

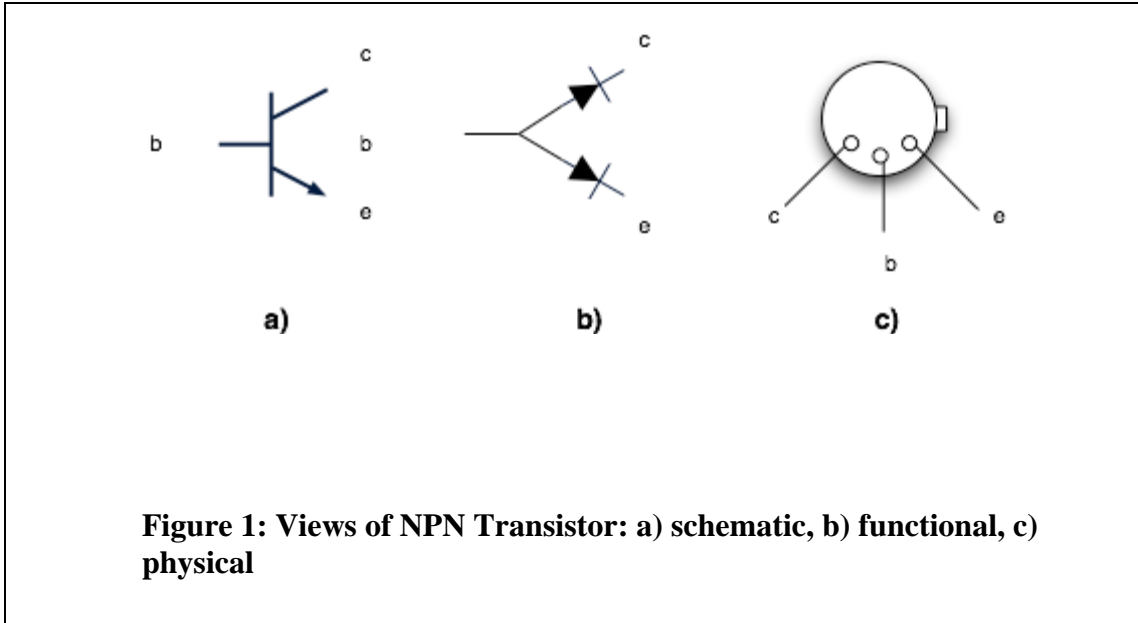
Bipolar Transistors I

The first test of a transistor

There are a number of questions in this write-up indicated by an asterisk (*), that you should address prior to coming to the lab.

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 by using the diode test option on a

