Mrs. M.S. Bhosale.

III Single phase AC Machines.

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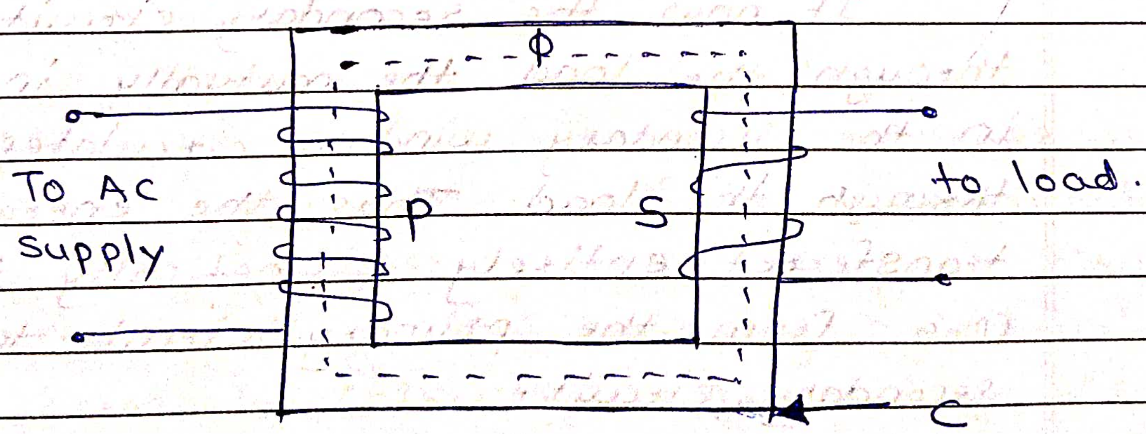
* Single Phase Transformer -

The transformer is a static device (with no rotating parts) which transfers electrical energy from one alternating current circuit to another with the desired change in voltage or current & without any change in frequency.

Construction of a single phase transformer -

It essentially consists of two windings (P & S), electrically separate but wound on a common laminated steel core (C). The vertical portions of the core on which these windings are placed are referred to as the limbs & the top & bottom portions are the yokes.

The winding (P) which is connected to the existing supply system & which receives energy from it is known as primary winding. The other winding (S) delivering energy to the load at the desired voltage is called the secondary winding.



Construction

Working principle –

The operation of the transformer is based on the principle of mutual induction between two circuits linked by a common magnetic field.

When the primary winding is connected to a.c. supply, applied alternating voltage circulates an alternating current through it. This current flowing through the primary winding produces an alternating flux (ϕ). Most of this varying flux links with the secondary winding through the iron core and induces an e.m.f. in it in accordance with Faraday's law of electromagnetic Induction.

This phenomenon due to which an alternating current in the primary winding produces an emf in the secondary winding is known as mutual induction & the emf induced in the secondary winding, is known as mutually induced emf or emf of mutual induction.

The frequency of this induced emf is the same as that of the supply voltage.

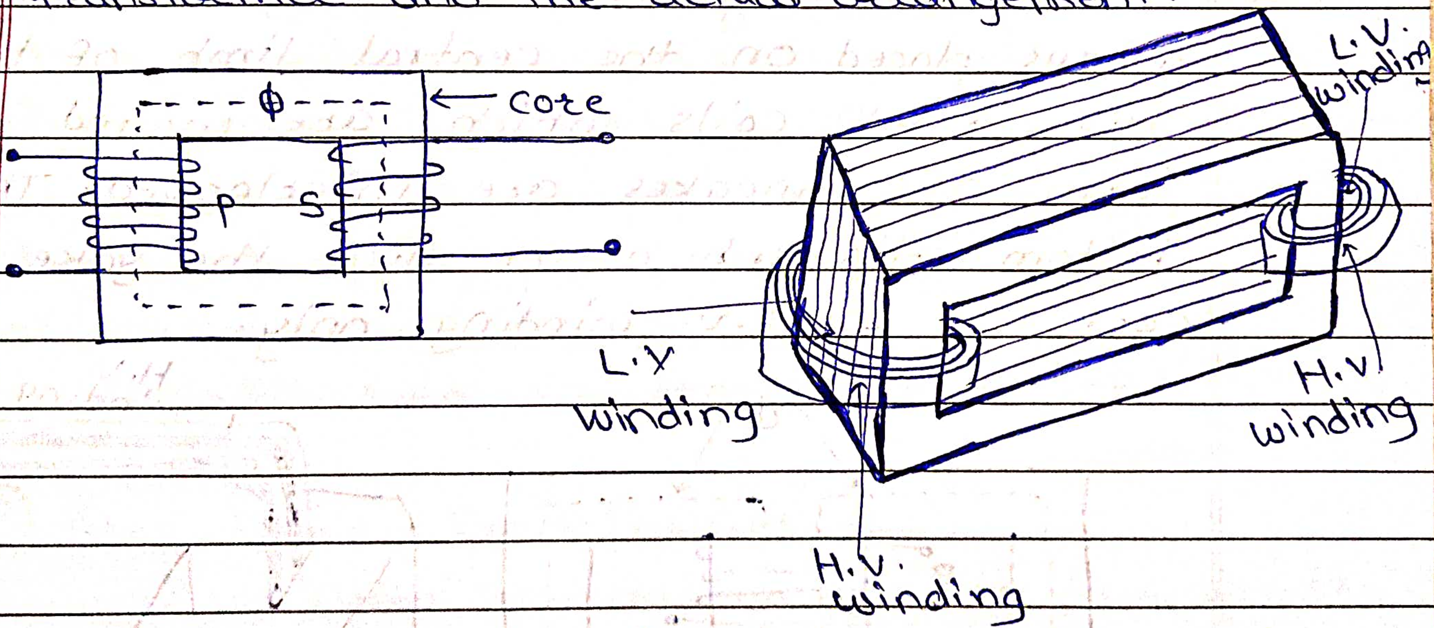
If now, the secondary circuit is closed through the load, the mutually induced emf in the secondary winding circulates current through the load. Thus the energy is transferred entirely magnetically through the core from the primary circuit to the secondary circuit.

* Types of Transformer –

- Transformers
  - Based on Core
    - Core type
    - Shell type
  - Based on Transformer Ratio
    - Step up
    - Step down
  - Based on service
    - Distribution
    - power

① Based on core – Ⓐ Core Type –

Fig shows diagramatically a core type transformer and the actual arrangement.



The core of this type of transformer is built of laminations to form a rectangular frame & provides a single magnetic circuit.

The windings are normally cylindrical in form & concentric, low voltage winding being placed near the core.

Both the windings are uniformly distributed over two limbs of the core.

These windings surround considerable portion of the core.

Since the windings are distributed on two limbs, natural cooling is more effective.

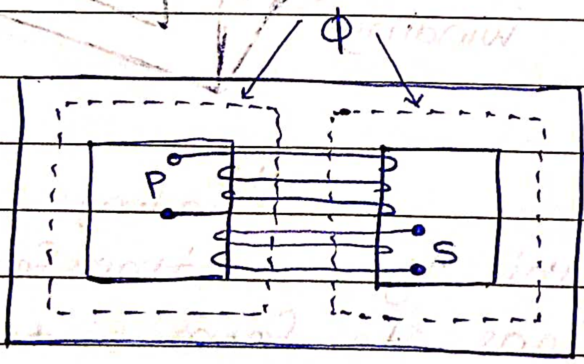
The coils can be withdrawn for repairs just by dismantling laminations of the top yoke.

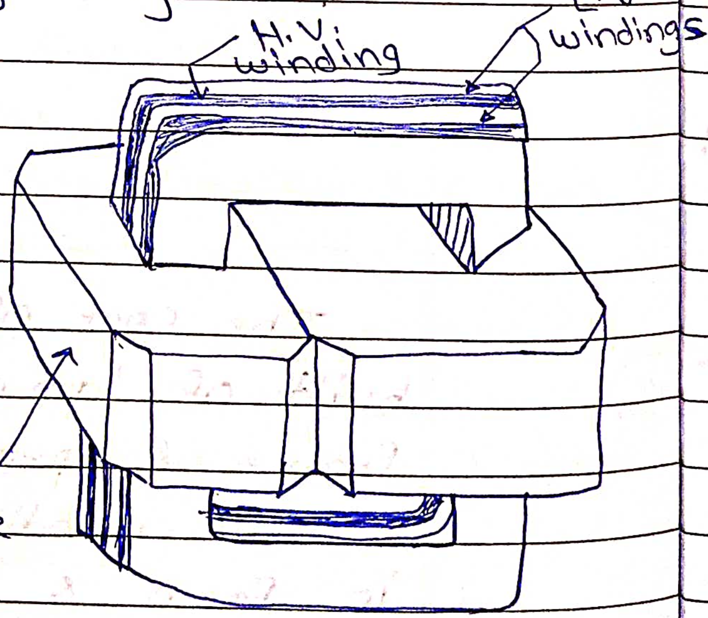
(B) Shell type -

Fig shows elementary scheme of a shell type transformer & other shows the actual piece.

The core of this type of transformer provides double magnetic circuit.

The windings are normally sandwitch type, always placed on the central limb of the core. H.V. & L.V. coils which are wound in the form of pancakes are interleaved. The top & bottom coils which are near the yoke of the core are of L.V. winding only.





Shell type.

The core nearly surrounds the windings placed on the central limb of the core.

This feature is useful from the point of view of providing mechanical Protection to the windings.

Since the coils are placed on one limb only & are surrounded by the core, natural cooling is poor.

When the coils are to be withdrawn for repairs, large number of laminations are to be dismantled.

(2) Based on transformer Ratio -

(A) Step up Transformer -

When primary windings are ~~greater~~ less than secondary windings then that type of transformer is called as step up transformer.

let Np be the primary windings & Ns be the secondary windings.

$\therefore$ for step up transformer $N_p < N_s$

(B) step down Transformer -

When primary windings are greater than secondary windings then that type of transformer is called as step down transformer

let Np be the primary windings & Ns be the secondary windings.

$\therefore$ for step down transformer $N_p > N_s$

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③ Based on Services –

Ⓐ Distribution transformer –

A distribution transformer is the type of transformer that performs the last voltage transformation in a distribution grid. It converts the voltage used in the transmission lines to one suitable for household & commercial use.

Ⓑ Power transformer –

power transformers are electrical instruments used in transmitting electrical power from one circuit to another circuit without changing the frequency.

* EMF Equation –

When the primary winding (P) is connected to the ac supply, an alternating current flowing through it produces an alternating flux (ϕ). This varying flux links with the secondary winding (S) through the core & produces an emf in it by mutual induction. but this flux produced by the primary winding while passing through the magnetic core links not only the turns of secondary winding but also the turns of the primary winding itself. therefore an emf is also induced in the primary winding due to self induction.

$\therefore$ calculation/mathematical expressions for these emf's induced in the primary & secondary windings are as follows –

let,

N_1 - No. of turns of primary winding

N_2 - No. of turns on secondary winding

Φ_m - maximum value of the alternating flux linking both the windings in wb.

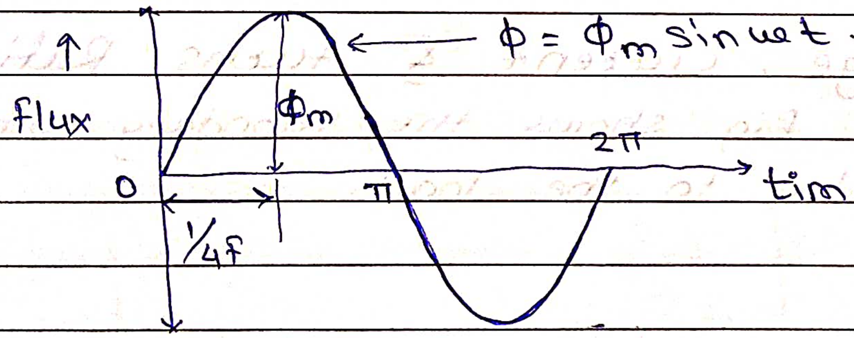
f - frequency of supply in hertz.

Fig shows one cycle of sinusoidal flux established in the core by the sinusoidally varying alternating current in the primary winding.

