# UNIT-I.

## INTRODUCTION.

### INTRODUCTION TO MECHATRONICS:

→ Mechatronics is a word originated in Japan in 1980's to denote the combination of technologies which go together to produce industrial robots.

→ The word, mechatronics is composed of "mecha" from mechanism & the "tronics" from electronics.

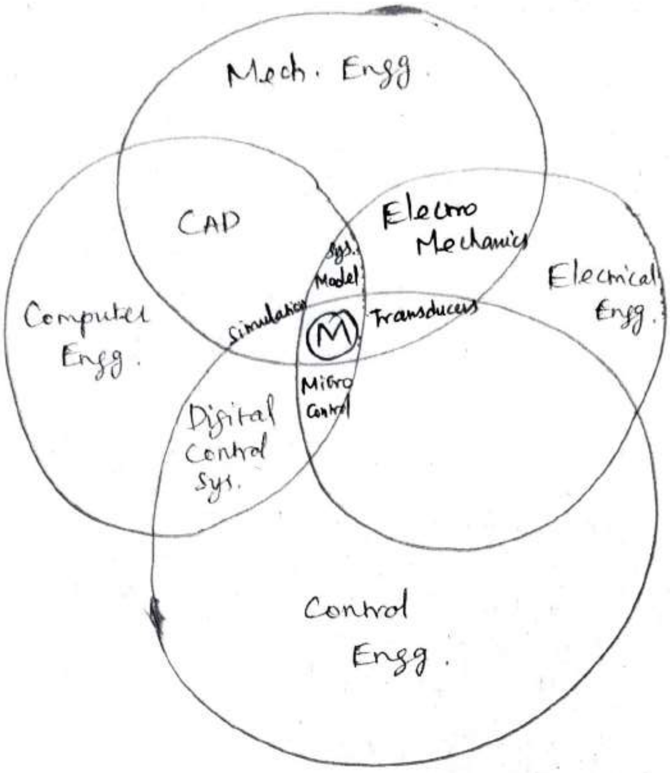
→ According to the mechatronics from UK a formal definition of mechatronics is "the synergistic integration of Mechanics & Mechanical Engineering, Electronics, Computer Technology & IT to produce (or) enhance products & systems".

→ W. Bolton defines mechatronics as "A Mechatronic system is not just a marriage of electrical & mechanical systems & is more than just a control system; it is a complete integration of all of them".

→ In other words, technologies & developed products will be incorporating electronics more & more mechanisms, intimately & organically & making it impossible to tell where one ends & other begins.

→ Mechatronics brings together the areas of technology involving sensors & measurement systems, drive & actuation system, analysis of behaviour of the system, control system & micro-processor system.

Graphical representation of Mechatronics.




Elements of Mechatronics system:

Actuators & sensors

↓

Signals & conditioning

↓

Digital Logic systems.

↓

Software & Data acquisition systems.

↓

Computers & Display Devices.

(i) Actuators & sensors:

- Actuators & sensors are mostly come under mechanical systems.

→ The actuators produce motion.

→ The sensors detect the state of the system parameters, I/p's & O/p's.

(ii) Signals & conditioning:

- The Mechatronics system deal with two types of signals & Conditioning. (They are 'I/p' & O/p).

a) I/p: I/p devices receive the 'I/p' signals from the mechatronic sys. & then send to the control circuits for processing.

Ex:- Analog to Digital convertors.

b) O/p: The 'O/p' signals from the sys. are send to o/p / Display devices.

Ex:- Analog convertors, Display decoders, Amplifiers.

(iii) Digital Logic sys:

→ Digital logic sys. (or) devices control overall system operation.

→ The various digital logic sys. are micro-controllers, programmable Logic controllers (PLC), sequencing & Timing controls, Control algorithms.

(iv) Software & Data Acquisition sys:

→ Software is used to control the acquisition of data through DAC board.

→ Data acquisition sys. acquires the 'o/p' signals from sensors in the form of voltage, frequency, Resistance, etc.

(v) Computers & Display Devices:

→ Computers are used to store large No. of data & process further through softwares.

→ Display devices are used to give visual feedback to the user

Ex:- LED, CRT, LCD, etc.,

## NEED FOR MECHATRONICS:

(i) Dynamic market conditions.

(ii) Producing next generation products.

(iii) Integration of modern technologies in products.

(iv) Variety in product ranges.

(v) Batch production runs.

(vi) change in design perspective.

(vii) Product Quality & consistency.

(viii) Ease of re-configuration of the process.

(ix) Demand for increased flexibility.

## EMERGING AREAS OF MECHATRONICS:

→ M/c vision.

→ Automation & Robotics.

→ Dev. of Un-manned vehicles.

→ Design of sub-sys. for automotive Engg.

→ Sensing & control sys.

→ Operations & Maintenance of CNC M/c's.

→ Expert sys. & Artificial Intelligence.

→ Industrial electronics & consumer products.

→ Medical mechatronics & medical imaging sys.

→ Structural dynamic sys.

→ Transportation & vehicular sys.

→ Diagnostic & reliability techniques.

→ CIM sys.

→ Micro/Nano mechatronics.

→ Mechatronics in Energy sys.

→ Human-M/c interface.

→ Mechatronics applications in cyber-physical sys.

CLASSIFICATION OF MECHATRONICS:

They are,

| | Fundamental Theories |
|---|---|
| (i) Conventional<br>(ii) Micro-electro mechanical sys. (MEMS). & | 1. Classical Mechanics.<br>2. Electro-magnetics. |
| (iii) Nano-electro mechanical sys. (NEMS). | 1. Quantum theory.<br>2. Nano-electro-mechanics. |

# Mechatronics Approach.

Sys. Dev. Tasks.

Modeling, Analysis, integrate, design, testing & refinement

↕

Sensors & Transducers

Actuators

Controllers.

Mechatronic sys.

| | |
|---|---|
| Structural components | Electronics (Analog/Digital) |
| Energy sources | Software |
| Hydraulic & Pneumatic devices | Signal processing |
| Thermal devices | I/p & o/p Hardware |

Mechanical Engineering ⟷ Electrical & computer Engg.

→ When performing an integrated design of a mechatronic sys, the concepts of Energy/power

## CONCEPTS OF MECHATRONICS APPROACH:

- Mechatronic sys. which employs an integrated & Con-current approach for design, development & implementation provides much better performance than a sys. formed by inter-connecting a set of independently designed & manufactured components.

- Generally, a product based on mechatronic sys. approach will be,

  → More efficient &
  → Cost effective,
  → More precise & accurate.
  → More reliable,
  → More flexible & functional & less mechanically complex,

compared to a non-mechatronic approach based product that needs a similar level of effort in its development.

- The mechatronic approach will result,

  → Higher Qlty of products & services,
  → ↑ performance,
  → ↑ reliability & approaching some form of optimality.

→ It will enable the dev. & [P] of electro-mechanical sys. efficiently, rapidly & economically.

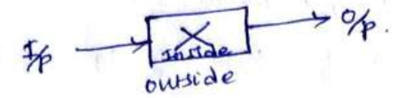
→ Relevant technologies for mechatronic Engg. should concern all stages of,

  ⇒ Design,
  ⇒ Development,
  ⇒ Integration,
  ⇒ Instrumentation,
  ⇒ Control,
  ⇒ Testing,
  ⇒ Operation, &
  ⇒ Maintenance of a mechatronic sys.

## INTRODUCTION TO MECHATRONICS SYSTEMS: (They are, a) Sys., b) Measurement sys., c) Ctrl sys.)

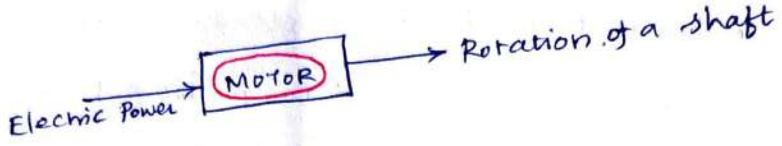
a) system:

- Thought of as a "box" which has an I/P & an O/P & where we are not concerned with what goes on inside the box,




- But only the rel. b/w the O/P & I/P.

- Ex:-




b) Measurement sys:

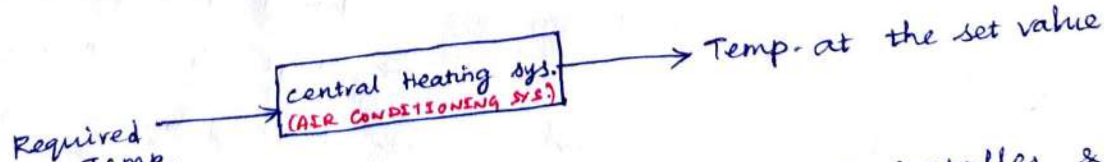
- Thought of as a "black box" which is used for making measurements.
- It has as its I/P the Qnty being measured & its O/P the value of that Qnty.

- Ex:-


c) Control sys:

- Thought of as a "black box" which is used to Ctrl its O/P to some particular value (or) Particular sequence of values.

- Ex:-




- You set the req. 'T' on the thermostat (or) Controller & the heating furnace adjusts itself to pump water through radiators & so produce the req. 'T' in the house

2. MECHATRONICS SYSTEM COMPONENTS:

* They are,

a) Measurement sys. & its Constituent elements.
Ex:
- sensor.
- signal conditioner.
- Display sys.

b) Ctrl sys.

(•) Feedback ctrl sys. – Ex:- Thermostat.
→ Feedback Ctrl for Human Body 'T'.
→ Feedback ctrl for Room 'T'.
→ Feedback ctrl for picking up a pencil.

(•) Open & closed-loop sys. (Ex:- Switch, Electric Fire)

(•) Basic Elements of a closed-loop sys. (Ex:- Shaft speed ctrl.)
→ Comparison Element. (Ex:- Comparator.)
→ Ctrl Element. (Ex:- Switch.)
→ Correction Element. (Ex:- Actuator - Heater (or) valves.)
→ Process Element. (Ex:- Room (or) Water Tank.)
→ Measurement Element. (Ex:- Thermo-couple.)

(•) Sequential controllers. (Q:- Domestic washing m/c.)

- Ex:- Relays.
- Cam-operated switches. (∵ Mech. switches.)
- {Hard-wired circuits.}
  replaced by
- μP-Switches. (i.e., Micro-Processor switches) — Software pgm are used.

(•) μP-based controllers.

- Ex:- Programmable logic controller.

NOTE: (APPLICATIONS OF CONTROL SYS.)

a) open & closed loop sys. → Water Level controller.
→ shaft speed control.

b) Sequential controllers → Washing machine control.

c) μP-based Controllers → Automatic Camera.
→ Engine-Management sys.

A) MEASUREMENT SYS.

• Ex:- Digital Thermometer

* • A measurement sys. & its constituent Elements.

Qnty Being measured → $\boxed{\text{Sensor (Thermocouple)}}$ $\xrightarrow{\text{e.m.f}}$ $\boxed{\text{Signal Conditioner (Amplifier)}}$ → $\boxed{\text{Display (Pointer)}}$ → Value of the Qnty.

- Small emf can be changed into bigger.

SENSOR:

✓ Qnty being measured by giving as its o/p a signal which is related to the Qnty.

✓ Ex:- Thermocouple - "Temp. sensor". (I/p - Temp. & O/p - E.M.F. which is related to 'T' Value)

SIGNAL CONDITIONER:

✓ Ex:- Amplifier.

✓ Takes the signal from sensor & Manipulates it into a Condition which is suitable for either display, or, in the case of a Ctrl sys, for use to exercise.

DISPLAY:

✓ Be a pointer moving across a scale or a digital read-out.

* • DEFINITION:

✓ Thought of as a "Black Box" which is used for making measurements

✓ It has as its 'I/p' the Qnty being measured & its 'O/p' the value of that Qnty.

✓ Ex:- Temp. → $\boxed{\text{THERMO-METER}}$ → No. on a scale.

## B) CONTROL SYSTEMS:

• **DEFINITION:**

- Thought of as a "Black Box" which is used to crl its 'o/p' to some particular value (or) particular sequence of values.

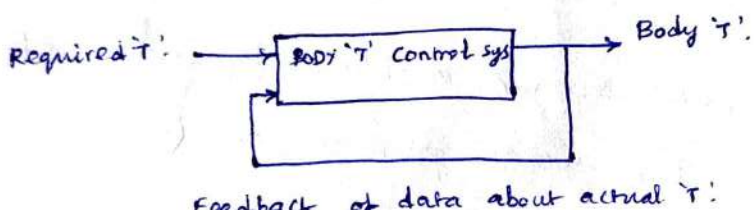
- Ex:-

Required Temp. ⟶ [Central Heating sys (AIR CONDITIONING SYS)] → Temp. at the set value.

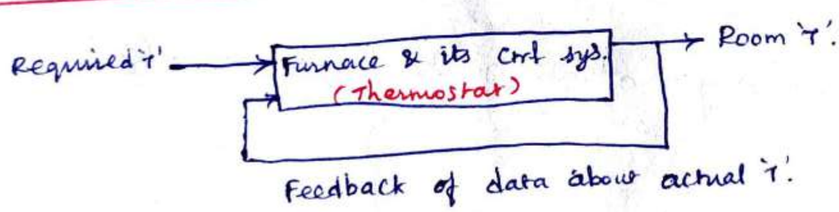
- You set the req. 'T' on the thermostat (or) controller & the heating furnace adjusts itself to pump water through radiators & so produce the req. 'T' in the house.

• FEED-BACK CONTROL SYS: (To crl 'T', Liquid level, fluid flow, P etc.) - are maintained constant.

* (i) Feed back crl for [H] body 'T'.



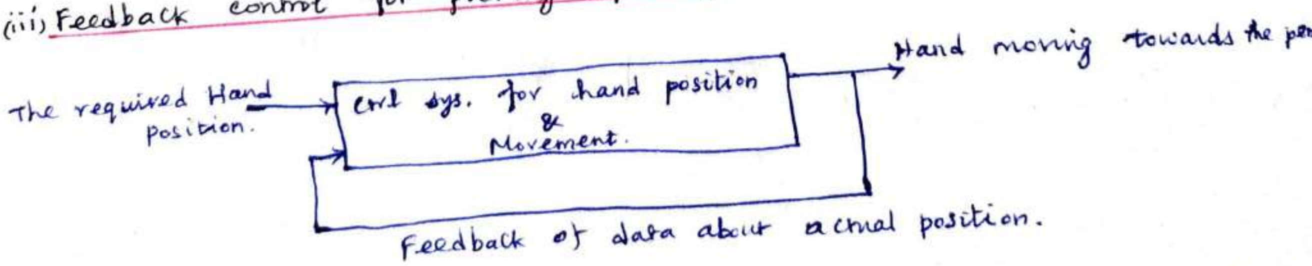

(ii) Feedback crl for room Temp. (T).




• Ex:- To crl the 'T' of a centrally heated house (i.e., AIR CONDITIONING SYS.)

→ [H] as a control Element - Because, [H] to stand near the furnace. on/off switch with a thermometer & switch the furnace ON (or) OFF acc. to the thermometer reading.

(iii) Feedback control for picking up a pencil.




→ This control sys. is crlling the positioning & movement of yr hand.

+ Involves consistently & accurately positioning a moving part (or) maintaining a constant speed.

NOTE! • FEED BACK CONTROL SYS:

(i) FEED BACK CONTROL FOR HUMAN BODY TEMP. (T)

* ♀ [M] - whether you are in a cold or Hot Environment.

- To maintain this constancy your body has a 'T' - Ctrl sys.

→ If your 'T' begins to ↑-se above the normal you sweat,

→ If it ↓-ses you shiver.

→ Both these are Mechanisms which are used to restore the body T back to its normal value.

- The ctrl sys. is maintaining constancy of 'T'.

→ TECHNIQUE:

✓ The sys. has an I/p from sensors which tell it what the 'T' is & then compares this data with what the 'T' should be & provides the appropriate response in order to obtain the required 'T'.

(ii) FEED BACK CONTROL FOR ROOM TEMP. (T).

* The more usual feedback ctrl sys. has a thermostat or controller which automatically switches the furnaces on or off according to the difference b/w the set 'T' & the actual 'T'.

* This control sys. is maintaining constancy of 'T'.

(iii) FEEDBACK CONTROL FOR PICKING UP A PENCIL.

→ If you go to pick up a pencil from a bench there is a need for you to use a ctrl sys. to ensure that yr hand actually ends up at the pencil.

→ This is done by you observing the position of your hand relative to the pencil & making adjustments in its position as it moves towards the pencil.

→ There is a feedback of information about yr actual hand position so that you can modify yr reactions to give the required hand position & movement.

※ ⇒ Thus in a chemical process there may be a need to maintain the level of a liquid in a tank to a particular level or to a particular 'T'.

C) OPEN- & CLOSED-LOOP SYSTEMS: CONCEPTS OF MECHATRONICS APPROACH:

* Difference b/w O & C Sys.

① → Motor ; O-sys.

(i) → Speed of rotation of the shaft might be der. solely by the initial setting of a knob which effects the 'V' applied to the motor.

→ Any changes, in the supply 'V', the chara. of the motor as a result of 'T' changes,

(or)

the shaft load will change the shaft speed but not be compensated for.

→ There is no feedback loop.

→ The o/p from the sys has no-effect on the I/p-signal.

(ii) C-sys.

→ The initial setting of the ctrl knob will be for a particular shaft speed & this will be maintained by feedback,

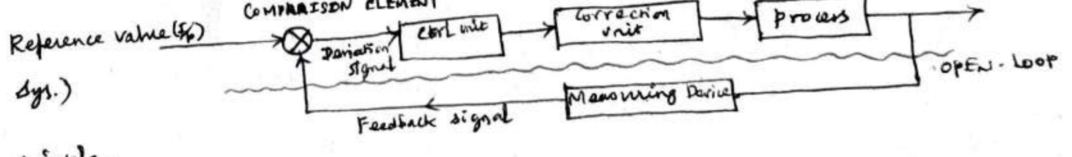
→ Regardless of any changes in supply 'V', Motor chara., (or) Load (P).

→ o/p does have an effect on the I/p-signal, modifying it to maintain an o/p-signal at the req. value.

Ad:- • Relatively accurate in matching the actual to the req. values.

• More complex.

• So more costly with a greater chance of breakdown as a consequence of the greater No. of components.




(i) Ad:- (Open Loop sys.)

• Relatively simple.

• Consequently low cost with generally good reliability.

Dis-Ad:-

• However, they are often in-accurate since there is no correction for error.

5

• Comparison Element (Comparator)

NOTE! * → Compares the required or reference value of the variable condition being crlled with the measured value of what is being achieved &

✓ produces an error signal.

✓ It can be regarded as adding the reference signal, which is '+ve', to the measured value signal, which is '-ve'. } ①

*• Error signal = Reference value signal − Measured value signal.

How? * ✓ Feedback signal fed into the comparator. (But, same pp's)

⇒ '+ve' feedback signal can be added to the i/p - signal } ②

⇒ '-ve' feedback signal can be subract to the i/p - signal. (ie, Reference value.)

• Control Element. (Switch)

(i) → Decides what action to take when it receives an error signal.

(ii) → Ex:- ○ Signal to operate a switch (or) open a valve.

→ Crl plan being used by the element may be just to supply a signal which switches ON (or) OFF,

⇒ when there is an error,

⇒ As in a room thermostat.

→ perhaps a signal which ∝ opens (or) closes a valve acc. to the size of the error.

(iii) → Crl plans may be hard-wired sys in which the crl plan is permanently fixed by the way the elements are connected together

(or)

→ Programmable sys where the crl plan is stored within a memory unit & may be altered by reprogramming it.

• Correction Element. (Actuator).

* → Used for the element of a correction unit that provides the power to carry out the control action.

→ The correction element produces a change in the process to correct (or) change the crlled condition.

Thus it might be a switch which switches on a heater & so ↑ses the 'T' of the process

(or)

valve which opens & allows more liquid to enter the process.

D) SEQUENTIAL CONTROLLERS :

• DEF: Used when crrl is such that actions are strictly ordered in a 't'
(or)
even driven sequence.

- such crrl could be obtained by an electrical circuit with sets of
⇒ Relays (or)
⇒ cam-operated switches, & ⇒ Limit switches. } ~~analog~~ (ELEMENTS OF MECHATRONICS)

which are wired-up in such a way as to give the required sequence.

- such hard-wired circuits are now more likely to have been replaced by
⇒ $\mu p$-controlled sys,
⇒ with the sequencing being crrlled by means of a software pgm.

• IMPORTANCES:

→ There are many situations where crrl is exercised by items being switched [ON] (or) [OFF] at particular preset times
(or)
※ values in order to control processes & give a step sequence of operations.

• Ex: ( Next page - step-1 - simple procedures)

C) WASHING MACHINE CONTROL. (SEQUENTIAL CONTROLLERS.)

1. - No. of operations have to be carried out in the correct sequence.

Simple procedures

- These may involve a pre-wash cycle when the clothes in the drum are given a wash in cold water,
  - Followed by a main wash cycle when they are washed in hot water,
- then a rinse cycle when the clothes are rinsed with cold water a No. of 't',
  - followed by spinning to remove water from the clothes.
- Each of these operations involves a No. of steps.

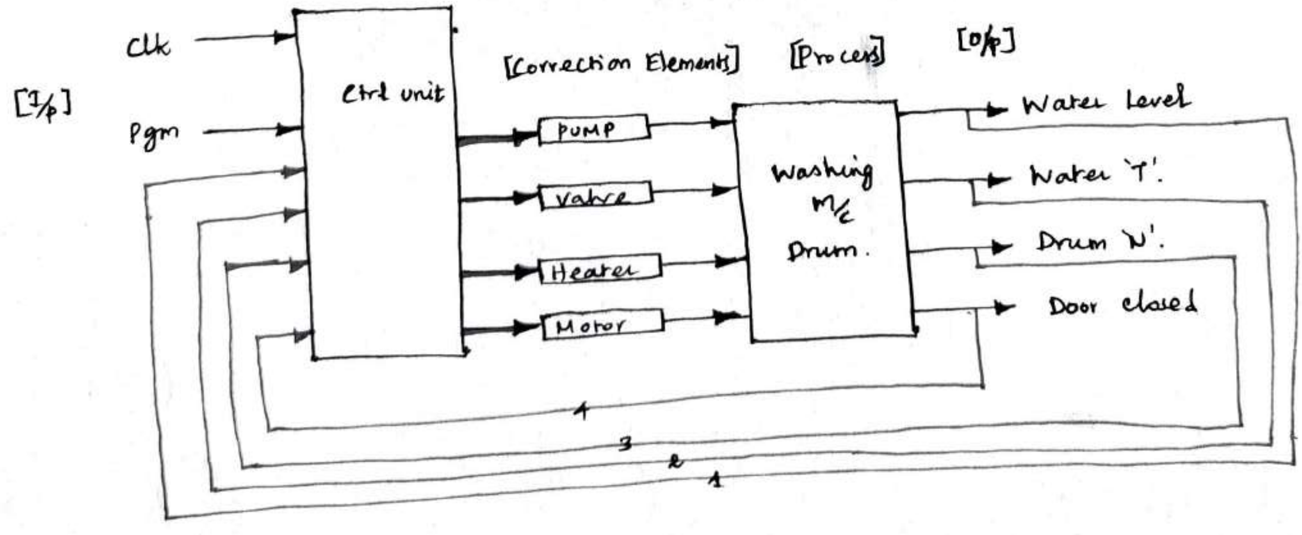
2. • Ex:

Simple operations:

→ Pre-wash cycle involves opening a valve to fill the m/c drum to
- the required level,
- closing the valve,
- Switching on the drum motor to rotate the drum for a specific 't',
- & operating the pump to empty the water from the drum.

→ The operating sequence is called a pgm, the sequence of instructions in each pgm being pre-defined & 'built' into the controller used.

3. washing-m/c sys:



General concepts:- (Mech. concepts)

The sys. used for mech. sys. (washing m/c controller), which involved a set of Cam-operated switches. (ie., Mechanical Switches)

→ When the m/c is switched on, a small electric motor slowly rotates its shaft,

✓ Giving an amount of rotation ∝ to 't'.

→ Its rotation turns the controller cams so that each in turn operates electrical switches &

so switches on circuits in the correct sequence.

→ The contour of a cam determines the 't' at which it operates a switch.

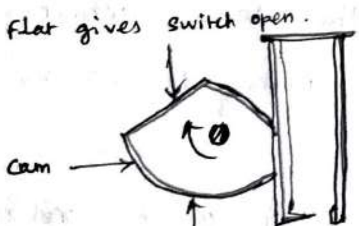
→ Thus the contours of the cams are the means by which the pgm is specified & stored in the m/c.

