Name ______________________

Date ______________________

Instructor ______________________

EXPERIMENT

8

Bipolar Junction Transistor (BJT) Characteristics

OBJECTIVES

1. *To determine transistor type (npn, pnp), terminals, and material using a digital multimeter (DMM).*
2. *To graph the collector characteristics of a transistor using experimental methods and a curve tracer.*
3. *To determine the value of the alpha and beta ratios of a transistor.*

EQUIPMENT REQUIRED

Instruments

DMM
Curve tracer (if available)

Components

Resistors

(1) 1-kΩ
(1) 330-kΩ
(1) 5-kΩ potentiometer
(1) 1-MΩ potentiometer

Transistors

(1) 2N3904 (or equivalent)
(1) Transistor without terminal identification

Supplies

DC power supply

EQUIPMENT ISSUED

Item	Laboratory serial no.
DMM	
Curve tracer	
DC power supply	

RÉSUMÉ OF THEORY

Bipolar transistors are made of either silicon (Si) or germanium (Ge). Their structure consists of two layers of *n*-type material separated by a layer of *p*-type material (*npn*), or of two layers of *p*-material separated by a layer of *n*-material (*pnp*). In either case, the center layer forms the base of the transistor, while the external layers form the collector and the emitter of the transistor. It is this structure that determines the polarities of any voltages applied and the direction of the electron or conventional current flow. With regard to the latter, the arrow at the emitter terminal of the transistor symbol for either type of transistor points in the direction of conventional current flow and thus provides a useful reference (Fig. 8.2). One part of this experiment will demonstrate how you can determine the type of transistor, its material, and identify its three terminals.

The relationships between the voltages and the currents associated with a bipolar junction transistor under various operating conditions determine its performance. These relationships are collectively known as the characteristics of the transistor. As such, they are published by the manufacturer of a given transistor in a specification sheet. It is one of the objectives of this laboratory experiment to experimentally measure these characteristics and to compare them to their published values.

PROCEDURE

Part 1. Determination of the Transistor's Type, Terminals, and Material

The following procedure will determine the type, terminals, and material of a transistor. The procedure will utilize the diode testing scale found on many modern multimeters. If no such scale is available, the resistance scales of the meter may be used.

a. Label the transistor terminals of Fig. 8.1 as 1, 2, and 3. Use the transistor without terminal identification for this part of the experiment.

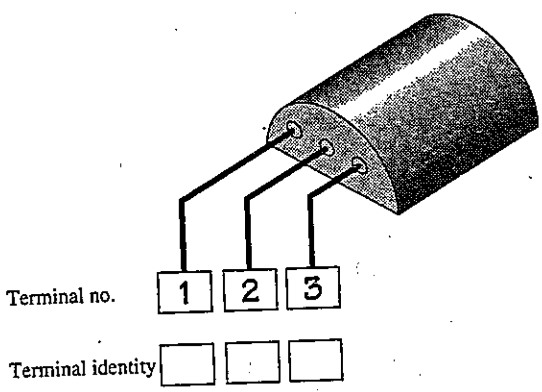

Figure 8-1 Determination of the identities of BJT leads.

b. Set the selector switch of the multimeter to the diode scale (or to the 2 kΩ range if the diode scale is unavailable).

c. Connect the positive lead of the meter to terminal 1 and the negative lead to terminal 2. Record your reading in Table 8.1.

TABLE 8.1

	Meterleads connected to BJT		*Diode check reading*
Step	*Positive*	*Negative*	*(or highest resistance range)*
c	1	2	
d	2	1	
e	1	3	
f	3	1	
g	2	3	
h	3	2	

d. Reverse the leads and record your reading.

e. Connect the positive lead to terminal 1 and the negative lead to terminal 3. Record your reading.

f. Reverse the leads and record your reading.

g. Connect the positive lead to terminal 2 and the negative lead to terminal 3. Record your reading.

h. Reverse the leads and record your reading.

i. The meter readings between two of the terminals will read high (O.L. or higher resistance) regardless of the polarity of the meter leads connected. Neither of these two terminals will be the base. Based on the above, record the number of the base terminal in Table 8.2.

