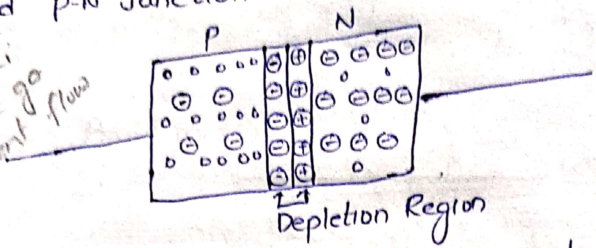
unit-4 Diodes & Transistors

Anode / cathode

P-N Junction diode :- (unidirection current flow one junction)
When a p-type Semi Conductor is Suitably joins with n-type Semi conductor a thin layer formed at contact Surface is called P-N Junction

Conventional electron ki opposite go current flow

P-N ⇒ majority holes, Minority elec.
N ⇒ majority e⁻, minority hole



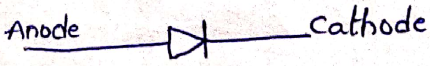
The above figure the left Side material is p-type Semi Conductor. It has high Concentration of holes & right Side material is n-type Semi conductor it has high Concentration of free electrons

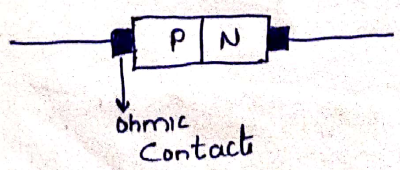
n-type :- pentavalent Impurities
p-type :- trivalent

⇒ At this junction there is a tendency for free electrons to ~~refuse~~ diffuse (move) over to p-Side, this process is known as diffusion. Due to this diffusion in n-region is combined with the free electrons (positive charge) built on holes and hence positive ions built on p-Side. N-Side and negative ions

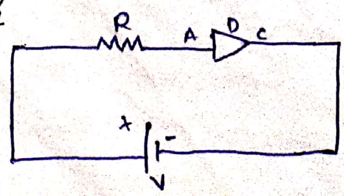
⇒ when a sufficient number of positive ions and negative ions are formed on both sides of the junction, further diffusion is prevented because of Immovable ions Created potential drop across P-N Junction. This P-N junction is called depletion region or ~~Barrier~~ potential Barrier. (Voltage)

⇒ The potential Barrier of Ge is 0.2V
⇒ The potential Barrier of Si (silicon) is 0.7V

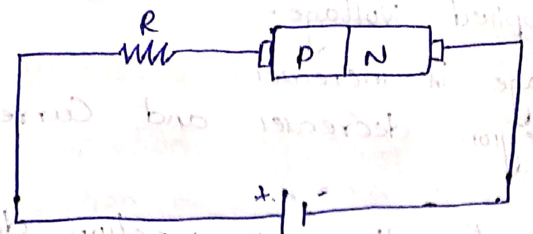


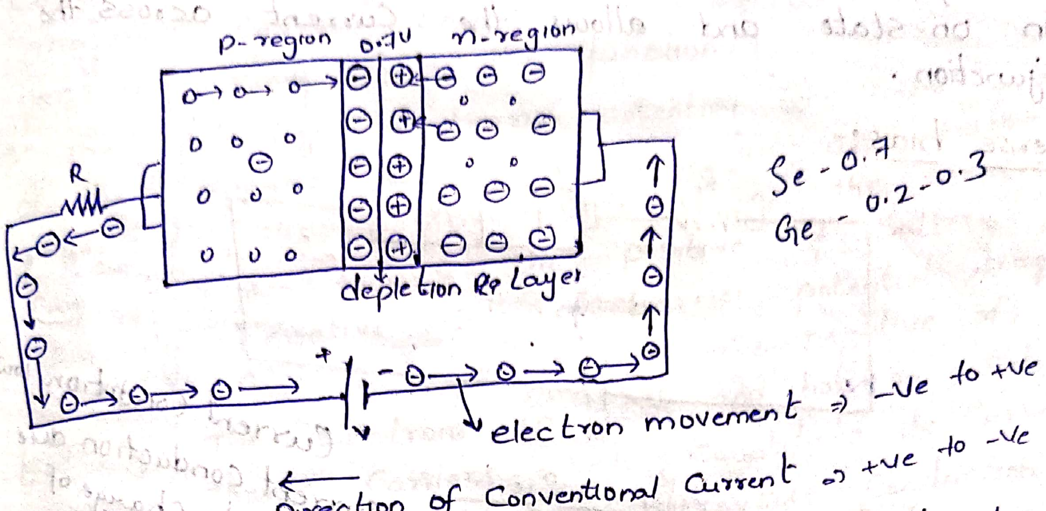


Forward Bias



electron movement
Current Conduction
electrons moves to p region





Se - 0.7
Ge - 0.2-0.3

Biasing :- Applying external D.C source to electrical Component

forward Bias :- +ve terminal of p. Voltage to +ve (Anode) of diode

Biasing :- It is the process of applying external D.C Source to any electronic Component is called biasing

⇒ Biasing is two types
(i) Forward Bias
(ii) Reverse Bias

Forward Bias :- When +ve terminal of the voltage source is connected to p-region of diode and negative terminal of battery or voltage source is connected to n-region of diode. Hence the diode is set to be in forward Bias mode.

⇒ The forward voltage facilitates the moment of majority carriers across the junction.

⇒ ~~The~~ If the applied forward voltage is less than potential Barrier (Depletion region voltage) there is no conduction in the diode.

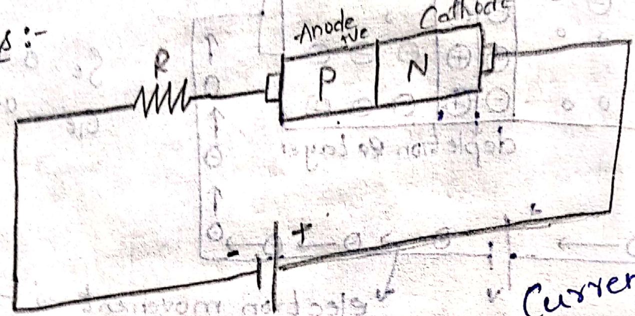
⇒ The applied voltage more than the Barrier potential then the conduction starts in the diode. Due to flow of electrons from n-region to p-region and holes move towards from p-region to n-region.

by the force of applied voltage.

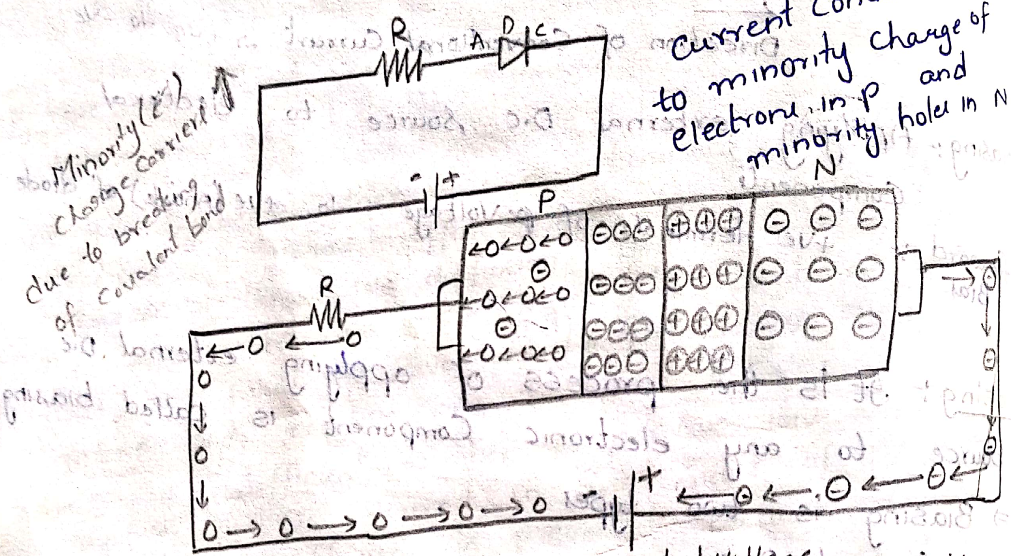
⇒ If the forward voltage is increases (applied voltage) width of depletion region decreases and Current increases gradually.

⇒ In forward bias mode the p-n junction diode is in on-state and allows the Current across the junction.

Reverse bias :-



Current Conduction low



When the p-n junction is reverse biased the negative terminal attracts the holes in the p-region, away from the junction. The positive terminal attracts the free electrons in the n-region away from the junction. No charge Carrier is able to cross the junction. As electrons and holes both move away from the junction, the depletion region widens. This creates more positive ions and hence more positive ions and hence more positive charge in the n-region and more negative ions and hence more negative charge in the n-region. This is because the applied voltage helps the barrier potential.

Key point :- Reverse biasing increases the width of the depletion region.

⇒ As depletion region widens, barrier potential across the junction also increases, However, this process cannot continue for long time. In the steady state, majority current ceases as holes and electrons stop moving away from the junction.

⇒ The polarities of barrier potential are same as that of the applied voltage. Due to increased barrier potential, the positive side drags the electrons from p-region towards the positive of battery. Similarly negative side of barrier potential drags the holes from n-region towards the negative of battery. The electrons on p-side and holes on n side are minority charge carriers, which constitute the current in Reverse biased condition. Thus reverse conduction takes place.

⇒ The Reverse current flows due to minority charge carriers which are small in number. Hence reverse current is always very small.

Key point :- The generation of minority charge carriers depends on the temperature and not on the applied reverse bias voltage. Thus the reverse current depends on the temperature i.e thermal generation and not on the Reverse voltage applied.

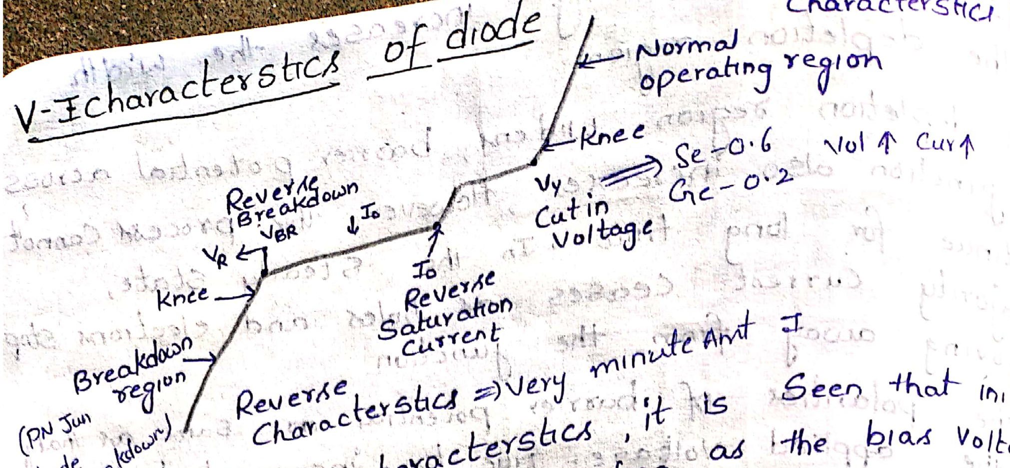
for a constant temperature, the reverse current is almost constant though reverse voltage is increased upto a certain limit. Hence it is called reverse saturation current and denoted as I_o.

Key point :- Reverse saturation current is very small of the order of few microampers for germanium and few nanoamperes for silicon p-n junction diodes

⇒ The dynamic resistance is most important in practice whether the junction is forward or Reverse biased.

Ion - Recombination of ~~e~~ & holes

V-I Characteristics of diode



⇒ In forward characteristics, it is seen that initially forward current is small as long as the bias voltage is less that the barrier potential. At a certain voltage close to barrier potential, current increases rapidly. The voltage at which diode current starts increasing rapidly is called as cut in voltage. It is denoted by V_γ. Below this voltage, current is less than 1% of maximum rated value of diode current. The cut-in voltage for germanium is about 0.2 V while for silicon it is 0.6 V.

⇒ It is important to note that the breakdown voltage is much higher and practically diodes are not operated in the breakdown condition. The voltage at which breakdown occurs in is called reverse breakdown voltage denoted as V_{BR}. Before the breakdown

Key point: Reverse current is very very small and can be practically neglected.

⇒ The Reverse biasing produces a voltage drop across the diode denoted as V_R which is almost equal to applied reverse voltage.

Breakdown in Reverse Biased.

Though the reverse saturation current is not dependent on the applied reverse voltage. If reverse voltage is increased beyond particular value, large reverse current can flow damaging the diode. This is called reverse breakdown of a diode. Such a reverse breakdown of a diode can take place

1. Avalanche effect ⇒ Minority Carrier velocity ↑ electron free ayi Kinetic charges ↑ Current ↑
2. Zener effect

Breakdown lo operate cheyyadaniki Zener diode use chestham
Rev voltage ↑ electric field ↑ electrons fill ayyi covalent bond break avuthadi

Breakdown due to the Avalanche effect:-

Though reverse Current is not dependent on reverse Voltage, if reverse Voltage is Increased at a particular value, Velocity of minority Carriers Increases. Due to the kinetic energy associated with the minority Carriers with the atoms. The collision make the electrons to break the Covalent bonds. These electrons are available as minority Carriers and get accelerated due to high reverse Voltage. They again collide with another atoms to generate more minority Carriers. This is called Carrier multiplication. Finally large number of minority Carriers move across the junction, breaking the p-N junction. These large number of minority Carriers give rise to a very high reverse Current, This effect is called avalanche effect and the mechanism of destroying the junction is called reverse breakdown of a p-n junction. The Voltage at which the breakdown of a p-n junction occurs is Called Reverse breakdown Voltage. The Series resistance must be used to avoid breakdown condition limiting the reverse Current.

