THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

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

Experiment #7:
Designing and Measuring a Common-Emitter 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_C	Basic/Resistor	Determined in Prelab
Resistor	--- Ω	R_E	Basic/Resistor	Determined in Prelab
Resistor	--- Ω	R_{E1}	Basic/Resistor	Determined in Prelab
Resistor	4kΩ	R_L	Basic/Resistor	---
Resistor	8Ω	R_L	Basic/Resistor	---
Resistor	10kΩ	R_{test}	Basic/Resistor	---
Capacitor	--- F	C_{C1}, C_{C2}, C_{B1}	Basic/Capacitor	Determined in Prelab
Transistor	2N3904	Q_1	Transistors/BJT_NPN/2N3904	NPN BJT

Table 1 – Component List

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 (A_V) with and without load in laboratory
- Measure R_{in}, R_{out} with and without load in laboratory

PRELAB

Part I – Generate Equipment List

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

Part II – Common-Emitter Amplifier Design

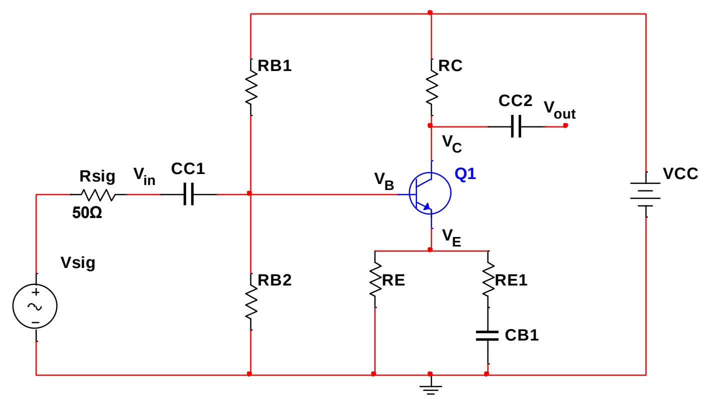

Figure P.1 – Common-Emitter Amplifier with Emitter Degeneration Parallel Resistor

1. **Read** the tutorial "**Designing a Common-Emitter Amplifier**" for help completing this prelab.
2. **Design** a **common-emitter amplifier** using a 2N3904 NPN BJT to meet the following specifications (hand in all calculations):
    - Quiescent Current (I_{CQ}) = 1mA
    - V_{CC} = 20V
    - A_{Vo} (unloaded) = -100 V/V
    - R_{in} = 4kΩ
    - R_L = 4kΩ
    - V_{in} = 10mV @ 10kHz
3. **Determine** the voltage gain (**A_V**) with load.
4. **Determine** the output impedance (**R_{out}**) **without the load**.
5. **Determine** the output impedance (**R_{out}**) **with the load**.

Part III – Common-Emitter 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}. Ensure that both voltages are plotted with their own y-axis as done in the previous lab.
    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. **R_{in}**(AC) = V_{in} / I_{in}. **Plot** and **measure** the input current **I_{in}** to determine **R_{in}**(AC).
    d. **R_{out}**(AC) = V_{out} / I_{out}. **Plot** and **measure** the output current **I_{out}** to determine **R_{out}**(AC).
    e. **Increase** V_{in} until V_{out} is distorted (looks like a clipped sine wave). For the maximum value of V_{in}, what is V_{out}? Does it match the calculated max voltage swing from the IV curve for the 2N3904 transistor?

LAB

Part I – Bias Point Verification (DC Measurements)

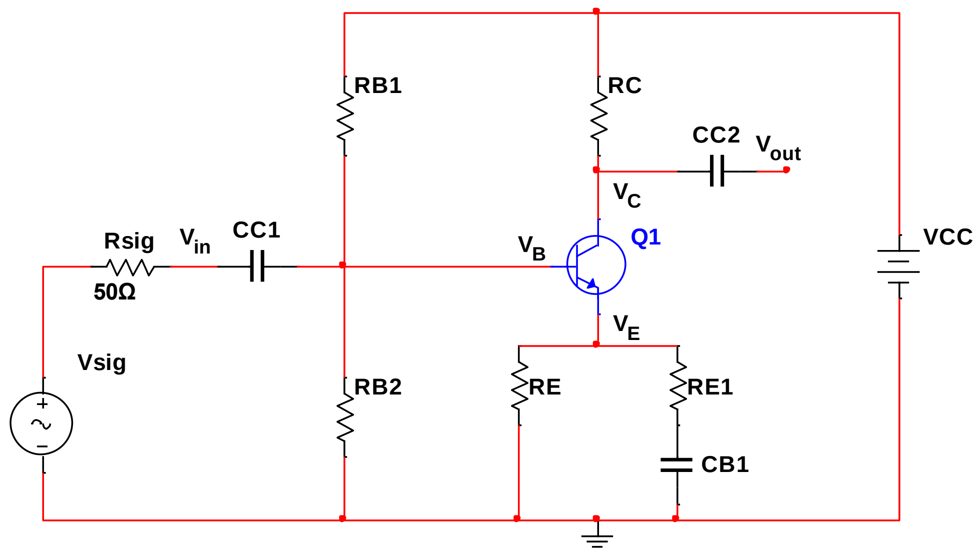

Figure 1.1 – Common-Emitter Amplifier with Emitter Degeneration Parallel Resistor

