# BJT

Page No.
Date

→ Transistor is an electronic device consisting of 2 PN junctions formed by sandwiching either P-type or n-type semiconductor b/w a pair of opposite types.

→ 2 types of semiconductor

- **Unipolar Junction transistor :-**

Current conduction is due to one type of charge carriers [either $e^-$ or holes].

- **Bipolar Junction transistor :-**

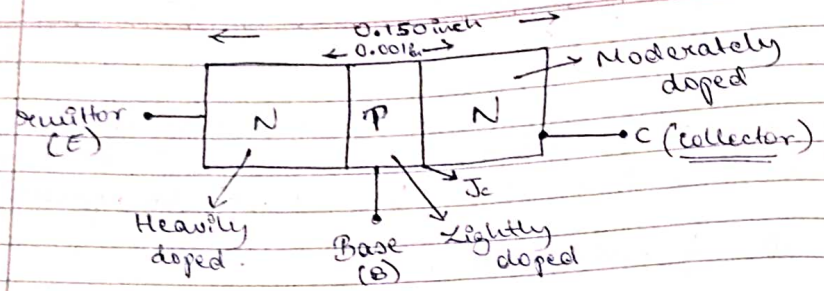
Current conduction is due to both type of charge carriers [holes & $e^-$ both].

→ **Types of BJT :-**

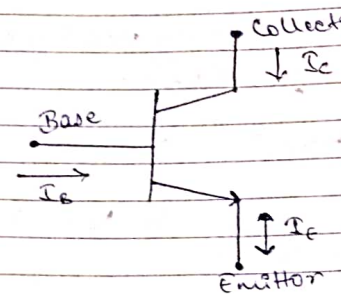
- NPN Transistor
- PNP Transistor

→ **NPN Transistor :-**

NPN is obtained when a P-type layer of semiconductor is sandwiched b/w 2 n-type layer of semiconductor.




(a) Schematic diag of nPN Transistor.




(b) Symbol

→ There are 3 terminal one taken from each type of Semiconductor

- Emittor
- Base
- Collector.

→ Emittor -: The section on one side that supplies charge carriers (e⁻).

→ It is heavily doped region.
→ It is always forwardly biased

→ Base -: The middle layer b/wⁿ the emittor & collector.

→ It is thin & lightly doped region.

→ Collector -: The section on the other side which collects charge carriers (e⁻)

→ It is moderatly doped region.
→ It is always reverse biased.

NOTE -:

During transistor operation, Much heat is produced at the collector June, so collector is made larger to dissipate the heat.

→ The junction b/wⁿ e & b is emittor base June or emittor base diode.

→ The ratio of total width to center layer is 150 : 01.

## * Transistor characteristics :-

- Input
- Output
- Current Gain

→ **Input :-**

It is a Plot of input current as a function of input voltage, Keeping the output voltage current.

→ **Output :-**

It is a Plot of output current vs output voltage at a constant input current.

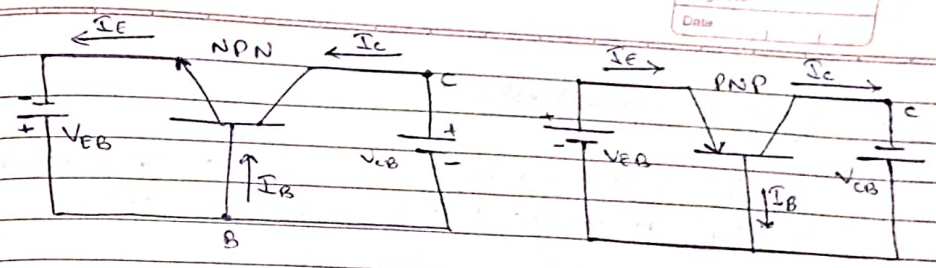
→ **Current Gain charac :-**

It is a Plot of output current vs input current at constant output voltage.

## * CE, CB & CC config :-

→ **Common Base Config :-**

For both NPN & PNP Transistor.




NPN Transistor

PNP Transistor

- Input current & output current maybe direct or Alternating current.
- Amplification factor or current amplification factor :-

$$\alpha_{dc} = \frac{I_C}{I_E}$$ → DC current Gain.

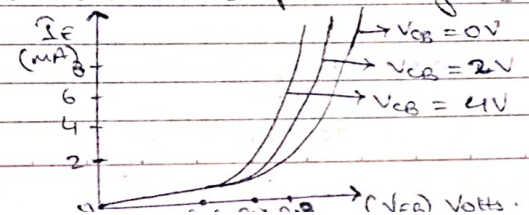
→ It is defined as the ratio of collector current ($I_C$) to the emitter current ($I_E$).

$$\alpha_{AC} = \frac{\Delta I_C}{\Delta I_E}$$ → AC current Gain.

- In Practice, $\alpha_{dc} = \alpha_{AC}$ which ranges from 0.90 to 0.998.

## * Input charac :-

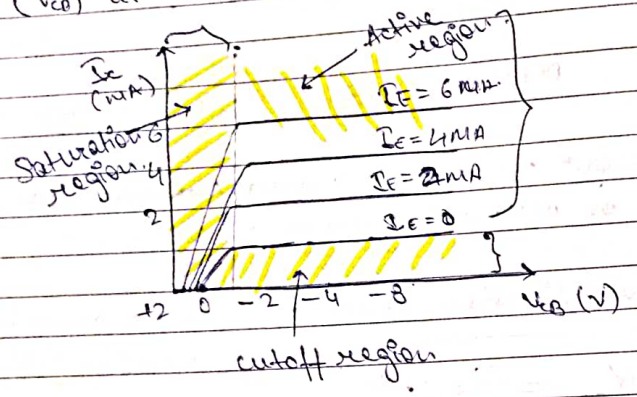
It is a plot of input current ($I_E$) vs input voltage ($V_{EB}$) at constant output voltage ($V_{CB}$).



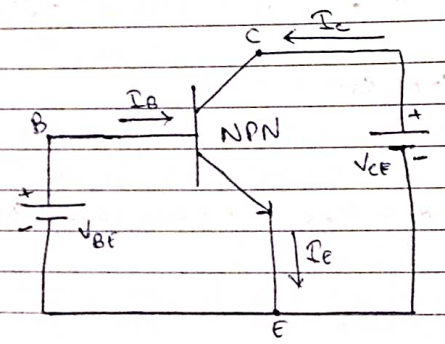

Input Char.

