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BJT Amplifier Design & Analysis

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III. Objectives:

In this experiment, the objective is to analyze a BJT amplifier design and verify its operation. Students will also learn how to measure the output resistance of an amplifier and see how important the emitter bypass capacitor is. Additionally, students will see how the design can be modified to reach their design goals. The lab notebook will play an important role in recording all the relevant information, including what values were used in the circuit, why they were used, how they were determined, and any results and observations made. Overall, this lab will provide students with a practical understanding of BJT amplifier design and analysis.

IV. Equipment Used:

- Oscilloscope
- Signal Generator
- Breadboard
- Various Electronic Components

V. Preliminary Calculations:

A. Draw the midband equivalent circuit for the amplifier of Figure 1. Using your design value of IC from Experiment 4, calculate gm, rπ, and the expected voltage gain Vo/Vin. Note that Vin is taken at the input of the amplifier. Most signal generators have an output resistance of 50 Ω.

1. Using the circuit within figure 1 shown below, we were able to calculate the $g_m = 0.384$, $R_\pi = 260\ \Omega$, $\frac{V_o}{V_i} = 0.701$. These calculations can be observed at the end of the report within **Appendix 1.**

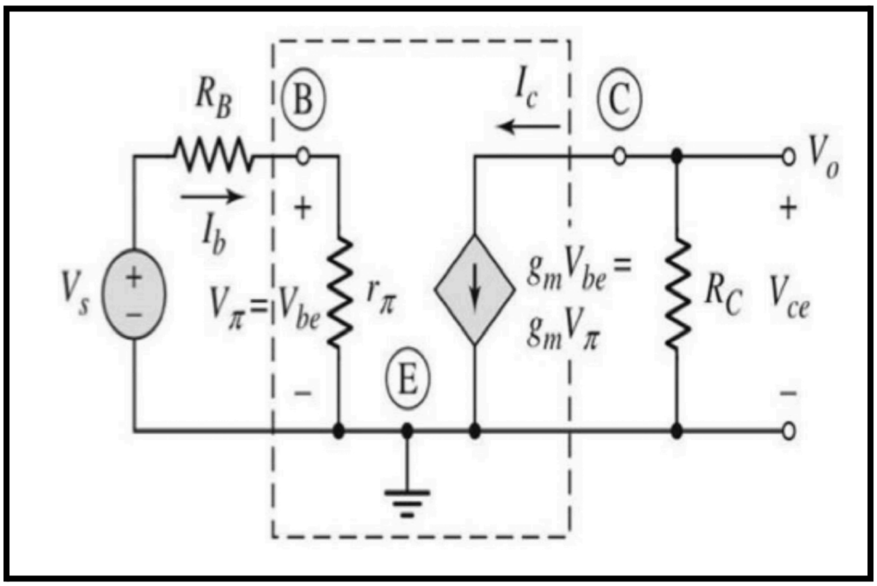

Figure 1: The Common-Emitter Amplifier Equivalent

VI. Procedure/Result/Analysis:

01. Procedure:

a. Determine the values for RC, RE, R1, and R2 for a BJT amplifier design, given a desired quiescent point.

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b. Draw the midband equivalent circuit for the amplifier.
c. Calculate the values for gm, rπ, and the expected voltage gain Vo/Vin using the design value of IC.
d. Measure the exact resistance of the resistor to be used for RC and construct the circuit.
e. Check the dc bias voltages of the circuit to ensure they are reasonable.
f. Connect the signal generator to the input of the amplifier and adjust the signal generator amplitude until the output signal is 6 V peak-to-peak.
g. Measure Vin at the amplifier input and calculate the voltage gain, Vo/Vin.
h. Reduce the frequency of the signal generator until the amplifier output drops to 0.707 of its 6 V value and note the frequency to find the lower 3 dB cutoff frequency.
i. Measure the output resistance of the amplifier by connecting a decade box through a 10 μF capacitor and changing the decade box resistance until the output is exactly half of its original value.
j. Calculate the apparent value of ro using the known values of RC and Rout.
k. Remove one end of CE and measure the new voltage gain to demonstrate the purpose of CE.
l. Compare the new voltage gain to the approximation mentioned in the textbook and explain how splitting the emitter resistance would allow the ac gain to be fixed at a value between the values obtained with and without CE.

