How to use the ST NFC Sensor TAG evaluation board

Introduction

The STEVAL-SMARTAG1 NFC sensor tag platform is an NFC-enabled sensor node with inertial and environmental digital MEMS sensors, an STM32 microcontroller and a dynamic NFC tag for communication with NFC readers such as tablets and smartphones.

You can use the NFC-enabled sensor node as the basis for your own designs and as a platform to test and develop NFC-enabled applications with the STM32 Open Development Environment (STM32 ODE).

The ST NFC Sensor TAG platform is also an evaluation tool to help you assess the performance of the sensors and the capabilities of the NFC dynamic tag embedded on the STEVAL-SMARTAG1 evaluation board.

The board has a small and thin form factor, which makes it particularly useful for deployment in field research and data collection activities that help refine application-specific algorithms.

Figure 1. STEVAL-SMARTAG1 NFC sensor tag

1 Evaluation board overview

1.1 Featured components

Figure 2. **STEVAL-SMARTAG1 components**

The STEVAL-SMARTAG1 evaluation board includes the following components and features:

1. STM32L031K ultra-low power ARM Cortex-M0+ MCU with 32 Kbytes Flash, 32 MHz CPU. The device includes 1 Kbyte data EEPROM and 8 Kbytes RAM plus an extensive range of enhanced I/O and peripherals (12-bit ADC, 2 comparators, 1 low-power 16-bit timer, 3 general purpose 16-bit timers, 1 RTC, 1 SysTick, 2 watchdogs, I2C, SPI, USART and a low-power UART).
2. LIS2DW12 3-axis MEMS accelerometer, ultra-low power, configurable single/double tap recognition, free-fall, wakeup, portrait/landscape, 6D/4D orientation detections. User selectable full scale of 2, 4, 8 or 16 g; output data rates from 1.6 to 1600 Hz; 32-level FIFO buffer.
3. LPS22HB ultra-compact piezo-resisitive absolute pressure sensor, 260-1260 hPa, 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.
4. 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.
5. STLQ015 150 mA, ultra-low quiescent current linear voltage regulator. Input voltage range from 1.5 to 5.5 V, typical dropout of 112 mV. The device features a quiescent current which is just 1.4 µA at maximum output current. The device includes short-circuit constant-current limiting and thermal protection.
6. ST25DV64K 64 Kbit dynamic NFC/RFID tag, NFC Forum type V with I2C interface, fast transfer mode and energy harvesting. The device has 64 Kbit of electrically erasable programmable memory (EEPROM) and offers two interfaces: the first interface is an I2C serial link to the host microcontroller, the second interface is a RF link activated when the device acts as a contactless memory powered by the received carrier electromagnetic wave.

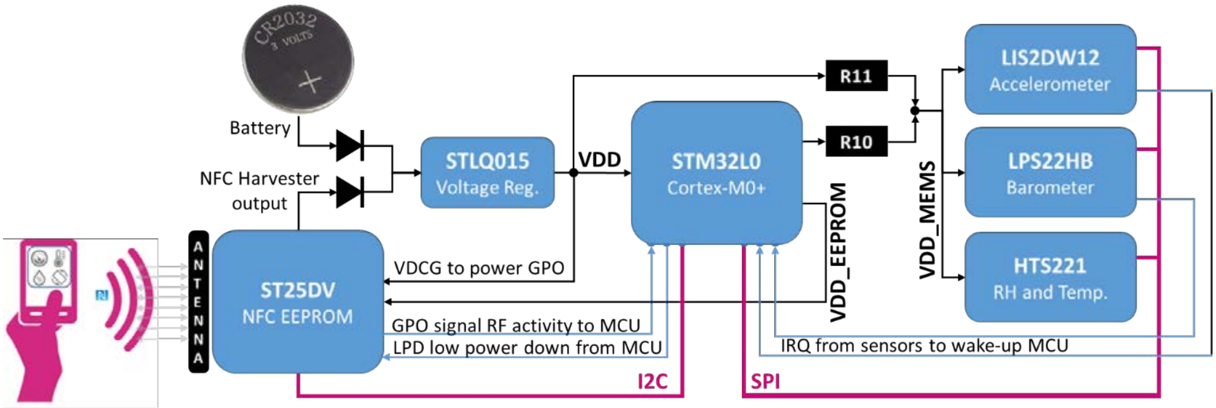
1.2 System architecture

The sensor node can be powered by a coin-cell battery (CR2032) or by the output of the NFC harvester (when it is enabled and when the RF field is strong enough). The power source with the highest output voltage is automatically selected by the diodes in OR-configuration.

Note: If the battery is present, the output of the harvester is not used if the voltage from the battery is higher.

The voltage is regulated to 1.8 V and fed to the VDD line. The voltage regulator is not strictly required if only the battery is used. The output harvester, on the other hand, requires regulation.

Figure 3. STEVAL-SMARTAG1 block diagram

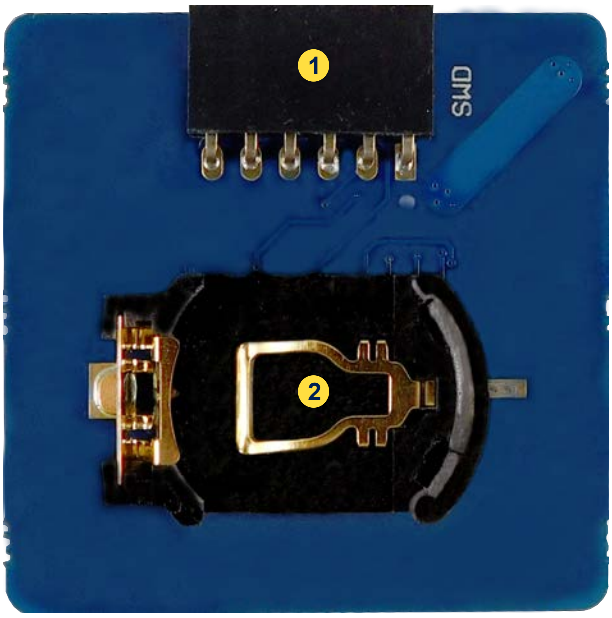


The VDD line powers the microcontroller, which in turn can power the MEMS sensors (VDD_MEMS) and the NFC EEPROM (VDD_EEPROM). The advantage of using the VDD_MEMS or VDD_EEPROM GPIOs of the microcontroller to power the other components in the system is that power can be completely cut-off by setting the GPIO to the high-impedance state. If the other components in the system are powered by the VDD line, you can activate their low Power-down mode (if available).

When the system is awake, the microcontroller can power the MEMS sensors, take readings, process the data and store the information in the NFC EEPROM. The NFC reader can read data from the EEPROM and write configuration information to it, which the microcontroller uses to configure the system.

Figure 4. **STEVAL-SMARTAG1 battery holder and SWD connector**

- 1. SWD connector to ST-Link/V2
- 2. Battery holder CR2032



2 Power path configuration

MEMS sensors are normally powered by the microcontroller through solder bridge R10 with a 0-Ω resistor.

Note: The microcontroller in stop mode can still power the MEMS sensors as the GPIO state is maintained.

The state of the GPIO connected to VDD_SENS (PB8) must be kept high to power the sensors. When sensors are powered by the microcontroller, you must follow the appropriate power up and power down sequence.

If you leave R10 open and populate solder bridge R11 with a 0-Ω resistor, the MEMS sensors are powered directly from the VDD line and not from the microcontroller. This can be useful if you want the MEMS sensors to be able to wake up the microcontroller in Standby or Stop mode. In Standby mode, the microcontroller GPIOs are in the high-impedance state and cannot power the MEMS sensors.

Note: R10 (MEMS power gating) and R11 (always-on MEMS) are mutually exclusive.

Table 1. Solder bridge details for power Path configuration

Solder bridge	Power source	Power sink
R11 (enables always-on MEMS)	VDD (OUT of STLQ015)	VDD_MEMS
R10 (enables MEMS power gating)	VDD_SENS (PB8 of STM32L0)	VDD_MEMS

RELATED LINKS

2.1.2 Battery mode on page 5

5.1 Power up and power down sequences when microcontroller supplies power on page 10

5.2.2 Internal regulator in low-power mode, limited clock speed (HSI is off, MSI max 131kHz) and limited peripherals (no ADC) on page 11

5.2.3 Internal regulator is off, very limited clock speed (HSI/HSE/MSI are off) and no peripherals (only wake-up logic and IWDG) on page 11

2.1 Operating mode based on the selected power path

2.1.1 Battery-less mode

In Battery-less mode, the power can be derived from the energy harvesting feature of the NFC EEPROM. In this mode, you can perform a one-shot measurement of the MEMS sensors while the STEVAL-SMARTAG1 is powered by the NFC reader.

2.1.2 Battery mode

You can battery power the board by inserting a coin cell battery (CR2032) in the holder on the back of the board.

By default, MEMS sensors are powered by the microcontroller through the solder bridge R10.

In battery mode, you can take measurements in the following ways:

- SYNCHRONOUS SAMPLING and LOGGING: at a regular rate, usually controlled by the RTC of the host microcontroller.
- ASYNCHRONOUS SAMPLING and LOGGING: when an event is detected by the event detection logic embedded in MEMS sensors (only accelerometer and ambient pressure sensor can wake up the microcontroller). If the microcontroller uses Standby mode, the MEMS sensors must be powered directly by the VDD line through solder bridge R11.

Note: R10 (MEMS power gating) and R11 (always-on MEMS) are mutually exclusive.

Table 2. **Application operating modes, MCU mode and power path configuration**

Application operating mode	MCU mode between sampling	Power path solder bridge
Battery-less: one-shot driven by NFC reader	n/a	R10 (power gating) or R11 (always-on MEMS)
Battery: synchronous sampling driven by RTC	Stop with RTC	R10 (power gating) or R11 (always-on MEMS)
	Standby with RTC	R10 (power gating) or R11 (always-on MEMS)
Battery: asynchronous sampling driven by MEMS events	Stop without RTC	R10 (power gating) or R11 (always-on MEMS)
	Standby without RTC	Must use R11 (always-on MEMS)
Battery: synchronous and asynchronous driven by RTC and MEMS	Stop with RTC	R10 (power gating) or R11 (always-on MEMS)
	Standby with RTC	Must use R11 (always-on MEMS)

2.2 ST25DV NFC EEPROM features

The ST25DV64K NFC EEPROM can receive power from the RF field or from the VDD pin. On the STEVAL-SMARTAG1 evaluation board, the VDD pin is connected to the VDD_EEPROM line controlled by the host microcontroller.

