The City College of New York
Grove School of Engineering
EE 32200 – Electrical Engineering Laboratory II
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Lab Report Experiment # 4
Audio Amplifier (Part 1)

Instructor: Ritesh Chaudhuri

Azizur Rahman
Hasan Uchchas

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Objective :
In this experiment we will design and build an audio amplifier circuit and then test its performance. An audio amplifier should be able to amplify its input signal without distortion.

Pre-lab:
The first part of the pre-lab is all hand calculations; we are to find the values of resistors and voltages at specific points as well as the collector current. To make our calculations easier, we will assume that β is infinite, which means that there is no input base current, the source resistance is 0, which doesn't lower the input voltage, because it won't create a voltage divider at the input. The formulas that we used to calculate all the values is shown in below which is given in lab manual.

$R_C = Z_{out}$

$I_C = (Vcc-Vcq)/Rc$

$re = Vt/Ic$

$R_{E1} = (Rc/gain)-re$

$V_B = I_C(R_{E1} + R_{E2}) + V_{BE}$

$R2=(Zin *Vcc)/Vb$

$R1=Vb*R2/(Vcc-Vb)$

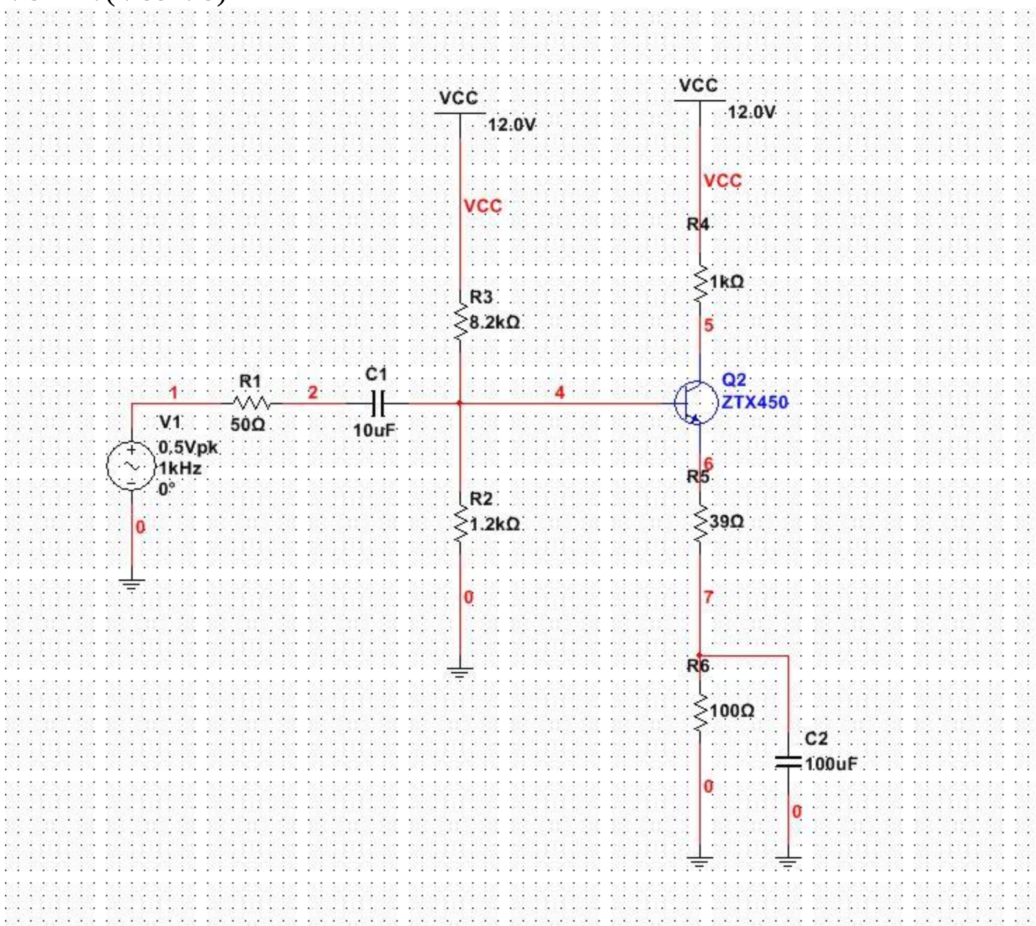

Figure1: circuit with the calculated resistor value.

