MECHATRONICS

LECTURE NOTE

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(1) INTRODUCTION TO MECHATRONICS

Definition of Mechatronics.

* Mechatronics can be defined as the application of electronics and computer technology to control the motions of mechanical systems.

* Mechatronics is a coordinated and concurrently developed integration of mechanical engineering with electrons and intelligent computer control in the design and manufacture of products and processes.

Mechanism + Electronics = Mechatronics

Ex

- Automatic Washing machine
- Digital fuel injection System
- Engine management System.

Advantages & disadvantages of Mechatronics

Advantages

- The products produced are cost effective and very good quality.
- High degree of Flexibility
- Greater extent of machine utilization
- Greater productivity
- High life expected by proper maintenance.

Disadvantages

- Higher initial cost of the system.
- Imperative to have knowledge of different engineering fields for design and implementation.
- It is expensive to incorporate mechatronics approaches to existing cold systems.
- Specific problem of various systems will have to be addressed separately and properly.

Characteristics of mechatronics system

- High quality product.
- Safe.
- Low cost.
- portable produced quickly
- Serviceability maintainability and upgradeability

Application of Mechatronics

- Mechatronics has a wide range of applications as discussed in the following subsections.

Design and modeling

- Design and modelling are simplified to a large extent by the use of mechatronics system.
- Basically design involves drawing analysis and documentation.

Robotics

→ Robot Technology uses mechanical electronics and computer systems.

→ A robot is a multifunctional reprogramable machine used to handle materials tools or any special items to perform a particular ta

Scope of Mechatronics in Industrial Sector

→ The scope of mechatronics in industrial sector are the following.

- To improve products and processes
- To develop novel mechanisms
- To design new products

→ In the industry large scale improvements have been made using mechatronic systems in flexible manufacturing engineering systems involving computer controlled machines robots automatic meterial conveying and overall supervisory control.

→ Low volume, more variety higher levels of flexibility reduced lead time in manufacture and automation in manufacturing.

Components of Mechatronics system :

* Mechatronics system can be divided into the following :

→ physical systems modeling
→ sensors and Actuators
→ signals and system
→ computer and logic systems
→ software and data Acquisition

→ **Physical systems modeling**

- Mechanics of solids
- Translational and Rotational systems
- Fluid systems
- Thermal systems
- micro and nano systems
- Rotational Electromagnetic mems
- physical system Analogies

→ **Sensors and Actuators**

- Fundamentals of time and Frequency
- Sensor and Actuator characteristics
- Sensors
  - → Liner and rotational Sensors
  - → Acceleration Sensors
  - → Force, torque and pressure Sensors

→ Flow sensors
→ Ranging and proximity sensing
→ Light detection image, and vision system
→ micro and nano sensors

- Actuators
  → Electro-mechanical actuators
  → motors. DC motors AC motors and Stepper motors
  → piezoelectric actuators
  → micro and nano actuators.

* Signals and System
- mechatronics modeling
- Signals and systems in mechatronics
- Response of dynamic systems
- Root locus methods
- Frequency response methods
- Stable variable methods
- Stability controllability and observability
- Design of digital filters
- optimal control design
- Neural networks and Fuzzy systems.
- Identification and design optimization

* Computer and Logic system

- Communication systems
- Fault detection
- Logic system design
- Asynchronous and synchronous sequential logic.
- computer architectures and microprocessors
- programmable logic controllers
- Embedded control computers.

* Software and Data Acquisition

- Data acquisition systems
- Transducers and measurement system
- A/D and D/A conversion
- Amplifiers and signal conditioning
- software engineering • Data recording

Importance of Mechatronics in automation

→ In the domain of factory automation mechatronics has far-reaching effects in manufacturing.

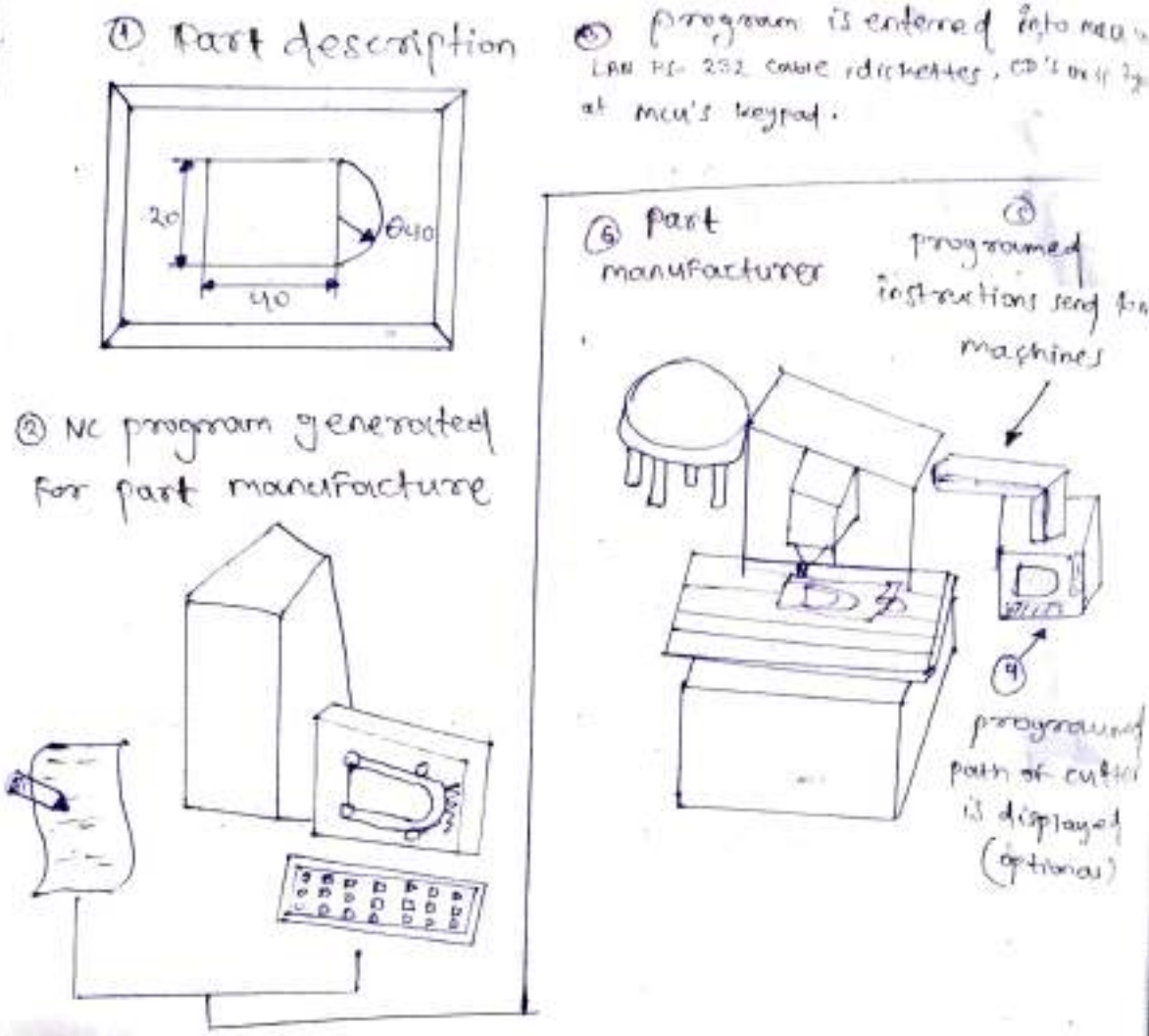
→ Major constituents of factory automation include

- computer numerically controlled (CNC) machines.
- Robots
- Automation systems
- computer integration of all functions of manufacturing.

- Low volume more variety higher levels of flexibility reduced lead time in manufactu... and automation in manufacturing and assem... are likely to be the future needy of and mechatronic systems will play an important ... in this coterx.

Computer numerical control machines

- A computer numerical control is a NC system that utilizes a dedicated computer to perform all basic numerical control functions



(Working of CNC machine)

Function of CNC

- The principal functions of CNC are
  - → Machine tool control.
  - → In process compensation
  - → Improved programming and operating features
  - → Diagnostics.

Machine tool control

- It is the prime function of the CNC System to control the machine tool.
- This involves conversion of the part program instructions into machine tool motion through the computer interface and servo system.

In-process compensation

→ It is closely related function to machine tool control.

→ This involves the dynamic correction of the machine tool motions for change or errors which occur during processing.

- The main options are as follows.
  - → Adjustment for errors sensed by in-process inspection probes and gauges
  - → Recomputation of axis positions when an inspection probe is used to locate a datum reference on a workpart.

Improved programming and operating features

- The soft wired control has permitted the introduc programming and operating features.
- The main features are as follows.
  - → Editing of part programs at the machine.
  - → Graphic display of the tool path to verify the tape.
  - → provision of various typs in interpolation. circular, parabolic, and cubic
  - → support of old customary units and new metric units use of specially written subroutines.

Diagnostics

- It is more flexible in the sense that modification can be made to the program rather than making completely new tape as with older conventional N systems.
- The weakest link is least used the tape is read only once and the program is stored in the memory for repetitive machining.
  - → To minimise of downtime.
  - → To give warning about failure of component
  - → To contain a certain amount of redundancy of components which are considered unreliable.

Arc Welding robot

→ Arc welding robot is the a mechanized programmable tools, which completely automate a welding process by both performing the weld and handling the part.

→ Welding robot is commonly used for welding gas metal arc welding and resistance spot welding arc in high production applications such as the automotive industry.

→ Welding robot is a relatively new application of robotics even through robots were first introduced into US industry during the 1960s.

→ The major components of arc welding robots are the manipulator or the mechanical unit and the controller which acts as the robot's "brain"

→ processes such as while often automated are not necessarily equivalent to robot welding since a human operator sometimes prepares the materials to be welded.

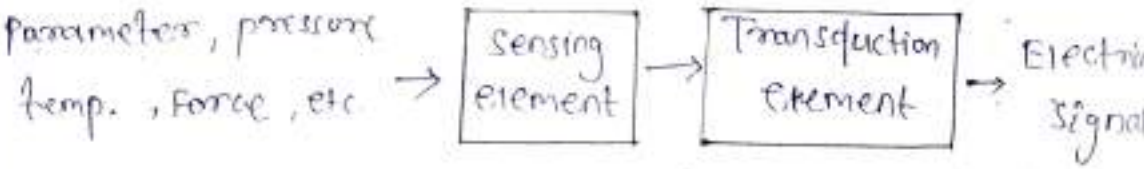
Defination of Transducers

→ Transducer is an electronic device which converts one form of energy to another form of energy

→ Transducers are the devices which converts physical parameters into an electrical signal.

→ It also converts mechanical force or displacement into an electrical signal.

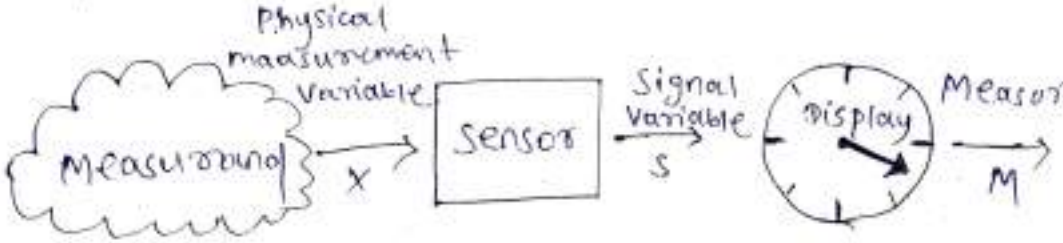
→ Transducer contains two parts that are closely related to each other the sensing element and transduction element.



