UM3375

User manual

Getting started with the EVLSERVO1

Introduction

The EVLSERVO1 is a reference design for driving low-voltage and high-current servo motors.

It is based on the STSPIN32G4, a system-in-package integrating in a 9x9 mm VFQFPN package, a triple high-performance half-bridge gate driver with a rich set of programmable features, and a mixed signal STM32G431 microcontroller.

The EVLSERVO1 has a very compact form factor of 50 mm x 80 mm x 60 mm and consists of two boards stacked up together.

The system is designed to drive 3-phase brushless motors delivering up to 2 kW of power out of the box with provided heatsink or 3 kW if adding an external fan for cooling. The system is intended for applications with nominal bus voltage up to 48 V but is designed to manage overvoltage conditions up to 75 V.

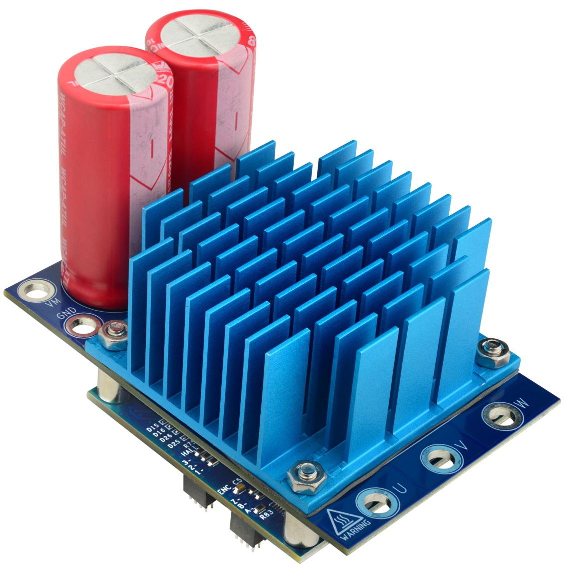
A dedicated circuitry is available to control bus voltage in case of regenerative motor braking. Power from the motor can be dissipated in one external resistor, clamping the bus voltage at the required safe level.

Monitoring is available for the power stage in case of overheating, overvoltage, and overcurrent. Triple-shunt topology is used for the sensing of motor winding currents in differential mode.

The board is ready for FOC and 6-step control algorithms and can run in sensorless mode or use up to two position feedbacks simultaneously. Hall sensors, incremental encoder, and absolute encoder with UART or SPI communication are supported with differential or single-ended wiring.

A CAN transceiver is also provided for robust communication in industrial environments.

Figure 1. **EVLSERVO1**



1 Safety and operating instructions

1.1 General terms

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

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

The kit is not electrically isolated from the high-voltage supply DC input. The demonstration 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 DC line. This prevents the occurrence of shock when touching any single point in the circuit but does not prevent shock when touching two or more points in the circuit. 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.

1.2 Intended use of demonstration board

The board is designed for evaluation 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.

1.3 Installing the demonstration board

- The installation and cooling of the demonstration board must be in accordance with the specifications and target application
- The motor drive converters must be protected against excessive strain. 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).

1.4 Operating the demonstration board

To operate the board properly, 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 demonstration board must be equipped with additional control and protective devices in accordance with the applicable safety requirements (that is, 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 performing 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 demonstration 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 board after disconnection from the voltage supply as several parts like heatsinks and transformers may still be very hot.
The kit is not electrically isolated from the DC input. The USB interface of the board does not insulate the 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 insulated gloves and safety glasses.
   – Take adequate precautions and install the board in such a way to prevent accidental touch. Use protective shields such as an insulating box with interlocks if necessary.

2 Acronyms and definitions

The list of acronyms and definitions used in this document is seen in Table 1.

Table 1. List of acronyms and definitions

	Description
ADC	Analog-to-digital converter.
CAN	Controller area network. A robust communication standard used for data transmission among electronic control units connected in a local network.
FOC	Field oriented control. A driving algorithm for 3-phase motors, which allows to control the position of the rotor magnetic field with respect to the stator magnetic field.
Half-bridge	Structure composed by one high-side and one low-side MOSFET connected (refer to Figure 9). Each phase of a 3-phase motor is usually driven by a half-bridge structure.
MCU	Microcontroller unit
OPAMP	Operational amplifier
PGA	Programmable gain amplifier.
PWM	Pulse width modulation
Shunt resistor	The shunt resistor is placed on the source of the low-side MOSFET, to measure the current flowing in the load.

3 Hardware and software requirements

The use of the EVLSERVO1 board requires the following software and hardware:

- A Windows® PC (Windows 10) to install the software packages
- One STLINK-V3SET debugger/programmer or equivalent
- One 3-phase brushless DC motor with compatible voltage and current ratings
- An external DC power supply with cables
- One power resistor for managing the regenerative braking (optional)
- One fan for active cooling of the system (optional).

4 Getting started

The system is composed by two connected boards, the SERVO_CTRL1 and the SERVO_INV1, as shown in Figure 2 and Figure 3.

To use the system:

1. Connect the three motor terminals to the connectors CON4, CON6, and CON7 of SERVO_INV1, taking care of the windings sequence.
2. Connect the programmer and debugger to the board SERVO_CTRL1 using connector J1.
3. Develop your application or use the MCSDK 6.3.0 or greater to easily generate a 6-step or FOC firmware that is ready to use.
4. Supply the system via CON1 and CON3 connectors on SERVO_INV1 taking care of polarity; the red LED2 on SERVO_CTRL1 turns on to indicate the presence of supply voltage.
5. Upload the firmware on the STSPIN32G4 microcontroller with a dedicated tool such as STM32CubeProgrammer and run the motor.

Ratings of the board are listed in Table 2.

Table 2. EVLSERVO1 specifications

Parameter		Value
Input voltage	Nominal	From 10 V to 48 V
	Peak	75 V
Output current	Passive cooling (1) (2)	42 A_{rms}
	Active cooling (1) (2) (3)	63 A_{rms}
Output power	Passive cooling (1) (2)	2 kW
	Active cooling (1) (2) (3)	3 kW
External resistor current	Peak	90 A
	Passive cooling (1)	31 A_{rms}
	Active cooling (1) (3)	47 A_{rms}

1. *With an ambient temperature of 25 °C.*
2. *With a switching frequency of 10 kHz.*
3. *Ducted airflow greater than 12 m^3/h.*

5 Hardware description and configuration

An overview of the boards with the placement of main components is available in Figure 2.