## ★ Output characteristic :-

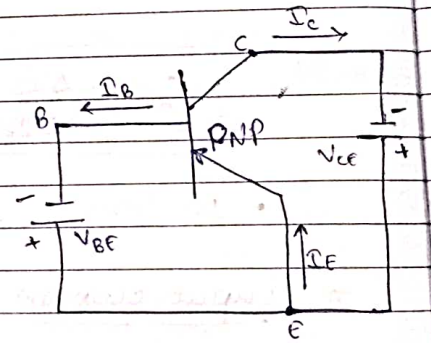
It is a Plot of output current ($I_C$) vs output voltage ($V_{CB}$) at Constant input current ($I_E$).




## → Common Emitter Config :-




★ NPN transistor.




★ PNP transistor

• Base current Amplification factor :-

$$\boxed{\beta_{dc} = \frac{I_C}{I_B}}.$$

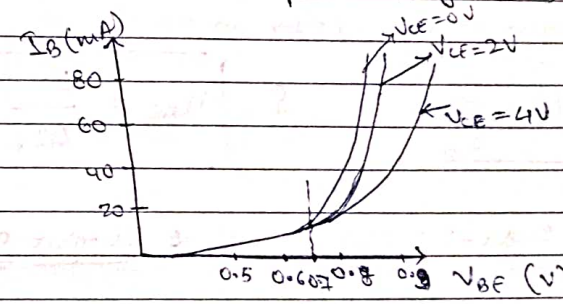
It is defined as the ratio of collector current to the base current.

$$\boxed{\beta_{AC} = \frac{\Delta I_C}{\Delta I_B}}.$$

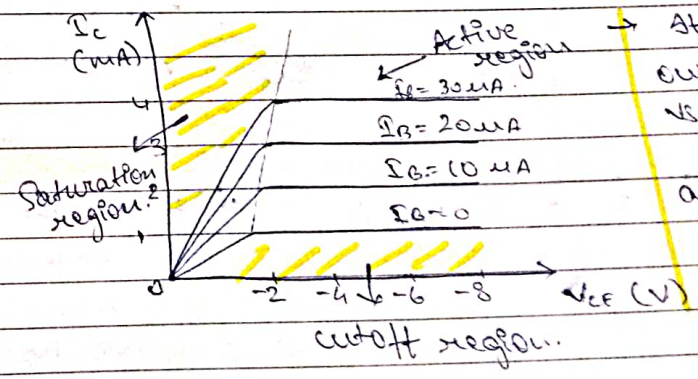
• In Practice, $\beta_{ac} = \beta_{dc}$. which range 20 to 500

## ★ Input characteristic :-

→ It is a plot of input current ($I_B$) vs input voltage ($V_{BE}$) at Constant output voltage ($V_{CE}$).

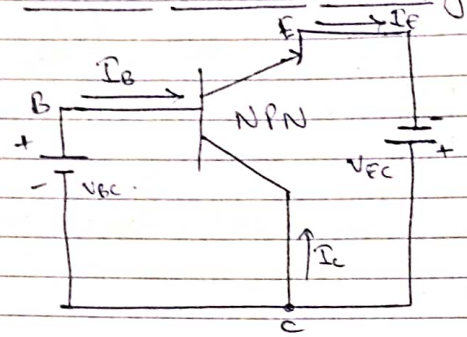



## ★ Output characteristic :-

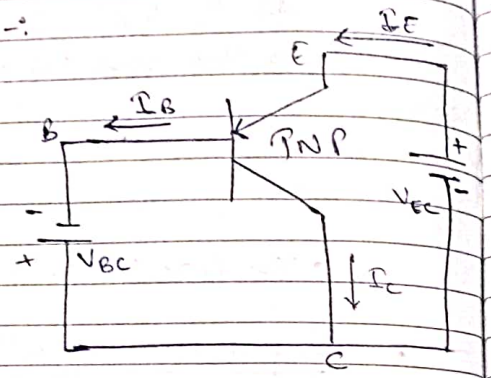



→ It is Plot of output current vs output voltage at const. input current.

→ Common Collector Config -:




NPN Transistor

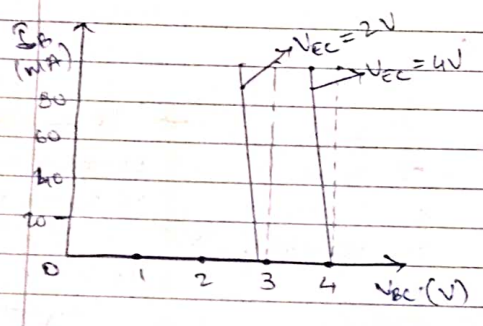



PNP Transistor

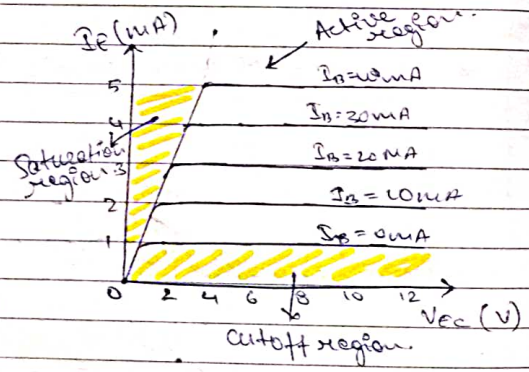
• Current Amplification factor -:

$$\boxed{n_{dc} = \frac{I_E}{I_B}} \quad \& \quad \boxed{n_{AC} = \frac{\Delta I_E}{\Delta I_B}} \Big|_{V_{EC} = \text{const}}$$

☆ Input char -:




☆ Output char -:




Imp.

☆ Relation b/wⁿ $\alpha_{dc}$ & $\beta_{dc}$ -:

⇒ • $\alpha_{dc} = \frac{I_C}{I_E}$ • $\beta_{dc} = \frac{I_C}{I_B}$ • $n_{dc} = \frac{I_E}{I_B}$

So from above eqⁿ.

$$\boxed{\alpha_{dc} = \frac{\beta_{dc}}{\beta_{dc} + 1}} \quad \& \quad \boxed{\beta_{dc} = \frac{\alpha_{dc}}{1 - \alpha_{dc}}}$$

☆ Relation b/wⁿ $\alpha_{dc}$ & $n_{dc}$ -:

⇒ $\boxed{\alpha_{dc} = \frac{n_{dc} - 1}{n_{dc}}}$ —(13) & $\boxed{\beta_{dc} = n_{dc} - 1}$

☆ Relⁿ b/wⁿ $\alpha_{dc}$ & $\beta_{dc}$ & $n_{dc}$ -:

$$\boxed{n_{dc} = \frac{\beta_{dc}}{\alpha_{dc}}}$$

NOTE

• In transistor voltage breakdown occurs in 2 types namely -:

• Avlanche Breakdown.
• Punch through & Reach through

Page No.
Date

* Common Emitter circuit is most efficient.
  - High current gain
  - High voltage & Power gain
  - Moderate Output to Input Impedance Ratio

# JFET

Page No.
Date

(*) Junction field effect transistor.

