EE2073 Project Report

Automatic Volume Control for Audio Amplifier System

Name: Shoon Zhen Yong

Matric No: U1920283L

Project Group: EJ07 Group 10 (A)

School of Electrical and Electronic Engineering

Academic Year 2020/21

Semester 2

Table of Contents

Chapter 1: Introduction

The purpose of this project is to build and design an Automatic Volume Controller for an Audio Amplifier System. It is designed as a controller which controls the gain of the amplifier system automatically so that the desired output level of volume can be obtained.

Both software and hardware implementations are used to perform this function.

For software, LabVIEW is used to sample the input signal and implement digital-analogue conversion. The analogue output signal from VU meter subsystem will be fed back to LabVIEW and undergo Analog to Digital Conversion (ADC). Then, LabVIEW will detect and analyse the digital signal and make appropriate modification. The modified signal is then converted to analogue through Digital to Analog Conversion (DAC) and finally VCA subsystem will alter the gain of the system to produce desired audio output level. The block diagram of Audio Amplifier System is shown in Appendix 1.1

For hardware, the three cascaded subsystems are namely Volume Controlled Amplifier (VCA) subsystem, Power Amplifier (PA) subsystem and Volume Unit (VU) meter. A photo of the setup of the system is shown in Appendix 1.2

Chapter 2: Voltage Controlled Amplifier (VCA) Subsystem

2.1 Overview

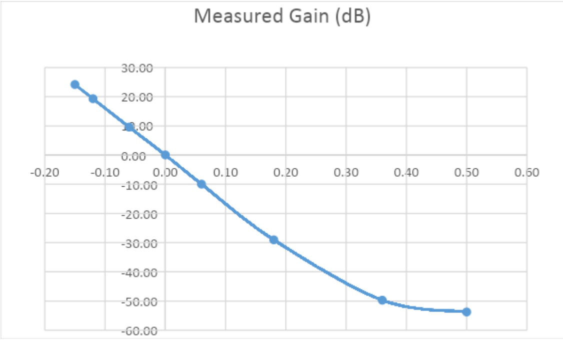
VCA is an audio signal processing subsystem of the overall audio amplifier system which by applying a control voltage (Vc-) at Pin 3, the gain or attenuation characteristic can be controlled. [1] The THAT 2180C (THAT Corporation) and OP 275 (Analog Devices) are ideal integrated circuits for the VCA subsystem. The equivalent circuit diagram and terminal configuration of (a) THAT 2180C and (b) OP 275 are shown in Appendix 2.1. Set up of VCA subsystem is shown in Appendix 2.2.

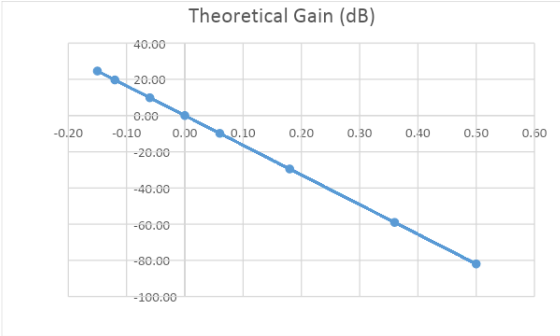
2.2 Results and Discussions

The required formulae for calculations is shown in Appendix 2.3.

Vin (Vpp)	Vc (V)	Vout (Vpp) (V)	Measured Gain = Vout/ Vin	Measured Gain (dB)	Theoretical Gain (dB)
1.10	0.50	0.00226	0.0021	-53.75	-81.97
0.59	0.36	0.00193	0.0033	-49.71	-59.02
0.52	0.18	0.01838	0.0353	-29.03	-29.51
0.30	0.06	0.09543	0.3181	-9.95	-9.84
0.32	0.00	0.322	1.0063	0.05	0.00
0.18	-0.06	0.542	3.0111	9.57	9.84
0.13	-0.12	1.2	9.2308	19.30	19.67
0.13	-0.15	2.1	16.1538	24.17	24.59

Table 2.2.1: Gain measurement of VCA subsystem





Graph 2.2.2: Measured Gain (dB) vs.Vc (left) and Theoretical Gain (dB) vs.Vc (right)

From the graph above, we can deduce that both graphs are have a downward slope

Slope (Measured Gain) = (0.05- (-29.03)) / (-0.18) = -161.56
Inverse of slope (Measured Gain) = 1 / (-161.56) = -6.19m dB/V
Inverse of slope (Theoretical Gain) = -6m dB/V

The Vc sensitivity value (inverse of slope) for both measured and theoretical gain is close to each other with a discrepancies of 3.17% which is less than 10%.

Chapter 3: Power Amplifier (PA) Subsystem

3.1 Overview

PA subsystem is the core that provide the required gain and amplifies the power to drive the speaker by raising input signal. LM380N (Appendix 3.1) integrated circuit chip is used in this subsystem. Its internal voltage gain is fixed at 34dB (50). The IC is to be supplied with a power of +15V.

3.2 Results and Discussions

Waveform of input and output signal of PA system is shown in Appendix 3.2.

From Appendix 3.2, By applying the formula of **gain (dB) = 20 log_10(Vout/Vin)**, the measured gain is 31.59 dB (using the value of Vout is 3.8V and Vin is 0.1V). From the experiment, the expected gain is 34dB. From the results, the discrepancies between measured and expected gain is 7.63% which is tally with the expected result.

