Analog & Digital Electronics

Course No: PH-218

BJT

Lec-7: Biasing schemes and stability of BJT

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Biasing of BJT

➢ **Biasing refers to the application of D.C. voltages to setup the operating point in such a way that output signal is undistorted throughout the whole operation.**

➢ **Also once selected properly, the Q point should not shift because of change of I_C due to**

(i) β variation due to replacement of the transistor of same type
(ii) Temperature variation

Stabilization

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

➢ **Stabilization of operating point is necessary due to**
❖ **Temperature dependence of I_C**
❖ **Individual variations**
❖ **Thermal runaway**

Stabilization

Temperature dependence of I_C & Thermal runaway

$$I_C = \beta I_B + (\beta + 1) I_{CBO}$$

- I_{CBO} is strong function of temperature. A rise of 10°C doubles the I_{CBO} and I_C will increase (β+1) times of I_{CBO}

- The flow of I_C produce heat within the transistor and raises the transistor temperature further and therefore, further increase in I_{CBO}

- This effect is cumulative and in few seconds, the I_C may become large enough to burn out the transistor.

- The self destruction of an unstablized transistor is known as thermal runaway.

Stability Factor

- The rate of change collector current I_C with respect to the collector leakage current I_{CBO} is called stability factor, denoted by S.

$$S = \left(\frac{dI_C}{dI_{CBO}}\right)$$

Lower the value of S, better is the stability of the transistor.

Stability Factor

➢ **The rate of change collector current I_C with respect to the collector leakage current I_{CBO} at constant β and I_B is called stability factor, denoted by S.**

$$I_C = \beta I_B + (\beta + 1) I_{CBO} \qquad \textbf{(1)}$$

Differentiating equation (1) w.r.t I_C

$$1 = \beta\left(\frac{dI_B}{dI_C}\right) + (\beta + 1)\frac{dI_{CBO}}{dI_C}$$

$$1 = \beta\left(\frac{dI_B}{dI_C}\right) + \frac{(\beta + 1)}{S}$$

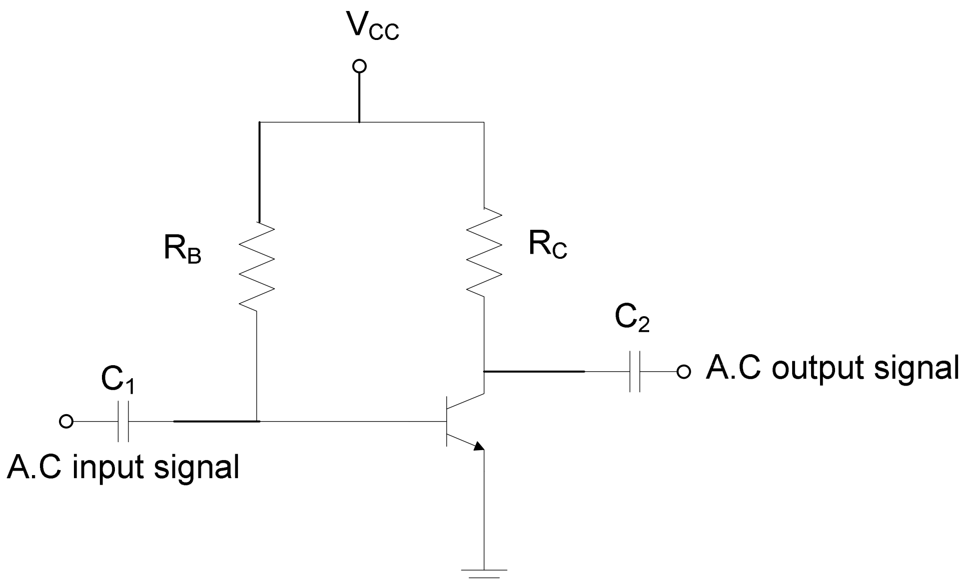
$$S = \frac{(\beta + 1)}{1 - \beta\left(\frac{dI_B}{dI_C}\right)}$$

Different biasing schemes

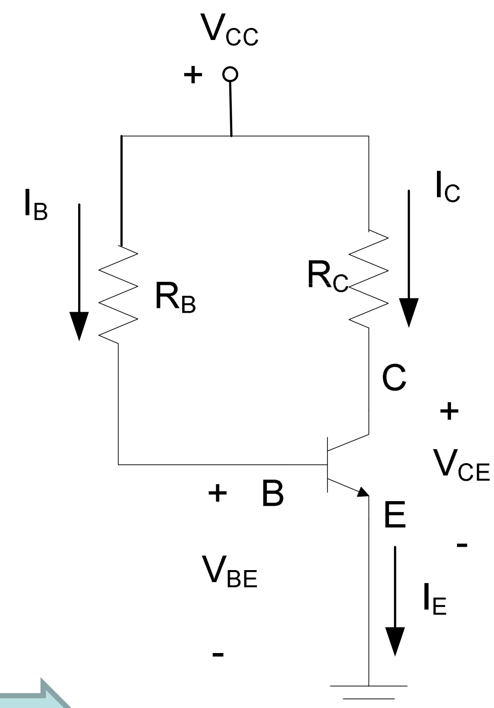
(i) Fixed bias (base resistor biasing)
(ii) Collector base bias
(iii) Emitter bias
(iv) Voltage divider bias

