

IES / GATE

Electronics & Telecommunication Engineering

VOLUME-IV

**Analogue Electronic Circuits
Digital Electronics**

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Introduction

Analog Electronic Circuit:-

A circuit which can process analog signals.



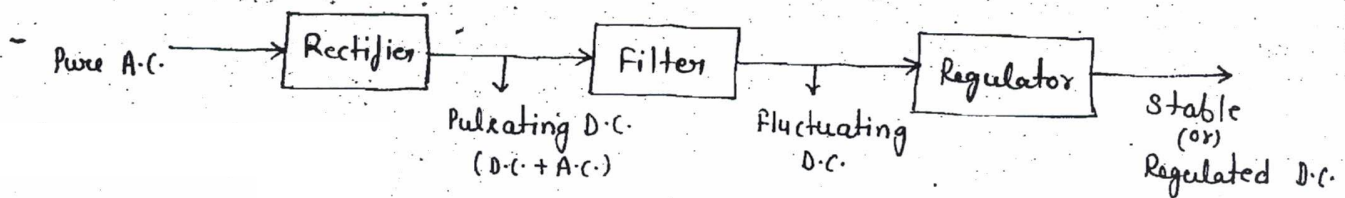
→ Since majority of real time signals are analog in nature so they can be directly processed using analog circuit where as digital processing requires analog to digital and digital to analog conversion.

→ An analog circuit can also operate at higher power levels.

Power Supply:-

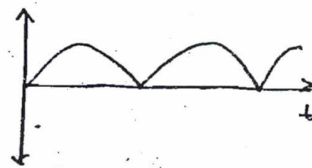
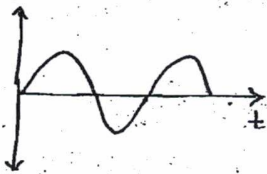
It is an electronic system which converts A.C. Power into D.C. Power.

A.C. to D.C. conversion is required because majority of electronic appliances operate with DC power. A regulated power supply is an interconnection of rectifier, filter and regulator.



Rectifier:-

A circuit which can convert a pure A.C. signal into pulsating D.C. signal (or) A circuit which converts a bidirectional signal into unidirectional signal.



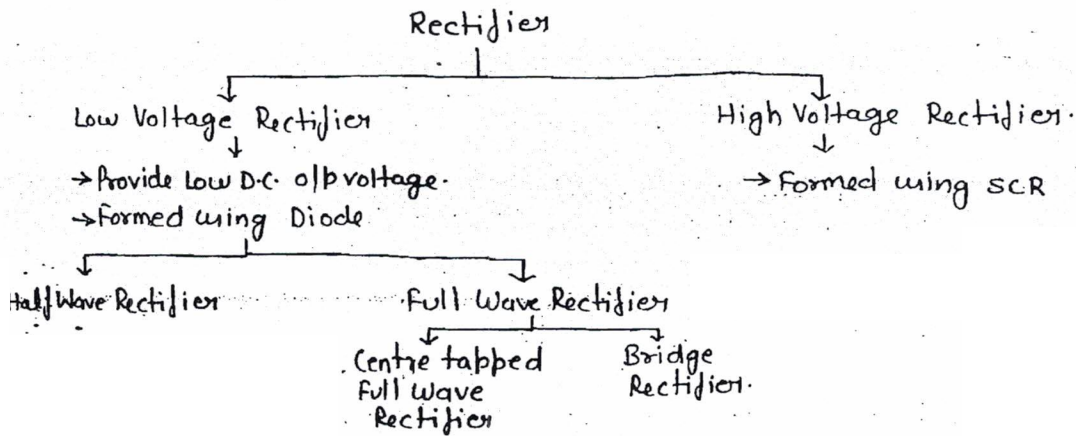
Pure A.C.:-

- It has periodic variations.
- It is bidirectional.
- It has zero avg. or D.C. value.
- No higher harmonics except fundamental frequency (f_0).

Pulsating D.C.:-

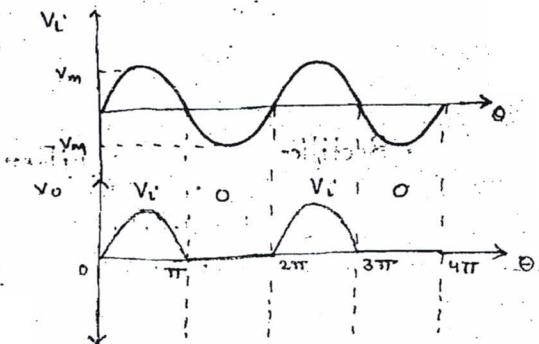
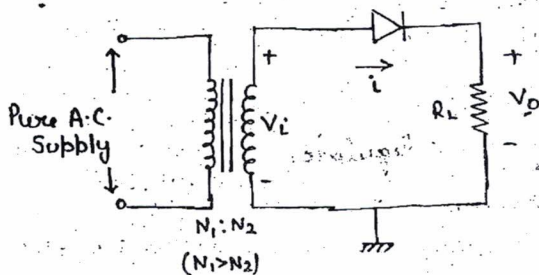
- It has periodic variations.
- It is unidirectional.
- It has non zero average or D.C. value.
- It has higher harmonics.

Periodic variation of pulsating D.C. signal indicates presence of A.C. component and non zero avg. indicates presence of D.C. component therefore Pulsating D.C. is considered to be combination of A.C. and D.C.



HALF WAVE RECTIFIER:-

Step down transformer is used in all low voltage rectifiers. It converts pure A.C. voltage having higher R.M.S value into pure A.C. voltage having smaller R.M.S. value.