Parameter	Minimum	Typical	Maximum	Units
Vcc		12		Volts
Gain	15	20	30	V/V
Zin	800	1000	1200	Ohms
Zout	700	1000	1200	Ohms
Maximum output swing without clipping	7			Vpp

Resistor	Capacitor	Quiescent Voltages and Current
R_1=1.2k ohm	C_B=10uf	V_B=1.3
R_2=8.2kohm	C_E=100uf	V_E=.83
R_c=1k ohm		V_{CQ}=6
R_{E1}=39 ohm		I_{CQ}=6mA
R_{E2}=100 ohm		

The R_C is given as Zout of the amplifier, which is typically 1kΩ. V_{CQ} is given as the value that would give the maximum output swing, which is 6V, since the transistor has a gain of 2V/V. We will be using the typical values of the parameters to do our calculations.
I_{CQ} is the current going through the collector of the BJT and is given as

$$I_{CQ} = \frac{V_{CC} - V_{CQ}}{R_C} = 6mA$$

r_e is the impedance of the transistor and we can find it once we convert it into the small signal equivalent circuit of the BJT.

$$r_e = \frac{V_T}{I_C} = 4.17\Omega$$

As an approximation, the gain is given as the impedance looking up at the Vout over the impedance looking down. Therefore,

$$Gain = R_C/(r_e + R_{E1})$$

Which can be written as

$R_{E1} = \frac{R_C}{Gain} - r_e \approx 39\Omega.$

V_E is the voltage at the emitter and is given by

$$V_E = \frac{R_{E2} + R_{E1}}{I_C} = 0.83V$$

And V_B is the voltage at the base and is given as

$$V_B = V_E + V_{BE} = 1.3V$$

Where V_{BE} is equal to 0.7V. An alternative way of finding V_B is to do a voltage divider across R_1,

$$V_B = V_{CC}[\frac{R_1}{R_1 + R_2}]$$

Which should give us the same answer, 1.3V.

Z_{in} is the impedance looking into the base of the BJT and is given as

$$Z_{in} = R_1 * \frac{R_2}{R_1 + R_2}$$

We will use this equation along with the alternative equation to find V_B to find R_1 and R_2, with a little manipulation, we will find that

$$\frac{V_B}{V_{CC}} = \frac{Z_{in}}{R_2}$$

$R_2 \approx 820\Omega$

R_1 is then found as follows,

$$R_1 = Z_{in}R_2/(R_2 - Z_{in})$$

$R_1 \approx 1.2k\Omega$

The capacitors C_B and C_E are included in this amplifier to reduce the noise given off by the input signal source.

Computer Simulations:

We were to used standard resistor values that we acquired through our hand calculations then run DC bias point analysis using Multisim. Our design is shown in Figure 1.