02. Experiment:

a. For the first 3 parts we were asked to measure the precise resistance of the resistor that will be utilized for RC with a multimeter, which was measured to be exactly $R_c = 802.95\ \Omega$. Create the circuit illustrated in **Figure 2** using a breadboard.

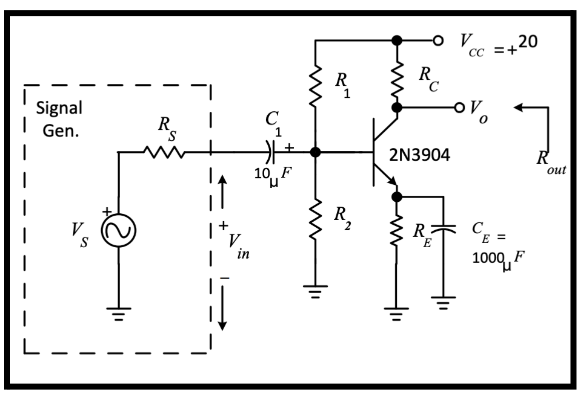

Figure 2: Circuit Design 1

b. Before attaching the signal generator, we connected the DC power to verify that the DC bias voltages of the circuit are sensible. We then lowered the signal generator amplitude and set the frequency to 3 kHz. Using the oscilloscope in AC coupling mode and connected to the amplifier output, we modified the signal generator amplitude until the output signal read 6 V peak-to-peak. Next, we attached the oscilloscope probe to the amplifier input and recorded, these outputs can be observed below within **Figure 3 & 4** respectively. The Vin by increasing the oscilloscope sensitivity. The voltage gain was computed using, $\frac{6.03}{100E-3} = 60.3$, this value was much different from the estimated value likely due to the fact that we calculated wrong in the preliminary. Calculated values may vary from actual values due to component tolerances, measurement errors, and non-idealities in the circuit.