→ The sequence of instructions & the instructions used in a particular washing pgm are det. by the set of Cams chosen.

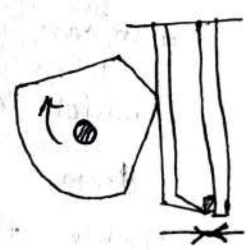
→ With modern washing m/c the controller is a $\mu P$ &

→ the pgm is not supplied by the Mech. arrangement of cams but by a software pgm.

a) Rotation of the cam - ~~closing~~ Open. the switch contacts.




b) closing.



• MECHATRONIC SYS:

① ⇒ For the pre-wash cycle, an electrically operated valve is opened,

when a current (I) is supplied &

switched off when it ceases.

⇒ This valve allows cold-water into the drum for a period of 't'

det. by the profile of the cam

(or)

Ⓐ the o/p from the μp used to operate its switch.

⇒ However, since the requirement is a specific level of water in the

washing m/c drum,

• There needs to be another Mechanism which will stop the water

going into the tank,

• During the permitted 't',

• when it reaches the required level.

⇒ A sensor is used to give a signal when the water level has

reached the preset level &

• Give an o/p from the μp which is used to switch off the

current to the valve.

⇒ In the case of a cam-controlled valve, the sensor actuates a switch

which closes the valve admitting water to the washing m/c

drum.

⇒ when this event is completed the μp, ~~or the rotation~~

✓ or the rotation of the cams,

✓ initiates a pump to empty the drum.

② → for the main-wash cycle,

⇒ The μp gives an o/p which starts when the pre-wash part of the pgm is completed.

⇒ In the case of the cam-operated sys, the cam has a profile such that it starts its op. when the pre-wash cycle is completed.

⇒ It switches a 'I' into a circuit to open a valve to allow cold water into the drum.

⇒ This level is sensed & the water shut off when the required level is reached.

⇒ The μp (or) cams then supply a 'I' to activate a switch which applies a larger 'I' to an electric heater to heat the water.

⇒ A 'T'-sensor is used to switch off the 'I', when the water-T reaches the preset value.

⇒ The μp (or) cams then switch on the drum motor to rotate the drum.

⇒ This will continue for the 't' det. by the μp (or) cam-profile before switching off.

⇒ Then the μp (or) cam switches on the 'I' to a discharge pump to empty the water from the drum.

③ → The rinse part of the op.

⇒ Now switched as a sequence of signals to open valves which allow

✓ cold water into the m/c,

✓ switch it off,

✓ operate the motor to rotate the drum,

✓ operate a pump to empty the water from the drum, &

✓ repeat this sequence a No. of 't'.

④ → The final part of the op.

⇒ When the μp (or) a cam-switches on just the motor,

✓ At a higher 'N' than for the rinsing, to spin the clothes.

MICRO-PROCESSORS BASED CONTROLLERS (μP).

→ Now rapidly replacing the Mech. cam-operated controllers &

• Being used in general to carry out ctrl fn's.

→ Ad: • Greater variety of pgms become feasible.

• In many simple sys. there might be just an embedded μ-controller, this being a μp with memory all Integrated on one chip, which has been specifically programmed for the task concerned.

• A more adaptable form is the programmable Logic controller.

→ This is a μp-based controller which uses pgrammable memory to store instructions & to implement fn's such as,

- Logic,
- sequence,
- timing,
- Counting &
- Arithmetic to ctrl events &
- Can be readily reprogrammed for different tasks.

-LOGIC CONTROLLER.

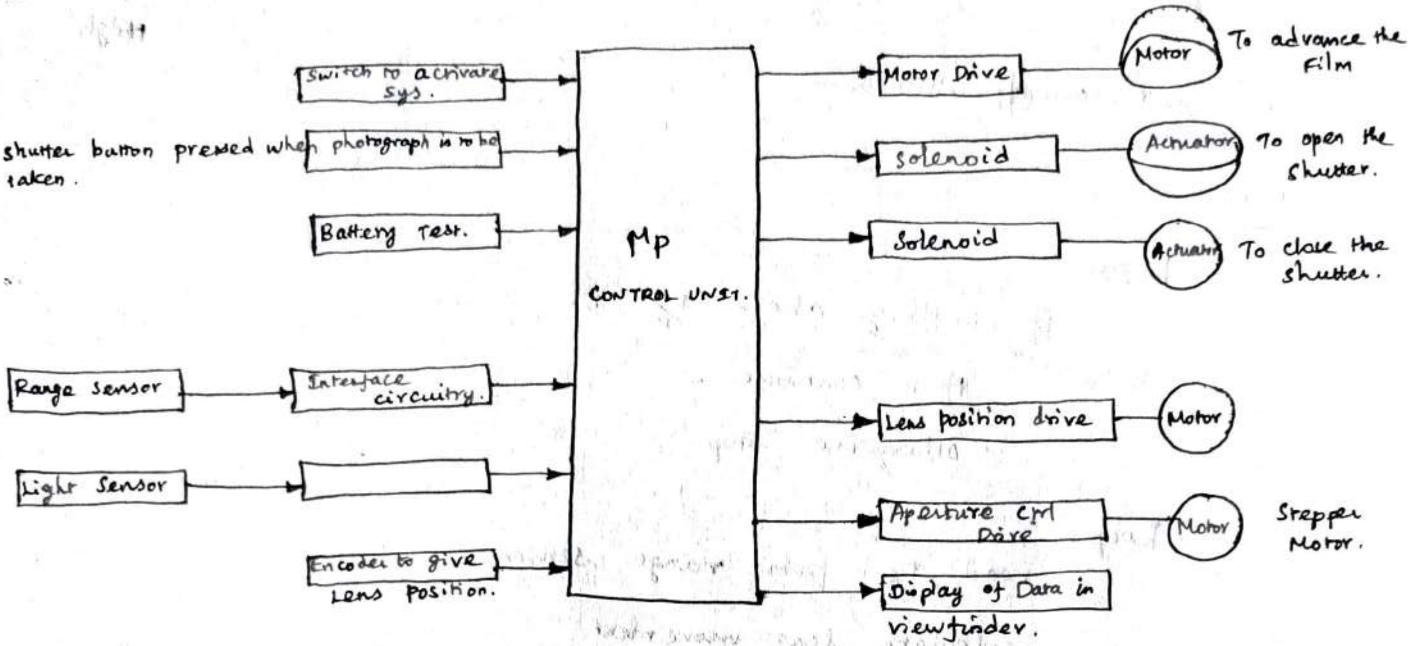

→ The I/p's being signals from, say, switches being closed &

→ the pgm used to der. how the controller should respond to the I/p's &

→ the O/p it should then give.

## AUTOMATIC CAMERA.

- The modern Camera is likely to have automatic focusing & Exposure.
- Basic aspects of a µp-based sys. that can be used to ctrl the focusing & Exposure.




- When the switch is operated to activate the sys. & camera pointed at the obj. being photographed,
  ⇒ the µp - takes in the I/p from the range sensor &
  ⇒ sends an o/p to the lens position drive to move the lens to achieve focusing.
- The lens position is fed back to the µp, so that the feedback signal can be used to modify the lens position acc. to the I/p from the range sensor.
- The Light sensor gives an I/p to the µp which then gives an O/p to det, if the photographer has selected the shutter controlled rather than aperture controlled mode,
  ⇒ The 't' for which the shutter will be opened.
- When the photograph has been taken, the µp gives an O/p to the motor drive to advance the film ready for the next photograph.

✓ - The decisions [ is there an I/p signal on a particular I/p-Line

(or)

Nor & if there is o/p a signal on a particular o/p-Line]

are logic decisions with the 'I/p & o/p' signals either being low (or) High

to give on-off states.

✓ PGM:

begin

if battery check I/p 'ok'

then continue.

otherwise stop.

Loop

read I/p from range sensor.

calculate lens movement.

o/p signal to lens position drive.

I/p data from lens position en-coder.

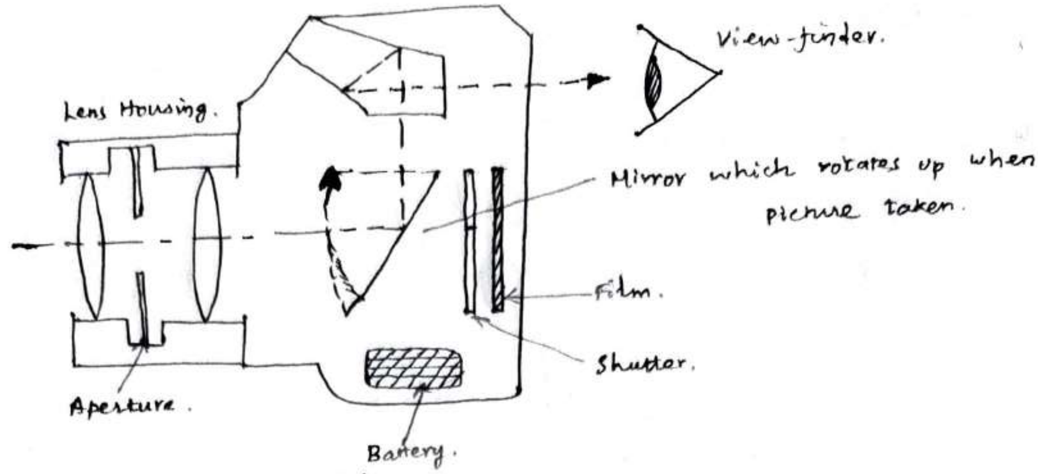
Compare calculated 'o/p' with actual 'o/p'.

stop 'o/p' when lens is correct position.

send in-focus signal to viewfinder display.

etc.

— Reflex CAMERA:

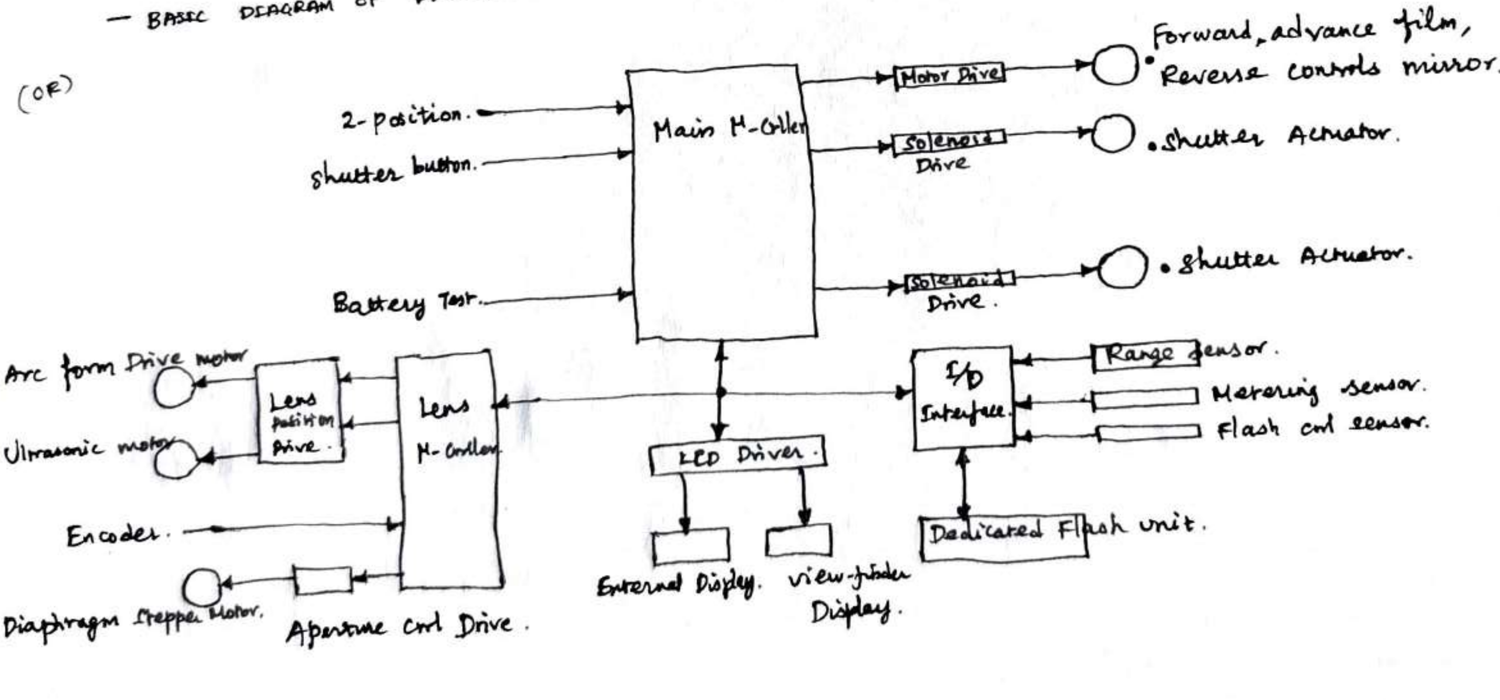



- Basic features of the Canon EOS model,
  - Automatic,
  - Auto-focus,
  - Reflex Cameras.

- The cameras have interchangeable lenses.
- There is a Main Micro-controller M68HC11 in the camera body &
  - Another Micro-controller in the lens housing,
  - the two communicating with each other when a lens is attached to the Camera body.

— BASIC DIAGRAM OF ELECTRONIC SYS.

(OR)



CLOSED LOOP CONTROL SYS:

A) WATER LEVEL CONTROLLER.

- Fn: To maintain a constant water level in a Tank.

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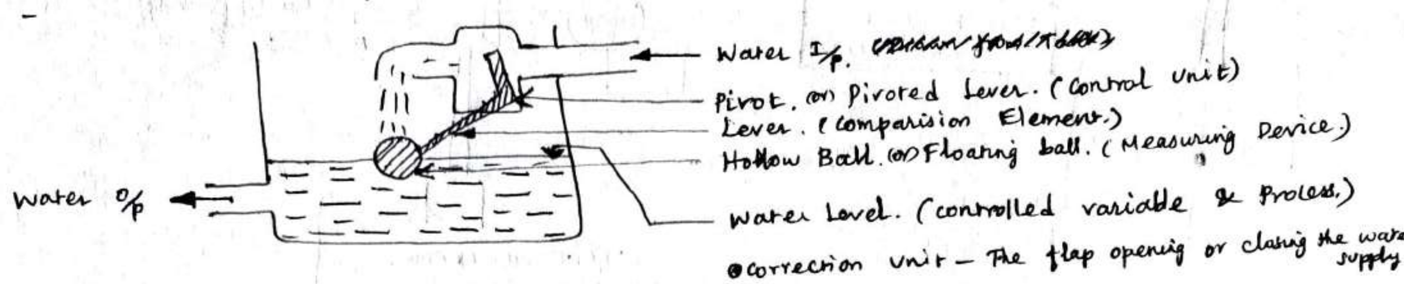



- Just involving Mech. Elements.

- Reference value is the initial setting of the lever arm arrangement, so that it just cut-off the water supply at the required level.

operations:

- 1) When water is drawn from the tank, the float moves downwards with the water level.
  This causes the lever arrangement to rotate & so allow water to enter the tank.
- 2) This flow continues until the ball has risen to such a height that it has moved the lever arrangement to cut-off the water supply.

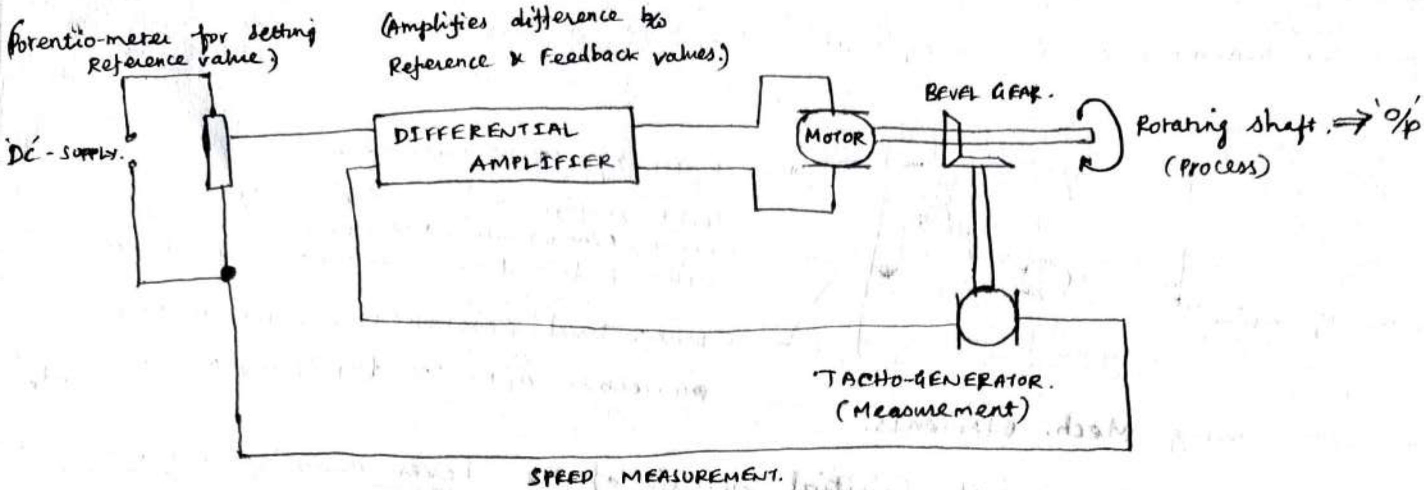
In Mechatronic sys:

- Controlled the liquid level by means of an electronic ctrl sys.
- A level sensor supplying an electrical signal which is used,
  - → After suitable signal conditioning,
  - → As an 'I/p' to a computer where it is compared with a set value signal & the difference b/w them,
  - → The error signal,
  - → Then used to give an appropriate response from the computer 'O/p'.
- This is then, after suitable signal conditioning, used to ctrl the movement of an actuator in a flow ctrl valve & so det. the amount of water fed into the tank.

4

B) SHAFT SPEED CONTROL.

→ Simple automatic cTrl sys. for the 'N' of rotation of a shaft.




(i) Potentio-meter – Set the reference value.

- i.e., what 'v' is supplied to the differential Amplifier as the reference value for the required 'N' of rotation.

(ii) Differential Amplifier – Used to both compare & Amplify the difference b/w the reference & Feed-back values.,

- i.e., it amplifies the error signal.

(iii) The amplified error signal is then fed to a "Motor" which in turn adjusts the 'N' of the rotating shaft.

(iv) The 'N' of the rotating shaft is measured using a Tacho-generator, connected to the rotating shaft by means of a pair of bevel gea

(v) The signal from the Tacho-generator is then fed back to the differential amplifier.

## COMPARISON OF OPEN & CLOSED LOOP CONTROL SYS:

### (*) OPEN LOOP SYS:

1. Any change in O/p has no effect on the I/p.
2. O/p measurement is not required for operation of sys.
3. Feedback element is absent.
4. Error detector is absent.
5. It is inaccurate & unreliable.
6. Highly sensitive to the disturbances.
7. Highly sensitive to the environmental changes.
8. Bandwidth is small.
9. Generally are stable in nature.
10. Sample to construct & cheap.
11. Highly affected by non-linearities.

#### DIS-ADVANTAGES:

* Inaccurate & un-reliable.
* Can not sense environmental changes.
* To maintain → Quality & Accuracy, → recalibration of the controller is necessary time to time.

### (*) CLOSED LOOP SYS:

1. Changes in O/p, affects the I/p.
2. O/p measurement is necessary.
3. Feedback element is present.
4. Error detector is necessary.
5. Highly accurate & reliable.
6. Less sensitive.
7. Less sensitive.
8. Large.
9. Stability is the major consideration while designing.
10. Complicated to design & hence costly.
11. Reduced effect of non-linearities.

#### DIS-ADVANTAGES:

* complicated & time consuming from design point of view & hence costlier.
* Due to feedback, system tries to error time to time.
* Tendency to ~~overcorrect~~ overcorrect the error may cause oscillations without bound in the system.

#### AD-VANTAGES:

* Accuracy is always very high.
* There is reduced effect of non-linearities & distortions.
* Sense environmental changes.
* Band width, i.e., operating freq. zone for such system is very high.

# SENSORS AND TRANSDUCERS.

**o SENSOR:** [ I/p signal (Measurand) → Sensor $\xrightarrow[\text{Analog/Digital}]{\text{Sensor Data}}$ Micro-Controller (signal processing communication) → Network Display. ]

- Sensor is a device, that detects (or) measure a physical Quantity [Temp., pressure, speed, position].
- Sensor convert the physical parameters (or) Quantities into either digital or analog electrical signals.

**o TRANSDUCER:**

- Transducer is a device, that converts a primary form of energy [Mechanical, thermal, Electro-magnetic, optical, Chemical etc] into a corresponding signal with a different energy form.
- Primary Signal → Sensing Element $\xrightarrow{\text{Secondary Signal}}$ Conversion (or) Control Element $\xrightarrow[\text{O/p-Signal}]{\text{Transducer}}$ To indicator (or) Controller.

**o SELECTION OF SENSORS:**

- In selecting a sensor for a particular application there are number of factors that need to be considered:

(i) The nature of the measurement required,

Ex:-

→ The variable to be measured,
→ its nominal value,
→ the range of values,
→ the accuracy required,
→ the required speed of measurement,
→ the reliability required,
→ the environmental conditions under which the measurement is to be made.

(ii) The nature of the output required from the sensor,
- this determining the signal conditioning requirements in order to give suitable output signals from the measurement.

iii) Then possible sensors can be identified, taking into account such factors as their,

→ Range,
→ Accuracy,
→ Linearity,
→ speed of response,
→ Reliability,
→ Maintainability,
→ Life,
→ Power supply requirements,
→ Ruggedness,
→ Availability,
→ cost.

- The selection of sensors cannot be taken in isolation from a consideration of the form of output that is required from the system after signal conditioning, and thus there has to be a suitable marriage between sensor and signal conditioner.

o CLASSIFICATION OF SENSORS:

(i) According to power supply,

(ii) operation,

(iii) Function,

(iv) Performance characteristics. (Static & Dynamic)

a) Static characteristics. [Values are given after steady state conditions are reached.]

→ Accuracy,
→ Precision,
→ Sensitivity,
→ Resolution,
→ Repeatability,
→ Range, etc.

b) Dynamic characteristics. [with time varying Input.]

→ Response time.
(Time taken by a system to produce an output)

→ Time constant.
(How fast it will react to change.)

# STATIC & DYNAMIC CHARACTERISTICS:

## • STATIC CHARACTERISTICS:

→ Static characteristics are the values given when steady-state conditions occur., ie., the values given when the transducer has settled, down after having received some I/p.

→ The terminology defined above refers to such a state.

## • DYNAMIC CHARCTERISTICS:

→ Dynamic characteristics refer to the behaviour b/w the time that the I/p value changes & the time that the value given by transducer settles down to the steady-state value.

→ Dynamic characteristics are stated in-terms of the response of the transducer to I/p's in particular forms.

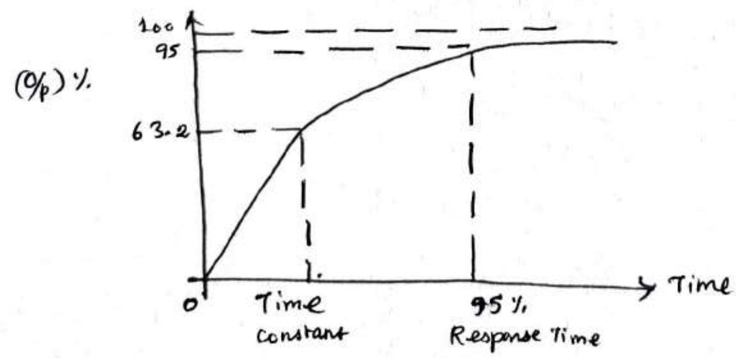
→ Ex:-

✓ This might be a step I/p when the I/p is suddenly changed from '0' at a constant value, (or) a ramp I/p when the I/p is changed at a steady state, (or) a sinusoidal I/p of a specified frequency.

### (i) Response Time:

• This is the time which elapses after a constant I/p, a step I/p, is applied to the transducer up to the point at which the transducer gives an O/p corresponding to some specified percentage.

$\boxed{\text{Ex:}}$ 95% of the value of the I/p. [Response to a step I/p].




