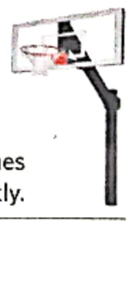
Paper -2

BJT (Bipolar Junction Transistor)

A BJT or Bipolar junction transistor is a well known bipolar device i.e. current conduction is due to both the types of charge carriers, holes, and free e^-. It is a semiconducting device formed by sandwiching a thin slice of P-Type material between two slices of N type material or thin slice of N type material between 2 slices of P-type material. accordingly there are 2 types of transistors NPN and ~~PNP~~ PNP both these transistors have 3 seperate regions namely ~~Emmitter~~ Emmitter, base and Collector. The function of the emmitter is to emit or inject majority carriers into the base. It is a heavily doped region.



Stand as a basket in life that the obstacles in the form of ball comes and passes away but cant stay permanently.

i.e. there are a large no. of ~~mg.~~ majority carriers in this region, the base has the function of passing the majority carriers coming from the emmitter into the collector. It is therefore a very thin region and lightly doped, i.e. very few majority carriers are present in base.

The collector has the function of collecting the majority carriers coming from the emmitter thry. the base. hence it is more wider than the emmitter, and also moderately doped.

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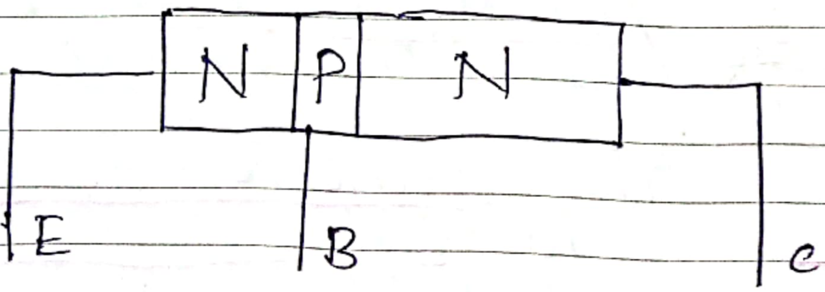
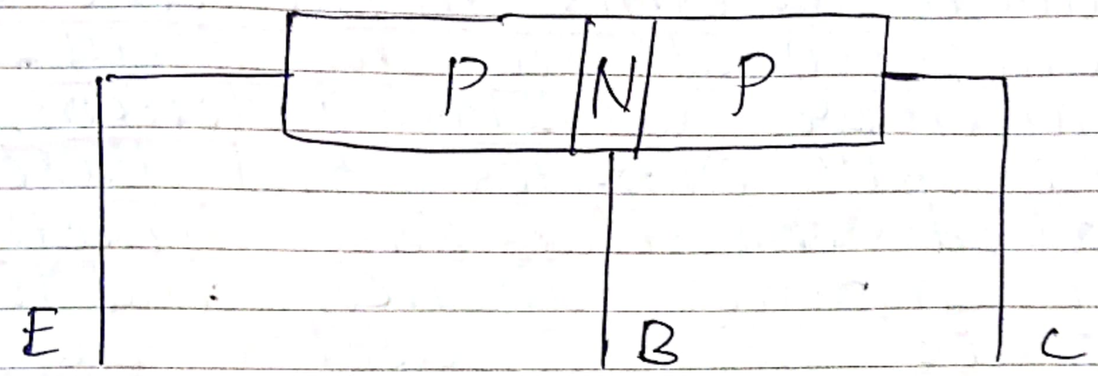
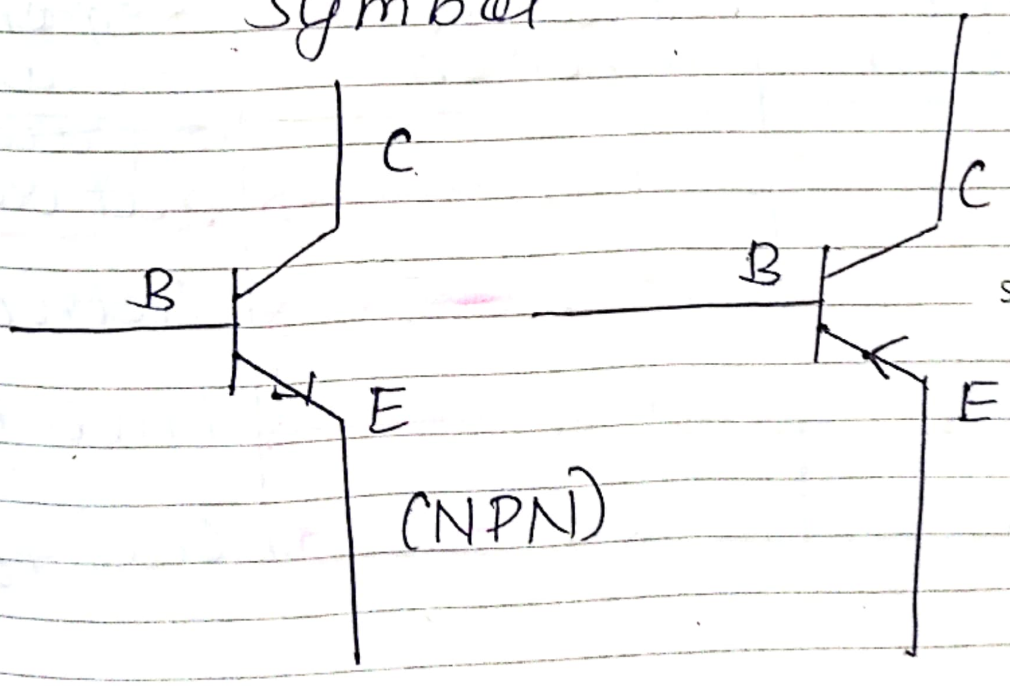
Structure





