# EVSPIN32F06Q1S3: 3-phase 3 shunt inverter based on STSPIN32F0601

## Introduction

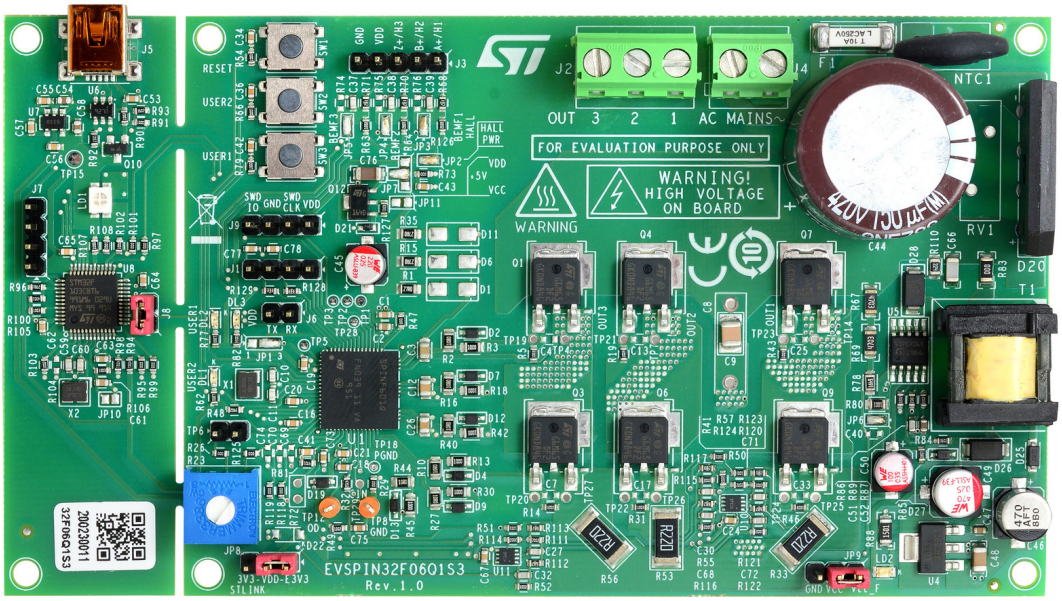
The EVSPIN32F06Q1S3 board is a 3-phase complete inverter based on the STSPIN32F0601Q controller, which embeds a 3-phase 600 V gate driver and a Cortex®-M0 STM32 MCU. The power stage features STGD6M65DF2 IGBTs, but can be populated with any IGBT or Power MOSFET in DPAK or powerFLAT 8x8 HV package. The board has a three-shunt sensing topology, and the sensored or sensorless field-oriented control (FOC) 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. EVSPIN32F06Q1S3 evaluation board**



# 1 Main features

The EVSPIN32F06Q1S3 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
- Output current up to 4.5 $A_{peak}$
- STGD6M65DF2 IGBTs Power stage featuring:
  - $V_{(BR)CES}$ = 650 V
  - $V_{CE(sat)}$ = 1.55 V @ IC = 6 A
- Dual footprint for IGBT/MOSFET packages
  - DPAK
  - PowerFlat 8x8
- Three-shunt current sensing, suitable for:
  - Triple or dual 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 EVSPIN32F06Q1S3 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 EVSPIN32F06Q1S3 board to the PC
- 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 the following:

- Power stage supply voltage between 35 $V_{AC}$ (50 $V_{DC}$) and 280 $V_{AC}$ (400 $V_{DC}$)
- Overcurrent protection set to 4.5 $A_{peak}$

To start your project with the board:

- Check the jumper position according to the target configuration (see Section 5).
- Connect the motor on the connector J2 taking care of the motor phases' sequence.
- Supply the board through AC Mains connector J4. The LED2 ( LD2, green) will turn on.

Develop your application using code examples provided or the STM32 FOC MC Library.
Please refer to the respective user manual for details.

# 5 Hardware description and configuration

Figure 2 shows the position of the main circuitry blocks of the board.

