Getting started with the STEVAL-ESC002V1 electronic speed controller reference design

Introduction

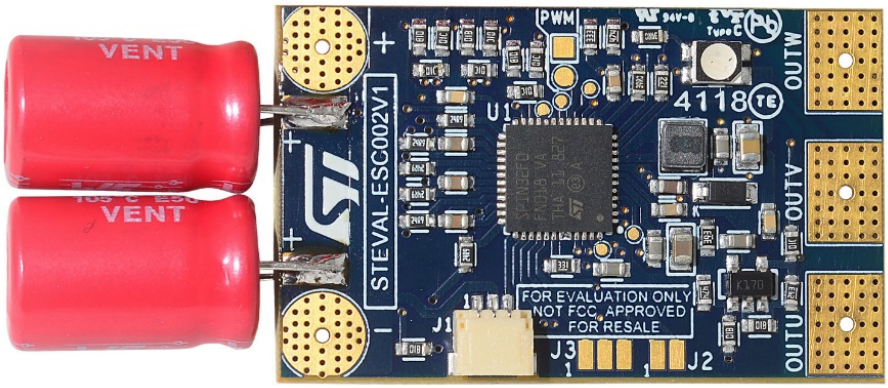
The STEVAL-ESC002V1 electronic speed controller (ESC) reference design can be used with different kind of drones, from small racing ones to bigger light drones used for surveying and any 3-phase BLDC application requiring a compact form factor and high speed rotation performance.

Together with the STSW-ESC002V1 firmware package, it implements a sensorless voltage mode six-step driving.

The board is based on the STSPIN32F0A advanced 3-phase brushless motor controller that embeds an ARM® Cortex®-M0 processor, voltage regulators, signal conditioning circuitry and gate drivers in a small 7x7 mm2 QFN package.

Power stage is based on the low resistance (2.8 mΩ) and high speed STL140N6F7 MOSFETs, designed in STripFET™ F7 technology and able to deliver up to 20 A of continuous current.

Figure 1. STEVAL-ESC002V1 reference design: top view with bulk capacitors mounted



1 Safety precautions

Warning:
Some of the components mounted on the board could reach hazardous temperature during operation.

While using the board:

- Do not touch the components
- Do not cover the board
- Do not put the board in contact with flammable materials or with materials releasing smoke when heated

After operation, allow the board to cool down before touching it.

2 Main features and target applications

The STEVAL-ESC002V1 reference design features:

- Based on the STSPIN32F0A:
  - Extended operating voltage from 6.7 to 45 V
  - Three-phase gate drivers with 600 mA sink/source capability and integrated bootstrap diode
  - 32-bit ARM® Cortex®-M0 core operating up to 48 MHz clock frequency
  - 4-kByte SRAM and 32-kByte Flash memory with option bytes used for write/readout protection
  - 3.3. V buck converter with overcurrent, short-circuit, and thermal protection
  - 12 V LDO linear regulator with thermal protection
  - 3 rail-to-rail operation amplifiers for signal conditioning
  - Comparator for overcurrent protection with programmable threshold
  - UVLO protection on each power supply
  - Extended temperature range: -40 to +125 °C
- Designed for sensorless six-step driving with BEMF sensing through operational amplifiers embedded in the STSPIN32F0A
- 2S to 6S LiPo battery pack
- Output current up to 20 A_{RMS}
- Overcurrent protection
- Battery voltage sensing
- UART and I²C interfaces
- RGB LED
- SWD interface to program and debug
- Embedded bootloader
- Very compact and light design: 25 x 40.5 mm PCB size
- RoHS and WEEE compliant

The STEVAL-ESC002V1 reference design mainly targets light drones for professional and recreational purposes, and any 3-phase brushless application requiring a high speed rotation performance.

3 Hardware overview

The STEVAL-ESC002V1 drives a single three-phase brushless motor.

Figure 2. STEVAL-ESC002V1 components (top view)

