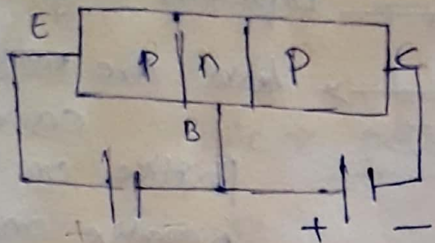
Junction Transistor

1. A bipolar Junction Transistor is a Solid state device, which is mainly used as the Amplifier.

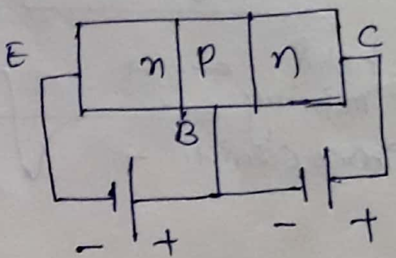
2. Transistor transfers a weak Signal from the low resistance input Circuit to the high resistance output Circuit.

Type of Junction Transistors :-

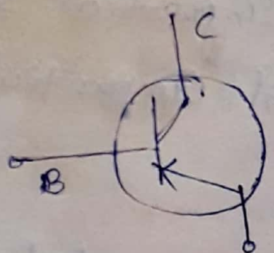
(a)



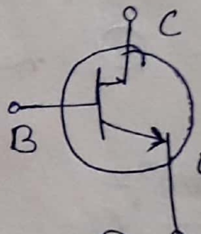
(b)



Symbols

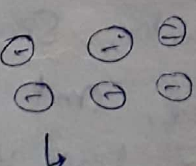


(a) Pnp Transistor

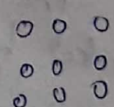


(b) npn Transistor

An Arrow head is placed on the Emitter, and its direction represents the direction of Conventional Current, i.e., the ~~direction of~~ motion of holes and hence its opposite direction to the flow of Electrons.



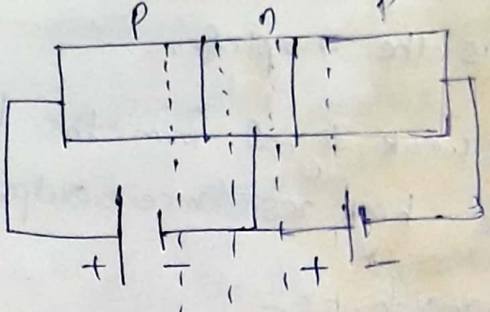
Trivalent Impurit.



Pentavalent Impurity

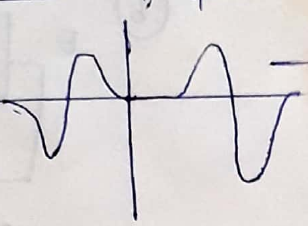
1. Trivalent Impurities: They are ready to accept the electrons. They becomes the negative charged ions.
2. Pentavalent Impurities: They are ~~dp~~ ready to donate electrons, they becomes the + vechange donors.

Working of P-n-P Transistor :-



Depletion Region

Depletion Region



① P-side Trivalent Impurities, so depletion is downwards

② n-side Pentavalent Impurities, So depletion is upwards

Operation :-

① The Emitter-base junction is forward biased, the large number of holes present in the Emitter region are repelled by the positive potential of the bias voltage and they move towards the junction and diffuse into the base region.

② Since the base is n-type semiconductor, electrons are majority charge carriers in the region.

③ But Base is lightly doped, so the most of charge carriers pass through the base region without recombination. These are collected by the Collector, Since the Collector-base junction is reverse biased, and holes are easily attracted by the negative potential of bias voltage.

Hear Recombination of electrons and holes in the base region gives rise to base current. If the Emitter Current I_E and Collector Current I_C then

$$I_E = I_C + I_B \quad \text{— ①}$$

Collector-to-base leakage Current :-

The Reverse bias voltage applied across the collector-base junction there is a small Reverse Current flows, denoted as I_{CBO}. This current is called as the Collector-Base leakage current.

* This current is present even when the forward voltage across the Base-Emitter junction is removed.

Taking the leakage current into account

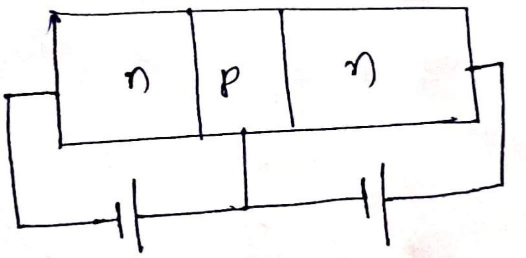
$$\boxed{I_C = \alpha_{dc} I_E + I_{CBO}} \quad \text{--- (2).}$$

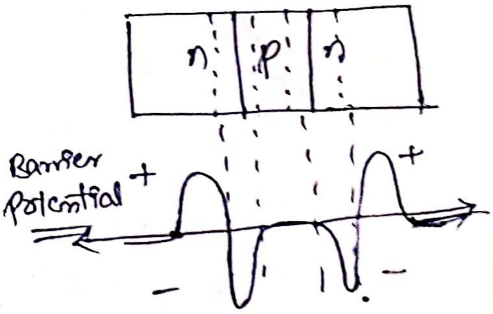
$\alpha_{dc} \rightarrow$ 0.96 to 0.99

From (2)
$$\alpha_{dc} = \frac{I_C - I_{CBO}}{I_E}$$

By ignoring I_{CBO}
$$\alpha_{dc} = \frac{I_C}{I_E}.$$

Working of n-p-n Transistor:-





→ When the Emitter base junction is forward Bias, the large no. of electrons are repelled by the -ve Terminal of Battery and they diffuse across the Emitter-base junction.

→ The base which is p-type material, is very lightly doped and hence there are few holes are in the region.

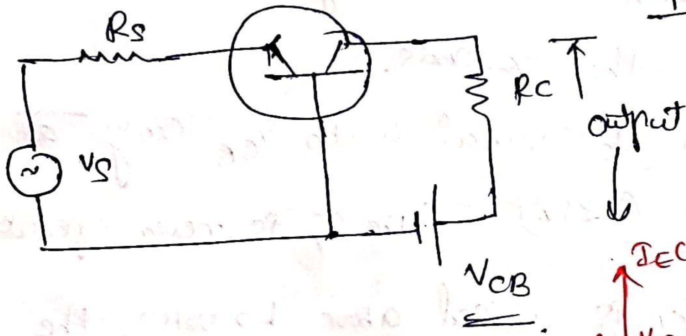
→ Some of the electrons are crossing the base region and reach the Collector base junction.

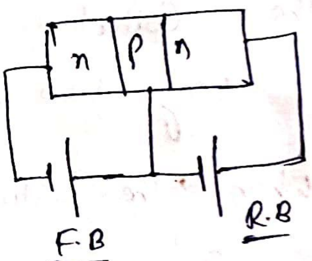
Transistor Connections :-

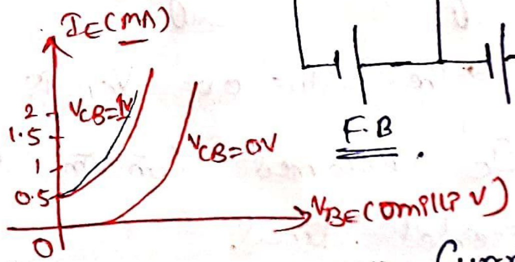
1. Common base Connection
2. Common Emitter Connection
3. Common collector Connection.

Common base Connection:-

The input is applied between the Emitter and base and output is taken across the Collector and base.







Input characteristics:-

1. It is the curve between the Emitter current I_E and Emitter-base voltage V_{BE} at constant Collector-Base voltage V_{CB}. The Emitter current generally taken along y-axis and Emitter-base voltage along x-axis.

2. From the graph,
(or) The I_E increases rapidly with small increase in Emitter to base voltage.

3. The Emitter Current is almost Independent of Collector to Base voltage V_{CB}. This leads to Collector to Base voltage and I_E both are Independent to Each other.

(or)

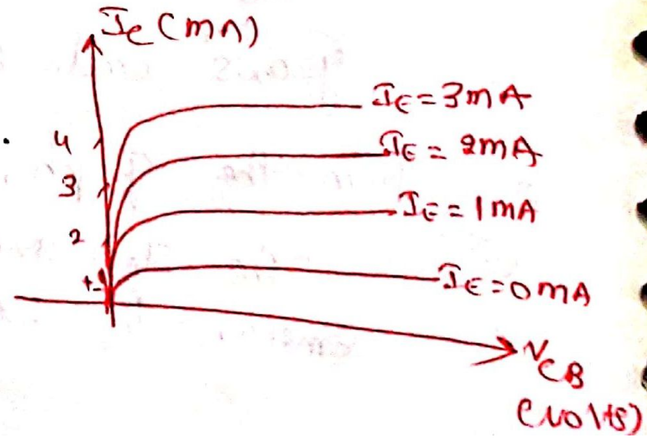
Input Resistance:-

$$r_i = \frac{\Delta V_{BE}}{\Delta I_E} \text{ at Constant } V_{CB}$$

~~Output Resistance:-~~

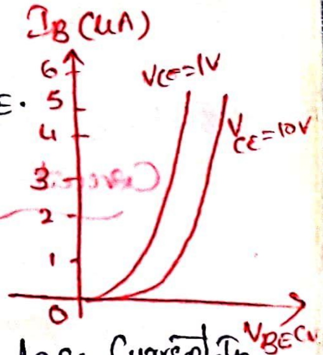
Output characteristics:-

1. It is the Curve b/w the I_C & V_{CB} at any Constant I_E.
2. Generally I_C is taken across the y-axis and V_{CB} is taken across the x-axis.
3. The Collector Current I_C varies with V_{CB} only at very low voltages (<1V.) (The T_r is never operated)
4. When the value of V_{CB} is raised above 1-2 volts, the I_C Becomes Constant and is Indicated by straight horizontal lines.
5. A very Large change in the Collector-base voltage produces only a tiny change in Collector Current.
6. $r_o = \frac{\Delta V_{CB}}{\Delta I_C}$ at Constant I_E.



Common Emitter Connection :—

1. Input is applied b/w base and Emitter and output is taken from the Collector and Emitter.
2. Here, Emitter of the Transistor is Common to both input and output Circuits.
3. The important characteristics of this circuit arrangement are the input characteristics and output characteristics.
4. **Input Characteristics :—**
4. It is the Curve between the base Current I_B and base-Emitter voltage V_{BE} at Constant Collector-Emitter voltage V_{CE}.
5. Keeping V_{CE} Constant, note the base Current I_B for various values of V_{BE}.
6. Taking I_B along y-axis, V_{BE} along x-axis, this gives the input characteristics.
7. As Compared to CB arrangement, I_B increases less rapidly with V_{BE}. Therefore, input resistance of a CE Circuit, is higher than that of CB Circuit.
8. Input Resistance $r_i = \frac{\Delta V_{BE}}{\Delta I_B}$ at Constant V_{CE}.



Output Characteristics :—

1. It is the Curve b/w the Collector Current I_C and Collector-Emitter voltage V_{CE} at Constant base Current I_B.
2. keeping the base Current I_B fixed at some value, taking I_C along y-axis, V_{CE} along x-axis. This gives the o/p charact.
3. The I_C varies with V_{CE} for V_{CE} b/w 0 & 1V only, after this I_C is almost Independent of V_{CE}.

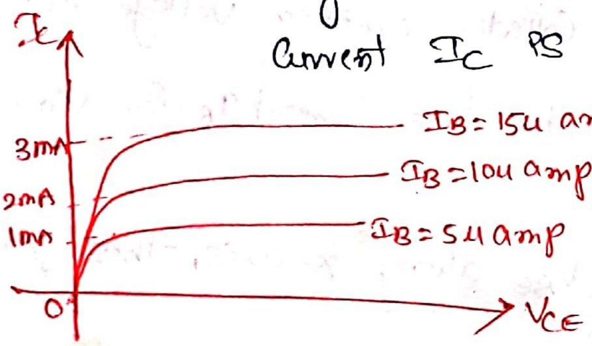
4. The value of V_{CE} upto which collector current I_C changes with V_{CE} is called knee voltage (V_{knee}).

5. The transistors are always operated in the region above knee voltage.

6. Above knee voltage, I_C is almost constant.

7. A small increase in I_C with increasing V_{CE} is caused by collector depletion layer getting wider and capturing a few more majority carriers before electron-hole combinations occur in the base area.

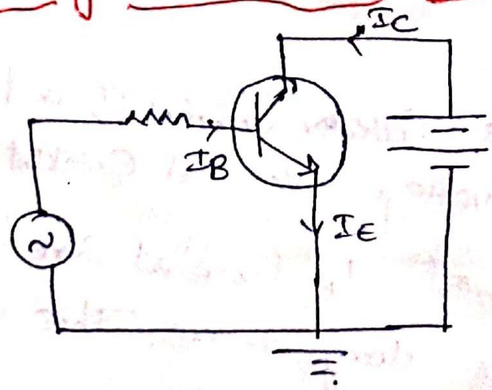
8. For any value of V_{CE} above knee voltage, the collector current I_C is approximately equal to the $\beta \cdot I_B$.



9. output Resistance $r_o = \frac{\Delta V_{CE}}{\Delta I_C}$ at constant I_B.

10. Output Resistance of a CE circuit is less than that of CB circuit. Its value is in the order of $50 K\Omega$.

Circuit diagram for CE arrangement :-



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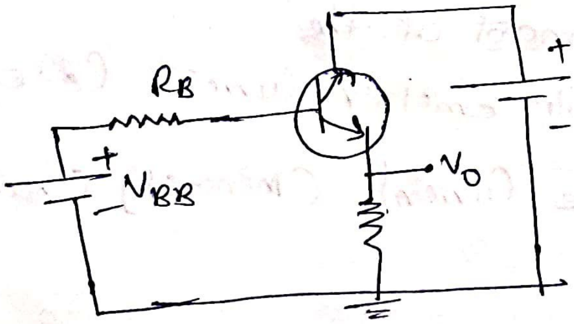
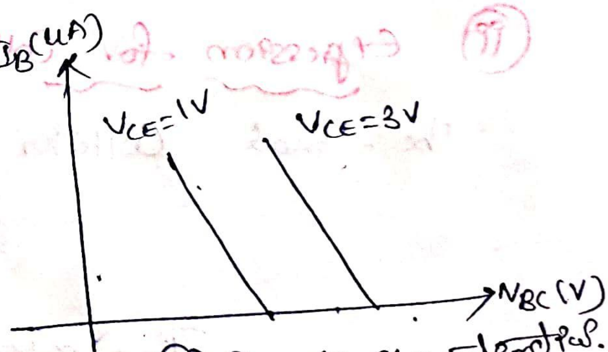
Common Collector Connection:-

1. The input is applied B/w the base and collector while the output is taken between the emitter and collector.
2. Collector of transistor is common to the both input and output parts.
3. Here the load resistor R_L is connected to emitter terminal. The load resistor R_L itself acts as the bias for emitter base junction.
4. The operation of the circuit is similar to the common emitter configuration.
5. When the base current is I_{CO}, emitter current will be zero. So no current flows through the load.
6. Base current should be increased so that emitter current is some finite value and transistor comes out of region.

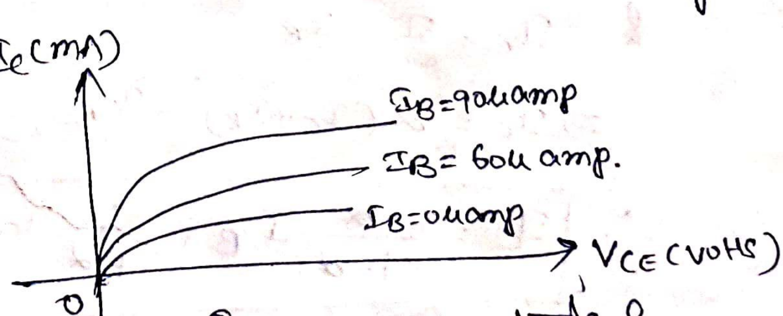
(Input characteristics I_B Vs V_{BC}) ; (output characteristics I_E Vs V_{CE})

Circuit Diagram:-





(a) Input characteristics.



(b) Output characteristics.

Some of the parameters :-

(i) Current amplification Factor (α) :-

1. It is the Ratio of Output Current to the Input Current.
In a Common base Connection, the Input Current is the Emitter Current I_E and output Current I_C.