**Figure 2. EVSPIN32F06Q1S3 --board functions**

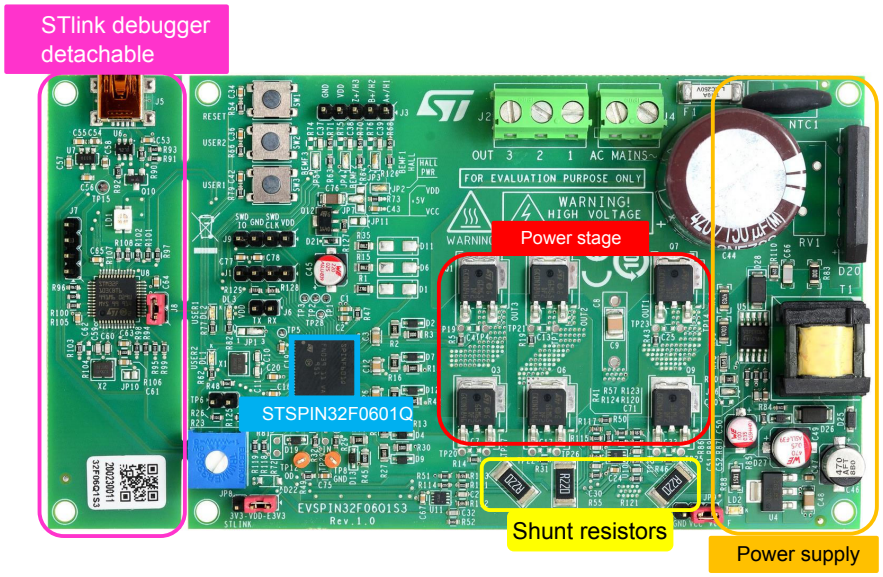



Figure 3 shows the position of the connectors and jumpers of the board.