TABLE 8.2

Part 1 (i):	Base terminal	
Part 1 (j):	Transistor type	
Part 1 (k):	Collector terminal	
Part 1 (k):	Emitter terminal	
Part 1 (l):	Transistor material	

j. Connect the negative lead to the base terminal and the positive lead to either of the other terminals. If the meter reading is low (approximately 0.7 V for Si and 0.3 V for Ge or lower resistance), the transistor type is *pnp;* go to step **k**(1). If the reading is high, the transistor type is *npn*; go to step **k**(2).

k. (1) For *pnp* type, connect the negative lead to the base terminal and the positive lead alternately to either of the other two terminals. The lower of the two readings obtained indicates that the base and collector are connected; thus the other terminal is the emitter. Record the terminals in Table 8.2.

(2) For *npn* type, connect the positive lead to the base terminal and the negative lead alternately to either of the other two terminals. The lower of the two readings obtained indicates that the base and collector are connected; thus the other terminal is the emitter. Record the terminals in Table 8.2.

l. If the readings in either (1) or (2) of Part 1(k) were approximately 700 mV, the transistor material is silicon. If the readings were approximately 300 mV, the material is germanium. If the meter does not have a diode testing scale, the material cannot be determined directly. Record the type of material in Table 8.2.

Part 2. The Collector Characteristics

a. Construct the network of Fig. 8.2.

b. Set the voltage V_{R_B} to 3.3 V by varying the 1-MΩ potentiometer. This adjustment will set $I_B = V_{R_B}/R_B$ to 10 μA as indicated in Table 8.3.

c. Then set V_{CE} to 2 V by varying the 5-kΩ potentiometer as required by the first line of Table 8.3.

d. Record the Voltages V_{R_C} and V_{BE} in Table 8.3.

e. Vary the 5-kΩ potentiometer to increase V_{CE} from 2 V to the values appearing in Table 8.3. Note that I_B is maintained at 10 μA for the range of V_{CE} levels.

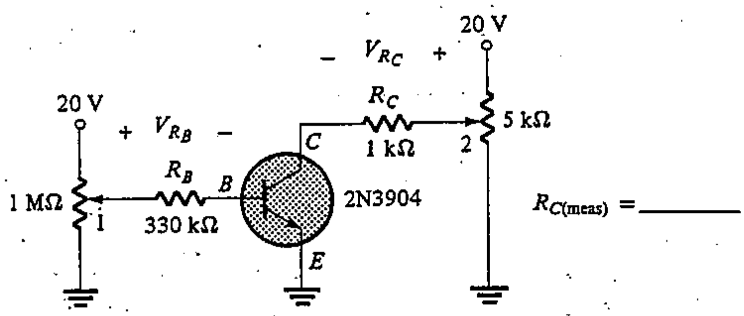

Figure 8-2 Circuit to determine the characteristics of a BJT.

f. For each value of V_{CE} measure and record V_{R_C} and V_{BE}. Use the mV scale for V_{BE}.

g. Repeat steps 2(b) through 2(f) for all values of V_{R_B} indicated in Table 8.3. Each value of V_{R_B} will establish a different level of I_B for the sequence of V_{CE} values.

h. After all data have been obtained, compute the values of I_C from $I_C = V_{RC}/R_C$ and I_E from $I_E = I_C + I_B$. Use the measured resistor value for R_C.

i. Using the data of Table 8.3, plot the collector characteristics of the transistor on the graph of Fig. 8.3. That is, plot I_C versus V_{CE} for the various values of I_B. Choose an appropriate scale for I_C and label each I_B curve.