Fixed Bias

➢ **This form of biasing is also called *base bias.* The single power source is used for both collector and base of transistor, although separate batteries can also be used.**



D.C. Equivalent



Using KVL in the base-emitter loop

$$V_{CC} - I_B R_B - V_{BE} = 0 \; ; \; I_B = (V_{CC} - V_{BE})/R_B$$

$$I_C = \beta I_B = \beta(V_{CC} - V_{BE})/R_B$$

Q(V_{CE},I_C) is set

Using KVL in the collector-emitter loop

$$V_{CC} - I_C R_C - V_{CE} = 0; \; V_{CE} = V_{CC} - I_C R_C$$

Fixed Bias

Advantages:

- **Operating point can be shifted easily anywhere in the active region by merely changing the base resistor (R_B).**
- **A very small number of components are required.**

Disadvantages:

- **Poor stabilization**
- **High stability factor($S=\beta+1$ because I_B is constant so $dI_B/dI_C = 0$), hence prone to thermal runaway**

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.**

How the Q point is affected by changes in V_{BE} and I_{CBO} in fixed bias?

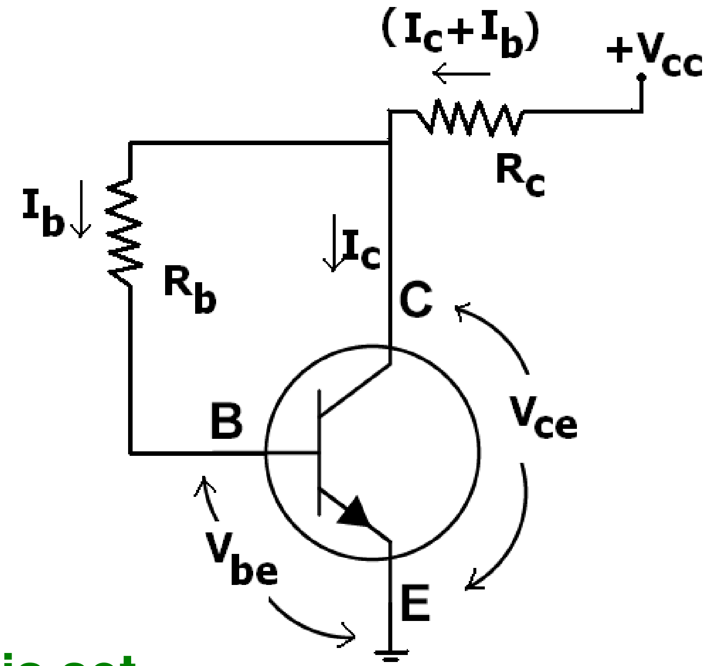
$I_B = (V_{CC}-V_{BE})/R_B \qquad I_C = \beta I_B$

Collector base bias

➢ This configuration employs negative feedback to prevent thermal runaway and stabilize the operating point.

➢ In this form of biasing, the base resistor R_B 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

$$V_{CC} = (I_C+I_B)R_C + V_{CE} \quad (1)$$

$$V_{CE} = I_B R_B + V_{BE} \quad (2)$$

Since, $I_C = \beta I_B$ so from equation (1) & (2)

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta)R_C}$$

$Q(V_{CE},I_C)$ is set

Collector base bias

Advantages:

➢ Better stabilization compared to fixed bias

Disadvantages:

➢ This circuit provides negative feedback which reduces the gain of the amplifier.

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.

How the bias stability is improved in collector base bias?

If I_C becomes larger than design value, it causes an increase voltage drop across R_C hence smaller value of V_{CE} which in turn causes I_B to be smaller than its design value. Since $I_C = \beta I_B$ thus I_C will also tend to be reduced towards its original value.

