Name ______________________
Date ______________________
Instructor ______________________

EXPERIMENT

9

Fixed- and Voltage-Divider Bias of BJTs

OBJECTIVE

To determine the quiescent operating conditions of the fixed- and voltage-divider-bias BJT configurations.

EQUIPMENT REQUIRED

Instrument

DMM

Components

Resistors

(1) 680-Ω
(1) 2.7-kΩ
(1) 1.8-kΩ
(1) 6.8-kΩ
(1) 33-kΩ
(1) 1-MΩ

Transistors

(1) 2N3904 or equivalent
(1) 2N4401 or equivalent

Supplies

DC power supply

EQUIPMENT ISSUED

Item	Laboratory serial no.
DMM	
DC power supply	

RÉSUMÉ OF THEORY

Bipolar transistors operate in three modes: cutoff, saturation, and linear. In each of these modes, the physical characteristics of the transistor and the external circuit connected to it uniquely specify the operating point of the transistor. In the cutoff mode, there is only a small amount of reverse current from emitter to collector, making the device akin to an open switch. In the saturation mode, there is a maximum current flow from collector to emitter. The amount of that current is limited primarily by the external network connected to the transistor; its operation is analogous to that of a closed switch. Both of these operating modes are used in digital circuits.

For amplification with a minimum of distortion the linear region of the transistor characteristics is employed. A DC voltage is applied to the transistor, forward-biasing the base-emitter junction and reverse-biasing the base-collector junction, typically establishing a quiescent point near or at the center of the linear region.

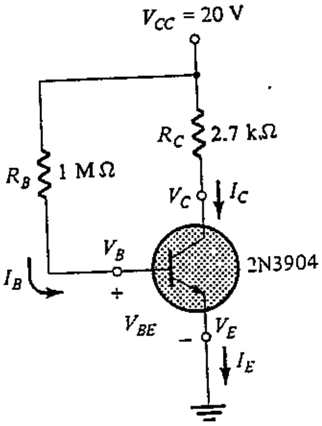
In this experiment, we will investigate two biasing networks: the fixed-bias and the voltage-divider-bias configuration. While the former is relatively simple, it has the serious drawback that the location of the Q-point is very sensitive to the forward current transfer ratio (β) of the transistor and temperature. Because there can be wide variations in beta and the temperature of the device or surrounding medium can change for a wide variety of reasons, it can be difficult to predict the exact location of the Q-point on the load line of a fixed-bias configuration.

The voltage-divider bias network employs a feedback arrangement that makes the base-emitter and collector-emitter voltages primarily dependent on the external circuit elements and not the beta of the transistor. Thus, even though the beta of individual transistors may vary considerably, the location of the Q-point on the load line will remain essentially fixed. The phrase "beta-independent biasing" is often used for such an arrangement.

PROCEDURE

Part 1. Determining β

a. Construct the network of Fig. 9.1 using the 2N3904 transistor. Insert the measured resistance values.



$R_{B(meas)}$ = ________

$R_{C(meas)}$ = ________

+

V_{CE}

−

Figure 9-1

b. Measure the voltages V_{BE} and V_{R_C}.

V_{BE} (measured) = ________
V_{R_C} (measured) = ________

c. Using the measured resistor values calculate the resulting base current using the equation

$$I_B = \frac{V_{R_B}}{R_B} = \frac{V_{CC} - V_{BE}}{R_B}$$

and the collector current using the equation

$$I_C = \frac{V_{R_C}}{R_C}$$

The voltage V_{R_B} was not measured directly for determining I_B because of the loading effects of the meter across the high resistance R_B.

Insert the resulting values of I_B and I_C in Table 9.1

d. Using the results of step 1(**c**) calculate the value of β and record in Table 9.1. This value of beta will be used for the 2N3904 transistor throughout this experiment.

