EE2073 Project Report

Automatic Volume Control for Audio Amplifier System

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Chapter 1 Introduction

This project is to design and build an automatic volume control for Audio Amplifier System. There are mainly three part of the system, which are voltage controlled amplifier (VCA), power amplifier (PA) and volume unit level meter (VU meter).

The first subsystem, the Voltage-Controlled Amplifier (VCA) allow the control of audio gain through the control voltage. By hanging the control voltage, I can either amplify or attenuate the input signal.

The second subsystem is Power Amplifier, its purpose is to increase the audio signal from VCA so that the signal is strong enough to drive the speaker.

The third subsystem is the Volume Unit Meter. It can measure the volume of the Audio signal.

After three subsystem is constructed, we integrate all subsystem into a functional audio amplifier, transforming it from a open loop to close loop system. We also write a python program to allow the close loop system to adjust its volume according to the user set point.

In this project, we utilize four IC chip to drive our system (OP275, CA3140, LM 380 and THAT_2180). We also utilize STM32 microcontroller to control our amplifier system. Besides, we also use inductor to reduce noise and smooth the voltage fluctuation.

Before start constructing the circuit, in Lab1 and 2, we setup a Python development environment using Miniconda. In lab 2, we were introduced ADC and DAC concepts to acquire and generate time sampled voltage signal. We use Jupiter notebook to set DC voltage, generate waveform and acquired the example data from the controller channel.

In Lab3, we explore waveform generation(sinusoidal, triangular, sawtooth). I have observed the effect of modulation on time-domain signals and spectra.
In Lab 4, I have calibrated the DC offsets for accurate signal generation.

Chapter 2 Labs, Results and Discussion

2.1. Voltage Control Amplifier (VCA)

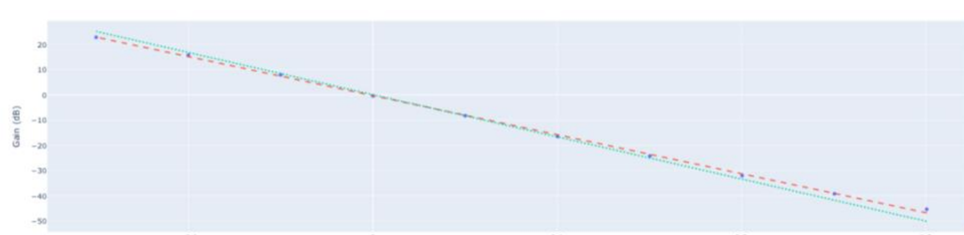
VCA is to control the gain/attenuation via a control input voltage. This system utilize THAT 2180C IC and OP275 IC, both operating at a supply voltage of 13.5V. The specified gain of the VCA is defined by:

$$\mathrm{GdB} = \frac{\mathrm{Vc}}{-0.006(1 + 0.0033\Delta \mathrm{T})}$$

Results

Amplitude(V)	Va (V)	Vin-pp(V)	Vout-pp(V)
3.0	5.4	5.61	0.03
2.2	4.5	3.72	0.04
2.4	3.6	3.77	0.094
2.2	2.7	3.77	0.23
1.0	1.8	2	0.29
1.5	0.9	1.96	0.753
1.7	0	2.03	1.92
0.90	-0.9	1.84	4.54
0.82	-1.8	1.58	9.61
0.84	-2.7	1.7	23.22

Discussion



The gain is control by the control voltage Vc which is related to Va through voltage divider. From the graph, when Va is positive, it gives strong attenuation, hence the Vout is only 0.03Vpp. While Va is negative, is gives strong amplification, the Vout rises to 23.22 Vpp.

VCA dynamically control the audio output based on control voltage, this allows the output volume to remain within a suitable range, preventing distortion in high level.

The experiment successfully demonstrates the VCA characteristics, which is the gain is negatively proportional to Va.

The lab 5 is my first lab that require me to build VCA using breadboard and controller. I barely finished the project on time. But I enjoy playing with the circuit, and I learned how to connect the circuit neatly through the videos played in the Lab by Teaching Assistant.

2.1. Power Amplifier (PA)

This lab's objective is to build and analyze the frequency response of a Power Amplifier using LM380N IC. The IC provide 34dB of voltage gain. We measured the peak-to peak input and output voltage of different frequency.

The power amplifier core function is to take a small input and increase its power to drive the speaker.