The flux grows from zero to its max value Φ_m in one quarter of the cycle.

i.e. in a time $t = 1/4f$ seconds.

$$\therefore \text{Average rate of change of flux} = \frac{\Phi_m}{t} = \frac{\Phi_m}{1/4f} = 4\Phi_m f \ \frac{wb}{sec.}$$



then from faraday's law of electromagnetic induction,

Average emf induced in each turn = Average rate of change of flux.

$$= 4\Phi_m f \ \text{volts}$$

For a sine wave -

$$\text{Form factor} = \frac{\text{RMS value}}{\text{Average value}} = 1.11$$

∴ RMS value of emf induced in each turn

$= 1.11$ (Average Value)

$= 1.11 \times 4 \phi_m f$

$= 4.44 \phi_m f$ volts

∴ RMS value of induced emf in primary winding,

$E_1 = (\text{Induced emf / turn}) \times \text{No. of primary turn}$

$= 4.44 \phi_m f \times N_1$ volts

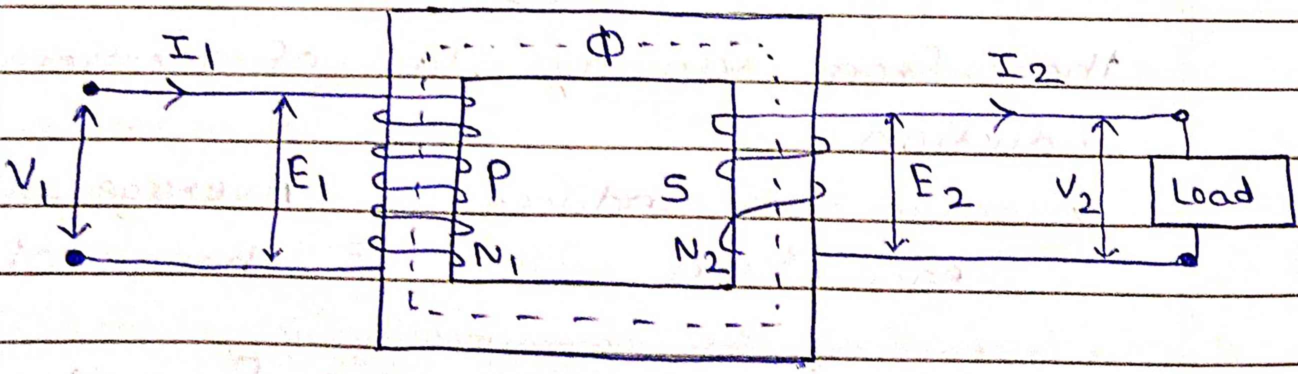
$$\boxed{E_1 = 4.44 \phi_m f N_1} \text{ volts}$$

Similarly, RMS value of induced emf in the secondary winding is given by,

$$\boxed{E_2 = 4.44 \phi_m f N_2} \text{ volts}$$

* Voltage, Current & turns Ratio –

Fig shows the secondary winding connected to the load.



Voltage, current & turns Ratio.

Let N_1 & N_2 be the number of turns of the primary & secondary windings respectively & E_1 & E_2 the RMS values of induced emf in the corresponding windings.

then the emf equations we have,

$$E_1 = 4.44\, \phi_m f N_1 \text{ volts } \&$$

$$E_2 = 4.44\, \phi_m f N_2 \text{ volts.}$$

&

$$\frac{E_1}{E_2} = \frac{4.44\, \phi_m f N_1}{4.44\, \phi_m f N_2}$$

$$\therefore \boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}}$$

at No load

$$V_2 = E_2$$

& when primary current being very small

then $V_1 \approx E_1$

$$\therefore V_1 = E_1$$

$\therefore$ above eqn can be written as,

$$\boxed{\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2}}$$

Thus the primary & the secondary terminal voltage of a transformer are proportional to the respective number of turns.

The ratio of primary to secondary w.r.t. terminal voltage is known as voltage ratio & the ratio of primary to secondary turns is known as turns ratio of the transformer.

- Transformation ratio $K = \frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1}$

If
$K > 1$ i.e. $V_2 > V_1$ transformer is called as step up transformer.

If
$K < 1$ i.e. $V_2 < V_1$ transformer is called as step down transformer.

If
$K = 1$ i.e. $V_2 = V_1$ transformer is called a one to one transformer.

For current,

$$\text{Power i/p} = \text{Power o/p}$$
$$V_1 I_1 \cos\phi_1 = V_2 I_2 \cos\phi_2$$

Where I_1 & I_2 are currents in primary & secondary windings. $\because P = VI\cos\phi$
$\cos\phi_1$ & $\cos\phi_2$ are corresponding power factors.

$$V_1 I_1 = V_2 I_2$$
$$\frac{I_1}{I_2} = \frac{V_2}{V_1}$$

combining all equations -

$$\boxed{\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = K}$$

Currents are inversely prop. to voltage & turns ratio.

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* Power losses –

The following power losses may occur in a practical transformer.

(A) Iron loss or core loss
(B) Copper loss or I^2R loss
(C) Stray loss
(D) Dielectric loss.

(A) Iron loss occurs in the magnetic core of the transformer due to flow of alternating magnetic flux through it. For this reason Iron loss is called as core loss.

(B) Copper loss OR I^2R loss –

power loss in a transformer that occurs in both the primary & secondary windings due to their ohmic resistance is called copper loss or I^2R loss.

(C) Stray loss –

In a practical transformer, a fraction of the total flux follows a path through air & this flux is called leakage flux. This leakage flux produces eddy currents in the conducting or metallic parts like tank of transformer. These eddy currents cause power loss which is known as stray loss.

(D) Dielectric loss –

The power loss occurs in Insulating materials like oil, solid insulation of transformer etc. is known as dielectric loss.

* A.C. Motors —

Single phase induction motors are more preferred over a three phase induction motor for domestic, commertial applications.

The single phase induction motor has two main parts one is stator (which is stationary) and other is rotor (which is rotating).

Stator —

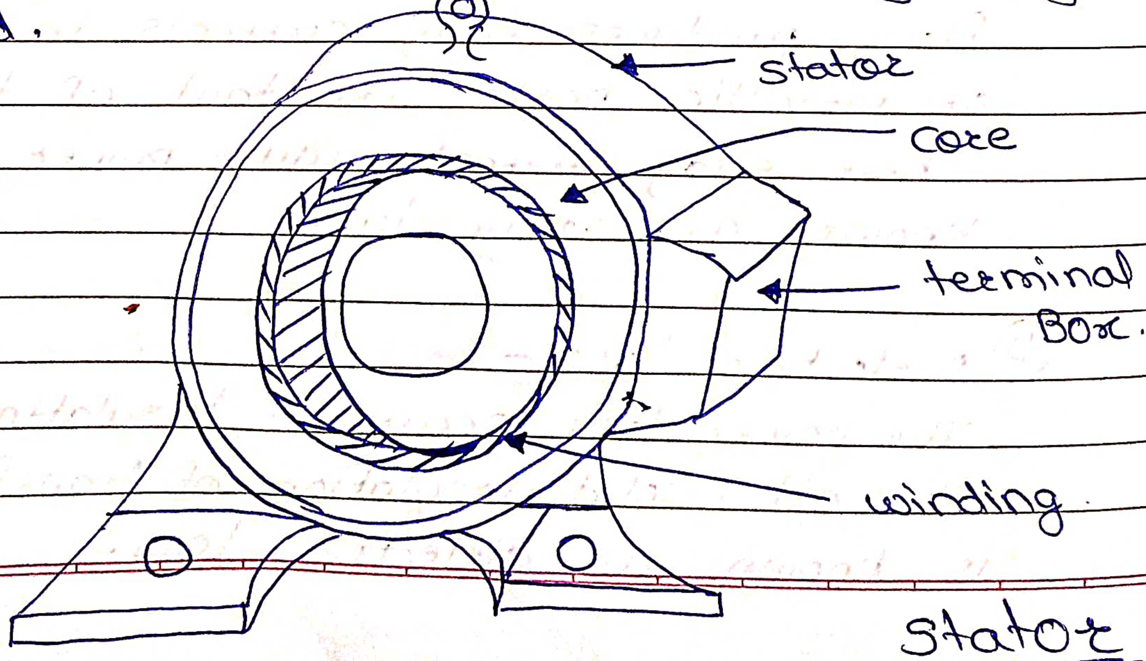
It is the stationary part of the motor as shown in fig. It has three main parts.

1. Outer frame
2. Stator core
3. stator windings.

① Outer frame/body of the motor to support the stator core & the stator windings.

② The stator core is built up of thin sheets laminations which are usually 0.3 to 0.5 mm thick the stator core carries the alternating flux which produces eddy current & hysteresis losses.

③ The stator core carries the stator winding which is connected across a single phase AC supply which produces a rotating magnetic field.

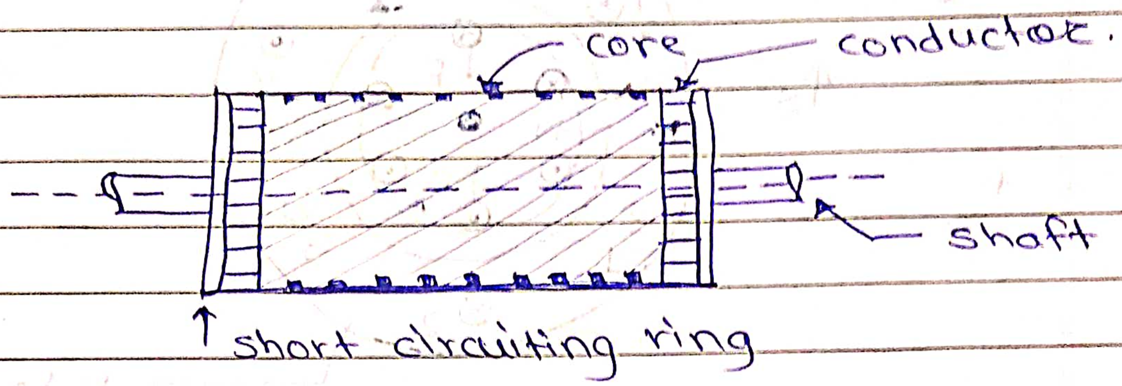


Stator

Rotor –

It is the rotating part of the motor as shown in fig. This rotor is called squirrel cage as appear like cage.

The rotor has aluminium or copper bars which are permanently circuited at both ends by conducting end rings.



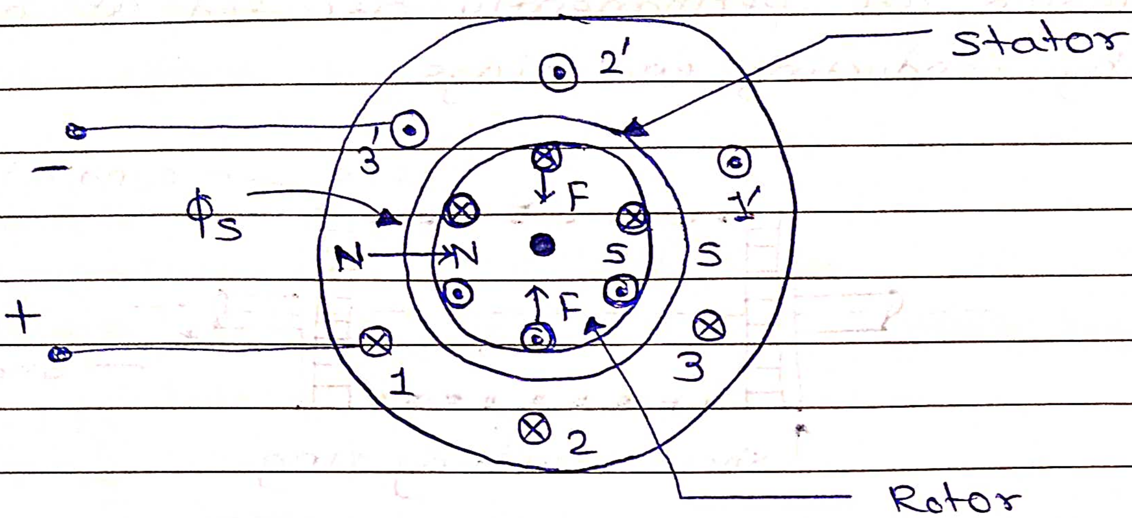
Rotor

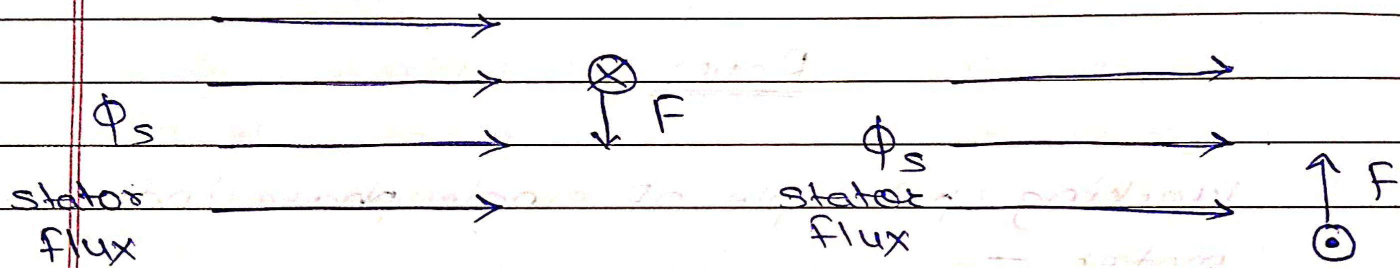
Working principle of single phase induction motor –

When the stator winding of a single phase induction motor is connected to single phase a.c. supply a magnetic field is developed, the axis of this magnetic field is stationary in the horizontal direction.

