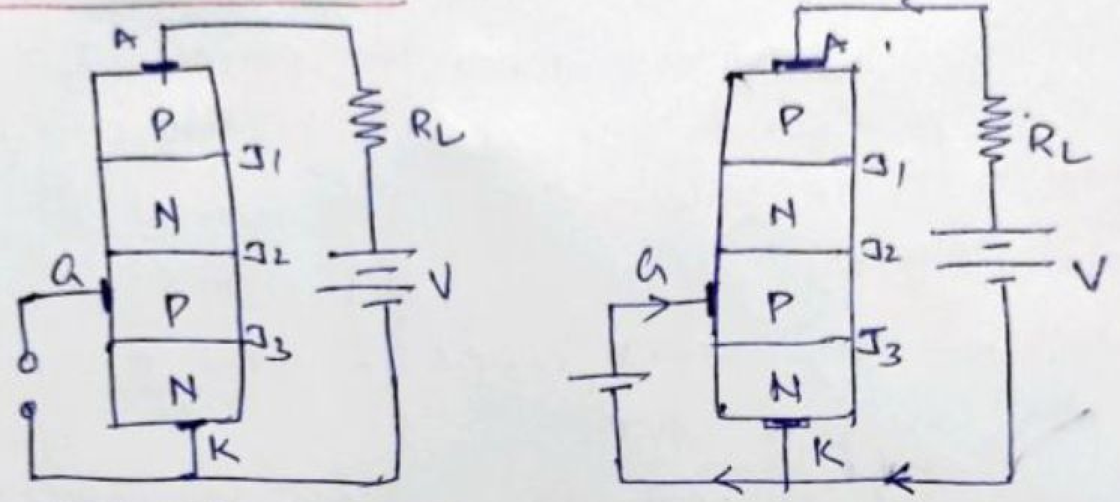
SILICON CONTROLLED RECTIFIER (SCR)

It is a four layer semiconductor device being alternate of P-type and N-type silicon. Fig 2 (a) shows the structure of SCR while in Fig 2(b) shows its symbolic representation. It is obvious from the figure that it consists of three Junctions J_1, J_2 and J_3 (J_1 and J_3 operate in forward direction while middle operates in reverse direction) and three terminals known as anode A, cathode K and gate G.

The function of gate is to control the firing of SCR. It conducts only in one direction i.e, from anode to cathode and hence constitutes unidirectional device.

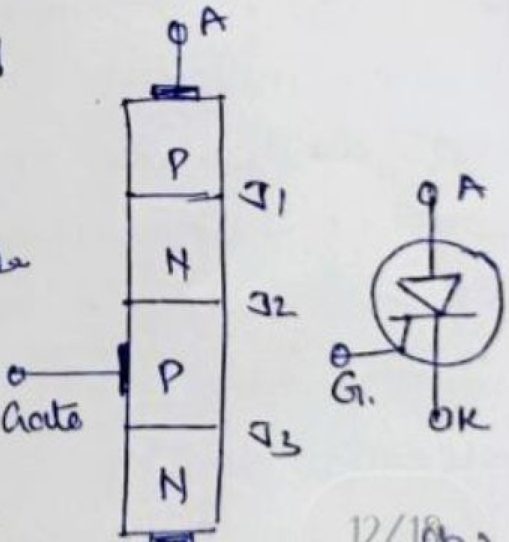
<u>Operation of SCR.</u>



(a) gate is open (b) gate is positive

Fig ②. operation of SCR.

In SCR, a load is connected in series with anode and anode is kept at positive potential with respect to cathode with the help of a battery. The operation of SCR can be studied when the gate is open and when the gate is positive w.r.t cathode. The situation are shown in Fig ②.



(a)

Fig ①. structure and symbolic representation of SCR.

<u>When the gate is open</u>, no voltage is applied at the gate. Under this condition, junctions J_1

and J_3 are forward biased while the junction J_2 is reverse-biased. Due to ~~this~~ reverse-biased of junction J_2, no current flows through R_L and hence the SCR is cut off. However, when the anode voltage is increased, a certain critical value (break over voltage) is reached when the junction J_2 breaks down. The SCR now conducts heavily and is said to be in ON state. ~~Here~~ The current is limited only by the power supply and the load resistance. The current keeps flowing indefinetely untill the circuit is open.

