$ = 650 V
  - $V_{CE(sat)}$ = 1.55 V @ I_C = 6 A
- Dual footprint for IGBT/MOSFET packages
  - DPAK
  - PowerFlat 8x8
- Single-shunt current sensing, suitable for:
  - Sensored or sensorless 6-step algorithm
  - Sensored or sensorless single-shunt vector (FOC) algorithm
- Digital Hall sensors and encoder input
- Smart shutdown overcurrent protection
- Bus voltage sensing
- 15 V VCC and 3.3 V VDD supplies
- Embedded ST-LINK/V2-1
- Easy user interface with buttons and trimmer
- RoHS compliant

1.1 Target applications

- Home and industrial refrigerators compressors
- Industrial drives, pumps, fans
- Air conditioning compressors & 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 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 or isolating distances 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 operate properly 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 non-conductive and stable work surface.
   - Use adequately insulated clamps and wires to attach measurement probes and instruments.
2. Electrical Safety:
   - Remove power supply from the board and electrical loads before performing any electrical measurement.
   - 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. The USB interface of the board does not insulate host computer from high voltage. When the board is supplied at a voltage outside the ELV range, a proper insulation method such as a USB isolator must be used to operate the board.

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, insulating box with interlocks if necessary.

3 Hardware and software requirements

Using the EVSPIN32F06Q1S1 evaluation board requires the following software and hardware:

- A Windows PC (XP, Vista, Win 7 , Win 8, Win 10) to install the software package
- A mini-B USB cable to connect the EVSPIN32F06Q1S1 board to the PC
- A 6-step firmware or the STM32 PMSM FOC Software Development Kit (available on www.st.com)
- A 3-phase brushless PMSM DC 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. The USB interface of the board does not insulate host computer from high voltage. When the board is supplied at a voltage outside the ELV range, a proper insulation method such as a USB isolator must be used to operate the board.*

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 5.5 A_{peak}

To start your project with the board:

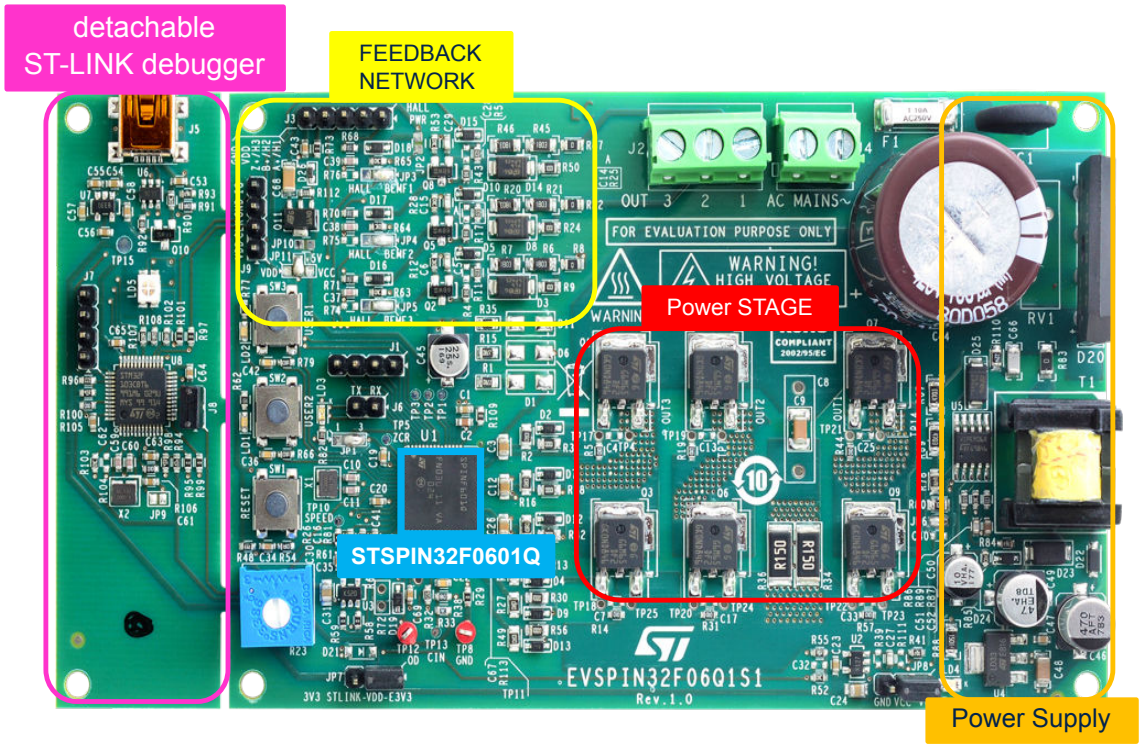
1. Check the jumper position according to the target configuration (see Section 5).
2. Connect the motor on the connector J2 taking care of the motor phases sequence.
3. Supply the board through AC mains connector J4. The LD4 LED (green) turns on.

