

22/4/24 BJT Biasing & Stabilization

1) Biasing: Applying DC voltages in order to obtain the operating point (Q-point) is called Biasing.

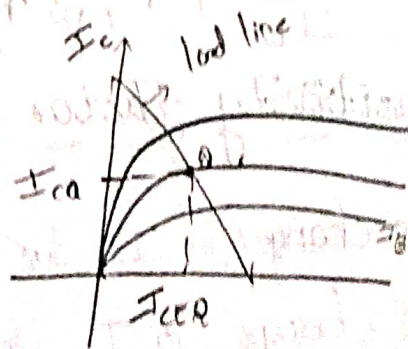
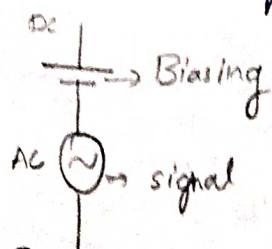
2) Need of BJT: we want to establish the operating point around which the AC signal will oscillate or the AC will be superimposed about the DC-load line.

3) DC load line: It is the straight line equation derived from the output KVL eqn in the output loop of BJT circuit. The study of characteristics of load is called load line. Operating point of BJT is (I_C, V_{CE}) .

→ Q-point or DC operating point is derived from intersection of load line and output characteristics.

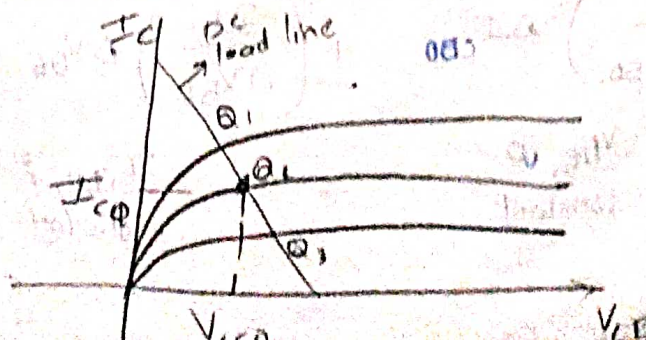
→ It tells about the region of operation of BJT.

4) Q-point: Q-point is chosen in the middle of loadline because the BJT operates in the Active Region and we can ensure that a point neither enters the saturation nor cutoff region and remain in Active Region and works like a proper Amplifier.



5) Q-point stability:

Q-point is stable implies that it doesn't fluctuates due to environmental conditions.



$$I_c = \frac{V_{CC} - V_{CE}}{R_C}$$

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

$$y = mx + c$$

$$y = I_c \quad x = V_{CE} \quad m = -\frac{1}{RC} \quad c = \frac{V_{CC}}{R_0}$$

$$X=0 \quad V_{CE}=0 \quad I_C = \frac{V_{CC}}{R_C}$$

$$y=0 \quad I_c=0 \quad V_{CE} = V_{CC}$$

→ Due to change in biasing and Temperature Q-point changes.

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

If $T \uparrow$, $I_{CBO} \uparrow$, $I_C \uparrow$ then,

Q - point enters into satⁿ region.

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

$\beta_f \uparrow \Rightarrow V_{BE} \downarrow \Rightarrow I_B \uparrow, I_C \uparrow$
 @ 12 point shift

Q point shift upwards then it will enter into $\text{Q} \rightarrow \text{sat}^n$ region

$$\beta = \frac{I_C}{I_B} \uparrow \uparrow, \beta \uparrow, I_C \uparrow \quad Q \rightarrow \text{sat}^n \text{ regions}$$

Sensitivity factor (s) :

$$\Delta I_C = \text{change in } I_C \text{ due to change in } I_{CBO} + \text{change in } I_C \text{ due to change in } V_{BE} + \text{change in } I_C \text{ due to change in } \beta.$$

$$\Delta I_C = \left(\frac{\partial I_C}{\partial I_{CBO}} \right) \Delta I_{CBO} + \left(\frac{\partial I_C}{\partial V_{BE}} \right) \Delta V_{BE} + \left(\frac{\partial I_C}{\partial \beta} \right) \Delta \beta$$

