Brindavan College of Engineering

Department of Mechanical Engineering

NOTES

Of
Mechatronics
*18ME744*

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UNIT – I MECHATRONICS, SENSORS AND TRANSDUCERS

MECHATRONICS:

It field of study that implies the synergistic integration of electronic engineering, electrical engineering, control engineering and computer technology with mechanical engineering for the design, manufacture, analyse and maintenance of a wide range of engineering products and processes".`
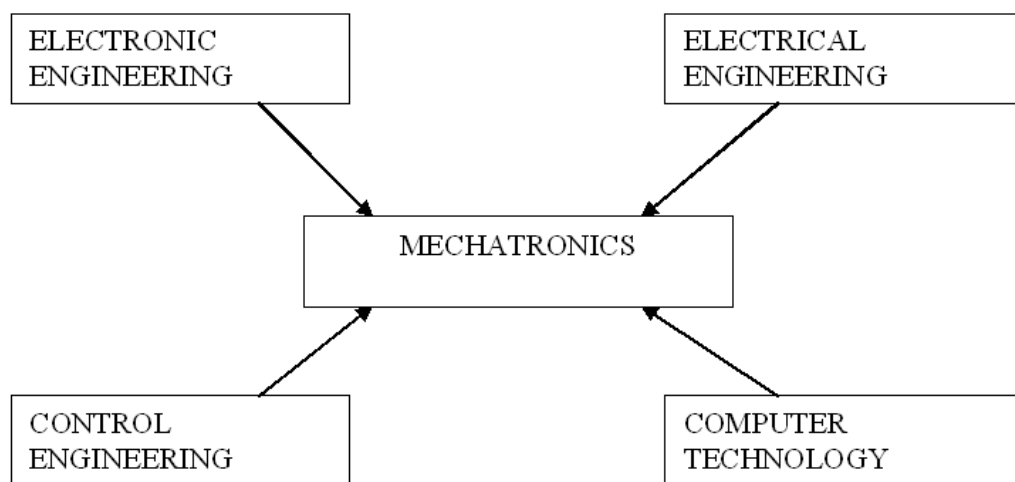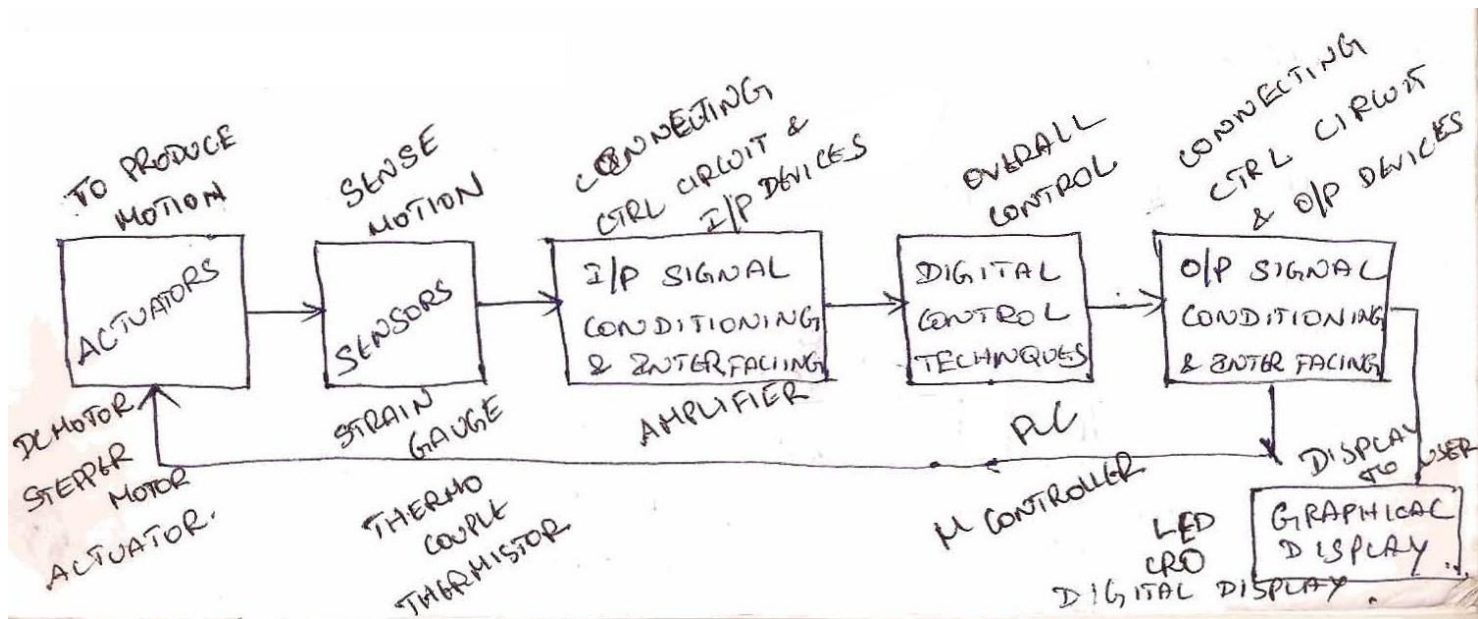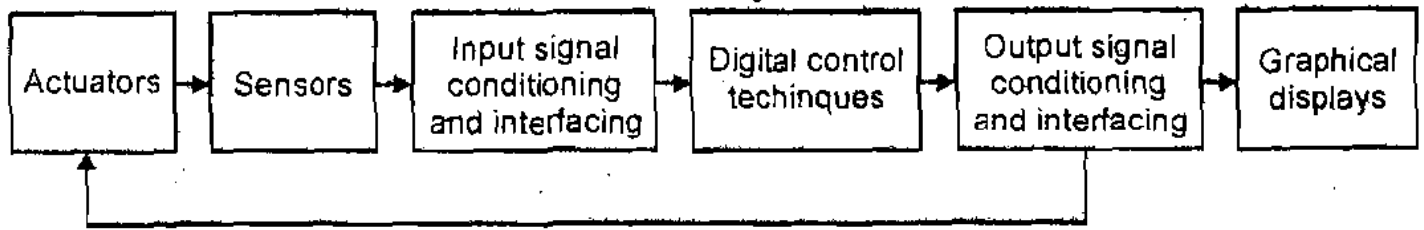

SYSTEM:

A system may be defined as a black box which has an input and an output. System concerned only with the relationship between the input and output and not on the process going inside the box.
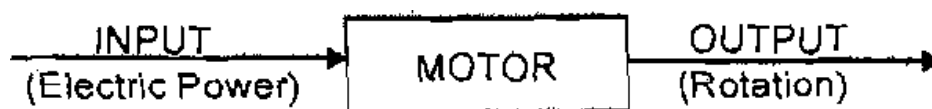
Here, the input is the electric power and the output after processed by the system is rotation. The system is motor.

MECHATRONIC SYSTEM:

Actuators: Solenoids, voice coils, D.C. motors, Stepper motors, Servomotor, hydraulics, pneumatics.

Sensors: Switches, Potentiometer, Photoelectrics, Digital encoder, Strain gauge, Thermocouple, accelerometer etc.

Input signal conditioning and interfacing: Discrete circuits, Amplifiers, Filters, A/D, D/D.

Digital control architecture: Logic circuits, Microcontroller, SBC, PLC, Sequencing and timing, Logic and arithmetic, Control algorithm, Communication.

Output signal conditioning and interfacing: D/A D/D, Amplifiers, PWM, Power transistor, Power Op - amps.

Graphical displays: LEDs, Digital displays, LCD, CRT

The actuators *produce motion or cause some action;*

The sensors *detect the state of the system parameters, inputs and outputs;*

Digital devices *control the system;*

Conditioning and interfacing circuits *provide connection between the control circuit and the input/output devices*;

Graphical displays *provide visual feedback to users.*

MEASUREMENT SYSTEM:

A measurement system can be defined as a black box which is used for making measurements. It has the input as the quantity being measured and the output **as** a measured value of that quantity.
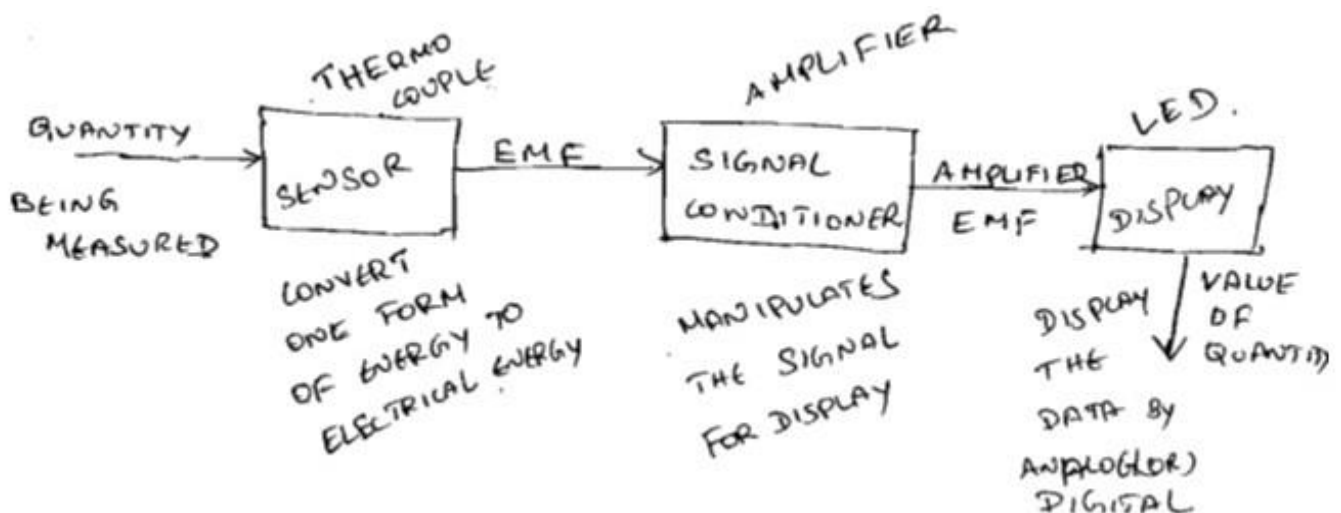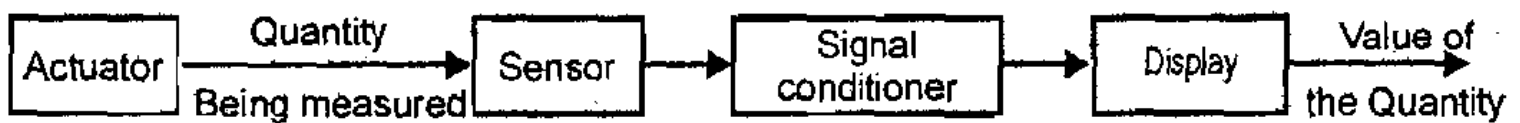
Example:
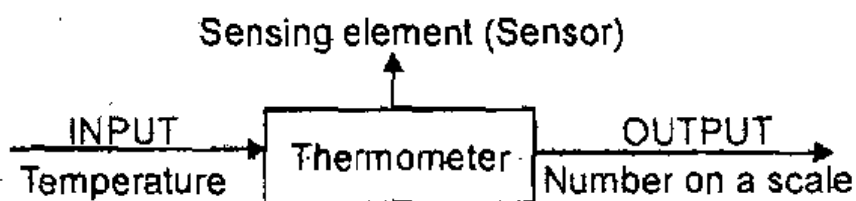
Elements of Measurement Systems:

Measurement system consists of the following three elements.

      a) Sensor   **b)** Signal conditioner   **c)** Display System

Sensor:

A sensor consists of transducer whose function is to convert the one form of energy into electrical form of energy. A sensor is a sensing element of measurement system that converts the input quantity being measured into an output signal which is related to the quantity

Example:

Temperature Sensor	– Thermocouple
Input	– Temperature
Output	– E.M.F (Electrical Parameter).

Signal Conditioner:

A signal conditioner receives signal from the sensor and manipulates it into a suitable condition for display. The signal conditioner performs filtering, amplification or other signal conditioning on the sensor output.

Example:

|	
Temperature measurement	– Single Conditioner function (Amplifier)
Input	– Small E.M.F value (From sensor)
Output	– Big E.M.F Value (Amplified).

Display System:

A display system displays the data (output) from the signal conditioner by analog or digital. A digital system is a temporary store such as recorder.

Example:

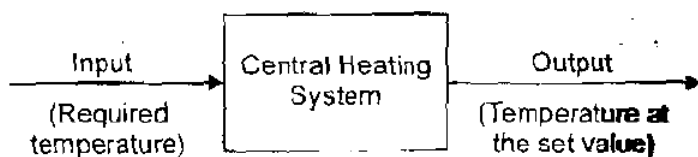|	
Display	– L.E.D (or) Number on scale by pointer movement
Input	– Conditioned Signal (from signal conditioner)
Output	– Value of the quantity (Temperature)

Temperature Measurement System:

(Sensor)   (Signal conditioner)   (Display system)
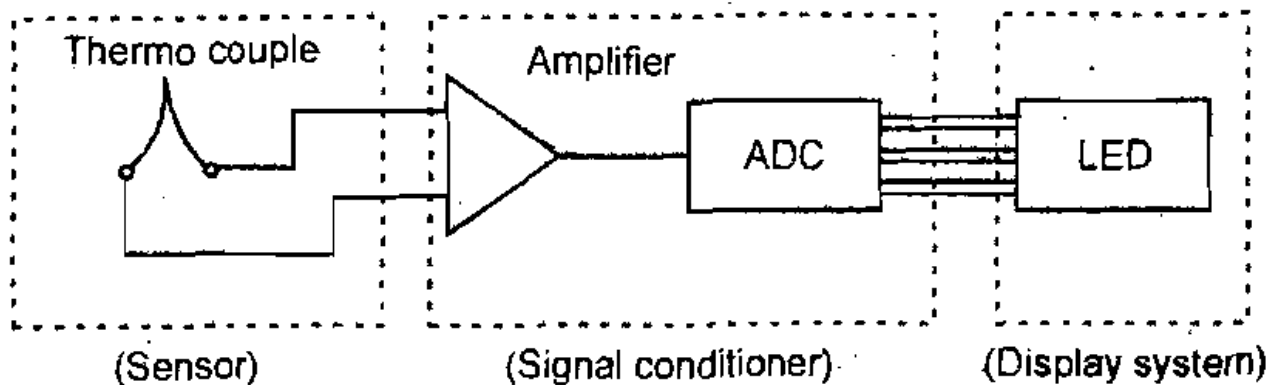
CONTROL SYSTEM:

A black box which is used to control its output in a pre-set value

Example:

	Control system	-	Air conditioning Unit
	Input	-	Surrounding temperature
	Output	-	Preset value (Temperature maintained in a house)

OPEN LOOP CONTROL SYSTEM:

❖ If there is **no feedback** device to compare the actual value with desired one.

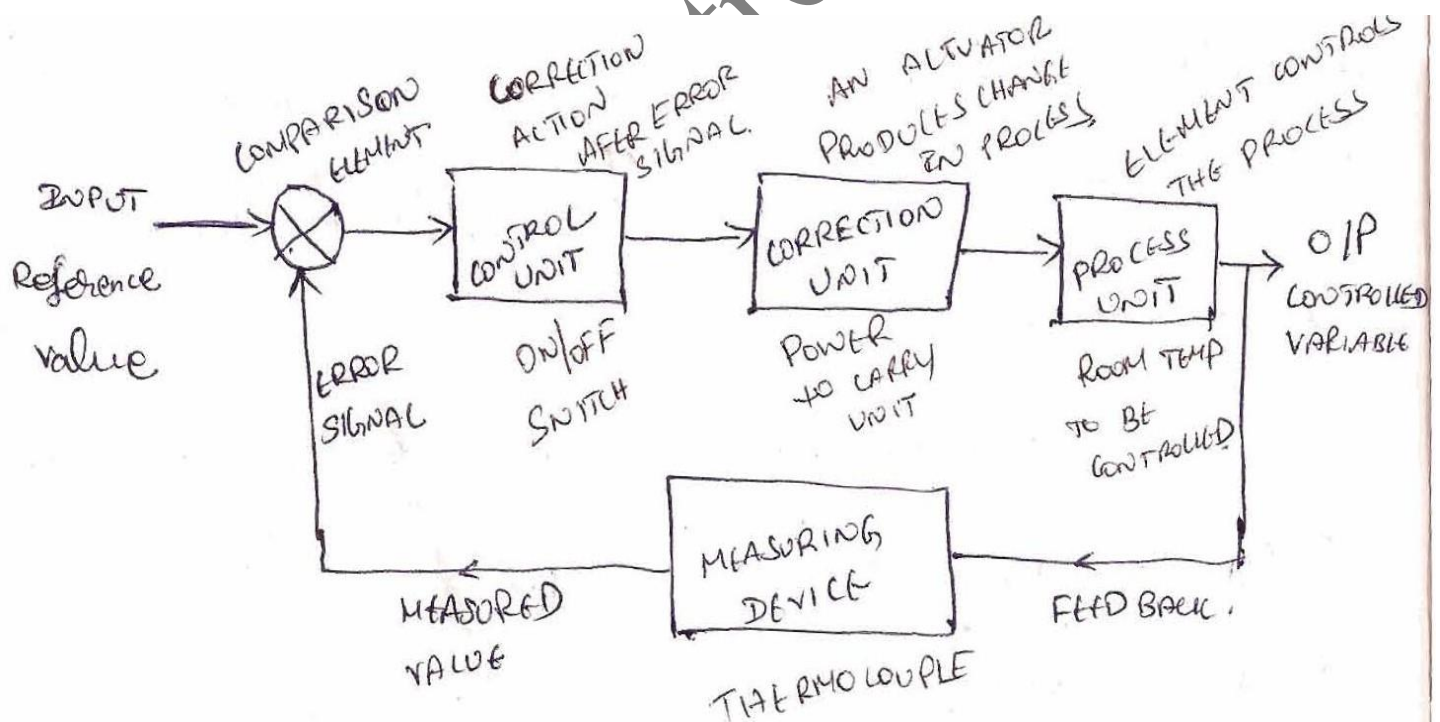❖ No control over its input
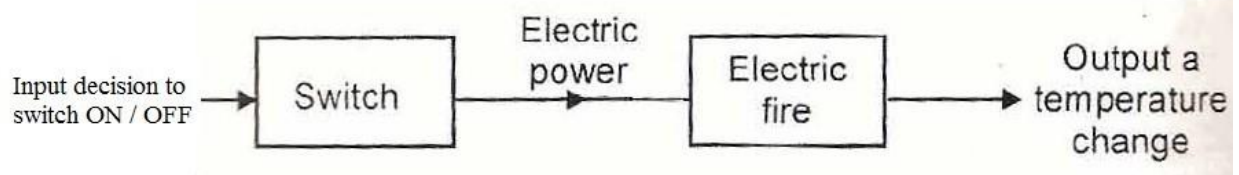
CLOSED LOOP CONTROL SYSTEM:

❖ If there is **feedback** device to compare the actual value with desired one.
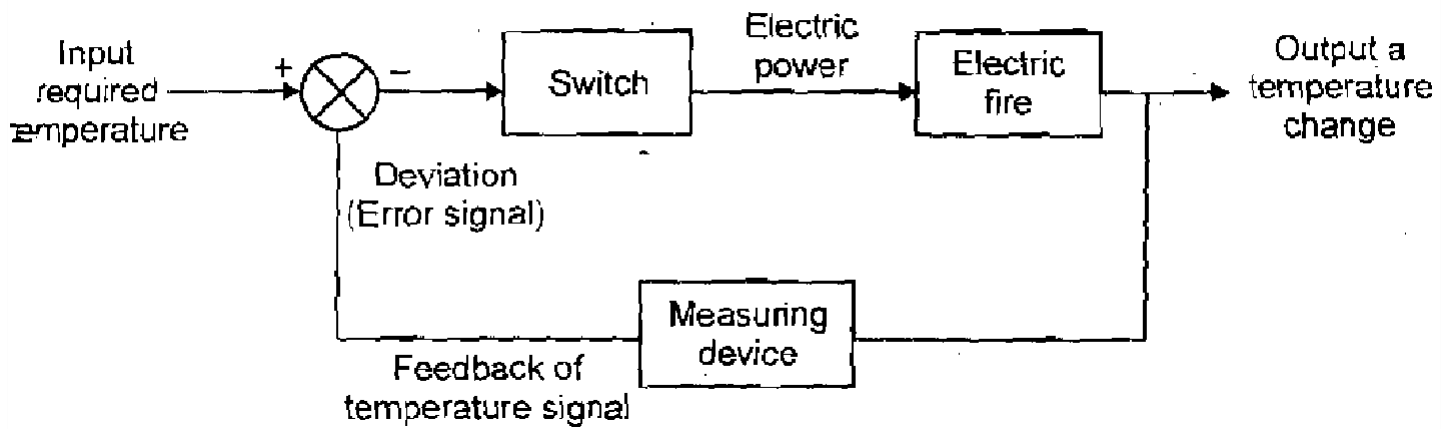
Elements of Closed Loop System:

The elements of closed loop control system are

- ❖ Comparison Unit
- ❖ Control Unit
- ❖ Correction Unit
- ❖ Process Unit
- ❖ Measurement Device

1. Comparison Element

This element compares the required or reference value of the variable condition being controlled with the measured value and produces an error signal.

$$Error\ Signal\ =\ Reference\ value - measured\ value$$

2. Control Element

This element decides the corrective action to be taken when an error signal is received by it.

Example: A signal to operate switch ON/OFF or valve open / close.

3. Correction Element

Correction element is an actuator that produces a change in a process to correct or change the controller condition. It also provides the power to carry out the control action, hence it is known as actuator.

4. Process Element

An element that controls the process is known as process element.

Example: Room temperature of a house is being controlled.

5. Measurement Element

The measurement element produces a signal related to the variable condition of the process that is being controlled.

Example: Thermocouple gives EMF related to temperature.

EXAMPLES:

System of Controlling Room Temperature

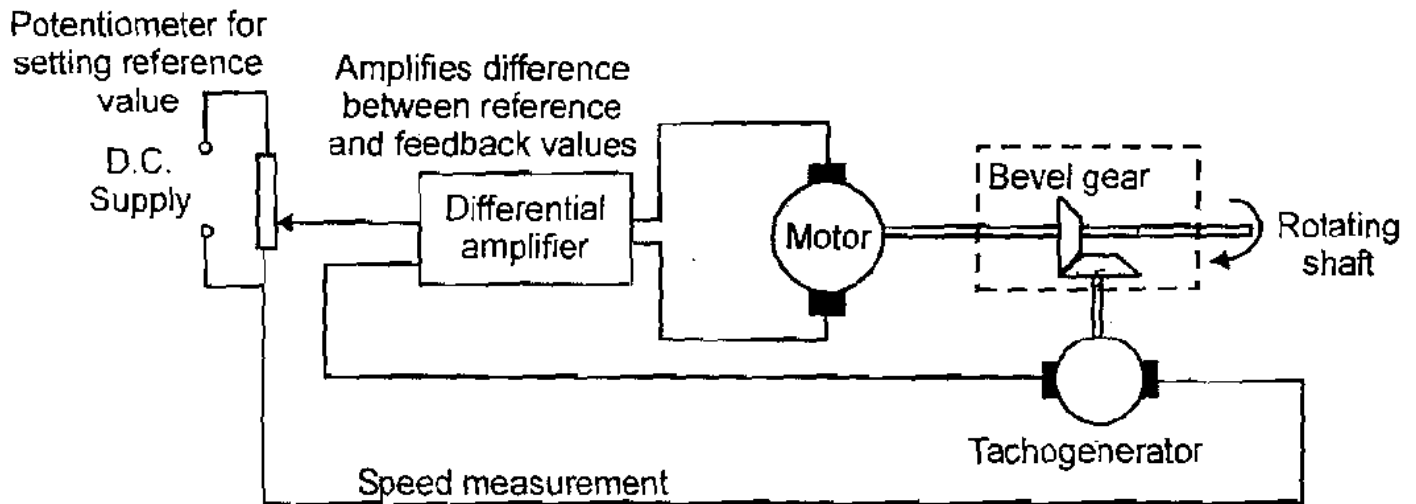|	
Controlled Variable	: Room temperature
Reference Variable	: Required Room temperature (pre-set value)
Comparison Element	: Person compares the measured value with required value
Error Signal	: Different between the measured and required temperatures.
Control Unit	: Person
Correction Unit	: The switch on the fire
Process	: Heating by the fire
Measuring Device	: Thermometer.

System of Controlling Water Level

Controlled variable	: Water level in the tank
Reference variable	: Initial setting of thc float and lever position
Comparison Element	: The lever
Error signal positions	: Difference between the actual & initial *setting* of the lever
Control Unit	: The pivoted lever
Correction Unit	: The flap opening or closing the water supply
Process	: The water level in the tank
Measuring device	: The floating ball and lever
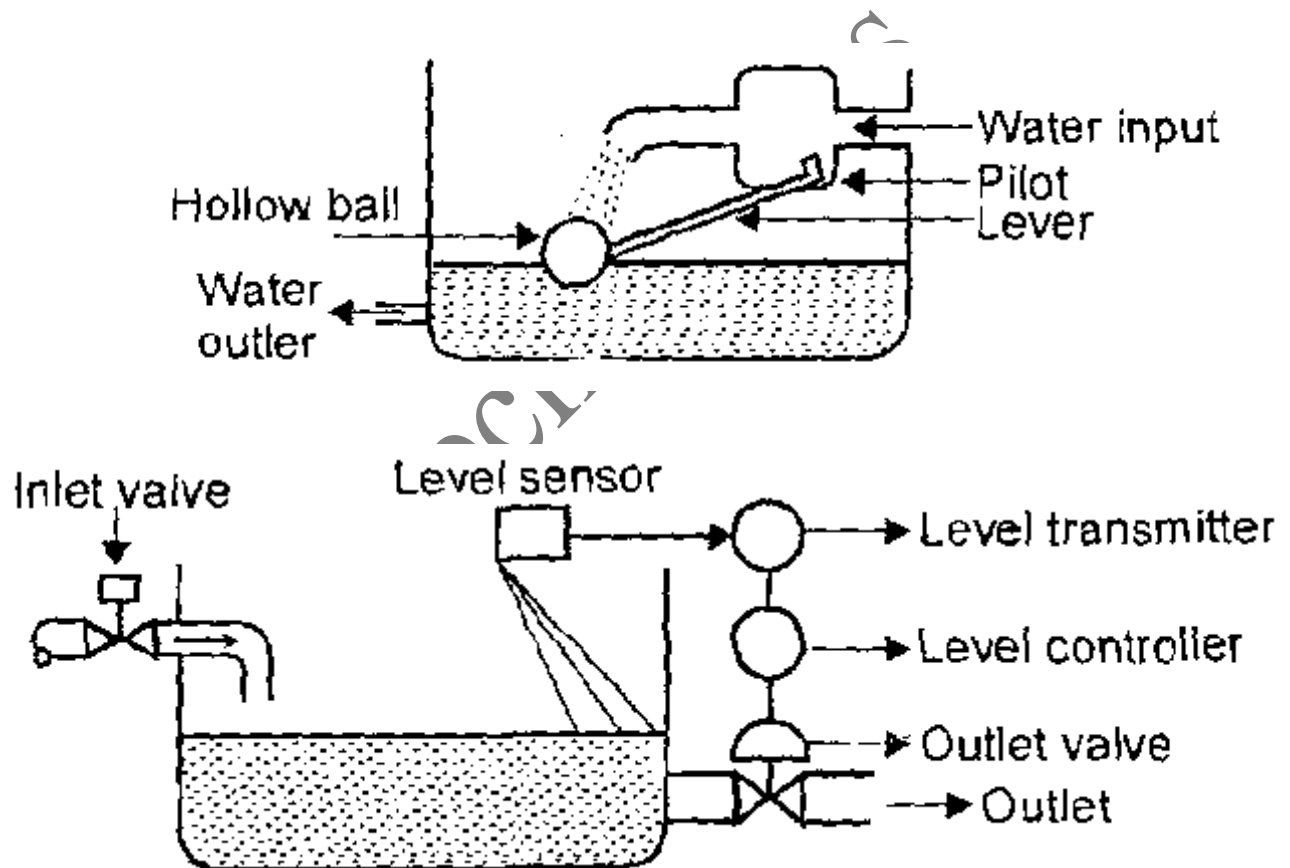
Automatic Speed Control of Rotating Shaft

Potentiometer	- To set the reference value (Voltage to be supplied to differential *amplifier)*
Differential amplifier	- To compare amplify the difference between the reference and feedback values

Tachogenerator   - To measure the speed of the rotating shaft and is connected

to the rotating shaft by means of a pair of level gears.

SEQUENTIAL CONTROLLERS:

It is used to control the process that are strictly ordered in a time or sequence

DOMESTIC WASHING MACHINE:
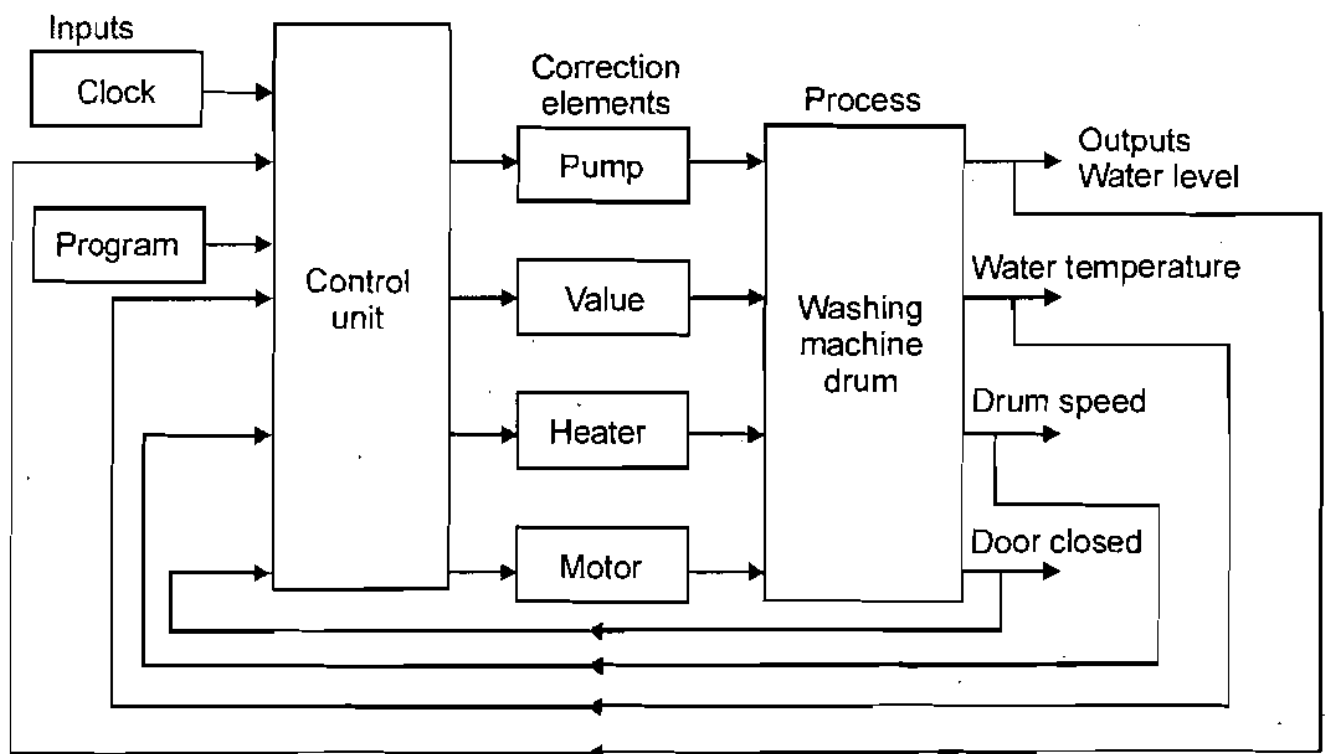
Pre Wash Cycle:

Pre-wash cycle may involve the following sequence of operations.

❖ Opening of valve to fill the drum when a current is supplied

- ❖ Microprocessor is used to operate the switch for opening closing the valve.
- ❖ Closing the valve after receiving the signal from a sensor when the required level of water is filled in the washing drum.
- ❖ Stopping the flow of water after the current is switched off by the microprocessor.
- ❖ Switch on the motor to rotate for stipulated time.
- ❖ Initiates the operation of pump to empty the water from the drum.
- ❖ Pre-wash cycle involves washing the clothes in the d m by cold water.