Results

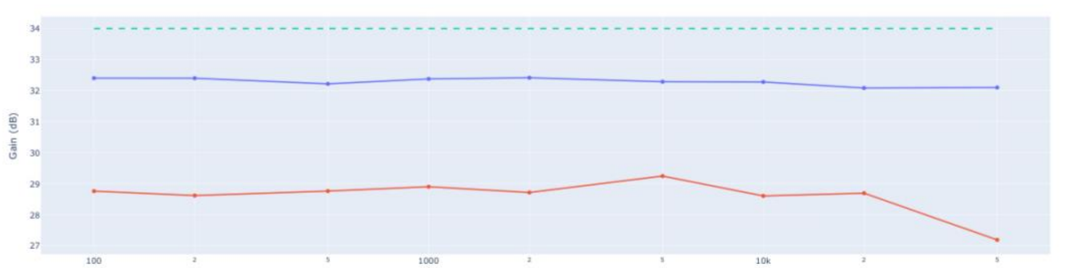
Amplitude: 0.1V

Frequency(Hz)	Vin-pp(V)	Vout-pp(V)
100	0.202	8.44
200	0.20232	8.43
500	0.20267	8.27
1000	0.192	7.98
2000	0.199	8.34
5000	0.199	7.69
10000	0.187	7.64
20000	0.190	7.65
50000	0.191	7.7

Amplitude : 0.2V

Frequency(Hz)	Vin-pp(V)	Vout-pp(V)
100	0.384	10.52
200	0.391	10.54
500	0.382	10.46
1000	0.375	10.45
2000	0.385	10.49
5000	0.359	10.42
10000	0.399	10.76
20000	0.394	10.74
50000	0.457	10.46

1. For both 0.1 and 0.2 V, the output voltage seems to remain stable. This has demonstrated that the Power Amplifier can steadily amplify the audio signal within 100-50000 Hz.
2. Increasing the input amplitude from 0.1 to 0.2 V make the output voltage higher.
3. From the data we got, we observe a slightly decrease in output voltage in 1k-10k Hz. We could not figure out why, but it is probably because of the internal frequency dependent behavior of the IC chip.



Green line is the theoretical gain, blue is the measured gain at 0.1V, red is the measured gain at 0.2V. From the Gain versus frequency graph, for the 0.1V gain is stable correspond to different frequency. As for the 0.2V gain, it is lower around 28dB, probably due to the amplifier clipping at higher input levels.

2.1. Volume Unit Meter (VU Meter)

The objective of this lab is to build a VU meter using the CA3140 IC. The VU meter measure the output from PA and provide feedback to the controller so that it can automatic control the volume.

In this experiment, We measured the input and output signal (Vin, Vout1, Vout2,Vout3) at different Amplitude to determine the Gain of the circuit.

Results

Amplitude	Vin-pp(V)	**Vout1-pp(V)**	**Vout2-pp(V)**	**Vout3-rms(V)**
4.2	**7.77**	**3.1**	**2.34**	**0.305**
3.4	**6.32**	**2.69**	**1.94**	**0.344**
3.2	**5.95**	**2.52**	**1.82**	**0.32**
2.0	**3.73**	**1.7**	**1.26**	**0.293**
2.5	**4.73**	**2.04**	**1.5**	**0.368**
1.7	**3.32**	**1.53**	**1.16**	**0.341**
1.0	**1.99**	**1.02**	**0.944**	**0.345**
0.2	**0.385**	**0.014**	**0.253**	**0.01442**
0.4	**0.76**	**0.0167**	**0.49**	**0.02**

Discussion

The purpose of our VU meter circuit is to reflect the loudness level of PA. But the signal from PA is AC and often very small. Hence, We connect a CA3140 Op Amp to amplify the signal. Besides, we also connect two diodes, which perform rectifier that convert the AC signal at Vout1 to a rectified DC signal at Vout2. We also connect few resistors to set the Gain. The measured Gain drop when Vin increase according to the (Figure 7.1) in the appendix. Theoretically, the Gain should be constant. But our real VU meter circuit behaves differently due to the OP AMP output swing limitation of (CA 3140). This caused the downward trend of Figure 7.3.

Next, the measured gain is approximately 0.65, which is close but lower than the theoretical value of -0.7. The minor deviation is possibly due to the op amp forward voltage effect.

The graph of Vout3 versus Vin(Figure 7.2) below demonstrate that the output of VU meter rises with the increasing input signal Amplitude. This demonstrate that the system has successfully perform amplitude detection. As the input increase from 2 to 8, the Vout3 stable between 0.1 to 0.13, represent a smooth DC signal corresponds to the input signal.

