UNIT-III

Bipolar Junction transistor (BJT)

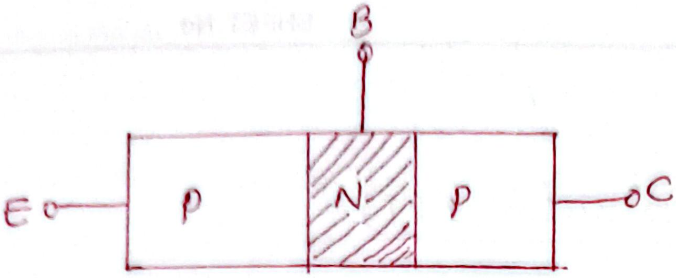
BJT (Bipolar junction transistor):

- Bipolar junction transistor (BJT) is a three terminal semiconductor device. terminals are Emitter, Base and Collector.
- The operation of the device depends on the interaction of both majority and minority charge carriers hence the name is bipolar.
- It is smaller in size.
- It is used in amplifiers, oscillators and as a switch in digital circuits.
- It has wide applications in computers, satellites and other modern communication systems.

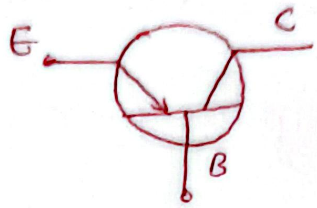
Construction of BJT

- BJTs are two types. They are
  1. PNP transistor.
  2. NPN transistor.

1. PNP-transistor:- The BJT consists of a silicon (or germanium) crystal in which a thin layer of N-Type silicon is sandwiched b/w two layers of P-type silicon. This transistor is called as PNP-transistor.

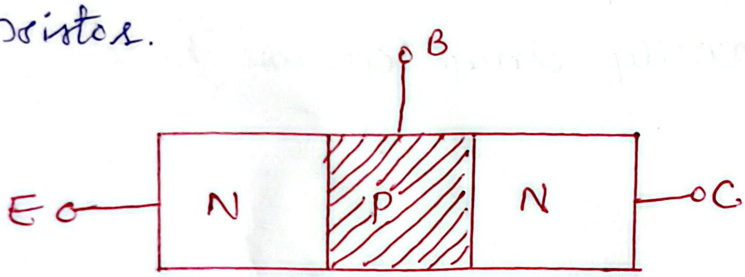


layer formate

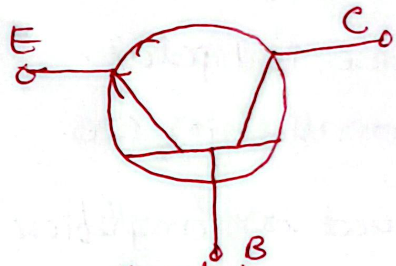


symbol

2. **NPN transistor:-** A BJT consists of a silicon (or germanium) crystal in which a thin layer of p-type silicon sandwiched b/w two layers of N-type silicon. this transistor is called NPN transistor.



layer formate



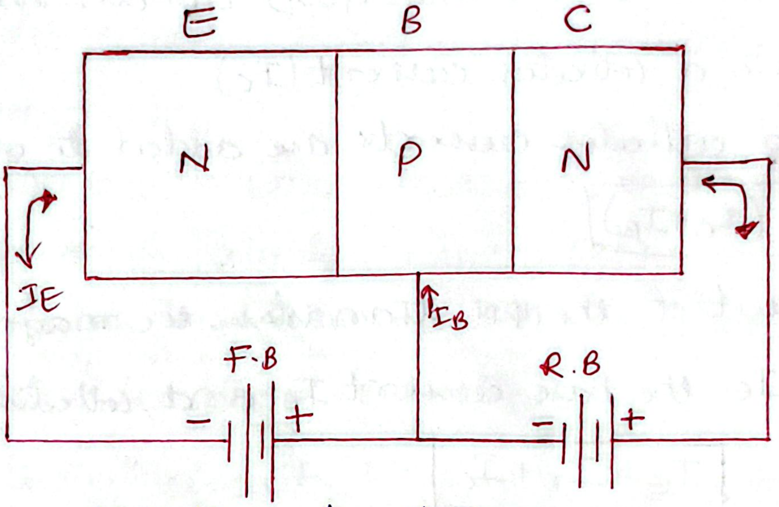
symbol

- The arrow in the emitter specifies the direction of current flow when EB junction is forward biased.
- Emitter is heavily dopped so that it can injects a large number of charge carriers into base.
- Base is lightly dopped and thin. It passes most of the injected charge carriers from emitter to collector.
- Collector is moderately dopped. it collects charge carriers from emitter and Base.

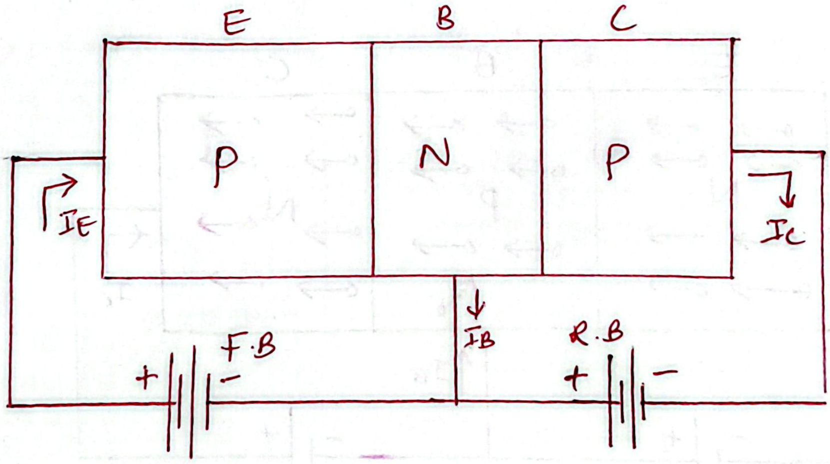
Transistor Biasing:-

Usually the emitter base junction is forward biased and collector base junction is in reverse biased.