Let $V_i = V_m \sin \omega t = V_m \sin \alpha$

$V_m =$ Peak A.C. input.

$\frac{V_m}{\sqrt{2}} =$ R.M.S A.C. i/p.

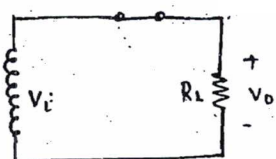
ω or $f_0 =$ Line Frequency or frequency of A.C. supply.

Operation:-

Let V_i be +ve ($0 < \alpha < \pi$)

When V_i is +ve diode is F.B. \equiv S.C.

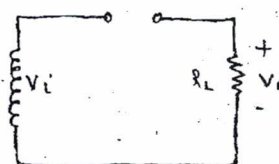
$V_o = V_i$



Let V_i be -ve ($\pi < \alpha < 2\pi$)

When V_i is -ve diode is R.B. \equiv O.C.

$V_o = 0$



V_i appears across the diode in O.C. condition only.

Analysis of Half Wave Rectifier :-

① Instantaneous o/p Current :- (i)

* $0 < \alpha < \pi$:- Diode is F.B. $\equiv R_F$ (A few ohm)

By KVL in secondary loop

$$-V_i + iR_F + iR_L = 0$$

$$i = \frac{V_i}{R_F + R_L}$$

$$i = \frac{V_m \sin \alpha}{R_F + R_L}$$

Let $\boxed{\frac{V_m}{R_F + R_L} = I_m}$ Peak o/p Current

$$\boxed{i = I_m \sin \alpha}$$

* $\pi < \alpha < 2\pi$:- Diode is R.B. $\boxed{i \cong 0}$

Silicon diode is a better rectifying device because it has much smaller reverse current (nA).

Thus

$$\boxed{i = \begin{cases} I_m \sin \alpha & ; 0 < \alpha < \pi \\ 0 & ; \pi < \alpha < 2\pi \end{cases}}$$

② D.C. output current :- (I_{DC})

$$I_{DC} = \text{Avg. value of } i = \frac{\text{Area}}{\text{Period}}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} i \, d\alpha$$

$$= \frac{I_m}{2\pi} \int_0^{\pi} \sin \alpha \, d\alpha$$

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

D.C. Load Current.
Avg. Load Current.

③ R.M.S. o/p current :- (I_{rms})

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2 \, d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2 \alpha \, d\alpha}$$

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

④ R.M.S. A.C. o/p current :- (I'_{rms})

Therefore

The o/p of rectifier is a combination of A.C. and D.C. components

$$i = \text{D.C.} + \text{A.C. component}$$

$$i = I_{DC} + i'$$

$$i' = i - I_{DC}$$

$$I'_{rms} = \text{R.M.S. value of } i' = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i'^2 \, d\alpha}$$

$$\begin{aligned}
 I_{rms} &= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (i - I_{DC})^2 d\alpha} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2 d\alpha + \int_0^{2\pi} I_{DC}^2 d\alpha - 2 \int_0^{2\pi} i I_{DC} d\alpha} \\
 &= \sqrt{I_{RMS}^2 + I_{DC}^2 - 2 I_{DC}^2}
 \end{aligned}$$

$$\boxed{I_{rms}' = \sqrt{I_{RMS}^2 - I_{DC}^2}}$$

I_{rms}' is also called reading of A.C. Ammeter because an A.C. ammeter connected in series with R_L records I_{rms}' .

Ripple Factor:-

Ripple factor refers to the unwanted A.C. component present in the output of rectifier.

Ripple factor is a measure of the amount of A.C. component in ripple.

Since A.C. component is unwanted, ripple factor should be smaller and ideally it should be zero.

Mathematically it is defined as:-

$$\begin{aligned}
 \gamma &= \frac{\text{R.M.S. A.C. Component}}{\text{D.C. Component}} \\
 &= \frac{V_{rms}'}{V_{DC}} \text{ or } \frac{I_{rms}'}{I_{DC}} \\
 &= \frac{\sqrt{I_{RMS}^2 - I_{DC}^2}}{I_{DC}} = \sqrt{\frac{I_{rms}'^2}{I_{DC}^2}} \\
 &= \sqrt{\frac{\pi^2 - 1}{4}}
 \end{aligned}$$

$$\boxed{\gamma = 1.21}$$

In the o/p. of half wave rectifier A.C. component is greater than D.C. Component

Input Power (P_i):-

It is the avg. of product of instantaneous voltage across secondary winding and instantaneous current through secondary winding.

$$P_i = \text{Avg. value of } \{V_i \times I_i\}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_i \times I_i d\alpha$$

$$= \frac{1}{2\pi} \int_0^{2\pi} (R_F + R_L) I^2 d\alpha$$

$$\boxed{P_i = I_{rms}^2 (R_F + R_L)}$$

Efficiency (η):-

Efficiency is a measure of the ability of a rectifier to convert input power into D.C. power.

Mathematically,

$$\eta = \frac{\text{D.C. o/p power}}{\text{i/p power}}$$

$$\eta = \frac{I_{DC}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100\%$$

$$\eta = \frac{(I_m / \pi^2) R_L}{(I_m^2 / 4) R_F + R_L} \times 100 = \frac{400}{\pi^2} \frac{R_L}{R_F + R_L} \%$$

$$\eta = 40.528 \frac{R_L}{R_F + R_L} \%$$

$$\eta = 40.528 \frac{R_L}{R_F + R_L + R_s} \%$$

R_s = Secondary Resistance.

If diode is ideal or $R_F = 0$ then maximum efficiency of 40.53% is obtained.