$$\Delta I_C = S \cdot \Delta I_{CBO} + S' \Delta V_{BE} + S'' \Delta \beta$$

S is maximum, $S \gg S' \forall S''$

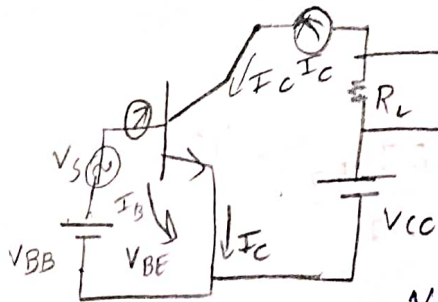
Ideal value of $S = 1$

Practical values of S is less than 20.

If ' s ' have high point, operating point have less point which is stable. $S = 0.9$, $S = 2$

out of three stability factors, S is most significant because if S is within tolerable limit then others s' & s'' are guaranteed to remain within tolerable limits.

Transistor as an Amplifier (converts weak signal to strong signal)



$$Q_{pt} = (I_C, V_{CE})$$

It is used to fix the operating points

$V_{BB} = V_{BE} \rightarrow$ It is when no signal

$$V_{BB} + V_S = V_{BE} + \Delta V_{BE} \rightarrow (1)$$

$$\gamma_i = \frac{\Delta V_{BE}}{\Delta I_B} \quad V_O = V_{BB}$$

$$\boxed{V_S = \Delta V_{BE}} \quad (1) \quad V_i = V_{BE}$$

Apply KVL to o/p loop

$$V_{CC} - I_C R_L - V_{CE} = 0$$

$$V_{CE} = V_{CC} - I_C R_L \rightarrow \text{no signal}$$

$$\boxed{\Delta V_{CE} = 0 - \Delta I_C R_L} \rightarrow \text{due to signal}$$

$$\boxed{\Delta V_{CE} = V_O = -\Delta I_C R_L} \rightarrow \text{phase shift of } 180^\circ$$

$$\text{w.k.t } \Delta I_C = \beta \Delta I_B$$

$$\text{Voltage gain} = \frac{\text{output}}{\text{Input}} = \frac{-I_C R_L}{(\Delta I_B) \gamma_i} = -\frac{\beta}{\gamma_i} R_L$$

$$\gamma_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

$$A_V = -g_m R_L$$

$$A_P = \frac{\Delta V_{CE} \cdot \Delta I_C}{\Delta V_{BE} \cdot \Delta I_B} = A_V \beta$$

$$A_p = -g_m R_L \beta$$

$$A_p = -\beta^2 R_L$$

23/3/24

1) Stabilization: The technique of making operating point independent of variation of $T (I_{CBO}, V_{BE}, \beta)$ & device parameter variations.

2) Derivation of S

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

$$S = \left. \frac{\partial I_C}{\partial I_{CBO}} \right|_{V_{BE}, \beta \text{ constant}}$$

DH. wrt I_C

$$\frac{\partial I_C}{\partial I_C} = \beta \frac{\partial I_B}{\partial I_C} + (1 + \beta) \frac{\partial I_{CBO}}{\partial I_C} \quad ||s$$