- Due to forward bias of emitter base junction the emitter current flow through the base into collector.
- Due to reverse bias of base collector junction, almost the entire emitter current flows through the collector circuit.



NPN transistor Biasing



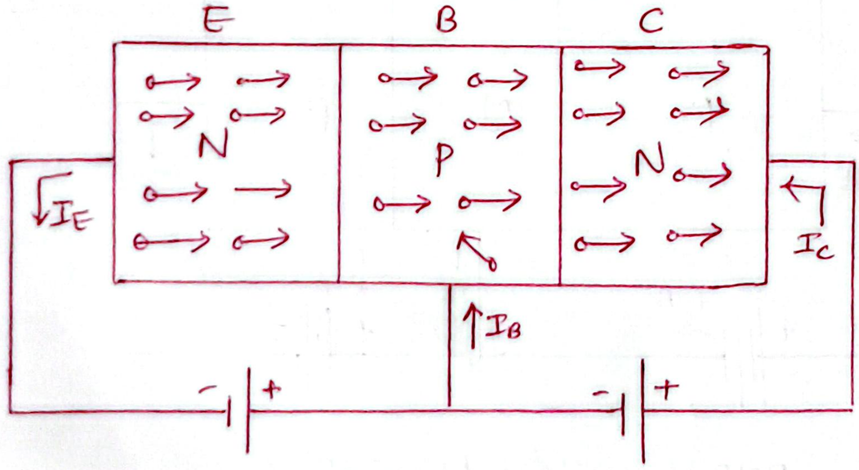
PNP transistor Biasing.

Operation of NPN transistor

- The forward bias applied to the emitter base junction of NPN transistor. Due to this lot of electrons move from emitter region to the base region.
- As base is lightly dopped with p-type impurity. then the no. of holes in base region is very small and hence the no. of electrons combine with holes in base region. is also very small
- Hence a few electrons combine with hole and to constitute a base current (I_B)
- The remaining electrons (more than 95%) crossover into collector region to constitute a collector current (I_C)
- Thus the base and collector currents are added to get Emitter current

i.e $\boxed{I_E = -(I_C + I_B)}$

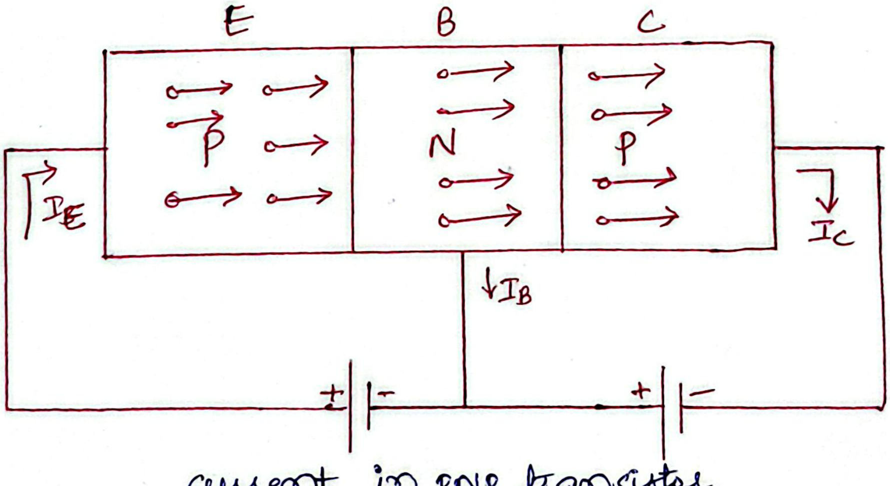
- In external circuit of the NPN transistor. the magnitudes of emitter current I_E, the base current I_B and collector current I_C are related by $\boxed{I_E = I_B + I_C}$



current in NPN transistor

Operation of ~~pnp~~ PNP transistor

- The forward biased applied to the emitter base junction of PNP transistor causes a lot of holes from the emitter region to base region.
- As the base is lightly doped with N-type impurity, the no. of electrons in the base region is very small
- Hence the no. of holes combined with electrons in the N-type base region is also very small
- Hence a few holes combined with electrons to generate base current (I_B).
- The remaining holes (more than 95%) moves into the collector region to generate collector current (I_C)
- Thus the collector and Base current summed up to give Emitter current. (I_E). i.e $\boxed{I_E = -(I_B + I_C)}$
- In the external circuit of PNP bipolar junction transistor the magnitude of emitter current I_E, Base current I_B and collector current I_C are related by. $\boxed{I_E = I_B + I_C}$



current in PNP transistor.

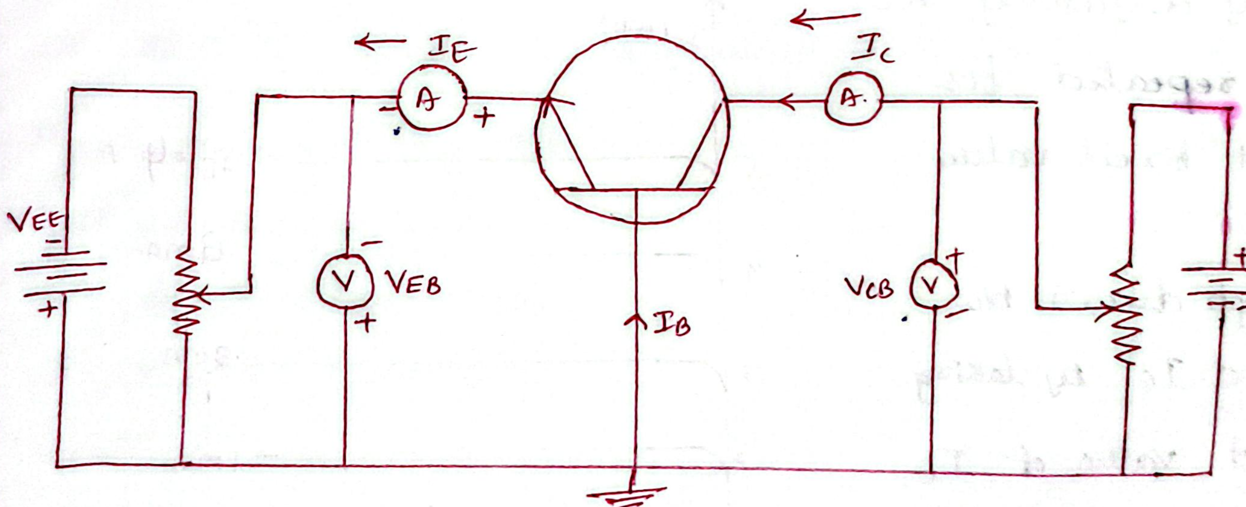
Types of Configurations:-

- When a transistor connected in a circuit, one terminal is used as input terminal, other terminal is used as o/p terminal and third terminal used as common to the i/p and o/p.
- Depending upon the i/p, o/p and common terminal, a transistor can be connected in three configurations.

