BEEE (ELT-112)
BE-Ist Year , 2^{nd} Sem

Learning Objectives

The purpose of this course is to make students understand Electronics & Electrical Engg. fundamentals and to transfer specific skills, knowledge, values and attitudes, so that students can explain how electric, magnetic circuits and semiconductors are applied in practice.

Learning Outcomes

1. Students will be able to understand the basic concepts of an electric circuit DC and AC(both single phase and three-phase circuits in sinusoidal steady state).
2. Students will be able to comprehend the basic features and applications of different types of electric motors.
3. Students will be able to get an idea about the semiconductor physics and devices based upon it.

❖ AC & DC CIRCUITS

Conductor: A conductor is a material that allows electric current to pass through it. Types of metals such as silver and copper are usually the best conductors.

Resistor: Resistors do not allow electric current to pass through them as easily as conductors. As electrons move through a resistor, they cause friction. This friction creates heat, and the material gets warmer and sometimes lights up.

Insulators: These are the materials which do not allow any current to pass through them. These protect us from the harm that electric current can cause. Wires are always covered with an insulator. Rubber, plastic, and glass make the best insulators.

Current: It is the flow of electrons in the circuit or movement of charge from one terminal to another. It is given by time rate of change of electric charge as mathematically given by following equation.

$$I = dq/dt \qquad (1 \text{ Amp} = 1 \text{ Coulomb/sec})$$

Voltage: Voltage is the difference in energy level of a unit charge located at each of two points in a circuit, and therefore, represents the energy required to move the unit charge from one point to the other. It is generally denoted as V and measured in Volts.

$$\text{Also, } 1 \text{ Volt} = 1 \text{ Joule/Coulomb} = 1 \text{ N}\cdot\text{m/coulomb}$$

Power: Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, which is one joule per second. Electric power is usually produced by electric generators, but can also be supplied by sources such as electric batteries. It is given by the product of voltage and current as mathematically given by the below equation

$$P = I\,V \qquad (1\ \text{Watt} = 1\ \text{Volt}\cdot\text{Amp} = 1\ \text{Joule/sec})$$

Resistance: It is the opposition to the flow of charge. Resistance is measured in Ohms (Ω). A mathematical expression for resistance is

$$R = \rho \frac{l}{A} \quad ; \text{where}$$

$l : The\,length\,of\ the\,conductor\,(meters)$

$A : The\,cross-sectional\,area\,(meters^2)$

$\rho : The\,resistivity\,(\Omega \cdot m)$

Ohm's Law: The current flowing through the electric circuit is directly proportional to the potential difference across the circuit and inversely proportional to the resistance of the circuit, provided the temperature remains constant. Ohm's law is mathematically represented by the following equation.

$$V=IR$$

Types of current:

- **Direct current (DC):** generated from batteries and some special generators.
- **Alternating current (AC):** household current which varies with time.

Active elements: The elements which can generate energy, also called self-generating type. Example: Voltage and current sources, Batteries.

Passive elements: The elements which cannot generate energy Example: Resistors, Capacitors and Inductors (but can store energy).

Two elements are in **series** if the current that flows through one must also flow through the other. Current remains same in series connection.

Two elements are in **parallel** if they are connected between (share) the same two (distinct) end nodes. Voltage remains same in parallel connection.

Kirchhoff's Current Law (KCL): It states that the algebraic sum of all currents entering a node is zero or sum of currents entering a node is equal to sum of currents leaving a node.

Kirchhoff's Voltage Law (KVL): It states that the algebraic sum of voltages around any loop in a circuit is zero.

Fundamentals of Alternating Quantities:

Instantaneous value: Instantaneous value is the magnitude of the sinusoid at a point in time.

Average value: The average value of a sinusoid signal is the integral of the sine wave over one full cycle. This is always equal to zero.

RMS value: RMS voltage and current are used to calculate the average power associated with the voltage or current signal in one cycle.

$$V_{RMS} = \frac{\sqrt{2}}{2} V_p = 0.707 V_p$$

$$P_{Ave} = \left(V_{RMS}{}^2\right) / R$$

Form factor is defined as being the shape of an AC waveform and is the RMS voltage divided by the average voltage; form factor = RMS value/average value

Time Period: The time taken in seconds by a voltage or a current to complete one cycle is called Time Period. It is denoted by (T).

Wave Form: The shape obtained by plotting the instantaneous values of an alternating quantity such as voltage and current along the y axis and the time (t) or angle (θ=wt) along the x axis is called waveform.

Frequency: The number of cycles made per second by an alternating quantity is called frequency. It is measured in cycle per second (c/s) or hertz (Hz) and is denoted by (f).

Phase Angle: The phase angle is an angular measurement of the position of one sinusoid signal with respect to a reference.

Inductor: An inductor is a passive electronic component that stores energy in the form of a magnetic field. In its simplest form, an inductor consists of a wire loop or coil. The inductance is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of material around which the coil is wound.

Capacitor: A capacitor is a passive electronic component that stores energy in the form of an electrostatic field. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric. The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the dielectric constant of the substance separating the plates.

Impedance: It is a comprehensive expression of any and all forms of opposition to electron flow, including both resistance and reactance. It is present in all circuits, and in all components. When alternating current goes through an impedance, a voltage drop is produced that is somewhere between 0° and 90° out of phase with the current. Impedance is mathematically symbolized by the letter "Z" and is measured in the unit of ohms (Ω), in complex form.

