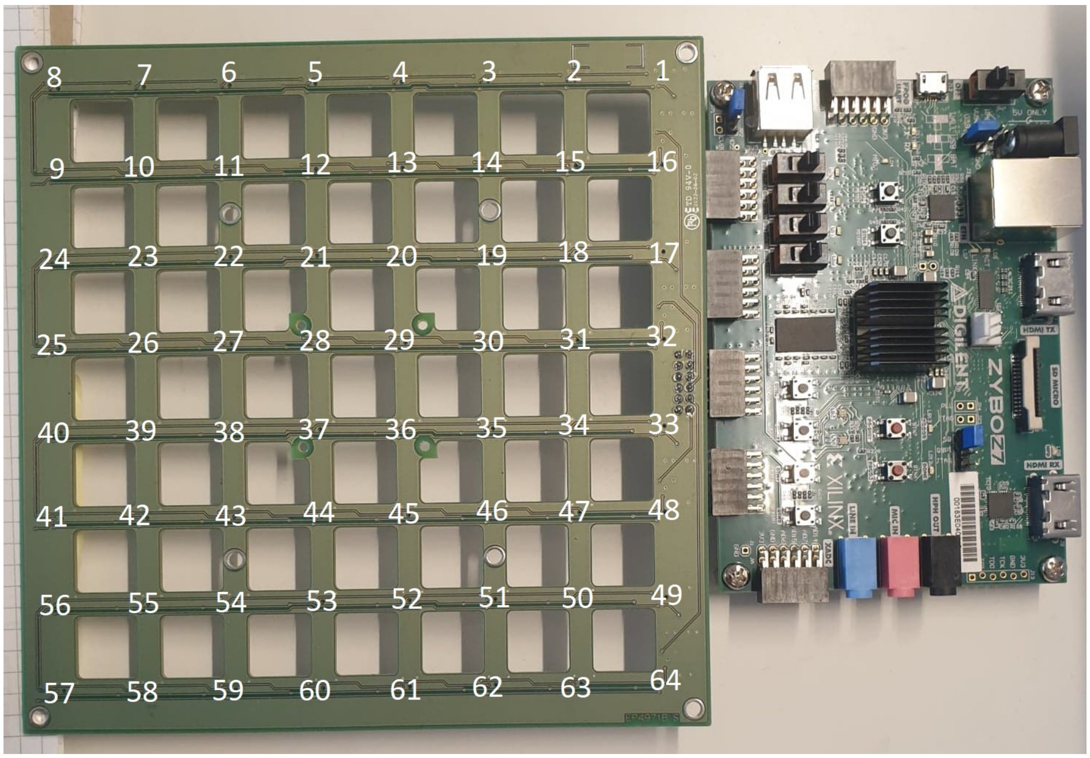
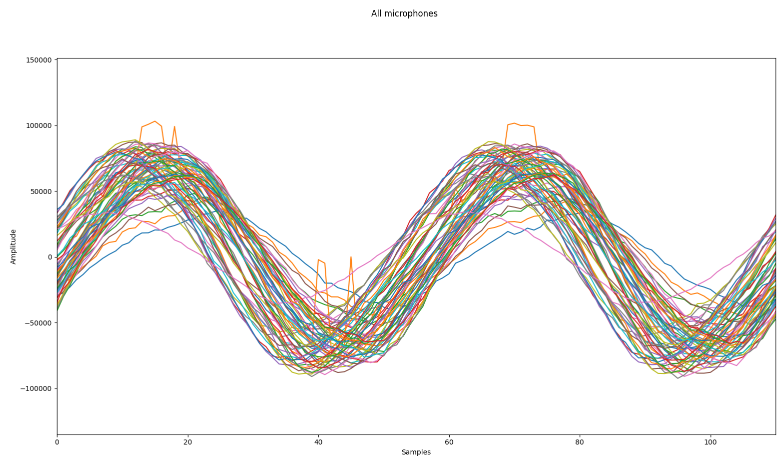
Testing the arrays

