

WKT : $I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$

$$I_C = \beta I_B + (1+\beta) I_{CBO} \quad \left[\beta = \frac{\alpha}{1-\alpha} ; 1+\beta = \frac{1}{1-\alpha} \right]$$

where $I_{CBO} \rightarrow$ rev-saturation current in CB confⁿ

$\therefore (1+\beta) I_{CBO} = I_{CEO} \rightarrow$ rev. satⁿ current in CE confⁿ

$$\therefore \boxed{I_C = \beta I_B + I_{CEO}}$$

if I_{CEO} is ignored $\because$ its value is very small

$$\therefore I_C = \beta I_B$$

$$\boxed{\beta = \frac{I_C}{I_B}} \quad \beta > 1$$

* Common Collector Configuration:

$$I_C = \alpha I_E + I_{CBO} \rightarrow \textcircled{1}$$

$$\& \ I_E = I_B + I_C$$

$$\text{put } \boxed{I_C = I_E - I_B} \text{ in } \textcircled{1}$$

$$I_E - I_B = \alpha I_E + I_{CBO}$$

$$\Rightarrow I_E (1-\alpha) = I_B + I_{CBO}$$

$$I_E = \left(\frac{1}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

$$= (1+\beta) I_B + (1+\beta) I_{CBO} \quad \left[\frac{1}{1-\alpha} = 1+\beta = \beta \right]$$

$$\boxed{I_E = \beta I_B + \beta I_{CBO}}$$

$$\text{ignore } I_{CBO} \Rightarrow \boxed{I_E = \beta I_B}$$

$$\boxed{\beta = \frac{I_E}{I_B}}$$

The op characteristics of CC is same as CE configuration.

bcoz. $I_E \approx I_C$

$\beta \rightarrow$ is the AC current gain ($\Rightarrow$ current amplⁿ factor in CC confⁿ).

WKT : $I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$

$$I_C = \beta I_B + (1+\beta) I_{CBO} \quad \left[\beta = \frac{\alpha}{1-\alpha} ; 1+\beta = \frac{1}{1-\alpha} \right]$$

where $I_{CBO} \rightarrow$ rev-saturation current in CB confⁿ

$\therefore (1+\beta) I_{CBO} = I_{CEO} \rightarrow$ rev. satⁿ current in CE confⁿ

$\therefore \boxed{I_C = \beta I_B + I_{CEO}}$

if I_{CEO} is ignored $\because$ its value is very small

$\therefore I_C = \beta I_B$

$$\boxed{\beta = \frac{I_C}{I_B}} \quad \beta > 1$$

* Common Collector Configuration:

$$I_C = \alpha I_E + I_{CBO} \rightarrow \textcircled{1}$$

$\& I_E = I_B + I_C$

put $\boxed{I_C = I_E - I_B}$ in $\textcircled{1}$

$$I_C - I_B = \alpha I_E + I_{CBO}$$

$$\Rightarrow I_E (1-\alpha) = I_B + I_{CBO}$$

$$I_E = \left(\frac{1}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

$$= (1+\beta) I_B + (1+\beta) I_{CBO} \quad \left[\frac{1}{1-\alpha} = 1+\beta = \beta \right]$$

$$\boxed{I_E = \beta I_B + \beta I_{CBO}}$$

ignore $I_{CBO} \Rightarrow \boxed{I_E = \beta I_B}$

$$\boxed{\beta = \frac{I_E}{I_B}}$$

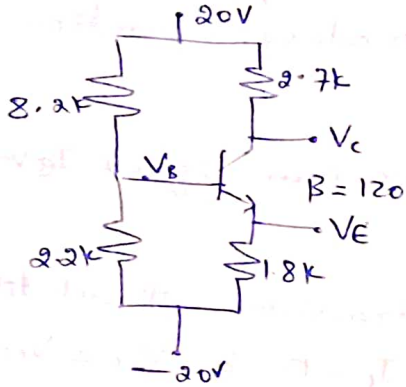
The op characteristics of CC is same as CE configuration.

bcz: $I_E \approx I_C$

$\beta \rightarrow$ is the AC current gain ($\Rightarrow$ current amplⁿ factor) in CC confⁿ.

(2)

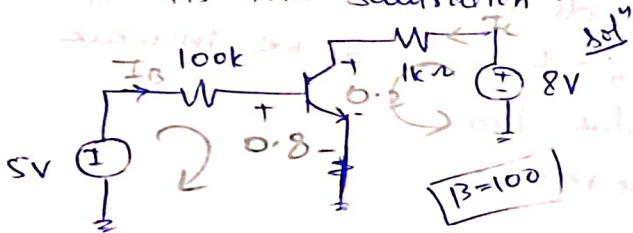
Q4) Find : V_C & V_B



$$\text{KVL} : \frac{20 - V_C}{2.7k} = I_C$$

$$I_C = \beta I_B$$

Q4) Find the region of operation of BJT. Assume the transistor is in Saturation.



Standard values for Si tr.

$$V_{BEsat} = 0.8V$$

$$V_{CEsat} = 0.2V$$

$$\text{KVL to i/p loop} : -5 + 100k I_B + 0.8 = 0$$

$$\Rightarrow I_B = 42\mu A$$

$$\text{KVL to o/p loop} : -8 + I_C R_C + 0.2 = 0$$

$$\Rightarrow I_C = 7.8mA$$

$$\therefore \beta_{forced} \text{ (or) } \beta_{min} = \frac{I_{Csat}}{I_{Bmin}} = 185.71 > \beta_{given}$$

$\therefore$ the given tr. is in Active region.

$\therefore$ in Active region : $V_{BE} = V_{BEActive} = 0.7V$

$$\therefore \text{KVL to i/p loop} : -5 - I_B 100k + 0.7 = 0$$

$$\Rightarrow I_B = 43\mu A$$

$$V_B = 5 - 100k \times 43\mu A = 0.7V$$

$$\therefore I_C = \beta I_B = 4.3mA$$

$$\text{also } -8 + I_C R_C + V_C = 0$$

$$\Rightarrow V_C = 3.7V$$

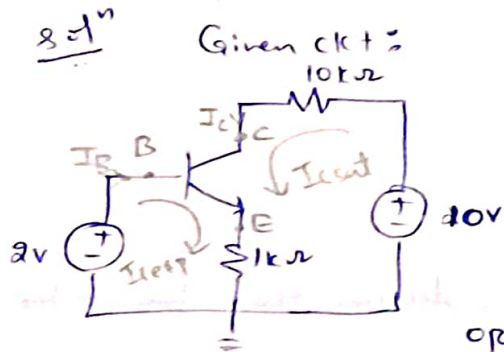
$V_C > V_B \Rightarrow$ Active region.

note : don't use

$$I_C = \beta I_B \text{ in sat}^n \text{ reg}$$

(5)

Ques) For the BJT ckt shown, assume that the β of the transistor is very large and V_{BE} is $0.7V$. Find the mode of operation of BJT



if β is very large, then we can ignore I_B value
 $\therefore I_B = \frac{I_C}{\beta} \approx 0$

$\therefore$ if $I_B = 0$ then transistor will act like an open ckt $\therefore I_C = 0$ & $V_{CE} = V_{CC}$

i.e., entire 10V will be across the transistor open ckt & will appear across collector & emitter terminals $\therefore$ the mode of operation is Cutoff mode.

