UM1901

User manual

Getting started with the software package for analog and digital MEMS microphones in X-CUBE-MEMSMIC1 expansion for STM32Cube

Introduction

The X-CUBE-MEMSMIC1 software provides the complete STM32 middleware to build applications using analog and digital MEMS microphones. The software expands the STM32Cube range of solutions and is easily ported across different MCU families.

The package contains sample applications for the acquisition of PDM signals from up to four digital MEMS microphones, PDM to PCM conversion and real-time streaming of audio data to a PC via a standard USB audio-input driver.

It also contains sample applications for the acquisition of the audio signal from analog MEMS microphones through a dedicated third-party external analog to digital converter or through the embedded STM32 ADC.

Some advanced processing application examples included exploit the ST AcousticBF and AcousticSL libraries to provide specific examples of beamforming and sound source localization functions.

The package also offers an example of ultrasound condition monitoring (UltrasoundFFT) that calculates the FFT of the analog microphone signal and streams the result to a PC GUI via USB.

The software provides implementation examples for STM32 Nucleo platforms equipped with the X-NUCLEO-CCA02M2 expansion boards, featuring two on-board MEMS microphones (MP34DT06J) as well as headers to connect additional microphones via ST coupon boards based on the digital MEMS microphone (STEVAL-MIC001V1, STEVAL-MIC002V1 and STEVAL-MIC003V1).

The package also offers an example to exploit the Performance Mode of the MP23DB01HP MEMS audio sensor multi performance mode digital microphone available on the STEVAL-MIC006V1 coupon board.

Other examples included support the X-NUCLEO-AMICAM1 expansion board featuring three on-board MP23ABS1 analog MEMS microphones and optional additional analog microphone coupon board (STEVAL-MIC004V1).

X-CUBE-MEMSMIC1 also includes demonstrations for the STEVAL-STWINKT1B (and STEVAL-STWINKT1) SensorTile Wireless Industrial Node (STWIN) development kit and for the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards.

1 Acronyms and abbreviations

Table 1. List of acronyms

Acronym	Description
ADC	Analog to digital converter
BSP	Board support package
HAL	Hardware abstraction layer
I^2S	Integrated interchip sound
IDE	Integrated development environment
PCM	Pulse code modulation
PDM	Pulse density modulation
SAI	Serial audio interface
SPI	Serial peripheral interface
USB	Universal serial bus

2 X-CUBE-MEMSMIC1 software expansion for STM32Cube

2.1 Overview

The X-CUBE-MEMSMIC1 software package expands STM32Cube functionality with the following key features:

- Complete middleware to build applications using MEMS digital microphones (MP34DT06J, IMP34DT05 and MP23DB01HP when using the STEVAL-MIC006V1 coupon board) and analog microphones (MP23ABS1 and IMP23ABSU)
- Easy portability across different MCU families thanks to STM32Cube
- Audio input class USB driver to allow the recognition of the device as a standard USB microphone and enable audio streaming
- PC-based streaming using third-party standard audio editors
- Free, user-friendly license terms
- Microphone acquisition sample implementation available on the X-NUCLEO-CCA02M2 expansion board when connected to a P-NUCLEO-WB55, NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-F746ZG development board
- High performance microphone acquisition and streaming via USB available on the X-NUCLEO-CCA02M2 expansion board when connected to a STEVAL-MIC006V1 microphone coupon board and a P-NUCLEO-WB55, a NUCLEO-F401RE or NUCLEO-F746ZG development board
- Microphone acquisition sample implementation available on the X-NUCLEO-AMICAM1 expansion board when connected to a NUCLEO-L476RG or NUCLEO-L4R5ZI
- Microphone acquisition sample implementation available on the STEVAL-STWINKT1B (and STEVAL-STWINKT1) evaluation kit and STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards
- Advanced processing applications based on ST acoustic libraries for NUCLEO-F401RE, NUCLEO-L4R5ZI development board and STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit, including AcousticBF (real-time beamforming) sample and AcousticSL (real-time sound source localization) sample
- Ultrasound FFT analysis demonstration available on the STEVAL-STWINKT1B (and STEVAL-STWINKT1) and on the X-NUCLEO-AMICAM1 expansion board when connected to a NUCLEO-L476RG or NUCLEO-L4R5ZI

This software enables the acquisition of up to four digital MEMS microphones through I²S, SPI, SAI or DFSDM peripherals and performs PDM to PCM format conversion, the main standard for audio communication and processing.

The package allows also the acquisition of up to four analog MEMS microphones through I²S, SPI or DFSDM using on-board external ADC or STM32 embedded ADC.

Exploiting the capabilities of the included audio-input USB driver, the device is recognized as a standard multichannel USB microphone by Windows® or any Unix-like system; it can perform signal streaming to a host system for data recording and further processing using any standard audio editor, even if any software with a standard USB audio interface can be used to interact with the device.

2.2 Architecture

This STM32Cube expansion enables development of applications using digital or analog MEMS microphones.

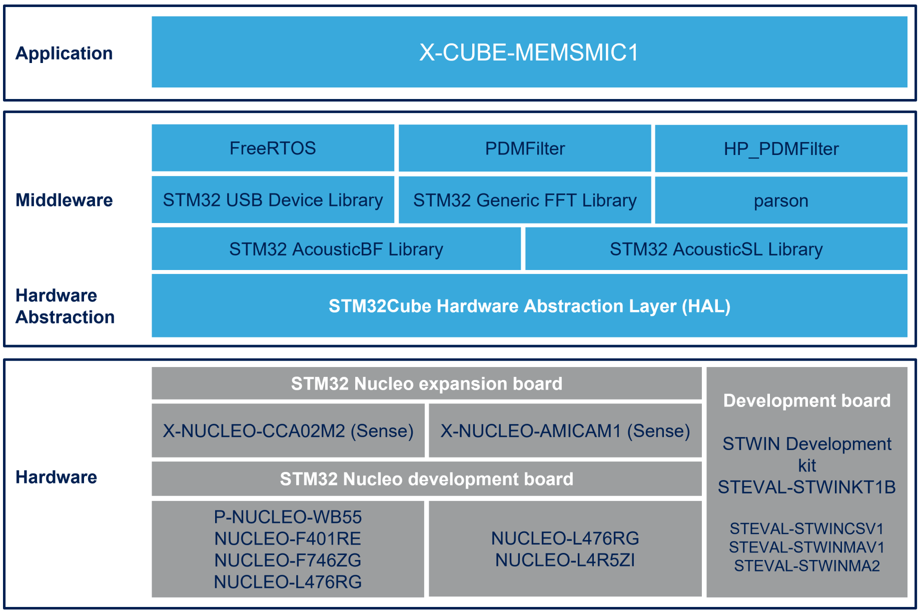
It is based on the STM32CubeHAL hardware abstraction layer for the STM32 microcontroller and extends STM32Cube with a specific board support package (BSP) for the microphone expansion board and middleware components for audio processing and USB communication with a PC.

The software layers used by the application software to access and use the microphone expansion board are:

- STM32Cube HAL layer: provides a generic, multi-instance set of APIs to interact with the upper layers (the application, libraries and stacks). It consists of generic and extension APIs based on a common architecture which allows other layers like the middleware layer to function without specific Microcontroller Unit (MCU) hardware configurations. This structure improves library code reusability and guarantees easy device portability.
- Board Support Package (BSP) layer: is a set of APIs which provides a programming interface for certain board specific peripherals (LED, user button etc.). This interface also helps in identifying the specific board version and provides support for initializing required MCU peripherals and reading data.

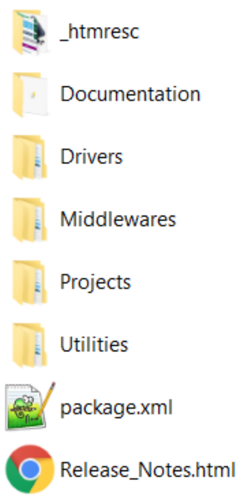
For the microphone expansion board, it provides the interface for MP34DT06J digital MEMS microphones and MP23ABS1 analog MEMS microphone.

Figure 1. **X-CUBE-MEMSMIC1 software architecture**



2.3 Folder structure

Figure 2. **X-CUBE-MEMSMIC1 package folder structure**



The following folders are included in the software package:

- **Documentation**: contains a compiled HTML file generated from the source code and detailed documentation of the software components and APIs
- **Drivers**: contains the HAL drivers and the board-specific drivers for supported board and hardware platforms, including those for the on-board components and the CMSIS vendor-independent hardware abstraction layer for the ARM® Cortex®-M processor series
- **Middlewares**: contains libraries and protocols for the PDM to PCM conversion, beamforming (AcousticBF), sound source localization (AcousticSL) and the audio-input USB driver
- **Projects**: contains sample applications for a STEVAL-STWINKT1B (and STEVAL-STWINKT1) , a P-NUCLEO-WB55, a NUCLEO-F401RE, a NUCLEO-L476RG, a NUCLEO-L4R5ZI or a NUCLEO-F746ZG platform to access microphone data, with three development environments, IAR Embedded Workbench for ARM, RealView Microcontroller Development Kit (MDK-ARM-STR) and STM32CubeIDE
- **Utilities**: contains the PC GUI to run UltrasoundFFT example. The PC software is built in Qt environment and is available both in source code and as an executable application

2.4 APIs

Detailed descriptions of all the functions and parameters of the user APIs user can be found in a compiled HTML file located in the Documentation folder.

2.5 Sample application description

The package includes several microphone-based applications covering a range of use cases, from the simple microphone acquisition to the advanced audio processing. The following applications are provided in the **Projects** directory with ready-to-build projects for multiple IDEs:

- microphone acquisition and streaming via USB, supported by the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansions, the STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit, and the X-NUCLEO-CCA02M2 expansion board with a P-NUCLEO-WB55, NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-F746ZG board and supported by the X-NUCLEO-AMICAM1 expansion board with a NUCLEO-L476RG or a NUCLEO-L4R5ZI
- high performance microphone acquisition and streaming via USB, supported by the X-NUCLEO-CCA02M2 expansion board when connected to a STEVAL-MIC006V1 coupon board with a P-NUCLEO-WB55, a NUCLEO-F401RE or a NUCLEO-F746ZG board
- AcousticBF sample: real-time adaptive beamforming application using the PDM signals acquired via two digital MEMS microphones and the AcousticBF middleware to create a virtual directional microphone pointing to a fixed direction. It is supported by an X-NUCLEO-CCA02M2 expansion boards with a NUCLEO-F401RE board or by an X-NUCLEO-AMICAM1 expansion board with a NUCLEO-L4R5ZI board
- AcousticSL sample: real-time sound source localization application using four signals acquired via digital MEMS microphones and the AcousticSL middleware to estimate the arrival direction of an audio source. It is supported by the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards plugged onto the STEVAL-STWINKT1 development kit, by the X-NUCLEO-CCA02M2 expansion boards on a NUCLEO-F401RE board or by an X-NUCLEO-AMICAM1 expansion board on a NUCLEO-L4R5ZI board
- UltrasoundFFT sample: an ultrasound condition monitoring application that calculates the FFT of the analog microphone signal and streams the result to a PC GUI via USB. The microphone sampling rate is set by default to 192 kHz whereas the microphone bandwidth is up to 80 kHz. It is supported by the X-NUCLEO-AMICAM1 expansion board on a NUCLEO-L476RG or a NUCLEO-L4R5ZI , the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansions and by the STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit

2.5.1 Microphone streaming via USB

This section describes the microphone streaming application via USB. Section 2.5.1.1 Digital MEMS microphone audio acquisition strategy provides an overview of the digital MEMS microphone acquisition strategies and principles adopted.

Section 2.5.1.2 Analog MEMS microphone acquisition strategy shows the basilar analog MEMS microphone acquisition strategies and principle used.

