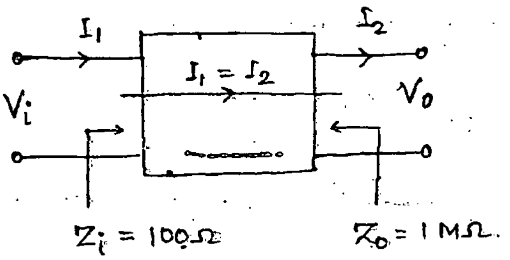
Bipolar Junction Transistor

Diode Drawbacks :-
1. It can't be amplifier.
2. It can't be inverter.

Two Port Network.



$$P_o = I_2^2 \cdot Z_o$$
$$P_i = I_1^2 \cdot Z_i$$
$$\Rightarrow P_V = \frac{P_o}{P_i}$$

$$\Rightarrow P_V = \frac{Z_o}{Z_i} = \frac{1 M\Omega}{100\Omega} = 10^4 \Omega.$$

$$\Rightarrow \boxed{P_o > P_i}$$

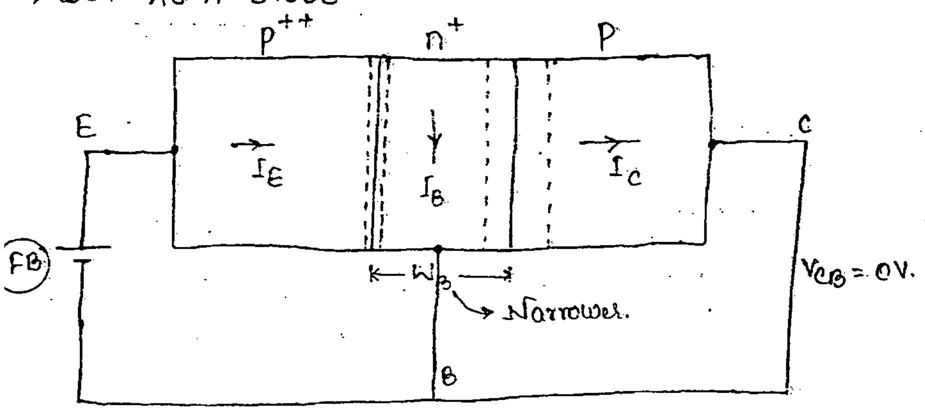
TRANSISTOR
↓
Transfer + resistor

"Transfer of current from one impedance level to other impedance level".

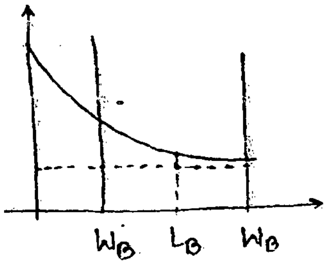
19/10/14.

Basic Transistor Operation.

→ BJT AS A DIODE



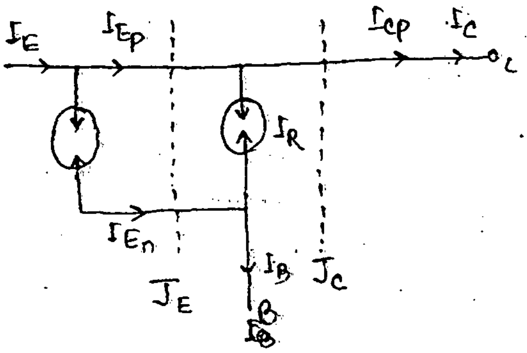
~~V_E~~ V_{EB} = constant ; $\frac{W_B}{L_B} << 1$; $V_{CB} = 0$.



$\frac{W_B}{L_B} << 1$ (width of the base is narrow).

$V_{CB} = 0$.

$$\boxed{e^{-W_B/L_B} = 1 - \frac{W_B}{L_B}} \rightarrow \text{Linear.}$$



I_R = Recombination current.

I_{Ep} = diffusion current.

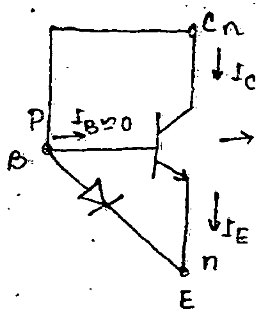
$I_E \uparrow = I_{Ep} \uparrow + I_{En}$ (constant)

$I_C \uparrow = I_{Cp} \uparrow$

$I_B \downarrow = I_R \downarrow + I_{En}$ (constant).

$I_E = I_B \downarrow + I_C$

$I_B \simeq 0 \Rightarrow \boxed{I_E \simeq I_C}$



→ BJT AS A DIODE.

BJT DESIGN PARAMETER.

1. Emitter injection Efficiency :-

$$\boxed{\gamma = \frac{I_{Ep}}{I_E}} \Rightarrow \gamma = \frac{I_{Ep}}{I_{Ep} + I_{En}} = \frac{1}{1 + \frac{I_{En}\,(\text{constant})}{I_{Ep} \uparrow}} \simeq 1.$$

$\boxed{\gamma \simeq 1}$

2. Base Transport Factor (β^*)

$$\boxed{\beta = \frac{I_{CP}}{I_{EP}}} \qquad \beta = \frac{I_{EP} - I_R}{I_{EP}} = 1 - \frac{I_R \downarrow}{I_{EP}\uparrow} \simeq 1$$

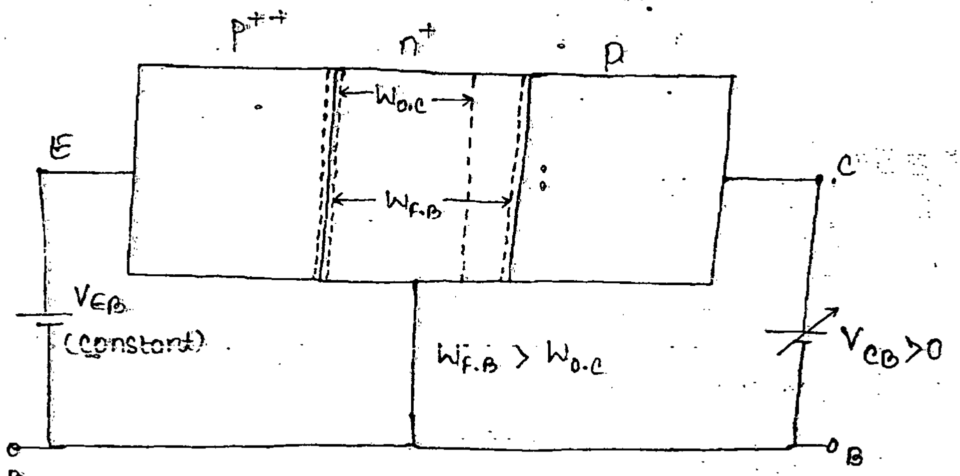
$$\boxed{\beta \simeq 1.}$$

3. Current Gain (α).

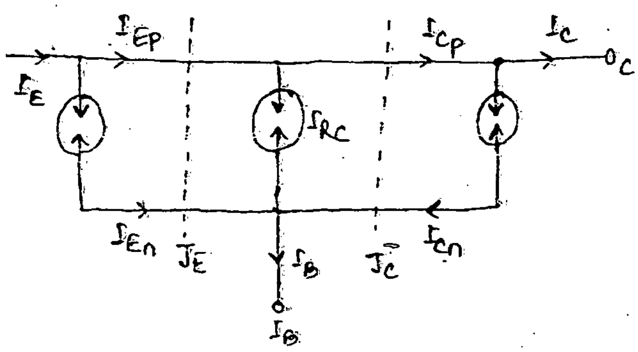
$$\boxed{\alpha = \frac{I_C}{I_E}} \;;\; \alpha = \frac{I_{CP}}{I_E} = \frac{I_{CP}}{I_{EP}} \cdot \frac{I_{EP}}{I_E} = \beta^* . \gamma$$

$$\boxed{\alpha = \beta^* . \gamma}$$

☐ TESTING OF BJT IN SATURATION :



V_{EB} = constant ; $\frac{W_B}{L_B} << 1$; $V_{CB} > 0$ (FB)



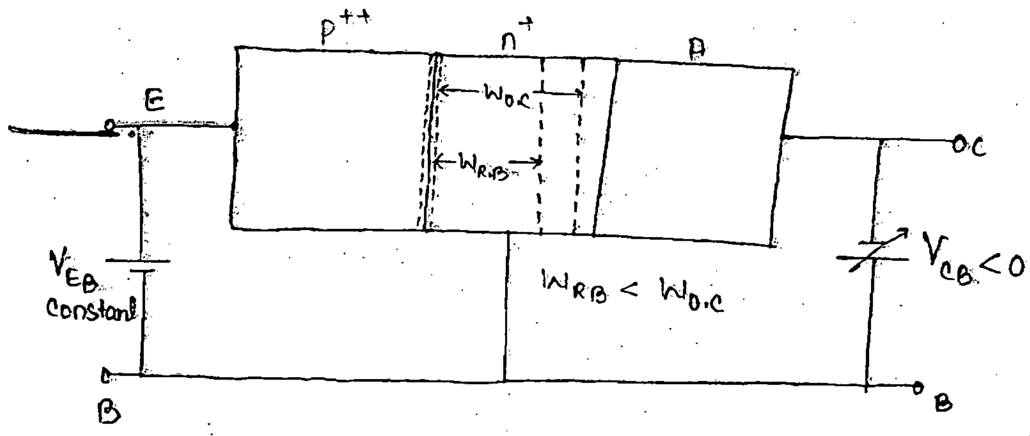
$I_E \downarrow = I_{EP}\downarrow + I_{En}$ (constant)

$I_C \downarrow = I_{CP}\downarrow + I_{Cn}\uparrow$

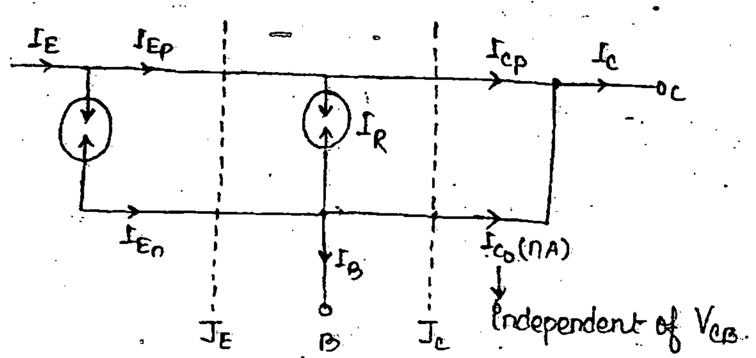
$I_B \uparrow = I_R \uparrow + I_{Cn}\uparrow + I_{En}$ (constant)

BJT is failure in Saturation region.

TESTING OF BJT IN ACTIVE REGION.



V_{EB} = constant ; $\frac{W_B}{L_B} << 1$; $V_{CB} < 0$ (RB).



$I_E = I_{Ep}\uparrow + I_{En}$ (constant)

$I_c = I_{cp}\uparrow + I_{co}$ (negligible) $\Rightarrow I_E \simeq I_{cp} \rightarrow$ BJT is good in Active Region.

$I_B = I_{En} + I_R \downarrow - I_{co}$ (negligible)
(const)

DESIGN CONDITION IN BJT.

1. Doping Level :- $N_E >> N_B$, $N_B > N_C$ } Integrated BJT.

$N_E >> N_B$, $N_B \simeq N_C$ } Discrete BJT. (Normal transistor)

2. $\frac{W_B}{L_B} << 1$:-

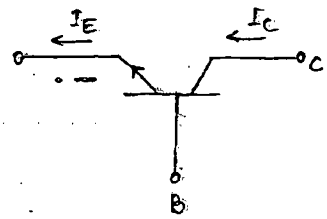
Width of Base should be narrow.

3. Area collector > Area Emitter > Area Base :-

Power loss across collector > Power loss across Emitter.

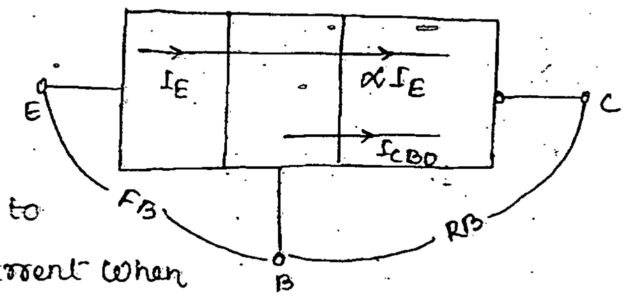
BJT CONFIGURATION.

1. COMMON BASE. (CB)



$\boxed{\alpha = \frac{I_C}{I_E}}$; $\boxed{I_C = \alpha . I_E}$; $\boxed{\alpha = 0.9 \text{ to } 0.99}$

Magnitude Analysis :-



Where I_{CBO} = collector to Base leakage current when i/p is open (Emitter)

$$\boxed{I_C = \alpha I_E + I_{CBO}}$$

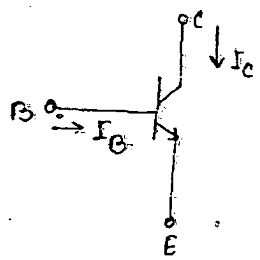
$$I_E = I_B + I_C$$

$$I_C = \alpha (I_B + I_C) + I_{CBO}$$

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

$$\Rightarrow \boxed{I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} . I_{CBO}}$$

2. COMMON EMITTER (CE)



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

β = 20 to 500.

β = 20 to 50 (Power amplifier)

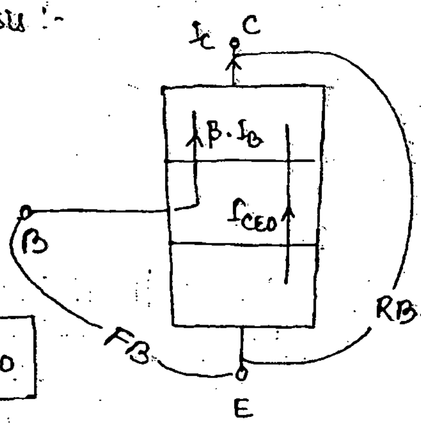
β = 50 to 150 (Voltage amplifier)

β = 15 to 500 (Integrated amplifier ⇓ OP AMP.

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

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} \quad \boxed{\alpha = \frac{\beta}{1+\beta}} \quad \boxed{\frac{1}{1-\alpha} = \cancel{1+\beta}}$$

Magnitude Analysis :-



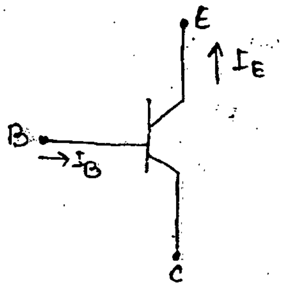
$$\boxed{I_C = \beta I_B + I_{CEO}} \rightarrow CE$$

$$\boxed{I_C = \frac{\alpha}{1-\alpha} \cdot I_B + \frac{1}{1-\alpha} \cdot I_{CBO}} \rightarrow CB$$

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

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

3. COMMON COLLECTOR (CC).



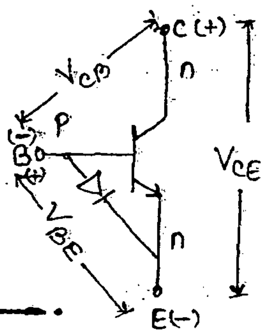
$$\boxed{\gamma = \frac{I_E}{I_B}}$$

$$\gamma = \frac{I_E}{I_B} = \frac{I_E}{I_E - I_C} = \frac{1}{1 - \frac{I_C}{I_E}} = \frac{1}{1-\alpha} = 1+\beta.$$

$$\Rightarrow \boxed{\gamma \approx \beta}$$

SYMBOLS AND NOTATIONS OF BJT

npn



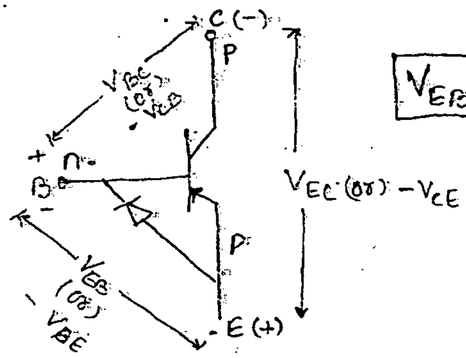
$$\boxed{V_{BE} + V_{CB} = V_{CE}}$$

$V_{CE} \rightarrow$ lower $\rightarrow$ (-)

$\downarrow$ higher $\rightarrow$ (+)

ily V_{BE} & V_{CB}.

PNP



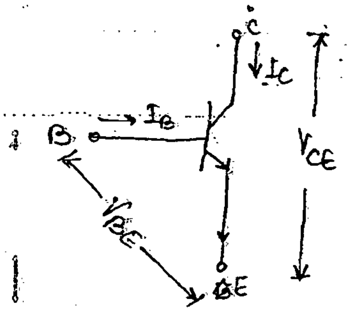
$$\boxed{V_{EB} + V_{BC} = V_{EC}}$$

☐ BJT OPERATING REGIONS.

REGION	J_E	J_C	
Active Region	FB	RB	→ Amplifier
Saturation Region	FB	FB	Switching (NOT)
Cut off Region	RB	RB	
Reverse active region	RB	FB	→ (X) attenuator

☐ GRAPHICAL ANALYSIS OF BJT.

1. COMMON EMMITER (CE).



Input parameters :- V_{BE}, I_B.

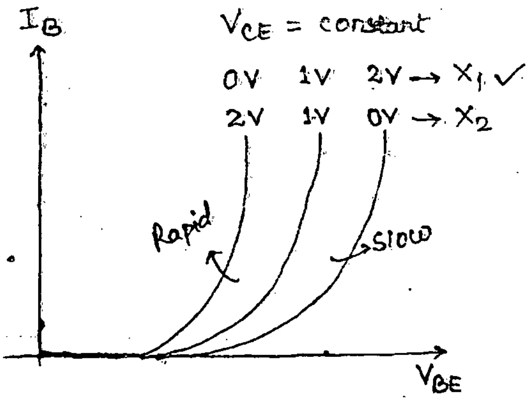
Output parameter :- V_{CE}, I_C

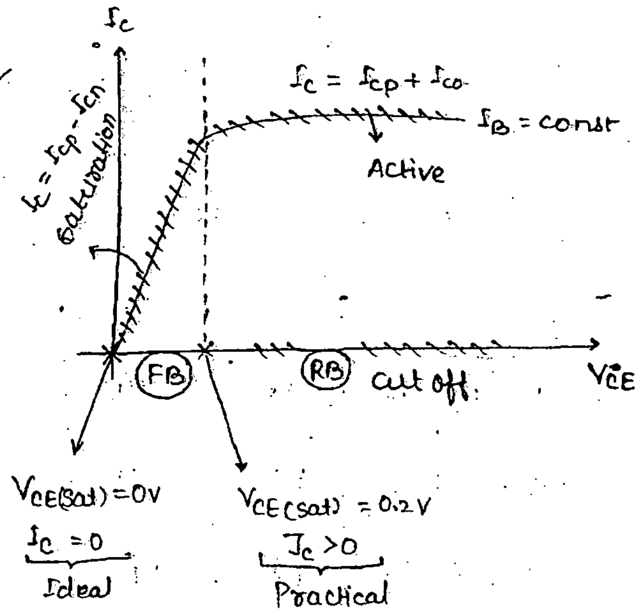
NOTE:→ 1. To get the i/p characteristics of BJT o/p voltage should be constant (width of base can change)

2. o/p current can't change i/p current because BJT is a unilateral device.

3. To get the ~~o/p characteristics of~~ BJT i/p current should be constant because BJT is a <u>current controlled</u> device.

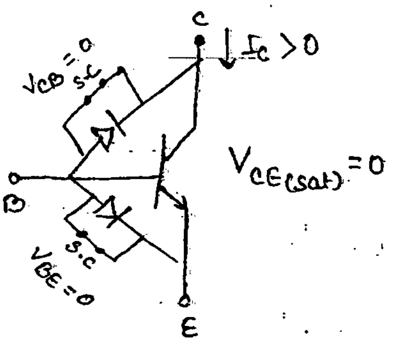
∵ I/p impedance is low ∴ ~~hence~~ short CKted ∴ current controlled.

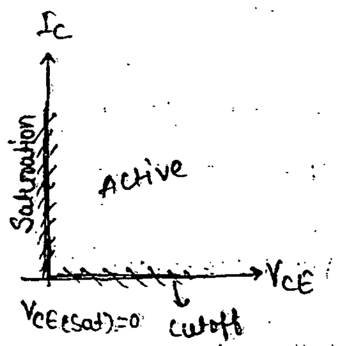




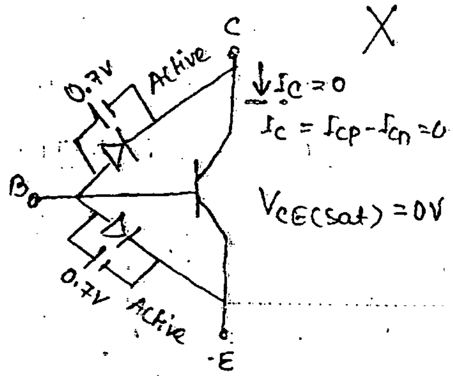
As $V_{CE} \uparrow$ $W_B \downarrow$ $I_R \downarrow$ $I_B \downarrow$.

<u>Ideal (Saturation)</u>

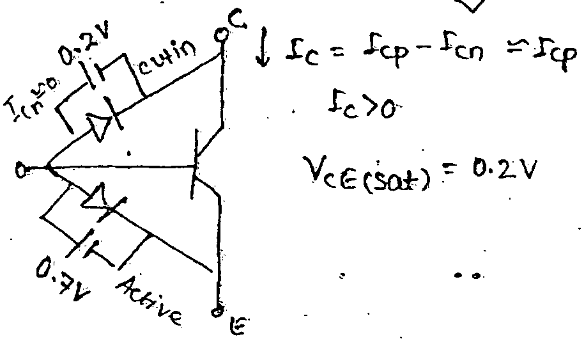




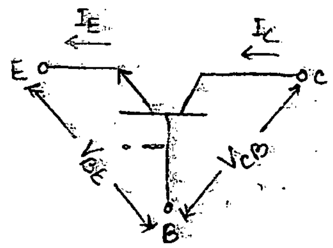
<u>Practical (Saturation)</u> X

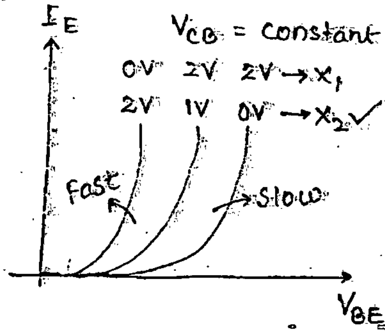


<u>Saturation (Practical)</u> ✓

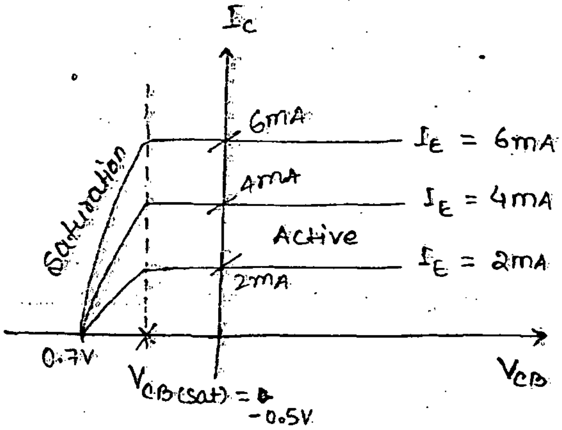


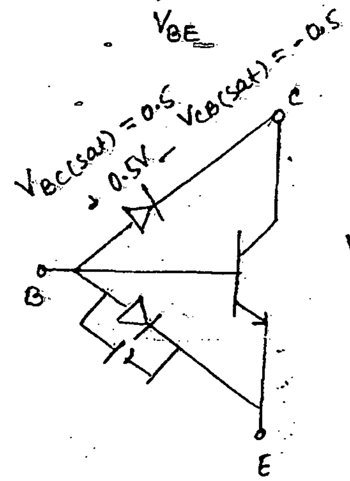
2. COMMON BASE (CB)





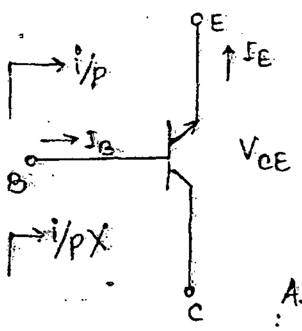
$V_{CB}\uparrow\ W_B\downarrow\ I_R\downarrow\ I_B\downarrow\ I_{Ep}\uparrow\ I_E$

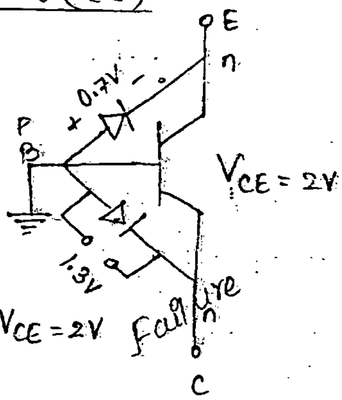




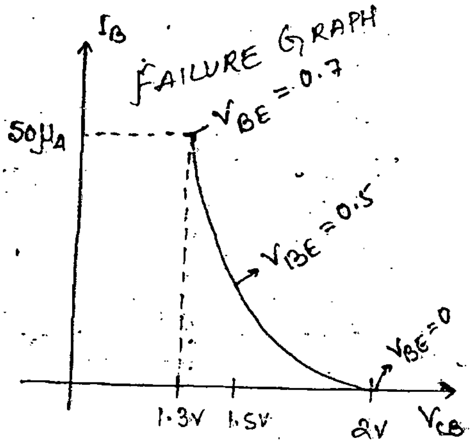
$V_{CE(sat)} = 0.2V$

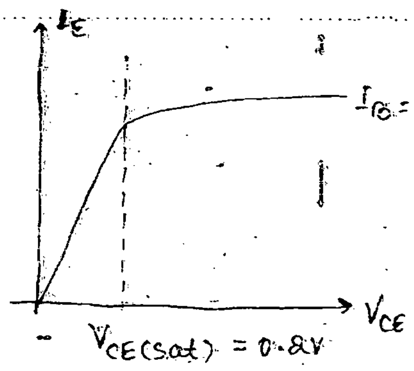
3. COMMON COLLECTOR (CC)





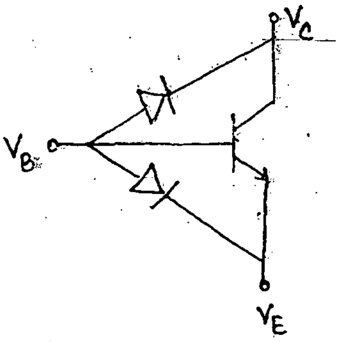
Assume $V_{CE} = 2V$





TESTING OF BJT IN DIFFERNT OPERATING REGION.

