POLITEKNIK MALAYSIA
TUANKU SULTANAH BAHIYAH

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KOLEJ KOMUNITI MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

DJM50113 INDUSTRIAL AUTOMATION

VOLUME 1

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SYNOPSIS

THE INDUSTRIAL AUTOMATION explains the fundamental concepts of industrial automation including the mechanical system, actuator control and sensory devices in based on process specification. It also gives students an understanding of modern industrial automation technology.

COURSE LEARNING OUTCOMES(CLO):

CLO1: Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices. (C2, PLO1)

CLO2: Develop control structure for industrial automation system based on process specification. (P4,PLO5)

CLO3: Demonstrate good communication skills in group on assigned topic. (A3,PLO10)

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Introduction And Basic Concept Of Automation

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.

CHAPTER 1

1.0 Introduction And Basic Concept Of Automation

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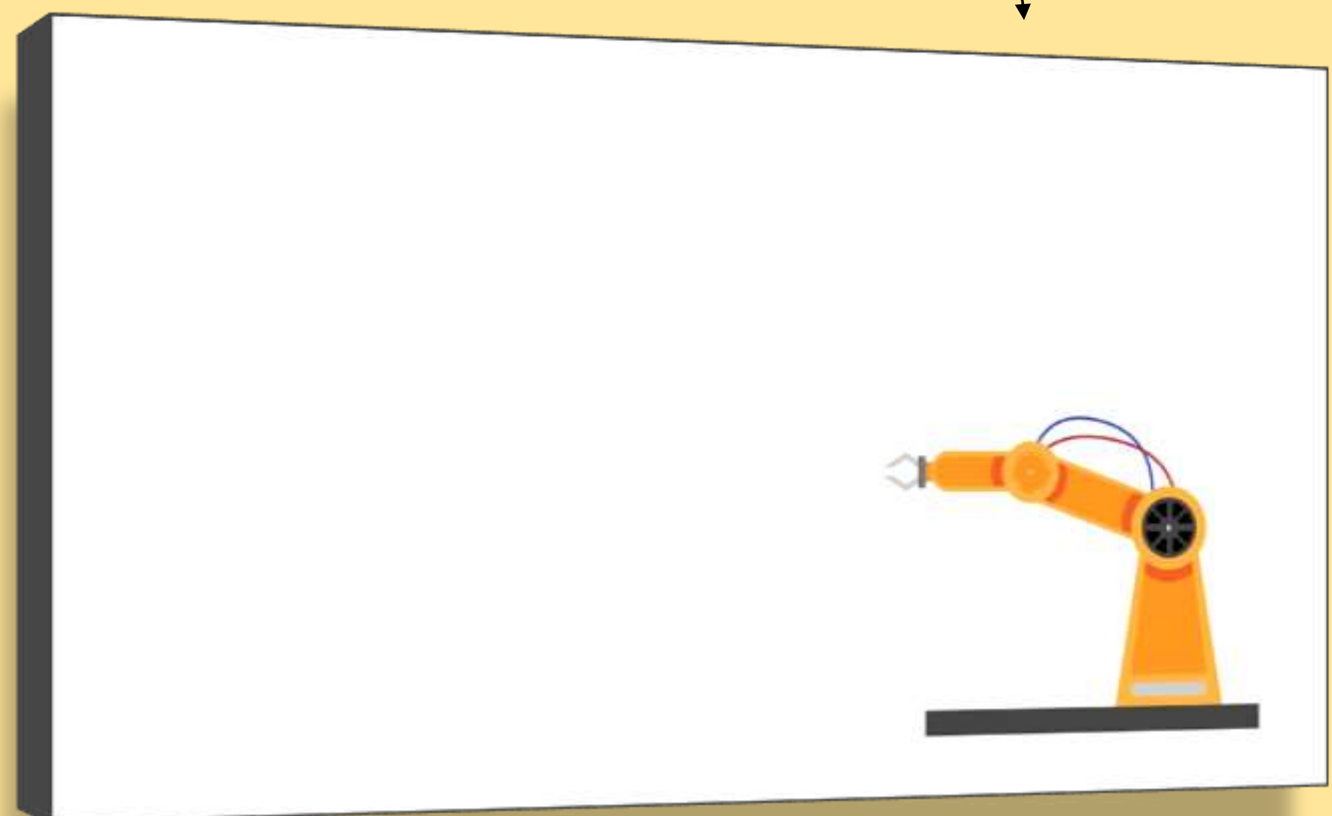
- 1.1.1 Definition of industrial automation
- 1.1.2 State the advantages & disadvantages
- 1.1.3 Identify types of automation
- 1.1.4 Describe the Automation in production system

1.2 Explain the basic concept of automation terminology
- 1.2.1 Describe the Basic Concept following:
  - a. Link and Joint
  - b. Degree of freedom (DOF)
  - c. Orientation Axes
  - d. Position Axes
  - e. Tool Centre Point (TCP)
  - f. Work envelope/workspace
  - g. Speed
  - h. Payload
  - i. Repeatability
  - j. Accuracy
  - k. Settling Time
  - l. Control Resolution
  - m. Coordinates

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

WHAT IS INDUSTRIAL AUTOMATION??
LET'S WATCH THIS VIDEO



1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

1.1.1 Definition of Industrial Automation

Definition Industry:

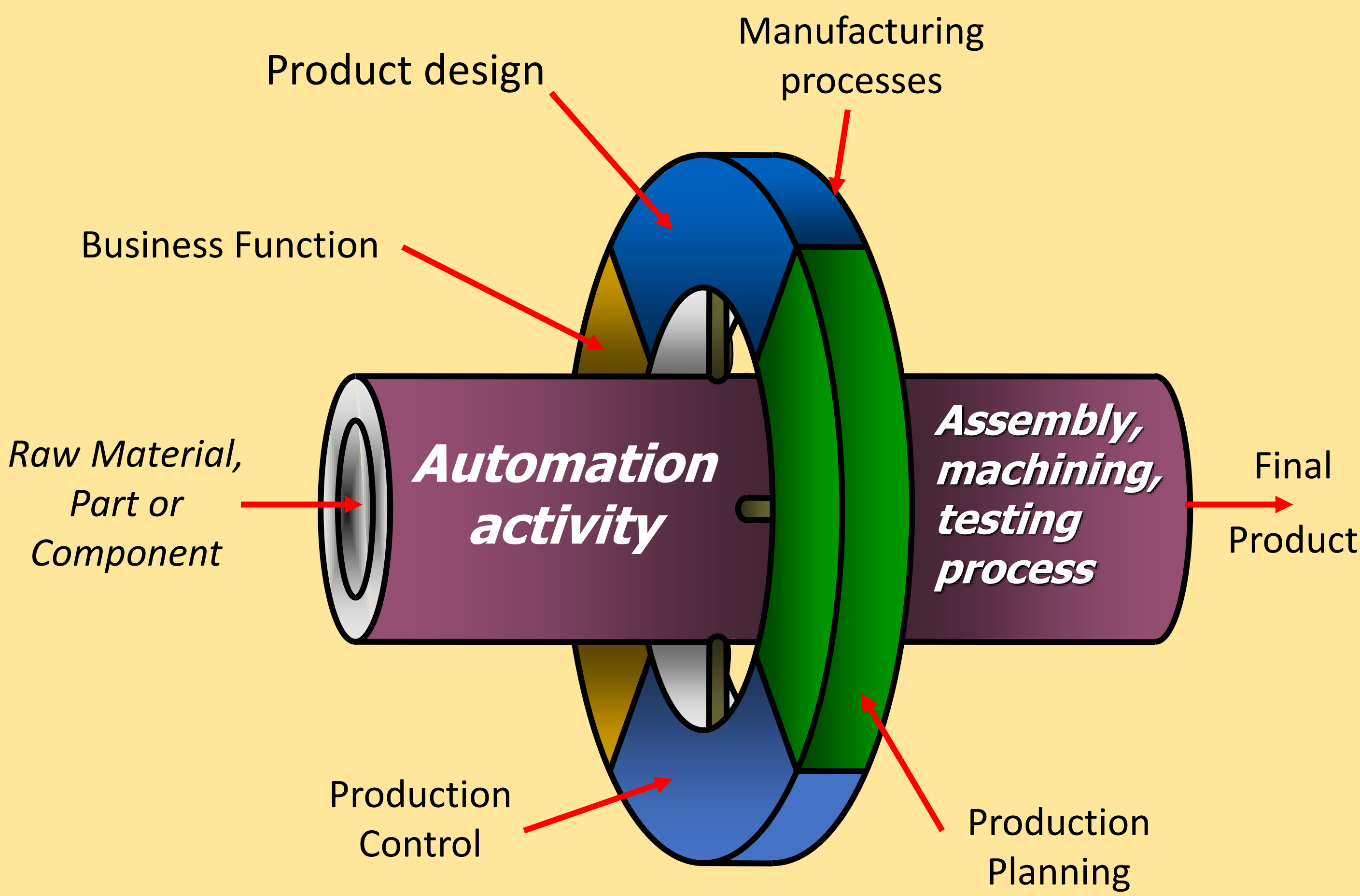
Systematic Economic Activity that could be related to Manufacture /Service/ Trade.

Definition Industrial Automation:

Automation is a set of technologies that results in operation of machines and systems without significant human intervention and achieves performance superior to manual operation

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

AUTOMATION CONCEPT



1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

1.1.2 State the advantages & disadvantages

1. To increase labour productivity

- Automating a manufacturing operation usually increases production rate and labour productivity. This means greater output per hour of labour input.

2. To reduce labour cost

- Ever-increasing tabor cost has been and continues to be the trend in the world's industrialized societies. Consequently, higher investment in automation has become economically justifiable to replace manual operations. Machines are increasingly being substituted for human lahar to reduce unit product cost.

3. To migrate the effects of labour shortages

- There is a general shortage of labour in many advanced nations and this has stimulated the development of automated operations as a substitute for labour.

4. To reduce or eliminate routine manual and clerical tasks

- An argument can be put forth that there is social value in automating operations that are routine, boring, fatiguing, and possibly irksome. Automating such tasks serves a purpose of improving the general level of working conditions.

5. To improve worker safety

- By automating a given operation and transferring the worker from active participation in the process to a supervisory role, the work is made safer.

6. To improve product quality

- Automation not only results in higher production rates than manual operations. It also performs the manufacturing process with greater uniform and conformity to quality specifications. Reduction attraction defect rate is one of the chief benefits of automation.

7. To reduce manufacturing lead time

- Automation helps to reduce the elapsed time between customer order and product delivery, providing a competitive advantage 10 the manufacturer for future orders

8. To accomplish processes that cannot be done manually

- Certain operations cannot be accomplished without the aid of a machine. These processes have requirements for precision, miniaturization or complexity of geometry that cannot be achieved manually.
- Examples include certain integrated circuit fabrication operations, rapid prototyping processes based on computer graphics (CAD) models, and the machining of complex, mathematically defined surfaces using computer numerical control. These processes can only be realized by computer controlled systems.

9. To avoid the high cost of not automating

- There is a significant competitive advantage gained in automating a manufacturing plant. The advantage cannot easily be demonstrated on a company's project authorization form. The benefits of automation often show up in unexpected and intangible ways, such as in improved quality, higher sales, better labour relations, and better company image.

1. Higher Start-up cost and the cost of operation

- Automated equipment includes the high capital expenditure required to invest in automation. An automated system can cost millions of dollars to design, fabricate, and install.

2. Higher Cost of Maintenance

- A higher level of maintenance needed than with a manually operated machine. These include buying electromechanical devices such as electromechanically valve, sensory devices, and smart devices.

3. Unemployment

- A disadvantage often associated with automation, is worker displacement. Due to the fact that manual laborers are being replaced by robots or other automated machineries, this results to mass lay-off. A lot of people are losing their jobs especially those who work in the manufacturing industry such as a car factory.

4. Not economically justifiable for small scale production

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

1.1.3 Identify types of automation

Automated manufacturing systems can be classified into three basic types:

1 Fixed Automation

2 Programmable Automation

3 Flexible Automation

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

1

Fixed Automation

- Fixed/hard automation is designed for large volume production of a single product or task. The machine layout is designed to the fixed sequence of operations.

Pros:

- Typically, lower build costs compared to programmable and flexible options.
- Improved product consistency.
- Operates at high speed for a high production rate.
- Lower unit cost for each piece sold.

Cons:

- Machine layout inflexible, so alterations to design are costly and time-consuming.

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

- Examples of fixed automation include machining transfer lines found in the automotive industry, automatic assembly machines, and certain chemical processes.

- This is relatively useful for many companies who use automation to create food products of one type and variant. It allows them to effectively produce that item and package it in bulk.

- Coco Cola continues to use this automation in their factories. This allows for the production of large quantities of the soft drink, allowing Coco Cola to meet high demands of their classic soft drink.

2 Programmable Automation

- Programmable automation allows the production equipment and automation to be altered to changing needs. This is done by controlling the automation through a program, which can be coded in certain ways for the automation to change the sequence of automation.
- It's used more commonly in low to medium levels of production, often being most suitable for batch production.
- Programmable automation will often be used by factories who make different variants of foods. This allows them to make batches, from a few dozen to potentially thousands at a time, of one product. If the product needs changing, it simply needs to be reprogrammed.

Pros:

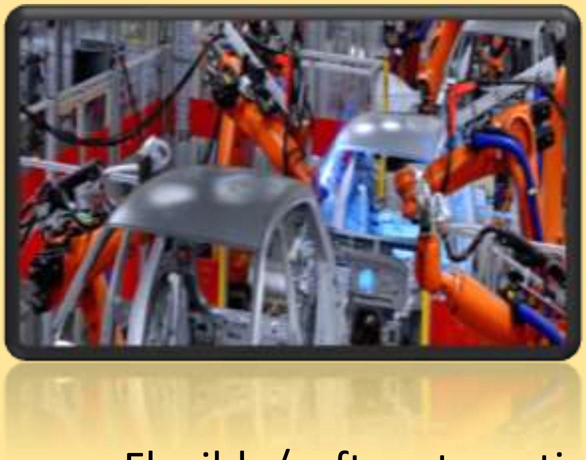
- Flexible system
- Suitable for batch runs from 50 to 1000 unit

Cons:

- Re-configuring the system can still be time-consuming.
- This system requires an upfront substantial investment for general purpose programmable equipment.

Advantages include:

- ✓Flexibility to change products if needed
- ✓Suitable if batch production is required
- ✓Disadvantages include:
- ✓Expensive for equipment
- ✓Lower production levels
- ✓Often time-consuming to change products
- ✓This type of automation is well suited f
- ✓Low/Medium demand and occasional changes in products.



3

Flexible Automation

- Flexible/soft automation is an extension of programmable automation, but with less time lost for reprogramming or tool changes. This automation is for the manufacturer that needs to run a variety of products with no downtime between batches.

Pros:

- Continuous production includes in sequence product variables.
- Medium production.

Cons:

- Higher initial investment than fixed or programmable.
- Components that allow for quick changes, such as a robot arm, will need logic controllers, sensors and lasers.
- Skilled labor for part changes, maintenance, and other supervisory duties.

Fixed

Best suited for high volume production lines with consistent production design

- Unit costs are low and production output is high.
- Unit costs are low and production output is high.

Programmable

Best suited for a variety of action sequences that occur in batches including new additions to sequence repertoires.

- Automated sequences are reprogrammable.
- Reprogramming new sequences is time consuming and output is low.

Flexible

Best suited for various program sequences that cannot be executed in batches.

- Automated sequences can change without lags.
- Expensive initial implementation.

1.1 DESCRIBE THE CONCEPT OF INDUSTRIAL AUTOMATION

1.1.4 Describe the automation in production system

- A production system is a collection of people, equipment, and procedures organized to perform the manufacturing operations of an organization.
- A production system consists of facilities and manufacturing support systems (Figure 1).

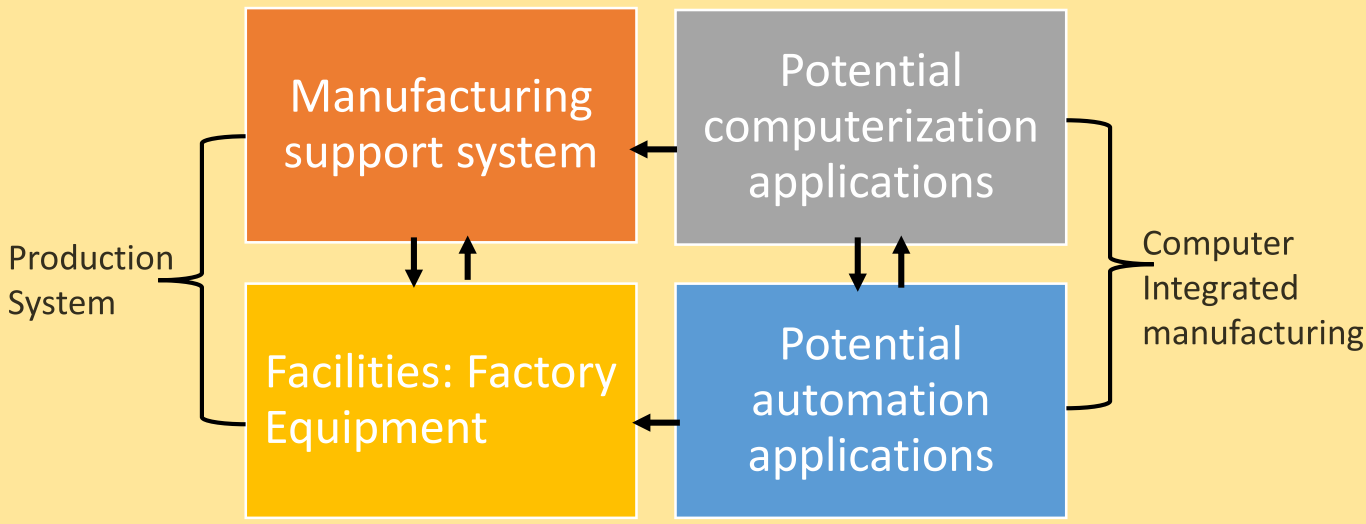


Figure 1

i. Facilities—The factory, the equipment in the factory, and the way the equipment is organized around the shop floor.
ii. Manufacturing support systems—The set of procedures used to manage production and to solve technical and logistics problems met in manufacturing processes.

These systems include product design, planning and control, logistics and other business functions.

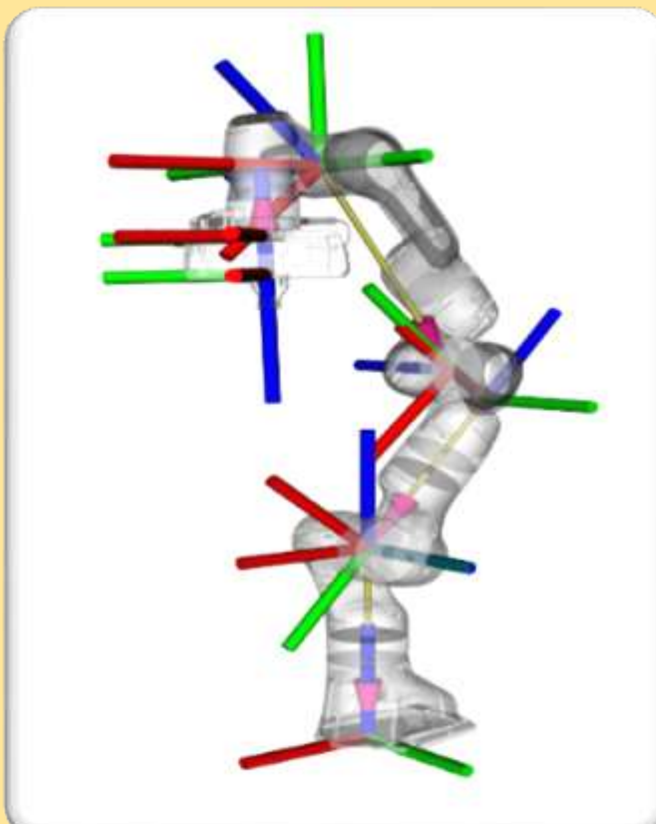
Three categories of manufacturing systems

Category	Description
Manual Work System	• One or more workers performing one or more task without powered tools. Typical example is the material handling task. • In production tasks the use of hand tools is pre-dominant, sometimes with optional work holder. • Example include: Filling milled parts, checking quality of parts with micrometers, moving cartons using a dolly and assembling machinery using hand tools.
Worker Machine System	• A human worker operates powered equipment in various combinations of one or more workers and one or more pieces of equipment. • Relative strengths of humans and machines are combined. • Example include: machinist operating engine lathe, a filter working with an industrial robot, a crew of workers operation a rolling mill and personnel performing work on a mechanized conveyor.
Automated Systems	• Process is performed by machine without the direct participation a human worker. • Automation uses a programmed of instructions and a control system for implementations. • Two sub categories which semi automated and full automated. • Semi automated implies only part of the work cycle is completely automated with other work done by a human worker. • Fully automated has the capacity to operate for extended periods of time with no human interaction. • Example include: Injection moulding machines and automated processes of oil ferneries and nuclear power plants.

1.2 EXPLAIN THE BASIC CONCEPTS OF AUTOMATION TERMINOLOGY

1.2.1 Describe the basic concept following:

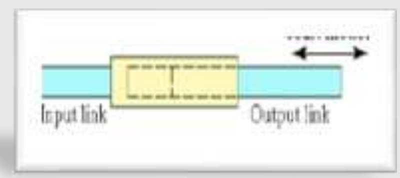
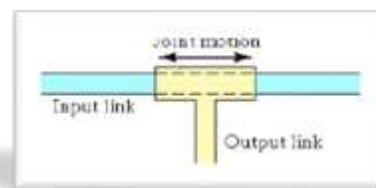
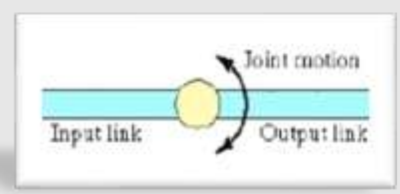
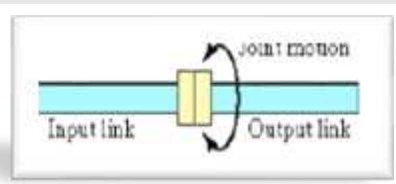
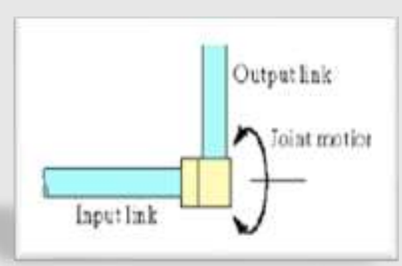
a. Link and Joint
b. Degree of freedom (DOF)
c. Orientation Axes
d. Position Axes
e. Tool Centre Point (TCP)
f. Work envelope/workspace
g. Speed
h. Payload
i. Repeatability
j. Accuracy
k. Settling Time
l. Control Resolution
m. Coordinates



1.2 EXPLAIN THE BASIC CONCEPTS OF AUTOMATION TERMINOLOGY

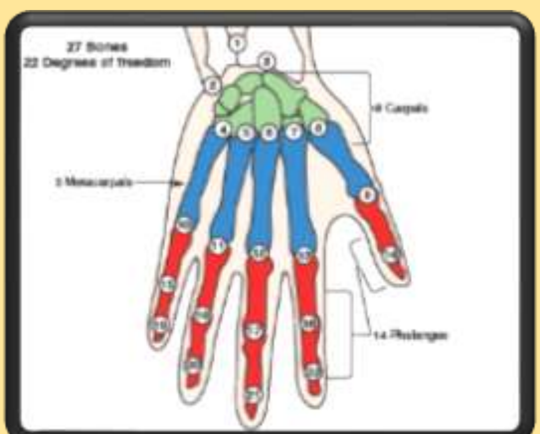
1.2.1 Describe the basic concept following:

a. Link and Joint

Joint	Description	Schematic
Linear Joint	<u>Type L joint</u> The relative movement between the input link and the output link is a translational sliding motion with the axes of the two links parallel.	
Orthogonal Joint	<u>Type O joint</u> The relative movement between the input link and the output link is a translational sliding motion. But the output link is perpendicular to the input link.	
Rotational Joint	<u>Type R joint</u> This provides rotational relative motion with the axis of rotation perpendicular to the axes of the input and output links.	
Twisting Joint	<u>Type T joint</u> This provides rotary motion, but the axis of rotation is parallel to the axes of the two links.	
Revolving Joint	<u>Type V joint</u> The axis of the input link is parallel to the axis of rotation of the joint. The axis of the output link is perpendicular to the axis of rotation.	