When the RF field is present and strong enough, no DC voltage is needed on the VDD_EEPROM line. The NFC interface is active and the EEPROM can be read and written by the NFC reader.

When a DC voltage is present on the VDD_EEPROM line, the I2C interface is active. In this case the EEPROM can be read and written by the host microcontroller via I2C.

3 Features of the STEVAL-SMARTAG1 evaluation board

3.1 Interface arbitration

When both NFC and I2C interfaces are active, the device observes the “first talk, first served” principle.

During an RF transaction, I2C commands are not acknowledged (NoAck). The RF transaction is terminated in one of the following ways:

1. the End-of-Frame (EOF) of the request is received (and no response is needed)
2. the EOF of the response is received
3. the RF field is removed.

During an I2C transaction, RF requests receive no response or 0Fh response codes. The I2C transaction is automatically terminated in one of the following ways:

1. on the I2C stop condition
2. on any I2C error
3. if I2C timeout occurs
4. if VDD power is removed.

You must take arbitration into account as communication between the NFC reader and the NFC EEPROM or between the NFC EEPROM and the host microcontroller may not function as expected.

If the communication protocol consists of several transactions, the sequence of transactions on one interface may be interrupted if control is given to the other interface. To solve this problem, the ST25DV GPO signal can be used.

3.2 General purpose output (GPO) pin

The GPO pin can be used to alert the host microcontroller of RF events or NFC EEPROM processing activity.

The STEVAL-SMARTAG1 embeds the JF variant of the ST25DV64K dynamic NFC/RFID tag with CMOS GPO pin, where the interrupt consists of pulling the state high or emitting a short high-level pulse. The pulse is emitted after the `End-of-Frame` (EOF) of the response for a duration set in IT_TIME register.

The GPO pin can be configured to react to following events:

1. RF_USER event: the GPO level is controlled by the NFC reader/writer through the `Manage GPO set/reset` command. If RF_USER is selected, other events do not change the GPO status, but are still recorded in the IT_STS_Dyn register.
   – Example: the remote application running on the NFC reader/writer, asserts the GPO by writing the `GPO set/reset` command and the firmware is programmed to block the I2C interface and abort any I2C transaction when the GPO is asserted.
2. RF_ACTIVITY event: GPO level goes high from the `End-of-Frame` of the received command to the `End-of-Frame` of the response.
3. RF_INTERRUPT event: GPO emits a pulse when the NFC reader issues a `Manage GPO interrupt` command.
4. FIELD_CHANGE event: GPO automatically emits a pulse when the RF field state appears or disappears. When RF disappears, the pulse is emitted only if a DC power supply is available on VDD_EEPROM. The pulse is not emitted if RF_SLEEP mode is set. The RF field status is recorded in the IT_STS_Dyn register (FIELD_FALLING, FIELD_RAISING flags).
   – Example: the GPO is configured to automatically generate an interrupt when the RF field is activated/deactivated and the firmware is programmed to react by reading the NFC EEPROM, check the status of the RF field and proceed accordingly. This is useful when the NFC device is only a reader which cannot write and issue commands to the NFC EEPROM.

Note: If the NFC EEPROM is only powered by the NFC field and the NFC field is removed, the microcontroller may not be able to read the status of the RF field. The read operation should therefore timeout, assuming that the field has been removed.

5. RF_PUT_MSG event: GPO emits a pulse when a message is successfully written by RF to RAM (mailbox).

6. RF_GET_MSG event: GPO emits a pulse when a message is successfully read by RF from RAM (mailbox).
7. RF_WRITE event: GPO emits a pulse when a valid RF write operation is completed on the EEPROM.

3.3 Energy harvesting (EH)

The NFC EEPROM has an analog output pin which is used to deliver an unregulated analog voltage when Energy Harvesting (EH) mode is enabled and the RF field strength is sufficient. When EH mode is disabled or the RF field strength is not sufficient, the analog output pin is set to a high-impedance state.

The NFC EEPROM has an EH_MODE static control register which is used to define the EH mode after boot. The possible modes are listed below:

- forced active after boot (EH_MODE=0)
- activated on demand (EH_MODE=1)

At boot, the EH_MODE flag is used to set the EH_CTRL_Dyn dynamic control register. The following settings control whether harvesting is enabled or disabled:

- EH_MODE=0: harvesting is enabled (EH_EN=1)
- EH_MODE=1: harvesting is disabled (EH_EN=0)

After boot, the EH_MODE setting has the effects listed below:

- EH_MODE=0: automatically sets EH_EN=1 and activates harvesting
- EH_MODE=1: no effect on EH_EN or the harvesting status until next reboot.

The application can set/reset EH_EN to activate/deactivate the harvesting at any time. EH_EN can be set even if the device is in RF disabled mode, RF sleep-mode, or Low-power mode.

During boot, harvesting is disabled to avoid misconfiguration of the device.

Note: *When harvesting is active, communication is not guaranteed.*

RELATED LINKS

AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

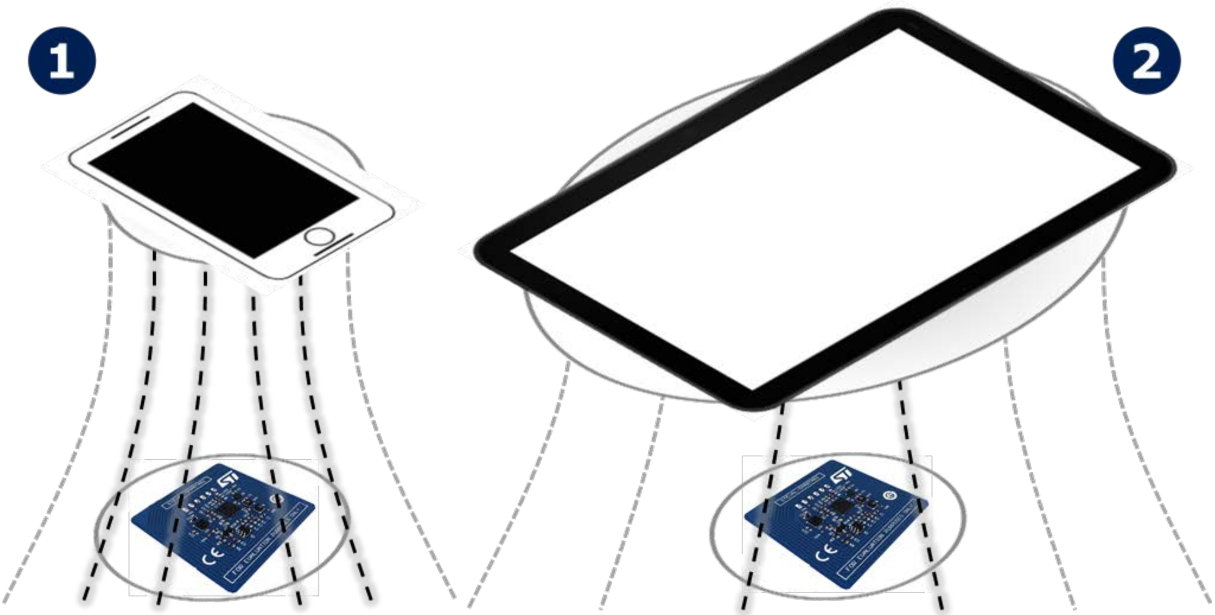
4 RF communication performance

For reliable communication, RF antennas should be in close proximity to each other and similar in shape and size.

When the form factors of communicating antennas are highly dissimilar, the area overlap is small and the magnetic flux generated by the transmitting antenna does not concatenate with the receiving antenna as expected, which has a negative impact on communication.

Figure 5. Impact of NFC antenna form-factor

- 1. NFC antennas have similar forms: good magnetic coupling
- 2. NFC antennas have highly dissimilar forms: poor magentic coupling



The CRC included in the communication frame checks that data read from or written to the NFC EEPROM is correct, and several attempts might be required before the operation is completed successfully.

Energy harvesting performance is also affected by antennas with differing form factors.

RELATED LINKS

12.1 STV25DV NFC EEPROM on page 28

AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

5 STM32L0 microcontroller

The microcontroller always receives power from the VDD line and can provide power to the following components:

- ST25DV NFC EEPROM through the VDD_EEPROM line.

Note: The VDCG pin of the NFC EEPROM always receives power directly from the VDD line: VDCG powers the GPO pin, which can go high even if VDD_EEPROM has no power.