<u>When the gate is positive</u> w.r.t cathode, junction J_3 is forward biased while junction J_2 is reverse biased. As shown in Fig (2)(b), electrons from N type material move across junction J_3 towards gate while hole from P type material moves across junction J_3 towards cathode. So gate current starts flowing. Due to this gate current, anode current increases. This in turn makes more electrons available at junction J_2. In an extremely smal time, junction J_2 breaks down and SCR conducts heavily. Once SCR starts conducting, the gate loses all controls. The current keeps flowing indefinetely untill the circuit is open.

—x—

ZENER DIODE AS VOLTAGE REGULATOR.

From the zener characteristics, under the reverse bias condition, the voltage across the diode remains almost constant although the current through the diode increases as shown in region AB. Thus the voltage across the zener diode serves as a reference voltage. Hence the diode can be used as voltage regulator.

In Fig below, it is required to provide constant voltage across load resistance R_L, where as the input voltage may be varying over a range. As shown, zener diode is reverse biased and as long as the input voltage does not fall below V_Z, the voltage across the diode will be constant and hence the load voltage will also be constant.

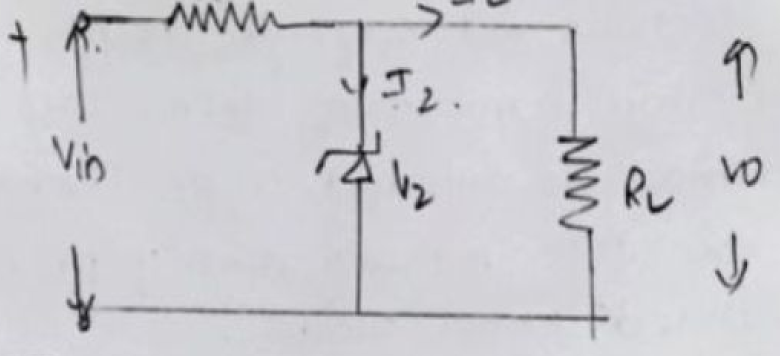


Fig. zener diode as voltage Regulator.

The 2 breakdown mechanisms are :

i) Zener breakdown

ii) Avalanche breakdown.

i) ZENER BREAKDOWN :-

Zener breakdown takes place in very thin junction i.e when both sides of junctions are very heavily doped and consequently the depletion layer is narrow. When a small reverse bias voltage is applied, a very strong electric field is set up across the thin depletion layer. This field is enough to break or rapture the covalent bonds. Now extremely large number of electrons and holes are produced which constitute the reverse saturation current (zener current). Zener current is independent of the applied voltage depends only on the external resistance.

ii) Avalanche breakdown:-

This type of breakdown takes place when both sides of junction are lightly doped and consequently the depletion layer is large. In this case, the electric field across the depletion layer is not so strong to produce zener breakdown. Here, the minority carriers accelerated by the field collide with the semi-conductor atoms in the depletion region.

Due to the collision with valence electrons, covalent bonds are broken and electron hole pairs are generated. These new carriers so produced acquire energy from applied potential and in turn produce additional carriers. This forms a cumulative process called as avalanche multiplication. The break down is called avalanche mechanism as shown in Fig below. This breakdown occurs at higher reverse voltages.