Figure 7.1

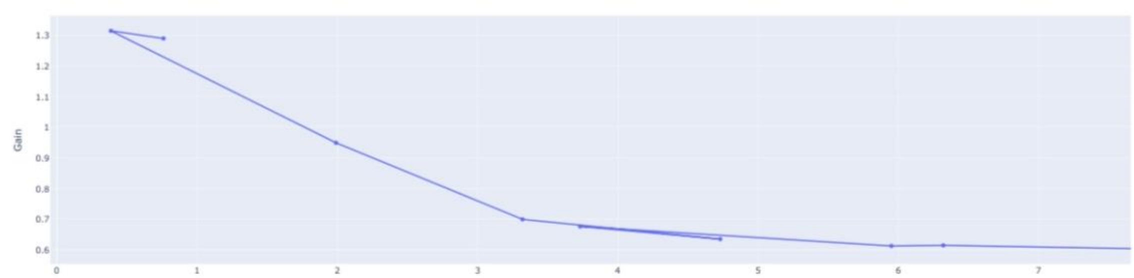
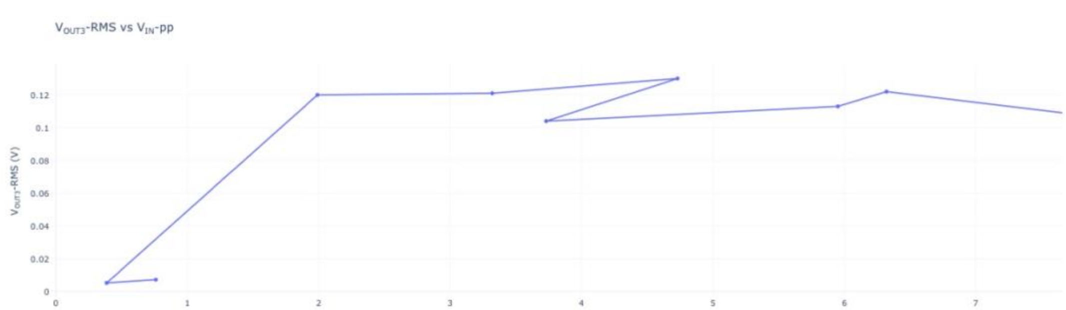


Figure 7.2



2.4. System Integration and Demonstration

The complete audio amplifier system, consist of VCA PA and VU meter was integrated in this lab. The objective is to test the system performance in the amplifying audio system, while monitor the volume signal of the VU meter. This is a open loop system means no feedback is in the circuit, we can only adjust the Va to adjust the V audio. First, we connect the circuit to the controller according

The measured results shows that Vaudio and V volume will change according to Va and the input amplitude. As the Va decrease the output autio signal increased, but it can only reach 9.52 Vpp as the highest value. These measurement from the table correctly demonstrate the relationship between Va and the Vout, which is a inversely propotional relationship.

This experiement confirm that the circuit is functioning well, where the Vu meter can provide indicator of the loudness of the audio system. We learn an important things from this is to check the circuit via the short circuit test before connect it to the microcontroller.

Amplitude(V)	Va(V)	Vsignal-pp(V)	Vaudio-pp(V)	Vvolume-pp(V)
4.2	5.4	7.72	1.27	0.128
3.4	4.5	6.31	2.37	0.159
2.2	3.6	4.18	3.81	0.19
1.0	2.7	2.03	4.44	0.152
0.85	1.8	1.72	9.21	0.205
0.37	0.9	0.72	9.52	0.24
0.09	0	0.202	7.04	0.19
0.04	-0.9	0.102	8.87	0.21

In the last part of the lab, we implement and test the automatic volume control system for the audio amplifier. The main purpose is to transform the circuit from open loop to close loop. The VCA will adjust the audio gain while the VU meter measures the loudness of the volume. We implement a python step up / down control algorithm to adjust the feedback automatically.

The step-up-down algorithm compare the measured Vvolume to our desire manual set point. If the output volume is below the set point, the controller decreased Va to increase the VCA gain. In Contrast, when the output volume is above the set point, it increase Va to decrease the gain. This control function will repeatedly ran every 10ms using the RepeatTimer function class().

