

# Lecture

on

**TRANSISTOR BIASING**

**&**

**STABILIZATION**

# Transistor Biasing

The basic function of transistor is amplification. The process of raising the strength of weak signal without any change in its general shape is referred as faithful amplification. For faithful amplification it is essential that:-

1. Emitter-Base junction is forward biased
2. Collector- Base junction is reversed biased
3. Proper zero signal collector current

**The proper flow of zero signal collector current and the maintenance of proper collector emitter voltage during the passage of signal is called transistor biasing.**

## **WHY BIASING?**

If the transistor is not biased properly, it would work inefficiently and produce distortion in output signal.

## **HOW A TRANSISTOR CAN BE BIASSED?**

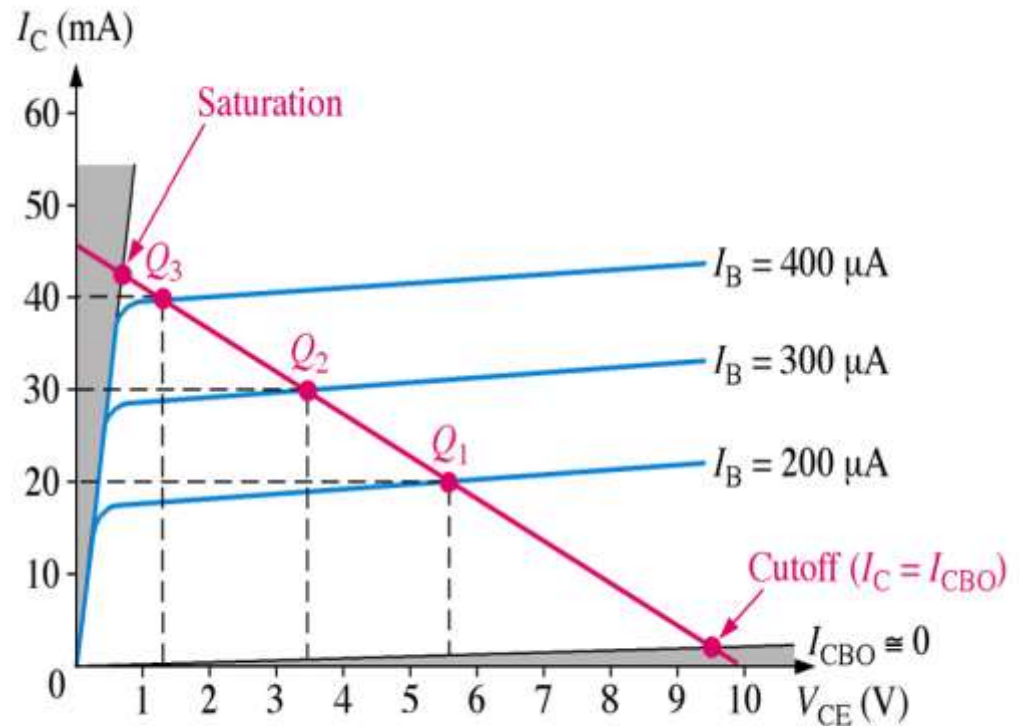
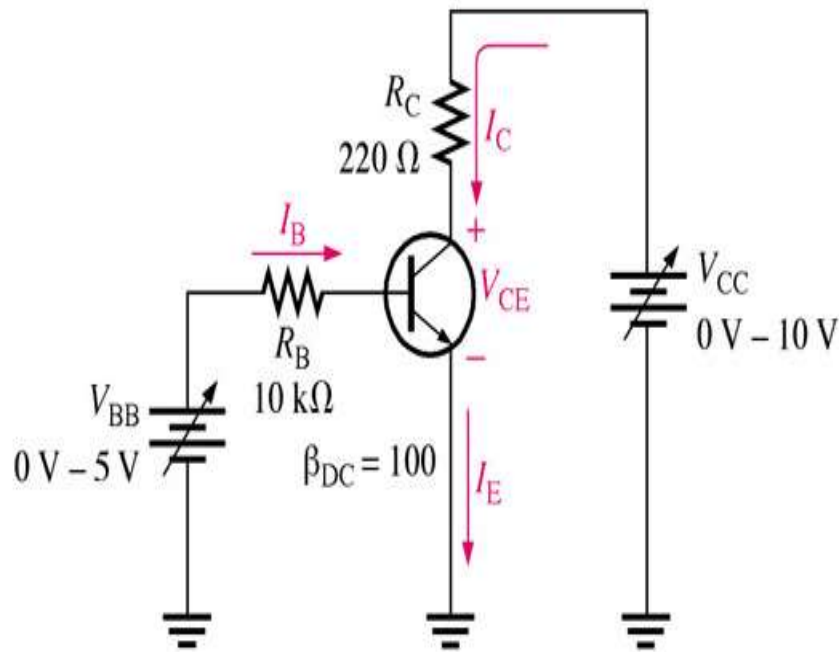
A transistor is biased either with the help of battery or associating a circuit with the transistor. The later method is more efficient and is frequently used. The circuit used for transistor biasing is called the biasing circuit.