(Block diagram of transducer)

→ The sensing element is called as the sensor. It is a device producing measurable response to change in physical conditions.

→ Do you know how the transducers look like?



(A simple instrument model)

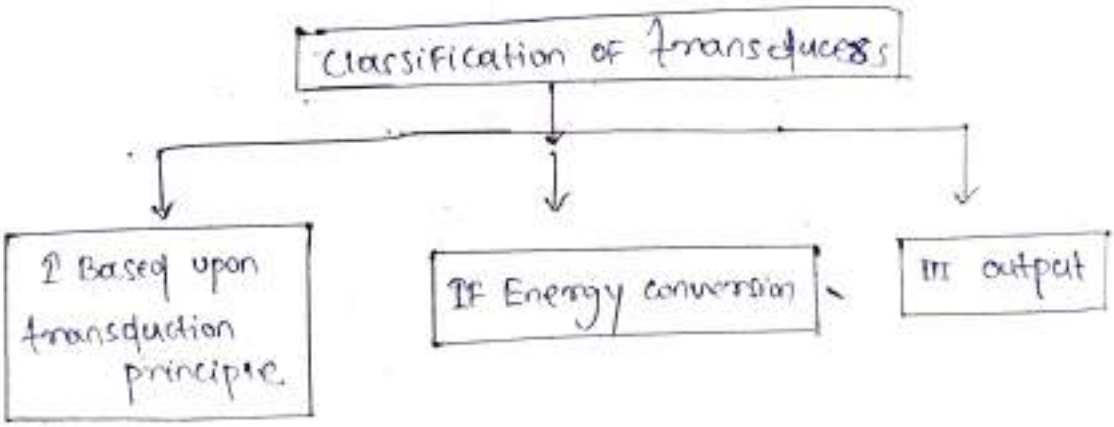
Examples:

- LDR converts brightness to resistance.
- Thermistor converts temperature to resistance.
- Microphone converts sound to voltage.
- LED converts electricity to light.

Basic requirements of transducers.

Ruggedness, Linearity, Repeatability, No hysteresis, High reliability and stability, Good dynamic response, Economical in size, High output signal quality, High sensitivity.

Classification of transducers



(1) Based upon the transduction principle

Mechanical transducers

- The mechanical transducers are transducer that respond to change in the physical condition of the system and gives output in other form.

Electrical transducers

- An electrical transducer is a device that co... the non electrical quantity to an electrical qu... that is proportional to the input quantity.

Energy Conversion

Passive transducer

- They are externally powered transducers.
- In passive transducer pysical quantity conv... as a change in an electrical parameters su... as Resistance Inductance and capacitance.

Passive Transducer

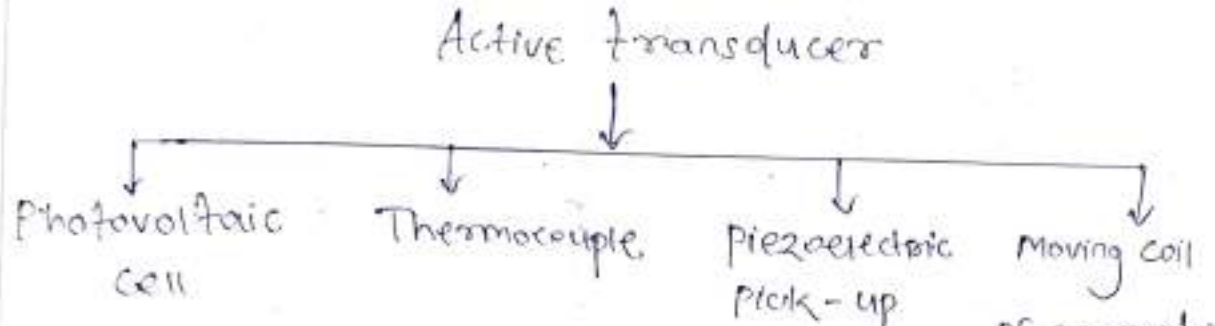
- Resistance
  - Potentiometric device
  - Resistance strain gauge
  - Hotwire meter
  - Resistance thermometer
  - Thermistor
  - Resistance hygrometer
  - photoconductive cell
- Capacitance
  - ① Capacitance microphone
  - ② Variable capacitance
  - ③ pressure gauge
- Inductance
  - ① Magnectic ... transducer
  - ② Reluctance ... differential transform...
  - ③ Eddy current...
  - ④ photo-emissive ...
  - ⑤ photo-multiple ...

Active transducer

Active transducer does not require an external power source for its operation.

It converts the physical quantity in the form of electrical voltage or current

It is known as self generating type transducers



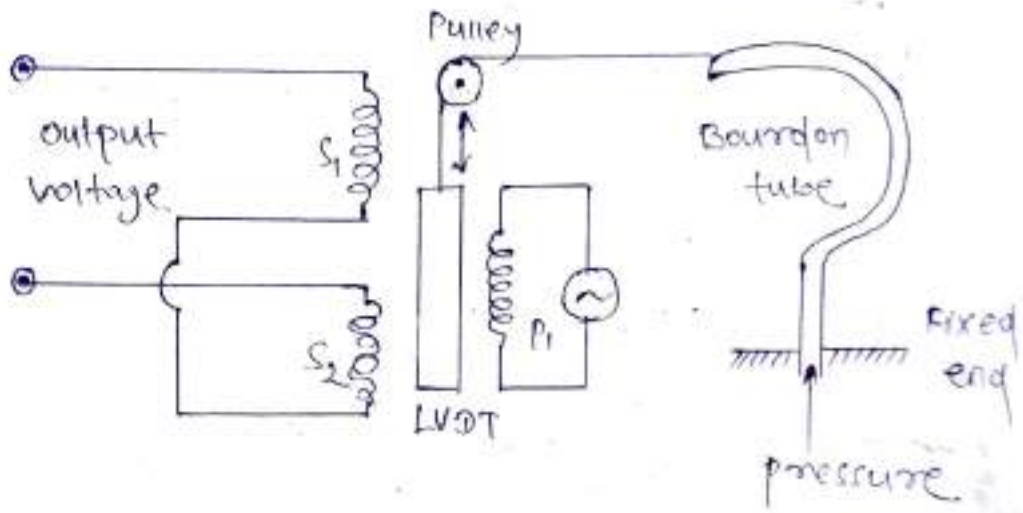
Based upon the output

primary and secondary transducers

- The mechanical device converts the physical quantity to be measured into into a mechanical signal. Such mechanical device are called as the primary transducer.
- The electrical device then converts this mecanical signal into a corresponding electrical signal Such electrical device are known as the secondary transducer.
- The Bourdon's tube acts as a primary transducer which converts a pressure into displacement.

Analog and digital transducers

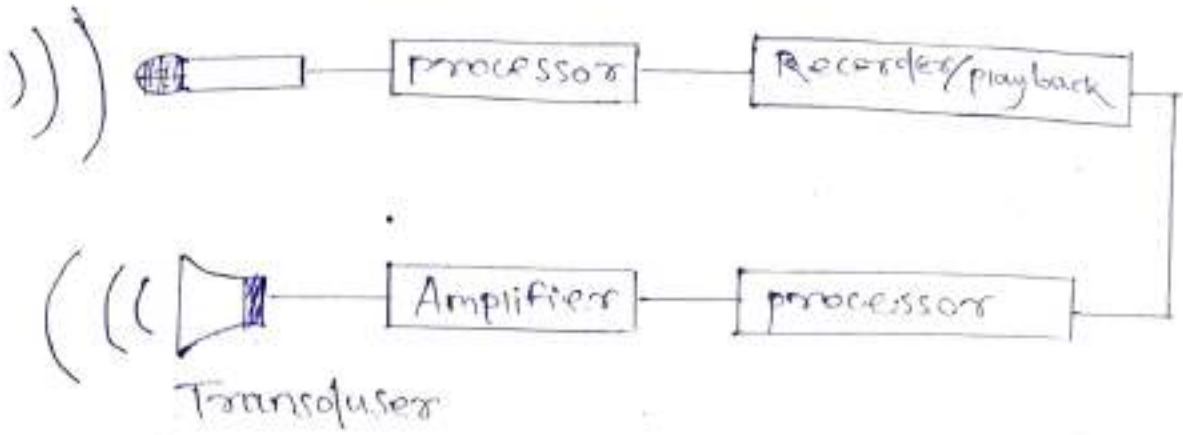
- The output of these transducer is in the analog form that means it is a continuous function of time.
- The output of these transducer is in the digital form that means it is the form of digital pulses discrete in time.



(pressure measurement)

Transducer and Inverse transducer

- Transducer convert non electrical quantity electrical quantity while inverse transducer convert electrical to a non electrical quantity
- For example microphone is a transducer which converts sound signal into an electrical signal whereas loudspeaker is an inverse transducer which converts electrical singnal into sound singnal



(Transducer and Inverse transducer)

Advantages of electrical transducers

- Electrical amplification and attenuation can be done easily and that too with static devices.
- The effect of friction are minimized
- The electrical output can be easily used transmitted and processed for the purpose of measurement.
- The electrical systems can be controlled with a very small power level.
- The output can be indicated and recorded remotely at a distance from the sensing medium.
- The output can be modified to meet the requirements of the indicating or controlling units. The signal magnitude can be related in terms of the voltage and current.

Electro Mechanical Transducer

- Electromechanical Transducer is a device for converting mechanical motion into electric current or voltage and vice versa.
- Electromechanical transducer are used primarily as actuating mechanisms in automatic control system and as sensors of mechanical motion in automation and measurement technology.
- They may be classified according to the conversion principle used as resistive, electromagnetic and electrostatic types.
- The sensitivity $\epsilon = \Delta y / \Delta x$

  where, Δy is the change in the output quantity y.

  Δx is the change in the input quantity x.
- It is no dimension

Applications

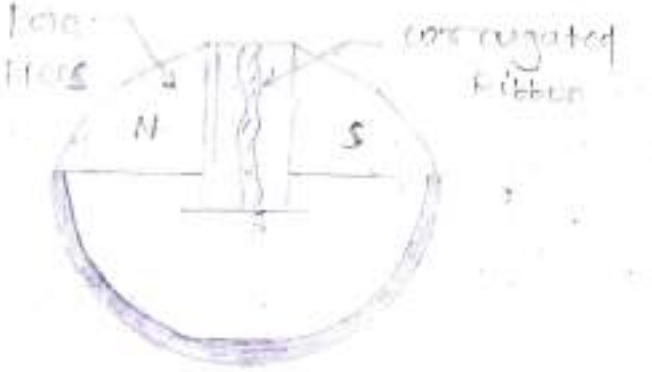
- Electromechanical transducers are used in
  - → A loudspeaker.
  - → A microphone
  - → Galvanometer etc.