To find out the characteristics of PA across a range of frequencies, NI ELVIS Bode Analyzer is used to carry on frequency sweep measurement, so that we can get the entire frequency response of Bode plot [1]. Screenshots of Bode Analyzer are shown in Appendix 3.3 (range from 0.01V to 0.19V)

When Vp is small (eg. from 0.01 to 0.11V), the gain is constant. When Vp increases to a larger value (eg. 0.19V), the gain starts to fluctuate a lot within the frequency range of 100 Hz to 200kHz

PA subsystem acts like a low pass filter because voltage is only allowed in the low frequency region as the gain can be seen sustain or remain constant at low frequencies and fall off at high frequencies.

Chapter 4: Volume Unit (VU) Meter Subsystem

4.1 Overview

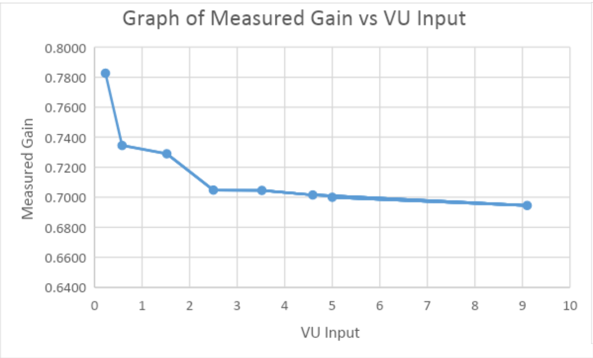
VU Meter detects peak voltage of output signal generated by PA subsystem, which will feedback to the controller to control the input amplitude [1]. Pin diagram of CA3140 is shown in Appendix 4.1.

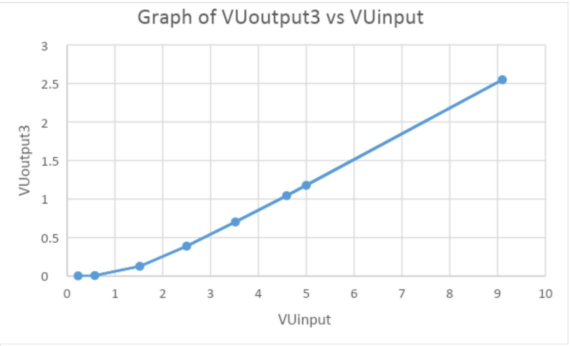
When we run NI ELVIS and launch FGEN (1kHz sinusoidal waveform with Vpp = 5V), VU Output 1, 2 and 3 are recorded in Appendix 4.2.

4.2 Results and Discussions

VU_{input} (V_{pp})	$VU_{output1}$ (V_{pk})	$VU_{output2}$ (V_{pk})	$VU_{output3}$ (V_{RMS})	Measured Gain = 2 $VU_{output2}$ / VU_{input}
5	2.34	1.75	1.177	0.7000
9.1	3.80	3.16	2.548	0.6945
4.59	2.192	1.61	1.043	0.7015
3.52	1.809	1.24	0.702	0.7045
2.50	1.434	0.881	0.388	0.7048
1.52	1.066	0.554	0.126	0.7289
0.58	0.69	0.213	0.006	0.7345
0.23	0.53	0.09	0.002	0.7826

Table 4.1.1: Gain Measurement





Graph 4.1.2: Measured Gain vs VUinput (left) and VUoutput3 vs VUinput (right)

From the graph of *Measured Gain vs VUinput (left), the* theoretical measured gain is –R2/R1 = 3.3k/4.7k = 0.702. From the graph above, as the VU input (Vpp) increases, the measured gain gets closer to 0.7 which tallies with the theoretical gain value.

From the graph of *VUoutput3 vs VUinput (right)*, the graph of VUoutput3 against VUinput is approximately a straight line relationship. Hence, the functionality of VU meter to manipulate the output waveform is met as we can change the value of VUoutput3 by changing the VUinput.

Chapter 5: Integration for Audio Amplifier System

5.1 Overview

Integration of the system is the cascade of the three subsystems, VCA, PA and VU meter to form a complete Audio Amplifier System with volume control.

5.2 Results and Discussions

Sinusoidal waveforms with different peak-to peak amplitude from FGEN were used to observe the audio output and gain.

All screenshots of waveform are shown in Appendix 5.1.

Audio Input (V_{pp})	V_c (V)	Audio Output (V_{pp})	Gain (dB)	$VU_{output3}$ (V_{RMS})
1.100	0.500	0.019	-35.414	0.003
0.590	0.360	0.040	-23.371	0.010
0.520	0.180	0.730	2.946	0.255
0.300	0.060	3.950	22.390	1.380
0.320	0.000	12.740	32.000	4.500
0.180	-0.060	14.150	37.910	5.150
0.130	-0.120	15.100	41.301	5.550
0.110	-0.150	15.260	42.843	5.500

Table 5.2.1: Audio Amplification System Testing

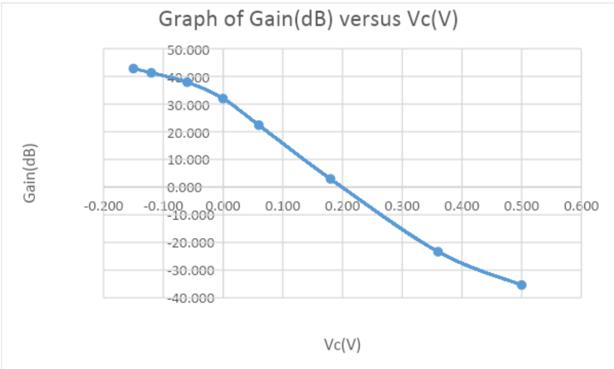


Table 5.2.2: Gain (dB) vs Vc (V)

The graph is a straight-line graph with negative gradient, where the gain decreases as Vc increases. The audio amplifier is to amplify signal according to control voltage. This allows input signal to be amplified with different gain for different Vc.