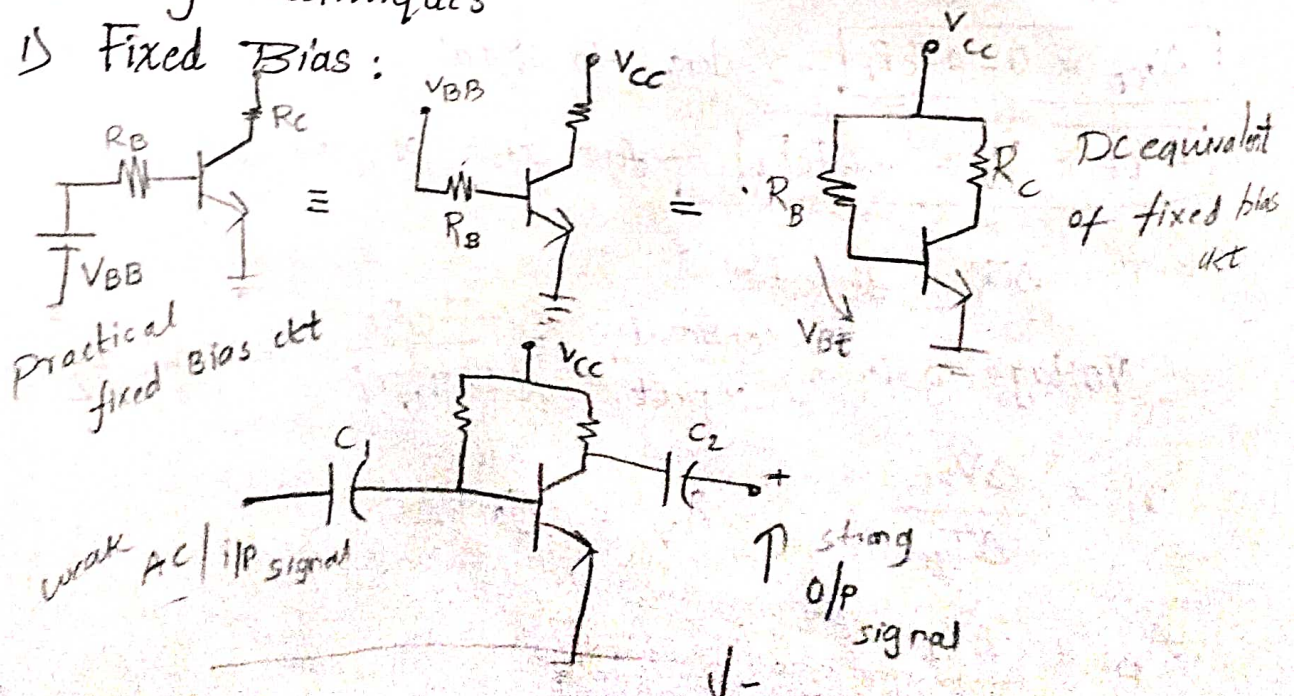
$$1 = \beta \frac{\partial I_B}{\partial I_C} + \frac{(1 + \beta)}{S}$$

$$S = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

Stabilization techniques

→ Biasing techniques

1) Fixed Bias:



Capacitor $\rightarrow$ O.C at d.c
 Capacitor $\rightarrow$ S.C at AC

$$X_c = \frac{1}{2\pi f_c} \quad f_{dc} \rightarrow 0$$

C_1 and C_2 are called coupling capacitors $X_c = \frac{1}{0} = \infty$

$$Q = (I_c, V_{CE}) \quad I_c = \beta I_B$$

$$X_c = 0 \quad f_{ac} \neq 0$$

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

$$I_c = \beta \left(\frac{V_{CC} - V_{BE}}{R_B} \right)$$

$$V_{CE} = V_{CC} - I_c R_c \rightarrow \textcircled{1}$$

$$\uparrow T \rightarrow \uparrow I_{CBO} \rightarrow \uparrow I_c \rightarrow \downarrow V_{CE} \rightarrow \text{Thermal Runaway}$$

Due to increasing the Temperature, device get damage $\rightarrow$ self damage of device

The thermal runaway takes place in BJT. It is process of self damage of BJT because of overheating the power dissipation at collector junction due to increase in I_c with increase in I_{CBO} . The power dissipation at collector junction increases in form of which again raises temperature and cycle continues.

$$S = \frac{\partial I_c}{\partial I_{CBO}} \text{ at constant } V_{BE} \text{ \& } \beta$$

$$S = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_c}}$$

$$\rightarrow \beta \text{ is very large (then poor stability)}$$

$$S' = \frac{\partial I_c}{\partial V_{BE}} \left| \text{at constant } I_{CBO} \text{ \& } \beta \right.$$

