LABORATORY #1
TRANSISTOR CHARACTERISTICS

EQUIPMENT

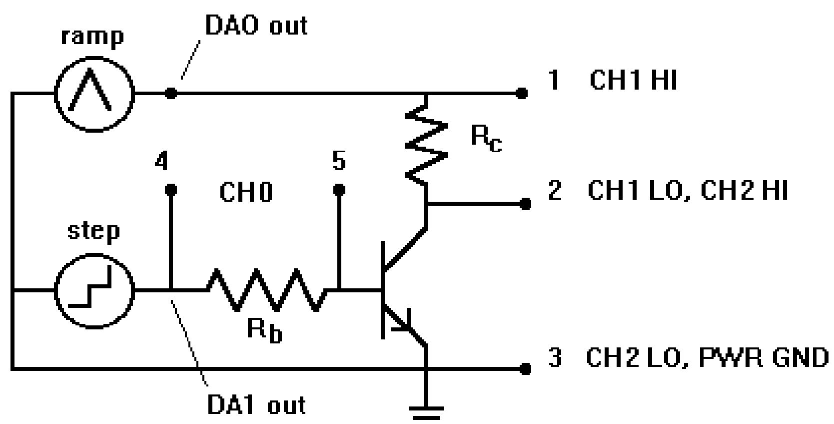
486 computer with DAS-16 data acquisition board
"Testpoint " data acquisition software
2N5210 transistor
various resistors

INTRODUCTION

The most basic device in electronic instrumentation is the amplifier. The basic element of many amplifiers is the transistor. In this laboratory you will measure the characteristics of an NPN bipolar transistor. In the next laboratory you will use it to make amplifiers. The present day, standard method for acquiring and storing data for later analysis uses a computer with an analog to digital converter (A/D) that converts the voltages from measuring devices into digital form for storage. You will use such a system for a number of labs in this course. In this lab you will use this system with a program that we have prepared for you to apply a sequence of voltages to the base and collector of a transistor while simultaneously measuring voltages at various points in the circuit. This will measure the I,V (current, voltage) characteristic of the device which is fundamental to the design of any circuit which uses it. The I,V data are used to determine the small signal h parameters of the device

SUMMARY OF THE MEASUREMENT

In this experiment you will measure the IV characteristics of the 2N5210 transistor. This is an NPN device with the pins arranged as shown on the right in Fig 1(not the same for all transistors). In order to do so you will use a circuit shown on the left.



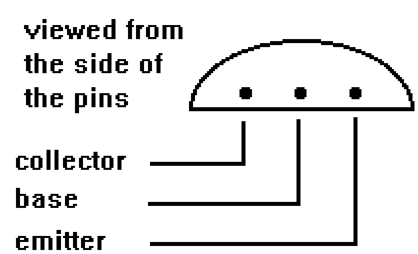


FIGURE 1

Use R_b ~ 1 MΩ and R_c = 220 Ω. The first measurement will require connecting a triangle function (ramp) voltage to the collector and a staircase (step) function voltage to the base. Since R_b is so large and V_{be} is almost constant, this constitutes an approximate current source for the base. For each step value of the base bias, the collector voltage will be swept over most of its operating range by the triangle function. You will record the voltages between points 1 and 2 as well as those between points 2 and 3 of Figure 1 for the entire sequence. when these voltages are plotted they will provide a family of curves similar to those of figure 6.4 (p. 194) of the text.

PROCEDURE

CONNECT THE CIRCUIT

The first task is to connect the circuit as shown in figure 1. Use your protoboard for the circuit and then run wires to the computer I/O (input-output) terminal board, illustrated in Figure 2. For the first measurement, the triangle function will be on digital to analog (D/A) output channel DA0 (terminal 9) and the step function on channel D/A channel DA1 (terminal 27). The voltage across the collector resistor will measure the emitter-collector current so that point #1 of Figure 1 should be connected to CH1 HI and point #2 to CH1 LO. The emitter-collector voltage is measured between points #2 and #3 in Figure 1. Point #2 should be connected to CH2 HI and point #3 to CH2 LO as well as to PWR GND. The base current is measured by the voltage across R_b. In order to obtain voltages from the D/A outputs, D/A0 REF IN (10) and D/A1 REF IN (26) must be connected to reference voltages. Set the negative output side (left) of your power supply to -10 V and connect it to both of these terminals. This will set the range of the D/A output voltages to swing between 0 and +10 V. Don't forget the common ground connection for protoboard, I/O board and positive terminal of reference supply.