Currents are induced in the rotor conductors by transformer action. these currents being in such a direction as shown in fig.

The force experienced by the upper half conductors thus no torque is developed at starting. However it has been observed that if the rotor is given an initial rotation in any direction, the single phase induction motor develops torque & the rotor continues to pick up speed in that particular direction. Thus the single phase induction motor is not self starting & needs special starting.





Rottor Uconductors (upper half)

Rotor conductors (lower half).

Internal working of single phase induction motor.

Mrs. M. S. Bhosale.

Semiconductor  Devices

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Types of materials -

1. Conductors - Which allows the flow of an electrical current.
   e.g. - All metals.
2. Semiconductors - conductivity lies between that of conductor & insulator.
   e.g. - Silicon, Germanium
3. Insulators - Does not conduct an electrical current
   e.g. - Rubber, plastic, wood.

* Semiconductors - Si & Ge.

Types - Intrinsic type
Extrinsic type → P type / → N type

Intrinsic - pure semiconductors
Extrinsic - Impure — " —

Impurity is added into intrinsic semicond'rs.
Doping is the process of adding impurity.
If trivalent (having 3 ele⊖s in its valence shell) impurity is added to pure (intrinsic) type of semiconductor then that type is called as 'P' type extrinsic semiconductor & when pentavalent impurity (having 5 ele⊖s in its valence shell) is added then that type is called as 'N' type Extrinsic semiconductor.
Trivalent impurities are Indium, Galium, Boron & pentavalent — " — are phosphorous, Arsenic, Antimony.

As temperature increases the conductivity of semiconductor increases.

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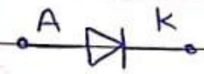
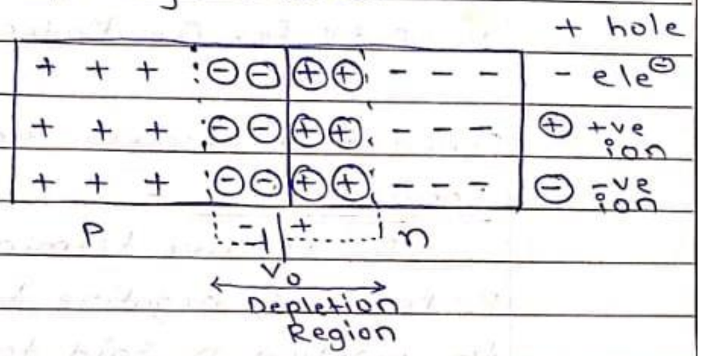
* P-n junction Diode-

For forming a p-n junction diode, P type semiconductor is not joined with n type semiconductor. But one side of a single crystal of germanium or silicon is doped with acceptor (P-type) impurity & the other side is doped with donor (n-type) impurity atoms. The junction is formed where the P type & n type regions meet.



A - Anode (P type)
K - Cathode (N type)



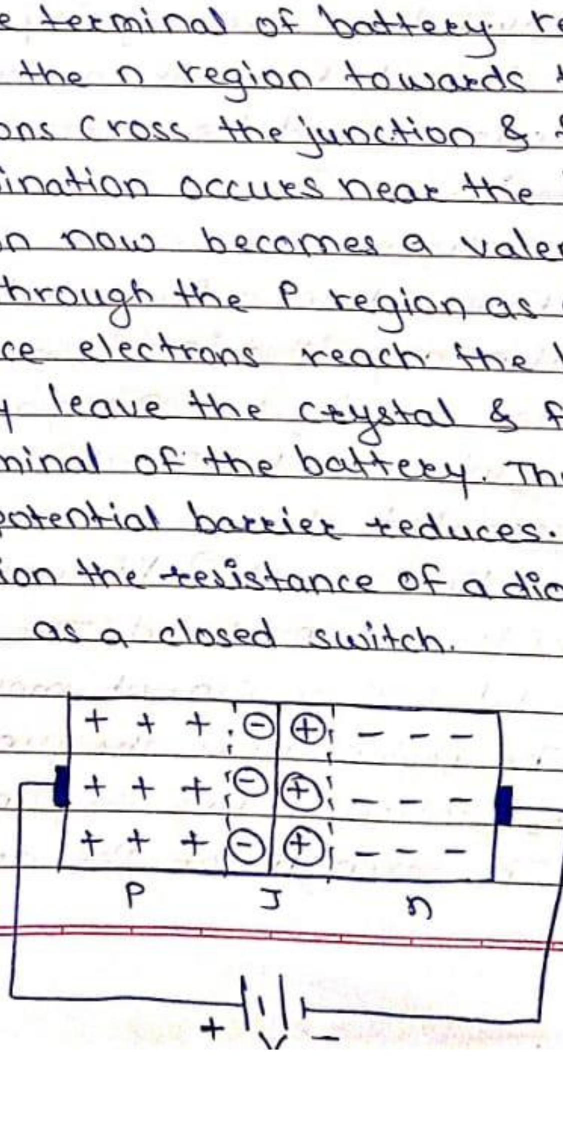
In P type holes are majority charge carriers & in n type free electrons are majority charge carriers. The diode is unbiased i.e. external voltage is not applied to it.

Free electrons on the n side diffuse or spread in all directions. When a free electron diffuses across the junction, a positive ion is produced in the n region. Soon after entering the P region, the free electron combines with a hole. Therefore, that hole disappears & the associated atom becomes a negative ion. Thus each ~~typ~~ time an ele⊖ diffuses across the junction a pair of ions is produced. The ions are fixed in the crystal & they cannot move like free ele⊖s & holes. The region near the junction is free from holes. & electrons. This region is called depletion layer. The strength of the depletion layer goes on increasing with each ele$^{\ominus}$ crossing the junction. But at a point the internal repulsion of the depletion layer stops further diffusion of free electrons across the junction. The depletion layer acts like a barrier. The difference of potential across the depletion layer is called barrier potential (V_0). This is also called as internal potential barrier. $V_0 = 0.7\,V$ for Si diodes & $V_0 = 0.3\,V$ for Ge diodes.

* Forward & Reverse Biasing of a p-n jun^n diode -

(A) Forward Bias -

The positive terminal of a battery is connected to p-region & negative terminal to the n-region then the junction is said to be forward biased.
The negative terminal of battery repels the free electrons in the n region towards the junction. These electrons cross the junction & fall into holes. This recombination occurs near the junction & a free electron now becomes a valence electron. It travels through the p region as a valence ele$^{\ominus}$ when valence electrons reach the left end of the crystal, they leave the crystal & flow into the positive terminal of the battery. Thus due to forward biasing the potential barrier reduces. In forward biased condition the resistance of a diode is very low & diode acts as a closed switch.



Forward Biased pn junction diode

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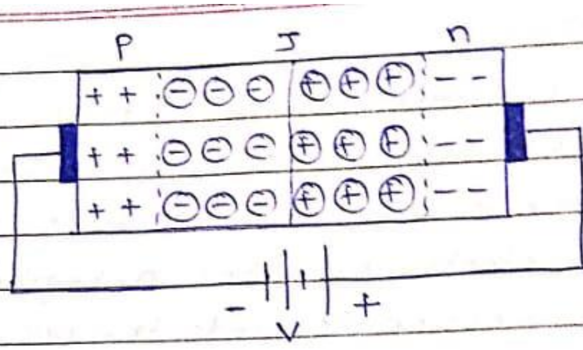
(B) Reverse Bias -

The positive terminal of a battery is connected to n-region & negative terminal to the P-region. then the junction is said to be reverse biased.
The free electrons in the n-region are forced away from the junction towards the positive terminal of source (battery). Holes in the P region move away from the junction towards the negative terminal. therefore the width of the depletion layer increases. The depletion layer stops increasing when its difference of potential equals the source of vtg.

In reverse biased condition the resistance of a diode is very high & diode acts as an open switch.

Minority carriers are produced by the thermal energy. The reverse current caused by the minority carriers is called the reverse saturation current (I_o). This current is independent of increase in the voltage. only an increase in temperature can increase I_o. For silicon diodes I_o approximately doubles for each $10^\circ c$ rise in temperature. If we increase the reverse voltage, at a particular voltage the diode can conduct heavily. This increase in current is due to collisions between the free electrons & valence electrons. The voltage at which the current increases rapidly for a reverse biased junction is called breakdown voltage. In most of the diodes the reverse voltage is always kept less than breakdown voltage otherwise the diode may get destroyed by excessive power dissipation.

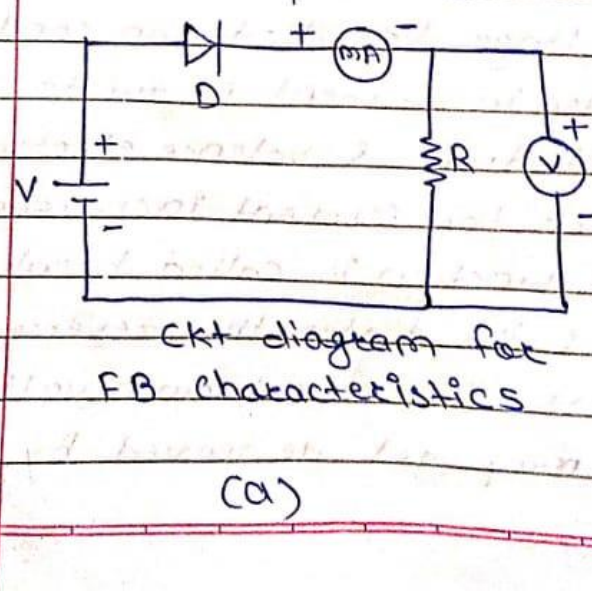


Reverse Biased p-n junction diode.

* V-I characteristics of p-n junction Diode -

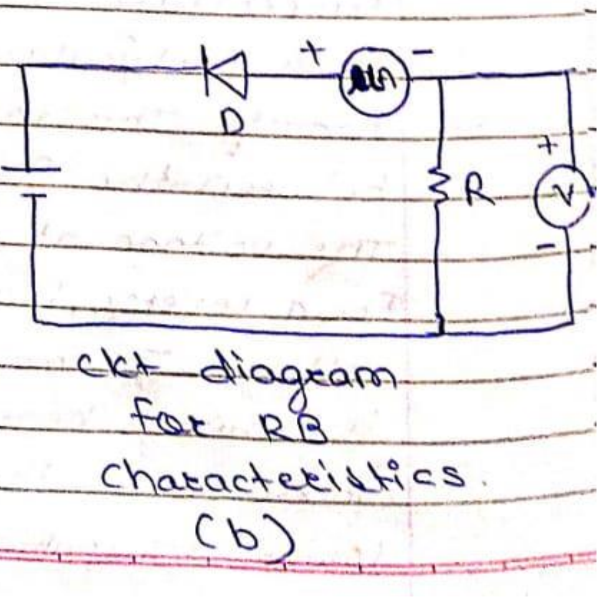
(A) Forward characteristics -

The ckt is connected as shown in fig (a). The voltage is increased from zero in steps & current is recorded by the milliammeter. The forward characteristics is not a straight line. for small value of forward vtg (0.7 V for si & 0.3V for Ge) the forward current is zero. when applied vtg is greater than V_o, a small current flows as shown by the curve OA. Beyond V_o, small increase in voltage produces a large increase in current. The voltage at which the current starts to increase rapidly is called as knee/ cut in/ offset voltage. This voltage is equal to the barrier potential.



ckt diagram for FB characteristics

(a)



ckt diagram for RB characteristics.

