unit-5 (Rectifiers)

↳ 4 diodes

A.C to D.C (pulsating)

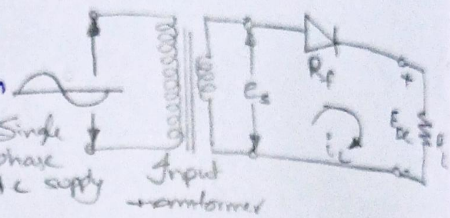
Half Wave Rectifier :-

In half wave Rectifier, rectifying element conducts only during positive half cycle of input a.c supply. The negative half cycle of a.c supply are eliminated from the output

this Rectifier circuit consists of Resistive load, rectifying element i.e p-n junction diode, and the Source of a.c voltage, all connected in Series. The Circuit diagram shown in fig. usually the Rectifier circuits are operated from ac main supply. To obtain the desired d.c Voltage across the load, the ac Voltage is applied to rectifier circuit using suitable step-up or step down transformer, mostly a step down one with necessary turns ratio

↳ Secondary winding more

primary winding more



Half wave rectifier

⇒ The Input Voltage to the half wave rectifier circuit is a Sinusodial voltage, having a frequency which is the supply frequency, 50HZ

equal winding : Centre tapped.

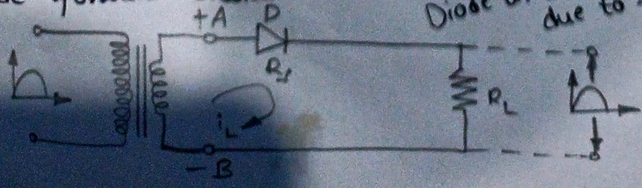
Operation of the Circuit

→ During the positive half cycle of Secondary ac voltage, terminal (A) becomes positive w.r.t terminal (B). The diode is forward biased and the current flows in the circuit in the clockwise direction. The current will flow for almost full positive half cycle. This current is also flowing through Load Resistance R_L hence denoted as i_L, the Load Current. Reverse bias lo output raadhu due to open circuit.

forward bias lo output +ve half cycle vasthundhi

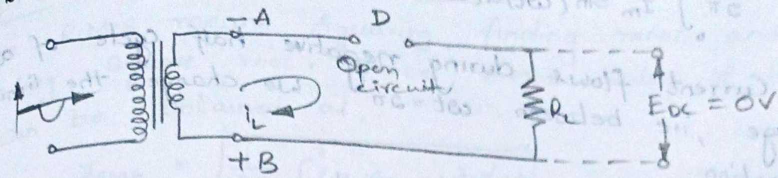
During negative half cycle when terminal (A) is negative w.r.t terminal (B), diode becomes reverse biased. Hence no current flows in the circuit. Thus the circuit current which is also the load current, is in the form of half sinusoidal pulses.

a) Diode forward biased



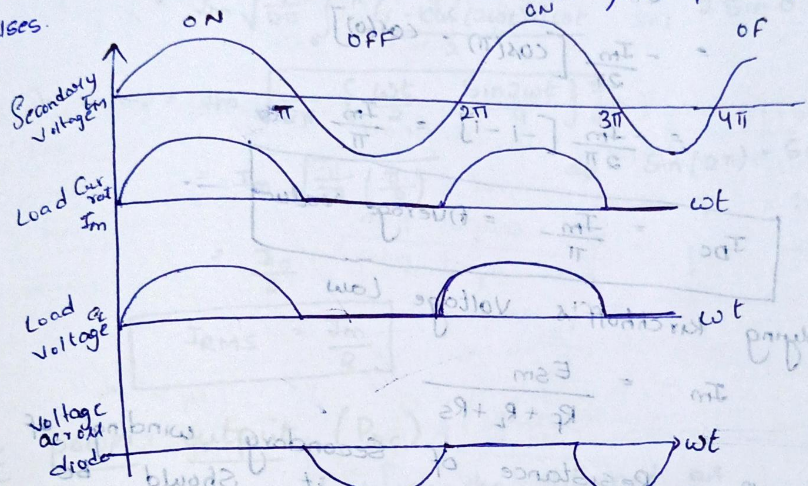
Diode on condition due to forward bias at positive half cycle

b) Diode Reverse biased :



Diode off Condition due to Reverse bias at Negative cycle

the load voltage, being the product of load current and load resistance, will also be in the form of half sinusoidal pulses.



the d.c output waveform is expected to be a straight line but the half wave Rectifier output in the form of positive sinusoidal pulses.

Average D.C Load Current (I_{DC})

The Average or d.c values of alternating current is obtained by integration.

for finding out the average value of an alternating waveform, we have to determine the area under the curve over one complete cycle i.e from 0 to 2π and then dividing it by the base i.e 2π

Mathematically current waveform can be described as

$i_L = I_m \sin\omega t$ for $0 \le \omega t \le \pi$

$i_L = 0$ for $\pi \le \omega t \le 2\pi$

I_m = peak value of load current

$$I_{DC} = \frac{1}{2\pi} \int_0^{2\pi} i_L \, d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{2\pi} I_m \sin(\omega t)\, d(\omega t)$$

⇒ As no current flows during negative half cycle of a.c input voltage, i.e between $\omega t = 2\pi$, we change the limits for Integration

$$I_{DC} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin(\omega t)\, d(\omega t)$$

$$= \frac{I_m}{2\pi}\left[-\cos(\omega t)\right]_0^{\pi}$$

$$= -\frac{I_m}{2\pi}\left[\cos(\pi) - \cos(0)\right]$$

$$= -\frac{I_m}{2\pi}\left[-1-1\right] = \frac{I_m}{\pi}$$

$$\therefore \boxed{I_{DC} = \frac{I_m}{\pi} = \text{Average value}}$$

Applying Kirchhoff's Voltage Law

$$I_m = \frac{E_{sm}}{R_f + R_L + R_S}$$

where R_S = Resistance of Secondary winding of transformer. If R_S is not given it should be neglected while calculating I_m