• Ex:- If a mercury-in-glass thermometer is put into a hot liquid there can be quite an appreciable time elapse, perhaps as much as 100's (or) more, before the thermo-meter indicates 95 % of the actual temperature of the liquid.

ii) Time constant:

- This is the 63.2% response time.
- A thermo-couple in air might have a time constant of perhaps (40 – 100) s.
- The time constant is a measure of the inertia of the sensor & so how fast it will react to changes in its I/p; the bigger the time constant the slower will be its reaction to a changing I/p - signal.

iii) Rise Time:

- This is the time taken for the O/p to rise to some specified percentage of steady - state O/p.
- often the rise time refers to the time taken for the O/p to rise from (10%) of the steady-state value to 90 (or) 95% of the steady-state value.

iv) Settling time:

- This is the time taken for the O/p to settle to within some percentage.
- e.g. 2%, of the steady-state value.

# 1. RESISTIVE, CAPACITIVE & INDUCTIVE TRANSDUCERS:

## • RESISTIVE TRANSDUCER:

• A resistive sensor is a transducer (or) Electro-mechanical device that converts a mechanical change such as displacement into an electrical signal that can be monitored after conditioning.

• Resistive sensors are,

(i) Potentiometers.

(ii) Strain gauges.

(iii) Thermistors.

### (i) POTENTIO-METERS:

• Potentiometer is a variable resistor that is commonly used as a sensor.

• A potentiometer has three terminals:

→ one for power I/p,

→ one for a ground &

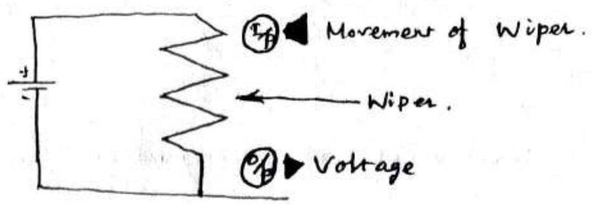
→ one to provide a variable voltage O/p.

• A potentiometer is a Mechanical device, whose resistance can be varied by the position of the movable contact on a fixed resistor,

• The movable contact slides across the resistor to vary the resistance & as a result varies the voltage O/p of the potentiometer.

• The O/p becomes higher (or) Lower depending on whether the movable contact is near the resistor's supply end (or) ground end.

• THEORY OF OPERATION:




→ A potentiometer is an electro-mechanical device containing a movable wiper arm that maintains electrical contact with a resistive surface.

→ The wiper is coupled mechanically to a movable member or linkage.

→ The wiper & resistive surface form a voltage divider circuit when voltage is applied across the entire resistance within the potentiometer.

→ The only theory involved in application is the voltage divider rule, which is derived directly from ohm's Law.

The formula for Linear voltage 'O/p' is simply:

$$\text{'O/p' Voltage} = \frac{(\text{Wiper Resistance})^{*}\ (\text{I/p - Voltage})}{(\text{Total Length})}.$$

→ This formula can be easily re-arranged to find any component.

⇒ Note that all potentiometers draw power through the resistor at all times.

✓ using a very high resistance potentiometer can reduce the power drawn.

✓ This has the unfortunate side effect of creating a high-impedance 'O/p' to the next stage of the instrumentation chain.

✓ We usually desire a low-impedance source so that the I/p-Impedance of the next stage does not affect the accuracy of the measurement.

✓ Design with potentiometer sensors becomes a trade-off between current consumption & Impedance matching.

⇒ Potentiometer can also have logarithmic scales.

✓ Logarithmic pots can be very useful as part of the signal-conditioning of a sensor.

✓ If a measurement is inherently exponential then a logarithmic pot can be used to compensate.

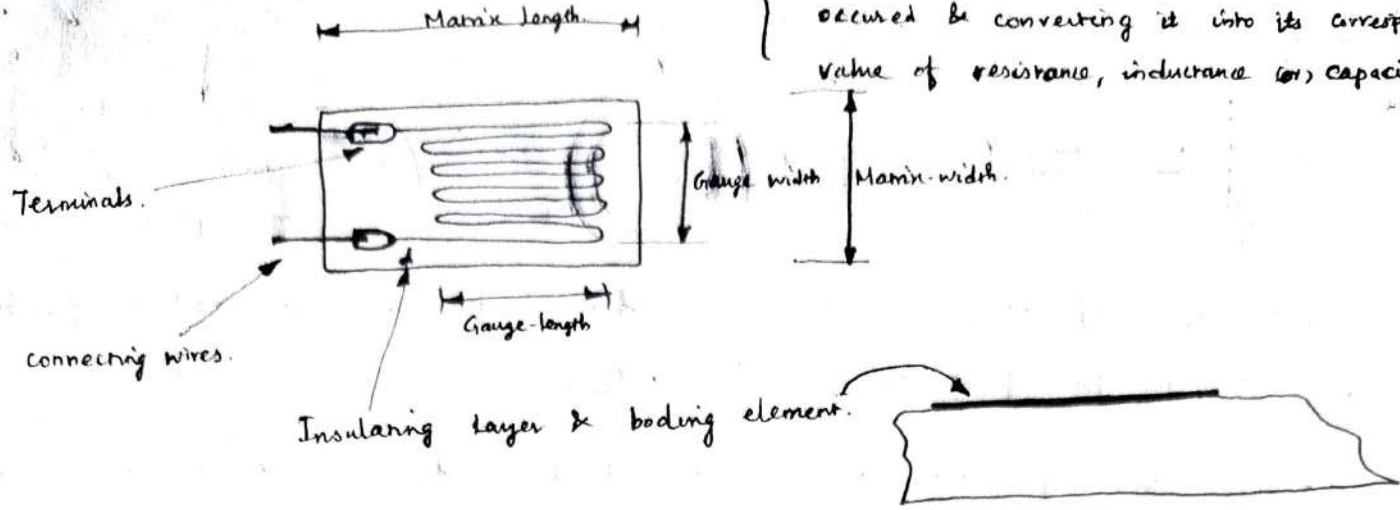
✓ This is why Logarithmic pots are used for volume control in audio-work.

- Perceived Sound is an exponential quantity (dB).

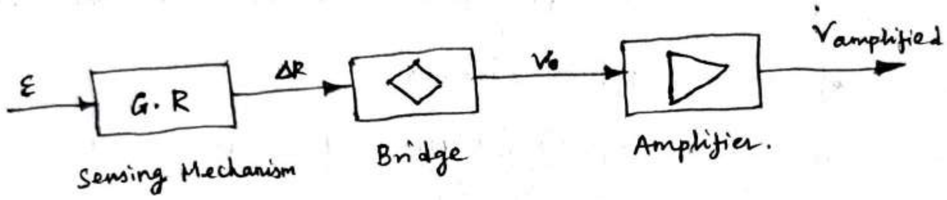
※ APPLICATION: [String pot Design — String is attached around a spring loaded drum so that Linear motion is converted to rotary motion]

(ii) STRAIN GAUGES:

15 { • To measure the change in displacement occured by converting it into its corresponding value of resistance, inductance (or) capacitance}




- One of the most common ways to measure strain.
- The strain-guage is part of a Multi-stage process that generates a voltage signal proportional to the strain.




- The electrical resistance strain gauge is a metal wire (a), metal foil (b) strip, or a strip of semi-conductor material (c) which is wafer-like & can be stuck onto surfaces like a postage stamp.
- When subject to strain, its resistance (R) changes, the fractional change in resistance ($\Delta R/R$) being proportional to the strain ($\varepsilon$).,

ie, $\frac{\Delta R}{R} = G\varepsilon$

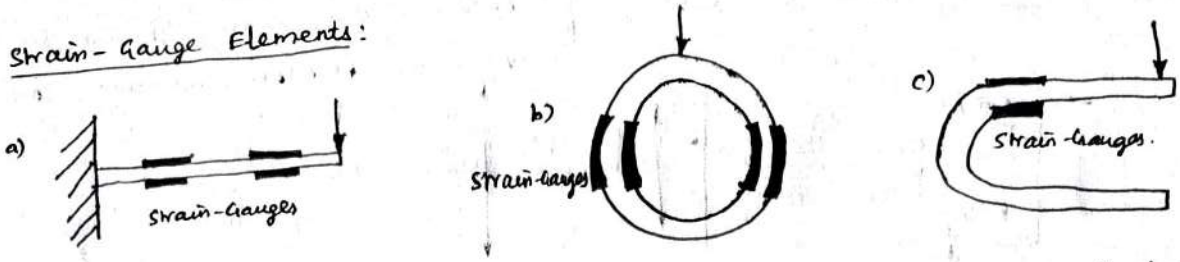
where, G – Gauge factor. (a) Metal wire & (b) Metal foil strip ⇒ 2.0
(c) Silicon p & n-type semi-conductor ⇒ ±100.

$\left[G = \frac{\text{Fractional change in Resistance}}{\text{Fractional change in strain}}\right]$

- The gauge factor is normally supplied by the manufacturer of the strain-guages from a calibration made of a sample of strain-gauges taken from a batch.
- The calibration involves subjecting the sample gauges to know strains & measuring their changes in resistance.
- A problem with all strain-gauges is that their resistance not only changes with strain but also with temperature.

● OPERATIONS:

Strain- Gauge Elements:




✓One form of displacement sensor has strain-Gauges attached to flexible elements in the form of cantilevers, rings (or) U-shapes.

✓ when the flexible element is bent (or) deformed as a result of a forces being applied by a contact point being displaced, then the electrical resistance strain-gauges mounted on the element are strained & so give a resistance change which can be monitored.

✓ The change in resistance is thus a measure of the displacement (or) deformation of the flexible element.

✓ Such arrangements are typically used for linear displacements of the order of 1 mm to 30 mm & have a non-linearity error of about ±1% of full-range.

● DIS-ADVANTAGES:

✓ O/p is not linear with strain,

✓ very temperature dependent,

✓ usually have a much lower strain limit than metallic type,

✓ more expensive than metallic type.

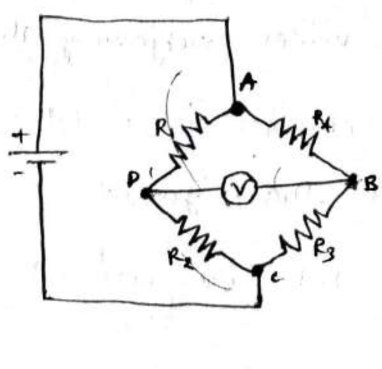
● APPLICATIONS:

✓ Pressure measurement,

✓ Acceleration measurement,

✓ Temperature measurement.

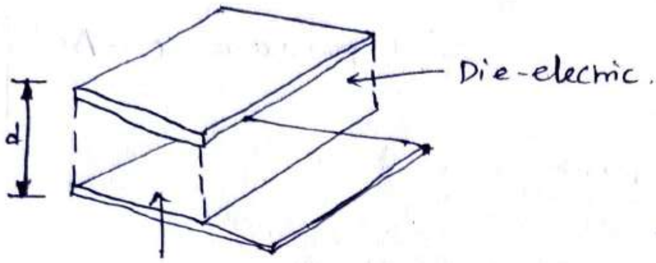
● Ex:- Wheat-Stone Bridge.




$R_1, R_2, R_3$ & $R_4$ - Strain-Gauges

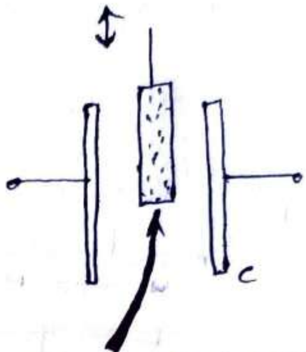
## 1.8. CAPACITIVE TRANSDUCER:

* Measure a change in capacitance through a change in distance (d) between two plates.
* Measures capacitance change through a change in over-lapping area (A), resulting from plate movement (or) a change in die-electric constant, $\varepsilon$.




over-lapping Area, A.

$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$ (Farads.)




Material of relative permittivity, $\varepsilon_r$.

* Applications:

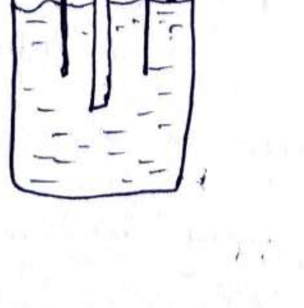
→ To measure, displacement,
- Pressure,

[Differential pressure transmitters]
- Acceleration.

→ To measure the Liquid Levels

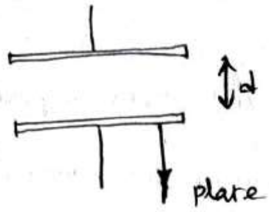
• For liquid level measurements two electrodes are placed in the liquid, & the die-electric constant varies between them according to the liquid level.

Thus, capacitance between electrodes is a direct indication of liquid level.



※ • Capacitive sensors for the monitoring of linear displacements might thus take the forms shown in Fig.

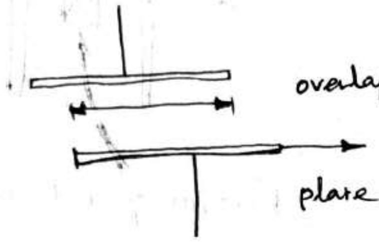
a)




[one of the plates is moved by the displacement so that the plate separation changes.]

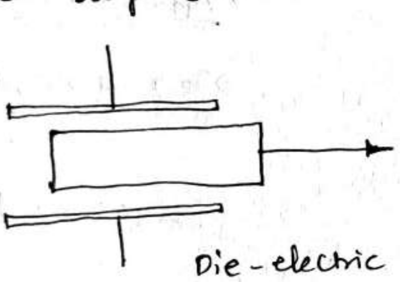
$\therefore$ Capacitance, $C - \Delta C = \left[\dfrac{\varepsilon_0 \varepsilon_r A}{d + x}\right]$

b)



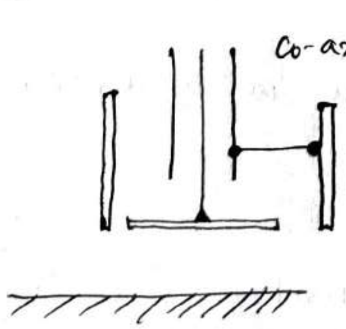

[The displacement causes the area of overlap to change.]

c)




[The displacement causes the di-electric between the plates to change]

<u>EXAMPLE</u>:- CAPACITIVE PROXIMITY SENSOR.




• One form of capacitive proximity sensor consists of a single capacitor plate probe with other plate being formed by the object, which has to be metallic & earthed.

✓ As the object approaches so the plate separation of the capacitor changes, becoming significant & detectable when the object is close to the probe.

c) INDUCTIVE SENSORS:

* An Inductive sensor is designed such that the quantity to be measured alters the (self) inductance of the sensor's coil, to produce either a change in current through the coil (or) a change in voltage across the coil.

→ One of the most common ways producing such a change is use to a movable core which moves back and forth inside a coil, where a permeability is varied as the core is displaced within the coil.

→ The core is usually made of a highly permeable material such as ferrite and Iron.

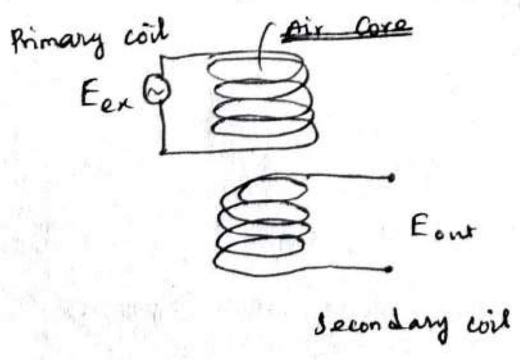
* INDUCTIVE TRANSDUCERS:

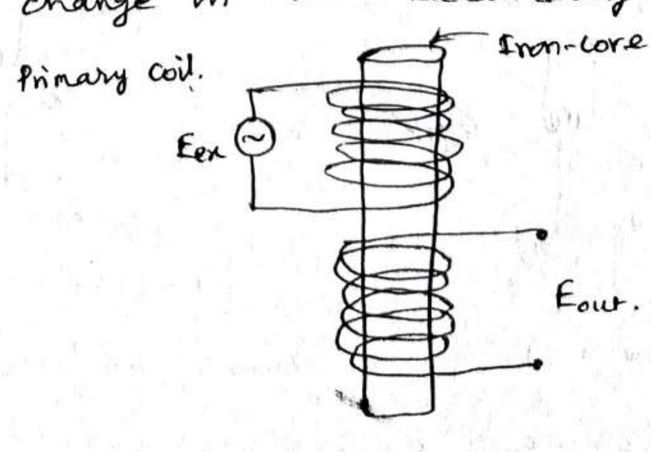
→ Consider a set of two coils sharing the same core; i.e., a transformer basically.

• Note that One of the coil (Primary coil) is driven by a power source, while the other (secondary coil) produces a voltage induced from the primary coil.

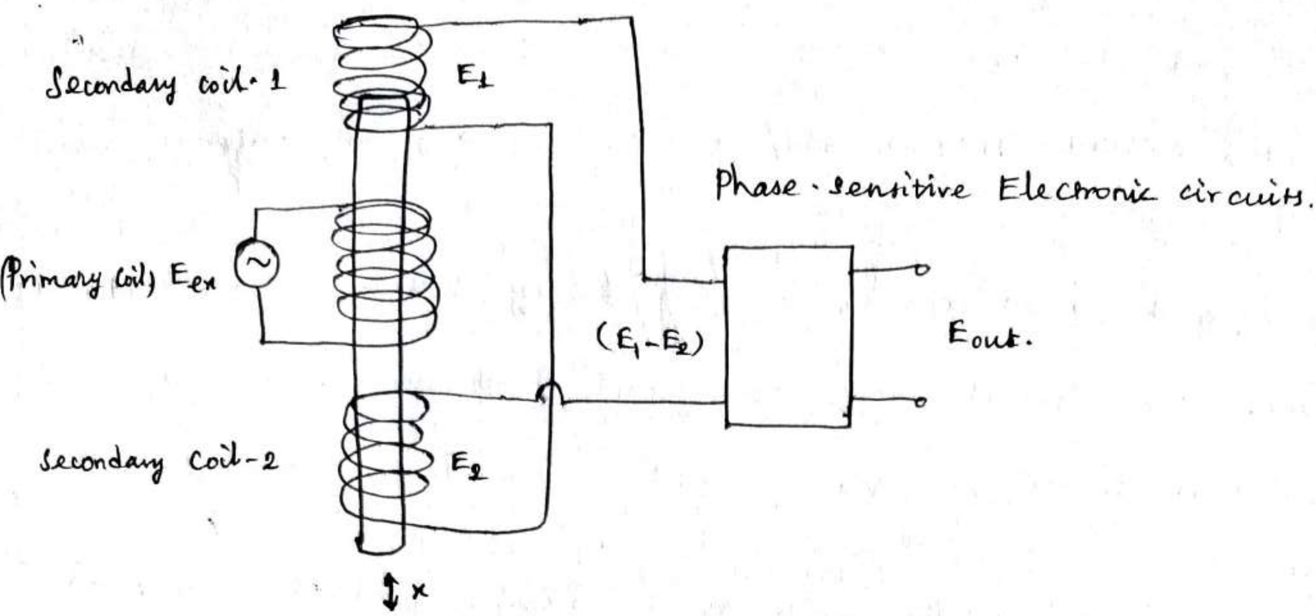
→ The voltage on the secondary coil depends on mutual inductance between the two coils.

• If the core is made movable in response to the displacement of a target object, the mutual inductance will change, resulting in a voltage change in the secondary coil.

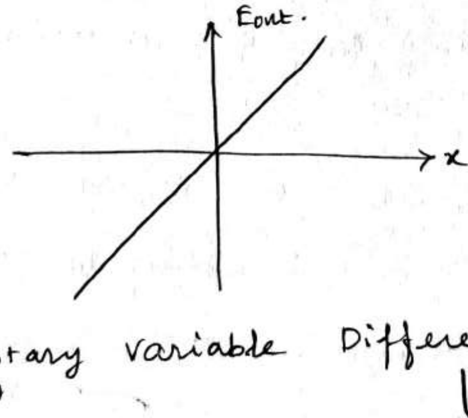


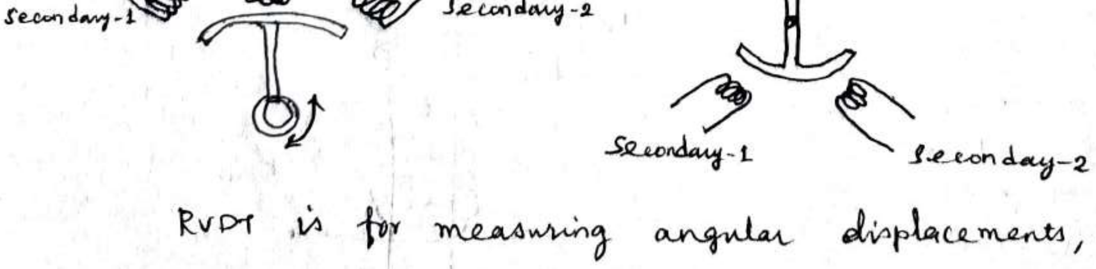
## LVDT - Linear Variable Differential Transformer:




- The above device can be extended to a LVDT, whose principle operation is the same, but with two secondary coils.
- These are wound in opposite directions such that if the core moves to either direction, the voltage in one of the secondary coils increases while it decreases in the other, generating a non-zero voltage output.
- When the core is located at the center, the output is zero.




RVDT - Rotary Variable Differential Transformer.




RVDT is for measuring angular displacements, and operates in the same manner as a LVDT.

# 7. TEMPERATURE & PRESSURE SENSORS:

## A) TEMPERATURE SENSOR:

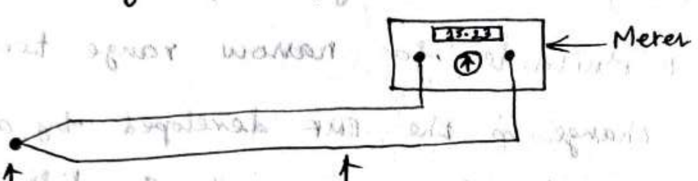
### (i) THEMO-COUPLES:

* When two wires with dissimilar electrical properties are joined at both ends and one junction is made hot & the other cold, a small electric current is produced proportional to the difference in the temperature.

* Seebeck discovered this effect.

* It is true no matter how the ends are joined so the cold end may be joined at a sensitive milli-volt meter.

* The hot junction forms the sensor end.




DEF: (How it works?)
* Made up of two different metals joined at one end to produce a small voltage at a given temperature.

• ADVANTAGES:

* Self-powered (does not require a current or voltage source).
* Rugged.
* In-expensive.
* Simple.

• DIS-ADVANTAGES:

* Extremely low voltage output (mV).
* Not very stable.
* Needs a Reference point.

⊙ APPLICATIONS:

(i) High Temperature applications.

Made up: • Made of up two different metals.

Ex:- A type 'J' is made up of Iron & Constantan.

• Temp. range > Type-J: [0°C to 750°C].

(ii) RESISTANCE TEMPERATURE DETECTOR (RTD).

* Listed below is some temp. measurement applications for which the use of a RTD is normally preferred over a thermo-couple:

(i) Temperature of turbine inlet steam whose design temperature is close to the max. allowable temp. for piping & Equipment.

(ii) Temp. of permanent turbine test points.

(iii) Avg. Temp. of nuclear reactor coolant.

(iv) Avg. combustion turbine inlet air Temp.

(v) Condenser cooling water inlet to outlet temp. gain.

(vi) Motor stator winding & bearing Temp's.

* Thermo-couples are not suitable for narrow range temp. measurements.
* This is because the change in the EMF developed by a thermocouple over a narrow temp. range is very small & different to measure.
* Therefore, for narrow spans (or) small temp. differences a RTD is re-commended.

How it works? → Utilizes the fact that resistance of a metal changes with Temp.

Make up? → Traditionally made up of platinum, Nickel, Iron (or) copper wound around an insulator.

Temp. Range → From about (−196°C to 482°C).

Advantages:
→ stable.
→ Very accurate.
→ change in resistance is linear.

Dis-Advantages:
→ Expensive.
→ current source required.
→ small change in resistance.
→ self heating.
→ Less rugged than thermo-couples.

(iii) THERMISTOR:

• How it works?

→ Like the RTD .. a thermistor uses the fact that resistance of a metal changes with temperature.

