EE321 Lab - week 6 - Intro to transistors

17th August 2005

1 Purpose

The purpose of this experiment is to introduce transistors.

2 Overview

You need to make voltage and current measurements on a transistor using the available equipment.

The first step is to use an ohm-meter to confirm that on the simplest level, it looks like a pair of diodes. Later, you will see that part of its behavior really is a diode, but another part of its behavior is very unlike a diode.

The second step is to make current measurements, keeping V_{CE}(collector to emitter voltage) constant. (well ... almost constant)

The third step is to put a resistor in series with the collector, and repeat the measurements, showing how the transistor can be used as an amplifier.

The fourth step is to put it on a "curve tracer", and make a graph of its characteristics. Since we have only one curve tracer, you will probably need to come back later to do this part.

Since you will be making precision measurements, it is important that all connections must have as low resistance as possible. It is best to build it entirely on the binding posts.

3 Parts and equipment needed

- A diode (use the one from last time)
- PN2222 transistor (in the bin incorrectly marked "2N2222")
- 100k resistor
- 100 ohm resistor
- 2 portable meters.
- The DVM on the bench.
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4 Procedure

4.1 Check your equipment

Before beginning the real experiment, verify that your equipment is working.

1. Set all three meters to voltage, 200 volt scale.
2. Connect all three, in parallel, across a HP power supply.
3. With the power supply still off, turn the current adjustment all the way down, then up by a turn.
4. Turn on the power supply, and adjust it so all meters read 40 volts. Confirm that all meters read within 1% of the same.
5. Readjust the power supply for 1 volt. To get more resolution, set the meters to the 2 volt scale. Confirm that all meters read within 1% of the same.

4.2 Using an ohm-meter

You can use an ohm-meter to quickly check a transistor.

To see the idea, measure the resistance of a diode, in both directions. You will see that it conducts one way but not the other. Which way does it conduct?

While you are at it, measure the "resistance" of the diode using all possible scales on the meter. Do they all give the same reading? Why not?

Now that you have seen how the meter works on a diode, measure a transistor. You need to measure all possible combinations. That is 6 readings. You don't need to do it on all scales.

It should look like a pair of diodes. How are they connected? If it doesn't look like two diodes, the transistor is bad.

4.3 Keeping V_{CE} (almost) constant

For this step, you will need 3 meters. Use the bench meter, and two portable meters. Build this circuit. The 100 ohm resistor provides protection against miswiring and bad transistors. It is also used to sense the collector current. It lets the collector voltage vary a little, but we will ignore that.

Use the fixed bench power supply for 5 volts, and the HP variable supply for the base bias. Measure the 5 volt supply, so you know the exact voltage.

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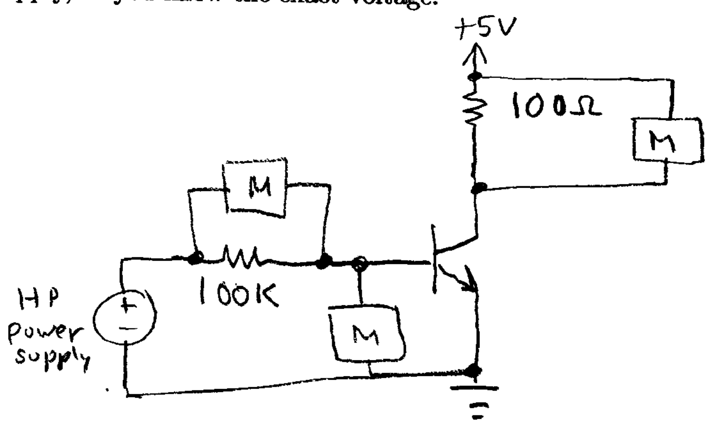

Fill in this chart. Adjust the base power supply to achieve the desired collector current (I_C) as measured on the meter. Then read V_{BE}(base to emitter voltage) from its meter. Then determine I_B (base current) indirectly by measuring the voltage across the series base resistor.

~~You might not be able to get 10 mA collector current with this circuit. If this is the case, make the other measurements, then change the base resistor to 100k and try again.~~

V_{Rb}	V_{Rc}	V_{BE}	I_B	I_C	β
				10 mA	
				3.16 mA	
				1 mA	
				.316 mA	
				.1 mA	

After filling in the chart, determine "beta" (β) by the formula: $\beta = I_C/I_B$. This is the "current gain" of the transistor. It says that when you vary the base current, the collector current varies by β times that much. It will probably be between 100 and 200.

