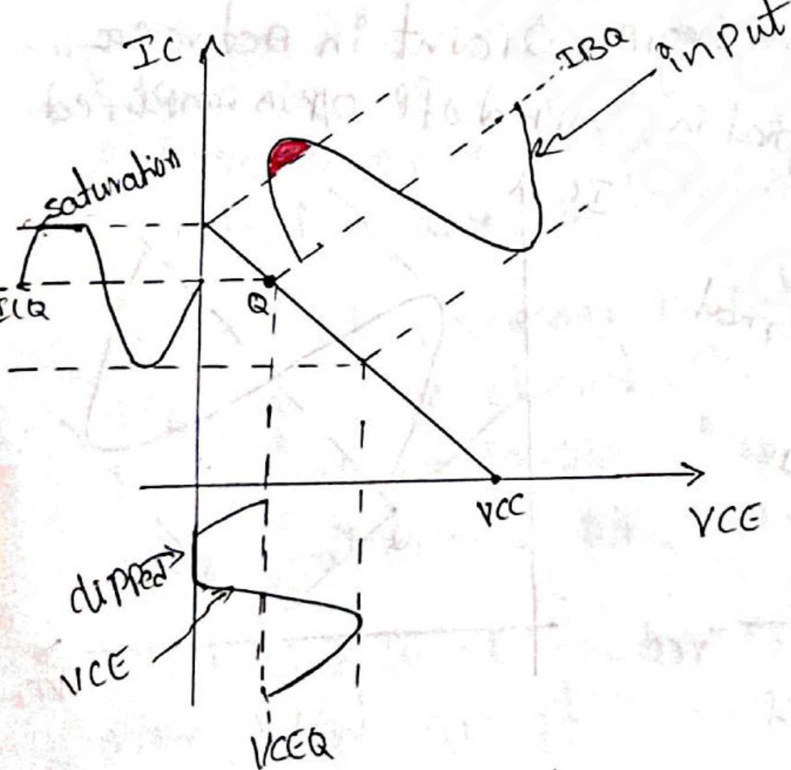
unit - IV

Transistor Biasing and stabilization.

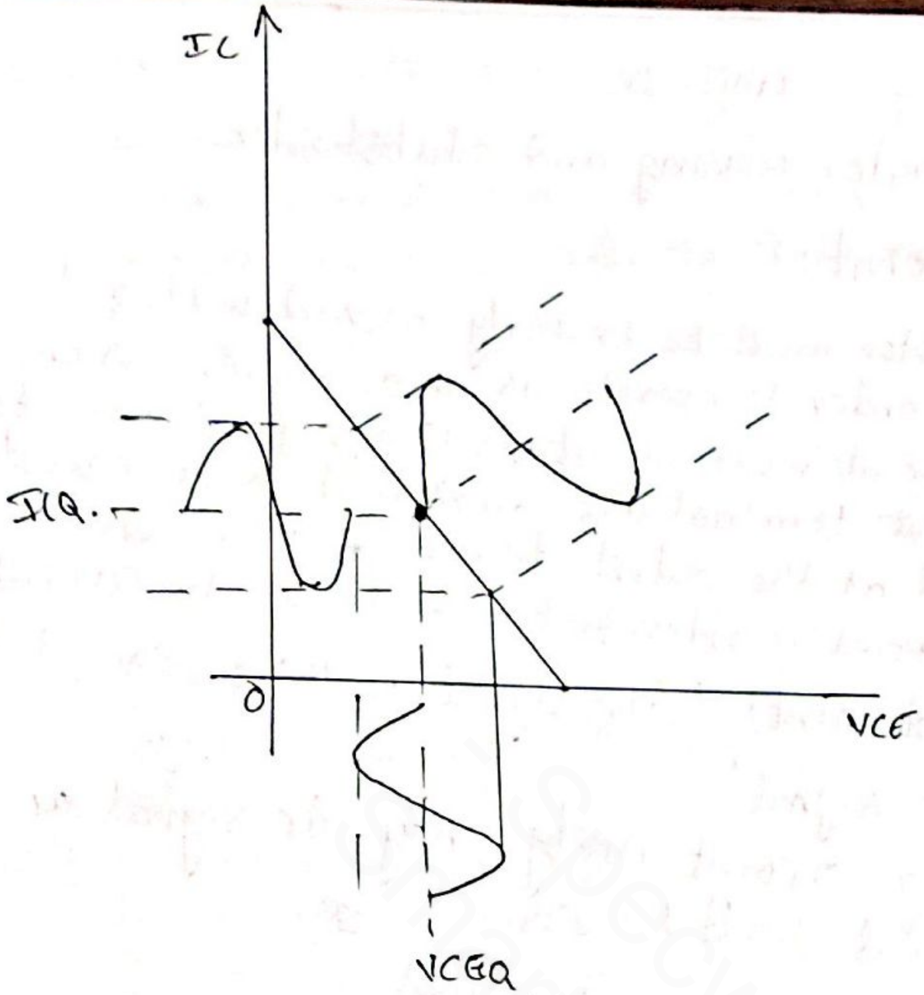
operating point:

A transistor must be properly biased with a dc voltage in order to operate as an amplifier. A dc operating point must be set so that signal variations at the input terminal are amplified and accurately reproduced at the output terminal. The dc operating point is often referred to as the QPoint (Quiescent Point) (i/p signal will be equal to zero ie AC signal.).

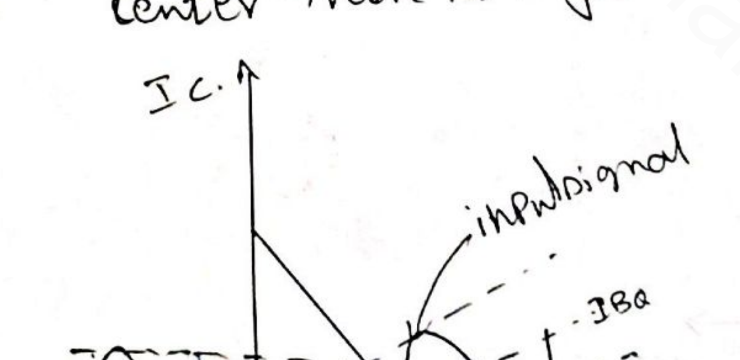
For finding QPoint apply only dc signal as i/p AC signal should be equal to zero.

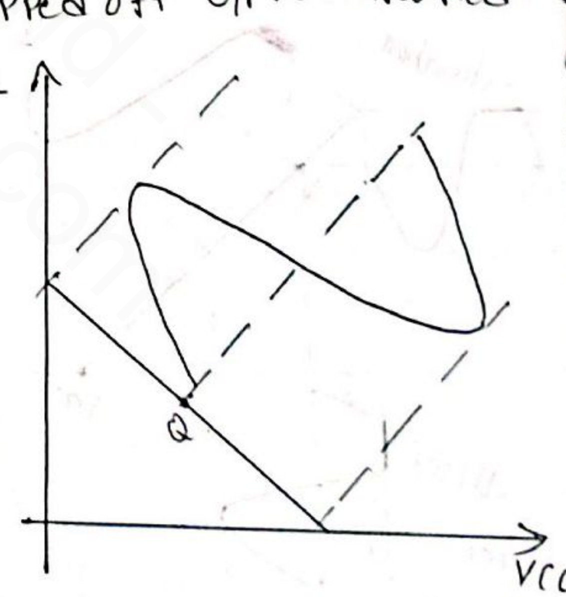


Transistor is driven into saturation because the QPoint is too close to saturation for the given input signal.

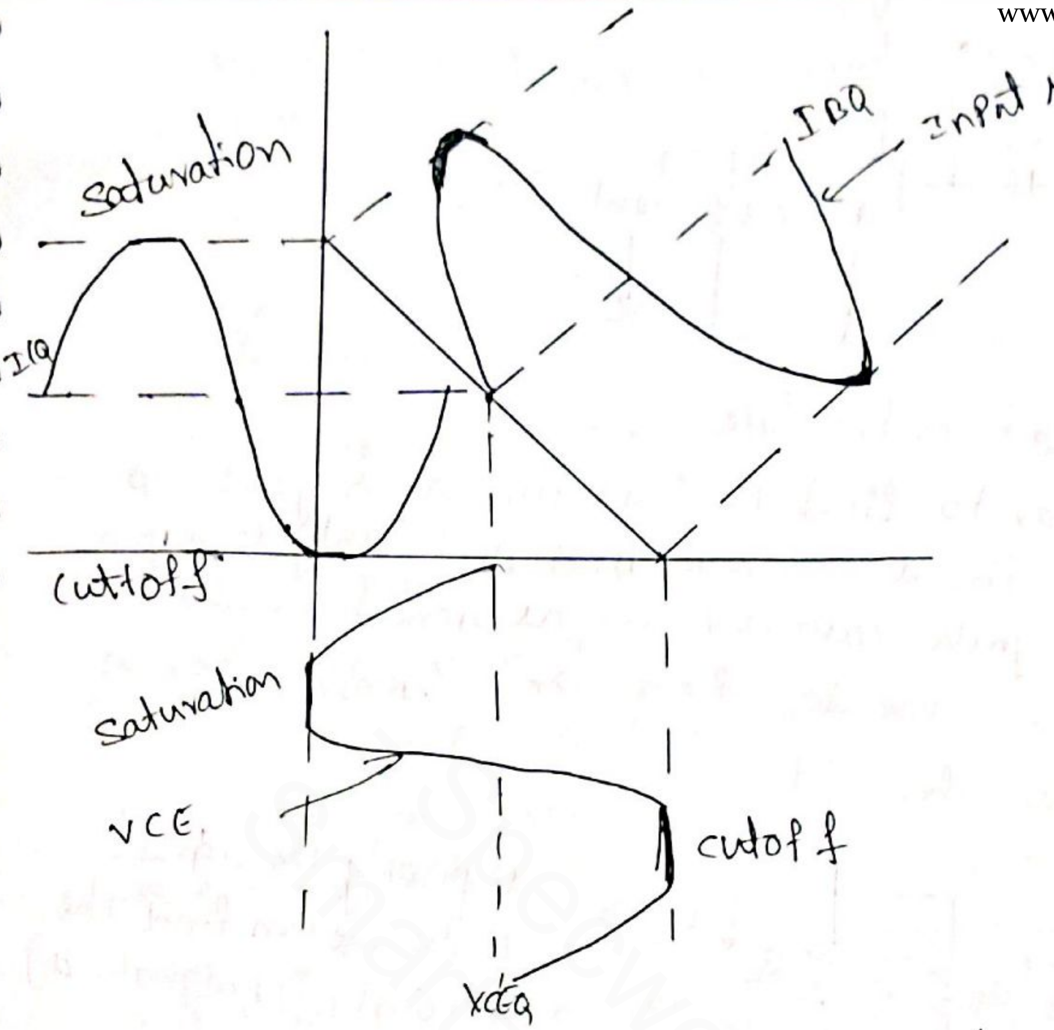


Transistor is in active region. Q Point in Active region center then no signal is clipped off O/P is amplified.





Transistor is driven into cutoff because the Q Point is too close to cutoff for the given input signal

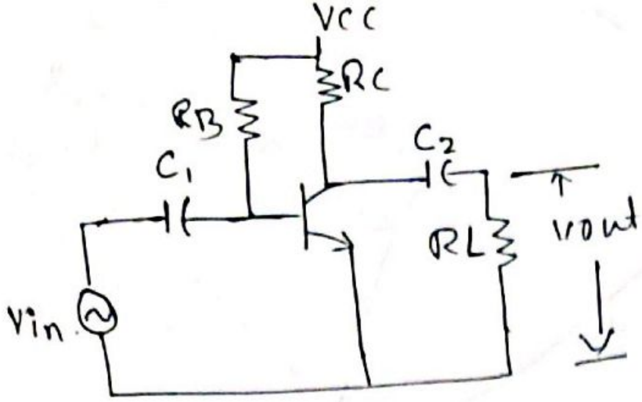


Transistor is driven into both saturation as cutoff because the input signal is too large.

If Q point is nearer to cutoff or saturation then the signals are clipped off, from above figure. If the i/p signals are larger then beyond the cutoff as saturation also signals at the o/p will be clipped off

If QPoint is at center as i/p AC signal is small then output signal is replica of i/p signal.

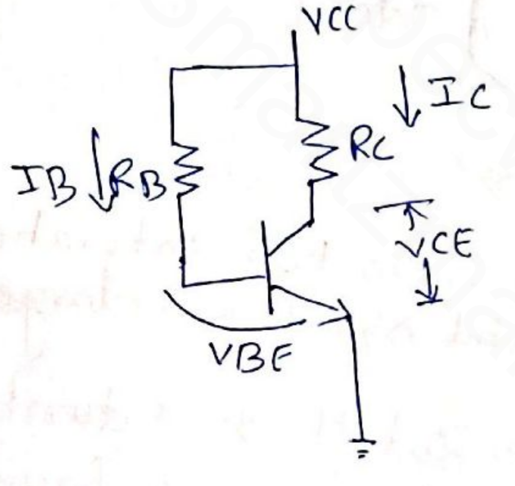
To maintain QPoint at center are two reasons
1. To act as an amplifer
2. If Q varries o/p signal is not replica of i/p signal.



DC load line: DC load line

In order to find DC load line, AC signal i/p should be Equal to zero. And Apply only DC signal For dc signals capacitor act as opened since $X_C = 1/2\pi f C$ for dc $f=0$ $X_C = 1/2\pi(0) \cdot C$ $X_C = \infty$

so redraw the ckt.



By Apply DC signal only we can find the Q point (i/p signal = 0)

For load line analysis we have to do the

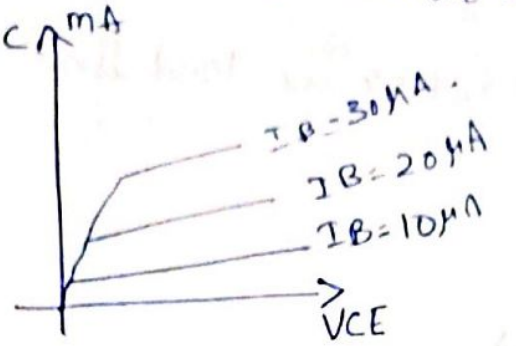
1. actual characteristics of CE characteristics
2. Draw a straigh line is called load line by applying kirchoff's law to the ckt & find where it touches x-axis & y-axis.

To find a Point.

3. combine both actual characteristics of CE & load line kirchoff's law. (touching x-axis & y-axis find out)

4. find mid point of x axis & y axis is Q Point.

1. Draw the actual characteristics of CE characteristics.



2. Apply kirchoff law to the ckt to find Eq related to VCE and IC.

$V_{CC} = I_C \cdot R_C + V_{CE}$

X-axis touches when $I_C = 0$.

$V_{CC} = V_{CE} \Rightarrow \boxed{V_{CE} = V_{CC}.}$

I_{C} min we get minimum collector current when the subtraction term $\frac{V_{CE}}{R_C}$ in Eq (a) is Maximum.

$V_{CC} = I_C \cdot R_C + V_{CE} \Rightarrow I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C}$ — (a)

that is what we have applied supply that will be the drop.