2. The Ratio of Change in the Collector Current to the Change in the Emitter Current at Constant Collector - base Voltage is known as the Current - amplification Factor i.e.,

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at Constant } V_{CB}.$$

3. $\alpha < 1$

4. α is Increased by decreasing the Base Current.

(ii) Expression for Collector Current :-

The total Collector Current Consist of the
(i) Part of Emitter Current (αI_E)
(ii) Leakage Current (Minority Charge)

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

& $$I_E = I_C + I_B$$

$$\Rightarrow I_C = \alpha(I_C + I_B) + I_{CBO}.$$

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

Note :- In CB Configuration, a small Current (I_C) flows even when the Emitter Current is zero. This is Leakage Collector Current and is denoted by I_{CBO}.

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(iii) Base Current amplification factor:—

1. In Common Emitter Connection, input current is I_B and output current is I_C.

2. The Ratio of change in the collector current (ΔI_C) to the change in the base current (ΔI_B) is known as the Base current amplification factor i.e.,

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

3. In almost any transistor, less than 5% of emitter current flows as the base current. Therefore the value of 'β' is generally greater than the 20.

Usually, its value is ranges from 20 to 500.

(iv) Relation b/w the α & β:—

A simple relation exist b/w the α & β. This can be derived as follows:

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

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

$$\therefore \beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C} = \frac{1}{\left(\frac{\Delta I_E}{\Delta I_C}\right) - 1} = \frac{1}{\left(\frac{1}{\alpha} - 1\right)}$$

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

Note:—

1. As "α" approaches to unity, β approaches to ∞.
2. In otherwords, Current gain in the Common Emitter Connection is very high.

(iv) Expression for Collector Current :— (In terms of I_{CEO})

In Common Emitter Circuit, I_B is the input current and I_C is the output current.

we know that $I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$. (1)

From Expression (1), it is apparent that if $I_B = 0$, the collector current will be current to the emitter.

This is abbreviated as I_{CEO}, means Collector to Emitter Current when the base is open.

$$\Rightarrow I_{CEO} = \frac{1}{1-\alpha} I_{CBO}$$

$$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + I_{CEO}.$$

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

(v) Collector Current amplification factor (γ) :—

1. In Common Collector Circuit, the input current is the base current (I_B), output current is the emitter current I_E.
2. The Ratio of change in Emitter Current (ΔI_E) to the change in base current (ΔI_B) is known as the Current amplification factor.
3. It is denoted by $\gamma = \frac{\Delta I_E}{\Delta I_B} > 1$

Relation between the α and γ :—

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

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

$$\Rightarrow \boxed{\gamma = \frac{1}{1-\alpha}}$$

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Expression for ~~Collector~~ Emitter Current:— (In terms of β):—

we know that $I_C = \alpha I_E + I_{CBO}$.

But $I_E = I_C + I_B$.

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

$$\Rightarrow I_E(1-\alpha) = I_B + I_{CBO}.$$

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

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

Problems:—

1. In a Common base Connection, $I_E = 1$ mamp, $I_C = 0.95$ milli amp. Calculate the value of I_B?

   Ans:- $I_B = 0.05$ m amp.

2. In a CB Configuration, α is 0.9. If the I_E is 1 mamp. Determine the value of base Current?

   Ans:- $I_B = 0.1$ milli amp.

   $I_C = \alpha I_E$
   $= 9 \times 10^{-4}$

3. In a CB, $I_C = 0.95$ milli amp, $I_B = 0.05$ mamp. Find the value of $\alpha = ?$

   $I_B = ?$

   Ans:- $\alpha = 0.95$

   $\beta = 19$

   $\alpha = \frac{\beta}{1+\beta} = 0.95$

4. In a CB, the Emitter Current is 1 mamp. If the Emitter Circuit is open, the Collector Circuit (is) Current is 50 u amp. Find the Total Collector Current. Given that $\alpha = 0.92$.

   Ans:- $I_C = 0.97$ milli amp.

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

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

   $= 0.92m + 50u$

   $= 0.97$ m Amp.

(5) 1. In a Common base connection, $\alpha = 0.95$. The voltage drop across the $2k\Omega$ resistance which is connected in the Collector is 2volts. Find the base Current.

Ans: from data, $I_C = 2/2K = 1$ milli amp.

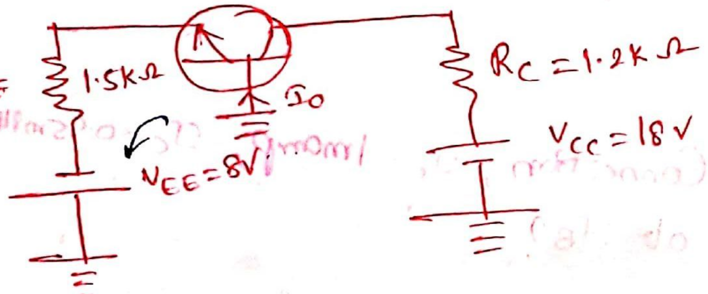
$\alpha = 0.95$

$I_E = I_C/\alpha = 1\text{milli}/0.95$

$I_E = 1.052$ milli amp.

$I_B = 0.52$ milli amp.

(6). For the CB circuit, Determine I_C and V_{CB}. Assume the transistor to be silicon?



$-V_{EE} + V_{BE} + I_E R_E = 0$.

$I_E = \dfrac{V_{EE} - V_{BE}}{R_E}$

$= \dfrac{8 - 0.7}{1.5k}$

$I_E = 4.8667$ milli amp

for CB → $I_C \cong I_E$.

$-V_{CC} + I_C R_C + V_{CB} = 0$.

$V_{CB} = V_{CC} - I_C R_C$

$= 18 - (4.88\text{milli})(1.2K)$

$\therefore \boxed{V_{BC} = 12.16 \text{ Volts}}$

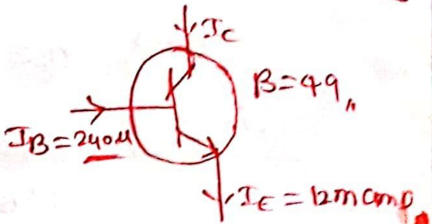
(7) Find the value of β if (i) $\alpha = 0.9$ (ii) $\alpha = 0.98$ (iii) $\alpha = 0.99$

Ans: (i) $\beta = 9$ (ii) $\beta = 49$ (iii) $\beta = 99$.

(8) Calculate I_E in a transistor for which $\beta = 50$ & $I_B = 20\mu$amp.

Ans: $I_E = 1.02$ milli amp.

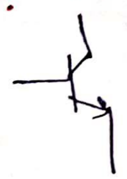
(9) Find the α rating of the transistor shown in figure. Hence determine the value of I_C using both α and β rating of the transistor.



Ans:- $\alpha = 0.98$; $\beta = 49$ (Given)

$I_C = 11.76$ milli amp.

(10) For a transistor, $\beta = 45$, voltage drop across the $1k\Omega$ which is connected in the collector circuit is 1 volt. Find the base current for common emitter connection?



Ans:- $\beta = 45$: $R_L = 1k\Omega$

$V_0 = 1$

$I_C = 1$ milliamp.

$I_B = 22.22\,\mu$ amp.

(11) A transistor is connected in CE configuration in which the collector supply voltage is 8 volts and the voltage drop across the resistance R_C is connected in the collector circuit is 0.5 V. The value of $R_C = 800\Omega$. If $\alpha = 0.96$ determine the =!

(a) V_{CE} (b) $I_B = ?$

Ans:- (a) $V_{CE} = 7.5$ volts (b) $I_C = 0.625$ milli amp.

(12). An n-p-n transistor at room temperature has its emitter is disconnected. A voltage of 5 volts is applied b/w collector and base. with collector positive, a current of 0.2μ amp flows. when the base is disconnected and the same voltage is applied b/w collector and emitter, the current is found to be 20μ amp. Find α, I_E & I_B, I_C is 1milli amp.

Ans:- $I_{CBO} = 0.2\mu$ amp.

$I_{CEO} = 20\mu$ amp.

$I_{CEO} = \dfrac{I_{CBO}}{1-\alpha}$

$\Rightarrow \alpha = 0.99$

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

$\Rightarrow I_C = 1m$ amp: $\Rightarrow I_B = 10\mu$; $I_E = 1010\mu$ amp

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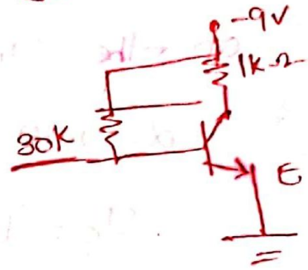
(13) For the transistor AF114 connected as shown in figure: Determine value of I_B, I_C, V_{BC} given that $V_{CE} = -0.07V$ and $V_{BE} = -0.21$ volts.

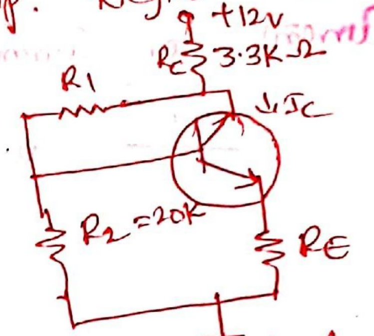


Ans:- $I_C = -8.93$ milli amp.

$I_B = -0.293$ milli amp.

$V_{BC} = -0.14$ volts.

(14) If $\alpha = 0.98$ and $V_{BE} = 0.6$ volts, find R_1 in the circuit shown. Neglect Reverse saturation current. Emitter current $I_E = -2$ mamp.



(15) A transistor is operated at a forward current of 2μ amp. and with collector open circuited. Calculate the junction voltage V_C & V_E, the collector to emitter voltage V_{CE} assuming $I_{CO} = 2\mu amp$, $I_{EO} = 1.6\mu amp$ and $\alpha = 0.98$

Solution:-

$I_C = 0$ since collector junction is open.

we know that, $I = I_0 (e^{V/\eta V_T} - 1)$

$I_E = I_{EO} (e^{V_E/\eta V_T} - 1) \Rightarrow V_E = \eta V_T \left(\ln\left(1 + \frac{I_E}{I_{EO}}\right)\right)$

$\Rightarrow V_E = 0.1853$ volts

Similarly lly $V_C = V_T \ln\left(1 + \frac{I_C}{I_{CO}}\right)$

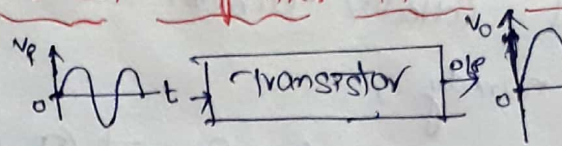
$V_C = V_T \ln\left(1 - \frac{\alpha I_E}{I_{CO}}\right)$

$\therefore \boxed{V_C = 0.179 \text{ volts}}$

$V_{CE} = V_C - V_E = -0.006$ Volts

(B) Transistor Acts as an Amplifier in CE arrangements:

Operation:



(I) (1) During the positive half cycle of the signal, the forward bias across the Emitter - base junction is increased.

(2) Therefore, more electrons flows from the Emitter to the collector via the base. This cause an increase in the collector current.

(3) The increased collector current produces a greater voltage drop across the collector Load Resistance R_C.

(II) (i) During the negative half cycle of the signal, the forward bias across the Emitter - base junction is decreased. Therefore, collector current decreases.

(ii) This results in decreased output voltage in opposite direction.

In this way we achieve the faithful amplification at o/p side.

Operation Explanation: - (In terms of Collector Currents):

(1) When no signal is applied, the input is forward biased by the battery voltage V_{BB}.

(2) D.C collector current I_C flows in the collector circuit. This is called zero signal collector current.

(3) When the signal voltage is applied, the forward bias on the Emitter - base junction increases (or) decreases depends upon whether the signal is positive (or) negative.

(4) During the positive half cycle of the signal, the forward bias on (E-B) junction is increased, causing total current i_C to increase. Reverse will happen for the half of the cycle.

The Total Collector Current consists of Two Components, namely.,

(i) The D.C Collector Current (I_C) due to bias battery V_{BB}.

(ii) The A.C Collector Current (I_C') due to Signal,

$$\therefore \quad I_{Total} = I_C + I_C'$$

Note:-

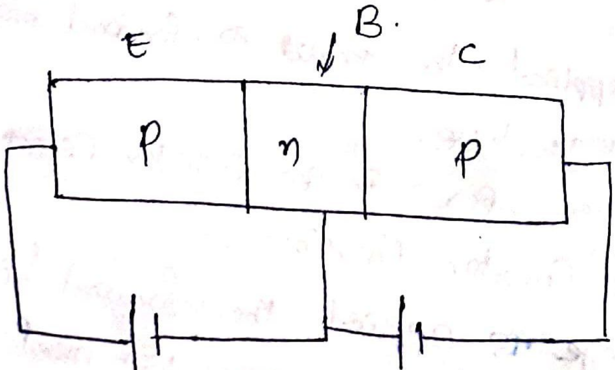
(i) The useful output is voltage drop across the collector load R_C' due to a.c Component.

(ii) The purpose of zero signal Collector Current is to Ensure that the Base - Emitter junction is forward biased at all Times."

Early Effect:-

"The dependence of the Effective width of the base on Collector-to-base voltage is called as the Early Effect."

Due to this reduction of the Effective width of the base, there can be slight increase in the Collector Current even if the base - voltage is decreased slightly.



$V_{CB} \uparrow$ width of Base $\downarrow$

Field Effect Transistors :-

1. BJT — Current controlled device
   (o/p characteristics of the device are controlled by base current not by base voltage)

2. FET — Voltage controlled device.
   (o/p characteristics are controlled by input voltage) not by input current.

Disadvantages of BJT :-

1. It has a low input impedance.
2. It has considerable noise level.

* Low input impedence is because of base-emitter forward bias. This problem may be improved by careful design and use of more than one transistor, yet to it is very difficult to achieve more than a few mega ohms.
  input resistance.

→ FET has more than 100 megaohms input

* FET is generally much less noisy than the ordinary (or) bipolar transistors.

Types of Field Effect Transistors :-

(i) Junction Field Effect Transistor (JFET)

(2) Metal Oxide Semiconductor Field Effect Transistor (MOS FET)

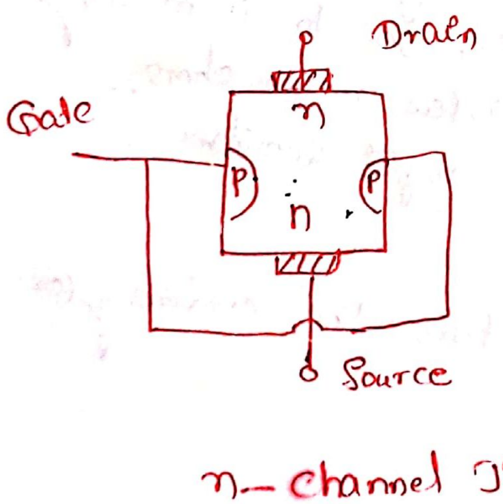
(A) Junction Field Effect Transistor (JFET) :-

1. A JFET is a Three Terminal semiconductor device in which Current Conduction is by one type of charge Carriers i.e., Electrons (or) holes.

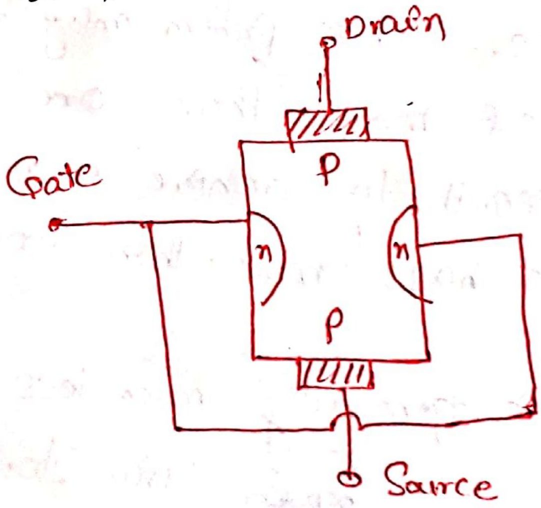
2. It is Controlled by means of an Electric field b/w the gate Electrode and Conducting channel of the device.
The JFET has high input impedance and low noise level.

