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

Experiment #6:
Biasing an NPN BJT – Introduction to CE, CC, and CB Amplifiers

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	16kΩ	R_{B1}	Basic/Resistor	---
Resistor	8.2kΩ	R_{B2}	Basic/Resistor	---
Resistor	(2) 1kΩ	R_C, R_E	Basic/Resistor	---
Capacitor	(3) 47μF	C_{C1}, C_{C2}, C_{B1}	Basic/Capacitor	---
Transistor	2N3904	Q_1	Transistors/BJT_NPN/2N3904	NPN BJT

Table 1 – Component List

OBJECTIVES

· To verify the operating point for a Beta Stabilized Biasing Network
· To verify the voltage gain (A_V) of a Common Emitter (CE) Amplifier
· To verify the voltage gain (A_V) of a Common Collector (CC) Amplifier
· To verify the voltage gain (A_V) of a Common Base (CB) Amplifier
· Compare the gain of the three types of amplifier configurations
· To compare measured characterization results to simulation results

PRELAB

Part I – Generate Equipment List

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

Part II – Hand Calculations for DC Bias Point

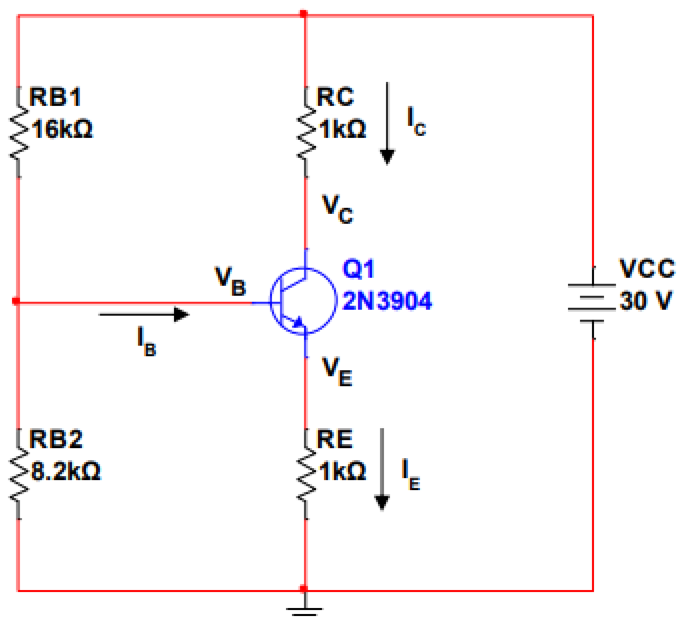

Figure P.2.1 – Beta Stabilizing Network

1. **Hand calculate** the values for I_B, I_E, I_C, V_B, V_E, V_C, V_{BE}, V_{CE}, and V_{CB} for the circuit in **Figure P.1**. Assume that **β = 180**. **Show all work**. Read the tutorial "**Bias Point Analysis in Multisim**" for help calculating these values.

Part III – DC Bias Point Simulation

1. **Build** the circuit in **Figure P.1** in Multisim using the 2N3904 BJT. Perform a **Bias Point Analysis** (DC Operating Point) for the circuit in Multisim following the tutorial. Show the DC voltages and DC currents at each node.
2. **Submit** the table produced by the simulation showing all DC values for the circuit.