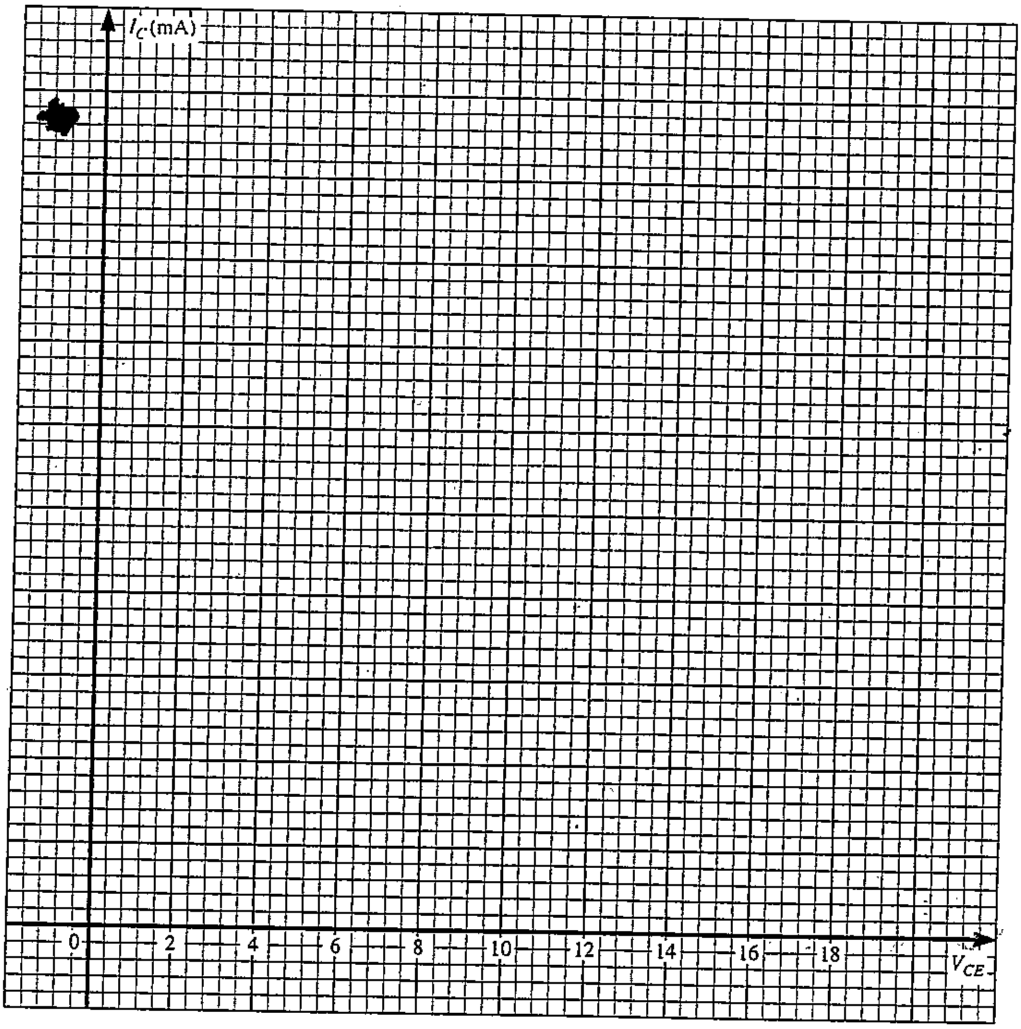

Figure 8-3 Characteristic curves from the experimental data of Part 2.

Part 3. Variation of α and β

a. For each line of Table 8.3 calculate the corresponding levels of α and β using $\alpha = I_C/I_E$ and $\beta = I_C/I_B$ and complete the table.

b. Is there a significant variation in α and β from one region of the characteristics to another?

TABLE 8.3
Data for Construction of Transistor Collector Curve and Calculations of Transistor Parameters

V_{RB} (V) (meas)	I_B (μA) (calc)	V_{CE} (V) (meas)	V_{RC} (V) (meas)	I_C (mA) (calc)	V_{BE} (V) (meas)	I_E (mA) (calc)	α (calc)	β (calc)
		2						
		4						
		6						
3.3	10	8						
		10						
		12						
		14						
		16						
		2						
		4						
		6						
6.6	20	8						
		10						
		12						
		14						
		2						
		4						
9.9	30	6						
		8						
		10						
		2						
13.2	40	4						
		6						
		8						
		2						
16.5	50	4						
		6						

In which region are the largest values of β found? Specify using the relative levels of V_{CE} and I_C.