- LIS2DW12, LPS22HB and HTS221 MEMS sensors:
  - through the VDD_MEMS line if R10 is populated with a 0-Ω resistor
  - directly through the VDD line if R11 is populated with a 0-Ω resistor

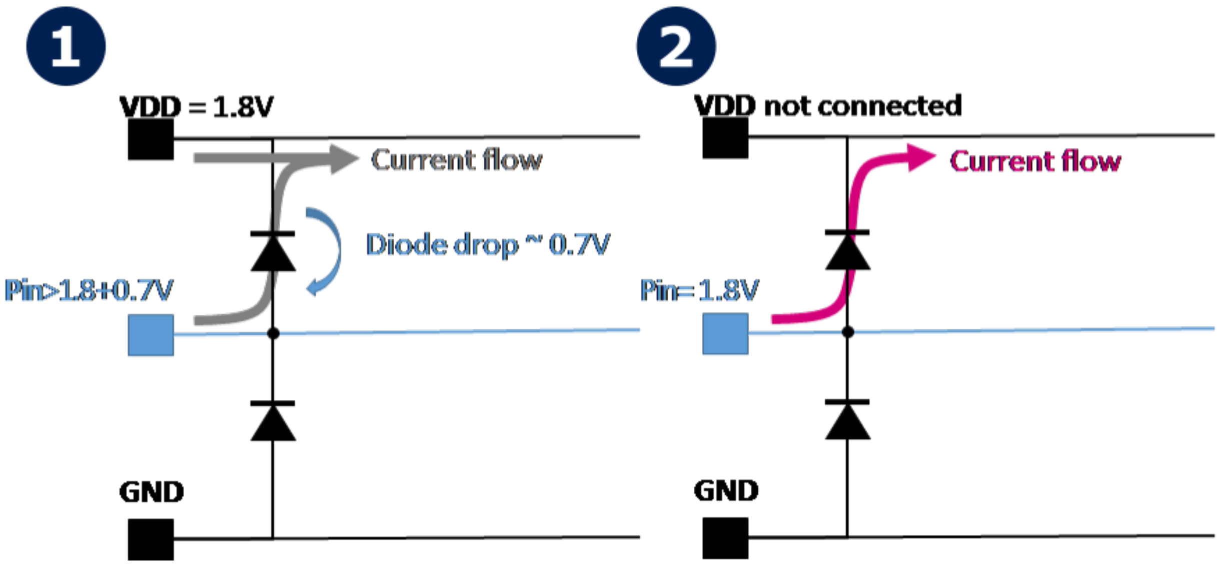
5.1 Power up and power down sequences when microcontroller supplies power

You must observe power up and power down sequences when the microcontroller supplies power to other components in the system.

Incorrect sequences can allow power from the communication bus to flow through the protection diodes on component pins when VDD is not connected.

Figure 6. Unwanted current through protection diodes when VDD is disconnected

- 1. Pin with normal overvoltage condition: voltage is clamped by the active diode
- 2. Pin powered when VDD is not connected: unwanted current flows through diode



RELATED LINKS

2 Power path configuration on page 5
2.1.2 Battery mode on page 5
8 Application firmware hints and tips on page 21
AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

5.1.1 Power up sequence

Step 1. Supply power to VDD_MEMS (or VDD_EEPROM) by pulling the corresponding GPIOs up.

Before initiating any transaction with powered components, wait few milliseconds to let the voltage complete the transient and stabilize, and to let the components complete their power-on-reset.

Peak current may be observed at this time, because by-pass capacitors are being charged.

Step 2. Activate the communication bus SPI (or I2C) through appropriate GPIO settings.

5.1.2 Power down sequence

Step 1. De-activate the communication bus by setting corresponding GPIOs to high-impedance state.

Step 2. Remove power from VDD_MEMS (or VDD_EEPROM) by setting corresponding GPIOs to pull-down state.

In theory, you can also remove power by setting the GPIOs to the high-impedance state, to not discharge the by-pass capacitors. However, any leakage will cause the voltage to drop slowly, which may cause memory corruption in powered components. If the voltage does not drop under the power-on-reset (POR) threshold, then the corruption is not corrected at power up, and powered components may not behave as expected. The POR threshold for MEMS sensors is typically 0.1 V.

5.2 STM32L0 power modes

The microcontroller offers several modes with different power and speed profiles based on the internal regulator.

RELATED LINKS

DS10668: Ultra-low-power ARM Cortex-M0+ MCU with 32-Kbytes Flash, 32 MHz CPU

5.2.1 Internal regulator in normal mode

- Run, CPU on, all peripherals can be on
  - Range 1, clock up to 32 MHz, 156-159 µA/MHz from Flash, 140-146 µA/MHz from RAM
  - Range 2, clock up to 16 MHz, 131-140 µA/MHz from Flash, 112-131 µA/MHz from RAM
  - Range 3, clock up to 4.2 MHz, 115-140 µA/MHz from Flash, 96-115 µA/MHz from RAM
- Sleep, CPU off, all peripherals can be on, 0.36 µs wake-up time
  - Range 1, clock up to 32 MHz, 46 µA/MHz
  - Range 2, clock up to 16 MHz, 28-33 µA/MHz
  - Range 3, clock up to 4.2 MHz, 28-49 µA/MHz Flash on, 25-36 µA/MHz Flash off

5.2.2 Internal regulator in low-power mode, limited clock speed (HSI is off, MSI max 131kHz) and limited peripherals (no ADC)

- Low Power Run, 3 µs wake-up time, 32-131 kHz, 18.5-32 µA from Flash, 6.3-17 µA from RAM
- Low Power Sleep, CPU off, 32 µs wake-up time, 32-131 kHz, 13-15.5 µA Flash on, 3.2 µA Flash off
- Stop, CPU off, Flash off, RAM retention, 3.5 µs wake-up time to Run from RAM, 5 µs wake-up time to Run from Flash; GPIOs state is maintained, R10 (MEMS power gating) is usually populated to power MEMS sensors through the microcontroller, but R11 (always-on MEMS) can also be used.
  - With RTC, 0.6-0.8 µA
  - Without RTC, 0.35-0.38µA

RELATED LINKS

2 Power path configuration on page 5
2.1.2 Battery mode on page 5

5.2.3 Internal regulator is off, very limited clock speed (HSI/HSE/MSI are off) and no peripherals (only wake-up logic and IWDG)

- Stand-by, CPU off, Flash off, no RAM retention, 50-65 µs wake-up time; GPIOs in high-impedance; R11 is usually populated to enable wake-up from always-on MEMS sensors
  - With RTC, 0.39-0.57 µA (R10 can be used if wake-up by RTC only)
  - Without RTC, 0.23-0.26 µA (R11 must be used: wake-up by MEMS)

RELATED LINKS

2 Power path configuration on page 5
2.1.2 Battery mode on page 5

5.3 STM32L0 clock power consumption and accuracy

The system clock can be driven by a high-speed external oscillator (HSE, 1-25 MHz), or by the high-speed internal RC oscillator (HIS, 16 MHz), or by the multi-speed oscillator (MSI, seven frequencies from 65 kHz to 4.2 MHz). HSI and MSI can be calibrated and trimmed in software by using an external clock source.

The RTC, real-time clock, can be driven by a low-speed external oscillator (LSE 32.768 kHz), or by the low-speed internal RC oscillator (LSI 37-38 kHz), or by the HSE, whatever the system clock. LSI can be calibrated and trimmed in software by using the HSI which has higher accuracy. LSE can exploit a secondary external clock source (50 or 60 Hz) to further increase accuracy.

Note: *To reduce cost and power consumption, the STEVAL-SMARTAG1 evaluation board does not include an external crystal.*

RELATED LINKS

AN4631: How to calibrate an STM32L0xx internal RC oscillator

AN4759: Using the hardware real-time clock (RTC) in low-power modes with STM32 microcontrollers

5.3.1 RC oscillator characteristics

In the STEVAL-SMARTAG1, the system clock can be driven by HSI or MSI, and the RTC is driven by LSI.

The characteristics of the different internal RC oscillators are listed below:

- LSI low-speed internal RC oscillator:
  - frequency range 26-56 kHz, typical 37 kHz
  - frequency drift -10% to +4% for 0 to 85°C temperature range
  - 200 µs startup time
  - power consumption <510 nA, typical 400 nA.
- MSI multi-speed internal RC oscillator:
  - frequencies 65.5 kHz, 131 kHz, 262 kHz, 524 kHz, 1.05 MHz, 2.01 MHz, 4.2 MHz
  - frequency drift ±3% for 0-85°C
  - frequency also drifts 2.5 %/V when VDD range is 1.65-3.6 V
  - frequency drift reduced to ±0.5 % after calibration with an external clock
  - start-up+stabilization time are inversely proportional to selected frequency, from 30+40 µs at 65 kHz down to 3.5+2 µs at 4.2 MHz
  - power consumption is proportional to selected frequency, from 0.75 µA at 65 kHz up to 15 µA at 4.2 MHz
- HSI high-speed internal RC oscillator:
- frequency 16 MHz
- frequency drift is ±1 % when temperature is 25 °C, ±1.5 % from 0 to 55 °C, ±2% from -10 to +70 °C, -5.45 % to +3.25 % from -40 to +125 °C and VDD from 1.65 V to 3.6 V
- 3.7 µs start-up time
- power consumption <140 µA, typical 100 µA.

Note: *Even with calibration, the internal RC oscillators are less accurate than an external crystal oscillator or ceramic resonator (whose drift is limited to tens of ppm).*

RELATED LINKS

AN4631: How to calibrate an STM32L0xx internal RC oscillator

AN2867: Oscillator design guide for STM8AF/AL/S and STM32 microcontrollers

AN4759: Using the hardware real-time clock (RTC) in low-power modes with STM32 microcontrollers

6 MEMS sensors

Each sensor consists of the following parts parts:

1. the Micro Electro Mechanical System (MEMS) with sensing element
2. the dedicated ASIC with analog acquisition chain, the analog-to-digital converter (ADC) and the dedicated digital signal processing (DSP) and control logic.

6.1 LIS2DW12 interrupt generation and embedded functions

The LIS2DW12 accelerometer has a dedicated internal engine to process acceleration data. The device has to be in an active operating mode (not power down). The interrupt generator can be configured to detect the following events:

- Free-fall event: when the device is in free fall, acceleration data is near zero. The user can define a threshold and a duration. The free-fall event is detected if data from all enabled axis is under the programmed threshold for the minimum programmed duration.
- Wake-up event: the user can choose to use high-pass filtered data or low-pass filtered data summed with a programmable offset (independent for each axis). The low/high-pass filters are configurable and the wake-up event is detected if the filtered data from any of the enabled axes is over the threshold for the minimum programmed duration.
- 6D/4D orientation event: the user can choose to use unfiltered data or low-pass filtered data (the low-pass filter is the same as mentioned above). A specific 6D orientation is detected when one axis (positive or negative) is above the programmed threshold, while the other two are below the threshold, for the minimum programmed duration. 4D is a subset of 6D; in this configuration the Z axis is not used.
- Single/Double tap event: the single tap event is detected when the high-pass filtered data exceeds the programmed threshold and then returns below it within the programmed shock time window (the high-pass filter is the same as mentioned above); the double tap event is detected when a first tap is detected, and a second tap is detected after the programmed quiet time window but before the maximum latency time window. For reliable detection of short duration shock events, you should configure the device to use a high sampling rate (e.g., 400 Hz).
- Activity/Inactivity event: uses the same data as selected for the wake-up event. If inactivity is detected (data below the programmed threshold for the programmed duration), the device automatically goes to low-power mode and reduces the sampling rate down to 12.5 Hz to minimize power consumption; if activity is detected (wake-up event) the device automatically returns to the programmed operating mode and sampling rate.
- Stationary/Motion event: is a particular case of Activity/Inactivity event; event detection is the same but the device does not change power mode or sampling rate.

