UMxxxx
USER MANUAL
Evaluation Board
STEVAL-WESU1

Introduction

The STEVAL-WESU1 is a System Evaluation Board designed to provide a cost effective solution for precise motion sensing in wearable applications. The system is featuring a low power ARM Cortex-M3 microcontroller unit (STM32L151), an iNEMO inertial module (LSM6DS3), a high performance magnetometer (LIS3MDL), a barometric pressure sensor (LPS25HB), a Bluetooth® low energy wireless network processor (BLUENRG-MS) and power management circuitry that allows fast charging and precise energy estimation (STNS01 and STC3115). The connectivity granted by the best in class BLUENRG-MS and supported by the integrated balun (BALF-NRG-01D3) permit to maximize the RF performances with low area occupancy and design effort and pass the RF Test for FCC certification (FCC ID: S9NWESU1) and IC certification (IC ID: 8976C-WESU1).

An Android and iOS APP, available on Google Play and Apple Store, can be used for displaying information sent by the STEVAL-WESU1 through BLE connectivity as well as for setting operative modes.

Figure 1. STEVAL-WESU1 evaluation board

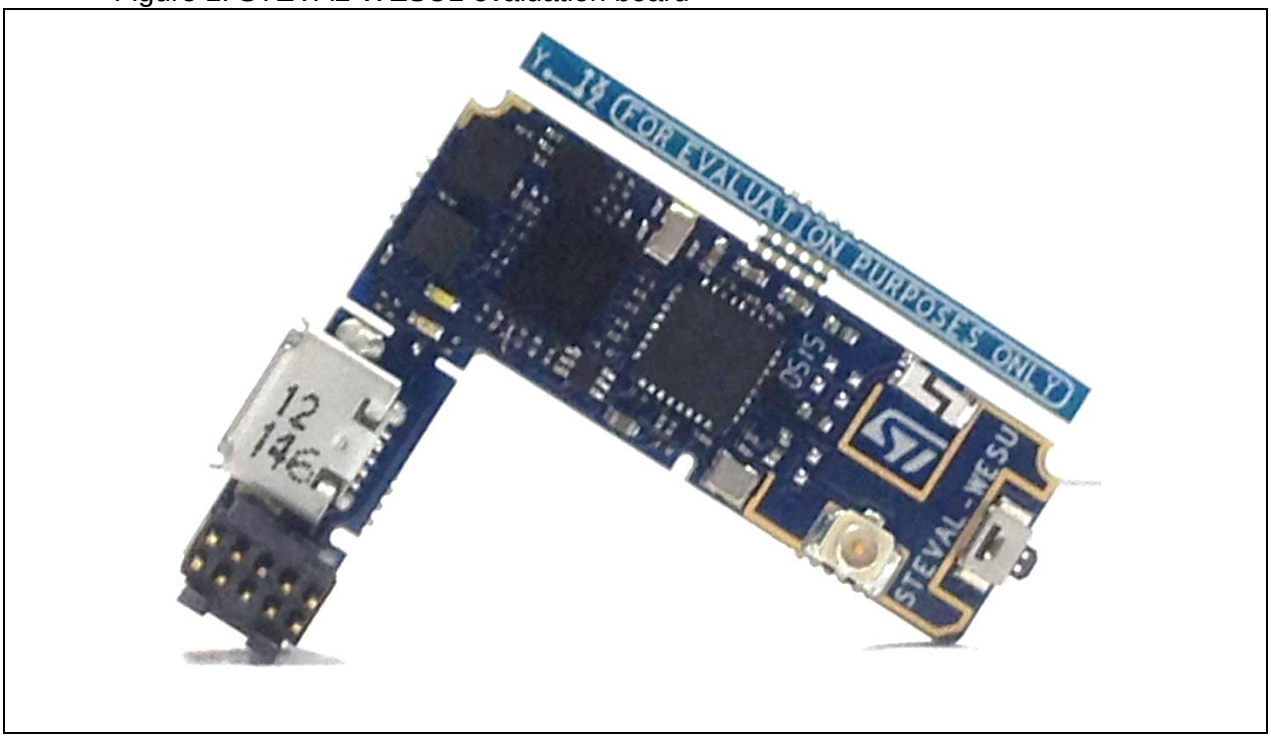


Table of Contents

1 Board Description and Getting started

The STEVAL-WESU1 is a System Evaluation Board designed and optimized in order to be a reference design for users would made their own wearable electronic devices. In fact, the system architecture is made up of hardware, firmware and software solutions to accelerate the overall development of all applications: from embedded end-customer devices to mobile software development. The design choices have been taken to address accurate motion tracking suitable for training in every kind of activity or sport.

Main Components:

- STM32L151VEY6, ultra-low-power ARM Cortex-M3 MCU with 512 Kbytes FLASH, 48kBytes of RAM in WLCSP100 package
- BLUENRG-MS, Bluetooth Low Energy (BLE) single-mode network processor, compliant with Bluetooth specification core 4.0
- BALF-NRG-01D3, 50 Ω balun for BLUENRG-MS transceiver with integrated harmonic filter
- LSM6DS3, iNEMO inertial module 3D accelerometer (±2/4/8g) + 3D gyroscope (±245/500/2000dps)
- LIS3MDL, MEMS 3D magnetometer (±4/8/12/16 gauss)
- LPS25HB, MEMS pressure sensor, 260-1260 hPa absolute digital output barometer
- STC3115, Gas gauge IC with alarm output
- STNS01, Li-Ion linear battery charger
- STLQ015XG30R, linear voltage regulator

The Figure 2 shows a function block diagram of the board where the sensors and the BLUENRG-MS are connected to microcontroller through two separate SPI peripherals, meanwhile the power management is driven by I2C peripheral. The system can be powered with USB connected to PC or through specific battery. The USB is also used for battery recharge. Figure 3 shows the block diagram of the RFIC BLUENRG-MS.

