UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 7 – BJT AMPLIFIER CONFIGURATIONS AND INPUT/OUTPUT IMPEDANCE

OBJECTIVES

The purpose of this experiment are to familiarize the student with

- the response of the three Bipolar Junction Transistor (BJT) amplifier configurations.
- the measurement of the input and output impedances of a Bipolar Junction Transistor single-stage amplifier.

INTRODUCTION

BJT Amplifier Configurations

There are three basic BJT amplifier configurations that are generally identified as: common-emitter, common-base, and common-collector (sometimes called the emitter-follower). Each of these configurations exhibit certain characteristics that make them more desirable in certain circuit applications than the others. A qualitative comparison of these three configurations is shown below in Table 7-1.

Table 7-1. Qualitative BJT Amplifier Comparison

	Common-emitter	common-base	common-collector
Input Impedance	Medium	Low	High
Output Impedance	Medium	High	Low
Current Gain	High(β)	Low(α)	High
Voltage Gain	High	High	Low
Power Gain	High	Medium	Low

Generally, the common-emitter and common-collector have a lower frequency bandwidth than the common-base. This can be attributed to such effects caused by the intrinsic device capacitances and how the transistor is configured in relation to these capacitances. A common cause of the loss of bandwidth is the Miller effect, which is covered in most analog electronics textbooks.

BJT Amplifier Input/Output Impedance

While the input impedance of an amplifier is in general a complex quantity, in the midband range it is predominantly resistive. Input impedance is defined as the ratio of imput voltage to input current. It is calculated from the AC equivalent circuit as the equivalent resistance looking into the input with all current cources replaced by an open and all voltage sources replaced by a short. The significance of input impedance is that it provides a measure of the loading effect of the amplifier. A low input impedance translates to a poor low-frequency response and a large input power requirement. For example, Op-Amps have a very large input impedance, and therefore, a good low- frequency response and a low input power requirement.

Likewise, output impedance is in general a complex quantity, but is predominantly resistive in the midband range. To calculate output impedance one must remove the load resistor and determine the impedance looking back into the AC equivalent amplifier circuit. Again it is necessary to replace all current sources with an open and all voltage sources with a short. The significance of output impedance is that it provides a measure of the driving power of an apmlifier. The ideal output impedance is zero; an amplifier with a low ouotput impedance can provide a larger output current without a significant reduction in the output voltage.

In the laboratory, impedances at a point of interest are usually found by either setting up a test voltage source and finding the resulting current or by setting up a test current source and finding the resulting voltage. In this laboratory experiment the first of these methods will be used. At the frequencies of interest the capacitors in the circuit of Figure 7-1 will have an insignificant impedance and are therfore considered to be an AC short. The DC supply can also be considered as an AC short to ground. The above approach is applicaple for either input or output impedance measurements. When measuring the ouput impedance it is important to remember that the input source of the original amplifier circuit must be replaced by an AC short. The detailed technique for finding the input and output impedances can be found in any analog electronics textbook.

