UNIT - III

BIPOLAR JUNCTION TRANSISTOR

→ A Bipolar junction Transistor (BJT) is a three terminal Semicon device in which the operation depends on the interaction of both majority and minority carriers and hence the name Bipola

→ BJT is Smaller in Size, it is Used in amplifier & oscillator circuits and as a Switch in digital circuits.

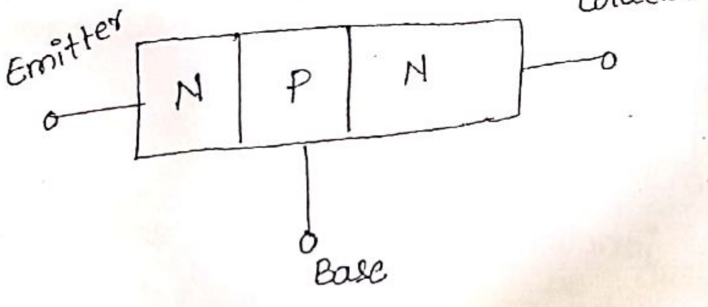
→ It had wide applications in computers, Satillite & other modern communication Systems.

* Construction of BJT & BJT Symbol :-

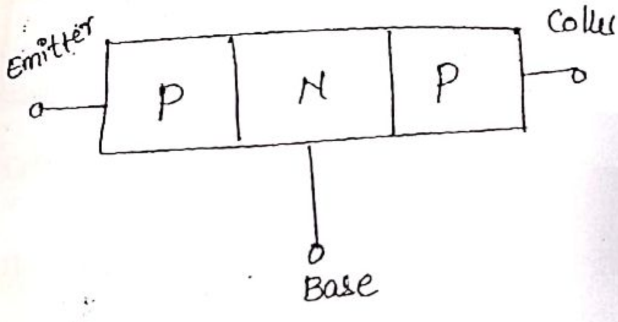
→ A transistor is basically a silicon (Si) or Germanium (Ge) crystal containing three Seperate regions.

→ In which a thin layer of N-type silicon is Sandwiched between two layers of P-type silicon. This transistor is reffered to as PNP.

→ In an NPN transistor, a layer of P-type material is Sandwiched between two layers of N-type material. The two types of the BJT are represented as

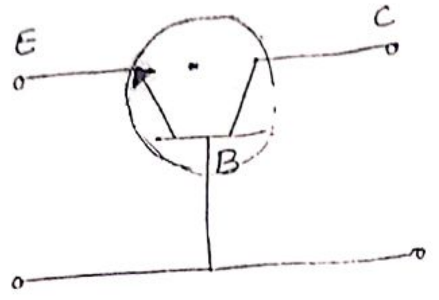


(a) NPN Transistor

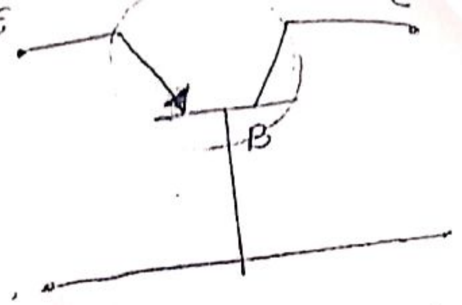


(b) PNP Transistor

fig (1) Bipolar transistor construction.



(a) NPN Transistor circuit symbol



(b) PNP Transistor circuit symbol.

→ The middle region is called Base and outer two regions are called emitter and collector, The outer layers although they are of same type but their functions can't be changed.

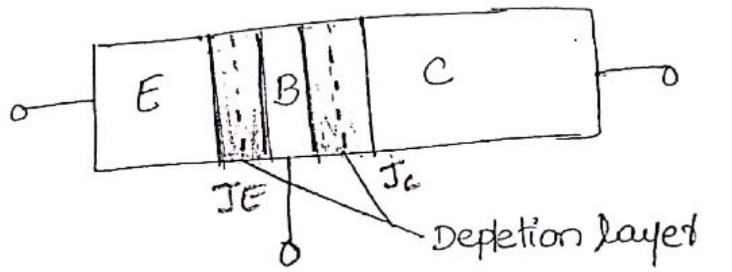
→ They have different physical & electrical properties.

→ In most transistors, emitter is <u>heavily doped</u>. Its job is to emit or inject electrons into base.

→ These bases are lightly doped & very thin, it passes most of the emitter - injected electrons on to the collector.

→ The doping level of collector is intermediate between the heavy doping of emitter and the light doping of the base.

→ The collector is so named because it collects electrons from base. The collector is the largest of the three regions, it must dissipate more heat than the emitter or base.



→ The transistor has two junctions. one between emitter & base and other b/w base & collector

→ when transistor is made, the diffusion of free electrons across the junction produces two depletion layers r each of these depletion layers, the barrier potential 0.7 for Si transistor & 0.3 for Ge transistor. The depletion layers don't have the same width, because different regions have different doping levels.

→ The more heavily doped a region is, the greater the concentration of ions near the junction.

→ This means the depletion layer penetrates more deeply into the base & slightly into emitter. Similarly it penetrates more into collector. The thickness of collector depletion layer is large while the base depletion layer is small.

J_E = Emitter Junction
J_C = collector "

Regions of operation :-

		J_E	J_C	
→ Active Region	-	F.B	R.B	→ Amplifier
Saturation Region	-	F.B	F.B	→ I_{max}
Cut off Region	-	R.B	R.B	→ I_{min}
Inverse Region	-	R.B	F.B	

→ When transistor operated in active region signal has to pass from low resistance region to high resistance region. Hence transistor can be used as Amplifier.

→ To have switch operation in transistor it should be operated in b/w saturation and cut-off region.

