**Lab 7: Bipolar Junction Transistors**

U.C. Davis Physics 116A

**INTRODUCTION**

The purpose of this lab is to measure some DC and AC characteristics of a transistor (a bipolar junction transistor, or BJT) in two useful circuit configurations, the emitter follower amplifier and the common emitter amplifier. Background material for this lab can be found in the text, *Bobrow,* sections 7.1-7.3 and 9.1.

**1. DC properties of BJT in the Common Collector Configuration**

In this section, you will see what the transistor does in a common collector (emitter follower) circuit and what the entire circuit does. Construct the emitter follower circuit shown in figure 1.



Figure 1: An emitter follower amplifier

 First we will examine the base-emitter junction. Use the potentiometer to set *V*B to approximately 0.25, 0.5, 0.7, 1.0, 2, 4, 8, and 14 volts. For each setting measure *V*B, *V*in, and *V*E. From these data, calculate *VBE =VB -VE*, *I*B and *I*E from Ohm's law, *I*C *I*E *I*B, and *h*fe *I*C /*I*B. Put all of this in one data table.

 To analyze these data, plot *I*B *vs. V*BE. This will look like a nearly vertical line, but since the base-emitter junction is a forward biased diode, it is actually part of diode exponential curve. On the same graph, plot a calculated diode curve that approximately fits your data. Also on the same graph, indicate how a straight line can fit these data points fairly well. This line represents an "effective resistance" *rpi* for the base of the transistor. From the slope of this line, calculate *rpi* using Ohm's law.

 Now plot ln(*IB*) *vs. VBE.* In Lab 6, we made similar plots for diodes. We noted that:



Do the data for the base-emitter junction fall on a straight line in your log-lin plot? If so, do the slope and intercept has the values that you would expect?

 Now, looking at the data and both of the graphs, answer these questions: What is the range of *V*BE? Does *V*BE stay at approximately 0.7V? What does it mean for a transistor to be in its "active region"? Does the transistor stay in its active region? Is ? Is (within a factor of 2)? A BJT in common-collector configuration is often described as a "current amplifier". How is this transistor functioning as a current amplifier in this circuit?

 For your lab report, include the data table, the two *I*B *vs. V*BE graphs with data points and calculated curves, and a discussion which includes answers to the questions in the previous paragraph.

**2. DC properties of the Common Emitter Amplifier**

In this section, you will build and analyze a common emitter amplifier, a popular transistor amplifier circuit. Use 1 k resistors for *RC* and *RE*. Use a 10 k resistor for *RB*. Build the amplifier as shown in figure 2.



Figure 2: A common emitter amplifier (DC config.)

 First, set VB to 5.75 V. Now, find the bias conditions of the transistor. That is, find the voltages and currents in the circuit with no AC input signal. This is also called the "quiescent point", the "operating point", or the "DC" conditions for the circuit. To do this, measure *Vin*, *V*B, *V*E , and *V*C. Then use Ohm's law to calculate *IB*, *I* E and *I*CQ . Compare the *IB* you get using Ohm’s law to  using the you found in section 1. What value do you get for *V*BE? Is the transistor in the active region?

 We are now going to map out the *iC* vs. *vCE*characteristic of this transistor. First draw in the DC load line and identify the Q point. You will now make a series of measurements. For each setting, you will measure *VC, VE, Vin,* and *VB*. You will use those data to calculate *iB, iE, iC,* and *vCE.* You will use four different collector resistors, *RC* = 470 , 1 k, 1.5 k, and 2.2 k. For each *RC*, you will set the potentiometer to generate four different base currents, iB = 10, 20, 30, 40 A. Once you have made all of these measurements, draw a family of four *iC* vs. *vCE* characteristic curves, and draw the four corresponding load lines.

**3. AC properties of the CE amplifier**

Now we will study the AC performance of this amplifier. First consider the bias resistors, *R1* and *R2*. Remember the design parameter for the bias resistors is that *RB* < (0.1) (**)(*REAC*), where *REAC* is the AC resistance on the emitter (*RE*||*RE2* from fig. 3), and *RB* = *R1*||*R2*. Select a combination of resistors that will give a *VBB* = 5.75 V. Recall that *R1*=*RB/(1-VBB/VCC)*, and *R2=RBVCC/VBB*. Try to select single resistors for *R1* and *R2*. Pick values close to your design rather than using combinations of multiple resistors. Remember resistors have a 5% variation, so you do need to more accurate than 5% (otherwise you would be using more expensive 1% resistors).

 Replace the potentiometer from the Fig. 2 circuit with bias resistors *R1* and *R2* as shown in Fig. 3. These bias resistors set the Q point of the amplifier. Then connect the function generator as *v*in. Use a 0.1 F capacitor for *Cin.* Set the function generator to generate a 0.5V peak-to-peak 10kHz sine wave as the input signal. (Note: the emitter bypass capacitor and the load capacitors not yet connected. These are still open circuits). Monitor *v*in and *v*out simultaneously with the oscilloscope (Channels 1 and 2, be sure to AC couple channel 2) and sketch them on the same set of axes. Measure the gain of this amplifier. Compare it to the calculated gain, *RC/ RE*. Why should the gain of this amplifier be *RC/RE* and not ? Note the phase difference from input to output. Many amplifiers invert the signals they amplify.

 Explore the behavior of the amplifier a little more by using different frequencies (100 Hz, 1 kHz, 10 kHz, 100 kHz – Keep *vin* at 0.5 V), and amplitudes for *v*in (0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0 – Keep *vin* at 10 kHz). The output of an ideal amplifier should always look just like the input multiplied by the gain. However, real amplifiers only work correctly over a limited range of output voltages and frequencies. Determining these ranges is an important part of 116A's classroom work. See if you can determine approximately the minimum and maximum frequencies for which the gain is constant. Also, see if you can determine the range of acceptable output voltages. Try to determine what causes each of these limits.

 Measure the DC output level at *VC*. (Make sure to take the AC coupling off channel 2 to make this measurement). Next connect a 0.1 F load capacitor and a 1 k load resistor, now measure the DC level of *Vout* at the load resistor. Why is this different? Has the gain changed with the load resistor connected? Next connect a 4.7 F emitter bypass capacitor and a 100  RE2. What is the gain now? Is it what you expected? Draw the AC load line for these three configurations. Explore the limits to the output voltage swing for each configuration.

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Figure 3: A common emitter amplifier (AC config.)

**4. Properties of pnp transistors**

How would you modify your circuit to use a 2N3906 pnp transistor? Try it. Do you get the gain that you expect?