Ans: Tr is in saturation region: because as we increase I_B value I_C also $\uparrow$ but V_{CE} value $\downarrow$.

Now, if we assume tr. in Active region:

Apply KVL to i/p loop: $-2 + I_E R_E + V_{BE} = 0$

$$\Rightarrow I_E = \frac{2 - 0.7}{1k} = 1.3mA$$

$$I_E =$$

$$I_{Csat} = \frac{10 - V_{CEsat}}{10k + 1k} = \frac{9.2}{11} mA$$

$$V_{BEsat} = 0.8V$$

↓
Standard Value

I_{Cexp} :

KVL to BE loop

$$2 - V_{BEsat} - I_{Cexp} \cdot 1k = 0$$

$$2 - 0.8 - I_{Cexp} \cdot 1k = 0$$

$$I_{Cexp} = 1.2mA$$

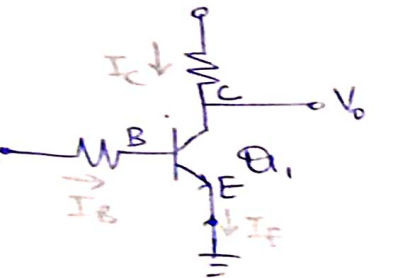
once tr. is reached the saturation point it no more depends on i/p voltage (or) current.

$I_{Cexp} > I_{Csat}$ So, Tr. is in Saturation region.

* BJT as Inverter :-

(3)

$$V_{CEsat} = 0.2V \text{ for } Si \\ = 0.1V \text{ for } Ge$$



Common emitter
Fig: Inverter ckt

In cut-off region : $I_B = 0$

In this region both the junctions are RB when operating point for the BJT enters the cutoff region, the BJT is OFF. Hence, the collector current becomes almost zero & collector voltage almost equals V_{CC}

$$\text{i.e., } V_{CE} = V_{CC}, I_C = I_B = 0$$

The transistor is virtually an open ckt. b/w collector & emitter.

i.e., $V_{BE} < 0.6V \rightarrow \text{Cutoff } I_B = I_C = 0$
 $V_{BE} = 0.6 \text{ to } 0.7 \rightarrow \text{Active Region}$
 $V_{BE} > 0.8V \rightarrow \text{Saturation Region}$

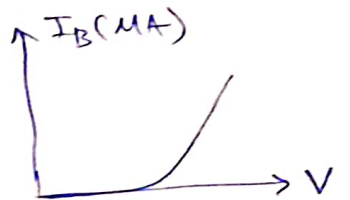
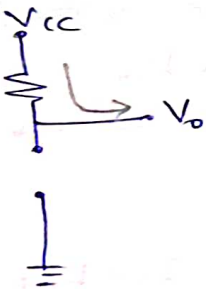
CASE 1 : when $V_{in} < 0.6V$
 let $V_{in} = 0.2V \text{ Low}$

$\Rightarrow Q_1 = \text{OFF} \rightarrow \text{Cutoff}$

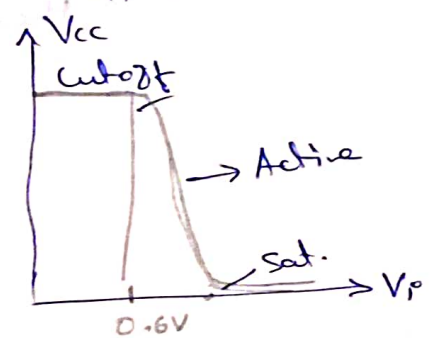
$$V_o = V_{CE} = V_{CC} - I_C R_C$$

$$I_B = I_C = 0$$

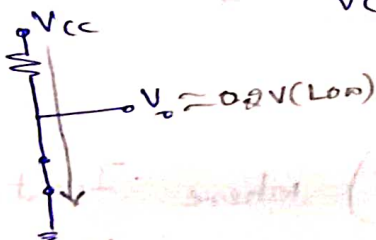
$$\Rightarrow V_o = V_{CE} \approx V_{CC}$$



o/p characteristics



CASE 2 :- $V_{in} = \text{high} > 0.8 \rightarrow \text{Saturation} \rightarrow \text{ON}$
 $V_{CE} = 0.2 = V_o = \text{Low}$



↓
 b/cot in Sat

large I_C flows & V_C falls to a very low value called $V_{CE(sat)}$, typically around 0.2V for a Si transistor

Truth Table

V_{in}	V_{out}
0 Low (0.2V)	H (V_{CC})
1 H (> 0.8V)	L (0.2V)

$$I_E = I_C + I_B$$

Active region $I_C = \beta I_B$

$$I_E = (1 + \beta) I_B \rightarrow \text{Active (or) linear region}$$

$$\text{in sat}^n \text{ region : } I_E = I_{Csat} + I_B$$

$$\text{where } I_{Csat} = \beta I_{Bmin}$$

1. E-B (P-n) junction

Openckt if $V_P > V_n \rightarrow$ FB

$$(V_P - V_n)_{oc} \geq V_{BEactive}$$



ON $\rightarrow$ active or satⁿ

it is in active region

then calculate I_C, I_B, I_E , use $I_C = \beta I_B$ ---

then V_{CE}

Calculate $V_{CE} = a \dots$ for npn & V_{EC} for pnp

if $a > 0.2V \rightarrow$ active

if $a \leq 0.2V \rightarrow$ satⁿ $\rightarrow I_C = \beta I_B$ is invalid.

* In active region I_C & I_B are related by $I_C = \beta I_B \rightarrow$ Ampl^r.

, In satⁿ region I_C & I_B are not related

becoz η_{FE} in I_B will not give I_C .

