Getting started with the STM32Cube function pack for acoustic echo cancellation

Introduction

FP-AUD-AEC1 is an STM32Cube function pack which features an example fully focused on acoustic echo cancellation and provides an implementation of a USB smart speaker use case with microphone.

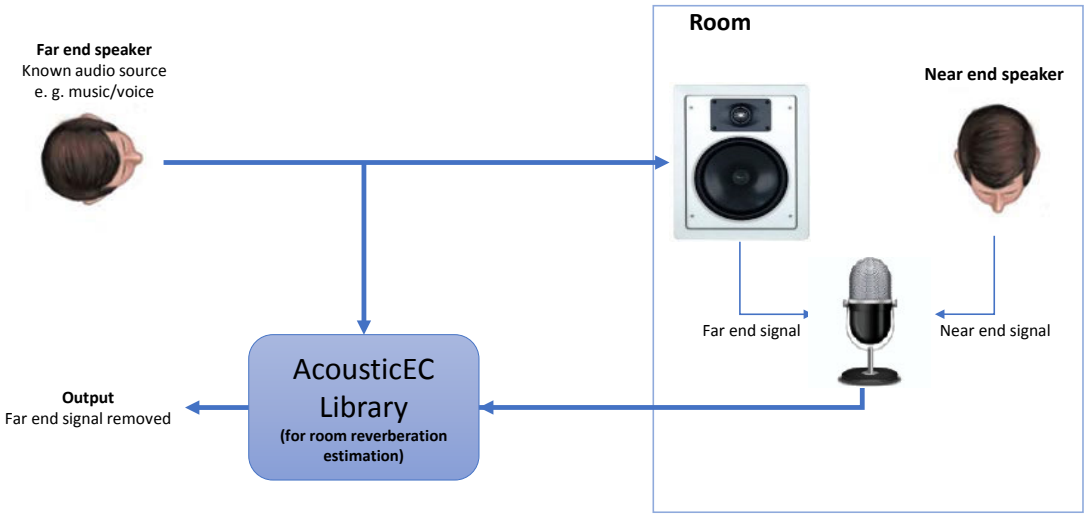
The package includes the AcousticEC library which provides an implementation for a real-time echo cancellation routine based on the MDF algorithm SPEEX implementation.

The function pack also includes an implementation example for NUCLEO-F446RE or NUCLEO-F746ZG development boards equipped with X-NUCLEO-CCA01M1 expansion board, based on the STA350BW Sound Terminal 2.1-channel high-efficiency digital audio output system, or X-NUCLEO-CCA02M2 expansion board, based on digital MEMS microphones and designed around MP34DT06J digital microphones.

After the initialization of all the required elements, the device is recognized by a host PC as a USB microphone and USB speaker at the same time.

You can record and save the real-time audio streaming and, in the meanwhile, send the preferred audio signal to the loudspeaker connected to the expansion board. The stereo track contains the processed signal in which the acoustic echo cancellation has removed the far-end signal from the audio acquired by a microphone and an omnidirectional microphone as a reference.

Figure 1. FP-AUD-AEC1 demo scheme



RELATED LINKS

Visit the STM32Cube ecosystem web page on www.st.com for further information

1 FP-AUD-AEC1 software expansion for STM32Cube

1.1 Overview

FP-AUD-AEC1 function pack expands STM32Cube functionality.

The package key features are:

- Specific example fully focused on acoustic echo cancellation
- Implementation of a USB smart speaker use case with microphone
- Based on STM32 AcousticEC library
- Support for audio in/out streaming via USB through a dedicated USB AUDIO IN OUT class

