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 Qpoint 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:

$$R_B = h_{FE}\frac{V_{CC} - 0.6}{I_{CQ}} \tag{2.1}$$

$$R_C = \frac{V_{CC} - V_{CEQ}}{I_{CQ}} \tag{2.2}$$

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).

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

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,

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

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:

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

$$R_C = \frac{V_{CC} - V_{CEQ} - V_E}{I_{CQ}} \tag{2.6}$$

$$R_{B1} = h_{FE} \frac{V_{CC} - V_E - 0.6}{10 I_{CQ}} \tag{2.7}$$

$$R_{B2} = h_{FE} \frac{V_E + 0.6}{10 I_{CQ}} \tag{2.8}$$

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

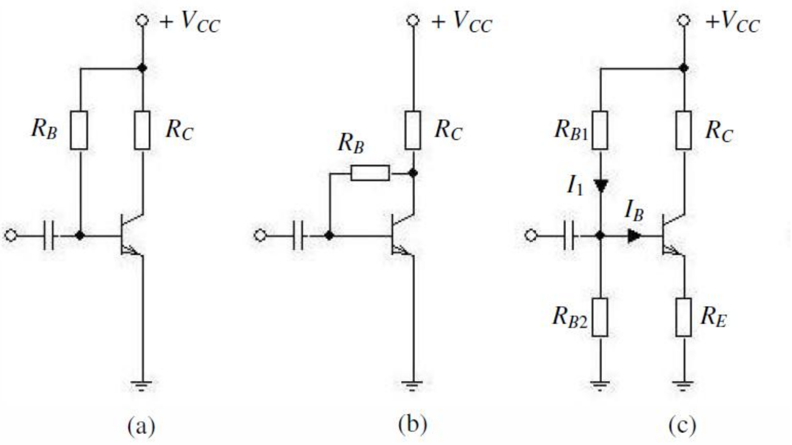
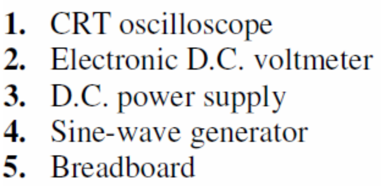


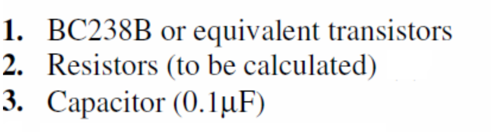
Figure 2-1: Basic Bipolar Transistor biasing circuits

EQUIPMENT



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

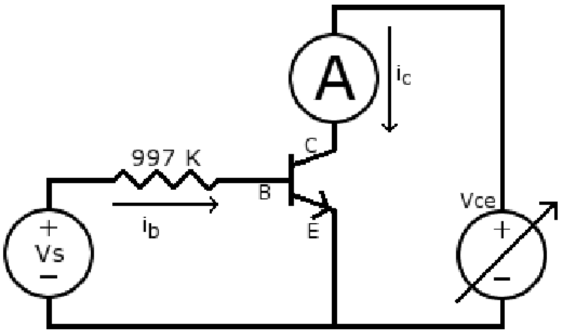
COMPONENTS



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 MΩ , but the real value was 997 KΩ. 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

	COLLECTOR 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 $V_{CC} = 12\text{V}$, $V_{CEQ} = 6\text{V}$; $I_{CQ} = 1\text{mA}$ and $h_{FE} = 200$.

$R_B =$ ……… $R_C =$ ………

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}.

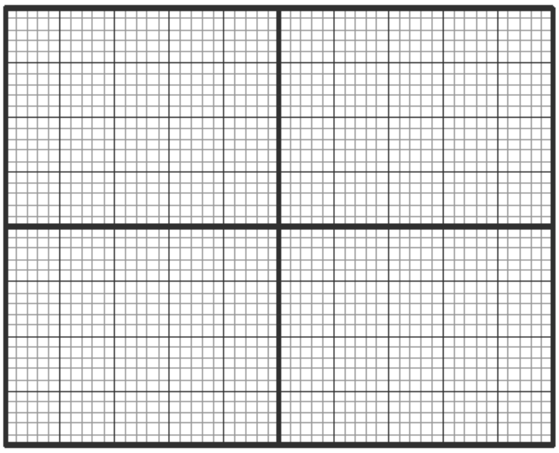
$I_{CQ} =$ ……… $V_{CEQ} =$ ……… $h_{FE} =$ ………

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*.

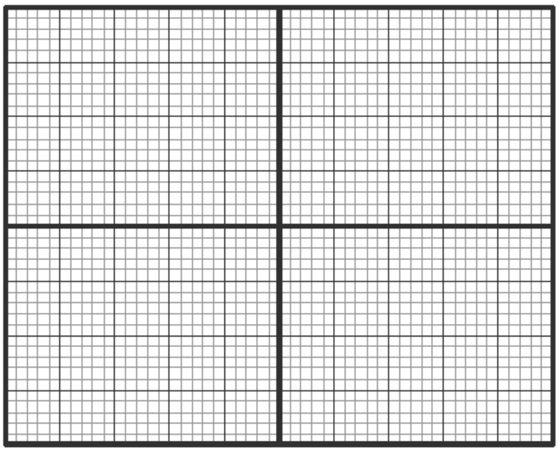
d) Connect an oscilloscope to the collector of the transistor and apply a 10kHz sinusoidal voltage to the base through a 0.1µF capacitor, increase the input voltage until any perceptible distortion occurs at the output signal. Then reduce the signal to one half and measure the peak-to-peak input and 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.