2.5.1.1 Digital MEMS microphone audio acquisition strategy

A digital MEMS microphone can be acquired via different peripherals, such as SPI, I²S, GPIO, SAI or DFSDM. It requires an input clock and it outputs a PDM stream at the same frequency of the input clock. This PDM stream is further filtered and decimated for conversion into PCM standard for audio transmission.

Two different digital MEMS microphones can be connected on the same data line, configuring the first to generate valid data on the rising edge of the clock and the other on the falling edge, by setting the L/R pin of each microphone accordingly. On the X-NUCLEO-CCA02M2 expansion boards, two microphones share the same data line and can be managed differently, depending on the MCU capabilities.

If a digital filter for sigma delta modulators (DFSDM) peripheral is available, the microphones can be routed to DFSDM channels, otherwise use the I²S peripheral for the first and the second microphone and the SPI peripheral for the third and the fourth or use the SAI peripheral (if available).

2.5.1.1.1 DFSDM microphone acquisition

The DFSDM peripheral generates the clock needed by the microphones and reads the data on the rising and falling edges of each PDM line.

The acquired signals become an input to DSFDM filters for hardware filtering and decimation to generate standard PCM streams.

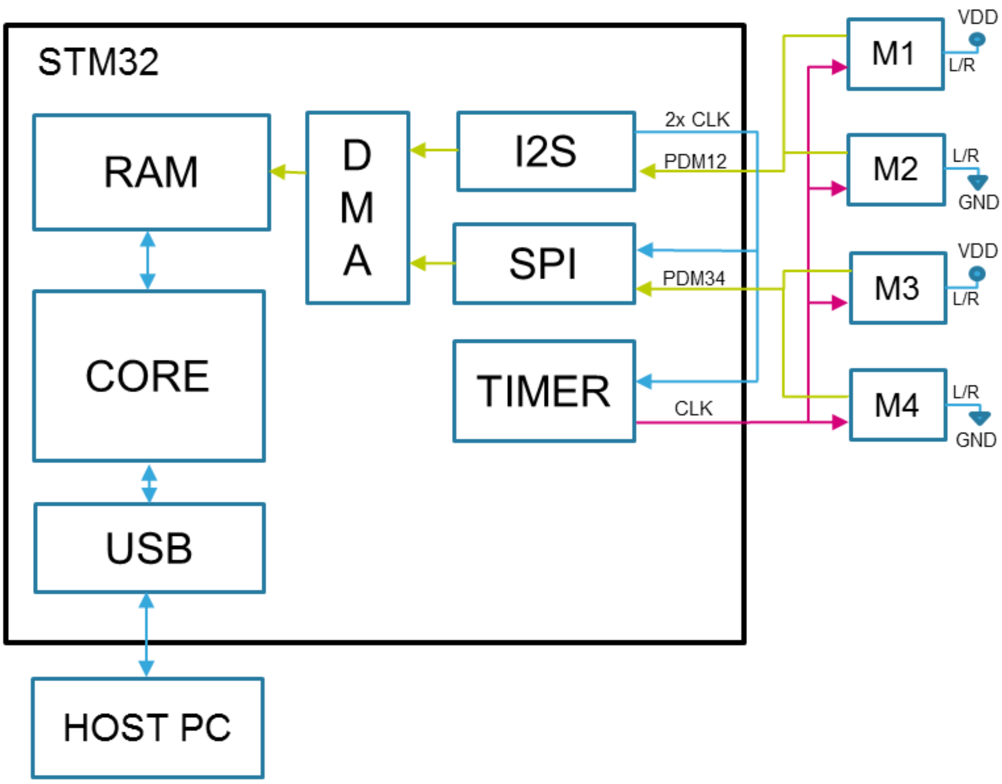
An additional software high pass filtering stage removes any DC offset in the output stream. DMA is used to reduce MCU load.

2.5.1.1.2 I²S and SPI microphone acquisition

In this scenario, a precise clock signal is generated by the I²S peripheral while the SPI is configured in slave mode and is fed by the same timing signal generated by I²S. This clock is then halved by a timer and input to the microphones. The SPI and I²S peripherals operate at twice the microphone frequency to read the data on both the rising and falling edges of the microphone clock, thus reading the bits of two microphones each.

A software demuxing step separates the signal from the two microphones and allows further processing like PDM-to-PCM conversion. For further information regarding MEMS microphone and PDM-to-PCM decimation, please refer to application note AN3998 on www.st.com.

Figure 3. General acquisition strategy using I²S and SPI



For single microphone acquisition, the correct microphone timer is generated directly by I²S and one single microphone data line is read by the same peripheral.

2.5.1.1.3 SAI microphone acquisition

Like DFSDM, the SAI peripheral with PDM interface is able to generate the precise clock needed by the microphones and can read the data on the rising and falling edges of each PDM line.

Unlike DFSDM, however, SAI cannot convert PDM to PCM in hardware, thus a software for the conversion is needed after data acquisition.

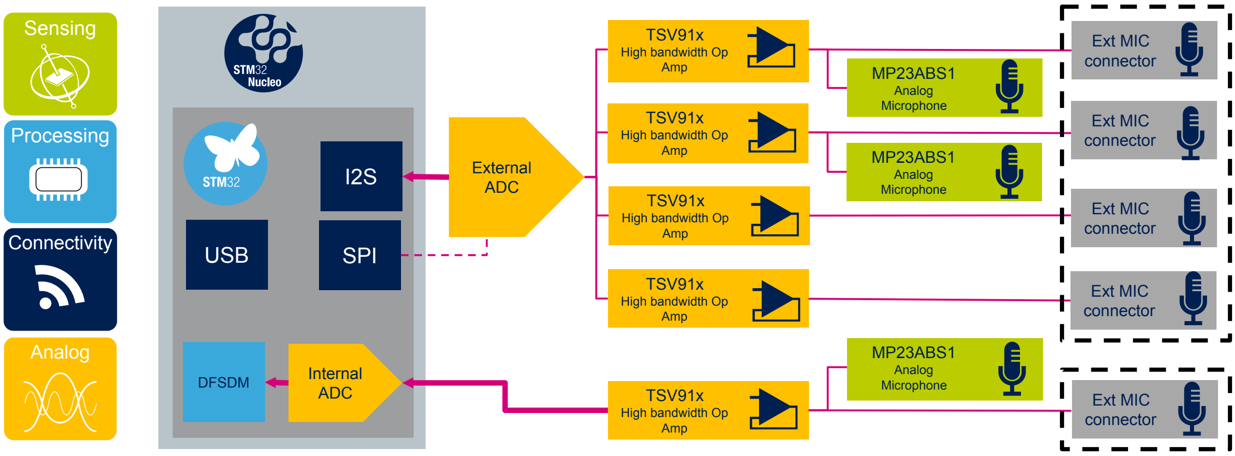
2.5.1.2 Analog MEMS microphone acquisition strategy

The X-NUCLEO-AMICAM1 expansion board implements an amplification stage for each microphone, based on TSV91x operational amplifiers, and allows microphone recording using either a dedicated third-party external analog to digital converter, mounted on-board, or the embedded STM32 ADC.

Two different solutions are implemented on the X-NUCLEO-AMICAM1 expansion board to allow MP23ABS1 evaluation in different scenarios:

- a low power and low cost solution using STM32 embedded ADC and TSV912 operational amplifier
- the use of a third party external ADC and TSV914 amplifier

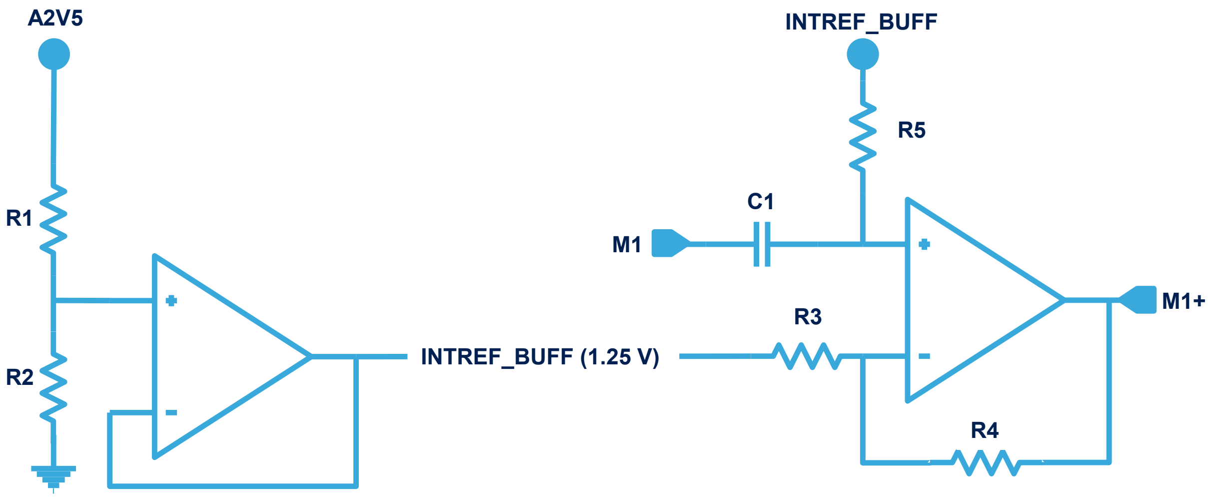
Figure 4. **X-NUCLEO-AMICAM1 expansion board block diagram**



2.5.1.2.1 Amplification stage and signal acquisition - internal ADC

The STM32 analog to digital converter is used in single ended configuration: the microphone signal, in this case, is amplified around a common mode which is equal to half the VREF provided to the STM32 analog supply input (for further details on the power scheme, see Figure 22. X-NUCLEO-AMICAM1 expansion board: power supply scheme).

Figure 5. **X-NUCLEO-AMICAM1 expansion board: amplification of a single microphone**



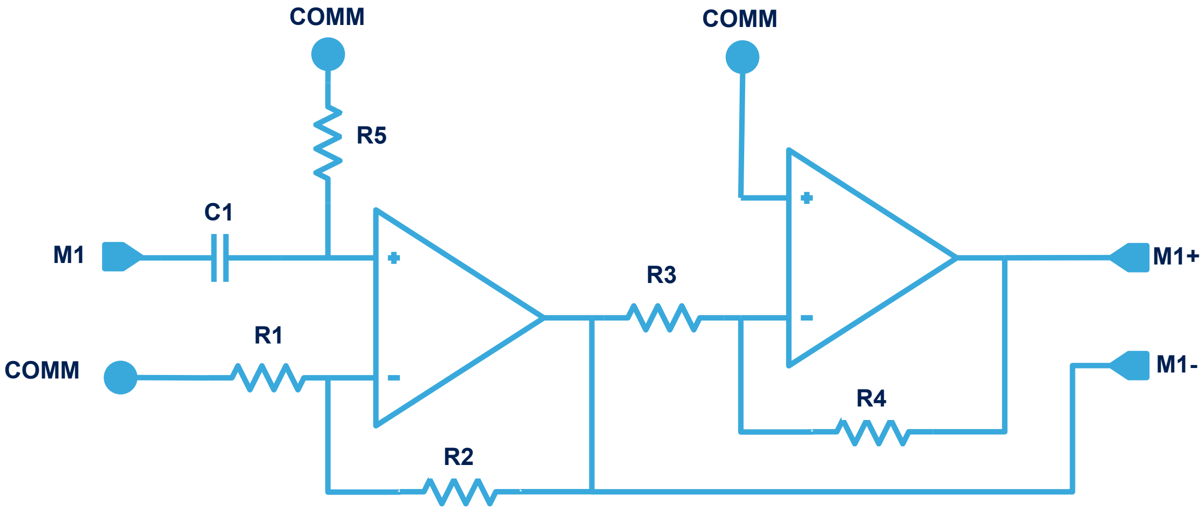
The first operational amplifier is used as a buffer for the bias signal generated by a voltage divider (with R1 equal to R2); the second one adds a gain equal to $1 + \frac{R4}{R3}$ to the microphone signal which is then routed to the STM32 ADC.

