EVALSTDRIVE601: 3-phase power board based on STDRIVE601

Introduction

The EVALSTDRIVE601 board is a 3-phase power board based on the STDRIVE601 triple gate driver. The power stage features STGD6M65DF2 IGBTs, but can be populated with any IGBT or power MOSFET in DPAK or powerFLAT 8x8 HV package.

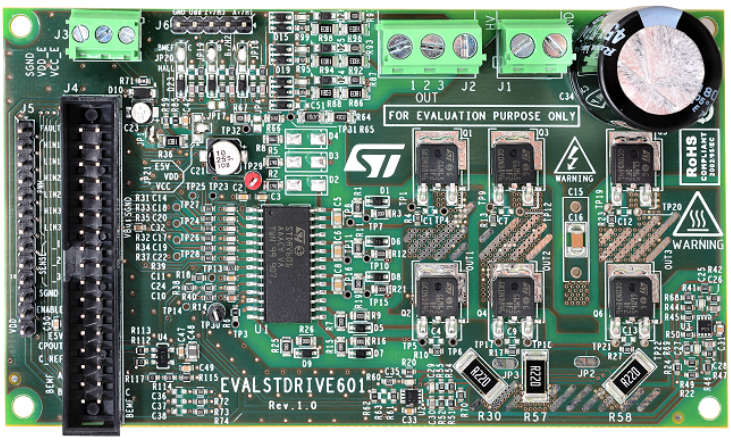
The board is designed to support a 3-shunt or a single-shunt current sensing topology. It allows to execute a 6-Step or FOC algorithm in either sensorless or sensored mode. A strip connector allows easy interfacing with an MCU control board, such as an STM32 Nucleo board. This allows driving permanent magnet synchronous motors (PMSMs) and brushless DC (BLDC) motors.

The board includes three power supply domains:

- HV : high voltage power supply, used by the power bridge to drive the load;
- VCC : driver power supply, used to supply the driver and, optionally, external Hall sensors
- VDD (+3.3 V) : logic power supply, used for onboard OpAmps power supply and logic interfacing with an external MCU

Debug and configuration of firmware can be performed with standard STM32 tools through an STLINK debugger on the Nucleo control board.

Figure 1. EVALSTDRIVE601- Evaluation board



1 Main features

The EVALSTDRIVE601 has the following features:

- Input voltage VCC from 9 V_{DC} to 20 V_{DC}
- High voltage rail up to 600 V_{DC} (limited to ~400 V_{DC} due to onboard components)
- 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 package:
  - PowerFlat 8x8
  - DPAK
- Configurable overcurrent protection threshold (5.5 A_{peak} default)
- Selectable single or 3-shunt current sensing topology, suitable for:
  - Single-shunt/3-shunt vector (FOC) algorithm and 6-step algorithm
- Digital Hall sensors and encoder input for sensored control algorithm
- BEMF detection network for 6-step sensorless control algorithm
- Smart shutdown overcurrent protection
- Bus voltage sensing
- 450 V bulk capacitor
- 34-pin connector for MCU interfacing
- RoHS compliant

1.1 Target applications

- 3-phase motor drives
- Fans
- Pumps
- Refrigerator compressors
- Industrial inverters

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.

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.

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 heatsinks and transformers may still be very hot.

3. Personal Safety

- Always wear suitable personal protective equipment such as 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 insulating box with interlocks if necessary.

Warning:

The kit is not electrically isolated from the AC/DC input. The USB interface of any board connected to the EVALSTDRIVE601 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 Hardware and software requirements

Using the EVALSTDRIVE601 evaluation board requires the following software and hardware:

- A windows PC (XP, Vista, Win 7, Win 8, Win 10) to install the software package
- An STM32 Nucleo board with related USB cable to be connected to the PC by means of a usb isolator
- X-NUCLEO-IHM09M1: Motor control connector expansion board for STM32 Nucleo, to easily connect the EVALSTDRIVE601 board to the Nucleo board via ST morpho connector
- A 6-step firmware package or the STM32 PMSM FOC Software Development Kit (available on www.st.com)
- A 3-phase BLDC or PMSM motor with compatible voltage and current ratings
- External DC power supply.