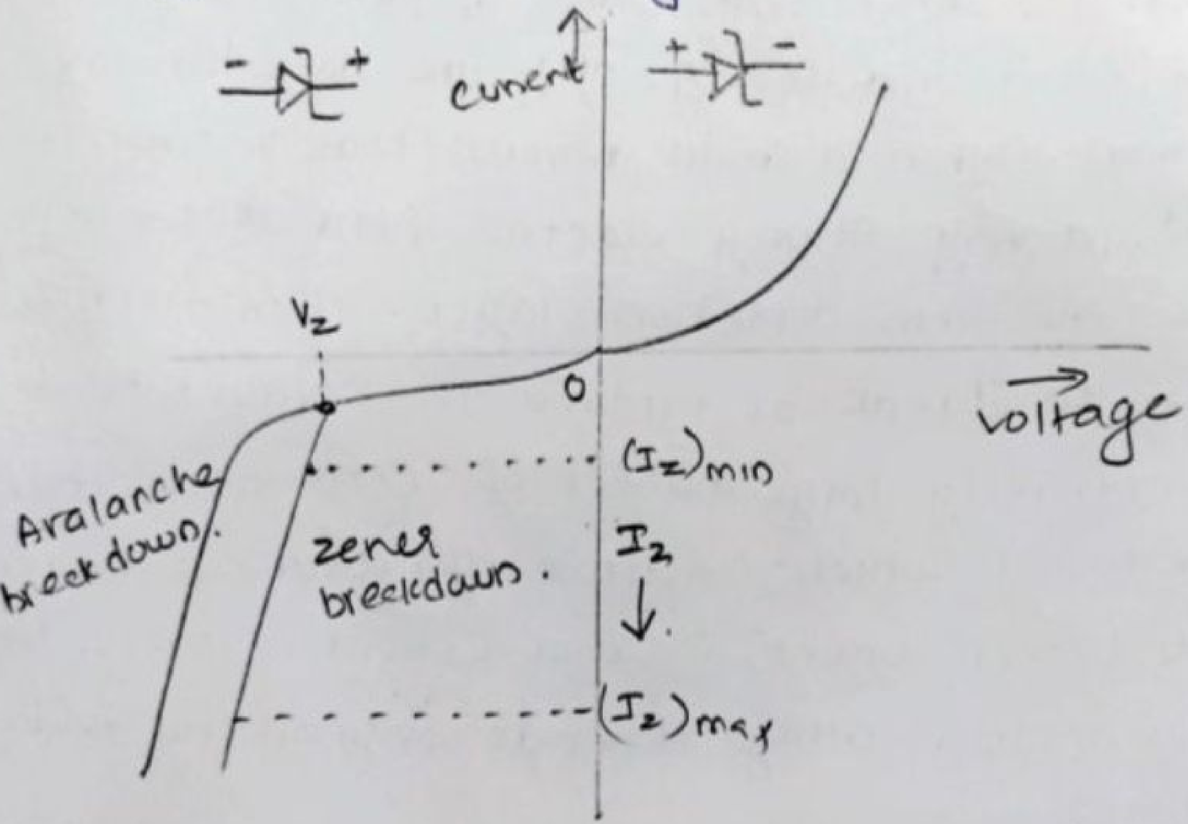


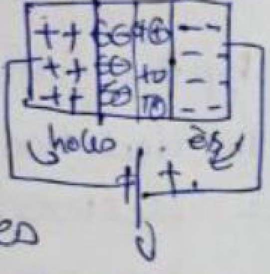
Fig. Showing zener and avalanche breakdowns.

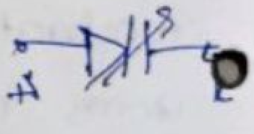
Q4: VARACTOR DIODE

The varactor, also called a varicap, tuning or voltage variable voltage capacitor diode, is also a junction diode with a small impurity dose at its junction, which has the useful property that its junction or transition capacitance is easily varied. ~~etc~~

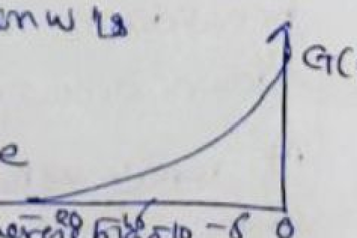
When any diode is reverse biased, a depletion region is formed, as seen in fig. The larger the reverse bias applied across the diode, the width of the depletion layer 'W' becomes wider. By ↓ the reverse bias voltage, the depletion region ~~reg~~ width 'W' becomes narrower. This depletion region is ~~em~~ devoid of majority carriers and acts ~~a~~ like an insulator preventing conduction b/w the N and P regions of the diode, just like a dielectric, which separate the two plates of capacitor. The varactor diode ~~circuit~~ with its symbol.

As the capacitance is inversely proportional to the distance b/w the plates ($C_T \propto \frac{1}{W}$), the transition capacitance C_T varies inversely with the reverse voltage as shown in fig. Consequently, an ↑ in reverse bias voltage will result in an increase in the depletion region width and a subsequent decrease in transition capacitance C_T.