→ Transistor should not be operated in Inverse region.

Operation and current components of NPN Transistor :-

The forward bias applied to the emitter base junction of NPN transistor causes lot of electrons from emitter region to crossover to the base region.

→ As base is lightly doped with p-type impurity, the number of holes in the base region is very small & hence the number of electrons that combine with holes in the p-type base region is also very small.

→ Few electrons combine with holes to constitute base current I_B. The remaining electrons (more than 95%) crossover into the collector region to constitute collector current I_C. The base current I_B & collector current I_C added to give emitter current

i.e $I_E = -(I_C + I_B)$.

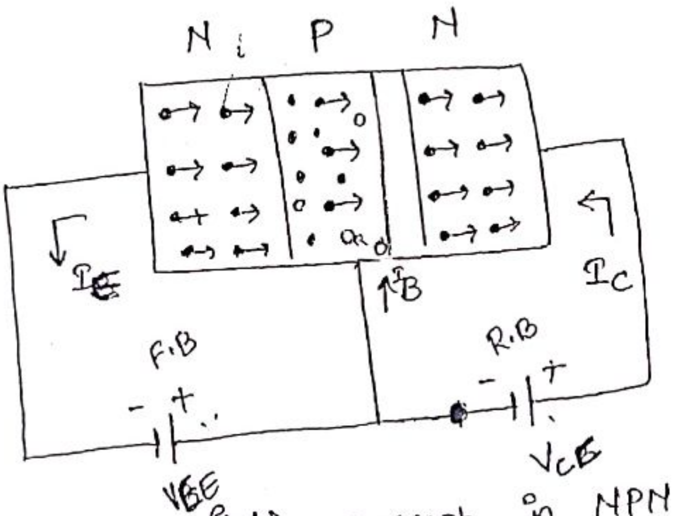


fig.(i) current in NPN transistor.

→ In the external circuit the NPN bipolar junction transistor, the magnitude of emitter current I_E, I_B & I_C are related as.

$$I_E = I_C + I_B$$

Operation and current components of PNP transistor:-

The forward bias applied to the emitter - base junction of a PNP transistor causes a lot of holes from the emitter region to cross over to the base region.

As the base is lightly doped with N-type impurity, the no. of electrons in base region is very small & hence the no. of holes combined with electrons in the N-type base region is also very small.

A few ~~elec~~ holes combined with electrons ~~(in the N-type base region is)~~ to constitute a base current I_B.

The remaining holes (more than 95%) crossover into the collector region to constitute a collector current I_C.

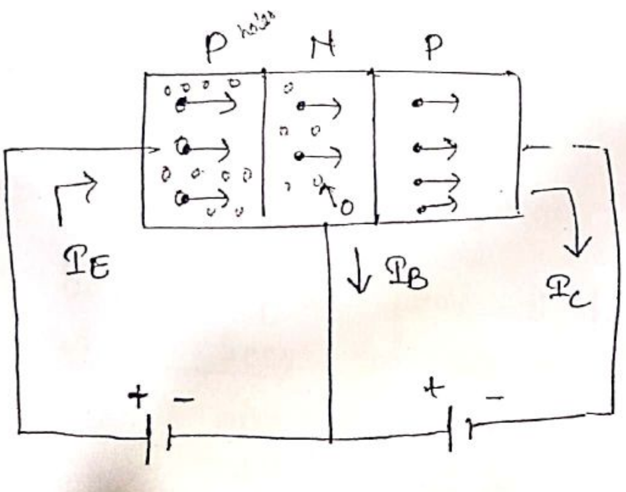
Thus I_C & I_B when added to gives the I_E

$$I_E = -(I_C + I_B)$$

In the External ckt of the PNP BJT, the magnitude of the emitter current I_E, I_B & I_C are related by

$$\boxed{I_E = I_C + I_B} \quad -(1)$$

This Eqns gives the fundam relationship b/w the currents in BJT ckt.



fig(a). Current in PNP transistor

→ This fundamental Eqn shows that there are current amplification factor α & β in Common base transistor configuration & Common emitter transistor configuration respectively for static (dc) currents & small changes in the currents.

* Large signal current gain (α) :-

→ The large signal current gain of CB transistor is defined as the ratio of Negative of the Collector - current increment to the emitter current change from cutoff ($I_E = 0$) i.e

$$\alpha = -\frac{(I_C - I_{CBO})}{I_E - 0} \quad \text{——} (2)$$

I_{CBO} or I_{CO} ⇒ Reverse saturation current flowing through the reverse biased collector ~~current~~ base junction i.e the collector to base leakage current with emitter open. I_{CBO} is negligi

$$\alpha = \frac{I_C}{I_E} \quad \text{——} (3)$$

→ I_C & I_E are flowing in opposit directions, α is positive. α Ranges from 0.90 to 0.995. α is not a constant but varies with emitter current & V_{CB} & temperature.

General Transistor Equation :- In the active region of transistor the emitter is forward biased and the collector is reverse biased. The generalised Expression for I_C for collector junction Volt V_C & emitter current I_E is given by

$$I_C = -\alpha I_E + I_{CBO}\left(1 - e^{V_C/V_T}\right) \quad \text{——} (4)$$

V_C is negative, $|V_C|$ is very large compared with V_T then above Eqn reduces to

$$I_C = -\alpha I_E + I_{CBO} \quad \text{——} (5)$$

Current ... configuration ... tively

Relation among I_C, I_B & I_{CBO} :-

From Eqn (5)

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

I_C & I_E are flowing in opposite direction

$$I_E = -(I_C + I_B)$$

$$\therefore \; I_C = -\alpha[-(I_C + I_B)] + I_{CBO}$$

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

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

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

let $\beta = \frac{\alpha}{1-\alpha}$ — (6)

$1+\beta \Rightarrow$

$1 + \frac{\alpha}{1-\alpha} = \frac{1-\alpha+\alpha}{1-\alpha} = \frac{1}{1-\alpha}$

$$\boxed{I_C = \beta I_B + (1+\beta) I_{CBO}} \quad \text{— (7)}$$

* Relation among I_C, I_B & I_{CEO}

→ In the CE transistor I_B is the I/P current & I_C is O/P current. If Base ckt is open i.e. $I_B = 0$, then small collector current flows from collector to emitter.