For bais Stabilization : $R_B << \beta R_C$

$$I_C = \beta\left[\frac{V_{CC} - V_{BE}}{R_B + (1+\beta)R_C}\right]$$

If $R_B << \beta R_C$

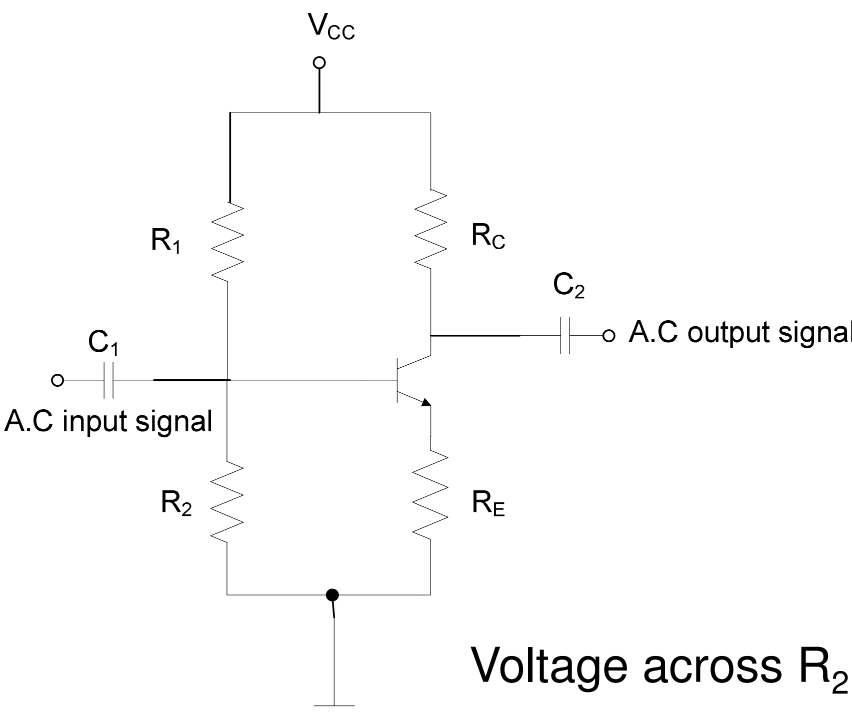
$$I_C = \frac{V_{CC} - V_{BE}}{R_C}$$

Voltage Divider Bias

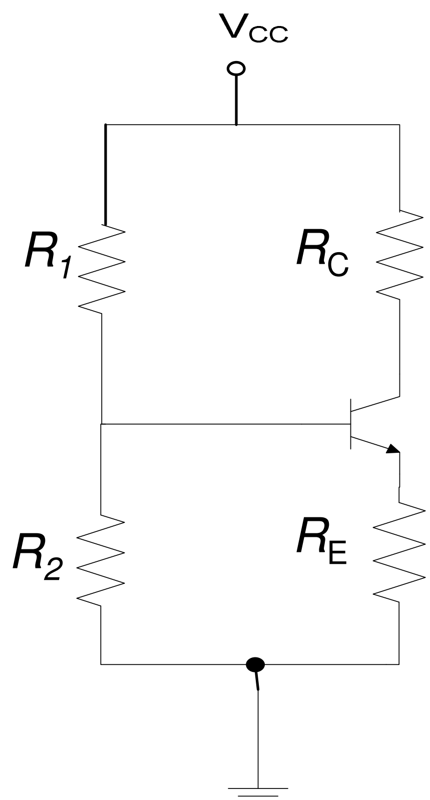
- This is the most widely used method to provide biasing and stabilization to a transistor.

- In this form of biasing, R_1 and R_2 divide the supply voltage V_{CC} and voltage across R_2 provide fixed bias voltage V_B at the transistor base.

- Also a resistance R_E is included in series with the emitter that provides the stabilization.



Voltage across R_2

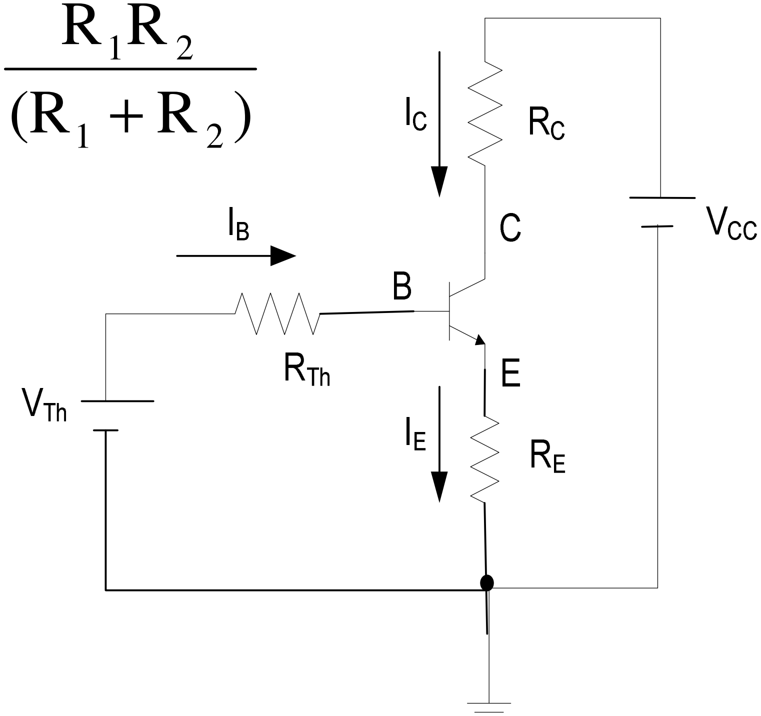


V_B = Voltage across R_2 (**ignoring base current**)

