

Lab 4: BJT Amplifiers – Part I

Objectives

The objective of this lab is to learn how to operate BJT as an amplifying device. Specifically, we will learn the following in this lab:

- The physical meaning of the low-frequency small-signal parameters of BJT and ways to measure them
- The three configurations of BJT amplifiers, i.e., common emitter (CE), common collector (CC), and common base (CB). CE configuration is also referred to as the “inverter” configuration, and CC and CB are referred to as the emitter (or voltage) follower and current buffer, respectively.
- BJT is always biased in the forward-active region (FAR) in an amplifier
- The transfer function for the three BJT amplifier configurations
- The meaning of biasing for transistor circuits

Introduction

This lab will equip you with the knowledge and understanding to explain the behavior of BJT in two of the three amplifier configurations mentioned above. You will learn how to bias a BJT in FAR and how to set the operating point for an amplifier.

For detailed theory about the three configurations, please refer to Chapter 6 (Bipolar Junction Transistors) of Sedra & Smith or an equivalent text.

Preparation

1. Simulate in PSpice the CE amplifier in Fig. 4-2.
 - Obtain the transfer function of the amplifier.
 - Determine the DC input voltage to bias the BJT in the center of the linear region.
 - Determine the small-signal (AC) gain of the amplifier at the operating point above.
2. Repeat step 2 for the emitter follower in Fig. 4-3.

Procedure

1. Small-signal parameters of BJT

We will use the configuration shown in Fig. 4-1 to measure the small-signal parameters of the BJT to be used in all remaining parts of this lab. In this circuit, the BJT needs to remain in FAR in order to provide a large voltage gain (please refer to Lab 3 or your textbook about the definition of FAR if necessary). To bias the BJT in FAR, you will need to vary the base current I_B to make sure that the collector voltage is close to $V_{CC}/2$. A load resistor of 1k is to be used in this circuit.

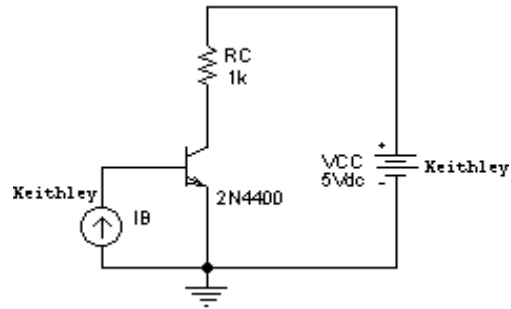


Figure 4-1: Configuration used to measure small-signal BJT parameters

- g_m : Transconductance, defined as

$$g_m = \left. \frac{\partial I_C}{\partial V_{BE}} \right|_{V_{CE}=\text{constant}} \quad (4-1)$$

This parameter is found by measuring the ratio of the incremental changes in collector current and base-emitter voltage by slightly varying the base current from the operating point. You will need to vary V_{CC} to make sure that V_{CE} is constant in your measurement.

- β_0 : AC current gain, defined as

$$\beta_0 = \left. \frac{\partial I_C}{\partial I_B} \right|_{V_{CE}=\text{constant}} \quad (4-2)$$

This parameter is found by measuring the ratio of the incremental changes in collector current and base current by slightly varying the base current from the operating point. You will also need to vary V_{CC} to make sure that V_{CE} is constant in your measurement.

- r_π : Input resistance, or base-emitter resistance, defined as

$$r_\pi = \left. \frac{\partial V_{BE}}{\partial I_B} \right|_{V_{CE}=\text{constant}} \quad (4-3)$$

This parameter is found by measuring the ratio of the incremental changes in base-emitter voltage and base current by slightly varying the base current from the operating point. You will also need to vary V_{CC} to make sure that V_{CE} is constant in your measurement.

- r_o : Output resistance, or collector-emitter resistance, defined as

$$r_o = \left. \frac{\partial V_{CE}}{\partial I_C} \right|_{V_{BE}=\text{constant}} \quad (4-4)$$

This parameter is found by measuring the ratio of the incremental changes in collector-emitter voltage and collector current by slightly varying V_{CC} . How would you make sure V_{BE} is constant in this measurement?

- $V_{CE,SAT}$: Saturation voltage is the minimum voltage you will see across the collector-emitter junction. To measure this value you can increase the base current until you see no significant decrement in the collector-emitter voltage.