Figure 2. SERVO_CTRL1 board: position of connectors, LEDs, switches, and test points

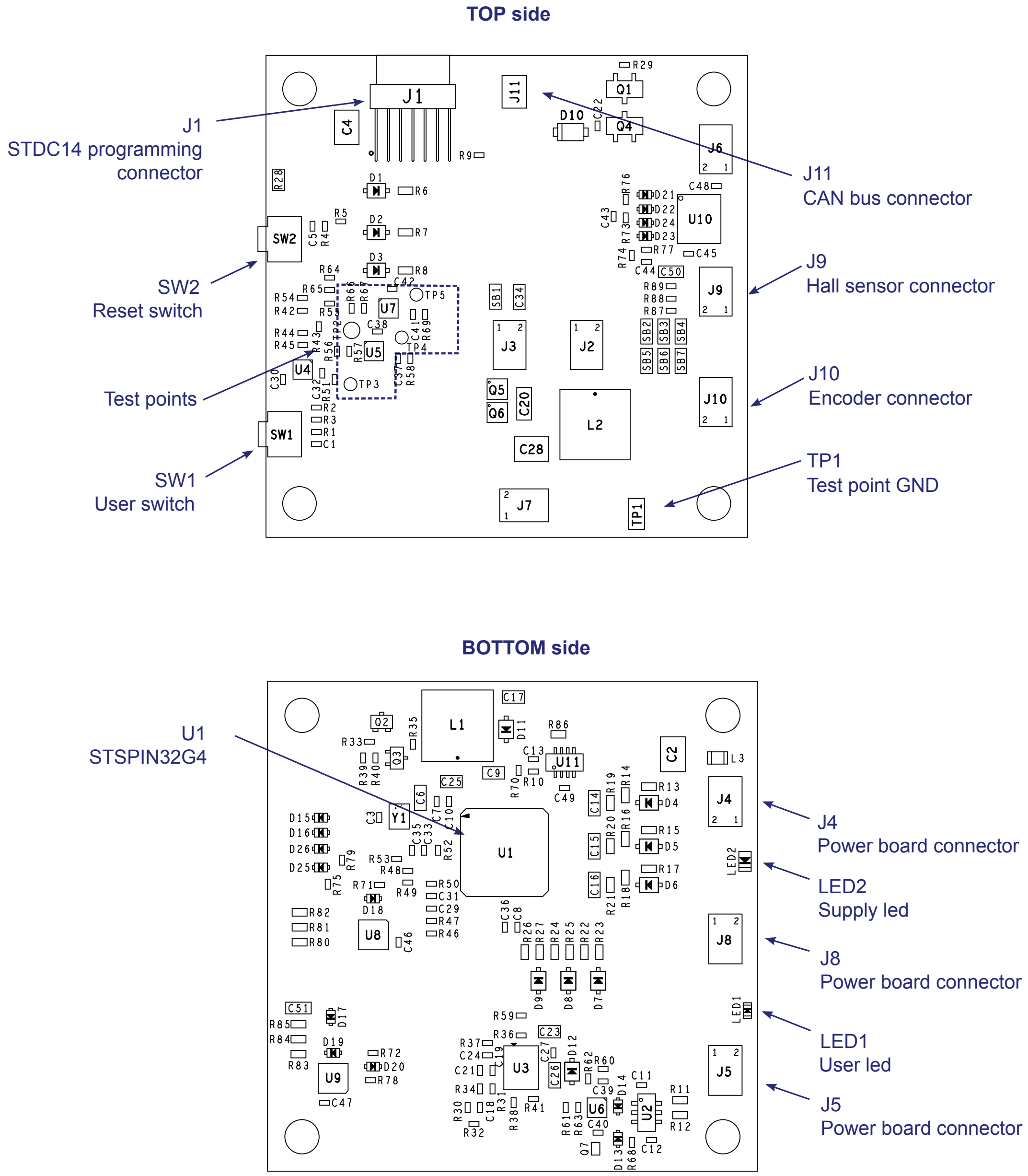
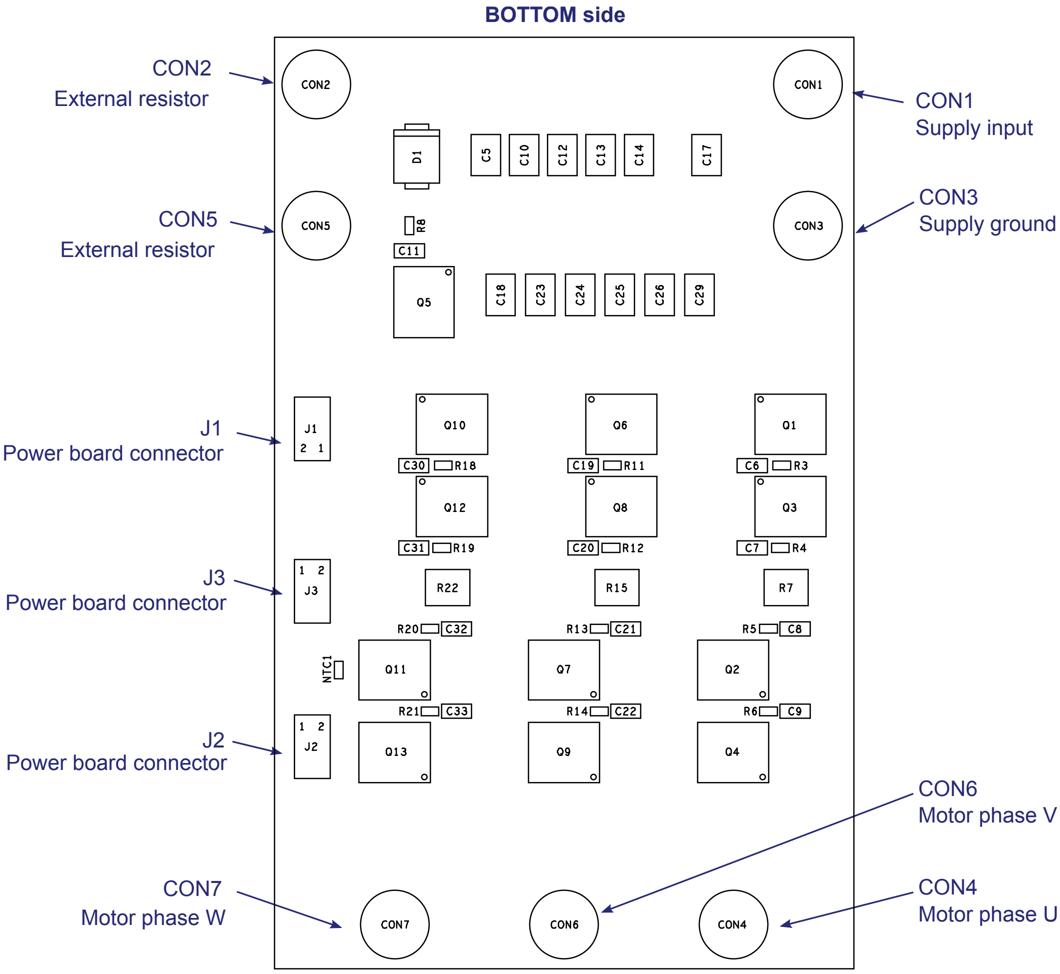


Figure 3. SERVO_INV1 board: position of connectors



5.1 Connectors and test points

Table 3 provides the description of the connectors available on the SERVO_CTRL1 board while test points are presented in Table 4. A description of connectors available on the SERVO_INV1 board is provided in Table 5.

