Phy 415/515 Lab #5 2009 BJT Transistors and Emitter Followers

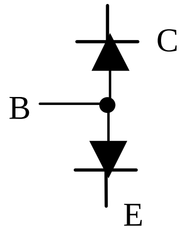

Figure 1. Diodes in an npn transistor.

Prelab: due at beginning of lab

1. The junctions in an npn transistor form diodes as in Figure 1. Predict the outcome of experiment part 1.2.
2. The junctions in a pnp transistor are as shown in Figure 2. Predict the outcome of experiment part 1.3.
3. Plot (using Excel or other software) the theoretical base current versus base-emitter voltage for an npn transistor with a saturation base current of I_{sb}= .01 pA (10^{-14} A). This is the same as for the diode, so $I_b = I_{sb}\left(e^{\frac{qV}{kT}} - 1\right)$.

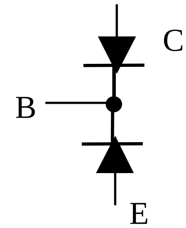

Figure 2. Diodes in a pnp transistor.

4. Consider the voltage divider in Figure 3. This is what the circuit of Figure 7 would look like if it didn't have the transistor. a) what is the output if, as in our circuit, R_b=R_E=1 kΩ? b) What is the "gain" (ratio of output voltage to the input voltage of 5V)? c) If R_E is changed to 100 Ω, what is the output voltage and gain?
5. For the circuit of Figure 7,

a) From your plot in problem 3, what base-emitter voltage is required to have a base current of 0.05 mA? What is the base voltage in this circuit **if the transistor has β=50 (collector current of 2.5 mA)**? (Hint: just use a base-emitter voltage of 0.558 if you are having trouble with problem 3).

b) What voltage on the Kepco power supply provides .05 mA through the base resistor?

c) If the Kepco power supply voltage is raised by 0.1 volt, what is the new emitter voltage? (hint: start by assuming the base-emitter voltage doesn't change, and see if you get a consistent answer)

d) What is the voltage gain (ratio of change in the emitter voltage to change in the Kepco voltage) of the circuit?

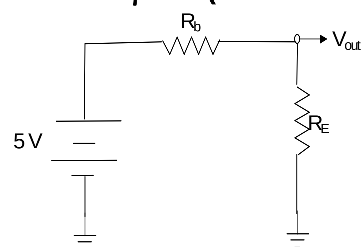

Figure 3. Resistor divider.

__1. Checking the transistors on the ohmmeter

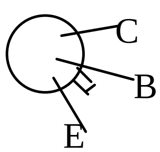

Figure 4. Pin diagram (top view) of the "tin can" type transistors. The metal tab marks the emitter. The base is between it and the collector.

___1.1. Ohmmeter

Plug banana-to-alligator cables into the DVM and set it on 20 MΩ scale.

___1.2.NPN

Take a 2N2102 npn transistor. The pin connections are shown in Figure 4. Note the resistance from the base to the collector and from the base to the emitter if the red ohmmeter lead is connected to the base. Repeat for the black lead at the base, and for the resistance between the collector and the emitter with both polarities. **Which measurements show low resistance? Why?**

___1.3. PNP

Repeat the measurements of part 1.2 with the pnp transistor type 2N3906. The pin connections are shown in Figure 5 (this is a different kind of case, which has nothing to do with whether it is npn or pnp). **Which measurements show low resistance? Why?**

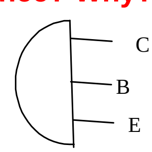

Figure 5. Top view of pnp transistor pins.

___1.4.Don't kill the multimeter.

Switch the multimeter scale to volts on the 20 V scale before proceeding.

___2. Wavetek, Power Supply, and Voltage probes

___2.1.Breadboard

Create columns on the breadboard for the Kepco power supply and the wavetek. Connect the grounds of the wavetek and the power supply..

___2.2. Calibrate Voltage Probes

Connect the red and black alligator clips on the voltage probes to wires in the "+V" and ground columns of the breadboard. Calibrate the computer voltage probes using the wavetek on dc to supply a voltage, read with the DVM.

