Bias Stabilization :-

Only the fixing of a suitable operating point is not sufficient but it is also to be ensured that the operating point remains stable. i.e. it does not shift due to change in temperature or due to variations in transistor parameters (due to replacement of transistor). It is not possible in practice unless special efforts are made to achieve it.
The maintenance of the operating point stable is known as stabilization.
The stabilization of operating point is essential because of (i) temperature dependance of Collector current I_c (ii) individual variations and (iii) thermal runaway.

Stability factor:

The degree of success achieved in stabilizing I_c in the face of variations in I_{CEO} ~~(ICO)~~ (or I_{co}) ~~in terms of~~ is expressed in terms of stability factor 'S' and it is defined as the rate of change of collector current w.r.t. I_{co} keeping β and V_{BE} constant

$$S = \left.\frac{dI_c}{\partial I_{co}}\right|_{\text{at constant } \beta \text{ and } V_{BE} \,(\text{or } I_B)}$$

General Expression for Stability factor :-

$$S = \frac{\Delta I_c}{\Delta I_{co}} = \frac{\partial I_c}{\partial I_{co}}$$

$$I_c = \beta I_B + (1+\beta) I_{co}$$

Partial Differentiation w.r.t. I_c

$$1 = \beta \frac{\partial I_B}{\partial I_c} + (1+\beta)\frac{\partial I_{co}}{\partial I_c}$$

$$(1+\beta)\frac{\partial I_{co}}{\partial I_c} = 1 - \beta \frac{\partial I_B}{\partial I_c}$$

$$\frac{\partial I_{co}}{\partial I_c} = \frac{1-\beta\left(\frac{\partial I_B}{\partial I_c}\right)}{(1+\beta)}$$

$$\frac{\partial I_c}{\partial I_{co}} = \frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_c}\right)}$$

$$\boxed{S = \frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_c}\right)}}$$

Transistor Biasing Circuits :-

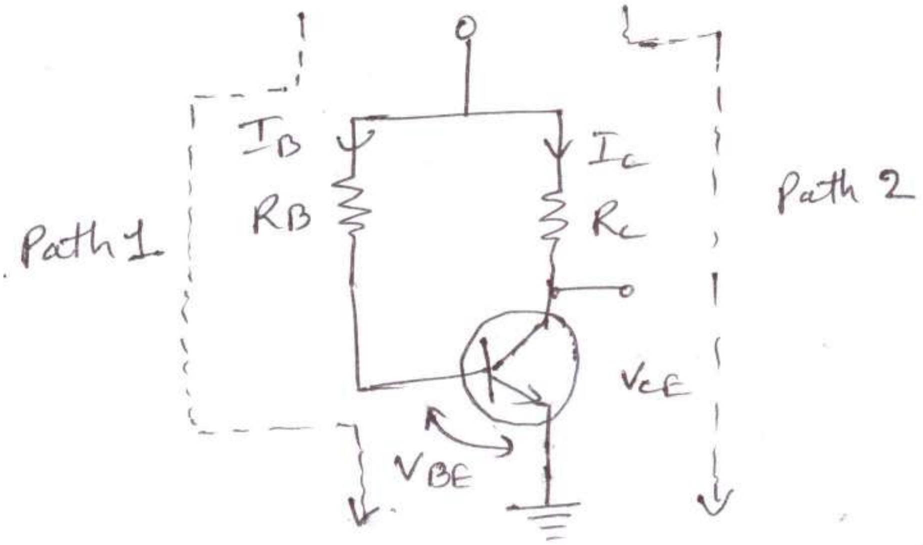
A biasing network associated with a transistor should fulfill the following requirements

(i) Establish the operating point in the middle of the active region of the characteristics, so that on applying the input signal the instantaneous operating point does not move either to the cut off region or to the saturation region, even at the extreme values of the input signal.

(ii) Stabilize the collector current I_c against temperature variations.

(iii) Make the operating point independent of transistor parameters so that replacement of transistor by another of the same type in the circuit does not shift the operating point.

(i) Fixed Bias Circuit :-



The base current can be determind by applying Kirchhoff's voltage law on path 1.

