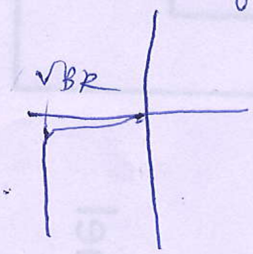
LECTURE 16/10/20

(1)

BREAKDOWN MECHANISMS IN DIODE

In reverse biased condition as long as the reverse bias voltage is less than the breakdown voltage, the diode current is small and almost constant at Io (reverse saturation current)

But when the reverse voltage increases beyond a certain value large diode current flows. This is called the breakdown of diode and corresponding voltage is called reverse breakdown voltage VBR of the diode.



There are 2 breakdown mechanisms

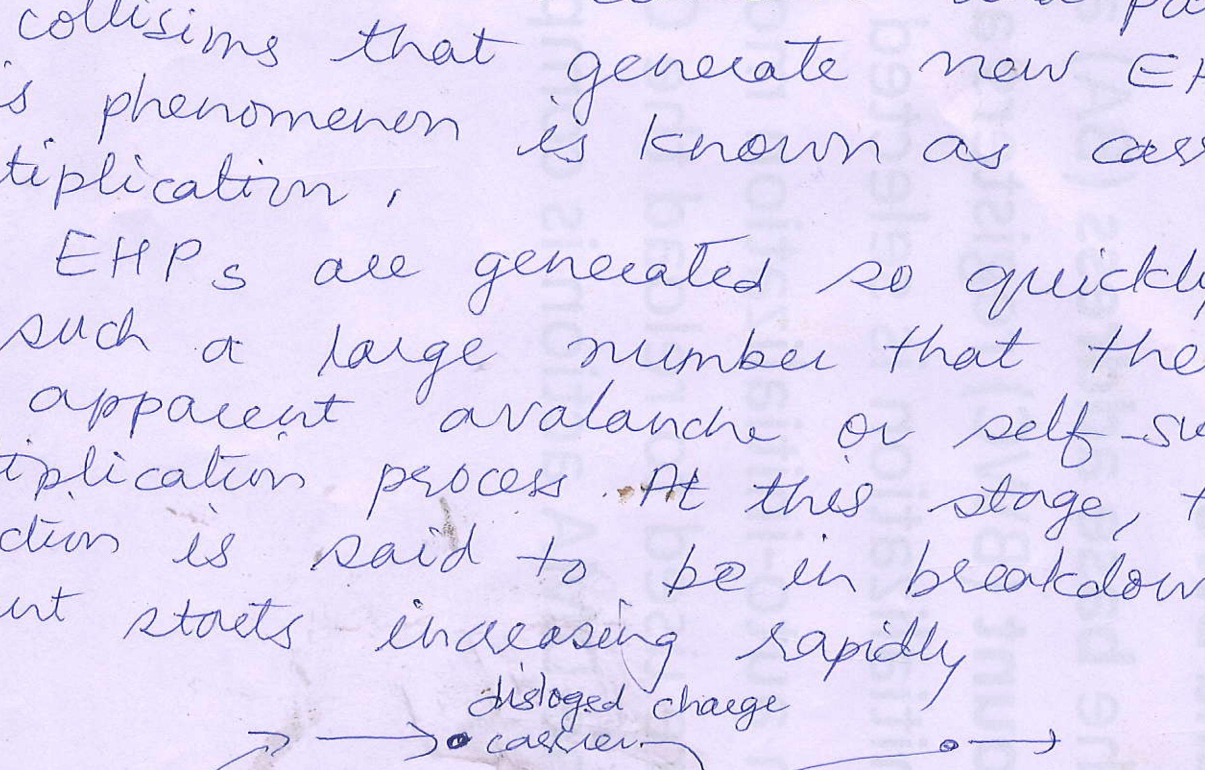
(1) AVALANCHE BREAKDOWN

In reverse bias, a small reverse current Io flows in diode due to movement of minority charge carriers namely electrons from p material and holes from n ~~materia~~ material. Majority carriers move away from the junction whereas minority carriers cross the junction.

As the applied reverse bias voltage becomes larger, the minority charge carriers accelerate. There are collisions between these carriers and the electrons involved in the covalent bonds of the crystal structure.

If the applied voltage is increased, the velocity and hence kinetic energy ($K.E. = \frac{1}{2} mv^2$) of electron increases. If such an electron clashes against electron involved in covalent bond then the collision gives bind-valence electron enough energy to enable it to break its covalent bond. Thus one electron by collision creates an electron hole pair. These secondary particles are also accelerated and participate in collisions that generate new EHP. This phenomenon is known as carrier multiplication,

EHPs are generated so quickly and in such a large number that there is an apparent avalanche or self-sustained multiplication process. At this stage, the junction is said to be in breakdown and current starts increasing rapidly



Diodes having reverse breakdown voltage of 7.6V show avalanche breakdown The doping is light in these diodes

(2) ZENER BREAKDOWN

When p-n junction is heavily doped, the depletion region is very narrow, So under reverse bias conditions, the electric field across depletion layer is very intense. Such an intense field is enough to pull the electrons out of the valence band of the stable atoms such a creation of free electron is called Zener effect and the mechanism is called Zener breakdown.