Average D.C Load Voltage (E_{DC})

It is the product of average D.C load current and the load Resistance R_L.

$$E_{DC} = I_{DC} R_L$$

Substituting value of I_{DC} $\quad I_{DC} = \frac{I_m}{\pi}$

$$E_{DC} = \frac{I_m}{\pi} R_L$$

$$= \frac{E_{sm}}{(R_f + R_L + R_S)\pi} R_L$$

R.M.S Value of Load Current

The R.M.S means squaring, finding mean and then finding square root. Hence R.M.S value of load current can be obtained as,

$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{\pi}(I_m \sin\omega t)^2 d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi}(I_m^2 \sin^2\omega t \, d(\omega t)}$$

$\cos 2\theta = 1 - 2\sin^2\theta$

$2\sin^2\theta = 1 - \cos 2\theta$

$$= I_m\sqrt{\frac{1}{2\pi}\int_0^{\pi}\frac{(1-\cos(2\omega t)d\omega t}{2}}$$

$$= I_m\sqrt{\frac{1}{2\pi}\left\{\frac{\omega t}{2} - \frac{\sin 2\omega t}{4}\right\}_0^{\pi}}$$

as $\sin(2\pi) = \sin(0) = 0$

$$= I_m\sqrt{\frac{1}{2\pi}\left(\frac{\pi}{2}\right)}$$

$$= \frac{I_m}{2}$$

$$\boxed{I_{RMS} = \frac{I_m}{2}}$$

D.C power output (P_{DC})

The d.c power output can be obtained as

$$P_{DC} = E_{DC} \cdot I_{DC} = I_{DC}^2 R_L$$

$E_{DC} = I_{DC} \cdot R_L$

$P_{DC} = I_{DC} \cdot I_{DC} \cdot R_L$

$= I_{DC}^2 \cdot R_L$

$$\text{D.C power output} = I_{DC}^2 R_L$$

$$= \left[\frac{I_m}{\pi}\right]^2 R_L$$

$$= \frac{I_m^2}{\pi^2} R_L$$

$V = IR$

$I = \frac{V}{R}$

$$P_{DC} = \frac{I_m^2}{\pi^2} R_L$$

$$I_m = \frac{E_{sm}}{R_f + R_L + R_S}$$

$$P_{DC} = \frac{E_{sm}^2 R_L}{\pi^2 [R_f + R_L + R_S]^2}$$

A.C power Input (P_{AC})

The power input taken from the secondary of transformer is the power supplied to the resistances namely load resistance R_L, the diode resistance R_f and winding resistance. The a.c power is given by

$$P_{AC} = I^2_{RMS} [R_L + R_f + R_S]$$

but

$$I_{RMS} = \frac{I_m}{2}$$

$$P_{AC} = \frac{I^2_m}{4} [R_L + R_f + R_S]$$

Rectifier efficiency (η)

The Rectifier efficiency is defined as the ratio of output d.c power to input a.c power

$$\eta = \frac{\text{D.C output power}}{\text{A.C input power}}$$

$$= \frac{P_{DC}}{P_{AC}}$$

$$\eta = \frac{\frac{I^2_m}{\pi^2} R_L}{\frac{I^2_m}{4} [R_f + R_L + R_S]} = \frac{(4/\pi^2) R_L}{R_f + R_L + R_S}$$

$$\eta = \frac{0.406}{1 + \left(\frac{R_f + R_S}{R_L}\right)}$$

If $(R_f + R_S) << R_L$ as mentioned earlier, we get the maximum theoretical efficiency half wave rectifier as

$$\% \eta_{max} = 0.406 \times 100$$
$$= 40.6 \%$$

Thus in half wave rectifier, maximum 40.6 % a.c power gets converted to d.c power in the load. if the efficiency of Rectifier is 40% then what happens to the remaining 60% power; It is present interms of ripples in the output which is fluctuating component present in the output

Key point :- Thus more the rectifier efficiency, less are the tripple contents in the output

Ripple factor (γ)

It is seen that the output of half wave rectifier is not pure d.c but a pulsating d.c. The output contains pulsating components called ripples. ideally there should not be any ripples in the rectifier output. The measure of such ripples present in the output is with the help of a factor called ripple factor denoted by γ. It tells how smooth is the output.

Key point :- Smaller the ripple factor closer is the output to a pure d.c

The ripple factor expresses how much successful the circuit is, in obtaining pure d.c from a.c input.

