**The George Washington University**
**School of Engineering and Applied Science**
**Department of Electrical and Computer Engineering**
**ECE 20 - LAB**
**Experiment # 7**

*Designing and Measuring a Common-Collector (Emitter-Follower) 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 | RE |

**Table 1.1**

**Objectives:**

- To design a common-collector amplifier to meet a set of specifications
- To simulate the designed common-collector amplifier
- To build the designed common-collector amplifier
- Measure Voltage gain (Av) and Current gain (Ai) 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-Collector Amplifier" for help.
3. Design a common-collector 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 | 1 V/V |
| Rin (DC) | 70**k**Ω |
| RL | 510Ω |
| v*in* | 10mV @ 10kHz |

   a) Using hand calculations, determine the current gain (Ai) for the amplifier without any load.
   b) Using hand calculations, determine the input impedance (RIN) for the amplifier without any load.
   c) Using hand calculations, determine the output impedance (ROUT) for the amplifier without any load.
4. Build the amplifier you've designed in SPICE, use 50 ohms for Rsig. Attach a 100meg load resistor to simulate an 'unloaded' amplifier.
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 (with and without any load). 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) Increase Vin until Vout is distorted (looks like a clipped sine wave). What is the maximum value of Vin just as Vout is clipped? Does it match you calculated max

voltage swing from your IV-Curve for the 2N3904 transistor? Reset Vin to 10mV for the remainder of the simulations below.

8. Perform a Transient Analysis, show 5 cycles of In and Iout (with and then without any load). Ensure that Iin and Iout are plotted in sub-windows, as done in lab 5. Place a label at the peak of Iin and Iout; make sure to mark this at the same point in time.
   a) Determine the small signal current gain of the amplifier (Ai) with load and without load. Verify that it approximates your calculations.
9. Perform a Transient Analysis, show 5 cycles of Vin and Iin (with and then without any load). Ensure that Vin and Iin are plotted in sub-windows, as done in lab 5. Place a label at the peak of Vin and Iin; make sure to mark this at the same point in time.
   a) Rin(AC) = $V_{in}$ / $I_{in}$, determine Rin(AC) with and without load, verify that it approximates your calculations.
10. Perform a Transient Analysis, show 5 cycles of Vout and Iout (with and then without any load). Ensure that Vout and Iout are plotted in sub-windows, as done in lab 5. Place a label at the peak of Vout and Iout; make sure to mark this at the same point in time.
    a) Rout(AC) = $V_{out}$ / $I_{out}$, determine Rout(AC) with and without load, verify that it approximates your calculations.

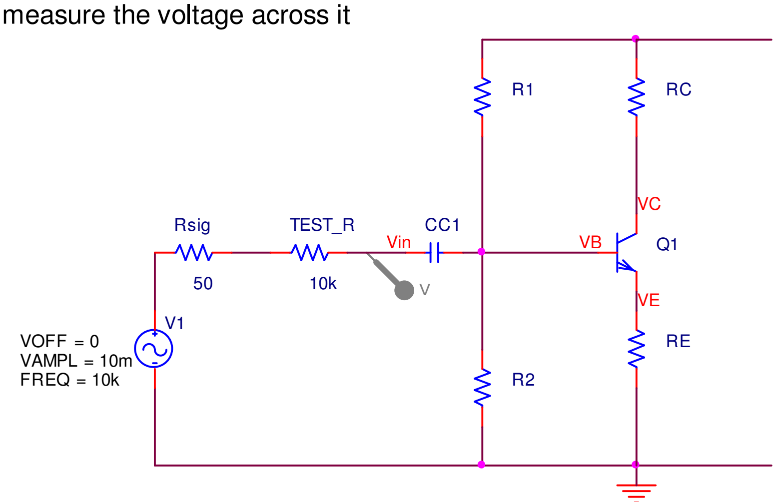
**Lab:**

*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 Collector Amplifier Measurement (Small signal measurements)*

1. Remove the 510 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 2, to remove any noise
5. You may add a large capacitor between VCC and GND to remove any additional noise in the circuit
6. Measure $v_{out}$, $v_{in}$ with NO load; determine $Av_0$ (no load)
7. Measure $v_{out}$, $v_{in}$ with load; determine Av
8. Use the following procedure to measure Rin = $v_{in}$ / $I_{in}$
    a. Remove the load resistor
    b. Because the scope can only measure Voltage (not current), we use the following technique to determine Rin:
        - You have previously recorded $v_{in}$ (unloaded)
        - 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)

9. Increase Vin until Vout saturates/clips, record the value of Vin where saturation occurs
10. Calculate Ai (loaded and unloaded)
11. Calculate Rout = $v_{out}$ / $I_{out}$ (loaded and unloaded)

*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.
- What is the maximum output voltage swing of your amplifier (Part II – Step 9)?
    - 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?
- Is the voltage gain load dependent?
- Is the common-collector amplifier suitable for small or large loads?