→ This is denoted by I_{CEO}, the collector-emitter current with base open. This current I_{CEO} is also called the collector to emitter leakage current

→ In this CE configuration of the transistor, the emitter ... is forward biased and collector base junction is reverse ... and hence the collector current I_C is the sum of the ... of the emitter I_E reaches the collector & collector-emitter leakage current I_{CEO}.

→ ∴ The part of I_E reaches collector is equal to $(I_C - I_{CEO})$

The large signal current gain (β) is defined as

$$\beta = \frac{I_C - I_{CEO}}{I_B} \quad \text{———} \quad (8)$$

$$I_B \beta = I_C - I_{CEO}$$

$$\boxed{I_C = \beta I_B + I_{CEO}} \quad \text{———} \quad (9)$$

* Relation b/w I_{CBO} & I_{CEO}

From eqn (7) & (9) we get the relation b/w the leakage currents of transistor common-base & common emitter (CE) configurations

$$I_{CEO} = (1+\beta) I_{CBO} \quad \text{———} \quad (10)$$

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

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

From this eqn, the collector emitter leakage current (I_{CEO}) in CE configuration is $(1+\beta)$ times larger than that in CB configuration. As I_{CBO} is temperature dependent, I_{CEO} varies by large amount when temperature of the junction changes.

Expression for emitter current

The magnitude of emitter-current is

$$I_E = I_C + I_B$$

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

From eqn (7) $I_C = (1+\beta) I_{CBO} + \beta I_B$ Sub this eqn (7) in above eqn. we get

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

$$I_E = I_C + I_B$$

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

$$I_E = (1+\beta) I_{CBO} + (1+\beta) I_B \quad \text{———— (11)}$$

Sub eqn (6) into eqn (11) we get

$\beta = \frac{\alpha}{1-\alpha}$ ——

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

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

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

$$\boxed{I_E = \frac{1}{1-\alpha} I_{CBO} + \frac{1}{1-\alpha} I_B} \quad \text{———— (12)}$$

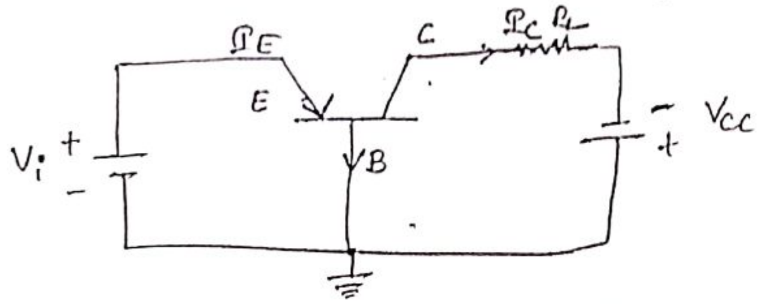
DC current gain (β_{dc} or h_{FE}) :- The dc current gain is defined as the ratio of the collector current I_C to the base current I_B

$$\beta_{dc} = h_{FE} = \frac{I_C}{I_B} \quad \text{———— (13)}$$

As I_C is large compared to I_{CEO}, the large signal current gain 'β' & the dc current gain (h_{FE}) are approximately equal.

ansistor as an Amplifier :-

A load resistor is connected in series with the collector supp Voltage V_{CC} of CB transistor configuration.



fig(1). CB Transistor Configuration

→ A small change in the I/p Voltage b/w emitter & base, say ΔV causes relatively large change in emitter current, ΔI_E.

→ A fraction of this change in current is collected & passed through R_L and is denoted by α'.

∴ corresponding change in voltage across the load resistor R_L due to this current is $\Delta V_o = \alpha' R_L \Delta I_E$.

→ Voltage amplification $A_V = \frac{\Delta V_o}{\Delta V_i} > 1$ and thus the transis acts as an amplifier.

→ For amplifier conditions have to be satisfied are

$A_I >> 1$

$A_V >> 1$

Types of transistor Amplifier Configuration :-

→ when a transistor is to be connected in a ckt, one terminal is used as an input terminal, other terminal is used as an o/p terminal and the third terminal is common to the I/p & o/p terminal.

→ A transistor amplifier can be connected in three configurations

(1) CB Configuration :-

→ This is also called grounded base configuration. In this configu emitter is the input terminal, collector is the o/p terminal and base is the common terminal.

