Figure 1: Zewail University

Electro-optic Sensors

Mohammed Harraz - Amr Khaled
IDs: 202200128- 202200809
Mentor: Dr. Nehad Moustafa
Zewail University - EGYPT

Contents

1 Abstract

This project aims to design and implement a transistor-based **audio amplifier circuit**. Using a three-stage transistor configuration, the amplifier enhances the amplitude of the input signal to meet specific gain requirements. The circuit must be optimized to achieve a voltage gain (A_v) of **4.5** while incorporating a mechanism to control the gain dynamically from $A_v = 4.5$ to a maximum value. The design will consider operating conditions such as a supply voltage of **12V** (V_{DD}) and ensure stable operation without significant loading effects.

The project combines theoretical design, practical implementation, and circuit analysis to optimize performance and meet the outlined specifications. Adjustments to component values and configurations will be made to ensure reliable and efficient operation.

2 Introduction

Audio amplifiers are essential in applications ranging from communication systems to entertainment devices. This project explores the design and optimization of a **three-transistor audio amplifier**. The provided schematic serves as a baseline, where the roles of various components, including capacitors, resistors, and transistors, contribute to signal amplification and stability.

Key aspects of the project include:

1. **Component Selection**: Choosing suitable resistors and capacitors to achieve the desired gain and frequency response.

2. **Circuit Modifications**: Introducing controls for gain variability without affecting the circuit's stability or quality.

3. **Testing and Evaluation**: Verifying performance through theoretical calculations, simulations, and real-world measurements.

