Getting started with the STEVAL-FCU001V1 flight controller unit evaluation board for mini drones

Introduction

The STEVAL-FCU001V1 evaluation board is designed as a simple platform to develop flight controller unit (FCU) solutions for quadcopters.

A complete sample firmware project allows the designer to begin flying small or medium sized quadcopters equipped with DC motors (thanks to four 30 V-6 A on-board MOSFETs), and larger quadcopters with external ESCs (i.e., STEVAL-ESC001V1 or STEVAL-ESC002V1).

The user can control the board via BLE connectivity (using a smartphone or a tablet) or via an RF receiver module connected to the PWM input port.

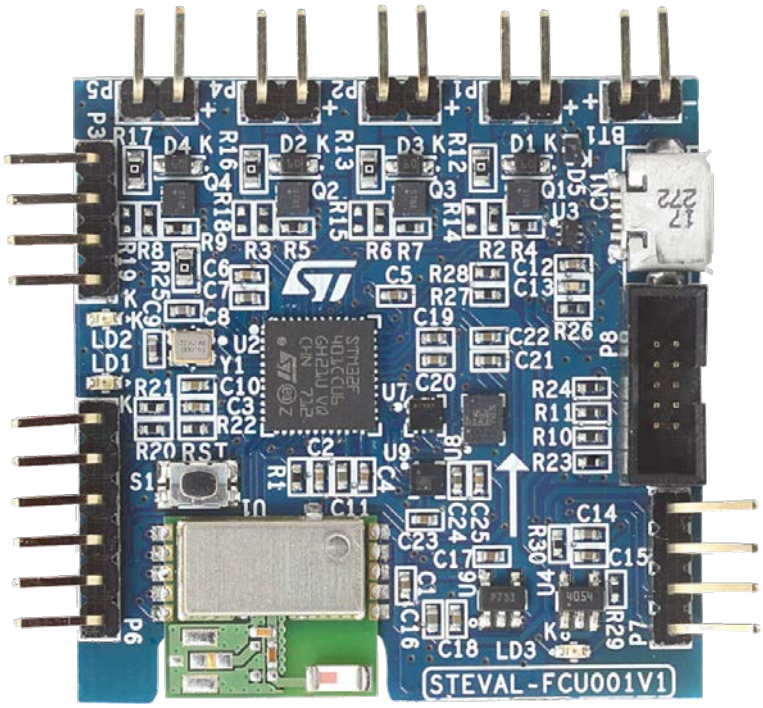
The system embeds a high performance ARM® Cortex®-M4 microcontroller unit (STM32F401), an iNEMO inertial module (LSM6DSL), a Bluetooth® low energy module (SPBTLE-RF) and power management circuitry that allows battery fast charge (STC4054) and four STL6N3LLH6-N-channel 30 V, 6 A STripFET H6 Power MOSFET to drive a quadcopter motors.

An additional barometric pressure sensor (LPS22HD) provides altitude estimation and a high performance magnetometer (LIS2MDL) supports e-Compass functionality.

This reference design can be used to develop more sophisticated auto-navigation algorithms thanks to more than 100 DMIPS available on the STM32 and the scalability of the board which can be connected to the Teseo-LIV3F GNSS module.

The system passed the RF test for FCC certification, IC certification and ARIB certification.

Figure 1. STEVAL-FCU001V1 evaluation board



1 Getting started

1.1 Board overview

The STEVAL-FCU001V1 evaluation board main components are:

- STM32F401 – 32-bit MCU with ARM® Cortex®
- LSM6DSL – iNEMO intertial module: 3D accelerometer and 3D gyroscope
- LIS2MDL – High performance 3D magnetometer
- LPS22HD – MEMS pressure sensor: 260-1260 hPa absolute digital output barometer
- SPBTLE-RF – Very low power module for Bluetooth Smart v4.1
- STL6N3LLH6 - N-channel 30 V, 6 A STripFET H6 Power MOSFET
- STC4054 - 800 mA standalone linear Li-Ion battery charger

It features:

- Compact flight controller unit (FCU) evaluation board complete with sample firmware for a small or medium sized quadcopter
- On-board lipo 1-cell battery charger
- Possibility to directly drive 4 DC brushed motors through the low voltage on-board MOSFET or alternatively use external ESC for DC brushless motor configuration

1.2 Package contents

The STEVAL-FCU001V1 evaluation board package contains:

- the evaluation board itself
- the ST-LINK adapter with its programming cable to be used with the ST-LINK/V2
- a blister containing the spare connectors to be mounted on the board

Figure 2. STEVAL-FCU001V1 evaluation board: package contents

1.3 System requirements

To use the board, the following system specifications are required:

- a Windows PC (7, 8, 8.1, 10) with a pre-installed STM32 software development tool (IAR-EWARM, MDK-ARM-STM32or SW4STM32).