Definition :-

Mathematically ripple factor is defined as the ratio of R.M.S value of the a.c component in the output to the average or d.c component present in the output

$$\text{Ripple factor } \gamma = \frac{\text{R.M.S value of a.c component of output}}{\text{Average or d.c component of output}}$$

Now the output current is composed of a.c component as well as d.c component

Let I_{ac} = r.m.s value of a.c component present in output

I_{DC} = d.c component present in output

I_{RMS} = R.M.S value of total output current

$$I_{RMS} = \sqrt{I_{ac}^2 + I_{DC}^2}$$

$$I_{ac} = \sqrt{I_{RMS}^2 - I_{DC}^2}$$

$$\text{Ripple factor} = \frac{I_{ac}}{I_{DC}} \quad \text{--- as per definition}$$

$$\gamma = \frac{\sqrt{I_{RMS}^2 - I_{DC}^2}}{I_{DC}}$$

$$\boxed{\gamma = \sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1}}$$

This is the general expression for ripple factor and can be used for any rectifier Circuit

Now for a half wave Circuit

$$I_{RMS} = \frac{I_m}{2} \quad \text{while} \quad I_{DC} = \frac{I_m}{\pi}$$

$$\gamma = \sqrt{\left(\frac{\left(\frac{I_m}{2}\right)}{\left(\frac{I_m}{\pi}\right)}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{4} - 1}$$

$$= \sqrt{1.4674}$$

$$\boxed{\gamma = 1.211}$$

This indicates that the ripple contents in the output are 1.211 times the d.c component 121.1% of dc component

<u>Key point</u> :-

The Ripple factor for half wave Rectifier is very high which indicates that the half wave Circuit is a poor converter of a.c to d.c

$$I_{DC} = \frac{I_m}{\pi}$$

$$I_m = \frac{E_{sm}}{R_f + R_L + R_s}$$

$$E_{DC} = I_{DC} \cdot R_L$$

$$I_{RMS} = \frac{I_m}{2}$$

$$P_{DC} = E_{DC} \cdot I_{DC} = I_{DC}^2 \cdot R_L$$

$$I_{RMS}^2 [R_L + R_f + R_s]$$

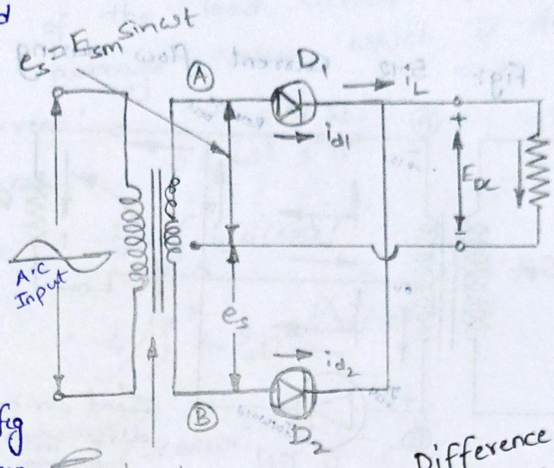
$$P_{AC} =$$

Full wave Rectifier

The full wave Rectifier Conducts during both positive and negative half cycles of input a.c supply.

In order to rectify both the half cycles of ac input two diodes are used in the Circuit. The diodes feed a common load R_L with the help of a centre transformer.

The a.c voltage is applied through a suitable power transformer with proper turns ratio.



⇒ The full wave rectifier circuit is shown in the fig.

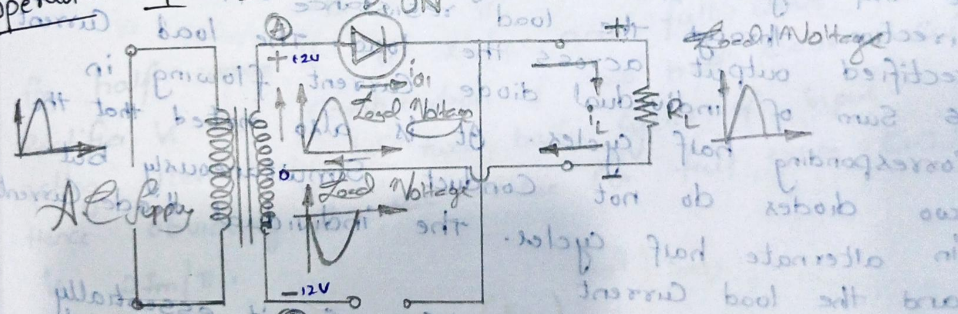
⇒ for the proper operation of the Circuit, a Centre tap on the Secondary winding of the transformer is essential.

Difference b/w Full wave Rectifier and half wave

(full wave) Negative cycle - +ve and cycles is central tapped at output

(Half wave) Negative Cycle - 0V +ve cycle.

operation of the Circuit

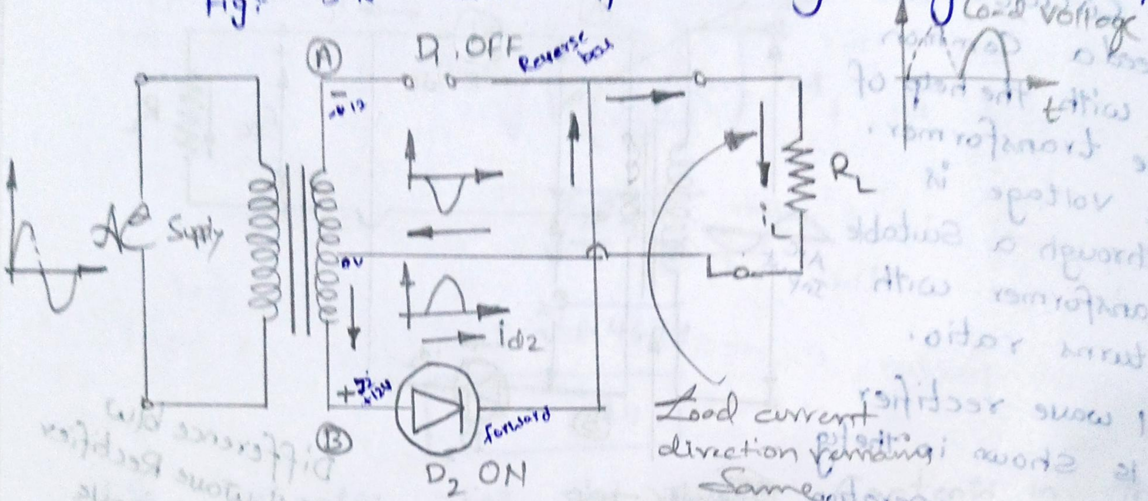


Consider the positive half cycle of a.c input voltage in which terminal (A) is positive and terminal (B) negative. The diode D_1 will be forward biased and hence will conduct, while diode D_2 will be Reverse biased and will act as an open Circuit and will not Conduct. This is illustrated in the fig.

