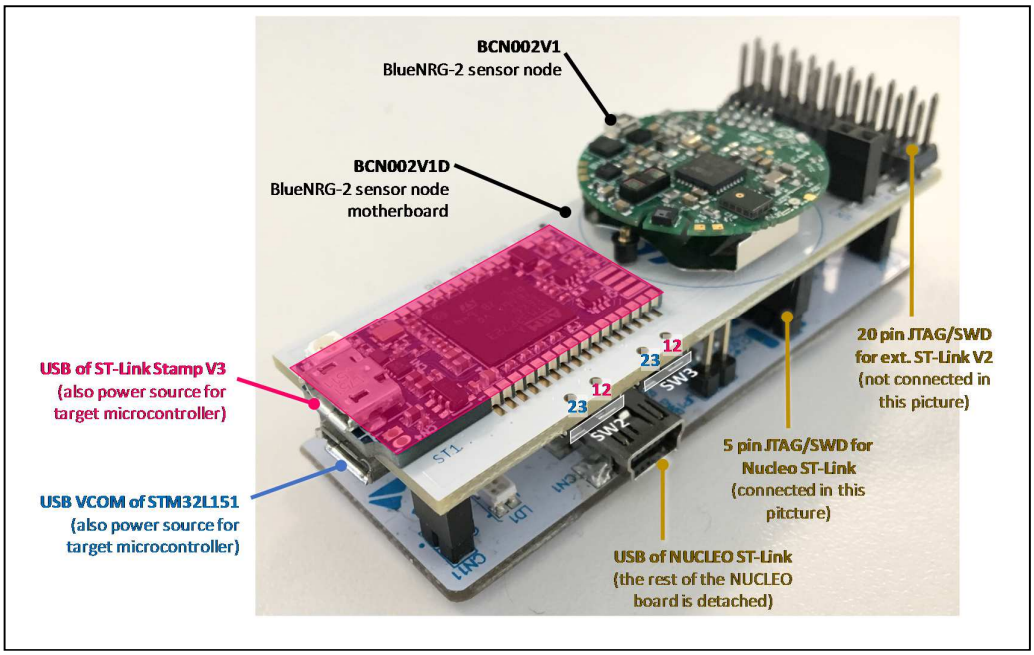
STEVAL-BCN002V1B

Technical Description Document



What is STEVAL-BCN002V1B?

It is an evaluation boards kit based on two boards:

STEVAL-BCN002V1

- BlueNRG-232: Bluetooth Low Energy single-mode system-on-chip, compliant with Bluetooth 5.0 specifications
- BALF-NRG-02D3: ultra-miniature balun and harmonic filter
- LSM6DSO: iNEMO 6DoF inertial module, ultra-low power and high accuracy
- LIS2MDL: Magnetic sensor, digital output, 50 gauss magnetic field dynamic range, ultra-low power high performance 3-axis magnetometer
- VL53L1X: Long distance ranging Time-of-Flight sensor based on ST FlightSense technology
- MP34DT05TR-A: MEMS audio sensor omnidirectional digital microphone, 64 dB SNR, -26 dBFS sensitivity, top-port, 122.5 dBSPL AOP
- LPS22HH: Ultra-compact piezo-resistive absolute pressure sensor, 260-1260 hPa, digital output barometer, full-mold dust resistant, holed LGA package (HLGA)
- HTS221: Capacitive digital sensor for relative humidity and temperature
- CR2032 Battery powered (not included)

STEVAL-BCN002V1D

- Daughter board to reprogram and debug firmware running on sensor board
- ST BlueMS and BlueNRG-Mesh demo Apps available on Android (Google Play) and iOS (iTunes)
- Target Applications:
  - Internet of Things, Smart Building, Home and City
  - Tracking System, Supply Chain/ Cold-Chain Management
  - Smart Agriculture (soil control, animal activity tracking, etc.)

General Description

STEVAL-BCN002V1B Is a bundle kit based on STEVAL-BCN2V1, multi sensors board based on BlueNRG-2 SoC Bluetooth Low Energy 5.0 Application processor. This board is embedding difference sensor as Accelerometer, Gyroscope, Magnetometer, Pressure, Humidity, Time-of-Flight, Microphone and is powered by a common coin battery, CR2032. This sensor board is connecting to Bluetooth LE enabled smartphone, using ST BlueMS APP available on Google Play and iTunes stores. The Adapter board, STEVAL-BCN002V1D is used to program, debug and power the board via USB.

