22/12/2021 INTRODUCTION To ELECTRONICS ENGINEERING:

UNIT-1:

*Semi-Conductor: is a material whose resistance & conductance lies between that of conductors & insulators.

Resistivity: C < SC < I

Conductivity: C > SC > I

→ As temperature ↑ses; semiconductor acts as a conductor as resistivity ↓ses

* Temp. coefficient of resistance of Semi-conductor is -ve

* Temp. coeff. of conductance of semi-conductor is +ve

Eg: Si → 4 val e⁻s, Ge → 4 val e⁻s.

Trivalent → B

Pentavalent → P.

* Flow of e⁻s from high potential to low potential is called CURRENT.

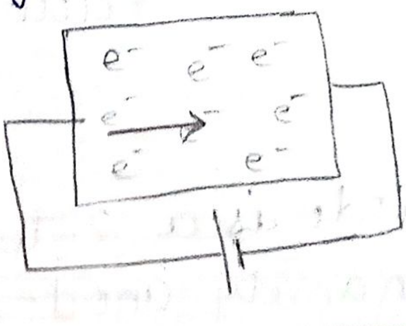
* Ways to free the valence electrons from nucleus influence:

→ External Electric field

→ Light / photon energy.

→ Increase in Temp. i.e. Heat supply.

→ Doping.



Intrinsic Semi-Conductor: Semi-conductor in its purest form (or) Semi-conductor before doping

Extrinsic Semi-conductor: Intrinsic semi-conductors are converted to extrinsic semi-conductor by doping

Hole → +ve charge carrier (hypothetical).
e^- → −ve charge carrier (existing).

* Holes & electrons move in opp. direction.

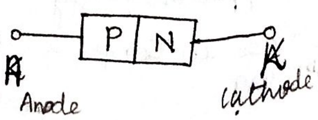
TRIVALENT]
PENTAVALENT] — DOPING — [Holes → Majority → P-types
[Electrons → Majority → N-types

* Doping is to add trivalent/pentavalent impurities to a pure semi-conductor.

* Need of Doping:
To increase the conductivity of semi-conductor.
To improve electrical properties of semi-conductor.

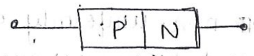
* P-N JUNCTION DIODE:

Diode < Di = 2, electrodes



Diode is a 2-terminal device with 2 electrodes namely anode & cathode.

Construction: ~~P&N~~ Diode is formed by fusing P&N-type SC materials by special fabrication technique.

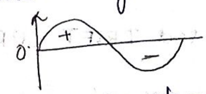


Symbol:

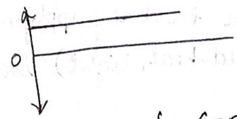
• Diode is a UNI-DIRECTIONAL DEVICE (conducts only in one direction).
• Diode acts as a switch as its is uni-directional.
• Diode is mainly used for rectification. (RECTIFIER)

RECTIFIER: Converts AC to DC

AC → alternating current → changes direction



DC → direct current → +ve quadrant.



DC is used for charging.
Home appliances requires DC. } Computers require AC

Charge carriers → Holes, Electrons

APPLICATIONS: (RECTIFIER)
→ Rectifier is used for charging
→ Home appliances requires DC.

* TYPES OF CURRENTS INVOLVED IN DIODES.
1) Drift Current
2) Diffusion current.

Movement of charge carriers from high concentration region to low concentration region is ~~called~~ in ~~DIF~~ non-uniformly doped semi-conductor is called DIFFUSION CURRENT.

* When p&n type materials are ~~do~~ fused to form diode i.e. movement of holes from p-type to n-type the flow of holes is called diffusion current → Beginning Stage.

Shifting something with external force → Drift.

- Moving ~~to~~ charge carriers ~~from~~ in one direction by an external force is called DRIFT CURRENT.
- Movement of charge carriers from valence band ~~from~~ to conduction band by applying external energy (electric field, heat, light) is called DRIFT CURRENT.

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* Compare Diffusion current & Drift current:

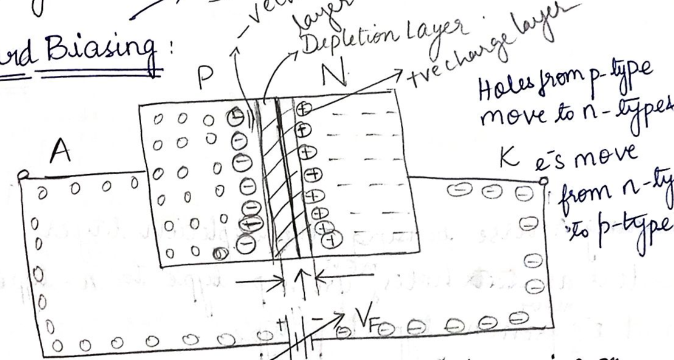
DIFFUSION	DRIFT
1) Movement of charge carriers from high conc. to low conc.	1) movement of charge carriers from V.B to CB.
2) It is done directly without any force.	2) It is done using some external force i.e. heat, light.
3) It flows during the beginning of construction	3) It flows even after the construction of diode.
4) It depends on doping as it happens only in non-uniformly doped.	4) It does happen in uniformly & non-uniformly doped semi-conductor.