Circuit Design

2.1 Hand Analysis

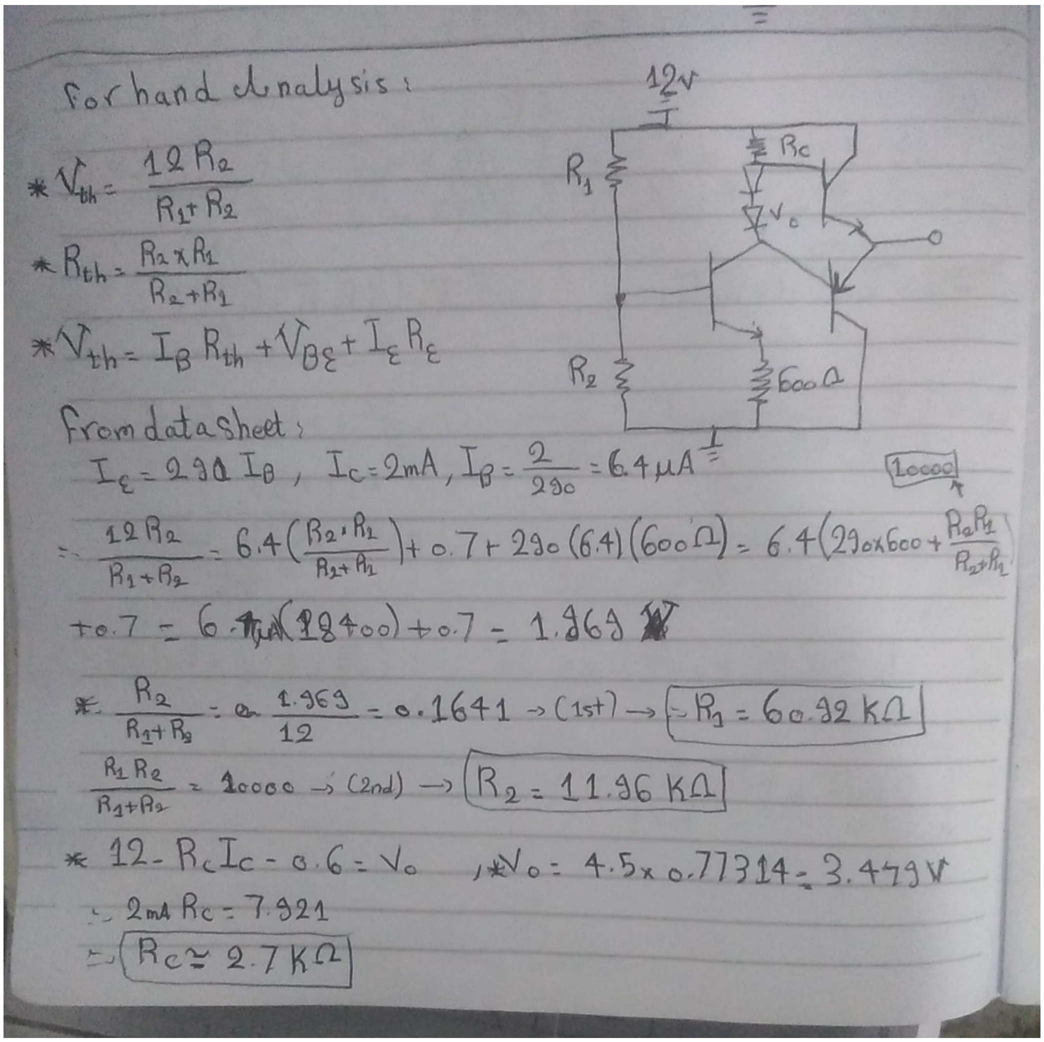

Figure 2: *Hand Analysis Calculations to find RC,1,2 Values*

The hand analysis of the transistor amplifier circuit involves calculating the resistor values R_1, R_2, and R_C based on the given design requirements and assumptions. Below is the step-by-step process:

1. **Thevenin Voltage (V_{th}) and Thevenin Resistance (R_{th})**:

$$V_{th} = \frac{12R_2}{R_1 + R_2}, \quad R_{th} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

2. **Base Voltage Equation (V_B)**: The voltage at the base is given by:

$$V_{th} = I_B \cdot R_{th} + V_{BE} + I_E \cdot R_E$$

where V_{BE} is typically $0.7\,\mathrm{V}$, $I_E \approx I_C$, and $I_B = \frac{I_C}{\beta}$.

3. **From the Datasheet and Assumptions**: - $\beta = 290$ (DC current gain of the transistor) - $I_C = 2\,\mathrm{mA}$ - $I_B = \frac{2}{290} = 6.4\,\mu\mathrm{A}$

   Substituting the values into the base voltage equation, we calculate R_1 and R_2.

4. **Resistor Calculations**: Using the voltage divider rule:

$$\frac{R_2}{R_1 + R_2} = \frac{1.269}{12} \quad \Rightarrow \quad \frac{R_2}{R_1 + R_2} = 0.1641$$

   This gives:

$$R_1 = 6.32\,\mathrm{k}\Omega, \quad R_2 = 11.96\,\mathrm{k}\Omega$$

5. **Collector Resistance (R_C)**: The desired gain is $A_v = 4.5$, so:

$$V_o = 4.5 \times 0.77314 = 3.479\,\mathrm{V}$$

   With $V_{CC} = 12\,\mathrm{V}$, we calculate R_C using:

$$R_C = \frac{V_o}{I_C} = \frac{3.479}{2 \times 10^{-3}} \approx 2.7\,\mathrm{k}\Omega$$

2.2 LT-Spice Circuit Design

The complete circuit design incorporates the calculated resistor values ($R_1 = 6.32\,\mathrm{k}\Omega, R_2 = 11.96\,\mathrm{k}\Omega, R_C = 2.7\,\mathrm{k}\Omega$) and is optimized to achieve the desired gain and stable operation.

