Pre-lab 8: Transistor Amplifiers

Current source

We've used a lot of voltage sources so far; now let's see how to make a current source. Let's analyze the circuit in Figure 1:

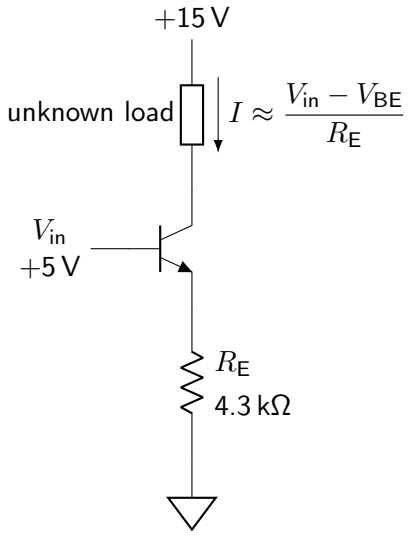


Figure 1: BJT current source (more properly, a current *sink*).

Voltage $V_{in} = +5\,V$ applied to the base causes an emitter voltage $V_E \approx V_{in} - 0.6\,V = 4.4\,V$. That voltage across $R_E = 4.3\,k\Omega$ amounts to an emitter current

$$I_E = \frac{4.4\,V}{4.3\,k\Omega} \approx 1\,mA.$$

Since the base current is much smaller ($1\,mA/100 = 0.01\,mA$), the collector current must be nearly equal to the emitter current, thus $I_C \approx 1\,mA$. And, this statement is independent of what's connected to the collector, as long as that unknown load allows the collector voltage to remain higher than the emitter voltage. It's magic! And we'll use that magic to create one of the most important circuits BJT circuits: an *amplifier*.

Common-Emitter Amplifier

Think about the current source above. Imagine that input voltage wiggles by a small amount, so that

$$V_B = V_{in} + v_{in}, \tag{1}$$

where V_{in} is the DC (constant) component, and v_{in} is the AC (varying) component of the input voltage.

The emitter voltage wiggles by the same amount $v_E = v_B$, which changes the voltage across R_E by the same amount. That results in a variation of the emitter current

$$i_E = \frac{v_{in}}{R_E}. \tag{2}$$

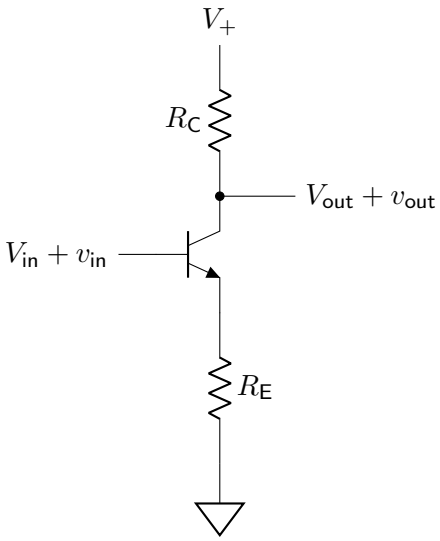


Figure 2: Common-emitter amplifier.

The collector current changes by the (almost) same amount $i_C = i_E$. Now we connect the collector to the positive power supply voltage $V_+ = 15\,\text{V}$ through a "load" resistor R_C, as shown in Fig. 2.

The output voltage (at the bottom of R_C) is given by

$$V_{out} = V_+ - R_C I_C. \tag{3}$$

When the collector current varies by $i_C = v_{in}/R_E$, the output voltage will wiggle by

$$v_{out} = -R_C i_C = -v_{in}\frac{R_C}{R_E}. \tag{4}$$

This is an amplifier, with a "voltage gain" equal to

$$g = -\frac{R_C}{R_E}. \tag{5}$$

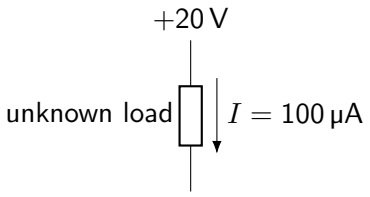
For example, if we choose the collector resistor R_C to be ten times the emitter resistor R_E, the output signal will be ten times larger in amplitude than the input signal. (And, by the way, inverted.) Our only job is to make sure there's base current, and that the collector current is set so that the BJT is neither cutoff nor saturated.

That's pretty exciting: we have a circuit that can output a larger voltage than we put in, and our gain can be greater than 1!

Pre-lab 8 Hand-in

Name: _____

Pre-lab 8.1 Draw an npn-BJT current source, to sink 100 µA from a load that is returned to +20 V. (In non-techie terms, your circuit connects to the bottom side of a load whose top side is connected to +20 V, and should cause 100 µA of current to flow, as shown below.)



From the last lab:

Pre-lab 8.2 Use a follower with the base driven from a voltage divider to provide a stiff source of $+5$ volts from an available regulated $+15$V supply. Allow for a maximum current load of 25 mA. Choose your resistor values so that the outut voltage doesn't drop more than 5% under full load. [Hint: think about "droop" in the voltage divider if the transistor starts to pull too much base current. The base current should be at least 10 times smaller than whatever the voltage divider pulls to ground.]