~~Ej FB RB~~ ~~Cj FB RB~~ ~~Saturation cut-off~~

Symbol

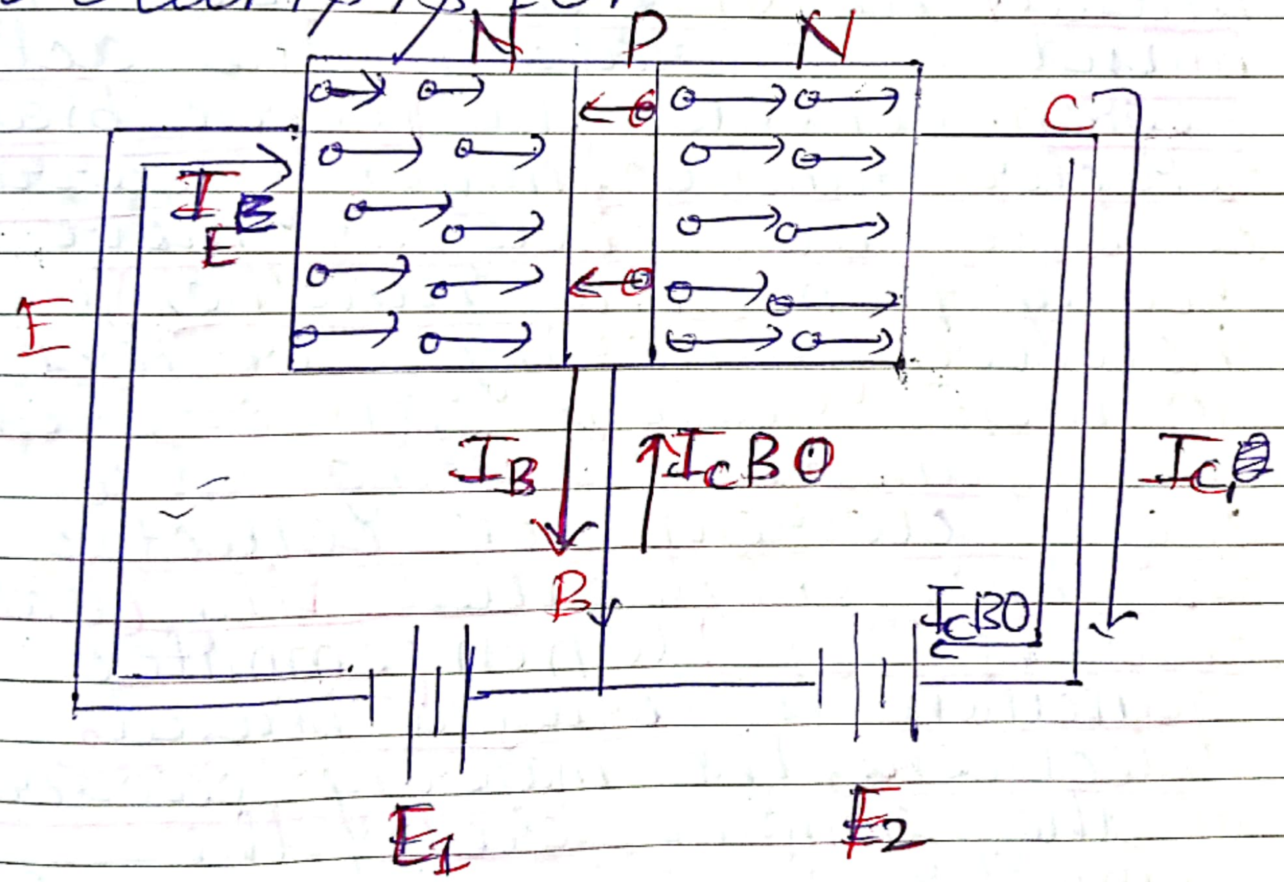


The arrow in the symbol always points in the dirn of conventional current flow, a transistor has 2PN junctions, one betn emmitter and base called emmitter-base junction or emmitter junction and the other betn collector and base called collector-base junction or simply, collector junction. There are four diff. ways of biasing the 2PN junctions which is shown in the table.