Figure 2. Functional Block Diagram

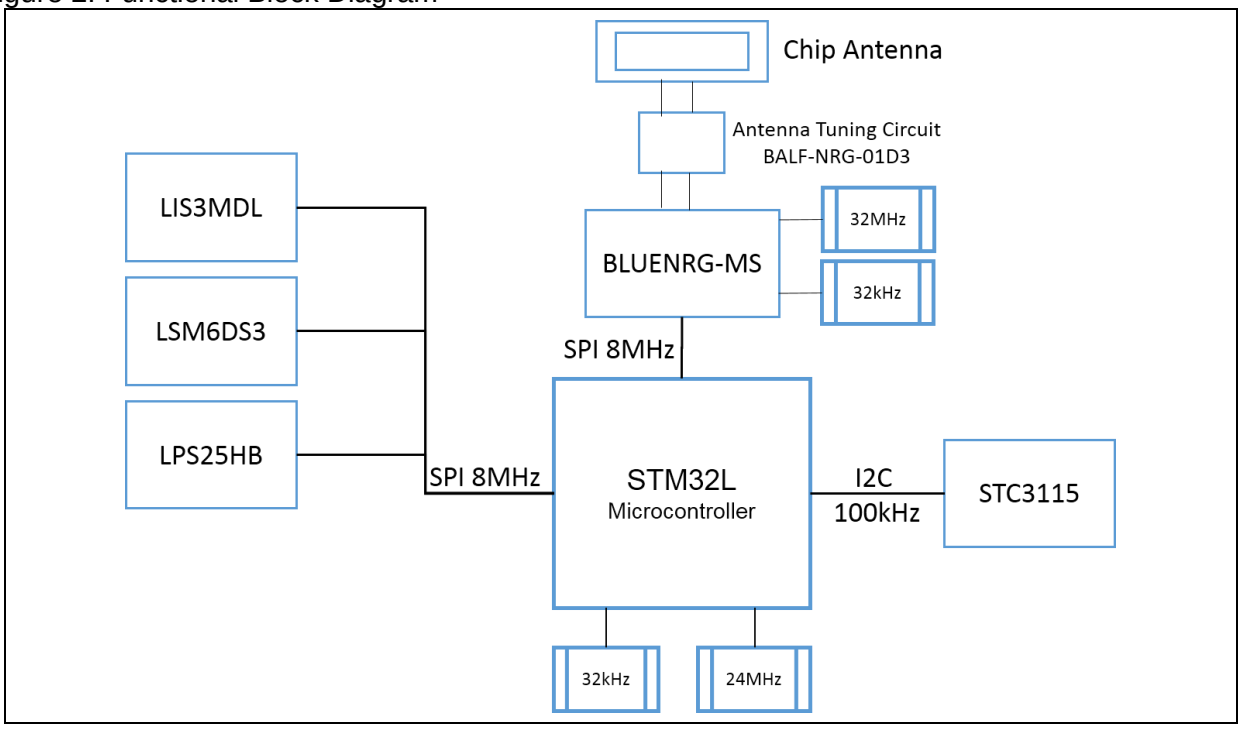
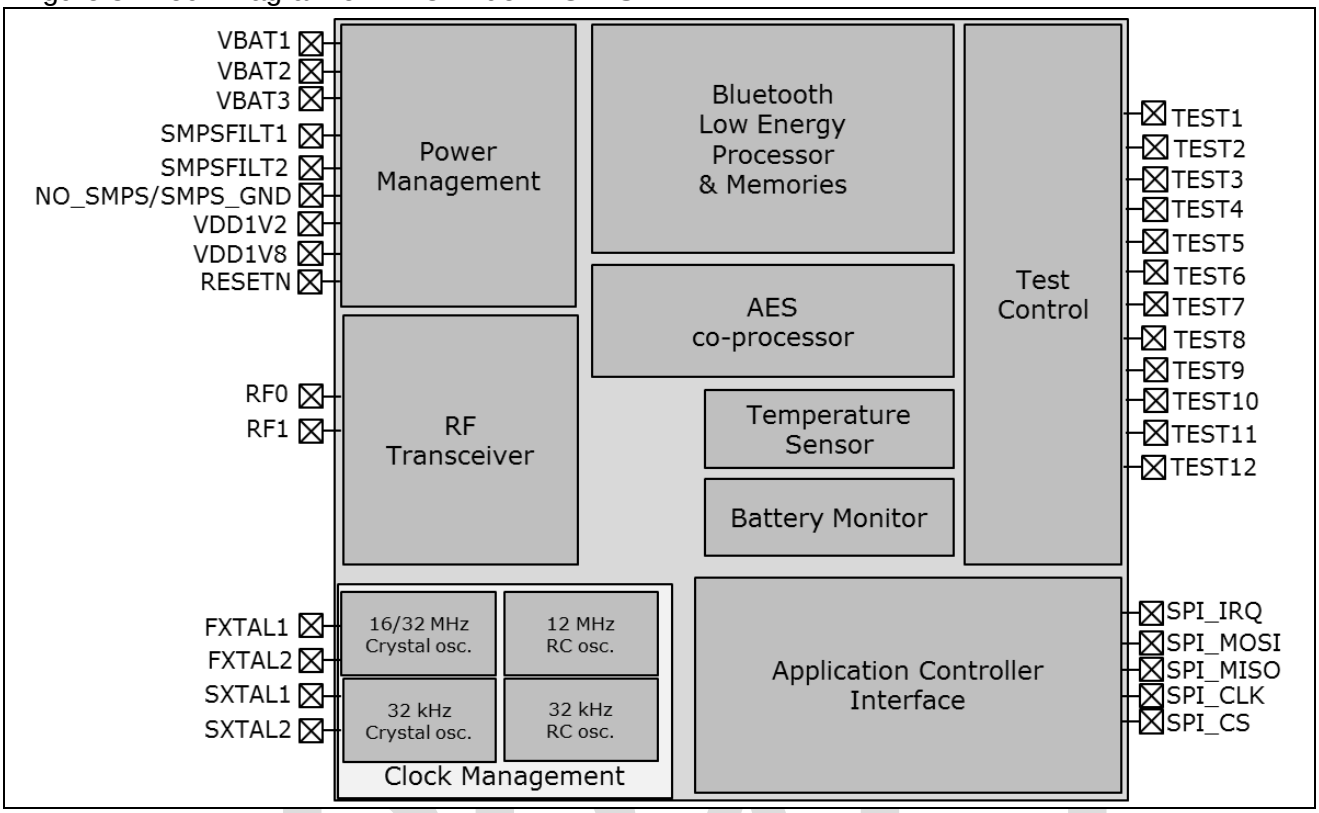