(b)

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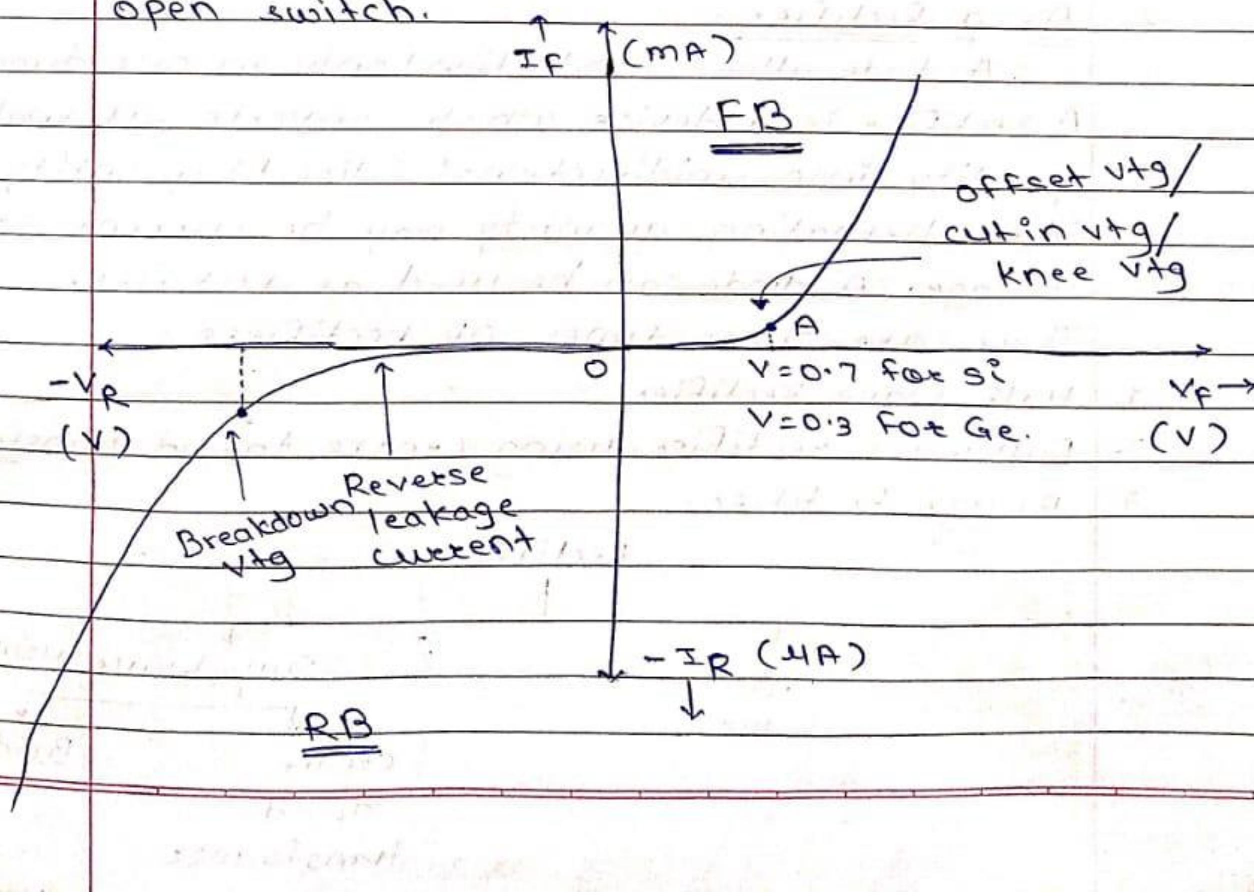
A current limiting resistor is always used in series with a diode. This limits the current to less than the maximum current rating of the diode. The diode offers very low resistance in the forward biased cond?

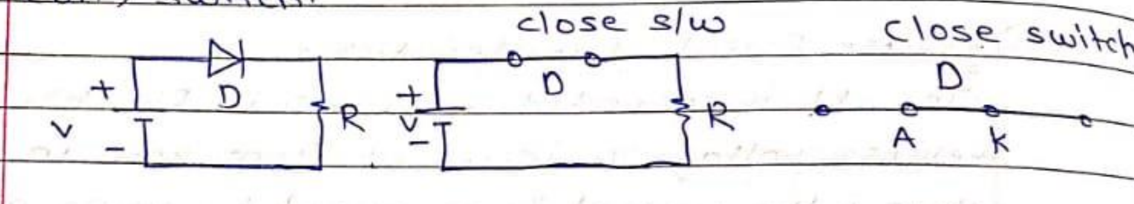
(B) Reverse Biased Characteristics -
The ckt is connected as shown in fig (b). The reverse voltage is increased from zero in suitable steps & the current is measured by using micro-ammeter. As reverse voltage is increased from zero reverse current increases & equals reverse saturation current I_0. When voltage is increased further at a particular voltage the current may increase rapidly. This is called as breakdown voltage. When reverse vtg is less than breakdown voltage the diode offers a high resistance & acts as an open switch.



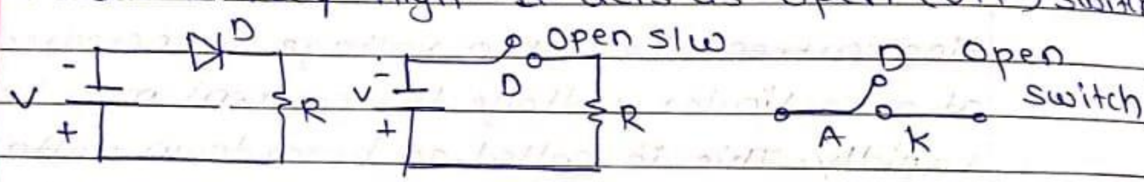
* Applications of P-n junction Diode -

1. As a switch -

In forward biased condition, the resistance of a diode is almost zero. It acts as a closed (on) switch.



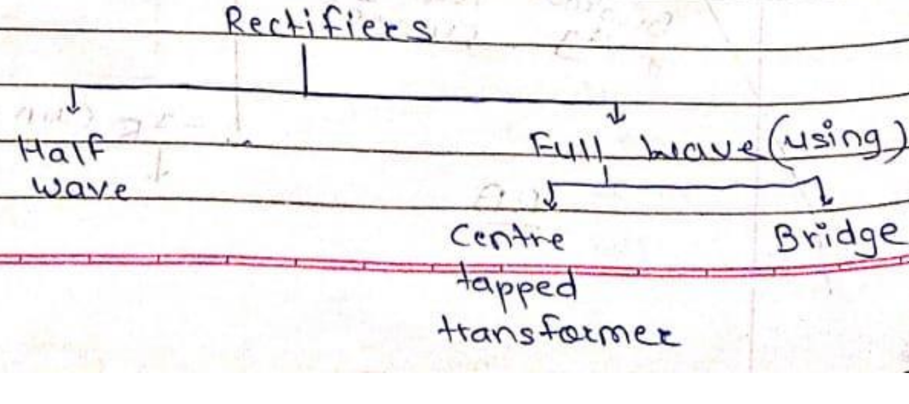
In reverse biased condition the resistance of a diode is very high. It acts as open (OFF) switch



2. As a Rectifier -

A diode allows conduction only in one direction. A rectifier is a device which converts alternating quantity into unidirectional (direct) quantity. The alternating quantity may be current or voltage. A diode can be used as rectifier.
There are three types of rectifiers.

1. Half wave Rectifier
2. Full wave rectifier using centre-tapped transformer
3. Bridge Rectifier.



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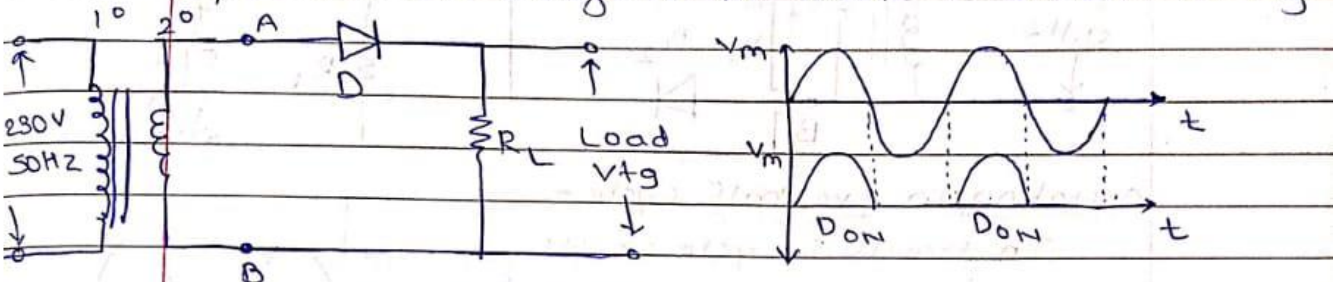
(A) Half Wave Rectifier - (HWR)

In half wave rectifier, the rectifier is on only during one half cycle of the ac supply. so o/p is produced only in that half cycle. The o/p is supposed to be zero in the other half cycle. the ckt diagram of HWR is shown in fig.

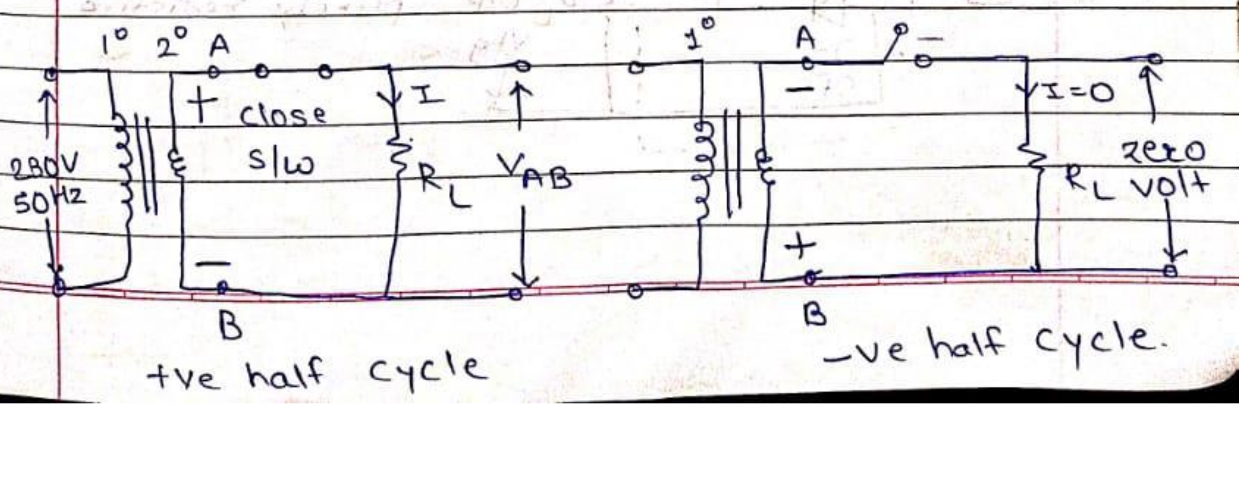


Operation in the positive half cycle -

In positive half cycle of i/p vtg A is +ve with respect to B. Hence the diode is forward biased & starts conducting. The voltage V_{AB} appears almost as it is across the load resistance The load voltage is thus positive & almost equal to instantaneous secondary voltage V_{AB}.

Operation in negative half cycle -

In negative half cycle of i/p. A is -ve with respect to B. Hence the diode is reverse biased & offers a very high resistance. therefor the load voltage & the load current both are zero.



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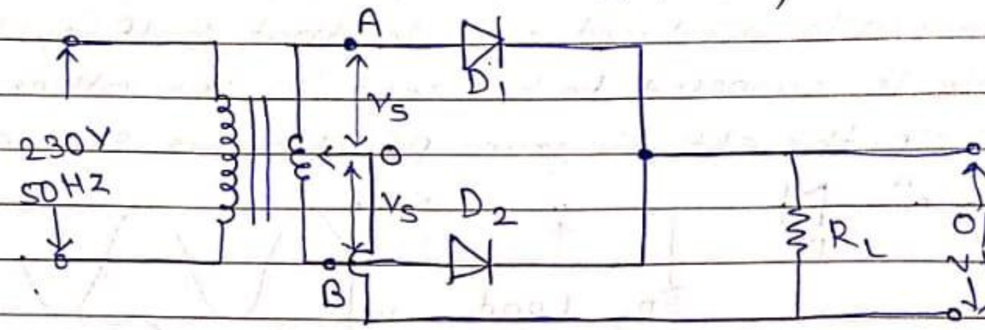
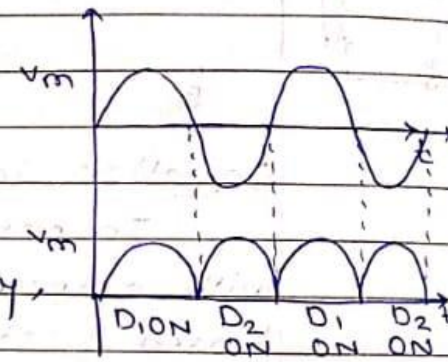
(B) Full Wave Rectifier with center tapped Transformer.