Condition for BJT in satⁿ

$$I_B \geq I_{Bmin}$$

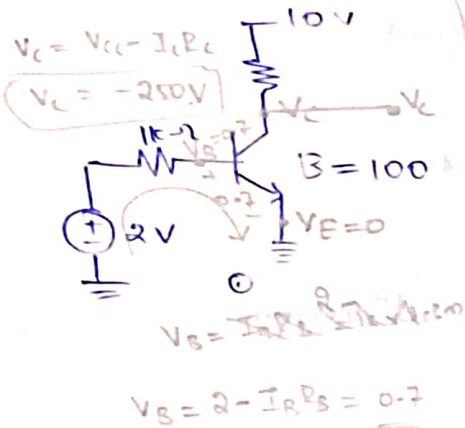
$$I_B \geq \left(\frac{I_{Csat}}{\beta} \right) \text{ where } I_{Csat} = \beta I_{Bmin}$$

$$V_{CE} = V_{CESat} = 0.2V$$

Q

Problems on transistor region of operation of BJT.

ex Find the region of operation of BJT in the given ckt.



2nd Two methods

→ Assume that Tr is in Active mode
find I_c, I_e, I_b & V_c, V_e, V_b

$V_{BE} = 0.7$ & $V_c > V_b$ (active mode)
otherwise saturation.

→ Assume that Tr is in Saturation mode
find I_c, I_e, I_b & V_c, V_e, V_b

Satⁿ Region

$$B > \beta_{min}$$

Bypassed is what we find.

$$B_{forced} = \frac{I_{c sat}}{I_{b sat}}$$

not sat means Tr is in Active.

(1) Assume Active region.

Apply KVL for IB loop

$$-2 + I_B 1k + 0.7 = 0$$

$$\Rightarrow I_B = 1.3 \mu A = 1.3mA$$

$$I_c = \beta I_B = 100 \times 1.3m = 130mA$$

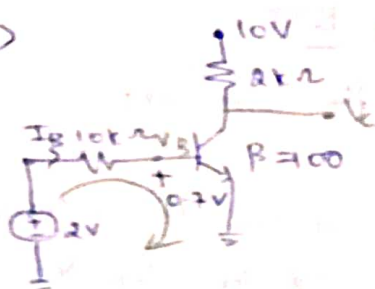
$$\text{from fig 0 } V_c = 10 - I_c R_c = -250V$$

$$\& V_b = 2 - I_b R_b = 0.7V$$

$$V_c \neq V_b \Rightarrow I_c \& I_b \text{ are FB}$$

$\Rightarrow$ Satⁿ region.

Q2)



8.17 kVL to i/p loop Assume: Active region

$$\Rightarrow -2 + I_B 10k + 0.7 = 0$$

$$\Rightarrow I_B = \frac{1.3}{10k} = 0.13 \text{ mA}$$

$$I_C = \beta I_B$$

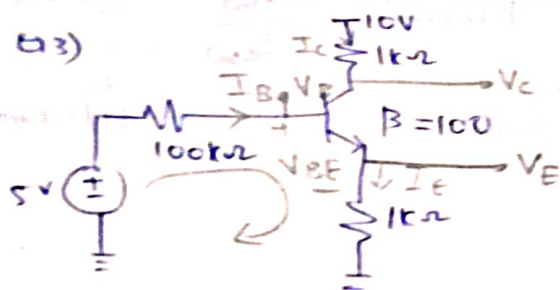
$$I_C = 100 \times 0.13 / 10k = 1.3 \text{ mA}$$

$$V_C = 10 - 1.3 \times 2k$$

$$V_C = 10 - 2.6 = -1.6 \text{ V} \Rightarrow I_C \text{ is in FB} \Rightarrow \text{sat}^n \text{ region}$$

$$V_B = 2 - 10k \times 0.13 \text{ mA} =$$

Q3)



Assume Active region:

kVL to i/p loop:

$$-5 + 100k I_B + 0.7 + I_E 1k = 0$$

$$I_E = I_B + I_C$$

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

$$V_C = 10 - 2.1 \text{ mA} \times 1k$$

$$V_C = 7.9 \text{ V}$$

$$V_E = I_E R_E = 2.1 \text{ mA} \times 1k = 2.1 \text{ V}$$

$$V_{BE} = V_B - V_E$$

$$V_B = V_{BE} + V_E = 0.7 + 2.1 = 2.8 \text{ V}$$

$$\Rightarrow V_C > V_B \therefore \text{Active Region}$$

$$\Rightarrow I_C \rightarrow RB, I_E \rightarrow FB$$

$$I_B [100k + (\beta + 1) 1k] = 4.3$$

$$I_B = \frac{4.3}{100k + 101k} = \frac{4.3}{201} \text{ mA} = 0.021 \text{ mA}$$

$$I_C = \beta I_B = 100 \times 0.021 \text{ mA} = 2.1 \text{ mA}$$

$$I_E = I_C + I_B = 2.1 \text{ mA}$$

$$\text{Check } V_{BE} \Rightarrow 5 - 2.1 \text{ mA} \times 10k = 2.9$$

* Relation b/w α & β : (c)

WKT $\beta = \frac{I_c}{I_B}$ $\alpha = \frac{I_c}{I_E}$

& $I_E = I_B + I_c \Rightarrow I_B = I_E - I_c$

$$\beta = \frac{I_c}{I_B} = \frac{I_c}{I_E - I_c} = \frac{I_c / I_E}{\frac{I_E - I_c}{I_E}} = \frac{\alpha}{1 - \alpha}$$

$$\therefore \boxed{\beta = \frac{\alpha}{1 - \alpha}}$$

$$\alpha = \beta(1 - \alpha)$$

* Relation b/w α , β & γ : $\alpha = \beta - \alpha\beta$

$$\gamma = \frac{I_E}{I_B}$$

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

$$\boxed{\alpha = \frac{\beta}{1 + \beta}}$$

WKT $I_B = I_E - I_c$

$$\gamma = \frac{I_E}{I_E - I_c} = \frac{I_E / I_E}{\frac{I_E - I_c}{I_E}}$$

$$\boxed{\gamma = \frac{1}{1 - \alpha} = 1 + \beta}$$

WKT : $\alpha = \frac{I_E}{I_c}$, $\beta = \frac{I_c}{I_B}$

$$I_E = \frac{I_c}{\alpha}$$

$$I_c = \beta I_B$$

$$\Rightarrow I_E = \frac{\beta I_B}{\alpha}$$

$$(or) \boxed{I_E = \frac{\beta}{\alpha} I_B}$$

$\alpha = \frac{I_E}{I_c}$, $\beta = \frac{I_c}{I_B}$

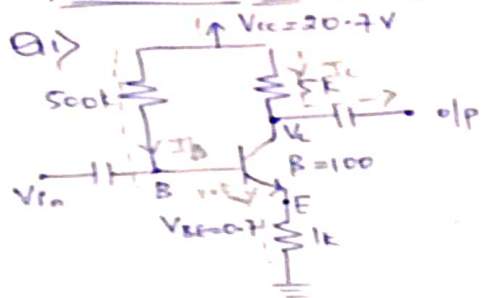
$$I_E = \alpha I_c$$

$$I_c = \beta I_B$$

$$I_E = \alpha \beta I_B$$

$$I_E = \frac{\beta}{\beta + 1} \beta I_B$$

Problems on BJT:



calculate I_B, I_C, V_C

$$\text{NKT: } \alpha = \frac{I_C}{I_E} \quad \beta = \frac{I_C}{I_B}$$

$$I_E = \frac{I_C}{\alpha} \quad I_E = \frac{I_C}{\beta + 1}$$

$$I_E = \frac{\beta I_B}{\beta + 1} \Rightarrow \left(\frac{\beta}{\beta + 1}\right) I_B$$

$$\alpha = \beta / \beta + 1$$

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

Apply KVL to i/p side:

$$20.7 - 500 I_B - 0.7 - I_E = 0 \quad \text{--- (1)}$$

$$\text{put } I_E = (\beta + 1) I_B \text{ in (1)}$$

$$\Rightarrow 20.7 - 500 I_B - 0.7 = 0$$

$$\text{Now } I_B = \frac{20}{500} \text{ mA} = \frac{1000}{30} \mu\text{A}$$

$$I_B = 33.3 \mu\text{A}$$

$$\text{Now } I_C = \beta I_B = 33.3 \mu\text{A} \times 100$$

$$I_C = 3.3 \text{ mA}$$

$$\text{KVL to o/p side: } 20.7 - I_C R_C = V_C = 18.5 \text{ V} \quad (4.2 \text{ V})$$

Q2)

- $I_C = \beta I_B$ holds good in Active region
- $I_E = I_C + I_B$ " " " Satⁿ region
- $I_C = \beta I_B$ does not hold good in Satⁿ region

- To check the transistor is ON.

$$V_{BE} > V_{BE \text{ active}}$$

$$(\text{or}) V_A > V_K \text{ i.e., } J_E \text{ is FB.}$$

- Once transistor is ON, again we get two possibilities i.e. the transistor is active (or) Satⁿ region.

$$\text{in Satⁿ region } V_{CE} = 0.2 \text{ V}$$

$$\text{in Active region } V_{CE} > 0.2 \text{ V.}$$

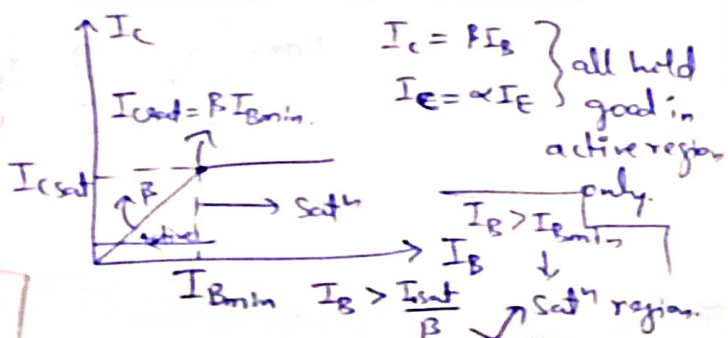
- In Cutoff region all the currents

$$I_C, I_B \text{ \& } I_E = 0.$$

beoz both J_E \& J_C are RB

- The all Current gain eq^{ns} α, β \& γ will hold good only in Active region.

$$I_C = \beta I_B \quad \left| \quad I_B < I_{B \text{ sat}} / \beta \right|$$



(4)

Q16) In the ckt. shown, the Si BJT $\beta = 50$. Assume $V_{BE} = 0.7V$ & $V_{CE(sat)} = 0.2V$. Find the region of operation of BJT also R_C value.

Solⁿ Assume Active region

$\therefore$ Apply KVL to i/p loop (or BE loop)

$$-5 + 50k \cdot I_B + V_{BE} = 0$$

$$\Rightarrow I_B = 86 \mu A \rightarrow (1)$$

$$I_C = \beta I_B = 50 \times 86 \mu A = 4.3 mA$$

$$V_B = 5 - 50k \cdot 86 \mu A = 0.7V$$

Apply KVL to o/p loop:

$$-10 + I_C R_C + V_{CE} = 0$$

$$\text{Given } V_{CE(sat)} = 0.2V$$

$$\therefore -10 + I_{C(sat)} R_C + V_{CE(sat)} = 0$$

$$I_{C(sat)} = \frac{9.8}{R_C} \rightarrow (2)$$

$$I_B \geq \frac{I_{C(sat)}}{\beta} \Rightarrow 86 \mu A \geq \frac{1}{50} \left(\frac{9.8}{R_C} \right)$$

$$\Rightarrow R_C \geq 2.27 k\Omega$$

$$\beta_{min} \text{ or } \beta_{forced} = \frac{I_{C(sat)}}{I_{Bmin}} = 37.9 < \beta_{given}$$

$\therefore$ Given transistor is in Satⁿ region

Q1) A silicon transistor is biased in CE confⁿ,
if $\beta = 100$, $I_C = 1\text{mA}$ then what is the value of I_B .

solⁿ :- We have In CE

$$\beta = \frac{I_C}{I_B} \Rightarrow I_B = 1\text{mA} \times 100$$

$$\boxed{I_B = 0.1\text{A}}$$

Q2) A silicon transistor has $\beta = 100$ & $\alpha = 0.98$ then
the value of β is

solⁿ $\beta = 1 + \alpha = \underline{101}$

Q3) A commonbase dc current gain of a transistor
is 0.967. If the emitter current is 10mA,
what is the value of base current?

solⁿ

$$\alpha = 0.967 \quad \& \quad I_E = 10\text{mA}$$

$$\text{for CB, } \alpha = 0.967 = \frac{I_C}{I_E} = \frac{I_C}{10}$$

$$\Rightarrow I_C = 9.67\text{mA}$$

$$I_E = I_C + I_B$$

$$\Rightarrow \boxed{I_B = 0.33\text{mA}}$$

Q4) A transistor has $\beta = 100$. If the $I_C = 40\text{mA}$.
Find the value of I_E

$$\text{Ans:- } 40.4\text{mA}$$

Pg:- 137
in Shalivahan
book

Q15) A transistor has $\beta = 150$. Find the collector & base currents if $I_E = 10 \text{ mA}$