- ST-LINK/V2 (or equivalent) in-circuit debugger/programmer, its USB driver (STSW-LINK009) and, optionally, the STM32 ST-LINK utility for firmware download (STSW-LINK004).
- a lipo 1-cell battery to be connected to the battery connector (BT1) for stand-alone operation or a USB type A to Micro-USB male cable to connect the STEVAL-FCU001V1 evaluation board to the PC for power supply.
- four DC motors suitable for 3.7 V operation directly connected to the board, or four DC brushless motors with four matching electronic speed controllers (such as the ST reference design STEVAL-ESC001V1 or STEVAL-ESC002V1 evaluation boards).
- four propellers suitable for the motors chosen

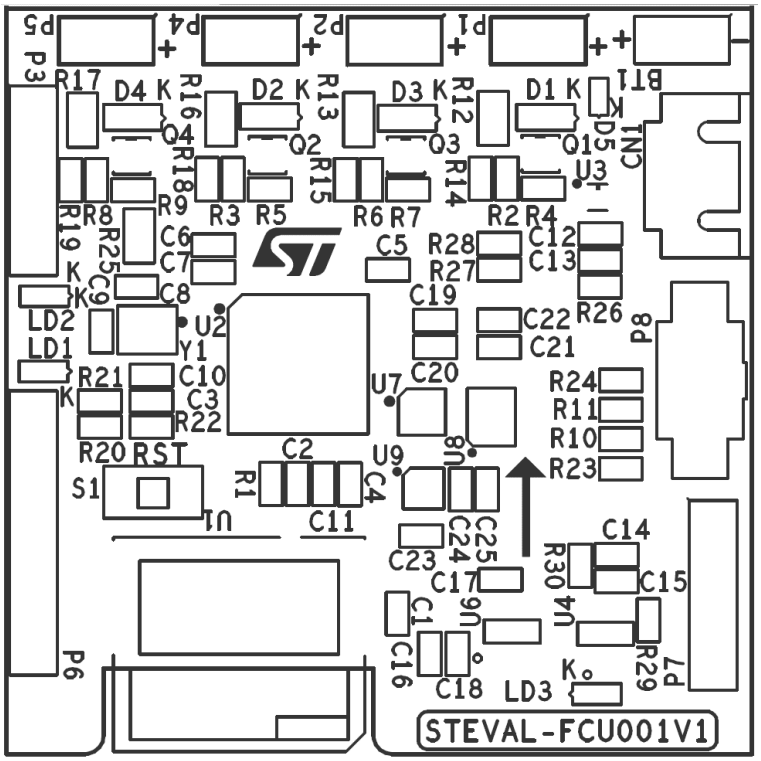
Note: The user must choose the propellers, motors and ESC on the basis of the quadcopter size and weight.

2 System setup guide

The board is provided without a pre-installed firmware, but the firmware (STSW-FCU001) open source code is available on Github for download.

Step 1. Connect a lipo 1-cell battery to the battery connector BT1 (see the following picture).

Figure 3. STEVAL-FCU001V1 evaluation board silkscreen and connector positioning



Step 2. Connect the ST-LINK adapter included in the package to the ST-LINK/V2 and the STEVAL-FCU001V1 evaluation board.

Step 3. Connect a USB cable to a PC and to the micro-USB connector (CN1) to supply the board.

Step 4. Check that the LD3 is switched ON.

Step 5. Download from GitHub the STSW-FCU001 firmware package.

Step 6. Program the board (refer to the software user manual).

Note: It is recommended to connect the USB cable during the programming phase to avoid issues on the power supply.

Step 7. Mount the STEVAL-FCU001V1 on a quadcopter mechanical frame.

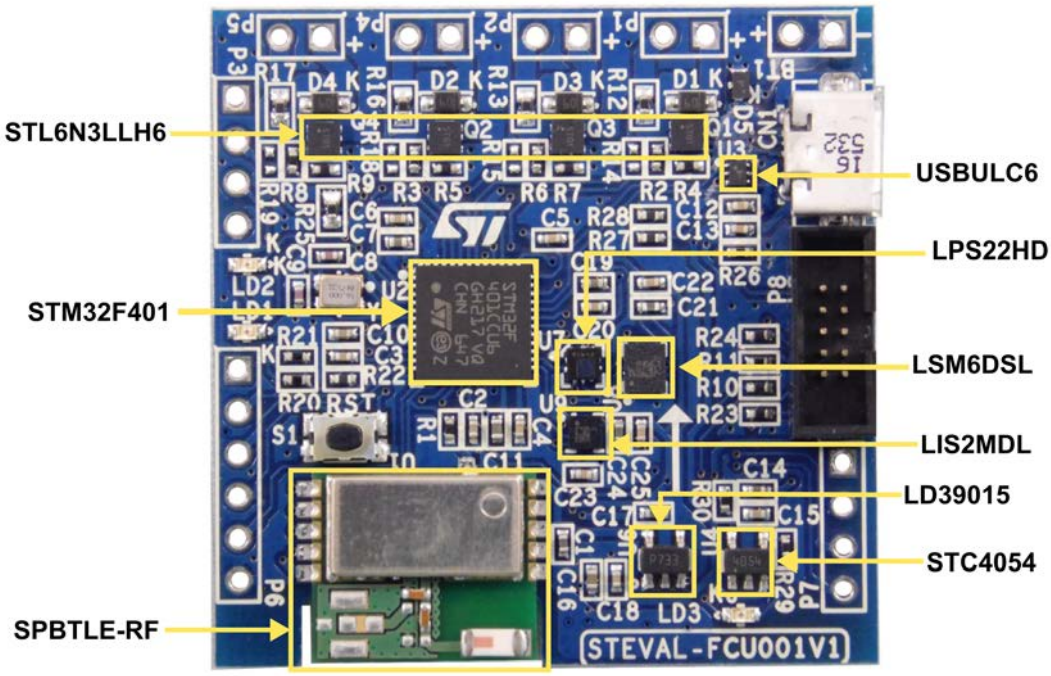
Once the firmware fine tuning session finishes, you can remove the connection to the micro-USB cable and the ST-LINK/V2 and fly your drone.