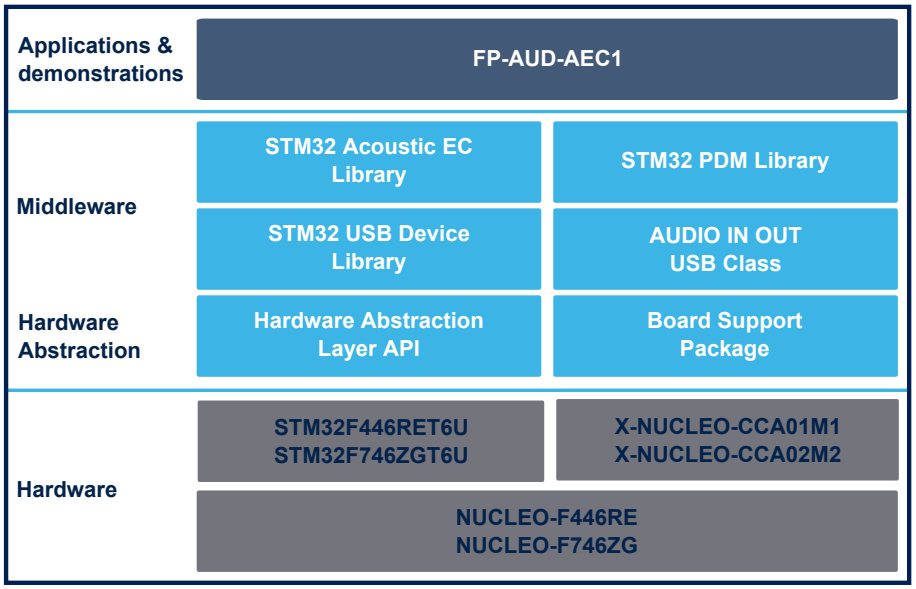
1.2 Architecture

The software is based on the STM32CubeHAL, the hardware abstraction layer for the STM32 microcontroller. The package extends STM32Cube by providing a board support package (BSP) for the expansion boards and some middleware components for serial communication with a PC.

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

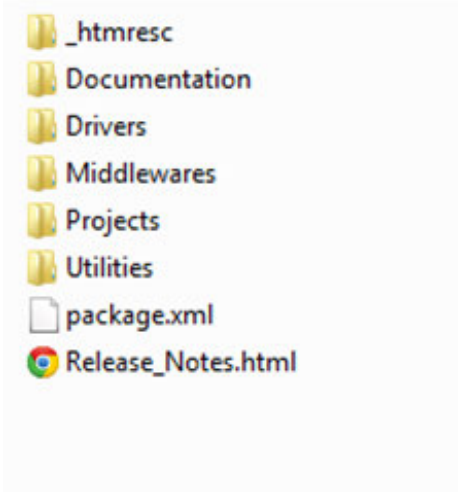
- the **STM32Cube HAL layer**, which provides a simple, generic, multi-instance set of application programming interfaces (APIs) to interact with the upper application, library and stack layers. It has generic and extension APIs and is directly built around a generic architecture and allows successive layers like the middleware layer to implement functions without requiring specific hardware configurations for a given microcontroller unit (MCU). This structure improves library code reusability and guarantees an easy portability on other devices.
- the **board support package** (BSP) layer, which supports all the peripherals on the STM32 Nucleo except the MCU. This limited set of APIs provides a programming interface for certain board-specific peripherals like the LED, the user button, etc. This interface also helps in identifying the specific board version.

Figure 2. FP-AUD-AEC1 function pack architecture



1.3 Folder structure

Figure 3. **FP-AUD-AEC1 package folder structure**



The following folders are included in the software package:

- **Documentation**: contains a compiled HTML file generated from the source code detailing the software components and APIs (one for each project).
- **Drivers**: contains the HAL drivers and the board-specific drivers for each supported board or hardware platform, 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 to handle PDM to PCM conversion, acoustic echo cancellation and USB communication with the host PC.
- **Projects**: contains a sample application provided for the NUCLEO-F746ZG and NUCLEO-F446RE platforms with three development environments: IAR Embedded Workbench for ARM, RealView Microcontroller Development Kit (MDK-ARM) and STM32CubeIDE.

1.4 APIs

Detailed technical information with full user API function and parameter description are in a compiled HTML file in the “Documentation” folder.

1.5 Sample application description

An example application using the X-NUCLEO-CCA01M1 and X-NUCLEO-CCA02M2 expansion boards with either NUCLEO-F446RE or NUCLEO-F746ZG boards is provided in the “Projects” directory. Ready to be built projects are available for multiple IDEs.