V_{CE} (drop) $= V_{CC}$ (supply)

$I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C} \Rightarrow I_C \min = \frac{V_{CC}}{R_C} - \frac{V_{CC}}{R_C} = 0$

$\boxed{I_C \min = 0}$ X-axis Point $= (V_{CC}, 0)$

Y-axis touches when $V_{CE} = 0$

$V_{CC} = I_C \cdot R_C + V_{CE}$

$V_{CC} = I_C \cdot R_C + 0$

$\boxed{I_C = \frac{V_{CC}}{R_C}.}$

I_C max we get maximum collector current if subtraction term the $\frac{V_{CE}}{R_C}$ is minimum in Eq. (a)

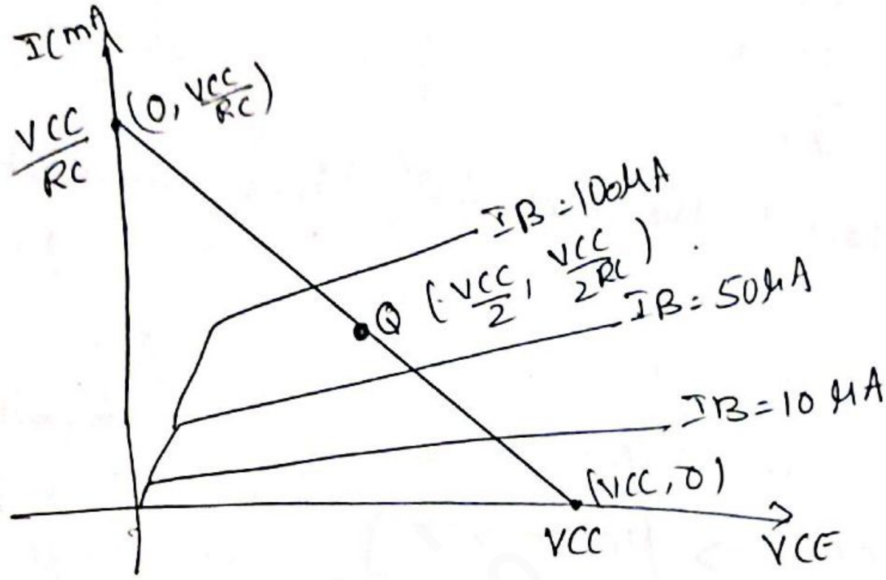
$I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C}.$

It implies we get Maximum collector current $I_C$max when $V_{CE} = 0$ i.e where the load line it touches the Y axis.

$I_C max = \frac{V_{CC}}{R_C} - 0$ $\boxed{I_C max = \frac{V_{CC}}{R_C}}$ Y axis =

y axis point $\left(V_{CE}=0,\ I_C = V_{CC}/R_C\right)$ $\left(0, V_{CC}/R_C\right)$

3. combine actual CE characteristics & load line



4. find the mid point for x axis term & y axis terms.

$$Q = \left(\frac{0 + V_{CC}}{2},\ \frac{\frac{V_{CC}}{R_C}+0}{2}\right)$$

$\because V_{CE}=0 + V_{CE}=V_{CC}$

$I_{Cmax} = \frac{V_{CC}}{R_C} + I_{Cmin}=0$

Q point in mid point $Q = \left(\frac{V_{CC}}{2},\ \frac{V_{CC}}{2R_C}\right)$

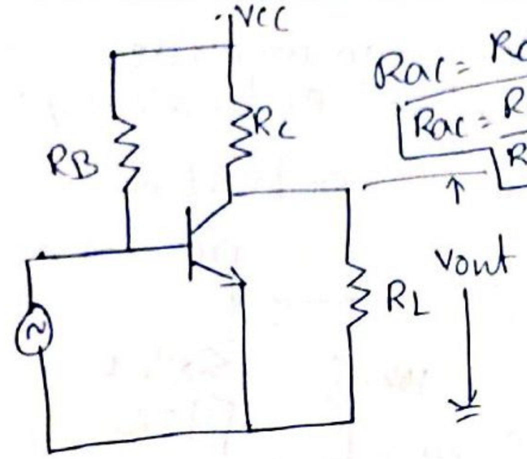
AC load line : AC load line.

Q point is located at the center of load line.
Q point is find out at the zero input AC signal condition of the circuit.

To draw the AC load line we have to apply both AC signals & dc signals. so that AC load line should also passes through the operating point Q.

since we are applying ac signal supply the capacitors act as short circuit.

For AC load line the resistance at output Rac is combination of Rc & RL from fig.



$R_{ac} = R_C \| R_L$

$$\boxed{R_{ac} = \frac{R_C R_L}{R_C + R_L}}$$

To draw the ac load line two end points & maximum VCE w maximum IC when the signal is applied are required.

Maximum $V_{CE} = V_{CEQ} + I_{CQ} \cdot R_{ac}$ on the VCE axis

Maximum $I_C = I_{CQ} + \frac{V_{CEQ}}{R_{ac}}$

which locates the point on the I_C axis.

~~VCE~~: For AC load line both AC w DC.

$V_{CE} = V_{CEdc} + V_{CEAC}$

$V_{CE} = \left(\frac{V_{CC}}{2} + \frac{V_{CC}}{2R_C} \cdot R_{ac}\right)$ → touches x-axis.

$V_{CEdc} = V_{CEQ} = \frac{V_{CC}}{2}$

$V_{CEAC} = \frac{I_{CQ}}{\cancel{R_{ac}}} R_{ac}$

$V_{CEAC} = I_{CQ} \cdot R_{ac}$

$I_{CQ} = \frac{V_{CC}}{2R_C}$

$V_{CEAC} = \frac{V_{CC}}{2R_C} \cdot R_{ac}$.

$I_C = I_{C\cancel{dc}} + I_{CAC}$

$= I_{CQ} + I_{CAC}$

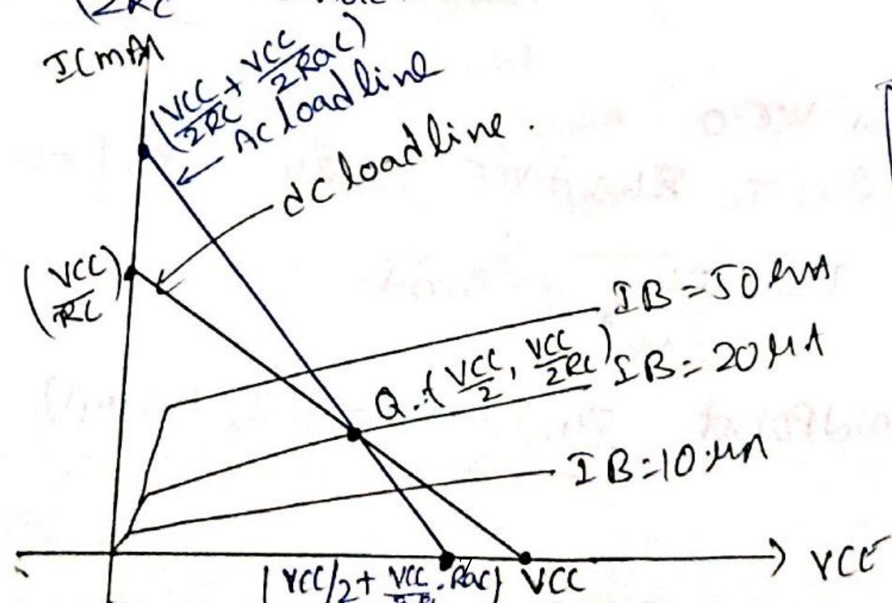
$I_{Cdc} = I_{CQ} = \frac{V_{CC}}{2R_C}$.

$I_{CAC} = \frac{V_{CEQ}}{R_{ac}}$ $\qquad I = V/R$ $\qquad V_{CEQ} = \frac{V_{CC}}{2}$

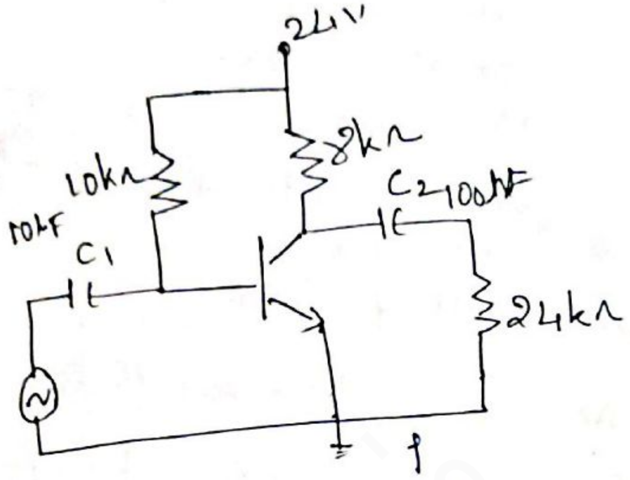
$= \frac{V_{CC}}{2R_{ac}}$

$I_C = \left(\frac{V_{CC}}{2R_C} + \frac{V_{CC}}{2R_{ac}}\right)$ — touches — Y axis

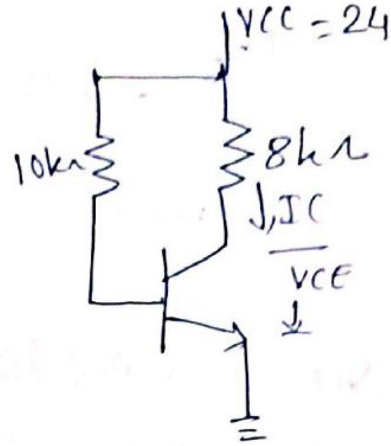
$$\boxed{R_{ac} = \frac{R_C \cdot R_L}{R_C + R_L}}$$



For the following ckt transistor is an amplifier shown in figure draw the DC load line, AC load line &
find Q point.

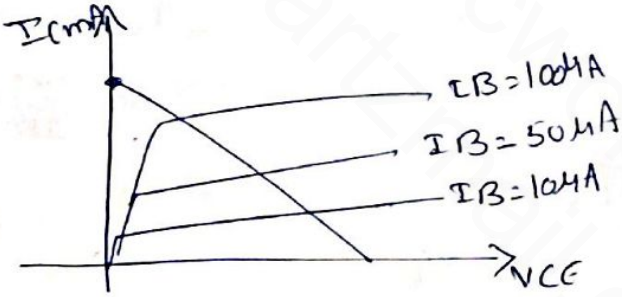


DC load line



DC load line 1. AC signal = 0. 2. Apply only DC. Capacitors opened.

3. actual characteristics



4. Apply KVL Eq. across out loop.

$24 = I_C \cdot 8k\Omega + V_{CE}$

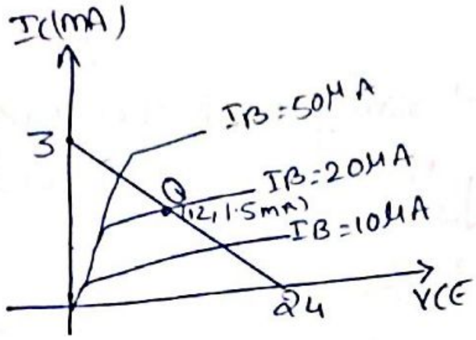
X-axis touches $I_C = 0$. $\boxed{V_{CE} = 24V}$

Y axis touches $V_{CE} = 0$

$24 = I_C \cdot 8k\Omega + V_{CE} \Rightarrow 24 = I_C \cdot 8k\Omega + 0$

$I_C = \frac{24}{8 \times 10^3} = 3mA.$

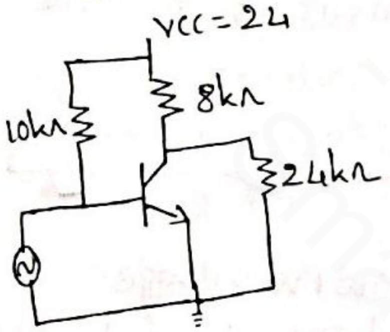
Q Point is MidPoint $\left(\frac{24}{2}, \frac{3mA}{2}\right) = (12, 1.5mA)$



Acloadline:

Apply both AC and DC signals to draw the AC loadline.

Since AC is applied capacitor is short.



$$R_{ac} = R_L \parallel R_C = \frac{8\times 24}{8+24} = 6k\Omega$$

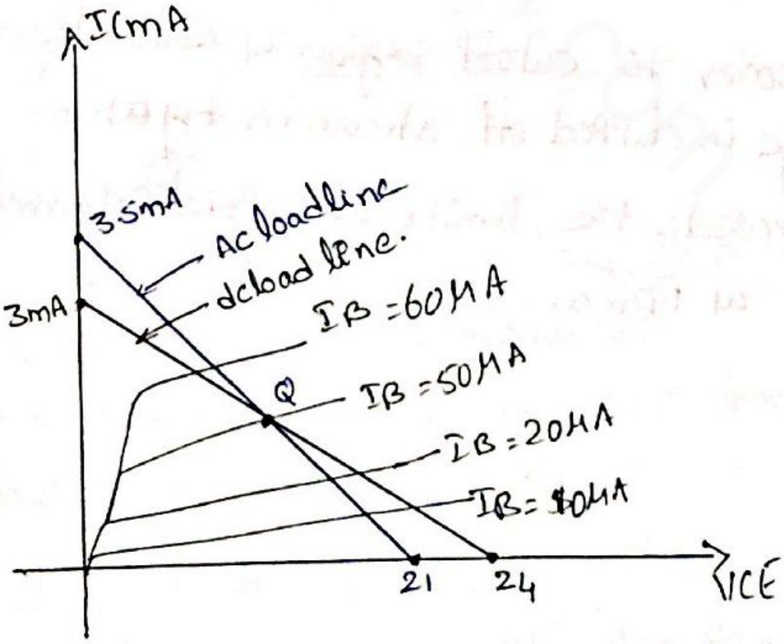
$$V_{CE} = V_{CEQ} + I_{CQ} \cdot R_{ac}$$

$$= 12 + (1.5)\times 6\times 10^3$$

$$V_{CE} = 21V$$

$$I_C = I_{CQ} + \frac{V_{CEQ}}{R_{ac}} = 1.5mA + \frac{24}{6k\Omega}$$

$$I_C = 3.5mA$$



Need for Biasing:

Biasing: The Process of choosing of proper supply voltages and resistors for obtaining the desired QPoint is called biasing.

Need for biasing: The Purpose of biasing a circuit is to Establish a proper stable dc operating point.

The QPoint should be choosen such that

1. It should not Exceeds the limits of operation.
2. It should not nearer to saturation or cutoff regions.
3. It should be in Active region. (a Midpoint for the dcload line.

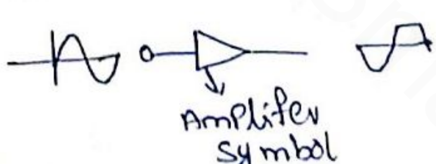
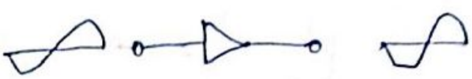


fig (a)

out Put voltage is clipped by cutoff region



out Put voltage clipped by saturation.

fig (b)

If Q Point is nearer to cutoff region or saturation region then output voltage is clipped off shown in fig (a). b.

It should not Exceeds the limits of operation. such as the manufacturer or $P_{Dmax} \leq V_{CE} \cdot I_C$

Bias stability:

The Q point of a circuit is defined by specific values w/ the Q point of circuit has to maintained const.

