Lab 6 Bipolar Transistors I

There are questions in parts 5, 6, and 7 below indicated by an asterisk (*) that you should address prior to coming to the lab. Prepare to copy your answers into your lab notebook.

1. First test of a transistor

This lab uses an NPN transistor, the 2N2219. Like any NPN transistor, it incorporates two PN junctions, as shown in Fig. 1 (b).

You can make a crude test of your transistor's health by using the diode test option on

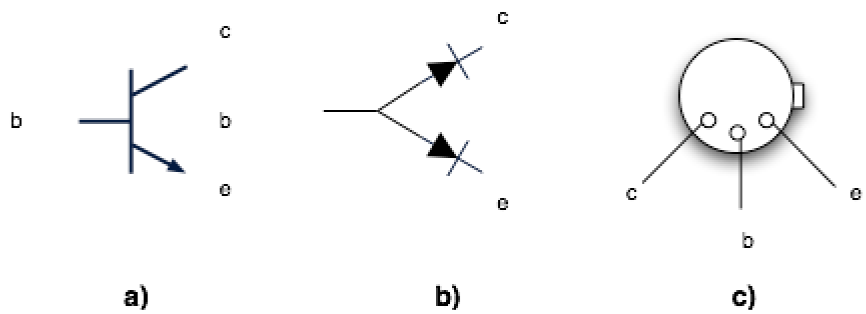

Figure 1: Views of NPN Transistor: a) schematic, b) functional, c) physical. The emitter is next to the tab.

a multimeter. This option sets the terminals of the multimeter so as to forward bias the junction and then to read the voltage across it. For a silicon transistor like the 2N2219 you expect to find a forward voltage on the order of 0.7 volts. Test both the base-collector and the base-emitter junctions of your transistor. Describe your results. [3 p]

2. Common emitter characteristics

The goal of this section is to make a plot showing the collector current I_C vs. the collector-emitter voltage V_{CE} for several different values of the base current I_B.

To eliminate some of the repetitious work you will use the LabView program "NEW Tran_param.vi." Fig. 2 shows the circuit that is used to do the measurement. The voltage on the collector is swept through a range of values chosen by the user for several values of the base voltage. The collector current is determined by measuring the voltage drop across the (nominally) 1k resistor, and the base current is obtained similarly by measuring the voltage drop across the 1M resistor. The resistors should be measured with the multimeter and their exact values entered into the program windows. Instructions on wire connections between the protoboard and the LabView circuitry can be found by following the selections within the program: File-> VI Properties-> Documentation.

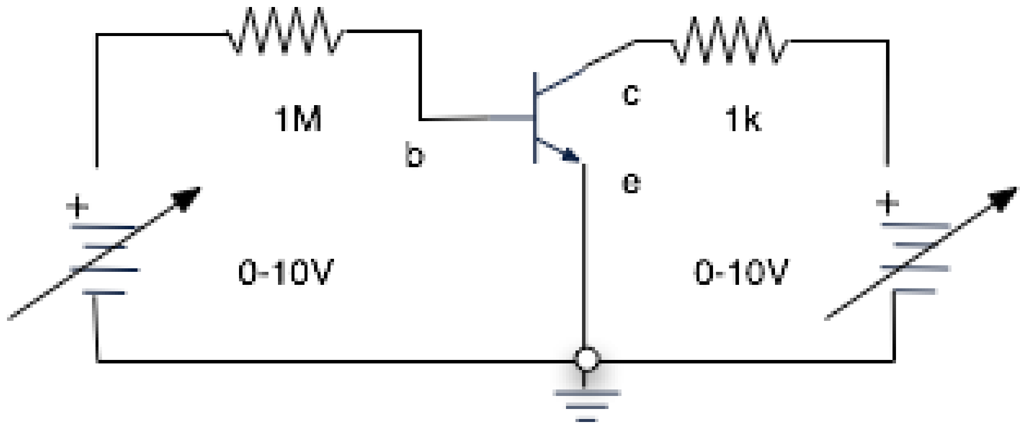

Figure 2: Test circuit for 2N2219. The battery voltages will be supplied by LabView.

Follow these steps:

(1) Enter the values of the resistors as measured.
(2) Enter base-voltage range (0-10 V) and number of values (e.g. 10).
(3) Enter collector-voltage range (0-10 V) and number of points (e.g. 40).

You activate the program with the Run button (open arrow). The program will return a plot similar to Fig. 3 with the base currents corresponding to each trace given in boxes to the left of the plot.