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

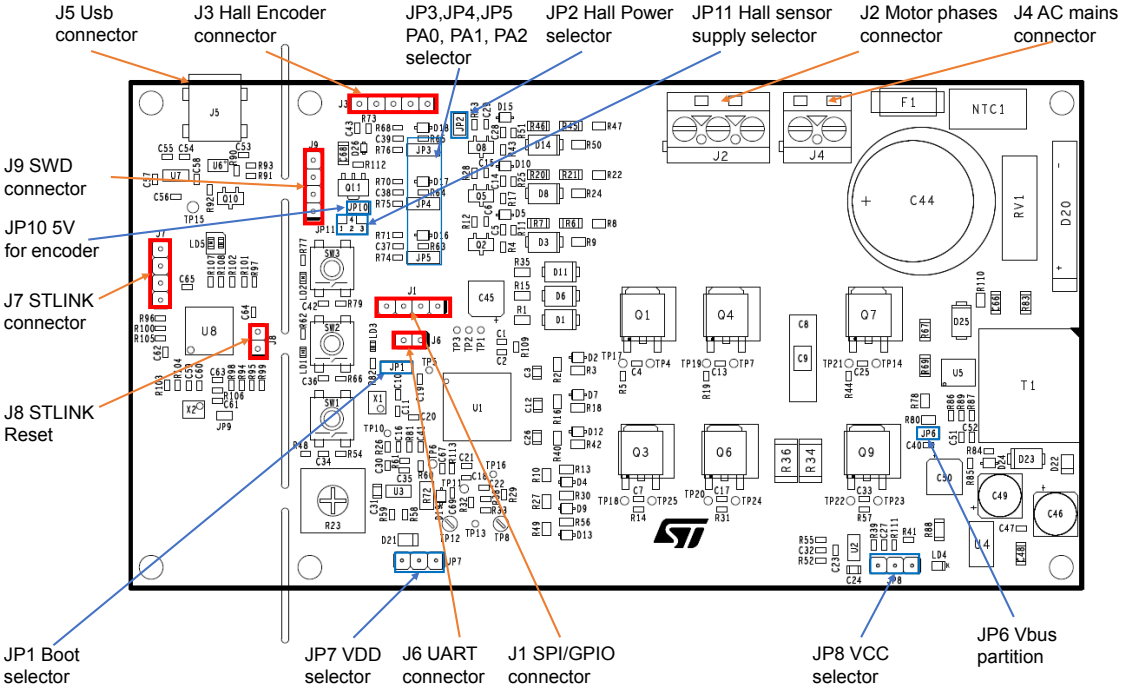


Table 1. Hardware jumper settings

Jumper	Permitted configurations	Default Condition
JP1	Selection of boot from Flash (2-3 Closed) or System/SRAM (1-2 closed)	2-3 closed
JP2	Selection Hall encoder power supply to VDD	Open
JP3	Selection PA0 connected to BEMF1 (1-2 closed) or Hall 1 (2-3 closed)	1-2 closed
JP4	Selection PA1 connected to BEMF2 (1-2 closed) or Hall 2 (2-3 closed)	1-2 closed
JP5	Selection PA2 connected to BEMF3 (1-2 closed) or Hall 3 (2-3 closed)	1-2 closed
JP6	Selection VBUS feedback partition	Closed
JP7	Selection VDD connected to power supply (1-2 closed) or STLINK (2-3 closed)	1-2 closed
JP8	Selection VCC connected to power supply (1-2 closed) or external supply (VCC=pin 2 GND=pin 3, jumper removed)	1-2 closed
JP10	Selection 5V supply for Encoder sensor power	Open
JP11	Selection Encoder sensor power to VDD (1-2 closed), VCC (2-3 closed) or 5V (2-4 closed)	2-4 closed

Table 2. Connectors

Name	Pin	Label	Description
J1	1-2-3-4	J1	SPI interface or customizable GPIOs
J2	1	OUT3	3-phase BLDC motor phases connections
	2	OUT2	
	3	OUT1	
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	-	J5	USB input ST-LINK
J6	1	RX	UART
	2	TX	
J7	1	J7	ST-LINK power supply
	2		SWCLK of ST-LINK
	3		GND
	4		SWDIO of ST-LINK
J8	1-2	J8	ST-LINK reset
J9	1	VDD	Auxiliary connector for SWD mode debugging/programming
	2	SWD CLK	