3 Hardware description

The STEVAL-FCU001V1 main components are:

- STM32F401CCU6 - high performance ARM® Cortex®-M4 MCU with 256 Kbytes of Flash memory, 64 kBytes of RAM in a UFQFPN48 package
- SPBTLE-RF - Bluetooth low energy (BLE) module with on-board chip antenna, compliant with Bluetooth specification core 4.1
- LSM6DSL - 3D accelerometer (±2/4/8/16 g) and 3D gyroscope (±125/245/500/1000/2000 dps)
- LIS2MDL - MEMS 3D magnetometer (±50 gauss magnetic dynamic range)
- LPS22HD - MEMS pressure sensor, 260-1260 mBar absolute digital output barometer
- STL6N3LLH6 - 30 V 6 A STripFET H6 Power MOSFET in a PowerFLAT 2x2 package
- STC4054 - 800 mA Li-Ion and lipo battery charger directly from USB
- LD39015 - low quiescent voltage regulator
- USBULC6-2M6 ultra large bandwidth ESD protection

Figure 4. STEVAL-FCU001V1 evaluation board components



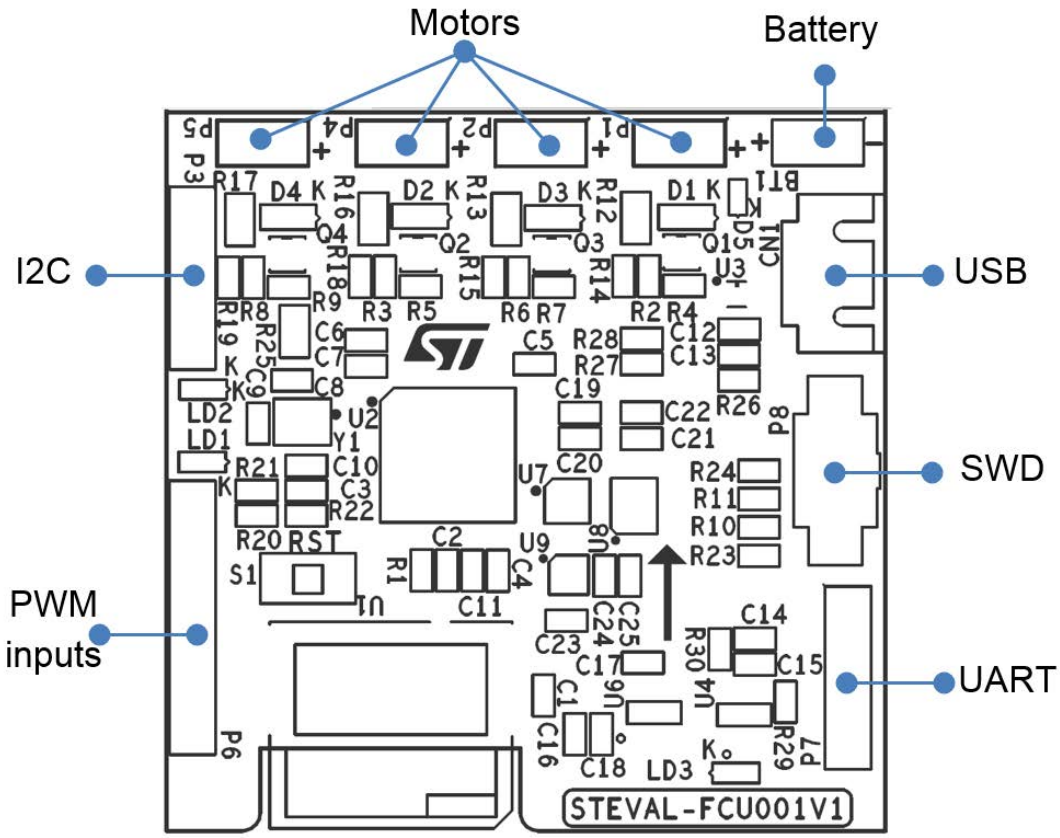
3.1 Board connectors

The STEVAL-FCU001V1 evaluation board includes several hardware connectors (see Figure 5. STEVAL-FCU001V1 evaluation board connector description):

- USB micro B female plug
- Battery 2-pin header connector
- 4 motor 2-pin header connectors
- UART 4-pin header connector
- I²C 4-pin header connector
- PWM input 6-pin header connector
- Micro SWD connector (1.27 mm pitch)

As shown in Figure 4. STEVAL-FCU001V1 evaluation board components, some of these connectors have not the pins soldered on the board to leave the maximum freedom to users.

Figure 5. STEVAL-FCU001V1 evaluation board connector description



The board can be powered by USB connector or by 1-cell battery.

By connecting both, the embedded battery charger uses the USB current to charge the battery.

Considering the specific application, it is highly recommended to use a LiPo battery with a high value of maximum discharge current rating (this parameter is often indicated with "number of C" where "C" is battery capacity).

