Name ______________________

Date ______________________

Instructor ______________________

EXPERIMENT

10

Emitter and Collector Feedback Bias of BJTs

OBJECTIVE

To determine the quiescent operating conditions of the emitter and collector feedback bias BJT configurations.

EQUIPMENT REQUIRED

Instrument

DMM

Components

Resistors

(2) 2.2-kΩ
(1) 3-kΩ
(1) 390-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

This experiment is an extension of Experiment 9. Two additional arrangements will be investigated in this experiment: emitter bias and collector feedback circuits.

Emitter Bias Circuit

The emitter bias configuration in Fig. 10.1 can be constructed using a single or a dual power supply. Both configurations offer increased stability over the fixed bias of Experiment 9. In particular, if the beta of the transistor times the resistance of the emitter resistor is large compared to the resistance of the base resistor, the emitter current becomes essentially independent of the beta of the transistor. Thus, if we exchange transistors in a properly designed emitter-bias circuit, the changes in I_C and V_{CE} should be small.

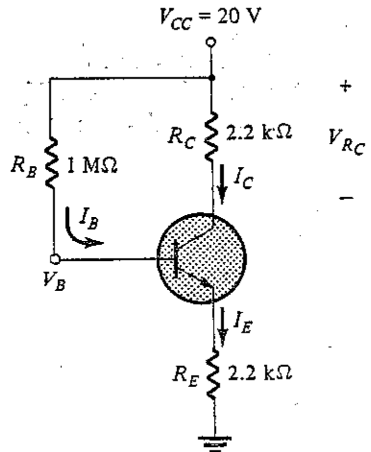
Collector Feedback Circuit

If we compare the collector feedback bias circuit configuration in Fig. 10.2 with the fixed bias of Experiment 9 it is noted that for the former, the base resistor is connected to the collector terminal of the transistor and not to the fixed supply voltage V_{CC}. Thus the voltage across the base resistance of the collector feedback configuration is a function of the collector voltage and the collector current. In particular, this circuit demonstrates the principle of negative feedback, in which a tendency of an output variable to increase or decrease will result in a reduction or increase in the input variable respectively. For instance, any tendency on the part of I_C to increase will reduce the level of V_C which in turn will result in a lower level of I_B offsetting the trend of I_C. The result is a design less sensitive to variations in its parameters.

PROCEDURE

Part 1. Determining β

a. Construct the network of Fig. 10.1 using the 2N3904 transistor. Insert the measured resistor values.



$R_{B(meas)}$ = ________
$R_{C(meas)}$ = ________
$R_{E(meas)}$ = ________

Figure 10-1

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

V_B (measured) = ________

V_{R_C} (measured) = ________

c. Using the results of Part 1(**b**) and the measured resistor values calculate the resulting base currents I_B and I_C using the following equations:

$$I_B = \frac{V_{CC} - V_B}{R_B} \text{ and } I_C = \frac{V_{R_C}}{R_C}.$$

Record in Table 10.2.

I_B (from measured) = ________

I_C (from measured) = ________

d. Using the results of step 1(**c**) calculate the value of β and record in Table 10.2. This value of beta will be used for the 2N3904 transistor throughout the experiment.

β (calculated) = ________

Part 2. Emitter-Bias Configuration

a. Using the β determined in Part 1, calculate the values of I_B and I_C for the network of Fig. 10.1 using measured resistor values and the supply voltage V_{CC}. In other words, perform a theoretical analysis of the network. Insert the results in Table 10.1.

I_B (calculated) = ________

I_C (calculated) = ________

How do the calculated values compare with the measured values of Part 1(**c**)?

b. Using the β determined in Part 1 calculate the levels of V_B, V_C, V_E, V_{BE}, and V_{CE} and insert in Table 10.1.

c. Energize the network of Fig. 10.1 with the 2N3904 and measure the voltages V_B, V_C, V_E, V_{BE}, and V_{CE}. Insert in Table 10.2.

How do the calculated and measured results of Tables 10.1 and 10.2 compare for the 2N3904 transistor? In particular, comment on any results that do not compare well.

TABLE 10.1

	Calculated Values						
Transistor Type	V_B volts	V_C volts	V_E volts	V_{BE} volts	V_{CE} volts	I_B μA	I_C mA
2N3904							
2N4401							

TABLE 10.2

	Measured Values					(Calc. from Measured Values)		
Transistor Type	V_B volts	V_C volts	V_E volts	V_{BE} volts	V_{CE} volts	I_B μA	I_C mA	β
2N3904								
2N4401								

d. Replace the 2N3904 transistor of Fig. 10.1 with the 2N4401 transistor and measure the resulting voltages V_B and V_{R_C}. Then calculate the currents I_B and I_C using measured resistance values. Finally calculate the value of β for this transistor. This will be the value of beta used for the 2N4401 transistor throughout this experiment. Record the levels of I_B, I_C, and β in Table 10.2.