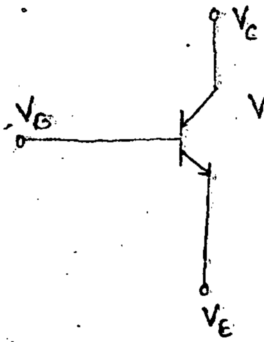
TEST - 1



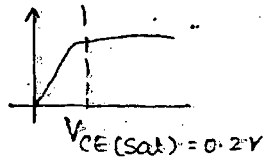
$\left.\begin{array}{l} V_B > V_E \\ V_B > V_C \end{array}\right\}$ Saturation

$\left.\begin{array}{l} V_B > V_E \\ V_B < V_C \end{array}\right\}$ Active.

TEST - 2



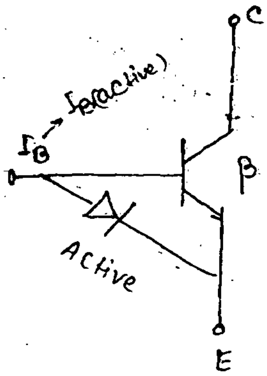
$V_{CE} = V_C - V_E$

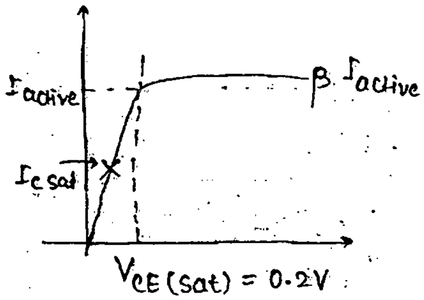


If $V_{CE} > V_{CE(sat)} \rightarrow$ Active

$V_{CE} < V_{CE(sat)} \rightarrow$ Saturation.

TEST - 3

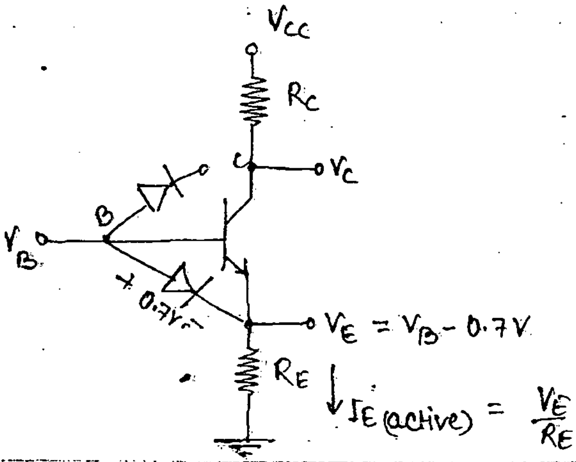




$I_C = \beta I_B \longrightarrow$ Active

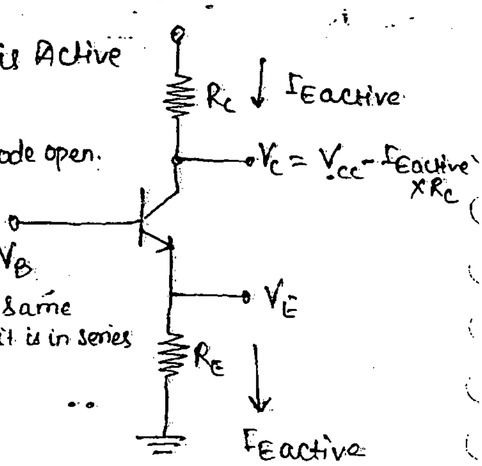
$I_C < \beta I_B \longrightarrow$ Saturation

WAY OF SOLVING PROBLEM.



Assume Q is Active

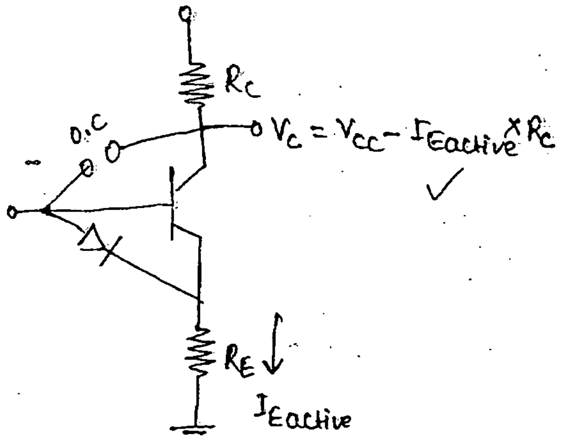
Assume BC diode open.



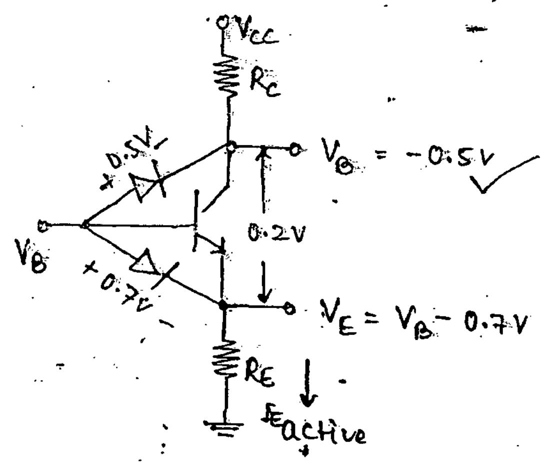
$I_{E active}$ will be same because it is in series

~~Case-I~~ | Case II

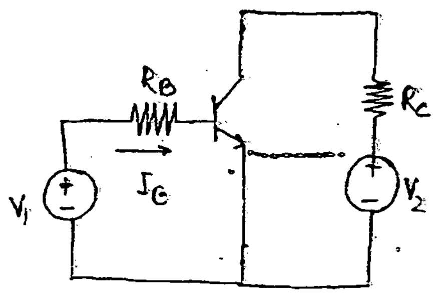
$V_C > V_B$ (Active)



$V_C < V_B$ (Saturation)

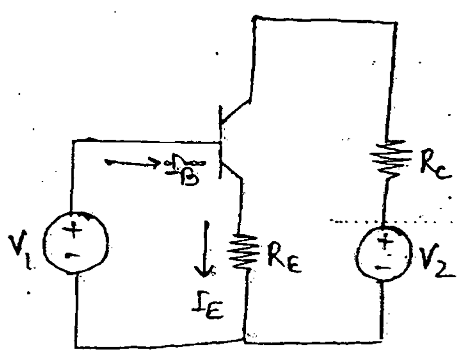


☐ DUAL BATTERY DESIGN.



$$V_1 = I_B R_B + V_{BE}$$
(or)
$$V_1 = I_E \cdot \frac{R_B}{1+\beta} + V_{BE}$$

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



$$V_1 = I_E R_E + V_{BE}$$
(or)
$$V_1 = I_B \cdot (1+\beta) R_E + V_{BE}$$

Ch-4

Q1. I_Q current come from diode.

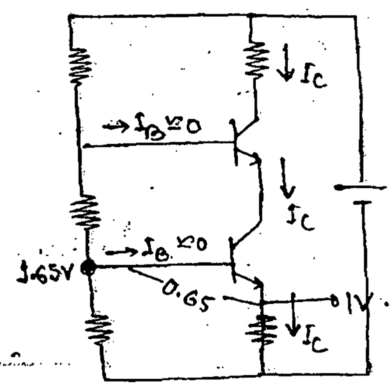
$V_E = V_B - 0.7 = 0 - 0.7 = 0.7$

V_B is grounded

$\therefore I_Q = 8\,mA.$

<u>NOTE</u> :- Testing of operating Region depends on two Parameters → (1) i/p Battery
(2) Collector Resistor R_C.

Ch-4.
<u>Q8.</u>



$V_{BE} = 0.65V$

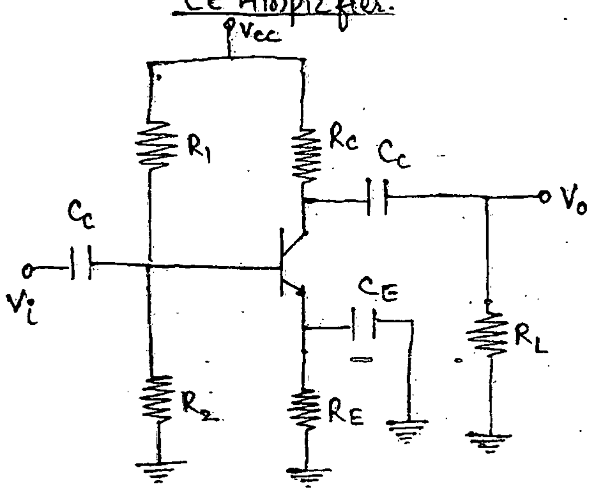
β is large. ⇒ $\beta\uparrow = \frac{I_C}{I_B\downarrow}$

∴ $I_B \simeq 0$.

☐ BJT BIASING:

→ DC LOAD LINE AND OPERATING POINT Q.

<u>CE Amplifier.</u>

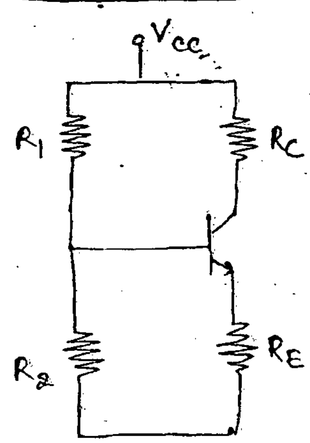


<u>DC Analysis</u>

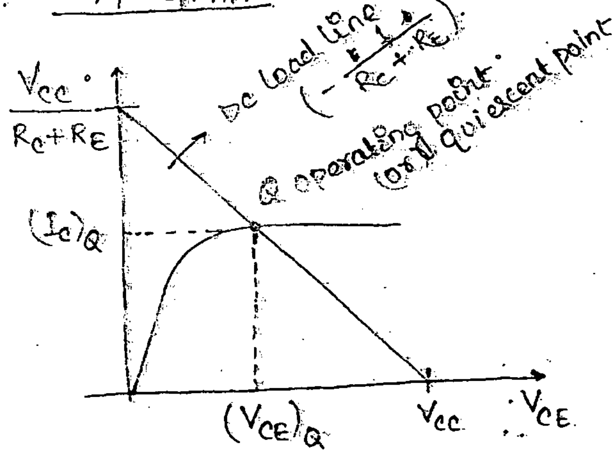
(1) AC Should be grounded.

(2) $X_C \propto \frac{1}{f} \rightarrow \infty$ (O.C)
$f \rightarrow = 0$ (DC)

<u>DC Model</u>



O/P GRAPH



O/P Loop Equation (∴ o/p resistance is taken)

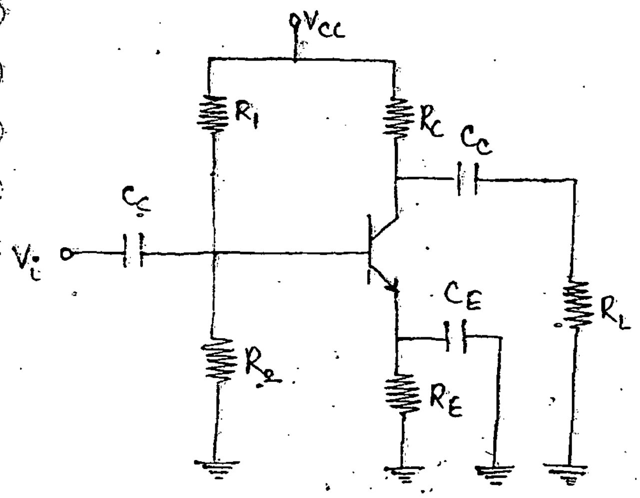
$$V_{CC} = I_C(R_C+R_E) + V_{CE}$$

$$I_C = \left[-\frac{1}{R_C+R_E}\right]V_{CE} + \frac{V_{CC}}{R_C+R_E}$$

$$\downarrow \quad Y \qquad \downarrow \quad M \qquad \downarrow \quad X \qquad \downarrow \quad C$$

→ AC LOAD LINE

CE Amplifier

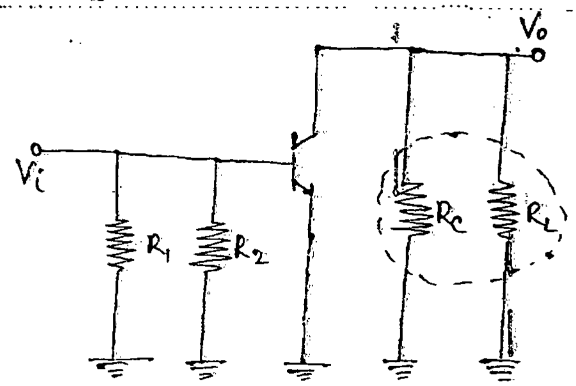


Ac Analysis

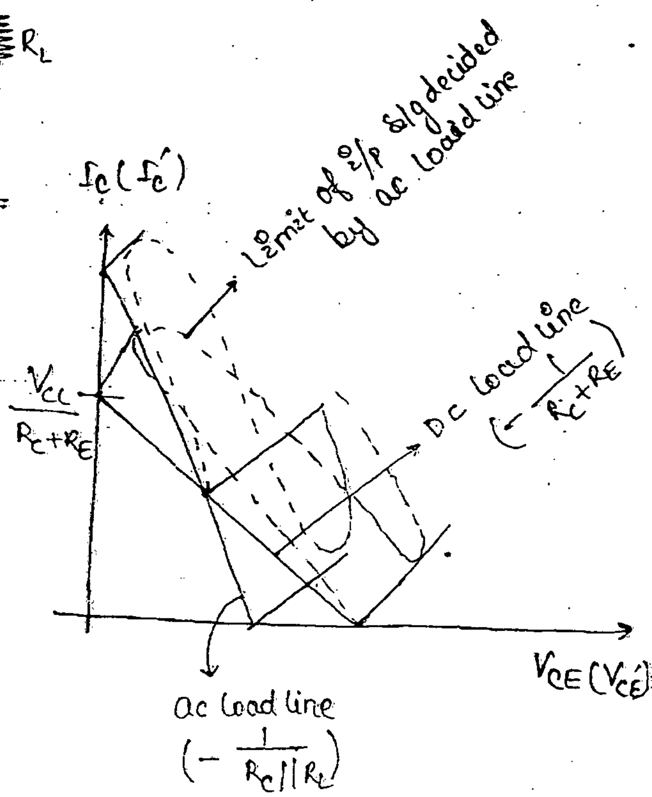
(1) DC should be grounded.

(2) $X_C \propto \frac{1}{f \to \infty} \to 0$ (S-C)

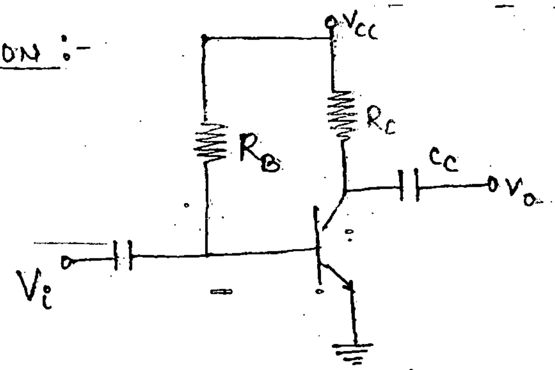
Ac Model



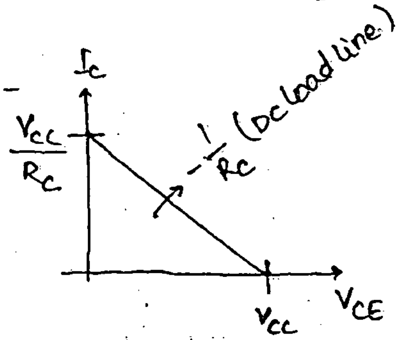
$R_{ac} = R_C || R_L$

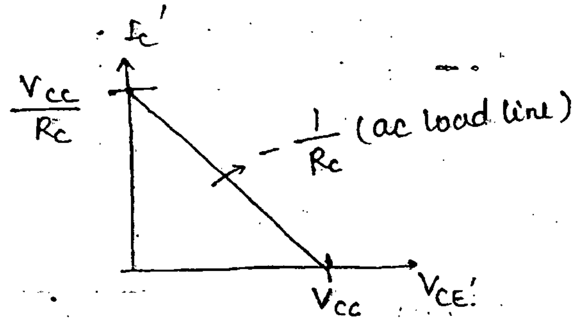


QUESTION :-

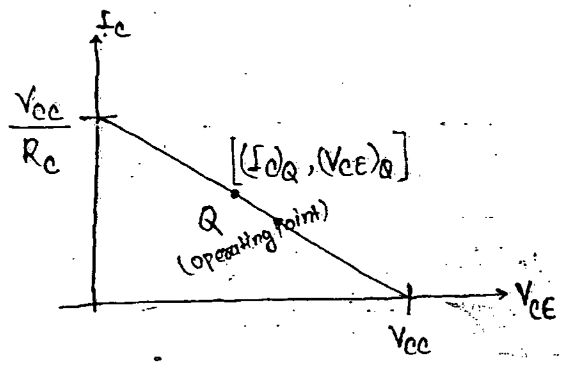


SOLUTION :-





→ TEMPERATURE DEPENDENCE ON BJT PARAMETER.

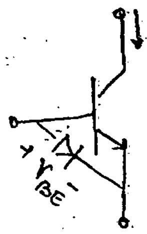


$\therefore$ Q is unstable.

$(I_C)_Q$ depends upon :-

(1) I_{CO} ; $I_E = \beta I_B + (1+\beta) I_{CO}$

(2) V_{BE} ; $I_C = I_0 \, e^{V_{BE}/V_T}$



(3) $I_C = \beta I_B$

$I_E = \underbrace{I_0 e^{V_{BE}/V_T}}_{\text{diode eq}^n}$

☐ BIASING.

It is a technique of circuit which makes the operating point stable w.r.t temperature variation.

1. I_{CO} VS TEMPERATURE.

I_{CO} increases by 7% for every °C rise in temperature.

'OR'

I_o doubles for every 10°C rise in temperature.

2. V_{BE} Vs TEMPERATURE.

$$\frac{dV_{BE}}{dT} = -2.5\ mV/°C. \qquad T\uparrow;\ V_{BE}\downarrow;\ I_C\downarrow.$$

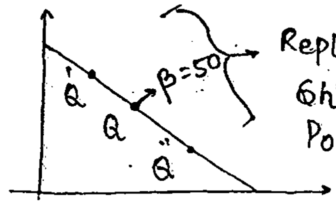
3. β :-

(a) β Vs Temperature

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

$T\uparrow$ $\underset{\text{(Neglected)}}{I_{CO}\uparrow}$ $I_C\uparrow$ $\beta\uparrow$.

(b) β Replacement Problem.



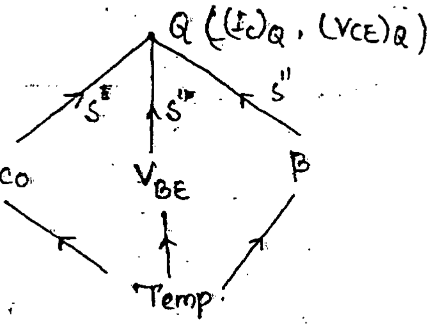
Replacing a transistor shifts the operating point Q because of mismatching.

STABILITY FACTOR. (S)

It is measure of variation of Q-point with respect to temperature.

$$S' = \left.\frac{\partial I_C}{\partial I_{CO}}\right|_{\underset{\text{const}}{V_{BE},\beta}} \qquad S' = \left.\frac{\partial I_C}{\partial V_{BE}}\right|_{\underset{\text{const}}{I_{CO},\beta}}$$

$$S'' = \left.\frac{\partial I_C}{\beta}\right|_{\underset{\text{const}}{I_{CO},V_{BE}}}$$



S Factor :- $I_C = \beta I_B + (1+\beta)\cdot I_{CO}$

d. w.r to I_C

$$\Rightarrow 1 = \beta\cdot\frac{\partial I_B}{\partial I_C} + (1+\beta)\frac{\partial I_{CO}}{\partial I_C} \quad 1/S$$

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

<u>conclusion</u> :- 1. The most dominate parameter w.r.t temp is I_{CO}.

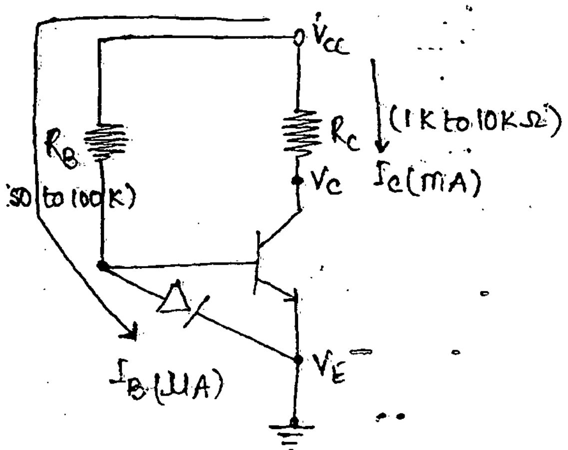
2. Ideally the stability factor should be zero. Pratically it should be minimum in value.

Biasing ckt

- Stabilization ckts.
  - Fixed Bias ($S = 10$)
  - Collector to Base bias ($S \simeq 45$)
  - Voltage divider Bias (or) Self Bias (or) Emitter Bias (or) Universal Bias ($S \simeq 1$)
- Compensation ckts
  - Diode
  - Thermistors: $T\uparrow, R_T\downarrow$
  - Sensistors: $T\uparrow R_S\uparrow$

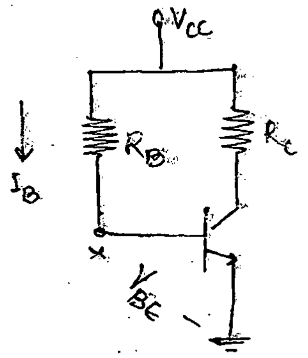
1. FIXED BIAS

<u>Single Supply Design</u>



$\boxed{\frac{R_B}{R_C} >> 1}$ $\boxed{(V_{CE})_Q = \frac{V_{CC}}{2}}$

$\boxed{V_B > V_E}$ $\boxed{V_C > V_B}$ → Active Region.



I/P Loop

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

$$\boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B}} \rightarrow \text{Fixed.}$$

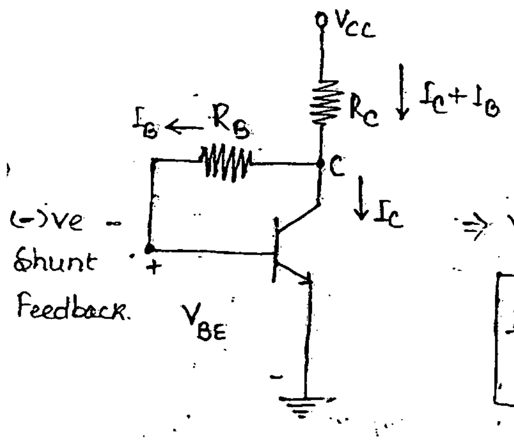
fixed

$$I_C = \beta I_B \rightarrow \text{fixed}$$

S Factor :- $S = \dfrac{1+\beta}{1-\beta \dfrac{\partial I_B}{\partial I_C}}$ $\Rightarrow$ $I_B = \dfrac{V_{CC} - V_{BE}}{R_B}$ $\Rightarrow$ d. w.r. to I_C

$$\frac{\partial I_B}{\partial I_C} = 0 \Rightarrow \boxed{S = 1+\beta}$$

2. COLLECTOR TO BASE BIAS



I/P Loop

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

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

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

O/P Loop

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

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

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

i/p $\quad$ o/p

Stabilization.

$T\uparrow; I_{CO}\uparrow; I_C\uparrow; (I_C + I_B)R_C\uparrow; V_{CE}\downarrow; I_B\downarrow;$
$I_C\downarrow$

$$\boxed{I_B \propto V_{CE}}$$

S-factor.

$$V_{CC} = I_B(R_B+R_C) + I_C R_C + V_{BE} \rightarrow \text{i/p loop.}$$

d. w.r. to I_C

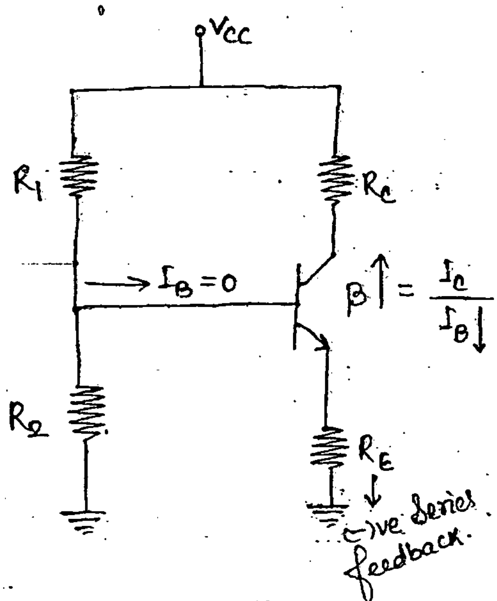
$$\Rightarrow 0 = \frac{\partial I_B}{\partial I_C}(R_B+R_C) + R_C + 0 \quad \Rightarrow \boxed{\frac{\partial I_B}{\partial I_C} = -\frac{R_C}{R_B+R_C}}$$

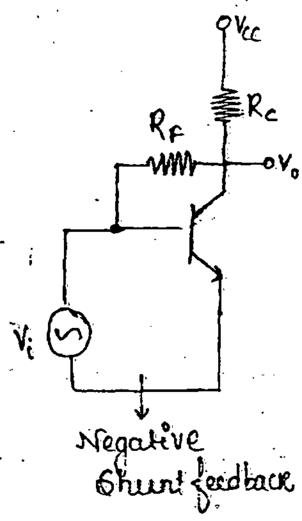
$$\boxed{S \doteq \frac{1+\beta}{1+\beta\cdot\frac{R_C}{R_B+R_C}}} \qquad S = \frac{(1+\beta)\cdot(R_B+R_C)}{R_B+(1+\beta)R_C} \Rightarrow S = \frac{(1+\beta)\cdot \cancel{R_C}\left[1+\frac{R_B}{R_C}\right]}{\cancel{R_C}\left[1+\beta+\frac{R_B}{R_C}\right]}$$

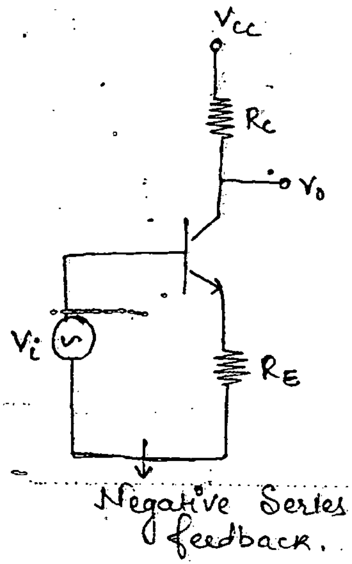
$$\Rightarrow \boxed{\frac{R_B}{R_C} << 1} \quad \boxed{S \simeq 1}$$

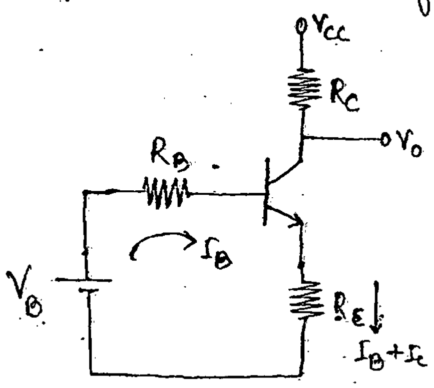
Against assumption ∴ Failure.