⇒ The diode D_1 supplies the load Current, i.e $i_L = i_{d1}$. This current is flowing through upper half of secondary winding while the lower half of secondary winding of the transformer carries no current since diode D_2 is reverse biased and act as an open circuit.

In the next half cycle of a.c voltage, polarity reversed and terminal (A) becomes negative and (B) positive. The diode D_2 conducts being forward biased, while D_1 does not, being reverse biased as shown in figure

Fig:- 5.12 Current flow during negative half cycle

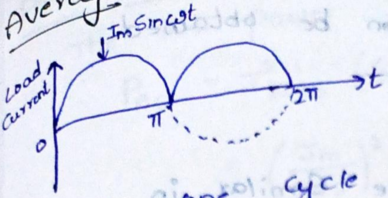


The diode D_2 Supplies the load Current i.e $I_L = i_{d2}$.
Now the lower half of the Secondary winding Carries the Current but the upper half does not.

⇒ It is noted that the load Current flows in both the half cycles of a.c voltage and in the same direction through the load resistance. Hence we get rectified output across the load. The load Current is Sum of individual diode Current flowing in Corresponding half cycles. It is also noted that the two diodes do not Conduct Simultaneously but in alternate half cycles. the individual diode Currents and the load Current

⇒ thus the full wave rectifier Circuit essentially Consists of two half wave rectifier Circuits working independently (working in alternate half cycle of a.c) of each other but feeding a Common load. the output load Current is still pulsating d.c & not pure d.c

Average D.C Load Current (I_{DC})



Consider one cycle of the load current i_L from 0 to π to obtain the average value which is d.c value of load current.

$$0 \le \omega t \le \pi$$

$$i_L = I_m \sin \omega t$$

$$I_{av} = I_{DC} = \frac{1}{\pi} \int_0^{\pi} i_L \, d(\omega t)$$

$$= \frac{1}{\pi} \int_0^{\pi} I_m \sin \omega t \, d(\omega t)$$

$$= \frac{I_m}{\pi} \left[(-\cos \omega t)_0^{\pi} \right]$$

$$= \frac{I_m}{\pi} \left[-\cos \pi - (-\cos 0) \right]$$

$$= \frac{I_m}{\pi} \left(+1 - (-1) \right]$$

$$I_{DC} = \frac{2 I_m}{\pi}$$

for half wave it is I_m/π and full wave Rectifier is the combination of two half wave circuits acting alternatively in two half cycles of input. Hence obviously the d.c value for full wave circuit is $2I_m/\pi$.

Average D.C Load voltage (E_{DC})

The d.c load voltage is

$$E_{DC} = I_{DC} R_L = \frac{2 I_m R_L}{\pi}$$

Sub I_m, $$E_{DC} = \frac{2 E_{sm} R_L}{\pi [R_f + R_s + R_L]} = \frac{2 E_{sm}}{\pi \left[1 + \frac{R_f + R_s}{R_L} \right]}$$

But as R_f and $R_s << R_L$

hence $$\frac{R_f + R_s}{R_L} << 1$$

$$E_{DC} = \frac{2 E_{sm}}{\pi}$$

R.M.S Load Current (I_{RMS})

The R.M.S value of Current can be obtained.

$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i_L^2 \, d(\omega t)}$$

Since two half wave rectifier are similar in operation we can write.

$$I_{RMS} = \sqrt{\frac{2}{2\pi}\int_0^{\pi} (I_m \sin\omega t)^2 \, d(\omega t)}$$

$\cos 2\theta = 1 - 2\sin^2\theta$

$$= I_m \sqrt{\frac{1}{\pi}\int_0^{\pi}\left[\frac{1-\cos 2\omega t}{2}\right] d(\omega t)}$$

$$I_{R.M.S} = I_m \sqrt{\frac{1}{2\pi}\left[[\omega t]_0^{\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{\pi}\right]}$$

$$= I_m \sqrt{\frac{1}{2\pi}[\pi - 0]}$$

$$= I_m \sqrt{\frac{1}{2\pi}(\pi)}$$

$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

R.M.S Value of the Load Voltage

As the load is resistive, the r.m.s value of the Load Voltage

$$E_{L(RMS)} = I_{R.M.S} \cdot R_L = \frac{I_m}{\sqrt{2}} R_L$$

D.C power output (P_{DC})

$$\text{D.C power output} = E_{DC} I_{DC} = I_{DC}^2 R_L$$

$$P_{DC} = I_{DC}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$P_{DC} = \frac{4}{\pi^2} I_m^2 R_L$$

Sub I_m, we get,

$$P_{DC} = \frac{4}{\pi^2} \frac{E_{sm}^2}{(R_s + R_f + R_L)^2} \times R_L$$

Power input (P_{AC})