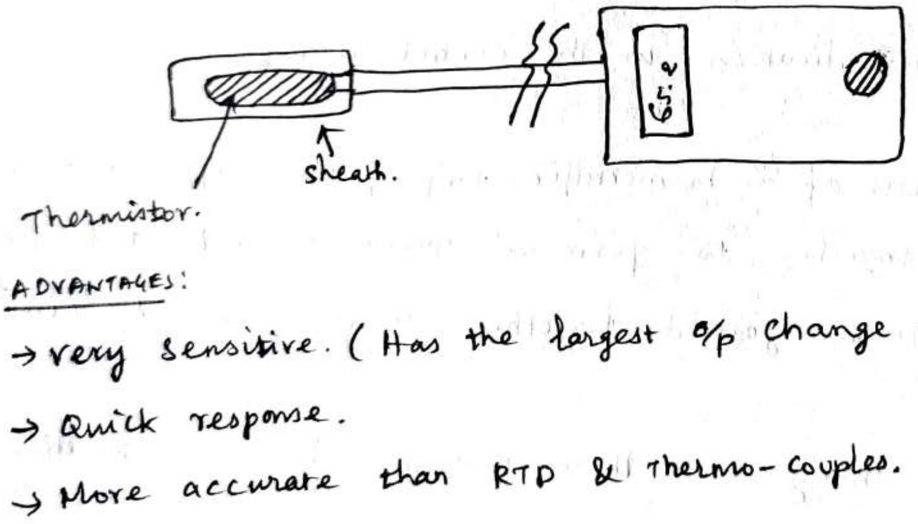
• Make up:

→ Generally made up of semi-conductor materials.

• Temp. range:

→ About (−45°C to +150°C).

* A special type of resistance sensor is called a "Thermistor".
* They are made from a ~~small~~ piece of semi-conductor material.
* The material is special because the resistance changes a lot for a small change in temp. & so can be made into a small sensor & it costs less than platinum wire.
* The temp. range is limited.
* The relationship between resistance & temp. is of the form, $R = Ae^{B/\theta}$




• ADVANTAGES:

→ very sensitive. (Has the largest o/p change from I/p. Temp.)

→ Quick response.

→ More accurate than RTD & thermo-couples.

• DIS-ADVANTAGES:

→ o/p is a non-linear function.

→ Limited Temp. range.

→ Require a current source.

→ self heating.

→ Fragile.

(iv) BI-METALLIC THERMOMETER:

DEF:
* In an Industry, there is always a need to measure & monitor Temp. of a particular spot, field (or) locality.
* The industrial names given to such Temp. sensors are Temp. indicators (or) Temp. Gauges. All those temp. gauges belong to the class of instruments that are known as "Bi-metallic sensors".

BASIC PRINCIPLES:

(i) A Metal tends to undergo a volumetric dimensional change (expansion & contraction), according to the change in Temp.

(ii) Different metals have different co-efficient of Temp's.

→ The rate of volumetric change depends on this co-efficient of Temp.

APPLICATIONS:

→ If the temp. to be measured is not required for,

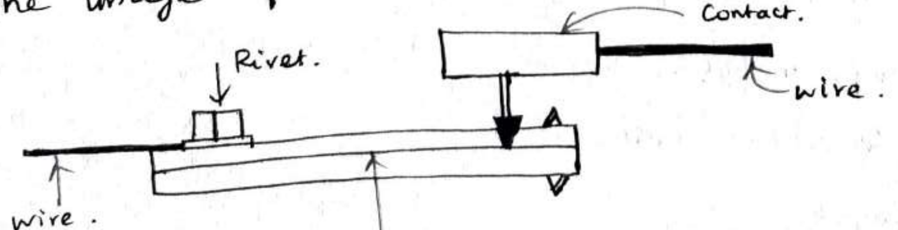
⇒ Automatic control,

⇒ Recording, (or)

⇒ Indication in the control room.

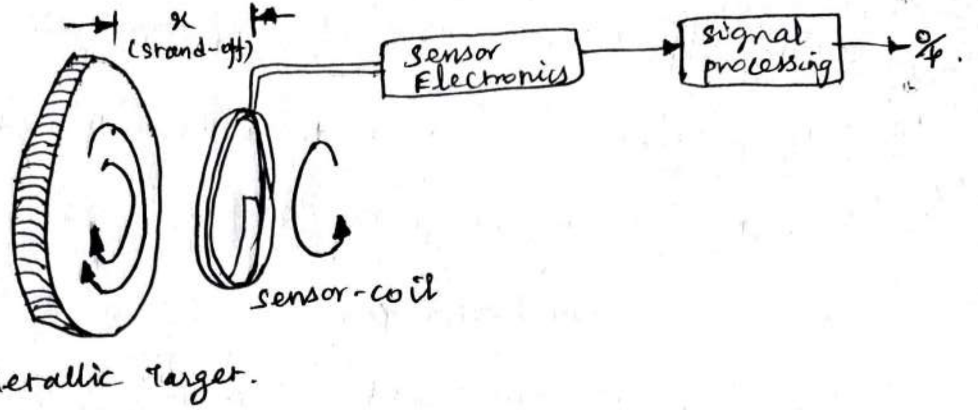
WORKING:

* The device consists of a bi-metallic strip of two different metals & they are bonded together to form a spiral (or) a twisted Helix.
* Both those metals are joined together at one end by either welding (or) riveting.
* It is bonded so strong that there will not be any relative motion between the two.
* The image of a bi-metallic strip is shown below.




- Bimetallic strips are available in different forms like, [Helix, Cantilever, Spiral & Flat].
- The thermal stability of the bi-metallic thermometer is an inherent chara. of the metals used & continued operation cannot be assured above 471°c.

• Eddy-current sensor configuration:




- Eddy current sensor consists of 4-components.

  a) sensor coil,

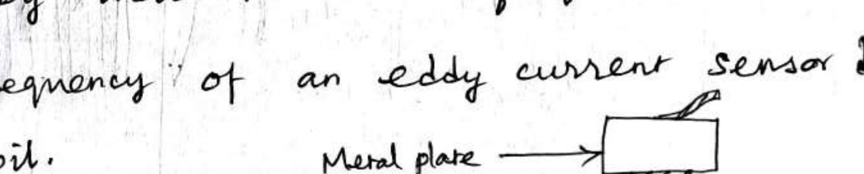
  b) Target,

  c) sensor drive electronics, &

  d) signal processing block.

- Eddy current sensors work most efficiently at high-oscillation frequencies nearby their resonance frequencies.
- The resonance frequency of an eddy current sensor depends on the sensor coil.

• Eddy-current:




- It is caused when a conductor is exposed to a changing magnetic-field due to relative motion of the field source & conductor. (or) due to variations of the field with time.
- The eddy-current generates a opposite magnetic-field, which superimposes with the exciting magnetic field.
- As consequence the impedence (z) of the sensor coil changes.

## HALL EFFECT SENSOR:

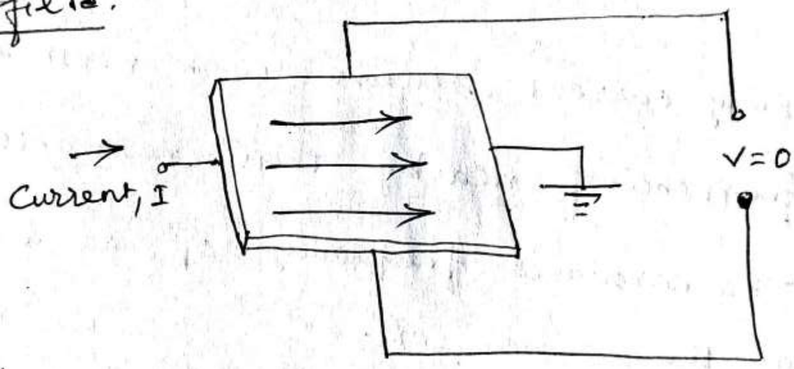
→ Hall effect sensor is a type of magnetic sensor.

- Hall effect sensor is a transducer that varies its 'o/p' voltage in response to changes in magnetic field.

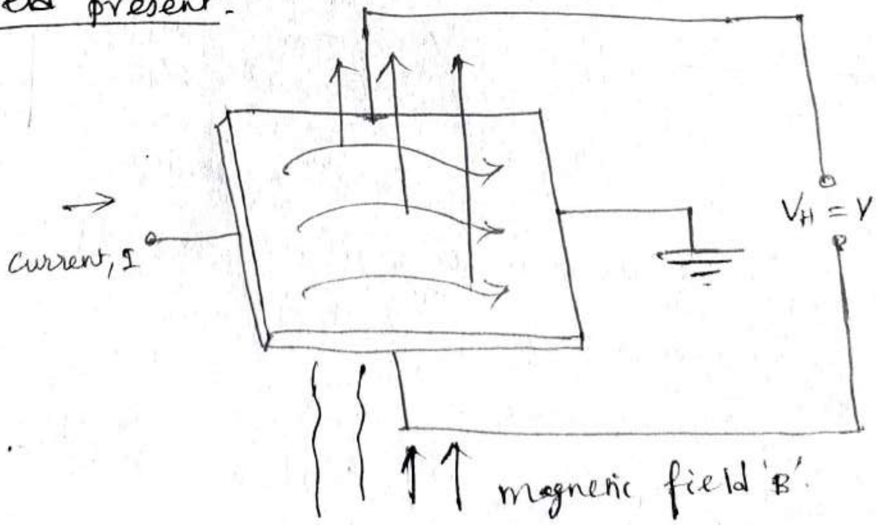
→ When a conductor (or) semi-conductor with current flowing in one direction was introduced $\perp^r$ to a magnetic field, a voltage could be measured at right angles to the current path.

- When a current carrying conductor is placed into a magnetic field, a voltage will be generated $\perp^r$ to both the current & the field. This principle is known as "Hall Effect".

- When no magnetic field:




- When magnetic field present:




$\therefore V_H \propto IB.$

$\Rightarrow V_H = k_H \dfrac{IB}{t}.$

where,

$k_H$ - Hall co-efficient.

$t$ - Thickness of the Hall element.

LIGHT SENSOR:

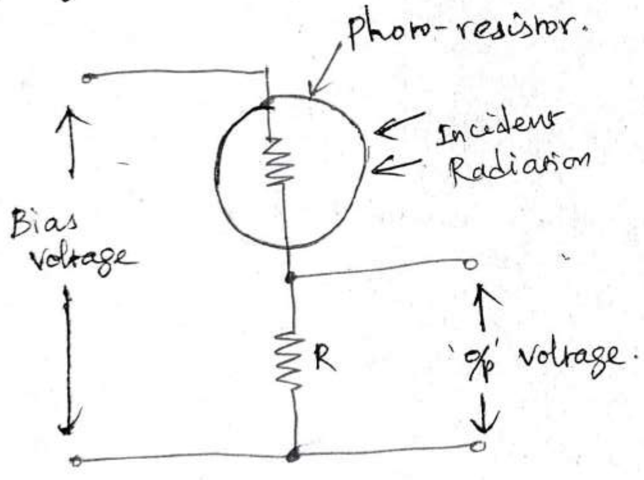
→ A light sensor (or) detector converts the radiant power it absorbs into a change of a device parameter such as resistance, surface charge, current (or) voltage.

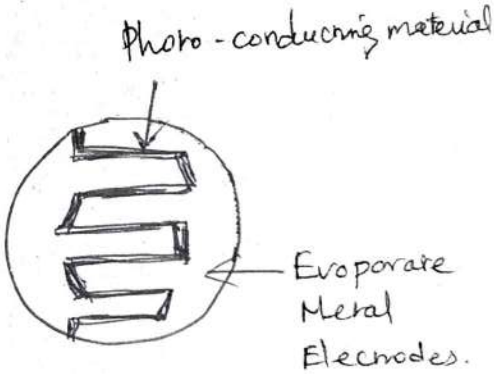
⇒ Photo-resistor:

* A photo-resistor consists of a slab of semi-conductor material on the faces of which electrodes are deposited to allow the resistance to be monitored.

* The increase in conductivity, caused by the absorption of photons increasing, electrons & holes is the basis for the operation of the photoresistive detector.

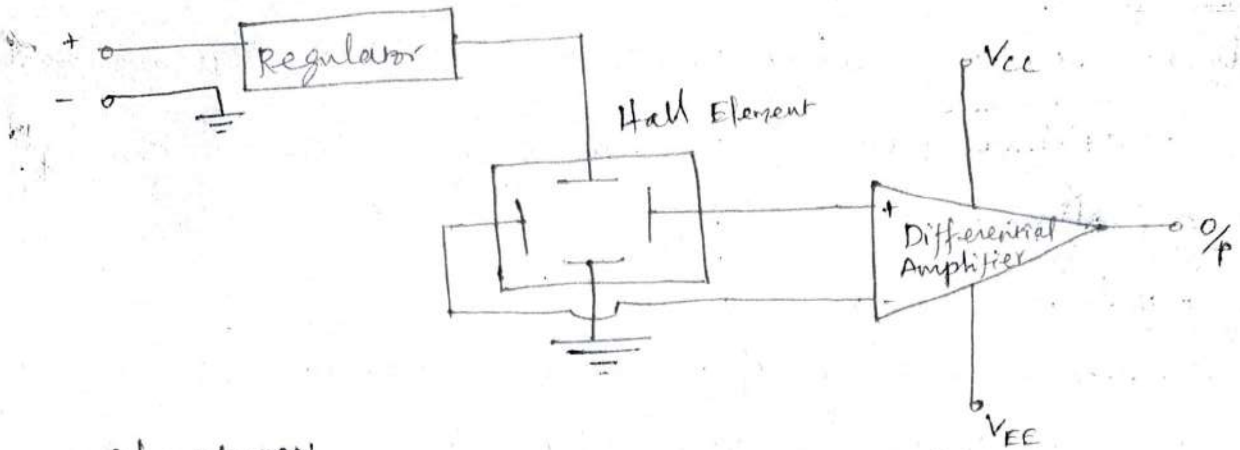
* Photo-conductive devices used for the detection of long wavelength infrared radiation should be cooled because of the noise caused by fluctuations in the thermal generation of charge.




* A simple light detector circuit employing a photo-resistor, an ↑ in light illumination cause the resistance of the photo-resistor to ↓ & the o/p voltage to ↑.

* The photon-induced current is proportional to the length of the electrodes & inversely proportional to their separation.




• <u>Advantages:</u>

→ Hall sensors are used for proximity switching, positioning speed detection, & current sensing applications.

→ Hall sensors are commonly used to time the speed of wheels & shafts

→ ·

• <u>Advantages:</u>

→ Relative low cost compared to electro-magnetic switches.

→ High frequency operation is possible.

→ No contact bounce problem.

• <u>Dis-advantages:</u>

→ Sensor becomes weak during offset effects caused by mis-alignment of contact in Hall element & piezo-resistive effects.

# UNIT-IV

## PROGRAMMABLE LOGIC CONTROLLER.

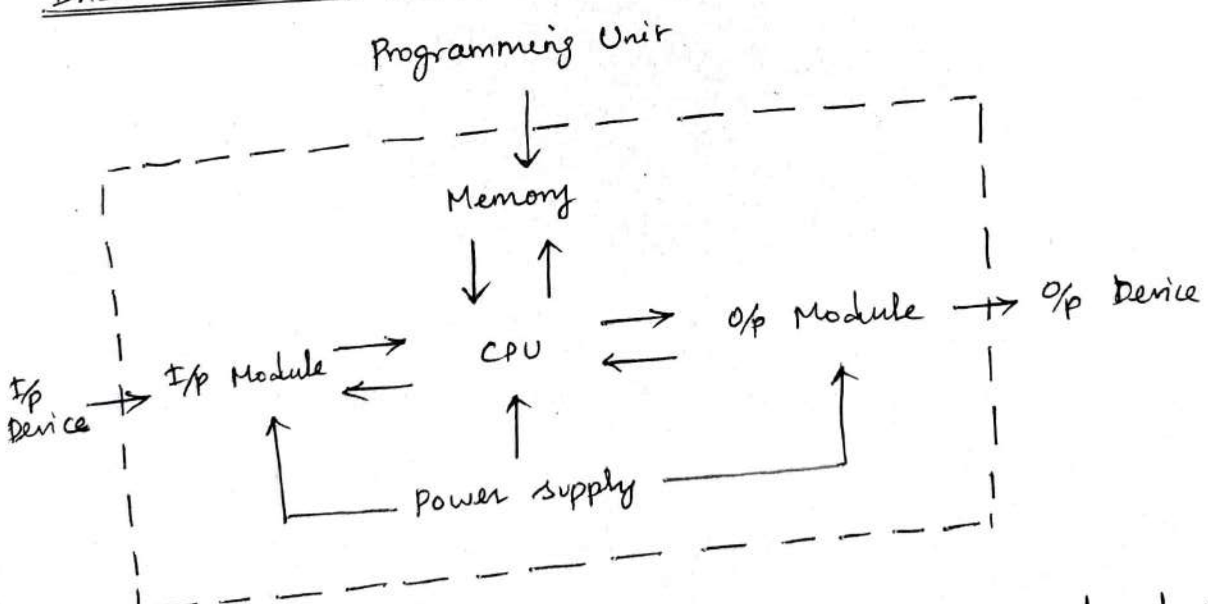
### DEFINITION: PLC.

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

### APPLICATION: PLC.

- Control & operation of Automated Mfg. process Equipment & Machinery.
- Packaging & Filling equipment,
- chemical Mixing,
- Conveyor systems & Distillation etc.

### BASIC STRUCTURE: PLC.




✓ The structure of PLC is based on the same principles of computers architecture; it is capable of performing other functions such as,

→ Counting,

→ Logistics,

→ neumerical applications.

→ Comparing & processing of signals.

- A typical PLC can be divided into four parts. They are,

(i) I/p & O/p Modules.

(ii) CPU - Central Processing Unit.

(iii) Memory.

(iv) Programming Unit.

(v) Processor.

(i) I/p & O/p Modules:

→ - The I/p Module receives information from extended devices & sends to processor & communicates the processed information to the External devices through O/p Modules.

→ - The I/p devices are mechanical switches, photo sensors, temperature sensors, flow sensors & other type of sensors, keypads etc.,

→ - The O/p devices may include solenoid valves, Relays, contactors, Lights, Horns, Heating elements, Fans, Motor starter, Signal Amplifiers, Conveyor belt, lift, automation door etc.,

(ii) CPU: (Programming Device)

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

(iii) Memory:

- The memory unit contains the program stored in it.
- The programs were written with control actions to be executed by the micro-processor for the input given.
- RAM is a temporary storage device used to store ladder diagram & for testing & evaluation.

Then it is stored in ROM, where changes can't done.

(iv) Programming unit:

→ ✓ The programming unit is used to enter the required program into the memory of the processor.

✓ The program is developed in the device & then transferred to the memory unit of the PLC.

→ ✓ Programming device also enters the required program using ladder logic into the memory of the processor.

✓ The sequence of operation & ultimate control of equipment machinery is specified & determined by the ladder program.

✓ While entering the ladder program, the program device is normally connected to the controller.

✓ Actual programming is usually achieved by pushing keys (or) a keyboard & can be programmed by people without much computer programming experience.

→ ✓ There are normally 3-approaches followed by the program,

(i) Use of hand-held programmer,

(ii) terminal with video display unit,

(iii) a PC with appropriate software.

(v) Memory:

✓ The memory unit contains the program stored in it.

- The programs were written with control actions to be executed by the micro-processor for the input given.

✓ RAM is a temporary storage device used to store ladder diagram & for testing & evaluation.

✓ Then it is stored in ROM where changes can't done.

✓ For network programmed PLC's, the final PLC's program is downloaded into a special re-programmable ROM (EPROM, PROM & EEPROM) in the PLC.

↓ Electrically Erasable

✓ Memory may be either volatile (Temporary) (or) Non-volatile (Permanent) type

I/p & O/p PROCESSING:

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

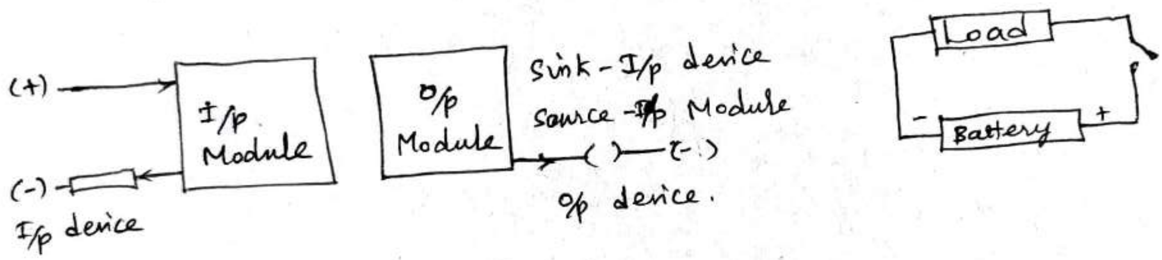
a) Sourcing:

✓ If a switch is connected to the positive of the battery & current flows from positive to negative, it is said to be the sourcing the current. So, the I/p device receives current from the input module.

✓ For the PLC, input unit (I/p), hence input module is the source of the current.

✓ For the PLC O/p unit, O/p module is the source of current as it supplies current to the O/p devices.

✓ Sourcing O/p units for interfacing with solenoids.




b) Sinking:

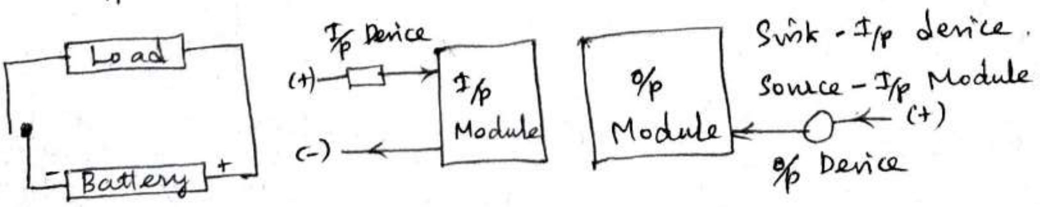
→ ✓ Hence, the I/p device supplies current to the I/p module.

✓ For the PLC I/p unit, hence the I/p module is the sink for the current.

✓ Sinking I/p units are used for interfacing with electronic equipment.

→ ✓ So, if a switch is connected to the negative of the battery & current flows from Positive (+) to negative (-), by conventional current flow direction, it is said to be the sinking for current.

✓ For the PLC O/p unit, the current flows from O/p device to the O/p Module then the O/p module is the sink for current.



## STEPS INVOLVED IN I/p & O/p PROCESSING:

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

(i) Scan the I/p's associated with one rung of the ladder program.

(ii) Solve the logic operation involving those I/p's.

(iii) Set / Reset the O/p's for that rung.

(iv) Move on the next rung & repeat the operations 1, 2, 3.

Scan all I/p's
↓
Carry out program
↓
Update O/p's.

Repeat sequence

- The two methods of I/p & O/p processing operations are,
  - (i) Continuous Updating,
  - (ii) Mass I/p & O/p Copying.

### Continuous Updating

(i) Fetch & decode the 1st pgm instruction.

(ii) Scan there relevant I/p's.

(iii) Scan the relevant I/p's etc. for the remaining pgm. instructions.

(iv) Update O/p's.

(v) Report the entire sequence.

### Mass I/p & O/p Copying.

(i) Scan all the I/p's & copy into RAM.

(ii) Fetch & decode ~~&~~ execute all the pgm. instructions in sequence.

(iii) Copy all the O/p instructions to RAM.

(iv) Update all O/p's.

(V) Repeat the sequence.