3. VOLTAGE DIVIDER BIAS.









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

$$\boxed{R_B = R_1 // R_2}$$

I/p Loop.

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

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

d. w.r. I_C

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

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

$$\Rightarrow S = \frac{(1+\beta)\left(1+\frac{R_B}{R_E}\right)}{\cancel{1+}\beta + \frac{R_B}{R_E}} \Rightarrow \boxed{\frac{R_B}{R_E} << 1} \; ; \; \boxed{S \simeq 1}$$

DESIGN CONDITIONS.

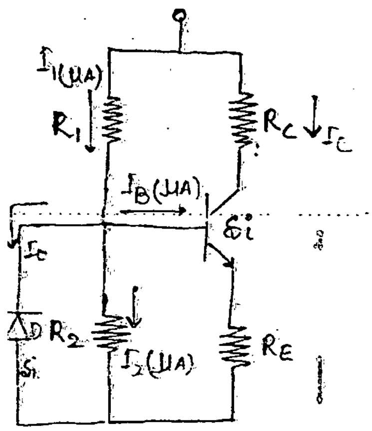
1. If $\frac{R_B}{R_E} << 1$; the stability factor is nearer to unity.

2. To get R_B value less take a condn $R_1 > R_2$.

3. If R_E increases (-)ve feedback in the ckt increases which will affect the S/g gain in a.c analysis.
To solve this problem take a capacitor in parallel to feedback resistor R_E.

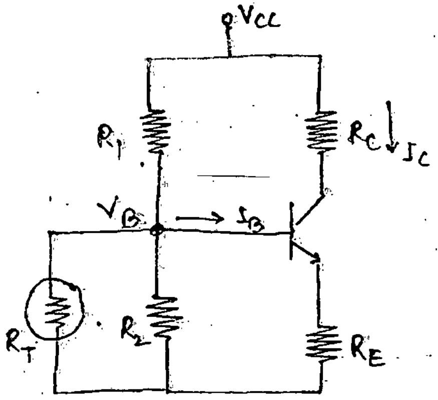
4. $\frac{R_B}{(1+\beta) R_E} << 1$; $\boxed{R_B << (1+\beta) R_E}$

▣ COMPENSATION THROUGH DIODE.



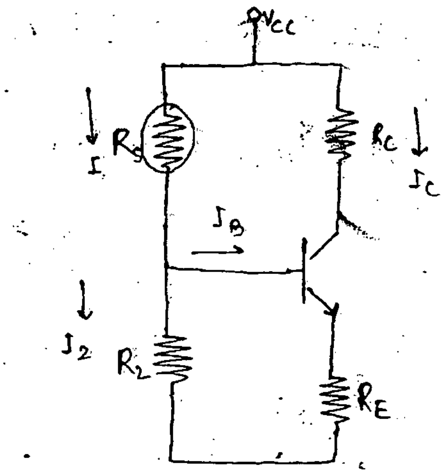
$T\uparrow \; I_{CO}\uparrow \; I_o\uparrow \; I_B\downarrow \; \therefore I_C\downarrow$

2. COMPENSATION THROUGH THERMISTOR.



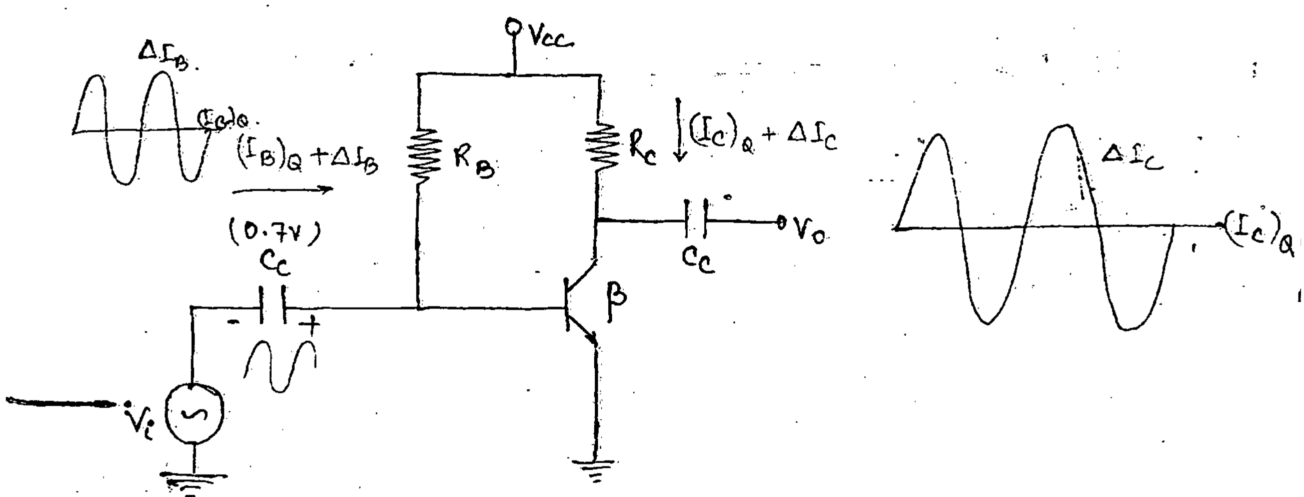
$T\uparrow \; I_{CO}\uparrow \; R_T\downarrow \; V_B\downarrow \; I_B\downarrow \; I_C\downarrow$

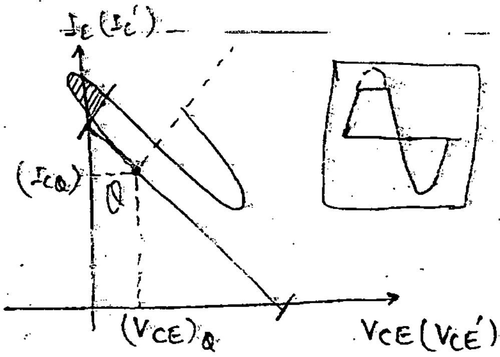
3. COMPENSATION THROUGH SEMISTOR.

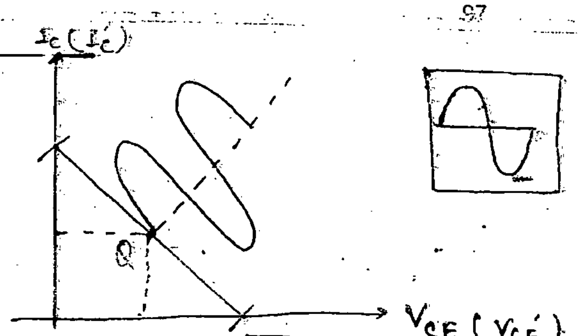


$T\uparrow \; I_{CO}\uparrow \; R_S\uparrow \; I\downarrow \; I_B\downarrow \; \therefore I_C\downarrow$

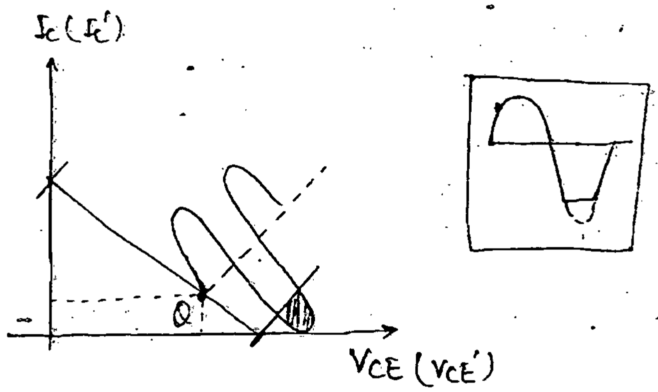
◻ POSITION OF OPERATING POINT ON DC LOAD LINE.



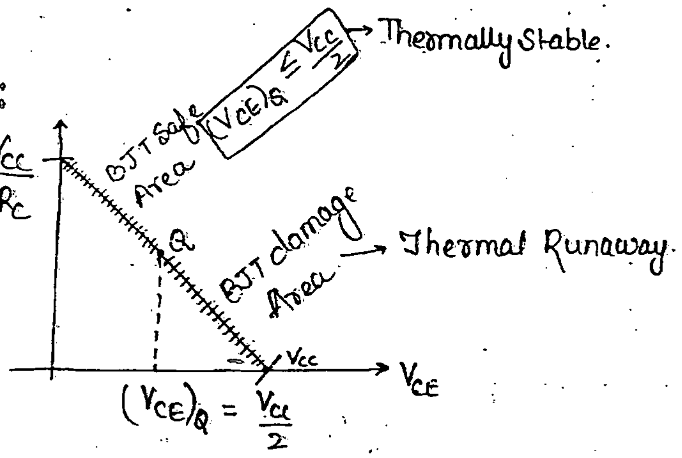




$$\boxed{(V_{CE})_Q = \frac{V_{CC}}{2}}$$

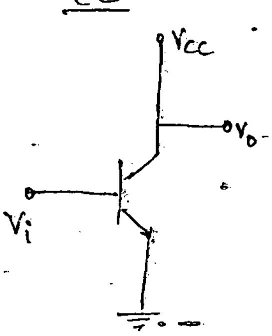


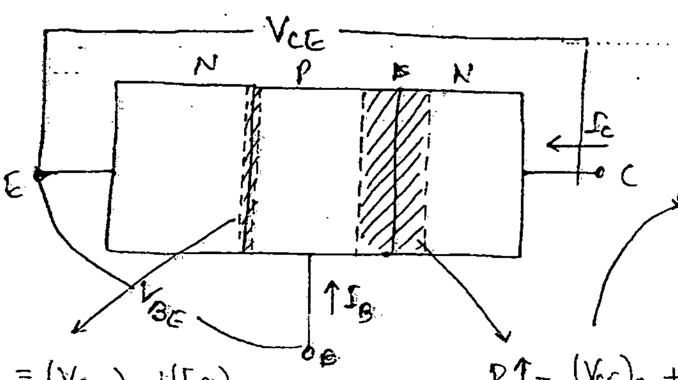
NOTE :-



THERMAL ~~R~~UNAWAY IN BJT.

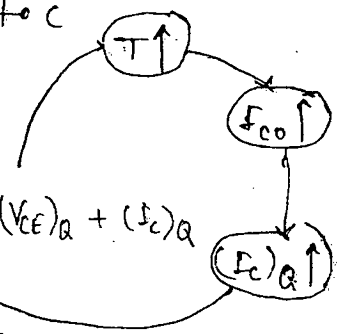
CE



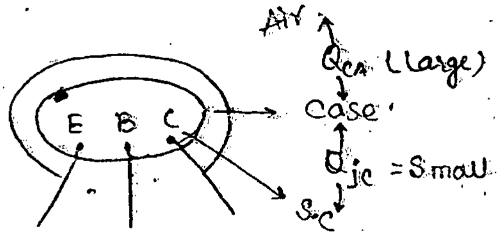


$P_D = (V_{BE})_Q + (I_B)_Q$
(Neglected)

$P_D \uparrow = (V_{CE})_Q + (I_C)_Q$



PRACTICAL VOLTAGE TRANSISTOR DESIGN.



$T_j - T_A \propto P_D$

$\propto \rightarrow \theta$

$$\boxed{T_j - T_A = \theta P_D}$$

Where ; T_j = Junction Temperature.

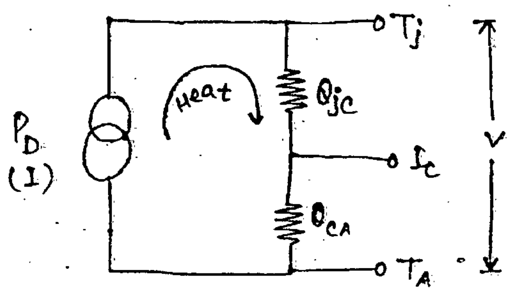
T_A = Ambient Temperature.

P_D = Power Dissipation

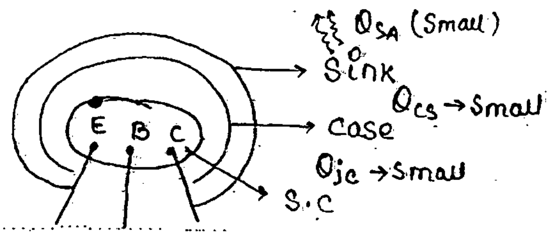
θ = Thermal Resistance

$$\boxed{P_D \downarrow = \frac{T_j - T_A}{\theta}} \text{ mW}$$

$\theta \rightarrow \theta_{jc} + \theta_{CA}$ (large)



POWER TRANSISTOR DESIGN

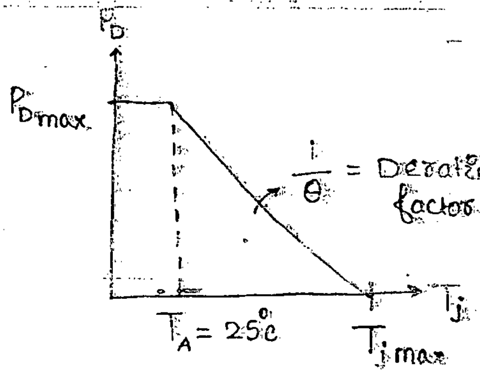


$$\boxed{P_D \uparrow = \frac{T_j - T_A}{\theta}} \text{ Watt.}$$

$\theta \rightarrow \underbrace{\theta_{jc} + \theta_{CS} + \theta_{SA}}_{\text{Small}}$

QUESTION :→ Design a Voltage transistor with a max^m power dissipation $P_{D\,max}$ = 100mW and Temp $T_{j\,max}$ = 200°C (si)

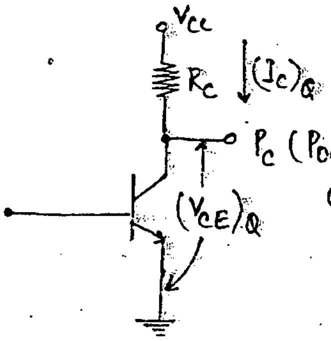
SOLUTION :→



$$\theta = \frac{T_j - T_A}{P_D} \quad °c/mw.$$

$$\Rightarrow \frac{1}{\theta} = D = mw/°c.$$

Power Dissipation P_D



P_c (Power generated at collector) $= V_{cc}(I_c)_Q - (I_c)_Q^2 \cdot R_c$

$= (I_c)_Q \{ V_{cc} - (I_c)_Q R_c \}$

$= \underline{(V_{CE})_Q \times (I_c)_Q = P_D}$

$\boxed{\frac{\partial P_c}{\partial T_j} < \frac{1}{\theta}} \rightarrow$ Thermal Stability

$\boxed{\frac{\partial P_c}{\partial T_j} > \frac{1}{\theta}} \rightarrow$ Therma Runaway

☐ CONDITION FOR THERMAL STABILITY

$$\frac{\partial P_c}{\partial T_j} < \frac{1}{\theta} \quad \Rightarrow \quad \frac{\partial P_c}{\partial T_j} = \frac{\partial P_c}{\partial I_c} \cdot \frac{\partial I_c}{\partial I_{co}} \cdot \frac{\partial I_{co}}{\partial T_j}$$

1. $P_c = V_{cc} I_c - I_c^2 R_c$

   d.w.r. to I_c

   $$\frac{\partial P_c}{\partial I_c} = V_{cc} - 2 I_c R_c$$

2. $\frac{\partial I_c}{\partial I_{co}} = S$

3. $\frac{\partial I_{co}}{\partial T_j} = 0.07 I_{co}$

$$\boxed{(V_{cc} - 2 I_c R_c) \times S \times 0.07 I_{co} < \frac{1}{\theta}}$$

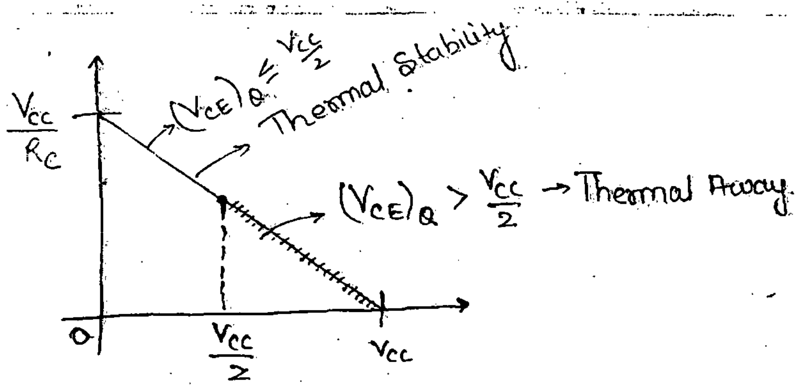
$(V_{cc} - 2 I_c R_c) \rightarrow$ (−)ve, $I_{co} \rightarrow$ Temp, $\frac{1}{\theta} \rightarrow$ (+)ve

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

$2 V_{CE} = 2 V_{cc} - 2 I_c R_c$

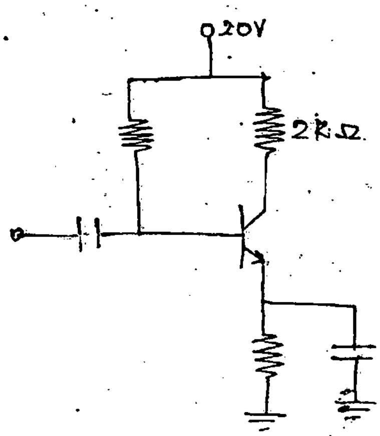
$2 V_{CE} - V_{cc} = V_{cc} - 2 I_c R_c$

$$\Rightarrow \boxed{(2(V_{CE})_Q - V_{cc}) \times S \times 0.07 I_{co} < \frac{1}{\theta}}$$



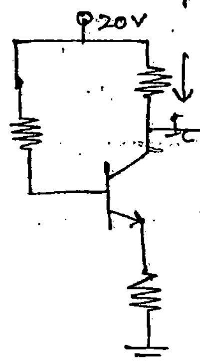
Ch-5

Q9.



If Notation is in ~~capital letters~~ then it is DC.

⇒



$$I_B = \frac{20 - 0.7}{430K + (1+50)1K}$$

$I_B = 40\,\mu A$.

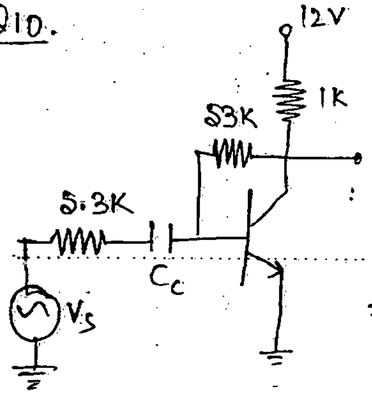
$I_C = \beta I_B$.

$\Rightarrow I_C = 50 \times 40$

$= 2\,mA$.

$\therefore V_C = 16V$.

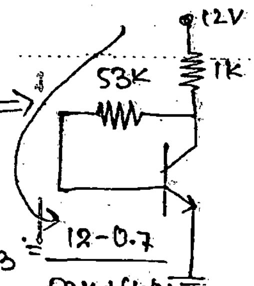
Q10.



V_{CE} → capital letter → DC

$h_{ie} \to \infty$, $h_{fe} \to \infty$ → AC → No use.

⇒



$$I_B = \frac{12-0.7}{53K+(1+60)1K}$$

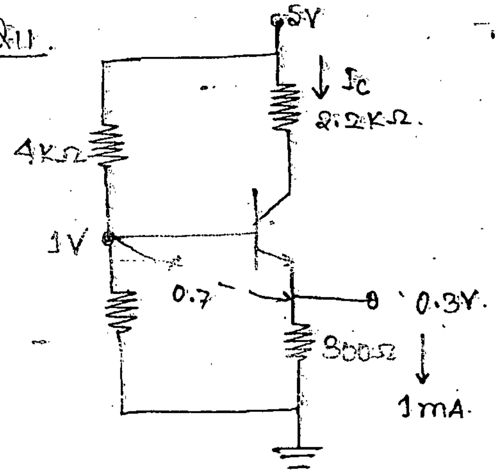
$$\Rightarrow I_B = \frac{12-0.7}{53K + (1+60)1K}$$

$I_B = 99\,\mu A$.

$I_C + I_B = 6\,\mu A$

$\Rightarrow V_{CE} = 6V$.

Q11.



$\because$ β is very large.

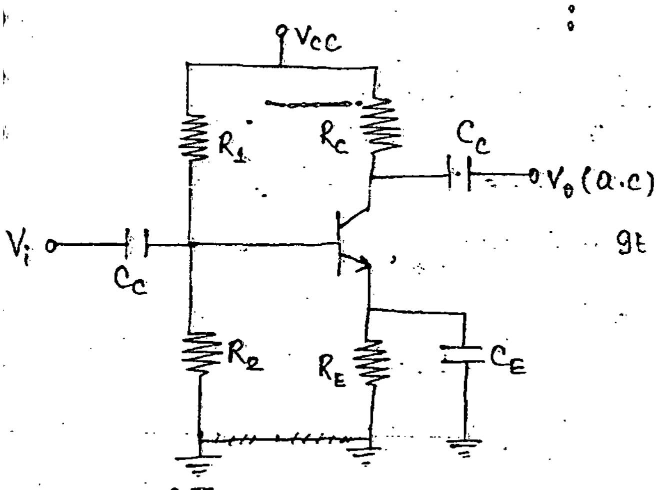
$\therefore$ $I_B \simeq 0$.

$V_{CE} = 2.5V$

□ APPLICATIONS OF BJT.

1. COMMON EMITTER

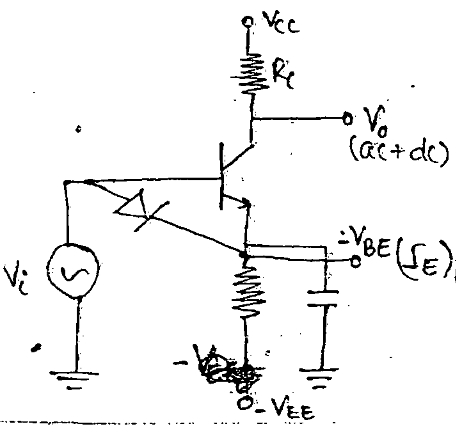
RC COUPLED / SMALL SIGNAL / VOLTAGE AMPLIFIER / AC AMPLIFIER.



Require single battery.

It is used in Noise amplification.

DIRECT COUPLED / DC AMPLIFIER / INTEGRATED AMPLIFIER.

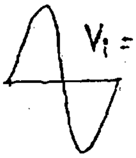


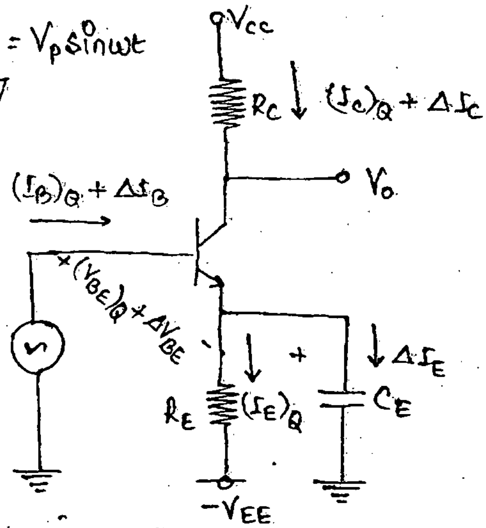
Require two battery.

$-V_{BE}$ $(I_E)_Q = \dfrac{V_{EE} - V_{BE}}{R_E}$

It gives high Gain.