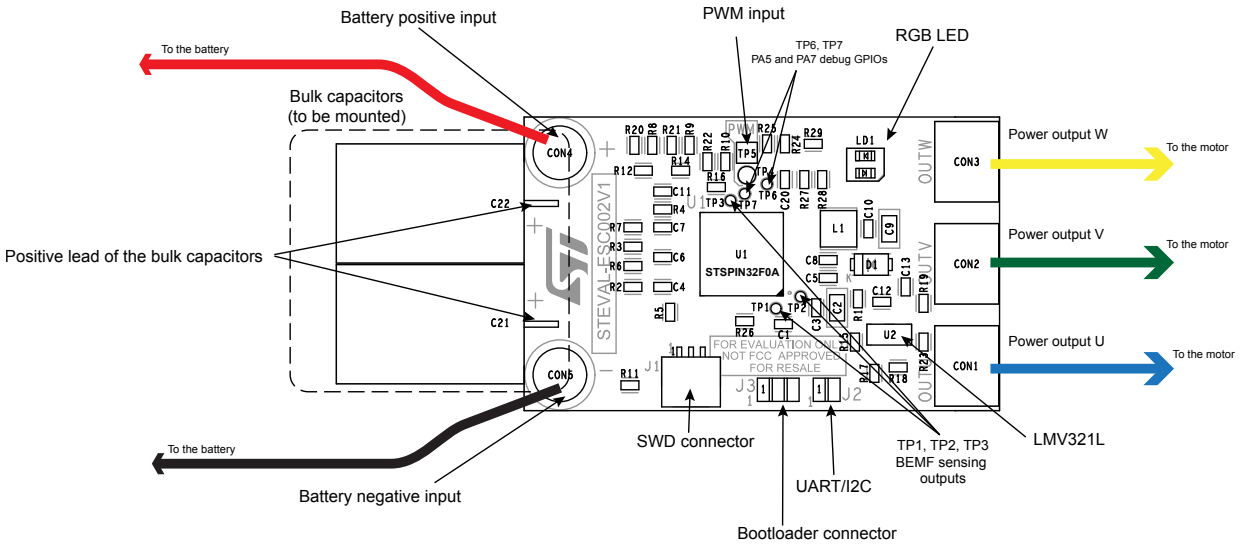


Figure 3. STEVAL-ESC002V1 components (bottom view)

