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ELECTRONICS ENGINEERING

Analog Electronics

By-Ifteqar Ahamad Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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24/06/25

(1) BJT Circuits < Biasing, Amplifier } 2-3 Que.

Gate – 12 Marks

(2) MOSFET Circuits < Biasing, Amplifier } 3-4 Marks

(3) opamp } 3-4 Marks

(4) Diode Circuits. } 3 Marks

(5) other topic
- i) Multistage Amplifier
- ii) Feedback "
- iii) Differential "
- iv) oscillator

} 1-2 Marks

Extra topic for ESE

(i) JFET Biasing & Amplifier
(ii) Power amplifier
(iii) Tuned amplifiers } only basics
(iv) Timer IC (IC 555)

Prelims ESE : 12 to 15 Question.
Mains : 100 M.

Analog sir

Books:-

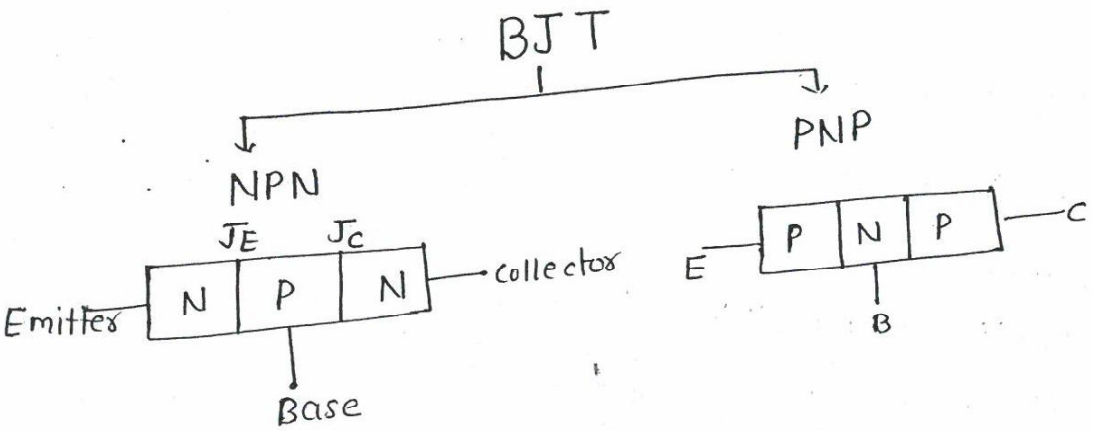
(i) Microelectronic Circuits
— Sedra & Smith

(ii) Electronic Circuit
— Neamen

Bipolar Junction Transistor (BJT): — chapter-3

BJT → Bipolar (current flow due to majority & minority charge)

MOSFET → unipolar (current flow only due to majority charge)



J_E: Emitter – base junction

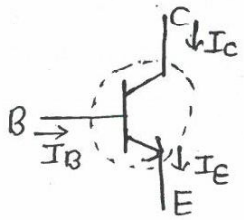
J_C: Collector – base junction.

Mode of operation	J_E	J_C	Application
(1) cut-off	RB	RB	off switch (very high resistance)
(2) Saturation	FB	FB	ON switch (very low resistance)
(3) Active Mode/ Forward active mode.	FB	RB	Amplifier (Excellent Transistor Action)
(4) Reverse Active/ Inverse Active.	RB	FB	BJT is not used in reverse active mode because BJT behave as attenuator (Gain < 1)

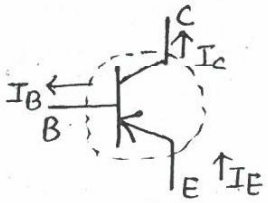
→ BJT is used digitalized (used in switch).

$$\text{Gain} = \frac{O/P}{i/P}$$

I/p Transistor TTL → Reverse active mode.



NPN



PNP

KCL: $\boxed{I_E = I_B + I_C}$ ** → for both NPN & PNP.

