Indian Institute of Technology Hyderabad

Course: Electronic Devices & Circuits Lab

Course Code : EE2301

Lab Assignment 6

Microphone to Speaker Circuit

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1 Introduction

This lab experiment is based on amplification of weak sound signals from a microphone to drive a speaker. A Microphone-to-Speaker circuit has many applications like sound recording, public address systems etc. The circuit is broadly divided into two parts: one part takes the audio input from the microphone and uses a transistor to amplify the signal. The second part takes the amplified signal and further amplifies it using an operational amplifier to play it loudly on a speaker. The two parts are put together to demonstrate amplification of audio signals in real time.

2 Aim of the Experiment

To construct a circuit that takes audio input from a microphone, amplifies it and plays the output on a speaker in real time.

3 Experimental Setup and Working Principle

Components Used:

For Microphone Circuit

1. BC547 Transistor ($\times 1$)
2. Electret Microphone ($\times 1$)
3. 220 $k\Omega$ Resistor ($\times 1$)
4. 10 $k\Omega$ Resistors ($\times 2$)
5. 10 μF Capacitors ($\times 2$)
6. 220 μF Capacitor ($\times 1$)

For Amplifier Circuit

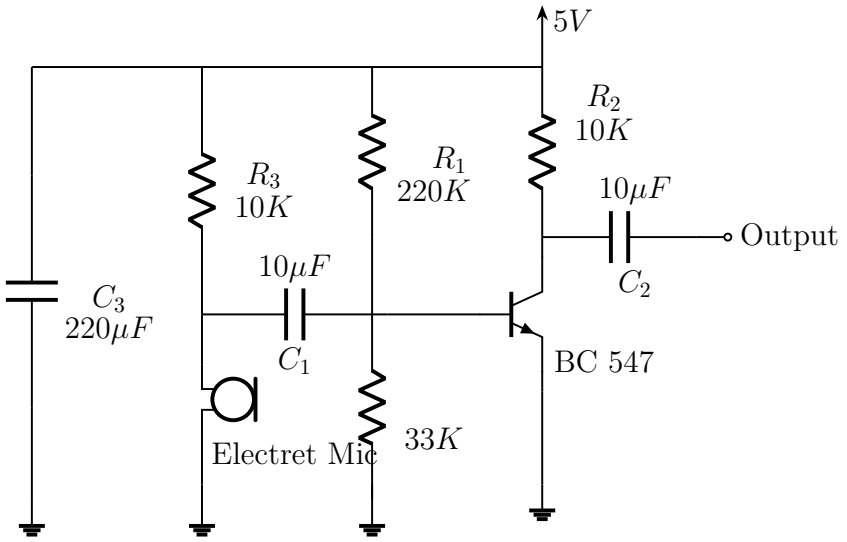
1. LM386 Operational Amplifier ($\times 1$)
2. $1k\Omega$ Potentiometer ($\times 1$)
3. 10 μF Capacitors ($\times 3$)
4. 220 μF Capacitor ($\times 1$)
5. 100 μF Capacitor ($\times 1$)
6. 4.7 nF Capacitor ($\times 1$)

7. 10 Ω Resistor (×1)
8. 0.5W Speaker (×1)

The circuit consists of 2 parts: The Microphone preamplifier circuit that takes audio input through the microphone and an audio amplification circuit that plays the amplified audio through the speaker.

3.1 Microphone Pre-Amplifier Circuit

The following is the circuit used:



The components used in the circuit and their functions are explained below:

1. Electret Microphone (M_1)

   The microphone used is an electret microphone. An electret is a dielectric material that contains a dipole. This is used in the microphone to provide a charge Q across the diaphragm of the microphone. Therefore, the diaphragm works as a capacitor. When sound is played into the microphone, the diaphragm vibrates changing its capacitance since the geometrical properties are momentarily changed. The charge is still same so the change in voltage is given by:

   $$V = \frac{Q}{\Delta C}$$

   Therefore, the audio signal is converted into an electrical signal that can now be amplified.

2. R_3 $10k\Omega$ Resistor

   The electret microphone contains an internal Field-Effect Transistor that requires a power source to operate. This power is provided to the microphone through the $10k\Omega$ resistor to limit excess current.

3. C_1 $10\mu F$ Capacitor

   This is a coupling capacitor that blocks out any DC current flowing. This is required to prevent the speaker from getting damaged.

4. BC547 NPN Transistor

   This is the main amplification component of the circuit. The NPN Transistor is connected in Common Emitter Configuration: the emitter is grounded, the input signal is being provided between base and emitter and output is being taken between collector and emitter.

   Resistors R_1 and R_2 are used to provide a bias to the signal to ensure the transistor works in its active region. This is because the input voltage can be both negative and positive, but the transistor will not be able to amplify negative signals without a bias as they are out of its active region.

