EE321 – Lab 11

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 β 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 5.10 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 ($100\ \mu$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?
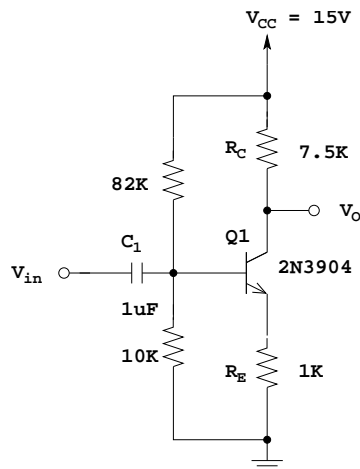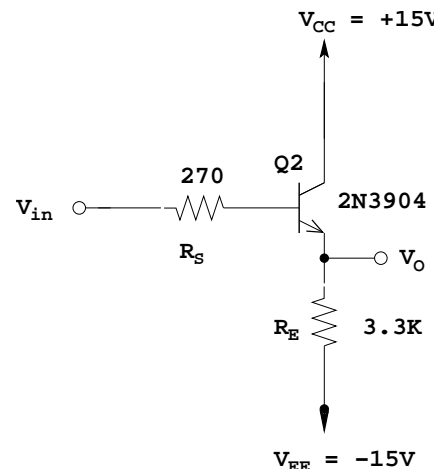

Figure 1.

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 ± 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 β of your transistor.

6. Simulate an input source with 10 kΩ source resistance by setting $R_S = 10$ kΩ (see Figure 3). Measure the output impedance Z_{out} by loading the output with about 220 Ω 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 Ω by working at a signal frequency of about 10 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?
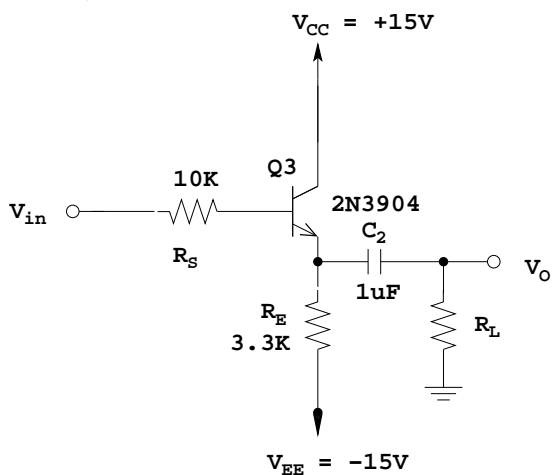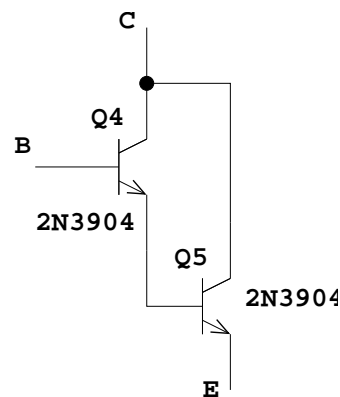

Figure 3.

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 β of 200. (See Pages 478 to 483 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 kΩ. The amplifier has a voltage gain of 1, an input resistance and an output resistance as found above. The load is 220 Ω.

   (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?