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

$$\beta = \frac{V_{CC}}{R_c} - \frac{V_{BE}}{R_c} + (1 + \beta) I_{CBO} \rightarrow \textcircled{1}$$

$$S' = \frac{\partial I_C}{\partial V_{BE}} = -\frac{\beta}{R_B}$$

Diff^{co} w.r.t β

$$\frac{\Delta I_C}{\Delta I_B} = \frac{V_{CC} - V_{BE}}{R_C} + I_{CB0}$$

$$\frac{\partial I_C}{\partial I_B} = I_B + I_{CB0}$$

$$S'' = I_B$$

for fixed bias confⁿ. Determine I_C , V_{CE} , β , and R_B given
 $R_C = 2.7 \text{ k}\Omega$, $I_B = 20 \mu\text{A}$, $I_E = 4 \text{ mA}$, $V_{CE} = 7.2 \text{ V}$

$$I_C = \beta I_B$$

$$I_E = I_C + I_B$$

$$I_C = I_E - I_B$$

$$= 4 \times 10^{-3} - 20 \times 10^{-6} = 3.98 \text{ mA}$$

$$\beta = \frac{I_C}{I_B} = \frac{3.98 \times 10^{-3}}{20 \times 10^{-6}} = 199$$

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

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

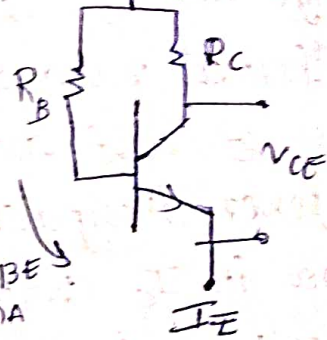
$$V_{CE} = V_{CC} - I_C R_C$$

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

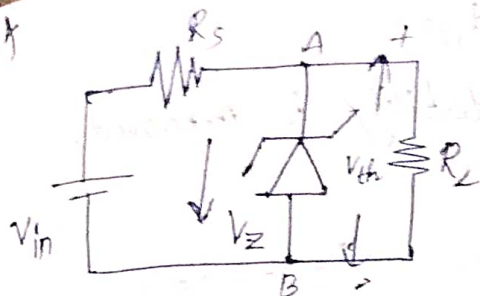
$$R_B = \frac{18 - 0.7}{20 \times 10^{-6}}$$

$$7.2 + 3.98 \times 10^{-3} \times 2.7 \times 10^3 = V_{CC} \quad R_B = 862.3 \text{ k}\Omega$$

$$V_{CC} = 18 \text{ V}$$



21/5/21



To check ZD is in Break down Region

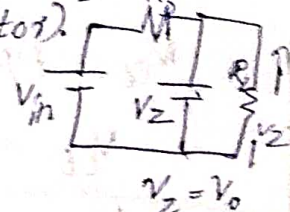
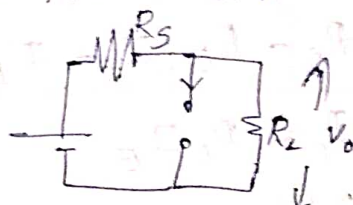
① ^{first} Open circuit the ZD

$$V_{th} = \frac{V_{in} R_L}{R_s + R_L} > V_Z$$

① $V_{th} > V_Z \Rightarrow$ ZD is in BDR (Voltage Regulator)

② $V_{th} < V_Z \Rightarrow$ ZD is not in BDR

equivalent ckt is

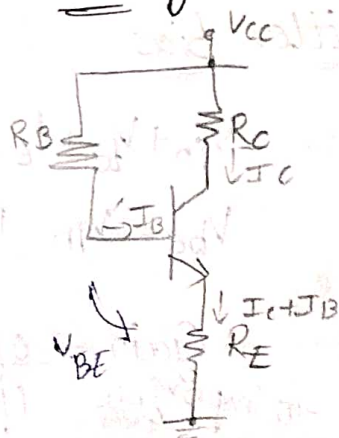


$\rightarrow$ Minimum Power rating of ZD $P_{Z_{min}} = V_Z I_{ZK}$

$\rightarrow$ Maximum Power rating of ZD $P_{Z_{max}} = V_Z I_{Z_{max}}$

Emitter Biasing Ckt

DC equivalent ckt
 $\rightarrow$ when capacitors
act as o.c



$$-V_{CC} + R_B I_B + V_{BE} + (I_C + I_B) R_E = 0$$

$$S = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

Diff. w.r.t I_C

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

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

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

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

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

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

$$(1 + \beta)R_E \gg R_B$$

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

Compared to fixed Bias stability is improved.

from eq (1)

