UM2663

User manual

Multi-sensor predictive maintenance kit with IO-Link device stack

Introduction

The STEVAL-BFA001V2B is an industrial reference design kit for condition monitoring (CM) and predictive maintenance (PdM).

The hardware consists of a highly compact (50 x 9 x 9 mm) industrial sensor board specifically designed for real industrial applications, and the necessary debugging tools, cables, plugs and adapters for an industrial communications scenario. The connection is managed using a standard multipolar cable with one wire used for IO-Link data.

The layout is designed to meet IEC61000-4-2/4 and EN60947 requirements for industrial applications.

The STSW-BFA001V2 firmware package (freely available on www.st.com) includes dedicated algorithms for advanced time and frequency domain signal processing and analysis of the high bandwidth 3D digital accelerometer for vibration monitoring. The package includes pressure, relative humidity and temperature sensor monitoring samples as well as audio algorithms for acoustic emission (AE).

The firmware runs on the high performance STM32F469AI, ARM® Cortex®-M4, 32-bit microcontroller. The sensor data analysis results can be displayed on a user PC terminal emulator via wired connectivity or the related IO-Link master board interface.

IO-Link device stack v1.1. (for evaluation purposes, with some limitations) is included in object library format with IO-Link Device Descriptor (IODD) for all measurements and with dedicated examples to demonstrate device interoperability with any master tool. It supports BLOB transfer for vibration and acoustic FFT data, event generator and parameter configuration.

The package includes a GUI to demonstrate the IO-Link device features when connected to the STEVAL-IDP004V2 multi-port master evaluation board or to the P-NUCLEO-IOM01M1 STM32 Nucleo pack.

Figure 1. STEVAL-BFA001V2B predictive maintenance reference kit

1 Features

- Kit content:
  – Sensor node (marked STEVAL-IDP005V2; not available for separate sale)
  – Communication adapter board (marked STEVAL-UKI001V2; not available for separate sale)
  – STLINK-V3MINI programming and debugging interface
  – Cables and connector
- Main supply voltage: 18 - 32 V
- Main components of the sensor node:
  – 32-bit ARM® Cortex®-M4 core for signal processing and analysis (STM32F469AI)
  – Ultra-wide bandwidth (up to 6kHz), low-noise, 3-axis digital vibration sensor (IIS3DWB)
  – Absolute digital pressure sensor (LPS22HB)
  – Relative humidity and temperature sensors (HTS221)
  – Digital microphone sensors (IMP34DT05)
  – IO-Link PHY device (L6362A)
  – EEPROM (M95M01-DF) for data storage
  – Step-down switching regulator and LDO regulator (L6984 and LDK220)
  – ESD protection (ESDALC6V1-1U2, SMBJ33CA)
- Complete set of firmware demo examples based on 3D accelerometer library with advanced frequency and time domain signal processing for predictive maintenance, including:
  – Programmable FFT size (256, 512, 1024, 2048), overlapping and averaging
  – Programmable windowing (Flat Top, Hanning, Hamming, Rectangular)
  – Speed RMS moving average, acceleration max. peak
  – Programmable threshold for warning and alarm conditions in spectral band
- Microphone algorithms for:
  – PDM to PCM
  – Sound pressure level (SPL)
  – Audio FFT
- IO-Link device stack v1.1 protocol and IO-Link Device Descriptor (IODD) for all measurements included (provided by TEConcept GmbH)
- M12 standard industrial connector
- SWD connector for debugging and programming capability
- Reset button
- Expansion connector with GPIO, ADC, I²C bus, timer
- Designed to meet IEC industrial standard requirements

RELATED LINKS

Visit the STEVAL-BFA001V2B web page for the most up to date resources and reference material

1.1 Package components

- One STEVAL-IDP005V2[(1)] sensor node reference design (10 x 50 mm).
- One adapter for ST-LINK programming and debugging tool - STEVAL-UKI001V2.
- STLINK-V3MINI debugger/programmer for STM32 and STDC14 flat cable.
- One 0.050” 10-pin flat cable.
- One 4-pole cable with M12 female connector.
- One 4-pole mount M12 connector plug, with male contacts.

1. *This board is not available for separate sale*

Figure 2. **STEVAL-BFA001V2B package contents**

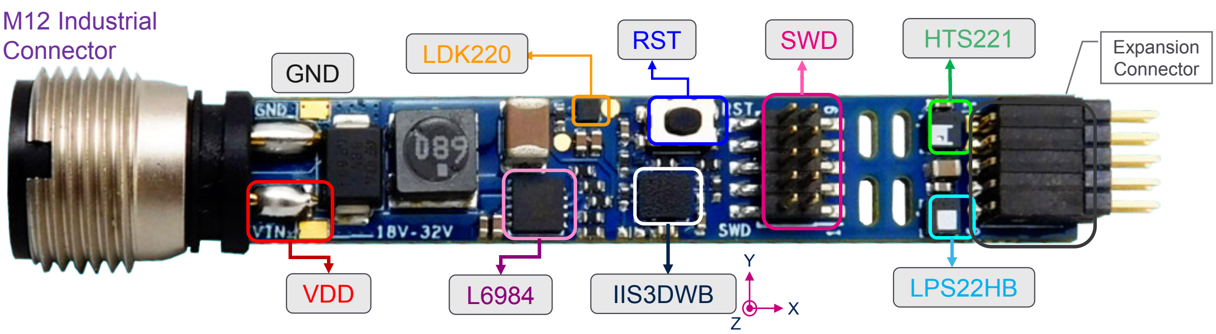


Figure 3. **Industrial sensor node - top view**

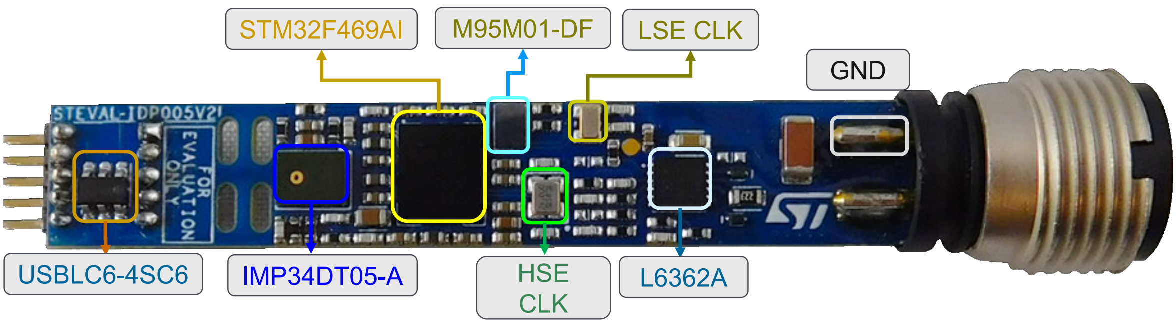


Figure 4. **Industrial sensor node - bottom view**

1.2 System requirements

The industrial sensor node in the STEVAL-BFA001V2B package is supplied with the Predictive_Maintenance_SRV firmware. To run the demo, you need the following items:

- A Windows[1] PC with a serial line terminal application like TeraTerm.
- A USB micro-B connector.
- A generic power supply (range 18 to 32 V).
- An IO-Link master hardware tool for IO-Link projects only.

1. version 7 or higher

To develop your own project, you will also need the following items:

- A Windows[1] PC with IAR, KEIL or System Workbench for STM32 firmware development environment.
- Microsoft.NET Framework 4.5 or higher (for the GUI only).
- IO-Link master interface tool like TEConcept control tool (for IO-Link project only).
- ST-LINK utility for binary firmware download.

1. version 7 or higher

RELATED LINKS

Find the latest embedded software version of the ST-LINK utility on the ST website

1.3 How to run the demo supplied with the firmware

Unpack the STEVAL-BFA001V2B kit and follow the steps below to run the `STSW-BFA001V2\Projects\Demonstrations\Predictive_Maintenance_SRV` predictive maintenance demonstration firmware loaded on the industrial sensor node.

Step 1. Connect the STEVAL-UKI001V2 adapter to the STEVAL-IDP005V2 sensor node through the 10 pin flat cable.

Step 2. Connect the STEVAL-UKI001V2 adapter to the STLINK-V3MINI programmer/debugger board through the STDC14 flat cable.

Step 3. Supply power.

Step 4. Connect the STLINK-V3MINI to the PC through the USB micro-B cable.

Step 5. Open and configure your terminal emulator.
For TeraTerm settings, see the `teraterm_tpl.INI` file included in the corresponding Misc example folder.

Step 5a. Set the following parameters:
- Name: COM Port name
- Baud Rate: 230400
- Data:8
- Parity: None
- Stop Bit: One
- Flow Control: None

Step 6. Press the Reset button on the STEVAL-UKI001V2 (or STEVAL-IDP005V2).

Step 7. Insert the new parameters and/or press [**ENTER**], then press [**Y**] and [**Enter**] to start monitoring.

RELATED LINKS

4 How to supply power to the sensor node on page 14
5.1 Connection through an STLINK-V3MINI on page 16
7.1 Outputs for the acoustic analysis project on page 27

2 Industrial sensor node hardware architecture

Figure 5. STEVAL-IDP005V2 top side components

- JP1 - IO-Link 4-position M12 A-coded connector
- J1 - SWD connector
- J2 - Auxiliary connector
- SW1 - Reset button
- L1 - Shielded power inductor
- U1 - L6984 step-down switching regulator
- U2 - LDK220 LDO
- U4 - IIS3DWB ultra-wide bandwidth 3D digital vibration sensor
- U6 - HTS221 humidity and temperature sensor
- U8 - LPS22HB pressure sensor

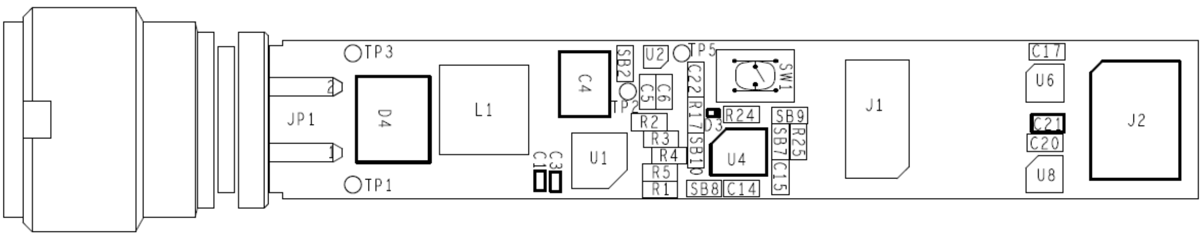
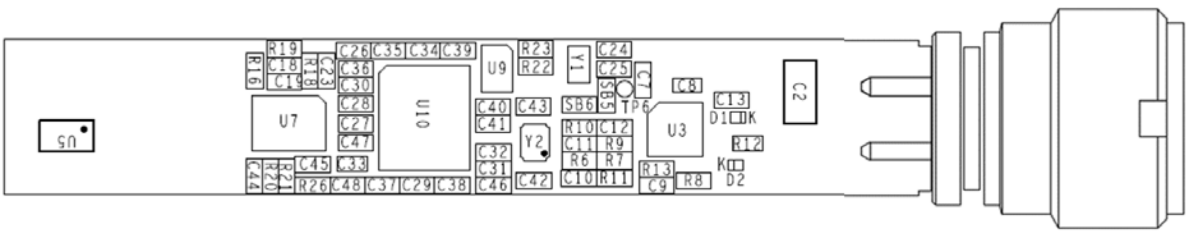


Figure 6. STEVAL-IDP005V2 bottom side components

- U3 - L6362A IO-Link communication transceiver
- U7 - IMP34DT05 digital microphone
- U9 - M95M01-DF 1-Mbit serial SPI bus EEPROM
- U10 - STM32F469AI ARM® Cortex®-M4 32-bit MCU
- Y1 - 32.768 kHz crystal
- Y2 - 24 MHz crystal



The whole system consists of the following functional subsystems:

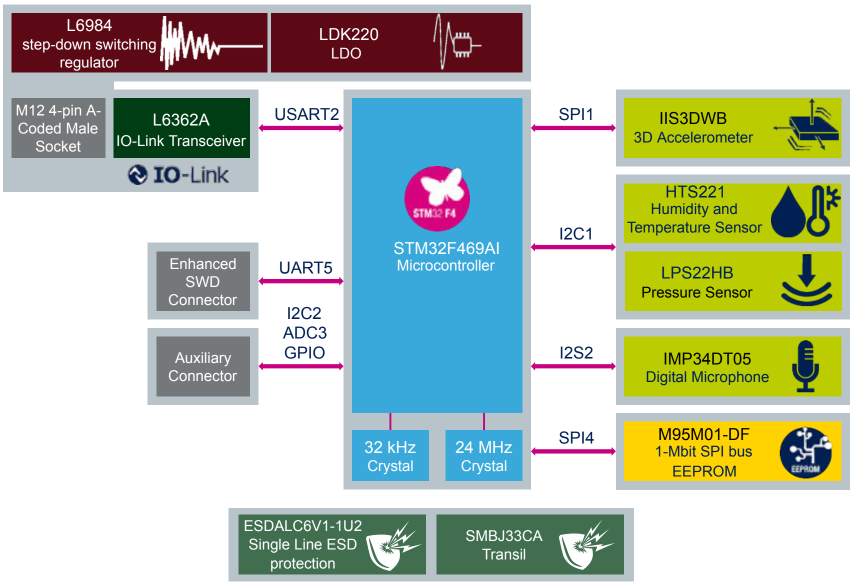
1. Power management
2. Microcontroller
3. MEMS sensors
4. EEPROM
5. Wired connectivity
6. External connectors

The sensors are connected to the microcontroller through separate bus SPI and I²C peripherals.

The connectivity options are:

- UART and I²C on the expansion connectors.
- IO-Link on the M12 male socket.

Figure 7. **STEVAL-IDP005V2 functional block diagram**

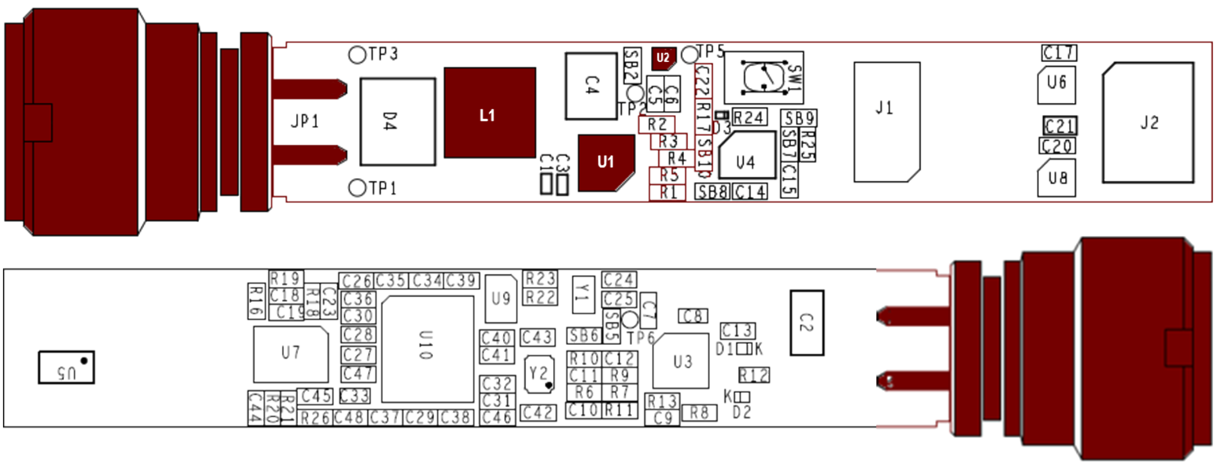


2.1 Power management

The power management stage of the STEVAL-IDP005V2 can accept an 18 to 32 V_{DC} input through the M12 A-coded 4-pin male connector (JP1) and provide 3.3 V_{DC} / 200 mA voltage output to its digital components.

- U1 - L6984 step-down switching regulator
- U2 - LDK220 LDO

Figure 8. **Power management system**



2.1.1 L6984

The L6984 is a step-down monolithic switching regulator able to deliver up to 400 mA DC. The output voltage adjustability ranges from 0.9 V. The fixed 3.3 V V_{OUT} requires no external resistor divider. The "Low Consumption Mode" (LCM) maximizes the efficiency at light load with controlled output voltage ripple. The "Low Noise Mode" (LNM) makes the switching frequency almost constant over the load current range. The PGOOD open collector output can implement output voltage sequencing during the power-up phase. The synchronous rectification, designed for high efficiency at medium - heavy load, and the high switching frequency capability make the size of the application compact. Pulse-by-pulse current sensing on low-side power element implements an effective constant current protection.

2.1.2 LDK220

The LDK220 is a low drop voltage regulator, which provides a maximum output current of 200 mA from an input voltage in the range of 2.5 V to 13.2 V, with a typical dropout voltage of 100 mV. A ceramic capacitor stabilizes it on the output. The very low drop voltage, low quiescent current and low noise make it suitable for industrial applications. The enable logic control function puts the LDK220 in shutdown mode allowing a total current consumption lower than 1 µA. The device also includes a short-circuit constant current limiting and thermal protection.

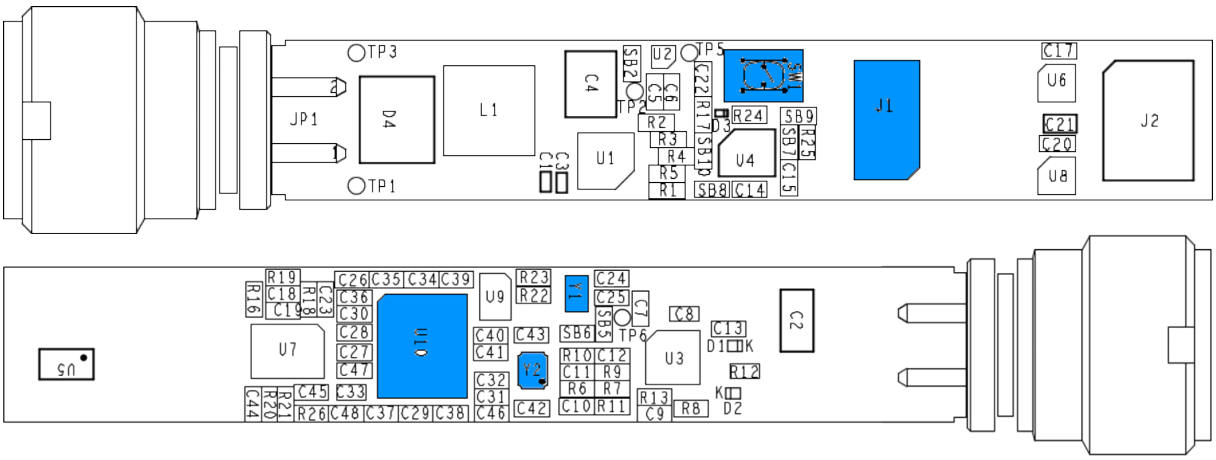
2.2 Microcontroller

The STEVAL-IDP005V2 embeds an STM32F469AI (U10) ARM®Cortex®-M4 32-bit MCU.

The board has a Serial Wire Debug (SWD) connector (J1) for MCU programming and debugging. This connector routes UART pins as well.

The board also has a reset button (SW1) to restart the microcontroller.

Figure 9. Microcontroller subsystem



2.2.1 STM32F469AI

The STM32F469AI microcontroller is based on the high-performance ARM® Cortex®-M4 32-bit RISC core operating at a frequency of up to 180 MHz. The Cortex®-M4 core features a Floating point unit (FPU) single precision which supports all ARM® single-precision data processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The device incorporates high-speed embedded memories (Flash memory up to 2 Mbytes, up to 384 Kbytes of SRAM), up to 4 Kbytes of backup SRAM, and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

The device offers three 12-bit ADCs, two DACs, a low-power RTC, twelve general-purpose 16-bit timers including two PWM timers for motor control, two general-purpose 32-bit timers, and a true random number generator (RNG).

The microcontroller features the following standard and advanced communication interfaces:

- Up to three I2Cs.
- Six SPIs, two I2Ss full duplex. To achieve audio class accuracy, the I2S peripherals can be clocked via a dedicated internal audio PLL or via an external clock to allow synchronization.
- Four USARTs plus four UARTs.
- One SAI serial audio interface.

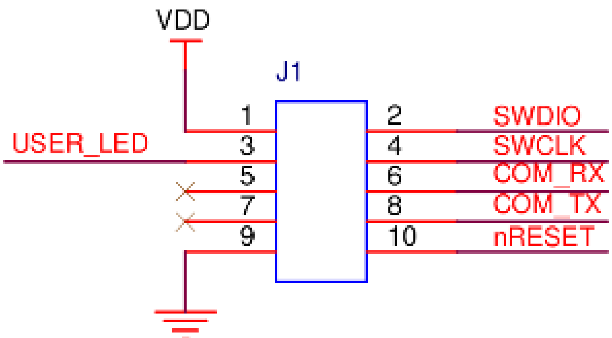
The STM32F469AI device operates in the -40 to +105 °C temperature range from a 1.7 to 3.6 V power supply.

2.2.2 Enhanced SWD connector

The STEVAL-IDP005V2 has a 1.27 mm pitch, 10-contact, 2-row board-to-board connector. The connector can be used for the following purposes:

- To program the microcontroller via a dedicated adapter (STEVAL-UKI001V2) connected to the programming tool (STLINK-V3MINI).
- As an expansion connector that routes the UART pins, to connect the sensor node with a PC COM port. A further IO for USER_LED is also routed.

Figure 10. Enhanced SWD connector schematic

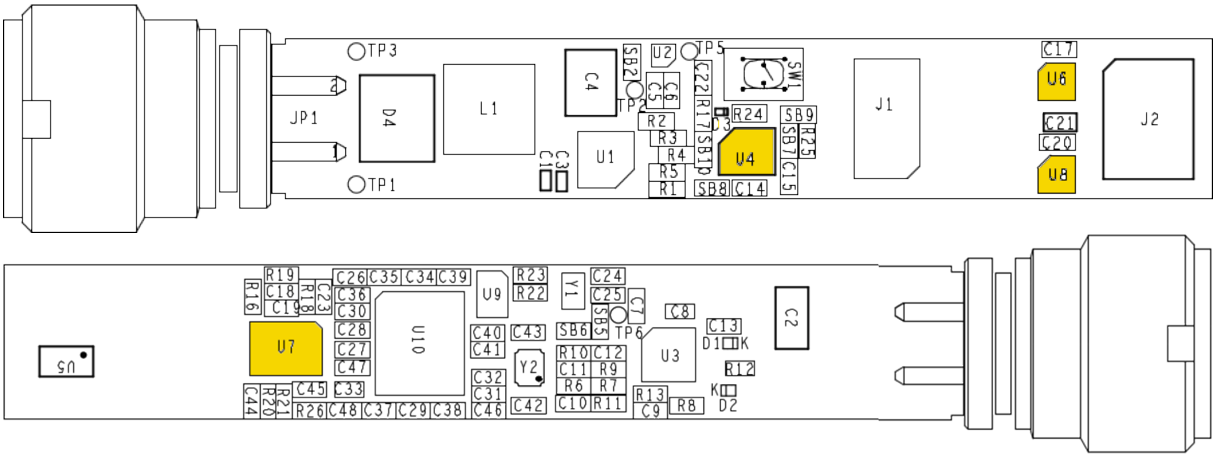


2.3 Sensors

The STEVAL-IDP005V2 embeds several sensors to detect vibration, environmental parameters and sound parameters. The sensor data is analyzed with algorithms running on the STM32F469AI microcontroller with FPU.

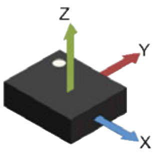
Figure 11. **Sensor array subsystem**

U4 - IIS3DWB ultra-wide bandwidth 3D digital vibration sensor
U6 - HTS221 humidity and temperature sensor
U8 - LPS22HB pressure sensor
U7 - IMP34DT05 digital microphone



2.3.1 IIS3DWB

The IIS3DWB system-in-package features a 3-axis digital accelerometer with low noise over an ultra-wide and flat frequency range. The wide bandwidth, low noise, highly stable and consistent sensitivity, together with its extended operating temperature range (up to +105 °C), make the device particularly suitable for vibration monitoring in industrial applications.



The high performance delivered at low power consumption, together with the digital output and the embedded digital features like the FIFO and the interrupts are enabling features for battery-operated industrial wireless sensor nodes. The IIS3DWB has a selectable full-scale acceleration range of ±2/±4/±8/±16 g and is capable of measuring accelerations with a bandwidth up to 5 kHz with an output data rate of 26.7 kHz. A 3 kB first-in, first-out (FIFO) buffer is integrated in the device to avoid any data loss and to limit intervention of the host processor.

The IIS3DWB includes a self-test capability for verifying sensor operation in the final application.

The IIS3DWB is available in a 14-lead plastic land grid array (LGA) package and is guaranteed to operate over an extended temperature range from -40 °C to +105 °C.

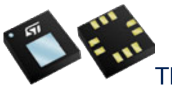
2.3.2 HTS221

The HTS221 is an ultra-compact sensor for relative humidity and temperature. It includes a sensing element and a mixed signal ASIC to provide the measurement information through digital serial interfaces.

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.

The HTS221 is available in a small top-holed cap land grid array (HLGA) package guaranteed to operate over a temperature range from -40 °C to +120 °C.

2.3.3 LPS22HB

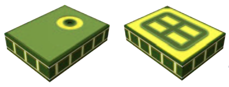


The LPS22HB is an ultra-compact piezoresistive absolute pressure sensor which functions as a digital output barometer. The device comprises a sensing element and an IC interface which communicates through I2C or SPI from the sensing element to the application.

The sensing element, which detects absolute pressure, consists of a suspended membrane manufactured using a dedicated process developed by ST.

The LPS22HB is available in a full-mold, holed LGA package (HLGA). It is guaranteed to operate over a temperature range extending from -40 °C to +85 °C. The package is holed to allow external pressure to reach the sensing element.

2.3.4 IMP34DT05



The IMP34DT05 is an ultra-compact, low-power, omnidirectional, digital MEMS microphone built with a capacitive sensing element and an IC interface.

The sensing element, capable of detecting acoustic waves, is manufactured using a specialized silicon micromachining process dedicated to producing audio sensors.

The IC interface is manufactured using a CMOS process that allows designing a dedicated circuit able to provide a digital signal externally in PDM format.

