Chapter 14

SEMICONDUCTOR ELECTRONICS

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CLASSIFICATION OF SOLIDS

On the basis of conductivity

- On the basis of the relative values of electrical conductivity (σ) or resistivity (ρ = 1/σ), the solids are broadly classified as:

- ***Metals:*** They possess very low resistivity (or high conductivity).

$$\rho \sim 10^{-2} - 10^{-8}\ \Omega\ \text{m}$$
$$\sigma \sim 10^{2} - 10^{8}\ \text{S m}^{-1}$$

- ***Semiconductors:*** They have resistivity or conductivity intermediate to metals and insulators.

$$\rho \sim 10^{-5} - 10^{6}\ \Omega\ \text{m}$$
$$\sigma \sim 10^{5} - 10^{-6}\ \text{S m}^{-1}$$

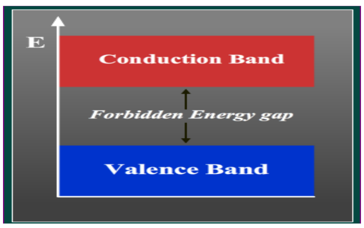
- ***Elemental semiconductors:*** Si and Ge
- ***Compound semiconductors***:
  Inorganic: CdS, GaAs, CdSe, InP, etc.
  Organic: anthracene, doped pthalocyanines, etc.
  Organic polymers: polypyrrole, polyaniline, polythiophene, etc.

- ***Insulators:*** They have high resistivity (or low conductivity).

$$\rho \sim 10^{11} - 10^{19}\ \Omega\ \text{m}$$
$$\sigma \sim 10^{-11} - 10^{-19}\ \text{S m}^{-1}$$

ENERGY BANDS IN SOLIDS

- In a solid each electron will have a different *energy level.*
- The range of energy possessed by the electrons in a solid is called the **energy band.**



Valence band

- Valence band is the range of energy possessed by the valence electrons.
- It is the most occupied band.

Conduction band

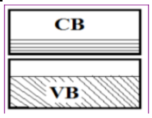
- Conduction band is the range of energy possessed by **the conduction electrons**.
- It is the least occupied band.

Forbidden energy gap

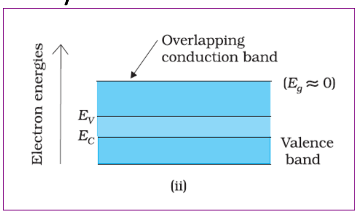
- The energy difference between the bottom of the conduction band and the top of the valence band is called the **forbidden energy gap**.

Energy band in metals

- In certain metals the **conduction band is partially filled** and **the valence band is partially empty**.



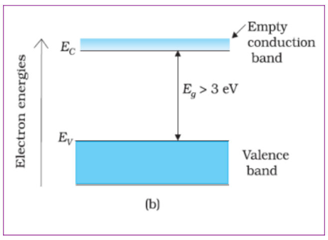
- Then the electrons in the lower levels of valence band move to its higher levels making conduction possible.
- In some other metals **the valence band and the conduction band overlap each other.**
- Then the electrons in the valence band can easily move to the conduction band



- As the temperature increases in a **metal** the electrons in the valence band get enough energy to reach the conduction band.
- As the number of free electrons increases the number of collisions increases.
- So the resistance of a metal increases with temperature.

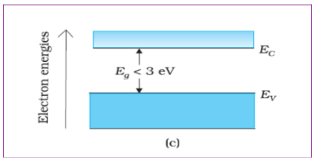
Energy band in Insulator

- The band gap energy is greater than 3 eV
- No free electrons are available in the conduction band.



Energy Band in Semi conductors

- The energy gap is small (<3 eV) compared to insulators.



- At absolute zero of temperature there are no electrons in the conduction band of a **semiconductor**.
- As the temperature increases electrons in the valence band get enough energy to reach the conduction band.
- So the resistance of semiconductors decreases with temperature.

SEMICONDUCTORS

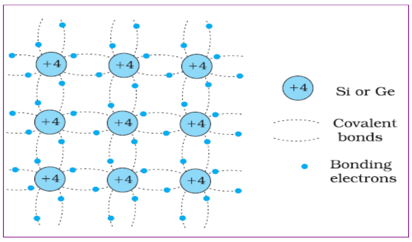
- At low temperatures, semiconductor behaves as an insulator.
- At room temperature some electrons leaves valence band and reaches conduction band and helps in conduction process.

Hole

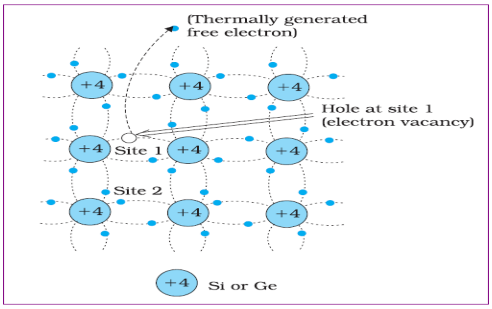
- The ***vacancy of electrons (deficiency of electrons)*** in valence band is called **hole.**
- **A hole is equivalent to a positive charge.**
- In a semiconductor both electrons and holes are charge carriers.

Commonly used semiconductors

- Commonly used semiconductors are Si and Ge.
- Every Si or Ge atom tends *to share one of its four valence* electrons with each of its four nearest neighbor atoms, and also *to take share of one electron from each such neighbor.*



- As the temperature increases, more thermal energy becomes available to these electrons and some of these electrons may break–away and holes are created.



Classification of semiconductors

- In general semiconductors can be classified as **intrinsic semiconductors** and **extrinsic semi conductors**.