It is a unipolar - transistor, which acts a voltage controlled current devices & is a device in which current at 2 electrodes is controlled by action of an electric field at an P-n Junction.

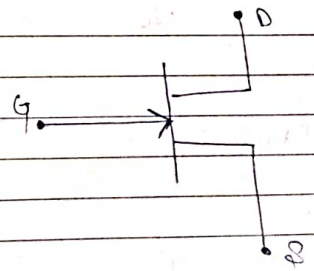
(*) Metal Oxide Semiconductor feild effect transistor.

→ n - channel JFET
→ P - Channel JFET.

(*) n - channel :- (current is carried by $e^-$).

A small bar of extrinsic semiconductor material, n-type is taken & its two ends, 2 ohmic contacts are made which is drain & source terminal of FET.

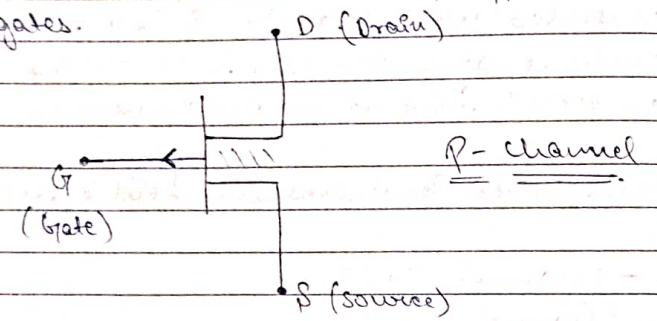
Heavily doped electrodes of P type material form P-n Junction on each side of the bar. The thin region b/w 2 - P gates is called the channel.




n channel JFET.

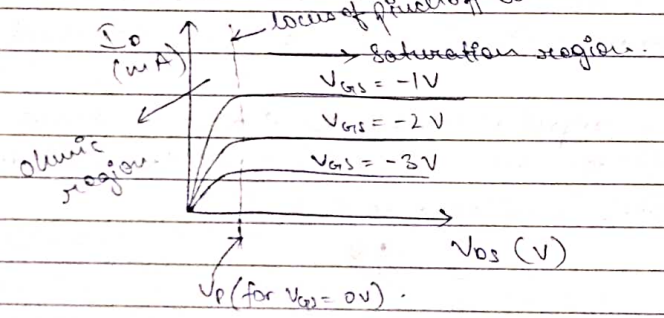
## P- channel JFET :- (current is carried by holes).

The device could be made of P-type bar with 2-n type gates.




## Drain or Current voltage charac :-

When the drain current ($I_D$) is plotted with $V_{DS}$ for diff values of $V_{GS}$.




## Channel Resistance ($R_D$) :-

$$R_D = \frac{R_0}{[1-(V_{GS}/V_P)]^2}$$

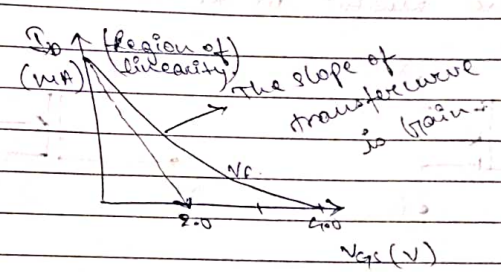
$R_0$ is resistance for $V_{GS} = 0V$.

## Transfer charac :-

It is a plot of output (drain) current versus input controlling quantity (Gate-Source voltage) i.e. $V_{GS}$).

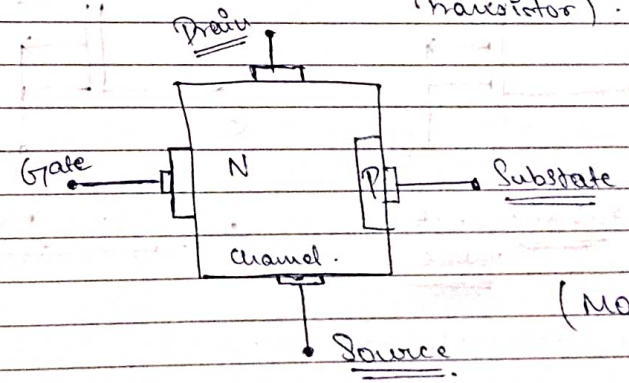
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2.$$

* The input output relationship of JFET is not linear.




## MOSFET :-

Also Known as IGFET (Insulated Gate Feild Effect Transistor).



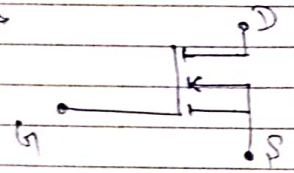

(MOSFET).

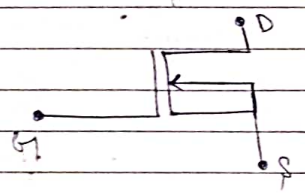
## MOSFET

- Enhancement mode
  - P-chan.
  - n-Chan.
- Depletion mode
  - P-Chan
  - N-Chan.

- N-channel Mosfet are known as NMOS.

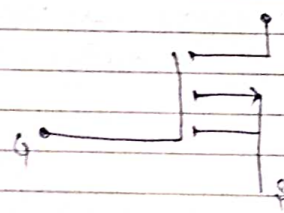
n-channel →

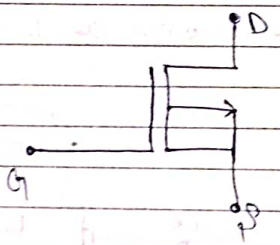



- Enhancement mode
- Depletion Mode.

- P-Channel → PMOS.