they are
1. Common base (CB) configuration
2. Common Emitter (CE) configuration
3. Common collector (CC) configuration

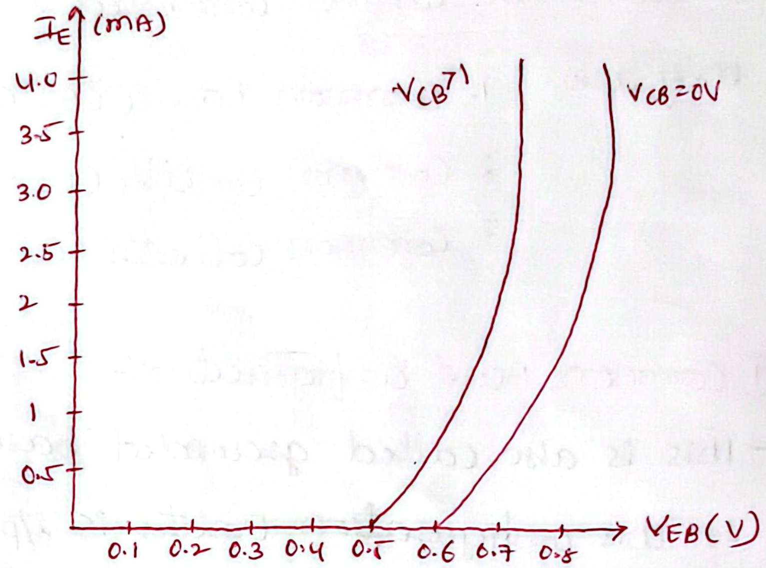
① Common Base configuration:-

- This is also called grounded base configuration. in this configuration Emitter is i/p terminal, collector is o/p terminal and Base is common terminal.
- The circuit diagram shows the NPN transistor in common base configuration.



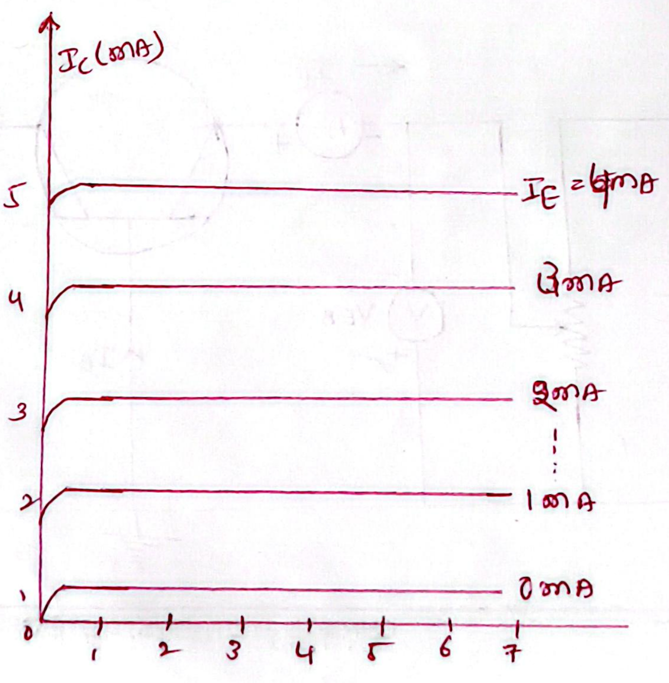
Input characteristics:-

- To determine the i/p characteristics the collector Base voltage (V_{CB}) is kept constant at zero volt and emitter current (I_E). Emitter Base voltage (V_{EB}) is increased from zero in suitable equal steps by increasing V_{EE}.
- This is repeated for higher fixed values of V_{EE}.
- The graph drawn b/w emitter current I_E and V_{EB} at constant V_{CB}
- When V_{CB} is equal to zero. then emitter base junction is forward Biased. so that emitter current (I_E) increased rapidly.



Output characteristics:-

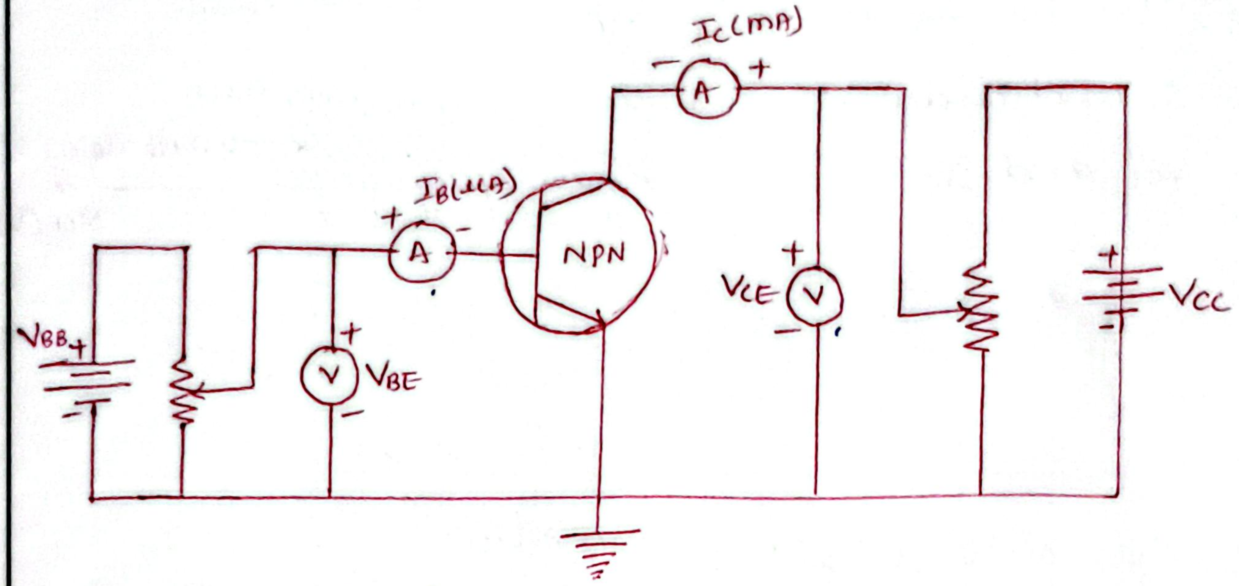
- To determine output characteristics the emitter current (I_E) is kept constant and increase the values of I_C, V_{CB} by suitable value equal by adjusting V_{CC}.
- This is repeated for different fixed values of I_E.
- The graph drawn b/w V_{CB} and I_C by taking constant value of I_E.



