EXPERIMENT #3 TRANSISTOR BIASING

Bias (operating point) for a transistor is established by specifying the quiescent (D.C., no signal) values of collector-emitter voltage V_{CEQ} and collector current I_{CQ} . Reliable operation of a transistor over a wide range of temperatures requires that bias voltage and current remain stable. However, variations of reverse-bias collector current I_{CO} , and emitter-base junction voltage with temperature preclude stable bias unless external compensating circuits are used. Bias stabilizing circuits may employ resistors, thermistors, diodes, etc.

The choice of the operating point of a transistor is determined by several factors, such as maximum voltage swing, allowable operating region and small signal parameters. If the *Q*point shifts, the output signal might get clipped or the transistor may go out of the safe operating region. *Figure 2-1* shows three types of transistor biasing circuits. The configuration shown in the *Figure 2-1a* is the simplest way of biasing a bipolar transistor. There is no stabilization in this circuit hence any change in the transistor parameters or the ambient temperature will shift the *Q*-point. For a desired V_{CEQ} and I_{CQ} pair, the resistor values may be calculated as follows:

$$R_B = h_{FE} \frac{V_{CC} - 0.6}{I_{CO}}$$
(2.1)

$$R_{C} = \frac{V_{CC} - V_{CEQ}}{I_{CQ}}$$
(2.2)

In order to stabilize the operating point, some kind of negative feedback must be used at the expense of a reduced voltage gain. *Figure 2-1b* shows one of the simplest bias circuits of this kind. If the *Q*-point of the circuit tends to shift, the base current, which is proportional to V_{CE} , will increase or decrease accordingly to compensate for this shift. The equation (2.2) is also valid for this circuit provided that $h_{FE} >> 1$ (which is true for most modern transistors). R_B can then be obtained from the equation (2.3).

$$R_B = h_{FE} \frac{V_{CEQ} - 0.6}{I_{CQ}}$$
(2.3)

The inclusion of an emitter resistance always improves the bias stabilization. But the collector current and the voltage are still depending on hFE. In order to get a bias, which is independent of transistor parameters, the base of the transistor must be driven from a voltage source. That is, the equivalent output impedance of the source must be low compared to the input impedance of the transistor. If,

$$R_B = \frac{R_{B1}R_{B2}}{R_{B1} + R_{B2}} << h_{FE}R_E$$
(2.4)

this condition is satisfied in the circuit in the *Figure 2-1c*. The voltage source to drive the base is obtained using voltage dividing resistors R_{B1} , R_{B2} . Assuming the bleeder current, I_1 , is ten times larger than the base current, $I_B = IC / hFE$, (this assumption usually satisfies the equation 2.4) the resistor values may be easily evaluated as follows:

$$R_E = \frac{V_E}{I_{CQ}} \tag{2.5}$$

$$R_{c} = \frac{V_{cc} - V_{cEQ} - V_{E}}{I_{cQ}}$$
(2.6)

$$R_{B1} = h_{FE} \frac{V_{CC} - V_E - 0.6}{10I_{CO}}$$
(2.7)

$$R_{B2} = h_{FE} \frac{V_E + 0.6}{10I_{CO}}$$
(2.8)

The quiescent voltages and currents of this circuit are quite independent of transistor parameters and temperature and are functions of resistance values only.



Figure 2-1: Basic Bipolar Transistor biasing circuits

EQUIPMENT

- 1. CRT oscilloscope
- 2. Electronic D.C. voltmeter
- **3.** D.C. power supply
- 4. Sine-wave generator
- 5. Breadboard

COMPONENTS

- 1. BC238B or equivalent transistors
- **2.** Resistors (to be calculated)
- 3. Capacitor (0.1µF)

PROCEDURE

The first step in creating the data charts for measuring the BJT's characteristics is to construct a test circuit. Here, we are using a simple circuit with only one resistor, two voltage supplies, an ammeter, and the BJT. The circuit was constructed with the following schematic:



We will use three experimental trials, with a different Vs for each trial. Since the voltage drop across the Base-Emitter junction is a constant 0.7 volts, the remainder of Vs must drop across the resistor. This allows us to find the value of the base current. The resistor used was labeled 1 M Ω , but the real value was 997 K Ω . For each of the three trials (V_{BE}=20V, 25V and 30V), vary V_{CE} between 0.02 volts and 20 volts and measure the resulting collector current, I_C. Fill the following table wih the data you collected.

Table 2.1

		DLLECTOR CURRENT (I _C)		
V _{CE} (Volts)	V _s =20 V	V _S =25 V	V _s =30 V	
0.02				
0.04				
0.06				
0.08				
0.1				
0.12				
0.14				
0.16				
0.18				
0.2				
0.3				
0.4				
0.5				
1.0				
3.0				
5.0				
7.0				
9.0				
11.0				
13.0				
15.0				
17.0				
19.0				
20.0				

After finishing the first step continue with the following steps:

1. a) Calculate the values of R_B and R_C in Figure 2-1a for $V_{CC} = 12$ V, $V_{CEQ} = 6$ V; $I_{CQ} = 1$ mA and $h_{FE} = 200$.

 $R_B = \dots R_C = \dots$

b) Setup the circuit. Use the nearest standard values for resistors. Measure and note the collector current I_{CQ} and collector emitter voltage V_{CEQ} . Calculate the real h_{FE} of the transistor, using the measured I_{CQ} .

$$I_{CQ} = \dots \qquad \qquad V_{CEQ} = \dots \qquad \qquad h_{FE} = \dots$$

c) Exchange your transistor with other specimens of the same type. Measure once more V_{CEQ} and I_{CQ} for at least four different transistors. Fill in the blanks on *Table-2.1*.

d) Connect an oscilloscope to the collector of the transistor and apply a 10kHz sinusoidal voltage to the base through a 0.1μ F capacitor, increase the input voltage until any perceptible distortion occurs at the output signal. Then reduce the signal to one half and measure the peak-to-peak input and output voltages on the oscilloscope. Calculate the voltage gain. Increase the input voltage again until a small distortion occurs at the output signal. Then change your transistor and sketch the waveforms.

$$A_V(a) =$$



2. a) Calculate R_B and R_C of Figure 2-1b to obtain the same operating points as in 1-a.

$$R_B = \dots R_C = \dots$$

b) Repeat *1-b*, *1-c* and *1-d*. Fill in the blanks in *Table-2.1*.

 $A_V(b) = \dots$



3. a) Calculate all resistor values of *Figure 2-1c*, for $V_{CEQ} = 5.5$ V; $I_{CQ} = 1$ mA; $V_E = 1$ V

 $R_{B1} = \dots \qquad \qquad R_{B2} = \dots \qquad \qquad R_C = \dots \qquad \qquad R_E = \dots$

b) Repeat *1-b*, *1-c* and *1-d*. Fill in the blanks in *Table-2.1*.

$$A_V(c) = \dots$$



Outputs



	1.1		•	•
1.3	b	e	Ζ-	2
	~	-	_	_

Figure #	2-a		2-b		2-c	
Specimen #	V _{CEQ}	I _{CQ}	V _{CEQ}	I _{CQ}	V _{CEQ}	I _{CQ}
1						
2						
3						
4						
Max. Variation						

Note: Xmax in Table 2.1 is the maximum variation of the 4 specimens. For example V_{CEQ} is maximum for specimen 2 and it is minimum for specimen 4. Than Max. Variation will be $V_{CEQ(2)} - V_{CEQ(4)}$.