FUNDAMENTALS OF ELECTRICAL & ELECTRONICS ENGG LAB

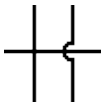
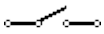
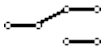
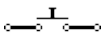
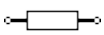
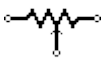
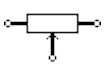
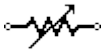
UNIT-1

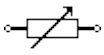
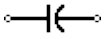
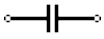
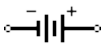
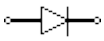
Electrical Safety

Electrical Symbols

Electrical symbols and electronic circuit symbols are used for drawing schematic diagram. The symbols represent electrical and electronic components.

Table of Electrical Symbols

Symbol	Component name	Meaning
	Electrical Wire	Conductor of electrical current
	Connected Wires	Connected crossing
	Not Connected Wires	Wires are not connected
	SPST Toggle Switch	Disconnects current when open
	SPDT Toggle Switch	Selects between two connections
	Pushbutton Switch (N.O)	Momentary switch - normally open
	Pushbutton Switch (N.C)	Momentary switch - normally closed
	Resistor	Resistor reduces the current flow.
	Resistor	
	Potentiometer	Adjustable resistor - has 3 terminals.
	Potentiometer	
	Variable Resistor / Rheostat	Adjustable resistor - has 2 terminals.

	Variable Resistor / Rheostat	
	Capacitor	Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC.
	Capacitor	
	Inductor	Coil / solenoid that generates magnetic field
	Voltage Source	Generates constant voltage
	Current Source	Generates constant current.
	AC Voltage Source	AC voltage source
	Battery	Generates constant voltage
	Voltmeter	Measures voltage. Has very high resistance. Connected in parallel.
	Ammeter	Measures electric current. Has near zero resistance. Connected serially.
	Lamp / light bulb	Generates light when current flows through
	Diode	Diode allows current flow in one direction only - left (anode) to right (cathode).
	Motor	Electric motor
	Fuse	The fuse disconnects when current above threshold. Used to protect circuit from high currents.
	Fuse	

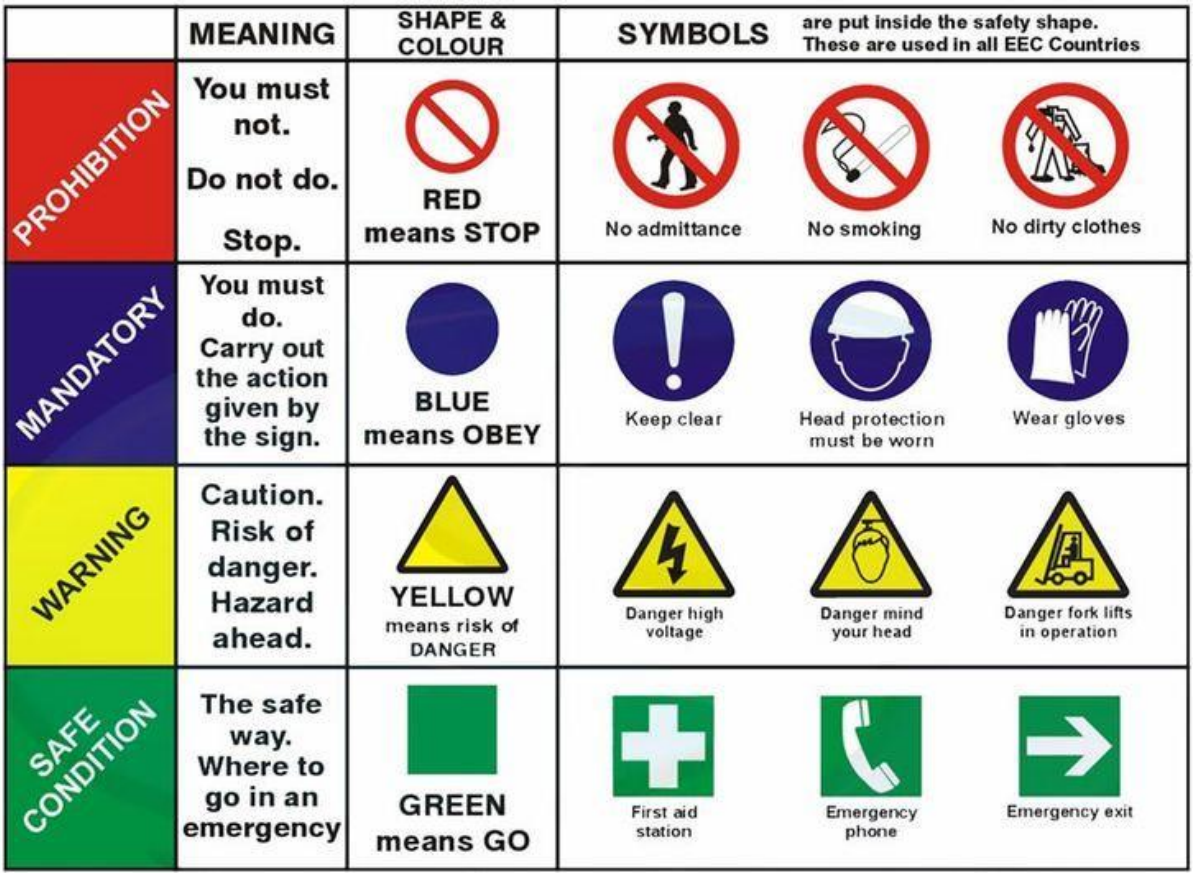
Electrical safety signs

A warning Icon in a picture symbol intended to alert you, and/or to instruct you how to avoid a potentially hazardous condition.

Most safety signs and symbols fall into one of four categories:

- Prohibition
- Warning
- Mandatory
- Emergency

Each category has its own specific colour and sign shape that remains consistent around the world as per safety regulations. By getting to know the key characteristics of each type of symbol, you'll be able to easily identify whether a sign is asking you to stop doing something, start doing something, take precautions, or advising you of emergency equipment or facilities.



Demonstrate and practice use of PPE

Personal protective equipment (**PPE**) is protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection.

Basic PPE consists of:

- Cotton protective clothing with long sleeves
- Helmet or hard hat
- Goggles for eye protection
- Gloves (leather or rubber)
- Hearing protectors
- Safety footwear

Demonstrate how to free a person from electrocution

The danger from an electrical shock depends on the type of current, how high the voltage is, how the current travelled through the body, the person's overall health and how quickly the person is treated.

An electrical shock may cause burns, or it may leave no visible mark on the skin. In either case, an electrical current passing through the body can cause internal damage, cardiac arrest or other injury. Under certain circumstances, even a small amount of electricity can be fatal.

Steps to a free a person from electrocution:

- You should first attempt to turn off the source of the electricity (disconnect).
- If you cannot locate the electrical isolating source, you can use a non-conducting object, such as a wooden pole, to remove the person from the electrical source.
- Try to prevent the injured person from becoming chilled.
- Apply a bandage. Cover any burned areas with a sterile gauze bandage, if available, or a clean cloth. Don't use a blanket or towel, because loose fibers can stick to the burns.
- Begin CPR (Cardio Pulmonary Resuscitation)if the person shows no signs of circulation, such as breathing, coughing or movement.
- Call 911 or your local emergency number.

First aid

First aid is the first and immediate assistance given to any person suffering from either a minor or serious illness or injury. The 3P’s of first aid are:

- PRESERVE Life
- PREVENT Injury

- PROMOTE Recovery

First Aid: Bandaging steps

- Dress the wound. Put on gloves or use other protection to avoid contact with the victim's blood.
- Cover the bandage. Wrap roller gauze or cloth strips over the dressing and around the wound several times.
- Secure the **bandage**. Tie or tape the **bandage** in place.
- Check circulation.

First Aid: Heart Attack steps

Heart attacks can be very dangerous and scary for the person suffering it. A heart attack occurs when the flow of blood to the heart is blocked.

As soon as you find someone is having a probable heart attack make sure you follow the below steps to ensure his/her safety:

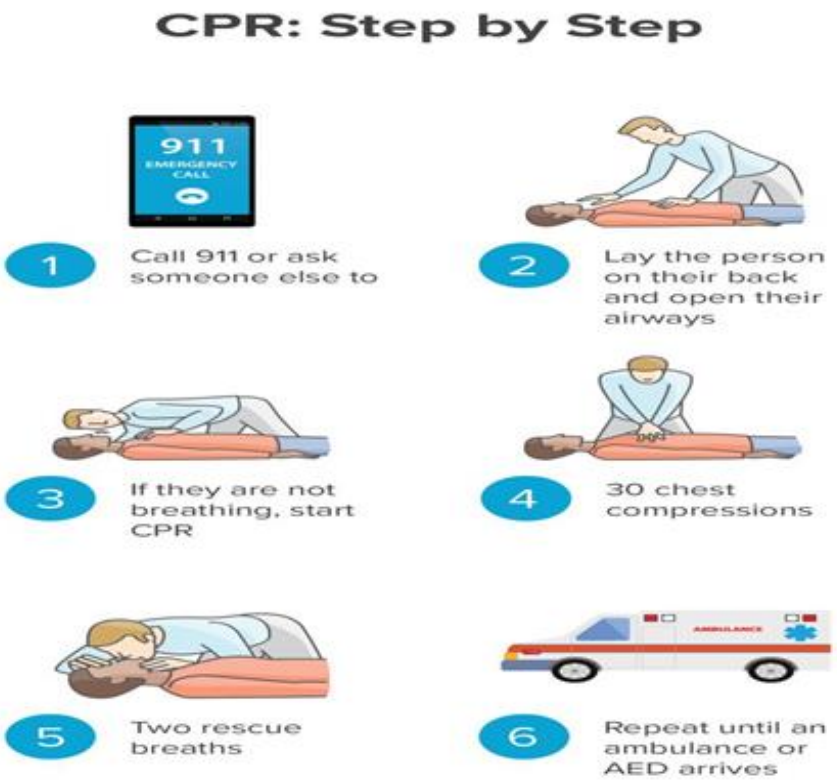
- Make the patient sit down and make him/her feel relaxed and at ease.
- Loosen the clothing on the patient. If he/she is wearing a tie make sure you remove it.
- Ask the patient if he/she is under any medication for any known heart conditions. If so make sure that the patient gets the medicine as soon as possible. The most popular medicine given to patients with a weak heart is nitroglycerin or aspirin.
- If the pain refuses to subside even after giving the patient enough rest and even after taking his/her medication, call for immediate medical assistance.
- If the person becomes unresponsive or unconscious after the episode, make sure that you call for emergency help and begin CPR.

First Aid: CPR

CPR (Cardio Pulmonary Resuscitation) is a lifesaving first aid method that can be used to ensure that the patient has a steady blood flow which is crucial in saving the patient life.

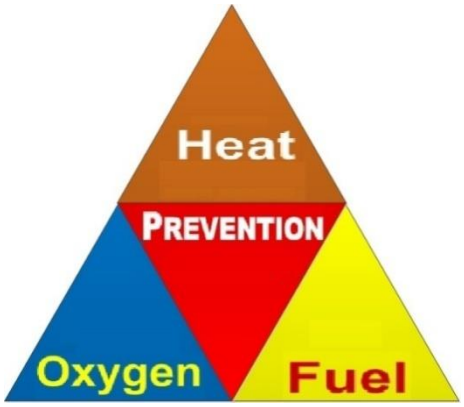
CPR follows the basic C-A-B principle in the order of compressions, airway and breathing. CPR methods vary for according to the age of the person, however for all adults CPR is done by following the below steps:

- Call 911 or ask someone else to.
- Lay the person on their back and open their airway.
- Check for breathing. If they are not breathing, start CPR.
- Perform 30 chest compressions.
- Perform two rescue breaths.
- Repeat until an ambulance or automated external defibrillator (AED) arrives.



Fire safety

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products



The Fire Prevention Triangle - Heat, Oxygen and Fuel

A fire needs three elements - heat, oxygen and fuel. Without heat, oxygen and fuel a fire will not start or spread.

Causes of fire

- Cooking equipment.
- Heating.
- Smoking in bedrooms.
- Electrical equipment.
- Candles.
- Faulty wiring.
- Flammable liquids.

