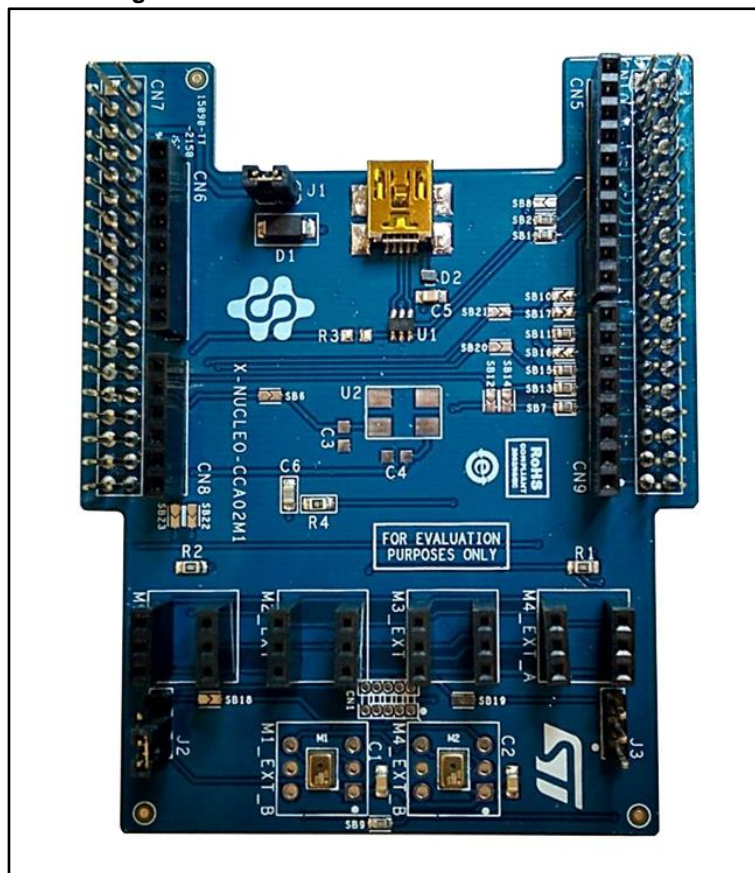## Getting started with the digital MEMS microphone expansion board based on MP34DT01-M for STM32 Nucleo

Introduction

The X-NUCLEO-CCA02M1 is an evaluation board based on digital MEMS microphones. It is compatible with the Morpho connector layout and is designed around STMicroelectronics MP34DT01-M digital microphones. It has two microphones soldered on board and it is compatible with digital microphone coupon boards such as STEVAL-MKI129Vx and STEVAL-MKI155Vx. The X-NUCLEO-CCA02M1 allows synchronized acquisition and streaming of up to four microphones through peripherals I²S, SPI or DFSDM. 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 1: X-NUCLEO-CCA02M1 evaluation board

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1   Getting started

This section describes the hardware requirements for the X-NUCLEO-CCA02M1 evaluation board.

1.1   Hardware requirements

The X-NUCLEO-CCA02M1 is an expansion board for use with STM32 Nucleo boards (refer to UM1724 on www.st.com for further information).

The STM32 Nucleo board must be connected to the X-NUCLEO-CCA02M1 board, as shown below.