Figure 3. Block Diagram of RFIC: BlueNRG-MS



1.1 Getting started

The system is delivered fully assembled and connected with battery and with LDO off (shipment mode, with 2uA power consumption).

It can be simply switched ON with USB-powered cable insertion (micro B male plug). The USB port connector can be used for battery charging.

The system takes up to 160mA (@5V) to recharge the battery; for this reason you can use both USB wall adapter and PC port with this capability. Two LEDs (LED1 and LED2, see Figure 3) describes the Application Status and the Battery Charging Status.

The Charging LED (LED 2) could be:

- Light ON, the USB plug is correctly connected and the board is charging;
- Light OFF, the board is not charging (use USB cable reconnection to force re-start);
- Blinking (approximately at 1Hz), charging failure (e.g. over-temperature, three wires battery not connected);

It is important to avoid deep discharge (< 30%) to maintain battery integrity and to prevent long-term malfunctioning.

The User Button (see Figure 4) can be pressed to enter and exit the Stop MODE.

At power on the Application LED (LED1) starts with one smooth blink and in normal operation it blinks at 2s interval; after BLUENRG-MS connection the blinking interval becomes 1s and STEVAL-WESU1 system reads sensors data and sends it to a Bluetooth Smart Ready device; the data is displayed using a dedicated App.

A custom (1.27 mm pitch) SWD connector is used to have a compact solution, since to program the on-board STM32L151 it has been included in the package a specific adapter useful to be connected to a programmer tool (e.g. ST-LINK/v2).