As the frequency of FGEN increased to 100kHz (For the case of Vc = 0V and Vpp = 0.32V), The Vpp value and Vrms value decrease.As the frequency increases by approx. 300 times, the waveform fluctuates even more.

Chapter 6: Manual Volume Control for Audio Amplifier System

6.1 Overview

Manual Volume Control is a control system which the operator provides modification of volume control based on VU meter reading [1]. Since there is no feedback in this system, it can be considered as an open loop system [1]. A screenshot of Function Generator and Block Diagram of Manual Volume control is found in Appendix 6.1.

6.2 Results and Discussions

Function Generator is set to 300Hz sinusoidal wave and a tone of sound is produced. As the frequency of the sine wave is increased, the pitch of the sound increases. As the VCA control voltage varies within the range from -0.18V to 0.54V, the volume of the speaker changes.

Chapter 7: Automatic Volume Control For Audio Amplifier System

7.1 Overview

The Automatic Volume Control can be implemented through a closed-loop system and the output of the VU Meter feedbacking to the input of the VCA with a Step-Up-Down Controller shown in Appendix 7.1

When the audio output falls below the set point value, the u(n) or more intuitively, V_c will be decreased. From previous results, a decreased V_c will result in an increased gain, and vice versa. Then, the audio output volume will automatically fluctuate about r_0, the set point value to maintain a constant audio output. The effect is to improve output audio quality by automatically control the volume of audio input. The screenshots of set up of circuit and block diagram is shown in Appendix 7.2. In the block diagram, the black needle indicates the set point value r0 whereas the red needle indicates the value of z(n)

7.2 Results and Discussions

With function generator set at 1Vp-p and 300 Hz, we vary the r_0 from 0 to 1, the volume of the sound increases with increasing r_0 value.

The chip starts to heat up after some time during the operation. This is due to drawing of excess current into the circuit and the excess current dissipated as heat. In the closed loop system, the analog signal changing to digital signal simultaneously to match the ro and zo value. Hence, continuous looping causes the chip to heat up

Chapter 8: Problems and Solutions

When integrating the circuit, the issue that we encountered is there is no sound heard from the speaker. To troubleshoot the issue, firstly we checked all the circuit connections to ensure there is no loosen of components and all components are not too short. Then, we check the current through each single subsystems (VCA, PA and VU Meter subsystems), ensure that the subsystems are not short-circuited. Then, we check through each subsystems with the multimeter, ensuring that all the subsystems and circuits are connected.

Chapter 9: Conclusion

In the end of the day, we were able to complete everything in the lab manual to build an Audio Amplifier System. Our system worked well and was able to generate sound and perform audio amplification. By connecting the system to PC through audio jack, we were able to play songs as well.

From this 10 Weeks of lab session, I learnt the function of various IC chips as the main basic blocks of a complicated system and the cascading of various subsystems into one system. Besides, I was also able to learn to use ELVIS and LabView to build block diagram, testing circuits through their built-in functions. From the hands-on session, I also learnt that the implementation of the audio system was not easy as it seems to be, as there exists various kinds of errors such as human mistakes, faulty components etc. Hence, we should always be mindful to check on everything before proceeding to the next phase of work.

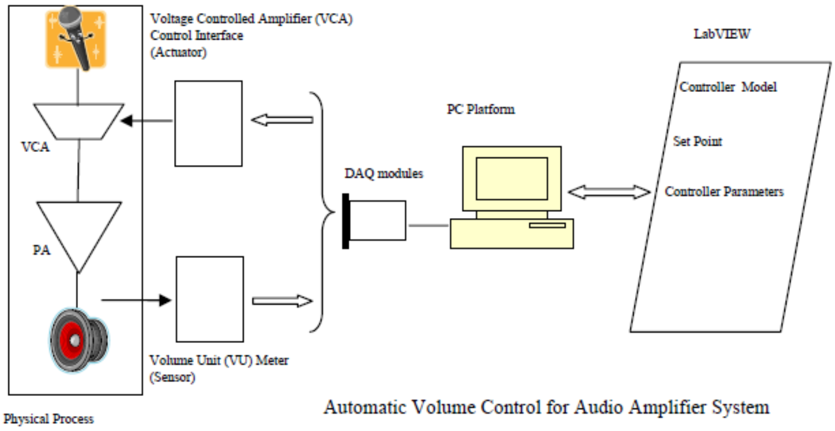
This lab session has also helped me to gain insights and hands-on real world applications by applying theoretical knowledge learnt from the class. It enables me to have a clearer vision on what I want to pursue in the future.

Reference

[1] Nanyang Technological University, School of Electrical and Electronic Engineering, "EE2073 Introduction to EEE Design and Project - Lab Manual," 2020.