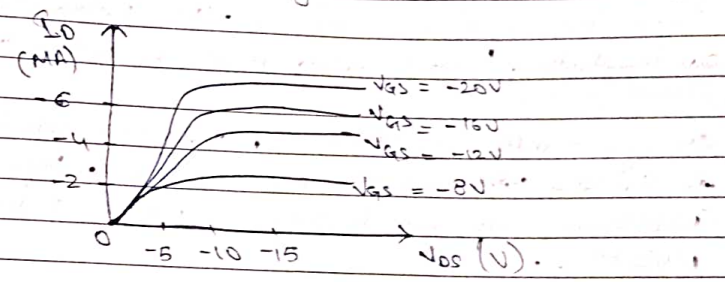



- Enhancement mode
- Depletion Mode.

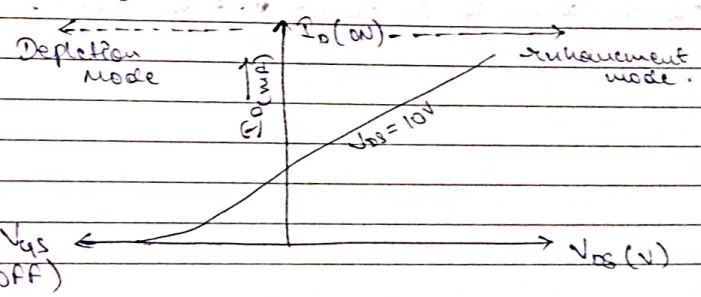
## DRAIN characteristics of MOSFET :-

Drain characteristics are drawn b/w drain current $I_D$ & drain voltage source $V_{DS}$.




## Transfer characteristics of MOSFET :-

Transfer characteristic is define as the change in value of $V_{DS}$ with change in $I_D$ & $V_{GS}$ in both depletion & enhancement mode.




## Application of MOSFET :-

- Employed in extremely extensive freq. applications.
- Regulation of DC motors.

## Construction of MOSFET & JFET?

→ The construction of MOSFET is bit similar to FET. An oxide layer is deposited on substrate to which gate terminal is connected. The oxide layer acts as an insulator. (That's why it is also called IGFET).

In construction of MOSFET, a lightly doped substrate is diffused with heavily doped region. Depending upon substrate they are known as P-type & n-type MOSFET.

→ JFET is constructed using long channel of semiconductor material. Depending upon construction process if JFET contains great no. of positive charge carriers is called P-type JFET. & if it has large no. of negative charge carrier then it is called n-type JFET.

# Amplifiers.

## Feedback :-

It is the process of injecting some energy from output to input.

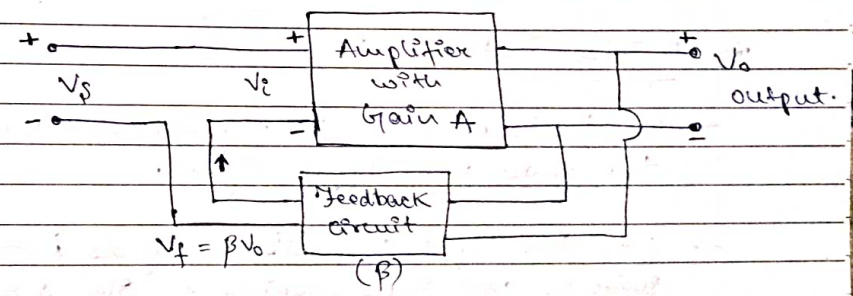
The amplifier which use feedback principle are known as feedback amplifier.

## Principle of feedback Amplifier :-

→ A feedback amplifier generally consist of 2 parts They are the amplifier & the feedback circuit.

→ The feedback circuit usually consist of resistors.

→ Diag :-




• Overall gain ($A_f$) = $\frac{\text{Output Voltage}}{\text{Inp. Signal Voltage}} = \frac{V_o}{V_s}$.

Page No.
Date

(*) eq of Gain of feedback Amplifier with negative feedback

→ $A_f = \frac{A}{1+A\beta}$.

(*) eq. of Gain of feedback Amplifier with positive feedback

→ $A_f = \frac{A}{1-A\beta}$

∴ $\frac{V_o}{V_s} = \frac{A}{1 \pm A\beta}$

(*) Types of feedback :-

(⊙) Positive feedback :-

→ The feedback in which the feedback energy is in the phase with input signal.

→ Both the input & feedback signals introduce a phase shift of 180° thus making a 360° resultant phase shift around the loop, to be finally in phase with input signal.

Page No.
Date

• Advantages :-

→ Inc. Gain

• Disadventages :-

→ Increase distortion
→ Instable.
→ Noisy

(⊙) Negative feedback :- (Mostly employed).

→ The feedback in which the feedback energy is out of phase with the input & thus opposes it.

→ In this amplifier introduces a phase shift of 180° into the circuit while the feedback network produces no phase shift (zero). Thus the resultant feedback voltage $V_f$ is 180° out of phase with input signal ($V_{in}$).

• Advantages :-

→ Stability of gain inc.
→ Reduction in noise
→ Reduction in Distortion

• Disadvantages :-

→ Gain is reduced.

NOTE → 2 types of Negative feedback circuits :-

• Negative Voltage feedback
• Negative Current feedback.

(⊙) Applications of Negative feedback Amplifiers :-

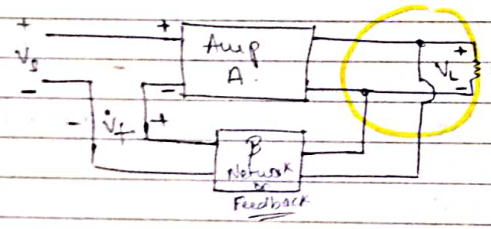
→ electronic Amplifiers
→ RPS (Regulated Power supplies).
→ Large bandwidth Amplifiers

## Loop Gain :-

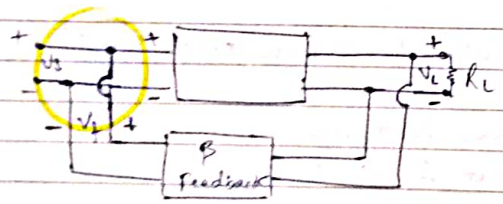
Loop Gain is a function of how much output is fed back into the input.