COMMON EMITTER AMPLIFIER ANALYSIS.





$$(I_C)_Q + \Delta I_C = I_C'$$

$$(I_E)_Q + \Delta I_E = I_E'$$

$$(V_{BE})_Q + \Delta V_{BE} = V_{BE}'$$

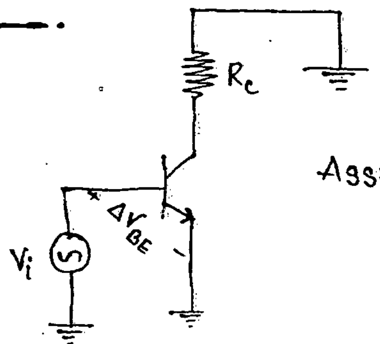
$$(I_B)_Q + \Delta I_B = I_B'$$

$$\Rightarrow (I_E)_Q = I_0 \cdot e^{(V_{BE})_Q/V_T} \rightarrow \text{diode current}$$

$$(I_E)_Q + \Delta I_E = I_0 \cdot e^{((V_{BE})_Q + \Delta V_{BE})/V_T}$$

$$\Rightarrow \cancel{(I_E)_Q} \Rightarrow I_E' = \underbrace{I_0 \cdot e^{(V_{BE})_Q/V_T}}_{(I_E)_Q} \cdot e^{\Delta V_{BE}/V_T} \Rightarrow \boxed{I_E' = (I_E)_Q \cdot e^{\Delta V_{BE}/V_T}}$$

AC Model.



$$\boxed{I_E' = (I_E)_Q \, e^{V_i/V_T}} \rightarrow \text{Non linear device.}$$

Assume :- $V_i = V_p \sin\omega t$

$$I_E' = (I_E)_Q \, e^{V_p \sin\omega t / V_T}$$

$$\Rightarrow I_E' = (I_E)_Q \left[1 + \frac{V_p \sin\omega t}{V_T} + \frac{1}{2!} \cdot \frac{V_p^2}{V_T^2} \cdot \sin^2\omega t + \dots \right]$$

$$= (I_E)_Q \left[1 + \frac{V_p}{V_T} \cdot \sin\omega t + \frac{1}{2!} \cdot \frac{V_p^2}{V_T^2} \left(\frac{1 - \cos 2\omega t}{2} \right) + \dots \right]$$

$$\Rightarrow I_E' = \underbrace{(I_E)_Q \left[1 + \frac{V_p^2}{4V_T^2} \right]}_{\text{offset unwanted}} + (I_E)_Q \cdot \frac{V_p}{V_T} \cdot \sin\omega t - \underbrace{\frac{V_p^2}{4V_T^2} (I_E)_Q \cos 2\omega t}_{2^{nd} \text{ harmonic}} + \dots$$

$$\% \text{ Distortion} = \frac{|B_2|}{|B_1|} = \frac{(I_E)_Q \cdot \frac{V_p^2}{4V_T^2}}{(I_E)_Q \cdot \frac{V_p}{V_T}} = \frac{V_p}{4V_T}$$

$$\boxed{\% \text{ Distortion} = \frac{V_p}{4V_T}} \quad \text{or} \quad \boxed{\% \text{ Distortion} = \frac{V_p}{100\,mV}}$$

Best testing s/g : $V_i = 1\,mV \sin\omega t$.

$$\boxed{V_p << 4V_T} \Rightarrow I_E' = (I_E)_Q + \frac{(I_E)_Q}{V_T} \cdot V_p \sin\omega t$$

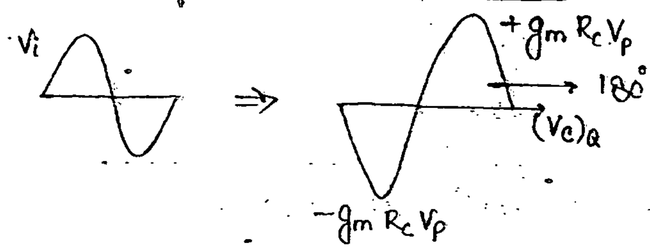
$$I_C' = \alpha I_E'$$

$$I_C' = \alpha (I_E)_Q \cdot \left[1 + \frac{V_p}{V_T} \sin\omega t\right]$$

$$V_0 = V_{cc} - I_C' R_C$$

$$= \underbrace{V_{cc} - \alpha (I_E)_Q R_C}_{(V_C)_Q} - \underbrace{\underbrace{\frac{(I_C)_Q}{V_T} \cdot R_C}_{g_m \cdot R_C}}_{A_V} \cdot \underbrace{V_p \sin\omega t}_{V_i}$$

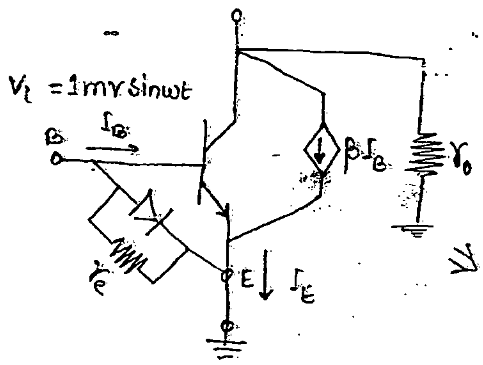
$$\boxed{V_0 = (V_C)_Q - g_m \cdot R_C V_p \sin\omega t}$$

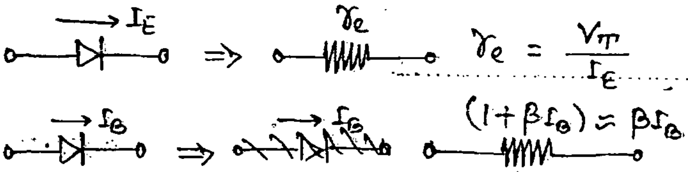


→ 180° phase shift property. (inverter)

CHARACTERISTICS OF COMMON EMITTER AMPLIFIER.

Small Signal Theory.

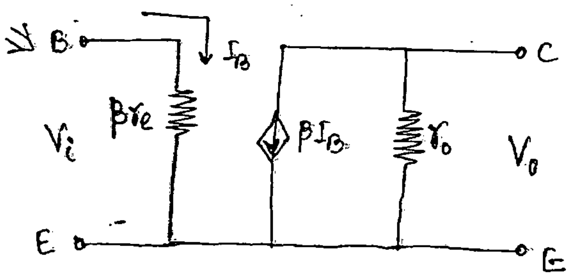




$r_e = \frac{V_T}{I_E}$

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

$; \quad (1+\beta) r_e = \frac{V_T}{I_B}.$



1. $Z_i = \frac{V_i}{I_B}$

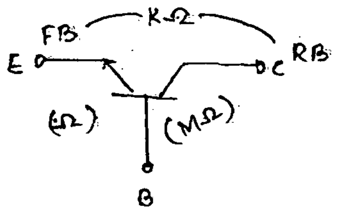
$\boxed{Z_i = \beta r_e}$

Assume ; $r_e = 10\Omega$ (1Ω to 25Ω)

$\beta = 100$ (50 to 150).

$Z_i = 1K\Omega$.

2. $\boxed{Z_0 = r_0} = 80K\Omega$.



3. $\boxed{V_0 = -\beta I_B r_0}$

$= -\beta \cdot \frac{V_i}{\beta r_e} \cdot r_0$

$\boxed{\frac{V_0}{V_i} = -\frac{r_0}{r_e}} \Rightarrow \left|\frac{V_0}{V_i}\right| > 1$

4. $\boxed{A_I = \beta > 1}$

→ PROPERTIES OF COMMON EMITTER AMPLIFIER.

1. The i/p impedance is Moderate.
2. The O/p impedance is also moderate.
3. The Voltage gain is greater than 1.
4. current gain is also greater than 1.

<u>NOTE</u>:- In most of the practical appl^n CE amplifier is used because the power gain is high.

2. COMMON BASE AMPLIFIER.

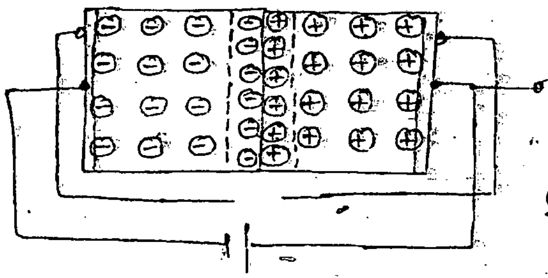
→ <u>Diode capacitance</u> :-

Diode capacitance

↓ Transition capacitance (C_T) ⇓ Depletion which occurs in RB

↓ Diffusion capacitance. C_D ⇓ Diffusion always occur in FB where depletion is neglected

1. Transition capacitance (C_T) :- ~~(Typically C_T = 3pf)~~



"The rate of change of charge w.r.t Voltage" → Capacitance

"The rate of change of immobile charge in the depletion region w.r.t reverse bias voltage" → C_T

$$C_{//} = \frac{\varepsilon A}{d} \quad (\text{or}) \quad \boxed{C_T = \frac{\varepsilon A}{W}} \Rightarrow W \propto \sqrt{V_j} \text{ (Alloy type)}$$

$$W \propto \sqrt[3]{V_j} \text{ (Grown Jn)}$$

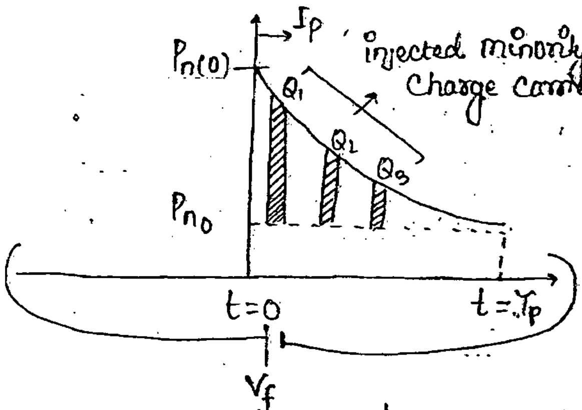
$$\left.\begin{aligned} W &\propto \sqrt{V_j + V_R} \\ W &\propto \sqrt[3]{V_j + V_R} \end{aligned}\right\} RB.$$

$$\boxed{C_T \propto \frac{1}{\sqrt{V_j + V_R}}} \rightarrow \text{Alloy type.} \qquad \boxed{C_T \propto \frac{1}{\sqrt[3]{V_j + V_R}}} \rightarrow \text{Grown Junction}$$

$$\boxed{C_T \propto \frac{1}{(V_R)^n}}$$ where $n = \frac{1}{2} \rightarrow$ alloy type.

$n = \frac{1}{3} \rightarrow$ Grown ju^n.

2. Diffusion capacitance (C_D) :- (Typically C_D = 100pf)



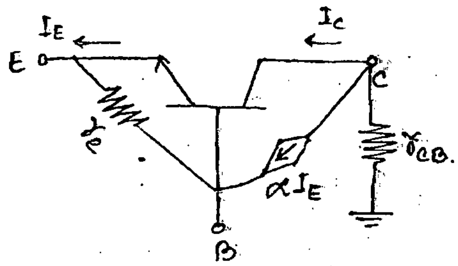
"The rate of change of charge w.r.t Voltage" → capacitance.

"The rate of change of injected minority carrier charge w.r.t to forward bias Voltage" → C_D

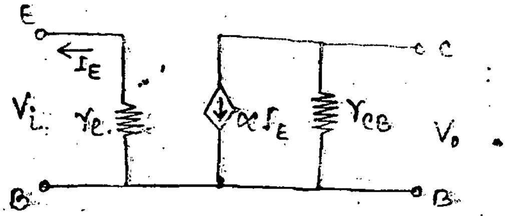
$$Q = I_P \cdot \tau_P \; ; \; C_D = \frac{dQ}{dV} = \tau_P \cdot \frac{\partial I_P}{dV} = \tau_P \cdot \frac{I_P (DC)}{V_T}$$

$$\boxed{C_D = \tau_P \cdot \frac{I_P}{V_T}}$$

→ CHARACTERISTICS OF COMMON BASE AMPLIFIER.



⇒



1. $\boxed{Z_i = \frac{V_i}{I_E} = r_e}$

$Z_i = 1\Omega$ to 25Ω.

2. $\boxed{Z_o = r_{CB}} = 4M\Omega$

3. $V_o = -\alpha I_E r_{CB}$.

$V_o = -\alpha\left(\frac{-V_i}{r_e}\right) r_{CB}$.

$\boxed{\frac{V_o}{V_i} = \frac{r_{CB}}{r_e} > 1}$

4. $\boxed{A_I = \alpha \simeq 1}$

⇓

Current Buffer

$P_{CB} = A_V \cdot A_I$

$\boxed{P_{CB} = A_V}$

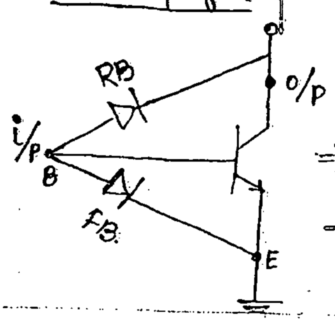
→ PROPERTIES IN COMMON BASE AMPLIFIER.

1. The i/p impedance is low.
2. The o/p impedance is high.
3. The voltage gain is greater than 1.
4. The current gain is nearly unity (current Buffer)

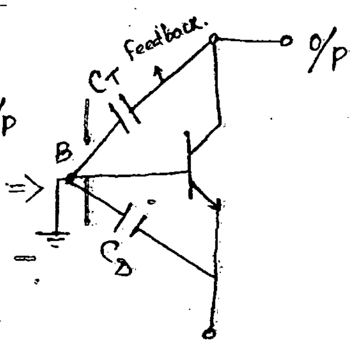
NOTE:- In practical appl^n CB amplifier is used whenever high bandwidth is required.

→ COMMON BASE AMPLIFIER IN HIGH FREQUENCY.

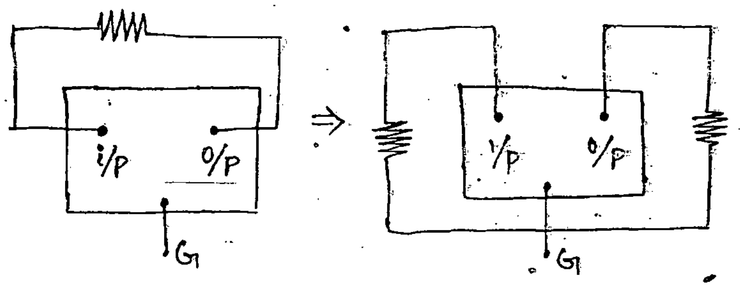
CE Amplifier



⇒

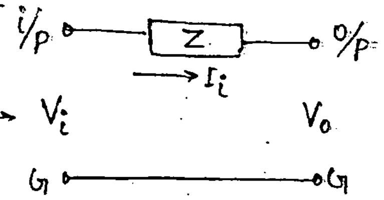


Millers Theorem :→



$\boxed{Z_1 = \frac{Z}{1-K}}$ (K = A_v) $\boxed{Z_2 = \frac{Z_K}{K-1}}$

Proof :-



$$I_i = \frac{V_i - V_o}{Z} = \frac{V_i\left[1 - \frac{V_o}{V_i}\right]}{Z}.$$

$$Z_1 = \frac{V_i}{I_i}$$

$$Z_1 = \frac{V_i}{I_i} = \frac{Z}{1 - \left(\frac{V_o}{V_i}\right)} \rightarrow K.$$

$$Z_1 = \frac{Z}{1 - A_v} \qquad Z_2 = \frac{Z \cdot A_v}{A_v - 1}$$

$$\frac{1}{C_{T_1}} = \frac{1}{C_T} \cdot \frac{1}{1 - A_v} \qquad A_v >> 1 \text{ (open loop gain)}$$

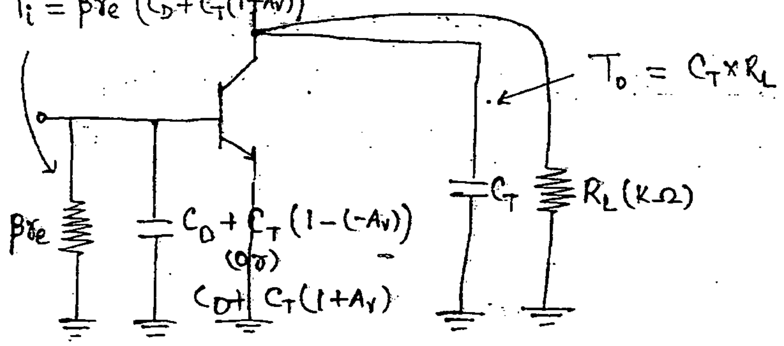
$$Z_2 \simeq Z..$$

$$\boxed{C_{T_1} = C_T(1 - A_v)} \qquad \frac{1}{C_{T_2}} = \frac{1}{C_T} \Rightarrow \boxed{C_{T_2} \simeq C_T}$$

CE amplifier

Miller capacitive effect

$T_i = \beta r_e (C_D + C_T(1+A_v))$



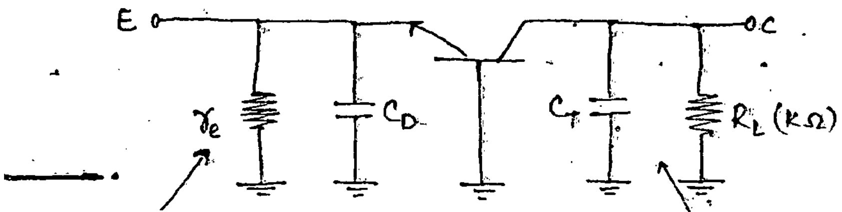
$$\omega_{B.W} = \frac{1}{T}$$

$$T = T_i + T_o.$$

$$T_i >> T_o.$$

$$\boxed{\omega_{B.W} \downarrow = \frac{1}{T_i \uparrow}}$$

common Base amplifier



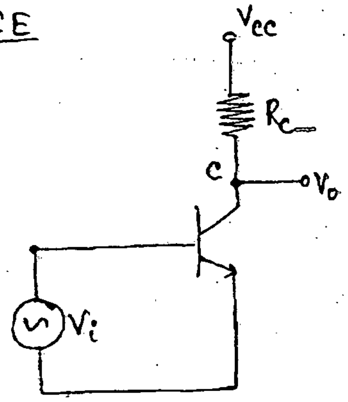
$T_i = C_D \times r_e$

$T_o = C_T R_L$

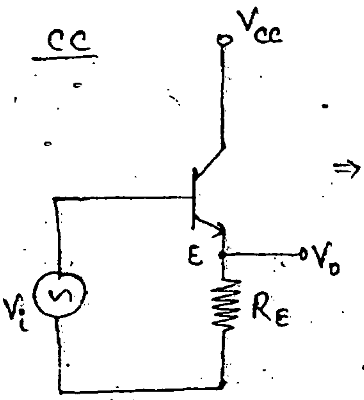
$$\boxed{\omega_{B.W}\uparrow = \frac{1}{T\downarrow}}$$

3. COMMON COLLECTOR AMPLIFIER.

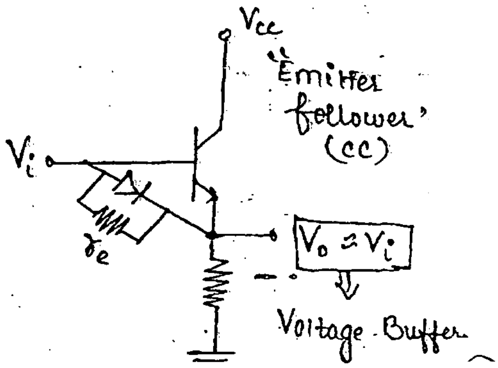
CE

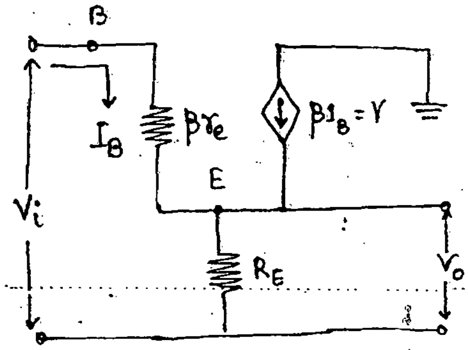


CC



$\Rightarrow$





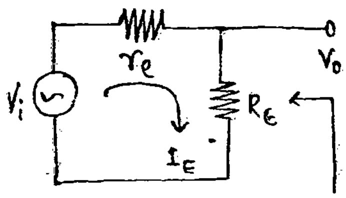
1. $Z_i = \frac{V_i}{I_B}$

$Z_i = \beta r_e + (1+\beta) R_E$

Assume $\beta = 100$; ~~r_e~~ $= 10\Omega$; $R_E = 10K$

$Z_i = 1K\Omega + 1M\Omega \Rightarrow Z_i = 1M\Omega$.

2. $Z_o = \frac{V_o}{I_E}$



$Z_o = r_e // R_E$

$\boxed{Z_o = r_e}$

$\Downarrow$

impedance matching property.

3. $A_V = \frac{V_o}{V_i} = \frac{R_E}{r_e + R_E}$

$R_E >> r_e$.

$\boxed{A_V = 1} \rightarrow$ Voltage Buffer

4. $\boxed{A_I = Y = 1+\beta > 1}$

$P_{cc} = A_V \cdot A_I$

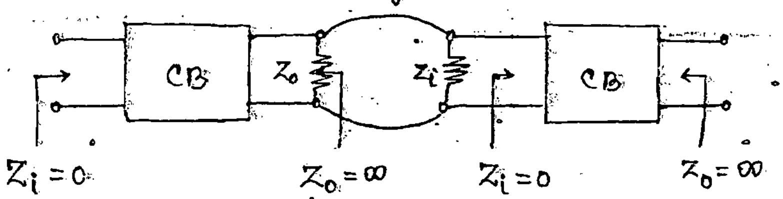
$\boxed{P_{cc} = A_I}$

→ PROPERTIES IN COMMON COLLECTOR AMPLIFIER

1. The i/p impedance is high.
2. The o/p ~~impedance~~ impedance is low (Impedance Matching)
3. The Voltage gain is nearly unity.
4. The current gain is greater than 1.

<u>NOTE</u>:- In pratical appl^n cc amplifier is used whenever impedance matching is required.

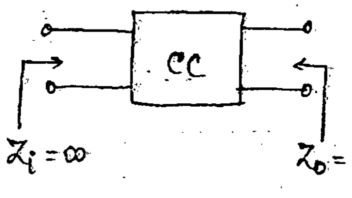
<u>Impedance Matching</u>:→



Power ⇒ 0

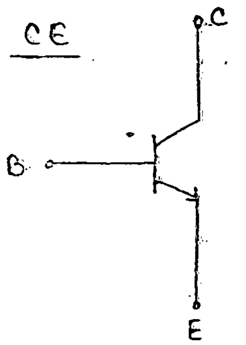
$$A_V = \frac{V_o}{V_i} = \frac{I_o Z_o}{I_i Z_i}$$

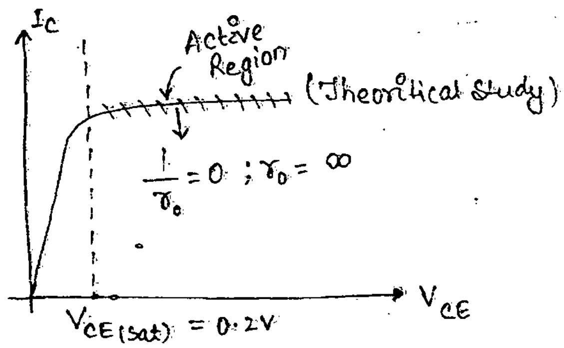
$$\boxed{A_V = A_I \cdot \frac{Z_o}{Z_i}} \qquad \boxed{Z_i = Z_o} \Rightarrow \boxed{A_V = A_i}$$

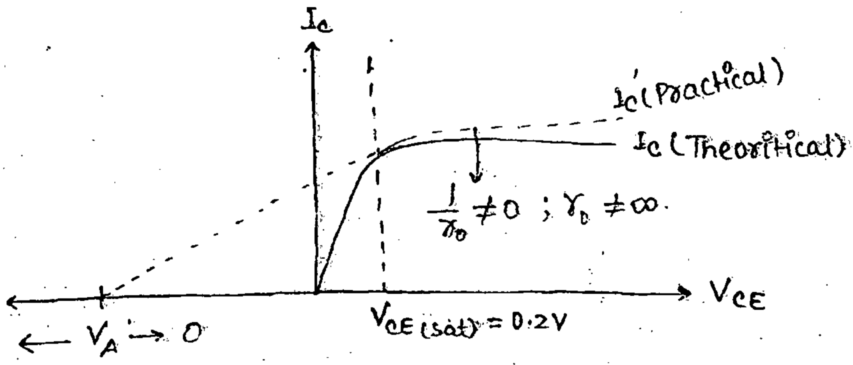


☐ EARLY EFFECT (OR) BASE WIDTH MODULATION.

<u>CE</u>







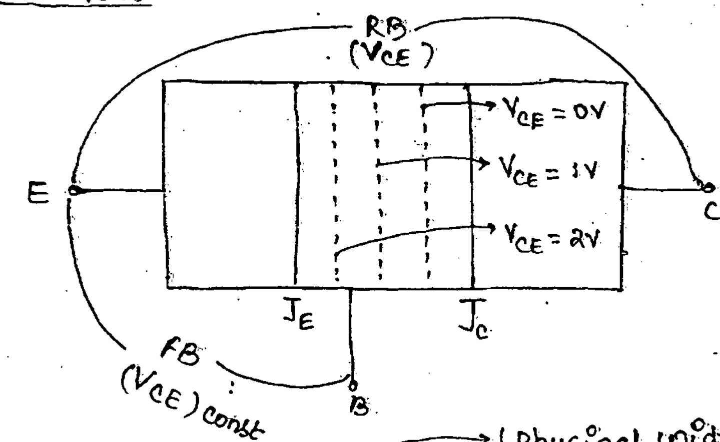
$$I_C = I_0 . e^{V_{BE}/V_T} \quad ; \quad I_C' = I_0 \, e^{V_{BE}/V_T} \left[1 + \frac{V_{CE}}{V_A}\right]$$

$$\frac{1}{r_o} = \frac{\partial I_c'}{\partial V_{CE}} = \frac{I_0 e^{V_{BE}/V_T}}{V_A} = \frac{(I_c)_Q}{V_A} \Rightarrow \boxed{r_o = \frac{V_A}{(I_c)_Q}}$$

Typically $V_A = 1000$. ; $(I_c)_Q = 1 mA$

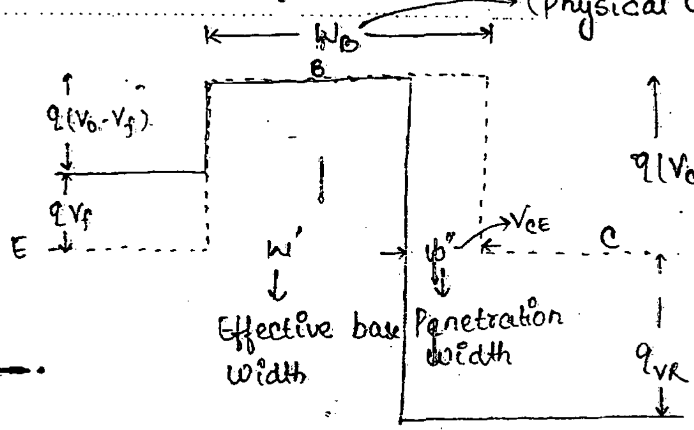
$\therefore \boxed{r_0 = 1 M\Omega}$

ANALYSIS :-



$V_{CE}\uparrow$ $W_B\downarrow$ $I_R\downarrow$ $I_B\downarrow$ $I_{Ep}\uparrow$

$I_E\uparrow$ $I_{cp}\uparrow$ $I_c\uparrow$



$\boxed{W_B = W' + W''}$

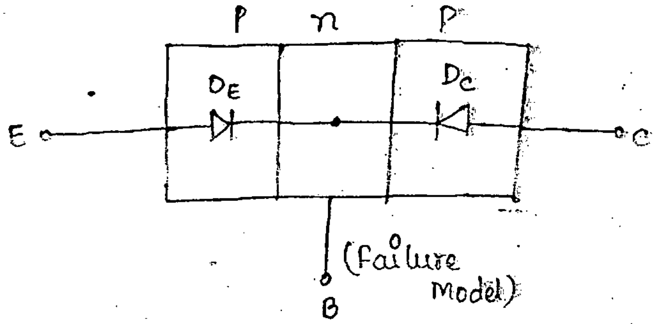
Early effect

$V_{CE}\uparrow$ $W''\uparrow$ $W'\downarrow$

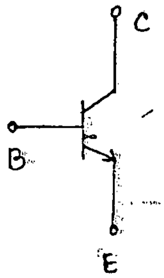
W_B = constant

$\left.\begin{array}{l} W_B = W'' \\ W' = 0 \end{array}\right\}$ Punch through (or) Reach through

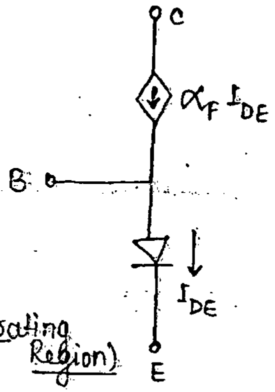
EBBERS MOLL MODEL OF BJT.