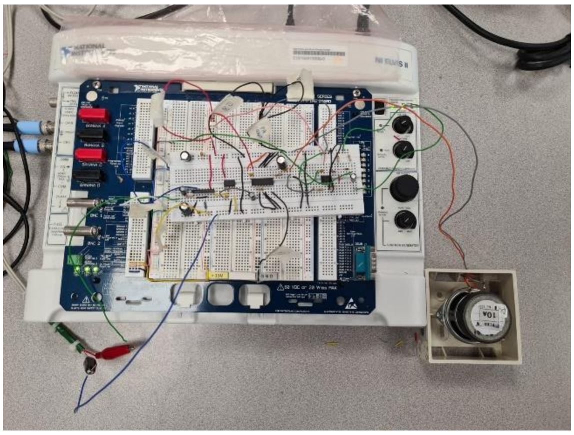
Appendix

1.1 Block Diagram of Audio Amplifier System

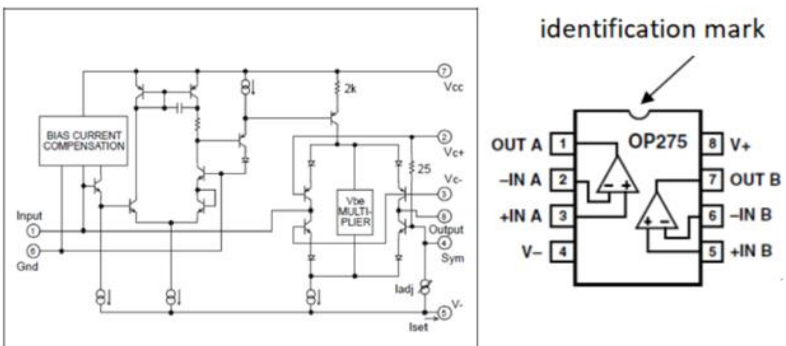


Automatic Volume Control for Audio Amplifier System

1.2 Set up of system

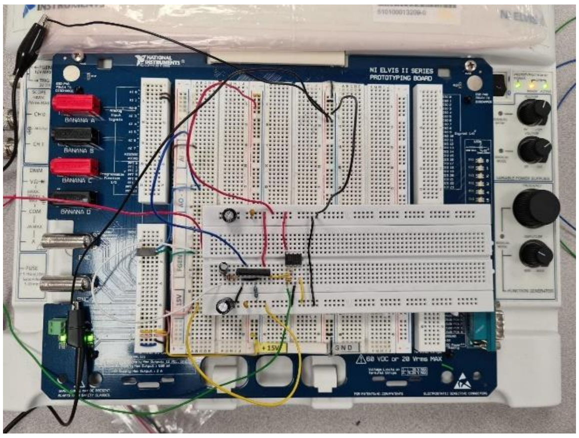


2.1. (a)THAT 2180C and (b) OP 275



(a) (b)

2.2. Set up of VCA subsystem



2.3. Required Formula

Theoretical Gain (dB) formula:

$$G\ (dB) = \frac{-V_c}{(0.0061)(1 + 0.0033\Delta T)}$$

where ∆ T is the difference between room temperature (25 degrees Celsius) and actual temperature and is assumed to be -2 degrees Celsius and Vc sensitivity is 6mV/dB.

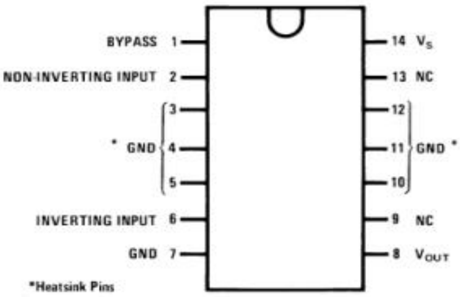
The **Measured Gain (dB)** formula:

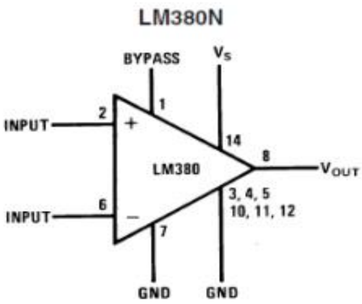
$$G\ (dB) = 20 \log_{10}(V_{OUT}/V_{IN})$$

The **inverse** of the slope of the graph:

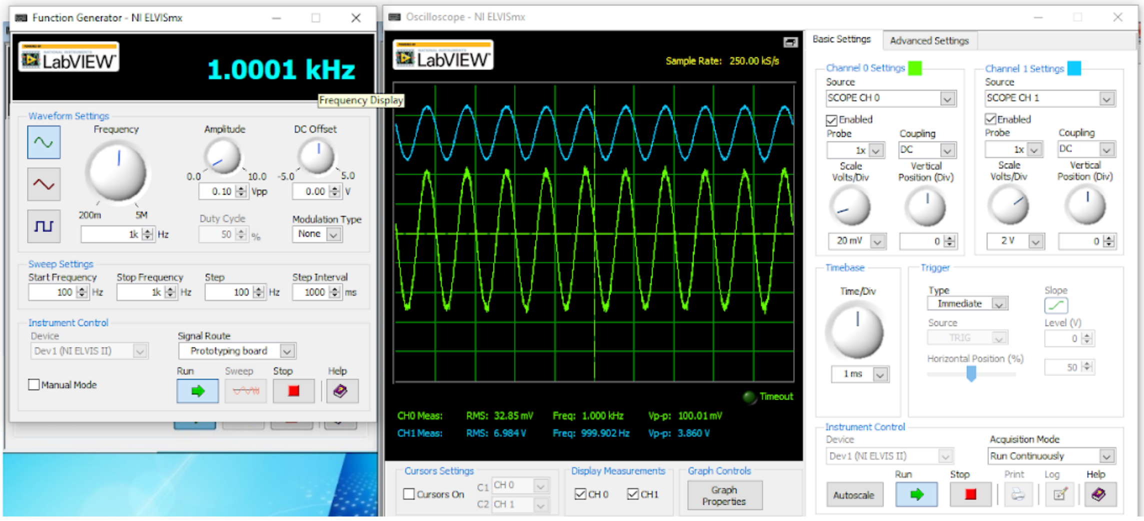
$$\text{Inverse of slope} = \frac{1}{\text{slope of graph}}$$

