

The George Washington University
School of Engineering and Applied Science
Department of Electrical and Computer Engineering
ECE 20 - LAB
Experiment # 5

Biasing an NPN BJT - Introduction to CE, CC, CB Amplifiers

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	16k Ω Resistor	R1
Resistor	R	8.2k Ω Resistor	R2
Resistor	R	1k Ω Resistor	RC
Resistor	R	1k Ω Resistor	RE

Table 1.1

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 spice simulation

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. For the circuit in figure P.1, hand calculate the values for I_B , I_E , I_C , V_B , V_E , V_C , V_{BE} , V_{CE} , & V_{CB} ; assume $\beta=180$; show all work. Read the tutorial "Bias Point Analysis in SPICE" for help.
3. Build the circuit in figure P.1 in SPICE, use part Q2N3904 for Q1. Perform a Bias Point Analysis for the circuit in SPICE. Show the DC voltages and DC currents at each node; submit a separate screenshot for each.

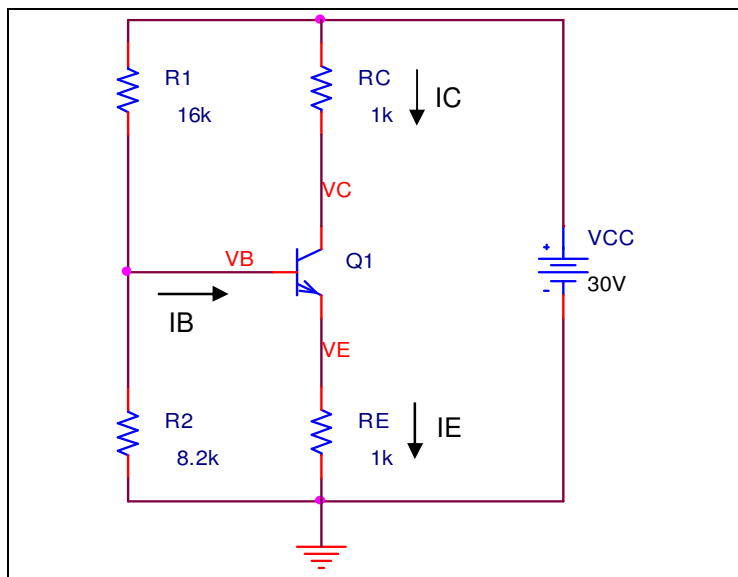


Figure P.1- Beta Stabilizing Network

Common Emitter (CE) Amplifier

4. Using the biasing circuit you've constructed for the BJT, apply a small input signal (10mV @10kHz) to the base of the transistor, as shown in figure P.2. We refer to this signal as "**Vsig**"
 - a) Perform a transient simulation, plot 5 cycles of the voltage coming off the **collector** terminal. This signal will be considered "**Vout**."
 - i. In the plot window, choose from the menu: Plot ->Add Plot to Window
 - ii. Return to the schematic and place a voltage probe on **Vin (NOT Vsig)**; each probe should have its own y-axis with a common x-axis in the plot window.
 - iii. Place a label at the peak of **Vin**, and peak of **Vout**; make sure to mark this at the same point in time.
 - b) Determine the small signal voltage gain of the amplifier A_v , using the formula: $A_v = V_{out}/V_{in}$, use the peak voltages found in step a)iii) above.
 - i. Is A_v positive or negative?
 - ii. For a common emitter amplifier, is the input in phase with the output?