The EVALSTDRIVE601 can even be used as a standalone board connected to a 3-phase load by directly driving driver's input signals through the onboard connector.

4 Getting started

The maximum ratings of the board are the following:

- Power stage supply voltage up to 400 V_{DC} (limited by onboard bulk capacitor)
- Overcurrent protection threshold set to 5.5 A_{peak} (configurable).

To start your project with the board:

- Check the jumper position according to the target configuration (see Section 5).
- Connect the Nucleo board to the EVALSTDRIVE601 through the expansion board
  - Connect motor phases to terminals J2.1, J2.2, J2.3 taking care of the motor phases' sequence.
  - Supply the board through connector J1 (HV) and J3 (VCC), taking care of correct polarity.

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. EVALSTDRIVE601 – Board function description – TOP view

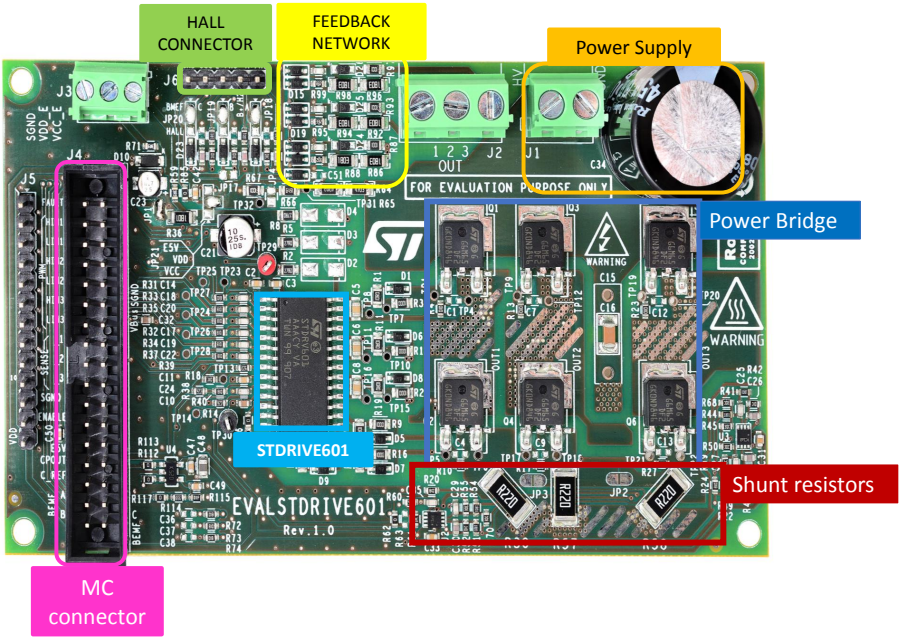


Figure 3 shows the position of the connectors and jumpers of the board.