3.1. Pin diagram and schematic diagram of LM380 (Power Amplifier IC)

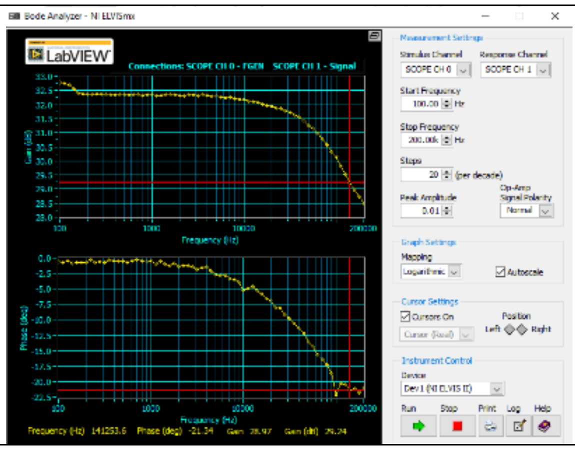


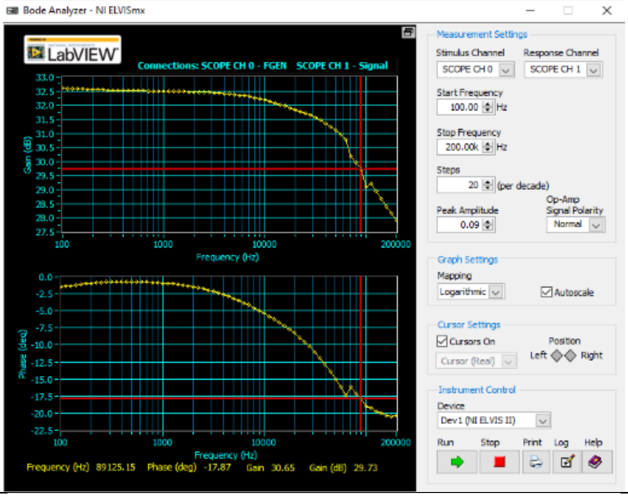
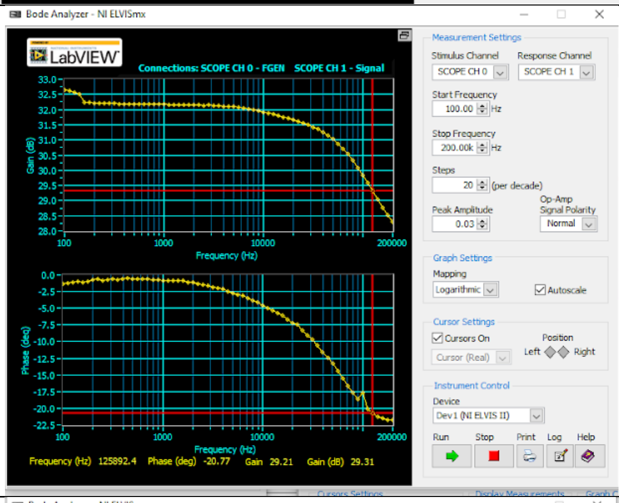
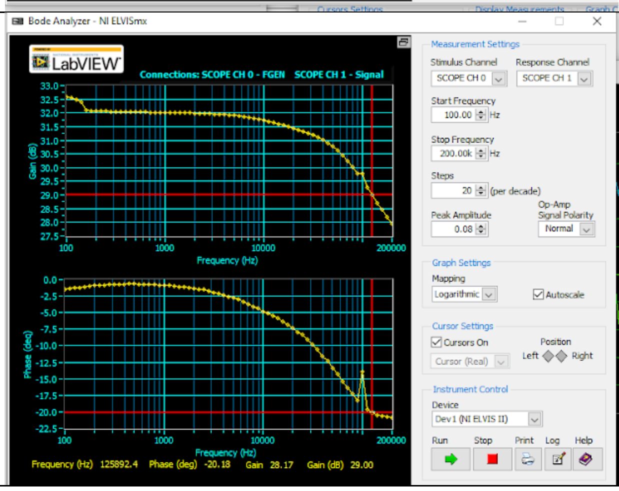