Emmitter junction	Collector junction	Region of operation
FB	FB →	Saturation
FB	RB →	Active
RB	FB →	Inverted
RB	RB →	Cut-off

Paper-II

Working of NPN transistor



Consider an NPN Transistor which has its connection made as shown above. Supply E_1 has its -ve terminal connected to emmiter and +ve terminal to base. ∴ Emmiter junction ~~is~~ is forward biased. Collector is made +ve ~~w~~ w.r.t to base by supplying E_2 so that collector junction is reverse biased. The NPN transistor is now biased to operate in the active region. Consider the reverse biased collector junction, majority carriers of base and collector move away from the junction, however. minority carriers in these regions can ~~cr~~ cross the junction resulting in a small current bet^n collector and base only, called the leakage current I_{CBO}. When emmiter junction is forward biased, electrons, the majority carriers in the emmiter cross the emmiter junction into the base, holes in the base cross the junction into the ~~B~~ ~~emitt~~ emmiter this diffusion of holes and free

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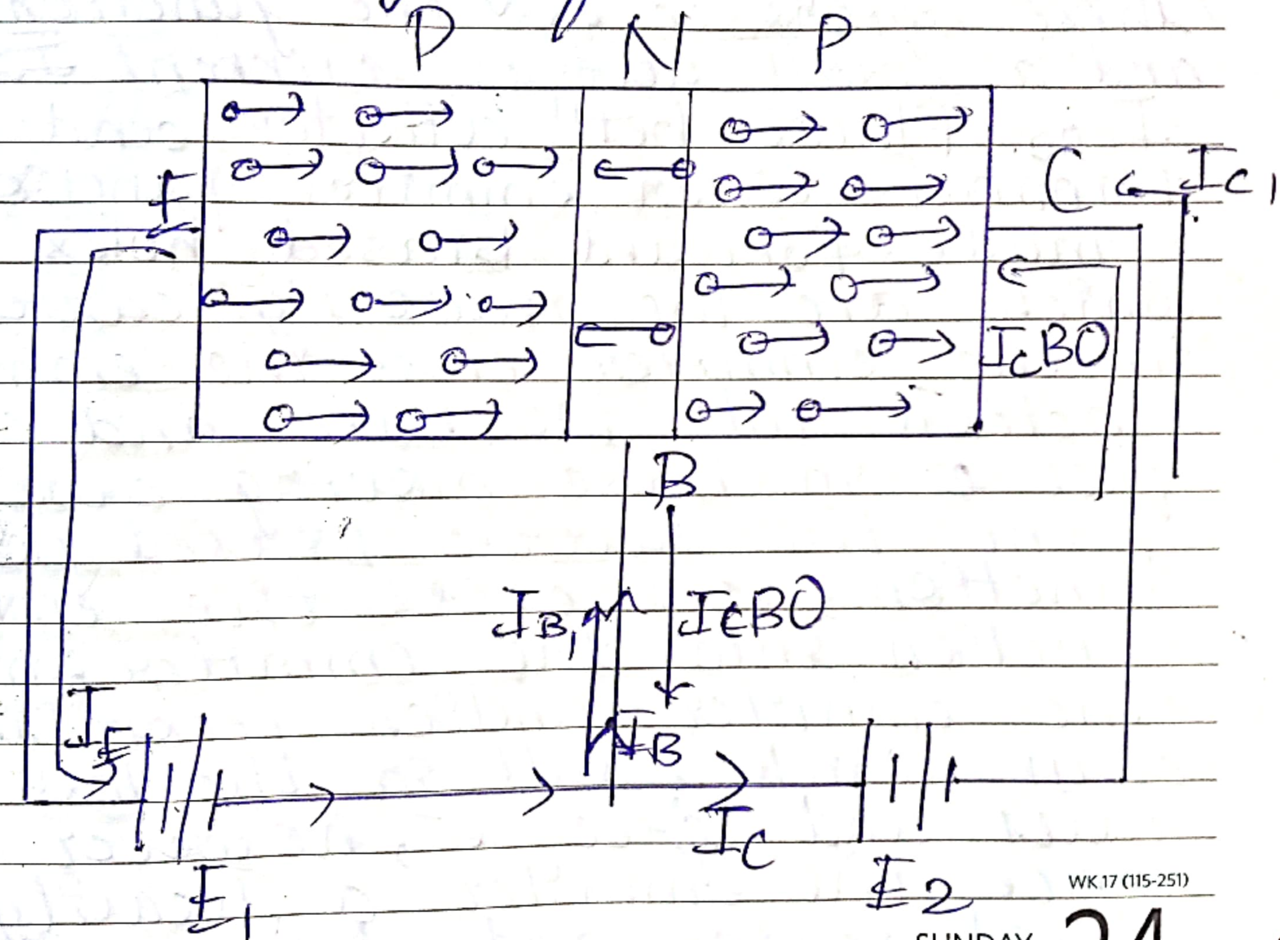
is seen because emmiter junction is forward biased, recombinations occur near the emmiter junction and every recombination eliminates a hole and a free e^-, however in a transistor emmiter is a heavily doped region and base a lightly doped one, the no. of e^- in the emmiter is much more than the no. of holes in the base hence only a few e^- are lost by the emmiter due to recombinations, most of the e^- from the emmiter reach the base and then move on to the collector region, they flow out of the collector towards the +ve terminal of supply E_2 constituting the current I_C, at the same time covalent bonds break in the base creating fresh holes and free e^-. The holes are simply replacing all the holes lost by the base due to recombinations, the e^- so created flow out of the base constituting a ~~cur~~ current I_B, a large no. of e^- from base and collector reach the +ve terminal of E_I. From the -ve terminal e^- enter the emmitter constituting the emmitter current I_E, the flow of e^- into or out of the collector is called the collector current and here the total collector current has two parts,