The IMP34DT05 is a low-distortion digital microphone with a 64 dB signal-to-noise ratio and -26 dBFS ±3 dB sensitivity.

The IMP34DT05 is available in a top-port, SMD-compliant, EMI-shielded package and is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

2.4 Memory

The STEVAL-IDP005V2 has non-volatile memory which can store up to 1-Mbits of data.

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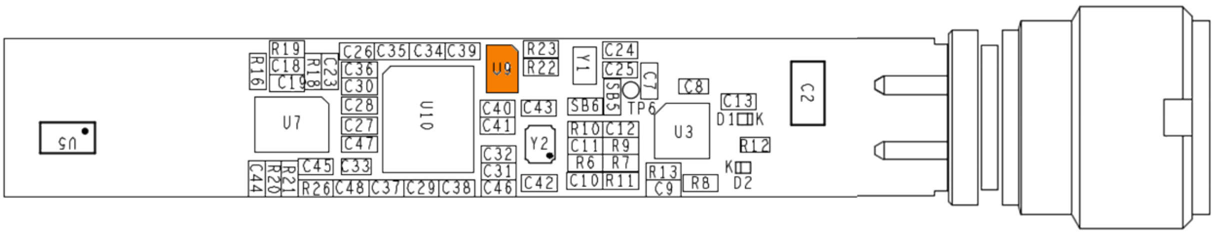
Figure 12. EEPROM subsystem

U9 - M95M01-DF 1-Mbit serial SPI bus EEPROM



2.4.1 M95M01-DF

The M95M01 electrically erasable programmable memory (EEPROM) id organized as 131072 x 8 bits, accessed through the SPI bus.

The M95M01-DF can operate with a supply range from 1.7 V up to 5.5 V. This device is guaranteed for the -40 °C/+85 °C temperature range.

The M95M01-DF offers an additional Identification Page (256 bytes), which can be used to store sensitive application parameters that can subsequently be permanently locked in Read-only mode.

2.5 IO-Link communication

The STEVAL-IDP005V2 board has IO-Link connectivity available on the M12 A-coded connector with the IO-Link device stack v1.1 runs on the microcontroller embedded.

IO-Link is an industrial standard for hardware connectivity. The standard specifies:

- the number of wires needed for the bus installation
- the colors to distinguish supply voltage from the IO-Link bus line
- connector pinouts.

The standard also establishes two different data communication methods:

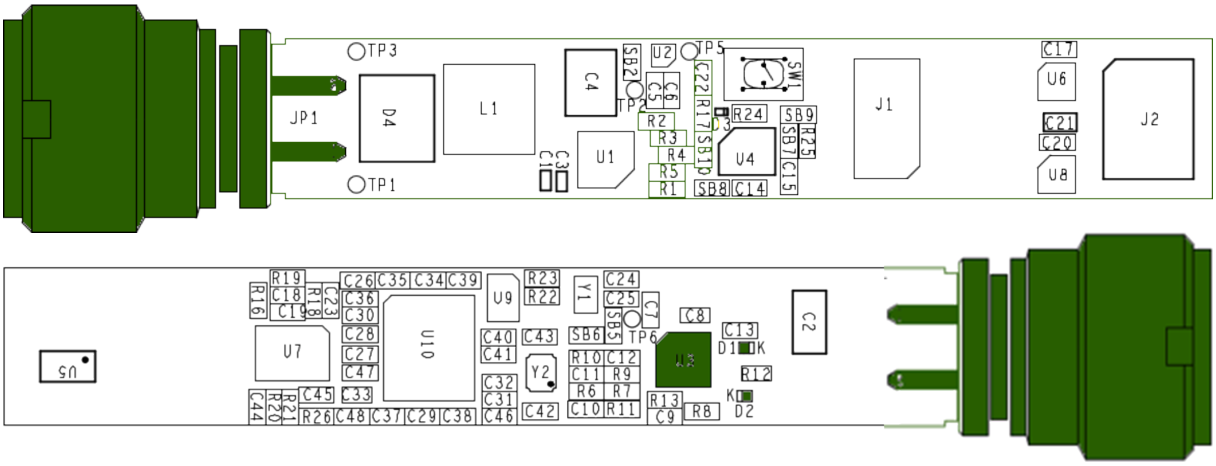
1. Pure serial data communication (SDCI) with a detailed protocol structure to manage sensor parameters and sensor data.
2. A simple level transition high to low and vice versa to signal the sensor status only.

The use of an IO-Link system offers several advantages, like:

- Automatic detection and parameterization of the IO-Link device: the operating parameters of devices are stored in the master during setup. Once connected, the master recognizes the device and enables automatic startup. If a device like a sensor fails, it can be replaced and parameterization data stored in the master is automatically downloaded to the replacement device.
- Device monitoring and diagnostics: IO-Link allows equipment components and systems to be monitored and proactively managed. Diagnostics provided by IO-Link devices lets the control system track data and trends, facilitating preventive and predictive maintenance and improving machine uptime.
- Changes on the fly: parameters can be quickly adjusted for installed devices while the machine is running, reducing time consumption.
- Reduced component costs: by exploiting the configuration capabilities of IO-Link, a device can be configured to have different output functions.

Figure 13. IO-Link subsystem

U9 - L6362A IO-Link communication transceiver device IC



2.5.1 L6362A

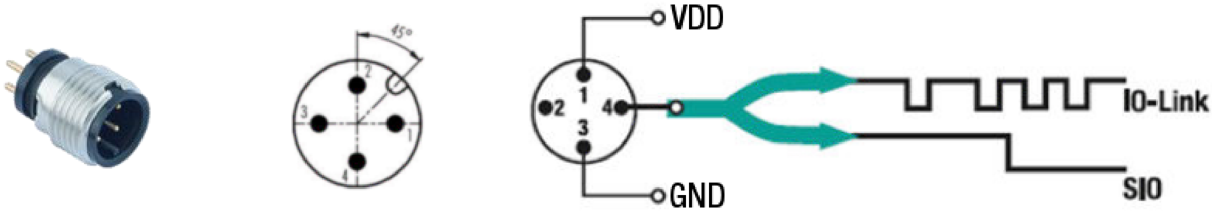
The L6362A is an IO-Link transceiver device compliant with PHY2 (3-wire connection) supporting COM1 (4.8 kbaud), COM2 (38.4 kbaud) and COM3 (230.4 kbaud) modes. The output stage can be configured as high-side, low-side or push-pull by hardware connection, and it can drive resistive, capacitive and inductive loads.

The IC can interface a sensor node to a master unit using both the Serial Data Communication Interface (SDCI) based on IO-Link protocol and the Standard I/O mode (SIO). Communication is managed using the 24 V industrial bus voltage. The L6362A is protected against reverse polarity across VCC, GND, OUTH, OUTL and I/Q pins. The IC is also protected against output short-circuits, overvoltage and fast transient conditions (±1 kV, 500 Ω and 18 μF coupling).

2.5.2 IO-Link connector

The IO-Link connector is M12 A-coded 4-pin.

Figure 14. **IO-Link connector and signals**



2.6 Auxiliary connections

The STEVAL-IDP005V2 comes with a 10-pin auxiliary connector for:

- V_{DD} and GND
- SMBus (I²C)
- One ADC channel
- Two timers

The above pins can still be used as GPIOs.

The mounted J2 auxiliary female connector mates with the male-male connector in the kit.

3 STEVAL-UKI001V2 adapter board

This is an adapter for STLINK-V3MINI programmer/debugger tool and STEVAL-IDP005V2.

You can use STLINK-V3MINI through the STEVAL-UKI001V2 adapter to program and debug the target application. You can also use the STLINK-V3MINI Virtual COM Port Driver as a UART interface. This allows you to keep using the USB cable that connects the kit to your PC.

The STEVAL-UKI001V2 includes a reset button to reset the STEVAL-IDP005V2 and the user LED1, the additional push button e LED are not driven by STEVAL-IDP005V2, but reserved for future use. Refer to the schematic below.

Figure 15. STEVAL-UKI001V2 schematic

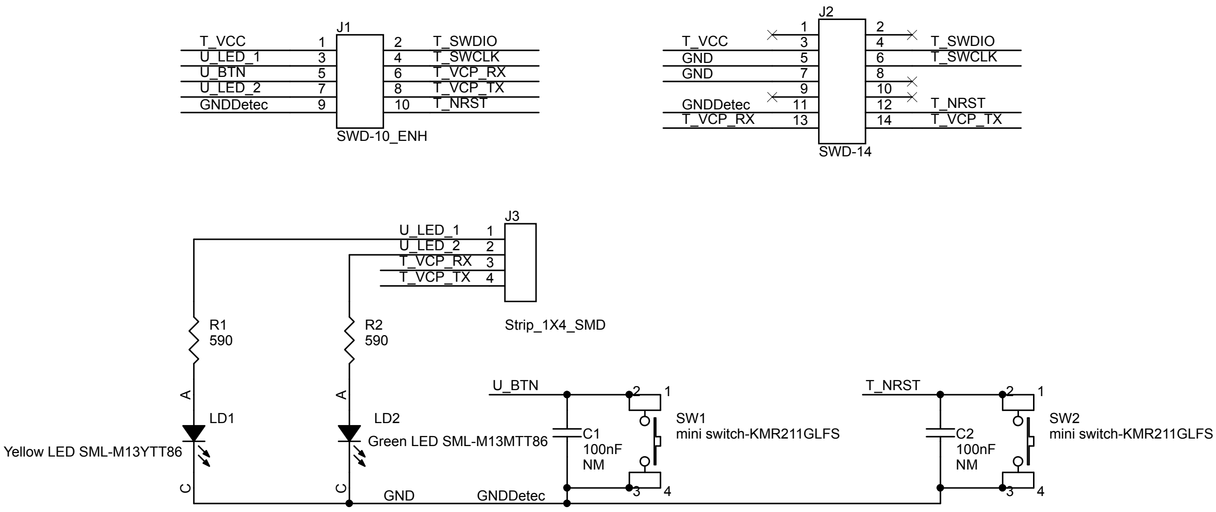
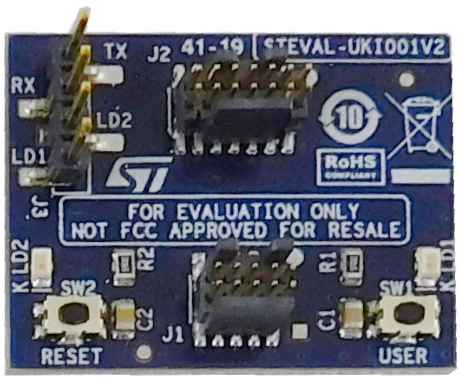


Figure 16. STEVAL-UKI001V2 top view



4 How to supply power to the sensor node

The kit includes the necessary cable and connectors to power the sensor node.

Figure 17. **4-wire cable with free ends and an M12 A-coded 4-pin female connector**

Figure 18. **4-pole cable mount connector plug with male contacts**

RELATED LINKS

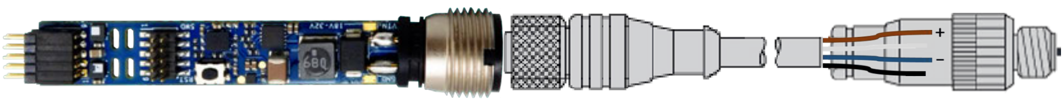
1.3 How to run the demo supplied with the firmware on page 4

4.1 Supply power directly from a DC power supply

You can power the board directly from a DC power supply using only the cable provided in the kit.

Step 1. Connect the cable to an 18 – 32 V_{DC} power supply:
- – Pin 1 (brown wire) to positive
- – Pin 3 (blue wire) to negative

Figure 19. **Power supply connection (without IO-Link master board)**



4.2 Supply power through an IO-Link master board

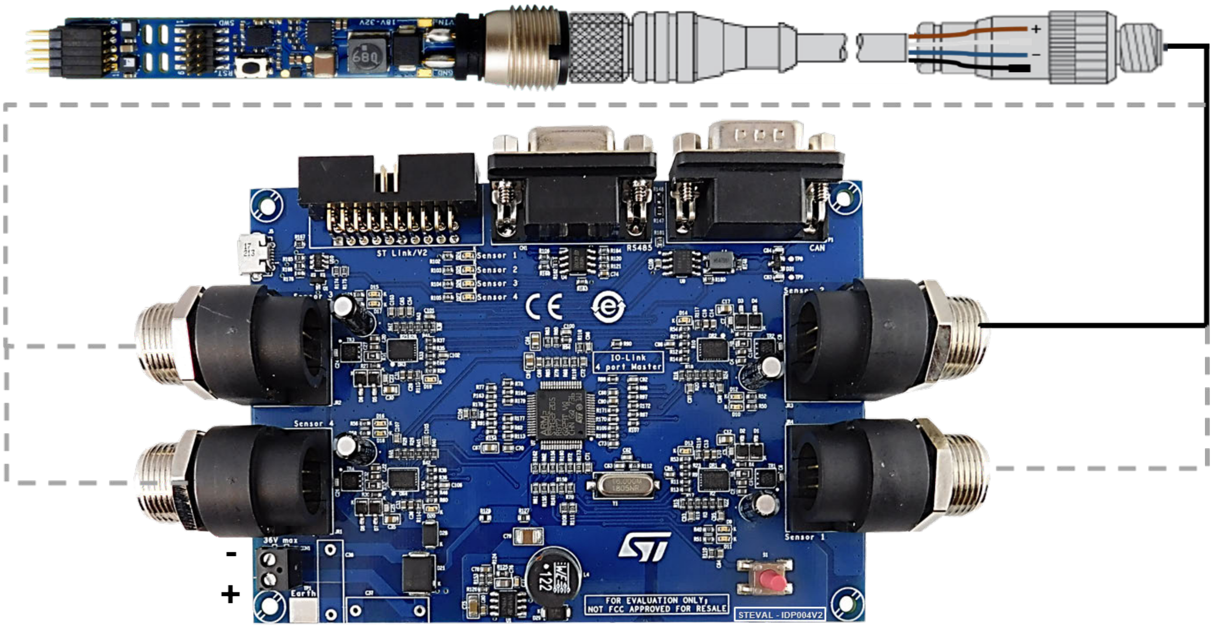
You can supply power via an IO-Link master board using the cable and connectors provided in the kit.

Step 1. Attach the 4-pole cable mount connector plug with male contacts to the cable.

Step 2. Connect the female end to the STEVAL-IDP005V2 board and the male end to the master tool (e.g., STEVAL-IDP004V2 master board).

Step 3. Power the STEVAL-IDP004V2 IO-Link master board with an 18 to 32 V_{DC} supply through screw connector CON1.

Figure 20. STEVAL-IDP005V2 power supply connection (through IO-Link master board)



5 Sensor node board connections

The STEVAL-IDP005V2 needs to be linked with a PC to manage the data coming from the board. The connection can either be through a serial communication adapter (STLINK-V3MINI) or an IO-Link master multi-port board (STEVAL-IDP004V2).

5.1 Connection through an STLINK-V3MINI

The STLINK-V3MINI debugger/programmer tool connected to the STEVAL-IDP005V2 lets you update the firmware on latter. It also allows UART communication with a PC using the STLINK-V3MINI Virtual COM Port.

To enable UART communication:

Step 1. Install the STM32 Virtual COM Port Driver (STSW-STM32102) on your PC.

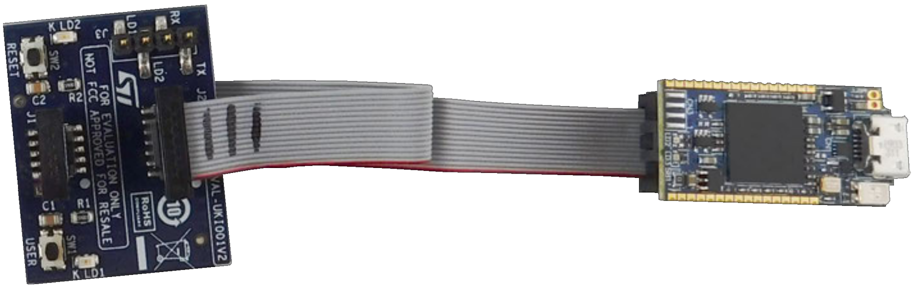
Step 2. Run a terminal emulator like TeraTerm, etc.

To set up a connection for firmware update.

Step 3. Respecting the polarity connect the 10-pin flat IDC cable to STEVAL-UKI001V2.

Step 4. Connect the STEVAL-UKI001V2 to STLINK-V3MINI using the STDC14 pin flat cable.

Figure 21. connection between STLINK-V3MINI and STEVAL-UKI001V2



Step 5. Connect the STLINK-V3MINI to the PC through the USB micro-B cable.

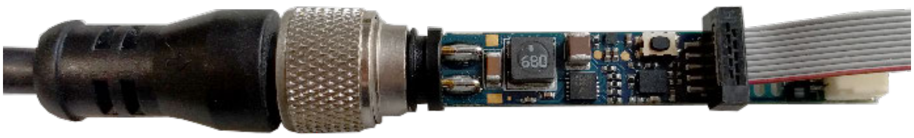
Step 6. Use the 4-wire cable with free ends and an M12 A-coded 4-pin female connector (e.g. Telemecanique Sensors XZCP1141L2).

Step 7. Connect the M12 A-coded 4-pin female connector of the cable to JP1 (IO-Link connector) of the STEVAL-IDP005V2.

Step 8. Connect wire 1 (VIN) and wire 3 (GND) of the cable to a power supply able to provide 18 to 32 V_{DC}.

Step 9. Respecting the polarity, connect the free end of the 10-pin flat IDC wire cable to J1 (SWD connector) of the STEVAL-IDP005V2.
The STEVAL-IDP005V2 is ready to be programmed with new firmware.

Figure 22. IO-Link and SWD connection



Step 10. To display data, open a terminal emulator, configured with baud rate 230400, 8N1 parameters, and run it to monitor and log application data on the PC.

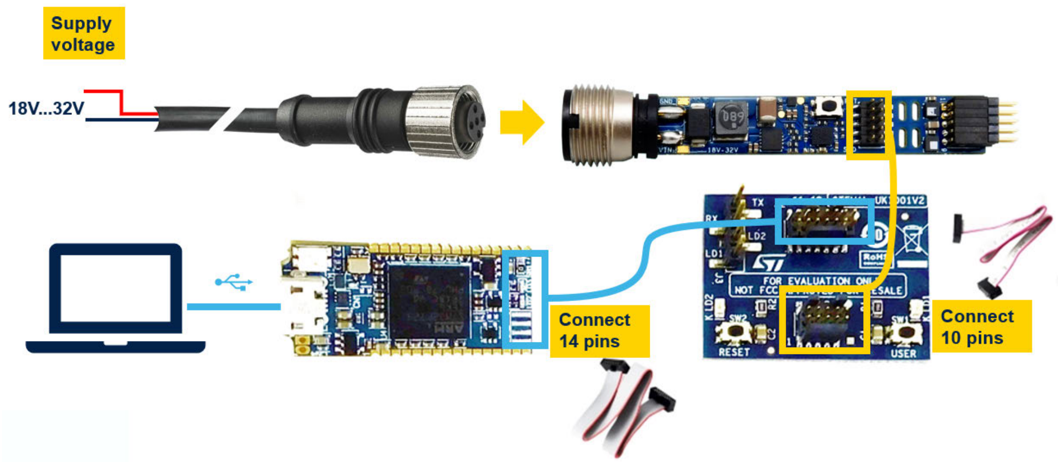


Figure 23. STEVAL-BFA001V2B complete setup kit connection in stand-alone mode

RELATED LINKS

1.3 How to run the demo supplied with the firmware on page 4
6.2.4.3 Demonstrations folders on page 23
7.1 Outputs for the acoustic analysis project on page 27
8 Projects with IO-Link on page 43
8.1 How to run projects via IO-Link on page 43

5.2 Connection through an IO-LINK master tool

The STEVAL-IDP005V2 can be connected to any master tool through IO-Link protocol via the M12 connector. The following procedure provides an example physical IO-Link connection between the STEVAL-IDP005V2 sensor node and a PC using the STEVAL-IDP004V2 master multi-port board or a P-NUCLEO-IOM01M1 STM32 Nucleo pack with an L6360 master IC for each IO-Link port.

Step 1. Ensure that none of the boards are connected to a power supply.

Step 2. Assemble the Telemecanique Sensors XZCP1141L2 (4-wire cable) with the Telemecanique Sensors XZCC12MDM40B (4-pole connector).

Step 3. You can also use a preassembled 4-wire cable (not provided in the package) with M12 A-coded 4-pin connectors, male on one end and female on the other.

Step 4. Plug the female M12 connector of the cable to the STEVAL-IDP005V2.

Step 5. Plug the male M12 connector of the cable to a free port of the four ones that are in the STEVAL-IDP004V2.

Step 6. Connect the RS485 dongle (not present in the package) and install the related driver to create the physical connection between PC and master board.

For correct communication, use the reference pinout on the DB9 connector shown below.

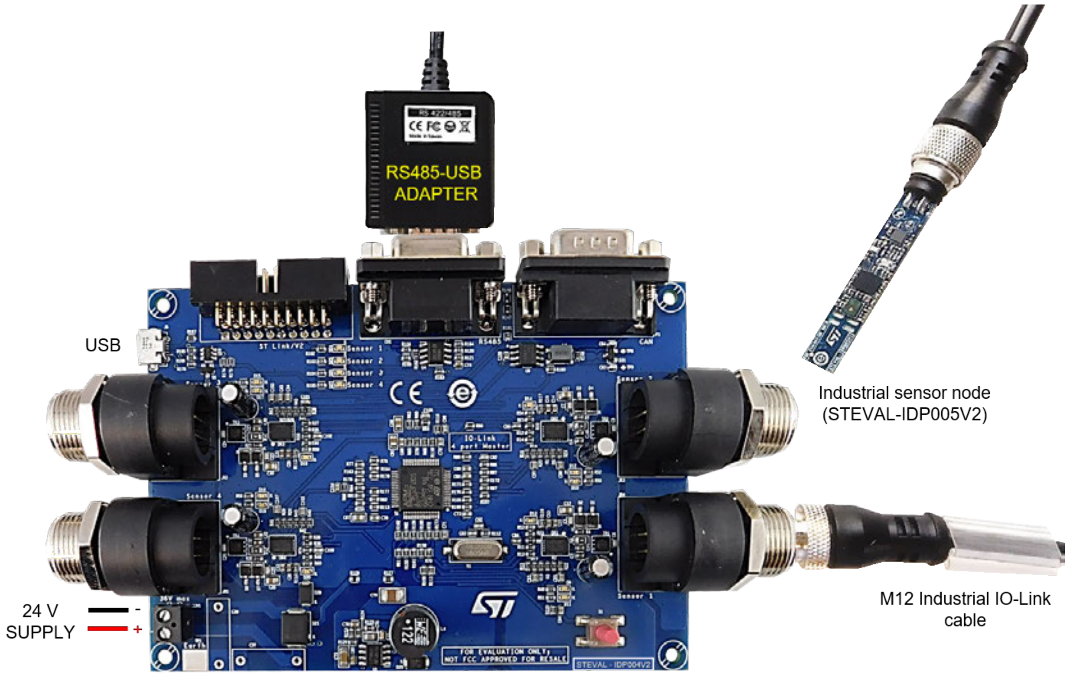
Table 1. RS485 Connector pinout

PIN Number	PIN Description
1 , 4	Inverting receiver input and inverting driver output
2 , 8	Non inverting receiver input and non-inverting driver output
6 , 7 , 9	Not connected
3 , 5	Ground

Step 7. Connect an 18 to 32 V (typ. 24 V) supply voltage through screw connector CON1 on the board to run the system.

Step 8. Open the master software interface and enable the power on by suitable command.

Figure 24. STEVAL-IDP004V2 and STEVAL-IDP005V2 connections



RELATED LINKS

6.2.4.3 Demonstrations folders on page 23

8 Projects with IO-Link on page 43

9 Graphical user interface overview on page 45

8.1 How to run projects via IO-Link on page 43

6 Firmware overview

The STSW-BFA001V2 software is an expansion of the STM32Cube environment with functions to help you develop applications using inertial, environmental and microphone sensors. The firmware includes sample condition monitoring and predictive maintenance applications based on ultra wide bandwidth 3D digital accelerometer, environmental and acoustic MEMS sensors.

The software uses the following lower layers:

- Low level STM32Cube HAL layer to provide all the MCU communication peripherals APIs compatible with STM32Cube framework.
- Low level drivers to facilitate sensor configuration and data reception with dedicated APIs that are compatible with STM32Cube framework.
- Medium level board support package (BSP) layer to provide on-board sensor control and data reception at the application level.

The middleware libraries built on top of the lower layers provide the following features:

- Middleware, including algorithms for advanced time and frequency domain signal processing for vibration analysis:
  - For the frequency domain:
    - Programmable FFT size (256, 512, 1024, 2048)
    - Programmable FFT input data overlapping
    - Programmable FFT input data windowing (Flat Top, Hanning, Hamming, Rectangular)
    - Programmable FFT output averaging
    - Programmable FFT subrange analysis
    - HP filtering to reduce accelerometer offset
    - Accelerometer max peak evaluation
    - Accelerometer integration to evaluate Speed
    - Moving RMS speed evaluation
- Middleware with microphone algorithms:
  - PDM to PCM
  - Sound pressure
  - Audio FFT
- Third party Middleware (provided by TEConcept) including IO-Link device stack v1.1 in library format:
  - IO-Link Device Descriptor (IODD) to provide all measurements (Baud rate: COM3 speed).
  - Process data cyclically sent to the master to update several data measurements.
  - Binary Large OBject (BLOB) acyclically sent by request from the master.
  - Parameters and Thresholds configurable directly from the Master interface (i.e. by TEConcept control tool).
  - BLOB transfer support for vibration and acoustic FFT data transfer.
  - Events device generation for Time and Frequency Domain.
- Sample application:
  - Monitor environmental, acoustic and vibration data.
  - Read algorithm outputs through a terminal emulator.
  - Programmable warning and alarm thresholds in the time domain and across spectral bands.
- Demonstration example firmware:
  - To demonstrate device interoperability with any master tool.
  - Supports BLOB transfer for vibration and acoustic FFT data.
  - Event generator for alarm and warning from configurable time and frequency domain thresholds.
  - Parameter configuration for MotionSP settings and thresholds (with parameter custom ISDU).