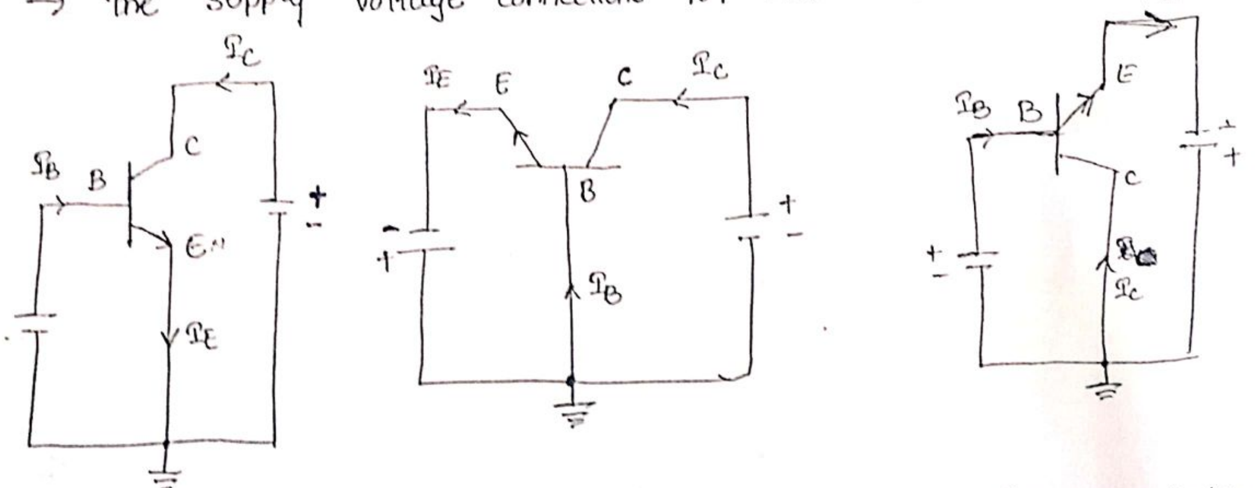
(2) CE Configuration :-

→ This is called grounded emitter configuration. In this configuration base is the I/p terminal, collector is the o/p terminal & emitter is the common terminal.

3) CC Configuration :-

→ This is also called grounded collector configuration. In this configuratio base is the input terminal, emitter is the o/p terminal and collector is the common terminal.

→ The supply voltage connections for normal operation of NPN transis



(a) Common emitter Configuration (b) Common Base Configuration (c) Common Collector Configuration

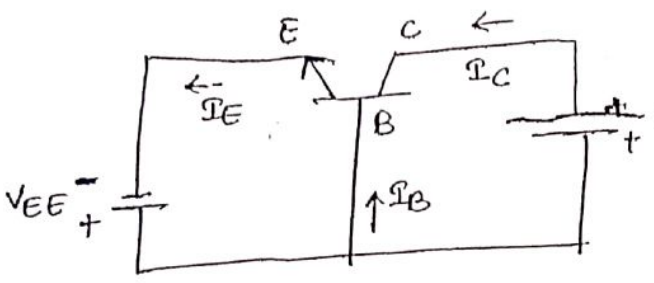
Common base characteristics :-

→ To understand the complete electrical behaviour of a transis it is necessary to study the interrelation of various curren & voltages.

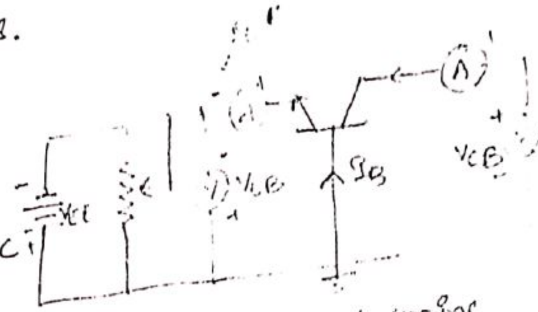
→ These relationship can be plotted graphically which are common known as the characteristics of transistor.

→ The important characteristics of transistor in any configur are the I/p & o/p characteristics.

(PN)



fig(1) common base configuration



fig(1). ckt to Determine CB chars

→ In this configuration input is applied between emitter & base and output is taken from the collector & base. Hence base of the transistor is common to both I/p & o/p ckt.

Input parameters → I_E & V_{BE} , I/p chars V_{BE} & $I_E \big|_{V_{CB}=K}$

output parameters → I_C & V_{CB} , o/p chars V_{CB} Vs $I_C \big|_{I_E=}$

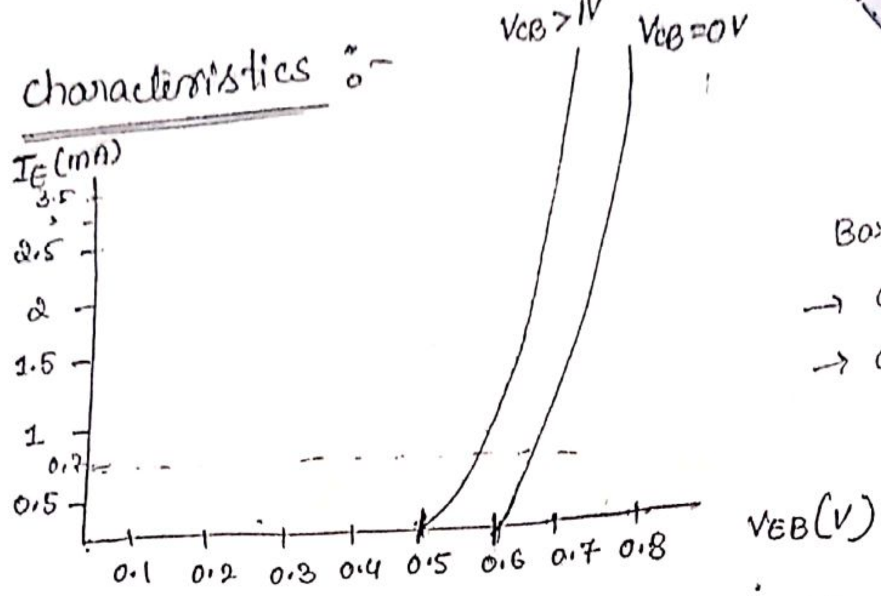
Input characteristics :-

→ To determine the I/p characteristics, the base-collector voltage V_{CB} is kept constant at zero volt & the emitter current increased from zero to suitable steps by increasing V_{BE}. This is repeated for higher fixed values of V_{CB}.