The a.c power input is given by

$$P_{AC} = I^2_{RMS}(R_f + R_S + R_L)$$

$$= \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_S + R_L)$$

$$P_{AC} = \frac{I^2_m (R_f + R_S + R_L)}{2}$$

Substituting value of I_m we get,

$$P_{AC} = \frac{E^2_{sm}}{(R_f + R_S + R_L)^2} \times \frac{1}{2} \times (R_f + R_S + R_L)$$

$$P_{AC} = \frac{E^2_{sm}}{2(R_f + R_S + R_L)}$$

Rectifier efficiency (η)

$$\eta = \frac{P_{DC}\text{ output}}{P_{AC}\text{ input}}$$

$$\eta = \frac{\frac{4}{\pi^2} I^2_m R_L}{\frac{I^2_m (R_f + R_S + R_L)}{2}}$$

$$\eta = \frac{8 R_L}{\pi^2 (R_f + R_S + R_L)}$$

But if $R_f + R_S << R_L$, neglecting it from denominator

$$\eta = \frac{8 R_L}{\pi^2 (R_L)} = \frac{8}{\pi^2}$$

$$\% \eta_{max} = \frac{8}{\pi^2} \times 100 = 81.2\%$$

⇒ This is the maximum theoretical efficiency of full wave rectifier.

Ripple factor (γ)

As derived earlier in case of half wave rectifier the ripple factor is given by as expression

$$\text{Ripple factor} = \sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1}$$

for full wave $I_{RMS} = \frac{I_m}{\sqrt{2}}$

$$I_{DC} = \frac{2I_m}{\pi}$$

Substituting the above eqn

$$\text{Ripple factor} = \sqrt{\left[\frac{I_m/\sqrt{2}}{2I_m/\pi}\right]^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{8} - 1}$$

$$\text{Ripple factor} = \gamma = 0.48$$

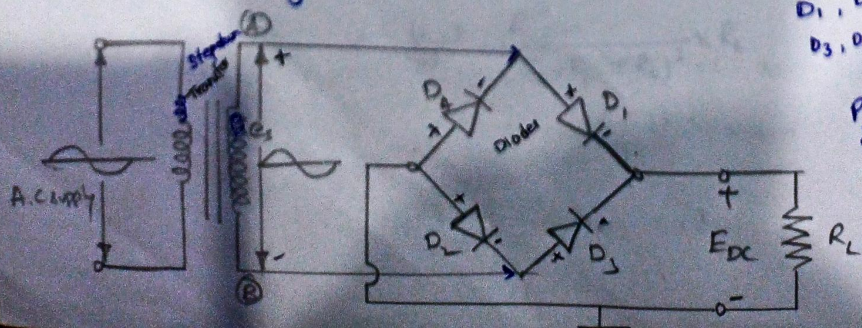
Key point :- This indicates that the ripple contents in the output component which is much less that for the half wave circuit

/ Bridge Rectifier :-

The bridge rectifier circuits are mainly used as
a) A power rectifier circuit for converting a.c power to d.c power, and
b) A rectifying system in rectifier type a.c, meters, such as a.c. voltmeter; in which the a.c voltage under measurement is first converted into d.c and measured with conventional meter. In this system, the rectifying elements are either copper oxide type or selenium type