⑧ D.C. Diode Voltage:- ($V_{diode,dc}$)

It is the avg. value of the instantaneous voltage across the diode.

$0 < \alpha < \pi$ Diode is in F.B.

$$V_{diode} = I R_F \approx 0 \quad [\because R_F \text{ is small}]$$

$\pi < \alpha < 2\pi$ Diode is in R.B.

V_i appears across diode.

$$V_{diode} = V_i = V_m \sin \alpha$$

$$V_{diode} = \begin{cases} 0 & ; 0 < \alpha < \pi \\ V_m \sin \alpha & ; \pi < \alpha < 2\pi \end{cases}$$

D.C. Diode voltage is

$$V_{diode,dc} = \text{Avg. of } V_{diode}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_{diode} d\alpha = \frac{1}{2\pi} \int_0^{\pi} 0 d\alpha + \frac{1}{2\pi} \int_{\pi}^{2\pi} V_m \sin \alpha d\alpha$$

$$V_{diode,dc} = -\frac{V_m}{\pi}$$

⑨ No Load D.C. o/p Voltage:- (V_{DCNL}) :-

It is the D.C. o/p voltage of a rectifier when load current is zero.

$$V_{DCNL} = V_{oc} |_{I_{DC} = 0}$$

$$V_{diode,dc} + V_{DCNL} = 0$$

$$V_{DCNL} = -V_{diode,dc}$$

$$V_{DCNL} = \frac{V_m}{\pi}$$

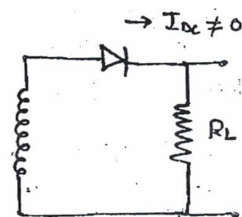
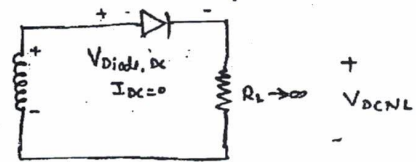
V_{DCNL} is also called maximum o/p D.C. voltage.

⑩ Full Load D.C. o/p Voltage:- (V_{DCFL}) :-

It is the o/p voltage of a rectifier when load current is not zero.

When load current flows D.C. voltage drop takes place in D.C. resistance of secondary winding and across the diode.

$$V_{DCFL} = V_{DCNL} - \text{Internal voltage Drop}$$



$$V_{DCFL} = \frac{V_m}{\pi} - I_{DC} R$$

where $R = R_{sw} + R_F$

or

$$V_{DCFL} = I_{DC} \cdot R_L$$

sp If $R_L \downarrow$ then $I_{DC} \uparrow \rightarrow I_{DC} \times R \uparrow \rightarrow V_{DCFL} \downarrow$

\rightarrow D.C. o/p voltage of a rectifier decreases with increase in load current.

1) Regulation Factor:-

It is a measure of the change in D.C. o/p voltage due to change in load current.

Mathematically,

$$\% \text{ Regulation} = \frac{V_{DCNL} - V_{DCFL}}{V_{DCFL}} \times 100\%$$

$$= \frac{(V_m/\pi) - \{(V_m/\pi) - I_{DC} R\}}{I_{DC} R_L} \times 100\%$$

$$\% \text{ Regulation} = \frac{R}{R_L} \times 100\%$$

where $R = R_{sw} + R_F$

sp

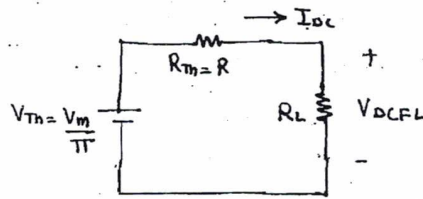
If winding and diode are ideal then %age regulation becomes zero.

For a power supply %age regulation should be zero ideally.

1) Thevenin's Equivalent Circuit:-

$$V_{DCFL} = \frac{V_m}{\pi} - I_{DC} R$$

\downarrow V_m \downarrow R_{Th}



Peak Inverse voltage (or) PIV:-

It is the maximum voltage which appears across diode in a non conducting state i.e. in reverse bias in a rectifier.

PIV = Max. Diode voltage when diode is R.B.

$$= |V_m \sin \alpha|_{\max}$$

$$\boxed{PIV = V_m}$$

Diode will be safe if PIV is less than breakdown voltage.

Transformer Utilization Factor (TUF):-

It is the ratio of D.C. o/p power and A.C.

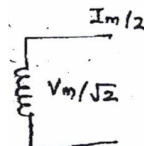
rating of the transformer secondary winding.

or any winding A.C. rating is the product of R.M.S voltage across the winding and R.M.S current through the winding.

A.C. rating is expressed in volt-Ampere.

$$TUF = \frac{P_{DC}}{\text{A.C. rating of secondary}}$$

$$= \frac{I_{DC}^2 R_L}{(V_m/\sqrt{2}) (I_m/2)}$$



$$\begin{aligned}
 \text{TUF} &= \frac{I_m^2 \times 2\sqrt{2} R_L}{\pi^2 \cdot V_m I_m} \\
 &= \frac{2\sqrt{2} I_m^2 R_L}{\pi^2 I_m^2 (R_F + R_L)}
 \end{aligned}$$

$$\boxed{\text{TUF} = 0.286 \frac{R_L}{R_F + R_L}}$$

Maximum TUF = 0.286 or 28.6%.

