Rectifier $\rightarrow$ AC voltage into pulsating DC converter

Half-Wave Rectifier :-

(i) Average or dc load ~~co~~ current :-

I_{av} or $I_{dc} = \frac{I_m}{\pi} = 0.318\, I_m$ (Ideal)

(2) RMS or AC load current :-

$$\boxed{I_{rms} = \frac{I_m}{2}}$$

(3) $\boxed{V_{dc} = \frac{V_m}{\pi} = \underset{\text{Ideal}}{0.318(V_m)} \text{ or } \underset{\text{Non Ideal}}{0.318(V_m - V_k)}}$

(4) $\boxed{V_{rms} = \frac{V_m}{2}}$

(5) Ripple factor (γ) $= 1.21 = \sqrt{(FF)^2 - 1}$ | $F.F = 1.57$

(6) $\boxed{\text{Peak Inverse Voltage (PIV)} \geq V_m}$

(7) $\%\eta = 40.57\%$

Full wave Rectifier :-

(A) Bridge Rectifier :-

(1) $I_{dc} = \frac{2 I_m}{\pi} = \underset{\text{(Ideal)}}{0.636\, I_m}$ ~~or 0.636 (Vm-2Vk)~~

(2) $\boxed{V_{dc} = \frac{2V_m}{\pi} = \underset{\text{(I)}}{0.636\, V_m} \text{ or } \underset{\text{(N.I)}}{0.636(V_m - 2V_k)}}$

Date
Page

(3) $\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}}$ $\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$

(4) $\% \eta = 81.06\%$

(5) $\gamma = 0.48$

(6) $f_R = 2 f_s$

(7) $\boxed{P.I.V \geq V_m}$ ✓

(B) Center - Tapped Transformer :-

$\boxed{P.I.V \geq 2V_m}$ ✓

Zener Diode as Voltage Regulator

Case-I :- V_i & R_L are fixed

→ Calculate V_{Th} across the Zener diode.

→ (A) If $V_{Th} \geq V_z \Rightarrow$ ON

(B) If $V_{Th} < V_z \Rightarrow$ OFF

$\boxed{V_{Th} = V_i \cdot \frac{R_L}{R + R_L}}$

SubCase (A) :- Replace diode by equivalent battery of V_z & use KCL & KVL to calculate all the values.

SubCase (B) Replace diode by open circuit & use KVL & KCL to calculate all the values.

Case II :- V_i fixed & R_L variable.

(i) Condition for min. load resistance (R_L) to activate Zener diode (ON) :-

$\rightarrow$ $\boxed{\text{Voltage accross Z.D} = V_Z}$

$$\boxed{R_{L_{min}} = \frac{V_Z \cdot R}{V_i - V_Z}}$$

$I_R = I_{Z_{min}} + I_{L_{max}}$

$\Rightarrow I_{Z_{min}} = I_R - I_{L_{max}}$

$= \left(\frac{V_i - V_Z}{R}\right) - I_{L_{max}}$

$$\boxed{I_{L_{max}} = \frac{V_L}{R_{L_{min}}} = \frac{V_Z}{R_{L_{min}}}}$$

(ii) Condition for max R_L :-

$R_{L_{max}} \Rightarrow I_{L_{min}} \Rightarrow I_{Z_{max}}$.

$P_{Z_{max}} = I_{Z_{max}} \cdot V_Z \Rightarrow \boxed{I_{Z_{max}} = \frac{P_{Z_{max}}}{V_Z}}$

$$\boxed{R_{L_{max}} = \frac{V_L}{I_{L_{min}}} = \frac{V_Z}{I_{L_{min}}}}$$

$\rightarrow I_{L_{min}} = I_R - I_{Z_{max}}$

$= \left(\frac{V_i - V_Z}{R}\right) - \left(\frac{P_{Z_{max}}}{V_Z}\right)$

Case - III V_i variable & R_L fixed

(i) Condition for min^m V_i :-

$V_{Th} = V_Z$

$$\Rightarrow \boxed{(V_i)_{min} = \frac{V_Z(R + R_L)}{R_L}}$$

(II) Condition for max. V_i :-

$(V_i)_{max}$ is limited by $(I_Z)_{max}$.