Introduction of microphone and Loudspeaker

- In a communication system like
  - → Public address system
  - → Telephone
  - → Radio
  - → Television
  - → The information is sound signal
  - → This sound signal is converted into an electrical signal by a microphone.
  - → Electrical signal is converted to sound signal by a loudspeaker.

Classification of microphones

- Based on principle of working
  - pressure operated microphones
    - → carbon microphone
    - → condenser microphone
    - → crystal microphone
    - → Moving coil microphone
  - → Velocity operated microphones or pressure gradient microphones.
    - Ribbon microphone



(Ribbon Microphone)

- Based on output impedance
  - Low Impedance microphones are
    - → Carbon microphone
    - → moving coil microphone
  - High impedance microphones are
    - → crystal microphone
    - → condenser microphone.

- Based on polar or directional characteristics.
  - omni directional microphones are
    - -> Carbon microphone
    - -> condenser microphone
    - -> crystal microphone
    - -> moving coil microphone.

omni directional microphone

- Bi-directional microphones
  - -> Ribbon microphone

(Bi-directional ribbon microphone)

- cardioid microphones.

Specifications of microphones

Sensitivity

→ It is defined as the electrical output in volts for the input sound pressure of one micro-bar at 1 kHz

Signal To Noise Ratio

→ It is the ratio of output in the presence of sound to the output in the absence of sound.

→ It is measured in decibels dB.

Frequency Response

→ This is the in outpot which no where related to the input of a microphone in audio frequency range

Distortion

- The change in output which is no where related to the input is known as distortion.
- Types of Distortion
  - → Non Liner Distortion
  - → phase Distortion

output Impedance

- The impedance measured between output terminals of a microphone is known as its output impedance.
- It measured in ohms.

Directivity pattern

- Directivity pattern is the graph which shows microphne output for sound input coming from different angles.
- omni directional pattern
  → omni directional pattern indicates that the microphone responds equally in all direction.
- cardioid pattern
  → cardioid pattern indicates that the microphone responds well only in a limited direction.

Tranducer Actuating mechanism

→ An actuating mechanism usually consists of a motor, a transmission and control units. It is to control the flow of fluids or gases consist of a valve or gate which is moved by hydraulic or electrical drive.

→ An actuator is a device that is responsible for moving or controlling a mechanism or system.

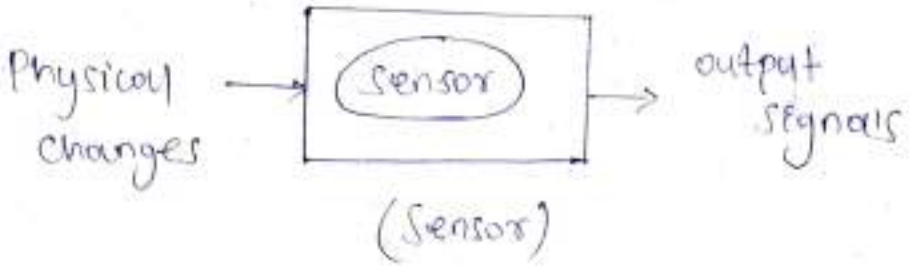
→ It is controlled by a signal from a control system or manual control.

→ An actuator is the mechanism by which a control system acts upon an environment.

Displacement and position Sensor

Sensor

- The sensor is a device that measure the physical quantity into an easily readable signal
- It gives accurate readings after calibration.



(Sensor)

- Example - The mercury used in the thermometer converts the measured temperature into an expansion and contraction of the liquid which is easily measured with the help of a calibrated gl tube.
- The photo sensor the infrared or ultraviolet lig

Displacement Sensor

→ A displacement sensor is used to measure travel range between where an object is and a reference position.

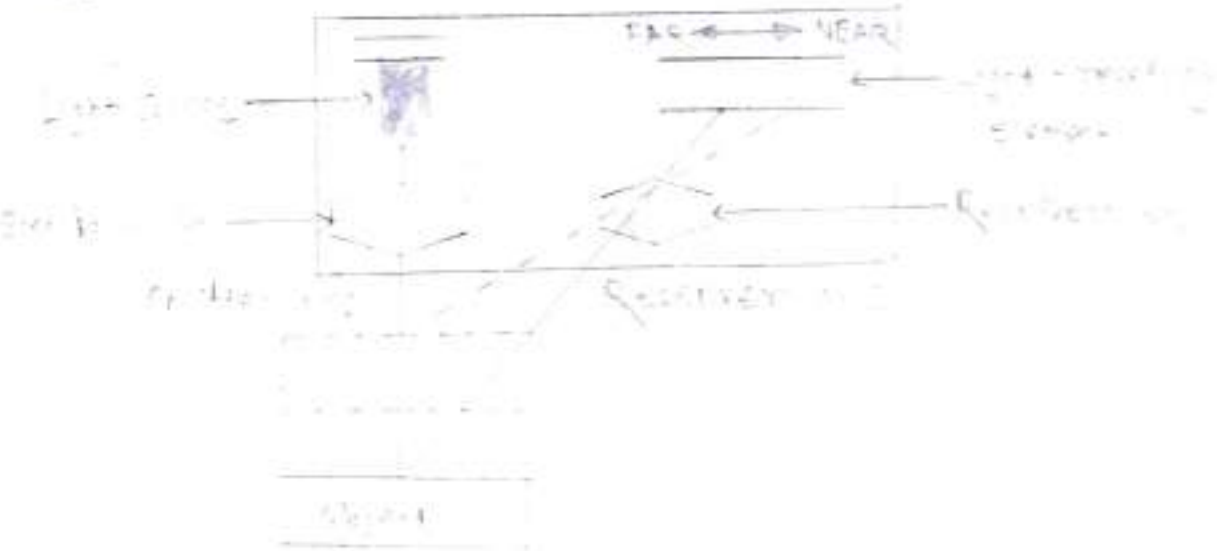
→ measurements with linear displacement sensors can be classified into two large categories.

- Non-contact measurement here there is no direct contact with the target only through light or magnetic field / and waves.
- contact measurement It is performed in direct contact with the target

operating principles

→ Light from the light source is condensed by the lens and directed onto the object.

→ Light reflected from the object is condensed onto a one-dimensional position sensing device by the receiving lens.

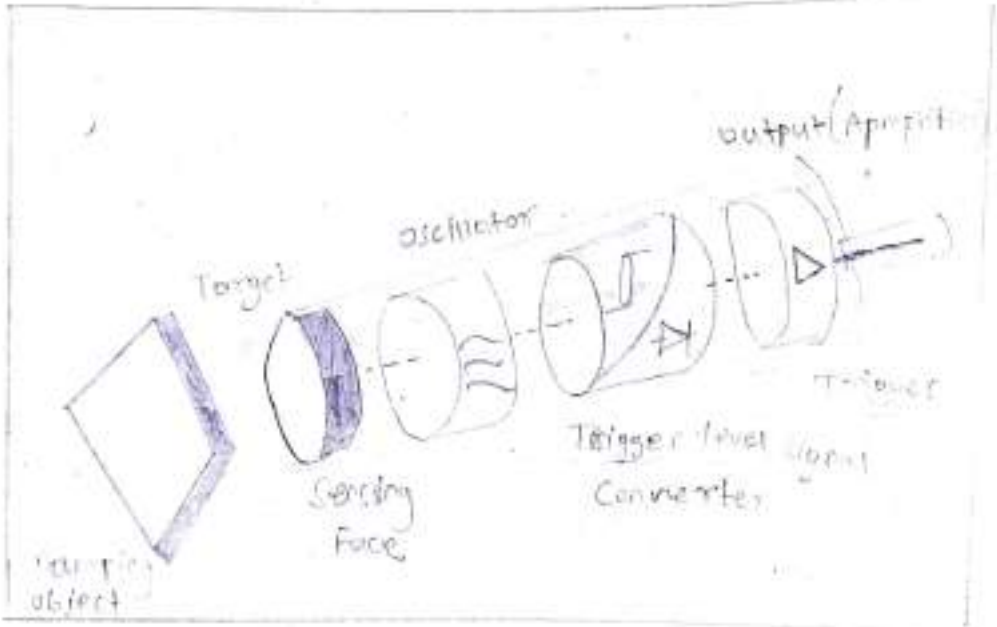


Applications

- Measuring whether the thickness of rolled steel sheet is uniform whether the thickness laminated glass is within the standards etc.

Positions Sensors

- positions sensors are devices that can detect the movement of an object or determine its relative position measured from an established reference point. These types of sensors can also be used to detect the presence of an object or its absence.
- A position sensor is a sensor that facilitates measurment of mechanical position.



Operating principle

- optical position sensors operate using one of two principles. In the first type, light is transmitted from an emitter and sent to receiver at the other end of the sensor. In the second type the emitted light signal is reflected from the object being monitored returned towards the light source.

- These sensors allow for detection of metallic objects in front of the sensor head without any physical contact of the object itself being detected.

Applications

→ position sensors are used across industries such as automotive, medical agriculture.

→ Robotics, industrial processing etc.

Velocity, Motion, Force and pressure

Velocity Sensors

→ A velocity sensors is a sensor that responds to velocity rather than absolute position.

→ For example: Dynamic microphone are velocity recivers movement causes the coil to move relative to the magnt which in turn generates a vatage that is proportional to the velocity of that movement.

→ Likewise, many electronic keyboards used for music are velocity sensitive.

→ There are two type of velocity sensor.

- Moving coil.
- piezoelectric

Moving Coil

- The moving coil contains a coil supported by springs and a permanently fixed magnet and require no output signal amplifiers. movement causes the coil move relative to the magnet which in turn generates a voltage that is proportional to the velocity of the movement.

Piezoelectric

- Piezoelectric sensor are similar to a piezoelec accelerameter, except that the output of th device is proportional to the velocity of the transducer.

uses

- used in gas turbines, axial compressors, small and mid-size pumps.
- These sensors detect high frequency vibration signals related to bearing supports. vibration in turbine / compressor vanes, ball bearings no in gears etc.

Pressure sensors

→ A pressure sensor is a device that senses pressure and converts it into an electric signal

→ A pressure sensors is a device equipped with a pressure-sensitive element that measures the pressure of a gas or a liquid against a diaphragm mode of stainless, etc. and converts the measured value into an electrical signal as an output.

Uses

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

Motion sensors

→ A motion sensor is an electrical device that utilizes a sensor to detect nearby motion.

→ Motion sensors are an important component of any security system. When a sensor detects motion it will send an alert to your security system.

→ There are three type of motion sensors that are used frequently.

- Passive Infrared (PIR)
- Microwave
- Dual Tech / Hybrid.

Uses

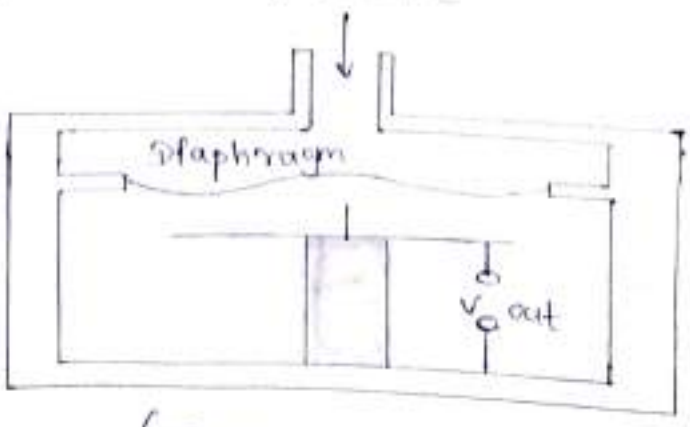
- Motion sensor have found wide use in commer applications.
- one common application is activating automatic door openers in buriness and public. building.
- They form a vital component of security. automated lighting control, home control and other useful system.