Main Wash Cycle:

Main wash cycle involves washing the clothes in the drum by hot water and the sequence of operations in main wash is as follows:

- ❖ Cold water is supplied after the Pre-wash cycle is completed.
- ❖ Current is supplied in large amount to switch on the heater for heating the cold water.
- ❖ Temperature sensor switches off the current after the water is heated to required temperature.
- ❖ Microprocessor or cam switch ON the motor to rotate the drum
- ❖ Microprocessor or cam switches on the current to a discharge pump to empty the drum.

Rinse Cycle:

Rinse cycle involves washing out the clothes with cold water a number of times and the sequence of operations in a Rinse cycle are as follows:

- ❖ Opening of valve to allow cold water into the drum when the microprocessor are given signals to supply current after the main wash cycle is completed.
- ❖ Switches off the supply current by the signals from microprocessor
- ❖ Operation of motor to rotate the drum
- ❖ Operation of pump to empty the drum and respect this sequence a number of times.
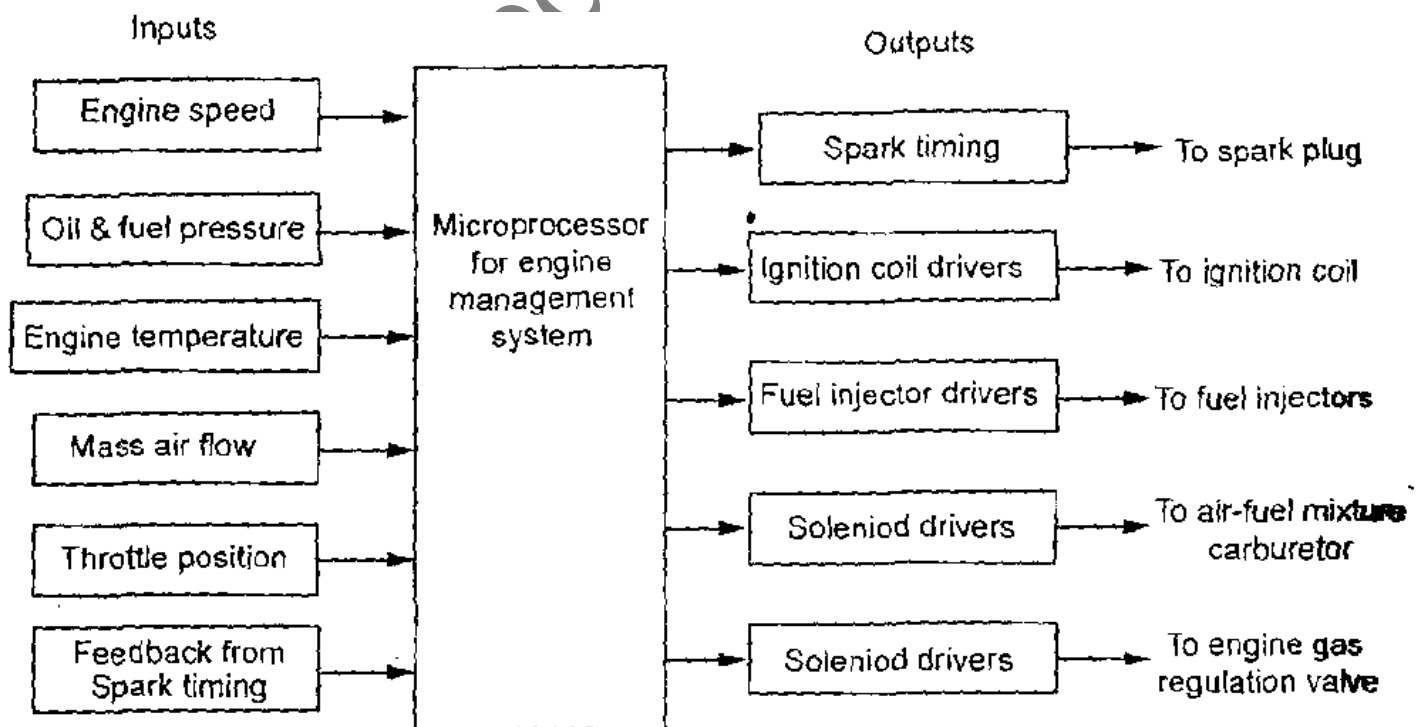
Spinning Cycle

Spinning cycle involves removing of water from the clothes and the sequence of operations is

- ❖ Switching on the drum motor to rotate it at a higher speed than a rinsing cycle.

AUTOMATIC CAMERA:
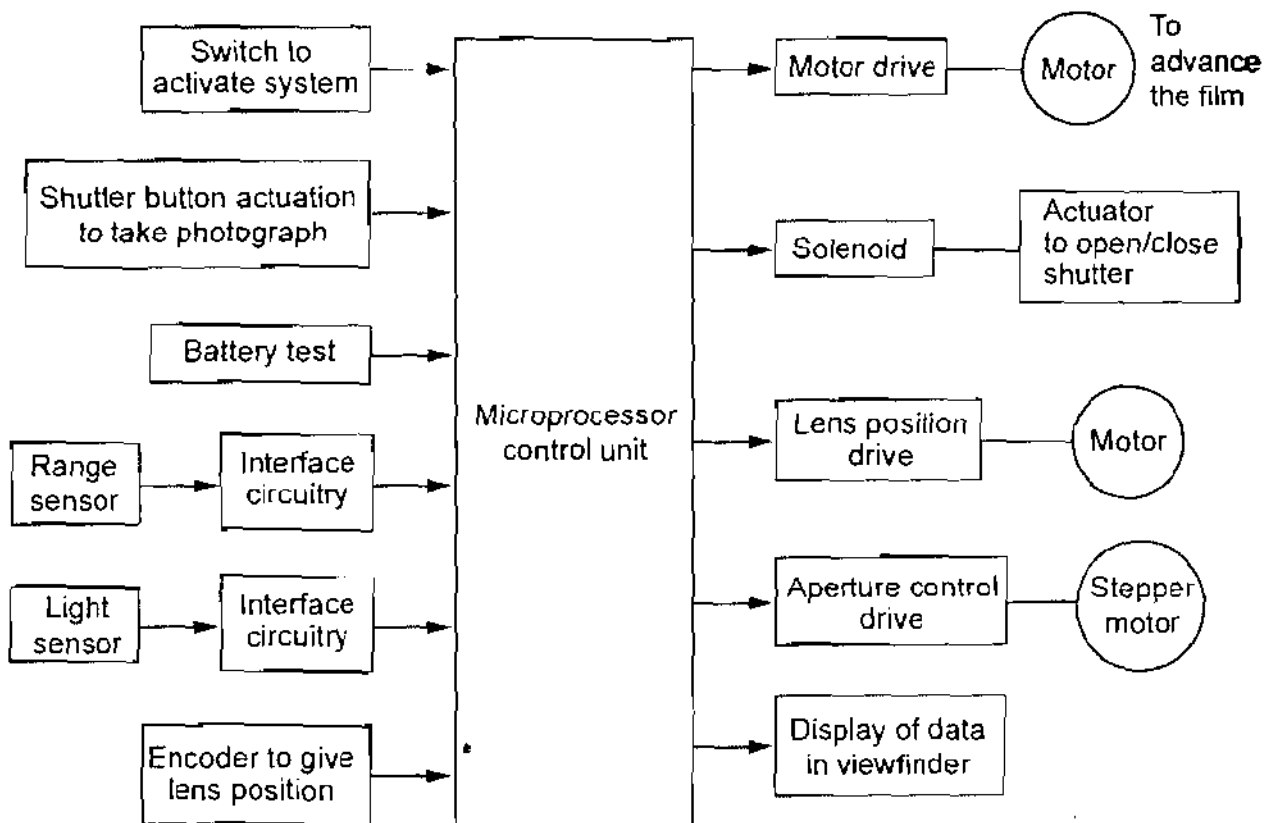
ENGINE MANAGEMENT SYSTEM:

SENSORS

Transducers:

It is an element which is subjected to physical change experience a related change.

Example: Tactile Sensors.

Sensors:

It is an element which is not subjected to physical change experience a related change.

Example: LVDT

PERFORMANCE TERMINOLOGY:

Static Characteristics:

Range and Span:

❖ The range of a transducer defines the limits between which the input can vary.

❖ The difference between the limits (maximum value - minimum value) is known as span.

❖ For example a load cell is used to measure force. An input force can vary from 20 to 100 N. Then the range of load cell is 20 to 100 N. And the span of load cell is 80 N (i.e., 100-20)

Error:

❖ The algebraic difference between the indicated value and the true value of the measured parameter is termed as the error of the device.

❖ Error = Indicated value — true value

❖ For example, if the transducer gives a temperature reading of 30°C when the actual temperature is 29° C, then the error is + 1°C. If the actual temperature is

❖ 3 1° C, then the error is — 1°C.

Accuracy:

❖ Accuracy is defined as the ability of the instrument to respond to the true value of the measure variable under the reference conditions.

❖ For example, a thermocouple has an accuracy of ± 1° C. This means that reading given by the thermocouple can be expected to lie within + 1°C (or) — 1°C of the true value.

❖ Accuracy is also expressed as a percentage of the full range output (or) full scale deflection.

❖ For example, a thermocouple can be specified as having an accuracy of ±4 % of full range output. Hence if the range of the thermocouple is 0 to 200°C, then the reading given can be expected to be within + 8°C (or) — 8°C of the true reading.

Sensitivity:

❖ The sensitivity is the relationship showing how much output we can get per unit input.

❖ sensitivity = Output / Input

Precision:

❖ It is defined as the degree of exactness for which the instrument is intended to perform.

Hysteresis error:

❖ When a device is used to measure any parameter plot the graph of output Vs value of measured quantity.

❖ First for increasing values of the measured quantity and then for decreasing values of the measured quantity.

❖ The two output readings obtained usually differ from each other.
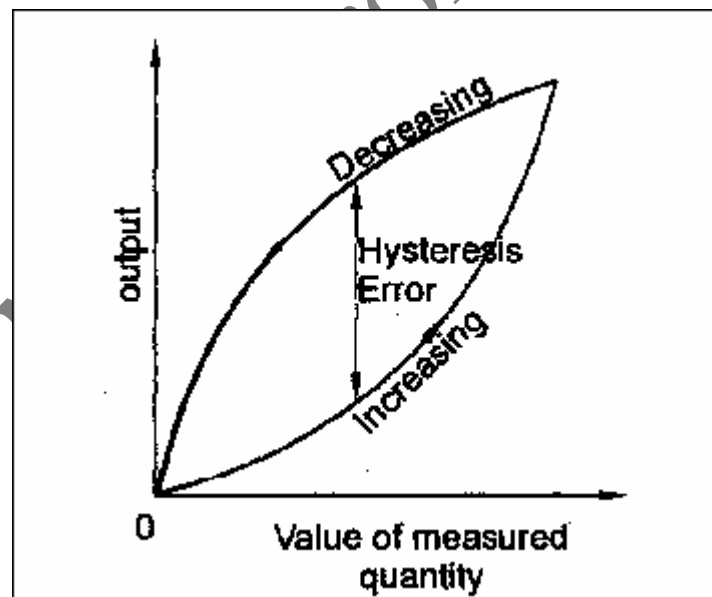
Repeatability:

❖ The repeatability and reproducibility of a transducer are its ability to give the same output for repeated applications of the same input value.

Reliability:

❖ The reliability of a system is defined as the possibility that it will perform its assigned functions for a specific period of time under given conditions.

Stability:

❖ The stability of a transducer is its ability to give the same output when used to measure a constant input over a period of time.

Drift:

❖ The term drift is the change in output that occurs over time.

Dead band:

❖ There will be no output for certain range of input values. This is known as dead band. There will be no output until the input has reached a particular value.

Dead time:

❖ It is the time required by a transducer to begin to respond to a change in input value.

Resolution:

❖ Resolution is defined as the smallest increment in the measured value that can be detected.

❖ The resolution is the smallest change in the input value which will produce an observable change in the input.

Backlash:

❖ Backlash is defined as the maximum distance (or) angle through which any part of a mechanical system can be moved in one direction without causing any motion of the attached part.

❖ Backlash is an undesirable phenomenon and is important in the precision design of gear trains.

SELECTION OF DISPLACEMENT, POSITION & PROXIMITY SENSOR:

❖ Size of the displacement (mm)

❖ Displacement type (Linear or angular)

❖ Resolution required

❖ Accuracy Required

❖ Material of the object

❖ Cost

DISPLACEMENT SENSORS

❖ Displacement sensors are contact type sensor

Types of Displacement sensors:

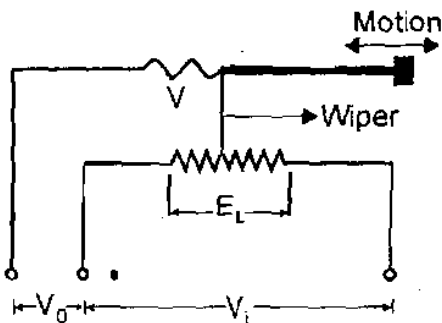❖ Potentiometer

❖ Strain gauge

❖ Capacitive sensors

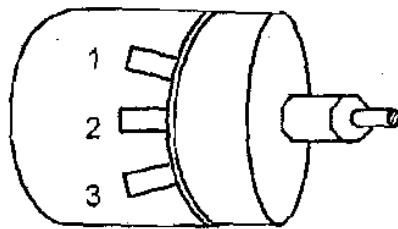❖ Linear variable differential transformer

POTENTIOMETER

PRINCIPLE:

❖ It works on *variable resistance transduction principle*

Linear or Rotary potentiometer is a variable resistance displacement transducer which uses the variable resistance transduction principle in *which the displacement or rotation is converted into a potential difference* due to the movement of *sliding contact over a resistive element*

Linear Potentiometer   Rotary Potentiometer
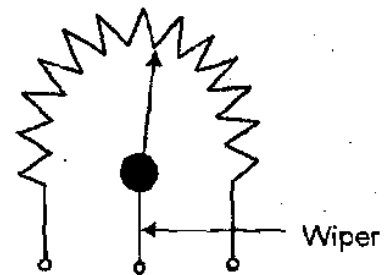
CONSTRUCTION & WORKING:

❖ A resistor with three terminals.

❖ Two end terminal & one middle terminal (wiper)

❖ Two end terminal are connected to external input voltage

❖ One middle and one end terminal as output voltage

❖ The slider determines the magnitude of the potential difference developed

Characteristics:

Resistance element   =   Precision Drawn wire with a diameter of about 25
                               to 50 microns, and wad over a cylindrical or a flat
                          mandrel of ceramic, glass or Anodized

Aluminium. 2mm to 500 mm in case of linear pot.

    =   For high resolution, wire is made by using ceramic

(cermet) or conductive plastic film due to low noise

levels.

Wipers (Sliders)	=	Tempered phosphor bronze, beryllium copper or other precious alloys.
Wire Material	=	Strong, ductile and protected from surface corrosion by enamelling or oxidation. Materials &e alloys of copper nickel, Nickel chromium, and silver palladium.
	=	Resistivity of wire ranges from 0.4 $\mu\Omega$m to 13 $\mu\Omega$m
Resistance range	=	20Ω to 200KΩ and for plastic 500Ω to 80KΩ
Accuracy	=	Higher temperature coefficient of resistance than the wire and so temperature changes have a greater effect Accuracy.

STRAIN GAUGE:

Strain gauges are passive type resistance sensor whose electrical resistance change when it is stretched or compressed (mechanically strained) under the application of force.

The electrical resistance is changed due to the change in length (increases) and cross sectional area (decreases) of the strain gauge.

This change in resistance is then usually converted into voltage by connecting one, two or four similar gauges as an arm of a Wheatstone bridge (known as Strain Gauge Bridge) and applying excitation to the bridge. The bridge output voltage is then a measure of strain, sensed by each strain gauge.

Unbonded Type Strain Gauges:

❖ In unbonded type, fine wire filaments (resistance wires) are stretched around rigid and electrically insulated pins on two frames.

❖ One frame is fixed and the other is movable.

❖ The frames are held close with a spring loaded mechanism.

❖ Due to the relative motion between two frames, the resistance wires are strained.

❖ This strain is then can be detected through measurement of the change in electrical resistance since they are not cemented with the surfaces, they can be detached and reused.

Bonded Type Strain Gauges:

❖ Bonded **type** strain gauges consists of resistance elements arranged in the form of a grid of fine wire, which is cemented to a thin paper sheet or very thin Bakelite sheet, and covered with a protective sheet of paper or thin Bakelite.

❖ The paper sheet is then bonded to the surface to be strained. The gauges have a bonding material which acts an adhesive material during bonding process of a surface with the gauge element.

Classification of Bonded Type Strain Gauges:

❖ Fine wire gauges

❖ Metal foil gauges
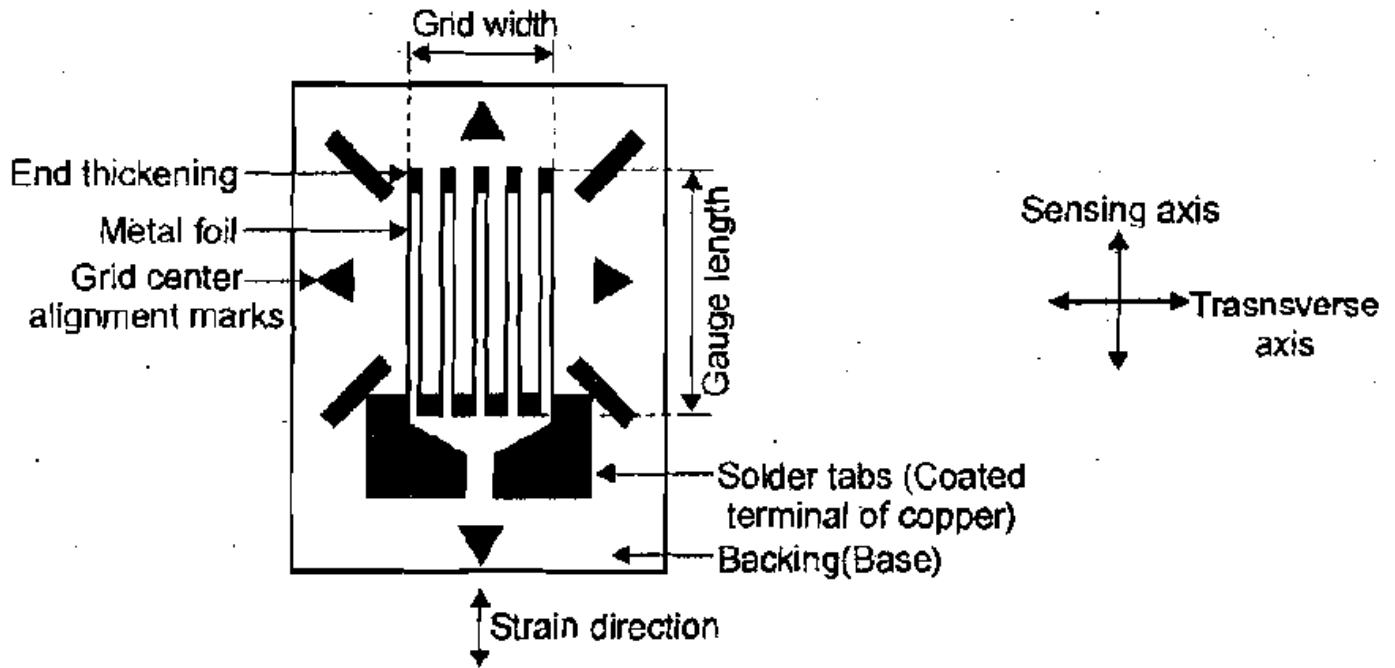
❖ Semiconductor filament type

Fine Wire Gauges:

❖ Wire of 3 to 25 microns diameter is arranged in the form of grid consisting of parallel loops
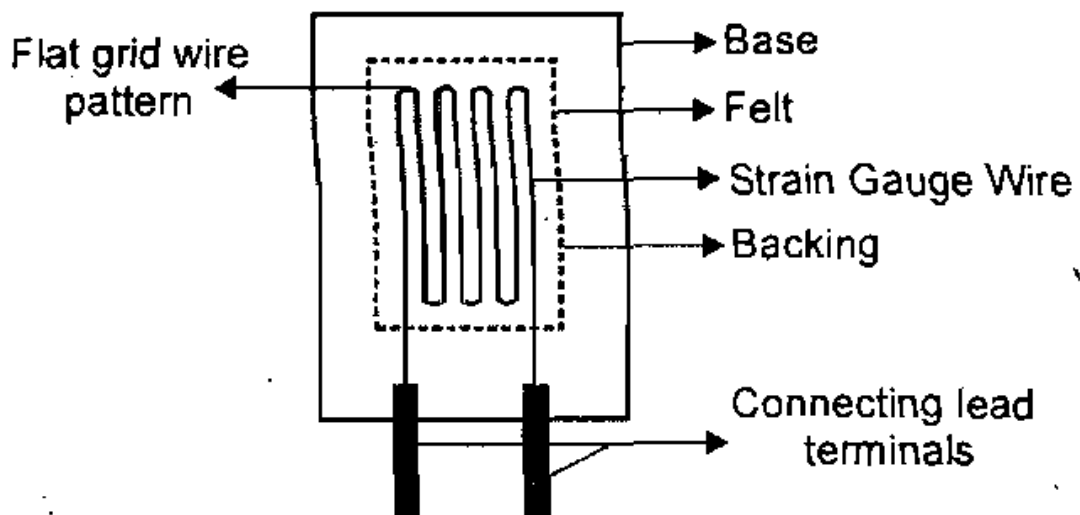

Metal Foil Gauges:

❖ A thin foil of metal, deposited as a grid pattern onto a plastic backing material using polyimide

❖ Foil pattern is terminated at both ends with large metallic pads

❖ Entire gauge size 5- 15mm

❖ Adhesive directly bonded to the gauge usually epoxy

Semiconductor Filament Type:

- ❖ The gauges are produced in wafers from silicon or germanium crystals
- ❖ Special impurities such as boron is added
- ❖ It is mounted on an epoxy resin backing with copper on nickel leads
- ❖ Filament about 0.05mm thick 0.25mm wide and 1.25 to 12mm length
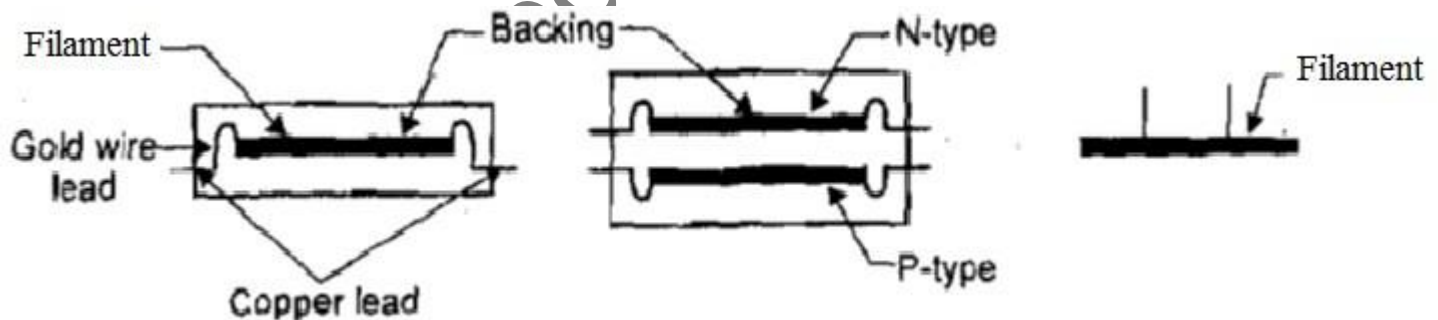
CAPACITIVE SENSORS:

❖ It is used for measuring, displacement, velocity, force etc..

Principle:

It is passive type sensors in which _equal and opposite charges_ are generated on the plates due to voltage applied across the plate which is _separated by_ dielectric material.

Formula:

The capacitance 'C' of a parallel plate capacitor is given by

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$

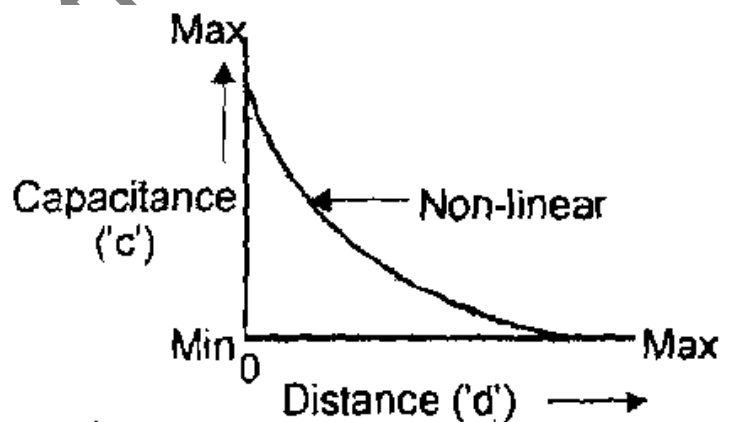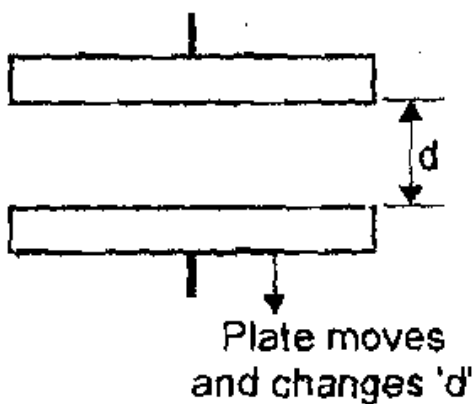where ε_r = Permittivity of the dielectric between the plates [= 1 for air]

ε_0 = Permittivity of free space [= 8.854×10^{-12} F/m for air]

A = Area of overlap between two plates in m²

d = Distance between two plates in m.

By Changing the Distance between Two Plates:

❖ The displacement is measured due to the change in capacitance

Plate moves
and changes 'd'

By Varying the Area of Overlap:

❖ The displacement causes the area of overlap to vary

❖ The capacitance is directly proportional to the area of the plates and varies linearly with changes in the displacement between the plates
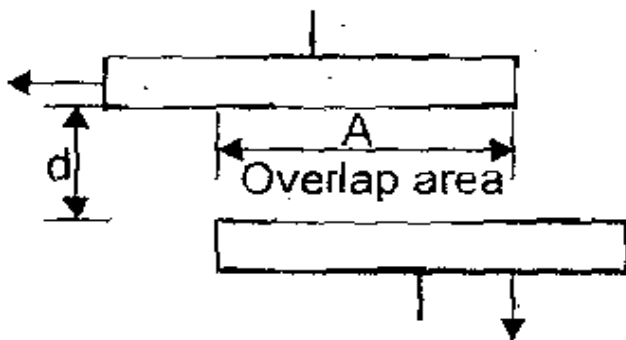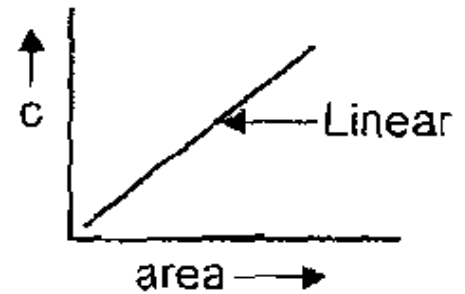
Plate moves
and changes 'A'

By Varying the Dielectric Constant:

- ❖ The change in capacitance can be measured due to change in dielectric constant as a result of displacement.
- ❖ When the dielectric material is moved due to the displacement, the material causes the dielectric constant to vary in the region where the two electrodes are separated that results in a charge in capacitance.

Dielectric moves
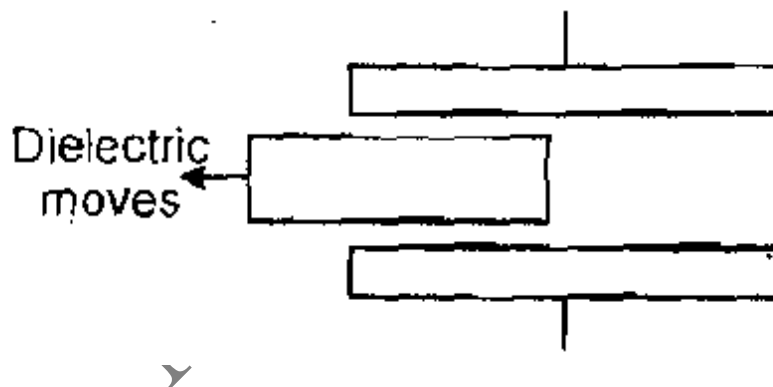
Push Pull Sensor:

- ❖ Push pull displacement sensor is used to overcome the non-linearity error.
- ❖ The sensor consists of three plates with the upper pair forming one capacitor and the lower pair forming another capacitor.
- ❖ The displacement moves central plate between the two other plates.
- ❖ If the central plate moves downwards.
- ❖ The plate separation of the upper capacitor increases and the separation of the lower one decreases.

$$\therefore C_1 = \frac{\varepsilon_0 \varepsilon_r A}{d + x}$$

$$C_2 = \frac{\varepsilon_0 \varepsilon_r A}{d - x}$$
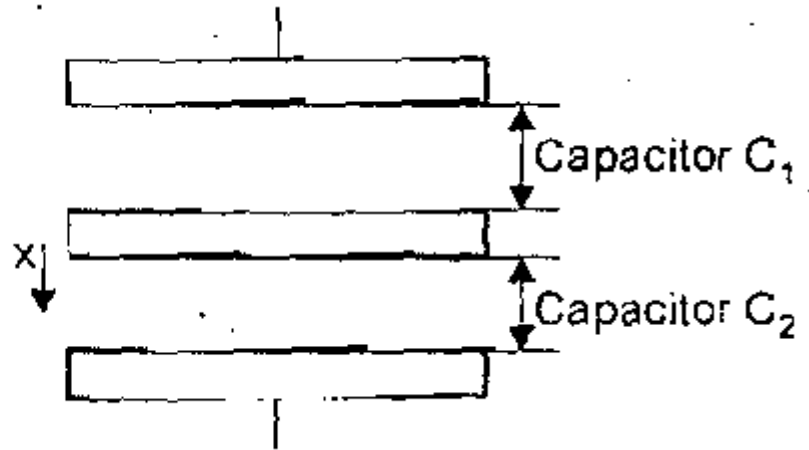
LINEAR VARIABLE DIFFERENTIAL TRANSFORMER:

❖ It consists of three symmetrically spaced coils.

❖ The centre coil is primary coil and other two are secondary coil

❖ Secondary coils are connected in series opposition and equally positioned with respect to primary coil

❖ The output voltage is proportional to the displacement of the core from null position
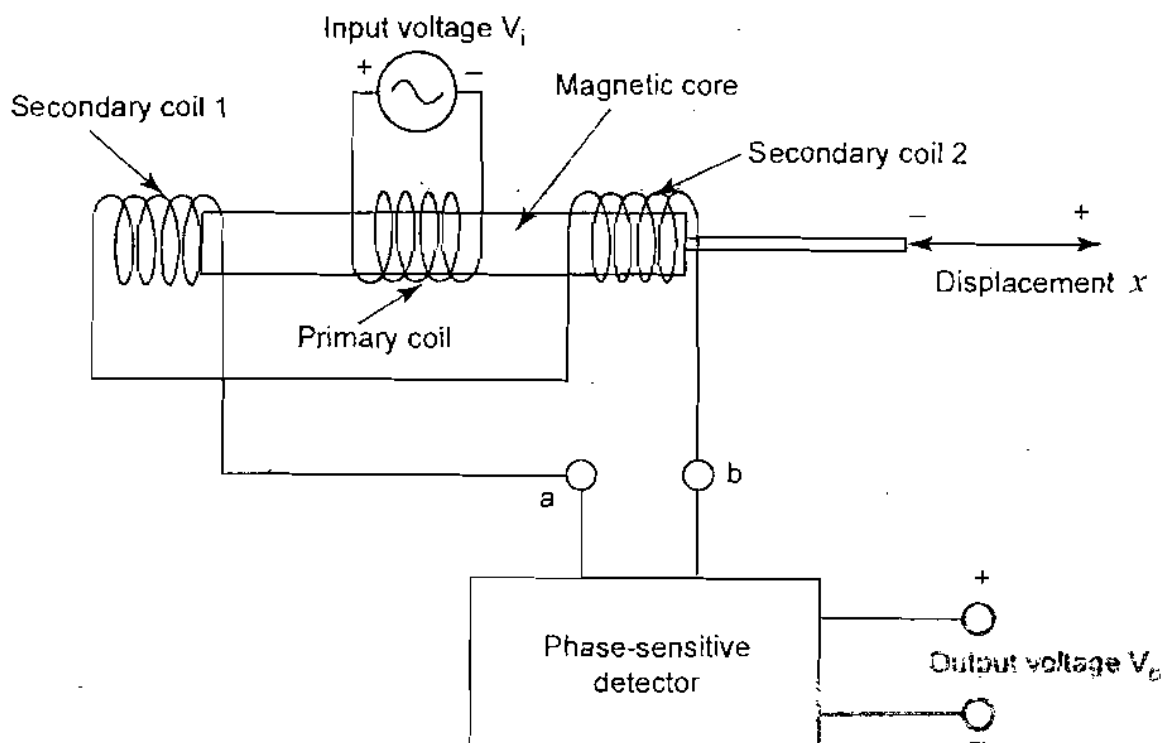
PROXIMITY SENSORS

❖ Proximity sensors are non – contact type sensor.