TUF is useful in calculation of D.C. o/p power if A.C. rating of secondary winding is known.

$$\boxed{P_{DC} = \text{TUF} \times \text{A.C. Rating}}$$

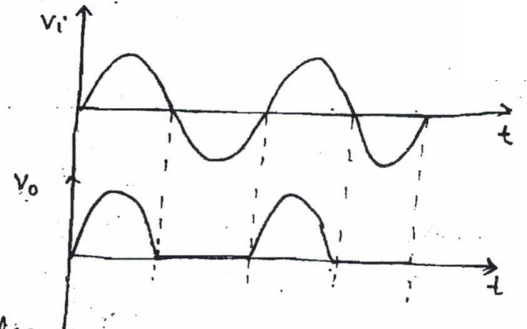
15) Frequency of o/p:- (Ripple Frequency):-

Since time period of i/p and o/p waveform is equal their frequencies will be the same

$$\boxed{\text{Ripple frequency} = f_0}$$

where $f_0 =$ Line frequency
or
A.C. Supply frequency.

Output waveform is non sinusoidal therefore it also has higher harmonics which can be found in the trigonometric fourier series of V_o .

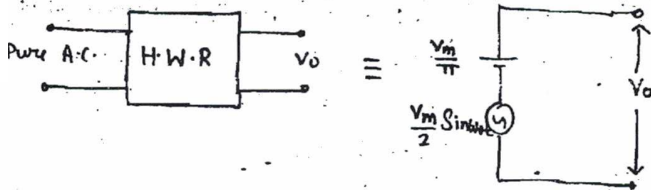


$$V_o \approx \underbrace{\frac{V_m}{\pi}}_{\text{D.C. Component}} + \underbrace{\frac{V_m}{2} \sin \omega t}_{\text{A.C. Component}} - \frac{2V_m}{\pi} \sum_{R=\text{even}} \frac{\cos R \omega t}{(R+1)(R-1)}$$

A.C. Component
A.C. Component (Harmonics)

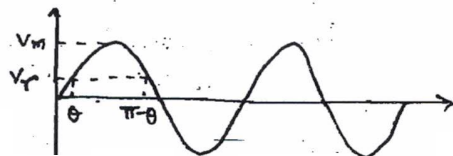
If higher harmonics are neglected then

$$V_o = \frac{V_m}{\pi} + \frac{V_m}{2} \sin \omega t$$



16) Angle of Conduction:-

It is the duration for which diode conducts in a rectifier. If diode is ideal conduction takes place from 0 to π therefore angle of conduction will be 180° .



If diode has cut-in voltage V_r conduction occurs when i/p voltage exceeds cut in voltage therefore a non ideal diode conducts from θ to $\pi - \theta$ and conduction angle becomes $180^\circ - 2\theta$.

At $\alpha = \theta$

$$V_i = V_m \sin \theta = V_r$$

$$\sin \theta = \frac{V_r}{V_m}$$

hence,

$$\theta = \sin^{-1} \left\{ \frac{V_r}{V_m} \right\}$$

d) Form Factor:-

It is the ratio of R.M.S value and average value.

$$F.F = \frac{I_{rms}}{I_{avg}} = \frac{I_{rms}}{I_{dc}}$$

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

$$= \pi/2$$

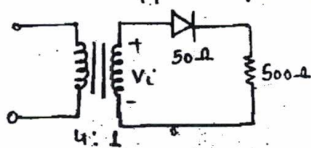
$$F.F = 1.57$$

F.F. is a measure of smoothness in the waveform. Smaller F.F. indicates greater smoothness.

$$r = \sqrt{(F.F)^2 - 1}$$

- b:- A half wave rectifier uses a 4:1 transformer and a diode with $R_F = 50\Omega$.
 If load resistance is 500Ω and primary voltage is 220 V rms, 50 Hz. Calculate
 (i) D.C. o/p current and voltage (ii) A.C. o/p current and voltage
 (iii) DC diode current and voltage (iv) RMS o/p current and voltage
 (v) PIV and Ripple frequency (vi) I/p power and D.C. o/p power (vii) % efficiency & Regulation.

sol:-



$$V_i = \frac{220}{4} = 55 \text{ V rms}$$

$$\frac{V_m}{\sqrt{2}} = 55$$

$$V_m = 55\sqrt{2} = 77.78 \text{ Volts}$$

$$I_m = \frac{V_m}{R_F + R_L} = 141.42 \text{ mA}$$

Since Diode and R_L are connected in series D.C. diode current will be same as D.C. o/p current.

i) $PIV = V_m = 77.78 \text{ Volts}$
 $f_o = 50 \text{ Hz}$ } Ans

ii) $\% \eta = 40.5 \frac{R_L}{R_F + R_L} = 36.81\%$ Ans

$\% \text{ Regulation} = R \times 100\% = \frac{50}{50} \times 100 = 10\%$ Ans

(i) D.C. o/p current & D.C. o/p voltage

$$I_{dc} = \frac{I_m}{\pi} = \frac{141.42}{\pi} = 45.02 \text{ mA}$$

$$V_{dc} = \frac{V_m}{\pi} = \frac{77.78}{\pi} = 24.75 \text{ V} = I_{dc} R_L$$
 } Ans