## Topologies of feedback Amplifier :-

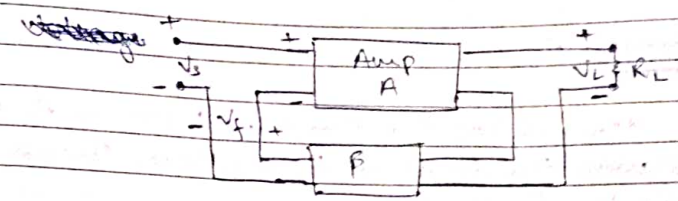
- Voltage - Series (Series - Shunt feedback)
- Voltage - Shunt (Shunt - Shunt feedback).
- Current - Series (Series - Series feedback).
- Current - Shunt (Shunt - Series feedback).

- 

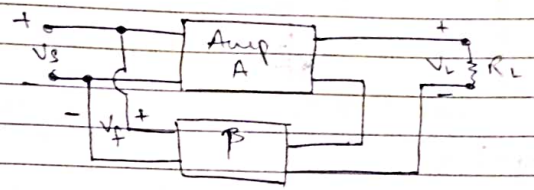
→ Voltage - Series.

- 

→ Voltage - Shunt.

- 

Current - Series.

- 

Current - Shunt.

## Sensitivity :-

It is defined as the ratio of fractional change in gain with the feedback to fractional change in gain without the feedback.

$$S = \frac{\frac{dA_f}{A_f}}{\frac{dA}{A}}$$

## De-Sensitivity :-

Indicates the fraction by which voltage gain has been reduced due to feedback.

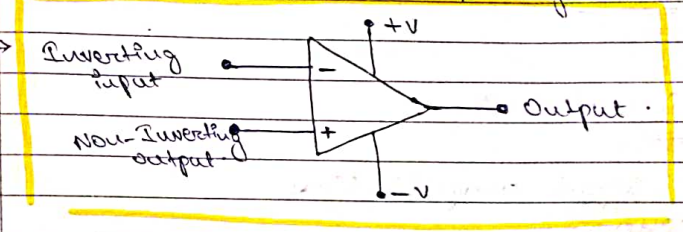
## Distortion with feedback :-

$$D' = \frac{D}{1 + A_v B}$$

# O.P. Amplifier

## Operational Amplifier :-

- → An operational amplifier is a high gain electronic voltage amplifier with 2 inputs & a single output.
- → Operational amplifiers were used to primarily performed mathematical operations such as addition, substraction, integration & differentiation.
- →




- → Output voltage is given by :-

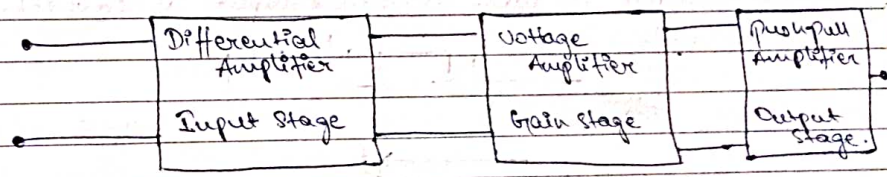
$$V_o = A_v V_d.$$

where;

$A_v$ = open loop voltage gain

$V_d$ = Diff. b/w voltage at input terminals.

- →




Block-Diag.

• → O-P- Amplifier contains following stages -:

• **Input stage** -: This stage provides most of the voltage gain req.

• **Gain stage** -: Provides addition gain req. contains a chain of cascaded amp.

• **Output stage** -: Push-pull amplifier is used at output stage.

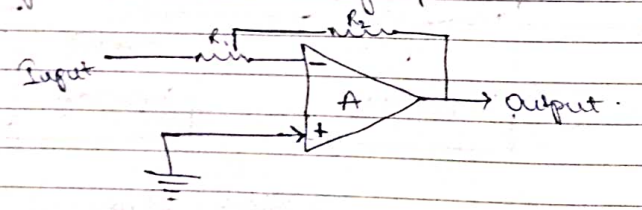
(*) • → **Applications** -:

- AC & DC signal complification.
- Active filters.
- Oscillators
- Comparator.
- Regulators.

(*) • → **Inverting & Non-Inverting mode of operations** -:

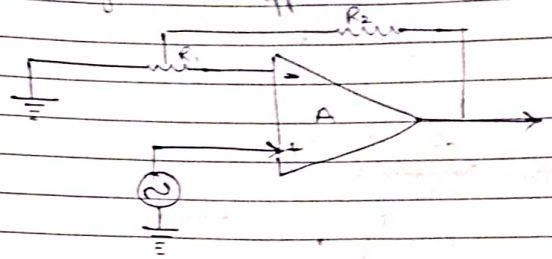
• **Inverting mode** -:

In this config, the signal is applied at inverting input & non-inverting input is connected to ground.




• **Non-Inverting** -:

When the signal is applied at non-inverting input.



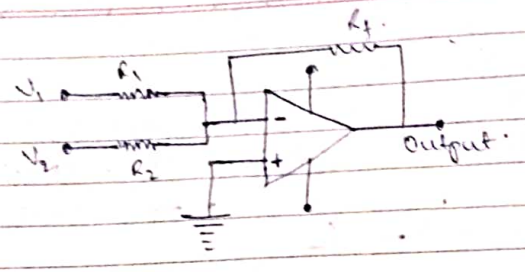

(*)

| • Inverting | • Non-Inverting. |
|---|---|
| → Type of feedback used is voltage shunt. | → Type of feedback used is voltage series. |
| → Input & output voltage of this amplifier are 180° out of phase. | → Output & Input voltage are in phase. |
| → Voltage gain $= \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$ | → Voltage gain $= \frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$ |
| → Input Impedence is $R_1$ | → Input Impedance is high. |

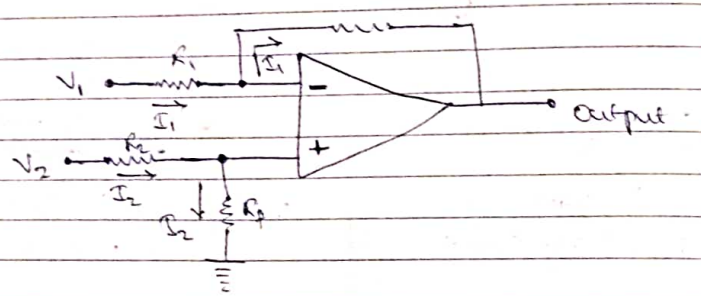
(*) **OP Amp. Adders & Subtractor** -:

• Adders can be obtained by using either non-invert. mode or differential amplifier.