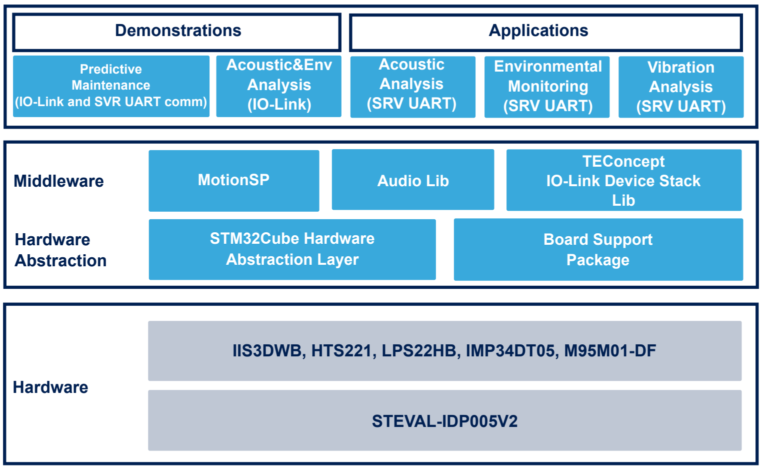
The firmware package includes a dedicated PC GUI to plot the data coming from STEVAL-IDP005V2 when it is connected to the IO-Link master multi-port evaluation board (STEVAL-IDP004V2).

6.1 Firmware architecture

The firmware is based on the STM32Cube framework for applications running on the STM32 microcontroller.

The package provides a board support package (BSP) for the MEMS and Microphone sensors and other devices used for IO-Link communication. The package also contains middleware for signal and audio processing, plus a third party library to use a device IO-link stack.

Figure 25. **STSW-BFA001V2 firmware architecture**



The following firmware layers access and use the hardware components:

- STM32Cube HAL layer: generic Application Programming Interfaces (APIs) which interact with higher level applications, libraries and stacks. The APIs are based on the common STM32Cube framework so other layers like middleware can function without requiring specific hardware information for a given microcontroller unit (MCU).
- Board support package (BSP) layer: provides firmware support for the STM32 (excluding MCU) peripherals. These APIs provide a programming interface for certain board-specific components like LEDs, user buttons, etc. The APIs can also fetch board serial and version information, as well as support initializing, configuring and reading data from sensors. The BSP provides the drivers for the STEVAL-IDP005V2 board peripherals to connect to the microcontroller peripherals.

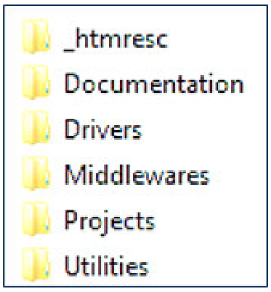
This firmware package expands the functionality of the STM32Cube platform with the following features for specific industrial applications:

- Low and middle level drivers to connect all the on-board MEMS sensors:
  - Pressure and temperature sensor (LPS22HB)
  - Humidity and temperature sensor (HTS221)
  - Accelerometer sensors (IIS3DWB)
  - Digital Microphone audio sensor (IMP34DT05)
- Complete BSP functions to allow applications to access sensors. The data acquisition from different sensors is provided via SPI and I²C.
- Several sample firmware projects divided into two main groups:
  - Applications: examples that use motion, environmental and acoustic measurements, including middleware algorithms focused on vibration and acoustic analysis and environmental monitoring.
  - Demonstrations: projects designed to demonstrate predictive maintenance with the STEVAL-IDP005V2, using the IO-Link connectivity and the standard UART; plus a dedicated project for acoustic analysis using IO-Link connectivity with the master board (STEVAL-IDP004V2).

6.2 Firmware folder structure

The STSW-BFA001V2 package is developed using the standard STM32Cube framework structure shown below.

Figure 26. **STSW-BFA001V2 firmware folder structure**



6.2.1 Documentation

The documentation folder contains a compiled HTML file generated from doxygen comments in the source code. The folder also has documentation regarding the firmware framework, drivers for the on-board components and APIs to manage the different functions.

Note: For more information, open the STEVAL-BFA001V2.chm help file in the documentation folder.

6.2.2 Drivers

All firmware packages compliant with the STM32Cube framework contain the following main groups:

- BSP: board-specific drivers for the HW components.
- CMSIS: vendor-independent hardware abstraction layer for the ARM Cortex-M series, including DSP libraries used for the projects.
- STM32F4xx_HAL_Drivers: microcontroller HAL libraries.

The board support package files are grouped into two main folders with the low level hardware device drivers and the board-specific medium level drivers:

- Components: includes a set of platform-independent device drivers for LPS22HB, HTS221, IIS3DWB, M95M01-DF, as well as common files.
- STEVAL-IDP005V2: includes a set of medium level drivers for each hardware subsystem. You can use the drivers in your application to control and configure the functionality of different measurement datatypes.

These APIs abstract the on-board hardware and connectivity devices contained in the STEVAL-IDP005V2 module for use by applications.

6.2.3 Middleware

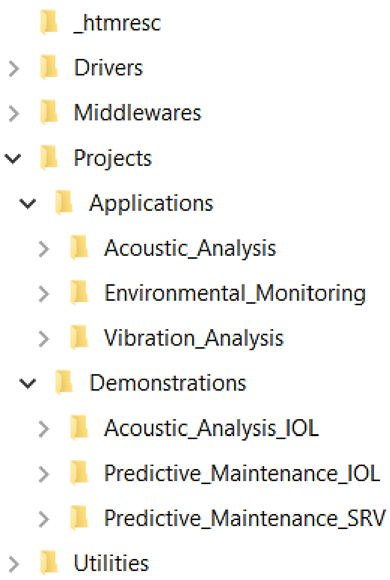
The Middleware folder contains four libraries that give higher level applications access to APIs for:

- Acoustic (STM32_Audio, STM32_AcousticDB_Library),
- Motion signal processing analysis (STM32_MotionSP_Library),
- IO-Link device stack protocol (coming from a third party and released in library format).

6.2.4 Projects

The Projects directory contains several user projects under Applications and Demonstrations subfolders.

Figure 27. **Projects folders**



All the projects are available for the following integrated development environments (IDE):

- IAR Embedded Workbench® for ARM® (EWARM) by IAR systems®
- Microcontroller Development Kit for ARM® (MDK-ARM) by Keil®
- System Workbench for STM32 (SW4STM32) by AC6 (free IDE)

6.2.4.1 *Standard files for all projects*

The standard STM32Cube application files have the same configuration as any standard example using the STM32 HAL libraries, plus the peripherals used for demonstration purposes in the following files:

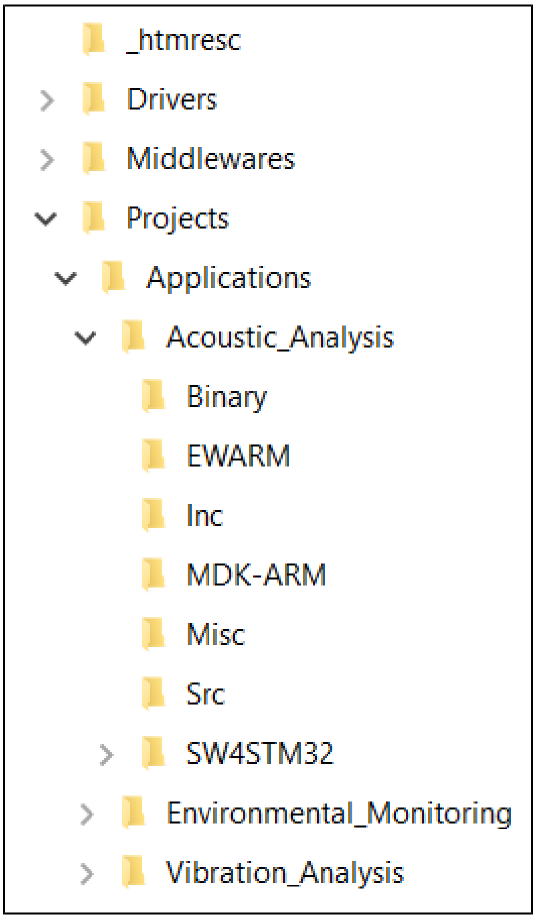
- main.c: APIs for system clock configuration and all the standard include files for the other APIs defined in HAL libraries, BSP and Middleware.
- stm32f4xx_hal_msp.c: APIs for application-level peripheral initialization.
- stm32f4xx_hal_it.c: APIs for all interrupt handlers.
- TargetPlatform.c: APIs available for any project to configure all the required peripherals and features.

6.2.4.2 *Applications folder*

The Applications folder includes separate projects and reference firmware to monitor (through serial communication via the STEVAL-UKI001V2) the following types of data from the STEVAL-IDP005V2:

1. Vibration data: with vibration analysis based on accelerometer data for diagnostic purposes.
2. Audio data: retrieves sound data such as sound pressure level and sound power spectrum.
3. Environmental data: retrieves environmental data such as humidity, temperature and pressure.

Figure 28. **Application folders for Acoustic Analysis**

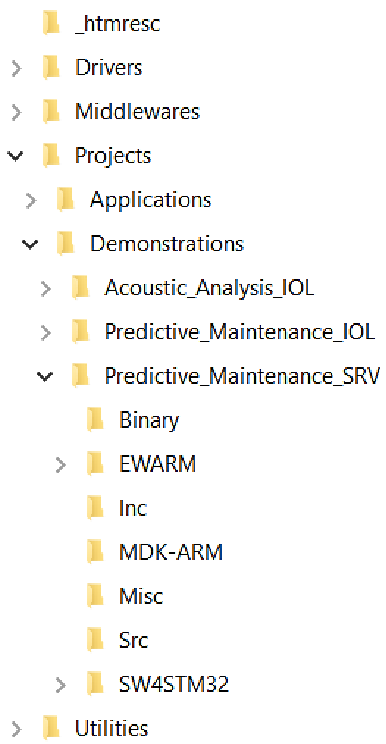


6.2.4.3 *Demonstrations folders*

The Demonstrations folder includes projects for the STEVAL-IDP005V2:

- Predictive Maintenance:
  - with serial communication via UART through the STEVAL-UKI001V2
  - with IO-Link protocol communication through a master tool
- Acoustic Analysis:
  - with IO-Link protocol communication through a master tool

Figure 29. **Demonstrations folder example (Predictive Maintenance SRV)**



The Predictive Maintenance project is used to analyze vibration data against threshold parameters for the same measurement datatype evaluated. The project includes an algorithm to determine status information with respect to time and frequency domain parameters.

Two different approaches for Predictive Maintenance are available to retrieve and analyze sensor data for equipment status evaluation:

1. The Predictive_Maintenance_SRV project uses standard communication with a PC via the STEVAL-UKI001V2 connected to STLINK-V3MINI
2. The Predictive_Maintenance_IOL project uses the IO-Link communication PHY, interfacing the STEVAL-IDP005V2 with the STEVAL-IDP004V2 master board that sending the received data via a USB (or RS485-USB adapter) to a PC.

RELATED LINKS

5.1 Connection through an STLINK-V3MINI on page 16
5.2 Connection through an IO-LINK master tool on page 17
9 Graphical user interface overview on page 45

6.2.4.3.1 Application-specific files for standard communication

The application-specific APIs for the Predictive_Maintenance_SRV project are found in the following files:

- main.c
  – APIs for sending the application information to the terminal screen (via Service UART)
  – APIs for sensor initialization (accelerometer, humidity, pressure and temperature)
  – APIs for sensor measurement (accelerometer, humidity, pressure and temperature)
  – APIs for external memory Init (EEPROM)
  – APIs for accelerometer parameters that can be configured by the user, and accelerometer INT management
  – APIs for time domain and frequency domain analyses

- data_communication_srv.c: APIs to run the CLI configuration command and to monitor requested processing outputs.
- MotionSP_Manager.c: to interface with middleware functionality.

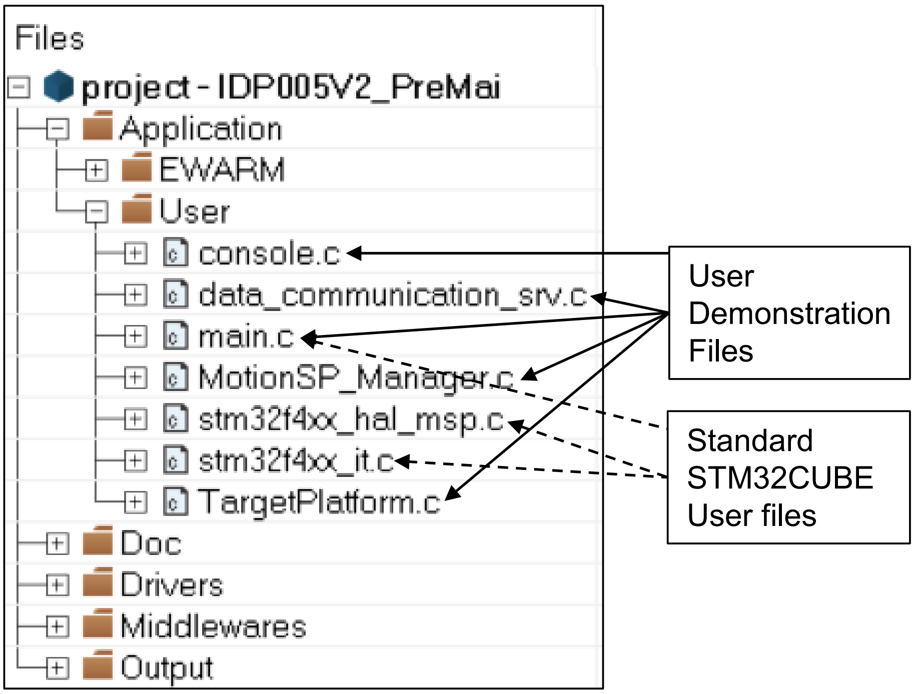


Figure 30. User files for Predictive_Maintenance_SRV project

6.2.4.3.2 Application-specific files for IO-Link communication

The application-specific APIs for the Predictive Maintenance_IOL project are found in the following files:

- main.c
  – APIs for the standard application running (Clock configuration, GPIO callback and IO-Link stack register callback)
- data_communication_srv.c and console.c:
  – APIs designed to send some information about the application status using the SRV UART when all the debugging toolchain is connected.
- MotionSP_Manager.c and MotionSP_Thresholds.h:
  – APIs to use all the middleware functionalities, also for IO-Link stack purpose.
  – Default initialization for the thresholds using some structure with constant value.
- application.c and audio_application.c
  – APIs to interface and adapt all the features in the IO_link device stack library for execution in main. These APIs develop customized structures to send sensor and processing datatypes via the process data.
  – APIs for IO-Link device stack initialization
  – APIs for sensor measurement insertion inside the IO-Link buffer to send
  – APIs for insertion of time and frequency domain results in the IO-Link buffer to be sent
- app_blob_transfer.c:
  – APIs to use the BLOB transmission method.
- iold_app_callbacks.c
  – APIs to control via callbacks, all the write and read operation done using the IO-Link device stack.
- eventhandler.c
  – APIs to configure all the events to send to the master.

- eepromhandler.c, nvmhandler.c
  - APIs for memory management.

The SRC/hsal folder contains specific files released by the stack provider to allow appropriate interfacing of all the device stack features included in the medium level middleware APIs.

7 How to run projects via Service UART

Perform the following steps for any of the projects available for Service UART:

Step 1. Connect the STEVAL-IDP005V2 to the STLINK-V3MINI

Step 2. Power on the STEVAL-IDP005V2

Step 3. Connect the STLINK-V3MINI to a USB PC and download the dedicated firmware.

Step 4. Run a terminal emulator like TeraTerm on your PC.
Be sure to use the correct COM port and UART parameters: 921600/8-N-1 for acoustic project and 230400/8-N-1 for the other example projects. You can find the TeraTerm configuration file in the MISC project folder.

Step 5. Press the reset button to restart the application.

7.1 Outputs for the acoustic analysis project

Figure 31. Terminal emulator screenshot for acoustic analysis firmware

```
UART Initialized

STMicroelectronics STEVAL-BFA001V2
        Board - STEVAL-IDP005V2
        Application - Acoustic Analysis
        Version 1.0.0

STM32F4xx Libraries & IDE informations:
        (HAL 1.7.6_0)
        Compiled Oct 16 2019 16:12:06 (IAR)

MCU informations
        MCU Dev. ID      : 0x434
        MCU Rev. ID      : 0x1000
        MCU unique ID    : 0x393735303136510300lF0037
        MCU Flash Size   : 2048 Kbytes
        MCU SYSCLK       : 180.00 MHz
        MCU HCLK         : 180.00 MHz
        MCU PCLK1        : 45.00 MHz
        MCU PCLK2        : 90.00 MHz

Starting project ...

        ACOUSTIC
        ANALYSIS

RTC Initialization
        16 Oct 2019 16:12:06

Microphone Initialization:
        Initialized audio status
        Initialized audio devices
        Initialized audio application
        Started microphone acquisition

        Audio Sampling Frequency       : 16000 Hz
        FFT size                       : 1024
        FFT bin width                  : 15.625 Hz
        FFT windowing                  : HANNING
        Audio Power Spectrum Update Time: 1500 ms

        +-----------+----------------+-----------------------------------------------------------------+
        |           | Sound Pressure | Audio Power Spectrum (Max Power)                                |
        +-----------+----------------+-------------+---------------+---------------------------------------+
        | IMP34DT05 |     52 dB(SPL) | 7500.000 Hz |  -35.47 dB(FS) | ---------------------------------    |
        +-----------+----------------+-------------+---------------+---------------------------------------+
```

The log file from the terminal emulator stores the following information:

- the measured sound pressure and its acquisition time
- the measured average power spectrum with its peak and its acquisition time.

Figure 32. Acoustic analysis terminal emulator log file

```
àUART Initialized

STMicroelectronics STEVAL-BFA001V2
        Board - STEVAL-IDP005V2
        Application - Acoustic Analysis
        Version 1.0.0

STM32F4xx Libraries & IDE informations:
        (HAL 1.7.6_0)
        Compiled Oct 16 2019 14:47:27 (IAR)

MCU informations
        MCU Dev. ID      : 0x434
        MCU Rev. ID      : 0x1000
        MCU unique ID    : 0x393735303136510300 1F0037
        MCU Flash Size   : 2048 Kbytes
        MCU SYSCLK       : 180.00 MHz
        MCU HCLK         : 180.00 MHz
        MCU PCLK1        : 45.00 MHz
        MCU PCLK2        : 90.00 MHz

Starting project ...

RTC Initialization
        16 Oct 2019 14:48:00

Microphone Initialization:
        Initialized audio status
        Initialized audio devices
        Initialized audio application
        Started microphone acquisition
        Audio Sampling Frequency        : 16000 Hz
        FFT size                        : 1024
        FFT bin width                   : 15.625 Hz
        FFT windowing                   : HANNING
        Audio Power Spectrum Update Time: 1500 ms

+-----------+----------------+-------------------------------------
|           | Sound Pressure | Audio Power Spectrum (Max Power)
+-----------+----------------+-------------+----------------+----
| IMP34DT05 |    --- dB(SPL) | -----.--- Hz | ----.-- dB(FS) |
+-----------+----------------+-------------+----------------+----
 48 dB(SPL)
   15.625 Hz |  -51.53 dB(FS) | ---------------------------
   31.250 Hz |  -53.87 dB(FS) | --------------------------
   46.875 Hz |  -56.24 dB(FS) | -------------------------
   62.500 Hz |  -58.18 dB(FS) | -------------------------
   78.125 Hz |  -60.46 dB(FS) | ------------------------
   93.750 Hz |  -60.95 dB(FS) | ------------------------
  109.375 Hz |  -61.73 dB(FS) | -----------------------
  125.000 Hz |  -62.35 dB(FS) | -----------------------
  140.625 Hz |  -63.35 dB(FS) | -----------------------
  156.250 Hz |  -65.71 dB(FS) | ----------------------
  171.875 Hz |  -65.86 dB(FS) | ----------------------
  187.500 Hz |  -65.99 dB(FS) | ----------------------
  203.125 Hz |  -66.93 dB(FS) | ---------------------
  218.750 Hz |  -68.10 dB(FS) | ---------------------
  234.375 Hz |  -68.00 dB(FS) | ---------------------
  250.000 Hz |  -68.05 dB(FS) | ---------------------
```

(omissis)

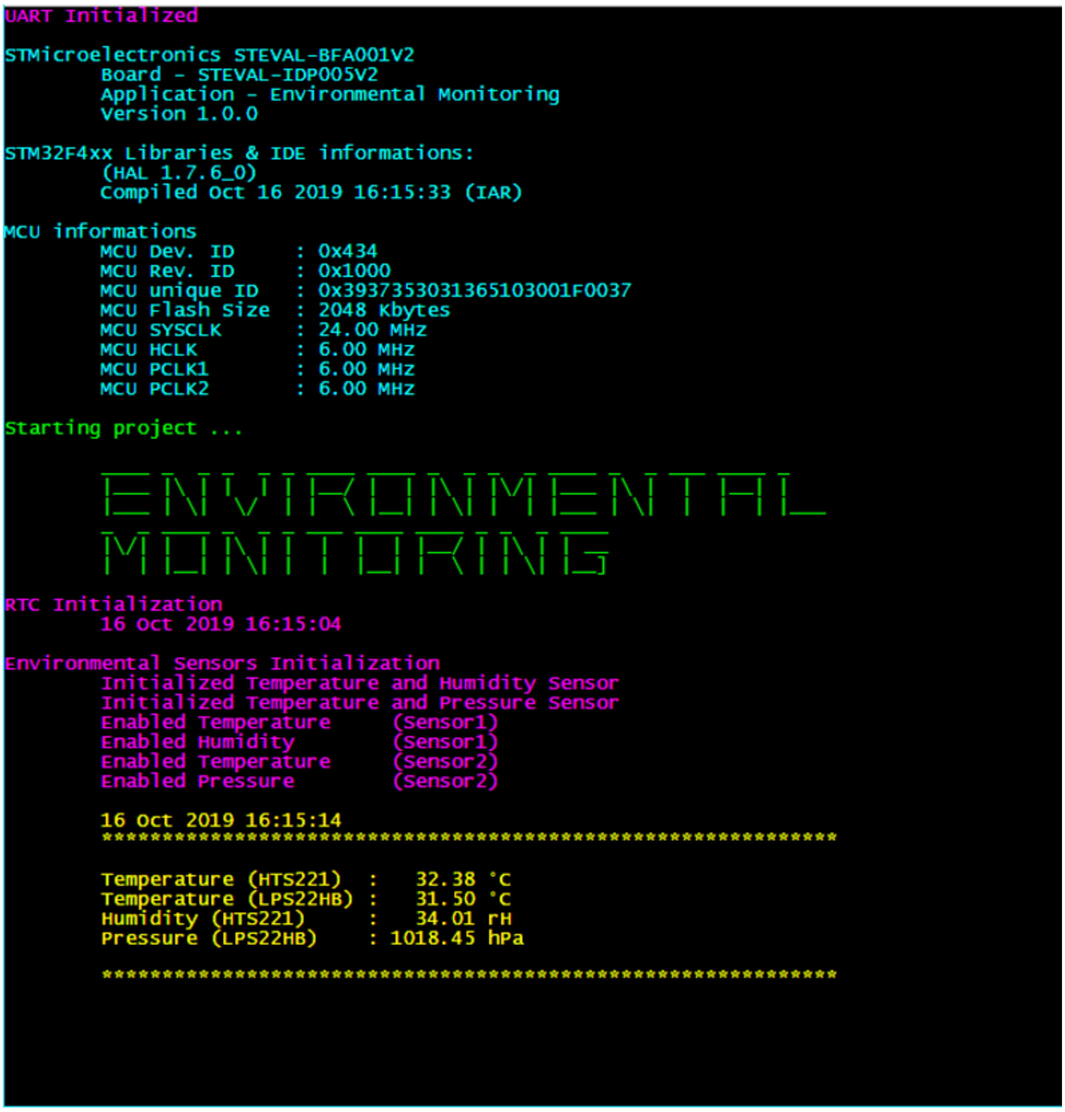
```
  7906.250 Hz | -110.24 dB(FS) | ----
  7921.875 Hz | -106.26 dB(FS) | ------
  7937.500 Hz |  -99.97 dB(FS) | --------
  7953.125 Hz | -101.58 dB(FS) | --------
  7968.750 Hz |  -95.01 dB(FS) | ----------
  7984.375 Hz |  -47.31 dB(FS) | -----------------------------
  7984.375 Hz |  -47.31 dB(FS) | -----------------------------
  51 dB(SPL)
  51 dB(SPL)
  51 dB(SPL)
```

RELATED LINKS

1.3 How to run the demo supplied with the firmware on page 4
5.1 Connection through an STLINK-V3MINI on page 16

7.2 Outputs for the environmental monitoring project

Figure 33. Terminal emulator screenshot while running environmental monitoring firmware



The log file from the terminal emulator stores the following information:

- the measured sound pressure and its acquisition time

Figure 34. Environmental monitoring terminal emulator log file

```
UART Initialized

STMicroelectronics STEVAL-BFA001V2
        Board - STEVAL-IDP005V2
        Application - Environmental Monitoring
        Version 1.0.0

STM32F4xx Libraries & IDE informations:
        (HAL 1.7.6_0)
        Compiled Oct 16 2019 12:38:15 (IAR)

MCU informations
        MCU Dev. ID      : 0x434
        MCU Rev. ID      : 0x1000
        MCU unique ID    : 0x3937353031365103001F0037
        MCU Flash Size   : 2048 Kbytes
        MCU SYSCLK       : 24.00 MHz
        MCU HCLK         : 6.00 MHz
        MCU PCLK1        : 6.00 MHz
        MCU PCLK2        : 6.00 MHz

Starting project ...

RTC Initialization

        Day? (16)
        16 Oct 2019 12:38:15

Environmental Sensors Initialization
        Initialized Temperature and Humidity Sensor
        Initialized Temperature and Pressure Sensor
        Enabled Temperature     (Sensor1)
        Enabled Humidity        (Sensor1)
        Enabled Temperature     (Sensor2)
        Enabled Pressure        (Sensor2)
```

```
16 Oct 2019 12:38:15
**************************************************************

Temperature (HTS221)  :   28.12 °C
Temperature (LPS22HB) :   27.46 °C
Humidity (HTS221)     :   41.41 rH
Pressure (LPS22HB)    : 1018.56 hPa

**************************************************************

16 Oct 2019 12:38:20
**************************************************************

Temperature (HTS221)  :   28.10 °C
Temperature (LPS22HB) :   27.46 °C
Humidity (HTS221)     :   41.57 rH
Pressure (LPS22HB)    : 1018.81 hPa

**************************************************************

16 Oct 2019 12:38:25
**************************************************************

Temperature (HTS221)  :   28.06 °C
Temperature (LPS22HB) :   27.47 °C
Humidity (HTS221)     :   41.56 rH
Pressure (LPS22HB)    : 1018.80 hPa

**************************************************************
```

7.3 Outputs for the vibration analysis project

Figure 35. **Terminal emulator screenshot while running vibration analysis firmware**

The bottom part of the screen lists the stored parameters for the analysis and prompts you to change some of these parameters. Press [**y**] to change parameters you want and [**Enter**] to scroll the parameters.