Pg:-137
in Shalivahan

Ans:- $I_C = 9.93 \text{ mA}$, $I_B = 0.07 \text{ mA}$

Q16) For a transistor ckt having $\alpha = 0.98$, $I_{CBO} = I_{CO} = 5 \mu\text{A}$ & $I_B = 100 \mu\text{A}$, find I_C & I_E

Pg:-
139

Ans:- $I_C = 5.15 \text{ mA}$
 $I_E = 5.25 \text{ mA}$

Q17) Calculate the values of I_C & I_E for a transistor with $\alpha_{dc} = 0.99$ & $I_{CBO} = 5 \mu\text{A}$ I_B is measured as $20 \mu\text{A}$

Pg:-
140

Ans:- $I_C = 2.48 \text{ mA}$, $I_E = 2.5 \text{ mA}$

Q18) An Ideal transformer is rated at $2400/120 \text{ V}$ 9.6 kVA , & has 50 turns on the secondary side. Calculate (a) the turns ratio, (b) No. of turns on the primary side & (c) the current ratings for the primary & secondary windings.

Pg:-
578
in Charles
Alexander

Ans:- (a) $k = 0.05$
(b) $N_1 = 1000 \text{ turns}$
(c) $I_1 = 4 \text{ A}$, $I_2 = 80 \text{ A}$.

Q19) The primary current to an Ideal transformer rated at $2200/110 \text{ V}$ is 5 A . Calculate (a) turns ratio, (b) the Sec. Current

Pg:-
578

Ans:- $k = 1/20$, $I_2 = 100 \text{ A}$.

①

②

Given $N_D = N_C \cdot e^{\frac{-(E_C - E_F)}{kT}}$

at 0 K: $N_D = N_{D0}$

$E_F = E_{F0}$

$N_{D0} = N_C \cdot e^{\frac{-(E_C - E_{F0})}{kT}} \rightarrow \textcircled{1}$

$E_C - E_{F0} = 0.3 \text{ eV}$, at room temp $kT = 0.03 \text{ eV}$.

a) N_D is increased by a factor of 2

$N_D = 2 N_{D0}$

$2 N_{D0} = N_C \cdot e^{\frac{-(E_C - E_F)}{kT}} \rightarrow \textcircled{2}$

$\frac{\textcircled{2}}{\textcircled{1}} \Rightarrow 2 = e^{\frac{-(E_C - E_F + 0.3 \text{ eV})}{kT}}$

$\ln(2) = -E_C + E_F + 0.3$

$-E_C + E_F \Rightarrow 0.02 - 0.3$

$\Rightarrow \boxed{E_C - E_F \Rightarrow 0.2793 \text{ eV}}$

Similarly when N_D becomes four times

$\boxed{E_C - E_F = 0.25 \text{ eV}}$

①

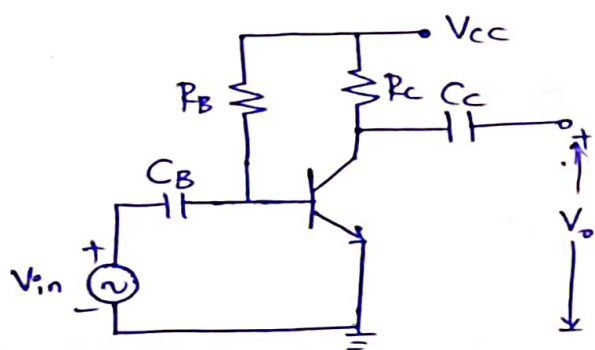
a) Discuss the different types of transistor biasing ckt.
Derive an expression of the stability factor in Self-biasing circuit

Sol Biasing is a technique of stabilizing transistor against variation of temperature, leakage current & β

There are three types of biasing techniques.

- 1) Fixed Bias
- 2) Collector to Base bias
- 3) Self bias.

Fixed Bias:

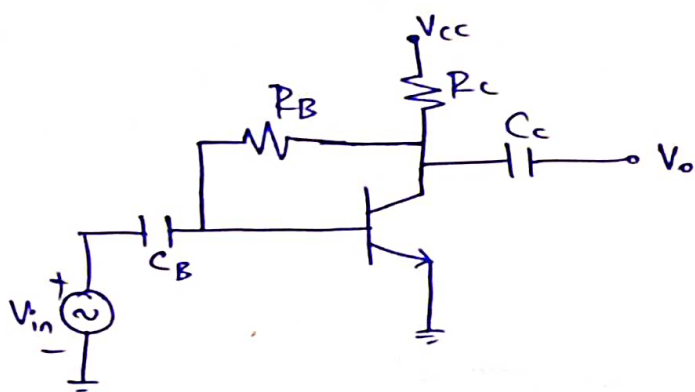


For DC,

$$I_c = \beta I_B \rightarrow \text{①}$$

From eqn ①, it is clear that there is no negative feedback for D.C component. i.e. change in β affects I_c . Hence it is not desirable.

Collector to Base Bias:

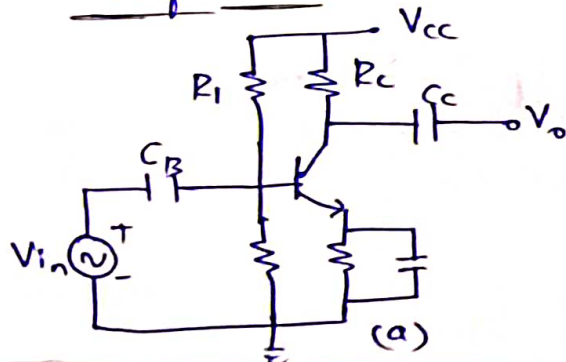


• This biasing technique provides feedback not only for D.C but also for A.C. Hence gain reduces in both the case.

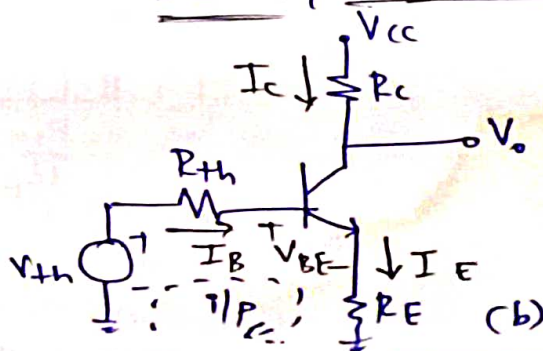
• This bias ckt. provides an eqn $I_E = I_c$ which is independent of β when.

$$R_c \gg R_B / \beta + 1$$

Self-Bias:



DC - equivalent ckt.