**Figure 3. EVSPIN32F06Q1S3 - main components and connector positions**

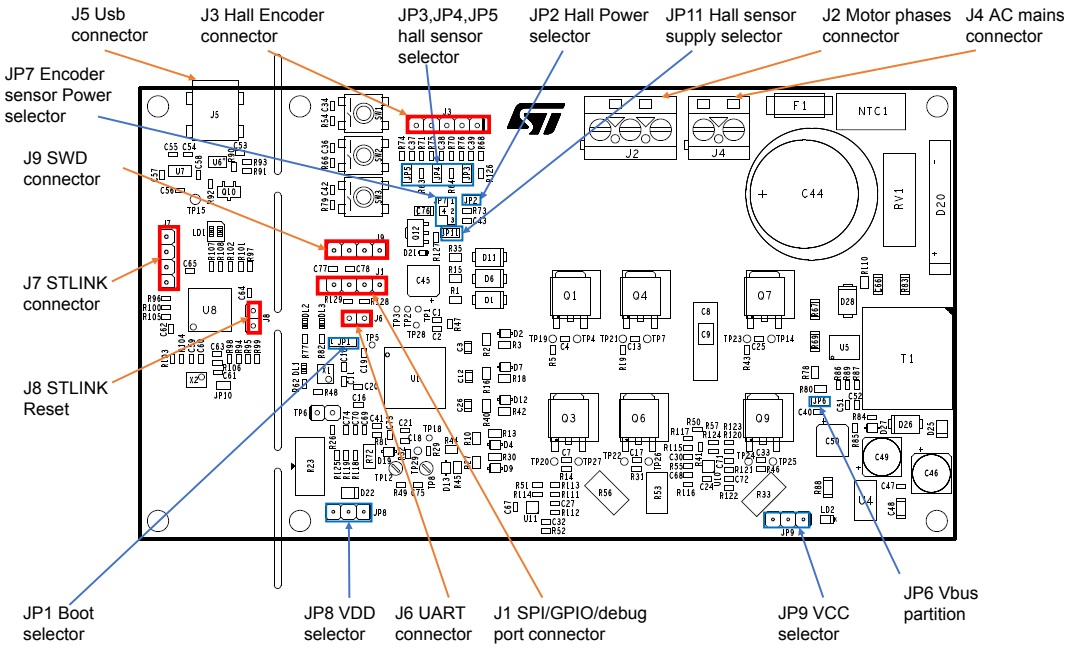


**Table 1. Hardware setting jumpers**

| 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 | closed |
| JP3 | Selection PA0 connected to Hall 1 | closed |
| JP4 | Selection PA1 connected to Hall 2 | closed |
| JP5 | Selection PA2 connected to Hall 3 | closed |
| JP6 | Selection VBUS feedback partition | closed |
| JP7 | Selection Encoder sensor power to VDD (1-2 closed) , VCC (2-3 closed) or +5V (2-4 closed) | 2-4 closed |
| JP8 | Selection VDD connected to power supply (1-2 closed)<br>or STLINK (2-3 closed) | 1-2 closed |
| JP9 | Selection VCC connected to power supply (1-2 closed)<br>or external supply (VCC=pin 2 GND=pin 3, jumper removed) | 1-2 closed |

**Table 2. Connectors and test points description**

| Name | Pin | Label | Description |
|---|---|---|---|
| J1 | 1-2-3-4 | J1 | SPI interface, simulated DAC debug port (pins 3,4) or customizable GPIOs |
| J2 | 1 | OUT3 | 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 description**

| Name | Pin | Label | Description |
|---|---|---|---|
| TP1 | - | TP1 | RES1 |
| TP2 | - | TP2 | RES2 |
| TP3 | | TP3 | RES3 |
| TP4 | - | TP4 | OUT 3 |
| TP5 | - | TP5 | PB8 GPIO |
| TP6 | - | TP6 | PA4 GPIO, PA3 GPIO (SPEED) |
| TP7 | - | TP7 | OUT 2 |
| TP8 | - | TP8 | GND – signal ground |
| TP12 | - | TP12 | OD – SmartSD timing open drain output |
| TP14 | - | TP14 | OUT 1 |
| TP15 | - | TP15 | 3V3 STLINK USB voltage |
| TP18 | - | TP18 | PGND – power ground |
| TP19 | - | TP19 | High side channel 3 gate |
| TP20 | - | TP20 | Low side channel 3 gate |
| TP21 | - | TP21 | High side channel 2 gate |
| TP22 | - | TP22 | Low side channel 2 gate |
| TP23 | - | TP23 | High side channel 1 gate |
| TP24 | - | TP24 | Low side channel 1 gate |
| TP25 | - | TP25 | SENSE channel 1 |
| TP26 | - | TP26 | SENSE channel 2 |
| TP27 | - | TP27 | SENSE channel 3 |
| TP28 | - | TP28 | PA12 GPIO |
| TP29 | - | TP29 | CIN – comparator positive input |

# 6 Board description

## 6.1 Sensorless

The evaluation board can be used in FOC sensorless mode without modifications, current signals are read through shunt resistors, amplified and brought to MCU ADC channels 5, 6 and 7.

## 6.2 Hall/Encoder motor speed sensor

The EVSPIN32F06Q1S3 evaluation board supports the digital Hall and quadrature encoder sensors for motor position feedback.

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 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 JP7 selects the power supply for sensor supply voltage:

- JP7 pins 1-2 CLOSED : Hall sensors powered by VDD ( 3.3 V )
- JP7 pins 2-3 CLOSED : Hall sensors powered by VCC ( 15 V )
- JP7 pins 2-4 CLOSED : Hall sensors powered by V5_Hall (+5 V)

