Infineon UltraHub

User manual

About this document

Scope and purpose

This user manual provides information about using and evaluating the Infineon analog and digital XENSIV™ MEMS ultrasonic transceivers with the help of the UltraHub evaluation kit. This user manual familiarizes you with the UltraHub evaluation board and guides you through the initial hardware and software setup and measurements. Detailed information about access to serial interface and protocol definitions are included.

Intended audience

Design, verification, test and software engineers can use this document to gain an understanding of the functionality and connections of the UltraHub evaluation kit.

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1 Introduction

This document serves as a manual for evaluating up to four Infineon XENSIV™ MEMS ultrasonic transceivers using the UltraHub evaluation kit. The evaluation board provides an USB audio interface to stream audio data from ultrasonic transceivers with audio recording and editing software.

1.1 Prerequisites

1.1.1 Hardware

- Infineon UltraHub motherboard
- Infineon XENSIV™ MEMS ultrasonic sensing shield
- Micro USB cable

1.1.2 Software

- Audio editing software that supports 192 kHz and 24-bit recording
- FT9xx programming utility for firmware update (optional)

2 Features

2.1 Summary of features

- Micro USB-powered device
- Audio and ultrasonic data streaming over USB interface (USB audio 2.0)
- 192 kHz sampling rate
- 24-bit four-channel audio data
- Mode switch for DFU mode
- LED indicators for each of the four ultrasonic transceivers on the sensing shield
- Serial interface to read software ID
- Serial interface to send and receive configuration parameters
- EEPROM for storing transceiver, board ID and user configuration settings

2.2 Block diagram

The UltraHub system is the evaluation platform for Infineon XENSIV™ MEMS-based ultrasonic transceivers. It consists of two parts:

- UltraHub motherboard with microcontroller and audio codec
- UltraHub sensing shield, i.e., shields with up to four ultrasonic transceivers (digital or analog)

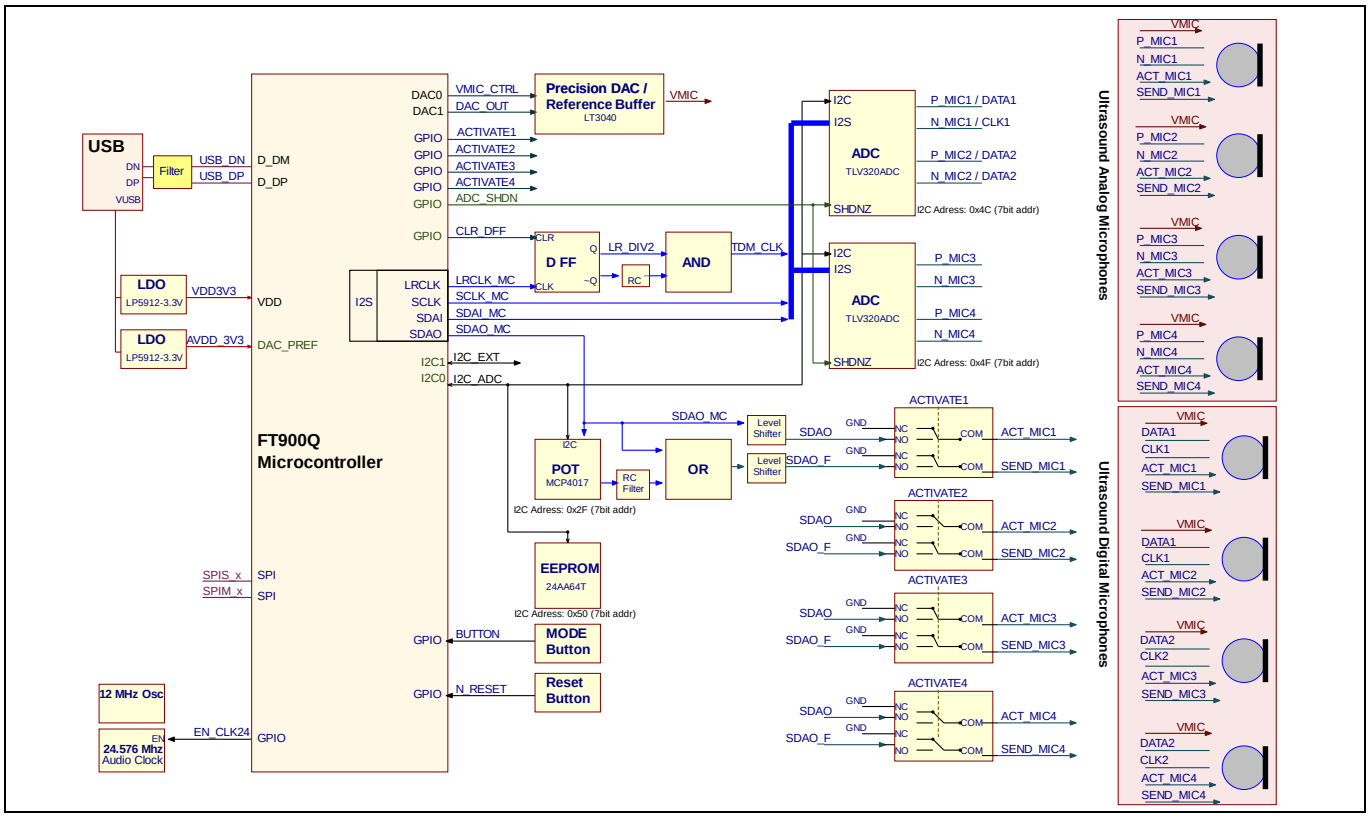

Figure 1 Top-level schematic of the UltraHub evaluation kit

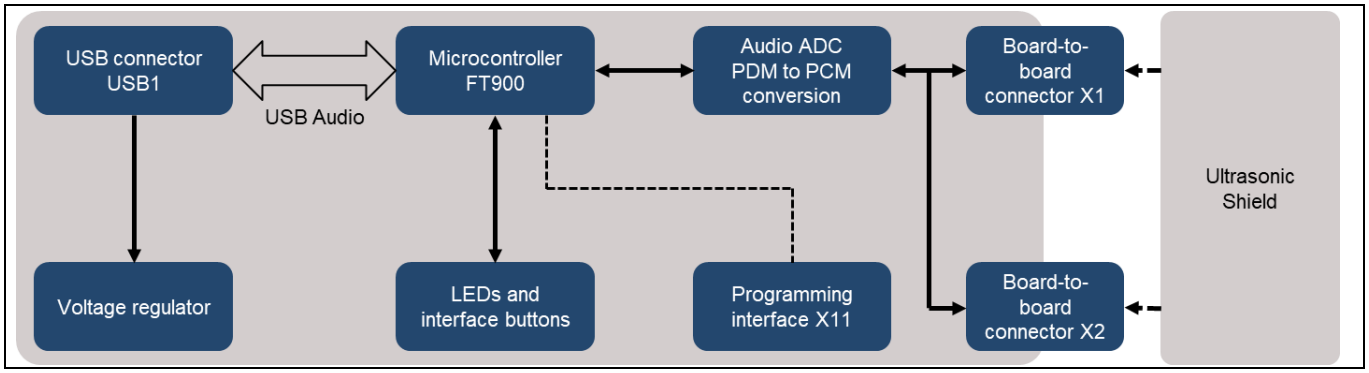

Figure 2 UltraHub motherboard block diagram

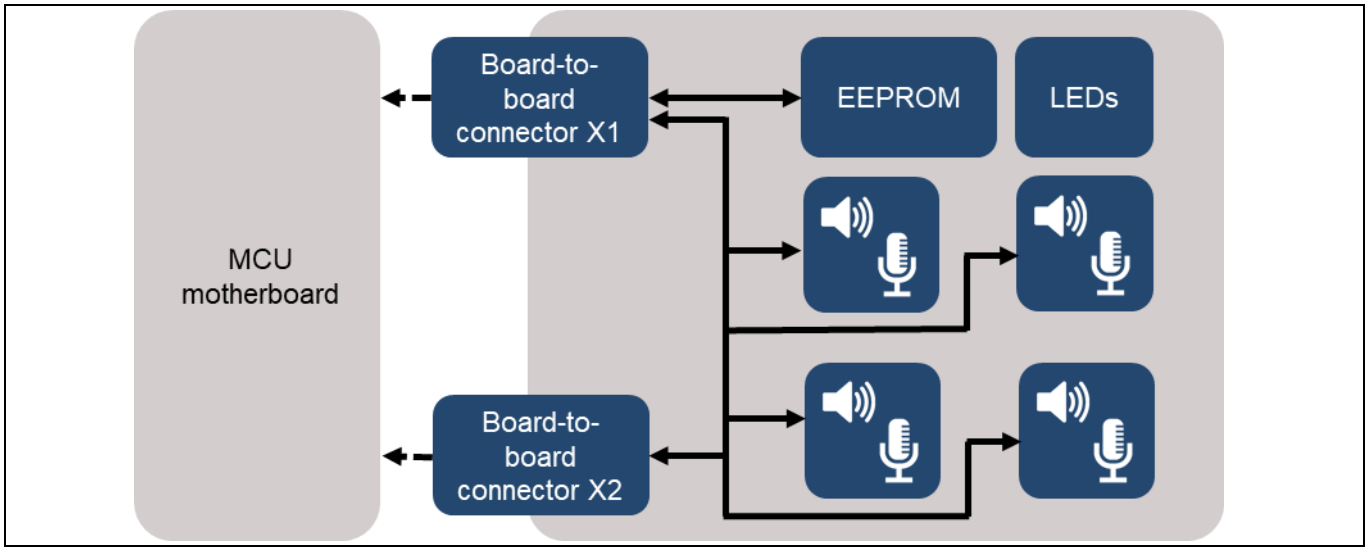

Figure 3 UltraHub sensing shield block diagram

2.3 Initial setup

The board is powered by the Micro USB connector. Connect the board via the Micro USB cable to the host PC. Figure 5 shows how the UltraHub sensing shield connects to the MCU baseboard. The mechanical connectors have markers X1 and X2, which should coincide with the same marking on the shield (see Figure 4). The UltraHub sensing shield is equipped with four LEDs, which turn on based on the actuation of the corresponding transceiver.

2.1 USB communication

The evaluation board is powered through the Micro USB port. Connect the board to the host computer to stream the audio data from the transceivers. Any audio recording or editing software (e.g., Audacity) can be used to record and evaluate the microphones.

