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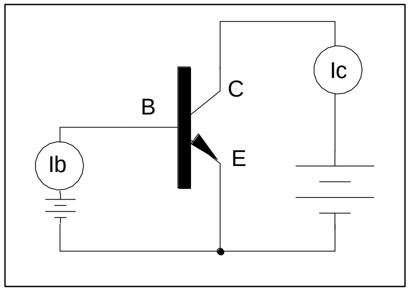
Lab 08

Bipolar and Field Effect Transistors

A. Bipolar Transistors



1. Here is what we are going to do.

    a. We are going to force some current into the B-E diode junction of a bipolar transistor and call it "base current" (Ib). We are going to look to see how much "collector current" (Ic) that causes the transistor to create. We are going to divide the collector current by the base current and call that the transistor's current gain, or beta (β).

    b. We are going to then see if the transistor's current gain changes as the collector current changes (it should). The transistor manufacturer can optimize beta for a particular current by black magic and powdered bat wings to have a rather broad "peak" at a particular collector current.

    c. Just like we saw with resistors, there is a universal standard for transistors. If the manufacturer wants to call their transistor, for example, a 2N4400, there are published specifications using the "2N" prefix that the manufacturer has to meet. In particular, the 2N4400 SHOULD have a beta peak somewhere around 100 milliamperes. That may or may not occur with our lab transistors (I'll tell you why verbally, not to be repeated).

2. Beta. Take one transistor of each of the two different styles. The small black transistor ("Flat Face") package is called a "TO-92" (once again, an industry standard). The large ("Metal Tab") is an industry standard called a "TO-220".

   a. Procedure:

      A. Obtain one of the two types of transistor. Identify it (if possible) by the 2N number (i.e. 2N918, 2N2222, and so on).

      B. Use this

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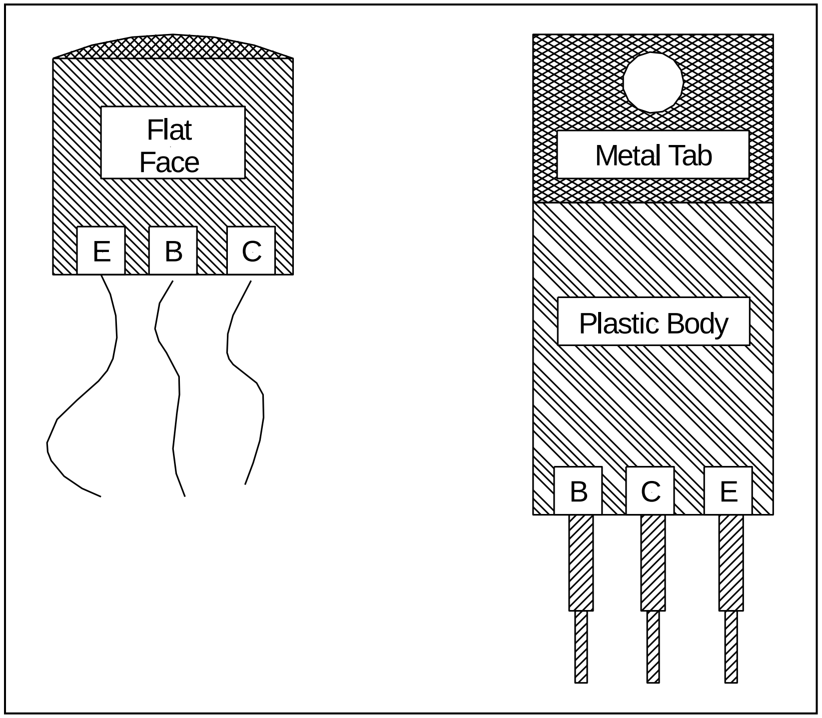
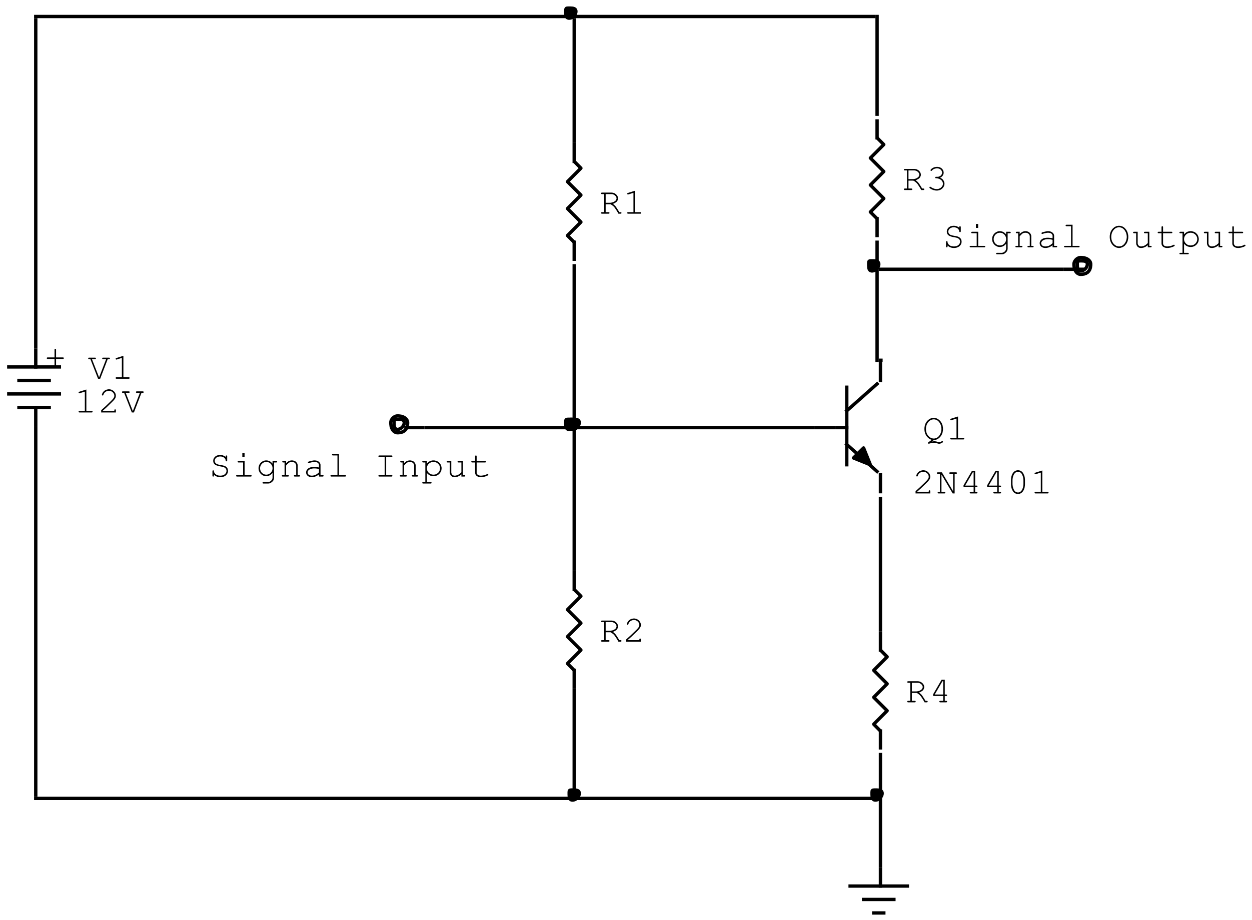
      drawing to identify emitter, base, and collector.