$$I_{R_{max}} = I_{Z_{max}} + I_L \quad \text{fixed} \left\{ \because I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} \right\}$$

fixed, fixed

$$\boxed{V_{i_{max}} = I_{R_{max}} \times R + V_Z}$$

Case - IV Both V_i & R_L variable

(Range of V_i is given & we have to calculate range of R_L)

$$\boxed{R_{min} = \frac{V_{i_{max}} - V_Z}{I_{R_{max}}}}$$

$$\boxed{R_{max} = \frac{V_{i_{min}} - V_Z}{I_{R_{min}}}}$$

$$\boxed{I_R \geq I_Z + I_L} \Rightarrow \boxed{\frac{V_i - V_Z}{R} \geq I_Z + I_L} \quad (2)$$

Calculate R using eq. (2) for limiting values of V_i & take the minimum value of R.

Common-Emitter Configuration

→ C.E. configuration acts as Current Amplifier

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

$I_C = \beta I_B + \underbrace{(\beta+1) I_{CBO}}_{I_{CEO} \approx 0}$

$\Rightarrow I_C = \beta I_B$

→ The contribution of leakage current in CE configuration is much ~~more~~ significant while in C.B configuration, it is very low.

$\boxed{\beta = \frac{I_C}{I_B}}$ → Amplification Factor

$\boxed{50 \le \beta \le 400}$

i/p Current → I_B

i/p Voltage → V_{BE}

o/p curr. ⇒ I_C

o/p voltage ⇒ V_{CE}

J_1	J_2	Region of Operation
F.B	R.B	Active ⟶ Amplifier
F.B	F.B	Saturation ⟶ 'ON'
R.B	R.B	Cutoff ⟶ 'OFF'

Common-Base Configuration

$\boxed{I_E = I_B + I_C}$ — (1)

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

Reverse saturation current

$$\boxed{\alpha = \frac{I_C \;(\text{o/p})}{I_E \;(\text{i/p})}}$$

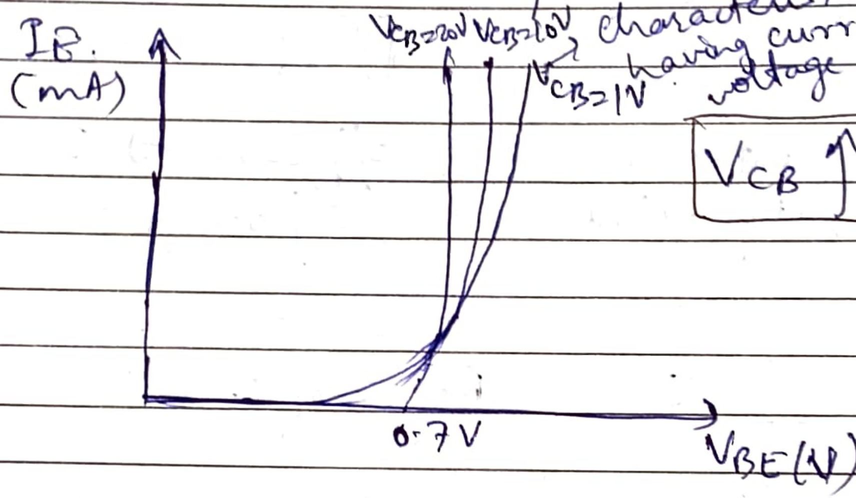
Common base current gain / Amplification Factor

$$\boxed{0.95 \le \alpha \le 0.98}$$

Input Characteristics (i/p I vs i/p V for diff values of o/p V)

i/p I = I_E
i/p V = V_{BE}

o/p I = I_C
o/p V = V_{CB}



characteristic of F.B diode having current I_E & voltage V_{BE} across it

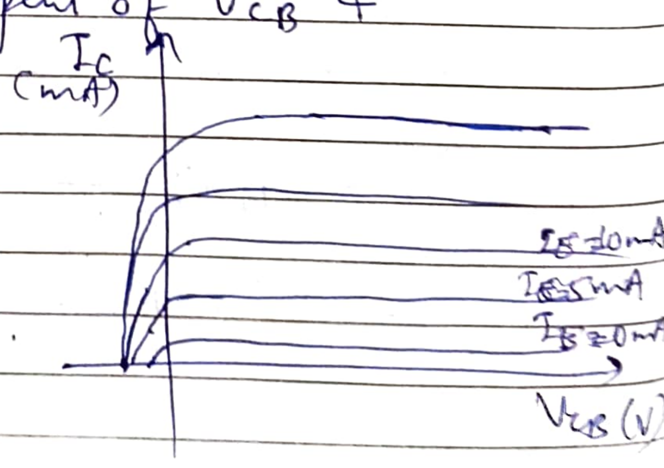
$$\boxed{V_{CB}\uparrow \Rightarrow I_E \uparrow}$$