Force Sensors

→ A force sensors is a sensors that helps in measuring the amount of force applied to object.

→ By observing the amount of change in the resistance values of force sensing resistors the applied force can be calculated.

→ They are used to measure compression, force strain and load.



(Force sensors)

uses

- Some of the applications of force sensor that uses in musical instruments, as carrocerpancy sensors, in foot-pronation systems, augmented reality etc.

Temperature and Light Sensors

Temperature sensors

- A temperature sensors is a device used to measure temperature. This can be air temperature, liquid temp. or the temp.. of solid matter.
- There are two different types of temp. Sensors. Such as,
  - Contact temp. Sensors.
  - Non-contact temp. sensors.

Contact temperature sensors

→ In contact type temperature sensor, sensor is placed in contact with the measured object. The measures the temp. when the heat of the contact surface/object is balance.

→ This kind of sensors includes thermocouples, resistance temperature detector (RTD) and thermistors etc.

Non - contact temperature sensors

→ In a non-contat temp. sensors the infrared radia emitted from the measured object this radiation fo on sensor & equipvalent temperature is shown/ displayed in the sensor. so without any contact we can measure temperature of an object.

→ A radiation temp. sensors belonges to this cate

Uses

- They can be used to detect temperature of solid liquids or gases.
- Motors - there are many different aspects of motors and most of thiese require temp. measurement to ensure the motor itself does not overheat.

Light Sensors

- The light sensor is a passive device that converts the light energy into an electrical signal output.
- Light sensors are more commonly known as photoelectric Devices or photo sensors because they convert light energy into an electronic signal.

(Light Sensor)

Types of light sensors

- There are different types of light sensors availiable mainly.

  → Photoresistor

  → photodiodes

  → Phototransistors.

Mechanical Actuators

Mechanical actuators or mechanisms are devices which can be considered to be motion converters in that they transform motion from one form to some other required form.

Machine

It is an apparatus for applying mechanical power consisting of a number of interrelated parts, each having a definite function.

- A machine is the assembly of resistant bodies or links whose relative motions are successfully constrained so that available energy can be converted into useful work.
- Machines are used to transmit both motion and force.
- Kinematic Link or Element

Kinematic element is a resistant body or an assembly of resistant bodies which go to make a part or parts of a machine connecting other parts which have motion relative to it

Example

piston, piston rod and cross head.. one link

Connecting rod with big and small end bearings.. second link.

Crankshaft and Flywheel... third link.

Characteristics of a link

A link should have two characteristics

1. It should have relative motion.
2. It must be a resistant body.

Types of Link

- Rigid Link
- Flexible Link
- Fluid link

Difference between machine and structure

Machine	Structure
(1) Parts of a machine move relative to each other.	(1) The members of a structure do not move relative to one another.
(2) It transforms the available energy into some useful work.	(2) No energy is transformed into useful work.
(3) The links may transmit both power and motion Ex. Shaper, lathe etc	(3) The members of a structure transmit force only Ex. Roof truss Frame etc.

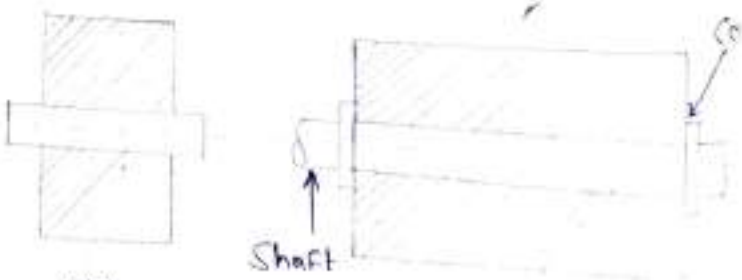
Kinematic pair

A kinematic pair is a two links that permits relative motion.

The relative motion between the elements or links that form a pair is required to be completely constrained or successfully constrained.

- **Completely constrained motion**

When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.



(Completely constrained motion)

Ex The motion of a square bar in a square hole, and the motion of a shaft with collars at each end are the example of the completely constrained motion

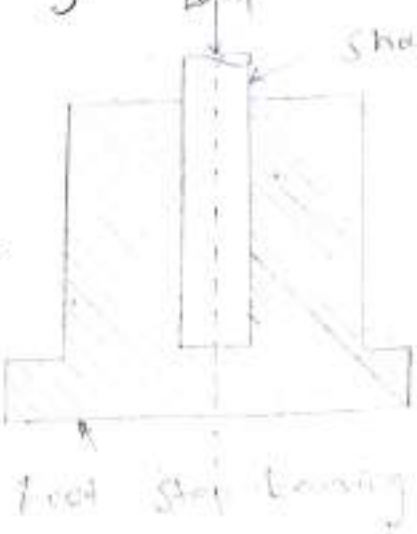
- In completely constrained motion

When the motion between a pair can take place in more than one direction than motion is called an incompletely constrained motion.

(Incompletely constrained motion)

Successfully constrained motion

The motion is said to be successfully constrained when the motion between the elements forming a pair, is such that constrained. motion is not completed by itself, but by some means.



Classification of kinematic pairs.

The kinematic pairs may be classified on the following consideration.

1. Nature of relative motion between the elements
2. Nature of contact between the element.
3. Nature of the mechanical arrangement for complete or successful constraint between the element.

1. Classification based on nature of relative motion between the elements.

(i) Sliding pair (ii) Turning pair
(iii) Rolling pair (iv) Screw pair
(v) Spherical pair.

Mechanism

When one of the links of a kinematic chain is fixed the chain is known as mechanism. It may be used for transmitting or transforming motion.

Ex. Engine indicators, typewriter ect.

Mechanisms are two types.

Simple mechanisms - A mechanism with four links as simple mechanism.

Compound mechanism - The mechanism with more four links is known as compound mechanism. It may be made by adding two or more simple mechanisms.

Inversion of Mechanism

As we know that when one of the links in a kinematic chain is fixed, it is called a mechanism. Therefore, we can obtain as many mechanisms as the number of links in a kinematic chain by fixing in turn different links in a kinematic chain. This method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as inversion of the mechanism.

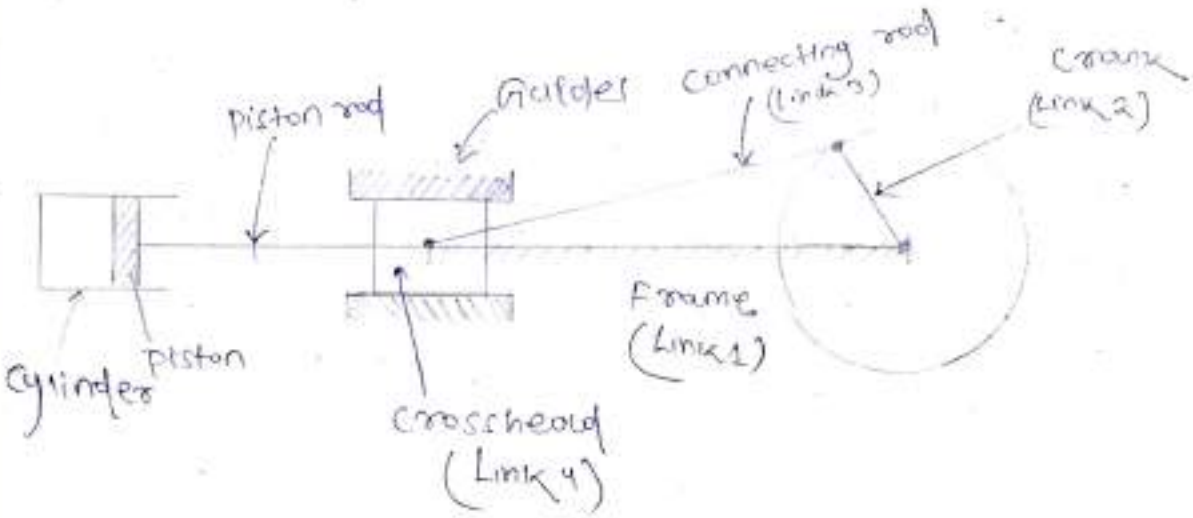
Slider crank chain

A single slider crank chain is a modification of the basic four bar chain. It consists of one sliding pair and three turning pairs. It is usually found in reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating motion and vice versa.

A. In a single slider crank chain the link 1 and 2, links 2 and 3 and links 3 and 4 form three turning pair while links 4 and 1 form a sliding pair.

Some important Inversions of Slider crank chain

1. Pendulum pump
2. Oscillating cylinder engine
3. Rotary I.C engine
4. Crank and Slotted lever quick return motion mechanism.
5. Withourth quick return motion mechanism



(Single Slider crank chain)

Gear drive

- A gear is a wheel provided with teeth which mesh with the teeth on another wheel, or on to a rack, so as to give a positive transmission of motion from one component to another.

- Gears constitute the most commonly used device for power transmission or for changing power speed ratio in a power system.
- A number of devices such as differentials, transmission gear boxes; planetary drives etc. used is many construction mechanics employ gears as basic component.

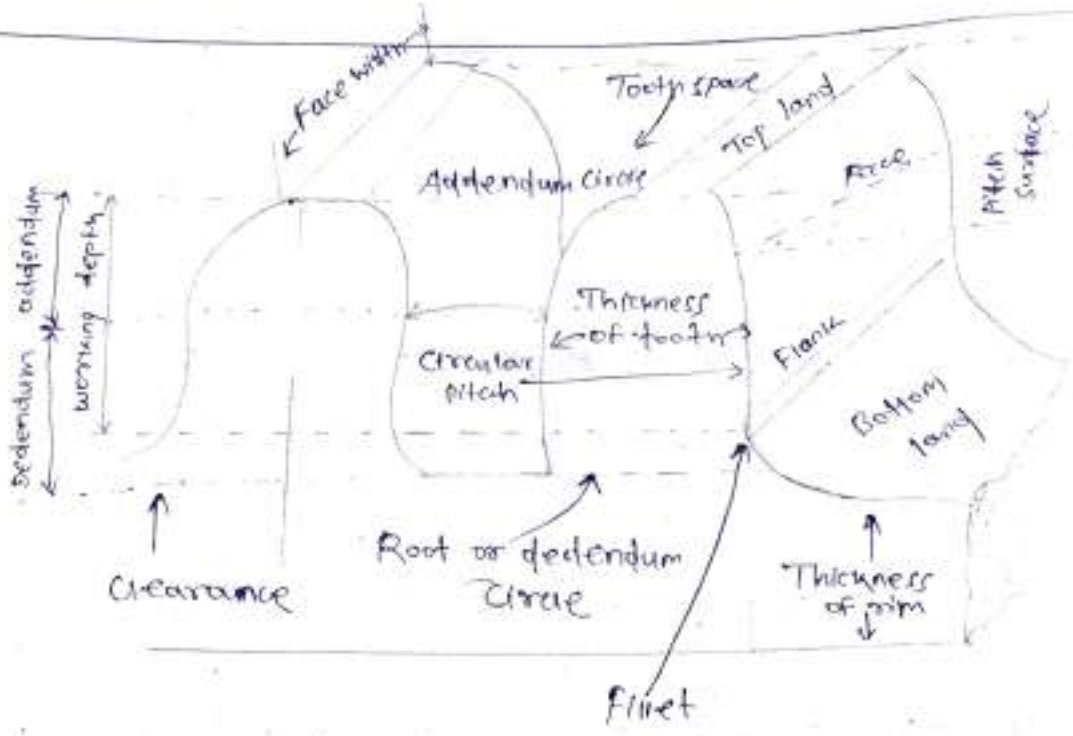
Advantages and disadvantages of toothed gearing.