Thus, a 500 mAh battery with a discharge rating of 50 C has a maximum sustained load of 25 amps: this value has to be compared with the sum of the current absorbed by the motors (x4) and the on-board electronics, which is negligible with respect to the motors.

Table 1. Battery 2-pin header connector (BT1)

Pin	Signal	Description
+	VBAT+	1-cell lipo battery (3.4 to 4.2 V)
-	GND	

Note: The + is placed on the board left side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation). It is important to ensure correct polarity connection as reverse battery protection is not implemented

The four motor connectors can be used to connect a 1 cell 3.7 V motor to each of them or to external ESCs. Depending on the kind of motor, you have to sold the male strip line on the board or directly on the motors pins.

In the STSW-FCU001, an association between Px connector and motor placement on the drone structure has been considered (for further information, refer to UM2512 on www.st.com).

Table 2. Motor 2-pin header connectors (P1, P2, P4, P5)

Pin	Signal	Description
1	VBAT+	To be connected to motor (+) for DC motors(1)
2	MOTOR-	To be connected to motor (-) for DC motors(2)

1. *Not connected for external ESC*
2. *To be connected to PWM inputs for external ESC*

Note: The + is placed on the board right side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation).

As in many commercial flight controllers, the STEVAL-FCU001V1 hosts a UART and a I²C to connect external peripherals.

Table 3. UART 4-pin header connector (P7)

Pin	Signal	Description
1	VDD	3.3 V of STM32
2	GND	
3	USART1_RX	RXD for STM32
4	USART1_TX	TXD for STM32

Note: Pin 1 is placed on the board top side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation).

Table 4. I2C 4-pin header connector (P3)

Pin	Signal	Description
1	VDD	3.3 V of STM32
2	I2C2_SDA	
3	I2C2_SCL	
4	GND	

Note: Pin 1 is placed on the board top side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation).

The STSW-FCU001 evaluation software has been designed to offer the possibility of controlling the drone by a smartphone app (AppDrone) and by an external remote controller.

In this case, a remote controller RX module has to be connected to the STEVAL-FCU001V1 evaluation board P6 connector.

Table 5. PWM inputs 6-pin header connector (P6) lists the signals over the pins.

The firmware implementation is compatible with pulse period modulation (PPM) receiver, and:

- CH1 is related to AIL control with roll function
- CH2 is related to ELE control with pitch function
- CH3 is related to THR control with thrust function
- CH4 is related to RUD control with yaw function

Table 5. PWM inputs 6-pin header connector (P6)

Pin	Signal	Description
1	VBAT+	Directly connected to battery (+)
2	TIM2_CH1	TIM2_CH1 for RF RX PWM IN signal CH1
3	TIM2_CH2	TIM2_CH2 for RF RX PWM IN signal CH2
4	TIM2_CH3	TIM2_CH3 for RF RX PWM IN signal CH3
5	TIM2_CH4	TIM2_CH4 for RF RX PWM IN signal CH4
6	GND	

Note: Pin 1 is placed on the board top side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation).

Table 6. Debugging micro SWD connector (P8)

Pin	Signal	Description
1	VDD	
2	SWDD	SWD debugging data line
3	GND	
4	SWCLK	SWD debugging clock line
5	GND	
6	N.C.	
7	GND	
8	N.C.	
9	GND	
10	NRST	NReset for STM32

For further details on debugging, refer to Section 3.2 ST-LINK/V2 connection.

Note: Pin 1 is placed on the board bottom right side (refer to Figure 4. STEVAL-FCU001V1 evaluation board components for board orientation).

3.2 ST-LINK/V2 connection

To update the firmware, use the ST-LINK/V2 debugger programmer by plugging the adapter and the cable (provided in the STEVAL-FCU001V1 package as described in Section 1.2 Package contents) to the board and then to the laptop.

Figure 6. ST-LINK/V2 connected to the STEVAL-FCU001V1 evaluation board via adapter

Note: ST-LINK/V2 is not included in the package. Go to www.st.com to order it.

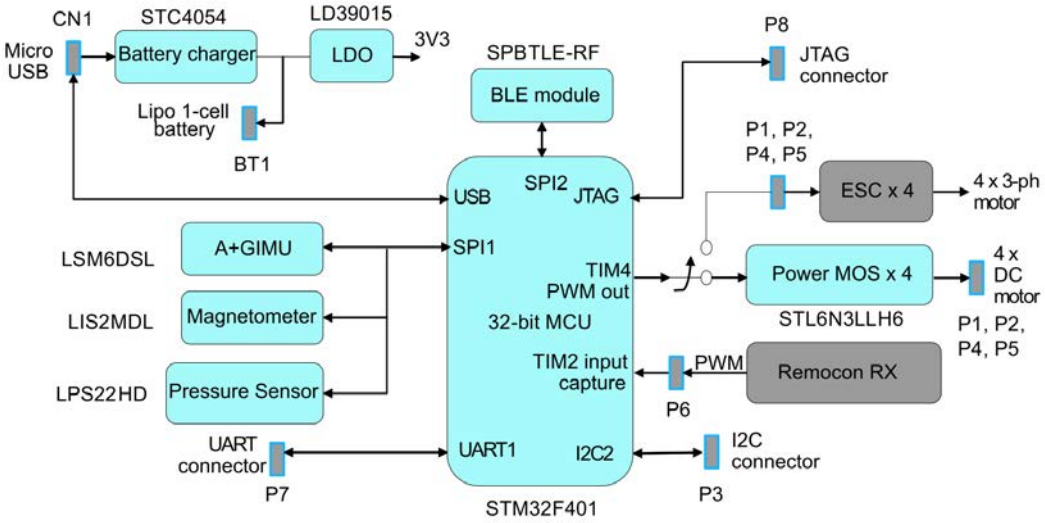
3.3 Hardware architecture overview

The whole system can be split in five different subsystems:

- Microcontroller
- Sensors
- Connectivity
- Battery management
- DC motor drivers

The sensors and the BLUENRG-MS devices are connected to the microcontroller through two separate SPI peripherals.

Figure 7. STEVAL-FCU001V1 evaluation board functional block diagram



4 Schematic diagrams

Figure 8. **STEVAL-FCU001V1 – circuit schematic (1 of 4)**

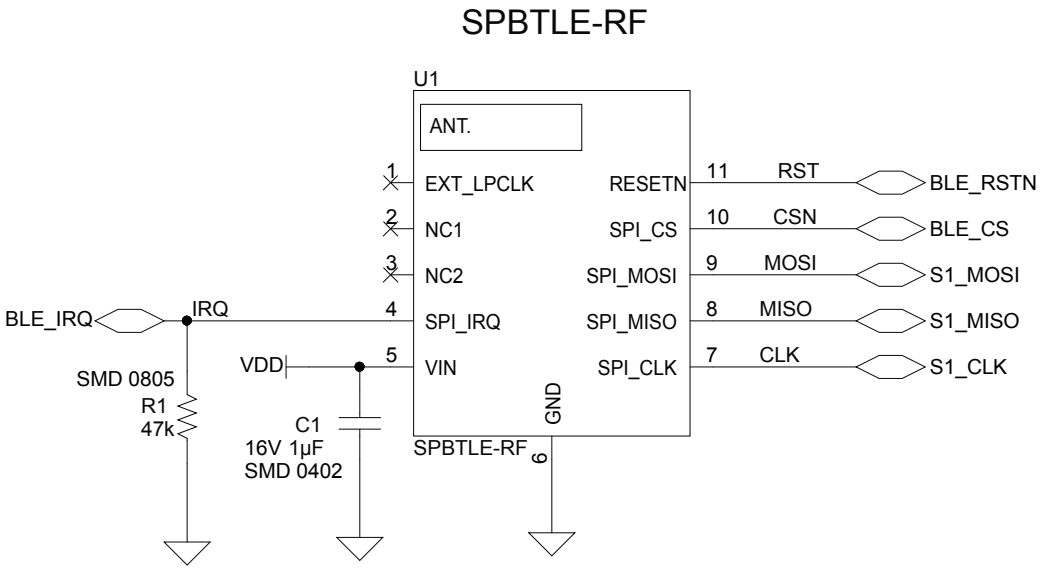


Figure 9. **STEVAL-FCU001V1 – circuit schematic (2 of 4)**