Single and double tap recognition may be used to enable user interaction even if the system has no button. As an example, a sequence of double taps can be used to switch operating mode. The on-board LED can be used to signal feedback information.

6.1.1 LIS2DW12 FIFO buffer

The LIS2DW12 accelerometer has a first-in first-out data buffer (FIFO), which can store 32 samples for each of the three output channels (X, Y and Z). Interrupts can be generated when the FIFO buffer stores a given number of samples (FIFO threshold level), or when it is full, or when it overflows (overrun). The FIFO can work in the following modes:

- Bypass mode: the FIFO buffer is disabled and cleared.
- FIFO mode: the FIFO buffer collects data until it is full, then stops.
- Continuous mode: the FIFO buffer collects data continuously, when it is full oldest samples are overwritten as in a circular buffer. The host microcontroller may read the data before it is overwritten thanks to the FIFO full and FIFO threshold level interrupts.
- Continuous-to-FIFO mode: the FIFO buffer collects data continuously but switches to FIFO mode as soon as the selected interrupt occurs. This mode is especially useful to capture data before and after a specific event.
- Bypass-to-Continuous mode: the FIFO buffer is disabled but switches to continuous mode as soon as the selected interrupt occurs. This mode is useful for capturing data after an event has occurred.

6.1.2 LIS2DW12 drop in replacements

The accelerometer selected for the STEVAL-SMARTAG1 comes in an LGA-12 package, but there are several other pin-to-pin compatible drop-in replacements, listed below:

- LSM303AGR digital smart accelerometer and magnetometer: LIS2DH accelerometer + LIS2MDL magnetometer.
- LSM303AH enhanced digital smart accelerometer and magnetometer: LIS2DS + LIS2MDL magnetometer. The magnetometer consumes 200 µA in high-resolution mode (3 mg RMS noise) at 20 Hz; 50 µA in low-power mode at 20 Hz; 1.5 µA in power down-mode.
- LIS2DH12 lowest-cost digital smart accelerometer: 11-2 µA in normal mode (220 µg/sqrtHz RMS noise) at 50-1 Hz; 6 µA in low-power mode at 50 Hz; 0.5µA in power-down.
- LIS2DS12 digital smart accelerometer: 150 µA in high-performance mode (120 µg/sqrtHz RMS noise) at 12.5 to 6400 Hz; 12.5 µA in low-power mode at 100 Hz, 8 µA at 50 Hz, 4 µA at 12.5 Hz, 2.5 µA at 1 Hz; 0.7 µA in power-down.
- LIS2DW12 lowest-power digital smart accelerometer: 90 µA in high-performance mode (90 µg/sqrtHz RMS noise) at 12.5 to 1600 Hz; 5 µA in low-power mode at 100 Hz, 3 µA at 50 Hz, 1 µA at 12.5 Hz, 0.38 µA at 1.6 Hz; 50 nA in power-down mode.

6.2 LPS22HB acquisition chain

The LPS22HB pressure sensor can perform a one-shot measurement and then return to power-down mode, or it can operate in continuous mode with a programmable sampling rate (1, 10, 25, 50 or 75 Hz). In both cases, the measurements can be taken in normal low-noise mode, or in low-power mode to minimize current consumption. When continuous mode is selected, an optional low-pass filter can be enabled with a programmable cut-off frequency.

A programmable offset can be subtracted from measured data:

- Offset compensation: the offset measured with one-point calibration (OPC) can be stored in specific registers (RPDS) and then subtracted from subsequent measurements (OPC compensated data = data – RPDS*256).
- Auto-zero mode: the measured pressure can be stored in specific registers (REF_P) and then subtracted from subsequent measurements (AZ compensated data = data – REF_P).

6.2.1 LPS22HB interrupt generation and FIFO buffer

The LPS22HB pressure sensor can be configured to generate interrupt events related to pressure acquisitions and FIFO status. The interrupt can be generated when a new pressure or temperature sample is available, or when the compensated data exceeds a programmed threshold (THS_P) in the positive (PHE flag) or negative direction (PLE flag).

- Normal compensation: OPC compensated data goes to output registers, FIFO and interrupt threshold logic.
- AUTOZERO=1: AZ compensated data goes to output registers, FIFO and interrupt threshold logic.
- AUTORIFP=1: OPC comp. data goes to output register and FIFO, while AZ comp. data goes to interrupt logic.

The FIFO buffer can store up to 32 pressure samples (24 bits each) and 32 temperature samples (16 bits each). The FIFO can work in the following modes:

- Bypass mode: the FIFO buffer is disabled and cleared.
- FIFO mode: the FIFO buffer collects data until it is full or the programmed threshold level is reached, then stops.
- Stream mode: the FIFO buffer collects data continuously, when it is full or the threhsold level is reached, oldest samples are overwritten as in a circular buffer. The host microcontroller may read the data before it is overwritten thanks to the FIFO full and FIFO threshold level interrupts. The last sample is kept in the FIFO even if fully read.
- Stream-to-FIFO mode: the FIFO buffer collects data continuously but switch to FIFO mode as soon as the selected interrupt occurs. This mode is especially useful to capture data before and after a specific event.
- Bypass-to-Stream mode: the FIFO buffer is disabled but switch to stream mode as soon as the selected interrupt occurs. This mode is useful to capture data after an event has occurred.

- Bypass-to-FIFO mode: the FIFO buffer is disabled but switch to FIFO mode as soon as the selected interrupt occurs. This mode is useful to capture data after an event has occurred.
- Dynamic Stream mode: same as the stream mode but last sample is not kept in the FIFO buffer when it is fully read.

6.3 LPS22HB vs HTS221 ambient temperature measurement

The temperature sensor in LPS22HB is designed to compensate for temperature effects in ambient pressure measurements, while temperature sensor HTS221 is designed and characterized for ambient temperature measurements.

In the STEVAL-SMARTAG1 evaluation board, ambient temperature is read from the HTS221 because of its higher accuracy and wider range with respect to the LPS22HB. If the application needs a high data rate (above 12.5 Hz), you can use the LPS22HB temperature sensor.

The characteristics of the embedded temperature sensors are listed below:

- LPS22HB:
  – temperature sensor operating range from -40 to +85 °C
  – sensitivity 100 LSB/°C
  – absolute temperature accuracy ±1.5 °C (from 0 to 65 °C)
  – data rate: 1, 10, 25, 50 75 Hz
- HTS221
  – temperature sensor operating range from -40 to +120 °C
  – sensitivity 64 LSB/°C
  – temperature absolute accuracy ±1°C (from 0 to 60 °C)
  – ±0.5 °C (from 15 to 40 °C)
  – data rate 1, 7 or 12.5 Hz
  – Response time 15 s (time to 63%)
  – Long term drift 0.05 °C/year

6.3.1 HTS221 acquisition chain

The MEMS sensors, microcontroller and NFC EEPROM all have embedded temperature sensors that are designed to measure the temperature of the silicon, not the ambient temperature. On the hand, the temperature sensor embedded in HTS221 has the physical properties and the accuracy required for ambient temperature measurement.

6.3.1.1 *How to calculate relative humidity*

The raw output of the humidity acquisition chain is stored in two 8-bit registers (HUMIDITY_OUT_H and _L), which must be concatenated to obtain a 16-bit, two’s complement value (H_OUT). The raw output is already temperature-compensated. Calibration coefficients to derive relative humidity (RH) from raw humidity outputs are stored in the device. Factory calibration is performed at two different humidity levels and one temperature.

The sequence to calculate RH is shown below:

Step 1. Set RH0 from the first true RH during calibration:

$$\mathrm{RH0} = \frac{\mathrm{H0\_rH\_x2}}{2}$$

Step 2. Set RH1 from the second true RH during calibration:

$$\mathrm{RH1} = \frac{\mathrm{H1\_rH\_x2}}{2}$$

Step 3. Set H0 from the first raw H output during calibration:

$$\mathrm{H0} = \mathrm{H0\_T0\_OUT}$$

Step 4. Set H1 from the second raw H output during calibration:

$$\mathrm{H1} = \mathrm{H1\_T0\_OUT}$$

Step 5. Set H from the current raw H output:

$$\mathrm{H} = \mathrm{H\_OUT}$$

Step 6. Calculate the current RH percentage by linear interpolation:

$$RH = RH0 + \frac{(RH1 - RH0) \times (H - H0)}{(H1 - H0)} \tag{1}$$

6.3.1.2 *How to calculate temperature*

The raw output of the temperature acquisition chain is stored in two 8-bit registers (TEMP_OUT_H and _L), which must be concatenated to get a 16-bit two's complement value (T_OUT). Calibration coefficients to derive Temperature in degrees Celsius from raw temperature output are stored in the device. Factory calibration is performed at two different temperatures.

The sequence to calculate Temperature in degrees Celsius is shown below:

Step 1. Set MSB of true temperatures during calibration:

$$MSB1 = T1T0MSB\&0x03$$
$$MSB0 = T1T0MSB/4$$

Step 2. Set T0degC from the first true T in degrees Celsius (two's comp):

$$T0degC = (T0\_degC\_x8 + MSB0*256)/8$$

Step 3. Set T1degC from second true T in degrees Celsius (two's comp):

$$T1degC = (T1\_degC\_x8 + MSB1*256)/8$$

Step 4. Set T0 from first raw T output during calibration:

$$T0 = T0\_OUT$$

Step 5. Set T1 from second raw T output during calibration:

$$T1 = T1\_OUT$$

Step 6. Set T from current raw T output during calibration:

$$T = T\_OUT$$

Step 7. Calculate current Temperature in degrees Celsius:

$$T = T0deg + \frac{(T1deg - T0deg)*(T - T0)}{(T1 - T0)} \tag{2}$$

6.3.2 HTS221 system integration

For reliable and consistent measurements, your system should be designed to maximize sensor exposure to the external environment while minimizing error sources.