Fire Precautionary Activities

- Keep doorways, corridors, and other paths clear and unobstructed. Make sure that all electrical appliances and cords are in good condition. Do not overload electrical outlets.
- Keep ignition sources away from flammable liquids and gases.
- Do not tamper with any fire system equipment such as smoke detectors, pull stations, or fire extinguishers. Doing so is a criminal offense.
- Good Housekeeping is Crucial.
- Maintain Machinery and Electrical Items.
- Store and Use Chemicals Responsibly.
- Test the Fire Alarm System Regularly.
- Only Smoke in Demarcated Areas.

DO treat every fire alarm as an emergency. If the alarm sounds, exit the building immediately.

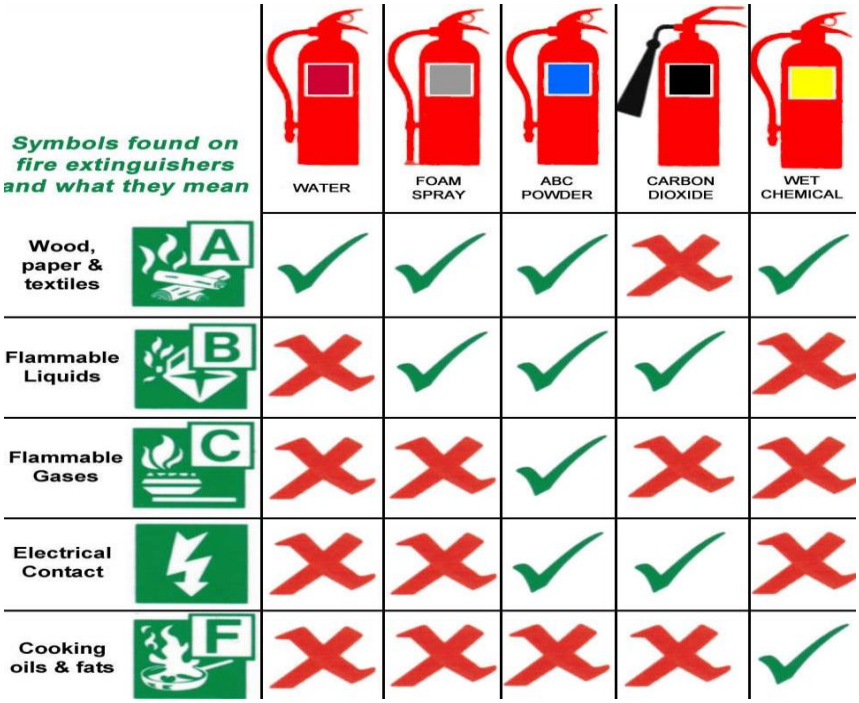
Fire extinguisher

A portable device that discharges a jet of water, foam, gas, or other material to extinguish a fire.

There are 5 main fire extinguisher – Water, Foam, Dry Powder, CO2 and Wet Chemical.

Types of fire and fire extinguisher

Class A: This type of fire is caused by combustible materials like paper, cloth, and wood.
Class B: More serious than a fire involving wood or paper, a Class B fire is fuelled by flammable liquids like oil or gasoline.
Class C: If you experience an electrical fire, it's a Class C fire. Your extinguisher will work for flames occurring on fuse boxes, appliances, and wiring.
Class D: This fire is caused by combustible metals like sodium or magnesium.
Class K: For fires that occur on the stovetop, like burning oil or grease, a fire extinguisher must include a Class K symbol.



Fire rescue

Steps to follow during fire hazards:

- If a fire occurs in your home, GET OUT, STAY OUT and CALL FOR HELP.
- Immediately pull the nearest fire alarm pull station as you exit the building.
- When evacuating the building, be sure to feel doors for heat before opening them to be sure there is no fire danger on the other side.
- If there is smoke in the air, stay low to the ground, especially your head, to reduce inhalation exposure.
- Once away and clear from danger, call your report contact and inform them of the fire.

Moving injured people during emergency:

If the victim cannot stand, is unconscious or the room is filled with smoke, you can move the victim:

- By crawling while the victim holds onto your shoulders/neck (conscious victim).

- By grabbing their shoulders/shirt, cradling their head in your arms and pulling.

- By rolling them onto a blanket or sleeping bag and pulling.

- By grabbing their feet and pulling.

Inform relevant authority about any abnormal situation

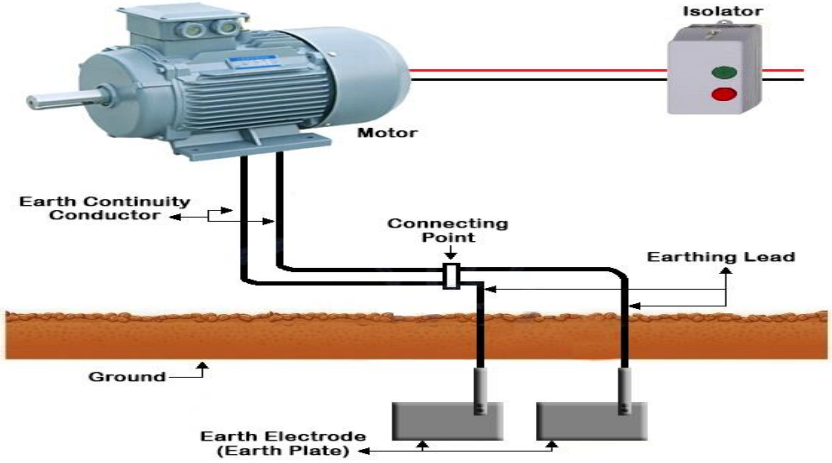
It's always necessary to keep the relevant authority informed for further inspection and maintenance. If it is a fault concerned to a HV line its necessary to inform the KPTCL by using emergency helpline number (for BESCOM 1912). Call 102 or 108 for medical emergency ambulance service, call 101 for Fire Extinguisher vehicle, Call 100 police, in case of other emergency. You can also call on 112 for any emergency.

Figure: BESCOM (Call 1912) and Fire Brigade (Call 101) in emergency

Figure: Medical Ambulance (Call 108) Police (Call 100) in emergency.

Earthing

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. The earthing provides the simple path to the leakage current.



There are three methods of earthing widely used,

- **Pipe earthing:** A galvanized steel perforated pipe inside the ground connects the electrical conductors to the earth.

- **Plate earthing:** A copper plate or galvanized plate is buried in an earth pit below ground level. The plate electrode connects the electrical conductors to the earth.

- **Strip earthing:** A galvanized strip electrode inside the ground connects the electrical conductors to the earth.

UNIT-2

Electrical Fundamentals

Sources of electrical energy

Electrical energy is a form of energy resulting from the flow of electric charge. Energy is the ability to do work or apply force to move an object. In the case of electrical energy, the force is electrical attraction or repulsion between charged particles.

Sources of electrical energy can be classified into two types

- Conventional sources of electrical energy
- Non - Conventional sources of electrical energy (Renewable sources of electrical energy)

Conventional sources of electrical energy are

- Water or hydro power
- Thermal power
- Diesel power
- Nuclear power

Non - Conventional sources of electrical energy are

- Solar power
- Wind power
- Tidal power
- Geo – thermal power

Electrical current, voltage, emf, potential difference, resistance with their SI units

Electric current: Continuous flow of electrons in a conductor, in a particular direction is called electric current. It is represented by I and its SI unit is Ampere.

Voltage or Electric Potential: Voltage or Electric Potential is defined as the amount of potential energy or electrical pressure between two points in a circuit. One point has more charge than another. This difference in charge between two points is called Voltage OR Electric Potential. It is represented by V and its SI unit is Volts.

EMF (Electro Motive Force): Electromotive force is defined as the electric potential produced by either electrochemical cell or by changing the magnetic field. EMF is the energy per unit charge exerted by an energy source or force which circulates the current. It is represented by E and its SI unit is Volts.

Potential difference: Electric Potential Difference is the difference in electric potential (V) between the final and the initial location when work is done upon a charge to change its potential energy. It is represented by ΔV and its SI unit is Volts.

Resistance: Electrical resistance of an object is a measure of its opposition to the flow of electric current. It is represented by R and its SI unit is ohms(Ω).

Meters used to measure different electrical quantities

Ammeter

An ammeter (from ampere meter) is a measuring instrument used to measure the **current** in a circuit (in **amps**). The ammeter is usually connected in **series** with the circuit in which the current is to be measured. Figure shows AC and DC ammeter.

Voltmeter

A voltmeter is an instrument used for measuring electric **potential difference** between two points in an electric circuit in **volts**. It is connected in **parallel**. . Figure shows AC and DC voltmeter.

Wattmeter

A wattmeter is an instrument for measuring the **electric power** (or the supply rate of electrical energy) in **watts** of any given circuit.

Ohmmeter

An ohmmeter is an electrical instrument that measures **electrical resistance** in **ohms**.

Digital Multimeter

A digital multimeter is a test tool used to measure two or more electrical values -principally voltage (volts), current (amps) and resistance (ohms).

Megger

The Megger (Megohmmeter) is the instrument uses for measuring the resistance of the insulation. It works on the principle of comparison.

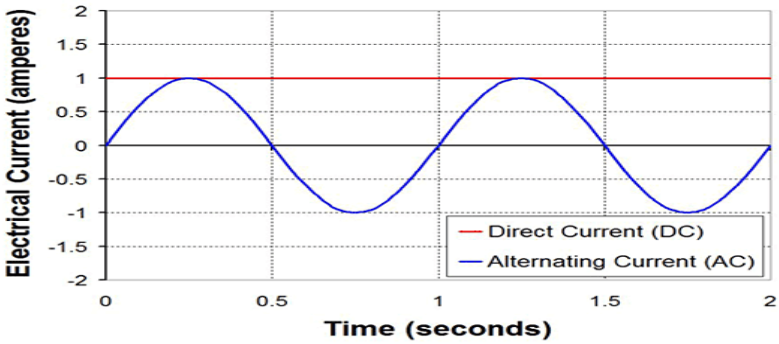
Tong tester

An electrical meter with integral AC current clamp is known as a tong tester. A clamp meter measures the vector sum of the currents flowing in all the conductors passing through the probe. measures high value current.

Sl No	Parameter	SI unit	Instrument used to measure
1	Current(I)	Amperes	Ammeter, Multimeter
2	Voltage(V)	Volts	Voltmeter, Multimeter
3	Resistance(R)	Ohms	Multimeter, Ohmmeter, Megger, LCR meter
4	Power(P)	Watts	Wattmeter
5	High currents	Amperes	Tong tester

Supply systems

AC and DC



Alternating current (AC) is an electric current which changes both in magnitude and direction, at regular intervals of time. It is used in kitchen appliances, televisions, fans and electric lamps etc.

Direct current (DC) is an electric current that is uni-directional, so the flow of charge is always in the same direction. It is used in many household electronics and in all devices that use batteries.

Relationship between V, I and R. (Ohms law)

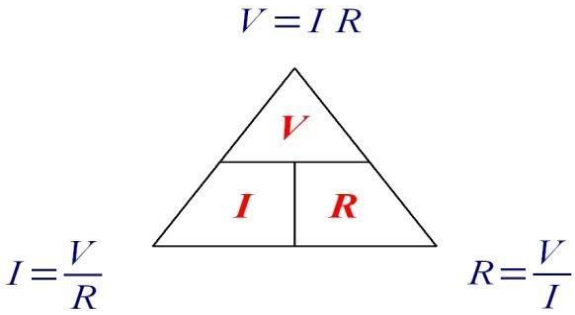
Ohm's Law states that “The current flowing through a conductor is directly proportional to the applied voltage and inversely proportional to the resistance of the conductor at constant temperature”.

Mathematically, $I \propto V/R$ or $V/I = \text{Constant} = R$

Where "R" is a Constant of proportionality and is called Resistance of the Conductor.

Ohm's law equation: V = IR, where V is the voltage across the conductor, I is the current flowing through the conductor and R is the resistance offered by the conductor to the flow of current.

The magic triangle which gives the relationship between the V, I&R is as shown below.