~~Some Problems are of th~~

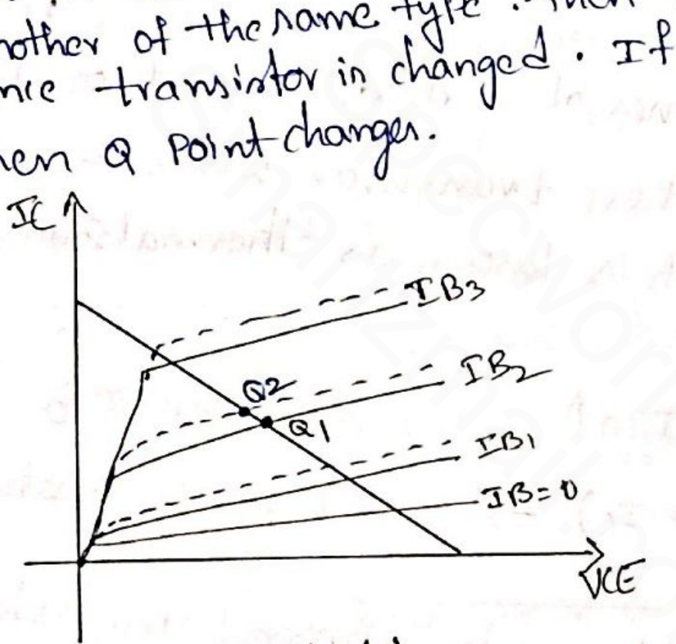
Some of the Problems of maintaining the operating Point stable.

1) If β value changes by changing of transistor.

2) Thermal instability.

If β value changes by changing of transistor.

let us assume that the transistor is replaced by another of the same type. Then β value (hFE) changes since transistor is changed. If β changes I_C changes then Q Point changes.



Q1 — before tr. changed

Q2 → after tr. changed.

Thermal instability:

A second very important cause for bias instability is a variation in temperature.

As Temperature changes I_{CO} changes. I_{CO} current doubles for 10°C temperature.

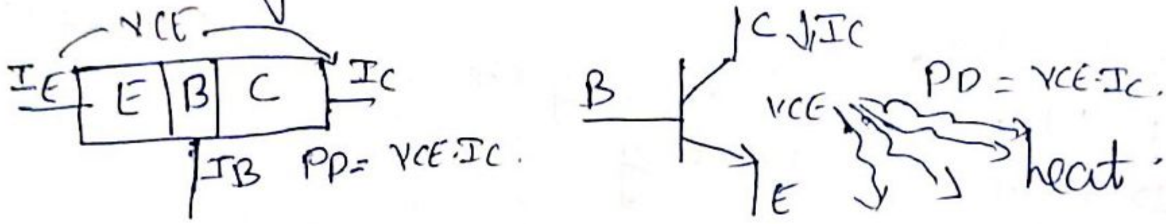
$$I_C = \beta I_B + (1+\beta) I_{CO}.$$

As I_{CO} increases, ~~then~~ with temperature then I_C increases then Q Point also changes.

If I_C increases power dissipation increases since

$P_D = V_{CE} \cdot I_C$.

If power dissipation increases means that releasing of power energy in-terms of heat.



If P_D increases heat increases If heat increases temperature increases. If temperature increases I_{CO} increases If I_{CO} increases I_C increases this is a cumulative processes at particular current of I_C

$P_D >>> P_{D max}$ then transistor wille be damaged this is known as thermal runaway or thermal instability.

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

$I_C \uparrow \Rightarrow P_D \uparrow (P_D = V_{CE} \cdot I_C) \Rightarrow$ Heat $\uparrow \Rightarrow$ Temperature $\uparrow$

If $P_D >>> P_{D max}$ transistor damaged. this is known as thermal runaway.

Stabilization Factors:

Biasing a transistor in the active region to maintain the operating point stable by keeping I_C, V_{CE} constant. The techniques normally used to do so may be classified in two categories

1> stabilization techniques.

2> compensation techniques.

compensation technique:

compensation technique refer to use of temparature (dependent) sensitive devices such as diodes transistor thermistors & sensistors.

stabilization techniques: (Biasing techniques)

Stabilization technique refer to use of temparature (independent) ~~not sensi~~ insensitive devices such as resistors.

The resistive biasing circuit which allow I_B to vary so as to keep I_C relatively constant with variations in I_{CO}, β & V_{be}.

stabilization-factors

If temparature changes the I_C current changes due to three parameters.

1. I_{CO}

For 10°C rise of temparature I_{CO} doubles. then I_C increases. since

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

2. V_{be}

If temparature increases of one degree centigrade then V_{be} voltage decreases of 2.5mV.

$V_{be} = -2.5\,mV/°C$ If V_{be} changes I_B changes then I_C changes. (V_{be} Voltage Forward bias voltage at JE.)

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

3. β [hFE]

If temparature ~~ch~~ increases I_{CO} increases I_C increases then β increases since $h_{FE} = \beta = \frac{\Delta I_C}{\Delta I_B}$.

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Since I_C increased β increases if β increases

then $I_C = \beta \cdot I_B$.

β values also changes w.r.t temparature.

Since I_C dependents on three parameters I_{CO}, V_{be}, β there are three stabilization factors. S, S', S''.

stability factor S:

The extent to which the collector current I_C is stabilised with varying I_{CO} is measured by a stability factors S.

S can be defined as rate of change of collector current I_C with respect to collector leakage current I_{CO} by keeping both V_{be} & β as constant.

$$\boxed{S = \frac{dI_C}{dI_{CO}} \quad V_{be}, \beta \text{ const}}$$

as we know for CE ~~con~~ Amplifier. as

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

$$S = \frac{dI_C}{dI_{CO}} \Rightarrow$$

differentiating the above Equation with respect to I_C we get

$$1 = \beta \cdot \frac{dI_B}{dI_C} + (1+\beta) \frac{dI_{CO}}{dI_C}.$$

$$1 - \beta \frac{dI_B}{dI_C} = (1+\beta) \frac{dI_{CO}}{dI_C}$$

$$1 - \beta \frac{dI_B}{dI_C} = \frac{1+\beta}{S}$$

$$\boxed{S = (1+\beta) / 1 - \beta \frac{dI_B}{dI_C}}$$

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

S should be small as possible to have better thermal stability.

stability factor S'

The stability factor S' is defined as the rate of change of I_C with V_{BE} keeping I_{CO}, and β constant.

$$S' = \frac{dI_C}{dV_{be}} \sim \boxed{S' = \frac{dI_C}{dV_{be}} \quad I_{CO}, \beta \text{ const.}}$$

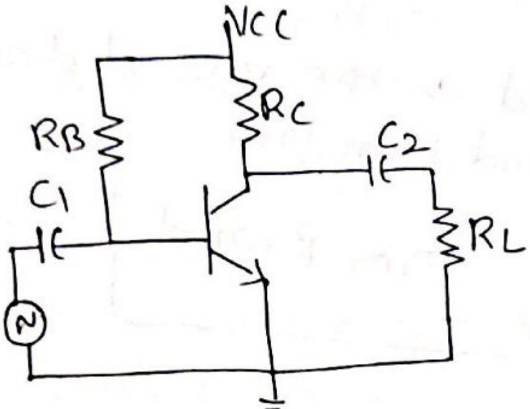
stability factor S''

The stability factor S'' is defined as ~~of~~ chorate of change of I_C w.r.t β keeping I_{CO}, u V_{BE} const.

$$S'' = \frac{dI_C}{d\beta} \quad \boxed{S'' = \frac{dI_C}{d\beta} \quad I_{CO}, V_{be} \text{ const}}$$

stabilization techniques or Biasing techniques or methods of transistor Biasing.

Fixed bias or Base Resistor method:



To measure the Q Point we have to go for dc Analysis. For DC Analysis apply only DC voltage only.

Steps to find Q Point.

1. AC (i/p signal) = zero.
2. Apply only DC signal.
   For DC $f=0$ $X_C = 1/2\pi fC$ $X_C = \frac{1}{0} = \infty$ $\boxed{X_C = \infty}$
3. capacitor opened.
4. $Q(V_{CE}, I_C)$

<u>To find I_C</u>:

a) apply KVL Eq. across i/p loop find I_B (at Base)

b) $I_C = \beta I_B$.

<u>To find VCE</u>:

Apply KVL Eq. across o/p loop (collector)

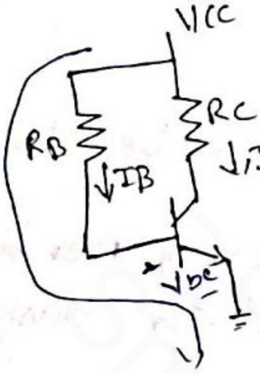
<u>Steps to find stability factor S</u>

1. write the formula $S = 1+\beta / 1-\beta \frac{dI_b}{dI_C}$
2. Apply KVL Eq. to i/p mesh.
3. Substitute or Put $I_E = I_C + I_b$; simplify the Expression.

4. Differentiate the Equation by using I_B w.r.t I_C so that dI_B/dI_C

5. Substitute $\frac{dI_B}{dI_C}$ in the $S = \frac{1+\beta}{1-\beta \frac{dI_b}{dI_C}}$

To find Qpoint.



To find IC

a) Apply KVL Equation across i/p loop.

$V_{CC} = I_B R_B + V_{be}$.

$V_{be} = 0.7$ Si
$= 0.2$ Ge. } so neglect.

$I_B = V_{CC}/R_B$.

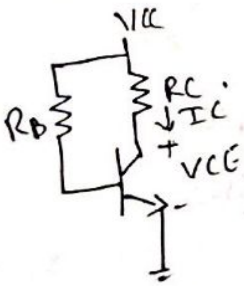
$V_{CC} = I_B R_B$.

b) $I_C = \beta I_B$

$$\boxed{I_C = \beta\left(\frac{V_{CC}}{R_B}\right)}$$

To find VCE

Apply KVL Eq. across O/P loop (collector)



$V_{CC} = I_C \cdot R_C + V_{CE}$

$V_{CE} = V_{CC} - I_C \cdot R_C$.

$$Q = (V_{CE}, I_C) = \left(V_{CC} - I_C R_C,\ \beta\left(\frac{V_{CC}}{R_B}\right)\right)$$

To find stability factors:

1. $S = 1+\beta / 1-\beta \frac{dI_b}{dI_C}$

2. Apply KVL Eq. to i/p loop.

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

differenciate w.r.t I_C

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

$$0 = \frac{dI_B}{dI_C} R_B + (0)$$

$$\frac{dI_B}{dI_C} = 0$$

substitute $\frac{dI_B}{dI_C} = 0$ in $S = 1+\beta / 1-\beta \frac{dI_B}{dI_C}$

$S = 1+\beta / 1-0 \Rightarrow \boxed{S = 1+\beta}$

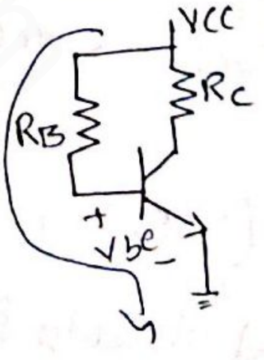
If S is smaller value of S better will be the thermal stability.

since β is a large quantity this is a very poor bias.

$\therefore$ in practice the circuit is not used for biasing the base.

To find S' steps

1. Apply KVL Eq. across i/p loop.
2. Put $I_E = I_C + I_B$.
3. Put $I_B = \frac{I_C - (1+\beta) I_{C0}}{\beta}$ $\because I_C = \beta I_B + (1+\beta) I_{C0}$
4. differenciate I_C with respect to V_{be}.



Apply KVL Eq across i/p loop;

$$V_{CC} = I_B \cdot R_B + V_{be}$$

Put $I_E = I_C + I_B$

3. Put $I_B = \frac{I_C - (1+\beta) I_{C0}}{\beta}$

$$V_{CC} = \left(\frac{I_C - (1+\beta) I_{C0}}{\beta}\right) R_B + V_{be}$$

$$Vcc = \frac{I_C}{R_B} - \frac{(1+\beta)}{\beta} I_{C0} R_B + V_{be}$$

differenciate above Eq. I_C w.r.t V_{be}.

$$0 = \frac{1}{\beta} R_B \cdot \frac{dI_C}{dV_{be}} - 0 + \frac{dV_{be}}{dV_{be}}$$

$$0 = \frac{R_B}{\beta} \frac{dI_C}{dV_{be}} + 1 \qquad \frac{dI_C}{dV_{be}} = -1/\frac{R_B}{\beta} = -\beta/R_B$$

$$\boxed{S' = -\beta/R_B}$$

Relationship b/n S & S'

$S = 1+\beta$

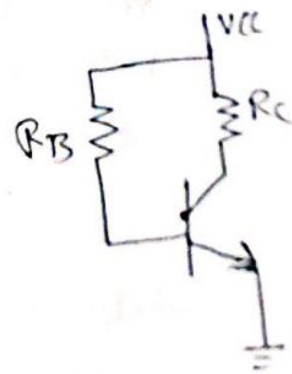
$S' = -\beta/R_B$ Add & sub 1

$$S' = \frac{-\beta+1-1}{R_B} = \frac{-(1+\beta)+1}{R_B} = \frac{-S+1}{R_B}$$

$$S' = \frac{-S+1}{R_B}.$$

To find S'' steps

1. Apply KVL Equation across i/p loop.
2. Put $I_E = I_C + I_B$
3. Put $I_B = \frac{I_C - (1+\beta)I_{C0}}{\beta}$
4. find I_C in terms of voltage
5. Differenciate I_C w.r.t to β.



$$Vcc = I_B R_B + V_{be}$$

$$Vcc = \left(\frac{I_C - (1+\beta)I_{C0}}{\beta}\right) R_B + V_{be}$$

$$Vcc = \frac{I_C}{\beta} - \frac{(1+\beta)}{\beta} I_{C0} \cdot R_B + V_{be} \qquad 1+\beta = \beta$$

$$Vcc = \frac{I_C}{\beta} - I_{C0} R_B + V_{be}$$

$$Vcc = \frac{I_C}{\beta} - V' + V_{be}$$

$$Vcc = \frac{Ic}{\beta} - V' + Vbe$$

$$Vcc \cdot \beta + V'\beta - Vbe \cdot \beta = Ic.$$

$$\boxed{Ic = \beta(Vcc + V' - Vbe)} \quad — (a)$$

$$\frac{dIc}{d\beta} = (Vcc + V' - Vbe)(1).$$

$$\frac{dIc}{d\beta} = Vcc + V' - Vbe$$

from above Eq. (a) $Ic = \beta(Vcc + V' - Vbe)$

$$\frac{dIc}{d\beta} = \frac{Ic}{\beta}. \Rightarrow \boxed{S'' = \frac{Ic}{\beta}} \quad \boxed{S'' = \frac{Ic}{\beta}}$$

$$S'' = \frac{Ic}{\beta}$$

Relation ship b/n S'' & S

$S = 1+\beta$

multiply & divide numarator & denominator by $1+\beta$;

$$S'' = \frac{Ic(1+\beta)}{\beta(1+\beta)} = \boxed{\frac{S \cdot Ic}{\beta(1+\beta)} = S''}$$

~~Emitt~~

→ smaller value of s better will be ~~the~~ thermal stability.