(ii) $I_{rms} = r I_{dc} = \sqrt{I_{rms}^2 - I_{dc}^2} = 1.21 \times 45.02$

$$I_{rms} = 54.47 \text{ mA}$$
 Ans

$$V_{rms} = I_{rms} \times R_L = 54.47 \times 10^{-3} \times 500$$

$$V_{rms} = 27.24 \text{ Volt}$$
 Ans

(iii) $I_{diode, dc} = I_{dc} = 45 \text{ mA}$ Ans

$$V_{diode, dc} = -\frac{V_m}{\pi} = -24.75 \text{ Volts}$$
 Ans

(iv) $I_{rms} = \frac{I_m}{2} = \frac{141.42}{2} = 70.71 \text{ mA}$ Ans

$$V_{rms} = \frac{V_m}{2} = 38.89 \text{ Volts}$$
 Ans

(v) $P_{i/p} = I_{rms}^2 (R_F + R_L) = 2.75 \text{ Watts}$

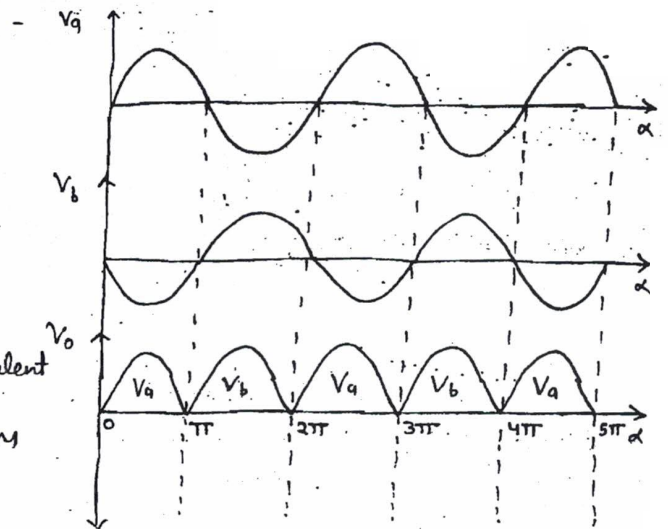
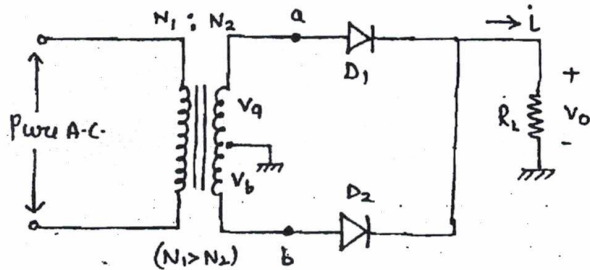
$$P_{o/p, dc} = I_{dc}^2 R_L = 1.0134 \text{ Watts}$$

FULL WAVE RECTIFIER:-

Center Tapped Full Wave Rectifier:-

- * Secondary winding of transformer is center tapped i.e. winding is divided into two halves and each half has equal no. of turns.
- * If primary winding has N_1 turns then each half of secondary winding has N_2 turns.
- * V_a and V_b are equal in magnitude but opposite in sign i.e. $V_b = -V_a$

If $V_a = V_m \sin \alpha$
then $V_b = -V_m \sin \alpha$

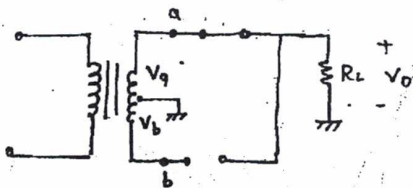


- * A Full wave rectifier is functionally equivalent to two half wave rectifiers.
- * D_1 performs rectification of V_a and D_2 performs rectification of V_b .

operation:-

1- $0 < \alpha < \pi$:-

- V_a is +ve $\Rightarrow D_1$ is F.B. \equiv S/C
- V_b is -ve $\Rightarrow D_2$ is R.B. \equiv O/C

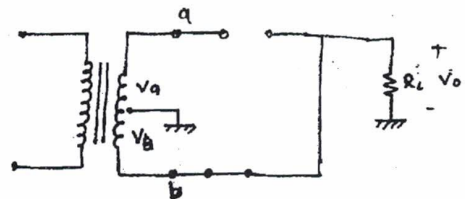


As node a is connected to R_L so V_a appears across R_L .

$V_o = V_a$

2- $\pi < \alpha < 2\pi$:-

- V_a is -ve $\Rightarrow D_1$ is R.B. \equiv O/C
- V_b is +ve $\Rightarrow D_2$ is F.B. \equiv S/C



As node b is connected to R_L so V_b appears across R_L .

$V_o = V_b$

Analysis of Full Wave Rectifier:-

① Instantaneous o/p Current:-

$0 < \alpha < \pi$:-

D_1 is F.B. \equiv R_F

By KVL $V_a = iR_F + iR_L$

$i = \frac{V_a}{R_F + R_L}$

$I = \frac{V_m \sin \alpha}{R_F + R_L} = I_m \sin \alpha$

$\pi < \alpha < 2\pi$:-

D_2 is in F.B. \equiv R_F

By KVL $V_b = i(R_F + R_L)$

$i = \frac{V_b}{R_F + R_L} = -\frac{V_m \sin \alpha}{R_F + R_L}$

$I = -I_m \sin \alpha$

Thus,

$$i = \begin{cases} I_m \sin \alpha & ; 0 < \alpha < \pi \\ -I_m \sin \alpha & ; \pi < \alpha < 2\pi \end{cases}$$

D) D.C. o/p Current :-

$$I_{DC} = \text{Avg. of } i = \frac{1}{2\pi} \int_0^{2\pi} i \, d\alpha$$

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

E) R.M.S. o/p Current :-

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2 \, d\alpha}$$

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

F) R.M.S. A.C. o/p Current :-

$$I'_{rms} = \text{rms value of } i' = \text{rms value of } (i - I_{DC})$$

$$I'_{rms} = \sqrt{I_{rms}^2 - I_{DC}^2}$$

G) Ripple Factor :-

$$r = \frac{I'_{rms}}{I_{DC}} = \sqrt{\left(\frac{I'_{rms}}{I_{DC}}\right)^2 - 1}$$

$$r = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1}$$

$$r = 0.483$$

In the o/p of Full wave rectifier A.C. component is less than D.C. Component.