1. Due to I_{CBO}
2. Due to I_{C_1}

$$\therefore I_C = I_{C_1} + I_{CBO}$$

The total base current of the transistor $I_B = I_{B_1} - I_{CBO}$ and $I_E = I_C + I_B$

Working of PNP



Emmiter is +ve w.r.t base and collector is -ve w.r.t base, ∴ the PNP transistor is biased to operate in the active region with collector junction reverse biased, no majority carriers in collector and base can cross the junction, only minority carriers of these regions cross the junction and a small reverse current ~~ICB~~ I_{CBO} flows betn collector and base terminals, when emmiter junction is made forward biased holes which are the majority carriers in the emmiter cross the emmiter junction into the base and free e^- in base moving away from the reverse biased collector junction, now cross the emmiter junction into the emmiter, near the emmiter junction recombinations occur which result in the loss of holes and free e^-, however since the emmiter a heavily doped region and base a lighty doped one, only a few holes are lost by the emmiter due to recombinations, most of the holes ∴ reach the collector from the emmiter, for every such hole that reaches the collector an e^- is released from the -ve terminal of E_2 to neutralize that hole, this flow of e^- into the collector constitutes the current I_{CB}, at the same time covalent bonds are broken in the emmiter creating fresh holes and free e^-. These e^- flow out of the emmiter towards the +ve terminal of E_1, constituting the emmiter current I_E, from the -ve terminal of E_1, a few e^- enter the base to replace those e^- lost by the base due to recombinations, this constitutes the current I_{B1} the total base current is $\therefore$

$I_B = I_{B1} - I_{CBO}$ $\quad$ $I_E = I_C + I_B$

$I_C = I_{C1} - I_{CBO}$

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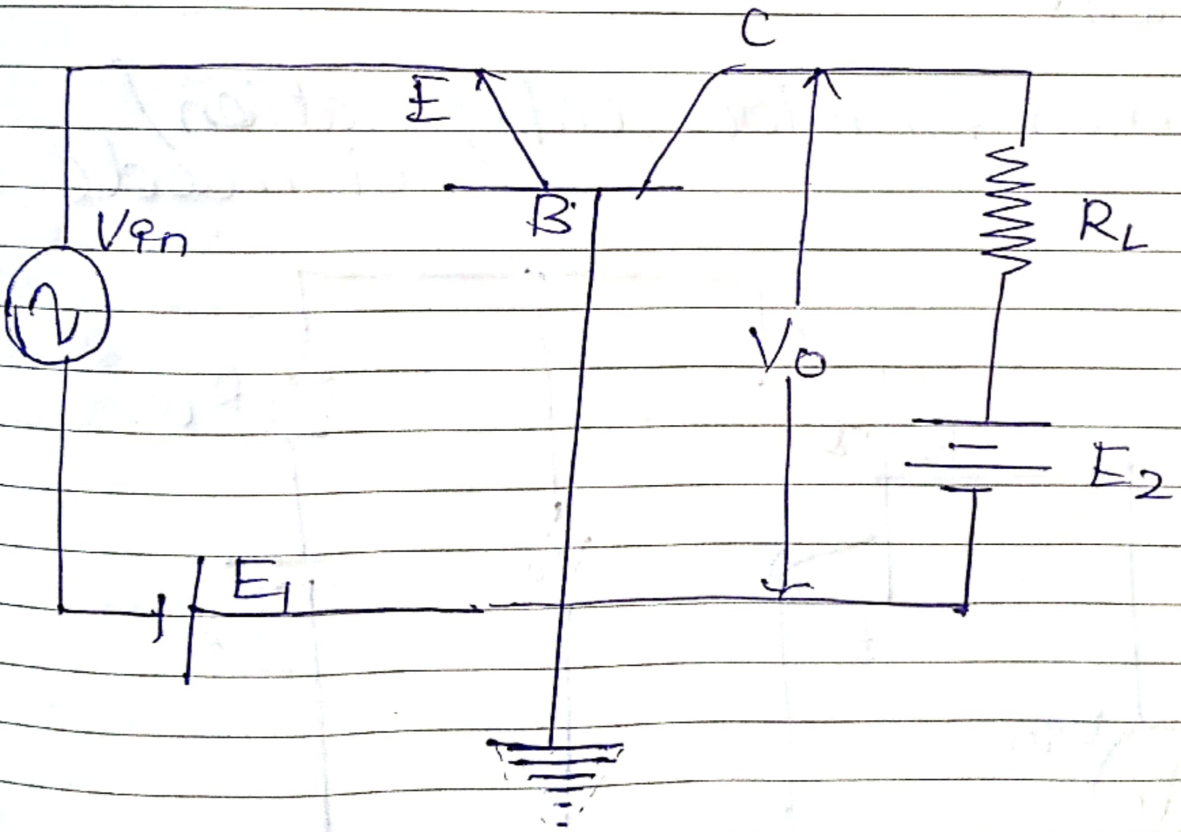
20	21	22	23	24	25	26
27	28	29	30	31		