Figure 2: X-NUCLEO-CCA02M1 on STM32 Nucleo board
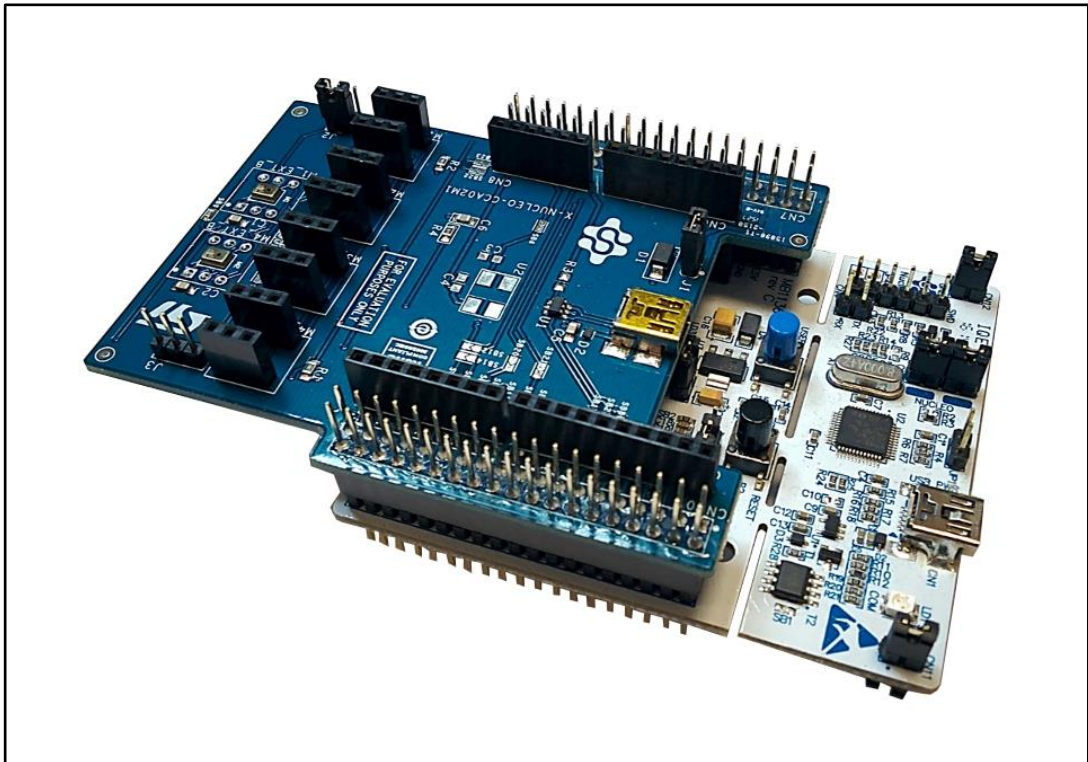
The connection between the STM32 Nucleo and the X-NUCLEO-CCA02M1 is designed for use with any STM32 Nucleo board. When mounting the X-NUCLEO-CCA02M1 on the STM32 Nucleo, ensure that all the pins are aligned with their corresponding connector. It is very important to handle both boards carefully during this operation to avoid damaging or bending the male/female pins and connectors.

ESD prevention measures must also be implemented to avoid damaging any X-NUCLEO-CCA02M1 board components.

1.2   System requirements

Using the Nucleo boards with the X-NUCLEO-CCA02M1 expansion board requires the following software and hardware:

- a Windows® (XP, Vista, 7, 8) PC for the software

- a USB type A to Mini-B USB cable to connect the Nucleo to the PC for installation of the board firmware package (order code: X-CUBE-MEMSMIC1); a utility running on the user's PC will complete the demo.

The user PC must have the following characteristics:

- at least 128 MB of RAM
- 40 MB of available hard disk space for the X-CUBE-MEMSMIC1 firmware package and relative documentation, available on www.st.com.

2 Hardware description

The board allows the user to test the function of the STMicroelectronics MEMS microphones. For this purpose, two MP34DT01-M digital MEMS microphone are mounted on the board and 6 headers (4 mounted with 2 additional footprints) are available for connecting additional microphones using digital microphone coupon boards (STEVAL-MKI129Vx or STEVAL-MKI155Vx), for further information refer to www.st.com.

The connection between the X-NUCLEO-CCA02M1 and the STEVAL-MKI155V1 is shown in *Figure 3: "Connection with STEVAL-MKI155V1"*.

The board interfaces with the STM32 Nucleo microcontrollers via the I²S, SPI or DFSDM peripherals for the synchronized acquisition of up to 4 microphones. The board also provides USB streaming using the STM32 Nucleo microcontroller USB peripheral; for this purpose, a USB connector is available as well as the footprint to mount a dedicated oscillator that can be used to feed the host MCU through the OSC_IN pin.

Solder bridges are used in order to choose from different options, depending on the number of microphones and the MCU peripherals involved.