Advantages

1. High effectency
2. Long service life.
3. High compact.
4. More compact
5. Can operate at high speeds
6. Can be used where precise timing is required.
7. Large power can be transmitted.
8. possibility of being applied for a wide range of torques, speeds and speed ratios.

Disadvantages

1. Special equipment and tools are required to manufacture the gears.
2. When one wheel gets damaged the whole set up is affected.
3. Noisy in operation at considerable speeds.



(Terms of gears)

1. Pitch circle - It is an imaginary circle which would transmit the same motion as the actual gear, by pure rolling action.

2. Addendum circle - A circle concentric with the pitch circle and bounding the outer ends of the teeth is called an addendum circle.

3. Addendum - It is the radial distance between the pitch circle and addendum circle.

4. Dedendum circle - It is a circle concentric with the pitch circle and bounding the bottom of the tooth.

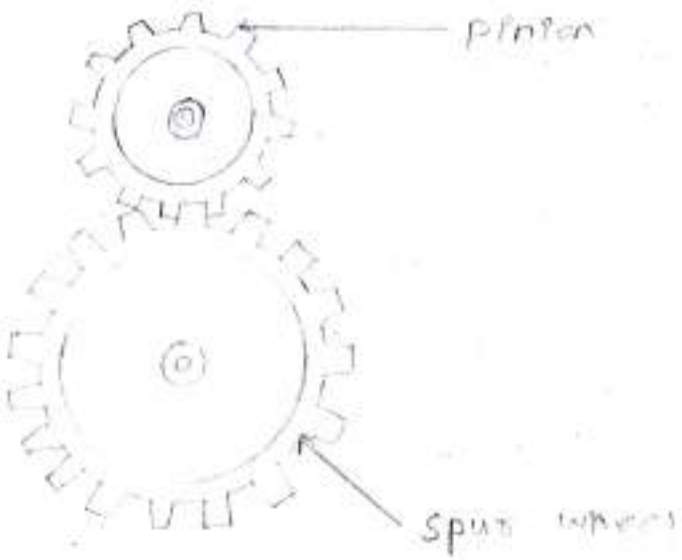
5. Clearance - The difference between the addenda of ~~the~~ and addendum is called as clearance.

Types of gears

Spur gear

A spur gear is a gear wheel or pinion for transmitting motion between two parallel shafts. This is the simplest form of geared drive. The teeth of the gear. Normally the teeth are of involute form. Illustrates a spur gear drive, consisting of a pinion and a spur wheel.

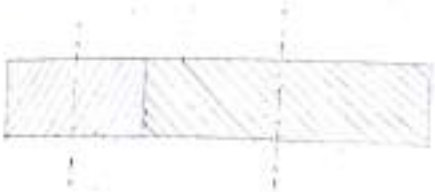
The efficiency of power transmission by these gears is very high and may be as much as 99%. In case of high-speed gears with good material and workmanship of construction and good lubrication in operation. under average conditions, efficiency of 96-98% are commonly attainable.



(spur gear)

2. Helical gear

helical gear is one in which teeth instead of being parallel with shaft as in ordinary spur gears. are inclined. This ensures smooth action and more accurate maintenace of velocity ratio

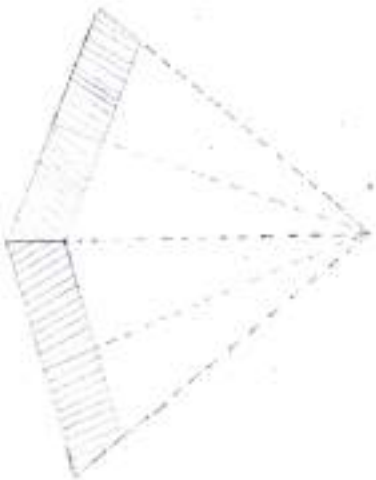


(Helical gear)

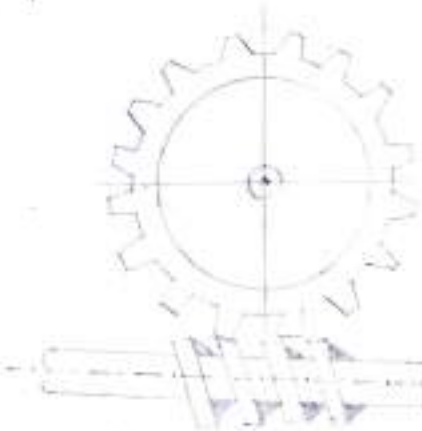
(Double helical gear)

A disadvantage is that the inclination of the teeth sets up a lateral thrust. A method of neutralising this lateral or axial thrust is to use double-helical gears (also known as Herring bone gear)

3. Bevel gear



(Bevel gear)



(Worm gear)

→ Bevel gear

A bevel gear transmits motion between two shafts which intersect. If the shaft are right angles

Electrical Actuator

Actuator: A mechanical device or a system which has motion or movement is called an actuator.

Actuation System: A group of elements which is responsible directly or indirectly for imparting motion to an actuator is called an actuation system.

Electrical actuator: An actuator receiving electrical energy for motion is called an electrical actuator.

→ Electrical actuators systems include the following

* **Switching devices**

1. Mechanical switches
   - Solenoids
   - Relays
2. Solid state switches:
   - Diodes
   - Tyristors
   - Transistors

Drive systems

1. D.C Motors
2. A.C motors.

Mechanical switches

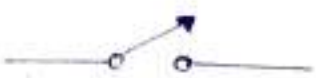
→ Mechanical switches are those where in switching action is by the application of force on the switch and during switching action mechanical elements move with the switch. These switches consists of one or more pair of contacts which are mechanically closed or opened and in doing so make or break electrical circuit.

• Mechanical switches are specified in terms of number of poles and throws.

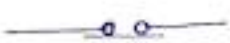
- Poles (P) are number of separate circuits that can be completed by the same switching action.
- Throws (T) - are number of individual contact for each pole.

• There are many designes for limit "switches" including push-button and levered microswitches

NO push button



SPST



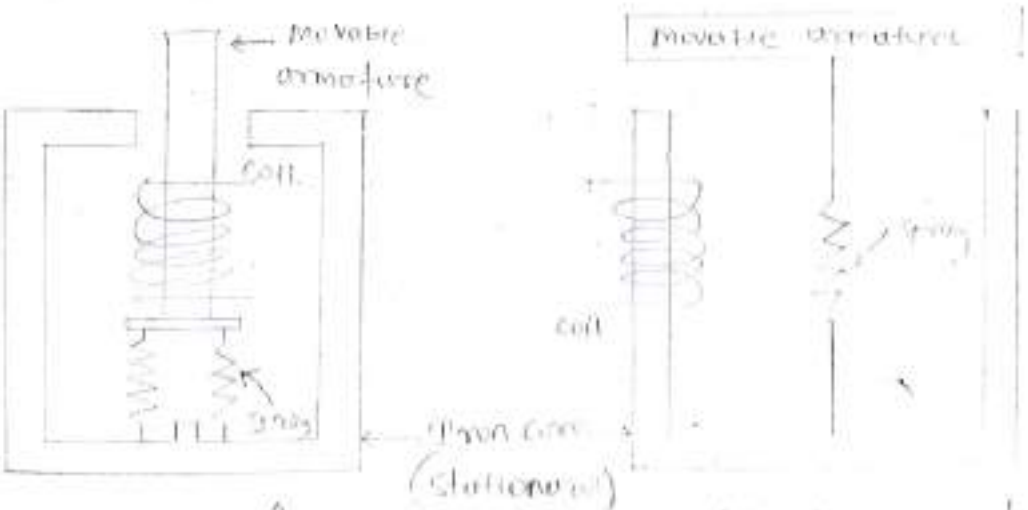
NC push button

SPDT

- The SPST switch is a single pole (SP), single throw (ST) device that opens or closes a single connection.
- The SPDT switch changes the path between two different throw positions.

(i) SOLENOIDS

A "solenoid" consists of coil and a movable iron core called the armature. When the current is passed through the coil it gets energized and consequently the core moves to increase the flux linkage by closing the air gap between the cores. The movable core is usually spring-loaded to allow the core to retract when the current is switched off.



(Solenoids)

D.C MOTORS

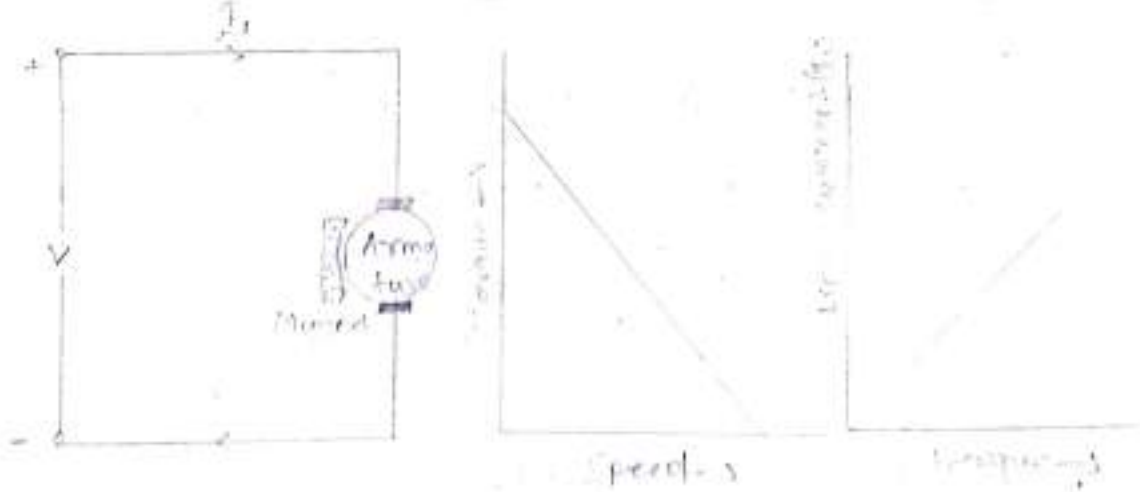
D.C (Direct current) motors find wide application in a large number of mechatronic designs because of the torque-speed characteristic achievable with different electrical configurations.

The speeds of the D.C motors can be smoothly controlled and in most cases are reversible.

These motors can respond quickly since they have a high ratio of torque to rotor inertia.