Transistor configurations/Modes

The main use of a transistor is as an amplifier, an amplifier is basically a 4 terminal device with two input and two output terminals, one input and one output terminal is kept connected to one another and serves as the common terminal i.e. common to both input and output circuits, a transistor is a 3 terminal device, to make it work as an amplifier one of it's 3 terminals must be made the common terminal depending upon which terminal is made common we have ~~3~~ 3 diff. transistor configurations/modes or 3 diff. ways of using a transistor as an amplifier

Common base configuration / CB mode



This configuration is so called ∵ base is the common terminal common to input and

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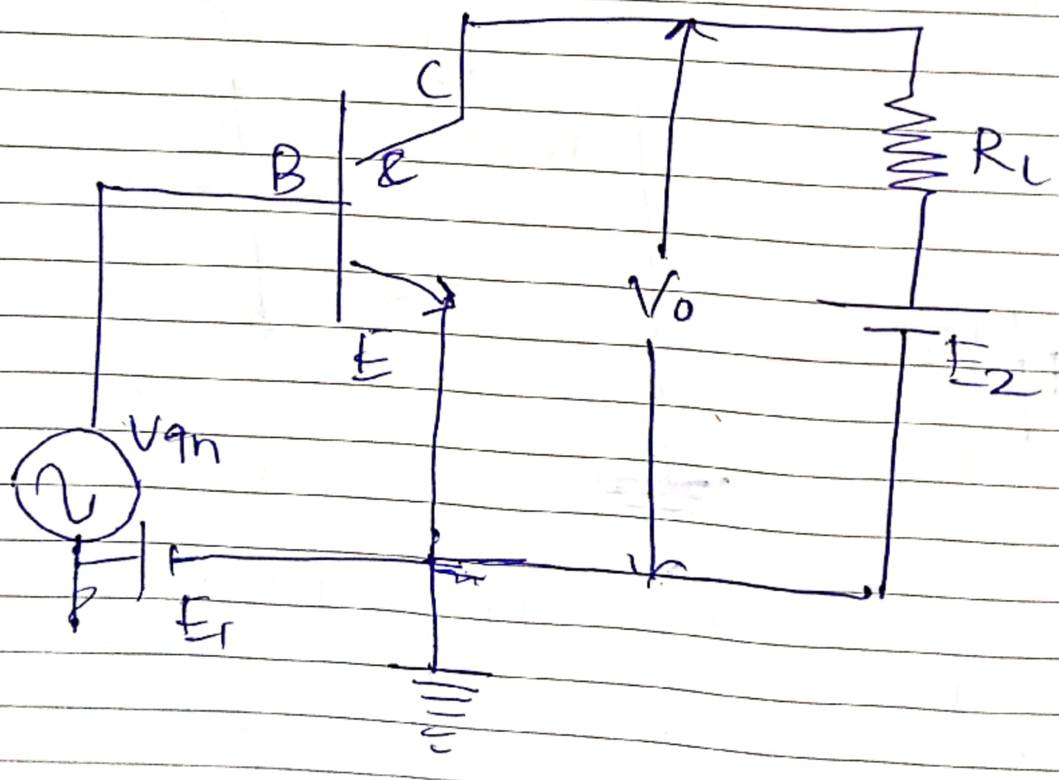
27	28	29	30	31		