STEVAL-BCN002V1 Detailed description

The STEVAL-BCN002V1 includes the following components and features:

- **BLUENRG-2** Bluetooth low-energy wireless system-on-chip: the device includes an ultra low-power ARM Cortex-M0 MCU with 256KB Flash and 24KB RAM with retention, plus an extensive range of enhanced I/O and peripherals (10bit ADC, 2 general purpose 16bit timers, watchdog and RTC, DMA controller, PDM stream processor, 2 I2C, 1 SPI, 1 UART, up to 26 GPIOs). The embedded Cortex-M0 runs at 32MHz and supports the radio stack and the user application. The device support BLE 5.0 stack and proprietary 2.4GHz stack. The device can work with an external 16 or 32MHz crystal, and with an internal 32kHz ring oscillator or an external 32kHz crystal (which enable lowest power sleep mode). The device includes an integrated linear regulator and a DC-DC converter (requires an external inductor and enables lowest power active mode). Power consumption down to 1uA with active BLE stack (sleep mode); 1.9mA when CPU is running, RAM and Flash on (active mode); 8.3mA TX peak current at -2dBm output power. Up to +8dBm output power, up to 96dB link budget.
- **BALF-NRG-02D3** 50ohm nominal input / conjugate match to BlueNRG transceiver with integrated harmonic filter.
- **LSM6DSO** inertial digital module with 3-axis **accelerometer** and 3-axis **gyroscope**. Ultra-low power (0.55mA in combo high-performance mode at the highest datarate, 6.6kS/s). Configurable free-fall, wakeup, 6D/4D orientation detection (to support portrait and landscape mode detection), single/double tap recognition; automatic detection for activity/inactivity and stationary/motion condition; advanced algorithms

for pedometer, step detector and step counter; significant motion and relative tilt; up to 16 finite state machines (FSM) to process accelerometer, gyroscope or external sensor data. User selectable full scale of 2, 4, 8 or 16g and 125, 250, 500, 1000 or 2000dps; output data rates from 12.5 to 6600Hz, bandwidth up to 3kHz. The device includes 9KB FIFO buffer for 2 internal sensors and up to 4 external sensors.

- **LIS2MDL** ultra low-power high-performance 3-axis **magnetic** digital sensor, 50 Gauss magnetic dynamic range. Selectable resolution/power trade-off. Output data rate up to 150Hz. RMS noise down to 3mgauss in high-performance mode with low-pass filter active. Embedded intrinsic offset cancellation. Embedded registers for hard-iron offset subtraction. Configurable interrupt.
- **LPS22HH** ultra-compact piezo-resistive **absolute pressure** digital sensor, 260-1260hPa, digital output barometer, full-mold, holed LGA package. The sensing element, which detects absolute pressure, consists of a suspended membrane manufactured using a dedicated process developed by ST.
- **HTS221** capacitive digital sensor for **relative humidity and temperature**. The sensing element consists of a polymer dielectric planar capacitor structure capable of detecting relative humidity variations and is manufactured using a dedicated ST process.
- **MP34DT05-A** compact low-power omnidirectional digital top-port **microphone** with a capacitive sensing element; 0.2% THD+N and 64dB signal-to-noise ratio at 1kHz and 94dBSPL, 0.7% THD+N at 1kHz and 110dBSPL, 122.5dBSPL acoustic overload point, -26dBFS +/-3dB sensitivity, PDM output (1.2 to 3.25MHz), up to 24kHz bandwidth.
- **VL53L1X** long distance **ranging Time-of-Flight** sensor based on ST's FlightSense™ technology. 940nm class 1 laser emitter, 16x16 SPAD receiving array with integrated lens (27deg field of view). Ranging frequency from 1 to 50Hz (repeatability improves at lower data rate, 2.5mm standard deviation with 200msec measurement); Ranging distance from 4cm to 400cm (under 4cm the device will detect a target but measurement will not be accurate). Ranging error within 20mm.

STEVAL-BCN002v1 System architecture

The BLE sensor node is powered by a coin-cell battery (CR2032). The voltage is NOT regulated because all sensors and the BlueNRG-2, they can all operate at the voltage range of the battery. Moreover, the BlueNRG-2 has its own embedded linear power regulator and switching mode power converter (DC-DC).