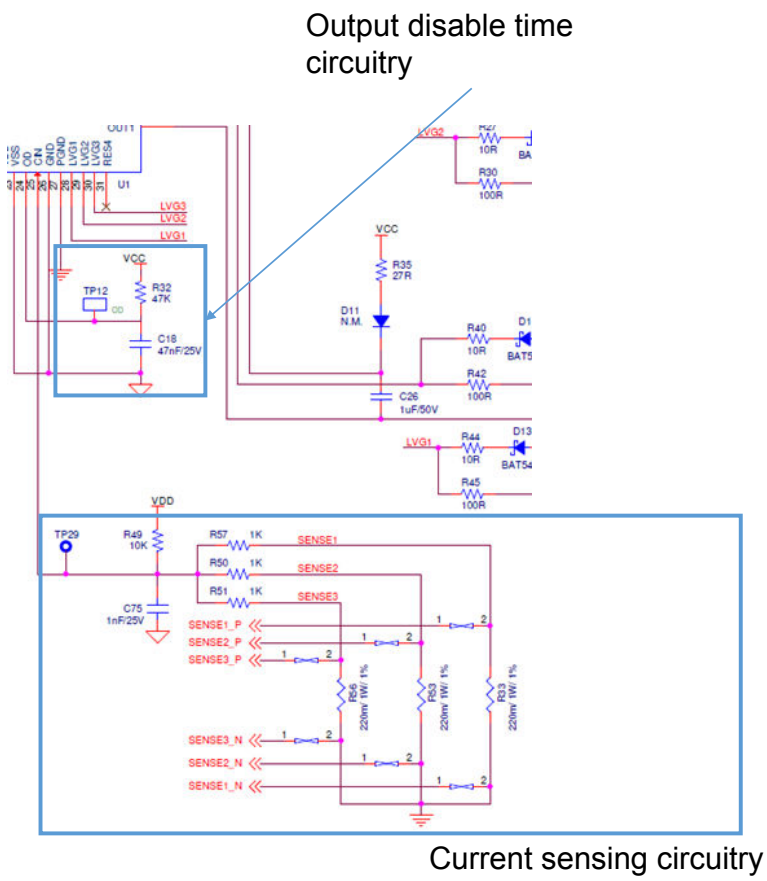
The MCU of STSPIN32F0601Q can decode Hall/Encoder sensor outputs configuring jumpers as follows:

- JP3 CLOSED, PA0 connected to Hall1
- JP4 CLOSED, PA1 connected to Hall2
- JP5 CLOSED, PA2 connected to Hall3

## 6.3 Overcurrent detection and current sensing measurement

The EVSPIN32F06Q1S3 evaluation board implements overcurrent protection based on the STSPIN32F0601Q integrated comparator. The shunt resistors measures the load current bringing the voltage signal associated to load current to the CIN pin (TP29). 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. EVSPIN32F06Q1S3 - Current sensing and disable time circuitry**




By default the evaluation board has an overcurrent threshold set to $I_{OC\_typ}$= 4.5 A and a restart time after fault detection of ~560us

Overcurrent threshold can be modified changing R49 bias resistor, R57, R50, R51 loop resistors and R33, R53, R56 shunt resistors according to the following formulas:

- $V_{REF\_typ}$ = 460 mV
- VDD = 3.3 V
- $R_{SHUNT}$= R33 = R53 = R56 = 220 mΩ
- $R_{PU}$ = R49 = 10 kΩ
- $R_{LOOP}$ = R57 = R50 = R51 = 1 kΩ

If $R_{SHUNT}$ << $R_{LOOP}$:

$$I_{OC\_typ} \cong V_{REF\_typ} \cdot \frac{(3R_{PU} + R_{LOOP})}{R_{SHUNT} \cdot R_{PU}} - VDD \cdot \frac{R_{LOOP}}{R_{SHUNT} \cdot R_{PU}} \quad (1)$$

The *output disable time* can be monitored on the OD pin (TP12) and is determined mainly by the time required to recharge the 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

$$t_2 \cong C18 \cdot R49 \cdot ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right) \quad (2)$$

## 6.4 Bus voltage circuit

The EVSPIN32F06Q1S3 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 PB1 GPIO (channel 9 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 DL1: turned on when user 2 button is pressed
- LED DL2: turned on when user 1 button is pressed
- LED DL3: turned on when VDD is on (MCU stage powered )