Table 1.1 gives the details of the three basic circuit components of Electrical Engineering.

Element	V/I Relation	DC Steady-State
Resistor	$v_R(t) = R\, i_R(t)$	V = I R
Capacitor	$i_C(t) = C\, \dfrac{d\, v_C(t)}{dt}$	I = 0; open
Inductor	$v_L(t) = L\, \dfrac{d\, i_L(t)}{dt}$	V = 0; short

Table 1.1 Circuit components

Ref: Table 1.1. http://slideplayer.com/slide/9020464/

❖ POWER IN AC CIRCUITS

Active Power: The power which is actually consumed or utilized in an AC Circuit is called True power or Active Power or real power. It is measured in kilo watt (kW) or MW. It is the actual outcomes of the electrical system which runs the electric circuits or load.

Reactive Power: The power which flows back and forth that mean it moves in both the direction in the circuit or react upon itself, is called Reactive Power. The reactive power is measured in kilo volt ampere reactive (kVAR) or MVAR.

Apparent Power: The product of root mean square (RMS) value of voltage and current is known as Apparent Power. This power is measured in kVA or MVA.

True power = voltage x current in phase with the voltage

Reactive power = voltage x current out of phase with the voltage

The phasor diagram for an inductive circuit is shown below in fig 1.1

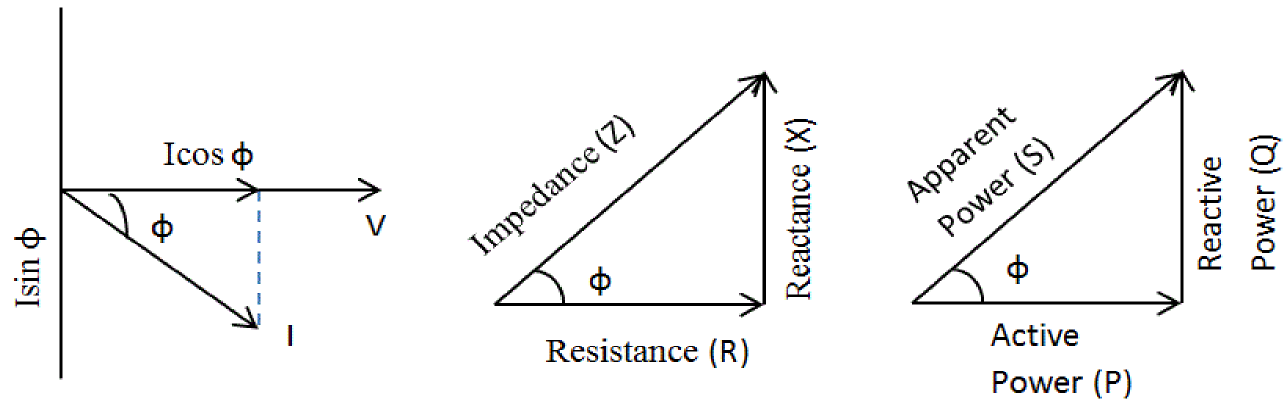


Fig-1.1

Ref: Fig-1.1: http://www.circuitzoom.com/what-is-power-factor/

❖ Three Phase Systems

A **3 phase** generator basically consists of a rotating magnet (called the rotor) surrounded by a stationary winding (called the stator). Three separate windings or coils with terminals a - a', b - b' and c - c' are physically placed 120 degrees apart around the stator.

Two possible configurations in three phase system

1. **Y - connection (star connection)**
2. **Δ - connection (delta connection)**

Table 1.2 brings out the comparison between the star and delta connections**.**

Star (Y) Connection	**Delta (Δ) Connection**
In STAR connection, the starting or finishing ends (Similar ends) of three coils are connected together to form the neutral point. A common wire is taken out from the neutral point which is called Neutral.	In DELTA connection, the opposite ends of three coils are connected together. In other words, the end of each coil is connected with the start of another coil, and three wires are taken out from the coil joints
There is a **Neutral** or **Star Point**	No Neutral Point in Delta Connection
Three phase four wire system is derived from Star Connections **(3-Phase, 4 Wires System)** We may Also derived 3 Phase 3 Wire System	Three phase three wire system is derived from Delta Connections **(3-Phase, 3 Wires System)**

from Star Connection	
Line Current is Equal to Phase Current. i.e. Line Current = Phase Current $\mathbf{I_L = I_{PH}}$	Line Voltage is Equal to Phase Voltage. i.e. Line Voltage = Phase Voltage $\mathbf{V_L = V_{PH}}$
Line Voltage is √3 times of Phase Voltage. i.e. $\mathbf{V_L = \sqrt{3}\, V_{PH}}$	Line Current is √3 times of Phase Current. i.e. $\mathbf{I_L = \sqrt{3}\, I_{PH}}$
The Total Power of three phases could be found by $\mathbf{P = \sqrt{3} \times V_L \times I_L \times Cos\Phi}$ **…. Or** $\mathbf{P = 3 \times V_{PH} \times I_{PH} \times Cos\Phi}$	The Total Power of three phases could be found by $\mathbf{P = \sqrt{3} \times V_L \times I_L \times Cos\Phi}$ **… or** $\mathbf{P = 3 \times V_{PH} \times I_{PH} \times Cos\Phi}$
The speeds of Star connected motors are slow as they receive **1/√3** voltage.	The speeds of Delta connected motors are high because each phase gets the total of line voltage
In Star Connection, the phase voltage is low as 1/√3 of the line voltage, so, it needs low number of turns, hence, saving in copper.	In Delta connection, The phase voltage is equal to the line voltage, hence, it needs more number of turns.
Low insulation required as phase voltage is low	Heavy insulation required as Phase voltage = Line Voltage.
In Power Transmission, Star Connection system is general and typical to be used.	In Power Distribution and industries, Delta Connection is general and typical to be used.

