THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Experiment #8:
Designing and Measuring a Common-Collector Amplifier

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	--- Ω	R_{B1}	Basic/Resistor	Determined in Prelab
Resistor	--- Ω	R_{B2}	Basic/Resistor	Determined in Prelab
Resistor	--- Ω	R_E	Basic/Resistor	Determined in Prelab
Resistor	510Ω	R_L	Basic/Resistor	---
Resistor	10kΩ	R_{test}	Basic/Resistor	---
Capacitor	--- F	C_{C1}, C_{C2}	Basic/Capacitor	Determined in Prelab
Transistor	2N3904	Q_1	Transistors/BJT_NPN/2N3904	NPN BJT

Table 1 – Component List

OBJECTIVES

· To design a common-collector (emitter-follower) amplifier to meet a set of specifications
· To simulate the designed common-collector amplifier
· To build the designed common-collector amplifier
· Measure Voltage gain (A_V) and Current gain (A_i) with and without load in the laboratory
· Measure R_{in} and R_{out} with and without load in the laboratory

PRELAB

Part I – Generate Equipment List

1. Read through the lab manual and generate an equipment list.

Part II – Common-Collector Amplifier Design

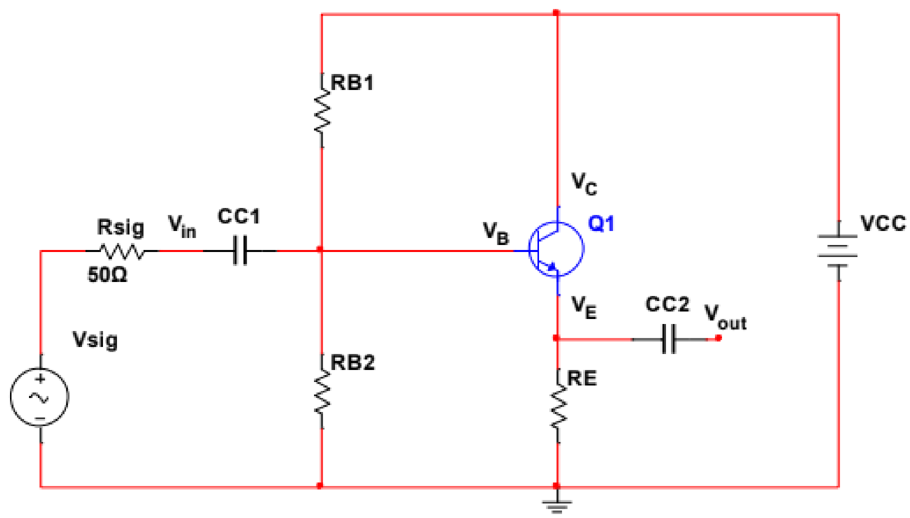

Figure P.1 – Common-Collector Amplifier

1. **Read** the tutorial "**Designing a Common-Collector Amplifier**" for help completing this prelab.
2. **Design** a **common-collector amplifier** using a 2N3904 NPN BJT to meet the following specifications (hand in all calculations):
   - Quiescent Current (I_{CQ}) = 1mA
   - V_{CC} = 20V
   - A_V = 1 V/V
   - R_{in} = 70kΩ
   - R_L = 510Ω
   - V_{in} = 10mV @ 10kHz
3. **Calculate** the current gain (**A_i**) for the amplifier **without the load**.
4. **Calculate** the input impedance (**R_{in}**) for the amplifier **without the load**.
5. **Calculate** the output impedance (**R_{out}**) for the amplifier **without the load**.