	3	GND	
	4	SWD IO	

Table 3. **Test points**

Name	Pin	Label	Description
TP1	-	TP1	RES1
TP2	-	TP2	RES2
TP3		TP3	RES3
TP4	-	TP4	OUT 3
TP5	-	TP5	PB8 GPIO
TP6	-	TP6	PA7 GPIO
TP7	-	TP7	OUT 2
TP8	-	TP8	GND – signal ground
TP10	-	TP10	PA3 GPIO (speed)
TP11	-	TP11	PB1 filtered output
TP12	-	TP12	OD – SmartSD timing open drain output, unlatch and restart input
TP13	-	TP13	CIN – comparator positive input
TP14	-	TP14	OUT 1
TP15	-	TP15	3V3 STLINK USB voltage
TP16	-	TP16	PGND - power ground
TP17	-	TP17	High side gate 3
TP18	-	TP18	Low side gate 3
TP19	-	TP19	High side gate 2
TP20	-	TP20	Low side gate 2
TP21	-	TP21	High side gate 1
TP22	-	TP22	Low side gate 1
TP23	-	TP23	SENSE
TP24	-	TP24	SENSE
TP25	-	TP25	SENSE

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:

- JP3 pins 1-2 closed, PA0 connected to BEMF1
- JP4 pins 1-2 closed, PA1 connected to BEMF2
- JP5 pins 1-2 closed, PA2 connected to BEMF3

6.2 Hall/Encoder motor speed sensor

The EVSPIN32F06Q1S1 evaluation board supports the digital Hall and quadrature encoder sensors for motor position feedback. The sensors can be connected to the STSPIN32F0601Q 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 JP2 is closed.

The jumper JP11 selects the power supply for sensor supply voltage:

- JP11 pins 1-2 closed : Hall sensors powered by VDD (3.3 V)
- JP11 pins 2-3 closed : Hall sensors powered by VCC (15 V)
- JP11 pins 2-4 closed : Hall sensors powered by 5V supply