# BIAS STABILITY

- ❖ Through proper biasing, a desired quiescent operating point of the transistor amplifier in the active region (linear region) of the characteristics is obtained. It is desired that once selected the operating point should remain stable. The maintenance of operating point stable is called Stabilisation.
  
- ❖ The selection of a proper quiescent point generally depends on the following factors:
  - (a) The amplitude of the signal to be handled by the amplifier and distortion level in signal
  - (b) The load to which the amplifier is to work for a corresponding supply voltage
  
- ❖ The operating point of a transistor amplifier shifts mainly with changes in temperature, since the transistor parameters —  $\beta$ ,  $I_{CO}$  and  $V_{BE}$  (where the symbols carry their usual meaning)—are functions of temperature.

# The DC Operating Point

For a transistor circuit to amplify it must be properly biased with dc voltages. The dc operating point between saturation and cutoff is called the **Q-point**. The goal is to set the Q-point such that that it does not go into saturation or cutoff when an ac signal is applied.



(a) DC biased circuit

# Requirements of biasing network

- Ensuring proper zero signal collector current.
- Ensuring  $V_{CE}$  not falling below 0.5V for Ge transistor and 1V for Silicon transistor at any instant.
- Ensuring Stabilization of operating point. (zero signal  $I_C$  and  $V_{CE}$ )

# The Thermal Stability of Operating Point ( $S_{I_{CO}}$ )

❖ **Stability Factor S:-** The stability factor  $S$ , as the change of collector current with respect to the reverse saturation current, keeping  $\beta$  and  $V_{BE}$  constant. This can be written as:

The Thermal Stability Factor :  $S_{I_{CO}}$

$$S_{I_{CO}} = \left. \frac{\partial I_C}{\partial I_{CO}} \right|_{V_{be}, \beta}$$

This equation signifies that  $I_C$  Changes  $S_{I_{CO}}$  times as fast as  $I_{CO}$

Differentiating the equation of Collector Current  $I_C = (1+\beta)I_{CO} + \beta I_B$  & rearranging the terms we can write