V_B (measured) = ________

V_{R_C} (measured) = ________

e. Using the beta determined in step 1(**d**), perform a theoretical analysis of Fig. 10.1 with the 2N4401 transistor. That is, calculate the levels of I_B, I_C, V_B, V_C, V_E, V_{BE}, and V_{CE} and insert in Table 10.1.

f. Energize the network of Fig. 10.1 with the 2N4401 transistor, measure V_B, V_C, V_E, V_{BE}, and V_{CE}, and insert in Table 10.2.

How do the calculated and measured results of Tables 10.1 and 10.2 compare for the 2N4401 transistor? Discuss any results that appear different by more than 10%.

g. Calculate the percent change in β, I_C, V_{CE}, and I_B using the equations first presented in Experiment 9 and repeated here for convenience. Record the results in Table 10.3.

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

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

TABLE 10.3
Percent Changes in β, I_C, V_{CE}, and I_B

%Δβ	%ΔI_C	%ΔV_{CE}	%ΔI_B

Part 3. Collector Feedback Configuration ($R_E = 0\ \Omega$)

a. Construct the network of Fig. 10.2 using the 2N3904 transistor. Insert the measured resistor values in Fig. 10.2.

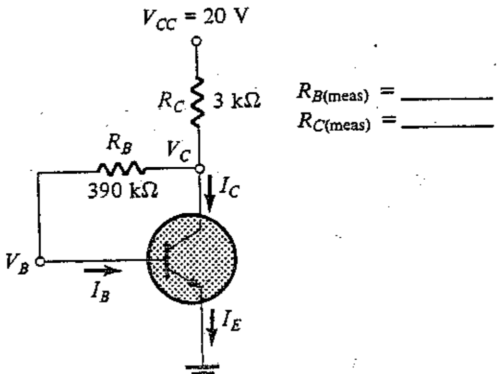


Figure 10-2 Collector Feedback

b. Using the beta determined in Part 1, calculate the values of I_B, I_C, V_B, V_C, and V_{CE} and insert in Table 10.4.

c. Energize the network of Fig. 10.2, measure V_B, V_C, and V_{CE}, and insert in Table 10.5. Calculate the currents I_B and I_C using measured resistance values and the fact that $I_C \cong V_{R_C}/R_C$. Insert the current levels in Table 10.5.

How do the calculated and measured results of Tables 10.4 and 10.5 compare for the 2N3904 transistor?

d. Replace the 2N3904 transistor of Fig. 10.2 with the 2N4401 transistor of Part 1, calculate the values of I_B, I_C, V_B, V_C and V_{CE}, and insert in Table 10.4.

e. Energize the network of Fig. 10.2 with the 2N4401 transistor and measure V_B, V_C, and V_{CE}. Insert all measurements in Table 10.5. Calculate I_B and I_C from measured values and then insert the current levels in Table 10.5.

How do the calculated and measured results of Tables 10.4 and 10.5 compare for the 2N4401 transistor?

f. Calculate the percent changes in β, I_C, V_{CE}, and I_B using the equations of Part 1(g). Record the results in Table 10.6.

TABLE 10.4

	Theoretical Calculated Values				
Transistor Type	V_B *volts*	V_C *volts*	V_{CE} *volts*	I_B *μA*	I_C *mA*
2N3904					
2N4401					

TABLE 10.5

	Measured Values			(Calc. from Measured Values)	
Transistor Type	V_B *volts*	V_C *volts*	V_{CE} *volts*	I_B *μA*	I_C *mA*
2N3904					
2N4401					

TABLE 10.6
Percent Changes in β, I_C, V_{CE}, and I_B

%Δβ	%ΔI_C	%ΔV_{CE}	%ΔI_B

Part 4. Collector Feedback Configuration (with R_E)

a. Construct the network of Fig. 10.3 using the 2N3904 transistor. Insert the measured resistance values in Fig. 10.3.

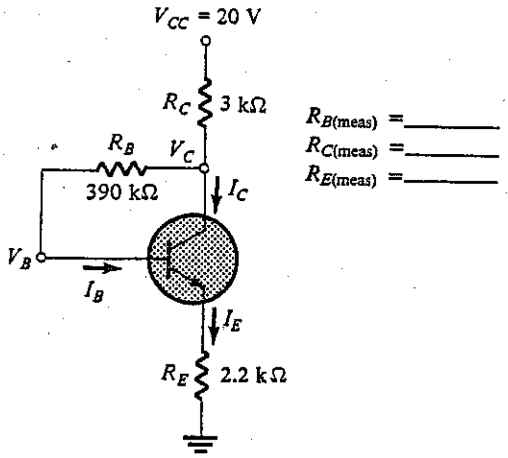


Figure 10-3 Collector feedback circuit.

b. Using the beta determined in Part 1, calculate the values of I_B, I_C, I_E, V_B, V_C, and V_{CE} and insert in Table 10.7.

c. Energize the network of Fig. 10.3, measure V_B, V_C, V_E, and V_{CE}, and insert in Table 10.8. In addition, calculate the currents I_B, I_C, and I_E from measured values using measured resistor values. Insert the current levels in Table 10.8.