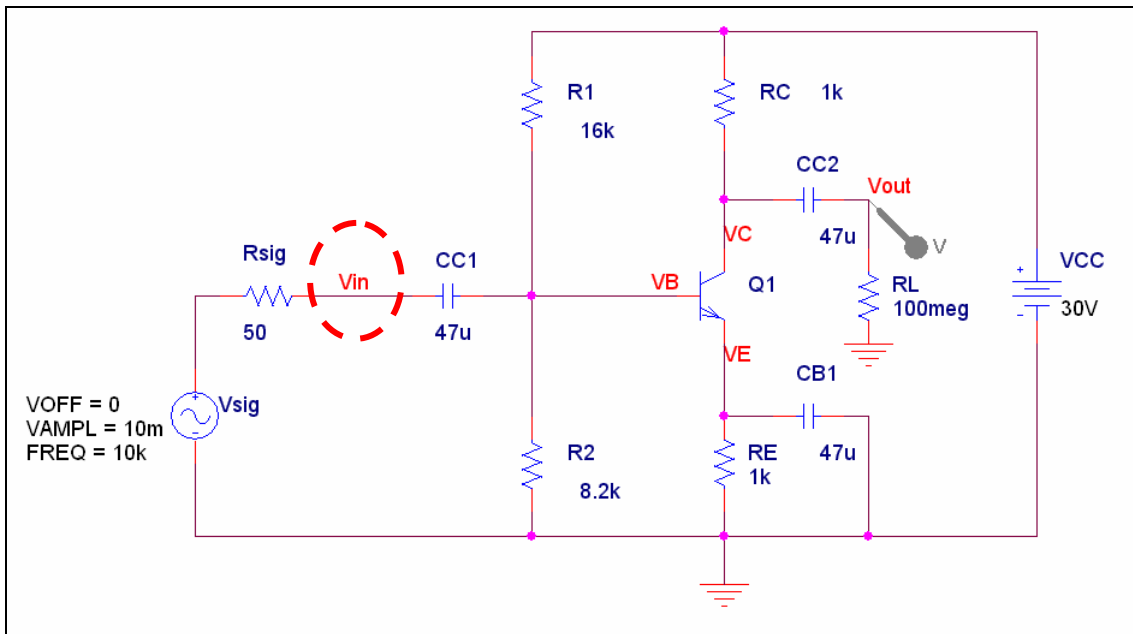


Figure P.2 – Common Emitter Amplifier

Common Collector (CC) Amplifier

5. Alter the circuit constructed in P.2 to match the circuit shown in figure P.3. This is known as a Common-Collector configuration. Apply a small input signal (10mV @10kHz) to the base of the transistor, as shown in figure P.3.
- Perform a transient simulation, plot 5 cycles of the voltage coming off the **emitter** terminal. This signal will be considered "**Vout**."
 - In the plot window, choose from the menu: Plot ->Add Plot to Window
 - Return to the schematic and place a voltage probe on **Vin** (*not Vsig*); each probe should have its own y-axis with a common x-axis in the plot window.
 - Place a label at the peak of **Vin**, and peak of **Vout**; make sure to mark this at the same point in time.
 - Determine the small signal voltage gain of the amplifier A_v , using the formula: $A_v = V_{out}/V_{in}$, use the peak voltages found in step a)iii) above.
 - Is A_v positive or negative?
 - For a common collector amplifier, is the input in phase with the output?