$$S_{I_{CO}} = \frac{1+\beta}{1 - \beta (\partial I_B / \partial I_C)}$$

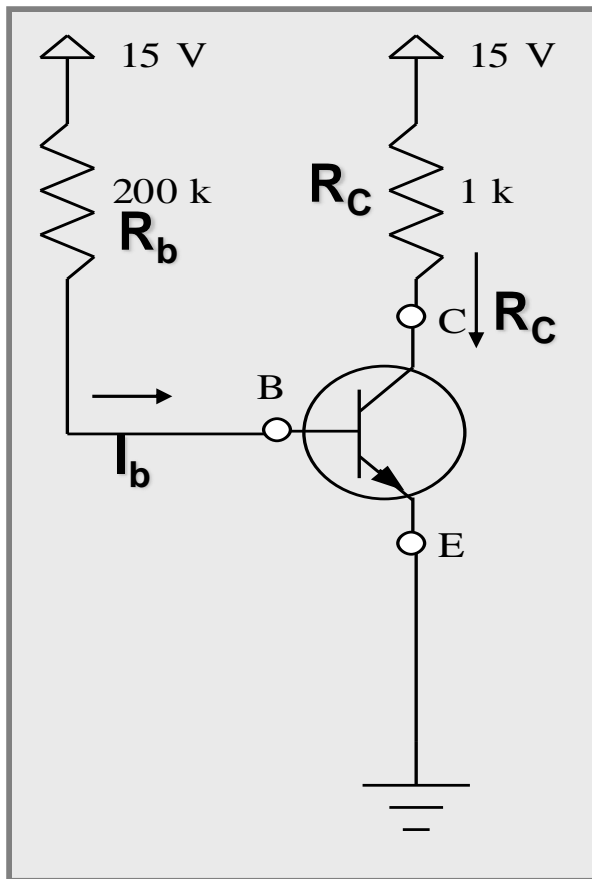
It may be noted that Lower is the value of  $S_{I_{CO}}$  better is the stability

# Various Biasing Circuits

- **Fixed Bias Circuit**
- **Fixed Bias with Emitter Resistor**
- **Collector to Base Bias Circuit**
- **Potential Divider Bias Circuit**



# The Fixed Bias Circuit



The Thermal Stability Factor :  $S_{I_{CO}}$

$$S_{I_{CO}} = \left. \frac{\partial I_C}{\partial I_{CO}} \right|_{V_{be}, \beta}$$

General Equation of  $S_{I_{CO}}$  Comes out to be

$$S_{I_{CO}} = \frac{1 + \beta}{1 - \beta (\partial I_b / \partial I_C)}$$

Applying KVL through Base Circuit we can write,  $I_b R_b + V_{be} = V_{CC}$

Diff w. r. t.  $I_C$ , we get  $(\partial I_b / \partial I_C) = 0$

$S_{I_{CO}} = (1 + \beta)$  is very large  
Indicating high un-stability

### **Merits:**

- It is simple to shift the operating point anywhere in the active region by merely changing the base resistor ( $R_B$ ).
- A very small number of components are required.

### **Demerits:**

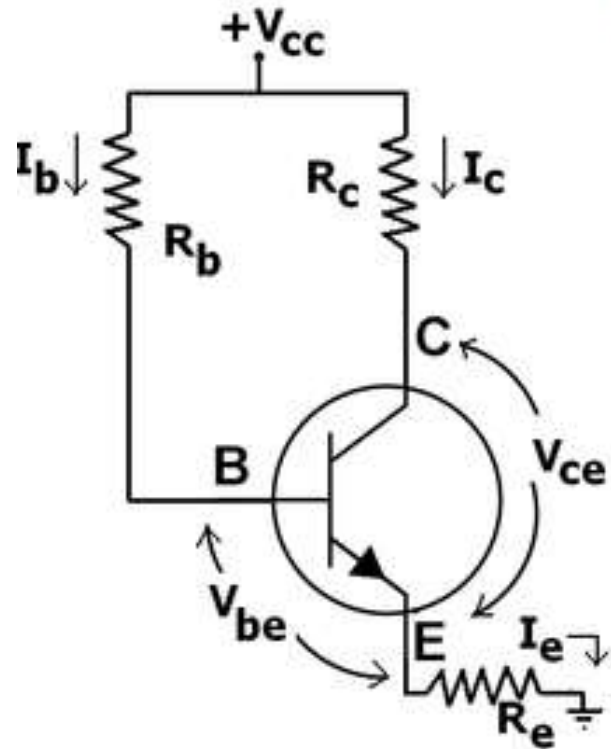
- The collector current does not remain constant with variation in temperature or power supply voltage. Therefore the operating point is unstable.
- When the transistor is replaced with another one, considerable change in the value of  $\beta$  can be expected. Due to this change the operating point will shift.
- For small-signal transistors (e.g., not power transistors) with relatively high values of  $\beta$  (i.e., between 100 and 200), this configuration will be prone to thermal runaway. In particular, the stability factor, which is a measure of the change in collector current with changes in reverse saturation current, is approximately  $\beta+1$ . To ensure absolute stability of the amplifier, a stability factor of less than 25 is preferred, and so small-signal transistors have large stability factors.