BIASING OF PN JUNCTION DIODE:

→ Biasing is applying external electric field to the diode to have a control over the current flowing through it.

→ closed switch / onstate

Forward Biasing:



The region where charge carriers are not moving or not able to move; that region is called Depletion layer.

At the time of depletion layer formation; the device is said to be off.

* After application of voltage, depletion region slowly (↑ing) vanishes at V_F and the diode carries a maximum a current.

* When the diode changing from off state to on-state, the voltage at which it happens, is called

BREAKOVER VOLTAGE/CUT-IN VOLTAGE/KNEE VOLTAGE.

• Current is called forward current: (I_F)

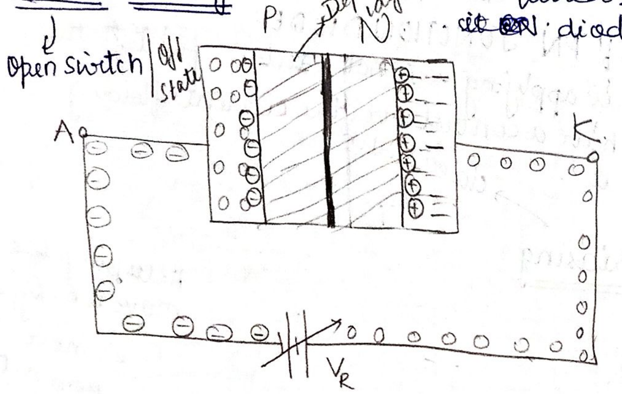
$Si \rightarrow 0.6$ to $0.7V$

$Ge \rightarrow 0.3$ to $0.4V$

is required to make ~~it ON~~ diode ON.

* ~~REVERSE BIASING~~

* Reverse Biasing:



During reverse biasing; the depletion layer widens as holes move from p-type to n-type and e⁻s move from n-type to p-type.

* At a time; the flow of e⁻s & holes stops and the diode switches off. When the reverse voltage is applied; the e⁻s from the battery flow towards p-type and e⁻s in p-type repel each other and same happens near n-type i.e. holes from battery are repelled by holes present.

* Due to which the flow of charge carriers starts once again and the diode switches ON.

This results in reverse biasing.

Current is called reverse current (I_R)

* V-I Characteristics of Diode:

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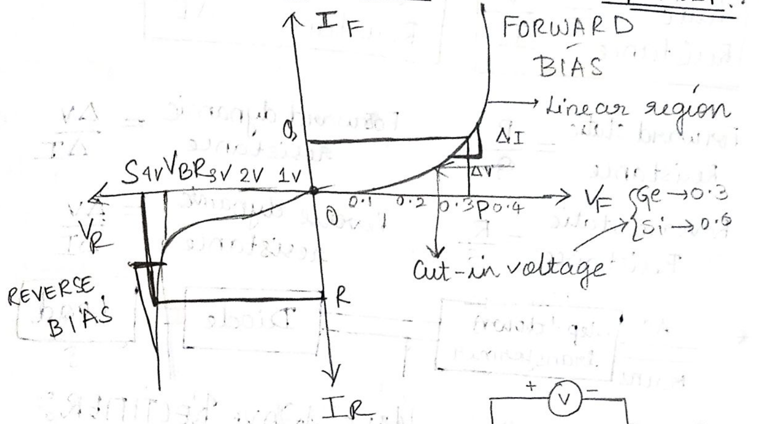
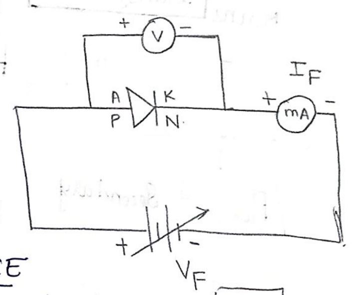


CIRCUIT DIAGRAM.



* The resistance offered by the diode where DC flows is called STATIC RESISTANCE

* The resistance offered by the diode where AC flows is called DYNAMIC RESISTANCE.

* Diode offers 4 types of resistance i.e.

1. Forward bias → Static, Dynamic

2. Reverse bias → Static, Dynamic

$$\text{Resistance of diode} = \frac{1}{\text{Slope of the curve}}$$

Static Resistance $= \frac{V}{I}$

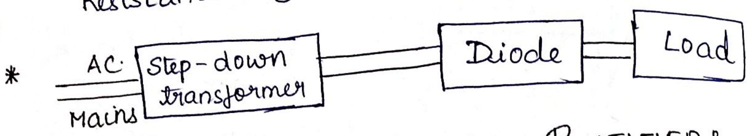
Dynamic Resistance $= \frac{\Delta V}{\Delta I}$

Forward static Resistance $= \frac{P}{Q}$.

