# Electronics
# Lecture 3

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**Zener Diode:**

A Zener Diode is also known as break down diode is a heavily doped semiconductor device that is designed to operate in the reverse direction. When the voltage across the terminals of a Zener diode reversed and the potential reaches the Zener voltage or knee voltage the junction break down and the current flows in reverse direction. *This effect is known as Zener effect*. A Zener diode operates like a normal diode when it is forward biased, however when connected in reverse biased mode a small leakage current flows through the diode. As the reverse voltage increases to the predetermined break down voltage, current starts flowing through the diode. The current increases to a maximum after which it is stabilizes and remains constant over a wide range of applied voltage.

Avalanche break down occur at high reverse voltage. When a high value reverse voltage applied to the junction the free electron gains sufficient energy and accelerates at very high velocities. These free electrons moving at high velocity collides other atoms and knocks off more electrons and as a result a large number of electrons generated by increasing diode current rapidly. For avalanche break down Zener voltage must be 6 volts. At the Zener break down region a small increase in voltage results in the rapid increase of the electric current.

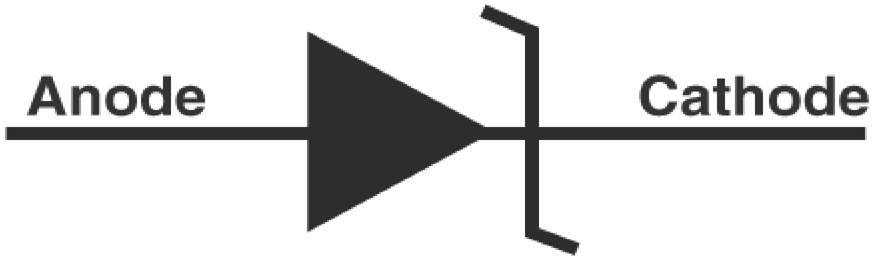



Fig 1

**LED (Light Emitting Diode):**

The increasing use of digital displays in calculator, watches and all forms of instrumentation has contributed to an extensive use of LED. The two types in common use to perform this function are the light emitting diode (LED) and light crystal diode (LCD).

The LED is a diode that gives off visible or invisible(infrared) light when energized. The recombination requires that the energy possessed by the unbound free electron be transferred to another state. In all semiconductor $p - n$ junctions some of this energy is given off in the form of heat and some in the form of photons. $Si$ and $Ge$ are not used because in the  recombination, greater percentage of energy converted into the form of heat.

On the other hand diodes constructed of $GaAs$ emit light in the infrared zone during the recombination process at the $p - n$ junctions. Even though the light is not visible, infrared LED have numerous application where visible light is not a desirable effect. Though other combinations of elements a coherent visible light can be generated. The basic construction of an LED with the standard symbol used for the device. The external metallic conducting surface connected to the p-type material is smaller to permit the emergence of the maximum number of photons of light energy when the device is forward biased. It is also noted that the recombination of the injected carrier due to the forward biased junction result in emitted light at the site of recombination.

There will be some absorption of some package of photon energy in the structure itself, but a very large percentage can leave. It is interesting to note that invisible light has a lower frequency spectrum than visible light. The two quantities are related by

$$\lambda = \frac{c}{f} \rightarrow (iv)$$

Here c is the speed of light, $\lambda$ is wavelength in meters and $f$ is the frequency in Hertz.

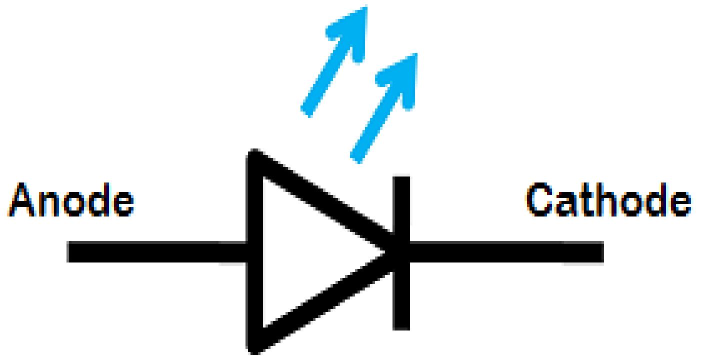


Fig 2

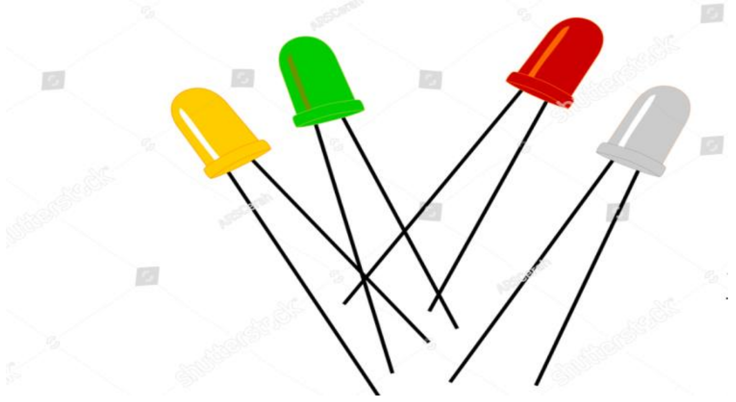


Fig 3

This certainly places $GaAs$ in the wavelength zone typically used in infrared devices. $GaAsP$ with a band gap of $1.9\ eV$ the resulting wavelength is $654\ nm$ which is the centre of red zone making it excellent compound semiconductor for LED production. Therefore in general, the wavelength and frequency of light of a specific colour are directly related to the energy band gap of the material.

**Photo Diode:**

A photo diode is a semiconductor $p - n$ junction device that converts the light into electrical current. The current is generated when photons are absorbed in photo diode. Larger the intensity of incident light, larger be the change in conductivity of the semiconductor. Therefore by measuring the resistance of the semiconductor one can measure the intensity of the optical signal.

The simplest photo diode is a reversed biased $p - n$ diode. If such an $p - n$ diode is illuminated with light photons having energy $hv = Eg$ ,the electron hole pair generated in the depletion layer or near the junction will be separated by junction field and made to flow across the junction. There would be a change in the reverse saturation current measuring which on illumination can give the values of light intensity.

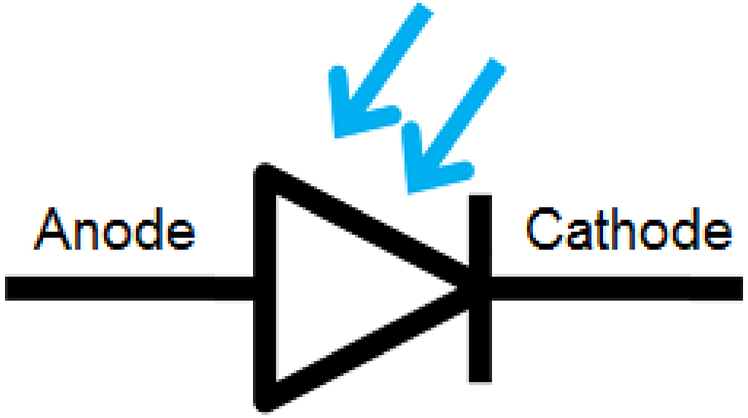



Fig 4

Fig 5

**Solar Cell:**

The solar cell is branded as a large area photo diode because it converts solar energy into electrical energy, though solar cell works on bright light. When sunlight strikes a solar cell electron in the silicon are ejected which results formation of holes. If this happens in electric field, the field will move electron to the $n-type$ and holes to the $p-type$.

It is the form of photo voltaic cell defined as a device whose electrical characteristic such as current, voltage or resistance vary when exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules popularly known as solar panel.

The common single junction silicon solar cell can produce a maximum open circuit voltage 0.5 to 0.6 volts approximately. Solar cell are described as being photovoltaic irrespective of the source is sunlight or artificial light.