Construction Details :-

A JFET Consists of a P-Type (or) N-Type silicon bar Containing Two PN Junctions at the sides.
The bar forms Conducting channel for the Charge Carriers.
→ If the bar is n-Type, it is called n-channel JFET
→ If the bar is p-Type, it is called p-channel JFET.



n-channel JFET



P-channel JFET.

Two PN Junctions are Connected internally and a Common Terminal called gate is taken out.
Other Terminals Source and drain taken out from the bar.

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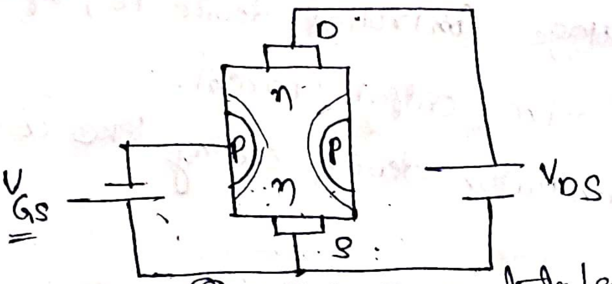
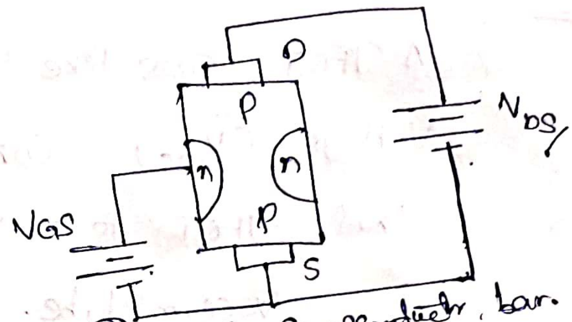
JFET polarities:-

① Voltage b/w the gate and source is ~~Interchangable~~ such that gate is reverse biased. This is normal way of JFET connection. The drain and source are interchangeble i.e., either end can be used as the source and other end used as drain.



ⓐ n-type semiconductor bar.



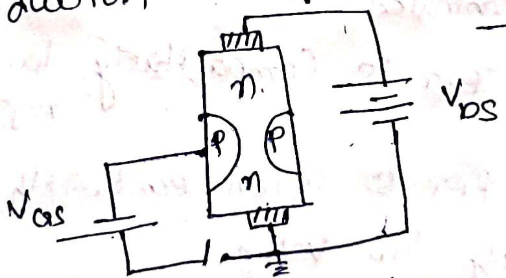
ⓑ P-type semiconductor bar.

working principle of JFET:-

ⓐ when a V_{DS} is applied, V_{GS} is zero, the two pn junctions at sides of the bar establish depleation layers. The electrons will flow from source to drain through a channel b/w the depleation layers. The size of the layers determine the width of channel and hence current conduction through the bar.

→ V_{GS} – switch is open and width of depleation layer is small.

ⓑ

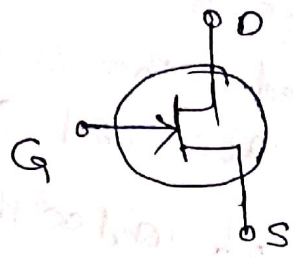


when a reverse voltage is applied b/w the gate and source the width of depleation layers is increased. This reduces the width of conducting channel, thereby increasing the resistance of n-type bar.

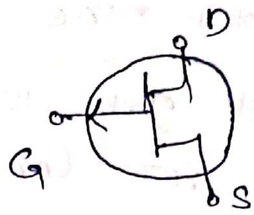
Consequently, the current from source to drain is decreased.

(11)

Schematic Symbol of JFET :—



(a) n- channel JFET



p-channel JFET.

Note :—

(i) A JFET acts like a voltage controlled device i.e., input Voltage (V_{GS}) Controls the output Current.

Thus, JFET is a Semiconductor device acting like a vaccum tube.

→ JFET devices are more like vaccum tubes, than are bipolar Transistors and hence are able to take over many vaccum-tube functions.

:- Difference Between JFET and Bipolar Transistor :—

1. BJT is a bipolar device.
2. BJT has very low input impedance.
3. BJT is a Current Controlled device.
4. The noise level in FET is Comparitively lower than the BJT.
5. The demerit of FET is Gain-Bandwidth ~~Ratio~~ Product is relatively low value.

(i) In a JFET, there is only one type of carrier, holes in p-type channel, and electrons in n-type channel. For this reason it is also called a unipolar Transistor.

(ii). As input circuit is reverse biased, it offers very high input impedance. (FET)

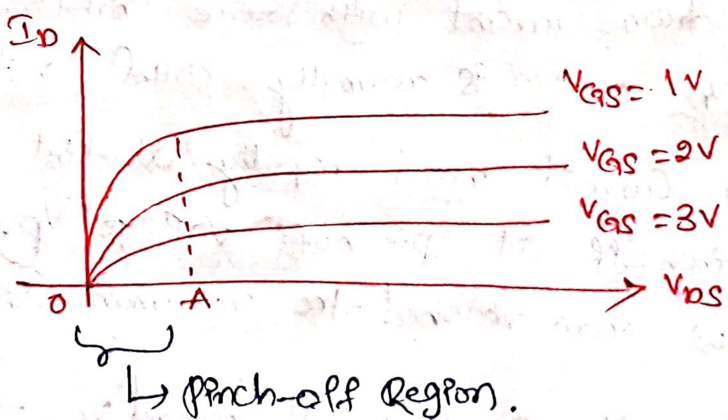
(iii) As the gate is Reverse biased, therefore it carries very small current. obviously, JFET is just like a vacuum tube where control grid carries extremely small current.

(iv). A Bipolar Transistor uses a current into its base to control a large current b/w the collector and emitter. whereas JFET uses a voltage to control the input & o/p. Thus Bipolar is a characterised by the current gain and whereas JFET gain is characterised by Transconductance i.e., change in output current to the input voltage.

(v) In JFET, there are no junctions, as an ordinary Transistor. The conduction is through an n-Type (or) p-Type semiconductor material. For this reason, noise level in JFET is very small.

Output characteristics of JFET :-

1. The curve b/w the drain current (I_D) and drain to source voltage (V_{DS}) of a JFET at constant gate-source voltage is known as the output characteristics of JFET.



(i) At first, Drain current rises rapidly, with Drain to Source voltage (V_{DS}) but then becomes constant. The Drain-Source voltage above which drain current becomes constant is known as the pinch-off voltage. The Region OA is called pinch-off Region.

(ii) After pinch off, voltage the channel width becomes so narrow that depletion layers almost touch each other. The Drain current pass through the small passage between the layers.
Therefore increase in drain current is very small with V_{DS} above pinchoff voltage. Consequently drain current remains constant.

Parameters of JFET :-

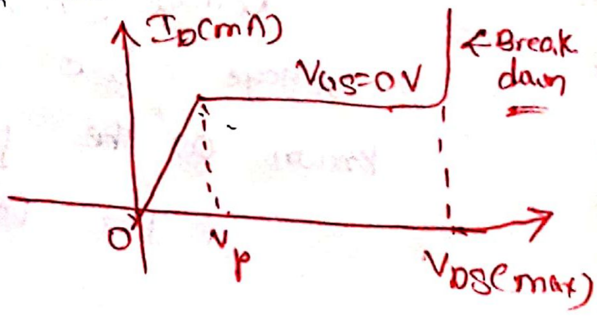
In the analysis of a JFET circuit, the following important terms are often used

1. Shorted - gate drain current (I_{DSS})
2. Pinch-off voltage (V_P)
3. Gate - Source cutoff voltage ($V_{GS(off)}$)

(1) Shorted -gate drain current (I_{DSS}) :-

It is the drain current with source short-circuited to gate. This (i.e $V_{GS}=0$) is normally called short-gate condition.
The drain current rises rapidly at first and then levels off at pinchoff voltage V_P. The drain current has now reached the maximum value I_{DSS}.

→ When the V_{DS} is increased beyond V_P, the depletion layer expand the top of the channel. The channel now acts as a current limiter and holds drain current constant at I_{DSS}.



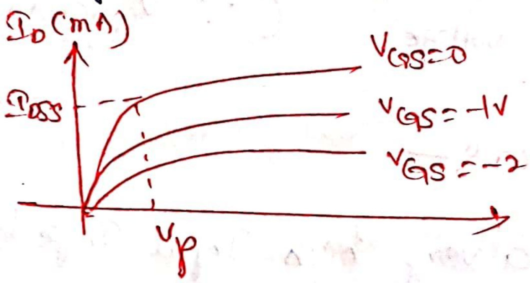
② **Pinch off voltage:-** It is the minimum drain-Source voltage at which the drain current essentially becomes the constant.

→ The highest curve is for $V_{GS} = 0V$, the circuit (short) gate condition.

For values of V_{DS} greater than V_p, the drain current is almost constant.

→ When V_{DS} is equals to V_p, the channel is effectively closed and does not allow further increase in drain current.

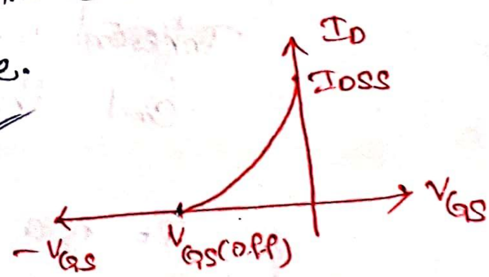
→ It may be noted that for proper function of JFET, it is always operated for $V_{DS} > V_p$.



③ **Gate - Source Cutoff voltage $V_{GS(off)}$:-**

It is the gate - Source voltage where the channel is completely cutoff and the drain current becomes zero.

→ The gate voltage at which the channel is cutoff is called gate source cutoff voltage.



Notes:-

① $V_{GS(off)}$ will always have the same magnitude value as V_p.

② for Eg:- If $V_p = 6V$: $V_{GS(off)} = -6$ volts.

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3. V_p is the value of V_{DS} that causes the JFET to become a constant current device. It is measured at $V_{GS} = 0V$ and will have a constant drain current $= I_{DSS}$.

However, $V_{GS(off)}$ is the value of V_{GS} that causes the I_D to drop to nearly zero.

Expression for Drain Current :-

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

(or)

I_D = Drain Current at given V_{GS};

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

I_{DSS} = shorted-gate drain Current

$(\because V_{GS(cutoff)} = V_p)$

V_{GS} = gate-Source voltage

Advantages of JFET :-

1. It has a very high input impedance. This permits high degree of isolation b/w the input & output circuits.

2. The operation of JFET depends upon the bulk material current carriers that donot cross junctions. Inherent noise of tubes (due to high-Temperature) and those of transistors are not present in a JFET.

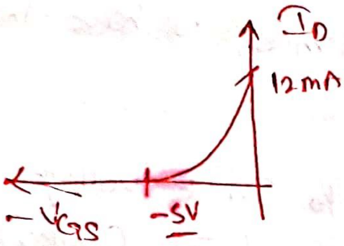
3. It is a negative Temperature co-efficient of Res. This avoids the risk of thermal runway.

4. Higher power gain. Eliminates the necessity of using driver stages.

5. Smaller Size, longer life, High Efficiency.

Problems:-

① Figure shows the Transfer characteristic of a JFET. write the equation for a drain current?



Ans:-

$V_{DSS} = 12$ milli amp.

$V_{GS(off)} = -5$

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

Ans:- $$I_D = 12m\left(1 + \frac{V_{GS}}{5}\right)^2$$

② A JFET has the following parameters:-

$I_{DSS} = 32$ milli amp; $V_{GS(off)} = -8V$, $V_{GS} = -4.5$ volts.

Find the value of drain current?

Ans:-

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

$$= 32m\left(1 - \frac{4.5}{8}\right)^2$$

$$= 6.12 \text{ m amp.}$$

③ A JFET has a drain current of 5mamp. If $I_{DSS} = 10$mamp. and $V_{GS(off)} = -6$volts. Find the value of (i) V_{GS} (ii) V_P.

Ans:- $V_{GS} = -1.76$ volts

$V_P = -V_{GS(off)} = 6$ volts

Advantages of FET:-

(i). It has good thermal stability.

(2) JFET can be used as a symmetrical bilateral switch.

(3) By means of small charge stored on internal capacitance, it acts as a memory device.

(4). It is simpler to fabricate and occupies less space in IC form. So package density is high.

A.C Drain Resistance :- (r_d):-

It is denoted by r_d.

Corresponding to the A.C plate Resistance, we have the A.c drain Resistance.

It is the Ratio of Change in the drain to Source voltage to the change in the drain current at Constant gate - Source voltage i.e.,

$$\text{a.c drain Resistance } r_d = \frac{\Delta V_{DS}}{\Delta I_d} \text{ at const } V_{GS}$$

For instance, if a change in drain voltage of 2 volts produces a change in the drain current of 0.02 milli amp.

$$\text{A.C Drain Resistance } r_d = \frac{2\,\text{Volts}}{0.02\,mA} = 100\,K\Omega$$

Trans Conductance :- (g_{fs}):-

It is the Ratio of Change in drain Current (ΔI_D) to the Change in the gate-to-Source voltage at Constant drain - Source voltage i.e.,

$$\text{Trans Conductance } (g_{fs}) = \frac{\Delta I_d}{\Delta V_{GS}} \text{ at const } V_{DS}$$

→ The Control that the gate voltage has over the drain Current is measured by Trans Conductance g_{fs} and is Similar to the Trans Conductance of tube (g_m).

→ Trans Conductance of a JFET is usually expressed either in mA/volts (or micro ohms.

for Example if change in gate voltage 0.1 volts, Causes Them a change in drain current of 0.3 milli amp

Then, the transconductance $g_{fs} = \frac{0.3 \text{ milli}}{0.1} = 3 \times 10^{-3}$ mA/V

$= 3000\mu$ mhos.

Amplification Factor :- (μ) :-

It is the ratio of change in drain-source voltage (ΔV_{DS}) to the change in the gate to source voltage at constant drain current. i.e.,

Amplification factor $\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}}$ at constant I_D.

Amplification factor of a JFET indicates how much more control the gate voltage has over drain current than has the drain voltage.

For instance, if a amplification factor of a JFET is 50, it means that the gate voltage is 50 times as effective as the drain voltage in controlling the drain current.

Relation among JFET parameters :-

The relationship among JFET parameters can be established as under, we have the

$$\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} \quad \text{—— (1)}$$

$$\Rightarrow \mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} \times \frac{\Delta I_D}{\Delta I_D}.$$

$$\mu = \frac{\Delta V_{DS}}{\Delta I_D} \times \frac{\Delta I_D}{\Delta V_{GS}}$$

$$\therefore \boxed{\mu = r_d \times g_{fs}}$$

i.e., Amplification factor = a.c drain Resistance x Transconductance.

① when a Reverse gate voltage of 15v is applied to a JFET the gate current is 10^{-3} u amp. Find the Resistance b/w the gate & source?

$V_{GS} = 15V$; $I_D = 10^{-3}\mu$ amp.

$\Rightarrow$ Gate to Source Resistance $= \frac{V_{GS}}{I_G} = \frac{15}{10^{-9}} = 15 \times 10^{9}$

$= 15{,}000 M\Omega$

② when V_{GS} of a JFET changes from -3.1 volts to -3v, the drain current changes from 1 milli amp to 1.3 milli amp. What is the value of transconductance?

$\Delta V_{GS} = -3.1 + 3 = 0.1$ volts

$\Delta I_D = 1.3m - 1$ milli $= 0.3$ milli amp.

$\therefore$ Trans Conductance $g_{fs} = \frac{\Delta I_D}{\Delta V_{GS}} = \frac{0.3 \text{ milli}}{0.1V}$

$= 3$ mamp/volts

$\therefore g_{fs} = 3000\mu$ amp/volts.

③. The following readings were obtained experimentally from a JFET:-

V_{GS}	0V	0V	-0.2V
V_{DS}	7V	15V	15V
I_D	10 mamp	10.25m amp	9.65 milli amp.

Determine (i) a.c drain Resistance (ii) Transconductance (iii) Amplification factor.

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Solution:-

(i) With V_{GS} constant at ~~dev~~. 0V, the increase in V_{DS} from 7V to 15V increases the drain current from 10m to 10.25milli i.e.,

Change in drain - Source voltage $\Delta V_{DS} = 15 - 7 = 8$ Volts.

Change in drain Current $= \Delta I_D = 10.25 - 10 = 0.25$ milliamp

A.c Drain Resistance $= (r_d) = \frac{\Delta V_{DS}}{\Delta I_D}$.

