UNIVERSITY OF MIAMI
Department of Electrical and Computer Engineering
EEN 311

You will get the full points for this experiment if you complete the Preliminary Work.

Name: ________________
Section: ________________
Date: ________________

EXPERIMENT 6

NPN PN2222
Vbe=Vdrop=0.7V

DC AND AC CHARACTERISTICS OF TRANSISTORS

PURPOSE: In the first part of this experiment, the commom-emitter output characteristics of an npn bipolar junction transistor will be investigated using a transistor curve tracer. The purpose of the second part is to verify the voltage and currents in a fixed bias circuit. In spite of its simplicity, a fixed bias circuit does not effectively stabilize a transistor's quiescent point. Consequently, the Q-point is affected by the transistor's current gain β. In the final part, the voltages and currents in a self bias circuit will be verified. This bias scheme is often used because the base current is made small compared to the currents through the two base "voltage-divider" resistors. Consequently, the base voltage, and therefore the collector current, is stabilized against changes in the transistor beta.

Preliminary Work

1) Using the formulas

$$I_E = I_C + I_B, \qquad \alpha = \frac{I_C}{I_E}, \qquad \beta = h_{FE} = \frac{I_C}{I_B},$$

Where I_C, I_E, and I_B are the collector, emitter, and base currents of a BJT, respectively, find:

i. α in terms of β.
ii. β in terms of α.

2) Find the expressions for R_B and R_C in terms of β, V_{CC}, V_{CEQ}, and I_{CQ} for the fixed bias circuit of Fig. 3.1. Assume that V_{BE} = 0.7 V; V_{CEQ} and I_{CQ} are the desired quiescent point values.

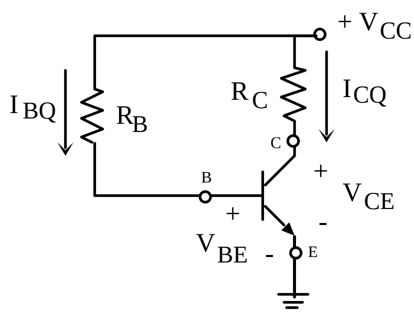


Figure 3.1 Simple Fixed Bias Circuit.

3) The following figure is a self biased common-emitter amplifier stage.

a) Find the Thevenin Equivalent of the part of the circuit between points a & b as shown.

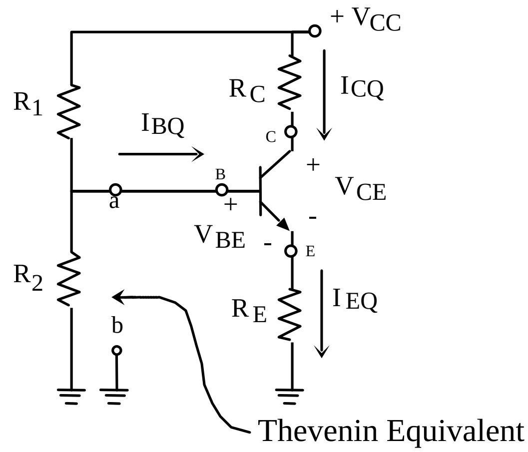


Figure 3.2 Self Biased Common-Emitter Amplifier

b) Find the expressions for R_C and R_E in terms of V_{CEQ}, I_{CQ} (the desired Q-point values), and V_{CC}. Assume that $\beta \gg 1$, $I_{CQ} \cong I_{EQ}$, and $V_{EQ} = 0.1V_{CC}$.

c) Redraw the circuit replacing the part to the left of points a& b by the Thevenin Equivalent V_{Th} and R_{Th}. Find the expression for V_{Th} in terms of V_{BE}, I_{CQ}, β, and R_E. The base-to-emitter voltage drop, V_{BE}, is given by $V_{BE} \cong 0.7$ V for a Si transistor, when operating properly. Also, choose R_{Th} as $R_{Th} = 0.1(\beta + 1)R_E$. This selection for R_{Th} will provide good voltage stability with respect to temperature. Q-point stability and temperature effects will be investigated in Experiment 13.

d) Justify the selection $R_{Th} = 0.1(\beta + 1)R_E$ mentioned in part (c).

e) Find the expressions for R_1 and R_2 in terms of R_{Th}, V_{Th}, and V_{CC} by solving the expressions for R_{Th} and V_{Th} found in part (a) simultaneously.

Experimental Procedure

I. BJT Characteristics:

The output characteristics (I_C vs V_{CE} for different I_B's) of the given transistor will be investigated using a *Transistor Curve Tracer*.

a) Connect your transistor to the transistor test panel.

