An audio amplifier

fall 2020

1 Tasks

An audio frequency (AF) amplifier will be simulated, constructed and tested. The tasks include testing an electret microphone as the signal source for the AF amplifier.

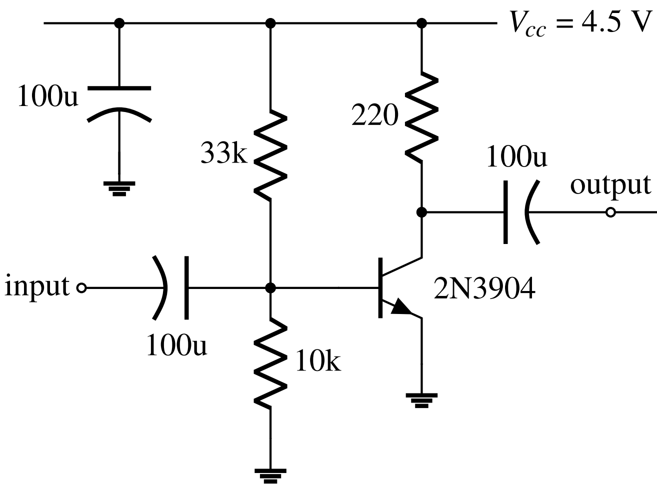

Figure 1: The audio amplifier.

Table 1: Components needed to construct and test the amplifier

component	value/tyoe	purpose/description	pcs
C	100 μF	DC block/supply filter	3
R	220 Ω	collector bias	1
R	33 kΩ	base bias	1
R	1 kΩ	dummy load	2
R	10 kΩ	base bias / electret bias	2
transistor	2N3904		
breadboard			
jumper wire	1...2 cm	emitter, mic gnd	2
electret microphone	MCKPCM-97H45P-40DB	only for testing	
piezo speaker		only for testing	

2 Purpose of the amplifier

The purpose of the circuit is to amplify the signal that we obtain from the microphone. That signal is then routed to the amplitude modulator. The microphone signal is fairly low. It can be as low as below 4...10 $\mathrm{mV_{pp}}$. That is too little to be observed with the Virtual Bench oscilloscope. To drive the amplitude modulator we need about 0.2...0.5 $\mathrm{V_{pp}}$. Thus the voltage gain of the amplifier should be 50.

2.1 Biasing

Collector is biased to approximately 2.7 V which is more or less in the middle of V_{cc} and zero. The collector current is $(V_{cc} - 2.7\ \mathrm{V})/220 = 8.2$ mA. The base-to-emitter voltage is about 0.7 V. Base current is settled (to about 0.04 mA) with the 33k and the 10k bias resistors.

2.2 DC blocks

The 100-uF capacitors work as DC blocks. The reactance of such capacitor is $(\frac{-1}{\omega C})$ is (minus) 16 Ω at 100 Hz and (minus) 0.16 Ω at 10 kHz.

The obvious job of the DC blocks is to keep the biasing DC from being conducted out from the amplifier. However the DC blocks allow the AC currents to flow: (1) from the microphone to the base-emitter-junction of the BJT and (2) from the collector to the amplitude modulator. The third DC-block filters audio frequency noise from the DC supply, or in other words, keeps the V_{cc} at steady 4.5 V.

3 Simulation

Simulate the circuit with MultiSim in time domain (see Fig.). Launch the function generator and oscilloscope from the MultiSim schematic. Use the following settings:

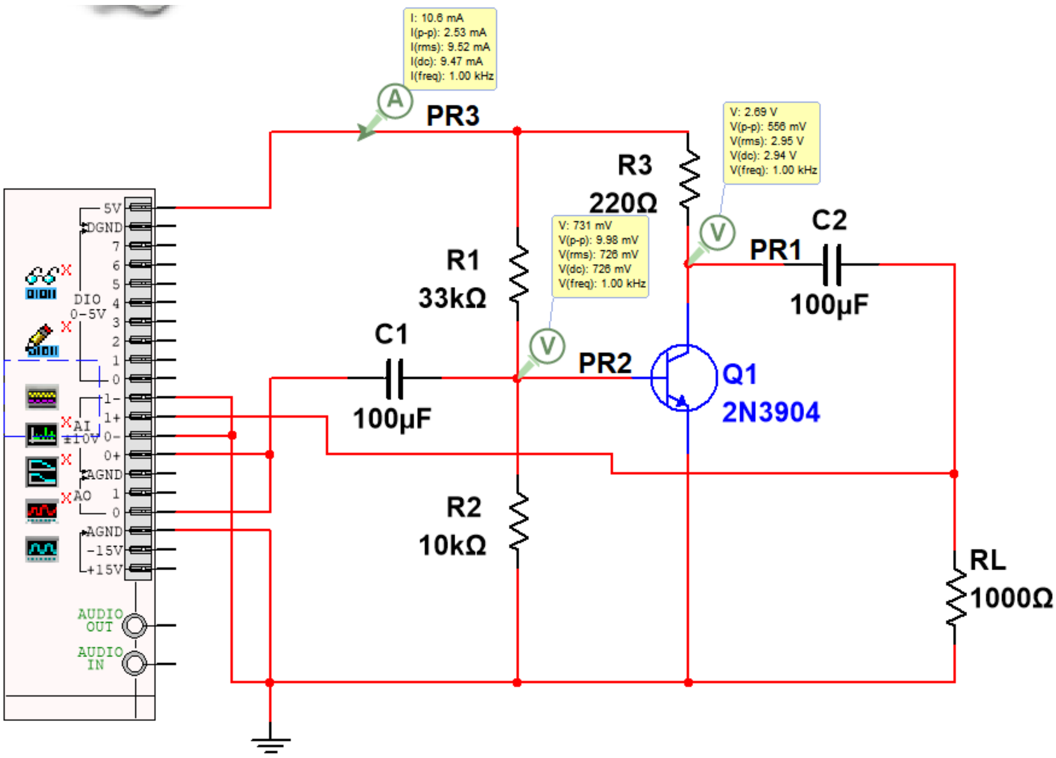

Figure 2: Schematic diagram for the simulations. The load resistor ($R_L = 1$ kΩ) is a dummy load. It mimics the loading effect the the audio modulator is going to possess in the final transmitter.

Function generator:

- Frequency: 1 kHz
- Amplitude: 0.01 Vpp
- Signal Route: AO0
- Device: Simulate NI MyDAQ

Oscilloscope:

- Channel 0 Settings, Source AI 0, Enabled ✓
- Scale Volts/Div: 10 mV
- Channel 1 Settings, Source AI 1, Enabled ✓
- Scale Volts/Div: 100 mV
- Time/Div: 500 us
- Device: Simulate NI MyDAQ

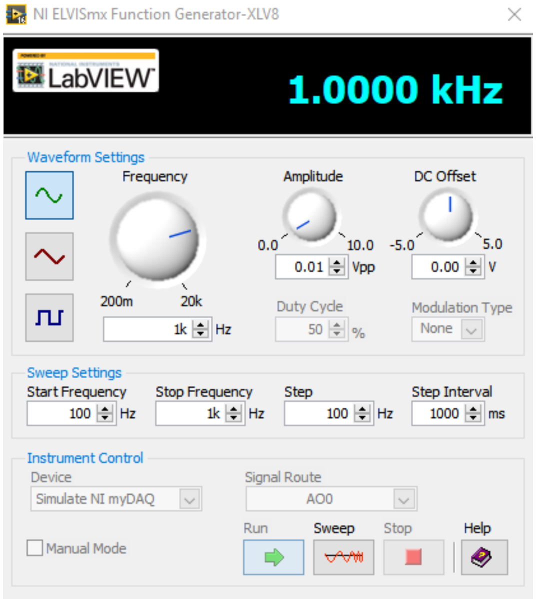

Figure 3: Use 1-kHz frequency and 0.01-Vpp amplitude in the function generator.