Figure 4. Board Layout – top layer

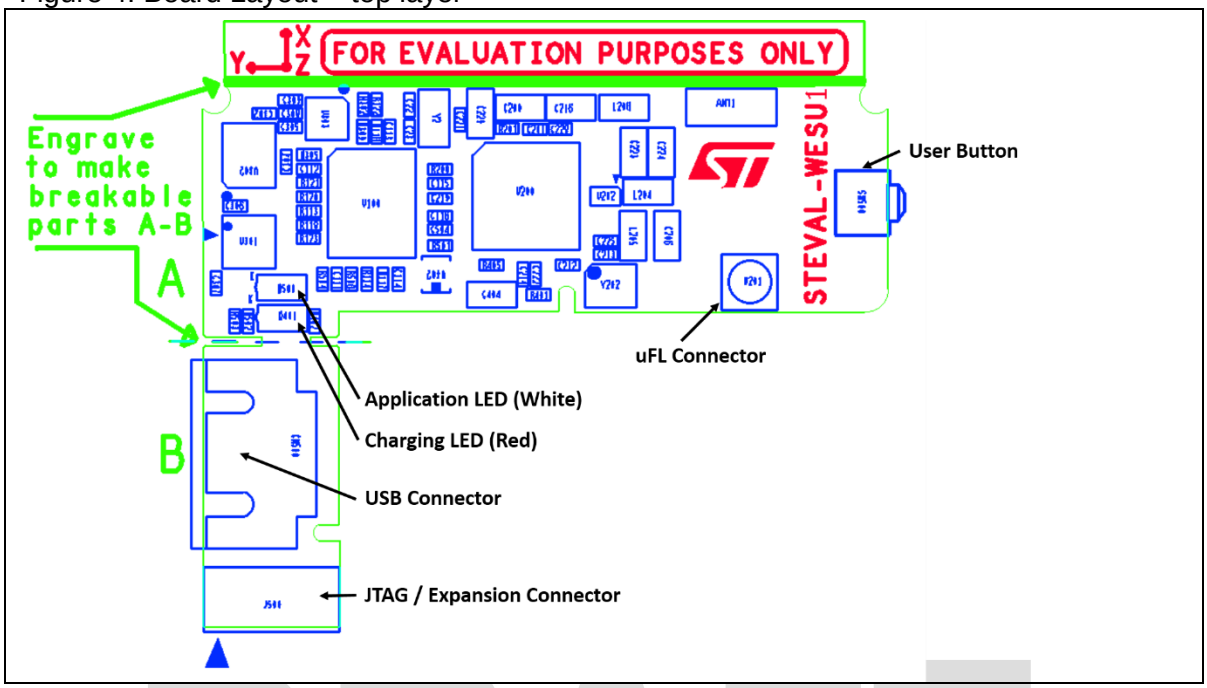
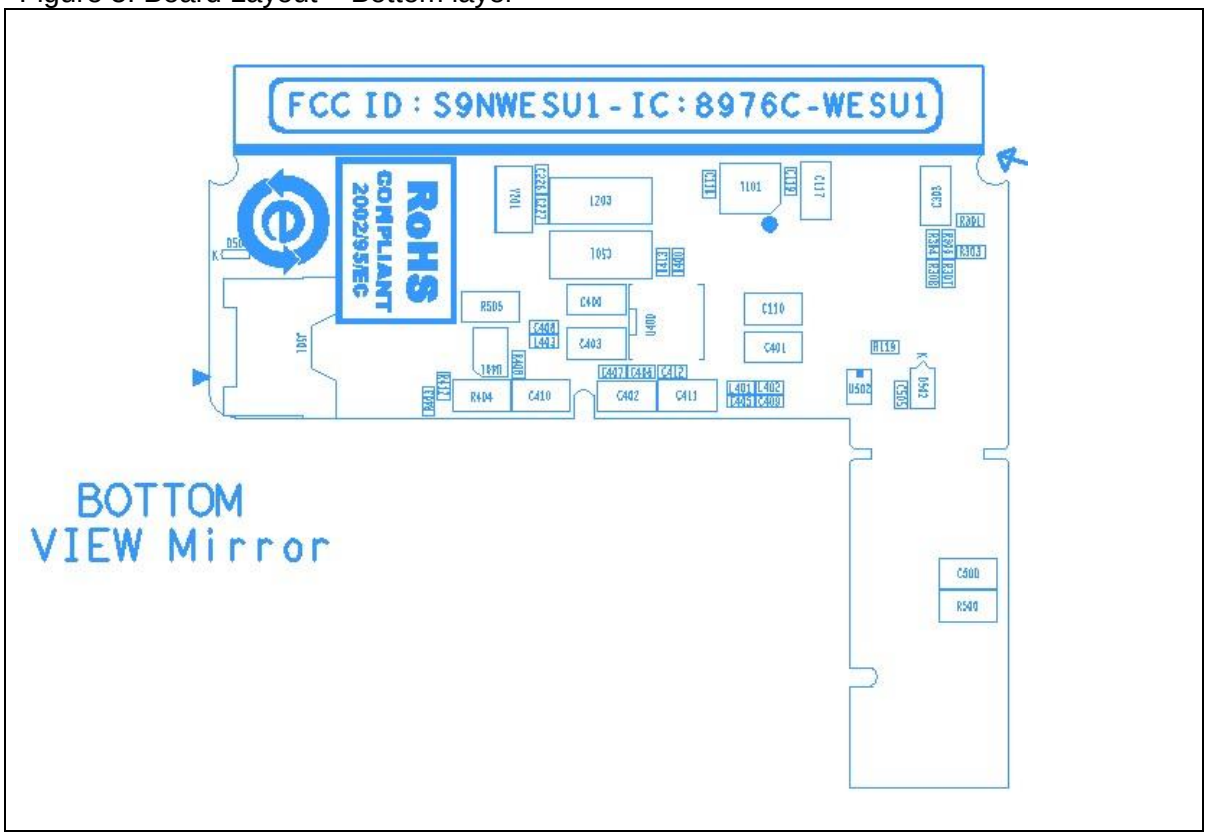


Figure 5. Board Layout – Bottom layer



Once it has been verified the battery is enough charged, the board is ready to be used. To visualize the information sent through the Bluetooth Low Energy connectivity is fundamental to install one of the App available for the Smartphone and Tablet:

- ST WESU Android App, available on Google Play;
- ST WESU iOS App available on Apple Store.

To use this App is need a Smartphone or Tablet supporting the BLE connectivity, i.e. iPhone 4S and subsequent or, an Android based device with Android OS 4.3 or higher.

2 Hardware description

This section describes the main components present on the board and described in Figure 3 and 4.

2.1 Microcontroller

STM32L151VEY6 is an ultra-low-power microcontroller unit based on ARM Cortex M3. It features a great range of low power modes and an efficient voltage scaling that allows power saving.

2.2 Sensors

Thanks to their overall integration level the embedded sensors offer great flexibility in terms of accuracy of the system and in terms of power consumption.
The integrated sensors perfectly fit the needs of an accurate AHRS algorithm (e.g. embedded iNEMO-Engine running on the STM32L151VEY6), height estimation and everything needed for wearable motion tracking: from extreme low power activity tracker to more advanced motion reconstruction.

