MINI PROJECT 3

MULTI-TRANSISTOR AMPLIFIERS

Objectives

To become familiar with, and understand, some of the characteristics of several multi-transistor amplifiers/circuits.

Introduction

In this mini project you will "wire up" and "test" (using your chosen simulation software) a cascode amplifier, an amplifier consisting of a common-base stage followed by a common-collector stage in cascade, a differential amplifier, and an AM modulator.

References

ELEC 301 Course notes.
Standard Values List http://ecee.colorado.edu/~mcclurel/resistorsandcaps.pdf
A. Sedra and K. Smith, "Microelectronic Circuits," 5th, 6th, or 7th Ed., Oxford University Press, New York.

Part 1 The Cascode Amplifer.

Layout the cascode amplifier shown in figure 3.1 using your simulation software and 2N2222A transistors. The minimum specifications for this amplifier are given in table 3.1. Assume that the source resistance used is 50Ω, that V_{CC} = 20V, and that there is a 50kΩ load at the output of the amplifier.

Table 3.1 Cascode Amplifier Specifications.

$\mathbf{R_{out}}$ (value at mid band)	$\mathbf{R_{in}}$ (minimum value at mid band[1])	$\mathbf{\lvert A_v \rvert}$ (minimum value at mid band)	$\mathbf{f_L}$ (maximum value for low-f cut-in)
2.5 kΩ ± 250Ω	5 kΩ	50	500 Hz

You are required to design the cascode to meet the above specifications. Start by calculating the resistor values needed to bias the circuit. Once you have the calculated resistor values for the bias, you should change them to the closest commonly available resistance values. Assuming a large capacitor for C_B, use C_B = 150 μF, you should obtain values for all of the other capacitances. You are also required to obtain the desired small-signal parameters for your circuit.

A. Measure the d.c. operating point of your cascode amplifier.

B. Plot the Bode plots for magnitude and phase and compare your estimates of the locations of the ω_{L3dB} and ω_{H3dB} with your calculated values.

C. Using the magnitude Bode plot, pick a mid band frequency. Using this frequency, adjust the amplitude of the input signal to your amplifier until you feel that the output signal, viewed in the time domain, is becoming non-linear (you can vary the amplitude of the input signal and plot the voltage transfer curve, amplitude of v_o vs v_s).

D. Measure the input impedance of your amplifier at mid band (include everything other than the 50Ω source resistance) and compare this with the input impedance that you designed for.

Report: Discuss your observations, compare your measurements with your predictions, and discuss any insights gained.

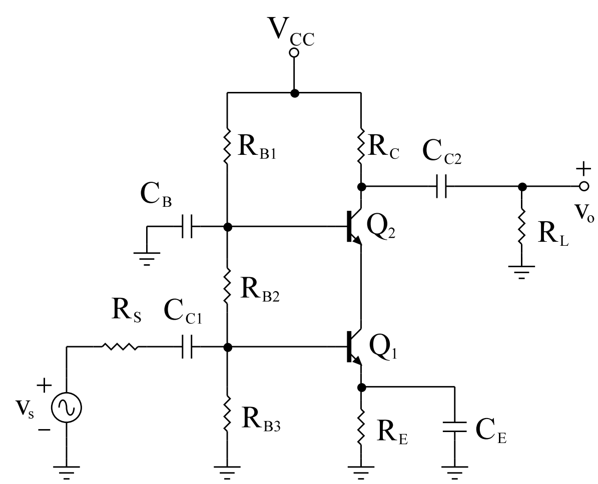

Figure 3.1 The Cacode Amplifier.

[1]Note: you may have to add a component to achieve this input resistance, the question is where?

Part 2. Cascaded Amplifiers — The Common-Base followed by the Common-Collector.

The circuit shown in figure 3.2 is to be used as a repeater in an analog, 50Ω coaxial cable system. It should be designed so that at mid band it has an input impedance, R_i, and an output impedance, R_o, that are both equal to 50±5Ω. Q1 and Q2 should both be 2N3904s.

