ECE 3274
Common-Collector (Emitter-Follower) Amplifier Project

1. Objective
This project will show the biasing, gain, frequency response, and impedance properties of a common collector amplifier.

2. Components

<table>
<thead>
<tr>
<th>Qty</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2N2222 BJT Transistor</td>
</tr>
</tbody>
</table>

3. Introduction
The common collector amplifier is one of the most useful small-signal amplifier configurations. The main characteristics of the common collector amplifier are high input impedance, low output impedance, less than unity voltage gain, and high current gain. This amplifier is most often used as a buffer or isolation amplifier to connect a high impedance source to a low impedance load without loss of signal. The load seen by the amplifier’s signal source is the input impedance of the amplifier. With a high input impedance, the CC amplifier loads the source very lightly. Therefore, the signal source is isolated or buffered from the rest of the circuit. The maximum current gain for the CC amplifier is Beta + 1. This high current gain allows the CC amplifier to increase the power of the signal. These power and current gains make the CC amplifier a practical choice as an output stage amplifier driving several devices.

The same biasing scheme and frequency response approximation technique as used for the common emitter amplifier can also be used for the common collector amplifier. The only change that needs to be made in biasing is that the voltage across the emitter resistor $R_e$ is usually larger for the common collector to allow a greater output voltage swing.

4. Requirements
Your amplifier design must meet the following requirements.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Gain</td>
<td>$</td>
</tr>
<tr>
<td>Low Frequency Cutoff</td>
<td>Between 100 Hz and 300 Hz</td>
</tr>
<tr>
<td>High Frequency Cutoff</td>
<td>Between 50 kHz and 150 kHz</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>Between 1kΩ to 4kΩ</td>
</tr>
<tr>
<td>Output Voltage Swing</td>
<td>2.0 $V_F$</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>180 Ω</td>
</tr>
<tr>
<td>Power Supply Voltage</td>
<td>10 V$_{dc}$</td>
</tr>
</tbody>
</table>

Table 1. Common-collector amplifier requirements.

5. Prelab Design Project
Find $r_o$, $\beta_{AC}$ and $\beta_{DC}$
Design a common-collector amplifier using the schematic shown in Figure 1 and meeting the requirements in table 1. You should refer to your class notes, textbook, instructor, and other reference material to help you design the circuit. Start with the DC design and then move onto the AC design. Find $r_o$, $\beta_{AC}$ and $\beta_{DC}$ from the CC transistor curves (higher current).

Units must be included as well (it is permissible use a table of final values for clarity if you would prefer, but again, all work must be shown clearly somewhere). Use the following fixed component values in your circuit:
5.1 DC Bias
Begin by designing the DC bias for the amplifier. Once you have designed the DC bias network, use the transistor characteristics for the 2N2222 transistor to determine the transistor parameters for where you are operating. Note that there is no single correct answer and that your design may differ significantly from your classmates. You should show all work and walk through all calculations. You must calculate and show all of the following values. Note the $r_o$, $\beta_{AC}$ and $\beta_{DC}$ are from the transistor curves at your Q-point. Choose a design value for $R_{in}$ and calculate the $R_{b1}$, and $R_{b2}$ based on that desired value. Do Not use $I_{rb1} = 3*I_{b}$, and $I_{rb2} = 2*I_{b}$ method.

<table>
<thead>
<tr>
<th>Component Values</th>
<th>Amplifier Parameters</th>
<th>Voltages and Currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{b1}$</td>
<td>Beta dc</td>
<td>$V_{ce}$</td>
</tr>
<tr>
<td>$R_{b2}$</td>
<td>Beta ac</td>
<td>$V_{be}$</td>
</tr>
<tr>
<td>$R_{e}$</td>
<td>$r_{in}$</td>
<td>$V_e$</td>
</tr>
<tr>
<td></td>
<td>$r_{o}$</td>
<td>$I_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_c$</td>
</tr>
</tbody>
</table>

Table 3. DC Bias and Amplifier Parameters
5.2 AC Design
Design the ac characteristics of the amplifier. You must calculate and show all of the following values. We will set the zeros for the low frequency break point at the same frequency.

\[ BW_{shrinkage} = \sqrt{2^{1/n} - 1} \]
Where \( n = 2 \) number of low frequency zeros at the same frequency.

\[ F_L = (F_{Cin} + F_{Cout}) / (BW_{shrinkage} \times n). \]
We need adjust the frequency because of bandwidth shrinkage.
Set \( F_{cin} = F_{cout} = F_L \times (BW_{shrinkage}) \)

\[ C_{in} = 1/(2\pi F_{cin} R_{ci}) \quad C_{out} = 1/(2\pi F_{cout} R_{cout}) \]

We will set the poles for the high frequency break point at the same frequency so we will use the band shrinkage factor.

\[ F_{chi} = F_{chi2} = F_{H'} = FH / \sqrt{2^{1/n} - 1} \]
Where \( n = 2 \) number of high frequency poles.