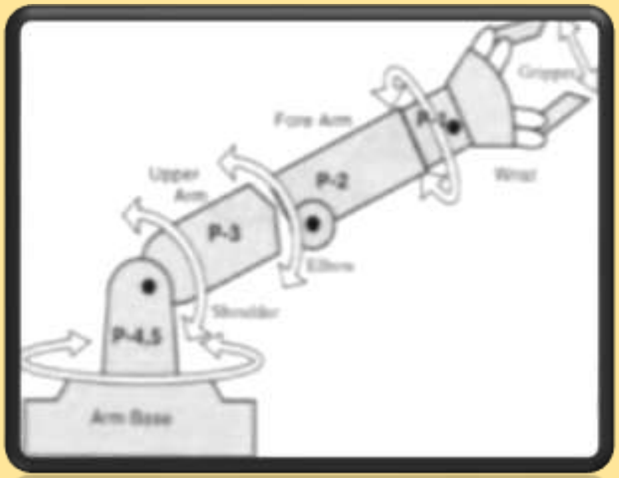
b. Degree of freedom (DOF)

- Each joint on the robot introduces a degree of freedom. Each DOF can be a slider, rotary, or other type of actuator.
- Robots typically have 5 or 6 degrees of freedom. 3 of the degrees of freedom allow positioning in 3D space, while the other 2 or 3 are used for orientation of the end effector.
- 6 degrees of freedom are enough to allow the robot to reach all positions and orientations in 3D space.
- 5 DOF requires a restriction to 2D space, or else it limits orientations.
- 5 DOF robots are commonly used for handling tools such as arc welders



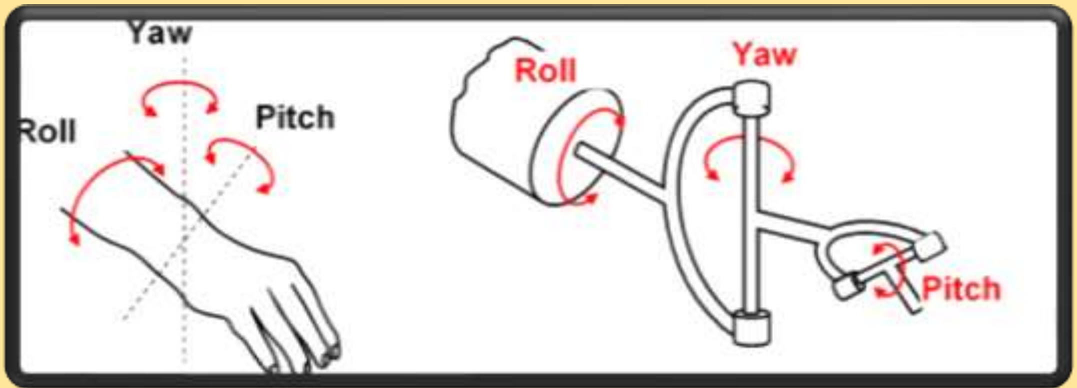
Each joint represents a degree of freedom.
There are 22 joints and thus 22 degree of freedom in the human hand.

b. Degree of freedom (DOF)



- The robot has five degrees of freedom.
- It hove move in five independent ways.
- Base Joint: This joint allows movement of 350° rotational motion.
- Shoulder Joint: This joint allows movement of 120° rotational motion.
- Elbow Joint: This joint allows movement of 135° rotational motion.
- Wrist Joint: This joint allows movement of 340° rotational motion.
- Gripper: This joint allows movement of 2 linear motions (open and close actions).

c. Orientation Axes



- The angle formed by the major axis of an object relative to a reference axis.
- It must be defined relative to a three dimensional coordinate system.
- If the tool is held at a fixed position, the orientation determines which direction it can be pointed in.
- Roll, pitch and yaw are the common orientation axes used.

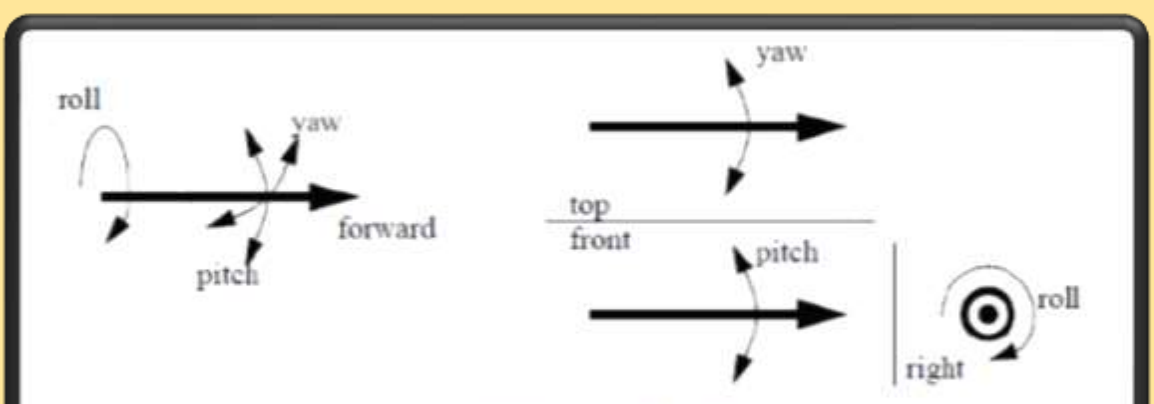
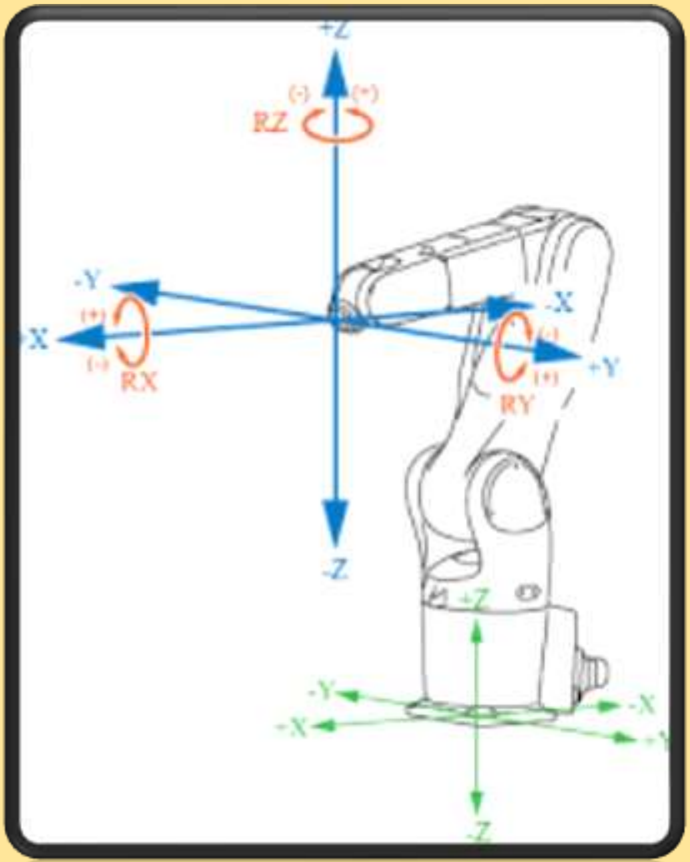


Figure 1.14: Orientation Axes

d. Position Axes

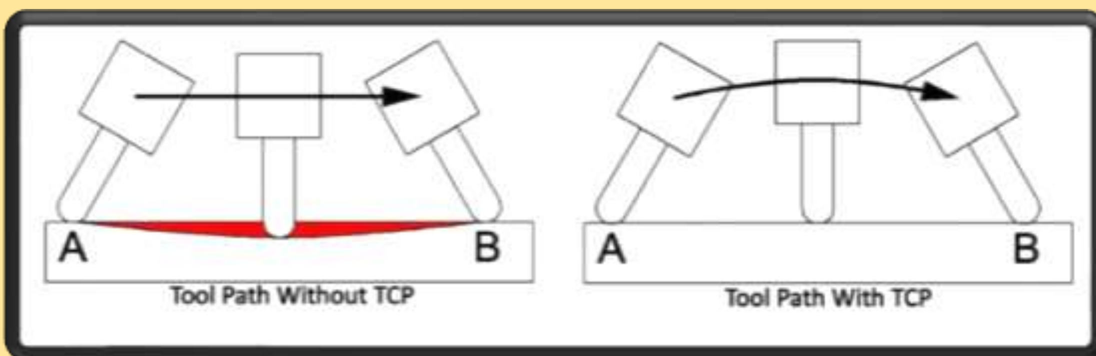


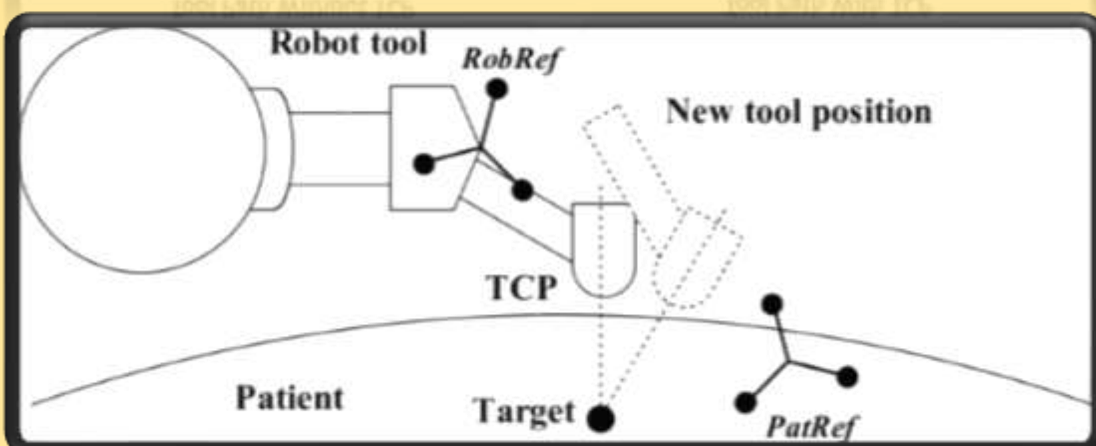
- The tool, regardless of orientation, can be moved to a number of positions in space.
- Various robot geometries are suited to different work geometries.
- The definition of an object's location in 3-D space, usually defined by a 3-D coordinate system using X, Y, and Z coordinates.
- Part of a robot can move to a spot within its work envelope, using devices that tell it exactly where it is.

e. Tool Centre Point (TCP)

- A Tool Center Point or (TCP) is used to create the necessary adjustment. This allows the controller to shift the coordinate system to keep track of the tool instead of the arm's end.

- Once the TCP has been set, rarely does it cause issues with the system unless some external factor has caused it to change, like a hard crash. If the robot has suffered a hard crash, damage to the robotic tool may have changed its physical location





f. Work envelope/workspace

- Work envelope is the volume/area where the robotic arm can perform task/work.
- The space in which a robot can operate is its work envelope, which encloses its workspace.
- While the workspace of the robot defines positions and orientations that it can achieve to accomplish a task, the work envelope also includes the volume of space the robot itself occupies as it moves.

g. Speed

- Speed is the rate of movement from point to point done by robots under the control of the program.
- It is a measure of the speed of the device.

h. Payload

- The payload indicates the maximum mass the robot can lift before either failure of the robots, or dramatic loss of accuracy.

i. Repeatability

- The degree ability of a robotic arm to detect targets has been set correctly and then returns to its original point in the work cell.

- The robot has a high repeatability will be able to repeat the task with the right repeatedly without error.

j. Accuracy

- The degree of ability that can be made by a robotic arm to move to a certain point in the work cell as we enter the coordinates in the off-line programming station (off-line programming).

k. Settling Time

- The settling time is the time required for the robot to be within a given distance from the final position.
- During a movement, the robot moves fast, but as the robot approaches the final position is slows down, and slowly approaches.

l. Control Resolution

- Capability of robot's positioning system to divide the motion range of each joint into closely spaced points.

m. Coordinates

- Combination of both the position of the origin and orientation of the axes.
- Points are programmed in the cells identified job position by using the values of the coordinates x, y and z of the tools midpoint and extension angles at the wrist axis robot arm is pitch, roll and yaw.

EXERCISE

1. Define Automation.
2. State the main objectives of a modern industry (at least five) and explain the role of automation in helping achieve these.
3. Differentiate between Automation and Mechanization.
4. What are different types of Automation?
5. Can you give an example of an automated system, which contains a control system as a part of it?
6. List some major points why automation is required in industry.
7. What are the advantages and disadvantages of automation?
8. Discuss the concept of low cost automation with the help of suitable example.
9. Discuss the basic elements of an automated system.
10. Describe with neat sketch close loop and open loop control system.
11. How do you classify assembly lines? Explain.
12. Why does an automated system achieve superior performance compared to a manual one? Can you give an example where this happens?
13. During a technical visit to an industry how can you identify the type of automation prevailing there from among the above types?
14. For what kind of a factory would you recommend computer integrated manufacturing and why?
15. What kind of automation would you recommend for manufacturing
    i. Light bulbs
    ii. Garments
    iii. Textile
    iv. Cement
    v. Printing
    vi. Pharmaceuticals
    vii. Toys

EXERCISE

16. What is meant by a production system, and what categories of production system are generally specified.
17. Manufacturing systems depend for their operation on the interaction of manual labor and automation. What are the categories of manual labor / automation that can be identified? What mode of automation do these categories usually operate in?
18. When is automation used in a manufacturing system? Describe the three types of automation that can be used in a manufacturing system.
19. Manual labor is used alongside automation in production systems. Name a number of the issues that affect the use of manual labor in production systems.
20. What elements should a strategy for automation implementation consider?
21. Describe the role of Industrial Automation in ensuring overall profitability of a industrial production system. Be specific and answer point wise. Give examples as appropriate.
22. State TWO types of robot control systems and sketch the control system diagram.
23. Name and sketch FIVE types of robots joint with arrow indicate the movement of the joint.
24. Explain the following for the basic concept of Automation.
    i. Degree of Freedom (DOF)
    ii. Tool Center Point (TCP)
    iii. Work Envelope
    iv. Pay load
    v. Repeatability
    vi. Accuracy
    vii. Settle time
    viii. Control Resolution

CHAPTER 2

Component and Applications of Automation System

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.

CHAPTER 2

2.0 Component and Applications of Automation System

2.1 Describe the basic component of an automation system

2.2 Explain the automation system in an application

2.3 Illustrate the function of an automation systems

2.3.1 Describe specifications of an automation systems relate automation system in industry

2.0 COMPONENT AND APPLICATIONS OF AUTOMATION SYSTEM

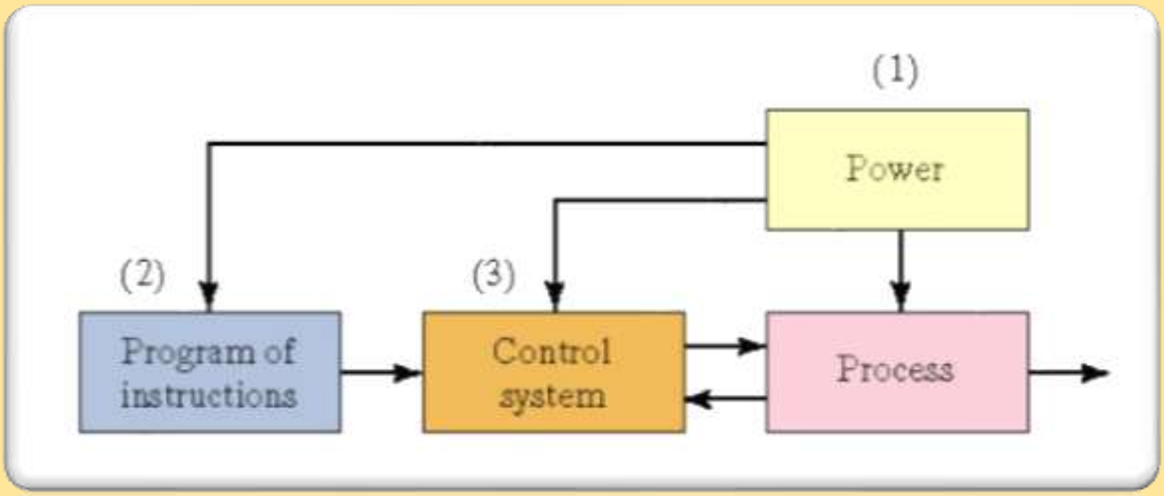
2.1 Describe the basic component of an automation system

Basic elements of an automated system

1. Power - to accomplish the process and operate the automated system.

2. Program of instructions – to direct the process.

3. Control system – to actuate the instructions.



Power to accomplish the automated process:

1. Power for the process
   - To drive the process itself
   - To load and unload the work unit
   - Transport between operations

2. Power for automation
   - Controller unit
   - Power to actuate the control signals
   - Data acquisition and information processing

3. Electricity - The Principal Power Source
   - Widely available at moderate cost
   - Can be readily converted to alternative forms example mechanical, thermal and light.
   - Low level power can be used for signal transmission, data processing, and communication.
   - Can be stored in long-life batteries

4. Program of Instructions
   - Set of commands that specify the sequence of steps in the work cycle and the details of each step.
   - Example is a CNC part program.
   - During each step, there are one or more activities involving changes in one or more process parameters.
   - Example:
     - Temperature setting of a furnace
     - Axis position in a positioning system
     - Motor on or off

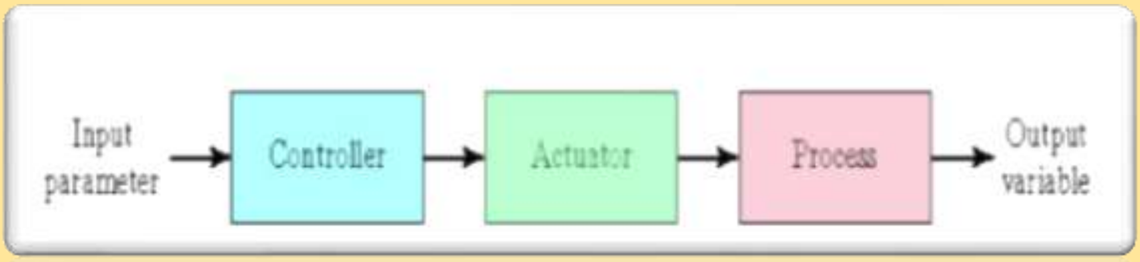
Control System –has two types

1. Open-loop control

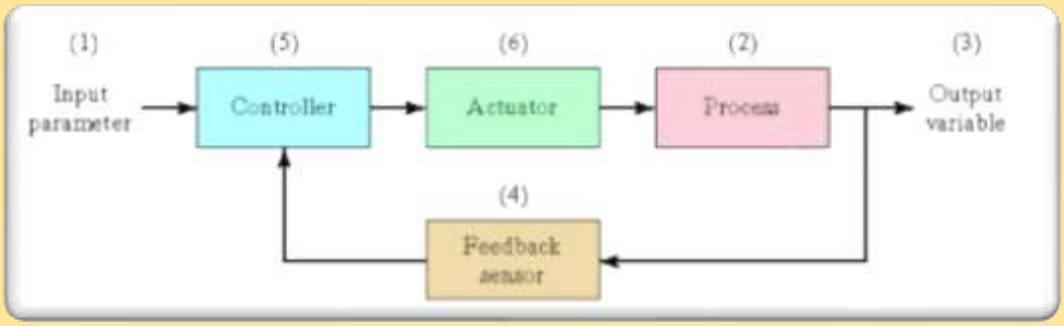
Open loop systems are usually appropriate when the following conditions apply:

1. The actions performed by the control system are simple.
2. The actuating function is very reliable.
3. Any reaction forces opposing the actuation are small enough to have no effect on the actuation.

If these characteristics are not applicable, then a closed loop control system may be more appropriate.



2. Closed-loop control



A closed loop control system consists of six basic elements:

1. Input parameter
2. Process
3. Output Variable
4. Feedback sensor
5. Controller Actuator

When to use an Open-Loop Control System

- Actions performed by the control system are simple
- Actuating function is very reliable
- Any reaction forces opposing the actuation are small enough as to have no effect on the actuation
- If these conditions do not apply, then a closed-loop control system should be used

Advanced automation functions

- Safety monitoring
- Maintenance and repair diagnostics
- Error detection and recovery

Safety Monitoring

- Use of sensors to track the system's operation and identify conditions that are unsafe or potentially unsafe.
- Reasons for safety monitoring
  - To protect workers and equipment
- Possible responses to hazards:
  - Complete stoppage of the system
  - Sounding an alarm
  - Reducing operating speed of process
  - Taking corrective action to recover from the safety violation

2.2 Explain the automation system in a application

Day To Day Life

ATM

Vending machines

Car Wipers

Starting the vehicle

Painting robots

Soldering machines

Automatic capping machines

Example: Painting Robot

Painting robots apply coatings with great precision and evenness. They are usually employed in a manufacturing environment. In particular, the automobile industry has used painting robots for many years.

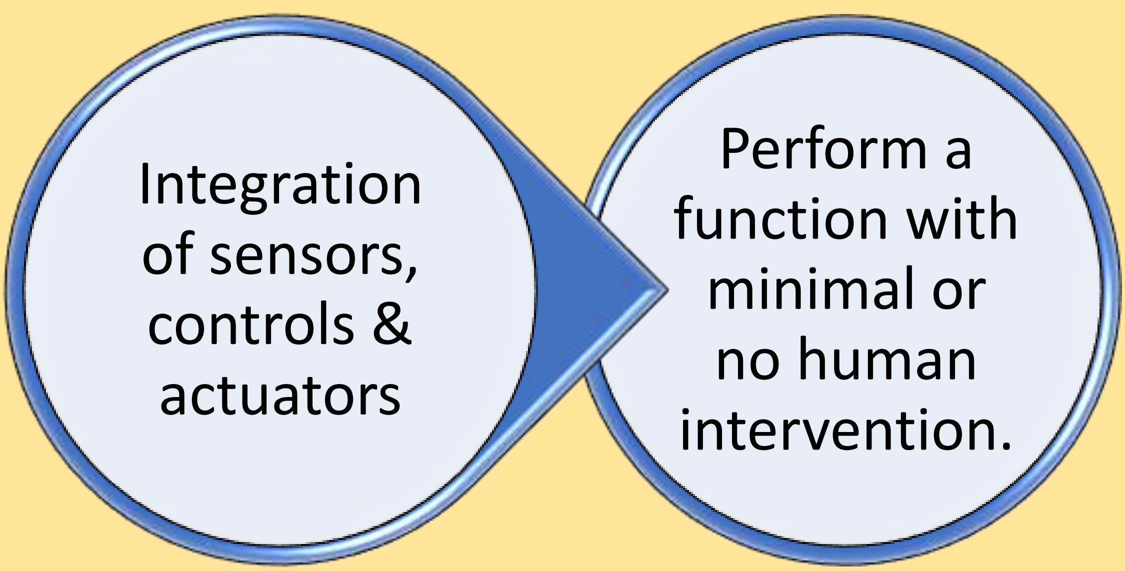
The types of manufacturers using painting robots:

- Automobile
- Glass
- Aerospace And Defense
- Smartphone

2.3 Illustrate the function of an automation systems

2.3.1 Describe specifications of an automation systems relate automation system in industry

What is an Automation System?