The basic bridge rectifier circuit

D_1, D_2 - F.B
D_3, D_4 - R.B

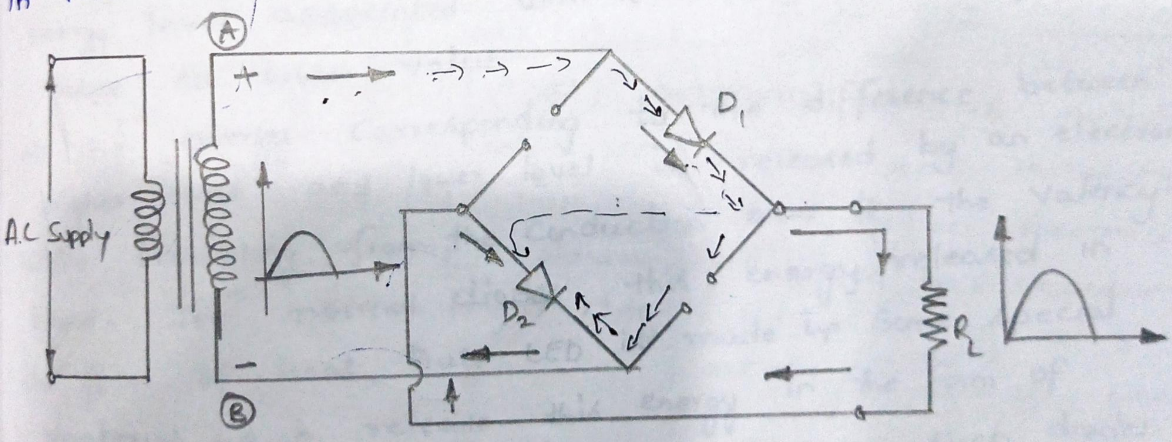


primary winding ↑
Secondary winding low

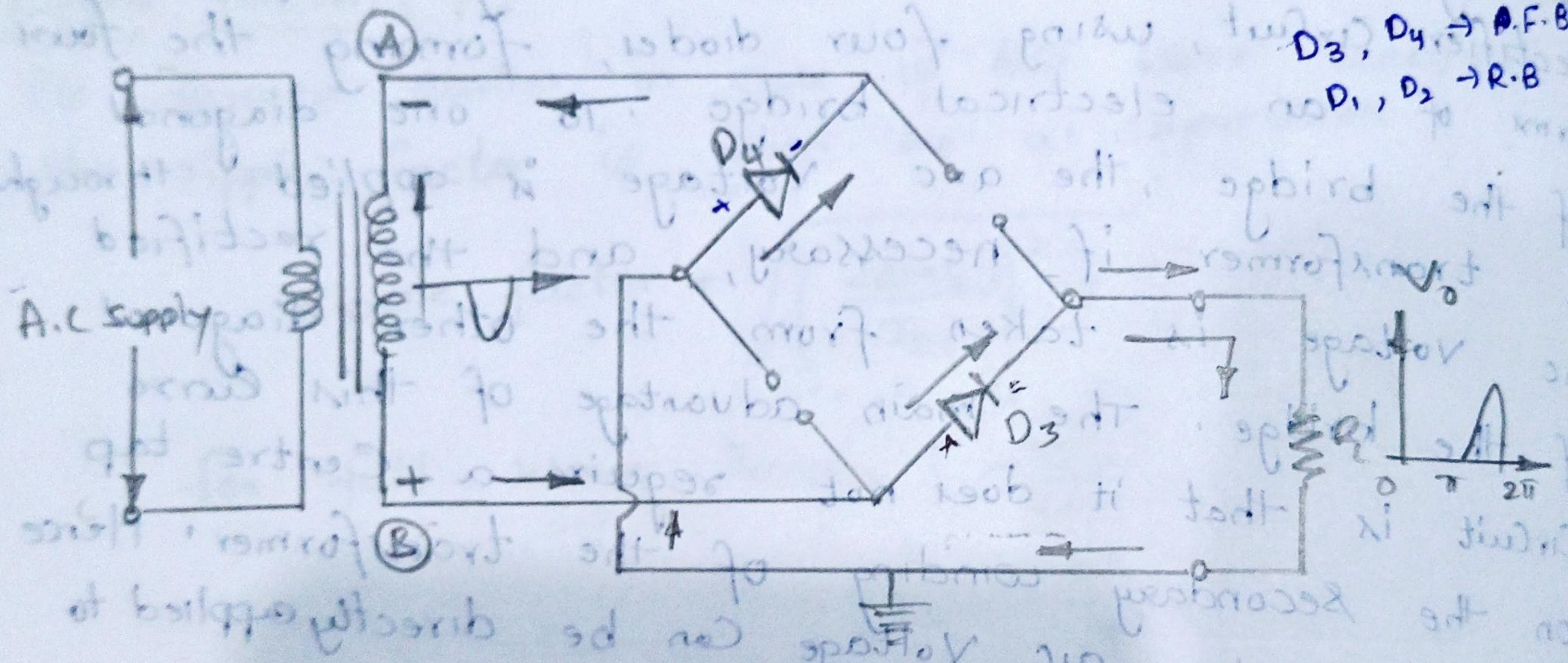
The bridge rectifier circuit is essentially a full-wave rectifier circuit, using four diodes, forming the four arms of an electrical bridge. To one diagonal of the bridge, the a.c voltage is applied through a transformer if necessary, and the rectified d.c voltage is taken from the other diagonal of the bridge. The main advantage of this circuit is that it does not require a centre tap on the secondary winding of the transformer. Hence wherever possible, a.c voltage can be directly applied to the bridge.

Operation of the Circuit :-

Consider the positive half of ac input voltage. The point A of secondary becomes positive. The diode D_1 and D_2 will be forward biased while D_3 & D_4 reverse biased. The two diodes D_1 and D_2 conduct in series with the load and the current flow



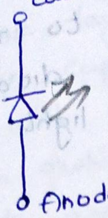
In the next half cycle, when the polarity of a.c voltage reverses hence point B becomes positive diodes D_3 and D_4 are forward biased, while D_1 and D_2 reverse biased. Now the diodes D_3 and D_4 conduct in series with the load and the current flows



· Current flow during negative half cycle

The waveforms of load Current and Voltage remain exactly as shown before in full wave rectifier

Light emitting diode :-



The Led is an optical diode, which emits light when forward biased. The Symbol of LED which is Similar to p-n junction diode apart from the two arrows indicating that the device emits the light energy. i.e, converts electrical energy to Light energy.

Forward bias vachenappudu light emit avutundi

Basic operation

Whenever a p-n junction is forward biased, the electrons cross the p-n junction from the n type semiconductor material and recombine with the holes in the p-type Semi conductor material. The free electrons are in the Conduction band while the holes are present in the valency band.

⇒ When a free electron recombine with hole, it falls from conduction band to a valency band. Thus the energy level associated with it changes from higher value to lower value

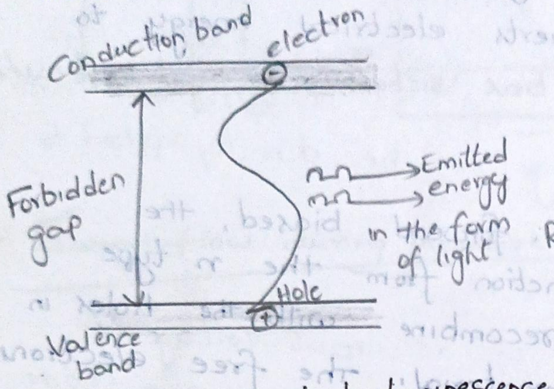
⇒ The energy Corresponding to the difference between higher level and lower level is released by an electron while travelling from the Conduction band to the Valency band. In normal diodes, this energy released in the form of heat, But LED is made up Some special material which release this energy in the form of photons which emit the light energy. Hence such diodes are called light emitting diodes.