Part IV – Common Emitter (CE) Amplifier

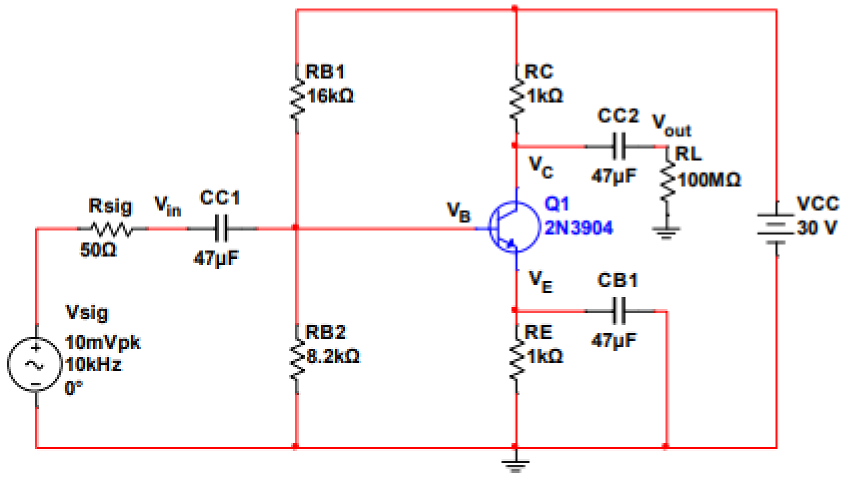

Figure P.4.1 – Common Emitter Amplifier

1. **Using** the biasing circuit you have constructed for the BJT, apply a small input signal (10mV @ 10kHz) to the base of the transistor in series with a 50Ω resistor, as shown in **Figure P.4.1**. We refer to this signal as **V_{sig}**. The resistor models the 50Ω impedance of the function generator (Wavegen).
2. **Perform** a **transient analysis** to plot five cycles of the input and output voltage as labeled in **Figure P.4.1**. Because the output is amplified and much greater than the input voltage, follow these steps to adjust the axes to clearly show values for both the input and output waveforms.
   a. **Right click** on any axis to get to axis properties. **Label** the left axis **Input Voltage (V)**.
   b. **Label** the **Right axis** as **Output Voltage (V) and** check the box to **enable** this axis.
   c. Click the **Traces** tab in the Graph Properties window. You can switch between traces using the Trace ID field and specify which axes it uses to plot the waveform. Ensure that **V(in)** uses the **left axis** for its y-vertical axis and that **V(out)** uses the **right axis**.
   d. Go back to the **Left axis** and **Right axis** tabs and click the **Auto-range** button for each.
   e. **Click Apply** to save these changes. Your graph should look similar to **Figure P.4.2**.
   f. **Add data labels** to the peaks of **V_{in}** and **V_{out}** at the **same** point in time.
3. **Determine** the small signal voltage gain of the amplifier **A_V** using the formula **$A_V = V_{out}/V_{in}$** and the peak voltages found above.
   a. Is A_V positive or negative?
   b. For a common emitter amplifier, is the input in phase with the output?