Table 3. Connectors on SERVO_CTRL1 board

Name	Pin	Label	Description
J1	-	J1	STDC14 connector for programming and debugging STSPIN32G4
J9	1	1	Hall-effect sensor 1 negative terminal
	2	2	Hall-effect sensor 1 positive terminal
	3		Hall-effect sensor 2 negative terminal
	4		Hall-effect sensor 2 positive terminal
	5		Hall-effect sensor 3 negative terminal
	6		Hall-effect sensor 3 positive terminal
	7		Sensors ground
	8		Sensors supply voltage
J10	1	1	Encoder out A negative terminal
	2	2	Encoder out A positive terminal
	3		Encoder out B negative terminal

Name	Pin	Label	Description
J10	4		Encoder out B positive terminal
	5		Encoder zero negative terminal
	6		Encoder zero positive terminal
	7		Sensors ground
	8		Sensors supply voltage
J11	1	CAN-	CAN bus signal low
	2	CAN+	CAN bus signal high
	3		CAN bus ground
	4		CAN bus ground
J4	1	1	Gate signal for high side power switch 3
	2	2	Reference signal for high-side power switch 3
	3		Gate signal for high-side power switch 2
	4		Reference signal for high-side power switch 2
	5		Gate signal for high-side power switch 1
	6		Reference signal for high-side power switch 1
	7		Supply voltage from power board
	8		Supply voltage from power board
J5	1	1	Gate signal for low-side power switch 3
	2	2	Ground
	3		Gate signal for low-side power switch 2
	4		Ground
	5		Gate signal for low-side power switch 1
	6		Ground
	7		Gate signal for breaking resistor power switch
	8		Ground
J8	1	1	Shunt resistor 3 positive signal
	2	2	Shunt resistor 3 negative signal
	3		Shunt resistor 2 positive signal
	4		Shunt resistor 2 negative signal
	5		Shunt resistor 1 positive signal
	6		Shunt resistor 1 negative signal
	7		NTC positive signal
	8		NTC negative signal

Table 4. Test points on SERVO_CTRL1 board

Label	Description
TP1	Ground
TP2	Analog ground
OPO1	Output of operational amplifier 1
OPO2	Output of operational amplifier 2
OPO3	Output of operational amplifier 3

Table 5. Connectors on SERVO_INV1 board

Name	Pin	Label	Description
CON4	-	U	Output for motor winding 1
CON6	-	V	Output for motor winding 2
CON7	-	W	Output for motor winding 3
CON2	-	VM	External resistor terminal
CON5	-	BRK	External resistor terminal
CON3	-	GND	Supply ground
CON1	-	VM	Supply input
J1	-	J1	Mating with J4 of SERVO_CTRL1 board
J2	-	J2	Mating with J5 of SERVO_CTRL1 board
J3	-	J3	Mating with J8 of SERVO_CTRL1 board

5.2 User interface

The board provides the following components to interface with the user:

- Switch SW1: user switch 1
- Switch SW2: to reset STSPIN32G4
- LED1: user yellow LED, turned on when the user switch 1 is pressed too
- LED2: system red LED, turned on when supply voltage is present.

5.3 Programming and debugging

The EVLSERVO1 provides a J1 connector to program firmware on the STSPIN32G4. The J1 provides STDC14 pinout featuring both SWD and UART interfaces that simplify communication with the PC through a virtual com port. One STLINK-V3SET debugger/programmer can be mated to J1 using its flat cable. The mating of this flat cable with J1 must be with the plastic notch toward the upper side.

5.4 Speed - position feedback

The EVLSERVO1 supports the following types of sensors for motor position feedback:

1. Digital Hall sensors
2. Quadrature encoder
3. Absolute encoder with SPI or UART compatible communication interface

It is possible to connect and use Hall sensors and the encoder simultaneously.

5.4.1 Hall sensors

Two data transmission modes are supported for Hall sensors:

- Differential mode (default configuration) supporting RS422 standard over H1+/H1-, H2+/H2-, and H3+/H3- terminals of the J9 connector
- Single-ended mode. In this configuration only H1+, H2+, and H3+ terminals are used. To enable this mode, 1 kOhm pull-up resistors R87, R88, and R89 must be mounted and diodes D22, D24, and D26 must be moved to D21, D23, and D25.

Solder jumpers allow to select the sensors supply voltage (only one solder jumper must be mounted):

- SB2 closed for 5 V supply (default configuration)
- SB3 closed for VCC (8 V to 15 V) supply
- SB4 closed for 3.3 V supply.

When using differential mode, the 5 V supply must be used due to current consumption.

The logic level outputs of the three Hall sensors H1, H2, and H3 are connected to the PB6, PB7, and PB8 pins of the microcontroller and can be routed to channels TIM_CH1, TIM_CH2, and TIM_CH3 of timer TIM4 respectively.

5.4.2 Quadrature encoder

Encoder inputs support two data transmission modes:

- Differential mode (default configuration) supporting RS422 standard over A+/A-, B+/B-, and Z+/Z- terminals of the J10 connector
- Single-ended mode. In this configuration only A+, B+, and Z+ signals are used. To enable this mode, diodes D16, D18, and D20 must be moved to D15, D17, and D19.

Solder jumpers allow to select the sensors' supply voltage (only one solder jumper must be mounted):

- SB5 closed for 5 V supply (default configuration)
- SB6 closed for VCC (8 V to 15 V) supply
- SB7 closed for 3.3 V supply.

When using differential mode, the 5 V supply must be used due to current consumption.

The logic level outputs A, B, and Z are connected to the PB4, PB5, and PB3 pins of the microcontroller and can be routed to channels TIM_CH1, TIM_CH2, and TIM_ETR of timer TIM3 respectively.

5.4.3 Absolute encoder

Support for one absolute encoder is provided through the same connector of the quadrature encoder so they are mutually exclusive. The absolute encoder is supported in differential transmission mode supporting RS422/RS485 standards.

For using an absolute encoder with SPI compatible peripheral, the PD2 pin must be set high by the microcontroller. The PB3, PB4, and PB5 pins can be routed to the SPI_SCK, SPI_MOSI, and SPI_MISO channels of the SPI3 peripheral. In this configuration the A+/A- terminals are wired to the encoder data output port, the B+/B- to the encoder data input port, and Z+/Z- to the serial clock. The 120 Ohm termination resistors R84 and R85 must be removed if termination is embedded at encoder side.

For using an absolute encoder with UART compatible interface in half-duplex mode, the PD2 pin is set high during transmission and toggled low for data reception from the encoder. The PB3 pin can be routed to the USART_TXRX channel of the USART2 peripheral that is configured in half-duplex mode using the same line for transmission and reception alternatively. In this configuration only the Z+/Z- terminals are used.

For using an absolute encoder with UART compatible interface in full-duplex mode, the PD2 pin is set high. The PB3 and PB4 pin can be routed respectively to the USART_TX and USART_RX channels of the USART2 peripheral. In this configuration the Z+/Z- terminals are wired to the encoder input port while A+/A- to the encoder output port. The 120 Ohm termination resistors R85 must be removed if termination is embedded at encoder side.

5.5 Current sensing

The EVLSERVO1 board provides the sensing of current flowing through motor windings in both directions as required by the Field Oriented Control algorithm.

With reference to the schematic in Figure 7, the sensing is based on the three operational amplifiers (OPAMPs) U4, U5, and U7. A differential current sensing is implemented for better rejection of common-mode signal.