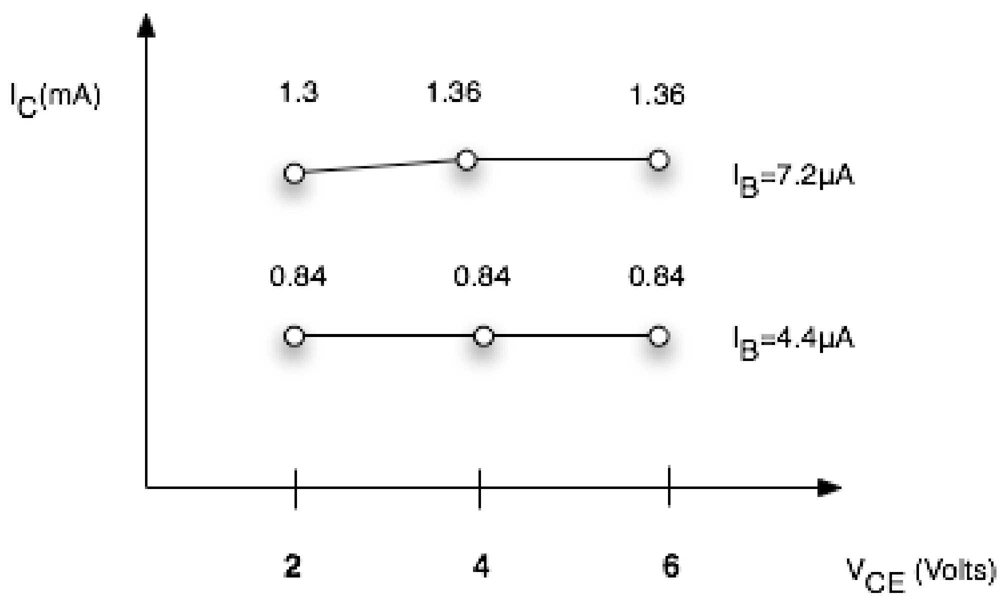

Figure 3: Collector Current vs. Collector-Emitter Voltage.

(a) Draw the circuit and its connection to LabView with all the parameters. [3 p]
(b) Print the program output from the screen and mark the traces with the values of the base current in μA shown in the boxes. Increasing base current, resulting from increasing base voltage, are in boxes from top to bottom. PRINT 1 [4 p]

3. Calculating β

The current gain of the transistor, β, is the change in collector current divided by the change in base current. From the data in Fig. 3, choosing V_{CE} =6 volts as typical, one can calculate β as follows:

$$\beta = \frac{(1.36 - 0.84)\times 10^{-3}}{(7.2 - 4.4)\times 10^{-6}} = 186.$$

Using the data in your program output, calculate β for your transistor for three different base currents: high, medium, and low. How consistent is β? [4 p].

4. The transistor as a switch

Replace the 1k collector resistor in the circuit in Fig. 2 by a 10k resistor (remember to change the resistance in LabView). Try to make the measurements of the collector characteristics now with this larger collector resistor. You'll probably find that when there is any base current at all, the voltage drop on the collector resistor is so large that you can't get V_{CE} at all close to the supply voltage. The active region of the I_C vs V_{CE} plot has shrunk. You are looking at the switching characteristics of a transistor. The transistor tends to be either **on** (large collector current) or **off** (no collector current).

(a) Use LabView to print a plot like the plot in Part 2(b) with the increased resistor. PRINT 2 [4 p]
(b) On your printout draw a load line for a 10-volt source (the maximum V_{CE}) and a 10-kohm resistor. Compare with the limits of your traces. [2 p]

5. The common-emitter amplifier

Set up the circuit in Fig. 4. The capacitor AC-couples the signal generator to the transistor amplifier so that the generator does not upset the DC operating point (quiescent point) adjustment. A better way to put that is to say that the capacitor DC-decouples the signal generator from the amplifier.

(a) *Draw the circuit and explain why the gain of this amplifier is about 10. [3 p]
(b) *Explain why the bias resistors R_1 and R_2 make a sensible voltage divider for biasing the base given the goal of making the quiescent value of $V_{out} \approx 5$ V. You may assume that the transistor has $\beta \approx 100$ and $V_{BE} \approx 0.6$V. [3 p]
(c) Using an input amplitude of 50 mV and a frequency of 100 Hz, measure the voltage gain of the amplifier by comparing the input and output AC signals on a scope. Is the amplifier an inverting amplifier? Print the display of your DPO showing simultaneously the input and output signals. PRINT 3 [4 p]

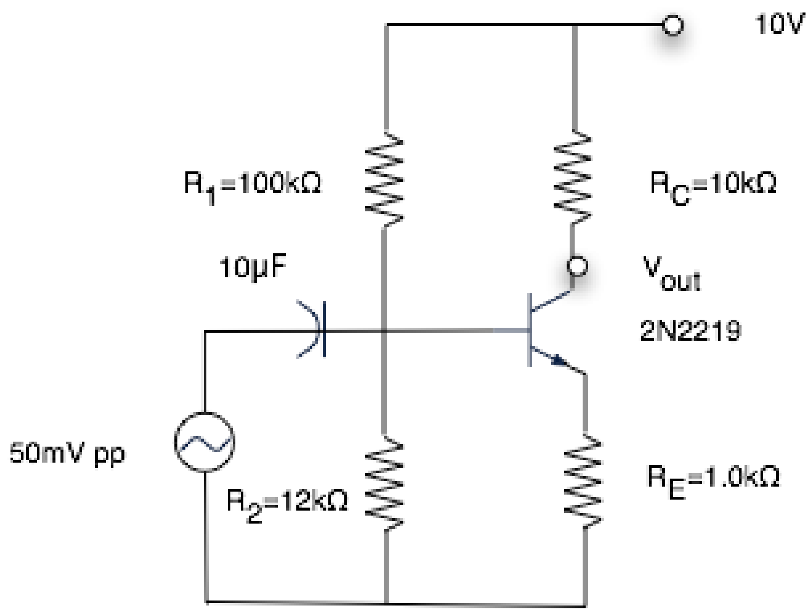

Figure 4: Common-emitter amplifier.