After the initialization of all the required elements (microphones, audio output, USB communication and streaming), digital MEMS microphone acquisition starts and drives the whole application: when a millisecond of the microphone signal is made available by the BSP layer, several operations are performed concurrently, depending on the current status of the application.

The processed audio is streamed to 2 interfaces at the same time:

- USB: the device is recognized by a host PC as a standard USB, a USB microphone and a USB speaker at the same time. It can record and save the real-time audio streaming and, in the meanwhile, send an audio signal to the speaker.

  The stereo track contains the processed signal, in which the acoustic echo cancellation has removed the far end signal from the audio acquired by a microphone, and an omnidirectional microphone as a reference.
- I^2S: the MCU I^2S peripheral is connected to the STA350BW mounted on the X-NUCLEO-CCA01M1 expansion board. In this way, the processed signal can be reproduced by a loudspeaker connected to the expansion board.

2 System setup guide

2.1 Hardware description

2.1.1 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.

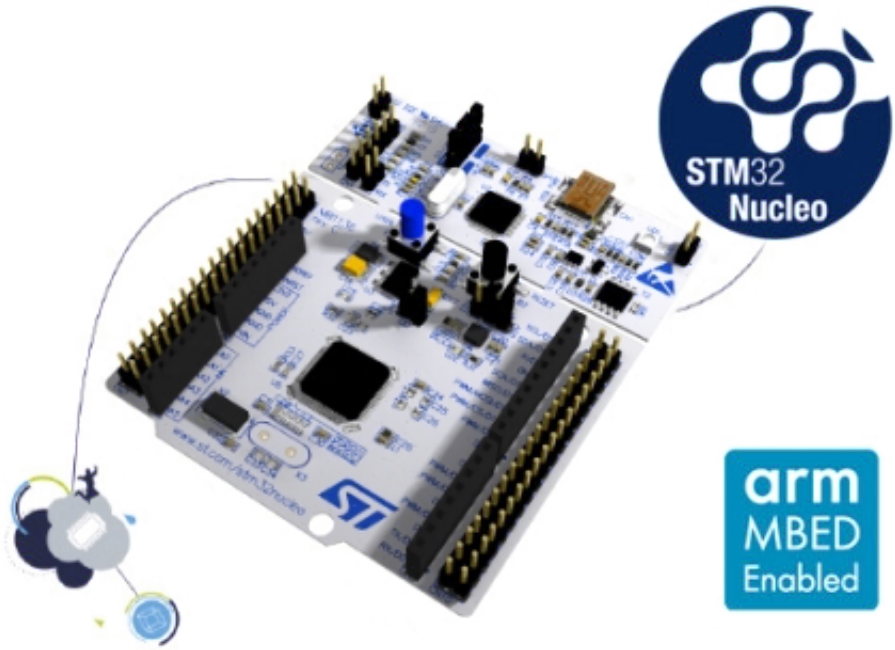
The Arduino connectivity support and ST morpho connectors make it easy to expand the functionality of the STM32 Nucleo open development platform with a wide range of specialized expansion boards to choose from.

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 4. STM32 Nucleo board



2.1.2 X-NUCLEO-CCA01M1 expansion board

The X-NUCLEO-CCA01M1 expansion board is based on the STA350BW Sound Terminal 2.1-channel high-efficiency digital audio output system.