From the code, if the measured volume (z) is below the set volume (r0), the u(Va) will decrease to increase the VCA gain and raise the volume, and vice versa.

```python
def control():
    global u
    v_volume, _ = vscope.measure_volt()
    r0 = set.value
    z = v_volume / max_volume * 100
    if z < r0:
        u -= delta
    elif z > r0:
        u += delta
    u = np.clip(u, va_min, va_max)
    vscope.generate_wave(2, None, 0, 1000, u)
    vol.value = z
```

However, when we adjust the slider to louder volume, the output audio start to distorts, this indicated that the control function is not 100% reliable and accurately revoke every 10ms. When we increase Va, the audio start with distortion and waited a few seconds later then it returns to normal volume with no distortion. The reason that the control function did not respond instantaneously may because of the system and software limitations.

Conclusion

Me and my teammate successfully constructed the Automatic Volume Control Amplifier System. By varying the control voltage, the output audio will start with minor distortion, then after 2 second it will return to normal operation. We deduce that this is due to the control function is not 100% accurately invoked every 10ms. The VCA system demonstrate how a control voltage Va can adjust the gain. The Power amplifier successfully amplify the signal from Va to drive the load. The VU meter correctly provides feedback to the controller.

During the process of building the circuit, I have strengthened my skill in constructing, testing and analyzing the circuit. I think testing the circuit is an important part, because me and my teammate once stuck on a problem in Lab 8 for 2 hours. We cannot get the correct graph of V signal and V audio. This is because we do not do short circuit testing after connecting all the wire. After the short circuit test, we have found out that the circuit voltage is not close to the theoretical value. We have wrongly connected a wire inside the breadboard. After fixing the circuit, we have successfully obtained the right graph. This demonstrates the important of testing the circuit before start generating all the graph. All in all, I really benefit a lot from this lab because I had the chance to build a real electronic system, and I also learned a lot from the Teaching Assistant. They always be patient and provide us with help whenever we encounter problem.