Permanent magnet (D.C) motors

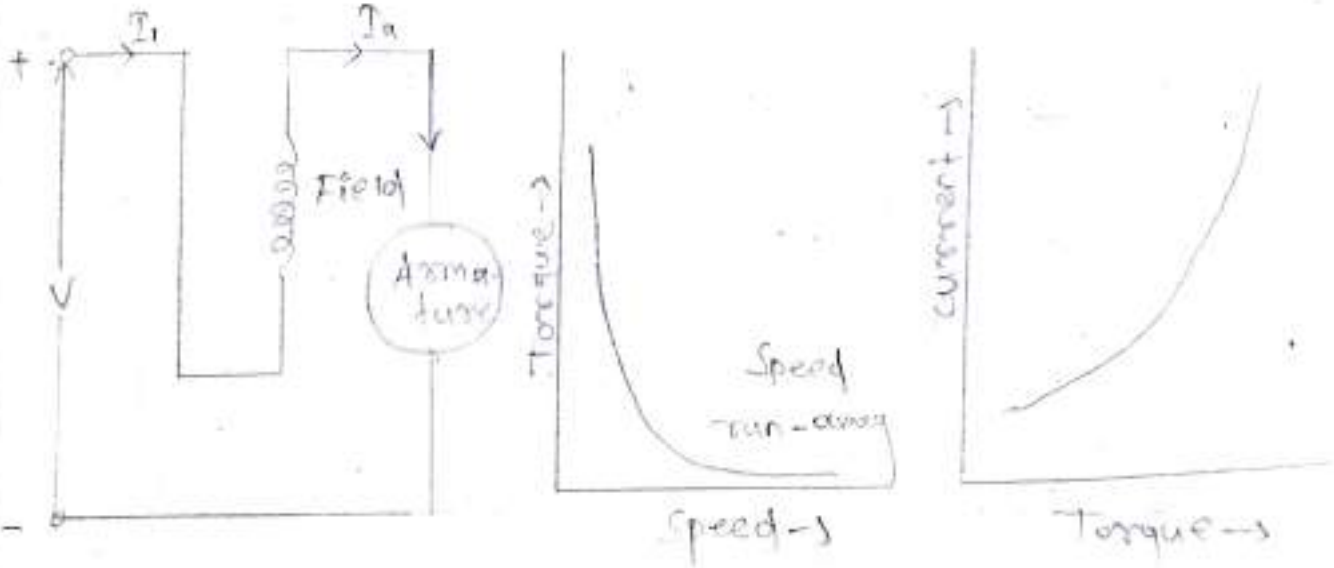
In these motors field excitation is obtained by suitably mounting permanent magnets no the stator. magnets made from ferrites or rare earth are used.



A PM motor is lighter and smaller than others, equivalent D.C. motors because the field strength of permanent magnets is high.

D.C Series motors

In this type of motor armature and field windings are connected in series so the armature and field currents are equal



These motors exhibit very high starting torques, highly variable speed depending on load, and very high speed when the load is small.

The torque-speed curve for a series motor is hyperbolic in space, implying an inverse relationship between the torque and speed and nearly constant power over a wide range.

A.c Motors

(i) Single phase:

(a) Induction:

- Squirrel cage.
  - Split phase
  - Capacitor start
  - permanent split capacitor
  - Shaded pole
  - Two-Value capacitor.
- wound rotor
  - Repulsion
  - Repulsion start
  - Repulsion induction

(b) Synchronous:

- Shaded pole
- Hysteresis
- Reluctance
- permanent magnet.

(ii) Polyphase:

(a) Induction:

- wound rotor
- Squirrel cage

(iii) Universal motors.

- In modern control systems D.C motors are mostly used.

Stepper motors

A stepper motor, a special type of D.C motor, is an incremental motion machine. It is a permanent magnet or variable reluctance D.C motor and has the following characteristics:

(i) It can rotate in both directions.
(ii) It can move in precise angular increments.
(iii) It can sustain a holding torque at zero speed.
(iv) It can be controlled with digital circuits.

- A stepper motor moves in accurate equal angular increments, known as steps, in response to the application of digital pulses to an electric drive circuit. The number and rate of pulses control the position and speed of the motor shaft.

- The stepper motor is used in digitally controlled position control system in open loop mode. The point command is in the form of pulses to turn a shaft through a specified angle.

- Stepper motors are either bipolar, requiring two power sources or a switchable polarity power source or unipolar, requiring only one power source.

→ Generally, stepper motors produce less than 1 H.p and are therefore used only in low-power position control application.

Construction and working

- A stepper motor consists of a slotted stator having multi-pole, multi-phase winding and a rotor structure carrying no winding.
- The rotors may be of the permanent magnet or variable reluctance type.
- stepper motors ~~may be of the permanent magnet or~~ operate with an external drive logic circuit. when a train of pulse is applied to the input of the drive circuit, the circuit supplies currents to the stator windings of the motor to make the axes of the air-gap field around in coincidence with the input pulses.

Specification and control of steper motors

1. Permanent magnet Stepper motor.

In the case of a permanent magnet stepper motor. the stator consists of wound poles the rotor poles are permanent magnets.

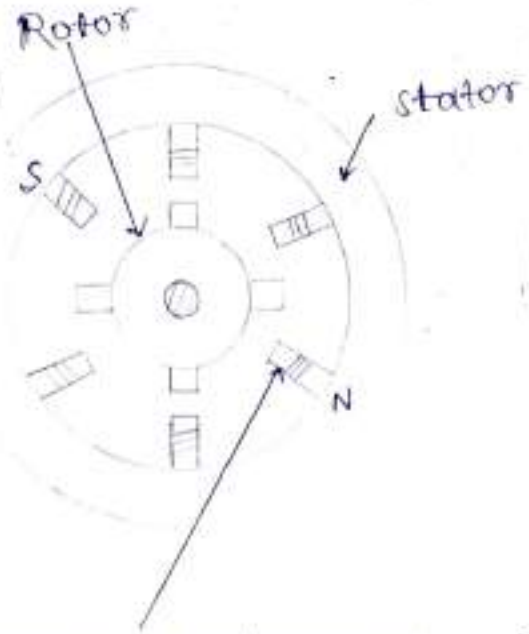
(i) Phase I

(ii) Phase II

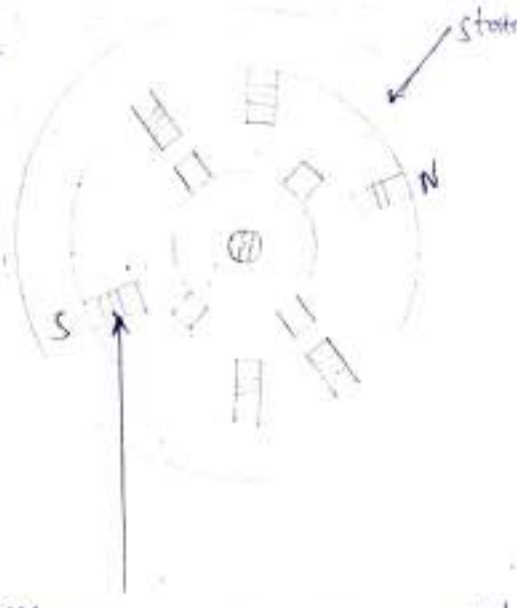
- The rotor is made of Ferrite or rare-earth material which is permanently magnetised.
- The stator stack of phase II is staggered from that of phase I by an angle of 90°.
- Each phase is provided with double coils to simplify the switching arrangement
- This type of motor has the advantage of small residual holding torque, called detent torque, even when stator is not energized.

2. Variable reluctance stepper motor.

- A variable-reluctance stepper motor has no permanent magnet on the rotor and the rotor employed is a Ferro-magnetic multi-toothed one.



(i) This pair of poles energised by current being switched to them and rotor to position



(ii) This pair of poles energised by current being switched to them to give next step.

Servo Motors D.C & A.C

The term servo or servo mechanism refers to a feedback control system in which the controlled variable is.

- Mechanical position
- Time derivatives velocity and acceleration

Types of servo-motors

1. D.C Servo-motors
2. A.C Servo-motors

1. D.C Servo-motors

These motors are preferred for very high power systems since they operate more efficiently.

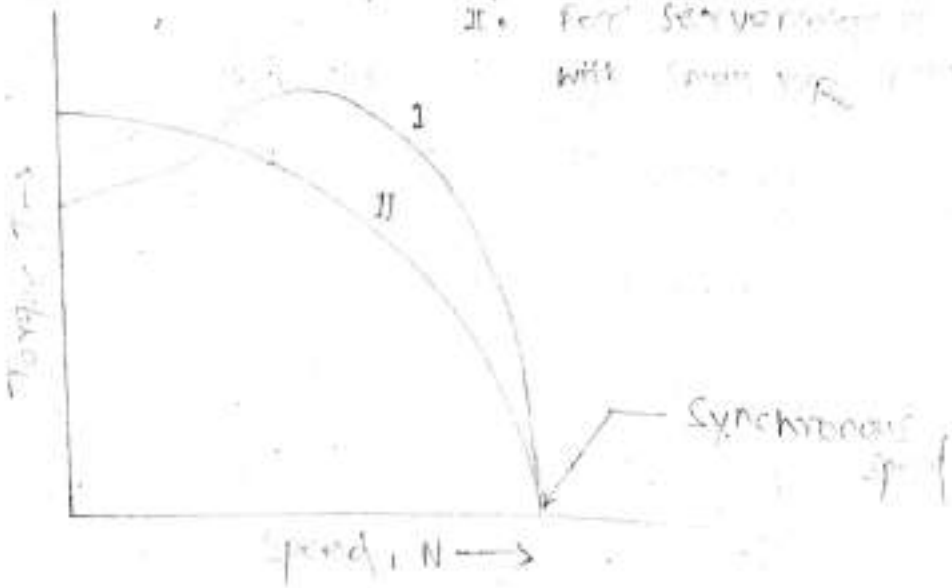
(i)- Series motors

- This motor has a high starting torque.
- It draws large current.
- The speed regulation is poor.
- Reversal can be obtained by reversing field voltage polarity with split series field winding.

A.C SERVO MOTORS

Applications

- These motors are best suited for low power applications.
- precision servo-motors are used in
  - Instrument servo
  - computers
  - Inertial guidance system etc.
- The mechanical output power of A.C servo-motor varies from 2 watts to a few hundred watts.
- An A.C servo-motor is basically a two-phase induction motor except for certain special design features.



(Torque-Speed characteristics)

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

INTRODUCTION

PLCs are specialized industrial devices for interfacing to and controlling analog and digital devices.

(programmable logic controller)

- They are designed with a small instruction set suitable for industrial control applications.
- They are usually programmed with ladder logic, which is a graphical method of laying out the connectivity and logic between various inputs and outputs.
- A programmable logic controller (first conceived in 1968) is a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes.

ADVANTAGES OF A PLC

1. LOW cost.
2. Easy to install
3. Ensures increased productivity
4. Faster operational speed.
5. provides high reliability and easier maintenance
6. Can withstand harsh industrial environment/ manufacturing environment.
7. provides consistency in manufacturing
8. Can input / output both analog and digital signals
9. Small size
10. PLC modules can be added, depending upon the input / output requirements.
12. Easier Troubleshooting.