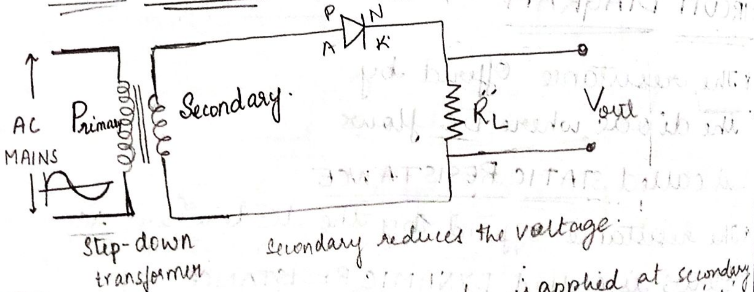
Forward dynamic resistance $= \frac{\Delta V}{\Delta I}$

Reverse static Resistance $= \frac{R}{S}$

Reverse dynamic resistance $= \frac{\Delta V}{\Delta I}$



CIRCUIT DIAGRAM: HALF-WAVE RECTIFIER:



eg: 12v transformer ⇒ 12V power supply is applied at secondary winding

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INPUT = AC
OUTPUT = DC

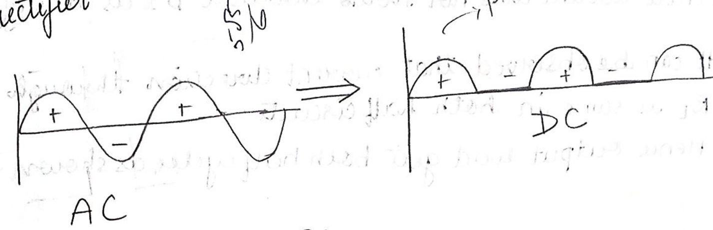
Diodes are used as clippers (clipping circuits)
clampers (clamping circuits)

During +ve half cycle primary passes the current, a reduced value to secondary and it passes +ve current to p-type; the diode acts as closed switch and is forward biased, circuit is complete and current flows.

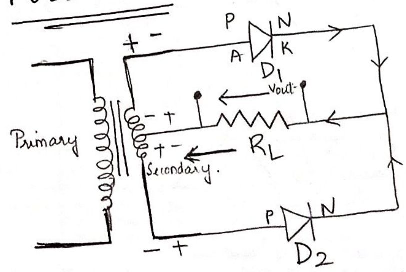
During −ve half cycle; primary passes it to secondary and it passes −ve current to p-type; diode acts as open switch and is reverse biased; circuit is open and current does not flow.

The −ve half cycle is suppressed in half-wave rectifier.

Almost half of the energy is wasted in half-wave rectifier.



FULL-WAVE RECTIFIER:



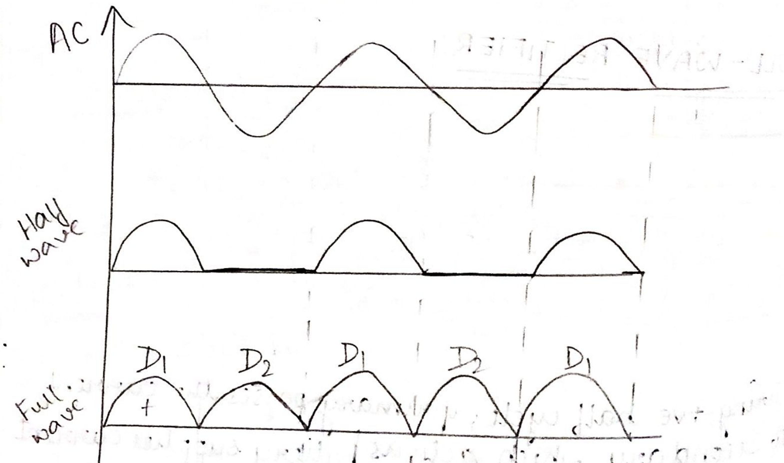
CENTRE TAPPED FULL WAVE RETIFIER.

During +ve half cycle; primary passes the current to secondary which acts as battery supplies current to the circuit; only D1 is in ON state and D2 is in OFF state. This implies D1 is in forward bias and hence current flows from upper end of secondary and current flows through R_L ending at −ve ~~terminal of~~ secondary centre.

Current does not flow through D2 as it is off.

During -ve half cycle; current flows from primary to secondary where secondary ~~ka~~ acts as battery; supplies current to the circuit; where D1 is in OFF state and D2 is in ON state. This implies D2 is in forward bias & hence current flows from lower end of secondary & flows through R_L & ends at +ve terminal of secondary centre. Current does not flow through D1 as it is off.