$\therefore r_d = 32 K\Omega$.

(ii) With V_{DS} constant at 15Volts, drain current changed from the 10.25mamp to 9.65milli amp as V_{GS} is changed from 0Volts to −0.2 Volts.

$\therefore \Delta V_{GS} = 0.2 - 0 = 0.2$ Volts,

$\Delta I_D = 10.25 - 9.65$

$\Delta I_D = 0.6$ milli amp.

$\therefore$ Trans Conductance : $g_{fs} = \frac{\Delta I_D}{\Delta V_{GS}} = \frac{0.6m}{0.2}$

$$\boxed{\therefore g_{fs} = 3000\, \mu \text{ mhos}}$$

(iii) Amplification factor $\mu = g_{fs} \times r_d$

$= 3000\mu \times 32K$

$= 96\,000m = 96$.

$$\boxed{\therefore \mu = 96}$$

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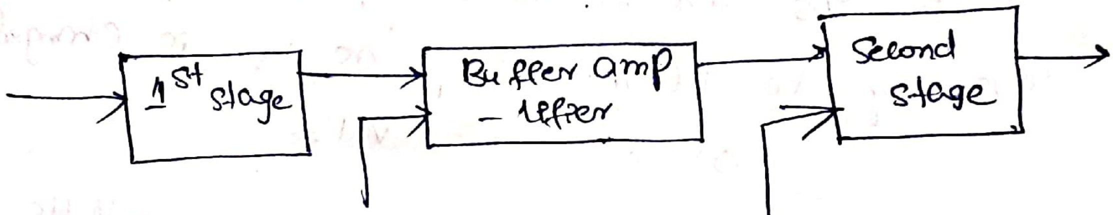
JFET Applications:-

The high input impedance, low output impedance and low noise level makes JFET for superior to the bipolar Junction Transistor.

Applications of ~~BJT~~ FET

1. As a buffer amplifier.
2. RF ~~stage~~ amplifier.
3. phase shift oscillator.

(a) As a buffer amplifier:-



High input impedance (light loading of preceeding stage)

low output impedance. All the output from the buffer reaches to input of second stage.

The high input impedance of JFET means light loading of the preceeding stage. This permits almost entire output from first stage to appear buffer input side.

The low output impedance of JFET can drive heavy loads (or small load Resistances). This ensures the all the output from the buffer reaches the input of second stage.

(b) Phase shift oscillators:-

The High input impedance of JFET is especially valuable in phase-shift oscillators to minimise the loading effect.

(c). As RF amplifier:-

In Communication Electronics, we have to use RF (JFET) Amplifier in a Reciever instead of BJT Amplifier for the following reasons.

(1) The noise level of a JFET is very low. The JFET will not generate significant amount of noise and is thus useful as an RF amplifier.

(2) The Anteena of the Receiver receives a weak signal that has an Extreemely low amount of Current. Since JFET is voltage Controlled device, it will respond to low current signal provided by the anteena.

Metal Oxide Semiconductor FET:- (MOSFET)

1. It is an important semi-Conductor device and is widely used in many Circut applications.

2. The input impedance of a MOSFET is much more than that of JFET because of very small leakage current.

3. The MOSFET Can be used in any of Circuits Covered for the JFET.

Therefore, all the equations apply equally well to the MOSFET and JFET in amplifier Circuits.

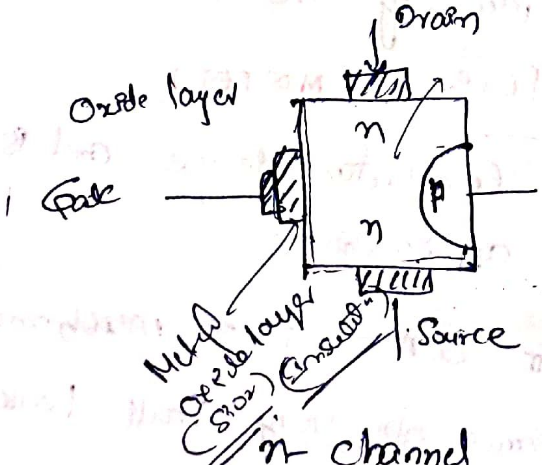
Construction Details:-

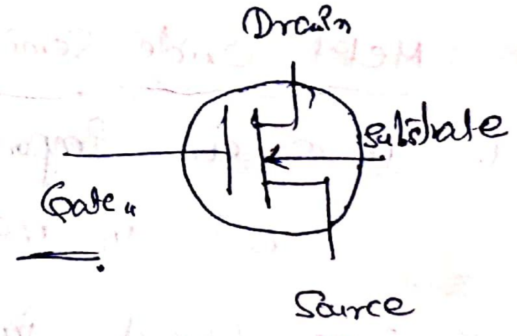
① It shows the Construction Details of n-channel MOSFET. It is similar to JFET except with the following modifications.

→ NO: ① There is only one single p-Region. The Region is called Substrate.

② A Thin layer of metal oxide layer is deposited over the left side of the channel, and metal ~~oxide~~ gate is deposited over the oxide layer. As SiO_2 is an insulator, gate is insulated from the channel. For this reason, MOSFET is sometimes called insulated gate FET.

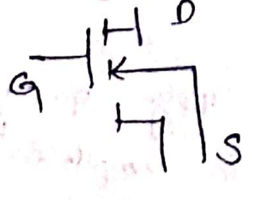
③ Like JFET, a MOSFET has Three terminals. ① Source, gate, drain.



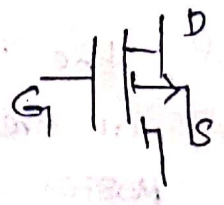


n channel MOSFET Diagrams

n-channel MOSFET:- (enhancement)

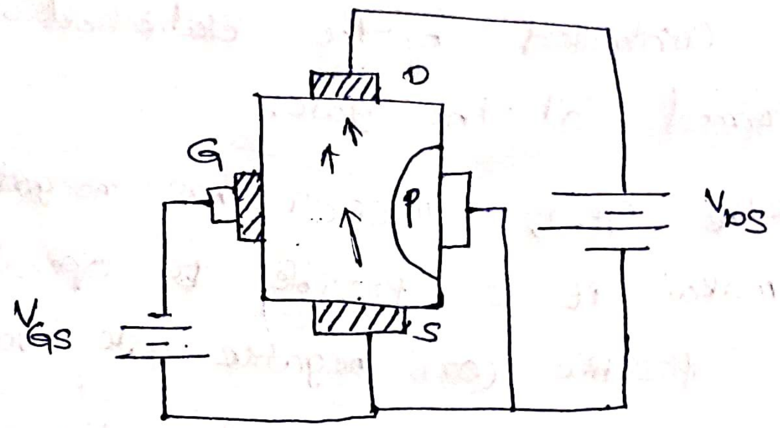


P-channel MOSFET



Working Principle of MOSFET :— (Enhancement MOSFET),

1. Figure shows the circuit diagram of MOSFET.



2. Instead of gate diode as in JFET, here the gate is formed as the small capacitor.

3. One plate of this capacitor is the gate and other plate is the channel with metal oxide as the dielectric.

4. When the -ve voltage is applied to the gate, electrons are accumulate on it. These electrons repeal the conduction band electrons in the n-channel. Therefore less number of electrons are made available for current conduction through the channel.

5. The greater negative voltage on the gate, the lesser is the current conduction through the from the the source to drain.

6. If the gate is given positive voltage, more electrons are made available in the n-channel. Consequently, current from the source to drain increases.

1. In a MOSFET, the Source to drain Current is Controlled by the Electric field of capacetor formed at the gate.

2. Unlike the JFET, a MOSFET has no gate diode. This makes it is possible to operate the device with positive (or) negative gate voltage.

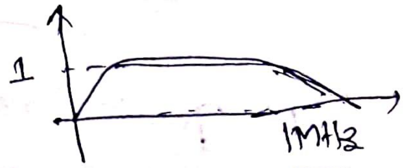
3. As the gate forms a capacetor, therefore, negligible current flows from the whether positive (or) negative voltage is applied to gate.

Gain Bandwidth Product:

Gain Bandwidth Product of an operational amp ~~an~~ the device is 1MHz, it means that the gain of the device falls to unity at 1MHz.

When the device is wired for unity gain, it will work up to 1MHz without Excessively distorting the signal.

$$\underline{Gain \times BW = 1}$$



Enhancement Mode MOSFET

Operation: 1. If the Substrate is grounded, and a positive voltage is applied at the gate, the positive charge on the Gate "G" induced an Equal amount of negative charge on the Substrate side B/w the Source and drain regions.

Thus an electric field is produced B/w the Source and drain regions.

The direction of Electric field is perpendicular to the plates of capacitor through the oxide.

The negative charge of electrons which are minority charge carriers in the P-type substrate forms an inversive layer. As the positive voltage on the gate increases, the induced negative charge in the semiconductor increases.

Hence, the conductivity increased and current flows from Source to drain through channel increases. The Drain Current is Enhanced.

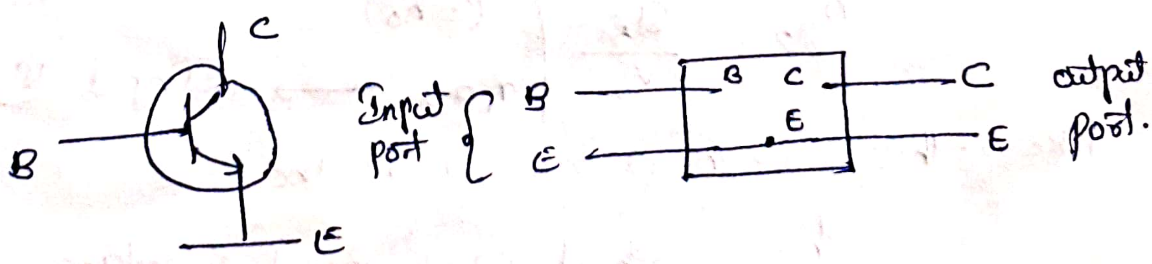
h-Parameters (Transistor at low frequencies)

plan :-

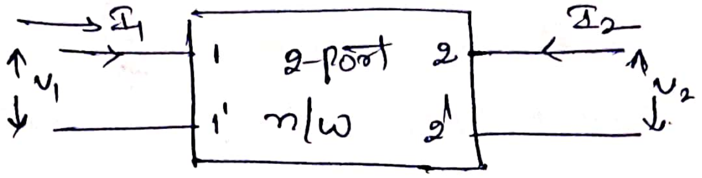
BJT as a Two-port network :-

1. BJT is a 3-Terminal Electronic device, the three terminals are Emitter (E), base (b), Collector (c). During normal operation as an amplifier, the weak A.C signal is applied b/w one pair of Terminals (B and E in a CE amplifier), and the amplified signal is taken across the second pair of Terminals (C and E in a CE amplifier).

Thus in a CE Transistor amplifier, the Emitter is common to the both input and output ports, and the virtually becomes a 2-port network.



H-parameters Explanation :-



$V_1 = f(I_1, V_2)$

$I_2 = f(I_1, V_2)$

Express the dependent variables in terms of independent variable Because it is a current controlled device.

So → I_1, V_2 Independent
V_1, I_2 dependent

The Defining Equations are the.

$$V_1 = h_{11} I_1 + h_{12} V_2 \quad \text{—} (1)$$

$$I_2 = h_{21} I_1 + h_{22} V_2 \quad \text{—} (2)$$

Hear $h_{11}, h_{12}, h_{21}, h_{22}$ are called hybrid parameters.

Hear:

$h_{11} = \left.\dfrac{V_1}{I_1}\right|_{V_2=0}$ $(= h_i)$ → output is short circuited.

$h_{21} = \left.\dfrac{I_2}{I_1}\right|_{V_2=0}$ $(= h_f)$ → output is short circuited.

$h_{12} = \left.\dfrac{V_1}{V_2}\right|_{I_1=0}$ $(= h_r)$ → Input is open circuited.

$h_{22} = \left.\dfrac{I_2}{V_2}\right|_{I_1=0}$ $(= h_o)$ → Input is open circuited.

like this we have call it as the

h_{11} = short circuit input impedance parameter.

h_{21} = short circuit forward current Transfer Ratio.

h_{12} = open – Circuit Reverse voltage Transfer Ratio.

h_{22} = Open – Circuit output Admittance parameters.

Hear:

$h_{11}, h_{12}, h_{22}, h_{21}$ → are called hybrid parameters.

$$h_{11} = \frac{V_1}{I_1}\Big|_{V_2=0}; \quad h_{12} = \frac{V_1}{V_2}\Big|_{I_1=0}; \quad h_{21} = \frac{I_2}{I_1}\Big|_{V_2=0}; \quad h_{22} = \frac{I_2}{V_2}\Big|_{I_1=0}$$

⇒ $h_{11} = h_i$

$h_{12} = h_r$

$h_{21} = h_f$

$h_{22} = h_o$.

⇒ (i) $V_i = h_i I_o + h_r V_o$, and we have the

(ii) $I_o = h_f \cdot I_i + h_o V_o$

⇒ The above Relationships holds good for any Transistor operating in CB, CE, CC mode.

→ For a CE Transistor mode, we have

$V_i = h_{ie} I_i + h_{re} V_o$

$I_o = h_{fe} I_i + h_{oe} V_o$.

→ For a CB Transistor mode, we have

$V_i = h_{ib} I_i + h_{rb} V_o$

$I_o = h_{fb} I_i + h_{ob} V_o$.

And, also for a CC Transistor amplifier, we have the

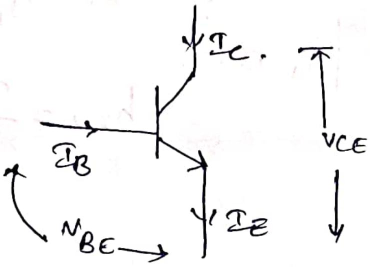
$$V_i = h_{ic} I_i + h_{rc} V_o.$$

and

$$I_o = h_{fc} I_i + h_{oc} V_o.$$

For example:-

Let us consider the CE configuration:-



From this circuit

$I_i = I_b$; $V_o = V_{CE}$; $V_i = V_{BE}$

$I_o = I_c$.

H-parameters for the above circuit:-

$$V_1 = h_{11} I_1 + h_{12} V_2$$

$$I_2 = h_{21} I_1 + h_{22} V_2.$$

$\Rightarrow$ $V_{BE} = h_{ie} I_b + h_{re} V_o$

$I_c = h_{fe} I_b + h_{oe} V_{CE}$.

Ily:-

CB:- $I_i = I_E$; $I_o = I_c$; $V_i = V_{BE}$; $V_o = V_{CB}$.

$\Rightarrow$ $V_{BE} = h_{ib} I_E + h_{rb} V_{CB}$.

$I_c = h_{fb} I_E + h_{ob} \cdot V_{CB}$.

Ily

CC:- $I_i = I_b$; $I_o = I_E$; $V_o = V_{CE}$; $V_i = V_{BC}$

$\Rightarrow$ $V_{BC} = h_{ic} I_b + h_{rc} V_{CE}$

$I_E = h_{fc} I_b + h_{oc} V_{CE}$.

Note:-

1. The First of the above Equation is called the "Voltage Equation" and second of the above Equation is called the "Current Equation".