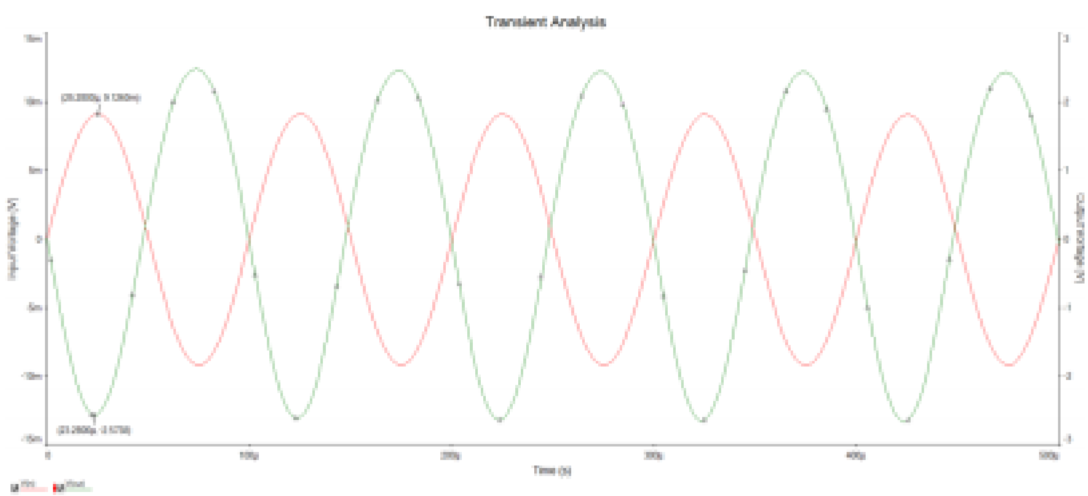

Figure P.4.2 – Input and Output Voltages Plotted with Separate Y-Axes

Part V – Common Collector (CE) Amplifier

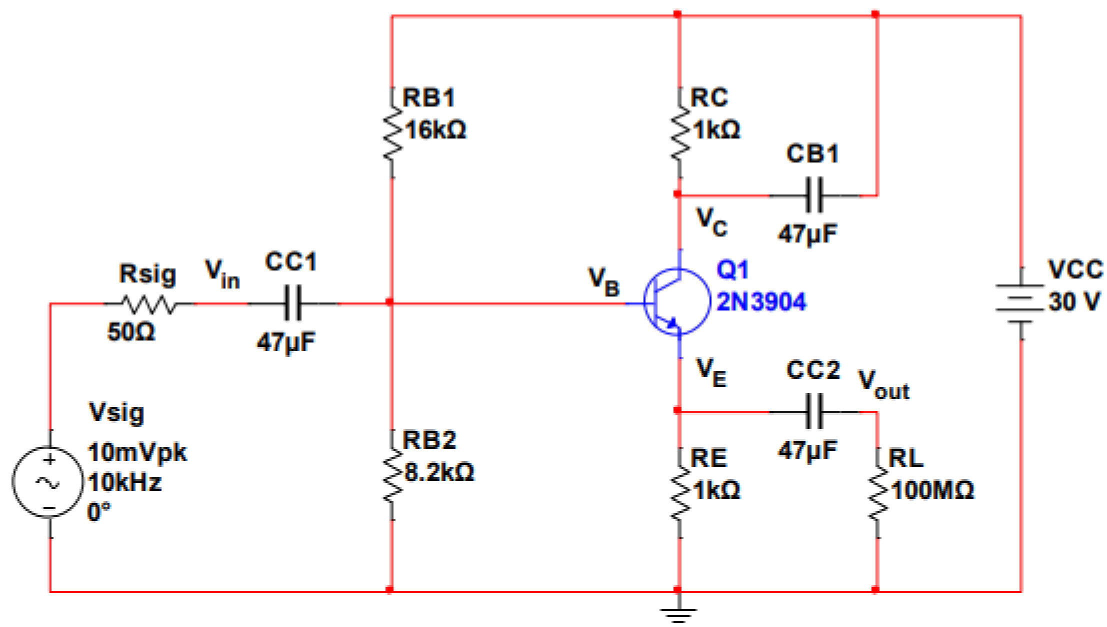

Figure P.5.1 – Common Collector Amplifier

1. **Alter** the common emitter amplifier to match the circuit shown in **Figure P.5.1**.

2. **Perform** a **transient analysis** to plot five cycles of the input and output voltage as labeled in **Figure P.5.1**. Follow the same procedure from above for adjusting the axes if necessary.
   a. **Add data labels** to the peaks of $\mathbf{V_{in}}$ and $\mathbf{V_{out}}$ at the **same** point in time.

3. **Determine** the small signal voltage gain of the amplifier $\mathbf{A_V}$ using the formula $\mathbf{A_V = V_{out}/V_{in}}$ and the peak voltages found above.
   a. Is A_V positive or negative?
   b. For a common collector amplifier, is the input in phase with the output?