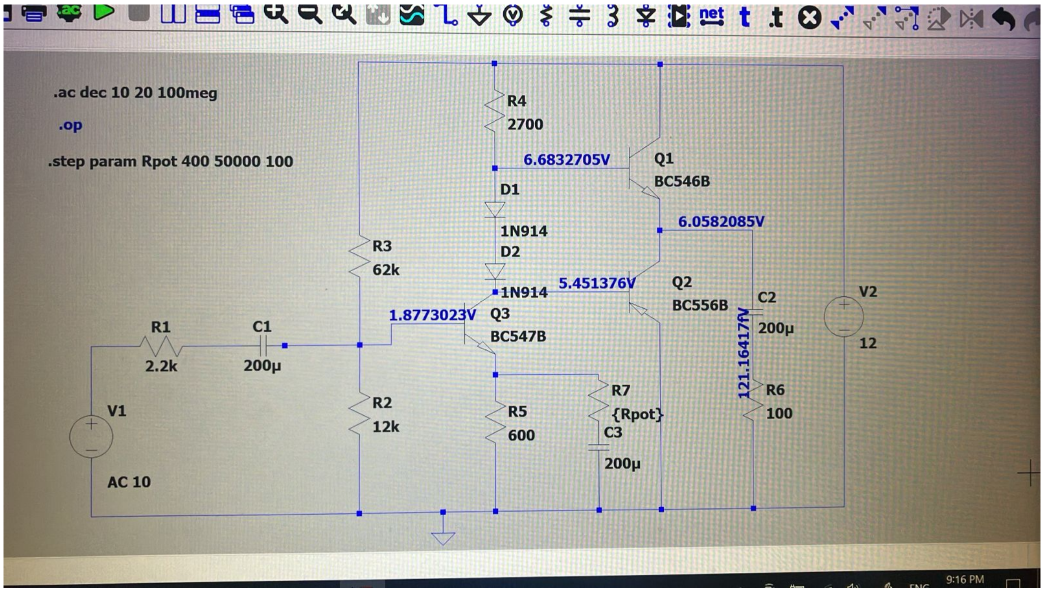

Figure 3: *LT-Spice Circuit Design*

3 PCB Design

The printed circuit board (PCB) is a critical component of the audio amplifier project.

3.1 PCB Components

The PCB is designed to accommodate the following components:

- Transistors (Q_1, Q_2, Q_3): 2SC1815 and 2N3904
- Resistors (R_1, R_2, R_C):
  - $R_1 = 6.32\,\mathrm{k\Omega}$
  - $R_2 = 11.96\,\mathrm{k\Omega}$
  - $R_C = 2.7\,\mathrm{k\Omega}$
- Capacitors:
  - $C_1 = 0.1\,\mu\mathrm{F}$
  - $C_2 = 47\,\mu\mathrm{F}$
  - $C_3 = 220\,\mu\mathrm{F}$
- Power supply: $12\,\mathrm{V}$
- Output load: $600\,\Omega$ speaker

