

ECEN 326 Lab 9

Frequency Response of a Cascode BJT Amplifier

Circuit Topology

Circuit schematic of the cascode amplifier is shown in Fig. 1. Capacitors C_B and C_C are used for AC coupling, whereas C_D and C_E are AC bypass capacitors. C_F is a small capacitance that will be used to control the higher 3-dB frequency of the amplifier.

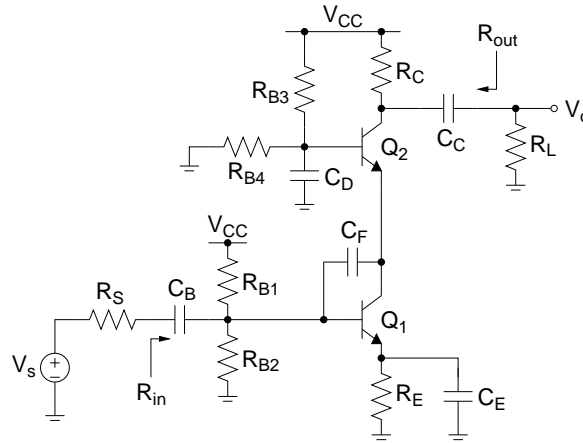


Figure 1: Cascode BJT amplifier.

DC Biasing and Mid-band Frequency Response

For this section, assume that $C_B = C_C = C_D = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$. You can find the DC collector currents (I_{C1} and I_{C2}) and the resistor values following the analysis provided in Lab #2. Since the topology and the requirements are slightly different, you need to make minor modifications to the design procedure and equations.

Low Frequency Response

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

$$\omega_L \approx \frac{1}{R_{1s}C_B} + \frac{1}{R_{2s}C_E} + \frac{1}{R_{3s}C_D} + \frac{1}{R_{4s}C_C} \quad (1)$$

where

$$R_{1s} = R_S + (R_{B1} \parallel R_{B2} \parallel r_{\pi 1}) \quad (2)$$

$$R_{2s} = R_E \parallel \left(r_{e1} + \frac{R_{B1} \parallel R_{B2} \parallel R_S}{\beta + 1} \right) \quad (3)$$

$$R_{3s} = R_{B3} \parallel R_{B4} \quad (4)$$

$$R_{4s} = R_C + R_L \quad (5)$$

High Frequency Response

The higher 3-dB frequency (ω_H) can be estimated using open-circuit time constant analysis

$$\omega_H \approx \frac{1}{R_{1o}C_{\pi 1} + R_{2o}(C_{\mu 1} + C_F) + R_{3o}C_{\pi 2} + R_{4o}C_{\mu 2}} \quad (6)$$

where

$$R_{1o} = r_{\pi 1} \parallel (r_{b1} + (R_{B1} \parallel R_{B2} \parallel R_S)) \quad (7)$$

$$R_{2o} = R_{1o} + r_{e2} + g_{m1} R_{1o} r_{e2} \quad (8)$$

$$R_{3o} = r_{\pi 2} \parallel \frac{1}{g_{m2}} \quad (9)$$

$$R_{4o} = R_C \parallel R_L \quad (10)$$

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

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

Calculations and Simulations

Assuming $C_B = C_C = C_D = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$, and using 2N3904 BJTs, design a cascode amplifier with the following specifications:

$$V_{CC} = 5 \text{ V} \quad R_S = 50 \Omega \quad R_L = 1 \text{ k}\Omega$$

$$R_{in} \geq 250 \Omega \quad I_{supply} \leq 8 \text{ mA} \quad |A_v| \geq 50 \quad \text{0-to-peak unclipped output swing} \geq 1.5 \text{ V}$$

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 for both transistors using DC operating point analysis (C_π , C_μ and r_b are usually listed as C_{pi} , C_{mu} and r_x (or $1/g_x$), respectively). Calculate f_H using Eq. (6) and compare it with the simulation result obtained in Step 3.
5. Calculate the value of C_F to have $f_H = 20 \text{ kHz}$. Simulate the circuit to verify your result, and adjust the value of C_F if necessary.
6. Calculate C_B , C_C , C_D and C_E to have $f_L = 500 \text{ Hz}$. Simulate the circuit to verify your result, and adjust the values of capacitors if necessary.
7. Compare the value of f_H for $C_F = 0$ with that of the common-emitter amplifier designed in the previous lab. Also compare the values of C_F required to obtain $f_H = 20 \text{ kHz}$. Comment on the differences.

Measurements

1. Construct the amplifier you designed.
2. Measure I_C , V_C , V_B and V_E for both transistors. 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} .