Part III – Common-Collector Amplifier Simulation

1. **Build** the amplifier you have designed in Multisim. Use 50Ω for R_{sig}.
2. **Run** a **DC Operating Point Analysis** to determine the DC bias voltages and currents in the circuit.
    a. **Show** the DC **voltages** and DC **currents** at every node.
    b. **Verify** that the simulated DC values approximate your calculations.
3. **Run** a **Transient Analysis** to show five cycles of V_{in} (**not** V_{sig}) and V_{out} (**with** and **without** the load). Ensure that both voltages are plotted with their own y-axis as done in previous labs.
    a. Place labels at the peaks of V_{in} and V_{out} making sure to mark this at the **same point in time**.
    b. **Determine** the small signal voltage gain of the amplifier (**A_V**) **with** and **without** the load. **Verify** that it approximates your calculations.
    c. **Increase** V_{in} until V_{out} is distorted (looks like a clipped sine wave). **What** is the maximum value of V_{in} just as V_{out} is clipped? Does it match your calculated mac voltage swing from your IV-curve for the 2N3904 transistor? Reset V_{in} to 10mV for the remainder of the simulations below.
4. **Run** a **Transient Analysis** to show five cycles of I_{in} and I_{out} (**with** and **without** the load). Ensure that both currents are plotted with their own y-axis as done in previous labs.
    a. Place labels at the peaks of I_{in} and I_{out} making sure to mark this at the **same point in time**.
    b. **Determine** the small signal current gain of the amplifier (**A_i**) **with** and **without** the load. **Verify** that it approximates your calculations.
5. **Run** a **Transient Analysis** to show five cycles of V_{in} and I_{in} (**with** and **without** the load). Ensure that both values are plotted with their own y-axis as done in previous labs.
    a. Place labels at the peaks of V_{in} and I_{in} making sure to mark this at the **same point in time**.
    b. **R_{in}** (AC) = V_{in} / I_{in}. **Determine R_{in}** (AC) **with** and **without** the load. **Verify** that it approximates your calculations.
6. **Run** a **Transient Analysis** to show five cycles of V_{out} and I_{out} (**with** and **without** the load). Ensure that both values are plotted with their own y-axis as done in previous labs.
    a. Place labels at the peaks of V_{out} and I_{out} making sure to mark this at the **same point in time**.
    b. **R_{out}** (AC) = V_{out} / I_{out}. **Determine R_{out}** (AC) **with** and **without** the load. **Verify** that it approximates your calculations.

<u>LAB</u>

Part I – Bias Point Verification (DC Measurements)

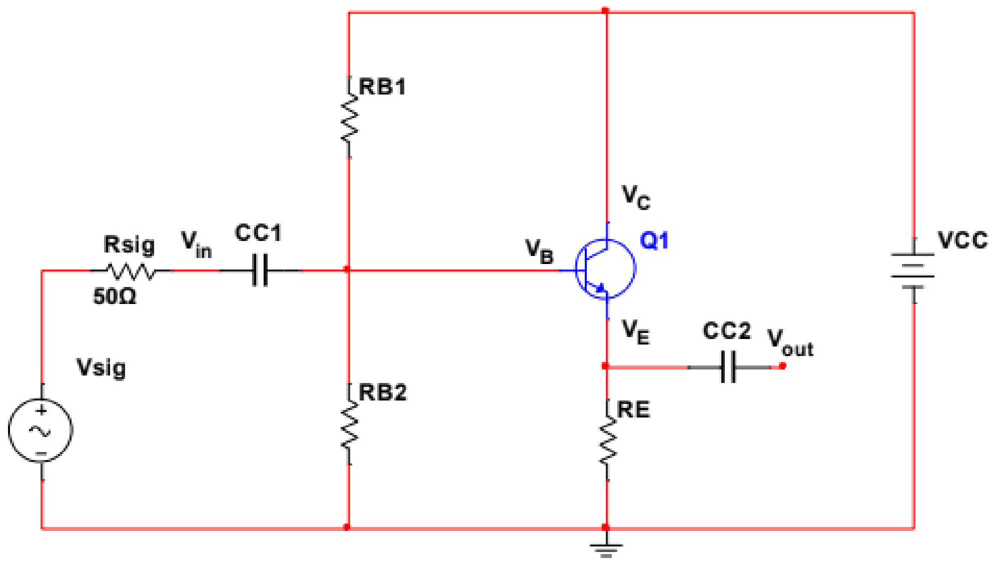

Figure 1.1 – Common-Collector Amplifier

1. **Before building** the circuit in **Figure 1.1**, **measure** the exact resistances of **all** resistors using the DMM. **Record** these values.
2. **Build** the circuit in **Figure 1.1** using transistor 2N3904 and the resistor values found in the prelab.
3. **Before** attaching the function generator (Wavegen), oscilloscope, or the load:
   a. **Measure** V_B, V_E, and V_C using the DMM.
   b. From the measured voltages, **calculate** V_{BE}, V_{CE}, V_{CB}, I_B, I_E, I_C, and **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}, and β in a single table for analysis in your lab report.