The OPAMPs' outputs PC1, PC2, and PC3 (test points TP3, TP4, and TP5) can be routed respectively to channel 7, 8, and 9 of both ADC1 and ADC2 to implement current measurements.

According to Eq. (1), the gain of the network is:

Equation 1

$$\frac{V_O}{I} = G \cdot R_S = 20 \cdot 500\mu\Omega = 0.01\frac{V}{A} \quad (1)$$

- V_O is the amplified output voltage
- I is the current flowing through motor winding
- G is the gain of the amplifying network
- R_S is the value of shunt resistor.

Footprints are available to mount filtering capacitors on OPAMPs' feedback (C30, C37, and C41).

5.6 Overcurrent protection

The EVLSERVO1 board implements double protection of the power stage from an overcurrent condition thanks to:

1. Drain-source voltage monitoring of each power MOSFET.
2. Comparator sensing the shunt resistors' current.

5.6.1 Drain-source voltage monitoring

The STSPIN32G4 embeds a circuitry that measures the voltage between the drain and the source of each MOSFET (V_{DS}) and compares it with a specified threshold. When the MOSFET is turned on and its V_{DS} is greater than the threshold, the anomalous condition is detected, and the protection is triggered after a deglitch time: all MOSFETs are turned off whatever the driving inputs.

The threshold is set on the SCREF pins of the STSPIN32G4 at approximately 1.03 V, through the resistor dividers given by R9 and R10.

The STSPIN32G4 provides configurable deglitch filtering time via firmware to 2 µs, 3 µs, 4 µs, and 6 µs (default).

The protections remain latched when triggered: the STSPIN32G4 returns operative forcing all the driving inputs low for at least 100 us or via firmware procedure.

The voltage drop on each low-side MOSFET is measured between its drain and GND, therefore the voltage drop on the shunt resistor contributes to the measure.

Although not recommended, the protections can be disabled replacing R9 with a jumper and removing R10.

For details about V_{DS} monitoring, refer to the STSPIN32G4 datasheet.

5.6.2 Embedded comparator

The EVLSERVO1 board implements overcurrent protection with one comparator integrated in the STSPIN32G4. The motor current is measured via the voltage drop produced on shunt resistors and amplified via a differential gain stage as shown in Section 5.5. When peak current exceeds a selected threshold, the protection is triggered.

The protection requires the configuration of the fast rail-to-rail comparator COMP3. The positive input of the comparator must be connected to the PA0 pin of the microcontroller where the current measures are available while the negative input must be internally connected to DAC3 channel1 to set a proper overcurrent threshold.

The overcurrent threshold can be derived with the following Eq. (2).

Equation 2

$$V_{OC} = \left(\frac{V_{REF+}}{2} + \frac{G \cdot R_S \cdot I_{OC}}{3}\right) \tag{2}$$

- V_{OC} is the overcurrent threshold voltage applied to the comparator negative input through DAC3
- V_{REF+} is the voltage of the VREFP pin (3.3 V by default)
- G is the gain of the sensing stage (20 by default)
- R_S is the value of the shunt resistor (500 µΩ by default).

Overcurrent values computed for different threshold voltages are reported in Table 6.

Table 6. Overcurrent thresholds

Threshold	Peak current
1.65 V+0.2 V	60 A
1.65 V+0.3 V	90 A
1.65 V+0.4 V	120 A

To avoid spurious triggering of the protection, a digital deglitch filtering or blanking can also be configured. For details refer to the STM32G4 reference manual (see www.st.com.)

5.7 Bus voltage sensing

The EVLSERVO1 board provides the sensing of bus voltage that can be used in firmware to protect in case of undervoltage or overvoltage. This signal is set through a voltage divider with attenuation 0.04 by the motor supply voltage (resistors R46 and R47) and sent to the PA1 pin of the microcontroller. PA1 can be connected to the positive input of comparator COMP1 or to channel 2 of both ADC1 and ADC2.

5.8 PCB temperature sensing

The board provides one NTC thermistor placed in proximity to the power stage to sense the temperature of the surrounding MOSFETs. The thermistor can be used in firmware to implement thermal shutdown and protect the power stage in case of overheating. The NTC signal is available on the PC0 pin of the MCU and can be routed to channel 6 of both ADC1 and ADC2.

The following Eq. (3), derived from the β model of the NTC thermistor, can be used to obtain a temperature estimate from the voltage value on PC0:

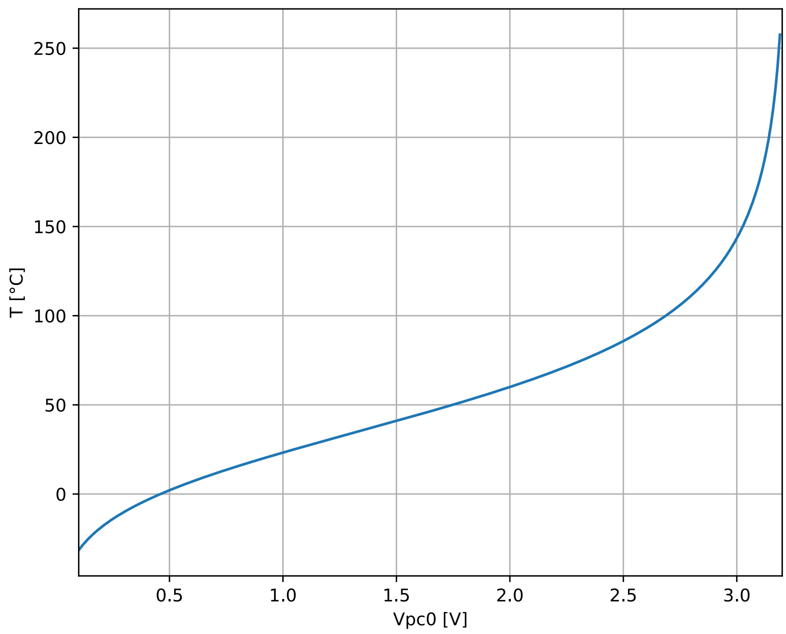
Equation 3

$$T(V_{PC0}) = \frac{1}{\frac{1}{\beta} \cdot ln\left(\frac{R52 \cdot \left(\frac{V_{REFP}}{V_{PC0}} - 1\right) - R53}{R^0_{NTC}}\right) + \frac{1}{T^0}} \quad (3)$$

- $T(V_{PC0})$ is the estimated temperature in Kelvin
- V_{PC0} is the voltage on the PC0 pin
- β is 3455 K, the β constant of the selected NTC thermistor in the range 25 °C – 100 °C
- R^0_{NTC} is 10 kΩ, the thermistor resistance at 298 K
- T^0 is 298 K.

The plot of Eq. (3) above is shown in Figure 4.

Figure 4. Thermistor temperature with respect to voltage on PC0 pin



5.9 CAN bus

The CAN bus is available on the board.

The STSPIN32G4 integrates one FDCAN communication interface to manage the data layer of the CAN protocol. The interface is compliant with ISO 11898-1: 2015 (CAN protocol specification version 2.0 part A, B) and CAN FD protocol specification version 1.0. The physical layer of the CAN protocol is managed by an external transceiver, the TCAN330.