H) Input Power (P_i) :-

$$P_i = \frac{1}{2\pi} \left[\int_0^{\pi} V_a \cdot i \, d\alpha + \int_{\pi}^{2\pi} V_b \cdot i \, d\alpha \right]$$

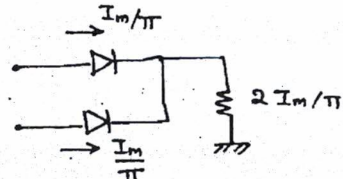
$$= (R_F + R_L) \cdot \frac{1}{2\pi} \int_0^{2\pi} i^2 \, d\alpha$$

$$P_i = I_{rms}^2 (R_F + R_L)$$

I) Efficiency (η) :-

$$\begin{aligned} \% \eta &= \frac{P_{DC}}{P_i} \times 100 \% \\ &= \frac{I_{DC}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100 \% \\ &= \frac{4I_m^2 \times 2 R_L}{\pi^2 I_m^2 (R_F + R_L)} \times 100 \% \\ &= \frac{800}{\pi^2} \frac{R_L}{R_F + R_L} \times 100 \% \end{aligned}$$

$$\% \eta = 81 \frac{R_L}{R_F + R_L} \%$$



⑧ D.C. Diode Voltage:-

Consider diode D_1

Let V_{diode} be the instantaneous voltage across D_1

$0 < \alpha < \pi$:-

D_1 is F.B.

$$V_{diode} = I R_f \approx 0$$

$\pi < \alpha < 2\pi$:-

D_2 is in F.B.

By KVL

$$V_b - V_a + V_{diode} = 0$$

$$V_{diode} = V_a - V_b$$

$$V_{diode} = 2V_m \sin \alpha$$

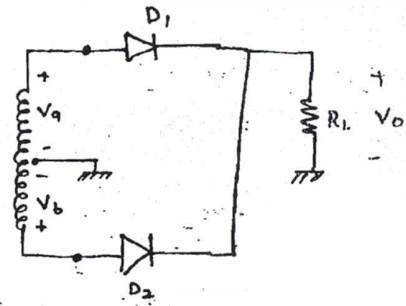
Thus

$$V_{diode} = \begin{cases} 0 & ; 0 < \alpha < \pi \\ 2V_m \sin \alpha & ; \pi < \alpha < 2\pi \end{cases}$$

DC Diode voltage is

$$V_{diode, DC} = \frac{1}{2\pi} \int_0^{2\pi} V_{diode} d\alpha$$

$$V_{diode, DC} = \frac{2V_m}{\pi}$$



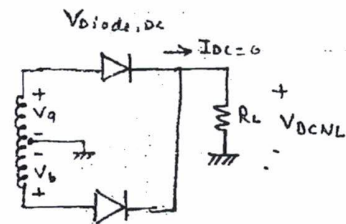
⑨ No Load D.C. o/p voltage (V_{DCNL}):-

$$V_{DCNL} = V_{DC} \Big|_{I_{DC} = 0}$$

By KVL

$$-0 + V_{diode, DC} + V_{DCNL} = 0$$

$$V_{DCNL} = \frac{2V_m}{\pi}$$



⑩ Full Load DC. o/p Voltage (V_{DCFL}):-

$$V_{DCFL} = V_{DC} \Big|_{I_{DC} \neq 0}$$

$V_{DCFL} = V_{DCNL} - \text{Internal voltage drop}$

$$V_{DCFL} = \frac{2V_m}{\pi} - I_{DC} R$$

where $R = \frac{R_{sw}}{2} + R_f$

or

$$V_{DCFL} = I_{DC} \cdot R_L$$

⑪ Regulation factor:-

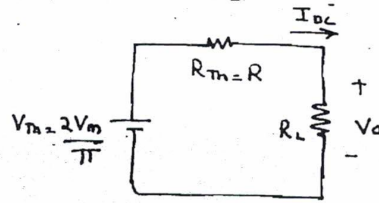
$$\% \text{ Regulation} = \frac{V_{DCFL} - V_{DCNL}}{V_{DCFL}} \times 100\%$$

$$\% \text{ Regulation} = \frac{R}{R_L} \times 100\%$$

⑬ Thevenin's Equivalent :-

$$V_{ocFL} = \frac{2V_m}{\pi} - I_{DC} R$$

\downarrow \downarrow
 V_m R_m



⑭ Peak Inverse Voltage :-

PIV = $|V_{o\text{diode}}|_{\text{max}}$ when diode is in Reverse bias
 $= |2V_m \sin \alpha|_{\text{max}}$

$PIV = 2V_m$

⑮ Transformer Utilization Factor (or) TUF :-

Secondary circuit in full wave rectifier is combination of two half wave rectifiers therefore the value of TUF with respect to secondary winding is two times the TUF in half wave rectifier.