Observe the pattern of $I_B$vs. V_{BE}. Does it look familiar? It should!

4.4 Letting V_{CE}vary.

If you changed the value of the base resistor, put it back to the original value. Change the 100 ohm collector resistor to 1K. Remove the ammeter from the collector circuit. Connect it to measure the collector voltage (V_{CE}) instead. Here is the circuit:

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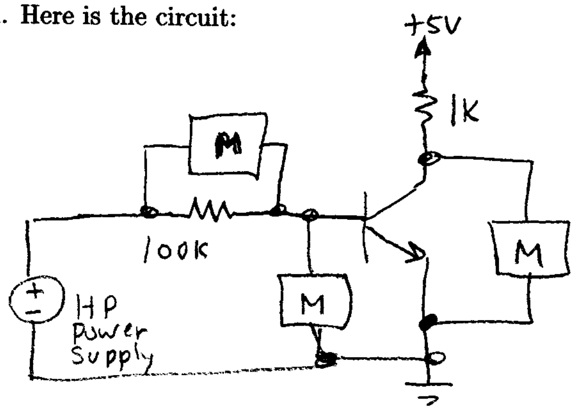

Adjust the base supply in steps to get the same base currents (I_B)as you had in the previous section. The other measurements associated with the base (V_{RB}, V_{BE}) should be the same, too, or very close. Don't worry if they change a little.

After filling in the measurements in the chart, calculate ΔV_{BE} and $\Delta V_{CE}$by the difference between adjacent readings. Then calculate the "voltage gain" as $\frac{\Delta V_{CE}}{\Delta V_{BE}}$.

V_{Rb}	V_{Rc}	V_{BE}	I_B	I_C	β	V_{CE}	ΔV_{BE}	ΔV_{CE}	gain
							XXX	XXX	

5 Your report

5.1 Summary

Give a summary for "the boss's boss". In one or two sentences, tell what you did.

1. In a table, state your values for I_s, n, the correlation coefficient, beta, and gain.
2. Write this last, but put it on the cover.

5.2 More detailed summary

The detailed summary should be about 1 page:

1. A chart showing important results, including a comparison to calculations and simulation.
2. A paragraph with a summary of your experience. It should include a statement of the important concepts that you learned.
3. Write this second to last, but put it on the first inside page.

5.3 Journal

Your report should include a journal of what you did, with enough detail that someone else can repeat your experiment, complete with mistakes, and with the exact equipment that you used.

5.4 Theory.

Based on your measurements, using the data for 1 mA, calculate the value of I_S for the base-emitter diode, assuming that $V_T = .026$ and $N = 1$. Compare this value to what you measured for the power diode. It should be much lower.

Based on information from class, and the book, calculate the expected values for what you measured. Compare your measurements to the predictions. Explain the differences.

5.5 Simulate it

Normally you would simulate before building, but this time you can do it after building.

Simulate your circuit using the parameters you measured.

Here's my netlist:

```
.model mytransistor npn (bf= 120 is=1E-15 nf=1)
Q1 ( 1 2 0) mytransistor
Rbase ( 3 2) 1.Meg
Rc ( 4 1) 1.K
Vbase ( 3 0) DC 1.
Vcc ( 4 0) DC 5.
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As with the diode, you need a ".model" statement. This time, instead of a "D" for diode, you need "NPN" to say that it is an "NPN" transistor. Then you need to specify transistor parameters. The ones we have so far are "BF" which is the "beta" or current gain that you measured, "IS" which is the saturation current of the base-emitter diode, and "NF", which is the "N" from the diode.

Now you can run it:

```
print dc vbe(Q1) vce(Q1) ib(Q1) ic(Q1) v(3)
dc Vbase 1 100 dec 2
```

This will give you a chart with some of the data you measured. It should match.

Your report should include the results of a simulation run. You can make gnucap save what you did with the ">" command. Before you start, give the command "> file_to_save_in", and it will save everything that shows on the screen into a file. Then, for your report, edit the file to remove excess clutter.