ROLL No ....   SHEET No. ....

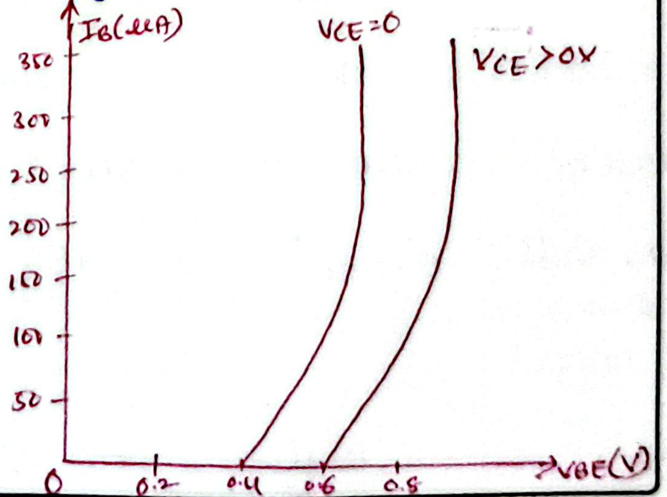
CE configuration:-

- This is also called grounded emitter configuration in this configuration Base is input, collector is output and emitter is common terminal.
- The circuit diagram show the NPN transistor common emitter configuration



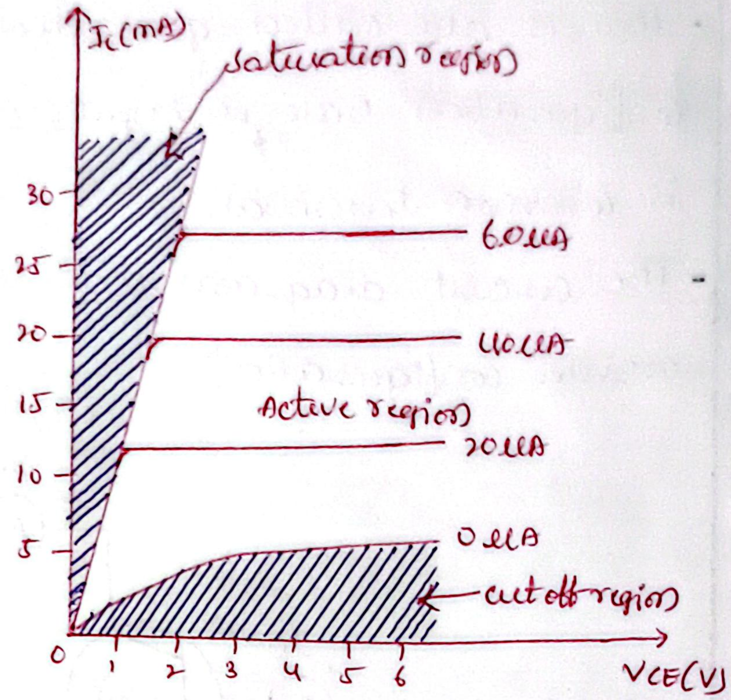
Input characteristics:-

- To determine the i/p characteristics the collector to emitter voltage (V_{CE}) kept constant at zero volt and increase the values of I_B, V_{BE} by adjusting suitable value of V_{BB}.
- This is repeated for different fixed values of VCE
- The graph drawn b/w I_B, V_{BE} by keeping constant VCE.



output characteristics:-

- To determine the output characteristics of CE configuration. the base current (I_B) is kept constant and increased I_C, V_{CC} values by adjusting suitable equal steps from zero.
- This is repeated for various values of I_B. and draw graph b/w V_{CE} and I_C.



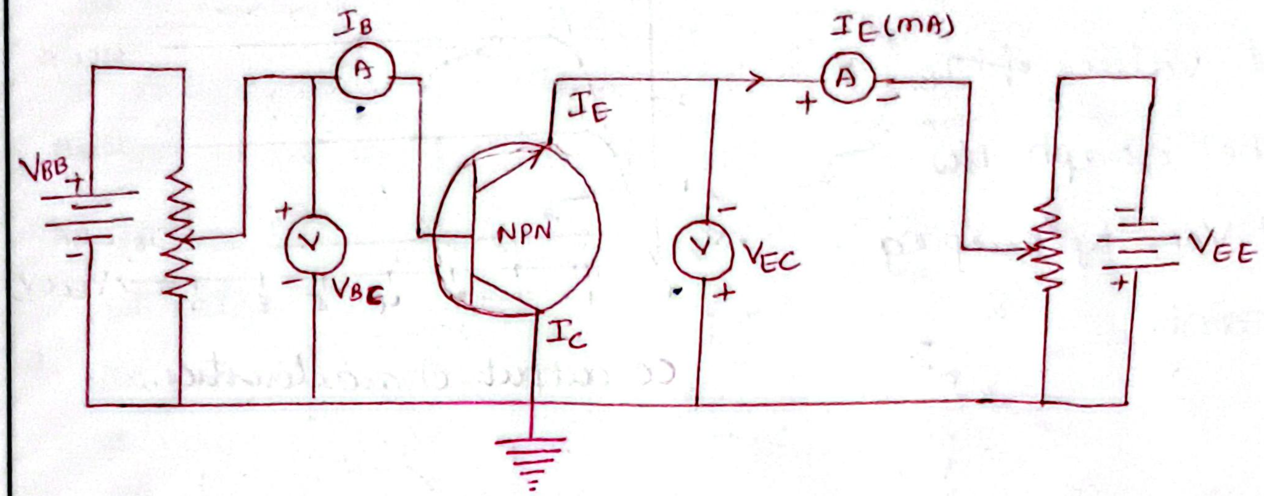
Comparision of CB, CE, CC configuration.