How do the calculated and measured results of Tables 10.7 and 10.8 compare for the 2N3904 transistor?

d. Replace the 2N3904 transistor of Fig. 10.3 with the 2N4401 transistor. Using the beta of Part 1 calculate the values of I_B, I_C, I_E, V_B, V_C, and V_{CE} and insert in Table 10.7.

e. Energize the network of Fig. 10.3 with the 2N4401 transistor, measure V_B, V_C, V_E, and V_{CE}, and insert in Table 10.8. In addition, calculate the currents I_B, I_C, and I_E from measured values using the measured resistor values. Insert the current levels in Table 10.8.

How do the calculated and measured results of Tables 10.7 and 10.8 compare for the 2N4401 transistor?

f. Calculate the percent changes in β, I_C, V_{CE}, and I_B using the equations appearing in Part 1(g) and insert in Table 10.9.

TABLE 10.7

	Theoretical Calculated Values						
Transistor Type	V_B *volts*	V_C *volts*	V_E *volts*	V_{CE} *volts*	I_B *μA*	I_C *mA*	I_E *mA*
2N3904							
2N4401							

TABLE 10.8

	Measured Values				(Calc. from Measured Values)		
Transistor Type	V_B *volts*	V_C *volts*	V_E *volts*	V_{CE} *volts*	I_B *μA*	I_C *mA*	I_E *mA*
2N3904							
2N4401							

TABLE 10.9
Percent Changes in β, I_C, V_{CE}, and I_B

%Δβ	%ΔI_C	%ΔV_{CE}	%ΔI_B

Part 5. Computer Exercise

a. Perform a DC analysis of the network of Fig. 10.1 using PSpice Windows. Obtain all network currents and voltages.

b. Repeat the above analysis for the collector-feedback configuration of Fig. 10.3.

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 emitter-bias configuration of Fig. 10.1.

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

b. Compute the saturation current $I_{C_{sat}}$ for the collector-feedback configuration of Fig. 10.2.

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

c. Compute the saturation current $I_{C_{sat}}$ for the collector-feedback configuration of Fig. 10.3.

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

d. What is the effect of beta on the calculations of Exercises 1(**a**), 1(**b**), and 1(**c**) of this exercise?

2. For the three configurations investigated in this experiment, how did the Q-point location (defined by I_C and V_{CE}) change when the 2N3904 transistor was replaced with the 2N4401? That is, how did the Q-point shift position 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?

3. a. Determine the ratio of the change in I_C, V_{CE}, and I_B due to changes in beta and complete Table 10.10. Use the results of Parts 2, 3, and 4 to obtain the percent changes indicated.

TABLE 10.10

	$\frac{\%\Delta I_C}{\%\Delta\beta}$	$\frac{\%\Delta V_{CE}}{\%\Delta\beta}$	$\frac{\%\Delta I_B}{\%\Delta\beta}$
Emitter bias			
Collector feedback ($R_E = 0\ \Omega$)			
Collector feedback (with R_E)			

b. How does the figure of merit defined by Eq. 9.2 (repeated here for convenience) compare for each configuration of Table 10.10?

$$S(\beta) = \frac{\%\Delta I_C}{\%\Delta\beta}$$

Which appears to have the better stability factor?

c. Do the remaining sensitivities [$S(\beta)$] of Table 10.10 support the fact that one configuration is more stable than the other?

4. **a.** For the emitter-bias configuration of Fig. 10.1 develop an equation for I_C in terms of the other elements (resistors, V_{CC}, β) of the network. Use the fact that $(\beta + 1) \cong \beta$.

b. Divide the numerator and denominator of the equation obtained in Exercise 4(**a**) by β.

c. Based on the results of Exercise 4(**b**) what relationship must exist between the elements of the network to minimize the effect of changing levels of β on the level of I_C?

5. **a.** For the collector feedback configuration of Fig. 10.2 develop an equation for I_C in terms of the other elements (resistors, V_{CC}, β) of the network. Use the fact that $(\beta + 1) \cong \beta$.

b. Divide the numerator and denominator of the equation obtained in Exercise 5(a) by β.

c. Based on the results of Exercise 5(**b**) what relationship must exist between the elements of the network to minimize the effect of changing levels of β on the level of I_C?.

6. a. For the collector feedback configuration of Fig. 10.3 develop an equation for I_C in terms of the other elements (resistors, V_{CC}, β) of the network. Use the fact that $(\beta + 1) \cong \beta$.

b. Divide the numerator and denominator of the equation obtained in Exercise 6(a) by β.

c. Based on the results of Exercise 6(**b**) what relationship must exist between the elements of the network to minimize the effect of changing levels of β on the level of I_C?

7. Comparing the results of Exercises 4(**c**), 5(**c**), and 6(**c**) which configuration would appear to have the least sensitivity to changes in beta for resistor values of about the same magnitude?

Does the above conclusion compare favorably with the conclusion of Exercise 3(**b**)?