Table 1.2.Comparison of Star and Delta Connection

Ref:Table1.2.https://instrumentationtools.com/difference-between-star-y-and-delta-%CE%B4-connections/#.Wk8uENKWbIU

❖ Magnetic Circuits

Magnetic field: It is surrounding a magnet and its influence is felt by any other magnetic element. It may be an attractive or a repulsive influence. The strength is defined as the force experienced by unit magnetic North pole placed at a point. It is measured in Tesla or Weber/m^2.

Characteristics of Magnetic field lines.

(i) The direction of the magnetic field is indicated by the arrow in the line at any point (Tangent).

(ii) The field lines comes out of the North pole and get into the South pole (closed loops are formed).

(iii) The strength of magnetic field is indicated by the closeness of the field lines. More the lines, more will be the lesser the lines lesser will be the field strength.

(iv) No two field will intersect each other-if they intersect there will be two different directions for field at the same point which is not possible.

Magnetic field around a current carrying straight conductor. Insert a wire carrying current through a hole at the middle of a cardboard. When a current I is passed through the wire, surrounding the wire, magnetic field will be created. When you springle iron fillings, on the board, they will all settle in concentric rings. The direction of North pole is given by the arrow. Reversal current will reverse the magnetic field.

Right hand Thumb rule. Hold the wire carrying current in your right hand, such that the thumb indicates the direction of current, then the folded fingers will indicate the presence of magnetic field (lines) surrounding the wire.

Fleming's Left-Hand Rule. Stretch the first three fingers of the left hand (as suggested in fig1.2) mutually perpendicular to each other such that the fore finger points the direction of magnetic field, the middle finger points the direction of current, then the thumb will indicate the direction of force experienced by the conductor. It is to be applied when the current and field are perpendicular to each other.

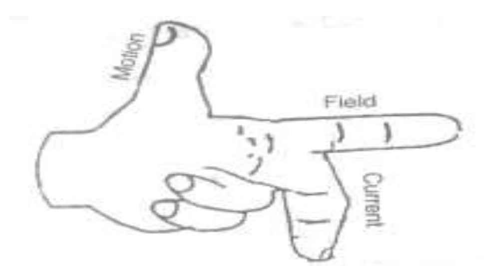


Fig. 1.2 Fleming's left hand rule

Ref: Fig 1.2: https://en.wikibooks.org/wiki/GCSE_Science/The_motor_effect

Magnetic Flux. It is defined as the product of the magnetic field and the area through which magnetic field passes perpendicularly. ϕ = BA when field passes perpendicular to the plane of the coil. It is measured in Weber.

Table 1.3 brings out the comparison between Electrical and Magnetic Circuits

Electrical	Magnetic	Magnetic Units
Voltage v	Magnetomotive force $\mathfrak{F} = Ni$	Amp-turns
Current i	Magnetic flux ϕ	Webers Wb
Resistance R	Reluctance $\mathfrak{R}$	Amp-turns/Wb
Conductivity $1/\rho$	Permeability μ	Wb/A-t-m
Current density J	Magnetic flux density B	Wb/m^2 = teslas T
Electric field E	Magnetic field intensity H	Amp-turn/m

Table 1.3. Comparison of Electrical and Magnetic Circuit.

Ref: Table 1.3. http://conceptsofelectricaltheory.blogspot.in/2015/10/

Fleming's Right hand Rule. Stretch the first three figures of the right mutually perpendicular to each other such that ht fore finger gives the direction of magnetic field and the thumb points the direction of the mention of a conductor then, the middle finger will give the direction of the induced current.

First Law of Faraday's Electromagnetic Induction state that whenever a conductor are placed in a varying magnetic field emf are induced which is called induced emf, if the conductor circuit are closed current are also induced which is called induced current.

Method to change magnetic field:

- By moving a magnet towards or away from coil
- By moving a coil into or out of the magnetic field
- By changing area of a coil placed in a magnetic field
- By rotating the coil relative to the magnet

Second Law of Faraday's Electromagnetic Induction state that the induced emf is equal to the rate of change of flux linkages (flux linkages is the product of turns, n of the coil and the flux associated with it).

Self-inductance: The inductance of the coil is defined as the property of the coil due to which it opposes the change of current flowing through it. Inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it. The unit of inductance is Henry (H).

Mutual Inductance: Mutual inductance is the effect that a changing current in a coil producing an induced voltage in a nearby coil.

Coefficient Of Coupling: The fraction of magnetic flux produced by the current in one coil that links with the other coil is called coefficient of coupling between the two coils. It is denoted by (k).Two coils are taken coil A and coil B, When current flows through one coil it produces flux; the whole flux may not link with the other coil coupled, and this is because of leakage flux by a fraction (k) known as Coefficient Of Coupling. k=1 when the flux produced by one coil completely links with the other coil and is called magnetically tightly coupled.k=0 when the flux produced by one coil does not link at all with the other coil and thus the coils are said to be magnetically isolated.