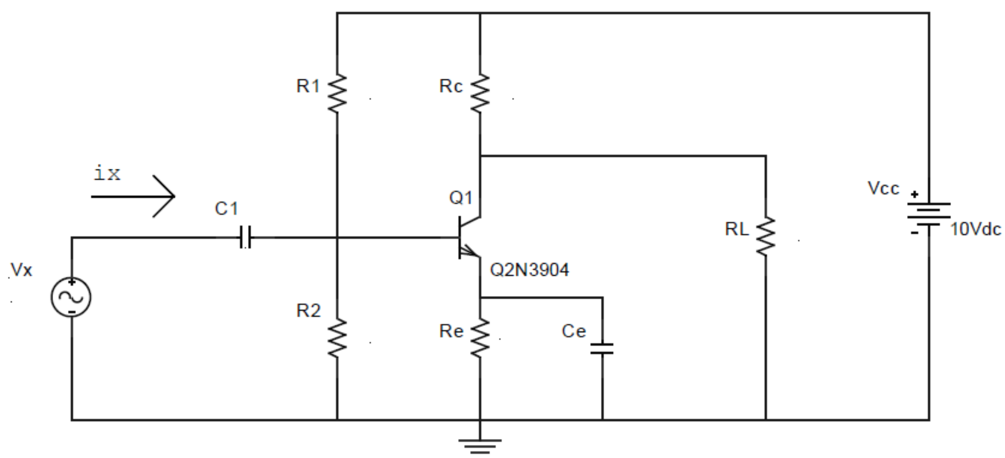

Figure 7-1 Inserting Test Voltage to Find Input Impedance

The determination of input impedance in the laboratory can be achieved by applying an AC source to the input via a known sourcing resistance. Figure 7-2 shows the required measurement setup. C_i is included only as a coupling capacitor and has essentially zero impedance at the measurement frequency. Voltages V_x and V_i are measured and used to calculate the input current I_i.R_i is simply the ratio of V_i to I_i.

For the determination of output impedance, the circuit of Figure 7-3 is utilized. Impedances of the coupling capacitors C_1 and C_2 are insignificant at the measurement frequency. By measuring voltages V_x and V_o the current through the 1kΩ resistor Io can be calculated. The output impedance is then the ratio of V_o to I_o.

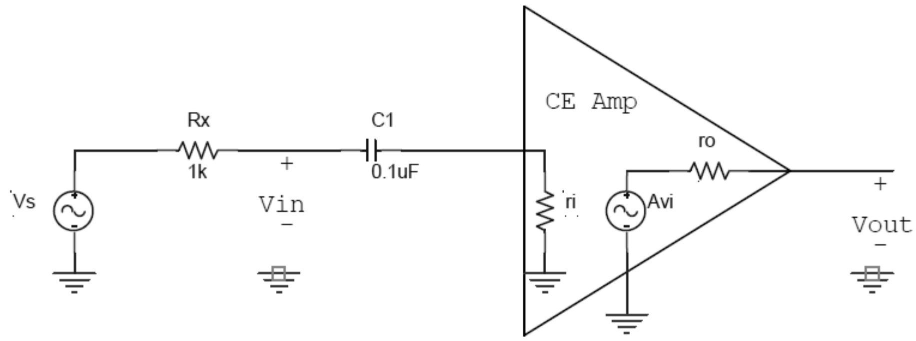

Figure 7-2 Input Impedance Measurement Setup

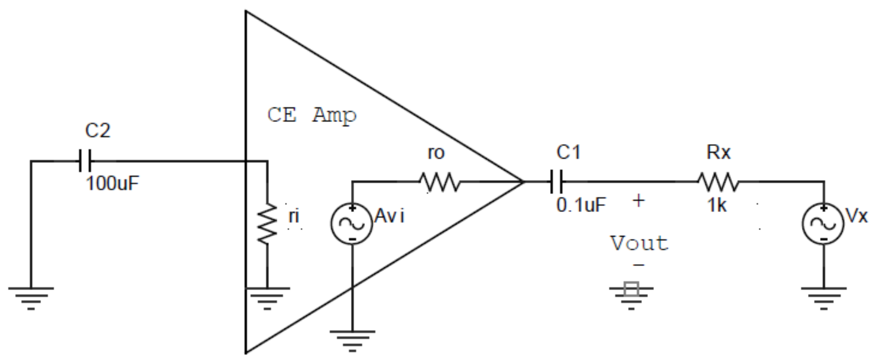

Figure 7-3 Output Impedance Measurement Setup

PRELAB

BJT Amplifier Configurations

1. Obtain the maximum manufacturer's specifications for the following parameters for the 2N3904 transistor.
   a. Collector-Base Voltage, VCBO:
   b. Collector-Emitter Voltage, VCEO:
   c. Emitter-Base Voltage, VEBO:
   d. Continuous Collector Current:
   e. Power Dissipation @ 25oC:
2. For the circuit of Figure 7-4, calculate values for R_1, R_2, and R_c to properly bias the BJT such that the quiescent emitter current is approximately 1.5 mA and the quiescent collector to emitter voltage is approximately 5V. Assume $\beta = 100$, $R_e = 1k\Omega$, $V_A = 100V$, $V_{BEon} = 0.7V$, and $V_t = 25mV$. (Hint: Use standard resistor values less than or equal to 100kΩ and as close as possible to the calculated values.)