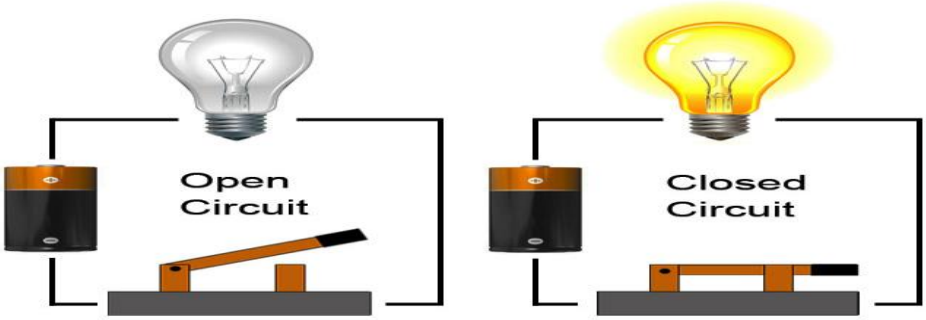
Behaviour of V, I in Series DC circuits

- When a number of electrical components are connected in series, the same current flows through all the components of the circuit.
- The applied voltage across a series circuit is equal to the sum total of voltage drops across each component.
- The voltage drop across individual components is directly proportional to its resistance value.

Behaviour of V, I in Parallel DC circuits

- Voltage drops are the same across all the components connected in parallel.
- Current through individual components connected in parallel is inversely proportional to their resistances.
- Total circuit current is the arithmetic sum of the currents passing through individual components connected in parallel.
- The reciprocal of equivalent resistance is equal to the sum of the reciprocals of the resistances of individual components connected in parallel.

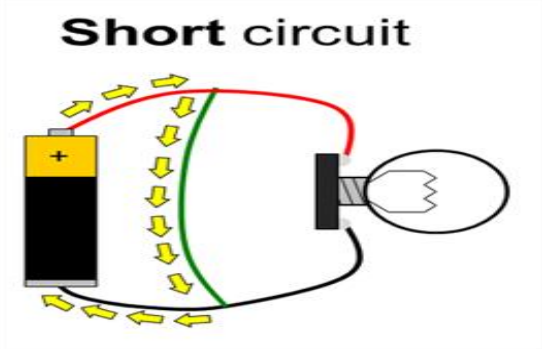
Open circuit, close circuit and short circuit



Open circuit: Open circuit is an incomplete electrical circuit in which no current flows. path of current has been interrupted or broken. The open circuit shows like **OFF** condition or fault condition. The resistance of an open circuit is considered to be infinity as no current flow.

Closed circuit: Closed circuit is a complete electrical circuit through which current can flow in an uninterrupted path. It is closed loop path. The closed circuit shows like **ON** condition or working condition. The resistance of a closed circuit is considered to be zero as current will flow without opposition.

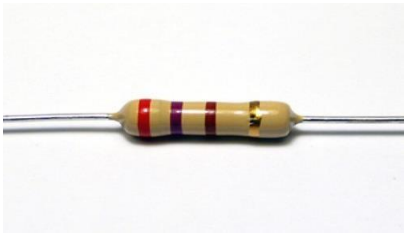
Short circuit: Short circuit is a faulty or accidental connection between two points of different potential in an electric circuit, bypassing the load and establishing a path of low resistance through which an excessive current can flow. It can cause damage to the components if the circuit is not protected by a fuse.



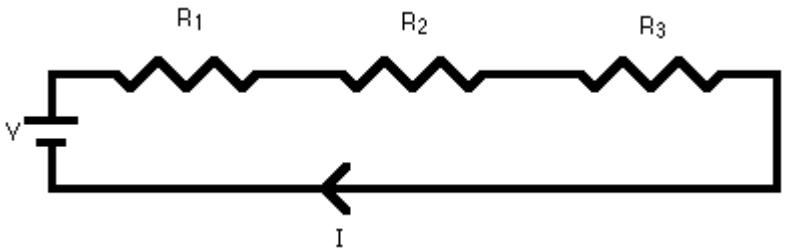
Resistances in series and resistances in parallel connection

Resistors in series combination

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits.



In the following example the resistors R_1, R_2 and R_3 are all connected together in series.



Resistors are said to be connected in “Series “, when they are connected end to end so that the same current flows through them as it can only take one path.

The equation given for calculating the total voltage in a series circuit which is the sum of all the individual voltages added together is given as:

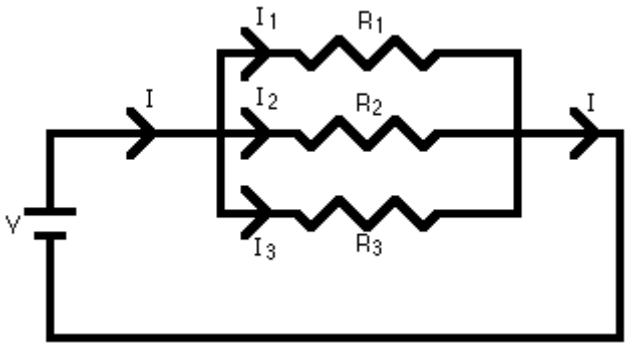
$$V_{TOTAL}=V_1+V_2+V_3=IR_1+IR_2+IR_3$$

Where V_1, V_2 and V_3 are voltage drop across R_1, R_2 and R_3Respectively

Then the amount of current that flows through a set of resistors in series will be the same at all points in a series resistor network. R_T of the series circuit must be equal to the sum of all the individual resistances connected in series, that is

$$R_T=R_1+R_2+R_3$$

Resistors in parallel combination



When the resistances R_1, R_2&$R_3$are connected in such a way that, their starting ends are of all connected together to a common point and their finishing ends are all connected together to another common point as shown in the figure.

Then in our parallel resistor example below the voltage across resistor R_1 equals the voltage across resistor R_2 which equals the voltage across R_3 and which equals the supply voltage. Therefore, for a parallel resistor network this is given as:

$$V_{R1}=V_{R2}=V_{R3}=V$$

In the previous series resistor network, we saw that the total resistance, R_T of the circuit was equal to the sum of all the individual resistors added together. For resistors in parallel the equivalent circuit resistance R_T is calculated differently.

Here, the reciprocal (1/R) value of the individual resistances are all added together instead of the resistances themselves with the inverse of the algebraic sum giving the equivalent resistance as shown. Then the inverse of the equivalent resistance of two or more resistors connected in parallel is the algebraic sum of the inverses of the individual resistances.

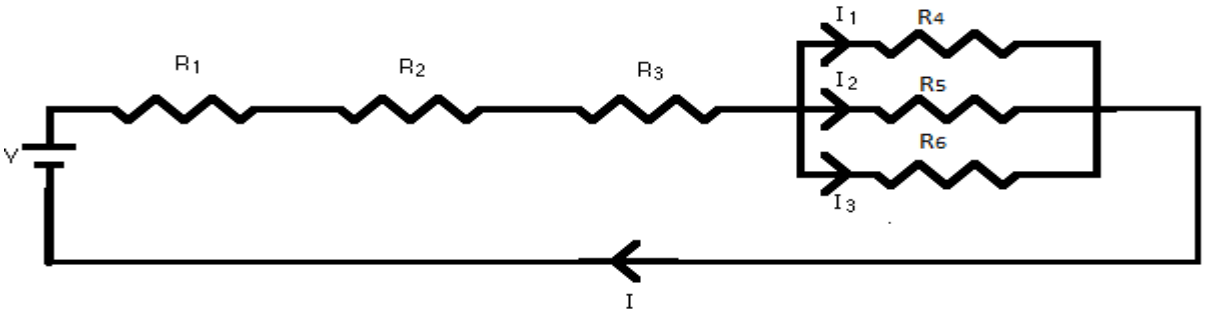
$$\frac{1}{R}=\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}$$

$$R_T=\frac{R1\,R2\,R3}{R1R2+R2R3+R3R1}$$

The total current, I_T entering a parallel resistive circuit is the sum of all the individual currents flowing in all the parallel branches.

$$I_{TOTAL}=I_{R1}+I_{R2}+I_{R3}$$

Series and parallel Combination of resistor

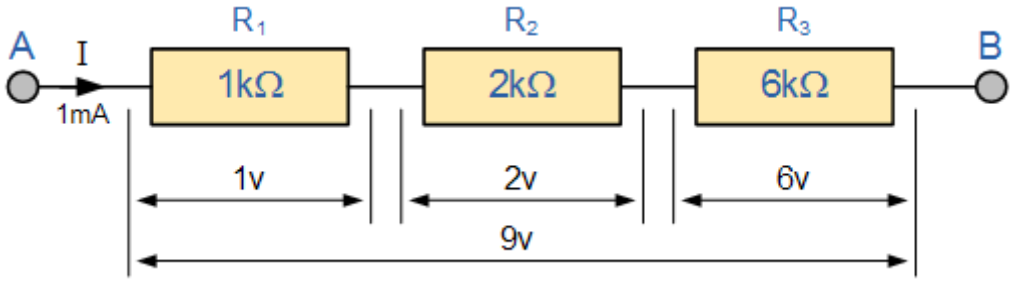


The resistors are connected as shown in figure such combination is connected across the supply voltage. It forms a series – parallel combination. Total resistance is given by

$$R_T = (R_1 + R_2 + R_3) + (R_4R_5R_6/R_4R_5+R_5R_6+R_6R_4)$$

Problem on resistors in series

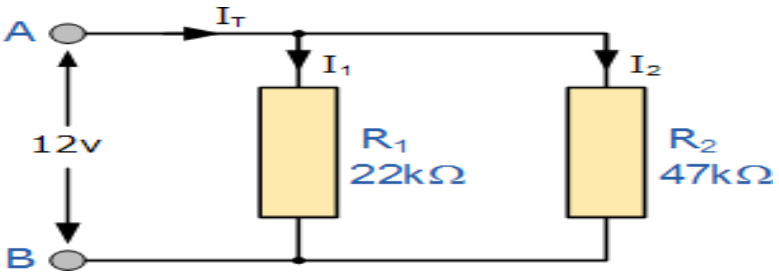
In the following circuit calculate the total resistance R_T or R_{EQ}



$$R_{EQ} = R_1 + R_2 + R_3 = 1k\Omega + 2k\Omega + 6k\Omega = 9k\Omega$$

Problem on resistors in parallel

Consider the following circuit which has only two resistors in a parallel combination

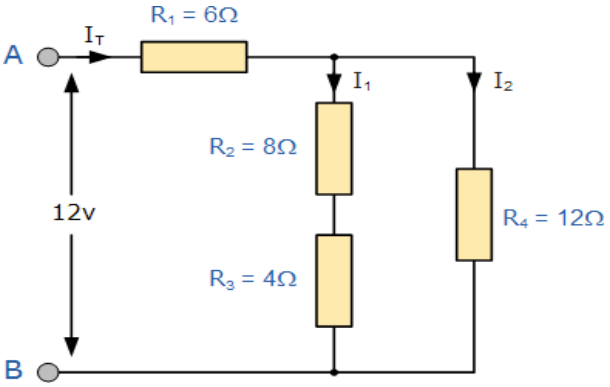


Solution: Using our formula above for two resistors connected together in parallel we can calculate the total circuit resistance, R_T as:

$$R_T = \frac{22k\Omega x 47k\Omega}{22k\Omega + 47k\Omega} = 14985\Omega \text{ or } 15k\Omega$$

Problem on Series and parallel Combination of resistor:

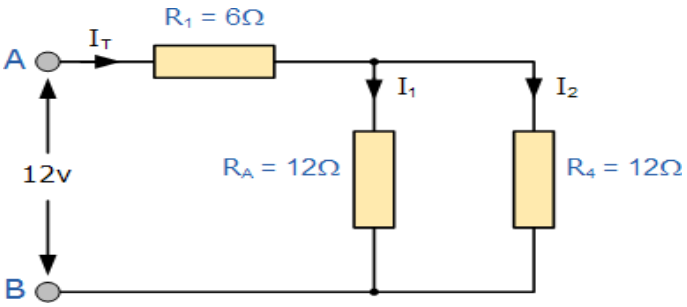
In the following circuit calculate the total current (I_T) taken from the 12v supply.



we can see that the two resistors, R2 and R3 are actually both connected together in a "SERIES" combination so we can add them together to produce an equivalent resistance. The resultant resistance for this combination would therefore be:

R2 + R3 = 8Ω + 4 Ω = 12 Ω

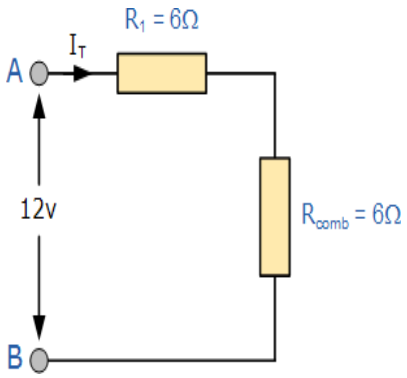
So, we can replace both resistors R2and R3 above with a single resistor of resistance value12 Ω



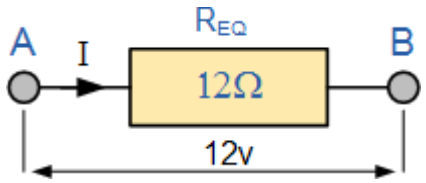
So, our circuit now has a single resistor R_A in "PARALLEL" with the resistor R_4. Using our resistors in parallel equation we can reduce this parallel combination to a single equivalent resistor value.

$$R_{(Combination)} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{R_{(Com)}} = 6\Omega$$

The resultant resistive circuit now looks something like this:



We can see that the two remaining resistances, R1 and R(comb) are connected together in a "SERIES" combination and again they can be added together (resistors in series) so that the total circuit resistance between points A and B is therefore given as:



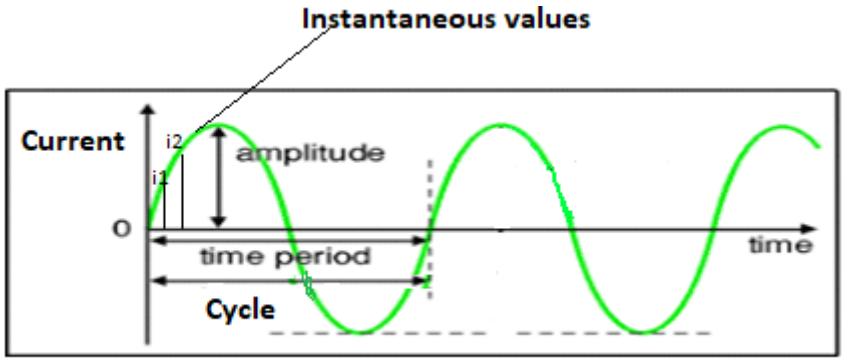
R (A – B) = Rcomb + R1 = 6 Ω + 6 Ω = 12 Ω.

A single resistance of just 12 Ω can be used to replace the original four resistors connected together in the original circuit.

Now by using Ohm´s Law, the value of the circuit current (I) is simply calculated as:

$$Circuit\ Current(I) = \frac{V}{R} = \frac{12}{12} = 1Ampere$$

AC Sine wave



A sinusoidal voltage source produces a voltage that varies as a sine wave with time.
A sinusoidal current source produces a current that varies with time. The sinusoidal varying function can be expressed either with the sine function or cosine function.

Amplitude: The amplitude of a wave refers to the maximum value of that alternating quantity either in the positive direction or negative direction. Represented by Em or Im and It is measured in volts or amps.

Time period (T): The time period of a wave is the amount of time it takes to complete one cycle. It is measured in seconds.

Cycle: One set of positive and negative values of an alternating quantity is called cycle.

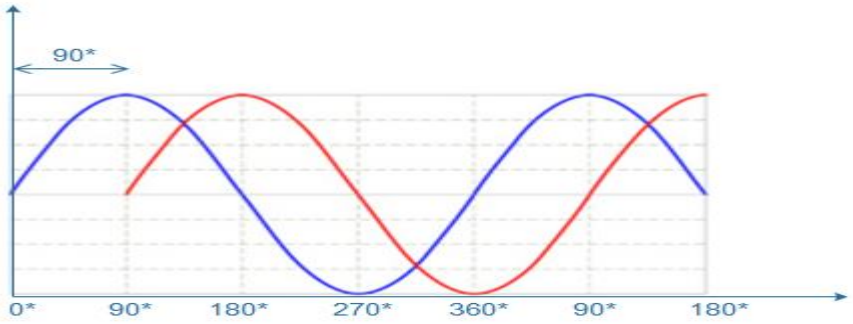
Frequency (F): The number of cycles completed by an alternating quantity in one second is called frequency. It is measured in hertz (Hz). Frequency of AC voltage generated in India is 50Hz.

$$\text{Frequency} = \frac{1}{\text{Periodic time}} \quad \text{or} \quad f = \frac{1}{T}\ \text{Hz}$$

$$\text{Periodic time} = \frac{1}{\text{Frequency}} \quad \text{or} \quad T = \frac{1}{f}\ \text{sec}$$

Phase: The phase involves the relationship between the position of two alternating quantity of a point in particular time on the sinusoidal waveform. It is represented by Φ and its unit is any angular unit such as degrees or radians.

Phase can be measured in distance, time, or degrees. If the peaks of two signals with the same frequency are in exact alignment at the same time, they are said to be in phase. Conversely, if the peaks of two signals with the same frequency are not in exact alignment at the same time, they are said to be out of phase.



This above figure shows two waves 90^0out of phase.

Phase Difference: It is used to describe the angular displacement in degrees or radians when two or more alternating quantities reach their maximum or zero values in the same direction during a period of one cycle. The above figure shows 90^0(π/2 radians)phase difference. It is represented by $\Delta\Phi$ and its unit is degrees or radians.

Electrical work, power and power factor

Electrical work: For electrical energy to move electrons and produce a flow of current around a circuit, work must be done, that is the electrons must move by some distance through a wire or conductor. The work done is stored in the flow of electrons as energy. Thus "Work" is the name we give to the process of energy. It is represented by W and its unit is joule (J).

Electrical power: Electrical power is the rate, per unit time, at which electrical energy is transferred by an electric circuit. OR Electric power is the rate at which work is done. The SI unit of power is the watt, or joule per second. Wattmeter is used for measuring the electric power.

$$P = \text{Work done/time} = \text{Energy/time}$$

Power factor: Cosine of the angle (Φ) between the applied voltage and the total current in a circuit is called the power factor. Power factor meters used for measuring the power factor.

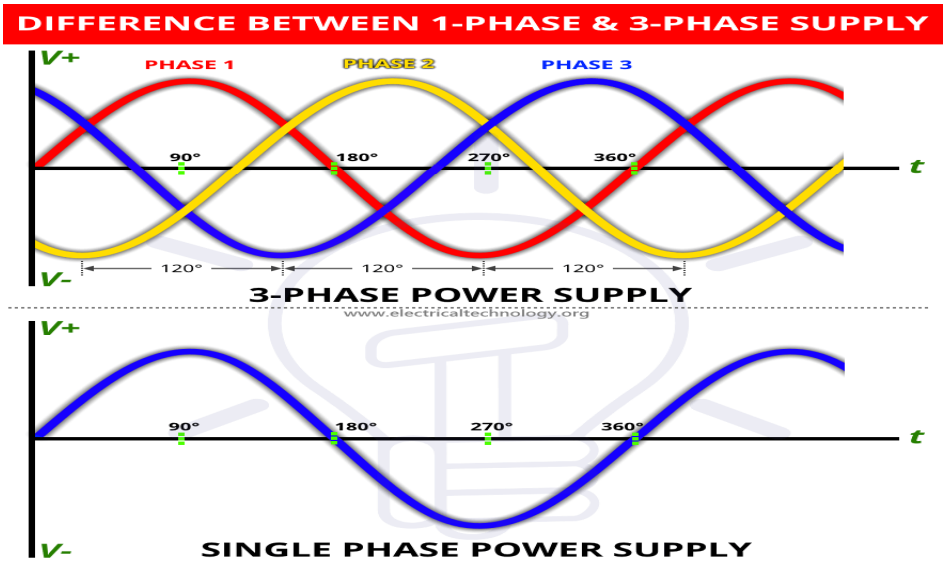
$$\text{Power Factor} = \cos \Phi$$

Electrical energy

Energy is defined as the amount of work done.Electrical energy is a form of energy resulting from the flow of electric charge.The SI unit of Electrical energy is the joule OR kilowatt hours (kWh).Energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device.

$$\text{Energy} = \text{Power} \times \text{Time}.$$

Single phase and Three phasesupply



Single-Phase Supply: In a Single-Phase Power Supply, the power is distributed using only two wires called Phase and neutral. Since AC Power takes the shape of a sinusoidal wave. It is very common form of power supply to most small power requirement. Almost all residential supplies are single phase supplies.

Three Phase Supply: A Three Phase Power Supply consists of three power wires (or the three phases).In a three-phase power supply system, each AC Power Signal is 120^0 out of phase with each other. Three phase power supply is usually the preferred network for commercial and industrial loads.

UNIT 3

Protective Devices and Wiring circuits

Necessity of Protective Devices

A device used to protect equipment, machinery, components and devices, in electrical and electronic circuit, against short circuit, over current and earth fault, is called as protective devices.

Protective devices are necessary to protect electrical appliance or equipment against

- Short Circuit
- Abnormal variations in the supply voltage
- Overloading of equipment
- To protect operator against accidental contact with the faulty equipment

Various Protective devices and their functions

Fuse: An electrical fuse is a safety device in the circuit that protects electrical systems by breaking the connection when a short circuit is occurring. The fuse wire is made up of tin and lead alloy because of its high resistance and low melting point.

Glass cartridge fuse: Cartridge fuses are cylindrical in shape and have contact points at each end.

HRC (High Rupture Capacity) fuse: It is a type of cartridge fuse, in which the fuse element is enclosed within a transparent capsule, usually made up of ceramic material.

Kit-kat fuse: It is a semi conductor fuse, enclosed fuse for domestic uses. It is connected in series with the circuit.

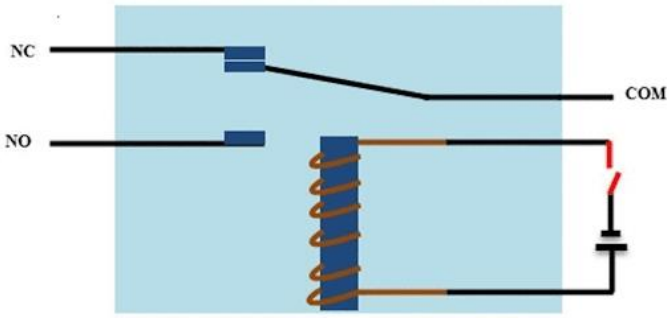
MCB(Miniature Circuit Breaker):It automatically switches OFF electrical circuit during any abnormal condition in the electrical network such as overload & short circuit conditions.

MCCB (Moulded Case Circuit Breaker): It is another type of electrical protection device which is used when load current exceeds the limit of a miniature circuit breaker.

RCCB (Residual Current Circuit Breaker): It is a current sensing device, which can automatically measure and disconnect the circuit whenever a fault occurs in the connected circuit or the current exceeds the rated sensitivity.

ELCB (Earth-leakage Circuit Breaker): It is a safety device used in electrical installations with high Earth impedance to prevent shock.

Relay: Relays are switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit.



Different types of electrician and wiring tools and their function

Electrical tools are used to do the electrical work like electrical wiring installations by using this tool we can do the installation of electrical wire properly and quickly.

Pliers: Pliers can be used for cutting, twisting, bending, holding, and gripping of wires and cables. The handles of the pliers will be insulated and it can't be considered as sufficient protection.

Wire strippers: Wire strippers are used to remove the insulation of wires, mostly medium-sized wires ranging from gauge 10 to gauge 16. Wire strippers are also used to remove the insulation of rubber covered wires from gauge 26 to gauge 10.

Electrician Knife: These knives are used by lineman to remove the insulation of big cables in high and low voltage transmission lines

Screwdrivers: Screwdrivers can be used to loosen or tighten screws with slotted heads, screwdrivers are in various size and shape. Screwdrivers are made up of steel and they are tempered at the tip. According to the size and shape of screw different types of screwdrivers are used.

Hammers: Hammers are tools which are used for pounding and pulling out of nails, there are soft and hard-faced hammers. Hard faced hammer can be used to strike hard objects and they have a cylindrical-shaped head. The soft-faced hammer is used for the rewinding process. Mostly soft-faced hammers are made up of rubber or plastic.