- Mechanical design: if there is a vent hole in the STEVAL-SMARTAG1 evaluation board housing, the hole diameter should be maximized and the dead volume enclosed should be minimized; two or more vent holes are preferable to create a laminar airflow and minimize the response time. Avoid materials that absorb humidity.
- Mechanical stress: any mechanical force applied directly or indirectly to the sensor may affect the output. Do not bend or curve the STEVAL-SMARTAG1 evaluation board.
- Heat convection or temperature gradients on the board may affect the sensor. Keep metal lines and planes (e.g., the ground plane) away from the sensor. Milled slits further increase decoupling. Insulation may be required to isolate the STEVAL-SMARTAG1 board from convective and conducted heat.
- Light exposure may affect temperature and humidity measurements.

The internal heating element can be used to speed up sensor recovery in case of condensation. Heater control must be switched on and off by the firmware running on the host microcontroller. Humidity and temperature data should not be read until the heating cycle has finished.

The STEVAL-SMARTAG1 evaluation board is designed for ultra-low power operation to allow a very long battery life (3-10 years on a typical CR2032 coin battery, depending on the application). Power and heat generated on the board is therefore very limited. Possible sources of conducted heat, such as the NFC EEPROM, the microcontroller and the LED, have been placed as far as possible from MEMS sensors to increase measurement accuracy and avoid the need for milled slits to isolate HTS221 temperature sensor.

RELATED LINKS

AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

7 How to program and debug the board

To set up your debugging and programming environment, you need the following items:

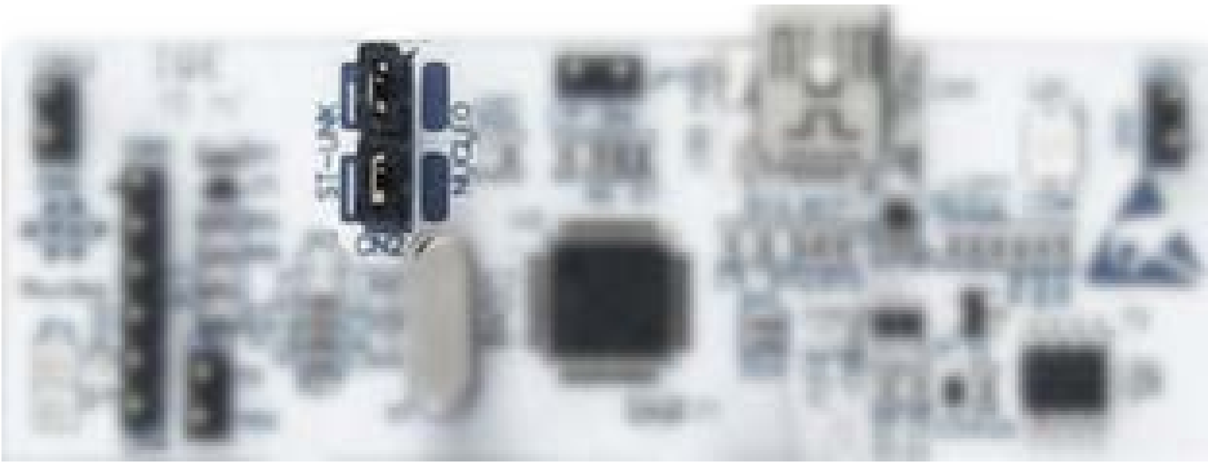
- An ST-Link/V2 in-circuit debugger and programmer. You can find an ST-Link/V2 debugger included as a snap-off section on any STM32 Nucleo development board
- The STSW-LINK004 ST-Link utility software package installed on your PC.

Step 1. Insert a CR2032 battery in the battery holder on the back of the STEVAL-SMARTAG1 evaluation board to power the target microcontroller.

Figure 7. **Battery inserted in cradle on rear of STEVAL-SMARTAG1 evaluation board**

Step 2. Ensure both jumpers on CN2 on the ST-Link/V2 board are open.

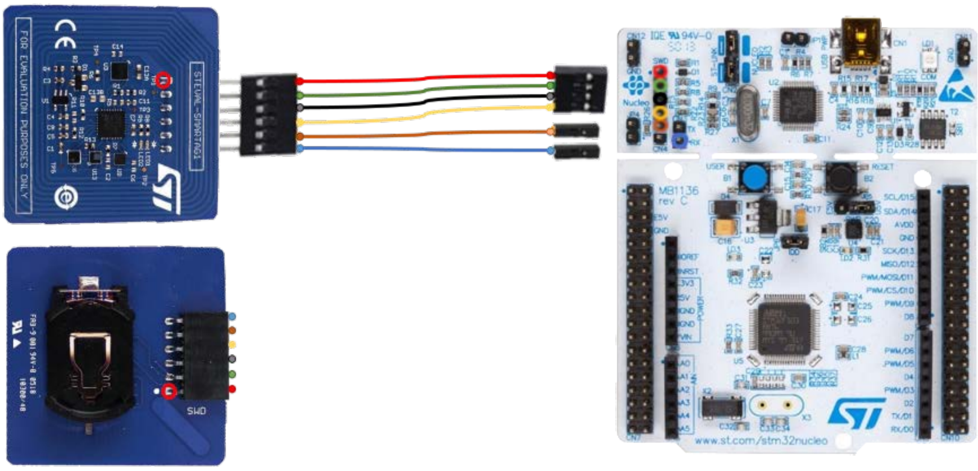
Figure 8. **CN2 connector on ST-Link/V2 in-circuit debugger and programmer**



Step 3. Plug the STEVAL-SMARTAG1 evaluation board on the 5-pin connector of the ST-Link/V2 board.

Figure 9. **SWD connector pinout and connections to ST-Link/V2**

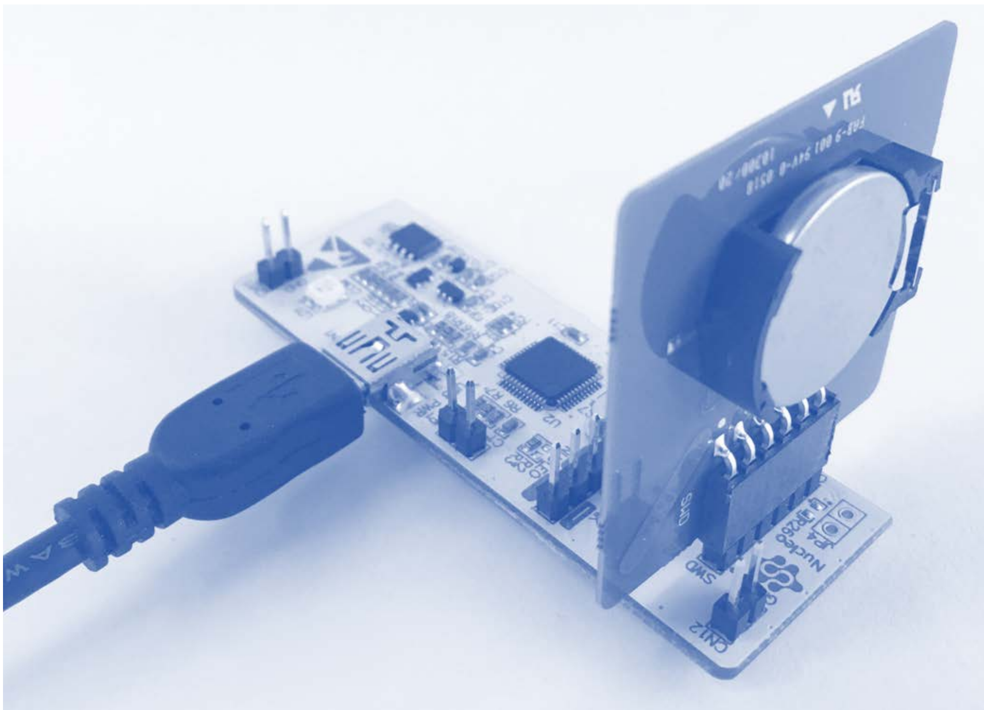
- red (VDD)
- green (SWCLK)
- black (GND)
- yellow (SWDIO)
- orange (NRST)
- blue (USART2_TX)



Step 4. Connect the ST-Link/V2 to the PC using a USB cable.

Once the blue cable is connected, you can use the ST-Link/V2-1 virtual COM port interface on the USB in transmit mode from the STEVAL-SMARTAG1 evaluation board to your PC.

Figure 10. **STEVAL-SMARTAG1 programming and debugging setup**



Step 5. Program the device in one of the following ways

- Drag and drop the .bin file on the virtual device which appears in the file explorer

– Drag the .bin or .hex file in the ST-Link Utility GUI, select [**Target**]>[**Connect**] and then [**Target**]>[**Program&Verify**] (the Erase Chip option may be necessary to successfully program the device).

Note: To keep the board under reset without removing power, you can connect the NRST orange cable to the ground on CN12 in the top left corner of the STM32 Nucleo development board.

8 Application firmware hints and tips

The advantage of storing settings (which sensors are enabled, sampling times, etc.) in the NFC EEPROM instead of the microcontroller Flash is that an NFC reader can directly read and write the application settings.

The application should monitor the ST25DV GPO signal to avoid conflicts when reading and writing to the NFC EEPROM via I2C. A conflict can occur if an NFC device tries to access the EEPROM using the NFC interface at the same time.

Different GPO configurations are available to fit different user cases:

- For NFC devices that can only read the NFC EEPROM, the ST25DV GPO pin should be configured to automatically signal any changes in the RF field (FIELD_CHANGE).
- For NFC devices that can read and write the NFC EEPROM, you can configure the ST25DV GPO as in the previous point (FIELD_CHANGE setting) or configure it so that it is controlled by the remote device (RF_USER setting) by writing GPO set/reset commands to the NFC EEPROM.