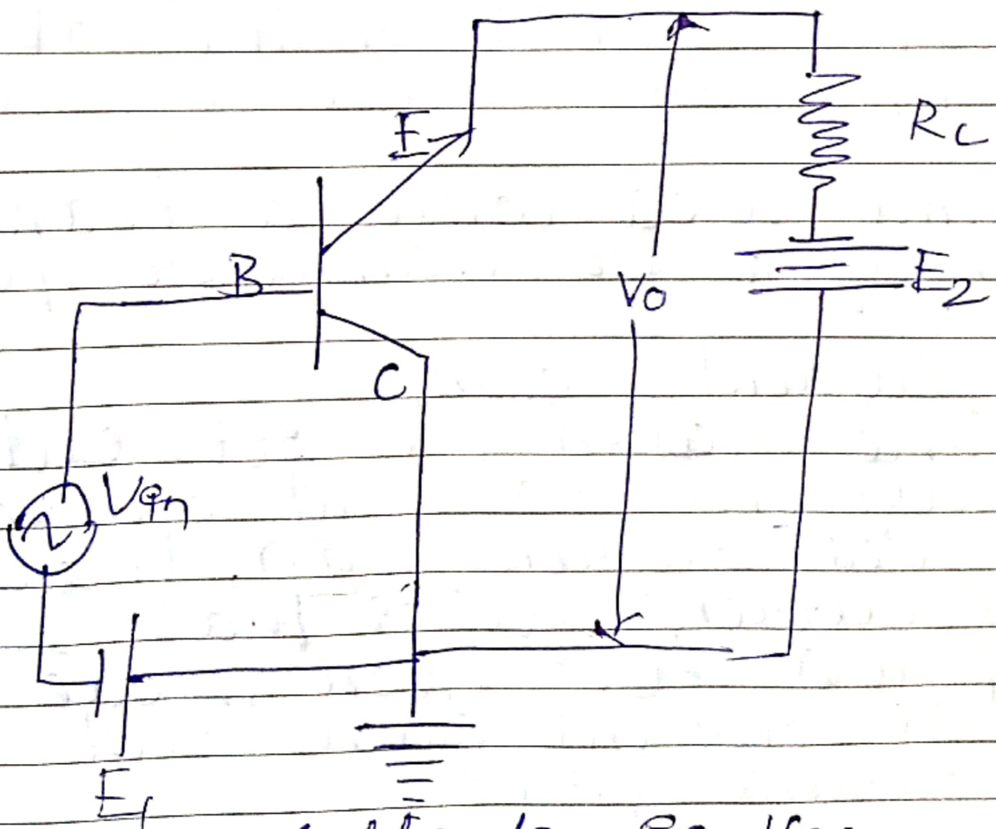
output circuits the signal to be amplified V_{in} is given to the input terminal i.e. emmiter, and the amplified output (V_o) is obtained at the collector, Supplies E_1 and E_2 biased the transistor into the active region.

Common Emmiter Configuration / CE mode



In this mode Emmiter is the common terminal, base the input terminal and collector output terminal. E_1 and E_2 supplies biased the transistor into the active region

CC mode



Collector is the

IMPORTANT

NOTES

Record the list of things you might want to do.

common terminal in this mode, Emmitor is the output terminal and base the input terminal supply E_1 reverse biased the collector junction and E_2 forward biases the Emmiter junction, so that transistor is biased into active region.

Note:
For a PNP transistor all the supply polarities in the above configurations should be reversed.

Terms used with a transistor amplifier or transistor parameters

(i) Current gain.
The ratio of ~~out~~ output current to input current is called current gain, there are 2 current gains that can be found for each mode i.e. DC current gain and AC current gain

DC Current gain is the ratio of DC output current to DC input current.

AC Current gain is the ratio of change in output current to the change in input current.

The current gain in the $\boxed{CB}$ $\boxed{mode}$ is indicated by $\boxed{\alpha}$. For this mode output current is collector current and input current is emmitter current. ∴ α_{DC}

$$\alpha_{DC} = \frac{I_C}{I_E}$$

where I_C and I_E are the DC values of collector and emmiter currents respectively.

$\cancel{\alpha_{AC} = \Delta I}$

$$\alpha_{AC} = \frac{\Delta I_C}{\Delta I_E}$$

ΔI_C indicates change in collector current due to a change ΔI_E in emmiter current. The value of α is found at a particular collector to base voltage and is always less than 1 because collector current of a transistor is always less than its emmiter current. The current gain in the CE mode is indicated by β. Base current is the input current and collector current is the output current.

$\therefore$ $\cancel{\beta_{DC} =}$

$$\beta_{dc} = \frac{I_C}{I_B}$$

$$\beta_{AC} = \frac{\Delta I_C}{\Delta I_B}$$

The value of β is found at a particular collector to emmiter voltage and it is very high because base current of a transistor is normally is μA, whereas it's collector current is much greater in mA. The current gain in the CC mode is indicated by γ

$$\gamma_{dc} = \frac{I_E}{I_B}$$

$$\gamma_{ac} = \frac{\Delta I_E}{\Delta I_B}$$

The value of γ is found at a particular collector emmitter voltage and is also very high.

Relation betn α and β

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

the same relation can also be written as

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

$$I_E = I_C + I_B$$

$\div$ thro. by I_B

$$\frac{I_E}{I_B} = \frac{I_C}{I_B} + 1$$

$$\gamma = \beta + 1$$

Relation bet^n γ and α

$$I_E = I_C + I_B$$

$\div$ thrg. by I_E

$$1 = \frac{I_C}{I_E} + \frac{I_B}{I_E}$$

$$1 - \alpha = \frac{I_B}{I_E} \qquad \because \alpha = \frac{I_C}{I_E}$$

$$\therefore \gamma = \frac{I_E}{I_B} = \frac{1}{1-\alpha}$$

~~Gar~~ In a certain transistor circuit a change in emm. current of 1 mA produces a change in collec. current of 0.99 mA, find current gain

$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E} = \frac{0.99}{1} = 0.99\,mA$$

If the current gain of the transistor in the CE mode is 100, find α

$$CE = \beta = 100$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{100}{101} = \cancel{9}0.99$$