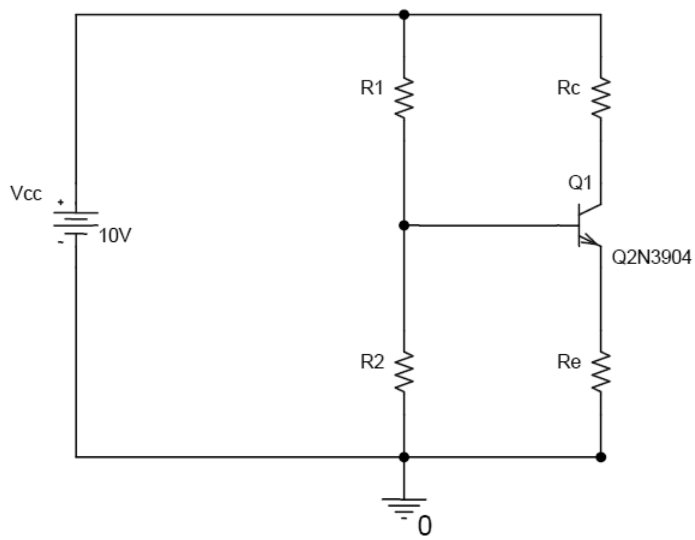

Figure 7-4 BJT Biasing Configuration

3. Hand calculate the mid-band voltage gain for each of the three configurations (Shown in Figures 7-5, 7-6, and 7-7) using the hybrid-π small signal model. Use 10K for the load resistor. (Hint: Assume that the capacitors are short circuits to AC voltages and open circuits to DC voltages.)