Electric drill: These devices are used to drill holes in metal sheets and concrete walls, they can be used to make holes in building structures for the passage of wires and conduit. They can be useful for indoor and outdoor wiring.

Soldering tools: Soldering tools can be used to make splices and tap connections in wires. Many connections can be done with the help of this device. Soldering must be done perfectly in order to get a better connection.

Wire gauge: Wire gauge can be used to measure the thickness or diameter of the wires, it can be used in sizing conductors. The wire gauge can be used to measure from gauge 0 to 36.

Hacksaw: Hacksaws can be used to cut metal conduit and armoured cable, it can also be used to cut the small and medium-sized metals.

Wire crimper: A wire crimp tool is one of the best ways to repair wires causing faulty circuit connections. Investing in a good quality crimp tool ensures a long-lasting seal and will give you decades of reliable use.

Electrical tester: An electrical tester can measure a variety of electrical parameters, from current and voltage to resistance, continuity and beyond.

Procedure of care and maintenance of wiring tools

- Keep Power Tools Clean. Dust and grime can bring your power tools to a grinding halt if left unchecked over time.
- Store Power Tools Correctly.
- Inspect for Wear or Damage.
- Lubricate Moving Parts.

- Keep Batteries in Shape.

Wiring Systems

Electrical Wiring is a process of connecting cables and wires to the related devices such as fuse, switches, sockets, lights, fans etc to the main distribution board.

Different types of wiring systems are

- Surface conduit
- concealed conduit
- PVC casing capping

Surface conduit: If conduits (pipe, channel or tube through which liquid, gas or electrical wires can pass) installed on roof or wall, it is known as surface conduit wiring. in this wiring method, they make holes on the surface of wall on equal distances and conduit is installed then with the help of plugs. Suitable for industrial applications

Concealed Conduit: If the conduit is hidden inside the wall slots with the help of plastering, it is called concealed conduit wiring. Obliviously, it is the most popular, beautiful, stronger and common electrical wiring system nowadays. Suitable for domestic applications.

PVC casing capping: It is one of the simplest forms of electric wiring systems. PVC (polyvinyl chloride aplastic polymer) insulated wires are placed in the plastic casing and covered with a cap, hence the name 'Casing Capping'. Casing is a rectangular strip where the cables run through it having grooves. Suitable for extra connections.

Types of wires, cables used for different current and voltage ratings

Wire is a single electrical conductor, whereas a cable is a group of wires.

An electric cable has the purpose of transporting electrical energy from one point to another. Depending on their final application, cables can have different configurations, always basing their design on national and international regulations.

There are mainly 5 types of wire

- **Triplex Wires:** Triplex wires are usually used in single-phase service drop conductors, between the power pole and weather heads. They are composed of two insulated aluminium wires wrapped with a third bare wire which is used as a common neutral. The neutral is usually of a smaller gauge and grounded at both the electric meter and the transformer.

- **Main Feeder Wires:** Main power feeder wires are the wires that connect the service weather head to the house. They're made with stranded or solid THHN (Thermoplastic High Heat-resistant Nylon coated) wire and the cable installed is 25% more than the load required.

- **Panel Feed Wires:** Panel feed cables are generally black insulated THHN wire. These are used to power the main junction box and the circuit breaker panels. Just like main power feeder wires, the cables should be rated for 25% more than the actual load.

- **Non-Metallic Sheathed Wires:** Non-metallic sheath wire, or Romex, is used in most homes and has 2-3 conductors, each with plastic insulation, and a bare ground wire. Since it's relatively cheaper and available in ratings for 15, 20 and 20 amps, this type is preferred for in-house wiring.

- **Single Strand Wires:** Single strand wire also uses THHN wire, though there are other variants. Each wire is separate and multiple wires can be drawn together through a pipe easily. Single strand wires are the most popular choice for layouts that use pipes to contain wires.

An electric cable is measured in volts and, depending on these, they are categorized into one group or another:

- **Low Voltage cables (up to 1,000 V):** (also called (0,6/1 kV) The cables in this section are used for industrial power installations in various fields (general industry, public installations, infrastructures, etc.). They are designed according to international standards.
- **Medium Voltage cables:** from 1 kV to 36 kV. They are used to distribute electricity from electrical substations to transformer stations.
- **High Voltage cables:** from 36 kV. They are used to transport electricity from the generating plants to the electrical substations.

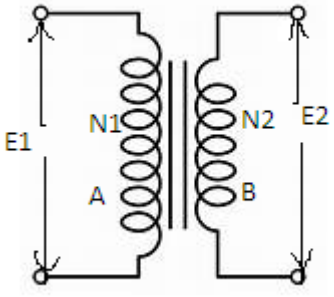
UNIT-4

Electrical Machines and Batteries and UPS

Transformer

Transformer is a static device which transfers power from one circuit to another circuit without changing frequency. It can step – up or step- down the voltage with a corresponding decrease or increase in current.

Working principle of Transformer



Transformer works on the principle of "mutual induction". That is whenever the flux produced by coil 'A' links with another coil 'B', an emf is induced in the coil B as shown in the figure. This induced emf is proportional to the rate of change of flux and the number of turns of coil 'B'

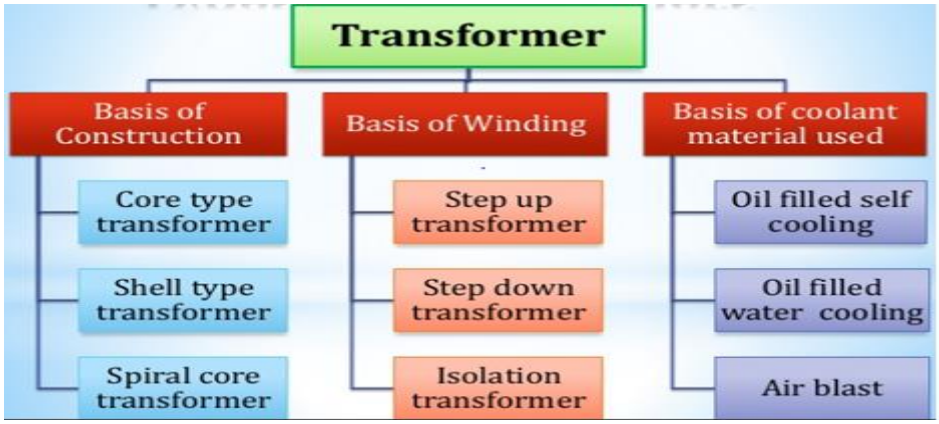
i.e $E2 \propto \Phi 1\, N2$ volts

Transformation ratio

The transformation ratio is defined as the ratio of the secondary voltage to the primary voltage. It is denoted by K.

$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

Types of transformer



Applications of transformer

- Transformers are used to step up and step down voltage in power transmission and distribution systems
- Step – up transformers are used in step generating and receiving stations.
- Step – down transformers are used in substations and distribution stations
- Used in TV, refrigerators, radios, SMPS etc.
- Used in welding
- Core type transformers are used for high capacity
- shell type transformers are used for lower capacity

Induction motor

Motors which convert alternating current energy into mechanical energy are known as AC motors. Induction motor is a type of AC motor.

Induction motors are classified according to the number of phases

1. Single phase induction motors
    - Split phase induction motor
    - Capacitor type induction motor
    - Shaded- pole type induction motor
    - Universal induction motor
    - Repulsion induction motor
2. Three phase induction motor
    - Squirrel – cage induction motor

- Wound rotor induction motor

Necessity of starters

When a 3-phase induction motor is directly connected to the supply, it takes heavy current at starting i.e 5 to 7 times the full load current and creates a large voltage drop in the line. Due to this,

- Motor windings may be damaged.
- Neighbouring consumers are inconvenienced.

To avoid this and also to give protection to the motor against over currents, staters are used.

DOL (Direct – ON – Line) starter – used up to 5 HP

It is a method of starting a 3 phase induction motor. In a DOL Starter, an induction motor is connected directly across its 3-phase supply, and the DOL starter applies the full line voltage to the motor terminals. Despite this direct connection, no harm is done to the motor. A DOL motor starter contains protection devices.

DOL starter is a device consist of main contactor, protective devices and overload relay which is used for motor starting operations. It is used for low rating usually below 5HP motors.

STAR-DELTA starters – used from 5 HP to 15 HP

A star delta starter is the most commonly used method for the starting of a 3 phase induction motor. In star delta starting an induction motor is connected in through a star connection throughout the starting period. Then once the motor reaches the required speed, the motor is connected in through a delta connection. A star delta starter will start a motor with a star connected stator winding. When motor reaches about 80% of its full load speed, it will begin to run in a delta connected stator winding.

STAR-DELTA starters consist of Contactors (Main, star and delta contactors). Time relay (pull-in delayed). Three-pole thermal overcurrent release 1. Fuse elements.

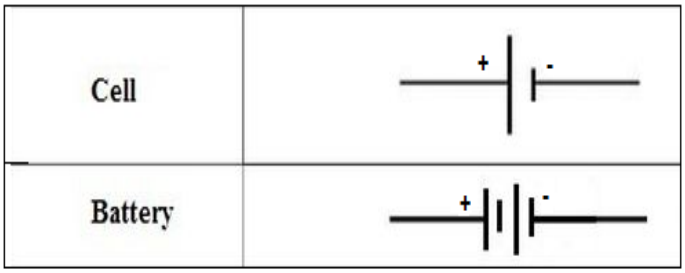
Different causes and remedies for a failure of starter and induction motor

Fault	Causes	Remedies
Motor does not start on load	a) No supply voltage b) Driven equipment jam & Motor shaft jammed	a) Check voltage at Motor Terminals. b) Ensure freeness of driven equipment and motor shaft.
Motor starts and gets trips	a) Terminal voltage is low. b) Backup fuse blowing.	a) Ensure rated voltage OR increase relay setting slightly. b) Correct rating of backup fuse to be used.
Motor connected but does not picks up full speed.	a) No supply of voltage b) Motor may be overloaded	a) Check voltage between each two phases. b) Reduce load
Noise	a) Foundation is not Rigid. b) Belt pulley misalignment	a) Ensure rigidity. b) Correct the alignment.
Shaft broken	a) Misalignment of pulley b)Impact / sudden load or sudden reversal of direction	a) Ensure proper alignment of motor and driven equipment. b) Select suitable shaft material with proper heat treatment.

Battery

Cell is an electro – chemical device, which converts chemical energy into electrical energy and vice-versa.

Battery is the combination of two or more cells connected either in series or parallel or in series – parallel combination.



Types of Battery

There are 2 types of batteries

1. Primary battery
2. Secondary battery

1. Primary battery

The battery which cannot be recharged and reused after discharge are called as primary battery.

2. Secondary battery

The battery which can be recharged and reused after discharge are called secondary battery.

Types of secondary batteries

- Lead – acid battery
- Lithium-ion battery
- Nickel- cadmium battery etc

Sealed Maintenance Free (SMF) battery: These batteries are sealed and require no maintenance, as the electrolyte is not in the form of solution they are sealed.

Electrolyte is in the form of paste and hence no leakage. It can be placed in any position and distilled water not required. It is strong and robust.

Modular battery: These are advanced energy solutions that can be connected in parallel or series to increase capacity or voltage. They are widely used for devices that require high capacity or high voltage in order to operate.

Conditions for fully charged and discharged Lead Acid battery

Fully charged Battery

- Voltage of each cell will be 2.3 to 2.4 volts.
- Anode will be dark chocolate brown in colour and cathode will be Gray in colour.
- Specific gravity of electrolyte will be 1230 to 1300.
- Oxygen is liberated at anode and hydrogen at cathode. This is called gassing.

Fully discharged battery

- Both anode and cathode will become white Gray in colour.
- Specific gravity of electrolyte will be 1180
- Voltage per cell will be 1.8 volts

Selection criteria of batteries for different applications.

- Size and weight
- Interconnection
- Battery maintenance
- Rate and depth of discharge
- Balancing and management systems

Rating of the battery or Ampere-hour capacity

It is the product of rated discharge current and number of hours of discharge. It is expressed in Ampere hours.

Efficiency of battery

The efficiency of a battery can be calculated as the amount of power discharged by the battery divided by the amount of power delivered to the battery.