   The base-emitter junction is forward biased. This causes the electrons in emitter (n-type) to flow into the base (p-type), therefore emitter current (I_E) flows out of the emitter. The collector-emitter junction is reverse biased so electrons flow out of collector. Current (I_C) flows into the collector. This means if there is base current I_B flowing into the base, the current equation is given by:

   $$I_E = I_B + I_C$$

   In the active region, the collector-emitter voltage does not affect the collector current. Instead, changes in I_B cause significant changes in I_C, given by the relation:

   $$\beta = \frac{I_C}{I_B}$$

   where β is the DC Current Gain of BC547 Transistor, which has a minimum value of 110, as per the datasheet. This means there is a minimum 110 times amplification of the input current, and therefore the input voltage.

5. C_2 $10\mu F$ Capacitor

   This is another coupling capacitor used to block out DC components before the output signal. The DC component occurs due to the biasing of the transistor

and is not a part of the audio signal. This is required as DC components can damage the speaker.

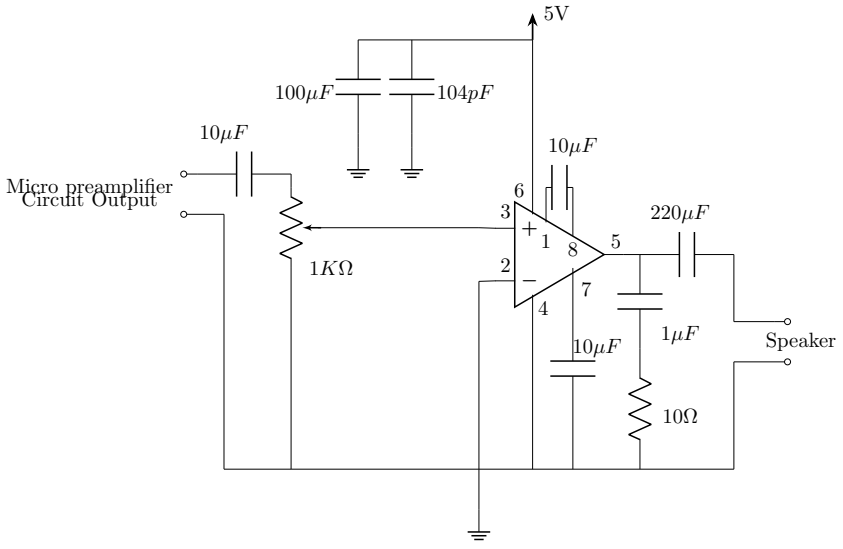
6. C_3 $220\mu F$ Capacitor

   This is a decoupling/bypass capacitor. Its function is to filter out any noise or fluctuations in the $+V_{cc}$ supply rail and to keep the supply voltage smooth. The capacitor gets charged upto the supply voltage when the circuit is turned on and maintains the voltage when there are small fluctuations in the supply. If there are any AC components in the signal, it essentially provides a short circuit to the ground so such signals are filtered out. This filtering ensures there is no unwanted noise introduced in the system from the power source.

This explains the functioning of the microphone pre-amplifier circuit. The output signal is now the input of the second part of the circuit: the audio amplifier.

3.2 Audio Amplifier Circuit

The following is the circuit used:



The components used in the circuit and their functions are explained below:

1. Input $10\mu F$ Capacitor

   There is a $10\mu F$ coupling capacitor applied right after the input to block out any DC components in the input signal as these can damage the speaker.

2. $1k\Omega$ Potentiometer

The filtered signal from the above capacitor is passed through a potentiometer, that acts as a voltage divider. It allows a fraction of the input voltage to pass through, essentially acting as a volume-controlling knob.

3. LM386 Operational Amplifier

   This is the active element of the circuit which performs amplification of the signal. The LM386 is a low-voltage amplifier with gain adjustable between 20 and 200. It has 8 pins whose functions and use in our circuit are given below:

   - Pins 1, 8 (Gain Control Pins) - These pins are used to adjust gain of the amplifier. The default gain is 20, but we can increase it by adding an appropriate RC circuit across these pins. In our circuit, we have left it at gain 200.
   - Pins 2, 3 (Input Pins) - The input signal to the op-amp is given through these pins. Pin 2 is the negative pin (inverting input), connected to ground and pin 3 (non inverting input) is connected to the output of the potentiometer.
   - Pins 4, 6 (Power Supply Pins) - Pin 4 is the negative power supply, connected to ground and Pin 6 is the positive power supply, connected to the positive rail (4 - 12V is suitable).
   - Pin 7 (Bypass Terminal) - This terminal is connected with a $10\mu F$ capacitor to the ground to act as a bypass capacitor (filters out any AC components to avoid unwanted noise).
   - Pin 5 (Output Pin) - This pin is the output pin of the op-amp. The amplified input signal with suitable gain is at this pin. A $1\mu F$ capacitor and 10Ω resistor is connected across this output to filter out high-frequency noise, acting as a low-pass filter with cutoff:

     $$f = \frac{1}{2\pi RC} = 15.91\text{kHz}$$

     This is close to the upper limit of our hearing range so is most likely noise and does not affect the audio. These high-frequency components could be introduced due to the amplifier, or power supply rail (despite the bypass capacitors, to be on the safe side), or from external RF interference.