2. h_{ie} is Input Impedance, h_{oe} is out Impedance } If there is No Reactive Elements in the Circuit, Then we can calculate it as the ⇒ Resistance

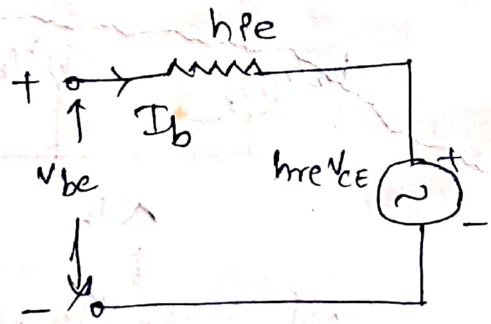
$$\Rightarrow \quad Z = R + jX; \quad Y = G + j\omega C$$

$$Z = R + jX \qquad Y = G + jX$$

If $X = 0$: for Both two Cases

Then $Z = R$; $Y = G$

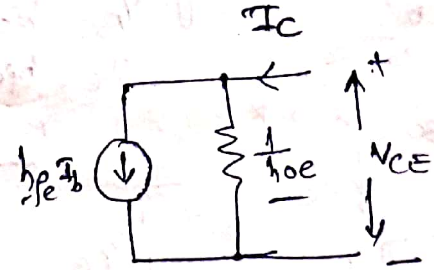
Letus Consider the Circuit diagrams:-



$$\Rightarrow V_{be} = h_{ie}I_b + h_{re}V_{CE}$$

&

$$I_c = h_{fe}I_b + \frac{V_{CE}}{(1/h_{oe})}$$



$$\Rightarrow I_c = h_{fe}I_b + h_{oe} \cdot V_{CE}$$

Note:- ① Here "$h_{re}V_{CE}$", — dependent Voltage Source

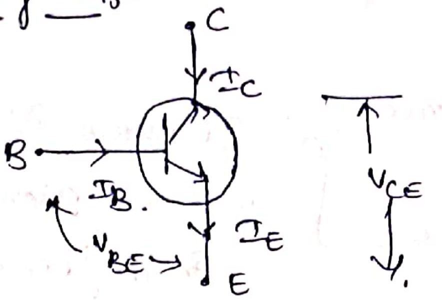
② And also "$h_{fe}I_b$", — dependent Current Source

Now the transistor Amplifier can be replaced by the same equivalent circuits.

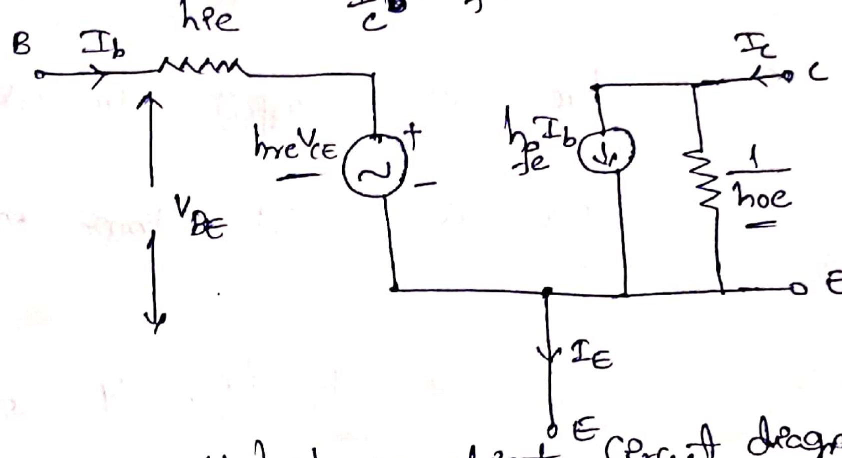
$V_{BE} = h_{ie} I_b + h_{re} V_{CE}$

$I_C = h_{fe} I_b + h_{oe} V_{CE}$

Symbol:-



(a) Circuit Symbol



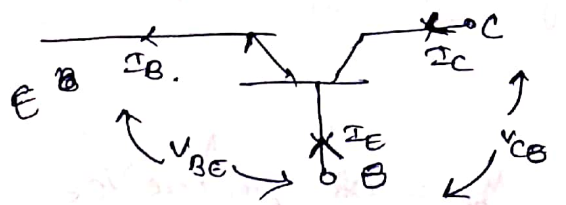
Hybrid Equivalent Circuit diagram

Illy (CB):-

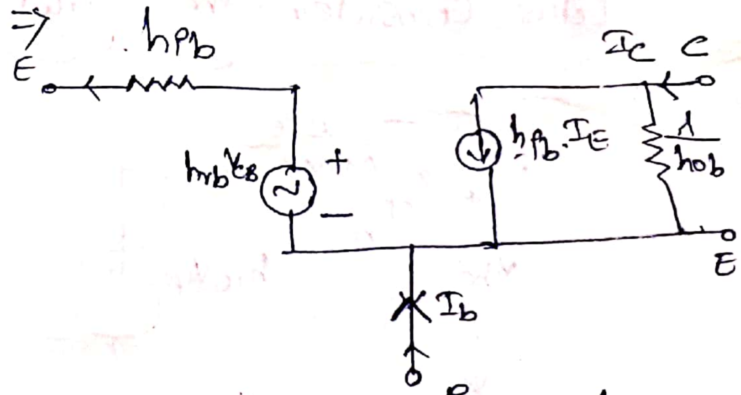
Illy $V_{BE} = h_{ib} I_E + h_{rb} V_{CB}$

$I_C = h_{fb} I_E + h_{ob} V_{CB}$

Symbol:-



(a) Circuit Symbol



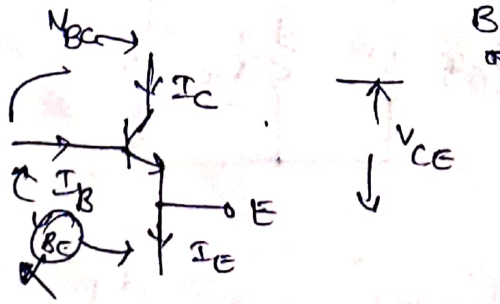
Hybrid Equivalent Circuit diagram.

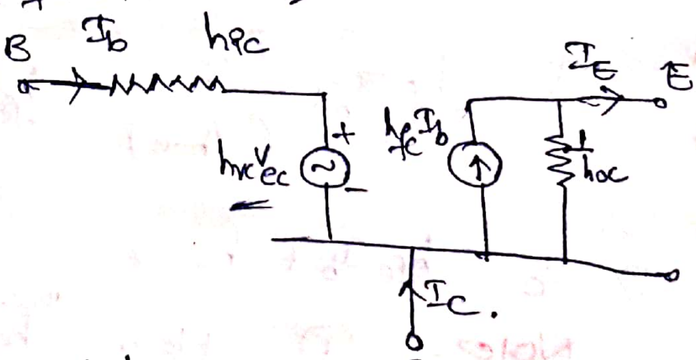
Illy (CC):-

Illy $V_{BC} = h_{ic} I_B + h_{rc} V_{CE}$

$I_E = h_{fc} I_B + h_{oc} V_{CE}$

Symbol:-





Hybrid Equivalent Circuit diagram

Typical parameter values:-

H-parameters		Mode of operation CB	CE	CC
1	1. h_i (ohms)	20	1000	1000
2	2. h_r	3×10^{-4}	2.5×10^{-4}	$\simeq 1$
3	3. h_f	-0.98	50	-50
4	4. $1/h_o$ (KΩ)	2000	40	40.

$1/h_o$ = output resistance.

Conversion formulae:-

The h-parameters of CB, CE, CC configurations are interrelated, and the conversion formula are given below hear: ⇒

CB	CE	CC
$h_{ib} = \frac{h_{ie}}{1+h_{fe}}$	$h_{ie} = \frac{h_{ib}}{1+h_{fb}}$	$h_{ic} = h_{ie}$
$h_{ob} = \frac{h_{oe}}{1+h_{fe}}$	$h_{oe} = \frac{h_{ob}}{1+h_{fb}}$	$h_{oc} = h_{oe}$
$h_{fb} = \frac{-h_{fe}}{1+h_{fe}}$	$h_{fe} = \frac{-h_{fb}}{1+h_{fb}}$	$h_{fc} = -(1+h_{fe})$
$h_{rb} = \frac{h_{ie}\cdot h_{oe}}{1+h_{fe}} - h_{re}$;	$h_{re} = \frac{h_{ib}\cdot h_{ob}}{1+h_{fb}} - h_{rb}$	$h_{rc} \simeq 1$.

Note:- 1. CB parameters are obtained directly from the CE parameters, by replacing the e by b.

2. Similarly CE parameters are obtained from CB parameters by replacing "b by e".

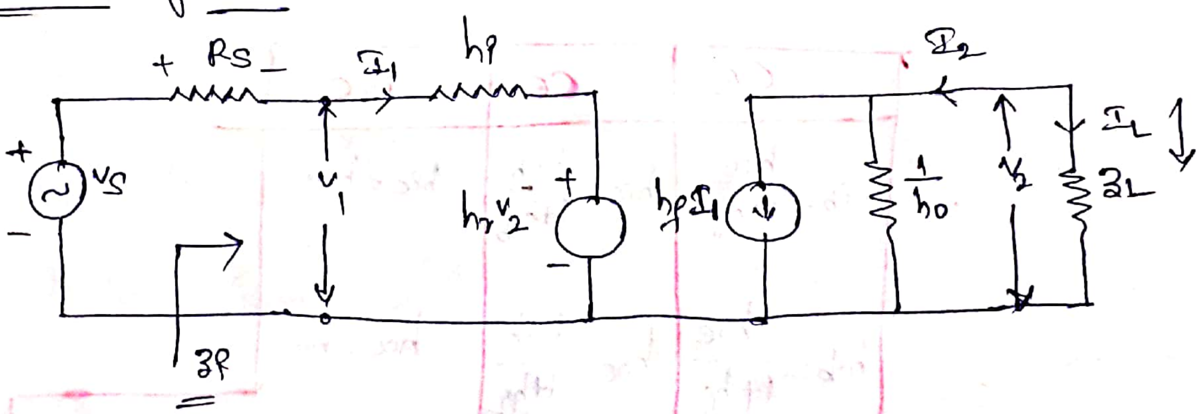
Transistor Amplifier parameters :-

The following parameters are of importance, in the context of a Transistor amplifiers...

1. Input Impedance (Z_i)
2. output Impedance (Z_o).
3. Current Gain (A_I)
4. Voltage Gain (A_V)

whatever the mode of operation, the Transistor can be visualised as a 2-port network, and hence the amplifier can be visualized (or) represented as the ---

:- Circuit operation :-



Current gain of the Transistor amplifier is the ratio of the output current to input current.

It is denoted by $A_I = \frac{\text{output Current}}{\text{Input Current}}$

$$A_I = \frac{I_L}{I_i} = \frac{-I_2}{I_1}$$

$I_2 = ?$

$(- V_2 +)$

$$-I_2 + h_f I_1 + \frac{V_2}{(1/h_o)} = 0 \quad \text{——— (1)}$$

$$\Rightarrow \quad I_2 = h_f I_1 + h_o V_2.$$

But $V_2 = ?$

$$I_2 = h_f I_1 + h_o(+I_L Z_L)$$

$$I_2 = h_f I_1 + h_o(-I_2 Z_L)$$

$$I_2(1 + h_o Z_L) = h_f I_1$$

$$\Rightarrow \quad \frac{I_2}{I_1} = \frac{h_f}{1 + h_o Z_L}$$

$$\Rightarrow \boxed{\therefore \; A_I = \frac{-h_f}{1 + h_o Z_L}}$$

This is the most general form of the Expression for Current gain.

Input Impedance :- (Z_i)

The input impedance of a Transistor amplifier is the impedance we can see, looking into input terminals.

$$\text{Input impedance } Z_i = \frac{V_i}{I_i}.$$

$$-V_1 + h_i I_1 + h_r V_2 = 0.$$

$$V_I = h_i I_1 + h_r V_2$$

Here $V_2 = I_L Z_L \Rightarrow V_2 = \underline{-I_2 Z_L}$.

$$v_P = h_P I_P + h_r(-I_2 Z_L)$$

$$V_P = h_P I_1 + h_r(-I_2 Z_L)$$

$$V_I = h_P I_1 + h_r\left(-\frac{I_1 \cdot h_f}{1+h_o R_L}\right) \cdot Z_L$$

$$\Rightarrow \boxed{\frac{V_I}{I_1} = h_P - \frac{h_r h_f}{1+h_o R_L} \cdot Z_L}$$

(or)

$$\boxed{\frac{V_1}{I_1} = h_P - \frac{h_r h_f}{1+h_o R_L} \cdot R_L}$$

Voltage gain:- (A_V):-

voltage gain of the Transistor amplifier is the Ratio of the Output voltage to the Input voltage.

$$A_V = \frac{V_o}{V_P}$$

$$\Rightarrow A_V = \frac{V_2}{V_1} = \frac{+I_L Z_L}{V_1}$$

$$= \frac{-I_2 \cdot Z_L}{V_1}$$

$$= +\frac{A_I \cdot I_P \cdot Z_L}{V_P}$$

$$\Rightarrow \boxed{A_V = \frac{A_I \cdot Z_L}{Z_I}}$$

Here $A_{VS} = ?$

$$A_{VS} = \frac{V_2}{V_S}$$

$$= \frac{V_2}{V_1} \cdot \frac{V_1}{V_S}$$

$$A_{VS} = A_V \cdot \frac{V_1}{V_S}$$

Input Current

$$I_1 = \frac{V_1}{R_S + Z_I}$$

$$V_1 = I_1 Z_I$$

$V_1 = (V_s \cdot Z_i) / (R_s + Z_i)$

$$\boxed{\therefore A_{vs} = \frac{A_v \cdot Z_i}{R_s + Z_i}}$$

If, from the above expression we get $R_s = 0$ then

$$A_{vs} = \frac{A_v \cdot \cancel{Z_i}}{\cancel{Z_i}}$$

$$\boxed{\therefore A_{vs} = A_v}$$

||ly $A_{IS} = ?$

$$A_{IS} = \frac{I_L}{I_S}$$

(or) since $I_L = -I_2$

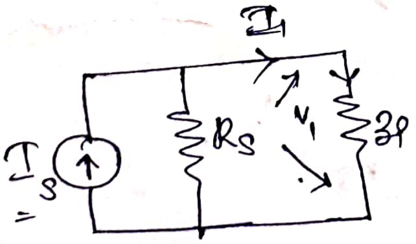
$$A_{IS} = -\frac{I_2}{I_S}$$

$$A_{IS} = \frac{-I_2}{I_1} \cdot \frac{I_1}{I_S}$$

If input is current source:

$$= (A_I) \cdot \frac{I_1}{I_S}$$

from the circuit diagram (Input side)



$$-I_S + \frac{V_1}{R_s} + I_i = 0.$$

$$\Rightarrow I_1 = I_S - \frac{V_1}{R_s}$$

$$I_1 = I_S - \frac{I_1 \cdot Z_i}{R_s}$$

$$I_1\left(1 + \frac{Z_i}{R_s}\right) = I_S \Rightarrow \frac{I_1}{I_S} = \frac{R_s}{R_s + Z_i}$$

$$\boxed{\therefore \frac{I_1}{I_S} = \frac{R_s}{R_s + Z_i}}$$

$$\therefore A_{IS} = A_I \cdot \frac{R_s}{R_s + Z_i}$$

Output Admittance :- (Y_o).

Output Admittance (Y_o) $= \frac{1}{Z_o}$.

$$Y_o = \frac{1}{\left(\frac{V_2}{I_2}\right)} = \frac{I_2}{V_2}.$$

From output loop

$$-I_2 + h_f I_i + \frac{V_2}{(Y_{h_o})} = 0.$$

$$-I_2 + h_f I_i + h_o \cdot V_2 = 0.$$

$$\Rightarrow I_2 = h_f I_i + h_o V_2$$

$$\Rightarrow \frac{I_2}{V_2} = h_f\left(\frac{I_i}{V_2}\right) + h_o.$$

Again the from Circuit diagram, Input Side

Input Loop :-

By applying KVL :- $-V_1 + h_i \cdot I_i + h_r V_2 = 0.$

If $V_s = 0 \Rightarrow$ Then $V_1 = -I_1 \cdot R_S.$

$$\Rightarrow I_1 \cdot R_S + h_i I_i + h_r V_2 = 0.$$

$$\therefore \frac{I_i}{V_2} = \frac{-h_r}{R_S + h_i}$$

$$\Rightarrow \frac{I_2}{V_2} = h_f\left(\frac{-h_r}{h_i + R_S}\right) + h_o.$$

Output Admittance is depends upon the Source Resistance

$$Y_o = \frac{I_2}{V_2} = \frac{-h_f h_r}{h_i + R_S} + h_o.$$

$$\boxed{\therefore Y_o = h_o - \frac{h_r h_f}{h_i + R_S}}$$

Example Problems

(1) A Voltage source V_s of internal Resistance $R_S = 750\,\Omega$, drives a CE Transistor amplifier. The load is a resistance of $2000\,\Omega$. The h-parameters are: $h_{ie} = 1000\,\Omega$, $h_{re} = 2.5\times10^{-4}$, $h_{fe} = 50$ and $h_{oe} = 25\,\mu A/V$.