From D.C Analysis of the ckt. shown in above figure (b)
Let V_{th} & R_{th} be the Thevenin voltage

- The self biasing technique is shown in fig (a)
 - Here Resistor R_1 & R_2 will bias the transistor where as Capacitor C_B clamps the signal over D.C.
 - The Resistor R_E offer feedback for D.C & not for A.C because of capacitor C_E
- + The stability factor of the self-bias ckt is obtained as follows.

Apply KVL to i/p loop

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

$$\Rightarrow V_{th} - I_B R_{th} - V_{BE} - (I_C + I_B) R_E = 0$$

differentiate above eqⁿ w.r.t I_C .

$$\therefore 0 - \frac{\partial I_B}{\partial I_C} R_{th} - 0 - \left(1 + \frac{\partial I_B}{\partial I_C}\right) R_E = 0$$

$$\Rightarrow \frac{\partial I_B}{\partial I_C} (R_{th} + R_E) = R_E$$

$$\therefore \frac{\partial I_B}{\partial I_C} = \frac{-R_E}{R_{th} + R_E} \rightarrow (2)$$

$\therefore$ The stability factor S is

$$S = \frac{\partial I_C}{\partial I_{C0}} = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

$$= \frac{1 + \beta}{1 - \beta \left(\frac{R_E}{R_{th} + R_E} \right)} \text{ from (2)}$$

$$S = \frac{1 + \beta}{1 + \beta \frac{R_{th}}{R_E} + 1} \quad \text{if } R_E \gg R_{th}$$

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

Q3) Develop an expression for the stability factor for collector to base bias arrangement. Also explain how the collector to base bias circuit will stabilize the operating point for variation of β .

Solⁿ

Stability factor (S):

The value of collector current in a transistor is given as

$$I_C = \beta I_B + (1 + \beta) I_{C0} \rightarrow (1)$$

diff. wrt I_C

$$1 = \frac{\partial}{\partial I_C} (\beta I_B) + \frac{\partial}{\partial I_C} [(1 + \beta) I_{C0}]$$

Assuming β as constant, we get

$$1 = \beta \times \frac{\partial I_B}{\partial I_C} + (1 + \beta) \frac{\partial I_{C0}}{\partial I_C}$$

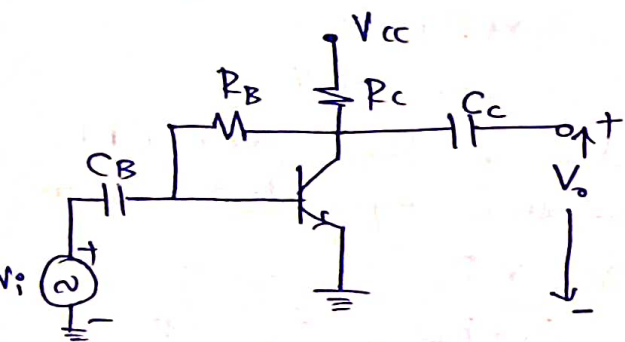
where $S = \frac{\partial I_C}{\partial I_{C0}}$

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

$$\Rightarrow S = S \cdot \beta \left[\frac{\partial I_B}{\partial I_C} \right] + (1 + \beta)$$

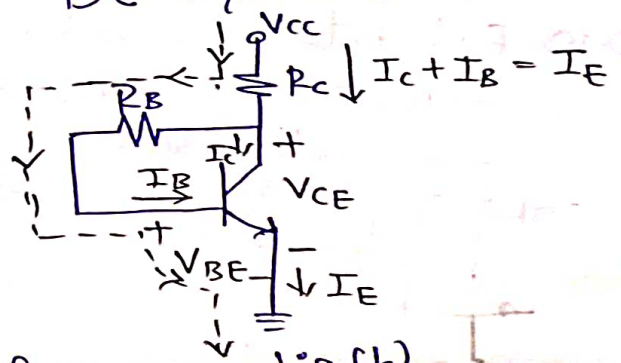
$$S \left[1 - \beta \left(\frac{\partial I_B}{\partial I_C} \right) \right] = (1 + \beta) \Rightarrow \boxed{S = \frac{1 + \beta}{1 - \beta \left(\frac{\partial I_B}{\partial I_C} \right)}}$$

+ Collector to base bias amplifier



fig(a)

DC equivalent ckt:



fig(b)

• Here R_B provides feedback for AC signals, from DC analysis fig(b)

Apply KVL to i/p loop

$$-V_{CC} + I_C R_C + I_B R_B + V_{BE} = 0 \rightarrow (1)$$

$$I_B = \frac{I_E}{\beta + 1} \rightarrow (2)$$

put (2) in (1)

$$V_{CC} = I_E R_C + \frac{I_E}{\beta + 1} R_B + V_{BE}$$

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

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

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

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

$$\Rightarrow I_E = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{\beta + 1}}$$

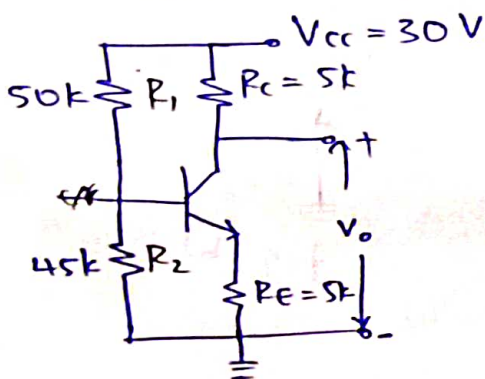
The above eqⁿ can be made independent of 'β'

$$\text{if } R_C \gg \frac{R_B}{\beta + 1}$$

at that time we can write

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

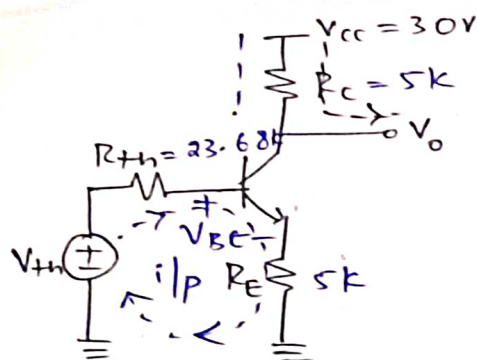
Q4) Estimate I_C & V_o for given ckt. with
 $I_{CBO} = 10 \mu A$, $\beta_{FE} = 100$, Given $V_{BE} = 0.6 V$



solⁿ Considering the given ckt. in Thevenin equivalent form

$$V_{th} = \frac{V_{CC} \times R_2}{R_1 + R_2} = \frac{30 \times 45}{50 + 45} = 14.21 V$$

$$R_{th} = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2} = 23.68 k\Omega$$



(3)

From KVL to i/p loop:

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

$$I_B = 25.74 \mu A$$

$$I_C = \beta I_B = 100 \times 25.74 \times 10^{-6} \Rightarrow I_C = 2.574 \text{ mA}$$

From KVL to outer loop

$$I_C = \frac{V_{CC} - V_O}{R_C} \Rightarrow V_O =$$

$$\Rightarrow V_O = V_{CC} - I_C R_C = 30 - 2.574 \times 10^{-3} \times 5 \times 10^3$$

$$V_O = 17.13 \text{ V}$$

Q5) The leakage currents of a transistor, with usual notations are $I_{CEO} = 410 \mu A$ & $I_{CBO} = 5 \mu A$, the $I_B = 30 \mu A$. Find I_C .