Minimum value of S is '1'

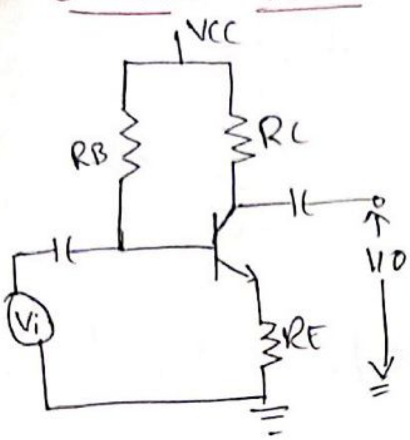
Maximum value of $S = 1+\beta$

If for Ideal Amp, $S=1$

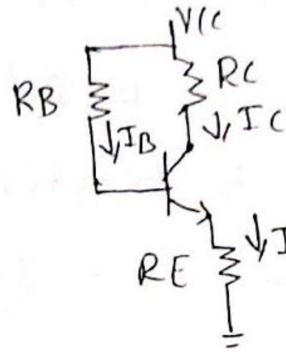
If $S < 1+\beta$ ckt is stable

$S = 1+\beta$ ckt is unstable.

Emitter - feedback bias



for Q Point cy DC Analysis



capacitors opened AC i/p = 0.

To find QPoint :

To find ~~IB~~ IC

Apply KVL Eoo. across i/p loop. to find IB

$$VCC = IBRB + Vbe + IE \cdot RE \qquad \because IE = Ic + IB$$

$$VCC = IBRB + Vbe + (Ic + IB) RE$$

$$VCC = IBRB + Vbe + ICRE + IBRE$$

$$IC = \beta IB$$

$$VCC = IBRB + Vbe + \beta \cdot IB RE + IBRE$$

$$VCC = IB(RB + \beta \cdot RE + RE) + 0.7 \cdot \text{ If } Si = 0.7V,\ Ge = 0.2V$$

$$\frac{VCC}{RB + \beta RE + RE} = IB$$

$$IB = \frac{VCC}{RB + RE(1+B)}$$

$$Ic = \beta IB$$

$$= \beta \left(\frac{VCC}{RB + RE(1+\beta)} \right)$$

To find VCE

Apply KVL Eoo. across o/p loop.

$$VCC = Ic \cdot Rc + VCE + IE \cdot RE$$

$$IE = IB + Ic$$

$$VCC = Ic Rc + VCE + IBRE + IcRE$$

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

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

$$V_{CC} = \beta I_B (R_C + R_E) + V_{CE} + I_B R_E$$

$$= I_B\left(\beta(R_C + R_E) + R_E\right) + V_{CE}$$

$$V_{CE} = V_{CC} - I_B\left(R_E(1+\beta) + \beta \cdot R_C\right).$$

$$Q = (V_{CE}, I_C)$$

$$\boxed{Q = \left(V_{CC} - I_B\left(R_E(1+\beta) + \beta R_C\right),\ \beta \cdot \frac{V_{CC}}{R_B + R_E(1+\beta)}\right).}$$

To find S

1. $\Rightarrow S = \dfrac{1+\beta}{1 - \beta \dfrac{dI_B}{dI_C}}$ V_{be}, β const.

Apply KVL eq. across i/p loop. & since I_B is there. we have to apply KVL eq. across i/p loop.

$$V_{CC} = I_B R_B + V_{be} + I_E \cdot R_E$$

$$I_E = I_C + I_B.$$

$$V_{CC} = I_B R_B + V_{be} + I_C \cdot R_E + I_B R_E$$

The eq. should be interms of I_B & I_C only.

differenciate w.r.t I_C

$$0 = \frac{dI_B}{dI_C} R_B + 0 + \frac{dI_C}{dI_C} R_E + \frac{dI_B}{dI_C} R_E$$

$$0 = \frac{dI_B}{dI_C}(R_B + R_E) + \frac{dI_C}{dI_C} R_E$$

$$0 = \frac{dI_B}{dI_C}(R_B + R_E) + R_E$$

$$\frac{dI_B}{dI_C} = -R_E / R_B + R_E$$

$$S = \frac{(1+\beta)}{1-\beta(-RE/RB+RE)}$$

$$S = \frac{(1+\beta)}{1+\beta(RE/RB+RE)}.$$

To find S'

$$S' = \frac{dIC}{dVbe} \quad ICo, \beta, \text{const}.$$

Vbe voltage across i/p loop, so apply kvl Equation across i/p loop.

$$VCC = IBRB + Vbe + IERE$$

$$IE = IC + IB$$

$$VCC = IBRB + Vbe + IC \cdot RE + IB \cdot RE$$

$$VCC = IB(RB+RE) + Vbe + IC \cdot RE$$

$S' = dIC/dVbe \rightarrow$ so in above Equation IC current only there ICO, B. should be there since ICO, B are const.

$$IC = IB\beta + (1+\beta)ICO.$$

$$IB = \frac{IC - (1+\beta)ICO}{\beta}$$

$$VCC = \left(\frac{IC - (1+\beta)ICO}{\beta}\right)(RB+RE) + Vbe + IC \cdot RE$$

$$VCC = \frac{IC}{\beta}(RB+RE) - \frac{(1+\beta)ICO(RB+RE)}{\beta} + Vbe + IC \cdot RE$$

differenciate above Eq. IC w.r.t Vbe ICO & B as const

$$0 = \left(\frac{RB+RE}{\beta}\right)\frac{dIC}{dVbe} - 0 + \frac{dVbe}{dVbe} + \frac{dIC}{dVbe}RE$$

$$0 = \frac{dIC}{dVbe}\left(\left(\frac{RB+RE}{\beta}\right) + RE\right) + 1$$

$$\frac{dIC}{dVbe} = -1 \Big/ \frac{(RB+RE) + \beta RE}{\beta}$$

$$\boxed{S' = -\beta / (RB+RE) + \beta RE}$$

Relationship b/n S and S'

$$S = 1+\beta / 1+\beta \left(\frac{RE}{RB+RE} \right) \Rightarrow S = \frac{(1+\beta)(RB+RE)}{(RB+RE)+\beta RE}$$

$$S' = \frac{-\beta+1-1}{(RB+RE)+\beta RE} = \frac{-(1+\beta)+1}{(RB+RE)+\beta RE}$$

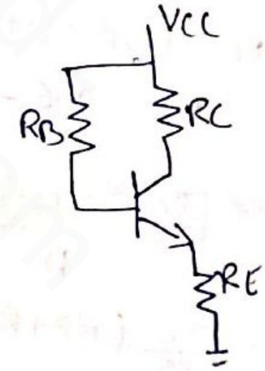
$$S' = -\frac{S}{(RB+RE)} + \frac{1}{(RB+RE)+\beta RE}$$

$$S' \cong = \frac{-S+1}{RB+RE}$$

To find S''

$$S'' = \frac{dIC}{d\beta} \quad ICo, Vbe \text{ const.}$$

Apply kvl eq. across i/p loop.



$VCC = IBRB + Vbe + IE\,RE$

$IE = IC + IB$

$VCC = IBRB + Vbe + ICRE + IBRE$

$VCC = IB(RB+RE) + Vbe + IC \cdot RE$

$$IB = \frac{IC - (1+\beta)ICO}{\beta}$$

$$VCC = \left(\frac{IC - (1+\beta)ICO}{\beta} \right)(RB+RE) + Vbe + IC \cdot RE$$

$$VCC = \left(\frac{IC}{\beta} - \frac{(1+\beta)}{\beta} ICO \right)(RB+RE) + Vbe + ICRE$$

$$V_{CC} = \frac{I_C}{\beta}(R_B+R_E) - \frac{(1+\beta)}{\beta} I_{CO}(R_B+R_E) + V_{be} + I_C R_E$$

$$1+\beta \simeq \beta.$$

$$V_{CC} = \frac{I_C}{\beta}(R_B+R_E) - \frac{\beta}{\beta} I_{CO}(R_B+R_E) + V_{be} + I_C R_E$$

$$V_{CC} = \frac{I_C}{\beta}(R_B+R_E) - I_{CO}(R_B+R_E) + V_{be} + I_C R_E$$

$$I_{CO}(R_B+R_E) = V'$$

$$V_{CC} = \frac{I_C}{\beta}(R_B+R_E) - V' + V_{be} + I_C R_E$$

$$V_{CC} = \frac{I_C}{\beta}(R_B+R_E) + I_C R_E - V' + V_{be}$$

$$V_{CC} = I_C\left(\frac{R_B+R_E}{\beta} + R_E\right) - V' + V_{be}$$

$$V_{CC} = I_C\left(\frac{R_B+R_E+\beta \cdot R_E}{\beta}\right) - V' + V_{be}$$

$$I_C = \frac{V_{CC} + V' - V_{be}}{\left(\frac{R_B+R_E+\beta \cdot R_E}{\beta}\right)} \quad \text{— (1)} \qquad d\left(\frac{u}{v}\right) = \frac{v u' - u \cdot v'}{v^2}$$

$$I_C = (V_{CC} + V' - V_{be}) \times \frac{\beta}{(R_B+R_E+\beta R_E)}$$

differenuate above Ecouation I_C w.r.t β. I_{CO}, V_{be} const

$$\frac{dI_C}{d\beta} = (V_{CC} + V' - V_{be})\left[\frac{R_B+R_E+\beta R_E(1) - \beta(0+0+R_E(1))}{(R_B+R_E+\beta R_E)^2}\right]$$

$$\frac{dI_C}{d\beta} = (V_{CC} + V' - V_{be})\,\frac{R_B+R_E+\cancel{\beta R_E} - \cancel{\beta R_E}}{(R_B+R_E+\beta \cdot R_E)^2}$$

$$\frac{dI_C}{d\beta} = (V_{CC} + V' - V_{be}) \cdot \frac{R_B+R_E}{(R_B+R_E+\beta \cdot R_E)^2}$$

From above Eqn ① I_C as

$$I_C = \frac{(V_{CC} + V' - V_{be})\,\beta}{(R_B + R_E + \beta R_E)}$$

$$S'' = \frac{(V_{CC} + V' - V_{be})}{(R_B + R_E + \beta R_E)} \cdot \frac{(R_B + R_E)}{(R_B + R_E + \beta R_E)}$$

$$= \left(\frac{I_C}{\beta}\right) \cdot \frac{R_B + R_E}{(R_B + R_E + \beta R_E)}$$

$$\boxed{S'' = \left(\frac{I_C}{\beta}\right) \frac{(R_B + R_E)}{R_B + R_E(1+\beta)}} \quad \text{— ②}$$

Relationship b/n S & S''

$$S'' = \left(\frac{I_C}{\beta}\right) \frac{R_B + R_E}{R_B + R_E(1+\beta)}$$

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

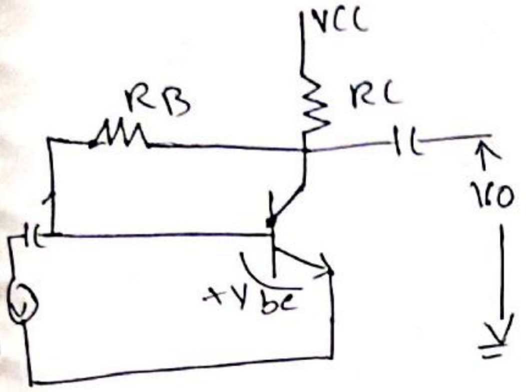
$$\frac{R_E + R_E}{R_B + R_E(1+\beta)} = \left(S/1+\beta\right) \quad \text{— ③}$$

S'' sub ③ in ②

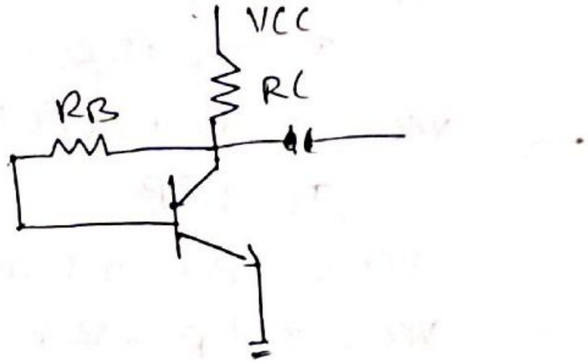
$$S'' = \left(\frac{I_C}{\beta}\right)\left(\frac{S}{1+\beta}\right)$$

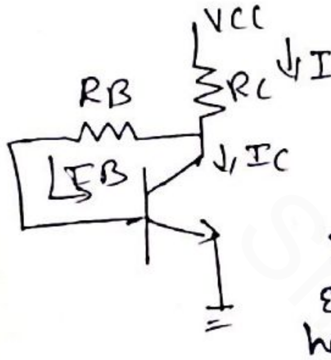
$$\boxed{S'' = \frac{S I_C}{\beta(1+\beta)}}$$

collector to Base Bais or collector feedback bias.



For Q Point w/ for DC analysis capacitors opened w/ AC i/p = 0.

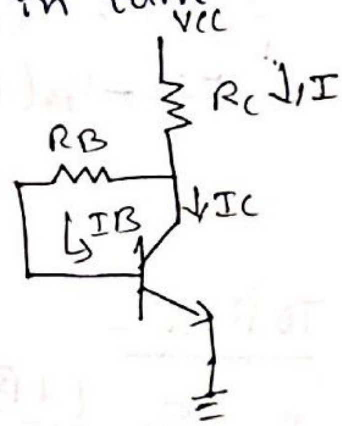




$I_C + I_B = I.$

If collector current I_C tends to increase due to either increase in temparature or transistor has been replaced by anyone Bhigher value, the voltage drop across R_C increases decreses V_{CE} w/ I_B decreases which in turn compensates I_C.

To find Q Point



To find IB (I_C)

Apply KVL Equation across i/p

$V_{CC} = I \cdot R_C + I_B R_B$

$I = I_C + I_B$

from collector I_B current is taken as feedback thats why cht is known as collector feed back bias.

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

$V_{CC} = I_C \cdot R_C + I_B \cdot R_C + I_B R_B$

$I_C = \beta I_B$

$V_{CC} = \beta I_B R_C + I_B R_C + I_B R_B$

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

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

$I_C = \beta I_B$

$I_C = \beta \times V_{CC} / R_C(1+\beta) + R_E$

To find V_{CE}

Apply KVL Eq. across o/p loop;

$V_{CC} = I \cdot R_C + V_{CE}$

$I = I_B + I_C$

$V_{CC} = I_B \cdot R_C + I_C R_C + V_{CE}$

$I_C = \beta I_B$

$V_{CC} = I_B R_C + \beta I_B R_C + V_{CE}$

$V_{CC} = I_B(R_C + \beta \cdot R_C) + V_{CE}$

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

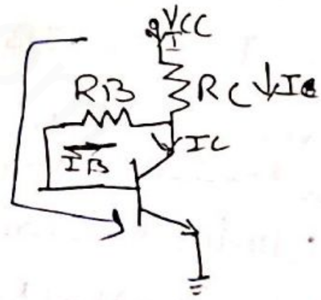
$V_{CE} = V_{CC} - I_B(R_C(1+\beta))$.

Q Point (V_{CE}, I_C)

$\left(V_{CC} - I_B(R_C(1+\beta)), \dfrac{V_{CC} \cdot \beta}{R_C(1+\beta)+R_E} \right)$.