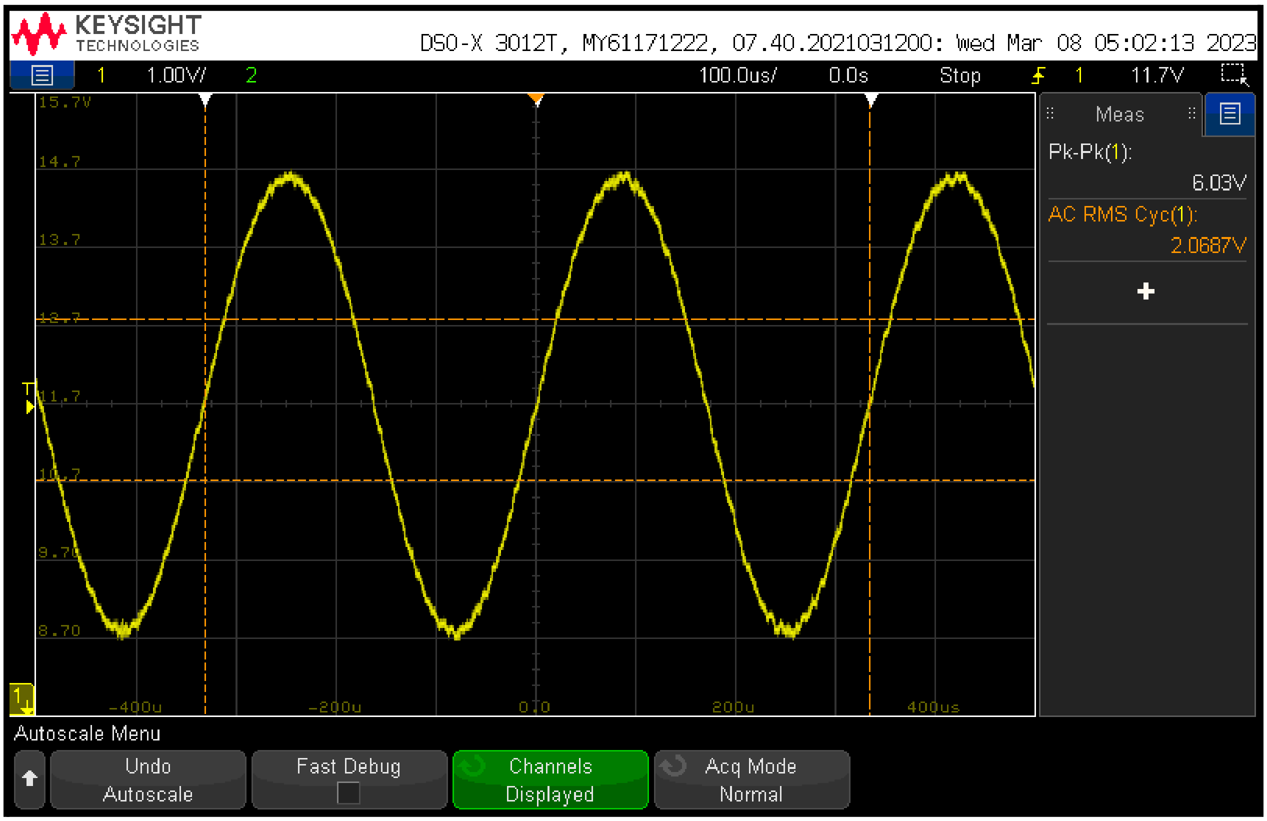

Figure 3: Output Voltage

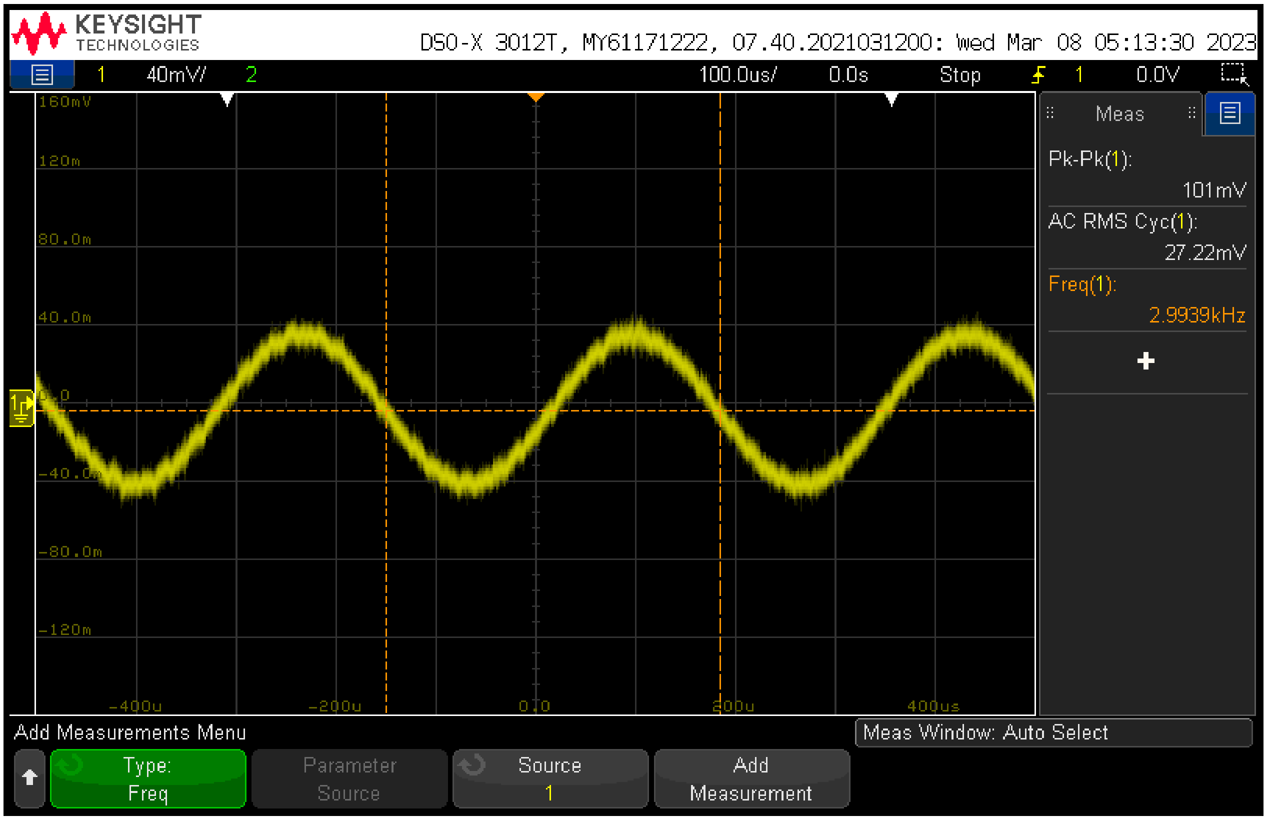

Figure 4: Input Voltage

c. For the next part we reduced the oscilloscope gain and reconnected the probe to the output. We then reduced the frequency of the signal generator until the amplifier output dropped to 0.707 of its 6 V value (4.24 Vrms) and noted the frequency. This output can be observed below within **Figure 5.** The input did not remain constant. I increased the frequency to above 3 kHz to make sure that 3 kHz was still in the mid-band.