SELECTION OF A PLC

1. Types of inputs / outputs required, such as.
   - Isolation
   - out-board power supply for input/output
   - Signal conditioning.
2. Input / output capability required.
3. Size of memory required. This is linked to the number of inputs / outputs and the complexity of program used.

USES OF PLCs

PLCs are widely used and extend from small-contained units for use with perhaps 20 digital inputs/outputs to modular systems which can be used for large number of inputs/outputs handle digital or analog inputs/outputs and also carry out PID control modes.

SPECIAL FEATURES

Although PLCs are similar to computers yet they have the following specific features to their use as controllers.

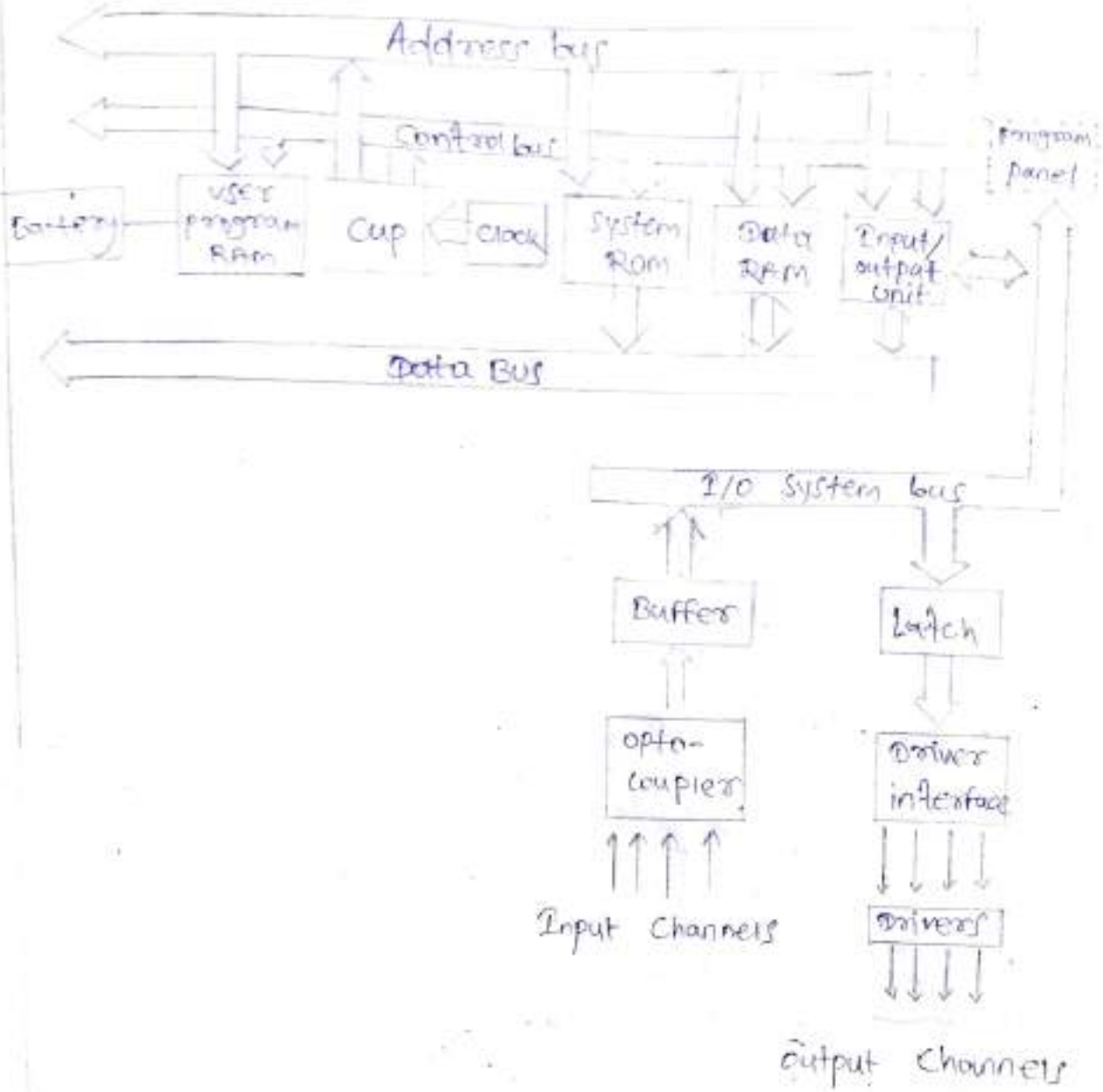
1. The interfacing for inputs and outputs is inside the controller.
2. Easily programmable. They have an easily understood programming language.

ARCHITECTURE BASIC INTERNAL STRUCTURE

A PLC consists of the following main components:

1. Central processing unit (CPU)
2. memory.
3. Input/output circuitry.

1. Central processing unit (Cpu)



- It is provided with a "clock" with a frequency of typically between 1 and 8 MHz. This frequency determines the operating speed of the PLC and provides the timing and synchronisation for all elements in the system.
- A "bus system" carries information and data to and from the Cpu. memory and input/ output units.

2. memory - The various memory elements available in a PLC are.

(i) A system ROM to give permanent storage for the operating system and fixed data.

(ii) RAM for user's program

(iii) Temporary buffer stores for input/output channels.

3. Input/output (I/O) circuitry:

- The I/o channel provides signal conditioning and isolation functions so that sensors and actuators can be generally directly connected to them without the need for other circuitry
- The basic form of programming commonly used with PLCs is ladder programming. This involves each program task being specified as through rung of a ladder.

(i) Continuous updating

(ii) Mass I/o copying

Input / output processing and programming

Input / output processing :-

"Ladder programming" is the basic form of programming commonly used with PLCs. This is as through a rung of a ladder. each program task being specified in

A PLC, when carrying out a program follows the sequence indicated below.

1. Scanning the inputs associated with a rung of the ladder.
2. Setting / reseting the outputs for that rung.
3. moving on to the next rung and repeating operations 1, 2, 3

5. moving on the next rung and repeating operations 1, 2, 3 continuing until the end of the program.

For input / output processing the following two methods

1/ Continuous updating

2/ Mass input / output copying

Programming

When a PLC programming is carried out, using ladder diagrams, a program is written in a similar manner to drawing a switching circuit.

The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines. The rungs of the ladder between these two verticals.

- Logic Function: AND, OR, NOR, NAND, EXCLUSIVE – OR (XOR)
- Latching: Sometimes there are situations where it is necessary to hold a coil energised, even when the input which energises it ceases.
- Sequencing: Invariably there are control situations where sequences of outputs are required with the switch from one output to another being controlled by sensors.

Mnemonics

In a ladder program each horizontal rung on the ladder represents a line in the program and entire ladder gives the complete program in ladder language. The programmer can enter the program into the PLC using a keyboard with the

graphic symbols for the ladder elements on using a computer screen and a mouse to select symbols, and the program panel or computer then translates these symbols into machine language that can be stored in the PLC memory.

Alternatively a program can also be entered by translating the ladder program into mnemonics each code corresponding to a ladder element and then enter these into the programming pannel or computer. These are then translated into machine language.

Master and jump Controls

A whole block of outputs can be simultaneously turned off or on by using the same internal relay contacts in each output rung so that switching it on or off effects every one of the rungs. An alternative way of programming to achieve the same effect is to use a master relay.

- Jumps. A function which is often provided with PLCs is the conditional jump function. Such a function enables programs to be designed so that if a certain condition exists then a section of program is jumped.

CHPT-5 ELEMENTS OF CNC MACHINES

Introduction to Numerical control of & CAD/CAM

Modern machine Tools - Newer machine tools have been built to absorb newer machining technologies to cope with newer and tougher materials. New technologies include Ultrasonic machining (USM), (ECM), LBM, etc. Numerical control, NC can be defined simply as control some or A-machine tool having a dedicated computer to help prepare the program and control some or all of the operations of the machine tool is called computer. Numerical control (CNC) machine tool.

NC MACHINES - NC machine assimilate a method of automation, where automation of medium and small volume production is done by some controles under the instruction of a program. The definition of NC as given by EIA is as under.

Working of NC machine - • The first two steps, component drawing and process pranning are similar in both operator controlled and NC machine tools.

• In the operator controlled machine tools, the operator controls the cutter position during manufacture and also makes necessary adjustments and corrections to produce the desired component. • Howere in NC machine tool the operator is replaced is replaced by the data processing part of the system and

Main elements of NC machine tool

1. The control unit
2. The drive unit.
3. The position feedback package
4. Magenetic box.
5. Manual control.

Advantages of NC machine

1. Accuracy achived is of high order
2. Reduced production cost per piece
3. Less scap.
4. High production rates
5. Less operator skill required
6. Excellent reliability
7. tooling cost Low.
8. production of complex parts
9. Elimination of special jigs & fixtures
10. Easy and effective production planning.

CNC MACHINES

Functions of CNC - 1. Machine tool control. 2. In-process tool control, 3- Improved programming and operating features, 4- Diagnostics.

Advantages (CNC)

1- Greater Flexibility, 2- Reduced data reading error, 3- Increased productivity 4- Consistent quality, 5. Automatic material handing. 6- Elimination of operator errors.

7. Lower labour cost.
8. Longer tool life. 9- Reliable operation.
10- CNC machine can diagnose program and can detect the machining malfunctioning even before the part is produced.

Disadvantages (CNC)

1. Higher investment cost.
2. Higher maintenance cost
3. costlier CNC personnel
4. Airconditioned places are required for the installation of the machines.
5. unsuitable for long run applications.
6. planned support facilities.

Application of (CNC)

- Drilling machines, • Turning machines
- Boring, milling, Grinding machinges
- pipe bending machines, Flame cutting
- welding, wire cut EDM & several other areas.

(CAM) - Computer Aided Design

important elements CAM - 1. CNC manufacturing and programming techniques
2- computer controlled robotics manufacture
3- Flexible manufacturing system (FMS).
4- Computer Aided Inspection (CAI) techniques.
5- Computer Aided Testing (CAT) techniques.

Advantages (CAM)

1- product obtained is superior in quality.
2. The manufactured from has a greater versatility.
3. Higher production rates with lower work for
4. There is less likelihood of human error.
5. The production processes can be repeated via storage of data.

(CAD) computer Aided Design

Advantages. 1- Drawings can be produced at a faster rate., 2- Drawings produced by CAD system are more accurate and neat.
3- In this system there is no repetition of the drawings. 4- cad systems assimilate several special draughting techniques which are not available with conventional means.
5- Design calculation and analysis can be carried out quickly.
6. Using CAD systems design can be integrate with other disciplines.

Software & hardware For CAD/CAM

Software - Software usually consists of a number of separate application packages to perform the desired function. The size of computer depends on the number and sizes of packages and number of work stations

Hardware - Hardware is reliability and speed of responce of the system. A wide range of standard software is available and generally it is not worth developing users own software. Through a system can be built up from standard software packages from different sources and standard hardware, it is often costly because of the considerable programming effort required to interface the packages to a common data base to provide user friendly software to adapt the system to the user's requirements.

Functioning of CAD/CAM System

→ CAD/CAM is an interactive computer graphic tool that enhances design and manufacturing functions to create a highly profitable product

→ It is not a standard tool which can be fitted into any company but has to be tailored to suit the needs of the company. It is rather complex technology and has wide potential for immediate benefits.