INTRINSIC SEMICONDUCTOR

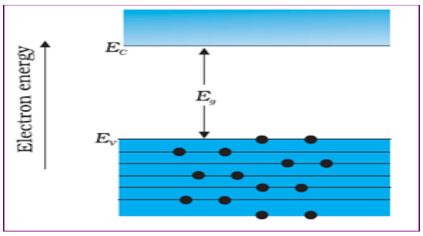
- Semiconductor in its pure form are called **intrinsic semiconductors**.
- In intrinsic semiconductors, the number of free electrons, n_e *is equal to the number of holes,* n_h.

$$n_e = n_h = n_i$$

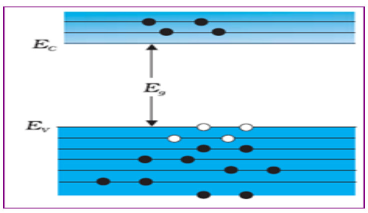
- Under the action of an electric field, these holes move towards negative potential giving the hole current, I_h.
- The total current, I *is* thus the sum of the electron current I_e *and the* hole current I_h:

$$I = I_e + I_h$$

Energy band in an intrinsic semiconductor at *T = 0*



Energy band in an intrinsic semiconductor at *T > 0*



- The methods to increase conductivity of an intrinsic semiconductor are **heating** and **doping.**

Doping

- The process of adding impurities to an intrinsic semiconductor so as to increase its conductivity is called **doping.**

EXTRINSIC SEMICONDUCTOR

- Doped semiconductors are called extrinsic semiconductors.
- The semiconductor crystal maintains an overall charge neutrality as the charge of additional charge carriers is just equal and opposite to that of the ionised cores in the lattice.

Energy band in extrinsic semiconductor

Dopants

- The impurity atoms used for doping are called **dopants.**
- There ***are two types of dopants*** used in doping the tetravalent Si or Ge:

- **Pentavalent (valency 5)**; like Arsenic (As), Antimony (Sb), Phosphorous (P), etc

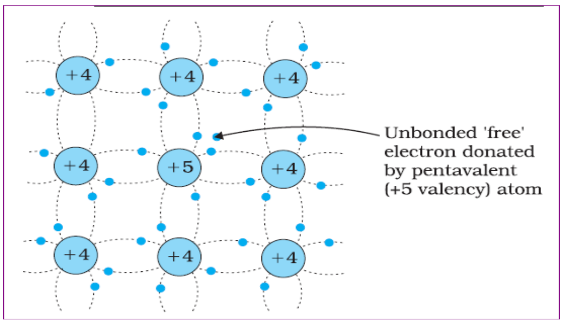
- **Trivalent (valency 3);** like Indium (In), Boron (B), Aluminium (Al), etc.

Types of extrinsic semiconductors

- n- type semiconductors
- p-type semiconductors

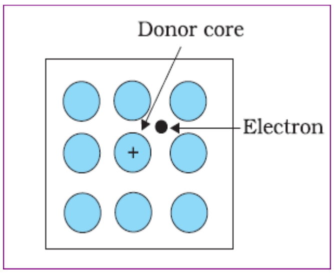
n-type semiconductor

- When a pentavalent impurity is added to an intrinsic semiconductor **Ge** or **Si** crystal, an n-type semiconductor is formed.



- Corresponding to each impurity atom added a free electron is created in the crystal.

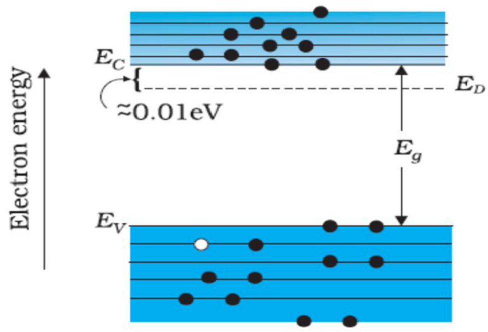
- In an n-type semiconductor **electrons are the majority charge carriers and holes are the minority charge carriers**
- Thus, the ***pentavalent dopant*** is donating one extra electron for conduction and hence is known as ***donor impurity***.



- As, Sb, P, Bi etc. are examples of pentavalent impurities.
- For n-type semiconductors,

$$n_e >> n_h$$

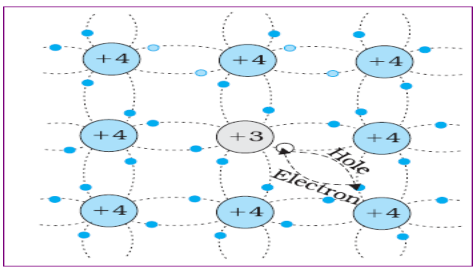
Donor energy level in the energy band diagram



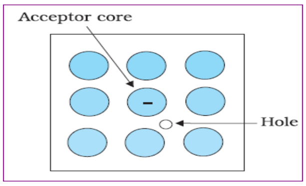
(a) $T > 0K$
one thermally generated electron-hole pair + 9 electrons from donor atoms

p-type semiconductor

- When a trivalent impurity added to an intrinsic semiconductor **Ge** or **Si** crystal, an p-type semiconductor is formed.
- Corresponding to each impurity atom added a free hole is created in the crystal.
- In a p -type semiconductor **holes are the majority charge carriers and electrons are the minority charge carriers.**



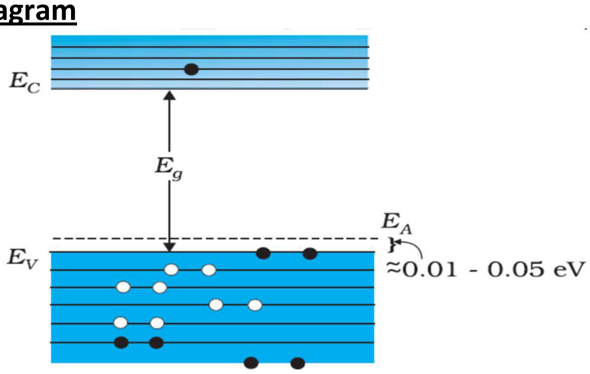
- The trivalent impurity atom which accepts the electron is called an **<u>acceptor</u>** atom.



- The **13th** group elements like **In**, **B**, **Al**, **Ga** etc. are examples of trivalent impurities.
- For a p-type semiconductor

$$n_h >> n_e$$

<u>Acceptor energy level in the energy band diagram</u>



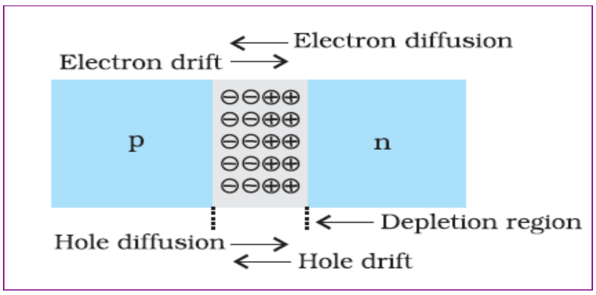
(b) $T > 0K$

<u>p-n JUNCTION</u>

- A junction formed when a p-type semiconductor and n-type conductor are brought together is called a p-n junction.