2.2.1 LSM6DS3

The LSM6DS3 is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 1.25 mA (up to 1.6 kHz ODR) in high performance mode and enabling always-on low-power features for an optimal motion experience for the consumer. Up to 8 Kbyte of FIFO with dynamic allocation of significant data (i.e. external sensors, time stamp, etc) allows the overall power saving of the system.. ST's family of MEMS sensor modules leverages the robust and mature manufacturing processes already used for the production of micro machined accelerometers and gyroscopes. The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element. The LSM6DS3 has a full-scale acceleration range of ±2/±4/±8/±16 g and an angular rate range of ±125/±245/±500/±1000/±2000 dps. High robustness to mechanical shock makes the LSM6DS3 the preferred choice of system designers for the creation and manufacturing of reliable products. The LSM6DS3 is available in a plastic land grid array (LGA) package.

2.2.2 LISM3DL

The LIS3MDL is an ultra-low-power high performance three-axis magnetic sensor. The LIS3MDL has user-selectable full scales of ±4/ ±8/ ±12/±16 gauss. The self-test capability allows the user to check the functioning of the sensor in the final application. The device may be configured to generate interrupt signals for magnetic field detection. The LIS3MDL includes an I2C serial bus interface that supports standard and fast mode (100 kHz and 400 kHz) and SPI serial standard interface. The LIS3MDL is available in a small thin plastic land grid array package (LGA) and is guaranteed to operate over an extended temperature range of -40 °C to +85 °C.

2.2.3 LPS25HB

The LPS25HB is an ultra-compact absolute piezo-resistive pressure sensor. It includes a monolithic sensing element and an IC interface able to take the information from the sensing element and to provide a digital signal to the external world.
Thanks to its great accuracy (1 Pa RMS, 24bit ADC resolution), its bandwidth (1 Hz – 25 Hz) and to its very low power consumption (4uA low power mode, 25uA high performance mode) the integration of this sensor is suitable for height estimation (e.g. VRU Vertical Reference Unit) and to enhance standard IMU performances with high frequency altitude reference.

2.3 BLUENRG-MS and BALF-NRG-01D3

The BLUENRG-MS is a very low power Bluetooth low energy (BLE) single-mode network processor, compliant with Bluetooth specification v4.1. The BLUENRG-MS can act as master or slave. The entire Bluetooth low energy stack runs on the embedded Cortex M0 core. The non-volatile Flash memory allows on-field stack upgrading. The BLUENRG-MS allows applications to meet the tight advisable peak current requirements imposed with the use of standard coin cell batteries. The maximum peak current is only 8.2 mA at 0 dBm of output power. Ultra low-power sleep modes and very short transition times between operating modes allow very low average current consumption, resulting in longer battery life. The BLUENRG-MS offers the option of interfacing with external microcontrollers using SPI transport layer.
BALF-NRG-01D3 is a 50Ω conjugate match to BLUENRG-MS (QFN32 package) that integrates balun transformer and harmonics filtering. It features high RF performances with a very small footprint and a RF BOM reduction. It has been chosen as the best trade-off for costs, area occupation and high radio performances. The layout has been optimized to match 4 layers design and a chip antenna.

2.4 Power management

The power management block includes the STNS01, the STLQ015 and the STC3115

2.4.1 STNS01 and STLQ015

The STNS01 is a linear charger for single-cell Li-Ion batteries.
In STEVAL-WESU1 system it is configured as battery charger and as power path selected between USB power source and battery power source.
The STNS01's battery charger is designed to charge single cell Li-Ion batteries up to 4.2 V using a CC-CV charging algorithm (see STNS01 datasheet for more details). When a valid input voltage is detected, the STNS01 starts the charge cycle and the CHG pin switches from high impedance to low level. The CHG pin is connected to LED2 to monitor the charger.
The charging status LED (LED 2) can be:

- solid ON: the USB plug is correctly connected and the board is charging;
- solid OFF: the board is not charging (use USB cable reconnection to force re-start);
- blinking (approx. 1Hz): charging failure (e.g. over-temperature, three wires battery not connected);

The SYS pin is the voltage output of STNS01 selected power path. That SYS pin is connected to the linear voltage regulator STLQ015XG30R that provide a 3V (VDD) to all other devices.
The STM32L151 is also connected to its SHDN pin to disconnect the power delivery to most of the devices and enable the shipment mode.

2.4.2 STC3115

The STC3115 includes the hardware functions required to implement a low-cost gas gauge for battery monitoring. The STC3115 uses current sensing, Coulomb counting and accurate measurements of the battery voltage to estimate the state-of-charge (SOC) of the battery. An internal temperature sensor simplifies implementation of temperature compensation. An alarm output signals a low SOC condition and can also indicate low battery voltage. The alarm threshold levels are programmable.
The STC3115 offers advanced features to ensure high performance gas gauging in all application conditions.