Output Characteristics

Plot of
⇒ o/p I (I_C) vs o/p V (V_{CB}) for various levels of i/p I (I_E)

⇒ I_C is independent of V_{CB} &

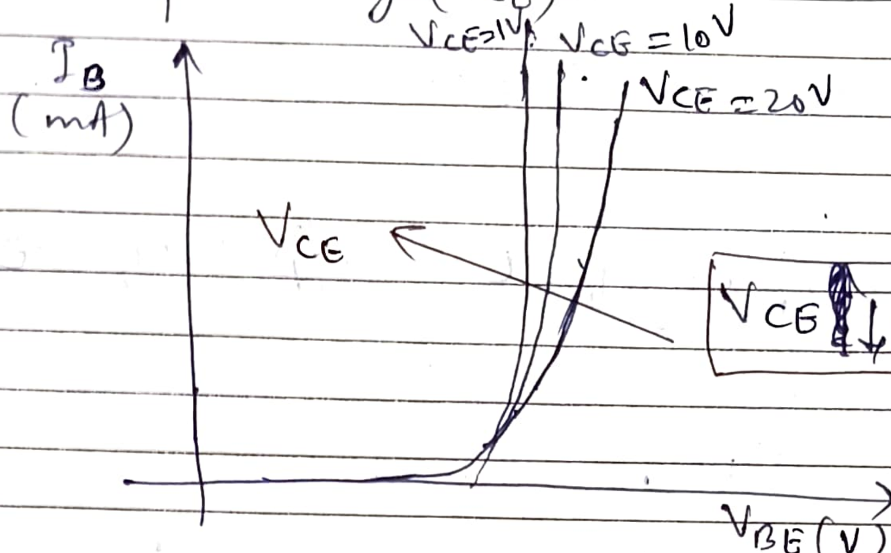
$$\boxed{I_C \simeq I_E}$$



C·E Configuration

Input characteristics :

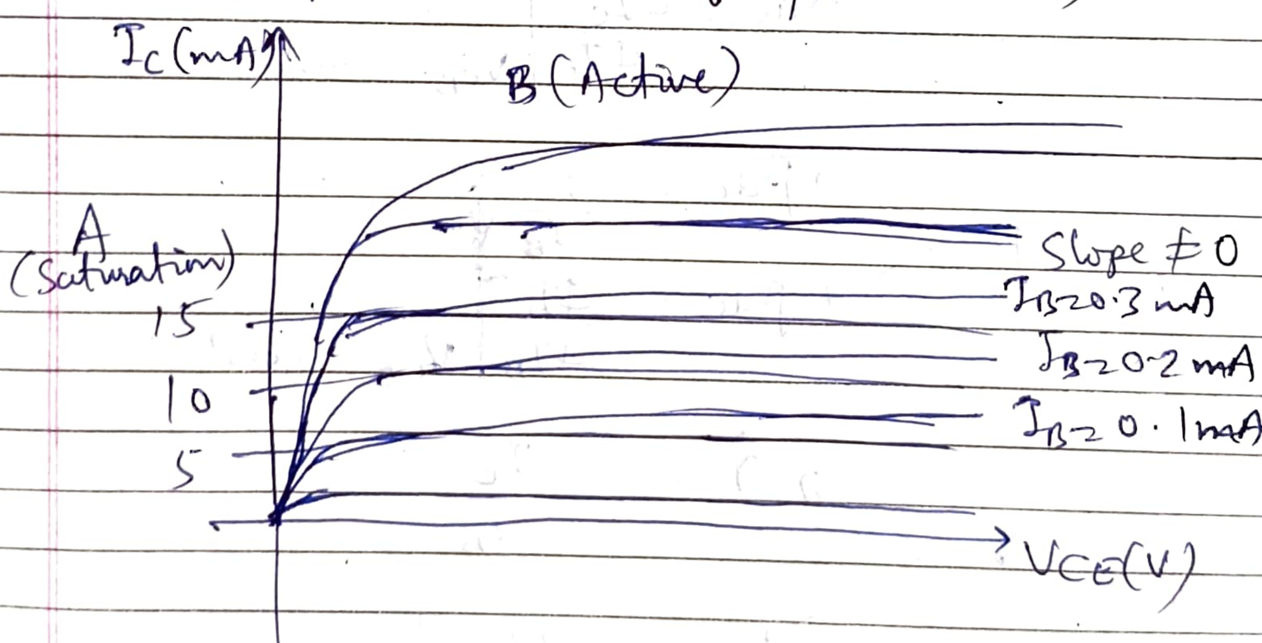
→ i/p I (I_B) Vs i/p V (V_{BE}) for diff values of output Voltage (V_{CE})



