The George Washington University
School of Engineering and Applied Science
Department of Electrical and Computer Engineering
ECE 20 - LAB
Experiment # 8

Designing a cascaded amplifier

Components:

Kit Part #	Spice Part Name	Part Description	Symbol Name (used in schematics throughout this lab manual)
2N3904 (2)	Q2N3904	NPN Bipolar Junction Transistor (BJT)	Q1
Resistor (2)	R	To be determined in prelab	R1, R2, RE
Resistor (1)	R	To be determined in prelab	RC
Capacitor (3)	C	To be determined in prelab	CC1, CC2, CC3

Table 1.1

Objectives:
- To design a two stage amplifier to meet specifications
- To simulate the designed two stage amplifier
- To build the designed two stage amplifier
- Measure the large signal and small signal characteristics is lab

Prelab: **(Submit electronically prior to lab meeting,** also have a printed copy for yourself during lab)
1. Read through lab, generate an equipment list.
2. Read the tutorial "*Cascading Amplifier Stages (CE to CC)"* to help you design an amplifier to meet specifications below
3. Design an multistage amplifier using a 2N3904 NPN BJT to meet the following specs (hand in all calculations):

Specification	Value
VCC	20V
RL	510Ω
Power dissipated by load	5.6mWatts RMS (10% margin of error)
v*in* (from a function generator)	70mV RMS @ 10kHz

    a) Show all calculations, determine Av for each stage (with load)
    b) Show all calculations, determine Ai for each stage (with load)
    c) Show all calculations, determine RIN, ROUT for each stage of your design
4. Build the amplifier you've designed in SPICE, use 50 ohms for Rsig.
5. Perform a Bias Point Analysis for the circuit.
    a) Show the DC **voltages** and DC **currents** at each node; submit a separate screenshot for each. Verify that the DC currents and node voltage approximate your calculations.
6. Perform a Transient Analysis, show 5 cycles of Vin (NOT Vsig) and Vout
    a) Plot Vin (not vsig), Vout for each stage (use markers to show values)
    b) Plot Iout for the CC stage
    c) Calculate the voltage gain for each stage
    d) Plot Vin, (not vsig), Vout, and peak power out for the entire amplifier (use markers to show values)
    e) Calculate the overall voltage gain and current gain for the entire amplifier

Lab:

In this lab you will construct the 2 stages of your amplifier separately and verify that each stage is working prior to cascading them. After each stage is verified, you will cascade them and characterize the overall amplifier that you've built.

Part I - Bias Point Verification (Large signal measurements)

1. Measure ALL resistors prior to building the amplifier using the Keithley 175 DMM
2. Construct the **common-emitter** portion of the amplifier first
   a. Attach a load resistor whose value = RIN of the **common-COLLECTOR** amplifier
3. **BEFORE** attaching the function generator + scope:
   a. Measure V_B, V_E, V_C using the Keithley 175 DMM
   b. From the measured voltages, calculate V_{BE}, V_{CE}, & V_{CB}, I_B, I_E, I_C, β
4. Place all hand calculated, simulated, and measured values for I_B, I_E, I_C, V_B, V_E, V_C, V_{BE}, V_{CE}, & V_{CB} in a single table for analysis in your lab writeup.
5. Construct the **common-collector** portion of the amplifier, do NOT attach it to the common-emitter yet:
   a. Attach the 510 ohm load
   b. Repeat steps 1-4 for the common-collector amplifier

Part 2 - Amplifier Measurements (Small signal measurements)

1. Keeping the two amplifier stages separate, for the **common-emitter** amplifier:
   a. Apply the 100mV, 10kHz input signal using the function generator
      • Note: the 10mV set on the function generator is "v_{sig}," NOT "v_{in}"
      • You may need to increase the function generator output to reach "Vin" = 100mV
      • Note: the output impedance of the function generator is 50Ω, this is "Rsig"
   b. Use Channel 1 of the digital oscilloscope to measure v_{in}
      • You CANNOT use autoset. Determine the proper period for the 10kHz signal
      • Ensure channel 1 is set for AC coupling
      • On the scope, setup a "filter" (see vertical menu) for CH 1, to remove any noise
   c. Use Channel 2 of the digital oscilloscope to measure v_{out}
      • You CANNOT use autoset. Determine the proper period for the 10kHz signal
      • Ensure channel 2 is set for AC coupling
      • On the scope, setup a "filter" (see vertical menu) for CH 2, to remove any noise
   d. You may add a large capacitor between VCC and GND to remove any additional noise in the circuit
   e. Measure v_{out}, v_{in} with NO load; determine Av_0 (no load)
   f. Measure v_{out}, v_{in} with load; determine Av, verify that is matches your simulations before continuing
   g. Measure RIN and ROUT for the common-emitter amplifier

2. For the **common-collector** amplifier
   a. You will need to set Vin = 2V, 10kHz to mimic the signal that would be coming out of the common-emitter amplifier
   b. Repeat steps 1b-1g for the common-collector amplifier

3. Cascade the common-emitter to the common-collector amplifier
   a. Remember to remove "RL" from the common-emitter amplifier, attach the common-collector as its new load, remember to use only 1 coupling capacitor between the stages
   b. Repeat steps 1a-1g for the entire amplifier

Analysis / Writeup

- Include all hand calculations in the final lab writeup.
- For each part of the lab, create tables to compare your hand calculated data, simulated data, and measured data. If there are waveforms, reprint the waveforms from your prelab in your lab report, to accurately compare them to the waveforms captured in lab.
- Calculate % error of difference between hand calculations, simulations, and measurements.
    - Compare: Output voltage swing (hand calculated, to simulated, to measured)
    - Compare: Output current swing (hand calculated, to simulated, to measured)
    - Compare: Rin, Rout (hand calculated, to simulated, to measured)
    - Compare: voltage gain, current gain (hand calculated, to simulated, to measured)
- Why would this setup be unable to drive an 8ohm load? What is needed in the final stage to make it able to drive an 8ohm load?