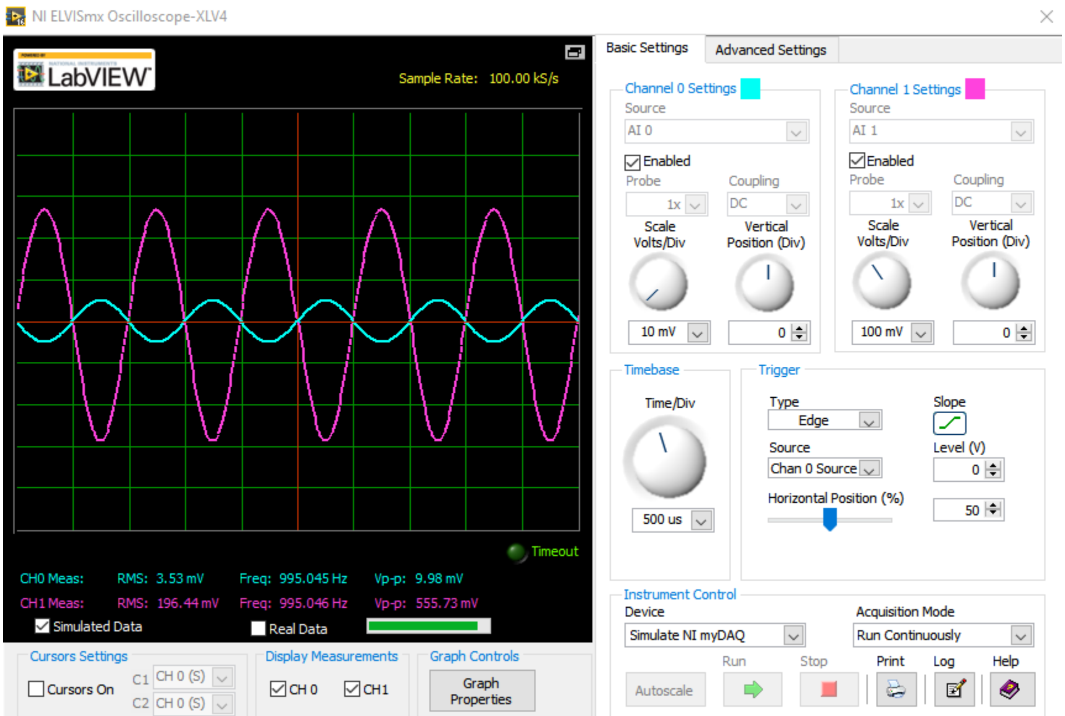

Figure 4: Simulated input and output voltages. Note the 10-mV/div, 100-mV/div and 500-us scales in the oscilloscope.

Determine your simulated voltage gain A_v and the total DC current consumption.
$A_v =$ __________(mVpp)/__________(mVpp) = __________.
$I_{dc} =$ __________ mA.
(Voltage gain should be ca. 50 and the current consumption should be ca. 10 mA.)

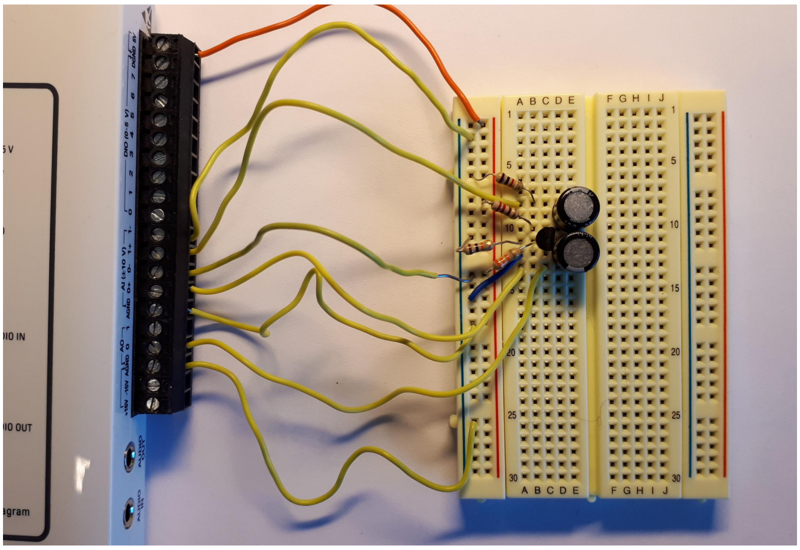

Figure 5: Amplifier testing with myDAQ.