Types of Proximity Sensor:

❖ Eddy current proximity sensor

❖ Inductive proximity sensor

❖ Pneumatic proximity sensor

❖ Proximity switches

EDDY CURRENT PROXIMITY SENSOR:

PRINCIPLE:

When a coil is supplied with alternating current, an *alternating magnetic field* is produced which *induces an EMF* on it. If there is a metal near to this *alternating magnetic field*, on EMF is induced in it. The EMF cause *current to flow*. This current flow is *eddy current*.
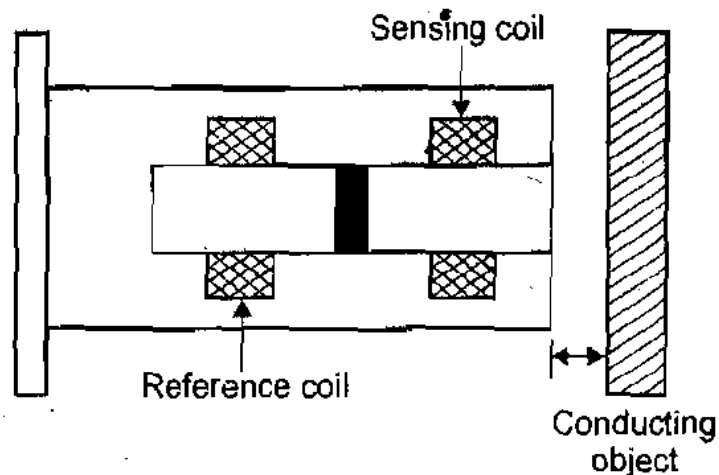
CONSTRUCTION & WORKING:

❖ It has two identical coils.

❖ One reference coil & another sensing coil which senses the magnetic current in the object.

❖ Eddy current start to flow due to AC(conducting object) close to sensor

❖ Eddy current produce a magnetic field to oppose the magnetic field generated by sensing coil.

❖ Due to this opposition reduction flux is created. To detect 0.001mm

INDUCTIVE PROXIMITY SENSORS:
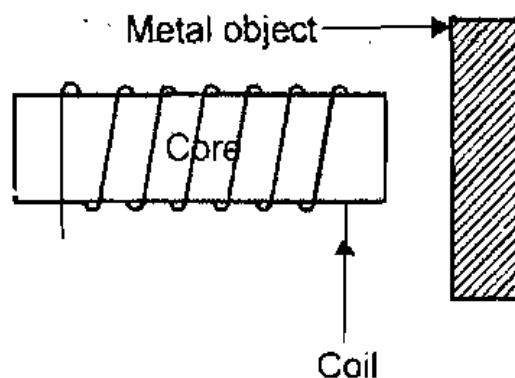
- ❖ It consists of coil wound round a core.
- ❖ Metal is close to coil *Inductance changes* occurs.
- ❖ It is suitable for ferrous metals

PNEUMATIC PROXIMITY SWITCHES:

- ❖ It is suitable for sensing non conducting materials
- ❖ Air is allowed to escape from the front side of the sensor.
- ❖ When there is no object air escapes freely.
- ❖ When there is an object, the escaping air is blocked and return backed to system.
- ❖ It is used to measure the range 3mm to 12mm
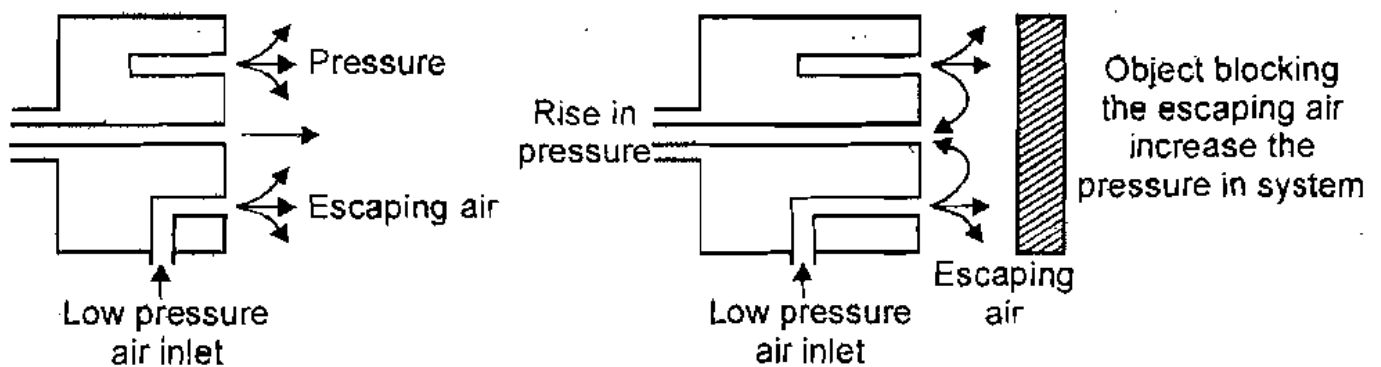
PROXIMITY SWITCHES:

- ❖ It is used in robotics for sensing elements
- ❖ It is also used in NC machines, material handling systems and assembly lines.
  - ➢ Micro switch
  - ➢ Reed switch
  - ➢ Photo sensitive switch
  - ➢ Mechanical switch

Micro Switch:

① Button to operate switch
② Spring ③ Switch contacts

Roller operated switches   CAM operated switches
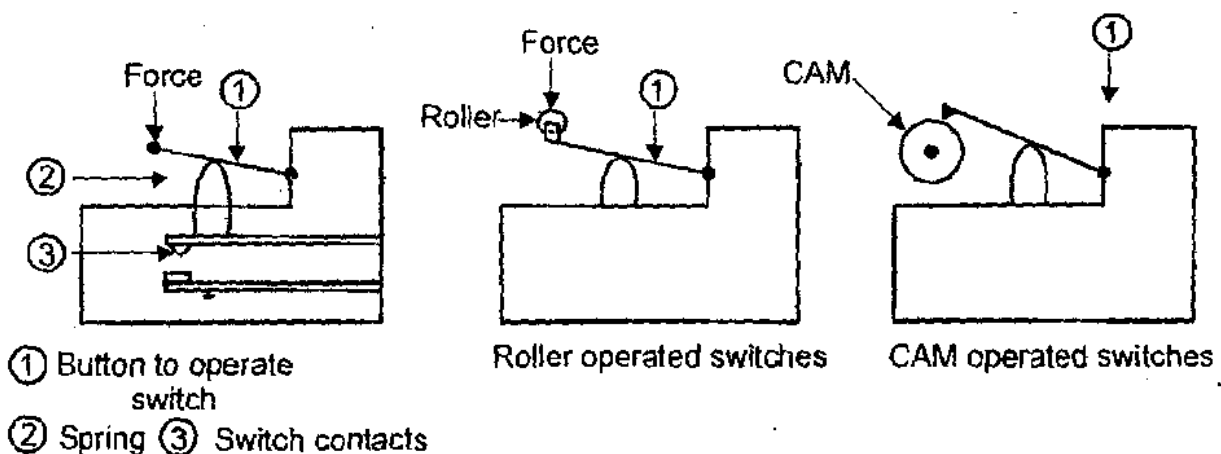
- ❖ It is limit switch operated by levers, rollers & cams
- ❖ It is switch which requires physical contact and small force to close the contacts.
- ❖ Example a **belt conveyor.**

Reed Switch:

- ❖ It is a non – contact proximity switch that consists of *two magnetic switch* contacts enclosed in a *glass tube fined* with an *inert gas*.
- ❖ When magnet is closed switch is operated.
- ❖ Used for high speed applications.
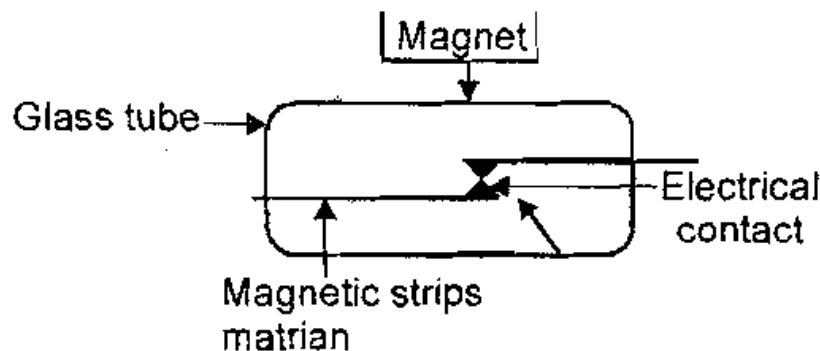
Photo Sensitive Devices:

(a) Object breaking the beam   (b) Object reflecting the beam
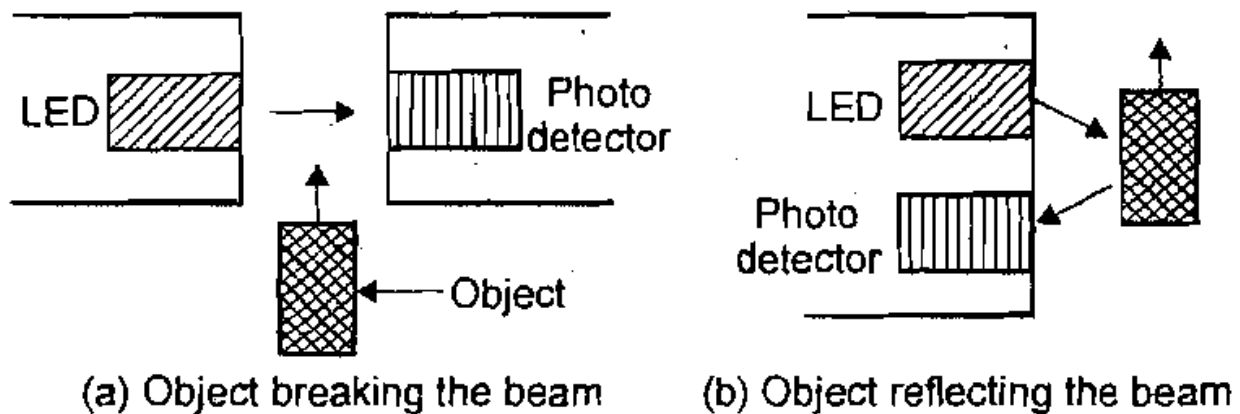
- ❖ It is used to sense opaque object.
- ❖ Photo detector receives a beam of light produced by the LED.
- ❖ Object is passed the beam gets broken or reflected when is detected.

OPTICAL ENCODERS

- ❖ It is used to measure position, velocity, acceleration and direction of movement of rotors.

INCREMENTAL ENCODERS

PRINCIPLE:

- ❖ When a beam of <u>*light passes through slots in a disc*</u>, it is <u>*sensed*</u> by the <u>*light sensor*</u> opposite to the light source
- ❖ When the disk is rotated, a pulsed output is *produced by sensor* with number of *pulses being proportional to the position of the disc* and *number of pulses per second* determines the *velocity* of the disk

CONSTRUCTION & WORKING:
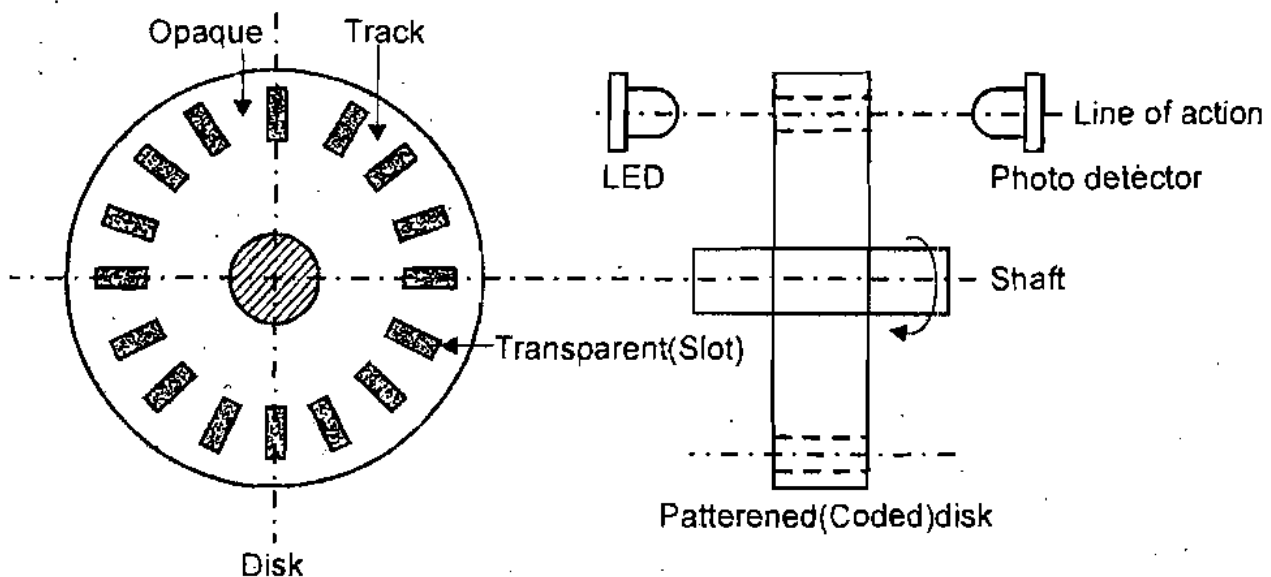
- ❖ It consists three components light source, coded disk and photo detector
- ❖ The disk is made up of plastic or glass.
- ❖ The disk consists of opaque and transparent segment alternatively.
- ❖ The wheel is between light and photo detector.
- ❖ The photo detector receives the light signal alternatively which is converted into electrical signal.

ABSOLUTE ENCODERS

PRINCIPLE:

- ❖ The principle of operation is that they provide a unique output corresponds to each rotational position of the shaft.
- ❖ The output is in the form of binary numbers representing the angular position.
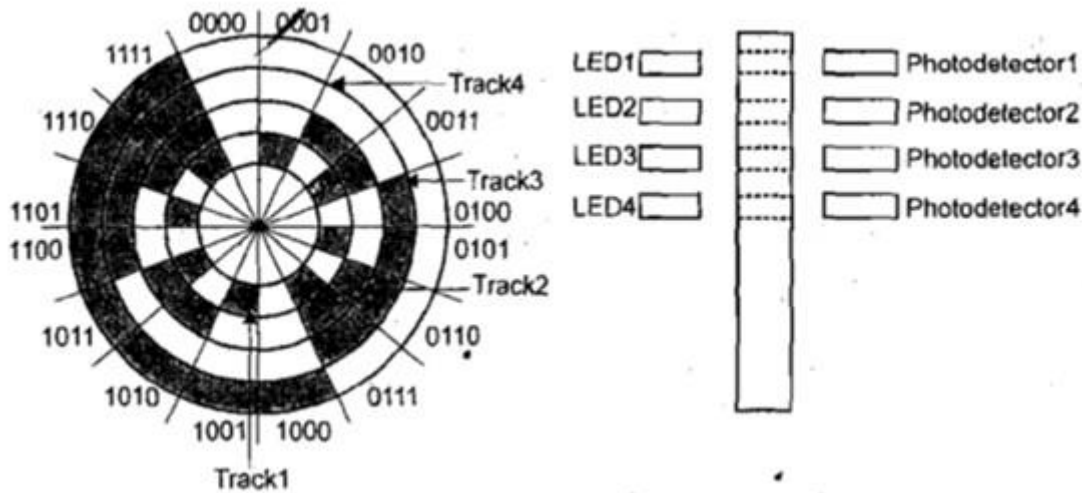
	Normal	Binary		Gray	Code	
0	0000			0000		
1	0001			0001		
2	0010			0011		
3	0011			0010		
4	0100			0110		
5	0101			0111		
6	0110			0101		
7	0111			0100		
8	1000			1100		
9	1001			1101		
10	1010			1111		

CONSTRUCTION & WORKING:

❖ The disc has four concentric slots and four photo detectors to detect the light pulse.

❖ The slots are arranged in such way that they give a binary number.

❖ It consist opaque and transparent segments. This pattern is called as track.

❖ The encoders have 8 to 14 slots.

❖ The number of the track determines the resolution of the encoder.

❖ The number of bits in binary number will be equal to the number of tracks.

HALL EFFECT SENSORS:

Principle:

❖ When a current carrying semiconductor plate is placed in a transverse magnetic field, it experiences a force (Lorentz force). Due to this action a beam of charged particles are forced to get displaced from its straight path. This is known as Hall Effect.

- ❖ A current flowing in a semiconductor plate is like a beam of moving charged particles and thus can be deflected by a magnetic field. The side towards which the moving electron deflected becomes negatively charged and the other side of the plate becomes positively charged or the electrons moving away from it.
- ❖ This charge separation produces an electrical voltage which continues until the Lorentz force on the charged particles from the electric field balances the forces produced by the magnetic field. The result is a traverse potential difference known as Hall voltage.
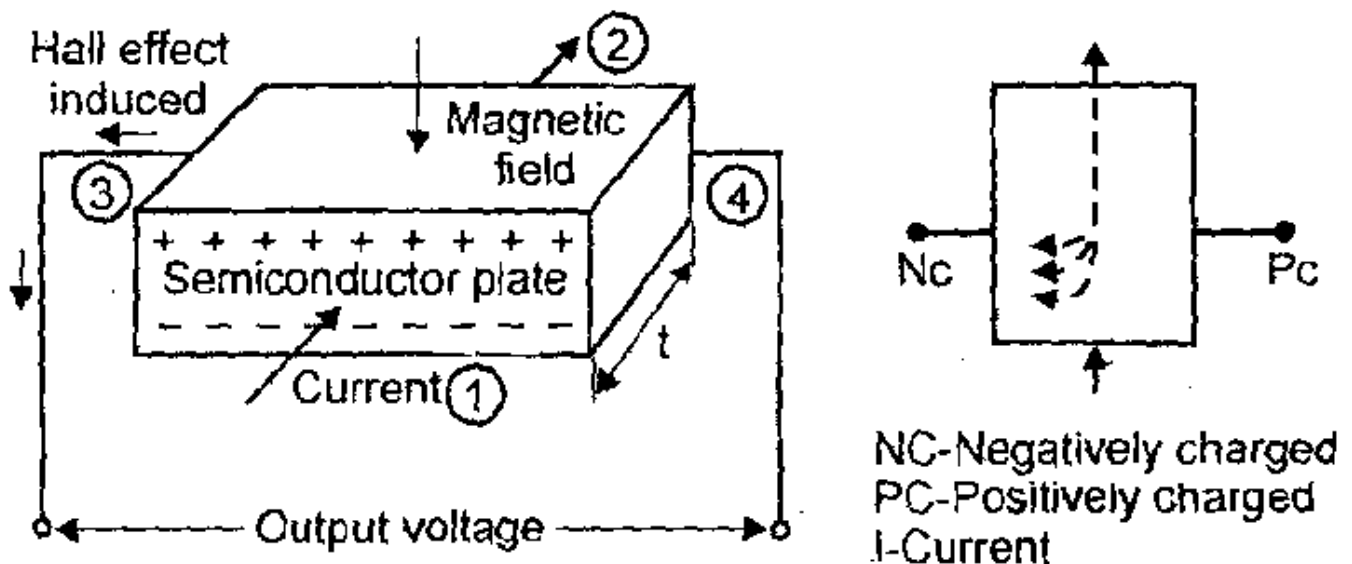
Construction & Working:

- ❖ Current is passed through leads **1** and **2** of the semiconductor plate and the output leads are connected to the element faces **3** and **4**.
- ❖ These output faces are at same potential when there is no transverse magnetic field passing through the element and voltage **known** as Hall voltage appears when a transverse magnetic field is passing through the element.
- ❖ This voltage is proportional to the current and the magnetic field.
- ❖ The direction of deflection depends on the direction of applied current and the direction of magnetic field
- ❖

FLUID SENSORS

FLUID PRESSURE SENSORS:

Diaphragm Type:

- ❖ In the diaphragm type sensor, when there is a difference in pressure between the two sides then the centre of the diaphragm becomes displaced.
- ❖ Corrugations in the diaphragm result in a greater sensitivity.
- ❖ This movement can be monitored by some form of displacement sensor, e.g: a strain gauge.
- ❖ A specially designed strain gauge is often used, consisting of four strain gauges with two measuring the strain in a circumferential direction while two measure strains in a radial direction
- ❖ The four *strain* gauges are then connected to form the arm of a Wheatstone bridge.
- ❖ While strain gauges can be stuck on a diaphragm, an alternative is to create a silicon diaphragm with the strain gauges as specially doped areas of the diaphragm.

Diaphragm types

Diaphragm pressure gauge
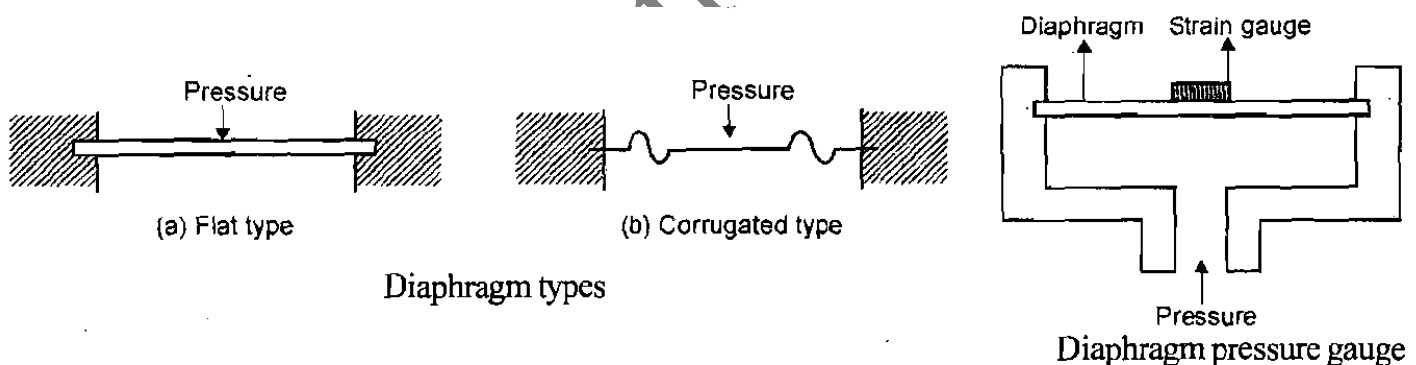
Capsule and Bellow Types:

- ❖ Capsules are two corrugated diaphragms combined to give greater accuracy
- ❖ Capsules and bellows are made up of stainless steel, phosphor bronze, and nickel with rubber and nylon

* Pressure range 10^3 to 10^8 Pa
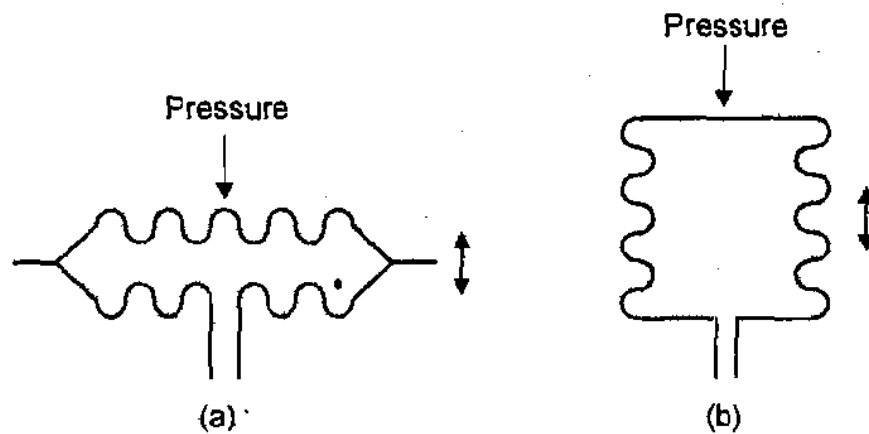
(a) Capsule, (b) bellows

Tube Pressure Sensor:

* A different form of deformation is obtained using a tube with an elliptical cross section
* Increase in pressure in tube causes it tend to circular cross – section
* C – Shaped tube is generally known as a Bourdon tube.
* C opens when pressure in the tube increases
* A helical form gives more sensitivity
* Tubes are made up of stainless steel, phosphor bronze, and nickel with rubber and nylon
* Pressure range 10^3 to 10^8 Pa

(a) Tube cross-section   (b) C-shaped tube   (c) Helical C/S tube
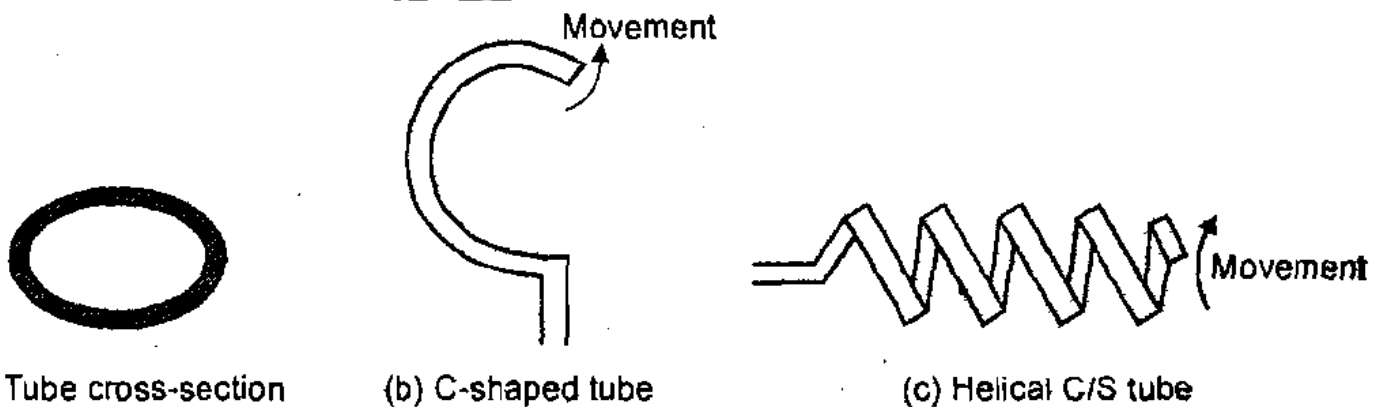
Piezoelectric Sensors:

* Piezoelectric materials when stretched or compressed generate electric charges with one face of the managerial becoming positively charged and the opposite face negatively charged.

- ❖ As a result a voltage is produced. The net charge q on a surface is proportional to the amount x by which the charges have been displaced, and since the displacement is proportional to the applied force F.

- ❖ **q** = **kx**= SF

- ❖ Where k is a constant and S a constant termed the charge sensitivity

Piezoelectricity

Piezoelectric capacitor
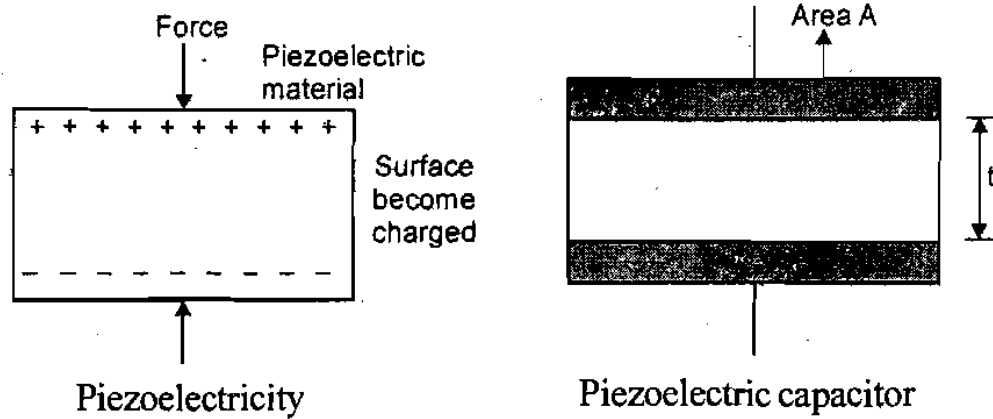
Tactile Sensor:

- ❖ It is used on fingertips of robot hands and for touch display screen

- ❖ It uses piezoelectric polyvinylidene fluoride (PVDF) film

- ❖ Two layers are separated by sift film

- ❖ The lower PVDF film has an *alternating voltage applied* to it *results in mechanical oscillations*

- ❖ Intermediate film transmits the vibration to upper film
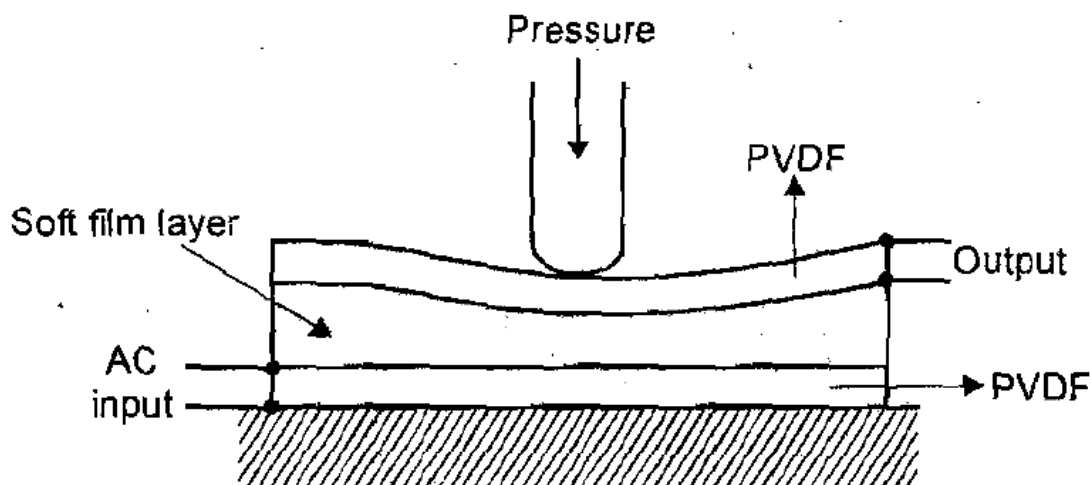
LIQUID FLOW SENSORS:

Turbine Flow Meter:

- ❖ The turbine flow meter and it consists of a multi-bladed rotor which is supported in the pipe along with the flow occurs.
- ❖ The rotor rotation depends upon the fluid flow and the angular velocity is proportional to the flow rate.
- ❖ The rotor rotation is determines the magnetic pick-up, which is connected to the coil.
- ❖ The revolution of the rotor is determined by counting the number of pulses produced in the magnetic pick up. The accuracy of this instrument is ± 3%.