Breakdown due to the Zener effect

The Breakdown of a p-n junction may occur because of one more effect called zener effect. When a p-n junction is heavily doped the depletion region is very narrow. So under reverse bias Conditions, the electric field across the depletion Layer is very intense. Electric field is Voltage per distance and due to narrow depletion region and high reverse Voltage, it is intense. Such an intense field is enough to pull the electrons out of the Valence bands of the stable atoms. So this is not due to the collision of Carriers with atoms. Such a Creation of free electrons is called zener effect which is different than the avalanche effect. These minority Carriers constitute very large current and mechanism is called Zener breakdown

Highly doped, then internal electric field ↑ So it occurs Zener effect cause Breakdown

Key point :-

The normal p-n junction diode is practically not operated in reverse breakdown region though may be operated in reverse biased condition.
The breakdown effects are not required to be considered for p-n junction diode. These effects are required to be considered for special diodes such as Zener diode as such diodes are always operated in Reverse breakdown condition.

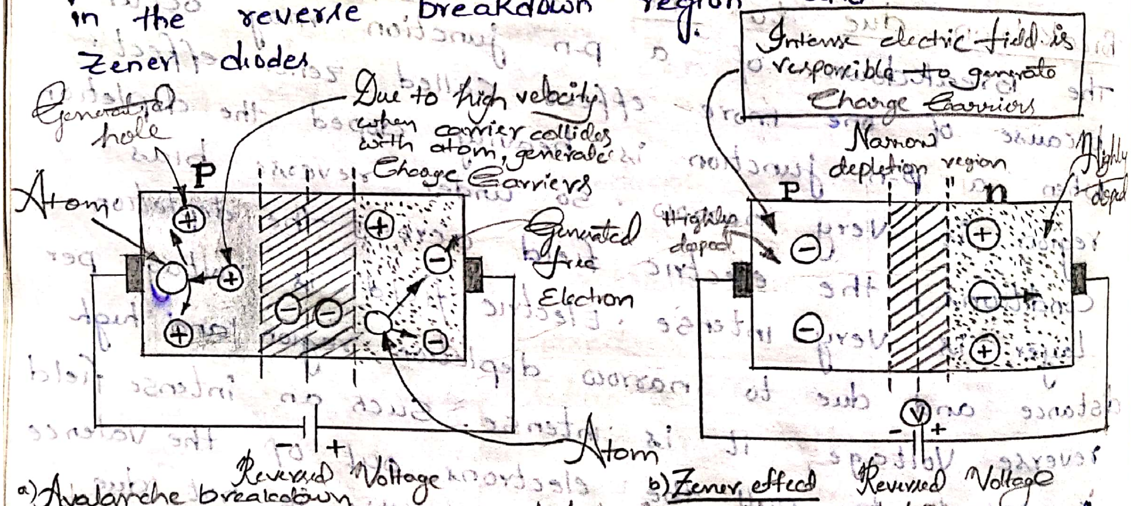
Why to avoid Reverse breakdown

⇒ Large Reverse voltage appears across the diode and large current flows through the diode in Reverse breakdown condition.

⇒ So large power gets dissipated which appears in the form of heat at the junction.

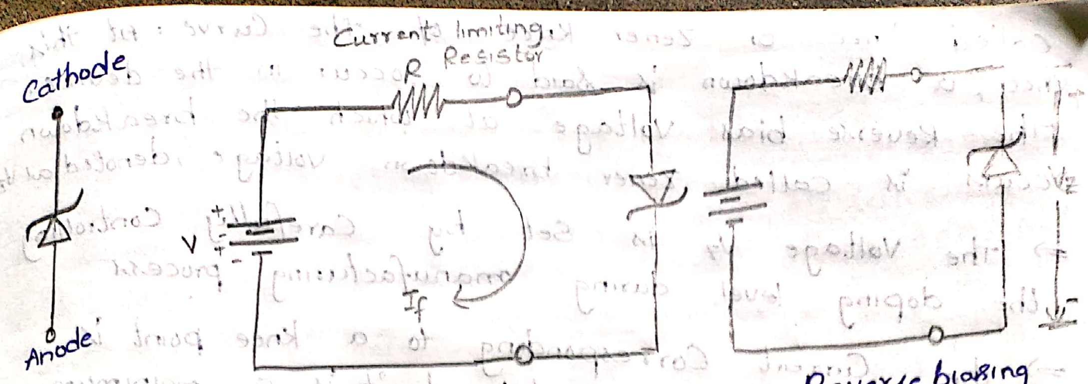
⇒ This increases junction temperature beyond the safe limits and this may damage the diode permanently.

So Reverse breakdown must be avoided for conventional diodes.
Some special diodes are manufactured to be operated in the reverse breakdown region and are called Zener diodes.



Zener diode specially operated in Reverse Bias condition.

The Zener diode is a Silicon p-n junction Semi Conductor device, which is generally operated in Reverse breakdown region. The Zener diode are fabricated with precise breakdown voltages by controlling the doping level during manufacturing. The Zener diode have breakdown voltage range from 3V to 200V. In 1934 a physical Cari Zener investigated the breakdown phenomenon in the p-n junction diode



Symbol forward biasing Reverse biasing

⇒ The D.C Voltage can be applied to the Zener diode so as to make it forward biased or reverse biased. practically Zener diode are operated in Reverse biased mode Zener diode is operating in breakdown region. [Voltage Regulator < Voltage Constant, Current ↑]

Characterstics of Zener diode :- [Voltage Regulator ↳ Application of Zener diode]

In the forward biased conditions, the normal zener diode operates in Similar rectifier diode and the zener diode is designated to be fashion. But the Zener diode condition. In Reverse operated in the reverse biased reverse saturation biased conditions, the diode carriers applied is less than Current till the reverse voltage when the Reverse the reverse breakdown voltage, the Current Voltage exceeds reverse breakdown Voltage across through it changes drastically but the voltage it remains almost constant. Such a breakdown region is a normal operating region for a Zener diode. The normal operating regions for a rectifier diode and a Zener diode [Voltage Regulator ga work chestundi]

⇒ The breakdown characterstics for a Zener diode is significantly important, as it is an operating region for the diode. when the Reverse Voltage applied to a zener diode is increased, initially the Current through it is very small, of the order of few μA or less. This is the reverse leakage Current of the diode, denoted by I_o. At a Certain reverse Voltage Current through Zener diode increases rapidly. The changes from a low value to large Value of Current is very sharp and well defined. Such a Sharp change in th reverse characterstics is

Called knee or zener knee of the curve. At this knee, a breakdown is said to occur in the device. The reverse bias voltage at which the breakdown occurs is called zener breakdown voltage, denoted as V_Z.

⇒ The voltage V_Z is set by carefully controlling the doping level during manufacturing process.

⇒ The current corresponding to a knee point is called zener knee current and it is a minimum current zener must carry to operate in reverse breakdown region. It is denoted as I_{ZK} or I_{Zmin}.

⇒ From the bottom of the knee, the zener breakdown voltage remains almost constant, through it increases slightly as the zener current I_Z increases. The current at which the nominal zener breakdown voltage is ~~apr.~~ specified is called zener test current denoted as I_{ZT}.

⇒ This value and corresponding zener voltage V_Z are specified on a datasheet of a zener diode. Every zener diode has a capacity to carry current. As current increases, the power dissipation $P_Z = V_Z I_Z$ increases. If this dissipation increases beyond certain value the diode may be damaged.

⇒ The maximum current a zener diode can carry safely is called zener maximum current and is denoted as I_{Zm} or I_{Zmax}.

⇒ In practical circuits to limit the zener current b/w I_{Zmin} and I_{Zmax} a current limiting resistor is used in series with the zener diode.

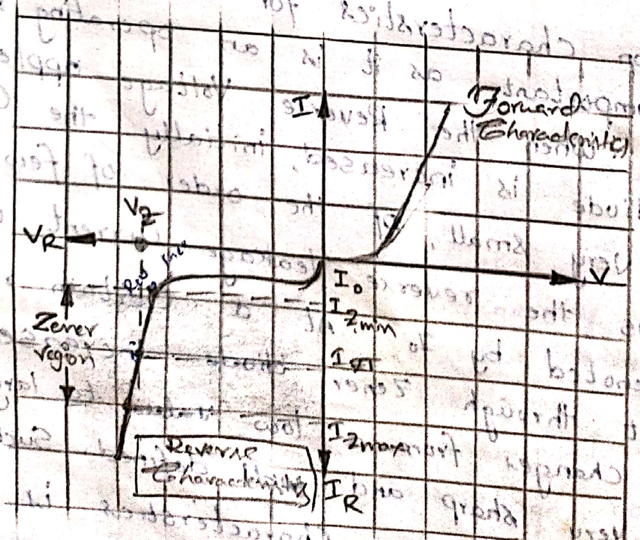


Fig. V-I Characteristics of zener diode

Transfer of resistance
Low Resistance to High
Current flow

Transistors (BJT) Bipolar Junction Transistor
↳ Current flow in Bidirectional
Current Controlled device

Junction Transistor :-

In 1951, William invented the first junction transistor. a Semiconductor that can be amplify electronic signals such as radio and television signals. It is essential ingredient of every electronic circuit, from the simplest amplifier or oscillator to the most elaborate digital computer. Thus a proper understanding of transistor is very important.

⇒ Before transistor the was achieved by using vacuum tubes as an amplifier. Now a days vacuum tubes are replaced by transistors because of following advantages of transistors

⇒ Low operating voltage
⇒ Higher efficiency
⇒ Small size and ruggedness and
⇒ Does not regeure any filament power

Transistor operator in Active Region

	F.B	R.B
	+ve to +ve	+ve to -ve
	-ve to -ve	-ve to +ve

⇒ Transistor is a three terminal device : Base, emitter and collector, can be operated in three configurations, Common base, Common emitter and Common collector. According to configuration it can be used for voltage as well as current amplification. The input signal of a small amplitude is applied at the base to get the magnified output signal at the collector. Thus provides an amplification of the signal. The Amplification in the transistor is achieved by passing input current signal from a region of low resistance to a region of high resistance. The concept of transfer of resistance has given the name (Transistor). In transistor, the output current is controlled or the input current and hence it is a current controlled device.

There are two types of transistors unipolar Junction transistor and bipolar junction transistor. In unipolar transistor the current conduction is only due to one type of carriers, majority carriers. The

Current Conduction in bipolar transistor is because of both the types of Charge Carriers, holes and electrons. Hence this is called Bipolar Junction transistor hereafter referred as a

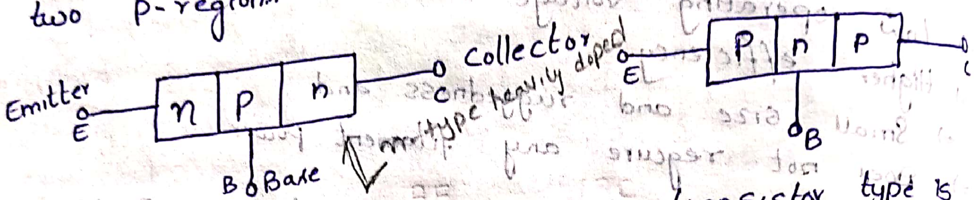
They are two types.

1) n-p-n type

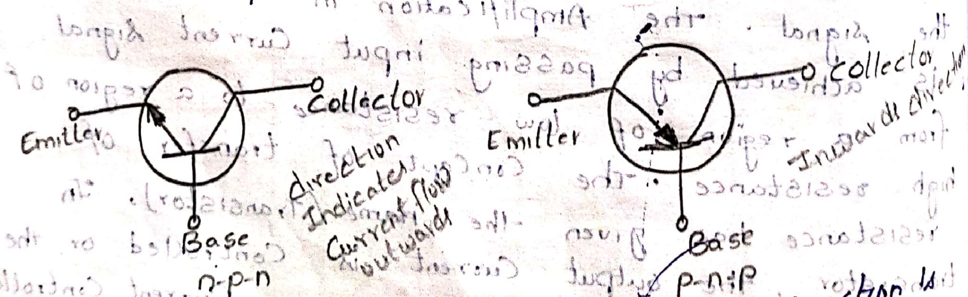
2) p-n-p type

Structure of Bipolar junction Transistor :-

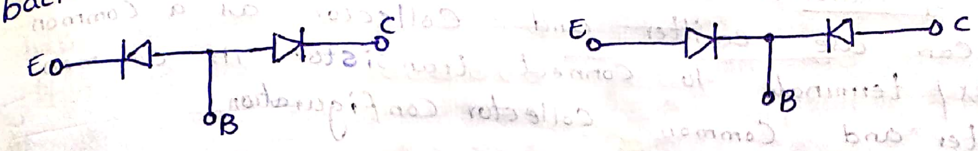
When a transistor is formed by sandwiching a single p-region between two n-regions. It is an n-p-n type transistor. The p-n-p type transistor has a single n region between two p-regions.