The configurable parameters are:

FS

The configurable values are: 2, 4 (default), 8, 16. See IIS3DWB datasheet for further details.

hpf

Cutoff frequency for internal hardware High Pass Filter (HPF) as per the following table:

Table 2. **HPF configuration**

HPF configuration	Cutoff frequency selected
4	ODR/4
10	ODR/10
20	ODR/20
45	ODR/45
100	ODR/100
200	ODR/200
400	ODR/400
800	ODR/800

FFT in size

FFT input array accelerometer size: 256, 512, 1024, or 2048 (default)

FFT OVL

Overlapping between the following FFT input array in percentage; use a value between 5% and 95% (75% default)

FFT window

Filter windowing type; choose from:
- 0 - Rectangular
- 1 - Hanning (default)
- 2 - Hamming
- 3 - Flat Top

Acq. time

Total acquisition time (in ms) to evaluate all the parameters for the time domain and frequency domain analysis in the same time.

RMS tau

Time parameter to include for the moving root mean square (RMS) evaluation (for speed and/or acceleration); choose a value from: 25, 50, 100, 150, 250, 500 (default), 1000, 1500 and 2000.

subrng

This parameter is available only in predictive maintenance project. Subrange FFT numbers to evaluate the frequency domain analysis results in each subrange frequency sector; choose a value from 8, 16 (default), 32, or 64 (this parameter is used by the condition monitoring project.

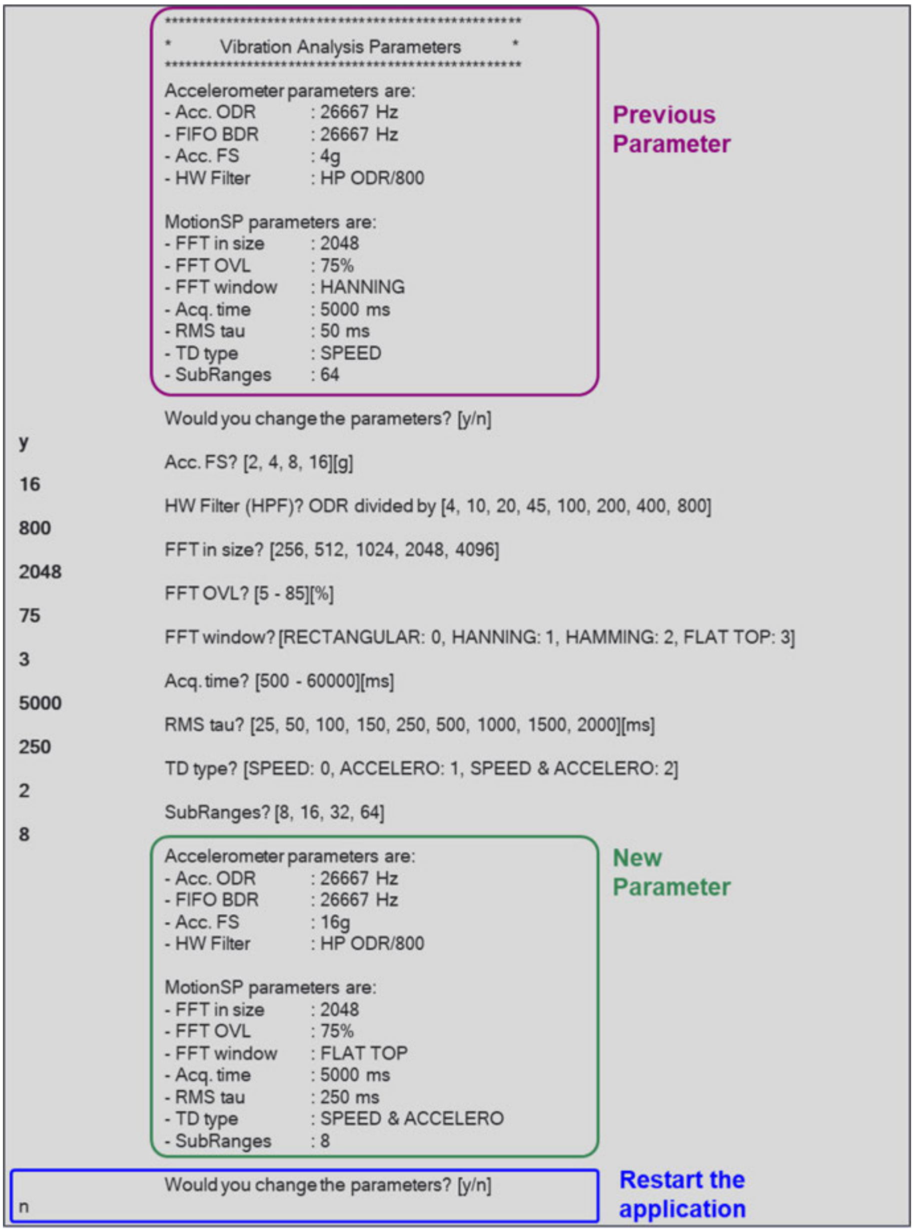
tdtype

Time domain datatype format:
- 0 - Speed RMS only (default)
- 1 - Acceleration RMS only
- 2 - Speed RMS and Acceleration RMS

Once you have inserted the new parameters, the command line interface prompts you to type [**y**] and press [**Enter**] to confirm the new values.

Pay attention to every parameter inserted via user terminal: ensure it overwrites the previous line in the window, so the next figure is simply a summary obtained through the "log" functionality.

Figure 36. Default parameter list and starting point



After the parameter setting phase, all the configurations are initiated and checked, and some information is also returned about the MotionSP algorithm that is about to be launched.

Figure 37. **MotionSP Initialization**

```
***************************************************
*         Vibration Analysis Parameters           *
***************************************************

Accelerometer parameters are:
- Acc. ODR        : 26667 Hz
- FIFO ODR        : 26667 Hz
- Acc. FS         : 2g
- HW Filter       : HP ODR/800

MotionSP parameters are:
- FFT in size     : 1024
- FFT OVL         : 75%
- FFT window      : HANNING
- Acq. time       : 5000 ms
- RMS tau         : 50 ms
- TD type         : SPEED

The measured accelerometer ODR is 26758 Hz

Wait while acquisition ongoing for 5.00 s ...
```

The terminal emulator shows the following information:

- Time domain analysis X-Y-Z arrays according to the tdtype and tacq (timing window) parameters, transmitting the data every 5 ms. The figure below lists the following information:
  - the real ODR evaluated by the algorithm in order to have a more accurate value for the FFT arrays;
  - the time domain datalog with the timestamp in the first column, and the X-Y-Z value chosen, in order to plot the RMS speed trend in mm/s.

Figure 38. **Time domain data**

```
The measured accelerometer ODR is 26758 Hz

Wait while acquisition ongoing for 5.00 s ...

|     *** Time Domain Data ***          |
| t [ms] |      Speed RMS [mm/s]        |
|        |    X    |    Y    |    Z    |
|   64530|   0.000|   0.000|   0.000|
|   64535|   0.000|   0.000|   0.000|
|   64541|   0.000|   0.000|   0.000|
|   64549|   0.013|   0.013|   0.037|
|   64557|   0.013|   0.014|   0.032|
|   64564|   0.013|   0.014|   0.032|
|   64572|   0.013|   0.020|   0.027|
|   64582|   0.012|   0.020|   0.027|
|   64589|   0.012|   0.020|   0.027|
|   64594|   0.012|   0.020|   0.027|
|   64599|   0.011|   0.019|   0.033|
|   64605|   0.012|   0.020|   0.034|
|   64610|   0.012|   0.019|   0.033|
|   64620|   0.012|   0.019|   0.034|
|   64627|   0.012|   0.018|   0.035|
|   64635|   0.012|   0.017|   0.034|
|   64640|   0.012|   0.017|   0.034|
|   64648|   0.011|   0.016|   0.031|
```

- Frequency Domain X-Y-Z arrays according to the parameter settings for the configured timing window (tacq) as well as the bin frequency information. The output shows the acceleration power spectrum in m/s².

Figure 39. Frequency domain data

```
|     *** FFT Spectral Analysis ***      |
|bin Freq|       Amplitude [m/s2]        |
|  [Hz]  |    X     |    Y     |    Z     |
|    0.00|  0.000|  0.000|  0.000|
|   26.13|  0.004|  0.005|  0.007|
|   52.26|  0.005|  0.010|  0.019|
|   78.39|  0.006|  0.014|  0.027|
|  104.52|  0.006|  0.008|  0.013|
|  130.65|  0.006|  0.005|  0.009|
|  156.79|  0.006|  0.005|  0.009|
|  182.92|  0.006|  0.005|  0.009|
|  209.05|  0.005|  0.005|  0.009|
|  235.18|  0.005|  0.005|  0.008|
|  261.31|  0.005|  0.005|  0.008|
|  287.44|  0.006|  0.005|  0.008|
|  313.57|  0.005|  0.005|  0.008|
|  339.70|  0.006|  0.005|  0.009|
|  365.83|  0.006|  0.005|  0.009|
|  391.96|  0.006|  0.005|  0.008|
|  418.09|  0.006|  0.005|  0.009|
|  444.22|  0.006|  0.005|  0.009|
|  470.36|  0.006|  0.005|  0.009|
|  496.49|  0.006|  0.005|  0.008|
|  522.62|  0.005|  0.005|  0.008|
|  548.75|  0.006|  0.005|  0.008|
|  574.88|  0.006|  0.005|  0.008|
|  601.01|  0.007|  0.005|  0.008|
|  627.14|  0.007|  0.005|  0.008|
|  653.27|  0.006|  0.005|  0.008|
|  679.40|  0.006|  0.005|  0.009|
|  705.53|  0.006|  0.005|  0.008|
|  731.66|  0.006|  0.005|  0.008|
```

- Frequency Domain final results, including the average number of FFTs used during processing.

Figure 40. FFT results

```
*** Frequency domain results ***

  FFT average for X axis has been performed on 519 items
  FFT average for Y axis has been performed on 519 items
  FFT average for Z axis has been performed on 519 items

  FFT max amplitude on X axis was    0.011 m/s2 @ 12804.12 Hz
  FFT max amplitude on Y axis was    0.014 m/s2 @    78.39 Hz
  FFT max amplitude on Z axis was    0.027 m/s2 @    78.39 Hz
```

- The maximum X-Y-Z acceleration peak.

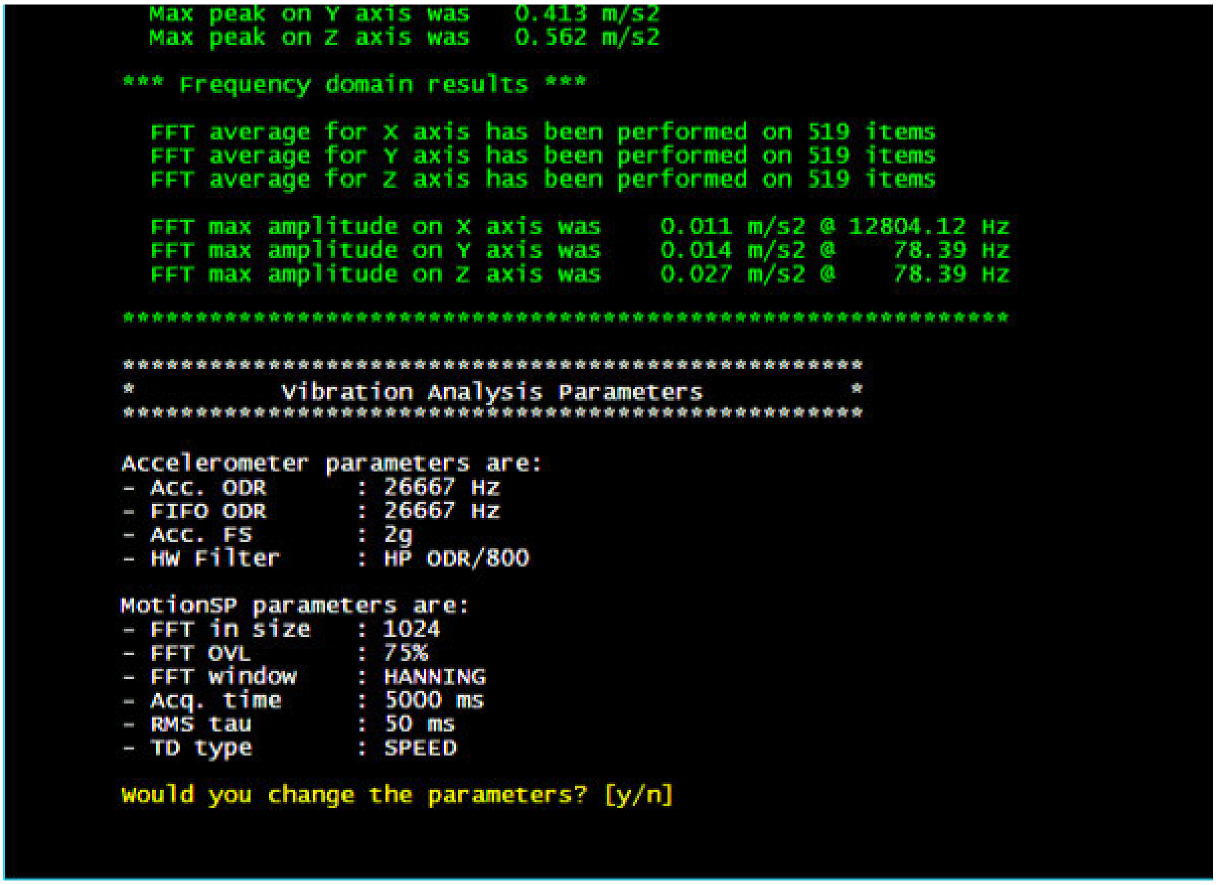
Figure 41. Maximum X-Y-Z acceleration peak

```
*** Time domain results ***

  Max peak on X axis was   0.483 m/s2
  Max peak on Y axis was   0.413 m/s2
  Max peak on Z axis was   0.562 m/s2
```

- The final step lets you change some parameters again and run a new analysis.

Figure 42. Summary window



7.4 Predictive Maintenance via Service UART

The Predictive Maintenance demonstration project is based on continuous comparison of vibration data with configurable threshold values, which may be provided by the machinery manufacturer. The aim is to monitor potentially damaging conditions that cannot be identified in conventional scheduled maintenance.

The sensor node firmware lets you modify time domain and frequency domain threshold parameters:

- Time domain thresholds with three different warning thresholds and three different alarm thresholds (one for each axes) to continuously compare against the following processed data:
  - Speed RMS
  - Acceleration Peak
- Frequency domain thresholds with warning and alarm thresholds for all the subranges. The thresholds can be changed using the MotionSP_thresholds.h configuration file.

Running this demonstration project, after a board reset, the terminal emulator shows the following information:

Figure 43. **Predictive Maintenance header log**

```
UART Initialized

STMicroelectronics STEVAL-BFA001V2
        Board - STEVAL-IDP005V2
        Demonstration - Predictive Maintenance
        Version 1.0.0

STM32F4xx Libraries & IDE informations:
        (HAL 1.7.6_0)
        Compiled Oct 18 2019 15:11:28 (IAR)

MCU informations
        MCU Dev. ID      : 0x434
        MCU Rev. ID      : 0x1000
        MCU unique ID    : 0x393735303136510300 1F0037
        MCU Flash Size   : 2048 Kbytes
        MCU SYSCLK       : 180.00 MHz
        MCU HCLK         : 180.00 MHz
        MCU PCLK1        : 45.00 MHz
        MCU PCLK2        : 90.00 MHz

Starting project ...

        PREDICTIVE
        MAINTENANCE

Environmental Sensors Initialization
        Initialized Temperature and Humidity Sensor
        Initialized Temperature and Pressure Sensor
        Enabled Temperature     (Sensor1)
        Enabled Humidity        (Sensor1)
        Enabled Temperature     (Sensor2)
        Enabled Pressure        (Sensor2)

MotionSP Initialization
        Initialized Acceleration Sensor
        Enabled Acceleration Sensor
        Vibration parameters have been set as default values
```

Typing [**y**] or [**n**] for the prompt on the terminal to change parameters allows you to to confirm or change each configuration parameter, as explained in the following figure.

Figure 44. **Sensor node parameter setting and configuration**

```
        ****************************************************
        *          Vibration Analysis Parameters           *
        ****************************************************

        Accelerometer parameters are:
        - Acc. ODR        : 26667 Hz
        - FIFO ODR        : 26667 Hz
        - Acc. FS         : 4g
        - HW Filter       : HP ODR/800

        MotionSP parameters are:
        - FFT in size     : 2048
        - FFT OVL         : 75%
        - FFT window      : HANNING
        - Acq. time       : 5000 ms
        - RMS tau         : 50 ms
        - TD type         : SPEED
        - SubRanges       : 8

        Would you change the parameters? [y/n]
```

The new parameters written by the user terminal are now fixed and ready to use by the library, which configures everything before starting the application, measuring time domain (1st array) and frequency domain (2nd array).

Figure 45. STEVAL-BFA001V2 parameter overview and analysis with time domain array

1. MotionSP parameter overview
2. Analysis start with time domain array

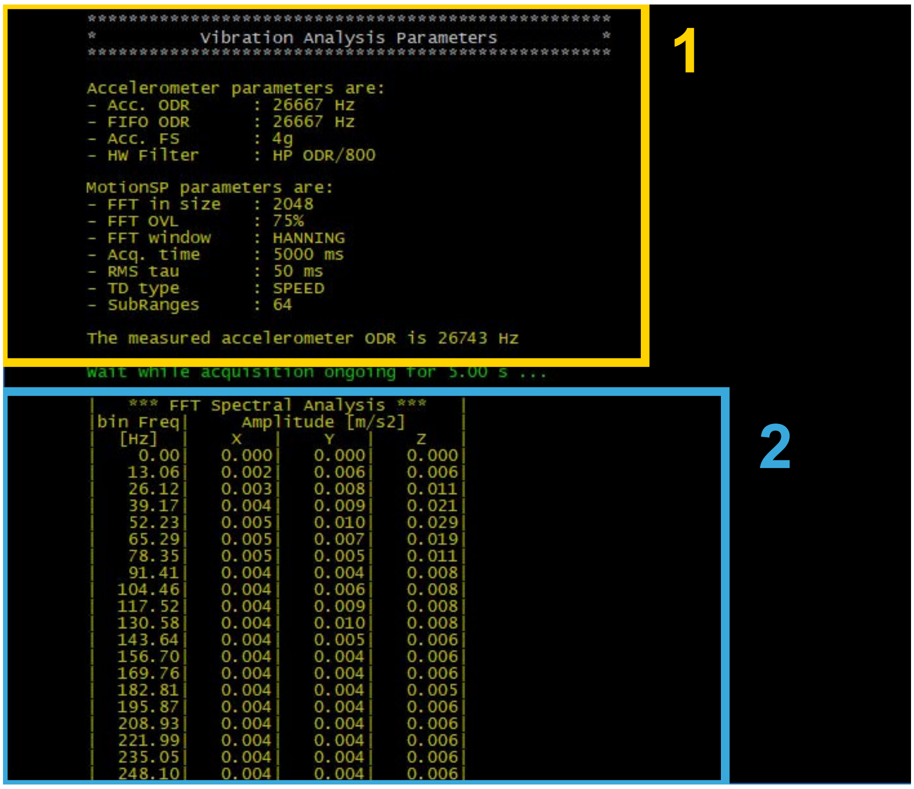
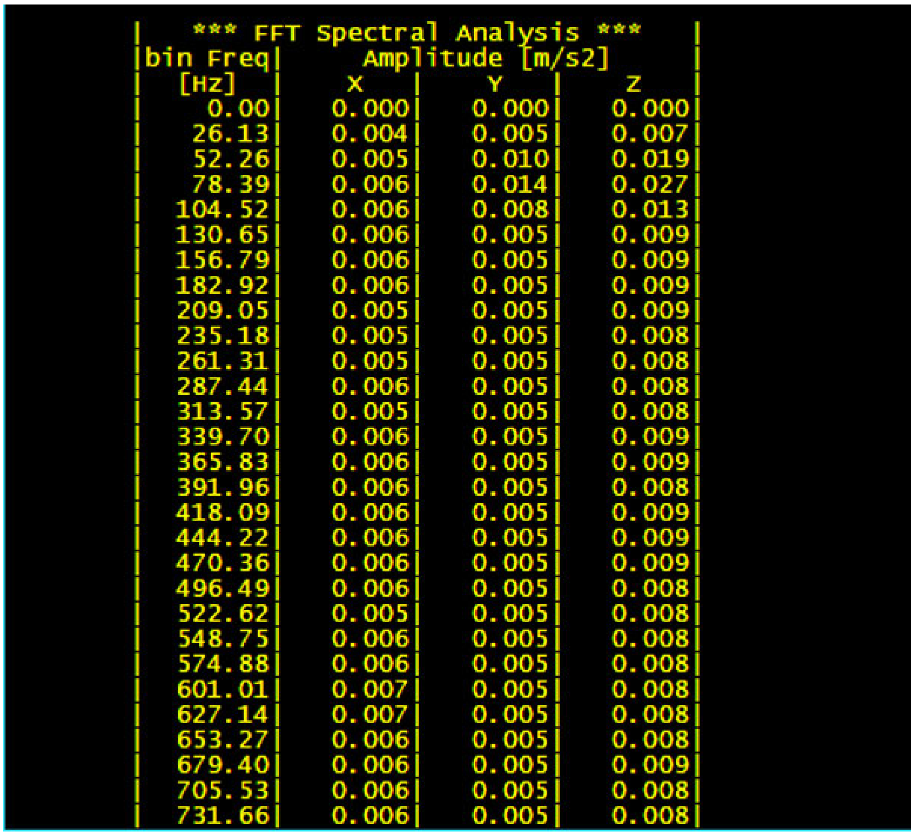


Figure 46. **STEVAL-BFA001V2 2nd analysis with frequency domain array**



*** FFT Spectral Analysis ***

bin Freq [Hz]	Amplitude [m/s2] X	Y	Z
0.00	0.000	0.000	0.000
26.13	0.004	0.005	0.007
52.26	0.005	0.010	0.019
78.39	0.006	0.014	0.027
104.52	0.006	0.008	0.013
130.65	0.006	0.005	0.009
156.79	0.006	0.005	0.009
182.92	0.006	0.005	0.009
209.05	0.005	0.005	0.009
235.18	0.005	0.005	0.008
261.31	0.005	0.005	0.008
287.44	0.006	0.005	0.008
313.57	0.005	0.005	0.008
339.70	0.006	0.005	0.009
365.83	0.006	0.005	0.009
391.96	0.006	0.005	0.008
418.09	0.006	0.005	0.009
444.22	0.006	0.005	0.009
470.36	0.006	0.005	0.009
496.49	0.006	0.005	0.008
522.62	0.005	0.005	0.008
548.75	0.006	0.005	0.008
574.88	0.006	0.005	0.008
601.01	0.007	0.005	0.008
627.14	0.007	0.005	0.008
653.27	0.006	0.005	0.008
679.40	0.006	0.005	0.009
705.53	0.006	0.005	0.008
731.66	0.006	0.005	0.008

The analysis results shown for this application are:

- Time domain values plus its threshold status about speed RMS and acceleration peak
- Frequency domain values about the FFT average numbers and the absolute maximum values detected in the whole power spectrum
- Frequency domain threshold status for each subrange analyzed
- General status for time and frequency domain

Figure 47. **STEVAL-BFA001V2 time domain predictive maintenance results**

1. FFT arrays
2. Time domain results and threshold status
3. FFT average numbers and results: max. amplitude per frequency