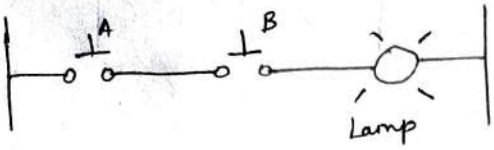
## PROGRAMMING: MNEMONICS.

| Mnemonics | Description. |
| --- | --- |
| LD | - Start a Rung with an open contact. |
| OUT | - An O/p. |
| AND | - A series element with an open contact & so an AND logic instruction. |
| OR | - A ∥el element with an open contact & so an OR logic instruction. |
| I | - A NOT logic instruction. |
| ....I | - Used in conduction with other instruction into indicate the inverse. |
| ORI | - A ∥el element with an closed contact & so NOR logic instruction. |
| Ah? | - A series element with an closed contact & 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. |

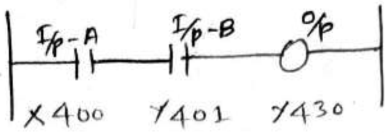
• Logic functions:

(i) AND - function:


$Y = A \cdot B$



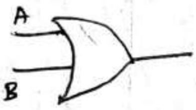

Ladder Diagram:



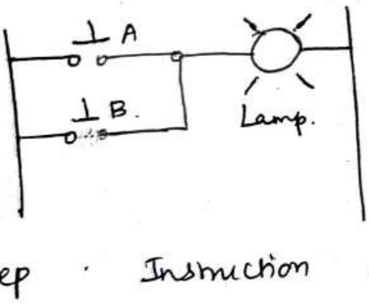

| * Step | Instruction | Address | Parameter | Description. |
|---|---|---|---|---|
| 0 | LD X400 | X400 | I/p | Start a rung with open contacts |
| 1 | AND X401 | X401 | AND Logic | Open contact AND logic fn'. |
| 2 | OUT Y430 | Y430 | O/p | O/p (or) terminate the rung. |

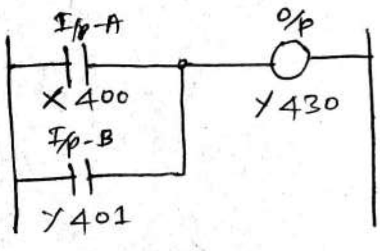
* → AND logic circuit represents the series circuit.
  → AND gate is composed with two I/p's & one O/p.
  → AND gate produce O/p, when both the I/p's are HIGH state.

(ii) OR - function:




$Y = A + B$.

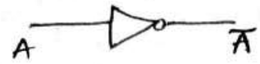


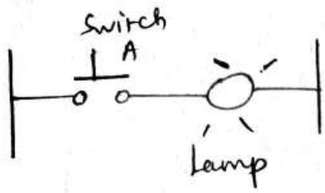




| * Step | Instruction | Address | Parameter | Description. |
|---|---|---|---|---|
| 0 | LD X400 | X 400 | I/p | Start a rung with open contacts |
| 1 | OR X401 | X 401 | OR Logic | Add as open content in $\parallel^{el}$. |
| 2 | OUT Y 430 | Y 430 | O/p | Terminate the rung. |

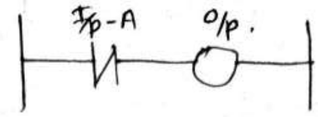
* → OR logic circuit represents the $\parallel^{el}$ circuit.
  → OR Gate is composed of 2 (or) more I/p's & 1-O/p.
  → OR operation is like addition of binary numbers.
  → OR gate produce O/p, when any 1 I/p are HIGH state.

(iii) NOT - function:



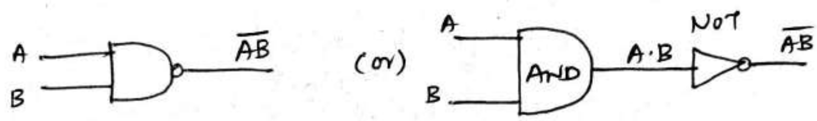



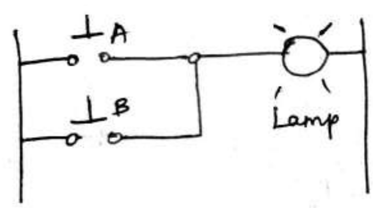

Ladder Diagram:

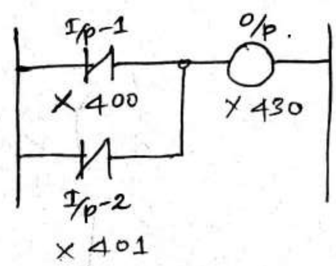



* → NOT 'fn' is also known as "Inverter".
  → NOT gate is Composed of single 'I/p' & a single 'O/p'.
  → The bubble, or circle, at the 'O/p' is the std. symbol used to represent inversion.
  → In NOT gate, there is an O/p, when there is no I/p & no O/p when there is an I/p.

(iv) NAND - function:



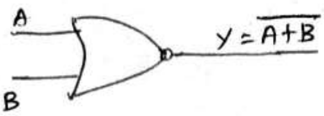



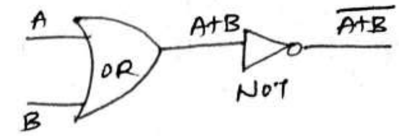

*

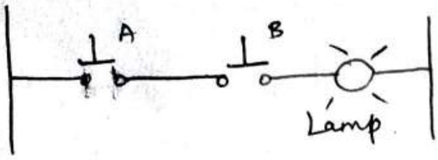
| Step | Instruction | Address | Parameter | Description. |
|---|---|---|---|---|
| 0 | LDI X400 | X400 | I/p | Start a rung with closed contacts. |
| 1 | ORI X401 | X401 | NOR Logic | Add a closed contact in $\|^{el}$. |
| 2 | OUT Y430 | Y430 | O/p | Terminate the rung. |

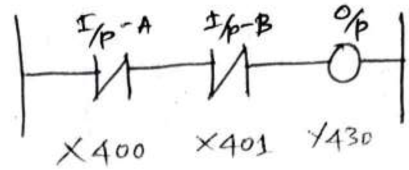
* → NAND is a Combination of AND & NOT gates.
  → Arrangement shows AND gate is followed by NOT gate. Hence, it is called NOT AND gate.
  → Both the I/p's 'A' & 'B' have to be at Low State to get the O/p at HIGH State.
  → NAND gate is Composed of two (or) more I/p with a single O/p.
  → Any one I/p is in Low state also O/p will be HIGH state.

(V) NOR - function:




| * Step | Instruction | Address | Parameter | Description. |
|---|---|---|---|---|
| 0 | LDI X400 | X400 | I/p | Start a rung with closed contacts. |
| 1 | ANI X401 | X401 | NAND Logic | Add a closed contact in series. |
| 2 | OUT Y430 | Y430 | O/p | Terminate the Rung. |

*
→ NOR is a combination of OR & NOT gates.

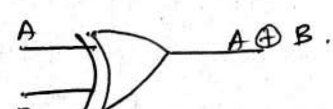
→ Arrangement shows OR gate is followed by NOT gate, Hence it is called NOT OR gate.

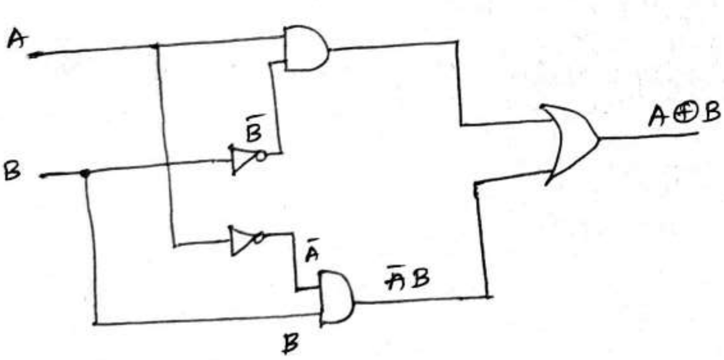
→ Both the I/p's 'A & B' have to be at Low state to get the 'O/p' at HIGH state.

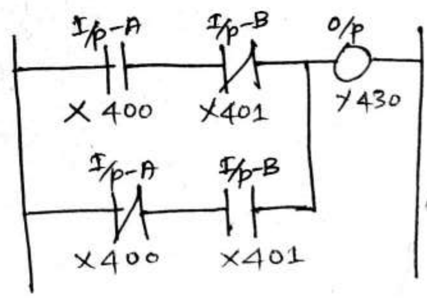
→ NOR Gate is composed of 2 (or) more 'I/p' with a single 'O/p'.

→ Any 1 - I/p is in HIGH state also 'O/p' will be Low state.

(Vi) Exclusive OR (X-OR) - function:-



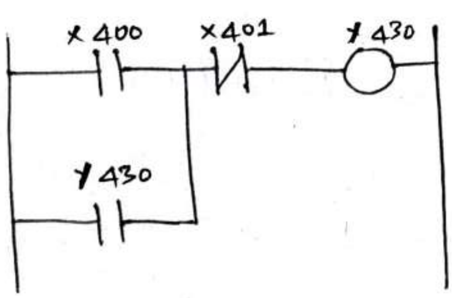

*
→ when both the I/p's are at Low state the 'O/p' will be at Low state

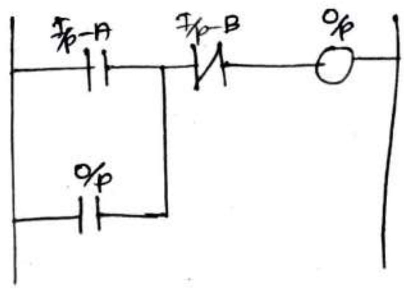
→ when both the I/p's are at HIGH state the 'O/p' will be at Low state

→ when any one 'I/p' is HIGH state the 'O/p' will be at HIGH state.

| * Step | Instruction | Address | Parameter | Description. |
|---|---|---|---|---|
| 0 | LD X400 | X400 | I/p | Start a rung with an open contacts. |
| 1 | ANI X401 | X401 | NAND Logic | Add a closed contact in series with I/p. |
| 2 | LDI X400 | X400 | I/p | Start a new rung with a closed contacts. |
| 3 | AND X401 | X401 | AND Logic | Add a open contact in series with I/p. |
| 4 | ORB | - | - | Do 'OR' operation b/w two sub circuits. |
| 5 | OUT Y430 | Y430 | O/p | Terminate the Rung. |

Latching:




* → It is necessary to hold an O/p coil energised, even when the I/p 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 it's O/p in an energised state until the next 'I/p' is updated.

TIMERS, COUNTERS AND INTERNAL RELAYS:

A) TIMERS:

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

- Types:

  (i) Delay ON Timers (or) ON delay timers.

  (ii) Delay off Timers (or) OFF delay timers.

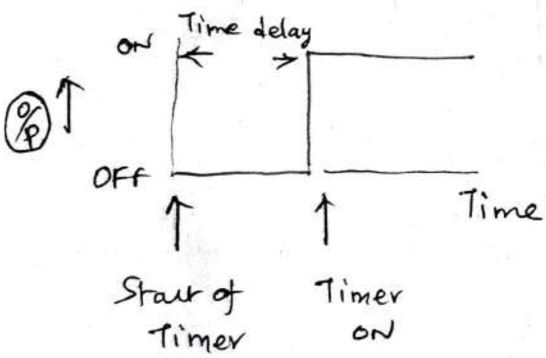
  (iii) Pulse Timers.

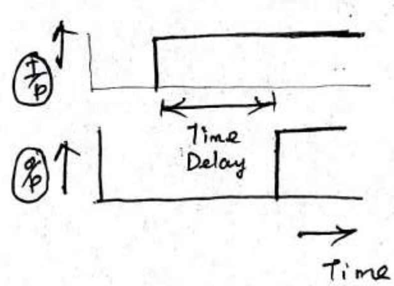
  (iv) cascaded Timers.

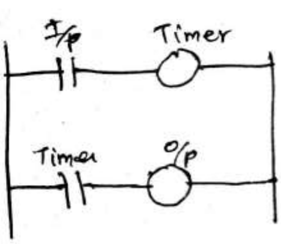
  (v) ON-OFF cycle Timers.

  (vi) One shot Timers.

(i) Delay ON Timers:



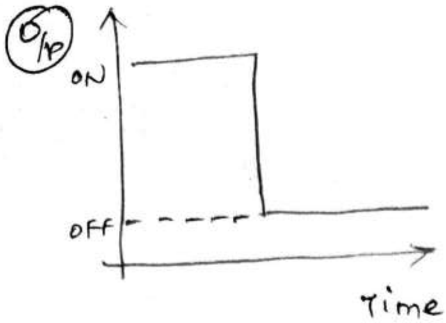



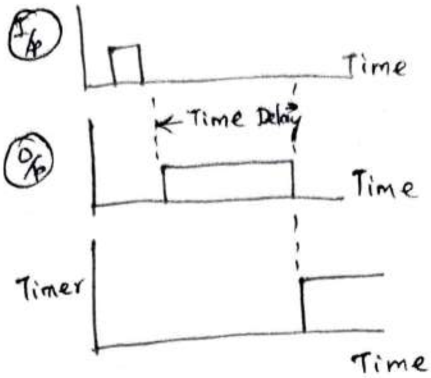

* → The term delay is used to indicate that this timer turns on, after waiting for a fixed time delay period.

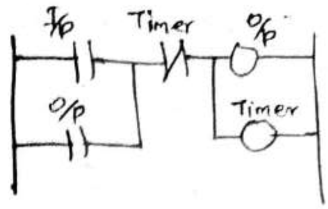
→ When there is an I/p, the timer is energised & starts timing, after some pre-set value the timer contacts are closed to O/p.

→ TON is used to denote ON-delay.
(Time-ON)

(ii) Delay OFF Timers:

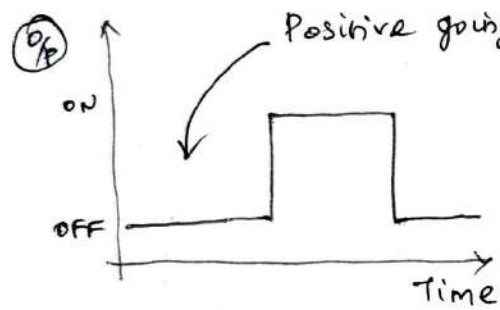


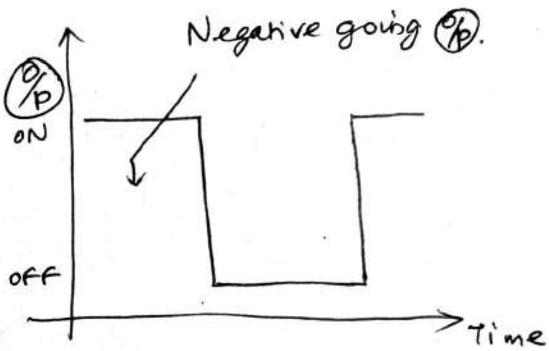




* ✓ OFF delay timers are maintained as ON for a fixed time of delay period before turning-off.
  ✓ TOF is used to denote OFF-delay.

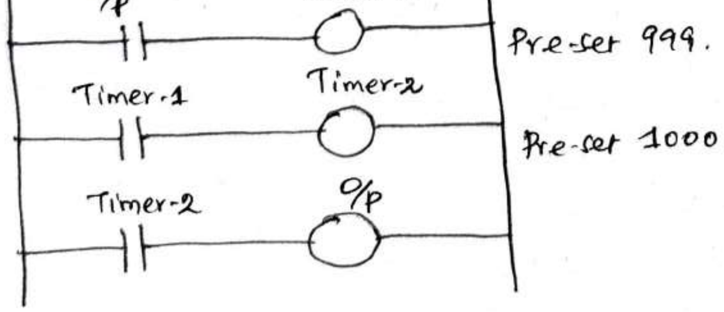
(iii) Pulse Timers:



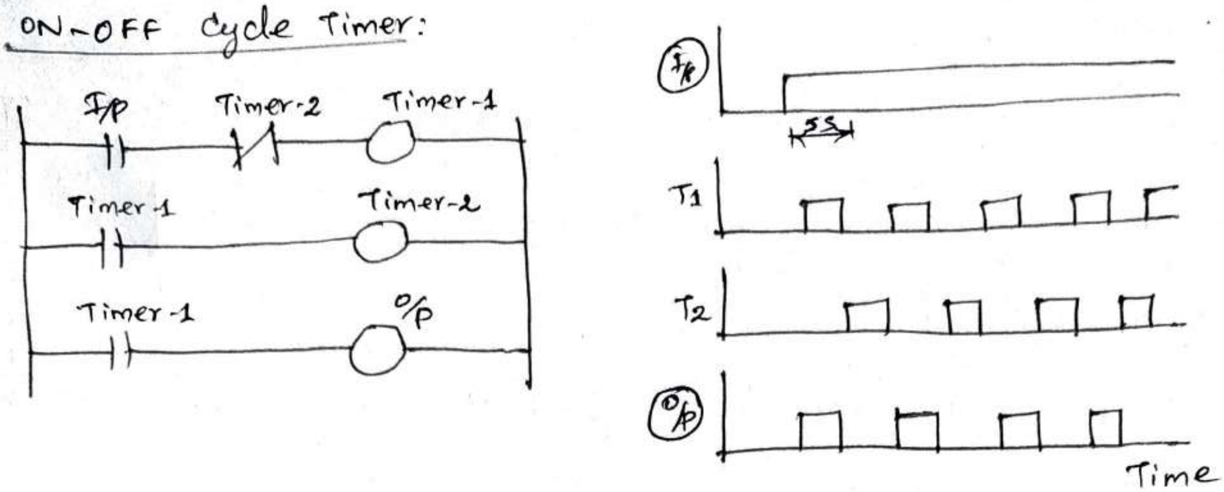




(iv) Cascaded Timers:

* → 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.

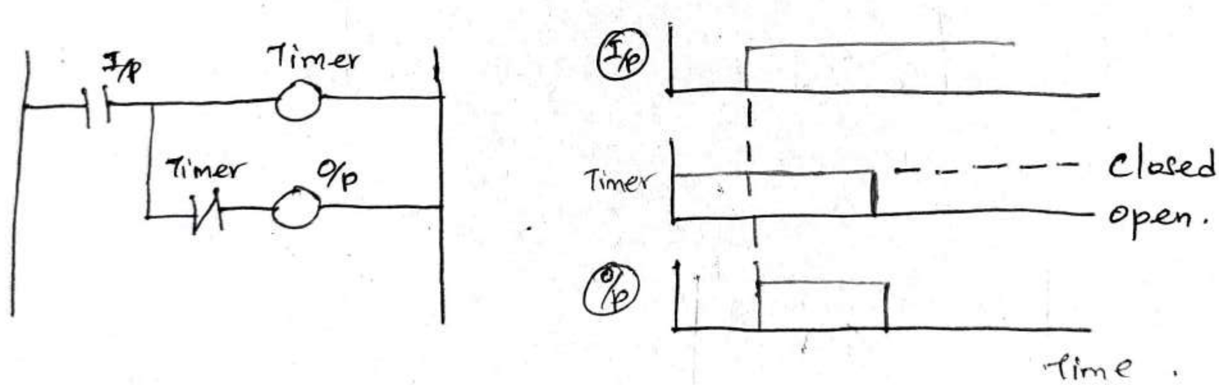


### (V) ON-OFF Cycle Timer:

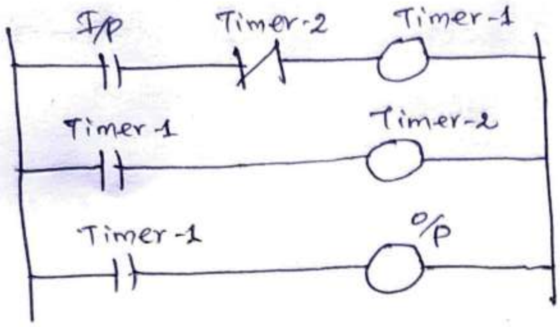


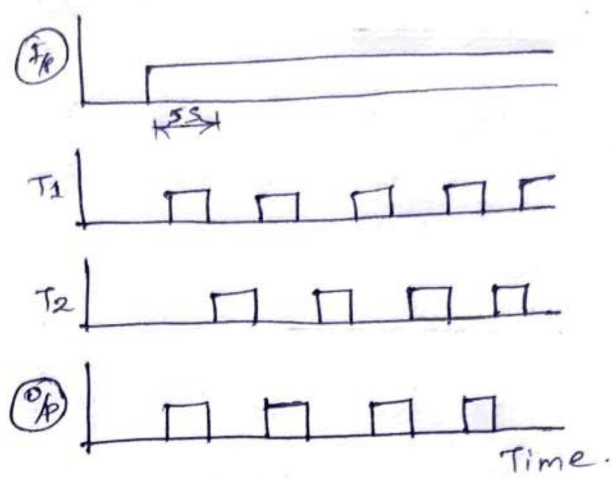

* ✓ Timers producing an O/p for some period & no O/p for some period & an O/p for some period.
* ✓ The timer is designed to switch an 'O/p' for 'T' sec & off for another 'T' sec.

### (vi) One Shot Timers:



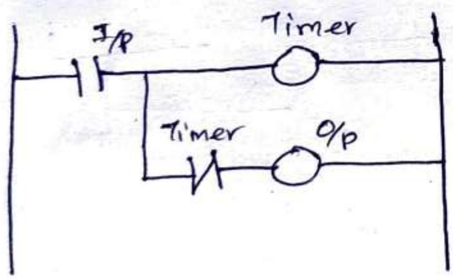
## (V) ON-OFF cycle Timer:

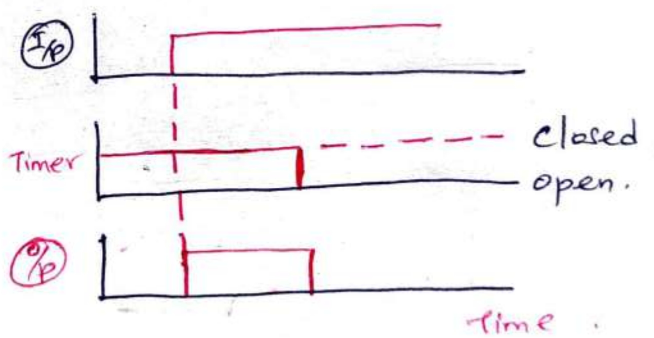


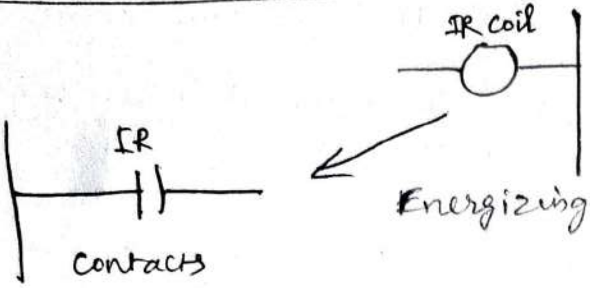

* Timers producing an O/P for some period & no O/P for some period & an O/P for some period.
* The timer is designed to switch an 'O/P' for 'T' sec & off for another 'T' sec.

## (vi) One Shot Timers:



## C) INTERNAL RELAY: (IR).




Energizing the coil activates the contact.

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

✓ IR can be very useful in the implementation of switching sequences.

- They are often used when there are programs with multiple 'I/p' 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 & then its o/p used to operate switching contacts on another rung of a program.

## DATA HANDLING:

→ Data handling instructions enable the PLC's to take on additional characteristics that are beyond the conventional relay equivalent instruction.

→ It allows the movement manipulation (or) storage of data in either single (or) multi-word groups from one data memory area of the PLC to another.

→ The operation that may be carried out with a PLC on data words normally include,

(i) Data movement.

(ii) Data Comparison.

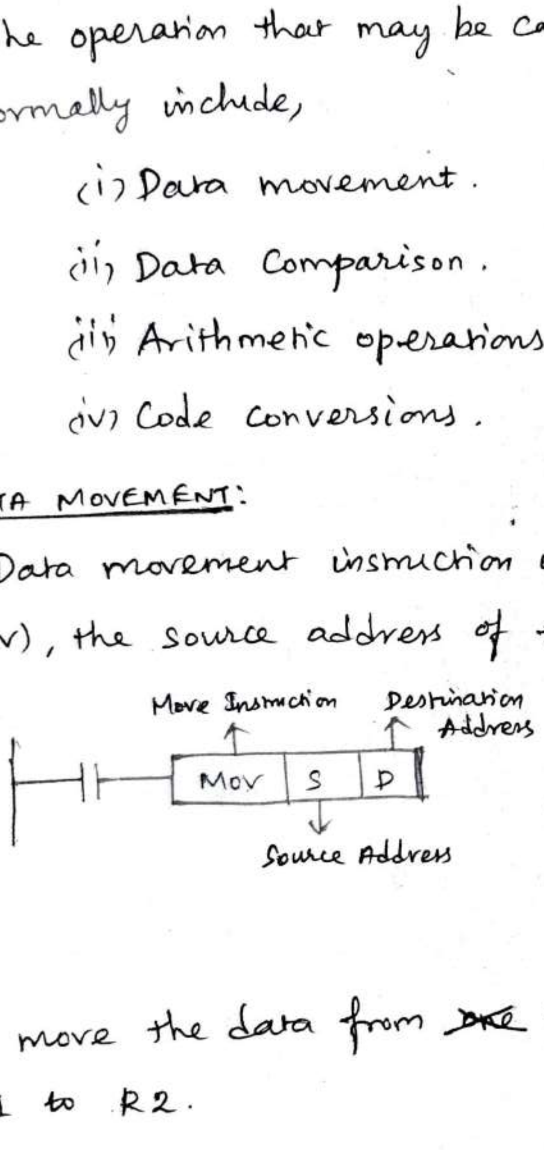
(iii) Arithmetic operations.