Property	CB	CE	CC
Input resistance	low (about 100Ω)	Moderate (about 750Ω)	High (about 750kΩ)
O/p Resistance	High (about 450kΩ)	Moderate (about 45kΩ)	low (about 25Ω)
current gain	1	High	High
voltage gain	about 150	about 500	less than 1
phase shift b/w input and output	0° or 360°	180°	0° or 360°
Application	For high frequency circuits	For audio frequency circuits	For impedance matching

Common collector Configuration:-

- This is also called grounded collector configuration. in this configuration, base is the i/p terminal, emitter is the o/p terminal and collector is common terminal.

- The circuit diagram shows the characteristics of NPN transistor in common collector configuration.

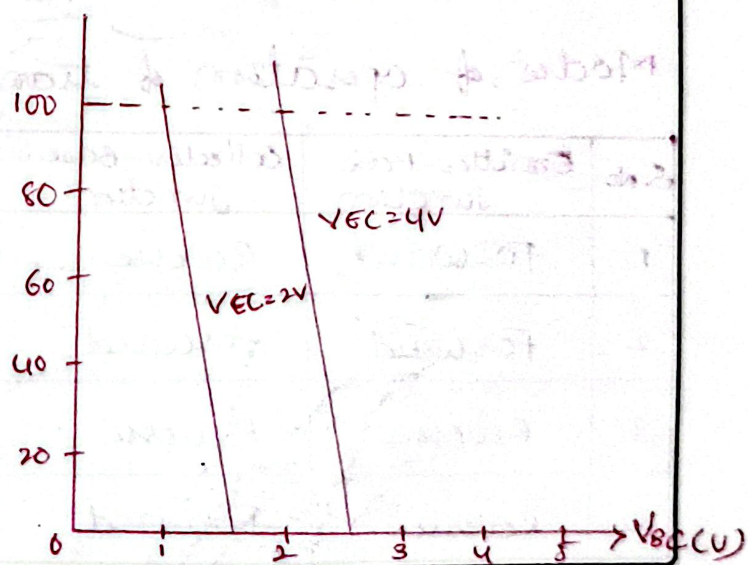


input characteristics:-

- To determine input characteristics, VCE is kept constant at suitable fixed value.

and increase I_B, V_{BC} by adjusting suitable value of V_{BB}.

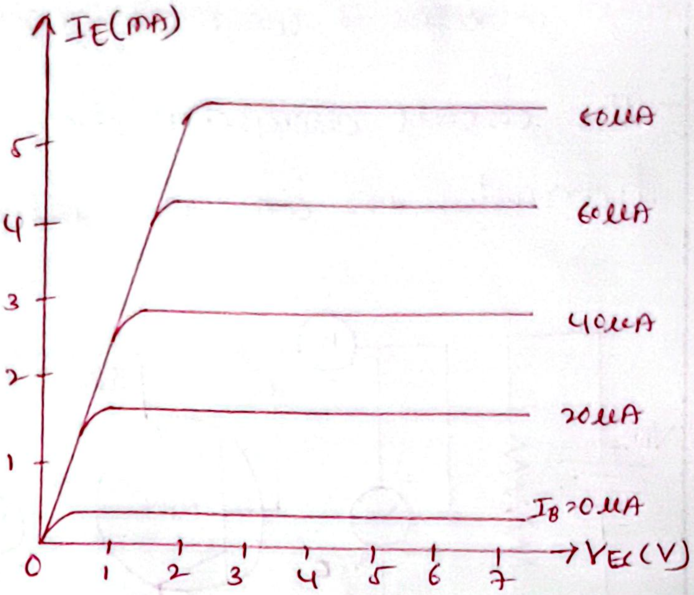
- This is repeated for different fixed values of V_{CE}.



- Draw the graph b/w I_B, V_{BC} by keeping V_{CE} constant.

Output characteristics:-

- The output characteristics determine by keeping base current (I_B) constant and increased the values of I_E, V_{CE} by adjusting suitable value of V_{EE}.
- This is repeated for different values of I_B.
- Draw the graph b/w I_E and V_{CE} by keeping I_B constant.



CC output characteristics.

Modes of operation of transistor

S.No	Emitter-Base junction	Collector-Base junction	Mode of operation	Application
1.	Forward	Reverse	Active Region	Amplifiers oscillators
2	Forward	Forward	Saturation Region	Switch ON/~~OFF~~
3	Reverse	Reverse	Cut off Region	Switch OFF
4	Reverse	Forward	inverse active region	Normally not used

ROLL No .... SHEET No. ....

Current amplification factor

- In a transistor amplifier with a.c input signal the ratio of change in output current to change in input current is known as current amplification factor.

- In CB configuration the current amplification factor

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

- In CE configuration the current amplification factor

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

- In CC configuration the current amplification factor

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

Relation b/w α, β

We know that $\Delta I_E = \Delta I_B + \Delta I_C$

By defination $\Delta I_C = \alpha \Delta I_E$

$\therefore$ $\Delta I_E = \alpha \Delta I_E + \Delta I_B$

$\Delta I_B = \Delta I_E (1-\alpha)$

Dividing above equation both sides by ΔI_C

$$\frac{\Delta I_B}{\Delta I_C} = \frac{\Delta I_E}{\Delta I_C}(1-\alpha)$$

$$\frac{1}{\beta} = \frac{1}{\alpha}(1-\alpha)$$

$$\beta = \frac{\alpha}{1-\alpha} \text{ and } \alpha = \frac{\beta}{1+\beta} \text{ (or) } \frac{1}{\alpha} - \frac{1}{\beta} = 1$$

- From the above relation it is cleared that the α approaches unity, β approaches infinity.
- The CE configuration is used in almost all transistors applications because of its high current gain (β)

Relation among α, β and γ :-

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

substituting $\Delta I_B = \Delta I_E - \Delta I_C$

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

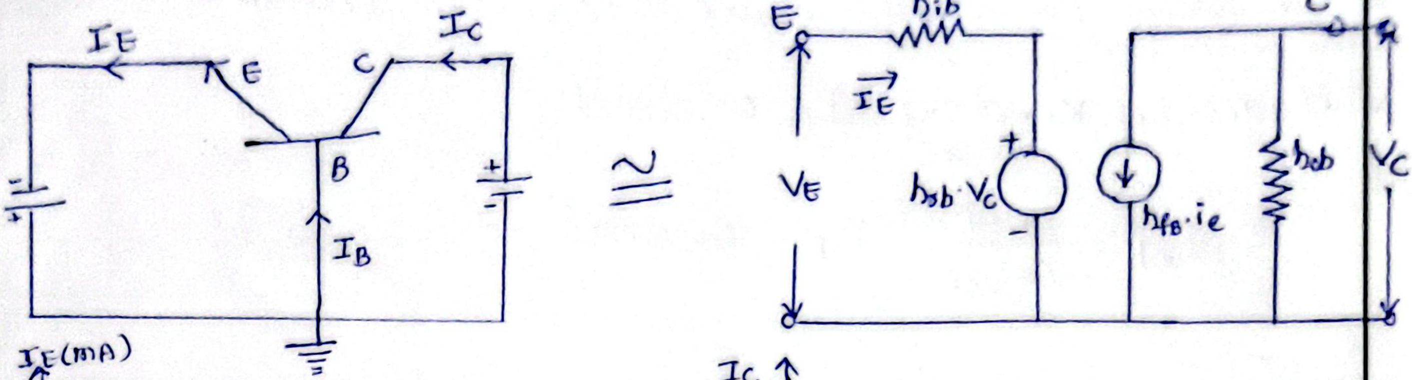
Dividing RHS numerator and denominator by ΔI_E

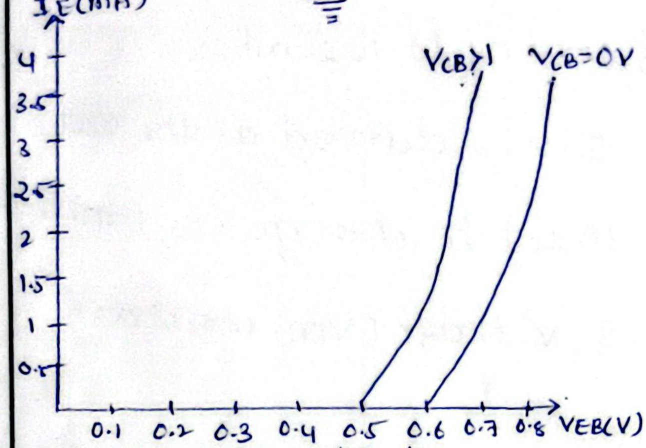
$$\gamma = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1-\alpha}$$

$$\therefore \gamma = \frac{1}{1-\alpha} = (\beta + 1)$$

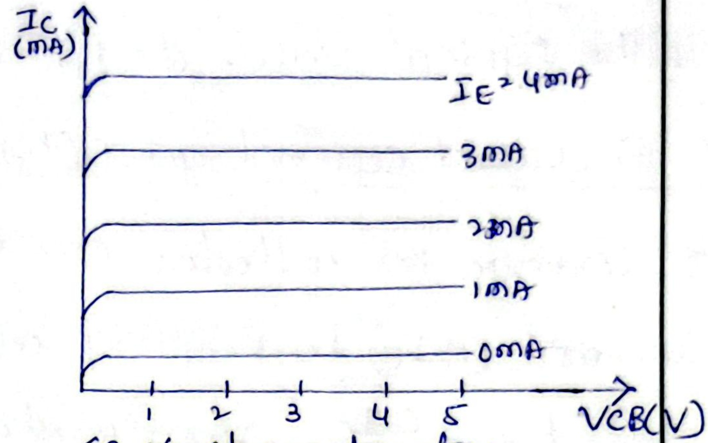
ROLL No ....   SHEET No. ....

BJT - CB characteristics H-parameters





CB i/p characteristics



CB o/p characteristics

- $\left.\begin{aligned} V_1 &= h_{11} I_1 + h_{12} V_2 \\ I_2 &= h_{21} I_1 + h_{22} V_2 \end{aligned}\right\}$ $\quad \begin{aligned} V_{EB} &= h_{ib} I_B + h_{rb} V_{CB} \\ I_C &= h_{fb} I_B + h_{ob} V_{CB} \end{aligned}$

The slope of CB characteristics will give four transistor parameters. these parameters have different dimensions

1. Input impedance (h_{ib}):- It is defined as the ratio of change in Emitter voltage (V_{EB}) to change in emitter current (ΔI_E). by o/p collector voltage (V_{CB}) kept constant.

$$\boxed{h_{ib} = \frac{\Delta V_{EB}}{\Delta I_E}, \; V_{CB} - \text{constant.}}$$

* The typical value of h_{ib} is from 20Ω to 50Ω

2. Output Admitance (h_{ob}):- It is defined as the ratio of change in collector current (ΔI_C) to change in collector voltage by keeping I_E constant

$$h_{ob} = \frac{\Delta I_C}{\Delta V_{CB}}, \quad I_E - \text{Constant}$$

* The typical value of h_{ob} is from 0.1 to 10 μ mhos.