## **Usage:**

- Due to the above inherent drawbacks, fixed bias is rarely used in linear circuits (i.e., those circuits which use the transistor as a current source). Instead, it is often used in circuits where transistor is used as a switch. However, one application of fixed bias is to achieve crude automatic gain control in the transistor by feeding the base resistor from a DC signal derived from the AC output of a later stage.

# Fixed bias with emitter resistor

The fixed bias circuit is modified by attaching an external resistor to the emitter. This resistor introduces negative feedback that stabilizes the Q-point.



## **Merits:**

- The circuit has the tendency to stabilize operating point against changes in temperature and  $\beta$ -value.

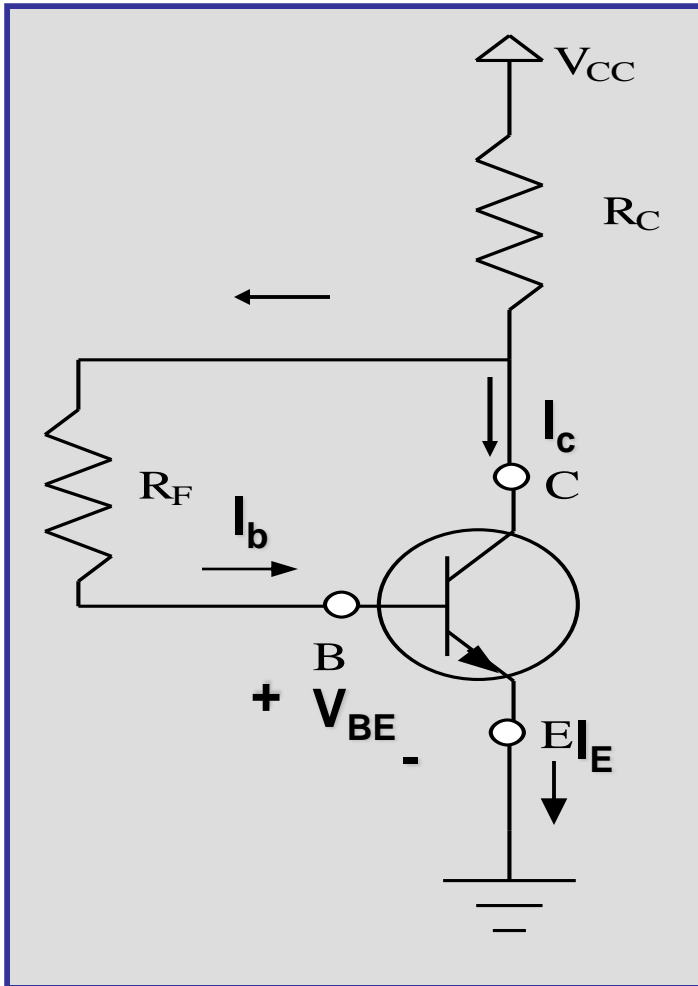
## **Demerits:**

- As  $\beta$ -value is fixed for a given transistor, this relation can be satisfied either by keeping  $R_E$  very large, or making  $R_B$  very low.
  - If  $R_E$  is of large value, high  $V_{CC}$  is necessary. This increases cost as well as precautions necessary while handling.
    - If  $R_B$  is low, a separate low voltage supply should be used in the base circuit. Using two supplies of different voltages is impractical.
- In addition to the above,  $R_E$  causes ac feedback which reduces the voltage gain of the amplifier.

## **Usage:**

The feedback also increases the input impedance of the amplifier when seen from the base, which can be advantageous. Due to the above disadvantages, this type of biasing circuit is used only with careful consideration of the trade-offs involved.

# The Collector to Base Bias Circuit



This configuration employs negative feedback to prevent thermal runaway and stabilize the operating point. In this form of biasing, the base resistor  $R_F$  is connected to the collector instead of connecting it to the DC source  $V_{CC}$ . So any thermal runaway will induce a voltage drop across the  $R_C$  resistor that will throttle the transistor's base current.