⇒ the middle region of each transistor type is called the base of the transistor. The region is very thin and lightly doped. The remaining two regions are called emitter and collector. The emitter and collector are heavily doped. But the doping level in emitter is slightly greater than that of collector and the collector region-area is slightly more than that of emitter.



A transistor has two p-n junctions, one junction is between the emitter and the base and is called the emitter base junction or simply the emitter junction. The other junction is b/w the base & the collector and is called collector - base junction or simply collector junction J_c. Thus transistor is like two pn junction diode connected back to back.



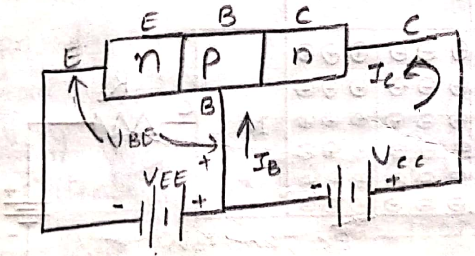
Biased Transistor

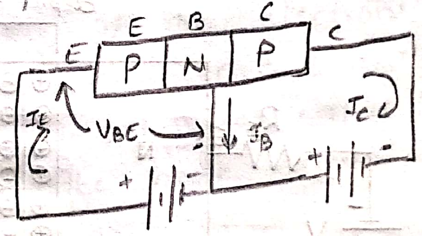
In order to operate transistor properly as an amplifier, it is necessary to correctly the two p-n junction with external voltages. Depending upon external bias voltage polarities used, the transistor works in one of the three regions.

1) Active region 2) Cut-off region 3) Saturation region

Region	Emitter base junction	Collector base junction
Active	forward biased	Reverse biased
Cut-off	Reverse biased	Reverse biased
Saturation	forward biased	forward biased.

⇒ To bias the transistor in its active region, the emitter base junction is forward biased while the collector - base junction in reverse biased.
Current flow is opposite to electron moment





The externally applied bias voltages are V_{EE} and V_{cc} which bias the transistor in its active region. the same for the npn the operation of the pnp is the electrons and holes, except that the roles of the current directions the bias voltages polarities and in both cases the are all Reversed. Note that the forward biased and the base-emitter (J_E) Junction is forward biased. collector base junction (J_C) is reversed biased. what happens inside with these biasing condition, the transistor.

No voltage ay the → Reverse bias
Some voltage → Forward.

Junction Emitter	Junction collector	
Reverse Bias	Reverse Bias	Cut off Region (off)
Forward Bias	Forward Bias	Saturated Region (ON)
F.B	R.B	Active Region (Amplifier) weak signal ← ga act ni high signal 5a (strengthens)

BJT operation :-

We can use emitter and Collector as a Common points/ terminals to connect transistor in Common emitter and Common collector configuration.

Emitter ki apply charna Source
collector ki apply charna Source

1) Common base configuration → Input ki output ki Common ga Base
2) Common emitter configuration ⇒ current gain & Voltage gain
3) Common collector configuration

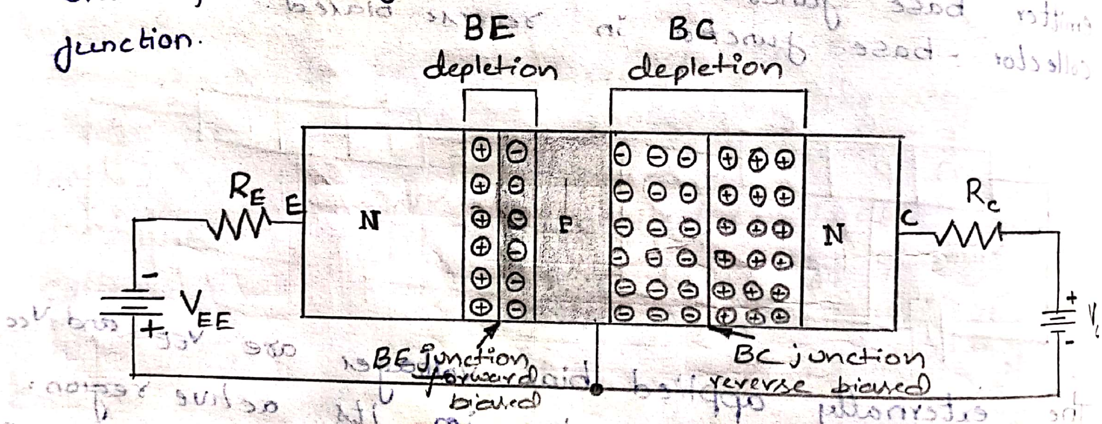
gain = output / Input

Key point :-

Regardless of circuit configuration, the base emitter junction is always forward biased while the collector base junction is always reverse biased, to operate transistor in active region.

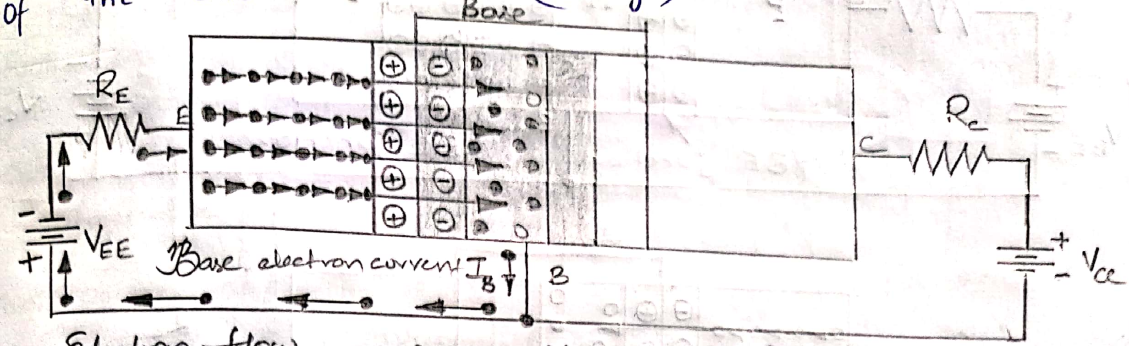
Operation of NPN Transistor :-

Let us consider the npn transistor. The base to emitter junction is forward biased by the d.c Source V_{EE}. Thus the depletion region at this junction is reduced. The collector to base junction is reverse biased, increasing depletion region at collector to base junction.

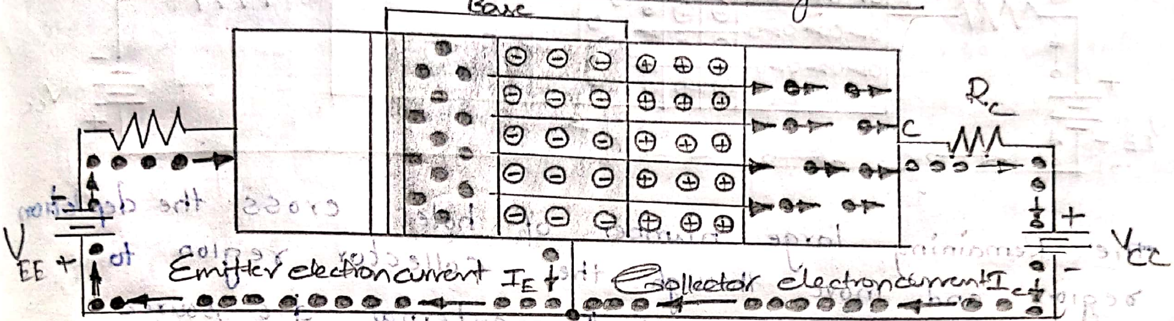


The forward biased EB junction causes the electron in the n-type emitter to flow towards the base. This constitute the emitter current I_E. As these electrons flow through the p-type base, they tend to combine with holes in p-region.

We know that the base region is very thin and lightly doped. The light doping means that the free electrons have a long life time in the base region. The very thin base region means than the free electrons have only a short distance to go to reach the collector. For these two very few of the electrons injected into the base from the emitter recombine with holes to constitute base current, I_B and the remaining large number of electrons cross the base region and move through the collector region to the positive terminal of the external d.c (storage) source



Electron flow across emitter-base junction

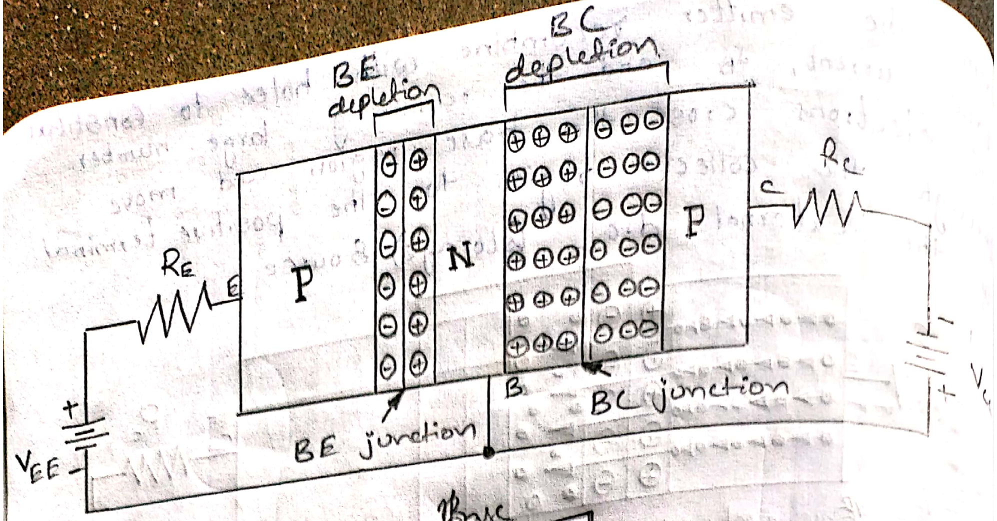


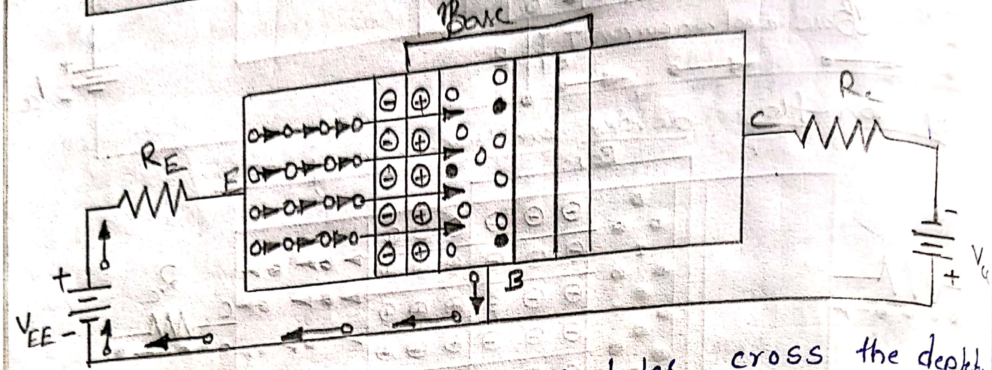
Electron flow across base-collector junction

This constitutes collector current I_c. thus the electron flow constitutes the dominant current in an npn transistor. Since, the most of the electrons from emitter flow in the collector circuit and very few combine with holes in the base. Thus the collector current larger than the base current.

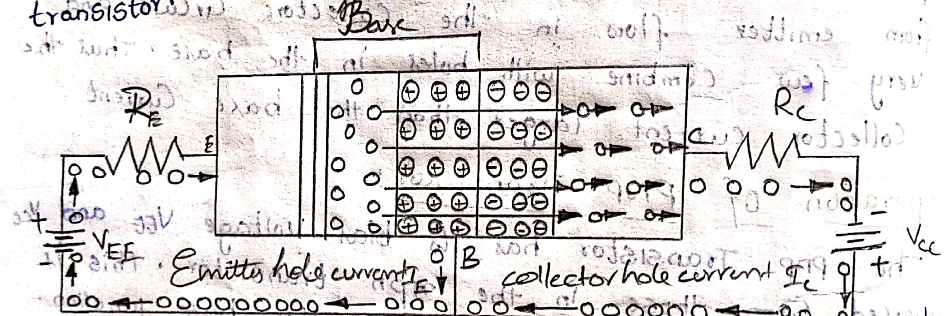
operation of PNP Transistor :-

The pnp transistor has its bias voltage V_{EE} and V_{cc} reversed from those in the npn transistor. This is necessary to forward bias the emitter base junction and reverse bias for collector base junction. The forward biased EB junction causes the holes in the p-type emitter to flow towards the base. this constitutes the emitter current I_E. As these holes flow through the n-type base they tend to combine with electrons in n-region. The base is very thin and lightly doped, very few of the holes injected into the base from the emitter recombine with electrons to constitute base current, I_B





the Remaining large number of holes cross the depletion region and move through the collector region to the negative terminal of the external d.c source. Thus the hole Current I_C constitutes Collector Current in a pnp flow constitutes the dominant Current in an pnp transistor.



Highly doped emitter ensures that the emitter Current in a pnp transistor consists almost entirely of holes and almost entirely of electrons in a npn transistor. Such a situation is desired since the Current which results from electrons or from holes crossing the emitter junction from base to emitter does not contribute carriers which can Reach the Collector.