It can be observed that current direction through R_L is same in both half circuits.
Hence output load gets both half cycles as shown.

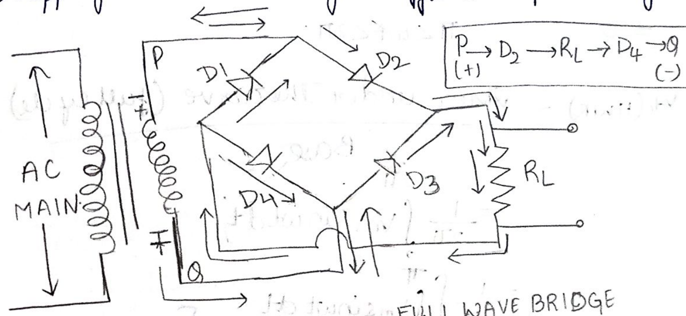


As output has pulses i.e. +ve half cycles, it is called pulsating DC

* Because circuit is using centre-tapped transformer; it called CENTRE-TAPPED FULL WAVE RECTIFIER.

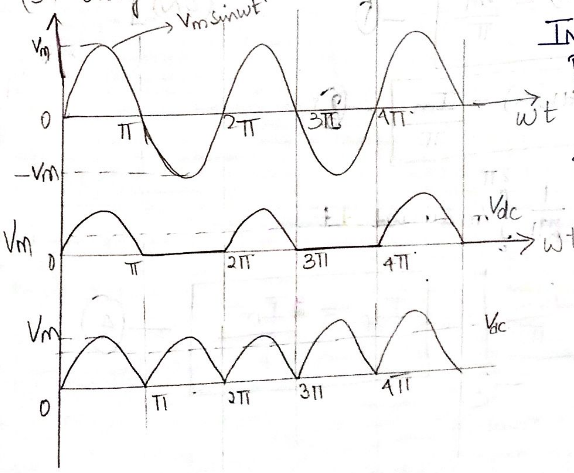
→ No energy loss: efficiency is high.

→ Tapping the centre exactly is difficult practically.



FULL WAVE BRIDGE RECTIFIER.

(1) + to −
(2) I_L through R_L same
(3) Only 2 diodes should be conducting



IMPORTANT PARAMETERS OF RECTIFIER:

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RIPPLE FACTOR & EFFICIENCY OF HWR & FWR

$V_0 = V_m \sin \omega t \quad ; 0 < \omega t < \pi$

$= 0 \quad ; \pi < \omega t < 2\pi$

$$V_{dc}(HWR) = \frac{\text{Area under the curve (full cycle)}}{\text{Base}}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} V_m \sin \omega t \, dt$$

$$= \frac{1}{2\pi} \left[\int_0^{\pi} V_m \sin \omega t \, dt + \int_{\pi}^{2\pi} V_m \sin \omega t \, dt \right]$$

*[Because diode operates in linear region once it becomes (ON)]

$$\boxed{V_{dc}(HWR) = \frac{V_m}{\pi}} \quad -(1)$$

$$\boxed{I_{dc}(HWR) = \frac{I_m}{\pi}} \quad -(3)$$

$$V_{dc}(FWR) = \frac{1}{2\pi} \int_0^{2\pi} V_m \sin \omega t \, dt$$

$$\boxed{V_{dc}(FWR) = \frac{2V_m}{\pi}} \quad -(2)$$

$$\boxed{I_{dc} = \frac{2I_m}{\pi}} \quad -(4)$$

$$I_{rms}^2 = \frac{1}{2\pi} \int_0^{2\pi} I_m^2 \sin^2 \omega t \, dt$$

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

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

$$= \frac{I_m^2}{2\pi} \left[\frac{\pi}{2} - \frac{1}{2} \left(\frac{\sin 2\omega t}{2} \right)_0^{2\pi} \right]$$

$$I_{rms}^2 = \frac{I_m^2}{2\cancel{\pi}} \cdot \frac{\cancel{\pi}}{2} = \frac{I_m^2}{4}$$

$$\boxed{I_{rms} = \frac{I_m}{2}} \qquad \boxed{I_{rms}(HWR) = \frac{I_m}{2}} \quad -(5)$$

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

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \qquad \boxed{I_{rms}(FWR) = \frac{I_m}{\sqrt{2}}} \quad -(6)$$

RIPPLE FACTOR (γ) OF RECTIFIER:

Ripple factor is the term or the parameter used to measure the amount of ripple contents available at the output of the rectifier and is expressed mathematically as below.

$$\gamma = \frac{\text{AC component at output}}{\text{DC component at output}}$$

$$\boxed{\gamma = \frac{I_{AC}}{I_{DC}}}$$

$$\boxed{I_{rms}^2 = I_{AC}^2 + I_{DC}^2}$$

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

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

$$\gamma_{HWR} = \sqrt{\frac{\pi^2}{4} - 1} = \sqrt{2.5 - 1} = \sqrt{1.5} \simeq 1.22$$