Part II – Common-Collector Amplifier Verification (Small-Signal Measurements)

1. **Apply** the 10mV, 10kHz input signal using the function generator (Wavegen) with **no load** attached. ***Note:*** *The 10mV (20mV$_{PP}$) set on the function generator (Wavegen) is "v_{sig}," NOT "v_{in}"* and the output impedance of the function generator (Wavegen) is 50Ω (R_{sig}).
2. **Use** CH-1 of the oscilloscope to measure $\boldsymbol{v_{in}}$.
   a. You **CANNOT** use autoset. Determine the proper period for the 10kHz signal.
   b. **Ensure** CH-1 is set for Peak to Peak to get the gain. Remember,
   $$\frac{Max\ Output}{Max\ Input} = \frac{V_{peak\ to\ peak\ output}}{V_{peak\ to\ peak\ input}}$$
   .
   c. For If you are experiencing any noise, add a shunt capacitor
   d. **Include** relevant measurements such as $\mathbf{V_{max}}$ on the waveform.
3. **Use** CH-2 of the oscilloscope to measure $\boldsymbol{v_{out}}$.
   a. You **CANNOT** use autoset. Determine the proper period for the 10kHz signal.
   b. **Ensure** CH-2 is set for **Peak to Peak to get the gain.**
   c. If you are experiencing any noise, add a shunt capacitor.
   d. **Include** relevant measurements such as $\mathbf{V_{max}}$ on the waveform.
4. You may add a large capacitor between $\mathbf{V_{CC}}$ and **GND** to remove any additional noise from the circuit.
5. **Measure** $\boldsymbol{v_{out}}$ and $\boldsymbol{v_{in}}$ with no load. **Determine $\mathbf{A_{V0}}$ (no load)**.
6. **Measure** $\boldsymbol{v_{out}}$ and $\boldsymbol{v_{in}}$ with load. **Determine AV.**
7. **Measure $\mathbf{R_{in}}$** = 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 $\mathbf{R_{in}}$:
      i. You have previously recorded $\boldsymbol{v_{in}}$.
      ii. **Attach** a 10kΩ resistor between the function generator (Wavegen) and your amplifier's input. **Measure** the **voltage** across it.

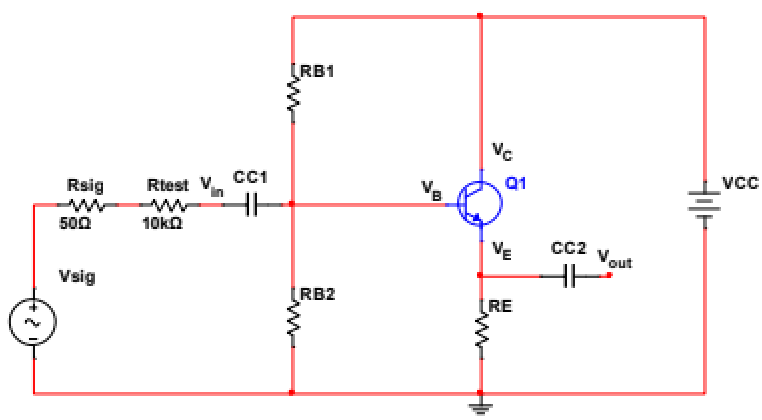

Figure 2.1 – Circuit with Inserted 10kΩ $\mathbf{R_{test}}$

      iii. **Use** Ohm's law to **calculate** the **current through** the 10kΩ resistor ($\mathbf{I_{in}}$).
      iv. Since the 10kΩ is in series with your amplifier, I_{in} is the same with or without the 10kΩ resistor.
      v. **Calculate $\mathbf{R_{in}}$ = $\boldsymbol{v_{in}}$ / $\mathbf{I_{in}}$** (use the value for v_{in} recorded **before** the 10kΩ resistor).
8. **Increase** v_{in} until $\boldsymbol{v_{out}}$ **saturates** (clips). **Record** the value of v_{in} where saturation occurs.
9. **Calculate $\mathbf{A_i}$** (loaded and unloaded).
10. **Calculate $\mathbf{R_{out}}$**
11. **Calculate $\mathbf{R_{out}}$ = $\boldsymbol{v_{out}}$ / $\mathbf{I_{out}}$** (loaded and unloaded).

POST-LAB ANALYSIS

1. **Include** all hand calculations in the final lab report.
2. For each part of the lab, **create tables** to compare your hand **calculated** data, **simulated** data, and **measured** data. If there are waveforms, include the waveforms from your prelab in your lab report to accurately compare them to the waveforms captured in lab.
3. **Calculate** percent error between hand **calculations**, **simulations**, and **measurements**.
4. **What** is the maximum output voltage swing of your amplifier?
    a. Did it **match** your calculations?
5. Is the **input impedance** (R_{in}) of a common-collector amplifier high or low? **Explain**.
6. Is the **output impedance** (R_{out}) of a common-collector amplifier high or low? **Explain**.
7. **Is** the voltage gain **load dependent**?
8. **Is** the common-collector amplifier suitable for driving **small loads** or **large loads**?