Max T.U.F_{sw} = 2 × 286

$TUF_{sw} \uparrow_{\text{max}} = 0.57$

TUF with respect to primary is defined as

$$TUF_{pw} = \frac{\text{D.C. o/p power}}{\text{A.C. rating of primary winding}}$$

$$= \frac{I_{DC}^2 \cdot R_L}{\frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}}$$

$\therefore V_m, I_m = V_m \cdot I_m = I_m^2 (R_F + R_L)$

$$TUF_{pw} = \frac{2 I_{DC}^2 R_L}{I_m^2 (R_F + R_L)} = \frac{2 \times 4}{\pi^2} \frac{R_L}{R_F + R_L}$$

$$= \frac{8}{\pi^2} \times \frac{R_L}{R_F + R_L} \times 100\%$$

$TUF_{pw} = 81 \frac{R_L}{R_F + R_L} \%$

Avg. TUF = $\frac{TUF_{pw} + TUF_{sw}}{2} = \frac{0.57 + 0.81}{2}$

$\text{Avg. TUF} = 0.69$

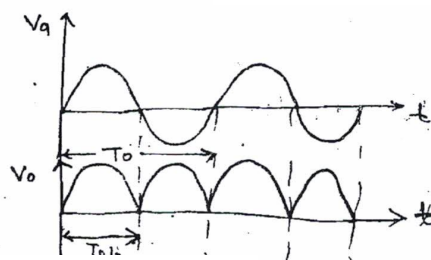
⑯ Ripple Frequency or Frequency of o/p :-

As time period of o/p is $T_0/2$, frequency of o/p will be two times the frequency of input.

$\text{Ripple frequency} = 2f_0$

Trigonometric Fourier series for signal voltage V_o is

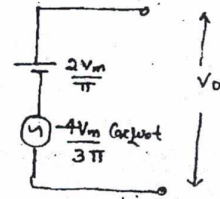
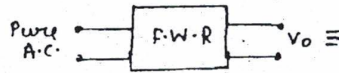
$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{\pi} \sum \frac{\cos k\omega t}{k^2}$



A.C. components has even harmonics i.e. $2\omega_0, 4\omega_0, 6\omega_0$ etc. It does not have fundamental frequency ω_0 . Due to this filtering process will be relatively easier in F.W.R

If higher frequency harmonics are ignored.

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi} \cos 2\omega_0 t$$



(16) Angle of Conduction:-

If diodes are ideal then each diode conducts for 180° and net conduction angle will become 360° .

If diodes are non ideal then each diode conducts for $180 - 2\theta$ and overall conduction angle becomes $360 - 4\theta$.

D_1 conducts from θ to $\pi - \theta$

D_2 conducts from $\pi + \theta$ to $2\pi - \theta$

where

$$\theta = \sin^{-1} \left[\frac{V_r}{V_m} \right]$$

(17) Form Factor:-

$$F.F = \frac{I_{rms}}{I_{dc}} = \frac{I_m/\sqrt{2}}{2I_m/\pi}$$

$$= \frac{\pi}{2\sqrt{2}}$$

$$F.F = 1.11$$

Advantages:-

- 1- Small Ripple Factor.
- 2- Larger efficiency.
- 3- Larger T.U.F.
- 4- Larger D.C. output voltage & current.
- 5- Filtering of A.C. component is easier.

Disadvantages:-

- 1- Higher Peak Inverse voltage (PIV).
- 2- It is necessary to use center tapped transformer which is costlier and bigger in size.

Ex: A Full wave rectifier uses a 2:1 center tapped transformer and diodes with internal resistance 50Ω . If load resistance is $1k\Omega$ and primary voltage is $120V$ R.M.S and $60Hz$. Calculate

- a) D.C. & A.C. Load current b) D.C. & A.C. Load voltage c) D.C. diode voltage & current
- d) PIV & Ripple factor e) Efficiency & regulator factor.

Sol: $\frac{V_p}{V_s} = \frac{2}{1} \Rightarrow V_s = 60 \text{ V}_{rms}$

$$V_m = 60\sqrt{2} \text{ volts}$$

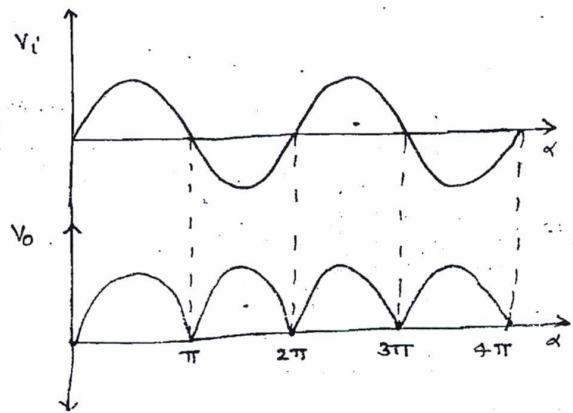
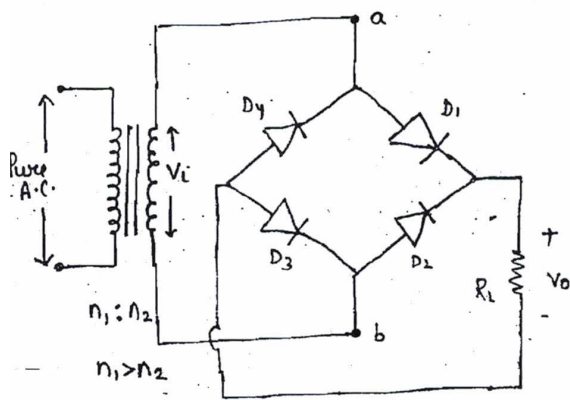
$$I_m = \frac{V_m}{R_F + R_L} = \frac{60\sqrt{2}}{1050} = 80.81 \text{ mA}$$

a) $I_{dc} = \frac{2}{\pi} I_m = 51.242 \text{ mA}$; $I_{rms} = \gamma \times I_{dc} = 0.483 \times 51.42 = 24.83 \text{ mA}$

- b) $V_{DC} = I_{DC} R_L = 51.42 \text{ Volt}$
 $V_{RMS} = \gamma \times V_{DC} = 24.83 \text{ Volt}$ Ans
- c) $V_{i(\text{diode, dc})} = \frac{2V_m}{\pi} = 54 \text{ Volt}$
 $I_{i(\text{diode, dc})} = \frac{I_m}{\pi} = 25.7 \text{ mA}$ Ans
- d) $P_{IV} = 2V_m = 169.7 \text{ Volt}$
 $f_0 = 60 \text{ Hz}$
 Ripple frequency = $2f_0 = 120 \text{ Hz}$ Ans
- e) $\gamma \cdot \eta = 81 \times \frac{R_L}{R_F + R_L} = 77.14\%$
 $\gamma \cdot \text{regulation} = \frac{R}{R_L} \times 100 = 5\%$ Ans

Bridge Rectifier:-

It uses a normal step down transformer and 4 diodes connected in the form of bridge network.