Application of automated production system

Work Cell Automation:

- Single Station Automated Cells System
- Automated Production Line
- Automated Assembly System
- Industrial Robotic Application

Automated Material Transfer & Automated Storage (AS)/Retrieval System (RS)

- Conveyor System
- Rotary Indexing Table
- X-Y Table
- Automated Guided Vehicle (AGV)
- AS/RS

Single Station Automated Cells System

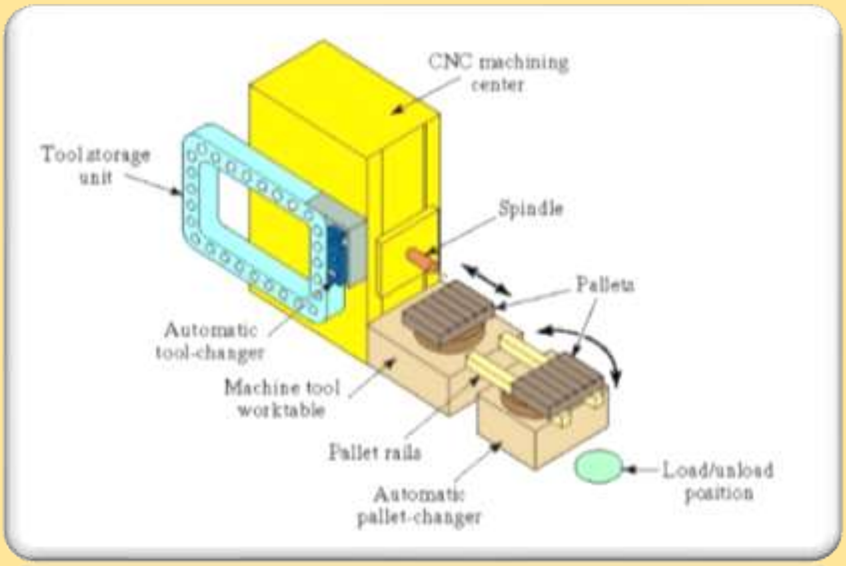
Introduction

- Most common manufacturing system in industry
- Operation is independent of other stations
- Perform either processing or assembly operations
- Can be designed for:
    1. Single model production
    2. Batch production
    3. Mixed model production

Applications of Single Station Automated Cells

- CNC MC with Automated Pallet Changer (APC) and parts storage subsystem
- CNC TC with robot and parts storage carousel
- Cluster of ten CNC TCs, each with robot and parts storage carousel, and time sharing of one worker to load/unload the carousels
- Plastic injection molding on automatic cycle with robot arm to unload molding, sprue, and runner
- Electronics assembly station with automated insertion machine inserting components into PCBs
- Stamping press stamps parts from long coil

Example Single Station Automated Cells System



CNC Machining Centre

- Machine tool capable of performing multiple operations that use rotating tools on a work part in one setup under NC control.
- Typical operations are milling, drilling and related operations.
- Typical features to reduce nonproductive time:
    - Automatic tool changer
    - Automatic work part positioning
    - Automatic pallet changer

Analysis of Assembly Systems

1. Part delivery system at workstations

- The parts delivery system at each station must deliver components to the assembly operation at a net rate that is greater than or equal to the cycle rate of the assembly work head.
- Otherwise, assembly system performance is limited by the parts delivery system rather than the assembly process technology.
- Component quality has an important effect on system performance.
- Poor quality – Jams at stations that stop the entire assembly system.

2. Multi-station assembly machines

- As the number of stations increases, uptime efficiency and production rate are adversely affected due to parts quality and station reliability effects.
- The cycle time of a multi-station assembly system is determined by its slowest station.
- Multi-station assembly systems are appropriate for high production applications and long production runs.

Industrial Robot Applications

1. The important factor of an industrial environment to promote the use of a robot to replace human labour

   - Work environment hazardous for human beings
   - Repetitive tasks and multi-shift operations
   - Boring, unpleasant task and infrequent changeovers
   - Performing at a steady pace
   - Operating for long hours without rest
   - Responding in automated operations
   - Minimizing variation

2. Industrial robot applications that tend to match these characteristic can be divided into four basic categories

   - Material handling applications
   - Processing operations
   - Assembly operations
   - Inspection operations

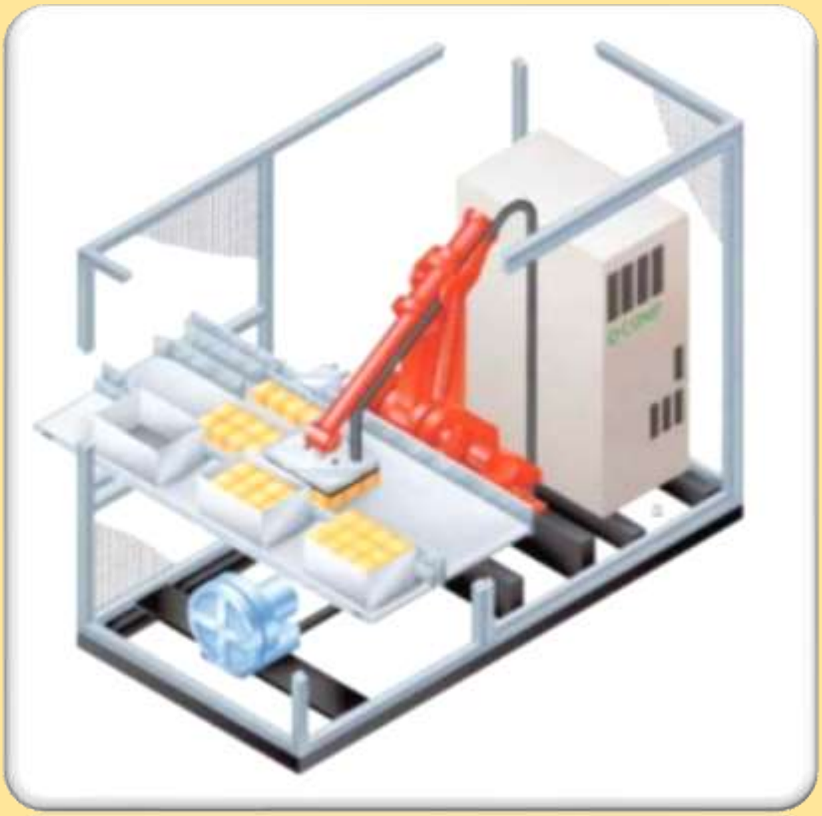
3. Material Handling Application

- Material handling applications involve the movement of material or parts from one location to another.
- Materials may be the raw material that goes into production or product ready for shipment.
- A robot to accomplish the transfer of materials is equipped with a gripper-type end effector. The gripper must be designed to handle the specific part or parts to move in the applications.

The robot must have the following features:

- The manipulator must be able to lift the part safely.
- The robot must have the reach needed.
- The robot must be a cylindrical coordinate type.
- The robot controller must have a large enough memory to store all of the programmed points so that the robot can move from one location to another.
- The robot must have the speed necessary for meeting the transfer cycle of the operation.

Robot Application in Material Handling



1. Part Placement

- Pick and place operation, pick up parts at one location and place them at a new location (transferring a part from one conveyor to another).
- A low technology robot of cylindrical coordinate type is usually sufficient pneumatically powered robots are often utilized.

2. Palletising and Depalletizing

- Many material-handling applications require the robot to stack parts one top of the other.

- That is, palletize them or to unstack parts by removing from the top one by one, that is, depalletize them.

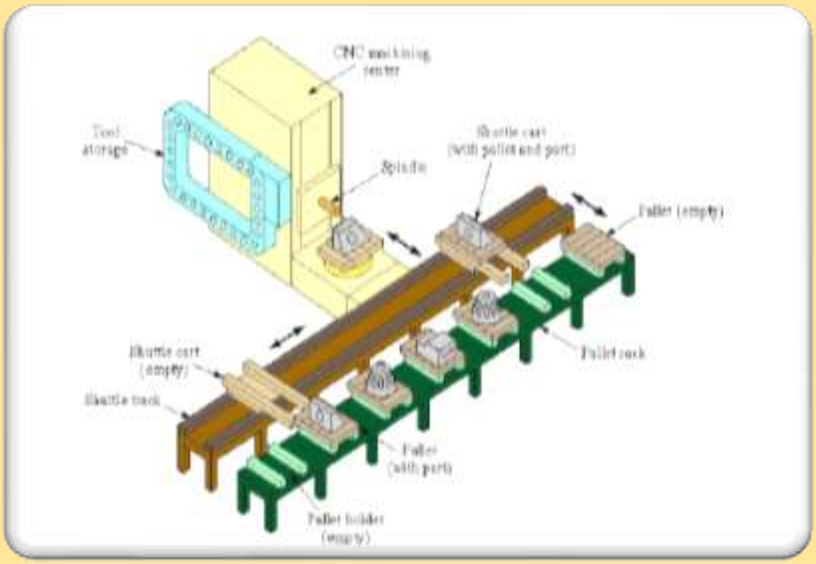
Palletising

- Could be the process of taking parts from an assembly line and stacking them into pallet.

Depalletizing

- It could be the process of taking the parts off the pallet and placing them on the assembly line.

Machine Loading and Unloading



The robot transfer parts into and/or from a production machine. There are THREE(3) possible cases:

- Machine loading in which the robot loads parts into a production machine, but the parts are unloaded by some other means.
- Machine unloading in which the raw materials are fed into machine without robot assistance. The robot unloads the part from the machine assisted by vision or no vision.
- Machine unloading in which the raw materials are fed into machine without robot assistance. The robot unloads the part from the machine assisted by vision or no vision.

Stacking and Insertion Operation

- It is the process in which the robot places flat parts on top of each other, where the vertical location of the drop-off position is continuously changing with each cycle.
- The inserting operation is the process where the robot inserts parts into components of divided carton

Processing Operations

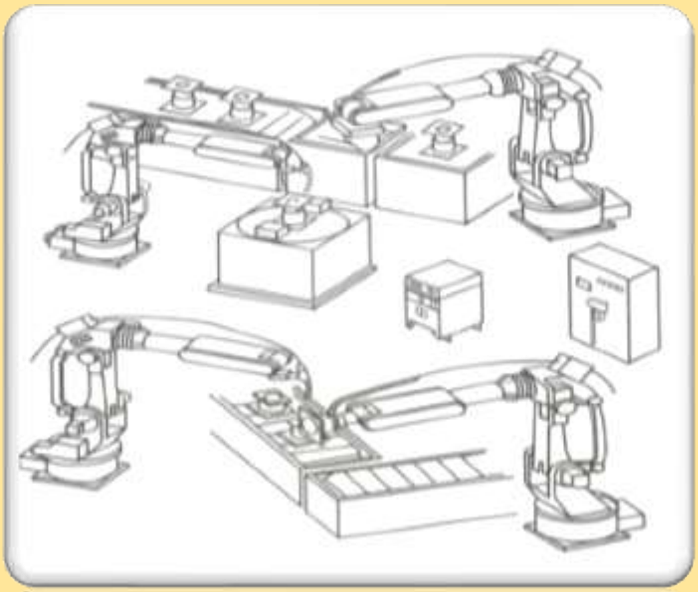
- Processing operations are those in which the robot performs a processing procedure on the part.

- The robot is equipped with some type of process tooling as its end effector, in order to perform the process, manipulates its tooling relative to the work part during the cycle.

Several example of Processing Operation:

- Spot welding/Continuous arc welding
- Spray painting
- Metal cutting and deburring operations
- Various machining operation like drilling, grinding, laser and water-jet cutting
- Adhesives and sealants dispensing

Spot Welding



- Spot welding is a metal joining process in which two sheet metal parts are fused together at localized points of contact.
- Types of robot used are usually large, with sufficient payload capacity to wield the heavy welding gun.
- Five or six axes needed to achieve the positioning and orientations required.
- Playback robots with point to point control are used and the programming is accomplished using the powered teach-pendant method.
- Jointed-arm and polar coordinate robots are the most common anatomies in the automobile spot welding lines.

Spray Painting

- The spray painting process makes use of spray gun directed at the object to be painted.
- Fluid flow through the nozzle of the spray gun to be dispersed and applied over the surface.
- The robot must be capable of continuous path control to accomplish the smooth motion sequences required in spray painting.
- Most convenient programming method is the manual teach-pendant.

Advantages:

- ❑ Human are removed from hostile environment.
- ❑ Less energy is needed for fresh air requirement and the need for protective clothing is reduced.
- ❑ Greater uniformity in paint application.
- ❑ Lower needs for ventilating the work area.
- ❑ The quality of painting is improved, reducing rework and warranty codes.
- ❑ Less paint and other materials are used.

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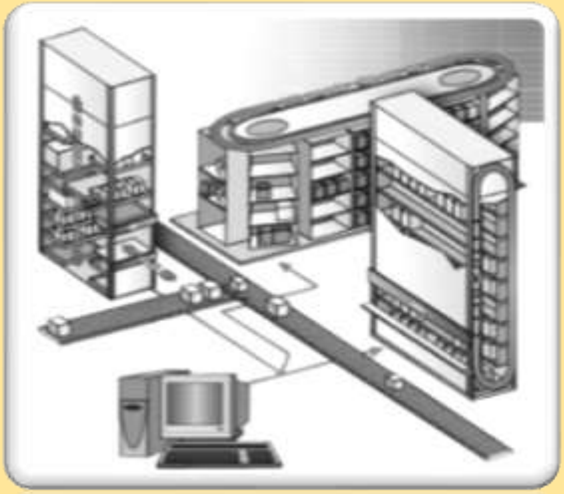
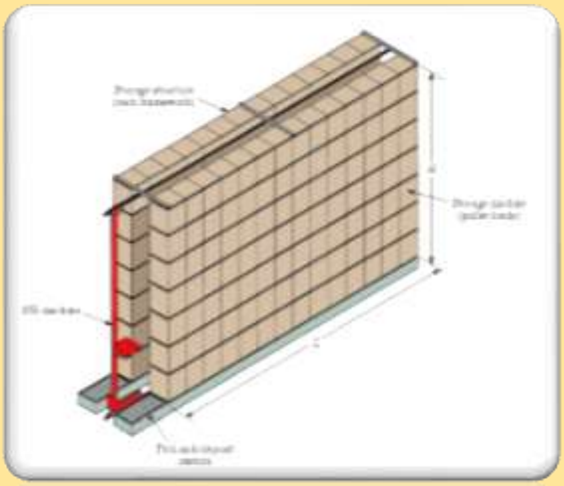
Automated Storage / Retrieval System (AS /RS)



- Rack system with mechanized or automated crane to store/retrieve loads



- Unit load on pallet AS/RS with one aisle

Types of Automated Storage / Retrieval System (AS /RS)

1. Unit load AS/RS
   Large automated system for pallet loads.

2. Deep-lane AS/RS
   Uses flow-through racks and fewer access aisles.

3. Mini load AS/RS
   Handles small loads contained in bins or drawers to perform order picking.

4. Man-on-board AS/RS
   Human operator rides on the carriage to pick individual items from storage.

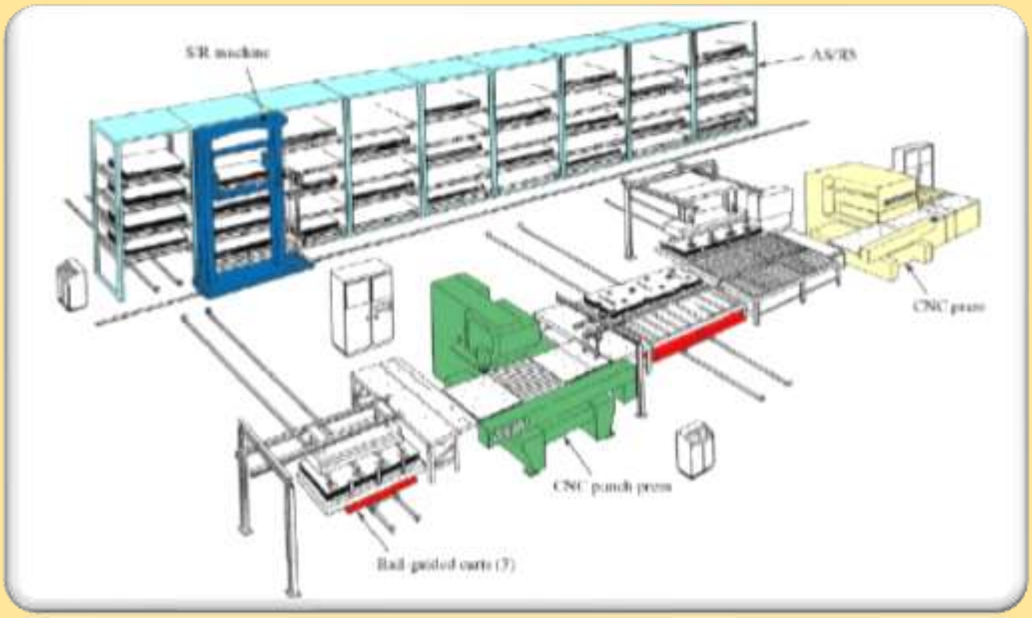
5. Automated item retrieval system
   Picks individual items.

6. Vertical lift storage modules (VLSM)
   Uses a vertical aisle rather than a horizontal aisle as in other AS/RS types.

Applications of Automated Storage / Retrieval System (AS /RS)

1. Unit load storage and retrieval
    - Warehousing and distribution operations.
    - AS/RS types: Unit load, deep lane (food industry).
2. Order picking
    - AS/RS types: Mini load, man-on-board, item retrieval.
3. Work-in-process storage
    - Helps to manage WIP in factory operations.
    - Buffer storage between operations with different production rates.
    - Supports JIT manufacturing strategy.
    - Kitting of parts for assembly.

Flexible Manufacturing System (FMS)



- A Flexible Manufacturing System (FMS) is a production system consisting of a set of identical and/or complementary numerically controlled machine which are connected through an automated transportation system.

- Each process in FMS is controlled by a dedicated computer (FMS cell computer).

- An example of a fabricating flexible manufacturing system for automated sheet-metal processing , based upon the flexible manufacturing system (FMS) at the Allen-Bradley Company.

- There are 26 workstations in the system.
- These perform all the processes necessary to complete the product, from assembly, sub-assembly, testing, and packaging.
- Workstation composition includes the use of linear and dial-indexing assembly machines, with pick-and-place robots performing the handing functions between workstations.
- Each step uses 100% automated testing to ensure very high quality levels.

EXERCISE

1. What are the three basic elements of automation?
2. Explain the difference between process parameters and process variables.
3. Outline the difference between open and closed loop control.
4. What makes advanced automation functions possible?
5. What is the automation levels hierarchy? Describe it briefly.
6. Draw the block diagram of a typical industrial control system.
7. Consider a motor driven position control system, as commonly found in CNC Machine drives. Identify the main feedback sensors in the system. Identify the major sources of disturbance. How is such a drive different from that of an automated conveyor system?
8. State the major aspect in which sequence/logic control systems differ from analog control systems.
9. State three major functions of a Production Control System.
10. Explore and find out concrete activities for production control under at least two of the above major functions in any typical factory such as a Power Plans or a Steel Plant.
11. Explain examples of application examples indicate automation.
12. Draw the Automation Level from bottom to top and identify the level.
13. Give examples of the above major functional level in any typical factor.
14. What are the types of manufactured products that may be produced by industry?
15. Define the difference between processing operations and assembly operations.

EXERCISE

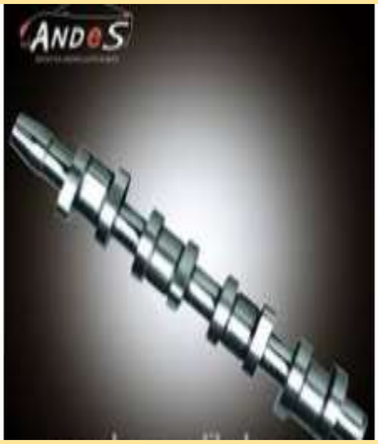
16. What are the ranges of production quantity? How is this related to production plants themselves?
17. What are the types of product variety that may be defined?
18. Explain three (3) modes of operation are typical of a modern maintenance and repair diagnostics subsystem.
19. Explain further on how safety monitoring can be determined as functions of Automation Systems?
20. Given three (3) examples of error recovery in an automated machining cell?
21. Use the internet or a company with which you are familiar to identify one example of an open loop and one example of a closed loop control system. Identify the various elements used in each system and how they operate. Describe how the control system works.

CHAPTER 3

Mechanical System: Component, Dynamics and Modeling

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.



CHAPTER 3

3.0 Mechanical System: Components, Dynamics and Modeling

3.1 Explain the Elementary Mechanical Concepts
- 3.1.1 Translation or Linear motion
- 3.1.2 Rotational Motion
- 3.1.3 Mechanical work and power

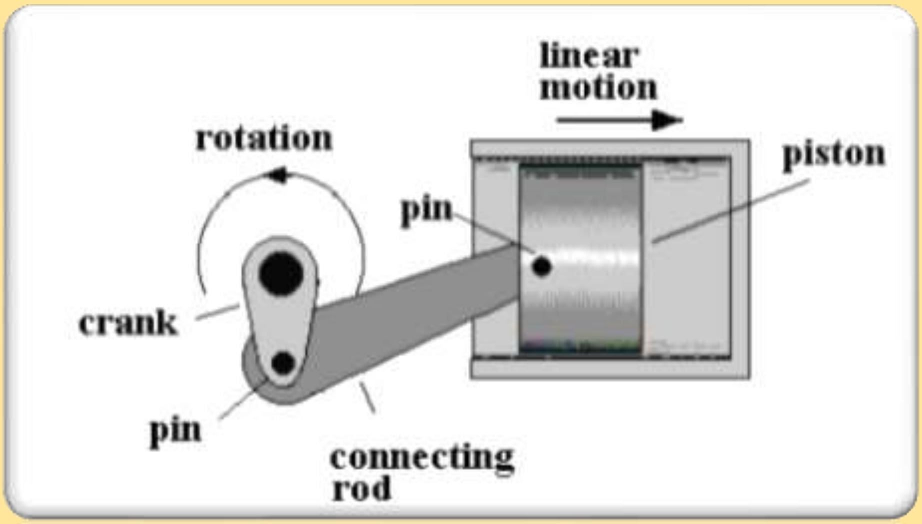
3.2 Explain the Motion Conversion
- 3.2.1 Rotary to Rotary Motion Conversion
- 3.2.2 Rotary to Linear Motion Conversion
- 3.2.3 Linkages
- 3.2.4 Couplers
- 3.2.5 The Concept of Power Transfer

3.3 Explain the Modeling of Mechanical System
- 3.3.1 Elements, Rules and Nomenclature
- 3.3.2 Translational Example
- 3.3.3 Rotational Example
- 3.3.4 Electrical Analog

3.4 Define the End Effector
- 3.4.1 The Grapping problem
- 3.4.2 Remote Centered Compliance Devices

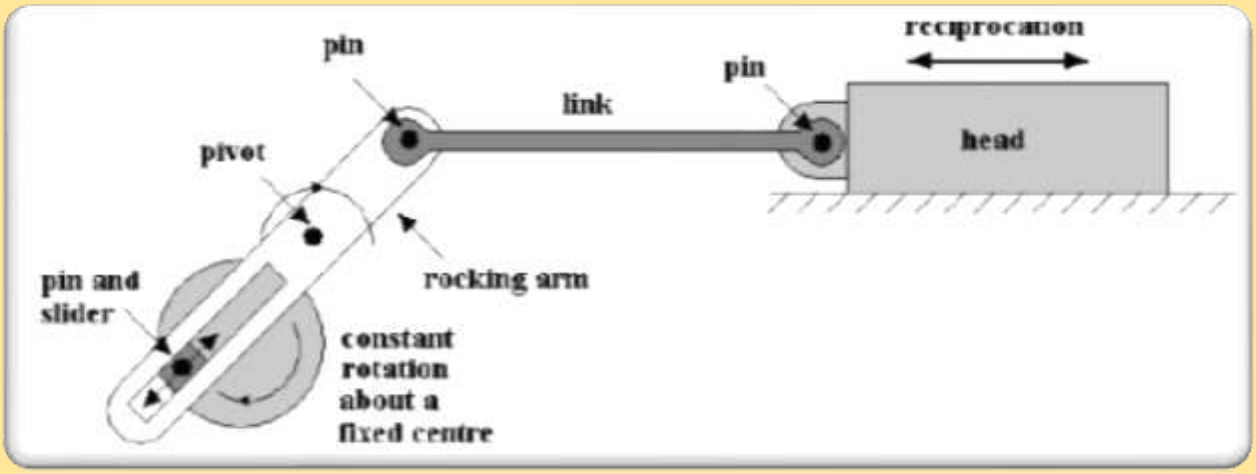
3.1 EXPLAIN THE ELEMENTARY MECHANICAL CONCEPTS

- A mechanism is used to produce mechanical transformation in a machine.
- This transformation could be any of the following.
    - It may convert one speed to a another speed.
    - It may convert one force to another force.
    - It may convert one torque to another torque.
    - It may convert force into torque.
    - It may convert one angular motion to another angular motion.
    - It may convert rotation motion into liner motion.
    - It may convert linear motion into rotation motion.