POWER SECTION FOR BLUENRG-2

The BlueNRG-2 in active mode can use the embedded linear voltage regulator (LDO) or the embedded DC-DC converter (DC-DC). The BLE sensor node includes the **inductor** needed by the DC-DC converter to enable the lowest power consumption in active mode:

- Active mode, CPU Flash and RAM on, LDO regulator: RX 14.5mA at 3V, TX 17.2mA when output power is +2dBm, range is 12-28.8mA when output is -14 to +8dBm
- Active mode, CPU Flash and RAM on, **DC-DC converter**: RX 7.7mA at 3V, TX 9mA at 3V when output power is +2dBm, range is 6.6-15.1mA when output is -14 to +8dBm

The BlueNRG-2 in sleep mode can use the internal 32kHz ring oscillator (RO) or an external 32kHz crystal oscillator (XO). The BLE sensor node includes the **32kHz crystal oscillator** to enable the lowest power consumption in sleep mode:

- Sleep mode, 32kHz RO (Ring oscillator), 24kB RAM retention: 2.1uA at 3V
- Sleep mode, 32kHz **XO (Crystal oscillator)**, 24kB RAM retention: 0.9uA at 3V

RADIO FREQUENCY SECTION

The Radio Frequency section of the BLE sensor node includes three elements:

- The first element is BALF-NRG-02D3, an ultra-miniature balun which integrates matching network and harmonics filter.
- The second element is a Π-network which provides the flexibility to get additional filtering and also provides access points for testing. This network is not populated as the integrated balun provides the necessary matching.
- The third element is the SMD 2.4GHz antenna which needs a specific clearance area on the PCB and specific passives for perfect tuning (FT1, FT2 and MT).

MEMS SENSOR SECTION

The Sensor section of the BLE sensor node includes inertial and environmental MEMS sensors connected to BlueNRG-2 by means of an I2C bus operated at 400kHz.

The MEMS microphone is connected to BlueNRG-2 using a dedicated line to transfer the PDM (Pulse Density Modulated) stream at 1.6MHz. The PDM stream is converted to PCM (Pulse Coded Modulation) by the integrated digital filter included in the ADC block on BlueNRG-2.

All sensors can generate interrupts, but in the BLE sensor node, only two interrupt pins are connected to BlueNRG-2 using dedicated and independent lines: the interrupt from the LIS2MDL magnetometer and the interrupt from the LSM6DSO accelerometer and gyroscope.

- The LIS2MDL magnetometer interrupt line is only push-pull and must have its own independent line. The interrupt pin of this sensor is connected to BlueNRG-2 to enable applications such as “reed-switch” (switch activated by an external magnet).
- The LSM6DSO smart accelerometer and gyroscope interrupt pin is an input at boot. It has an internal pull-down. If the pin is low at boot, the I2C interface is selected, otherwise the I3C interface is selected. The pin can be reconfigured as open-drain but the external pull-up would cause an additional power consumption. The interrupt pin of this sensor is connected to BlueNRG-2 to fully exploit the “smart” embedded processing (single/double tap recognition, free-fall, wakeup, portrait/landscape,

6D/4D orientation detection; activity/inactivity, stationary/motion detection; pedometer, step detector and step counter; up to 16 finite state machines to process

- The LPS22HH barometer interrupt pin is the same as for LSM6DSO: it is an input pin at boot and must be low so that I2C interface is activated. It can be configured as push-pull or open-drain after boot. The interrupt pin of this sensor is not connected to BlueNRG-2.
- The HTS221 relative humidity and temperature interrupt pin is push-pull at boot and can be reconfigured as open-drain after boot. The interrupt pin of this sensor is not connected to BlueNRG-2.
- The VL53L1X time-of-flight proximity interrupt line is only open-drain and would require an external pull-up. The interrupt pin of this sensor is not connected to BlueNRG-2.

From the application point of view, the dynamic of the environmental parameters is very slow. Therefore, an interrupt need not be used. The application can wake-up on a regular basis, every few seconds, perform one-shot measurements with the LPS22HH barometer or HTS221 relative humidity and temperature sensor, and trigger the corresponding action if specific conditions are met.

Also, from the application point of view, it is not convenient to keep the VL53L1X proximity time-of-flight sensor active, waiting for a gesture and a corresponding wake-up interrupt. The power consumption or the latency would be too high. The power consumption of VL53L1X ranges from 0.5mA for 1Hz measurements, up to 7mA for 10Hz measurements.