<u>Formation of a p-n junction</u>

- Two important processes occur during the formation of a p-n junction: ***<u>diffusion and drift</u>***



<u>Diffusion</u>

- The holes diffuse from p-side to n-side (p → n) and electrons diffuse from n-side to p-side (n → p).

- Due to diffusion, a layer of **<u>positive charge (or positive space-charge region) is developed on n-side</u>** of the junction and a layer of **<u>negative charge (or negative space-charge region) is developed on the p-side</u>** of the junction .

<u>Depletion region</u> **<u>(Depletion layer)</u>**

- The space-charge region on either side of the junction together is known as **depletion region**.
- In depletion region there are no free electrons and holes.

<u>Drift</u>

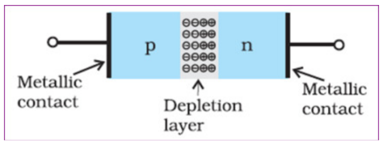
- The positive charge on n-side of the junction and negative charge on p-side of the junction develops an electric field.
- Due to this field, an electron on p-side of the junction moves to n-side and a hole on n- side of the junction moves to p-side.
- The motion of charge carriers due to the electric field is called **drift.**
- As the diffusion process continues, drift current increases.
- This process continues until the diffusion current equals the drift current.
- In a p-n junction under equilibrium there is *no net current.*

<u>Barrier Potential</u>

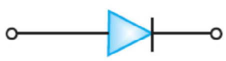
- The potential difference produced due to the diffusion of charge carriers across a p-n junction is called ***barrier potential***.
- The barrier potential limits further diffusion of holes and electrons.

<u>SEMICONDUCTOR DIODE (p-n junction Diode)</u>

- A semiconductor diode is a p-n junction with metallic contacts provided at the ends for the application of an external voltage.
- It is a two terminal device.



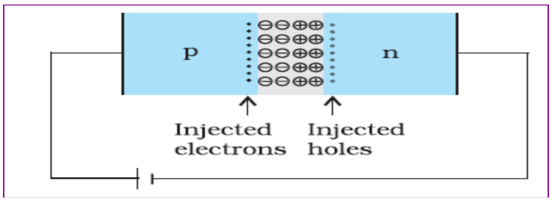
<u>Symbol</u>

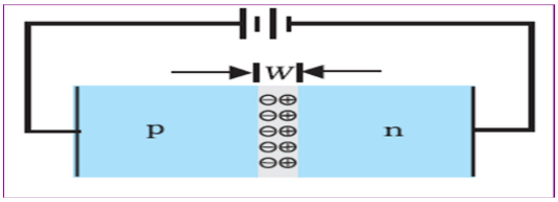


- The barrier voltage of a **Ge** diode is **0.2V** and that of a **Si** diode is **0.7V**.

p-n junction diode under forward bias

- In forward biasing the **p-side is connected** to the **positive terminal** of the battery and **n-side to the negative terminal**.

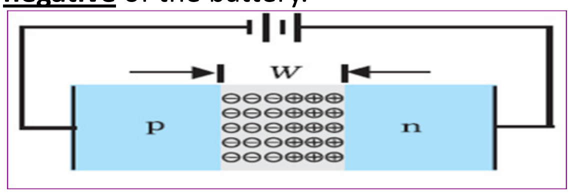




- Due to the applied voltage, electrons from n-side cross the depletion region and reach p-side and holes from p-side cross the junction and reach the n-side.
- This process under forward bias is known as **minority carrier injection.**
- **In forward bias**
    - The height of the barrier potential reduces for majority carriers.
    - The junction offers a very low resistance to the flow of current**.**
    - The current increases sharply with forward voltage
    - The width of depletion layer decreases**.**

p-n junction diode under reverse bias

- In reverse biasing **n-side is connected to positive** of the battery and **p-side to negative** of the battery.



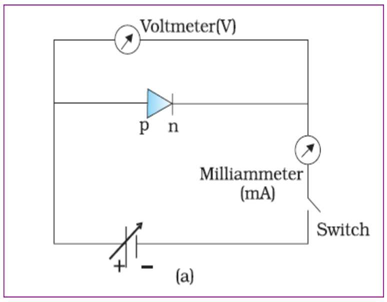
- The barrier height increases and the depletion region widens due to the change in the electric field.
- This suppresses the flow of electrons from n → p and holes from p → n.
- The current under reverse bias is essentially voltage independent up to a critical reverse bias voltage, known as **breakdown voltage (V_{br}).**

In reverse bias

- Height of barrier potential increases
- Junction resistance is very high for current flow
- The reverse current is very low and is due to minority carriers.
- The width of depletion layer increases.

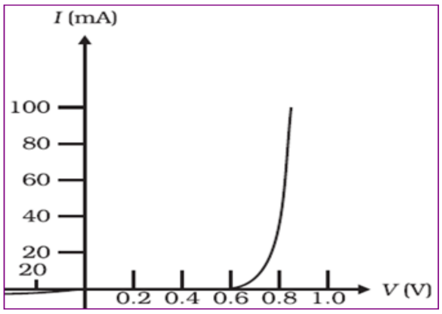
Forward characteristics of a Diode

Circuit diagram for studying fprward characteristics



Forward characteristics

- Forward characteristics are the graph between voltage and current of a forward biased diode.



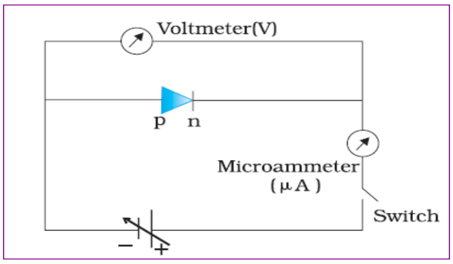
- After the characteristic voltage, the diode current increases significantly (exponentially), even for a very small increase in the diode bias voltage.
- This voltage is called the ***threshold voltage or cut-in voltage*** *(~0.2V for germanium diode and* ~0.7 V for silicon diode).

knee voltage

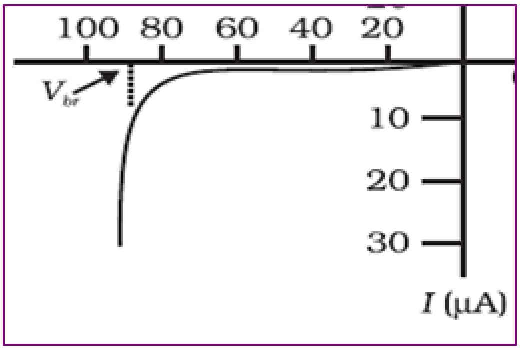
- The forward voltage after which the current through a diode increases linearly with voltage is called knee voltage.