~~γ_{HWR}~~

$$\boxed{\gamma_{HWR} \simeq 1.22} \text{ — } (9)$$

it is not used in practical

→ ripples are more

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

$$= \sqrt{\frac{\pi^2}{8} - 1} = \sqrt{1.25 - 1} = \sqrt{0.25}$$

$$= 0.48 \simeq 0.5$$

$$\boxed{\gamma_{FWR} \simeq 0.48} \text{ — } (10)$$

→ ripples are less

~~EFFICIENCY OF RECTIFIER: (η)~~

~~$\eta = \frac{P_{dc}}{P_{AC}}$~~

~~EFFIEN~~

EFFICIENCY OF RECTIFIER: (η)

$$\eta = \frac{I_{dc}^2 \times R_L}{I_{rms}^2 \times R_L}$$

$$\eta_{HWR} = \frac{\frac{I_m^2}{\pi^2}}{\frac{I_m^2}{4}} = \frac{4}{\pi^2} = 0.406$$

$$\boxed{\eta_{HWR} = 0.406 = 40.6\%} \text{ — } (11)$$

$$\eta_{FWR} = \frac{\frac{I_m^2 \times 4}{\pi^2}}{\frac{I_m^2}{2}} = \frac{8}{\pi^2} = 0.812$$

$$\boxed{\eta_{FWR} = 0.812 = 81.2\%} \text{ — } (12)$$

⇒ Expression for efficiency, above is neglecting the resistance of secondary winding (r_s) and the internal resistance of the diode (r_f).

* r_s & r_f values given in a problem; those values are considered only along with R_L in denominator i.e. AC.

* As only AC comes across r_s & r_f in the circuit.

⇒ $r_f = 0$ → ideal diode (internal resistance $= 0$).

*ELECTRONIC FILTERS:

→ Inductor filter (Choke filter) : connected in series
→ Capacitor filter : connected in ||el with Load.

$X_L = 2\pi f l$ → 'L' blocks AC (f = high); → 'L' allows DC (f = 0)

$X_C = \frac{1}{2\pi f C}$ → C allows AC (f = very high); → C blocks DC. (f = high)

Electronic filters are the circuits used to remove the unwanted AC components at the output of rectifier, so that only DC can reach the load.

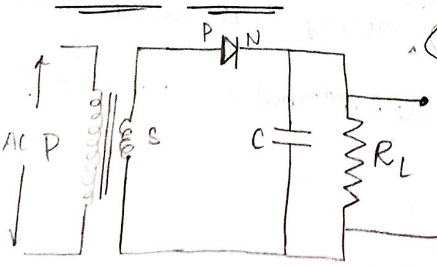
Inductors & Capacitors are used for this purpose because of their properties stated as above

TYPES : (high loads)

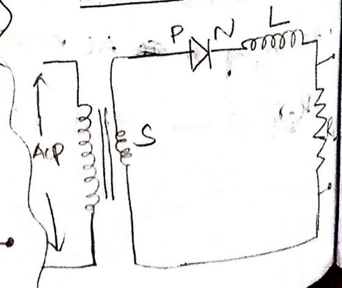
* CAPACITOR FILTER & INDUCTOR FILTER;
* L-TYPE FILTER; π-TYPE FILTER:

RECTIFIER $\xrightarrow[AC+DC]{}$ FILTERS $\xrightarrow[DC]{}$ LOAD

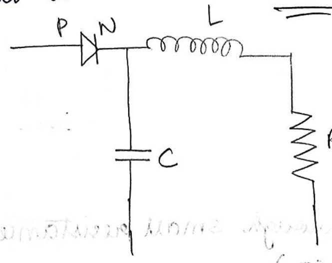
→ CAPACITOR FILTER:



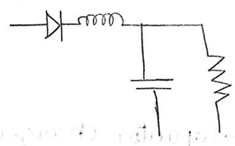
→ INDUCTOR FILTER:



If single capacitor is not sufficient to remove unwanted AC pulses; inductor is also used along with it as shown = L-TYPE FILTER:

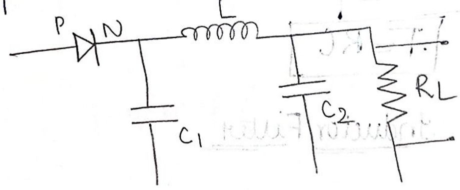


we can connect

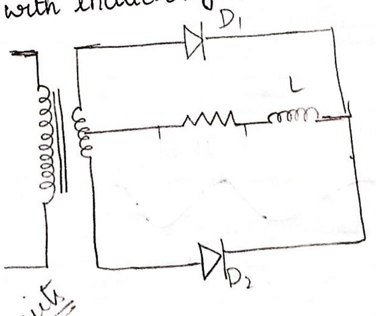


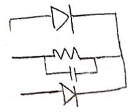
→ π-TYPE FILTER:

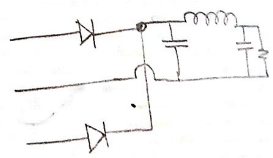
If L-type filter is not sufficient to remove entire AC components then π-filter can be used.