❖ TRANSFORMERS

Transformers are devices which work on the principal of electro-magnetic induction. It has two coils namely, primary and secondary should be the same. So when potential is increased, current will be decreased and vise versa.

A transformer will not work on DC. Electricity is generated in power houses. Power houses are situated at distant places wherefrom the generated power is to be taken to industries, commercial centres, residential colonies, and villages.

Types of Losses in a Transformer: There are various types of losses in the transformer such as iron losses, copper losses, hysteresis losses, eddy current losses, stray loss, and dielectric losses. The various types of losses are explained below in detail.

Transformer efficiency is defined as (applies to motors, generators and transformers): It is the ratio of output power to the input power of the transformer.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

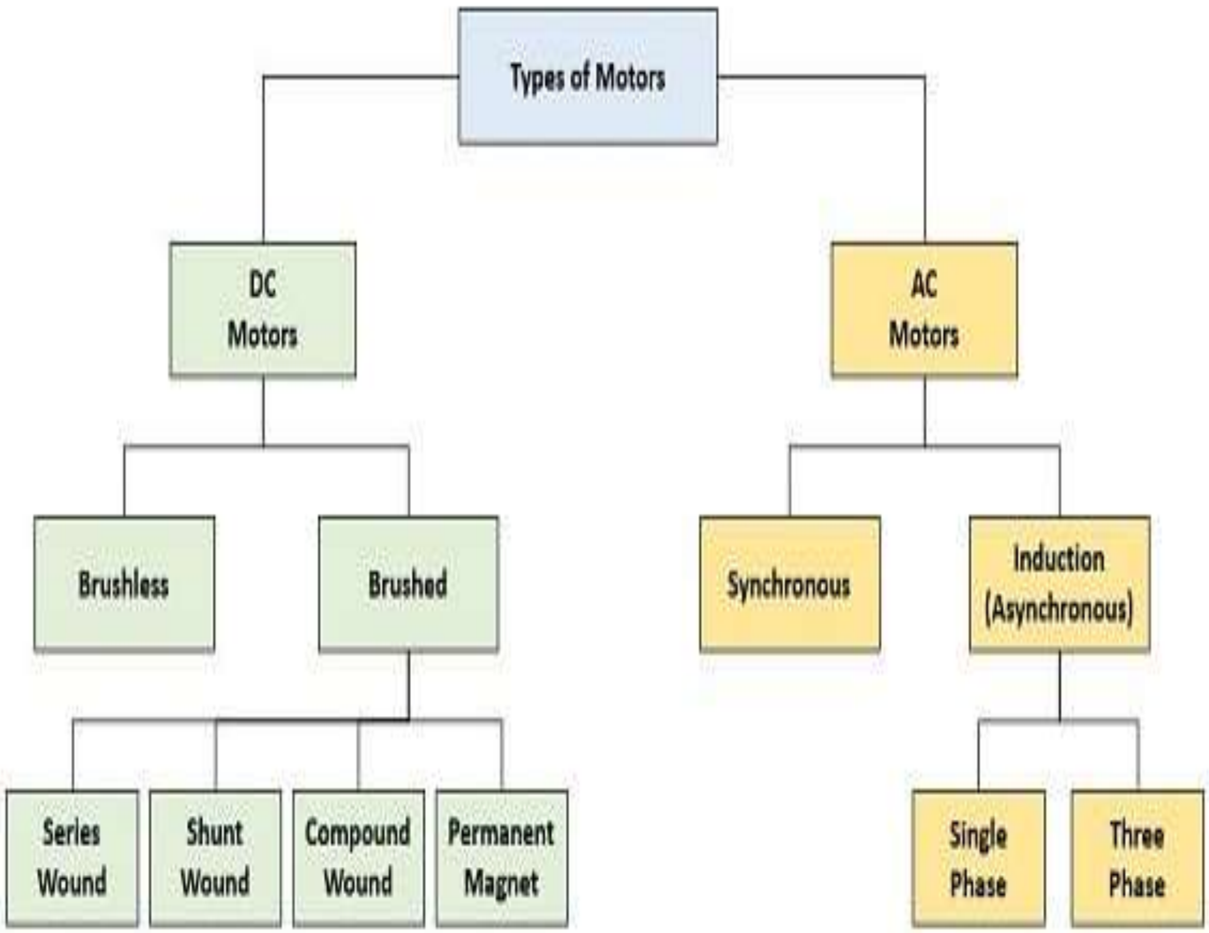
$$\eta = \frac{P_{out}}{P_{out} + P_{loss}} \times 100\%$$

❖ ROTATING ELECTRICAL MACHINES

Different types of motors

When purchasing a motor, it's often asked which technology is better, AC or DC, but the fact is that it is application and cost dependent.

Fig 1.3 brings out the classification of motors.