This process is called electroluminescence

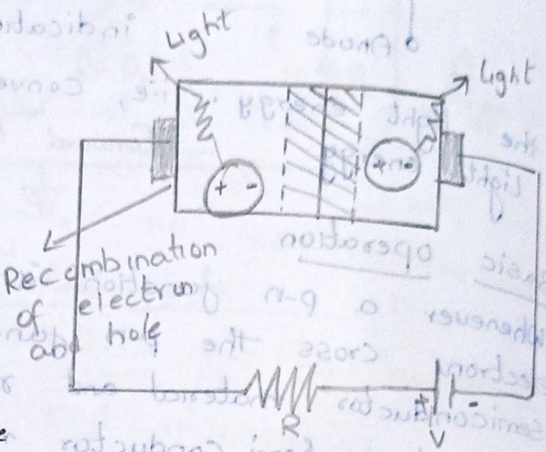
⇒ The basic principle of this process. The energy released in the form of light depends on the energy corresponding to the forbidden gap. This determines the wavelength of the emitted light. The wavelength determines the colour of the light and also determines whether the light is visible or invisible.

⇒ The Various impurities are also added during the doping process to Control the wavelength and

Colour of the emitted light. for normal silicon diode, the forbidden energy gap is 1.1eV and wavelength of the emitted light energy Corresponds to that of infrared light spectrum hence in normal diodes the light is not visible. The infrared light is not visible.



a) process of electroluminescence



b) Led forward biased

Materials used in LEDs

The LEDs use the materials like gallium arsenide, gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP). These are the mixtures of the elements gallium, arsenic and phosphorus. GaAsP produces red or yellow visible light while GaP emits red or green visible light. Some LEDs emits blue and orange light too

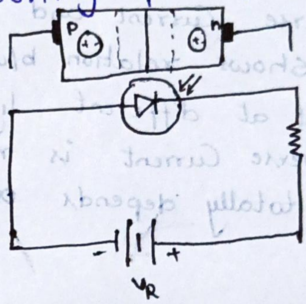
Construction of LED:

one of the methods used for the LED Construction is to deposite three Semi Conductor layers on the Substrate. In between p type and n type, there exists an active region. This active region emits light, when an electron and hole recombine. when the diode is forward biased, holes from p type and electrons from n type, both get driven into the active region. and when recombine, the light is emitted.

In this particular structure, the LED emit light all the way around the layered structure. Thus the basic layered structure is placed in a tiny reflective cup so that the light from the active layer will be reflected towards the desired exit direction. a)while the symbol of LED indicating identification of anode and cathode.

photodiode :-

The photodiode is a semiconductor p-n junction device whose region of operation is limited to the reverse biased region. the symbol of photodiode while the shows the working principle of photodiode.



The photodiode is connected in reverse biased condition. The depletion region width is large. under normal condition, it carries small reverse current due to minority charge carriers. when light is incident through glass windows on the p-n junction, photons in the light bombard the p-n junction and some energy is imparted to the valence electrons. Due to this, valence electrons are dislodged from the covalent bond and becomes free electrons. Thus more electron-hole pairs are generated. Thus total number of minority charge carriers increase and hence the reverse current increases. This is the basic principle of operation of photodiode.

photodiode Characterstics :

The photodiode is designed such that it is sensitive to the light.

When there is no light, the reverse biased photodiode carries a current which is very small and called dark current. It is denoted as I_λ. It is purely due to thermally generated minority carriers. When light is allowed to fall on a p-n junction through a small window, photons transfer energy to valence electrons to make them free. Hence reverse current increases. It is proportional to the light intensity. The photodiode. The fig 4.51 (a) shows the relation between reverse current and light intensity while the fig 4.51 (b) shows relation b/w reverse voltage and reverse current at different light intensities. It can be seen that reverse current is not dependent on reverse voltage and totally depends on light intensity.

Filters - Removes the Ripples

Inductor

L-Section filter

The filter is a device that allows passing the dc component of the load and blocks the ac component of the rectifier output. Thus the output of the filter Circuit will be a steady dc Voltage

=> The filter Circuit Can be Constructed by the Combination of Component like Capacitors, resistors and Inductors.

=> Inductor is used for its property that it allows only dc Components to pass and blocks ac Signals.

=> Capacitor is used to block the dc and allows ac to pass

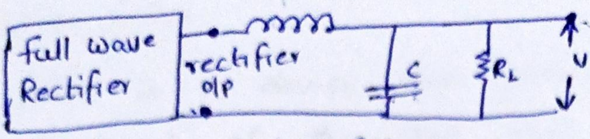
L-C filter can be two types : choke input L-Section filter and L-C Capacitor input filter

Choke input L-Section filter :-

Inductor filter increases the ripple factor with the increase in load Current.

A Capacitor filter has an inversly proportional ripple factor w.r.t load resistance. So both inductor filter and Capacitor filter are not Suitable for high purpose.

L-C inductor input or L-section filter Consists of an inductor L Connected in Series with a half or full wave rectifier and a Capacitor "c" across the load. This ~~ass~~ arrangement is also called a Choke input filter or L-Section filter because it's shape resembles and inverted L-Shape



L-Section filter

As shown in the circuit diagram above, the inductor L allows the dc to pass but restricts the flow of ac components. After a signal passes through the choke, if there is any fluctuation remaining the current, it will be fully by passed before it reaches the load by the capacitor because the value of X_C is much smaller than R_L.