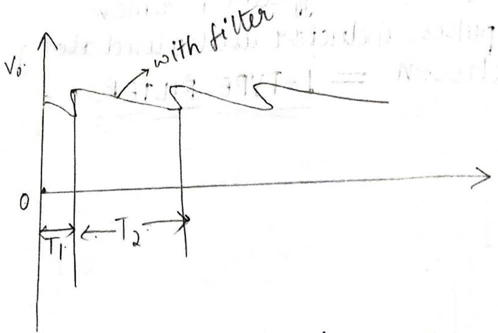
Q: Write the circuit diagram of full-wave rectifier connected with inductor filter.







Division

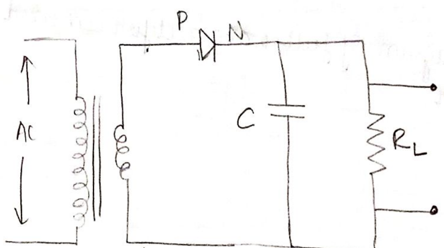


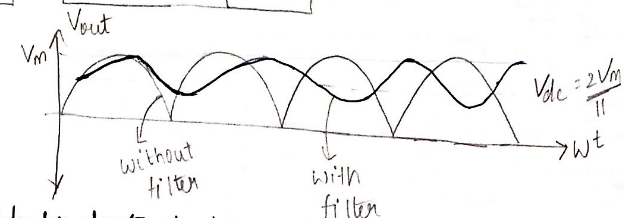
→ Capacitor charges through small resistance r_f hence charges faster (T_1) whereas it discharges through high resistance R_L hence discharges slowly. (T_2)

hence $\boxed{T_1 < T_2}$

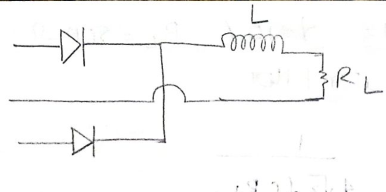
Because $\boxed{T = RC}$

11/01/2022 **Inductor Filter**





Inductor starts storing energy once it reaches Dc level. It does not stop at Vdc coz does not release energy instantly.



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*** RIPPLE FACTOR:**

FWR: → high load resistances

→ $\gamma_{capacitor\ filter} = \frac{1}{4\sqrt{3} f C R_L}$

→ $\gamma_{Inductor\ filter} = \frac{R_L}{3\sqrt{2}\omega L}$

$\omega = 2\pi f$

→ $\gamma_{L\cdot Type} = \frac{1}{6\sqrt{2}\omega^2 LC}$ → independent of R_L

→ $\gamma_{\pi\cdot Type} = \frac{\sqrt{2}}{8\omega^3 C_1 C_2 L R_L}$

f → frequency of input signal.
R_L → Load resistance
C → capacitance
ω → angular frequency.
L → Inductance.

* Capacitor filter is ~~used for~~ suitable for high load resistances & low load currents.

* Inductor filter is suitable for low load resistances & high load currents.

* $f = 60\,H_z$, $\gamma = 4\%$, $R_L = 100\,\Omega$, Inductor filter; $L = ?$ FWR.

$\gamma = \frac{R_L}{3\sqrt{2}\omega L}$

$L = \cancel{\frac{4}{100}}$ $\quad \frac{100 \times 100}{3\sqrt{2} \times 4(2\pi \times 60)} = \frac{104}{2030.4 \times \pi}$

$= 1.56\ H$

* $C = ?$ $f = 400\,Hz$ $\gamma = 10\%$ $R_L = 500\,\Omega$

FWR; Capacitor filter

$$\gamma_c = \frac{1}{4\sqrt{3}\,fCR_L}$$

$$C = \frac{1}{4 \times 1.73 \times 400 \times 50\cancel{0}} \quad \frac{1\cancel{0}\cancel{0}}{\times 1\cancel{0}}$$