Figure 3: Connection with STEVAL-MKI155V1
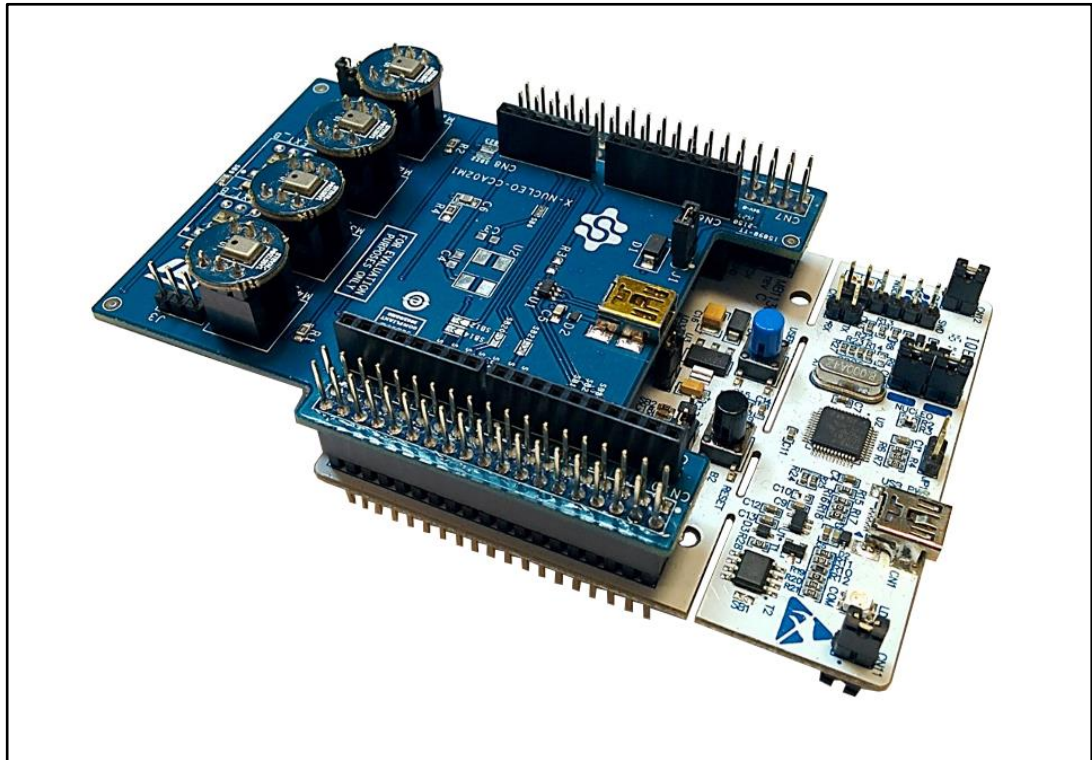
2.1 USB connector and power source

A USB connector available on the board supports audio streaming to the host PC. It can also be used to power the whole system , including the STM32 Nucleo board. To enable system power sourcing from the X-NUCLEO-CCA02M1 expansion board USB connector:

- close Jumper J1 on the X-NUCLEO-CCA02M1 expansion board
- place JP5 in position E5 on the STM32 Nucleo board

2.2 Audio acquisition strategy

A digital MEMS microphone can be acquired via different peripherals, such as SPI, I²S, GPIO 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-CCA02M1 expansion board, 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.

2.2.1 DFSDM microphone acquisition

The DFSDM peripheral generates the precise clock needed by the microphones and reads the data on the rising and falling edges of each PDM line. Acquired signals are then 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.
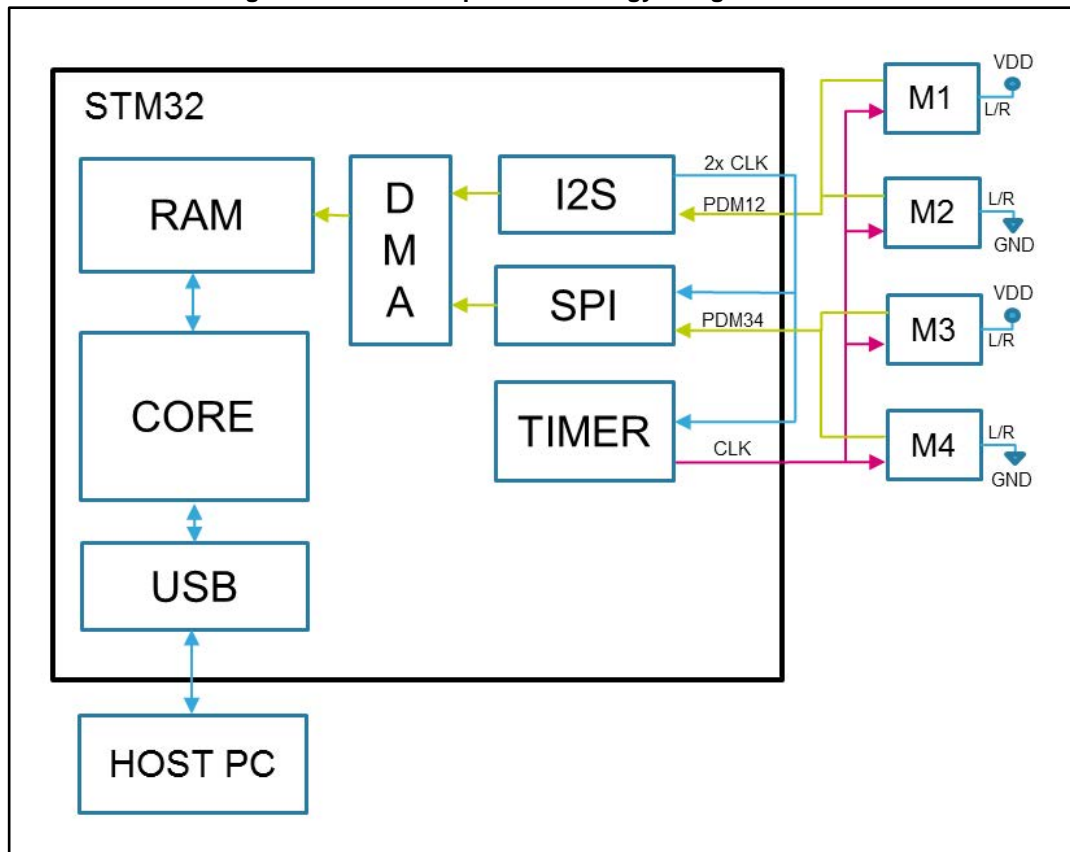
2.2.2 I²S and SPI microphone acquisition