Reverse characteristics of a diode

Circuit diagram



Reverse characteristics



Reverse saturation current(Leakage current)

- In the reverse bias of a diode if a voltage less than the breakdown voltage is applied very small constant current flows through the diode due to the minority charge carriers. This current is called reverse saturation current.

Breakdown voltage

- The reverse voltage at which the current increases sharply is called reverse breakdown voltage.
- the phenomenon in which reverse current increases sharply at break down voltage **is called Zener effect.**
- The breakdown of the diode at the critical reverse voltage due to the increased production of electron-hole pair is called ***avalanche breakdown*** .

Dynamic resistance

- It is the ratio of small change in voltage ΔV to a small change in current ΔI:

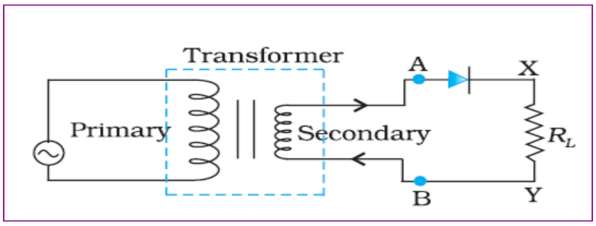
$$r_d = \frac{\Delta V}{\Delta I}$$

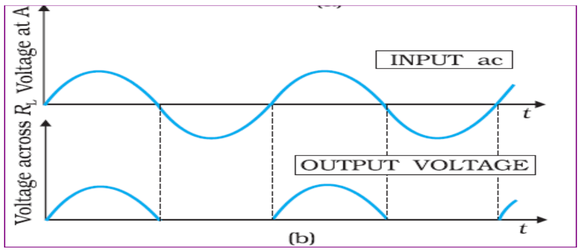
APPLICATION OF JUNCTION DIODE - RECTIFIER

- The process of conversion of ac current to dc current is called **rectification.**
- Device used for rectification is called rectifier.

Half wave Rectifier:

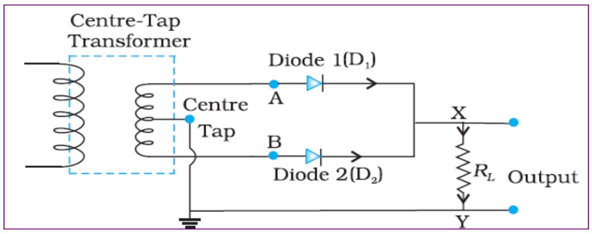
- It uses only one diode.
- The diode becomes forward biased only in the positive half cycle of ac.
- Efficiency is only 40.6%.

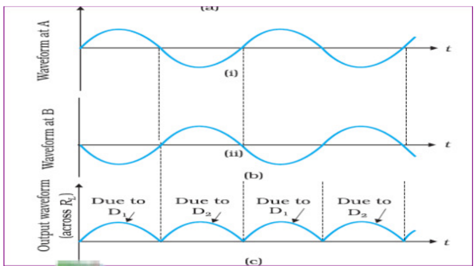




Full wave rectifier

- A simple full wave rectifier consists of two diodes.
- A centre tapped transformer is used in the circuit.
- During the positive half cycle first diode conducts current and second diode during negative half cycle.

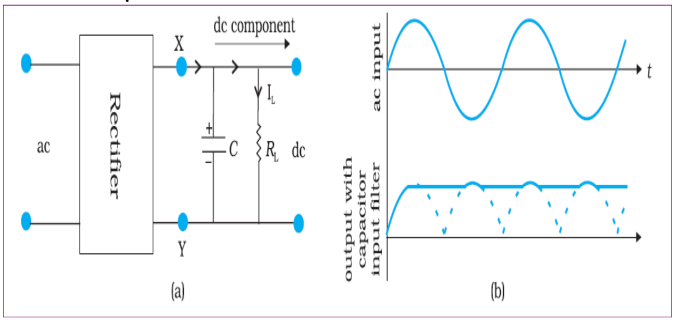




Filters

- The circuits used to filter out the ac ripples from the rectifier output are called **filters.**

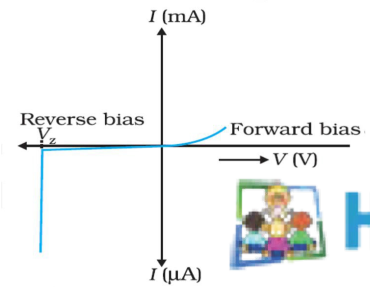
- The capacitor input filters use large capacitors.



SPECIAL PURPOSE p-n JUNCTION DIODES

Zener diode

- It is developed by C. Zener
- Zener diode is used in the reverse bias, in the breakdown region.
- Zener diode has a sharp break down voltage called **Zener voltage**.
- A zener diode is used as a voltage regulator.
- Zener diode is fabricated by heavily doping both p, and n- sides of the junction.
- When the applied reverse bias voltage (*V) reaches the breakdown voltage* (V_z) *of the Zener* diode, there is a large change in the current.
- Zener voltage remains constant, even though current through the Zener diode varies over a wide range. This property of the Zener diode is used for regulating supply voltages so that they are constant.



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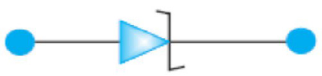
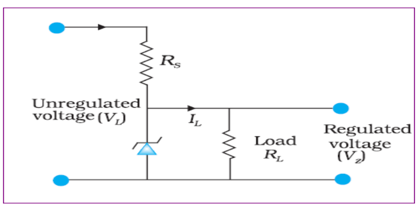


Zener diode as a voltage regulator(Stabiliser):



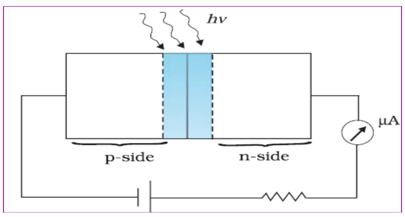
- The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance R_s *such that the Zener diode is reverse biased.*
- Any **increase/ decrease in the input voltage results in, increase/ decrease of the voltage drop across R_s *without any* change in voltage across the Zener diode**.
- Thus the Zener diode acts as a voltage regulator.