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

$$I_C = \beta I_B$$

$V_{CE} \rightarrow$ Apply KVL to o/p loop

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

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

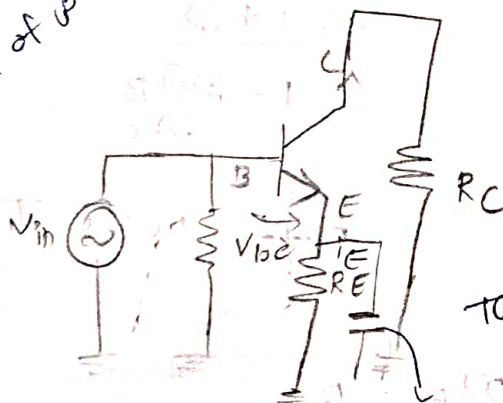
$V_{CE} > 0.2 \rightarrow$ Active Region

$V_{CE} < 0.2 \rightarrow$ saturation Region ($V_{BE} = 0.8V$)

Main Drawback $\rightarrow$ Gain is reduced.

AC Equivalent of emitter bias

I_C is independent of β
 $\beta R_E \gg R_B$



$$-V_{in} + V_{be} + I_E R_E = 0$$

$$V_{be} = V_{in} - I_E R_E$$

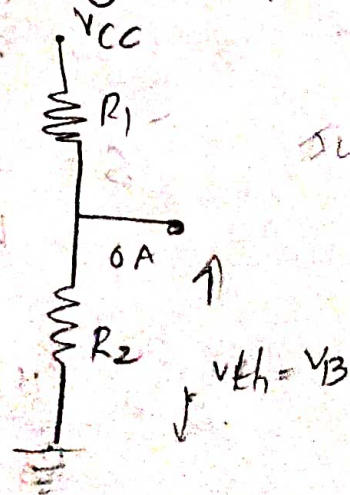
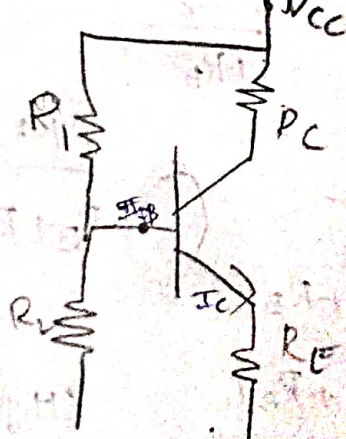
$$\text{Gain} = \frac{o/p}{i/p}$$

TO improve stability
 then set capacitor parallel
 to Resistor R_E

CE bypass capacitors $\rightarrow$

voltage Division Biasing

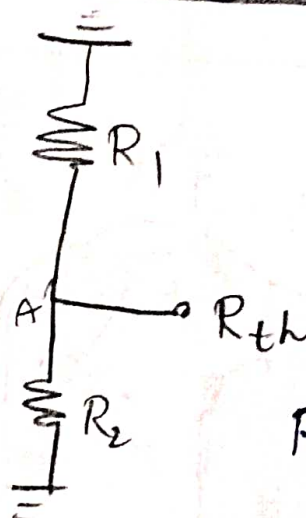
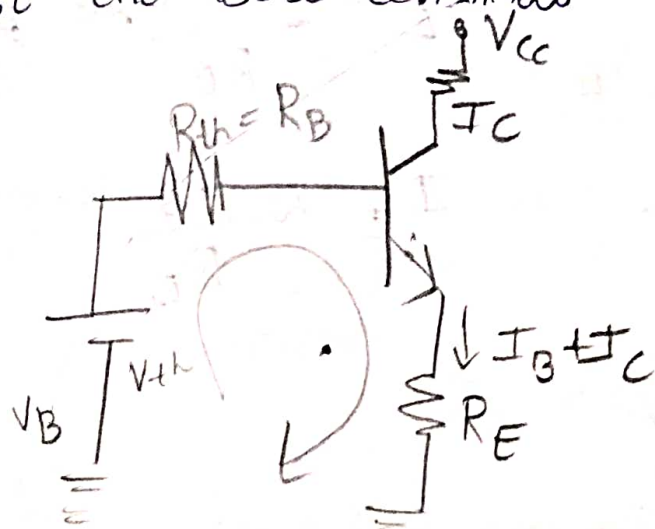
SELF BIASING CKT