3. Forward current gain (h_{fb}):- It is defined as the ratio of change in collector current (ΔI_C) to change in Emitter current (ΔI_E) by keeping collector voltage (V_{CB}) constant

$$h_{fb} = \frac{\Delta I_C}{\Delta I_E}, \quad V_{CB} - \text{constant}$$

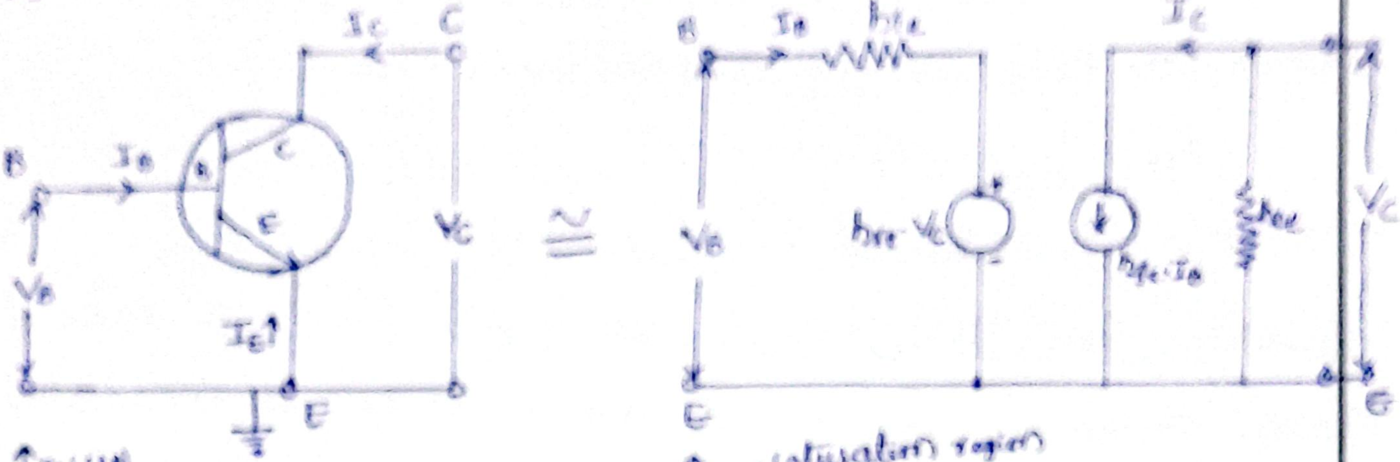
* The typical value of h_{fb} is from 0.9 to 1.0

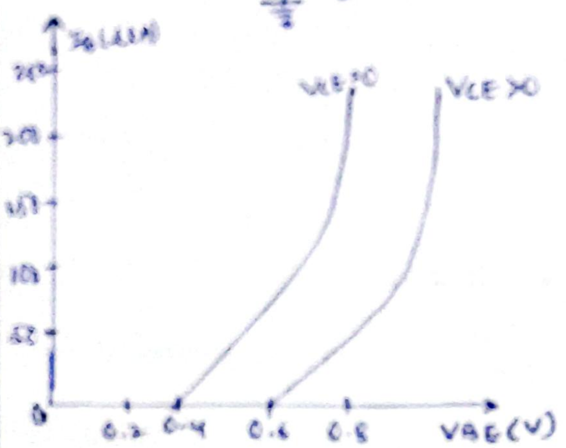
4. Reverse voltage gain (h_{rb}):- It is defined as the ratio of change in Emitter voltage (ΔV_{EB}) to change in collector voltage (ΔV_{CB}) by keeping I_E constant

$$h_{rb} = \frac{\Delta V_{EB}}{\Delta V_{CB}}, \quad I_E - \text{constant}$$

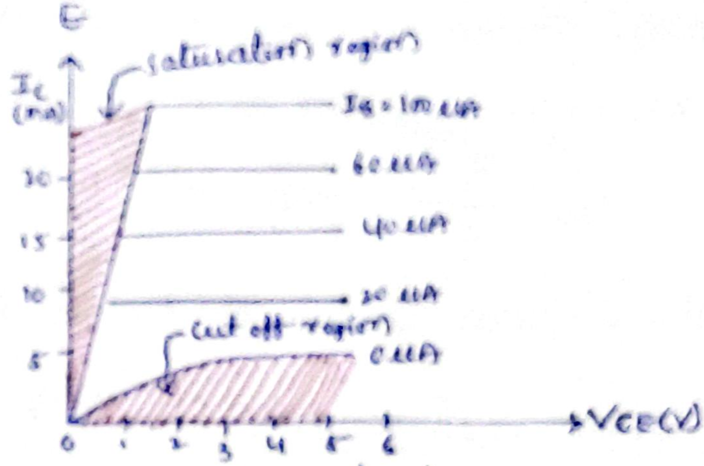
* The typical value of h_{rb} is from 10^{-5} to 10^{-4}

BJT - CE characteristic h-parameter





CE I/p characteristics



CE O/p characteristics.

- The slope of CE characteristics will give four transistor parameters these parameters have different dimensions They are commonly known as CE hybrid parameters

<u>Input impedance</u> (h_{ie}):- It is defined as the ratio of change in base voltage (ΔV_{BE}) to the change in base current (ΔI_B) by keeping collector voltage (V_{CE}) kept constant

$$\therefore h_{ie} = \frac{\Delta V_{BE}}{\Delta I_B}, \quad V_{CE} - \text{constant}$$

* The typical value of h_{ie} is from 500Ω to 2000Ω

2. Output admittance (h_{oe}):- It is defined as the ratio of change in collector current (ΔI_C) to change in collector Voltage By Keeping base current (I_B) Konstant.

$$h_{oe} = \frac{\Delta I_C}{\Delta V_{CE}} \text{ - } I_B - \text{constant}$$

* The typical value of hoe is from 0.1 to 10 µmhos.

3. Forward current gain (h_{fe}):- It is defined as the ratio of change in collector current to change in base current (ΔI_B) by Keeping Collector voltage (V_{CE}) constant.