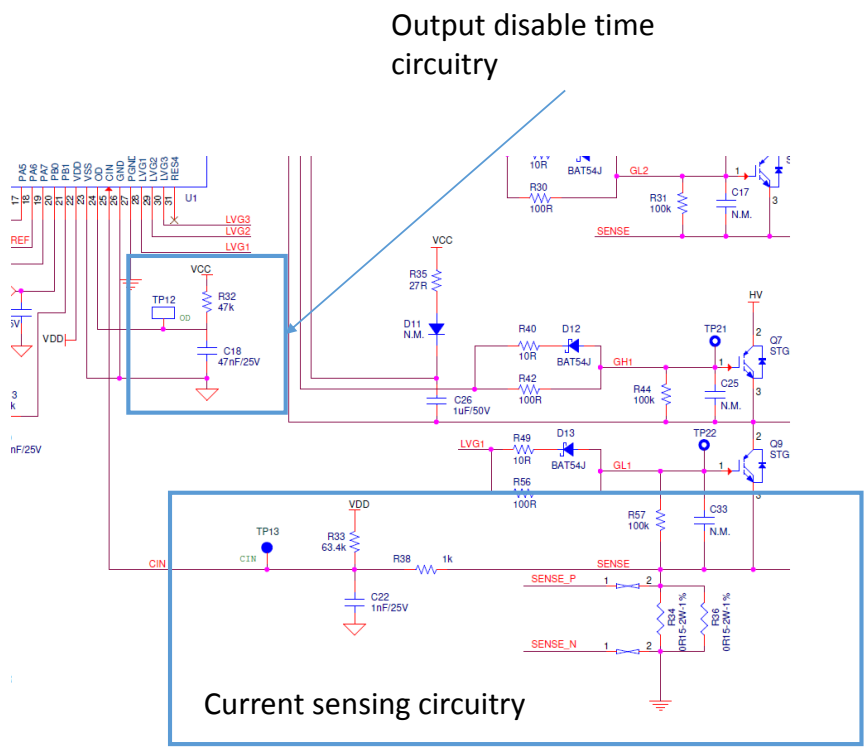
The MCU of STSPIN32F0601Q can decode Hall/Encoder sensor outputs configuring jumpers as follows:

- JP3 pins 2-3 closed, PA0 connected to Hall1
- JP4 pins 2-3 closed, PA1 connected to Hall2
- JP5 pins 2-3 closed, PA2 connected to Hall3

6.3 Overcurrent detection and current sensing measurement

The EVSPIN32F06Q1S1 evaluation board implements overcurrent protection based on the STSPIN32F0601Q integrated comparator. The single-shunt resistor measures the load current bringing the voltage signal associated to load current to CIN pin (TP13). 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}= 5.5 A and a restart time after fault detection of ~560 µs

Overcurrent threshold can be modified changing R33 bias resistor, R38 loop resistor and R34, R36 shunt resistors according to the following formulas:

- V_{REF_typ} = 460 mV
- VDD = 3.3 V
- R_{SHUNT} = R34//R36 = 75 mΩ
- R_{PU} = R33 = 63.4 kΩ
- R_{LOOP} = R38 = 1 kΩ

$$I_{OC\_typ} = V_{REF\_typ} \cdot \frac{(R_{PU} + R_{LOOP})}{R_{SHUNT} \cdot R_{PU}} - VDD \cdot \frac{(R_{PU} + R_{LOOP}) \cdot (R_{LOOP} + R_{SHUNT})}{R_{SHUNT} \cdot R_{PU} \cdot (R_{LOOP} + R_{SHUNT} + R_{PU})} \quad (1)$$

The *output disable time* can be monitored on the OD pin (TP12) and is determined mainly by the time required to recharge C18 capacitor up to V_{SSDh} threshold, according to the formulas:

- V_{SSDh} = 3.8 V
- V_{SSDl} = 0.56 V
- V_{OD} = VCC = 15 V

$$t_2 \cong C18 \cdot R32 \cdot \ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right) \quad (2)$$

6.4 Bus voltage circuit

The EVSPIN32F06Q1S1 evaluation board provides the bus voltage sensing. This signal is set through a voltage divider from motor supply voltage (VBUS) (R67, R69 and R78, R80), and sent to PB0 GPIO (channel 8 of the ADC) of the embedded MCU.