A good example is a crank, connecting rod and piston mechanism.

- If the crank is turned, angular motion is converted into linear motion of the piston and input torque is transformed into force on the piston.
- If the piston is forced to move, the linear motion is converted into rotary motion and the force into torque.
- The piston is a sliding joint and this is called PRISMATIC in some fields of engineering such as robotics.
- The pin joints allow rotation of one part relative to another. These are so called REVOLUTE joints in others areas of engineering.



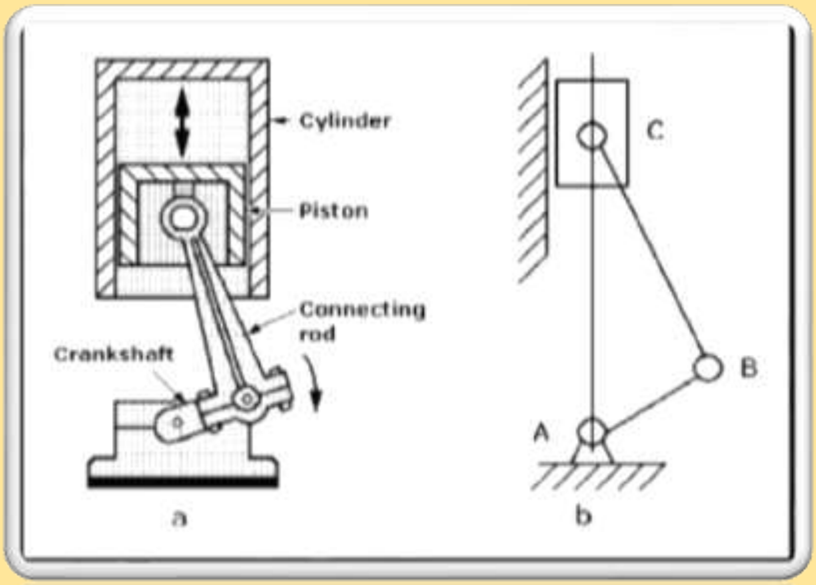
Mechanism used in shaping machines and also known as the Whitworth quick-return mechanism.

- The input is connected to a motor turning at constant speed.
- This makes the rocking arm move back and forth and the head (that carries the cutting tool) reciprocates back and forth.
- Depending on the lengths of the various parts, the motion of the head can be made to move forwards at a fairly constant cutting speed but the return stroke is quick.
- Note that that the pin and slider must be able to slide in the slot or the mechanism would jam. This causes problems in the solution because of the sliding link.

- The main point is that the motion produced is anything but simple harmonic motion and at any time the various parts of the mechanism have a displacement, velocity and acceleration.

- The acceleration gives rise to inertia forces and this puts stress on the parts in addition to the stress produced by the transmission of power.

- For example the acceleration of a piston in an internal combustion engine can be enormous and the connecting rod is subjected to high stresses as a result of the inertia as well as due to the power transmission.



(a) Cross section of a cylinder of an internal combustion engine showing piston reciprocation

(b) The skeleton outline of the linkage mechanism that moves the piston

MACHINES and MECHANISMS

Machines are devices used to alter, transmit, and direct forces to accomplish a specific objective.
A chain saw is a familiar machine that directs forces to the chain with the objective of cutting wood.

A *mechanism* is the mechanical portion of a machine that has the function of transferring motion and forces from a power source to an output. It is the heart of a machine.
For the chain saw, the mechanism takes power from a small engine and delivers it to the cutting edge of the chain.

Mechanism Terminology

- As stated, mechanisms consist of connected parts with the objective of transferring motion and force from a power source to an output.

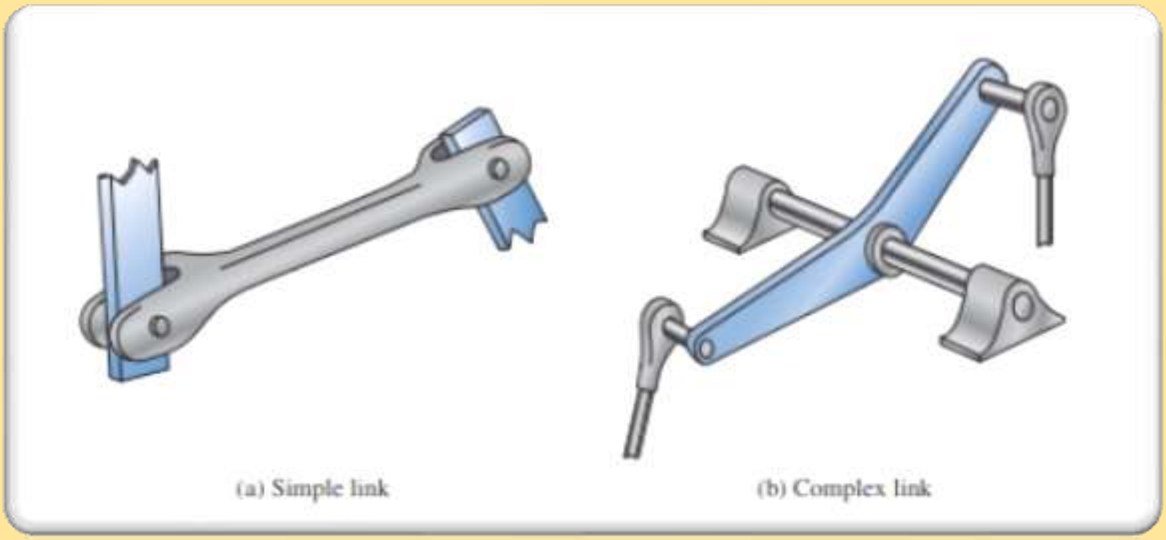
Linkage

- A linkage is a mechanism where rigid parts are connected together to form a chain.
- One part is designated the frame because it serves as the frame of reference for the motion of all other parts.
- The frame is typically a part that exhibits no motion.
- A popular elliptical trainer exercise machine is shown in Figure 3.

- In this machine, two planar linkages are configured to operate out-of-phase to simulate walking motion, including the movement of arms.
- Since the base sits on the ground and remains stationary during operation, the base is considered the frame.

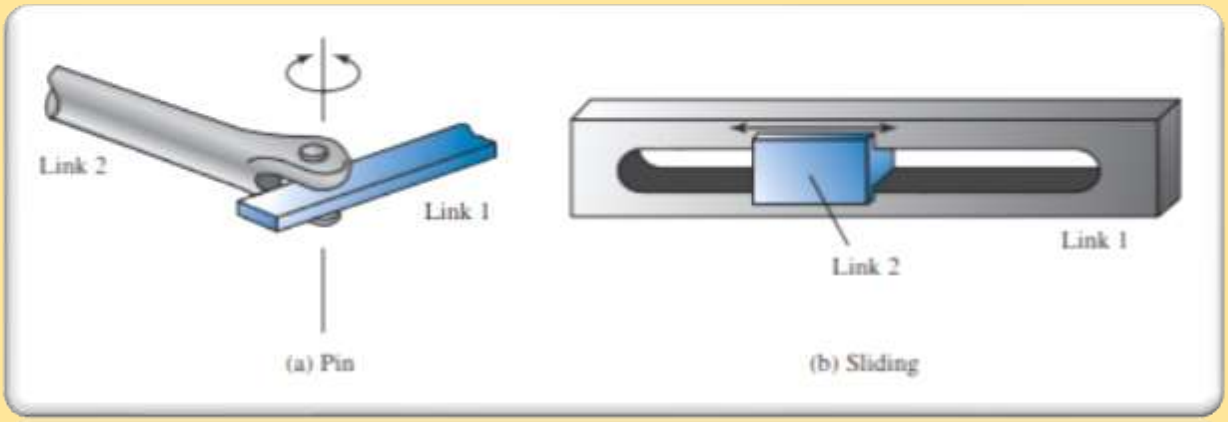
Links

- Links are the individual parts of the mechanism.
- They are considered rigid bodies and are connected with other links to transmit motion and forces.
- Theoretically, a true rigid body does not change shape during motion.
- Although a true rigid body does not exist, mechanism links are designed to minimally deform and are considered rigid.
- Elastic parts, such as springs, are not rigid and, therefore, are not considered links.



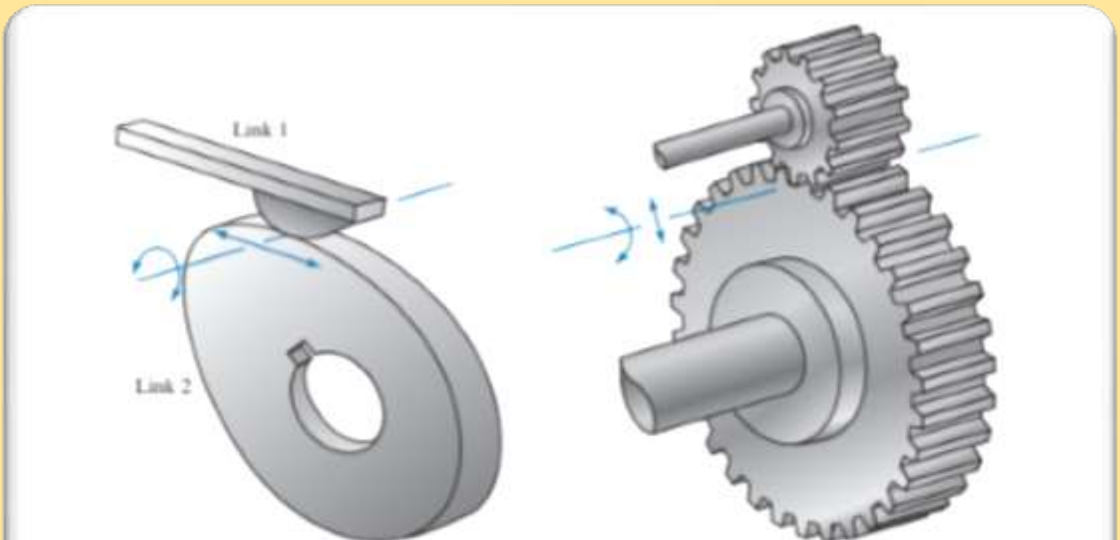
Joint

- A joint is a movable connection between links and allows relative motion between the links.
- The two primary joints also called full joints are the revolute and sliding joints.
- The revolute joint is also called a pin or hinge joint.
- It allows pure rotation between the two links that it connects.
- The sliding joint is also called a piston or prismatic joint.
- It allows linear sliding between the links that it connects.



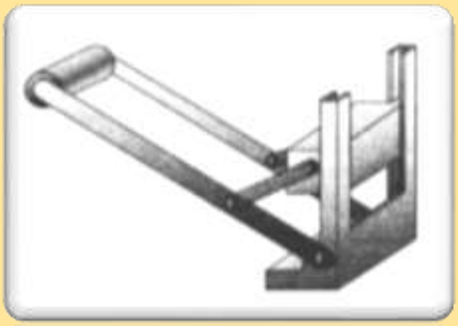
Cam Joint

- It allows for both rotation and sliding between the two links that it connects.
- Because of the complex motion permitted, the cam connection is called a higher-order joint, also called half joint.
- A gear connection also allows rotation and sliding between two gears as their teeth mesh.

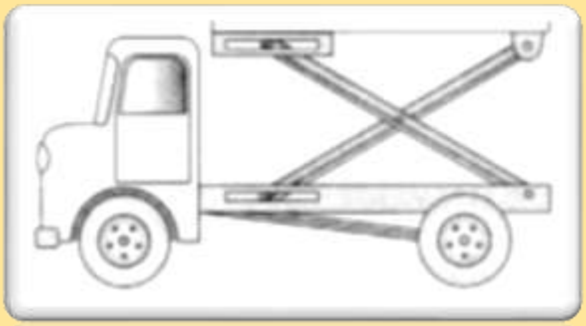


(a) Cam joint (b) Gear joint

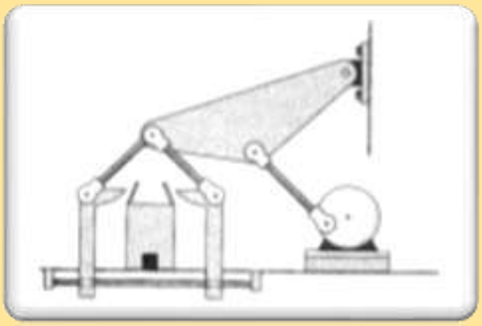
Examples of Mechanism



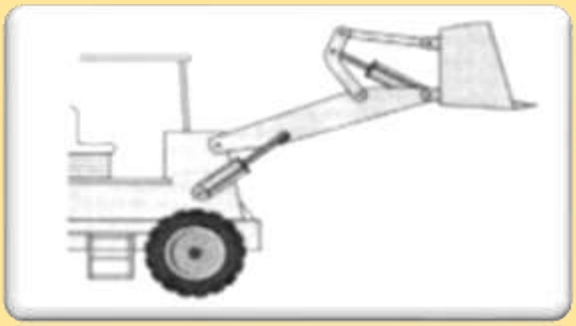
Can Crusher



Lift Platform



Device to close the top flap of boxes



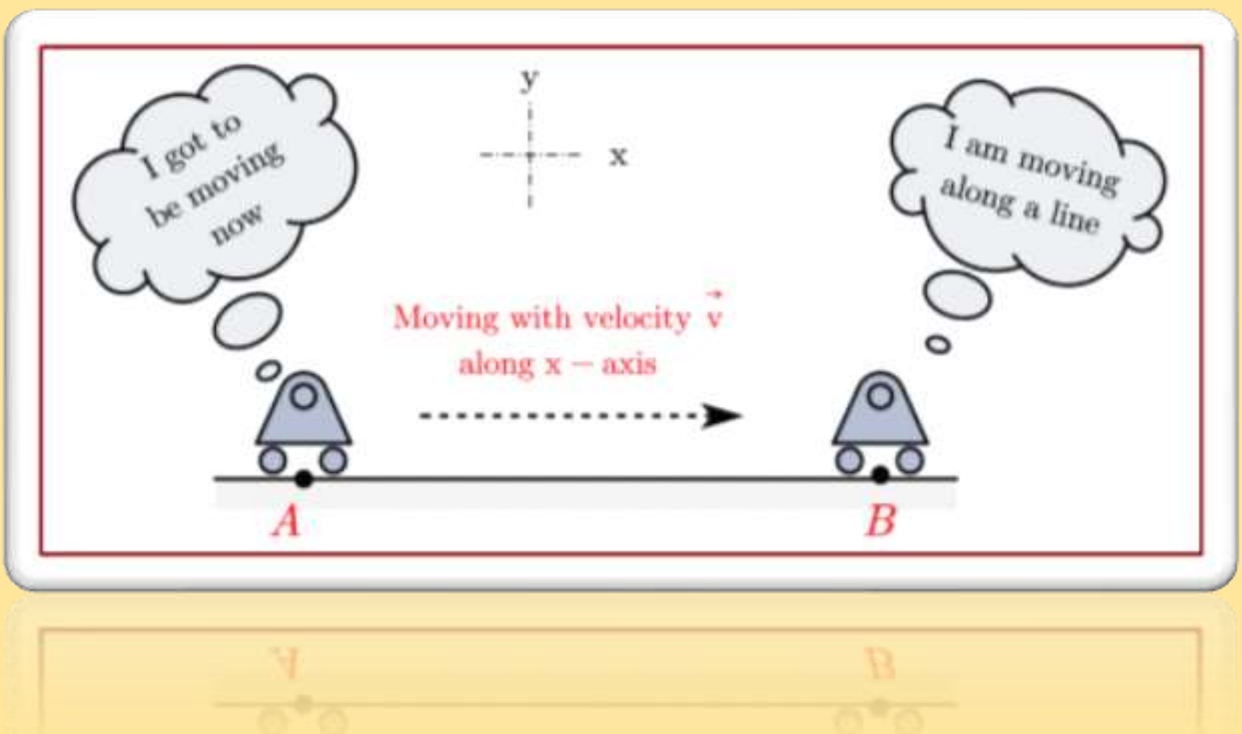
Loader Device

Rear window wiper

Simple Press

3.1.1 Translation or Linear motion

- The motion of translation is defined as a motion that takes place along a straight or curved path. In which all points of a moving body move uniformly in the same line or direction.
- If an object is executing translational motion then there is no change in its orientation relative to a fixed point.
- For example, a train moving in its track, a man walking on the road, birds flying in the sky.



WHAT IS THE DIFFERENCE??

LINEAR AND TRANSLATIONAL MOTION

- Linear motion (or rectilinear motion) means moving in a straight line.
- Translational motion or translational motion occurs when all points in a body move the same distance in the same amount of time.
- The translational motion does not always require that the object move in a straight line.
- We can use the term translational motion when the object is moving in 2- or 3-dimensional bodies.
- As stated earlier linear motion is a type of translational motion and is strictly a one-dimensional motion along a straight line.

COMPARISON OF LINEAR AND ROTATIONAL MOTION

3.1.2 Rotational Motion

- The motion of object around fix point or object is known as rotational motion.
- In rotation motion, the displacement is the angular displacement of θ in radian or angle.
- Inertia, J, is considered a property of an element that stores the kinetic energy of rotational motion.

All point on CD travel in circular arcs. The pits along a line from the center to the edge all move through the same angle in a time.

3.1.3 Mechanical Work and Power

- Work results when a force acts upon an object to cause a displacement (or a motion) or, in some instances, to hinder a motion.

Work = Force x Displacement x Cosine Ɵ

$$W = F \times d \times \cos \theta$$

- Mechanical Work on an object is the amount of mechanical energy transferred to that object by force.

- Power is defined as the rate at which work is done upon an object. Like all rate quantities, power is a time-based quantity. Power is related to how fast a job is done.

Power = Work / time

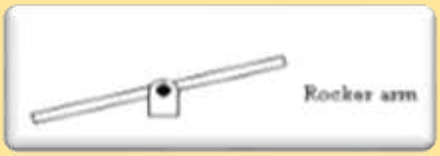
$$P = W / t$$

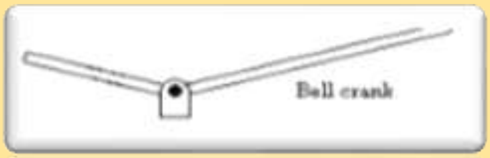
3.2 EXPLAIN THE MOTION CONVERSION

- Mechanical systems often include mechanisms such as levers, gears, linkages, cams, chains, and belts.

- They all serve a common basic function, the transformation of the motion of an input member into the kinematically related motion of an output member.

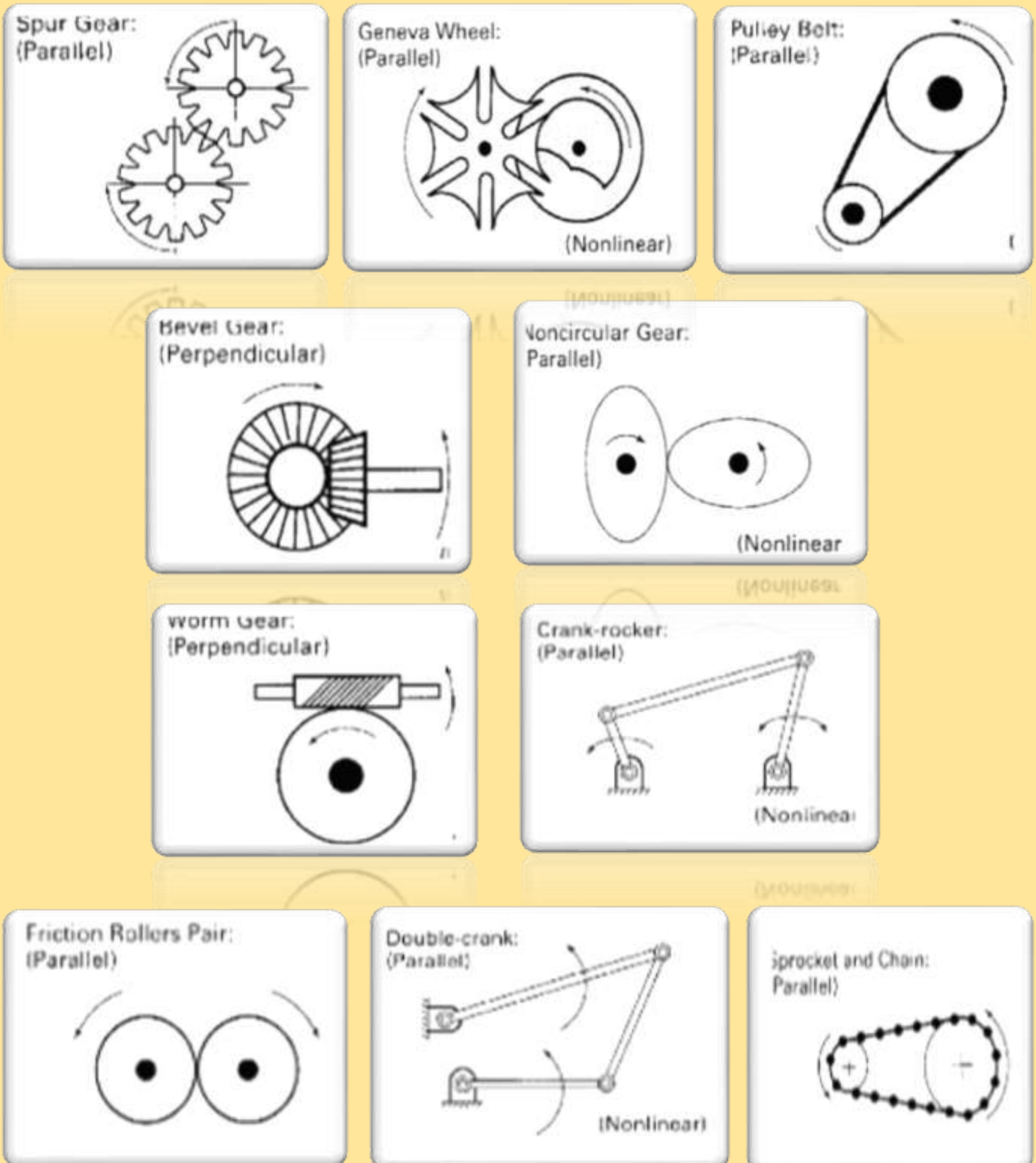
- Device for transforming motion:
  - rocker arm reverses motion
  - Bell crank amplifies motion
  - Crank transmits rotary motion