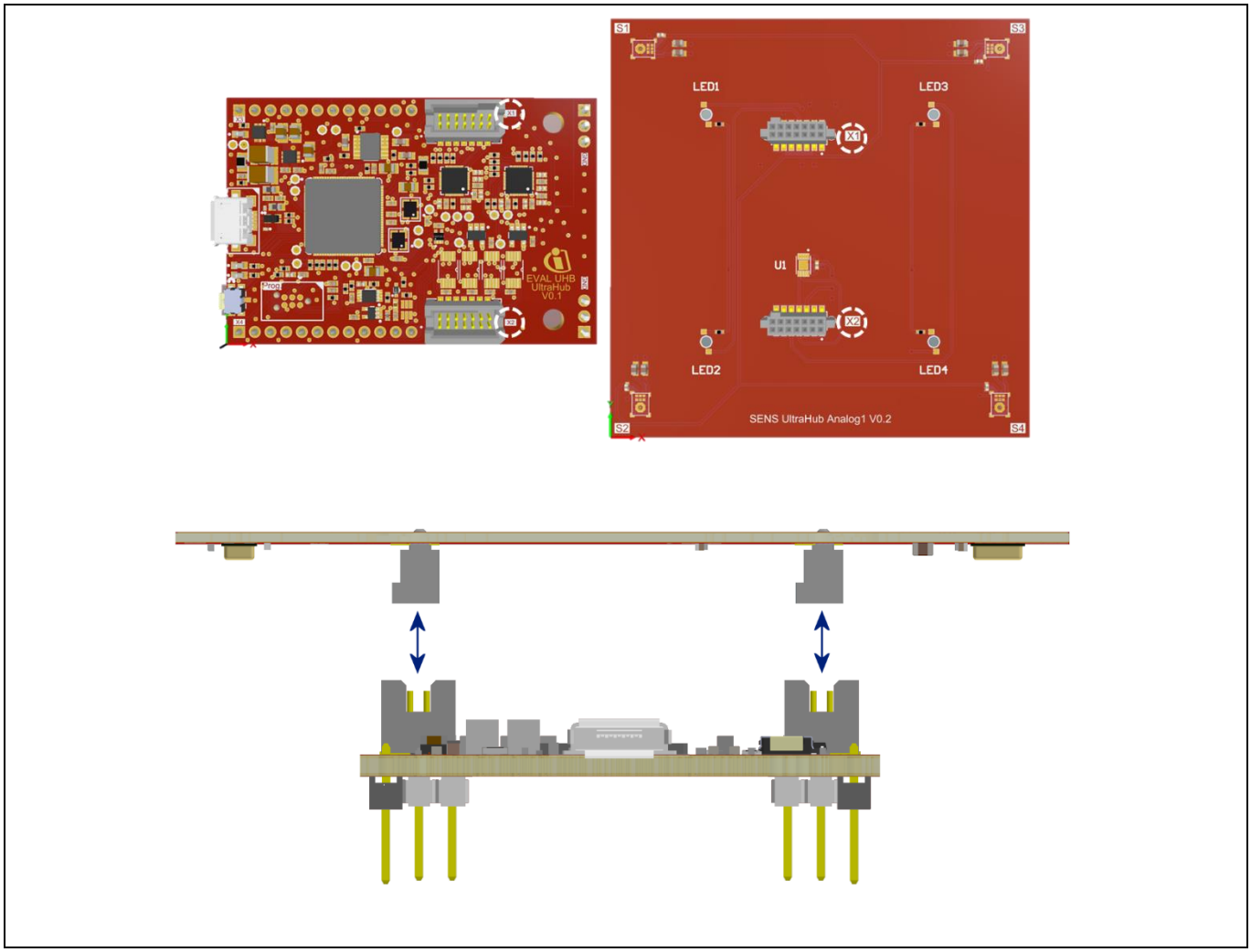

Figure 4 Indication markers and board-to-board connection of motherboard and sensing shield

2.2 Evaluation board connectors

The UltraHub evaluation board offers a wide variety of connectors, listed in Table 1.

Table 1 Connector list

Reference designator	Description
X1	Board-to-board connector for sensing shield
X2	Board-to-board connector for sensing shield
X11	Programming connector
USB1	Micro USB connector for power and audio streaming
X3	Side pins connector
X4	Side pins connector

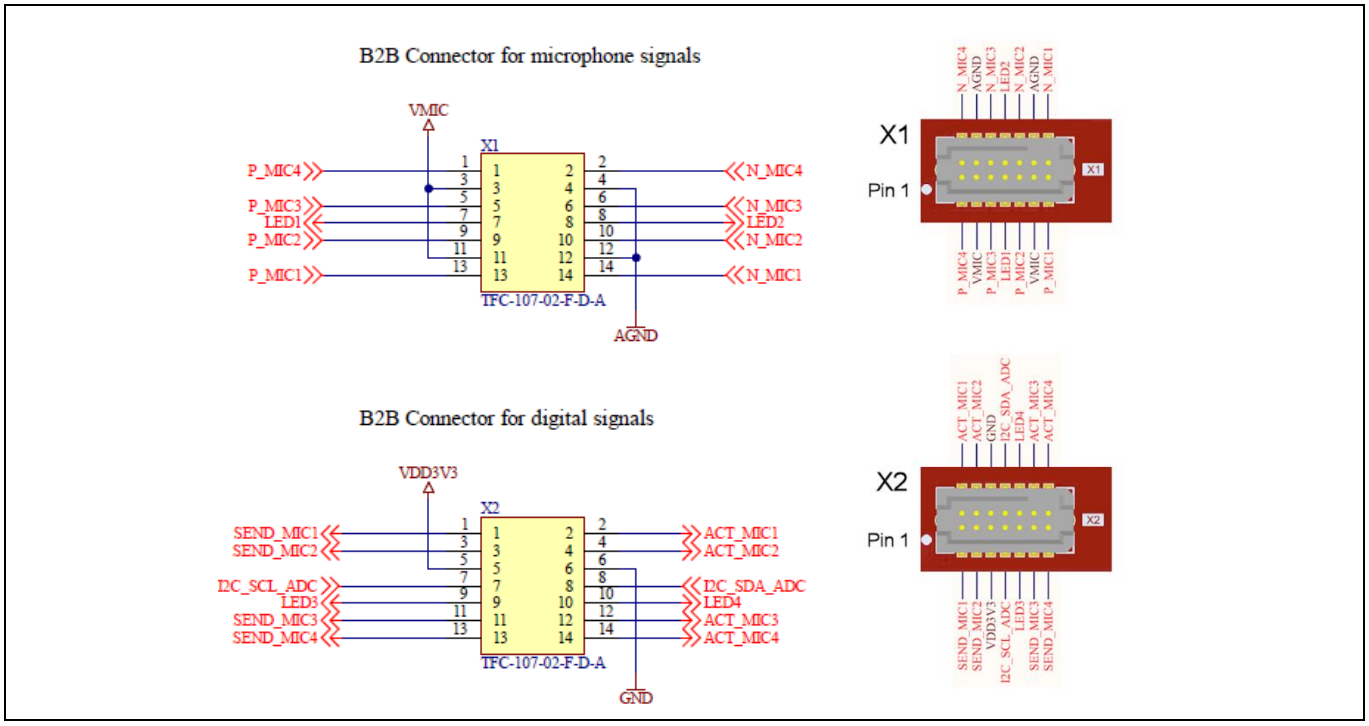

Figure 5 Schematic (a) and pad layout (b) of the connectors for the sensing shield

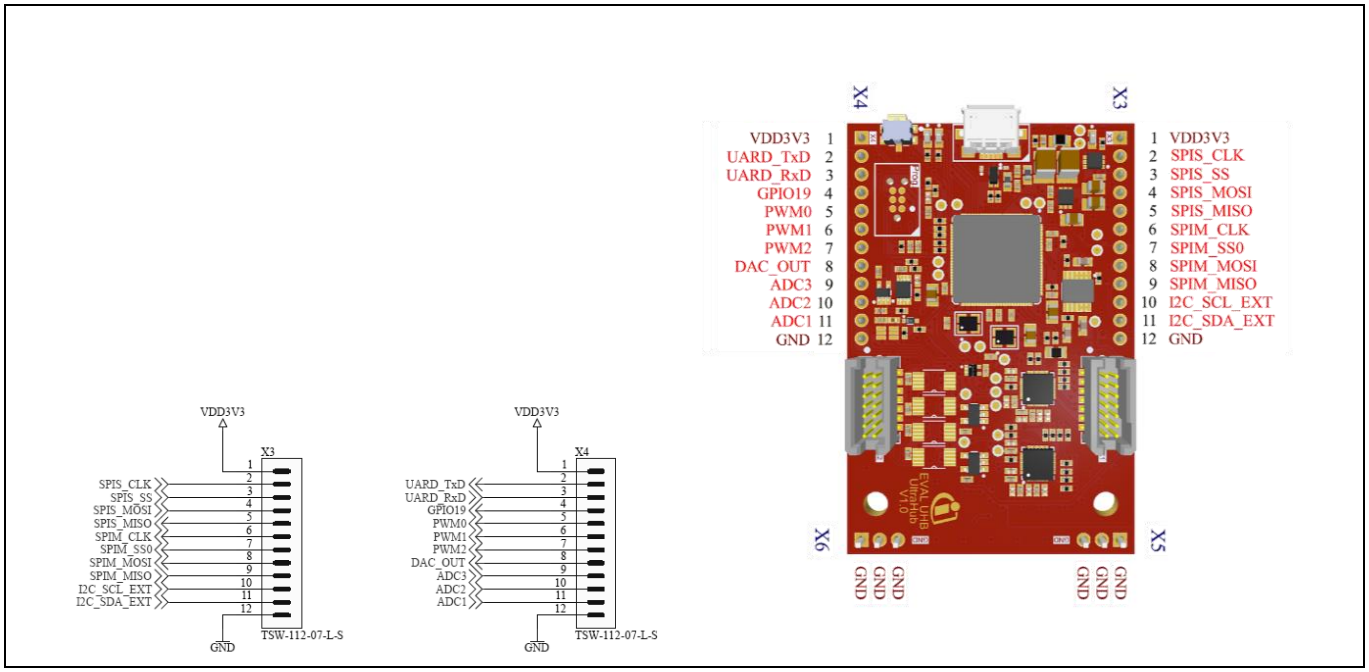

Figure 6 Schematic (a) and pad layout (b) of the motherboard side pins

2.3 Host computer setup

To enable the best performance with USB audio recording, the processor resource allocation should be adjusted for the best performance of background services. Please follow these steps to enable this in the Windows 10 operating system:

- Go to Control Panel > System and Security > System > Advanced system settings.
- Go to the “Advanced” tab and click on the “Settings” button under “Performance”.
- In the pop-up window of “Performance Options”, go to the “Advanced” tab, select “Background services” and apply changes.