Part VI – Common Base (CB) Amplifier

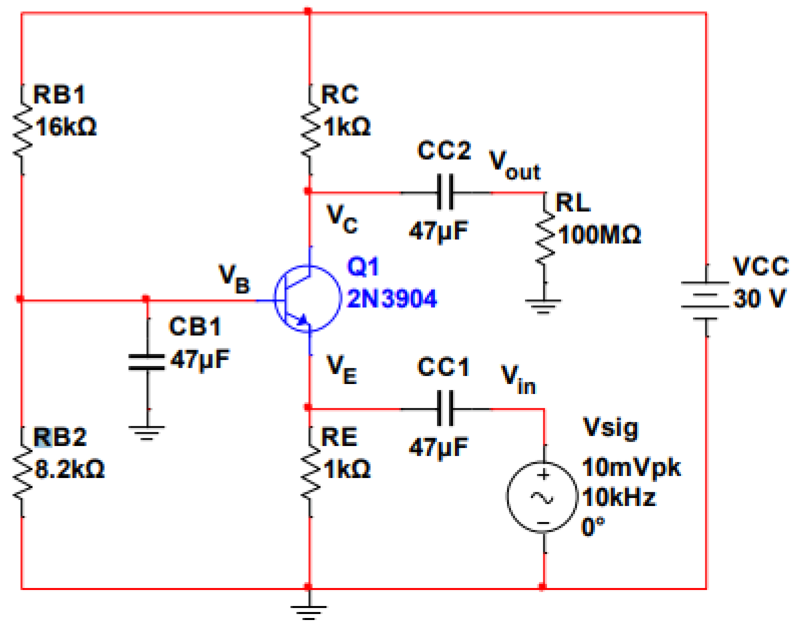

Figure P.6.1 – Common Base Amplifier

1. **Alter** either of the previous amplifiers to match the circuit shown in **Figure P.6.1**.

2. **Perform** a **transient analysis** to plot five cycles of the input and output voltage as labeled in **Figure P.6.1**. Follow the same procedure from above for adjusting the axes if necessary.

   a. **Add data labels** to the peaks of $\mathbf{V_{in}}$ and $\mathbf{V_{out}}$ at the **same** point in time.

3. **Determine** the small signal voltage gain of the amplifier $\mathbf{A_V}$ using the formula $\mathbf{A_V = V_{out}/V_{in}}$ and the peak voltages found above.
   a. Is A_V positive or negative?
   b. For a common base amplifier, is the input in phase with the output?

Notes

Keep the following in mind. These questions do not need to be answered in your prelab but give some thought to them prior to lab.

1. For each amplifier, we have measured V_{out} across a 100MΩ resistor. 100MΩ is so large that it is as if there is no load at all (like an **OPEN** circuit). The 100MΩ resistor is there simply to show where the output is and where a load would be attached.
2. The common emitter and common collector amplifier circuits have a 50Ω resistor in series with V_{sig}. This represents the output impedance of the signal generators in the lab.
3. Notice that the common base amplifier does not have a 50Ω resistor in series with V_{sig}. Why do you think this was necessary?
4. What do you think is the purpose of capacitors C_{C1}, C_{C2}, and C_{B1}? (Hint: think about the bias voltage)