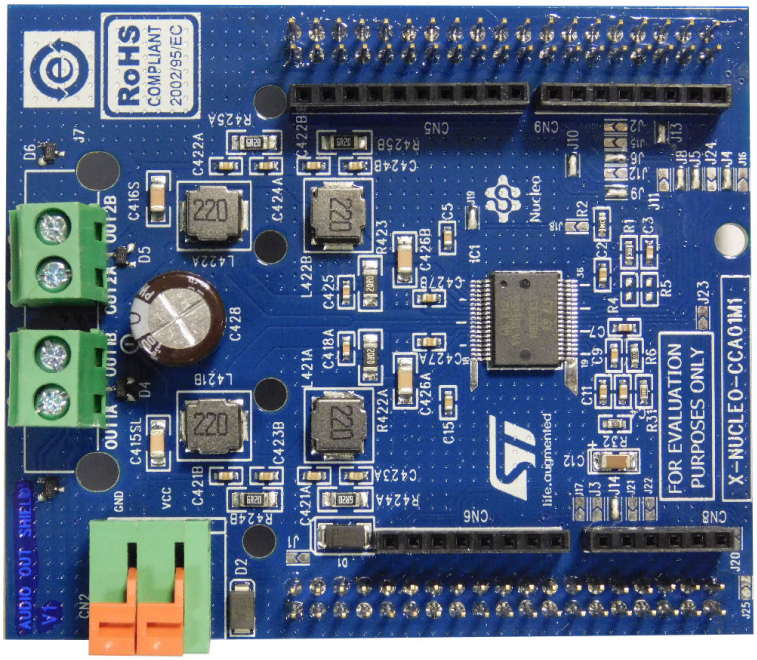
It can be plugged on top of an STM32 Nucleo development board and is compatible with the ST morpho connector layout, enabling the output of digital audio streaming to speakers connected directly to the board.

Up to two X-NUCLEO-CCA01M1 expansion boards can be plugged onto the same STM32 Nucleo for a four-channel digital audio output system.

Communication between the STM32 MCU and the STA350BW device is handled via the I²C bus for setup and control and the I²S or SAI buses for digital audio transmission.

The board has a dedicated connector to supply power for the output stage.

Figure 5. **X-NUCLEO-CCA01M1 expansion board**



2.1.3 X-NUCLEO-CCA02M2 expansion board

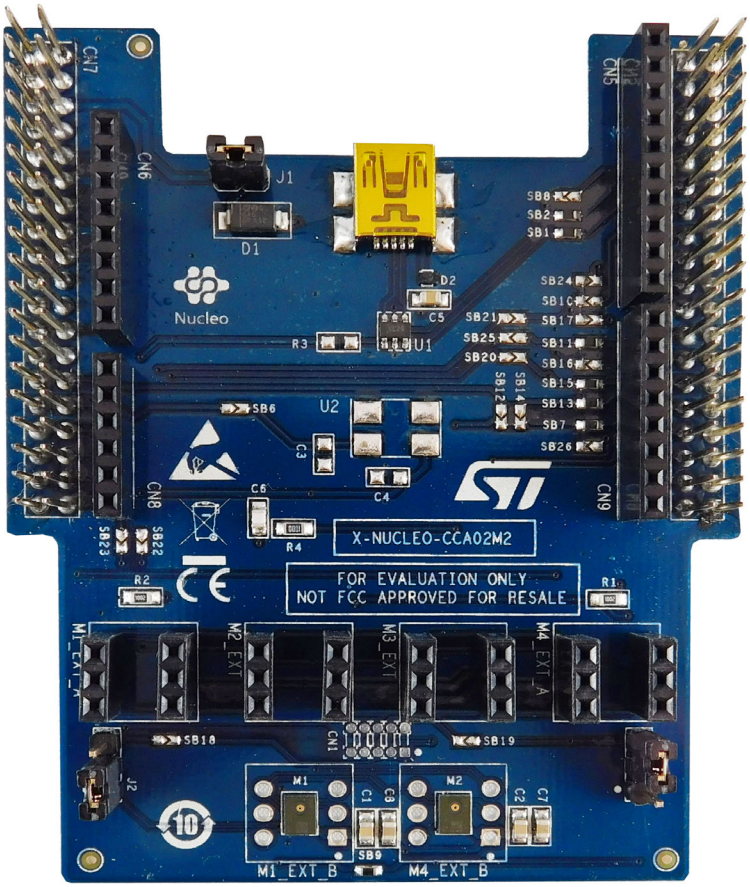
The X-NUCLEO-CCA02M2 expansion board has been designed around MP34DT06J digital MEMS microphone.

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 6. **X-NUCLEO-CCA02M2 expansion board**



2.1.4 Loudspeaker

When adopting an STM32 Nucleo-based system, a passive loudspeaker must be connected to the X-NUCLEO-CCA01M1 expansion board OUT1 connector.