Transistor Voltages and Currents :-

The Common emitter configuration is widely used amongst three transistor configuration. The main reason for the wide spread use of this circuit arrangemts are

⇒ The CE configuration is the only configuration which provides both voltage gain as well as current gain greater than unity. In case of CB configuration current gain is less than unity an in case of CC configuration voltage gain is less than unity. | CE

the power gain is a product of voltage gain and current gain. CE configuration provides voltage gain nearly equal to voltage gain provided by CB configuration and current gain nearly equal to current gain provided CC configuration. Thus the power gain of the CE amplifier is much greater than the power gain provided by the other two configurations and in CB are (voltage gain in CC and current gain less than unity)

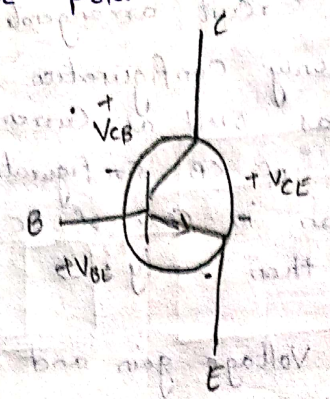
⇒ In a common emitter circuit, the ratio of output resistance to input resistance is small may range from 10Ω to 100Ω. This makes configuration an ideal for coupling b/w various transistor stages. However in others connections. the ratio of output resistance to input resistance is very large and hence coupling becomes highly inefficient due to large mismatch of resistance.

Note :- Maximum power is transferred from stage 1 to stage 2 when output resistance of stage 1 is equal to the input resistance of stage 2

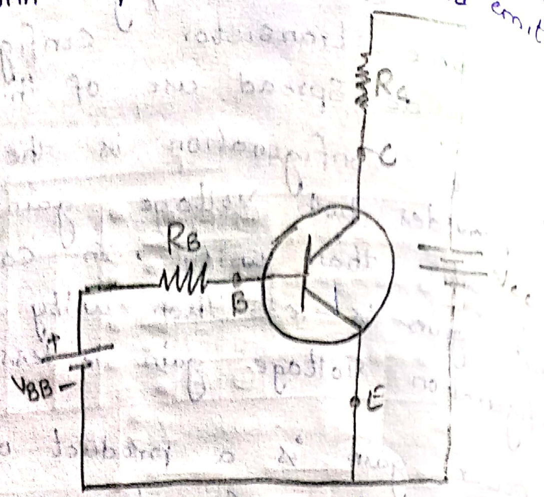
Transistor Voltages and its polarities for an npn

The terminal voltages between base and emitter is transistor. The voltage for base is positive than denoted as V_{BE} ; for V_{BE} the base is emitter because for npn transistor, the emitter biased positive with respect to the emitter is

The voltage b/w the collector & emitter is denoted as V_{CE} and the voltage b/w the collector and the base is denoted as V_{CB}. Since Collector is positive with respect to base and emitter the polarities



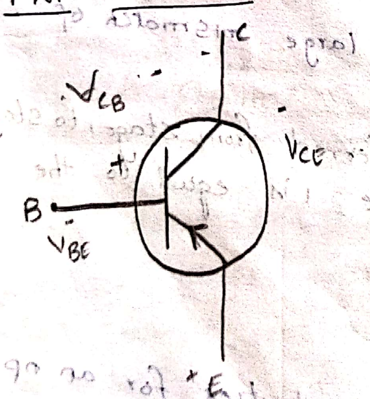
npn transistor voltage



Voltage Source Connections for npn trans

⇒ The npn transistor with voltage source connection: The voltage sources are connected to the transistor with series resistors. These resistors are called current limiting resistors. The base supply voltage V_{BB} is connected via resistor R_B and the collector supply voltage, V_{CC} is connected via resistor R_C. The negative terminals of both the supply voltages are connected to emitter terminal of the transistor. To make CB junction reverse biased, the supply voltage V_{CC} is always much larger than supply voltage V_{BB}.

PNP Transistor



The terminal voltages and its polarities for a pnp transistor, the For a pnp transistor, the base is biased negative w.r.t the emitter and the collector is made more negative than the base

Current Amplification factors Alpha (α) and Beta (β)

In transistor, the emitter current I_E is always equal to the sum of base and collector currents I_B and I_C respectively. This is true for both types of transistor. Hence

$$I_E = I_B + I_C$$

α_{dc} It is defined as the ratio of the collector current resulting from carrier injection to the total emitter current

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

⇒ Since $I_C < I_E$ the value of α_{dc} is always less than unity. It ranges from 0.95 to 0.995. It represents the current gain in the CB configuration

⇒ β_{dc} : It is defined as the ratio of the collector current to the base current.

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

Relation b/w α & β

W.K.T $\beta = \frac{I_C}{I_B}$ $\quad I_E = I_B + I_C$

i.e $I_B = I_E - I_C$

$I_E = I_C + I_B$

$$\beta = \frac{I_C}{I_E - I_C}$$

Dividing the numerator and denominator of R.H.S of eq (I_E)

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

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

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

W.K.T $\alpha = \frac{I_C}{I_E}$ $\quad I_E = I_B + I_C$

$$\boxed{\alpha = \frac{I_C}{I_B + I_C}}$$

Dividing numerator & denominator with I_B

$$\alpha = \frac{I_C/I_B}{I_B/I_B + I_C/I_B}$$

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

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

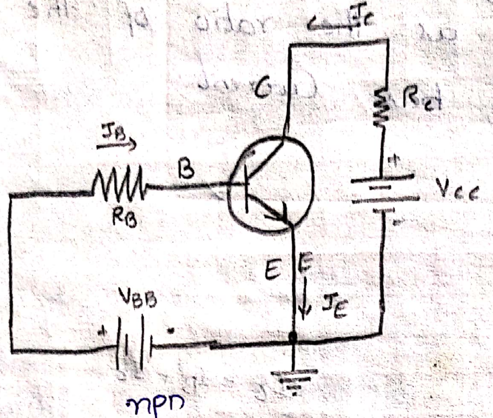
$\alpha = \frac{I_C}{I_E}$

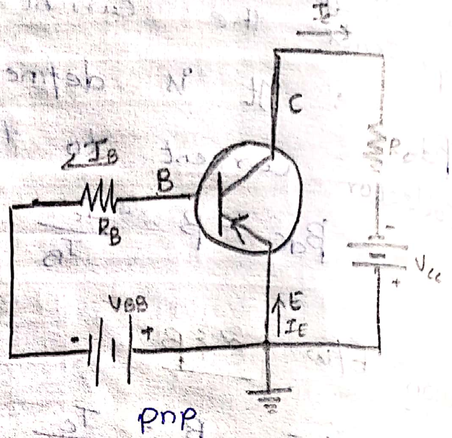
$\beta = \frac{I_C}{I_B}$

Scanned with OKEN Scanner

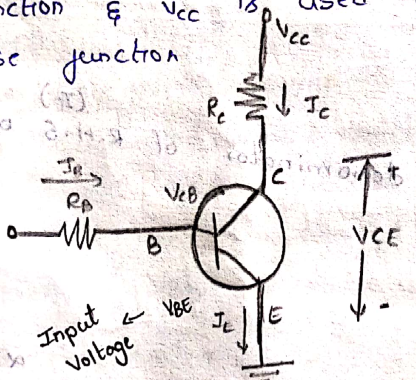
Common emitter Characterstics

In this Configuration input is applied between base & emitter and output is taken from Collector and emitter. Here emitter of the transistor is Common to both input and output Circuits and hence the name Common emitter Configuration. Common emitter Configuration for both npn and pnp transistors





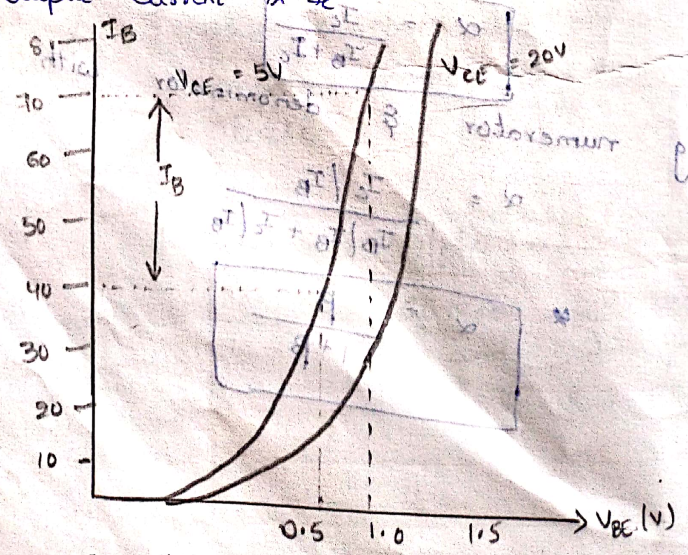
The bias Voltage V_{BB} forward biases the base-emitter junction & V_{cc} is used to Reverse bias the collector base junction



Shows the Input voltage and output voltages & Currents for the Common - emitter Configuration

Value

⇒ The input voltage in the CE configuration is the base emitter Voltage and the output voltage is the Collector - emitter Voltage. The input Current is I_B and the output Current is I_C



Input Characterstics of Transistor

Input characterstics output Current Controlled by Input Current

It is the Curve b/w Input Current I_B (base Current) and input Voltage V_{BE} (Base -emitter Voltage) at Constant Collector -emitter Voltage, V_{CE}. The base Current is taken along y-axis and base emitter Voltage V_{BE} is taken along x-axis. The Input characterstics of a typical transistor in Common-emitter Configuration.

⇒ As the Input to a transistor in the CE Configuration is b/w the base to emitter junction, the CE input characterstics resembles of a family of forward biased diode Curve.

⇒ After the Cut in Voltage the base Current (I_B) Increases rapidly with small increases in base emitter Voltage (V_{BE}). It means that dynamic (changing) input resistance is small in CE Configuration. It is the ratio of Change in base-emitter Voltage (ΔV_{BE}) to the resulting Change in base Current (ΔI_B) at Constant collector emitter Voltage V_{CE}

$$r_i = \frac{\Delta V_{BE}}{\Delta I_B} \quad V_{CE} = \text{Constant}$$

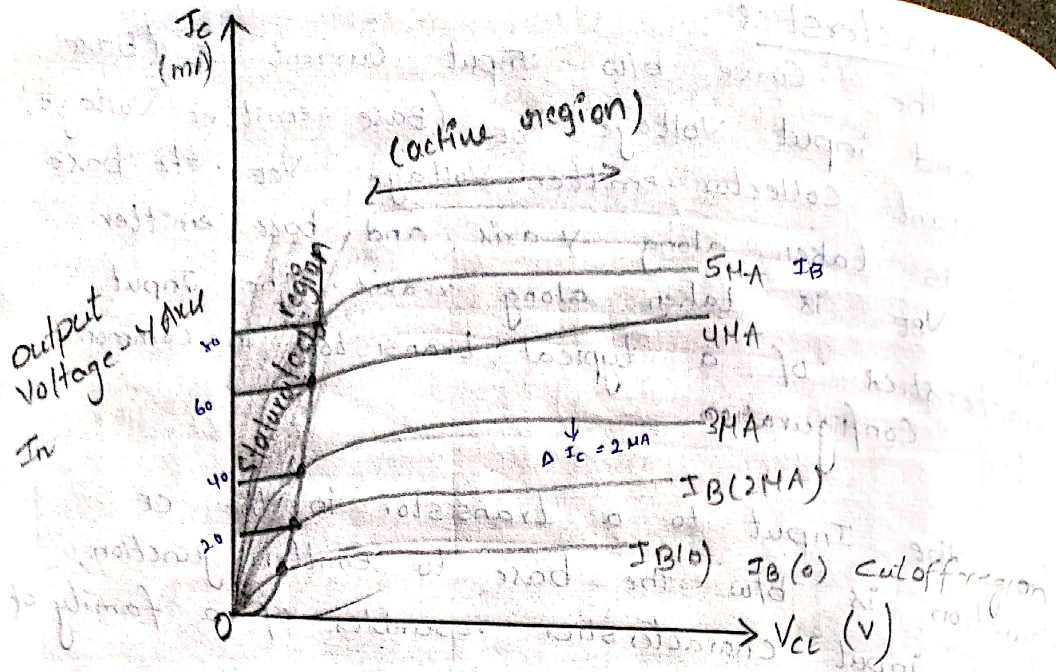
$V = IR$, $R = V/I$

ri = dynamic Resistance

⇒) for a fixed value of V_{BE}, I_B decreases as V_{CE} is Increased. A larger Value of V_{CE} results in a large reverse bias at collector-base p-n junction. This Increases the depletion region and reduces the effective width of the base. Hence there are fewer recombinations in the base region, reducing the base Current I_B.

B) output characterstics

1) This characterstics shows the relation b/w the Collector Current I_C and Collector Voltage V_{CE} for Various fixed values of I_B. This characterstics is often Called collector characterstics. A typical family of output characterstics for an n-p-n transistor in CE Configuration.