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[a] conversion.

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[a] For further information regarding MEMS microphone and PDM-to-PCM decimation, please refer to application note AN3998 on www.st.com.

Figure 4: 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.

2.3 Solder bridge configurations

Various board configurations are possible, depending on the use cases. MEMS microphones can be plugged into ST morpho pins, and thus to MCU peripherals, with appropriate solder bridges. Clock routing can also be changed according to specific needs.

2.3.1 Solder bridge roles

The table below lists the solder bridge functions with respect to audio acquisition strategies.

Table 1: Solder bridge description

Function	Solder Bridge
Connects USB DM pin from connector to MCU	SB1
Connects USB DP pin from connector to MCU	SB2
Routes onboard oscillator output to OSC_IN MCU pin	SB6
Connect MEMS clock to MCU timer output channel	SB7
Routes I²S clock to SPI clock	SB8
Merges onboard microphone PDMs in order to be acquired with 1 interface	SB9
Connects MIC34 PDM to MCU SPI	SB10
Connects MIC12 PDM to MCU I2S	SB11

Function	Solder Bridge
Clock from the DFSDM peripheral	SB12
I2S clock from MCU	SB13
Connects I²S clock directly to MIC clock without passing through timer	SB14
Connect I²S clock to MCU timer input channel	SB15
Connects MIC12 PDM to MCU DFSDM	SB16
Connects MIC34 PDM to MCU DFSDM	SB17

2.3.2 Sample use cases

In this section, we analyze specific use cases together with the corresponding solder bridge configurations. Custom setups are also possible for ad-hoc functionalities.

> SB1, SB2, SB6 are reserved for the USB or Oscillator pins and are not part of the audio acquisition process.

These configurations depend on the acquisition peripherals involved.

2.3.2.1 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: Solder bridge configuration for 1 or 2 microphone acquisition

SB	Status
SB7	Open
SB8	Open
SB9	Open/Close
SB10	Open
SB11	Open
SB12	Close
SB13	Open
SB14	Open
SB15	Open
SB16	Close
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open

In addition, 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

In this case, the PDM line of the third and fourth microphone is also routed to the MCU.

Table 3: Solder bridge configuration for 4 microphone acquisition

SB	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

In addition, J2 and J3 must be placed in position 2-3 for external microphone acquisition.

2.3.2.2 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 thus acquires the same microphone.