Ref: Fig 1.3.https://www.rs-online.com/designspark/different-types-of-motors-and-their-use

Table 1.4 below outlines the details for different types of motors

Type	Advantages	Disadvantages	Typical application	Typical drive, output
Self-commutated motors				
Brushed DC	Simple speed control Low initial cost	Maintenance (brushes) Medium lifespan Costly commutator and brushes	Steel mills Paper making machines Treadmill exercisers Automotive accessories	Rectifier, linear transistor(s) or DC chopper controller.
Brushless DC motor	Long lifespan Low maintenance High efficiency	Higher initial cost Requires EC controller with closed-loop control	Rigid ("hard") disk drives CD/DVD players Electric vehicles RC Vehicles UAVs	Synchronous; single-phase or three-phase with PM rotor and trapezoidal stator winding
Universal motor	High starting torque, compact, high speed.	Maintenance (brushes) Shorter lifespan Usually acoustically noisy Only small ratings are economical	Handheld power tools, blenders, vacuum cleaners, insulation blowers	Variable single phase AC, half-wave or full-wave phase-angle control with triac(s); closed-loop control optional.

AC synchronous motors				
Wound rotor synchronous motor (WRSM)	Synchronous speed Inherently more efficient induction motor, low power factor	More costly	Industrial motors	Fixed or variable speed, three-phase; VFD typically six-step CS load-commutated inverter type or VS PWM inverter type.
Hysterisis motor	Accurate speed control Low noise No vibration	Very low efficiency	Clocks, timers, sound producing or recording equipment, hard	Single-phase AC, two-phase capacitor-start, capacitor run motor

	High starting torque		drive, capstan drive	
Synchronous reluctance motor	Equivalent to SCIM except more robust, more efficient, runs cooler, smaller footprint Competes with PM synchronous motor without demagnetization issues	Requires a controller Not widely available High cost	Appliances Electric vehicles Textile mills Aircraft applications	VFD can be standard DTC type or VS inverter PWM type

Specialty motors				
Axial rotor motor	Compact design Simple speed control	Medium cost Medium lifespan	Office Equip Fans/Pumps, fast industrial and military servos	Drives can typically be brushed or brushless DC type
Stepper motor	Precision positioning High holding torque	Some can be costly Require a controller	Positioning in printers and floppy disc drives; industrial machine tools	Not a VFD. Stepper position is determined by pulse counting.

AC asynchronous motors				
AC polyphase squirrel-cage or wound-rotor induction motor (SCIM) or (WRIM)	Self-starting Low cost Robust Reliable Ratings to 1+ MW Standardized types.	High starting current Lower efficiency due to need for magnetization.	Fixed-speed, traditionally, SCIM the world's workhorse especially in low performance applications of all types Variable-speed, traditionally, low-performance variable-torque pumps, fans, blowers and compressors. Variable-speed, increasingly, other high-performance constant-torque and constant-power or dynamic loads.	Fixed-speed, low performance applications of all types. Variable-speed, traditionally, WRIM drives or fixed-speed V/Hz-controlled VSDs. Variable-speed, increasingly, vector-controlled VSDs displacing DC, WRIM and single-phase AC induction motor drives.
AC SCIM split-phase	High power high starting	Speed slightly below	Appliances Stationary Power Tools	Fixed or variable single-phase AC, variable speed being

capacitor-start	torque	synchronous Starting switch or relay required		derived, typically, by full-wave phase-angle control with triac(s); closed-loop control optional.
AC SCIM split-phase capacitor-run	Moderate power High starting torque No starting switch Comparatively long life	Speed slightly below synchronous Slightly more costly	Industrial blowers Industrial machinery	
AC SCIM split-phase, auxiliary start winding	Moderate power Low starting torque	Speed slightly below synchronous Starting switch or relay required	Appliances Stationary power tools	
AC induction shaded pole motor	Low cost Long life	Speed slightly below synchronous Low starting torque Small ratings low efficiency	Fans, appliances, record players	

Ref:Table1.4.http://www.electrical-knowhow.com/2012/05/classification-of-electric-motors-part_17.html

❖ SEMICONDUCTOR DEVICES

Semiconductor Basics: A semiconductor is neither a true conductor nor an insulator, but half way between. A number of materials exhibit this property, and they include germanium, silicon, gallium arsenide, and a variety of other substances.

Types of Semiconductor

(i) **Intrinsic Semiconductor**: A semiconductor in its pure state is called intrinsic semiconductor.

(ii) **Extrinsic Semiconductor:** A semiconductor doped with suitable impurity to increase its impurity, is called extrinsic semiconductor.

On the basis of doped impurity extrinsic semiconductors are of two types

(i) **N-type Semiconductor-** Extrinsic semiconductor doped with pentavalent impurity like As, Sb, Bi, etc in which negatively charged electrons works as charge carrier, is called n-type semiconductor. Every pentavalent impurity atom donate one electron in the crystal, therefore it is called a doner atom.

(ii) **P-type Semiconductor** - Extrinsic semiconductor doped with trivalent impurity like Al, B, etc, in which positively charged holes works as charge carriers, is called p-type semiconductor. Every trivalent impurity atom have a tendency to accept one electron, therefore it is called an acceptor atom.

P-N Junction: An arrangement consisting a p -type semiconductor brought into a close contact with n-type semiconductor, is called a p -n junction.
The current in a p-n junction is given by

$$k_B = I_o\,(e^{eV/k\,BT} - 1\,)$$

where Io is reverse saturation current, V is potential difference across the diode, and kB is the Boltzmann constant.