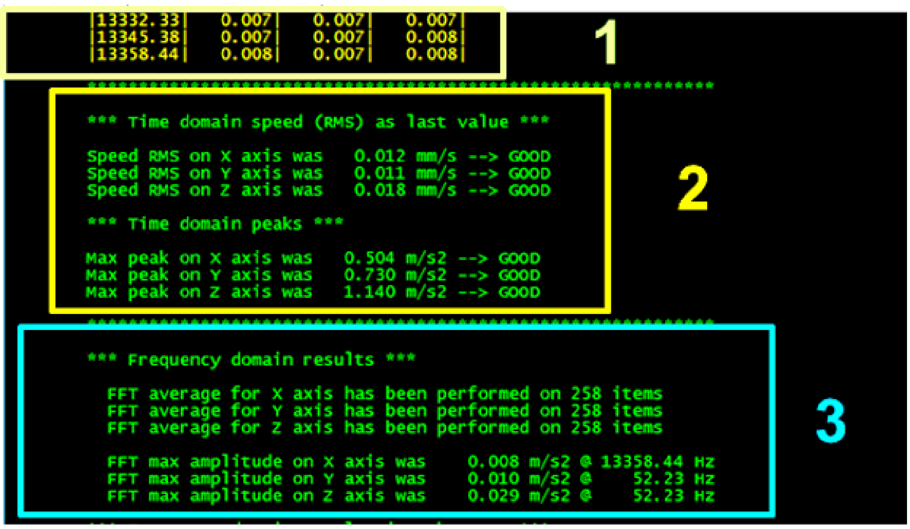
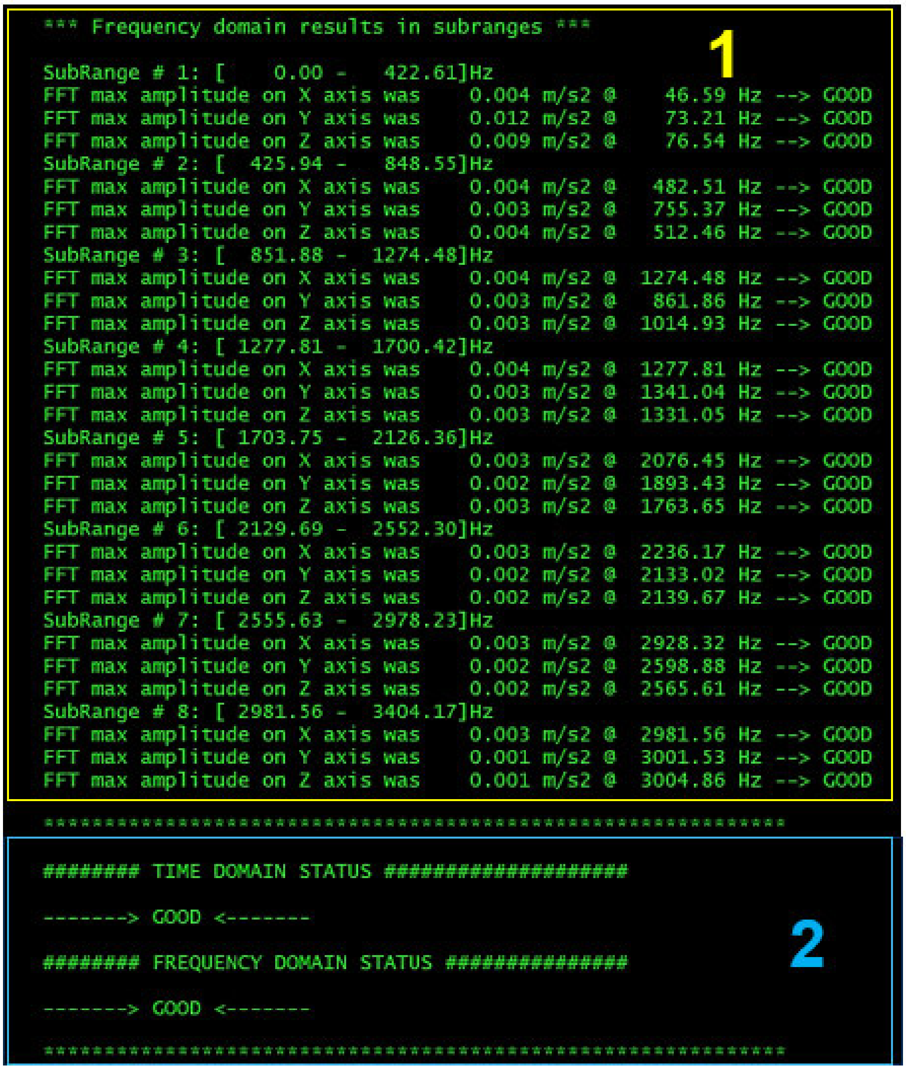


Figure 48. **STEVAL-BFA001V2 frequency domain subrange status and all status results**

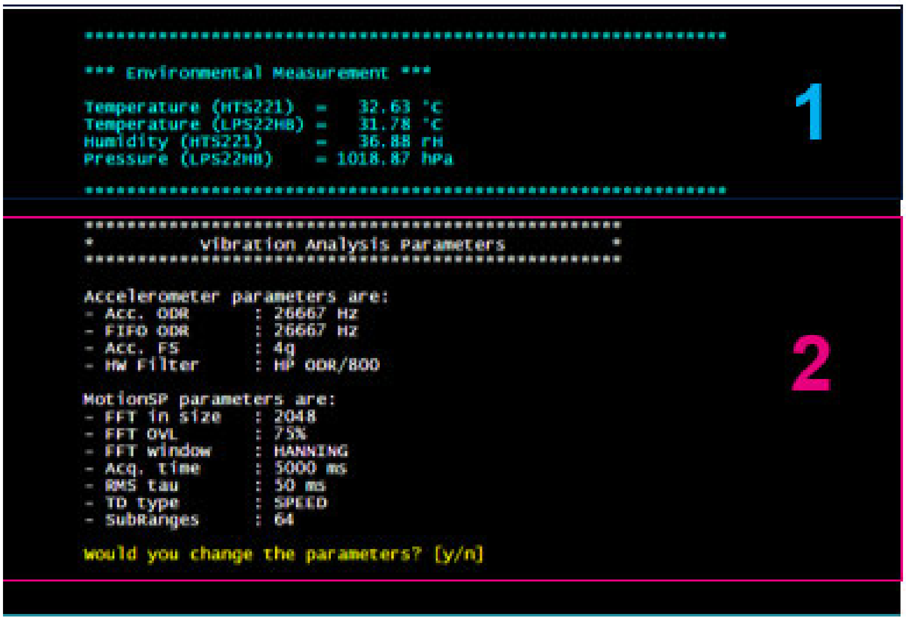
1. FFT subrange analysis, max. amplitude per frequency status
2. Time domain and frequency domain: all threshold status



The figure below shows the environmental measurements and parameters already configured with the opportunity of changing them before starting next analysis.

Figure 49. **STEVAL-BFA001V2 environmental measurement and parameter list**

1. Environmental measurements
2. Parameter overview for next analysis



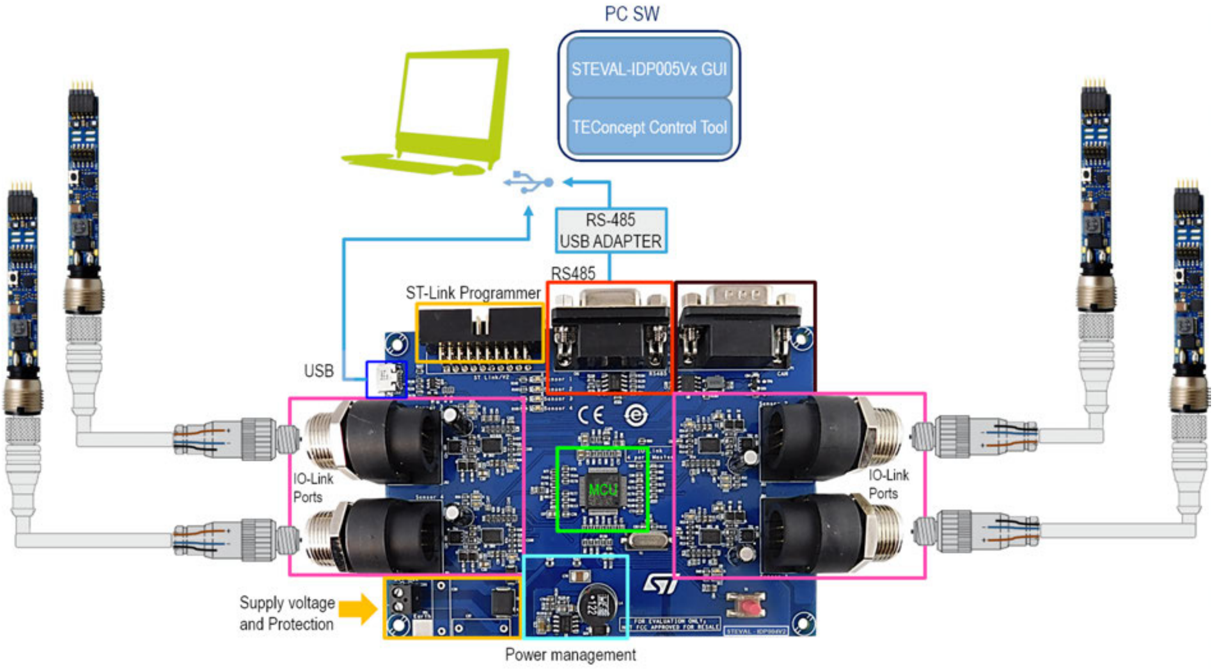
8 Projects with IO-Link

The STEVAL-IDP005V2 is able to communicate through its embedded IO-Link PHY device several data, using receive and transmit data and commands to and from any master tool.

The example provided here describes the interoperability between STEVAL-IDP005V2 and the STEVAL-IDP004V2 master board based on the IO-Link PHY master.

In the firmware package, there are two demonstration projects for gathering Predictive Maintenance and acoustic analyses data via IO-Link communication. Both projects require dedicated software installed on the PC to manage the master main functions and its communication with all the devices already connected via IO-Link wiring, as shown in the picture below.

Figure 50. IO-Link System setup with PC communication



The project example in the `STSW-BFA001V2\Projects\Demonstrations\Predictive_Maintenance_IOL` folder lets you run a dedicated demo which transmits and receives data via IO-Link, configuration parameters and specific events according to the analysis performed in the device.

Note: The embedded IO-LINK device stack is a time limited version for evaluation purposes, so after a fixed time you need to reset the hardware to restart the application.

RELATED LINKS

5.1 Connection through an STLINK-V3MINI on page 16
5.2 Connection through an IO-LINK master tool on page 17
9 Graphical user interface overview on page 45

8.1 How to run projects via IO-Link

Follow the steps described below, to run the application with IO-Link:

Step 1. Connect the STEVAL-IDP005V2 to the STEVAL-IDP004V2 (or other Master board with IO-Link stack embedded) using a standard 4- wire cable with M12 A-coded 4-pin connectors, male on one end and female on the other.

Step 2. Connect the STEVAL-IDP004V2 to the PC using a micro USB cable or a RS485-USB adapter.

Step 3. Connect the master board to the power supply

VIN = 20 to 32 V

Step 4. Install the SW tool that support the Master connection (STEVAL-IDP005Vx GUI, IO-Link Control Tool).

Step 5. After the installation, run the GUI and connect the Master board selecting the right COM port.

Step 6. Select the right device port with STEVAL-IDP005V2 wire connected, and switch on the device by pressing the power on button.

Step 7. Connect the STEVAL-IDP005V2 to the STLINK-V3MINI with STEVAL-UKI001V2 and update the firmware.

Use the binary file in `STSW-BFA001V2\Projects\Demonstrations\Predictive_Maintenance_IOL\Binary`

Step 8. Disconnect the assembly tool used for the firmware update, but leave the boards with IO-Link cable connected.

Step 9. Leave the Master board connected via USB cable (or RS-485/USB adapter) to your PC.

Step 10. Use the GUI to run an IO-Link application gather data and familiarize yourself with the the IO-Link features implemented in the projects.

RELATED LINKS

5.1 Connection through an STLINK-V3MINI on page 16
5.2 Connection through an IO-LINK master tool on page 17
9 Graphical user interface overview on page 45

9 Graphical user interface overview

The Predictive Maintenance project over IO-Link can be displayed using any IO-LINK master PC software tool, including the following GUI software packages:

- STEVAL-IDP005Vx GUI v2.0.0 released by ST: located in STSW-BFA001V2/Utilities.
- IO-Link Control Tool (CT) v3.9 released by TEConcept: located in STSW-BFA001V2/Utilities.

The tool is designed to help you set up an IO-Link project and facilitate command and data exchange between PC, STEVAL-IDP004V2 master board, and STEVAL-IDP005V2 sensor node. The tool provides the following features:

- Continuous data streaming from device to master, including environmental sensors measurements and post processing by MotionSP middleware related to time and frequency domain analysis
- MotionSP parameters values updating from master to device
- Time and frequency domain threshold values updating from master to device
- Post processing comparison data for time and frequency domain analysis, visible as event generated from device to the master.

Each control command sent by a GUI is managed by the master and sent to the device as an IO-Link message with information like data, parameters, or a larger data fragment (BLOB transmission frames).

When the sensor node receives a message from the master, it sends a response back to the master according to the IO-Link stack protocol, which is then sent re-directed to the GUI.

RELATED LINKS

5.2 Connection through an IO-LINK master tool on page 17
6.2.4.3 Demonstrations folders on page 23
8 Projects with IO-Link on page 43
8.1 How to run projects via IO-Link on page 43

9.1 How to run the STEVAL-IDP005Vx GUI

Before using the software, connect your PC the STEVAL-IDP004V2 or the P-NUCLEO-IOM01M1 via USB or RS485/USB adapter cable, and power supply the STEVAL-IDP004V2 such as already described.

This SW GUI is able to demonstrate the features of the IO-Link stack in reading and logging mode from the master/device system, without performing any control or action in writing mode.

When the application is running, you can monitor the data sent cyclically by the IO-Link stack in the [**Vibration Analysis**] and [**ENV Measurements**] pages, plus the stack event and status messages in the [**Flow Comm**] page, but you cannot change specific firmware parameters or threshold configurations.

The software can support both the projects available for predictive maintenance and acoustic analysis data communication over an IO-Link fieldbus.

Step 1. Run the GUI to open the main screen.

Figure 51. **Start GUI and insert Communication settings**

Step 2. Set PC-Master Board communication parameters:
- Name: COM Port name
- Baud Rate: 230400 Baud
- Data: 8
- Parity: None
- Stop Bit: One
- Flow Control: None

Step 3. Click the [**Connect**] button, and then select one of the [**Sensor [1-4]**] buttons for one or more sensor nodes connected to corresponding master board channels.

During this connection phase, the SW performs the following actions on the master and for each selected sensor node:

a. Programs the master ICs on the corresponding port to connect using the default configuration.

b. Powers on the device connected to the same port; its status is confirmed by a dedicated LED on the STEVAL-IDP004V2.

c. Starts the IO-Link connection, providing feedback on its status using another dedicated LED that blinks until the connection is established by the stack, after which then remains on. On successful connection, the corresponding button on the GUI changes color.

d. Starts the application and immediately sends data to the application pages, while the information regarding master - device stack communication is available in the [**Flow Comm**] page.

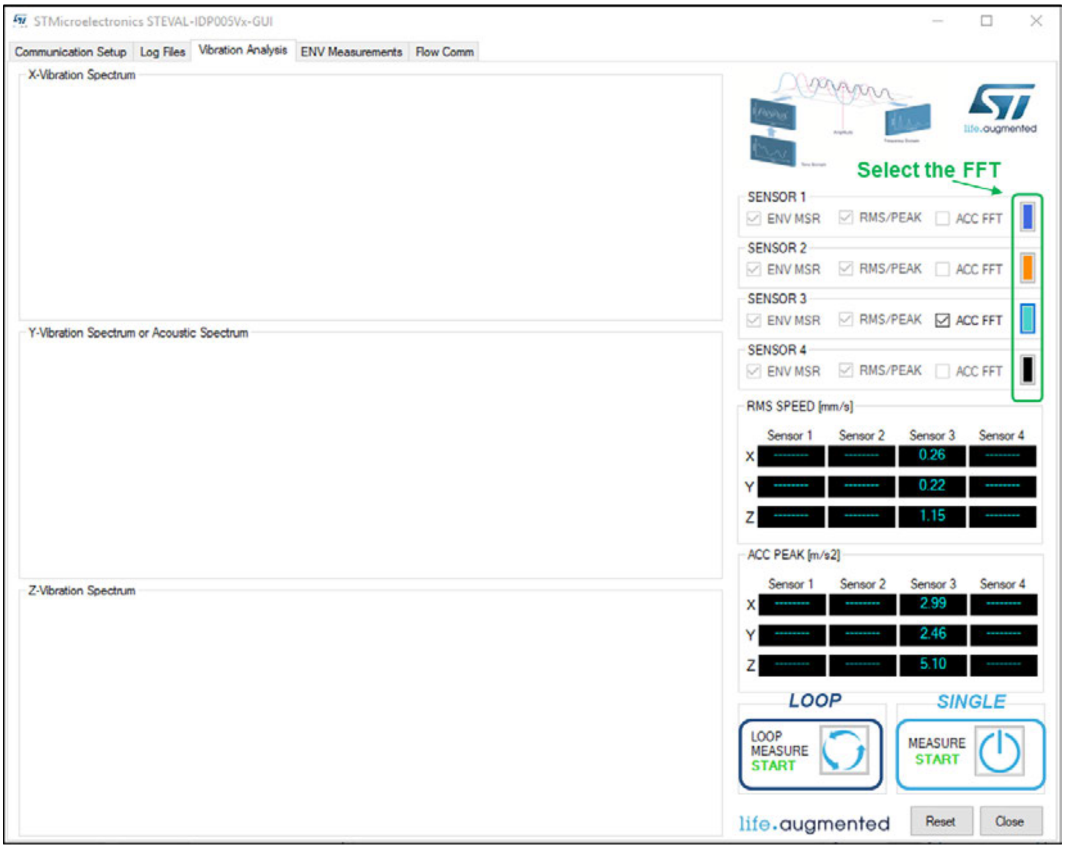
Figure 52. **STEVAL-IDP004V2 and STEVAL-IDP005V2 connected and application start**

9.1.1 How to view sensor and communication data in the GUI

The large volumes of data transmission required for vibration and acoustic plots are supported by a dedicated IO-Link transmission datatype named BLOB data, which allows up to 16384-byte data packages in the supported predictive and acoustic applications.

Step 1. Select the [**Vibration Analysis**] tab.

Figure 53. Vibration analysis tab



Step 2. In the sensors panel, check the field boxes to activate the different types of analyses you wish to perform on each sensor:

- ENV MSR (for environmental data shown in the [**ENV Measurements**] tab); always enabled for both the projects.
- RMS/PEAK (for time domain analysis values in 3D dedicated sector); always enabled but only used by the predictive maintenance project
- ACC FFT (for frequency domain analysis, available up to 3D); when enabled, it displays the 3D accelerometer FFT power spectrum for the predictive maintenance project, and a single FFT Acoustic spectrum (located in the Y-plot) for the acoustic analysis project.

Note: *You can select one of the colored check boxes along the right to enable all the available plots and measurements for a particular sensor.*

Step 3. Select one of the following options to start displaying the data:
– [**MEASURE START**] for a single plot
– [**LOOP MEASURE START**] for continuous plotting in loop mode

Figure 54. Frequency domain and time domain results

Step 4. Select the [**ENV Measurements**] tab to view the environmental data for the selected sensors.

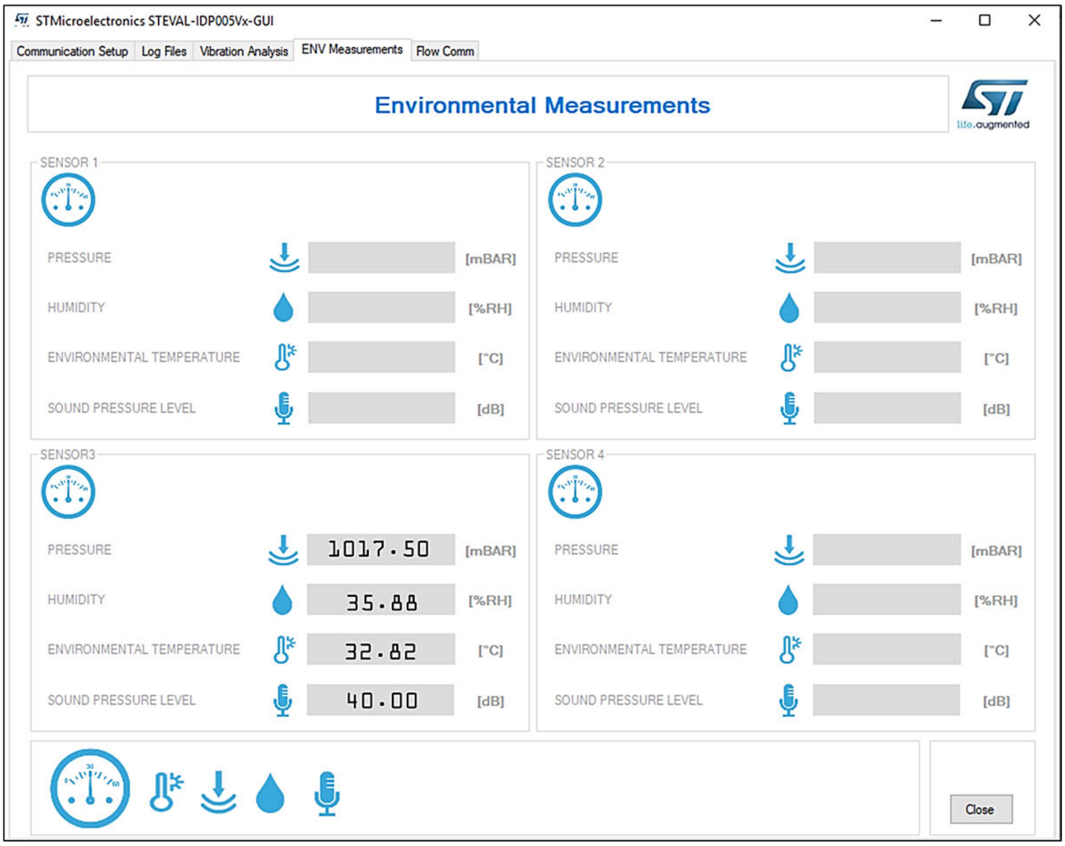
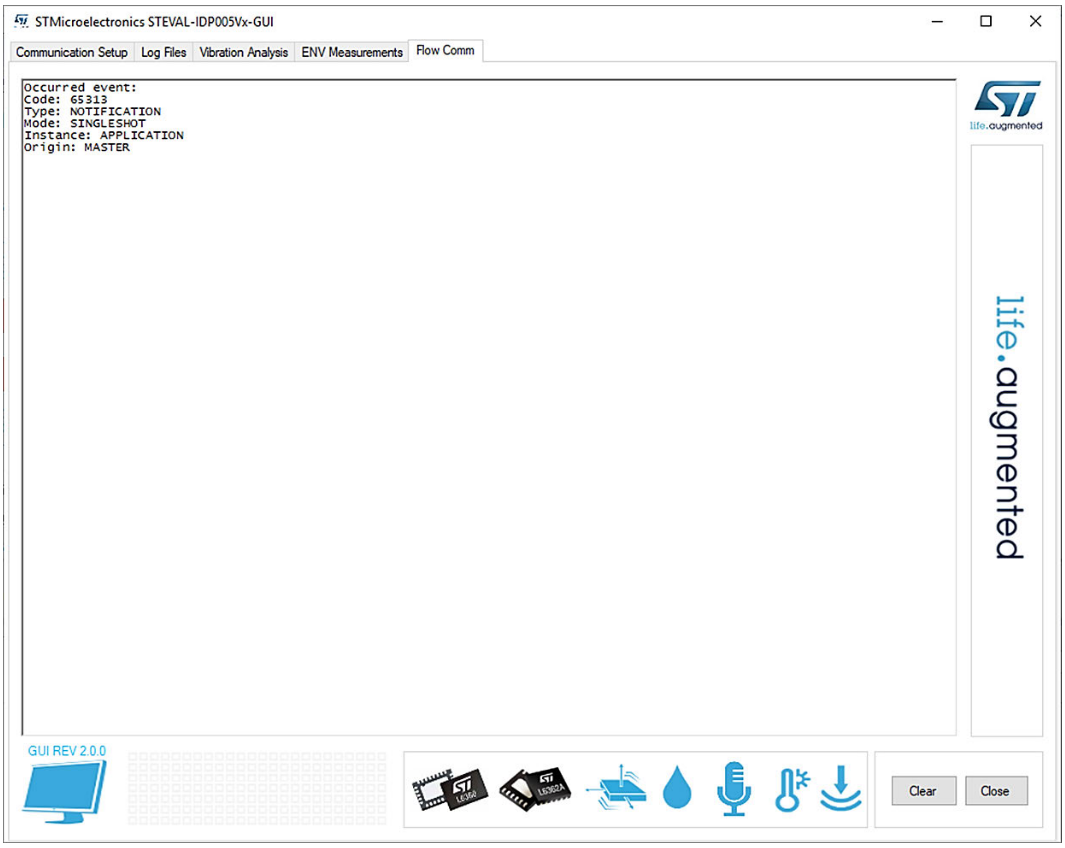


Figure 55. **Environmental Measurements**

Step 5. Select the [**Flow Comm**] tab to view the messages from the IO-Link master and the sensor nodes.

The information shown includes EVENT messages generated by the sensor nodes. A spreadsheet file with message code descriptions is provided in `STSW-BFA001V2\Projects\Utilities`.

Figure 56. Messages from the master and device stack



9.1.2 How to save the log files

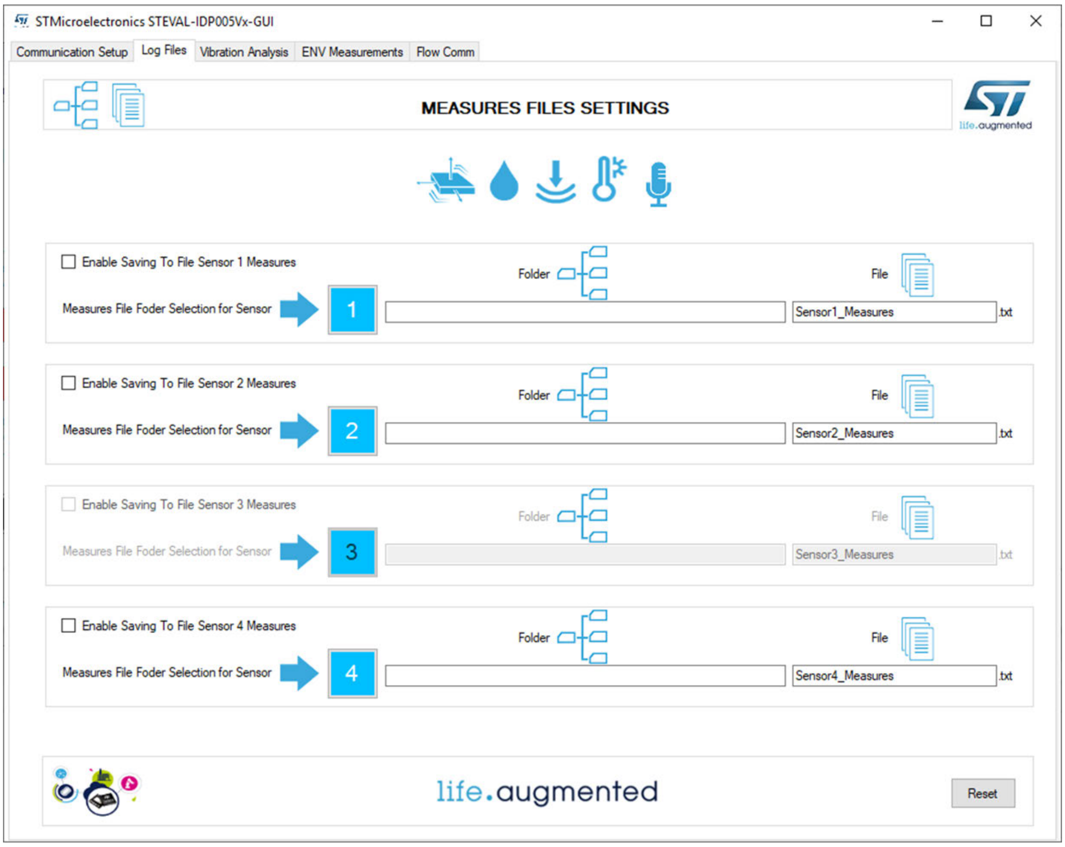
The [**Log Files**] page lets you configure the log for each connected sensor node. Follow the procedure below to store the communication history in a log file.