Table 4: Solder bridge configuration for 1 microphone acquisition

SB	Status
SB7	Open
SB8	Open
SB9	Open
SB10	Open
SB11	Close
SB12	Open
SB13	Close
SB14	Close

SB	Status
SB15	Open
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open

In addition, 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

In this case, 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: Solder bridge configuration for 2 microphone acquisition

SB	Status
SB7	Close
SB8	Open
SB9	Open /Close
SB10	Open
SB11	Close
SB12	Open
SB13	Close
SB14	Open
SB15	Close
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open

In addition, 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

In this case, 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 in order 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. For this use case you need the following SB configuration:

Table 6: Solder bridge configuration for 4 microphone acquisition

SB	Status
SB7	Close
SB8	Close
SB9	Open
SB10	Close
SB11	Close
SB12	Open
SB13	Close
SB14	Open
SB15	Close
SB16	Open
SB17	Open
SB18	Open
SB19	Open
SB20	Open
SB21	Open

In addition, J2 and J3 must be placed in position 2-3 for external microphone acquisition.

Other configurations are available, based on the MCU used.

When acquiring 4 microphones using an STM32 F746Nucleo-144 development board, JP6 jumper on the board must be opened.

3   Nucleo 144 support

In order to accept Nucleo-144 boards, morpho header connectors must be soldered on the relevant footprint available on the Nucleo.

You only need a pair of 2 x 38 pin stripline connectors for the expansion board; you don't need to solder the whole 2 x 80 pin header.

4 Connectors

The pin assignments for the Arduino UNO R3 and the ST morpho connectors are shown in *Table 7: "ST morpho connector table"* and *Table 8: "Arduino connector table"* respectively.

Table 7: ST morpho connector table

Connector	Pin	Signal	Remarks
CN7	1	MIC_CLKx2	If SB20 is closed
	3	MIC_PDM34	If SB20 is closed
	6	E5V	
	12	3V3	
	16	3V3	
	18	5V	
	20	GND	
	22	GND	
	24	V_IN	
	29	OSC_CLK_OUT	If SB6 is closed
	35	MIC_CLK_NUCLEO	If SB12 is closed
CN10	11	MIC_CLKx2	If SB8 is closed
	12	OTG_FS_DP_NUCLEO	If SB1 is closed
	14	OTG_FS_DM_NUCLEO	If SB2 is closed
	15	MIC_PDM34	If SB10 is closed
	25	MIC_PDM34	If SB17 is closed
	26	MIC_PDM12	If SB11 is closed
	27	MIC_CLKx2	If SB15 is closed
	28	MIC_PDM12	If SB16 is closed
	29	MIC_CLK_NUCLEO	If SB7 is closed
	30	MIC_CLKx2	If SB13 is closed

Table 8: Arduino connector table

Connector	Pin	Signal	Remarks
CN6	2	3V3	
	4	3V3	
	5	5V	
	6	GND	
	7	GND	
	8	V_IN	
CN5	6	MIC_CLKx2	If SB8 is closed
	4	MIC_PDM34	If SB10 is closed
CN9	7	MIC_PDM34	If SB17 is closed
	6	MIC_CLKx2	If SB15 is closed
	5	MIC_CLK_NUCLEO	If SB7 is closed