BlueNRG-2 features

BlueNRG-2 integrates a Bluetooth Low Energy radio (BLE), an ARM Cortex-M0 core, 12+12kB of RAM, 256kB of Flash memory and several peripherals: SPI (max 1MHz in slave mode, 8MHz in master mode), 2x I2C (standard 100kHz or fast 400kHz), and UART interfaces; 2x multi-function timer (MFT), DMA controller, RTC and watchdog, ADC with PDM stream processor.

The public key cryptography (PKA) and random number generator (RNG) are reserved for the BLE protocol stack, however the user application can also read the RNG.

The ADC features are: 10-bit, single or continuous acquisition at max 1MHz sampling frequency, 2x single ended or 1x differential signal (ADC1 and ADC2 pins), embedded channels for temperature and battery voltage sensing, embedded digital filter with down sampling. The embedded digital filter can be used to process the PDM stream coming from a digital MEMS microphone (1.6MHz or 0.8MHz) and convert it to audio PCM (8kHz to 50kHz when 1.6MHz clock is used for the microphone). The BlueNRG-2 sensor node does exploit the embedded digital filter of the ADC peripheral for PDM to PCM conversion when reading the PDM output of the MEMS microphone MP34DT05-A.

The low-speed clock is used in low-power mode and can be supplied by the internal RC oscillator or by an external crystal (32kHz +/-50ppm). The high-speed clock is supplied by a fast-starting internal RC oscillator (16MHz) while the external crystal is starting up. The high-speed external crystal (16 or 32MHz) is strictly required to enable the BLE radio.

In order to support the highest computational load, the 32MHz XO must be used. When 32MHz XO is used, the Cortex-M0, the DMA and the APB tree run at 32MHz while the rest of the clock tree runs at 16MHz. When 16MHz XO is used, the Cortex-M0 and all the clock tree runs at 16MHz.

BlueNRG-2 states

- Preactive (reachable from Reset, Standby or Sleep, goes to Active): after power-on-reset, all digital power supplies are stable; internal 16MHz and 32kHz RC oscillators are used.
- **Active** (reachable only from Preactive): the external high-frequency crystal is used (16MHz +/-50ppm or 32MHz) to enable BLE communication; the internal 16MHz RC oscillator is switched off; the higher the accuracy of the crystal, the lower the power consumption is; the BlueNRG-2 sensor node uses a 32MHz +/-10ppm crystal. In active mode the radio can be activated for transmission (TX) or reception (RX). **This is the state used by BlueNRG-2 when the user application is running or there is a BLE event to serve**.
- Standby (reachable from Active, can go to Preactive): RAM retention is used (12 or 24kB); 5 different GPIOs can be used to wake-up (IO9, IO10, IO11 which have an internal pull-up, and IO12, IO13 which require an external drive); the BlueNRG-2 sensor node uses IO11 connected to the user button, IO12 connected to the interrupt pin of LIS2MDL magnetometer, and IO13 connected to the interrupt pin of of LSM6DSO accelerometer and gyroscope. The wake-up time is typically 200us.
- **Sleep** (reachable from Active, can go to Preactive): RAM retention is used (12 or 24kB); the low-frequency oscillator is switched on to serve periodic BLE connection events; as in Standby state, 5 different GPIOs can also be used to wake-up. **This is the state used by the BlueNRG-2 tile to save power when the user application is not running and the device is waiting for a BLE event to serve**.