③ For a certain transistor $\alpha dc =$ and emm. current equals to 2 mA find collector and base current

$$\cancel{\alpha d}\ \alpha DC = 0.98$$

$$I_E = 2mA$$

$$I_C, I_B$$

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

$$I_C = \alpha DC \times I_E = 1.96\,mA$$

$$I_E = I_C + I_B$$

$$I_B = (2 - 1.96)\,mA$$

$$I_B = 0.04\,mA$$

Q4. collector current equals 2.9mA for a transistor if base current equals to ~~2.9mA~~ 100μA for a transistor find α DC

$$I_C = 2.9\,mA$$
$$I_B = 100\,\mu A$$

$$\alpha DC = \frac{I_C}{I_E} = \frac{2.9}{3} = 0.96\,mA$$

(5) In a transistor base current is 68 μA emm. current is 30mA & β equals to 440. find α and collec. current

$$I_E = I_C + I_B$$

$$30 = I_C + 0.068$$
$$I_C = 30 - 0.068$$
$$I_C = 29.932\,mA$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{440}{441}$$

(6) In a CB mode current amplification factor is 0.9, if emm. current equals to 1mA find base current

$\alpha = 0.9$ $I_E = I_B + I_C$

$\alpha = \frac{I_C}{I_E}$ $I_B = I_E - I_C$
$= 1 - 0.9$
$= 0.1mA$

$0.9 = \frac{I_C}{1 \times 10^{-3}}$

$I = 0.9mA$

(7) From the table given below find the current gain in the CB mode

V_{CE} (V)	I_C mA $I_B = 25$ mA	$I_B = 65\mu A$
5V	0.91	2.25
5V	0.92	2.45

~~β~~

$$\beta_{AC} = \cancel{Aic}\ \frac{\Delta I_C}{\Delta I_B}$$

$$= \frac{2.25 - 0.9}{65 - 25}$$

$$= \frac{1.34\,mA}{40\,\mu A}$$

$$\beta_{AC} = 33.5\cancel{8}$$

$$\begin{array}{r} \cancel{2}^{1}.\cancel{4}^{17}5 \\ -0.92 \\ \hline 1.53 \end{array}$$

$$\beta_{AC} = \frac{\Delta I_C}{\Delta I_B} = \frac{2.45 - 0.92}{65 - 25} = \frac{1.53}{40}$$

$$= \frac{1.53\,mA}{40\,\mu A}$$

$$= \frac{1.53}{40} \times 10^{-3+6}$$

$$= 0.03825 \times 10^3$$

$$= 38.25$$

Q8. In a CB mode α equals to 0.95 and voltage drop ~~ar~~ across 2KΩ resistor which ~~is~~

connected to the collector is 2V find base current.

$$I_C R_L = V_{RL}$$

$$I = \frac{V_{RL}}{R_L}$$

$$= \frac{2}{2 \times 10^3}$$

$$= 10^{-3}$$

$$I_C = 1mA$$

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

$$= \frac{1}{0.95}$$

$$I_E = 1.05mA$$

$$I_B = I_E - I_C$$

$$= 1.05 - 1$$

$$= 0.05mA$$

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17	18	19	20	21	22	23
24	25	26	27	28	29	30

Q.9 For a CE transistor $\beta = 45$ and voltage drop across
8 $1k\Omega$ resistor which is connected in the collector
9 circuit is 1V. Find I_B

$I_C = 1mA$, $\beta = 45$

10

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

11

12 $$I_B = \frac{1}{45}$$

1 $$I_B = 0.022$$

2

⇒ Q. Input resistance

3

The resistance offered by a resistor betn its input

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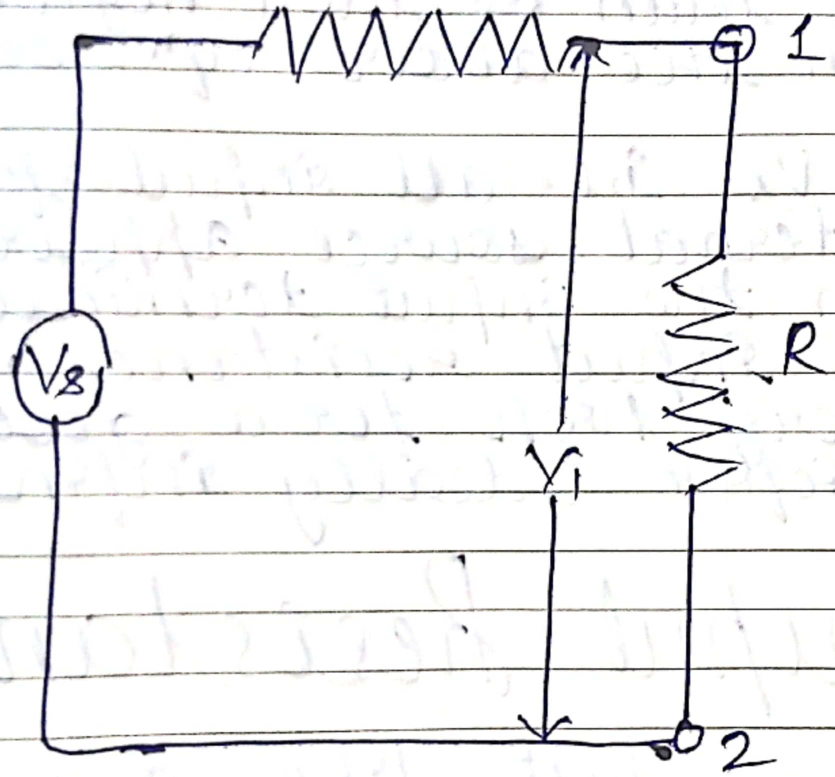
terminals is called input resistance. Suppose points 1 & 2 indicate the terminals R_1, V_s a voltage extended from external source and R_s internal resistance of a voltage source.