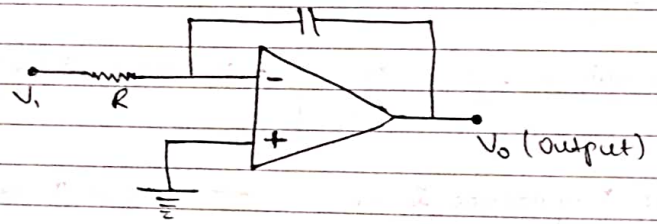
• So the inputs are applied through resistors to inverting terminal & non-inverting terminal is grounded.




## Subtractor circuit -:

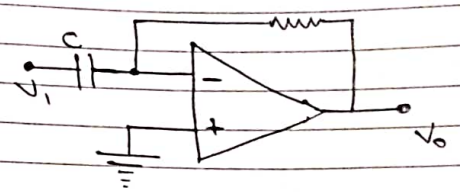



## Integrator -:



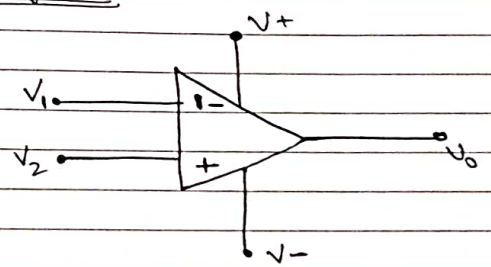

- The Integrator is an operational amplifier circuit which performs the mathematical operations of Integration.
- The circuit acts as an storage element which produces a voltage output that is proportional to time Integral of Input voltage.

## Differentiator -:




- This operational amp. circuit performs the math. operation of Differentiation.
- Produces a voltage that is ∝ Input voltage's rate of change.

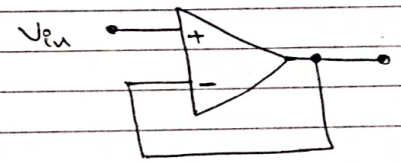
## Comparator -:




- A device that compares 2 voltages or currents & outputs.

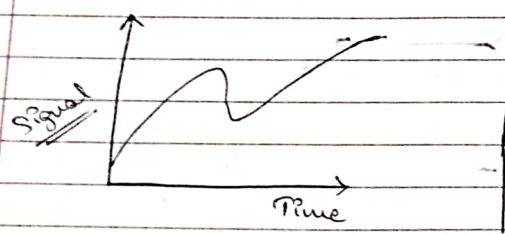
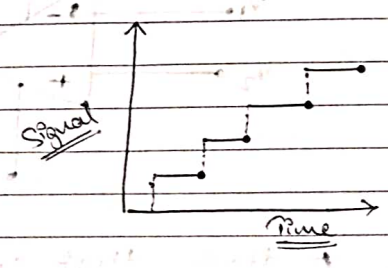
## Voltage follower -:

- It is an op amp circuits whose output voltage is equal to input voltage



# Unit → V

## Analog & Digital Signals :-

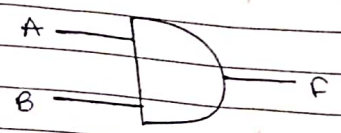
| Analog | Digital |
|---|---|
| • Continuous Signals. | • Discrete Signals. |
| • Represented by Sin waves. | • Represented by square waves |
| • Records sound wave as they are | • Converts into binary wave form. |
| • Continuous range of values | • Discontinuous values. |
| • Ex :- Human voice, Natural Sound. | • Ex :- Computers, optical drives. |
| •  |  |





## Logic Gates :-

• AND Gate :- • IC 7408.




⇒ $F = A.B$

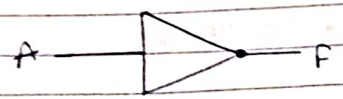
| A | B | F |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

• OR Gate :- • IC 7432

⇒ $F = A + B$

| A | B | F |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

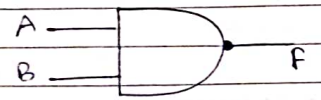
- **NOT Gate -:** • NOT IC 7404




$F = \overline{A}$ or $A'$.

| A | F |
|---|---|
| 0 | 1 |
| 1 | 0 |

- **NAND -:**

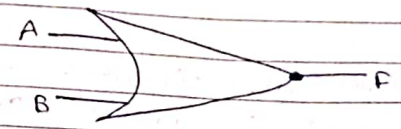



$F = (\overline{AB})$

| A | B | F |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

- NAND IC 7400.

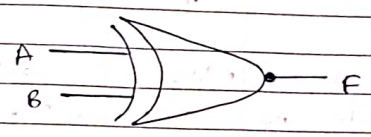
- **NOR -:** • NOR IC 7402




$F = (\overline{A + B})$

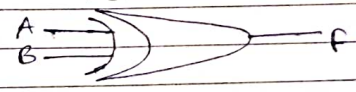
| A | B | F |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

- **XNOR -:**




| A | B | F |
|---|---|---|
| 0 | 0 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 1 | 1 |

- **XOR -:** • IC 7486.

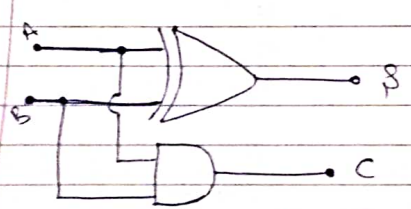


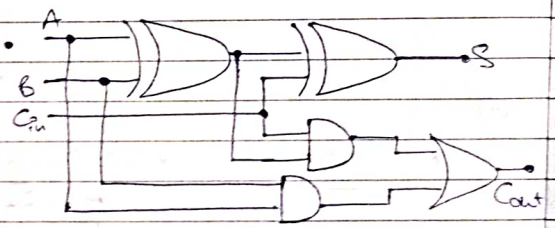

off

## Half & full Adders :-

- Adder is a digital logic circuit in electronics that is extensively used for addition for of no'.

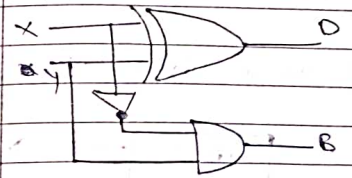
| Half adder | Full Adders. |
|---|---|
| → Adds 2 input bits. | • Adds 3 one bit no'. |
| • Consist of only one AND & ex-OR Gate. | • Consist of one OR Gate & 2 xOR & AND gate. |
| • Generates Sum & Carry bits as output. | • Generates sum of all 3 values with carry values. |
| • Good for measuring devices computers, calculators etc. | • Used in various digital processors, the add$^n$ of multiple bits. |
| • $C = A * B$<br>$S = A \oplus B$. | • $S = A \oplus B \oplus C_{in}$<br>$C_{out} = AB + (A \oplus B) C_{in}$. |

• 


• 


## Half Substractor.

- Used to perform subtraction of 2 single bits & generate the output.
- Outputs are Difference & borrow.