A. Use $V_{CC} = 12V$ and the 1/3 rule such that $V_{E1} = V_{CC}/3$ and $I_1 = 0.1I_{E1}$, and the design criteria that at mid band R_i and R_o both equal 50±5Ω and that the low-frequency cut-in (the low-frequency 3dB point) occurs at, or below, 1000Hz, to obtain design values for R_{E1}, R_{C1}, R_{B1}, R_{B2}, R_{E2}, C_{C1}, C_B and C_{C2} (Hint: assuming that the source will have an output impedance of 50Ω and that the repeater will be attached to a 50Ω load, since C_{C1} and C_{C2} will both "see" similar amounts of resistance, you can design them together to put the low frequency cut-in at 1000Hz and then design C_B so that is as small as possible without changing the low frequency cut-in).

B. Using resistor and capacitor values that are actually available and that are closest to your design values without changing any key design specification, "wire-up" your circuit and measure R_i and R_o at mid band. Adjust any of the resistance values that need to be adjusted in order to meet the design values for both R_i and R_o at mid band. Finally, measure the mid band voltage gain, $A_M = v_o/v_s$, for your amplifier without a load attached and without a source impedance (i.e., for $R_S = 0$).

C. Now, attach a source with an output impedance of 50Ω to the input and a 50Ω load to the output and obtain Bode plots for both the amplitude and phase. Find the low-frequency cut-in and the high frequency cut-off points. Adjust any low frequency capacitors accordingly to meet the specifications.

Report: Discuss your observations, compare your measurements with your predictions, and discuss any insights gained.

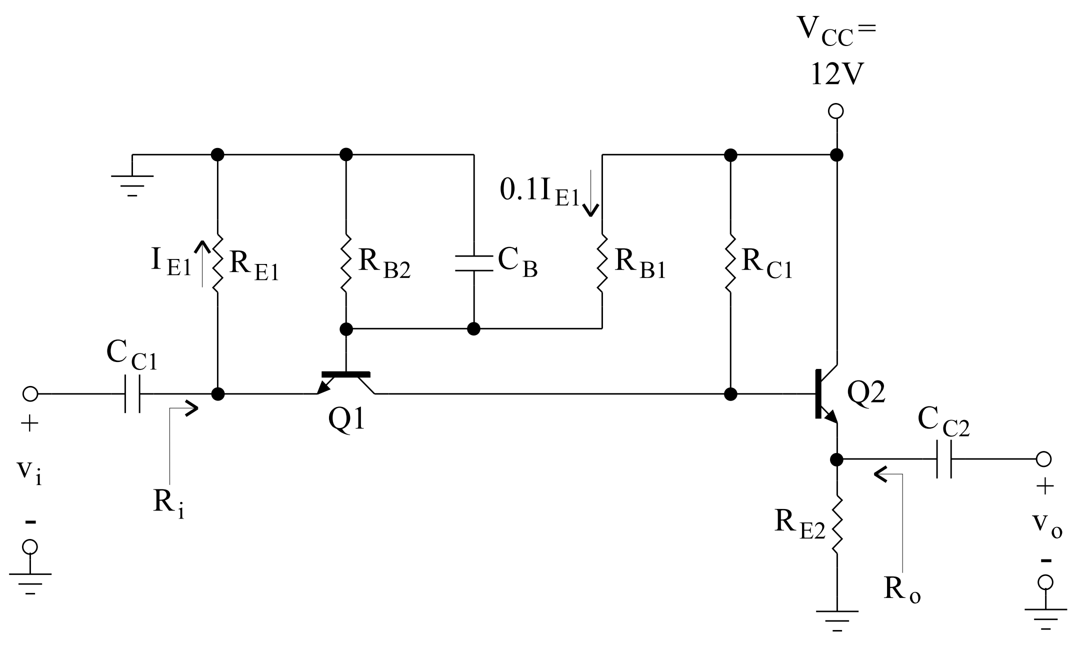

Figure 3.2. A Common-Base/Common-Collector Repeater.

Part 3. The Differential Amplifier.

Using the methods taught in class, design a differential amplifier (including the current source) with a ±12V power supply, using 2N2222A transistors and 8kΩ collector resistors and for which $I_{E1} = I_{E2} \approx 1mA$.