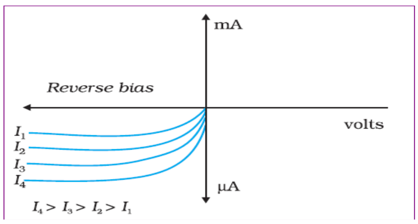
Optoelectronic junction devices:

- Devices in which conductivity changes due to photo-excitation

Photodiode

- A heavily doped p-n junction diode with a transparent window.
- Used as a photo detector.
- Operated under reverse bias
- When light (photons) with energy (*hv)* greater than the energy gap (E_g) *of the* semiconductor falls at the junction electron-hole pairs are generated.
- Due to the reverse bias the electrons move to n- region and holes to p-region giving rise a current in the external circuit.
- The current increases with intensity of light.
- A photodiode can be used as a photo detector to detect optical signals.





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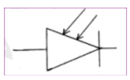


Light emitting diode (LED*)*

- It is a heavily doped p-n junction in forward bias.
- The diode is encapsulated with a transparent cover.

- An LED converts electrical energy to light energy.
- When an electron makes a transition from conduction band to valance band photons with energy equal to or slightly less than the band gap are emitted.
- As the forward current increases, intensity of light increases and reaches a maximum.
- The *V-I characteristics of a LED is similar to that of a Si junction* diode.
- LEDs that can emit red, yellow, orange, green and blue light are commercially available.
- The compound semiconductor **Gallium Arsenide – Phosphide** is used for making LEDs of different colors.
- The LEDs are used in remote controls, burglar alarm systems, optical communication, etc.

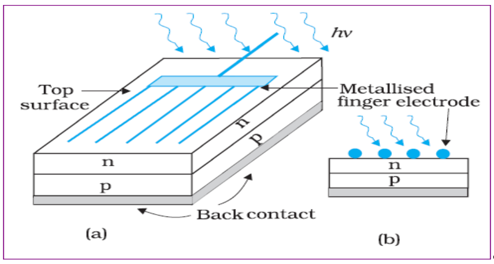
LEDs have the following advantages over conventional incandescent low power lamps:

- Low operational voltage and less power.
- Fast action and no warm-up time required.
- The light emitted is nearly monochromatic.
- Long life.
- Fast on-off switching capability.

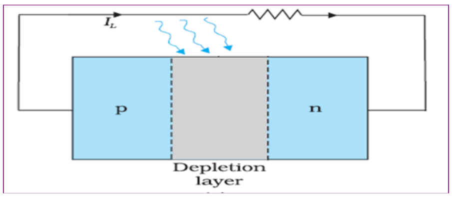
Symbol

Solar cell

- Solar cell is a junction diode used to convert solar energy into electrical energy.
- **The n- region is thin and transparent and the p – region is thick.**
- The p-end is coated with a metal (**back contact**).
- A metal finger electrode (metallic grid) is deposited at the n-end. This acts as a **front contact**.



- The generation of emf by a solar cell, has three basic processes: **generation, separation and collection.**
- **Generation** of e-h pairs due to light (with *hv* > E_g) close to the junction.
- **Separation** of electrons and holes due to electric field of the depletion region.
- Electrons are swept to n-side and holes to p-side;
- The **electrons reaching the n-side are collected** by the front contact and holes reaching p-side are collected by the back contact.
- Thus p-side becomes positive and n-side becomes negative giving rise to *photo voltage.*

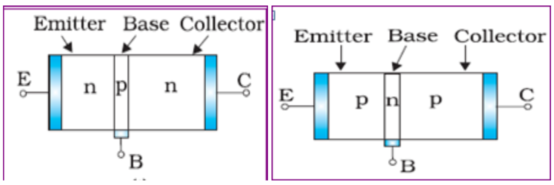


- Solar cells are made with semiconductors like Si , *Ga As ,CdTe Cu In Se2* ,etc.
- The important criteria for the selection of a material for solar cell fabrication are **band gap**, **high optical absorption, electrical conductivity**, **availability of the raw material**, and **cost**.

Symbol

JUNCTION TRANSISTOR

- Invented by J. Bardeen and W.H. Brattain
- A transistor has three doped regions forming two p-n junctions between them- hence called **bipolar junction transistor.**
- Two types are- n p n transistor and p n p transistor.



Emitter:

- Moderate size and heavily doped.
- *It supplies* a large number of majority carriers for the current flow through the transistor.

Base:

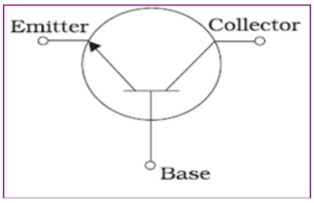
- This is the central segment.
- It is very thin and lightly doped.

Collector:

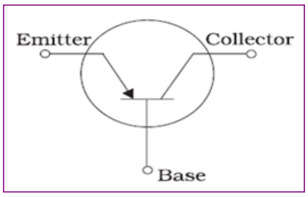
- This segment collects a major portion of the majority carriers supplied by the emitter.
- It is moderately doped and larger in size as compared to the emitter

Symbol

npn-transistor

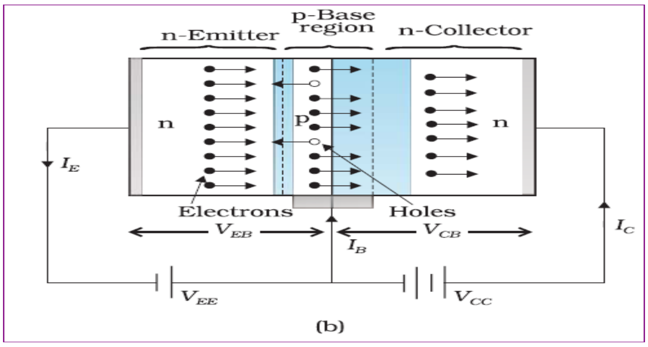


pnp-transistor



Transistor action

n-p-n Transistor

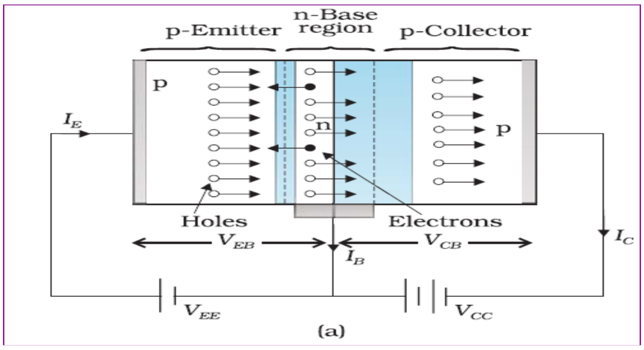


- The electrons from the emitter diffuse into the base (**emitter current**) and holes from the base diffuse into emitter.
- Since base is thin most of the electrons reach the collector and produces **collector current.**
- The recombination of electrons with holes at base constitutes **base current** which is very small.
- The emitter current is the sum of collector current and base current:

$$I_E = I_C + I_B$$

- This is the **transistor equation**.