From DC analysis we get the value of Vb(v1) ,Vc (v3), and Ve(V4) is

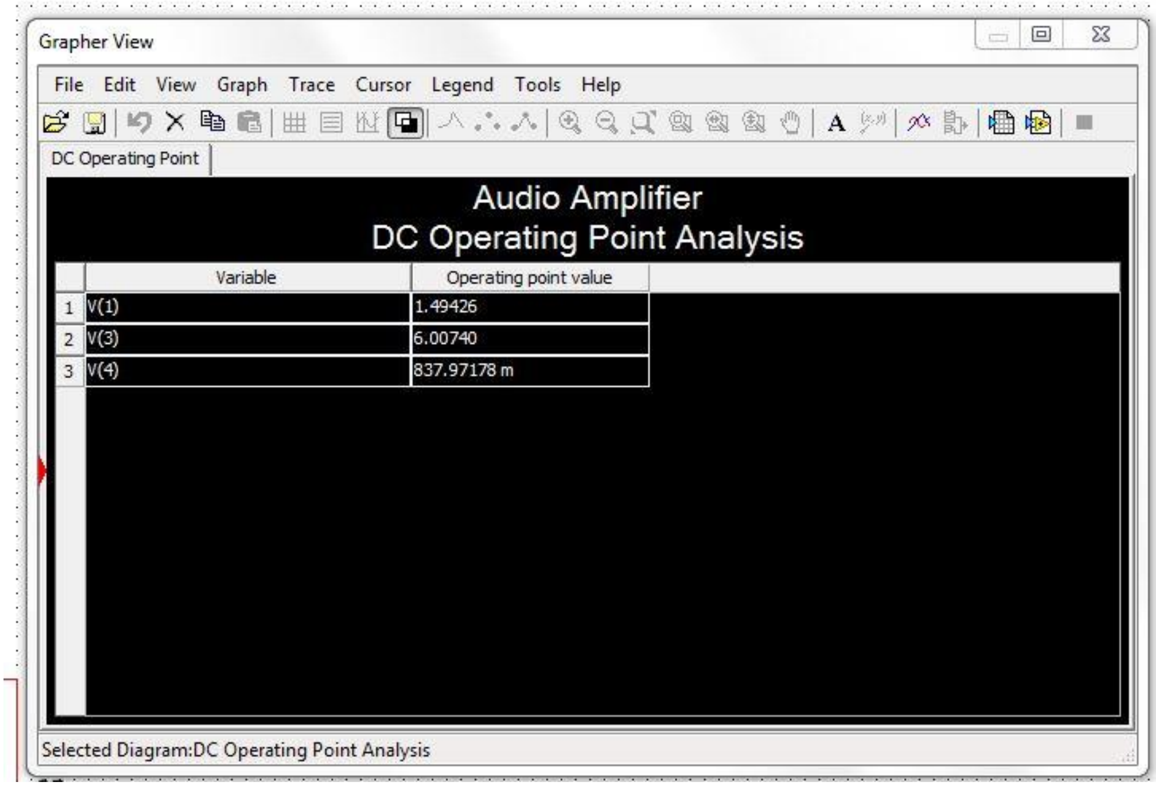

Figure: DC analysis of the figure 1.

Next, we ran a transient analysis with V_S set to 1kHz and R_S to 50Ω. Figure 2, 3, and 4 will show the different output waveforms for different voltage inputs of 50mVpp, 500mVpp, 1Vpp, respectively.