→ If BJT is in active region then

(i) $\boxed{I_C = \alpha I_E + I_{CO}}$ * $\cong \alpha I_E$

(ii) $\boxed{I_C = \beta I_B + (1+\beta) I_{CO}}$ * $\cong \beta I_B$

I_{CO}: Reverse saturation current of Collector junction (J_C)

α: Common base current gain

$\{\alpha = \beta^* \cdot \gamma\}$

Ideal BJT ($\alpha = 1$)

practical BJT ($\alpha < 1$)

β: Common emitter current gain

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

	α	β
Ideal BJT	1	∞
Practical BJT	$\cong 1$	large value.

→ $N_E >> N_B \Rightarrow \gamma \cong 1$

→ $W_B <<$ Diffusion Length $\Rightarrow \beta^* \cong 1$

$\alpha \cong 1$

β: large value.

→ β is a measured of amplification property of BJT.

Large β ⇒ Better amplification.

Note:-

$$I_E = I_{ES}\left(e^{V_{BE}/V_T} - 1\right) \text{ for NPN} \quad **$$

$$I_E = I_{ES}\left(e^{V_{EB}/V_T} - 1\right) \text{ for PNP}$$

I_{ES}: Reverse saturation current of J_E

$$I_{ES} \cong A q n_i^2 \times \frac{D_B}{W_B} \times \frac{1}{N_B} \quad **$$

A = Area of emitter junction (J_E)

→ Current in a BJT is proportional to the area of emitter junction.

D_B = Diffusion Const. of minority carrier in base region.

W_B = Base width.

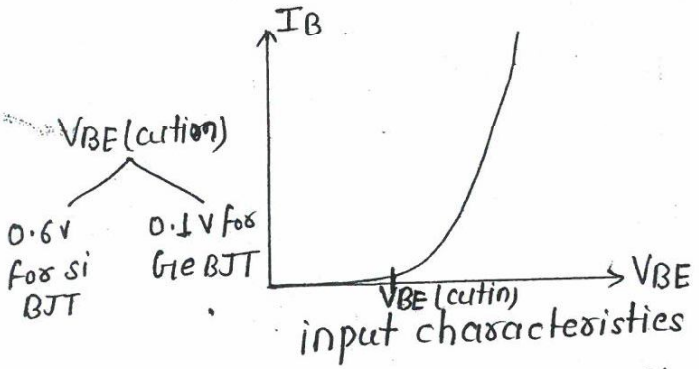
N_B = Base doping.

V_{BE} or V_{EB}: Voltage across emitter junction (J_E)

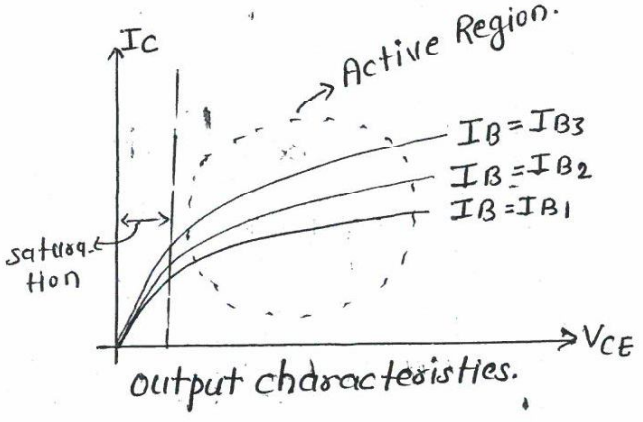
V_T : Thermal voltage $\left[V_T = \frac{T}{11600}\right]$ **

At T = 300 k.

$$V_T = 25.8\,mV \cong 26\,mV \quad **$$

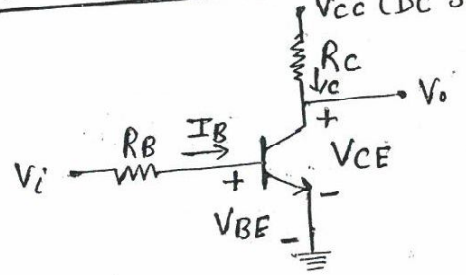


input characteristics



output characteristics.

→ **BJT behaves as a circuit:-**



V_i : Input voltage.

Assume that V_i is varied.

V_{AB} (↓ at A: +, ↓ at B: −)

Case(i) : If $V_i < V_{BE}$ (cutin)

→ BJT remains OFF.

