Common-Collector and Common-Emitter as Microphone Amplifiers

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***Abstract*— This paper investigates the operation and performance of microphone amplification using common-collector (CC) and common-emitter (CE) amplifiers. The experiment involves DC biasing the microphone, followed by AC coupling with a capacitor and resistor. Then a CC and CE amplifier are experimented with for voltage amplification. The paper explores the effectiveness of these configurations in enhancing the microphone's output signal. The analysis of the experimental data reveals the microphone's sensitivity and its ability to capture audio signal frequencies accurately. Oscilloscope measurements and digital multimeter readings are used to capture and analyze the circuit behavior. The experiment concludes with a summary of the findings, demonstrating the successful application of CC and CE amplifiers in microphone signal amplification. The practical implications of these results are discussed, demonstrating the usefulness of such a circuit as well as its performance.**

Keywords—BJT, Common-Collector, Common-Emitter, DC biasing, AC coupling, analog electret microphone, NPN

I. Introduction

A. Background Information & Applications of Bibolar Junction Transistor Amplifiers

The amplification of audio signals is a fundamental aspect of various electronic and communication systems. Electret microphones are commonly used in many applications because of their size, cheapness, and ability to convert sound waves into electrical signals with high sensitivity. These microphones, however, generate low-level signals that require amplification to be effectively utilized in downstream processing stages as seen in the EE-315 final project. Amplifiers, specifically common-collector (CC) and common-emitter (CE) configurations, are critical to enhance these signals while maintaining their integrity and quality.

The common-collector amplifier is known for its high input impedance and low output impedance, making it a buffer stage that prevents loading effects on the part of the circuit before [1]. This configuration is needed where signal stability and preservation of the original waveform is critical. The common-emitter amplifier provides significant voltage gain, making it useful for applications requiring substantial amplification of smaller signals. This configuration is widely used in audio amplification, radio frequency (RF) circuits, and other areas where signal strength needs to be increased for further processing. The procedures, measurements, and theory used in this lab experiment are directly applicable to the design and optimization of various audio equipment, such as headphones, smartphones, and music recording equipment. By understanding and implementing effective CE and CC circuits, we gain another tool in our toolkit for solving problems in circuit design.

II. Microphone Assembly & Testing

A. DC Biasing of Analog Microphone

The DC biasing of an analog electret microphone involved connecting the microphone (CMA-4544PF-W) in a circuit with a bias resistor of 10kΩ (nominally 9.8kΩ) and applying a supply voltage of 9V, as shown in Fig. 1. The voltage measured across bias resistor was 2.27V, indicating that the microphone drew a current of about 227 microamps. To verify the functionality of the microphone, an audio signal was generated using an app and played through earbuds placed close to the microphone. The output signal of the microphone was observed on an oscilloscope, showing a frequency close to the generated signal (~4100kHz), see Fig. 2. Additionally, a metronome was played, and another oscilloscope capture was taken seen in Fig. 3 to analyze the microphone's response to different. This setup confirmed that the microphone could effectively capture and output the audio signals as expected.

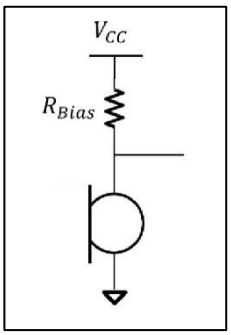

Fig. 1. DC Biasing Microphone [2]

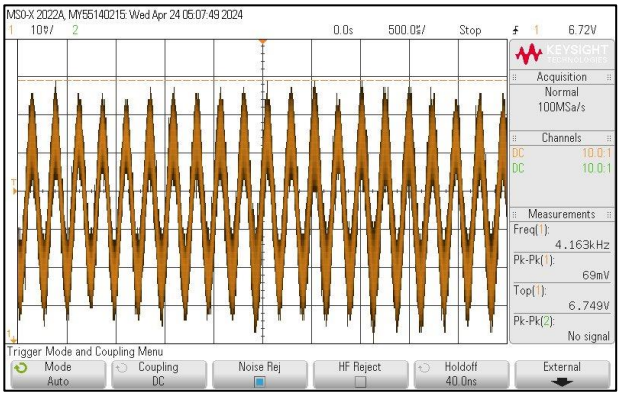

Fig. 2. Scope Capture of Output of Microphone (4.15kHz Sine Wave)

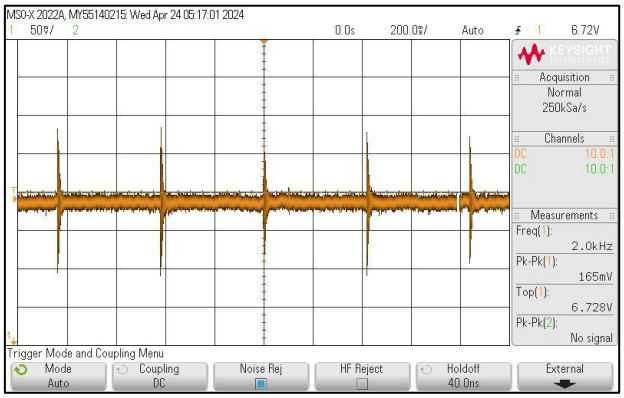

Fig. 3. Scope Capture of Microphone with Metronome (143.1 BPM)