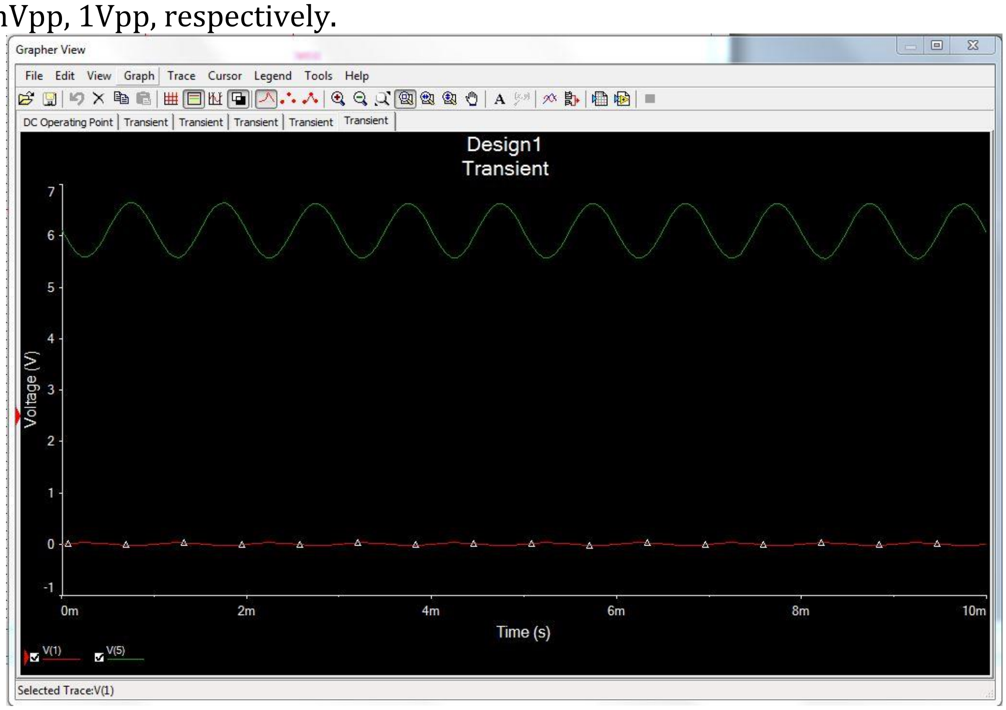

Figure: output voltage for 50mVpp input.

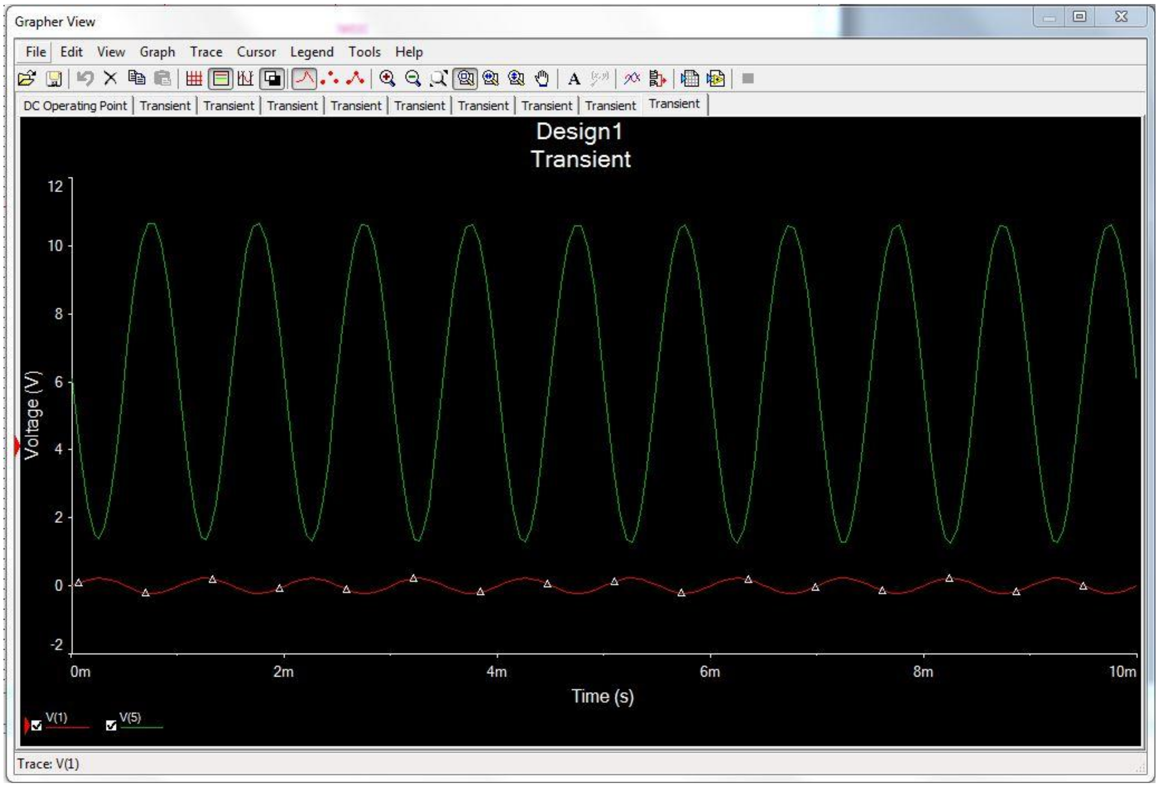

Figure: output voltage for 450mVpp input.