LAB

Part I – Bias Point Verification

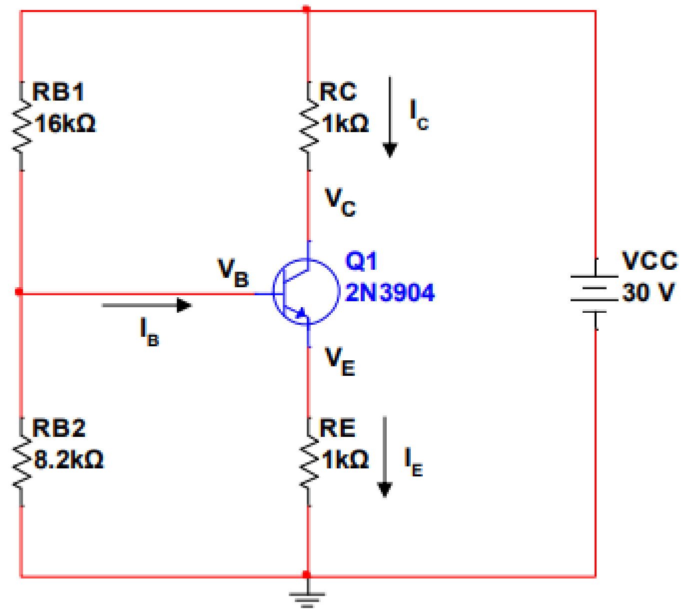

Figure 1.1 – Beta Stabilizing Network

1. **Before building** the circuit in **Figure 1.1**, **measure** the exact resistances of **R_C**, **R_E**, **R_{B1}**, and **R_{B2}** using the DMM. **Record** these values.
2. **Build** the circuit in **Figure 1.1** using transistor 2N3904.
3. **Use** the 2 different 3-24V power supplies to create the 30V potential difference for VCC.
4. **Measure V_B**, **V_E**, **V_C**, **V_{BE}**, **V_{CE}**, and **V_{CB}** using the DMM.
5. **Calculate** (do not measure), **I_B**, **I_C**, **I_E**, and β from the measured voltages and resistances.
6. **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