5 Board schematics

Figure 5: Board schematic (Part 1)
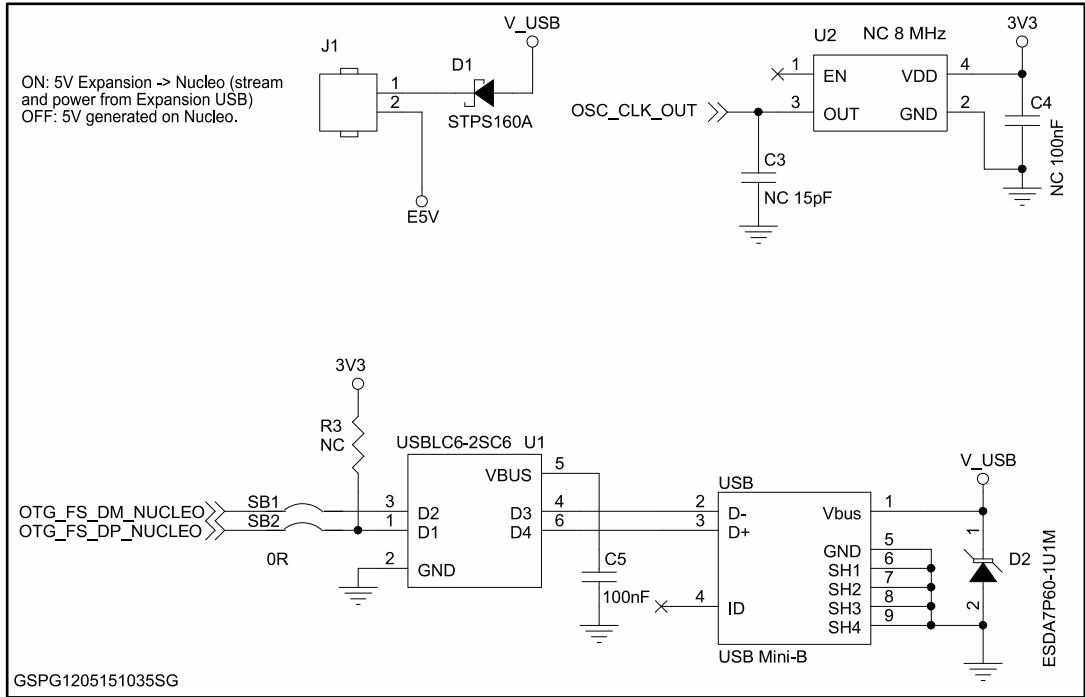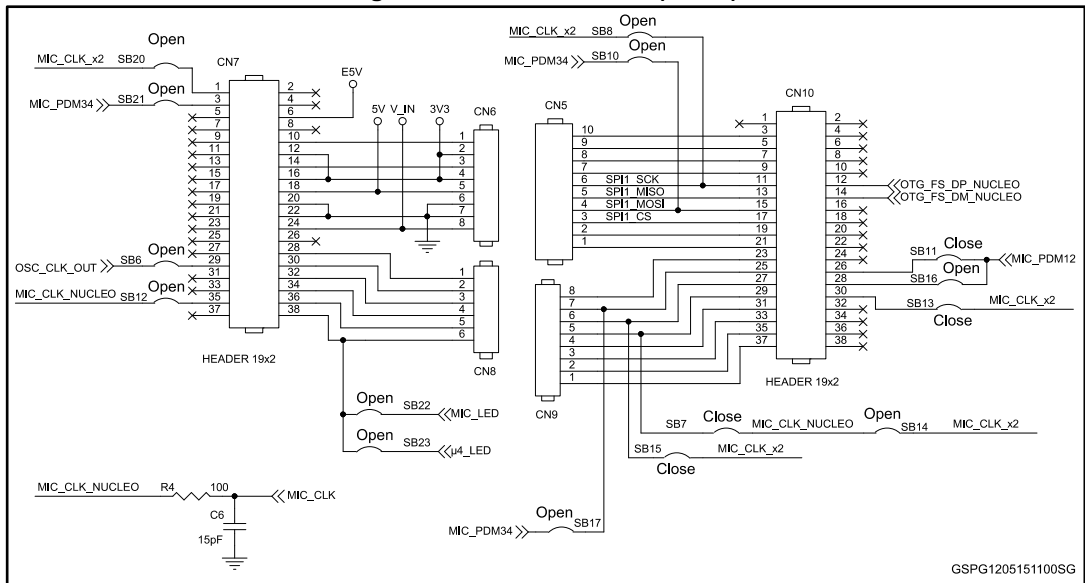

