Why do we need bias stabilization?

As the transistor is made up of semiconductor material, therefore the transistor parameters and characteristics are markedly temperature sensitive.

Due to this, Although the bias arrangement is correctly designed but these variations will shift the operating point and hence the desired mode of operation.

Thus, it is necessary to stabilize the bias in various transistor circuit.

The increase in temperature has an important effect on three transistor quantities I_{CO}, α and V_{BE}. (Note $I_{CO} \approx I_{CBO}$).

Stability factor.

It is the factor which determines the stability of a bias circuit. The lower the value of stability factor, the more stable will be the circuit.

It depends upon three parameters:-

1) $S = \dfrac{\Delta I_C}{\Delta I_{CO}}\Bigg|$ keeping V_{BE} and β const.

2) $S' = \dfrac{\Delta I_C}{\Delta V_{BE}}\Bigg|$ keeping I_{CO} and β const.

3) $S'' = \dfrac{\Delta I_C}{\Delta \beta}\Bigg|$ keeping I_{CO} and V_{BE} const.

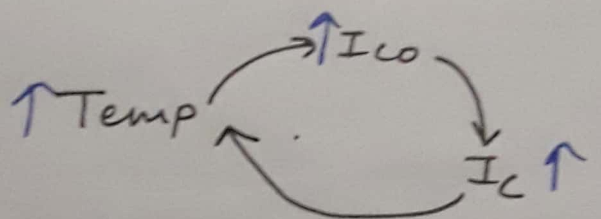
These expressions indicate that I_C is collectively dependent on ΔI_{CO}, ΔV_{BE} and $\Delta \beta$.

$$\Rightarrow \quad \Delta I_C = S\,\Delta I_{CO} + S'\,\Delta V_{BE} + S''\,\Delta \beta .$$

* Note :- Since S is significantly higher than S' and S'', therefore we should focus our attention more on the value of S.

Thermal Runway

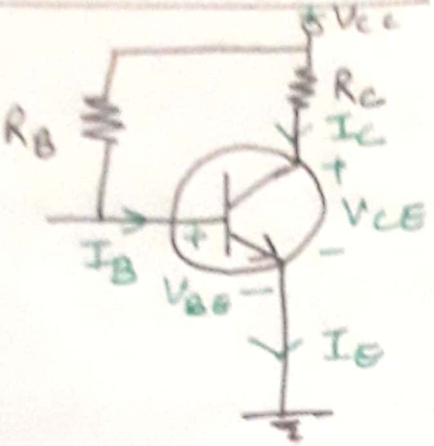
$$I_C = \beta I_B + (\beta + 1) I_{CO}.$$



As we keep on increasing temp, the leakage current I_{CO} increases which leads to increase in I_C which dissipates more heat and hence the temperature increases. This process goes on and this leads to a very high increase in temperature due to which the transistor may damage.

Stabilization Techniques

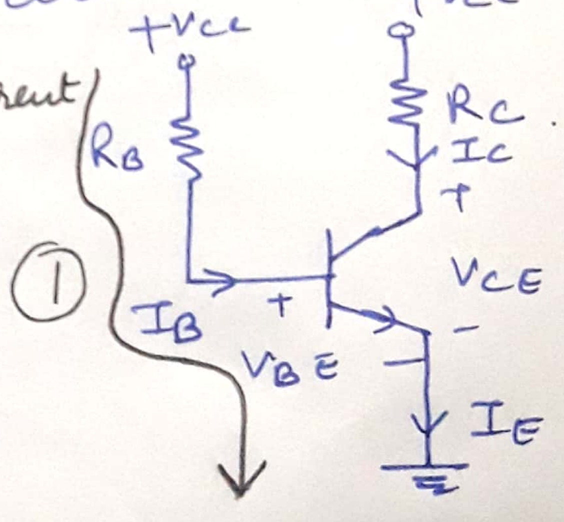
1) Fixed Bias circuit (Base Resistor Biasing)



[For numerical point of view, the terms written in green colour will be marked by ourselves [It is not given in the circuit].

Steps to find out the operating point (Q point)

* Finding of operating point is also known as d.c. Analysis of the circuit.



Step 1:- Calculate the base current I_B by applying KVL to the input loop (loop 1)

$$+V_{CC} - I_B R_B - V_{BE} = 0.$$

or

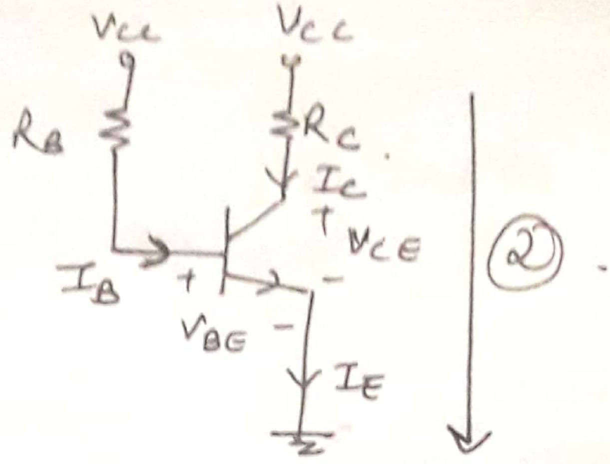
$$\boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B}} \quad \text{—— (1)}$$

(Generally, we take $V_{BE} = 0.7V$)

Step 2 :- Calculate $\boxed{I_{CQ} = \beta I_B}$ — (2).