$\boxed{V_{CE}\downarrow \Rightarrow I_B\uparrow}$

Output Characteristics

Plot of o/p curr. (I_C) vs o/p voltage (V_{CE}) for diff. ~~va~~ levels of i/p curr. (I_B).



→ I_C is independent of V_{CE} & $I_C=(\beta+1)I_{CBO}$

Common - Collector Configuration

Output characteristics

I_E Vs V_{CE} for various levels of I_B

I_E → o/p curr.

V_{CE} → output voltage

I_B → Input ~~voltage~~ current

$\boxed{I_E \approx I_C}$

→ o/p ch. of C.C = o/p ch. of C.E

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

Relation b/w α, β & γ

α → $\alpha_{dc} = \frac{I_C}{I_E}$

α → $\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}\Big|_{V_{CB} = const.}$

V_{CB} → output voltage

β → $\beta_{dc} = \frac{I_C}{I_B}$

β → $\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}\Big|_{V_{CE} = const}$

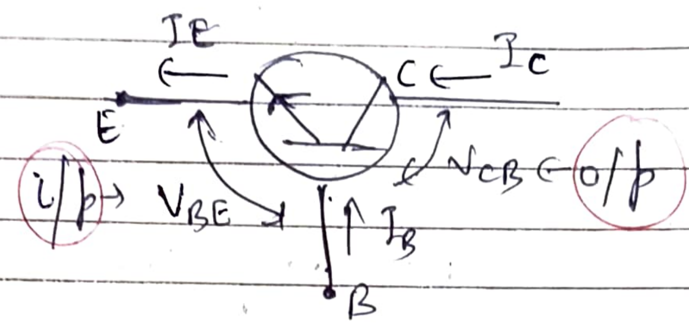
γ → $\gamma_{dc} = \frac{I_E}{I_B}$

γ → $\gamma_{ac} = \frac{\Delta I_E}{\Delta I_B}\Big|_{V_{CE} = const}$

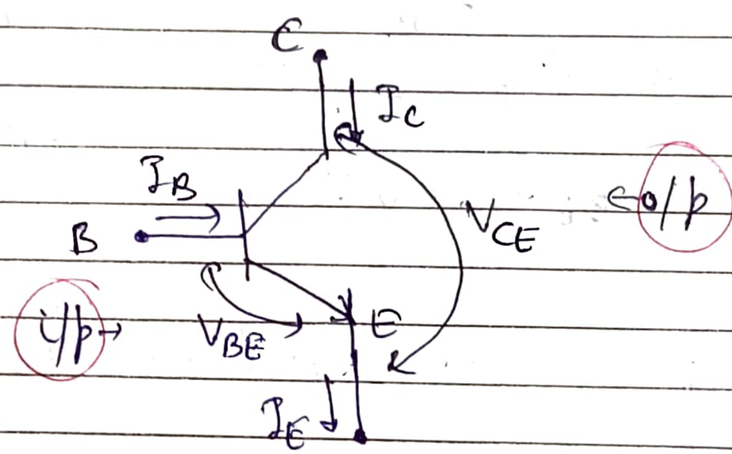
$$\boxed{\gamma = \beta + 1} = \boxed{\frac{1}{1-\alpha}}$$