The FWR consists of a step down center tapped transformer, two diodes & purely resistive load R_L

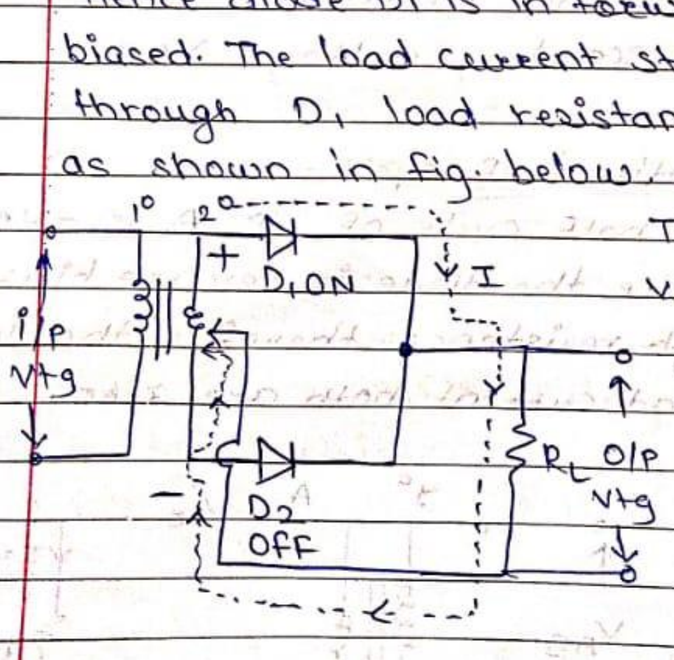


Operation in +ve half cycle -

In +ve half cycle of ac supply, 'A' point is +ve w.r.t. B & point 'O' is at 0V. thus V_{AO} is +ve & V_{BO} is -ve. Due to the center tapped secondary, V_{AO} & V_{BO} are always equal & opposite to each other.



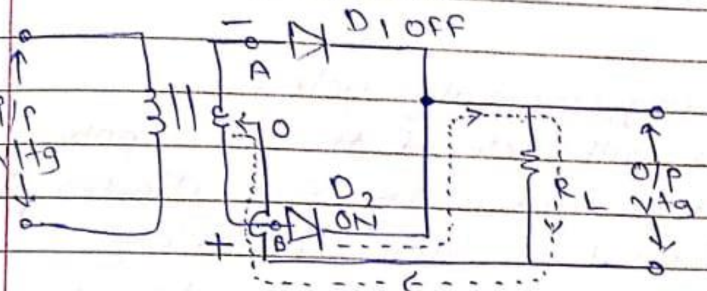
Hence diode D_1 is in forward biased & D_2 is reverse biased. The load current starts flowing from 'A' through D_1 load resistance R_L & back to point 'O' as shown in fig. below



The instantaneous load voltage is positive & approximately equal to V_{AO} As the load is purely resistive.

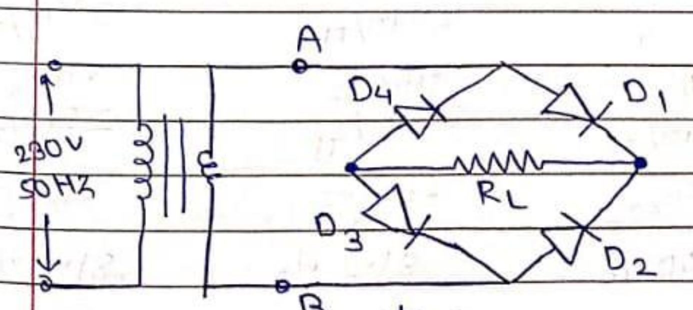
Operation in negative half cycle -

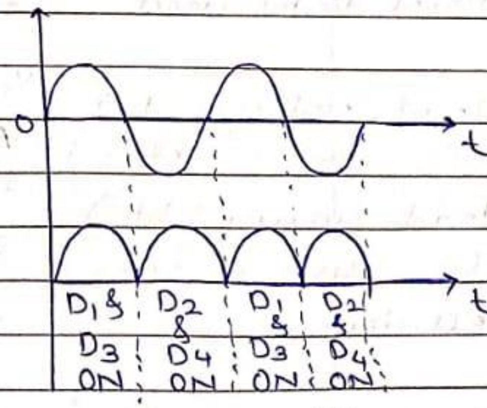
In -ve half cycle of ac supply the polarities of secondary induced voltages are as shown in fig. It shows VAO is negative & VBO is positive. Hence D_1 is reverse biased & D_2 is forward biased so D_1 acts as open ckted s/w & D_2 carries the entire load current.

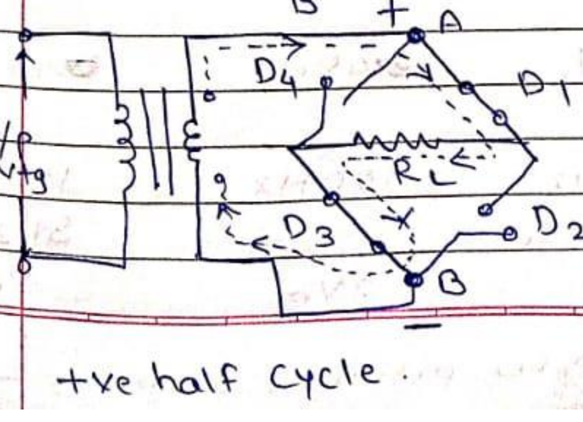


Ⓒ Bridge Rectifier -

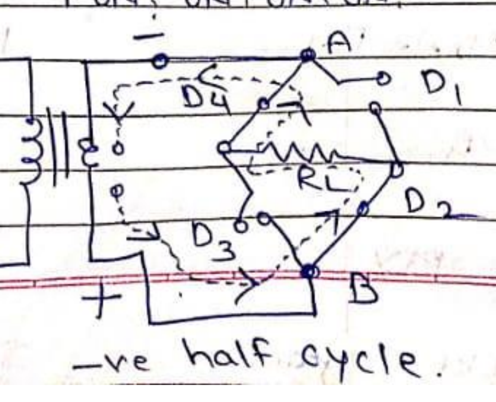
Bridge rectifier offers full wave rectification. The diodes conduct in pairs i.e. at any given instant of time, one pair of diodes either $D_1 D_3$ or $D_2 D_4$ will be conducting.







+ve half cycle.



-ve half cycle.

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operation in positive half cycle -

In +ve half cycle of the ac supply the secondary vtg V_{AB} is positive. therefore diodes D_1 & D_3 are forward biased & D_2 & D_4 are reverse biased. the equivalent ckt is as shown in fig. Note that the reverse biased diodes D_2 & D_4 act as open S/w's the load current & load voltage both are positive.

operation in negative half cycle -

In negative half cycle of the ac supply the secondary voltage V_{AB} is negative diodes D_2 & D_4 are forward biased & start conducting.
D_1 & D_3 are reverse biased hence do not conduct.
the equivalent ckt is shown in fig.

* comparision between HWR, FWR & Bridge.

Parameter	HWR	FWR	Bridge
No. of diodes used	1	2	4
load voltage (V_{dc})	V_m/π	$2V_m/\pi$	$2V_m/\pi$
Rms voltage (V_{rms})	$V_m/2$	$V_m/\sqrt{2}$	$V_m/\sqrt{2}$
load current (I_{dc})	I_m/π	$2I_m/\pi$	$2I_m/\pi$
Rms current (I_{rms})	$I_m/2$	$I_m/\sqrt{2}$	$I_m/\sqrt{2}$
Efficiency	40%	81.2%	81.2%
Ripple factor	121%	48%	48%
frequency	50 Hz	100 Hz	100 Hz
TUF	28.7%	69.3%	81.2%
PIV	V_m	$2V_m$	V_m

ckt diagram — Refer previous diagrams —

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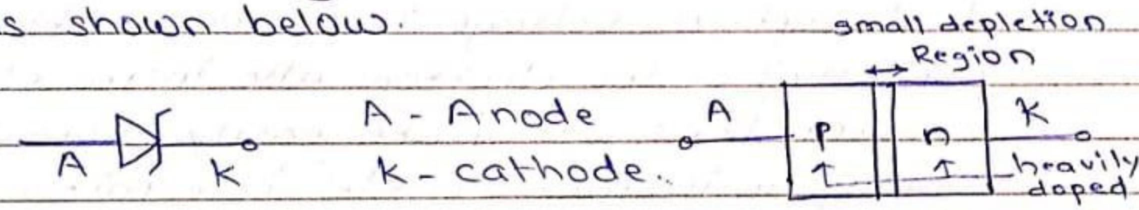
* Zener Diode -

Zener diodes are normal p-n junction diodes operating in a reverse biased condition. working of zener diode is similar to a p-n junction diode in forward biased condition but it acts as a voltage regulator in reverse biased.
Zener diode is a special type of diode which permits the flow of current in the forward dirn as well as in reverse direction. It is heavily doped & having two terminals i.e. Anode & cathode as shown below.



When we forward biased the zener diode, it behaves just like a normal p-n junction diode. due to 0.7 V or 0.3 V voltage drop which follows the diode equation. In reverse bias mode, zener diode do not conduct until the applied vtg exceeds or reaches a certain voltage i.e. zener voltage at which the diode is able to conduct the current up to the specified level without harming the device. The breakdown vtg is adjusted by controlling the level of doping. There are two types of breakdowns in zener diodes.

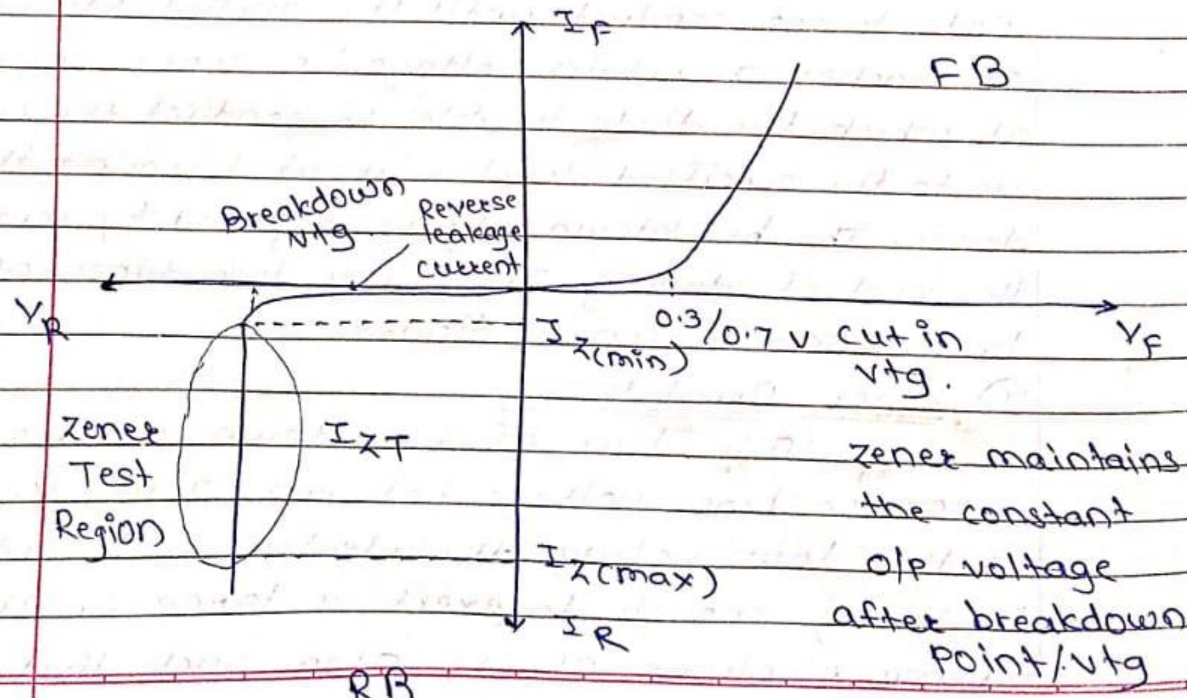
① Zener Breakdown -

This type of breakdown occurs for a reverse bias voltage between 2 to 8 V. Even at this low voltage the electric field intensity is strong enough to exert a force on the valence electrons of the atom such that they are seperated from the nuclei. This results in formation of mobile electron hole pairs, increasing the flow of current across the device.