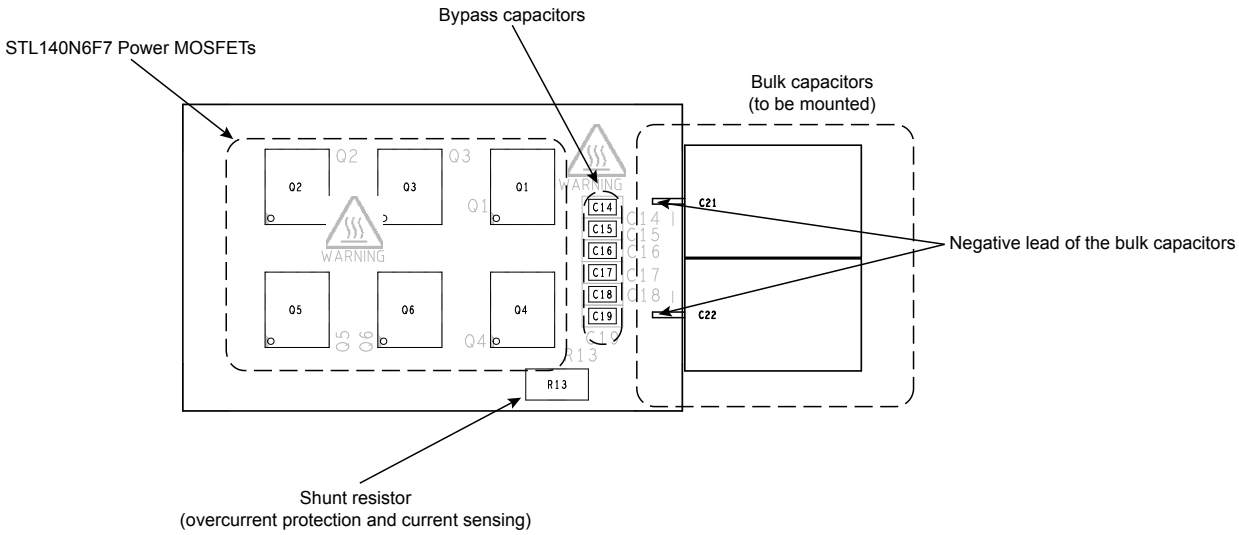


Table 1. Test points and connectors

Connector/ Test point	Pin	Signal	GPIO	Description
CON1	1	OUTU		Power output U. It has to be connected to one of the motor phases
CON2	1	OUTV		Power output V It has to be connected to one of the motor phases
CON3	1	OUTW		Power output W It has to be connected to one of the motor phases
CON4	1	VBUS		Supply voltage It has to be connected to the battery positive lead
CON5	1	GND		Ground It has to be connected to the battery negative lead
J1	1	SWD_CLK	PA14	SWD interface clock signal
	2	GND		Ground
	3	SWD_IO	PA13	SWD interface data signal
J2	1	TX/SCL	PB6	PB6 GPIO: • UART interface TX signal • I²C interface SCL signal
	2	RX/SDA	PB7	PB7 GPIO: • UART interface RX signal • I²C interface SDA signal
J3	1	TX	PA14	UART TX signal when the bootloader is running
	2	RX	PA15	UART RX signal when the bootloader is running
	3	BOOT0		Boot mode enabler (force high at power-up/reset)
TP1	1	OP3O	PF1	BEMF comparator output (phase U)
TP2	1	OP2O	PF0	BEMF comparator output (phase V)
TP3	1	OP1O	PB1	BEMF comparator output (phase W)
TP4	1	PWM_IN	PA6	Ground It has to be connected to the FCU PWM output
TP5	1	GND		Ground It has to be connected to the FCU PWM output
TP6	1	PA5	PA5	To debug
TP7	1	PA7	PA7	To debug

4 Setup

Step 1. Mount the bulk capacitors (included in the package) on the dedicated pads as shown in Figure 1 and Figure 2

Capacitors must be mounted as follows: negative lead (short one) on the bottom side and positive lead (long one) on the top side.

Warning:

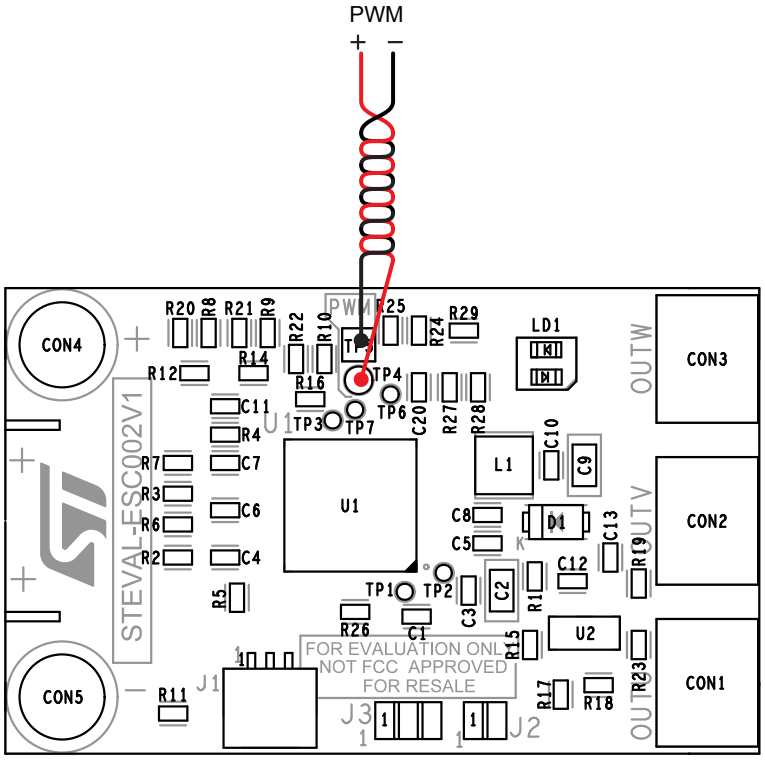
Do not operate without the bulk capacitors properly mounted to not damage the board and the battery.

Step 2. Solder the motor phases to the board as shown in Figure 1.

Color sequence is not important and affects only the rotation direction.

Step 3. Solder the FCU PWM output to the board as indicated in Figure 1: positive on TP4 (round pad) and negative on TP5 (square pad).

Figure 4. STEVAL-ESC002V1 PWM input from FCU connection details



Step 4. Connect the board to the battery or to a DC power supply as indicated in Figure 1 (supply range is from 2S to 6S).

Step 5. Supply the board.