UPS (uninterruptible power supply)

UPS stands for uninterruptible power supply. A UPS is an electrical apparatus that provides emergency power to a load where the main power fails.

There are 3 Types of UPS

- ON – Line UPS
- OFF – Line UPS
- Line – Interactive UPS

Application of UPS

Typical applications of UPS include: PCs, workstations, small file servers, Electronic Point of Sale (EPoS) terminals, Small Office and Home Office (SoHo) systems, Hi-Fis, satellite systems, routers, modems and switches etc.

Selection criteria of UPS

The following are the selection criteria for the selection of UPS

- Output power
- Batteries life
- Cost
- Vendor warranty and onsite service options
- Additional features

Sizing of UPS

There are several factors that influence sizing a UPS system, including the combined load of all the equipment the UPS will protect, scope for further system expansion, battery runtime and redundancy.

Correctly sizing an uninterruptible power supply is crucial – under sizing inevitably causes immediate problems, while initial oversizing will waste energy, money and valuable floor space.

The easiest way to ensure a correctly sized UPS system is to get prospective suppliers to undertake a full site survey where they can accurately assess your requirements. However, it is possible to broadly size a UPS by following a step-by-step process.

- **Critical or Non-Critical Load**: This starts with listing and reviewing all the equipment that will need to be protected by the UPS (Critical or non-critical).

- **Power Range**: The next step is to calculate the total power range for the combined critical load that needs protecting.

- **Potentially Problematic Loads**: Certain equipment (i.e., laser printers, blade servers, air conditioners, motors and compressors) have an inrush of current during start-up or draw higher currents in normal operation, which can cause the UPS to overload.

  For these types of load, good practice suggests two options: either remove them from the power protection system or oversize the UPS by a factor of at least three.

- **Battery Runtime**: This is the amount of time you want the UPS to keep equipment operating in the event of a power failure.

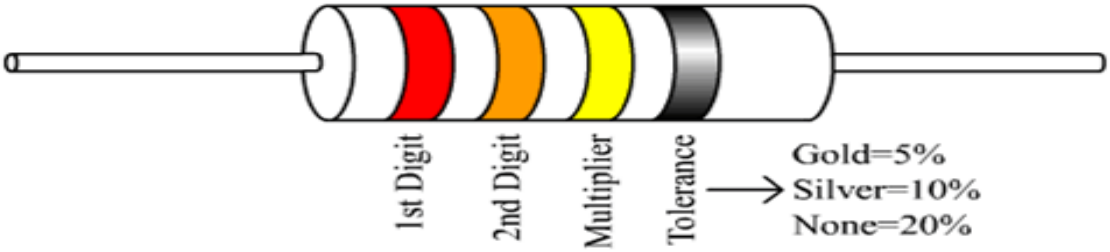
UNIT-5

Introduction to Electronic Devices and Digital Electronics

Compare Conductors, insulators and semiconductors with examples

BASIS FOR COMPARISON	CONDUCTORS	SEMICONDUCTORS	INSULATORS
Meaning	Conductor is a type of material that allows the current in one or more directions.	Semiconductor is a type of material which has a conductivity between conductors and insulators.	An insulator is a material that does not conduct current.
Conductivity	High.	Moderate.	Low.
Resistivity	Low.	Moderate.	Very High.
Temperature coefficient	Positive.	Negative.	Negative.
Current flow	Caused by the presence of free electrons.	It is caused by free electrons and holes.	It is caused by free electrons which are negligibly present.
Overlapping of bands	The valence and conduction bands are overlapped.	Valence band and conduction band are separated energy gap of 1.1eV.	Both the bands get divided by an energy gap of 6eV - 10eV.
Type of Bonds	Conductors are formed by a metallic bonding.	Semiconductors are formed by covalent bonding.	Insulators are formed by ionic bonds.
Examples	Gold, Bronze, Silver, Mercury, Copper, Brass, etc.	Silicon, Aluminium.	Mica, Rubber, Wood, Paper, etc.

Colour code of resistor



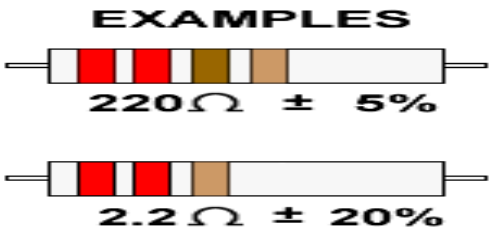
Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

To identify value of resistance of a resistor colour coding is used. Because size of the resistor is very small so we cannot print resistance value on the physical structure. Thus, we use coloured rings, these coloured painted bands produce a system of identification generally known as a Resistors Colour Code.

Generally, there are four colour rings on the resistor, first and second rings indicates the two digits of the resistance value. Third ring indicates the multiplier, fourth and final ring indicates the tolerance value. That means maximum change of the resistance value that may occur that depends on manufacturing process. Tolerance represented in % with + or – sign means value may increase or decrease from indicated value.

Colour code of resistors can easily remember by using the following sentence where each bold letter represents different colours.

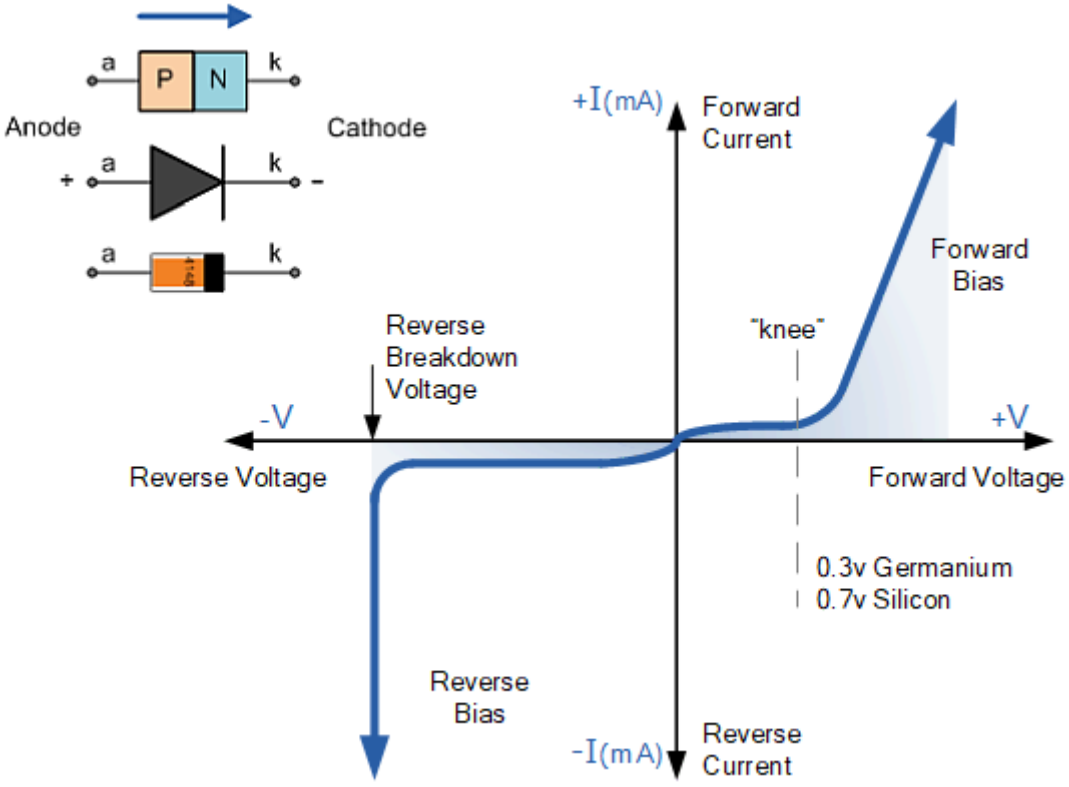
B B ROY of **G**reat **B**ritain had a **V**ery **G**ood **W**ife



PN junction diode

It is a two-element semiconductor device. Joining a P - type and N – type semiconductor by a suitable technique, forms a P – N junction diode.

It allows the current in one direction only. It ha two terminals Anode(A) and cathode(K). and one junction device.



A PN Junction Diode is one of the simplest semiconductor devices around, and which has the characteristic of passing current in only one direction only. However, unlike a resistor, a diode does not behave linearly with respect to the applied voltage as the diode has an exponential current-voltage (I-V) relationship and therefore we cannot described its operation by simply using an equation such as Ohm's law.

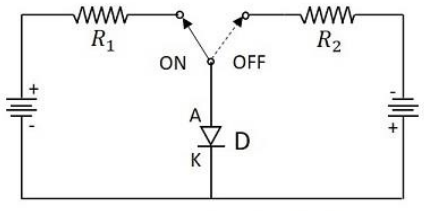
If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it can supply free electrons and holes with the extra energy they require to cross the junction as the width of the depletion layer around the PN junction is decreased.

By applying a negative voltage (reverse bias) results in the free charges being pulled away from the junction resulting in the depletion layer width being increased. This has the effect of increasing or decreasing the effective resistance of the junction itself allowing or blocking the flow of current through the diodes PN junction.

Diode as switch

Whenever a specified voltage is exceeded, the diode resistance gets increased, making the diode reverse biased and it acts as an open switch. Whenever the voltage applied is below the reference voltage, the diode resistance gets decreased, making the diode forward biased, and it acts as a closed switch.

The following circuit explains the diode acting as a switch.



Switching circuit using Diode

A switching diode has a PN junction in which P-region is lightly doped and N-region is heavily doped. The above circuit symbolizes that the diode gets ON when positive voltage forward biases the diode and it gets OFF when negative voltage reverse biases the diode.

Types of diodes and Applications

Different diodes are as follows

- PN junction diode
- Zener diode
- Light emitting diode (LED)
- Photo – diode
- Tunnel diode
- Laser diode etc

Applications of diodes are

- PN junction diode – used as a rectifier
- Zener diode – used as a voltage regulator
- Light emitting diode (LED) – used as indicators
- Photo diode – used in alarm circuits
- Tunnel diode – used in oscillators
- Laser diode etc – used in laser printers and optical fiber communications.

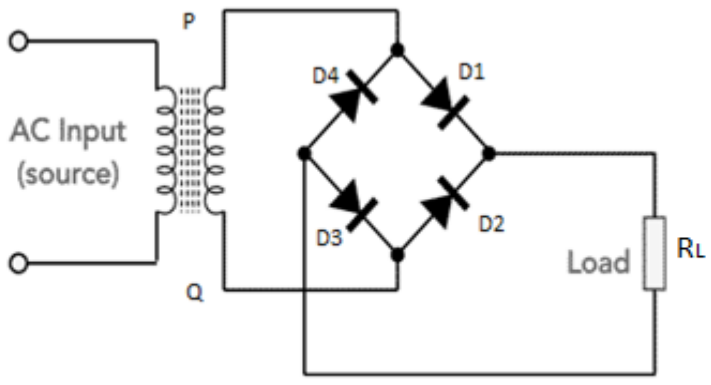
Rectifier

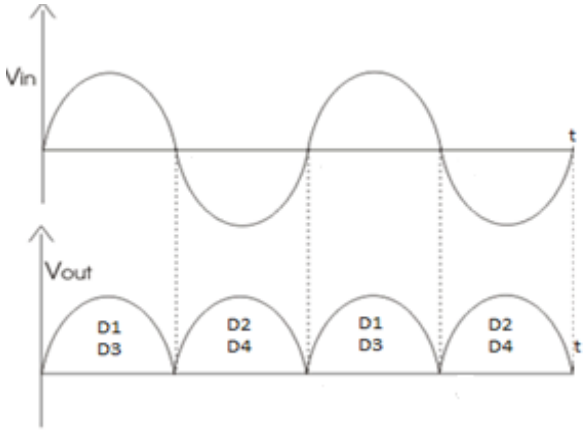
A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.

Need for AC to DC conversion

- AC signals cannot be stored and DC power or signals can be stored. Thus, to store the electrical energy we need to convert it into DC.
- Digital devices require constant voltages, thus to get those constant voltage levels (DC levels) we need to convert AC into DC using Rectifiers.
- For testing, monitoring any electronic device or system we require dc supply.