___2.3.Set collection rate

In the "experiment" menu, click on the "sampling" tab and set the experiment length to 1 second and the sampling speed to 4000 samples/s. Click on collect and make sure they are reading the voltage as you change the dc offset. Set the Wavetek to 5 V dc.

___3. Npn I vs V_{BE}

___3.1. I vs V_{BE} circuit

We will use an npn transistor of the type 2N2102 in "tin can" case. Wire the transistor as an emitter follower as shown in Figure 6. The voltmeter is placed to measure the collector-emitter voltage and probe 1 to measure the base-emitter voltage. Probe 2 measures the voltage across the emitter resistor, and hence the emitter current.

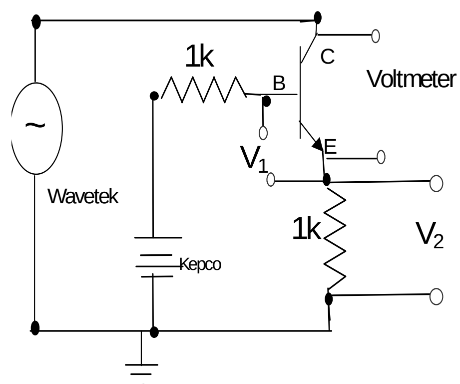

Figure 6. The npn transistor and voltage probes for measuring the collector current versus V_{BE}.

___3.2. Observe

Set the wavetek to 5V dc. Turn the Kepco voltage down until V_{BE} is close to zero (you can read the value on the computer screen as probe 1). The current should be about zero (probe 2) and the collector-emitter voltage (voltmeter) nearly equal to the Wavetek voltage. Adjust the Kepco until the transistor turns on, and observe the current go up and V_{CE} go down.

___3.3. ICE vs VBE

Click on "collect" and adjust the power supply voltage over the range 0-4 V. **For later: Fit the graph using the diode equation. What is the dependence of current on V_{BE}?**

___3.4. Move probe 1

Move voltage probe 1 so it is now measuring V_{CE}, as shown in Figure 7. Move the voltmeter to measure the current across the base resistor, and hence I_B. Set the Kepco to about 1 V. Reduce the wavetek dc offset to about 3 V. Leaving the dc bias on, change it to a 5 Hz sinewave with moderate amplitude (the amplitude is not critical).

___3.5. **ICE vs VCE with the transistor off**

Adjust the voltage of the Kepco so the transistor is off. Click on collect. Observe the plot of emitter current versus V_{CE} for this value of i_b. If the range of V_{ce} is too small (or large) adjust the wavetek and repeat. **Print the plot and save the data.** Return the Wavetek to dc, adjust the offset until probe 2 is reading a value in the flat part of the plot. **Record the voltmeter reading and the probe 2 reading. What is the current gain?**

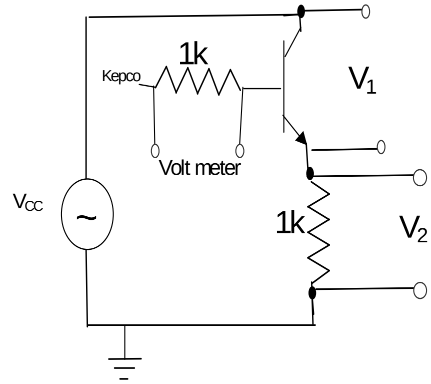

Figure 7. The voltage probes for measuring transistor characteristics.

___3.6. **ICE vs VCE with Transistor on**

Set the power supply voltage to a value just above that required to turn the transistor "on" in part 3.2. Return the wavetek to ac and Click on collect. Save your data(use the file name to note the base current value). As in the previous section use dc values to determine your current gain. Adjust the base current up and down and collect several plots.

___3.7. **Analysis (for later)**

Plot the I-V characteristic curves, all on the same plot, for the various base currents.