In which region are the smallest values of β found? Specify using the relative levels of V_{CE} and I_C.

c. Find the largest and smallest levels of β and mark their locations on the plot of Fig. 8.3 using the notations β_{max} and β_{min}.

d. In general, did β increase or decrease with increase in I_C?

e. In general, did β increase or decrease with increase in V_{CE}? Was the effect of V_{CE} on β greater or less than the effect of I_C?

Part 4. Determination of the Characteristics of a Transistor

Using a Commercial Curve Tracer

a. If available, use a curve tracer to obtain a set of collector characteristics for the 2N3904 transistor. Use the 10 µA step function for I_B and choose a scale for V_{CE} and I_C that matches the scales appearing in the plot of Fig. 8.3.

b. Reproduce the characteristics obtained on the graph of Fig. 8.4. Be sure to label each I_B curve and include the scale for each axis.

c. Compare the characteristics to those obtained in Part 2. Be specific in describing the differences between the two sets of characteristics.

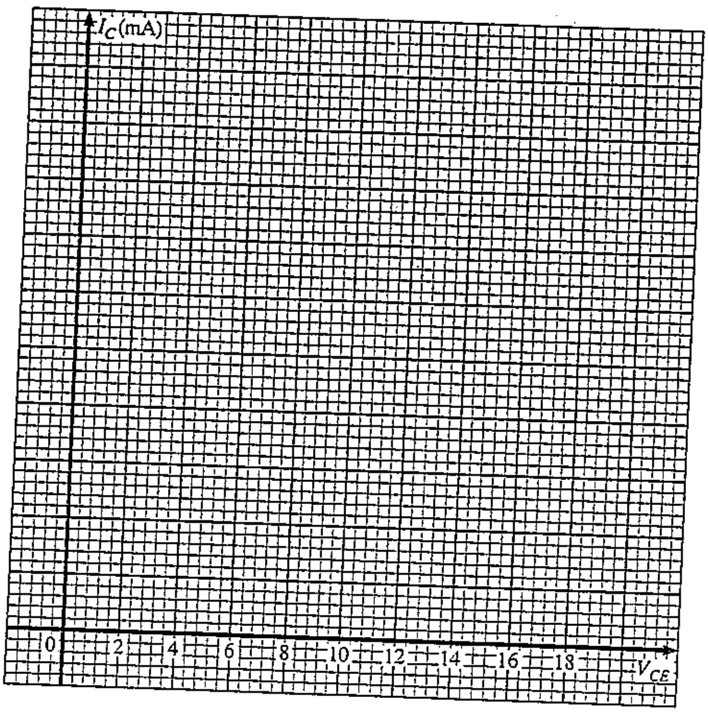

Figure 8-4 Characteristic curves obtained from a commercial curve tracer.

Exercises

1. Find the average value of β using the data of Table 8.3. That is, find the sum of the β values and divide by the number of values.

$\beta_{(av)}$ (calculated) = ____________

Where on the characteristics did the average value of β typically occur?

Is it reasonable to use this value of β for the transistor for most applications?

2. Determine the average value of V_{BE} using the data of Table 8.3. As in Exercise 1 find the sum of the V_{BE} values and divide by the number of values.

$V_{BE\ (av)}$ (calculated) = ____________

Is it reasonable to use the 0.7 V level in the analysis of BJT transistor networks where the actual value is unknown?

3. Careful inspection of the collector curves obtained by experimental measurements and by the curve tracer reveal that the slopes of constant base current are increasing positively (steeper) for higher base currents and higher levels of collector current. What is the effect of the increasing slope of the constant base current lines on the beta of the transistor?

Does the data of Table 8.3 substantiate the above conclusion?

If all the lines of constant base current were horizontal, what would be the effect on the beta ratio determined at any point on a particular base current curve?

If all the lines of constant base current were horizontal and equally spaced what would be the effect on the beta ratio determined anywhere on the characteristics?