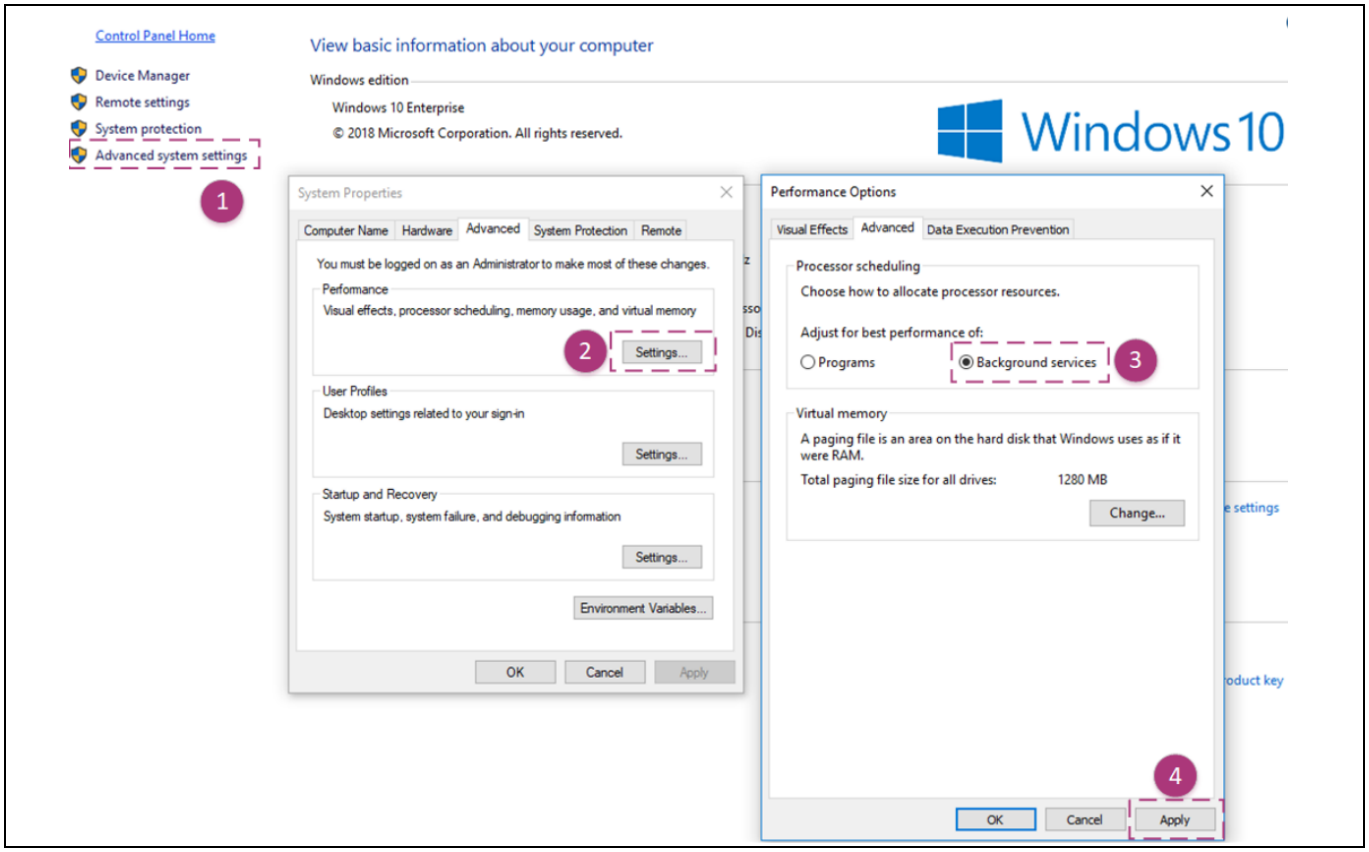

Figure 7 Host computer system settings

To enable the UltraHub to be opened in exclusive mode:

- Open “Windows Sounds Settings”.
- Choose UltraHub as input and click on “Device Properties”.
- Click on “Additional Device Properties”.
- In the “Advanced” tab, make sure that the two checkboxes under the “Exclusive Mode” section are set:
    1. Allow applications to take exclusive control of this device.
    2. Give Exclusive Mode applications priority.

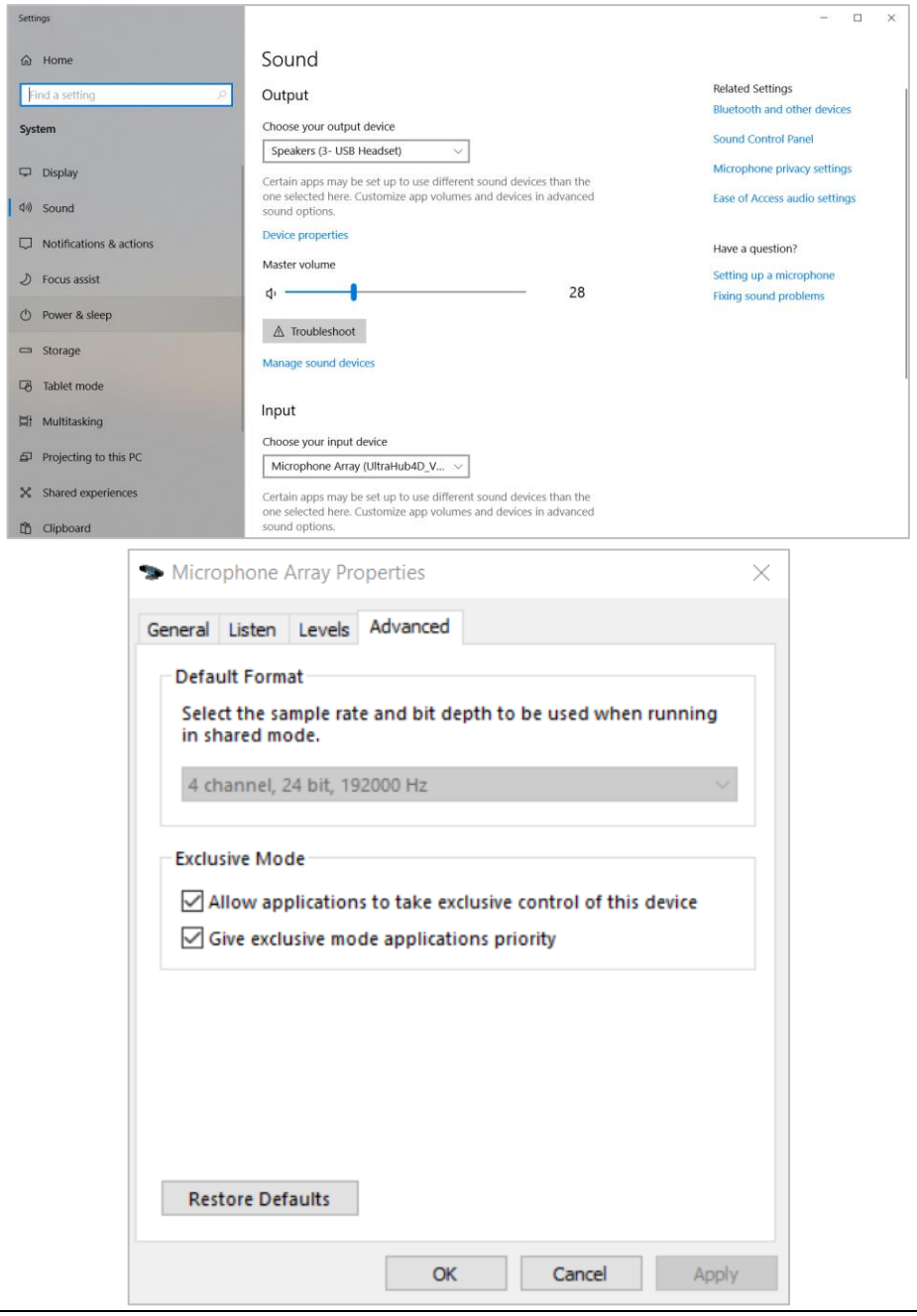

Figure 8 Exclusive Mode for UltraHub

2.4 Audacity software setup

Audacity is a free and open-source audio editor and recording application. Select the audio source as “Microphone Array (UltraHubX)” in the recording software, as shown in Figure 9. Select “Windows WASAPI” as the audio driver and “4” channels. The project rate should be edited to 192000 Hz.