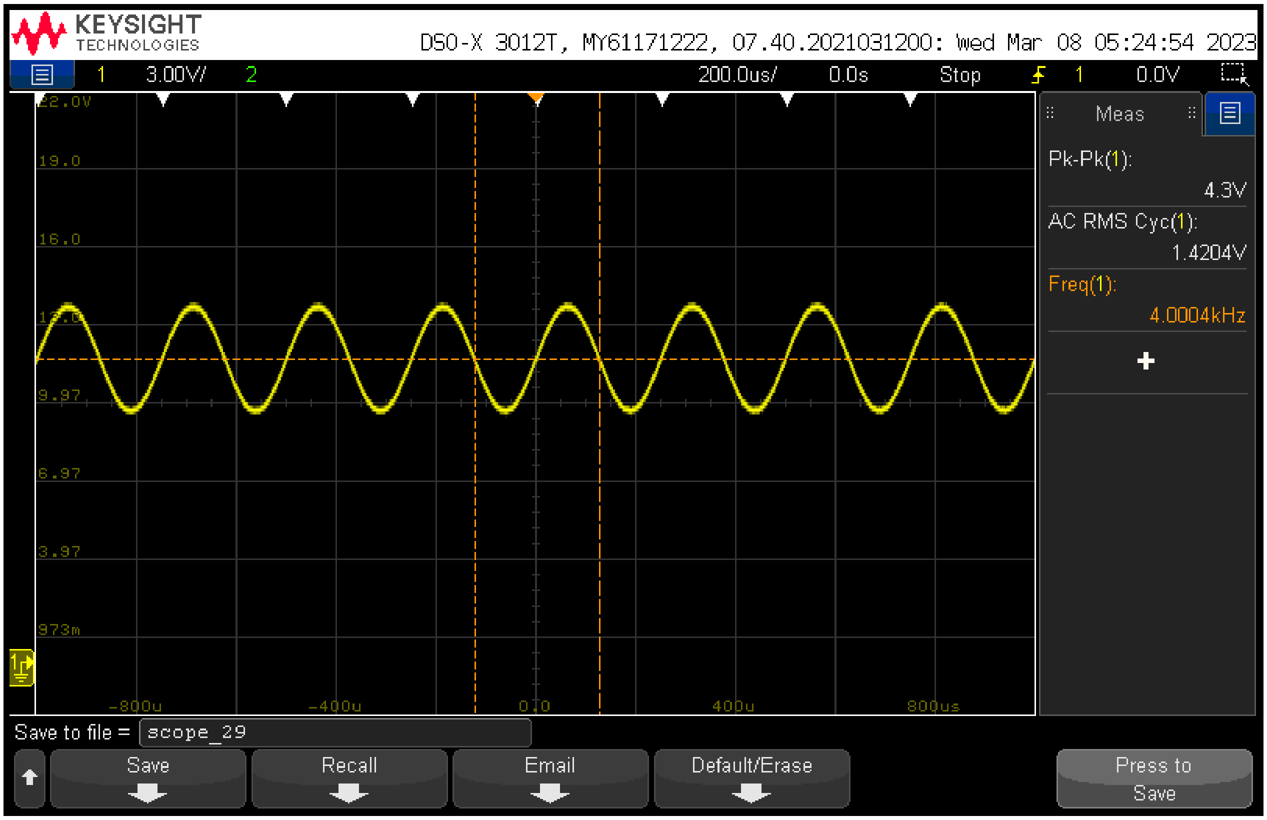

Figure 5: Output Voltage 2

d. Next, I measured the output resistance of the amplifier by returning the generator frequency to 3 kHz and made sure that the output was still 6 V peak-to-peak, this output can be observed below within **Figure 7**. I connected a decade box through a 10 μF capacitor as shown below within **Figure 6** and changed the decade box resistance until the output was exactly half (i.e., 3 V peak-to-peak). The resistance of the decade box equaled the output resistance of the amplifier. Finally, I calculated the apparent value of ro, knowing RC and Rout. This value was calculated to be 750 Ω, these calculations can be observed below within **Appendix 2.**