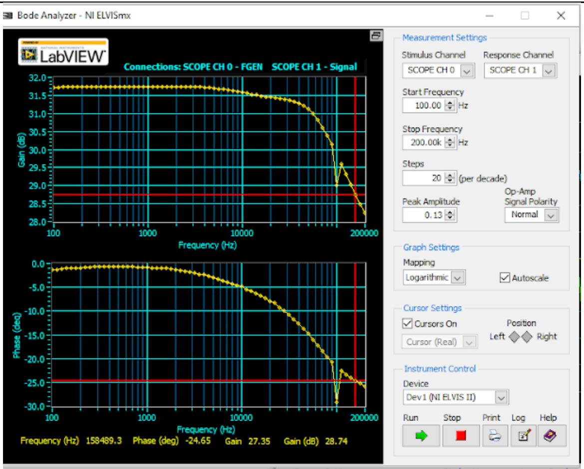
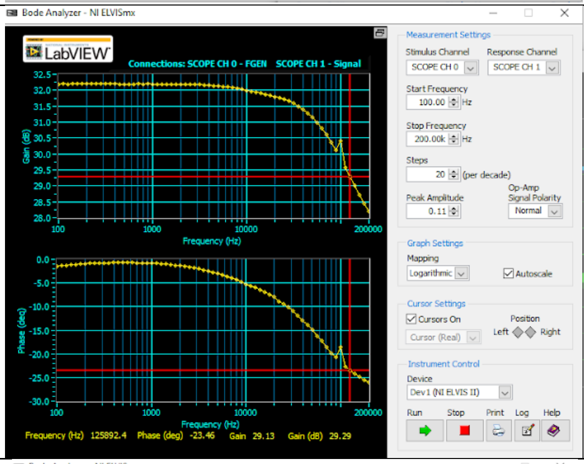
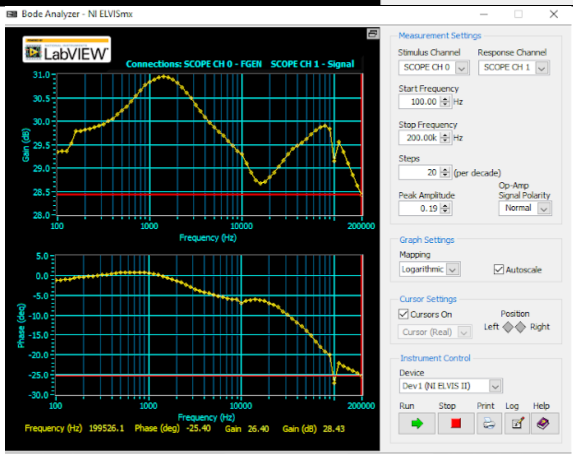
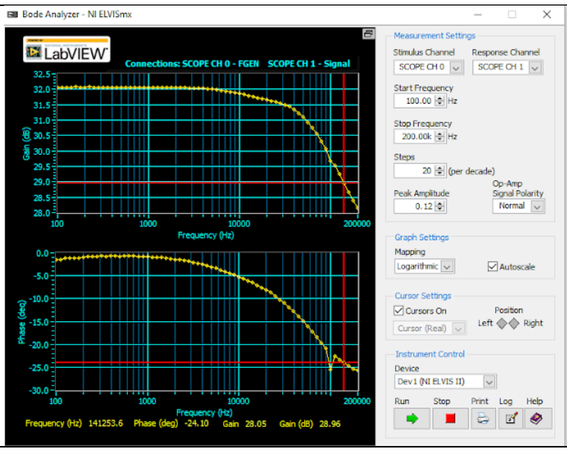
3.2. Waveform of input and output signal of PA system



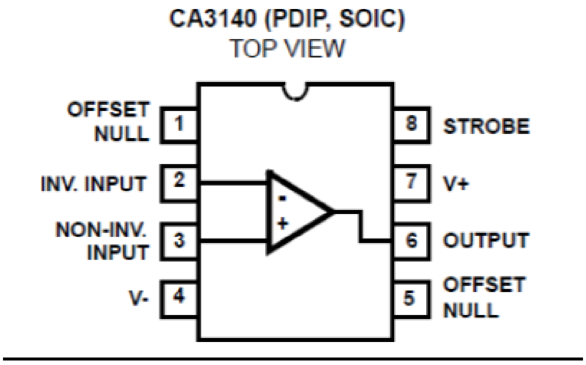
3.3. Bode Analyzer

V_p (V)	Bode Analyzer Window Capture
0.02V	
0.01 V	

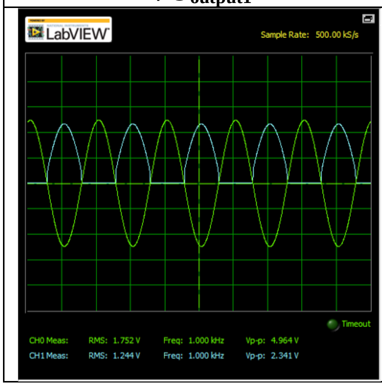
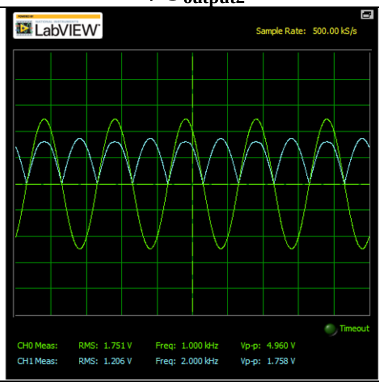
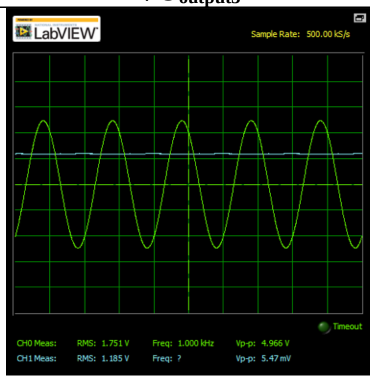
0.09V	
0.03V	
0.08V	

<table>
<tr><td>0.13V</td><td>
</td></tr>
<tr><td>0.11V</td><td>
</td></tr>
<tr><td>0.19V</td><td>
</td></tr>
<tr><td>0.12V</td><td>
</td></tr>
</table>