To find S

$S = \dfrac{1+\beta}{1-\beta \dfrac{dI_B}{dI_C}}$



Apply KVL equation across i/p loop:

$V_{CC} = I \cdot R_C + I_B R_B + V_{be}$

$I = I_B + I_C$

$V_{CC} = I_B R_C + I_C R_C + I_B R_B + V_{be}$

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

differenciate above Eq. I_B w.r.t I_C

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

$$0 = \frac{dI_B}{dI_C}(R_C+R_B) + \frac{dI_C}{dI_C}R_C + 0.$$

$$= \frac{dI_B}{dI_C}(R_C+R_B) + (1)\cdot R_C.$$

$$\frac{dI_B}{dI_C} = -R_C/R_C+R_B.$$

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

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

$$= \frac{1+\beta(R_C+R_B)}{R_C+R_B+\beta\cdot R_C} = \frac{(1+\beta)(R_C+R_B)}{R_B+R_C(1+\beta)}$$

$$S = \frac{(1+\beta)(R_C+R_B)}{R_B+R_C(1+\beta)}.$$

<u>To find S'</u>

$$S' = \frac{dI_C}{dV_{be}}.$$

Apply KVL equation across i/p loop;

$$V_{CC} = IR_C + I_B R_B + V_{be}$$

$$I = I_B + I_C$$

$$V_{CC} = I_B R_C + I_C R_C + I_B R_B + V_{be}$$

$$V_{CC} = I_B(R_C+R_B) + I_C\cdot R_C + V_{be}$$

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

$$VCC = I_B(R_C + R_B) + I_C R_C + V_{be}$$

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

$$VCC = \left(\frac{I_C - (1+\beta)I_{CO}}{\beta}\right)(R_C + R_B) + I_C \cdot R_C + V_{be}$$

$$VCC = \frac{I_C}{\beta}(R_C+R_B) - \left(\frac{1+\beta}{\beta}\right)I_{CO}(R_C+R_B) + I_C \cdot R_C + V_{be}$$

differenciate above Eqvation I_C w.r.t V_{be} & β, I_{CO} const

$$0 = \frac{(R_C + R_B)}{\beta}\frac{dI_C}{dV_{be}} - 0 + \frac{dI_C}{dV_{be}}R_C + \frac{dV_{be}}{dV_{be}}$$

$$= \left(\frac{R_C+R_B}{\beta}\right) \cdot \frac{dI_C}{dV_{be}} + \frac{dI_C}{dV_{be}}R_C + 1$$

$$\Rightarrow \frac{dI_C}{dV_{be}}\left(\left(\frac{R_C+R_B}{\beta}\right) + R_C\right) = -1$$

$$\frac{dI_C}{dV_{be}} = -1 \Big/ \left(\left(\frac{R_C+R_B}{\beta}\right) + R_C\right)$$

$$S' = -1 \Big/ \frac{(R_C+R_B)}{\beta} + R_C$$

Relationship b/n S & S'

$$S = \frac{1+\beta}{1 - \beta\frac{dI_B}{dI_C}} = \frac{1+\beta(R_C+R_B)}{R_B + R_C(1+\beta)} \simeq \frac{\beta(R_C+R_B)}{R_B+R_C(1+\beta)}$$

$$S' = \frac{-\beta}{R_B + R_C(1+\beta)} = \frac{-S}{(R_C+R_B)}$$

$$S' = \frac{-S}{(R_C+R_B)}$$

To find S''

Apply KVL Eq. across i/p loop;

$$V_{CC} = I R_C + I_B R_B + V_{be}.$$

$$I = I_C + I_B$$

$$V_{CC} = I R_C + I_B R_B + V_{be}$$

$$V_{CC} = I_C R_C + I_B R_C + I_B R_B + V_{be}$$

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

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

$$= \left(\frac{I_C - (1+\beta) I_{CO}}{\beta}\right)(R_C + R_B) + I_C R_C + V_{be}$$

$$V_{CC} = \frac{I_C}{\beta}(R_C + R_B) - \left(\frac{1+\beta}{\beta}\right) I_{CO} (R_C + R_B) + I_C R_C + V_{be}.$$

$$\left(\frac{1+\beta}{\beta}\right) = 1 \quad \because 1+\beta = \beta$$

$$V_{CC} = \frac{I_C}{\beta}(R_C + R_B) - I_{CO}(R_C + R_B) + I_C R_C + V_{be}$$

$$I_{CO}(R_C + R_B) = V'$$

$$V_{CC} = \frac{I_C}{\beta}(R_C + R_B) - V' + I_C \cdot R_C + V_{be}$$

$$V_{CC} = I_C \left(\frac{R_C + R_B}{\beta} + R_C\right) - V' + V_{be}$$

$$I_C = \frac{V_{CC} + V' - V_{be}}{\frac{R_C + R_B + \beta R_C}{\beta}} = \frac{\beta (V_{CC} + V' - V_{be})}{R_B + R_C(1+\beta)}$$

$$I_C = \beta \left(\frac{V_{CC} + V' - V_{be}}{R_B + R_C(1+\beta)}\right)$$

$$I_C = \beta \frac{(V_{CC} + V' - V_{be})}{(R_B + R_C(1+\beta))} = (V_{CC} + V' - V_{be}) \cdot \frac{\beta}{R_B + R_C(1+\beta)}$$

differenciate above equation I_C w.r.t to β & I_{CO} & V_{be} const

$$\frac{dI_C}{d\beta} = (V_{CC} + V' - V_{be}) \cdot \frac{[R_B + R_C(1+\beta)(1) - \beta(0 + R_C(1))]}{[R_B + R_C(1+\beta)]^2}$$

$$= (V_{CC} + V' - V_{be}) \cdot \frac{R_B + R_C(1+\beta) - \beta R_C}{(R_B + R_C(1+\beta))^2}$$

$$= (V_{CC} + V' - V_{be}) \cdot \frac{R_B + R_C + \beta \cancel{R_C} - \beta \cancel{R_C}}{[R_B + R_C(1+\beta)]^2}$$

$$= (V_{CC} + V' - V_{be}) \frac{R_B + R_C}{[R_B + R_C(1+\beta)]^2}$$

$$S'' = \frac{V_{CC} + V' - V_{be}}{R_B + R_C(1+\beta)} \cdot \frac{(R_B + R_C)}{R_B + R_C(1+\beta)}$$

~~Relati~~

$$S'' = \frac{I_C}{\beta} \cdot \frac{(R_C + R_B)}{R_B + R_C(1+\beta)}$$

$$\boxed{S'' = \frac{I_C(R_C + R_B)}{\beta(R_B + R_C(1+\beta))}}$$

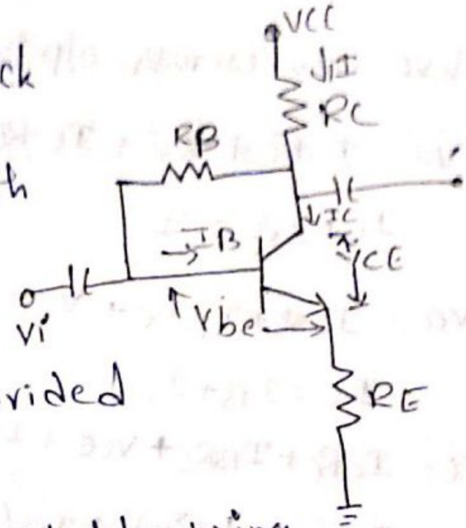
Relation ship b/n S & S''

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

$$S'' = \left(\frac{I_C}{\beta}\right)\left(\frac{S}{1+\beta}\right)$$

collector-Emitter feedback Bias.

The collector Emitter feedback bias circuit that can be obtained by applying both the collector-feedback and Emitter feedback.



The collector feedback Provided by using RB.

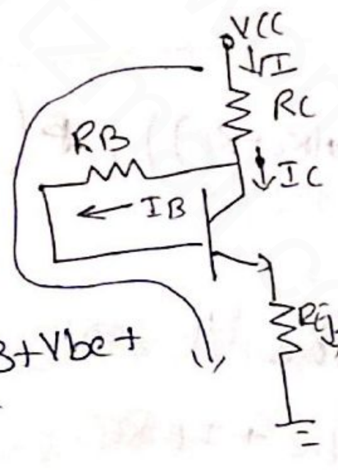
The Emitter feedback Provided by using RE.

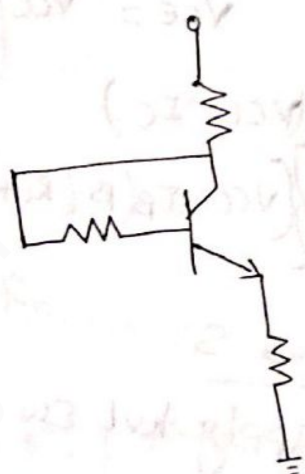
Both feedbacks are used to control the collector current I_C and the base current I_B in opposite directions so stability factor is increased.

To find Q Point

To find IB

Apply KVL eq. across i/p loop.





$V_{CC} = I R_C + I_B R_B + V_{be} + I_E R_E$

$I = I_B + I_C$

$I_E = I_B + I_C$

$V_{CC} = I_B R_C + I_C R_C + I_B R_B + V_{be} + I_B R_E + I_C R_E$

$= I_B(R_C + R_B) + I_C(R_C + R_E) + V_{be}$

$I_C = \beta I_B$

$V_{CC} = I_B(R_C + R_B) + \beta I_B(R_C + R_E) + V_{be}$

$V_{CC} = I_B\left((R_C + R_B) + \beta(R_C + R_E)\right) + V_{be}$

$I_B = \dfrac{V_{CC} - V_{be}}{(R_C + R_B) + \beta(R_C + R_E)}$ $\quad I_C = \beta I_B$

To find VCE

Apply kvl Eq. across o/p loop;

$$VCC = I \cdot RC + VCE + IE \cdot RE$$

$$IC + IB = I$$

$$VCC = IC RC + IB RC + VCE + IE RE$$

$$IE = IB + IC$$

$$VCC = IC RC + IB RC + VCE + IB \cdot RE + IC RE$$

$$VCC = IC(RC + RE) + IB(RC + RE) + VCE$$

$$IC = \beta IB.$$

$$VCC = \beta IB(RC + RE) + IB(RC + RE) + VCE$$

$$VCC = IB(\beta(RC + RE) + (RC + RE)) + VCE$$

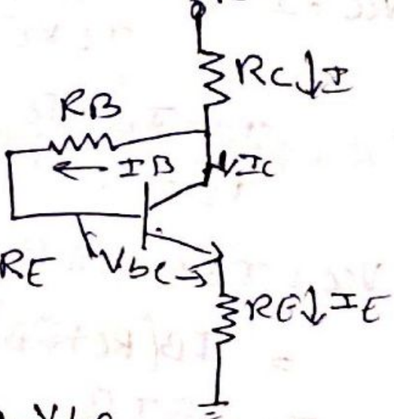
$$VCE = VCC - IB(\beta(RC + RE) + (RC + RE))$$

$$Q = (VCE, IC)$$

$$= \left\{ (VCC - IB(\beta(RC + RE) + (RC + RE))), \ \beta\left(\frac{VCC - Vbe}{(RC + RB) + \beta(RC + RE)}\right) \right\}$$

To find S

Apply kvL Eq. across i/p loop;



$$VCC = IRC + IB RB + Vbe + IE RE$$

$$I = IB + IC$$

$$IE = IB + IC$$

$$VCC = IB RC + IC RC + IB RB + Vbe + IB RE + IC RE$$

$$VCC = IB(RC + RB + RE) + IC(RC + RE) + Vbe$$

$$VCC = IB(RC + RB + RE) + IC(RC + RE) + Vbe$$

$$V_{CC} = I_B(R_C + R_B + R_E) + I_C(R_C + R_E) + V_{be}$$

differenciate above Eq I_B w.r.t. I_C.

$$0 = \frac{\partial I_B}{\partial I_C}(R_C + R_B + R_E) + \frac{\partial I_C}{\partial I_C}(R_C + R_E) + 0$$

$$= \frac{\partial I_B}{\partial I_C}(R_C + R_B + R_E) + (R_C + R_E)$$

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

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

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

To find S'

Apply KVL Eq. across i/p loop ;

$$V_{CC} = I \cdot R_C + I_B R_B + V_{be} + I_E \cdot R_E$$

$$I = I_B + I_C \quad I_E = I_B + I_C$$

$$V_{CC} = I_B(R_C + R_B + R_E) + I_C(R_C + R_E) + V_{be}$$

differenciate above Equation I_C w.r.t V_{be}. β, I_{10} const

so $I_B = \frac{I_C - (1+\beta)I_{10}}{\beta}$

$$V_{CC} = \frac{I_C - (1+\beta)I_{10}}{\beta}(R_C + R_B + R_E) + I_C(R_C + R_E) + V_{be}$$

$$V_{CC} = \frac{I_C}{\beta}(R_C + R_B + R_E) - \frac{(1+\beta)}{\beta} I_{10}(R_C + R_B + R_E) + I_C(R_C + R_E) + V_{be}.$$

differenciate above EQ: IC w.r.t. Vbe

$$0 = \left(\frac{R_C+R_B+R_E}{\beta}\right)\frac{dI_C}{dV_{be}} + 0 + \frac{dI_C}{dV_{be}}(R_C+R_E) + \frac{dV_{be}}{dV_{be}}$$

$$0 = \frac{dI_C}{dV_{be}}\left(\left(\frac{R_C+R_B+R_E}{\beta}\right) + (R_C+R_E)\right) + 1$$

$$\frac{dI_C}{dV_{be}} = -1 \Big/ \left(\frac{R_C+R_B+R_E}{\beta}\right) + (R_C+R_E)$$

$$S' = \frac{-\beta}{(R_C+R_B+R_E) + \beta(R_C+R_E)}$$

$$S' = -\beta \Big/ R_C(1+\beta) + R_E(1+\beta) + R_B$$

$$\boxed{S' = -\beta \Big/ R_C(1+\beta) + R_E(1+\beta) + R_B}$$

To find S''