$I_B = 0, I_C = 0$

$\Rightarrow V_{CE} = V_{cc} - I_C R_C$

$$\boxed{V_{CE} = V_{cc}}$$

Case(ii) : If $V_i > V_{BE}$ (cutin)

→ BJT starts conduction (allow for current is flow)

i.e I_B & I_C will flow.

$$\boxed{I_B = \frac{V_i - V_{BE}}{R_B}}$$

$$\boxed{I_C \cong \beta I_B}$$

↓ Active region

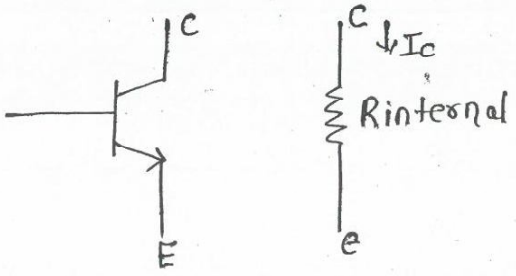
$$\boxed{V_{CE} = V_{cc} - I_C R_C}$$

If $V_i \uparrow \Rightarrow I_B \uparrow \Rightarrow I_C \uparrow \Rightarrow$ voltage drop ↑ (of R_C, $I_C \times R_C$) $= V_{CE} \downarrow$

→ In a BJT circuit I_C and V_{CE} has opposite variation i.e if I_C increases then V_{CE} decreases and vice-versa.

- In practical BJT
- V_{CE} decreases upto a minm value V_{CEsat} (0.2V for Si, 0.1V for Ge) **

→ V_{CE} sat the minimum possible voltage drop between Collector & emitter this voltage drops due to internal resistance of BJT.



→ For ideal BJT V_{CE} can decrease upto zero ('0') i.e $V_{CE\,sat} = 0$

→ If V_{CE} will becomes $V_{CE\,sat}$ then collector current (I_C) also const: then I_C can't increase further i/p voltage. Then BJT in said to be in saturation.

** If BJT is in saturation then

(i) $\boxed{V_{CE} = V_{CE\,sat}}$ *

(ii) I_C remains constant at $I_{C\,sat}$.

$$\boxed{I_{C\,sat} = \frac{V_{CC} - V_{CE\,sat}}{R_C}}$$ ** → Saturated I_C (or) Maximum I_C

(iii) I_B keeps increasing with V_i and hence $I_C = \beta I_B$ becomes invalid.

(iv) $\beta I_B > I_C$ (or) $\boxed{I_C < \beta I_B}$ **

(or) $\boxed{I_B > \frac{I_{C\,sat}}{\beta}}$

(v) I_E also increases with V_i becomes $\boxed{I_E = I_B + I_C}$

(vi) Forced β:—

→ It is the ratio of $I_{C\,sat}$ and I_B when BJT in saturation.

$$\boxed{\beta_{forced} = \frac{I_{C\,sat}}{I_B}}$$ ** → It is β when BJT is in a saturation.

→ If $V_i \uparrow \Rightarrow I_B \uparrow \Rightarrow \beta_{forced} \downarrow$

$$\boxed{\beta_{forced} < \beta_{Active}}$$ **

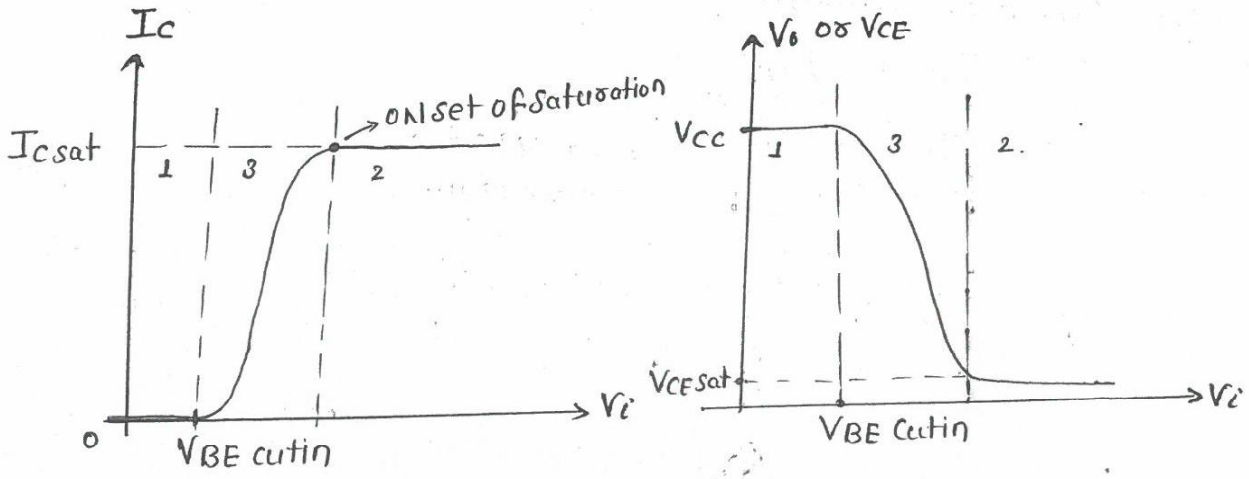
(vii) Overdrive (or) Degree of saturation :—