Find the (i) Current gain (ii) Voltage gain (iii) Overall Current gain A_{IS} (iv) Overall voltage gain (v) Input impedance (vi) Output impedance Z_o. Also compute the Power gain.

Ans:

$R_L = 2000\,\Omega$
$R_S = 750\,\Omega$
$h_{ie} = 1000\,\Omega$
$h_{re} = 2.5\times10^{-4}$
$h_{fe} = 50$
$h_{oe} = 25\,\mu A/V$

(i) Current gain $A_I = \dfrac{-h_{fe}}{1+h_{oe}R_L}$

$$A_I = \frac{-50}{1+(25\mu \cdot 2000)}$$

$$A_I = -47.6190$$

(ii) Voltage gain $A_V = \dfrac{A_I \cdot Z_L}{Z_i}$.

Hear Z_i = Input Impedance

$$A_V = \frac{A_I \cdot Z_L}{Z_i}$$

$$= \frac{(-47.6190)\times 2000}{976.190}$$

$$A_V = -97.5608$$

$$Z_i = h_i + h_r A_i \cdot Z_L$$

$$= h_i - \frac{h_r h_f}{1+h_o R_L} \cdot R_L$$

$$\Rightarrow Z_i = 1000 - \frac{(2.5\times10^{-4}\times 50)}{1+(25\mu\times2000)} \times 2000$$

$$= 1000 - 23.8095$$

$$Z_i = 976.190 \text{ ohms}$$

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(iii). Overall Current gain $(A_{IS}) = ?$

$$A_{IS} = \frac{A_I \cdot R_S}{R_S + Z_i}$$

$$\Rightarrow A_{IS} = \frac{(-47.6190) \times 750}{750 + 976.190}$$

$$A_{IS} = -20.6896$$

(iv) Overall Voltage gain $(A_{VS}) = ?$

$$A_{VS} = \frac{A_V \cdot Z_i}{R_S + Z_i}$$

$$= \frac{(-97.5608) \times (976.190)}{750 + (976.190)}$$

$$\Rightarrow A_{VS} = -55.172$$

(v). Output Admittance:-

$$y_o = h_o - \frac{h_r h_f}{h_{ie} + R_S}$$

$$y_o = (25\mu) - \frac{(2.5 \times 10^{-4} \times 50)}{1000 + 750}$$

$$\Rightarrow y_o = 1.7857 \times 10^{-5}$$

$$\Rightarrow y_o = 1.7857 \times 10^{-5}$$

Output Impedance: $Z_o = \frac{1}{y_o} = 56{,}000$

$Z_o = 56k$ ohms.

(vii) Power gain = Current gain x voltage gain

$$A_p = A_I \times A_V$$

$$= (-47.6190) \times (-97.5760)$$

$$= 4,646.47$$

$$A_p = 4.646K$$

Answers :-

$A_I = -47.6190$, $Z_i = 976.190\Omega$; $A_V = -97.5608$,

$A_{IS} = -20.6896$; $A_{VS} = -55.172$; $Y_o = 1.7852 \times 10^{-5}$ ℧

$Z_o = 56K$ ohms; $A_p = 4,646.47$.

(2) A common base transistor has the following h-parameters $h_{ib} = 20$, $h_{rb} = 3\times10^{-4}$, $h_{fb} = -0.98$, $h_{ob} = 5\times10^{-7}$ mhos. It is driven by voltage source V_s of internal Resistance $R_S = 1000\Omega$. If the load Resistance is 3000Ω, find A_I, A_V, A_{IS}, A_{VS}, Z_i, Z_o and A_p?

CB - Configuration

$h_{ib} = 20$

$h_{rb} = 3\times10^{-4}$

$h_{fb} = -0.98$

$h_{ob} = 5\times10^{-7}$ mhos

$R_S = 1000\Omega$

$R_L = 3000\Omega$

Current gain

(i) $$A_I = \frac{-h_{fb}}{1+h_{ob}\cdot R_L}$$

$$A_I = \frac{-(-0.98)}{1+(5\times10^{-7})\times3000}$$

$$A_I = 0.97853$$

voltage gain

(ii) $$A_V = \frac{A_I \cdot Z_L}{Z_i}$$

$$A_V = 140.593$$

$$Z_i = h_{ib} - \frac{h_r h_f}{1+h_o R_L} \cdot R_L$$

$$Z_i = 20 - \frac{(3\times10^{-4}\times-0.98)}{1+5\times10^{-7}\times3000} 3000$$

$$= 20.880$$

(iv). Overall Current gain $(A_{IS}) = ?$

$$A_{IS} = \frac{A_I \cdot R_S}{R_S + h_i}$$

$$= \frac{(0.97853) \times (1000)}{1000 + 20.880}$$

$$A_{IS} = \underline{0.9585}.$$

(v). Overall voltage gain $(A_{VS}) = ?$

$$A_{VS} = \frac{A_V \cdot h_i}{h_i + R_S}$$

$$= \frac{(140.593) \times (20.880)}{20.880 + 1000}$$

$$A_{VS} = \underline{2.8755}$$

(vi) output Admittance $(y_0) = ?$

$$y_0 = h_o - \frac{h_r h_f}{h_i + R_S}$$

$$= (5 \times 10^{-7}) - \frac{(3 \times 10^{-4} \times -0.98)}{20 + 1000}$$

$$= (5 \times 10^{-7}) + \frac{(3 \times 10^{-4} \times 0.98)}{1020}$$

$$y_0 = 7.882 \times 10^{-7}$$

$$y_0 = \underline{788.23\, n\, \mho}.$$

output Impedance $z_0 = \frac{1}{y_0} = \underline{1.2686\, M}$ ohms.

(vii) Power gain $A_P = A_V \times A_I$

$$= (140.593) \times (0.9853)$$

$$A_P = \underline{137.574}$$

(3) A voltage source V_s of internal Resistance $R_s = 800\Omega$, drives a CC - Transistor amplifier. The load Resistance is 2500Ω. The transistor h-parameters are.

$h_{ic} = 1000$, $h_{rc} = 1$, $h_{fc} = -50$, $h_{oc} = 25\mu$ amp/v.

Compute A_I, A_{IS}, A_v, A_{vs}, Z_i, Z_o and Power gain?

Ans:-

$R_s = 800\Omega$

$R_L = 2500\Omega$

$h_{ic} = 1000$

$h_{rc} = 1$

$h_{fc} = -50$

$h_{oc} = 25\mu$ amp/v

(i) Current gain

$$A_I = \frac{-h_{fc}}{1+h_{oc}R_L}$$

$$= \frac{-(-50)}{1+(25\mu)\times(2500)}$$

$$= \frac{50}{1.0625}$$

$$A_I = 47.058$$

(ii) Overall Current gain

$$A_{IS} = \frac{A_I \cdot R_s}{R_s + Z_i}$$

$$A_{IS} = \frac{A_I \cdot R_s}{R_s + Z_i} \quad \text{But } Z_i = ?$$

$$Z_i = h_{ic} - \frac{h_r h_f}{1+h_{oc}R_L} \cdot R_L$$

$$= 1000 - \frac{(1)(-50)\ (2500)}{1+(25\mu)(2500)}$$

$$Z_i = 118.64\text{K ohms}$$

(iii). Voltage gain

$$A_V = \frac{A_I \cdot Z_L}{Z_i}$$

$$= \frac{(47.058) \times 2500}{118.64k}$$

$$= 0.99155$$

$$\cong 1.$$

Overall voltage gain

$$A_{VS} = \frac{A_V \cdot Z_i}{Z_i + R_S}$$

$$= \frac{(0.99155) \times (118.64k)}{118.64k + 800}$$

$$= 0.9849$$

$$A_{VS} \cong 1$$

(iv) output Impedance:-

$$Y_o (Z_o) = h_o - \frac{h_r h_f}{h_i + R_s}$$

$$= (25\mu) - \frac{1 \times (-50)}{1000 + 800}$$

$$Y_o (Z_o) = 27.80m \text{ ohms}$$

$$Z_o = \frac{1}{Y_o} = \frac{1}{27.80m}$$

$$\rightarrow Z_o = 35.96 \text{ ohms}$$

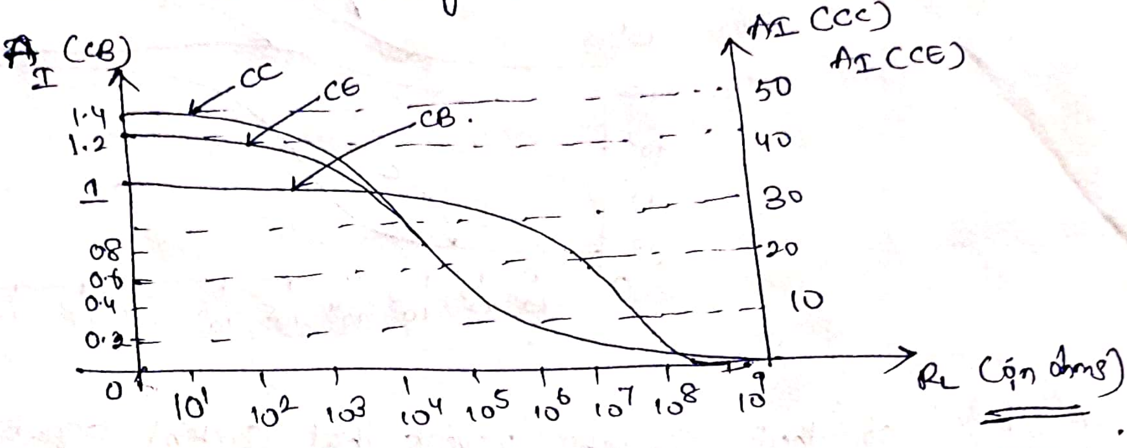
(v) Power gain $A_p = A_V \times A_I$

$$= 46.660$$

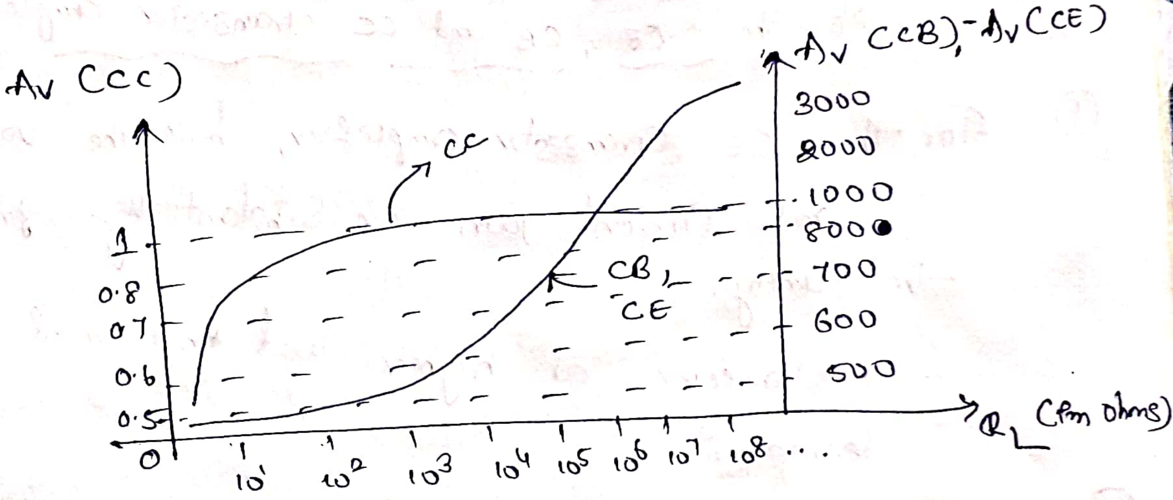
Variation of A_i, A_v, Z_i and Z_o :-

A_i, A_v, Z_i and Z_o are vary with the load impedance.

(i)

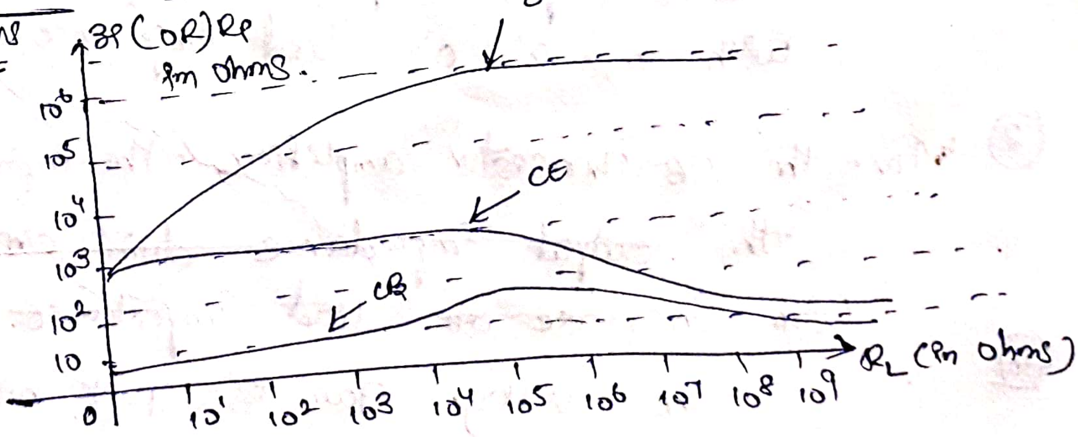


(ii)

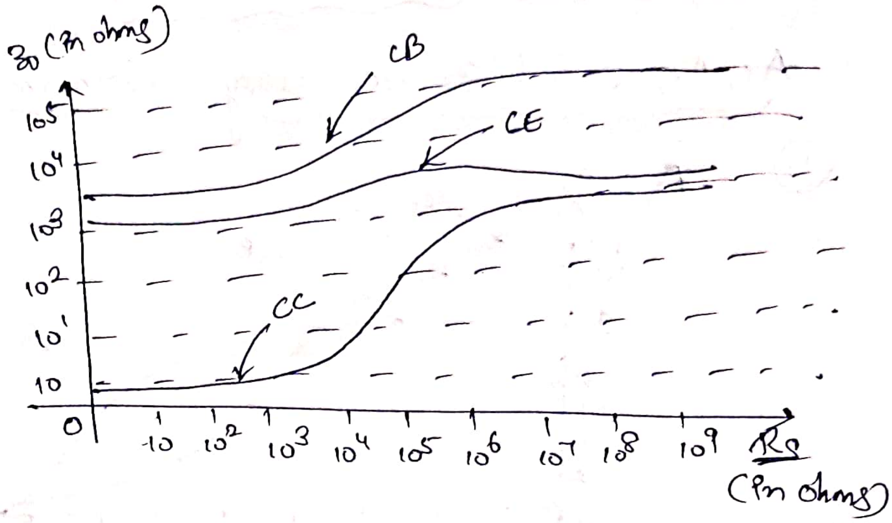


(iii) Z_{in} (or R_i) vs Z_L

in ohms



(iv) Z_0 vs R_s



A study of these graphs reveals that salient aspects of performance of the CE, CB and CC Transistor amplifiers,

① For the CE Transistor amplifier, both the voltage gain and Current gain are substantially greater than the unity.

→ However at higher load impedances, Current gain decreases

② For the CE Transistor amplifier, the input impedance and output impedance donot change very much with increase of load impedance.

③ For the CB Transistor amplifier, ~~the input resistance and the output impedance donot change very much,~~ ~~with increase of~~ load ~~impedance.~~

④ . the voltage gain is quite high and it is increased with R_L, although gain is less than unity.

④ For the CB Transistor amplifier, the input Resistance is the least, and output impedance is the highest. Its find useful application, when a load (high simple!)

requires a to be driven from the low impedance source.

(5) For the CC - Transistor amplifier, the current gain is quite high, but the voltage gain is less than unity.

(6). For CC - R_i is highest, R_o is lowest.

∴ The main application of CC is buffer stage b/w a high impedance source and low impedance load.

(7) The CB - Configuration ideally suits when a constant current source is needed.

Comparison of the Three Configurations:-

	Parameter	CE	CC	CB
1.	Current gain	High	High	low
2.	Voltage gain	High	low	High
3.	Input impedance	medium	High	low
4.	Output impedance	medium	low	High

-: Regulators & Regulation :-

Zener diode :-

A heavily doped crystal diode which has a sharp breakdown voltage is known as the zenerdiode.