___3.8. **Gain**

Set the Wavetek to 6 V dc. Move Probe 1 so it is measuring the voltage on the Kepco (from the red sign to ground). Click on collect and vary the Kepco voltage. **What is the voltage gain of the emitter follower? (Is it about 1?)**

___3.9. **Gain with low output impedance**

Change the **emitter** resistor to 100 Ω. **Is the gain still about 1?** Change the base resistor to 1 M Ω. Does the circuit still work?

__**4.Don't smoke the power supplies**

Turn off both the wavetek and the Kepco before you wire the next circuit and pay attention to where the ground connection is.

__**5.Pnp Transistor operation**

___**5.1. I vs V_{BE} circuit**

Switch to the pnp transistor. Wire the transistor as a pnp emitter follower as shown in Figure 7. Note that the highest voltage anywhere in the circuit is at ground. Use the NEGATIVE voltage side of the Kepco power supply for your base voltage. Set the wavetek to a negative dc bias. Note that the collector, not the emitter, is at the bottom of the diagram. Again, the voltmeter is placed to measure the collector-emitter voltage, probe 1 to measure the base-emitter voltage, and probe 2 measures the emitter current. As before, the red side of V_1 should be on the base.

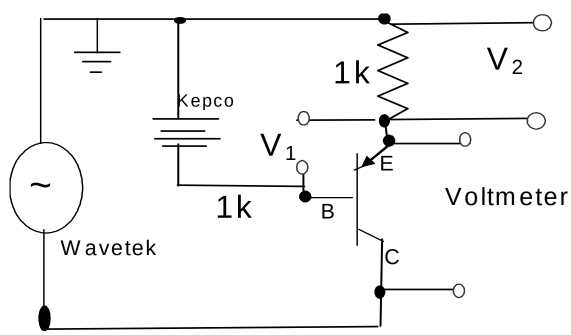

Figure 8. The pnp transistor and voltage probes for measuring ICE vs VBE.

___**5.2. Observe**

Adjust the Kepco voltage until V_{BE} is slightly positive (you can read the value on the screen as probe 1). The current should be about zero (probe 2) and the collector-emitter voltage (voltmeter) nearly equal to the Wavetek voltage. Adjust the Kepco until the transistor turns on, and observe the current go up and V_{CE} go down.

___**5.3. Take data**

Click on "collect" and adjust the kepco voltage over a large range. **What is the dependence of current on V_{BE}? Print and save the data.**

___**5.4. Move probe 1**

Move voltage probe 1 so it is now measuring V_{CE}, as shown in Figure 9. As before, the red side of the probe should be on the collector.

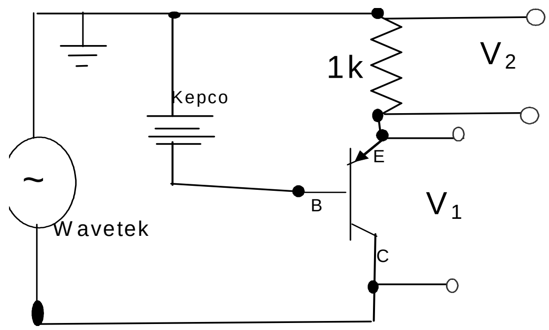

Figure 9. The pnp transistor and voltage probes for measuring ICE vs VCE.

___**5.5. ICE vs VCE with the transistor off**

Adjust the voltage of the Kepco so the transistor is off. Set the wavetek to ac. Click on collect. Observe the plot of collector current versus V_{CE} for this value of i_b. **Print the plot and save the data.**

___**5.6. ICE vs VCE with Transistor on**

Set the power supply voltage to just turn the transistor "on" as in part 4.2. Click on collect. Record the value of the Kepco voltage. Save your data(use the file name to note the base voltage value). Adjust the base voltage up and down and collect several plots.

___**5.7. Analysis (for later)**

Plot the I-V characteristic curves, all on the same plot, for the various base voltages.

___**5.8. Gain**

Set the Wavetek to dc. Note the value of the voltage V_1 and the Kepco voltage. Vary the Kepco voltage **What is the voltage gain of the emitter follower? (Is it about 1?)**