$$= \cancel{7.21 \times 10^{-6}}$$

$$= \cancel{7.21\,\mu F}$$

$$= \frac{10^{-5}}{4 \times 1.73 \times 20} = \frac{10^{-3}}{138.4}$$

$$= 0.00722 \times 10^{-3}$$

$$= \underline{\underline{7.21 \times 10^{-6}}}$$

* Problems on Rectifier

1) HWR: $R_L = 1000\,\Omega$, $V_{AC} = 325\,V$ (V_m), $r_f = 100\,\Omega$

$I_m = ? \rightarrow$ Peak value

$I_{DC} = ? \rightarrow$ avg value

$I_{rms} = ?$

$P_{dc} = ? = I_{DC}^2 R_L$

$P_{AC} = ? = I_{rms}^2 (r_f + R_L)$

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

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

$I_m = \frac{V}{1000} = \frac{325}{1100}$

$I_m = 0.295\,A$

$I_{DC} = \frac{0.295}{3.14} = \cancel{0.1035A} = 0.093\,A$

$I_{rms} = \frac{I_m}{2} = \cancel{0.20A}$

$= \underline{\underline{0.1475\,A}}$

$\cancel{P_{DC} = (0.1035)^2 \times 1000 = 10.7\,\Omega}$

$\cancel{= 10.7\,W}$

$\cancel{P_{AC} = (0.23)^2 (1100) = 58.19\,W}$

$\cancel{\eta = \frac{10.7}{58.19} = 0.183}$

$P_{DC} = I_{DC}^2 R_L \simeq 8.836\,W$

$P_{AC} = I_{rms}^2 (1100) = 23.769\,W$

$\eta = \frac{P_{DC}}{P_{AC}} = 0.3717 = 37.17\%$

2) $R_L = 3.5 \times 10^3\,\Omega$ $V_m = 240\,V$

$r_f + r_s = 800\,\Omega$

$I_m, I_{DC}, I_{rms}, P_{DC}, P_{AC}, \eta$.

3) HWR $V_{DC} = 24\,V$ $R_L = 500\,\Omega$

$r_f = 50\,\Omega$ $V_m = ?$

$V_{DC} = \frac{V_m}{\pi} = V_{DC} \rightarrow$ only when diode resistance is not there

$I_{DC} = \frac{V_{DC}}{R_L}$

$I_{DC} = \frac{24}{500} = 0.048\,A$

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

$= 0.1507\,A$

$V_m = I_m (R_L + r_f)$

$= 0.1507(550) = \underline{\underline{82.885\,V}}$

2) $R_L = 3.5\times10^3\,\Omega$ $\quad V_m = 240V$

$r_f + r_s = 800\,\Omega$

$I_m = \frac{V_m}{R_L + r_f + r_s} = \frac{240}{3500+800} = \frac{240}{4300}$

$= 0.0558A$

$= 55.8mA$

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

$= \frac{55.8mA}{3.14} = 17.77mA$

$I_{rms} = \frac{I_m}{2} = 27.9mA$

$P_{DC} = I_{DC}^2 R_L$

$= \cancel{1105.205}\ 1105205.15\times10^{-6}$

$= 1.105W$

$P_{AC} = I_{rms}^2(4300) = 3.34W$

4) FWR. $\quad \frac{N_1}{N_2} = \frac{20}{1} \quad V_p = 230V \quad f = 50Hz$

V_{DC}, PIV ; fout. all diodes are ideal $r_f = 0$

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{20}{1} = \frac{230}{V_s}$

$V_s = V_{rms} = 11.5V$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

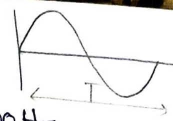
$V_m = 11.5\times1.41$

$= 16.21V$

$\frac{2V_m}{\pi} = \cancel{V_{rms}}\ V_{DC}$

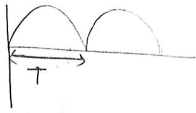
$V_{DC} = \frac{2\times16.21}{3.14}$

$\cancel{V_{DC} = 23V}$ $\quad V_{DC} = 10.32V$



Time period is halfed
frequency is doubled $\Rightarrow f = 2\times50 = 100Hz$

$PIV = V_m\ (FWR) = 16.26V$



Peak Inverse Voltage:

Maximum voltage can be applied to a diode in reverse bias without damaging it.

PIV →
- HWR (V_m)
- Centre Tapped ($2V_m$)
- Bridge (V_m)

5) 10:1 $\quad V_i = 220V \quad R_L = 500\,\Omega \quad f_{in} = 50Hz$

$V_{DC} = ?$, $I_{rms} = ?$ $P_{DC} = ?$ $P_{AC} = ?$; η;

PIV ; fout ; FWR:

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{10}{1} = \frac{220}{V_{rms}}$

$V_{rms} = 22V$

$V_m = V_{rms}\times\sqrt{2}$

$= 22\times1.41 = 31.02V$

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

$= \frac{2\times31.02}{3.14} = 19.75V$

$I_{rms} = \frac{I_m}{2} = 31.02mA$

$P_{DC} = (I_{DC})^2 R_L$

$\cancel{I_{DC} = \frac{V_{DC}}{R_L}}$

$\cancel{I_{DC} = \frac{2I_m}{\pi} = \frac{2\times620}{\pi}}$

$I_m = \frac{V_m}{R_L}$

$= \frac{31.02}{500}$

$= 62.04mA$

$PIV = V_m = 31.02V$

fout = 100Hz

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

$= \frac{2 \times 62.04}{3.14} = 39.5\,mA$

$P_{DC} = (I_{DC})^2 \times R_L = \cancel{780.125 kW}\ 780125 \times 10^{-}$

$= 0.0\cancel{78}W$

$P_{AC} = I_{rms}^2 (R_L)$

$= 48120.2 \times 10^{-6} W$

$= 0.048 W$

$\eta = \frac{P_{DC}}{P_{AC}} = 1.625$

13/01/2022

* **ZENER DIODE**: Very heavily doped P & N types

P N

3V Zener ⇒ constant output voltage

Zener voltage → specifically designed such that to produce constant output voltages (V_Z)

Zener diode acts as stabilisers/regulators.