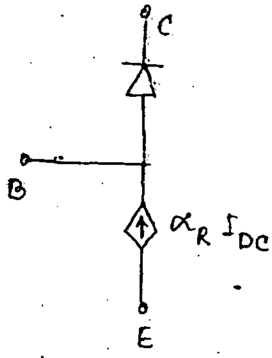
CE



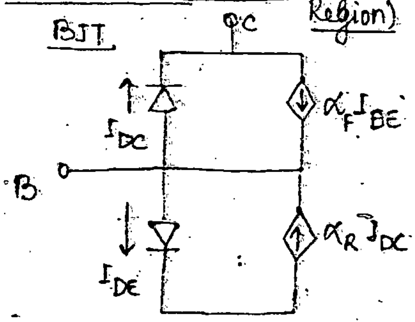
Forward Active Mode.



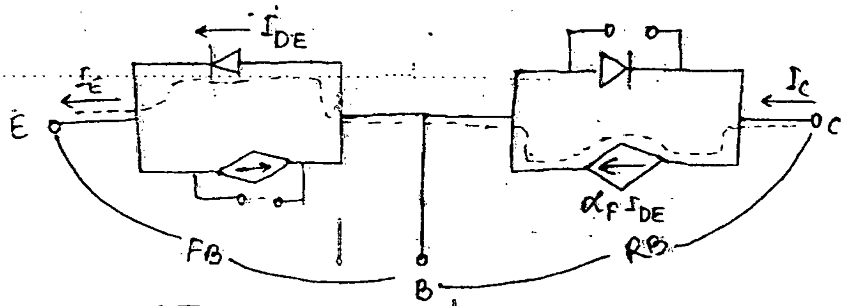
Reverse Active Mode.



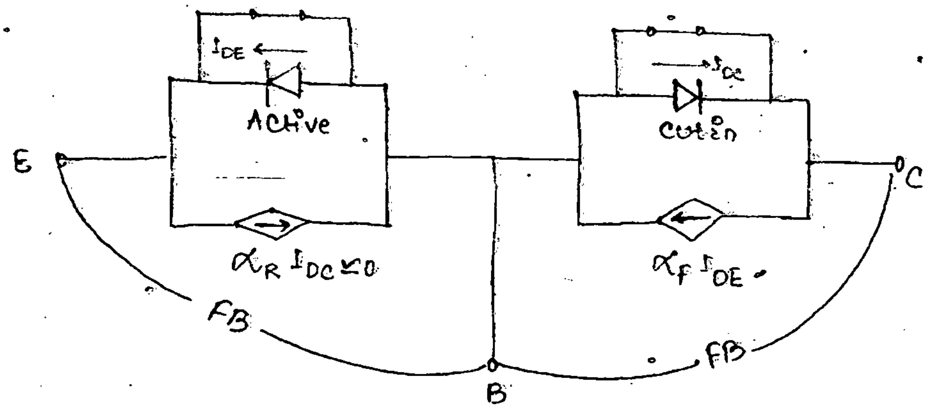
Ebber Model (Operating Region) BJT



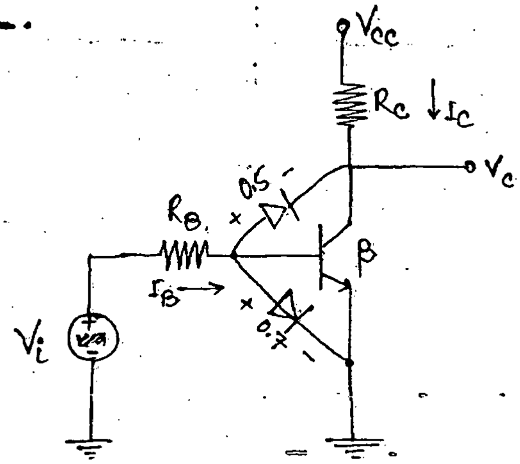
TESTING OF BJT IN ACTIVE REGION.



TESTING OF BJT IN SATURATION REGION.



☐ BJT AS A SWITCH.



cutoff

$V_i < 0.5\,V$

Q is in cutoff

$\therefore I_B = 0$.

$I_C = \beta I_B = 0$

$V_C = V_{CC} - I_C R_C$

$\boxed{V_C = V_{CC}}$

Active

$V_i = 0.5$ (cut in)

$I_B \simeq 0$

$V_i \geq 0.7$ (active)

$I_B > 0$

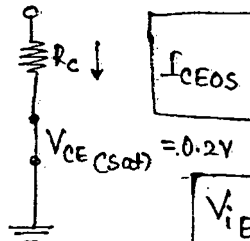
$I_C\uparrow = \beta I_B\uparrow$

$\boxed{V_C\downarrow = V_{CC} - I_C\uparrow R_C}$

$\boxed{V_C > V_B - 0.5}$

Edge of Saturation (EOS)

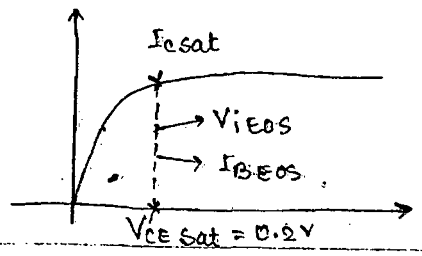
$\boxed{V_C = V_B - 0.5\,V}$



$\boxed{I_{CEOS} = I_{Csat} = \frac{V_{CC} - V_{CEsat}}{R_C}}$

$\boxed{I_{B\,EOS} = \frac{I_{CEOS}}{\beta}}$

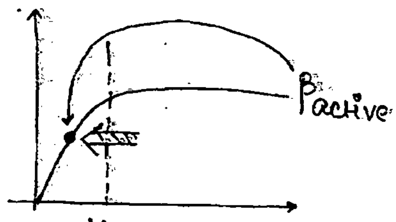
$\boxed{V_{iEOS} = I_{BEOS} \times R_B + V_{BE\,active}}$



Deep Saturation

$V_C < V_B - 0.5$

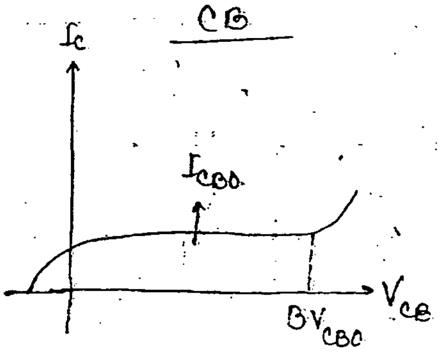
$$I_{C\,sat} = \frac{V_{CC} - V_{CE\,sat}}{R_C} = \frac{V_{CC} - 0.2}{R_C}$$

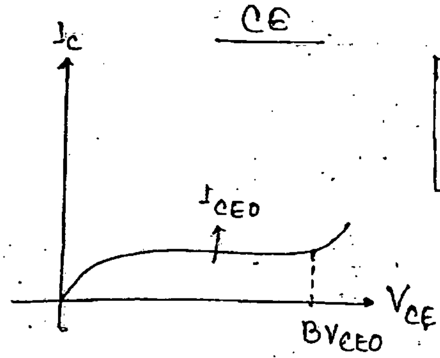


$$\boxed{\beta_{force} = \frac{I_{C\,sat}}{I_B > I_{BEOS}}}$$

$$\boxed{\text{Over drive Factor} = \frac{I_B}{I_{BEOS}}}$$

BREAKDOWN IN BJT.





$$\boxed{BV_{CEO} = \frac{BV_{CBO}}{\sqrt[n]{\beta}}}$$

$$\boxed{BV_{CEO} < BV_{CBO}}$$

Where, n = Avalanche multiplication factor (3 to 6)

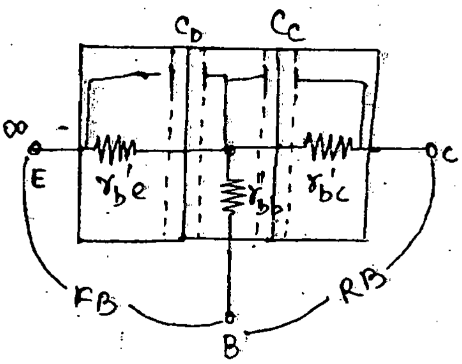
β = current gain of CE.

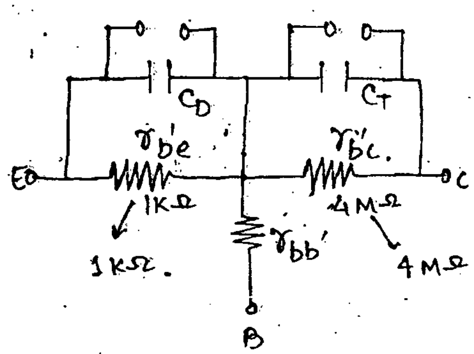
SMALL SIGNAL ANALYSIS OF BJT (VOLTAGE AMPLIFIER).

LOW FREQUENCY ANALYSIS

$f \to 0$

$X_c \to \frac{1}{f \to 0} = \infty$



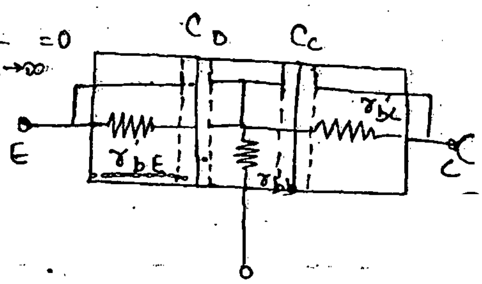


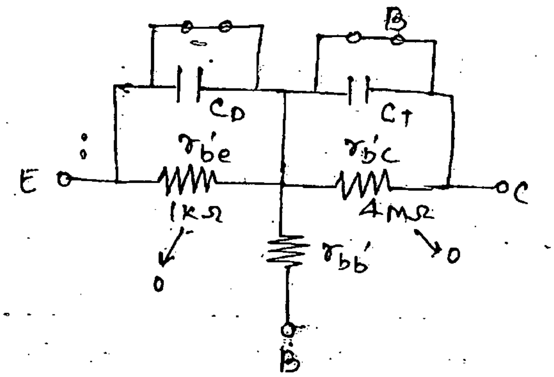
Note :- For low frequency analysis internal capacitor C_D & C_T are neglected

HIGH FREQUENCY ANALYSIS

$f \to \infty$

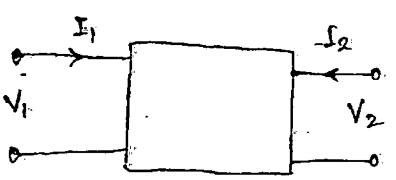
$X_c \to \frac{1}{f \to \infty} = 0$





NOTE :- For high frequency analysis internal capacitance C_D & C_T are taken into account.

LOW FREQUENCY ANALYSIS OF BJT.



Z parameter $V_1 = f(I_1, I_2)$, $V_2 = f(I_1, I_2)$ — Trans impedance amplifier (Z_f)

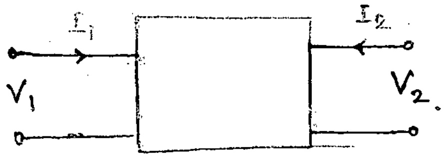
Y Parameter $I_1 = f(V_1, V_2)$, $I_2 = f(V_1, V_2)$ — Trans admittance (Y_f)

h parameter $V_1 = f(I_1, V_2)$, $I_2 = f(I_1, V_2)$ — current amplifier (h_f)

Voltage ampl^r (g_f)

$I_1 = f(V_1, I_2)$, $V_2 = f(V_1, I_2)$ — g parameter

☐ DESIGN OF AMPLIFIER WITH Z-PARAMETER.



$$V_1 = Z_i I_1 + Z_r I_2$$
$$V_2 = Z_f I_1 + Z_o I_2$$

$V_1 = f(I_1, I_2)$

$V_2 = f(I_1, I_2)$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_i & Z_r \\ Z_f & Z_o \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

Ideal amplifier

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ Z_f & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$\boxed{V_2 = Z_f I_1} \rightarrow$ ICVS.

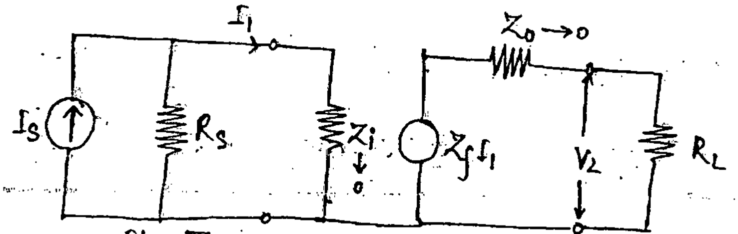
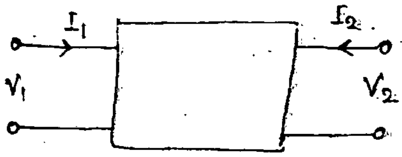


Fig: Trans Impedance Amplifier $\rightarrow Z_i = 0; Z_o =$

Note:- Ideal ampl^r is unilateral device

$\cancel{Z_r} = 0$

☐ DESIGN OF AMPLIFIER WITH Y-PARAMETER.



$$I_1 = Y_i V_1 + Y_r V_2$$
$$I_2 = Y_f V_1 + Y_o V_2$$

$I_1 = f(V_1, V_2)$

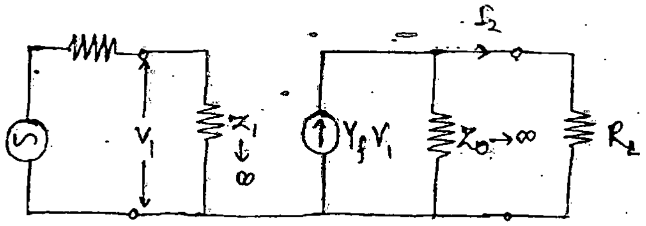
$I_2 = f(V_1, V_2)$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_i & Y_r \\ Y_f & Y_o \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

Ideal Amplifier

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ Y_f & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

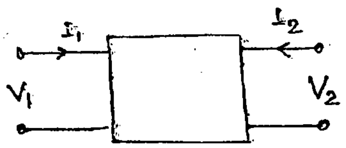
$\boxed{I_2 = Y_f V_1} \rightarrow$ VCIS



Trans admittance amplifier
(or)
Trans conductance amplifier
$Z_i = \infty$; $Z_o = \infty$
used in FET

Note:- Ideal ampl^r is a unilateral
$Y_r = 0$

DESIGN OF AMPLIFIER WITH H - PARAMETER



$$V_1 = h_i I_1 + h_r V_2$$
$$I_2 = h_f I_1 + h_o V_2$$

$V_1 = f(I_1, V_2)$

$I_2 = f(I_1, V_2)$

Case-1

$V_2 = 0$

$h_i = \dfrac{V_1}{I_1} \rightarrow$ i/p impedance

$h_f = \dfrac{I_2}{I_1} \rightarrow$ forward current gain

case-2.

$I_1 = 0$

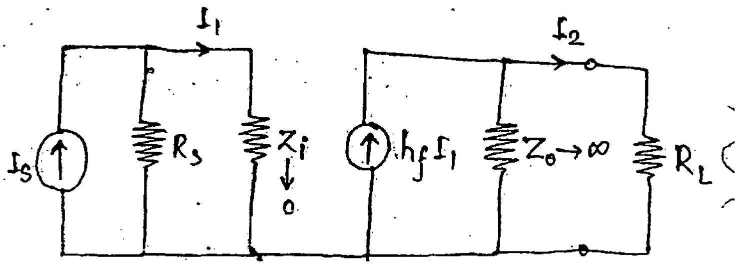
$h_r = \dfrac{V_1}{V_2} \rightarrow$ Reverse Voltage gain.

$h_o = \dfrac{I_2}{V_2} \rightarrow$ output admittance

Ideal Amplifier

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ h_f & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$\boxed{I_2 = h_f I_1} \rightarrow$ CCCS



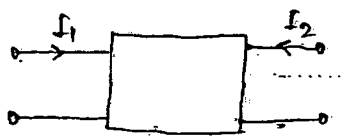
current amplifier

$Z_i = 0$; $Z_o = \infty$

Used in BJT

Note :- Ideal amplifier is a unilateral device $h_r = 0$

DESIGN OF AMPLIFIER WITH g - PARAMETER.



$$I_1 = g_i V_1 + g_r I_2$$
$$V_2 = g_f V_1 + g_o I_2$$

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_i & g_r \\ g_f & g_o \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$I_1 = f(V_1, I_2)$

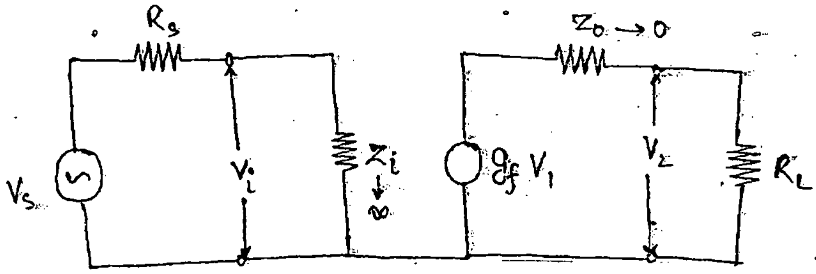
$V_2 = f(V_1, I_2)$

Ideal amplifier

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ g_f & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$\boxed{V_2 = g_f V_1} \rightarrow$ VCVS

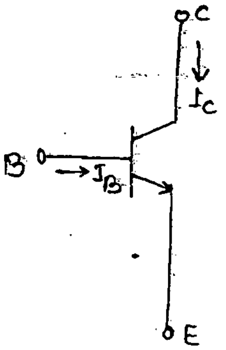
Note :- Ideal ampl^r is a unilateral device $g_r = 0$



Voltage Amplifier. used in opamp.
$Z_i = \infty$; $Z_0 = 0$

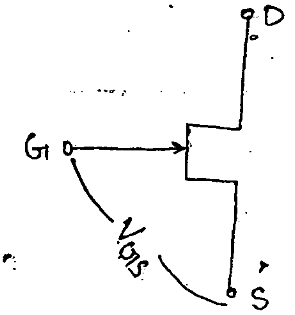
CONCLUSION.

BJT



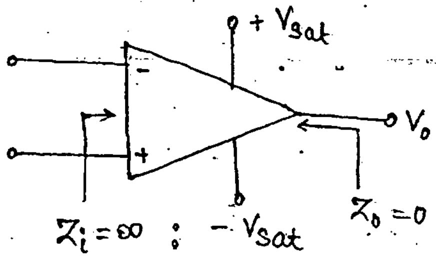
h-parameter
"CCCS"
$Z_i = 0$; $Z_0 = \infty$

FET

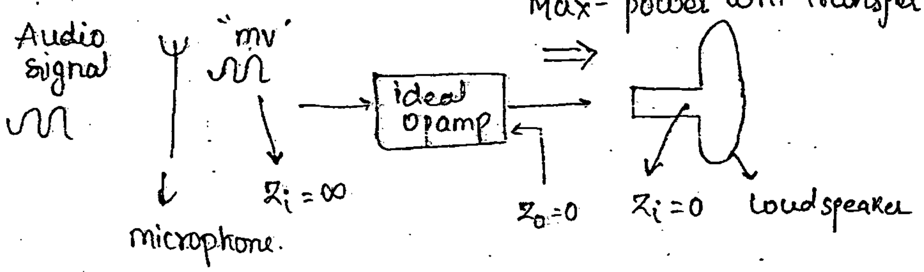


Y-parameter
"VCIS"
$Z_i = \infty$; $Z_0 = \infty$

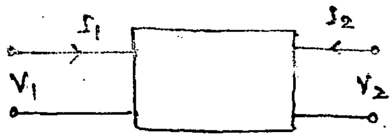
OP-Amp.



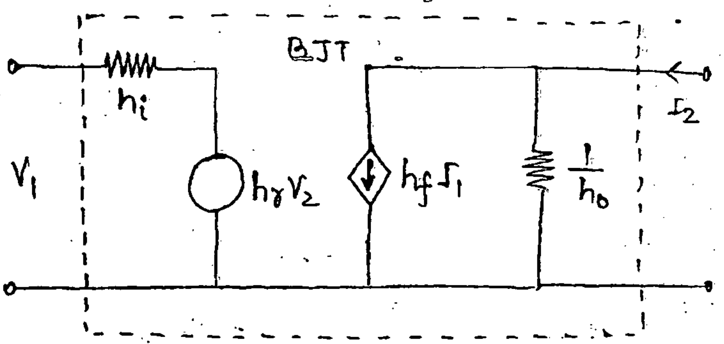
g parameter
Voltage amplifier (VCVS)



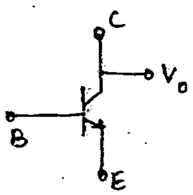
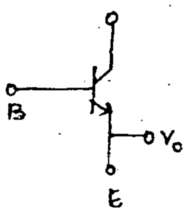
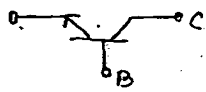
☐ H- PARAMETER MODEL OF BJT.



$$V_1 = f(I_1, V_2) \qquad \begin{bmatrix} h_i & h_r \\ h_f & h_o \end{bmatrix}$$
$$I_2 = f(I_1, V_2)$$



☐ TYPICAL VALUES OF H- PARAMETER.

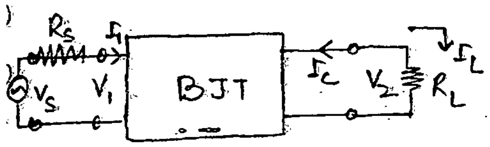
h-parameter	CE	CC	CB
			
h_i	1100 Ω	1100 Ω	22 Ω
h_f	50	−51	−0.98
Neglected: h_r	2.4×10^{-4}	$\simeq 1$	2.9×10^{-4}
Neglected: h_o	24×10^{-6} A/V	24×10^{-6} A/V	0.49×10^{-6} A/V

GE \ta G

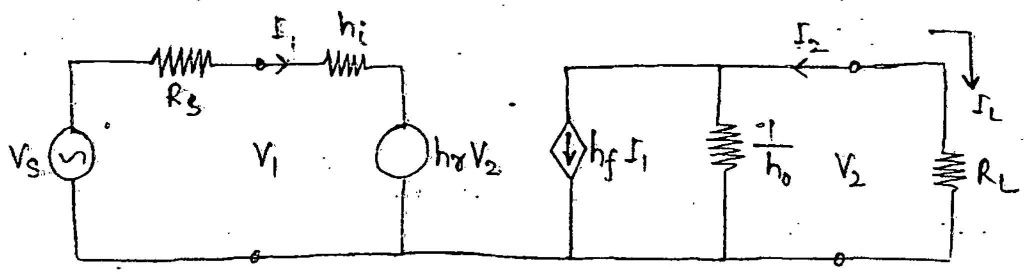
CE to CB	CB to CE	CE to CC
$h_{ib} = \dfrac{h_{ie}}{1+h_{fe}}$	$h_{ie} = \dfrac{h_{ib}}{1+h_{fb}}$	$h_{ic} = h_{ie}$
$h_{fb} = \dfrac{-h_{fe}}{1+h_{fe}}$	$h_{fe} = \dfrac{-h_{fb}}{1+h_{fb}}$	$h_{fc} = -(1+h_{fe})$
$h_{rb} = \dfrac{h_{ie}\cdot h_{oe}}{1+h_{fe}} - h_{re}$	$h_{re} = \dfrac{h_{ib}\cdot h_{ob}}{1+h_{fb}} - h_{rb}$	$h_{rc} \simeq 1$
$h_{ob} = \dfrac{h_{oe}}{1+h_{fe}}$	$h_{oe} = \dfrac{h_{ob}}{1+h_{fb}}$	$h_{oc} = h_{oe}$

IES

TRANSISTOR AMPLIFIER ANALYSIS (EXACT MODEL)



$\boxed{I_L = -I_2}$



Characteristics of amplifier

(1) Current gain $A_I = \dfrac{I_2}{I_1}$

(2) Input impedance $Z_i = \dfrac{V_1}{I_1}$

(3) Voltage gain $A_V = \dfrac{V_2}{V_1}$

(4) o/p impedance $Z_0 = \dfrac{V_2}{I_2}$

$\Bigg\}$ BJT

h-parameter.

$$V_1 = h_i I_1 + h_r V_2$$

$$I_2 = h_f I_1 + h_o V_2$$

$$V_2 = I_L R_L$$
$$= -I_2 R_L$$

$$I_L = -I_2$$

(1) A_I

$$A_I = \frac{I_L}{I_1} = \frac{-I_2}{I_1}$$

$$I_2 = h_f I_1 + h_o V_2$$

$$I_2 = h_f I_1 - h_o I_2 R_L$$

$$I_2(1 + h_o R_L) = h_f I_1$$

$$\boxed{A_I = -\frac{I_2}{I_1} = \frac{-h_f}{1 + h_o R_L}}$$

(2) Z_i

$$Z_i = \frac{V_1}{I_1} = h_i \frac{I_1}{I_1} + h_r \cdot \frac{V_2}{I_1} = h_i + h_r \left(-\frac{I_2}{I_1}\right) \cdot R_L$$

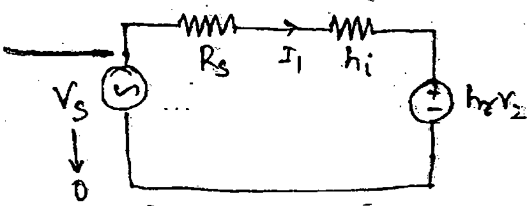
$$\boxed{Z_i = h_i + h_r A_I R_L}$$

(3) A_V

$$A_V = \frac{V_2}{V_1} = \frac{-\frac{I_2}{I_1} \cdot R_L}{\frac{V_1}{I_1}} \Rightarrow \boxed{A_V = \frac{A_I \cdot R_L}{Z_i}}$$

(4) Z_o

$$Z_o = \frac{V_2}{I_2} \;;\; Y_o = \frac{I_2}{V_2} = h_f \left|\frac{I_1}{V_2}\right| + h_o \cancel{\frac{V_2}{V_2}}$$

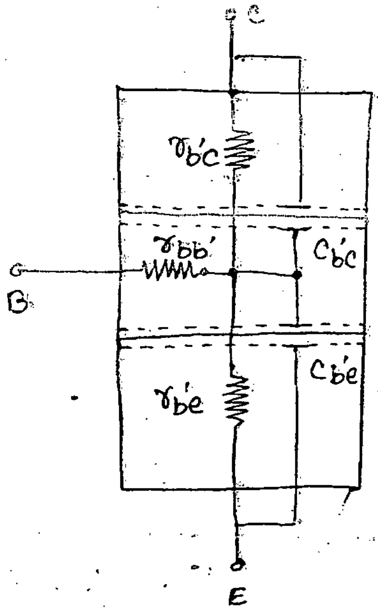


$$\frac{I_1}{V_2} = \frac{-h_r}{h_i + R_s}$$

$$Y_o := h_o - \frac{h_f h_r}{h_i + R_s}$$

$$\boxed{Z_o = \frac{1}{h_o - \frac{h_f h_r}{h_i + R_s}}}$$

⊡ HIGH FREQUENCY ANALYSIS OF BJT.