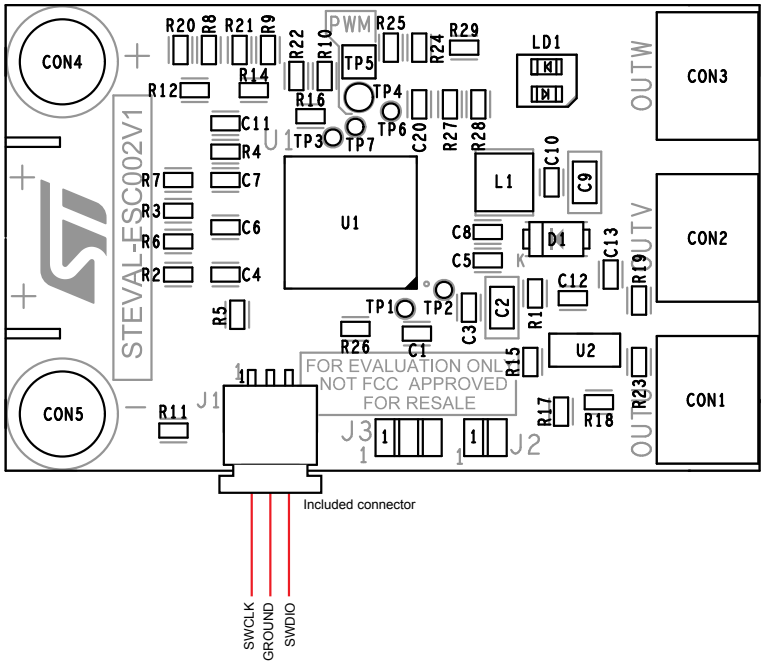
Step 6. Program the board through the SWD interface as described in the following section.

The board is ready to use.

4.1 Programming the board

The board is programmed through the microcontroller SWD interface. J1 and the included cable provide access to the SWD interface.

Figure 5. **STEVAL-ESC002V1 SWD connection details**



When the board is connected to the SWD programmer, you can program it in two ways.

Step 1. Write the binary included in the STSW-ESC002V1 firmware package or

Step 2. Compile and download the project included in the STSW-ESC002V1 firmware package (IAR Embedded Workbench for ARM 8.22).

5 Board PWM flowchart and interface parameters

After the setup procedure (see Section 4), the board is operative.

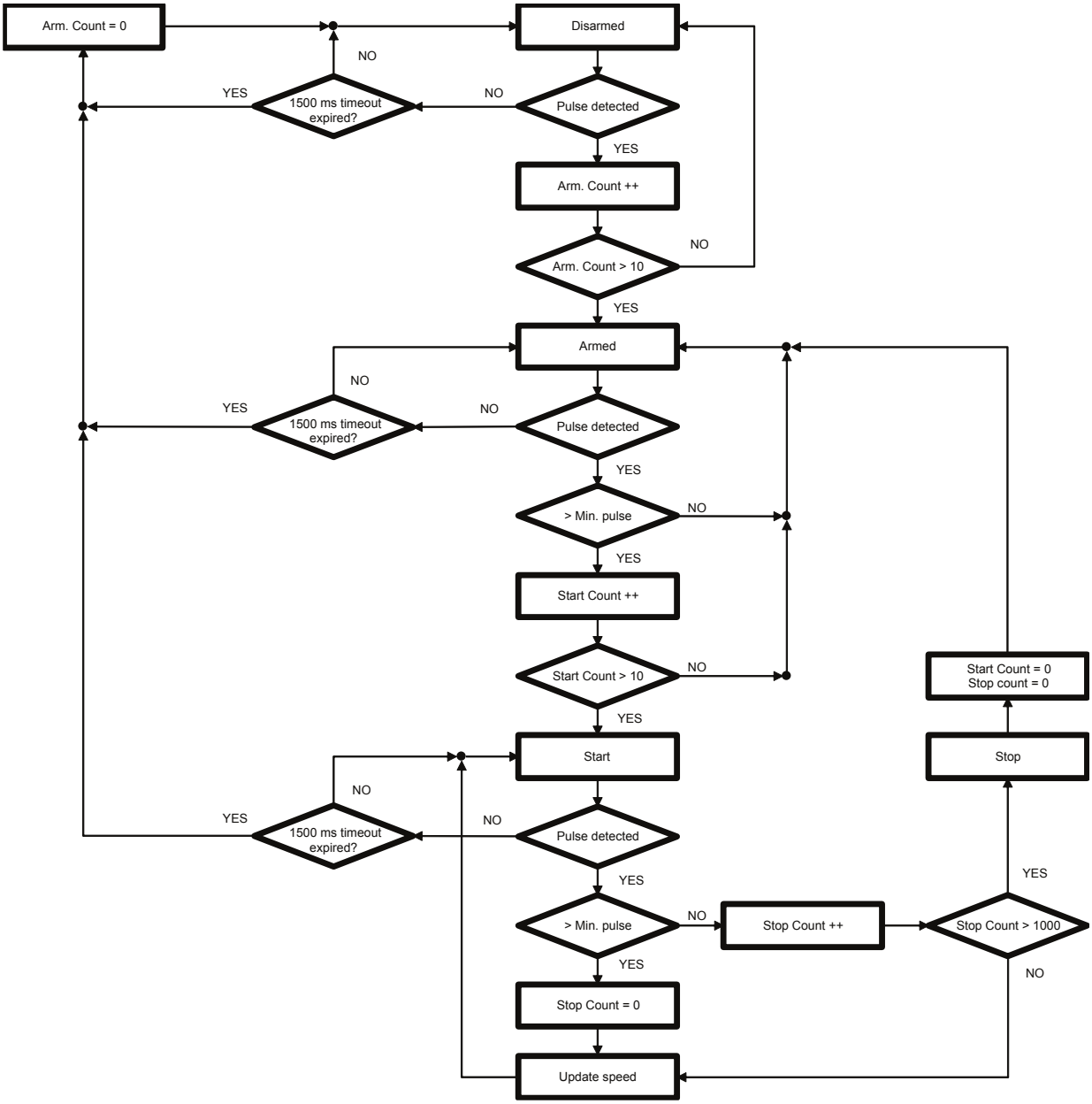
The STSW-ESC002V1 firmware monitors the pulse duration of the PWM input setting according to the voltage applied to the motor.