4 Construction

The way you lay out the components, or how long jumber wires you use, do not have any impact on the performance. However, consider building the circuit according to all the "good practices" learned so far, because then the possible debugging (with a little help from teachers. . .) is easier.

Good practices:

- Make the circuit compact.
- Minimize the amount of jumper wires.
- Do not splay the leads of components if not absolutely necessary. Respect the intended assembly pitch, typically multiples of 2.5 mm. Breadboard holes are 2.5 mm apart.
- Do not make the signal go "back and forth, all over place" on the breadboard. Keep the layout simple.
- Use the blue side rail for ground and the red for V_{cc}.

5 Testing

5.1 Testing DC operation

Once constructed, test the amplifier in myDAQ. Connect it to myDAQ as in the simulation. Check the base-to-emitter and collector-to-emitter DC voltages with the multimeter. Those should ca. 0.7 V and 2.5, respectively.

5.2 Testing operation in time domain

Keep the function generator and oscilloscope settings as they were in the simulations, except for the Instrument control: Don't forget to Change the Device to "myDAQ (NI myDAQ)" in both. Have "RealData" checked in the oscilloscope.

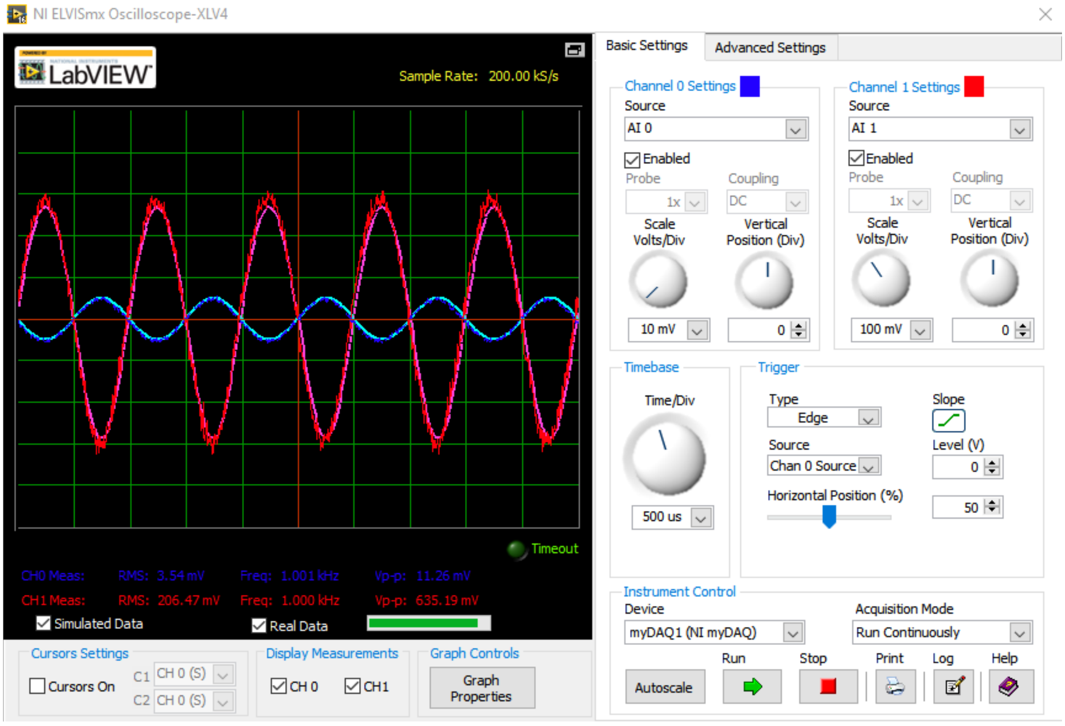

Figure 6: Oscilloscope view comparing real and measured AC in time domain. The blue (measured) and the light blue (simulated) input voltages are almost the same. Also the simulated output voltage is almost the same as the real output voltage, which seems to be a bit noisy.