Depending on the STM32 Nucleo development board, different ADC configurations are possible, enabling several acquisition strategies which may include oversampling, filtering and decimation using DFSDM hardware peripheral to gain in SNR and bit depth.

2.5.1.2.2 Amplification stage and signal acquisition - external ADC

The adopted third party analog to digital converter has a differential interface: the microphone amplification stage performs both gain addition and single to differential conversion to exploit the ADC dynamics.

Figure 6. **X-NUCLEO-AMICAM1 expansion board: amplification and conversion to differential**



The first operational amplifier adds a gain equal to $1 + \frac{R2}{R1}$, while the second one, configured in inverting configuration with R3 equal to R4, simply adds a phase shift of 180 degrees to the amplified signal.

The COMM represents the bias provided by the external ADC, which is controlled by an SPI interface, and microphone data are acquired by the STM32 through an I²S interface.

2.5.2 Application description

When digital MEMS microphones are used (X-NUCLEO-CCA02M2), the application example acquires the PDM outputs from the MEMS microphones, converts them into PCM format and streams the resulting signal to a host PC via USB. PDM to PCM conversion is performed using a software library when the system is based on I²S plus SPI or when using SAI peripheral; in other cases, DFSDM dedicated hardware is adopted. Synchronized acquisition of one microphones is possible by configuring the solder bridges appropriately.

PDM and PCM data is available in the application before being sent to the USB to facilitate the development and testing of microphone-based audio processing algorithms.

STM32 I²S, SPI, SAI, or DFSDM devices used for microphones acquisition are set up depending on the sampling frequency and number of channels. If available, the DFSDM peripheral is used to acquire up to four channels; otherwise, PDM signals are acquired through SAI (up to four microphones), I²S (up to 2 microphones) or both I²S and SPI peripherals (up to four microphones). Moreover, the USB driver is initialized and the relative descriptor is configured to match the correct channels and sample frequency configuration.

When analog MEMS microphones are used (X-NUCLEO-AMICAM1, STEVAL-STWINMAV1 and STEVAL-STWINMA2), the application example acquires the output signals from the internal or external ADC and streams the resulting signal to a host PC via USB.

Depending on the ADC selected and on the number of channels, the application sets up DFSDM (external ADC up to four channels), I²S (external ADC up to 2 channels) or SPI (external ADC up to four channels) peripheral.

After the configuration phase, acquisition begins and the device streams the signals to a host device as a standard multichannel USB microphone.

Note: The STEVAL-STWINKT1B contains a digital MEMS microphone (IMP34DT05) and an analog MEMS microphone (IMP23ABSU). IMP34DT05 is acquired through the DFSDM peripheral. IMP23ABSU is acquired through an internal ADC and the DFSDM peripheral.

Note: The positions of solder bridges and jumpers must be compliant with the desired microphone configuration; refer to Section 3.1.2 X-NUCLEO-CCA02M2 expansion board and Section 3.1.3 X-NUCLEO-AMICAM1 expansion board for more hardware setup details.

The audio-related firmware components are mainly concentrated in the `audio_application.c` and `usb_audio_if.c` files, which employ the dedicated X-NUCLEO-CCA02M2 or X-NUCLEO-AMICAM1 BSP layer and, when necessary, the PDM-to-PCM decimation library middleware. In this version, STM32 peripheral setup via the BSP layer is driven by the USB driver to allow total device control from the host PC. A different approach could be used to decouple USB and BSP functions by removing BSP functions from the USB interface file (`usb_audio_if.c`) and calling them in the application itself.

To set up the system for microphone acquisition and streaming (you can trace them in the application):

- check the HW configuration for solder bridges and jumpers (see Section 3.1.2 X-NUCLEO-CCA02M2 expansion board or Section 3.1.3 X-NUCLEO-AMICAM1 expansion board)
- initialize USB descriptor using `USBD_AUDIO_Init_Microphone_Descriptor(…)` according to the number of channels to be streamed
- initialize USB core and start USB functionalities with the functions: `USBD_Init(…)`, `USBD_RegisterClass(…)`, `USBD_AUDIO_RegisterInterface(…)`, `USBD_Start(…)`. This allows the device to be recognized as a standard USB microphone with the requested configuration
- All the required peripherals and middleware must be configured depending on the number of channels to be streamed and the desired sampling frequency to be achieved; these steps are performed inside the `usbd_audio_if.c` file, whose functions are called in response to the USB operations that start when the device is connected to the PC (enumeration, dataInput, etc.). The following BSP functions are used:
  - BSP Initialization: initializes the hardware peripherals and the PDM library, when necessary and depending on the desired acquisition settings
  - BSP Record: starts acquisition; a double buffer mechanism is implemented and an interrupt is generated every millisecond to allow data processing
  - BSP Stop: stops data acquisition
- The interrupt service routine for audio data acquisition is implemented as a callback in the `audio_application.c` file (`CCA02M1/CCA02M2/AMICAM1_AUDIO_IN_TransferComplete_CallBack(…)`). When using X-NUCLEO-CCA02M2 expansion board with P-NUCLEO-WB55, NUCLEO-F401RE or NUCLEO-F746ZG development boards, the software PDM-to-PCM conversion is performed; the BSP layer provides a millisecond of PDM data, demuxed and arranged as required by the decimation library.
  When using X-NUCLEO-CCA02M2 expansion board with NUCLEO-L476RG, PDM-to-PCM conversion is handled by hardware and the BSP layer provides the application PCM data, arranged as a standard multichannel PCM stream.
  When using X-NUCLEO-AMICAM1 expansion board, the BSP layer provides the output data from the proper STM32 peripheral, selected on the basis of the ADC used, and arranges it as a standard multichannel PCM stream.
  The user can modify this function, for example, to add DSP functions to the audio before sending it to USB via data transfer function.
  For further information about USB APIs, refer to the compiled HTML file located in the ‘Documentation’ folder.

Alternatively, configuration and initialization of the audio peripherals can be managed independently of the USB flow by directly calling the audio-related BSP functions from the application space. In this case, the user calls the BSP Initialization, Record and Stop functions as needed.

Note: Depending on the MCU used and the corresponding available resources, not all channels/sampling frequency combinations are allowed.

The configurations supported by each STM32 Nucleo board are:

- NUCLEO-L476RG: 1, 2 or 4 microphone acquisition and streaming at 8 kHz, 16 kHz, 32 kHz, 48 kHz or 96 kHz; 1 or 2 microphones at 192 KHz only when using X-NUCLEO-AMICAM1;
- P-NUCLEO-WB55, NUCLEO-F401RE or NUCLEO-F746ZG available only for X-NUCLEO-CCA02M2: 1, 2 or 4 microphone acquisition and streaming at 8 kHz, 16 kHz, 32 kHz or 48 kHz;
- STEVAL-STWINMAV1, STEVAL-STWINMA2 and NUCLEO-L4R5ZI (available only for X-NUCLEO-AMICAM1): 1, 2 or 4 microphone acquisition and streaming at 8 kHz, 16 kHz, 32 kHz, 48 kHz or 96 kHz; 1 or 2 microphones at 192 kHz;
- STEVAL-STWINKT1B: digital microphone acquisition and streaming at 8 kHz, 16 kHz, 32 kHz or 48 kHz; analog microphone acquisition and streaming at 8 kHz, 16 kHz, 32 kHz, 48 kHz, 96 kHz and 192 kHz.

2.6 AcousticBF example

The application is designed to acquire the two microphones soldered on the X-NUCLEO-CCA02M2 board, perform beamforming and stream two audio channels to a host PC via USB.

The audio streams contain:

- the algorithm output (first channel)
- an omnidirectional microphone as a reference (second channel)

Note: The positions of solder bridges and jumpers must be compliant with the 2 microphones configuration when using I²S (refer to Section 3.1.2 X-NUCLEO-CCA02M2 expansion board for more hardware setup details).

The application performs this sequence of operations:

- initializes and starts the USB audio input driver and middleware: this allows a host PC to recognize the device as a standard multichannel USB microphone
- initializes microphone acquisition using the relevant BSP function
- initializes the AcousticBF library
- starts the audio acquisition to trigger the library execution
- transmits processed data and the omnidirectional microphone reference to the USB driver every millisecond

The audio-related firmware components are mainly located in the `audio_application.c` and `usb_audio_if.c` files, which employ the dedicated X-NUCLEO-CCA02M2 BSP layer and the AcousticBF middleware.

USB and microphones initialization are the same as shown in Section 2.5.2 Application description.

Further details about the library API can be found in the chm help file in the Documentation folder.

Note: This application is supported by the X-NUCLEO-CCA02M2 expansion board when connected to a NUCLEO-F401RE and by the X-NUCLEO-AMICAM1 expansion board connected to a NUCLEO-L4R5ZI development board.

2.7 AcousticSL example

The application is designed to perform:

- acquisition of the four external microphones mounted on the X-NUCLEO-CCA02M2 board or acquisition of the four microphones mounted on the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards for the STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit
- acquisition of the two on-board microphones available on the X-NUCLEO-AMICAM1 expansion board
- sound source localization running based on those signals
- output of the localization result through the ST-LINK embedded virtual COM port
- streaming of two or four audio channels to a host PC via the STEVAL-STWINKT1B (and STEVAL-STWINKT1) , X-NUCLEO-AMICAM1 or the X-NUCLEO-CCA02M2 board and USB connector

Note: The position of solder bridges and jumpers must be compliant with the 4 microphones configuration when using I²S and SPI (refer to Section 3.1.2 X-NUCLEO-CCA02M2 expansion board for more hardware setup details).

The application performs this sequence of operations:

- initializes and starts the USB audio input driver and middleware: this allows a host PC to recognize the device as a standard multichannel USB microphone
- initializes microphone acquisition using the relevant BSP function
- initializes the AcousticSL library
- starts the audio acquisition to trigger the library execution
- transmits the two or four omnidirectional microphone streams to the USB driver every millisecond
- sends the AcousticSL results to a host PC on each library running cycle through ST-LINK VCP.

The audio-related firmware components are mainly concentrated in the `audio_application.c` and `usb_audio_if.c` files, which employ the dedicated STEVAL-STWINMAV1, STEVAL-STWINMA2, X-NUCLEO-AMICAM1 and X-NUCLEO-CCA02M2 BSP layer and the AcousticSL middleware.

USB and microphones initialization are the same as shown in Section 2.5.2 Application description.

Further details about the library API can be found in the chm help file in the Documentation folder.

Note: This application is supported by the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards for STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit, by the X-NUCLEO-AMICAM1 expansion board connected to a NUCLEO-L4R5ZI board and the X-NUCLEO-CCA02M2 expansion board when connected to a NUCLEO-F401RE.

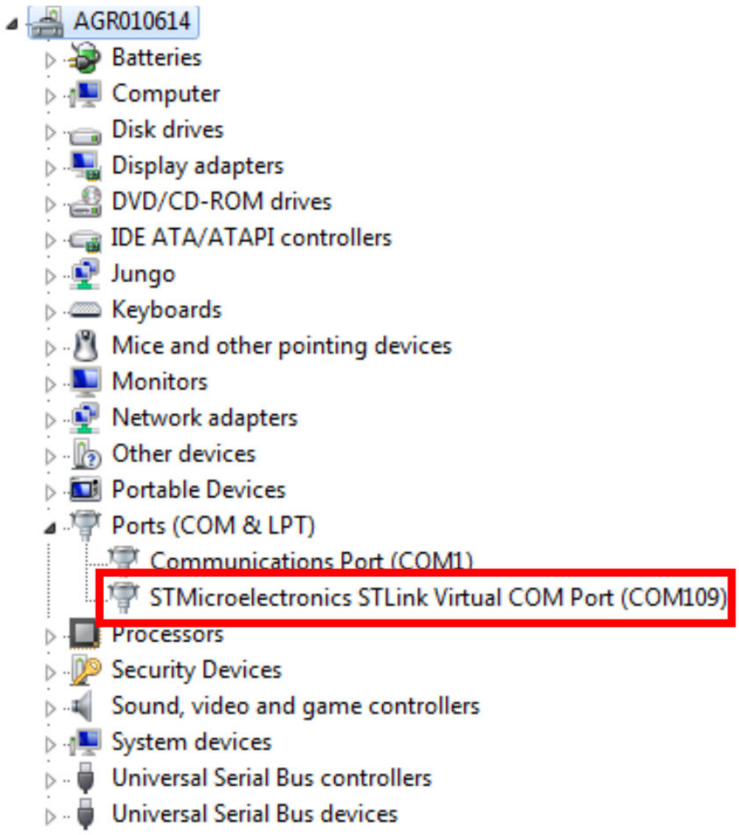
2.7.1 Program execution example

A third party serial communication software is required to be able to collect localization values. One possible solution is the free Putty software available at: http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html.