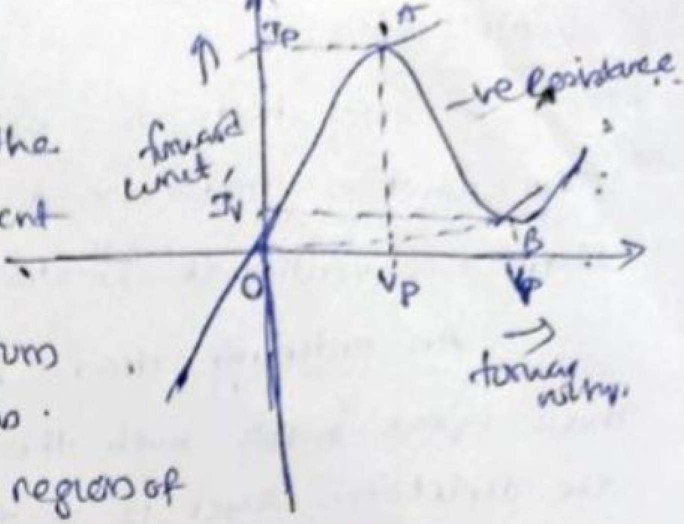
At zero volt, the varactor depletion region w is small, the cap is large at ≈ 600 pF. When the reverse bias voltage across the varactor is 15V, the capacitance is 30pF.

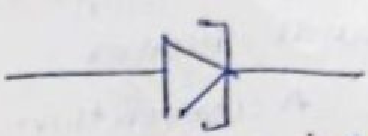


APP → used in FM, radio, TV Rx, AFC ckts, Parametric amp, tuning ckts.

V-I celś :-

The Right hand side portion is the denoted by point A. This current variation in the vicinity of original origin is due to quantum mechanical tunnelling of electrons through narrow space charge region of the junction. So as the voltage increases from zero to V_P, the current ↑ from zero to I_P.





Tunnel diode symbol.

When forward voltage is further increased, the diode current starts ↓ . The current decreases to I_V corresponding to valley voltage V_V. This is denoted by a point B. Thus from point A to B, the current decreases as voltage ↑. This results in negative resistance. In fact, this portion AB constitutes the most useful property of the diode. Hence tunnel diode can be used as a very high freq osc.

For voltages greater than V_V, currents starts ↑ as in case of conventional diode.

~~Tunneling theory with Energy band dia~~

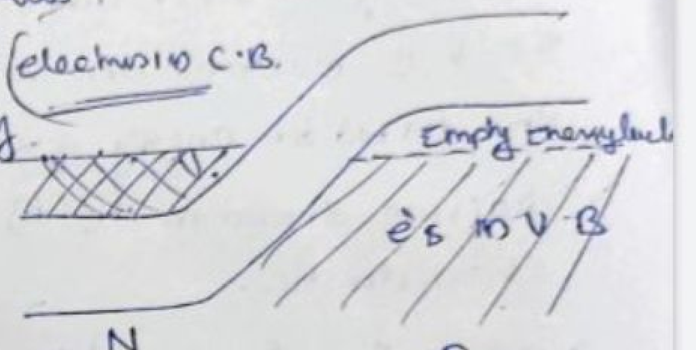
Energy band diagrams :-

The tunnelling phenomenon can be explained by considering the energy band diagram of p-type and n-type SC. materials. The fig shows the energy level diagrams of the tunnel diode for 3 interesting bias levels.

Shaded area shows the energy states occupied by electrons in the V.B, electrons in C.B.

Cross hatched region represent energy states in C.B occupied by ès.

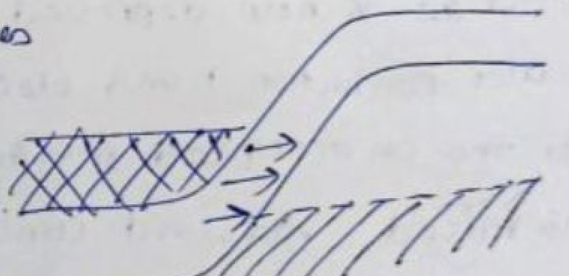
The levels to which the energy states are occupied by electrons on either side of the junction are shown by dotted lines.

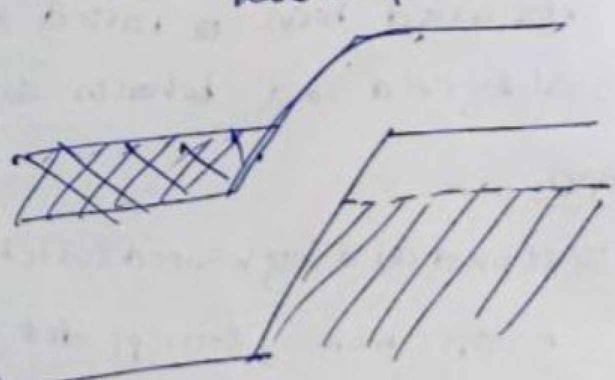


a) Zero bias voltage.