Power from NFC Energy Harvesting can be limited. If peak current absorption is too high, the system will not be able to start in battery-less mode. In battery mode, high current peaks should be avoided to prolong battery life and avoid brown-outs due to high internal resistance.

- Microcontroller power consumption can be reduced by running at only 2 MHz and entering Standby or Stop mode as soon as the task is executed. These modes may have RTC active to wake the system after a predefined time interval. In Stop mode, interrupt logic on any GPIO can wake-up the system; in Standby mode, a few specific pins can be used to wake the system (PA0 connected to the interrupt pin of the accelerometer LIS2DW12, PA2 connected to the interrupt pin of the barometer LPS22HB, and others not used in this reference design).
- MEMS sensor power consumption can be reduced by enabling Low-power mode (at the expense of RMS noise level) and reducing the output data rate (ODR) as much as possible.
- Overall peak current is reduced when components are activated in sequence and not simultaneously. For example, you can activate the accelerometer, take a sample and put it in Power-down mode, then switch to the ambient pressure sensor, then to the temperature and humidity sensor, and finally activate the NFC EEPROM to store the data and the output of the processing.

Table 3. Example of power consumption

	Active phase	Inactive phase (power not gated by MCU)
STM32L0 MCU	245 uA (Run, 2MHz)	<1 uA (stop or stand-by)
LED	150 uA (On)	0 uA (Off)
ST25DV NFC EEPROM	110-300 uA (read-write)	<1.5 uA (power-down)
LIS2DW12 Accel.	3 uA (LP, 50Hz)	0.05 uA (power-down)
HTS221 Rel. Humidity	22.5 uA (max avg, 1Hz)	0.5 uA (power-down)
LPS22HB Barometer	4 uA (LP, one-shot)	1 uA (power-down)
STLQ015 V regulator	1 uA	<0.2 uA

Note: As the microcontroller controls VDD_EEPROM and VDD_MEMS, you must observe specific power-up and power-down sequences.

RELATED LINKS

AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

5.1 Power up and power down sequences when microcontroller supplies power on page 10

9 System performance

An example application can perform the steps shown in Figure 11. FW code: MEMS and NFC active at same time (peak current) or Figure 12. FW code: power to MEMS first, then NFC (reduced current). The system is initialized, MEMS sensors are powered and data is read-out and processed, then NFC is powered to check the configuration and determine how the MEMS data should be handled.

Figure 11. FW code: MEMS and NFC active at same time (peak current)

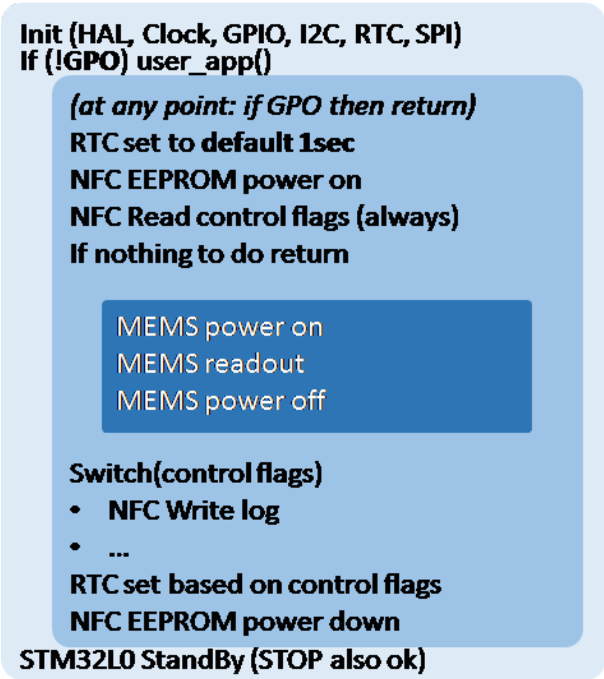
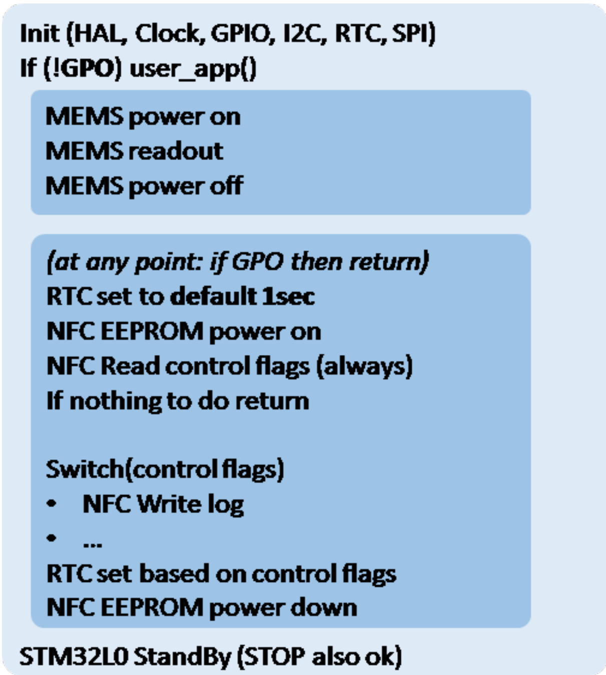


Figure 12. FW code: power to MEMS first, then NFC (reduced current)



Typical consumption profiles measured by an oscilloscope are listed below:

- Active phase: 420 µA average current for 360 ms (270 µA average current if LED is kept off)
- Inactive phase: <2.8 µA (stand-by or stop mode for the microcontroller, power to other components is gated by the MCU)

During the active phase, the in-rush current to charge the by-pass capacitors can be as high as 30-35 mA, but the pulse is very short (<0.1ms) and can be tolerated by a typical CR2032 battery.

Average current consumption for different time intervals, and estimated battery life are shown in the following figures.

Figure 13. Average current consumption in µA for the example application

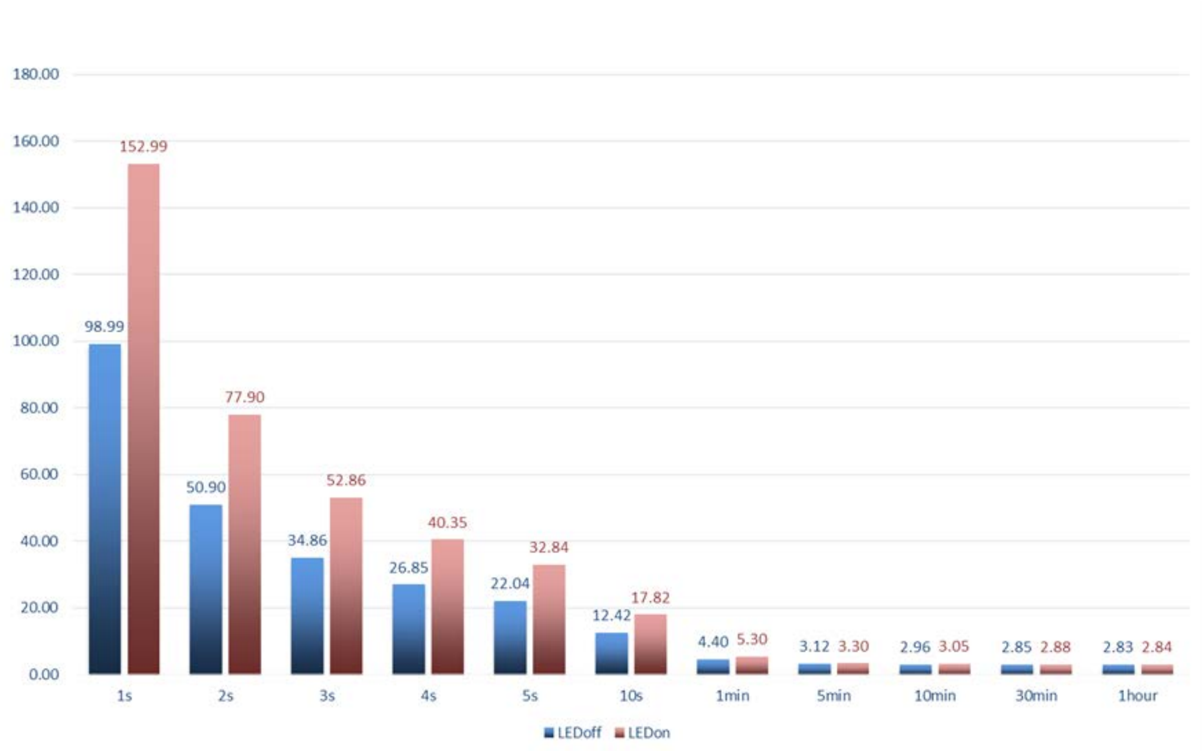
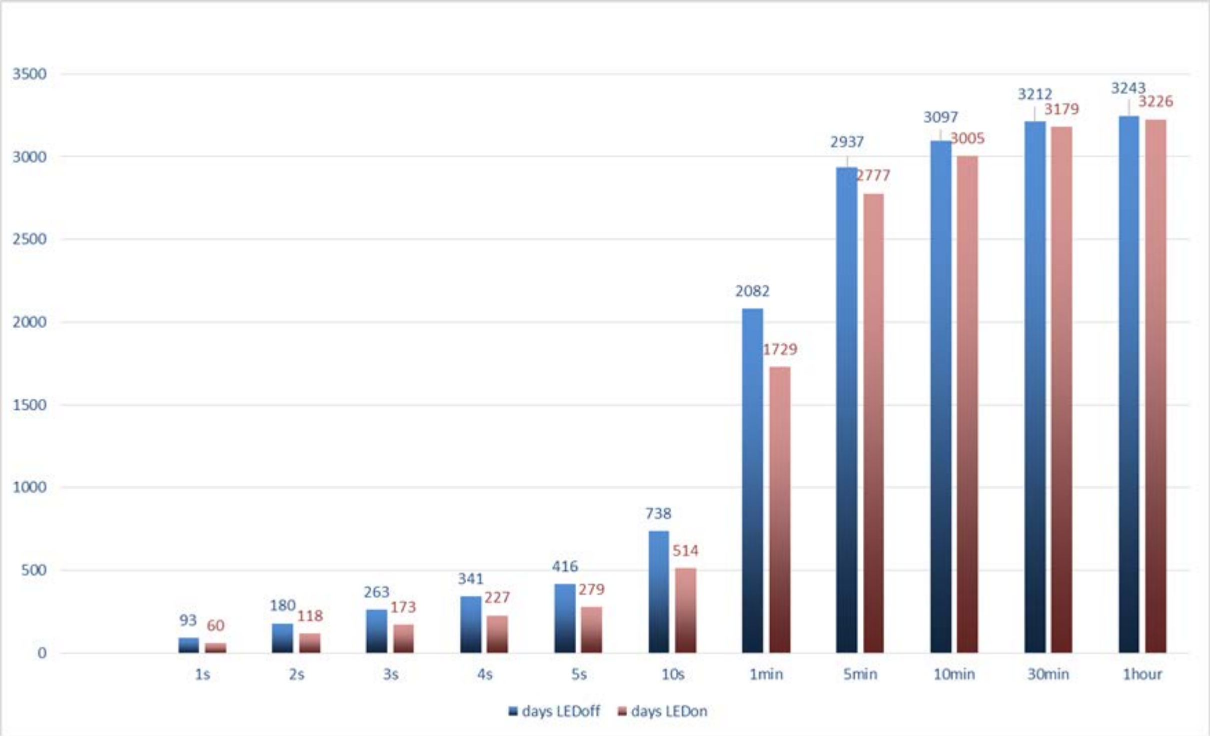