2) The value of β_{dc} of the transistor can be found at any point on the characteristics by taking the ratio I_C and I_B at that point, i.e $\beta_{dc} = \frac{I_C}{I_B}$. This is known as DC beta for the transistor for a fixed value of V_{CE}. If we take the ratio of small change in I_C, ΔI_C to small change in I_B, ΔI_B we get AC beta ;

$$\beta_{dc} = \frac{\Delta I_C}{\Delta I_B}\Bigg|_{\Delta V_{CE} = 0}$$

3) ⇒ from the output characteristics we can see that change in collector emitter voltage (ΔV_{CE}) causes the little change in the collector current for constant base current I_B. Thus the output dynamic resistance is high in CE configuration

$$r_o = \frac{\Delta V_{CE}}{\Delta I_C}\Bigg|_{I_B = \text{constant or } \Delta I_B = 0}$$

4) The output characteristics of common emitter configuration consists of three regions: Active Saturation and Cut-off

Active region : the region where the curves are approximately horizontal is the active region of the CE configuration. In the active region, the collector junction is reverse biased. As V_{CE} is increased, reverse bias increases. This causes depletion region to spread more in base than in collector, reducing the chances of recombinations in the base. This increases the value of α_{dc}. This early effect causes collector current to rise more sharply with increasing V_{CE} in the linear region of output characteristics of CE transistor

From Kirchoff's Current law (KCL)

We have $I_E = I_C + I_B$

Sub value of I_E in eq

$$I_C = \alpha(I_C + I_B) + I_{CO}$$

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

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

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

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

usually $I_B >> I_{CO}$ and hence $I_C = \beta I_B$ in the Active region.

Saturation region :-

If V_{CE} is reduced to a small value such as 0.2V then collector base junction becomes forward biased, since the emitter base junction is already forward biased by 0.7V. The input junction in CE configuration is base to emitter junction which is always forward biased to operate transistor in active region. Thus input characteristics of CE configuration is similar to forward characteristics of p-n junction diode. When both the junctions are forward biased, the transistor operates in the saturation region, which is indicated on the output characteristics. The saturation value of V_{CE} designated V_{CE}, usually ranges ~~for~~ between 0.1V to 0.3V

7) cut-off region :- when the input base current is made equal to zero, the collector current is the Reverse leakage current I_{CEO}. The region below $I_B = 0$ is the cut-off region of operation for the transistor. In this region, both the junctions of the transistor are reverse biased

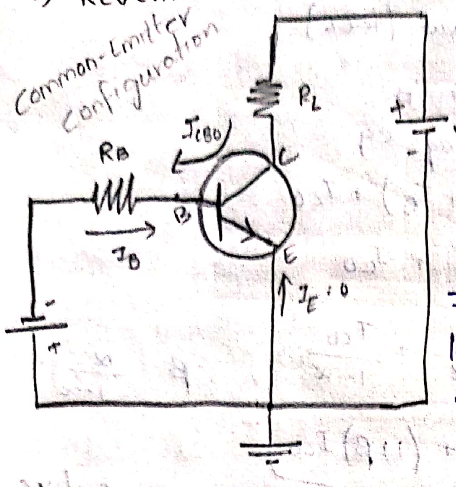
$$I_B = 0$$

$$I = I_E$$

$$I_C = (1+\beta) I_{CO} = \frac{I_{CO}}{1-\alpha} = I_{CEO}$$

The actual collector current with collector junction reverse biased and base open-circuited is designated by the symbol I_{CEO}.

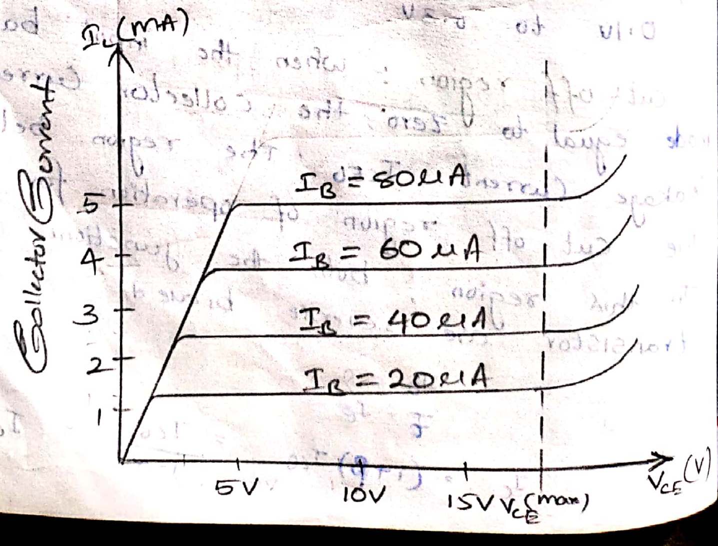
8) Reverse Collector Saturation Current :-



The collector current in a physical transistor when the emitter current is zero is designated by the symbol I_{CBO}. The $|I_{CBO}|$ is larger than I_{CO} since it also constitutes leakage current around the junction and across the surface. Another reason why I_{CBO} exceeds I_{CO} is that new carriers may be generated by collision in the collector junction transition region leading to avalanche multiplication of current & eventual breakdown. The I_{CBO} is a temperature positive. It approximately doubles for every 10°C increase in temperature for both Ge

9) In the active region, the collector base junction is reverse biased for every transistor there is limit on the maximum value for this reverse bias voltage. If this limit is exceeded the breakdown occurs in the transistor. This effect is commonly known as punch through effect.

This large current may damage resistor. Hence in practice maximum collector emitter voltage rating V_{CE} should never be exceeded for the safe operation of the transistor.



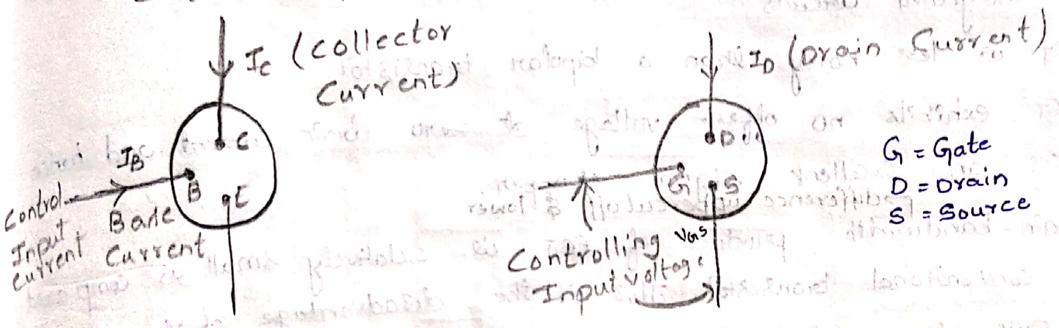
Field effect Transistors

Background

The field effect Transistor abbreviated as FET is an another semiconductor device like a BJT which can be used as an amplifier or switch, like BJT, FET is also a three terminal device however, the principle of operation of FET is completely different from that of BJT.

The three terminals of FET are named as Drain (D), Source (S) and gate (G). out of these three terminals gate terminal acts as a controlling terminal

Controlled output Current



BJT: Current controlled devices

FET : Voltage Controlled device ⇒ output current ni (Input) (GS) Voltage Control chestundhi

fig 7.1 Controlling element for BJT & FET

FET: Voltage Controlled Device

Input voltage output Current ni Control Chestundhi

As shown in the fig. 7.1, in BJT the output current, I_C is controlled by the base current I_B. Hence BJT is a current controlled device. On the other hand, in FET, the voltage applied between gate and source (V_{GS}) controls the drain current I_D. Therefore, FET is a voltage controlled device. The name "Field Effect" is derived from the fact that the output current flow is controlled by an electric field set up in the device by an externally applied voltage between gate and source terminals.

FET : Unipolar device

We know that in BJT, the current is carried by both electrons and holes, and hence the name "bipolar" junction transistor. However in FET, current is carried by only one type of charge particles, either electrons or holes. Hence FET is called unipolar device.

FET : Other important features

→ Like BJT, the parameters of FET are also temperature dependent. In FET, as temperature increases drain resistance also increases, reducing the drain current. Thus unlike BJT, thermal runaway does not occur with FET. Thus we can say that FET is more temperature stable as compared to the BJT.

→ FET has very high input impedance. Typically, it is in the range of one to several megaohms. Because FETs have higher input impedance than BJT they are preferred in amplifiers where high input impedance is required.

→ FETs require less space than for BJT's, hence they are preferred in integrated circuits.

→ FET is less noisy than a bipolar transistor.

→ FET exhibits no offset voltage at zero drain current, and hence makes an excellent signal chopper.

→ Gain-bandwidth (difference uppercutoff & lower) product of FET is relatively small as compared to conventional transistor. This is the disadvantage of the FET.

FET: Different Types and Application Areas

The FETs are categorized as:

→ Junction field Effect Transistors (JFETs),

→ Metal Semiconductor field Effect Transistors (MESFETs)

→ Metal oxide Semiconductor field Effect Transistors (MOSFETs)

The JFETs and MESFETs are further classified into two types as n-channel JFET/MESFET and p-channel JFET/MESFET and MOSFETs are further classified into two types as, depletion MOSFET and enhancement MOSFET. The fig 7.2 shows the different types of FETs.

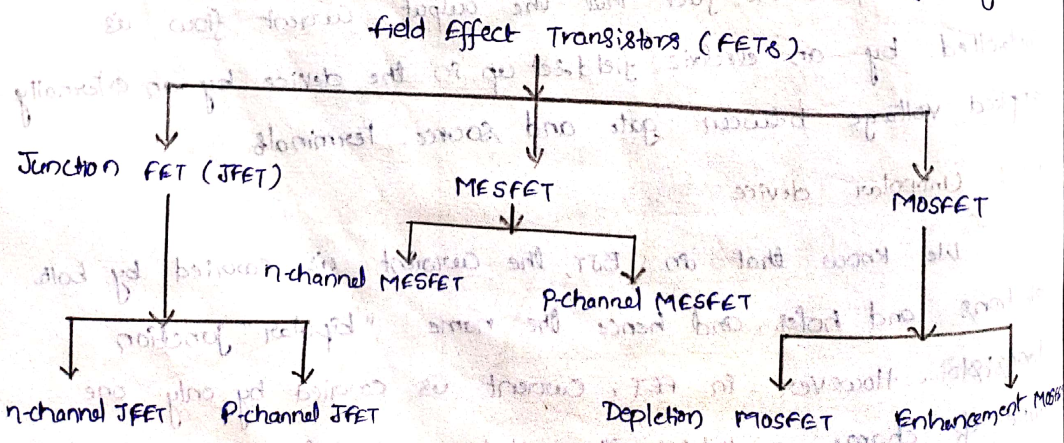


Fig 7.2. Different types of FETs

Construction of n-channel JFET and Symbol

The fig 7.3. shows structure and symbol of n-channel JFET. A small bar of extrinsic semi Conductor material, n type is taken and at its two ends, two ohmic contacts are made which are the drain and source terminals of FET. Heavily doped electrodes of p type material form p-n junctions on each side of the bar. The thin region between the two p gates is called the channel. Since this channel is in the n-type bar, the FET is known as n-channel JFET.

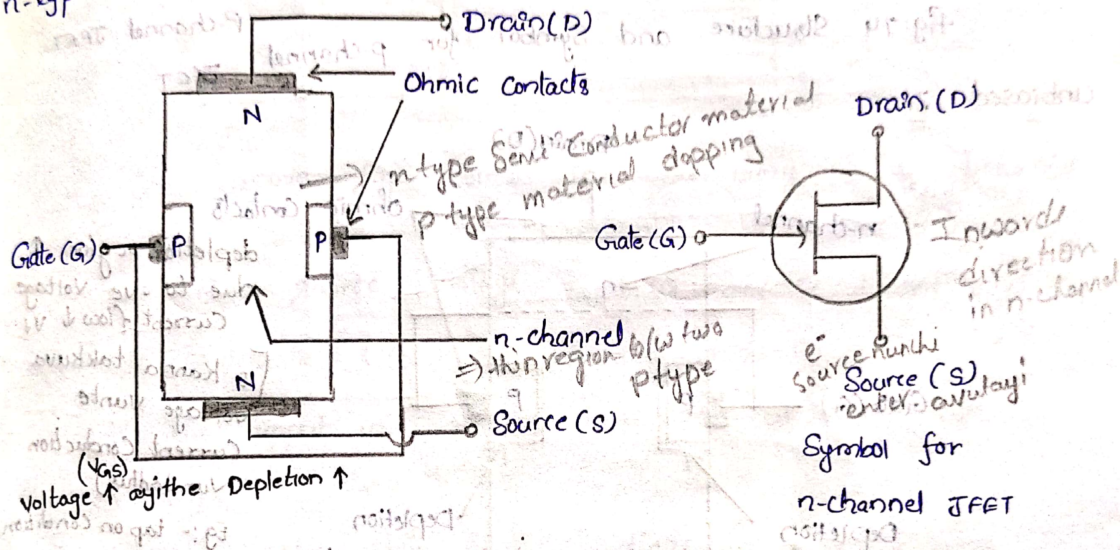
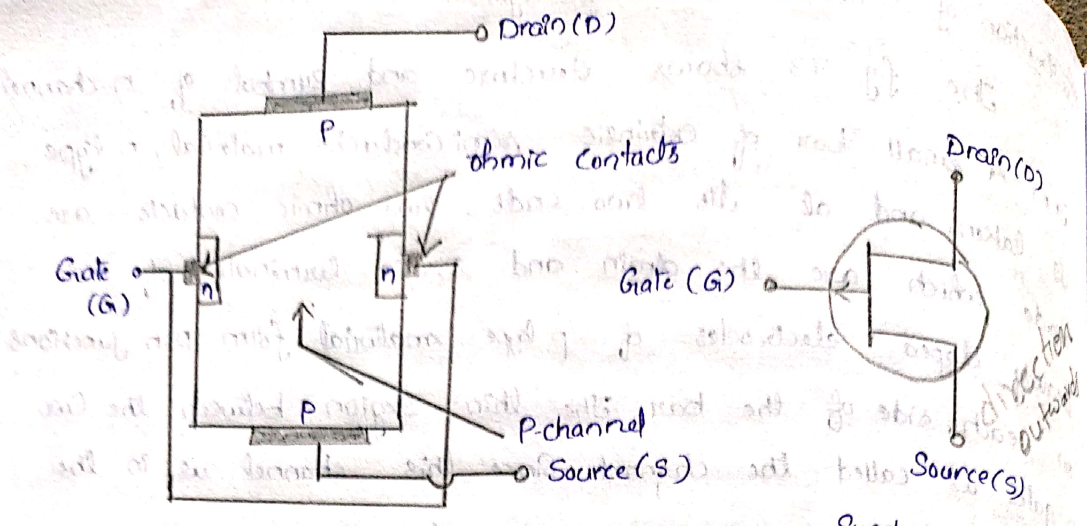


fig 7.3 Structure and Symbol for n-channel JFET

The electrons enter the channel through the terminal called source and leave through the terminal called drain. The terminals taken out from heavily doped electrodes of p type material are called gates. Usually these electrodes are connected together and only one terminal is taken out, which is called gate, as shown in the fig 7.3

Construction of p-channel JFET and Symbol

The device could be made of p type bar with two n type gates as shown in the fig 7.4. Then this will be p-channel JFET. The principle of working of n-channel JFET and p-channel JFET is similar, the only difference being that in n-channel JFET the current is carried by electron while in P-channel JFET, it is carried by holes.