Step 1. Select the [**Log Files**] tab.

Step 2. Check the [**Enable Saving To File Sensor X Measurements**] box.

Step 3. Click the corresponding square blue button and enter the folder path and file name for the log file.

Figure 57. Log file storage



9.2 How to use the TEC Control Tool (by TEConcept)

Before you begin, connect your PC to the STEVAL-IDP004V2 IO-Link master via USB or RS485/USB adapter cable and supply appropriate power.

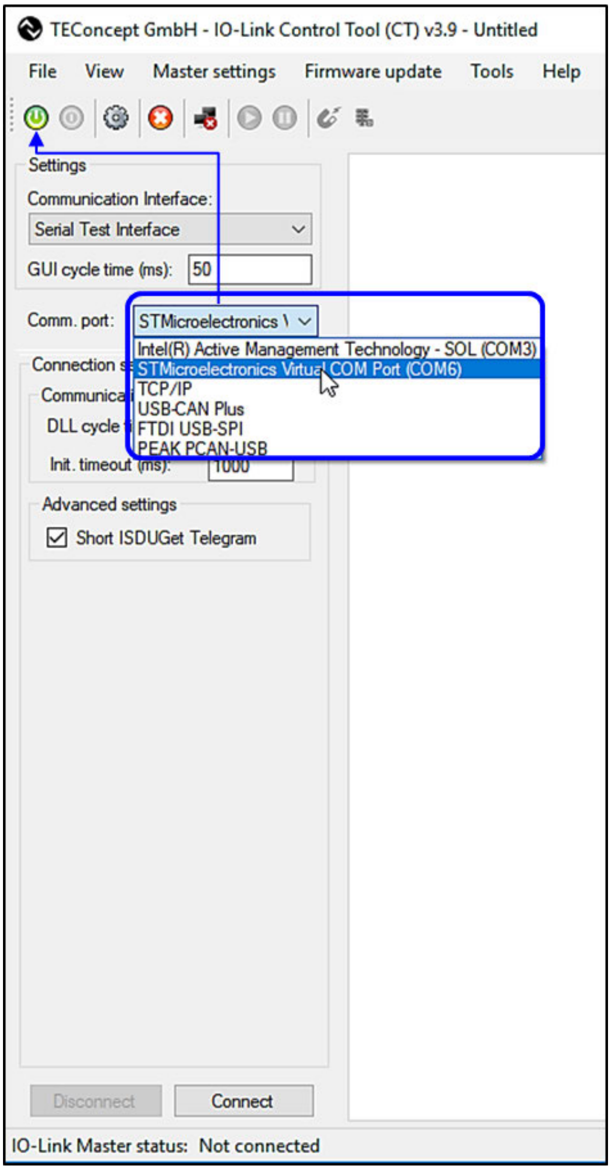
This graphical user interface by TEConcept demonstrates IO-Link functionality in terms of reading data, configuring parameters and thresholds for the MotionSP library, extracting events, and controlling BLOB transmission. The software implements several IO-Link Device Descriptor (IODD) files that configure the IO-Link master to work with different sensor nodes in a functional communication environment. The IODD for the STEVAL-BFA001V2 sensor node is located in the `STSW-BFA001V2/Utilities/STMicroelectronics-STEVAL-BFA001V2-IODD1.1` folder.

Follow the steps below to exchange data with the sensor node:

Step 1. Select the appropriate COM for the STEVAL-IDP004V2 IO-Link master connected via USB or RS485 USB adapter

Step 2. Select the green icon in the menu bar to enable the connection between the master and the PC.

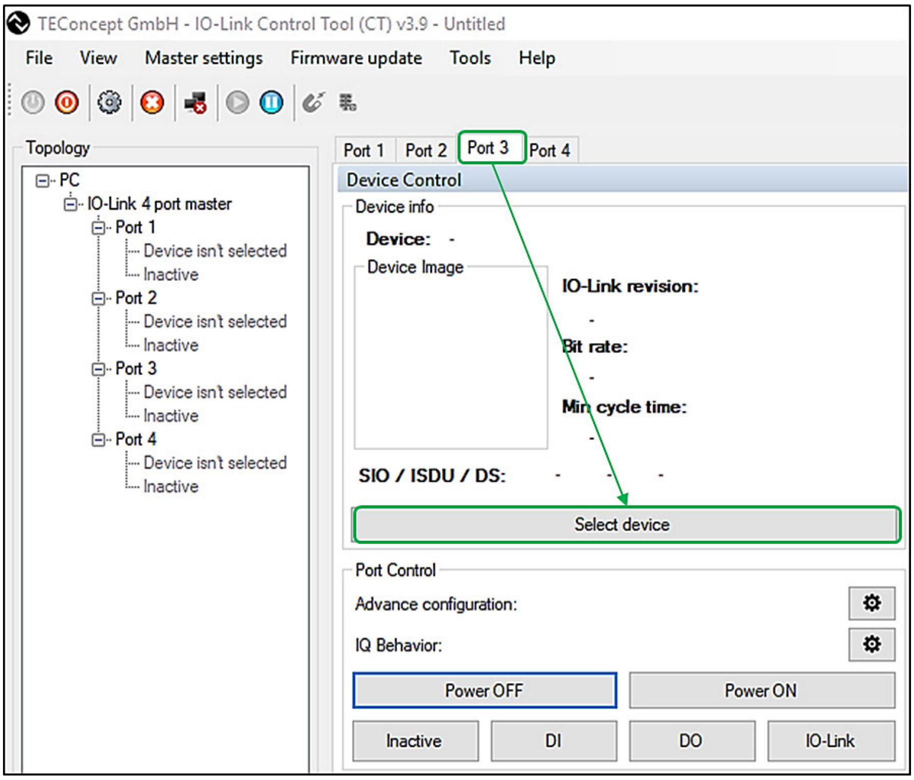
Figure 58. Start GUI, select the COM, and start the master application



Step 3. In the [**Device Control**] panel, select the [**Port x**] that corresponds with the connected device

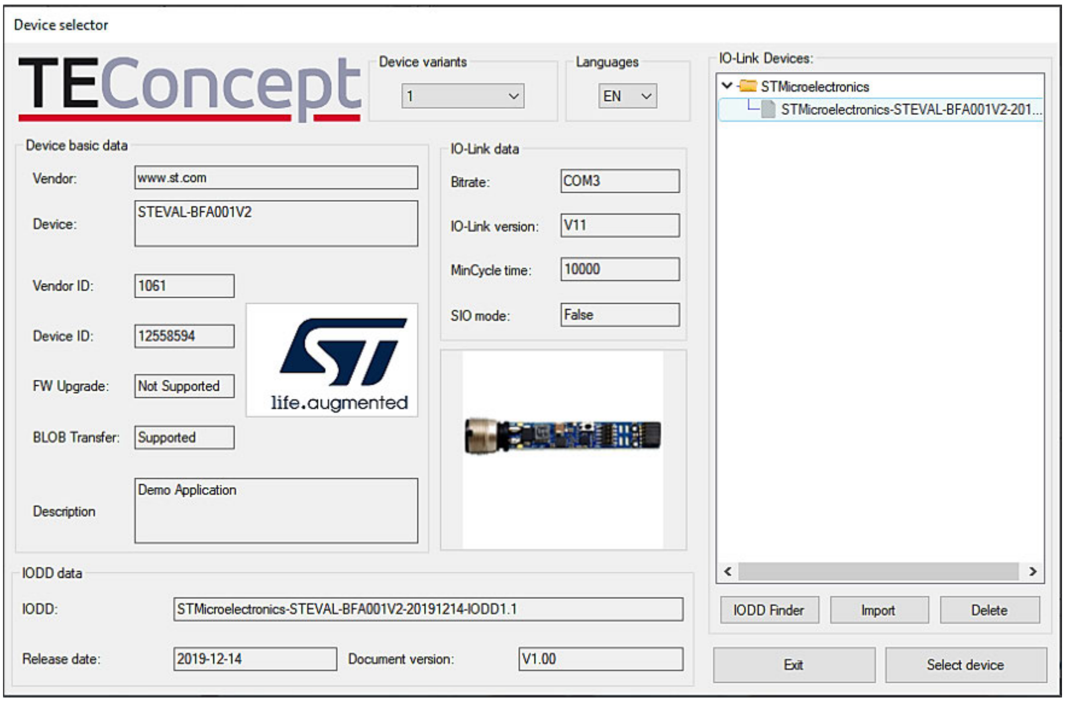
Step 4. Click the [**Select device**] button to list the associated IODD files.

Figure 59. **Port and associated IODD selection**



Step 5. Select the appropriate IODD file from the list, or import a new file using the [**Import**] button. Either double-click on the file name or click the [**Select Device**] button.

Figure 60. **Loading IODD file**



Step 6. Select the [**Power On**] button to supply the sensor node.

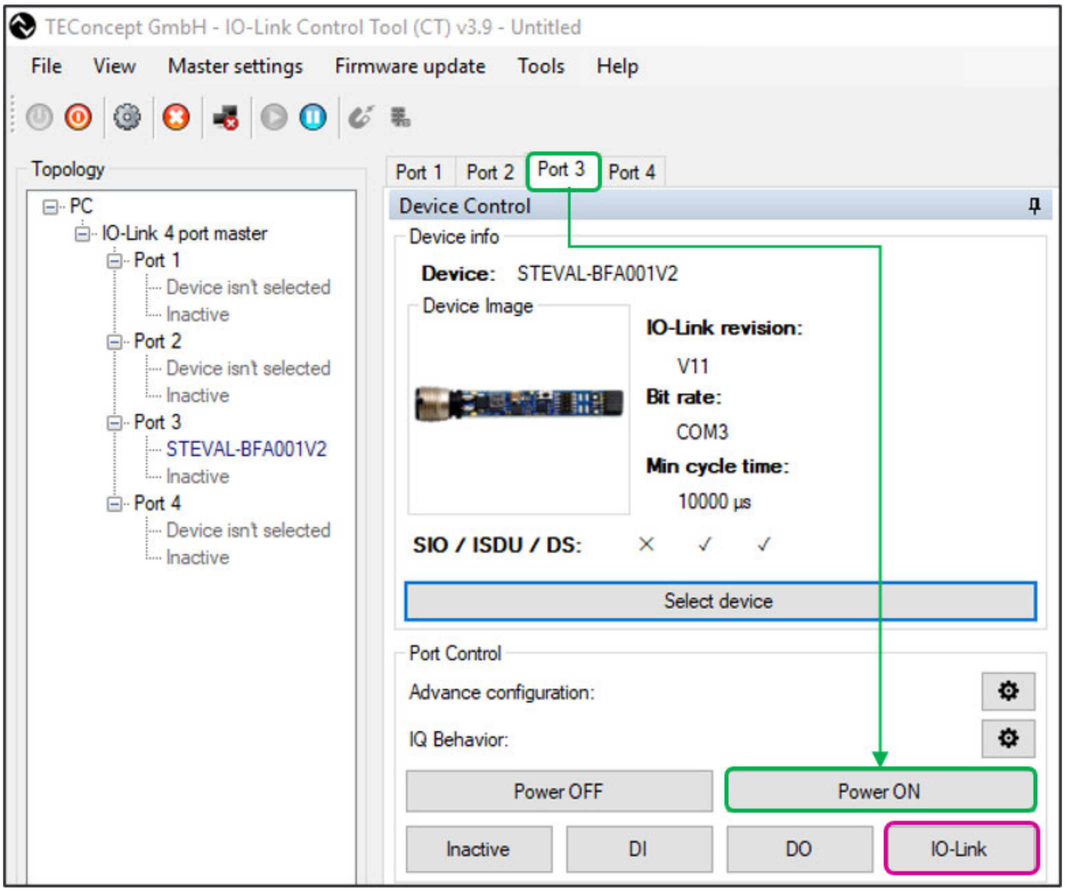
The powered status of the sensor node is indicated by a LED on the IO-Link master board.

Step 7. If you have not already done so, download the binary file in `STSW-BFA001V2\Projects\Demonstrations\Predictive_Maintenance_IOL/Binary` to the STEVAL-IDP005V2 sensor node MCU.

Step 8. Click the [**IO-Link**] button to initiate data communication.

A different LED on the IO-Link master board blinks until connection is established by the stack, after which the LED remains on.

Figure 61. Power On and IO-Link communication start



The application starts immediately updating the process data measured according to the Cycle Time configured in the IODD file (this value can be increased through the [**Advanced configuration**] menu.

Step 9. Observe the [**Parameters**] section.

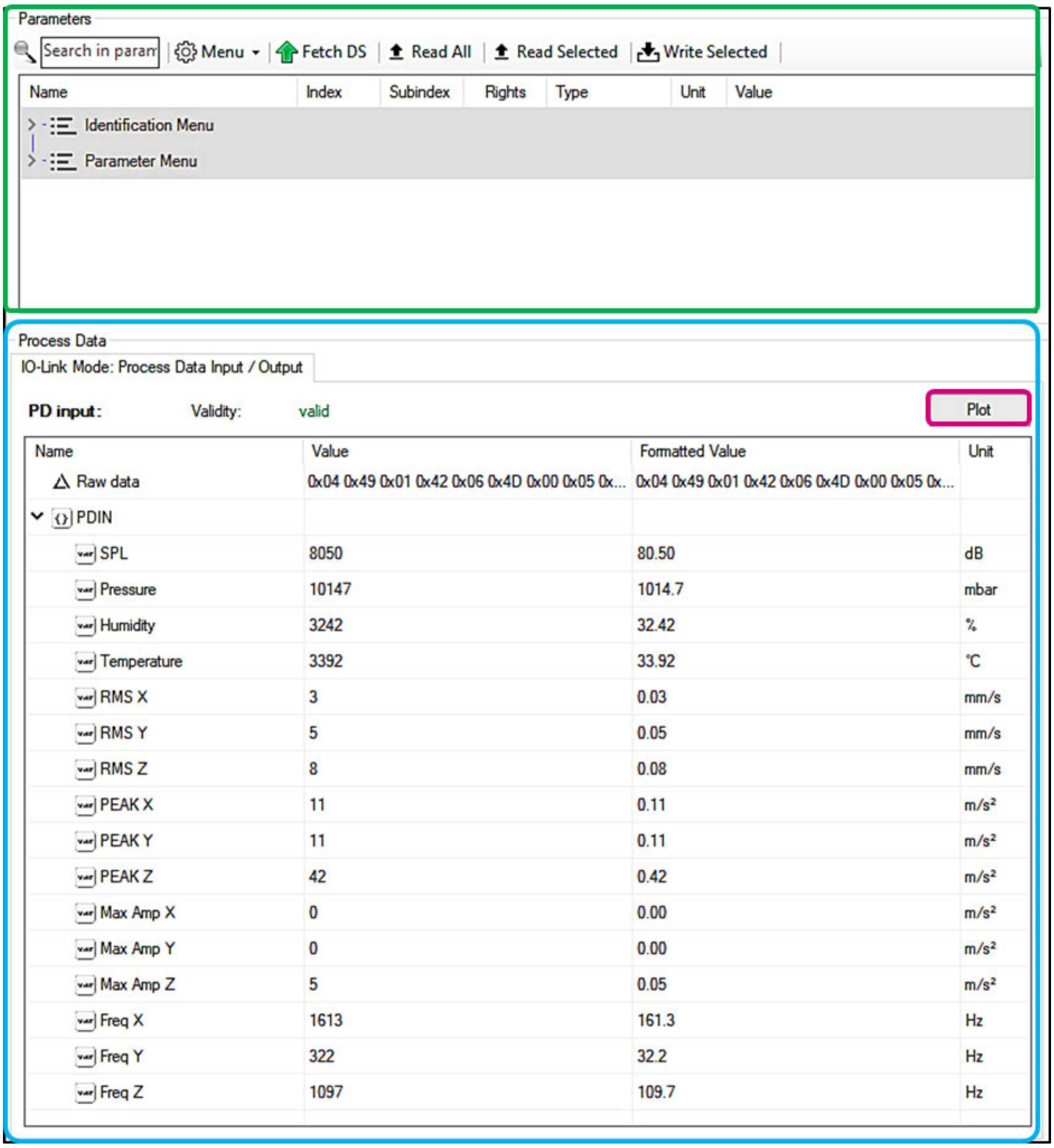
This section contains the following collapsible menus:

– [**Identification Menu**]: all the stack features and specs
– [**Parameter Menu**]: all the configurable settings for the MotionSP middleware

Step 10. Observe the [**Process Data**] section

This section shows the data sent by the device to the master every cycle time interval (10 ms in this example).

Figure 62. IO-Link control tool Parameters and Process Data sections



9.2.1 Process Data plots

The IO-Link stack is able to transmit up to 32-byte process data messages via the fieldbus every cycle time interval. The Predictive Maintenance application can therefore use up to 16 different 2-byte values.

You can verify trends in every measurement through data plotting. By clicking the [**Plot**] button, it is possible to monitor all the values together or individually.

1. Environmental measurements:
   – Acoustic Sound Pressure Level - SPL (in dB)
   – Atmospheric Pressure (in mbar)
   – Relative Humidity (in %)
   – Temperature (in °C)

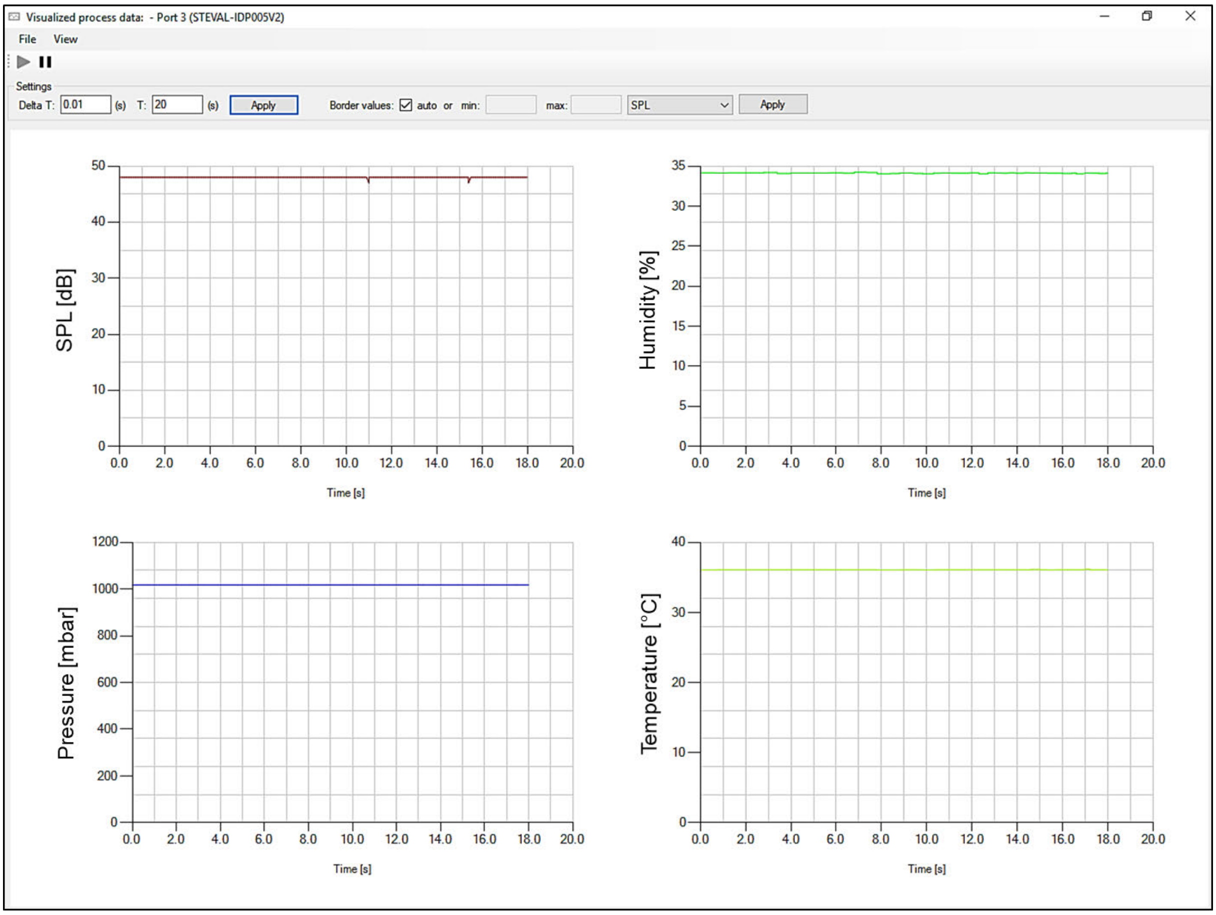
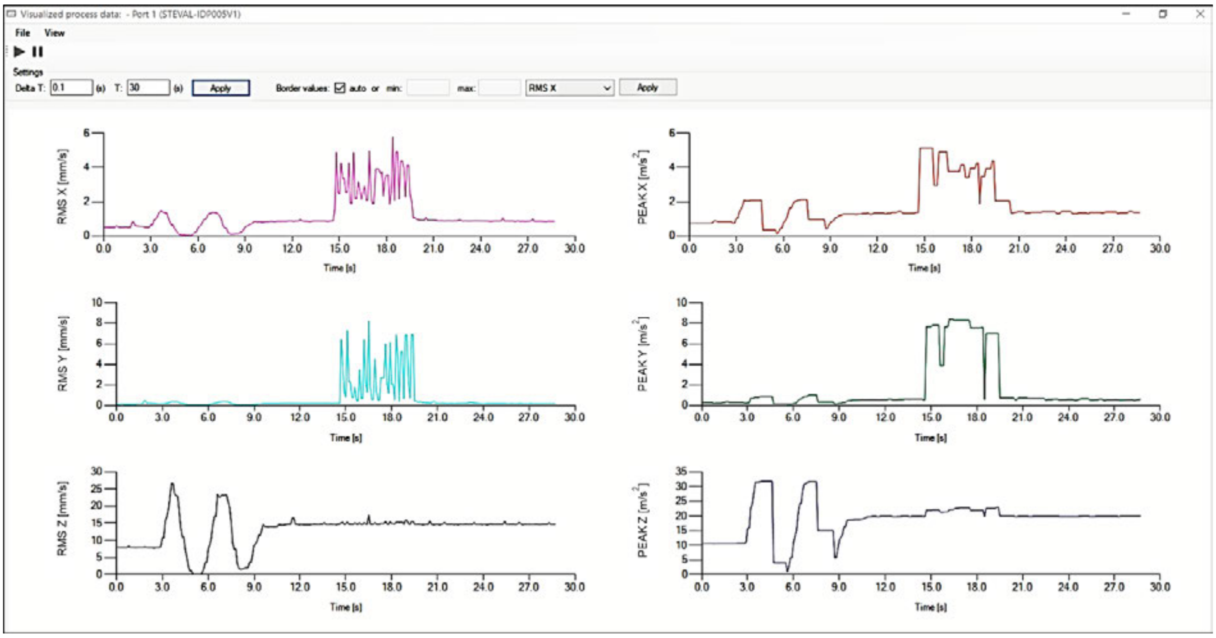


Figure 63. Data plot of environmental measurements

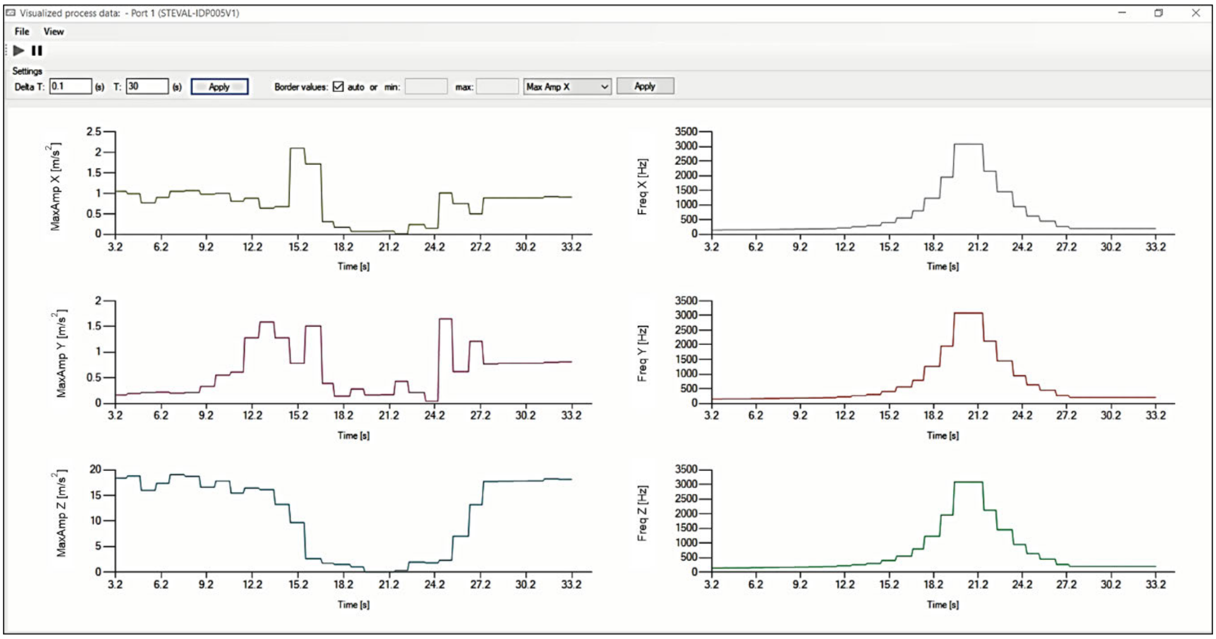
1. Time Domain Results:
   – X – Y – Z axes Vibrational Speed Root Mean Square (in mm/s)
   – X – Y – Z axes max acceleration Peak (in m/s2)

Figure 64. **Data plot of Time Domain analysis**



1. Frequency Domain results:
   - X – Y – Z axes acceleration FFT maximum amplitude (in m/s2)
   - X – Y – Z axes frequency of FFT maximum amplitude (in Hz)

Figure 65. **Frequency Domain analysis results data plot**



9.2.2 How to request BLOB data transmission

This procedure describes how to initiate a BLOB data request while the application is running:

Step 1. In the parameter panel, open [**Menu**]>[**BLOB Transfer**].