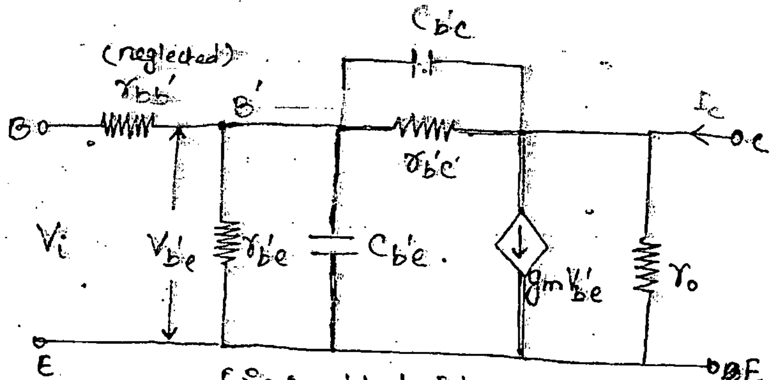
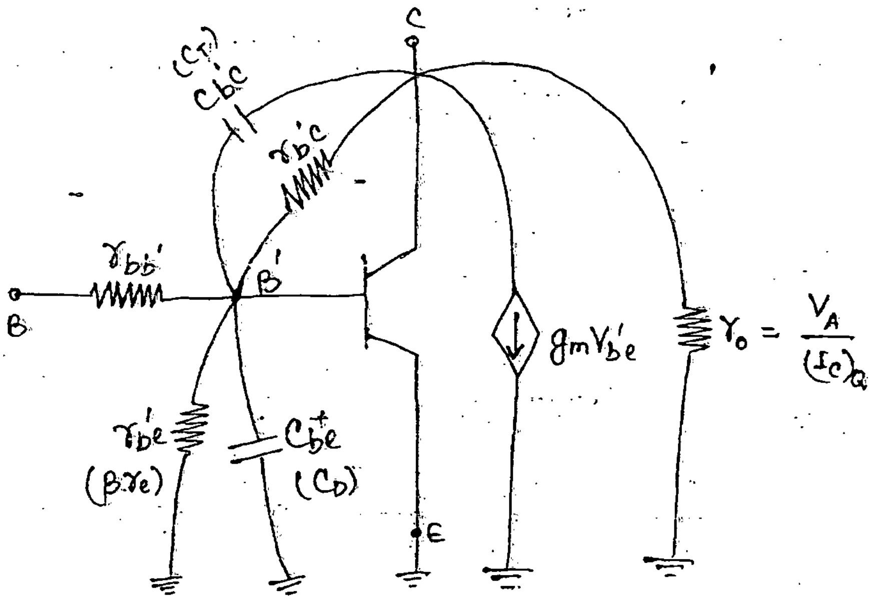


Fig: Hybrid π.



<u>Hybrid π Parameter:-</u>

$r_{bb'}$ → Base Spreading Resistance ($100\,\Omega$) (S.C)

$r_{b'e}$ → input Resistance ($1\,K\Omega$) or (r_π).

$r_{b'c}$ → Feedback Resistance ($4\,M\Omega$) (O.C)

r_{ce} → output Resistance (r_o) ($80\,K\Omega$).

$C_{b'e} \rightarrow$ Diffusion capacitance (C_π) (100pf)

$C_{b'c} \rightarrow$ Transition capacitance (C_μ) (5pf)

$g_m \rightarrow$ Transconductance $\left(50\frac{mA}{V}\right)$

CONCLUSION :- Hybrid π parameters depends on two important parameters $\rightarrow$ (1) Collector current $(I_C)_Q$

(2) Temperature (T).

☐ EXPRESSIONS FOR HYBRID π PARAMETER.

1. $\underline{g_m}$

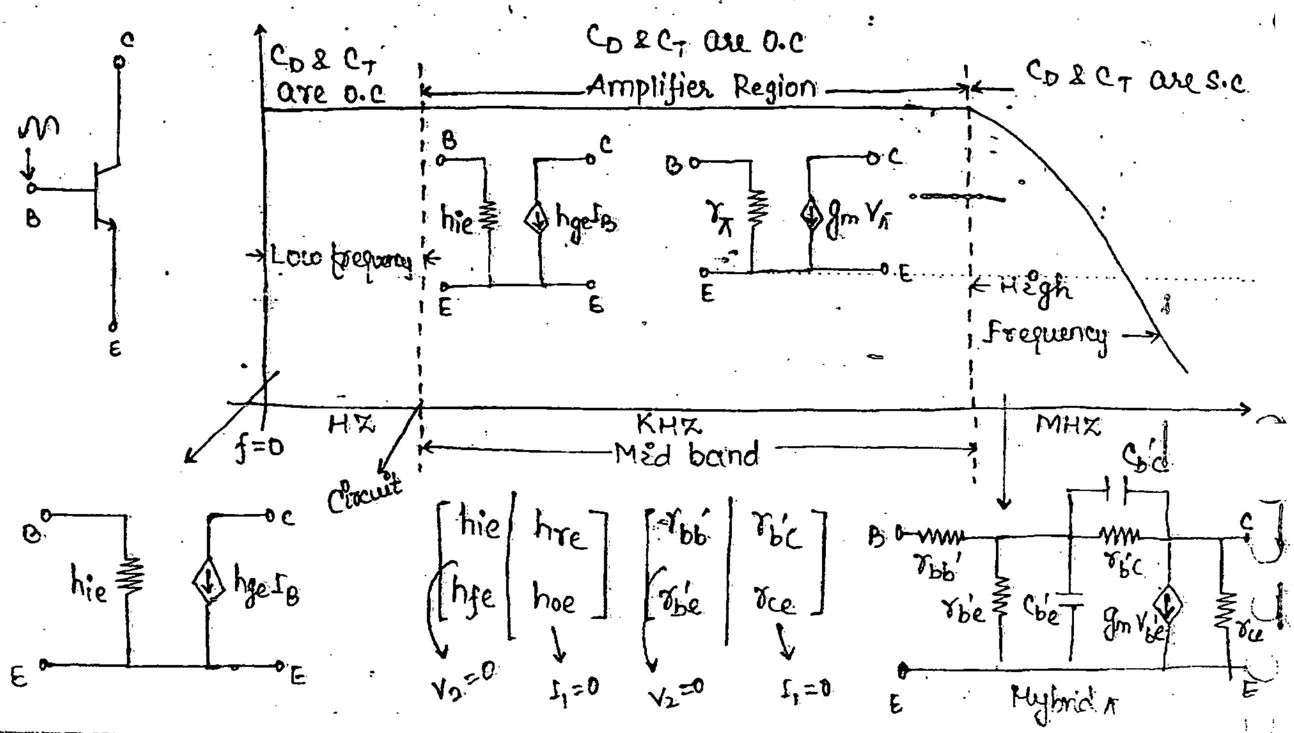
$$g_m = \frac{(I_C)_Q}{V_{b'e}} = \frac{(I_C)_Q}{(I_B)_Q\, r_{b'e}} = \frac{\cancel{(I_C)_Q}}{\cancel{(I_B)_Q}\,\cancel{\beta}\, r_e}$$

(1) $(I_C)_Q \uparrow$ $g_m \uparrow$ $A_V \uparrow$

(2) $T \uparrow$ $g_m \downarrow$ $A_V \downarrow$

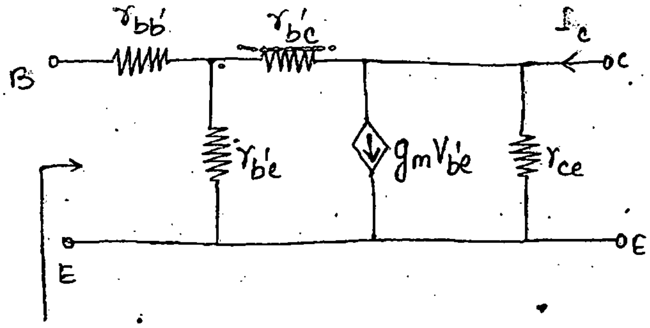
$$\boxed{g_m = \frac{1}{r_e} = \frac{(I_C)_Q}{V_T}} \qquad \boxed{g_m = \frac{(I_{CQ})}{T} \times 11{,}600}$$

<u>Concept of Amplifier</u> :-

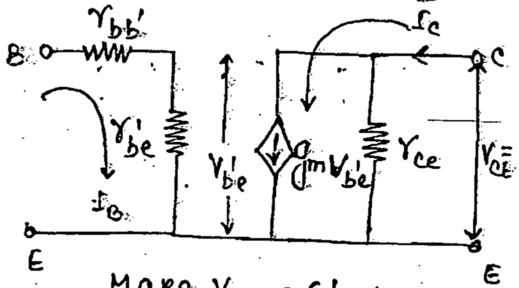


2. $r_{bb'}$ and $r_{b'e}$

Hybrid π (Mid point)



⇒

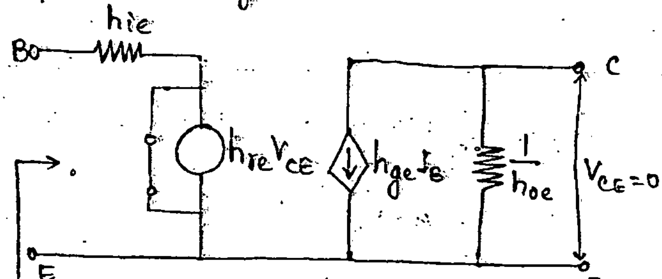


Make V_{CE} = Short ckt

$\therefore r_{b'c}$ = open.

$Z_i = r_{bb'} + r_{b'e}$

Low frequency (Mid band)



Make $V_{CE} \rightarrow$ Short

$Z_i = h_{ie}$

Hybrid π

$I_c = g_m V_{b'e}$

$I_c = g_m I_B r_{b'e}$

$\frac{I_c}{I_B} = g_m r_{b'e}$

$$\boxed{r_{b'e} = \frac{h_{fe}}{g_m} = \beta r_e}$$

h-parameter

$I_c = h_{fe} I_B$

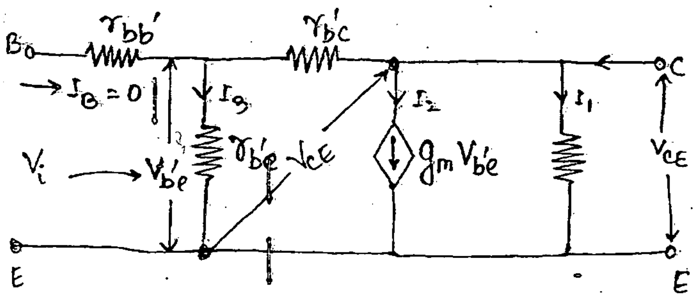
$\frac{I_c}{I_B} = h_{fe}$

$r_{bb'} + r_{b'e} = h_{ie}$

$$\boxed{r_{bb'} = h_{ie} - r_{b'e}}$$

3. $r_{b'c}$ and r_{ce}

Hybrid π (Mid band)

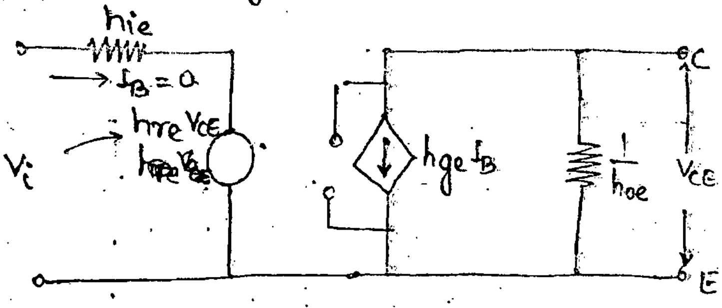


$V_i = V_{b'e} = \frac{V_{CE} \times r_{b'e}}{r_{b'e} + r_{b'c}}$

$(r_{b'c} >>> r_{b'e}) = \frac{\cancel{V_{CE}} \times r_{b'e}}{r_{b'c}} = h_{re}\cancel{V_{CE}}$

$$\boxed{r_{b'c} = \frac{r_{b'e}}{h_{re}}}$$

Low Frequency model (mid band)



$$h_{oe} = \frac{I_c}{V_{CE}}$$

$$I_c = \frac{V_{CE}}{r_{CE}} + g_m V'_{be} + \frac{V_{CE}}{r_{b'e} + r_{b'c}}$$

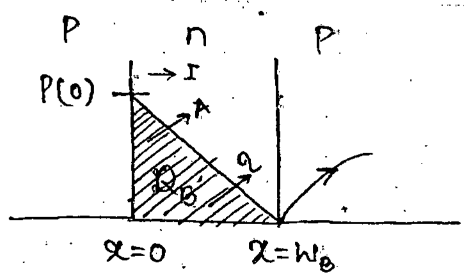
$$I_c = \frac{V_{CE}}{r_{CE}} + \overbrace{g_m r_{b'e}}^{h_{fe}} \frac{V_{CE}}{r_{b'e} + r_{b'c}} + \frac{V_{CE}}{r_{b'e} + r_{b'c}}$$

$$\boxed{h_{oe} = \frac{I_c}{V_{CE}} = g_{ce} + \cancel{h_{ge}} h_{fe} g_{b'c}}$$

$$\boxed{g_{ce} = h_{oe} - h_{fe} g_{b'c}}$$

$$\boxed{r_{ce} = \frac{1}{g_{ce}}}$$

→ DIFFUSION CAPACITANCE (C_π)



$$Q = -\frac{1}{2} P(0) \times q \times A \times W_B \quad \text{—(1)}$$

$$I = -A q D_B \frac{P(0) - 0}{0 - W_B}$$

$$I = +\frac{A q D_B P(0)}{W_B} \quad \text{—(2)}$$

Putting eqⁿ (2) in (1) we get

$$Q_B = \frac{I}{2 D_B} \cdot W_B^2$$

$$C_\pi = \frac{dQ_B}{dV} = \frac{W_B^2}{2 D_B} \cdot \frac{\partial I}{dV} \Rightarrow \boxed{C_\pi = \frac{W_B^2}{2 D_B} \cdot g_m}$$

$$\boxed{C_\pi = \frac{W_B^2}{2 D_B} \cdot \frac{1}{r_e}}$$

$$\boxed{C_\pi = \frac{W_B^2}{2 D_B} \cdot \frac{(I_c)_Q}{V_T}}$$

$$\boxed{C_\pi = T_B \cdot \frac{(I_c)_Q}{V_T}}$$

Where T_B = Base transition time

$$\boxed{T_B = \frac{W_B^2}{2 D_B} \text{ sec}}$$

→ TRANSITION CAPACITANCE (C_μ)

Diode :- $C_T \propto \frac{1}{(V_R)^n}$

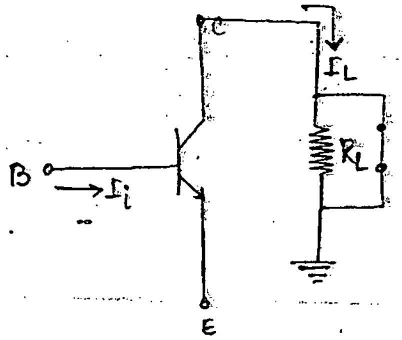
$n = \frac{1}{2}$ Alloy type

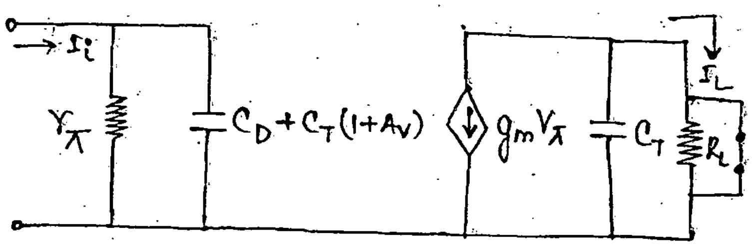
$n = \frac{1}{3}$ grown junction

BJT :- $\boxed{C_\mu \propto \dfrac{1}{(V_{CE})^n}}$

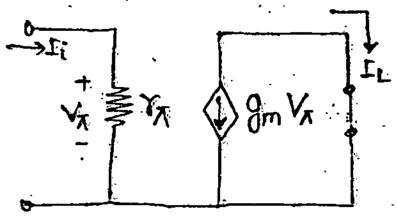
FREQUENCY RESPONSE OF BJT AMPLIFIERS.

→ CURRENT GAIN VS FREQUENCY (BJT).





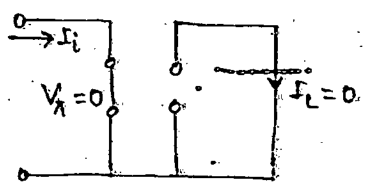
f=0



$$A_I = \frac{I_L}{I_i} = \frac{g_m \cancel{V_\pi}}{\cancel{V_\pi}/r_\pi} = g_m r_\pi = h_{fe}$$

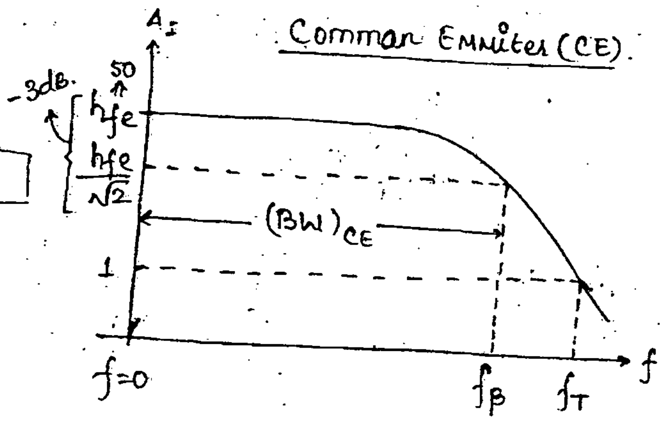
$$\boxed{A_I = h_{fe}}$$

f= ∞

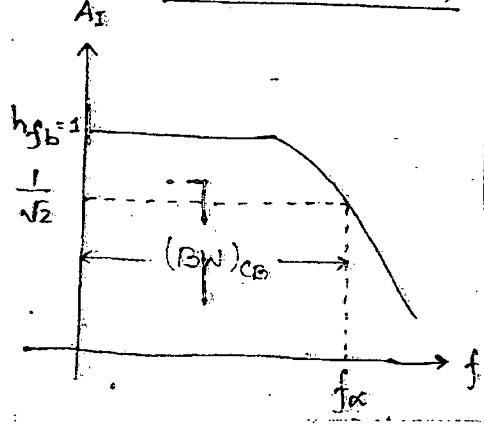


$$\boxed{A_I = 0}$$

Common Emmiter (CE).



Common Base (CB)



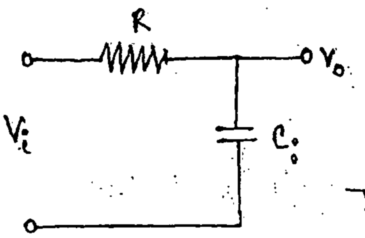
$$\boxed{f_\alpha > f_T > f_\beta}$$

* f_β (β cut off Frequency) :- It is the frequency at which CE Short ckt gain reduces by 3dB of its value.

* f_T (unity gain Band width Frequency) :- It is the frequency at which CE Short ckt current gain reduces to unity.

* f_α (α cut off Frequency) :- It is the frequency at which CB Short ckt current gain reduces by 3dB of its value

LOW PASS CIRCUIT.



$$T.F = \frac{V_{o(s)}}{V_{i(s)}} = \frac{\frac{1}{sC}}{R + \frac{1}{sC}} = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}}$$

$$T.F = \frac{1}{1 + j\omega CR} = \frac{1}{1 + j2\pi fRC} = \frac{1}{1 + j\frac{f}{f_{3dB}}}$$

where $f_{3dB} = \frac{1}{2\pi RC}$ $\Rightarrow$ $A_I = \frac{h_{fe}}{1 + j\frac{f}{f_\beta}}$

$$|A_I| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_\beta}\right)^2}}$$ When $f \to f_T \Rightarrow A_I = 1$, $1 = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f_T}{f_\beta}\right)^2}}$

$\frac{f_T}{f_\beta} \gg 1 \Rightarrow 1 = \frac{h_{fe}}{f_T/f_\beta} \Rightarrow \boxed{f_T = h_{fe} f_\beta}$

Relation b/w f_β, f_T and C_D & C_T.

$$f_\beta = \frac{1}{2\pi RC}$$

$$= \frac{1}{2\pi \beta r_e \; C_D + C_T(1 + A_V)}$$

$A_V = 0$ (Short ckt load)

$$\boxed{f_\beta = \frac{1}{2\pi \beta r_e (C_D + C_T)}}$$

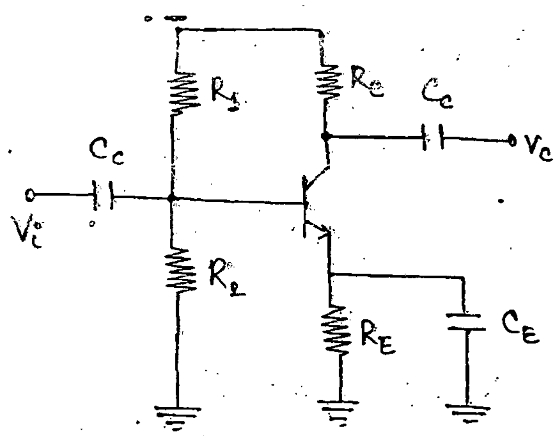
$$\boxed{f_T = \frac{1}{2\pi r_e (C_D + C_T)}}$$

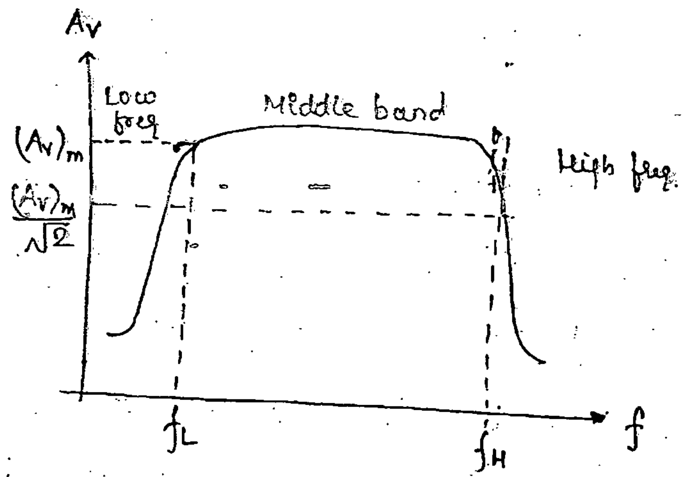
$$\boxed{f_T = \frac{g_m}{2\pi (C_D + C_T)}}$$

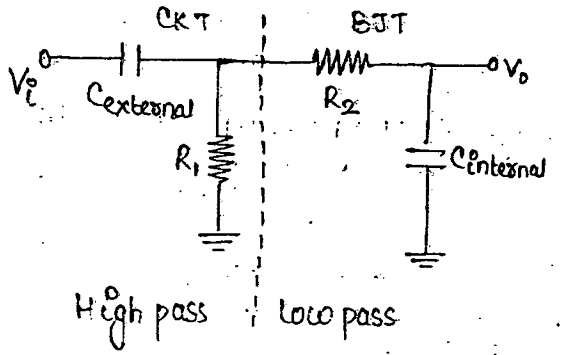
$$\boxed{f_\alpha = (1 + \beta) f_\beta}$$

Voltage Gain vs frequency

CE Amplifier







CAPACITORS

- Internal capacitor
  - Diffusion capacitance (C_D)
  - Transition capacitance (C_T)
- External capacitor
  - Coupling capacitor (C_C)
  - By Pass capacitor (C_E)

→ LOW FREQUENCY RANGE

* At low frequency range internal capacitor C_D and C_T are neglected because they are open circuit.
* But when the external capacitors C_C and C_E when they are open ckt they will create a problem for system response.