Magnetic pick-up coil
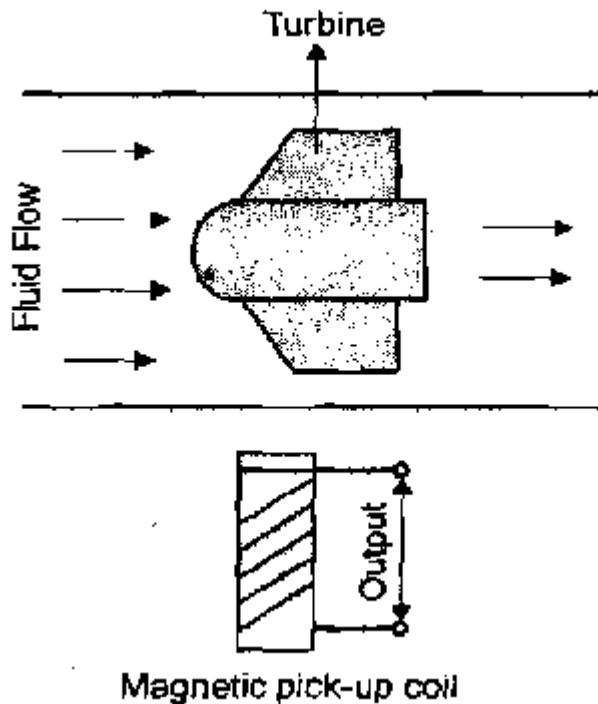
Orifice Plate:

- ❖ It is a simple disc with a central hole and it is placed in the tube through which the fluid flows.
- ❖ The pressure difference measured between a point equal to the diameter of the tube upstream and half the diameter of downstream.
- ❖ The accuracy of this instrument is ±1.5%.

Pressure difference

Orifice plate
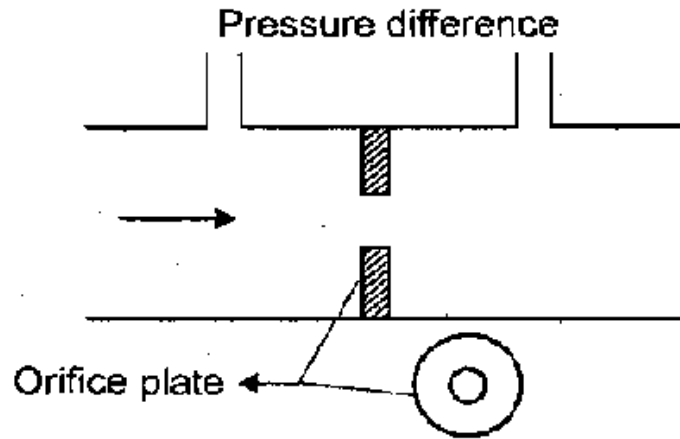
LIQUID LEVEL MEASUREMENT:

Differential Pressure Sensor:

- ❖ In this the differential pressure cell determines the pressure difference between base of the liquid and atmospheric pressure.

- ❖ The differential pressure sensor can be used in either form of open or closed vessel system.

Differential pressure cell

Atmosphere

(a) Open Vessel type   (b) Closed Vessel type
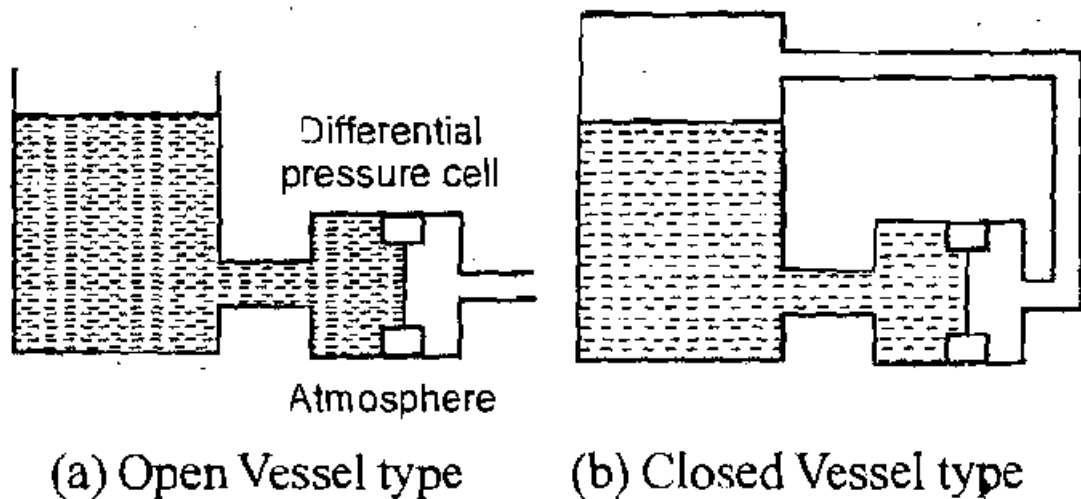
Float System:

- ❖ In this method the level of liquid is measured by movement of a float.

- ❖ The movement of float rotates the arm and slider will move across a potentiometer.

- ❖ The output result is related to the height of the liquid.
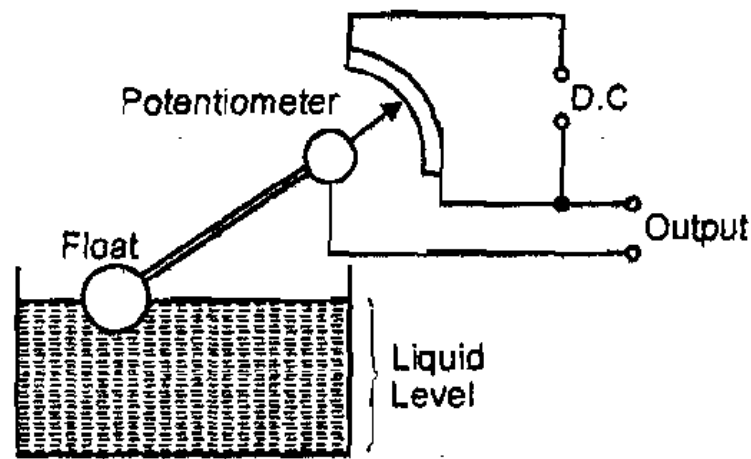
TEMPERATURE SENSORS:

Bimetallic Strips:

- ❖ A Bimetallic thermostat consists of two different metal strips bounded together and they cannot move relative to each other.

- ❖ These metals have different coefficients of expansion and when the temperature changes the composite strips bends into a curved strip, with the higher coefficient metal on the outside of the curve.

- ❖ The basic principle in this is all metals try to change their physical dimensions at different rates when subjected to same change in temperature.

- ❖ This deformation may be used as a temperature- controlled switch, as in the simple thermostat.
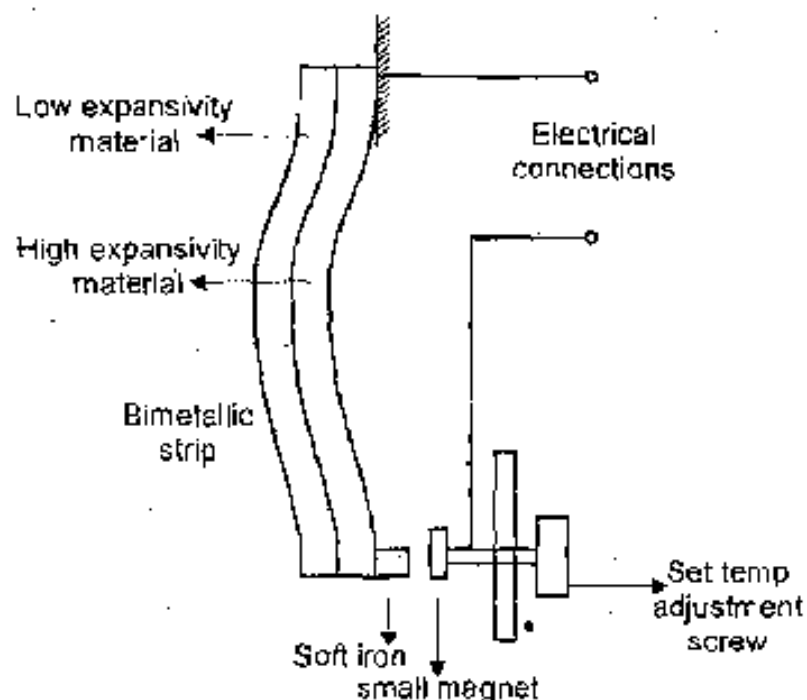
Resistance Temperature Detectors (RTDs):

❖ The materials used for RTDs are Nickel, Iron, Platinum, Copper, Lead, Tungsten, Mercury, Silver, etc.

❖ The resistance of most metals increases over a limited temperature range and the relationship between Resistance and Temperature is shown below.
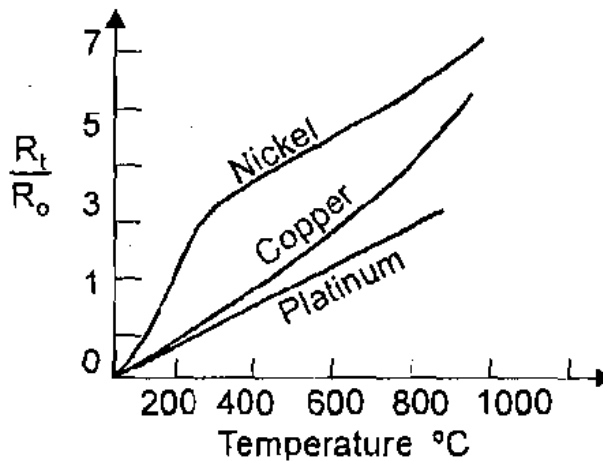
❖ The Resistance temperature detectors are simple and resistive elements in the form of coils of wire

❖ The equation which is used to find the linear relationship in RTD is

$$R_1 = R_0 (1 + \alpha t)$$

Constructional Details of RTDs:

❖ The platinum, nickel and copper in the form wire are the most commonly used materials in the RTDs.

❖ Thin film platinum elements are often made by depositing the metal on a suitable substrate wire- wound elements involving a platinum wire held by a high temperature glass adhesive inside a ceramic tube.
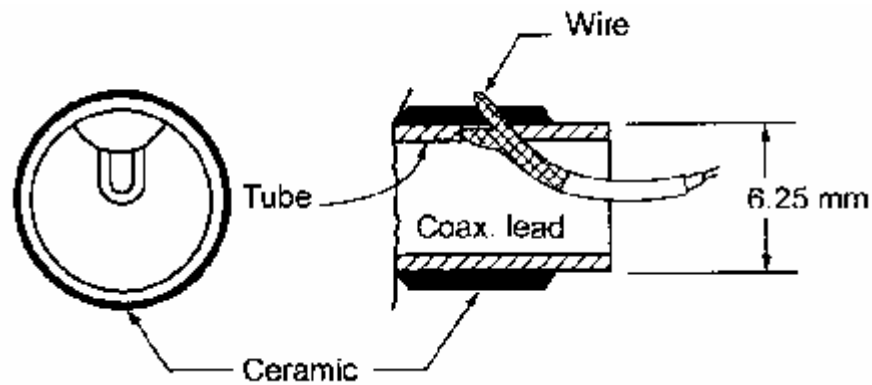
Thermistors:

- ❖ Thermistor is a semiconductor device that has a negative temperature coefficient of resistance in contrast to positive coefficient displayed by most metals.
- ❖ Thermistors are small pieces of material made from mixtures of metal oxides, such as Iron, cobalt, chromium, Nickel, and Manganese.
- ❖ The shape of the materials is in terms of discs, beads and rods.
- ❖ The thermistor is an extremely sensitive device because its resistance changes rapidly with temperature.
- ❖ The resistance of conventional metal-oxide thermistors decreases in a very non-linear manner with an increase in temperature.
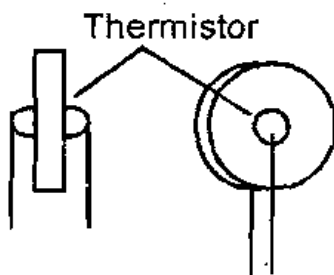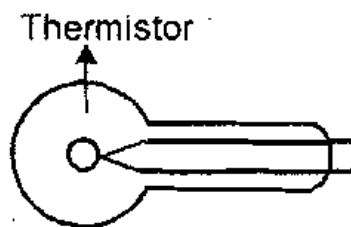
(a) Disc type   (b) Bead type   (c) Rod type
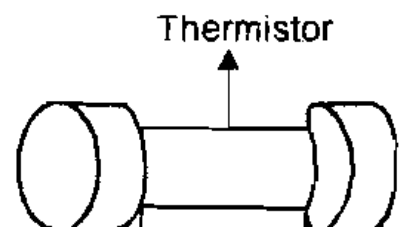
- ❖ The change in resistance per degree change in temperature is considerably larger than that which occurs with metals.
- ❖ The resistance-temperature relationship for a thermistor can be described by an equation of the form

$$R_t = Ke^{\beta/t}$$

- ❖ Where R_t, is the resistance at temperature t, with K and β being constant. Thermistors have many advantages when compared with other temperature sensors.
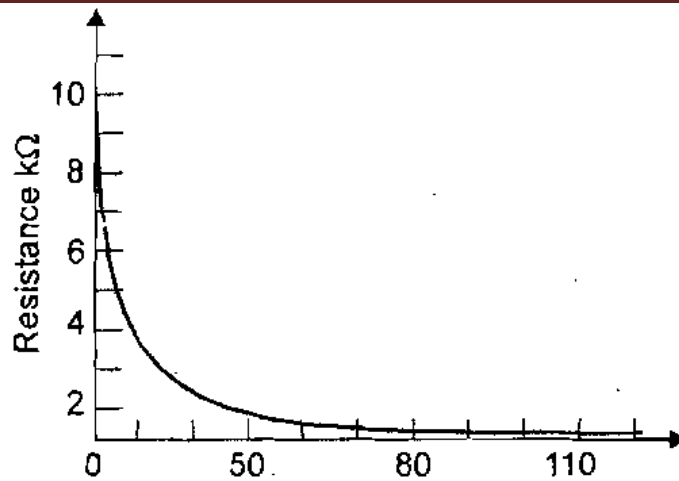
- ❖ The simple series circuit for measurement of temperature using a thermistor and the variation of resistance with temperature for a typical thermistor.
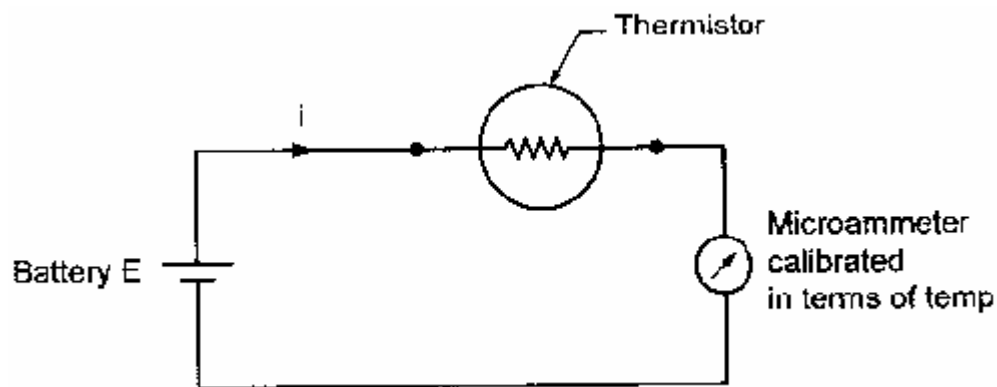
- ❖ The thermistor is an extremely sensitive device because its resistance changes rapidly with temperature.

Thermocouples:

- ❖ Thermocouples are based on the See back Effect.
- ❖ The thermocouple temperature measurement is based on a *creation of an electromotive force (emf)*.
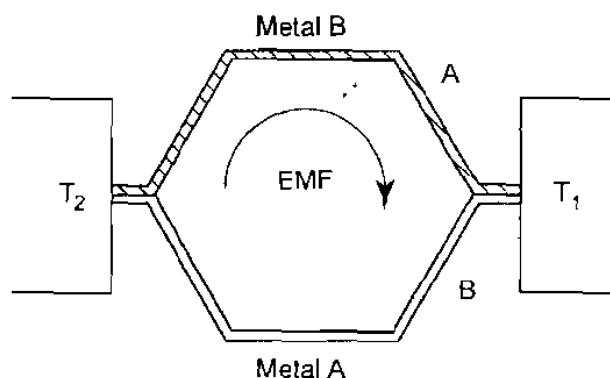
- ❖ "When two dissimilar metals are joined together an e.m.f will exist between the two points A and B, which is primarily a function of the junction temperature. The above said to be principle is *See back effect.*.
- ❖ The thermocouple consist of one hot junction and one cold junction
- ❖ Hot junction is inserted where temperature is measured
- ❖ Cold junction is maintained at a constant reference temperature.
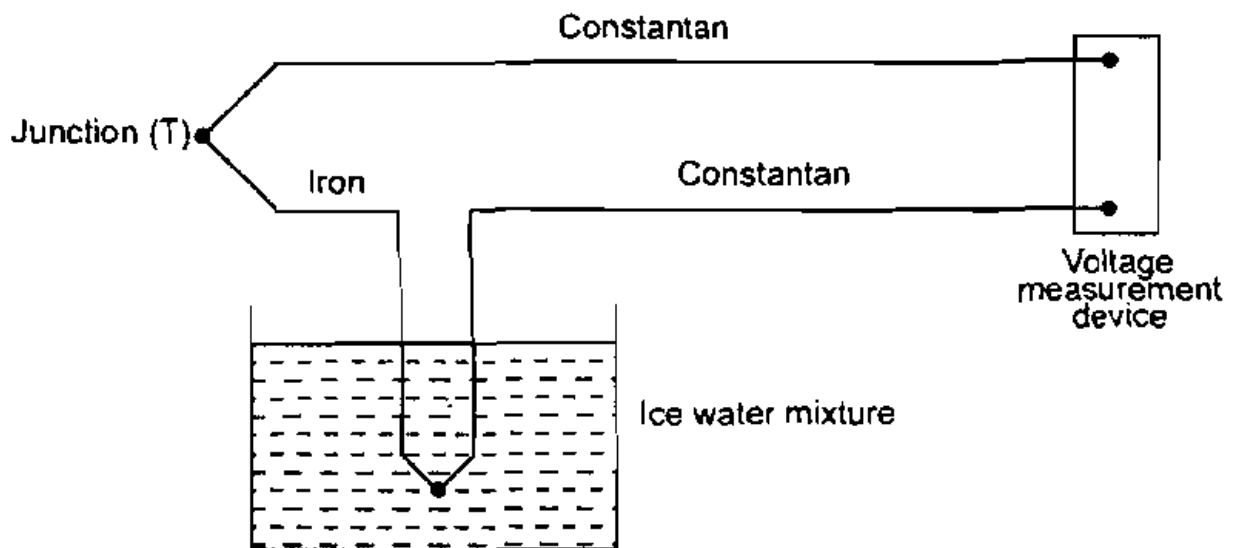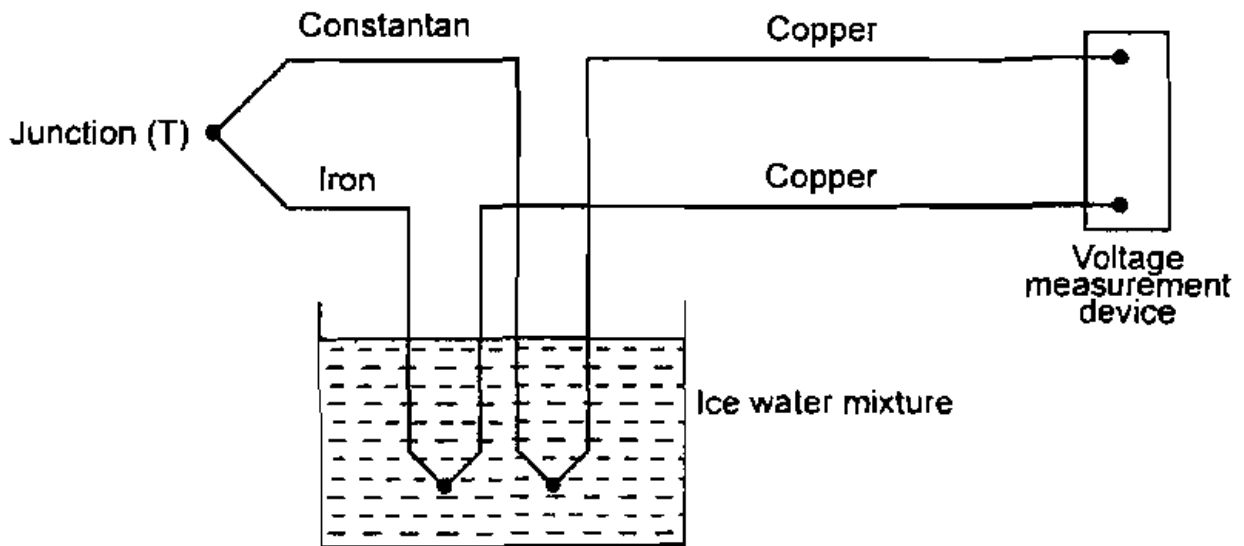
UNIT – III SYSTEM MODELS AND CONTROLLERS

BUILDING BLOCKS OF MECHANICAL SYSTEM:

Building block	Equation	Energy (or) Power dissipated
Translational		
Spring	$F = Kx$	$E = \dfrac{1}{2}\dfrac{F^2}{K}$
Dashpot	$F = C.\dfrac{dx}{dt}$	$P = CV^2$
Mass	$F = m.\dfrac{d^2x}{dt^2}$	$E = \dfrac{1}{2}mv^2$
Rotational		
Spring	$T = K\theta$	$E = \dfrac{1}{2}\dfrac{T^2}{K}$
Rotational damper	$T = C.\dfrac{d\theta}{dt}$	$P = C\omega^2$
Moment of Inertia	$T = I\dfrac{d^2\theta}{dt^2}$	$E = \dfrac{1}{2}I\omega^2$

BUILDING BLOCKS OF ELECTRICAL SYSTEM:

Element	Voltage	Current
Resistor	$V = iR$	$i = \dfrac{V}{R}$
Capacitor	$V = \dfrac{1}{C}\int i\,dt$	$i = C.\dfrac{dV}{dt}$
Inductor	$V = L\dfrac{di}{dt}$	$i = \dfrac{1}{L}\int V\,dt$

BUILDING BLOCKS OF ELECTRICAL, MECHANICAL, THERMAL & FLUID SYSTEM:

Elements	Electrical	Mechanical	Thermal	Fluid
Resistance	$R = \dfrac{V}{i}$	$B = \dfrac{F}{V}$	$R = \dfrac{\Delta T}{Q}$	$\dfrac{h}{Q}$
Capacitance	$C = i \Big/ \dfrac{dV}{dt}$	$M = F \Big/ \dfrac{dV}{dt}$	$C = Q \Big/ \dfrac{d(\Delta T)}{dt}$	$C = Q \Big/ \dfrac{dh}{dt}$
Inductance	$L = \dfrac{1}{i} \int V\, dt$	$K = \dfrac{F}{\text{Displacement}}$		

PROBLEMS:

1) **Derive a differential equation for the system shown in figure. The displacement of mass is 'y' and the input displacement is 'x'**
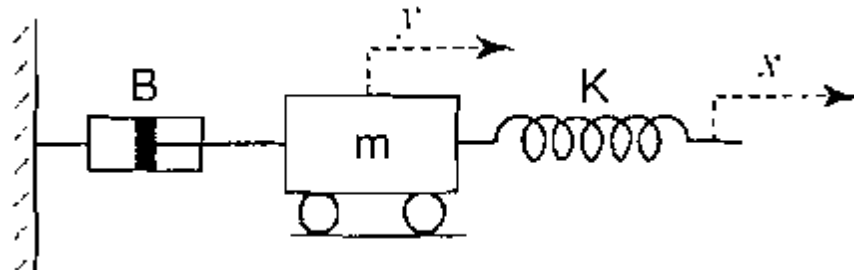
Solution:

The free body diagram for the given system can be drawn as follows:
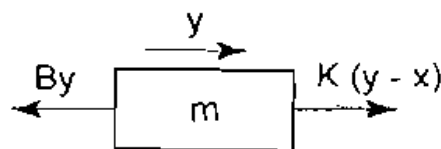
Net force applied to mass $m = -B\dfrac{dy}{dt} - K\left(y - x\right)$ ··· (1)

Also, net force $F = ma = m\dfrac{d^2y}{dt^2}$ ··· (2)

From (1) & (2)

$$m\frac{d^2y}{dt^2} = -B\frac{dy}{dt} - K(y-x)$$

$$m\frac{d^2y}{dt^2} + B\frac{dy}{dt} + Ky = Kx \qquad \cdots (3)$$

The nature of differential equation represents the 2nd order system.

Note: If *y* is the displacement, then velocity $V = \dfrac{dy}{dt}$ and acceleration $a = \dfrac{d^2y}{dt^2}$

If mass is neglected, the above system can be represented
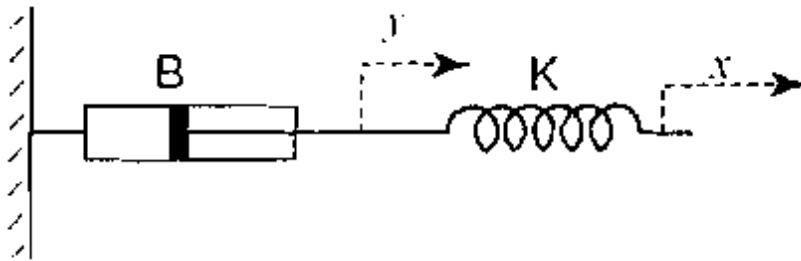
Put *m* = o in the final equation of (3)

Hence, $B\dfrac{dy}{dt} + Ky = Kx \qquad \cdots (4)$

Equation **(4)** also can be obtained by equating damping force to spring force

$$B\frac{dy}{dt} = K(x-y)$$

Therefore, the equation becomes

$$B\frac{dy}{dt} + Ky = Kx \qquad \cdots (5)$$

2) Derive a differential equation for the system shown in figure.

Solution:

The free body diagram for the given system can be drawn as follows:

Spring force due to $K_2 = K_2 (y - x)$

Note that the spring2 is subjected to end displacement x and y

Applying Newton's law of motion

Mass × Acceleration = **Sum** of forces acting on mass "*M*".

$$M \times \frac{d^2 y}{dt^2} = - \text{Spring force due to } K_1 - \text{Spring force due to } K_2 - \text{Damping force}$$

$$\qquad\qquad (SF1) \qquad\qquad\qquad (SF2) \qquad\qquad\qquad (DF)$$

$$= -K_1 y - K_2 (y - x) - B\frac{dy}{dt}$$

$$M^2 \frac{d^2 y}{dt^2} + B\frac{dy}{dt} + (K_1 + K_2) y = K_2 \dot{x} \text{, is the differential equation.}$$

3) Derive a differential equation for the system shown in figure.

Solution:

From a free body diagram, spring forces and damping force can be determined. Analyzing free body diagram for mass M_1;

$$SF_1 = K_1 x_1$$

$$SF_2 = K_2 (x_1 - x_2)$$

$$DF_1 = B_1 \frac{dx_1}{dt}$$

$$DF_2 = B_2 \frac{d(x_1 - x_2)}{dt}$$

From Newton's second law of motion

Mass * Acceleration = $- SF_1 - DF_1 - SF_2 - DF_2$

$$M_1 \frac{d^2 x_1}{dt^2} = - K_1 x_1 - B_1 \frac{dx_1}{dt} - K_2 (x_1 - x_2) - B_2 \frac{d(x_1 - x_2)}{dt}$$

$$M_1 \frac{d^2 x_1}{dt^2} + (B_1 + B_2) \frac{dx_1}{dt} + (K_1 + K_2) x_1 = B_2 \frac{dx_2}{dt} + K_2 x_2 \qquad \dots (1)$$

Free *body diagram for mass* M_2
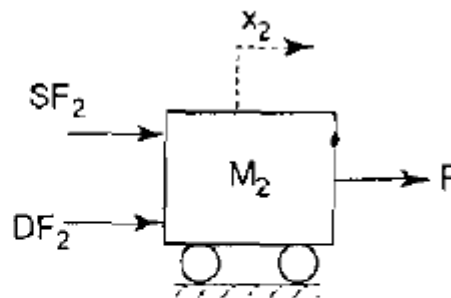
Mass x acceleration = $F + SF_2 + DF_2$

$$M_2 \frac{d^2 x_2}{dt^2} = +K_2 (x_1 - x_2) + B_2 \frac{d(x_1 - x_2)}{dt} + F$$

$$M_2 \frac{d^2 x_2}{dt^2} + B_2 \frac{dx_2}{dt} + K_2 x_2 = K_2 x_1 + B_2 \frac{dx_1}{dt} + F \qquad \ldots (2)$$

4) Consider two masses connected together by a spring of stiffness K₁ and the second mass is connected to a frame by a spring of stiffness K₂ as shown in figure. Obtain a system differential equation assuming the input 'x'
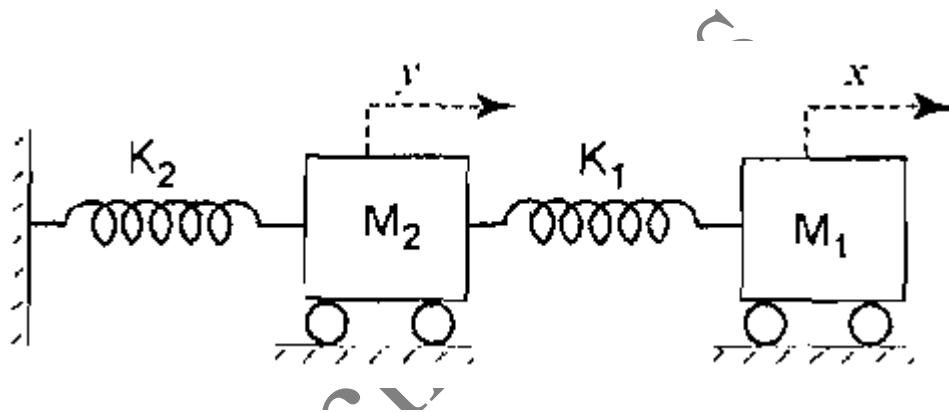
Solution:

Free body diagram for M_1
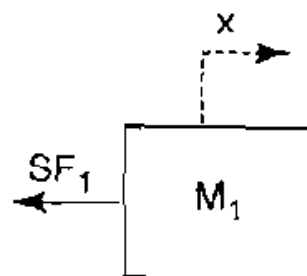
Differential equation for M_1

$$M_1 \ddot{x} = -SF_1 , \text{ where } SF_1 = K_1 (x - y) \qquad \ldots (1)$$

$$M_1 \frac{d^2 x}{dt^2} = -K_1 (x - y) \qquad \bullet \qquad \ldots (2)$$

Free body diagram for M_2
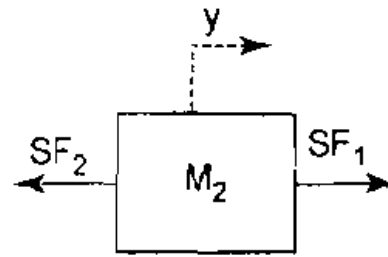
Differential equation for M_2

$$M_2 \frac{d^2 y}{dt^2} = - SF_2 + SF_1 \qquad \ldots \quad (3)$$

$$SF_1 = M_2 \frac{d^2 y}{dt^2} + SF_2 \qquad \ldots \quad (4)$$

Where $SF_2 = K_2 y$ and substitutes for SF_1 & SF_2, we have,

$$M_2 \frac{d^2 y}{dt^2} + K_2 y = K_1 (x - y)$$

Substituting for SF_1 from equation (2) in equation (3) we can write

$$M_2 \frac{d^2 y}{dt^2} = - SF_2 - M_1 \frac{d^2 x}{dt^2}$$

$$M_1 \frac{d^2 x}{dt^2} + M_2 \frac{d^2 y}{dt^2} = - K_2 y$$

$$\therefore \; M_1 \frac{d^2 x}{dt^2} + M_2 \frac{d^2 y}{dt^2} + K_2 y = 0 \qquad \ldots \quad (6)$$

In order to analyse the motion of M_2, we have to eliminate the variable x By differentiating equation (5) twice, we obtain

$$M_2 \frac{d^4 y}{dt^4} + (K_1 + K_2) \frac{d^2 y}{dt^2} = K_1 \frac{d^2 x}{dt^2} \qquad \ldots \quad (7)$$

Dividing equation (7) throughout by K_1,

$$\frac{M_2}{K_1} \frac{d^4 y}{dt^4} + \frac{(K_1 + K_2)}{K_1} \frac{d^2 y}{dt^2} = \frac{d^2 x}{dt^2} \qquad \ldots \quad (8)$$

Substituting (8) in equation (6)

$$M_1 \left\{ \frac{M_2}{K_1} \frac{d^4 y}{dt^4} + \frac{(K_1 + K_2)}{K_1} \frac{d^2 y}{dt^2} \right\} + M_2 \frac{d^2 y}{dt^2} + K_2 y = 0$$

$$\therefore \quad \frac{M_1 M_2}{K_1} \frac{d^4 y}{dt^4} + \left\{ \frac{M_1 (K_1 + K_2)}{K_1} + M_2 \right\} \frac{d^2 y}{dt^2} + K_2 y = 0$$

$$M_1 M_2 \frac{d^4 y}{dt^4} + (M_1 K_1 + M_1 K_2 + M_2 K_1) \frac{d^2 y}{dt^2} + K_1 K_2 y = 0$$

This is the final expression for the system output "y".