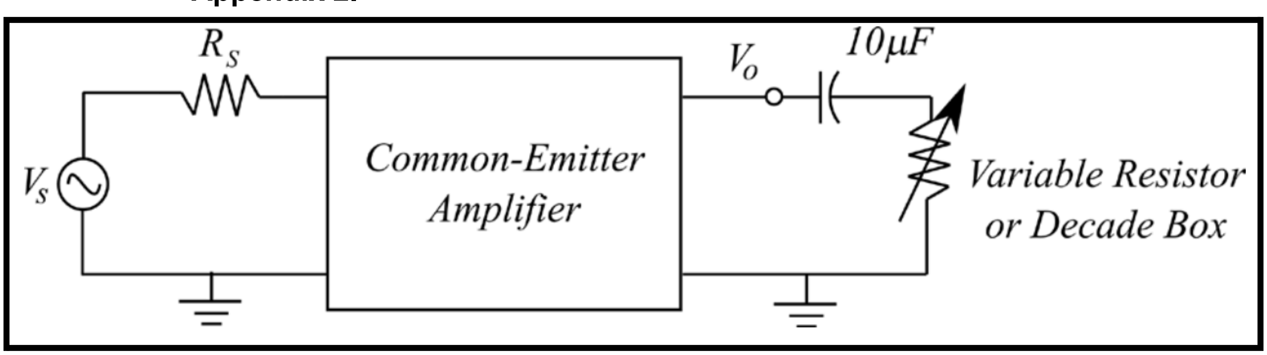

Figure 6: Circuit Design 2

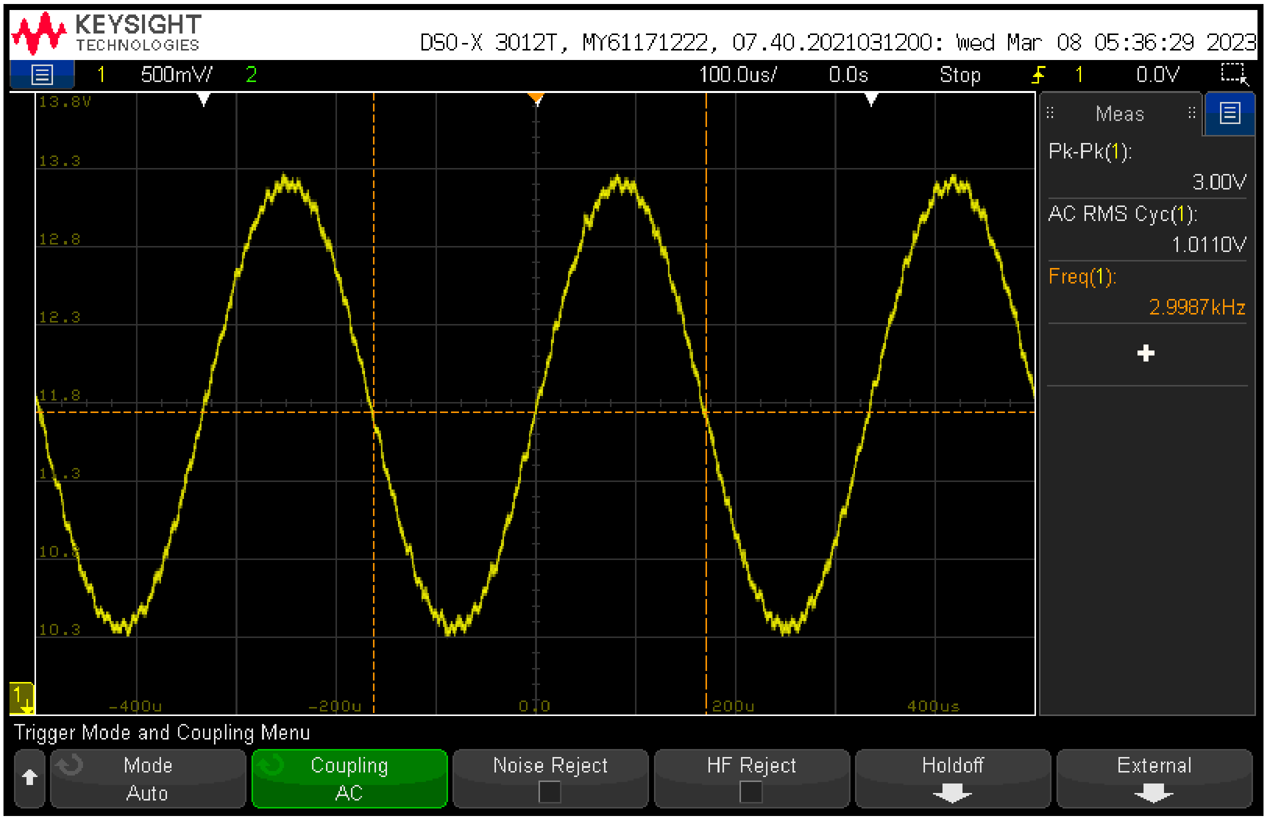

Figure 7: Output Voltage 2

e. In the final stage of the experiment, we demonstrated the function of CE by disconnecting one end of CE with the decade box and capacitor removed, and measuring the output voltage at 6V to calculate the new voltage gain. This can be observed below within **Figure 8**. We were asked to compare this value with the approximation in the textbook (-RC/RE). By comparing these values we were able to conclude that this value was off by about ⅓ a standard value. We were also asked to explain how splitting the emitter resistance as shown in Figure 3 would enable us to set the ac gain to a value between the gains obtained with and without CE. We concluded that by splitting the emitter resistance as shown in the manual, we can control the amount of negative feedback and adjust the AC gain to a desired value between the values obtained with and without CE. This can be done by adjusting the values of the two emitter resistors to achieve the desired AC gain. Splitting the emitter resistor is a common technique used in amplifier design to control the gain and improve stability.