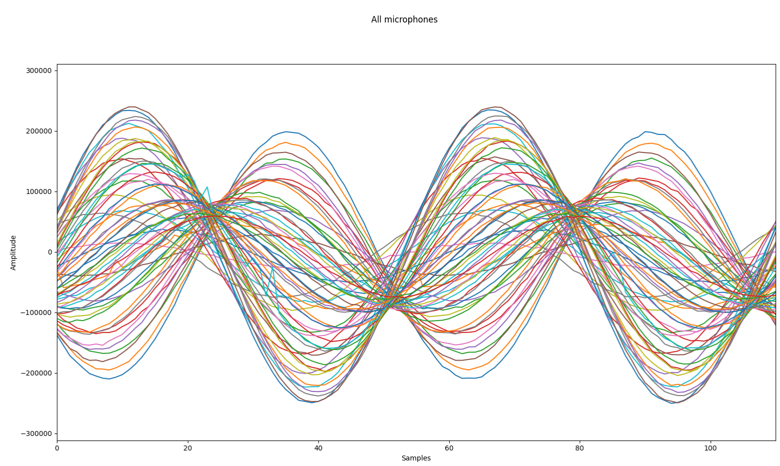


Intro

The results of these tests are very dependent on the type of audio source. A mobile phone usually has a lower quality speaker, however it gives good control over the direction of how the sound. Therefore it is recommended to have a sound source with a small and concentrated area of the speaker itself.



Mobil phone source at 2 meter distance



Speaker source at 2 meter distance

Recommended tone generator: szynalski

Version of FPGA-sampling used during the tests: Github release

Download the release above or clone the Test_Manual_version branch

Use the following BOOT.bin version BOOT.bin version 1.1

Checklist:

- Make sure the mini SD-card is inserted onto the FPGA, and that it is the right BOOT.bin.
- The JP5 pins on the fpga-board is set to SD.
- Make sure you have changed to the correct IP address on your PC. IPv4: 192.168.1.2 mask: 255.255.255.0.
- Also make sure you are using an open port on the PC.
- Turn on the power switch on the FPGA and after a few seconds the lights underneath the ethernet port should blink rapidly.

If you should need help with the installation or help to get the code running, please see the user manual under the project wiki. User-Manual

Test 1: Receiving real data and using the scripts

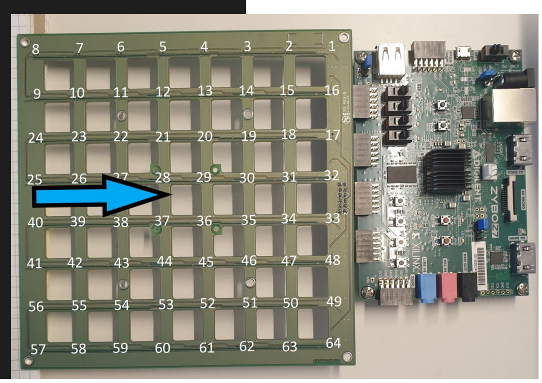
Assuming that everything is up and running, there are several tests that should be performed to ensure that an array is working as it should. This test is to make sure the array is outputting real data. If something is not set up correctly the Python scripts will receive only 0:s. In the root of the project there are two main folders: PL and PS. Under PS, go to the python_script folder. This is where all the scripts that will be used for the tests are.
Run the *listen_and_analyze.py* script and follow the instructions. Use your voice or a generated signal of your choice, this is just to ensure the array is sending data.

```
FPGA-sampling/ps/python_scripts/listen_and_analyze.py
Enter a filename to samples:
test
Enter time to record (seconds):
3
Enter the frequency of the audio source (Hz):
880
view data for a Horizontal line or vertical line. Enter [H/V]
```

Pick to either view data for a horizontal or vertical line by entering "h" or "v".
If "h" is entered you get the option to select one of eight horizontal lines:

```
view data for a Horizontal line or vertical line. Enter [H/V]
h
pick a horizontal line[Lx]
-----------------------------------
L1: | 8, 7, 6, 5, 4, 3, 2, 1
L2: | 9,10,11,12,13,14,15,16
L3: | 24,23,22,21,20,19,18,17
L4: | 25,26,27,28,29,30,31,32
L5: | 40,39,38,37,36,35,34,33
L6: | 41,42,43,44,45,46,47,48
L7: | 56,55,54,53,52,51,50,49
L8: | 57,58,59,60,61,62,63,64


write [Lx], where x is a number from 1-8
choice:
l1
press ENTER to start
```

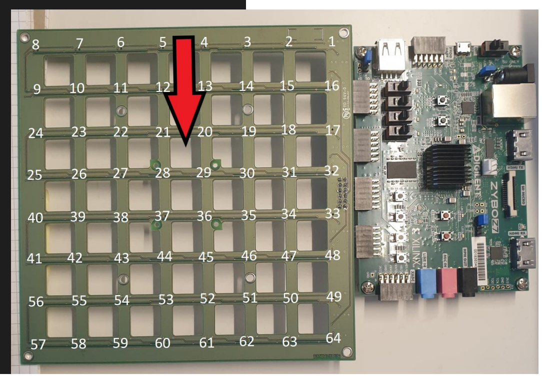


Pick a line, for example if you want to observe the line with mic 8-1, enter "l1".