5) **A rotational mechanical system representing motor trailer is shown in figure. Obtain differential equation for the system.**
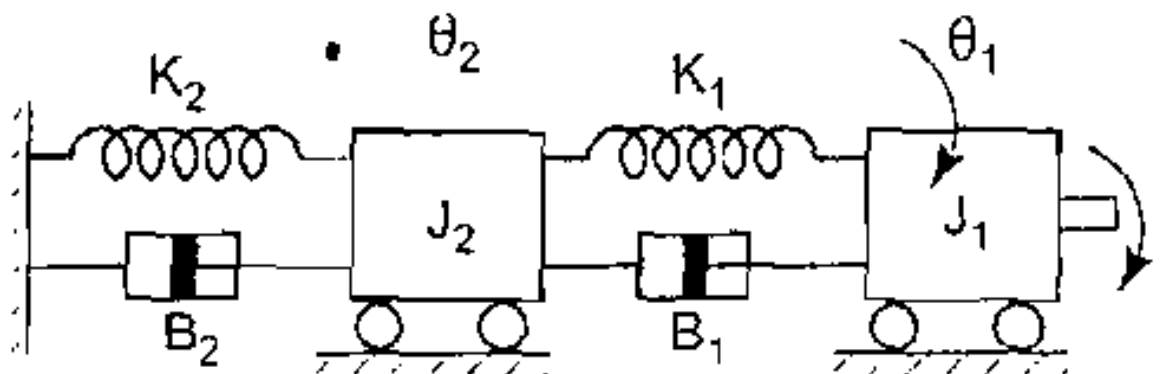
Solution:

Free body diagram for J_1
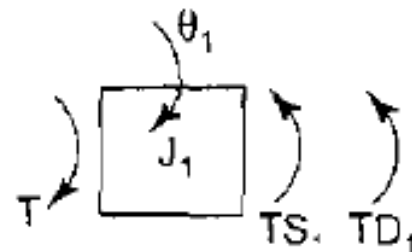
Figure 3.15(b)

TS_1 = Spring torque due to K_1 = $K_1 (\theta_1 - \theta_2)$

TD_1 = Damping torque due to B_1 = $B_1 \left(\dfrac{d\theta_1}{dt} - \dfrac{d\theta_2}{dt} \right)$

Applying Newton's second law of motion

$$J \alpha = \Sigma T,$$

$$J_1 \frac{d^2\theta_1}{dt} = -TD_1 - TS_1 + T$$

$$J_1 \frac{d^2\theta_1}{dt} + TD_1 + TS_1 = T \qquad \qquad \dots \ (1)$$

Substituting for TS_1 & TD_1 in (1), we have

$$J_1 \frac{d^2\theta_1}{dt} + B_1 \frac{d\theta_1}{dt} + K_1 \theta_1 = B_1 \frac{d\theta_2}{dt} + K_1\theta_2 + T \qquad \qquad \dots \ (2)$$

This is the differential equation for the rotor J_1,

Free body diagram for the rotor J_2
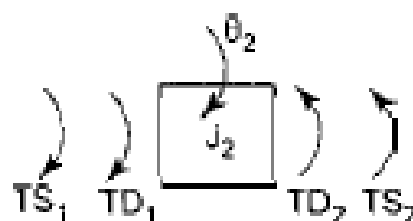
$TS_2 = $ Spring torque due to $K_2 = K_2\theta_2$

$TD_2 = $ Damping torque due to $B_2 = B_2\dfrac{d\theta_2}{dt}$

Applying Newton's second law of motion

$$J_2\frac{d^2\theta_2}{dt} = TS_1 + TD_1 - TS_2 - TD_2$$

$$J_2\frac{d^2\theta_2}{dt} + TD_2 + TS_2 = TS_1 + TD_1 \qquad (3)$$

Substitute for various damping and spring torque

$$J_2\frac{d^2\theta_2}{dt} + (B_1 + B_2)\frac{d\theta_2}{dt} + (K_1 + K_2)\theta_2 = B_1\frac{d\theta_1}{dt} + K_1\theta_1 \qquad \ldots \quad (4)$$

From equation (1), substituting (5) in (3)

$$\left(J_1\frac{d^2\theta_1}{dt} - T\right) = (TS_1 + TD_1) \qquad \ldots\ldots (5)$$

$$J_2\frac{d^2\theta_2}{dt} + TS_2 - TD_2 = -J_1\frac{d^2\theta_1}{dt} + T$$

$$J_2\frac{d^2\theta_2}{dt^2} + B_2\frac{d\theta_2}{dt} + K_2\theta_2 = -J_1\frac{d^2\theta_1}{dt} + T$$

$$J_1\frac{d^2\theta_1}{dt^2} + J_2\frac{d^2\theta_2}{dt^2} + B_2\frac{d^2\theta_2}{dt} + K_2\theta_2 = T \qquad \ldots \quad (6)$$

Equation (6) is the differential equation of the system

TYPES OF CONTROL MODES:

The Two – Step Mode:

❖ The two-step mode in which the controller is essentially just a switch which is activated by the error signal and supplied just an on-off correcting signal.

❖ An example of the two-step mode of control is the bimetallic thermoset at that might be used with a simple temperature control system.

❖ This is just a switch which is switched on or off according to the temperature then the bimetallic ship is in an off position and the heater is off.

❖ If the room temperature falls below the required temperature then the bimetallic strip moves into an on position and the heater is switched fully on. The controller in this case can be in only two positions, on or off.
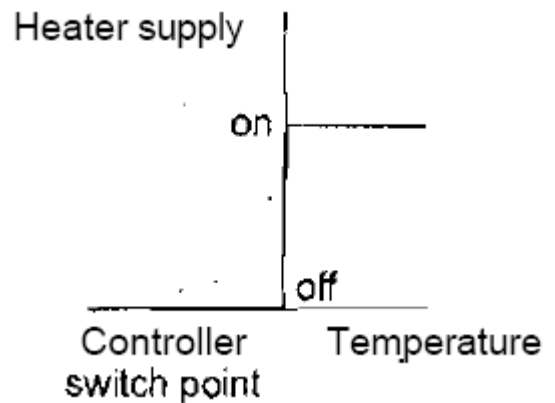
The Proportional Mode (P):

❖ The proportional mode (P) which products a control action that is proportional to the error. The correcting signal thus becomes bigger the bigger the error.

❖ Thus as the error is reduced the amount of correction is reduced and the correcting process slows down.
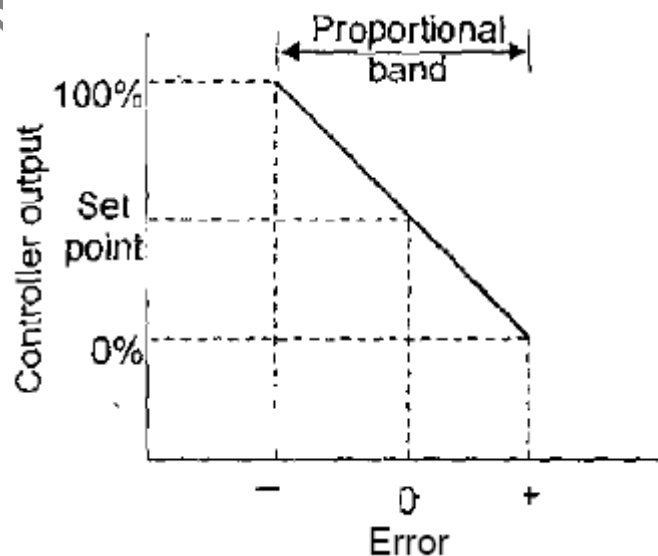
❖ The proportional mode, the size of the controller output is proportional to the size of the error.

Change in controller output $= K_p$

% Change in controller output from set point = K_p * % change in error

K   = 100 / Proportional Band

Change in Output (s)   = K_p * E(s)

Transformer function   = Change in Output (s) / E(s)

Electronic Proportional Controller:
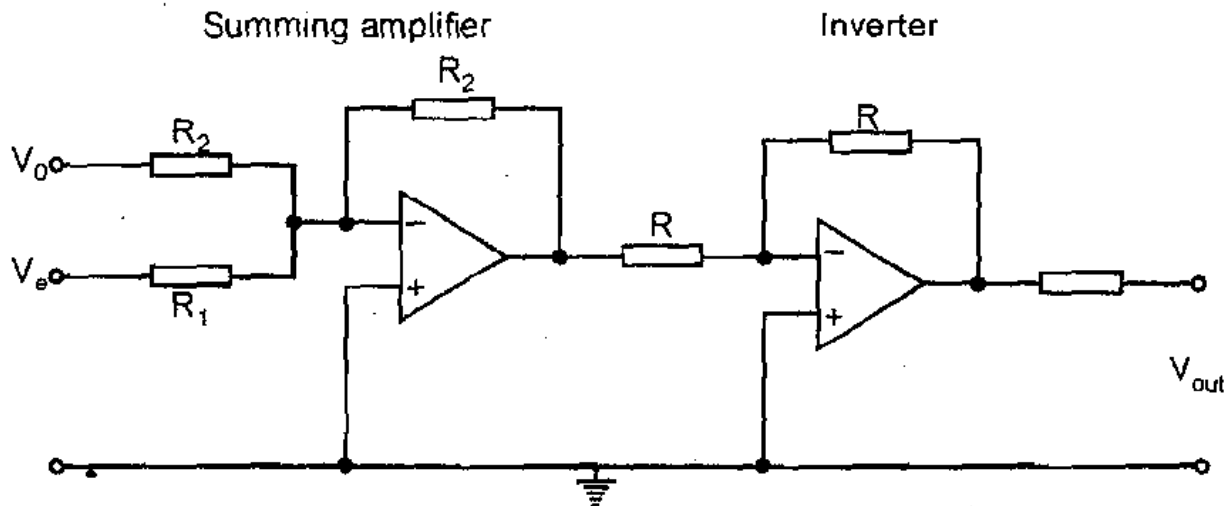
Example for Proportional Controller:
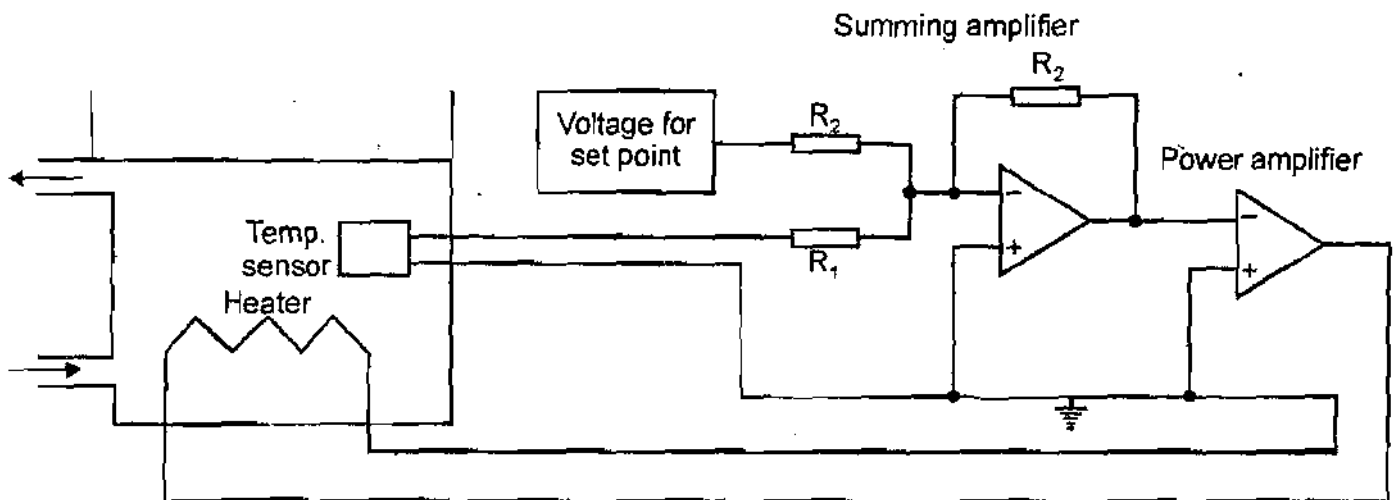
The Derivative Mode (D):

❖ The derivative mode (D) which products a control action that is proportional to the rate at which are errors is changing.

❖ When there is a sudden change in the error signal the controller gives a large correcting signal

❖ When there is a gradual change only a small corrections signal is produced. Derivative control can be considered to be a form of anticipatory control in that the existing rate of

change of error is measured, a coming larger error is anticipated and correction applied before the larger error has arrived.

❖ Derivative mode of control the change in controller output from the set point value is proportional to the rate of change with time of the error signal
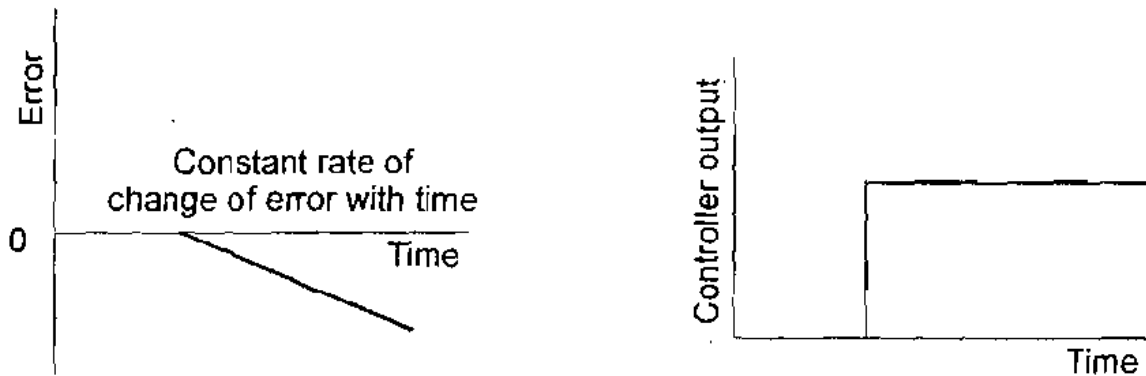
$$I_{out} - I_O = K_D \frac{de}{dt}$$

The transfer function is obtained by taking Laplace transforms, thus

$$(I_{out} - I_0)(s) = K_D s E(s)$$

Hence the transfer function is $K_D s$.
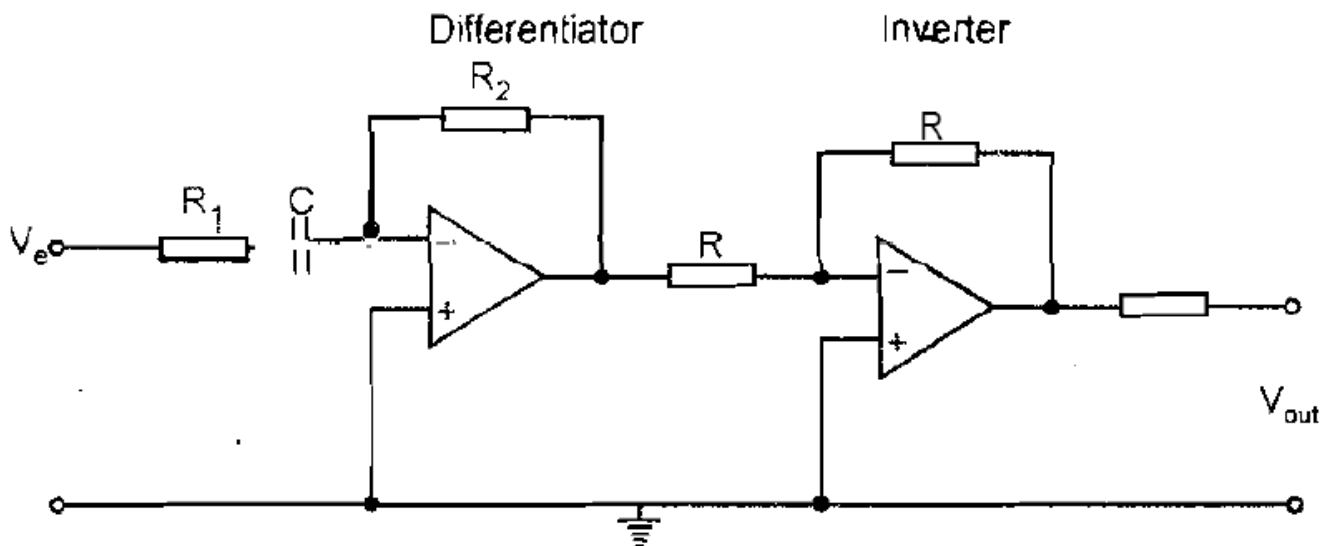
Proportional Plus Derivative Mode:

$$\text{Change in output from the set point} = K_P e + K_D \frac{de}{dt}$$

$$I_{out} = K_P e + K_D \frac{de}{dt} + I_0$$
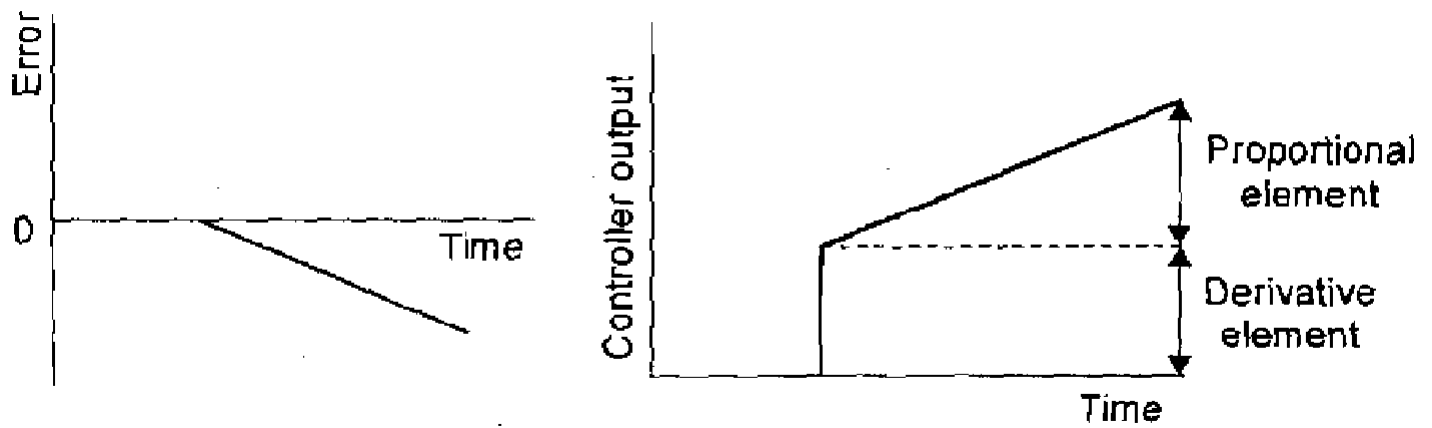
The Integral Mode (I):

❖ The integral mode (I) which produces a control action that is proportional to the integral of the error with time.

❖ Thus a constant error signal will produce an increasing correcting signal. The correction continues to increase as long the error persists.

❖ The integral mode of control is one where the rate of change of the control output I is proportional to the input error signal.
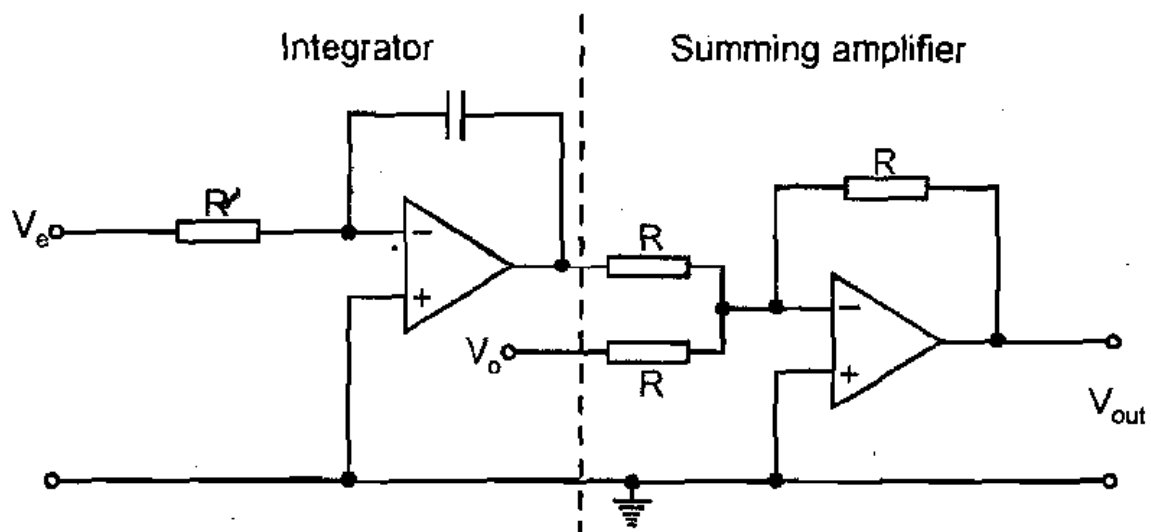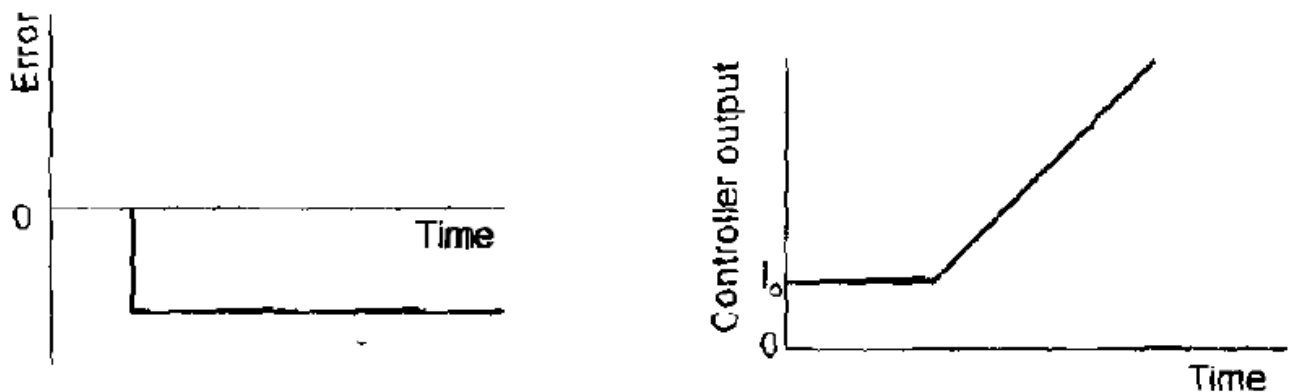
Proportional Plus Integral Control:

$$I_{out} = K_P\, e + K_I \int e\, dt + I_O$$

$$\text{Transfer Function} = K_p + \frac{K_I}{S}$$

$$= \frac{K_P}{S}\left(S + \frac{1}{T_1}\right)$$
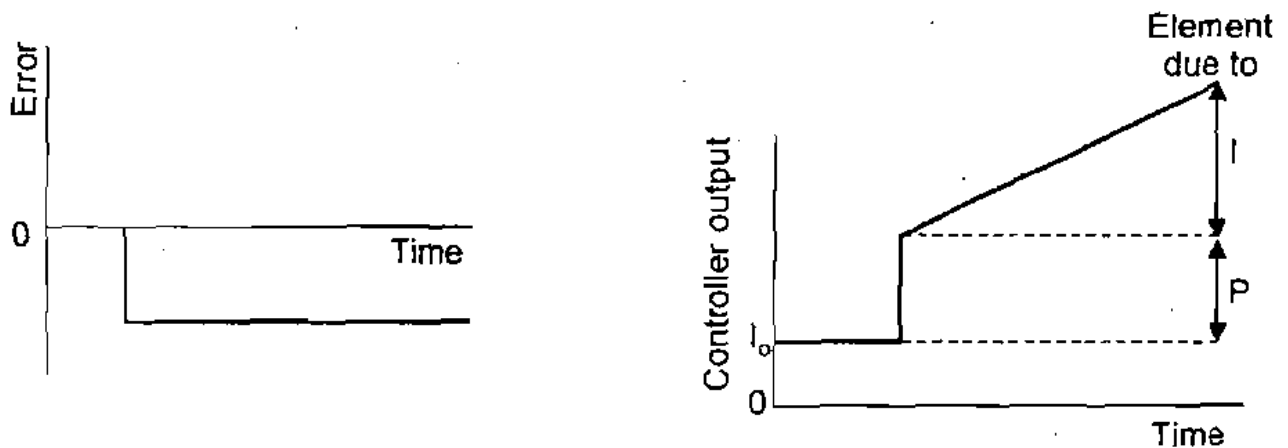
Combinations of Modes:

❖ Proportional plus derivative modes (PD), proportional plus integral modes (PI), proportional plus integral plus derivative modes (PID).

❖ The term three – term controller is used for PID control.

DIGITAL CONTROLLERS:

❖ The tern digital control is used when the digital controller, basically a microprocessor is in control of the closed-loop control system.

❖ The controller receives inputs from sensors, executes control programs and provides the output to the correction elements.

❖ The controllers require inputs which are digital, process the information in digital form and give an output in digital form.

❖ Since many control systems have analogue measurements an analogue-to-digital converter (ADC) is used forth inputs.

❖ A clock supplies a pulse at regular time intervals and dictates when samples of the controlled variable are taken by the ADC.

❖ The samples are then converted to digital signals which are compared by the microprocessor with the set point value to give the error signal.

❖ The microprocessor can then initiate a control mode to process the error signal and give a digital output.

❖ The control mode used by the microprocessor is determined by the program of instruction used by the microprocessor for processing the digital signals, i.e., the software.

❖ The digital output, generally after processing by a digital-to-analogue converter since correcting elements generally require analogue signals can be used to initiate the correcting action
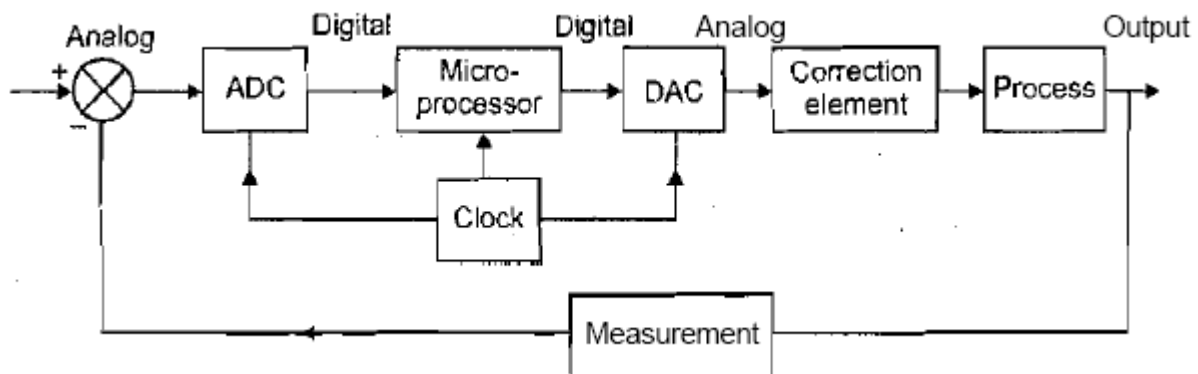
A digital controller basically operates the following cycle of events:

❖ Samples the measured value.

❖ Compares it with the set value and establishes the error.

❖ Carries out calculations based on the error value and stored values of previous inputs and outputs to obtain the output signal

❖ Sends the output signal to the DAC.

❖ Waits until the next sample time before repeating the cycle.

VELOCITY CONTROL:

❖ Consider the problem of controlling the movement of a load by means of a motor.

❖ Time will thus be taken for the system to respond to an input signal.

❖ A higher speed of respond, with fewer oscillations, can be obtained by using PD rather than just P control.

❖ There is, however, alternative of achieving the same effect and this is by the use of a second feedback loop which gives a measurement related to the rate at which the displacement is changing.

❖ This is termed velocity feedback.

❖ The velocity feedback might involve the use of a Tachogenerator giving a signal proportional to the rotational speed of the motor shaft and hence the rate at which the displacement is changing and the displacement might be monitored using a rotary potentiometer
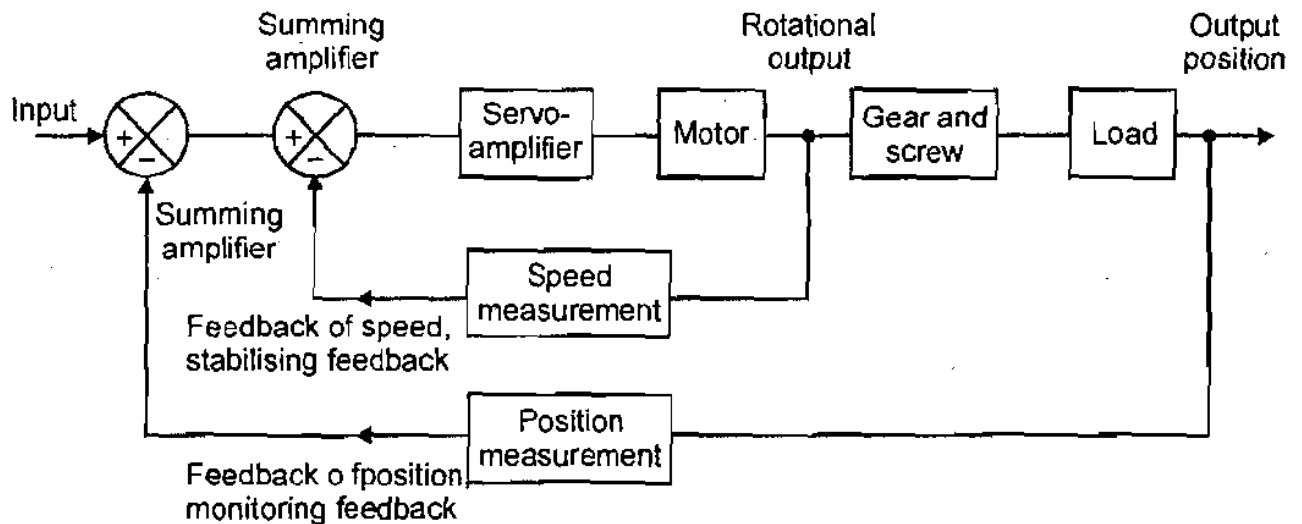
ADAPTIVE CONTROL:

❖ An adaptive control system which 'adapts' to changes and changes its parameters to fit the circumstances prevailing.

❖ The adaptive control system is based on the use of a microprocessor as the controller.

❖ Such a device enables the control mode and the control parameters used to be adapted to fit the circumstances, modifying them as the circumstances change.

Stages of Adaptive Control System:

❖ An adaptive control system can be considered to have three stages of operation.

❖ Starts to operate with controller conditions set on the basis of an assumed condition.

❖ The desired performance is continuously compared with the actual system performance.

❖ The control system mode and parameters are automatically and continuously adjusted in order to minimise the difference between the desired and actual system performance.