Note: The firmware does not monitor the PWM signal frequency. The algorithm considers only the duration of the positive pulses.

The STEVAL-ESC002V1 default behavior is described below.

1. At power-up the motor is stopped.
2. The ESC waits for at least `BSP_BOARD_IF_TIMx_ARMING_VALID_TON` pulses before arming (that is allowing the motor driving) the board. Even if the board is armed, the motor is not driven yet.
3. When at least `BSP_BOARD_IF_TIMx_START_VALID_TON` pulses longer than `BSP_BOARD_IF_TIMx_MIN_SPEED_TON_US` µs are detected, the motor is started.
4. When more than `BSP_BOARD_IF_TIMx_STOP_VALID_TO`N pulses shorter than `BSP_BOARD_IF_TIMx_MIN_SPEED_TON_US` µs are detected, the motor is stopped.
5. When the motor is running, the speed is proportional to the PWM pulse duration. The maximum speed is achieved when the pulse duration is `BSP_BOARD_IF_TIMx_MAX_SPEED_TON_US` µs.
6. If no pulses are detected for more than `BSP_BOARD_IF_TIMx_STOP_MS` ms, the motor is stopped and the board is disarmed, that is motor driving is not allowed.

Figure 6. STEVAL-ESC002V1 default behavior: PWM interface flowchart



The default values for the PWM monitoring code are listed in the following table.

Table 2. PWM interface parameters

Parameter	Description	Default
BSP_BOARD_IF_TIMx_STOP_MS	No-PWM timeout in ms	1500
BSP_BOARD_IF_TIMx_ARMING_VALID_TON	Number of valid PWM pulses (any duration) arming the board	10
BSP_BOARD_IF_TIMx_START_VALID_TON	Number of PWM pulses above minimum duration starting the motor	10
BSP_BOARD_IF_TIMx_STOP_VALID_TON	Number of PWM pulses below minimum duration starting the motor	1000
BSP_BOARD_IF_TIMx_MIN_SPEED_TON_US	Minimum pulse duration (corresponding to minimum speed) in µs	1060
BSP_BOARD_IF_TIMx_MAX_SPEED_TON_US	Maximum pulse duration (corresponding to maximum speed) in µs	2084(1)

1. *The value is calculated according to the following formula (BSP_BOARD_IF_TIMx_MIN2MAX_BITS = 10): BSP_BOARD_IF_TIMx_MIN_SPEED_TON_US + $2^{BSP\_BOARD\_IF\_TIMx\_MIN2MAX\_BITS}$. It is not possible to set an arbitrary value: the range changes according to the BSP_BOARD_IF_TIMx_MIN2MAX_BITS parameter.*