Today-



The actual input to the amplifier i.e. voltage across R_i. In the above figure is given by

$$V_i = I R_1$$

$$= \left(\frac{V_s}{R_s+R_1}\right) R_i$$

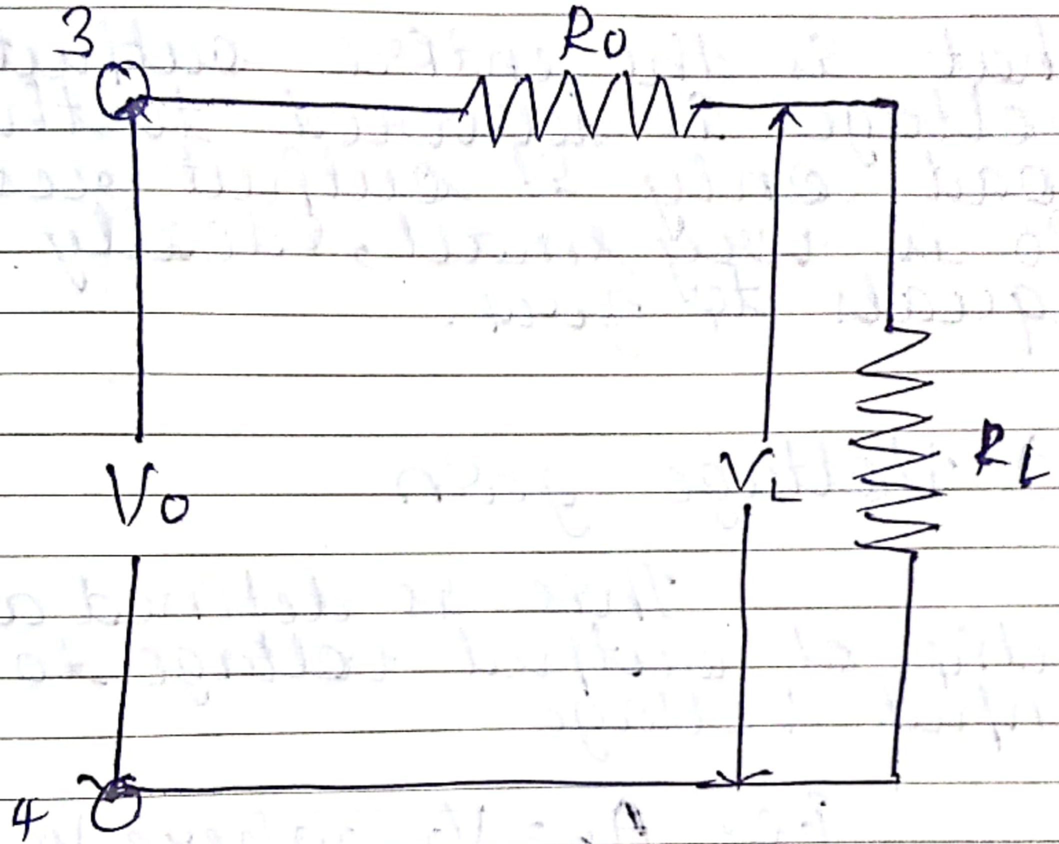
$$V_1 = \frac{R_i}{R_s+R_i} \times V_s$$

If R_i is very much greater than R_s then neglecting R_s in the above eqⁿ we have,

$V_i = V_s$ i.e. all input from the external source appears between the input terminals. hence input resistance must be very high for a good amplifier ideally infinite.

→ Output Resistance

Just like a voltage source an amplifier also has some internal resistance which is called it's output resistance R_0 (Rzero). In the figure shown below points 3 & 4 indicate the output terminals of the amplifier. V_0 (Vzero) is the output voltage and V_L is the actual voltage delivered to the load R_L



$$V_L = I \times R_2$$

$$= \frac{V_0}{R_0 + R_L} \times R_L$$

$$V_L = \left(\frac{R_L}{R_0 + R_L}\right) V_0$$

If R_0 is very much less than R_L then $V_L = V_0$.

That is the entire output voltage is delivered to the load only if output resistance R_o is very small, ideally equals to zero.

⇒ Voltage gain

This is defined as the ratio of output voltage to input voltage

i.e. $A_v = \frac{V_o}{V_i}$ where V_i is the input voltage and V_o is the output of the amplifier.