To set up the demo:

Step 1. Connect the NUCLEO-F401RE mini USB cable (USB type A to mini-B USB cable), the NUCLEO-L4R5ZI or the STLINK-V3MINI micro USB cable

Figure 7. **STLink Virtual COM port detection**



Step 2. Check the COM Port number assigned to the board in Windows Device Manager

Step 3. Open the serial utility and ensure the connection parameters are set to:
– Baudrate: 115200 for NUCLEO-L4R5ZI, 9600 for others
– Data bits: 8
– Stop bits: 1
– Parity: none
– Flow control: none

Step 4. Open the COM port

The localization results are shown.

Note: *Below a certain audio energy threshold, the library is not executed; in this case, localization is not computed and nothing is sent to the VCP.*

To record audio through the device, you need to install a third party software such as Audacity® freeware program to save or play the streamed signal.
Further information about Audacity® can be found at: http://audacityteam.org/?lang=en.

2.8 UltrasoundFFT

The UltrasoundFFT example calculates the FFT of the MP23ABS1 analog microphone available on the X-NUCLEO-AMICAM1 and on the STEVAL-STWINMAV1, or of the IMP23ABSU analog microphone available on the STEVAL-STWINKT1B (and STEVAL-STWINKT1) and STEVAL-STWINMA2. Then, it streams the result to a PC GUI (available in 'Utilities/UltrasoundFFT') via USB. The microphone sampling rate is set by default to 192 kHz whereas the microphone bandwidth is up to 80 kHz.

Thanks to the very high sampling frequency available, the application can be used to perform condition analysis in the ultrasound frequency domain on any kind of machinery.

After the startup sequence, the board is in idle state, waiting for the 'start' command from the PC GUI.

When the PC sends the command to the STEVAL-STWINKT1B (and STEVAL-STWINKT1) board through USB, the STM32 starts calculating and streaming the audio FFT values. Power Spectrum Density is plotted into the GUI and the user can choose thresholds in both energy and frequency ranges to easily find out the maximum energy bin.

Figure 8. UltrasoundFFT - power spectrum density vs. frequency

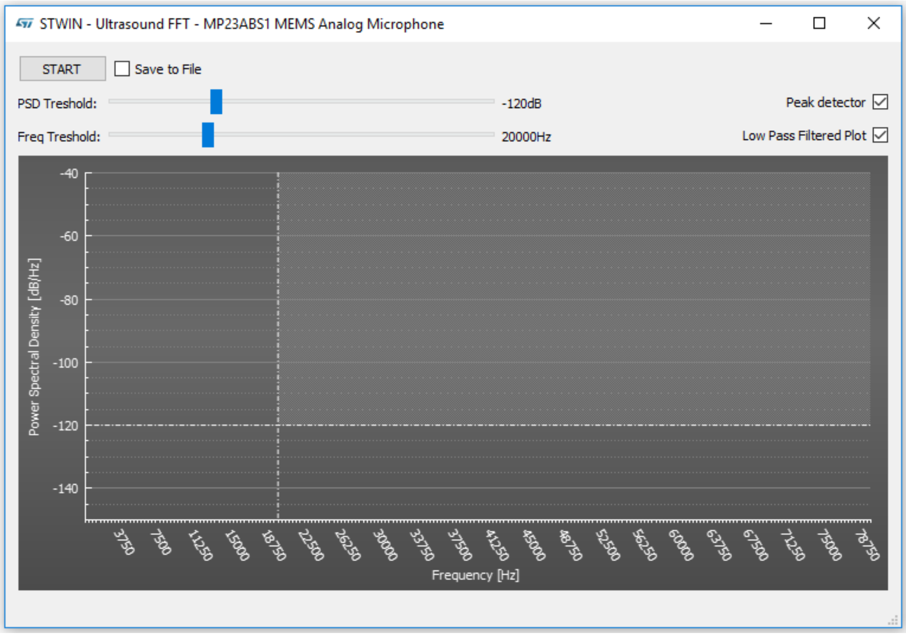
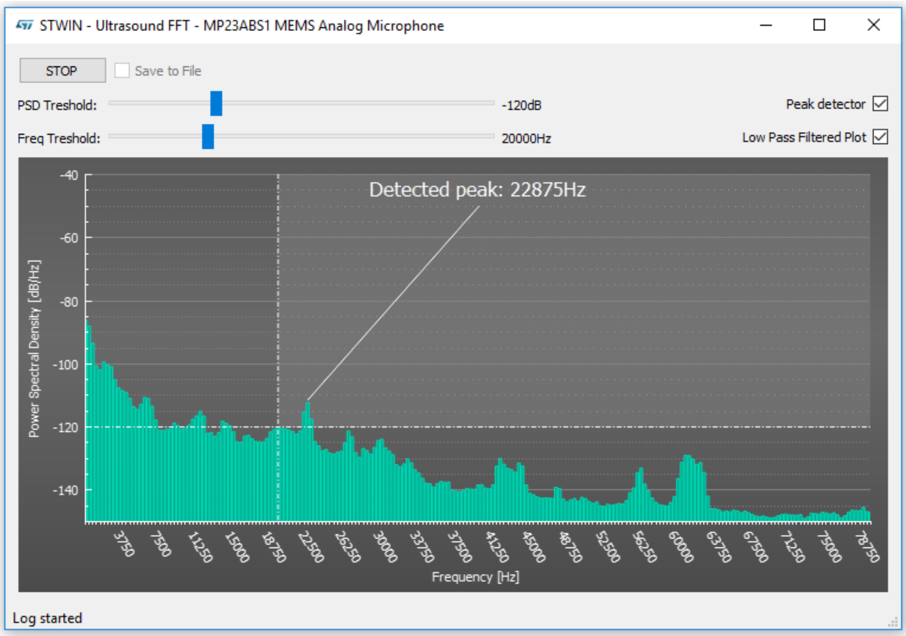


Figure 9. UltrasoundFFT - maximum energy bin



Through the GUI it is also possible to store the FFT values into a raw data file by checking the flag 'Save to file'. Files are saved in the folder 'Acquisition'; the file name is 'YYYYMMDD_HHMMSS.dat' (i.e: 20200117_155823.dat)

Figure 10. **UltrasoundFFT - save raw data**

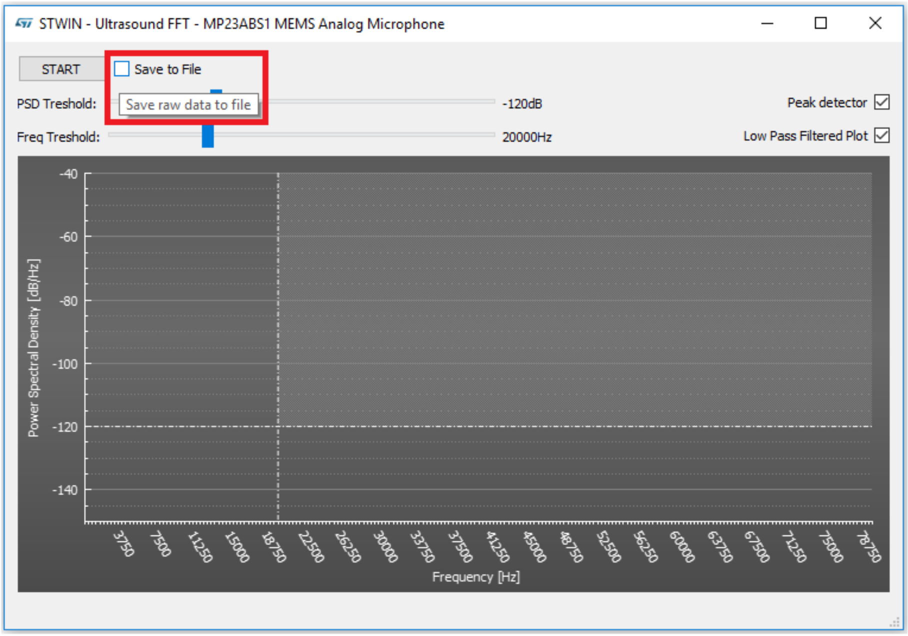
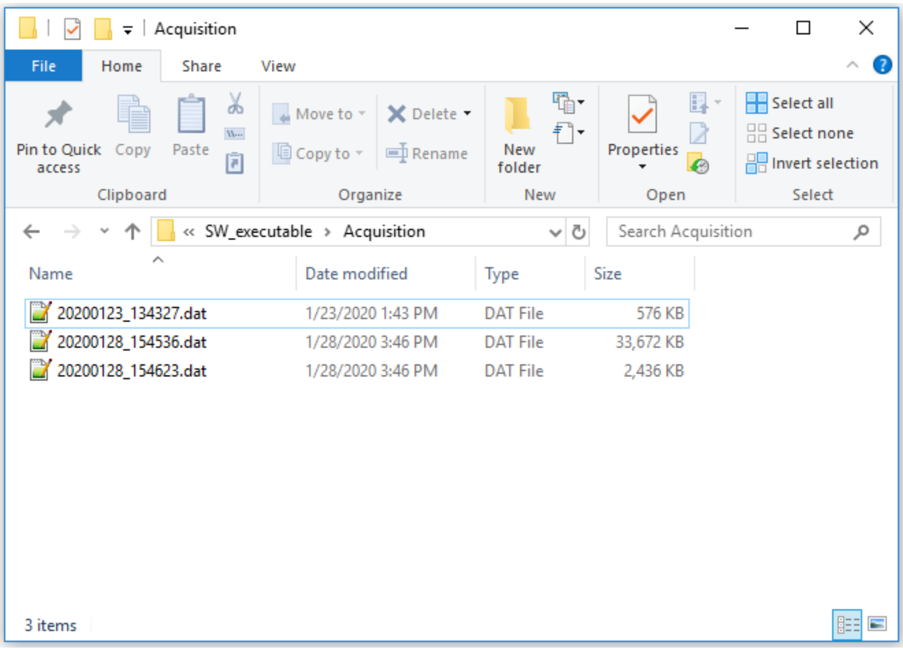


Figure 11. **FFT values saved into a raw data file**



The folder 'Utilities/UltrasoundFFT' contains also a Matlab and a Python scripts called 'ReadFFT' to plot the spectrogram of the data saved into the 'Acquisition' folder.

'ReadFFT.py' has been tested using Python 3.7 on Linux and Windows 10 (Anaconda environment).

'ReadFFT.m' has been tested using MATLABv2019a.

Note: This application is supported by the STEVAL-STWINMAV1 and STEVAL-STWINMA2 microphone array expansion boards, the STEVAL-STWINKT1B (and STEVAL-STWINKT1) development kit, and the X-NUCLEO-AMICAM1 expansion board connected to a NUCLEO-L4R5ZI or NUCLEO-L476RG development board.