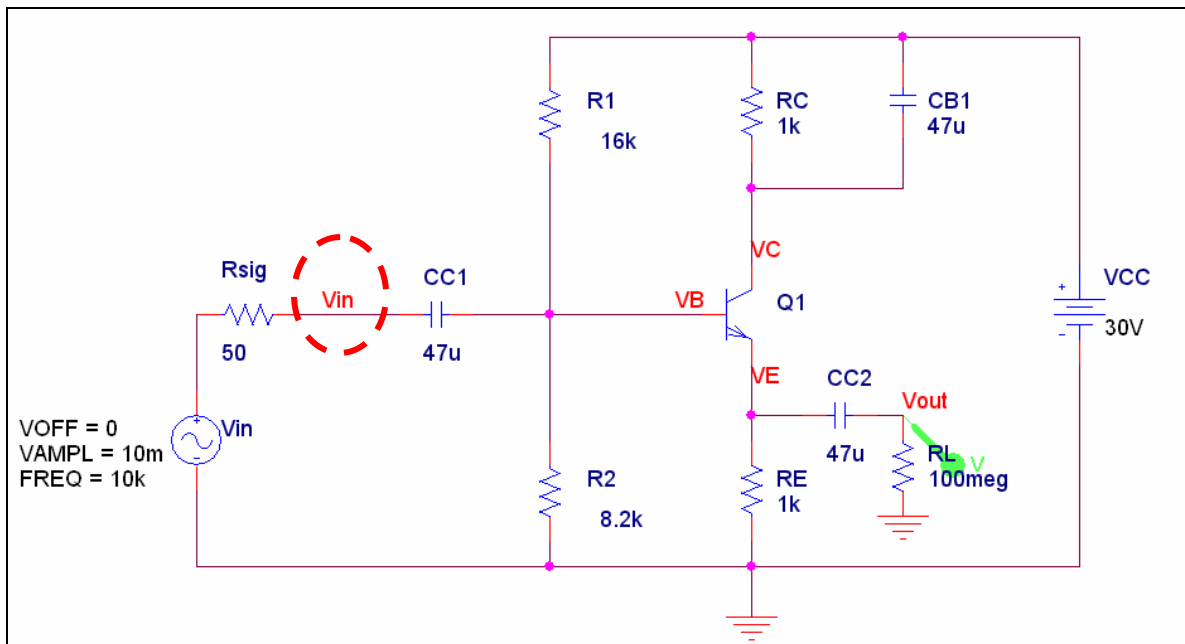


Figure P.3 – Common Collector Amplifier

Common Base (CB) Amplifier

6. Alter the circuit constructed above to match the circuit shown in figure P.4. This is known as a Common-Base configuration. Apply a small input signal (10mV @10kHz) to the emitter of the transistor, as shown in figure P.4.
 - a) Perform a transient simulation, plot 5 cycles of the voltage coming off the **collector** terminal. This signal will be considered “**Vout**.”
 - i. In the plot window, choose from the menu: Plot ->Add Plot to Window
 - ii. Return to the schematic and place a voltage probe on **Vin**; each probe should have its own y-axis with a common x-axis in the plot window.
 - iii. Place a label at the peak of **Vin**, and peak of **Vout**; make sure to mark this at the same point in time.
 - b) Determine the small signal voltage gain of the amplifier A_v , using the formula: $A_v = V_{out}/V_{in}$, use the peak voltages found in step a)iii) above.
 - i. Is A_v positive or negative?
 - ii. For a common base amplifier, is the input in phase with the output?

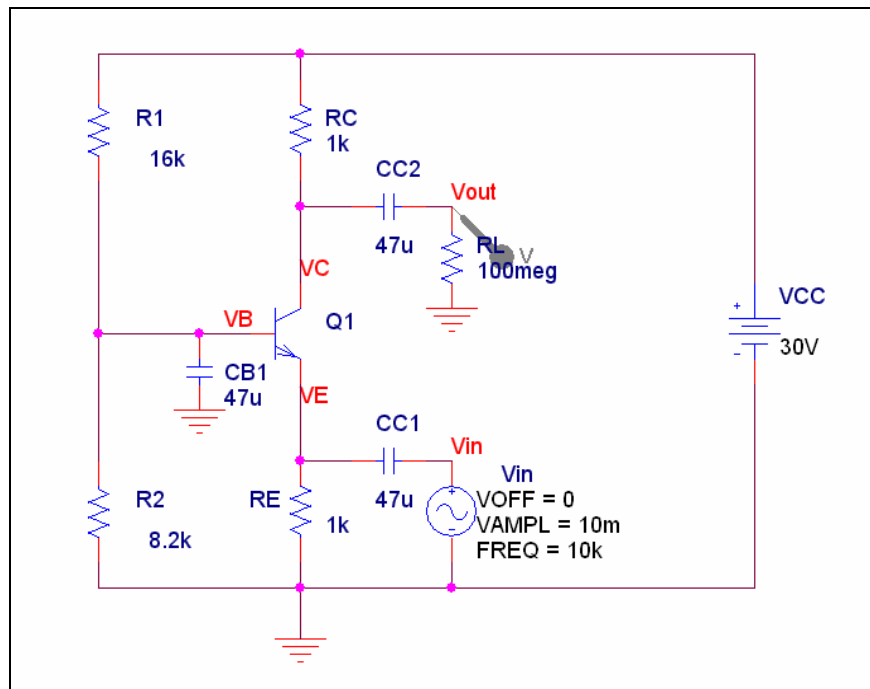


Figure P.4 – Common Base Amplifier

Things to notice (not to answer in prelab, but to give some thought to prior to lab):