Figure 3. EVALSTDRIVE601 – Main components and connectors position

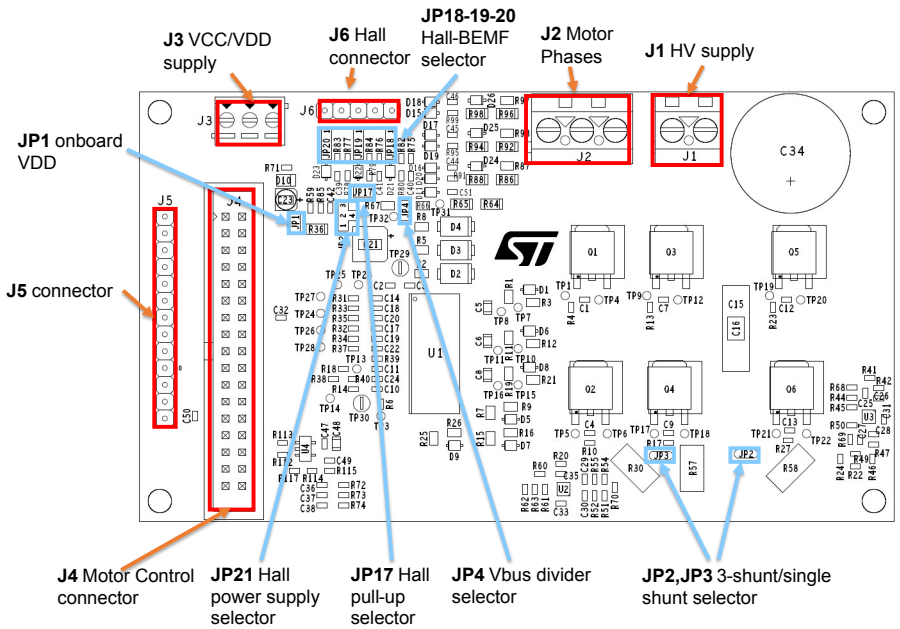


Table 1. Jumpers Hardware setting

Jumper	Description	Default Condition
JP1	Onboard VDD generation	CLOSED
JP2	SENSE 2-3 connection	OPEN
JP3	SENSE 1-2 connection	OPEN
JP4	HV divider selection: 126.5 (OPEN) or 145.8 (CLOSED)	OPEN
JP17	Power supply for Hall sensors pull-up	CLOSED
JP18	Selection MCU input connected to BEMF phase 1 (1-2 CLOSED) or Hall A (2-3 CLOSED)	1-2 CLOSED
JP19	Selection MCU input connected to BEMF phase 2 (1-2 CLOSED) or Hall B (2-3 CLOSED)	1-2 CLOSED
JP20	Selection MCU input connected to BEMF phase 3 (1-2 CLOSED) or Hall C (2-3 CLOSED)	1-2 CLOSED
JP21	Hall sensors' power selection to VCC (1-2 CLOSED), VDD (2-4 CLOSED) or 5 V (2-3 CLOSED)	2-4 CLOSED

Table 2. Connectors and test points description

Name	Pin	Label	Description
J1	1-2	HV-PGND	External high voltage supply terminal block
J2	1	OUT 1	Motor phases connections
	2	OUT 2	
	3	OUT 3	
J3	1	VCC_E	Driver power supply
	2	VDD_E	MCU/Logic power supply
	3	SGND	Driver ground
J4	1	FAULT	Driver FAULT signal
	2, 4, 6, 8, 10, 12, 16, 18, 20, 22, 24, 30, 32	SGND	GND
	3	HIN1	Driver HIN1
	5	LIN1	Driver LIN1
	7	HIN2	Driver HIN2
	9	LIN2	Driver LIN2
	11	HIN3	Driver HIN3
	13	LIN3	Driver LIN3
	14	VBus	Vbus feedback to MCU
	15	SENSE_1	Sense_1 to MCU
	17	SENSE_2	Sense_2 to MCU
	19	SENSE_3	Sense_3 to MCU
	21		GPIO_BEMF divider enable from MCU
	23	ENABLE	Driver enable signal from MCU

Name	Pin	Label	Description
J4	25	E5V	External 5V for Hall power supply
	26		NC
	27	CPOUT	Current Comparator output (CPOUT) signal to MCU
	28		VDD
	29	C_REF	Current Reference signal from MCU
	31	BEMF A	BEMF OUT1 or Hall A signal to MCU
	33	BEMF B	BEMF OUT2 or Hall B signal to MCU
	34	BEMF C	BEMF OUT3 or Hall C signal to MCU
J5	1	J5	Driver FAULT signal
	2		Driver HIN1
	3		Driver LIN1
	4		Driver HIN2
	5		Driver LIN2
	6		Driver HIN3
	7		Driver LIN3
	8		Sense_1 to MCU
	9		Sense_2 to MCU
	10		Sense_3 to MCU
	11		GND
	12		Driver enable signal from MCU
	13		VDD
J6	1	A+/H1	Hall/encoder sensors connector
	2	B+/H2	
	3	Z+/H3	
	4	Udd	Hall sensors/encoder supply
	5	GND	