p-n-p Transistor



Basic transistor circuit configurations

- The transistor can be *connected in* three configurations:

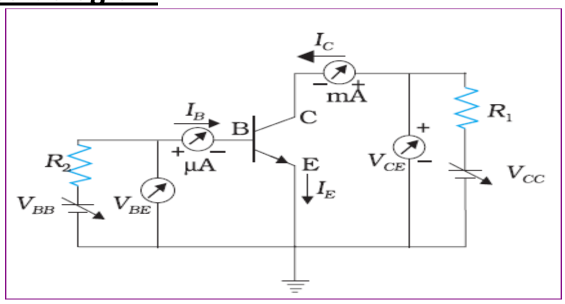
1. ***Common Emitter (CE),***
2. ***Common Base (CB),***
3. ***Common Collector (CC)***

Transistor characteristics

Common emitter transistor characteristics

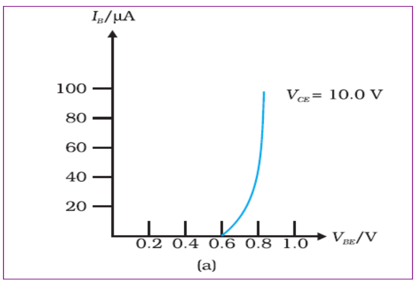
- The emitter is common to both input and output.
- The input is between the base and the emitter and the output is between the collector and the emitter.

Circuit diagram



Input characteristics

- The variation of the base current I_B with the base-emitter voltage V_{BE} at constant collector emitter voltage is called the **input characteristic.**



ac Input resistance (r_i)

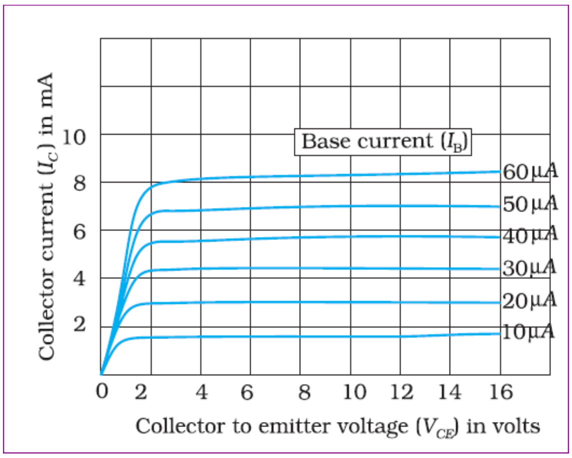
- This is defined as the ratio of change in base emitter voltage (ΔV_{BE}) *to the resulting change in base current* (ΔI_B) *at* constant collector-emitter voltage (V_{CE}).

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

- The reciprocal of the slope of the graph gives the input resistance.
- Its value changes with the operating current in the transistor.
- The value of input resistance can be a few hundreds to a few thousand ohms.

Output characteristics

- *The variation* of the collector current I_C with the collector-emitter voltage V_{CE} at constant base current is called the **output characteristic.**



ac output resistance (r_o)

- This is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) *to the change in collector current* (ΔIC) at a constant base current I_B .

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

- The reciprocal of the slope of the linear part of the output characteristics gives the output resistance.
- The output resistance is of the order of 100 kΩ.

Current amplification factor

- It is the ratio of output current to input current.

Common base

- The base is common to both input and output.
- Current amplification factor $\alpha = I_C/I_E$
- value of α ranges from 0.9-0.99

Common collector

- Collector is common to both input and output
- Current amplification factor $\gamma = I_E/I_B$
- Its value is greater than that of β

Common emitter

- In CE configuration it is the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}).

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

- This is also known as *small signal current gain and its value is very* large.
- The *dc* β *of the* transistor is given by

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

- The value of β ranges from 20-500

Relation between α and β

- We have **$I_C = \alpha I_E$** , thus

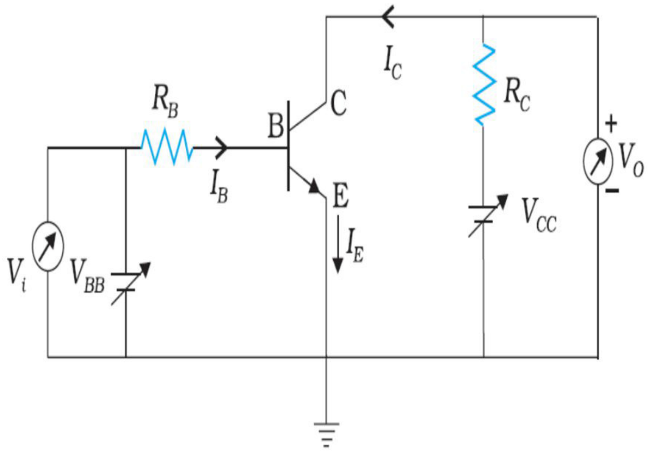
$$\beta = \frac{\alpha I_E}{I_B}$$

- But **$I_E = I_B + I_C$, $I_B = I_E - I_C$**
- Thus $\beta = \dfrac{\alpha I_E}{I_E - I_c}$
- That is, $\beta = \dfrac{\alpha}{1-\alpha}$

Transistor as a device

- The transistor can be used as a device application depending on the configuration used , the biasing of the E-B and B-C junction and the operation region namely cutoff, active region and saturation.