* The System response at low frequency range is a high pass Response.

* T.F of. high pass $T.F = \frac{S}{S + \frac{1}{R_1C_1}}$ → one pole, one Zero.

→ HIGH FREQUENCY RANGE.

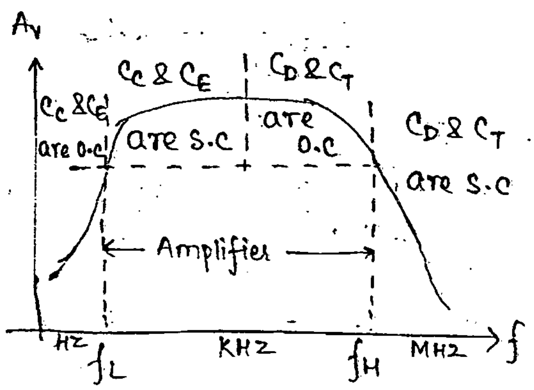
* At high frequency range external capacitor C_C & C_E are neglected because they are S.C.

* But the internal capacitance C_D & C_T when they are assumed to be S.C they will be create a problem for a System response

* The System response at high frequency range is a low pass response.

* T.F of low pass $T.F = \frac{K}{S + \frac{1}{R_2C_2}}$ → one pole

→ MID BAND RANGE.



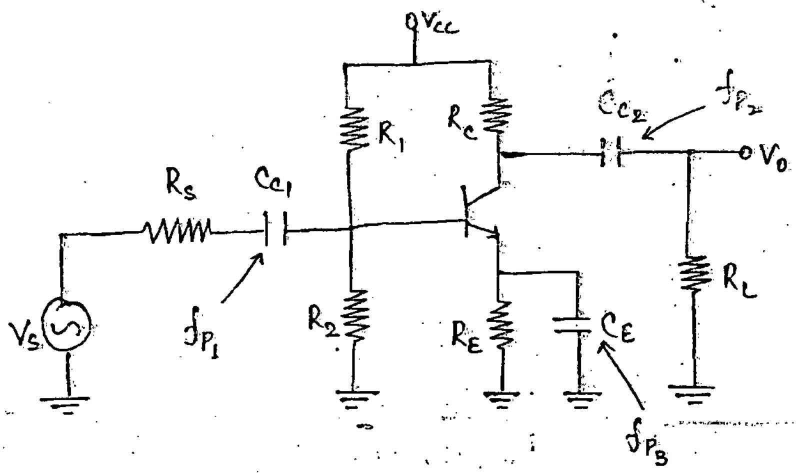
* In low frequency range mid band range frequency are considered as high frequency. Therefore external capacitor C_C & C_E are assumed to be S.C.

* At high frequency range mid band range frequency are considered as low frequency therefore internal capacitor C_D & C_T are assumed to be open ckted.

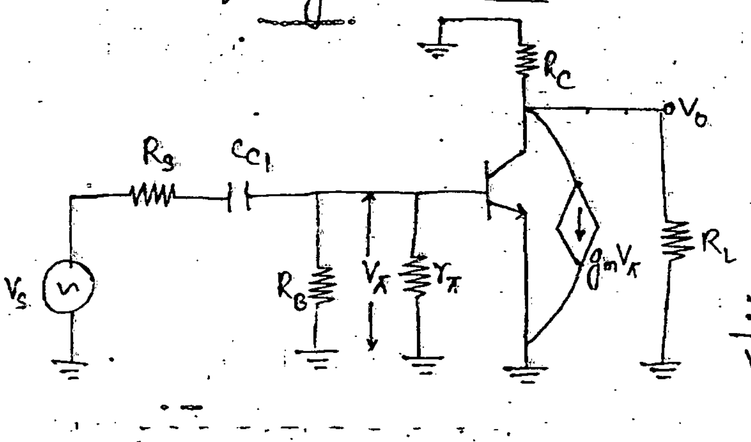
* In the Mid band range all the internal & external

capacitor are neglected. Therefore gain is independent of frequency.

LOWER 3dB FREQUENCY DESIGN



→ Pole Frequency across C_{C_1}



$$V_0 = -g_m V_\pi R_C // R_L$$

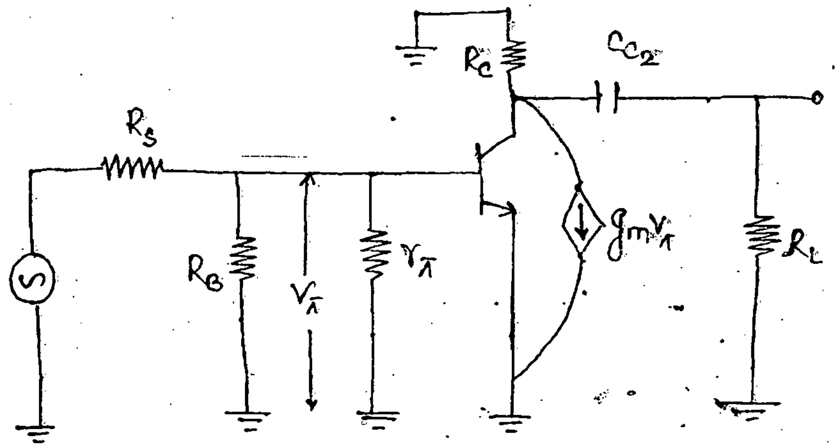
$$V_\pi = \frac{V_S \times R_B // r_\pi}{R_B // r_\pi + R_S + \frac{1}{sC_1}}$$

$$\frac{V_0}{V_S} = \frac{-g_m R_B // r_\pi \cdot R_C // R_L}{(R_S + R_B // r_\pi)} \cdot \frac{S}{S + \frac{1}{}}$$

$$\frac{V_0}{V_S} = \underbrace{\frac{-g_m R_B // r_\pi \; R_C // R_L}{(R_S + R_B // r_\pi)}}_{(A_V)_m} \cdot \frac{S}{S + \frac{1}{C_{C_1}(R_B // r_\pi + R_S)}}$$

$$\boxed{\omega_{P_1} = \frac{1}{C_{C_1}(R_B // r_\pi + R_S)}}$$

→ Pole frequency across C_{C_2}.



$$V_o = I_L \cdot R_L$$

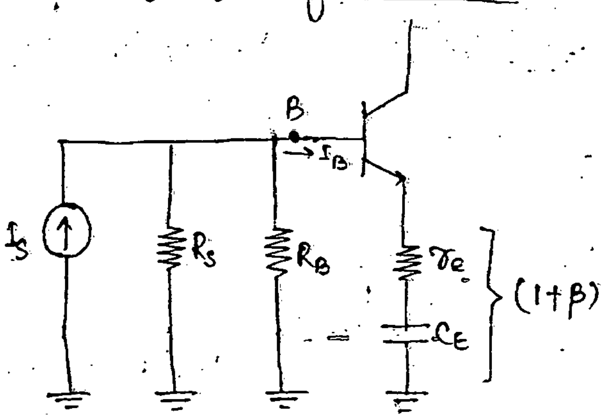
$$V_\pi = \frac{V_S \times R_B // r_\pi}{R_B // r_\pi + R_S}$$

$$V_o = \frac{-g_m V_\pi \times R_C}{R_C + R_L + \frac{1}{SC_2}} \cdot R_L$$

$$\frac{V_o}{V_S} = \underbrace{\frac{-g_m \cdot R_B // r_\pi \cdot R_C \cdot R_L}{R_B // r_\pi + R_S (R_C + R_L)}}_{A_m} \cdot \frac{S}{S + \frac{1}{C_{C_2}(R_C + R_L)}}$$

$$\boxed{\omega_{P_2} = \frac{1}{C_{C_2}(R_C + R_L)}}$$

→ Pole frequency across C_E



$$I_B = \frac{I_S \times R_S // R_B}{R_S || R_B + (1+\beta) r_e + \frac{(1+\beta)}{SC_E}}$$

$$\frac{1}{(R_S // R_B + (1+\beta) r_e) \cdot 1 + \frac{1+\beta}{SC_E (R_S || R_B + (1+\beta) r_e)}}$$

$$\frac{1}{S + \frac{1}{C_E \left(\frac{(1+\beta) r_e}{1+\beta} + \frac{R_S // R_B}{(1+\beta)} \right)}}$$

Practically

$R_S \simeq 0$

$$\frac{S}{S + \frac{1}{C_E r_e}}$$

$$\boxed{\omega_{P_3} = \frac{1}{C_E r_e}}$$

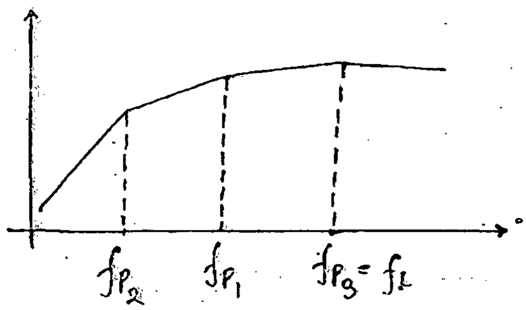
CONCLUSION :-

1) $f_{P_1}(C_{C_1}) = \dfrac{1}{2\pi C_{C_1}(R_S + R_B \| r_\pi)}$

2) $f_{P_2}(C_{C_2}) = \dfrac{1}{2\pi C_2 (R_C + R_L)}$

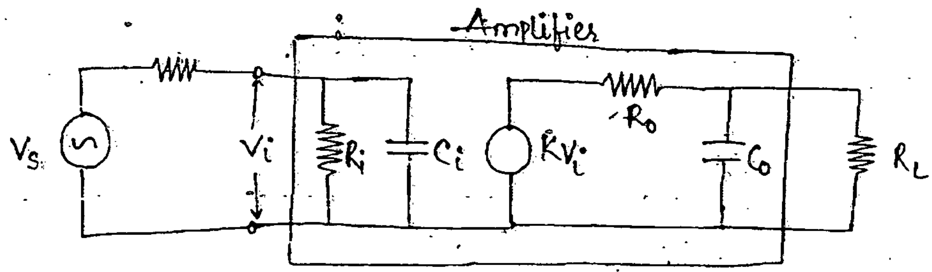
$$\boxed{f_{P_2} < f_{P_1} < f_{P_3}}$$

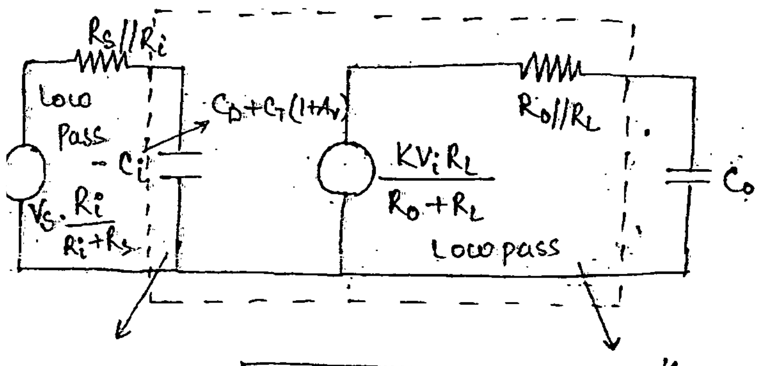
3) $f_{P_3}(C_E) = \dfrac{1}{2\pi C_E r_e}$.



$$\boxed{f_L = \frac{1}{2\pi C_E r_e}}$$

HIGHER 3dB FREQUENCY DESIGN.





T_i = input time constant

$$T_i = \frac{R_S \cdot R_i}{R_S + R_i} \times C_i$$

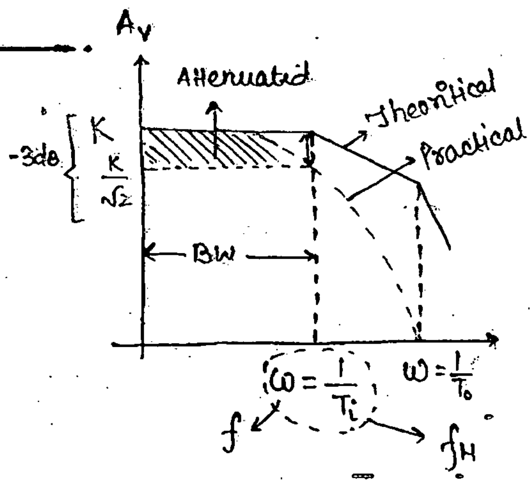
T_o = output time constant

$$T_o = \frac{R_o R_L}{R_o + R_L} \times C_o$$

$$T.F = \frac{K_1}{1 + sT_i} \qquad \boxed{K_1 \cdot K_2 = K} \qquad T.F = \frac{K_2}{1 + sT_o}$$

$$T.F = \frac{K}{(1 + sT_i)(1 + sT_o)} \Rightarrow T.F = \frac{K}{1 + sT_i} \Rightarrow \boxed{|T.F| = \frac{K}{\sqrt{1 + \omega^2 T_i^2}}}$$

$T_i >> T_o$

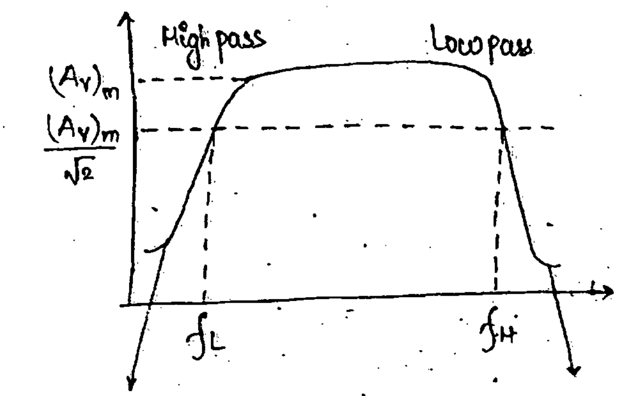


When $\omega \rightarrow \frac{1}{T_i}$

$$\boxed{T.F = \frac{K}{\sqrt{2}}}$$

$$\boxed{f_H = \frac{1}{2\pi \beta r_e (C_D + C_T(1+A_v))}}$$

PHASE ANALYSIS.



<u>Lower cut off frequency.</u>

$$\theta_l = + \tan^{-1}\left(\frac{f_L}{f}\right)$$

Where $f \rightarrow f_L$

$$\boxed{\theta_l = \tan^{-1} 1 = 45^\circ}$$

$$(A_v)_h = \frac{(A_v)_m}{1 + j\left(\frac{f}{f_H}\right)}$$

$$(A_v)_l = \frac{(A_v)_m}{1 - j\left(\frac{f_L}{f}\right)}$$

<u>Higher cut off frequency.</u>

$$\theta_h = - \tan^{-1}\left(\frac{f}{f_H}\right)$$

where $f \rightarrow f_H$

$$\boxed{\theta_h = - \tan^{-1} 1 = -45^\circ}$$

$$\boxed{\theta_{lCE} = 180^\circ + \theta_l} = 225^\circ$$

$$\boxed{\theta_{hCE} = 180^\circ + \theta_h} = 180^\circ - 45^\circ = 135^\circ$$

APPROXIMATE MODEL ANALYSIS IN LOW FREQUENCY. (CE)

Conditions.

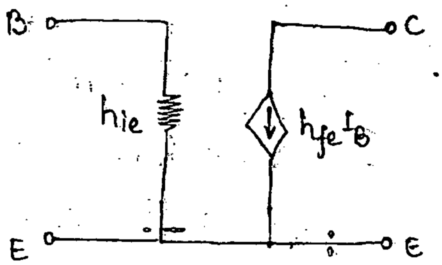
1. $h_{oe} R_L \leq 0.1$

   Ex :- $A_I = \dfrac{-h_{fe}}{1 + h_{oe} R_L} = \dfrac{-h_{fe}}{1+0.1} = -0.91 h_{fe}$.

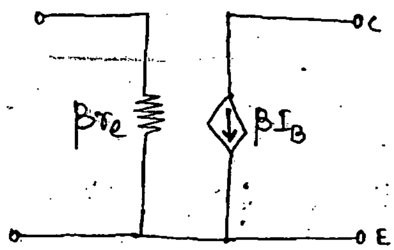
   $\boxed{R_L \leq 5K}$

2. h_{re} and h_{oe} are neglected.
3. It is valid only in CE mode.

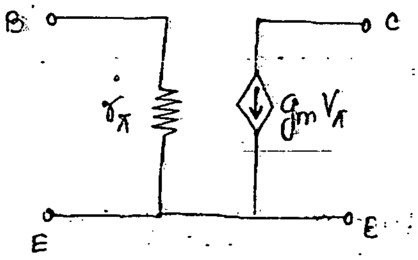
h-parameter model



re model



r_π Model



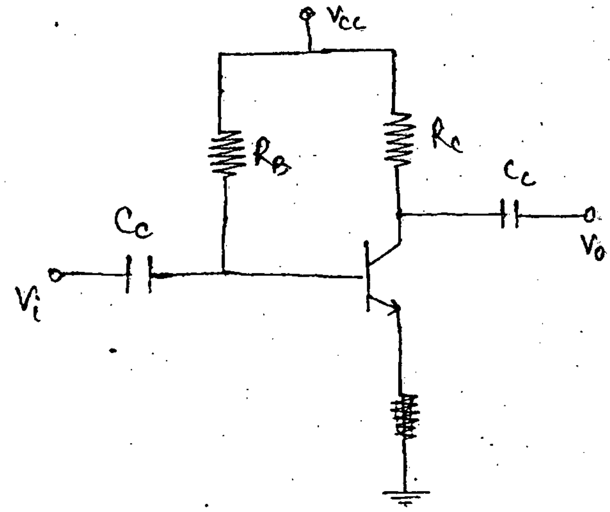
$\boxed{h_{ie} = \beta r_e = r_\pi}$

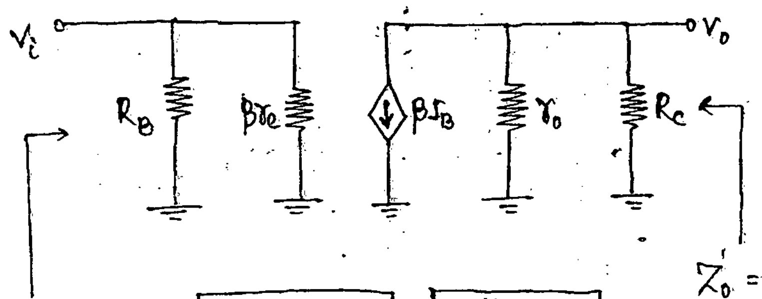
$\boxed{h_{fe} I_B = \beta I_B = g_m V_\pi}$

AMPLIFIERS MODELS.

1. Common Emitter bypass amplifier
2. Common emitter un bypass amplifier
3. Common collector amplifier
4. Common Base amplifier.

1. CE BY PASS AMPLIFIER





$$V_o = -\beta I_B \, r_o \| R_C$$
$$= -\beta I_B R_C$$
$$V_o = -\beta \cdot \frac{V_i}{\beta r_e} \cdot R_C$$
$$\boxed{\frac{V_o}{V_i} = -\frac{R_C}{r_e}}$$

$Z_i = R_B \| \beta r_e$ $\boxed{R_B \geq 10\beta r_e}$ $\boxed{r_o \geq 10 R_C}$

$= \beta r_e$

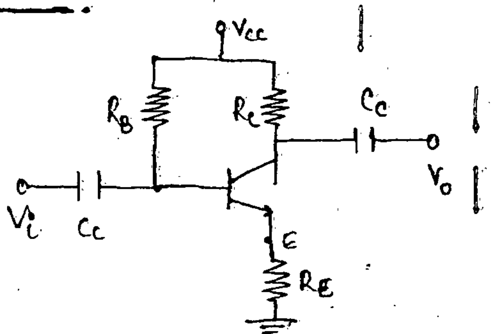
$Z_o = r_o \| R_C$

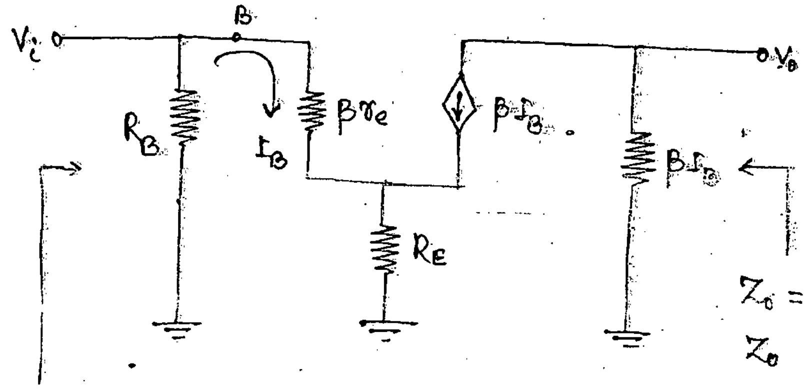
$= R_C$

Drawback :- 1. The gain is unstable because of dynamic resistance r_e.

2. The i/p impedance is low (For ideal ampl^r $Z_i = \infty$).

2. CE UN BY PASS AMPLIFIER.





$V_o = -\beta I_B \, r_o // R_c$

$= -\beta I_B R_c$

$= -\beta \cdot \dfrac{V_i}{\beta R_E} \cdot R_c$

$\boxed{\dfrac{V_o}{V_i} = -\dfrac{R_c}{R_E}}$

↓

Stability

$Z_o = r_o // R_C$

$Z_o = R_c$

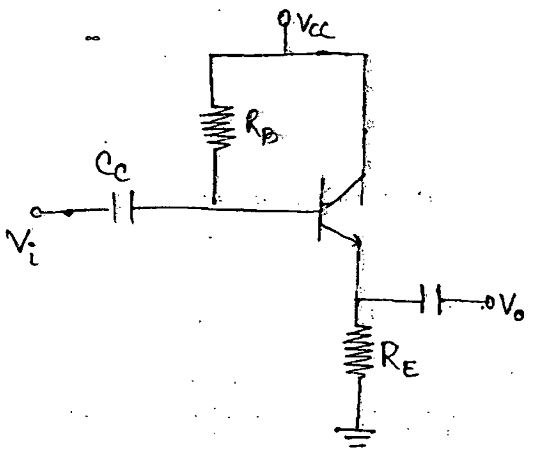
$Z_i = R_B // \beta r_e + (1+\beta) R_E$

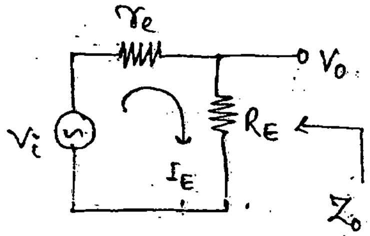
$Z_i = R_B // \beta R_E$ $\quad \boxed{\beta R_E \geq 10 \beta r_e}$

↓

high i/p impedance

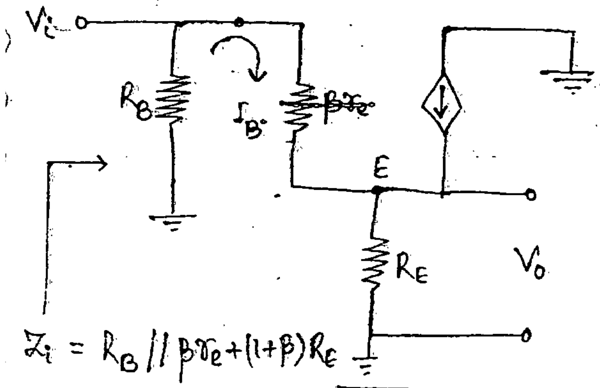
8. COMMON COLLECTOR AMPLIFIER.





$Z_o = R_E // r_e$

$Z_o = r_e$



$\boxed{A_V = \dfrac{V_o}{V_i} = \dfrac{R_E}{R_E + r_e}}$

$A_V = A_I \dfrac{Z_L}{Z_i}$

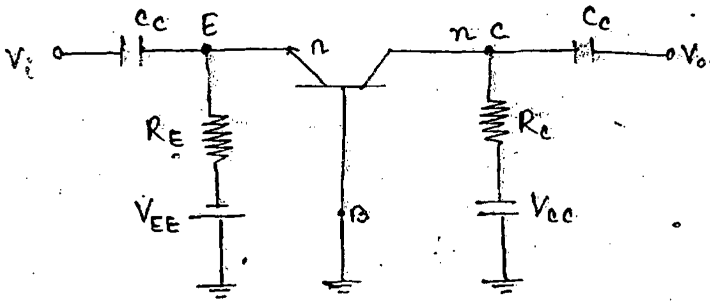
$1 = A_I \dfrac{Z_L}{Z_i}$ For Buffer $A_V = 1$

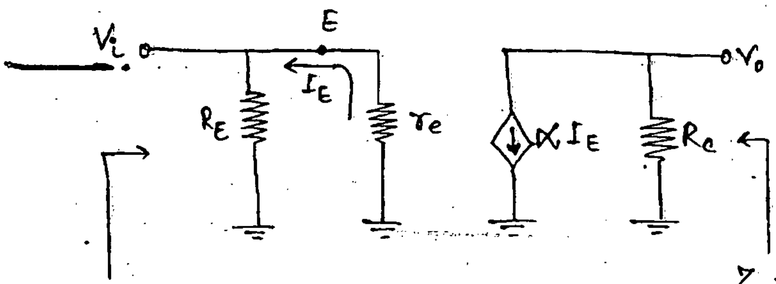
$\boxed{Z_i = A_I Z_L}$

$Z_i = R_B // \beta r_e + (1+\beta) R_E$

$Z_i = R_B // \beta R_E$ $\quad \boxed{\beta R_E \geq 10 \beta r_e}$

4. COMMON BASE COLLECTOR AMPLIFIER.





$V_o = -\alpha I_E R_c$

$V_o = -\alpha \left(-\frac{V_i}{r_e}\right) R_c$

$\boxed{\frac{V_0}{V_i} = \frac{R_c}{r_e}}$ $\alpha \approx 1$

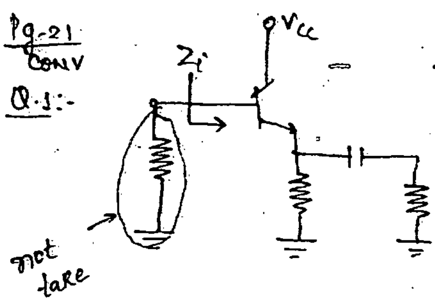
$Z_0 = r_c$

$Z_i = R_E || r_e$

$Z_i = r_e$

Pg-21 CONV

Q.1:-



$A_v = A_I \frac{Z_L}{Z_i}$

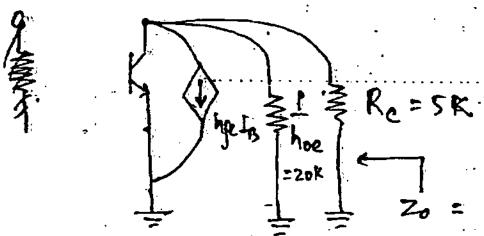
$1 = A_I \frac{Z_L}{Z_i}$

$Z_i = A_I Z_L = \beta R_E || R_L$

⇒ C becomes short ckt.