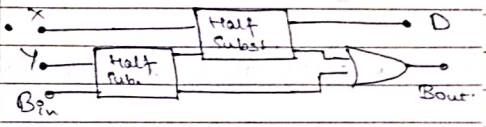
• 


• 

| X | Y | D | B |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |

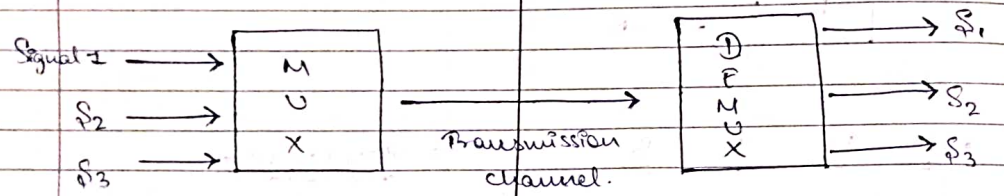
## Full Subtractor.

- Performs substraction involving 3 bits named minuend, subtrahend & borrowin.
- Output are difference & borrow.

• 


- Very lengthy.

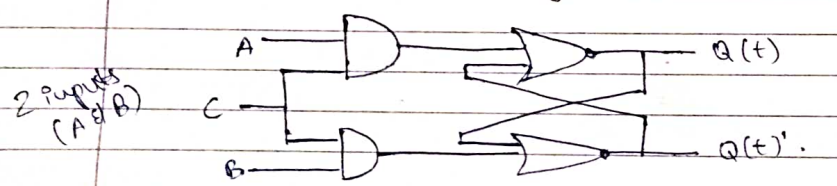
| Multiplexer | Demultiplexer |
|---|---|
| • Accepts multiple inputs of data but provides only a single output | • Accepts single input but directs it through multiple output. |
| • Converts from parallel to serial. | • Conversion from serial to parallel. |
| • Data selector. | • Data distributor. |
| • Acts as a digital switch | • Acts as a digital circuit. |




## Flip-flops :-

A flip-flop is a device which stores single bit of data.

One of its 2 states represents a "one" & other a "zero".




flip-flop.

## Shift Registors :-

A group of flip flop which is used to store multiple bits of data & the data is moved from one flip-flop to another is known as shift registor.

The flip-flop are connected in such a way that first flip-flop output becomes input of other flip-flop.

• Types :-

- Serial in Serial out.
- Serial in Parallel out.
- Parallel in Serial out.
- Parallel in Parallel out.
- Bi-directional shift registor.
- Universal shift registor.

## Counters :-

A device which stores the no of time a particular event has occured or a process has happened often in relationship to a clock

or.

It is a group of flip-flops with a clock signal applied.

- Asynchronous counters
- Ripple Counters.

# Unit → 1st

## Semiconductor :-

A semiconductor is a material which has electrical conductivity lies b/w^n ~~semi~~conductor & Insulator.

- **Properties :-**

→ Has negative temp. ~~of~~ coeff of resistance

→ At 0 K semiconductor behaves as insulators.

→ Conductivity inc. when doping rate is high.

## Fermi level :-

A highest energy level that an electron can occupy at absolute zero temperature.

Lies b/w^n valence band & conduction band.

## Energy Band Theory :-

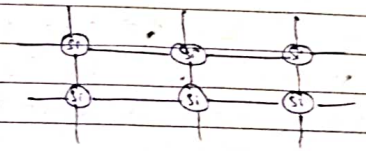
Each and every shell & subshell of atom contains a different energy level.

An atom has diff. energy levels.

## Semiconductors.

- **Intrinsic :-**

→ A pure semiconductor made of Si/Ge.




- **Extrinsic :-**

It is a type of semiconductor made by intrinsic semiconductor with added impurities to inc. its conductivity.

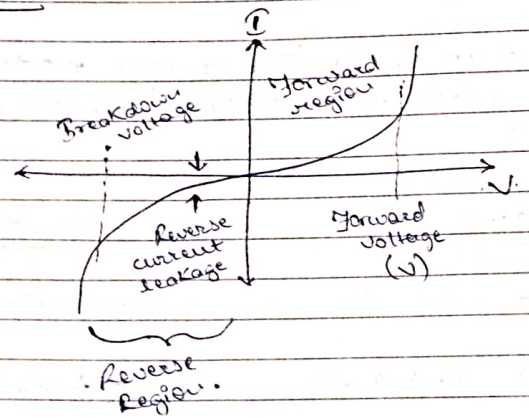
| P-type | N-type |
|---|---|
| • Trivalent impurity | • Pentavalent impurity |
| • Has $3e^-$ in last shell | • has $5e^-$ in last shell. |
| • Indium / Gallium Boron / Aluminium. | • Antimony / Arsenic. Phosphorus / Bismuth. |
| • $e^-$ acceptor. | • $e^-$ donor. |
| • When a trivalent impurity is added to Si/Ge its 3 valency are satisfied & one $e^-$ is deffecient. ↓ (hole) ⊕ | • When a pentavalent impurity is added to Si/Ge ~~to~~ 4 valencies are satisfied & 1 $e^-$ is additionally present. |

## P-N Junction :-

- P-N junc. is simply a interface b/w^n n-type & p-type semiconductor materials when joined.

- P-N junc. is formed by joining n-type & p-type semiconductor materials, which is a 2 terminal device that allows electric current in one direc^n & blocks it in another direc^n.

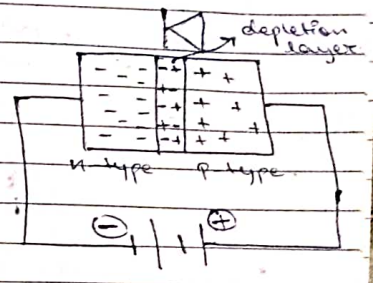
## VI char :-




- with help of curve we know the regions in which diode works.

- Zero bias
- Forward Bias
- Reverse Bias.

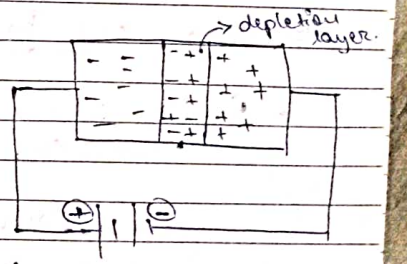
## Forward & Reverse Bias :-




- when p-n junc. is connected with external Battery such that positive terminal of battery is connected to p-type & negative to n-type.