Circuit diagram



- Applying Kirchhoff's voltage rule to the input and output sides of the circuit, we get,

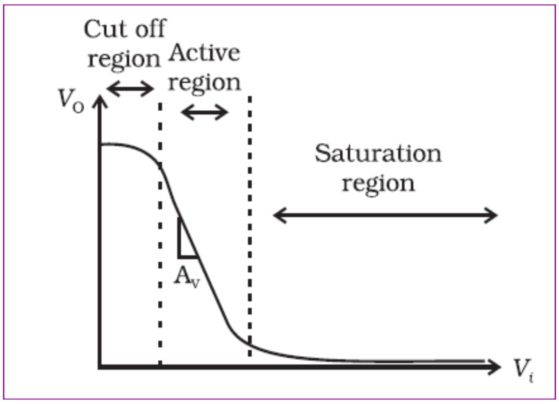
$$V_{BB} = I_B R_B + V_{BE} \qquad V_{CE} = V_{CC} - I_C R_C$$

- V_{BB} is the d.c input voltage V_i and V_{CE} is the d.c output voltage V_0. So, we have

$$V_i = I_B R_B + V_{BE}$$
$$V_0 = V_{CC} - I_C R_C$$

Variation of output voltage with input – transfer characteristics of a transistor

- A graph connecting input voltage and output voltage of a transistor is called transfer characteristics.



- When a transistor is used in the cut off or saturation state, it acts as a switch.
- If it is operated in the active region, it acts as an amplifier.

Cut off region

- In the case of Si transistor, as long as input *V_i is less* than 0.6 V, the transistor will be in cut off state and current *I_C will be zero.*
- Hence *$V_o = V_{cc}$*

Active region

- When *V_i becomes greater than 0.6 V the transistor is in active state with* some current *I_C in the output path and the output V_o decreases.*
- With increase of *V_i, I_C increases almost linearly* and so *V_o decreases linearly till its value becomes less than* about 1.0 V.

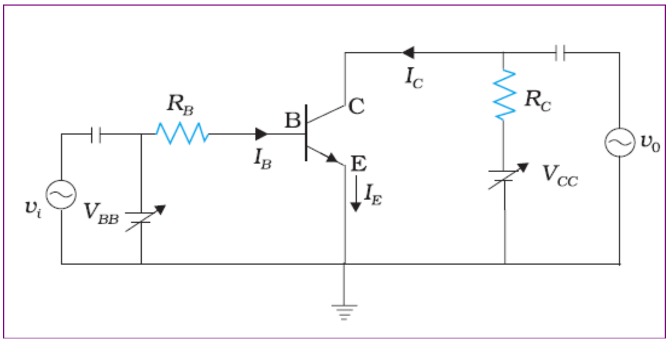
Saturation region

- When V_o becomes 1V the change becomes non linear and transistor goes into saturation state and further increase in V_i , V_o decreases towards zero.

Transistor as a switch

- When the transistor is used in the cutoff or saturation state it acts as a *switch.*
- At cut off state, transistor doesn't conduct-**switched off.**
- At saturation state the transistor conducts - **switched on.**
- *Thus* a ***low input switches the transistor off*** **and a** ***high input switches it on****.*

Transistor as an amplifier



- Amplifier is a device used to increase the amplitude of electrical signals.
- A transistor in active region acts as an amplifier.
- The operating point of a transistor amplifier is in the middle of the active region.
- When the small ac signal is applied in series with V_{BB}, the base current will have sinusoidal variations superimposed on the value of I_B.
- We have $\Delta I_C = \beta\, \Delta I_B$, so the changes in the base current are amplified and we get

amplified sinusoidal variations superimposed on the value of I_c.

- Large capacitor is used at the output to block dc voltages.
- The output is taken between the collector and the ground.

Current gain

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}$$

Voltage gain

- Applying Kirchhoff's voltage rule, to the input loop in **the absence of signal** ,we get

$$V_{BB} = V_{BE} + I_B R_B$$

- When a signal vi is applied, the changes in the voltages $\mathbf{V_{BE}}$ and $\mathbf{I_B R_B}$ are respectively $\mathbf{\Delta I_B r_i}$ and $\mathbf{\Delta I_B R_B}$.
- Thus

$$V_{BB} + v_i = V_{BE} + \Delta I_B r_i + I_B R_B + \Delta I_B R_B$$

- Therefore, the ac input signal voltage can be written as

$$v_i = \Delta I_B (R_B + r_i)$$

- Applying Kirchhoff's voltage rule to the output loop, we get,

$$V_{CE} = V_{CC} - I_C R_C$$

- The change in I_C due to change in I_B causes a change in the output voltage given by,

$$\Delta V_{CE} = \Delta V_{CC} - \Delta I_C R_C$$

- Since V_{CC} is constant, ΔV_{CC} =0, therefore

$$\Delta V_{CE} = -\Delta I_C R_C$$

- Therefore ac output signal voltage is given by

$$v_o = \Delta V_{CE} = -\Delta I_C R_C$$

- Thus the voltage gain is given by

$$A_V = \frac{v_o}{v_i} = \frac{-\Delta I_C R_C}{\Delta I_B (R_B + r_i)}$$

- Or $A_V = \frac{-\Delta I_C}{\Delta I_B}\left(\frac{R_C}{(R_B + r_i)}\right) = -\beta_{ac}\frac{R_C}{(R_B + r_i)}$

$$A_V = -\beta_{ac}\frac{R_C}{(R_B + r_i)}$$

- The negative sign represents that output voltage is opposite with phase with the input voltage.

Power gain

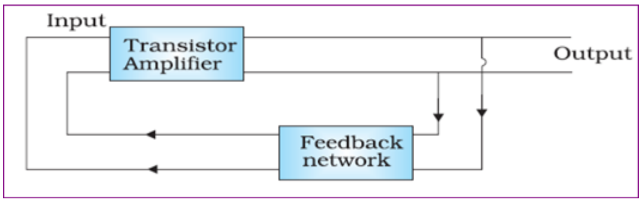
- The power gain A_p *can be expressed* as the product of the current gain and voltage gain.

$$A_p = \beta_{ac} \times A_v$$

$$A_P = -\beta_{ac}^{\ 2}\frac{R_C}{(R_B + r_i)}$$

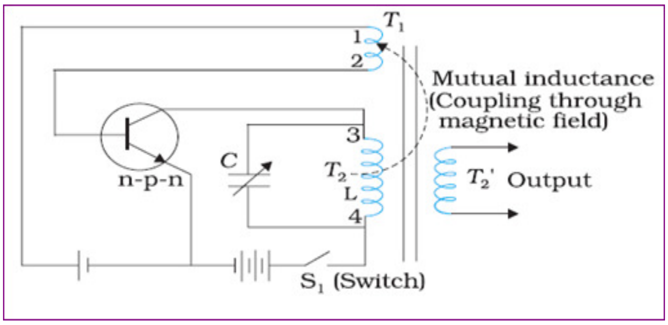
Transistor oscillator

- Oscillator is a device used to convert dc voltage into ac voltage.
- When a portion of the output power of an amplifier is returned back (feedback) to the input *in phase with the starting* power it acts as an oscillator.



- The feedback can be achieved by inductive coupling (through mutual inductance) or *LC or RC networks.*
- Some of the oscillators are , Colpitt's oscillator, Hartley oscillator, *RC-oscillator etc.*

Circuit diagram



- An **oscillator has three parts**
  - Oscillatory circuit or tank circuit or tuned circuit.
  - Feedback circuit
  - Transistor Amplifier

Oscillatory circuit or tank circuit or tuned circuit

- A parallel combination of an inductor L and a capacitor C acts as the tank circuit.
- This LC circuit produces electrical oscillations of frequency,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

- The oscillations produced by an LC circuit are damped oscillations.
- The feedback circuit compensates for the damping.

Feedback circuit

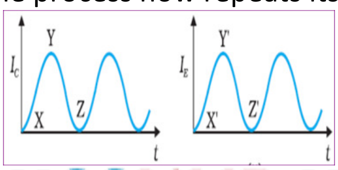
- A portion of the output power is returned back (fed back) in to the input in phase with the input power. This is called **positive feedback**.
- The feedback can be achieved by inductive coupling.

Amplifier

- A transistor in CE configuration is used as amplifier.
- The transistor amplifies the fed back voltage.

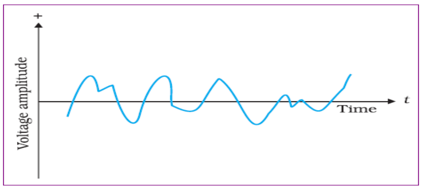
Working

- When V_{CC} is switched on, the collector current starts increasing through the coil L.
- Due to mutual induction emf is induced in the coils T_1 and T_2'.
- The emf across T_2' is the output.
- The emf across T_1 is fed back to the input.
- Due to continuous positive feedback the collector current goes on increasing and reaches the maximum value.
- Since the collector current has a constant value, no mutual induction occurs.
- Without continued feedback the collector current begins to fall.
- The decrease in collector current through the coil L induces emf in T_1.
- But this emf is in the opposite direction and it decreases the emitter current. So the collector current again decreases.
- This causes a further decrease in the emitter current and transistor goes to the cut-off state. Then I_E and I_C both become zero.
- The transistor now reached back to the original state.
- The whole process now repeats itself.

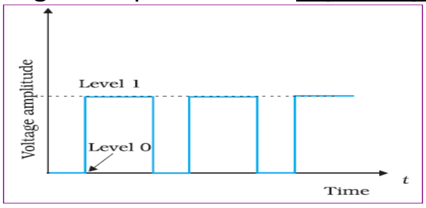


DIGITAL ELECTRONICS

- In digital circuits only two values (represented by 0 or 1) of the input and output voltage are permissible.
- The continuous, time-varying voltage or current signals are called **continuous or *analogue signals.***



- *A waveform in which only* discrete values of voltages are possible is a **digital signal.**



Logic gates

- A logic gate is a digital circuit that follows curtain *logical relationship* between the input and output voltages.
- The five common logic gates used are **NOT, AND, OR, NAND, NOR.**
- NOT, OR, and AND gates are **fundamental or basic gates.**
- NAND and NOR gates are called **universal gates.**

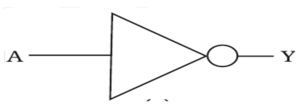
NOT gate

- This is the most basic gate, with one input and one output.
- It produces an inverted version of the input at its output.
- It is also known as an ***inverter.***
- The table which describes the input output relationship is known as **truth table.**

Truth table

Input	Output
A	Y
0	1
1	0

Symbol



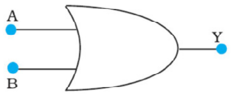
OR Gate

- It can have one output and any number of inputs.

Truth table

Input		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Symbol



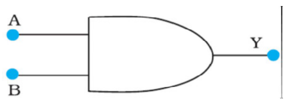
AND Gate

- It can have one output and any number of inputs.

Truth table

Input		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Symbol



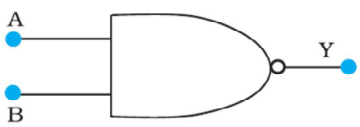
NAND Gate

- It is a combination of AND and NOT Gate

Truth table

Input		Output
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Symbol



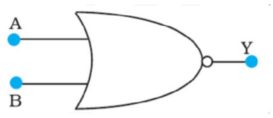
NOR Gate

- It is a combination of OR gate and NOT gate.

Truth table

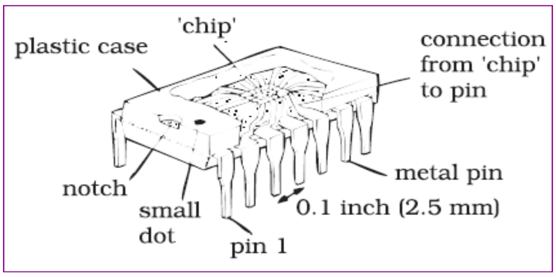
Input		Output
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Symbol



INTEGRATED CIRCUITS (IC)

- An entire circuit fabricated (consisting of many passive components like R and C and active devices like diode and transistor) on a small single block (or chip) of a semiconductor is called **integrated circuit.**
- Depending on nature of input signals, IC's can be grouped in two categories: **linear or analogue IC's** and **digital IC's**
- Depending upon the level of integration (i.e., the number of circuit components or logic gates), the IC's are termed as
- **Small Scale Integration, SSI (logic gates < 10)**
- **Medium Scale Integration, MSI (logic gates < 100)**
- **Large Scale Integration, LSI (logic gates < 1000)**
- **Very Large Scale Integration, VLSI (logic gates > 1000).**
- The most widely used IC technology is the *Monolithic Integrated Circuit.*



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