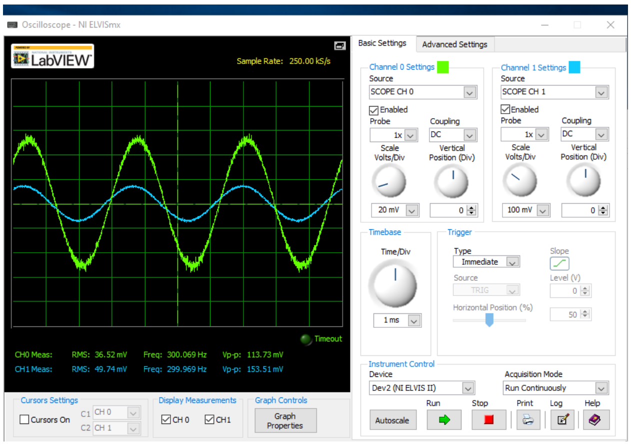
4.1. Pin Diagram of CA3140



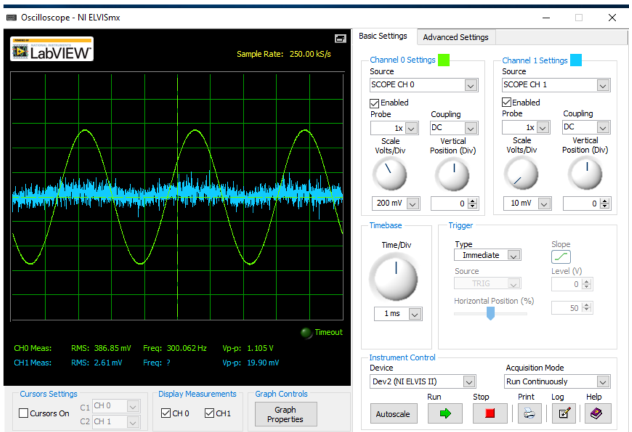
4.2. VU Output 1, 2 and 3

$VU_{output1}$	$VU_{output2}$	$VU_{output3}$
		

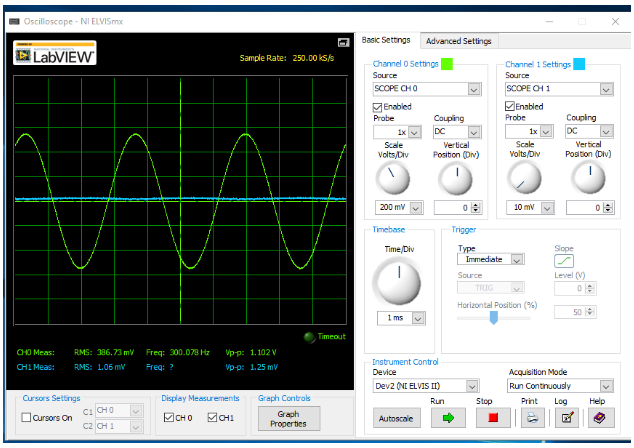
5.1. Waveforms obtained at Audio Output superimposed on Audio Input



Vpp = 0.1V, VC = 0.18V

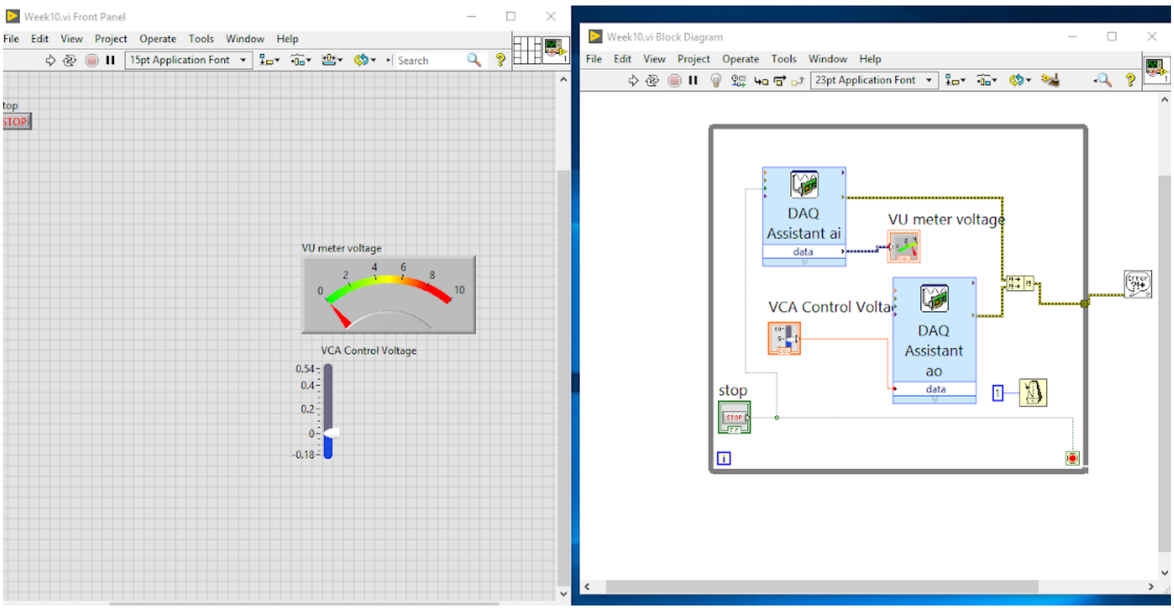


Vpp = 1.1V, VC = 0.5V



Waveform of VUoutput3

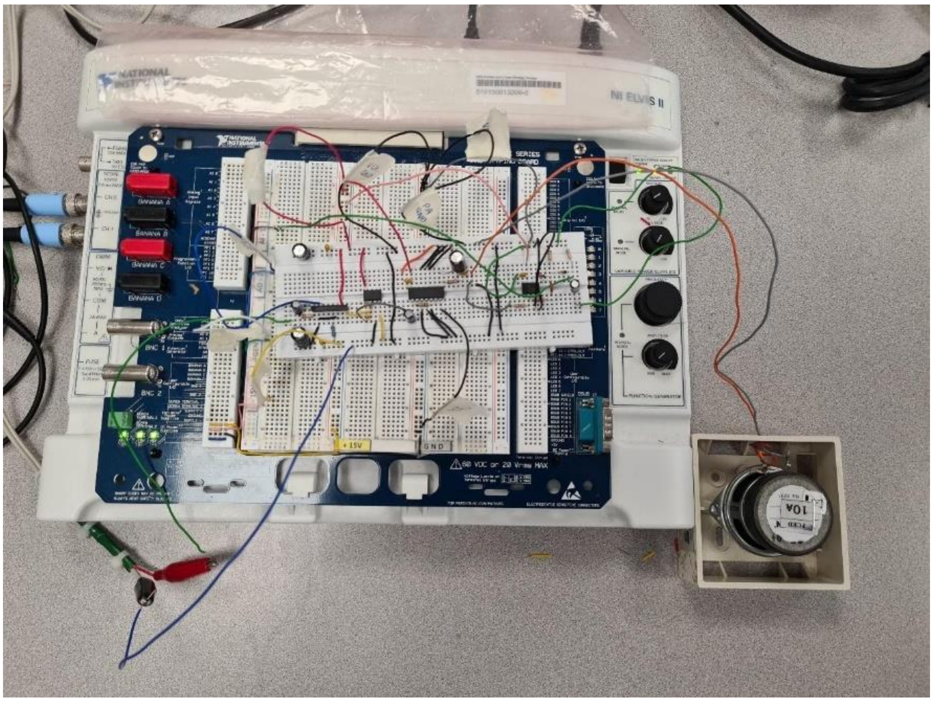
6.1. <u>Screenshot of Block Diagram of Manual Volume control</u>