Apply KVL equation across i/p loop

$$V_{CC} = I \cdot R_C + I_B \cdot R_B + V_{be} + I_E \cdot R_E$$

$$I = I_B + I_C$$

$$I_E = I_B + I_C$$

$$V_{CC} = I_B(R_C+R_B+R_E) + I_C(R_C+R_E) + V_{be}$$

$$I_B = \frac{I_C - (1+\beta)I_{C0}}{\beta} \qquad R_T = R_C + R_B + R_E$$

$$V_{CC} = \left(\frac{I_C - (1+\beta)I_{C0}}{\beta}\right)R_T + I_C(R_C+R_E) + V_{be}$$

$$V_{CC} = \left(\frac{I_C - (1+\beta)I_{C0}}{\beta}\right)(R_C+R_B+R_E) + I_C(R_C+R_E) + V_{be}$$

$$V_{CC} = \frac{I_C}{\beta}(R_C+R_B+R_E) - \left(\frac{1+\beta}{\beta}\right) I_{CO}(R_C+R_B+R_E) + I_C(R_C+R_E) + V_{be}$$

$$(1+\beta) \simeq \beta.$$

$$V_{CC} = \frac{I_C}{\beta}(R_C+R_B+R_E) - I_{CO}(R_B+R_C+R_E) + I_C(R_C+R_E) + V_{be}$$

$$S'' = \frac{dI_C}{d\beta} \qquad I_{CO}(R_B+R_C+R_E) = V'$$

$$V_{CC} = \frac{I_C}{\beta}(R_C+R_B+R_E) - V' + I_C(R_C+R_E) + V_{be}$$

$$V_{CC} = I_C\left(\frac{R_C+R_B+R_E}{\beta} + (R_C+R_E)\right) + V_{be} - V'$$

$$V_{CC} = I_C\left(\frac{R_C+R_E+R_B+\beta(R_C+R_E)}{\beta}\right) + V_{be} - V' \quad \text{--- (1)}$$

$$I_C = (V_{CC} - V_{be} + V') \times \frac{\beta}{(R_C+R_E+R_B)+\beta(R_C+R_E)}$$

$$\frac{dI_C}{d\beta} = (V_{CC} - V_{be} + V') \cdot \frac{(R_C+R_E+R_B)+\beta(R_C+R_E)(1) - \beta(R_C+R_E)}{[(R_C+R_E+R_B)+\beta(R_C+R_E)]^2}$$

$$= (V_{CC} - V_{be} + V') \frac{(R_C+R_E+R_B)}{[(R_C+R_E+R_B)+\beta(R_C+R_E)]^2}$$

$$= \frac{(V_{CC} - V_{be} + V')}{(R_C+R_E+R_B)+\beta(R_C+R_E)} \times \frac{\cancel{\beta}(R_C+R_E+R_B)}{[(R_C+R_E+R_B)+\beta(R_C+R_E)]}$$

$$= \frac{(V_{CC} - V_{be} + V')}{(R_C+R_E+R_B)+\beta(R_C+R_E)} \times \frac{R_C+R_E+R_B}{(R_C+R_E+R_B)+\beta(R_C+R_E)}$$

from (1)

$$S'' = \frac{I_C}{\beta} \cdot \frac{(R_C+R_E+R_B)}{(R_C+R_E+R_B)+\beta(R_C+R_E)}$$

$$S'' = \frac{I_C}{\beta}\left(\frac{R_C+R_E+R_B}{R_C+R_E+R_B+\beta(R_C+R_E)}\right)$$

Relationship b/n S & S''

$$S = \frac{(1+\beta)(R_C+R_B+R_E)}{(R_C+R_B+R_E)+\beta(R_C+R_E)}$$

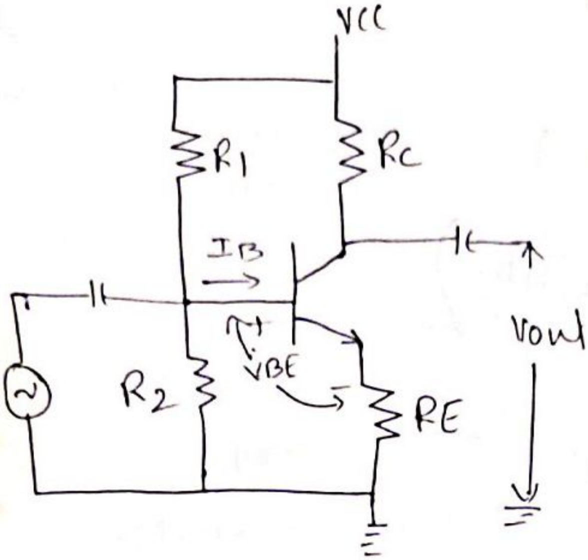
$$\therefore S'' = \frac{I_C}{\beta}\left(\frac{S}{1+\beta}\right)$$

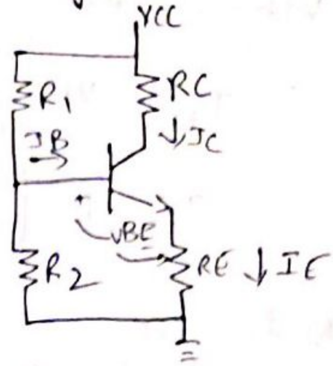
Voltage divider bias, self bias, or Emitter bias.

The self bias also called as Emitter bias or Emitter resistor and potential divider circuit that can be used for low collector resistance as shown in fig. The current in the Emitter resistor R_E causes a voltage drop which is in the direction to reverse bias the Emitter junction. For the transistor to remain in the active region, the base Emitter junction has to be forward biased. The required base bias is obtained from the power supply through the potential divider network of the resistance R_1 & R_2

If I_C tends to increase say due to increase in I_{CO} with temperature, the current in R_E increases. Hence the voltage drop across R_E increases there by decreasing the base current As a result I_C is maintained almost constant.

for operating point or dc Analysis





By applying Thenvenins Theorem to the circuit.

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

$$V_{th} = \frac{V_{CC} \cdot R_2}{R_1 + R_2}$$

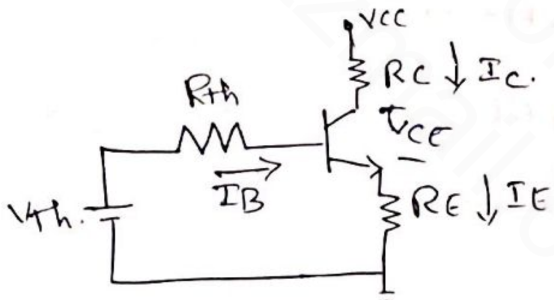
$V = IR$

$I = \frac{V_{CC}}{R_1}$

$V_{Th} = I \cdot R_{th}$

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

$V_{th} = \frac{V_{CC} \cdot R_2}{R_1 + R_2}$



<u>find Q Point</u>

$V_{th} = I_B \cdot R_{th} + V_{be} + I_E R_E$

$I_E = I_C + I_B$

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

$V_{th} = I_B R_{th} + V_{be} + I_C \cdot R_E + I_B \cdot R_E$

$V_{th} = I_B R_{th} + V_{be} + I_C R_E + I_B R_E$

$I_C = \beta \cdot I_B$

$V_{th} = I_B R_{th} + V_{be} + \beta I_B R_E + I_B R_E$

$V_{th} = I_B \cdot R_{th} + V_{be} + \beta I_B R_E + I_B R_E$

$V_{th} = I_B(R_{th} + \beta \cdot R_E + R_E)$

$I_B = V_{th} / (R_{th} + \beta \cdot R_E + R_E)$

$I_C = \beta \cdot \left(V_{th} / R_{th} + R_E(1+\beta) \right)$

To find V_{CE}

Apply KVL eq. from o/p loop.

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

$I_E = I_B + I_C$

$\cancel{I_C = \beta I_B}$

$\cancel{V_{CC} = \beta I_B + V_{CE} + I_B R_E} + I_C R_E$

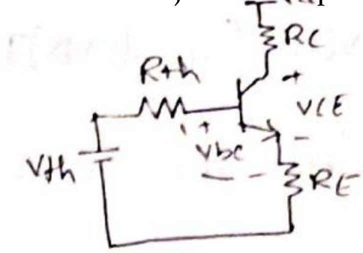
$\cancel{= I_B(\beta R_E + R_E + \beta R}$

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

$V_{CC} = I_C R_E + V_{CE} + I_B R_E + I_C R_E$

$= I_C (2R_E) + I_B R_E + V_{CE}$

$V_{CE} = V_{CC} - I_C (2R_E) + I_B \cdot R_E$



To find S

$$S = \frac{1+\beta}{1-\beta\frac{dI_B}{dI_C}}$$

Apply kvl Eq. across i/p loop.

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

$$I_E = I_C + I_B$$

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

differenciate above Eq. w.r.t I_C

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

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

$$\frac{dI_B}{dI_C} = \left(-R_E / R_{th} + R_E\right)$$

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

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

To find S' , $S' = \frac{dI_C}{dV_{be}}$.

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

$$I_E = I_C + I_B$$

$$V_{th} = I_B R_{th} + V_{be} + I_C R_E + I_B \cdot R_E$$

$$I_B = \frac{I_C - (1+\beta) I_{10}}{\beta}.$$

$$V_{th} = \left(\frac{I_C - (1+\beta) I_{10}}{\beta}\right)(R_{th} + R_E) + V_{be} + I_C R_E$$

$$V_{th} = \left(\frac{I_C - (1+\beta) I_{10}}{\beta}\right)(R_{th} + R_E) + V_{be} + I_C \cdot R_E$$

$\beta V_{th} = \left(I_C - (1+\beta)I_{CO}\right)(R_{th}+R_E) + \beta V_{be} + \beta I_C \cdot R_E$

diff. eqn. I_C w.r.t V_{be}, I_{CO} & β as const

$$0 = \frac{dI_C}{dV_{be}}(R_{th}+R_E) + 0 + \beta\frac{dV_{be}}{dV_{be}} + \beta \cdot R_E \frac{dI_C}{dV_{be}}$$

$$= \frac{dI_C}{dV_{be}}(R_{th}+R_E) + \beta \cdot + \beta \cdot R_E \frac{dI_C}{dV_{be}}$$

$$0 \Rightarrow \frac{dI_C}{dV_{be}}(R_{th}+R_E+\beta R_E) + \beta$$

$$\frac{dI_C}{dV_{be}} = -\beta / R_{th}+R_E+\beta R_E$$

$$\boxed{S' = -\beta / R_{th}+R_E+\beta \cdot R_E} \qquad S' = -\beta / R_{th}+R_E(1+\beta)$$

Relationship S & S'

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

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

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

$$S' = -\beta / R_{th}+R_E(1+\beta)$$

$$S' = (-\beta) \cdot \frac{S}{(1+\beta)(R_{th}+R_E)} \qquad S' = \frac{-\beta S}{(1+\beta)(R_{th}+R_E)}$$

To find S'' $\frac{\partial I_C}{\partial \beta}$ I_{10}, V_{be} const

Apply KVL eq across i/p loop:

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

$$I_E = I_C + I_B$$

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

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

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

$$I_B = \frac{I_C - (1+\beta) I_{10}}{\beta}$$

$$V_{th} = \left(\frac{I_C - (1+\beta) I_{10}}{\beta}\right)(R_{th} + R_E) + V_{BE} + I_C R_E$$

$$V_{th} = \frac{I_C}{\beta}(R_{th} + R_E) - \frac{(1+\beta)}{\beta} I_{10} (R_{th} + R_E) + V_{BE} + I_C R_E$$

$$V_{th} = I_C \left[\frac{R_{th} + R_E}{\beta} + R_E\right] - \left(\frac{1+\beta}{\beta}\right) I_{10} (R_{th} + R_E) + V_{be}$$

$$V_{th} = I_C \left(\frac{R_{th} + R_E + \beta R_E}{\beta}\right) - \left(\frac{1+\beta}{\beta}\right) I_{10} (R_{th} + R_E) + V_{be}$$

$$(1+\beta) = \beta.$$

$$V_{th} = I_C \left[\frac{R_{th} + R_E + \beta (R_E)}{\beta}\right] - I_{10} (R_{th} + R_E) + V_{be}$$

$$I_{10} (R_{th} + R_E) = V'$$

$$V_{th} = I_C \left(\frac{R_{th} + R_E(1+\beta)}{\beta}\right) - V' + V_{be}$$

$$\beta V_{th} = I_C (R_{th} + R_E(1+\beta)) - \beta V' + \beta V_{be}$$

$$I_C = \frac{V_{th} - V_{be} + V'}{R_{th} + R_E(1+\beta)} \times \beta.$$

$$I_C = \frac{\beta\left(V_{th} - V_{be} + V'\right)}{R_{th} + R_E(1+\beta)} = [V_{th} + V' - V_{be}] \times \frac{\beta}{R_{th} + R_E(1+\beta)}$$

$$\frac{dI_C}{d\beta} = [V_{th} + V' - V_{be}] \cdot \frac{[R_{th} + R_E(1+\beta)] - \beta[R_E]}{[R_{th} + R_E(1+\beta)]^2}$$

$$\frac{dI_C}{d\beta} = [V_{th} + V' - V_{be}] \cdot \frac{R_{th} + R_E(1) + \cancel{\beta R_E} - \cancel{\beta R_E}}{[R_{th} + R_E(1+\beta)]^2}$$

$$\frac{dI_C}{d\beta} = (V_{th} + V' - V_{be}) \cdot \frac{R_{th} + R_E}{[R_{th} + R_E(1+\beta)]^2}$$

$$\frac{dI_C}{d\beta} = \frac{V_{th} + V' - V_{be}}{R_{th} + R_E(1+\beta} \times \frac{R_{th} + R_E}{(R_{th} + R_E(1+\beta)}$$

$$S'' = \frac{I_C}{\beta} \frac{R_{th} + R_E}{R_{th} + R_E(1+\beta)}$$

Relationship b/n S and S''

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

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

$$S'' = \frac{I_C}{\beta} \cdot \frac{S}{(1+\beta)} \qquad S'' = \frac{S \cdot I_C}{\beta(1+\beta)}$$

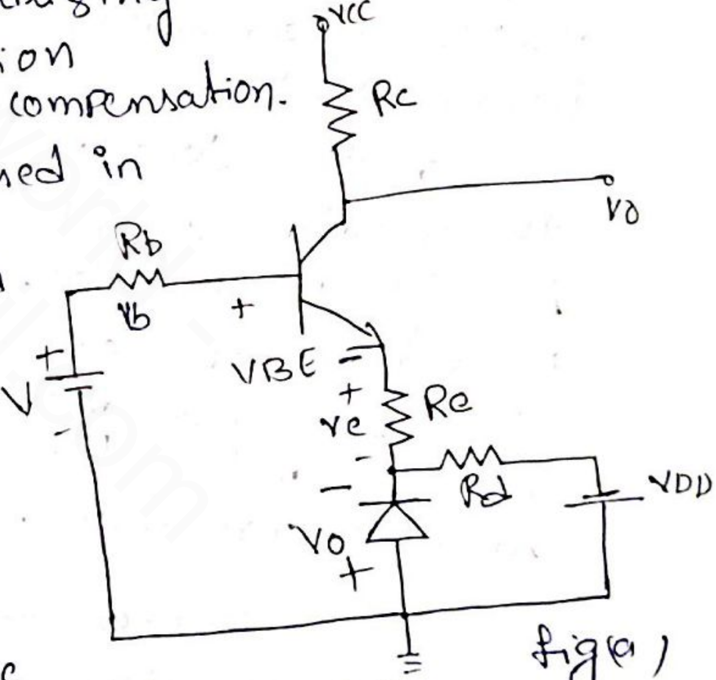
Bias compensation using Diodes:

The Bias circuit are used to limit the variation in the operating collector current I_C caused by variations in I_{CO}, V_{BE} & β. The circuits are examples of feedback Amplifier. In feedback Amplifier the gain is reduce drastically the amplification of signal.

Diode compensation
- Diode compensation for VBE (since IC depends on VBE)
- Diode compensation for I_{CO}.

Diode compensation for VBE:

In fig(a) circuit utilizing the self bias stabilization technique with diode compensation. The Diode is kept biased in the forward direction by the source V_{DD} and resistance Rd.



fig(a)

The diode is of same material as transistor. So that the voltage V_o across the diode will have same temperature coefficient (-2.5 mV/C) as the Base to Emitter voltage, VBE.

$V_{BE} \simeq V_o$ for temperature variations

i.e -2.5 mV/°C.

Apply KVL Eq. across base then

$$V = V_b + V_{BE} + V_e - V_o$$

$V = V_b + V_{BE} + V_C - V_0$.

V = const V_b = does not changes with temp.