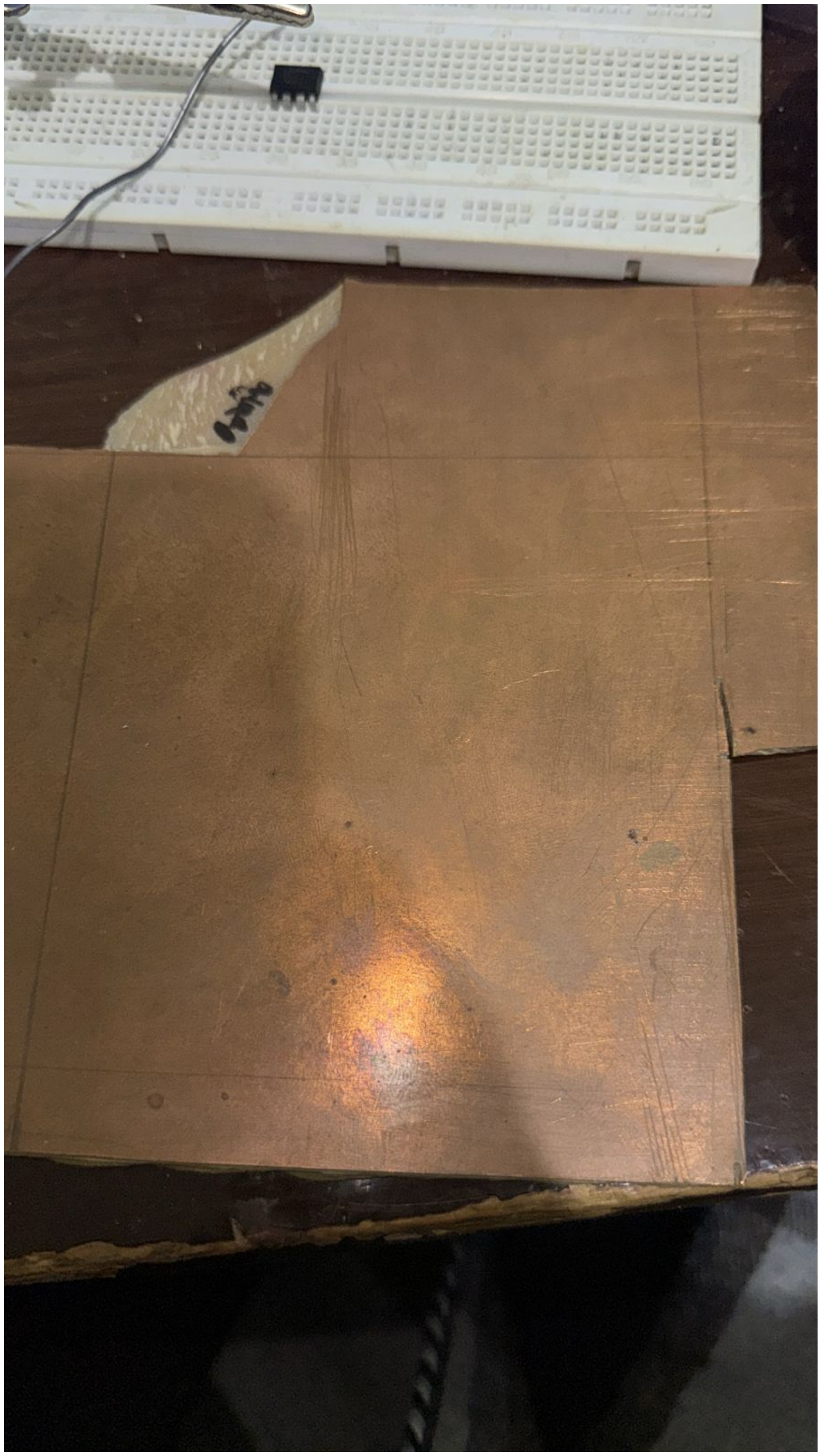

Figure 4: PCB Layout

The components are arranged to minimize noise and ensure proper heat dissipation. Signal paths are kept short to reduce interference.

3.2 Etching Process

The etching process involves transferring the PCB design to a copper-clad board and removing unwanted copper to leave only the desired traces. The steps are as follows:

1. **Printing the PCB Layout**: The layout is printed on glossy paper using a laser printer.

2. **Transferring the Layout**: The printed design is transferred onto the copper-clad board using a heat press or iron.

3. **Etching**: The board is immersed in a ferric chloride solution to remove excess copper, leaving only the printed circuit traces.

4. **Drilling and Soldering**: Holes are drilled for through-hole components, and the components are soldered onto the PCB.