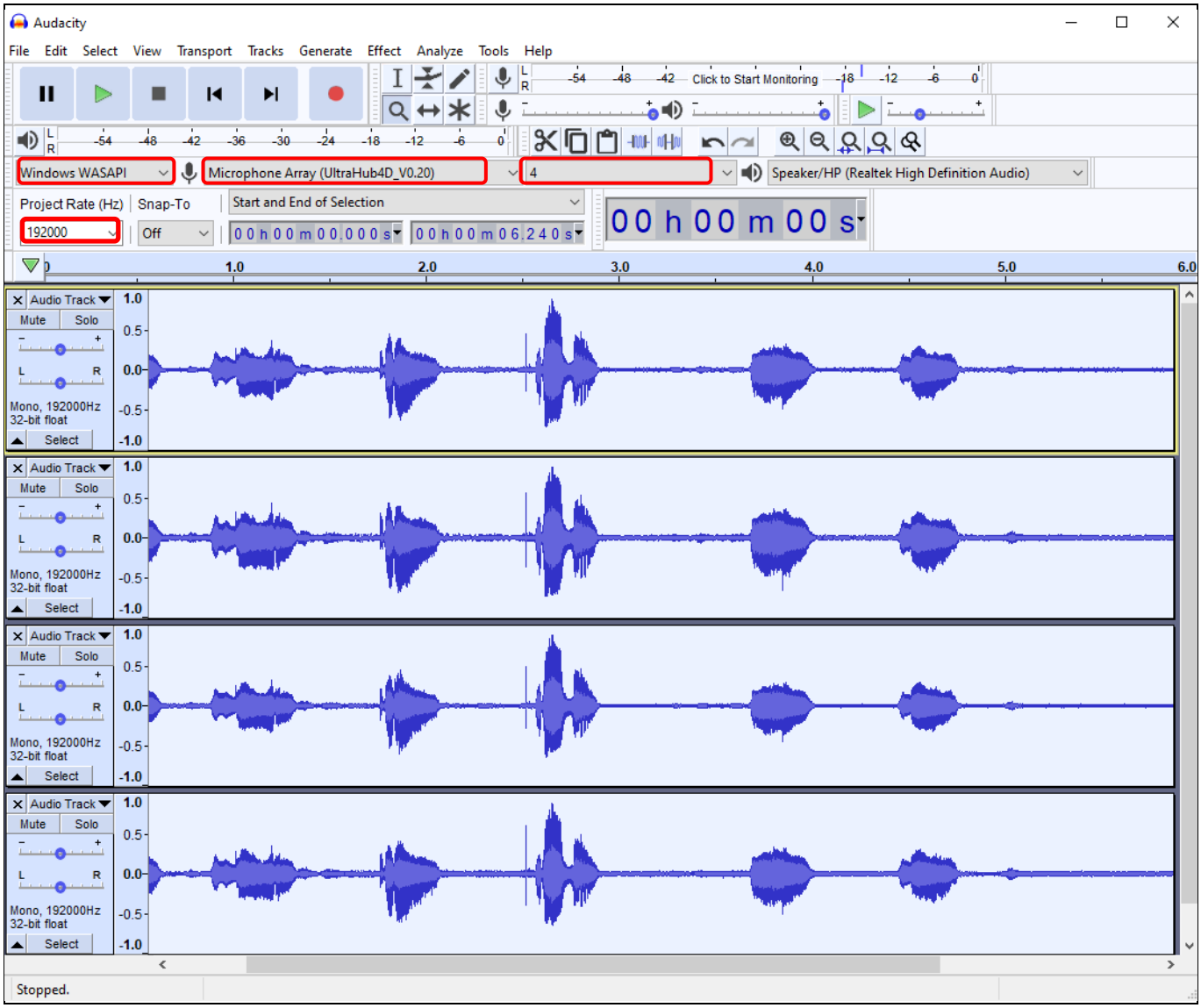

Figure 9 Recording from UltraHub in Audacity

3 Ultrasonic transmission configuration

3.1 Enabling ultrasonic transmission

The four channels on the sensing shields all record audio signals continuously. The ultrasonic transmitting functionality can instead be configured depending on which of the four channels is required to transmit the ultrasonic bursts according to the pulse-echo principle.

Default configuration sees only channel 1 active as transceiver, i.e., sending and receiving, and channels 2, 3 and 4 inactive, i.e., receiving only. Figure 10 illustrates the actuation patterns for the default configuration (A) as well as custom configuration (B), with all four transceivers active in sending mode.

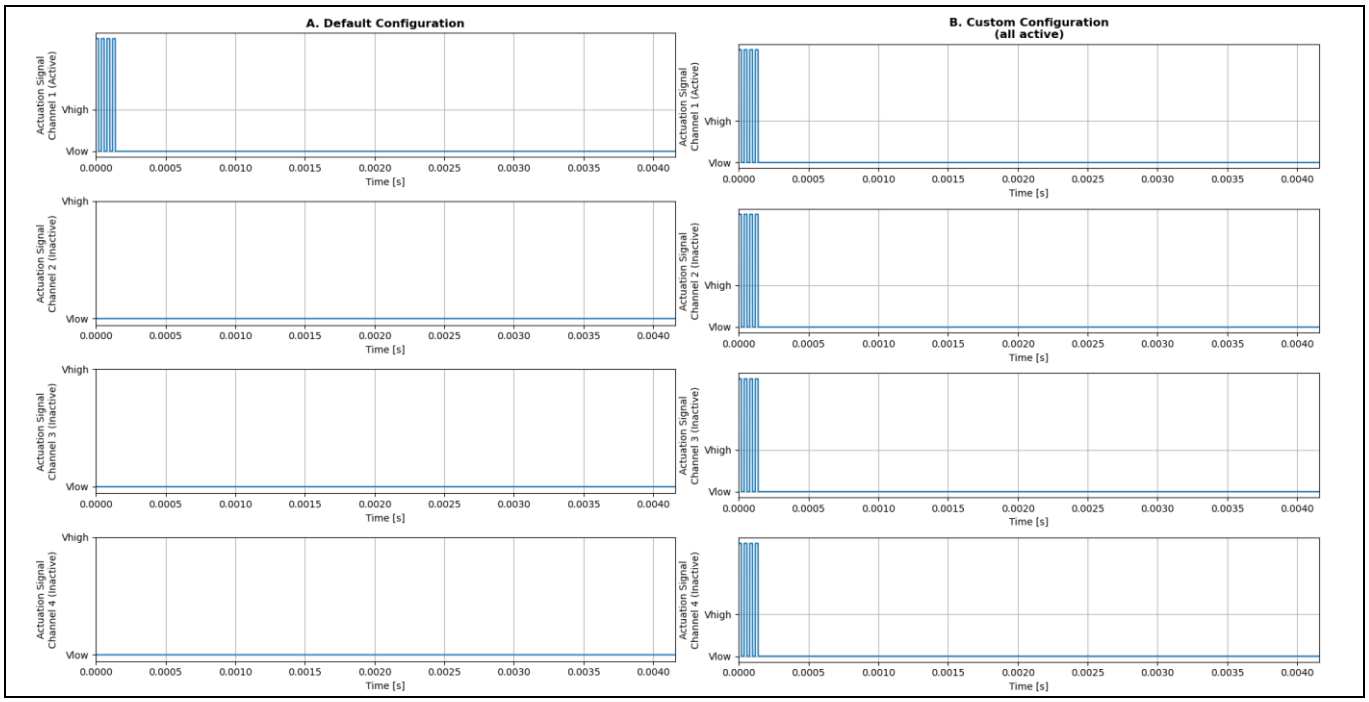

Figure 10 Examples of actuation signals for default (A) and custom configuration with all channels active (B)

3.2 Transmitting burst design

The ultrasonic transmitting patterns can be configured using a selection of parameters:

- Start frequency, i.e., frequency at the start of the actuation burst [20 to 90 kHz]
- End frequency, i.e., frequency at the end of the actuation burst [20 to 90 kHz]
- Number of pulses, i.e., number of cycles in the actuation burst [1 to 12 $pulses$]
- Pulse repetition time (PRT), i.e., the time interval between the start of one pulse and the start of the next one [3 to 500 ms]

The effect of the above parameters is illustrated in Figure 12.

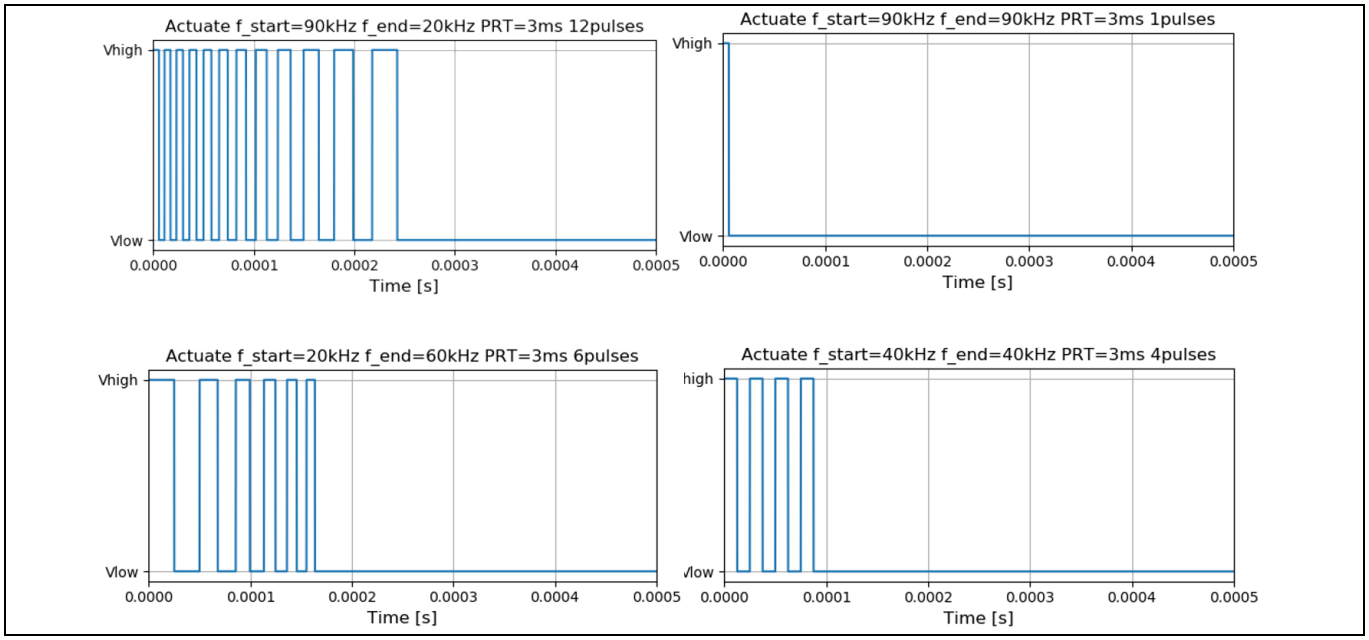

Figure 11 Examples of transmitting bursts varying start, end frequency and number of pulses

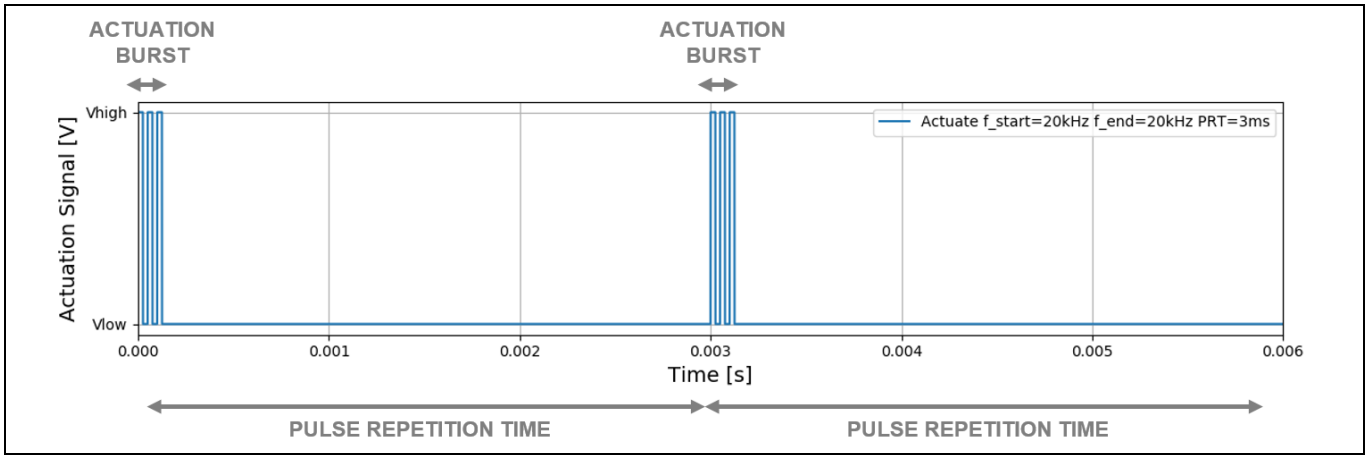

Figure 12 Representation of the PRT and actuation bursts

Note: While the PRT can be directly set by the user, the duration of the actuation burst can vary depending on start, end frequencies and number of pulses. The smaller the actuation frequencies are, the longer the actuation burst will be. The higher the number of cycles, the longer the actuation burst will be.