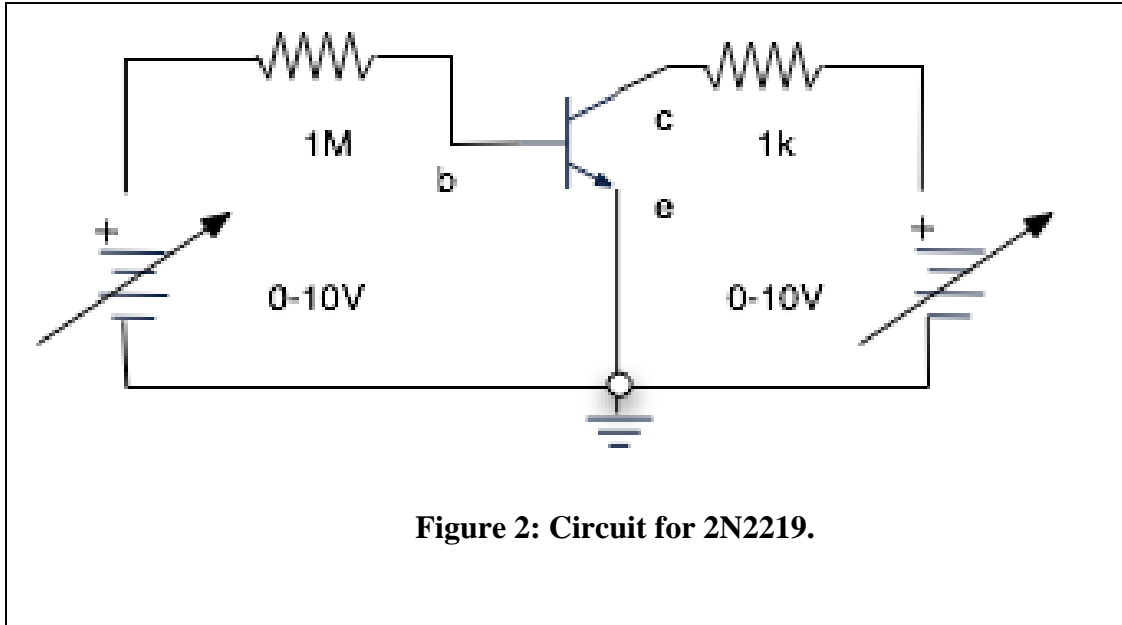


multimeter. This option sets the terminals of the multimeter so as to forward bias the junction and then to read the voltage across it. For a silicon transistor like the 2N2219 you expect to find a forward voltage of the order of 0.7 volts. Test both the base-collector and the base-emitter junctions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

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 .

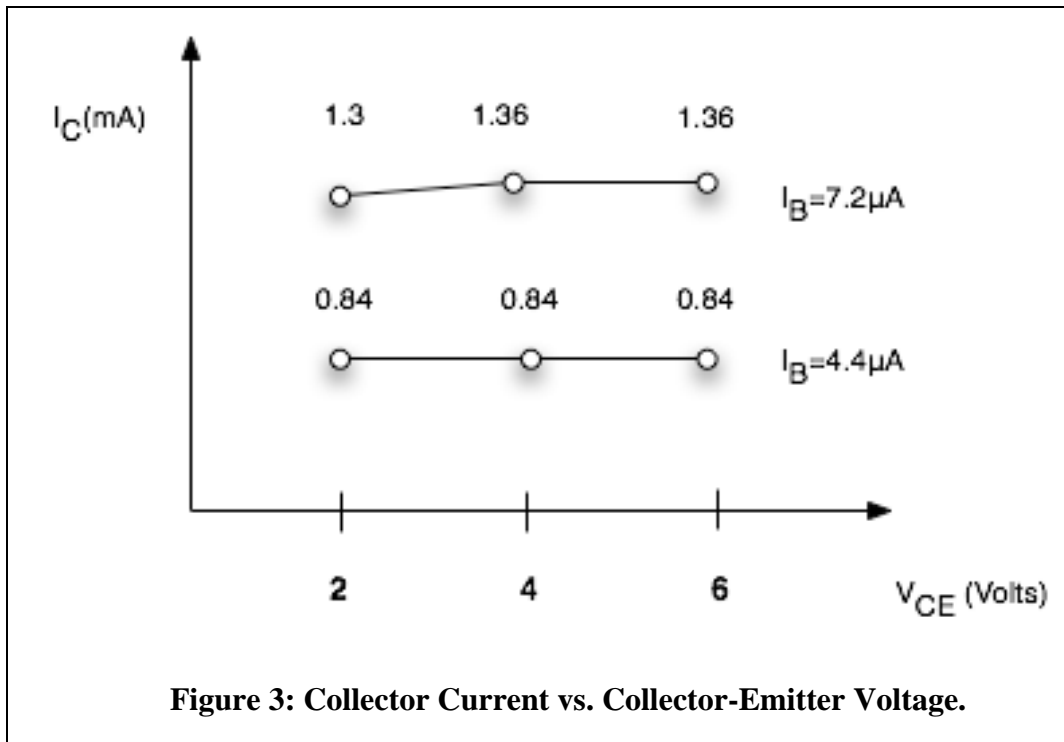
To eliminate some of the repetitious work we will do this using the LabView program Tran_param.vi. Figure 2 below shows the circuit that is used to do the measurement. The voltage on the collector is swept through a range of values chosen by the student for several values of the base voltage. The collector current is measured 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 used in the program. As before, 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.



Follow these steps:

- (1) Enter the values of the resistors.
- (2) Choose a range of values for the base voltage and the number of points to measure.
- (3) Similarly select a range for collector voltage and number of points.

You activate the program with the Run button. The program will return plots similar to the one below with the base currents corresponding to each line given in a register.