6 Schematic diagrams

Figure 7. **STEVAL-ESC002V1 circuit schematic (1 of 3)**

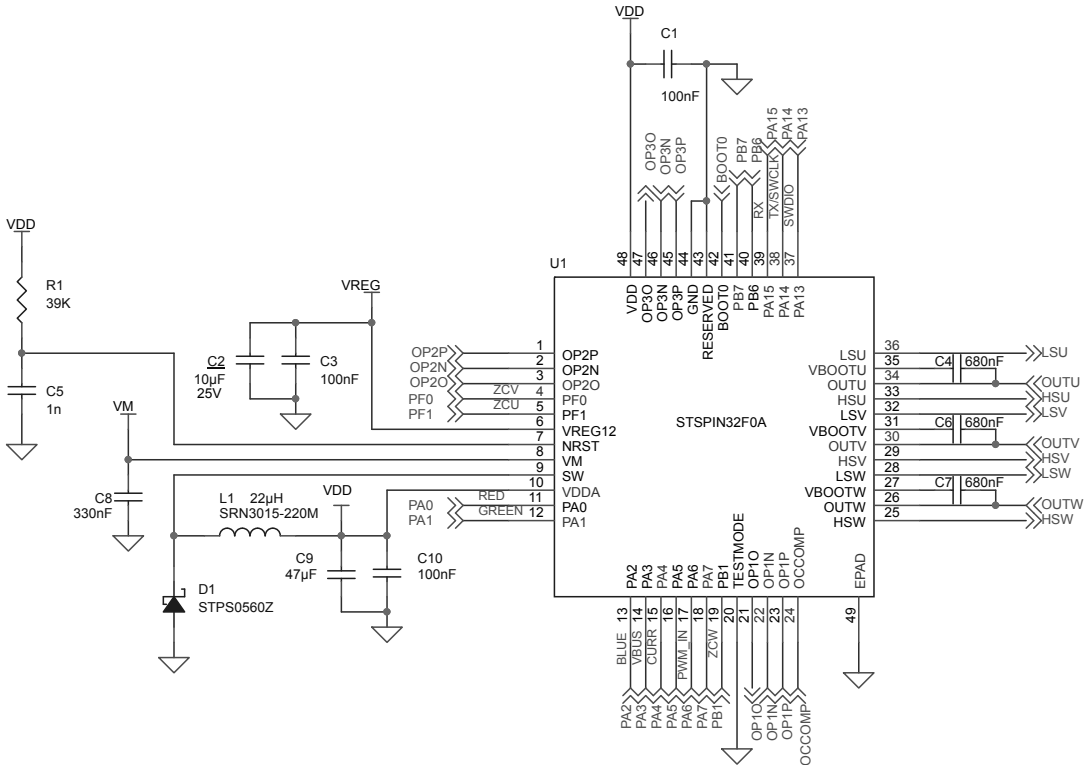


Figure 8. **STEVAL-ESC002V1 circuit schematic (2 of 3)**

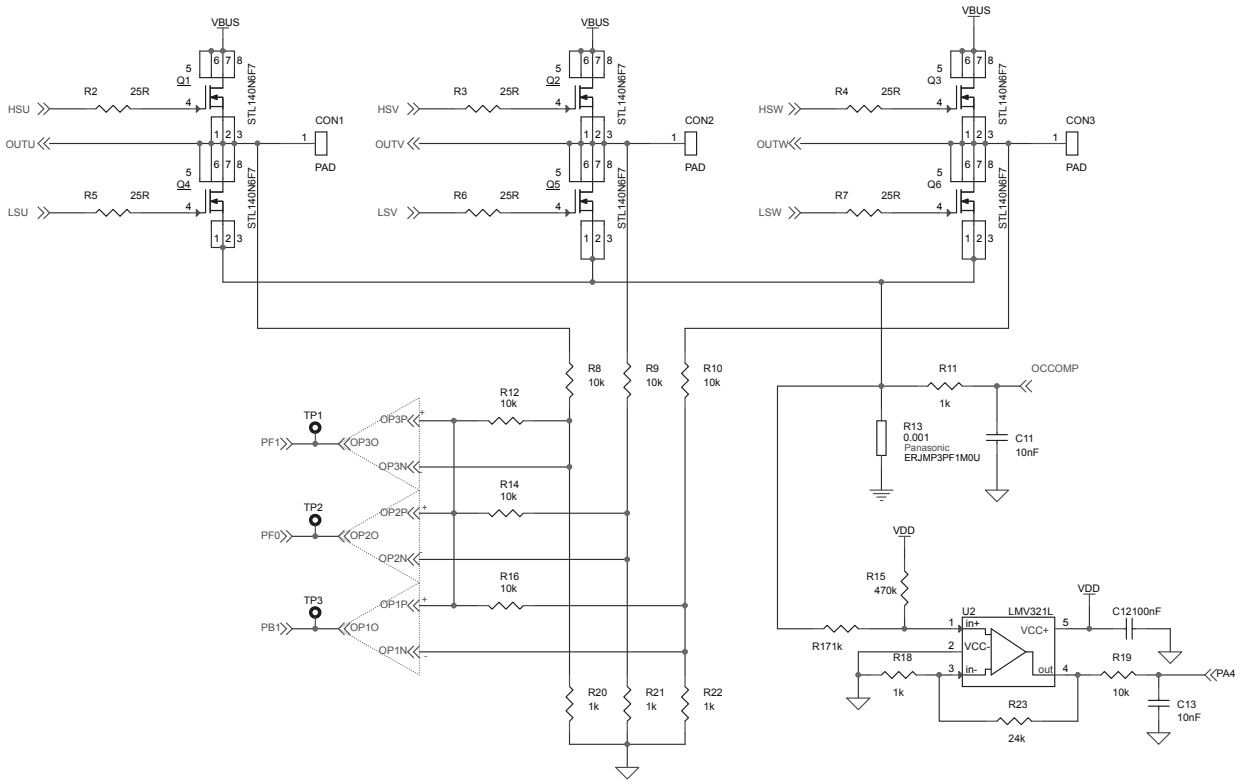