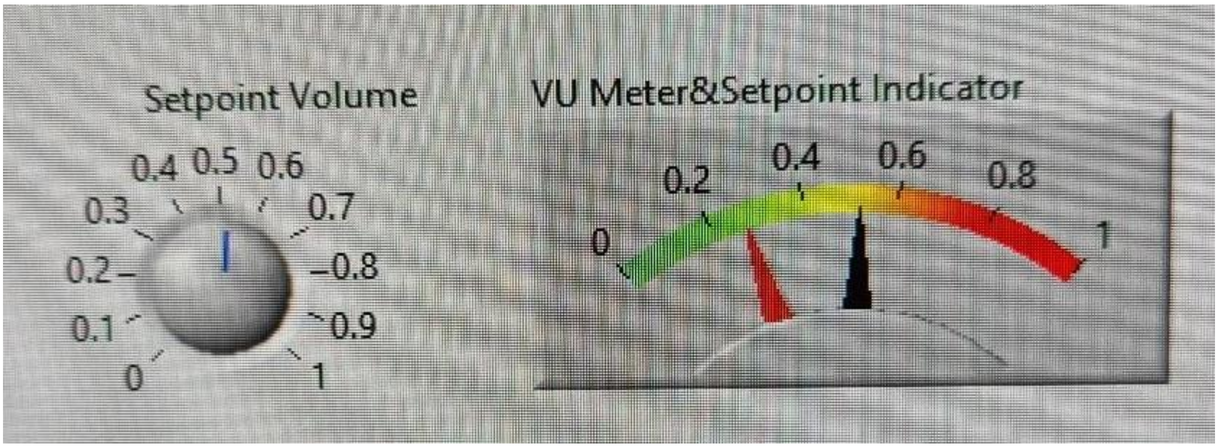


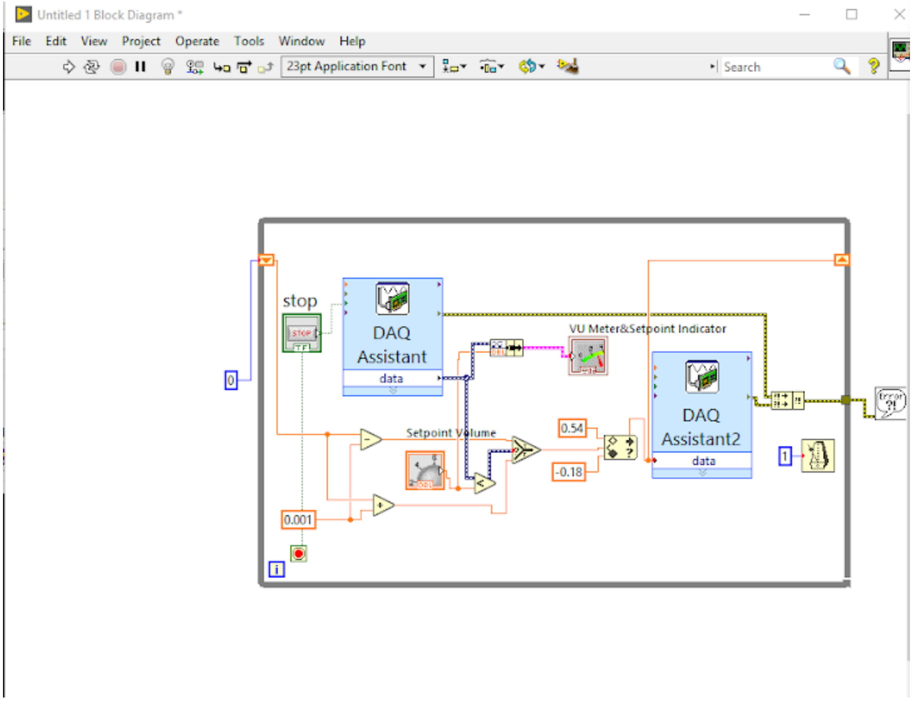
7.1 Step-Up-Down Controller Equation

$$u(n) = \begin{cases} u(n-1) - \Delta & e(n) > 0, z(n) < r_0 \\ u(n-1) + \Delta & e(n) < 0, z(n) > r_0 \end{cases}$$

7.2 Screenshots of Set Up and Block Diagram of Automatic Volume Control






Untitled 1 Block Diagram *
File Edit View Project Operate Tools Window Help
23pt Application Font
Search
stop
DAQ Assistant
data
VU Meter&Setpoint Indicator
Setpoint Volume
DAQ Assistant2
data
0.54
-0.18
0.001
0
1