Reference

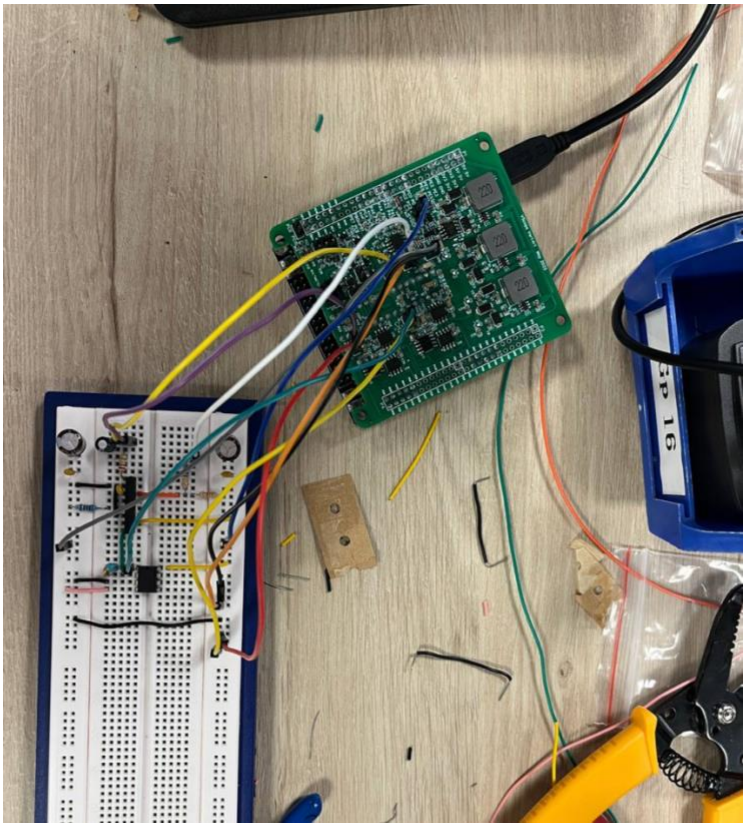
EE2073 Week1 and Week2 lecture slide

EE3073 Lab Manual

EE2073 Final Report Template, Hardware Datasheet

Appendix

Lab 5



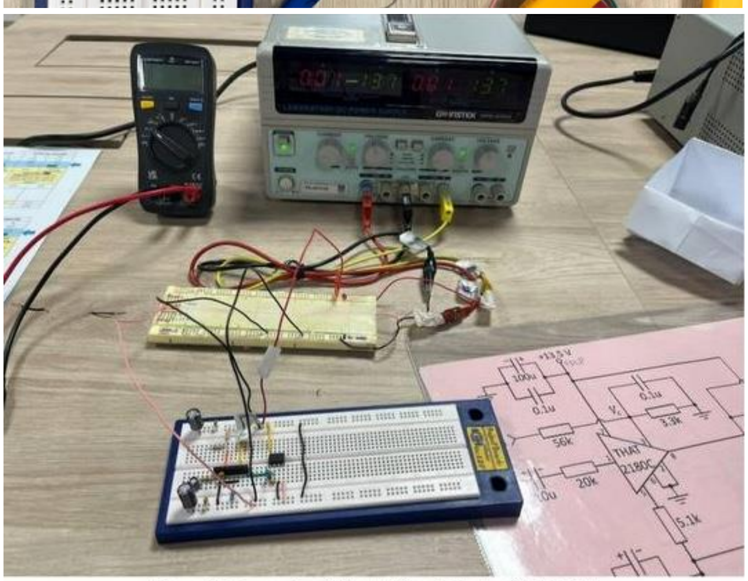
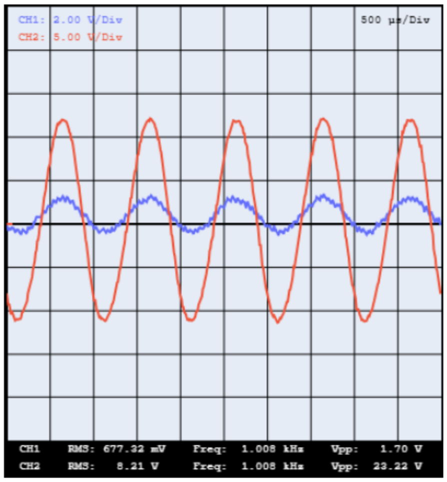
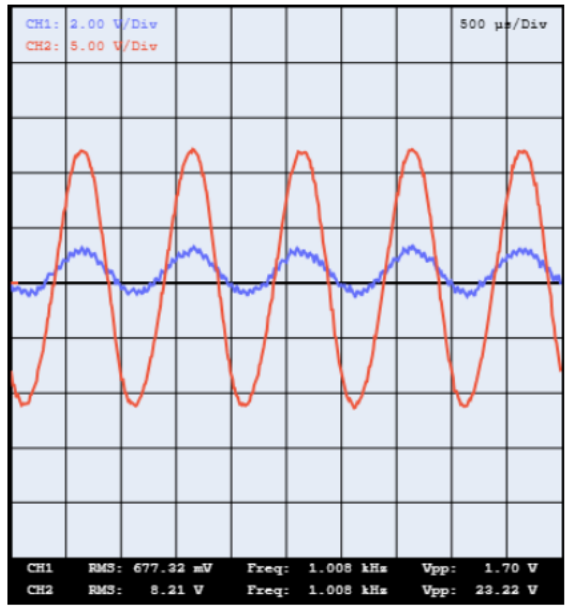


Figure 7: Example of Short Circuit Test with DMM

Lab 5 VCA circuit





Exemplary oscilloscopes traces in Lab 5.

Lab 6 (Screenshot of the wave obtained at 0.2 V amplitude)