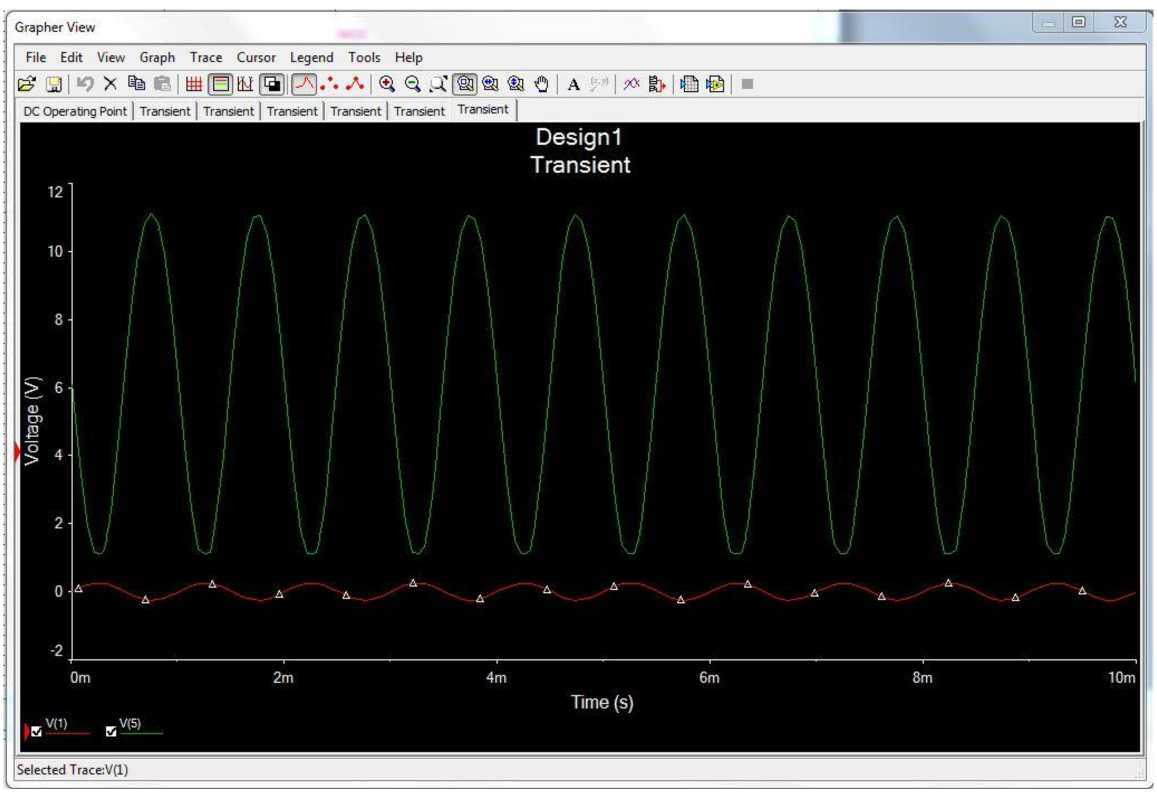

Figure: output for 500m Vpp input.