② Avalanche Breakdown -

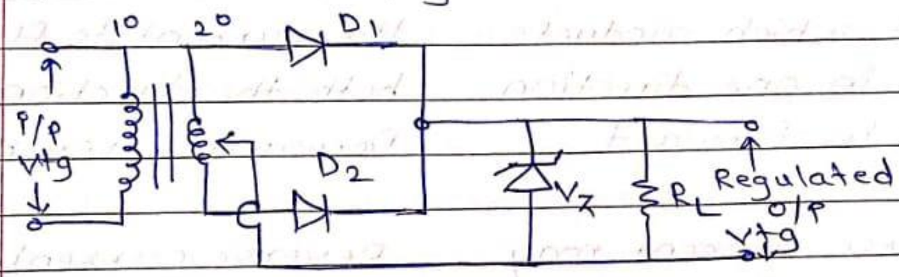
This type of breakdown occurs at the reverse bias voltage above 8 v. & higher. It occurs for lightly dopped diode with large breakdown voltage. As minority charge carriers flow across the device, they tend to collide with the ele⊖s in the covalent bond & cause the covalent bond to disrupt. As voltage increases the kinetic energy (velocity) of the electrons also increases & the covalent bonds are more easily disrupted, causing an increase in ele⊖ hole pairs. The Avalanche breakdown voltages increases with temperature.

characteristics of zener diode -

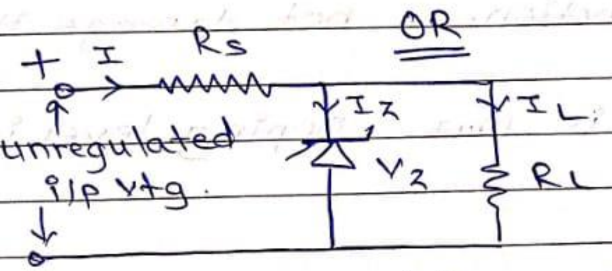


* Zener Diode as a voltage Regulator -

The main purpose of the voltage regulator is to maintain a constant voltage across load resistance. irrespective of the variations in the applied i/p vtg. diagram for zener diode as a vtg regulator is as shown in fig.



OR

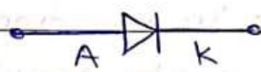
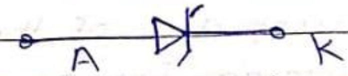


$I = I_Z + I_L$

- The source resistance Rs is connected in series with zener diode to limit the flow of current through the diode with voltage source connected across the combination. The cathode terminal of zener diode is connected to the positive terminal of the battery so that the zener diode is biased in reverse condition & will be operating in breakdown region.

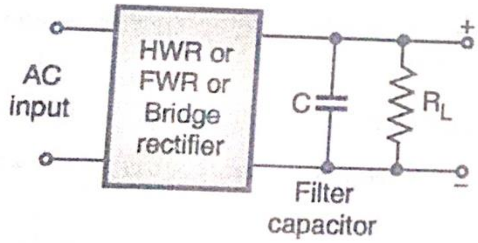
As the i/p voltage increases the current through the zener diode increases but the voltage drop remains constant. This ability to control itself can be used to great effect to regulate or stabilize a vtg source against supply variations. It turns out to be an important application of the zener diode as a voltage regulator.

Difference between P-n junction & zener diode.

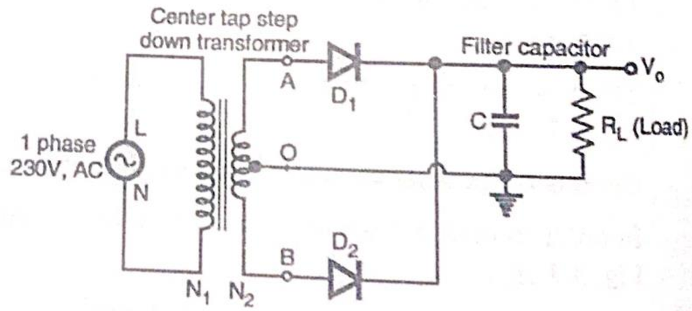
	P-n junction	zener
1		
2	It is a semiconductor diode which conducts only in one direction. only in forward	The diode which allows the current to flow in both the direction i.e. forward & reverse.
3	Reverse current may damage the junction.	Reverse current does not damage the jun^n.
4	Doping level is low	Doping level is high
5	P-n junction has no sharp reverse breakdown.	zener diode has sharp reverse breakdown.
6	It obey's the ~~om~~ ohm's law.	It doesnot obey the ohm's law.
7	It will be permanently damaged for a large reverse current.	will not be damaged for a large reverse current.
8	It is used for rectification purpose.	It is used as a voltage regulator, motor protection & wave shaping.

3.8 Capacitor Input Filter (Shunt Capacitor Filter) or C Filters :

- The shunt capacitor filter is used to reduce the ripple contents in the output of a rectifier to obtain a pure dc voltage.
- A full wave rectifier alongwith a capacitor input filter is as shown in Fig. 3.8.1(b).
- "C" is the filter capacitor which is connected across the load resistance R. The value of C is very large i.e. a few hundred microfarads in order to reduce the ripple successfully. The electrolytic capacitors are normally used as filter capacitors.
- We have shown a FWR with capacitor input filter in Fig. 3.8.1(b), however we can connect the filter capacitor across the output terminals of any other rectifier in a similar way, as shown in Fig. 3.8.1(a).



(a) Connection of filter capacitor



(b) FWR with capacitor input filter

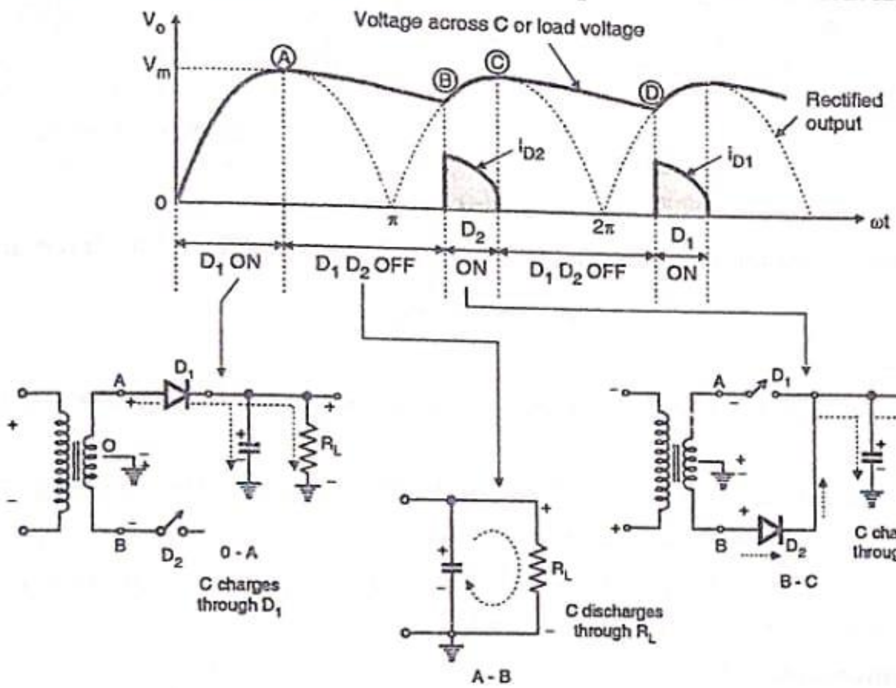
(B-114) Fig. 3.8.1

Why the name shunt capacitor filter ?

- The filter capacitor is connected across (in shunt with) the load. This filter is called as shunt capacitor filter.

3.8.1 Operation of FWR with a shunt Capacitor Filter :

- Fig. 3.8.2 shows the waveform of load voltage with the capacitor filter. Alongwith the waveforms the equivalent circuits for various intervals have been shown.
- Operation of the FWR with capacitor filter can be explained in four different intervals.



(B-115) **Fig. 3.8.2 : Load voltage waveform and equivalent circuits of FWR with a capacitor filter**

Operation in the interval 0 to A :

- The initial voltage on capacitor "C" is assumed to be zero. In the first positive half cycle of the supply, D_1 is forward biased and starts conducting. D_2 is reverse biased and acts as an open switch. Diode D_1 supplies for the charging current of the capacitor and the load current.
- Capacitor starts charging through D_1 and at the end of this interval i.e. at "A" it charges to the peak value of secondary voltage i.e. "V_m".

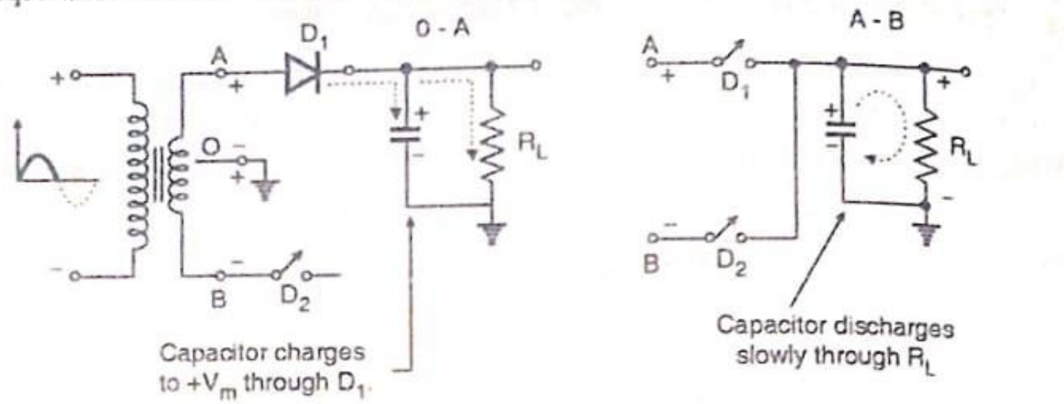
$\therefore$ At "A", voltage on C i.e. $V_C = V_m$

- After point "A" the instantaneous secondary voltage starts reducing as shown by the dotted waveform of rectifier output in Fig. 3.8.2. This will reverse bias the diode D_1, hence at "A", the diode D_1 is turned off. The equivalent circuit for this interval is shown in Fig. 3.8.3(a).

Operation in the interval A to B :

- During this interval, voltage on the capacitor is higher than rectifier output (shown by dotted lines). Hence D_1 and D_2 both remain off. The capacitor discharges exponentially through the load resistance R_L.

- As the value of R_L is much higher than R_F, the capacitor discharges slowly. Discharging time constant is "$R_L C$". Value of C is very large in order to make the discharging time constant as large as possible. This will reduce the ripple content in the output voltage.
- The equivalent circuit for this interval is shown in Fig. 3.8.3(b).



(a) Equivalent circuit for the interval 0 to A (b) Equivalent circuit for interval A to B

(B-116) Fig. 3.8.3

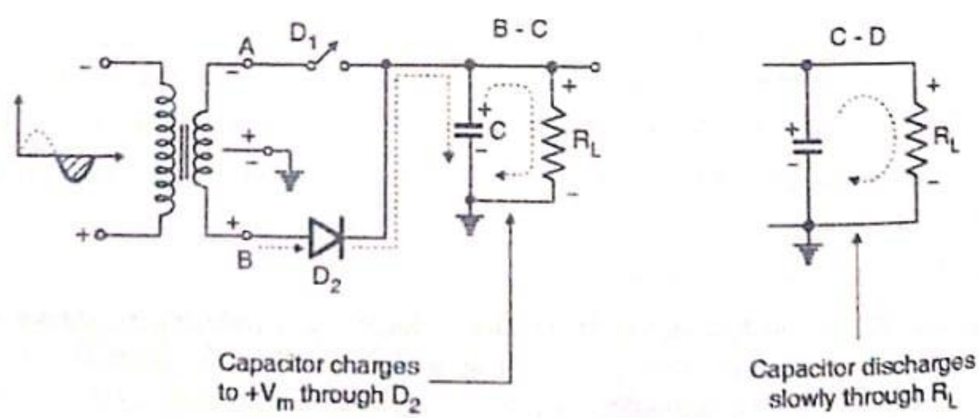
Operation in the interval B to C :

- At "B" the instantaneous rectified voltage is equal to the voltage on capacitor and after "B" it is greater than V_C.
- Therefore diode D_2 starts conducting at instant B. The capacitor charges through D_2 and at the end of this interval i.e. at point "C", the voltage on capacitor is again equal to $+V_m$.
- Due to this D_2 is reverse biased and stops conducting at point "C" as shown in Fig. 3.8.2. The equivalent circuit for this interval is shown in Fig. 3.8.4(a).

Operation in the interval C to D :

The operation in this interval is identical to that in the interval A to B.

The load voltage waveform of Fig. 3.8.2 with filter capacitor is very close to the pure dc voltage waveform.



(a) Equivalent circuit for the interval B to C (b) Equivalent circuit for the interval C to D

(B-117) Fig. 3.8.4

2.1 Introduction

The transistor is a solid-state device made up of silicon or germanium. The name transistor is derived from 'transfer resistor', meaning that it changes resistance. The transistor was invented in 1948 at the Bell Telephone Laboratories. The Nobel Prize in Physics was awarded to William Shockley, Walter Brattain and John Bardeen for the invention of transistor.