For the following, you may wish to use some of the function blocks available in your chosen simulation software to make your measurements, e.g., adder blocks and/or gain blocks with gains of -1:

A. "Wire-up" your circuit and plot the Bode plots, for both amplitude and phase, for a differential, small-signal input.

B. Using the methods taught in class, calculate the differential gain and f_{H3dB} for your design and compare your "predicted" values with those obtained in part A, above.

C. From the Bode plots obtained in part A, pick a "mid band" frequency and apply a small differential signal to the amplifier (e.g., $0.5mV_P$[1]) and "measure" the differential output voltage. Increase the differential input signal until you feel that the output signal, viewed in the time domain, is becoming non-linear and record the maximum input signal for which the output is linear.

Report: Discuss your observations, compare your measurements with your predictions, and discuss any insights gained.

[1]V_P means V_{Peak}. V_P is ½ the peak-to-peak voltage of an a.c. sinusoidal signal with no d.c. offset.

Part 4. The AM Modulator.

The circuit in figure 3.3 shows an AM modulator. “Wire-up” this circuit using your chosen simulation package using 2N2222A transistors (though you only need to look at the output over a few milli-seconds you should set the simulation times to at least 0.5 seconds for transients to subside).

In the modulator shown, the 100kHz signal is the carrier and the 1kHz signal is the input.

A. Apply a 50mVp, 1kHz sine wave to the input of the modulator, as shown in figure 3.3, and observe the differential output.

B. Vary the amplitude of the input signal between 10mVp and 100mVp and record what happens to the differential output signal. What is the largest input signal that results in an undistorted output signal?

C. Now change the input signal to a square wave and repeat part B. Record what happens to the output signal.

Report: Explain how the AM modulator shown works and model it. Also, discuss your observations, compare your measurements with your predictions, and discuss any insights gained.

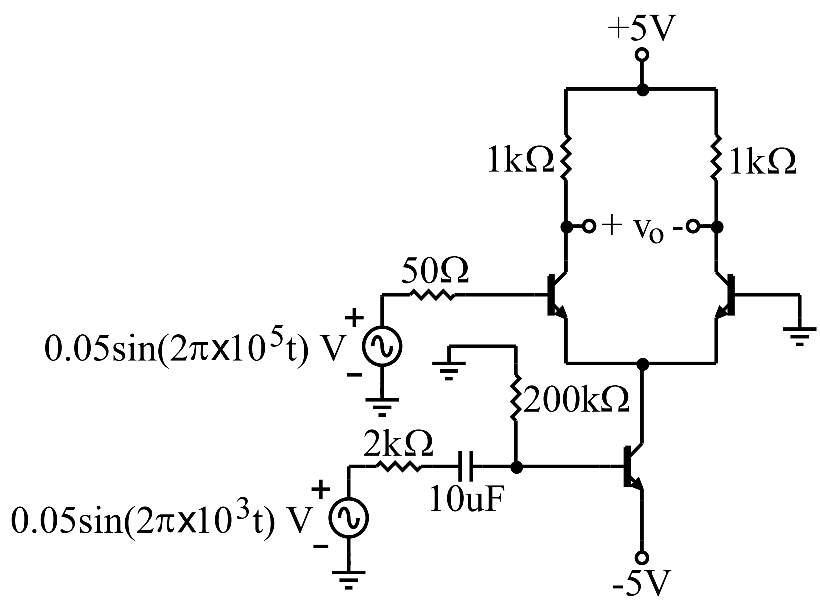

Figure 3.3. The AM Modulator.

<u>Report</u> — The report for this project should document the circuits that have been "built" and "tested." For each circuit, tabulate the calculated and simulated values. Discuss any observations that you made. You should present your calculations and/or data in the order that it was requested in this project sheet. In other words, present the calculations/data for Part 1A followed by the calculations/data for Part 1B, etc. The discussion for each part should be included following the calculations/data for that part, i.e., your discussion for Part 1 should come before you present your calculations/data for Part 2.