2.5 Connectors

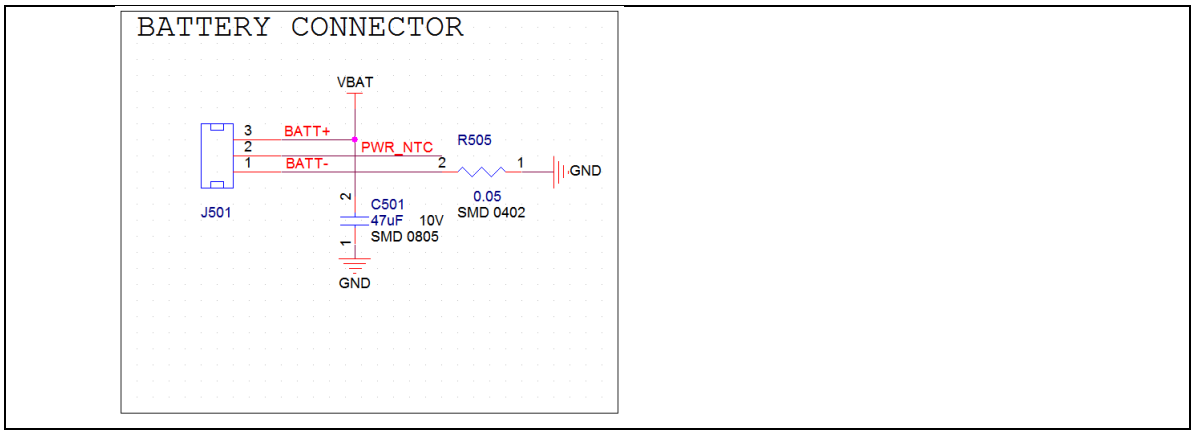
The following sub-sections describe the connectors of STEVAL-WESU1 board (see Figure 4 as reference). The STEVAL-WESU1 has “L” form factor (see Figure 4), suitable to host the battery (i.e. 12xd25mm @ 85 mAh) in plane with the PCB and optimize the final design.

Figure 5 Photo of STEVAL-WESU1 with Battery

2.5.1 Battery connector

Battery connector is placed on the shrink side of the board (see Figure 2). Its hardware connection is shown in Figure 6

Figure 6 Battery connector Schematic



2.5.2 SWD Connector and external peripherals

A custom 10 pin (1.27 mm pitch) connector is soldered. It can be used:

- to program on-board microcontroller through a dedicated adapter connected to programmer tool (like ST-Link) (Figure 7)
- as an expansion connector to allow user to access to other board features as described in Table1

Figure 7: SWD Connector

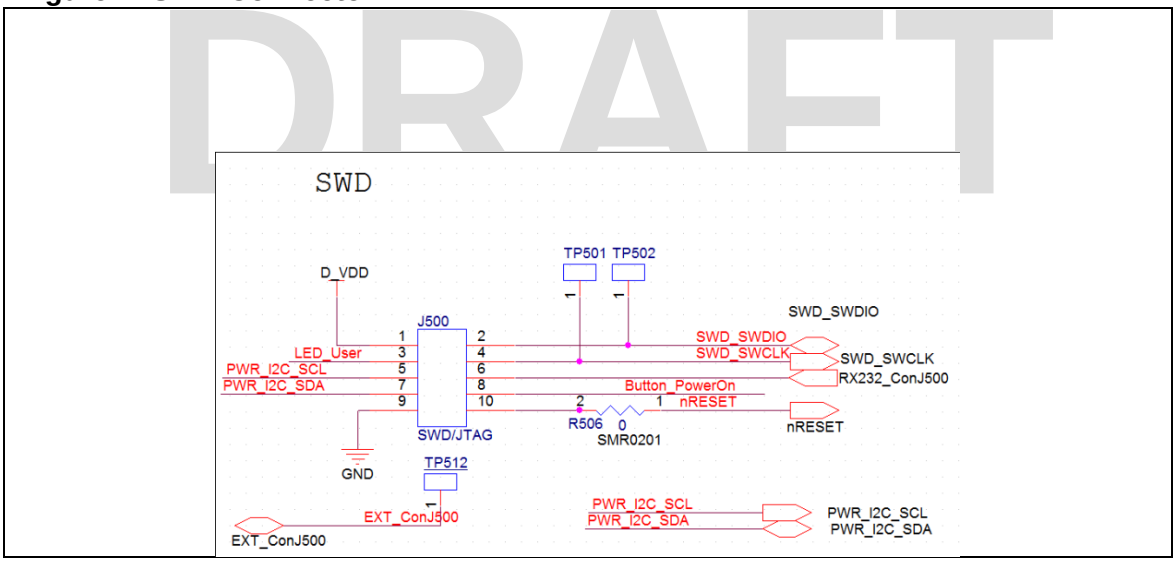


Table1 Expansion Connector GPIO Description

Expansion Connector GPIO Description						
Exp. Pin J500	Port/Pin	Default func.	Expansion PIN	PWM	USART	ADC
8	A2	Push Button	1	TIM2CH3	USART2_TX	ADC_CH2
3	B0	User LED	2	TIM3CH3		ADC_CH8
6	A3	-	3	TIM2CH4	USART2_RX	ADC_CH3
TP512	B12	-	4	TIM10CH1		ADC_CH18