Figure 7. **Loudspeaker connected to the board stack**

2.2 Software description

The following software components are required to create a suitable development environment for applications based on the STM32 Nucleo equipped with the audio expansion boards:

- FP-AUD-AEC1: STM32Cube function pack for acoustic echo cancellation. The FP-AUD-AEC1 firmware and related documentation is available on www.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) toolchain + ST-LINK
  - STM32CubeIDE + ST-LINK

2.3 Hardware setup

The following hardware components are needed:

- an STM32 Nucleo development platform (order code: NUCLEO-F446RE or NUCLEO-F746ZG)
- an STA350BW Sound Terminal expansion board (X-NUCLEO-CCA01M1)
- a digital MEMS microphone expansion board (X-NUCLEO-CCA02M2)
- two USB type A to Mini-B USB cable to connect the STM32 Nucleo and the X-NUCLEO-CCA02M2 to the PC (for serial communication and for microphone input, respectively)
- a passive loudspeaker

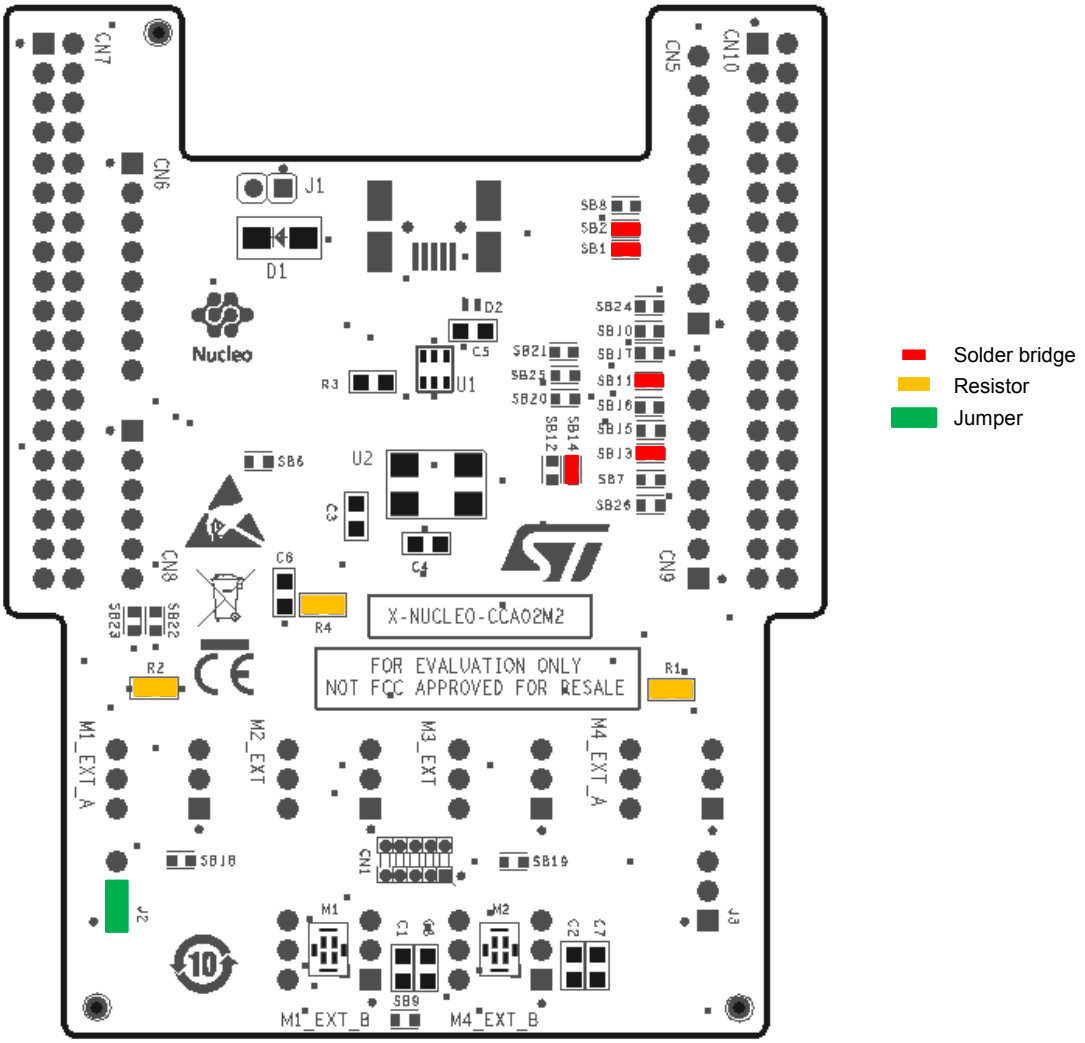
2.3.1 STM32 Nucleo and expansion board configuration