3.3 Actuation modes

The ultrasonic transceivers can be actuated according to two modes: parallel or cyclic.

- In parallel mode, the active transceivers (i.e., the transceiver selected as active by the user; by default, only transceiver number 1 is selected as active) are all actuated synchronously.
- In cyclic mode, the active transceivers (i.e., the transceiver selected as active by the user; by default, only transceiver number 1 is selected as active) are actuated one after the other. In cyclic mode, each frame is characterized by only one active transceiver at each pulse repetition time.

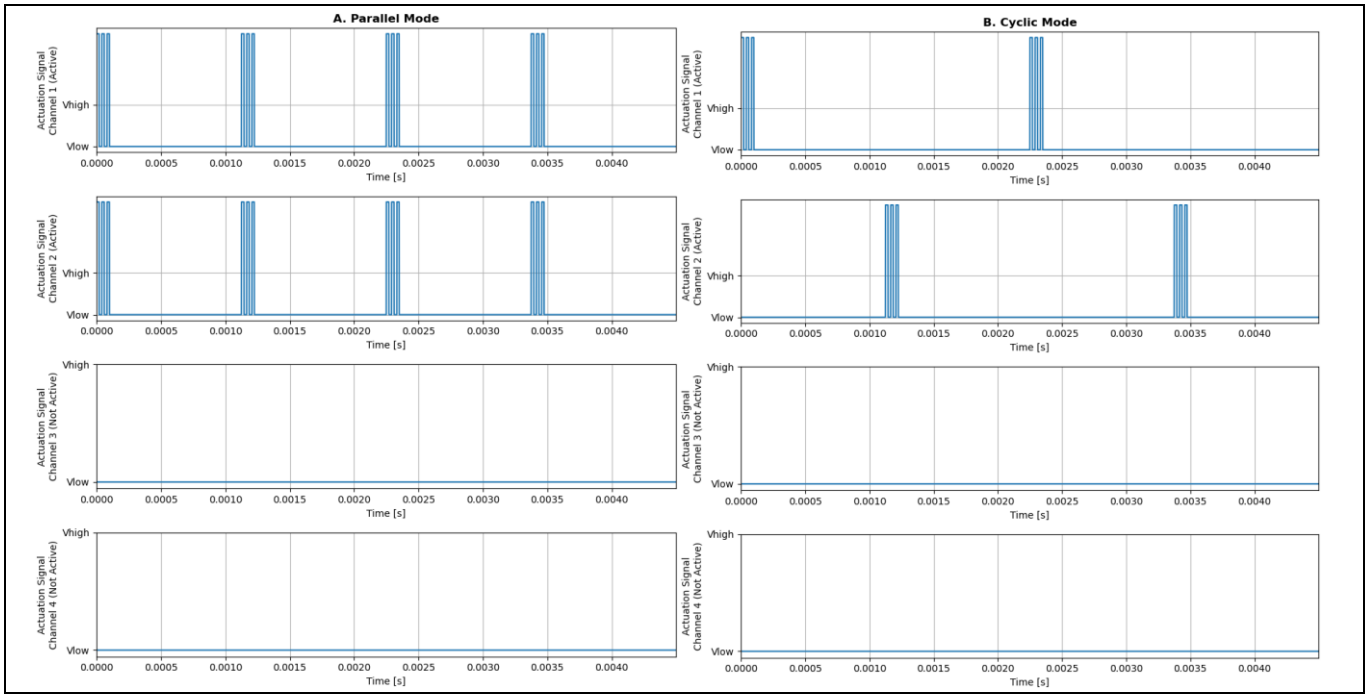

Figure 13 Comparison of parallel (A) and cyclic (B) actuation modes, two transceivers active

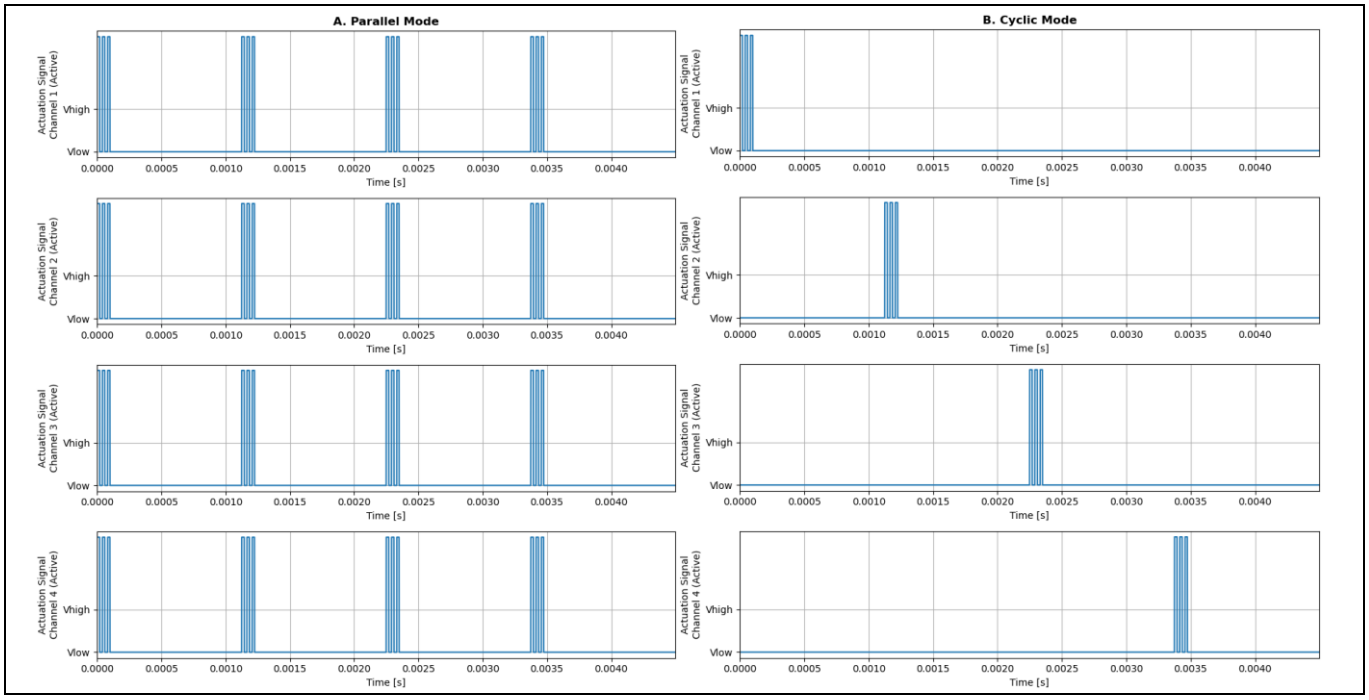

Figure 14 Comparison of parallel (A) and cyclic (B) actuation modes, four transceivers active

Note: The cyclic actuation is performed only on the transceivers selected as active. If only one transceiver is selected as active, no difference will be perceived between the two modes. If all four transceivers are selected as active, the actuation will cyclically involve all four channels.

4 Serial interface

USB communications device class (USB CDC) is a composite Universal Serial Bus device class. The UltraHub has both audio source and CDC end points. This allows for sending bytes to the serial interface using any serial terminal.

Note: Serial commands can be sent to the UltraHub only in idle state, i.e., when the UltraHub is not recording any audio.

4.1 Serial configuration

Baud:	19200
Parity:	None
Stop bits:	1
Byte size:	8
Timeout:	1

4.1.1 Device manager

The COM port of the connected UltraHub board can be seen in the Device Manager. Its description contains “USB Serial Device”, as shown in Figure 15.

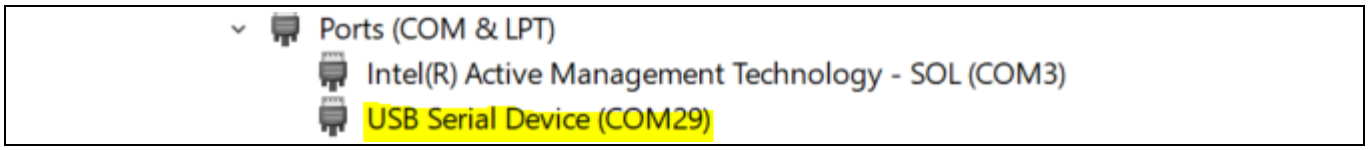

Figure 15 USB CDC interface description

4.1.2 Serial command protocol

The following protocol was implemented in the firmware to receive commands from the application. The user can send a message in the following format.

<Command><Specifier><Parameter><Termination>

Command:	1 byte
Specifier:	1 byte
Parameter:	4 bytes (last byte first)
Termination:	1 byte (0x0A)

The size of the return value depends on the type of message, and is defined in the API description.

4.2 API description

Table 2 summarizes the serial commands to configure the device.

Table 2 System commands

Command (HEX)	Specifier (HEX)	Parameter (lower limit, int)	Parameter (higher limit, int)	Information	Return
0x66	0x6C	20000	90000	Start frequency [Hz] of the ultrasonic transmitting chirp	Parameter set value. Length: 4 bytes
0x66	0x68	20000	90000	End frequency [Hz] of the ultrasonic transmitting chirp	Parameter set value. Length: 4 bytes
0x64	0x2C	1	12	Number of pulses in the ultrasonic transmitting chirp	Parameter set value. Length: 4 bytes
0x77	0x2C	1	500	Pulse repetition time (PRT) [ms]	Parameter set value. Length: 4 bytes
0x6E	0x6D	0x00	0x00	Returns the number of transceivers mounted on the board (read-only)	Parameter read value. Length: 4 bytes
0x6E	0x2C	0b0000	0b1111	Activate/deactivate ultrasonic transmission for each transceiver by bitwise selection of LSBParameter(3:0), D0: Transceiver 1 D1: Transceiver 2 D2: Transceiver 3 D3: Transceiver 4	Parameter set value. Length: 4 bytes
0x43	0x00	0x00	0x00	Read all configuration parameters (read-only)	Read nine words of size equal to 4 bytes: 0 – start frequency 1 – end frequency 2 – actuation pulses 3 – pulse repetition time 4 – number of transceivers 5 – active transceivers 6 – null 7 – device ID 8 – actuation mode
0x41	0x00	0x00	0x00	Save current configuration parameters to EEPROM	0 Length: 4 bytes
0x45	0x45	0x00	0x00	Update stored configuration parameters from EEPROM	0 Length: 4 bytes
0x68	0x00	0x00	0x00	Restore default configuration parameters	0 Length: 4 bytes
0x75	0x61	0	1	Set actuation mode: “0” – parallel actuation (all selected transceivers in parallel) “1” – cyclic actuation (one transceiver is transmitting after another)	Parameter set value. Length: 4 bytes
0x50	0x00	0x00	0x00	Get pulse and cycle length in bits	Return 14 integer values of UltraHub parameters.

Command (HEX)	Specifier (HEX)	Parameter (lower limit, int)	Parameter (higher limit, int)	Information	Return
					Each word is 4 bytes in size. LSB will be sent first 1. Word: I^2S speed = 24576000 Hz 2. Word: pulse repetition based on I^2S clock speed 3. Word: first frequency high/low length based on I^2S clock speed 4. Word: second frequency… 14. Word: 12th frequency
0x49	0x00	0x00	0x00	Get transceiver information as string of 32 characters (read-only)	Transceiver's name e.g., "IM70A135UT\n"
0xE9	0x00	0x00	0x00	Get the software version as string	Software ID e.g., "IFX-UltraHub: V0.81\n"

4.2.1 Sending commands using HTerm

Any terminal program for serial communication can be used to access the serial port. In the following examples, HTerm (www.der-hammer.info) is used as terminal program.

4.2.1.1 Setting actuation start frequency via HTerm

To configure the first actuation frequency as 34000 Hz, use the command in Table 3. Figure 16 shows how to set up the environment and send the desired command via HTerm. Type the values in hexadecimal to send the command, and click enter. Wait for the received data to appear.

Note: The LSB is transmitted first in parameter.

Table 3 Decimal value of frequency (34000 Hz) in Hex

Command (Hex)	Specifier (Hex)	Parameter		Terminator	Info	Return
		(Decimal)	(Hex)			
0x66	0x6C	34000	0x**84 D0**	0x0A	Start frequency [Hz]	Parameter set value. Length: 4 bytes

Transmitted bytes: 66 6C **D0 84** 00 00 0A

Received bytes: D0 84 00 00

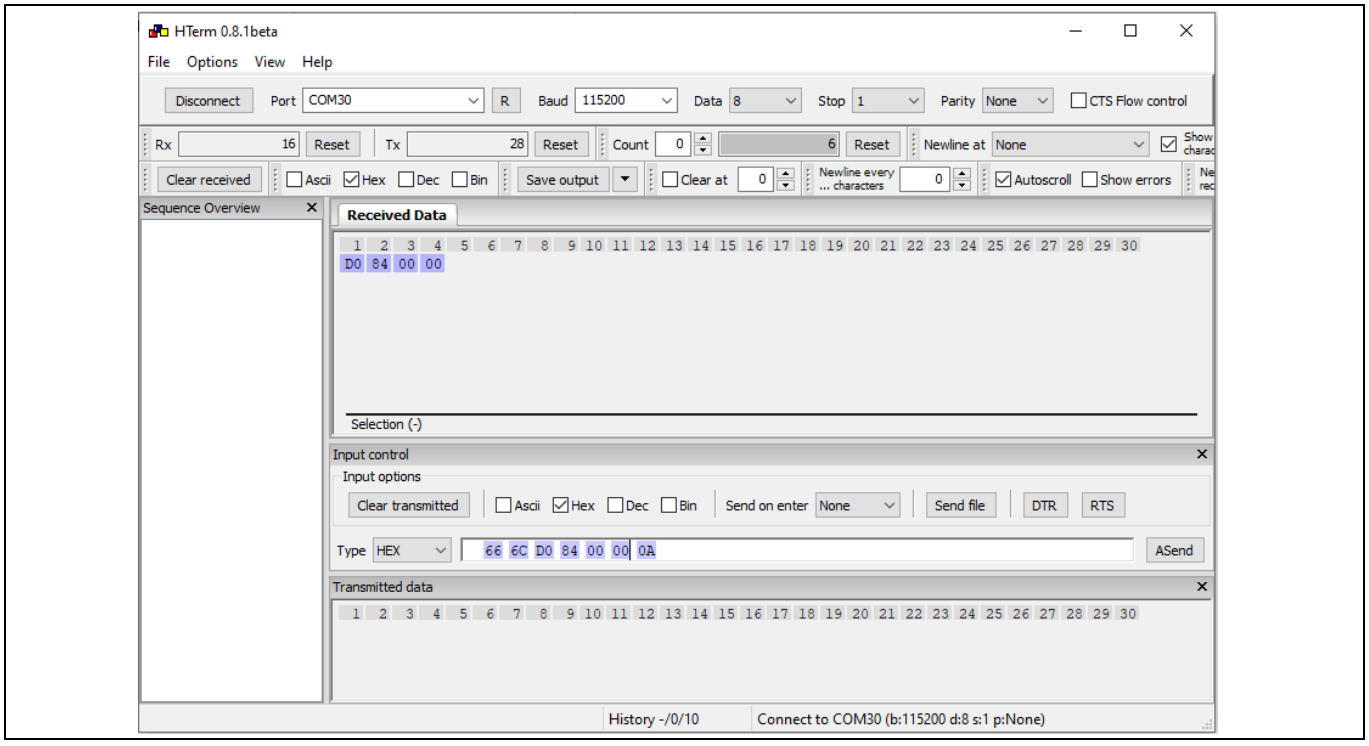

Figure 16 Setting actuation frequency via HTerm

The received bytes (LSB first) from the UltraHub board is the value set in the device. If the user inserts a parameter that is out of range, the value is set to the corresponding upper or lower limit value for the parameter, as in the following example.

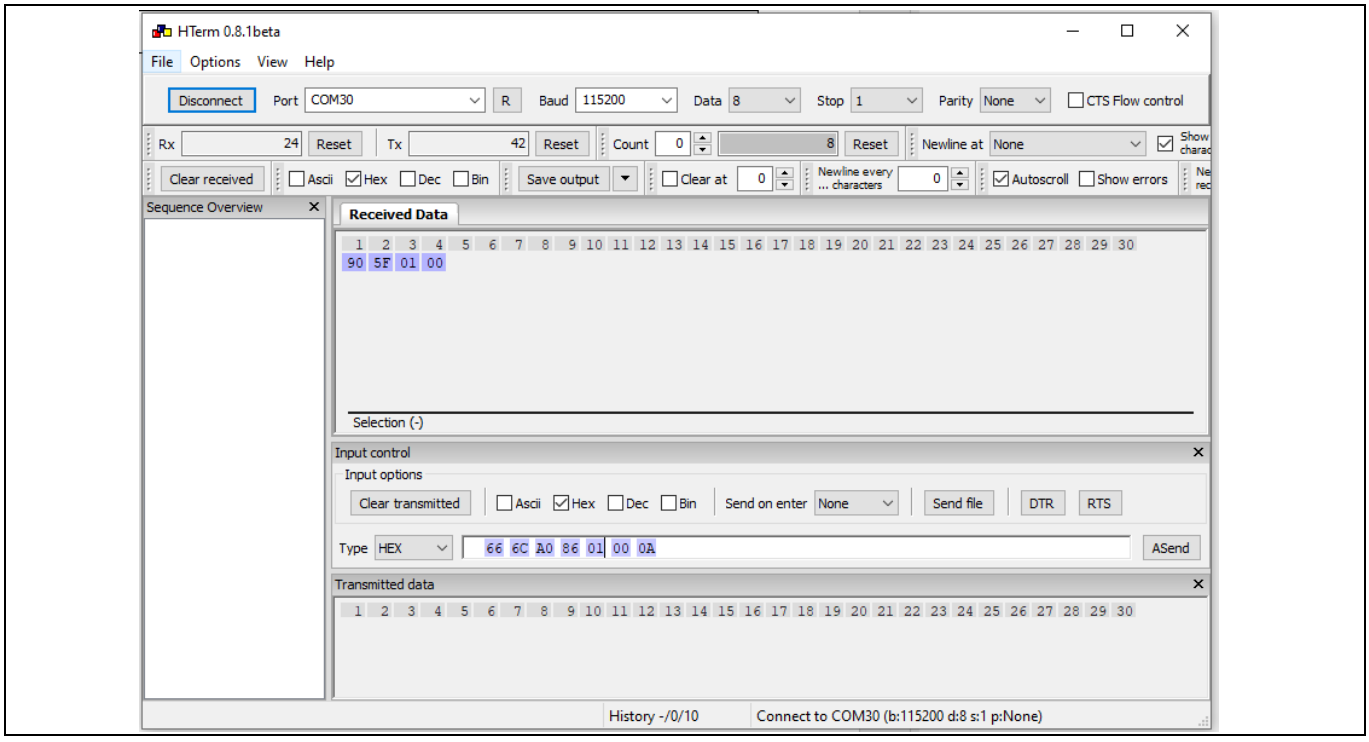

Figure 17 Sending out-of-limit value to device

Table 4 Decimal value of frequency (10000 Hz) in Hex

Command (Hex)	Specifier (Hex)	Parameter		Terminator	Information	Return
		(Decimal)	(Hex)			
0x66	0x6C	100 000	0x **01 86 A0**	0x0A	Start frequency [Hz]	Parameter set value. Length: 4 bytes

Transmitted bytes: 66 6C **A0 86 01** 00 0A (sending actuation start frequency = 100 000 (*0x 01 86 A0*))

Received bytes: 90 5F 01 00 (received value is 90000, which is the highest limit that can be set)

4.2.1.1 Setting active transceivers via HTerm

To configure the first transceiver as active, i.e., able to transmit, use the command in Table 6. Figure 16 shows how to set up the environment and send the desired command via HTerm. Type the values in hexadecimal to send the command, and click enter. Wait for the received data to appear.

Note: The LSB is transmitted first in parameter (see Table 5)

Table 5 Set bit corresponding to the transceiver

Transceiver 4	Transceiver 3	Transceiver 2	Transceiver 1
B3	B2	B1	B0

Table 6 Binary value of zero-actuating channels

Command (Hex)	Specifier (Hex)	Parameter		Terminator	Information	Return
		(Decimal)	(Hex)			
0x6E	0x2C	1	0x**00**	0x0A	Activate/deactivate ultrasonic transmission	Parameter set value. Length: 4 bytes

Transmitted bytes: 6E 2C **0x01** 00 00 00 0A

Received bytes: 0x01 0x00 0x00 0x00

To configure the first and the third transceivers as active, i.e., able to transmit, send the command via HTerm as illustrated in Figure 19.

Transmitted bytes: 6E 2C **0x03** 00 00 00 0A

Received bytes: 0x03 0x00 0x00 0x00

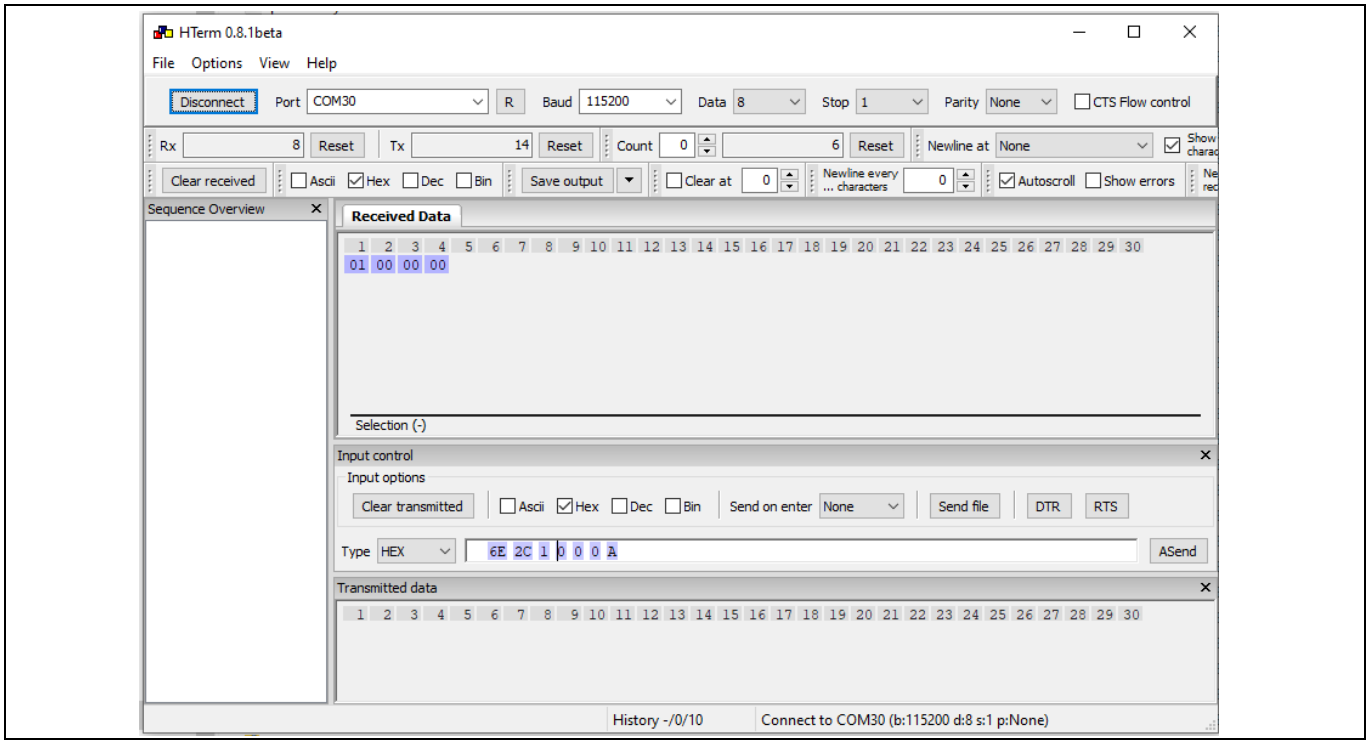

Figure 18 Setting transceiver 1 as active transceiver

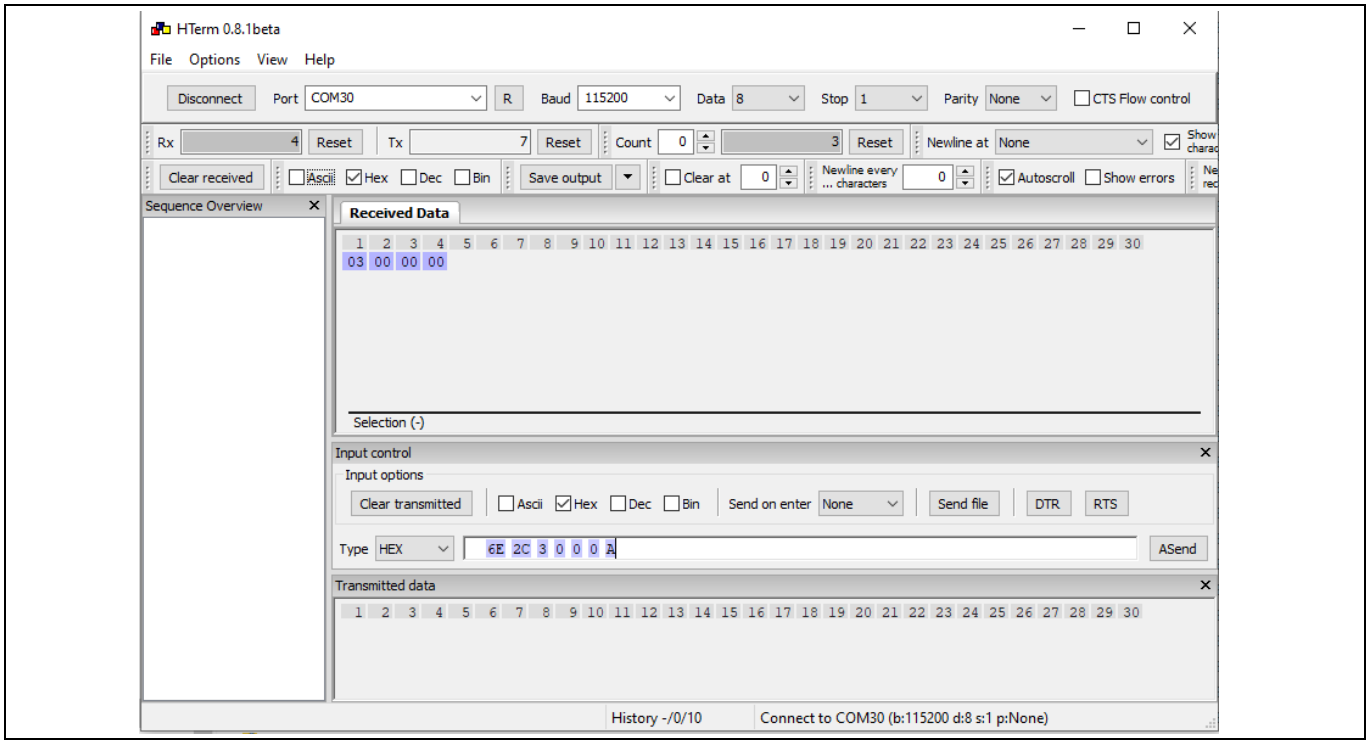

Figure 19 Setting transceiver 1 and transceiver 2 as active transceivers

5 Guide for firmware update

To update the firmware on the UltraHub evaluation board:

- Press the push-button for three seconds to turn on DFU mode on the microcontroller. An LED next to the USB connector indicates DFU mode. Check in the Device Manager that DFU mode is enabled.

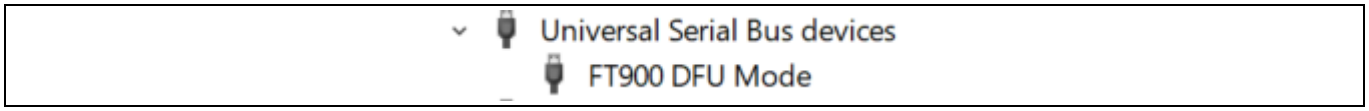

Figure 20 The microcontroller is in DFU mode from the Device Manager

- Download FT9xx Programming Utility (FT9xx_Toolchain_Setup_2.5.0)
- Select the option “Program via USB (DFU) interface”.

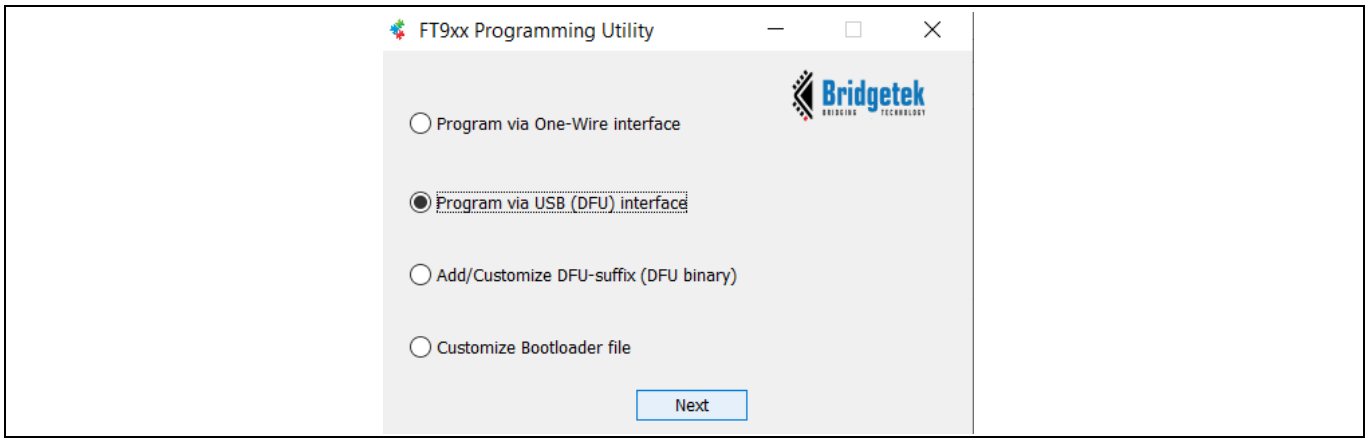

Figure 21 Select the option “Program via USB (DFU) interface”

- Scan and select the device of interest.

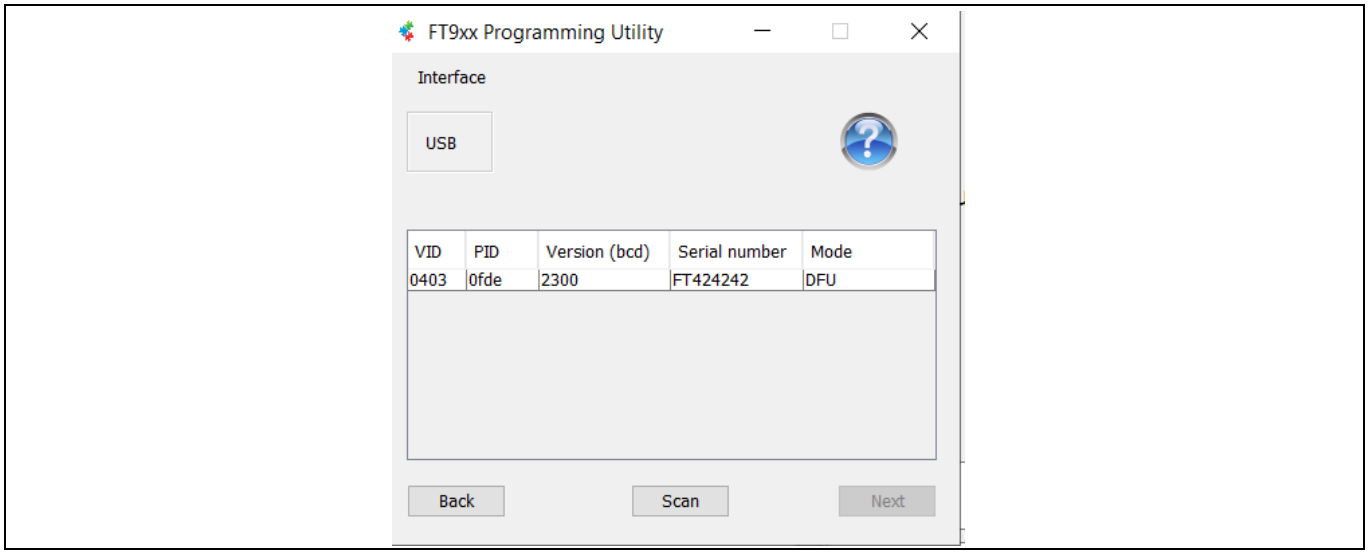

Figure 22 Scan and select device

- Select the proper binary file to Flash.

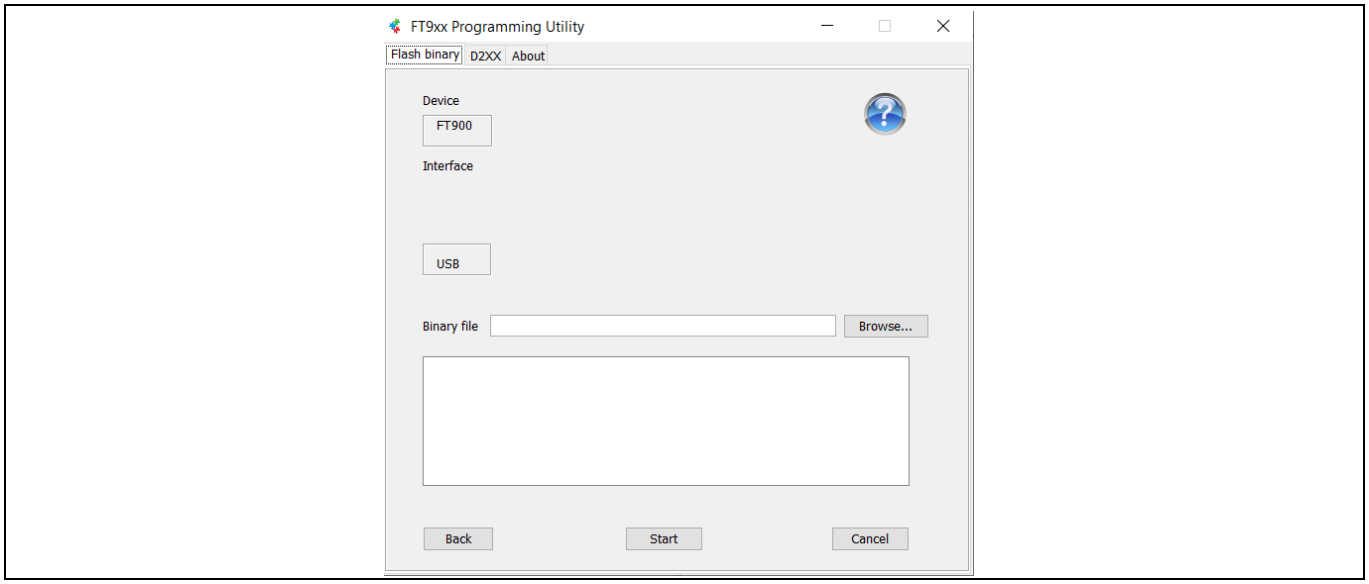

Figure 23 Browse to select the right binary file and Flash

6 Resonance measurements

As the geometry of the final sound channel shifts the resonance of the pure transceiver (compare product briefs of IM67D131UT and IM70A135UT) the resonance frequencies on the UltraHub shields are shifted compared to the bare transducer resonances. The following figure shows a comparison of the measured SPL at 10 cm distance of a type 2 sensing shield (see Figure 24), where only the center transducer (S1) is actuated vs. a transducer mounted on a thin flex-board.

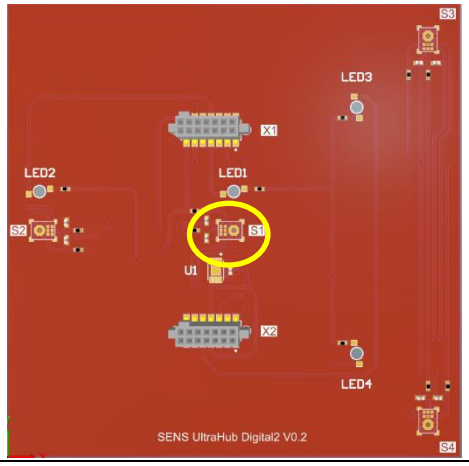

Figure 24 Layout of type 2 sensing shield

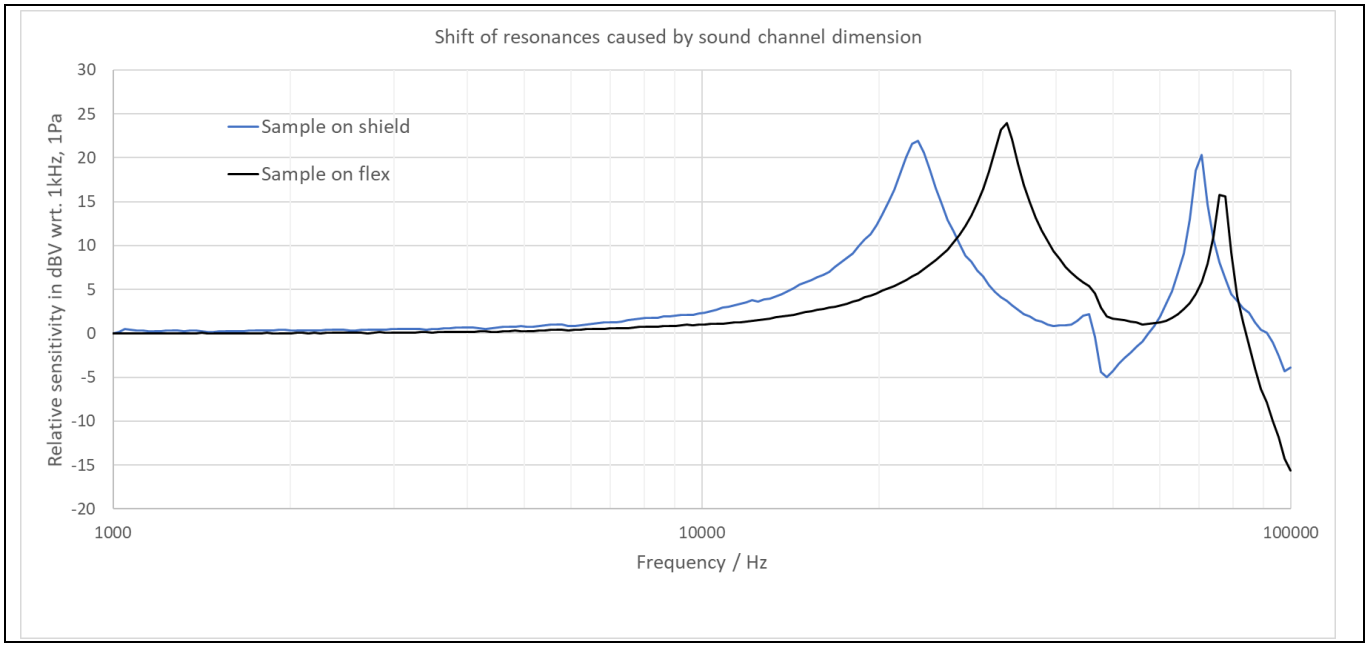

Figure 25 Impact of sound-channel dimension on resonance behavior of a device on sensing shield compared to a transducer mounted on a slim flex-board

As can be seen from Figure 25 the prolonged sound-channel due to the thickness of the sensing shield is downshifting both resonances. If the sound-channel in front of the device's sound port is further increased, this will lead to an additional downshift of both resonances which can be estimated by a transmission line model[1].

[1] Anzinger S. et al. (2019). Acoustic transmission line based modelling of microscaled channels and enclosures. JASA, 145(2), 968-976.

As the dimension of the sound-port opening on the shield is small compared to the acoustic wavelength, the directivity pattern in both resonances is almost omnidirectional as can be seen from the TX directivity plots in Figure 26. Thus, the shield offers a very broad field of view and any objects placed on a table next to the shield may therefore lead to static echoes. The static echoes can however be subtracted by a calibration routine provided within the GUI.

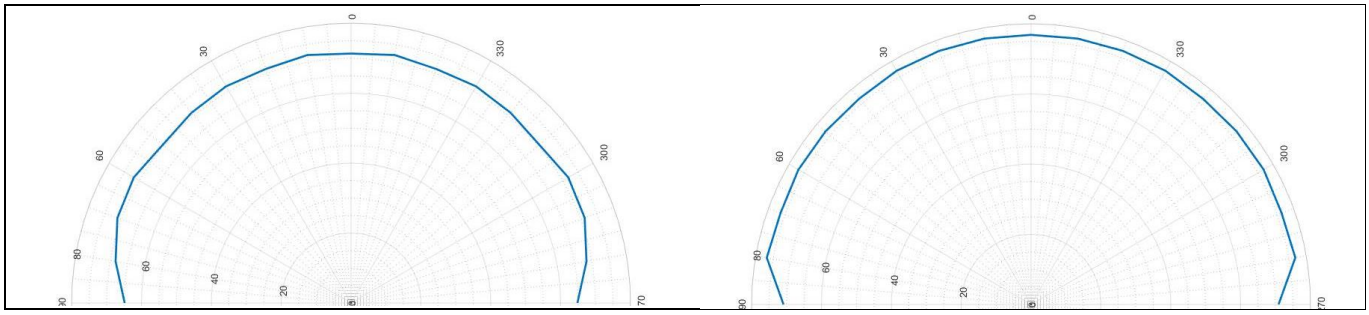

Figure 26 Directivity plots of the SPL at 24 kHz (left) and 85 kHz (right)

Revision history

Document version	Date of release	Description of changes
1.0	July 2021	Public release
1.1	August 2021	Top-level schematic and directivity measurements updated
1.2	October 2021	Ultrasonic transmission configuration added