1. A Zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage.

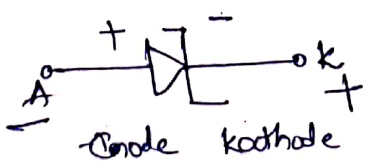
2. A Zener diode is always reverse connected. i.e. it is always reverse biased.

3. A Zener diode has sharp breakdown voltage, called zener voltage V_Z.

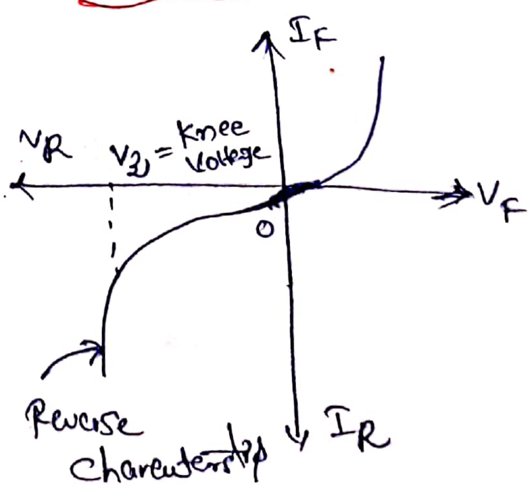
4. When forward biased, its characteristics are those of just ordinary diode.

5. A zener diode is not immediately burnt just because it has entered the breakdown region. As long as the external voltage / circuit connected to the diode limits the diode current to less than the burnout value, the diode will not burn out.

Circuit Symbol :-



Characteristics of zenerdiode :-



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Equalivalent Circuit of Zener diode:-

The analysis of zener diode can be made quite easy by replacing the zenerdiode by its Equivalent Circuit.

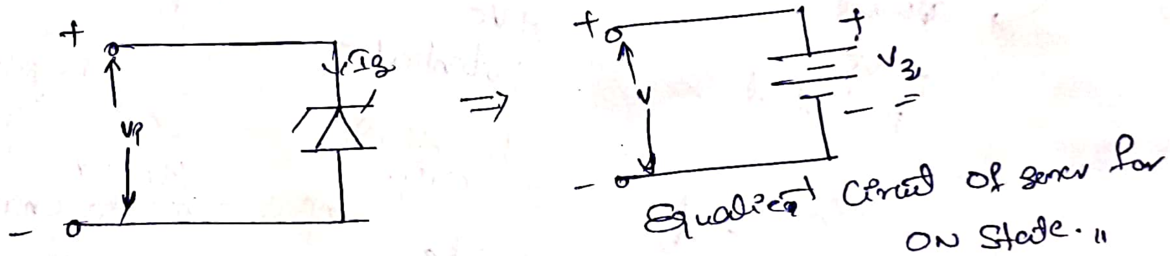
(i) ON State:-

→ When the reverse voltage across a zener diode is equal to or more than breakdown (V_Z) voltage, the current increases very sharply. In this region, the curve is almost vertical.

→ It means that the voltage across zener diode is constant at V_Z even though the current through the it changes.

→ Therefore in the breakdown region, an ideal zener diode can be represented by battery voltage V_Z.

→ Under such condition the diode is said to be in the "ON" state.

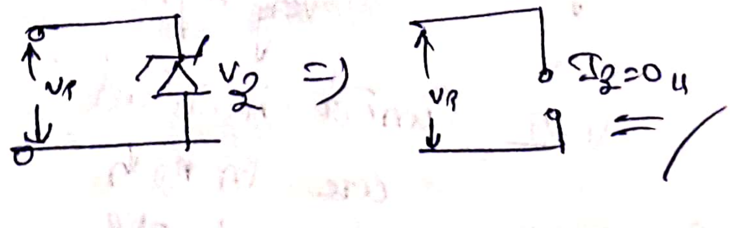


Equivalent Circuit of zener for ON State.

(ii) OFF State:-

When the Reverse voltage across the zener diode (V_Z) is less than the V_Z but greater than the 0 volts, the zener diode is in the OFF state.

Under such conditions, the zener diode can be represented by an open-circuited as shown in figure.

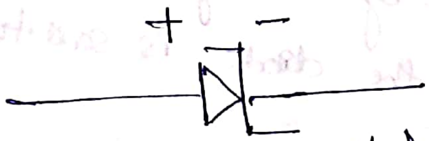


Zener Diode as a Voltage Regulator (Stabiliser) :-

Irrespective of changes of supply voltage (or) load Resistance, the load voltage is always maintained at a constant level.

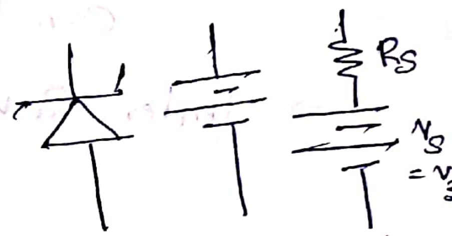
Zener Diode :-

Zener Diode is a reverse biased heavily doped p-n Junction Diode, which is operated in a breakdown region.



always −ve potential
+ve potential.

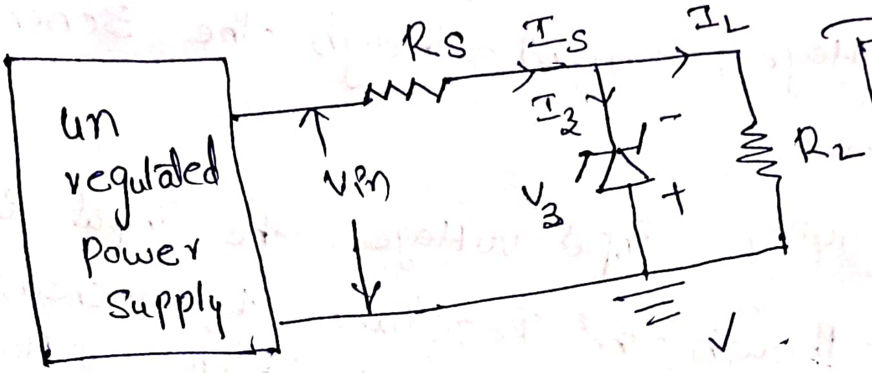
Ideal Diode
Practical Diode



Ideal p-n Junction Diode	Zener Diode characterist-
→ Rectifiers, clippers, clampers, v.m voltage multipliers.	→ Regulators, protecting ckts, Reference
1. It works in both Forward | Reverse	Only Reverse
2. lighty doped	heavily doped.
3. Dynamic Reverse in R.B is very high	is low.
4. V-I Current characterist are in Both First quadrant & III^rd^ quadrant.	R.B. characteristics are in III^rd^ quadrant.

Zener Voltage Regulator.

Below figure shows the simplest zener shunt regulator ckt:



$I_S = I_Z + I_L$

The principle:

Zener Diode operates in a Breakdown region, thereby maintaining a constant voltage across it for a long large in current through it.

In the circuit, Series Resistance (Rs) absorbs output voltage fluctuations and maintains a constant output voltage across the load Resistance.

Thus the Zener Diode maintains constant output voltage across the Diode.

If the circuit is properly biased and doped, then the load voltage 'V_o' remains constant irrespective of variations of input voltage Vin and load Resistance 'R_L'.

→ There are two types of regulation:

1. Regulation with supply voltage (line Regul)
2. Regulation with load volt (load Regulation)

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Regulation with line voltage:—

— When the input voltage is more than the Zener Diode voltage, current through the Zener Diode increases.

By varying input voltage, the input current through the Resistance R_S increases.

Increase in the input affects the voltage across the series resistor.

This would further affects Both the Zener voltage and load voltage But these changes would not happen in our circuit.

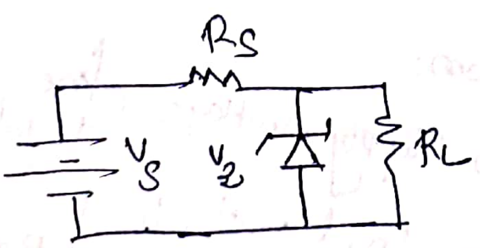
The Reason is by that time the diode enters into Breakdown region.

So it maintains a constant voltage across the load.

Mathematical Derivation :—

$V_S \uparrow$ varies (min - max).

$V_S \uparrow$ $I_S \uparrow$ $I_Z \uparrow$ I_L (constant)



$$V_Z = V_S \cdot \frac{R_L}{R_L + R_S}$$

$$\Rightarrow V_S = V_Z \cdot \left(\frac{R_L + R_S}{R_L}\right) \text{ volts}$$

This is the minimum Required voltage to turn on the Zener Diode.

$\underline{V_S} \uparrow \longrightarrow \uparrow$ max value.

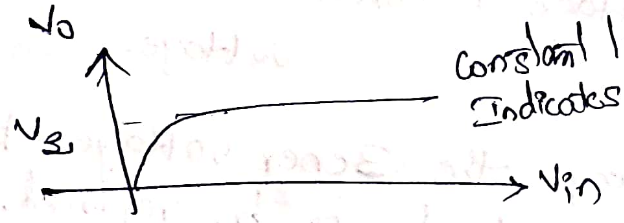
$\Rightarrow$ Then $\underline{I_S} \uparrow = I_R \uparrow +$

$$\underline{I_R} \uparrow = I_Z \uparrow + I_L .$$
$$\underline{\text{max}} .$$

$$\Rightarrow \underline{V_S} = V_R + V_Z$$

$$\underline{V_{S_{max}}} = (I_{R_{max}} \cdot R_S) + V_Z .$$

This is the maximum voltage (V_{in}) limited by the maximum Zener Diode Current.



Regulation with load :- (R_L).

$\underline{R_L} \uparrow \; I_L \downarrow \longrightarrow V_o$ may change.

$\Rightarrow$ we need to find the minimum R_L required to turn on Zener Diode.

$$V_Z = V_o \cdot \frac{R_L}{R_L + R_S} .$$

$\Rightarrow$

$$\Rightarrow V_o = \underline{V_Z} \cdot \left(\frac{R_L + R_S}{R_L} \right)$$

$$\underline{V_o} = V_Z \cdot \left(\frac{R_L + R_S}{R_L} \right)$$

$$V_o \cdot R_L = V_Z \cdot R_L + V_Z \cdot R_S .$$

$$(V_o - V_Z) R_L = V_Z \cdot R_S .$$

$$* \quad R_{L(min)} = \frac{V_Z}{V_o - V_Z} \cdot R_S$$

This is the minimum Resistance required to turn the (21) Zener Diode.

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$R_L(max) \rightarrow I_L \downarrow$

$I_S \downarrow \; I_R \downarrow \; I_Z \downarrow \; I_L(-)$.

$\Rightarrow \quad I_{L(min)} = I_R - I_{Z(min)}$.

$$\boxed{\therefore \; R_L(max) = \frac{V}{I_{L\,min}}}$$

Limitations :

1. The Output voltage is fixed and equal to zener voltage.

2. Inorder to change the zener voltage, the zener diode has to be replaced.

3. maximum Current rating of zener diode limits Current drawn by load.

4. There is no short circuit protection.

Zener Breakdown allows the Current to main the Controlled Breakdown Voltage. Zener Breakdown Voltage.

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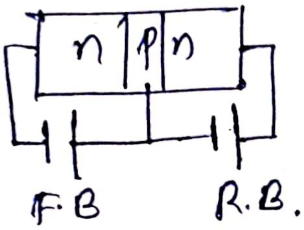
//

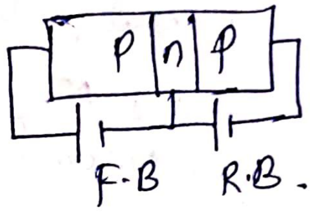
SSN

characteristics.

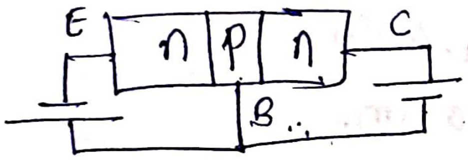
a).

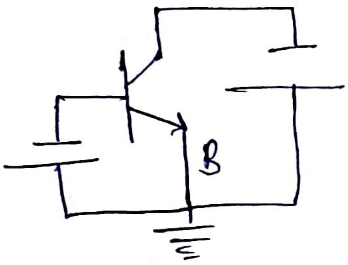


b).



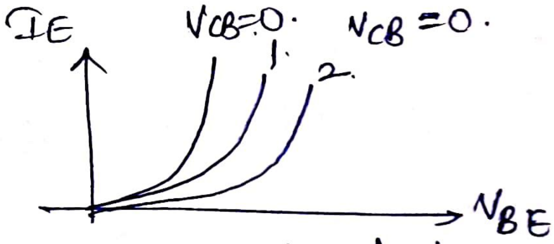
C.B configuration:





Input characteristics:

I_E, V_{BE} ⊥ V_{CB}.



Output characteristics:

I_C, V_{CB}, I_E

Transistor Biasing

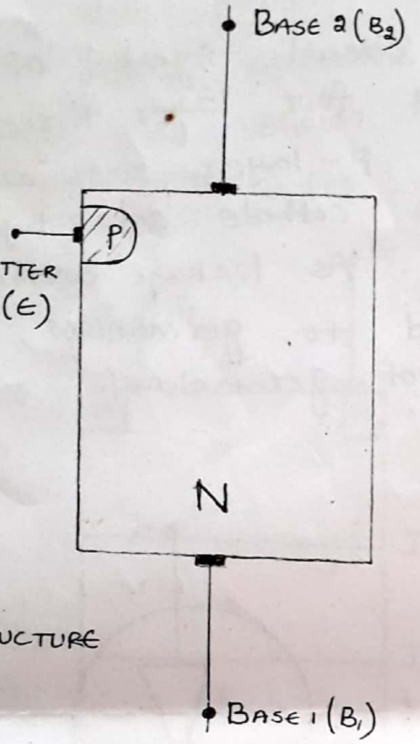
This chapter presents methods for establishing the quiescent operating point of a Transistor amplifier in the active region.

The operating point shifts with the changes in temperature (T) because the transistor parameters (β, I_{co} ...) are functions of T.

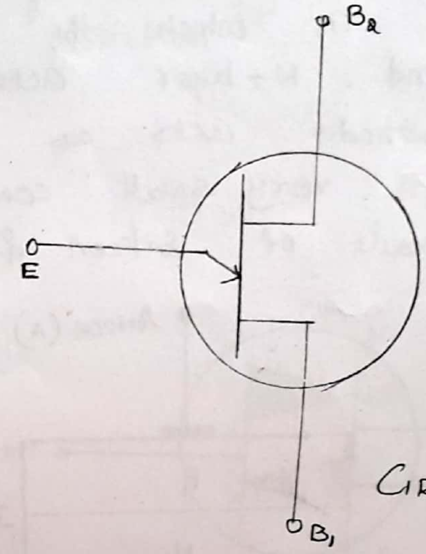
A criterion is established for comparing the stability of different biasing circuits.

UNI JUNCTION TRANSISTOR (UJT)

UJT is a three terminal semiconductor switching device. As it has only one PN Junction and three leads, it is commonly called as unijunction transistor.



STRUCTURE



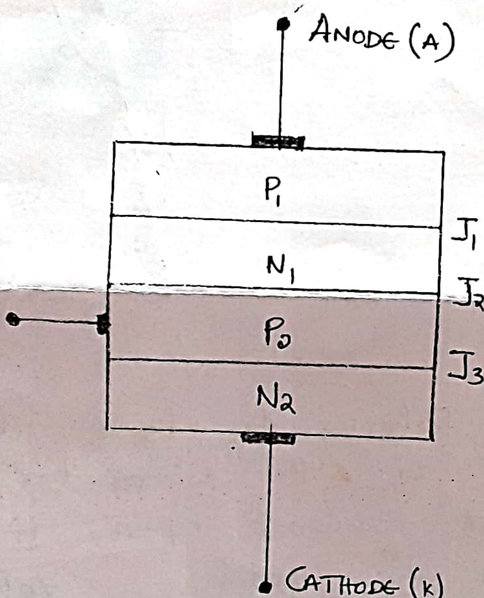
CIRCUIT SYMBOL

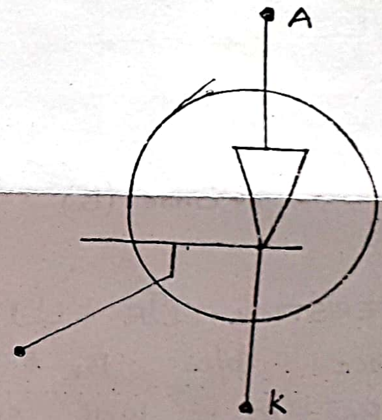
CHARACTERISTICS OF UJT: Refering to figure, the interbase resistance b/w B_2 & B_1 of the silicon bar is $R_{BB} = R_{B_1} + R_{B_2}$. With emitter terminal open; if voltage V_{BB} is applied b/w the two bases, a voltage gradient is established along the N-type bar. The voltage drop across R_{B_1} is given by $V_1 = nV_{BB}$ where the intrinsic stand, off ration $= R_{B_1}/(R_{B_1}+R_{B_2})$. The typical value on n ranges from 0.56 to 0.75. This voltage V_1 reverse biases the PN-junction & emitter current is cut off. But a small leakage current flows from B_2 to emitter due to minority carriers. If a positive voltage V_E is applied to the emitter, the PN junction will remain reverse biased so long as V_E is less than V_1. If V_E

exceeds V_1 by the certain voltage V_8 the diode becomes forward biased. Under this condition, holes are injected in to N-type bar.