When adopting an STM32 Nucleo-based system, some preliminary operations are needed to configure the expansion boards for specific use cases.

To build the whole system, the following steps are needed:

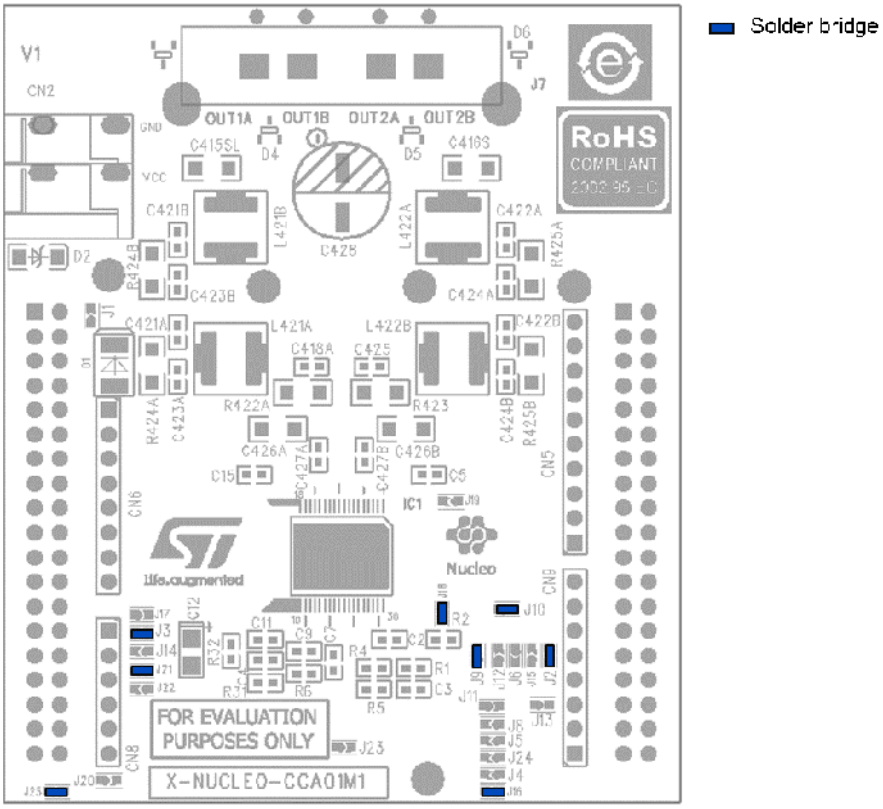
Step 1. Configure the X-NUCLEO-CCA02M2 as shown below:

Figure 8. X-NUCLEO-CCA02M2 soldered connectors



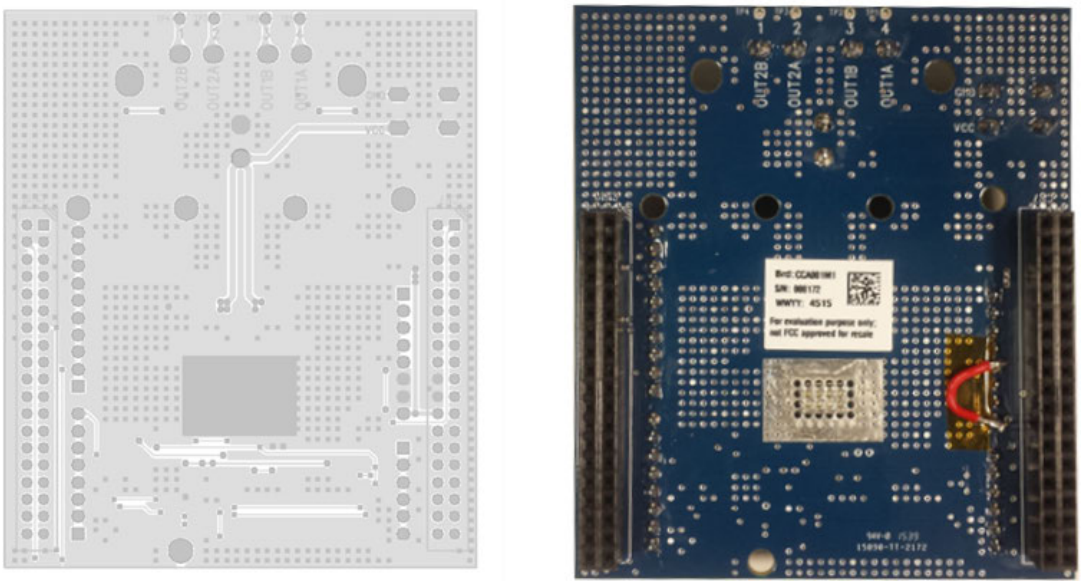
Step 2. Configure the X-NUCLEO-CCA01M1 to act as the second device, as shown below.

Figure 9. X-NUCLEO-CCA01M1 configuration



Step 3. Power the X-NUCLEO-CCA01M1 power stage using a wire connected between CN6.5 on the Arduino connector and CN2.VCC on the expansion board (or soldering a patch on the bottom side)

Figure 10. Wire connection on X-NUCLEO-CCA01M1



Step 4. Connect the passive loudspeaker to the X-NUCLEO-CCA01M1 OUT1 connector (refer to Section 2.1.4 Loudspeaker).

When the hardware setup is completed, the firmware can be loaded into the STM32 Nucleo board.

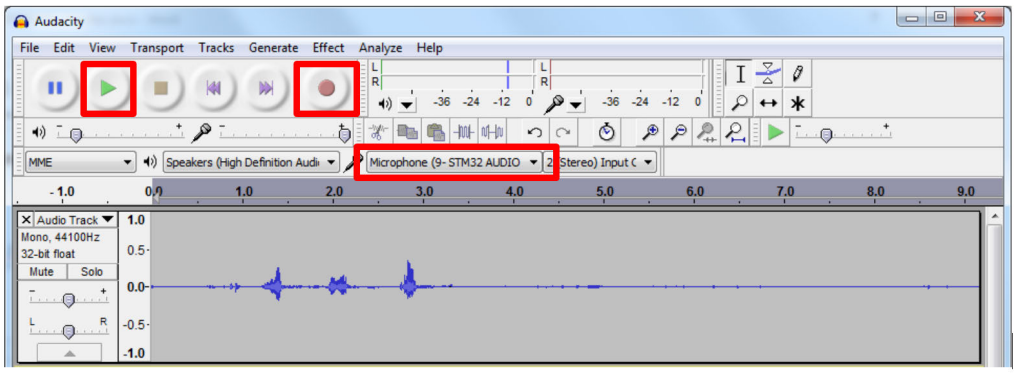
2.3.2 PC audio utility example: Audacity

To test the application and full capabilities of the FP-AUD-AEC1 application, a third-party recording and playback software is necessary to record and play the processed audio and evaluate the acoustic echo cancellation.

Audacity® is an open source, cross-platform program for recording and audio editing environment, freely available on the web.

To start audio recording and/or playback, check that the audio input device is STM32 AUDIO streaming in FS mode and then start recording and performing other functions using the interface.

Figure 11. Audacity for Windows



Revision history

Table 1. **Document revision history**

Date	Version	Changes
19-Jan-2021	1	Initial release.
08-Oct-2021	2	Updated Section 2.3.1 STM32 Nucleo and expansion board configuration.

Contents

List of figures

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