Lab 8: Bipolar Junction Transistors (BJTs)

Before you begin today's lab

- In this lab, we will use the variable "split" supply on your protoboard. Before you begin, use a multimeter and the knobs at the top of the protoboard to set V_+ (yellow rail) and V_- (blue rail) to $+15\,\text{V}$ and $-15\,\text{V}$, respectively.
- We will use two kinds of BJTs today, which look very similar. Make sure to check the part number on the flat face of the transistor (see Figure 1).

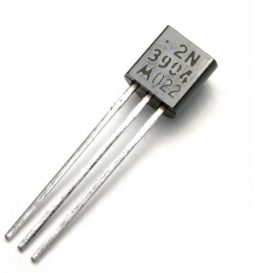


Figure 1: 2N3904 npn transistor.

Common-Emitter Amplifier

One of the most useful applications of BJTs is in *amplifying* signals. In a lab context, we will almost always use a convenient integrated circuit called an "operational amplifier" or "op-amp" for this purpose (more on this next week). But it's good to have some intuition for *how* op-amps amplify signals using transistor-based amplifier circuits like the one below.

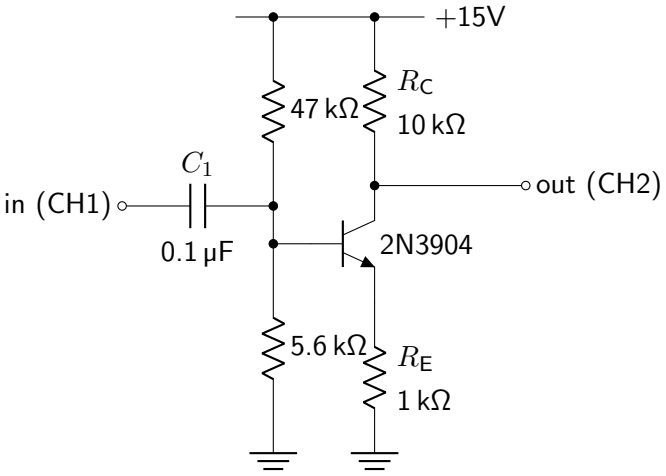


Figure 2: Common-emitter amplifier.

(a) What is the expected gain of the common-emitter amplifier of Figure 2?

$$G = \frac{v_{\text{out}}}{v_{\text{in}}} =$$

(b) What is the purpose of C_1 and the 47 kΩ/5.6 kΩ voltage divider?

(Hint: assume that the input voltage V_{in} is oscillating around 0 V.)

(c) Build the circuit. There are a lot of components, so try to make your circuit readable (and laid out as similarly to the diagram as possible); don't be afraid to space it out across your breadboard!

(d) Drive it with a 1 kHz, 100 mVpp sine wave from the Siglent function generator. Observe the gain of the circuit by measuring the amplitude of the waveform at the input and output: first use DC coupling on the scope, which allows you to see the collector's DC quiescent point. Then switch channel 2 to AC coupling to get rid of the DC offset, so you can crank up the scope's sensitivity. How does the measured gain compare with expectations?

(e) How does the common-emitter amplifier achieve power gain (more power in the output signal than was carried in the input signal)? Does it violate thermodynamics?

(f) Does an emitter follower, in contrast to a common-emitter amplifier, have voltage gain? Does it have power gain?

This type of circuit underlies the magic of *operational amplifiers* (op-amps), which we will look at next time. You will rarely (if ever) build a common-emitter amplifier again, but it is good to know what's going on behind the curtain of the op-amp's incredible convenience. Of more relevance, you'll also be able to understand in depth, and accommodate, the (mostly minor) shortcomings of op-amps.