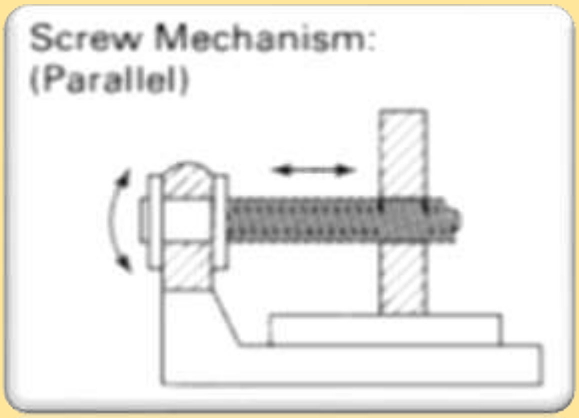


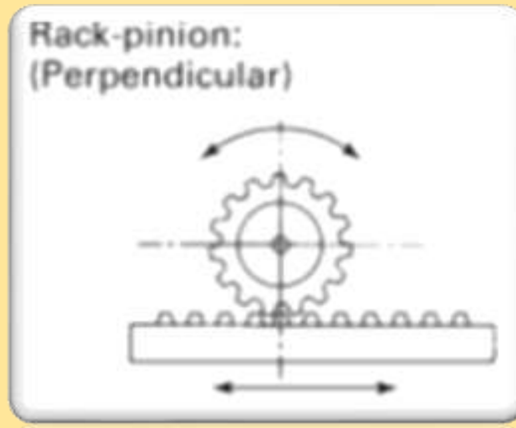
- Motion conversion transmission can be include:
  - Rotary to rotary motion conversion
  - Rotary to linear motion conversion

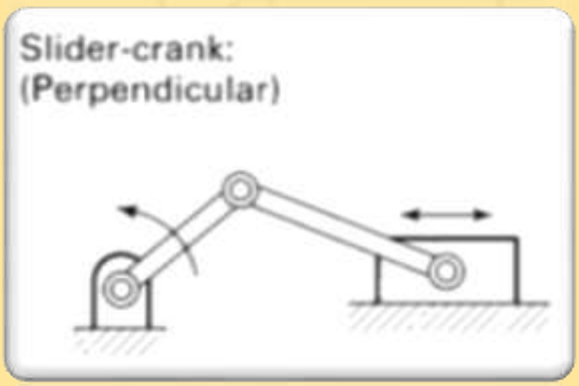
3.2.1 Rotary to Rotary Motion Conversion

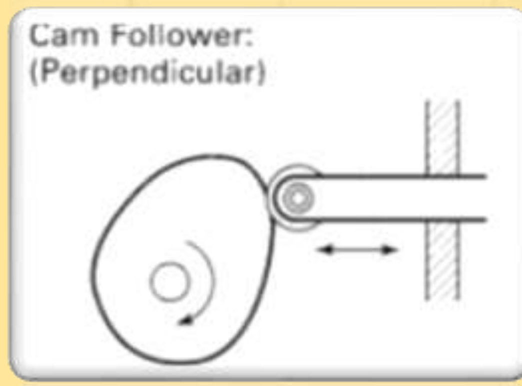


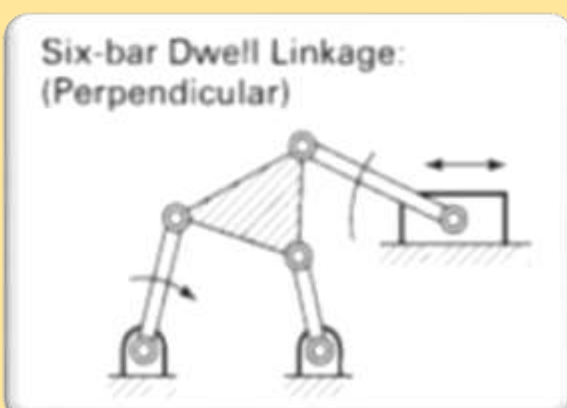
3.2.2 Rotary to Linear Motion Conversion

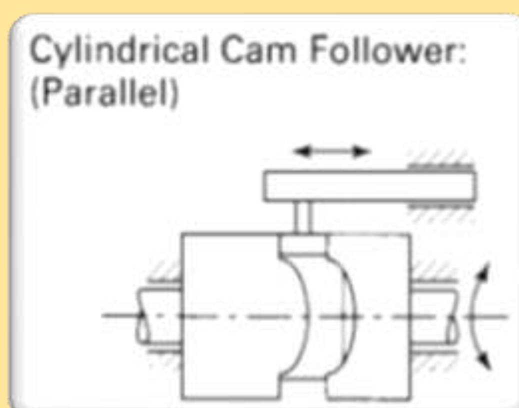






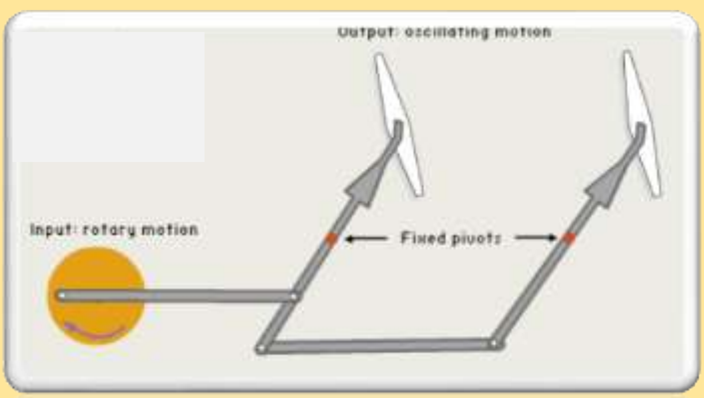






3.2.3 Linkages

- A linkage is a mechanism formed by connecting two or more of a force or make two or more objects move at the same time.
- Many different fasteners are used to connect linkages together yet allow them to move freely such as pins, end-threaded bolts with nuts, and loosely fitted rivets.
- There are two general classes of linkages:
  - ❑ Simple planar linkages and
  - ❑ Specialized linkages



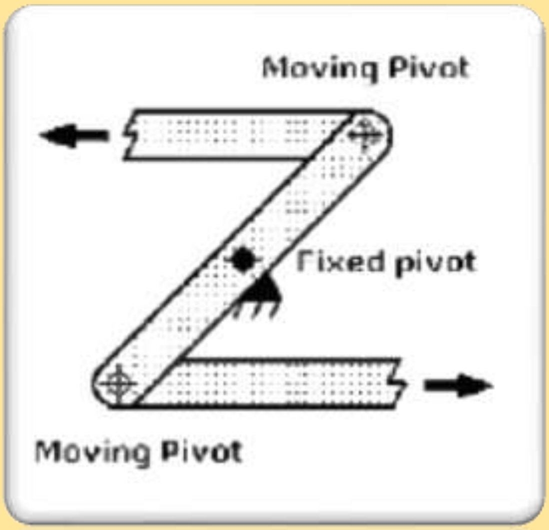
Windscreen wipers on a car

Sports Equipment

Simple Planer Linkages

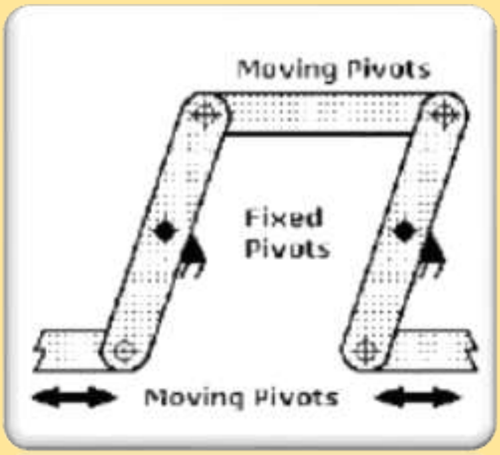
- Simple Linkages can make objects or force move in opposite directions; this can be done by using the input link as a lever.
- If the fixed pivot is equidistant from the moving pivots, output link movement will equal input link movement, but it will act in the opposite direction.

a) Reverse Motion Linkage



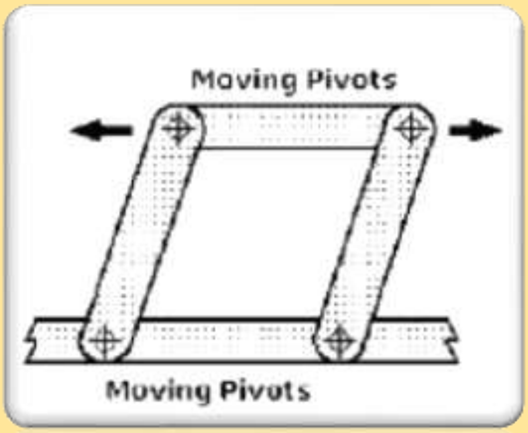
- It can make objects or force move in opposite directions; this can be done by using the input link as a lever.

b) Push Pull Linkage



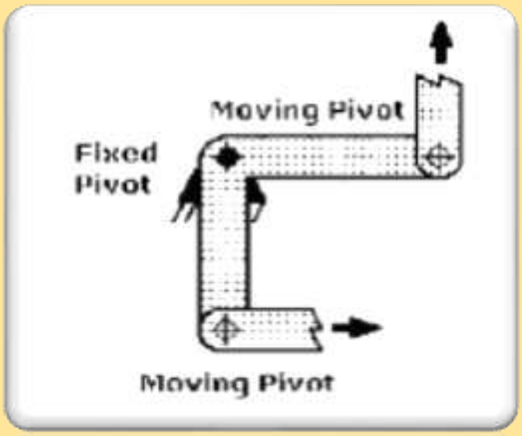
- It can make the objects or force move in the same direction; the output link moves in the same direction as the input link.

c) Parallel Motion Linkage



- It can make objects or forces move in the same direction, but at a set distance apart.

d) Bell Crank Linkage



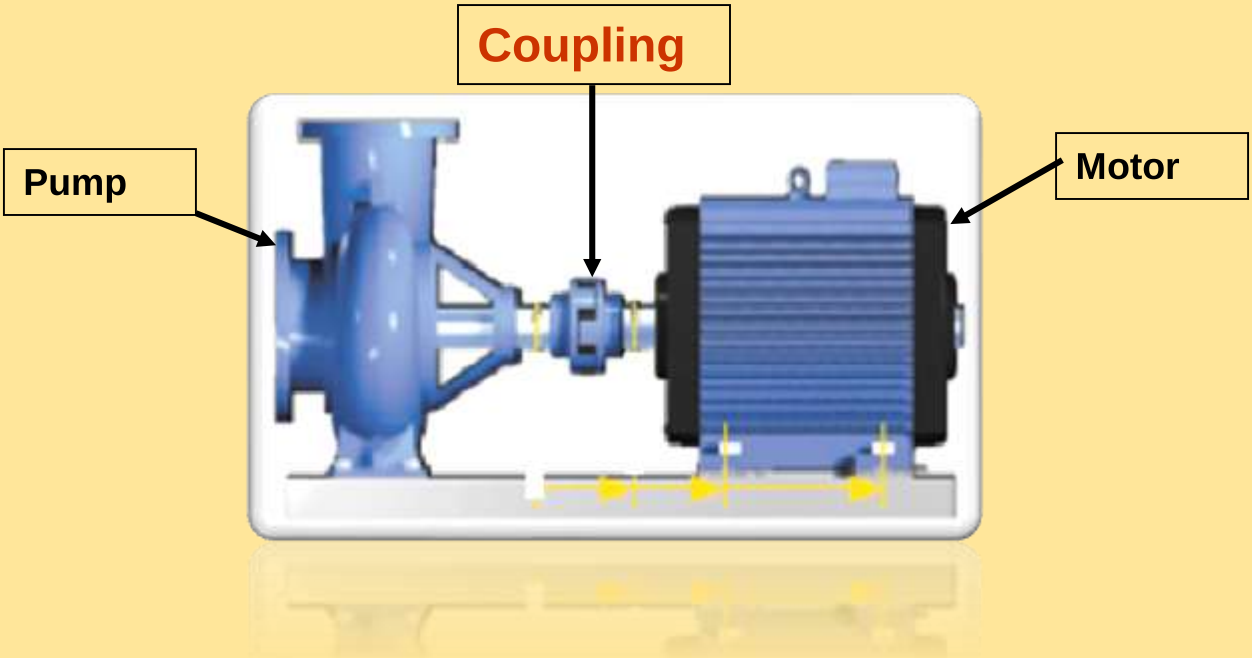
- It can change the direction of objects or force by 90°.
- This linkage rang doorbells before electric clappers were invented.
- More recently this mechanism has been adapted for bicycle brakes.

Lets see

HOW SEWING MACHINE WORKS

3.2.4 Couplers

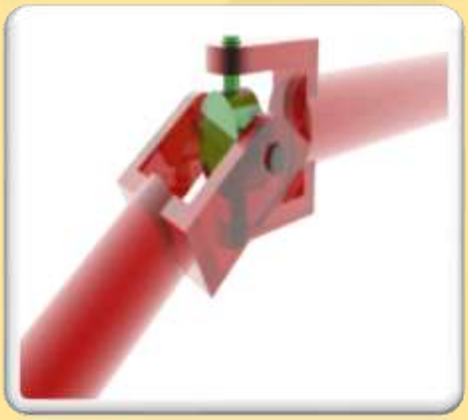
- Coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power.
- Uses of coupling are:
  - ✓ To provide connection of shafts of units made separately.
  - ✓ To allow misalignment of the shafts or to introduce mechanical flexibility.
  - ✓ To reduce the transmission of shock loads.
  - ✓ To introduce protection against overloads.
  - ✓ To alter the vibration characteristics.



Types of Coupling

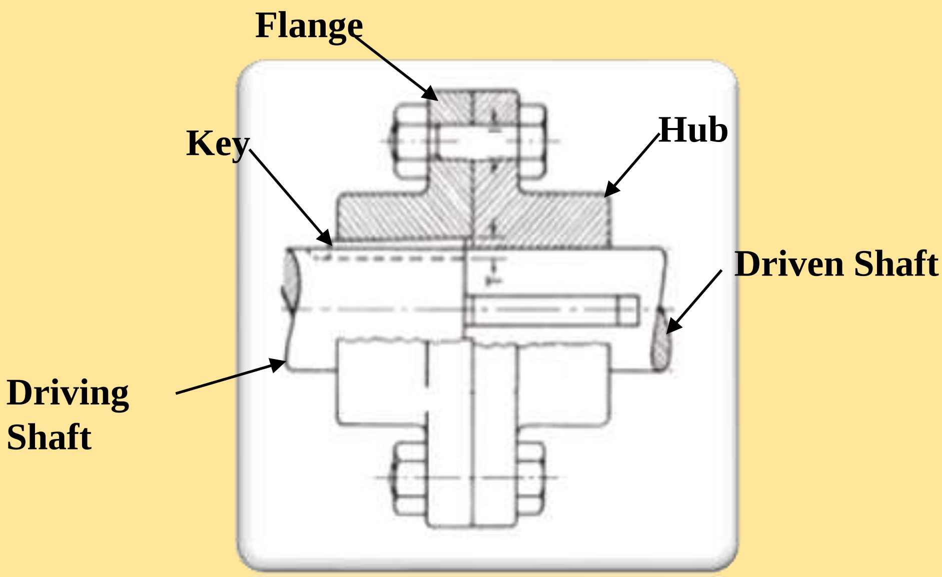
Rigid Coupling

Flexible Coupling



Universal Coupling

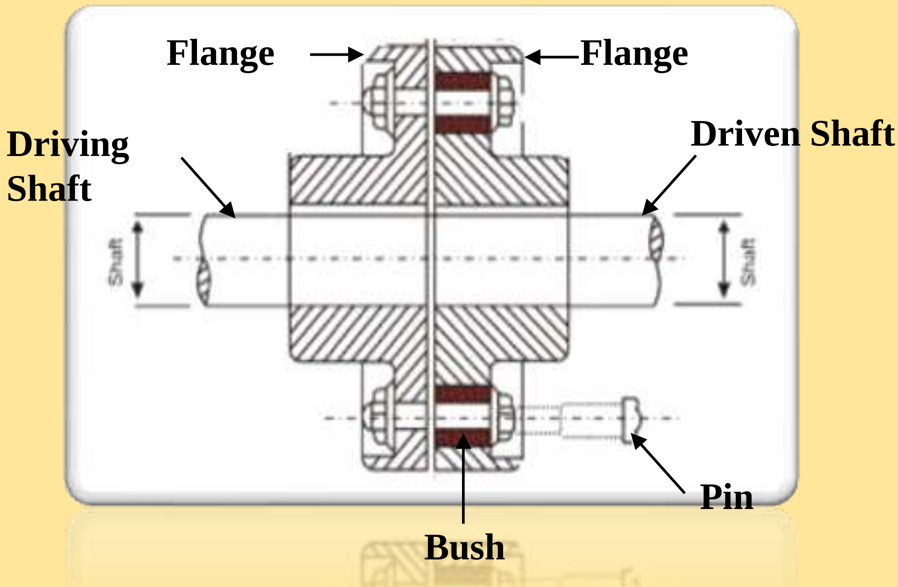
Rigid Coupling



Flanged Coupling

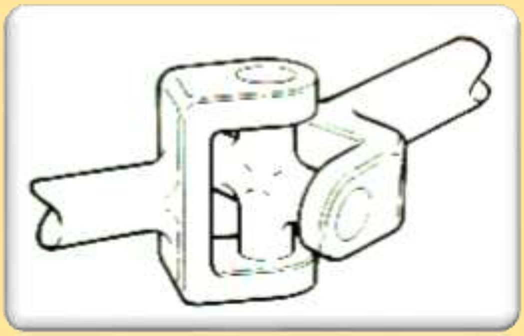
- Rigid couplings are used when precise shaft alignment is required.
- Simple in design and are more rugged.
- Generally able to transmit more power than flexible couplings.
- Shaft misalignments cannot be compensated.

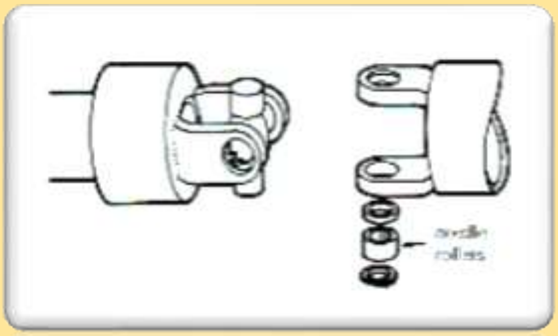
Flexible Coupling

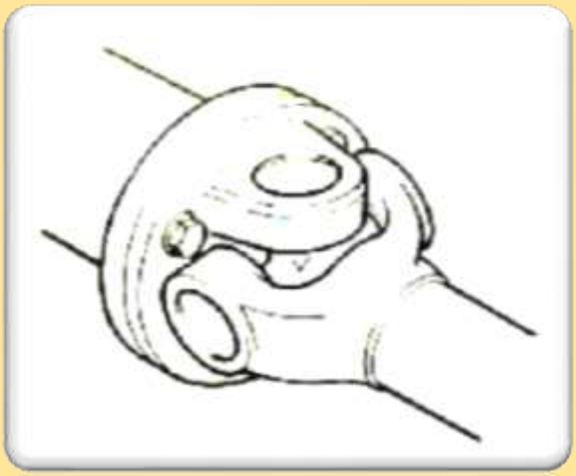


- A flexible coupling permits with in certain limits, relative rotation and variation in the alignment of shafts.
- Pins (Bolts) covered by rubber washer or bush is used connect flanges with nuts.
- The rubber washers or bushes act as a shock absorbers and insulators.

Universal Coupling

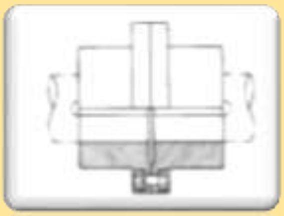






- Consist of two end yokes and a center bearing block.
- Provides for angular misalignment of up to 45 degrees.

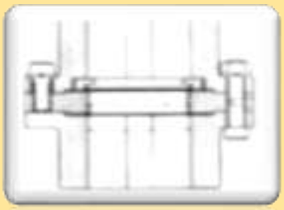
Example of Coupling



Flanged rigid

Split rigid

Roller chain
Mechanically flexible



Adjustable flanged
rigid

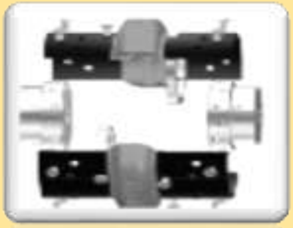
Spacer metal disk

Pin and bushing
elastomer

Sleeve type
elastomer

Diaphragm material
flexible

Gear type
Mechanically flexible



Spacer
elastomer

Advantages

- Torsionally stiff.
- No lubrication or maintenance.
- Good vibration damping and shock absorbing qualities.
- Less expensive than metallic couplings.
- More misalignment allowable than most metallic couplings.

Limitations

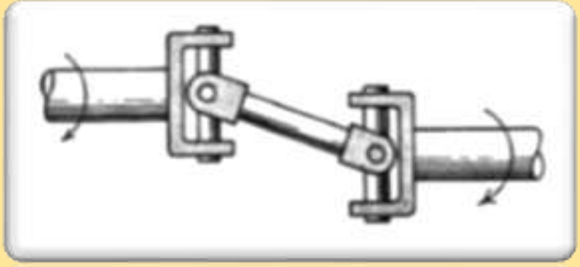
- Sensitive to chemicals and high temperatures.
- Usually not torsionally stiff enough for positive displacement.
- Larger in outside diameter than metallic coupling.
- Difficult to balance as an assembly

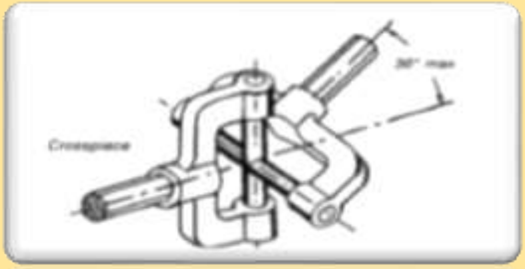
3.2.5 The Concept of Power Transfer

Power transfer mechanisms are normally divided into five general categories:

1. Belts (flat, round, V-belts, timing)
2. Chain (roller, ladder, timing)
3. Plastic-and-cable chain (bead, ladder, pinned)
4. Friction drive
5. Gears (spur, helical, bevel, worm, rack and pinion, and many others)

Transmission of power from a source, such as an engine or motor, through a machine to an output actuation is one of the most common machine tasks.