2.9 PC audio recording utility example: Audacity

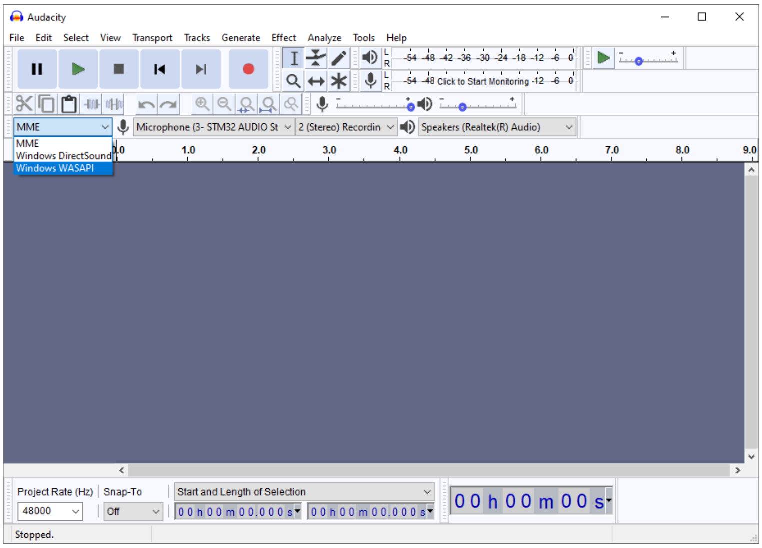
This section describes the use of the Audacity® application for multi-channel audio recording.

Audacity is a free, open source, cross-platform software package for recording and editing sounds and is available for Windows®, iOS®, GNU/Linux® other operating systems as a freeware audio editing environment (https://sourceforge.net/projects/audacity/).

By default, Audacity can support up to two microphones using MME host interface and up to four microphones using Windows WASAPI host interface. MME also allows handling the microphone gain inside the application.

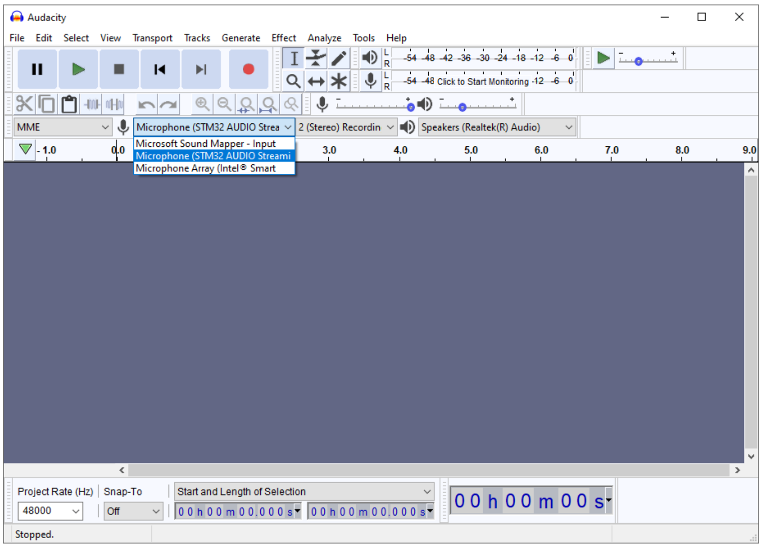
You can select the proper interface by clicking on the top-left widget. We recommend using MME to record one or two audio signals and to switch to Windows WASAPI only to record four microphones.

Figure 12. Audio host selection



As described in Section 3.3.5.2, once the board has been plugged to the PC, Windows automatically recognizes it as a USB microphone called "STM32 AUDIO Streaming in FS mode".

Figure 13. Device selection

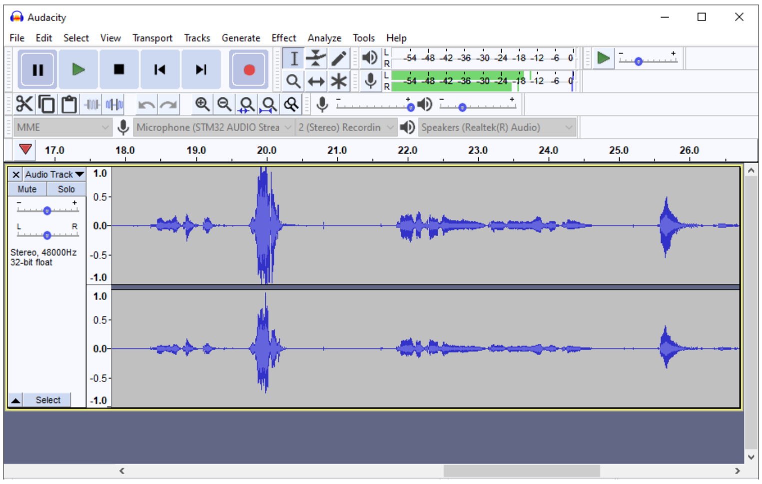


Windows installs the proper USB driver only the first time the board is plugged. So, if you rebuild the application changing the number of microphones or the sampling frequency or if you are experiencing some issues using Audacity, you should stop the Audacity recording, close the program, cancel the audio drivers and let Windows automatically reinstall it. See Section 3.3.5.2 for the full procedure.

Once the USB drivers have been properly installed, reopen Audacity to start recording.

To start audio recording, ensure that STM32 AUDIO Streaming in FS mode is the selected audio input device and proceed to record and play audio using from the interface shown below.

Figure 14. Audacity for Windows



3 System setup guide

3.1 Hardware description

3.1.1 STM32 Nucleo

STM32 Nucleo development boards provide an affordable and flexible way for users to test solutions and build prototypes with any STM32 microcontroller line.

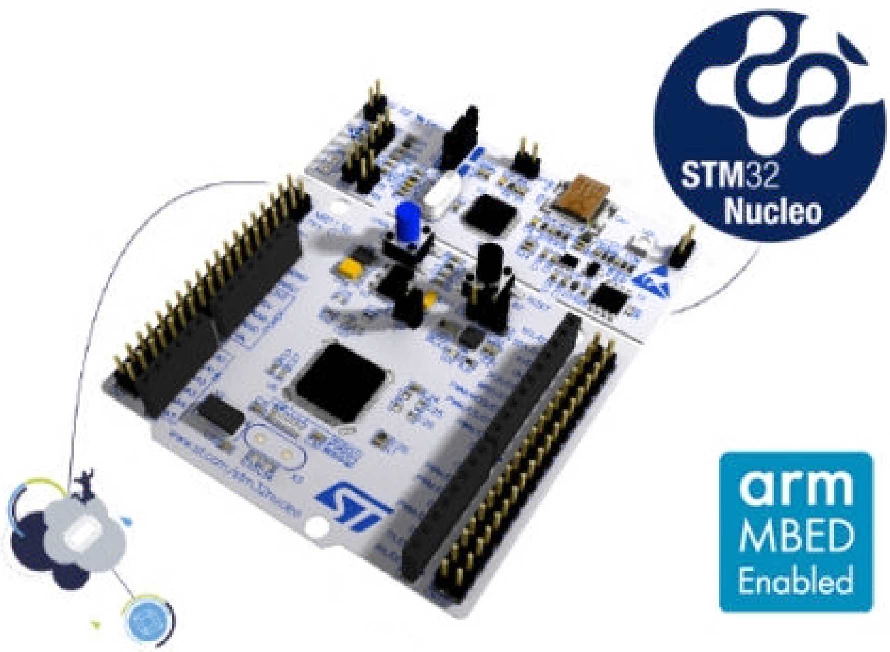
The Arduino connectivity support and ST morpho connectors make it easy to expand the functionality of the STM32 Nucleo open development platform with a wide range of specialized expansion boards to choose from.

The STM32 Nucleo board does not require separate probes as it integrates the ST-LINK/V2-1 debugger/ programmer.

The STM32 Nucleo board comes with the comprehensive STM32 software HAL library together with various packaged software examples for different IDEs (IAR EWARM, Keil MDK-ARM, STM32CubeIDE, mbed and GCC/ LLVM).

All STM32 Nucleo users have free access to the mbed online resources (compiler, C/C++ SDK and developer community) at www.mbed.org to easily build complete applications.

Figure 15. STM32 Nucleo board



3.1.2 X-NUCLEO-CCA02M2 expansion board

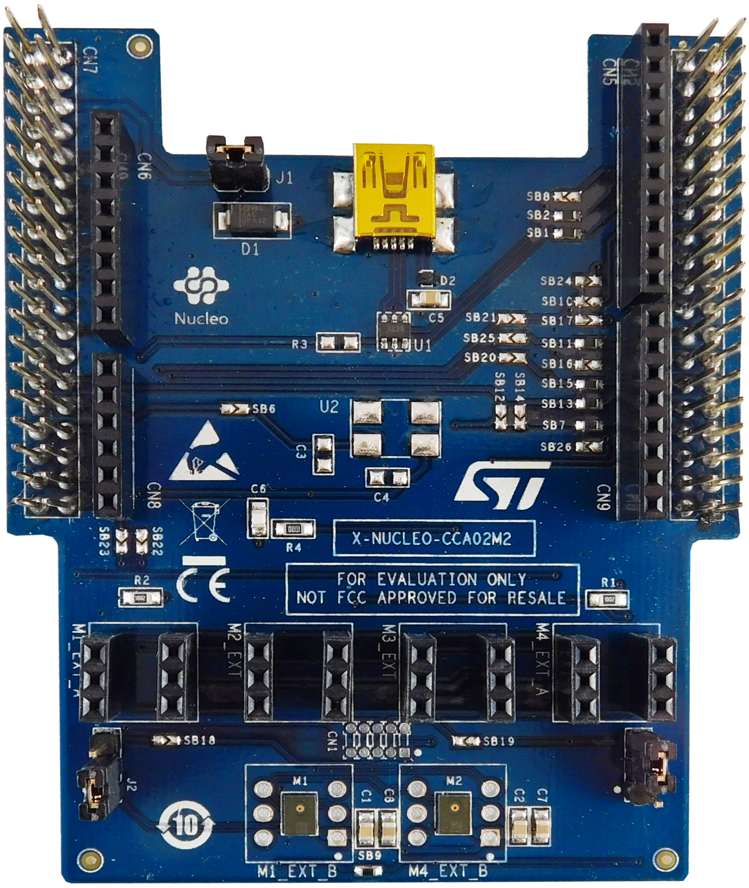
The X-NUCLEO-CCA02M2 expansion board has been designed around MP34DT06J digital MEMS microphone.

It is compatible with the ST morpho connector layout and with digital microphone coupon boards such as STEVAL-MIC001V1, STEVAL-MIC002V1 and STEVAL-MIC003V1.

The X-NUCLEO-CCA02M2 embeds two MP34DT06J microphones and allows synchronized acquisition and streaming of up to 4 microphones through I²S, SPI, DFSDM or SAI peripherals.

It represents a quick and easy solution for the development of microphone-based applications as well as a starting point for audio algorithm implementation.

Figure 16. **X-NUCLEO-CCA02M2 expansion board**



3.1.3 X-NUCLEO-AMICAM1 expansion board

The X-NUCLEO-AMICAM1 expansion board allows synchronized acquisition and streaming of up to 4 microphones at a maximum sampling rate of 192 KHz.

It represents a quick and easy solution to develop microphone-based applications and start implementing audio algorithms.

The expansion board is designed around the MP23ABS1 analog MEMS microphone and is compatible with the ST morpho connector layout and with analog microphone coupon boards (e.g., STEVAL-MIC004V1).

The X-NUCLEO-AMICAM1 embeds three MP23ABS1 microphones: two connected to an external ADC and one directly routed to the STM32 embedded ADC.

The analog amplification stage is achieved thanks to ST TSV91x wide bandwidth operational amplifiers.