Figure 14. **Estimated battery life in days with CR2032 220mAh**



Note: These figures are typical and do not account for variations with temperature or for variations due to tolerances. Consult the datasheets for detailed information.

10 STEVAL-SMARTAG1 schematic diagrams

Figure 15. STEVAL-SMARTAG1 schematics - MCU, SWD connector and test points

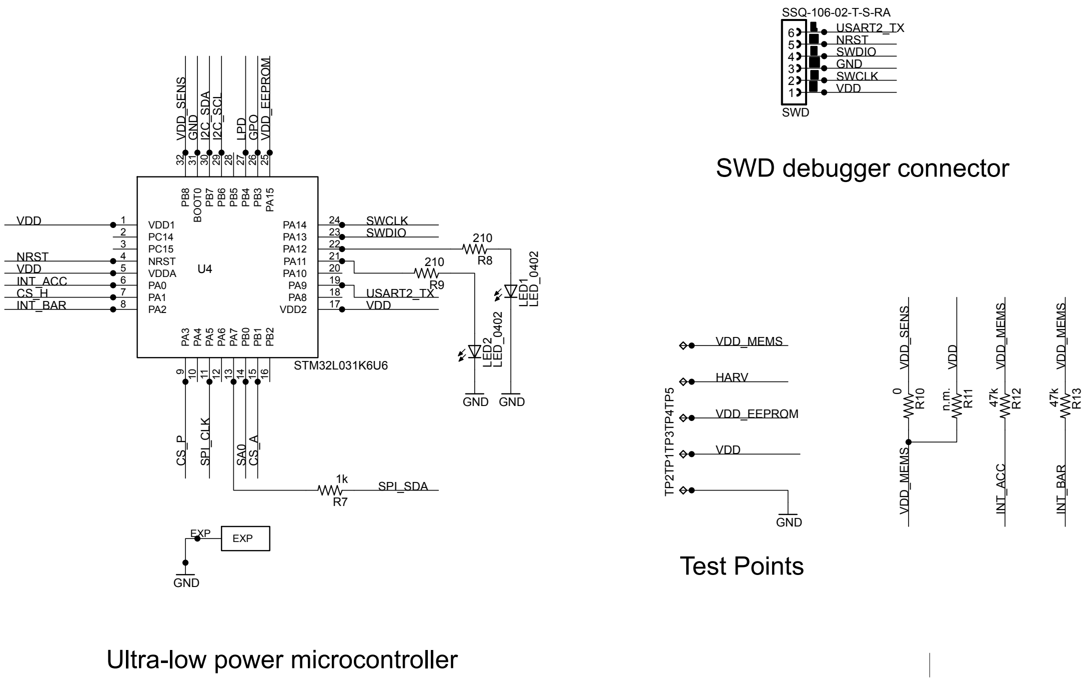


Figure 16. STEVAL-SMARTAG1 schematics - sensors

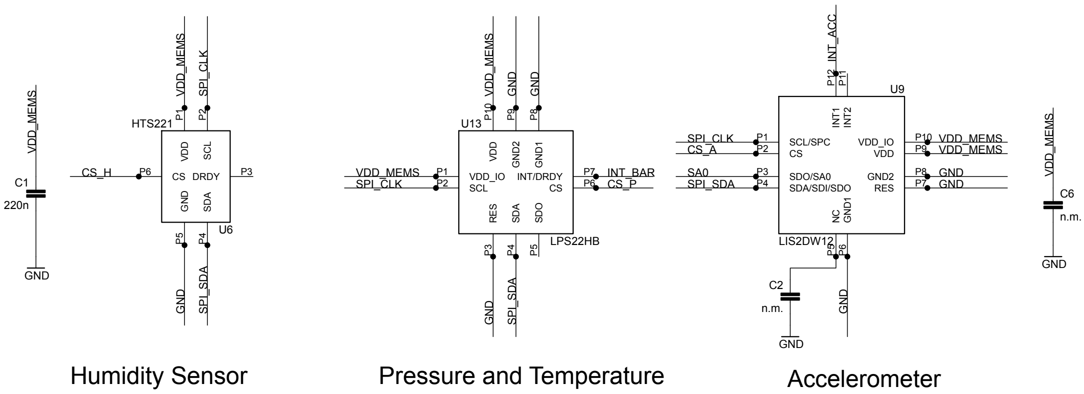
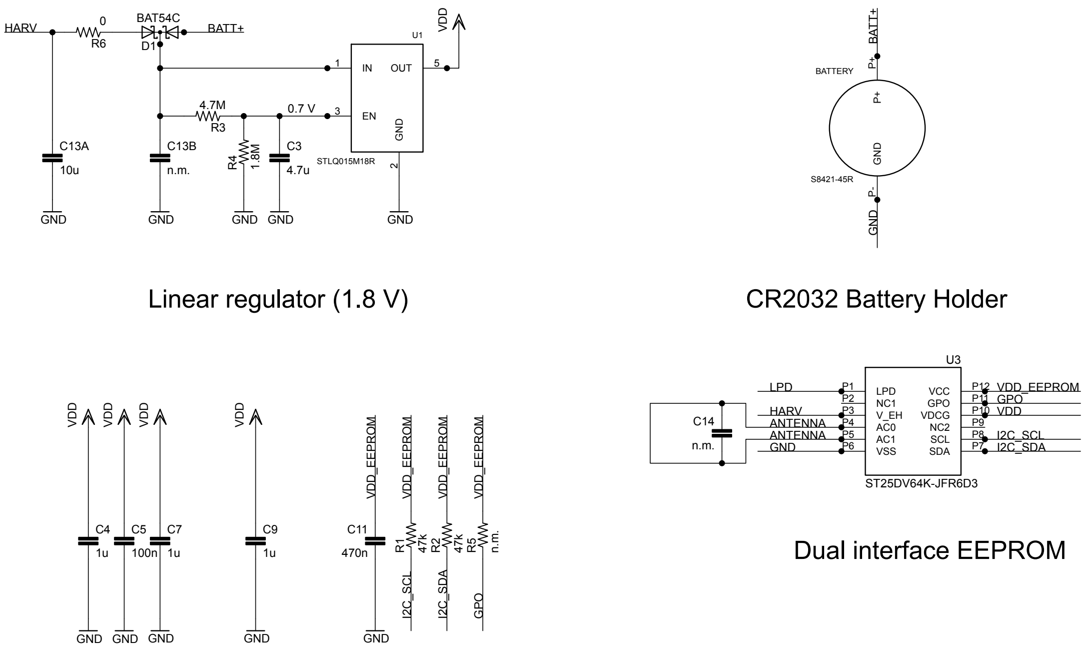


Figure 17. STEVAL-SMARTAG1 schematics - voltage regulator, battery holder and EEPROM



11 STEVAL-SMARTAG1 bill of materials

Table 4. Bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	1	U4	ARM Cortex-M0 32b MCU Microcontroller		ST	STM32L031K6U6
2	1	U1	Low drop linear regulator		ST	STLQ015M18R
3	1	U9	Ultra-low Power Accelerometer		ST	LIS2DW12
4	1	U6	Capacitive digital sensor for relative humidity		ST	HTS221
5	1	U13	Low-Power Pressure sensor		ST	LPS22HBTR
6	1	U3	64-Kbit Dynamic NFC/RFID tag		ST	ST25DV64K-JFR6D3
7	1	C14		not mounted		
8	5	R1, R2, R12, R13	RES SMD 47KΩ ±5% 1/16W 0402		Any	Any
9	1	C13A	CAP CER 10µF ±5% 6.3V X5R 0603		Any	Any
10	1	C13B	CAP CER 10µF ±5% 6.3V X5R 0603	not mounted	Any	Any
11	1	C1	CAP CER 0.22µF 16V X7R 0402		Murata	GRM155R71C224KA12D
12	1	C11	CAP CER 0.47µF 10V X5R 0402		TAIYO YUDEN	LMK105BJ474KV-F
13	3	C4, C7, C9	CAP CER 1µF 6.3V X5R 0402		Any	Any
14	1	C5	CAP CER 100NF 6.3V X5R 0402		Any	Any
15	1	R7	RES SMD 1KΩ ±5% 0402		Any	Any
16	1	R3	RES SMD 4.7MΩ ±5% 1/16W 0402		Any	Any
17	1	R4	RES SMD 1.8MΩ ±5% 1/16W 0402		Any	Any
18	2	R6, R10	RES SMD 0Ω 1/16W 0402		Any	Any
19	1	D1	Small signal Schottky diodes		ST	BAT54CFILM
20	1	BATT	RETAINER BATT CR2032 SMD		Harwin	S8421-45R
21	2	R8, R9	RES SMD 210Ω ±5% 0402		Any	Any
22	1	LED2	LED ORANGE 0402 SMD		Panasonic	LNJ847W86RA
23	1	LED1	LED GREEN 0402 SMD		Panasonic	LNJ347W83RA
24	1	C6	CAP CER 10µF ±20% 10V X5R 0402	not mounted	Samsung	CL05A106MP8NUB8
25	1	R11	RES SMD 0Ω 1/16W 0402	not mounted	Any	Any
26	1	SWD	SWD Debugger connector		Samtec	SSQ-106-02-T-S-RA
27	1	C3	CAP CER 4.7µF 6.3V X5R 0402		Any	Any
28	1	C2	CAP CER 0.22µF 16V X7R 0402	not mounted	Murata	GRM155R71C224KA12D
29	1	R5	RES SMD 47KΩ ±5% 1/16W 0402	not mounted	Any	Any

12 Safe operating use and conditions

Any use of this device not specified by the manufacturer may compromise the protection mechanisms that come with the device.