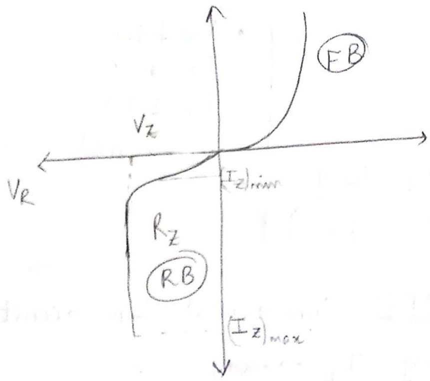
Zener breakdown voltage (V_Z) ranges from 3V to 300V meaning

If 100V Zener diode is used it provides 100 V constant at its output

* Zener diode protects home appliances microwaves, washing machines etc. ~~and~~ from natural AC fluctuations (surge currents) current spikes).

Hence zener diode is used as a voltage regulator

* AC Line ⟶ Zener Diode Regulator ⟶ Load Resistance



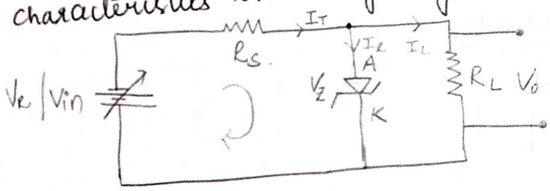
Line Regulation: Line is varying & load kept constant

Load Regulation: Load is varying & line kept constant

LINE REGULATION.

Zener diode is always used in reverse bias characteristics for voltage regulation.

$\boxed{I_T = I_Z + I_L}$



$V_{in} \geq V_Z$

LINE < R_L = const, V_{in} ⟶ vary

Load < R_L = vary, V_{in} = const

17/01/2022

LINE REGULATION: Predicting R_L from AC fluctuation.

$V_{in} \rightarrow$ vary $\Rightarrow R_L \longrightarrow$ const ; $I_L \longrightarrow$ const

- V_{in} ↑ses
  I_T ↑ses
  I_Z ↑ses
  $V_Z \rightarrow$ const (by virtue of its property)

- V_{in} ↓ses
  I_T ↓ses
  I_Z ↓ses
  $V_Z \longrightarrow$ const

LOAD REGULATION: $V_{in} \rightarrow$ const $I_T \longrightarrow$ const

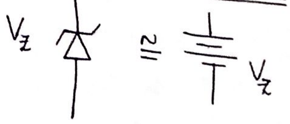
$R_L \longrightarrow$ vary $I_L \rightarrow$ vary.

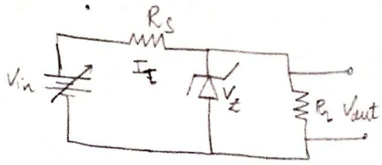
- R_L ↑ses
  I_L ↓ses
  I_Z ↑ses
  $V_Z \rightarrow$ const

- R_L ↓ses
  I_L ↑ses
  I_Z ↓ses (I_Z should not reduce beyond I_Z(min)
  $V_Z \rightarrow$ const

I_Z should not ↑se above I_Z(max)

* Equivalent circuits:





$$V_{in} = I_T R_S + V_Z$$

$$\boxed{R_S = \frac{V_{in} - V_Z}{I_T}}$$

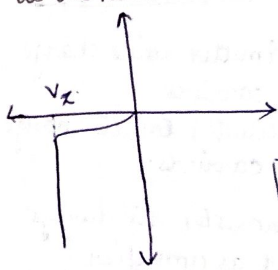
$$\boxed{R_S = \frac{V_{in} - V_Z}{I_Z + I_L}}$$

$$\boxed{I_Z = \frac{V_{in} - V_Z}{R_S} - I_L}$$

* Breakdown Mechanisms in Zener diode:

→ Zener breakdown
< 6V
Sufficient to pull the charge carriers from VB ~~atom~~; depletion layer is overcame.

→ Avalanche Breakdown
> 6V
heavy current flows through; due to ↑ses in velocity; collisions take place b/w atoms apart from pulling away charge carriers.



$$\boxed{V_Z \longrightarrow \text{const}}$$

* Continuous; successive multiplication of formation of charge carriers due to external electric field & heavy doping is called AVALANCHE

Regulated DC Voltage Power Supply: