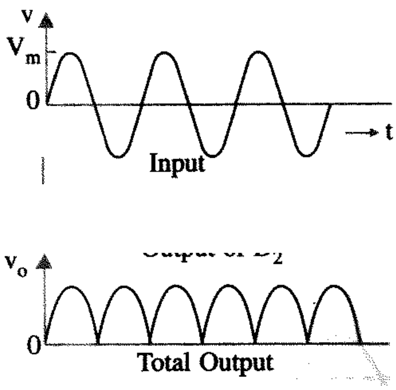
Ripple Factor:

The output of a rectifier consists of a small fraction of an AC component along with DC called the ripple. This ripple is undesirable and is responsible for the fluctuations in the rectifier output. Figure shows the ripple in the output of a rectifier.

The effectiveness of a rectifier depends upon the magnitude of the ripple component in its output. Asmaller ripple means that the rectifier is more effective.



Ripple in the output of a DC output.

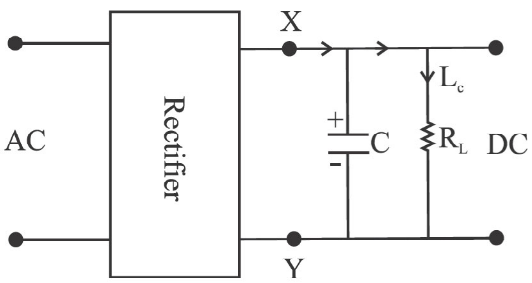
The ratio of root mean square (rms) value of the AC component to the value of the DC component in the rectifier output is known as the ripple factor, i.e.,

$$Ripple\ factor = \frac{r.m.s. value\ of\ AC\ component}{value\ of\ DC\ component}$$

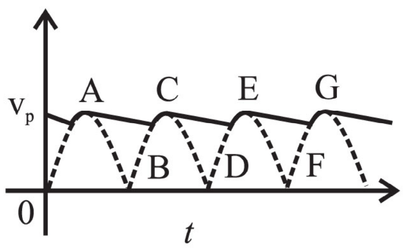
Filter circuits:

The output of a rectifier is in the form of pulses as shown in the second waveform in above fig. The output is unidirectional but the output does not have a steady value. It keeps fluctuating due to the ripple component present in it. A filter circuit is used to remove the ripple from the output of a rectifier.

A filter circuit is a circuit which removes the AC component or the ripple from a rectifier output and allows only the DC component.



Filter circuit with capacitor.



Output wave form after filtration.

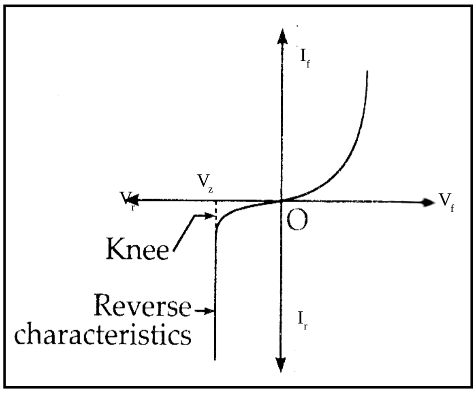
A capacitor filter:

As shown in above Fig. the pulsating DC voltage of a rectifier output is applied across the capacitor. As the voltage across the capacitor rises, capacitor gets charged to point A and supplies current to the load resistance. At the end of quarter cycle, the capacitor gets charged to the peak voltage shown as Vp in above fig. of the rectified output voltage. Now, the rectifier voltage begins to decrease, so that the capacitor starts discharging through the load resistance and the voltage across it begins to drop. Voltage across the load decreases only slightly, up to the point B, because the next voltage peak recharges the capacitor immediately. This process is repeated again and again and the output voltage waveform takes the form shown in above fig . This output is unregulated DC wave form. Voltage, regulator circuits are used to obtain regulated DC supply The capacitor filter circuit is widely used because of its low cost, small size and light weight. This type of filter is preferred for small load currents. It is commonly used in battery eliminators.

When a power supply is connected to a load, it is noticed that there is a drop in the output voltage. A power supply whose output changes when a load is connected across it is called *unregulated power supply.* When the output of a power supply remains steady even after connecting a load across it, it is called a *regulated power supply.* There are many ways in which a power supply can be regulated. A commonly used voltage regulator circuit uses a Zener diode.

Zener Diode

In the reverse bias pn-junction, it has been noted that when the reverse voltage applied to the pn-junction increases, at a critical voltage called as breakdown voltage the reverse current increases sharply to a high value. The breakdown region is the knee of the reverse characteristics as shown in figure .



The satisfactory explanation of this breakdown of the junction was first given by the American scientist C. Zener. Therefore, breakdown voltage is sometimes called the Zener voltage and the sudden increase in current is called Zener current. The breakdown or **Zener voltage depends upon the amount of doping.** If the diode is heavily doped, depletion layer will be thin and consequently the breakdown of the junction will occur at a lower reverse voltage. On the otherhand, a lightly doped diode has a higher breakdown voltage. When an ordinary p-n-junction diode is properly doped so that it has a sharp breakdown voltage is called as Zener diode.

By controlling doping levels zener diobes of breakdown voltage 2 V to 200 V can be manufactured.

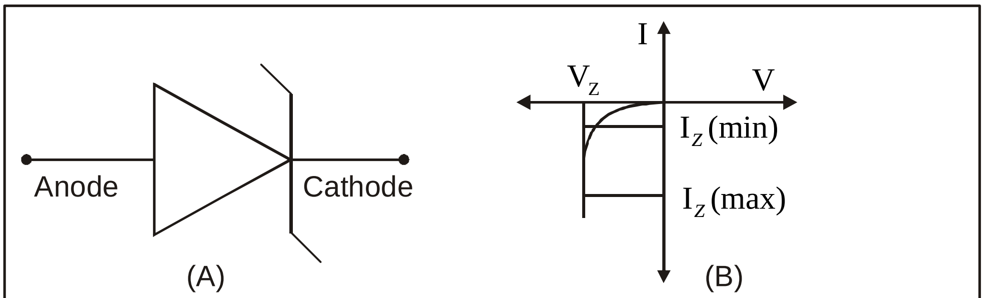
At Zener voltage the large current flows due to two effects such as Zener Effect and Avalanche effect.

At breakdown voltage the large number of electrons from covalent bonds are pulled out and produces large number of electron - hole pairs. Therefore current suddenly increases. Such effect is called as **Zener effect.**

At breakdown voltage the minority charge carriers are accelerated in depletion region. These accelerated charge carriers collides on other atoms and creates free electrons and holes. This process repeats suddenly and produces large number of electron hole pairs. As a result of which large current flows at breakdown voltage. Such effect is called as **Avalanche effect.**

Definition : “A properly doped pn-junction diode which has a sharp breakdown voltage is called as Zener diode.”

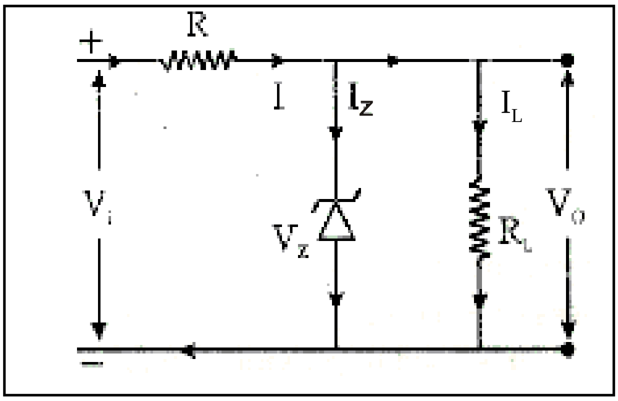
The symbol of Zener diode is as shown in figure,It should be noted, that it is just like an ordinary diode except that the bar is turned intoZ-shape. The following points should be noted about the Zener diode :



(A) Symbol (B) Zener diode characteristics

1. A Zener diode is always reverse connected, i.e. it is reverse biased.
2. The applied voltage must be equal or greater than zener voltage (V_z)
3. The Zener current should be between Iz(min) and Iz (max.)
4. A Zener diode has sharp breakdown voltage, called Zener voltage (V_z).
5. When forward biased, its characteristics are just those of an ordinary diode.

Zener diode as voltage regulator :



The power supply whose output (once set) remains constant irrespective of variations in line voltage or load current is called regulated power supply. Zener diode **is used** as voltage regulator or voltage stabilizer to **provide constant d.c. output.** The rectifier output is in the form of pulsating d.c. A filter circuit is used to obtain pure d.c. The pure d.c. output may vary in magnitude due to following reasons (i) The output d.c. changes **due to change in input a.c.**
(ii) The output d.c. changes due to change in load resistance. These difficulties are solved by using zener diode.

A zener diode when working in breakdown region can serve as a voltage regulator. A circuit for voltage regulator using zener diode is shown in figure.
The zener diode is connected in revese bias across the input voltage supplied to the load. The input voltage is assumed to be alwaus greater than zener voltage so that zener diode works in breakdown region. The variations in input voltage or load resistance are such that it will keep zener diode in zener breakdown region.
The load resistance 'R_L' is connected in parallel with diode. The constant voltage 'V_{out}' is available across load resistance.

'I' is total current supplied by power supply and flowing through 'R'.
'I_z' is current through zener diode.
'I_L' is load current through load resistance.
By appling KCL (Kirchhoff's current law)
$I = I_z + I_L$ .... (1)
Applying Kirchhoff's voltage law
$V_{in} = I.R. + V_z$ But $V_z = V_{out}$
$\therefore V_{in} = I.R. + V_0$ .... (2)

Case I :

Suppose 'R_L' is fixed and input voltage 'V_{in}' is increased. Due to increase in input voltage the total current 'I' increases. This increase in 'I' is absorbed by the zener diode and the current through load resistance remains constant and ultimately 'V_{out}' remains constant.

Due to decrease in input voltage the total current 'I' decreases. Due to decrease in 'I' the current through diode I_Z also decreases and 'I_L' remains constant.

Case II :

Suppose V_{in} is constant. When R_L increases, the load current I_L decreases and voltage drop $I_L.R_L$ will be constant. Hence V_{out} is constant. Due to decrease in I_L, I_Z will increase to maintain total current 'I' constant. But, still 'V_Z' is constant and ultimately V_{out} is constant.

When R_L decreases, the load current 'I_L' increases and voltage drop $I_L.R_L$ will be constant. Hence V_{out} is constant. Due to increase in I_L, I_Z will decrease to maintain total current I constant. But, still V_Z is constant and ultimately V_{out} is constant.

Application of Zener Diode :

The Zener diode is used when a constant voltage is required. It has a number of applications such as : Voltage regulator, Fixed reference voltage provider in transistor biasing circuits, Peak clipper or limiter in a wave shaping circuit, Protector against meter damage from accidental flucutations, etc.