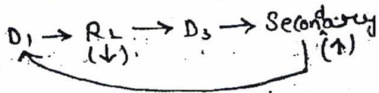
Operation:-

V_i is pure A.C. voltage of smaller R.M.S. values
 Let $V_i = V_m \sin \alpha$

(i) $0 < \alpha < \pi$:-

V_i is +ve node a is +ve w.r.t node b.
 Diode D_1 and D_3 are ON and diode D_2 & D_4 are OFF.

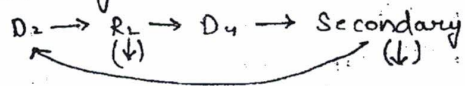
Current flow takes place in the loop consisting D_1 , R_L , D_3 and Secondary winding.



(ii) $\pi < \alpha < 2\pi$:-

V_i is -ve node a is -ve w.r.t node b.
 Diode D_2 & D_4 are ON and diode D_1 & D_3 are OFF.

Current flow takes place in the loop consisting of D_2 , R_L , D_4 & Secondary winding.



→ Current through the secondary winding is bidirectional.

→ Current through R_L is unidirectional or pulsating D.C. because it flows in downward direction.

Analysis of Bridge Rectifier:-

① Instantaneous o/p Current:-

$$i = \begin{cases} I_m \sin \alpha & ; 0 < \alpha < \pi \\ -I_m \sin \alpha & ; \pi < \alpha < 2\pi \end{cases}$$

where,

$$I_m = \frac{V_m}{2R_F + R_L}$$

② $I_{DC} = \frac{2 I_m}{\pi}$

③ $I_{RMS} = \frac{I_m}{\sqrt{2}}$

④ $I_{RMS} = \sqrt{I_{RMS}^2 - I_{DC}^2}$

⑤ $\gamma = 0.483$

⑥ $P_i = I_{RMS}^2 (2R_F + R_L)$

⑦ $\% \eta = \frac{\delta I R_L}{2R_F + R_L} \%$

⑧ DC Diode Voltage:-

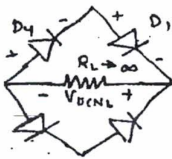
Considering D_1 ,

$$V_{diode} = \begin{cases} 0 & ; 0 < \alpha < \pi \\ V_m \sin \alpha & ; \pi < \alpha < 2\pi \end{cases}$$

$$V_{diode, DC} = \frac{1}{2\pi} \int_0^{2\pi} V_{diode} d\alpha$$

$$V_{diode, DC} = \frac{-V_m}{\pi}$$

⑨ No load DC o/p Voltage (V_{DCNL}):-



By KVL in loop D_1, D_4, R_L

$$V_{diode, DC} + V_{DCNL} + V_{diode, DC} = 0$$

$$V_{DCNL} = -2V_{diode, DC}$$

$$V_{DCNL} = +\frac{2V_m}{\pi}$$

⑩ Full Load DC o/p Voltage (V_{DCFL}):-

$$V_{DCFL} = \frac{2V_m}{\pi} - I_{DC} R$$

where,

$$R = R_{sw} + 2R_F$$

$$V_{DCFL} = I_{DC} \times R_L$$

⑪ Peak Inverse Voltage:-

$$PIV = |V_{diode}|_{max} \text{ when diode is in R.B.}$$

$$= |V_m \sin \alpha|_{max}$$

$$PIV = V_m$$

⑫

$$\text{Ripple frequency} = 2f_0$$

⑬

$$\text{Angle of Conduction} = 360^\circ - 4\theta$$

$$\theta = \sin^{-1} \left[\frac{2V_F}{V_m} \right]$$

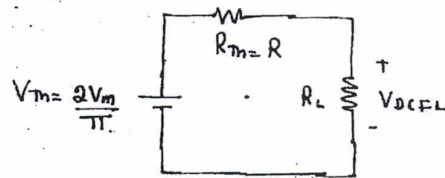
⑭

$$f \cdot F = 1.11$$

⑪ % Regulation:-

$$\% \text{ Regulation} = \frac{R}{R_L} \times 100\%$$

⑫ Thevenin's Equivalent Circuit:-



⑬ Transformer Utilization Factor:-

$$TUF = \frac{\text{D.C. o/p Power}}{\text{A.C. Rating of Secondary winding}}$$

$$= \frac{I_{DC} R_L}{\frac{V_m \cdot I_m}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}}}$$

$$= \frac{2 \times 4 I_m^2 R_L}{\pi^2 (R_L + 2R_F) I_m^2}$$

$$TUF = \frac{0.81 R_L}{2R_F + R_L}$$

$$TUF|_{max} = 81\%$$

Sub

If transformer of similar secondary AC ratings are used in the three rectifiers then maximum D.C. o/p power is the highest in the bridge rectifier.