$$I_C = \beta I_B$$

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

o.c the Base terminal



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

$$-V_B + I_B R_B + V_{BE} + (I_B + I_C) R_E = 0$$

Diff w.r.t I_C

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

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

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

$$R_E \gg R_B$$

$$S = 1$$

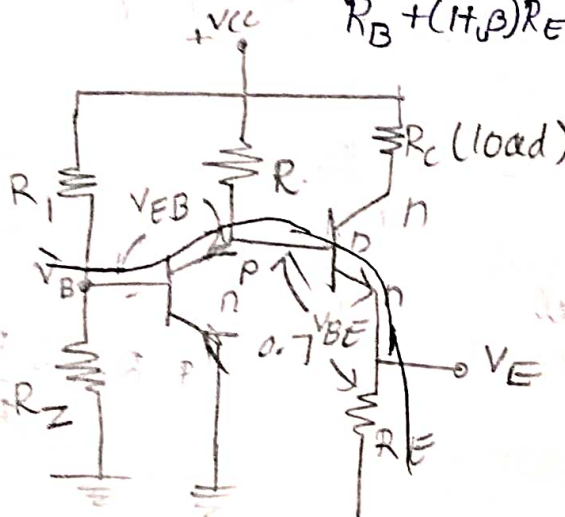
Stability is good than emitter Biasing ckt

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

→ To remove V_{BE} include pnp transistor along with npn

$$I_B = \frac{V_B - V_{BE} + V_{EB}}{R_B + (1+\beta)R_E}$$

$$I_B = \frac{V_B}{R_B + (1+\beta)R_E}$$



Apply KVL :

$$-V_B - V_{EB} + V_{BE} + I_C R_E = 0$$

$$I_E = \frac{V_B + (V_{EB} - V_{BE})}{R_E}$$

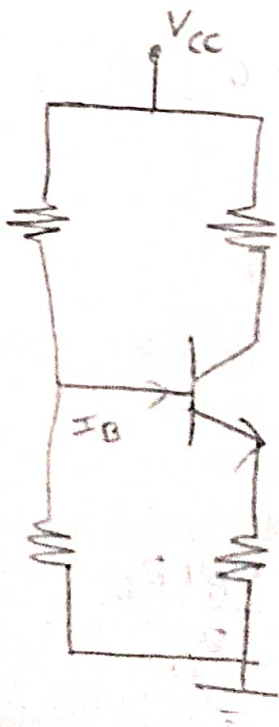
$$I_E \approx \frac{V_B}{R_E}$$

If β is very large

$$I_E \approx I_C$$

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

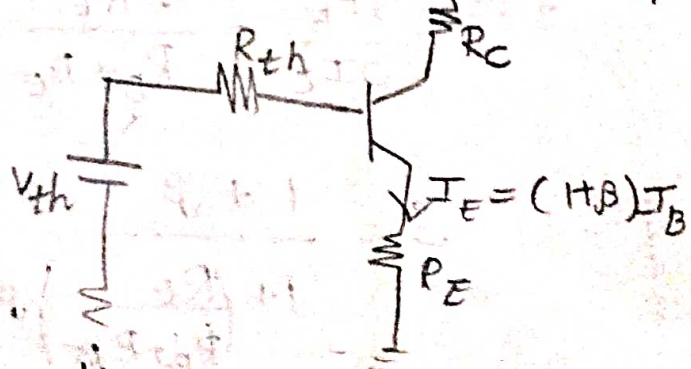
$$I_E = \beta I_B$$



O.C I_B

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

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



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

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

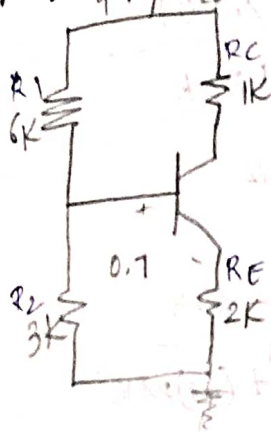
$$I_C = \beta I_B$$

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

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

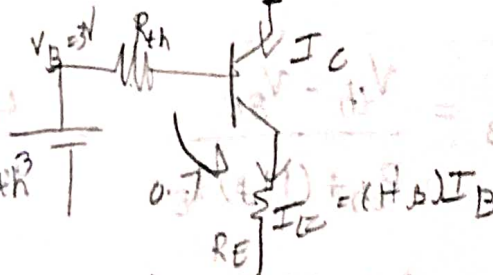
$$S = \frac{R_{th} + R_E}{R_E}$$

And node voltages & Branch currents. If $\beta = 50$
for below ckt.