- Depletion layer dec. (neutral layer)

- Forward Bias




- when p-n junc. is connected to external Battery such that positive terminal is connected to n-type & negative to p-type

- Depletion layer inc.

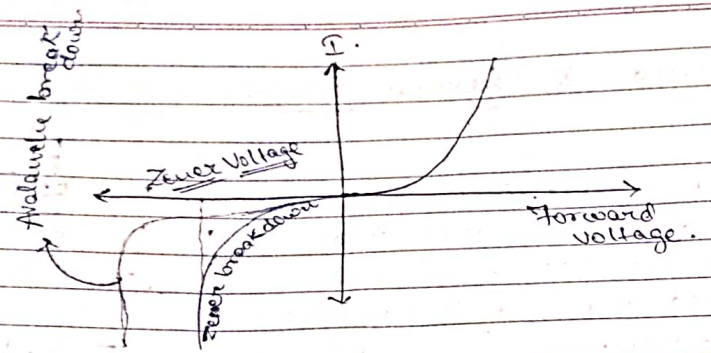
- Reverse Bias

- no current flow (act as open key)

## Zener Breakdown :-

- The reverse currents starts flowing in the junc. because of which depletion layer entirely vanishes. This process is known as Zener breakdown.

- Occurs in very thin depletion region.



- In Zener breakdown the Junc. is not completely damaged.
  The depletion layer regain its position after reverse voltage is removed.

## Avalanche Breakdown :-

- Occurs when a high reverse voltage is applied across the diode. (Higher than Zener brkdown Voltage).
  As we inc. the applied reverse voltage, the electric field across the Junction increases which will exert force on $e^-$ & free them from covalent bonds.
- Occurs in thick depletion layer.
- Junc. break down occurs, it can'nt regain its orig. pos.

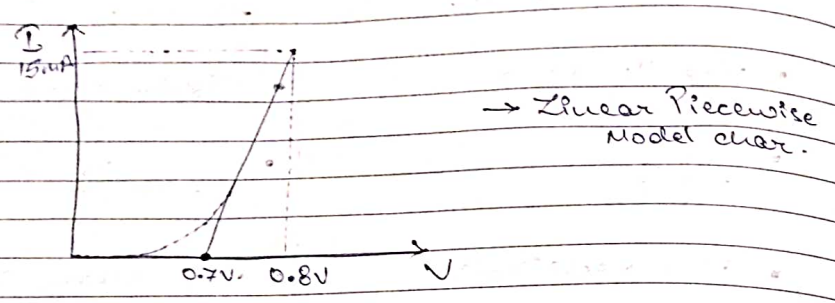
| PN Junc. Diode | Zener Diode |
|---|---|
| • It is a semiconductor device which conducts current flow in one direc. i.e. forward dir. | • The diode which allows the current to flow in both directions i.e. forward & reverse. |
| • Lightly doped | • Highly doped |
| • | • |
| • For rectification | • For voltage stabilizer, motor protection etc. |

## Junction Capacitance :-

When P-N Junc diode is connected in reverse bias no current flowing through it.
In that time both P & N Junc. acts as a electrode & depletion layer acts as a dielectric medium.
So in this situation electrical charge is stored. The situation is termed as Junction Capacitance.

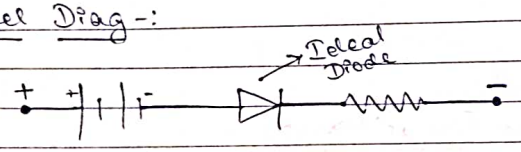
## Linear Piecewise Model :-

The approximation model in which a non-linear device behaves as a linear one for a particular range of voltages is called linear piecewise model.




- Ideal diode eqⁿ :- $I = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$.

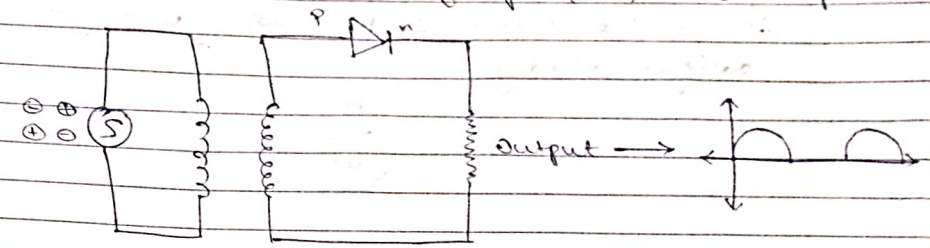
- Model Diag :-




## Junc. Diode as Rectifier :-

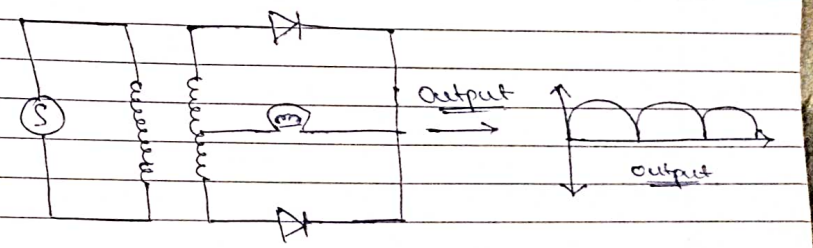
A electronic device which converts AC power to DC power.

## Half Wave Rectifier :- which rectifies only 1 half of input (AC) to DC output.




In first half cycle ⊕charge is connected to p-type & forward bias is generated & crnt will flow then in 2nd half cycle ⊖ve will flow through p-type so reverse bias is generated & no current will flow & cycle continues to give DC current.

## Full Wave Rectifier :- which rectifies both halves of AC Input to DC output.




In first cycle the diode is forward biased as ⊕ve charge go through p-type of 1st diode & second half cycle ⊕ve through p-type of 2nd diode

Page No.
Date

## Ripple factor :-

It is the ratio of RMS value of AC output voltage to the DC output voltage.

$$\gamma = \frac{V_{rms}^{AC}}{V_{rms}^{DC}}$$

## Efficiency :-

$$\frac{\text{Output power (DC)}}{\text{Input power (AC)}}$$

- Half wave ⇒ 40.6%.
- Full wave ⇒ 81.2%.