Forms of Adaptive Control System:

Adaptive control systems can take a number of forms. Three commonly used forms are:

❖ Gain-scheduled control

❖ Self – tuning

❖ Model-reference adaptive systems

Gain – Scheduled Control:

- ❖ With gain-scheduled control or, as it is sometimes referred to, pre-programmed adaptive control, pre-set changes in the parameters of the controller are made on the basis of some auxiliary measurement of some process variable.
- ❖ The term gain-scheduled control was used because the only parameter originally adjusted was gain
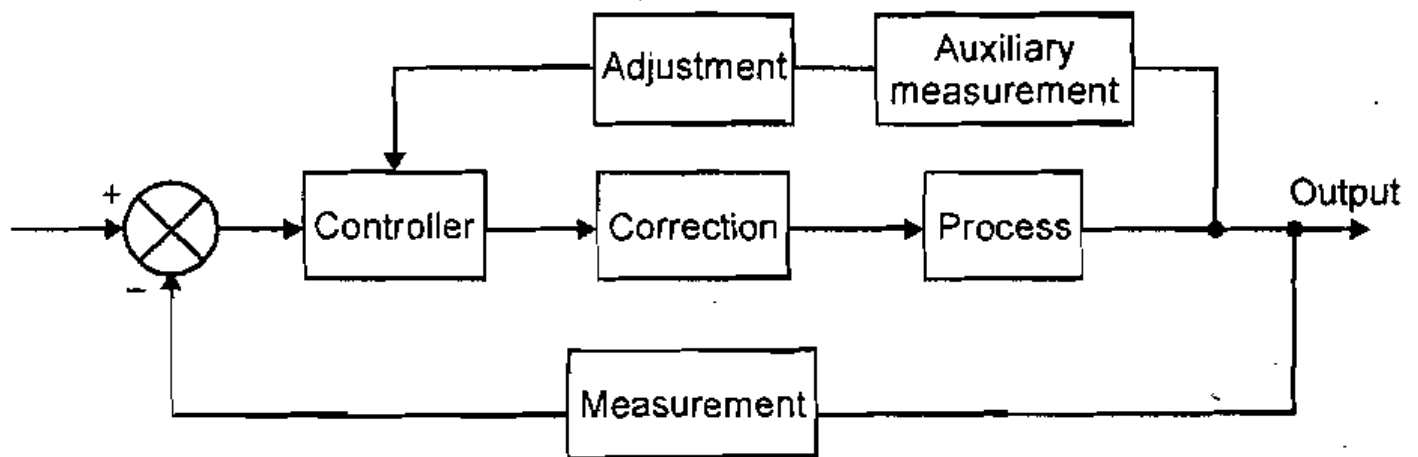
Self – Tuning:

- ❖ With self-tuning control the system continuously tunes its own parameters based on monitoring the variable that the system is controlling and the output from the controller.
- ❖ Self-tuning is often found in commercial PID controller, it generally then being referred to as auto-tuning.
- ❖ When the operator presses a button, the controller injects a small disturbance into the system and measures the response.
- ❖ Response is compared to the desired response and the control parameters adjusted, by modified Ziegler-Nichol rule, to bring the actual response closer to the desired response.
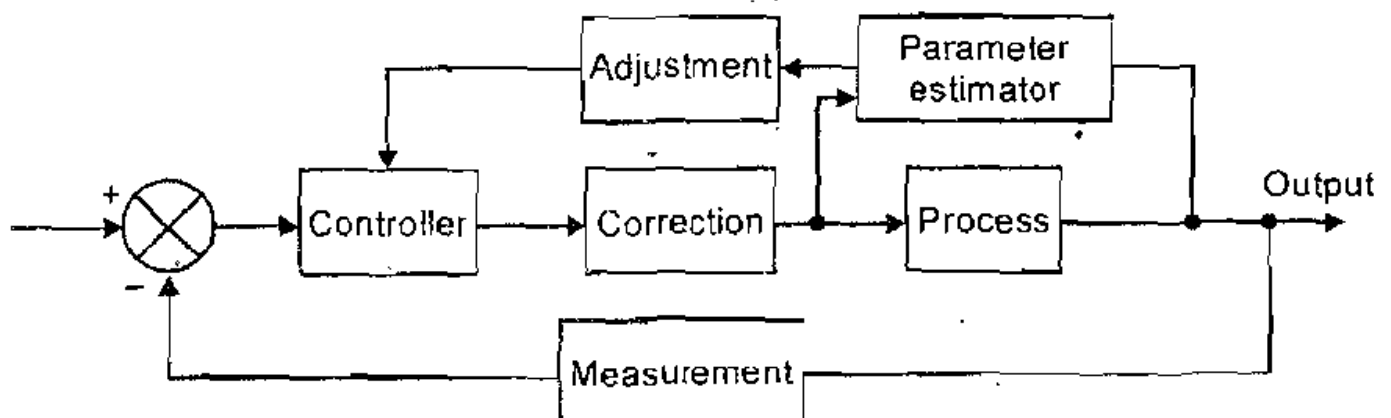
Model-Reference Adaptive Systems:

❖ The model-reference system an accurate model of the system is developed.

❖ The set value is then used as an input to both the actual and the model systems and the difference between the actual output and the output from the model compared. The difference in these signals is then used m adjusts the parameter of the controller to minimise the difference.
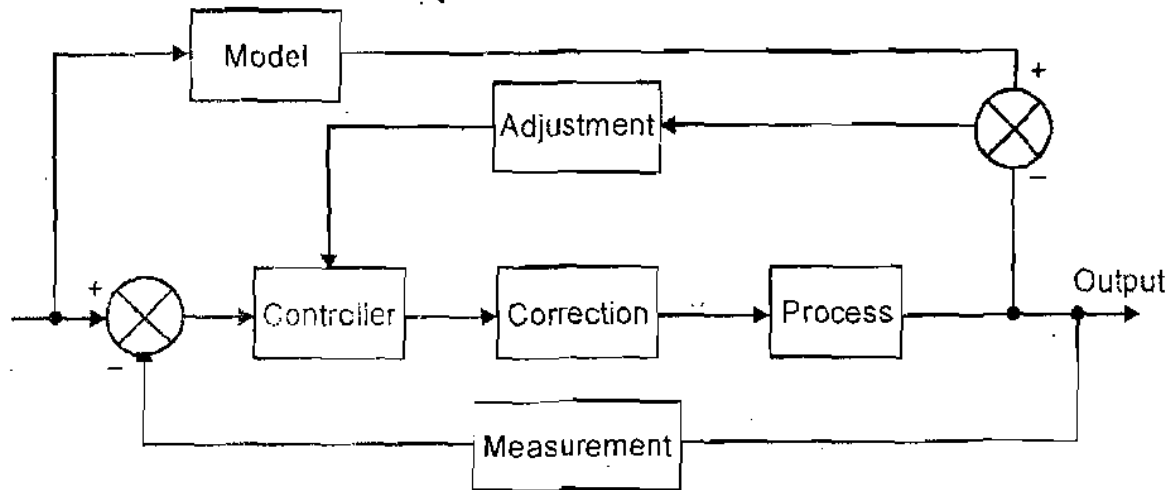
UNIT – IV PROGRAMMING LOGIC CONTROLLERS

DEFINITION OF PLC:

A programmable logic controller (PLC) Program is a specially designed digital operating microprocessor-based controller that uses a programmable memory for internal storage of instructing and for internal storage of instructing and for implementing function such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes.

BASIC COMPONENTS OF PLC:

The PLC hardware system consists of the basic components are

- ❖ Processor
- ❖ Memory
- ❖ Power Supply
- ❖ Input *I* Output modules
- ❖ Programming device
- ❖ Monitor
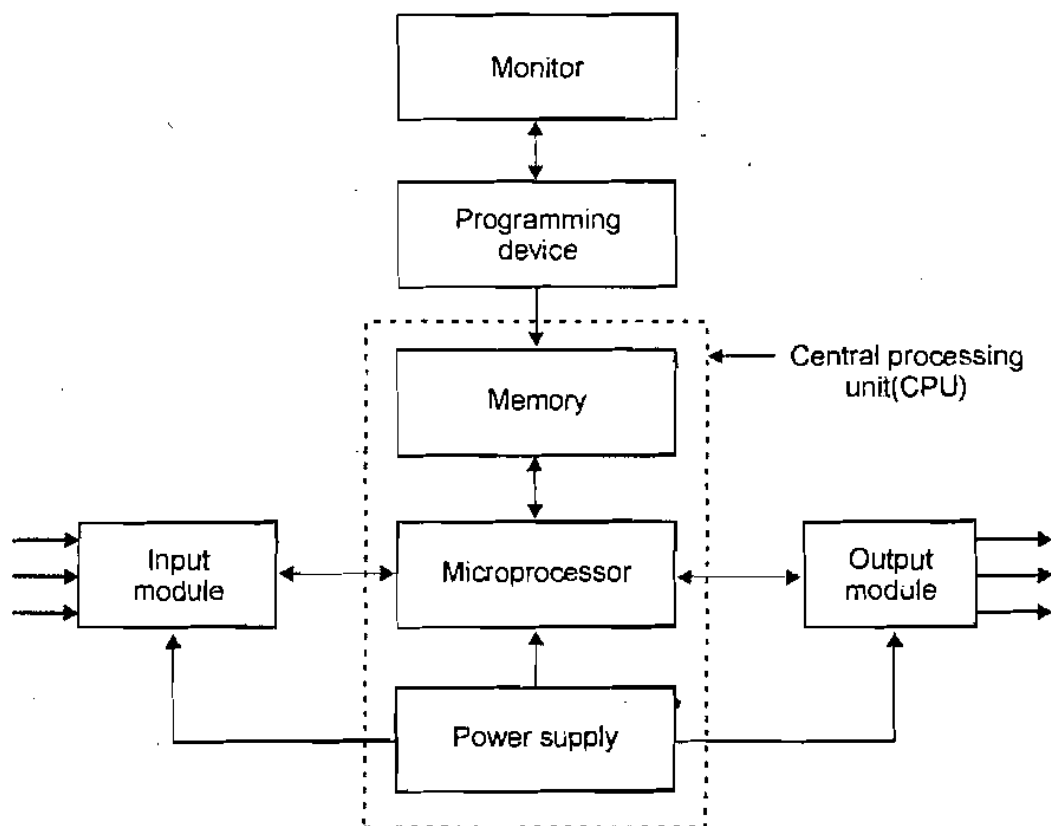
Processor:

- ❖ It is the heart of PLC

- ❖ He processor processes the signals from input module and generates controlling signals for the system
- ❖ It also scans and solve the logic of the user program
- ❖ It consists of ALU, microprocessor unit, memory unit and system power supply

Memory:

- ❖ The memory unit contains the program stored in it
- ❖ The programs were written with control actions to be executed by the microprocessor for the input given
- ❖ RAM is a temporary storage device used to store ladder diagram and for testing and evaluation
- ❖ Then it is stored in ROM where changes cannot done

Power Supply:

- ❖ The purpose of a power supply unit is to convert the main A.C voltage into a low - level D.C voltage (5V).
- ❖ The D.C. voltage is supplied to the processor and the circuits in the input and output interface modules.
- ❖ The power supply should be free from heavy loads, noises and voltage fluctuations.

Input / Output Modules:

- ❖ The Input module receives information from extended devices and sends to processor and communicates the processed information to the external devices through output modules.
- ❖ The Input devices are mechanical switches, photo sensors, temperature sensors, flow sensors, other type of sensors keypads etc.,
- ❖ The output devices may include solenoid valves, Relays, contactors, lights, Horns,
- ❖ Heating elements, fans, Motor starter, signal Amplifiers. Conveyor belt, lift, automatic door etc.,
- ❖ I/O devices are also called peripheral devices.

Programming Device:

- ❖ It is used to enter the required program into the memory of the CPU
- ❖ The program is developed in programming device and stored into memory unit

BASIC STRUCTURE OR (INTERNAL ARCHITECTURE) OF A PLC SYSTEM:
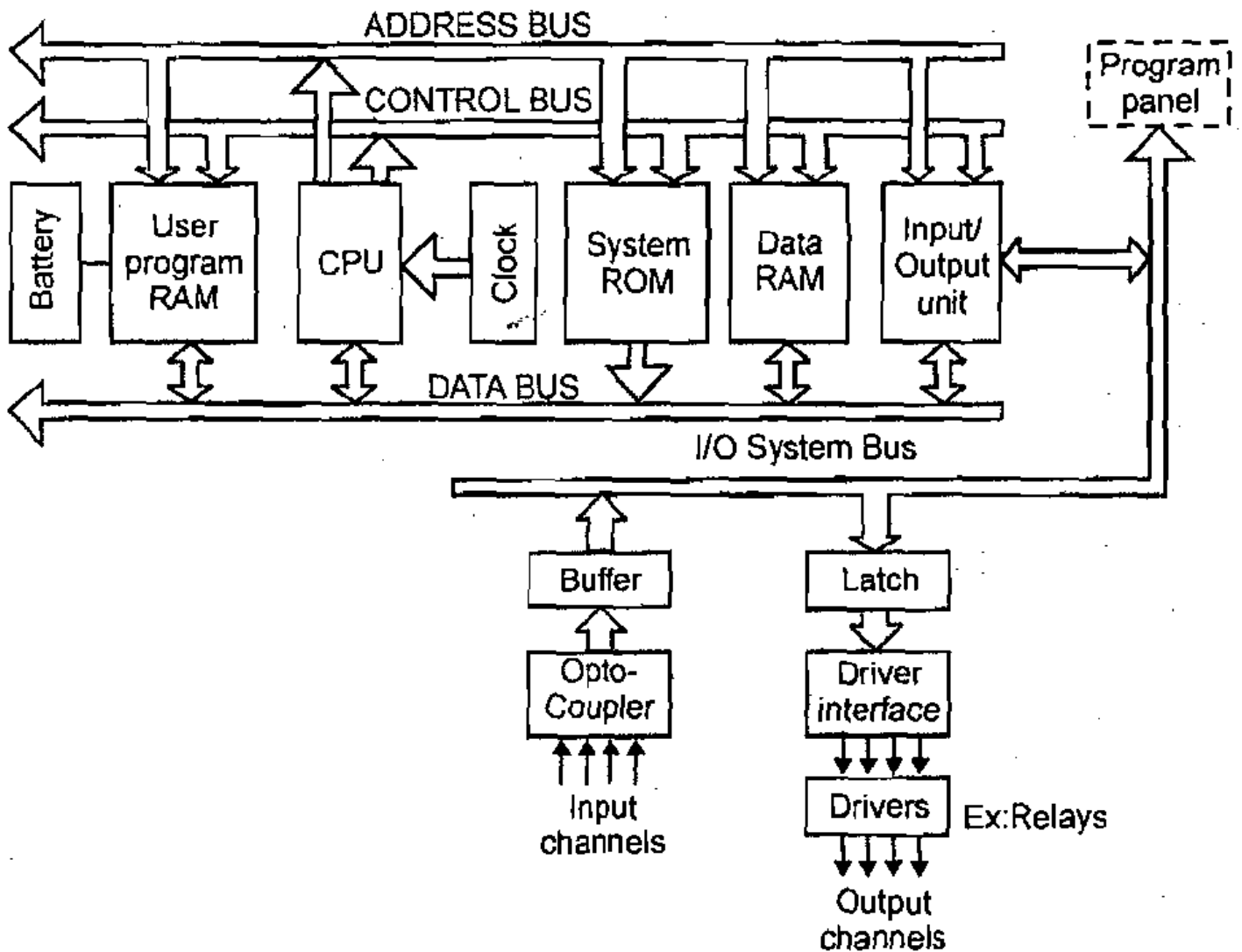
Central Processing Unit:

- ❖ The CPU controls and processes all the operations within the PLC.
- ❖ It is supplied with a clock with a frequency of typically between 1 to 8 MHz.
- ❖ This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system.
- ❖ The information within the PLC is carried by means of digital signals.
- ❖ The processor is a microprocessor that executes a program to perform the operations specified in a ladder diagram or a set of Boolean equations.
- ❖ The CPU consists of the following units

Arithmetic and Logic Unit (ALU):

- ❖ This unit performs data manipulation and arithmetic and logical operations on input I variable data and determines the proper state of the output variables.

❖ The arithmetic operation includes addition, subtraction etc., and logic operations include AND, OR, AND, EXCLUSIVE - OR.

Memory Unit:

❖ Memory termed registers located within the microprocessor and used to store information involved in a program execution.

❖ These programs contain control actions to be executed by the microprocessor for the given input. There are several memory elements in a PLC system.

❖ System Read-only Memory (ROM) gives permanent storage for the operating system and fixed data wed by the CPU.

❖ RAM for the user to develop program and acts a temporary memory.

❖ In addition, temporary buffer stores for the I/O channels.

Control Unit:

❖ A control unit is used to control the timing of operations.

❖ The processor functions under a permanent supervisory operating system that directs the overall operations from data input and output to execution of user programs.

❖ The controller can perform only one operation at a time. So, it scans each of the inputs sequentially, evaluates the ladder diagram program, provide each output(s), and then repeat the whole process.

❖ Hence, the timing control's necessary for a PLC system.

Memory Unit:

❖ The sequence of instructions to be executed, programs are stored in the memory unit.

❖ During entering and editing including Debugging, the program is stored in the temporary storages called RAM (Random Access memory).

❖ Once the program is completely finished (free & from errors).

❖ It may be 'burned' into ROM

❖ When the ROM is plugged into the PLC, the device is ready to be placed into service in the industrial environment.

❖ For network programmed PLCs, the final PLCs program is downloaded into a special re-programmable ROM (EPROM, PROM, and EEPROM) in the PLC.

❖ Memory may be either volatile type or Non-volatile type.

Volatile Memory:

- ❖ Volatile memory or temporary memory or Application memory is the user memory, where the user can enter and edit the program.
- ❖ Volatile memory will lose all its programmed contents if operating power is removed or lost.
- ❖ Therefore, necessary to provide a battery backup power to all times.

Non Volatile Memory:

- ❖ Non-volatile memory or permanent memory or system memory is (used) a system memory that stores the monitor a booting programs, lookup tables etc.,
- ❖ This usually programmed and supplied by the manufacturer.
- ❖ This controls the operation of PLC.
- ❖ It does not lose its content during power failure.
- ❖ It does not require any battery.
- ❖ The ROM memory offers the CPU to use only fixed amount of data.

The Different Types of ROMS are

- ❖ Mask programmed ROM
- ❖ PROM
- ❖ EPROM
- ❖ EEPROM

Mask Programmed ROM:

- ❖ It is a special type of ROM which is programmed during manufacturing.
- ❖ The programmed content stored by this type of ROM memory cannot be altered.

PROM:

- ❖ PROM stands for programmable Read only memory.
- ❖ It is a special type of ROM usually programed by manufacturer during manufacturing.
- ❖ It has the disadvantage of requiring special programming device and once programmed cannot be erased or altered.

EPROM:

- ❖ EPROM stands for electrically programmable Read only Memory.
- ❖ Here, the user programs electrically.

❖ One can erase the program completely by shining UV light source or quartz window in package.

❖ After the program chip is erased completely, program changes can be made.

❖ When the program developed in RAM, the manufacturers usually load it in EPROM to make permanent storage.

EEPROM:

❖ EEPROM - Electrically Erasable programmable Read-only memory.

❖ Even though, it is a non-volatile memory, it offers some programming flexibility as RAM.

❖ One **can** erase the program completely by electrical signals.

❖ Program changes can be made very easily with the use of a PC with EEPROM software.

❖ It can be electrically programmable by the user.

Buses:

❖ A set of parallel lines that provides communication between various devices of a system is termed as a Bus.

❖ The bus system carries information and data's to and from the CPU, Memory and I/O units.

❖ The information is transmitted in binary form as 0 or 1

❖ Digital signals or electrical signals are flowing inside the bus.

❖ It might be tracks on a printed circuit board (PCB) or wires in a ribbon cable.

❖ The PLC system contains four buses.

❖ They are namely Data Bus, Address Bus, Control bus and system bus.

Data Bus:

❖ The data bus contains 8, 16 or 32 parallel signal lines for sending data between the various devices of a system.

❖ An 8-bit microprocessor has an internal data bus which can handle 8-bit numbers.

❖ The double ended arrows on the bus line show that they are bidirectional.

❖ This means that CPU can read data in from memory or from I/O unit on these lines or it can send data out to memory or to I/O unit on these lines.

❖ Many devices in a system will have their outputs connected to the data bus, but only one device will have its output enabled at a time.

Address Bus:

❖ The Address bus contains 16, 20, 24 or 32 parallel signal lines to carry the Address of the memory locations for accessing stored data.

❖ Every memory location is given a distinct unique address to locate easily and accessed by the CPU either to read or write data.

Control Bus:

❖ The Control bus contains 4 to 10 parallel signal lines to carry the signals used by the CPU that are related to internal Control actions. Typical control bus signals are Memory read Memory write, I/O Read and I/O write.

I/O System Bus:

❖ The I/O system bus provide the communication between the I/O ports and I/O units

Input / Output Unit:

❖ The I/O units provide the interface between the system and the outside world, allowing for connections to be made through I/O channels to input / output devices.

❖ Programs are entered from a program panel through I/O unit.

INPUT / OUTPUT PROCESSING:

The sourcing and sinking are used to describe the way in which DC devices are connected to PLC

Sourcing:

❖ If a switch is connected to the positive of the battery and current flows from positive to negative, it is said to be the sourcing the current. So, the input device receives current from the input module.

❖ For the PLC, input unit, hence input module is the source of the current. For the PLC output unit, output module is the source of current as it supplies current to the output devices. Sourcing output units for interfacing with solenoids.
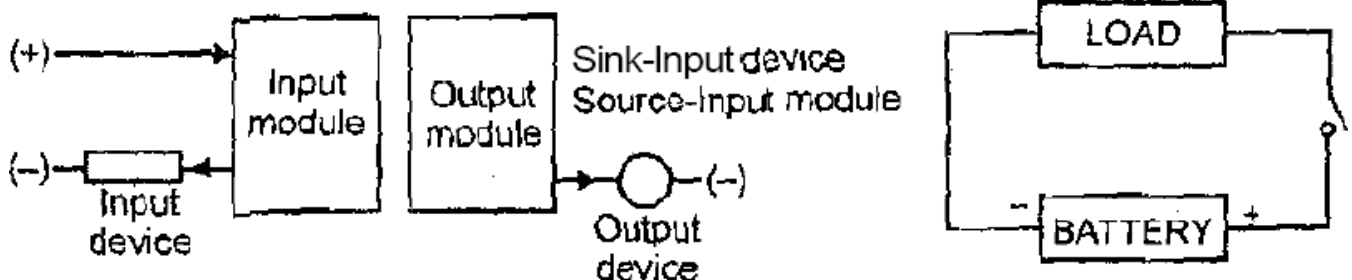
Sinking:

❖ Here, the input device supplies current to the input module. For the PLC input unit, hence the input module is the sink for the current. Sinking input units are used for interfacing with electronic equipment.

❖ So, if a switch is connected to the negative of the battery and current flows from positive to negative, by conventional current flow direction, it is said to be the sinking for Current. For the PLC output unit, the current flows from output device to the output module then the output module is the sink for current.
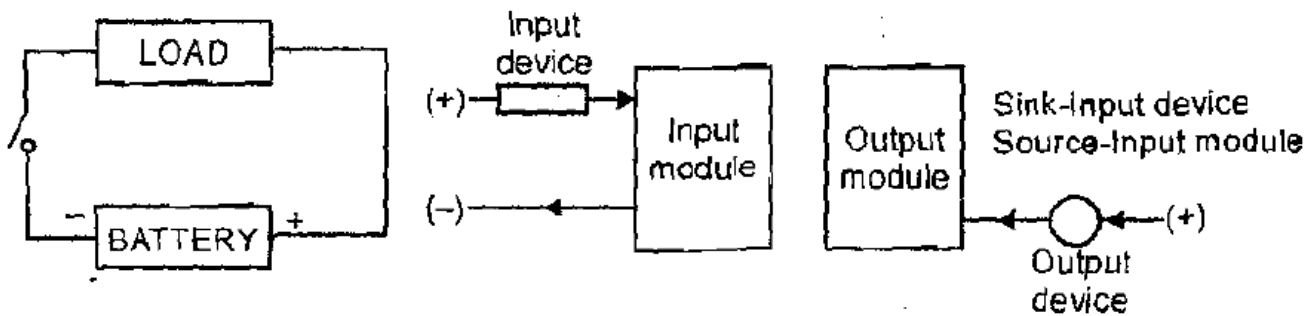
STEPS INVOLVED IN INPUT / OUTPUT PROCESSING:

The sequence followed by a PLC when carrying out a program can be **as** follows:

❖ Scan the inputs associated with one rung of the ladder program

❖ Solve the logic operation involving those inputs.

❖ Set / Reset the outputs for that rung

❖ Move on the next rung and repeat the operations 1, 2, 3
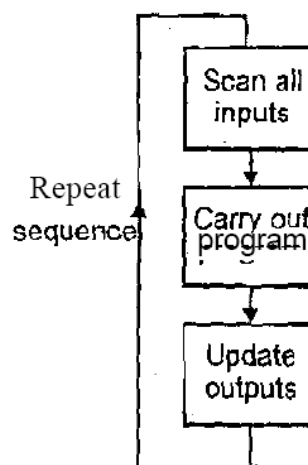
The two methods of Input/ Output processing operations are

➢ Continuous updating

➢ Mass Input / Output copying

Continuous Updating:

The sequence followed thus in continuous updating is as follows:

❖ Fetch and decode the first program instruction

❖ Scan there relevant inputs

❖ Fetch and decode the second program instruction

❖ Scan the relevant inputs etc. For the remaining program instructions

❖ Update outputs

❖ Report the entire sequence.

Mass Input / Output Copying:

The sequence followed in Mass I/O copying is thus:

❖ Scan all the inputs and copy into RAM

❖ Fetch and decode and execute all the program instructions in sequence

❖ Copy all the output instructions to RAM

❖ Update all outputs.

❖ Repeat the sequence

PLC LOGIC:

Instruction Code Mnemonics:

Mnemonics	Description
LD	Start a Rung with an open contact
OUT	An output
AND	A series element with an open contact and so an AND logic instruction.
OR	A parallel element with an open contact an so an OR logic instruction.
I	A NOT logic instruction
...I	Used in conduction with other instruction to indicate the inverse.
ORI	A parallel element with an closed contact and so NOR logic instruction
Ah?	A series element with an closed contact and so a NAND logic instruction.
LDI	Start a rung with a closed contact
ANB	AND logic instruction used with two sub circuits
ORB	OR logic instruction used with two sub circuits
RST	Reset shift register / counter
SHF	Shift
K	Insert a constant
END	End the ladder.

AND Logic Function:

- ❖ AND logic circuit represents series circuit
- ❖ AND gate is composed with two inputs and one output.
- ❖ AND gate produce output when both the inputs are HIGH state.
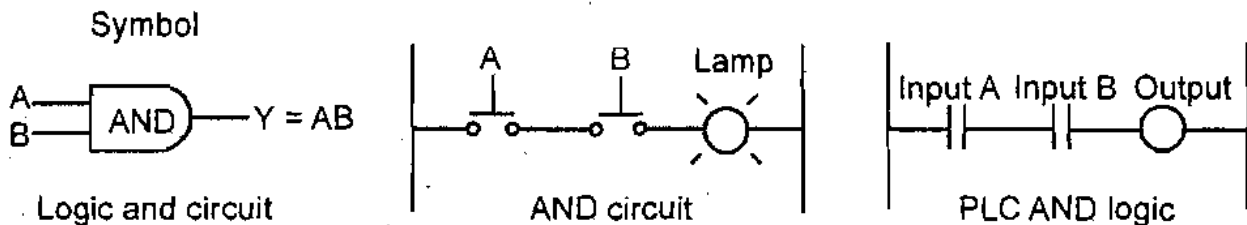
Output = Lamp

Input A	Input B	Output A.B
0	0	0
0	1	0
1	0	0
1	1	1

AND system
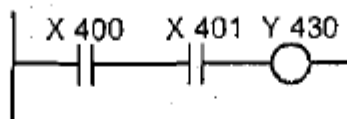
Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Strat a rung with open contacts
1	AND X401	X401	AND Logic	Open contant AND logic function
2	OUT Y430	Y430	OUTPUT	Output or terminate the rung.

OR Logic Function:

- ❖ OR logic circuit represents the parallel circuit.
- ❖ OR Gate is composed of two or more inputs and one output.
- ❖ OR operation is like addition of binary numbers.
- ❖ OR gate produce output when any one input are HIGH state.

PLC OR Logic
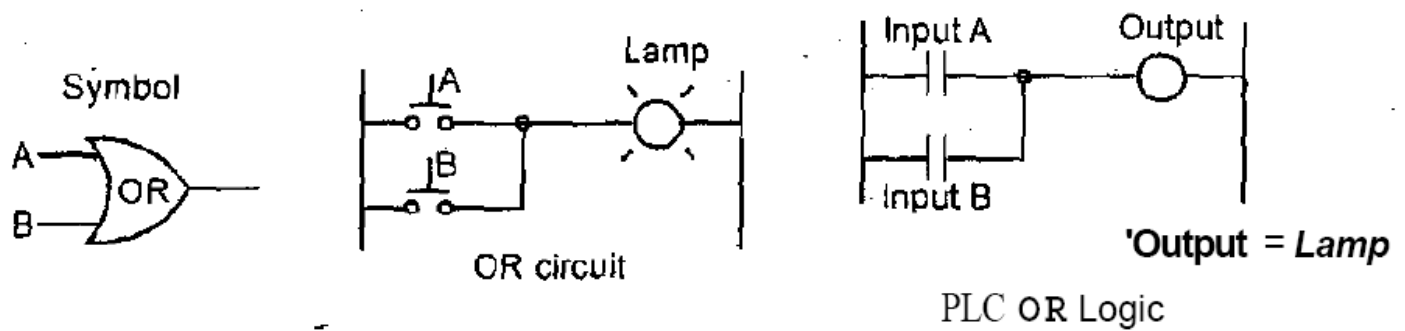
Input A	Input B	Output (A+B)
0	0	0
0	1	1
1	0	1
1	1	1

OR system
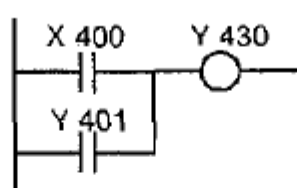
Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Start a rung with open contacts
1	OR X401	X401	OR Logic	Add as open content in parallel
2	OUT Y430	Y430	OUTPUT	Terminate the rung

NOT Logic Function:

❖ NOT function is also known as Inverter.

❖ NOT gate is composed of single input and a single output.

❖ The bubble, or circle, at the output is the standard symbol used to represent inversion.

❖ In NOT gate, there is an output, when there is no input and no output when there is an input
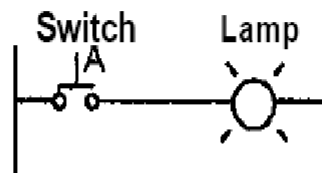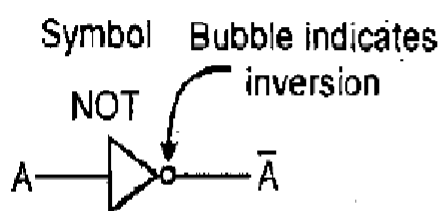
NOT circuit   PLC NOT Logic

*Output = Lamp
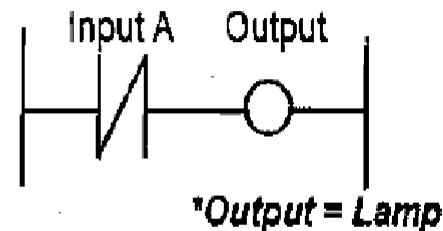
Input (A)	Output ($\overline{A}$)
X = A	X = $\overline{A}$
0	1
1	0

NAND Logic Function:

- ❖ NAND is a combination of AND and NOT gates.
- ❖ Arrangement shows AND gate is followed by NOT gate. Hence it is called NOT AND gate.
- ❖ Both the inputs A and B have to be at LOW state to get the output at HIGH state.
- ❖ NAND Gate is composed of two or more input with a single output.
- ❖ Any one input is in LOW state also output will be HIGH state

Symbol   NAND circuit   PLC NAND Logic

*Output = Lamp
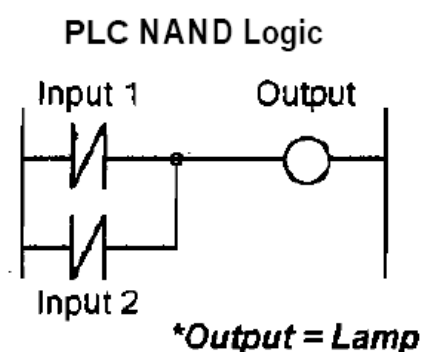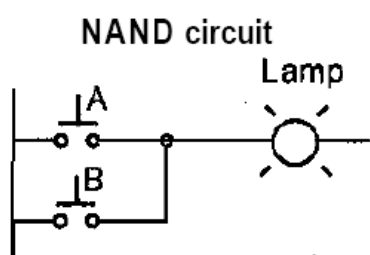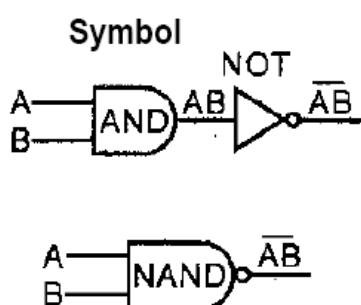
Input A	Input B	Output $\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0
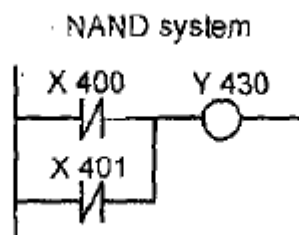
NAND system

Step	Instruction	Address	Parameter	Description
0	LDI X400	X400	INPUT	Start a rung with closed contacts
1	ORI X401	X401	NOR LOGIC	Add a closed contact in parallel
2	OUT Y430	Y430	OUTPUT	Terminate the rung.