STEVAL-BCN002V1 Component Layout

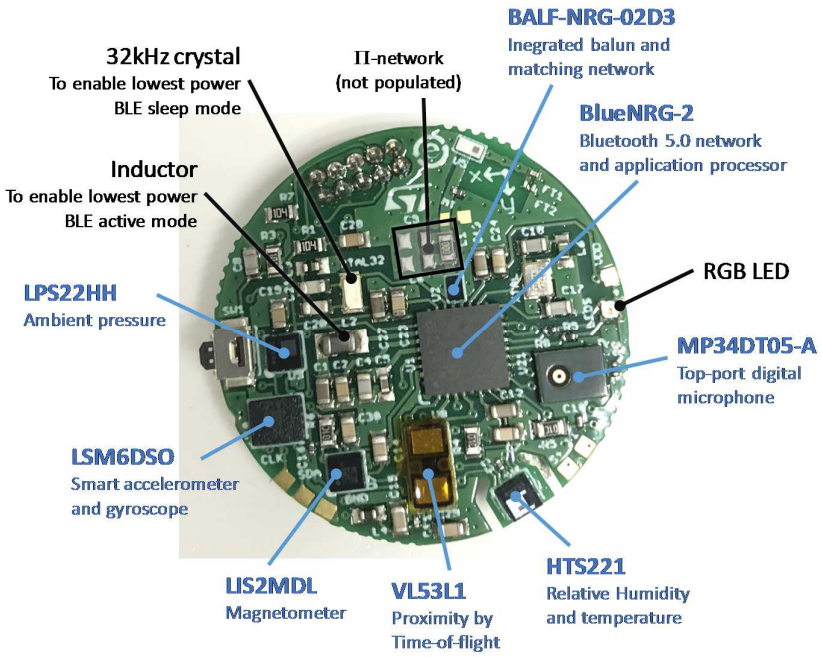


Figure 1: STEVAL-BCN002V1 top component layout

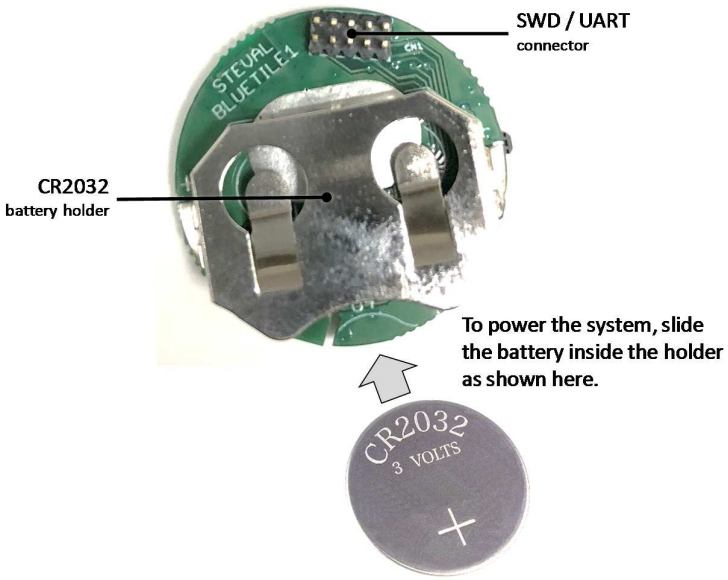


Figure 2 STEVAL-BCN002V1 bottom component layout

STEVAL-BCN002V1 Block Diagram

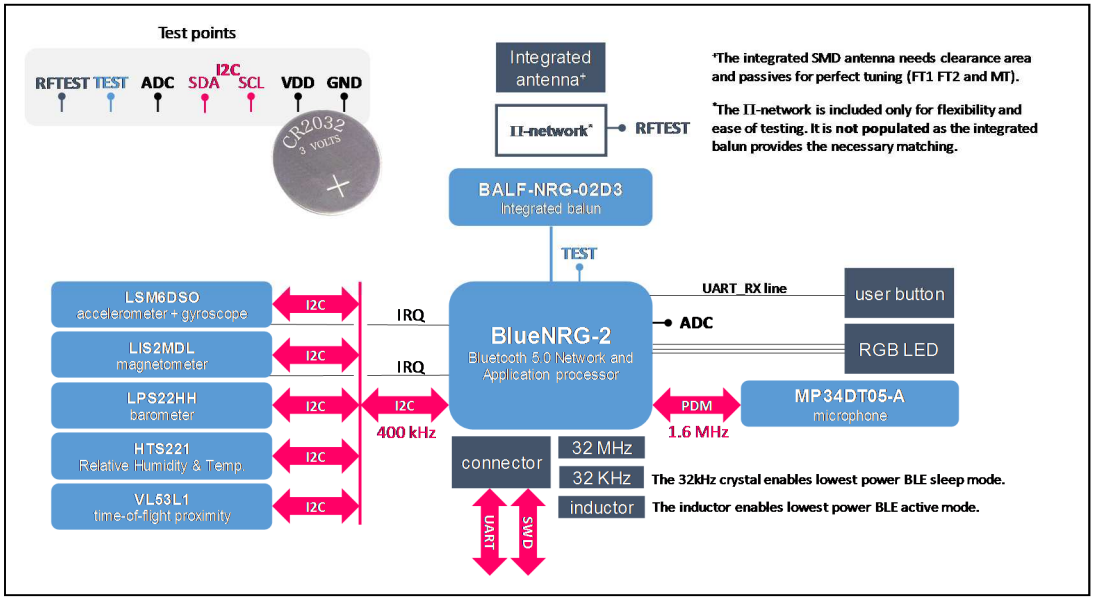
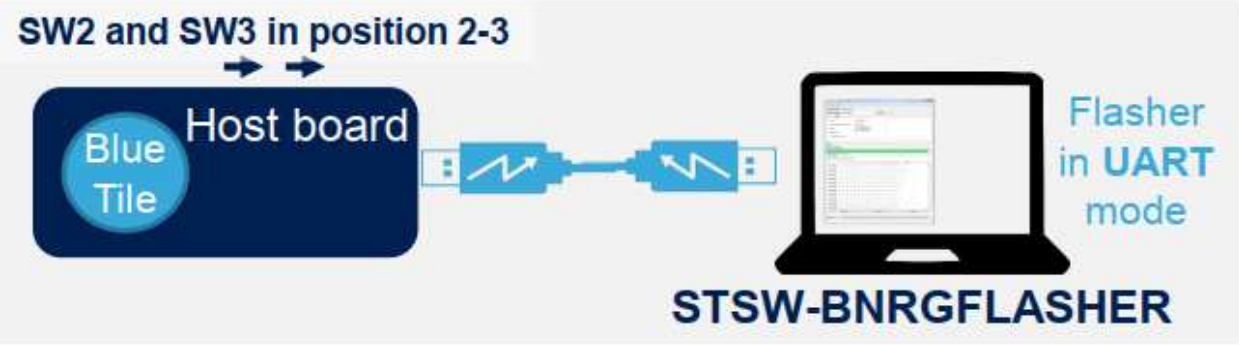