Table 3. Test points description

Name	Label	Description
TP1		Phase 1 high-side gate
TP2		W phase
TP3	PGND	Power GND
TP4		Phase 1
TP5		Phase 1 low-side gate
TP6		SENSE 1
TP7		HVG1
TP8		OUT1
TP9		Phase 2 high-side gate
TP10		HVG2

Name	Label	Description
TP11		OU2
TP12		Phase 2
TP13	CIN	CIN – comparator positive input
TP14	OD	OD – SmartSD Open Drain output, unlatch and restart input
TP15		HVG3
TP16		OUT3
TP17		Phase 2 low-side gate
TP18		SENSE 2
TP19		Phase 3 high-side gate
TP20		Phase 3
TP21		Phase 3 low-side gate
TP22		SENSE3
TP23		HIN1
TP24		LIN1
TP25		HIN2
TP26		LIN2
TP27		HIN3
TP28		LIN3
TP29		VCC
TP30	SGND	Signal GND
TP31		Vbus feedback
TP32		Signal GND

6 Board description

6.1 Sensorless

To configure the evaluation board for 6-step sensorless mode, the BEMF detection network must be enabled. Jumpers must be set in the following way:

- JP18 pins 1-2 CLOSED, MCU ADC channel connected to Bemf phase 1
- JP19 pins 1-2 CLOSED, MCU ADC channel connected to Bemf phase 2
- JP20 pins 1-2 CLOSED, MCU ADC channel connected to Bemf phase 3.

6.2 Hall/Encoder motor speed sensor

The EVALSTDRIVE601 evaluation board supports the digital Hall and quadrature encoder sensors for motor position feedback.

Sensors can be connected through the J6 connector as listed in the following table.

Table 4. Hall/Encoder connector (J6)

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
Udd	4	Sensors supply voltage (default VDD)
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 by means of jumper JP17.

Jumper JP21 selects the power supply for sensor supply voltage:

- JP21 pins 2-4 CLOSED (default): Hall sensors powered by VDD (3.3 V)
  - JP21 pins 2-1 CLOSED: Hall sensors powered by VCC
  - JP21 pins 2-3 CLOSED: Hall sensors powered by external 5 V.

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

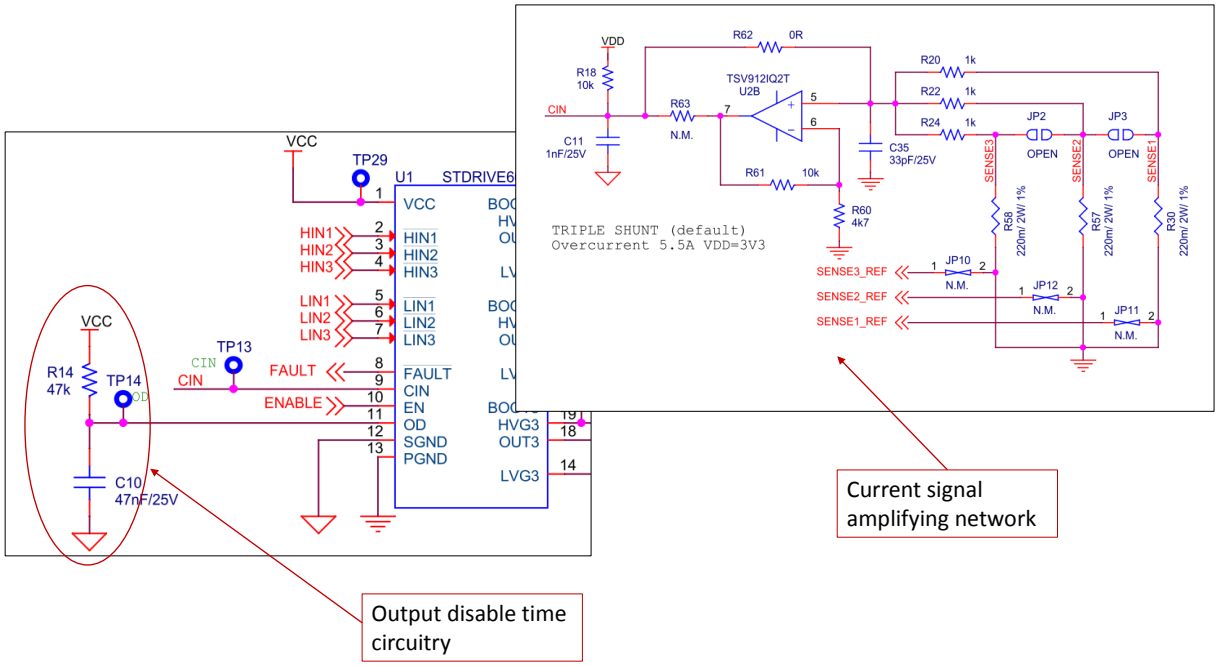
- JP18 pins 2-3 CLOSED, MCU ADC channel connected to Hall1
- JP19 pins 2-3 CLOSED, MCU ADC channel connected to Hall2
- JP20 pins 2-3 CLOSED, MCU ADC channel connected to Hall3.

