Lab 6: Transistors (Part 1, BJT's)

U.C. Davis Physics 116A

INTRODUCTION

The purpose of this lab is to measure some 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. EMITTER FOLLOWER (COMMON COLLECTOR) AMPLIFIER

In this section, you will see what the transistor does in an emitter follower circuit and what the entire circuit does. Construct the emitter follower circuit shown in figure 1.

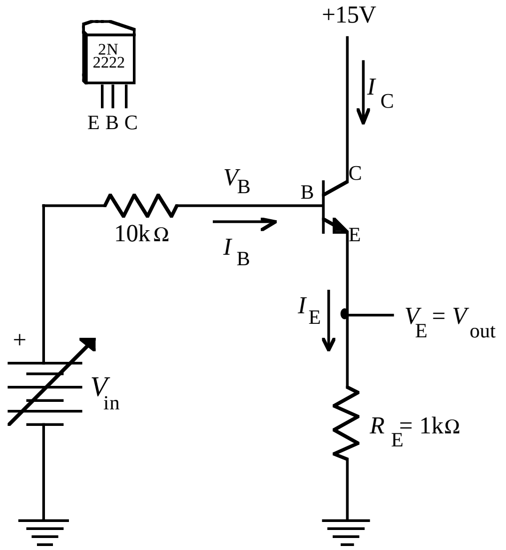

Figure 1: An emitter follower amplifier.

First, examine the behavior of the transistor. Set V_B to approximately 2,4,6,8,10,12, and 14 volts and for each V_B measure V_{in}, V_B (accurately), and V_E. From this, calculate $V_{BE} = V_B - V_E$, I_B and I_E from Ohm's law, $I_C = I_E - I_B$, and $h_{fe} = \beta = I_C / I_B$. Put all of this in one data table.

To analyze this 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" r_{pi} for the base of the transistor. From the slope of this line, calculate r_{pi} using Ohm's law. Now, looking at the data and the graph, 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 $I_C \approx I_E$? Is $\beta \approx 100$ (within a factor of 2)? A BJT 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 I_B *vs*. V_{BE} graph with data points and calculated curves, and a discussion which includes answers to the questions in the previous paragraph.

Now, examine the behavior of the entire circuit. Replace V_{in} with an AC. source v_{in}. Keep the input signal in the range $0\text{V} < v_{in} < 15\text{V}$. Monitor v_{in} and v_{out} simultaneously with the oscilloscope. Note that v_{out} "follows" v_{in} with a small voltage drop, much like the diode rectifier did last week. (The emitter follows the base, hence the name of this configuration.) What is the voltage gain of this circuit? What might be the use of a circuit with this gain? For your lab report, sketch v_{in} and v_{out}, indicating the voltage drop, give the gain of your amplifier, and describe why it is called an emitter follower and what it might be used for.

Optional: Try changing the value of R_E to 330Ω or 100kΩ and see what happens to the voltage drop. Can you explain this using a diode I-V curve? Also optional: What happens when $v_{in} > 15\text{V}$ or $v_{in} < 0\text{V}$?

2. COMMON EMITTER AMPLIFIER

In this section, you will build and analyze a common emitter amplifier, a popular transistor amplifier circuit. Build the amplifier as shown in figure 2 but *don't connect the AC source yet*. Just leave v_{in} floating for now.

First, find the bias conditions of the transistor. That is, find the voltages and currents in the circuit with no input signal. This is also called the "quiescent point", the "operating point", or the "DC" conditions for the circuit. To do this, measure V_B, V_E, and V_C, use Ohm's law to calculate I_E and I_C, calculate $I_B = I_C / \beta$ using the β you found in section 1, and calculate V_{BE}. The purpose of the resistors in the middle of the circuit, the "bias resistors", is to keep the transistor in its active region all the time. Is the transistor in its active region now?

Now connect the function generator to v_{in} and use a 1V peak-to-peak 10kHz sine wave as the input signal. Monitor v_{in} and v_{out} simultaneously with the oscilloscope and sketch them on the same set of axes. Measure the gain of this amplifier. Compare it to the calculated gain, R_C / R_E. Note the phase difference from input to output. Most amplifiers invert the signals they amplify.

Explore the behavior of the amplifier a little more by using different waveforms, frequencies, and amplitudes for v_{in}. 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 guess what causes each of these limits.

For your report, include your DC measurements and calculations with a brief discussion of whether the transistor is in its active region, a sketch of v_{in} and v_{out}, a comparison of your measured and calculated gain, and some approximate frequency and voltage limits with guesses as to their causes.

Optional: See how the gain changes when you add the 4.7µF capacitor (drawn with dashed lines). Can you explain this?

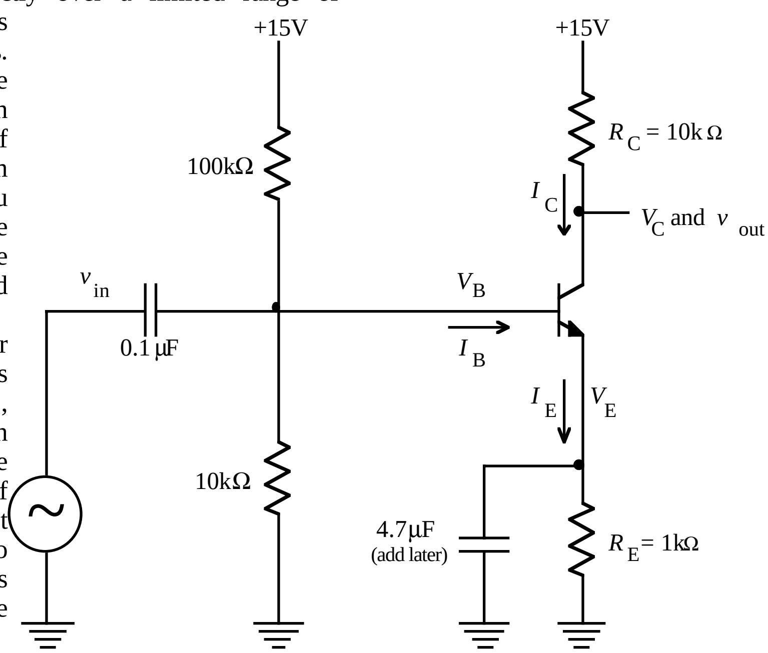

Figure 2: A common emitter amplifier.