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

$$\boxed{I_B = \frac{V_{cc} - V_{BE}}{R_B}}$$

$$\boxed{I_c = \beta I_B}$$

For Si Transistor
$V_{BE} = 0.7$
For Ge
$V_{BE} = 0.3$

Path - 2

$$V_{cc} = I_c R_c + V_{CE}$$

$$\boxed{V_{CE} = V_{cc} - I_c R_c}$$

$$Q = (V_{CEQ}, I_{CQ})$$

Stability in Fixed Bias.

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

$$I_B = \frac{V_{cc} - V_{BE}}{R_B}$$

$$\frac{\partial I_B}{\partial I_c} = 0$$

we know that

$$S = \frac{1 + \beta}{1 - \beta\left(\frac{\partial I_B}{\partial I_c}\right)}$$

$$\boxed{S = 1 + \beta}$$

Let $\beta = 100$,

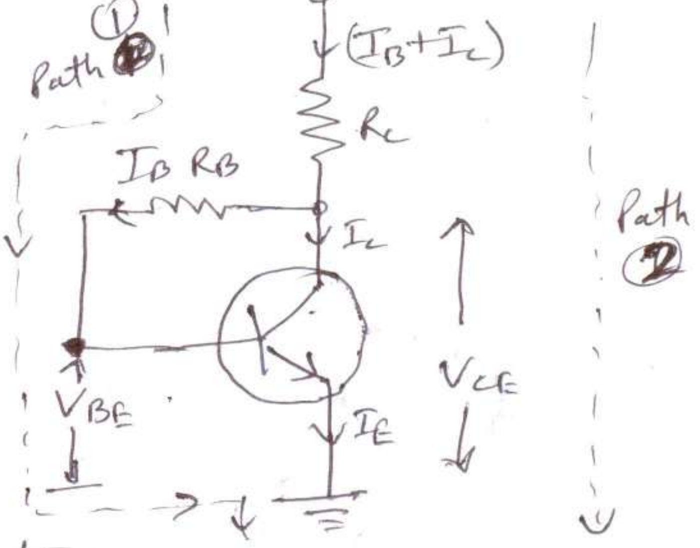
then $S = 101$

This value of S is very high and for stability this should be minimum.

~~Hence~~

(ii) Collector to Base Bias :-

It derives its name from the fact that voltage for R_B is derived from the collector. There exists a negative feedback effect which tends to stabilise I_c against changes either as a result of change in temperature or as a result of replacement of the transistor.



If the collector current I_c tends to increase, V_{CE} decreases due to larger voltage drop across the collector resistance R_c. The result is that base current I_B is reduced. The reduced base current in turn reduces the original increase in collector current I_c. Thus a mechanism exists in the circuit which does not allow collector current I_c to increase rapidly.

Path ① KVL

$$V_{cc} = (I_c+I_B)R_c + I_B R_B + V_{BE}$$

$$= (\beta I_B + I_B) R_c + I_B R_B + V_{BE}$$

$$\cancel{I_B}$$

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

$$= I_B \left[(\beta+1) R_C + R_B \right] + V_{BE}$$

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

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

$$\because \quad I_C = \beta I_B$$

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

Path 2

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

$$\boxed{V_{CE} = V_{CC} - (I_B + I_C) R_C}$$

and ~~$V_{CE} =$~~ we can also write.

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

$$\boxed{I_B = \frac{V_{CE} - V_{BE}}{R_B}}$$

$$\boxed{I_C = \beta I_B}$$

Stability factor

$$V_{CC} = (I_B + I_C) R_C + I_B I_B + V_{BE}$$

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

$$\frac{\partial I_B}{\partial I_C} = - \frac{R_C}{R_B + R_C}$$

$$\boxed{S = \frac{1+\beta}{1+\beta\left(\frac{\partial I_B}{\partial I_C}\right)}}$$