Terminals for CAN bus are available via the J11 connector.

5.10 Regenerative braking

The EVLSERVO1 allows the motor to actively slow down the mechanical load via regenerative braking. During regenerative braking the mechanical power of the load is transferred to the motor and in turn converted to electrical power that is injected into the inverter main supply.

This power injection results in an increase of the main bus voltage during the entire braking phase. The EVLSERVO1 provides dedicated circuitry to keep the bus voltage below a configurable threshold and ensure continuity of braking function. This is obtained by dissipating the extra electrical power via an external resistor (not provided with the system) that must be connected to terminals CON2 and CON5 of the SERVO_INV1 board.

The comparator U6 implements a thresholding of the VM bus voltage with hysteresis. When the VM turning-on voltage is reached, the external resistor is connected between the bus voltage and ground and remains connected up to the turning-off threshold is reached. The system performs a chopping to discharge VM voltage with intervention completely by hardware. It is possible to change intervention thresholds for the breaking circuitry referring to Figure 7 and following:

Equation 4

$$\boldsymbol{VM_{on}} = \frac{\boldsymbol{R}59 + \boldsymbol{R}60}{\boldsymbol{R}60} \cdot \frac{\boldsymbol{R}62}{\boldsymbol{R}62 + \boldsymbol{R}61 \backslash\backslash \boldsymbol{R}63} \cdot 3.3\boldsymbol{V} \tag{4}$$

$$\boldsymbol{VM_{off}} = \frac{\boldsymbol{R}59 + \boldsymbol{R}60}{\boldsymbol{R}60} \cdot \frac{\boldsymbol{R}62 \backslash\backslash \boldsymbol{R}63}{\boldsymbol{R}61 + \boldsymbol{R}62 \backslash\backslash \boldsymbol{R}63} \cdot 3.3\boldsymbol{V}$$

- $\boldsymbol{VM_{on}}$ is the bus voltage turning-on threshold for the external resistor (65 V by default)
- $\boldsymbol{VM_{off}}$ is the bus voltage turning-off threshold for the external resistor (default 62 V).

Engaging of the external resistor is also possible by firmware setting high pin PB10 of the microcontroller.

The external resistor should be selected according to the target power dissipation during regenerative braking. When selecting the power resistor, it should be noted that a significant short term overload for dissipated power is typically allowed, if intervention time is limited to a few seconds. This allows to select a smaller resistor in case braking phases are limited and enough time is available for cooling down of the power resistor. If, for example, a given resistor has a 200 W power rating with 10X overload for 5 seconds, then a peak power up to 2 kW could be dissipated every 500 seconds according to the following:

Equation 5

$$\boldsymbol{T} = \boldsymbol{T_{on}}\left(\frac{\boldsymbol{P_{brk}}}{\boldsymbol{P_{rms}}}\right)^2 \tag{5}$$

- $\boldsymbol{T}$ is the period for the pulsed intervention of braking resistor
- $\boldsymbol{T_{on}}$ is the turning-on time of the braking resistor
- $\boldsymbol{P_{brk}}$ is the power dissipated during braking
- $\boldsymbol{P_{rms}}$ is the power rating of the braking resistor.

The resistance value of the external resistor should be sized to obtain the peak power during braking according to Eq. (6)

Equation 6

$$\boldsymbol{R_{ext}} < \frac{\boldsymbol{VM_{max}^2}}{\boldsymbol{P_{brk}}} \tag{6}$$

- $\boldsymbol{R_{ext}}$ is the resistance value for the external resistor
- $\boldsymbol{P_{brk}}$ is the power dissipated during braking
- $\boldsymbol{VM_{on}}$ is the bus voltage turning-on threshold for the external resistor (65 V by default).

6 Bill of material

Table 7. **SERVO_CTRL1 board bill of material**

Item	Q.ty	Reference	Description	Value
1	1	CN1	1.27 mm dual pin socket 2x4	62200821821
2	1	CN2	1.27 mm dual pin socket 2x4	62200821821
3	1	CN3	1.27 mm dual pin socket 2x2	62200421821
4	5	C1, C31, C43, C44, C45	SMT ceramic capacitor 0402	1 nF, 6.3 V, 10%
5	2	C2, C4	SMT ceramic capacitor 1210	2.2 u, 100 V, 10%
6	15	C3, C5, C7, C8, C10, C12, C32, C36, C38, C40, C42, C46, C47, C48, C49	SMT ceramic capacitor 0402	100 nF, 6.3 V, 10%
7	1	C6	SMT ceramic capacitor 0603	2.2 uF, 6.3 V, 10%
8	1	C9	SMT ceramic capacitor 0805	220 nF, 100 V, 10%
9	2	C11, C27	SMT ceramic capacitor 0402	220 nF, 25 V, 10%
10	4	C13, C30, C37, C41	SMT ceramic capacitor 0402	N.M.
11	4	C14, C15, C16, C26	SMT ceramic capacitor 0603	1 uF, 25 V, 10%
12	1	C17	SMT ceramic capacitor 0805	2.2 nF, 100 V, 10%
13	1	C18	SMT ceramic capacitor 0402	1 nF, 50 V, 10%
14	1	C19	SMT ceramic capacitor 0402	270 pF, 6.3 V, 10%
15	1	C20	SMT ceramic capacitor 1206	1 uF, 100 V, 10%
16	1	C21	SMT ceramic capacitor 0402	7.5 nF, 10 V, 10%
17	1	C22	SMT ceramic capacitor 0603	22 nF, 25 V, 10%
18	1	C23	SMT ceramic capacitor 0805	100 nF, 100 V, 10%
19	1	C24	SMT ceramic capacitor 0402	120 nF, 6.3 V, 10%
10	1	C25	SMT ceramic capacitor 0805	10 uF, 25 V, 10%
21	1	C28	SMT ceramic capacitor 1210	22 uF, 10 V, 10%
22	4	C29, C33, C35, C39	SMT ceramic capacitor 0402	33 nF, 6.3 V, 10%
23	1	C34	SMT ceramic capacitor 0603	1 uF, 6.3 V, 10%
24	2	C50, C51	SMT ceramic capacitor 0603	100 nF, 25 V, 10%
25	5	D1, D2, D3, D11, D12	Small signal Schottky diode	BAT46
26	6	D4, D5, D6, D7, D8, D9	Small signal Schottky diode	BAT48
27	1	D10	100 V - 1 A power Schottky trench rectifier	STPST1H100
28	8	D13, D14, D16, D18, D20, D22, D24, D26	Small signal Schottky diode	BAT30K
29	6	D15, D17, D19, D21, D23, D25	Small signal Schottky diode	N.M.
20	1	J1	Surface mount micro header (1.27 mm) 0.050" pitch FTSH series	FTSH-107-01-L-DH
31	4	J2, J3, J6, J7	1.27 mm dual pin header 2x4	N.M.
32	5	J4, J5, J8, J9, J10	1.27 mm dual pin header 2x4	62130821021
33	1	J11	1.27 mm dual pin header 2x2	62130421021
34	1	LED1	SMT mono-color chip LED	YELLOW
35	1	LED2	SMT mono-color chip LED	RED
36	1	L1	WE-PD SMT shielded power inductor	18 uH, 1.41 A, 20%