SILICON CONTROLLED RECTIFIER (SCR):

The basic structure and circuit symbol of SCR is shown in fig. It is a four layer three terminal device in which the end P-layer acts as anode, the end N-layer acts as cathode and P-layer nearer to cathode acts as gate. As leakage current in silicon is very small compared to germanium, SCR's are made of Silicon & not germanium.



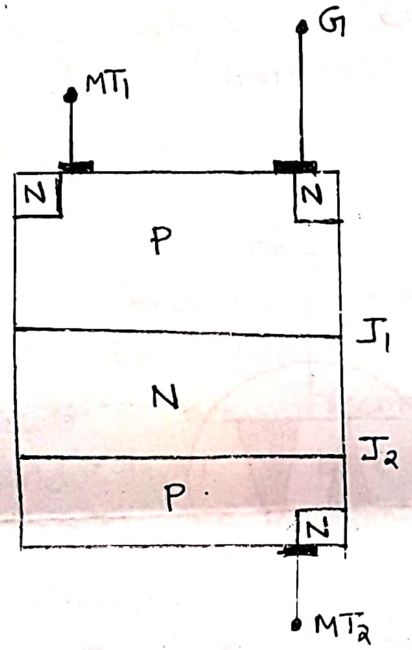


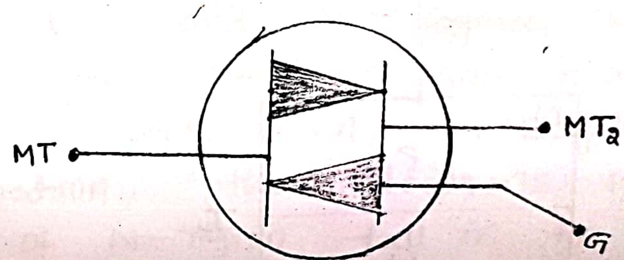
CIRCUIT SYMBOL

CHARACTERISTICS OF SCR :- The characteristics of SCR are shown in fig. SCR acts as a switch when it is forward biased. When the gate is kept open, if gate current $I_G = 0$ operation of SCR is similar to PNPN diode. When $I_G < 0$, the amount of reverse bias applied to J_2 is increased. So the break over voltage V_{BO} is increased. When $I_G > 0$ the amount of reverse bias applied to J_2 is decreased there by decreasing the break over voltage. Similar to that of ordinary PN diode. As the voltage at which SCR is switched 'ON' can be controlled by varying the gate current I_G. It is commonly called as controlled switch.

TRIODE AC SWITCH (TRIAC):

Triac is a three terminal semi conductor switching device which can control alternating current in a load. Its three terminals are MT_1, MT_2 are the gate (G). The basic structure & circuit symbol of a Triac are shown in fig. Triac is equivalent to two SCR's connected in parallel but in the reverse directions as shown in figure. So a triac will act as a switch for both direction.



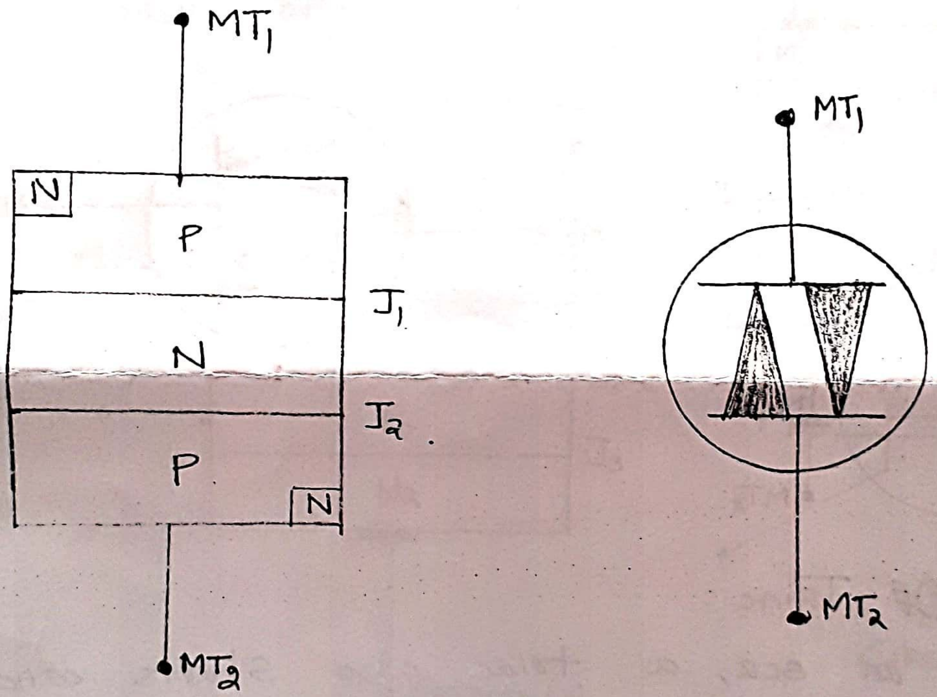


CHARACTERISTICS OF TRIAC:

Like an SCR, a triac also starts conducting only when the break over voltage is reached. Earlier to that the leakage current which is very small in magnitude flows through the device and therefore remains in the OFF state. The high inrush of current must be limited. Using external resistance, or it may otherwise damage the device. Triac is used for illumination control, temperature control.

DIODE AC SWITCH (DIAC):

The construction and symbol of diac are shown in fig. Diac is a three layer, two terminal semi-conductor device. MT_1 & MT_2 are the two main terminals which are interchangeable. It acts as a bidirectional. A valanche diode. It does not have any control terminal. It has two junctions J_1 & J_2. though the Diac resembles a bi polar transistor, the central layer is free from any connection with the terminals.



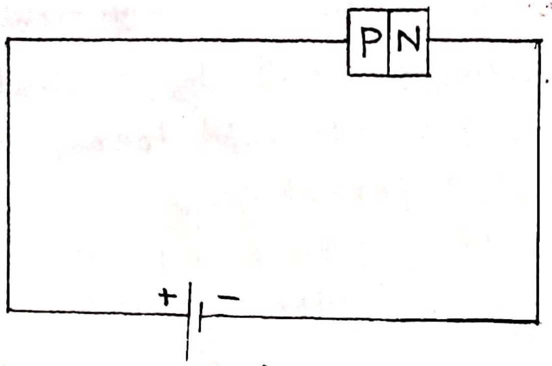
CHARACTERISTIC OF A DIAC: The characteristic of a Diac shown in fig, it acts as a switch in both directions. As the doping level at the two ends of the device is the same, the diac has identical characteristics for both positive and negative half of an a.c. cycle. During the positive half cycle, MT_1 is positive with respect to MT_2 in the negative half cycle. It is used as triggering device in Triac control. Circuits used for light dimming, motor speed control and heater control

LIGHT EMITTING DIODE (LED):

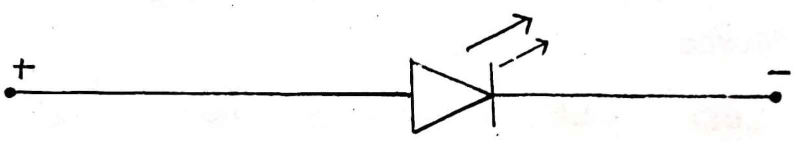
The light emitting diode (LED) is a PN junction device which emits light when forward biased, by a phenomenon called electromluminesence. In all PN junction, some of the energy will be radiated as heat and some in the form of Photons. In semi-conductors silicon & germanium, greater percentage of energy is given out in the form of heat & the emitted light is insignificant. In other materials such as gallium phosphide (GaP) or gallium arsenide phosphide (GaAsP), the no. of photons of light energy emitted is sufficient to create a visible light source.

LED under forward bias and its symbol when an LED is forward biased. the electrons and holes move towards the junction & recombinatron takes place. As a result of recombination, the electrons lying in the conduction bands of N-region fall in to the holes lying in the valence band of a P-region. The difference of energy b/w the conduction band & the valance band is radiated in the form of light energy.

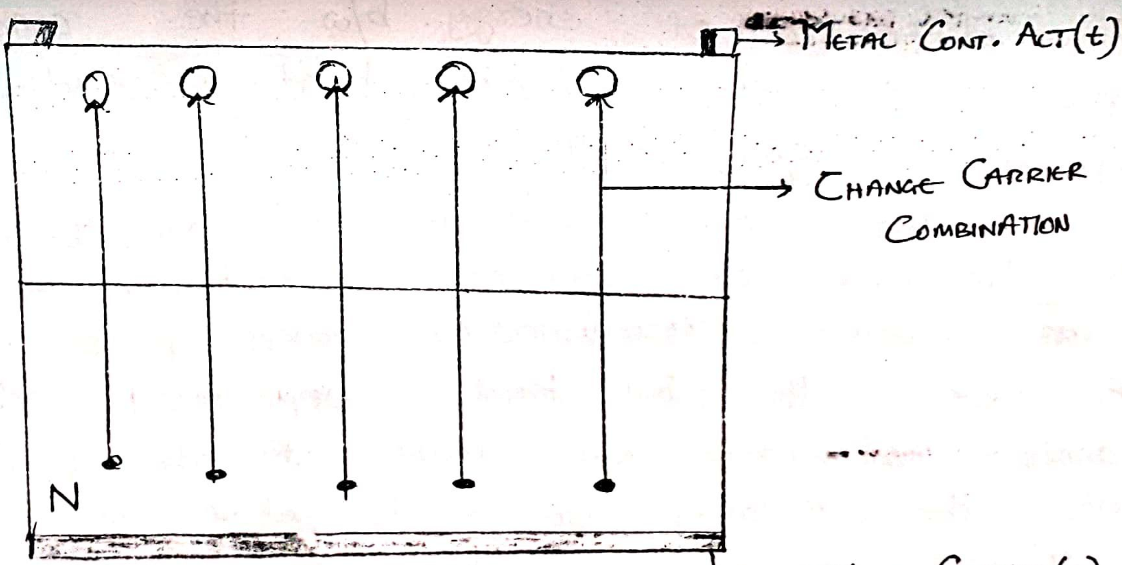
The basic structure of an LED shows recombinations of carriers & emission of light. Sine carrier recombination takes place in the P-layer, it is kept upper most. The metal anode connections are made at the outer edger of the p-layer so as to allow more central surface area for. the light to escape. LED's are manufactured with damed lenses in order to reduce the reabsorption problem.



(a)



(b)



(C)

● Electrons
O Holes.

LED :

a. LED Under Forward Bias.

b. Symbol.

c. Re-Combinations And Emission Of Light.

PHOTO DIODE :

Silicon photo diode is a light sensitive device also called Photo detector, which converts light signals in to electrical signals. The diode is made of a semi-conductor PN junction kept in a sealed plastic or glass casing. The cover is so designed that the light rays are allowed to fall on one surface across the junction. The remaining sides of the casing are painted to restrict the penetration of light rays. A lens permits light to fall on the junction, when light falls on the reverse biased PN photo diode junction, hole - electron pairs are created. The magnitude of the photo current depends on the number of charge carriers generated and hence, on the illumination of the diode element. This current is also affected by the frequency of the light falling on the junction of the photodiode. The magnitude of the current under large reverse bias is

$$I = I_s + I_0 \left(1 - e^{V/nV_T}\right).$$

Where,

I_0 = reverse saturation current.

I_s = short circuit current which is proportional to the light intensity.

V = Voltage across the diode.

V_T = Volt equivalent of temperature.

n = parameter, 1 for Ge & 2 for Si.

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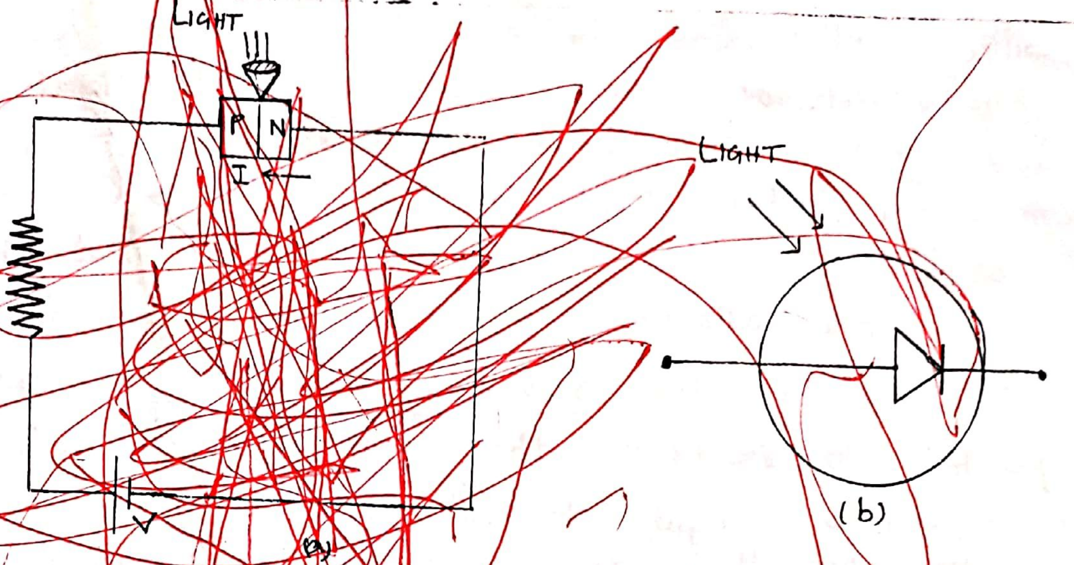
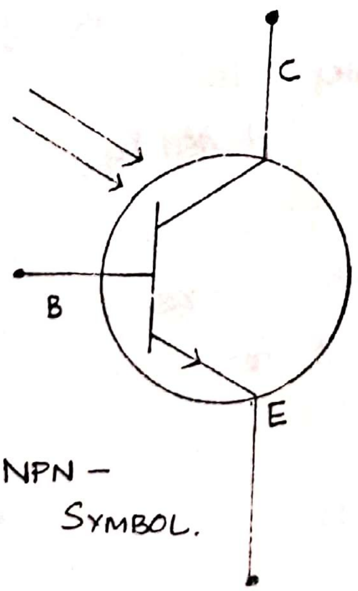


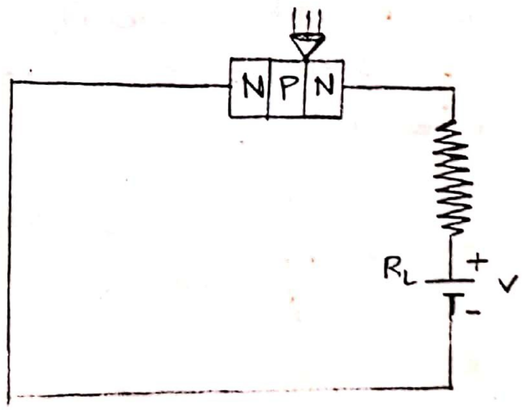
Photo Diode a). Construction.
b). Symbol.

Photo Transistor / Photo Diode :

It is a much more sensitive semiconductor photo device than the PN photodiode. The current produced by a photodiode is very low which cannot be directly used in control applications. Therefore this current should be amplified before applying to control circuits. When the photo-transistor is illuminated, it permits a greater flow of current.



NPN –
SYMBOL.



When $I_B = 0$, the collector current is given by

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

When the light is turned ON, additional minority