(iv) Code conversions.

### (i) DATA MOVEMENT:

Data movement instruction will contain the move data instruction (MOV), the source address of the data & destination address of the data.

Ex:-




| Step | Instruction. |
|---|---|
| 0 | LD X300 |
| 1 | MOV |
| 2 | R1 |
| 3 | R2. |

- To move the data from ~~one~~ Register R1 to R2.

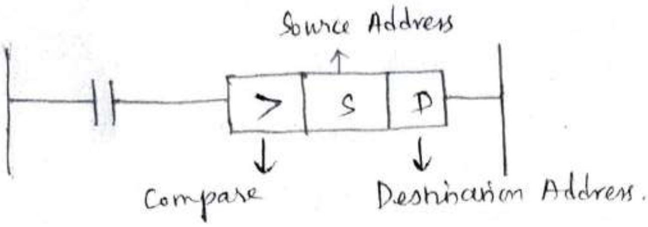
### (ii) DATA COMPARISON:

* Some basic comparisons are,

- Less than < (or) LES.
- Equal to = (or) EQU.
- Less than (or) equal to (≤ (or) <= (or) LEQ)
- Greater than > (or) GRT.
- Greater than (or) equal to (≥ (or) >= (or) GEQ)
- Not equal to (≠ (or) <> (or) NEQ).

* To Compare data, PLC's have separate comparison instruction with the source & destination address of the data.

Ex:- To compare the data in data register R1 to see if it is greater than the data in data register R2.

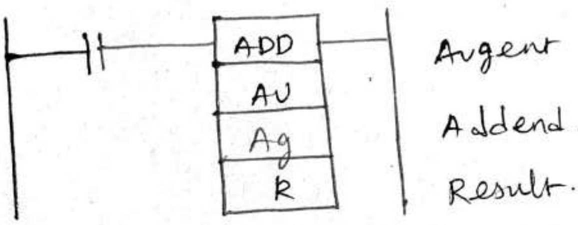



| Step | Instruction. |
|---|---|
| 0 | LD X300 |
| 1 | > |
| 2 | R1 |
| 3 | R2. |

(iii) ARITHMETIC OPERATIONS:

* Generally, addition (or) subtraction might be used to after the value of some sensor I/p-value, perhaps a correction (or) off-set term, or after the preset values of timers (or) counters.

Ex:- Add Data.



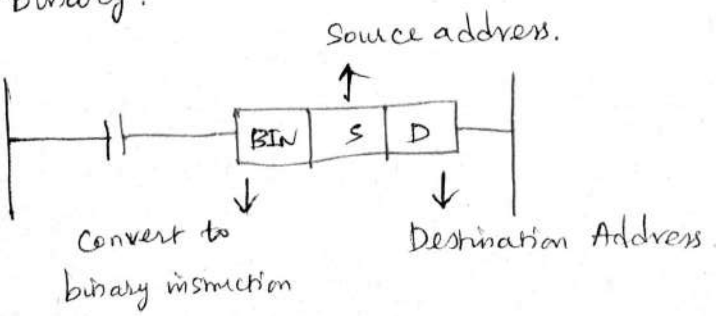

(iv) CODE CONVERSIONS:

→ All the internal operations in the CPU of PLC's are carried-out using binary numbers. Thus the I/p is a signal which is decimal; the processor converts the decimal to binary coded decimal (BCD).

→ Likewise, where the decimal 'O/p' is required, the conversion from binary to decimal is required. Such conversions are provided with most PLC's.

→ The data at the source address is in BCD & converted to binary & placed at the destination address.

Ex:- BCD to binary.



## SELECTION OF PLC:

(i) System Definition:

✓A technique of functional de-composition can be applied to define the whole sys., with hardware & software, as it is defining the program alone.

(ii) Choosing the I/O hardware:

- Various types of I/O modules are available, based on the type & speed of operation.
- A list of modules & the size of the PLC sys. are determined by knowing the member of any type of I/O line we need, & the no. of the lines available on a given module.

(iii) I/O timing consideration:

✓It is most important to determine how fast (speed of operation) the Sub-sys. of I/P program & O/P must react to changing I/P conditions.

- Normally, the speed of operation will be the sum of the 'I/P' hardware delays, plus the PLC Scan time plus any O/P hardware delays.

(iv) Analog I/O Module:

There are many terms used to set out to select analog modules for describing performance. They are as follows:

→ Resolution.
→ Isolation.
→ Voltage level.
→ current level. (I/O Module).

(v) Conversion Speed:

✓The choice of conversion speed basically depends on the No. of readings/sec., we need to capture.

(vi) Analog closed control:

✓ Analog I/p's sometimes are used as feedback to control a process by controlling relay o/p's (or) varying an analog o/p.

✓ In such case, scan speed must be estimated from the program size taking into account the execution speed of the controller module.

(vii) Counters, encoders & Positioning:

In order to select the PLC hardware, we need to consider,

a) the speed.

b) the total no. of pulses to be counted.

c) the positioning accuracy.

(viii) Communications:

✓ ~~All PLC's have some sort~~ of built in communications facility through the programmer port.

(ix) Choosing the correct processor:

✓ A PLC processor is selected based on,

→ Capacity,

→ functionality,

→ program speed &

→ size.

(x) Selecting Suppliers:

The choice of supplier for a PLC is based on the following,

→ Functionality & features.

→ Customer support.

→ customer acceptability.

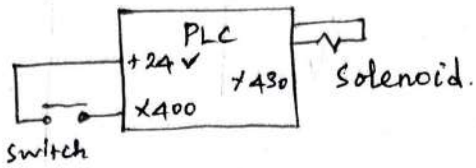
→ User knowledge. &

→ cost.

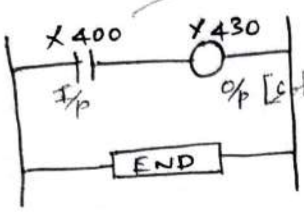
## PROBLEMS:

### I. LADDER DIAGRAM:

1. To illustrate the drawing of a ladder diagram, consider a situation where the 'o/p' from the PLC is to energize a solenoid when a normally open start switch connected to the 'I/p' is activated by being closed.

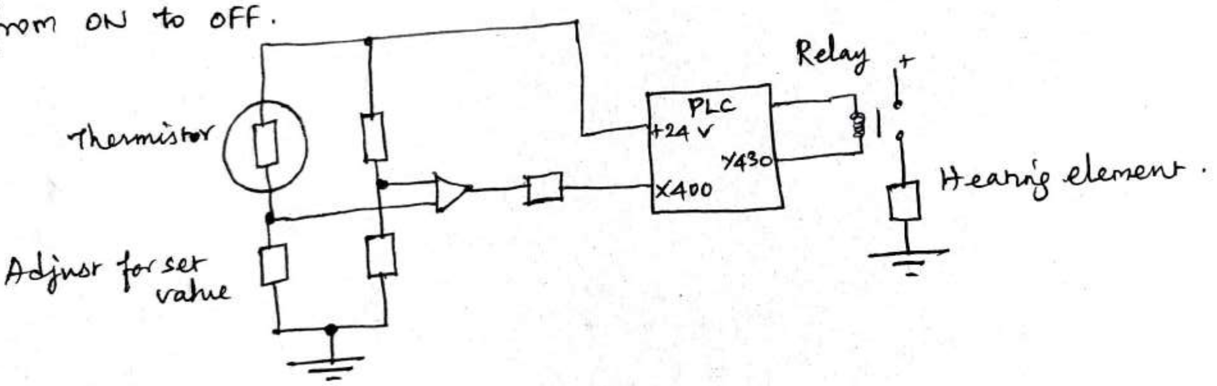



Solution:

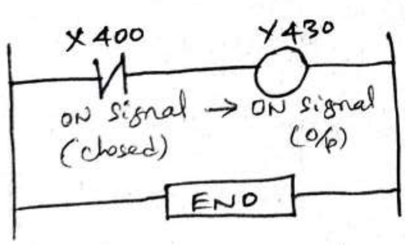



, when switch is closed - solenoid is activated.

2. Consider ~~ON-OFF~~ temperature control in which the I/p goes from low to high when the temperature sensor reaches the set temperature, then the 'o/p' goes from ON to OFF.




Solution:



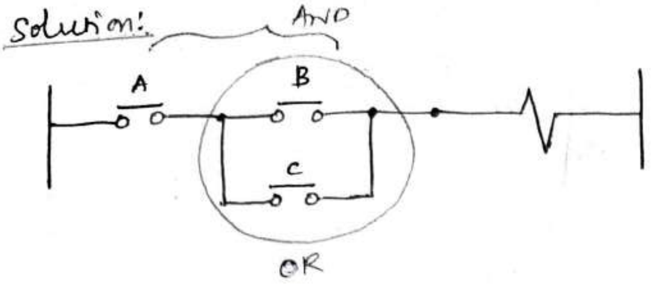

(opend) → OFF signal → 'o/p' → OFF signal.

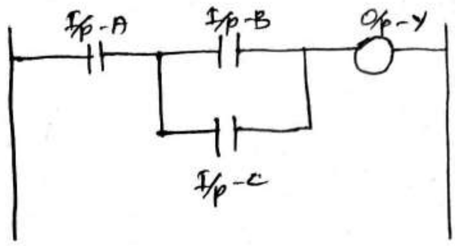
3. Consider a situation.

(i) Where a normally open switch 'A' must be activated & either of two other, normally open.

(ii) Switches 'B' & 'C' must be activated for a coil to be energized.

Solution:



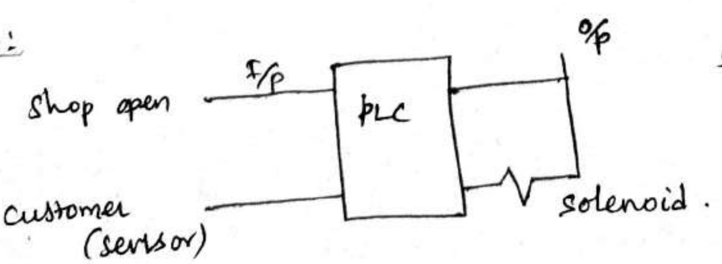




* Truth Table:

| I/p's | | | O/p. |
|---|---|---|---|
| A | B | C | Y |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

4. Consider the requirement for there to be an 'O/p' to the solenoid controlling the valve that will open a shop door when the shop-keeper has closed a switch to open shop & a customer approaches the door & is detected by a sensor which then gives a high signal.

Solution:



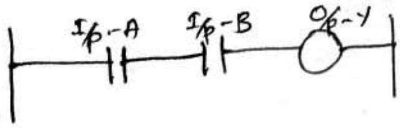

* Truth Table:

| shop open | Customer approaching | Solenoid. |
|---|---|---|
| Switch | sensor | O/p |
| OFF | OFF | OFF |
| OFF | ON | OFF |
| ON | OFF | OFF |
| ON | ON | ON |

ie.,

| I/p - A | I/p - B | O/p - Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

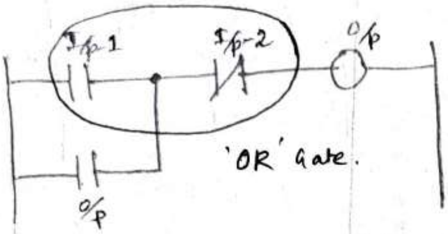
'AND' Gate Truth Table.




LATCHING:

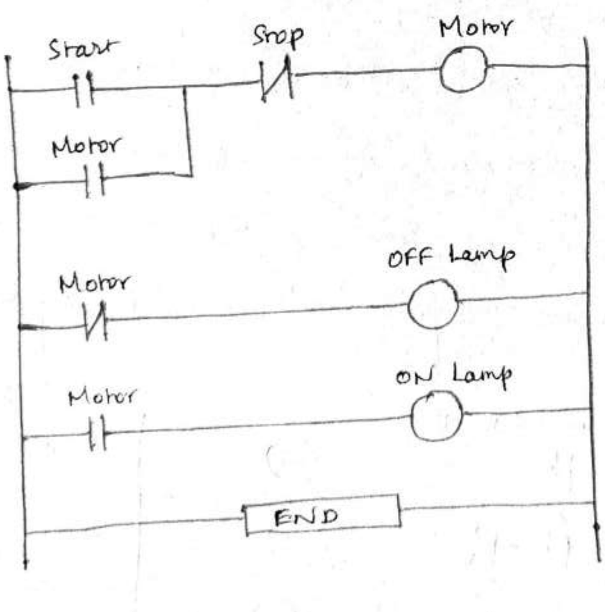
5. Consider a latch circuit, when input energized & closes, there is an O/p. However, when there is an 'O/p', a set of contacts associated with the 'O/p' is energized & closes.

Solution:




6. Consider the requirement for a PLC to control a Motor so that when the start signal button is momentarily pressed the motor starts & when the stop watch is used the motor switches OFF, signal lamps indicating when the motor is OFF & when ON.

Solution:

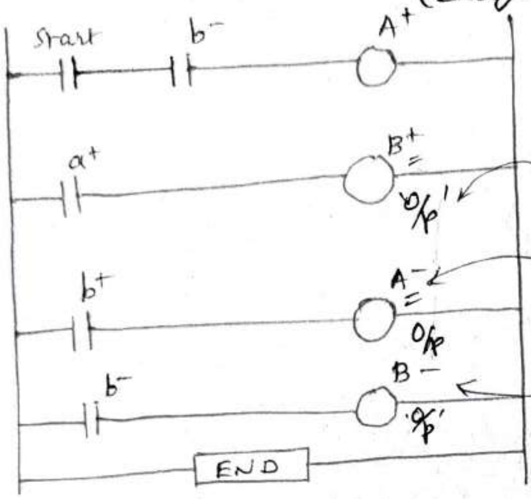


SEQUENCING:

7. Consider the requirement for a Ladder program for a pneumatic system with double solenoid valves controlling two double acting cylinders 'A' & 'B' if limit switches $a^-$, $a^+$, $b^-$, $b^+$ are used to detect the limits of the piston rod movements in the cylinders & the cylinder activation sequence $A^+$, $B^+$, $A^-$, $B^-$ is required.

Solution:

(Energized) 'A' - Extension.




'B' - Retracted.

'A' - extended; $a^+$ (switch) (Activated)

'B' - Extending, thus $b^+$ (switch)

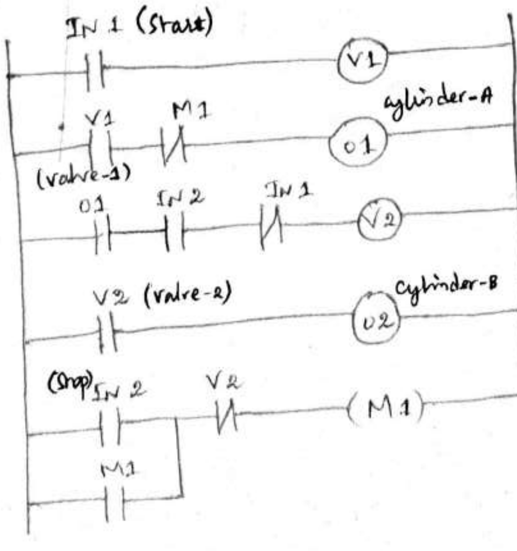
'A' - Retraction, $a^-$ (switch).

'B' - Retracting.

This concludes the program cycle & leads to the first rung again, which awaits the closure of the start switch before being repeated.

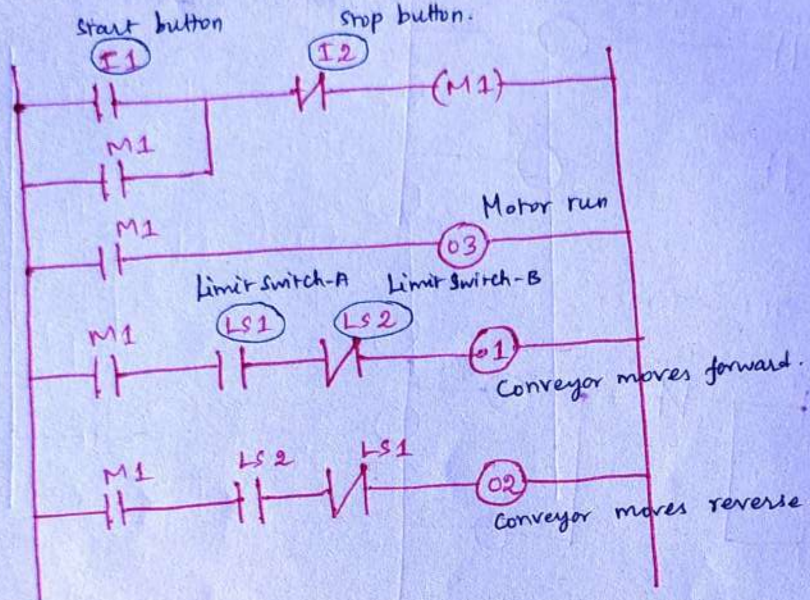
8. Create a ladder diagram for the following application: A pneumatic system with double solenoid valves controls two double acting cylinders 'A' & 'B'. The sequence of cylinder operations are as follows: cylinder 'A' extends followed by cylinder 'B' extending, then the cylinder 'B' retracts & finally the cycle is completed by the cylinder 'A' retracting. Explain the logic of the PLC circuit used.

Solution:



9. A work piece is loaded on a conveyor belt & operates b/w two limits of travel 'A' & 'B'. When limit switch at station 'A' activated, the conveyor moves forward. When limit switch at station 'B' is activated, the conveyor changes direction. Pressing the start button causes the motor to run in the forward direction, & pressing the stop button the motor. Create a ladder logic diagram & explain.

Solution:

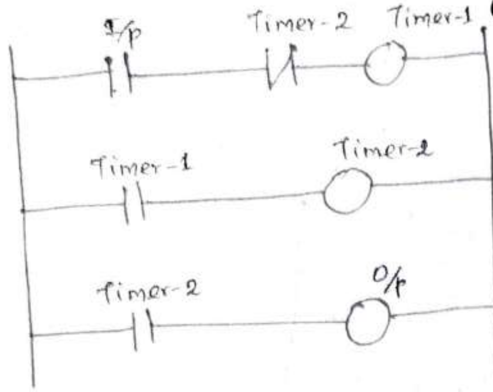


## TIMERS:

10. Consider a Timer circuit that can be programmed to cause an 'o/p' to go ON for 0.5 s, then OFF for 0.5 s, then off for 0.5 s, & so on.

Solution:

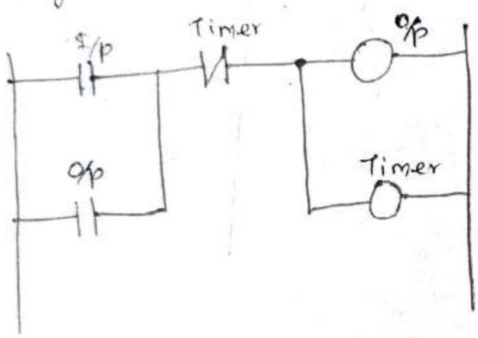
"ON-OFF cyclic Timer"



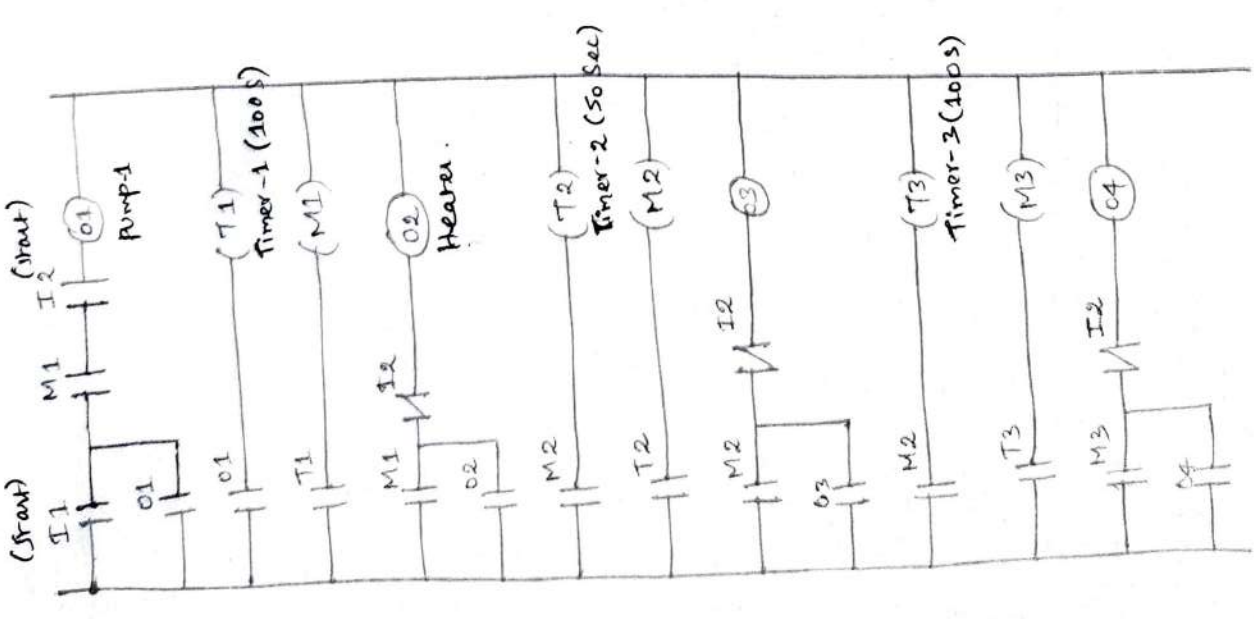

ON for (0.5 s, then OFF for 0.5 s, ON for 0.5 s)

(ON for 0.5 s, OFF for 0.5 s, ON for 0.5 s)

"Delay-OFF Timer"



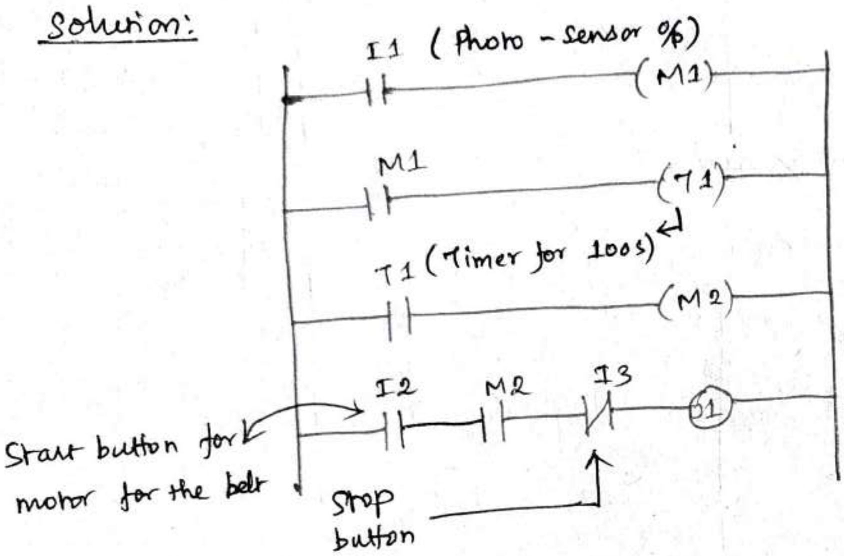

11. Device a circuit that could be used with a domestic washing m/c to switch on pump water for 100 s into the m/c, then switches off & switch on a heater for 50 s to heat the water. The heater is then switched off & another pump is to empty the water from the m/c for 100 s.




M1, M2, M3 — Memory coil.

12. Device a circuit that could be used with a conveyor belt, which is used to move an item to a workstation. The presence of item at the workstation is detected by means of breaking a contact activated by a beam of light to a photo sensor. There, it stops for 100 sec. for an operation to be carried out before moving on & off the conveyor. The motor for the belt is started by a normally open start switch & stopped by a normally closed switch.