Figure 17. X-NUCLEO-AMICAM1 expansion board

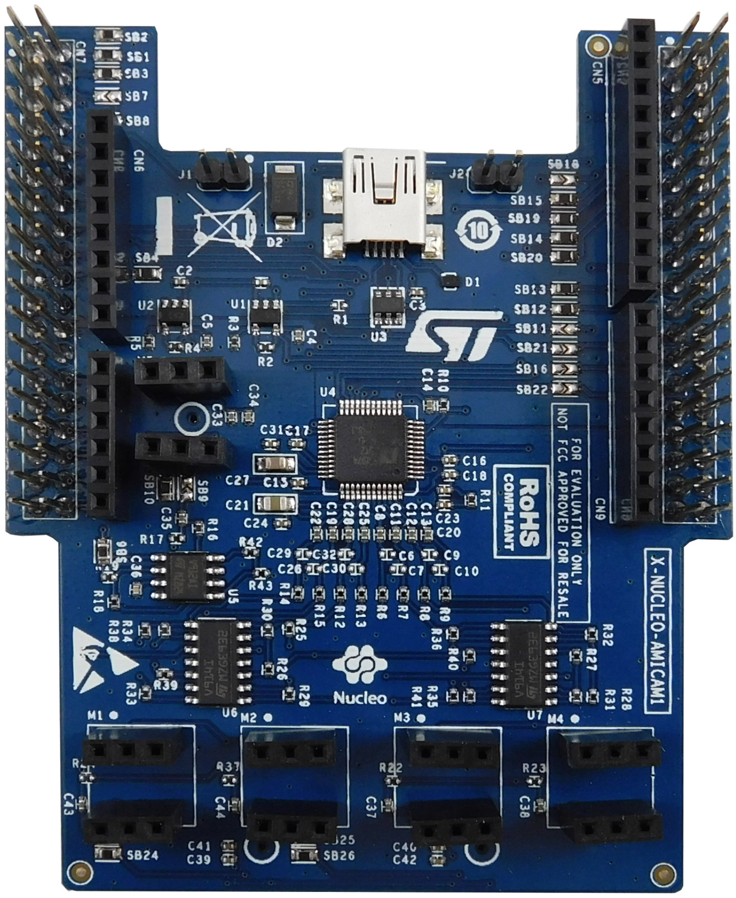
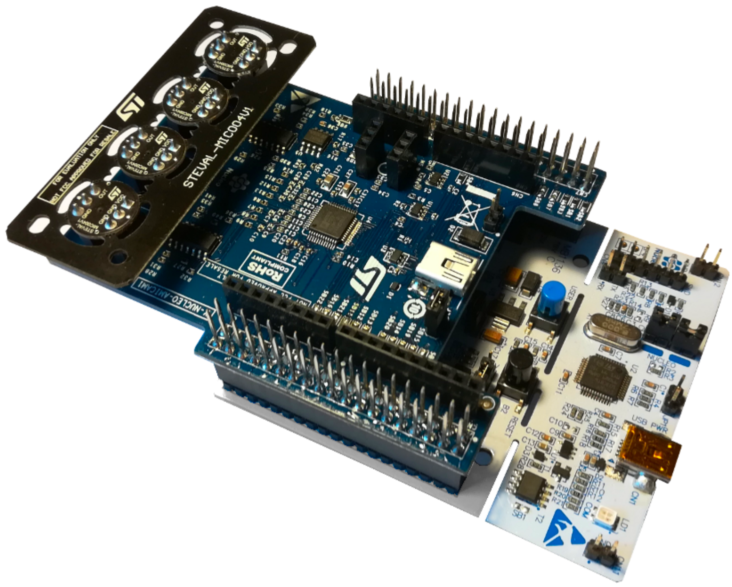


Figure 18. X-NUCLEO-AMICAM1, STM32 Nucleo and STEVAL-MIC004V1 stack



3.1.4 STEVAL-STWINKT1 and STEVAL-STWINKT1B development kit

The STWIN SensorTile wireless industrial node (STEVAL-STWINKT1B and STEVAL-STWINKT1) is a development kit and reference design that simplifies prototyping and testing of advanced industrial IoT applications such as condition monitoring and predictive maintenance.

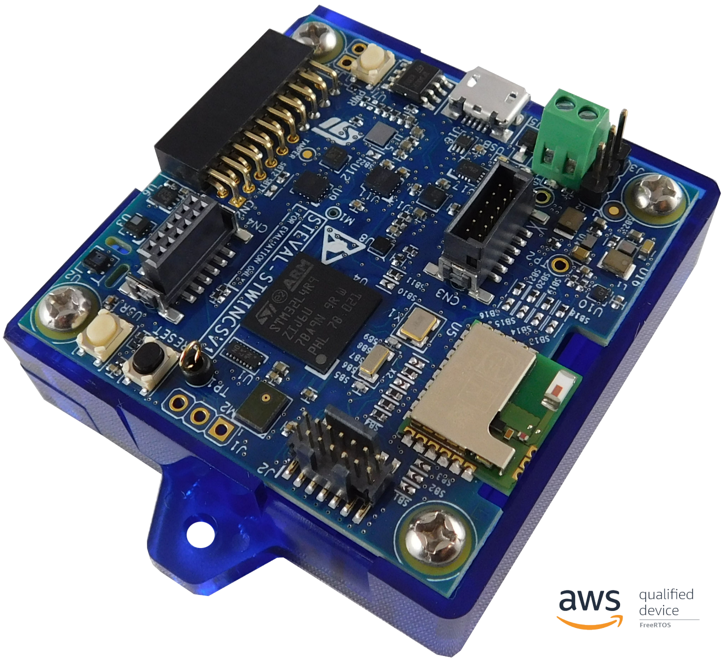
The kit features a core system board with a range of embedded industrial-grade sensors and an ultra-low-power microcontroller for vibration analysis of 9-DoF motion sensing data across a wide range of vibration frequencies, including very high frequency audio and ultrasound spectra, and high precision local temperature and environmental monitoring.

The development kit is complemented with a rich set of software packages and optimized firmware libraries, as well as a cloud dashboard application, all provided to help speed up design cycles for end-to-end solutions.

The kit supports BLE wireless connectivity through an on-board module, and Wi-Fi connectivity through a special plugin expansion board (STEVAL-STWINWFV1). Wired connectivity is also supported via an on-board RS485 transceiver. The core system board also includes an STMod+ connector for compatible, low cost, small form factor daughter boards associated with the STM32 family, such as the LTE Cell pack.

Apart from the core system board, the kit is provided complete with a 480 mAh Li-Po battery, an STLINK-V3MINI debugger and a plastic box.

Figure 19. **STEVAL-STWINKT1B SensorTile Wireless Industrial Node**



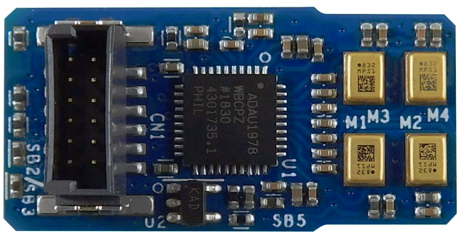
3.1.5 STEVAL-STWINMAV1 microphone array expansion

The STEVAL-STWINMAV1 microphone array expansion adds advanced audio sensing capabilities to the STEVAL-STWINKT1B (and STEVAL-STWINKT1) SensorTile Wireless Industrial Node (STWIN) kit for high frequency vibration monitoring applications.

The board includes four low-power, high signal-to-noise ratio (SNR) MP23ABS1 capacitive sensing microphones, supported by a very low drop voltage, low quiescent current and low-noise voltage regulator ideal for battery-powered applications such as STWIN.

The expansion board is connected via a dedicated 12-pin connector to the core system board, which runs the STSW-STWINKT01 firmware with dedicated BSP drivers and application examples for you to test and develop vibration monitoring in the ultrasound frequency ranges.

Figure 20. **STEVAL-STWINMAV1 microphone array expansion**



3.1.6 STEVAL-STWINMA2 microphone array expansion

The STEVAL-STWINMA2 microphone array expansion adds advanced audio sensing capabilities to the STEVAL-STWINKT1B (and STEVAL-STWINKT1) SensorTile Wireless Industrial Node (STWIN) kit for high frequency vibration monitoring applications.

The board includes four low-power, high signal-to-noise ratio (SNR) IMP23ABSU capacitive sensing microphones, supported by a very low drop voltage, low quiescent current, and low-noise voltage regulator, ideal for battery-powered applications such as STWIN.

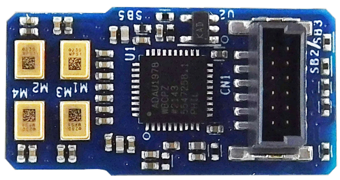
The expansion board is connected via a dedicated 12-pin connector to the core system board.

The combination of STWIN and STEVAL-STWINMA2 is supported thanks to the software examples provided within the X-CUBE-MEMSMIC1 expansion software package for STM32Cube.

The package includes one example of microphone data steaming via USB and one example of ultrasound condition monitoring (UltrasoundFFT) that calculates the FFT of the analog microphone signal and streams the result to a PC GUI via USB.

The microphone sampling rate is set by default to 192 kHz whereas the microphone bandwidth is up to 80 kHz.

Figure 21. STEVAL-STWINMA2 board



3.2 Software description

The following software components are needed in order to set up the development environment for creating applications for the STM32 Nucleo equipped with a MEMS microphone expansion board:

- X-CUBE-MEMSMIC1: an STM32Cube expansion for audio application development; the X-CUBE-MEMSMIC1 firmware and related documentation is available on st.com
- development tool-chain and compiler: the STM32Cube expansion software supports the following environments:
  - IAR Embedded Workbench for ARM® (EWARM) toolchain + ST-LINK
  - RealView Microcontroller Development Kit (MDK-ARM-STR) toolchain + ST-LINK
  - STM32CubeIDE + ST-LINK

3.3 Hardware and software setup

This section describes the hardware and software setup procedures, and the corresponding system setup.

3.3.1 Hardware setup

The following hardware components are needed:

1. an STM32 Nucleo development platform (suggested order code: NUCLEO-F401RE or NUCLEO-L476RG)
2. a microphone expansion board (order code: X-NUCLEO-CCA02M2 or X-NUCLEO-AMICAM1)
3. a USB type A to Mini-B USB cable to connect the STM32 Nucleo to the PC
4. a USB type A to Mini-B USB cable to connect the X-NUCLEO-CCA02M2 or X-NUCLEO-AMICAM1 to the PC for USB streaming

3.3.2 External microphone connection

The X-NUCLEO-CCA02M2 expansion boards are designed to support up to four external digital microphones based on the ST coupon daughterboard concept (part number: STEVAL-MIC001V1, STEVAL-MIC002V1 and STEVAL-MIC003V1).

For this purpose, four headers (`M1_EXT_A`, `M2_EXT`, `M3_EXT`, `M4_EXT_A`) allow operation along a linear array concept. Footprints for additional headers (`M1_EXT_B` and `M4_EXT_B`) can be used as an alternative to `M1_EXT_A` and `M4_EXT_A` to create a square-shaped microphone array.

Attention: *M1_EXT_A, M1_EXT_B and M4_EXT_A, M4_EXT_B share the same signals, so be careful not to plug both M4_EXT_A and M4_EXT_B or M1_EXT_A and M1_EXT_B at the same time to avoid possible microphone damage.*

On the X-NUCLEO-AMICAM1 expansion board five slots are available to plug an analog microphone coupon board in (e.g. STEVAL-MIC004V1). The expansion board allows synchronized acquisition and streaming of up to 4 microphones

3.3.3 Jumper configuration for X-NUCLEO-CCA02M2

The X-NUCLEO-CCA02M2 expansion board offers various solutions for microphone acquisition and USB streaming. Depending on your needs, you can choose to acquire on-board microphones or external microphones from one to four channels.

In this section, we analyze specific use cases together with the corresponding solder bridge configurations based on the acquisition peripherals involved. Custom setups are also possible for ad-hoc functions.