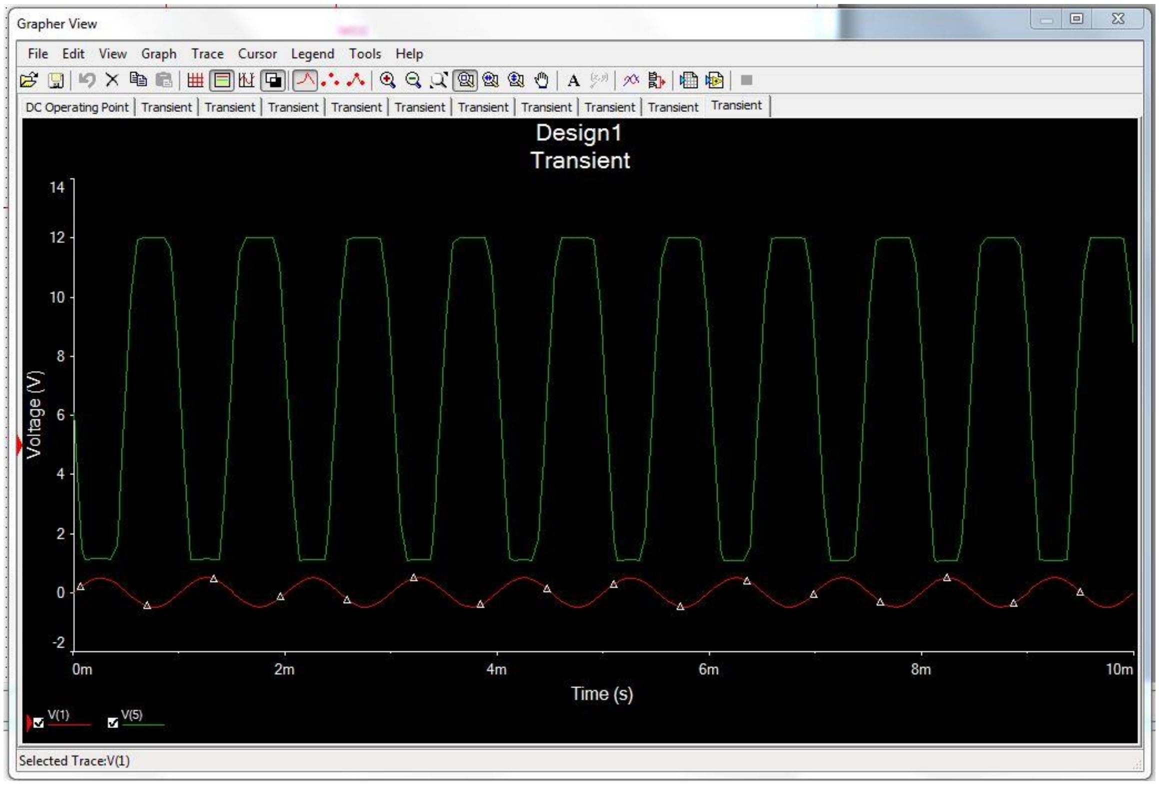

Figure: output waveform for 1 Vpp input.

As we can see, with a 50mVpp, 450mVpp and 500mVpp input, there is no distorting, however, once we have reach 1Vpp input, the output voltage is clipped on top and on the bottom. Our maximum input that does not create distortion is about 450mVpp. We obtain a gain of 9.575V/V with this input.

The reason why the plot would clip on the bottom and the top is because the amplifier is trying to amplify excessive voltage or current that is beyond its capacity.

The gain that we obtained with an input of 50mVpp is 8.63 V/V, which meets the gain specification of the table.

Laboratory Experiment:

For the laboratory portion, we constructed the design shown in Figure 1.

We kept the wires as short as possible to minimize inductance and added a 1000μf capacitor to bypass the power supply. This capacitor guarantees the power supply is an AC short.
We then measured the quiescent voltages at the base, collector, and emitter. We found that
V_B = 1.48V
V_E = 0.852V

And V_C = 5.9V
Our measured quiescent voltages match with our simulated quiescent voltages.

Figure 6 shows the oscilloscope image of our input and output when the function generator at 1kHz.