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}, \; V_{CE} - \text{constant}$$

* The typical value of h_{fe} is from 20 to 200

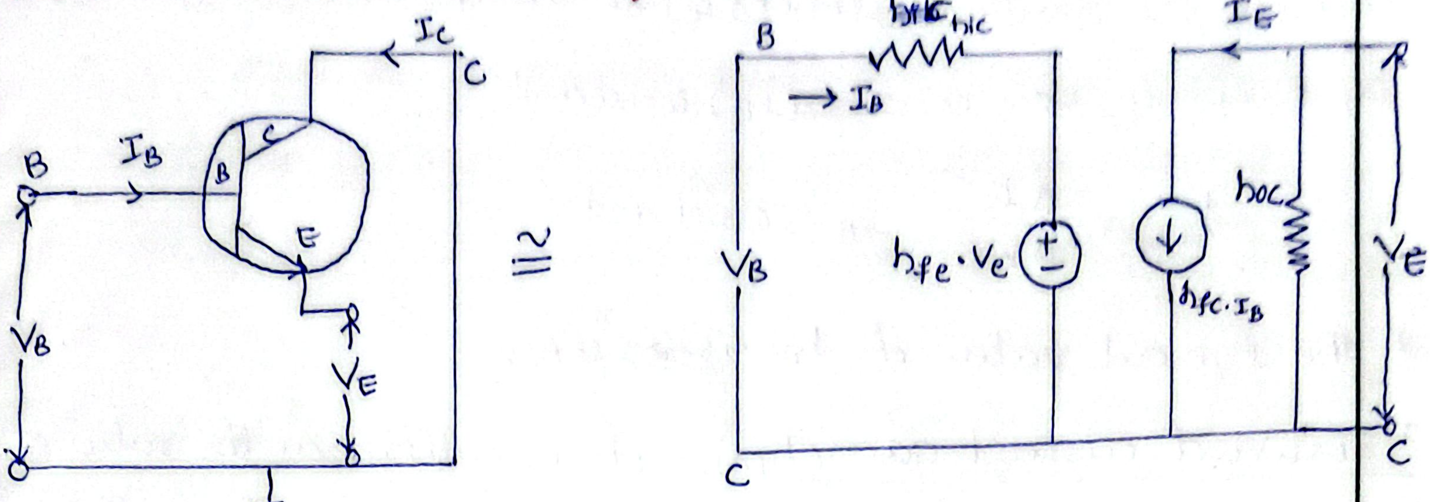
4. Reverse voltage gain (h_{re}):- It is defined as the ratio of change in the base Voltage (ΔV_{BE}) to change in collector Voltage (ΔV_{CE}) by keeping base current (I_B) constant

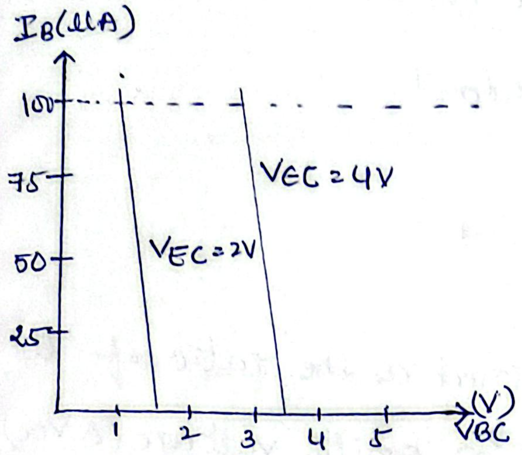
$$h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}}, \; I_B - \text{constant}$$

* Its typical value of hre is from 10^{-5} to 10^{-4}

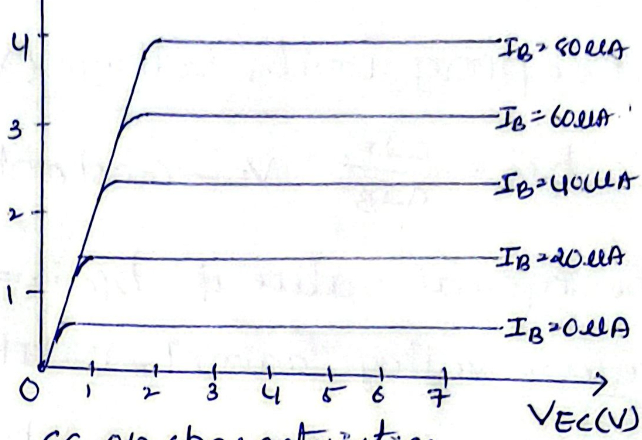
ROLL No .... SHEET No. ....

BJT-CC characteristics hybrid parameters





CC i/p characteristics



CC o/p characteristics

1. <u>Input impedance (h_{ic})</u>:- It is defined as the ratio of change of input voltage (ΔV_{BC}) to change of base current (ΔI_B) by keeping (V_{EC}) constant

$$h_{ic} = \frac{\Delta V_{BC}}{\Delta I_B}, \ V_{CE} - \text{constant}$$

* The typical range of h_{ic} is – 1100Ω

2. Output admitance(h_{oc}):- It is defined as the ratio of change in Emitter current(ΔI_C) to change in Emitter voltage(ΔV_{EC}) by keeping base curren(I_B) constant

$$\therefore h_{oc} = \frac{\Delta I_C}{\Delta V_{EC}}, \quad I_B - \text{constant}$$

* The typical value of h_{oc} is $-25 \mu A/V$

3. Forward current gain(h_{fc}):- It is defined as the ratio of change in Emitter current (ΔI_E) to change in base current (ΔI_B) by keeping Emiter voltage (V_E) is constant.

$$\therefore h_{fc} = \frac{\Delta I_E}{\Delta I_B} \quad V_E - \text{constant}$$

* The typical value of h_{fc} is $= -51$

4. Reverse voltage gain(h_{rc}):- It is defined as the ratio of the change in base voltage (ΔV_{BC}) to change in Emitter voltage (ΔV_{EC}) by keeping base current(I_B) constant.

$$\therefore h_{rc} = \frac{\Delta V_{BC}}{\Delta V_{EC}}, \quad I_B - \text{constant}$$

* The typical value of h_{rc} is $= 1$