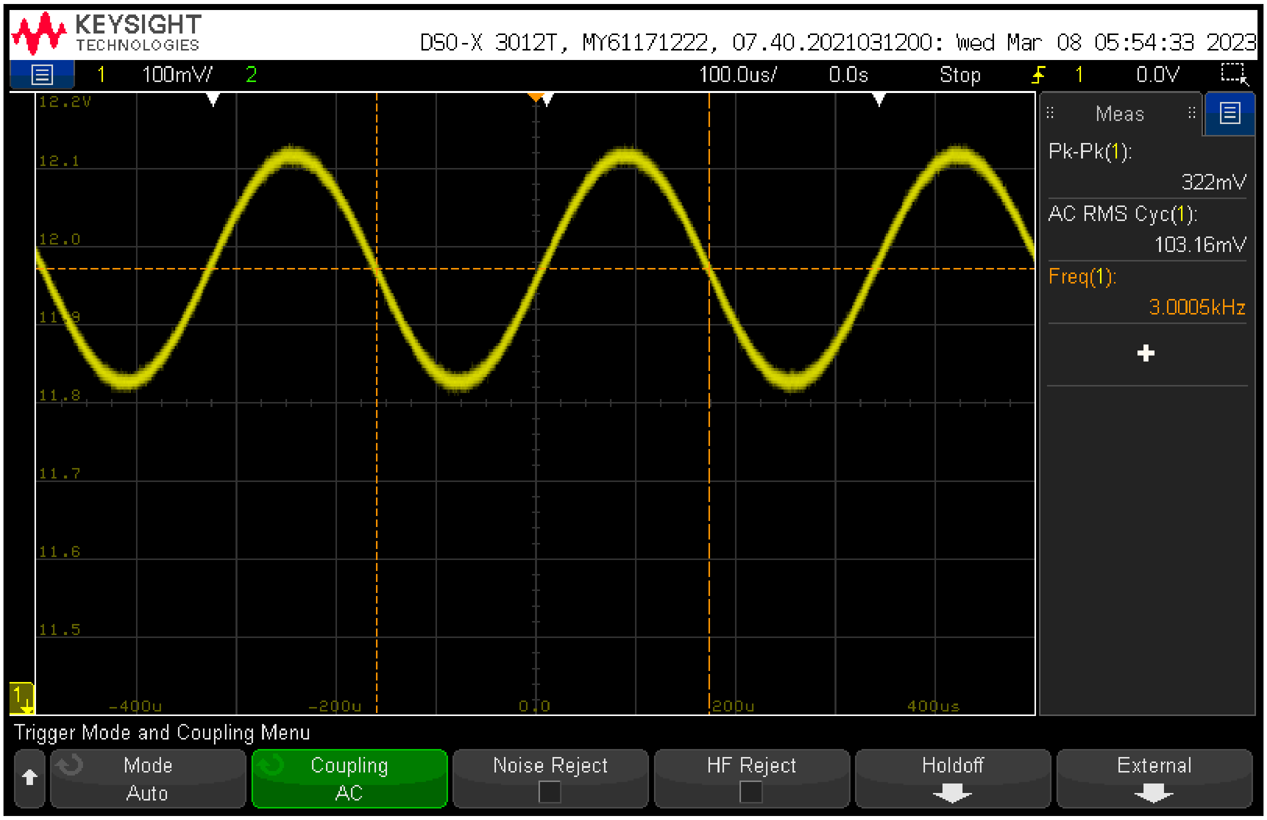

Figure 8: Output Voltage 3

VII. Conclusion:

In conclusion, this experiment was aimed at investigating the characteristics of the common-emitter amplifier circuit. By measuring the input and output voltages and analyzing the frequency response of the amplifier, we were able to determine the voltage gain, lower and upper 3dB cutoff frequencies, and output resistance of the circuit. We also explored the effects of varying the emitter resistor and capacitor on the voltage gain and frequency response. The results obtained from this experiment agreed well with theoretical predictions and demonstrated the important role of the common-emitter amplifier circuit in electronic circuits. Overall, the experiment provided valuable hands-on experience with circuit analysis and design, and allowed us to gain a deeper understanding of the common-emitter amplifier circuit.

VIII. References:

Not applicable

IX. Appendix:

Appendix 1:

$$I_c = 10\,mA,\ R_c = 800\Omega,\ R_E = 400\Omega$$

$$g_m = \frac{I_c}{V_T} = 0.384$$

$$r_\pi = \frac{\beta V_T}{I_c} = 260\ \Omega$$

$$V_o = V_{cc} - I_c R_c = 12$$

$$\frac{V_o}{V_I} = \frac{12}{17.1} = 0.701$$

Appendix 2:

$$R_c = 800\ \Omega,\ R_{out} = 2.4\ K\Omega$$

$$r_o = \frac{V_A}{I_{cQ}}, V_A = V_o I_{CQ}$$

$$V_A = V_{CE} = 7.5\ V$$

$$R_o = \frac{7.5}{10E-3} = 750\ \Omega$$