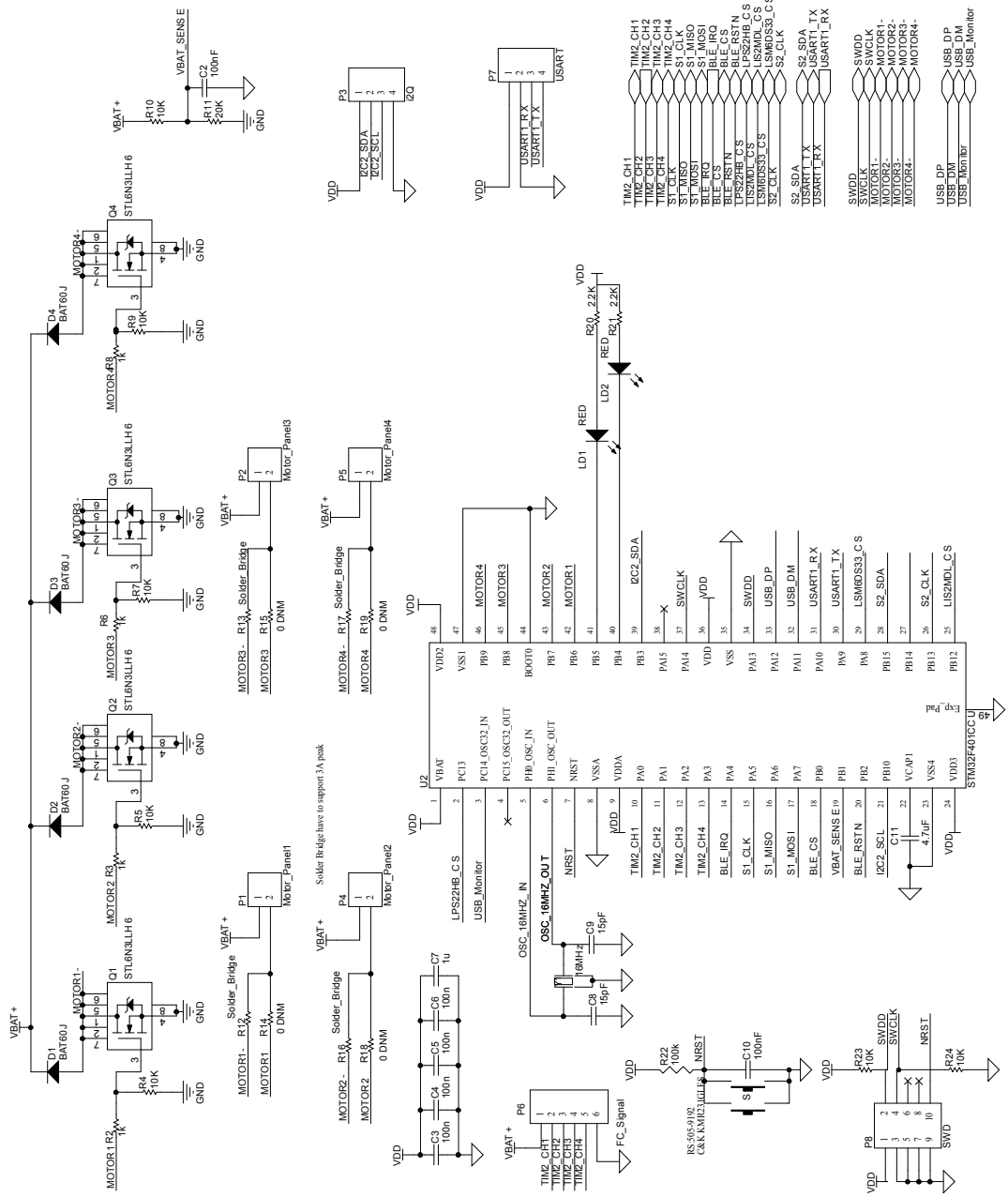


Figure 10. **STEVAL-FCU001V1 – circuit schematic (3 of 4)**

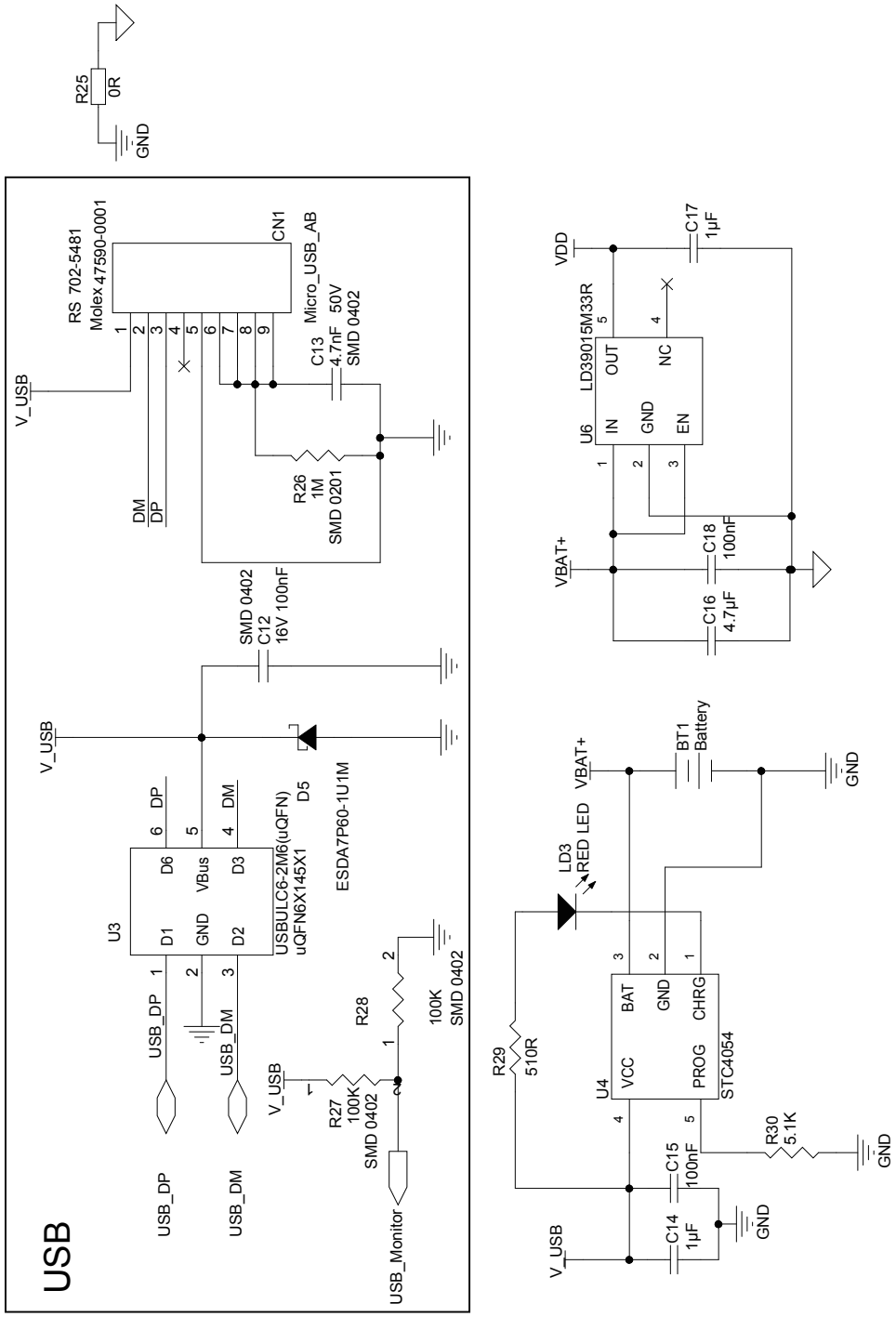
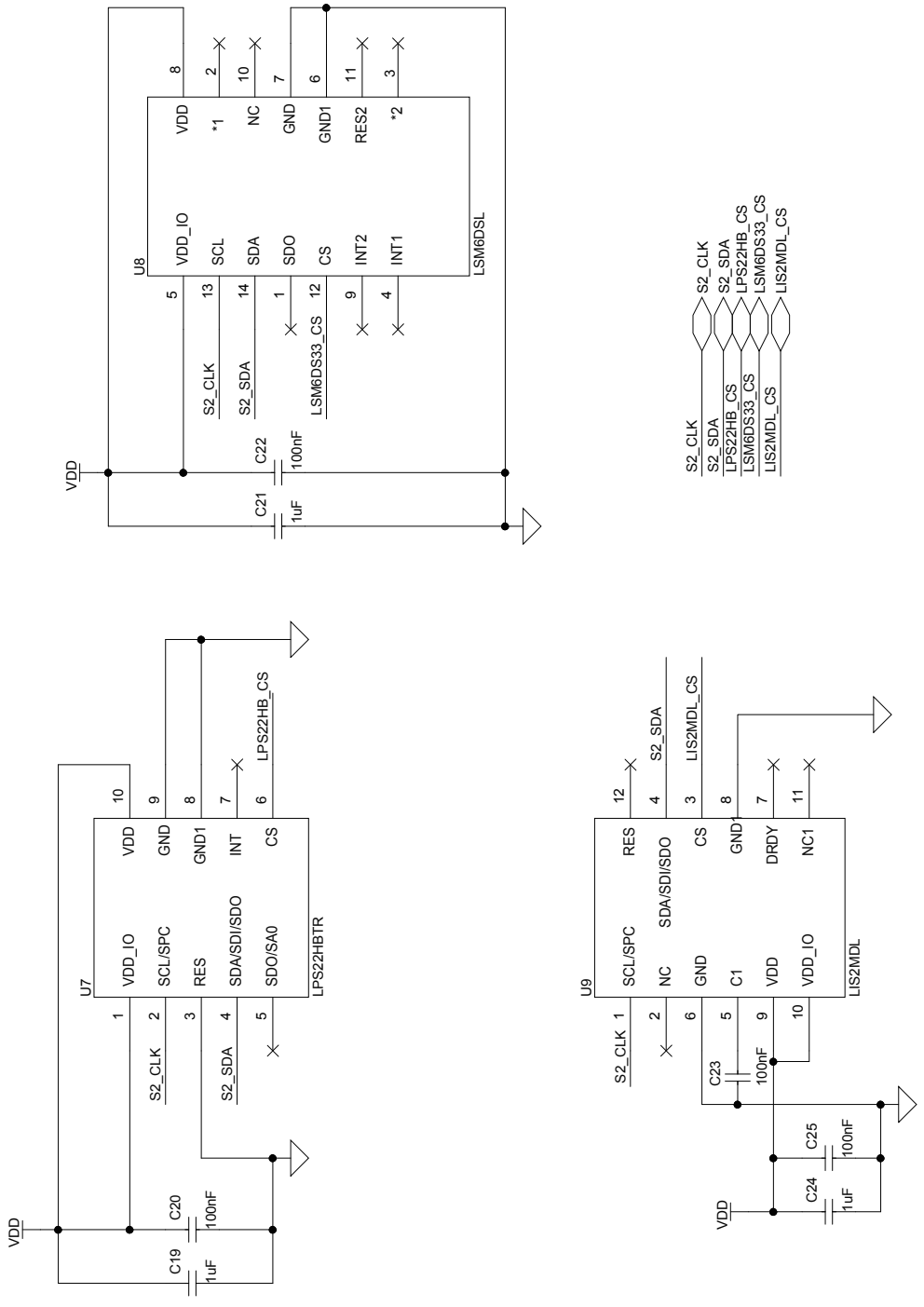