Figure 6: Board schematic (Part 2)
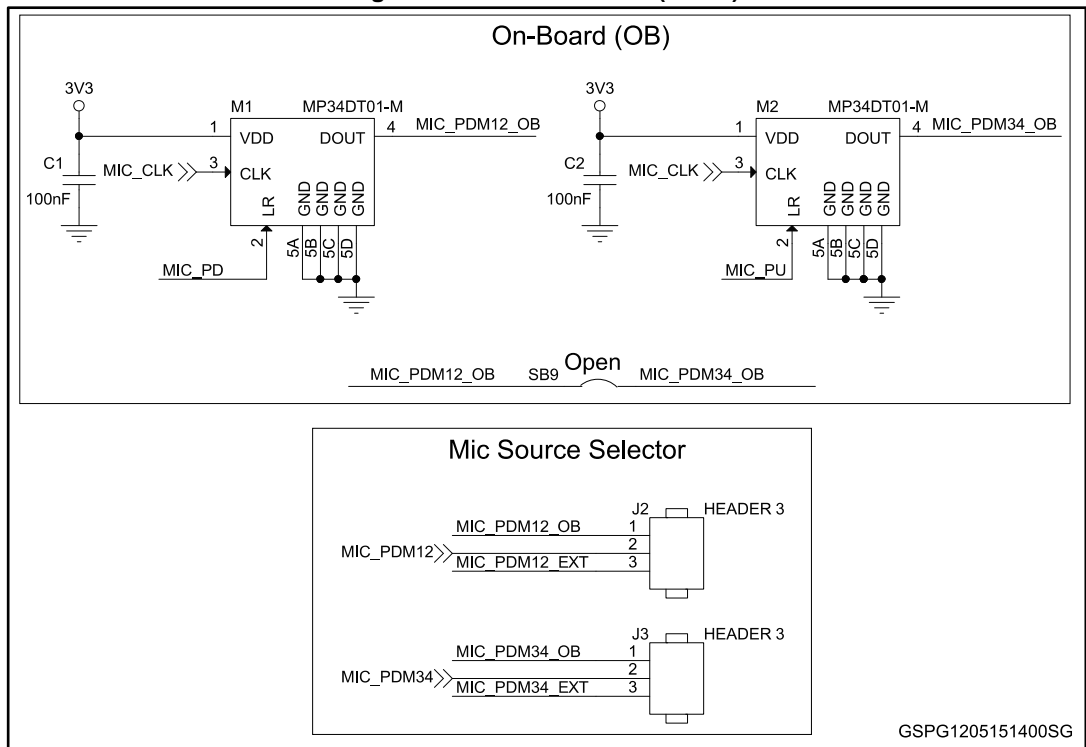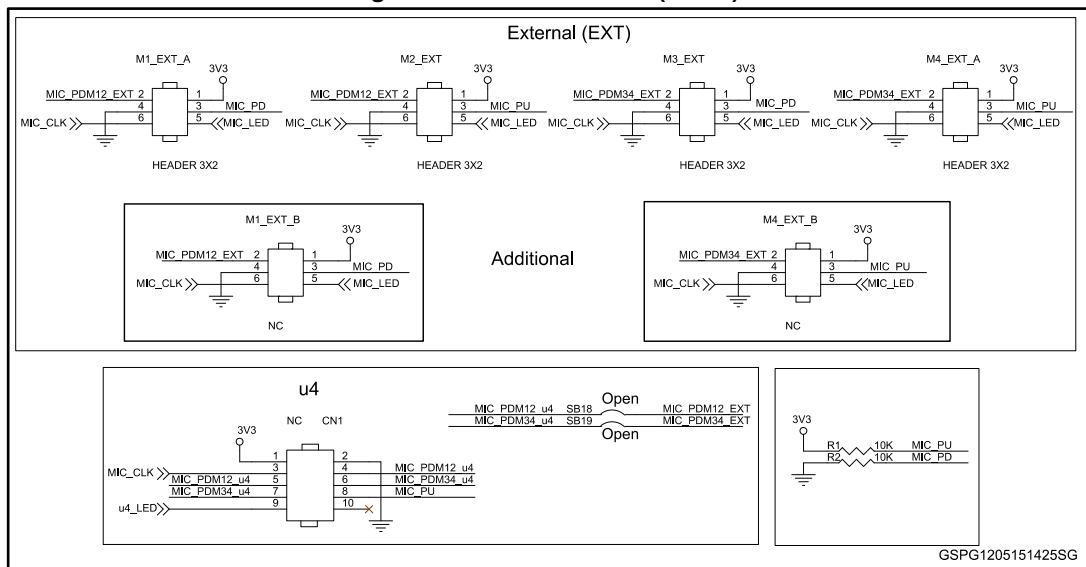
Figure 7: Board schematic (Part 3)