Note: SB1, SB2, SB6 are reserved for the USB or oscillator pins and are not involved in the audio acquisition process.

3.3.3.1 Jumper settings for DFSDM-based systems

1 or 2 microphone acquisition

The clock is generated by DFSDM peripheral and the PDM line of the first and second microphone is routed to the MCU.

Table 2. X-NUCLEO-CCA02M2: solder bridge configuration for 1 or 2 microphone acquisition

Solder bridge	Status
SB7	Open
SB8	Open
SB9	Open/closed
SB10	Open
SB11	Open
SB12	Close
SB13	Open
SB14	Open
SB15	Open
SB16	Close
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Open
SB25	Open
SB26	Open

Note: J2 must be placed in position 1-2 for on-board microphone acquisition or 2-3 when using an external microphone while J3 must be left open. When acquiring on-board microphones, close SB9 to acquire both of them.

4 microphone acquisition

The PDM line of the third and fourth microphone is also routed to the MCU.

Table 3. **X-NUCLEO-CCA02M2: solder bridge configuration for 4 microphone acquisition**

Solder bridge	Status
SB7	Open
SB8	Open
SB9	Open
SB10	Open
SB11	Open
SB12	Close
SB13	Open
SB14	Open
SB15	Open
SB16	Close
SB17	Close
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Open
SB25	Open
SB26	Open

Note: J2 and J3 must be placed in position 2-3 for external microphone acquisition.

3.3.3.2 *Jumper settings for I²S-plus-SPI-based systems*

1 microphone acquisition

The I²S peripheral is used directly to give the right clock to the microphone and to acquire the same microphone.

Table 4. **X-NUCLEO-CCA02M2: solder bridge configuration for 1 microphone acquisition**

Solder bridge	Status
SB7	Open
SB8	Open
SB9	Open
SB10	Open
SB11	Closed
SB12	Open
SB13	Closed
SB14	Closed
SB15	Open
SB16	Open
SB17	Open
SB18	Open
SB19	Open

Solder bridge	Status
SB20	Open
SB21	Open
SB24	Open
SB25	Open
SB26	Open

Note: J2 must be placed in position 1-2 for on-board microphone acquisition or 2-3 when using an external microphone, while J3 must be left open. If using external microphones, do not plug anything in `M2_EXT` header.

2 microphone acquisition

The I²S peripheral is used to generate twice the frequency needed by the microphones. In this scenario, the clock is then halved by the timer and routed to the microphones to give them the right clock. I²S therefore reads values from both edges of the merged PDM lines.

Table 5. X-NUCLEO-CCA02M2: solder bridge configuration for 2 microphone acquisition

Solder bridge	Status
SB7	Closed
SB8	Open
SB9	Open /closed
SB10	Open
SB11	Closed
SB12	Open
SB13	Closed
SB14	Open
SB15	Closed
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Open
SB25	Open
SB26	Open

Note: J2 must be placed in position 1-2 for on-board microphone acquisition or 2-3 when using external microphones, while J3 must be left open. When acquiring on-board microphones, close SB9 to acquire both of them.

4 external microphone acquisition

The I²S peripheral is used to generate a clock frequency that is twice the frequency needed by the microphones, and SPI is configured in slave mode to use such timing. As in the previous case, the clock is then halved by the timer and routed to the microphones to give the right clock. I²S and SPI read values from both the edges of the merged PDM lines.

Table 6. **X-NUCLEO-CCA02M2: solder bridge configuration for 4 microphone acquisition**

Solder bridges	Status
SB7	Closed
SB8	Closed
SB9	Open
SB10	Closed
SB11	Closed
SB12	Open
SB13	Closed
SB14	Open
SB15	Closed
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Open
SB25	Open
SB26	Open

Note: J2 and J3 must be placed in position 2-3 for external microphone acquisition.

Note: Other configurations are available, based on the MCU used.

Note: When acquiring 4 microphones using a NUCLEO-F746ZG development board, JP6 jumper on the board must be opened.

3.3.3.3 *Jumper settings for SAI-based systems*

1 or 2 microphone acquisition

The clock is generated by SAI peripheral and the PDM line of the first and second microphone is routed to the MCU.

Table 7. **X-NUCLEO-CCA02M2: solder bridge configuration for 1 or 2 microphone acquisition**

Solder bridge	Status
SB7	Open
SB8	Open
SB9	Open/closed
SB10	Open
SB11	Open
SB12	Open
SB13	Open
SB14	Open
SB15	Open
SB16	Open

Solder bridge	Status
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Open
SB25	Closed
SB26	Closed

Note: *J2 must be placed in position 1-2 for on-board microphone acquisition or 2-3 when using an external microphone while J3 must be left open. When acquiring on-board microphones, close SB9 to acquire both of them.*

4 microphone acquisition

The PDM line of the third and fourth microphone is also routed to the MCU.

Table 8. X-NUCLEO-CCA02M2: solder bridge configuration for 4 microphone acquisition

Solder bridge	Status
SB7	Open
SB8	Open
SB9	Open/closed
SB10	Open
SB11	Open
SB12	Open
SB13	Open
SB14	Open
SB15	Open
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open
SB24	Closed
SB25	Closed
SB26	Closed

Note: *J2 and J3 must be placed in position 2-3 for external microphone acquisition.*

3.3.3.4 Board power supply jumper

The on-board USB connector supports audio streaming to the host PC and can also be used to power the wholesystem up, including the STM32 Nucleo development board, by:

- closing jumper J1 on the X-NUCLEO-CCA02M2 expansion board
- placing JP5 in position E5 on the STM32 Nucleo board

When a P-NUCLEO-WB55 or NUCLEO-F746ZG is used, a micro-USB OTG connector is available on the STM32 Nucleo.

Important: *Do not connect the expansion board connector and the development board connector to the PC simultaneously.*

3.3.3.5 USB connection solder bridges

The X-NUCLEO-CCA02M2 USB connector is connected to DM and DP pins of the STM32 Nucleo board through SB1 and SB2 solder jumpers. You have to close them if you want to use USB communication, otherwise you can leave them open.

When a P-NUCLEO-WB55 is used, to allow USB communication through the X-NUCLEO-CCA02M2 USB connector, SB2 and SB4 on the P-NUCLEO-WB55 bottom side must be closed.

When a P-NUCLEO-WB55 or NUCLEO-F746ZG is used, SB1 and SB2 can be left open and the micro USB OTG connector on the STM32 Nucleo board can be used to be connected to the PC.

3.3.4 Jumper configuration for X-NUCLEO-AMICAM1

The X-NUCLEO-AMICAM1 expansion board provides USB streaming using the STM32 Nucleo microcontroller USB peripheral; a USB connector is available for data and power supply.

Solder bridges allow choosing from different options, depending on the number of microphones and the MCU peripherals involved.

3.3.4.1 Solder bridge and jumper settings

The X-NUCLEO-AMICAM1 expansion board can be connected to any STM32 Nucleo board. However, the related firmware offers an out-of-the-box package for some STM32 Nucleo boards.

When mounting the X-NUCLEO-AMICAM1 on the STM32 Nucleo, align all the pins with their corresponding connector.

Caution: Handle the boards carefully during this operation and implement ESD prevention measures to avoid damaging (or bending) the male/female pins, connectors and the expansion board components.

The default X-NUCLEO-AMICAM1 configuration allows the acquisition of two on-board microphones (M1OB and M2OB) through the external ADC mounted on the board.

The following configurations and use cases can also be implemented:

- 4 microphone acquisition using coupon boards (e.g. STEVAL-MIC004V1) and the external ADC
- single microphone acquisition using STM32 embedded ADC

3.3.4.1.1 4 microphone acquisition configuration

Step 1. Open SB24 and SB26 to disconnect M1OB and M2OB on-board microphones from the ADC

Step 2. Close SB23 and SB25 to connect M1 and M2 external headers to the ADC

Step 3. Mount coupon boards on the headers

Caution: Do not close SB23 and SB24 at the same time to avoid potential shortcircuit between M1OB on-board microphone and M1 external microphone if the coupon is mounted.
Do not close SB25 and SB26 at the same time: it will result in a potential shortcut between M2OB onboard microphone and M2 external microphone if the coupon is mounted.

3.3.4.1.2 Single microphone acquisition configuration

Step 1. Change the solder bridge configuration on the STM32 Nucleo to allow VREF routing to the appropriate STM32 pin as follows:

- On STM32 Nucleo-XXXXRX 64-pin boards (MB1136): open SB57
- On STM32 Nucleo-LXXXZX 144-pin boards (MB1312): open SB149, close SB 119
- On STM32 Nucleo-XXXXZX 144-pin boards (MB1137): open SB12

Step 2. Close J2 on the X-NUCLEO-AMICAM1 board.

Caution: Do not close J2 if the proper solder bridge is not open on the STM32 Nucleo board, as the STM32 Nucleo and the X-NUCLEO-AMICAM1 expansion board could be damaged.

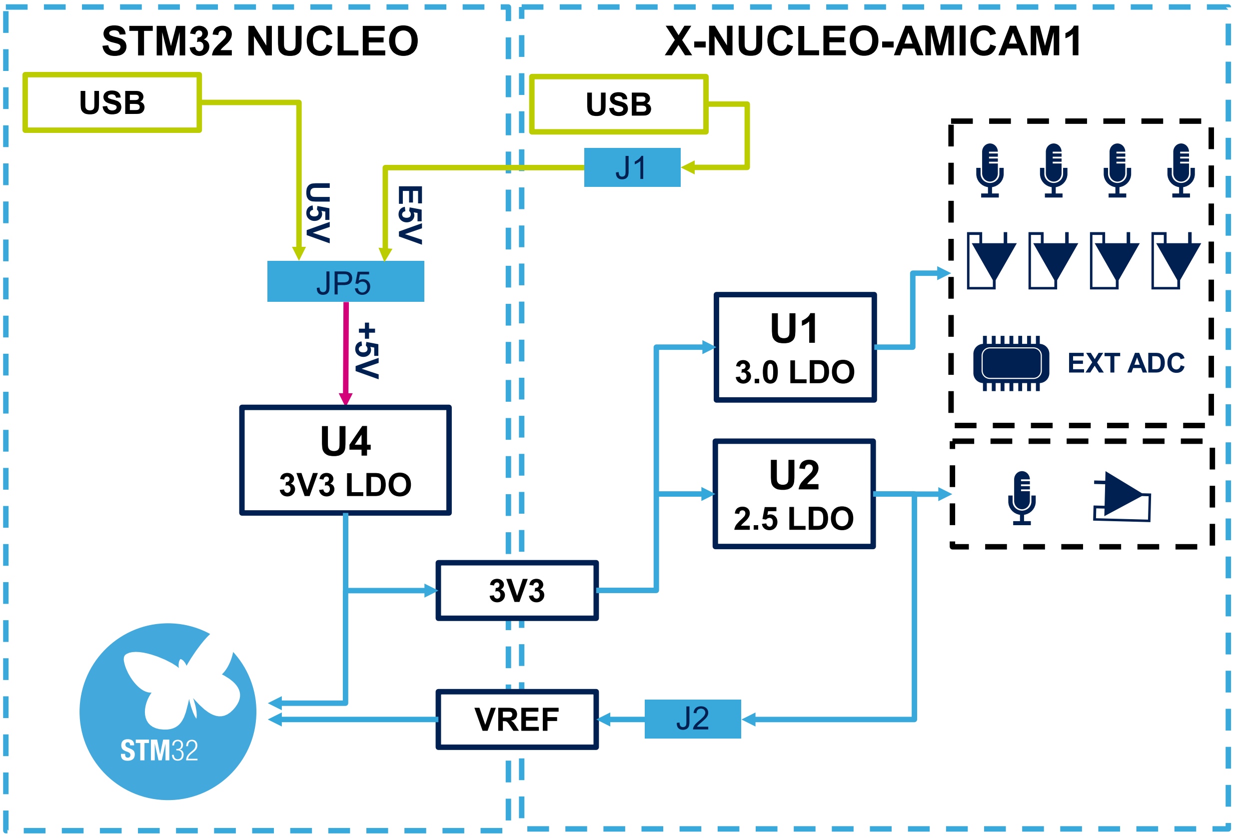
Step 3. Check SB9 and SB10 on the X-NUCLEO-AMICAM1.
– SB10 closed, SB9 open: acquisition of the on-board M3OB microphone
– SB10 open, SB9 closed: acquisition of an external coupon plugged onto M5 header

Caution: Do not close SB9 and SB10 at the same time as a potential shortcircuit could occur between M3OB on-board microphone and M5 external microphone if the coupon board is mounted.