3.3 EXPLAIN THE MODELING OF MECHANICAL SYSTEM

3.3.1 Elements, Rules and Nomenclature

Three Basic Mechanical Elements are:

1. Spring (elastic) element
2. Damper (frictional) element
3. Mass (inertia) element

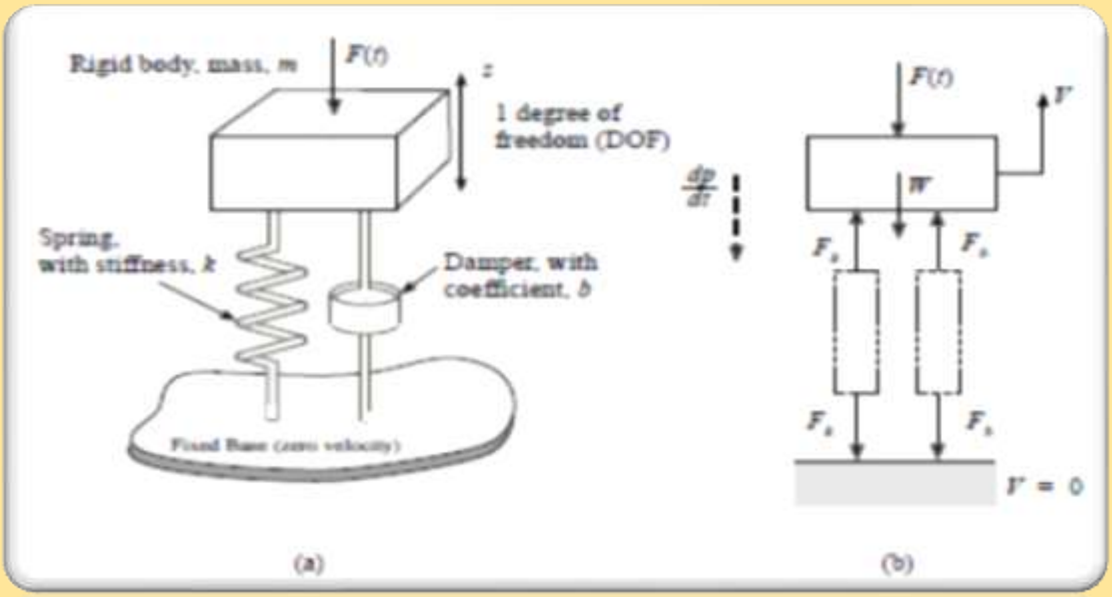
- When modeling translational and rotational systems it is common to break the system into parts. These parts are then described with Free Body Diagrams (FBDs).
- Spring, damper and mass are passive (non energy producing) devices.
- Driving Inputs will force and motion sources which cause elements to respond.
- Each of the elements has one of two possible energy behaviors:

1. stores all the energy supplied to it.
2. Dissipates all energy into heat by some kind of "frictional" effect

Dynamic Response of each element is important for:

1. Step response

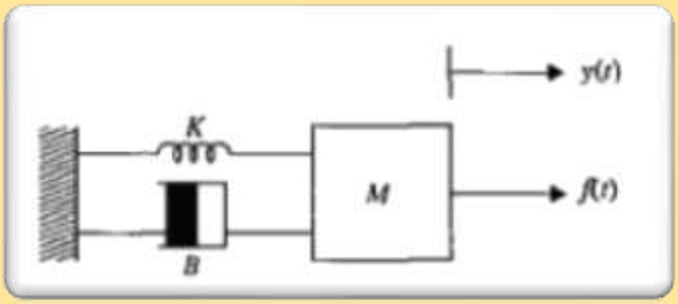
2. Frequency response



Mass-Spring-Damper:
A basic mechanical system that consists of a rigid body that can be translate in the z-direction

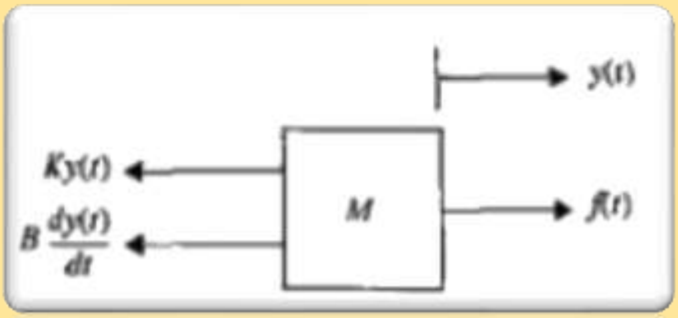
3.3.2 Translational Example

Consider the mass-spring-friction system shown below.



The linear motion concerned is in the horizontal direction.

The free-body diagram of the system is shown below.

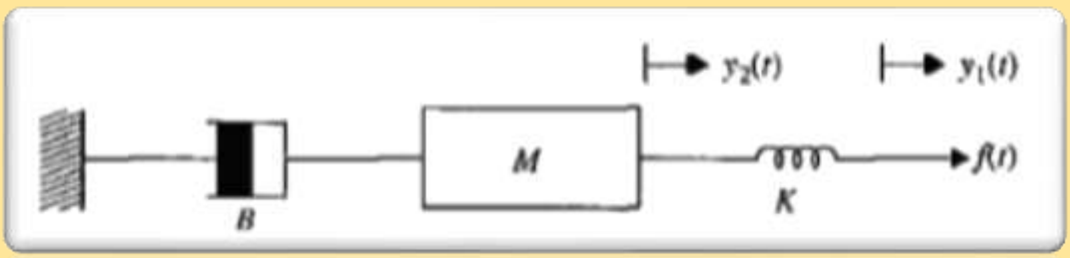


The force equation of the system is

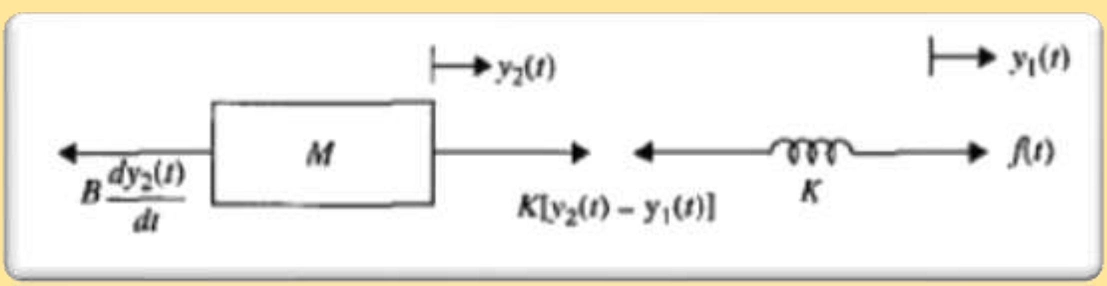
$$\boxed{f(t) - B\frac{dy(t)}{dt} - Ky(t) = M\frac{d^2y(t)}{dt^2}}$$

3.3.2 Translational Example

As another example of writing the dynamic equations of a mechanical system with translational motion, consider the system shown below.



Because the spring is deformed when it is subject to a force f(t), two displacements, y1 and y2 must be assigned to the end points of springs. The free body diagrams of the system shown below.



The force equations are:

$$f(t) = K[y_1(t) - y_2(t)]$$

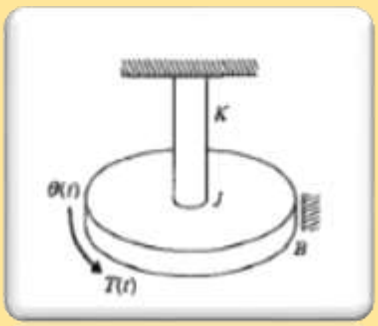
$$-K[y_2(t) - y_1(t)] - B\frac{dy_2(t)}{dt} = M\frac{d^2y_2(t)}{dt^2}$$

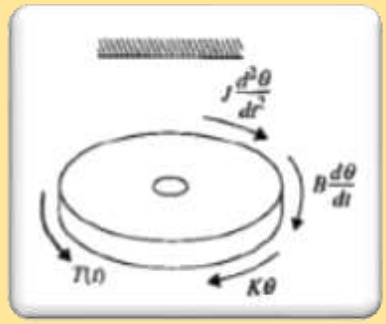
Rearranged in input/output as:

$$\frac{d^2y_2(t)}{dt^2} + \frac{B}{M}\frac{dy_2(t)}{dt} + \frac{K}{M}y_2(t) = \frac{K}{M}y_1(t)$$

3.3.3 Rotational Example

The rotational system consists of a disk mounted on a shaft that is fixed at one end. The moment of inertia of the disk about the axis of rotation is J.





The edge of the disk is riding on the surface, and the viscous friction coefficient between the two surfaces is B. The inertia of the shaft is negligible but the torsional spring is constant is K.

$$T(t) = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta(t)}{dt} + K\theta(t)$$

Assume the torque is applied to the disk, then the torque or moment equation about the axis of the shaft.

3.3.4 Electrical Analog

- Systems that can be represented by the same mathematical model but that are different physically are called analogous systems.

- Thus analogous systems are described by the same differential or integral differential equations or set of equations.

- The concept of analogous systems is very useful in practice for the following reasons:

  - The solution of the equation describing one physical system can be directly applied to analogous systems in any other field.

  - Since one type of system may be easier to handle experimentally than another, instead of building and studying a mechanical system (or hydraulic system or pneumatic system), we can build and study its electrical analog, for electrical or electronic systems are, in general, much easier to deal with experimentally.

3.4 DEFINE THE END EFFECTORS

The Wikipedia states:

"In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment."

ATI Industrial Automation says:

"A robotic end-effector is any object attached to the robot flange (wrist) that serves a function."

- In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment.
- The exact nature of this device depends on the application of the robot.
- In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or end) of the robot. At this endpoint the tools are attached.
- In a wider sense, an end effector can be seen as the part of a robot that interacts with the work environment.
- This does not refer to the wheels of a mobile robot or the feet of a humanoid robot which are also not end effectors—they are part of the robot's mobility.

- End effectors may consist of a gripper or a tool.

- The gripper can be of two fingers, three fingers or even five fingers.

- The end effectors that can be used as tools serve various purposes.

- Such as, spot welding in an assembly, spray painting where uniformity of painting is necessary and for other purposes where the working conditions are dangerous for human beings.

- Surgical robots have end effectors that are specifically manufactured for performing surgeries.

- This would include robotic grippers, robotic tool changers, robotic collision sensors, robotic rotary joints, robotic press tooling, compliance devices, robotic paint guns, robotic deburring tools, robotic arc welding guns, robotic trans guns.

- Grippers are active links between the handling equipment and the work piece or in a more general sense between the grasping organ (normally the gripper fingers) and the object to be acquired.

- Their functions depend on specific applications and include:

    1. Temporary maintenance of a definite position and orientation of the work piece relative to the gripper and the handling equipment.

    2. Retaining of static (weight), dynamic (motion, acceleration or deceleration) or process specific forces and moments.

    3. Determination and change of position and orientation of the object relative to the handling equipment by means of wrist axes.

    4. Specific technical operations performed with, or in conjunction with, the gripper.

- Grippers are not only required for use with industrial robot.

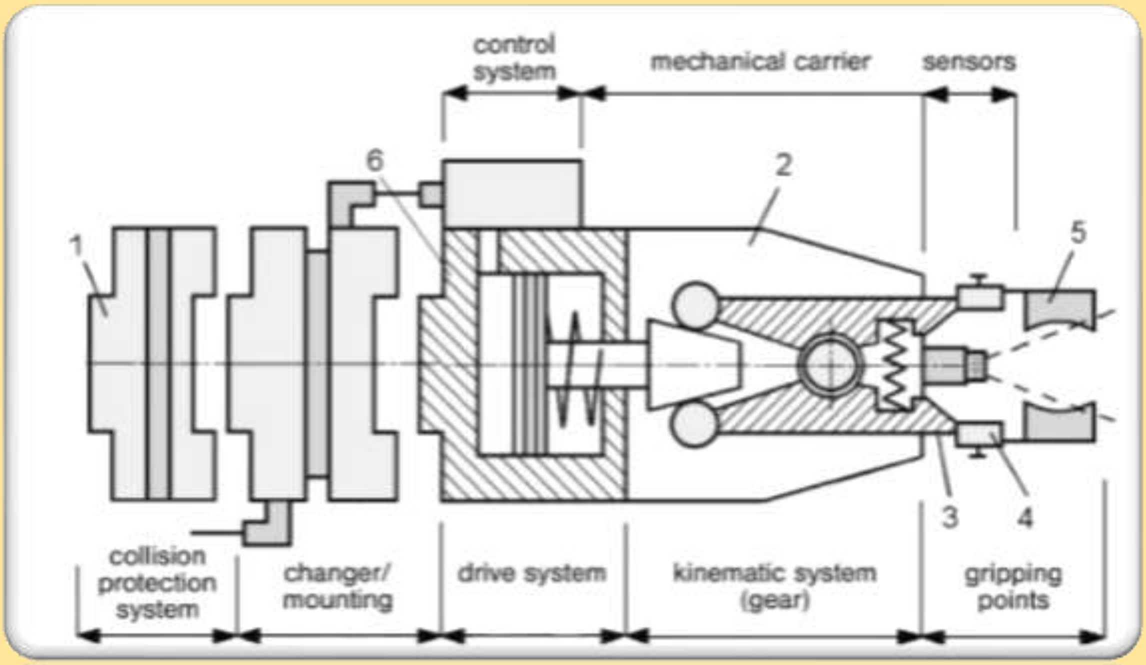
- They are a universal component in automation. Grippers operate with:

    1. Industrial robots (handling and manipulation of objects).
    2. Hard automation (assembling, micro-assembling, machining, and packaging).
    3. NC machines (tool change) and special purpose machines.
    4. Hand-guided manipulators (remote prehension, medical, aerospace, nautical)
    5. Work piece turret devices in manufacturing technology.
    6. Rope and chain lifting tools (load-carrying equipment).
    7. Service robots (prehension tools potentially similar to prosthetic hands).

Range of grippers fingers

- There are some characteristic terms that are often used in prehension technology. Grippers consist mostly of several modules and components.

- In the following, the most essential terms used will be explained considering as an example a mechanical gripper such as the one shown below.



Subsystems of a mechanical gripper

1. Remote centre compliance
2. Carrier
3. Gripper finger
4. Basic jaw
5. Flange

- Grippers are end effectors used to grasp and manipulate objects during the work cycle.

- The objects are usually work parts that are moved from one location to another in the cell.

- Machine loading and unloading applications fall into this category.

- Owing to the variety of part shapes, sizes, and weights, grippers must usually be custom designed.

- Types of grippers used in industrial robot applications include the following:

  1. Mechanical grippers, consisting of two or more fingers that can be actuated by the robot controller to open and dose to grasp the work part.

  2. Vacuum grippers, in which suction cups are used to hold flat objects.

  3. Magnetized devices, for holding ferrous parts.

  4. Adhesive devices, where an adhesive substance is used to hold a flexible material such as a fabric.

  5. Simple mechanical devices such as hooks and scoops.

- Mechanical grippers are the most common gripper type. Some of the innovations and advances in mechanical gripper technology include:

1. **Dual grippers**
   Consisting of two gripper devices in one end effector, which are useful for machine loading and unloading.

2. **Interchangeable fingers**
   It can be used on one gripper mechanism. To accommodate different parts, different fingers are attached to the gripper.

3. **Sensory feedback**
   The fingers that provide the gripper with capabilities such as:
   - Sensing the presence of the work part.
   - Applying a specified limited force to the work part during gripping (for fragile work parts).

4. **Multiple fingered grippers**
   Possess the general anatomy of a human hand.

5. **Standard gripper products**
   That are commercially available, thus reducing the need to custom-design a gripper for each separate robot application.

3.4 DEFINE THE END EFFECTORS

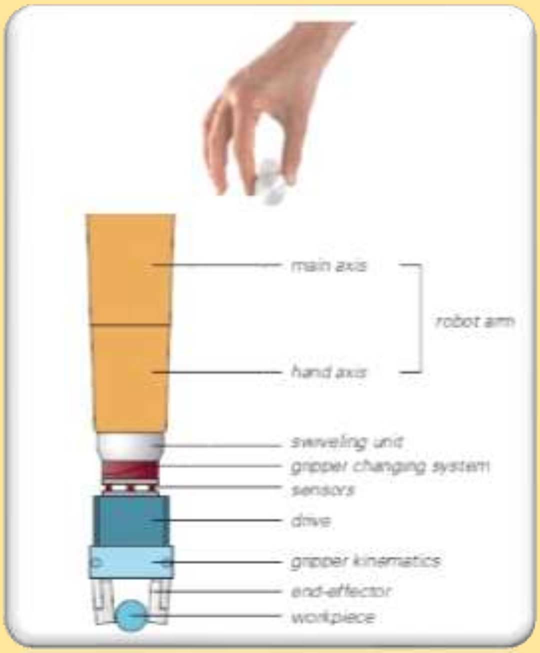
3.4.1 The Grapping problem

Robotic grasping is a complex field

- Hand design: high level (number of fingers, kinematic structure) and low-level (mechanism design, motors, materials).
- Hand control algorithms: high level (find an appropriate posture for a given task) and low-level (execute the desired posture).
- Information from sensors (tactile, vision, range sensing).
- Any pre-existing knowledge of objects shape, semantics and tasks (a cup is likely to be found on a table, should not be held upside-down)

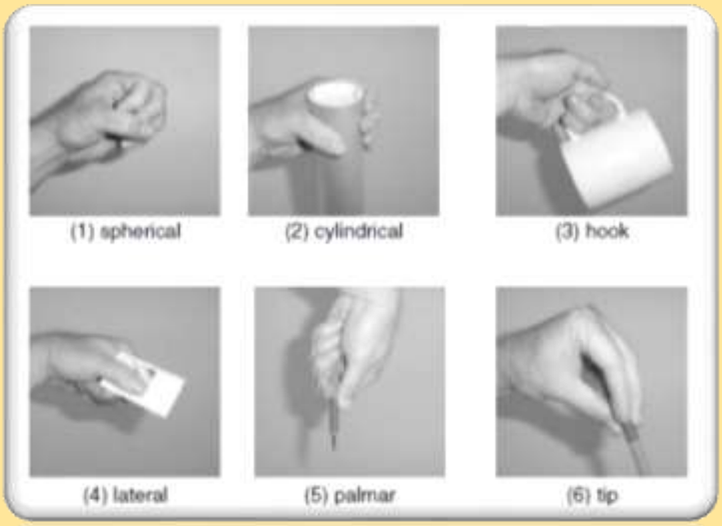
Human Grasping vs. Robotic Grasping

- Human performance provides both a benchmark to compare against, and a working example that we can attempt to learn from.
- However, it has proven very elusive to replicate.
- The human hand is a very complex piece of equipment, with amazing capabilities.
- Humans benefit from an unmatched combination of visual and tactile sensing.
- Human continuously practice grasping and manipulation, the amount of data they are exposed to dwarfs anything tried so far in robotics.



Grasping Stability

- Robotic grasping has been the topic of numerous research efforts.
- Stable object grasping is the primary goal of gripper design.
- The most secure grasp is to enclose the gripper jaws or finger around the center of gravity of the object.
- Six basic grasping patterns for human hands have been identified by Taylor and Schwarz in the study of artificial limbs.
- Six grasping forms of:
  - spherical
  - Cylindrical
  - hook
  - Lateral
  - Palmar
  - tip



Types of End Effector

There are 2 types of end effector:

- **Gripper** – use to grip, hold and move an object to another location.

- **Tools @ devices** and end-of-arm tooling @ equipment @ hardware - use to do work such as drilling, grinding, spraying paint or coating.

Factor in Selecting End Effector

i. The position of the component to be held must be reached.

i. Changes in the size of the components must be dealt with where it will affect the accuracy to put the components. The radius of the grip must be designed to follow the shape of the component.

iii. Appropriate power source is required to move the grip whether mechanical, electrical or pneumatic.

iii. Temperature and humidity working environment.

iii. Safety during operation.

iii. Problems and possible crooked and distortion on the grip.

vii. The cost of construction or the purchase of grip.

Gripping Ability

i. Grip the object to be gripped.

i. Adjustments can keep the object during the transportation stability.

iii. The effect of the object's position compared to the grip

Types of Robotic Grippers

i. Impactive – jaws or claws which physically grasp by direct impact upon the object.

i. Ingressive – pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fiber handling).

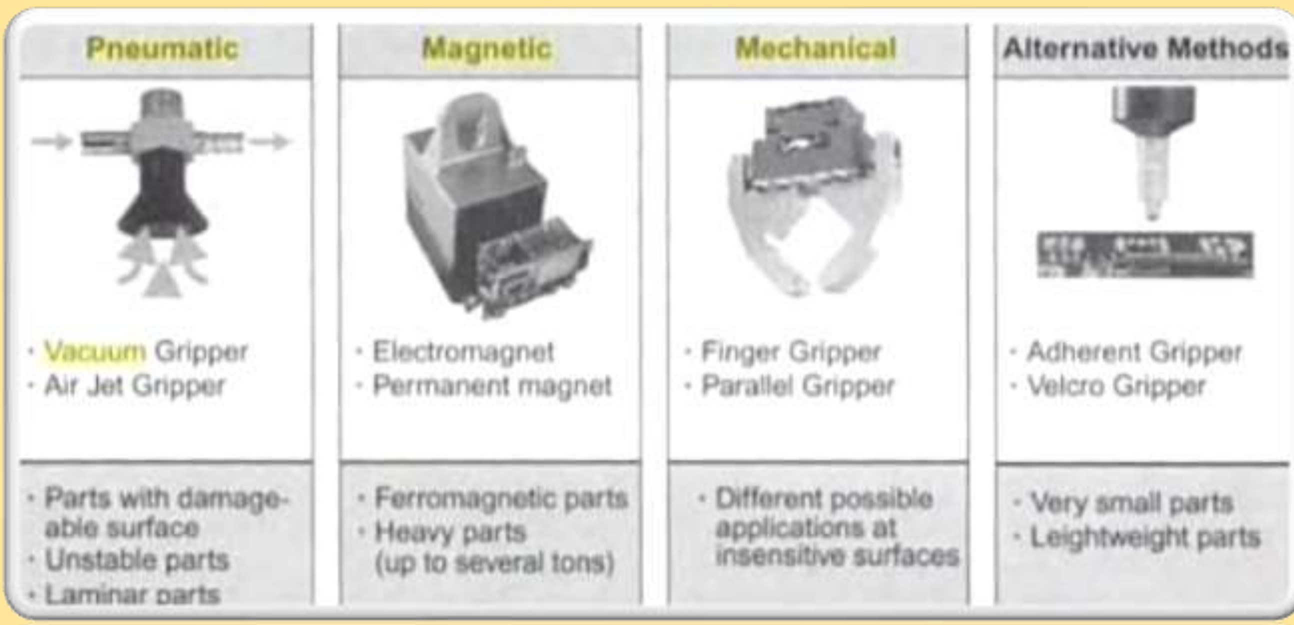
i. Astrictive – suction forces (includes magnetic) applied to the objects surface.

i. Contigutive – requiring direct contact for adhesion to take place (such as glue, surface tension or freezing)

Vacuum lifters, vacuum lifts & lifting devices

- Additional characteristics such as low weight, fast reaction, and being fail-safe are required. There are different techniques for gripping parts. Grippers are typically classified into 5 groups by performing principle:

  i. Mechanical grippers
  ii. Vacuum grippers
  iii. Magnetic devices
  iv. Flexible pneumatic devices
  v. Special purpose tools and special purpose devices



Different kinds of grippers

- With a market share of 66%, mechanical grippers are the most commonly used. Mechanical grippers can be subdivided by their kind of closing motion and their number of fingers.

i. **Three finger centric gripper** are typically used for gripping round and spherical parts.

i. **Two finger parallel grippers** perform the gripping movement with a parallel motion of their fingers, guaranteeing secure gripping because only forces parallel to the gripping motion occur.

- Because these gripper models can cause harm to the component surface, vacuum grippers are used for handling damageable parts.

- Two dimensional parts such as sheet metal parts are also handled by vacuum grippers.

- Using the principle of the Venturi nozzle, an air jet builds up a vacuum in the suction cup that holds the parts.

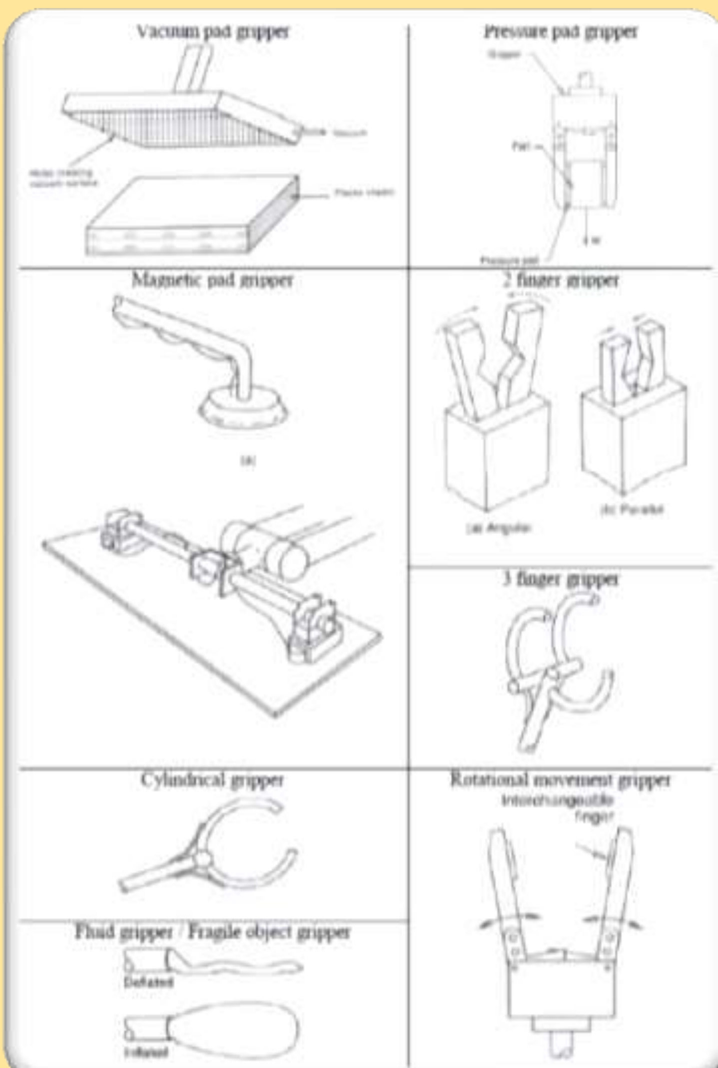
- When the air jet is turned off, the parts are automatically released.