$$V_{th} = \frac{9 \times 3K}{6K + 3K} = 3V$$

$$R_{th} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{18}{9} = 2K\Omega$$



$$-3V + 2K I_B + 0.7 + (1+\beta) I_B \cdot 2K\Omega = 0$$

$$-3V + 2K I_B + 0.7 + 51 I_B \times 2K = 0$$

$$\frac{2 \times 10^2 I_B}{100000} = 2.3$$

$$I_B = 1.094 \text{ mA} \quad 2.2115 \times 10^{-5}$$

$$I_C = \beta I_B$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 9 - 0.05 \times 1K - 0.051094 \times 2K$$

$$= 9 - 0.05 \times 1K - 0.051094 \times 2K \quad I_C = 0.05 \quad 50 \times$$

$$= -143.181$$

$$I_E = I_B + I_C$$

$$V_E = I_E R_E = 2K \times 0.051094$$

$$= 0.051094$$

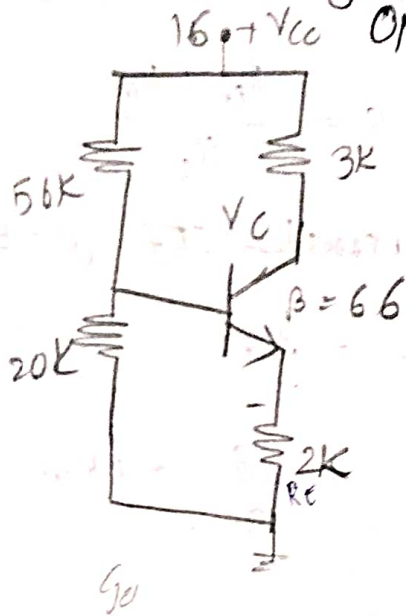
$$I_C = 1.105 \text{ mA}$$

$$I_E = I_B + I_C = 1.12 \text{ mA}$$

$$V_E = 1.12 \times 10^{-3} \times 2K = 2.25 \text{ V}$$

$$V_{CE} > V_E \rightarrow \text{Active}$$

for below Ckt Germanium transistor Amplifier, find Operating point & stability factor



$$V_{th} = \frac{16 \times 20K}{20K + 56K}$$

$$V_{th} = 4.21V$$

$$R_{th} = \frac{56K \times 20K}{56K + 20K}$$

$$R_{th} = 14.73K\Omega$$

$$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1 + \beta) R_E} = \frac{4.21 - 0.3}{14.73 \times 10^3 + (67) 2 \times 10^3}$$

$$I_B = 0.026mA$$

$$I_C = \beta I_B = 1.735mA$$

$$V_{CE} = V_{CC} - I_E R_C - I_E R_E$$

$$I_E = I_B + I_C = 0.026 \times 10^{-3} + 1.735$$

$$I_E = 1.73511$$

$$V_{CE} = 16 - 1.735 \times 3K - 1.735 \times 2K$$

A transistor with $\beta = 45$ is used with collector-base resistor (R) Biasing with Q -^{point} values of 5V for V_{CE} . If $V_{CC} = 24V$, $R_L = 10K\Omega$, $R_E = 270\Omega$. find the values of R and stability factor

$$R = 110K\Omega$$

$$S = 41.44$$

2) For collector to base bias configuration of silicon npn transistor with $V_{CC} = 20$, $R_C = 20K\Omega$, $R_B = 200K\Omega$, $V_{BE} = 0.7V$ and transistor current gain $\beta = 100$. find collector current I_C , V_{CE} and stability factor.

$$I_C = 0.87mA$$

$$V_{CE} = 10.4$$

$$S = 10$$