3.3.4.2 Board power supply jumpers

Power scheme is designed to provide separate supplies to the critical analog parts, which you can find on both the X-NUCLEO-AMICAM1 and the STM32 Nucleo boards.

Figure 22. **X-NUCLEO-AMICAM1 expansion board: power supply scheme**



All the analog supplies are generated starting from the 3V3 coming from the LDO on the STM32 Nucleo boards.

Starting from this source, two different regulators are used on the X-NUCLEO-AMICAM1 expansion board:
- U1 LDO which outputs 3 volts used by the microphones connected to the external ADC and all the relevant components
- U2 LDO which generates 2.5 volts and feeds the single microphone connected to the internal STM32 ADC as well as the STM32 analog reference

Note: in the standard board configuration, the single microphone (M3OB) connected to the STM32 ADC is disabled by default; to enable this feature two actions are required:
- *unsolder a solder bridge on the STM32 Nucleo (the solder bridge depends on the STM32 Nucleo type, as detailed in Section 3.3.4.1.2 Single microphone acquisition configuration)*
- *close J2 header*

Caution: Do not close J2 if the proper solder bridge is not open on the STM32 Nucleo board, as the STM32 Nucleo and the X-NUCLEO-AMICAM1 expansion board could be damaged (refer to Section 3.3.4.1 Board setup for further information).

The on-board USB connector supports audio streaming to the host PC and can also be used to power the whole system up, including the STM32 Nucleo board, by:

- closing jumper J1 on the X-NUCLEO-AMICAM1 expansion board
- placing JP5 in position E5 on the STM32 Nucleo development board

3.3.5 Software setup

This section lists the minimum requirements for the developer to setup the SDK, run the sample testing scenario based on previous descriptions and customize applications.

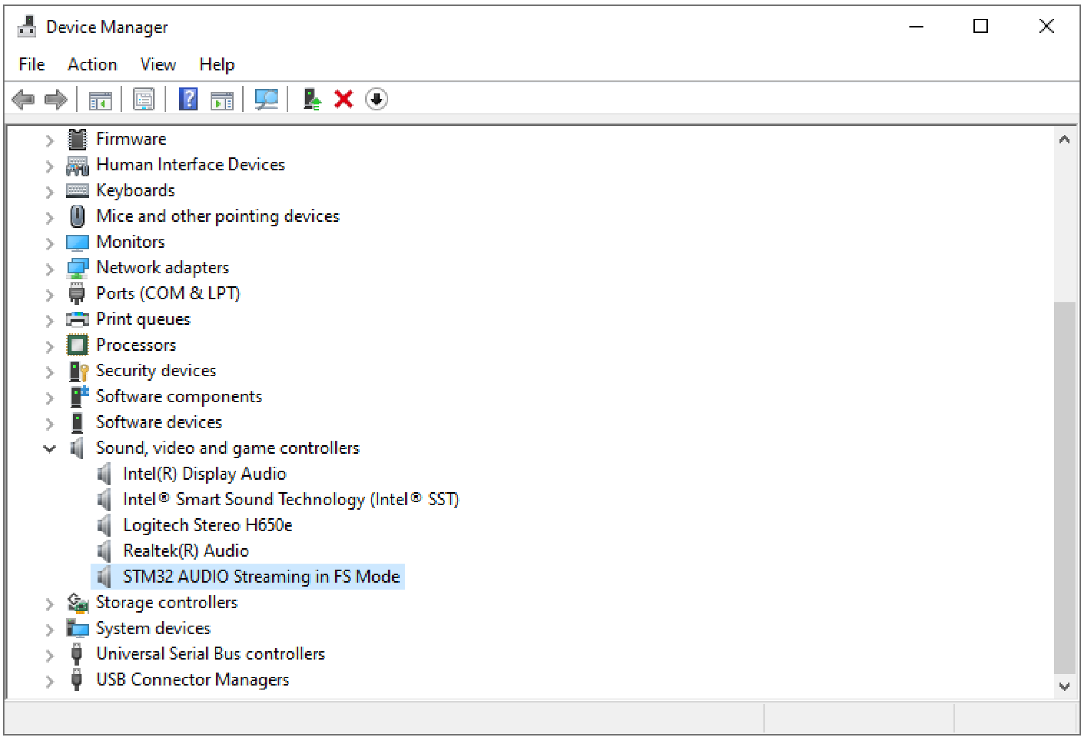
3.3.5.1 Development tool-chains and compilers

Select one of the integrated development environments supported by the STM32Cube expansion software and read the system requirements and setup information for the selected IDE provider.

3.3.5.2 Recognition of the device as a standard USB microphone in Windows

The sample application for audio acquisition and streaming includes an audio input USB driver that allows the device to be recognized as a standard USB microphone. After firmware download to MCU flash, jumper setup where needed, and STEVAL-STWINKT1B (and STEVAL-STWINKT1), X-NUCLEO-CCA02M2 or X-NUCLEO-AMICAM1 connection to PC via USB, check the device manager to ensure it has been recognized correctly, as shown in the figure below.

Figure 23. STM32 microphone in device manager



Windows installs the proper USB driver only the first time the board is plugged.

If you rebuild the application changing the number of microphones or the sampling frequency, you can experience some issues as USB drivers are not automatically updated.

In this case, you should manually delete the audio drivers and let Windows automatically reinstall it.

To do so, you should simply delete the “STM32 AUDIO Streaming in FS Mode” driver by just selecting it and deleting, unplugging the board and plugging it again. The updated drivers are automatically installed and the USB microphone should restart working as expected.

3.3.6 System setup guide

This section describes how to setup different hardware components before writing and executing an application on the STM32 Nucleo board with the MEMS microphone expansion board.

3.3.6.1 STM32 Nucleo and microphone expansion board setup

The STM32 Nucleo development board integrates the ST-LINK/V2-1 debugger/programmer. The developer can download the relevant version of the ST-LINK/V2-1 USB driver by searching STSW-LINK008 or STSW-LINK009 on www.st.com.

The X-NUCLEO-CCA02M2 or X-NUCLEO-AMICAM1 microphone expansion boards can be easily connected to the STM32 Nucleo through the ST morpho extension connector on the board. The microphone expansion board is capable of interfacing with the external STM32 microcontroller on STM32 Nucleo via I²C, I²S, SPI, SAI and USB.

Note: The STEVAL-STWINKT1B (and STEVAL-STWINKT1) can be used alone as it embeds microphones. To flash the board, you can use the STLINK-V3MINI compact in-circuit debugger and programmer included in the development kit. For further details, see UM2777, Section 3.

Revision history

Table 9. **Document revision history**

Date	Version	Changes
09-Jun-2015	1	Initial release.
27-Jan-2016	2	Throughout document added reference to NUCLEO-L476RG board and DFSDM peripheral option Updated Section 2.5: "Sample application description" Updated Section 3.3.3: "Jumper configuration"
11-Jul-2016	3	Updated Nucleo board compatibility information Updated Section 4.3.3.3: "Board power supply jumper" Updated Section 4.3.3.4: "USB connection solder bridges"
11-May-2017	4	Updated Section Introduction, Section 2.1 Overview , Section 2.2 Architecture, Section 2.3 Folder structure, Section 2.5 Sample application description, Section 2.5.1.1 Audio acquisition strategy and Section 2.5.2 Application description. Added Section 2.5.1 Microphone streaming via USB, Section 2.6 AcosuticBF example, Section 2.7 AcosuticSL example and Section 2.7.1 Program execution example.
19-Apr-2018	5	Updated Figure 1. X-CUBE-MEMSMIC1 software architecture. Removed references to NUCLEOF072RB and NUCLEO-L053R8 boards.
30-May-2019	6	Updated Section 2.5.2 Application description and Section 3.3.3.4 USB connection solder bridges. Added P-NUCLEO-WB55 board compatibility information.
02-Dec-2019	7	Added MP34DT06J microphone and X-NUCLEO-CCA02M2 expansion board compatibility. Added Section 2.5.1.1.3 SAI microphone acquisition, Section 3.1.3 X-NUCLEO-CCA02M2 expansion board, Section 3.3.4 Jumper configuration for X-NUCLEO-CCA02M2, Section 3.3.4.1 Jumper settings for DFSDM-based systems, Section 3.3.4.2 Jumper settings for I²S-plus-SPI-based systems, Section 3.3.4.3 Jumper settings for SAI-based systems, Section 3.3.4.4 Board power supply jumper and Section 3.3.4.5 USB connection solder bridges.
10-Jan-2020	8	Added MP23ABS1 microphone and X-NUCLEO-AMICAM1 expansion board compatibility information. Updated Introduction, Section 2.1 Overview, Section 2.2 Architecture, Section 2.3 Folder structure, Section 2.5.2 Application description, Section 3.3.1 Hardware setup and Section 3.3.2 External microphone connection. Added Section 2.5.1.2 Analog MEMS microphone acquisition strategy, Section 2.5.1.2.1 Amplification stage and signal acquisition - internal ADC, Section 2.5.1.2.2 Amplification stage and signal acquisition - external ADC, Section 3.1.4 X-NUCLEO-AMICAM1 expansion board, Section 3.3.5 Jumper configuration for X-NUCLEO-AMICAM1, Section 3.3.5.1 Solder bridge and jumper settings, Section 3.3.5.1.1 4 microphone acquisition configuration, Section 3.3.5.1.2 Single microphone acquisition configuration and Section 3.3.5.2 Board power supply jumpers. Removed Section 4 References.
20-Mar-2020	9	Updated Introduction, Section 2.1 Overview, Section 2.2 Architecture, Section 2.3 Folder structure, Section 2.5 Sample application description, Section 2.5.2 Application description, Section 2.7 AcousticSL example and Section 2.7.1 Program execution example. Added Section 2.8 UltrasoundFFT, Section 3.1.5 STEVAL-STWINKT1 development kit and Section 3.1.6 STEVAL-STWINMAV1 microphone array expansion.
01-Jul-2020	10	Updated Introduction, Section 2.1 Overview and Section 2.5 Sample application description.
07-Jan-2021	11	Throughout the document: removed references to the X-NUCLEO-CCA02M1 expansion board and added STEVAL-STWINKT1B compatibility information.
26-Oct-2021	12	Updated Figure 1. X-CUBE-MEMSMIC1 software architecture, Section 2.5 Sample application description, Section 2.5.2 Application description, Section 2.6 AcousticBF example, Section 2.8 UltrasoundFFT, Section 2.9 PC audio recording utility example: Audacity, Section 3.3.5.2 Recognition of the device as a standard USB microphone in Windows, and Section 3.3.6.1 STM32 Nucleo and microphone expansion board setup.
14-Nov-2022	13	Updated *Section 2.1 Overview* , *Section 2.5 Sample application description,* and *Section 3.3.5.2 Recognition of the device as a standard USB microphone in Windows.*

Date	Version	Changes
20-Sep-2023	14	Updated Section Introduction, Section 2.1 Overview , Section 2.2 Architecture, Section 2.4 APIs, Section 2.5.2 Application description, Section 2.7 AcousticSL example, Section 2.8 UltrasoundFFT. Added Section 3.1.6 STEVAL-STWINMA2 microphone array expansion.

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