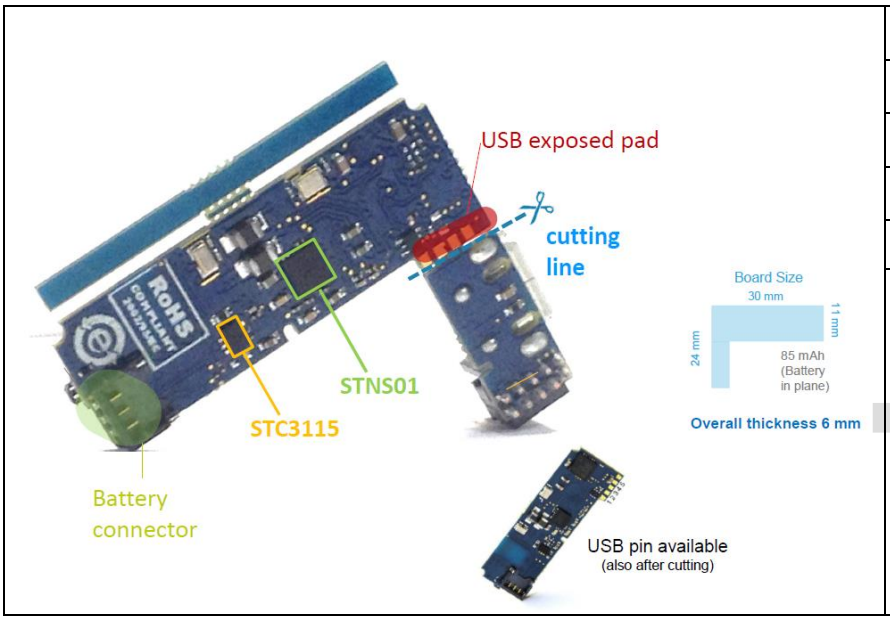
2.5.3 USB Connector

The USB connector accepts a micro USB type B and it is used to charge the battery or to power the board if battery is not present.

2.5.4 Exposed pad connector

STEVAL-WESU1 gives the possibility to reduce form factor by cutting PCB area hosting USB connector and expansion connector (see cutting line in 8). USB feature will be accessible by exposed pads on the bottom of the PCB (8). Firmware upgrade will be possible only over the air or via USB DFU.

Figure 8: STEVAL-WESU1 Exposed Pads



1: USB DP
2: USB 5V
3: GND
4: USB DM
5: TP512 – Expansion PIN 4 test point

2.5.5 uFL connector

The uFL connector U201 (not mounted) is connected to BLUENRG-MS RF path through C206 (not mounted). By soldering a 51pF capacitor and desoldering L204, the uFL connector RF path can be activated, useful for debug purposes.

2.6 Buttons and LEDs

The STEVAL-WESU1 board has 2 LEDs and only one button for user operations.

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

Model: STEVAL-WESU1

FCC ID: S9NWESU1

Any changes or modifications to this equipment not expressly approved by STMicroelectronics may cause harmful interference and void the user's authority to operate this equipment.

This device complies with part 15 of the FCC rules. 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.

For Class A Digital Devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

For Class B Digital Devices

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.

4 Formal notices required by the Industry Canada ("IC")

Model: STEVAL-WESU1

IC: 8976C-WESU1

English:

This Class A or B digital apparatus complies with Canadian CS-03.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

French:

Cet appareil numérique de la classe A ou B est conforme à la norme CS-03 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. 'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

5 Board schematic and bill of material

This section contains the bill of material and layout of the STEVAL-WESU1

5.1 Bill of material

BOM STEVAL-WESU1

Item	Q.ty	Reference	Part/Value	Voltage /Ampere /Ohm	Type / Additional Notes	Tolerance	Package	Manufacturer	Manufacturer Code	More Info
1	1	ANT1	2.4 GHz		Chip Antenna		SMD	Pulse	W3008C	
2	1	CN500	Micro_USB_AB					Molex	47590-0001	
3	5	C110,C200,C216,C401,C411	1uF	6.3V	Ceramic X5R	±10%	SMD 0402	Murata	GRM155R60J105KE19D	
4	23	C111,C112,C113,C114,C115,C116,C201,C219,C222,C225,C228,C302,C304,C305,C306,C307,C308,C309,C406,C407,C412,C504,C505	100nF	16V	Ceramic X5R	±10%	SMD 0201	Murata	GRM033R61C104KE84D	
5	4	C117,C303,C400,C404	10uF	6.3V	Ceramic X5R	±20%	SMD 0402	TDK	C1005X5R0J106M050BC	
6	2	C118,C119	10pF	25V	Ceramic C0G, NP0	±0.5pF	SMD 0201	TDK	C0603C0G1E100D030BA	