Sol

Given:

$$I_{CEO} = 410 \mu A$$

$$I_{CBO} = 5 \mu A$$

$$I_B = 30 \mu A$$

We have

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

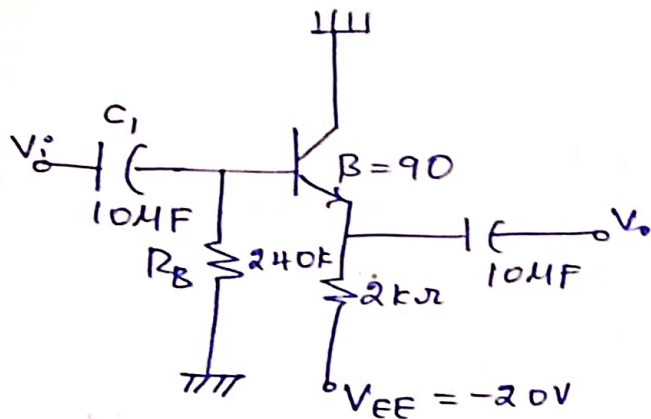
$$\Rightarrow \beta = \frac{I_{CEO}}{I_{CBO}} - 1 = \frac{410}{5} - 1 = 81$$

$$\beta = 81$$

$$\therefore I_C = \beta I_B + (1 + \beta) I_{CBO} \quad (\text{or}) \quad \beta I_B + I_{CEO}$$

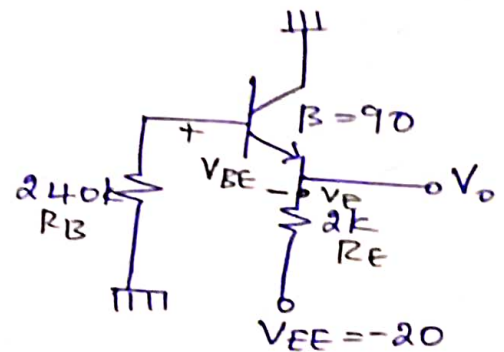
$$I_C = 2.84 \text{ mA}$$

Q6) Determine V_o & I_E for the following circuit.



Solⁿ

Consider the DC equivalent circuit



We have: $V_{BE} = 0.7V$ & $\therefore$ base terminal is connected to ground $V_B = 0$

$\therefore$ Apply KVL to i/p loop otherwise we can find I_E

$$\text{or } I_E = \frac{H.P - L.P}{R_E} = \frac{V_E - V_{EE}}{R_E}$$

$$\Rightarrow V_{BE} = V_B - V_E$$

$$0.7 = V_B - V_E$$

$$(\text{or}) \underline{V_E = -0.7V}$$

$$I_E = \frac{-0.7 - (-20)}{2 \times 10^3} = 9.65 \text{mA} \approx I_C$$

$$\boxed{I_E = 9.65 \text{mA}}$$

$$\therefore V_o = -20 + I_E R_E$$

$$= -20 + 9.65 \text{mA} \times 2 \text{k}$$

$$\boxed{V_o = -0.7V}$$

Q7) A p-n-p transistor has $V_{EB} = 0.8V$ at $I_C = 1A$ & what do you expect V_{EB} to become at $I_C = 10 \text{mA}$ & at $I_C = 5A$?

Solⁿ $V_{EB} = 0.8V, I_C = 1A$

$$I_C = I_S e^{V_{EB}/V_T}$$

$$V_T = 25.86 \text{mV at } 300K$$

$$I_S = I_C / e^{V_{EB}/V_T}$$

$$\Rightarrow I_S = 3.67 \times 10^{-14} A$$

For $I_C = 10 \text{mA}$ $V_{EB2}/26 \text{mV}$

$$10 \text{mA} = (3.67 \times 10^{-14}) e^{V_{EB2}/26 \text{mV}}$$

$$\Rightarrow \boxed{V_{EB2} = 0.6808V}$$

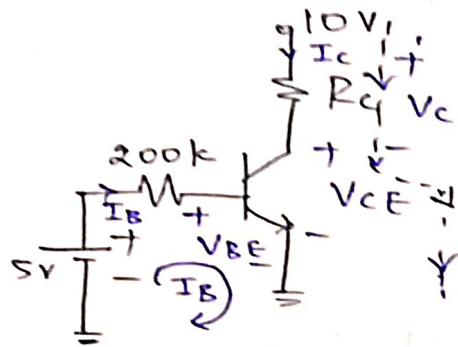
For $I_C = 5A$ $V_{EB3}/26 \text{mV}$

$$5 = (3.67 \times 10^{-14}) e^{V_{EB3}/26 \text{mV}}$$

$$\Rightarrow \boxed{V_{EB3} = 0.8418V}$$

(4)

Q8) A silicon transistor with $V_{BE(sat)} = 0.8V$ & $h_{fe} = 100$ $V_{CE(sat)} = 0.2V$ is used the circuit shown. Find the minimum value of R_C for which the transistor remains in saturation.



Solⁿ Given: $V_{BE(sat)} = 0.8V$
 $h_{fe} = \beta = 100$

$V_{CE(sat)} = 0.2V$

Apply KVL to o/p loop

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

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

$$= 10 - 0.2$$

Apply KVL to i/p loop, $I_C R_C = 9.8V \rightarrow \text{①}$

$$-5 + I_B 200k + V_{BE} = 0$$

$$I_B = \frac{5 - 0.8}{200k} = \frac{4.2}{200k}$$

$$\text{WKT } I_C = \beta I_B$$

$$\therefore I_C = 100 \times \frac{4.2}{200k}$$

$$I_C = 2.1mA$$

from eqⁿ ①

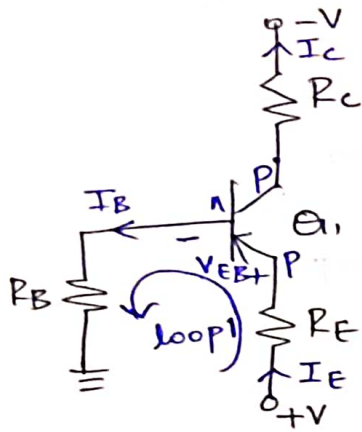
$$I_C R_C = 9.8$$

$$\Rightarrow R_C = 9.8 / I_C = 9.8 / 2.1mA$$

$$\boxed{R_C = 4.67k\Omega}$$

$\therefore$ The minimum value of R_C for which the transistor remains in saturation is $4.67k\Omega$

Q19) Derive an expression for stability factor of the ckt shown in fig.