When the bias is zero, these lines are at the same height.

Unless energy is imparted to the electrons from some external source, the energy possessed by the ès on the n-side of the junction is insufficient to permit them to climb over the junction barrier to the P-side.





→ However quantum mechanics show that there is a finite probability for the ès to tunnel through the junction to reach the other side, provided there are allowed empty energy states in the p-side of the junction at the same energy level.

Hence the forward current is zero.

When a small forward bias is applied to the junction, the energy level of the p-side is lower as compared to the N-side. As shown in fig (3)(b) electrons in the C.B of the N-side see empty energy level on the p-side. Hence tunnelling from N-side to p-side takes place. Tunnelling in other directions is not possible because the V.B electrons on the p-side are now opposite to the forbidden energy gap on the N-side. The energy band diagram shown in fig (b) is for the peak of the diode characteristic.

→ When the forward bias is raised beyond this point, tunnelling will ↓ as shown in fig (c). The energy of the p-side is now depressed further, with the result that fewer conduction band electrons on the N-side are opposite to the unoccupied p side energy levels. As the bias is raised, forward current drops. This corresponds to the -ve resistance region of the diode characteristic. As forward bias is raised still further, tunnelling stops altogether and behaves as a normal PN junction diode.

APPLICATIONS OF TUNNEL DIODE

(1) It is used as a high speed switch.

(2) As logic memory storage device

(3) as microwave osc

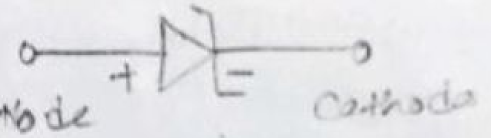
(4) used in relaxation osc.

Adv
1) low noise
2. Ease of operation
3. High speed
4. low power

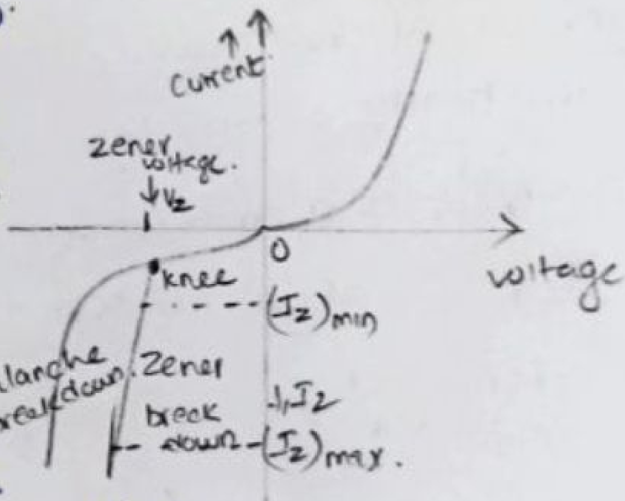
disadv
(1). voltage range over which it can be used is 1V or less.

ZENER DIODE CHARACTERISTICS :-

Zener diode is a reverse biased heavily-doped silicon (or germanium) P-N junction diode which is operated in the break down region. Due to higher temperature and current capability, silicon is prefered in comparison to germanium. The symbol of a zener diode is shown in fig below.



This is similar to a normal diode except the line representing the cathode is bent at both ends ie, like the letter Z for zener. The V-I characteristics is shown in fig below.



Fig

When a zener is forward biased its characteristics are just as those of ordinary diode.

It is also obvious from fig that as the reverse voltage applied to P-N junction is increased, a value is reached at which the current increases greatly from its normal cut off value. This voltage is called a zener voltage V_z or break down voltage. So, when a zener diode is reversed-biased it has sharp breakdown voltage called zener voltage V_z.

It is observed from the figure that below knee; the break down voltage V_z remains practically constant. This ability of the diode is called as "regulating ability". the regulating ability of zener diode is an important feature. This feature is used to maintain a constant voltage across its terminal over a operated range of zener current values $(I_{z(min)})$ and $(I_z)_{max}$. we consider the following two important points:-

1) There is a minimum value of zener current $(I_z)_{min}$ called break over current which must be maintained to keep the diode in break down or regulation region. If the current is reduced below the knew of the curve, the voltage changes drastically. So, the regulation is lost.

ii) There is a maximum value of zener current $(I_z)_{max}$ above which the zener may be damaged.

———— x ————