→ A curve is drawn b/w emitter current I_E & emitter base volt V_{EB} at constant collector base volt V_{CB}. The I/p chars are obtained as

$$r_i = \frac{\Delta V_{EB}}{\Delta I_E}\Big|_{V_{CB}=\text{constant}}$$

→ CB I/P characteristics :-

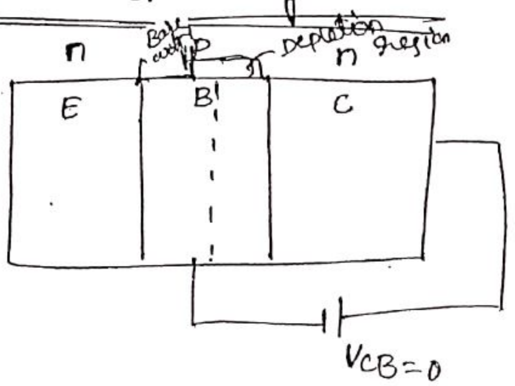


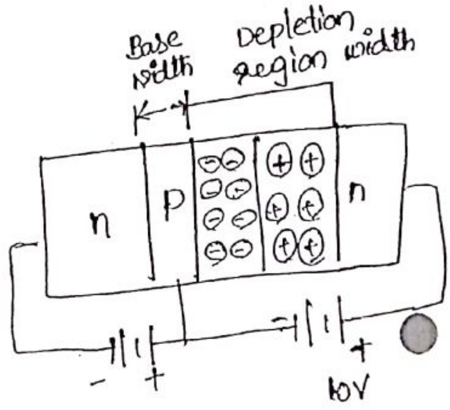
Barrier potential
→ 0.7V Si
→ 0.3V Ge

when $V_{CB}=0$ and emitter-base junction is forward biased, the junction behaves as a forward biased diode so that emitter current I_E increases rapidly with small increase in emitter base Volt V_{EB}.

when V_{CB} is ~~ited~~ keeping V_{EB} constant, the width of the base region will decrease. This effect results in an increase of I_E

Base width modulation or Early effect :-





As the Collector Volt V_{CC} is made to increase the reverse bias, the space charge width b/w collector & base tends to increase with the result that the effective width of the base decreases. This dependency of base width on collector emitter Volt is known as Early effect.

(or)

By having variation of base width w.r.t reverse bias we can obtain more o/p current for same I/p is known as Early effect.

... through or Breakdown :-

For Extremely large Voltages, the effective base width may be reduced to zero, causing Voltage breakdown in the transistor. This phenomenon is called the pinch through (or) Breakdown.

Output characteristics :-

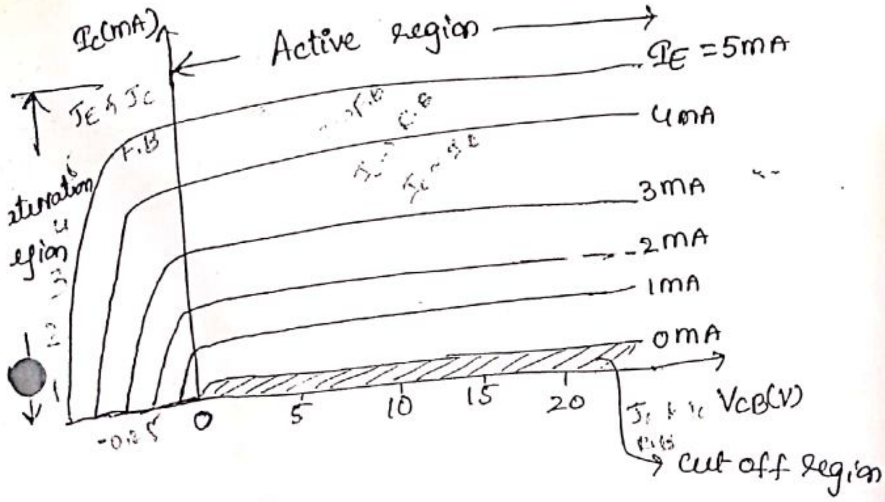
→ Emitter current I_E is kept constant at a suitable value by adjusting the V_{EB}.

→ Then V_{CB} is ... in suitable Equal Steps and the collector current I_C is noted for each value of I_E. This repeated for different fixed values of I_E.

→ Now the curves of I_C Vs V_{CB} are plotted for constant value of I_E & o/p chars are obtained.

$$R_o = \frac{\Delta V_{CB}}{\Delta I_C}\Big|_{I_E = K}$$

R_o → o/p dynamic Resist...



→ The output characteristics has three basic regions
(i) Active Region (ii) Cutoff Region (iii) Saturation region.

(i) Active Region :- For the operation in the active region, the emitter base region junction is forward biased while collector base junction is reverse biased. In this region collector current I_C is approximately Equal to the emitter current I_E & transistor works as an amplifier.

(ii) Saturation Region :-

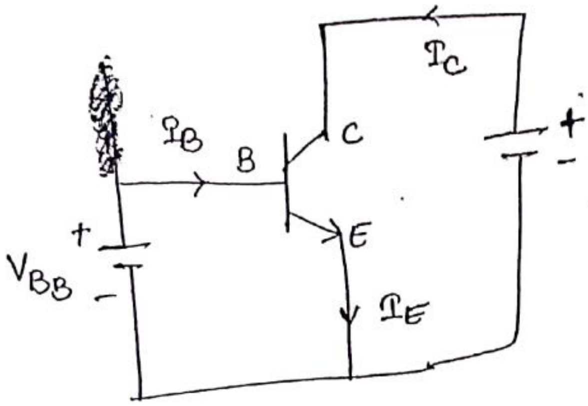
→ The Exponential increase in collector current as the voltage V_{CB} increases towards 0V. In this Saturation region, the emitter-base & collector base junctions are both forward biased.

iii) cut off Region :-

→ The region below the curve $I_E = 0$ is known as cut-off Region where the collector current is nearly zero & the collector base and emitter-base junctions of transistors are Reverse biased.