$A_V(a) =$ ………

Input



Outputs

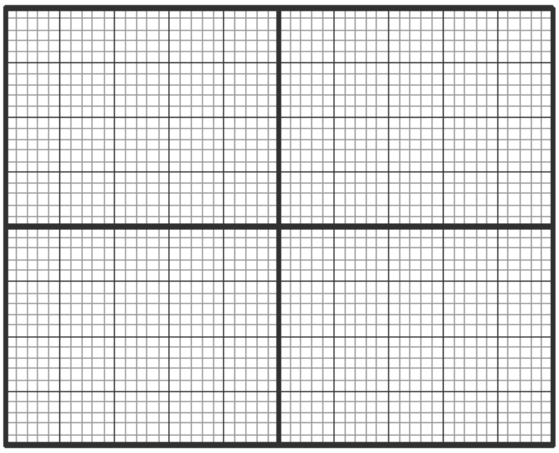


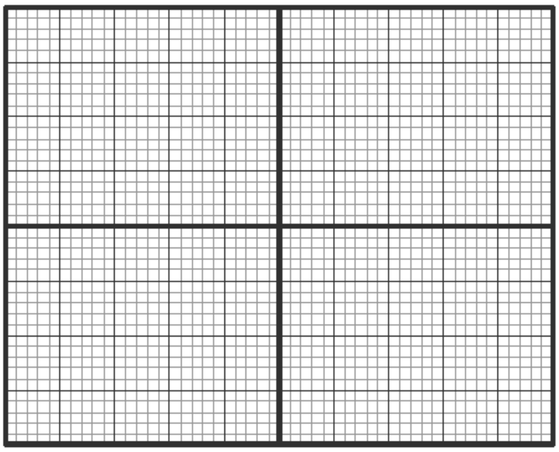
2. **a)** Calculate R_B and R_C of *Figure 2-1b* to obtain the same operating points as in *1-a*.

$R_B =$ ……… $R_C =$ ………

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

$A_V(b) =$ ………


Input

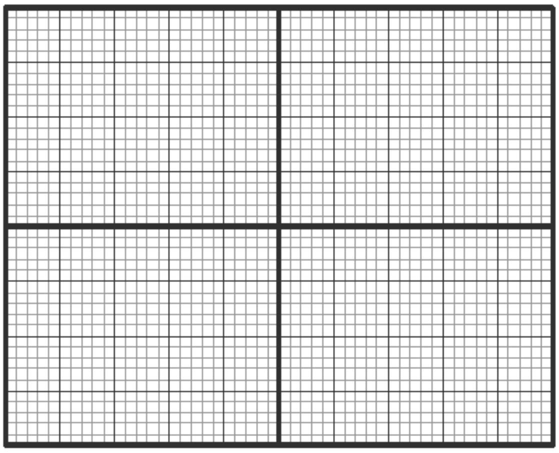

Outputs

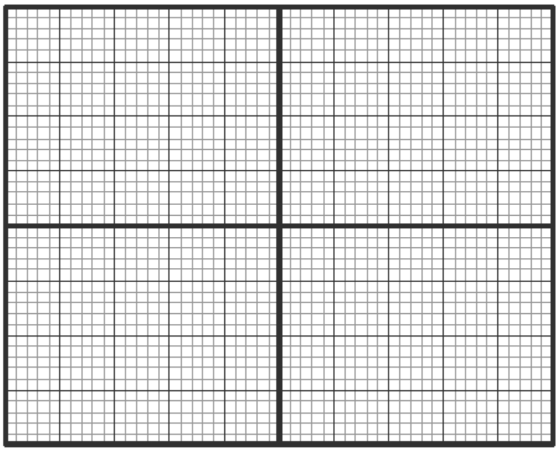
3. **a)** Calculate all resistor values of *Figure 2-1c*, for $V_{CEQ} = 5.5\text{V}$; $I_{CQ} = 1\text{mA}$; $V_E = 1\text{V}$

R_{B1} = ... R_{B2} = ... R_C = ... R_E = ...

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

$A_V\,(c)$ = ...


Input


Outputs

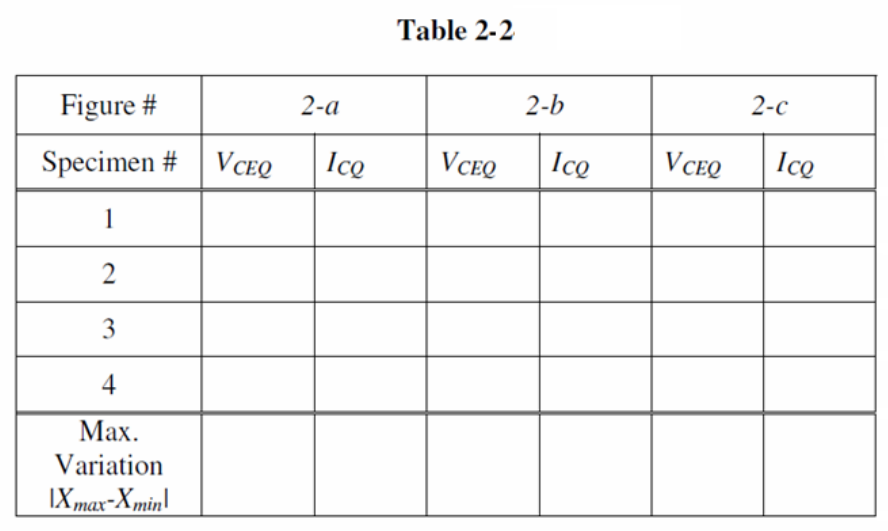


Table 2-2

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 $\lvert X_{max}-X_{min} \rvert$						

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 $V_{CEQ(2)}$ - $V_{CEQ(4)}$.