Part 2. Fixed-Bias Configuration

a. Using the β determined in Part 1, calculate the currents I_B and I_C for the network of Fig. 9.1 using the measured resistor values, the supply voltage, and the above measured value for V_{BE}. That is, determine the theoretical values of I_B and I_C using the network parameters and the value of beta.

I_B (calculated) = ________
I_C (calculated) = ________

How do the calculated levels of I_B and I_C compare to those determined from measured voltage levels in Part 1(**c**)?

b. Using the results of step 2(**a**) calculate the levels of V_B, V_C, V_E, and V_{CE}.

V_B (calculated) = ________
V_C (calculated) = ________
V_E (calculated) = ________
V_{CE} (calculated) = ________

c. Energize the network of Fig. 9.1 and measure V_B, V_C, V_E, and V_{CE}.

V_B (measured) = ________
V_C (measured) = ________
V_E (measured) = ________
V_{CE} (measured) = ________

How do the measured values compare to the calculated levels of step 2(**b**)?

Record the measured value of V_{CE} in Table 9.1.

d. The next part of the experiment will essentially be a repeat of a number of the steps above for a transistor with a higher beta. Our goal is to show the effects of different beta levels on the resulting levels of the important quantities of the network. First the beta level for the other transistor, specifically a 2N4401 transistor, must be determined. Simply remove the 2N3904 transistor from Fig. 9.1 and insert the 2N4401 transistor, leaving all the resistors and voltage V_{CC} as in Part 1. Then measure the voltages V_{BE} and V_{R_C} and, using the same equations with measured resistor values, calculate the levels of I_B and I_C. Then determine the level of β for the 2N4401 transistor.

V_{BE} (measured) = ________

V_{R_C} (measured) = ________

I_B (from measured) = ________

I_C (from measured) = ________

β (calculated) = ________

Record the levels of I_B, I_C, and beta in Table 9.1. In addition measure the voltage V_{CE} and insert in Table 9.1.

TABLE 9.1

Transistor Type	V_{CE} volts	I_C mA	I_B μA	β
2N3904				
2N4401				

e. Using the following equations calculate the magnitude (ignore the sign) of the percent change in each quantity due to a change in transistors. Ideally, the important voltage and current levels should not change with a change in transistors. The fixed-bias configuration, however, has a high sensitivity to changes in beta as will be reflected by the results. Place the results of your calculations in Table 9.2.

$$\% \Delta\beta = \frac{|\beta_{(4401)} - \beta_{(3904)}|}{|\beta_{(3904)}|} \times 100\% \qquad \% \Delta I_C = \frac{|I_{C(4401)} - I_{C(3904)}|}{|I_{C(3904)}|} \times 100\%$$

$$\% \Delta V_{CE} = \frac{|V_{CE(4401)} - V_{CE(3904)}|}{|V_{CE(3904)}|} \times 100\% \qquad \% \Delta I_B = \frac{|I_{B(4401)} - I_{B(3904)}|}{|I_{B(3904)}|} \times 100\% \tag{9.1}$$

TABLE 9.2
Percent Changes in β, I_C, V_{CE}, and I_B

%Δβ	%ΔI_C	%ΔV_{CE}	%ΔI_B

Part 3. Voltage-Divider Configuration

a. Construct the network of Fig. 9.2 using the 2N3904 transistor. Insert the measured value of each resistor.

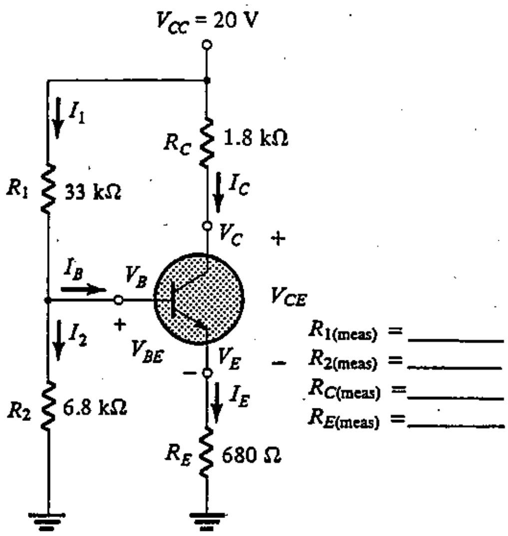


Figure 9-2

b. Using the beta determined in Part 1 for the 2N3904 transistor, calculate the theoretical levels of V_B, V_E, I_E, I_C, V_C, V_{CE}, and I_B for the network of Fig. 9.2. Insert the results in Table 9.3.