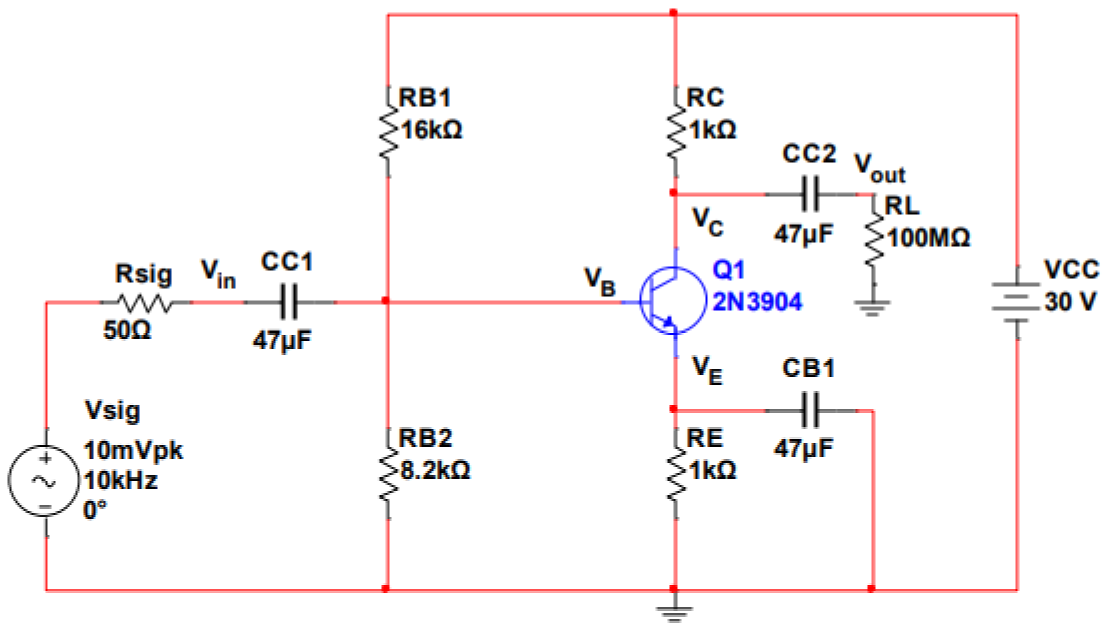

Figure 2.1 – Common Emitter Amplifier

1. **Build** the circuit in **Figure 2.1** using transistor 2N3904.
   a. Do **NOT** include R_{sig} (50Ω) in the construction of your circuit. This represents the output impedance of the function generator (Wavegen).
   b. Do **NOT** include R_L (100MΩ) in the construction of your circuit. This represents the input impedance of the oscilloscope.
2. **Connect** the largest capacitor in your kit between V_{CC} and **ground**.
   a. This removes all the noise from the source. Noise is amplified and mixes with the output.
3. **Apply** the **10mV**, **10kHz** input signal using the function generator (Wavegen) on the AD2.
4. **Use** CH-1 of the oscilloscope on the AD2 to measure 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. If you are experiencing any noise, add a shunt capacitor
   d. **Include** relevant measurements such as V_{max} on the waveform.
5. **Use** CH-2 of the oscilloscope on the AD2 to measure 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 V_{max} on the waveform.
6. **Calculate** A_V from the measured V_{out} and V_{in}.

Part III – Common Collector Amplifier Verification

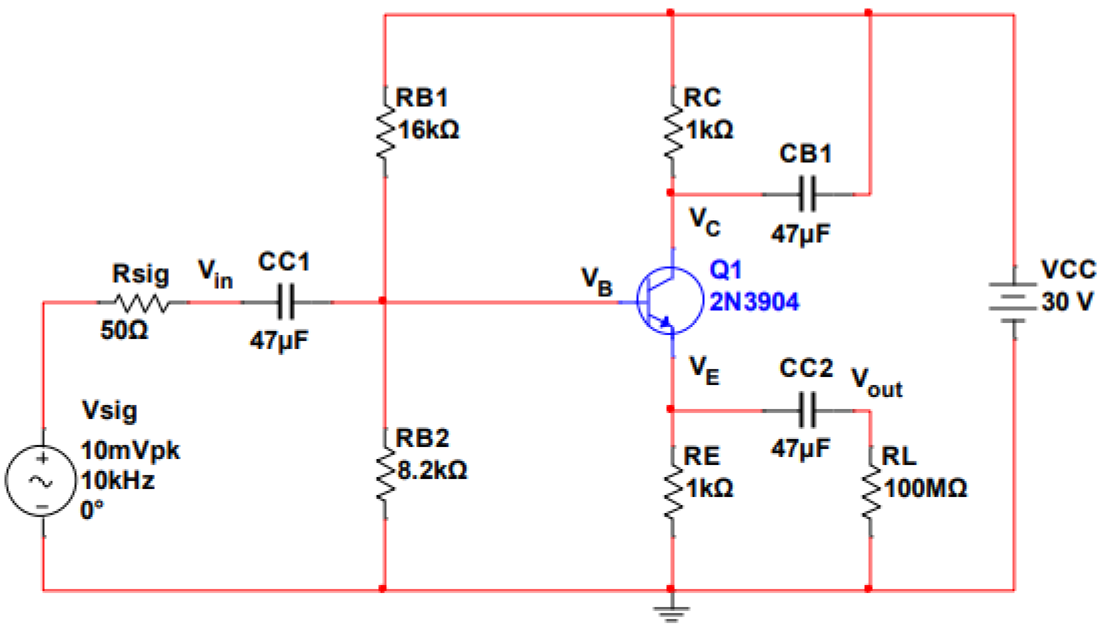

Figure 3.1 – Common Collector Amplifier

1. **Build** the circuit in **Figure 3.1** using transistor 2N3904.
   a. Do **NOT** include R_{sig} (50Ω) in the construction of your circuit. This represents the output impedance of the function generator (Wavegen).
   b. Do **NOT** include R_L (100MΩ) in the construction of your circuit. This represents the input impedance of the oscilloscope.
2. **Connect** the largest capacitor in your kit between $\mathbf{V_{CC}}$ and **ground**.
   a. This removes all the noise from the source. Noise is amplified and mixes with the output.
3. **Apply** the **10mV**, **10kHz** input signal using the function generator (Wavegen).
4. **Use** CH-1 of the oscilloscope to measure 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.**
   c. If you are experiencing any noise, add a shunt capacitor
   d. **Include** relevant measurements such as $\mathbf{V_{max}}$ on the waveform.
5. **Use** CH-2 of the oscilloscope to measure 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.
6. **Calculate** A_V from the measured $\mathbf{V_{out}}$ and $\mathbf{V_{in}}$.