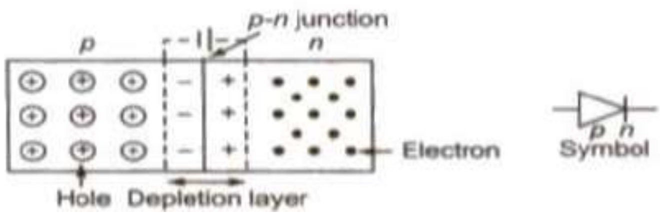


Fig: P-N Junction

Ref: Fig:https://circuitdigest.com/article/what-is-diode-types-working-pn-junction-theory

Terms Related to p-n Junction

(i) **Depletion Layer:** At p-n. junction a region is created, where there is no charge carriers. This region is called depletion layer. The width of this region is of the order of 106 m.

(ii) Potential Barrier: The potential difference across the depletion layer is called potential barrier. Barrier potential for Ge is 0.3 V and for Si is 0.7 V.

(iii)Forward Biasing: In this biasing, the p -side is connected to positive terminal and n-side to negative terminal of a battery. In this biasing, forward current flows due to majority charge carriers. The width of depletion layer decreases.

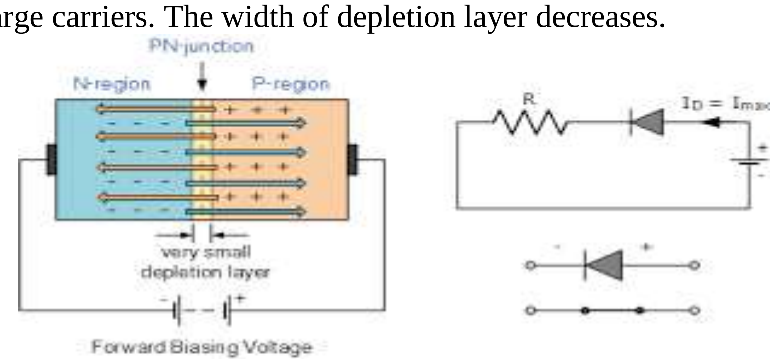


Fig: Forward Biasing

Ref: Fig: http://www.electronics-tutorials.ws/diode/diode_3.html

(iv) Reverse Biasing: In this biasing, the p-side is connected to negative terminal and n-side to positive terminal of a battery. In this biasing, reverse current flows due to minority charge carriers. The width of depletion layer increases. A p-n junction diode can be utilized as a rectifier. Zener diode, photo-diode, light-emitting diode, etc are specially designed p-n. junction diodes.

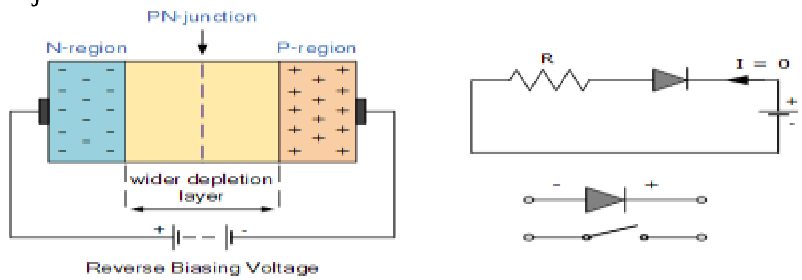
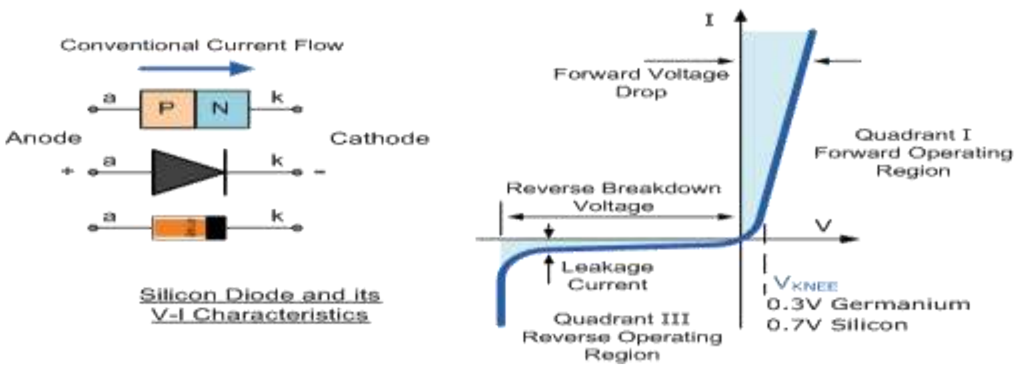


Fig: Reverse Biasing

Ref:Fig: http://www.electronics-tutorials.ws/diode/diode_3.html

P-N Junction Diode: P-N junction can be defined as the junction formed at combining point of P-Type & N-type material. The interface between the two regions is called as metallurgical junction. At this junction we can also observe that depletion region will be formed.



Ref:Fig: http://www.electronics-tutorials.ws/diode/diode_4.html

When a diode is Zero Biased no external energy source is applied and a natural Potential Barrier is developed across a depletion layer which is approximately 0.5 V to 0.7 V for silicon diodes and approximately 0.3 V of a volt for germanium diodes.

the diode is two terminal non-linear device whose I-V characteristic are polarity dependent as depending upon the polarity of the applied voltage, VD the diode is either Forward Biased, VD > 0 or Reverse Biased, VD < 0.