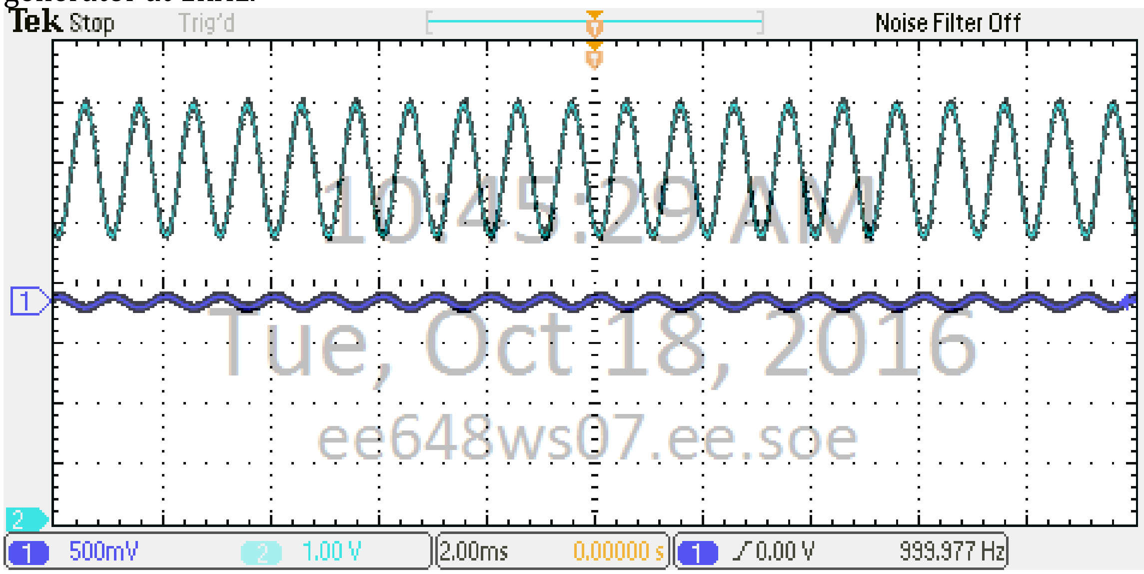

Figure: Output waveform for 1 kHz.

The gain obtained from this oscilloscope image is 16.5 V/V, which meets the specifications. The maximum undistorted output voltage swing of the amplifier was 9.2Vpp.

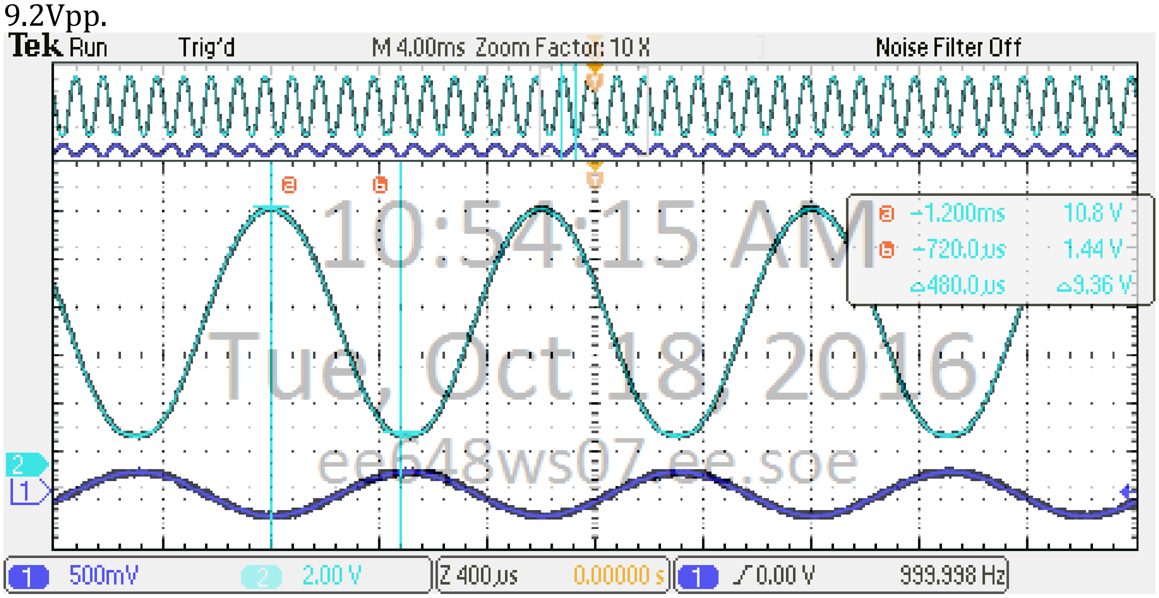

Figure: maximum undistorted output.

The maximum undistorted output voltage swing of the amplifier was 9.36Vpp, which gives us 15.09 V/V as the gain.

Next part of this laboratory is to change the different input frequencies to show when the gain would fall off or stabilize, it will be shown in the table and the Matlab Figure below.