- For each amplifier, we’ve measured V_{out} across a 100M Ohm resistor. 100 MOhm is so large it as if there is no load at all (like an OPEN circuit). The 100MOhm resistor is simply to satisfy SPICE.
- Circuits P2-P3 have a 50 Ohm resistor as V_{sig} . This represents the output impedance of the signal generators in the lab.
- Notice that circuits P4 does not have a 50 Ohm resistor as V_{sig} . Why do you think this was necessary?
- What do you think is the purpose for capacitors: CC1, CC2, CB1? (Hint: think about the bias voltage)

LAB:

Bias Point Verification

- Construct circuit in figure P.1 using transistor: 2N3904
- Use the +25 / -25 terminals on the power supply to create the 30V potential diff for: VCC
- Measure V_B , V_E , V_C , V_{BE} , V_{CE} , & V_{CB} using the Keithley 175 DMM
- Calculate (do not measure), I_B , I_C , and I_E
- 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.

Common Emitter Amplifier

- Construct circuit in figure P.2 in using transistor: 2N3904
 - Do NOT include RSIG (50ohm) in the construction of your circuit, this represents the output impedance of the signal generator
 - Do NOT include RL (100MOhm) in the construction of your circuit, this represents the input impedance of the oscilloscope
 - Connect a largest capacitor in your kit between VCC and ground
 - This will remove all the noise from the source. The noise is amplified and mixes with the output.
- Apply the 10mV, 10kHz input signal using the function generator
- Use Channel 1 of the digital oscilloscope to measure v_{in}
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 1 is set for AC coupling
 - For channel 1, use the scope to set a bandpass filter to clear the noise from the circuit
- Use Channel 2 of the digital oscilloscope to measure v_{out}
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 2 is set for AC coupling
 - For channel 2, use the scope to set a bandpass filter to clear the noise from the circuit
- Determine A_v from the measured V_{out} , V_{in}

Common Collector Amplifier

- Construct circuit in figure P.3 in using transistor: 2N3904
 - Do NOT include RSIG (50ohm) in the construction of your circuit, this represents the output impedance of the signal generator
 - Do NOT include RL (100MOhm) in the construction of your circuit, this represents the input impedance of the oscilloscope
 - Connect a largest capacitor in your kit between VCC and ground
 - This will remove all the noise from the source. The noise is amplified and mixes with the output.
- Apply the 10mV, 10kHz input signal using the function generator
- Use Channel 1 of the digital oscilloscope to measure v_{in}
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 1 is set for AC coupling
 - For channel 1, use the scope to set a bandpass filter to clear the noise from the circuit
- Use Channel 2 of the digital oscilloscope to measure v_{out}
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 2 is set for AC coupling
 - For channel 2, use the scope to set a bandpass filter to clear the noise from the circuit
- Determine A_v from the measured V_{out} , V_{in}

Common Base Amplifier

- Construct circuit in figure P.4 in using transistor: 2N3904
 - Do NOT include RL (100M Ω) in the construction of your circuit, this represents the input impedance of the oscilloscope
 - Connect a largest capacitor in your kit between VCC and ground
 - This will remove all the noise from the source. The noise is amplified and mixes with the output.
- Apply the 10mV, 10kHz input signal using the function generator
 - **The input impedance of the common-base amplifier is very small (nearly 1 Ω), the output impedance of your signal generator is 50 Ω . You must determine way to provide an impedance bridge between your function generator & the input terminal for your amplifier**
 - **Measure V_{in} AFTER your impedance bridge (not what comes out of the function generator, that is V_{sig})**
- Use Channel 1 of the digital oscilloscope to measure v_{in} (**NOT V_{sig}**)
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 1 is set for AC coupling
 - For channel 1, use the scope to set a bandpass filter to clear the noise from the circuit
- Use Channel 2 of the digital oscilloscope to measure v_{out}
 - You CANNOT use autose. Determine the proper period for the 10kHz signal
 - Ensure channel 2 is set for AC coupling
 - For channel 2, use the scope to set a bandpass filter to clear the noise from the circuit
- Determine A_v from the measured V_{out} , V_{in}

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 was the purpose of CC1, CC2, & CB1 in the amplifier circuits? What does the word "common" mean in each amplifier circuit?
- Discuss the impedance bridging circuit necessary in the case of the common-base amplifier.
- Why was an impedance bridging circuit not necessary for the common-emitter, and common-collector amplifiers?