CHAPTER - 5

[TRANSISTOR CIRCUITS]

❖ TRANSISTOR BIASING:-

- **The basic function of transistor is to do amplification. The weak signal is given to the base of the transistor and amplified output is obtained in the collector circuit.**
- **One important requirement during amplification is that only the magnitude of the signal should increase and there should be no change in signal shape.**
- **This increase in magnitude of the signal without any change in shape is known as *faithful amplification*.**
- **For this we have to provide input circuit (i.e. base-emitter junction) remains forward biased and output circuit (i.e. collector-base junction) remains reverse biased at all times.**
- To achieve faithful amplification the following basic conditions must be satisfied:-

    (i) Proper zero signal collector current

    (ii) Minimum proper base-emitter voltage (V_{BE}) at any instant

    (iii) Minimum proper collector-emitter voltage (V_{CE}) at any instant

- The fulfillment of these will ensure that transistor works over the active region of the output characteristics.
- The proper flow of zero signal collector current and the maintenance of proper collector-emitter voltage during the passage of signal is known as *Transistor Biasing*.
- The basic purpose of transistor biasing is to keep the base-emitter junction properly forward biased and collector-base junction properly reverse biased during the application of signal.
- This can be achieved with a bias battery or associating a circuit with a transistor.
- The second method i.e. with a bias battery or associating a circuit with a transistor is more efficient and is frequently employed.
- The circuit which provides transistor biasing is known as biasing circuit. The transistor biasing is very essential for the proper operation of transistor in any circuit.

✓ NEED OF TRANSISTOR BIASING:-

(i) It should ensure proper zero signal collector current.
(ii) It should ensure that V_{CE} does not fall below 0.5 V for Ge transistors and 1 V for Si transistors.
(iii) It should ensure the stabilization of operating point.

❖ STABILISATION: -

➢ The process of making operating point independent of temperature changes or variations in transistor parameters is known as *Stabilization*.

❖ **NEED FOR STABILIZATION:-** Stabilization of the operating point is necessary due to the following reasons :

- (i) Temperature dependence of IC
- (ii) Individual variations
- (iii) Thermal runaway

➢ The self-destruction of an unsterilized transistor is known as *Thermal Runaway*.

❖ STABILITY FACTOR :-

➢ The rate of change of collector current I_C w.r.t. the collector leakage current I_{CO} [= I_{CEO}] at constant β and I_B is called stability factor i.e.

✓ METHODS OF TRANSISTOR BIASING:-

- In the transistor amplifier circuits drawn so far biasing was done with the aid of a battery V_{BB} which was separate from the battery V_{CC} used in the output circuit. However, for simplicity and economy, it is desirable that transistor circuit should have a single source of supply the one in the output circuit (i.e. V_{CC}).
- The following are the most commonly used methods of obtaining transistor biasing from one source of supply:

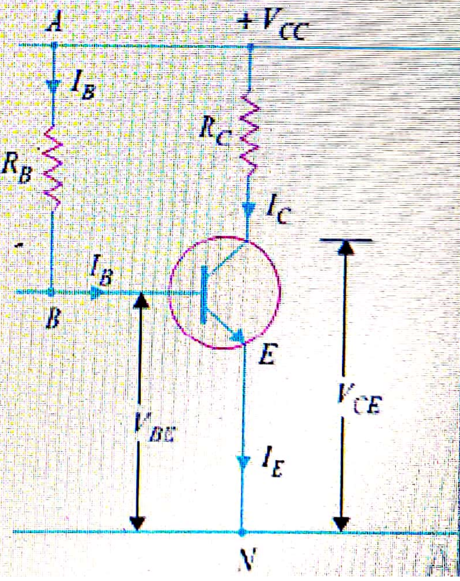
  (i) Base resistor method

  (ii) Biasing with collector-feedback resistor

  (iii) Voltage-divider bias

- In all these methods, the same basic principle is employed i.e. required value of base current (and hence I_C) is obtained from V_{CC} in the zero signal conditions.
- The value of collector load R_C is selected keeping in view that V_{CE} should not fall below 0.5 V for germanium transistors and 1V for silicon transistors.

❖ BASE RESISTOR METHOD:-



- In this method, a high resistance R_B (several hundred kΩ) is connected between the base and +ve end of supply for npn transistor and between base and negative end of supply for pnp transistor.
- Here, the required zero signal base current is *provided by* V_{CC} and it flows through R_B. It is because now base is positive w.r.t. emitter i.e. base-emitter junction is forward biased.
- The required value of zero signal base current I_B (and hence $I_C = \beta I_B$) can be made to flow by selecting the proper value of base resistor R_B.
- Circuit analysis:-

  It is required to find the value of R_B so that required collector current flows in the zero signal conditions.

  Let I_C be the required zero signal collector current.

  $\therefore I_B = I_C / \beta$

Considering the closed circuit ABENA and applying Kirchhoff's voltage law, we get,

$$V_{CC} = I_B R_B + V_{BE}$$

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

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} \quad \text{...} \quad (i)$$

As V_{CC} and I_B are known and V_{BE} can be seen from the transistor manual, therefore, value of R_B can found from exp. (i).

Since V_{BE} is generally quite small as compared to V_{CC}, the former can be neglected with little error.