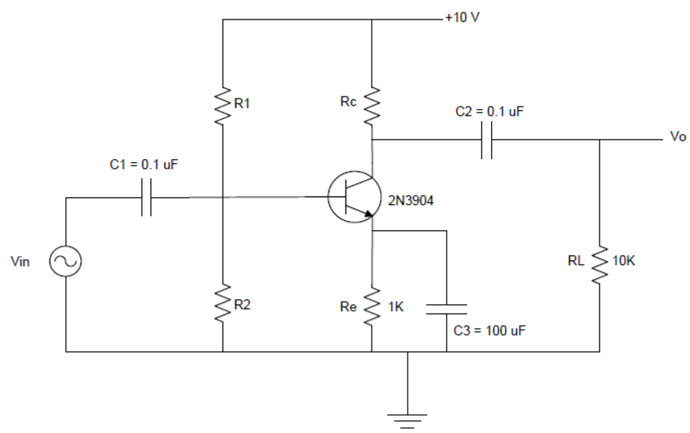

Figure 7-5 Common-Emitter Amplifier

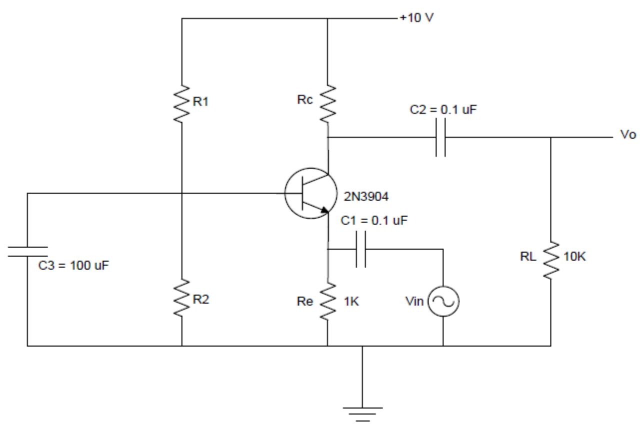

Figure 7-6 Common-Base Amplifier

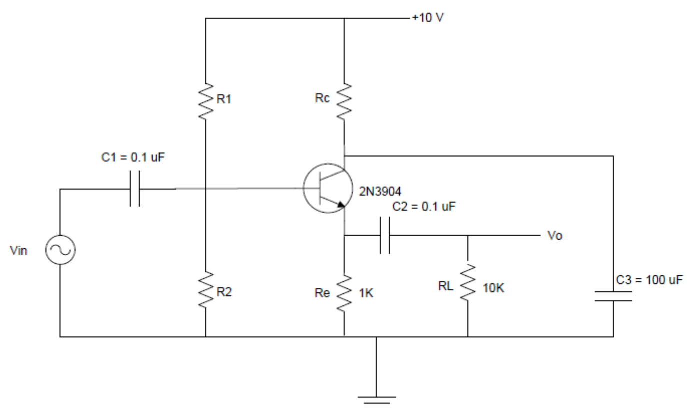

Figure 7-7 Common-Collector (Emitter-Follower) Amplifier

BJT Amplifier Input/Output Impedance

4. Given the circuit shown in Figure 7-8, find an appropriate value for the collector resistor R_C such that V_{CE} is approximately 5V. Assume that $\beta = 100$, $V_{BEon} = 0.7V$, $V_A = 100V$, and $V_t = 25mV$. The capacitors can be treated as an open circuit to DC. Why is this a good bias point?

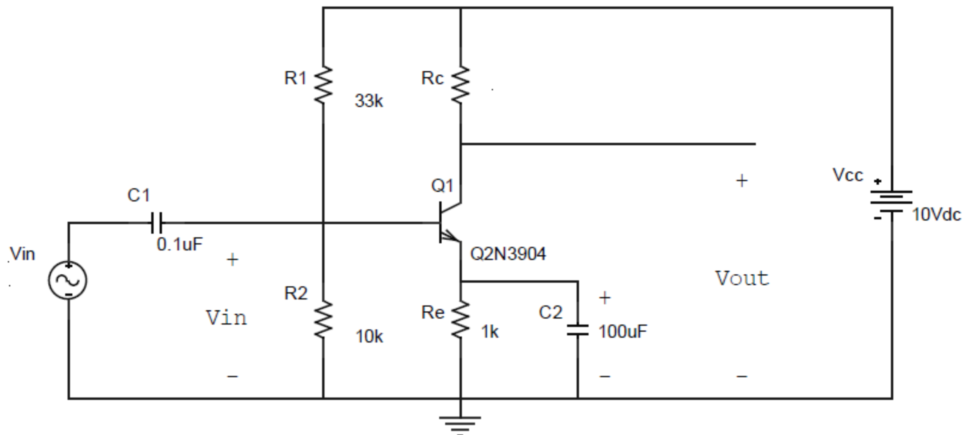

Figure 7-8 BJT Common-Emitter Amplifier

5. Calculate the values of the DC currents I_C, I_B, and I_E and DC voltages V_C, V_B, and V_E.
6. Using the hybrid-π small signal model and assuming all capacitors as short circuits to AC voltages, find the input and output impedances, r_i and r_o, respectively. Also, solve for the voltage gain $A_V = v_o/v_i$.

PROCEDURE

BJT Amplifier Configurations

1. Observe the circuit shown in Figure 7-5.
2. Before connecting the circuit, prepare the power supply for V_{CC} to ensure a DC voltage of +10V and adjust the function generator for V_{in} to an AC voltage of 30mV$_{p-p}$ or less. Use the resistors calculated in the Prelab. It may be necessary to use a voltage divider to achieve the proper input voltage from the signal generator.
3. Using a dual-trace oscilloscope, adjust and record the magnitude of the signal source V_{in} so that the output signal V_{out} is just beginning to distort at a frequency of 5kHz. Record the phase relationship between the input signal V_{in} and the ouput signal V_{out}.
4. Now vary the function generator until you find the upper and lower –3dB frequencies.
5. Turn off the power supply and function generator. Reconfigure the circuit to that shown in Figure 7-6.
6. Keep the same resistor values and perform the same procedure (steps2 to 4).
7. Turn off the power supply and function generator. Reconfigure the circuit to that shown in Figure 7-7.
8. Keep the same resistor values and perform the same procedure (steps2 to 4).