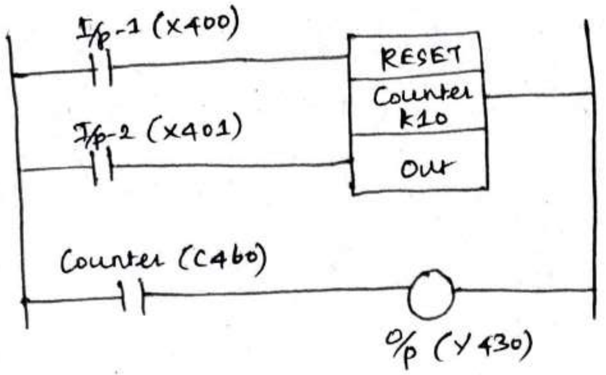
Solution:




$M_1, M_2$ - Memory coil.

## COUNTERS:

13. Consider a basic counting program.

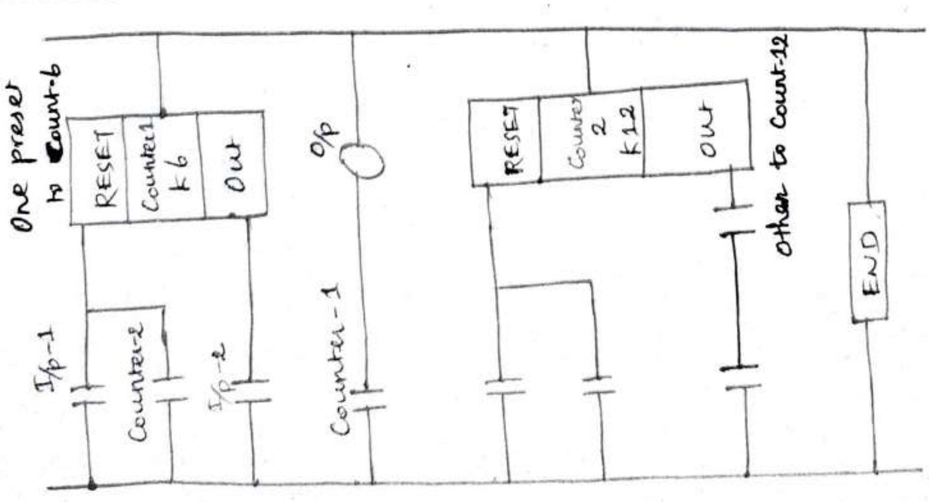



Solution:

| Step | Instruction. |
|---|---|
| 0 | LD ~~X~~400 |
| 1 | RST C460 |
| 2 | LD X401 |
| 3 | OUT C460 |
| 4 | K10 |
| 5 | LD C460 |
| 6 | OUT Y430 |

14. Consider the problem of the control for a 'm/c' which is required to direct 6 items along one path for packaging in a box, & then 12 items along another path for packaging in another box.

Solution:

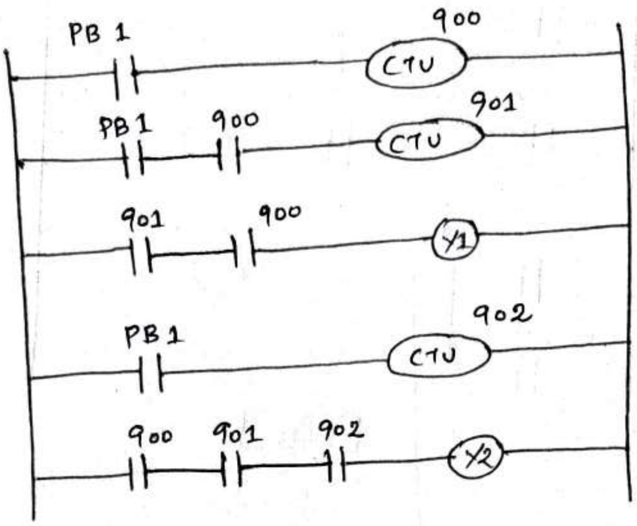


15. Study the ladder logic program in below fig. & answer the following questions.

(i) What type of counter has been used to program?

(ii) When would o/p Y1 be energized?

(iii) When would o/p Y2 be energized?




solution:

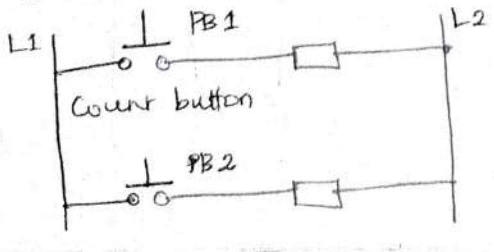
(i) The type of counter used is UP counter (CTU), the accumulated value in the UP counter (CTU) 'o/p' instruction will increment by one each time, there is a (0−1) transition of the 'I/p' logic.

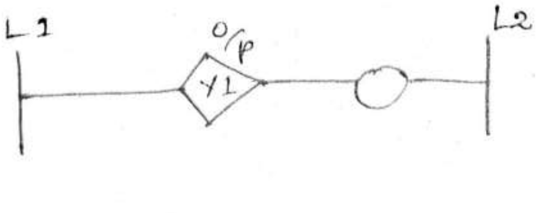
✓ A typical control application for a counter is to turn a device ON (or) OFF after a certain count is reached, since up counters increment their accumulated value only when the up counter logic I/p makes (0−1) transition.

✓ The rung condition must go from true to false & the back to true before the next count is registered.

(ii) The 'o/p' 'Y1' can be energized, when 900 & 901 are in start condition & which is in series connection to indicate AND logic.

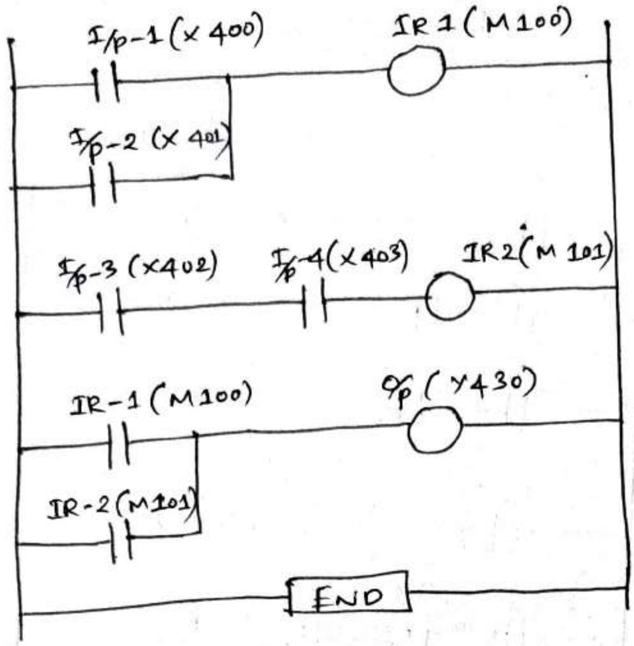
(iii) The 'o/p' 'Y2' is energized, when 900, 901 & 902 are in start condition & which is in series connection to indicate AND gate.



## INTERNAL RELAY (MARKER):

16. Consider the situation where the excitation of an 'O/p' depends on two different 'I/p' arrangements with Internal relays.




Solution:

| Step | Instruction | Comments. |
|---|---|---|
| 0 | LD X400 | Load 'I/p' at address X400. |
| 1 | OR X401 | OR 'I/p' X 400 at address X401. |
| 2 | OT M100 | 'O/p' stored at M1000. |
| 3 | LD X402 | Load 'I/p' at address X 402. |
| 4 | AND X403 | AND 'I/p' X 402 at address X403. |
| 5 | OUT M101 | 'O/p stored at M101. |
| 6 | LD M100 | Load 'I/p' at address M100. |
| 7 | OR M101 | 'OR' I/p M100 at address M101. |
| 8 | OUT Y430 | 'O/p' stored at Y430. |
| 9 | END | END. |

UNIT-V.

ACTUATORS AND MECHATRONICS SYSTEMS DESIGN.

TYPES OF STEPPER & SERVO MOTORS - CONSTRUCTION - WORKING PRINCIPLE - ADVANTAGES & DIS-ADVANTAGES:

A) STEPPER MOTOR:

• Stepper motor is a device that produces rotation through equal angles when digital pulses are supplied as input.

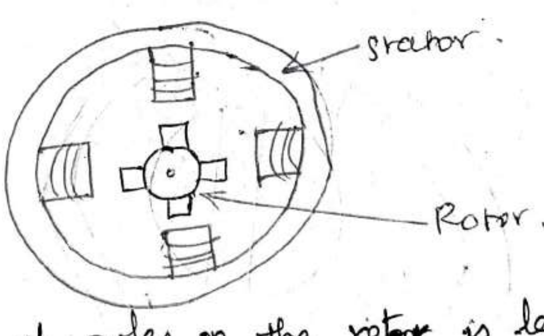
• In other words, the stepper motor transforms the electrical pulses in to equal increments of rotary shaft motion.

• Types:

Stepper Motor.
→ Variable reluctance
→ Permanent magnet
→ Hybrid.

(i) VARIABLE RELUCTANCE - STEPPER MOTOR:

CONSTRUCTION: * The rotor is made up of soft steel & it is cylindrical in shape with four poles.




* Usually the No. of poles on the rotor is less than no. of poles on the stator.

✓ The stator poles have windings & it is switched by means of electronic switching device.

✓ The function of the switching device is to switch the control windings in the stator of stepper motor.

WORKING: * When current is switched to a pair of windings in stator, a magnetic field is produced.

✓ The lines of force pass from stator poles to nearest set of poles on the rotor.

→ Applications:

- High accuracy positioning applications.

Ex: Computer Hard-Disc drives.

→ Advantages:

- These stepper motors combine the features of both variable reluctance & permanent magnet motor.
- Minimum step angle can be achieved.

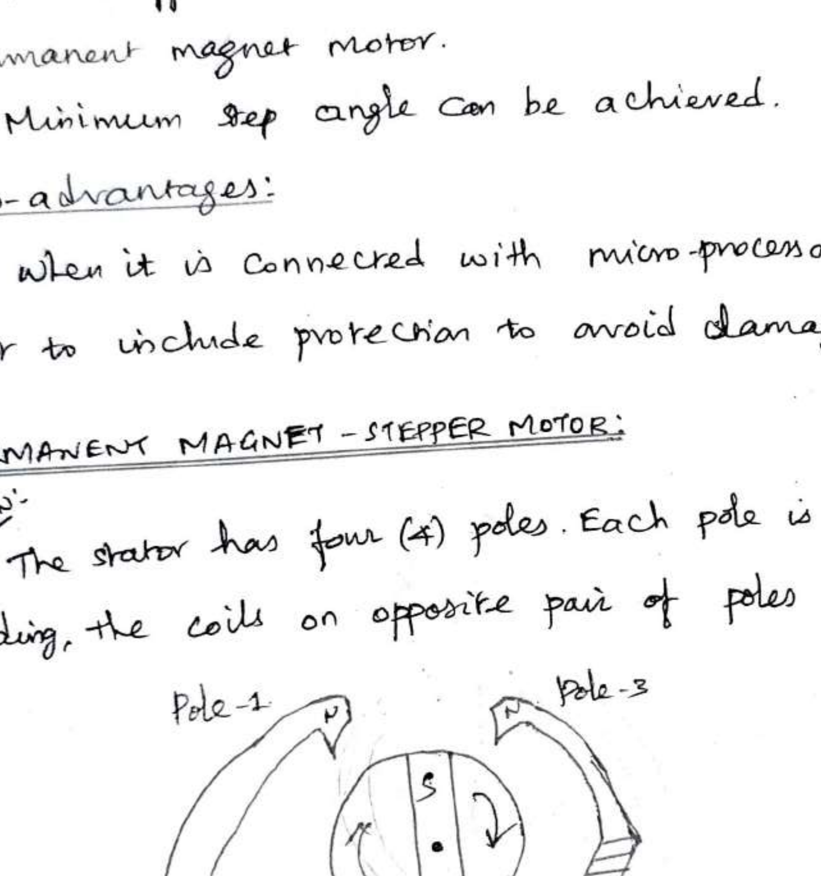
→ Dis-advantages:

- when it is connected with micro-processor output port, it is must to include protection to avoid damage to micro-processor.

(ii) PERMANENT MAGNET - STEPPER MOTOR:

CONSTRUCTION:

* The stator has four (4) poles. Each pole is wound with a field winding, the coils on opposite pair of poles being in series.




* The rotor is a permanent magnet & when current is switched to a pair of stator poles, the rotor will move to line-up with it.

WORKING:

* Thus for the currents given in the rotor moves to 45° position.
* If the current is switched, so that the polarities are reversed, the rotor will move a further 45° in order to line-up again.

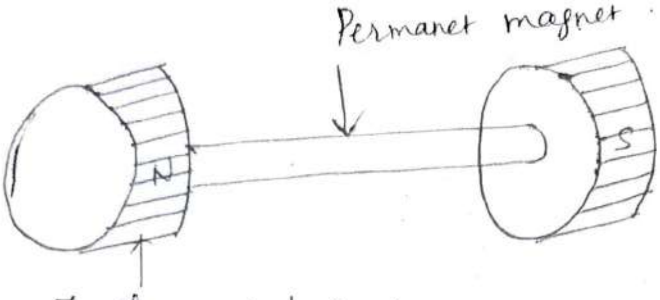
*Thus by switching currents through the coils, the rotor rotates by 45° steps.

* with this type of motor, step angle is 1.8°, 7.5°, 15°, 30°, 34° (or) 90° Can be achieved.

(iii) HYBRID - STEPPER MOTOR:

* It combines the features of both the variable reluctance & Permanent magnet motors.

CONSTRUCTION:




Teeth on end-caps.

* The permanent magnet is encased in Iron Caps which are cut to have teeth.

WORKING:

→ The rotor sets itself in minimum reluctance position if a pair of stator Coils is energised.

* In this stepper motor step angles of 0.9° & 1.8° are achieved.

Applications:

* High accuracy positioning Applications.

Ex:- Computer hard-disc drives.

Advantages:

→ These stepper motors combine the features of both Variable relucatance & permanent magnet motors.

→ Minimum step angle can be achieved.

Dis-Advantages:

→ When it is connected with Micro-processor output port, it is must to include protection to avoid damage to micro-processor.

STEPPER MOTOR SPECIFICATIONS:

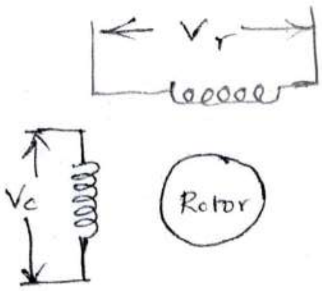
* Phase.
* Step angle.
* Holding torque.
* Pull-in torque.
* Pull-out torque.
* Pull-in rate.
* Pull-out rate.

SERVO-MOTORS:

A) AC - SERVO MOTORS:

* Basically an AC-servomotor is a two phase induction motor.

CONSTRUCTION:




$V_r$ - Reference winding.

$V_c$ - Control winding.

→ It consists of two stator windings namely reference winding & control winding.

→ These two windings are placed at 90° & excited by 'AC' voltage.

→ The reference winding is excited by a fixed voltage, $V_r$ & control winding voltage $V_c$ is 90° phase shifted w.r.to the reference voltage.

→ The rotor is ~~squirrel~~ cage (or) dragcap type having small diameter in-order to reduces the ~~inertia~~. (Inertia.)

WORKING:

→ The two windings are excited by voltage of magnitude & 90° phase shift.

→ It develops a magnetic field of constant magnitude rotating a synchronous speed.

→ The direction of rotation depends upon the phase relationship b/w $V_r$ & $V_c$.

→ The rotating magnetic field interacts with the currents & produces torque in the direction of rotation.

ADVANTAGES:

* Drift free AC amplifier.
* Low rotor inertia.
* Rugged construction.
* Rotor withstand at higher temperature.

DIS-ADVANTAGES:

* More expensive.

* Cannot work at open-loop.

* Required more maintenance.

CONTROL SCHEME FOR AN AC-SERVO-MOTOR:

→ The reference winding is excited by a reference voltage source.

→ The control winding is supplied by a zener amplifier having variable magnitude and polarity.

* Speed can be controlled by varying any one of the following.

→ Flux / pole (flux control)

→ Rheostatic control.

→ Voltage control.

## B) DC SERVO-MOTOR:

→ DC Motors which are used in servo-systems are called "DC-servo motors".

→ In DC servo-motors, field windings may be connected either in series with the armature (or) separate from the armature.

→ This motor provides high starting torque due to low inertia.

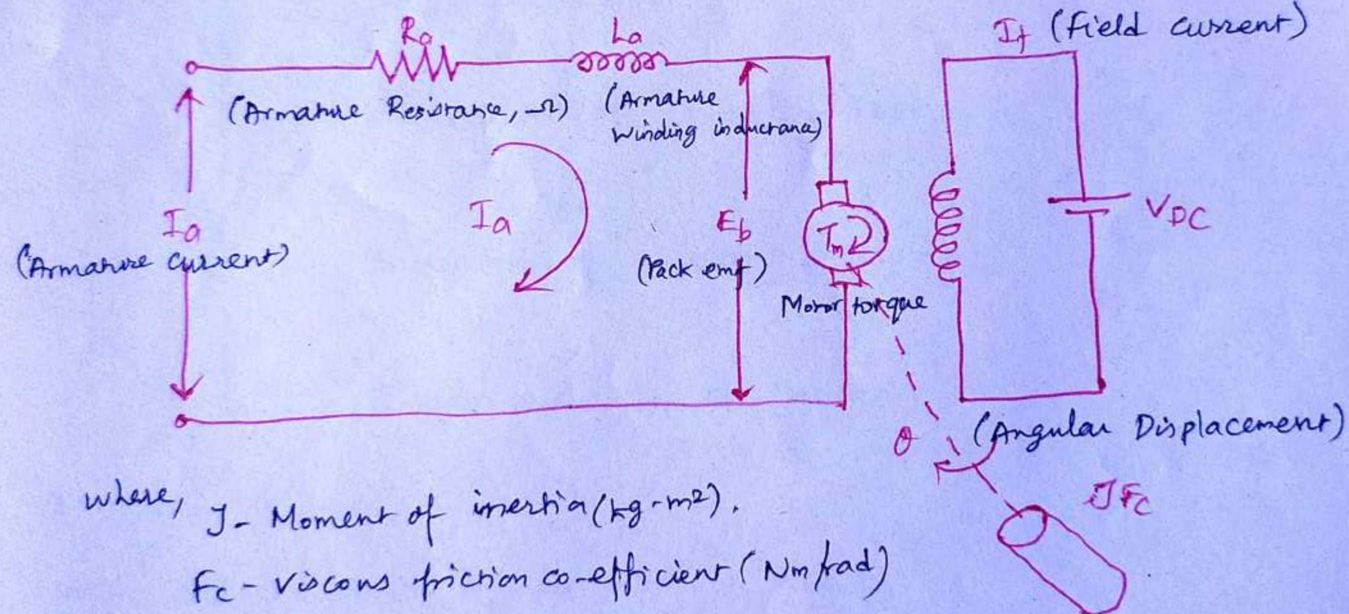
→ This low inertia can be achieved by reducing armature diameter with increasing armature length so that desired o/p power can be achieved.

TWO DIFFERENT CONTROL MODES:

(i) Armature control mode.

(ii) Field control mode.

### (i) Armature control of DC Servo-motor:




where, J - Moment of inertia ($kg\text{-}m^2$).

$F_c$ - viscous friction co-efficient (Nm/rad)

* In which the speed of the DC servo-motor is controlled by armature current with field current constant.

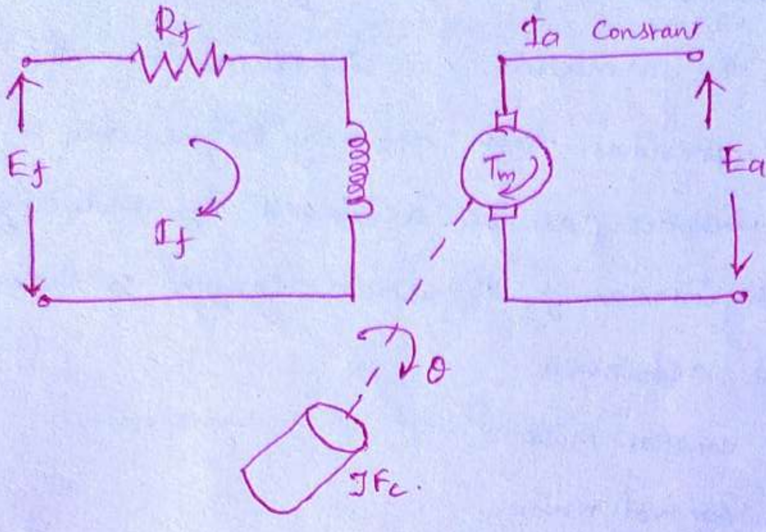
* The flux (ϕ) is proportional to the field current, $I_f$

$$\phi \propto I_f \quad (k_f - \text{constant}).$$

$$\phi = k_f I_f.$$

(ii) Field control of DC Servo-motor:

* In which the armature current is maintained constant & speed of the DC servo-motor is controlled by field voltage.



## DESIGN PROCESS:

The design process of mecharronic sysrem consists of the following srages.

### STAGES IN DESIGNING MECHATRONICS SYSTEM:

Need for Design

↓

Analysis of problem

↓

Preparation of specification.

↓

Generation of Possible solution.

↓

Evaluation.

↓

Production of Derailed Design.

↓

Production of working drawing.

↓

Implementation of Design.

(1) Need for design:

→ The design process begins with a need.

→ Needs are usually arise from dissarifaction with an existing sinarion.

→ Needs may come from inputs of operating of service personal (or) from a customer through sales. (or)

(ii) Analysis of Problem:

* Probably the most critical step in a design process is the analysis of the problem (i.e.,) to find out the true nature of the problem.

* The true problem is not always what it seems to be at the 1st glance.

(iii) Preparation of Specification:

The design must meet the required performance specifications. Therefore, specification of the requirements needs to be prepared 1st. The following are some of the specification.

→ Mass & dimensions of design.

→ Type & range of motion required.

→ Accuracy of the element.

→ I/p & O/p requirements of elements.

→ Operating environments.

(iv) Generation of Possible solution:

This stage is often known as "Conceptualisation stage".

→ The conceptualisation step is to determine the elements, mechanisms, materials, process of configuration that is some combination (or) other result in a design that satisfies the need.

→ This is the key step for employing inventiveness & creativity.

→ A virtual aspect of this step is synthesis.

(v) Selection of suitable solution (or) Evaluation:

→ This stage involves a through analysis of the design.

→ The evaluation stage involves detailed calculation, often computer calculation of the performance of the design by using an analytical model.

(vi) Production of detailed Design:

- The detail of selected design has to be worked-out.
- It might have required the extensive simulated service testing of an experimental model.

(vii) Production of working drawing:

- The finalised drawing must be properly communicated to the person who is going to manufacture.
- The communication may be oral presentation (or) a design report.

(viii) Implementation of Design:

The components per the drawings are manufactured & assembled as a whole system.

## TRADITIONAL DESIGN APPROACH:

Mechanical system

Mechanical linkages, drives, etc.

Hydraulic & Pneumatic Actuators

Electrical Motor, Switches etc.

## MECHATRONICS DESIGN APPROACH:

Mechanical system

Mechanical Linkages, drives etc.

Hydraulic & Pneumatic control.

Electrical Motor, switches, etc.

Electronic components, Computers & IT systems.

- The same sys. can be modified by a mechatronics approach.
- This sys. uses a micro-processor controlled thermo-couple as the sensor. Such a sys. has many advantages over a traditional design.
- The Bi-metallic thermo-stat is less sensitive compared to the thermo-diode. Therefore, the temperature is not accurately controlled.
- Also it is not suitable for having a different temperature at a different time of the day because it is very difficult to achieve.

- But the micro processor controlled thermo-diode sys. can overcome that difficulties & is giving precision & programmed control.
- This sys. is much more flexible..
- This improvement in flexibility is a common characteristic of the mechatronics system when compared with a traditional system.

CASE STUDIES OF MECHATRONICS SYS. – PICK AND PLACE ROBOT – ENGINE MANAGEMENT SYSTEM – AUTOMATIC CAR PARK BARRIER.