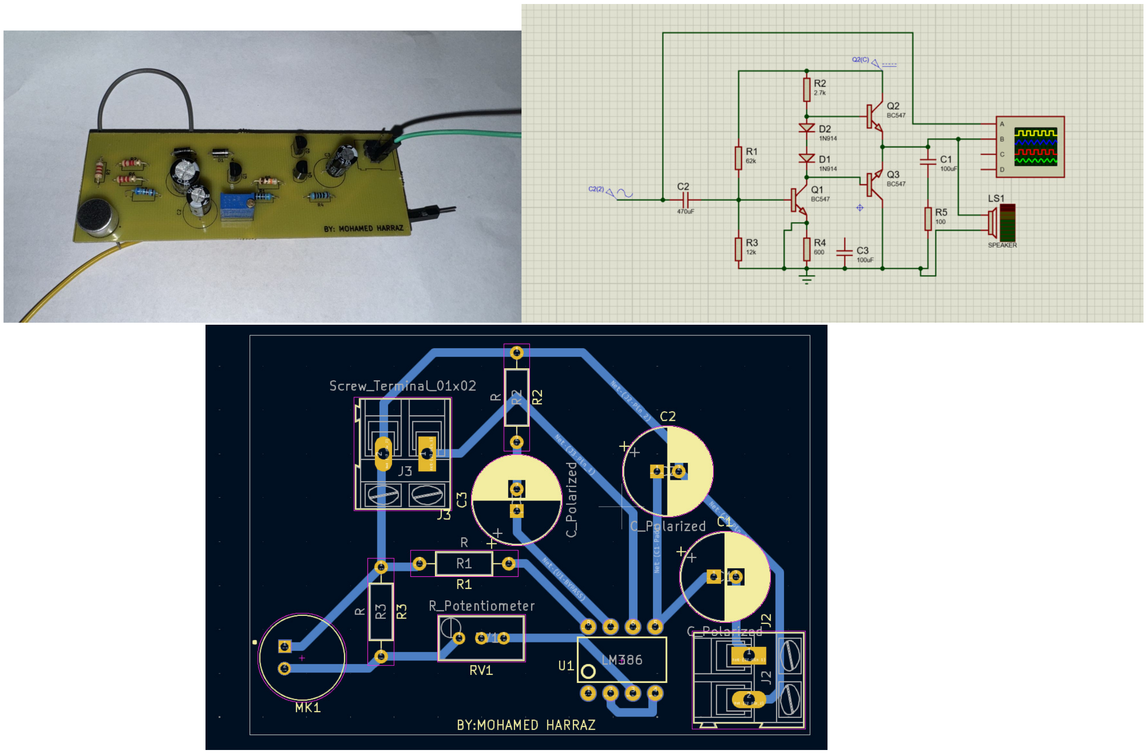

Figure 5: *PCP Design with layout and Schematic Diagram of the Audio Amplifier Circuit*