Q2. $h_{fe} = 100$; $h_{ie} = 2k\Omega$; $h_{re} = 0$; $h_{oe} = 0.05m$ mhos. $= \frac{1}{0.05}$

$= 20K\Omega$

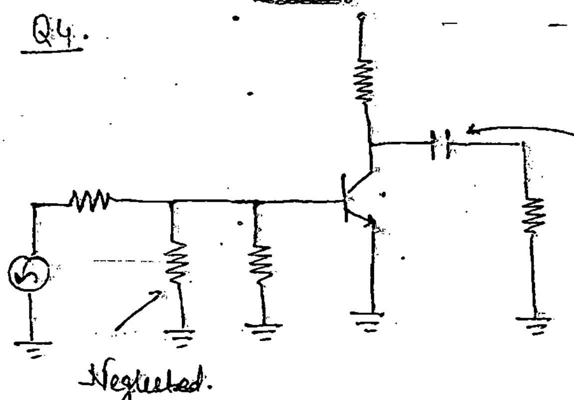


$Z_o = \frac{1}{h_{oe}} || R_c = 20K || 5K = 4K$

Q3. $\frac{V_o}{V_s} = -\frac{R_c}{r_e} = -\frac{4k}{25mV} \times 1mA$ | $\frac{4000}{25} = -160$ ↓ Phase shift.

$r_e = \frac{V_1}{(I_E)_Q} = \frac{25mV}{1mA} = 25$

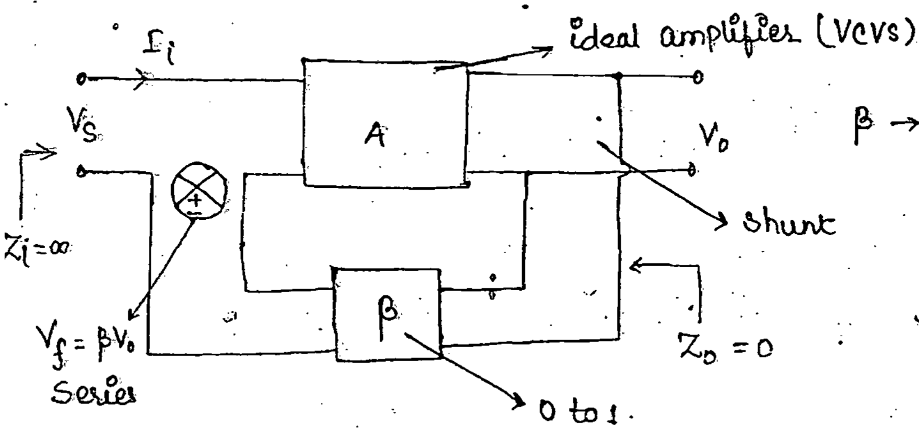
Q4.



$R_i = 1259\,\Omega$.

$$f_{3dB} = \frac{1}{2\pi C_{C2}(R_C+R_L)}$$

FEEDBACK AMPLIFIER.



β → Feedback fraction
(or)
Feedback Ratio
(or)
Reverse transmission factor.

Positive Feedback

$V_o = AV_i$ $\quad \boxed{1-A\beta=0}$

$V_i = V_s + V_f$ $\quad \boxed{A\beta=1}$

$V_o = A(V_s+\beta V_o)$

$V_o(1-A\beta) = AV_s$

$$\boxed{\frac{V_o}{V_s} = \frac{A}{1-A\beta}}$$

Negative feedback.

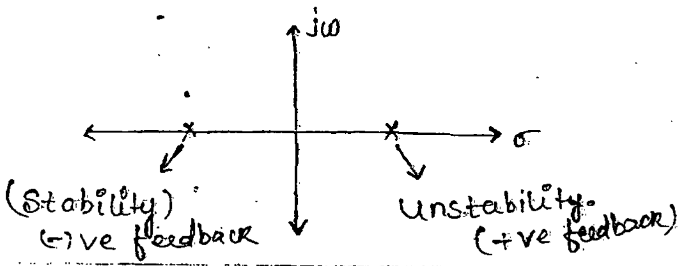
$V_o = AV_i$ $\quad \boxed{1+A\beta=0}$

$V_i = V_s - V_f$ $\quad \boxed{A\beta=-1}$

$V_o = A(V_s-\beta V_o)$

$V_o(1+A\beta) = AV_s$

$$\boxed{\frac{V_o}{V_s} = \frac{A}{1+A\beta}}$$



CONCLUSION :- 1. $A_{pf} > A > A_{nf}$

2. $A_{nf} = \dfrac{A}{1 + A_v \beta}$

$A_v = \dfrac{R_c}{r_e} = \dfrac{1k\Omega}{1\Omega} = 10^3 \quad A\beta >> 1 \quad \boxed{A_{nf} = \dfrac{1}{\beta}}$

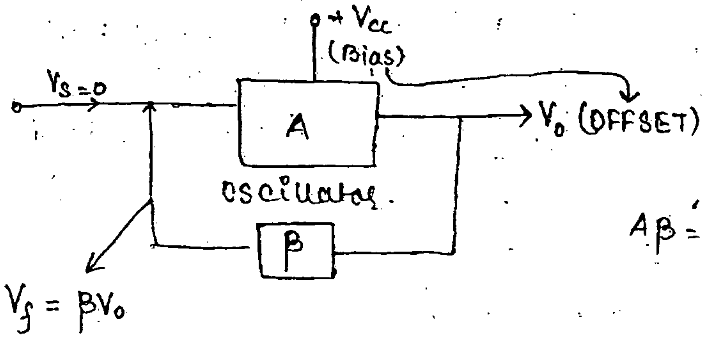
$\beta = 0$ to 1.

Stability concept.

Negative feedback is always applied for <u>Stable</u> system like amplifiers. (Stable Amplifiers).

3. $A_{pf} = \dfrac{A}{1 - A\beta}$

$|A\beta| = 1 \qquad A_{pf} = \dfrac{V_o}{V_s} = \dfrac{A}{0} \quad \boxed{V_s = 0}$



$A = \dfrac{V_o}{V_i} \; ; \; \beta = \dfrac{V_s}{V_o}$

$A\beta = 1 \Rightarrow \dfrac{V_o}{V_i} \cdot \dfrac{V_f}{V_o} = 1$

$\Rightarrow \boxed{V_f = V_i}$

oscillator.

NEGATIVE FEEDBACK AMPLIFIER. ~~ADVA~~

ADVANTAGE :-

1. <u>Stability of ac gain :-</u> Suppose there is small change in the internal resistance r_e of an amplifier. Then the fractional change of gain with feedback is $\dfrac{\partial A_f}{A_f}$

$A_f = \dfrac{A}{1 + A\beta}$

d. w.r.t A

$\dfrac{\partial A_f}{\partial A} = \dfrac{(1 + A\beta) \cdot 1 - A\beta}{(1 + A\beta)^2}$

$\dfrac{\partial A_f}{\partial A_f} = \dfrac{1}{(1 + A\beta)^2} \cdot \dfrac{\partial A}{A_f}$

$$\frac{\partial A_f}{A_f} = \frac{1}{(1+A\beta)^2} \cdot \frac{\partial A}{A} \cdot \cancel{(1+A\beta)}$$

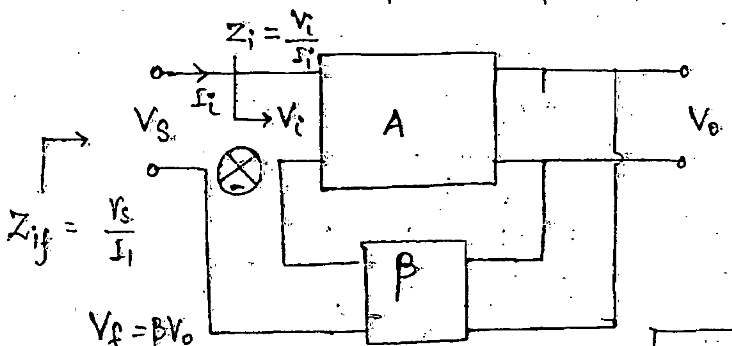
$$\boxed{\frac{\partial A_f}{A_f} = \frac{1}{(1+A\beta)} \cdot \frac{\partial A}{A}}$$

$\frac{1}{1+A\beta}$ = Sensitivity (S)

$1+A\beta$ = Desensitivity (D)

$$\boxed{\frac{\partial A_f}{A_f} < \frac{\partial A}{A}}$$

2. <u>Increase in Input impedance with Series fb.</u>



$V_i = V_s - V_f$

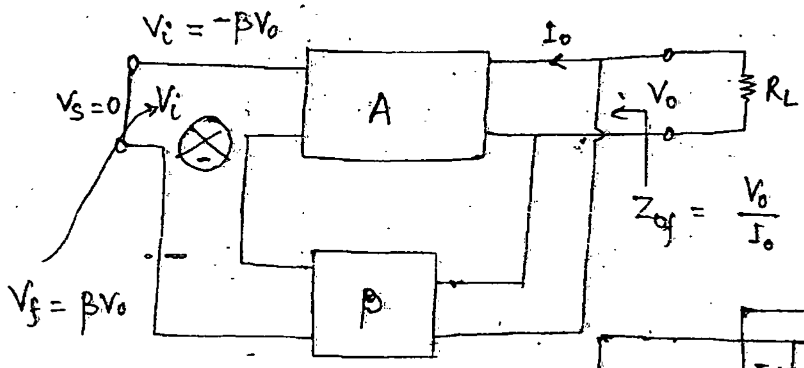
$= V_s - \beta V_o$

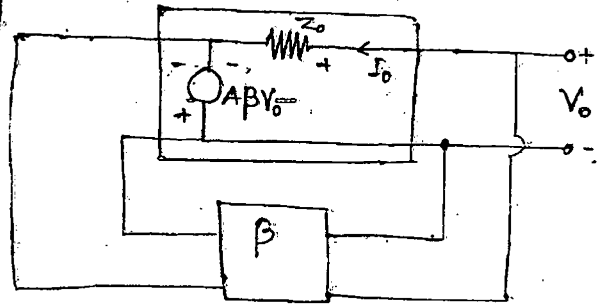
$V_i = V_s - A\beta V_i$

$\frac{V_i}{I_1}(1+A\beta) = \frac{V_s}{I_i}$

$$\boxed{Z_{if} = Z_i(1+A\beta)}$$

3. Decrease in o/p impedance by shunt feedback.





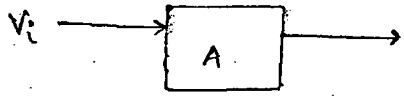
KVL @ o/p loop

$V_o + A\beta V_o = I_o Z_o$

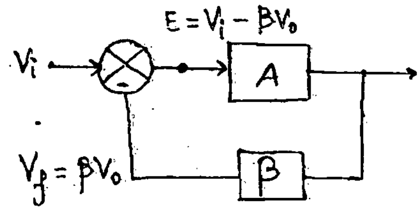
$V_o(1+A\beta) = I_o Z_o$

$$\boxed{Z_{of} = \frac{V_o}{I_o} = \frac{Z_o}{1+A\beta}}$$

4. Linearity



$$V_o = V_{offset} + AV_i + K_1 V_i^2 + K_2 V_i^3 + \dots$$



$$V_o = V_{offset} + AE + K_1 E^2 + K_2 E^3 + \dots$$

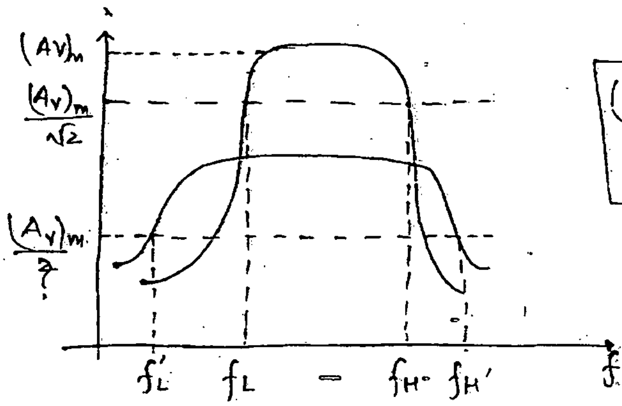
$$= V_{offset} + A(V_i - \beta V_o) + K_1 E^2 + K_2 E^2 + \dots$$

$$V_o(1 + A\beta) = V_{offset} + AV_i + K_1 E^2 + K_2 E^3 + \dots$$

$$V_o = \underbrace{\frac{V_{offset}}{1 + A\beta}}_{0} + \frac{A}{1 + A\beta} \cdot V_i + \underbrace{\frac{K_1 E^2 + K_2 E^3}{1 + A\beta}}_{0} + \dots$$

$$V_o = \frac{A}{1 + A\beta} \cdot V_i \qquad A\beta >> 1 \qquad \boxed{V_o = \frac{1}{\beta} V_i}$$

5. Increase in Bandwidth with Negative feedback.



Lower cutoff frequency

$$\boxed{(A_V)_L = \frac{(A_V)_m}{1 - j\left(\frac{f_L}{f}\right)}} \rightarrow \text{without feed back.}$$

$$(A_V)_{Lf} = \frac{(A_V)_L}{1 + (A_V)_L \beta}$$

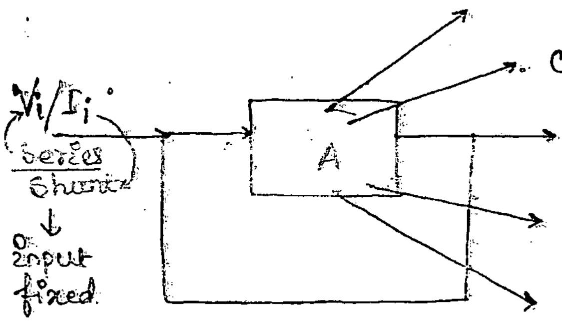
$$(A_V)_{Lf} = \frac{\frac{(A_V)_m}{1 - j(f_L/f)}}{1 + \frac{(A_V)_m}{1 - j(f_L/f)} \cdot \beta} = \frac{(A_V)_m}{1 + (A_V)_m \beta - j\left(\frac{f_L}{f}\right)}$$

$$\boxed{(A_V)_{Lf} = \frac{\frac{(A_V)_m}{1 + (A_V)_m \beta}}{1 - j\left(\frac{f_L}{1 + (A_V)_m \beta}\right) \cdot \frac{1}{f}}} \rightarrow \text{with feedback}$$

where $f_L' = \frac{f_L}{1 + (A_V)_m \beta}$

$$f_H' = f_H\,(1 + (A_V)_m \beta)$$

TOPOLOGY



Voltage amplifier $Z_i = \infty$; $Z_o = 0$

Current amplifier . $Z_i = 0$; $Z_o = \infty$

$\frac{V_o}{I_o}$ $\left(\frac{\text{Voltage}}{\text{current}}\right)$ → output fixed.

Transconductance $Z_i = \infty$; $Z_o = \infty$

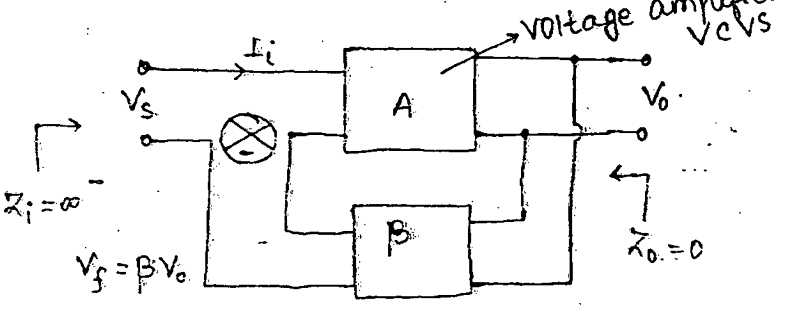
Trans Resistance amplifier $Z_i = 0$; $Z_o =$

Topology O/P		Topology I/P		Topology I/P	
Voltage	Series	Series	Voltage	Series	Shunt
Voltage	Shunt	Shunt	Voltage	Shunt	Series
Current	Series	Series	current	Series	Series
Current	Shunt	Shunt	current	Shunt	Series

Topology

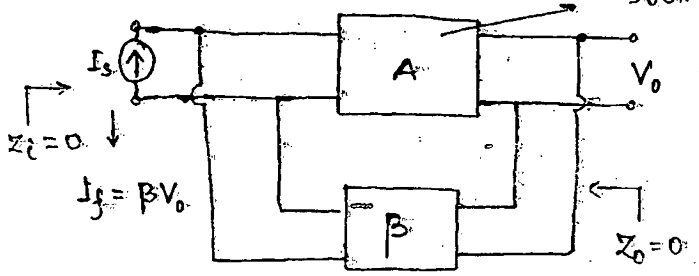
O/P	
Voltage	voltage
Voltage	current
current	Voltage
Current	current

VOLTAGE SERIES



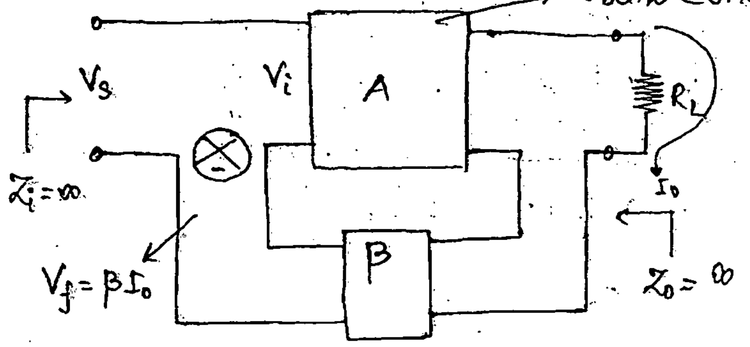
VOLTAGE SHUNT

Trans Resistance amplifier
$Z_i = 0$; $Z_o = 0$
ICVS



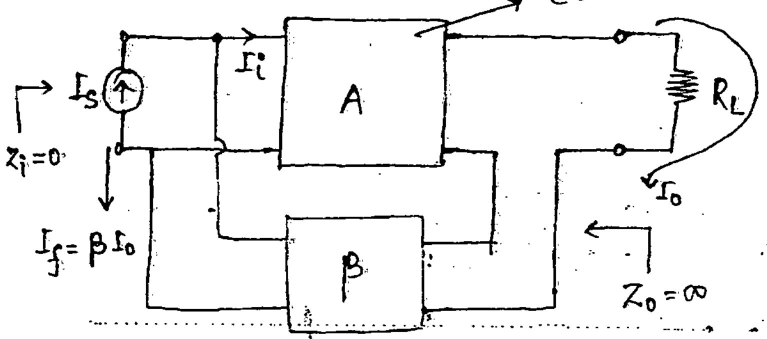
CURRENT SERIES

Trans conductance amplifier
VCIS

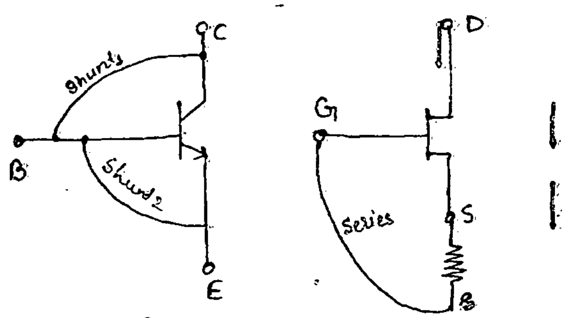


CURRENT SHUNT

current amplifier
ICIS

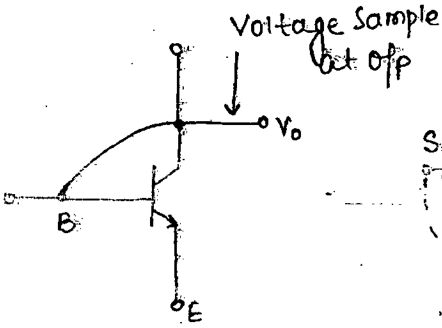


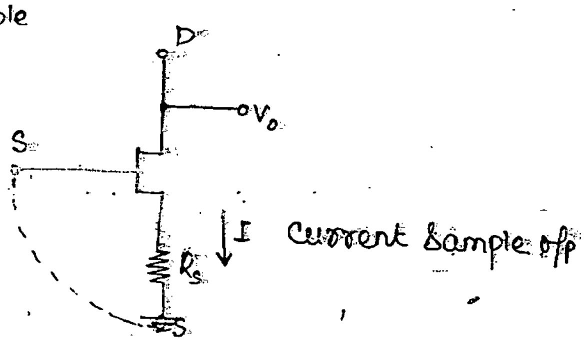
FEEDBACK ANALYSIS (BJT AND FET)



BJT FET

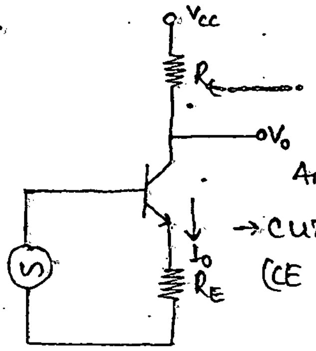
BJT FET





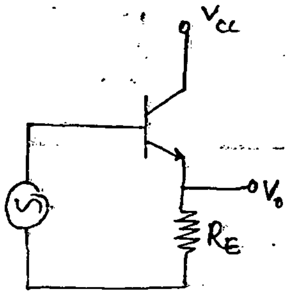
Question:-

1>



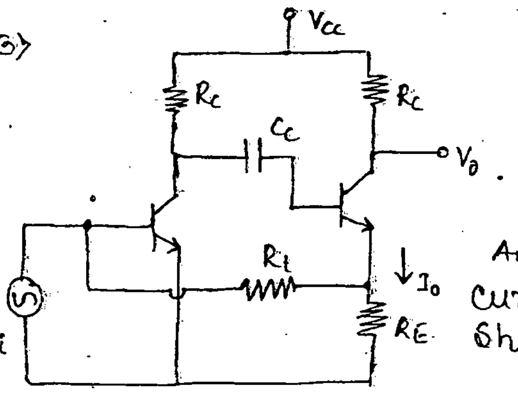
Ans:-
→ Current Series
(CE Unby Pass)

2>



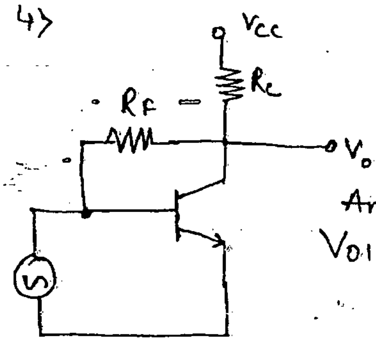
Ans:-
Voltage Series
(Emitter follower)

3>



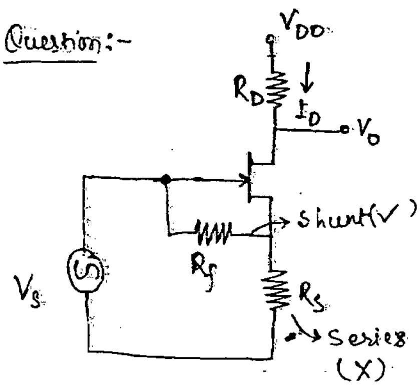
Ans:-
Current Shunt

4>



Ans:-
Voltage Shunt

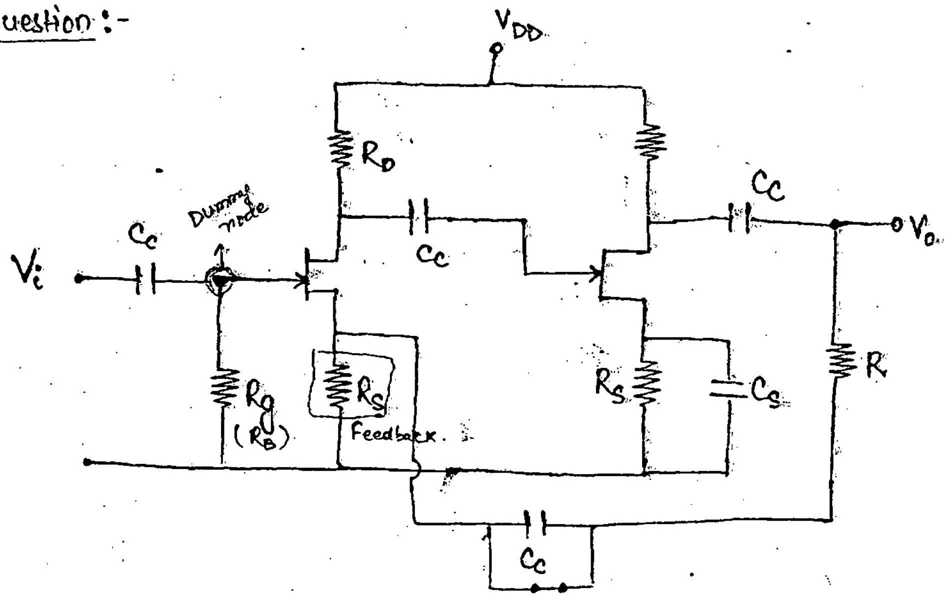
Question:-



Wherever Series & Shunt feedback are connected at a time in the ckt, shunt dominates ~~the~~ series effect

∴ Voltage Shunt.

Question :-



Ans :-
Voltage series