A new panel opens to execute an a-cyclical BLOB request from the master to the device. The data is plotted in the same panel.

The data from the sensor nodes are shown in the [**BLOB Transfer**] panel as large array byte sequences with up to 16,384 elements, which can be grouped into the following blocks:

a. 1st Block → 4096 Bytes → Bin Frequencies (1024 values in float)

b. 2nd Block → 4096 Bytes → FFT X-Amplitude (“ “ “ “)

c. 3rd Block → 4096 Bytes → FFT Y-Amplitude (“ “ “ “)

d. 4th Block → 4096 Bytes → FFT Z-Amplitude (“ “ “ “)

Step 2. Click the [**Save**] button.

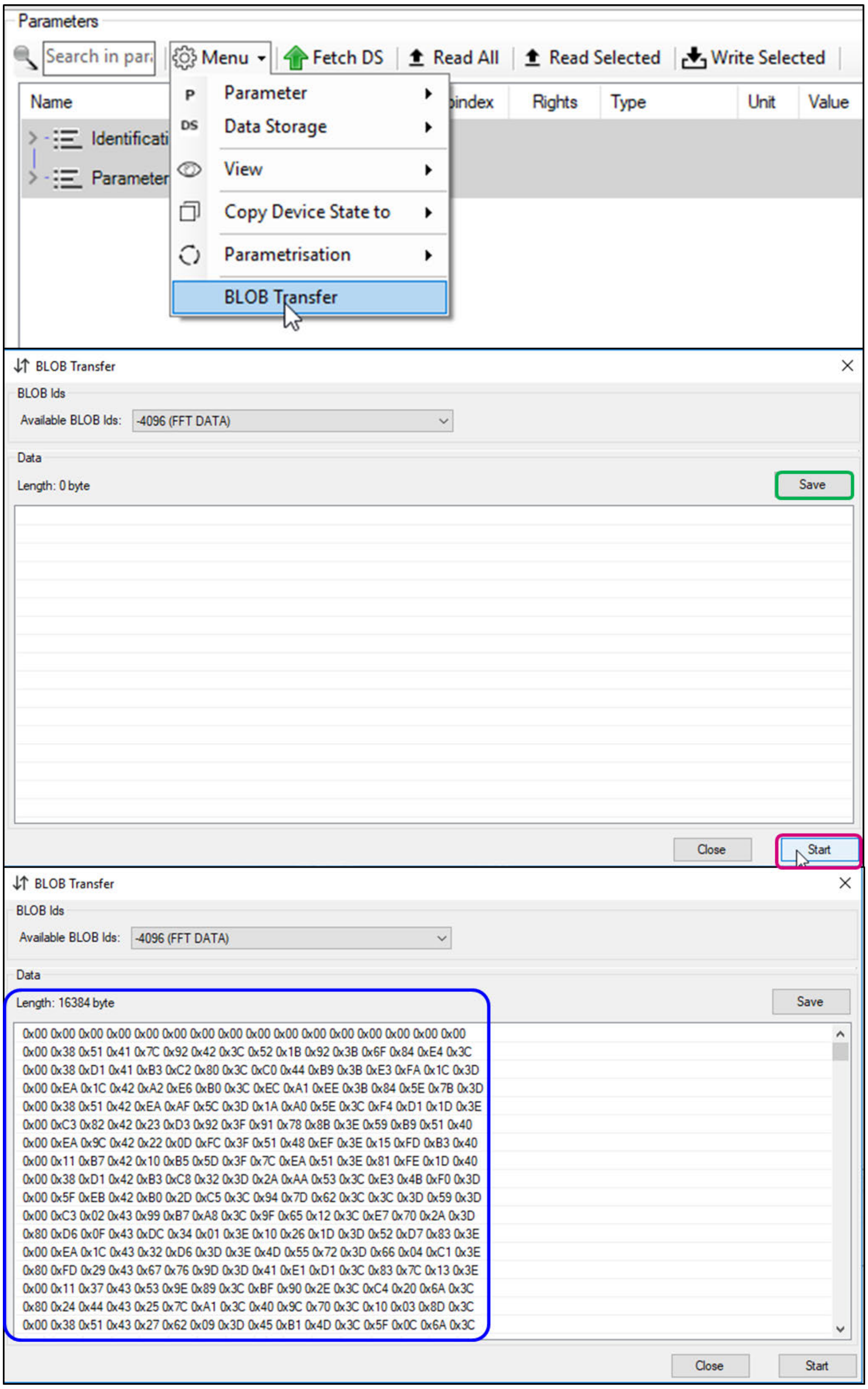


Figure 66. **Start BLOB transfer request and read data**

9.2.3 How to configure the MotionSP parameters

The TEC Control Tool used with the specific STEVAL-BFA001V2 IODD file lets you configure certain values associated with the communication between the IO-Link master board and the sensor node device. Follow the procedure below to update certain MotionSP middleware parameters associated with time and frequency domain analyses:

Step 1. Open the Parameter menu.

Step 2. Click the [**Read all**] button to read the parameters values used in the firmware.
The parameters have default values configured by firmware unless they are changed by the user.

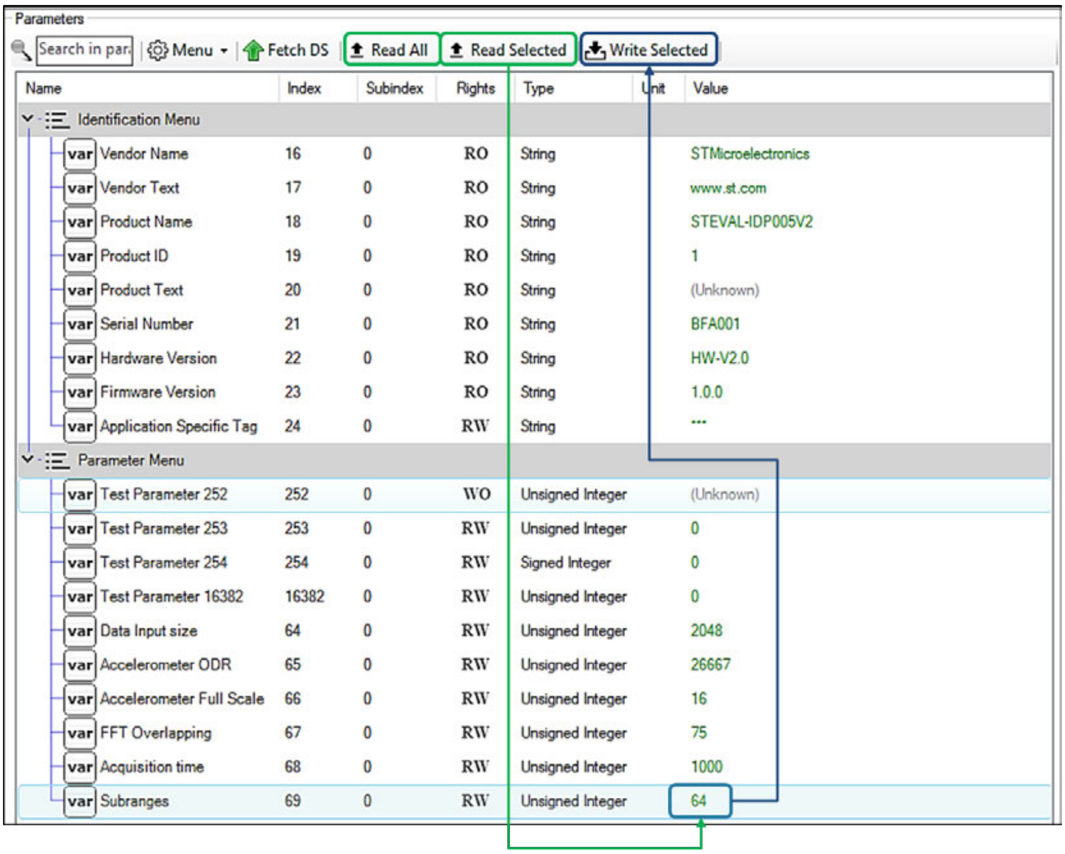
Step 3. Select any parameter and click the [**Read Selected**] button.
This allows you to read the value of any specific parameter.

Step 4. Select one of the following parameters and enter a corresponding permissible value in the Value column.
- DataInputSize: 256, 512, 1024, 2048 FFT sample number.
- Accelerometer ODR: Not configurable for the device used (IIS3DWB use just one: 26667 Hz).
- Accelero_Full_Scale: ±2g, ±4g, ±8g, ±16g.
- FFT_Overlapping: from 5% to 95%.
- Acquisition_time: from 500 to 60000 ms.
- Subranges: 8, 16, 32, 64 (different sectors to analyze the FFT output).

Note: Any values outside these sets or ranges will be ignored by the firmware.

Step 5. Click the [**Write Selected**] button.
The value will change from blue to green to confirm the transmission has been performed by the stack.

Figure 67. Parameter configuration



9.2.4 How to configure the time and frequency domain thresholds

The Predictive Maintenance application can compare incoming time and frequency domain data with threshold settings in the firmware (default values inside the `MotionSP_Thresholds.h` file). The device IO-Link stack supports Indexed Service Data Unit (ISDU) transmissions that you can use to modify the threshold values during Predictive Maintenance runtime execution, and therefore control when events are triggered due to excessive values.

The following example shows how to update the time domain thresholds while the application is running.

Step 1. Open the spreadsheet file for configuring thresholds, included in the software package.
`STSW-BFA001V2/Utilities/Thresholds configurator and Event reader.xls`
It provides a simple tool to convert the custom ISDU messages into a format the TEC Control tool can read.

Step 2. Open the Thresholds Configurator sheet within the spreadsheet file.

Step 3. Use the section for time domain threshold format conversion
The ISDU index is 0x0100

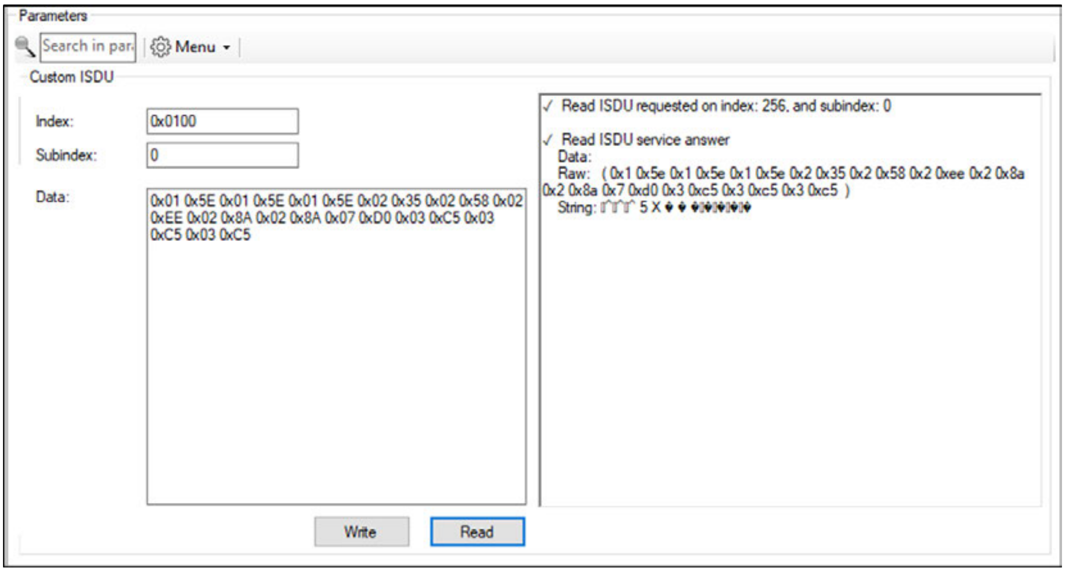
Step 4. Write the values to update in each cell and then copy the corresponding converted values.

Step 5. Ensure the master/device boards are connected, the IO-Link stack is initialized, and the application is running.

Step 6. In the TEC Control Tool, open [**Menu**]>[**Custom ISDU**] in the parameters section.
This panel allows you to write or read any customized ISDU indexed by the firmware stack.

Step 7. Perform the following tasks in the [**Custom ISDU**] section:
- write 0x0100 in the index panel
- leave 0 in the subindex panel
- Paste the converted values from the spreadsheet file into the Data panel
- check that everything is confirmed in the panel on the right

Figure 68. Threshold insertion



The same procedure can be executed to update all the frequency domain thresholds with appropriate values for the subgroup: 8 set for each custom ISDU.

9.2.5 How to read the events associated with time and frequency domain

The TEC Control tool provides a panel for each sensor on the main page listing the events generated by the device and master. This event log is generated according to IO-Link stack specifications, with an ID code for the cause of each event. The messages are only displayed after the analysis acquisition time has expired.

The following figure shows the information generated in the Events panel for an appropriately configured IODD.

Figure 69. **TEC Control event message panel**

Events (30)

Time	Code	Mode	Type	Source	Instance	Name
6:23:02 PM	36346	Event disappears	Error	Device application	Application	Event ALARM on axis X in Acc Peak
6:23:03 PM	36349	Event disappears	Warning	Device application	Application	Event WARNING on axis Y in Acc Peak
6:23:04 PM	36350	Event disappears	Error	Device application	Application	Event ALARM on axis Z in Acc Peak
6:23:17 PM	36011	Event appears	Warning	Device application	Application	Event WARNING on axis X in SUB10
6:23:17 PM	36013	Event appears	Warning	Device application	Application	Event WARNING on axis Y in SUB10
6:23:18 PM	36014	Event appears	Error	Device application	Application	Event ALARM on axis Z in SUB10
6:23:19 PM	36010	Event appears	Error	Device application	Application	Event ALARM on axis X in SUB10
6:23:19 PM	36011	Event disappears	Warning	Device application	Application	Event WARNING on axis X in SUB10

The more important fields in the list are:

- Time: Event timestamp (sent after the diagnosis is completed)
- Code: Event ID code (for Predictive Maintenance by IO-Link application; there are 396 possible events)
- Mode: Event status sent by the Device to the Master(1)
  - “Event appears” if the condition occurred during the analysis
  - “Event disappears” if the condition is no longer present when the analysis has finished
- Type: Event type related to the event source condition (Error or Warning)
- Source: Event ownership (Master or Device application)
- Instance: Only the word “Application” appears in the released project
- Name: Event cause description, for two different analyses:
  - Time Domain: The messages return the event cause in terms of TYPE, AXIS and analyzed measurements (Acceleration peak or Speed RMS)
  - Frequency Domain: The messages show information regarding the corresponding TYPE, AXIS, and SUBRANGE

1. *The Event Dispatcher controls the "Event appears" and "Event disappears" flow. Once the Event Dispatcher has sent an Event appears for a given EventCode, it shall not send it again for the same EventCode before it has sent an Event disappears for the same EventCode.*

Use the procedure below to determine the frequency of a certain anomaly:

Step 1. Open the file `STSW-BFA001V2/Utilities/ Thresholds configurator and Event reader.xls`

Step 2. Open the [**Event Reader**] sheet

Step 3. Open the filter window in the cell [**SUBRANGE Monitored**]

Step 4. Type the subrange number in the search box to find the frequency involved