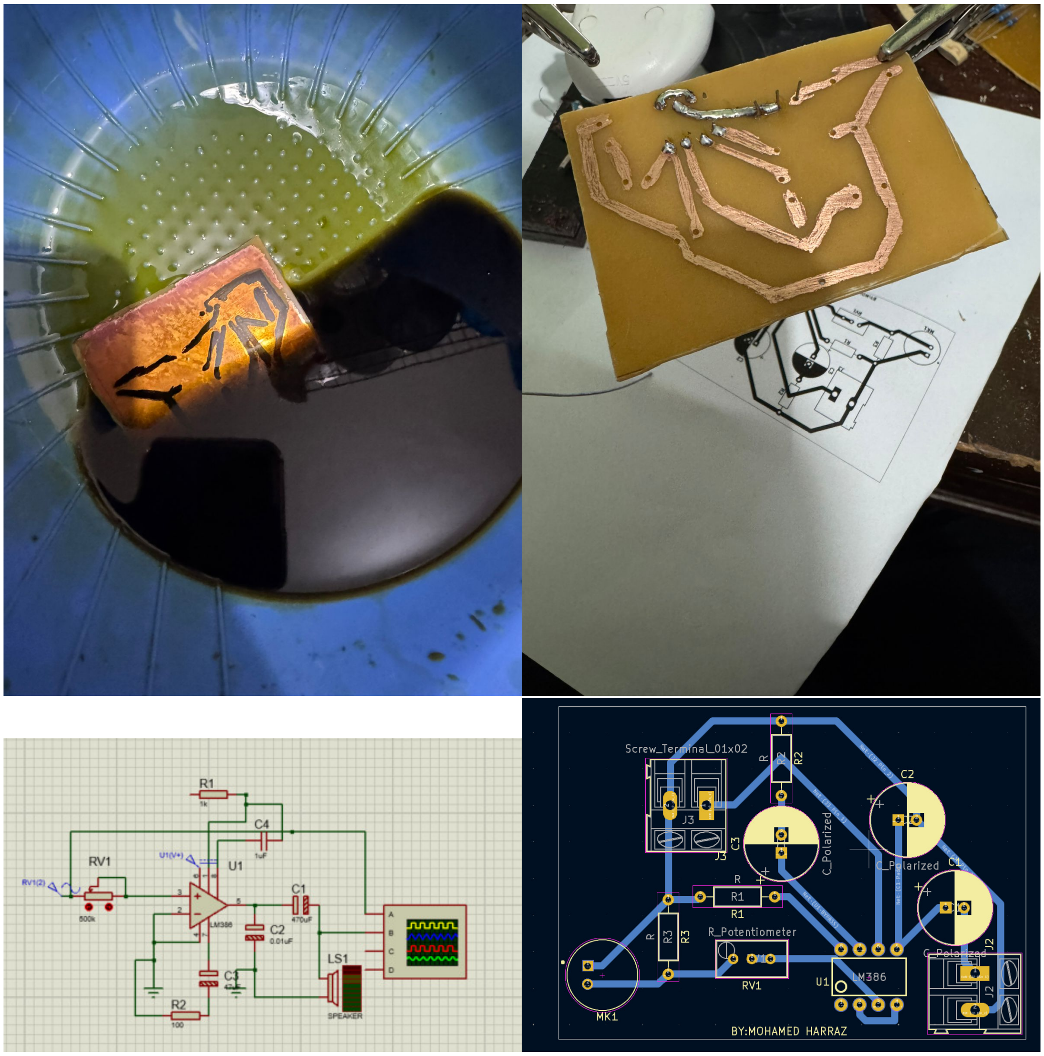

Figure 6: *A different design for the Amplifier*

The resulting PCB is cleaned and tested for continuity to ensure it meets the design specifications.

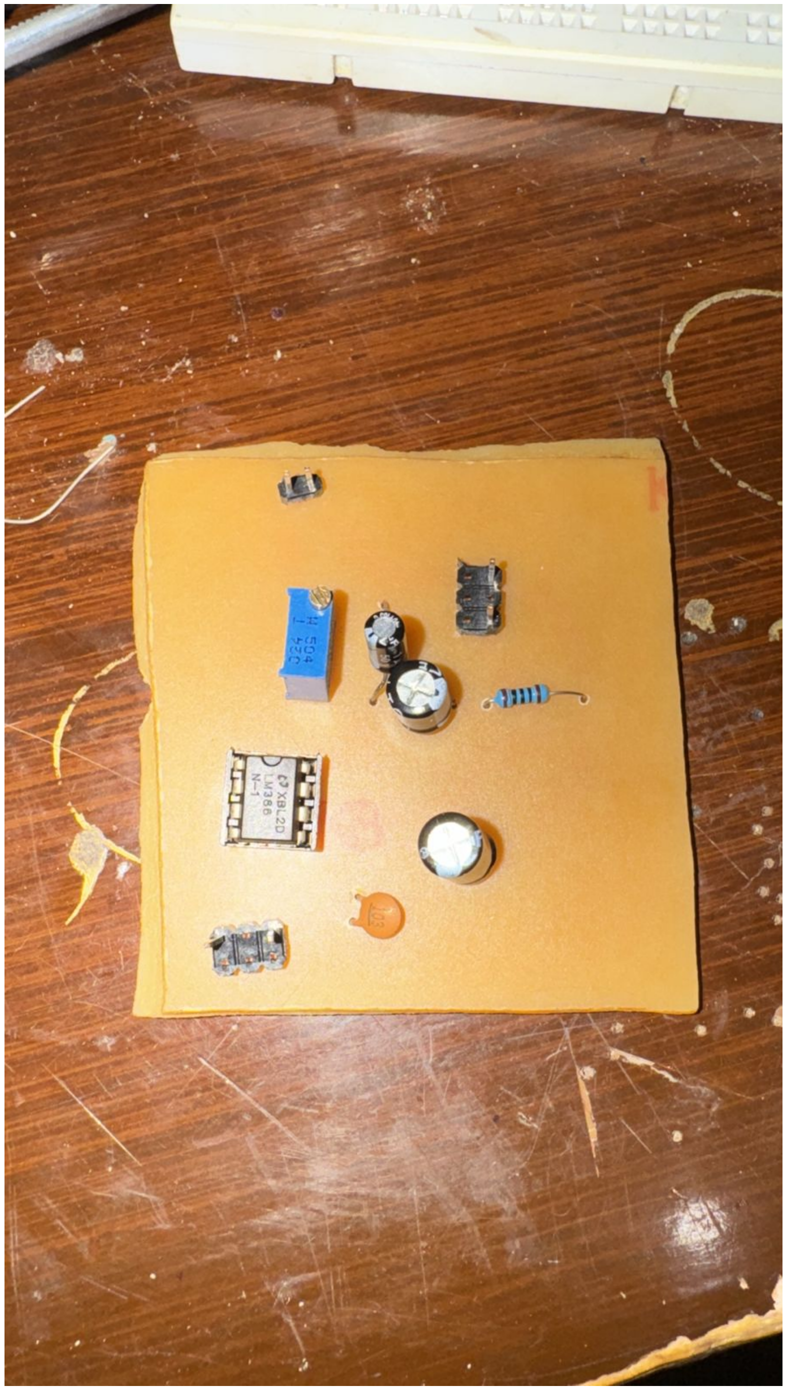

Figure 7: Circuit With Component

4 Results

The results obtained from the PCB-based audio amplifier project were analyzed in terms of performance metrics such as gain, signal quality, and circuit stability. .