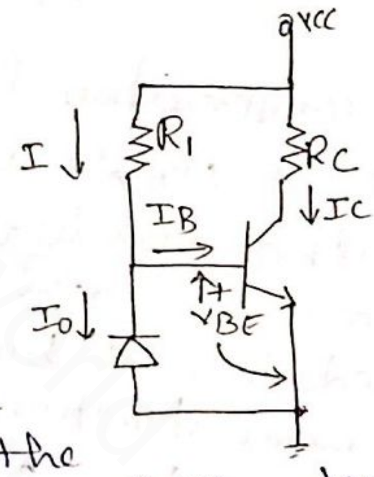
V = doesnot changes with temp.

V_C = " " " "

V_{BE} & V_0 changes with temparature (ie $-2.5mV/°C$) & both are in opposite polarities so then the changes in voltage due to temparature will be nullified.

Diode compensation for I_{CO}:

The stabilization against variations in I_{CO}, and is therefore useful for stabilizing germanium transistors.



If the diode & the transistor are of the same type and material, the Reverse saturation current I_0 of the ~~diode~~ diode will increase with temparature at the same rate as the transistor collector reverse saturation current I_{CO}.

$$I = I_B + I_0 \quad \text{— from figure} \quad —①$$

$$I_C = \beta I_B + (1+\beta) I_{CO}. \quad —②$$

from ① $I_B = I - I_0$.

Substitute in ②

$$I_C = \beta I - \beta I_0 + (1+\beta) I_{CO}.$$

$$I_C = \beta I - \beta I_0 + I_{CO} + \beta I_{CO}.$$

$$(\beta+1) \simeq \beta.$$

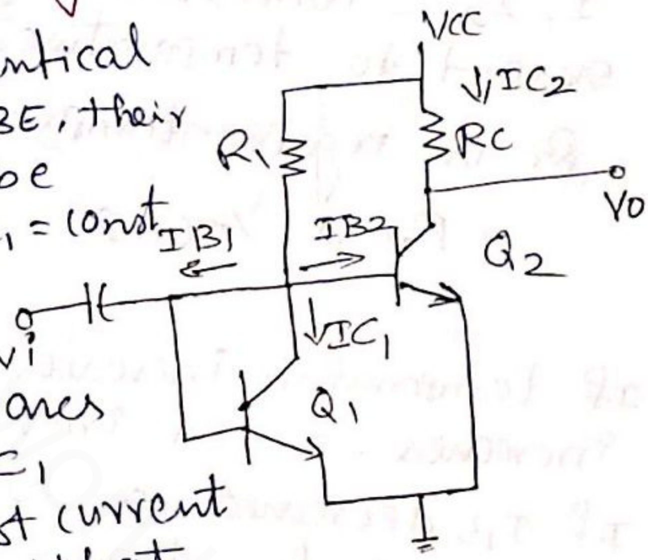
$I_C = \beta I - \beta I_0 + \beta I_{C0}$

If diode & transistor are of same type of material then $I_0 \cong I_{C0}$, then

$I_C = \beta I$

so that I_C remains constant even temparature changes.

Bias compensation using transistor.



If Q_1 & Q_2 are Identical and have the same VBE, their collector currents will be equal. hence $IC_2 = IC_1 = const$

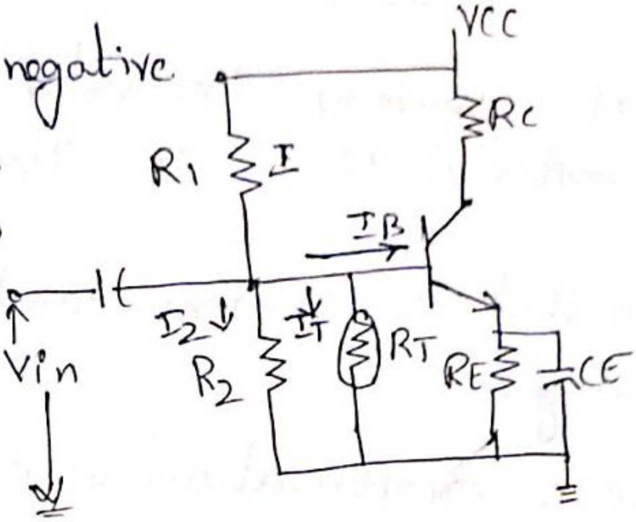
$I = IB_1 + IB_2 + IC_1$

If temparature increases The Q_1 transistor IC_1 increases. I in a const current due to temparature. so that IB_2 current decreases.

If IB_2 decreases then the current for tr. Q_2 $IC_2 = \beta IB_2 + (1+\beta) I_{CO_2}$ If IB_2 decreases & IC_2 current due to temparature increases then both are nullified. (since same amount of current ICO changed due to temparature.)

Thermistor & sensistor compensation.

Thermistor R_T, having a negative temperature coefficient is connected in parallel to R_2



$I = I_2 + I_T + I_B$

I, I_2 = const; with respect to temperature.

R_T is negative temperature co.efficient.

$R_T \propto 1/Temp.$ If Temp ↑ ⇒ R_T ↓, Temp ↓ ⇒ R_T ↑

If temperature increases R_T decreases then I_T increases. If I_T increases then I_B decreases. If I_B decreased as same amount of I_{CO} increased for transistor.

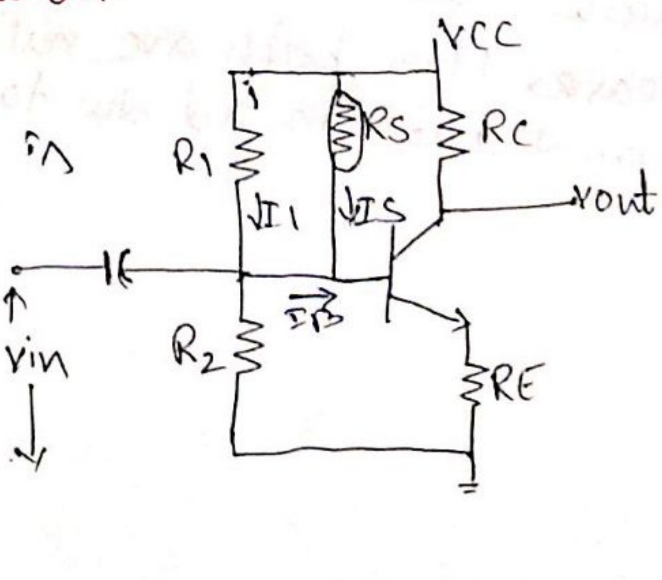
$I_C = \beta I_B + (1+\beta) I_{CO}$.

$= I_B \downarrow$ & $I_{CO} \uparrow$

so that I_C is maintained as constant.

sensistor compensation.

sensistor R_S, having a positive temperature is connected across R_1.



i.e Temp ↑ ⇒ R_S ↑
temp ↓ ⇒ R_S ↓

$I_B = I_1 + I_S.$

If temparature increases I_{CO} increases as R_S resistance increases

Temp $\uparrow \Rightarrow R_S \uparrow \Rightarrow I_S \downarrow \Rightarrow I_B = I_1 + I_S$

I_1 is const then I_B decreases.

$T\uparrow \Rightarrow R_S \uparrow \Rightarrow I_S \downarrow \Rightarrow I_B \downarrow.$

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

$I_B \downarrow$ as $I_{CO} \uparrow$

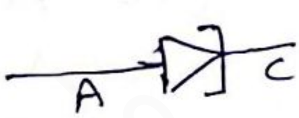
so that the collector current I_C is maintained as constant.

Tunnel diode:

If the concentraction of impurity atoms is greatly increased, i.e 1 Part in 10^3. The device characteristics are completly changed. This new diode was announced in 1958 Esaki. In P-n junction the concentration of impurity of about 1 Part in 10^8.

$$w \alpha \frac{1}{\sqrt{\text{Doping}}}$$ so width of the depletion layer will be thin.

symbol:



Tunneling Phenomenon:

$w \alpha 1/\sqrt{\text{doping}}$

The width of junction barrier varies inversly as the square root of impurity consentration. since doping concentration is high, the width of the barrier and thickness of the barrier is 1/50 of the wavelength of light. so that the charge carries will be penetrating through the depletion layer almost at the speed of light, as if there a tunnel (a Passage or way) in the tunnel diode and this quantum behaviour of the charge carriers is called tunneling phenemenon.

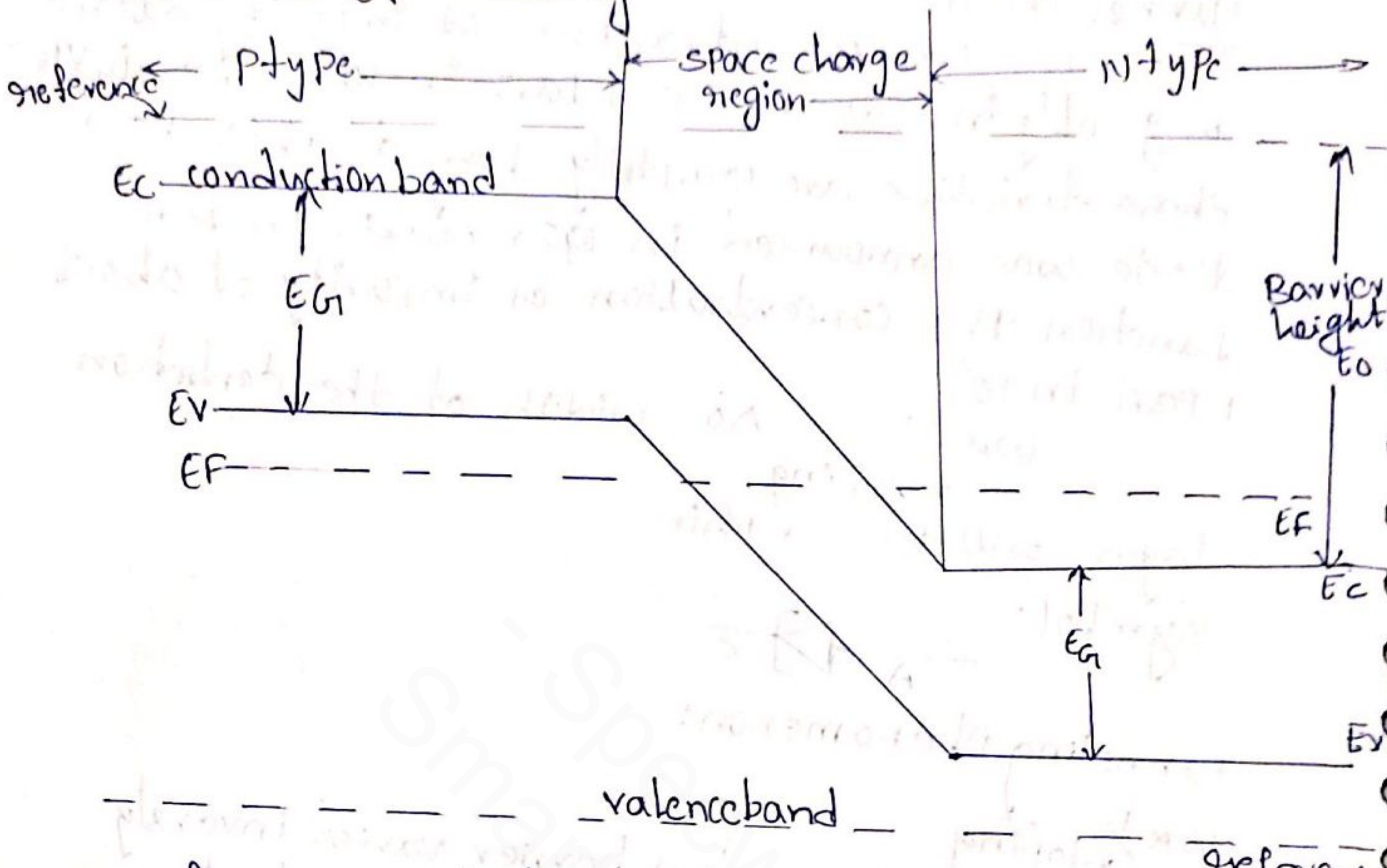
Material used:

In Tunnel diode, the popularly used material is gallium Arsenide.

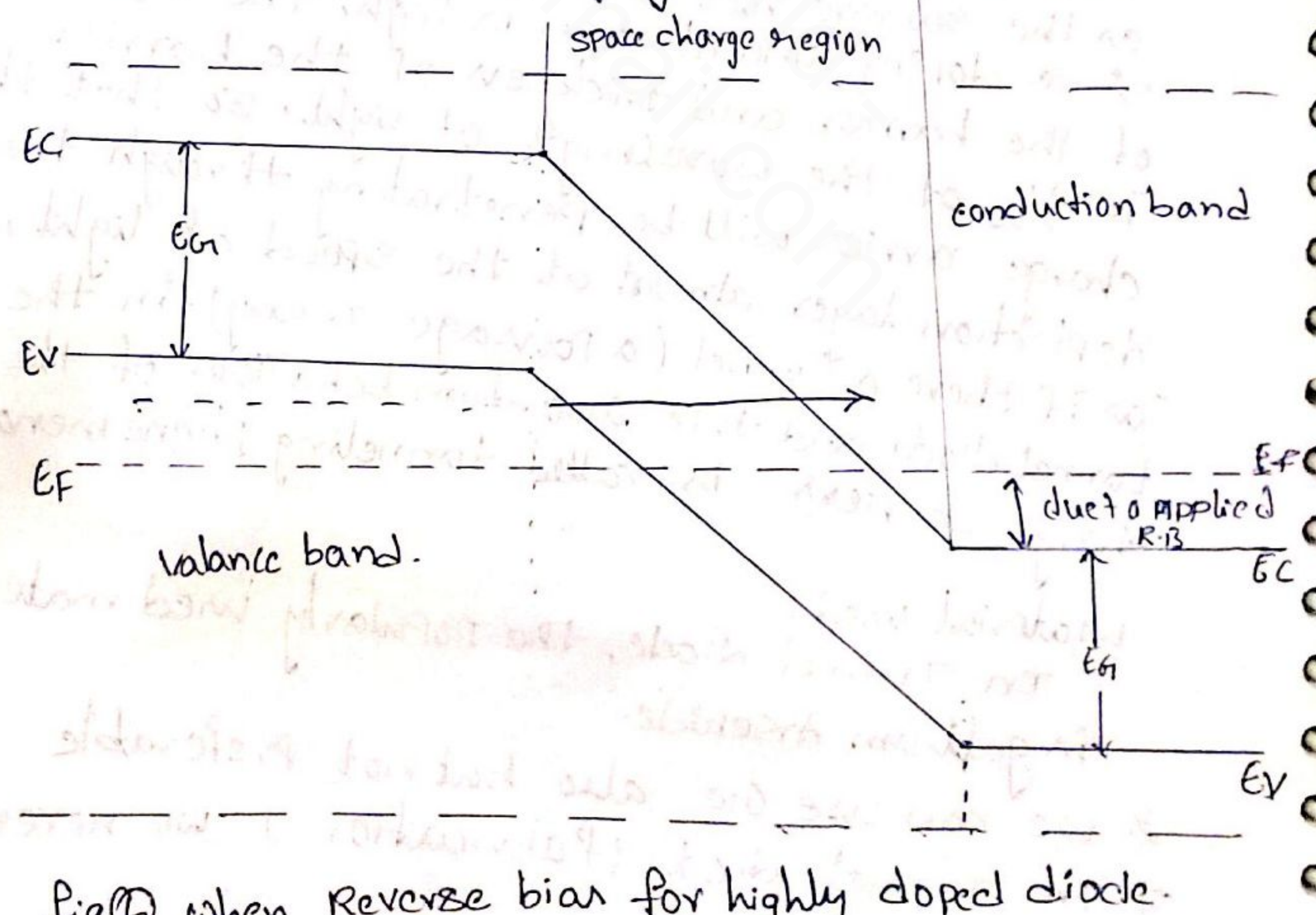
2. we can use Ge also but not Preferable

3. In Tunnel diode (fabrication) we never use silicon.

structure of heavily doped device:



fig@ open ckt for highly doped p-n diode.



fig(b) when Reverse bias for highly doped diode.