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

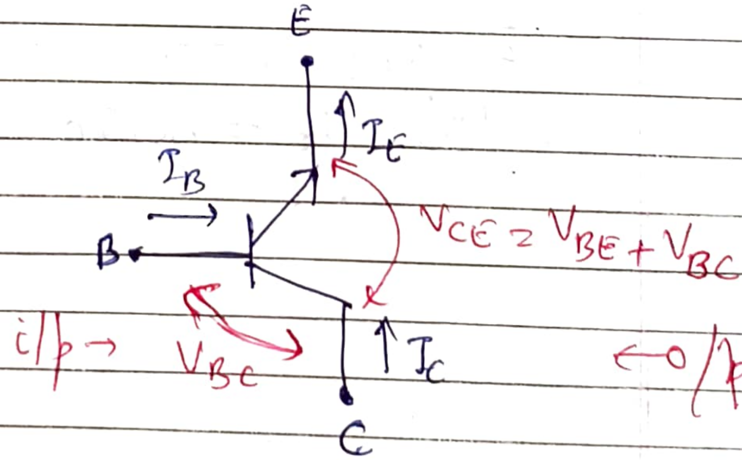
C-B ⇒



C·E ⇒



C·C ⇒



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

$I_B \rightarrow I_C = \beta I_B \longrightarrow V_{CE}$ ✓

Q pt (V_{CE}, I_C)
↳ operating pt.

(1) Fixed - Bias Configuration
or Base - bias Configuration

→ Simply apply K.V.L using following points

$\boxed{I_C = \beta I_B}$

$V_{BE} = \begin{cases} 0.7\,V \text{ (for Si)} \\ 0.3\,V \text{ (for Ge)} \end{cases}$

(2) Emitter - Bias Configuration

→ Simply apply K.V.L using following points –

(i) $\boxed{I_C = \beta I_B}$

(ii) $\boxed{I_E \simeq I_C}$ ✓

(iii) $V_{BE} = 0.7\,V$ (for Si)

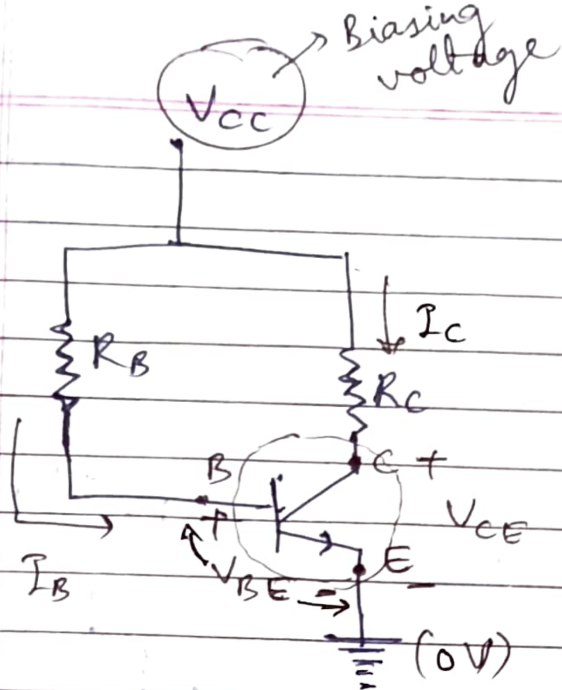
$I_E = I_B + I_C$
$= I_B + \beta I_B$
$\Rightarrow \boxed{I_E = (\beta + 1) I_B}$