NOR Logic Function:

❖ NOR is a combination of OR and NOT gates.

❖ Arrangement shows OR gate is followed by NOT gate. Hence it is called NOT OR gate.

❖ Both the inputs A and B have to be at LOW state to get the output at HIGH state.

❖ NOR Gate is composed of two or more input with a single output.

❖ Any one input is in HIGH state also output will be LOW state
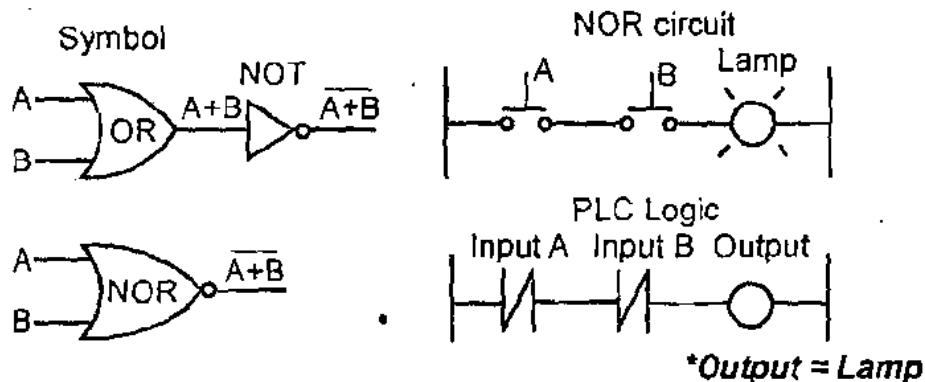
Input A	Input B	Output $(\overline{A+B})$
0	0	1
0	1	0
1	0	0
1	1	0

NOR system
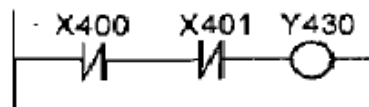
Step	Instruction	Address	Parameter	Description
0	LDI X400	X400	INPUT	Start a rung with closed contacts
1	ANI X401	X401	NAND Logic	Add a closed contact in series
2	OUT Y430	Y430	OUTPUT	Terminate the Rung.

Exclusive OR (XOR) Logic Function:

❖ When both the inputs are at LOW state the output will be at LOW state

❖ When both the inputs are at HIGH state the output will be at LOW state

❖ When any one input is HIGH state the output will be at HIGH state
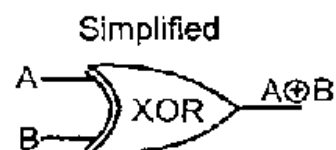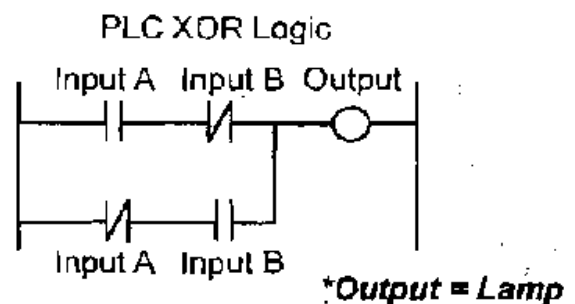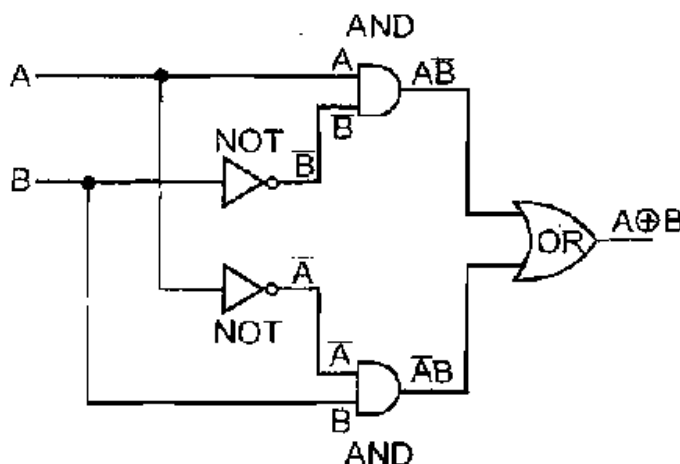
Input A	Input B	Output (A ⊕ B)
0	0	0
0	1	1
1	0	1
1	1	0

XOR system
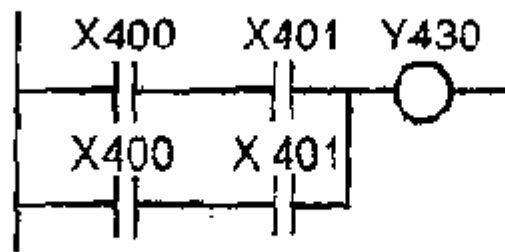
Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Start a rung with an open contacts
1	ANI X401	X401	NAND Logic	Add a closed contact in series with input
2	LDI X400	X400	INPUT	Start a new rung with a closed contacts
3	AND X401	X401	AND Logic	Add a open contact in series with input
4	ORB	-	-	Do 'OR' operation between two sub circuits
5	OUT Y430	Y430	OUTPUT	Terminate the Rung.

Latching:

❖ It is necessary to hold an output coil energized, even when the input ceases

❖ The term latch is used for the circuit used to carry out such an operation.

❖ Latch circuit is a self – maintaining circuit that maintains its output in an energized state until the next input is updated
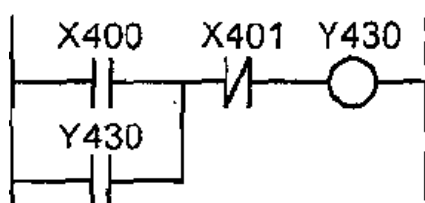
Latch circuit in Mitsubishi address form.
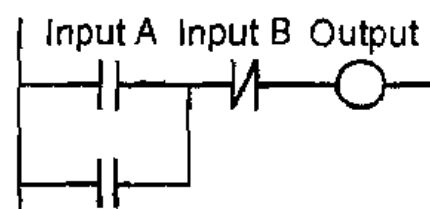
Output
Latch circuit

TIMER:

❖ A timer is a special counter ladder function that allows the PLC to perform timing operations based on a precise internal clock.

Types of Timers:

❖ Delay ON Timers or ON delay timers

❖ Delay OFF Timers or OFF delay timers

❖ Pulse Timers

❖ Cascaded Timers

❖ ON-OFF Cycle Timers

❖ One Shot Timers

Delay ON Timers:

❖ The term delay is used to indicate that this timer burns on, after waiting for a fixed time delay period.

❖ When there is an input, the timer is energised and starts timing, after some pre-set value, the timer contacts are closed to output.

❖ TON is used to denote ON-delay.
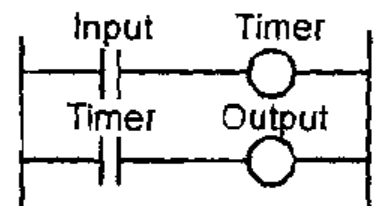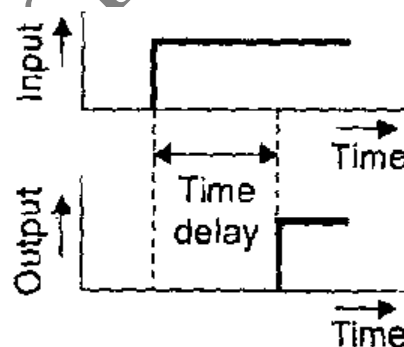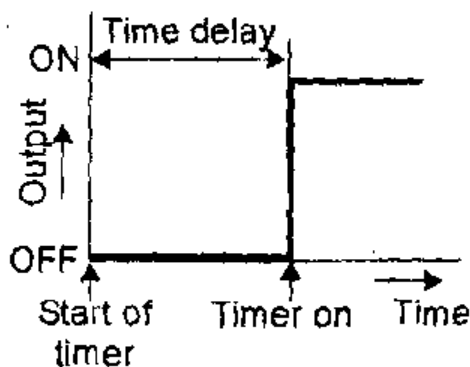
Delay OFF Timers:

❖ OFF delay timers are maintained as ON for a fixed time of delay period before turning off.

❖ TOF is used to denote OFF-delay.
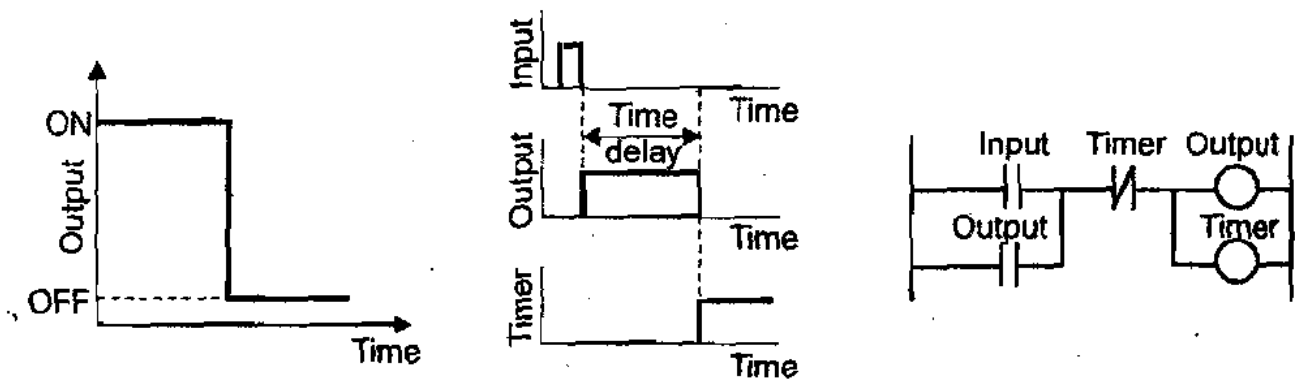
Pulse Timers:

- ❖ Pulse timer switches is another type of Timer which comes either ON or OFF for a fixed period of time as a function of pulses.

- ❖ TP is used to denote Pulse Timers
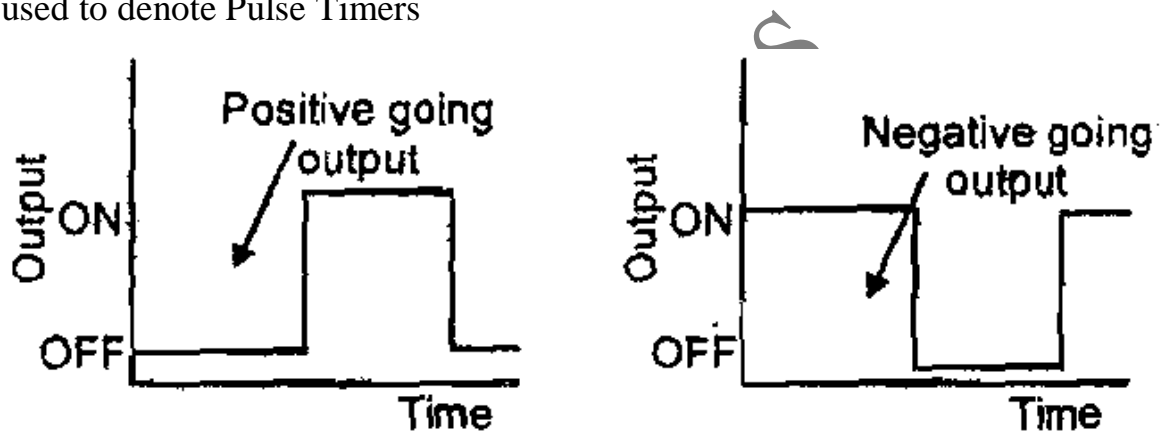
Cascaded Timers:

- ❖ Cascading means more elements are linked together to form a system.

- ❖ The cascading timers are linked together to give longer delay times which is easily achieved than just one timer.
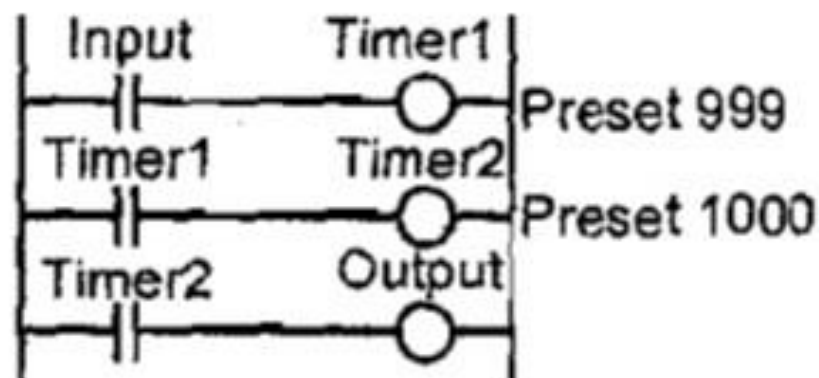
ON – OFF Cycle Timer:

❖ Timers producing an output for some period and no output for some period and an output for some period.

❖ The timer is designed to switch an output for T sec and off for another T second
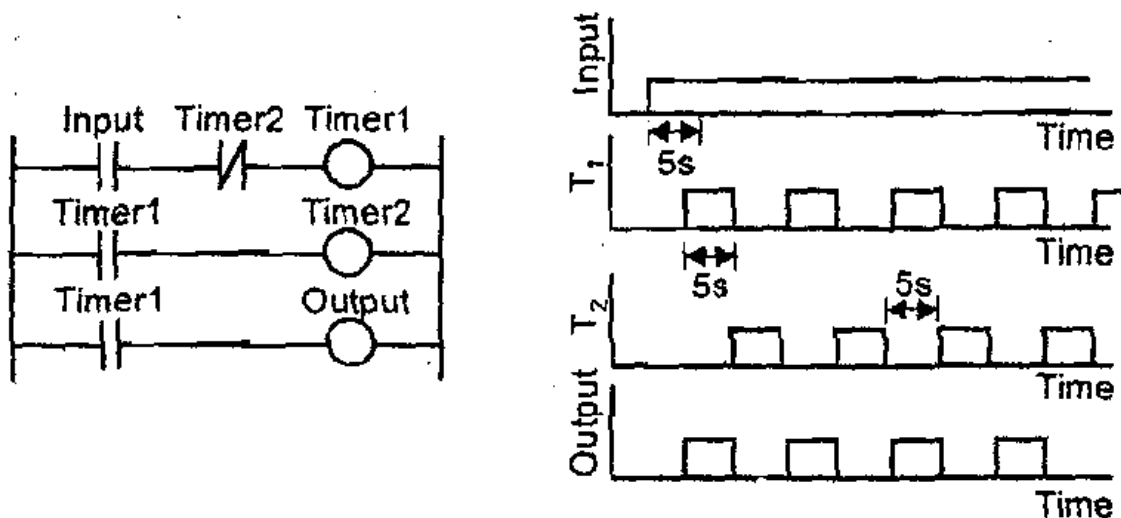
One Shot Timers:

❖ One shot timers produces an output for a fixed length of some initiation input.
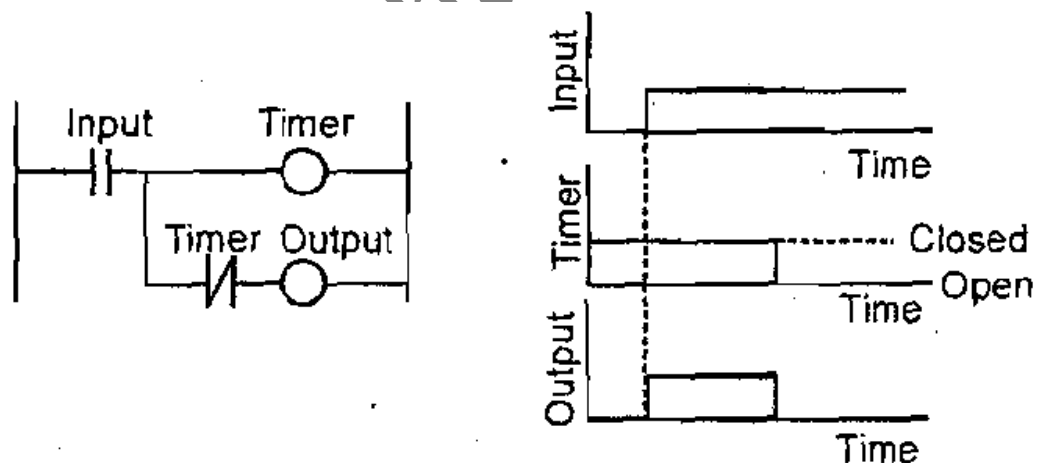
INTERNAL RELAY:

❖ An internal relay behaves like relays with their associated contacts, buy they are not actual relays whose simulations are controlled by the PLC software.

❖ Internal relays can be very useful in the implementation of switching sequences.

❖ They are often used when there are programs with multiple input conditions.

❖ They are also known as Auxiliary relays or markers.

❖ In using an internal relays, it has to be activated on one rung of a program and then its output used to operate switching contacts on another rung of a program.
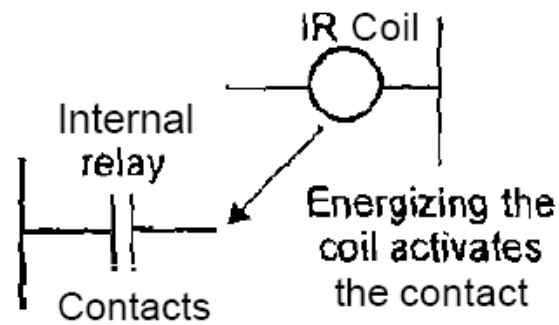
COUNTERS:

❖ Counters are used to count a specified number of contact operations.
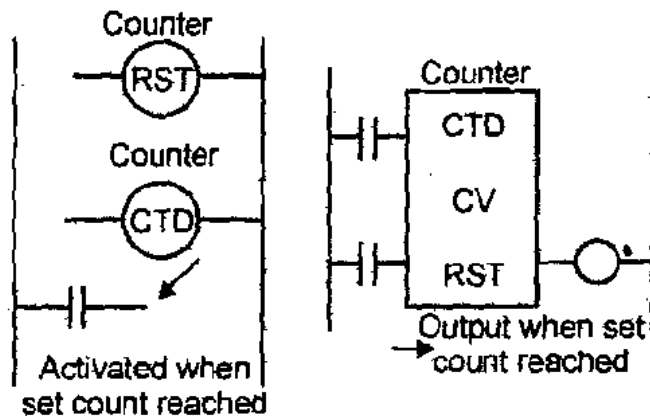
Types of Counters:

❖ Up Counters
❖ Down Counters

Up Counters:

❖ Up counters count up from the zero to pre – set value

❖ The events are added until the pre – set value is reached

❖ When the counter reaches the set value, its contacts change state

Down Counters:

❖ Down counters count down from the pre – set value to zero

❖ The events are subtracted until the pre – set value is reached

❖ When the counter reaches the Zero value, its contacts change state

SHIFT REGISTER:

❖ A shift register is an electronic storage device that allows the stored bits of one relay to get shifted into another relay.

DATA HANDLING:

The steps involved in data handling with a PLC system are

❖ Moving data from one memory location to another

❖ Comparison of Magnitudes of data

❖ Arithmetic operations

❖ Data conversion

Data – Handling Instruction	Source Address	Destination Address

Data Movement:

Instruction : MOV

Function : To copy a value from one address to another

Program:

LD X400

MOV

D1

D2
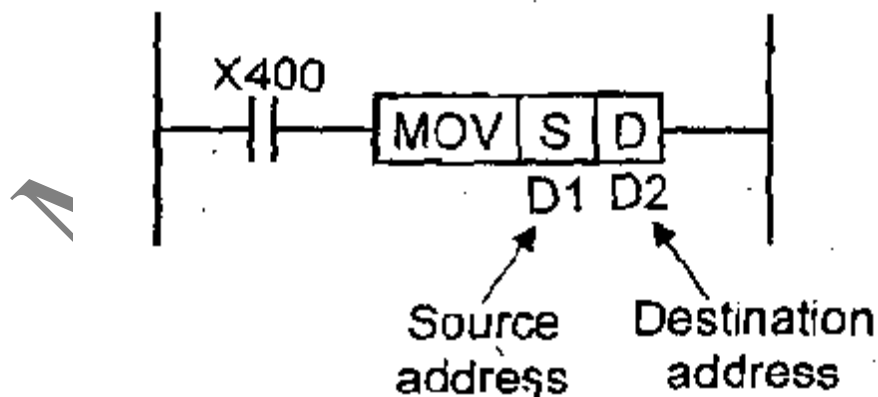
❖ When there is an input to X400,

❖ The data moves from the designated source address to the designated destination address.

❖ The data transfer might move a constant into a data register

Data Comparison:

❖ The data comparison instruction gets the PLC to compare two data values.

❖ It compare a pre – set value (1) to the input value (2)

Instruction : < or LES

= or EQU

> or GRT

≤ or LEQ

≠ or <> or NEQ

> or GEQ

❖ For data comparison the typical instruction will contain the data transfer instruction to compare the data from source address and designation address
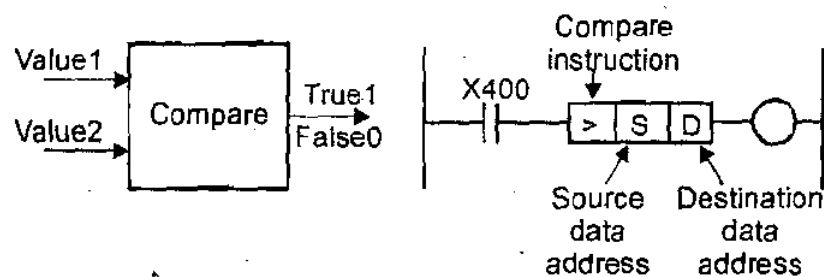
Example
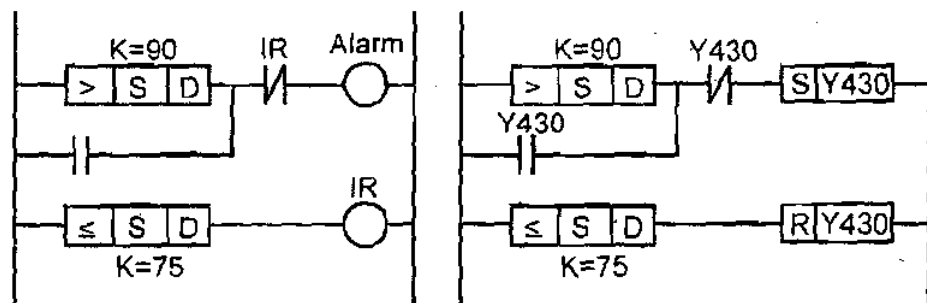
❖ It is required to sound an alarm if a sensor indicates a temperature above 90˚C and remain sounding until the temperature falls below 75˚C.
❖ For this, the ladder diagram is shown above.
❖ The input temperature data is inputted to the source address and the destination address contains the set value.
❖ When the temperature rises 90˚C or higher, the data value in the source address becomes ≥the destination address value and there is an output to the alarm which latches the input
❖ When the temperature falls to 75˚C or lower, the data value in the source address becomes < the destination address value and there is an output to the relay which then opens the contacts and so switches the alarm off.

Data Arithmetic Operations:

- ❖ PLCs are offered with the ability to carry out the arithmetic operations such as addition, subtraction, multiplication and division only.
- ❖ They cannot carry out exponential functions.
- ❖ Addition and subtraction operations are used to alter the value of data held in data registers.
- ❖ Multiplications are used to multiply some input before adding to or subtracting it from another.

Code Conversions:

- ❖ All the internal operations in the CPU of a PLC are carried out through binary numbers.
- ❖ Most PLCs provide BCD-to-binary and binary-to-BCD conversion for use.
- ❖ When a decimal (input) signal is given, BCD conversion is used.
- ❖ Similarly, when a decimal output is required, Decimal conversion is used.
- ❖ The data at the source address is in BCD and converted to binary and placed at the destination address.
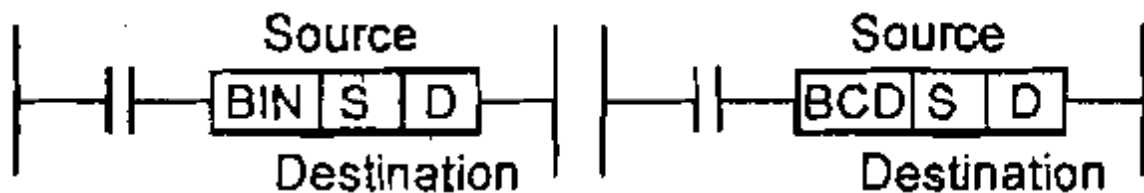
SELECTION OF PLCS

The selection process of PLC for a particular task depends on the following factors.

- ❖ Capacity of Input and Output
- ❖ No. of Inputs and Outputs
- ❖ Types of Inputs and Outputs
- ❖ Size of memory required I,
- ❖ Speed and Power required of the CPU

UNIT – V DESIGN OF MECHATRONICS SYSTEM

STAGES IN DESIGNING MECHATRONIC SYSTEMS:

The design of mechatronic systems can be divided into a number of stages.

The Need:

* ❖ The design process starts with the need of a customer.
* ❖ By adequate market research and knowledge, the potential needs of a customer can be clearly identified.
* ❖ In some cases, company may create a market need but failures are more in this area.
* ❖ Hence, market research technology is necessary.

Analysis of the Problem:

* ❖ This is the first stage and also the critical stage in the design process.
* ❖ After knowing the customer need, analysis should be done to know the true nature of the problem.
* ❖ To define the problem accurately, analysis should be done carefully

Preparation of a Specification:

* ❖ The second stage of the mechatronic process involves in the preparation of a specification
* ❖ The specification must be given to understand the requirements and the functions to be met.
* ❖ The specification gives mass dimensions, types, accuracy, power requirements, load, praying environments, velocity, speed, life etc.

Conceptualization:

* ❖ The possible solution should be generated for each of the functions required
* ❖It is generated by verifying the old problems or some newly developed techniques may be used

Optimization:

* ❖ This stage involves in a selection of a best solution for the problem
* ❖ Optimization is defined as a technique in which a best solution is selected among a group of solutions to solve a problem.
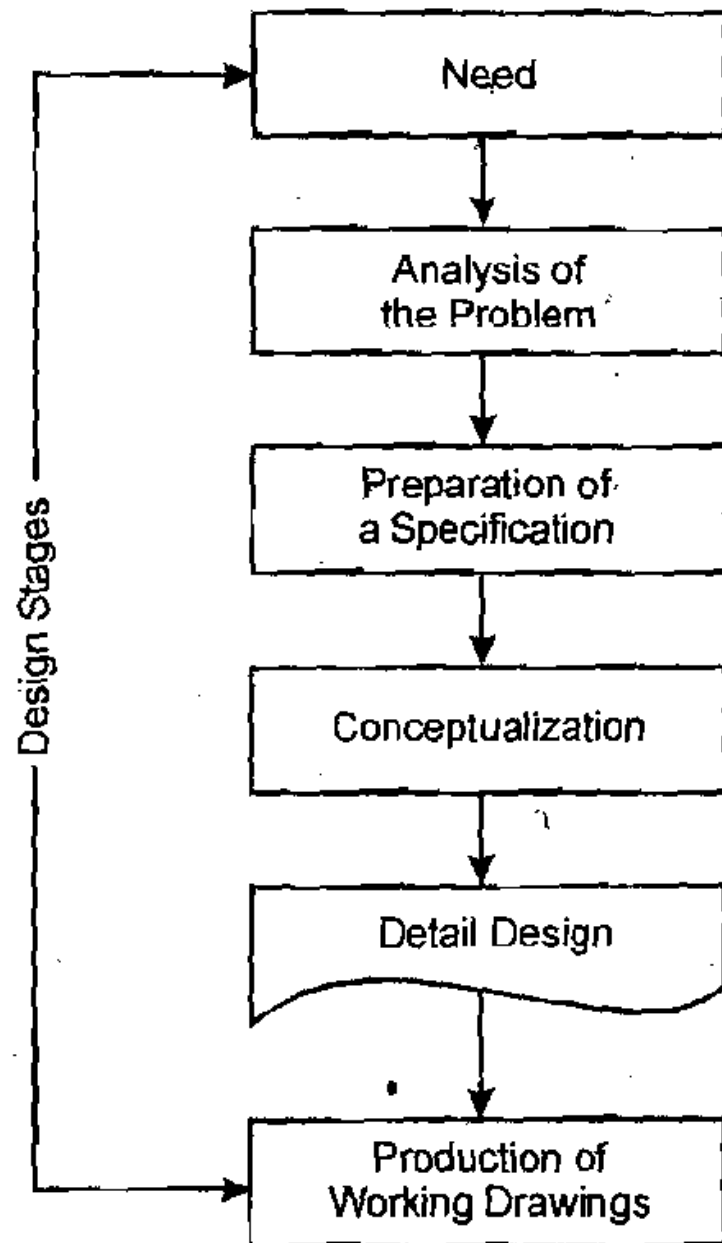
❖ The various possible solutions are evaluated and the most suitable solution is selected.

Detail Design:

❖ Once optimizing a solution is completed, the detail design of that solution is developed.

❖ This may require a production of prototype etc.

❖ Mechanical layout is to be made whether physically all component can be accommodated.

❖ Also whether components are accessible for replacement / maintenance are to be checked.

Production of working Drawings:

❖ The selected design or solution is then translated into working drawings, circuit diagrams, etc. So that the item can be made.

❖ Drawings also include the manufacturing tolerances for each component.

DIFFERENCE BETWEEN TRADITIONAL AND MECHATRONIC APPORACH

S.No	Traditional Approach	Mechatronics Approach
1.	Bulky system	Compact
2.	It is a complex process involving interactions between many skills and disciplines.	It is the basic of integration of various emerging technology with mechanical engineering.
3.	The control is accomplished by manually.	A microprocessor is used a controller by programming it.
4.	Complex mechanisms	Simplified mechanism may transferred to the software through programs.
5.	Non-adjustable movement cycles	Programmed movements.
6.	Constant speed drives	Variable speed drives
7.	Mechanical Synchronization	Electronic Synchronization
8.	Rigid heavy structures	Lighter Structures.
9.	Accuracy determined by tolerance of mechanism	Accuracy achieved by feedback
10.	Flexibility is less	Flexibility is more.
11.	Less accurate	More accurate.
12.	It consists of more components and moving parts.	It involves less components and moving parts
13.	Less w st	High cost.

POSSIBLE DESIGN SOLUTIONS:

Wind Screen – Wiper Motor:

❖ Wind screen wiper is a device which is used to clear from the front glass of the vehicles, during rainy season.

❖ In consists of an arm which oscillates back and forth in an arc like a wind screen wiper.

Mechanical Solution:

❖ It works like a four bar mechanism, when the crank rotates, the arm 1 rotates.

❖ This makes the arm 2 to oscillate the arm 3.
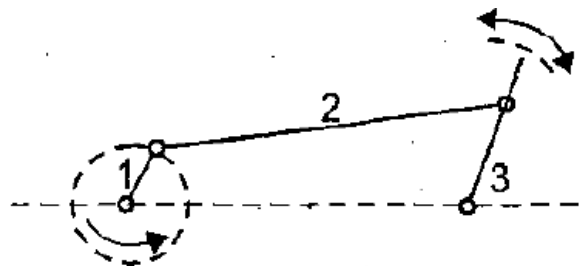
Mechatronics Approach:

❖ The mechatronics approach uses a stepper motor with microprocessor for controlling it.

❖ The input to the stepper is required to cause it to rotate a number of steps in one direction and then reverse to rotate the same number of steps in other direction.

❖ Transistors are used as a switch for controlling the stepper motor.

❖ To start and rotate the motor, the coils of the stepper motor are to be energised in a proper sequence. Stepper motor can be operated in two configurations.