- Heavy parts such as shafts are lifted not by mechanical grippers but with electromagnetic grippers.

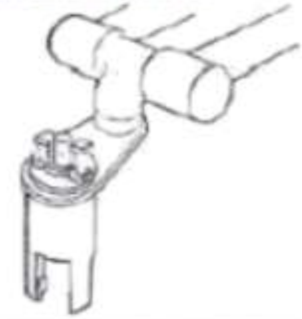
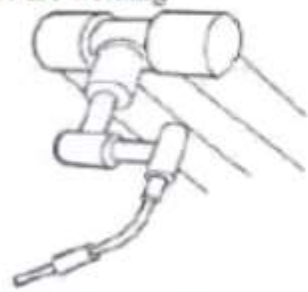
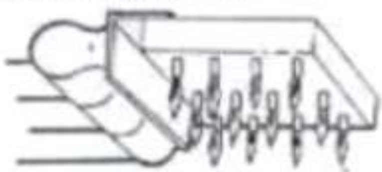
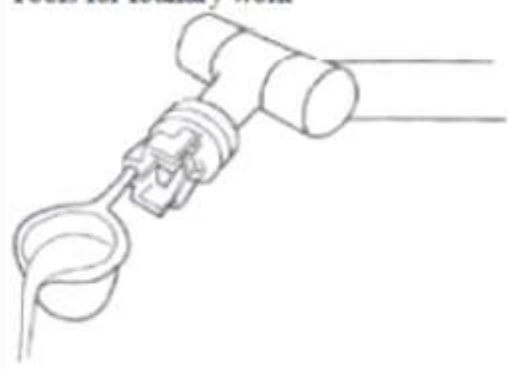
- However, secure handling, not exact positioning, is needed when using these grippers.

- To handle small and light parts, grippers using alternative physical principles, such as electrostatic and adherent grippers, are used because they do not exert any pressure that could cause damage to the part.

- Fields of application include micro assembly and electronics production.



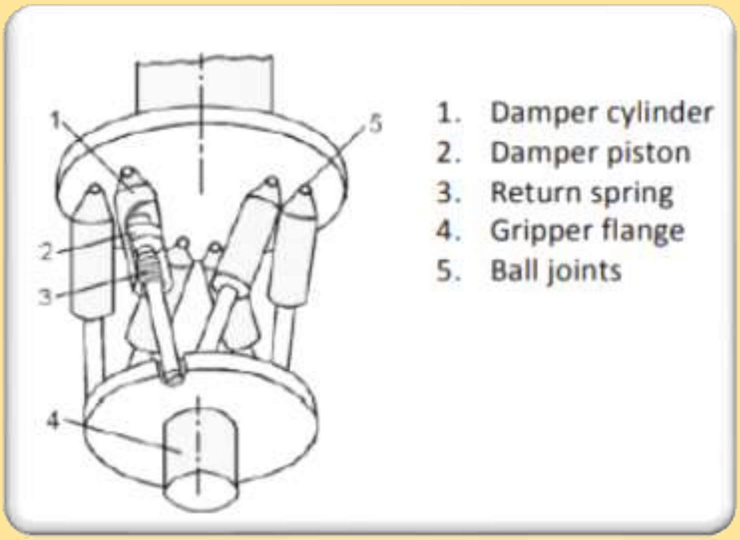
Types of Grippers

Type of end-of-arm tooling			
1.	Tools for welding points 	2.	Tools for installation nut 
3.	Tools for stud welding 	4.	Tools for arc welding 
5.	Tools for heating work 	6.	Tools for grinding work 
7.	Tools for spray paint or coating 	8.	Tools for foundry work 

Special Purpose tools and Special purpose devices

3.4.2 Remote Centered Compliance Devices

- In robotics, a Remote Center Compliance, Remote Center of Compliance or RCC is a mechanical device that facilitates automated assembly by preventing objects from jamming when they are inserted into a hole with tight clearance.

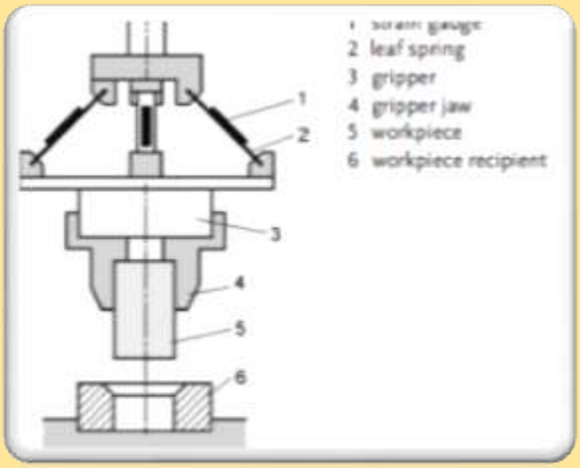


- Developed at the Draper Laboratories for an RCC which exhibits 6 degrees of freedom.

- It is suitable for the insertion of short bolts (diameter 12 to 58 mm, length 25 to 100 mm) where mechanical play may range from 12 to 24.

Instrumented Remote Centre Compliance (IRCC)

- Unlike the purely passive RCC systems, IRCC links actively compensate for angle and lateral displacements.

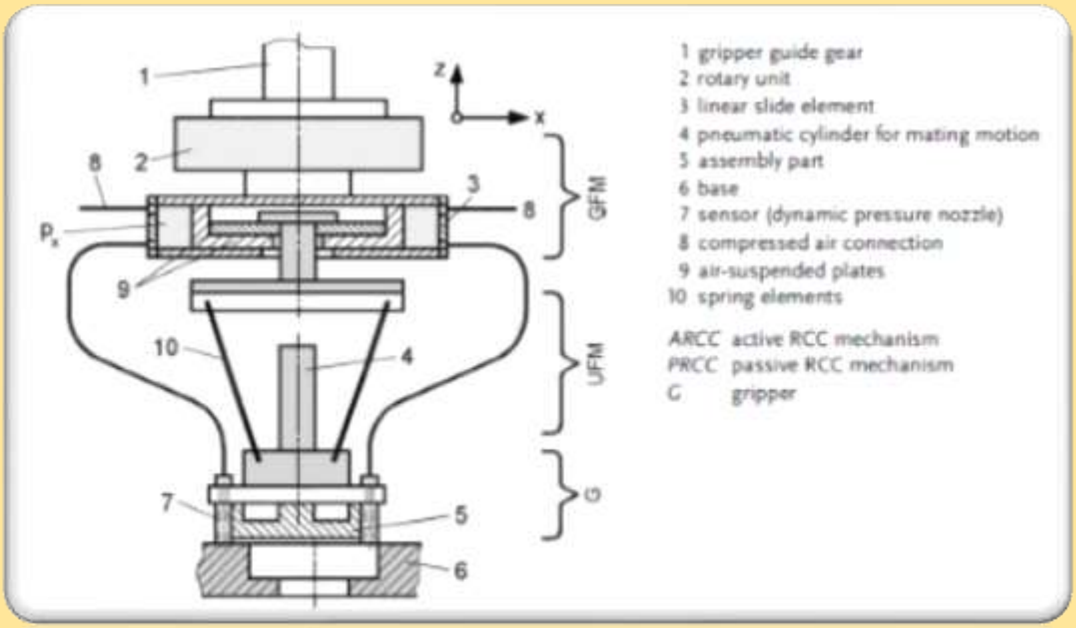


IRCC system using force measurement

- The compensation mechanism schematically shown above contains leaf springs as elastic elements.

- Deformation of these springs can be detected using strain gauges and the information used for position correction of the gripper.

- The below picture shown hybrid mating mechanism consisting of both passive and active systems



- The actively controlled part operates pneumatically in the x and y directions.

- Two dynamic pressure nozzles (sensors) are used to measure distances from the base flange.

- The pneumatic control equipment, which is directly coupled with the sensors, consists of air suspended displaceable plates.

- The displacement continues until all sensor orifices attain the same position relative to the base hole sides and the measured pressure differences in the control chambers vanish.

EXERCISE

1. Differentiate between Machines and Mechanism.
2. Name two types of links.
3. Describe three types of mechanical motion.
4. What are the different between translation motion and rotational motion?
5. Discuss the concept of translation motion and an example of rotational motion.
6. Discuss the concept of rotational motion and an example of rotational motion.
7. Name and draw three mechanical components that transform rotary to rotary motion.
8. Name and draw three mechanical components that transform rotary to translation motion.
9. What is the primary function of linkage?
10. Name five types of linkage.
11. Describe and sketches the Specialized Linkages.
12. What is the function of couplers?
13. Name two types of couplers.
14. Named two types of flexible coupling.
15. Discuss the mechanical flexible coupling.
16. What is the meaning of power transfer in mechanical concept?
17. Named five categories of power transfer mechanism.
18. Named three basic components in modeling of mechanical system.
19. What are Electrical Analogies?
20. Define the End Effectors

EXERCISE

21. Grippers are not only required use with industrial robot; They are a universal component in automation system. State five applications in automation that needs a gripper.
22. Give FIVE (5) factors in selecting end effector.
23. Explain the factor to be considered in Grasping problem.
24. Name SIX (6) types of grasping form.
25. Give THREE (3) types of robot end effector driven actuators.
26. Tooling’s are fixed the end of the robots arm. Name five (5) types of tooling that fixed at the robot arm.
27. Explain the Remote Centered Compliance Devices.
28. Named six types of forms of object prehension in robots.
29. Draw and named subsystem of a mechanical gripper.
30. What are Remote Centered Compliance Devices?

CHAPTER 4

Control Of Actuators In Automation Mechanisms

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.

CHAPTER 4

Control Of Actuators In Automation Mechanisms

4.1 Explain Stepper Motors
- 4.1.1 Describe principles of stepper motor operation
- 4.1.2 Explain Half Step Mode Operation
- 4.1.3 Explain Micro-step Mode
- 4.1.4 Describe additional Methods of Damping Rotor Oscillations
- 4.1.5 Describe permanent Magnet Stepper Motors
- 4.1.6 Describe stepper motor drives
- 4.1.7 Describe linear stepper motors

4.2 Implement control method of actuators
- 4.2.1 Apply control method for Brushless DC Motors
- 4.2.2 Apply control method for Direct Drives Actuator
- 4.2.3 Apply control method for Hydraulic Actuators
- 4.2.4 Apply control method for Pneumatic Actuators

4.1 EXPLAIN STEPPER MOTORS

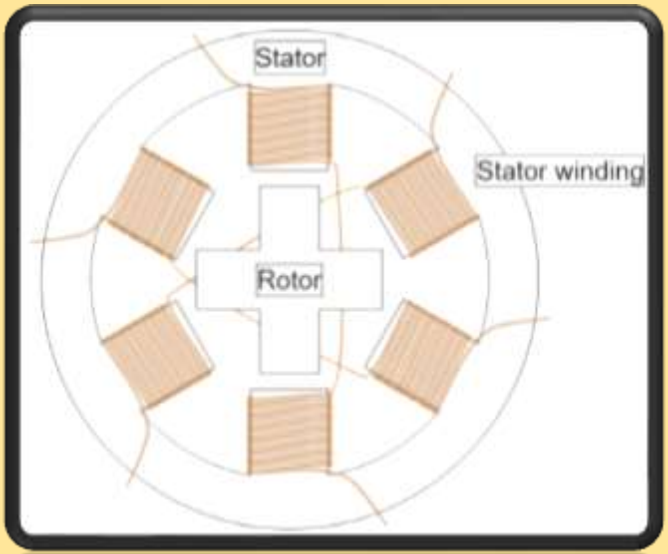
4.1.1 Describe principles of stepper motor operation

Working principles

Stepper motor is a brushless DC motor that rotates in steps. This is very useful because it can be precisely positioned without any feedback sensor, which represents an open-loop controller.

The stepper motor consists of a rotor that is generally a permanent magnet and it is surrounded by the windings of the stator.

As activated the windings step by step in a particular order and let a current flow through them they will magnetize the stator and make electromagnetic poles respectively that will cause propulsion to the motor. So that' the basic working principle of the stepper motors.



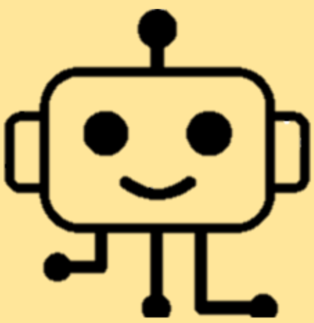
Cross-section of stepper motor

Stepper motors and drives, what is full step, half step and microstepping

- Stepper drives control how a stepper motor operates, there are three commonly used excitation modes for stepper motors, full step, half step and microstepping. These excitation modes have an effect on both the running properties and torque the motor delivers.

- A stepper motor ***converts electronic signals into mechanical movement each time an incoming pulse is applied to the motor.***

- Each pulse moves the shaft in fixed increments. If the stepper motor has a 1.8° step resolution, then in order for shaft to rotate one complete revolution, in full step operation, the stepper motor would need to receive 200 pulses, 360° ÷ 1.8 = 200.



Full step operation

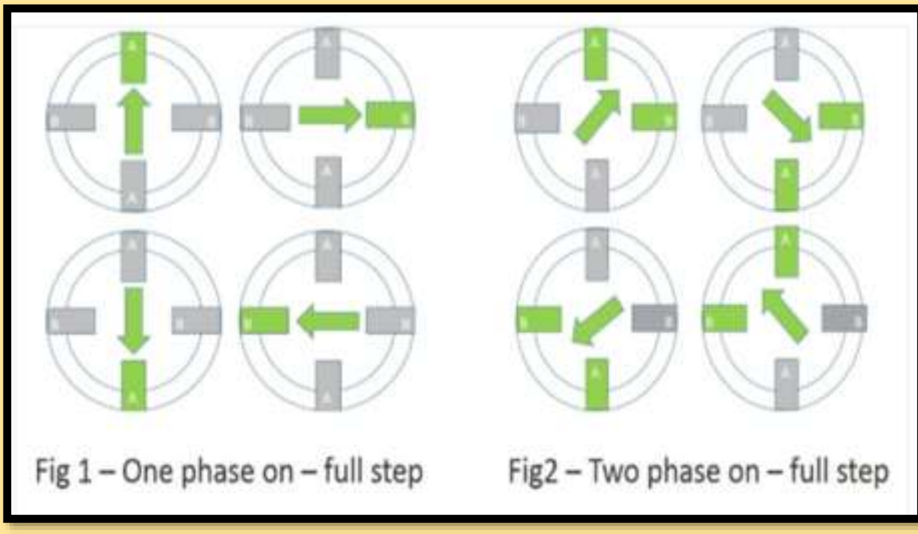
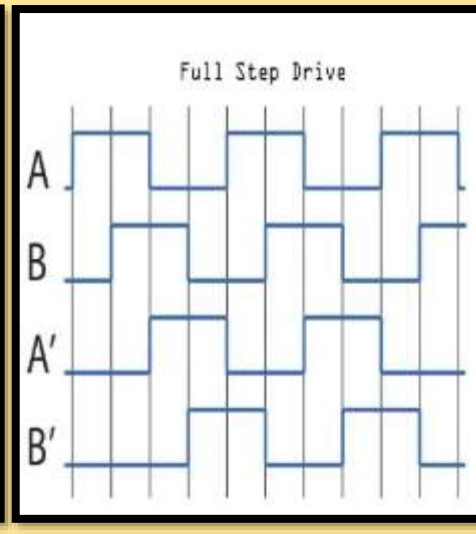


Fig 1 – One phase on – full step

Fig2 – Two phase on – full step



Four Steps per revolution i.e. 90 deg. steps.

In one-phase on - full step

- *Fig1, the motor is operated with only one phase energized at a time*. This mode requires the least amount of power from the driver of any of the excitation modes.

In two-phase on - full step

- *Fig2, the motor is operated with both phases energized at the same time. This mode provides improved torque and speed performance.* Two-phase on provides about 30% to 40% more torque than one phase on, however it requires twice as much power from the driver.

4.1.2 Explain Half Step Mode Operation

Half step operation

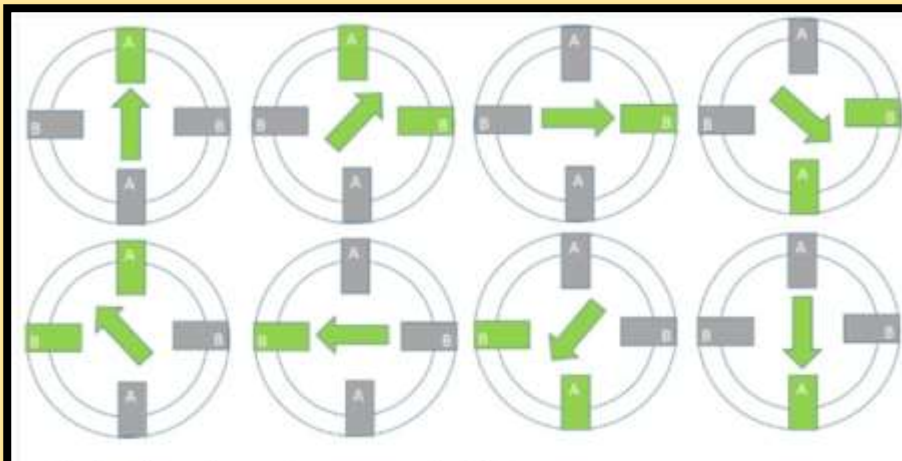
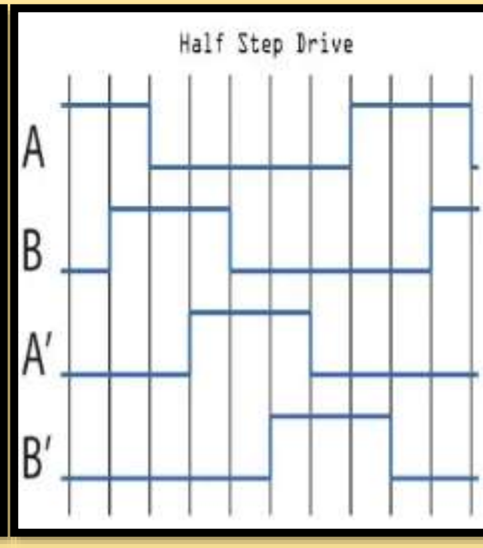


Fig3 - One-two phase on - half step



Eight steps per. revolution i.e. 45 deg. steps.

Half step excitation mode is a ***combination of one phase on and two phase on full step modes.*** This results ***in half the basic step angle***. This smaller step angle provides smoother operation due the increased resolution of the angle.

Half step produces about 15% less torque than two phase on - full step, however modified half stepping eliminates the torque decrease by increasing the current applied to the motor when a single phase is energized. See Fig3

4.1.3 Explain Micro-Step Mode Operation

Micro-step operation

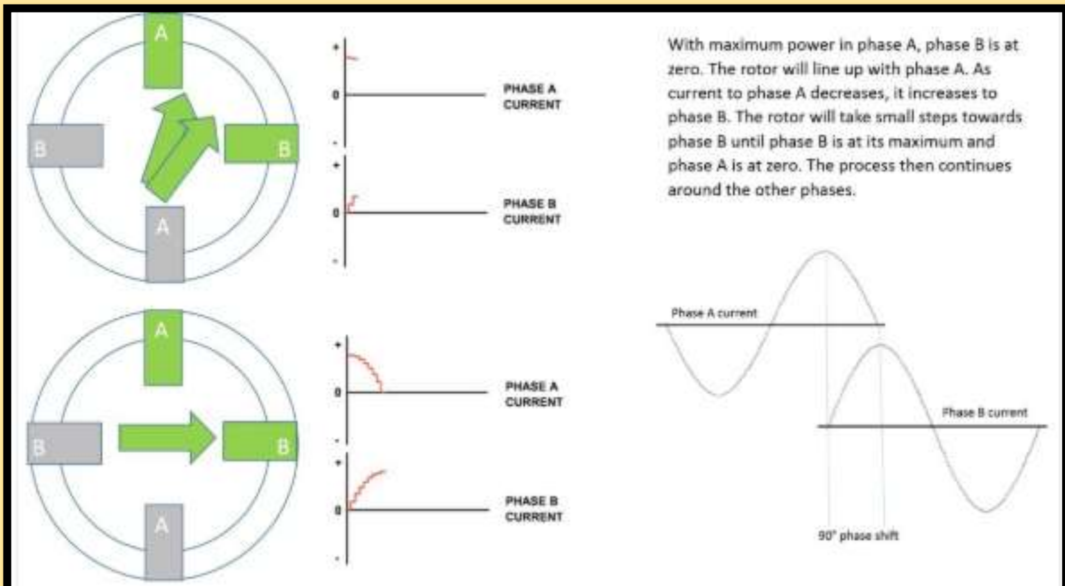


Fig 4 - Microstepping

Micro-stepping can *divide a motor's basic step by up to 256 times, making small steps smaller.* A Micro drive uses two current sinewaves 90° apart, this is perfect for enabling smooth running of the motor. You will notice that the motor runs is quietly and with no real detectable stepping action.

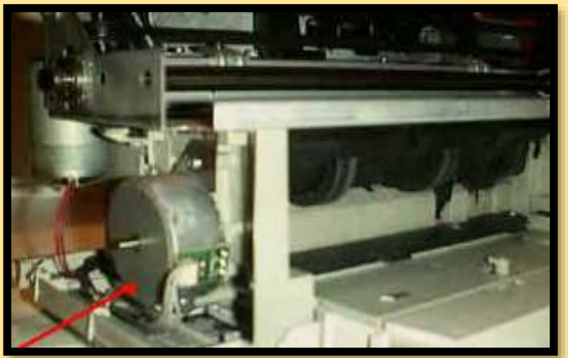
By controlling direction and amplitude of the current flow in each winding, the resolution increases and the characteristics of the motor improve, giving less vibration and smoother operation. Because the sinewaves work together there is a smooth transition from one winding to the other. When current increases in one it decreases in the other resulting in a smooth step progression and maintained torque output. See Fig4

4.1.4 Describe additional Methods of Damping Rotor Oscillations

It is well known *that rotor oscillation is one of the principal problems in the switched drive of a stepping motor*, and nowadays several methods for damping this oscillation have been suggested in which the switching sequence is changed in some manner.

In such methods, the excitation time of the stator windings must be tuned appropriately, or the effect of damping is insufficient and oscillation may be even amplified in some circumstances.

For example, if a stepping motor is used to drive a printer carriage then the system must come to rest for the printing of each letter. The operating speed of the printer is limited by the time taken for the system to settle to within the required accuracy at each letter position. The frequency of oscillation can be predicted for any motor/load combination from the static torque/rotor position characteristic, provided the system is lightly damped.



Paper feeder on printers

STEEPER MOTOR APPLICATION

CNC lathes

Advantages Stepper Motors

Flexibility

- Constant holding torque without the need for the motor to be powered.

Safer

- If anything breaks, the Stepper Motor will stop.

Longer Life

- Bearings are essentially the only part that will wear-out.