Determine your measured voltage gain A_v and the total DC current consumption.
$A_v =$ __________(mVpp)/__________(mVpp) $=$ __________.
$I_{dc} =$ __________ mA.
(Voltage gain should be ca. 50 and the current consumption should be ca. 10 mA.)

5.3 Testing operation in frequency domain

Perform a Bode analyzis. The result is more interesting, if you choose a low enough starting frequency, such as 2 Hz(!) Note however, that simulating at lower frequencies takes more time because, for each frequency point, myDAQ measures a number of cycles. The period $(1/f)$ is longer at low frequencies...
Choose linear magnitude scale for easy comparison with the A_v value that you already got from the time domain measurement. $|H(1\text{ kHz})| =$ __________ (no unit). What can you say about the bandwidth of the amplifier? Lower cutoff frequency: $f_{c1} =$ __________ Hz. Higher cutoff frequency: $f_{c2} =$ __________ Hz.
NOTE: Cut-off frequncy is often defined as the frequency where the magnitude of voltage gain has dropped down to 70.7% or $1/\sqrt{2}$. In terms of power, we can

say that the power gain has dropped to one half, however, this is true only if the amplifiers load and input impedances are equal.

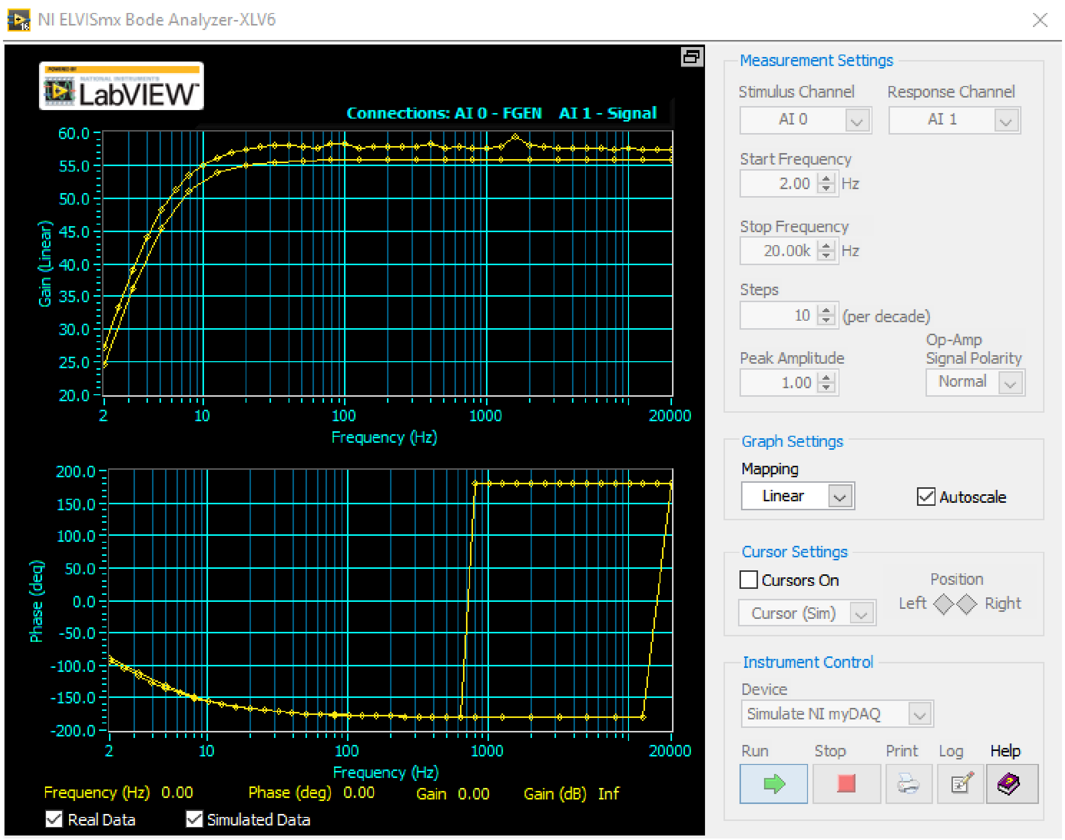

Figure 7: Bodeplot test screen in myDAQ. Note that the "Peak Amplitude" must be set to 0.01 V when real data is taken!

5.4 Testing with a microphone