Bridge rectifier without filter



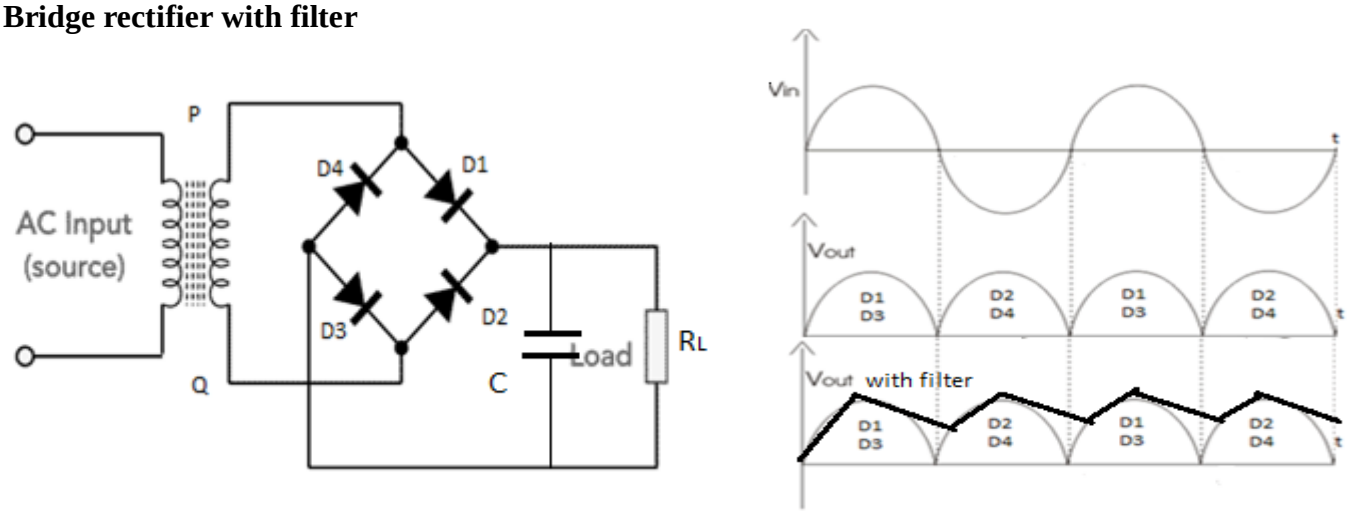


A full wave bridge rectifier consists of 4 diodes and a load.

During the positive half cycle of the input AC voltage, terminal P is positive with respect to Q. Diodes D1 and D3 are forward biased where as D2 and D4 are reverse biased. Hence the current flows through D1 and D3 and through load.

During the negative half cycle of the input AC voltage, terminal P is negative with respect to Q. Diodes D1 and D3 are reverse biased where as D2 and D4 are forward biased. Hence the current flows through D2 and D4 and through load. Therefore, current flowing through load is in same direction for both cycles of AC input voltage.

Bridge rectifier with filter



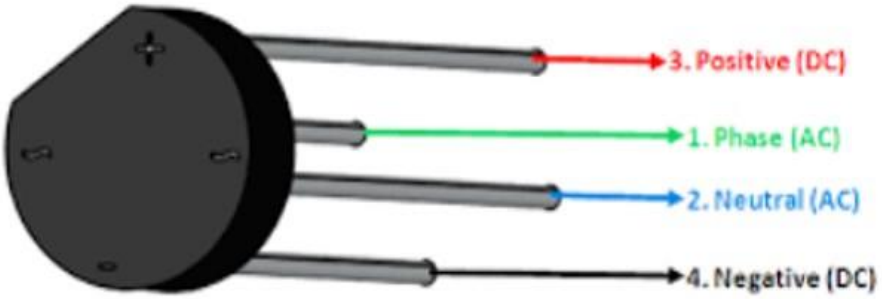
Bridge rectifier with filter works same as bridge rectifier without filter but across the load resistance R_L capacitor filter C is connected as shown in the circuit diagram.

The output Direct Current (DC) of the bridge rectifier contains small ripples. These small ripples can be reduced if we use the filter at the output. The filter normally used in the bridge rectifier is a capacitor filter. The filter converts the pulsating Direct Current (DC) into pure Direct Current (DC). The capacitor filter present at the output removes the unwanted AC components. Thus, a pure DC is obtained at the load resistor R_L.

Rectifier IC

The RB-156 is a commonly used Single Phase, compact and low-cost Bridge rectifier package. The maximum input AC voltage of this IC is 560V and the maximum value of DC current at the output is 1.5A hence it can be used in all countries for single phase mains supply.

It is a four-terminal device and internally consists of four diodes.



Pin Configuration Description

RB156 Bridge Rectifier consists of four pins in which two pins are AC input pins and the other two are DC output pins.
Pin# 01: Phase (AC)
It is an input pin where the phase wire of AC voltage supply is connected.
Pin# 02: Neutral (AC)
It is an input pin where the neutral wire of the AC voltage supply is connected.
Pin# 03: Positive (DC)
It is the output pin from where the rectified DC signal is obtained.
Pin# 04: Negative (DC)
It is the output pin that sends out a ground voltage signal of a rectifier.

Transistor (BJT)

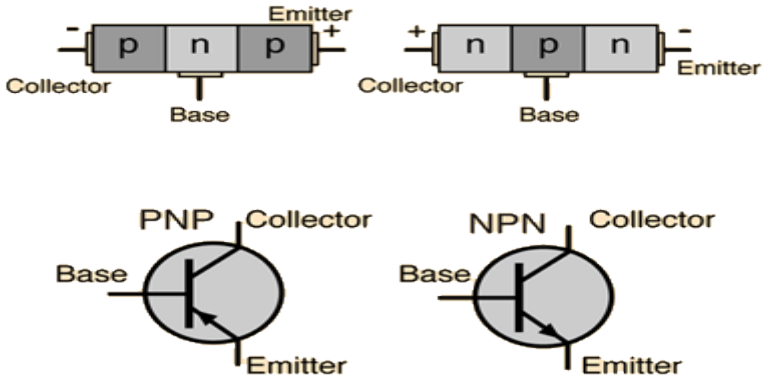
Transistor is a three terminal, two junction and three-layer P and N type semiconductor device.

Types of transistor

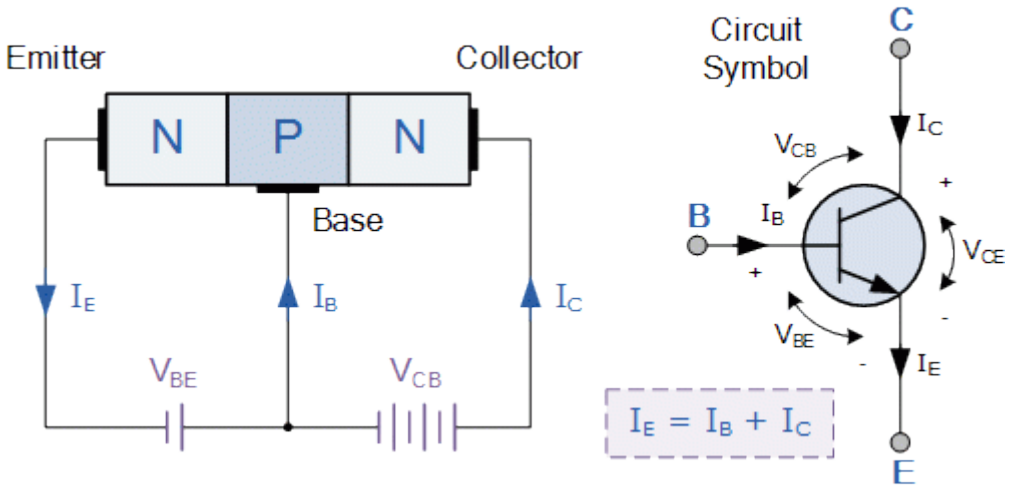
- NPN transistor
- PNP transistor

Transistor symbol and structure

A bipolar junction transistor consists of three regions of doped semiconductors. A small current in the center or base region can be used to control a larger current flowing between the end regions (emitter and collector). The device can be characterized as a current amplifier, having many applications for amplification and switching.



Working principle of transistor



For normal operation of a transistor the EB junction is always forward biased and CB junction is always reverse biased.

Fig shows the working of NPN transistor the negative voltage is applied to the N-type emitter, injects majority carriers(electrons) into the base. The base is connected to positive terminal, attracts these electrons. This constitutes the emitter current I_E.

Majority of these electrons cross the base and enter into the collector, constituting collector current I_C.

A small portion of electrons injected by the emitter into the base, constituting base current I_B. Hence the emitter current is the sum of base current I_B and collector current I_C. i.e $I_E = I_B + I_C$

Comparison of analog 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 are examples
It has Continuous range of values	It has Discontinuous values
Only be used in analog devices.	Suited for digital devices like computers

Digital systems

A digital system is a system which deals with discrete signal. The input and output of this system is two binary value which is 0 and 1. Digital systems contain devices such as logic gates, flip-flops, shift registers and counters. A computer is an example of a digital system.

Binary numbers, Boolean identities and laws

Number System Numbers are extremely important in our personal life. The Abacus is one of the earliest known calculators. New invention was digital system. There are various systems of arithmetic which are widely used in digital electronics.

1. **Binary Number System**: - The binary number system is base 2 system using 0 and 1.
2. **Octal Number System**: - The octal number system is base 8 system using 0 to 7.
3. **Decimal Number System**: - The decimal number system is base 10 system using 0 - 9
4. **Hexadecimal number System**: - The hexadecimal number system is base 16 system using 0 to 9 and A, B, C, D, E & F.

Binary Number System The binary number system is base 2 system where only digits 0 & 1 are used. In this numbering system all numbers are represented by 0‘s and 1‘s. Ex: - 01, 11, 10,110 etc.

Like normal algebra, Boolean algebra has a number of useful identities. An "identity" is merely a relation that is always true, regardless of the values that any variables involved might take on. Many of these are

very analogous to normal multiplication and addition, particularly when the symbols {0,1} are used for {FALSE, TRUE}.

The basic Laws of Boolean Algebra can be stated as follows:

- Commutative Law states that the interchanging of the order of operands in a Boolean equation does not change its result. For example:
  - OR operator → A + B = B + A
  - AND operator → A * B = B * A
- Associative Law of multiplication states that the AND operation are done on two or more than two variables. For example:
  A * (B * C) = (A * B) * C
- Distributive Law states that the multiplication of two variables and adding the result with a variable will result in the same value as multiplication of addition of the variable with individual variables. For example:
  A + BC = (A + B) (A + C).
- Annulment law:
  A.0 = 0
  A + 1 = 1
- Identity law:
  A.1 = A
  A + 0 = A
- Idempotent law:
  A + A = A
  A.A = A
- Complement law:
  A + A' = 1
  A.A'= 0
- Double negation law:
  ((A)')' = A
- Absorption law:
  A.(A+B) = A
  A + AB = A

De Morgan's Law is also known as De Morgan's theorem, works depending on the concept of Duality. Duality states that interchanging the operators and variables in a function, such as replacing 0 with 1 and 1 with 0, AND operator with OR operator and OR operator with AND operator.

De Morgan stated 2 theorems, which will help us in solving the algebraic problems in digital electronics. The De Morgan's statements are:

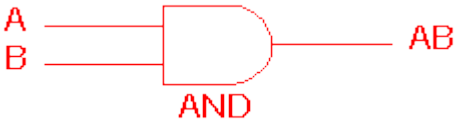
1. "The negation of a conjunction is the disjunction of the negations", which means that the complement of the product of 2 variables is equal to the sum of the compliments of individual variables. For example, (A.B)' = A' + B'.
2. "The negation of disjunction is the conjunction of the negations", which means that complement of the sum of two variables is equal to the product of the complement of each variable. For example, (A + B)' = A'B'.

Digital system building blocks

Logic gates perform basic logical functions and are the fundamental building blocks of digital system.

Digital systems are said to be constructed by using logic gates. These gates are the AND, OR, NOT, NAND, NOR, EXOR and EXNOR gates. The basic operations are described below with the aid of truth tables.

AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

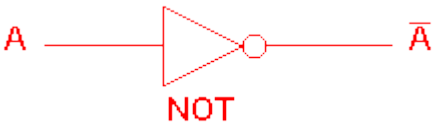
The AND gate is an electronic circuit that gives a high output (1) only if all its inputs are high. A dot (.) is used to show the AND operation i.e., A.B. Bear in mind that this dot is sometimes omitted i.e. AB

OR gate

2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

The OR gate is an electronic circuit that gives a high output (1) if one or more of its inputs are high. A plus (+) is used to show the OR operation.