<table>
<thead>
<tr>
<th>Component Values</th>
<th>Amplifier Parameters</th>
<th>Voltages, Currents, and Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_{cin} )</td>
<td>Voltage Gain</td>
<td>( V_{in} )</td>
</tr>
<tr>
<td>( C_{cout} )</td>
<td>Current Gain</td>
<td>( V_{out} )</td>
</tr>
<tr>
<td>( C_{hi} )</td>
<td>Power Gain (in dB)</td>
<td>( i_{in} )</td>
</tr>
<tr>
<td>Not Used ( C_{hi2} )</td>
<td>Low Frequency Cutoff</td>
<td>( i_{Load} )</td>
</tr>
<tr>
<td></td>
<td>High Frequency Cutoff</td>
<td>( p_{in} )</td>
</tr>
<tr>
<td></td>
<td>Input Resistance</td>
<td>( p_{out} )</td>
</tr>
<tr>
<td></td>
<td>Output Resistance</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Small Signal (ac) Amplifier Parameters

5.3 Computer-aided Analysis (25 points)
Once you have completed your amplifier designs, use LTspice to analyze their performance.
Note: **Must include LTspice schematics.** Generate the following plots:

(a) A time-domain plot of the input and output, with the output voltage of \( 2.0V_p \) at 5 kHz. The output should not have any distortion or clipping. Calculate the midband gain and indicate it on the plot. Compare this to your calculated values.

(b) An FFT of your time-domain waveform. Circle and indicate the height of any strong harmonics, in dB relative to your fundamental frequency at 5 kHz.

(c) A frequency sweep of the amplifier from 10 Hz to 1 MHz. Indicate the high and low break frequencies on the plot (these should correspond to the half-power, or the point 3dB below the midband gain). Compare these to your calculated values.

5.4 Prelab Questions
(a) How can you achieve maximum power transfer from the signal source to the input of the amplifier? Is the load resistance a factor in the answer? Show your calculations.

(b) Compare the results of the current gain found in prelab with the maximum possible gain of \( Beta + 1 \). Comment on any differences. Under what conditions is the maximum possible?
6. **Lab Procedure**

6.1. **Construct** the CC amplifier shown in Figure 1. Remember that $R_{\text{gen}}$ is internal to the function generator and is not in your circuit. Check the power ($I_e^2R_e$) in the Re if it is greater than 250mW to use two emitter resistors to equal your design value (Re) either in series or parallel. Record the values of the bias network resistors and the capacitors you used in the circuit.

6.2. Measure the following values:

   (a) **Vdc** Q-point: $V_{cc}$, $V_{be}$, $V_e$, $I_b$, $I_e$, $I_c$, $V_b$, $V_e$, and $V_c$
   
   If your Q-point $V_b$, $V_c$, and $V_e$ are not as expected. Remove the BJT and measure Base, Collector and Emitter nodes. $V_b$ = expected voltage, $V_c$ = $V_{cc}$, and $V_e$ = 0.

   (b) AC gains: Voltage, current, and power.

   (c) Maximum undistorted peak-to-peak output voltage.

   (d) Input and output resistance at 5kHz.

   (e) Low and high cutoff frequencies (half power point).

Recall that input impedance is given by $R_{\text{in}} = \frac{V_{in}}{I_{in}}$, $\text{lin} = \frac{V_{Ri}}{R_i}$; output impedance is given by $R_{\text{out}} = (V_{oc} - V_{load})/I_{load}$, voltage gain is given by $A_v = \frac{V_{out}}{V_{in}}$, and current gain is given by $A_i = \frac{I_{load}}{I_{in}}$. Where $V_{load}$ and $I_{load}$ is the voltage across the load and the current thru the load.

Additionally, plot the following:

   (a) Input and output waveform at the maximum undistorted value.

   (b) Power Spectrum showing the fundamental and first few harmonics.

   (c) Frequency response from 10 Hz to 1 MHz (set the input voltage to a value that does not cause distortion across the entire passband of the amplifier).

6.3. Replace the load resistor, $R_L$, with a 47Ω and a 820Ω resistor, and measure the maximum output swing and voltage gain without clipping. Comment on the loading effect, and remember to change back to the 180Ω load resistor after this step.
6.1. Component Values

\[
\begin{align*}
R_{b1}: & \quad \_\_\_ \quad R_{b2}: & \quad \_\_\_ \\
C_{in}: & \quad \_\_\_ \quad C_{out}: & \quad \_\_\_ \\
R_e: & \quad \_\_\_ \quad R_L: & \quad \_\_\_
\end{align*}
\]

6.2. Common-collector amplifier. There are three (4) printouts (Vin, Vout, Power spectrum, and ACsweep). Calculate \(I_B = I_E - I_C\)

\[
\begin{align*}
V_{dc} \text{ Q-Point:} & \quad V_{CE}: & \_\_\_ \quad V_{BE}: & \_\_\_ \quad V_{CC}: & \_\_\_ \\
I_B: & \quad \_\_\_ \quad I_C: & \quad \_\_\_ \quad I_E: & \quad \_\_\_ \quad V_C: & \_\_\_ \quad V_E: & \_\_\_
\end{align*}
\]

Gain: Voltage: \_\_\_ \quad Current: \_\_\_ \quad Power: \_\_\_

Voltage Output Swing: \quad \text{Max:} \_\_\_

Resistance at 5kHz: \quad \text{Input} \_\_\_ \quad \text{Output} \_\_\_

Frequency Response: \quad \text{Low cutoff:} \_\_\_ \quad \text{High cutoff:} \_\_\_

6.3. Common-collector amplifier with different load resistors. There are no printouts here.

47Ω Load resistor:

\[
\begin{align*}
\text{Gain:} & \quad \text{Voltage:} \_\_\_ \quad \text{Current:} \_\_\_ \quad \text{Power:} \_\_\_ \\
\text{Voltage Output Swing:} & \quad \text{Max:} \_\_\_
\end{align*}
\]

820Ω Load resistor:

\[
\begin{align*}
\text{Gain:} & \quad \text{Voltage:} \_\_\_ \quad \text{Current:} \_\_\_ \quad \text{Power:} \_\_\_ \\
\text{Voltage Output Swing:} & \quad \text{Max:} \_\_\_
\end{align*}
\]