BJT Amplifier Input/Output Impedance

9. Before connecting the circuit in Figure 7-8, make sure to adjust the power supply V_{CC} to +10V and adjust the function generator for V_S to a signal level of approximately 50mV$_{p-p}$ and a frequency of 1kHz.
10. Connect up the circuit as shown in Figure 7-8 using the resistor value for R_C calculated in the Prelab. Measure and record the DC bias voltages V_C, V_B, and V_E.
11. Measure and record the output voltage on the oscilloscope. Calculate the voltage gain A_V. Make sure there is no distortion in the output waveform, if any adjust the input to remove the distortion and make note of the change. Vary the input frequency and measure the output voltage in order to obtain the necessary data to create a frequency response plot for the voltage gain A_V.
12. Measure the input impedance r_i. To do this, use the setup shown in the circuit diagram in Figure 7-2. Use the input signal from the function generator (100mVp-p @ 4kHz).
13. Measure the value of v_{in}. Set up an equation relating v_x and v_{in}. Use that equation to solve for the value of the AC input impedance z_i.
14. Vary the frequency of the function generator in order to obtain the necessary data to plot a frequency response curve for the input impedance z_i. Take data points at multiples of 1, 2, and 5 (i.e. 1 2 5 10 20 50…etc.) in order to obtain adequate data for a log plot.
15. Measure the output impedance r_o. To do this, use the setup shown in the circuit diagram in Figure 7-3. Use the same input signal from the function generator (100mVp-p @ 4kHz).
16. Measure the value of v_{out}. Set up an equation relating v_{out} and v_x. Use that equation to solve for the value of the AC output impedance z_o.
17. Vary the frequency in order to obtain the necessary data to plot a frequency response curve for the output impedance z_o. Take data points at multiples of 1, 2, and 5 (i.e. 1 2 5 10 20 50…etc.) in order to obtain adequate data for a log plot.

DATA/OBSERVATIONS

INSTRUCTOR'S INITIALS: | | DATE: | |

POSTLAB

Post-Lab questions must be answered in each experiment's laboratory report.

BJT Amplifier Configurations

1. Plot voltage gain vs. frequency for the three amplifier configurations using Excel or similar spreadsheet software and the data obtained in the experiment. Plot all three curves on the same graph for comparison.
2. Indicate the differences in frequency response between the three amplifiers, i.e. location of the lower and upper –3dB frequencies, bandwidth, and voltage gain magnitude and phase.
3. For each of the three configurations perform an AC sweep (of appropriate range) using PSpice or Multisim. Compare these results with those obtained in the experiment.

BJT Amplifier Input/Output Impedance

4. Using the measured bias voltages, V_C, V_B, and V_E, calculate the bias currents I_C, I_B, and I_E. Compare these with the calculated bias currents found in the Prelab, are they in agreement?
5. Did the measured voltage gain A_V found in Step 11 (procedure) @ 1kHz agree with the calculated voltage gain found in the Prelab?
6. Did the measured input and output impedances r_i and r_o at 4kHz agree with the values calculated in the Prelab?
7. Taking the data obtained in Steps 11, 14, and 17, use Excel or a similar spreadsheet software and plot a frequency response curve for the voltage gain, input impedance, and output impedance.
8. Using PSpice or Multisim, perform an AC sweep for the voltage gain, input impedance, and output impedance of the common-emitter amplifier used in the lab. Compare the results obtained in the simulation with those that were plotted from the measured data, did the results agree?

Note: When plotting the frequency response curves make sure the x axis is log (i.e. 1 10 100 1000, etc.) in Excel and for PSpice or Multisim.