4.1 1. Voltage Gain (A_v)

The desired voltage gain was set at $A_v = 4.5$, and the measured values are as follows:

- **Theoretical Gain:** Based on the hand analysis, the calculated gain is:
$$A_v = \frac{R_C}{R_E} \approx 4.5$$
- **Simulated Gain:** Simulations using LTspice yielded a voltage gain of $A_v = 4.48$, closely matching the theoretical value.
- **Measured Gain:** During practical testing, the measured gain was $A_v = 4.42$. The slight deviation is attributed to real-world component tolerances and PCB layout parasitics.

4.2 2. Signal Quality

The quality of the amplified signal was evaluated:

- **Distortion:** The amplified signal showed minimal distortion at the specified input voltage range.
- **Frequency Response:** The amplifier operated effectively within the audio frequency range (20 Hz to 20 kHz), with no significant attenuation.

4.3 3. PCB Performance

The PCB design was evaluated for its performance:

- **Compactness:** The final PCB layout was compact and efficiently organized.

- **Stability:** The circuit showed stable operation with no oscillations or noise issues.
- **Thermal Performance:** The components remained within safe temperature ranges during prolonged operation.

4.4 4. Comparison of Results

The table below summarizes the theoretical, input(Vltage), and measured results for first and Second Circuit: For First one:

Parameter	**Theoretical**	**Input**	**Measured**
Voltage Gain (A_v)	4.5		4.43
Output Voltage (V_o)	3.479 V	100mV	4.17 V

Table 1: Comparison of Theoretical, input, and Measured Results

For Second Circuit:

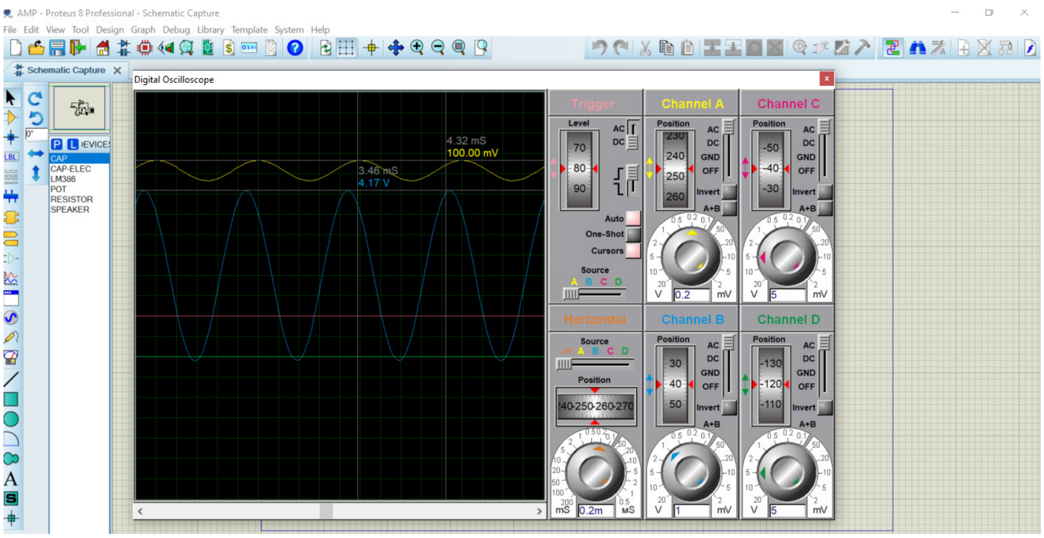

Figure 8: Results

5 Conclusion

We Conclude that our design for Audio amplifer has been succeeded with considering the value of Av close to 4.5 and Output Voltage close to 3.479 .Also,PCP design was effective to measure the the simulated values in real life.