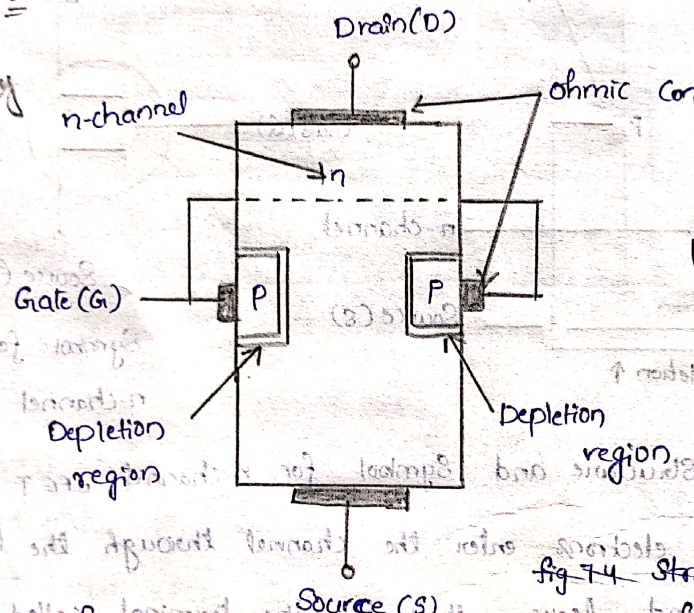


Symbol for P-channel JFET

fig 7.4 Structure and Symbol for p-channel JFET

Unbiased JFET

elu vonti voltage apply cheyyam



depletion region ↑ due to -ve Voltage Current flow ↓ Vt

[o Kanna takkuva Voltage vunte Current Conduction vundadhu]

Eg :- tap on Condition

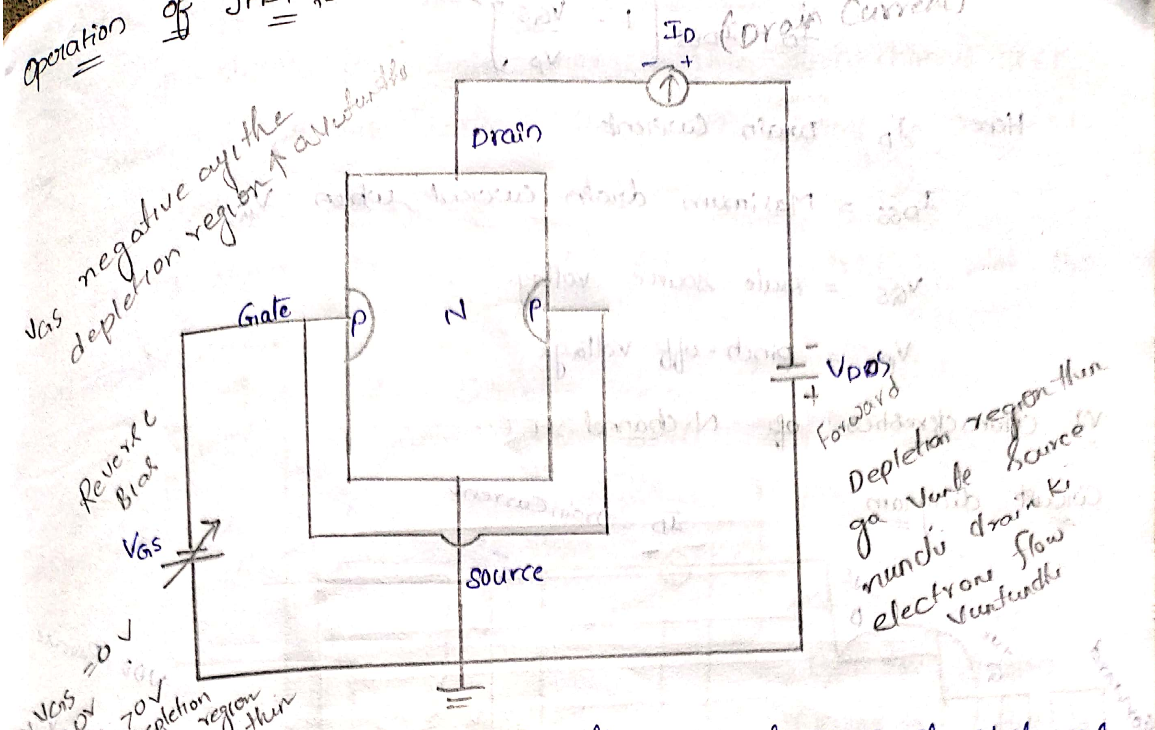
~~fig 7.4 Structure and symbol for p-channel JFET~~

fig 7.5 Junction field Effect Transistor

In the absence of any applied voltage, JFET has gate channel junctions under no bias conditions. The result is a depletion region at each junction, as shown in fig 7.5.

This represents same depletion region of a diode under no bias Conditions. Recall also that depletion region is that region which does not have any free carriers and therefore is unable to support conduction through the region

Operation of JFET :-



The above fig. shows the ckt diagram of N-channel FET.

The Gate - source voltage V_{GS} is reverse biased and drain source voltage (V_{DS}) is forward biase

i.e., the input is reverse bias and it offers high resistance. -ve voltage

When reverse Gate source voltage is kept constant. The drain current varies with output voltage (V_{DS}).

When reverse V_{GS} increases, the channel width decreases Consequently the drain current decreases.

i.e The output drain current is controlled by output voltage.

As the reverse V_{GS} increases to a particular voltage then the channel width is zero and drain current is also zero. This particular reverse voltage is known as "pinch off voltage". It is denoted by V_P.

depletion $\propto \frac{1}{\text{region/space channel width}}$

From the above explanation it is clear that the drain current through N-channel is depends upon the electric field extends with channel and provides the effect of decreasing in conduction to FET. Hence the name field effect transistor is given to its device.

Scanned with OKEN Scanner

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

Here I_D = Drain current

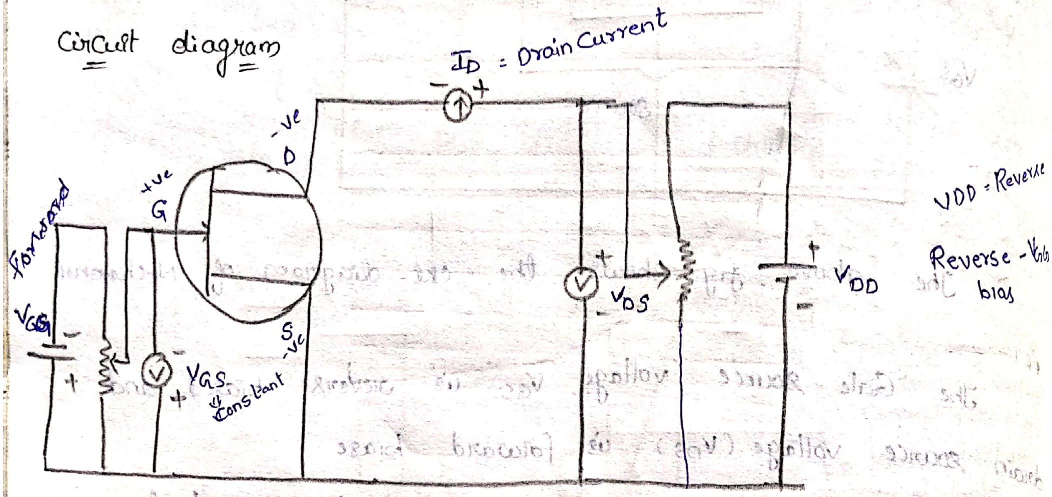
I_{DSS} = Maximum drain current when V_{GS}

V_{GS} = Gate source voltage

V_P = pinch-off voltage

VI characterestics of N-channel JFET :-

Circuit diagram



The above fig. shows the ckt diagram of N-channel JFET. , this ckt consists two d.c sources V_{GG} and V_{DD}.

V_{GG} source reverse biasing the gate source and V_{DD} forward biasing the drawn source.

The two rheostats are used to varying input and output voltages.

Output characteristics

A graph between output voltage V_{DS} and output current I_D at a constant input voltage V_{GS} is called output characteristics or Drain characteristics

Keeping the V_{GS} at a constant values. the drawn source voltage (V_{DS}) is varies in small steps and note the drain current I_D values.

A graph drawn between V_{DS} vs I_D at different fixed values of V_{GS}. The graph & table is shown in below.

V-I characterestics for n-channel JFET

It shows the drain characterestics of n-channel JFET. The curves represent between the drain current I_D and drain to source voltage V_{DS} for the difference

fig 7.9 shows the experimental setup required to plot this characteristics.

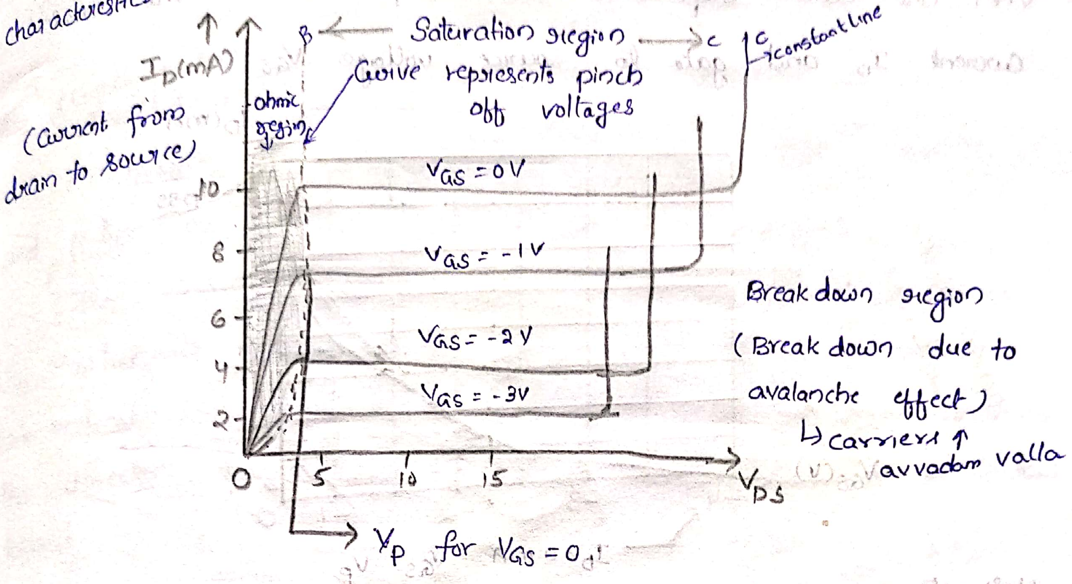


fig 7.8 Drain V-I characterestics of n-channel JFET

For low values of V_{DS} the I_D is linearly increases with V_{DS}.

i.e, the FET ~~betwee~~ behaves like ordinary resistor (i.e) obeys the ohms law and hence OA region is called "ohmic region", the point A is called.

As V_{DS} further increases, the I_D is non linearly increases upto a point B, after that I_D remains constant and independent on V_{DS}.

The drain source voltage current remains constant above which voltage of V_{DS} is called Pinch-off voltage.