Thus Equation (i) becomes, $R_B = \frac{V_{CC}}{I_B}$

- It may be noted that V_{CC} is a fixed known quantity and I_B is chosen at some suitable value. Hence, R_B can always be found directly, and for this reason, this method is sometimes called **fixed-bias method**.
- **Advantages :**
  (i) This biasing circuit is very simple as only one resistance R_B is required.-
  (ii) Biasing conditions can easily be set and the calculations are simple.
- **Disadvantages :**
  (i) This method provides poor stabilization.
  (ii) The stability factor is very high.

❖ BIASING WITH FEEDBACK CIRCUIT:-

- In this method, one end of R_B is connected to the base and the other end to the collector. Here, the required zero signal base current is determined not by V_{CC} but by the *collector-base voltage* V_{CB}. It is clear that V_{CB} forward biases the base-emitter junction and hence base current I_B flows through R_B. This causes the zero signal collector current to flow in the circuit.

➢ **Circuit Analysis:-**

The required value of R_B needed to give the zero signal current I_C can be determined as follows.

From the above circuit diagram, $V_{CC} = I_C R_C + I_B R_B + V_{BE}$

$$R_B = \frac{V_{CC} - V_{BE} - I_C R_C}{I_B} = \frac{V_{CC} - V_{BE} - \beta I_B R_C}{I_B} \quad (\because I_C = \beta I_B)$$

Alternately, $V_{CE} = V_{BE} + V_{CB}$ or $V_{CB} = V_{CE} - V_{BE}$

$$\therefore \quad R_B = \frac{V_{CB}}{I_B} = \frac{V_{CE} - V_{BE}}{I_B}; \quad \text{where} \quad I_B = \frac{I_C}{\beta}$$

➢ **Advantages :-**

(i) It is a simple method as it requires only one resistance R_B.

(ii) This circuit provides some stabilization of the operating point than fixed bias method.

➢ **Disadvantages:-**

(i) The circuit does not provide good stabilization.

(ii) This circuit provides a negative feedback which reduces the gain of the amplifier.

(iii)This will reduce the base current and hence collector current.

❖ **VOLTAGE DIVIDER BIAS METHOD:-**

➢ This is the most widely used method of providing biasing and stabilization to a transistor. In this method, two resistances R_1 and R_2 are connected across the supply voltage V_{CC} and *provide biasing*. The emitter resistance R_E *provides stabilization*. The name "voltage divider" comes from the voltage divider formed by R_1 and R_2. The voltage drop across R_2 forward biases the base- emitter junction. This causes the base current and hence collector current flows in the zero signal conditions.

➢ Circuit analysis:-

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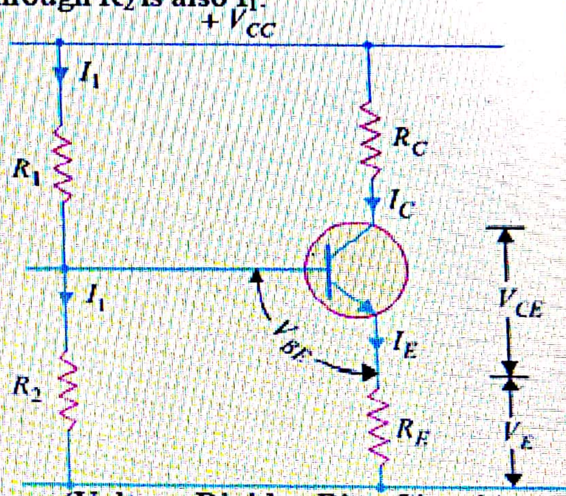
- **Circuit analysis:-**
- **Suppose that the current flowing through resistance R_1 is I_1. As base current I_B is very small, therefore, it can be assumed with reasonable accuracy that current flowing through R_2 is also I_1.**



(Voltage Divider Bias Circuit)

(i)Collector current I_C :-

$$I_1 = \frac{V_{CC}}{R_1 + R_2}$$

∴ Voltage across resistance R_2 is

$$V_2 = \left(\frac{V_{CC}}{R_1 + R_2}\right) R_2$$

Applying Kirchhoff's voltage law to the base circuit

$V_2 = V_{BE} + V_E = V_{BE} + I_E R_E$

$$I_E = \frac{V_2 - V_{BE}}{R_E}\ ; \quad I_C = \frac{V_2 - V_{BE}}{R_E}\ ; \quad \text{Since } I_E \simeq I_C$$

- Thus IC in this circuit is almost independent of transistor parameters and hence good stabilization is ensured. Due to this reason the potential divider bias has become universal method for providing transistor biasing.

(ii)Collector-emitter voltage (V_{CE}): -

Applying Kirchhoff's voltage law to the collector side,

$V_{CC} = I_C R_C + V_{CE} + I_E R_E = I_C R_C + V_{CE} + I_C R_E$ (As $I_C \simeq I_E$)

So, $V_{CC} = I_C (R_C + R_E) + V_{CE} \Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E)$

- **Advantages : -**
- In this circuit, excellent stabilization is provided by R_E. Consider the Following Equation,

  $V_2 = V_{BE} + I_C R_E$
- Suppose the collector current I_C increases due to rise in temperature. This will cause the voltage drop across emitter resistance R_E to increase.