7	1	C206	51pF NOT MOUNT	50V	Ceramic C0G	±10%	SMD 0402	Murata	GRM1555C1H510GA01D	Mandatory Use Manuf.Code Marked
8	2	C212,C213	12p	50V	CH	±0.1pF	SMD 0201	Murata	GRM0335C1H120GA01	Mandatory Use Manuf.Code Marked
9	2	C214,C221	100p	16V	Ceramic X7R	±10%	SMD 0201	Murata	GRM033R71C101KD01D	Mandatory Use Manuf.Code Marked
10	2	C223,C224	Not Mount	Not Mount	Not Mount	Not Mount	SMD 0402	Murata	Not Mount	
11	2	C226,C227, C22,C23	15p	25V	C0G	±0.1pF	SMD 0201	Murata	GJM0336C1E150FB01D	Mandatory Use Manuf.Code Marked
12	1	C229	150n	6.3V	Ceramic X5R	±10%	SMD 0402	Murata	GRM155R60J154KE01D	Mandatory Use Manuf.Code Marked
13	2	C402,C403	2.2uF	6.3V	Ceramic X5R(EIA)	±20%	SMD0402	Murata	GRM155R60J225ME95D	
14	3	C405,C408,C409	10nF	10V	Ceramic X7R	±10%	SMD 0201	Murata	GRM033R71A103KA01D	
15	1	C410	220nF	16V	Ceramic X7R	±10%	SMD 0402	Murata	GRM155R71C224KA12D	
16	1	C500	4.7nF	50V	Ceramic X7R	±10%	SMD 0402	Murata	GRM155R71H472KA01D	
17	1	C501	47uF	10V	Ceramic X5R	±20%	SMD 0805	TDK	C2012X5R1A476M125AC	
18	1	D401	RED		LED			VISHAY	VLMS1500-GS08	
19	1	D500	WHITE		LED			VISHAY	VLMW1500-GS08	
20	1	D501	ESDALC6V1-1U2		ST0201			ST	ESDALC6V1-1U2	**ST-SUPPLY**
21	1	D502	ESDA7P60-1U1M		QFN			ST	ESDA&P60-1U1M	**ST-SUPPLY**
22	1	J500	SWD/JTAG				THR 1.27 mm 2x5	SAMTEC	FTSH-105-01-F-D-K	
23	1	J501	CON3				SMT 3W 1.2	Molex	78171-0003	

							mm pitch			
24	1	L203	10uH			20%	SMD 0805	Murata	LQM21FN100M70L	Mandatory Use Manuf.Code Marked
25	1	L204	0R OHM			±0,1nH	SMD 0402	Murata	TBD	
26	1	L205,L206	3.9nH			±0,3nH	SMD 0201	Murata	LQG15HN3N9SO2D	Mandatory Use Manuf.Code Marked
27	3	L401,L402,L403	1.5 Ohm 215 mA				SMD 0201	Murata	BLM03BD471SN1D	
28	4	R113,R309,R405,R506	0			±1%	SMD 0201	ANY	ANY	
29	10	R116,R117,R119,R120,R121,R122,R123,R200,R201,R501	10k			±1%	SMD 0201	ANY	ANY	
30	5	R301,R302,R303,R307,R308	0			±1%	SMD 0201	ANY	ANY	
31	5	R114,R118,R304,R305,R306	0-NOT MOUNT			±1%	SMD 0201	ANY	ANY	
32	1	R400	2K			±1%	SMD 0201	ANY	ANY	
33	1	R401	1R			±1%	SMD 0201	ANY	ANY	
34	1	R402	60 - 0.05W			±1%	SMD 0201	ANY	ANY	
35	2	R403-R408	1K			±1%	SMD 0201	ANY	ANY	
36	1	R404	10K NTC - NOT MOUNT			±1%	SMD 0402	Vishay	NTCS0402E3103FLT	
37	1	R412	1M			±1%	SMD 0201	ANY	ANY	
38	1	R413	33K			±1%	SMD 0201	ANY	ANY	
39	1	R500	1M			±1%	SMD 0201	ANY	ANY	
40	2	R502,R503	100K			±1%	SMD 0201	ANY	ANY	
41	1	R504	100			±1%	SMD 0201	ANY	ANY	
42	1	R505	0.05			±1%	SMD 0402	WELWYN	LRCS0402-0R05FT5	
43	1	SW500	SW					Omron	B3U-3000P	

			PUSHBUTTON-DPST							
44	1	U201	U.FL connector - NOT MOUNT	50 Ohm - 6 Ghz	SMD Coaxial Connector		SMT	Hirose	U.FL-R-SMT-1(10)	
45	1	U100	STM32L151VEY6		WLCSP104			ST	STM32L151VEY6	**ST-SUPPLY**
46	1	U200	BLUENRG-MS		VFQPN32 5x5 mm			ST	BLUENRG-MSQTR	**ST-SUPPLY**
47	1	U202	BALF-NRG-01D3		FLIP CHIP 4 ball			ST	BALF-NRG-01D3	**ST-SUPPLY**
48	1	U301	LPS25HB		HLGA-10L (2.5 x 2.5x 0.76 mm)			ST	LPS25HB	**ST-SUPPLY**
49	1	U302	LSM6DS3		LGA-14L (2.5x3x0.83 mm)			ST	LSM6DS3	**ST-SUPPLY**
50	1	U303	LIS3MDL		VFLGA-12 (2.0x2.0x1.0 mm)			ST	LIS3MDL	**ST-SUPPLY**
51	1	U400	STNS01		DFN12L (3x3 mm)			ST	STNS01	**ST-SUPPLY**
52	1	U401	STC3115		CSP (1.4 x 2.0 mm)			ST	STC3115	**ST-SUPPLY**
53	1	U402	STLQ015XG30R		SOT666			ST	STLQ015XG30R	**ST-SUPPLY**
54	1	U502	USBULC6-2M6		uQFN			ST	USBULC6-2M6(uQFN)	**ST-SUPPLY**
55	2	Y2, Y201	NX2012SA 32k EXS00A-MU00389					NDK		
56	1	Y101	NX2016SA 24MHZ EXS00A-CS05544					NDK		
57	1	Y202	NX2016SA 32MHz EXS00A-CS06644					NDK		

5.2 Schematic

6 Revision history

Table 1: Table Title

Revision	Date of modification	Description of modification
0.2	July 15	Initial draft
0.3	July 15	Modified version
0.4	July 15	Changed name in STEVAL-WESU1