Item	Q.ty	Reference	Description	Value
37	1	L2	WE-PD performance SMT shielded power inductor	15 uH, 2.2 A, 20%
38	1	L3	WE-CBF SMT EMI suppression ferrite bead 0805	1 k, 1 A, 25%
39	1	Q1	100 V P-channel enhancement mode MOSFET	ZXMP10A13FT
40	1	Q2	N-channel enhancement mode MOSFET	BSS123WQ
41	1	Q3	Field effect transistor silicon N-channel MOS type (U-MOS III)	SSM3K15AFU
42	1	Q4	20 V N-channel enhancement mode MOSFET	DMN2056U
43	2	Q5, Q6	N-channel 100 V, 0.062 ohm typ., 4 A STripFET VII DeepGATE power MOSFET	STL3N10F7
44	1	Q7	Field effect transistor silicon P-channel MOS type	SSM3J15FV
45	2	R1, R4	SMT resistor 0402	100 k, 64 mW, 5%
46	1	R2	SMT resistor 0402	120, 64 mW, 5%
47	2	R3, R5	SMT resistor 0402	200, 64 mW, 5%
48	3	R6, R7, R8	SMT resistor 0603	10, 100 mW, 5%
49	1	R9	SMT resistor 0402	22 k, 64 mW, 1%
50	3	R10, R61, R62	SMT resistor 0402	10 k, 64 mW, 1%
51	1	R11	SMT resistor 0603	30, 100 mW, 5%
52	10	R12, R14, R16, R18, R19, R20, R21, R23, R25, R27	SMT resistor 0603	0
53	6	R13, R15, R17, R22, R24, R26	SMT resistor 0603	15, 100 mW, 5%
54	1	R28	SMT resistor 0805	10 k, 250 mW, 5%
55	1	R29	SMT resistor 0402	220 k, 64 mW, 5%
56	1	R30	SMT resistor 0402	19.6 k, 64 mW, 1%
57	1	R31	SMT resistor 0402	3.74 k, 64 mW, 1%
58	1	R32	SMT resistor 0402	680, 64 mW, 1%
59	2	R33, R35	SMT resistor 0402	22 k, 64 mW, 5%
60	1	R34	SMT resistor 0402	2.7 k, 64 mW, 1%
61	1	R36	SMT resistor 0402	2.2, 64 mW, 5%
62	1	R37	SMT resistor 0402	20.5 k, 64 mW, 1%
63	1	R38	SMT resistor 0402	47 k, 64 mW, 5%
64	1	R39	SMT resistor 0402	1 k, 64 mW, 5%
65	1	R40	SMT resistor 0402	N.M.
66	1	R41	SMT resistor 0402	825, 64 mW, 1%
67	6	R42, R43, R54, R55, R64, R65	SMT resistor 0402	2.55 k, 64 mW, 1%
68	6	R44, R45, R56, R57, R66, R67	SMT resistor 0402	102 k, 64 mW, 1%
69	1	R46	SMT resistor 0402	72.3 k, 64 mW, 1%
70	1	R47	SMT resistor 0402	3.01 k, 64 mW, 1%
71	3	R48, R49, R50	SMT resistor 0402	1 k, 64 mW, 1%
72	3	R51, R58, R69	SMT resistor 0402	51 k, 64 mW, 1%
73	1	R52	SMT resistor 0402	4.7 k, 64 mW, 1%
74	1	R53	SMT resistor 0402	100, 64 mW, 5%
75	1	R59	SMT resistor 0402	75 k, 64 mW, 1%

Item	Q.ty	Reference	Description	Value
76	1	R60	SMT resistor 0402	2 k, 64 mW, 1%
77	1	R63	SMT resistor 0402	200 k, 64 mW, 1%
78	11	R68, R70, R71, R72, R73, R74, R75, R76, R77, R78, R79	SMT resistor 0402	10 k, 64 mW, 5%
79	7	R80, R81, R82, R83, R84, R85, R86	SMT resistor 0603	120, 250 mW, 5%
80	3	R87, R88, R89	SMT resistor 0402	N.M.
81	3	SB1, SB2, SB5	SMT resistor 0603	0
82	4	SB3, SB4, SB6, SB7	SMT resistor 0603	N.M.
83	2	SW1, SW2	WS-TASU SMT tact switch	434351045816
84	1	TP1	40x71 mils SMD PAD	S1751-46R
85	1	TP2	TP for probe	N.M.
86	3	TP3, TP4, TP5	Test point - PCB 1.5 mm diameter	N.M.
87	1	U1	3-phase brushless motor controller embedding STM32G4 MCU	STSPIN32G4
88	1	U2	1 A low-side gate driver with configurable asymmetric sink/source	PM8851
89	1	U3	Wide 6 V to 75 V input voltage synchronous buck controller	L3751
90	3	U4, U5, U7	High bandwidths (20 MHz for gain = 4) micro-power (820 μA) rail-to-rail 5 V op amp	TSV991AIQ
91	1	U6	Rail-to-rail high-speed comparator	TS3011IYQ
92	2	U8, U9	3.3 V RS-485 compatible with 1.8 V I/Os and selectable speed 20 Mbps or 250 kbps	STR485E
93	1	U10	CMOS quad 3-state differential line receiver	ST26C32AB
94	1	U11	TCAN33x 3.3-V CAN transceivers with CAN FD (Flexible Data Rate)	TCAN330DCNT
95	1	Y1	1.8V-3.3V low-power precision CMOS oscillators	24 MHz, 10 ppm

Table 8. SERVO_INV1 board bill of material

Item	Q.ty	Reference	Description	Value
1	7	CON1, CON2, CON3, CON4, CON5, CON6, CON7	4 mm hole for power connection	N.M.
2	2	C1, C2	THT electrolytic capacitor	820 uF, 100 V, 20%
3	12	C5, C10, C12, C13, C14, C17, C18, C23, C24, C25, C26, C29	SMT ceramic capacitor	2.2 u, 100 V, 10%
4	13	C6, C7, C8, C9, C11, C19, C20, C21, C22, C30, C31, C32, C33	SMT ceramic capacitor	N.M.
5	1	D1	3 A - 100 V power Schottky rectifier	STPS3H100
6	1	HS1	Heatsink 50 mm x 50 mm x 25 mm with mounting holes at 43 mm x 43 mm	ATS-CPX050050025-124-C1-R0
7	3	J1, J2, J3	WR-PHD 1.27 mm SMT straight dual socket header WR-PHD	62330821021
8	1	NTC1	NTC thermistor	10 k, 1%
9	4	NT1, NT2, NT3, NT4	M3 hexagonal nut	M3