10 Schematic diagrams

Figure 70. STEVAL-UKI001V2 (adapter board) circuit schematic

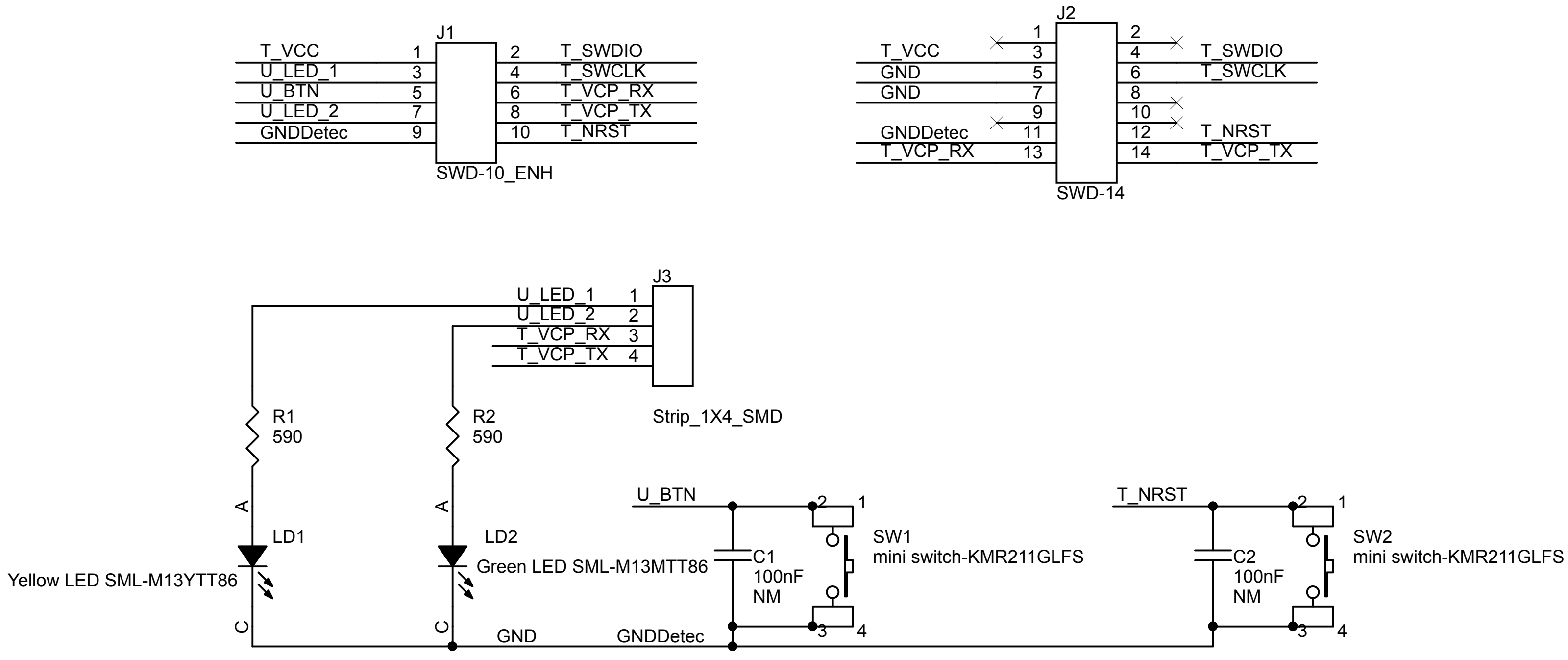


Figure 71. **STEVAL-IDP005V2 (main board) circuit schematic**

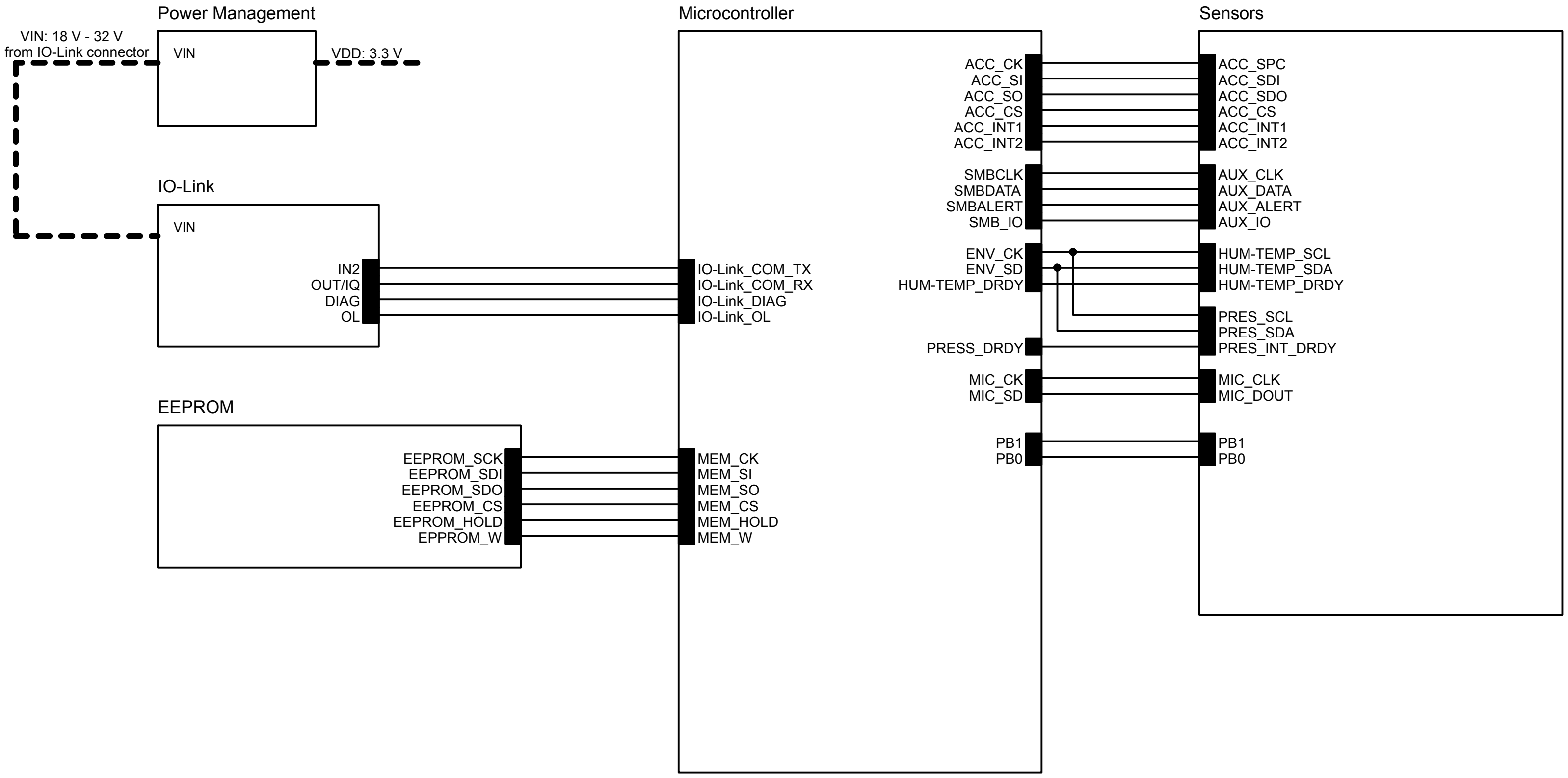


Figure 72. **STEVAL-IDP005V2 (main board) circuit schematic - power management**

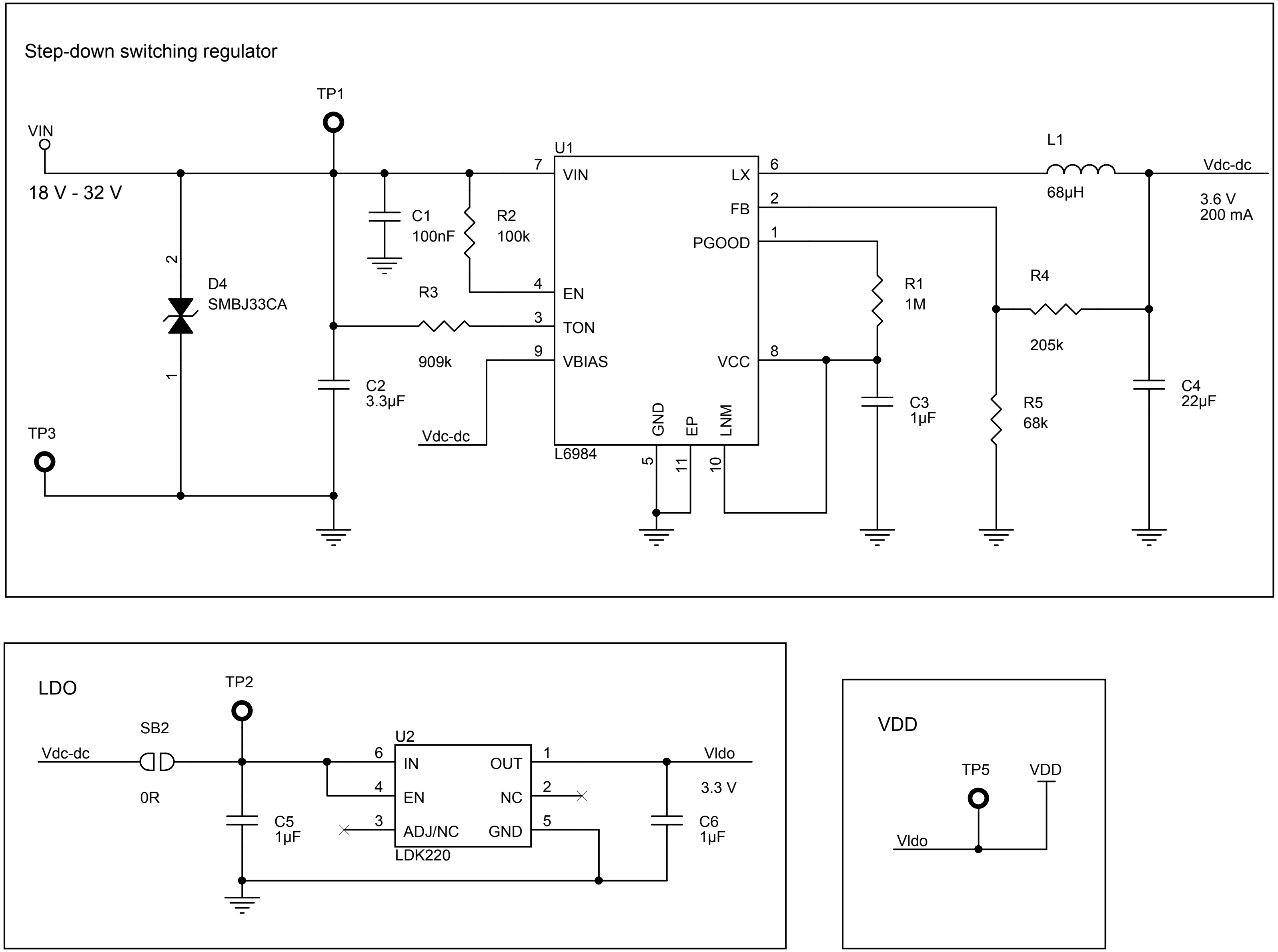


Figure 73. STEVAL-IDP005V2 (main board) circuit schematic - IO-Link

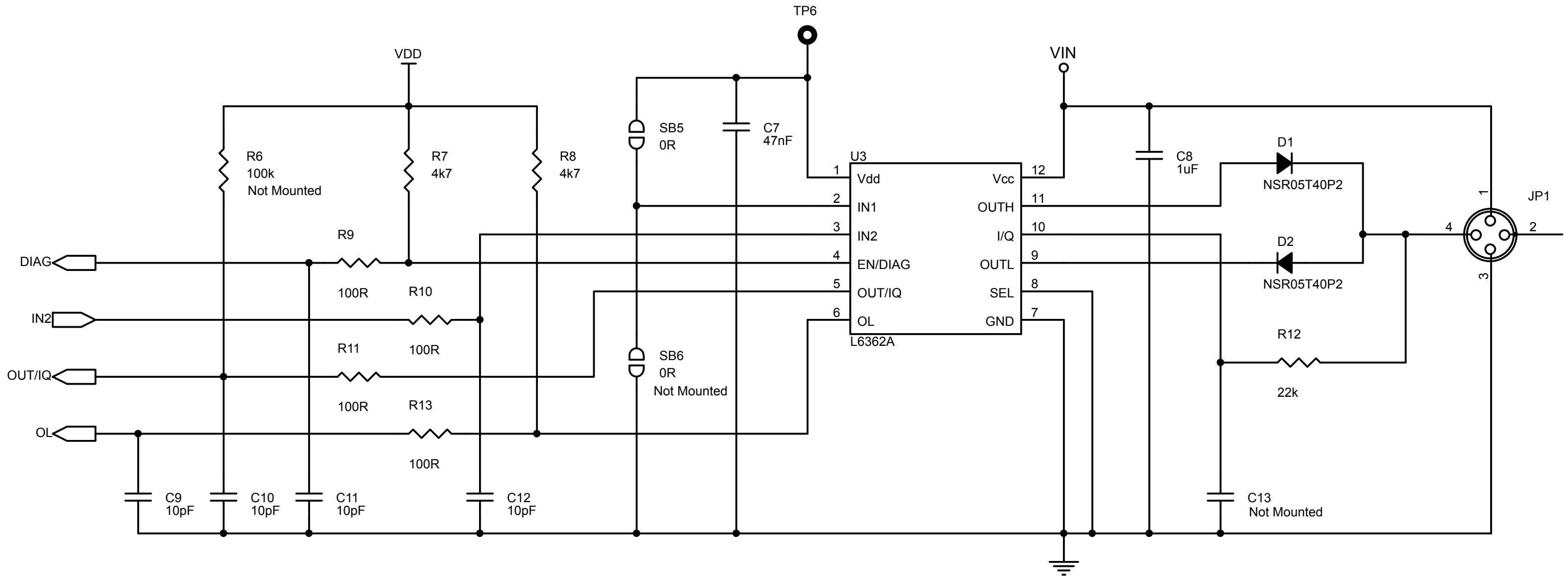


Figure 74. STEVAL-IDP005V2 (main board) circuit schematic - sensors

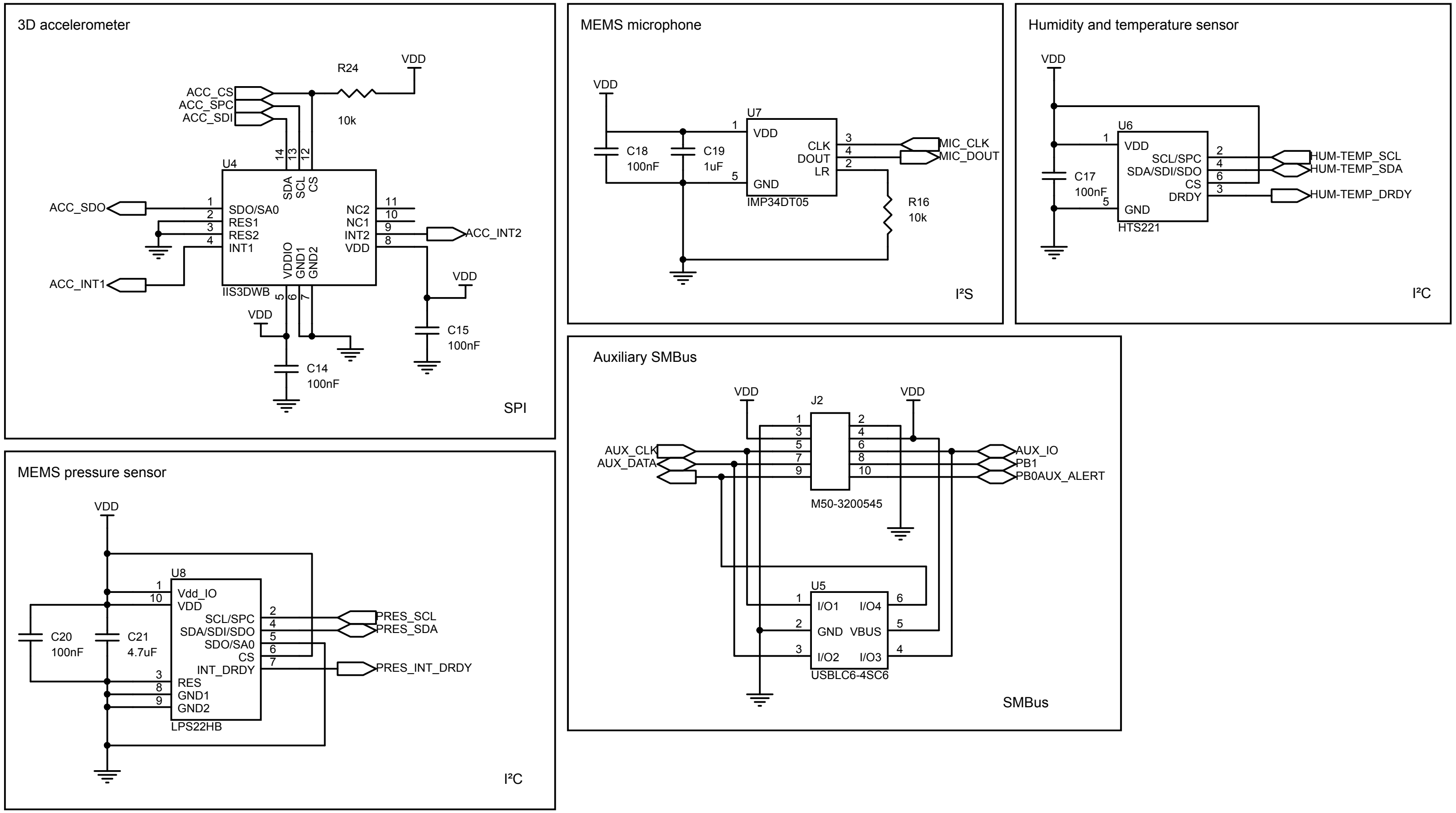


Figure 75. STEVAL-IDP005V2 (main board) circuit schematic - EEPROM

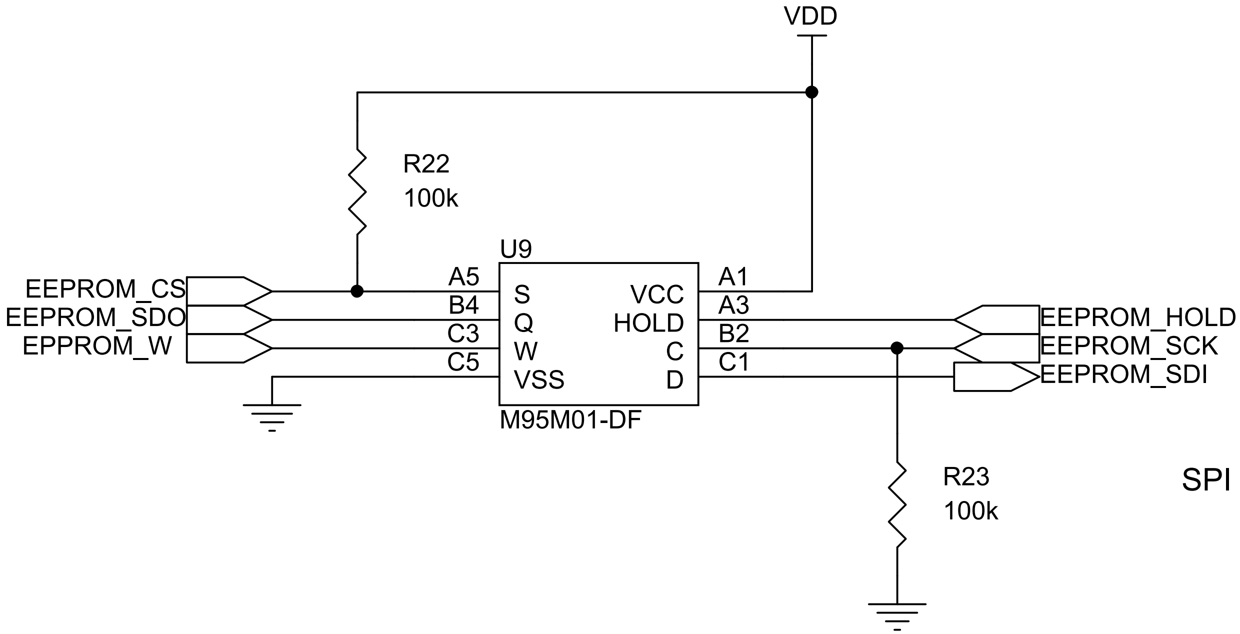


Figure 76. STEVAL-IDP005V2 (main board) circuit schematic - microcontroller (1 of 2)

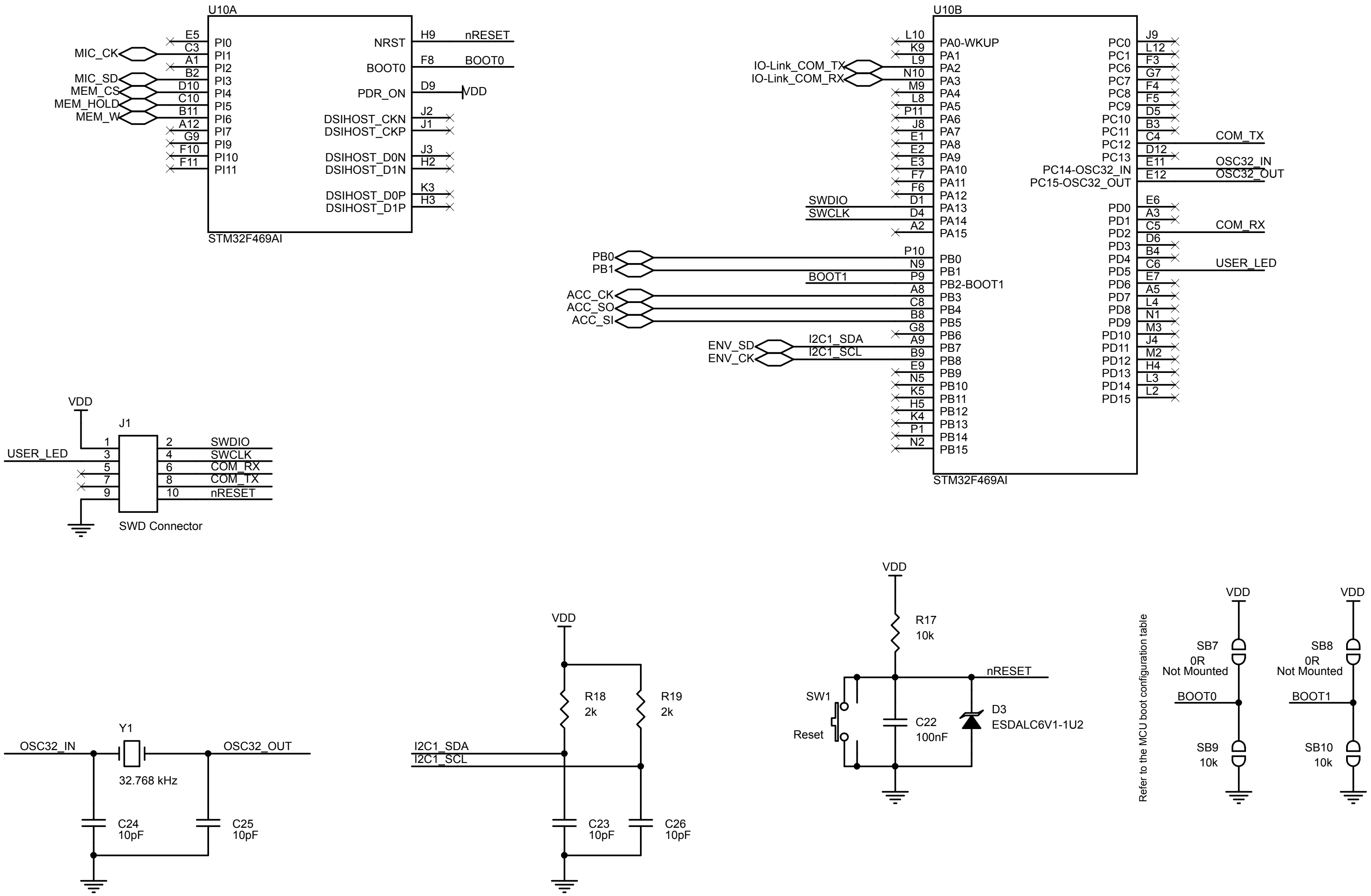
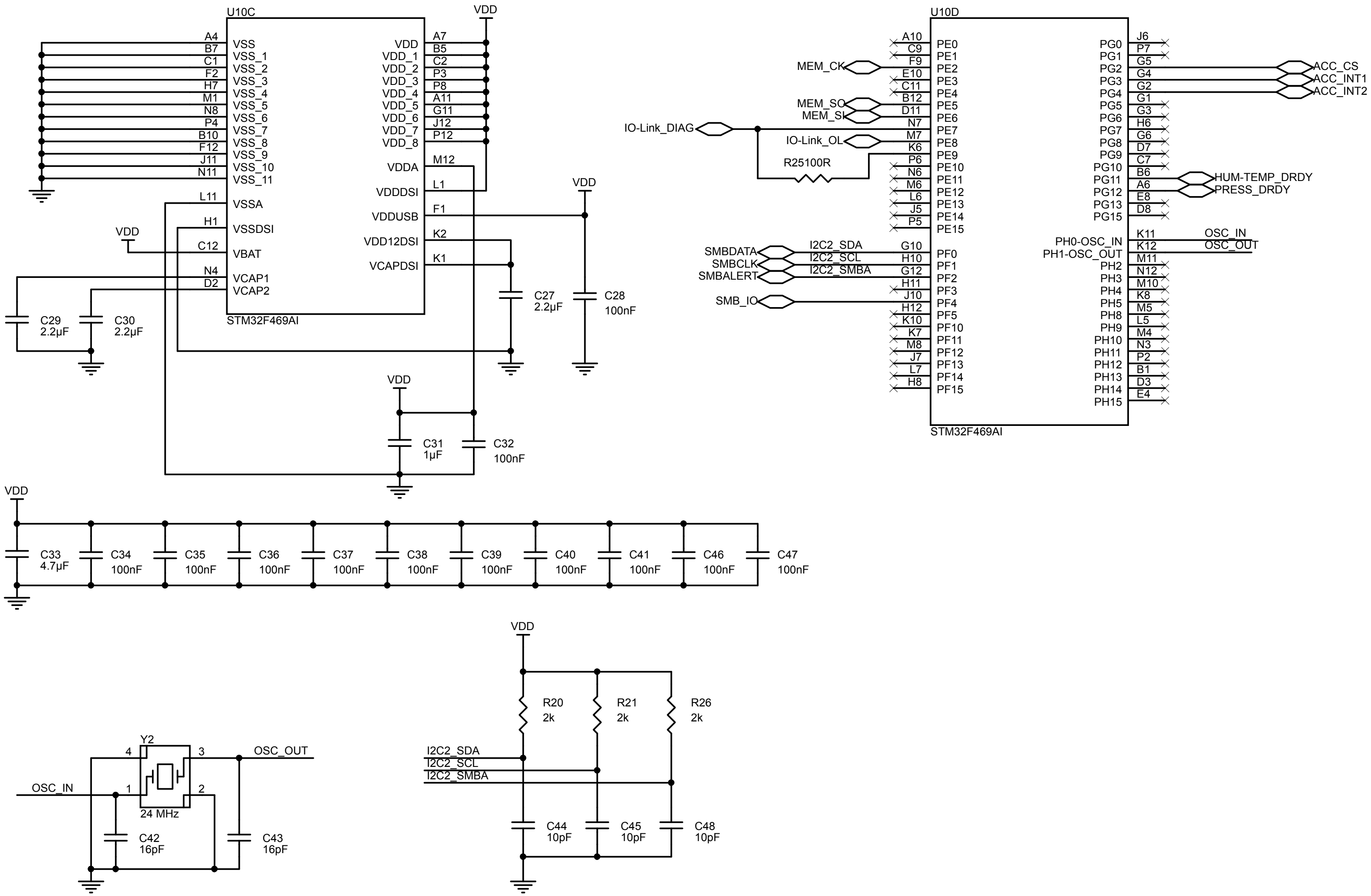


Figure 77. STEVAL-IDP005V2 (main board) circuit schematic - microcontroller (2 of 2)



11 Bill of materials

Table 3. **STEVAL-BFA001V2B bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	Table 4. STEVAL-IDP005V2		Sensor node	ST	Not available for separate sale
2	1	Table 5. STEVAL-UKI001V2		Communication adapter board	ST	Not available for separate sale
3	1	STLINK-V3MINI		Programming and debugging interface	ST	STLINK-V3MINI
4	1			Programming cable		
5	1	M12		4-pin female connector	Telemecanique Sensors	XZCP1141L2
					Katlax	CBF12-S44N0-02BPUR
6	1	M12		Male cable mount connector	Telemecanique Sensors	XZCC12MDM40B
					Katlax	CNM12-S4SP0-BP7

Table 4. **STEVAL-IDP005V2 bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	C1	100 nF SMD 0402 50 V ±10%	X7R-Ceramic Capacitor	TDK	C1005X7R1H104K050BB
2	1	C2	3.3 µF SMD 1206 50 V ± 10%	X8L-Ceramic Capacitor	TDK	CGA5L1X8L1H335K160AC
3	5	C3, C5, C6, C19, C31	1 µF SMD 0402 10 V ±10%	X7S-Ceramic Capacitor	Murata	GCM155C71A105KE38D
4	1	C4	22 µF SMD 1210 16 V ±20%	X7R-Ceramic Capacitor	TDK	CGA6P1X7R1C226M250AC
5	1	C7	47 nF SMD 0402 10 V ± 10%	X7R-Ceramic Capacitor	Murata	GRM155R71A473KA01D
6	1	C8	1 µF SMD 0603 50 V ±10%	X5R-Ceramic Capacitor	Murata	GRT188R61H105KE13D
7	9	C9, C10, C11, C12, C23, C26, C44, C45, C48	10 pF SMD 0402 10 V ±1%	C0G-Ceramic Capacitor	Kemet	C0402C100J5GACTU
8	1	C13	SMD 0402 10 V	Capacitor (not mounted)	/	/
9	17	C14, C17, C18, C20, C22, C28, C32, C34, C35, C36, C37, C38, C39, C40, C41, C46, C47	100 nF SMD 0402 10 V ±10%	X7R-Ceramic Capacitor	Wurth Elektronik	885012205018
10	1	C15	100 nF SMD 0402 10 V ±10%	X7R-Ceramic Capacitor	Wurth Elektronik	885012205018
11	2	C21, C33	4.7 µF SMD 0603 10 V ±10%	X7S-Ceramic Capacitor	TDK	C1608X7S1A475K080AC

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
12	2	C24, C25	10 pF SMD 0402 50 V ±5%	C0G-Ceramic Capacitor	Kemet	C0402C100J5GACTU
13	3	C27, C29, C30	2.2 µF SMD 0402 10 V ±10%	X7R-Ceramic Capacitor	TDK	C1005X7S1A225K050BC
14	2	C42, C43	16 pF SMD 0402 50 V ±5%	C0G-Ceramic Capacitor	Murata	GRM1555C1H160JA01D
15	2	D1, D2	NSR05T40P2 SOD-923	Schottky Barrier Diode	OnSemiconductors	NSR05T40P2T5G
16	1	D3	ESDALC6V1-1U2 SMD 0201	Single-line low capacitance Transil™ for ESD protection	ST	ESDALC6V1-1U2
17	1	D4	SMBJ33CA SMB DO-214AA 33V	600 W TVS in SMB	ST	SMBJ33CA
18	1	JP1	IO-Link CONN	IO-Link 4-position M12 A-coded connector	Binder	9043121204
19	1	J1	SMT Pitch 1.27 mm, 5x2	SWD Connector	Harwin	M50-3600542
20	1	J2	TH Pitch 1.27 mm, 5x2	Auxiliary Connector	Harwin	M50-3200545
21	1	L1	68 µH SMD (4.8x4.8x2.8 mm) Isat = 0.4 A/Rdc = 0.34 ohm ± 30%	Shielded Power Inductor	Wurth Elektronik	744043680
22	1	R1	1 M SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF1004X
23	3	R2, R22, R23	100 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF1003X
24	1	R3	909 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF9093X
25	1	R4	205 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF2053X
26	1	R5	68 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF6802X
27	1	R6	100 k SMD 0402 0.1 W ± 1%	Resistor (not mounted)	/	/
28	2	R7, R8	4 k7 SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2GEJ472X
29	5	R9, R10, R11, R13, R25	100 R SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF1000X
30	1	R12	22 k SMD 0603 0.1 W ± 1%	Resistor	Bourns	CR0603-FX-2202ELF
31	5	SB9, SB10, R16, R17, R24	10 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF1002X
32	5	R18, R19, R20, R21, R26	2 k SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2RKF2001X
33	2	SB2, SB5	0 R SMD 0402 0.1 W ± 1%	Resistor	Panasonic	ERJ-2GE0R00X
34	3	SB6, SB7, SB8	0 R SMD 0402 0.1 W ± 1%	Resistors (not mounted)	/	/
35	1	SW1	smd (L 4.6 x W 2.2 x H 1.9 mm)	Reset	C & K	KMR211GLFS
36	1	U1	L6984 VDFPN10 (3x3x1.0 mm)	36 V 400 mA synchronous step-down switching regulator	ST	L6984ATR

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
37	1	U2	LDK220 DFN6 (1.2x1.3x0.5 mm)	200 mA low quiescent current and low noise LDO	ST	LDK220PU33R
38	1	U3	L6362A VFDFPN 12L (3x3x0.90 mm)	IO-Link communication transceiver device IC	ST	L6362ATR
39	1	U4	IIS3DWB LGA-14L (2.5x3x0.83 mm)	Ultra-wide bandwidth, low-noise 3-axis digital accelerometer for industrial applications	ST	IIS3DWBTR
40	1	U5	USBLC6-4SC6 SOT-23-6	Very low capacitance ESD protection	ST	USBLC6-4SC6
41	1	U6	HTS221 HLGA-6L (2x2x0.9 mm)	Capacitive digital sensor for relative humidity and temperature	ST	HTS221TR
42	1	U7	IMP34DT05 HCLGA-4LD (3x4x1 mm)	MEMS audio sensor omnidirectional digital microphone for industrial applications	ST	IMP34DT05TR
43	1	U8	LPS22HB HLGA-10L (2x2x0.76 mm)	Ultra-compact piezoresistive absolute pressure sensor	ST	LPS22HBTR
44	1	U9	M95M01-DF WLCSP8 (2.578x1.716 mm)	1-Mbit SPI bus EEPROM with high-speed clock	ST	M95M01-DFCS6TP/K
45	1	U10	STM32F469AI WLCSP 168L DIE 434 12X14 P 0.4mm	High-performance advanced line, ARM Cortex-M4 core with DSP and FPU	ST	STM32F469AIY6TR
46	1	Y1	32.768 kHz smd (2.05x1.2x0.55mm) ±20ppm	Crystal	NDK	NX2012SA 32.768kHz EXS00A-MU00389
47	1	Y2	24 MHz smd (2x1.6x0.45 mm) ±20ppm	Crystal	NDK	NX2016SA 24.000MHz EXS00A-CS05544
48	1	PCB	50x8.5x1.2mm	PCB	Ermes	-
49	1	NA-supply only	Pitch 1.27 mm, 5x2	SWD Cable	Harwin	M50-9100542
50	1	NA-supply only	Pitch 1.27 mm, 5x2	Header Board to Board Connector	GCT	GTC BD030-10-A-A-0350-0300-L-G

Table 5. **STEVAL-UKI001V2 bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	2	C1, C2	100 nF, 16 V ±20% 0805 (2012 Metric) SMD	Ceramic capacitors	Any	Any
2	1	J1	SWD-10_ENH SMD 10 pos. 1.27 mm	Connector header	Samtec Inc.	FTSH-105-01-L-DV-K-TR
3	1	J2	SWD-14 14 pos. 1.27 mm	Connector header	Samtec Inc.	FTSH-107-01-L-DV-K
4	1	J3	Strip_1X4_SMD 10.16X5.08 mm SMD 4 pos. 2.54 mm	Connector header	Samtec Inc.	TSM-104-01-F-SV-P-TR
5	1	LD1	SML-M13YTT86 20 mA 0805 (2012 Metric) SMD	Yellow LED	Rohm Semiconductor	SML-M13YTT86
6	1	LD2	SML-M13MTT86 20 mA 0805 (2012 Metric) SMD	Greem LED	Rohm Semiconductor	SML-M13MTT86
7	2	R1, R2	590 0.125 W, 1/8 W ±1% 0805 (2012 Metric) SMD	Chip resistor	Any	Any
8	2	SW1, SW2	SPST-NO 0.05 A 32 V-KMR211GLFS 4.60 mm x 2.80 mm	Tactile switch	C&K	KMR211GLFS
9	1	PCB	FR4-32x25.3x1.6 mm 32x25.3x1.6 mm	PCB	Any	Any

Revision history

Table 6. Document revision history

Date	Version	Changes
14-Jan-2020	1	Initial release.
07-May-2020	2	Updated Section 10 Schematic diagrams, Figure 24. STSW-BFA001V2 firmware architecture and Section 3 STEVAL-UKI001V2 adapter board.
08-Feb-2021	3	Updated Section Introduction, Section 1.1 Package components, Section 5.1 Connection through an STLINK-V3MINI, Figure 31. Terminal emulator screenshot for acoustic analysis firmware, Figure 33. Terminal emulator screenshot while running environmental monitoring firmware, Section 7.3 Outputs for the vibration analysis project and Section 7.4 Predictive Maintenance via Service UART. Added P-NUCLEO-IOM01M1 compatibility information. Minor text changes.

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