Step 3 :-

Calculate V_{CEQ} by applying KVL at the output loop (Loop (2))



$$+V_{CC} - I_C R_C - V_{CE} = 0$$

or $\boxed{V_{CEQ} = V_{CC} - I_C R_C}$ — (3)

How to determine the Stability factor (S).

We have,

$$S = \left.\frac{\Delta I_C}{\Delta I_{CO}}\right| \text{constant } V_{BE} \text{ and } \beta .$$

For CE configuration,

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

differentiate whole equation w.r.t I_C.

$$\Rightarrow \quad 1 = \beta\left(\frac{dI_B}{dI_C}\right) + (\beta+1)\frac{dI_{CO}}{dI_C} .$$

$$\Rightarrow \quad \frac{dI_{CO}}{dI_C} = \frac{1 - \beta\left(\frac{dI_B}{dI_C}\right)}{\beta+1} .$$

$$\text{or} \quad \frac{dI_C}{dI_{CO}} = \frac{\beta+1}{1-\beta\left(\frac{dI_B}{dI_C}\right)} .$$

for fixed bias

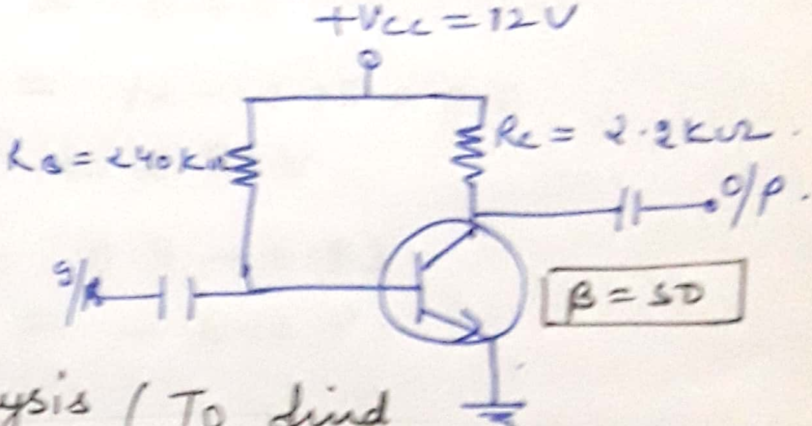
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

hence $\frac{dI_B}{dI_C} = 0$ ($\because$ V_{CC}, V_{BE} and R_B are const.)

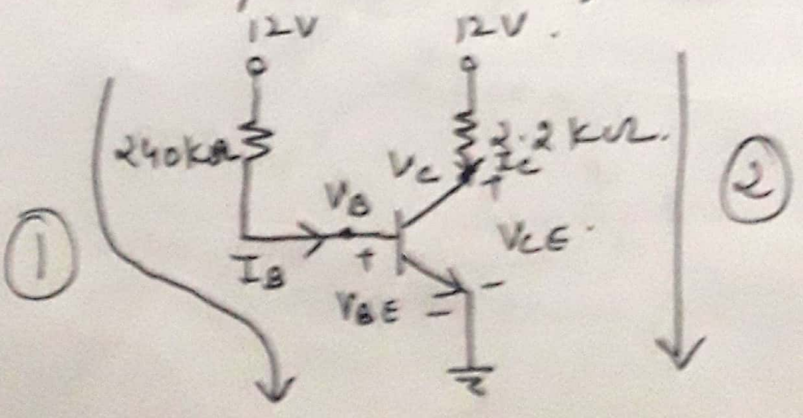
$\Rightarrow$ $\boxed{S = 1+\beta}$

* Since β is very large, therefore the stability factor for fixed bias is also very large and hence it is an unstable circuit.

Numerical :- For the following fixed bias circuit find (a) I_{BQ} and I_{CQ} (b) V_{CEQ} (c) V_B and V_C (d) V_{BC}.



Solution :- for d.c. Analysis (To find the operating point) the capacitors are removed from the circuit. (They act like open circuit).



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step 1 Applying KVL at loop 1.

$12 - 240 I_B - 0.7 = 0.$

$\Rightarrow \quad I_{B_Q} = \frac{12 - 0.7}{240} = 47.08 \, \mu A.$

step 2. $\quad I_{CQ} = \beta I_{BQ} = 50 \times 47.08 \times 10^{-6}$

$= 2.35 \, mA$

step 3. Applying KVL at loop 2.

$12 - 2.2 I_C - V_{CE} = 0.$

$\Rightarrow \quad V_{CE_Q} = 12 - 2.2 \times 2.35$

$= 6.83 \, V.$

$V_B = V_{CC} - I_B R_B = 12 - 47.08 \times 240 \times 10^{-3}.$

$= 0.7 \, V.$

$V_C = V_{CC} - I_C R_C = 12 - 2.35 \times 2.2$

$= 6.83 \, V.$

$V_{BC} = V_B - V_C = 0.7 - 6.83$

$= -6.13 \, V.$