From your breadboard, disconnect the wire coming from AO0. Connect microphone to your breadboard. Connect the positive terminal of the microphone to V_{cc} through a 10-kΩ resistor as shown in Fig. 8. (Which one is positive? – See Figure 9.) Turn around the input DC block (reverse polarity). Connect the positive terminal of the microphone to the amplifier input. Connect the negative terminal of the microphone to the ground.

The microphone needs to be biased because there is a preamplifier inside the microphone capsule. The microphone element draws ca. 0.2 mA DC. Hence, the voltage drop over the 10-kΩ bias resistor is ca. 2 V.

To test the circuit at home, whistle to the microphone, or if you can't, mumble instead.

Inclass we use a custom-made speaker for testing, see in Fig. 10. Connect the wires of a piezo speaker between myDAQ analogue output AO0 and AGND. Use the myDAQ Function Generator to produce a sound. Set the amplitude and frequency high enough to hear the sound (not too high value though!). Try for example 2.8 kHz and 2 Vpp. Bring the speaker close (3...5 cm) to the microphone and monitor the amplifier output with the myDAQ oscilloscope. You should see a reasonable signal (100...300 mVpp).

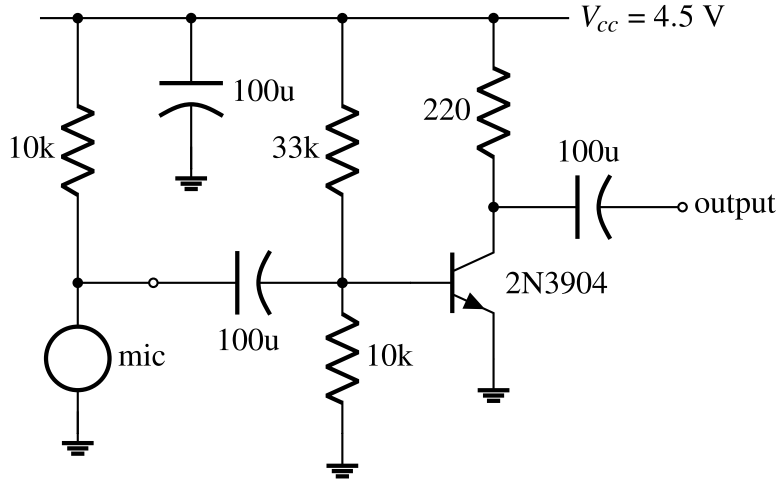

Figure 8: Microphone connected. The input DC block has been reversed because the DC voltage across the microphone (ca. 2.5 V) is higher than the base voltage (ca. 0.7 V).