- Selected components on the STEVAL-SMARTAG1 evaluation board have an operating temperature range from -40 to +85 °C. The ambient temperature and relative humidity sensor HTS221 has a larger operating range, up to +120 °C. Other components, such as the STM32L031 microcontroller and the ST25DV NFC EEPROM have an option with operating range up to +125 °C (but the RF interface only works up to +105 °C).
- Operating ambient pressure ranges from 260 to 1260 hPa. The LIS2DW12 accelerometer sensor may be sensitive to extreme changes in ambient pressure.
- Operating ambient relative humidity ranges from 0 to 100% rH. The STEVAL-SMARTAG1 board is not protected against water condensation. A suitable water-resistant coating should be applied to the board and its components. Any difference in the thermal expansion coefficient will create mechanical stress between the PCB and the plastic package of the components. This may affect MEMS sensors (LIS2DW12 accelerometer, LPS22HB ambient pressure sensor, HTS221 ambient temperature and relative humidity sensor). When coating is applied, the venting hole in the package of LPS22HB and HTS221 should be covered to avoid contaminating the sensing element.
- The main component that limits the temperature, humidity and ambient pressure operating range is the battery. Depending on their chemistry, typical batteries have very limited or no functionality at or below zero °C. Moreover, rechargeable batteries cannot operate above +45 °C. A suitable energy source must be selected for operation at low and high temperatures, ambient pressure or relative humidity.

Operating conditions for normal operation:

- Temperature between -40 and +85 °C, but care must be taken to ensure battery performance below 0 degrees, and above 45 degrees.
- Ambient pressure between 260 and 1260 hPa. Extreme values or fast variations may cause mechanical stress in the sensor package and affect measurement accuracy.
- Relative humidity between 0 and 100%. Use of the heating element in HTS221 may be required to restore sensor operation in case of condensation; the board is not protected against condensation of water.
- FCC part 15 Subpart C verification conditions: indoor environment, temperature up to 45 °C, humidity range between 20% and 80%.

12.1 STV25DV NFC EEPROM

The ST25DV64K-JFR6D3 is an NFC EEPROM in UFDFPN12 package, device grade 6: -40 to +85 °C; other packages and device grades are available.

Note:
- *When harvesting is active, RF communication is not guaranteed.*
- *When harvesting is active, its output is not used if the battery is present and it has a higher voltage (because of the diode-OR of energy sources).*
- *Mismatch in the form factors of NFC antennas may reduce harvester output and compromise RF communication.*

RELATED LINKS

AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication

4 RF communication performance on page 9

12.2 STM32L0 microcontroller

STM32L031K6U6 is a microcontroller in 32-pin UFQFPN package, temperature range 6: -40 to +85 °C; other temperature ranges are available for this package.

Note:
- *The RTC, real-time clock used for timestamps, is driven by LSI, low-speed internal RC oscillator. The frequency drift of LSI is -10% to +4% when the temperature is in the 0-85 °C range.*

- *The LSI can be calibrated and trimmed in the software by using the HIS, which has higher accuracy. However, even with calibration, the internal RC oscillators are less accurate than an external crystal oscillator or ceramic resonator (whose drift is limited to tens of ppm).*

RELATED LINKS

AN4631: How to calibrate an STM32L0xx internal RC oscillator

12.3 LIS2DW12, LPS22HB and HTS221 MEMS sensors

LIS2DW12 is a digital accelerometer in LGA12 package: -40 to +85 °C.

LPS22HB ambient pressure sensor in HLGA-10L package: -40 to +85 °C; 260 to 1260 hPa ambient pressure.

HTS221 relative humidity and temperature sensor in HLGA-6L package: -40 to +120 °C; 0 to 100% RH ambient relative humidity.

Note:
- *Any mechanical stress on the package (e.g., by PCB bending) may affect the measurement accuracy of the sensors.*
- *Conducted heat may affect measurement accuracy, especially for the environmental sensor HTS221.*

RELATED LINKS

AN4722: HTS221 digital humidity sensor: hardware guidelines for system integration

12.4 STLQ015M18R linear voltage regulator

STLQ015M18R linear voltage regulator in SOT23-5L package: storage temperature -65 to +150 °C, max. junction temperature 150 °C.

12.5 CR2032 Lithium/Manganese-Dioxide battery

A typical CR2032 Lithium/Manganese-Dioxide battery has 220 mAh nominal capacity and 3 V open-circuit voltage at room temperature. At -20 °C, open-circuit voltage is reduced from 3 V down to 2.2-2.7 V for 1 k-100 kΩ loads; capacity is reduced from 220 mAh o 45-175 mAh for 1 k-100 kΩ loads.

The inability of the battery to sustain peak currents at low temperatures may prevent correct system operation.

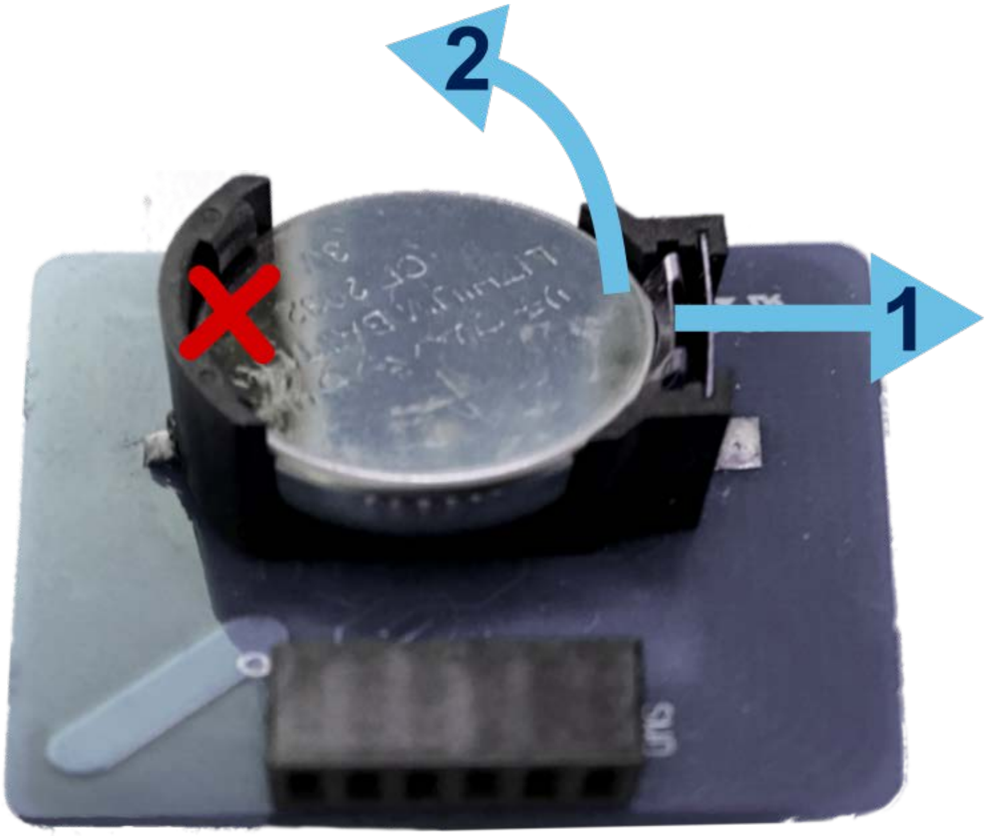
12.5.1 Safe battery removal

Attempts to remove the battery in an incorrect manner may provoke damage to the battery cradle or the board. The procedure below shows how you should remove the battery.

Step 1. Pull back and hold the metal tab

Step 2. Flip out the battery

Figure 18. Sequence to remove battery



13 Compliance Information

13.1 FCC Compliance Statement

Part 15.19

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.

Part 15.105

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.

Part 15.21

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.

13.2 IC Compliance Statement

Compliance Statement

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.

Déclaration de conformité

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'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.

A References

- AN4913: Energy harvesting delivery impact on ST25DVxxx behavior during RF communication
- DS10668: Ultra-low-power ARM Cortex-M0+ MCU with 32-Kbytes Flash, 32 MHz CPU
- AN2867: Oscillator design guide for STM8AF/AL/S and STM32 microcontrollers
- AN4631: How to calibrate an STM32L0xx internal RC oscillator
- AN4759: Using the hardware real-time clock (RTC) in low-power modes with STM32 microcontrollers
- AN5038: LIS2DW12 always-on accelerometer
- AN4833: Measuring pressure data from ST's LPS22HB digital pressure sensor
- TN1229: How to interpret pressure and temperature readings in the LPS22HB pressure sensor
- TN1218: Interpreting humidity and temperature readings in the HTS221 digital humidity sensor
- AN4722: HTS221 digital humidity sensor: hardware guidelines for system integration

Revision history

Table 5. Document revision history

Date	Version	Changes
13-Jun-2018	1	Initial release.

Contents

List of figures

List of tables