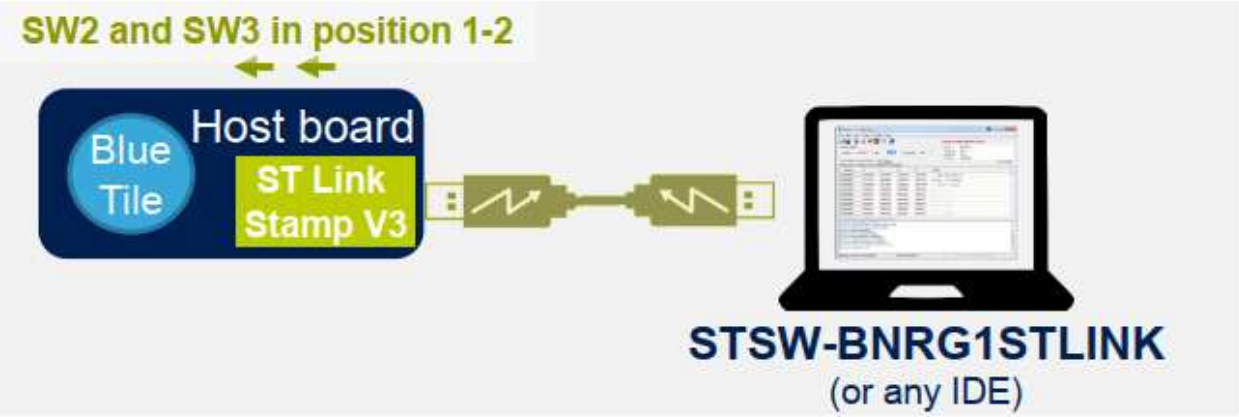
Figure 3: STEVAL-BCN002V1 block diagram

STEVAL-BCN002V1D Connection with PC via USB

The STEVAL'BCN002V1B can be connected to a PC for STEVAL-BCN002V1 FW programming



Optionally the STEVAL-BCN002V1B could mount also the STLINKv3 debugger to allow STEVAL-BCN002V1 firmware development activities.