LL GND	19		
CH0 LO	18	37	CH0 HI
CH1 LO	17	36	CH1 HI
CH2 LO	16	35	CH2 HI
CH3 LO	15	34	CH3 HI
CH4LO	14	33	CH4 HI
CH5 LO	13	32	CH5 HI
CH6 LO	12	31	CH6 HI
CH7 LO	11	30	CH7 HI
D/A 0REF IN	10	29	LL GND
D/A 0OUT	9	28	LL GND
-5V REF	8	27	D/A 1 OUT
PWR GND	7	26	D/A 1 REF IN

IP1	6	25	IP0/TRIG 0
IP2	5	24	IP1/GATE 0
OP1	4	23	OP0
OP3	3	22	OP2
CTR0 OUT	2	21	CTR 0 CLK IN
+5	1	20	CTR 2 OUT

FIGURE 2

USING THE SOFTWARE

The required staircase and triangle functions are already programmed into a "TestPoint" file. It can be loaded by double clicking with the mouse on the icon labeled ivtest3.(If you can't find ivtest3, double click on "TestPoint", select "Open" from the File Menu, change directory to c:\testpt\ and double click on ivtest3). With the file loaded, use the Mode menu to select "Run", not "Edit". Begin taking data by using the mouse to click the switch on screen to "on". If you wish to stop the program before completion, click the switch to the "off" position. Three plots will be shown on the screen: the staircase applied to the base, the triangle function applied to the collector and the family of I_C-V_{CE} curves. The axis scales will change during acquisition so as to let the data fill the window. All transistors are not identical; make some trial runs, adjusting the base resistance until the maximum collector current is about 5 milliamperes. The 2N5210 is a high gain (h_{fe} in the hundreds) high frequency transistor which may oscillate in your setup. If you get erratic data for this reason, try a small bypass capacitor (1000pf) from collector to ground and/or base to ground. Remember that the A/D inputs measure voltage. The current is the voltage across a resistor divided by the resistance. You knew that, but some of you will forget. You can verify the calibration of TestPoint data by using your DMM or scope to independently monitor the data taking.

DETERMINE THE FORWARD CURRENT GAIN PARAMETER h_{fe} AND THE OUTPUT ADMITTANCE h_{oe}

You want to have hard copy of your I_C-V_{CE} curves for this part of the lab. Use the print command in the file menu and it will appear on the laser printer. You can get an enlarged plot of the I-V curve for better estimates by clicking the **Inspect** button and the maximize button(upper right hand corner of the I-V window). You can also export the data to Origin as follows:

1) Select “Edit from the Mode menu.
2) Select the I-V window by clicking on it with the mouse.
3) Open Origin.
   a) Select two columns in the data window.
   b) Select “Paste Link” from the edit menu.
   c) Return to TestPoint.
4) Select “Run” from the Mode menu.
5) Mouse click on “on” to take data and automatically transfer to Origin. You can now process and plot the data in Origin as you please.

From the printed plot, determine an operating point near the center of the linear range of the transistor and estimate h_{FE} and h_{fe} in the neighborhood of this point. Use the same operating point to measure h_{FE} and h_{fe} in the next section. Use the slope of the I_C-V_{CE} curves to measure h_{oe}.

MEASURE I_c VS I_B DIRECTLY

You can also measure h_{fe} directly. For this purpose you will want to ramp the voltage to thebase resistor, measure the base and collector currents, for a fixed value of V_{CE}. Disconnect DA0 from the collector resistor and connect it to the base resistor, replacing DA1. Use the second power supply output to apply a constant positive voltage to the collector resistor. Reconnect the CH2HI and CH2LO input channels so as to measure the base current I_B and run the sequence so as to plot I_C vs. I_B. According to the defining hybrid differential equations, these measurements should be made at constant V_C. Since V_{CE} is not quite constant, suggest a modification to the circuit (and its limitations)which would reduce this problem. Alternatively, show that the slope of the I_C vs I_B curve is not quite equal to h_{fe} and make a correction using h_{oe} from the preceding section. Check the values of h_{fe} and h_{FE} determined by this method with your results in the previous paragraph.

MEASURE THE INPUT IMPEDANCE, h_{ie}

Describe a method for measuring h_{ie} and use it to estimate this parameter at the operating point used above.