(3) Collector - Feedback Biasing –

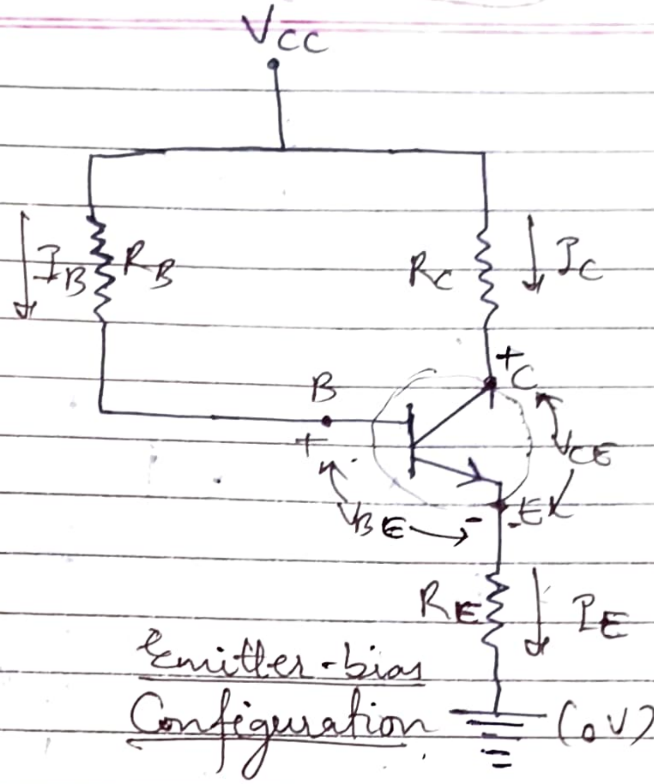
(1) $I = I_B + I_C$

(2) $V_{BE} = 0.7\,V$

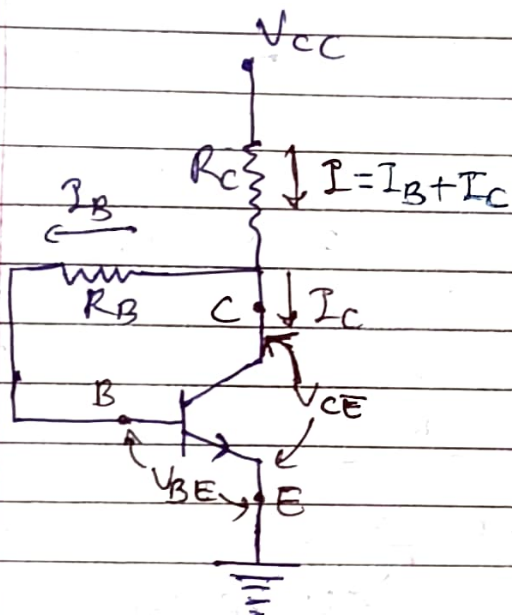
(3) $I_E = I_B + I_C \simeq I_C$



<u>Fixed-bias Configuration</u>

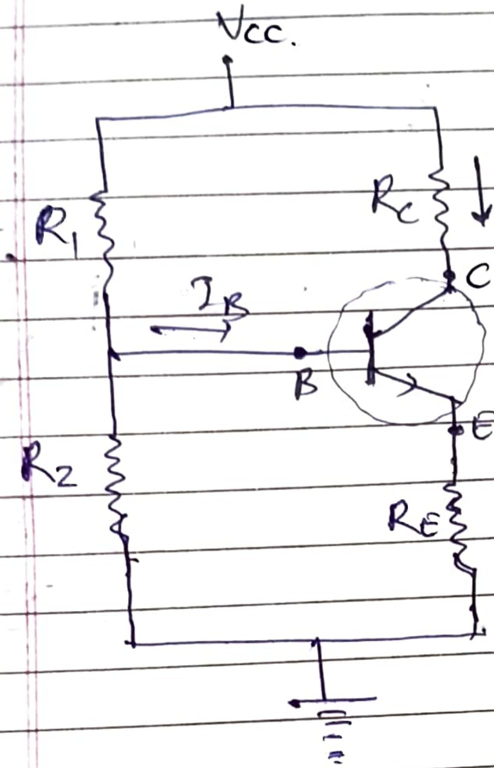


<u>Emitter-bias Configuration</u>

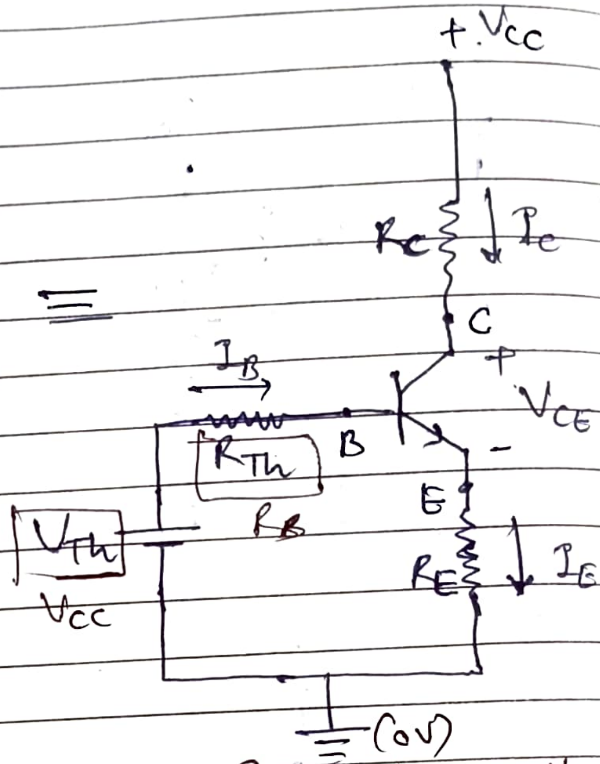


<u>Collector-Feedback biasing</u>

Voltage-Divider Configuration



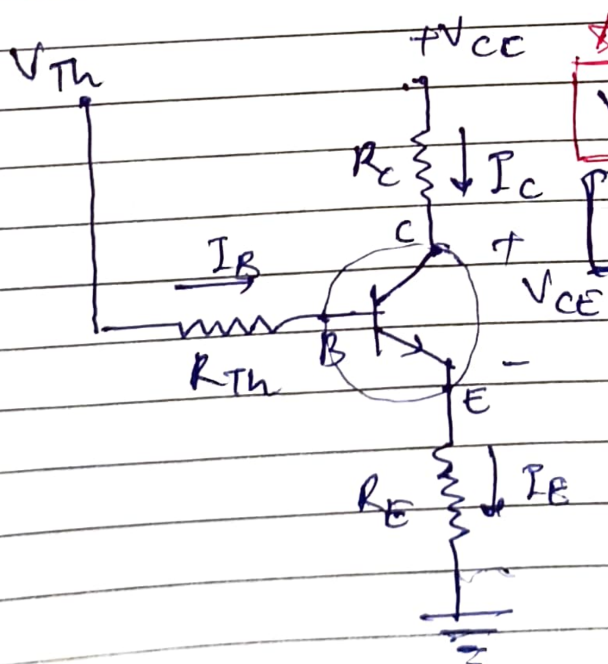
$\equiv$



Similar to emitter-bias config.

$$\boxed{R_{Th} = \frac{R_1 R_2}{R_1 + R_2}}$$

$$\boxed{V_{Th} = I R_2 = \frac{R_2 V_{CC}}{R_1 + R_2}}$$



★★ $\boxed{V_{Th} \approx V_B}$

[since voltage drop across R_{Th} is very small.]

n-channel Enhancement - Type MOSFET

$V_{GS}\uparrow \Rightarrow$ width of ch $\uparrow$

$$\boxed{V_{GD} = V_{GS} - V_{DS}}$$