A) PICK AND PLACE ROBOT:

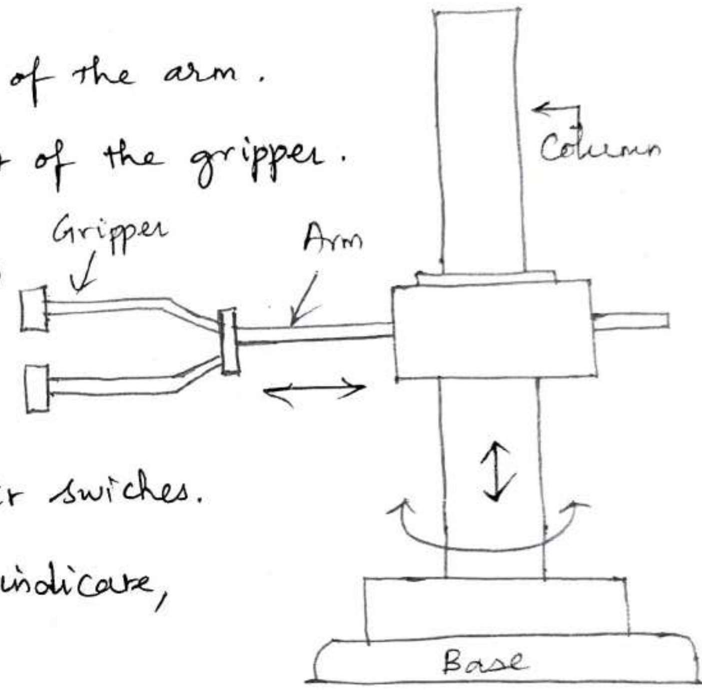
The pick & Place Robot has three axes about which can occurs. The following movements are required for this robot.

(i) Clock-wise & Anti-clock-wise rotation of the robot unit on its base.

(ii) Linear movement of the arm horizontally (i.e.,) extension (or) Contraction of arm.

(iii) Up & down movement of the arm.

(iv) Open & close movement of the gripper.

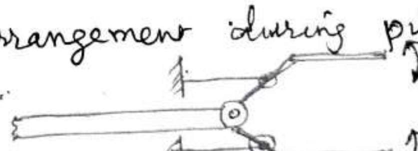



→* The forward movements can be obtained by pneumatic cylinders which are operated by solenoid valves with limit swiches.

* Limit switches are used to indicate, when a motion is completed.

→* The clock-wise rotation of the robot unit on its base can be obtained from a piston & cylinder arrangement during pistons forward movement.

*GRIPPER MECHANISM.



* IIIly counter clock-wise rotation can be obtained during backward movement of the piston in cylinder.

→* The upward movement of the arm can result from forward movement of the piston in a cylinder, whereas downward movement from its retardation.

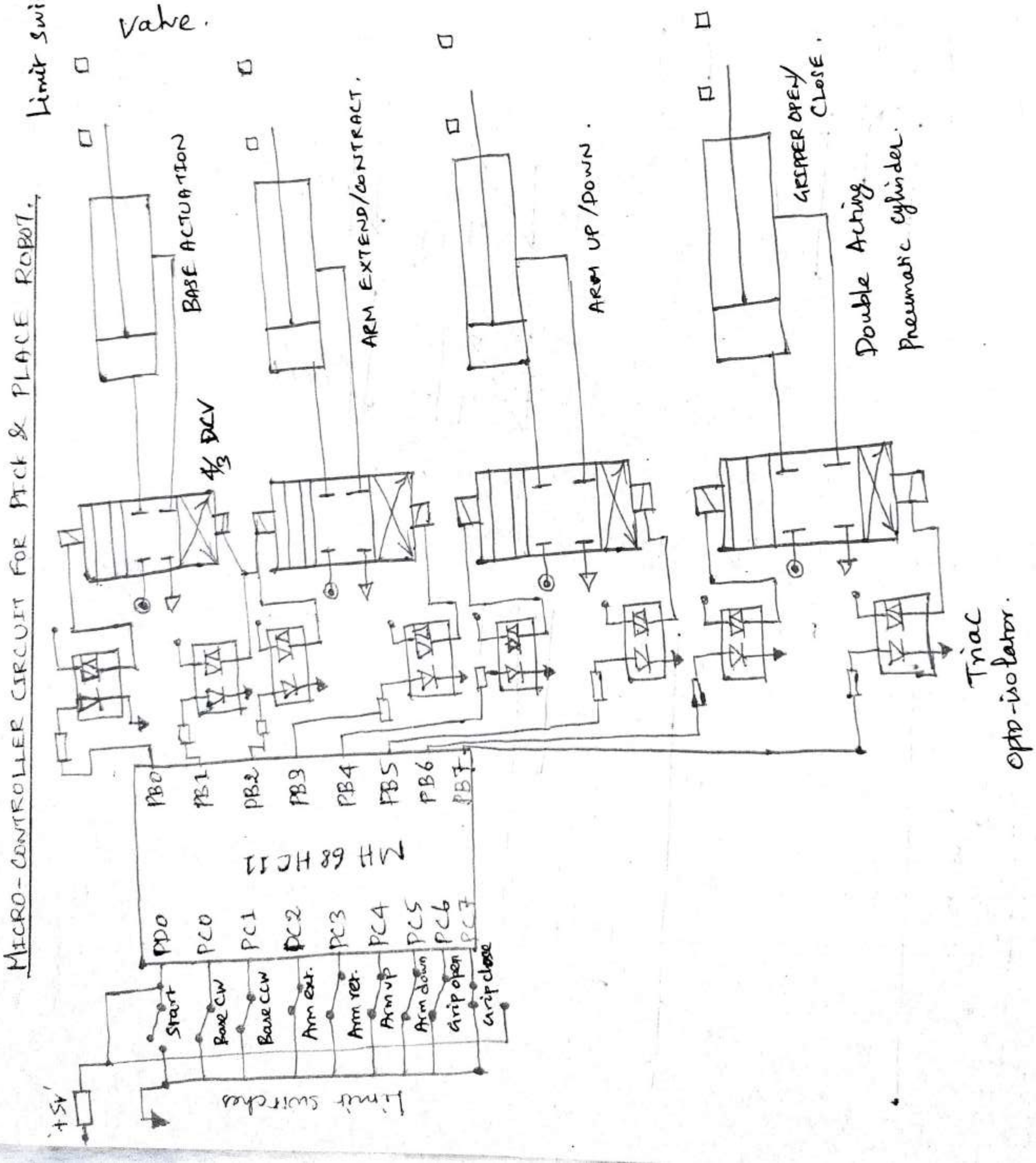
→* The gripper can also be operated in a similar way (i.e.,) gripper is opened during forward movement of the piston & closed during backward movement of the piston in the cylinder.

→ * A micro-controller used to control the solenoid valves of various cylinders.

* the micro-controller used of this purpose is M68HC11 type.
* A software program is used to control the robot.

→ * TRIAC opto-isolator consists of LED & TRIAC.

* If the 'I/p' of the LED is 1, it glows & activates the TRIAC to conduct the current to the solenoid valve.
* Otherwise, TRIAC will not conduct the current to the solenoid valve.



B) AUTOMATIC CAR PARK BARRIER:

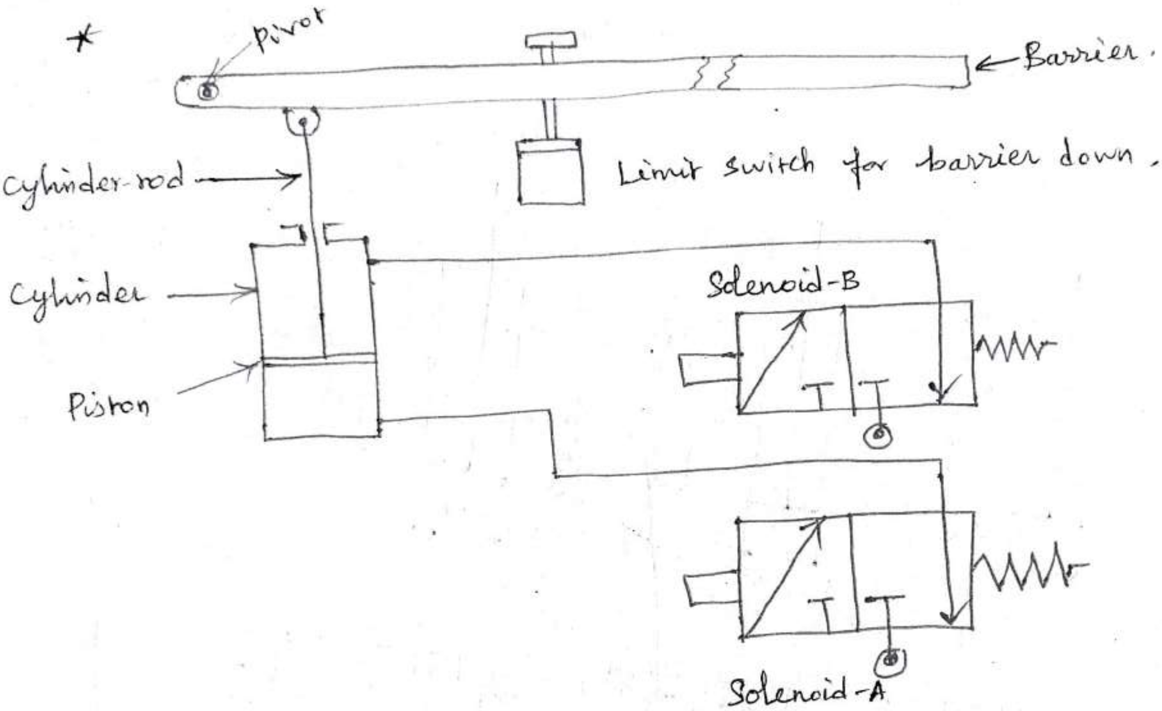
→ ✓ Consider an automatic car park barriers operated by coin inserts.

✓ The sys. uses a PLC for its operation. There are two barriers used named in - barrier & out - barrier.

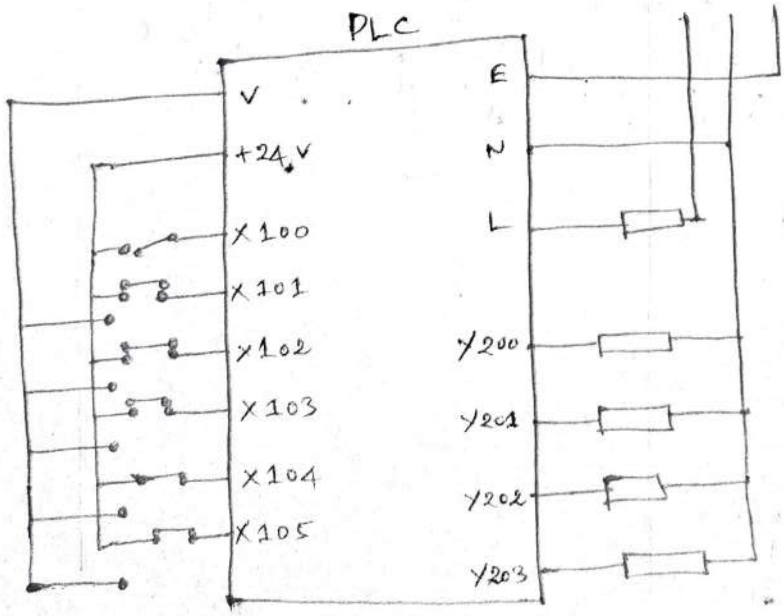
→ ✓ In barrier is used to open, when the correct money is inserted while out barrier opens when a car is detected in - front of it.

→ It consists of a barrier which pivoted at one end, two solenoid valves 'A' & 'B' & a piston cylinder arrangement.

*




* PLC Arrangement for operating barrier:



From, Fig. 2.

→ X-100 → Coin operated switch at entrance to car barrier.

X-101 → Switch activated, when entrance barrier up.

X-102 → Switch activated, when entrance barrier down.

X-103 → Switch activated, when car at exit barrier.

X-104 → Switch activated, when car at exit barrier up.

X-105 → Switch activated, when car at exit barrier down.

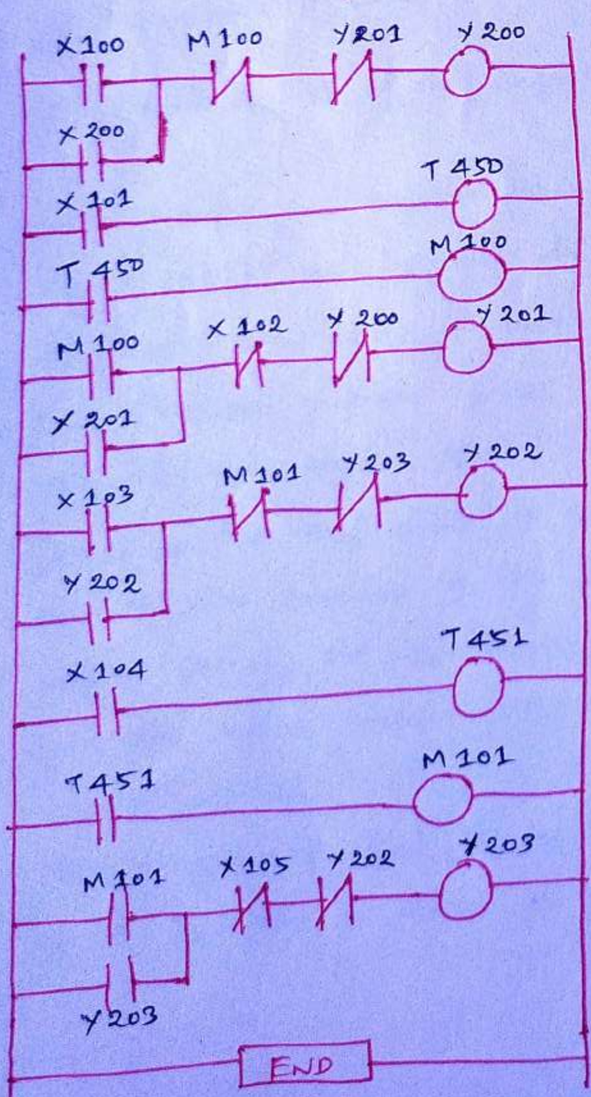
→ Y-200 → Solenoid valve 'A' for entrance barrier.

Y-201 → Solenoid valve 'B' for entrance barrier.

Y-202 → Solenoid valve 'A' for exit barrier.

Y-203 → Solenoid valve 'B' for exit barrier.

* Ladder program for PLC system:



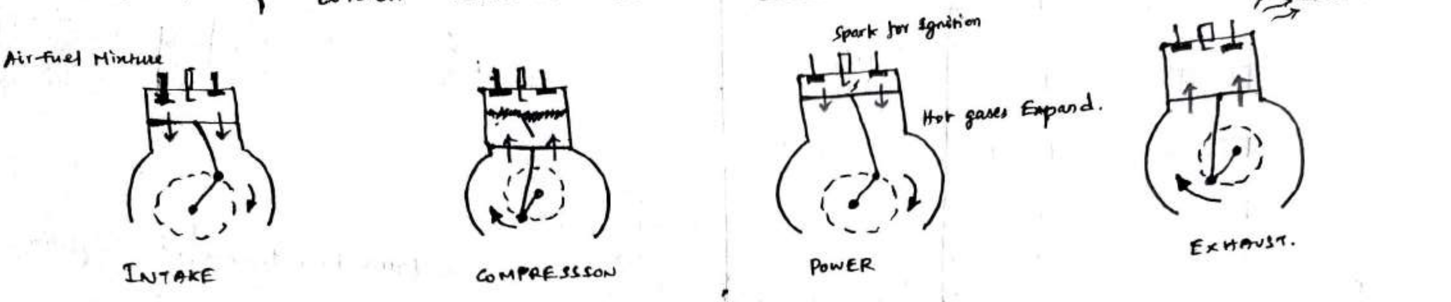

*M100 - Energised.

M101 - Energised.

B). ENGINE MANAGEMENT SYS.

- The engine Mng. sys of a car is responsible for managing the ignition & Fuelling req. of the engine.

Note: - With a 4-stroke I.C. Engine there are several cylinders, each of which has a piston connected to a common crankshaft & each of which carries out a 4-stroke sequence of op's.

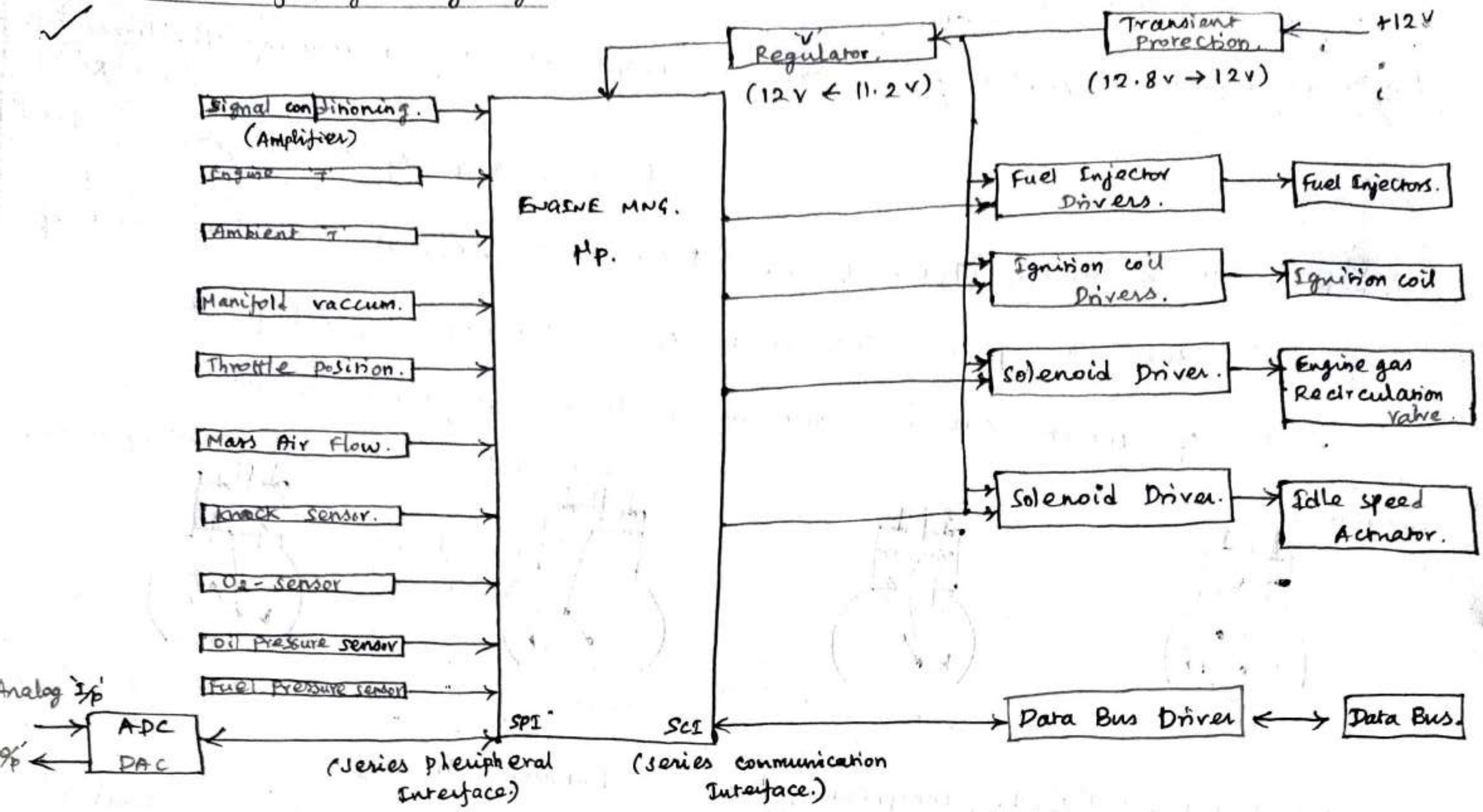



- Explaination: [Intake, compression, Power & Exhaust strokes.]
- The piston of each cyl. are connected to a common crankshaft & their power strokes occur at different 't', so that there is continuous power for rotating the crank-shaft.

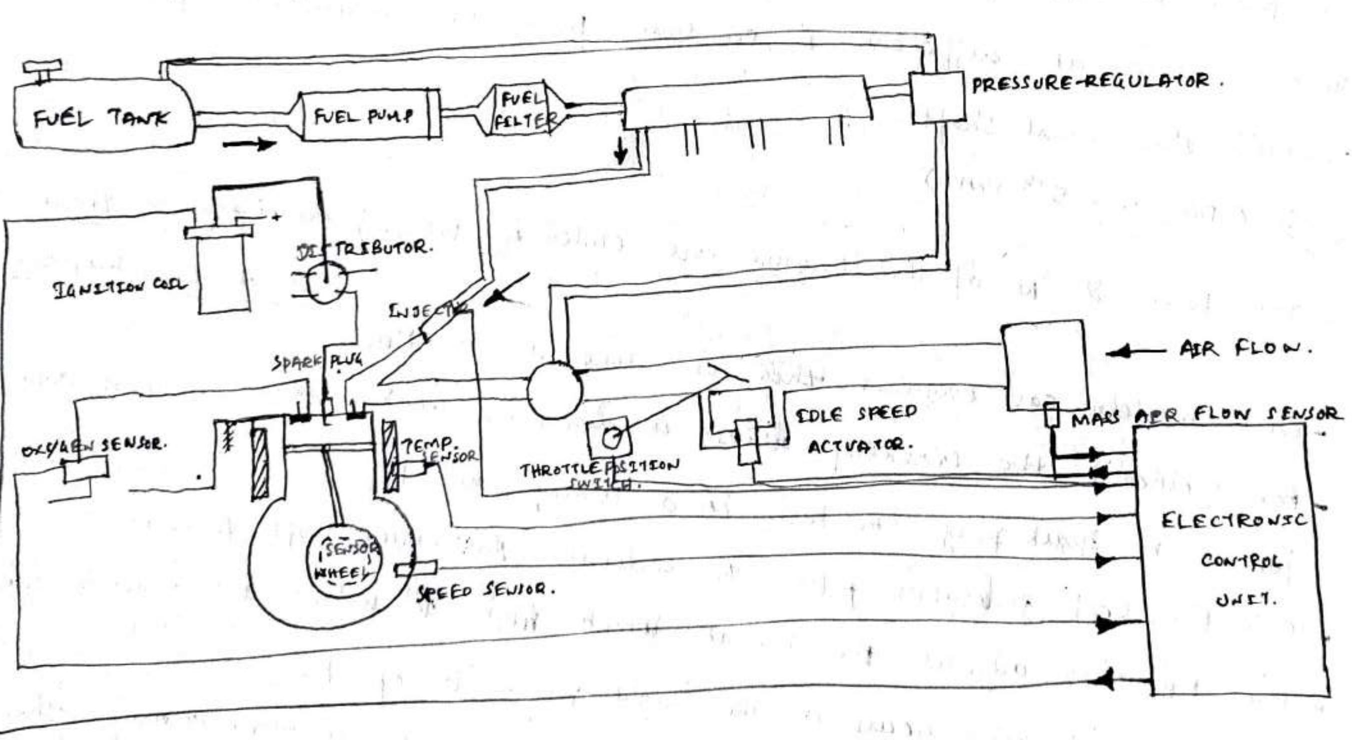
Mechatronic sys. ( Diagram - 5th UNIT.)

- The power & 'N' of the engine are ctrlled by varying the ignition timing & the Air-Fuel mixture.
- With modern car engines this is done by a Mp.
- For Ignition 't', the crankshaft drives a distributor which makes electrical contacts for each spark plug in turn & a timing wheel.
- This 't'-wheel generates pulses to indicate the crank-shaft position.
- The Mp then adjusts the 't'- at which high 'v' pulses are sent to the distributor so they occur at the 'right' moments of 't'.
- To ctrl the amount of Air-Fuel mixture entering a cyl. during the intake strokes, the Mp- varies the 't' for which a solenoid is activated to open the intake valve on the basis of I/p's received of the Engine-'T' & throttle position.
- The amount of fuel to be injected into the air stream can be det. by an I/p from a sensor of the mass Rate of Air-Flow, (or) computed from other measurements, & the Mp then gives an 'O/p' to ctrl a fuel injection valve.

◉ Elements of Engine-Mng- sys.




◉ An Engine Mng. Sys.




2

MECHATRONICS

- DEFINITION:

- Integration of
  - $\mu p$ - Ctrl sys,
  - Electrical sys, &
  - Mech. sys.

NOTE:

- Mechatronics has to involve a con-current approach to these following disciplines like as,
  - Mech.
  - Electrical.
  - Electronics &
  - Ctrl Engg.

rather than a sequential approach of developing, say, a Mech. sys then designing the electrical part & Micro-processor Part.

- Areas of Technology involving,
  - Sensors. & Measurement sys,
  - Drive & Actuation sys,
  - Analysis of the behaviour of sys,
  - Ctrl sys &
  - $\mu p$ sys.

9.