TABLE 9.3

2N3904	V_B	V_E	V_C	V_{CE}	I_E (mA)	I_C (mA)	I_B (μA)
Calculated [Part 3(**b**)]							
Measured [Part 3(**c**)]							

c. Energize the network of Fig. 9.2 and measure V_B, V_E, V_C, and V_{CE}. Record their values in Table 9.3. In addition, measure the voltages V_{R_1} and V_{R_2}. Try to measure the quantities to the hundredth or thousandth place. Calculate the currents I_E and I_C and the currents I_1 and I_2 (using $I_1 = V_{R_1}/R_1$ and $I_2 = V_{R_2}/R_2$) from the voltage readings and measured resistor values. Using the results for I_1 and I_2, calculate the current I_B using Kirchhoff's current law. Insert the calculated current levels for I_E, I_C, and I_B in Table 9.3.

How do the calculated and measured values of Table 9.3 compare? Are there any significant differences that need to be explained?

d. Insert the measured value of V_{CE} and calculated values of I_C and I_B from step 3(c) in Table 9.4 along with the magnitude of beta from Part 1.

e. Replace the 2N3904 transistor of Fig. 9.2 with the 2N4401 transistor. Then measure the voltages V_{CE}, V_{R_C}, V_{R_1}, and V_{R_2}. Again, be sure to read V_{R_1} and V_{R_2} to the hundredth or thousandth place to ensure an accurate determination of I_B. Then calculate I_C, I_1, I_2, and determine I_B. Complete Table 9.4 with the levels of V_{CE}, I_C, I_B, and beta for this transistor.

TABLE 9.4

Transistor Type	V_{CE} *(volts)*	I_C*(mA)*	I_B*(μA)*	β
2N3904				
2N4401				

f. Calculate the percent change in β, I_C, V_{CE}, and I_B from the data of Table 9.4. Use the formulas appearing in step 2(e), Eq. 9.1, and record your results in Table 9.5.

TABLE 9.5
Percent Changes in β, I_C, V_{CE}, and I_B

%Δβ	%ΔI_C	%ΔV_{CE}	%ΔI_B

Part 4. Computer Exercise

a. Perform a DC analysis of the network of Fig. 9.1 using PSpice Windows. Obtain all circuit voltages and currents.

b. Repeat the above analysis for the voltage-divider configuration of Fig. 9.2.

c. How do the results of steps 4(a) and 4(b) (using the appropriate beta) compare with the measured values of the experiment?

Problems and Exercises

1. a. Compute the saturation current $I_{C_{sat}}$ for the fixed-bias configuration of Fig. 9.1.

$I_{C_{sat}}$ (calculated) = ______

b. Compute the saturation current $I_{C_{sat}}$ for the voltage-divided bias configuration of Fig. 9.2.

$I_{C_{sat}}$ (calculated) = ______

c. Are the saturation currents of Exercises 1(**a**) and 1(**b**) sensitive to the beta of the transistor or changes thereof?

2. For both the circuits investigated in this experiment, how did the Q point location (defined by I_C and V_{CE} on the collector characteristics) change when the 2N3904 transistor was replaced with the 2N4401? That is, how did the Q-point shift location when a transistor with a higher beta was substituted? In particular, did the Q-points move toward saturation (high I_C, low V_{CE}) or cut-off (low I_C, high V_{CE}) conditions?