Sol Apply KVL for given ckt at i/p loop

$$-V + I_E R_E + V_{EB} + I_B R_B = 0 \rightarrow (1)$$

$$\text{WKT, } I_E = I_C + I_B \rightarrow (2)$$

$$\text{or } I_C = \beta I_B + I_{C0}(1 + \beta) \rightarrow (3)$$

put (2) in (1)

$$-V + (I_C + I_B) R_E + V_{EB} + I_B R_B = 0$$

$$V - V_{EB} = I_C R_E + I_B (R_B + R_E)$$

$$\text{put } I_B = \frac{I_C - I_{C0}(1 + \beta)}{\beta}$$

$$\Rightarrow V - V_{EB} = I_C R_E + (R_B + R_E) \left[\frac{I_C - I_{C0}(1 + \beta)}{\beta} \right] \rightarrow (4)$$

$$\text{WKT, } S = \frac{\Delta I_C}{\Delta I_{C0}} \Leftarrow \text{Stability factor}$$

diff. eqn (4) wrt I_C

$$\Rightarrow 0 = R_E + \frac{(R_B + R_E)}{\beta} \left[1 - (\beta + 1) \frac{\partial I_{C0}}{\partial I_C} \right] \quad \text{wrt } I_C$$

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

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

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

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

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

Q10) A transistor is $\textcircled{S}$ connected in CE configuration as an amplifier. The parameters of the transistor specified are:

$$I_B = 25 \mu A, I_{CBO} = 100 \text{ nA}, \beta = 100$$

Find its I_C , I_E , I_{CEO} & α .

Solⁿ Given data is for common emitter configuration amplifiers.

$$I_B = 25 \mu A$$

$$I_{CBO} = 100 \text{ nA}$$

$$\beta = 100$$

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

$$= 100 \times 25 \mu + 100 \text{ n}(1 + 100)$$

$$\boxed{I_C = 2.5101 \text{ mA}}$$

$$\Rightarrow I_E = I_C + I_B$$

$$= 2.51 \text{ m} + 25 \mu$$

$$\boxed{I_E = 2.5351 \text{ mA}}$$

$$\Rightarrow I_{CEO} = I_{CBO}(1 + \beta)$$

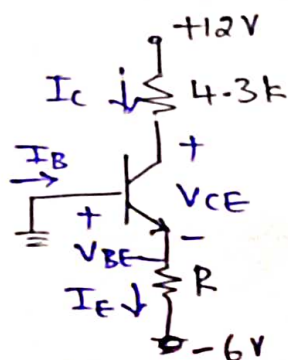
$$= (1 + 100) \times 100 \times 10^{-9}$$

$$\boxed{I_{CEO} = 10.1 \mu A}$$

$$\Rightarrow \alpha = \beta / \beta + 1 = \frac{100}{100 + 1}$$

$$\boxed{\alpha = 0.99}$$

Q11)



For the ckt shown: $V_{BE} = 0.7 \text{ V}$, $\beta = 50$, $V_{CE} = 4 \text{ V}$. Find R_E & stability factor's expression.

Ans:-

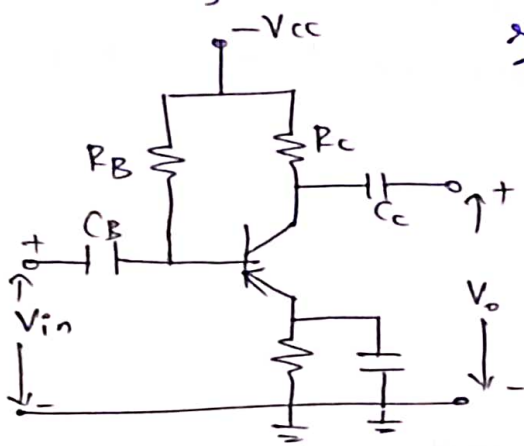
$$I_C = 5.3 / R_E, V_B = 0 \because B \text{ is given to gnd. \& } I_B$$

$$I_C \approx I_E$$

$$R_E = 2.61 \text{ k}\Omega$$

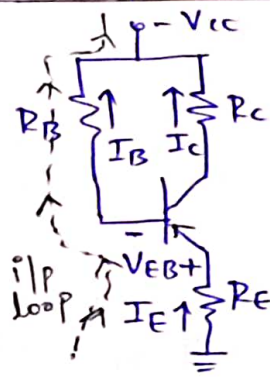
$$S = \frac{\partial I_C}{\partial I_{C0}} = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}} = \frac{1 + \beta}{1 + \beta \left[\frac{R_C}{R_E} + 1 \right]}$$

Q12) For the bias ckt. shown in fig. determine the value of R_B to yield an operating point at $I_C = 5\text{mA}$. Assume $\beta_0 = 60$, $V_{EB} = 0.7\text{V}$, $R_C = 500\Omega$, $R_E = 100\Omega$, $E_g - V_{CC} = -6\text{V}$.



What are advantages & one limitation of this type of biasing?

DC equivalent ckt.



Given: $I_C = 5\text{mA}$

$\beta_0 = 60$

$V_{EB} = 0.7\text{V}$

$R_C = 500\Omega$

$R_E = 100\Omega$

$V_{CC} = 6\text{V}$

Apply KVL to i/p loop

$$\Rightarrow I_E R_E + V_{EB} + I_B R_B - V_{CC} = 0$$

$$\Rightarrow R_B = \frac{V_{CC} - I_E R_E - V_{EB}}{I_B}$$

$$\Rightarrow R_B = \frac{V_{CC} - I_C R_E - V_{EB}}{I_C / \beta}$$

$$= \frac{6 - 5 \times 10^{-3} \times 100 - 0.7}{5 \times 10^{-3} \times \frac{1}{60}}$$

$$\Rightarrow \boxed{R_B = 57.60\text{k}\Omega}$$

Advantage: This Bias circuit is more stable than the fixed bias circuit

Disadvantage: For stability, the ratio R_B / R_E should be as small as possible.