Applying KVL through base circuit

we can write  $(I_b + I_C) R_C + I_b R_f + V_{be} = V_{cc}$

Diff. w. r. t.  $I_C$  we get

$$(\partial I_b / \partial I_C) = - R_C / (R_f + R_C)$$

$$\text{Therefore, } S_{I_{CO}} = \frac{(1 + \beta)}{1 + [\beta R_C / (R_C + R_f)]}$$

Which is less than  $(1 + \beta)$ , signifying better thermal stability

## Merits:

- Circuit stabilizes the operating point against variations in temperature and  $\beta$  (i.e. replacement of transistor)

## Demerits:

- As  $\beta$  -value is fixed (and generally unknown) for a given transistor, this relation can be satisfied either by keeping  $R_c$  fairly large or making  $R_f$  very low.
  - If  $R_c$  is large, a high  $V_{cc}$  is necessary, which increases cost as well as precautions necessary while handling.
  - If  $R_f$  is low, the reverse bias of the collector–base region is small, which limits the range of collector voltage swing that leaves the transistor in active mode.
  - The resistor  $R_f$  causes an AC feedback, reducing the voltage gain of the amplifier. This undesirable effect is a trade-off for greater Q-point stability.

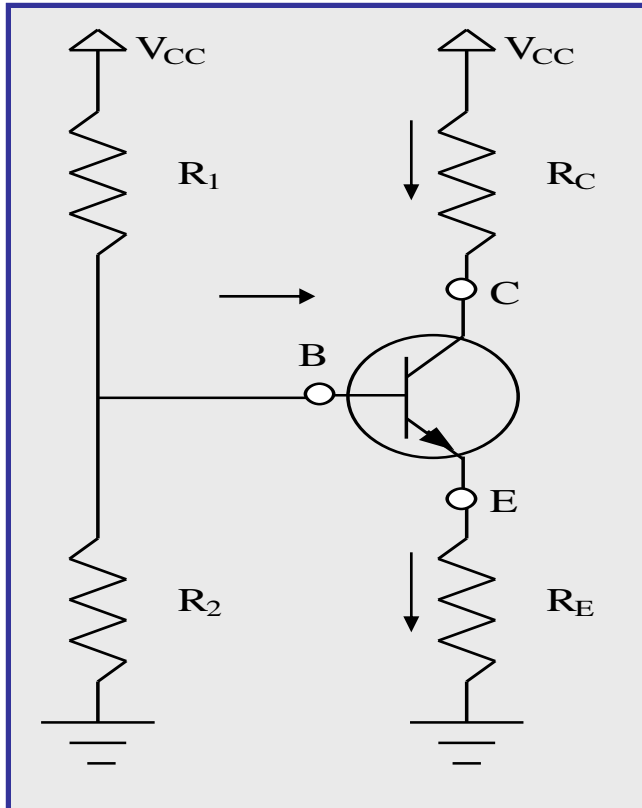
**Usage:** The feedback also decreases the input impedance of the amplifier as seen from the base, which can be advantageous. Due to the gain reduction from feedback, this biasing form is used only when the trade-off for stability is warranted.



## The Potential Divider Bias Circuit

This is the most commonly used arrangement for biasing as it provides good bias stability. In this arrangement the emitter resistance ' $R_E$ ' provides stabilization. The resistance ' $R_E$ ' causes a voltage drop in a direction so as to reverse bias the emitter junction. Since the emitter-base junction is to be forward biased, the base voltage is obtained from the  $R_1$ - $R_2$  network. The net forward bias across the emitter-base junction is equal to  $V_B$  - dc voltage drop across ' $R_E$ '. The base voltage is set by  $V_{CC}$  and  $R_1$  and  $R_2$ . The dc bias circuit is independent of transistor current gain. In case of an amplifier, to avoid the loss of ac signal, a capacitor of large capacitance is connected across  $R_E$ . The capacitor offers a very small reactance to ac signal and so it passes through the condenser.