Print the program output and mark the lines with the values of the base current in μA that may be looked up, for the consecutive base voltage setting indexed 0 to N-1, in a box in the display.

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 above, choosing $V_{\text{CE}} = 6$ volts as typical, one can calculate β as follows:

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

Calculate β for your transistor for a range of base currents and make a plot of β vs. I_{B} . Again, the base current in μA at any base voltage setting (0 to N-1) may be looked up in a box in the display.

The transistor as a switch

Replace the 1k collector resistor in the circuit above by a 10k resistor. Try to make the measurements of the collector characteristics now with this larger collector resistor. Probably you 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 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).

The common-emitter amplifier

Set up the circuit below. 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.

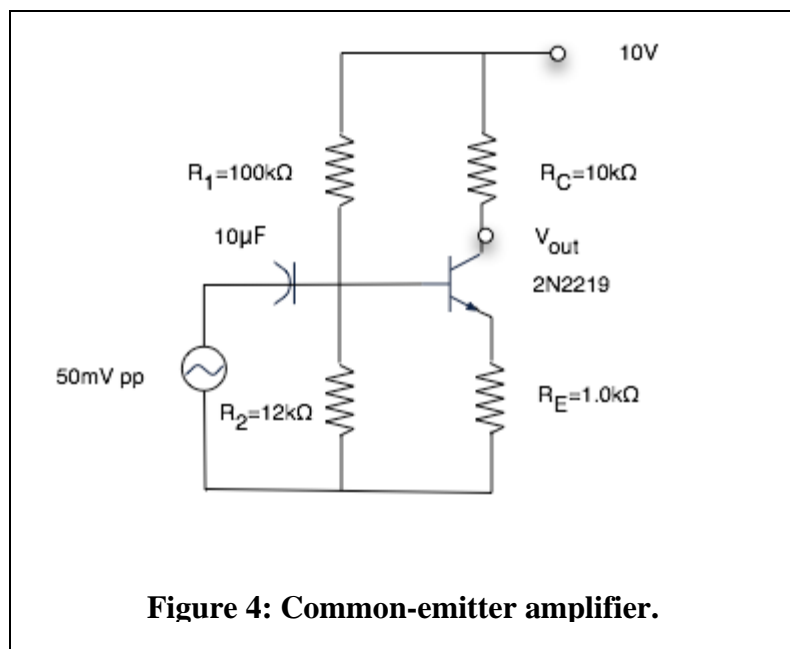


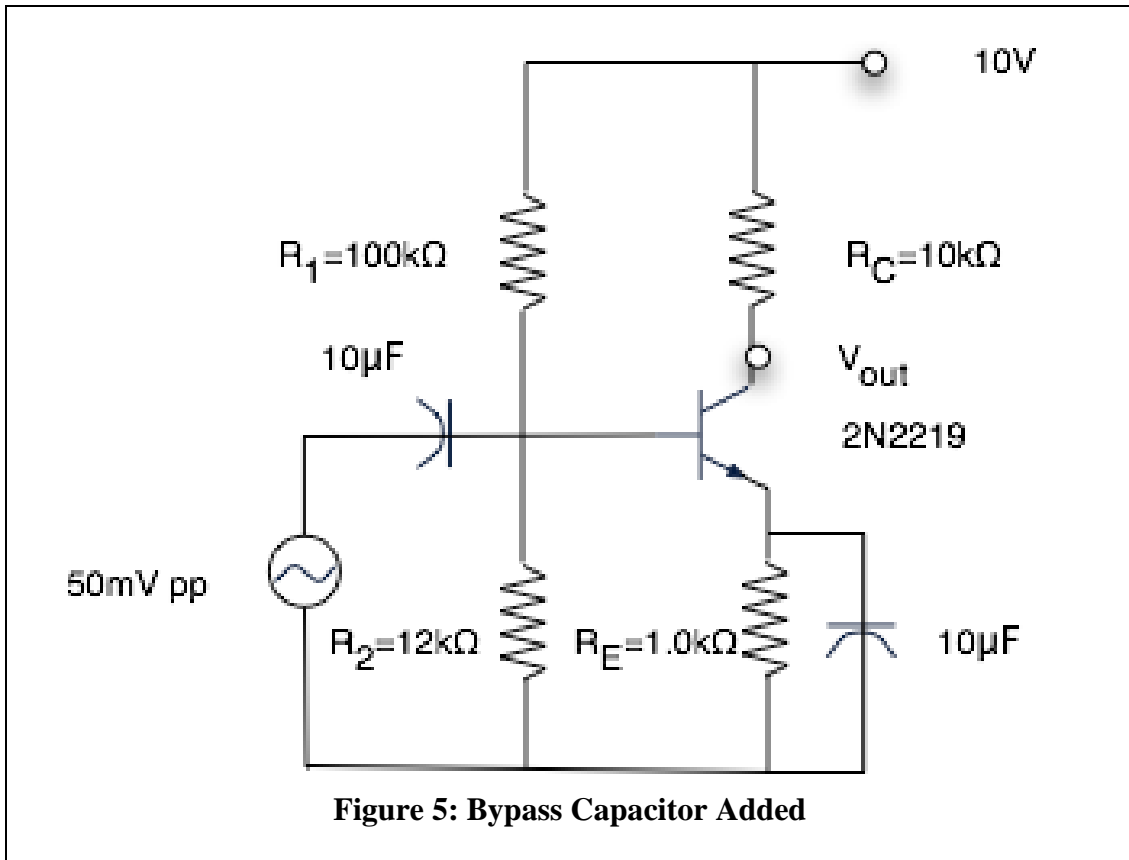
Figure 4: Common-emitter amplifier.