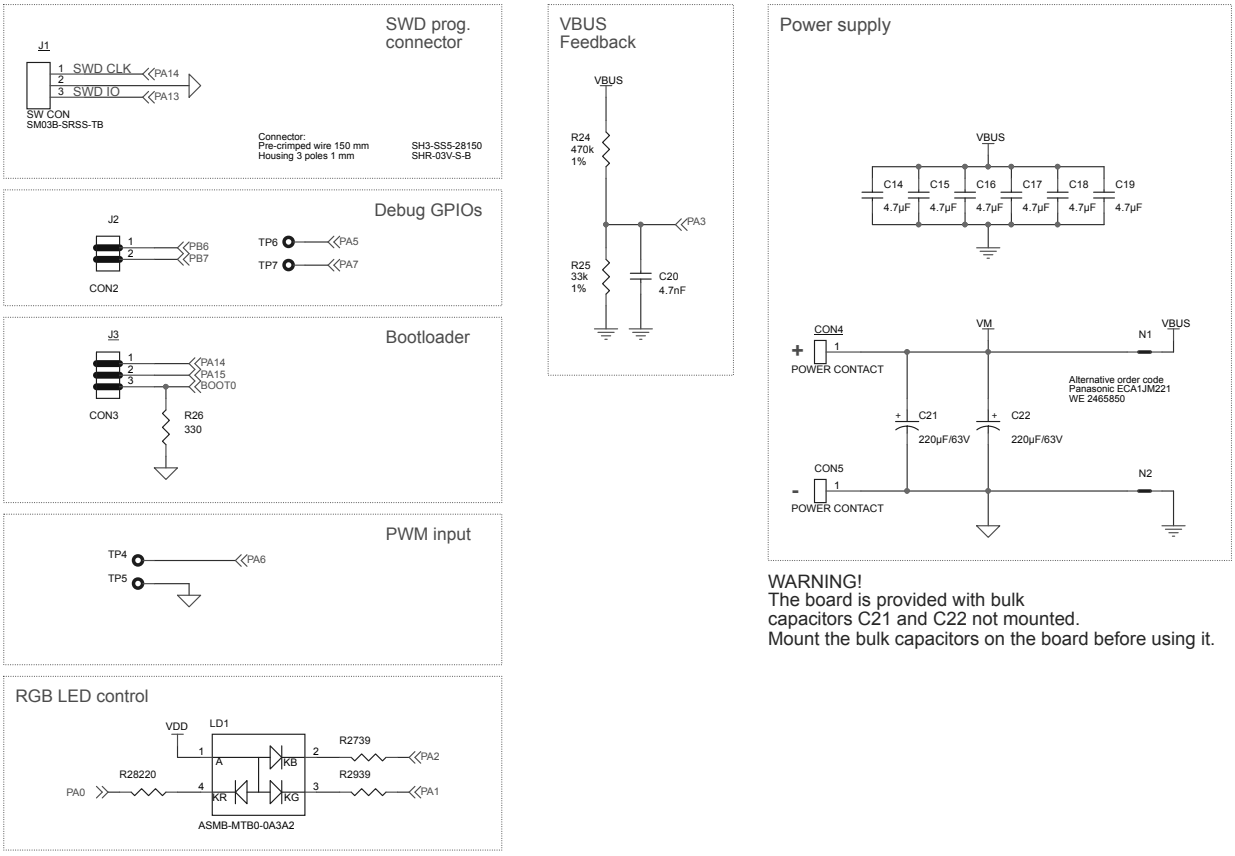


Figure 9. STEVAL-ESC002V1 circuit schematic (3 of 3)



WARNING!
The board is provided with bulk capacitors C21 and C22 not mounted.
Mount the bulk capacitors on the board before using it.