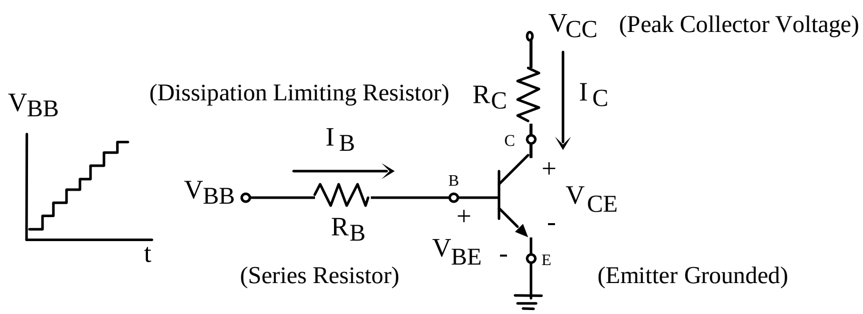
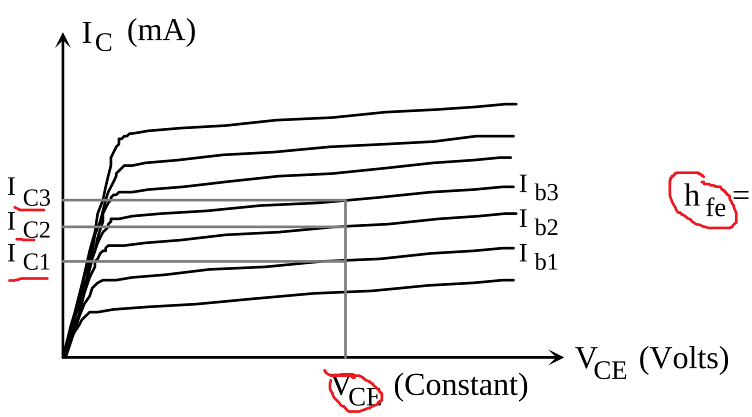


Figure 3.3 Configuration for Transistor Connection.

b) Obtain a copy of the characteristics displayed on the curve tracer. Collect your data in Table 3.1 (this will help you determine β_{DC} and β_{AC}, the static forward current ratio and the small-signal short circuited forward current ratio, respctively). Take readings for at least three different base current values from the output characteristics at V_{CEQ}. Remember that the readings should be made for a constant V_{CE} voltage and around the I_{CQ} of interest (see Fig. 3.4). h_{fe} will be calculated for two Q-points: V_{CEQ} = 10 V, I_{CQ} = 1 mA; and V_{CEQ} = 10 V, I_{CQ} = 10 mA.

hfe=179



$$h_{fe} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE} = \text{Constant}}$$

Figure 3.4 Typical BJT V_{CE} vs I_C characteristics.

V_{CEQ} = 10V, I_{CQ} = 1mA		V_{CEQ} = 10V, I_{CQ} = 10mA	
I_B (μA)	**I_C (mA)**	**I_B (μA)**	**I_C (mA)**
		55uA	9.8mA
	1.0	56.1uA	10.0

Table 3.1 Data for Calculating β_{DC} and β_{AC}.

c) Using the data in the table above, calculate three different values for β_{AC} as $\beta_{AC}=h_{fe}=\Delta I_C/\Delta I_B$. Then find the average of the three and record your experimental value for it below

At I_{CQ} = 1 mA and V_{CEQ} = 10 V: β_{AC} = 179

At I_{CQ} = 10 mA and V_{CEQ} = 10 V: β_{AC} = _______

d) Using the data in Table 3.1, calculate β_{DC} as $\beta_{DC} = I_{CQ}/I_{BQ}$ for I_{CQ} = 1 mA and V_{CEQ} = 10 V.

At I_{CQ} = 1 mA and V_{CEQ} = 10 V: β_{DC} = _______

e) Repeat part (d) for I_{CQ} = 10 mA and V_{CEQ} = 10 V.

At I_{CQ} = 10 mA and V_{CEQ} = 10 V: β_{DC} = _______

II. Fixed Bias Circuit:

a) Using the results of the second part of your Preliminary Work, select R_B and R_C for the following fixed bias circuit, given that

V_{CC} = 20 V, V_{CEQ} = 10 V, I_{CQ} = 10 mA, V_{BE} = 0.7 V.

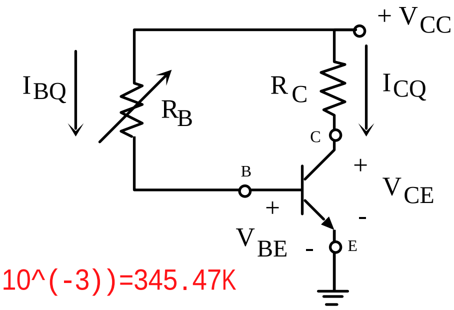
For β, use the result of Experimental Procedure part I.e.