    ➢ Full step Configuration

    ➢ Half step Configuration

CASE STUDIES IN MECHATRONIC SYSTEMS:

A Pick and Place Robot:
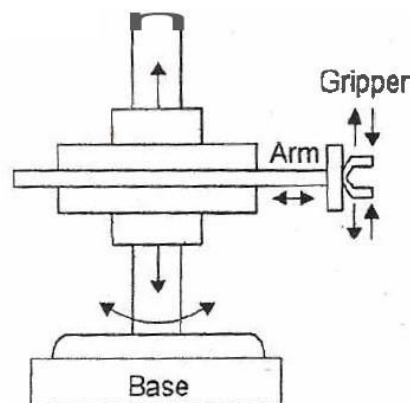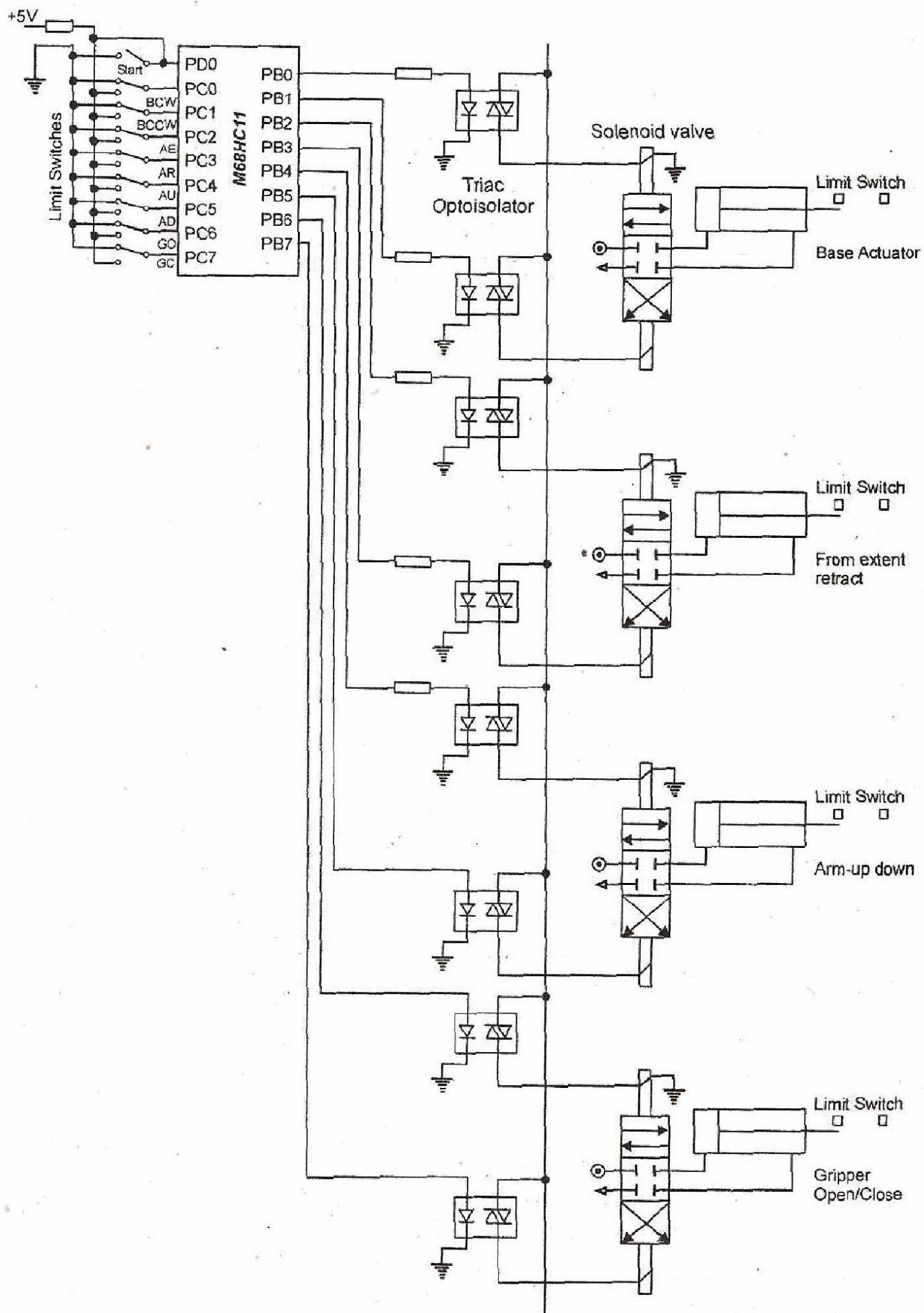
- ❖ The robot has three axes and about these three axes only motion occurs.
- ❖ The following movements are required for this robot
  - ➢ Clockwise and Anti-clockwise rotation of the robot unit on its base
  - ➢ Horizontal Linear movement of the arm to extend or contraction
  - ➢ Up and down movement of the arm and
  - ➢ Open or close movement of the gripper
- ❖ The above movements are accomplished by the use of pneumatic cylinders operated by solenoid controlled values with limit switches.
- ❖ The limit switches are used to indicate when a motion is completed.
- ❖ The clockwise rotation of the robot unit can be obtained from a piston and cylinder arrangement during its extension and that of counter clockwise during its retraction.
- ❖ The upward and downward movement of the arm can be obtained from a piston and cylinder arrangement during the extension and retraction of a piston respectively.
- ❖ Similarly, the gripper can be opened or closed by the piston in a linear cylinder during its extension.
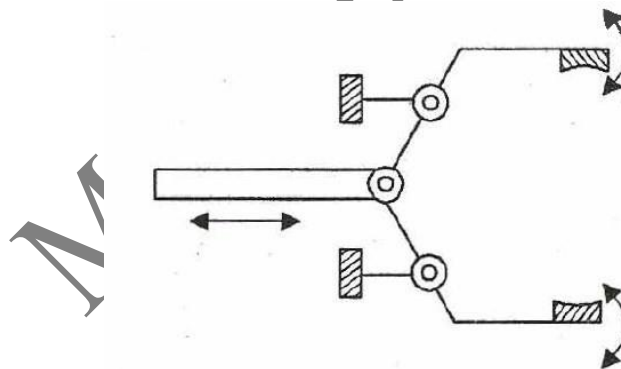
- ❖ The micro controller used to control the solenoid values and hence the movements of the robot unit.
- ❖ The type of microcontroller used in **M68C11**.
- ❖ A software program is used to control the robot.
- ❖ Eight C port lies $PC_0 - PC_7$, are used to sense the position of eight separate limit switches used for eight different robotic movements.
- ❖ Also one line from port D is used to start or stop the robot operation.
- ❖ The switch in its one position will provide +5V (a logic high signal), to the corresponding port lines and the switch in another position will provide 0V (a logic low signal), to the port lines.

- ❖ So the two positions of a switch will provide either a logic high or logic low to the corresponding $PC_0 - PC_7$, and PD, lines.
- ❖ Eight part B lines ($PB_0 - PB_7$) are used to control eight different movement. These are Base CW, Base CEW, Arm extends, Arm retract, Arm up, Arm down Gripper close and Gripper open of the robot.
- ❖ PB_0, is connected to the Triac optoisolator through a resistor.

- ❖ TRIAC isolator consists of LED and TRIAC.
- ❖ For example, when the base has to rotate in clockwise direction, a high signal is sent through line PB_0
- ❖ The diode is forward biased and the TRIAC optoisolation operates, regulating the supply to the solenoid value which in turn operated the piston rod of the pneumatic cylinder.
- ❖ The base clockwise continues the rotation till it reader the position of second limit switch

Automatic Car Park System:

- ❖ Consider the coin-operated car park system with barriers.
- ❖ The main requirement of the system is that, the in-barrier is to be opened to allow the car inside if correct money (coin) is inserted in the collection box.
- ❖ The out barrier is to be opened to allow the car outside, if the car is detected at the car park side of the barrier.
- ❖ The automatic car park barrier along with the mechanism to lift and lower it
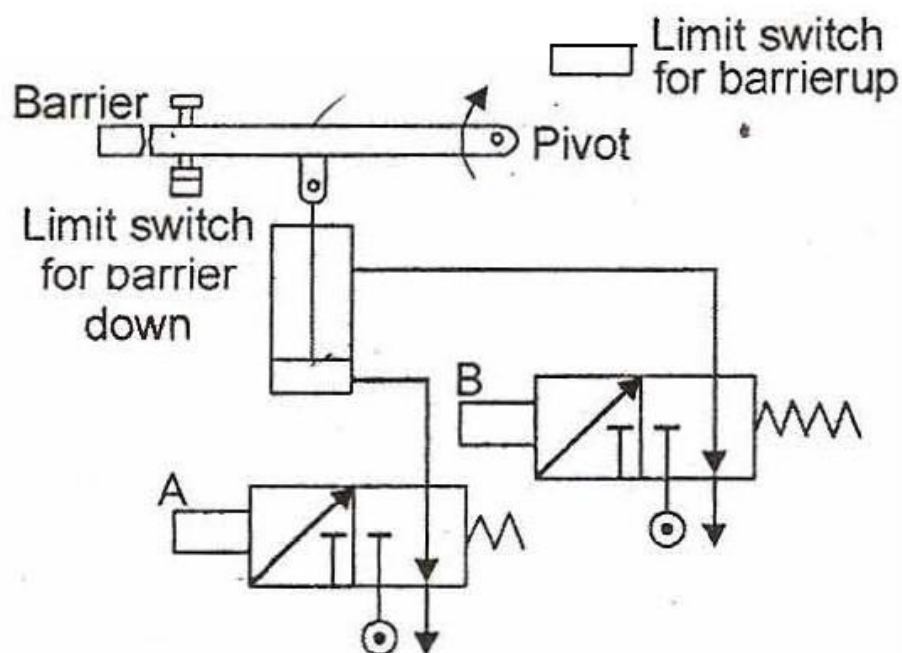
- ❖ When the current flows through the solenoid A & the piston in the cylinder extends to move upward and causes the barrier to rotate about its pivot and thus the barrier raises to allow the car inside.

- ❖ When the current flows through the solenoid A ceases, the spring on the solenoid valve makes the contacts to open and thus makes the valve to its original position.

- ❖ When the current flows through solenoid B, the piston in the cylinder moves downward end causes the barrier to get down.

- ❖ Limit switches are used to detect when the barrier is down and also when fully up.

- ❖ This control can be controlled by PLC
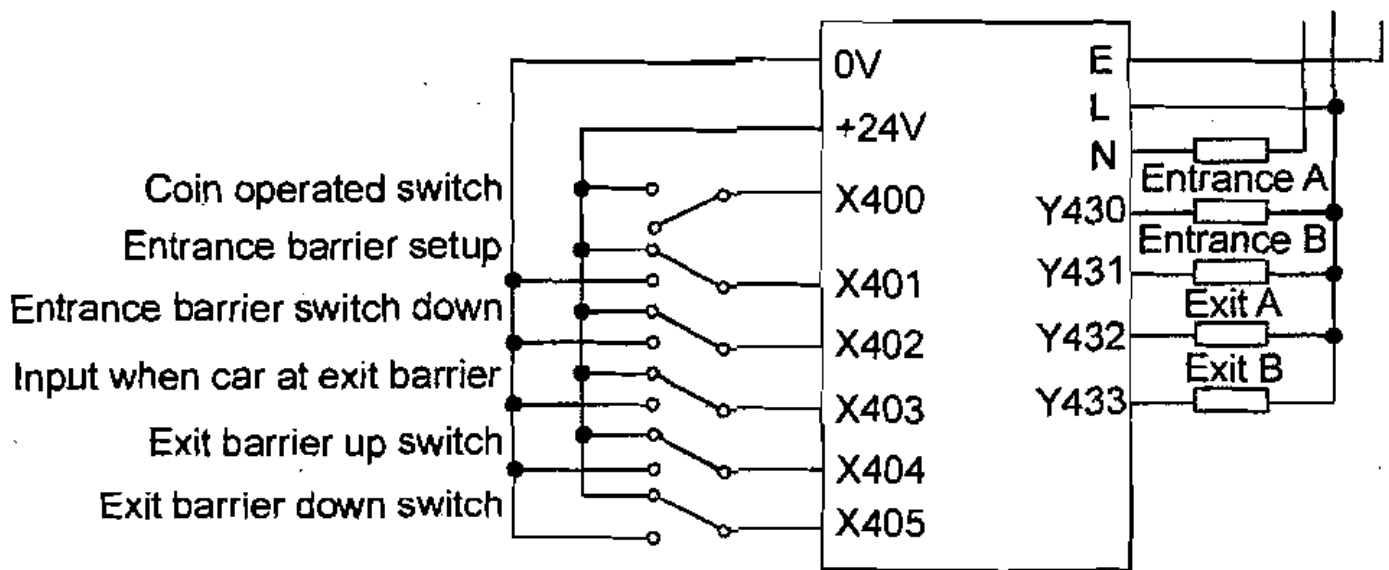
X400	–	coin operated switch at entrance to car park
X401	–	switch activated when entrance barrier is out
X402	–	switch activated when entrance barrier is down
X403	–	switch activated when car at exit barrier
X404	–	switch activated when exit barrier is -up
X405	–	switch activated when exit barrier is down
Y430	–	solenoid on valve A for entrance barrier
Y43 1	–	solenoid on valve B for entrance barrier
Y432	–	solenoid on valve A for exit barrier
Y433	–	solenoid on valve B for exit barrier

- Six inputs (**X400** to **X405**) is required for the PLC to sense the six limit switch position namely coin-operated switch, entrance barrier up switch, down switch, car at exit barrier switch, exit barrier up switch, Exit barrier down switch

- Whenever, a switch is operated, **0V** signal is provided to the corresponding inputs and otherwise **+24v** signal is provided to the inputs. Four outputs (**Y430** to **Y433)** are required to operate the two solenoid valves A and B.

Ladder rung	Description
X400 M100 Y431 Y430 / Y430	To lifl the entrance barrier coin-operated input X400 required, Y430 then energizes solenoid A
When barrier up Input X401 starts Timer — X401 T450 (K10) / T450 M100	After 10S, the IR M100 energized
M100 X402 Y430 Y431 / Y431	The energises the (Y431) solenoid B of entrance barrier and barrier comes down
X403 M101 Y433 Y432 / Y432	To lifl the exit barrier, can operated input X403, required, Y432 then energises solenoid A of exit barrier
When barrier up Input X404 starts Timer — X404 T451 (K10) / T451 M101	Afler 10S IR M101 energised.
M101 X405 Y432 Y433 / Y432	This energises the (Y433) solenoid B of the exit barrier comes down
END	

Program:

```
LD   X400

OR   Y430

ANI  M100

ANI  Y431

OUT Y430

LD   X401

OUT T450

K    10

LD   T450

OUT M100

LD   M100
OR   Y431
ANI  X402

ANI  Y430

OUT Y431

LD   X403

OR   Y432

ANI  M101

ANI  Y433

OUT Y432

LD   X404

OUT T451

K    10

LD  T45  1

OUT M101

LD   M101

OR   Y433

ANI  X405

ANI  Y432

OUT Y433

END
```

Mechatronics

- ❖ Assume a 10 sec delay for the car is to come inside the barrier and to go outside the barrier.
- ❖ These time delays provided by T450 and T451 energising their Internal relays respectively.

Engine Management System:

- ❖ Engine management system is now-a-days, used in many of the modem cars
- ❖ This car includes many electronic control systems such as microcontrollers for the control of various engine factors.
- ❖ The main objective of the system is to ensure that the engine is operated at its optimum settings.
- ❖ The engine management system of a car is responsible for managing the ignition and fuelling requirements of the engine.
- ❖ The power and speed of the engine are controlled by varying the ignition timing and the Air fue1 mixture.
- ❖ In modern cars, this is done by microprocessor.
- ❖ To control the ignition delay, the crank shaft drives a distribution which makes electrical contacts for each spark plug in turn and a timing wheel.
- ❖ This timing wheel generates pulses - to indicate the crankshaft position.
- ❖ The microprocessor then adjusts the timing at which high voltage pulses are sent to the distributor so that they occur at right moments of time.
- ❖ To control the amount of air-fuel mixture entering into a cylinder during the suction stroke, the microprocessor varies the time for which a solenoid is activated to the inlet valve on the basis of inputs received by the engine temperature and the throttle position.
- ❖ The amount of fuel to be injected into the air stream can be determined on input from a sensor of the mass rate of air, or computed from other measurements.
- ❖ The microprocessor then gives as output to control of fuel inject valve.
- ❖ The system hence consists of number of sensor for observing vehicle speed, Engine temperature, oil and fuel pressure, air flow etc.,
- ❖ These sensors supplies input signals to the microprocessor after suitable signal conditioning and provides output signals via drivers to actuate corresponding actuators.

Voltage regulator

Transient protection

+12V

Signal conditioning

Vehicle speed

Engine temp

Ambient temp

Mainfold vaccum

Throttle position

Mass air flow

Knock sensor

Oxygen sensor

oil pr. sensor

Fluid pr.sensor

Analog input

Analog output

Microprocessor

SPI

SCI

Fuel injection drivers — Fuel injectors

Injection coil drivers — Engine gas regulation valve

Solenoid drivers — Ignition coil

Solenoid drivers — IDLE speed actuator

Solenoid drivers — Data bus

Fuel tank

Fuel Pump

Fuel filter

Pressure regulator

Distributor

(+)

Ignition Coil

Spark plug

Injector

Oxygen sensor

Temp sensor

Throttle position switch

IDLE speed actuator

Airflow

Mass air flow sensor

Sensor wheel

Speed sensor

Electronic control unit

Engine Speed Sensors:

❖ The Engine speed sensor is an inductive type sensor used to measure or sense the engine speed.

❖ It consists of a coil and a sensor wheel.

❖ When the teeth of the wheel pass through the sensor, the inductance of the coil changes.

❖ This change in inductance produces an oscillating voltage.

Engine Temperature Sensor:

❖ The engine temperature sensor is used to sense the temperature of the engine.

❖ It is usually a thermistor or a thermocouple.

❖ The thermocouple consists of a bimetallic strip or a thermistor whose resistance changes when there is a variation in temperature of the engine.

Hot wire Anemometer:

❖ Hot wire anemometer is used as amass airflow rate sensor in which a heated wire gets cooled when air passes across it.

❖ The amount of coding depends on the mass flow rate.

Oxygen Sensor:

❖ The oxygen sensor is usually a closed end tube made of zirconium oxide with porous platinum electrodes on the inner and outer surfaces.

❖ When the temperature is above 300°C the sensor become permeable to oxygen ions so that melt age will be produced between the electrodes.

❖ The various drivers such as fuel injection drivers, ignition coil driver's solenoid drivers and are used to actuate actuators according to the signal by various sensors.

❖ Analog signals are converted into digital signals by using ADC and are sensed by various sensors which in turn sent to the microcontroller.

❖ The microcontroller compares these input values with the set points stored in its memory and it issues control signals to the corresponding our drivers.

❖ The output signals are converted into analogue signal by using ADC.

❖ The transient protection circuit prevents any sudden surge a rise or far in the power supply in the power supply to the micro controller.

❖ A+12V voltage regulator is used to supply the dc voltage required for the microcontroller operation.

Wireless Surveillance Balloon:

- ❖ Surveillance generally refers to monitoring or observing a person or a group of people h m a certain distance, frequently.

- ❖ Surveillance equipment is typically used in warfare and/or in counter-insurgency operations to monitor the activities of an enemy from a distance.

- ❖ Surveillance equipment may also be used to monitor hazardous situations from a distance, such as for example, as may be associated with chemical hazards, explosive hazards, and the like, so as to provide advance information to personnel responsible for controlling the hazards.

- ❖ Other applications may include search and rescue missions, police operations, and homeland security activities.

Elements of Wireless Surveillance Balloon:

Various essential elements of a wireless surveillance balloon are listed below:

- ❖ Sensors:
  - ➢ Image sensors
  - ➢ Thermal sensors
  - ➢ Audio sensors
  - ➢ Location sensors
  - ➢ Altitude sensors
  - ➢ A compass
  - ➢ Motion sensors

- ❖ Communication modules:
  - ➢ Located in the housing
  - ➢ Communication modules transmit data collected by the sensors

- ❖ An anchor line which may be adapted to anchor the deployable surveillance balloon to the housing after deployment

- ❖ A lighter-than-air (LTA) gas source which may be adapted to provide lighter than- air gas for inflation of the surveillance balloon during and / or after deployment

❖ Ancillary components which may facilitate the operation of the system, such as power sources, gas lines, wires, control circuitry, databases, displays, regulators, latches, springs, levers, gaskets, etc.
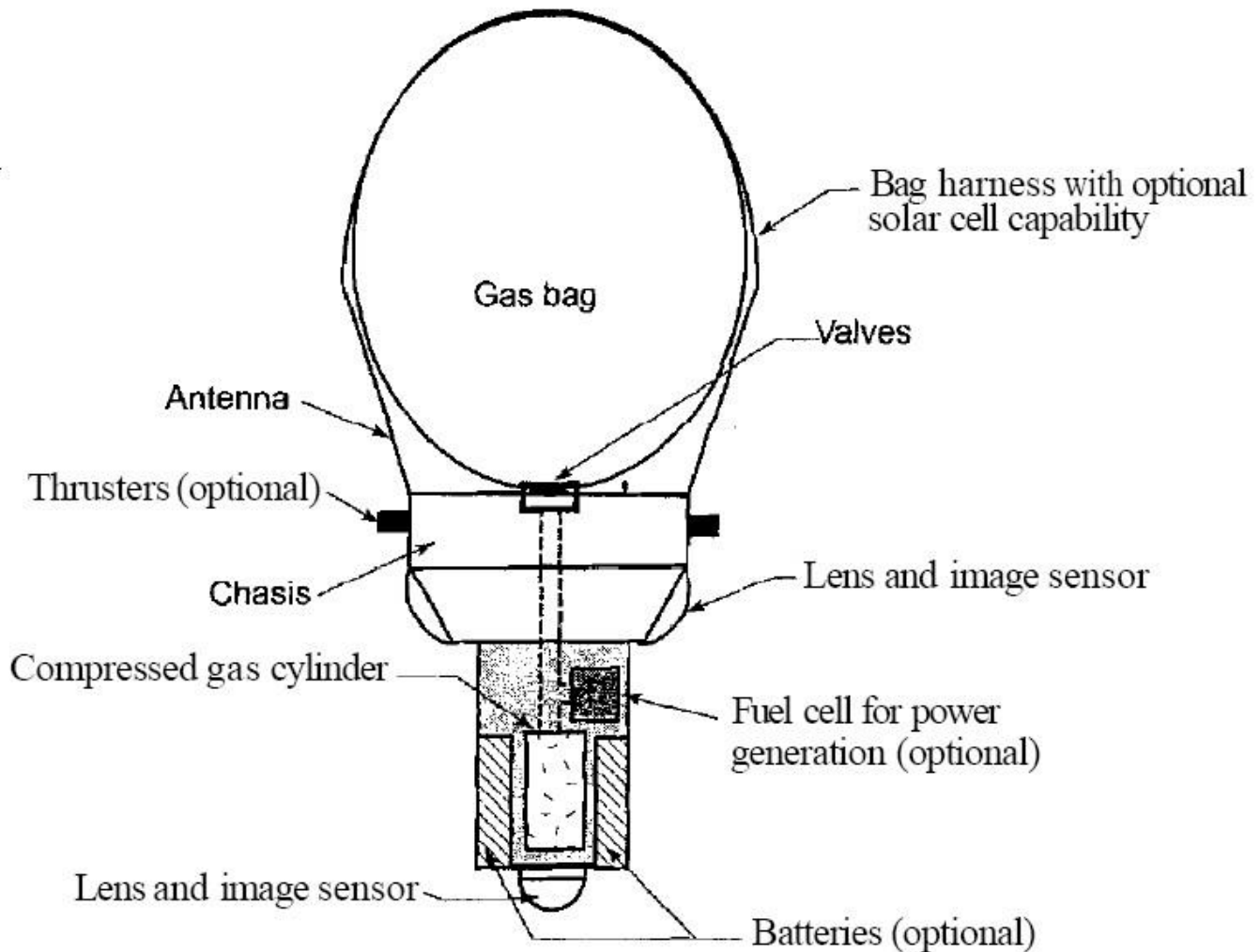
Applications of Wireless Surveillance Balloon:

❖ Wireless surveillance balloon have been used for various applications like:

❖ Border security (TARS) in military,

❖ Enhancing battlefield situational awareness.

❖ Coastal surveillance,

❖ Platform for mounting telecommunication, television. radio transmitters and Broadband equipment

❖ Aerial platform for scientific instrument testing,

❖ Aerial platform for weather prediction instruments,

❖ Terrestrial mapping

❖ For holding up large-array radio- telescopes.

Autonomous Mobile Robot:

A fully autonomous mobile robot has the ability to:

❖ Gain information about the environment

❖ Work for an extended period without human intervention

❖ Move either all or part of itself throughout its operating environment without human assistance

❖ Avoid situations that are harmful to people, property, or itself unless those are part of its design specifications.

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│            COLLABORATION              │
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                   ⬆
┌─────────────────────────────────────┐
│              AUTONOMY                 │
└─────────────────────────────────────┘
                   ⬆
┌─────────────────────────────────────┐
│              PLANNING                 │
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│      KNOWLEDGE REPRESENTATION         │
└─────────────────────────────────────┘
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│          SENSOR PERCEPTION            │
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│             LOCOMOTION                │
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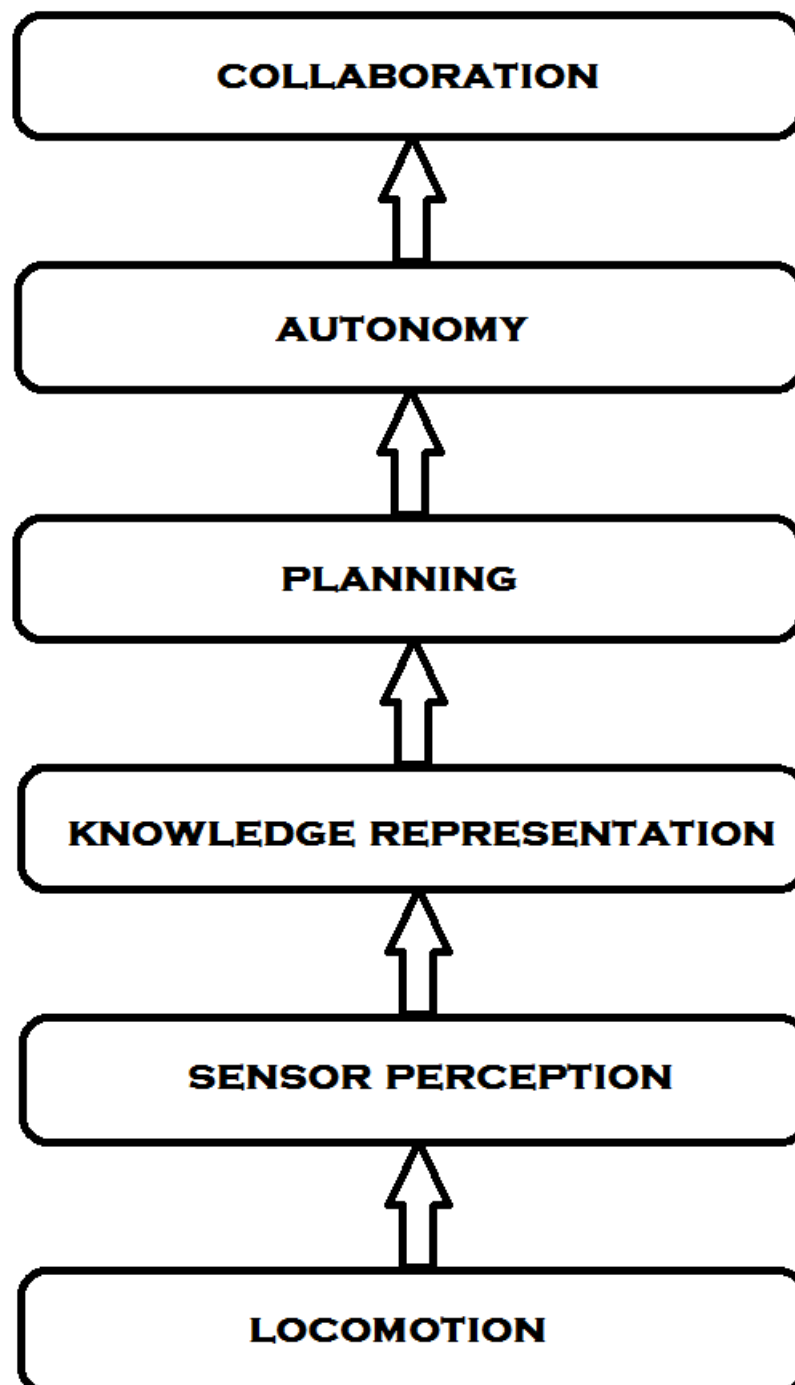
Elements of Autonomous Mobile Robot:

- ❖ Locomotion
- ❖ Sensor perception
- ❖ Knowledge representation
- ❖ Planning
- ❖ Autonomy
- ❖ Collaboration

Locomotion:

- ❖ Locomotion is the act of moving from place to place.
- ❖ Locomotion relies on the physical interaction between the vehicle and its environment.
- ❖ It is concerned with the interaction forces, along with the mechanisms and actuators that generate them.
- ❖ The different types of locomotion are:
  - ➤ Legged Locomotion
  - ➤ Snake Locomotion
  - ➤ Free-Floating Motion
  - ➤ Wheeled Locomotion

Sensor Perception:

- ❖ The robots have to sense their environment in order to navigate in it, detect hazards, and identify goals.
- ❖ Sensor fusion is an important capability, as no single sensor will be able to identify or classify all aspects of the arenas.
- ❖ The simulated victims are represented by a collection of different sensory signatures. They have shape and colour characteristics.
- ❖ Some simulated victims have motions such as waving, and some emit sounds such as low moans, calls for help, or simple tapping.
- ❖ All of the signals of life should be detected, identified, investigated further, and if confirmed as a victim, the location should be mapped.
- ❖ For obstacle detection, the sensors need to see far and only a logic response is required.
- ❖ Common sensors used in mobile robots for detecting obstacles are the digital infra-red (IR) sensor.

- ❖ Line tracing is normally required to distinguish between a white surface and a black one in order to provide guidance by the demarcation.

- ❖ For direction monitoring the obvious sensor to use is a compass, which echoes the bearing of the mobile robot in real time.

- ❖ Proximity sensors are used to sense the presence of an object close to a mechatronics device.

Knowledge Representation:

- ❖ In the mobile robot applications, the robots are expected to communicate to humans the location of victims and hazards.

- ❖ They would be providing a map of the environment they have explored, with the simulated victim and hazard location clearly identified.

- ❖ The environment that the robots operate in is three-dimensions, hence they should be able to map in three-dimensions.

- ❖ The area may change dynamically during operation time

Planning:

- ❖ The planning or behaviour generation elements of the robots build on the knowledge representation and the sensing elements.

- ❖ The robots must be able to navigate around obstacles, make progress in their mission take into account time as a limiting resource, and make time critical decisions.

- ❖ The planner should make use of an internal map generated by the robot and find alternative routes to exit the arenas that may be quicker or avoid arm that have become no longer traversable

Autonomy:

- ❖ The robots are designed to operate with humans.

- ❖ The level of interaction may vary significantly, depending on the robot's design and capabilities, or on the circumstances.

- ❖ Robots may communicate back to humans to request decisions, but should provide the human with meaningful communication of the situation.

- ❖ The human should provide the robot with high level commands, such as "go to the room on the left" rather that joystick the robot in that direction.

Collaboration:

❖ The final element to be evaluated in the robot's overall capabilities is collaboration among teams of robots.

❖ Multiple robots, either homogeneous or heterogeneous in design and capabilities, should be able to more quickly explore the area.

❖ The issues to be examined are how effectively they maximize coverage given multiple robots, whether redundancy is an advantage, and whether or how they communicate among themselves to assign responsibilities.

❖ The human may make the decisions about assignments for each robot a priority, but that would not be as desirable as seeing the robots jointly decide how to attack the problem when confronted in the field.

MECHATRONICS APPLICATIONS:

Clutch Control

Other inputs

Power Supply

Controller

Exhaust

W

W

Supply

Pressure signal

To cylinder

Cab

3 or 4 point suspension

Air spring

Chassis

Suspension control

Other inputs

Power Supply

Controller

Exhaust

W

W

Supply

Pressure signal

To cylinder

Diaphragm actuator

Brake shoes and wedge expander

Anti-lock brakes

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