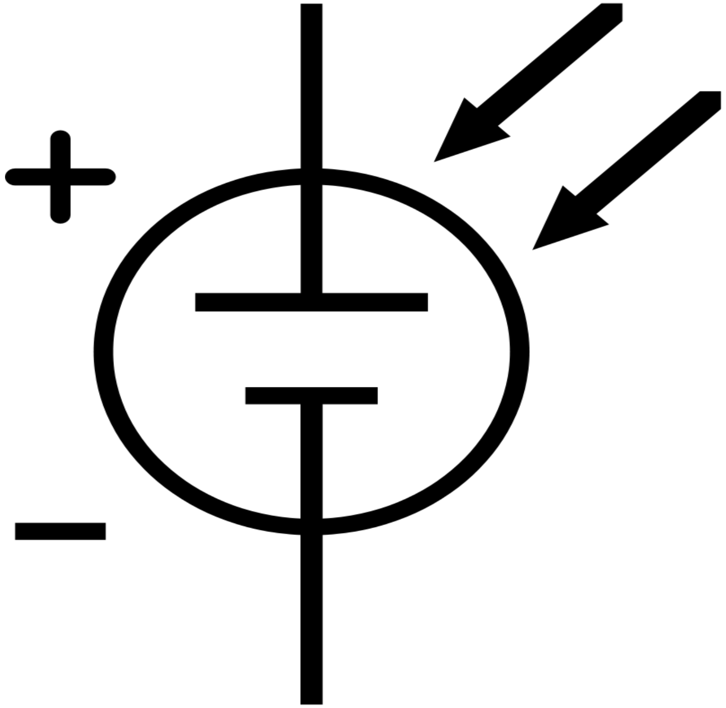



Fig 6

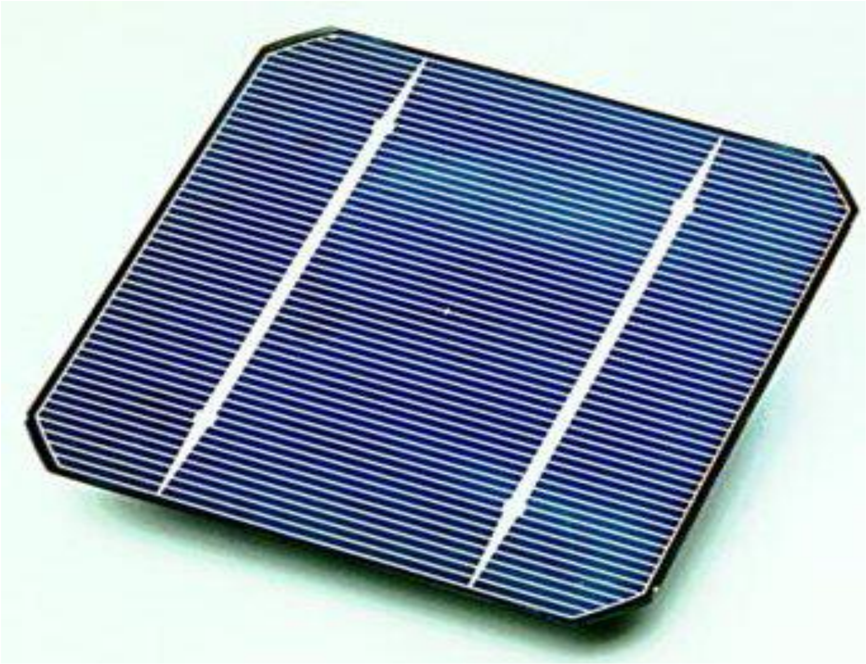


Fig 7

**Rectification:**

Let us now come to the most popular application of diode i.e. rectification. It is conversion of alternating current to direct current. This involves a device that only allows one way flow of electric charge. The simplest kind of rectifier circuit is the half wave rectifier circuit.

**Half wave Rectifier Circuit:**

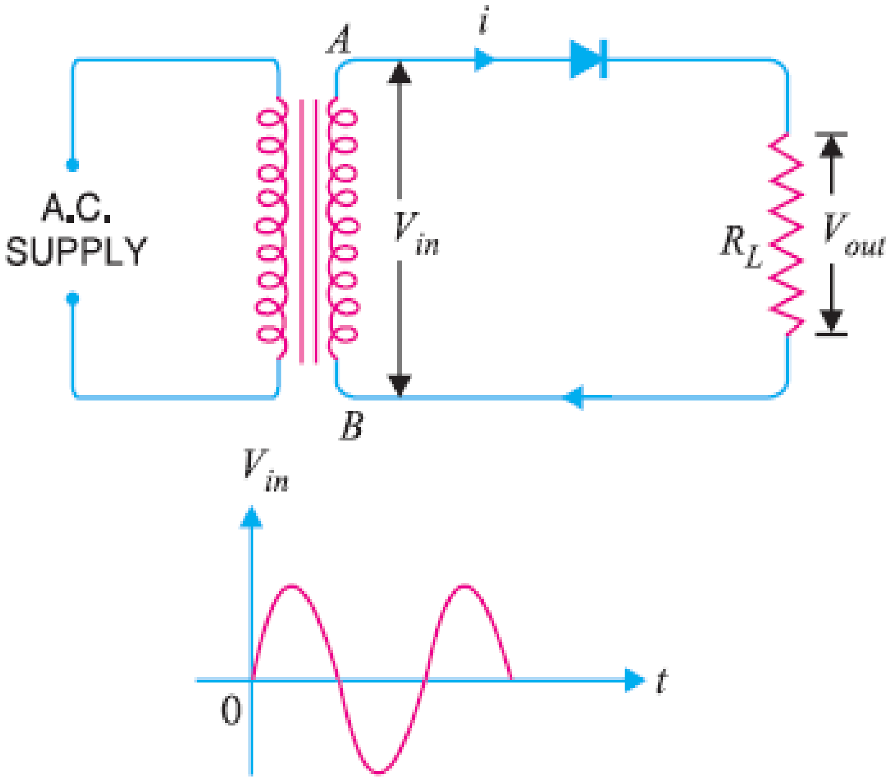
It is the simplest form of rectifier and requires only one diode for the construction of half wave rectifier circuit. This circuit consists three main components; a diode, a transformer and a resistive load. It is defined as a type of rectifier that allows only one half cycle of an AC voltage wave form to pass while blocking the other half cycle.

The efficiency of half wave circuit is

$$\rho = \frac{Output\ DC\ Power}{Input\ AC\ power} = \frac{P_{DC}}{P_{AC}} = 40.6\% \rightarrow (i)$$

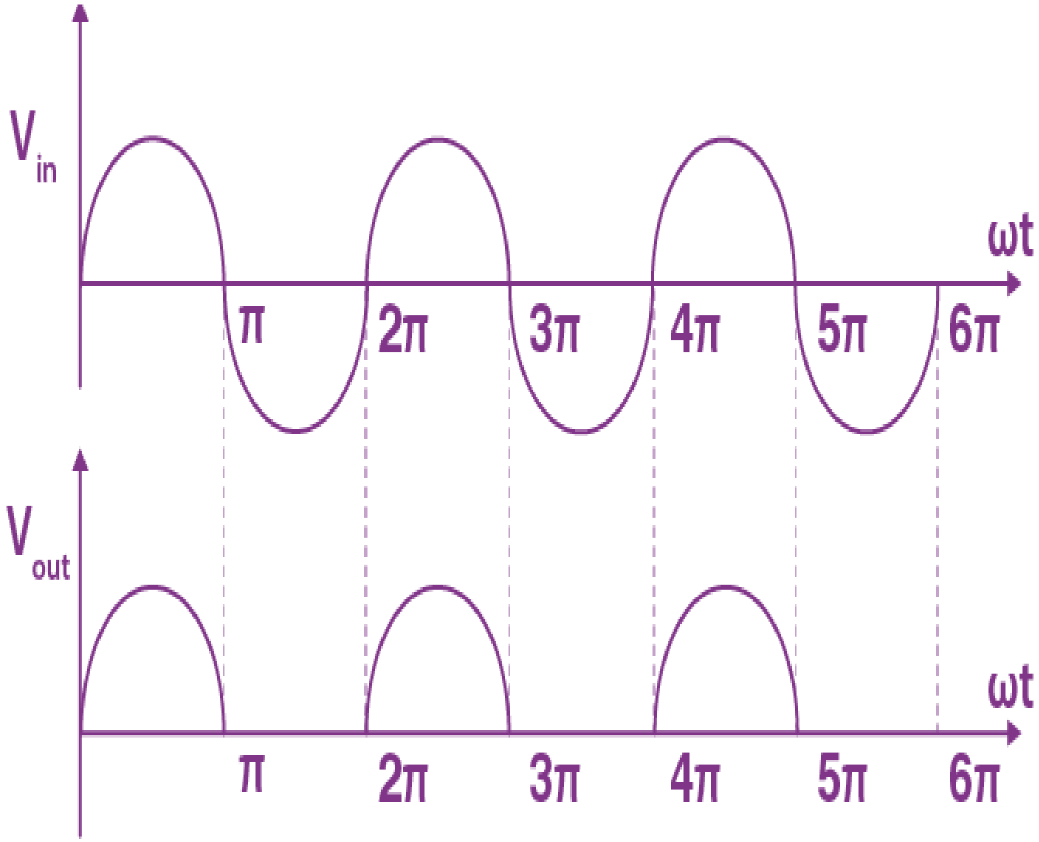
The Ripple Factor

$$\gamma = \sqrt{(\frac{V_{RMS}}{V_{DC}})^2 - 1} = 1.21 \rightarrow (ii)$$



A.C.
SUPPLY
A
B
i
$V_{in}$
$R_L$
$V_{out}$
$V_{in}$
0
t


Fig 8



$V_{in}$
ωt
π
2π
3π
4π
5π
6π
$V_{out}$
ωt
π
2π
3π
4π
5π
6π


Fig 9

The form factor is

$$Form\ Factor = \frac{RMS\ value}{Avarage\ Value}$$

The application of half wave circuit are as follows

- Signal demodulation purpose
- Rectification of signal
- Signal peak application

The disadvantage of half wave rectifier circuit are

- Power Loss
- Low input voltage
- Output contains lot of ripples

**Full Wave Rectifier Circuit:**

A full wave rectifier circuit is defined as a rectifier that converts the complete cycle of alternating current into pulsating DC. Significant power lost while using half wave rectifier is not feasible in application that needs a smooth and steady supply. Therefore full wave rectifier circuit is used. A full wave rectifier utilize the full cycle. The lower efficiency of half wave rectifier can be overcome by the full wave rectifier. In this method a centre taped transformer is used. This circuit consist of a step down transformer and two diodes that are connected  and centre taped. The output voltage is obtained across the load resistance. The input AC supplied to the full wave rectifier is very high.

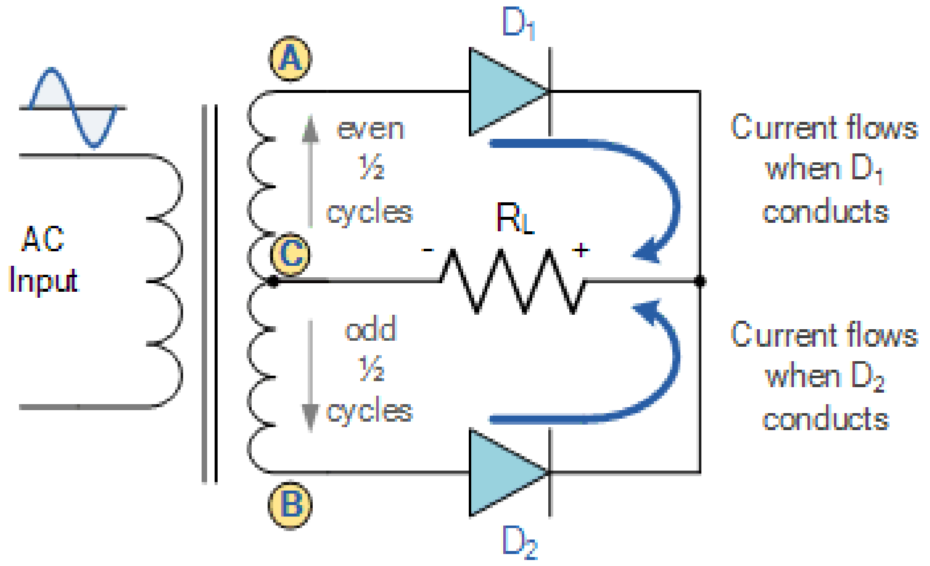



Fig 10

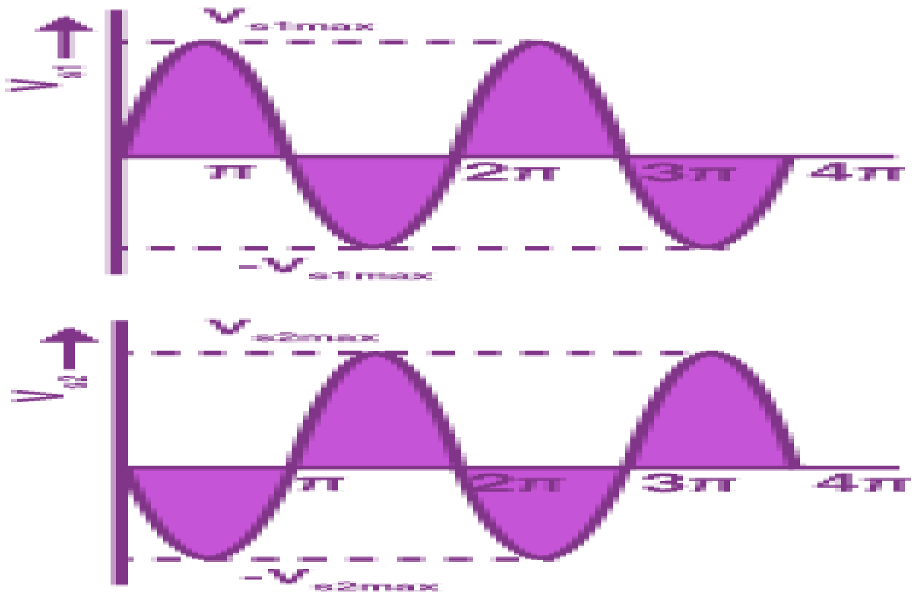



Fig 11 Input Waveform

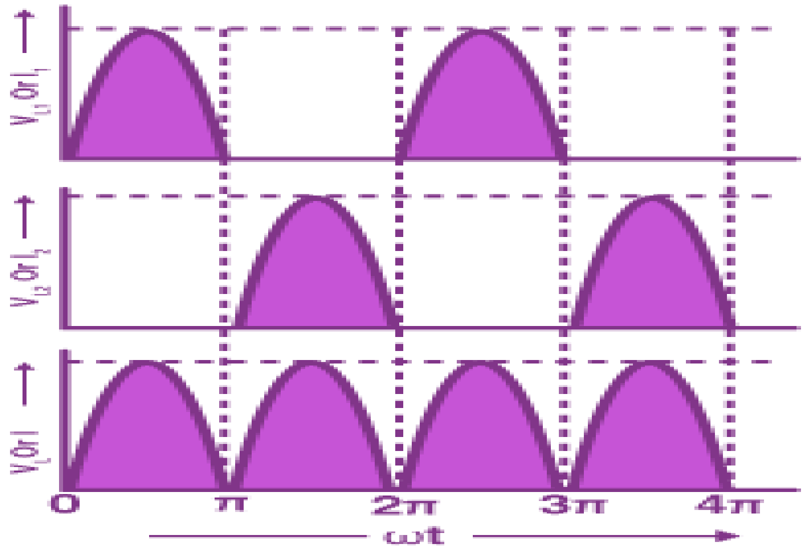



Fig 12 Output Waveform

The step down transformer in the rectifier circuit converts the high voltage AC into low voltage AC. The anode of the centre taped diodes is connected to the secondary windings and connected to the load resistor. During the positive half cycle of the alternating current the top half of the secondary winding becomes positive while second half of the secondary winding becomes negative. During the positive half cycle the diode $D_1$ is forward biased as it is connected to top of the secondary winding while $D_2$ is reverse biased as it is connected to the bottom of the secondary winding. Due to this Diode $D_1$ will conduct acting as short circuit and $D_2$ will not conduct acting as an open circuit. During the negative half cycle the diode $D_1$ is reverse biased and diode $D_2$ is forward biased.

Because the top half of the secondary circuit becomes negative and bottom half of the circuit becomes positive. Thus a full wave rectifier, DC voltage is obtained for the both positive and negative half cycle. The peak inverse voltage of full wave rectifier is double that of a half wave rectifier. The peak inverse voltage across $D_1$ and $D_2$ is $2Vmax$ .

The DC output voltage is

$$V_{DC} = \frac{2}{\pi} I_{max} R_L \rightarrow (iii)$$

The form factor

$$Form\ Factor = \frac{RMS\ current}{Average\ current} = 1.11 \rightarrow (iv)$$

The peak factor is

$$Peak\ Factor = \frac{Peak\ value\ of\ current}{RMS\ value\ of\ current} = \frac{I_{max}}{\frac{I_{max}}{\sqrt{2}}} = \sqrt{2} \rightarrow (v)$$

The efficiency of full wave rectifier is

$$\rho = \frac{DC\ output\ power}{AC\ output\ power} = 81.2\% \rightarrow (vi)$$

The ripple factor is

$$\gamma = 0.482$$

**Advantage :**

The efficiency is double than half wave rectifier.

The ripple factor is low than half wave rectifier.

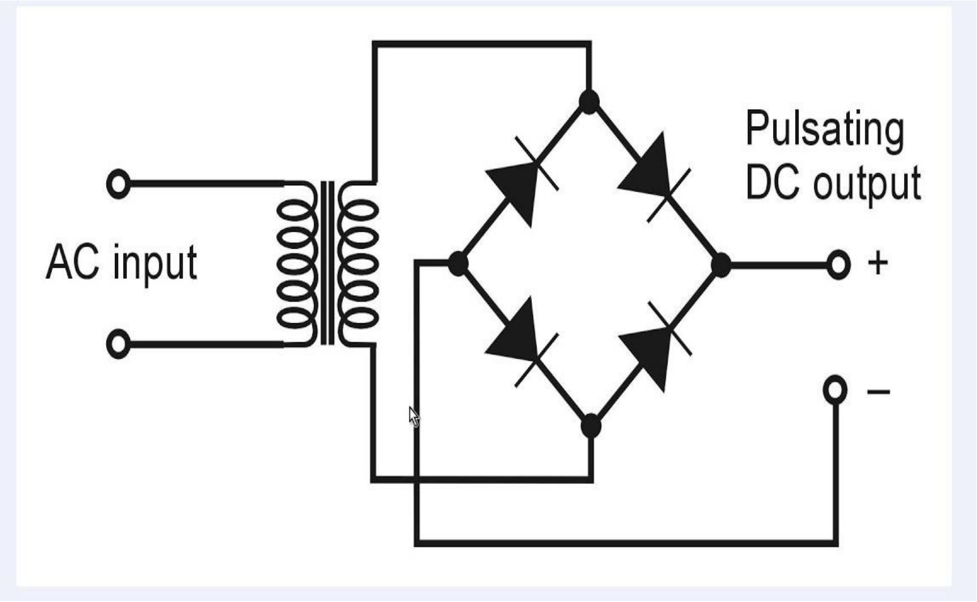
The output voltage and output power obtained in the full wave rectifier are higher than that obtained in half wave rectifier.

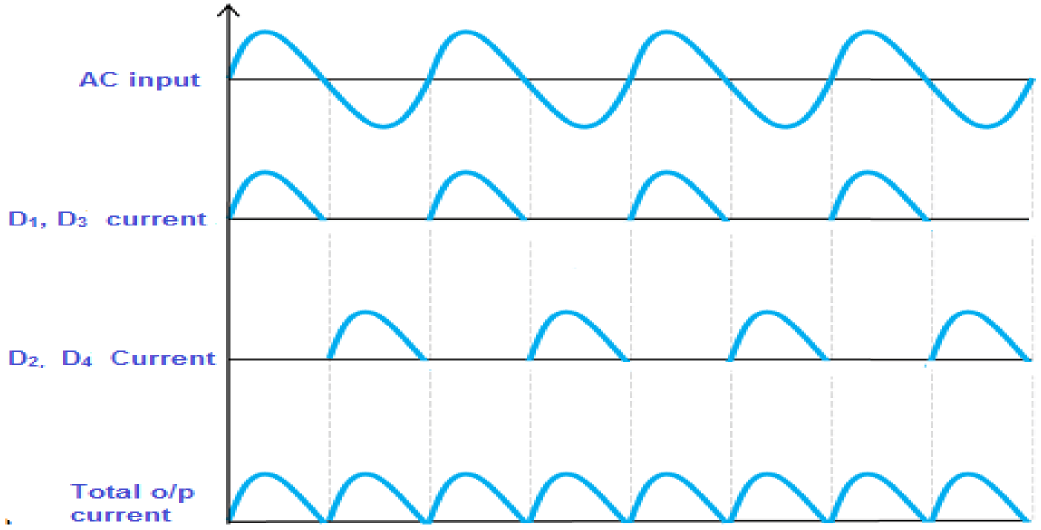
**Disadvantage:**

The only disadvantage of full wave rectifier is that they need more circuit elements that of half wave rectifier that make it costly.

**Bridge Rectifier Circuit:**

Bridge rectifier circuits that convert alternating current (AC) into direct current (DC) using diodes in bridge circuit configuration. Bridge rectifier typically comprises of four or more diodes. The output wave generated is of the same polarity irrespective of the polarity in input.



Bridge rectifier can be defined as a type of full wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert AC to DC current. Asa shown in $fig$ 6 the bridge rectifier circuit is made up of four diodes $D_1, D_2, D_3, D_4$and a load resistor $R_L$. The four diodes are connected in a closed loop configuration. The main advantage of this configuration is the absence of expensive transformer. Therefore the size and cost are reduced. The input signal is applied into point A and B. The output DC signal is obtain at the other two terminal through load resistance $R_L$. The four diodes are connected in such a way that only two diodes are conducted for each half cycle. The $D_1, D_2$ are conducted for positive half cycle and $D_3, D_4$ conduct for negative half cycle.

When AC signal is applied across the bridge rectifier, during the positive half cycle terminal A becomes positive and terminal B becomes negative. This results the diode $D_1$ and $D_3$ become forward biased, while $D_2$ and $D_4$ are in reverse biased. During the negative half cycle the terminal B becomes positive while terminal A becomes negative. This causes diode $D_2$ and $D_4$ to become forward biased, while $D_1$ and $D_3$ becomes reverse biased. The current flow across the load resistance $R_L$ is the same during positive and negative half cycle.

The ripple factor for bridge rectifier circuit is

$$\gamma = \sqrt{\frac{{V_{rms}}^2}{V_{DC}} - 1} \rightarrow (vii)$$

It is equal to i.e.

$$\gamma = .48$$

The efficiency is

$$\eta = \frac{DC\ output\ power}{AC\ output\ power} = 81.2\% \rightarrow (viii)$$

**Advantage:**

The efficiency is better than half wave rectifier circuit.

The DC output signal is smother.

In this case output signal is almost same with the input signal.

**Disadvantage:**

It is a complex circuit rather than half and full wave circuit. When more diodes are used more power loss occur. In bridge rectifier two diodes connected in series conduct in each half cycle, then voltage drop is higher in this case.