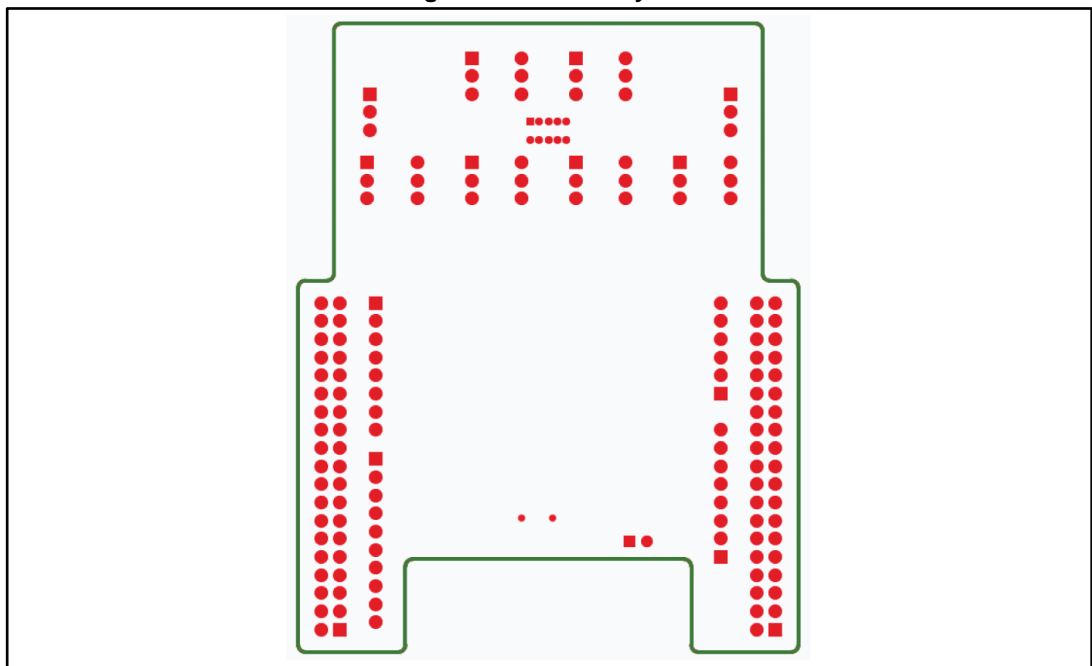**Figure 8: Board schematic (Part 4)**

6 Layout

Figure 9: Top layout
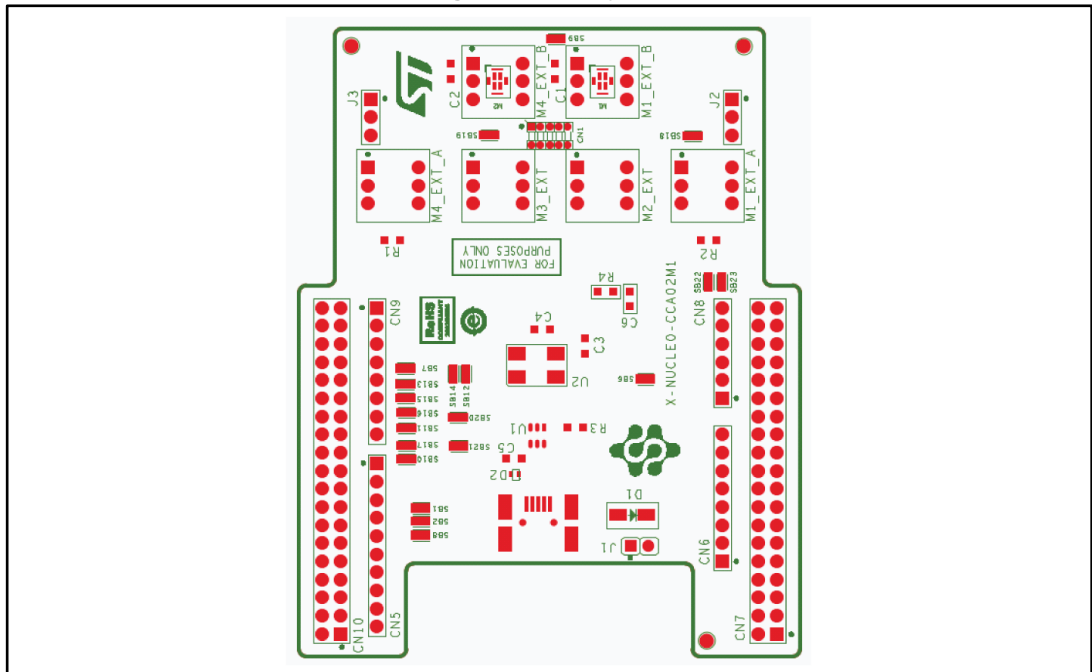
Figure 10: Bottom layout

7   Revision history

Table 9: Document revision history

Date	Revision	Changes
28-May-2015	1	Initial release.
28-Jan-2016	2	Minor text edits throughout document. Updated Section "Introduction". Updated Section 3.3: "Audio acquisition strategy". Updated Section 3.4: "Solder bridge configurations".
14-Jul-2016	3	Added Section 4: "Nucleo 144 support".
09-May-2017	4	Updated *Section 2.3.2.2: "Jumper settings for I²S-plus-SPI-based systems"*.

IMPORTANT NOTICE – PLEASE READ CAREFULLY