

## EE321 – Lab 9

## Bipolar Junction Transistors, Part II

In this lab we will investigate two bipolar junction transistor (BJT) amplifiers.

## The Common Emitter Amplifier

The amplifier circuit of last week's lab is impractical because the bias or operating point depends on the  $\beta$  of the transistor. The following bias technique controls the voltage across  $R_E$  and hence the emitter current  $I_E$ . It is similar to Example 4.7 of Sedra and Smith.

1. Construct the circuit in Figure 1 and measure the DC bias voltages at the base, emitter and collector. From your measurements, determine  $V_{BE}$  and  $V_{BC}$ . Is the transistor biased in its active mode? What are the DC (Q 'quiescent') values of  $I_C$  and  $I_E$ ?
2. Apply a triangle wave to the input and measure the voltage gain. Is the gain close to that found in the prelab?
3. The voltage gain can be increased by decreasing  $R_E$ . Reduce  $R_E$  to zero for signal frequencies by 'bypassing' it with a large capacitor ( $100\ \mu\text{F}$ ) in parallel with  $R_E$ . (Be sure to observe the correct polarity of the electrolytic capacitor.) Reduce the input amplitude and look at the output waveform.

Further reduce the input amplitude until the output is approximately linear and measure the gain. The gain has been increased to the large values, but at what expense?

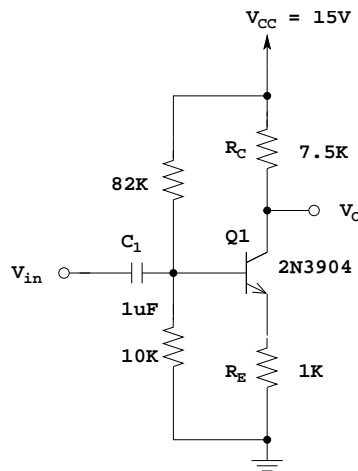


Figure 1.

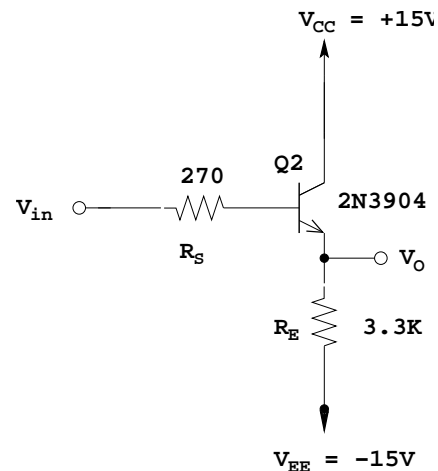


Figure 2.

## The Emitter Follower Amplifier

4. When the input signal is applied to the base and the output is taken at the emitter (Figure 2) the amplifier is called an *emitter follower*. This is because the emitter voltage 'follows' the base voltage. Emitter follower amplifiers are useful because they have a high input impedance and a low output impedance. They amplify the signal power by increasing its current, and are therefore sometimes called a 'current booster'.

Construct the circuit in Figure 2.

- With zero (ground input) or small input signal, measure and note the DC bias voltages.
  - With an input, measure the voltage gain (magnitude and sign).
  - The dynamic range of the output is the largest that it can be without saturating or clipping. Measure the dynamic range of the output voltage (decrease the supply voltages to  $\pm 12$  and measure both  $v_{out}$  limits). What causes the output to limit in each case (when is the transistor saturated, active, cutoff)?
  - What would happen to  $v_{out}$  if the emitter resistor were connected to ground instead of  $-15V$ ? Try it. What does this mean?
5. Measure  $Z_{in}$  at the base of the transistor in the following way.
- Increase the source resistance  $R_S$  until  $v_{out}$  is reduced by about 1/2 (or by some other value).
  - Sketch the equivalent circuit (use an equivalent circuit of an amplifier from Chapter 1, not the transistor model) and compute  $Z_{in}$  from your measurement.
  - From the theoretical result that  $Z_{in} = (\beta + 1)[r_e + R_E]$  and  $r_e = \alpha/g_m$ , estimate the  $\beta$  of your transistor.
6. Simulate an input source with  $10\text{ k}\Omega$  source resistance by setting  $R_S = 10\text{ k}\Omega$  (see Figure 3). Measure the output impedance  $Z_{out}$  by loading the output with about  $220\text{ }\Omega$  resistance. Use a DC blocking capacitor as shown to prevent the load from changing the bias voltages. Ensure that the capacitive impedance is small compared to  $220\text{ }\Omega$  by working at a signal frequency of about  $10\text{ kHz}$ . Decrease the input until the output is not clipped.

Sketch an equivalent circuit for the amplifier output and compute  $Z_{out}$  from your measurement. Compare with the theoretical value  $Z_{out} = [r_e + (R_S/(\beta + 1))] \parallel R_E$ . How much output voltage would you have gotten by connecting  $R_L$  directly to the source? ( $R_S$  is part of the source.) What does this show?

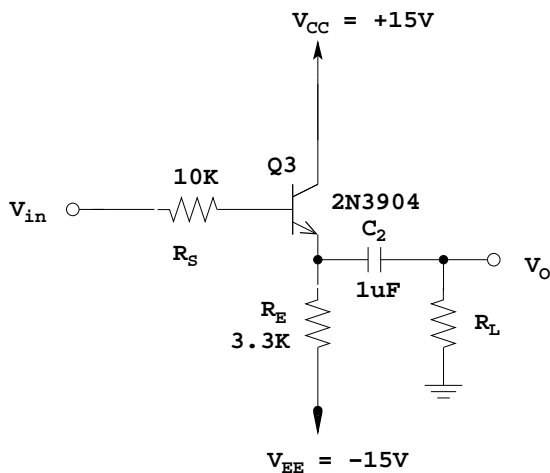


Figure 3.

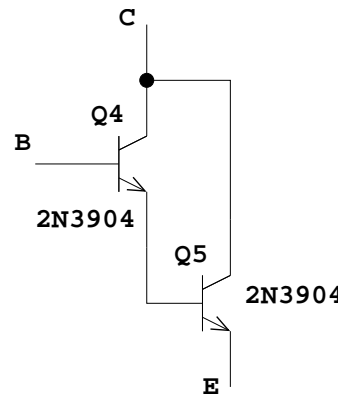


Figure 4.

7. **Extra Credit.** In the emitter follower (Figure 3) replace the transistor by two transistors connected in a Darlington configuration, (Figure 4): What is the effective beta of this ‘super beta’ transistor? Measure  $Z_{in}$  and  $Z_{out}$  of the follower now.

**Pre-Lab**

1. Find the gain for the circuit in Figure 1. The gain is approximately equal to the ratio  $R_C/R_E$ . This is because  $v_{in}$  controls  $v_e$ , and  $v_e = i_e R_E$  and because  $i_c \approx i_e$ .
2. Consider the emitter follower in Figure 2.
  - With  $V_B = 0$  V, find the bias currents. Use these to find  $r_e$  for the transistor model.
  - Find the input and output resistance of this circuit. The formulas are given in Parts 5 and 6. Assume a  $\beta$  of 200. (See Pages 290 to 295 of Sedra and Smith for the derivations.)
3. Consider a source, an amplifier, and a load (as was done in Chapter 1). The source is a sine wave with a 1 V amplitude and a source resistance of 10 k $\Omega$ . The amplifier has a voltage gain of 1, an input resistance and an output resistance as found above. The load is 220  $\Omega$ .
  - (a) What is the output voltage if the load is connected directly to the source?
  - (b) What is the output voltage if the source is connected to the input of the amplifier and the load to its output?