→ It is the ratio of actual β and forced β'

$$\boxed{\text{overdrive} = \frac{\beta}{\beta_{Forced}}}$$

→Overdrive is a measure of saturation level.

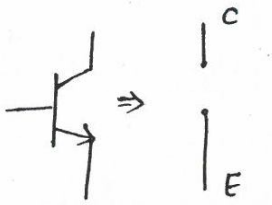
** Overdrive = 1 ⇒ onset of saturation.
overdrive > 1 ⇒ Weak saturation. [eg:- 1.5, 2, 2.1 etc]
overdrive >> 1 ⇒ strong saturation [Ex:- overdrive = 10, 11, 12 etc]



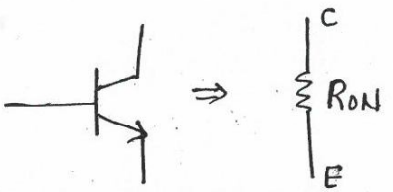
Region-(i) cutoff region [Ic = 0, VCE = Vcc] → open ckt (or) OFF switch

Region-(ii) Saturation region [Ic remains Const. w.r.t Vi]

Ic = Ic sat
VCE = VCE Sat
} ON switch



Region-(i)



Region-(ii)

RON: ON resistance of BJT

** $R_{ON} = \frac{V_{CE\,Sat}}{I_{C\,Sat}}$

RON: A few Ω

→ A practical BJT can't act as fully ON switch due to internal resistance.

→ For ideal BJT, RON = 0

Region-(iii) Active region [Ic and VCE vary with Vi]

→ **A BJT is said to be active if 'Ic' varies according to input Voltage (Vi)

→ When BJT is used as small signal amplifier. BJT is operated in active region. so that small variation in V_i can cause proporsanet change 'I_c'

→ The relation $I_c \cong \beta I_B$ is valid for active region upto onset of saturation.

→ At onset of saturation,

$$I_{csat} = \beta I_B$$

$$\boxed{I_B = \frac{I_{csat}}{\beta}}^{**} \rightarrow I_B \text{ at onset of saturation.}$$

$$\boxed{I_{Bmin} = \frac{I_{csat}}{\beta}}^{**} \rightarrow \text{It is minm base current required to operate BJT in saturation.}$$

$$\boxed{\begin{aligned} &I_B \geq I_{Bmin} \Rightarrow \text{BJT is in saturation.} \\ &I_B < I_{Bmin} \Rightarrow \text{BJT is in active region.} \end{aligned}}^{**}$$

Procedure to find operating region of BJT:-

Method-I

(i) Assume BJT in saturation.

$V_{CE} = V_{CE\,sat}$ < 0.2V for si BJT, 0.1V for Ge BJT

V_{BE} = use given value.

(ii) Calculate I_B and I_c independently.

(iii) Calculate I_{Bmin}

$$\boxed{I_{Bmin} = \frac{I_{csat}}{\beta}}^{**}$$

(iv) Compare I_B and I_{Bmin}

$I_B \geq I_{Bmin} \Rightarrow$ BJT is in Saturation.

$I_B < I_{Bmin} \Rightarrow$ BJT is in Active region.