LED LD2: turned on when VCC flyback is on (Gate Driver stage powered)

## 6.6 Debug

The EVSPIN32F06Q1S3 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 LD1 provides ST-LINK communication status information:

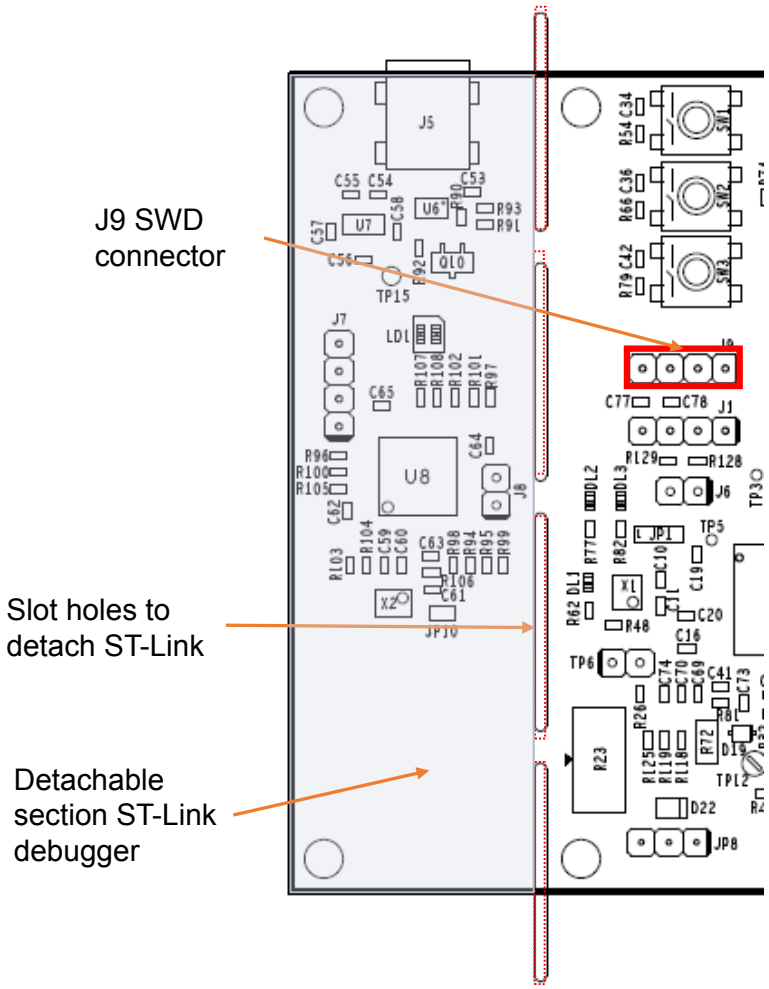
- Red LED flashing slowly: at power-on before USB initialization
- Red LED flashing quickly: following first correct communication between the PC and ST-LINK/V2-1 (enumeration)
- Red LED ON: initialization between the PC and ST-LINK/V2-1 is complete
- Green LED ON: successful target communication initialization
- 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. EVSPIN32F06Q1S3 - detachable section**




## 6.8 Using an external DC power supply

The EVSPIN32F06Q1S3 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 removing JP9 and connecting pin2 to the external supply (e.g. 12 V) and pin3 to GND.
- VDD can be provided by ST-LINK through JP8 (2-3 closed) or connecting JP8 pin2 to 3.3 V and GND to TP8.

# 7 References

This user manual provides information on the hardware features and use of the EVSPIN32F06Q1S3 evaluation board. For additional information refer to:

- EVSPIN32F06Q1S3 Data brief (schematics, bill of material, layout)
- STSPIN32F0601Q Datasheet
- STGD6M65DF2 Datasheet
- User manual ST-LINKV2 programmer

# Revision history

Table 5. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 01-Apr-2021 | 1 | Initial release. |
| 26-Jul-2023 | 2 | Added board maximum power in Section 1 Main features<br>Updated Section 6.3 Overcurrent detection and current sensing measurement |

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