→ usually this tool consists of a dedicated computer, which is connected to a number of work-stations. The system is used to assist in the design and manufacturing, through the use of an expandable set of linked software modules. → A designer can define dimension and display views of 2 dimensions, $2\frac{1}{2}$ dimensions and 3 dimensions. parts on modules. → It is possible to store complete details of designs on numerical control types for subsequent use on demand.

Features & Characteristics (CAD/CAM)

1. A major portion of the output of the engineering sector involves batch production and CAD/CAM offers immense cost and quality benefits for such requirements.
2. The work-in-progress, in batch production, is reduced considerably.
3. It is possible to produce at random all the variants and series of a product planned to be manufactured by a firm.
4. Such a system has inherent flexibility to cater to new models of the product in pipeline without major modification.
5. In such a system, several maching centres are arranged one after the other with robots and proper automatic materials handling equipment. Each machining centre is equipped with several tool magazines.
6. All the part programs for the different models are stored in the memory. System has only to identify the model of the product presented to a machine in order to complete the machining operations.
7. The system can be conceived in multiplies of 15-20 minutes operations. If certain operation take longer. Sometimes identical machines are introduced for each operation so that production can continue even if one machine goes down.
8. The components are loaded onto a pallet. means are provided to identify the exact model. By calling up and manipulating standard fixturing components, like studs, stops, clamps, bushes, it is possible to design a fixture for a component

already designed on the CAD/CAM system.

Application areas for CAD/CAM

1. Design and design analysis.

- CAD system would be best suited for drawing offices where frequent modification are required on drawing and several parts repeat.
- once a drawing is entered in the CAD system later modifications can be done quickly, and detail drawindwing. → NC tapes can be produced.

→ storing of the drawing is very convenient, easy. occupies very less space and symbols for electrical, hydraulic, control, instrumentation circuits can be called up quickly and positioned on the schematic drawing.

→ It is very convenient to calculate properties like weight center of gravity, moment of inertia. because 3D models can be easily produced

→ It is also possible to carry out finite element analysis by producing meshing for analysis.

2. Manufacture.

- With CAD/CAM system the complete NC part programming process can be carried out interactively, including post processing and production ~~of meshing for~~ of NC tape source programs in languages such as APT can be produced. systems can verify tapes by producing tool centre path plots.

ROBOTICS

Robotics is the art knowledge base and know how of designing, applying and using robots in the human endeavors.

or

Robotics is the science of designing and building robots suitable for real-life applications in automated manufacturing and non-manufacturing enviroments.

Advantages

1. Reliability
2. Increased Flexibility
3. Low cost in the long run.

LAWS OF ROBOTICS

→ Zeroth law. A robot must not injure humanity or through inaction. allow humanity to come to harm.

→ First law. A robot must not harm a human being or, through inaction, allow one to come to harm.

→ Second Law. A robot must always obey human beings unless it is in conflict with a higher order law.

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→ Second Law. A robot must always obey human beings unless it is in conflict with a higher order law.

Third Law. A robot must protect itself from harm unless that is in conflict with a higher order law.

The origin of word 'robot' is in the Czech word 'robota' meaning either a slave or a mechanical item that would help its master.

Definition of a Robot

A 'robot' is an automatic device that performs functions normally ascribed to humans or a machine in the form of a human.

or

"A robot is a software-controllable mechanical device that uses sensors to guide one or more end-effectors through programmed motions in a workpiece in order to manipulate physical objects.

FUNCTIONS OF A ROBOT

1. 'Sensing' the environment by external sensors.
   Example: vision, voice, touch, proximity
2. "Decision making" based on the information received from the sensors.
3. "performing" the task decided.

ADVANTAGES AND DISADVANTAGES

Advantages

1. Lifting and moving heavy objects
2. working in hostile environments
3. providing repeatability and consistency
4. working during unfavourable hours.
5. Increasing productivity, safety, efficiency and quality of products.
7. Achieving more accuracy than human beings.

Disadvantages

1. The robots lack capability to respond in emergencies.
2. The initial and installation costs of equipments of robots are quite high.
3. They replace human workers, thus causing resentment among workers.

TYPES OF INDUSTRIAL ROBOTS

Industrial robots can be broadly divided into two main groups as follows.

1. General purpose robots
2. special purpose robots.

1. General purpose robots

- These robots carry standard designes and parts and are readily available.
- They can be easily adapted to the users' requirements by attaching suitable end-effectors or fingers to them according to the requirement of the work, such as a part picking operation, welding operation, spry painting, etc.
- Since such robots are mass produced, they are cheaper.

2. Special purpose robots

- These robots are made to specific job requirement The ultimate user has of Feed his requirements and, based on them, these robots are specially designed and built to cater to such specific needs. obviously, their designing and manufacturing consumes a lot of time. As such they can not be readily available in market
- Since they can not be manufactured on mass scale, their prices are bound to be higher.

ROBOTIC SYSTEMS

A system is an integral whole of parts or subsystems. It has a specific goal or output for a given set of inputs a system may have many goals as well.

- A "robot" is a system as it combines several subsystems that interact themselves as well as with the environment in which the robot works.

(ii) To simply pick up and place the workpieces.

(iii) To interact with and work load a lathe, a milling machine or any equipment.

(iii) To perform some assembly work.

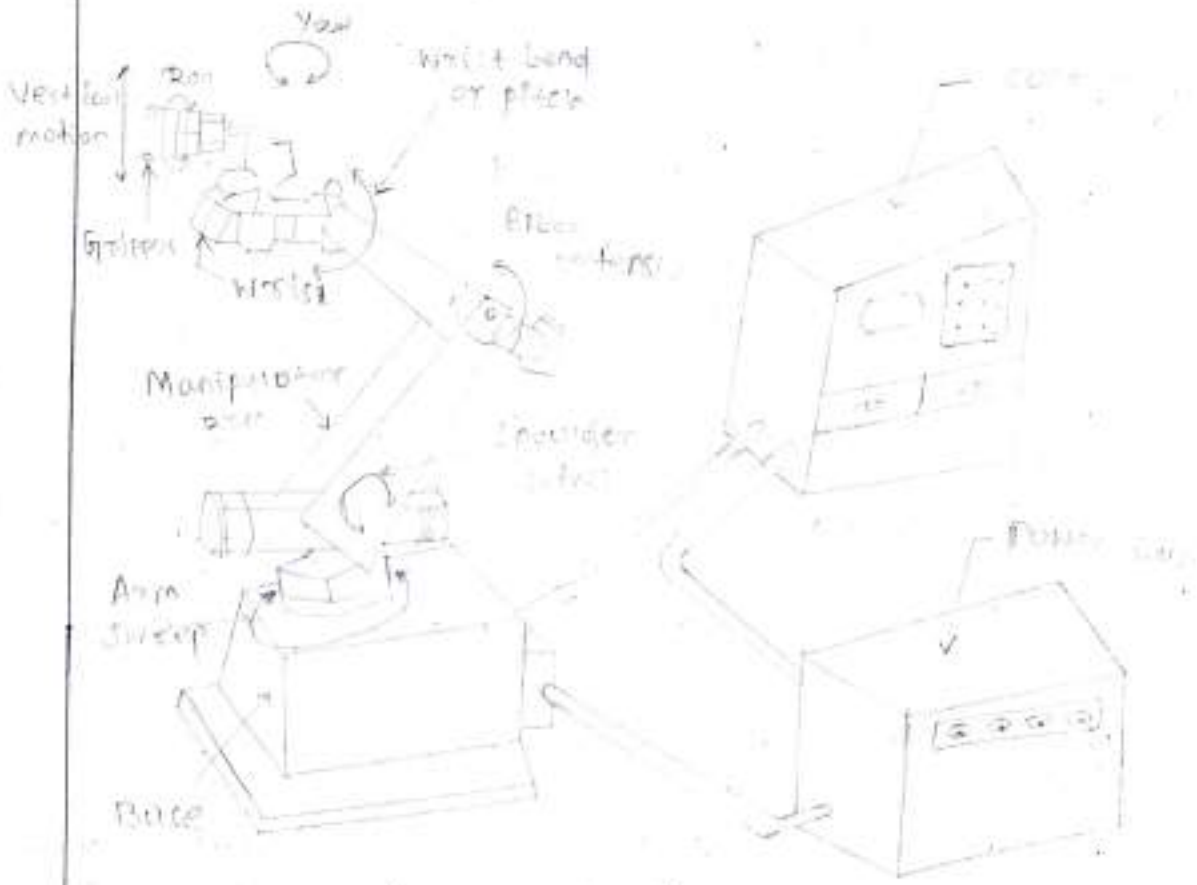
A suitable manipulator arm with specified coordinate systems to attain a designed reach in the working space.

A suitable control system with or without servo-mechanisms for sending signals to the drives or permitting storage of programmes and data for desired path planning with adequate speed and good accuracy.

Some sensors to feed back information for modifying the motion or pact.

A controller is provided with interfacing units. connected to external equipment in the outside world.

Robot Components



Robotic system - Main components of a robot and the basic motions The various components of a robot are enumerated and discussed below.

1. Base
2. manipulator arm
3. End-effector.
4. Actuators and transmissions
5. Controller
6. Sensors

1. Base

- The base may be fixed or mobile

2. Manipulator arm

- The most obvious mechanical configuration of the robot is the manipulator arm.
- There are several designs of the arm to facilitate movement within the work envelope with maximum possible load and speed with high precision and repeatability.
- The simplest robot may be a two or three-axes arm. The axis is meant to understand independent movement or degree of freedom (DOF)

3. End-effector

- Robot end-effector is the gripper or end of arm tooling mounted on the wrist of the robot manipulator arm.
- A robot performs a variety of tasks for which various tooling and special grippers are required to be designed.

The wide range of gripping methods include.

(i) Mechanical clamping
(ii) Magnetic gripping
(iii) Vacuum "

4. Actuators and Transmissions

Actuators

The robot arm can be put to a desired motion with its payload if actuator modules are fitted in to provide power drives to the systems.

(i) Pneumatic drives
(ii) Hydraulic drives
(iii) Electrical drives

Transmissions

'Transmissions' are elements between the actuators and the joints of the mechanical linkage.

They are generally used for the following 3 reasons.

(i) often the actuator output is not directly suitable for driving the robot linkage.
(ii) The output of the actuator may be kinematically different from the joint motion.
(iii) The actuators are usually big and heavy and often it is not practical to locate the actuator at the joint.

5. Controller

The "controller" provides the intelligence that is necessary to control the manipulator system.

It looks at the sensory information and computes the control commands that must be sent to the actuators to carry out the specified tasks.

- The user "interface" allows the use of a human operator to monitor or control the operation of the robot.

6. Sensors

The sensors perform the following function.

(i) To act feedback devices to direct further actions of manipulator arm and the end effector

(ii) To interact with the robot's working environment.

(i) TACTILE SENSORS

These are 'contact sensors' that must be brought in contact with the object to obtain signal to measure the necessary qualities.

(ii) Non-tactile sensors

These are 'contactless sensors' which sense the signals necessary but only within the specified range of distance from the object.

- Typical non-contact robotic sensors include.
  (a) proximity sensors
  (b) Electro-optical sensors (c) Range imaging sensors