- (a) *Explain why the gain of this amplifier is about 10.
- (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 $V_{out} \approx 5\text{ V}$. You may assume that the transistor has $\beta \approx 100$ and $V_{BE} \approx 0.6\text{ V}$.
- (c) Measure the voltage gain of the amplifier by comparing the input and output AC signals on a scope. Is the amplifier an inverting amplifier? Use an input amplitude of 50 mV and a frequency of 100 Hz. Print the display of your DPO showing simultaneously the input and output signals.

An emitter bypass

Add a 10 μF capacitor, observing the correct polarity, to bypass the emitter resistor as shown below and re-measure the gain of the amplifier. It should have increased substantially. Decrease the frequency to 50 Hz. What happens to the gain?

Can you explain why?



The emitter follower

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

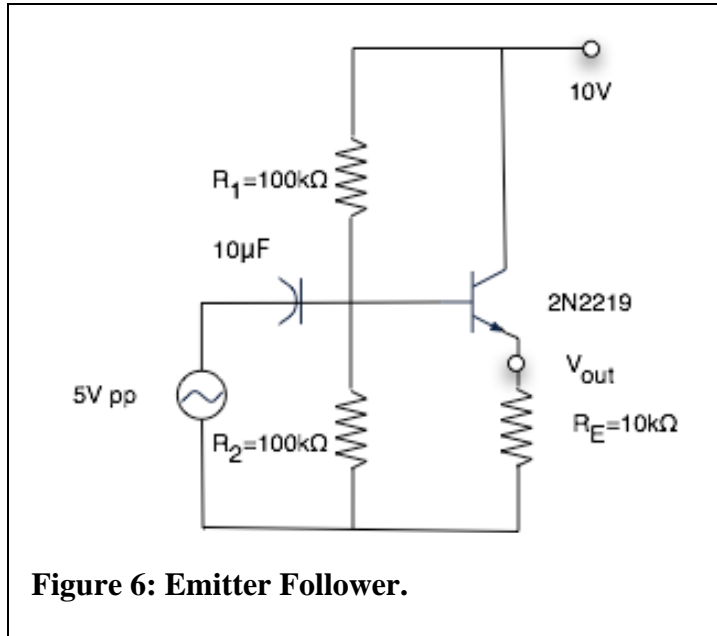


Figure 6: Emitter Follower.

- Construct the emitter follower circuit in Figure 6.
- *Explain why resistors R_1 and R_2 are approximately the same for an emitter follower, given that we would like the quiescent value of V_{out} to be about 5 volts.
- 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.
- Is this an inverting or non-inverting amplifier and why?