Zener Diode: The Zener diode behaves just like a normal general-purpose diode consisting of a silicon PN junction and when biased in the forward direction, that is Anode positive with respect to its Cathode, it behaves just like a normal signal diode passing the rated current.

The maximum voltage that a junction diode can bear without break down is called Zener voltage and the junction diodes possessing this voltage is known as Zener diode.

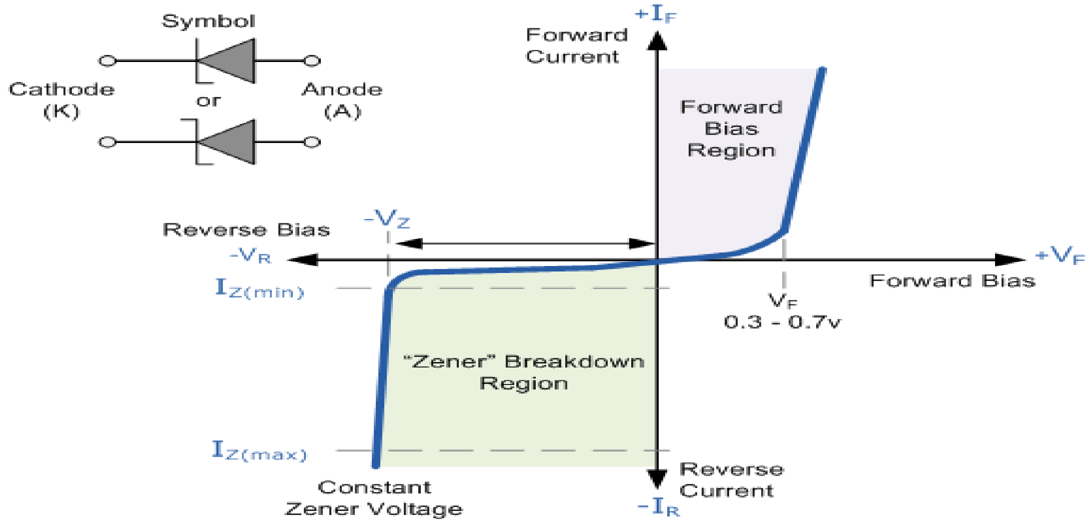


Fig: Zener Diode Characteristics

Ref: Fig: https://www.circuitartmattend.com/zener-diodes-function.html

❖ DIGITAL ELECTRONICS

Analog Signals

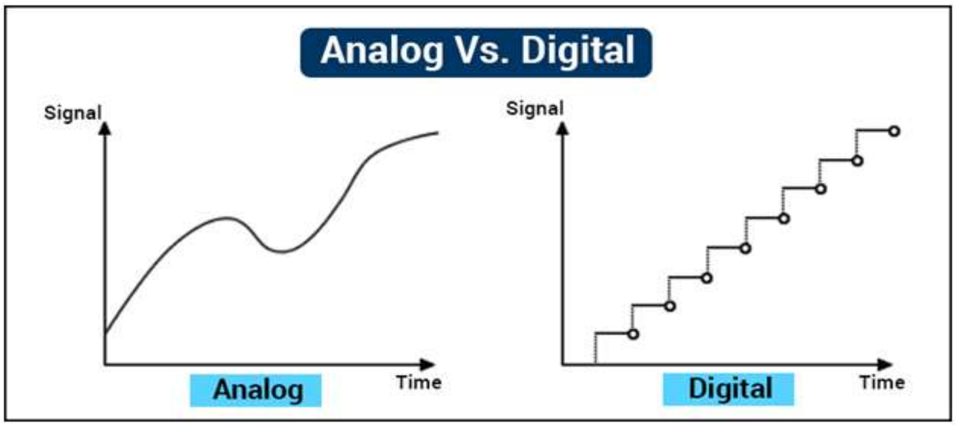
The analog signals were used in many systems to produce signals to carry information. These signals are continuous in both values and time.

Digital Signals

Unlike analog signals, digital signals are not continuous but signals are discrete in value and time. These signals are represented by binary numbers and consist with different voltage values.

Difference Between Analog And Digital Signal

Analog and Digital signals are the types of signals carrying information. The major difference between both signals is that the analog signals that has a continuous electrical, while digital signals non-continuous electrical.



Ref: Fig: https://byjus.com/physics/difference-between-analog-and-digital/

Difference Between Analog Signal And Digital Signal	
Analog Signals	**Digital Signals**
Continuous signals	Discrete signals
Represented by sine waves	Represented by square waves
Human voice, natural sound, analog electronic devices are few examples	Computers, optical drives, and other electronic devices
Continuous range of values	Discontinuous values
Records sound waves as they are	Converts into a binary waveform.
Only be used in analog devices.	Suited for digital electronics like computers, mobiles and more.

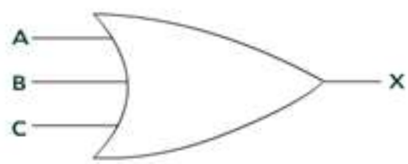
Ref:Table: http://semesters.in/signals-and-systems-introduction-notes-for-electronics-engineering-ppt-pdf/

Logic Gate: A digital circuit which allows a signal to pass through it, only when few logical relations are satisfied, is called a logic gate.

Truth Table : A table which shows all possible input and output combinations is called a truth table.