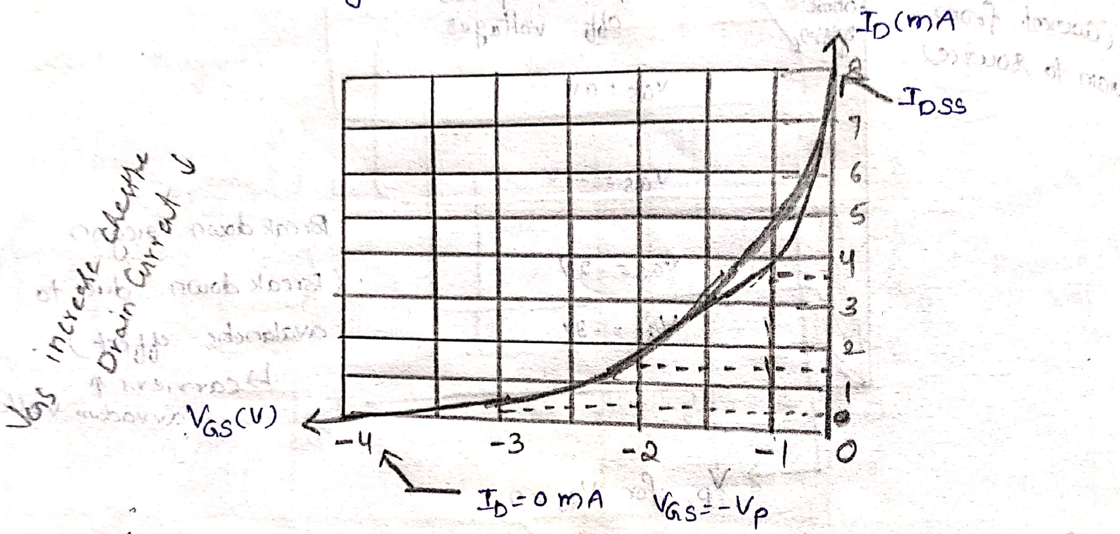
The region 'BC' is called active region or pinch-off region or saturation region.

If V_{DS} is increased beyond this point C. The FET enters into breakdown region then voltage corresponding to point 'C' is known as "Avalanche breakdown".

In the above graph, I_{DSS} is the maximum drain current
when $V_{GS}=0V$ or drain to source current when gate is short circuited

Transfer characteristics of n-channel JFET

fig 7.12 shows the transfer characteristics of n-channel JFET. The curve represents relationship between the drain current I_D and gate to source voltage V_{GS}.



Unijunction Transistor:- (UJT)

A unijunction transistor (UJT) is a device which does not belong to thyristor family but is used to turn on SCRs.

It is three terminal device, having two layers. It Consists of a slab of lightly doped n type silicon material. The two base contacts are attached to both the ends of this n-type surface. These are denoted as B_1 and B_2 respectively. A p-type material is used to form a p-n junction at the boundary of aluminium rod and n type silicon slab. The third terminal called emitter (E) is taken out from this p-type material. The n-type is lightly doped while p type is heavily doped. The basic construction is shown in fig 7.54.

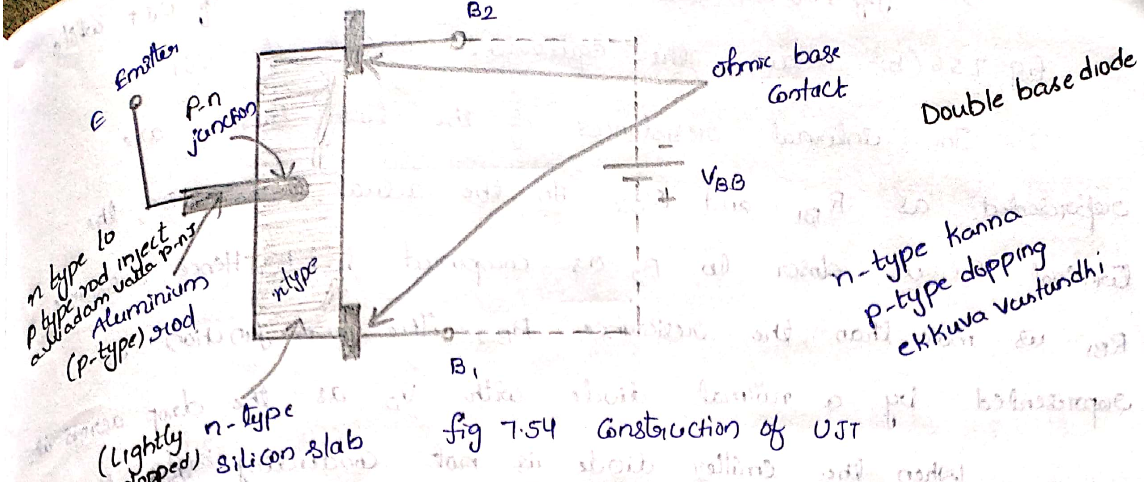


fig 7.54 Construction of UJT

As n type is lightly doped, it provides high resistivity and p-type as heavily doped. provides low resistivity.

The symbolic representation of UJT is shown in fig 7.55. The emitter is shown by an arrow which is at an angle to the vertical line representing n-type material. This arrow indicates the direction of flow of conventional current when UJT is forward biased.

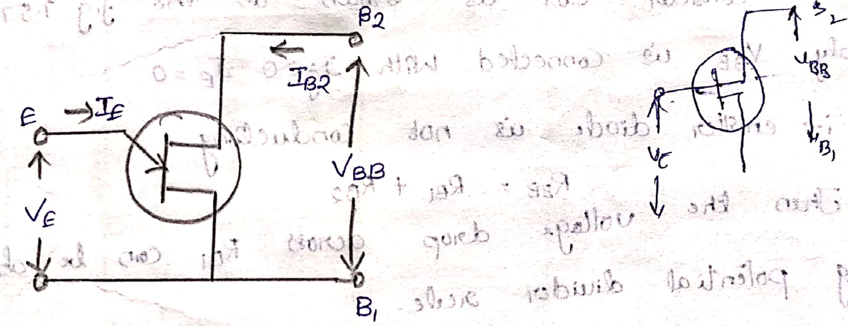
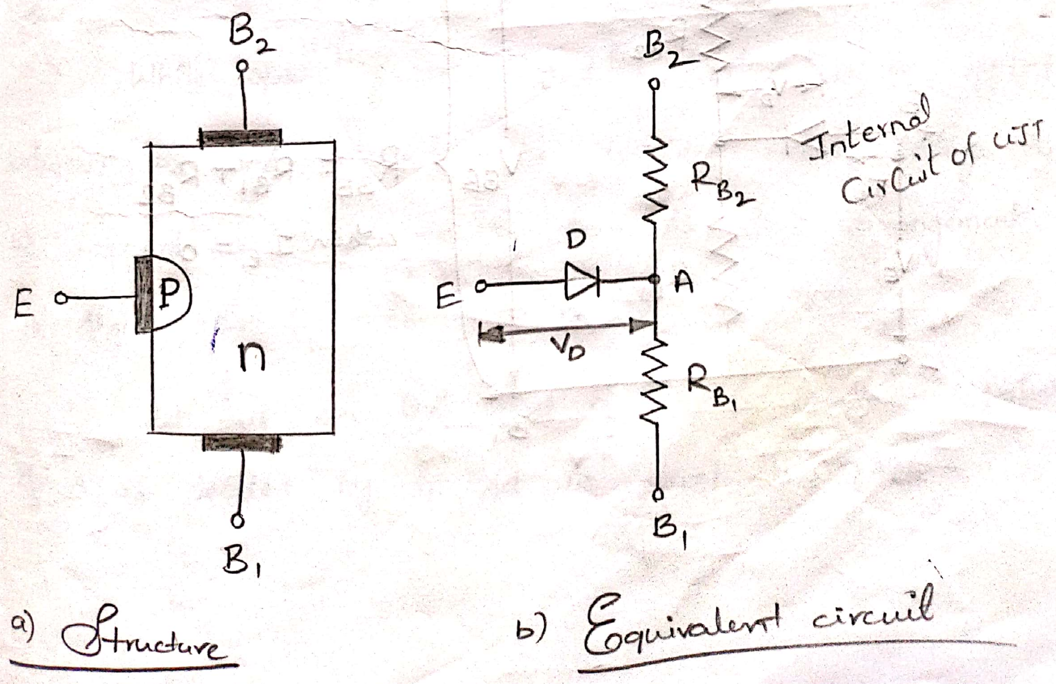


fig 7.55 Symbol of UJT

Equivalent circuit of UJT:- (diode Conduct avvakapothe)



The fig 7.56 (a) shows the basic structure of UJT while the fig 7.56 (b) shows the equivalent circuit of UJT.

The internal resistances of the two bases are represented as R_{B1} and R_{B2}. In the actual construction, the terminal E is closer to B_2 as compared to B_1. Hence resistance R_{B1} is more than the resistance R_{B2}. The p-n junction is represented by a normal diode with V_D as the drop across it.

When the emitter diode is not conducting then the resistance between the two bases B_1 and B_2 is called interbase resistance denoted as R_{BB}.

$$\therefore \quad R_{BB} = R_{B1} + R_{B2}$$

Its value ranges between $4K\Omega$ and $12K\Omega$.

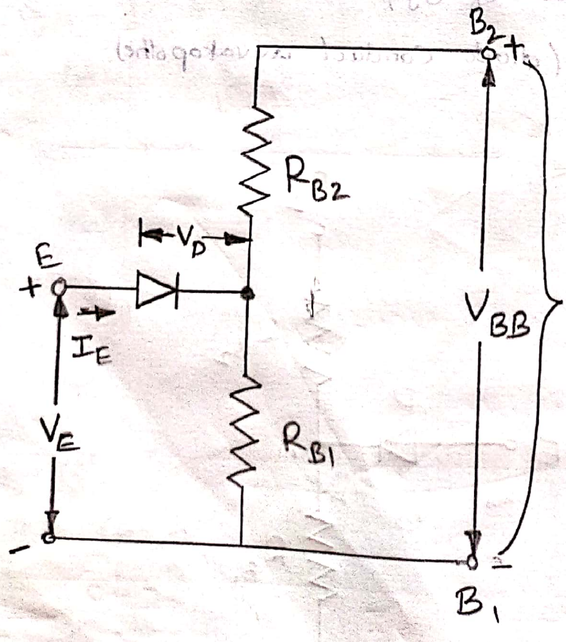
Intrinsic Stand off Ratio (η) diode conduct ayrthe

Consider UJT as shown in the fig 7.57 to which supply V_{BB} is connected. With ~~$I_g = 0$~~ $I_E = 0$

i.e emitter diode is not conducting

$$R_{BB} = R_{B1} + R_{B2}$$

Then the voltage drop across R_{B1} can be obtained by using potential divider rule.



$R_{BB} = R_{B1} + R_{B2}$

when $I_E = 0$

$\mapsto$ Total applied Voltage

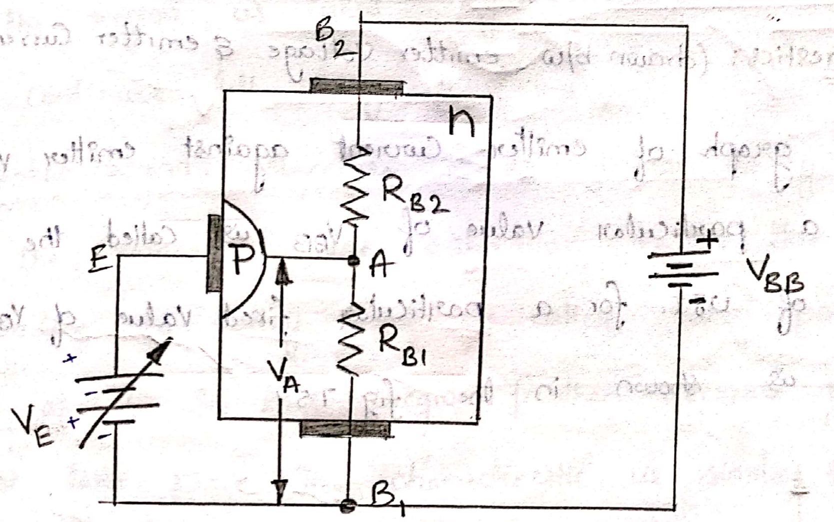
$$V_{RB1} = \frac{R_{B1} V_{BB}}{R_{B1} + R_{B2}} = \eta V_{BB} \quad \text{when } I_E = 0$$

eeta $\leftarrow \eta$ = Intrinsic stand off ratio $= \left. \dfrac{R_{B1}}{R_{B1} + R_{B2}} \right|_{I_E = 0}$

$$\eta = \left. \frac{R_{B1}}{R_{BB}} \right|_{I_E = 0}$$

The typical range of η is from 0.5 to 0.8. The voltage V_{RB_1} is called intrinsic stand off voltage because it keeps the emitter diode reversed biased for all the emitter voltage less than V_{RB1}.

Principle of operation



While operating an UJT, the supply V_{BB} is applied between B_2 and B_1 while the Variable emitter voltage V_E is applied across the emitter terminals. This arrangement is shown in fig 7.58.

Let us see the effect of change in V_E. The potential of A is decided by η and is equal to ηV_{BB}.

V_E = Applied voltage
V_A = Voltage at point A

Case 1 :- $V_E < V_A$

As long as V_E is less than V_A, the p-n junction is reverse biased. Hence emitter current I_E will not flow. Thus UJT is said to be OFF.