$$\boxed{S = \frac{1+\beta}{1+\beta\left(\frac{R_C}{R_B+R_C}\right)}}$$

Let $\beta = 100$, $R_C = 1\,k\Omega$ & $R_B = 9\,k\Omega$

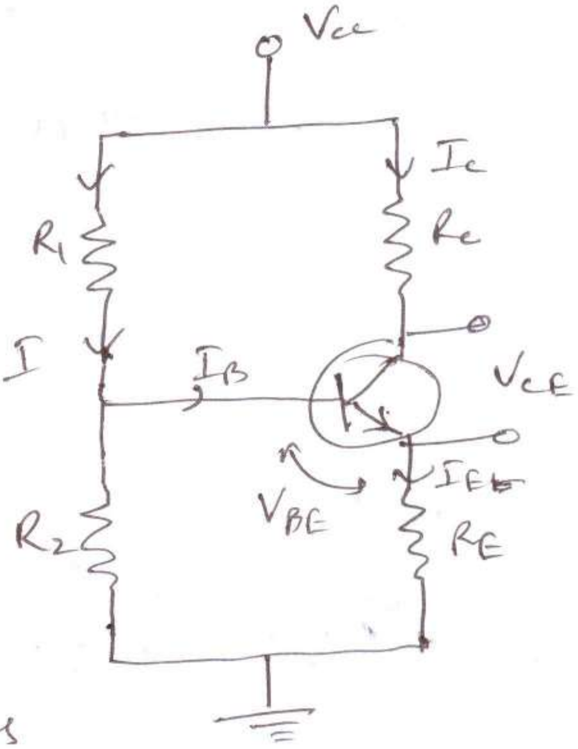
$$S = \frac{1+100}{1+100\left(\frac{1}{10}\right)} = \frac{101}{11}$$

$$\boxed{S \simeq 9}$$

for the same value of ($\beta = 100$) the stability of Collector to Base Biase is very much more than fixed biase.

Potential Divider Bias :-

[or Voltage Divider Bias
or Self Bias.]



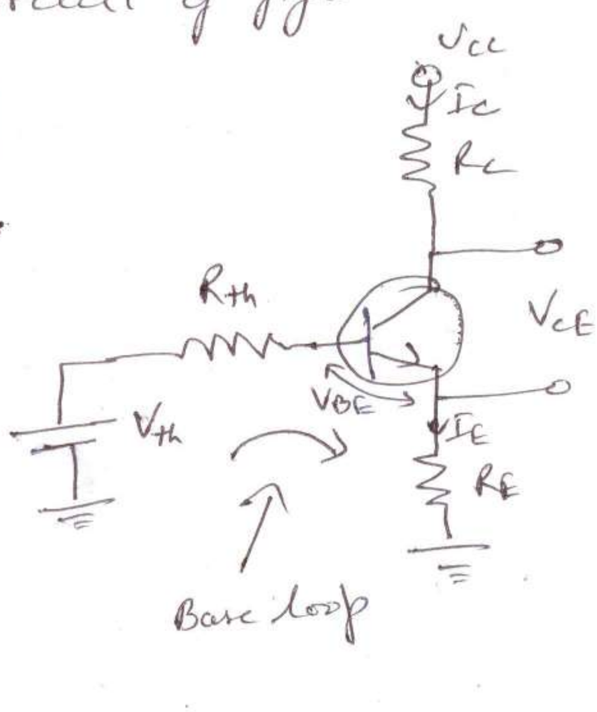
(fig. 1)

This is the most commonly used biasing arrangement. The name potential divider is derived due to the fact that the voltage devider is formed by the resistors R_1 and R_2 across V_{cc}. The emitter ~~resistance~~ R_E provides stabilization. The resistor R_E causes a voltage drop in a direction ~~to~~ so as to reverse biase the emitter junction. Since the emitter-base junction is ~~to~~ ~~be~~ forward biased, the base voltage is obtained from supply V_{cc} through R_1-R_2 network.

Thevenin's equivalent circuit of fig 1. is shown in fig. 2. From the ckt.

$$\boxed{R_{th} = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}}$$

$$\boxed{V_{th} = \frac{R_2}{R_1 + R_2} V_{cc}}$$



KVL in Base loop:-

$$V_{th} = I_B R_{th} + V_{BE} + I_E R_E \quad \text{---}.$$

$$\because I_E = I_B + I_C = I_B + \beta I_B = (1+\beta) I_B$$

$$\therefore V_{th} = I_B R_{th} + V_{BE} + (1+\beta) I_B R_E$$

$$\boxed{I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta) R_E}}$$

$$I_C = \beta I_B$$

$$V_{CC} = I_C R_C + V_{CE} + I_E R_E$$

$$\boxed{V_{CE} = V_{CC} - I_C R_C - I_E R_E}$$

Stabilizing factor

$$V_{th} = I_B R_{th} + V_{BE} + I_E R_E$$

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

$$I_B = \frac{V_{th} - V_{BE} - I_C R_E}{R_{th} + R_E}$$

$$\frac{\partial I_B}{\partial I_C} = - \frac{R_E}{R_{th} + R_E}$$

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