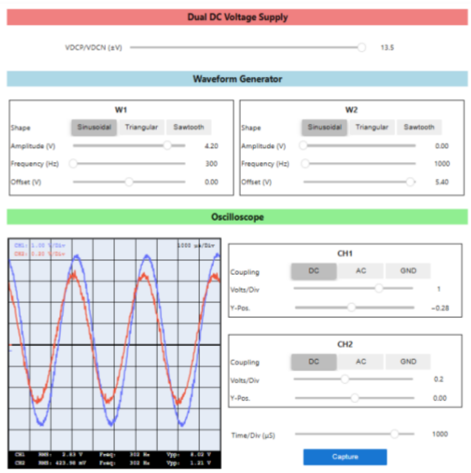
Screenshots for amplitude 0.2

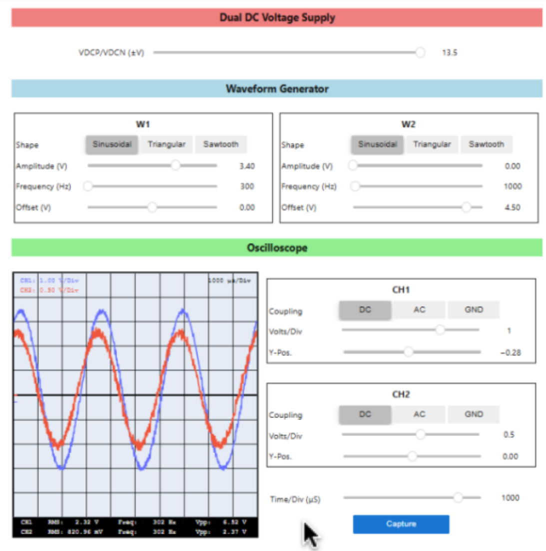
LAB 7

Graph of the oscilloscopes in Lab 7 (frequency:1kHz ; supply: 13.5V)

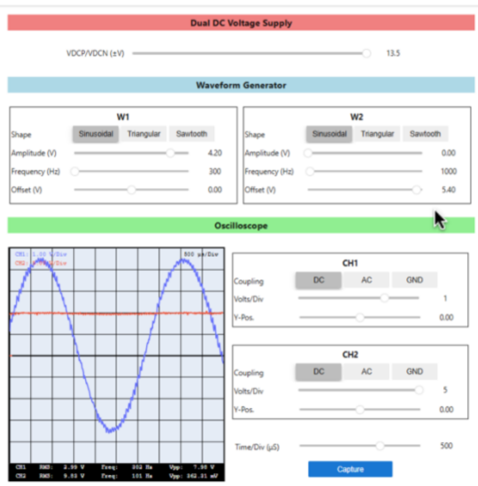
LAB 8

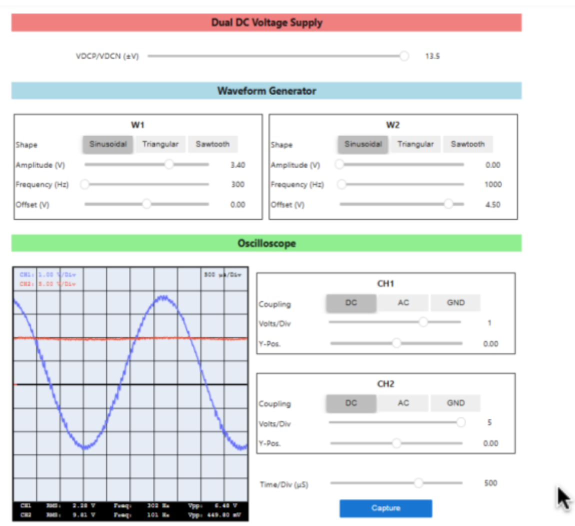
Some Measurements and Graphs from Oscilloscope for V_signal and V_audio





Measurements and Graphs for V_signal and V_volume





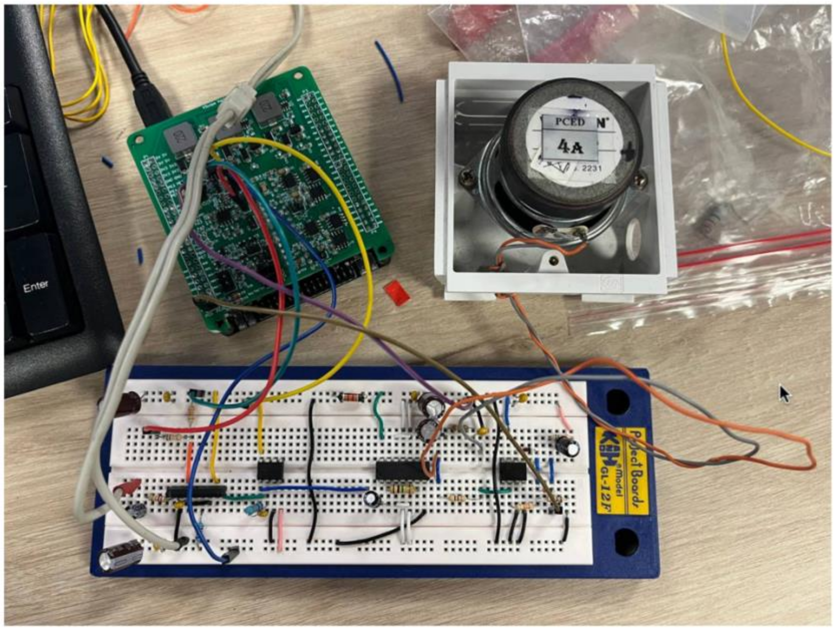


Photo of the VCA system.