LM741
LM324

beta=179

Rb=(Vcc-Vbe)/Ib
Rc=(Vcc-Vce)/Ic
Ic=beta*Ib

Rb=179*(20-0.7)/(10*10^(-3))=345.47K
Rc=1K



ICQ!=10mA

R_C = ________ R_B = ________

Figure 3.5 Fixed Bias Circuit.

IMPORTANT: Setup the circuit in Fig 3.5 and verify that the operating point V_{CEQ} and I_{CQ} are reasonably close to the desired design values used in (a), proceed with the measurements. If not, vary R_B until the desired values are obtained. Make a note of this fact and record the initial and final values of R_B.

R_{Bi} = ____________ R_{Bf} = ____________

b) Measure and calculate the following:

V_{CEQ} = ____________

V_{RC} = ______________ $I_{CQ} = \frac{V_{RC}}{R_C}$ = 10mA ___________

56.1uA

V_{RB} = ______________ $I_{BQ} = \frac{V_{RB}}{R_B}$ = 52.9uA ___________

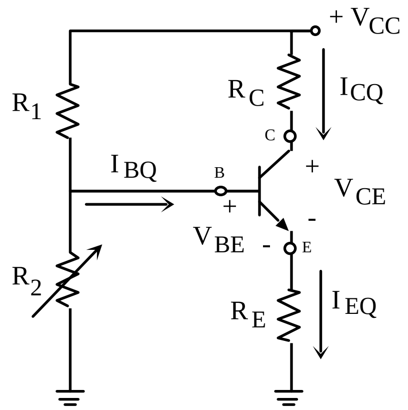
V_{BE} = ______________

III. Self Bias Circuit:

1) Using the results of the third part of your Preliminary Work, select R_C, R_E, R_1, and R_2 for the following self bias circuit, given that

$V_{CC} = 20$ V, $V_{CEQ} = 10$ V, $I_{CQ} = 1$ mA, $V_{BE} = 0.7$ V.

For β, use the result of Experimental Procedure part I.d.



Vcc=20V
Vceq=10V
Icq=1mA
Vbe=0.7V
beta=179

RTh=0.1*(beta+1)*Re
RTh=(R1*R2)/(R1+R2)
VTh=Vcc*R2/(R1+R2)
R1=Vcc*RTh/VTh=249.7K
R2=Vcc*RTh/(Vcc-VTh)=42.056K
Rc=(0.9Vcc-Vceq)/Icq=8K
Re=(0.1Vcc)/Icq=1.994K

$R_C =$ ________ $R_E =$ ________ $R_1 =$ ________ $R_2 =$ ________

Figure 3.6 Self Bias Circuit.

IMPORTANT: Setup the circuit in Fig 3.6 and verify that the operating point values V_{CEQ} and I_{CQ} are reasonably close to the desired design values, proceed with the measurements. If not, vary R_2 until the desired values are obtained. Make a note of this fact and record the initial and final values of R_2.

$R_{2i} =$ ___________ $R_{2f} =$ ___________

2) Measure and calculate the following:

$V_{CEQ} =$ ___________

$V_{RC} =$ _____________ $I_{CQ} = \dfrac{V_{RC}}{R_C} =$ __________

$V_{RE} =$ _____________ $I_{EQ} = \dfrac{V_{RE}}{R_E} =$ __________

$V_{BE} =$ _____________

Discussion of the Results

1) If you had to vary R_B and/or R_2 in Experimental Procedure parts II.b and III.b in order to obtain the desired values of V_{CEQ} and I_{CQ}, give possible reasons why your original design did not work and explain how changing R_B and/or R_2 helped to obtain the desired values.

2) Using the results of Experimental Procedure part II.b, calculate the static forward current gain of the transistor as $\beta = \frac{I_{CQ}}{I_{BQ}}$. Compare this to the one found in Experimental Procedure part I.c when V_{CEQ} = 10 V and I_{CQ} = 10 mA by finding the percentage error. What is the difference between the equation above and the one given by

$$\beta_{AC} = \frac{\Delta I_C}{\Delta I_B} ?$$

3) a) What is the range of the output active region for the fixed bias circuit if the output voltage is taken between the collector and the common ground, instead of between the collector and the emitter (i.e., V_C, instead of V_{CE})?
Assume that at saturation, V_{CE} = 0 V.
b) Repeat (a) for the self bias circuit.

4) Write a conclusion.