In this section we are going to investigate the characteristics of a single stage NPN bipolar transistor amplifier.



A. This is a single stage NPN bipolar transistor amplifer.

   a. R1 & R2 make a simple voltage divider to provide base current to turn the transistor on.
   b. R4 sets the emitter voltage (and therefore the collector current) to our chosen operating current.
   c. R3 sets the collector voltage approximately halfway between V1 and the emitter voltage.

B. Using the resistor values selected in class, construct the circuit on the trainer and measure the voltages to see if they are reasonably within the values selected in class.

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C. Use the applet https://www.falstad.com/circuit/ to simulate this circuit and see how close the applet comes to your measurements. What are some possible sources of differences between your measurements and the applet results?

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D. Now let's make a useful circuit now that we know how to measure and connect this circuit. We will NOT use approximations like we did with the circuit above, but do each resistor calculation from scratch.

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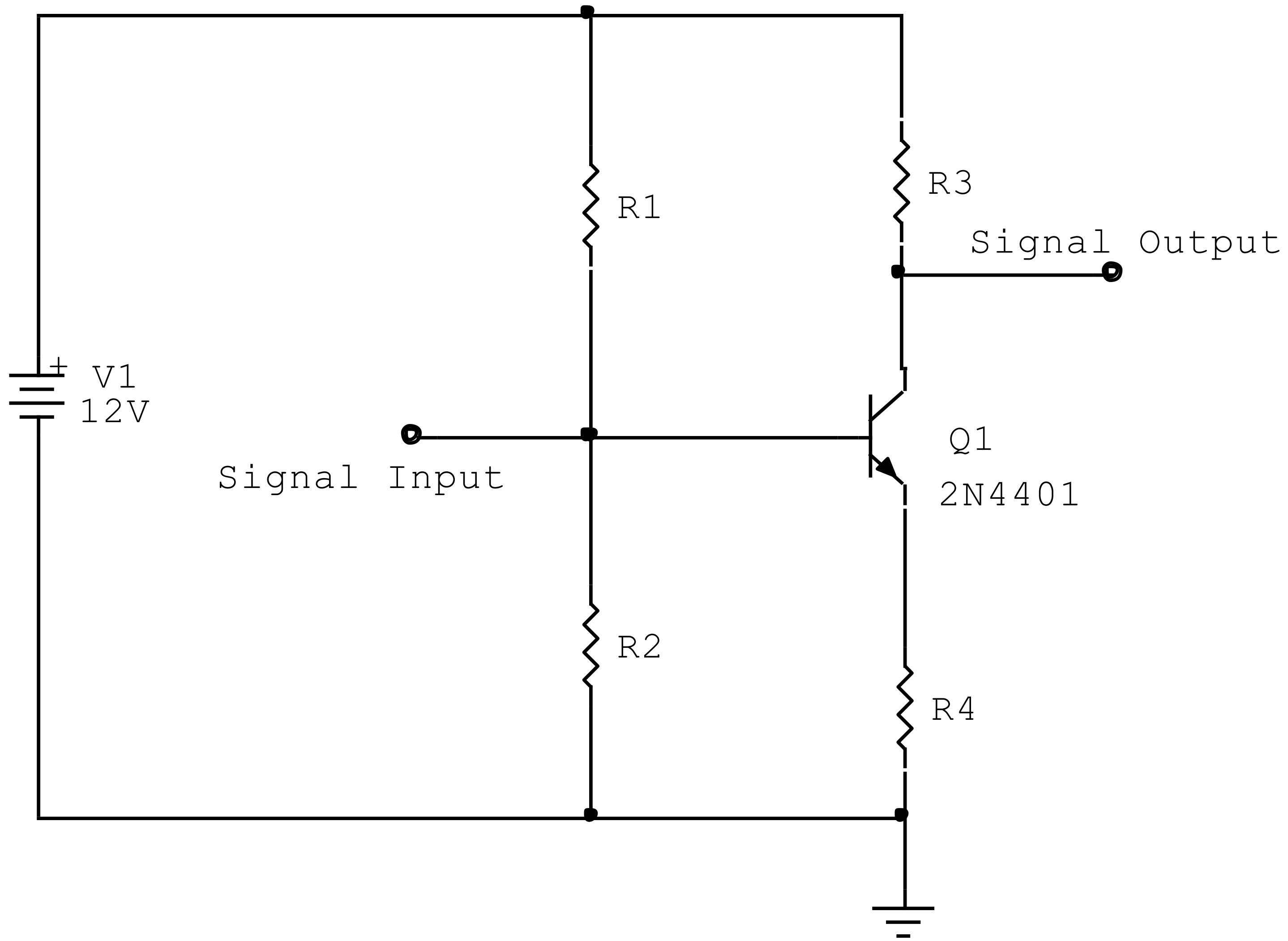

E. Here we go with the calculations:

   a. I want R3/R4 to be 10, to give me a voltage gain of 10, and I also want the voltage at the emitter to be 0.5 volts. I'd like R3 to be 10kΩ (brown-black-orange-gold) , so that forces R4 to be R3/10, or 1kΩ (brown-black-red-gold). That means that the emitter current is going to be I = E/R or 0.5/1000 = 0.0005 amperes or 500 E-6 amperes or 500 microamperes (micro = E-6). Put this number into memory.

   b. I want the collector voltage to be "around" 6 volts. Once again, the voltage drop across R3 is going to be 6 volts also (12/2=6) so if the collector current is equal to the emitter current, The voltage drop across R3 is going to be E = I*R = 500E-6 * 10 E3 = 5 volts, so if 5 volts drops across R3 there will be 7 volts from Q1 collector to ground. (12-5=7). Close enough. We could change around the emitter voltage to make it EXACTLY 6, but close enough for now.

   c. The problem now resolves itself to making the base exactly 0.7 volts above the emitter, which we forced to be at 0.5 volts. This makes the base voltage 0.7+0.5, or 1.2 volts. We can arbitrarily pick a value for R2, and to save on current drain, let's make it 47kΩ. (yellow-purple-orange-gold) This makes the current through R2 I=E/R = 1.2/47K = 1.2/47E3 = 25.5 E-6 or 25.5 microamps.

   d. Last value – R1. R1 needs to drop 12 – 1.2 or 10.8 volts. Since R1 and R2 are in series, the same current will flow through both of them, so to get 10.8 volts at 25.5 microamps, R1 = 10.8 / 25.5E-6. or 423kΩ . But they don't make 423k resistors. What to do?

   e. Nearest standard values are 390k and 470k. Remembering that the base of the transistor is going to suck some of that current away, let's take the LOWER of these values to provide just a bit more current. How about 390kΩ. (orange-white-yellow-gold)

F. Now rather than breadboard this up with "real" transistors, let's use the simulator at www.falstad.com/circuit to see if we are in the ballpark.
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G. If we have the time, perhaps we can use an audio oscillator and the oscilloscope ("scope") functions of the simulator to see if we get 10:1 gain out of this transistor.