STEVAL-BCN002V1D Block Diagram

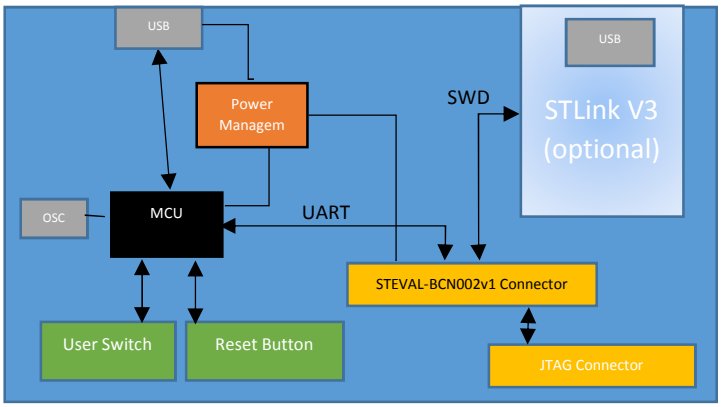


Figure 4: STEVAL-BCN002V1D block diagram

BlueNRG-2 Architecture

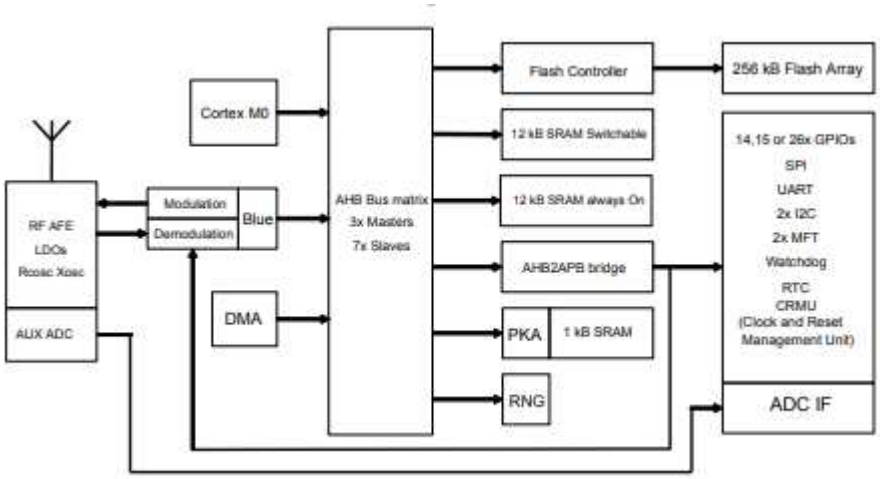


Figure 5: BlueNRG-2 Architecture

BlueNRG-2 Bluetooth low energy stack

The BlueNRG-2 is complemented with a Bluetooth low energy stack C library that provides: • Master, slave role support • GAP: central, peripheral, observer or broadcaster roles • ATT/GATT: client and server • SM: privacy, authentication and authorization • L2CAP • Link layer: AES-128 encryption and decryption The BlueNRG-2 can be configured to support single chip or network processor applications. The BlueNRG-2 supports LE data packet length extension, in compliance with Bluetooth smart v5.0. In the first configuration, the BlueNRG-2 operates as single device in the application for managing both the application code and the Bluetooth low energy stack. The whole Bluetooth low energy stack is provided as object code in a single library file whereas the GATT low energy profiles are provided as object codes in separate libraries. The figure below shows the single chip RF software layers

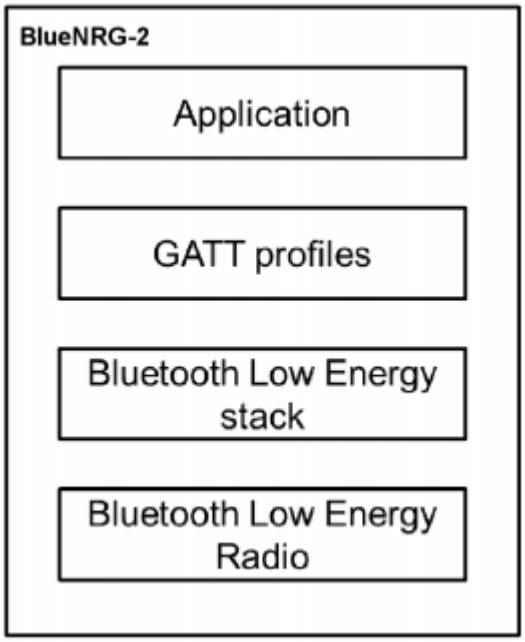


Figure 6: BlueNRG-2 Software Layers

Antenna

Antenna specifications	
Nr. Of authorized antenna types	1
Antenna type	Dedicated on PCB
Maximum total gain	+1.6 dBi max
External Power amplifier	Not present

Table 1: BLUENRG-M2SA Antenna specifications

The STEVAL-BCN002V1D mounts the ANT016008LCS2442MA1 multilayer ceramic antenna from TDK.