the output of fullwave rectifier is

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t + \cdots$$

(Fourier Series of F.W.R o/p)

$$V_o = \sum_{k=0,2,4,6\ldots} \frac{\cos k\omega t}{(k+1)(k-1)}$$

$$V_{dc} = \frac{2V_m}{\pi}, \quad V_{ac} = \frac{4V_m}{3\pi}$$

(2nd harmonic component is primary ac source)

$$I_{ac} = \frac{V_{ac}}{X_L} = \frac{4V_m}{3\pi} \times \frac{1}{X_L}$$

$$I_{rms} = \frac{I_{ac}}{\sqrt{2}} = \frac{4V_m}{3\pi\sqrt{2}} \cdot \frac{1}{X_L}$$

$$V_{rms} = I_{rms} \cdot X_C$$

$$= \frac{4V_m}{3\pi\sqrt{2}} \cdot \frac{X_C}{X_L}$$

Capacitor filter Ripple $\propto \frac{1}{R_L}$

$I_r \propto R_L$

ripple factor $\gamma = \frac{V_{rms}}{V_{dc}}$

$$= \frac{\frac{4V_m}{3\pi\sqrt{2}} \cdot \frac{X_C}{X_L}}{\frac{2V_m}{\pi}}$$

$$= \frac{2}{3\sqrt{2}} \cdot \frac{X_C}{X_L}$$

$$\gamma = \frac{\sqrt{2}}{3} \cdot \frac{X_C}{X_L}$$

$$\gamma = \frac{\sqrt{2}}{3} \cdot \frac{1}{2\omega C} \cdot \frac{1}{2\omega L}$$ [∵ because of 2nd harmonic Component $\frac{4V_m}{3\pi}$ consider]

$$= \frac{\sqrt{2}}{3} \frac{1}{4\omega^2 CL}$$

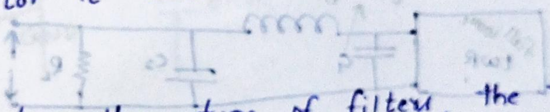
$$\gamma = \frac{\sqrt{2}}{12} \frac{1}{\omega^2 LC}$$

$$\boxed{\gamma = \frac{1}{6\sqrt{2}\,\omega^2 LC}}$$

CLC (or) π filter or Capacitor input filter

the name pi-filter implies to the resemblance of the Circuit to a π shape with two Shunt Capacitances (C_1 and C_2) and an Inductance filters.

As the rectifier output is provided directly into the Capacitor it also called a Capacitor input filter.



when Compared to other type of filters, the π-filter has Some advantages like higher dc Voltage and Smaller factor.

when higher output Voltage at light loads is required, an extra capacitor is added to LC filter to form π-Section filter CLC

So it is formed of two parts.

(i) C-filter by Capacitor C_1

(ii) LC filter by inductor L and Capacitor C_2

⇒ C_1 offers low resistance to ac Component obtained from rectified output. In this way C_1 passes large amount of ac to ground itself

Then dc Component moves towards 'L' it will easily pass through L but the ac which need not filtered by C_1 will be blocked

⇒ The C_2 by passes the final remaining ac Component of full wave rectifier output which Could not be filtered by L.

⇒ Now only dc Component will be available at the output.

Ripple factor:

It is given by

(gama) $\gamma_\pi = \gamma_c \cdot \gamma_{LC} \longrightarrow ①$

We know that

$\gamma_c = \frac{1}{4\sqrt{3} f C_1 R_L}$ and

$\gamma_{LC} = \frac{1}{6\sqrt{2}\,\omega^2 L C_2}$

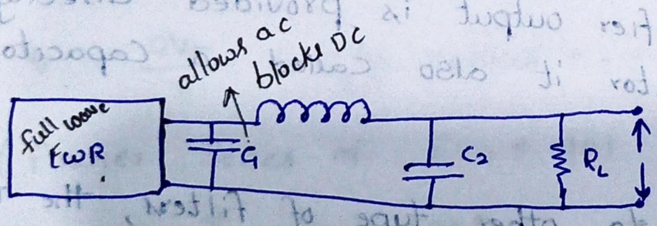
f = frequency

R_L = Load Resistance

C_1 = Capacitance,

$\omega = 2\pi f$

$f = \frac{\omega}{2\pi}$



π - Section filter

putting these Values in eqn ①

$$\gamma_\pi = \frac{1}{4\sqrt{3}\frac{\omega}{2\pi} C_1 R_L} \times \frac{1}{6\sqrt{2}\,\omega^2 L C_2}$$

$$= \frac{\pi}{12\sqrt{6}\,\omega^3 L C_1 C_2 R_L}$$

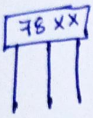
$$= \frac{\sqrt{2}\,\pi}{3\sqrt{3}\,(8\omega^3 L C_1 C_2 R_L)}$$

$$\gamma_\pi = \frac{0.854}{8\omega^3 L C_1 C_2 R_L}$$

Voltage Regulator:

A voltage regulator is a electronic circuit that provides a constant DC voltage irrespective of load current

→ The most widely used regulator is three terminal regulator



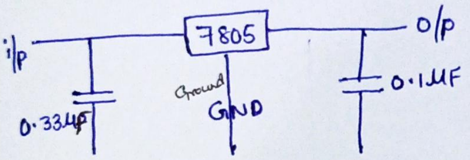
i/p GND o/p

fig: positive series regulator

i/p GND o/p

-ve series regulator

The simple circuit diagram for regulator is



The most commonly used three terminal regulator are 78XX and 79XX

→ The last two digit indicate the amount of output voltage of the IC

→ 78xx regulator provide fixed +ve voltage

→ 79xx regulator provide fixed -ve voltage

IC	output	IC	output
7805	5v	7905	-5v
7806	6v	7906	-6v
7808	8v	7908	-8v
7812	12v	7912	-12v

xx → output
78 = +ve
79 = -ve

Advantages of IC regulator

→ Low cost
→ easy to use
→ Simplify power supply design
→ Have additional features like built in protection, current limiting