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, 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-Emitter Amplifier Verification (Small-Signal Measurements)

1. **Apply** the 10mV, 10kHz input signal using the function generator with **no load** attached.
   Note: *The 10mV (20mV$_{PP}$) set on the function generator is "v_{sig}," NOT "v_{in}"* and the output impedance of the function generator 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 **AC coupling**.
   c. For CH-1, use the scope to set a **bandpass filter** to clear the noise from the circuit.
   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 **AC coupling**.
   c. For CH-2, use the scope to set a **bandpass filter** to clear the noise from the circuit.
   d. **Include** relevant measurements such as $\mathbf{V_{max}}$ on the waveform.
4. **Determine** $\mathbf{A_{Vo}}$ from the measured $\boldsymbol{v_{out}}$, $\boldsymbol{v_{in}}$.
5. **Measure** $\mathbf{R_{in}}$ = V_{in} / I_{in}.
   a. 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 and your amplifier's input. **Measure** the **voltage** across it.

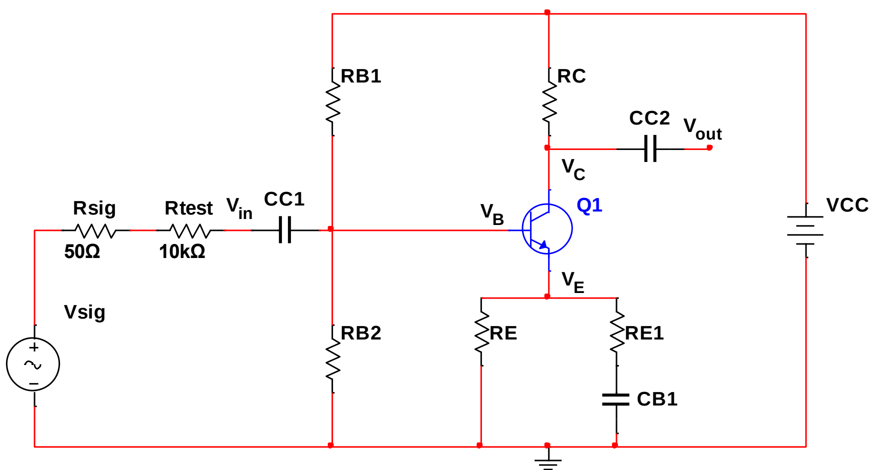

Figure 2.1 – Circuit with Inserted 10kΩ $\mathbf{R_{test}}$

      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).
6. **Increase** v_{in} until $\boldsymbol{v_{out}}$ **saturates** (clips). **Record** the value of v_{in} where saturation occurs.
7. **Attach** the 4kΩ load resistor and **measure** v_{out} (across the 4kΩ load). **Determine $\mathbf{A_V}$(loaded)**.
8. **Attach** an 8Ω load resistor and **measure** v_{out} (across the 8Ω load). **Determine $\mathbf{A_V}$(8Ω load)**.
   a. **Calculate** the **current** ($\mathbf{I_{out}}$) through this resistor.
9. **Attach** a load resistor that is the same size as $\mathbf{R_C}$ and **measure** v_{out} (across the load). **Determine $\mathbf{A_V}$($\mathbf{R_C}$ Ω load)**.
10. **Calculate $\mathbf{R_{out}}$(unloaded) = $\boldsymbol{v_{out}}$ / $\mathbf{I_{out}}$**.
    a. **Use** the value of $\boldsymbol{v_{out}}$ recorded when there was no load attached.
    b. **Use** the value of $\mathbf{I_{out}}$ calculated when there was an 8Ω load attached.

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-emitter amplifier high or low? **Explain**.
6. Is the **output impedance** (R_{out}) of a common-emitter amplifier high or low? **Explain**.
7. **When** the amplifier is attached a **load comparable to** R_C, **what effect** does it have on the **gain**?
8. **When** the amplifier is attached a **small load**, **what effect** does it have on the **gain**? **Explain why** this occurs.
    a. **What conclusion** can you draw about the type of load that a common-emitter amplifier can handle and still maintain gain?