There are two main types of transistors, the bipolar junction transistor (BJT) and the field-effect transistor (FET). The transistor can be used as an amplifier or as an electronic switch.

2.2 Types of Bipolar Transistors

A bipolar junction transistor (BJT) is a silicon or germanium crystal in which three regions are present. These are emitter(E), base (B) and collector (C). There are two junctions. One junction is between emitter and base and the other junction is between the base and the collector. Types of BJT are: (1) NPN and (2) PNP.

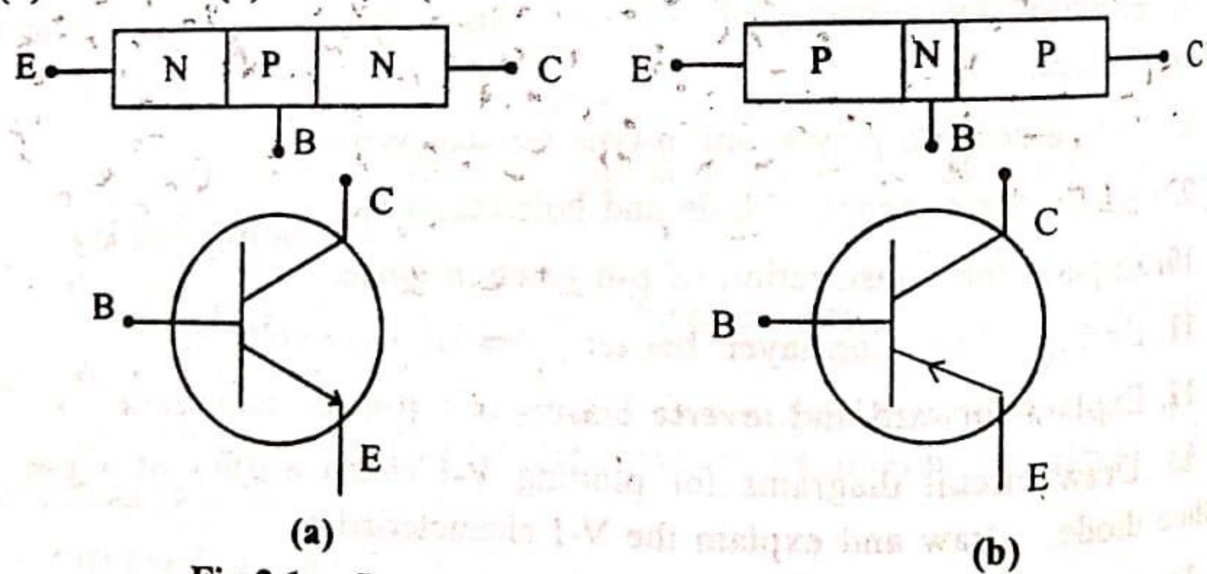


Fig.2.1 : *Junction transistors (a) NPN (b) PNP*

The function of an emitter is to emit electrons in a NPN transistor and to emit holes in a PNP transistor. As emitter is the source of charges, it is ***heavily doped***. The base is very ***lightly doped***. The doping of the collector region is between the heavy doping of the emitter and the light doping of the base. The area of collector region is maximum since it is required to dissipate more heat. The area of emitter region is smaller than that of collector. The area of base region is minimum to prevent recombination of holes and electrons in the base.

In the symbol of a transistor, the arrow indicates the direction of the conventional emitter current.

Biasing the transistor : A transistor can be biased in three ways.

1. Both junctions forward biased - In this method the emitter and collector currents are large. The transistor is in '*saturation*' state.

2. Both junctions reverse biased - In this method the current is negligible. The transistor is in '*cut off*' state.. Negligible reverse current is obtained because of minority charge carriers.

3. Emitter-base junction forward biased and collector-base junction reverse biased. In this method the transistor acts as an active device because it can amplify an input signal to produce a larger output signal. The transistor is in '*active*' state.

2.3 Operation of Transistors

2.3.1 Operation of a NPN transistor

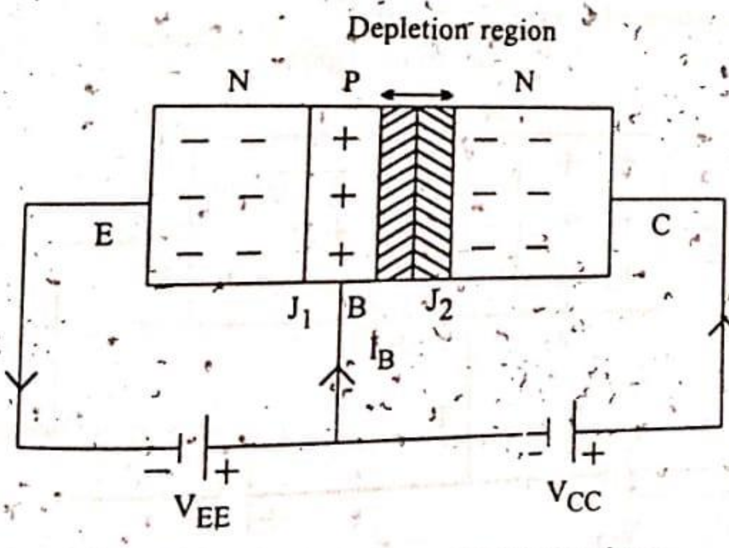


Fig.2.2 : *Currents in NPN transistor*

The emitter-base junction (J_1) is usually forward biased and the collector-base junction (J_2) is reverse biased. Under this condition, a stream of electrons leaves the negative terminal of battery V_{EE} and enters the emitter region. Electrons are majority charge carriers in N type emitter. Therefore, many electrons cross the junction J_1 and enter the base. At the same time a few holes from the base go to the emitter. Therefore,

$I_E = I_{nE} + I_{pE}$ where I_{nE} is current due to electrons and I_{pE} is the current due to holes.

As I_{pE} is very small, $I_E \simeq I_{nE}$.

When the electrons from emitter diffuse through the base, few electrons recombine with holes in base. Since base is lightly doped this number is about 2% only. Remaining about 98% electrons reach the depletion region. These holes are swept out of the base into collector by the reverse bias voltage. $I_C = I_{nc} + I_{co}$

where I_{nc} is the current due to electrons from emitter and I_{co} is the reverse leakage current due to thermally generated charge carriers.

The collector current is nearly equal to the emitter current. $I_E \simeq I_C$. $I_E = I_B + I_C$ where I_B is very small. The conventional directions of currents are shown in Fig.(2.2). The current in the crystal is due to holes and electrons, but the current in the external circuit is due to electrons only.

The students should remember that ***a transistor cannot be formed, by connecting two diodes back to back***. For such connection, you have four doped regions instead of three. There isn't a lightly doped base between an emitter and a collector.

2.3.2 Operation of a PNP transistor

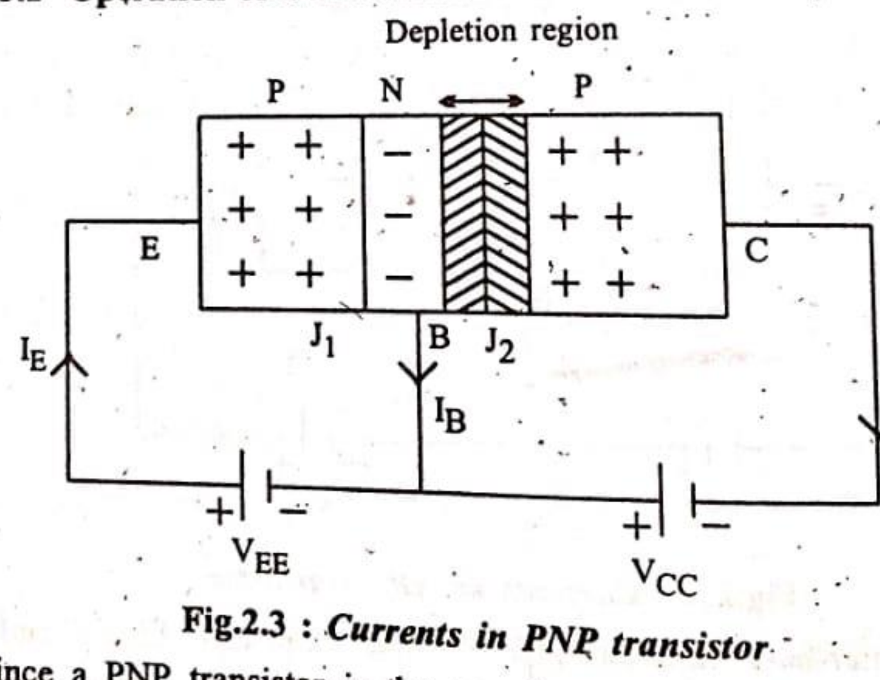


Fig.2.3 : *Currents in PNP transistor*

Since a PNP transistor is the complement of a NPN transistor, the students are advised to write the operation of a PNP transistor only by replacing electrons by holes and holes by electrons.

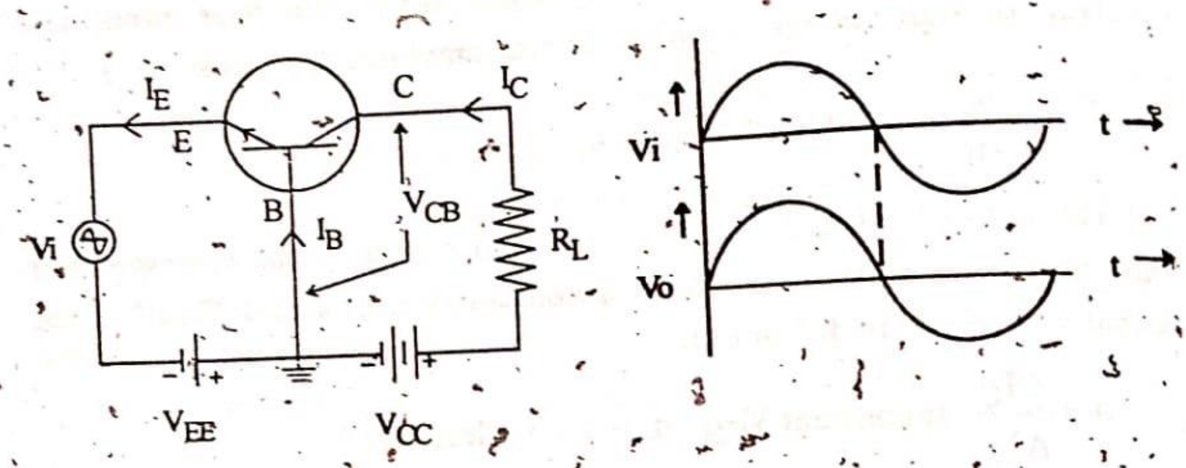
Here $I_E = I_{nE} + I_{pE}$ and as I_{nE} is very small, $I_E \simeq I_{pE}$

$1+\beta$

2.5 Configurations of A Transistor

There are three configurations of transistor. *Configuration* is the method of connecting any one terminal of transistor common to both input and output circuits.

1. Common base configuration (Grounded base configuration)



(a) (b)

Fig.2.4 : *Common base configuration (a) circuit diagram (b) waveforms*

In this configuration, the base is common to both the input and output. The emitter-base junction is forward biased and the collector base junction is reverse biased.

During a positive half-cycle of input signal V_i, the forward bias voltage V_{BE} decreases. Therefore, there is decrease in I_E and I_C. The collector to base voltage V_{CB} is given by $V_{CB} = V_{CC} - I_C R_L = V_O$.

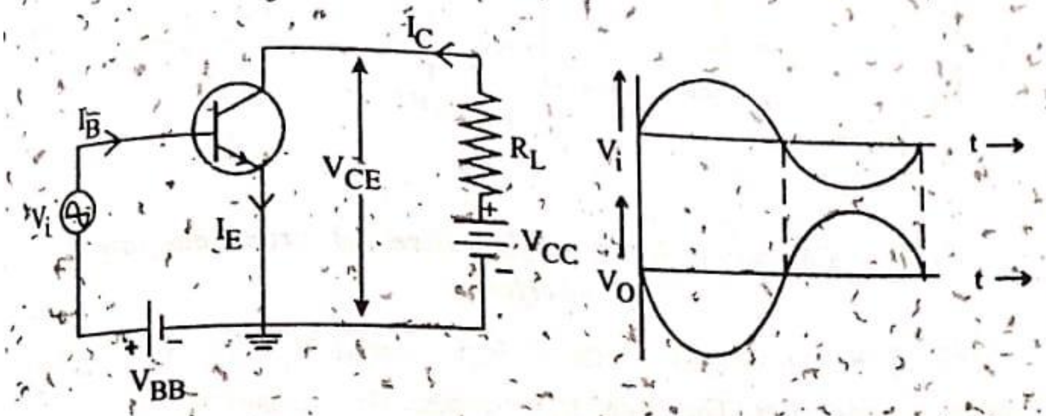
As I_C decreases, V_{CB} increases.