Common Emitter Configuration :-

In this configuration input is applied between base and emitter and output is taken from collector & emitter. Emitter of the transistor is common to both, input & o/p ckts.



fig(1) common emitter configuration

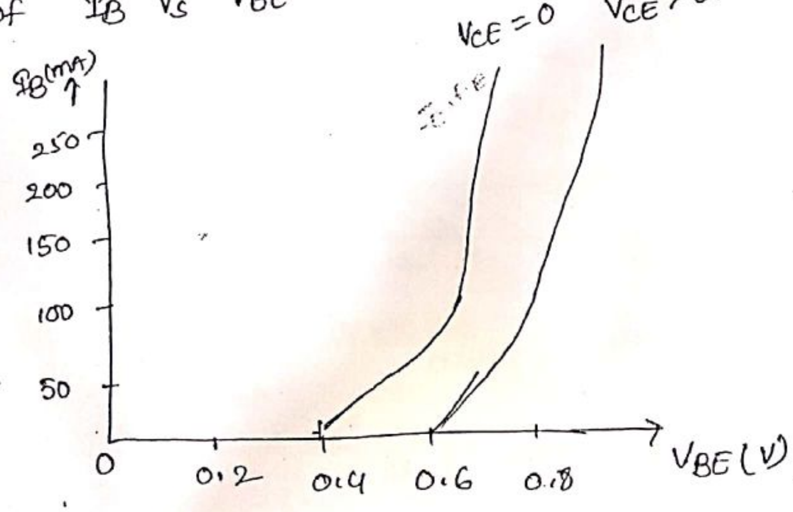
Input parameters V_{BE}, I_B ; I/p chars → V_{BE} Vs I_B $|_{V_{CE}=k}$

output " V_{CE}, I_C , o/p char → V_{CE} & I_C $|_{I_B=k}$

Input characteristics :-

To determine the input characteristics, the collector emitter Volt V_{CE} is kept constant at zero volt & base current is increased from zero in equal steps by increasing V_{BE}.

The value of V_{BE} is noted for each setting of I_B. This procedure is repeated for higher fixed values of V_{CE}, & the curves of I_B Vs V_{BE} are drawn.



→ when $V_{CE}=0$, the emitter base junction is forward biased junction behaves as a forward biased diode.

→ when V_{CE} increased, the width of the depletion region at the reverse biased collector - base junction will increase. Hence the effective width of the base will decrease. This effect causes a decrease in the base current I_B.

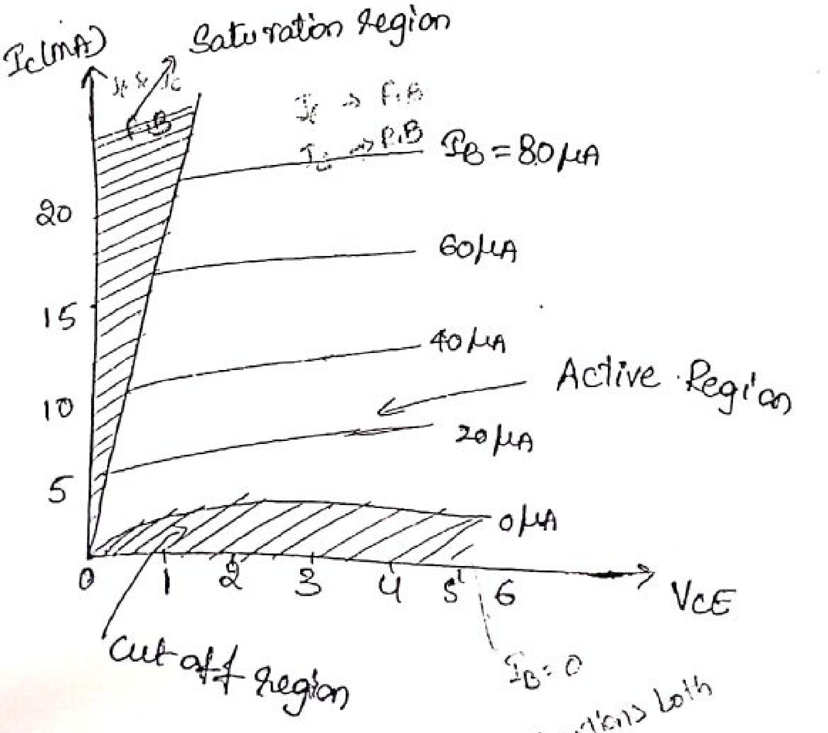
→ To get the same value of I_B as that for $V_{CE}=0$, V_{BE} should be increased. ∴ curve shifts to right as V_{CE} ↑es.

output characteristics :-

→ To determine the o/p chars, the base current I_B is kept constant at a suitable value by adjusting base-emitter voltage V_{BE}.

→ The magnitude of collector emitter voltage V_{CE} is increased in suita[ble] equal steps from zero & the collector current is noted for setting to V_{CE}, How the chars of I_C Vs V_{CE} are plotted for different constant values of I_B.

$$\beta = \frac{\alpha}{1-\alpha} \quad \& \quad I_C = (1+\beta) I_{CBO} + \beta I_B$$



fig(2) CE O/P chars

U-III (8)

→ ∴ large values of V_{CE}, due to early effect, a very small change in α is reflected in a very large changes in β

Ex:- $\alpha = 0.98$, $\beta = \frac{0.98}{1-0.98} = 49.$

$\alpha = 0.985$ $\beta = \frac{0.985}{1-0.985} = 66$

Here slight increase in α by about 0.5% results in an increase in β by 34%.