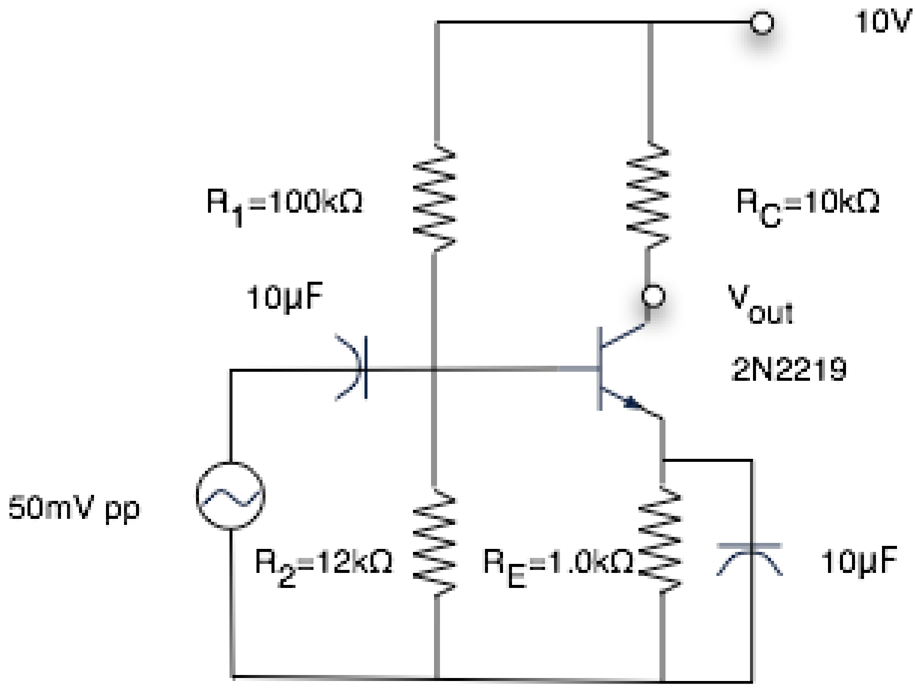

Figure 5: Bypass Capacitor Added

6. An emitter bypass

(a) Add a 10 µF capacitor, observing the correct polarity, to bypass the emitter resistor as shown in Fig. 5 and re-measure the gain of the amplifier. It should have increased substantially. [2 p]

(b) Decrease the frequency to 50 Hz. What happens to the gain? [2 p]

(c) *Can you explain why? [2 p]

7 The emitter follower

A few simple changes to the common emitter circuit above completely change the character of the amplifier.

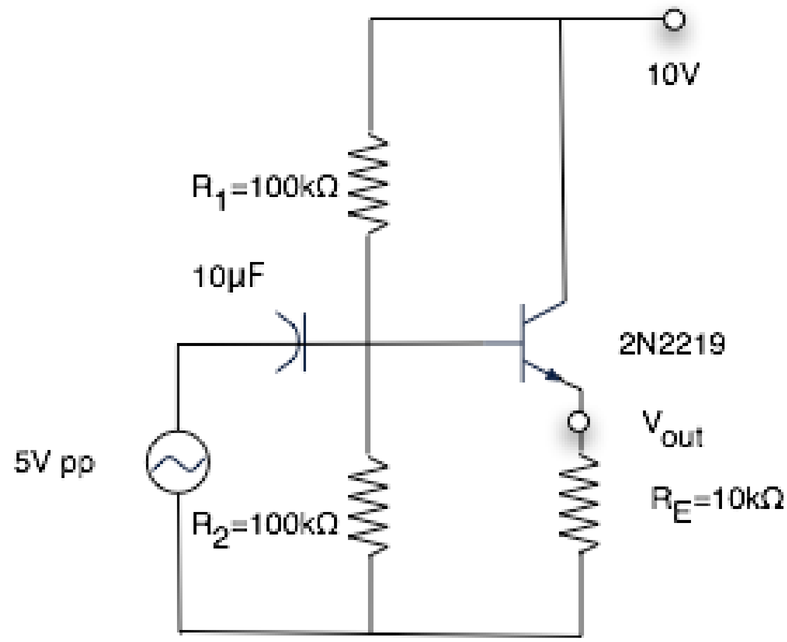

Figure 6: Emitter Follower.

(a) Construct the emitter follower circuit in Fig. 6 and draw it in your notebook [2 p]
(b) *Explain why resistors R_1 and R_2 are approximately the same for an emitter follower, given that we want the quiescent value of V_{out} to be about 5 volts. [2 p]
(c) Measure the voltage gain and show that it is close to unity. Print the display of your DPO showing simultaneously the input and output signals. PRINT 4. [4 p]
(d) Is this an inverting or non-inverting amplifier and why? [1 p]