The diodes having reverse breakdown voltage less than 5 v show the Zener break down and it occurs for heavily doped diodes.

Temperature dependance on breakdown voltages:

(1) AVALANCHE BREAKDOWN:

For lightly doped diodes the width of depletion region is large and field intensity is low. The breakdown possibility is because of avalanche effect. In such a case ~~as~~ if the temperature increases the vibrations of atoms in the crystal increases. The intrinsic holes ~~lattice~~

and electrons have less opportunity to impart sufficient energy between collisions due to vibrations to start the carrier multiplications. Thus voltage must be increased to cause the breakdown. So at higher temperatures, higher breakdown voltage is necessary. Therefore avalanche breakdown has positive temperature coefficient.

(2) ZENER BREAKDOWN

In heavily doped diodes the depletion region width is very small. The applied voltage produces an electric field which is very intense. If the temperature increases, valence electrons acquire high energy levels and it is easy for the applied voltage to pull such electrons from covalent bonds to make them free. Thus at high temperature the breakdown occurs at small voltage.

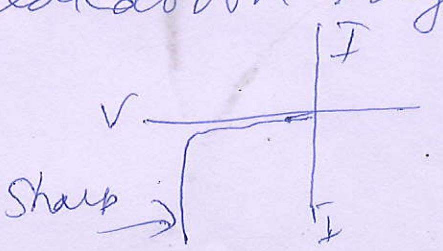
Therefore the breakdown voltage decreases as temperature increases.

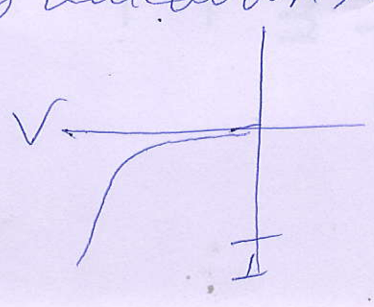
∴ Zener breakdown has -ve temp. coefficient.

Note: conventional or ordinary p-n diodes are never operated in reverse breakdown region, But Zener diodes are operated in reverse breakdown region

Comparison between Zener breakdown and Avalanche breakdown.

ZENER BREAKDOWN	AVALANCHE BREAKDOWN
(1) Breaking of covalent bonds due to intense electric field across the narrow depletion region. This generates a large number of free electrons to cause breakdown.	Breaking of covalent bonds is due to collision of accelerated charge carriers having large velocities and kinetic energy with adjacent atoms. There is carrier multiplication.
(2) Occurs for Zener diodes with $V_{BR} < 6V$	Occurs for Zener diodes with $V_{BR} > 6$
(3) Temperature coefficient is negative	Temperature coefficient is positive
(4) Breakdown voltage decreases as junction temperature increases	Breakdown voltage increases as the junction temperature increases
(5) Occurs for heavily doped diodes	Occurs for lightly doped diodes
(6) V-I characteristics is very sharp in breakdown region	V-I characteristic is not sharp in breakdown region





SPECIAL DIODES.

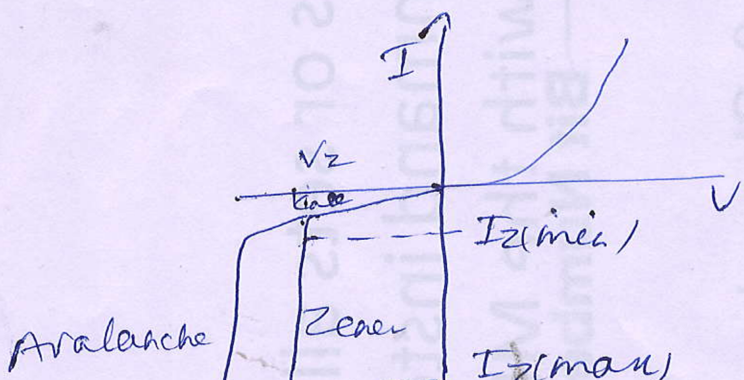
(1) ZENER DIODE:

It is heavily doped Si or Ge P-N junction diode which is operated in the breakdown region. They are fabricated with precise breakdown voltages by controlling the doping level during manufacturing.

Breakdown voltages :- 3V to 200V.

Symbol.

V-I characteristics.



When Zener is forward biased the characteristics are same as ordinary p-n diode. As the reverse voltage is increased, a value is reached at which the current increases greatly. This voltage is called V_Z Zener voltage or breakdown voltage.

Note (i) I_{Zmin}: minimum current which must be maintained to keep the diode in breakdown or regulation region. If the current is below $I_{Z(min)}$ the voltage changes drastically and regulation is lost.

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

Zener diode has 2 breakdown mechanism

(i) Zener (ii) Avalanche.

We have already studied them in detail

Zener diode, specifications:

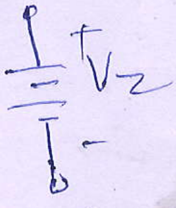
(i) Zener voltage V_Z: This is the reverse voltage across the Zener diode at which the reverse current increases sharply.

(ii) Max. power dissipation (P_Z): $P_Z = V_Z I_Z$

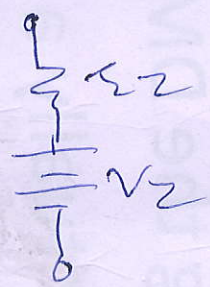
(iii) Zener resistance (r_Z): It is defined as change in values of Zener voltage between two points on reverse V-I curve

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

Zener diode equivalent circuit



Ideal equivalent circuit:



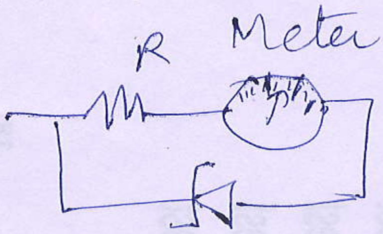
Practical equivalent circuit

ZENER DIODE APPLICATIONS:

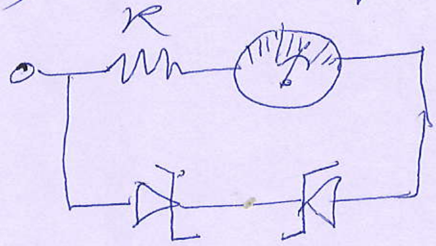
(i) Meter protector:

Zener diodes are employed in multimeter to protect the meter from accidental overloads

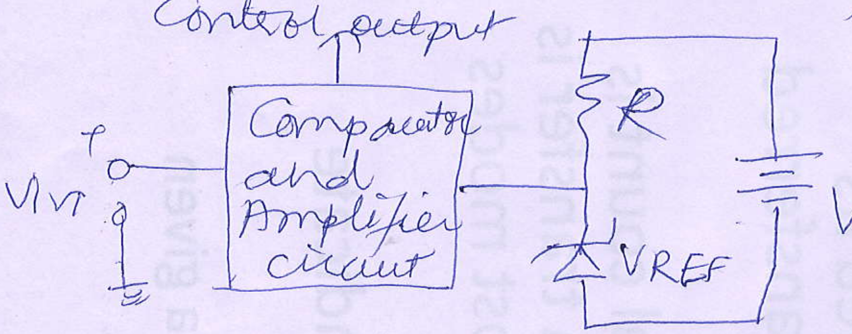
(i) Single polarity



(ii) Double polarity

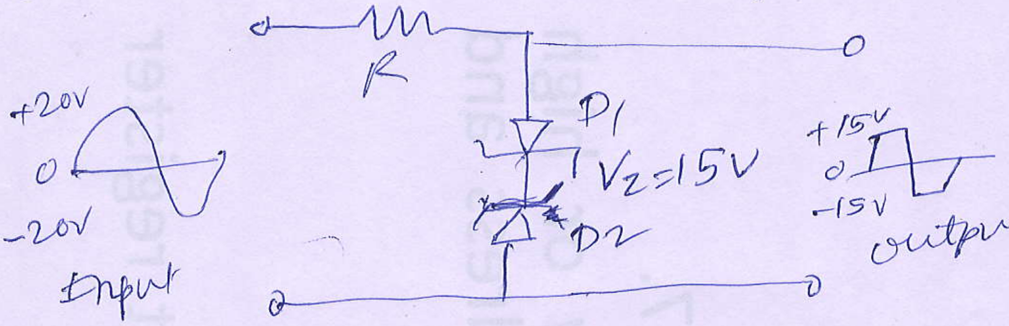


(2) Zener diode as a reference element
In many devices it is desirable that a constant voltage is maintained between two points. This voltage is used as a reference for comparing other voltages against it. The difference between the two voltages is usually amplified. Then the amplified voltage is used to perform some control function.



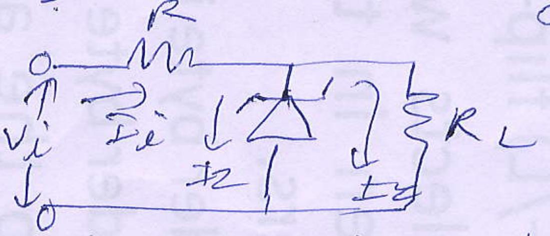
The V-I characteristic of Zener diode in its breakdown region is employed for this purpose. The value of R in the circuit is selected in such a way that the Zener diode operates well within its breakdown region. The voltage VREF is equal to V_Z. The voltage $V_{in} - V_{REF}$ gives the control output.

(3). Zener diode as peak clipper



D_1 & D_2 are two similar Zener diodes joined back to back across the input sine wave voltage. Let the peak input voltage be ±20V. Both diodes have V_Z = 15V. The output is wave with peak value of ±15V.

(4). In the voltage regulator.



The diode is selected with V_Z equal to the voltage desired across the load. The Zener acts as a bypass valve through which more current can pass when an increase in input voltage or decrease in load current occurs maintaining the voltage at the output nearly constant at V_Z. Excess voltage from input drops across R.

Note: This circuit cannot compensate for voltages on the input that fall below the desired output.