Part IV – Common Base Amplifier Verification

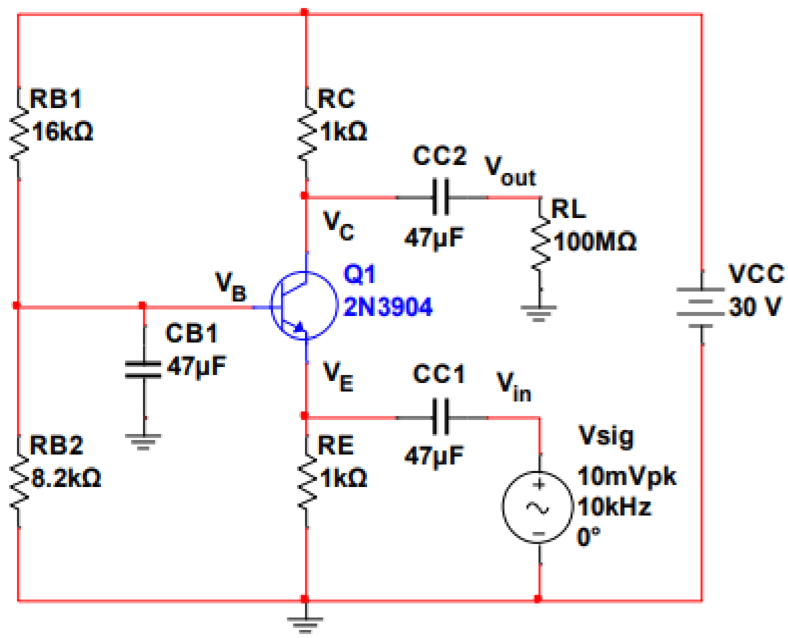

Figure 4.1 – Common Base Amplifier

1. **Build** the circuit in **Figure 4.1** using transistor 2N3904.
   a. Do **NOT** include R_{sig} (50Ω) in the construction of your circuit. This represents the output impedance of the function generator (Wavegen).
   b. Do **NOT** include R_L (100MΩ) in the construction of your circuit. This represents the input impedance of the oscilloscope.
2. **Connect** the largest capacitor in your kit between $\mathbf{V_{CC}}$ and **ground**.
   a. This removes all the noise from the source. Noise is amplified and mixes with the output.
3. **Apply** the **10mV**, **10kHz** input signal using the function generator (Wavegen).

   Note: *The input impedance of the common base amplifier is very small (nearly 1Ω); however, the output impedance of your signal generator is 50Ω. You must determine a way to provide an impedance bridge between your function generator (Wavegen) and the input terminal for your amplifier. Measure V_{in}* ***after*** *your impedance bridge rather than V_{sig} from the function generator (Wavegen).*
4. **Use** CH-1 of the oscilloscope to measure 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.**
   c. If you are experiencing any noise, add a shunt capacitor
   d. **Include** relevant measurements such as $\mathbf{V_{max}}$ on the waveform.
5. **Use** CH-2 of the oscilloscope to measure 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.
6. **Calculate** A_V from the measured $\mathbf{V_{out}}$ and $\mathbf{V_{in}}$.

<u>POST-LAB ANALYSIS</u>

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** was the purpose of $\mathbf{C_{C1}}$, $\mathbf{C_{C2}}$, and $\mathbf{C_{B1}}$ in the amplifier circuits?
5. **What** does the word "**common**" mean in each amplifier circuit?
6. **Discuss** the **impedance bridging** circuit necessary in the case of the common base amplifier.
7. **Why** was an impedance bridging circuit **not necessary** for the common emitter and common collector amplifiers?