Item	Q.ty	Reference	Description	Value
10	13	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13	N-channel enhancement mode standard level 100 V, 4.6 mOhm max., 125A, STripFET F8 power MOSFET	STL160N10F8
11	13	R3, R4, R5, R6, R8, R11, R12, R13, R14, R18, R19, R20, R21	SMT resistor	4.7, 100 mW, 5%
12	3	R7, R15, R22	Power metal strip resistors, Low value, high power, surface-mount, 4-Terminal	500 µ, 3 W, 1%
13	4	SC1, SC2, SC3, SC4	M3 cheese-head screw	M3x1 6 mm
14	4	SP1, SP2, SP3, SP4	M3 Round brass spacers 7 mm	963070042
15	1	TIM1	Thermally conductive Gap filler, 150x150 mm sp.0.5 mm. 1/9 of a panel needed	707-4645

7 Schematics

Figure 5. SERVO_CTRL1 board schematic (1 of 4): STSPIN32G4

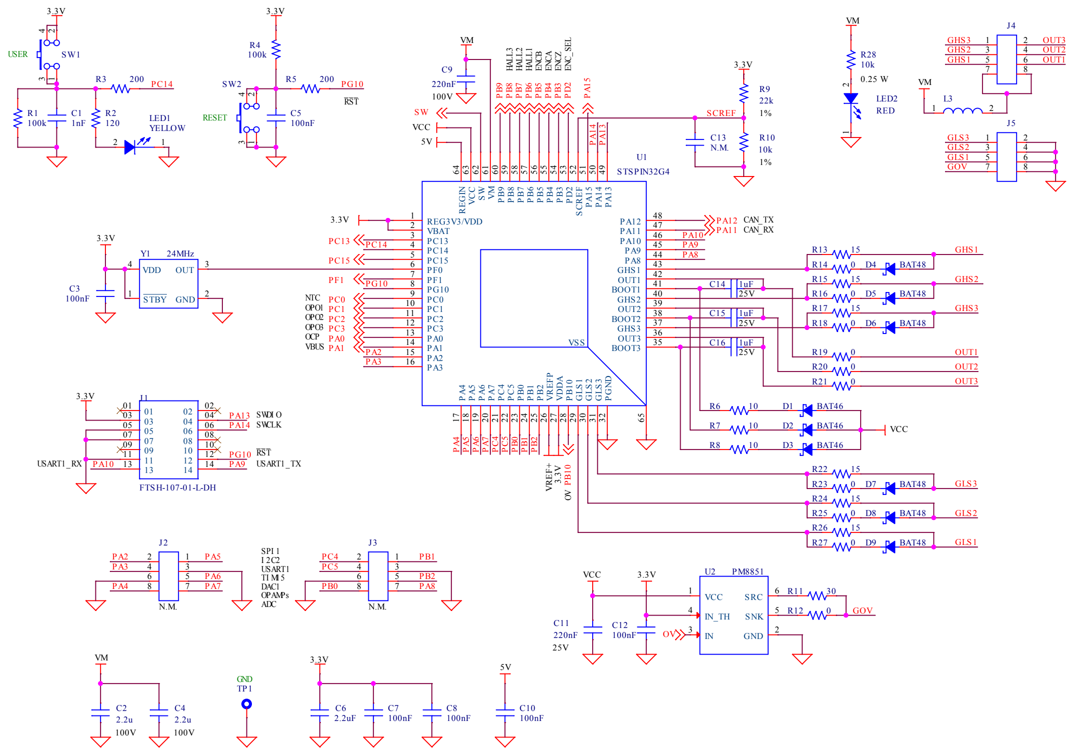


Figure 6. SERVO_CTRL1 board schematic (2 of 4): regulators

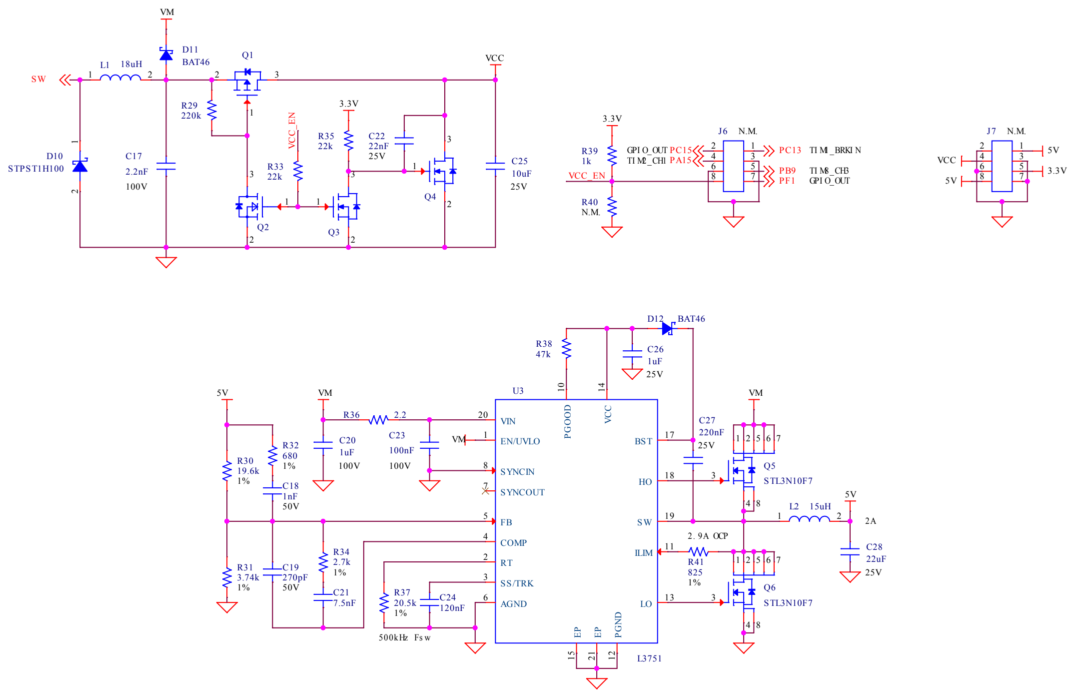


Figure 7. SERVO_CTRL1 board schematic (3 of 4): sensing

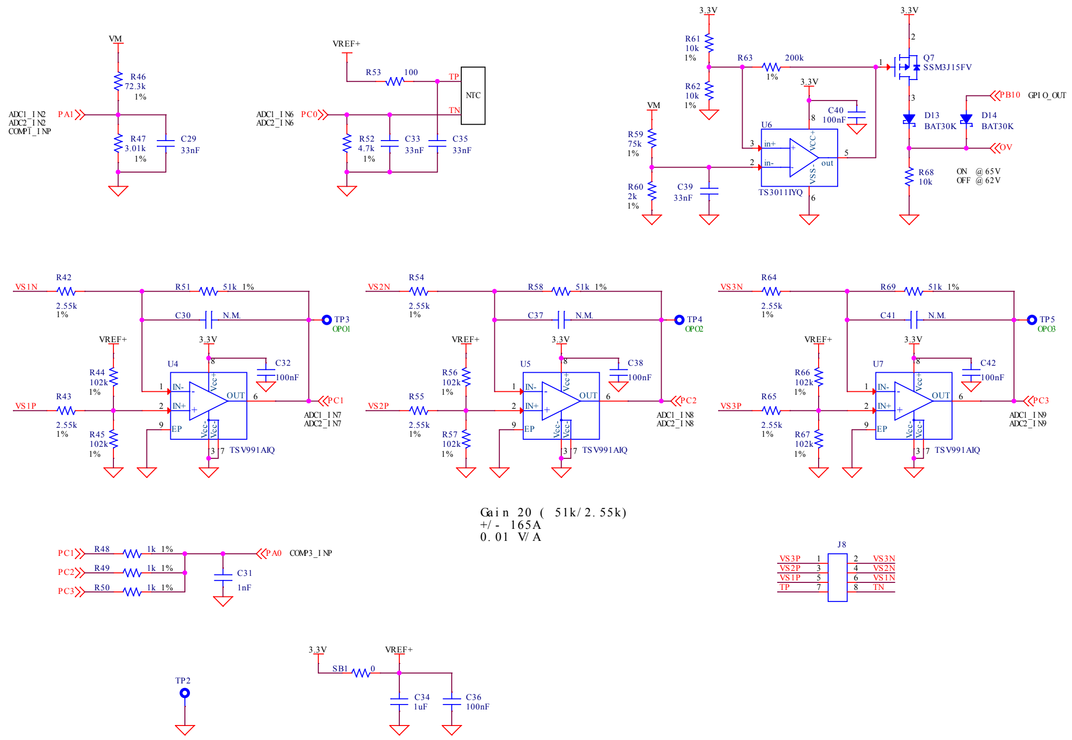


Figure 8. SERVO_CTRL1 board schematic (4 of 4): HALL sensors, encoder, CAN bus

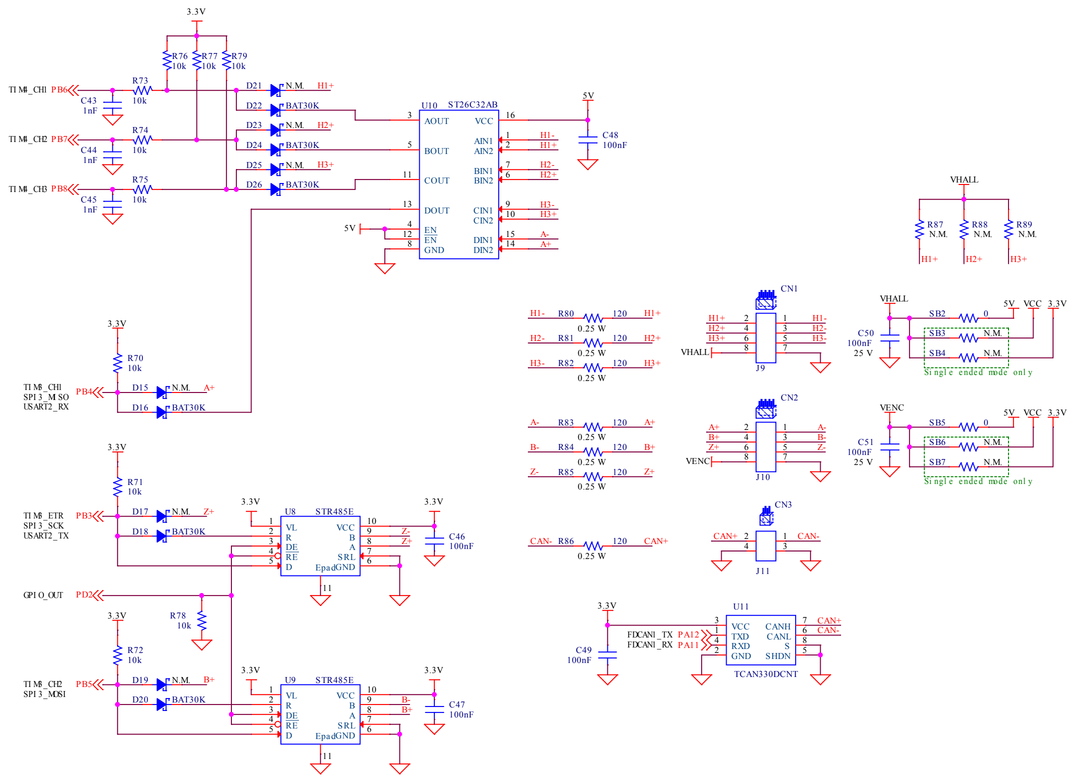
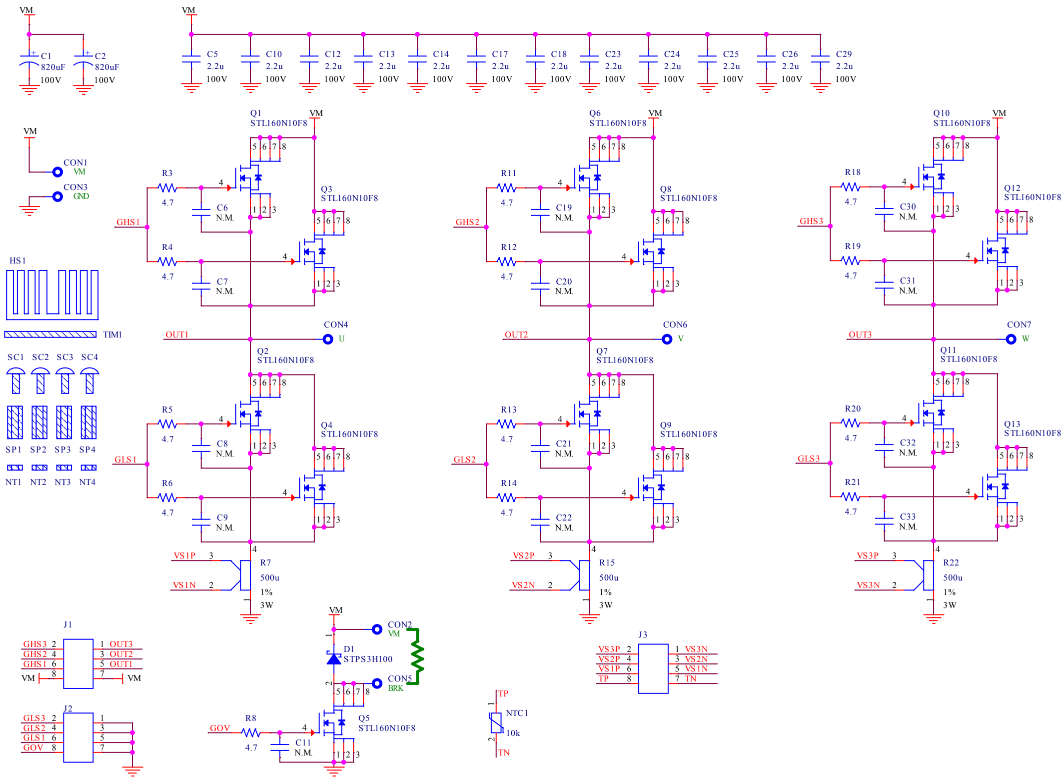


Figure 9. SERVO_INV1 board schematic (1 of 1): power stage



Revision history

Table 9. Document revision history

Date	Version	Changes
14-Nov-2024	1	Initial release.

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