Openckt :

For lightly doped p-n diode the fermi-level, the fermilevel E_F lies inside the forbidden energy gap ie E_G.

As we know $E_F = E_C - kT \ln\left(\frac{N_C}{N_D}\right)$ — for n-type.

for lightly doped diode semiconductor $N_D < N_C$ so that $\left(\frac{N_C}{N_D}\right)$ is positive number. so $E_F < E_C$ and the fermilevel lies inside the forbidden band.

For heavily doped diodes $N_D > N_C$ so $\frac{N_C}{N_D}$ is negative. so $\left(-kT\ln\left(\frac{N_C}{N_D}\right)\right)$ becomes +ve & get added with E_C so then $E_F > E_C$. so the fermilevel of E_F (n type material lies in the conduction band)

similarly the $E_F > E_V$ so the Fermilevel of E_F for p type material lies in the valance band. ($\because N_A > N_V$) as shown in fig a.

$$E_G = kT \ln\left(\frac{N_C \cdot N_V}{n_i^2}\right) \quad — ①$$

$$E_0 = kT\left(\ln\frac{N_C \cdot N_V}{n_i^2} - \ln\frac{N_C}{N_D} - \ln\frac{N_V}{N_A}\right) \quad — ②$$

from equations ① & ② from above discussion we can say that $E_0 > E_G$ (i.e so that the contact difference of potential energy E_0 now exceeds, the forbidden energy gap E_G. Hence the picture of open ckt for highly doped diode.

In fig ⓐ there are no filled states on one side of the junction & in fig (a) the energy levels of fermilevel is same on n side & p side. so no charge will flow in either directions, so no current.

volt - Ampere characteristics.

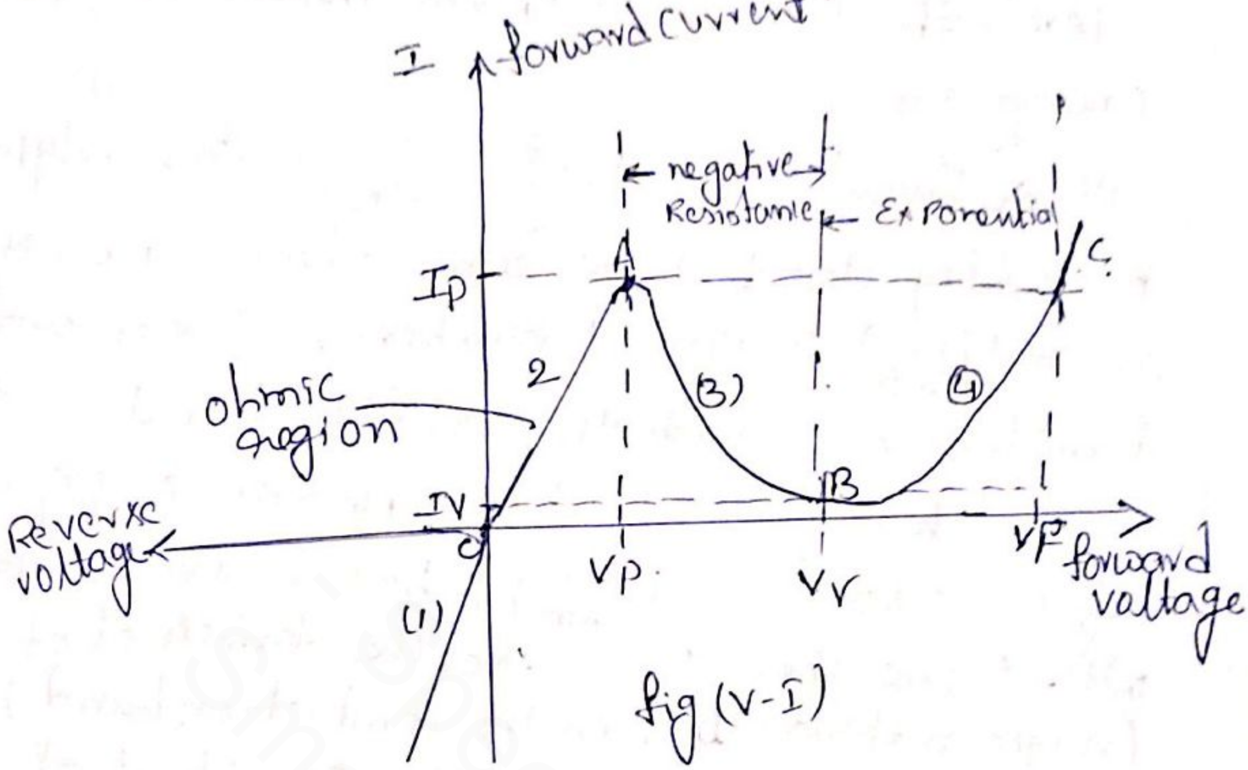


fig (V-I)

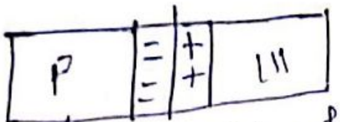
IP = Peak current corresponding voltage.
Vr = valley voltage.
VF = peak forward voltage

Reverse bias

let if reverse bias voltage applied, the height of the barrier increased. when compared to the open ckt. when the diode is reverse biased is applied the length of depletion layer will be increased.

Hence N side level must shift downward with respect to the P side level as shown in fig b)

In fig(b) the Energy levels of fermilevel is not same so the miniority carries tries to jump in to conduction band. for miniority carriers barrier will not come in to picture. since miniority carriers and the barriers are not same charge of the opposite side junction. i.e opposite charge of the opposite side junction.

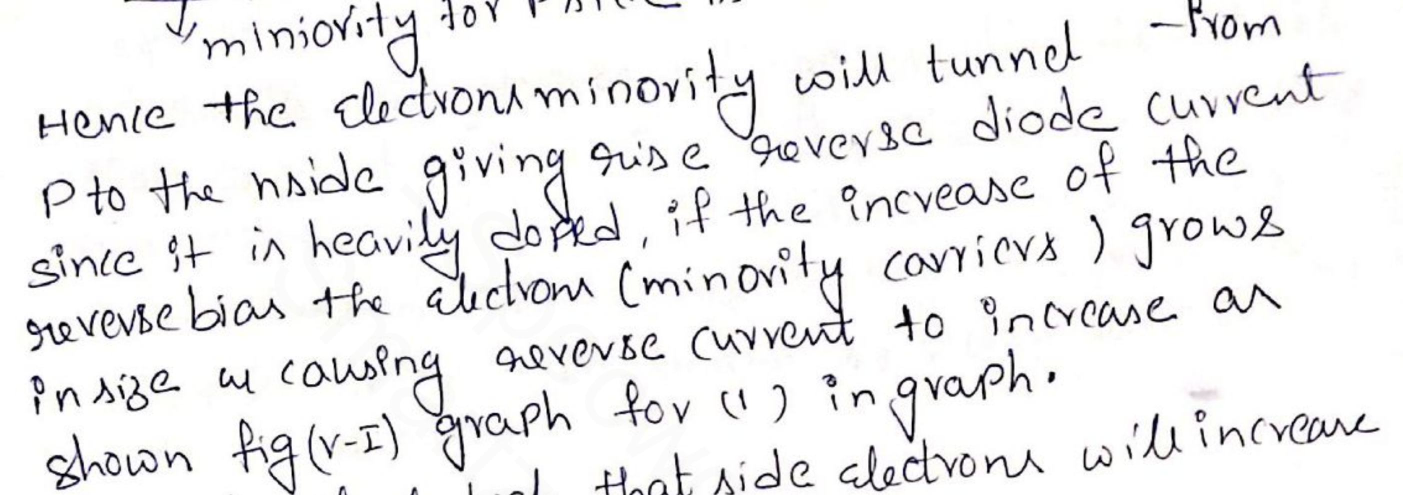


miniority for P side is electron.

Hence the Electrons miniority will tunnel from P to the n side giving rise reverse diode current since it is heavily doped, if the increase of the reverse bias the electron (minority carriers) grows in size as causing reverse current to increase as shown fig(V-I) graph for (1) in graph.

whose fermilevel high that side electrons will increase when we applied Enegry

Forward bias.



fig(c)

consider for forward bias is applied to the diode so that the potential barrier decreased.

. so E_G > Barrier height, hence n side levels must shift upward with respect to P side and Enegry band picture is indicated as shown in fig fig(c)

Photo Diode.

The interest in light sensitive devices has been increasing at an Exceptional rate in recent years. The resulting field of opto Electronics is receiving a great deal of research interest as efforts are made to improve Efficiency levels. light sources offers a unique source of Energy. The Energy transmitted as discrete packages called photons. has a level directly related to the frequency of the travelling light waves

$\boxed{W = hf}$ Joules. h = planck constant 6.624×10^{-34} Joule sec

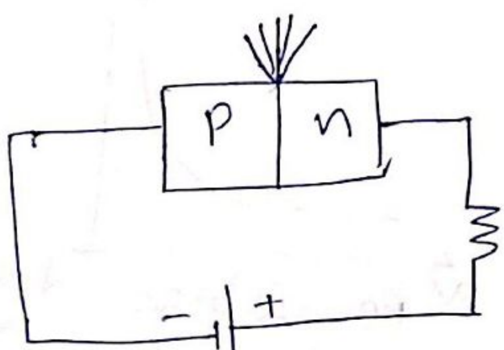
$\boxed{\lambda = v/f}$

λ = wavelength, meters

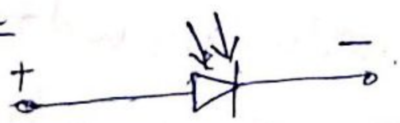
v = velocity of light 3×10^{8} m/sec

f = frequency of the travelling wave hertz.

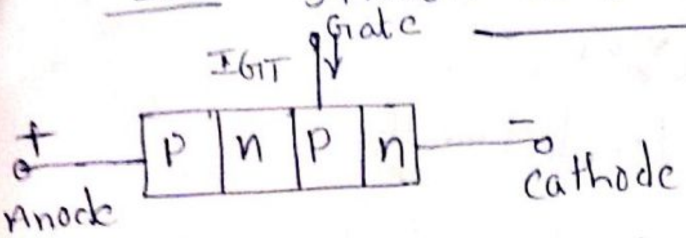
$1 \mathring{A} = 10^{-10}$ m.



Symbol

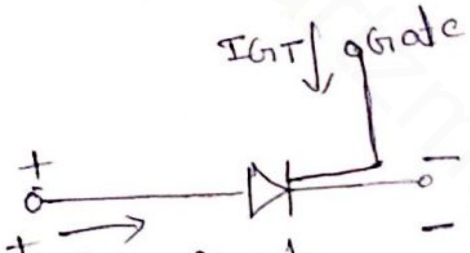


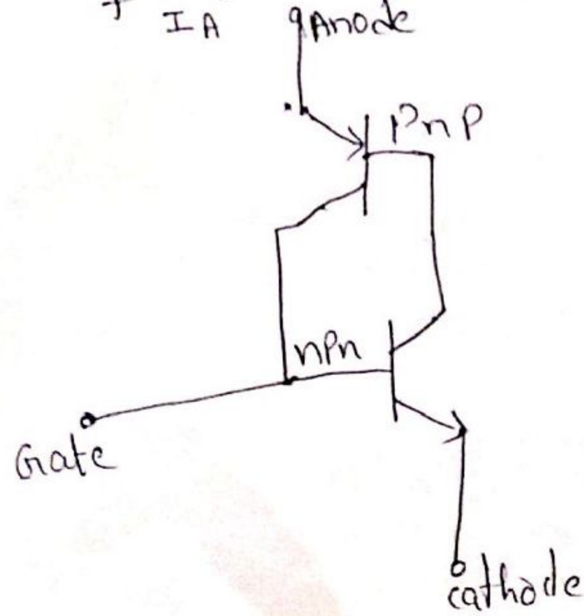
SCR silicon controlled rectifier.

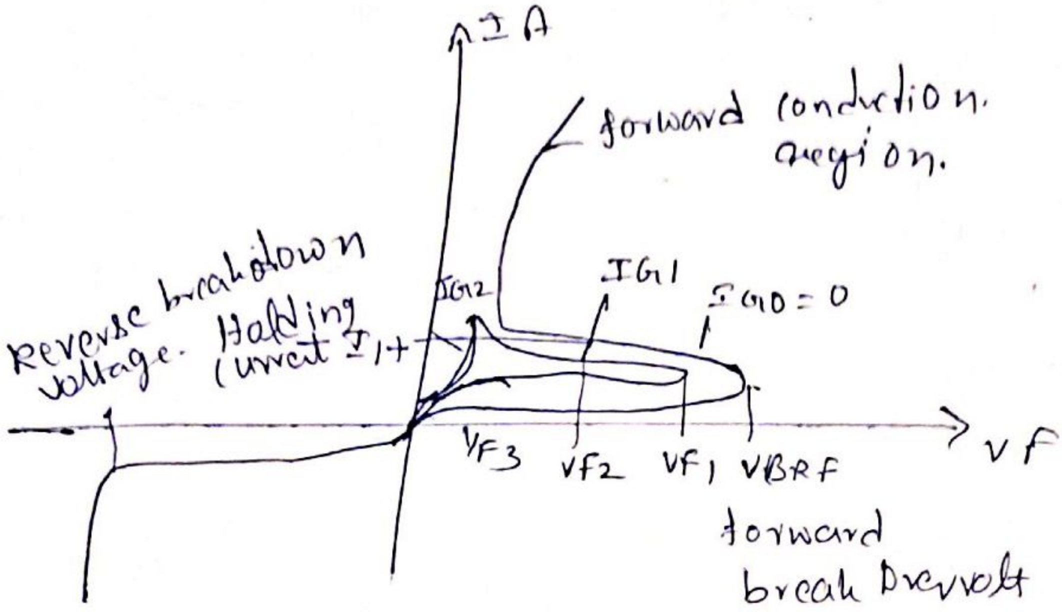


As terminology indicates the SCR is a rectifier constructed of silicon material with third terminal for control Processes. The basic operation of the SCR is different from that of the fundamental - two layer semiconductor diode in that a third terminal. called a gate, determines when the rectifier switches from the open circuit to the short circuit state. It is not enough to simply forward bias the anode to cathode region of the device.

symbol







1. Forwar breakdown voltage: VBRF is the voltage which the SCR enters the conduction region.

2. Holding current: I_H is the value of current below which the SCR switches from conduction state to the forward blocking region under stated condition.

3. Forwad & Reverse blocking regions are the regions corresponding to the open ckt condition for the controlled rectifier.

4. Reverse break down voltage is Equivalent to the zener or avalanche region of the fundamental two layer semiconductor diode.