Basic Logic Gates

(i) **OR Gate:** It is a two input and one output logic gate.

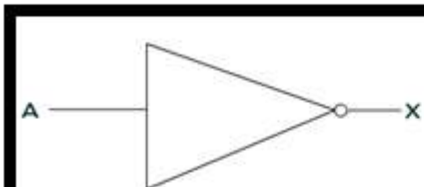


Inputs			Output
C	B	A	X
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

(ii) **AND Gate:** It is a two input and one output logic gate

Inputs			Output
C	B	A	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

(iii)**NOT Gate** It is a one input and one output logic gate.

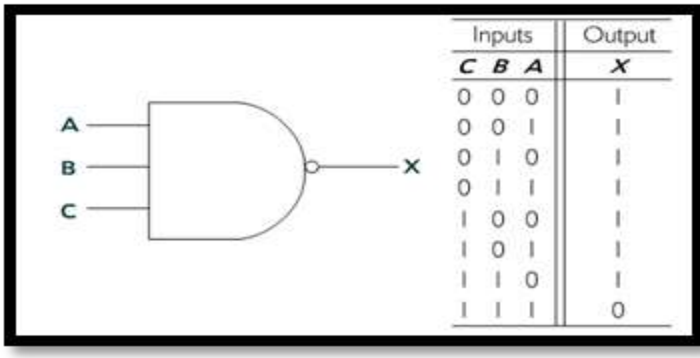


Inputs	Output
A	X
1	0
0	1

Ref: Fig: https://www.allaboutcircuits.com/worksheets/basic-logic-gates/

Combination of Gates

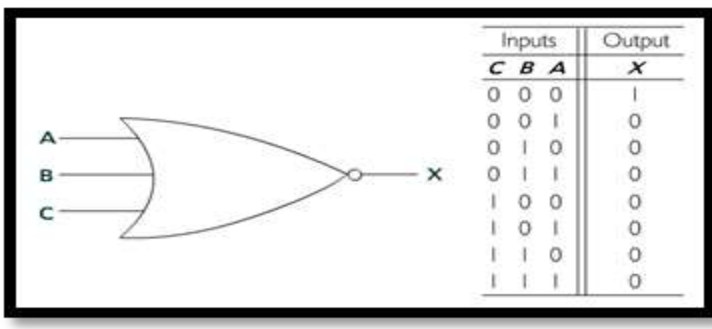
(iv) NAND Gate: When output of AND gate is applied as input to a NOT gate, then it is called a NAND gate.



C	B	A	X
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Boolean expression Y = A * B (Y equals negated of A AND B)

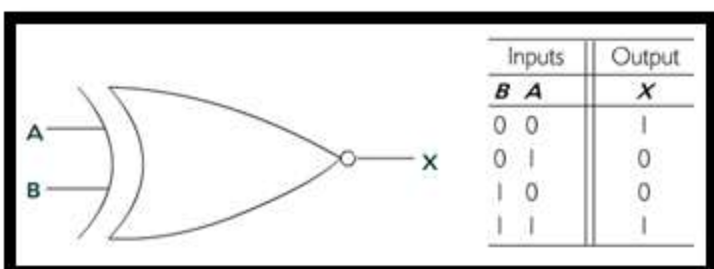
(v) NOR Gate: When output of OR gate is applied as input to a NOT gate, then it is called a NOR gate.



C	B	A	X
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Boolean expression Y = A + B (Y equals negated of A OR B)

(vi) Exclusive-NOR gate : The Exclusive-NOR gate always has two inputs only and produces one output as follows: output = 1 when inputs are both high or are both low, output = 0 when inputs are not similar .



B	A	X
0	0	1
0	1	0
1	0	0
1	1	1

Ref: Fig: https://www.allaboutcircuits.com/worksheets/basic-logic-gates/

Boolean Algebra

Boolean algebra has similar rules to other algebras and these rules are used to manipulate the expression at hand. Some of these basic rules are :

One variable:

A . A = A
A + A = A

One variable and 0 or 1:

A . 0 = 0
A . 1 = A
A + 0 = A
A + 1 = 1

DeMorgan's Theorem:

(A + B)' = A' . B'
(A . B)' = A' + B'

Associative:

(A . B) . C = A . (B . C)
(A +B) + C = A + (B + C)

Commutative:

A . B = B . A
A + B = B + A

Distributive:

A .(B + C) = A . B + A . C
A + (B . C) = (A + B) . (A + C)

Note: OR operator is represented by the '+' symbol and has the lowest precedence. NOT operator is represented by the " ' " symbol and has the highest precedence. AND operator is represented by '.' Symbol.

References

(i) Electric Circuits, Charles K. Alexander & Matthew N. O. Sadiku, 4th edition, McGraw-Hill. Publication
(ii) Electrical Engineering Fundamentals, Vincent Del Toro, 2nd edition, Prentice Hall of India
(iii) Basic Electrical Engineering, Nagrath, 2001, McGraw-Hill Education (India) Pvt Limited
(iv) users.wfu.edu/ecarlson/phy114/lectures/accircuits.pptnptel.ac.in/downloads/108105053/
(v) martin.feld.cvut.cz/~hajekj1/soubory_AE1B13VVZ/05_Magnetic_circuit.ppt
(vi) http://www.engineerlive.com/content/21559