→ Hence the o/p chars of CE configuration show a larger slop when compared with CB configuration.

- The o/p characteristics have three regions
(i) Saturation Region (ii) cut off Region (iii) Active region

→ The region of curves to the left of the line is called the saturation region. & the line is called saturation line. In this region both junctions are forward biased and an increase in the current doesn't cause a corresponding large change in I_C.

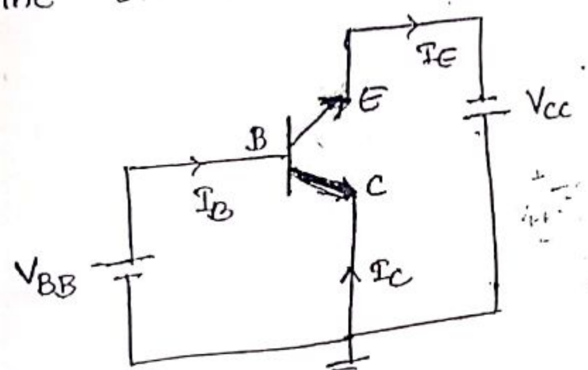
→ The ratio of $V_{CE(sat)}$ to I_C in this region is called saturation resistance.

- The Region below the curve for $I_B = 0$ is called the cut-off region. In this region both the junctions are reverse biased.

(iii) The central region where the curves are uniform in spacing and slop is called the active region. In this region emitter-base junction is forward biased and collector-base junction is reverse biased. If the transistor is to be ~~operated~~ used as a linear amplifier, it should be operated in the active region.

...mmon collector configuration :-

In this configuration input is applied between base and collector and output is taken from emitter and collector. Here collector of the transistor is common to both I/P & o/P ckts.

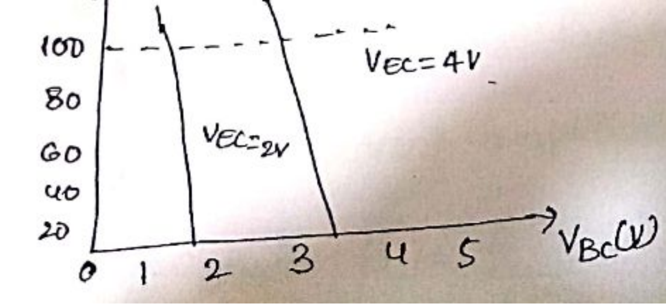


fig(1). common collector configuration

Input characteristics :-

→ To determine the I/P chars, V_{CE} is kept at a suitable fixed value. The base - collector voltage V_{BC} is increased in equal steps and the corresponding increase in I_B is noted.

→ This is repeated for different fixed values of V_{EC}, plots of V_{BC} Vs I_B for different values of V_{EC}.



Output characteristics :-

→ The o/p chars are Same as those of Common emitter config.

Comparision of CB, CE & CC Configurations.

Property	CB	CE	CC
Input resistance	Low (about 100Ω)	Moderate (about 750Ω)	High (about 750Ω)
Output resistance	High (about 450 kΩ)	Moderate (about 45kΩ)	Low (about 25Ω)
Current gain	1	High	High
Voltage again	About 150	About 500	less than 1
phase shift b/w I/P & o/P	0 or 360°	180°	0 or 360°
Applications	For high freq circuits	for Audio freq circuits	for Impedance matching.

* current Amplification factor :-

→ In a transistor amplifier with a.c. input signal, the ratio of change in o/P current to the change in input current is known as the current amplification factor.

→ In the CB configuration current amplification factor $\alpha = \frac{\Delta I_C}{\Delta I_E}$ — ①

→ " " CE " C.A.F $\beta = \frac{\Delta I_C}{\Delta I_B}$ — ②

→ " " CC " " $\gamma = \frac{\Delta I_E}{\Delta I_B}$ — ③

Relation b/w α & β

$$\Delta I_E = \Delta I_c + \Delta I_B$$

$\Delta I_C = \alpha \Delta I_E$

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

$\Delta I_B = \Delta I_E (1-\alpha)$ Dividing both sides by ΔI_C we get

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

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

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

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

$$\therefore \beta = \frac{\alpha}{1-\alpha} \quad \text{or} \quad \alpha = \frac{\beta}{1+\beta} \text{ --- (4)}$$

$\frac{\beta}{1+\beta}$ $\frac{\alpha}{1-\alpha}$ $1+\frac{\alpha}{1-\alpha}$

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

→ α approaches unity, β approaches to infinity.

* Relation among α, β & γ

→ In the CC transistor amplifier ckt I_B is I/P current & I_E is O/P current.

$I_E = I_C + I_B$

we know $\gamma = \frac{\Delta I_E}{\Delta I_B}$ - (3)

$$\Delta I_B = \Delta I_E - \Delta I_C \text{ ——— (5)}$$

Sub eqn (5) in eqn (3)

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$ Divide by ΔI_E on RHS

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

$$\gamma = \frac{1}{1-\alpha} = (\beta + 1) \text{ ——— (6)}$$

* Limits of operation (Breakdown in Transistors) :-

→ There is a possibility of voltage breakdown in transistor at high voltages.

→ There are two types of breakdown

(i) Avalanche multiplication or avalanche breakdown

(ii) Reach through or punch through

(i) Avalanche multiplication of breakdown :-

→ when a diode is reverse biased, there is a limit on the Voltag that can be applied which is the avalanche voltage.