Figure 11. **STEVAL-FCU001V1 – circuit schematic (4 of 4)**



5 Bill of materials

Table 7. **STEVAL-FCU001V1 bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	BT1	Battery Connector siptm2002	Strip Line male 1X2 pitch 2,54mm	ANY	DNM
2	1	CN1	Micro_USB 2,0 Female SMt microusb7025481		Molex	47590-0001
3	7	C1, C7, C14, C17, C19, C21, C24	1 µF 16 V ±10% smc0402	Ceramic capacitor XR7	ANY	
4	13	C2, C3, C4, C5, C6, C10, C12, C15, C18, C20, C22, C23, C25	100 nF 16 V ±10% smc0402	Ceramic capacitor XR7	ANY	
6	2	C8, C9	15 pF 16 V ±10% smc0402	Ceramic capacitor XR7	ANY	
7	2	C11, C16	4.7 µF 16 V ±10% smc0402	Ceramic capacitor XR7	ANY	
8	1	C13	4.7 nF 16 V ±10% SMC0402	Ceramic capacitor XR7	ANY	
9	4	D1, D2, D3, D4	BAT60JFILM 10v-3A sod323	Signal Schottky diode	ST	BAT60J
10	1	D5	ESDA7P60-1U1M SMD1610	Voltage Suppressor	ST	ESDA7P60-1U1M
11	3	LD1, LD2, LD3	smd0603	Red LED	ANY	ANY
13	1	P1	Motor_Panel1 siptm2002 2.54 mm	Strip Line male 1X2 pitch	ANY	DNM
14	1	P2	Motor_Panel3 siptm2002 2.54 mm	Strip Line male 1X2 pitch	ANY	DNM
15	1	P3	i2Q siptm4004 2.54 mm	Strip Line male 1X4 pitch	ANY	DNM
16	1	P4	Motor_Panel2 siptm2002 2.54 mm	Strip Line male 1X2 pitch	ANY	DNM
17	1	P5	Motor_Panel4 siptm2002 2.54 mm	Strip Line male 1X2 pitch	ANY	DNM
18	1	P6	FC_Signal siptm6006 2.54 mm	Strip Line male 1X6 pitch	ANY	DNM
19	1	P7	USART siptm4004 2.54 mm	Strip Line male 1X4 pitch	ANY	DNM

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
20	1	P8	SWD Ampmode10X1M27 1.27 mm	Connector 2X5 pitch	CNC Tech	3220-10-0100-00
21	4	Q1, Q2, Q3, Q4	STL6N3LLH6 powerFLAT2X2	Power MOSFET	ST	STL6N3LLH6
22	1	R1	47 k 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
23	4	R2, R3, R6, R8	100 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
24	7	R4, R5, R7, R9, R10, R23, R24	10 K 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
25	1	R11	20 K 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
26	4	R12, R13, R16, R17, R25	0 1/16 W ±1% smr0603	SMD Thick Film Resistor	ANY	
27	4	R14, R15, R18, R19	NA 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
28	2	R20, R21	2.2 K 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
29	3	R22, R27, R28	100 K 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
30	1	R26	1 M 1/16 W ±1% SMR0402	SMD Thick Film Resistor	ANY	
31	1	R29	510 R 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
32	1	R30	5.1 K 1/16 W ±1% smr0402	SMD Thick Film Resistor	ANY	
33	1	S1	Reset PushKMR22	Push button	C&K	KMR231GLFS
34	1	U1	SPBTLE-RF spbtrfle	Very low power module for Bluetooth v4.1	ST	SPBTLE-RF
35	1	U2	STM32F401CCU6TR UFQFPN48X7X7	High-performance ARM® Cortex® -M4 core accelerator	ST	STM32F401CCU6
36	1	U3	USBULC6-2M6(uQFN) uQFN6X145X1	Ultra large bandwidth ESD protection	ST	USBULC6-2M6
37	1	U4	STC4054GR SOT23L5	Li-Ion battery charger	ST	STC4054
39	1	U6	LD39015M33R sot23l5	Low quiescent current and low noise voltage regulator	ST	LD39015M33R
40	1	U7	LPS22HDTR HLGA10X2X2X07	MEMS nano pressure sensor	ST	LPS22HDTR

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
41	1	U8	LSM6DSL lga14X2m5X3X086	3D digital accelerometer and gyroscope	ST	LSM6DSL
42	1	U9	LIS2MDL lga12X2X2X1	Ultra-low-power, high-performance 3-axis magnetometer	ST	LIS2MDL
43	1	Y1	16 MHz 15 ppm quarzonx2520sa	Quartz	NDK	NX2520SA-16,000000MHz-STD-CSW-4
44	1		Olimex LTD ARM-JTAG-20-10	Mini-board and cable	Olimex	ARM-JTAG-20-10

6 Formal notices required by the U.S. Federal Communications Commission ("FCC")

FCC NOTICE: This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the manufacturer could void the user’s authority to operate the equipment.

Additional warnings for FCC

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference's by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

7 Formal product notice required by the Industry Canada ("IC")

Innovation, Science and Economic Development Canada Compliance - This device complies with Innovation, Science and Economic Development RSS standards. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the manufacturer could void the user’s authority to operate the equipment.

Conformité à Innovation, Sciences et Développement Économique Canada - Cet appareil est conforme aux normes RSS d'Innovation, Science et Développement économique. L'utilisation est soumise aux deux conditions suivantes: (1) cet appareil ne doit pas causer d'interférences nuisibles, et (2) cet appareil doit accepter de recevoir tous les types d’interférence, y comprises les interférences susceptibles d'entraîner un fonctionnement indésirable. Les changements ou les modifications non expressément approuvés par le fabricant pourraient annuler le permis d'utiliser l'équipement.

Revision history

Table 8. **Document revision history**

Date	Version	Changes
27-Nov-2017	1	Initial release.
09-May-2018	2	Corrected typo in Table 6. Debugging micro SWD connector (P8).
06-Feb-2019	3	Updated Figure 1. STEVAL-FCU001V1 evaluation board and Section 3.1 Board connectors. Added references to STEVAL-ESC002V1 evaluation board.

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