The George Washington University
School of Engineering and Applied Science
Department of Electrical and Computer Engineering
ECE 20 - LAB
Experiment # 6

Designing and Measuring a Common-Emitter Amplifier

Components:

Kit Part #	***Spice Part Name***	***Part Description***	***Symbol Name*** ***(used in schematics throughout this lab manual)***
2N3904	Q2N3904	NPN Bipolar Junction Transistor (BJT)	Q1
Resistor	R	To be determined in prelab	R1
Resistor	R	To be determined in prelab	R2
Resistor	R	To be determined in prelab	RC
Resistor	R	To be determined in prelab	RE

Table 1.1

Objectives:

- To design a common-emitter amplifier to meet a set of specifications
- To simulate the designed common-emitter amplifier
- To build the designed common-emitter amplifier
- Measure Voltage gain (Av) with and without load in laboratory
- Measure Rin, Rout with and without load in laboratory

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 "Designing a Common-Emitter Amplifier" for help.
3. Design a common-emitter amplifier using a 2N3904 NPN BJT to meet the following specs (hand in all calculations):

Specification	**Value**
Quiescent Current (Ic_Q)	1mA
VCC	20V
Av_0 (without load)	-100 V/V
Rin (DC)	4KΩ
RL	4KΩ
v*in*	10mV @ 10kHz

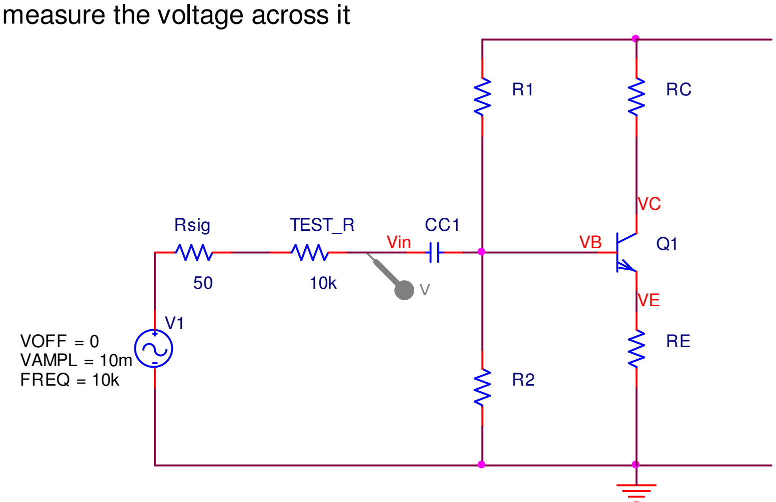
   a) Determine the voltage gain (Av) with load.
   b) Determine the output impedance (Rout) without the load
   c) Determine the output impedance (Rout) the load
4. Build the amplifier you've designed in SPICE, use 50 ohms for Rsig.
5. Perform a Bias Point Analysis for the circuit.
6. Show the DC **voltages** and DC **currents** at each node; submit a separate screenshot for each. Verify that the DC currents and node voltage approximate your calculations.
7. Perform a Transient Analysis, show 5 cycles of Vin (NOT Vsig) and Vout. Ensure that Vin and Vout are plotted in sub-windows, as done in lab 5. Place a label at the peak of Vin and Vout; make sure to mark this at the same point in time.
   a) Determine the small signal voltage gain of the amplifier (Av) with load and without load. Verify that it approximates your calculations.
   b) Rin(AC) = V_{in} / I_{in}. Use a current probe to measure I_{in}, determine Rin(AC)
   c) Rout(AC) = V_{out} / I_{out}. Use a current probe to measure I_{out}, determine Rout(AC)
   d) Increase Vin until Vout is distorted (looks like a clipped sine wave). For the maximum value of Vin, what is Vout? Does it match you calculated max voltage swing from your IV-Curve for the 2N3904 transistor?

Lab:
Part I - Bias Point Verification (Large signal measurements)

1. Measure ALL resistor using the Keithley 175 DMM prior to building the circuit
2. Construct the common emitter amplifier designed in the prelab.
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.

Part 2 - Common Emitter Amplifier Measurement (Small signal measurements)

1. Remove the 4k Ohm "load" from your amplifier
2. Apply the 10mV, 10kHz input signal using the function generator
   - Note: the 10mV set on the function generator is "v_{sig}," NOT "v_{in}"
   - Note: the output impedance of the function generator is 50Ω, this is "Rsig"
3. 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
4. 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 1, to remove any noise
5. Determine Av_0 from the measured v_{out}, v_{in}
6. Measure Rin = Vin / I_{in}
   a. Because the scope can only measure Voltage (not current), we use the following technique to determine Rin:
      - You have previously recorded v_{in}
      - Attach a 10kΩ resistor in-between the function generator & your amplifier's input, measure the voltage across it



      - Use Ohm's law to calculate the current through the 10kΩ resistor, this is "I_{in}"
      - Since the 10kΩ is in series with your amplifier, "I_{in}" is the same with our without the 10kΩ resistor
      - Calculate Rin = v_{in} / I_{in} (use the value for Vin recorded BEFORE the 10kΩ)
7. Increase Vin until Vout saturates/clips, record the value of Vin where saturation occurs
8. Attach the 4kΩ load resistor, measure Vout (across the 4kΩ) determine **Av (loaded)**
9. Attach an 8Ω load resistor, measure Vout (across the 8Ω) determine **Av (8Ω load)**
   a. **Calculate the current (Iout) through this resistor**

10. Attach load resistor that is the same size as RC, measure Vout (across the load Ω) determine Av (RCΩ load)
11. Calculate Rout (unloaded) = v_{out} / I_{out}
    a. Use the value of v_{out} recorded when there was no load attached
    b. Use the value of Iout calculated when there was an 8Ω load attached

<u>Analysis / Writeup</u>

- 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.
- What is the maximum output voltage swing of your amplifier (Part II – Step 7)?
    - Did it match your calculations?
- Is the input impedance (Rin) of a common emitter amplifier high or low?
- Is the output impedance (Rout) of a common emitter amplifier high or low?
- When the amplifier is attached a load comparable to RC, what effect does it have on the gain (part II – step 10)?
- When the amplifier is attached a small load, what effect does it have on the gain (part II – step 9)?
- Why when a small load is attached does the gain drop?
    - What conclusion can you draw about the type of load that a common emitter amplifier can handle and still maintain gain?