     There is another $220\mu F$ capacitor connected just before the speaker to filter out any unwanted DC components introduced as noise during the amplification process as they could damage the speaker. this filtered output is played as sound through the speaker.

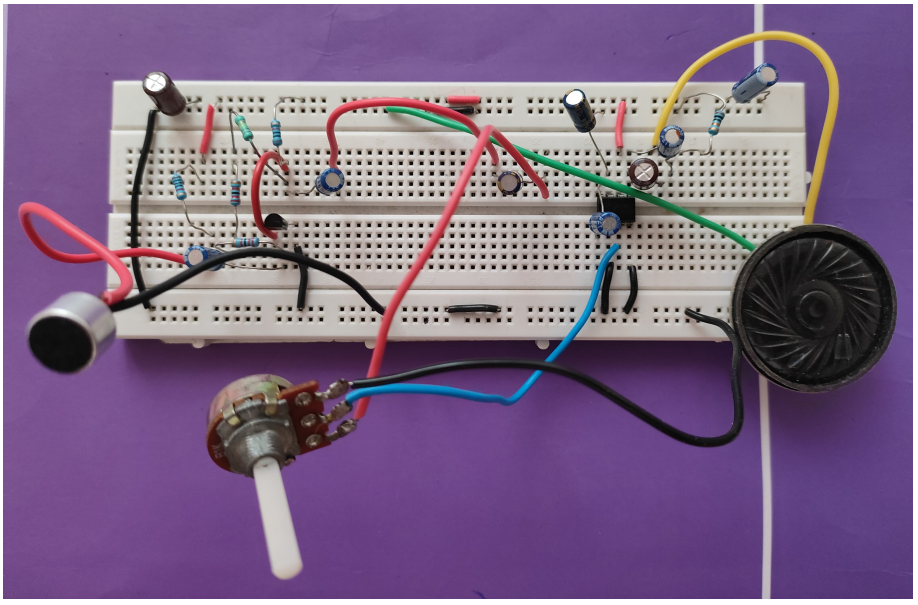
4. Decoupling and Bypass Capacitors

   Two capacitors $100\mu F$ and $104pF$ are connected between the positive voltage supply rail and ground. the $100\mu F$ capacitor acts as a decoupling capacitor, i.e. it charges up to the supply voltage and compensates for any sudden changes in the supply current. This ensures that the supply voltage is held smooth.

   The $104pF$ capacitor is used for bypass, i.e., if there is any noise in the power supply, this capacitor acts as a short circuit for them to the ground. This prevents ripples in the supply current.

This explains the functioning of the audio amplifier circuit.

A picture of the circuit is attached below. The microphone circuit is on the left side and the audio amplifier circuit on the right side.



4 Observations

Various type of audio inputs were given to the microphone. We experimented with some values of RC filters at the output to filter the sound and found the best fit to be $R = 10\Omega, C = 1\mu F$. The microphone was found to be sensitive to sounds up to 1m away, but for clear output, the audio source had to be close (within few centimeters) of the microphone.

To test, we spoke into the microphone and played music into it. The output was audible with significant gain from the speaker.

Microphone Pre-amplifier Circuit

- The electret microphone successfully captured audio signals and converted sound waves into electrical signals.
- The transistor amplification stage in the microphone circuit provided a voltage gain, making the low-level microphone signals suitable for further processing by the audio amplifier.

Audio Amplifier Circuit

- The LM386 audio amplifier amplified the input signal from the microphone circuit, driving the speaker with sufficient power to produce clear and audible sound.
- The output volume varied with the input amplitude, demonstrating the gain performance of the amplifier circuit. The input amplitude to the audio amplifier circuit was adjusted using the potentiometer.
- The RC circuit across the speaker eliminated high-frequency noise, leading to a clean output.
- The sound output from the speaker was clear with low distortion and low high-frequency noise.

5 Conclusion

The experiment successfully demonstrated the amplification of signals from a microphone and played it on a speaker in real time. The amplification was done in two stages, one using BJT and another using op-amp to drive the speaker. The decoupling/bypass capacitors prevented noise from entering the system and RC filters removed any noise introduced otherwise. The coupling capacitors helped to prevent damage of the speaker by attenuating DC signals. The circuit was observed to perform well for many audio inputs and can be used in basic audio applications.