ECEN 326 Lab 8
Frequency Response of a Common-Emitter BJT Amplifier

Circuit Topology

Circuit schematic of the common-emitter amplifier is shown in Fig. 1. Capacitors C_B and C_C are used for AC coupling, whereas C_E is an AC bypass capacitor used to establish an AC ground at the emitter of Q_1. C_F is a small capacitance that will be used to control the higher 3-dB frequency of the amplifier.

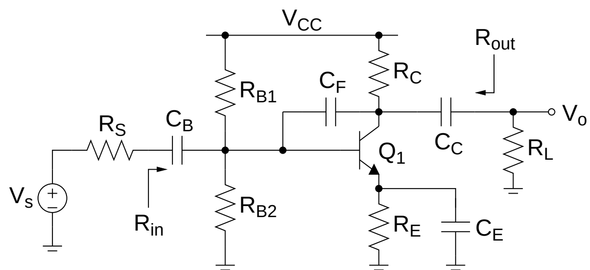

Figure 1: Common-emitter BJT amplifier.

DC Biasing and Mid-band Frequency Response

For this section, assume that $C_B = C_C = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$. You can find the DC collector current (I_C) and the resistor values following the analysis provided in Lab #1. Since the topology and the requirements are slightly different, you need to make minor modifications to the design procedure and equations.

Low Frequency Response

Figure 2 shows the low-frequency small-signal equivalent circuit of the amplifier. Note that C_F is ignored since its impedance at these frequencies is very high.

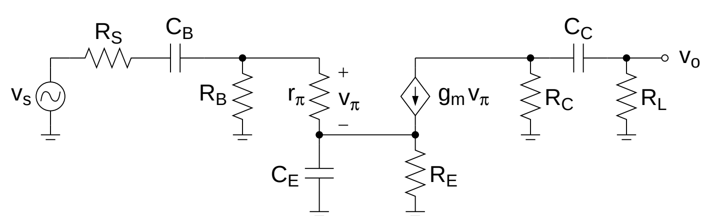

Figure 2: Low-frequency equivalent circuit.

Using short-circuit time constant analysis, the lower 3-dB frequency (ω_L) can be found as

$$\omega_L \approx \frac{1}{R_{1s}C_B} + \frac{1}{R_{2s}C_E} + \frac{1}{R_{3s}C_C} \tag{1}$$

where

$$R_{1s} = R_S + (R_B \parallel r_\pi) \tag{2}$$

$$R_{2s} = R_E \parallel \left(\frac{r_\pi + (R_B \parallel R_S)}{\beta + 1}\right) \tag{3}$$

$$R_{3s} = R_C + R_L \tag{4}$$

High Frequency Response

At high frequencies, C_B, C_C and C_E can be replaced with a short circuit since their impedances become very small. Figure 3 shows the high-frequency small-signal equivalent circuit of the amplifier.

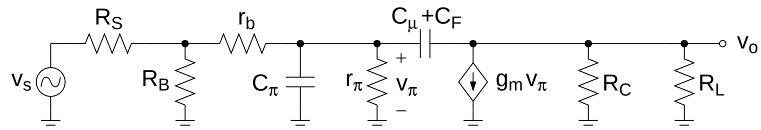

Figure 3: High-frequency equivalent circuit.

The higher 3-dB frequency (ω_H) can be derived as

$$\omega_H = \frac{1}{R_T\left[C_\pi + (C_\mu + C_F)\left(1 + g_m R_{CL} + \dfrac{R_{CL}}{R_T}\right)\right]} \tag{5}$$

where

$$R_T = r_\pi \parallel (r_b + (R_S \parallel R_B)) \tag{6}$$

$$R_{CL} = R_C \parallel R_L \tag{7}$$

Thus, if we assume that the common-emitter amplifier is properly characterized by these dominant low and high frequency poles, then the frequency response of the amplifier can be approximated by

$$\frac{v_o}{v_s}(s) = A_v \frac{s}{s + \omega_L} \frac{1}{1 + \dfrac{s}{\omega_H}} \tag{8}$$

Calculations and Simulations

Assuming $C_B = C_C = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$, and using a 2N3904 BJT, design a common-emitter amplifier with the following specifications:

$V_{CC} = 5\ V$	$R_S = 50\Omega$	$R_L = 1\ k\Omega$	
$R_{in} \geq 250\ \Omega$	$I_{supply} \leq 8mA$	$\lvert A_v \rvert \geq 50$	0-to-peak unclipped output swing $\geq$ 1.5 V

1. Show all your calculations, design procedure, and final component values.
2. Verify your results using a circuit simulator. Submit all necessary simulation plots showing that the specifications are satisfied. Also provide the circuit schematic with DC bias points annotated.
3. Using a circuit simulator, find the higher 3-dB frequency (f_H) while $C_F = 0$.
4. Determine C_π, C_μ and r_b of the transistor using DC operating point analysis (C_π, C_μ and r_b are usually listed as Cpi, Cmu and rx (or 1/gx),respectively). Calculate f_H using Eq. (5) and compare it with the simulation result obtained in Step 3.
5. Calculate the value of C_F to have f_H = 20 kHz. Simulate the circuit to verify your result, and adjust the value of C_F if necessary.
6. Calculate C_B, C_C, C_E to have f_L = 500 Hz. Simulate the circuit to verify your result, and adjust the values of capacitors if necessary.

Measurements

1. Construct the amplifier you designed.
2. Measure I_C, V_E, V_C and V_B. If any DC bias value is significantly different than the one obtained from simulations, modify your circuit to get the desired DC bias before you move onto the next step.
3. Measure I_{supply}.
4. Obtain the magnitude of the frequency response of the amplifier and determine the lower and higher 3-dB frequencies f_L and f_H.
5. At midband frequencies, measure A_v, R_{in}, and R_{out}.
6. Measure the maximum un-clipped output signal amplitude.

Report

1. Include calculations, schematics, simulation plots, and measurement plots.
2. Prepare a table showing calculated, simulated and measured results.
3. Compare the results and comment on the differences.

Demonstration

1. Construct the amplifier you designed on your breadboard and bring it to your lab session.
2. Your name and UIN must be written on the side of your breadboard.
3. Submit your report to your TA at the beginning of your lab session.
4. Measure I_{supply}.
5. Obtain the magnitude of the frequency response of the amplifier and determine the lower and higher 3-dB frequencies f_L and f_H.
6. At midband frequencies, measure A_v, R_{in}, and R_{out}.