NOT gate



NOT gate	
A	$\overline{A}$
0	1
1	0

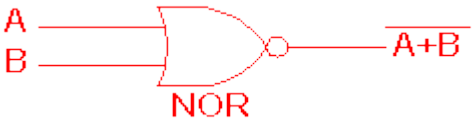
The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an inverter. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs.

NAND gate

2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if any of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

NOR gate



2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if any of the inputs are high.

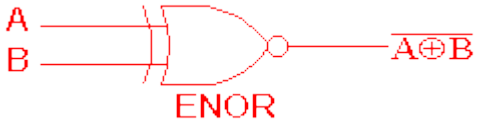
The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

EXOR gate

2 Input EXOR gate		
A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

The 'Exclusive-OR' gate is a circuit which will give a high output if either, but not both, of its two inputs are high. An encircled plus sign (⊕) is used to show the EOR operation.

EXNOR gate



2 Input EXNOR gate		
A	B	$\overline{A⊕B}$
0	0	1
0	1	0
1	0	0
1	1	1

The '**Exclusive-NOR**' gate circuit does the opposite to the EOR gate. It will give a low output if either, but not both, of its two inputs are high. The symbol is an EXOR gate with a small circle on the output. The small circle represents inversion.

The NAND and NOR gates are called universal gates since with these gates, we can realize all other gates and Boolean expressions.

IC (Integrated Circuit)

An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material that is normally silicon.

Advantages of IC

- Extremely small in size,
- Low power consumption,
- Reliability
- Reduced cost
- Very less weight
- Easy replacement.

Sensors

A device which detects or measures a physical property such as heat, light, sound, pressure etc and records, indicates, or otherwise responds to it.

Sensors detect the presence of energy, change into the transfer of energy. Sensors senses by receiving a signal from the device such as a transducer, then responding to the signal by converting it into an output that can easily be read and understood. These sensors convert a recognized signal into an electrical – analog or digital Signal – readable output. The light bulb converts the electrical energy into light and heat; however, it does not quantify how much light or heat. If the purpose of a device is to quantify an energy level, it is a sensor signal.

Types of sensors

Temperature sensor: A temperature sensor is a device that is designed to measure the degree of hotness or coolness in an object.

LM35 Temperature Sensor

The working of a temperature meter depends upon the voltage across the diode. The temperature change is directly proportional to the diode's resistance. The cooler the temperature, lesser will be the resistance, and vice-versa. The resistance across the diode is measured and converted into readable units of temperature (Fahrenheit, Celsius, Centigrade, etc.) and, displayed in numeric form over readout units.

Temperature sensors are used in Motors, Home appliances, Computers, Industrial equipment, Food Production and in medical equipment etc.

Pressure sensor: A pressure sensor is a device for pressure measurement of gases or liquids.

Pressure sensors have a sensing element of constant area and respond to force applied to this area by fluid pressure. The force applied will deflect the diaphragm inside the pressure sensor. The deflection of the internal diaphragm is measured and converted into an electrical output. This allows the pressure to be monitored by microprocessors, programmable controllers and computers along with similar electronic instruments.

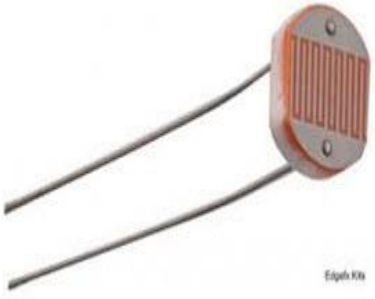
Pressure sensors are used in a wide range of industries, including the automotive industry, Biomedical Instrumentation, aviation and the marine industry etc.

Water sensor: Water sensors detect the presence of water and, when placed in locations where water should not be present or a leak.

The resistance is inversely proportional to the height of the water. The more water the sensor is immersed in, results in better conductivity and will result in a lower resistance. The less water the sensor is immersed in, results in poor conductivity and will result in a higher resistance. The sensor produces an output voltage according to the resistance, which by measuring we can determine the water level.

Water sensor are used in Washing machines, Dishwashers, Refrigerators with ice makers, Hot-water heaters, Sinks, Toilets etc

Light sensor: The light sensor is a passive device that convert this "light energy" into an electrical signal output. Light sensors are known as "Photo Sensors" because the convert light energy into electricity.



Light Dependent Resistor (LDR) or photoresistor is a special type of light sensor which is used in automatic light sensor circuit. LDR is a variable resistor and its resistance is controlled by light intensity. In the night time, if the light illuminated on LDR sensor decreases, then the LDR resistance goes very high. In the daytime, if the light is illuminated on LDR, then the resistance of LDR goes low. Hence, the resistance of LDR and the light illuminated on LDR are inversely proportional to each other. That variation of resistance is used to find the light intensity.

Light sensors have a lot of uses. The most common use in our daily lives is in cell phones and tablets. Most portable personal electronics now have ambient light sensors used to adjust brightness. Another common place use for light sensors is controlling automatic lights in automobiles and streetlamps.

Sound sensor: Sound detection sensor works similarly to our Ears, having diaphragm which converts vibration into electrical signals.

Sound sensor consists of an in-built capacitive microphone, peak detector and an that's highly sensitive to sound. Sound waves propagate through air molecules. Such sound waves cause the diaphragm in the microphone to vibrate, resulting in capacitance change. Capacitance change is then amplified and digitalized for processing of sound intensity.

Sound sensors are used in Consumer electronics such as phones, computers, music systems, burglar alarms, door alarm, Home automation, Ambient sound recognition and sound level recognition etc

Smoke sensor: A smoke detector is an electronic fire-protection device that automatically senses the presence of smoke, as a key indication of fire.

Ionization-type smoke alarms have a small amount of radioactive material between two electrically charged plates, which ionizes the air and causes current to flow between the plates. When smoke enters the chamber, it disrupts the flow of ions, thus reducing the flow of current and activating the fire alarm.

Smoke sensors are used in electronic fire-protection device that automatically senses the presence of smoke, as a key indication of fire, and sounds a warning to building occupants. Commercial and industrial smoke detectors issue a signal to a fire alarm control panel as part of a building's central fire alarm system.

Proximity Sensors: A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor is a non-contact sensor that detects the presence of an object (often referred to as the "target") when the target enters the sensor's field. Depending on the type of proximity sensor, sound, light, infrared radiation (IR), or electromagnetic fields may be utilized by the sensor to detect a target.

Figure shows **IR proximity sensor**. Active infrared sensors emit and detect infrared radiation. Active IR sensors have two parts: a light emitting diode (LED) and a receiver. When an object comes close to the sensor, the infrared light from the LED reflects off of the object and is detected by the receiver.

Used in automated production lines for object detection, position, inspection and counting. And used in smartphones to detect if a user is holding their phone near their face. Part detection on industrial conveyor systems. Collision detection on robots etc

Flow sensor: A flow sensor (more commonly referred to as a “flow meter”) is an electronic device that measures or regulates the flow rate of liquids and gasses within pipes and tubes.

The main working principle behind the working of this sensor is the Hall effect. According to this principle, in this sensor, a voltage difference is induced in the conductor due to the rotation of the rotor. This induced voltage difference is transverse to the electric current.

Used as Water flow sensors can measure the rate of flow of water either by measuring velocity or displacement. These sensors can also measure the flow of water like fluids such as measuring milk in a dairy industry etc.

Humidity sensor: A humidity sensor is a device that detects and measures water vapor.

The Resistive Humidity Sensor is usually made up of materials with relatively low resistivity and this resistivity changes significantly with changes in humidity. The relationship between resistance and humidity is inverse exponential.

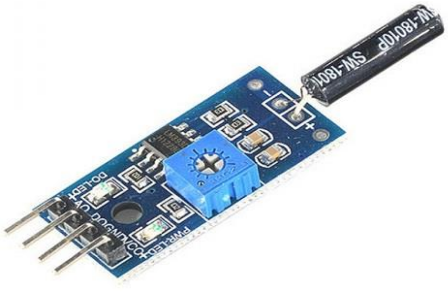
Widely used in consumer, industrial, biomedical, and environmental etc. applications for measuring and monitoring Humidity.

Voltage sensor: A voltage sensor is a sensor is used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine both the AC voltage or DC voltage level.

The resistor in the circuit works as a sensing element. The voltage can be separated into two resistors like a reference voltage & variable resistor to make a circuit of the voltage divider. A voltage supply is applied to this circuit. The output voltage can be decided by the resistance used in the circuit. So the voltage change can be amplified.

Voltages sensors are use in Power failure detection, Load sensing, Safety switching, Temperature control, Power demand control, Fault detection etc

Vibration sensor: A vibration sensor is a device that measures the amount and frequency of vibration in a given system, machine, or piece of equipment.



Vibration is most commonly measured using a ceramic piezoelectric sensor or accelerometer. An accelerometer is a sensor that measures the dynamic acceleration of a physical device as a voltage.

The applications of vibration sensors include different industries for measuring the vibration. The exclusive industrial characteristics will decide sensor characteristics.

Actuators

An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An actuator requires a control signal and a source of energy.

An actuator is a device that converts energy, which may be electric, hydraulic, pneumatic, etc., to mechanical in such a way that it can be controlled. The quantity and the nature of input depend on the kind of energy to be converted and the function of the actuator. Electric and piezoelectric actuators, for instance, work on the input of electric current or voltage, for hydraulic actuators, its incompressible liquid, and for pneumatic actuators, the input is air. The output is always mechanical energy.

Types and applications of actuators

- According to Type of Motion
    1. Linear
    2. Rotary Actuator
- According to type of Power Used
    1. Hydraulic
    2. Pneumatic
    3. Electrical
    4. Magnetic
    5. Mechanical Actuator

Actuators have applications in the following areas:

- In automation: used for packing, label scanning and printing and robotics control etc.
- In automobiles: used in car bannet control, door locking, window control etc.
- In medical industry: used in ventilators and patient handling
- Other machines: used in CNC machines to control tool movements, material handling machines robotic welding machines etc.

Relay as an actuator

A relay is regarded as a binary actuator as it has two stable states. Relays are either energized and latched or de-energized and unlatched. While an actuator acts as a device which helps to bring about necessary mechanical movements a relay basically works as a switch.

Microcontroller as a programmable device

A microcontroller contains has CPUs (processor cores) along with memory and programmable input/output peripherals. Microcontrollers are designed for embedded applications.

Microcontrollers are typically programmed in higher-level languages such as C, C++ or Java. One of the essential tools needed to program a microcontroller is an integrated development environment (IDE). Microcontroller are used to perform only one task. The systems designed using microcontroller are portable economical and consumes less power. Most popular manufacturers of microcontroller are Intel, Atmel, Philips Motorola etc.

Examples:8051,8052 etc. There are 8 bit, 16bit and 32bit microcontrollers available in the market.

Applications of Microcontroller

Microcontrollers are embedded inside large number of products found in automobiles, entertainment, instrumentation and consumer items.

Some of the real time applications are:

- In home appliances such as YV remote controllers, telephones, cameras, sewing machines, washing machines, microwave oven etc.
- In automobiles such as car security alarm, tri meter, transmission control etc.
- In modern digital electronics equipment's like storage oscilloscope, signal generator, refrigerators, air conditioners, cellular phones, toys, printers etc.

PLC and Their applications

A PROGRAMMABLE LOGIC CONTROLLER (PLC) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices.

PLCs are complex and powerful computers. But we can describe the function of a PLC in simple terms. The PLC takes inputs, performs logic on the inputs in the CPU and then turns on or off outputs based on that logic. The CPU monitors the status of the inputs. PLCs are the preferred method of controlling, measuring, and carrying out tasks in complex manufacturing and industrial applications.

Types of PLCs

- Integrated or Compact PLC
- Modular PLC
- Small PLC
- Medium PLC
- Large PLC

Applications of PLC

- A programmable logic controller (PLC) is an electronic device used in many industries to monitor and control construction systems and production processes.
- PLC 's are used in several industries like petrochemical, biomedical, cement manufacturing, oil and gas sector etc