B. *AC Coupling*

The circuit was further modified by adding another 10kΩ resistor (nominally 9.83kΩ) and a 100nF capacitor (nominally 100.9nF) to enhance its performance. This adjustment aimed to improve the signal stability and filtering capability of the setup. The output of the microphone was probed along with the voltage across the 10kΩ load resistor to evaluate the circuit's response. This AC coupled circuit was tested by playing an audio output of 4.15kHz and a metronome at 180BPM shown in Fig. 5 and Fig. 6. While monitoring the microphone's output, the load resistor was temporarily disconnected, which resulted in only a momentary change in the waveforms, demonstrating the circuit's stability under different load conditions. This behavior suggests that the circuit design effectively maintains signal integrity, even when the load is altered, thereby confirming its robustness in practical applications.

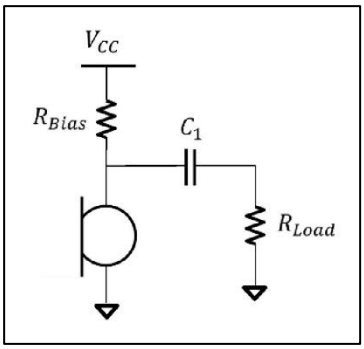

Fig. 4. AC Coupling of Microphone [2]

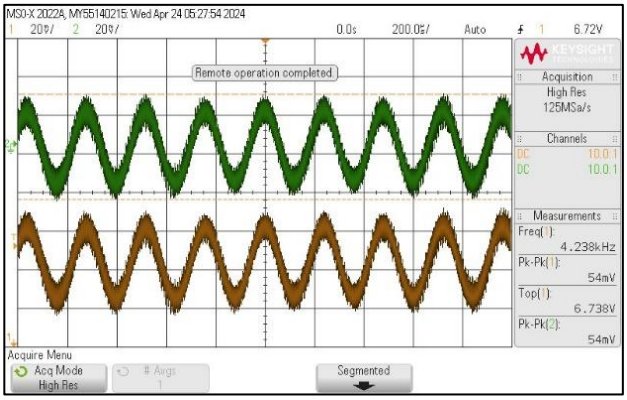

Fig. 5. Scope Capture of 4.15kHz signal (Microphone Output (Yellow) and Rload (Green))

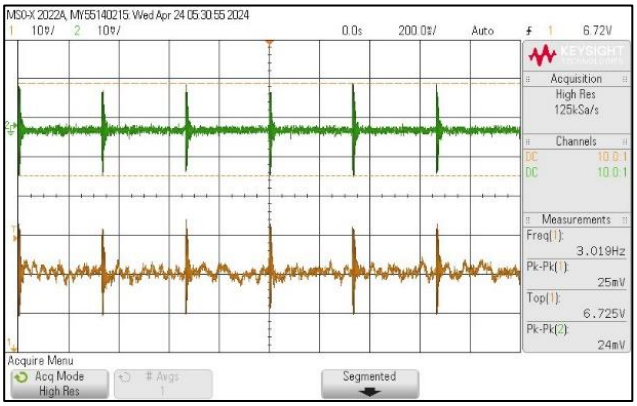

Fig. 6. Scope Capture of 180BPM Metronome

III. Bipolar Junction Transistor Amplification

A. *Addition of Common-Collector Amplifier*

In this part of the lab, a NPN BJT (2N3904) was added to the circuit as well as a 10kΩ (nominally 9.83kΩ) emitter resistor. The circuit was set up according to the instructions and assembly steps detailed in the lab instructions document as shown in Fig. 7 [2].

The emitter voltage was measured to be 6.08 V and the base voltage was measured to be 6.70 V. These measurements are consistent with the expected voltage drop across the bias resistor. According to the pre-lab calculations, the voltage across was anticipated to be approximately 6.7 V, which aligns well with the observed value (9V - (227µA * 10kΩ) = ~6.7 V). The base and emitter terminals were probed, and the load was detached while playing an audio signal. The oscilloscope captures shown in Fig. 8 demonstrate that the frequencies with the BJT in the circuit closely matched the actual frequencies from the app, indicating effective amplification and minimal distortion.