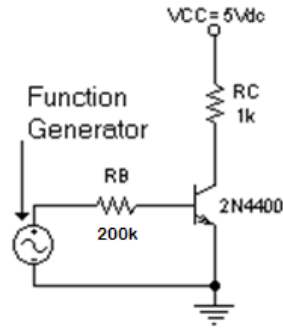


Figure 4-2: CE amplifier

2. Common-emitter amplifier

- Measure the I-V characteristic of the BJT using the program *BJT_IV_curve.vi*. Draw the load line of the CE amplifier in Fig. 4-2 on top of the I-V characteristic.
- Use the program *tranchar.vi* to obtain the transfer function of the amplifier.
- Use the information from the above steps to find the DC voltage of the input needed to place the BJT operating point in the middle of the linear region of the transfer function. This should yield a V_{CE} not too far from $V_{CC}/2$.
- Use the function generator as the input source, and set it up as follows
 - Waveform: sinusoidal
 - Offset: the DC input voltage you found
 - Amplitude: 0.1V
 - Frequency: 1kHz
- Use the oscilloscope to view the input and output waveforms. Record the small-signal (AC) voltage gain and the DC values of the collector voltage and the collector current.
- Increase the amplitude of the function generator until you see the output clipped at the top and bottom of the sine wave. Then use the XY display mode of the oscilloscope, and set the input signal to Channel 1 and the output signal to Channel 2. What you will see here is the transfer function of the CE amplifier. Use the cursors to measure the maximum as well as the minimum output voltages.

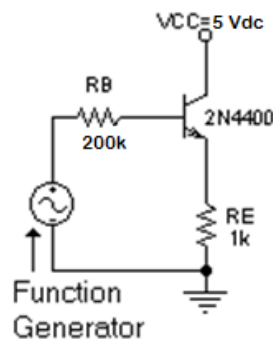


Figure 4-3: Emitter follower

3. Emitter follower

- Draw the load line of the emitter follower in Fig. 4-3 on top of the BJT I-V characteristic. Note that the load is R_E in this case (the output node of your follower is the emitter). You may assume $I_E \approx I_C$ in this step.
- Use the program *tranchar.vi* to obtain the transfer function of the follower.
- Use the information from the above steps to find the DC voltage of the input needed to place the BJT operating point in the middle of the linear region of the transfer function.
- Use the function generator as the input source, and set it up as follows
 - Waveform: sinusoidal
 - Offset: the DC input voltage you found
 - Amplitude: 0.1V
 - Frequency: 1kHz
- Use the oscilloscope to view the input and output waveforms. Record the small-signal (AC) voltage gain and the DC values of the emitter voltage and the collector current.
- Increase the amplitude of the function generator until you see the output clipped at the top and bottom of the sine wave. Then use the XY display mode of the oscilloscope, and set the input signal to Channel 1 and the output signal to Channel 2. What you will see here is the transfer function of the follower. Use the cursors to measure the maximum as well as the minimum output voltages.

Analysis

1. Using your knowledge about the small-signal parameters and the measured operating points of the BJT circuits, sketch the transfer function of the CE and emitter follower configurations you studied in this experiment. Compare your sketches with the curves you measured in the lab. What other information would you like to know in order to match your sketch to the measurement results precisely?
2. Is the value of R_B critical for the CE amplifier and the emitter follower? How sensitive is the amplifier small-signal (AC) gain to R_B ?

Lab 4 Report Instructions

Besides the general guidelines, report the following for this lab:

CE amplifier

1. Plot I-V curves for BJT with load line, show the load line equation used.
2. Sketch (by hand, PSpice or any drawing program) the CE circuit.
3. Plot V_{out} vs. V_{in} curve (transfer function curve), show the range of the linear region ($V_{in,min}$, $V_{out,max}$) and ($V_{out,min}$, $V_{out,max}$) and gain computed from the slope.
4. Show $V_{in,middle}$ and $V_{out,middle}$ in linear region.
5. Show AC gain obtained from oscilloscope readings, and the DC values of the V_{out} and I_{out} .
6. Show the V_{in} value to achieve V_{out} clipping. Explain why clipping occurred at this value.

Emitter follower

1. Plot I-V curve for BJT with load line, show the load line equation used.
2. Sketch (by hand, PSpice or any drawing program) the follower circuit.
3. Plot V_{out} vs. V_{in} curve (transfer function curve), show the range of the linear region ($V_{in,min}$, $V_{out,max}$) and ($V_{out,min}$, $V_{out,max}$) and gain computed from the slope. Explain the difference between the follower and the CE amplifier.
4. Show $V_{in,middle}$ & $V_{out,middle}$ in linear region.
5. Show AC gain obtained from oscilloscope readings, and the DC values of the V_{out} and I_{out} .
6. Show the V_{in} value to achieve V_{out} clipping. Explain why clipping occurred at this value.

Answer the questions in the Analysis section.