Case - I :- $\boxed{V_{DS} = 0} \Rightarrow \boxed{V_{GD} = V_{GS}} \Rightarrow$ Uniform d.R.

Width of channel is corresponding to the excess voltage.

$V_T \rightarrow$ given

$$\boxed{\text{Excess voltage} = V_{GS} - V_T}$$

Case - II :- $\boxed{V_{DS} > 0} \Rightarrow V_{GD}\downarrow \Rightarrow$ D becomes more +ve

$\Rightarrow$ ~~Channel~~ D.R on D side $\uparrow$ due to $\uparrow$ in r.b

$\Rightarrow$ Channel width becomes narrower on D-side

Case - III :- $\boxed{V_{DS_{sat}} = V_{GS} - V_T} \rightarrow$ Pinch-off condition

$\Rightarrow \boxed{V_{GD} = V_T}$

o/p i $\rightarrow I_D$ Controlling Variable $= V_{GS}$

o/p V $\rightarrow V_{DS}$

If $V_{DS} = 0 \Rightarrow V_D = V_S \Rightarrow$ ~~□~~ $I_D = 0$

For Saturation Region :- $\boxed{V_{DS} \geq V_{GS} - V_T}$

If $V_{DS} = V_{DS_{sat}} \Rightarrow \boxed{I_D = \text{const.}}$ (Pinch-off)