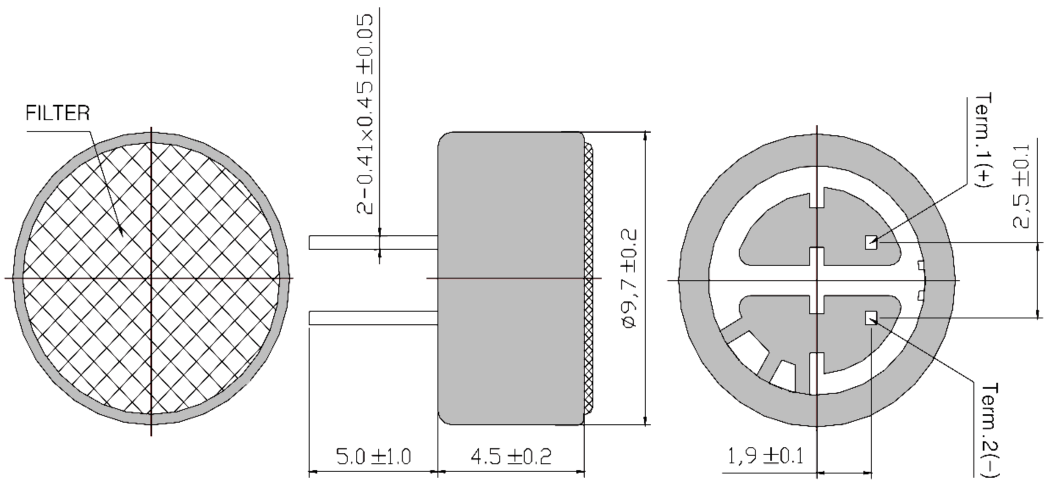

Figure 9: MCKPCM-97H45P-40DB-4808 microphone drawing. Note that negative terminal Term. 2 (−) connects to the metal capsule while the positive terminal Term. 1 (+) is isolated from it.

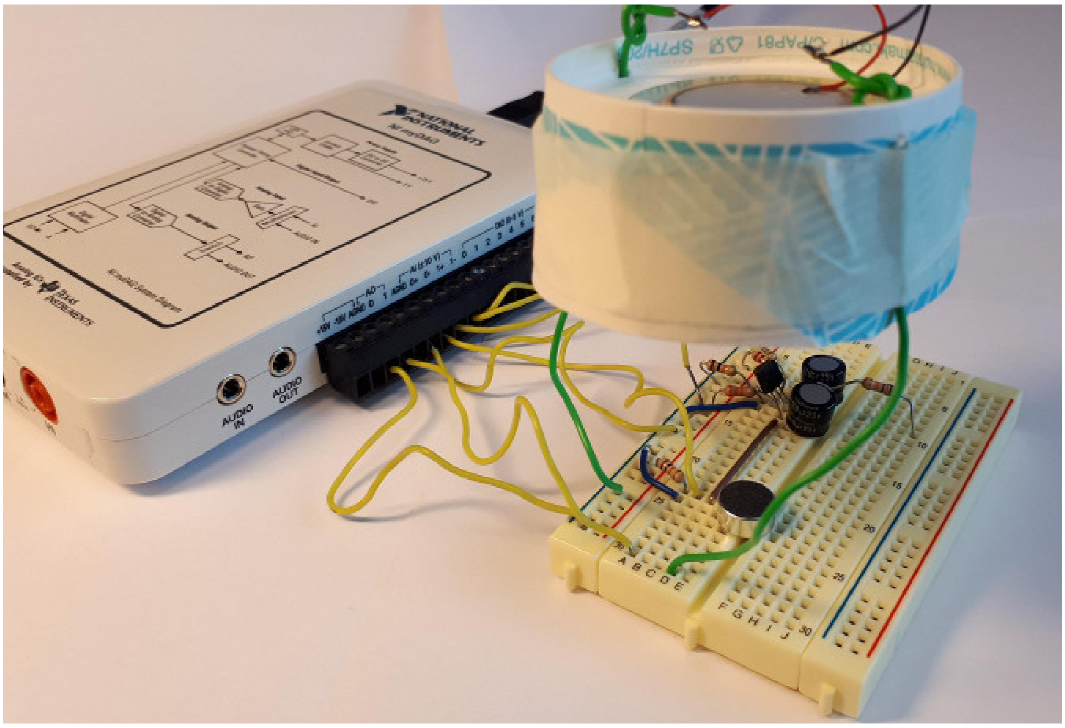

Figure 10: Testing the audio amplifier with an electret microphone element and a homebrew coffee-cup-piezo speaker (above the breadbord).