$V_p = V_D + V_{RB_1}$ $\boxed{V_p = V_A + V_D}$
V_D = voltage drop across the diode

Case 2: $V_E > V_P$

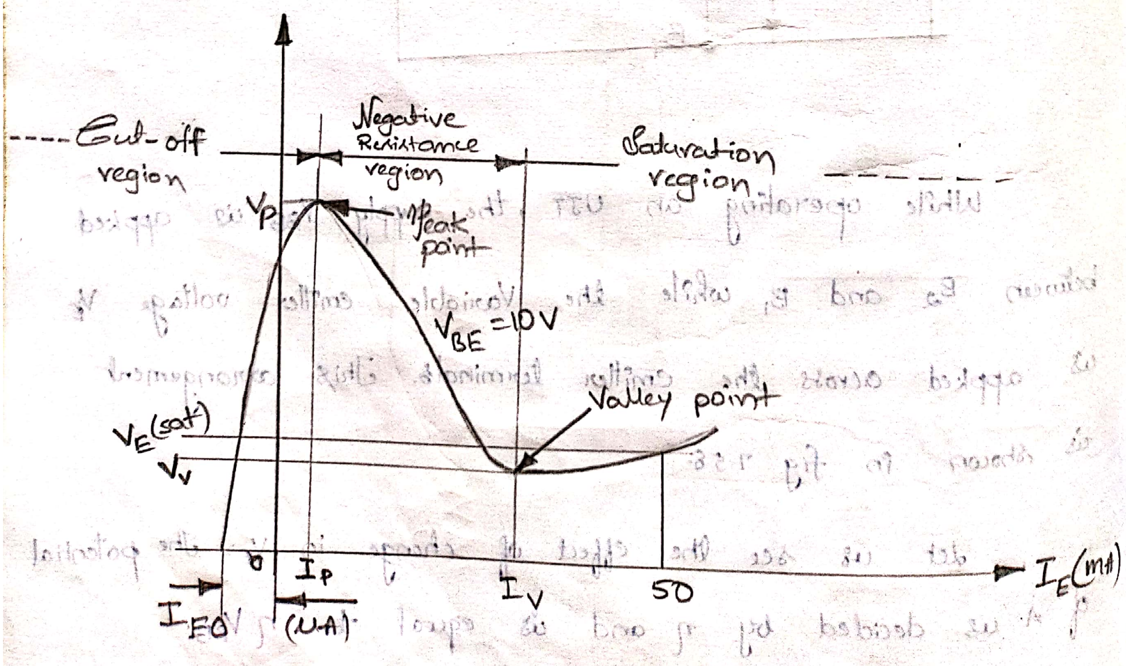
The diode drop V_D is generally between 0.3 to 0.7V. Hence we can write.

$$V_P = V_A + V_D = \eta V_{BB} + V_D$$

When V_E becomes equal to or greater than V_p the p-n junction becomes forward biased and current I_E flows. The UJT is said to be ON.

UJT characteristics: (drawn b/w emitter voltage & emitter Current)

The graph of emitter current against emitter voltage plotted for a particular value of V_{BB} is called the characteristics of UJT. for a particular fixed value of V_{BB} such characteristics is shown in the fig 7.59.



The characteristics of can be divided into three main regions which are,

1. cut-off region : The emitter voltage V_E is less than V_P
UJT(off condition) $I_E \approx 0$
and the p-n junction is reverse biased. A small amount of reverse saturation current I_{EO} flows through the device, which is negligibly small of the order of μA. This condition remains till the peak point.

2. Negative resistance region : When the emitter voltage V_E becomes
UJT(ON) $I\uparrow V\downarrow$
equal to V_P the p-n junction becomes forward biased and I_E starts flowing. The voltage across the device decreases in this region, though the current through the device increases. Hence the region is called negative resistance region. This region continues till valley point.
(peak point - valley point region)
-ve R

3. Saturation region : Increase in I_E further valley point I_V drives the device in the saturation region. The voltage corresponding to valley point is called valley point voltage denoted as V_V. In this region, further decrease in voltage does not take place. The characterestic is similar to that of a semiconductor diode, in this region.

The active region i.e. negative resistance region, the holes which are large in number on P-side, get injected into n-side. This cause increase in free electrons in the n-type slab. This increases the conductivity i.e., decreases the resistivity. Hence the resistance R_{B1} decreases in this region.

As the V_{BB} increases, the potential V_P corresponding to peak point will increase.

decrease ayi malli Increase ayina curve
(valley point nunchi increase avutundhi)
Akkada vunde current valley current

$I\uparrow V\uparrow$

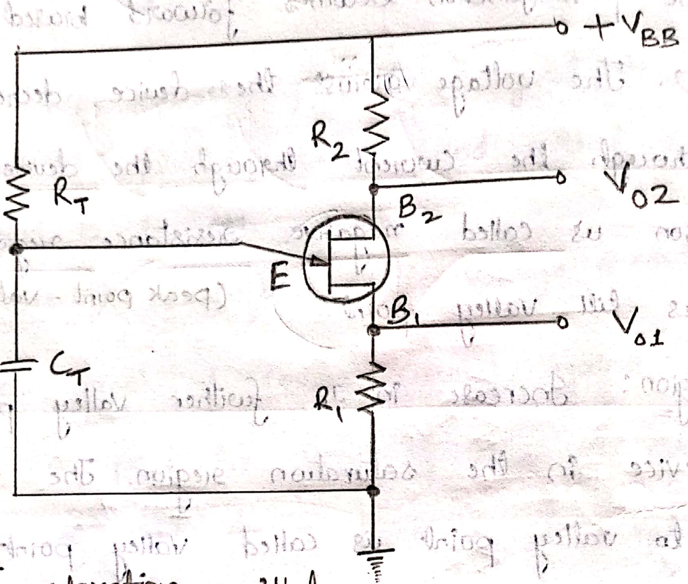
Scanned with OKEN Scanner

Applications

The UJT is mainly used in the triggering of other devices such as SCR. It is also used in the sawtooth wave generators and some timing circuits. The most popular application of UJT is as a relaxation oscillator to obtain short pulses for triggering of SCRs. Let us discuss UJT relaxation oscillator in detail.

UJT Relaxation Oscillator (generates the frequency).

Without applying any input results output uses in pulse circuit (digital ckt)



UJT relaxation oscillator

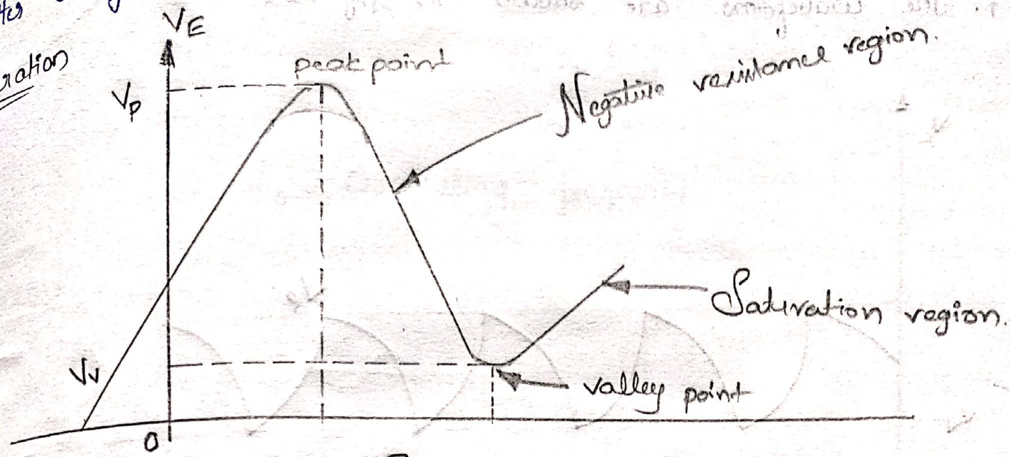
The pulse signal required to drive the digital circuits can be obtained from a single stage oscillator circuit using a particular device like unijunction transistor. Such a oscillator which uses UJT is called UJT relaxation oscillator. The basic circuit of UJT relaxation oscillator is shown in the fig 7.60.

The R_1 and R_2 are biasing resistances which are selected such that they are lower than interbase resistances R_{B1} and R_{B2}. The resistance R_T and the capacitance C_T decide the oscillating rate. The value of R_T is so selected that the operating point of UJT remains in the negative resistance region. The UJT characteristics and the negative resistance region

Current ~~~~ the Voltage ~~~~ region

Operation

of the characteristics are shown in fig 7.61. The characteristics of UJT shows the variation between V_E and I_E, where V_E is emitter voltage and I_E is emitter current.



UJT Characteristics

Capacitor C_T gets charged through the resistance R_T towards supply voltage V_{BB}. As long as the capacitor voltage is less than peak voltage V_P, the emitter appears as an open circuit.

$$V_P = \eta V_{BB} + V_D \longrightarrow (1)$$

peak voltage ki vellake discharge avutundhi UJT on

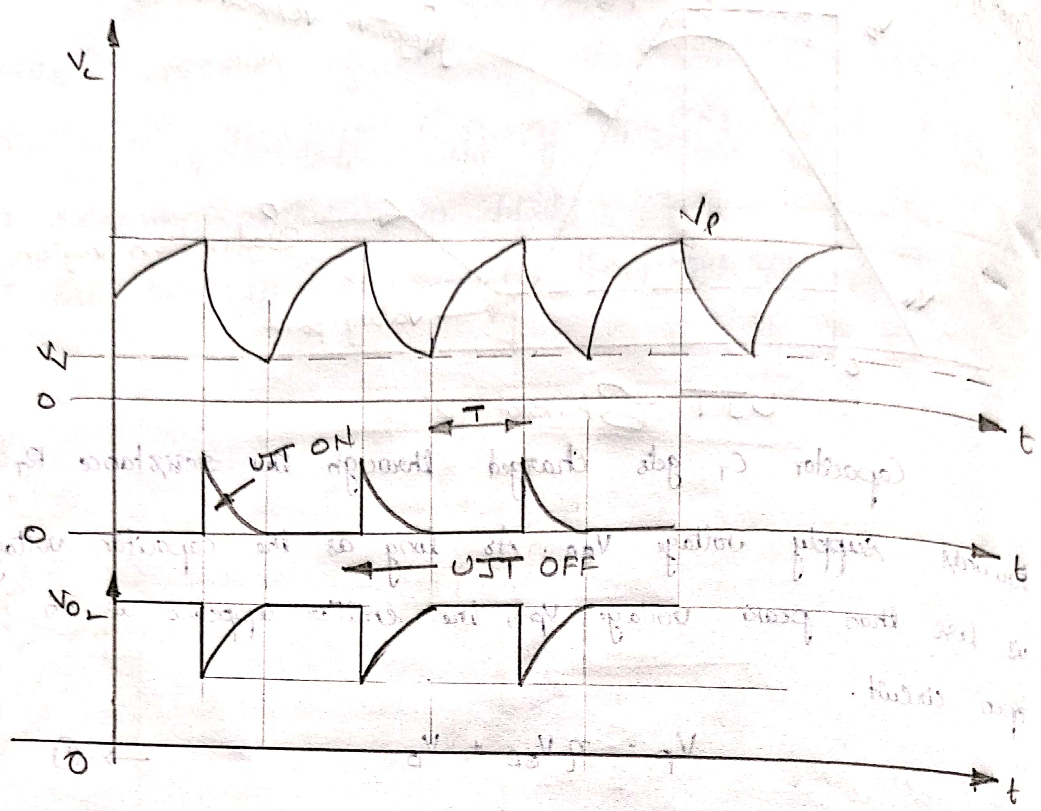
where η = stand off ratio of UJT

V_D = Cut-in voltage of diode

When the capacitor voltage V_C exceeds the voltage V_P, the UJT fires. The capacitor starts discharging through $R_1 + R_{B1}$ where R_{B1} [internal base] resistance. As R_{B1} is assumed negligible and hence capacitor discharges through R_1

Due to the design of R_1, this discharge is very fast, and it produces a pulse across R_1. When capacitor voltage falls below V_V i.e $V_C = V_E = V_V$, the UJT gets turned off. ~~charging time constant~~ The capacitor starts charging again.

The discharge time of the pulse is controlled by the time constant $C_T R_1$ while the charging time constant by $R_T C_T$. The waveforms are shown in fig 7.62



Waveforms of UJT relaxation oscillator

There is voltage drop across R_2 and voltage rise across R_1, when UJT fires.

The charging equation of the capacitor is given by

$$V_{C(t)} = V_V + V_{BB}\left[1 - e^{-t/R_T C_T}\right]$$

But

$$V_{C(t)} = V_P, \text{ at } t = T$$

$$V_P = V_V + V_{BB}\left[1 - e^{-T/R_T C_T}\right]$$

using the equation (1)

$$\therefore \eta V_{BB} + V_D = V_V + V_{BB}\left[1 - e^{-T/R_T C_T}\right]$$

Neglecting V_D and V_V to get approximate relation for T,

$$\eta = 1 - e^{-T/R_T C_T}$$

$$T = R_T C_T \ln\left[\frac{1}{1-\eta}\right]$$

$$f_0 = \frac{1}{T} = \frac{1}{R_T C_T \ln\left[\frac{1}{1-\eta}\right]}$$

f_0 = Oscillating frequency