Frequency	Vin	`Vout	Gain
10Hz	240mv	240mv	1
20Hz	240mv	480mv	2
40Hz	240mv	1.6V	6.67
70Hz	240mv	4.64V	19.3
100Hz	240mv	7.12V	29.3
150Hz	240mv	8.96V	37.3
300Hz	240mv	9.28V	38.7
600Hz	240mv	9.36V	39
1kHz	240mv	9.36V	39
3kHz	240mv	9.44V	39.3
10kHz	240mv	9.44V	39.3

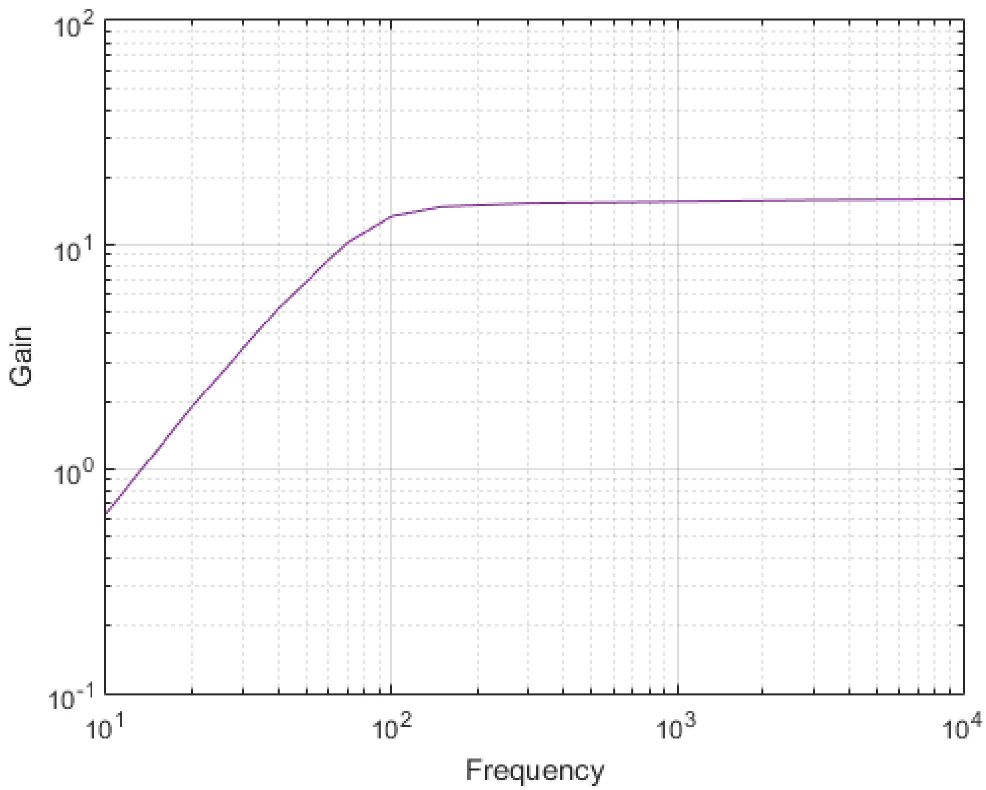

Figure: loglog plot of the table.

From Figure 8, we can see that our amplifier can only achieve a stabilized gain at high frequencies. This is because at low frequencies, C_B and C_E will no longer act as short and will contribute to the gain falling off at low frequency.

To find Zin and Zo, we find the values of R_S and R_{Load} that causes the gain to drop to half when its measured with $R_S = 0$ and $R_{Load} = \infty$, respectively. The values for the resistors were 1kΩ for R_S and R_{Load}.

Conclusion:

Therefore, the amplifier that we constructed meets the design specifications perfectly, with the gain being 16.5V/V, the Z_{in} 1kΩ same as the Z_{out}, and maximum output swing 9.36Vpp. The measured values were very close to the simulated values with a few % error, which is most likely due to the tolerance level of the resistors and the instrumental errors. Since our experiment meets the specifications, we can use this to connect to the power amplifier.