7 Bill of materials

Table 3. **STEVAL-ESC002V1 bill of materials**

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	3	CON1, CON2, CON3	RECT_PAD257R200D 35_43	Connectors	Any	-
2	2	CON4, CON5	pad221hole35_43	Connectors	Any	-
3	4	C1, C3, C10, C12	100 nF 50 V ±10% C0603 X7R	Capacitors	Any	-
4	1	C2	10 µF 25 V ±10% C0805 X7R	Capacitor	Any	-
5	3	C4, C6, C7	680 nF 16 V ±10% C0603 X7R	Capacitors	Any	-
6	1	C5	1 nF 50 V ±10% C0603 X7R	Capacitor	Any	-
7	1	C8	330 nF 50 V ±10% C0603 X7R	Capacitor	Any	-
8	1	C9	47 µF 6.3 V ±20% C0805 X5R	Capacitor	Any	-
9	2	C11, C13	10 nF 50 V ±10% C0603 X7R	Capacitor	Any	-
10	6	C14, C15, C16, C17, C18, C19	4.7 µF 50 V ±15% C0805 X5R	Capacitors	Any	-
11	1	C20	4.7 nF 50 V ±10% C0603 X7R	Capacitor	Any	-
12	2	C21, C22	220 µF 63 V ±20% D400p200-padsmt	Aluminium capacitors	Wurth Electronics	860020775019
					Panasonic	ECA1JM221
13	1	D1	STPS0560Z SOD-123	Power Schottky rectifier	ST	STPS0560Z
14	1	J1	SW CON SM03B-SRSS-TB	Jumper	JST	SM03B-SRSS-TB
15	1	J2	CON2 CON_2-pitch49_87-38x75	Jumper	Any	-
16	1	J3	CON3 CON_3-pitch49_87-38x75	Jumper	Any	-
17	1	LD1	PLCC-4	RGB LED	Avago	ASMB-MTB0-0A3A2
18	1	L1	22 µH 0.6 A ±20% SRN3015	Fixed inductor	Bourns	SRN3015-220M
19	2	N1, N2	SHORT		Any	-
20	6	Q1, Q2, Q3, Q4, Q5, Q6	STL140N6F7 PFLAT_6X5-8LEADS	N-channel 60 V, 0.0024 Ohm typ., 140 A STripFET F7 Power MOSFET in a PowerFLAT 5x6 package	ST	STL1401N6F7
21	1	R1	39 K 1/10 W ±5% R0603	Resistor	Any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
22	6	R2, R3, R4, R5, R6, R7	25 R 1/10 W ±5% R0603	Resistors	Any	-
23	3	R8, R9, R10	10 k 1/10 W ±1% R0603	Resistors	Any	-
24	3	R11, R17, R18	1 k 1/10 W ±5% R0603	Resistors	Any	-
25	3	R12, R14, R16	10 k 1/10 W ±1% R0603	Resistors	Any	-
26	1	R13	1 m 2 W ±1% R2010	Resistor	Panasonic	ERJMP3PF1M0U
27	1	R15	470 k 1/10 W ±5% R0603	Resistor	Any	-
28	1	R19	10 k 1/10 W ±5% R0603	Resistor	Any	-
29	3	R20, R21, R22	1 k 1/10 W ±1% R0603	Resistors	Any	-
30	1	R23	24 k 1/10 W ±5% R0603	Resistor	Any	-
31	1	R24	470 k 1/8 W ±1% R0603	Resistor	Any	-
32	1	R25	33 k 1/8 W ±1% R0603	Resistor	Any	-
33	1	R26	330 1/10 W ±5% R0603	Resistor	Any	-
34	2	R27, R29	39 1/10 W ±5% R0603	Resistors	Any	-
35	1	R28	220 1/10 W ±5% R0603	Resistor	Any	-
36	5	TP1, TP2, TP3, TP6, TP7	TP-SMD-diam0_762mm TP-D30	Test points	Any	-
37	1	TP4	TP-SMD-diam1_27mm TP-D50	Test point	Any	-
38	1	TP5	TP-SMD-square1_27mm TP-50x50	Test point	Any	-
39	1	U1	STSPIN32F0A VFQFPN48L7x7x1-49P	Advanced BLDC controller with embedded STM32 MCU	ST	STSPIN32F0A
40	1	U2	LMV321L SOT23-5L	Low-power, general-purpose operational amplifier	ST	LMV321LILT
41	3			Pre-crimped wire	JST	SH3-SS5-28150
42	1			Connector housing	JST	SHR-03V-S-B

Revision history

Table 4. **Document revision history**

Date	Version	Changes
17-Dec-2018	1	Initial release.

Contents

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