***

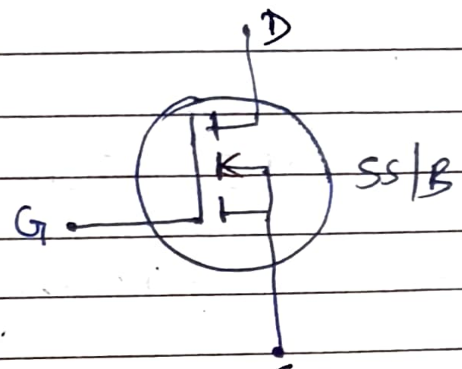
$$\boxed{I_D = k(V_{GS} - V_T)^2}, \quad k = \frac{I_D(on)}{[V_{GS}(on) - V_T]^2} \quad A/V^2$$

const. (given)

$V_{GS}\downarrow \Rightarrow \rho\downarrow \Rightarrow R\uparrow \Rightarrow$ Slope of Drain ch. $\downarrow$
$(\because \text{slope} = \frac{1}{R})$

For Triode Region :- $V_{DS} < V_{GS} - V_T$

$$I_D = 2k\left[(V_{GS}-V_T)V_{DS} - \frac{V_{DS}^2}{2}\right]$$



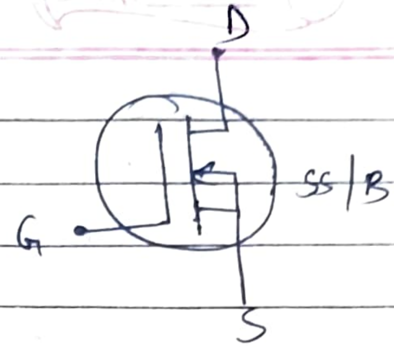
n-channel EMOSFET

n-channel Depletion - Type MOSFET

Working ≈ n-channel JFET

JFET	DMOSFET
→ $V_{GS} = 0$	$V_{GS} = 0$
→ $V_{GS} \le 0$	V_{GS} → +ve, → 0, → -ve
→ I_{DSS} is the max^m transistor current & I_{DSS} is the current I_D corr. to $V_{GS}=0$	→ Current I_D corr. to $V_{GS}=0$ is I_{DSS} but it is not max^m current
	V_{GS} more +ve ⇒ $I_D\uparrow$ rapidly
	V_{GS} more -ve ⇒ $I_D\downarrow$

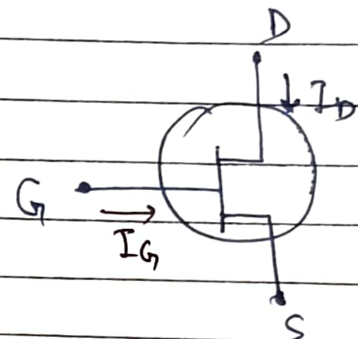
When $\boxed{V_{GS} = V_p} \Rightarrow I_D = 0$



$$\boxed{I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2}$$

JFET (n-channel)

→ $I_G = 0$ always due to r.b



n-channel JFET

Case-I : $V_{GS} = 0\,V$
Case II : $V_{GS} < 0$

} $V_{DS} > 0$

Pinch-off Condition :-
Two D-Rs seem to touch each other.

When $\boxed{V_{DS} > |V_p|}$:- (i) $\boxed{I_D = I_{SS} = \text{const}}$ → max^m current

JFET acts as a constant-current source

When $\boxed{V_{GS} < 0}$:- We obtain the sat. at lower value of V_{DS}

o/p i → I_D for various Controlling V → V_{GS}
o/p V → V_{DS}

Drain ch.

→ In ohmic region, JFET can be used as Voltage-controlled Resistor i.e. Var. Resistance

Slope = f(V_{GS}) & $V_{GS}\downarrow$ ⇒ Slope ↓ ⇒ R ↑

Resistance at $V_{GS}=0$

$$\boxed{r_d = \frac{r_0}{\left(1-\frac{V_{GS}}{V_P}\right)^2}}$$

$$\boxed{I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2}$$ (Non-linear)

const.

→ when $\boxed{V_{GS}=V_P}$ ⇒ $I_D=0$ ✓

→ when $V_{GS}=0\,V$ ⇒ $I_D = I_{DSS}$

Transfer ch. :-

o/p I → I_D V_S i/p V → V_{GS}

for const. o/p V → V_{DS}