6.3 Overcurrent detection and current sensing measurement

The EVALSTDRIVE601 evaluation board implements overcurrent protection based on the STDRIVE601 integrated comparator. Shunt resistors measure the load current bringing the voltage signal associated to load current and amplified by U2B OpAmp to CIN pin (TP13).

By default, the amplifying network is disabled, and the signal is brought directly from shunts to CIN pin through R62 resistor. When the sum of the voltages produced by currents flowing in the shunts and the offset due to R18 resistor exceeds the internal comparator threshold (460 mV typical), the integrated comparator is triggered, and all 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. **EVALSTDRIVE601 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 ~735 us for VCC = 12 V.

Overcurrent threshold can be modified changing R18 bias resistor, R20, R22, R24 loop resistors and R30, R57 and R58 shunt resistors according to the following formulas:

V_{REF_typ} = 460mV, VDD = 3.3 V, R_{SHUNT} = R30=R57=R58 = 220 mΩ, R_{PU} = 10 kΩ, R_{LOOP} = R20=R22=R24 = 1 kΩ

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

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

The *output disable time* can be monitored on the OD pin (TP14) and is determined mainly by the time required to recharge C10 capacitor up to the V_{SSDh} threshold, according to the formula:

V_{SSDh} = 3.8V, V_{SSDl} = 0.56V, V_{OD} = VCC

$$t_2 \cong C10 \cdot R14 \cdot \ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right)$$

6.4 Bus voltage circuit

The EVALSTDRIVE601 evaluation board provides the bus voltage sensing. This signal is set through a voltage divider (R64 to R67) from motor supply voltage (HV) and sent to the corresponding MCU ADC channel.

The default voltage divider is set to 126.5 and can be configured through JP4.

6.5 Debug

The EVALSTDRIVE601 evaluation board can be connected to an external Nucleo board with embedded 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 the UART pins of the ST-LINK MCU (UART1)
- Mass storage interface on USB.

The power supply for ST-LINK is provided by the host PC.

The programming/debugging phase of the MCU can be performed through Serial Wire interface available on the Nucleo Board. Please refer to the relevant Nucleo board user manual for additional details.

7 References

This user manual provides information on the hardware features and use of the EVALSTDRIVE601 evaluation board. For additional information refer to:

- EVALSTDRIVE601 Databrief (schematic, bill of material, layout)
- STDRIVE601 Datasheet
- STGD6M65DF2 Datasheet
- User manual of STM32 Nucleo board

Revision history

Table 5. **Document revision history**

Date	Version	Changes
29-Oct-2020	1	Initial release.

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