University of California, Davis
College of Engineering
Department of Electrical and
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EXPERIMENT No. 2
BIPOLAR TRANSISTORS

I. OBJECTIVE

To give a "feel" for transistor regions of operation and to demonstrate the measurement of Ebers-Moll parameters.

II. PROCEDURE

NOTE: *In this experiment you will measure the current flowing in the base and collectors of the transistors by measuring the voltage across the base and collector resistors as shown in Figure 1. Measure resistor values; don't assume color codes are exactly right.*

$$I_B = \frac{V_{RB}}{R_B} \qquad I_C = \frac{V_{RC}}{R_C}$$

(1) Connect the circuit shown in Figure 1. Increase V_{BB} until I_C = 1mA. Measure V_{BE} and V_{BC}. What region of operation is this? Measure I_B by measuring the voltage across R_B. What is β_F? What is α_F? Calculate I_{ES}.
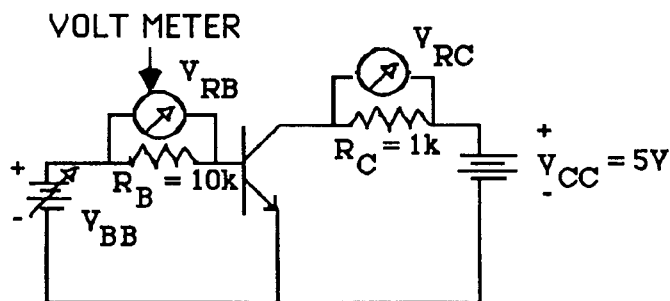

Figure 1.

(2) Vary V_{CC} from 0V to 10V and observe collector current in 2 regions of operation. Sketch I_C vs. V_{CE}. Verify by rough

approximation that the Ebers-Moll equations predict I_C variations in both regions. -

(3) Set both V_{BB} and V_{CC} to 5V. What is V_{BC}? What is V_{BE}? What region of operation is this? Measure I_B, I_C, and $V_{CE(sat)}$.

(4) Change V_{BB} to -3V. How much collector current flows? What region of operation is this? How much current does the Ebers-Moll model say should be flowing?

(5) Return the V_{BB} supply to its original polarity, but interchange the collector and emitter as shown in Figure 2. Increase the V_{BB} supply until $I_E = 0.5\text{mA}$. What region of operation is this? What is I_B? What are β_R and α_R? Calculate I_{CS}.
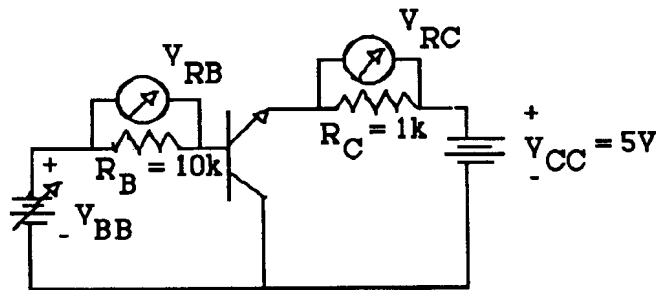

Figure 2.

(6) By solving the Ebers-Moll equations for V_{CE} in saturation, one obtains the result shown below. Use this equation to calculate the theoretical value of $V_{CE(sat)}$ and compare with the measured value in Step (3).

$$V_{CE(sat)} = \frac{kT}{q} \ln \left[\frac{\dfrac{1}{\alpha_R} + \dfrac{I_C}{\beta_R I_B}}{1 - \dfrac{I_C}{\beta_F I_B}} \right]$$

(7) Connect your transistor into the curve tracer and measure the large signal and small signal current gain, β_F and β_0 respectively, at $I_C = 10\text{mA}$ and $V_{CE} = 5\text{V}$.

2

NOTE: *The definition of β_o is $\beta_o = \left.\dfrac{i_c}{i_b}\right|_{V_{CE} = constant}$*

$= \left.\dfrac{\partial I_c}{\partial I_B}\right|_{dV_{CE}} = 0$.   The definition of β_F is $\beta_F = \dfrac{I_c}{I_B}$.

Notice that β_F is not always equal to β_o because β_F is a weak function of I_c.

Sketch your output. From the display, take data to allow a calculation of V_A and r_o. Also measure V_{CEsat} and the breakdown voltage BV_{CE}.

(8) Connect your transistor as a diode (fig. 3). Use the curve tracer to display I_d vs. V_d. Sketch your output. Note values of $V_D = V_{BE}$ for $I_D = 0.1, 1, 10$mA.
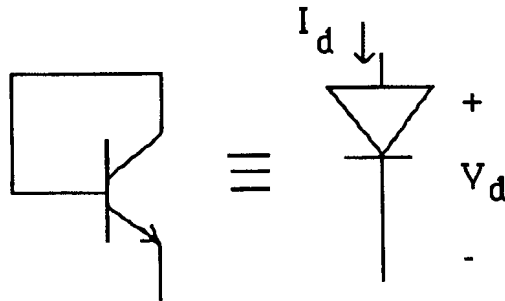

Figure 3.

OPTIONAL - Derive $V_{CE(sat)}$ equation in part (6) above.

Lab Results: Experiment 2 -BIPOLAR TRANSISTORS

II. PROCEDURE

(1)   Region: _____ β_F= _____

   α_F= _____ I_{ES}= _____

(3)   Region: _____ $V_{CE(sat)}$= _____

(4)   Region: _____ I_C= _____

(5)   Region: _____ β_R= _____

   α_R= _____ I_{CS}= _____

(6) $V_{CE(sat)}$= _____

(7)   Curve tracer data:

   β_F= _____ β_0= _____

   V_A= _____ r_0= _____

   $V_{CE(sat)}$= _____ BV_{CE}= _____

(8)

ID	VD
0.1mA	_____
1.0mA	_____
10mA	_____