During a negative half-cycle of V_i, V_{BE} increases. Hence, there is increase in I_E and I_C. This causes decrease in V_{CB}. Thus, input and output voltages are in phase. The input resistance is the lowest and the output resistance is the highest of three configurations.

Amplifier is the device which increases a signal applied at its input. Voltage gain is the ratio of output voltage to the input voltage.

In a CB (common base) amplifier, the voltage gain is high, but current gain (α) is less than one.

2: Common emitter configuration :



(a) **(b)**

Fig.2.5 : ***Common emitter configuration (a) circuit diagram (b) waveforms.***

In this type emitter terminal is common to both input and output signals. The emitter-base junction is forward biased and the collector-base junction is reverse biased. The collector to emitter voltage V_{CE} is given by

$V_{CE} = V_{CC} - I_C R_L = V_o$

During a positive half-cycle of input signal V_i, the forward bias voltage V_{BE} increases. Therefore, there is increase in I_E and I_C. Hence V_{CE} decreases according to the equation given above.

During negative half cycle of V_i, V_{BE} decreases, Therefore, there is decrease in I_E and I_C. This causes increase in V_{CE}. Therefore, there is a phase-shift of 180^0 between the input and output signals. The current gain (β), voltage gain and power gain are high in CE configuration. The values of input and output resistances are moderate. This property is useful for cascading CE amplifiers as impedance matching is not necessary.

3. Common collector configuration (Emitter follower) : In this configuration, collector is common to both input and output circuits. But the load (R_L) is connected to emitter. The output signal obtained in the emitter circuit follows the input signal as voltage gain is nearly one. Therefore, common collector configuration is also known as '***emitter follower***'.

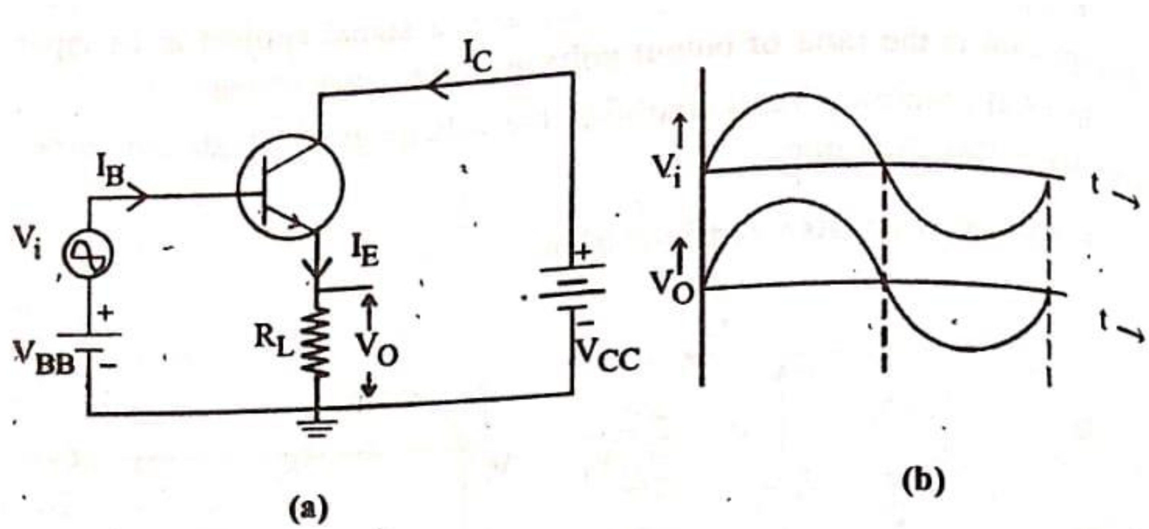


Fig.2.6 : *Common-collector configuration (a) circuit diagram (b) waveforms*

During the positive half-cycle of input signal V_i, the forward bias voltage V_{BE} increases. Therefore, I_E increases. This causes an increase in output voltage as $V_o = I_E.R_L$. Similarly, during the negative half cycle of input signal, the output signal also decreases. Thus, the input and output signals are in phase.

The current gain is high. But voltage gain is less than one. Power gain is low. Input resistance is the highest and the output resistance is the lowest of all configurations. Therefore, this type is useful for impedance matching. An amplifier having high output impedance can be connected to a load having low impedance.

Comparison :

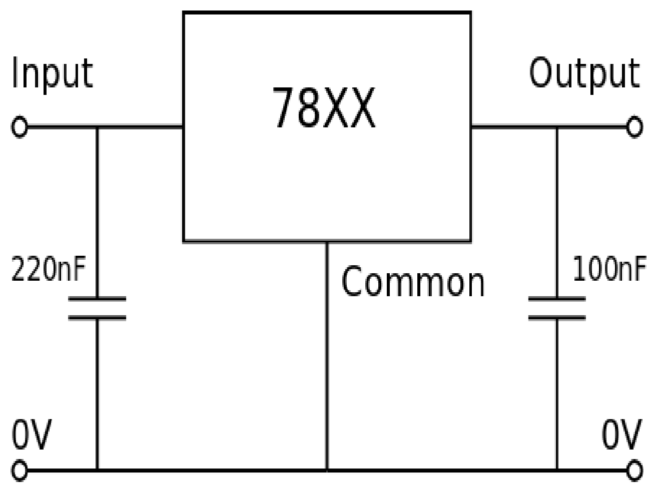
Parameter	Common base (CB)	Common emitter (CE)	Common collector (CC)
1. Phase shift between input and output	zero	180^{o}	zero
2. Current gain	less than 1	high	high
3. Voltage gain	high	high	less than 1
4. Power gain	moderate	high	low to moderate
5. Input resistance	low	moderate	high
6. Output resistance	high	moderate	low

Difference between CB CE &CC

(I/P terminals- B & E) **(O\P terminals- E & C)**

Parameter	Common Base	Common Emitter	Common Collector
Common Terminal	B	E	C
Input Terminal	E	B	B
Output Terminal	C	C	E
Input Voltage	V_{EB}	V_{BE}	V_{BC}
Output Voltage	V_{CB}	V_{CE}	V_{EC}
Input Current	I_E	I_B	I_B
Output Current	I_C	I_C	I_E
Amplification Factor	$\alpha = \mathrm{IC}/IE$	$\beta = IC/IB$	$\Upsilon = IE/IB$

IC 78XX

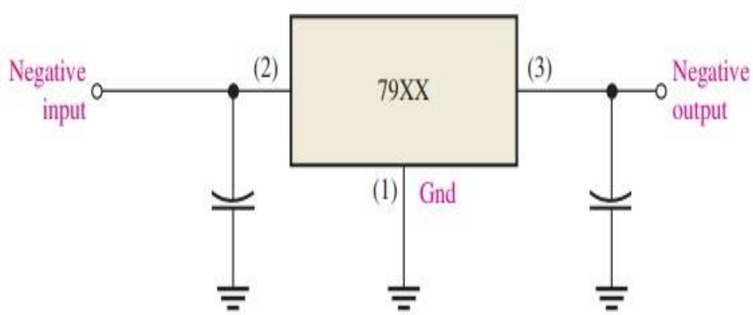


Features of IC 78XX:

- 1. Fixed Voltage Output: The 78XX series provides a fixed output voltage, with different variants available for specific voltage levels, such as 7805 (5V), 7812 (12V).
- 2. Positive Voltage Regulators: These ICs are positive voltage regulators, meaning they provide a stable, regulated positive voltage output relative to their ground pin.
- 3. Voltage Regulation: They offer good voltage regulation, maintaining a relatively constant output voltage even when the input voltage or load conditions vary.
- 4. Low Dropout: Some variants in the series have low dropout voltage, which means they can regulate the output voltage effectively even when the input voltage is only slightly higher than the desired output voltage.

- 5. Over current Protection: 78XX ICs typically include short-circuit and over current protection, safeguarding the IC and the connected circuitry.
- 6. Thermal Shutdown: They often have built-in thermal protection that shuts down the IC if it overheats, preventing damage due to excessive temperature.
- 7. Common Applications: These ICs are commonly used in a wide range of electronic devices and circuits to provide a stable power supply, such as in power adapters, battery chargers, and various other electronic devices.

IC 79XX



(a) Standard configuration

Type number	Output voltage
7905	-5.0 V
7905.2	-5.2 V
7906	-6.0 V
7908	-8.0 V
7912	-12.0 V
7915	-15.0 V
7918	-18.0 V
7924	-24.0 V

(b) The 79XX series

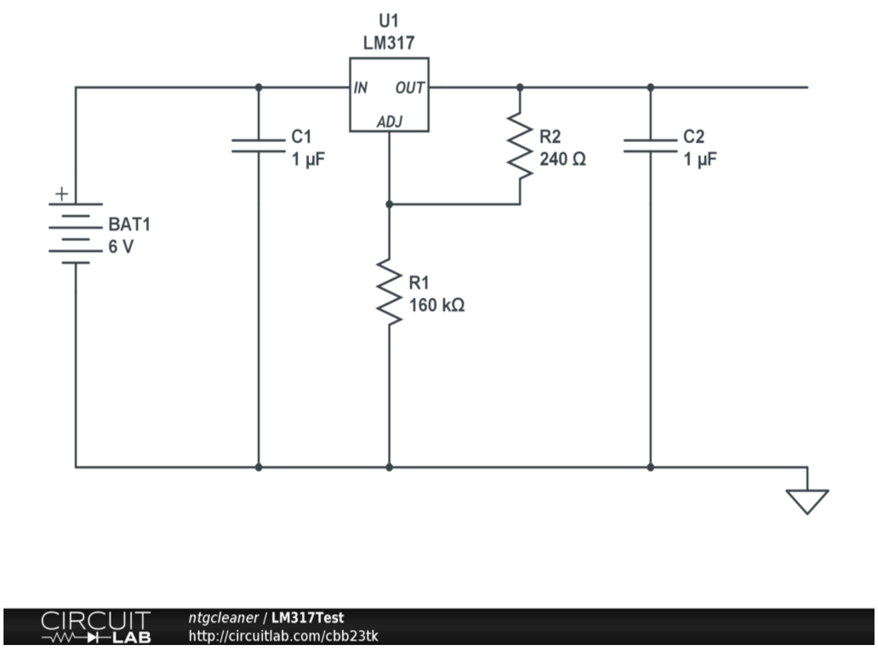
79XX series three-terminal fixed negative voltage regulators.

Features of IC 78XX:

- 1. Fixed Negative Voltage Output: The 79XX series provides a fixed negative output voltage, with different variants available for specific voltage levels, such as 7905 (-5V), 7912 (-12V), and so on.
- 2. Negative Voltage Regulation: These ICs are negative voltage regulators, meaning they provide a stable, regulated negative voltage output relative to their ground pin.
- 3. Voltage Regulation: Like the 78XX series, the 79XX series offers good voltage regulation, maintaining a relatively constant negative output voltage even when the input voltage or load conditions vary.
- 4. Low Dropout: Some variants in the series have low dropout voltage, which means they can regulate the output voltage effectively even when the input voltage is only slightly higher than the desired negative output voltage.

- 5. Over current Protection: 79XX ICs typically include short-circuit and over current protection, safeguarding the IC and the connected circuitry.
- 6. Thermal Shutdown: They often have built-in thermal protection that shuts down the IC if it overheats, preventing damage due to excessive temperature.
- 7. Common Applications: These ICs are used in electronic circuits that require a stable negative power supply, such as in amplifiers, operational amplifier

IC LM317



Features of IC LM317:

- 1. Adjustable Voltage Output: The LM317 is an adjustable voltage regulator, allowing you to set the output voltage to your desired level using external resistors.
- 2. Wide Input Voltage Range: It can operate over a wide input voltage range, typically from 1.25V to 37V, making it suitable for various applications.
- 3. Positive Voltage Regulator: LM317 is a positive voltage regulator, meaning it provides a stable, regulated positive voltage output relative to its ground pin.
- 4. Voltage Regulation: It offers good voltage regulation, maintaining a relatively constant output voltage even when the input voltage or load conditions vary.

- 5. Adjustable Output: The LM317 can be configured as both a constant voltage and constant current regulator by using external components. This makes it versatile for a wide range of applications, including battery chargers and LED drivers.
- 6. Current Limiting: It includes current limiting and thermal overload protection, which helps protect the IC from damage in case of over current or excessive temperature.
- 7. Common Applications: It is commonly used in various electronic devices and circuits where a stable and adjustable voltage source is required, such as in power supplies, battery chargers, and voltage-controlled oscillator circuits.