If "v" is entered, you similarly get the option to pick one of eight vertical lines.

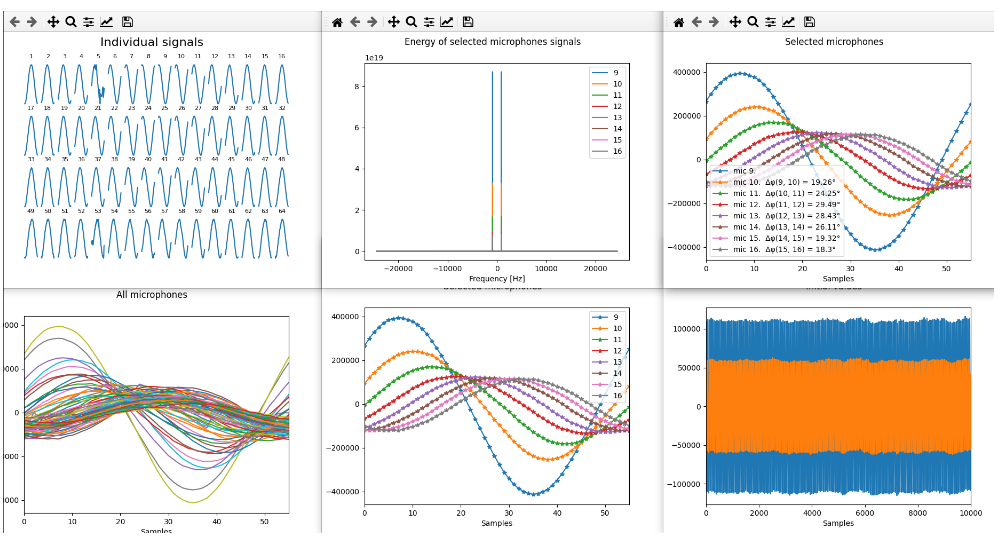
```
view data for a Horizontal line or vertical line. Enter [H/V]
v
pick a vertical Line[Lx]
L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 |
---------------------------------------
8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  |
9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 |
25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 |
41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 |
57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 |


write [Lx], where x is a number from 1-8
choice:
l1
press ENTER to start
```



Pick a line, for example if you want to observe the line with mic 8-57, enter "l1".

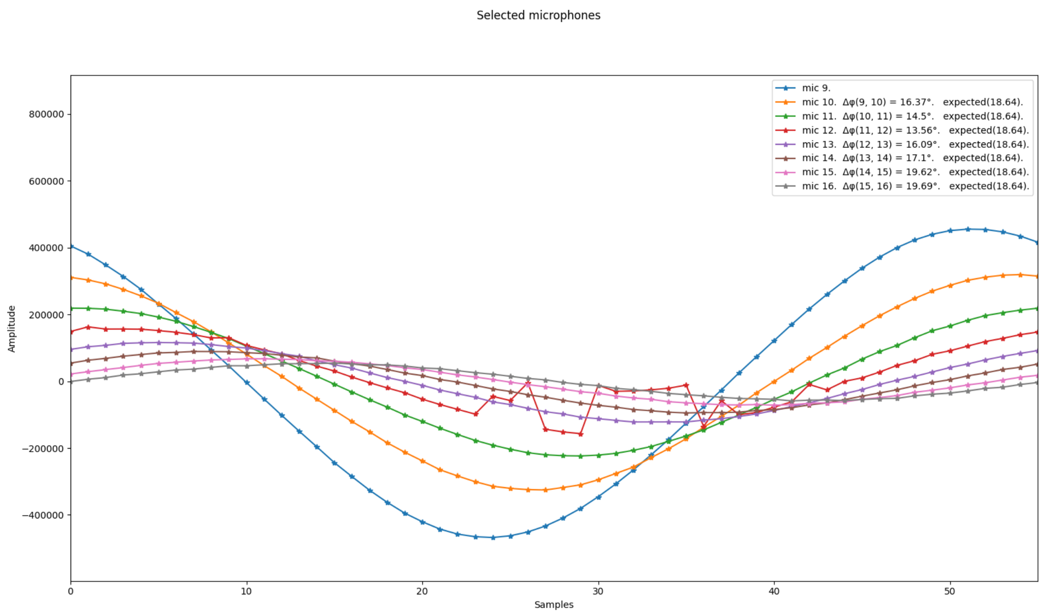
Pressing ENTER will start the recording, and after the recording-time has passed the graphs show up.



Graphs from the analyzer script

Test 2: Does every microphone work

This is a straightforward test to make sure every microphone actually works. Hold the generated signal aligned with the chosen line and at a distance of a few centimeter. Run *phase_test.py* and study the plots of the selected line over a period of the recorded signal. Do this with every line in the array. Signs of a broken microphone could be low amplitude, amplitude spikes, or other strange behaviour. Use a generated signal and place the audio source few centimeter away from the line you want to test.



On this particular array microphone 12 show signs of malfunction

Results of test 2 with array PCBA1:

Mic 12 and 60 show signs of error with recurring spikes in amplitude.

Mic 57 always has a very low amplitude compared to other the microphones.

Test 3: Does the microphones sample data simultaneously

The main purpose of this test is to ensure that the microphones sample data at the same time. To investigate this the script calculates the phase difference for each microphone relative to the previous microphone. The array is built so that the microphones in a line are spaced 2 cm apart. Therefore the audio source needs to be placed at the same vertical plane as the array to make sure that the distance between each microphone maintains 2 cm.
Do this test with multiple distances and frequencies of the audio source. Do several recordings before you move the audio source. Simply close the graph and a new recording is started immediately with the same settings entered at the start of the script. Repeat for other lines.

A platform is used to ensure the array and the audio source are at the same height, i.e the same vertical plane.

If the array and audio source are placed in the same vertical plane it makes it possible to estimate the phase difference of the microphones relative to the previous microphone. For example, if the frequency of the audio source is 880 Hz the phase difference for each microphone should be around 18.6 degrees, as can be seen in the equation below.

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 880 \text{ Hz} \approx 18.6° \tag{1}$$

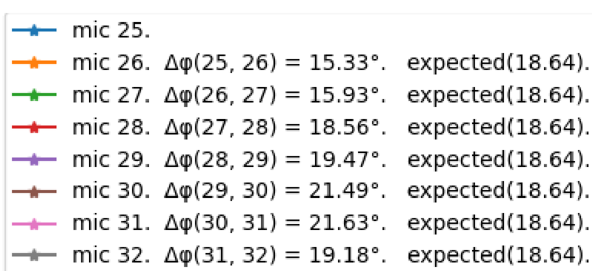
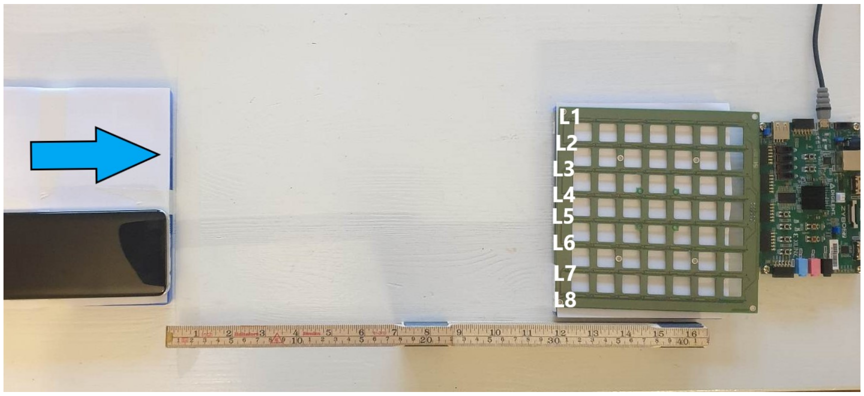


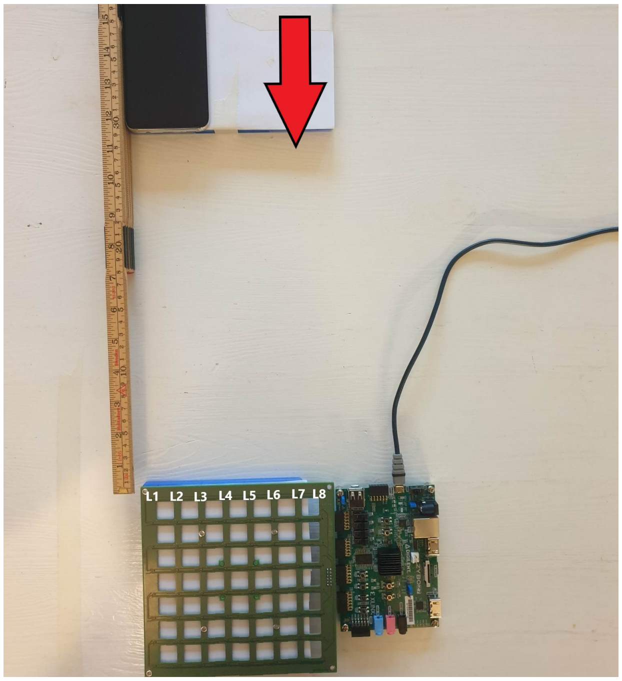
Figure 3: 880 Hz phase difference of the horizontal line L4.

Test 3 at 30 cm:
Place the audio source at a distance of 30 cm from the first microphone in the chosen line, and set the frequency of the generated sine signal to a selected frequency. Then set the recording time to 10 seconds.
Start the zybo and run the script *phase_test.py*. Follow the the instructions in the UI and pick a desired line to test. Start by going through every horizontal line of the array. Enter "h" to get the selection of horizontal lines and then then go through line L1 to L8. Make sure to align the speaker of the audio source to each line. The idea here is that if the microphone have the same physical distance from each other, they should also have a consistent phase difference relative to each other.



Place the audio source at a distance of 30 cm from the array and test the horizontal lines.

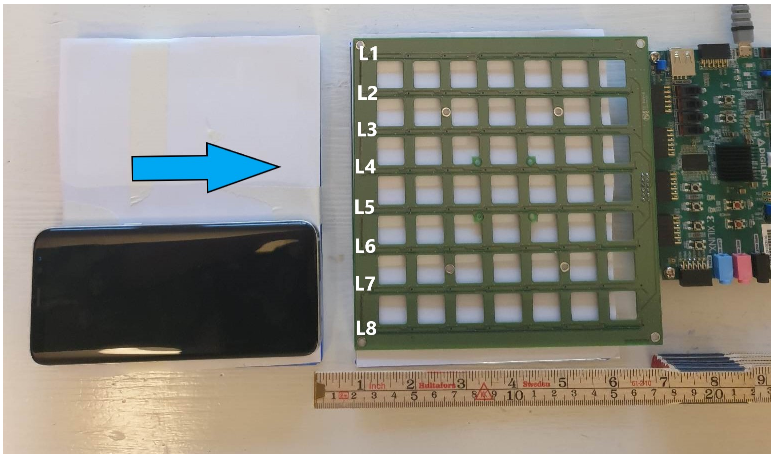
Do the same with the vertical lines.



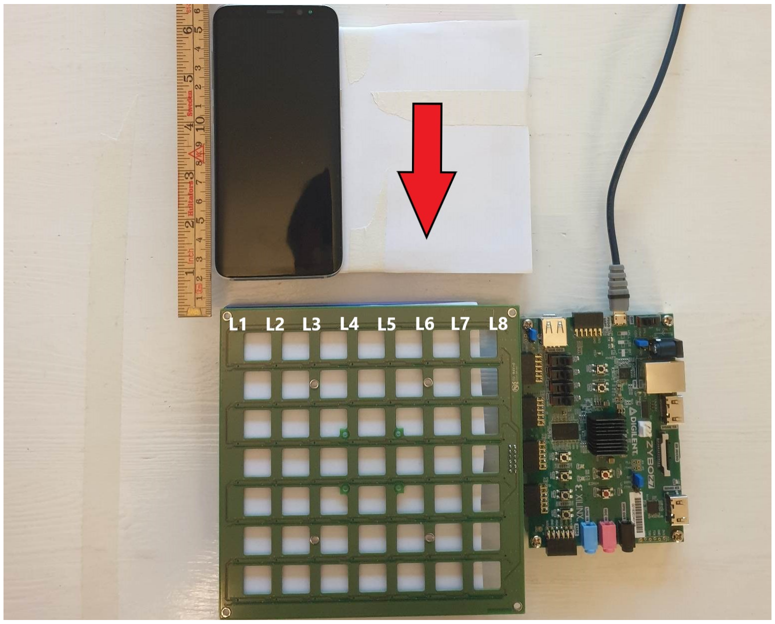
Place the audio source at a distance of 30 cm from the array and test the vertical lines.

Test 3 at 2 cm:

Repeat the steps above for the distance of 2 cm.



Place the audio source at a distance of 2 cm from the array and test the horizontal lines.



Place the audio source at a distance of 2 cm from the array and test the vertical lines.

Results of test 3 with array PCBA1 with horizontal lines at 30 cm and 880 Hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360^\circ \cdot f = \frac{0.02\ \text{m}}{340\ \text{m/s}} \cdot 360^\circ \cdot 880\ \text{Hz} \approx 18.6^\circ \tag{2}$$

Test 3. horizontal lines: 880hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK8: ref	MK7: 9.36°	MK6: 9.55°	MK5: 11.46°	MK4: 11.64°	MK3: 16.86°	MK2: 18.85°	MK1: 20.03°
L2 $\rightarrow$	MK9: ref	MK10: 10.63°	MK11: 9.62°	MK12: 10.12°	MK13: 11.82°	MK14: 14.98°	MK15: 19.55°	MK16: 19.77°
L3 $\rightarrow$	MK24: ref	MK23: 9.5°	MK22: 9.69°	MK21: 10.55°	MK20: 12.47°	MK19: 15.18°	MK18: 20.61°	MK17: 20.56
L4 $\rightarrow$	MK25: ref	MK26: 9.47°	MK27: 9.29°	MK28: 10.94°	MK29: 12.3°	MK30: 15.74°	MK31: 20.21°	MK32: 20.89°
L5 $\rightarrow$	MK40: ref	MK39: 9.45°	MK38: 10.22°	MK37: 11.41°	MK36: 12.92°	MK35: 16.84°	MK34: 22.79°	MK33: 23.1°
L6 $\rightarrow$	MK41: ref	MK42: 10.53°	MK43: 11.03°	MK44: 12.26°	MK45: 14.23°	MK46: 18.43°	MK47: 24.96°	MK48: 23.39°
L7 $\rightarrow$	MK56: ref	MK55: 10.9°	MK54: 9.85°	MK53: 12.69°	MK52: 16.06°	MK51: 21.42°	MK50: 31.08°	MK49: 27.18°
L8 $\rightarrow$	MK57: ref	MK58: 9.26°	MK59: 14.21°	MK60: 15.19°	MK61: 29.73°	MK62: 37.68°	MK63: 35.63°	MK64: 20.12°

Results of test 3 with array PCBA1 with vertical lines at 30 cm and 880 Hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 880 \text{ Hz} \approx 18.6° \quad (3)$$

Test 3. vertical lines: 880hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK8: ref	MK9: 55.7°	MK24: 22.15°	MK25: 17.28°	MK40: 16.23°	MK41: 13.04°	MK56: 12.62°	MK57: 15.26°
L2 $\rightarrow$	MK7: ref	MK10: 32.86°	MK23: 40.59°	MK26: 41.45°	MK39: 29.39°	MK42: 20.8°	MK55: 15.19°	MK58: 10.21°
L3 $\rightarrow$	MK6: ref	MK11: 16.81°	MK22: 16.23°	MK27: 18.79°	MK38: 26.81°	MK43: 36.76°	MK54: 36.7°	MK59: 25.23
L4 $\rightarrow$	MK5: ref	MK12: 13.98°	MK21: 15.41°	MK28: 16.73°	MK37: 20.82°	MK44: 24.42°	MK53: 27.73°	MK60: 26.88°
L5 $\rightarrow$	MK4: ref	MK13: 12.45°	MK20: 12.29°	MK29: 13.04°	MK36: 15.43°	MK45: 17.45°	MK52: 21.34°	MK61: 23.4°
L6 $\rightarrow$	MK3: ref	MK14: 8.1°	MK19: 9.22°	MK30: 9.76°	MK35: 10.63°	MK46: 11.68°	MK51: 14.47°	MK62: 21.94°
L7 $\rightarrow$	MK2: ref	MK15: 8.39°	MK18: 10.54°	MK31: 8.62°	MK34: 12.5°	MK47: 13.57°	MK50: 16.0°	MK63: 19.66°
L8 $\rightarrow$	MK1: ref	MK16: 8.05°	MK17: 10.56°	MK32: 8.85°	MK33: 13.28°	MK48: 13.65°	MK49: 16.02°	MK64: 18.77°

Results of test 3 with array PCBA1 with horizontal lines at 2 cm and 880 Hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 880 \text{ Hz} \approx 18.6° \tag{4}$$

Test 3. horizontal lines: 880hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK8: ref	MK7: 14.15°	MK6: 13.51°	MK5: 15.25°	MK4: 11.96°	MK3: 16.7°	MK2: 17.17°	MK1: 17.54°
L2 $\rightarrow$	MK9: ref	MK10: 16.37°	MK11: 14.5°	MK12: 13.56°	MK13: 16.09°	MK14: 17.1°	MK15: 19.62°	MK16: 19.69°
L3 $\rightarrow$	MK24: ref	MK23: 14.13°	MK22: 14.3°	MK21: 15.54°	MK20: 17.53°	MK19: 18.97°	MK18: 22.42°	MK17: 19.85
L4 $\rightarrow$	MK25: ref	MK26: 15.33°	MK27: 15.94°	MK28: 18.56°	MK29: 19.47°	MK30: 21.49°	MK31: 21.63°	MK32: 19.18°
L5 $\rightarrow$	MK40: ref	MK39: 15.55°	MK38: 17.38°	MK37: 19.26°	MK36: 20.02°	MK35: 21.36°	MK34: 21.2°	MK33: 18.52°
L6 $\rightarrow$	MK41: ref	MK42: 15.64°	MK43: 17.47°	MK44: 19.48°	MK45: 20.92°	MK46: 22.07°	MK47: 21.34°	MK48: 16.51°
L7 $\rightarrow$	MK56: ref	MK55: 17.75°	MK54: 17.39°	MK53: 19.51°	MK52: 20.07°	MK51: 20.0°	MK50: 20.98°	MK49: 17.07°
L8 $\rightarrow$	MK57: ref	MK58: 13.22°	MK59: 17.98°	MK60: 21.09°	MK61: 16.32°	MK62: 19.19°	MK63: 18.57°	MK64: 15.47°

Results of test 3 with array PCBA1 with vertical lines at 2 cm and 880 Hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 880 \text{ Hz} \approx 18.6° \quad (5)$$

Test 3. vertical lines: 880hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK8: ref	MK9: 12.32°	MK24: 16.71°	MK25: 14.91°	MK40: 16.46°	MK41: 16.2°	MK56: 15.58°	MK57: 20.49°
L2 $\rightarrow$	MK7: ref	MK10: 16.07°	MK23: 15.7°	MK26: 16.11°	MK39: 18.06°	MK42: 18.27°	MK55: 18.57°	MK58: 16.68°
L3 $\rightarrow$	MK6: ref	MK11: 16.14°	MK22: 16.41°	MK27: 17.66°	MK38: 20.27°	MK43: 19.72°	MK54: 18.75°	MK59: 18.23
L4 $\rightarrow$	MK5: ref	MK12: 15.32°	MK21: 17.37°	MK28: 19.39°	MK37: 21.47°	MK44: 20.4°	MK53: 20.27°	MK60: 18.8°
L5 $\rightarrow$	MK4: ref	MK13: 17.29°	MK20: 18.3°	MK29: 19.69°	MK36: 21.48°	MK45: 20.5°	MK52: 20.77°	MK61: 18.93°
L6 $\rightarrow$	MK3: ref	MK14: 15.17°	MK19: 17.09°	MK30: 17.93°	MK35: 19.3°	MK46: 19.47°	MK51: 19.2°	MK62: 19.61°
L7 $\rightarrow$	MK2: ref	MK15: 16.02°	MK18: 18.2°	MK31: 14.89°	MK34: 18.92°	MK47: 17.98°	MK50: 17.59°	MK63: 17.46°
L8 $\rightarrow$	MK1: ref	MK16: 13.43°	MK17: 15.78°	MK32: 13.67°	MK33: 17.07°	MK48: 16.45°	MK49: 17.16°	MK64: 18.14°

Results of test 3 with array PCBA1 with 440 Hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 440 \text{ Hz} \approx 9.3° \quad (6)$$

Test 3. horizontal lines: 440hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	57: ref	MK58: 9.81°	MK59: 11.83°	MK60: 11.44°	MK61: 8.96°	MK62: 8.94°	MK63: 7.52°	MK64: 5.7°

Test 3. horizontal lines: 440hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	57: ref	MK58: 4.75°	MK59: 7.23°	MK60: 6.17°	MK61: 2.85°	MK62: 3.26°	MK63: 2.41°	MK64: 1.59°

Test 3. vertical lines: 440hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	MK1: ref	MK16: 13.78°	MK17: 10.83°	MK32: 8.62°	MK33: 8.94°	MK48: 4.99°	MK49: 4.12°	MK64: 4.22°

Test 3. vertical lines: 440hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	MK1: ref	MK16: 7.98°	MK17: 8.16°	MK32: 4.9°	MK33: 7.74°	MK48: 5.81°	MK49: 5.66°	MK64: 4.75°

Results of test 3 with array PCBA1 with 1200hz audio source:

$$\phi = \frac{\Delta s}{v} \cdot 360° \cdot f = \frac{0.02 \text{ m}}{340 \text{ m/s}} \cdot 360° \cdot 1200 \text{ Hz} \approx 25.4° \quad (7)$$

Test 3. horizontal lines: 1200hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	57: ref	MK58: 30.64°	MK59: 36.25°	MK60: 29.63°	MK61: 23.88°	MK62: 20.95°	MK63: 21.77°	MK64: 21.71°

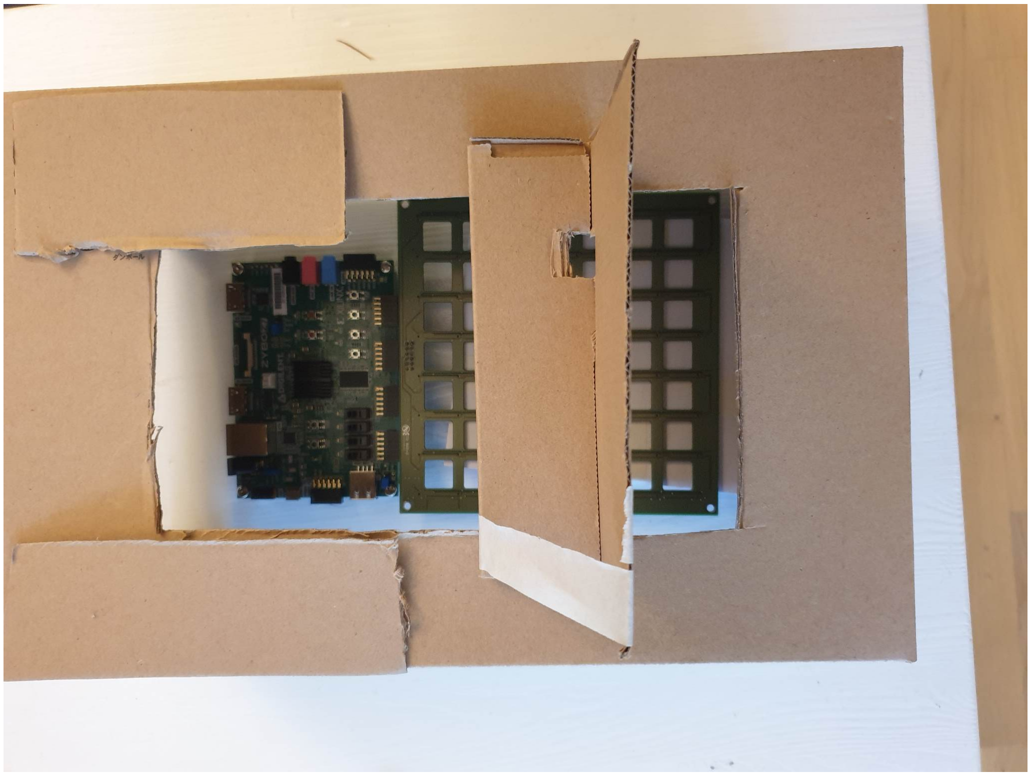
Test 3. horizontal lines: 1200hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L8 $\rightarrow$	57: ref	MK58: 21.05°	MK59: 23.3°	MK60: 24.46°	MK61: 17.14°	MK62: 22.63°	MK63: 31.52°	MK64: 38.17°

Test 3. vertical lines: 1200hz audio source at 30 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK1: ref	MK16: 34.75°	MK17: 41.52°	MK32: 27.3°	MK33: 22.56°	MK48: 18.73°	MK49: 22.64°	MK64: 41.67°

Test 3. vertical lines: 1200hz audio source at 2 cm								
Line	Ref	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$	$\Delta\phi$
L1 $\rightarrow$	MK1: ref	MK16: 21.51°	MK17: 23.16°	MK32: 18.33°	MK33: 20.76°	MK48: 22.5°	MK49: 32.5°	MK64: 42.87°

Bonus test that needs to be improved

Similarly as when the microphones were tested from the side, they can be tested from above. In that case, it its much harder to align the audio source correctly. If placed directly above two microphones, comparing the pair should give a 0 phase difference.



A simple top-down test implementation.

This test is considered unreliable with a cardboard stand, and should give better results with a real stand of higher height.