$$V_B = V_{CC} \frac{R_2}{(R_1 + R_2)}$$

Voltage Divider Bias

$$V_B = V_{Th} = V_{CC}\frac{R_2}{(R_1+R_2)} \qquad R_{Th} = R_1 \| R_2 = \frac{R_1 R_2}{(R_1+R_2)}$$



Base-Emitter Loop

$$V_{Th} - I_B R_{Th} - V_{BE} - (\beta+1) I_B R_E = 0$$

$$\text{or, } I_B = \frac{V_{Th} - V_{BE}}{R_{Th} + (\beta+1) R_E}$$

Collector- Emitter Loop

$$I_C = \beta I_B = \frac{\beta(V_{Th} - V_{BE})}{R_{Th} + (\beta+1) R_E} \qquad V_{CE} = V_{CC} - I_C R_C - I_E R_E = V_{CC} - I_C R_C - (I_C + I_B) R_E$$

For bais Stabilization : $R_{Th} << (\beta+1)R_E$

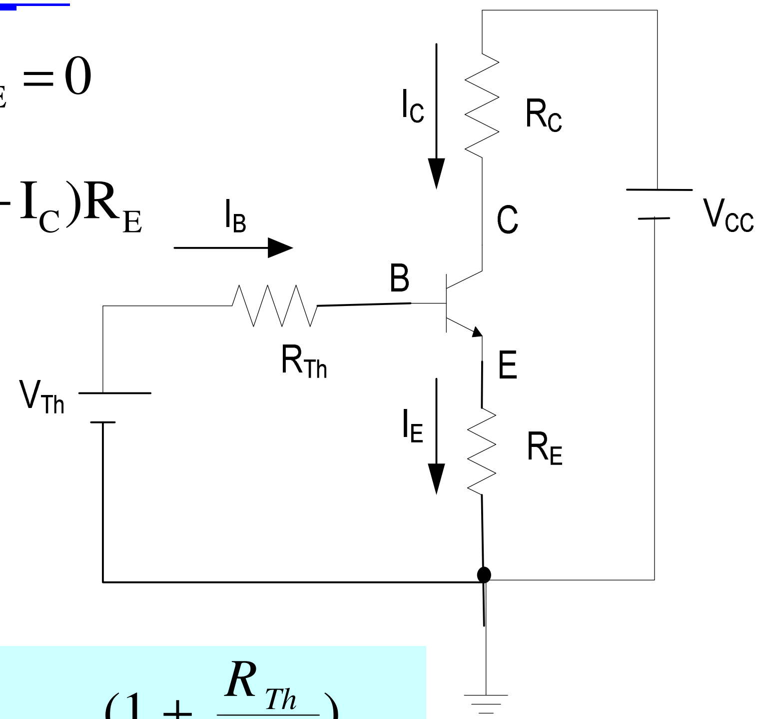
$$I_C \approx \frac{V_{Th} - V_{BE}}{R_E}$$

Stability factor for Voltage Divider Bias

$$S = \frac{(\beta + 1)}{1 - \beta\left(\frac{dI_B}{dI_C}\right)}$$

$$V_{Th} - I_B R_{Th} - V_{BE} - I_E R_E = 0$$

(1) $$V_{Th} = I_B R_{Th} - V_{BE} - (I_B + I_C) R_E$$



Differentiating equation (1) w.r.t I_C

$$V_{Th} = I_B R_{Th} - V_{BE} - (I_B + I_C) R_E$$

$$0 = R_{Th}\left(\frac{dI_B}{dI_C}\right) + \left(1 + \frac{dI_B}{dI_C}\right) R_E$$

$$\frac{dI_B}{dI_C} = -\frac{R_E}{R_{Th} + R_E}$$

$$S = (\beta + 1)\frac{(R_{Th} + R_E)}{R_E(\beta + 1) + R_{Th}}$$

$$S = (\beta + 1)\frac{\left(1 + \frac{R_{Th}}{R_E}\right)}{(\beta + 1) + \frac{R_{Th}}{R_E}}$$

- For stability, S should be small which can be achieved by making R_{Th}/R_E small. For very small R_{Th}/R_E ; S = 1 (ideal case)

- For very small R_{Th}/R_E : $R_2 \downarrow \longrightarrow R_{Th}$ current drawan by R_2 will be large.
  $R_E \uparrow \longrightarrow$ Large V_{cc} required. Hence comproise is made in selection.