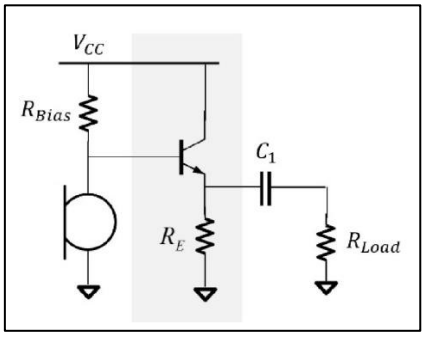

Fig. 7. Schematic of Common-Collector Amplifier [2]

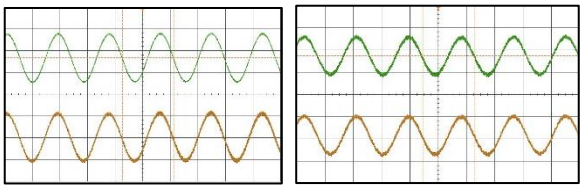

Fig. 8. Scope Capture of Base (Yellow) and Emitter (Green) with and without load resistor

B. *Addition of Common-Emitter Amplifier*

To configure a common emitter amplifier, resistors with the following values were integrated into the circuit as shown in Fig. 9: RB1 = (100k || 100k) ≈ 47kΩ (Nominal: 98.6k || 98.5k), RB2 = 200kΩ (Nominal: 200.0k), and RE = 3.3k (Nominal: 3.32kΩ). Additionally, the previous emitter resistor (RE) was reused for the collector resistor, and capacitors C1 = 100nF (Nominal: 94.7nF) and CE = 10µF (Nominal: 6.89µF) were added. Despite the variations in the capacitor values, CE remained above the minimum requirement of 1µF, ensuring correct functionality and performance.

The measured collector, base, and emitter potentials were 5.83 V, 1.67 V, and 1.046 V, respectively. These values were consistent with the pre-lab calculations, confirming the correct biasing of the CE amplifier. For testing, two different frequencies and two metronome BPMs were applied to the microphone input, and the voltage across the load resistor was measured, as seen in the scope captures in Fig. 10. The calculated gains [3] for each configuration are presented in Fig. 11. These results demonstrate the effectiveness of both the common-collector and common-emitter amplifiers in enhancing the signal strength from the microphone, validating the theoretical predictions and practical implementations outlined in the pre-lab preparations.

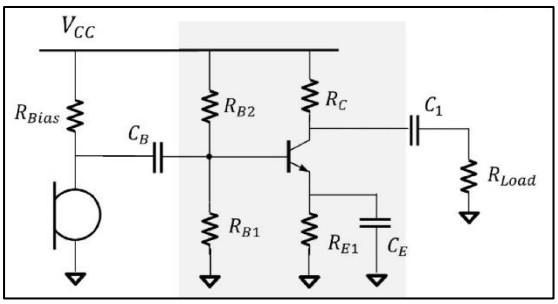

Fig. 9. Schematic of Common-Emitter Amplifier [2]

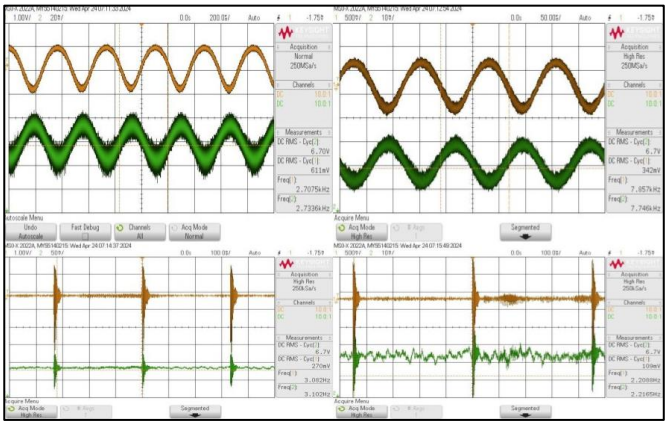

Fig. 10. Scope Captures of 2.7kHz and 8kHz sine waves, and 180BPM and 134BPM metronome

Frequency / BPM	Gain (V/V)
2.7 kHz	10.97
7.85 kHz	24.81
Metronome (180 BPM)	19.59
Metronome (134 BPM)	61.47

Fig. 11. Table of calculated Gain (V/V) for each corresponding measurement

IV. Conclusion

This lab focused on using common-collector (CC) and common-emitter (CE) amplifiers to amplify microphone signals. The procedures involved DC biasing an electret microphone, then AC coupling with a capacitor and resistor to stabilize the signal. The experimental data showed that both amplifier configurations effectively enhanced the microphone's output signal, confirming theoretical predictions. Oscilloscope measurements and digital multimeter readings validated the accurate capture of audio signal frequencies, highlighting the microphone's sensitivity and reliability. This lab demonstrates the successful application of CC and CE amplifiers in improving microphone performance, making them suitable for various audio equipment applications. We encountered challenges such as incorrect component values, which were resolved through verification and accurate measurement techniques. The insights from this paper underscore the critical role of amplifiers in audio signal processing and their potential for optimizing audio equipment performance.

References

[1] Common Collector Amplifier Circuit and Its Applications, https://www.elprocus.com/common-collector-amplifier-circuit-working/.

[2] Vladimir Prodanov, “WEEK #4: Common-Collector and Common-Emitter as Microphone Amplifiers,” unpublished.

[3] Vladimir Prodanov, Cal Poly EE-315 lectures, unpublished.