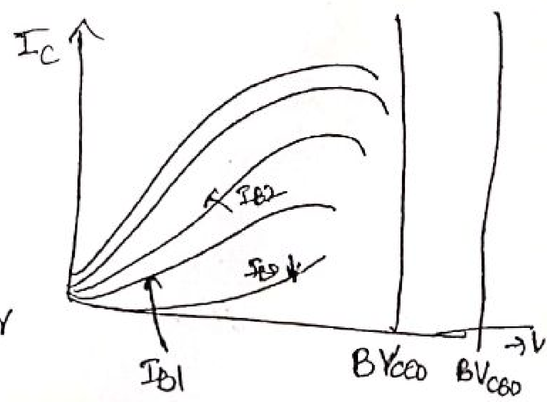
→ In transistor, the maximum reverse biasing Voltage which may be applied before breakdown b/w the collector and base terminal with emitter open is called breakdown Voltage BV_{CBO}.

→ ∴ An upper limit is set on the collector Voltage V_{CB} by avalanche breakdown in the reverse biased collector - base junctio

→ Breakdown may occur because of Avalanche multiplication of the current I_{CO} that crosses the collector junction. As a result multiplication, the current becomes MI_{CO}, where M is the avalanche multiplication factor.

→ At breakdown voltage BV_{CBO} multiplication factor M becomes infin & the current rises abruptly in the break down region.

$$M = \frac{1}{\left(1 - \frac{V_{CB}}{BV_{CBO}}\right)^n}$$



→ n depends on lattice material & carrier type, range is 2 to 10 for N type Si

$n \approx 4$ & for p-type $n \approx 2$

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3) A transistor has $I_B = 100\mu A$ & $I_C = 2mA$ Find (i) β of Transistor (ii) α (iii) I_E (iv) If I_B changes by $25\mu A$ & I_C changes by $0.6mA$. Find the value of new 'β'

Sol. (i) $\beta = \frac{I_C}{I_B} = \frac{2\times10^{-3}}{100\times10^{-6}} = 20$

(ii) $\alpha = \frac{\beta}{\beta+1} = \frac{20}{20+1} = 0.95$

(iii) $I_E = I_C + I_B$

$= 100\times10^{-6} + 2\times10^{-3}$

$= 2.1\times10^{-3}$

$= 2.1 mA$

(iv) $\beta = \frac{I_C}{I_B} = \frac{I_C + \Delta I_C}{I_B + \Delta I_B} = \frac{2\times10^{-3} + 0.6\times10^{-3}}{100\times10^{-6} + 25\times10^{-6}} = 20.8$

Calculate the value of inductance to use in the inductor filter connected to a full wave rectifier operating at 60Hz to provide a dc o/p with 4% ripple for a 100Ω load

Sol.

$$\gamma = \frac{R_L}{3\sqrt{2}\,\omega L}$$

$f_r = 60\,Hz$

$\gamma = 4\%$

$R_L = 100\Omega$

$$\Rightarrow \gamma = \frac{100}{3\sqrt{2} \cdot 2\pi f_r L}$$

$$0.04 = \frac{100}{3\sqrt{2} \times 2 \times \pi \times 60 \times L} \Rightarrow 0.04 = \frac{0.0625}{L}$$

$$L = \frac{0.0625}{0.04} = 1.563\,H$$

(2) Calculate the capacitance to use in a capacitor filter connected to a FWR operating at a standard aircraft power freq 400 Hz, if the ripple factor is 10% for a load of 500Ω

Sol

$$\gamma = \frac{1}{4\sqrt{3} f C R_L}$$

$f = 400\,Hz$

$\gamma = 10\%$

$R_L = 500\Omega$

$$0.01 = \frac{1}{4\sqrt{3} \times 400 \times C \times 500}$$

$$0.01 = \frac{1}{4\sqrt{3} \times 400 \times 500 \times C}$$

$$0.01 = \frac{0.721 \times 10^{-6}}{C}$$

$$C = \frac{0.721 \times 10^{-6}}{0.01} = 72.1\,\mu F$$

(3) Design a filter for full wave rectifier ... provide an o/p voltage for 10V with a load current of 200mA & the ripple is limited to 2%

$I_L = 200mA$ $\quad$ $r = 2\%$

$= 0.02$

$I_L = \frac{V_m}{R_L}$

$R_L = \frac{V_m}{I_L} = \frac{10}{200 \times 10^{-3}}$

$= 50\Omega$

$r = \frac{1.194}{LC}$

$0.02 = \frac{1.194}{LC}$

$LC = \frac{1.194}{0.02} \approx 59.7$

Critical Value $L = \frac{R_L}{3\omega} = \frac{50}{3 \times 2\pi \times f} \doteq 53\,mH$

(4) Design a CLC or π section filter for $V_{dc} = 10V$, $I_L = 200mA$ & $r =$ $L = 10H$

Sol. $I_L = \frac{V_{dc}}{R_L}$ $\quad$ $I_L = 200mA$ $\quad$ $r = \frac{\sqrt{2}}{50} \times \frac{1}{64 \times \pi^3 \times f^3 C_1 C_2 L}$

$R_L = \frac{V_{dc}}{I_L} = \frac{10}{200 \times 10^{-3}} = 50\Omega$

$\Rightarrow \frac{10}{200 \times 10^{-3}} = 50\Omega$

Ripple factor $\gamma = \frac{\sqrt{2}}{50} \times \frac{1}{64 \times \pi^3 \times}$

$\gamma = \frac{5700}{L C_1 C_2 R_L}$ $\quad$ $C_1 = C_2 = C$ $\quad$ $C^2 = 570$

$C = 24\mu F$

$0.02 = \frac{5700}{LC^2} = \frac{114}{LC^2} = \frac{11.4}{C^2}$