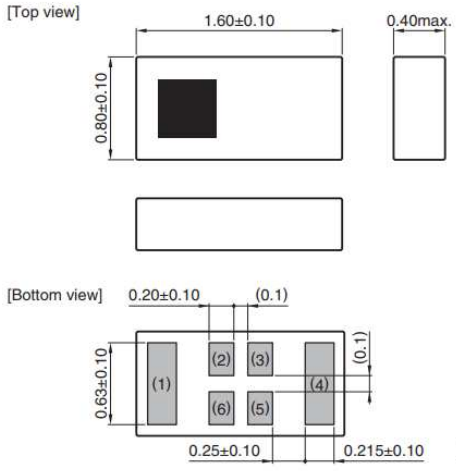
Dimensions (mm)

L	W	T
1.60 ±0.10	0.80 ±0.10	0.40 Max.

Figure 7: ceramic antenna

ANT016008LCS2442MA1

■SHAPES AND DIMENSIONS



Terminal functions

1	Radiator electrode
2	Dummy pad
3	Dummy pad
4	Feed point
5	Dummy pad
6	Dummy pad

Dimensions in mm

Figure 8: ANT016008LCS2442MA1 shape and dimensions

■ELECTRICAL CHARACTERISTICS

Item	Frequency Range (MHz)	Min.	Typ.	Max.
VSWR	2400 to 2484	—	1.60	3.0
Polarization			Linear	
PCB size (mm)			50×20	
Antenna keep-out area (mm)			5×3	
Characteristic Impedance (Ω)			50 (Nominal)	

・This is typical antenna performance with the standard PCB.

■TEMPERATURE RANGE

Operating temperature (°C)	Storage temperature (°C)
–40 to +85	–40 to +85

Figure 9: Antenna electrical characteristics and temperature range

Radio Features

The STEVAL-BC002V1B comes with embedded ceramic antenna.

The table below represents the antenna specifications.

BLUENRG-M2SA Radio Features		
Standard	5.0	Bluetooth Low Energy
Antenna	Embedded	
RF Frequency	2402-2480	MHz
Max Output Power	8	dBm

Table 2: BLUENRG-M2SA Radio Features

The table below represents the evaluation of exemption limit.

Declared by manufacturer					
Evaluation of Exemption Limit (separation distance 15mm)					
Max. Frequency (MHz)	Max. radiated power (dBm)	Max. antenna gain (peak) (dBi)	Max. level.		Exemption Limit (obtained by linear interpolation) (mW)
			(dBm)	(mW)	
2402	8	+1.6	9.6	9.12	15.15
2440	8	+1.6	9.6	9.12	14.94
2480	8	+1.6	9.6	9.12	15.15

Table 3: Evaluation of Exemption Limit

Given the values shown in tables above, the minimum usage distance is set to: 15 mm.

Software Development Kit

The STEVAL-BCN002V1B is complemented with a Software Development Kit (SDK) available for download at the following product web pages:

- www.st.com/bluetile
- https://www.st.com/content/st_com/en/products/evaluation-tools/solution-evaluation-tools/sensor-solution-eval-boards/steval-bcn002v1b.html

Aim of the SDK is to provide a comprehensive set of APIs to manage:

- Bluetooth Low Energy radio (aka Bluetooth Stack)
- Environmental sensors (aka Drivers)

The SDK includes prebuilt images to demonstrate the features of the STEVAL-BCN002V1B.

The SDK allows the application to set the maximum radio output power. The configurable values range from +8 to -18 dBm.

SDK Versioning

As any other piece of software, also the STEVAL-BCN002V1B SDK may evolve.

The SDK version is identified by two numbers separated by a dot as follow:

major.minor

with the following convention:

- Major: a change that impact the Bluetooth protocol layers part
- Minor: a change that impact the environmental sensor part

For example version 1.5

Firmware used certification test

The SDK includes the DTM application used for the certification tests. The DTM application allows to send BLE commands to the STEVAL-BCN002V1B from a PC

The DTM firmware version used for certification test is 1.X

Notes:

- No further radio parameters could be changed via software
- the output power set during certification test in laboratory was +8dBm. (This is the maximum configurable value). For this reason it is considered that the software is not a critical component.
- X stands for “Don’t care”. In this case it is not specified because it has no impact on the radio.
- Sometime a third number is used in the versioning system after the minor version. It is called “Point” and it is used just to indicate a change in the example applications. So it does not have any impact at all on the radio layers.