- JP6 closed (by default) allows to set the bus voltage divider to 145
- JP6 open allows to set the bus voltage divider 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 STSPIN32F0601Q 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 flyback is on (Gate Driver stage powered)

6.6 Debug

The EVSPIN32F06Q1S1 evaluation board embeds an ST-LINK/V2-1 debugger/programmer. The features supported by ST-LINK are:

- USB software re-enumeration
- Virtual com port interface on USB connected to PB6/PB7 pins of the STSPIN32F0601Q (UART1)
- Mass storage interface on USB

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

LED LD5 provides ST-LINK communication status information:

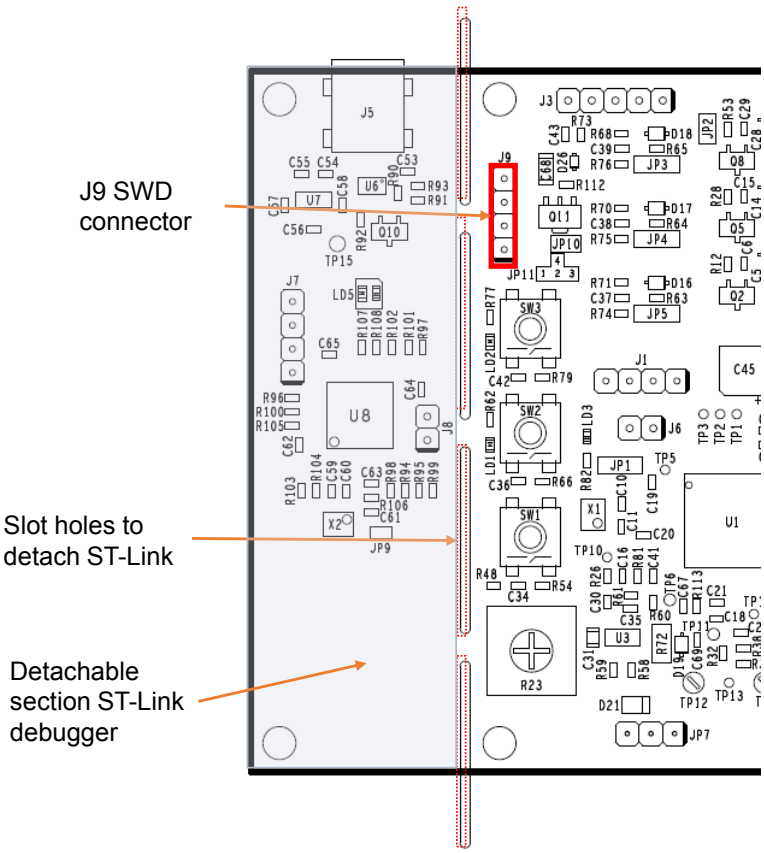
- Red LED flashing slowly: at power-on before USB initialization
- Red LED flashing quickly: following first correct communication between the PC and ST-LINK/V2-1 (enumeration)
- Red LED ON: initialization between the PC and ST-LINK/V2-1 is complete
- Green LED ON: successful target communication initialization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

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

6.7 ST-LINK detachable

Once the evaluation board is programmed, it is possible to detach the ST-LINK debugger, breaking the PCB along slot holes. The capability to program or debug STSPIN32F0601Q is still allowed by connecting an external ST-LINK to J9 SWD connector.

Figure 5. EVSPIN32F06Q1S1 detachable section



6.8 Using external DC power supply

The EVSPIN32F06Q1S1 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 external power supply:

- VCC is provided by removing JP8 and connecting pin2 to 15 V and pin3 to GND.
- VDD can be provided by ST-LINK through JP7 (2-3 closed) or connecting the JP7 pin2 to 3.3 V and GND to TP8.

7 References

This user manual provides information on the hardware features and use of the EVSPIN32F06Q1S1 evaluation board. For additional information refer to:

- EVSPIN32F06Q1S1 data brief (schematics, bill of materials, layouts)
- STSPIN32F0601Q datasheet
- STGD6M65DF2 datasheet
- User manual ST-LINKV2 programmer

Revision history

Table 5. **Document revision history**

Date	Version	Changes
02-Mar-2021	1	Initial release.
26-Jul-2023	2	Added board maximum power in Section 1 Main features Updated Section 6.3 Overcurrent detection and current sensing measurement

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