# The Potential Divider Bias Circuit

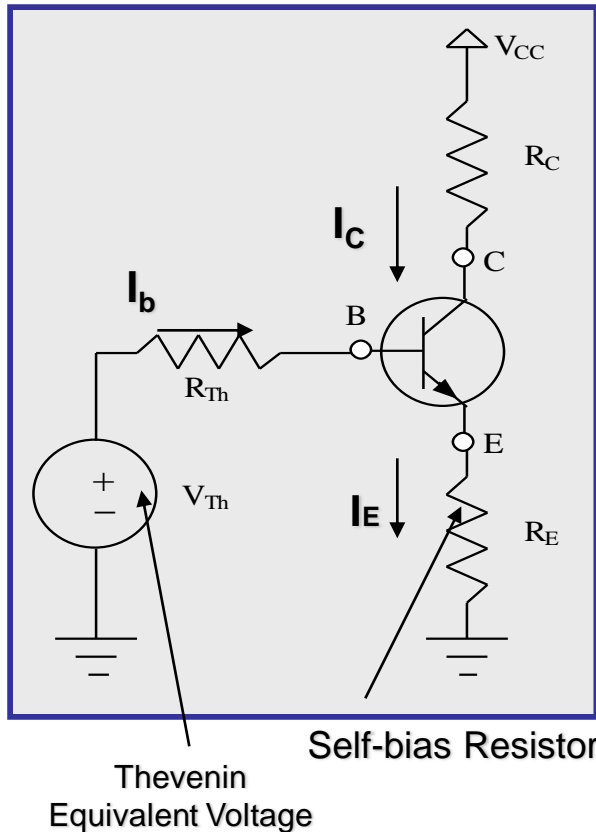


To find the stability of this circuit we have to convert this circuit into its Thevenin's Equivalent circuit

$$R_{th} = \frac{R_1 * R_2}{R_1 + R_2} \quad \& \quad V_{th} = \frac{V_{CC} R_2}{R_1 + R_2}$$

# The Potential Divider Bias Circuit

**Thevenin  
Equivalent Ckt**



Applying KVL through input base circuit

$$\text{we can write } I_b R_{Th} + I_E R_E + V_{be} = V_{Th}$$

$$\text{Therefore, } I_b R_{Th} + (I_C + I_b) R_E + V_{BE} = V_{Th}$$

Diff. w. r. t.  $I_C$  & rearranging we get

$$(\partial I_b / \partial I_C) = - R_E / (R_{Th} + R_E)$$

Therefore,

$$S_{I_{CQ}} = \frac{1 + \beta}{1 + \left[ \beta \frac{R_E}{R_E + R_{Th}} \right]}$$

This shows that  $S_{I_{CQ}}$  is inversely proportional to  $R_E$  and It is less than  $(1 + \beta)$ , signifying better thermal stability

## Merits:

- Operating point is almost independent of  $\beta$  variation.
- Operating point stabilized against shift in temperature.

## Demerits:

- As  $\beta$ -value is fixed for a given transistor, this relation can be satisfied either by keeping  $R_E$  fairly large, or making  $R_1 || R_2$  very low.
  - If  $R_E$  is of large value, high  $V_{CC}$  is necessary. This increases cost as well as precautions necessary while handling.
  - If  $R_1 || R_2$  is low, either  $R_1$  is low, or  $R_2$  is low, or both are low. A low  $R_1$  raises  $V_B$  closer to  $V_C$ , reducing the available swing in collector voltage, and limiting how large  $R_C$  can be made without driving the transistor out of active mode. A low  $R_2$  lowers  $V_{be}$ , reducing the allowed collector current. Lowering both resistor values draws more current from the power supply and lowers the input resistance of the amplifier as seen from the base.
  - AC as well as DC feedback is caused by  $R_E$ , which reduces the AC voltage gain of the amplifier. A method to avoid AC feedback while retaining DC feedback is discussed below.

## Usage:

The circuit's stability and merits as above make it widely used for linear circuits.

# Summary

- The Q-point is the best point for operation of a transistor for a given collector current.
- The purpose of biasing is to establish a stable operating point (Q-point).
- The linear region of a transistor is the region of operation within saturation and cutoff.
- Out of all the biasing circuits, potential divider bias circuit provides highest stability to operating point.

*THANK YOU*