Excellent Low Speed Torque

- Motor will drive many loads without having to utilize any additional gearing or gearbox mechanisms.

Excellent Repeatability

- Stepper Motor allow the shaft of the motor to return to the same location accurately offering excellent repeatability.

Overload Safe

- The motor cannot be damaged by mechanical overload

Very Reliable

- Very reliable since there are no contact brushes in the motor.

Disadvantages Stepper Motors

Low Efficiency

- The Stepper Motor draws substantial power (remembering holding torque) regardless of load.

The Torque of a Stepper Motor Declines Rapidly with Speed

No Feedback is Used to Indicate Potential Missed Steps

Low Torque to Inertia Ratio

- Cannot accelerate loads very rapidly and the motor can get very hot in high performance configurations.

Very Noisy

- Stepper Motor can be audibly very noisy at moderate to high speeds and have low output power for size and weight.

Holding Torque has to be Overcome

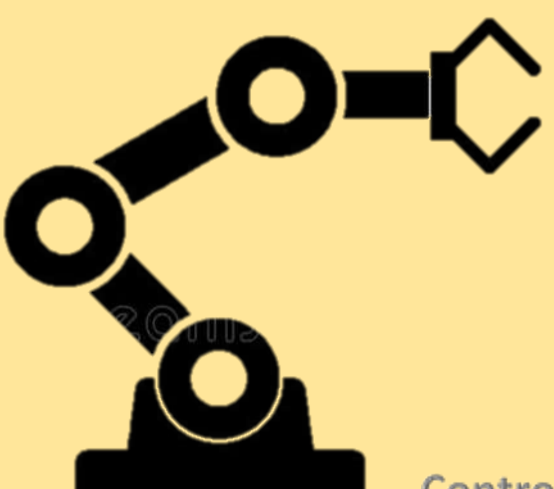
- Detent or holding torque has to be overcome in order for the motor to move, it reduces the ideal torque that the motor can produce when it’s running.

4.1.5 Describe Permanent Magnet Stepper Motors

The rotor is a permanent magnet that aligns with the magnetic field generated by the stator circuit.

This solution guarantees a good torque and also a detent torque. This means the motor will resist, even if not very strongly, to a change of position regardless of whether a coil is energized.

The drawbacks of this solution is that it has a lower speed and a lower resolution compared to the other types.



4.1.5 Describe Permanent Magnet Stepper Motors

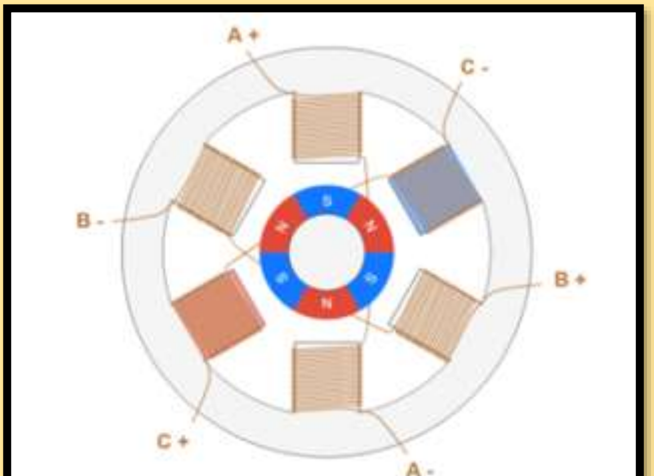
- Permanent-magnet stepper motors have smooth armatures and include a permanent magnet core that is magnetized width wise or perpendicular to its rotation axis.

- These motors usually have two independent windings, with or without centre taps.

- The most common step angles for PM motors are 45° and 90°, but motors with step angles as fine as 1.8° per step as well as 7.5, 15, and 30° per step are generally available.

- Armature rotation occurs when the stator poles are alternately energized and de-energized to create torque.

- A 90° stepper has four poles and a 45° stepper has eight poles, and these poles must be energized in sequence. Permanent-magnet steppers step at relatively low rates, but they can produce high torques and they offer very good damping characteristics.



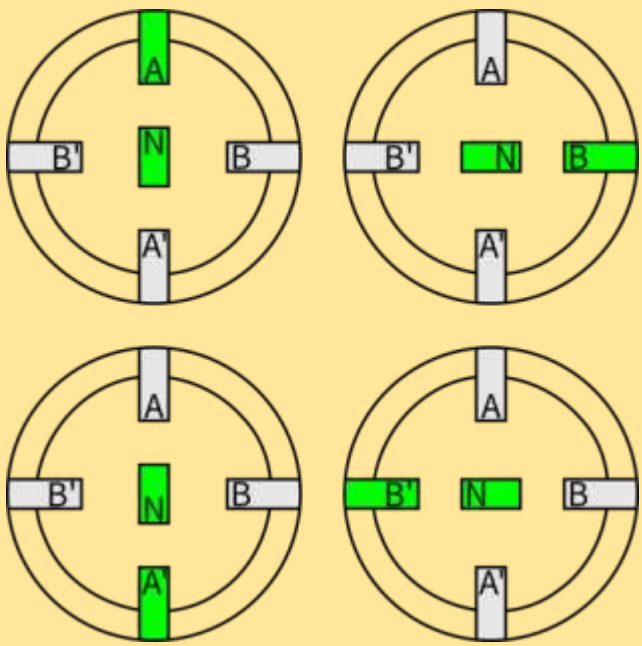
Permanent Magnet Stepper Motor

4.1.6 Describe Stepper Motors Drives

What are stepper drives and how do they work?

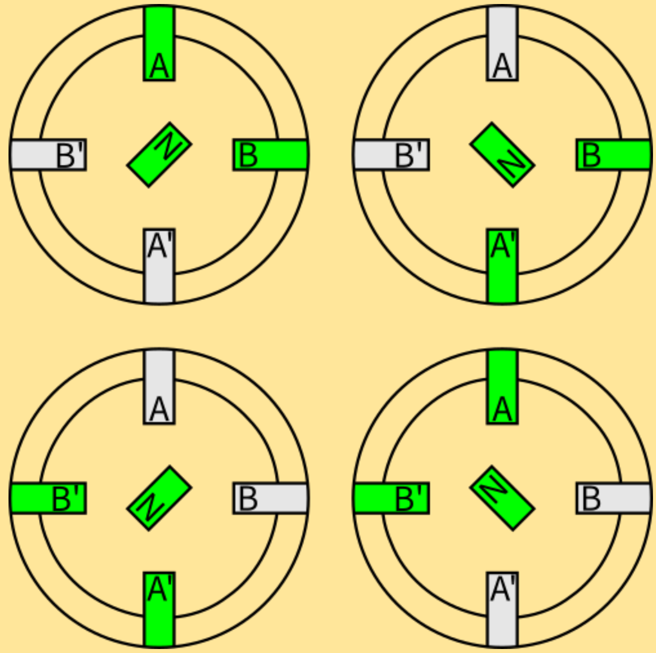
- A stepper drive is the driver circuit that controls how the stepper motor operates. Stepper drives work by sending current through various phases in pulses to the stepper motor. There are four types: **wave drives (also called one-phase-on drives), two-phase on, one-two phase-on drives** and **micro-stepping drives.**

- **Wave or one-phase-on drives** work with only one phase turned on at a time. Consider the illustration below. When the drive energizes pole A (a south pole) shown in green, it attracts the north pole of the rotor. Then when the drive energizes B and switches A off, the rotor rotates 90° and this continues as the drive energizes each pole one at a time.

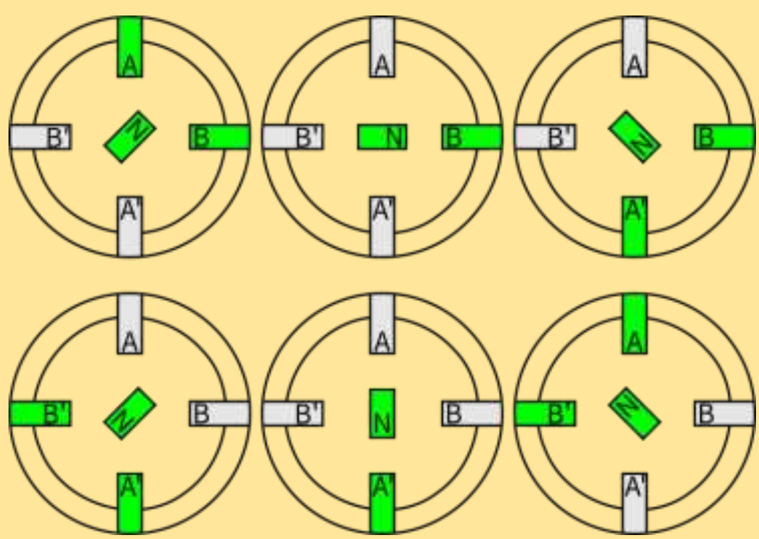


now you know

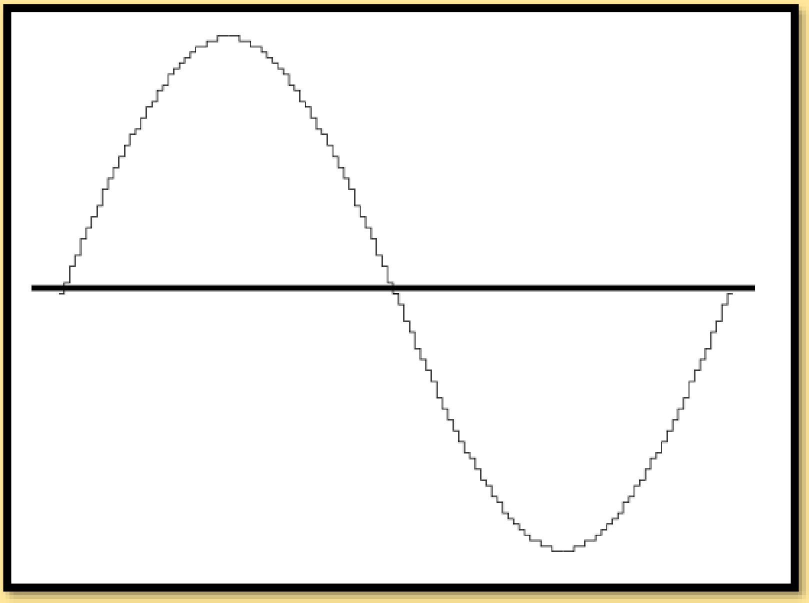
- **Two-phase-on drives** has its name because two phases are on at a time. If the drive energizes both A and B poles as south poles (shown in green), then the rotor’s north pole attracts to both equally and aligns in the middle of the two. As the energizing sequence continues on like this, the rotor continuously ends up aligning in-between two poles.



- **One-two phase-on drives** has its name for the way the drive energizes either 1 or 2 phases at any specific time. In this driving method, also known as half-stepping, the drive energizes pole A (shown in green) then energizes poles A and B then energizes pole B and so forth.



- One-two phase-on driving delivers finer motion resolutions. When two phases are on, the motor produces more torque. One caveat here: torque ripple is a concern because it may cause resonance and vibration.
- Related to one-two phase-on driving is micro-stepping.
- **Micro-stepping delivers** very fine motion resolutions. Here, the drive uses current regulation to prevent torque oscillations. With this technique, engineers can use stepper motors in more applications.
- In sort, a drive that is micro-stepping increases and decreases current along a sine wave, so no pole is fully on or off. Here is a sample micro-stepping sine-wave current:

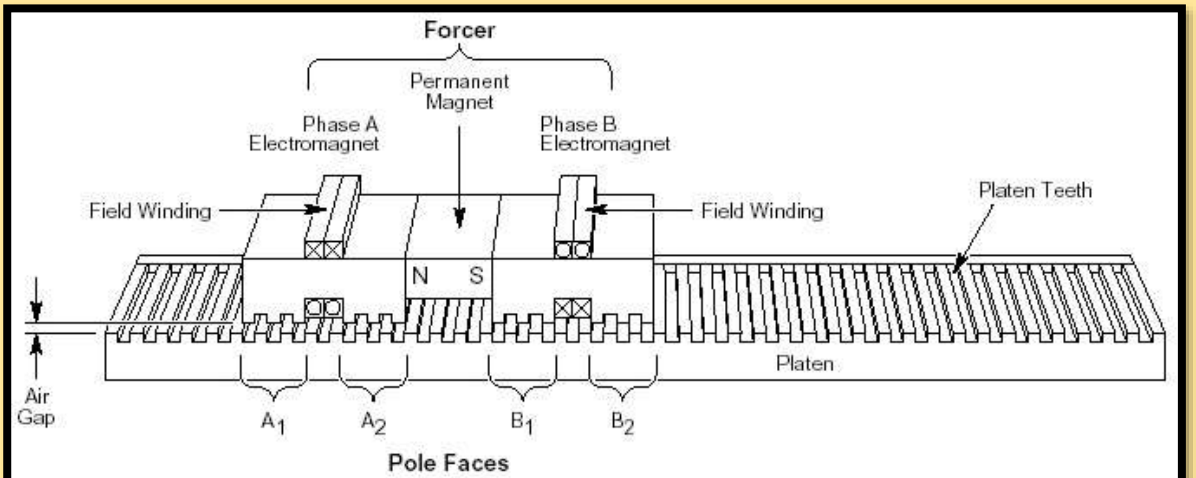


- Note the subtle jagged contour of the sine-wave current. While micro-stepping doesn't necessarily improve accuracy, it does get higher resolution than other driving modes—which is particularly helpful for applications in which the motor goes through no-load situations. During operation, motors can miss steps. However, micro-stepping spreads energy out instead of delivering it to the motor all at once, which can cause ringing and overshoot.

4.1.7 Describe Linear Stepper Motors

Linear stepper motor is essentially rotary stepper motor "unwrapped" to operate in straight line. Motor operates on electromagnetic principle and consists of moving "forcer" and stationary platen.

Linear stepper motors are available with either mechanical roller bearing or air bearings



linear-stepper-motor

Benefits of linear stepper motor are

- Higher resolution for positioning
- Smoothness at slow speeds
- Wider speed range

4.2 IMPLEMENT CONTROL METHOD OF ACTUATORS

4.2.1 Apply control method for Brushless DC Motors

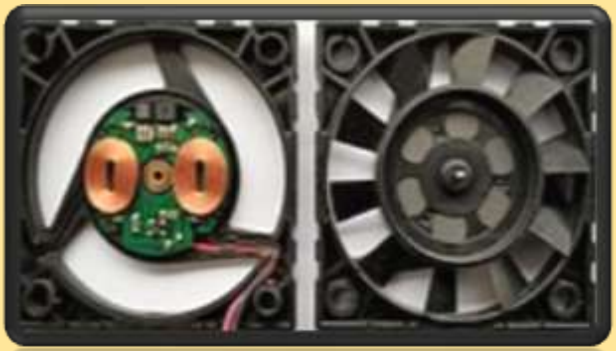
Brushless DC Motors

- A brushless DC electric motor (BLDC motor or BL motor), also known as an electronically commutated motor (ECM or EC motor) or synchronous DC motor, is a synchronous motor using a direct current (DC) electric power supply.

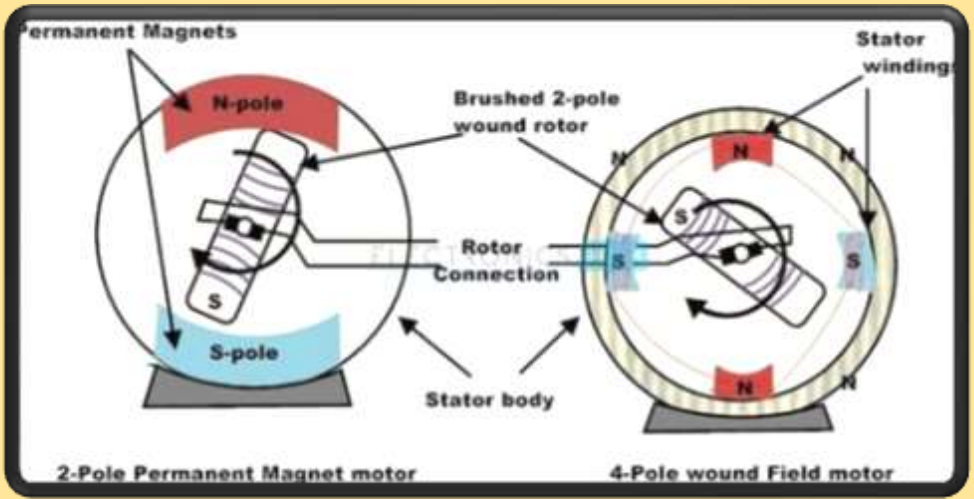
- It uses an electronic controller to switch DC currents to the motor windings producing magnetic fields which effectively rotate in space and which the permanent magnet rotor follows.

- The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor. This control system is an alternative to the mechanical commutator (brushes) used in many conventional electric motors.

The motor from a 3.5 in floppy disk drive

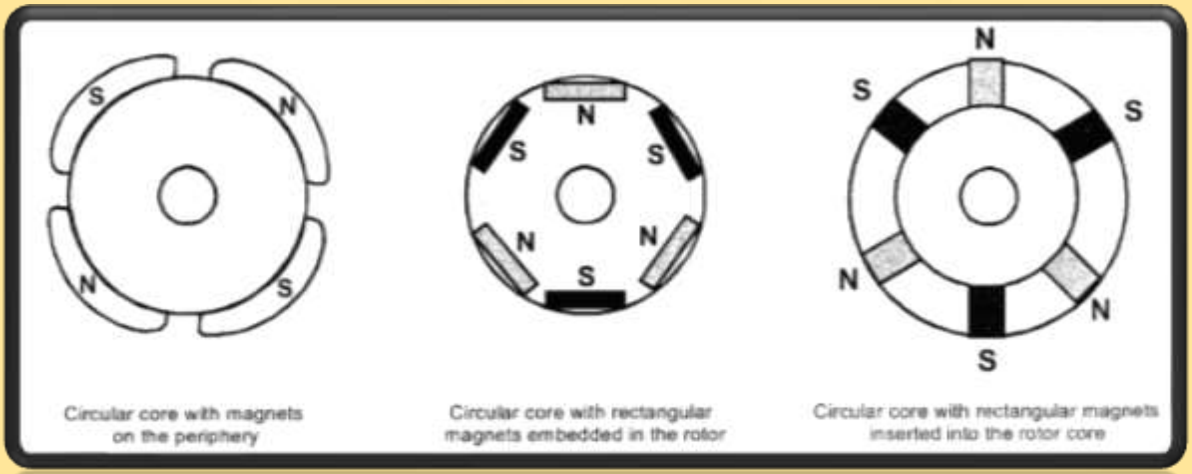


DC brushless ducted fan



BLDC Motor

BLDC Motor Stator

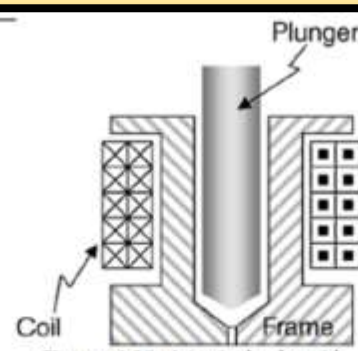


BLDC Motor Rotor

4.2.2 Apply control method for Direct Drives Actuator

- Solenoid Type Devices
- Solenoids, is the simplest electromagnetic actuators that are used in linear as well as rotary actuations for valves, switches, and relays. As the name indicates, a solenoid consists of a stationary iron frame (stator), a coil (solenoid), and a ferromagnetic plunger (armature) in the center of the coil.

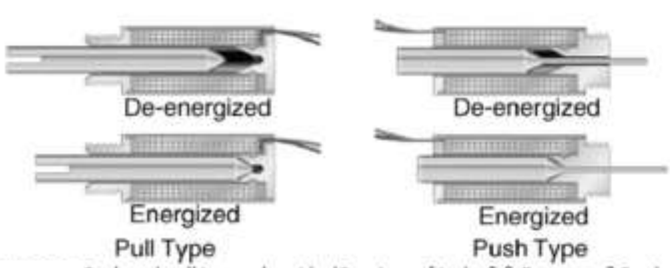
Assorts of solenoid actuators



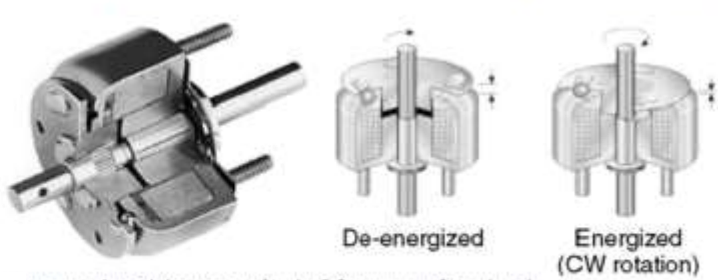
: A typical solenoid

- As the coil is energized, a magnetic field is induced inside the coil. The movable plunger moves to increase the flux linkage by closing the air gap between the plunger and the stationary frame. The magnetic force generated is approximately proportional to the square of the applied current I and is inverse proportional to the square of the air gap , which is the stroke of the solenoid

Typical force-stroke curve of solenoids. (Courtesy of Magnetic Sensor Systems.)

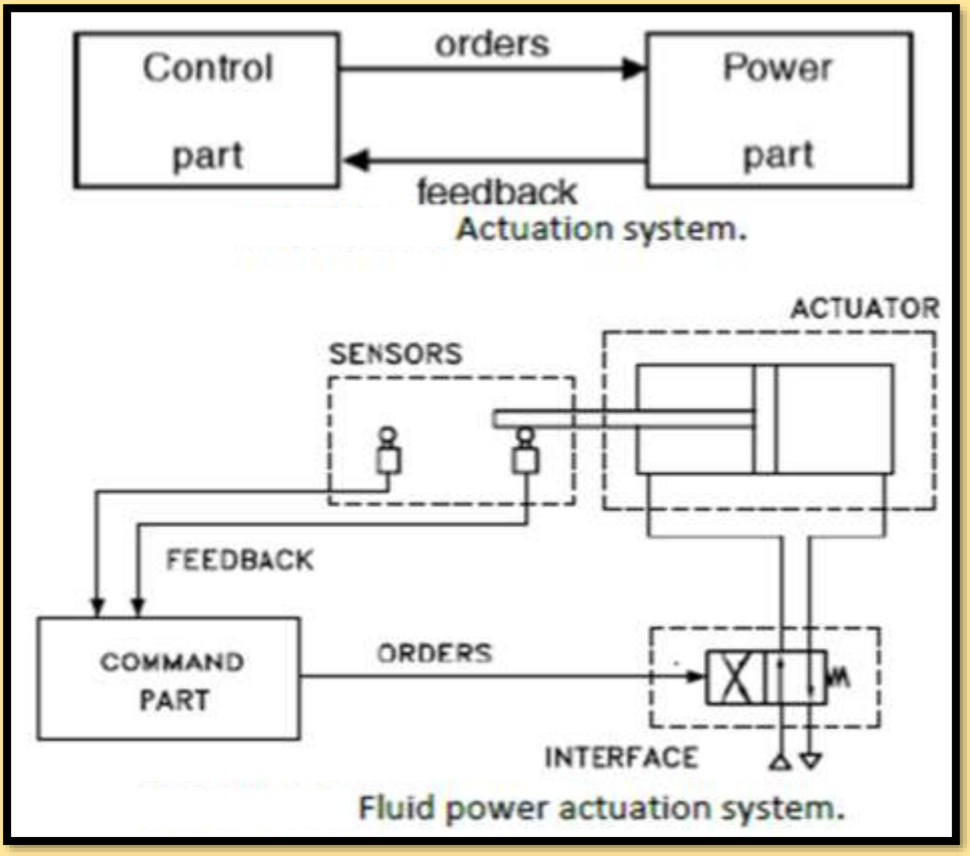


Push and pull type solenoids. (Courtesy of Ledex® & Dormeyer® Products.)



Rotary solenoid. (Courtesy of Ledex® & Dormeyer® Products)

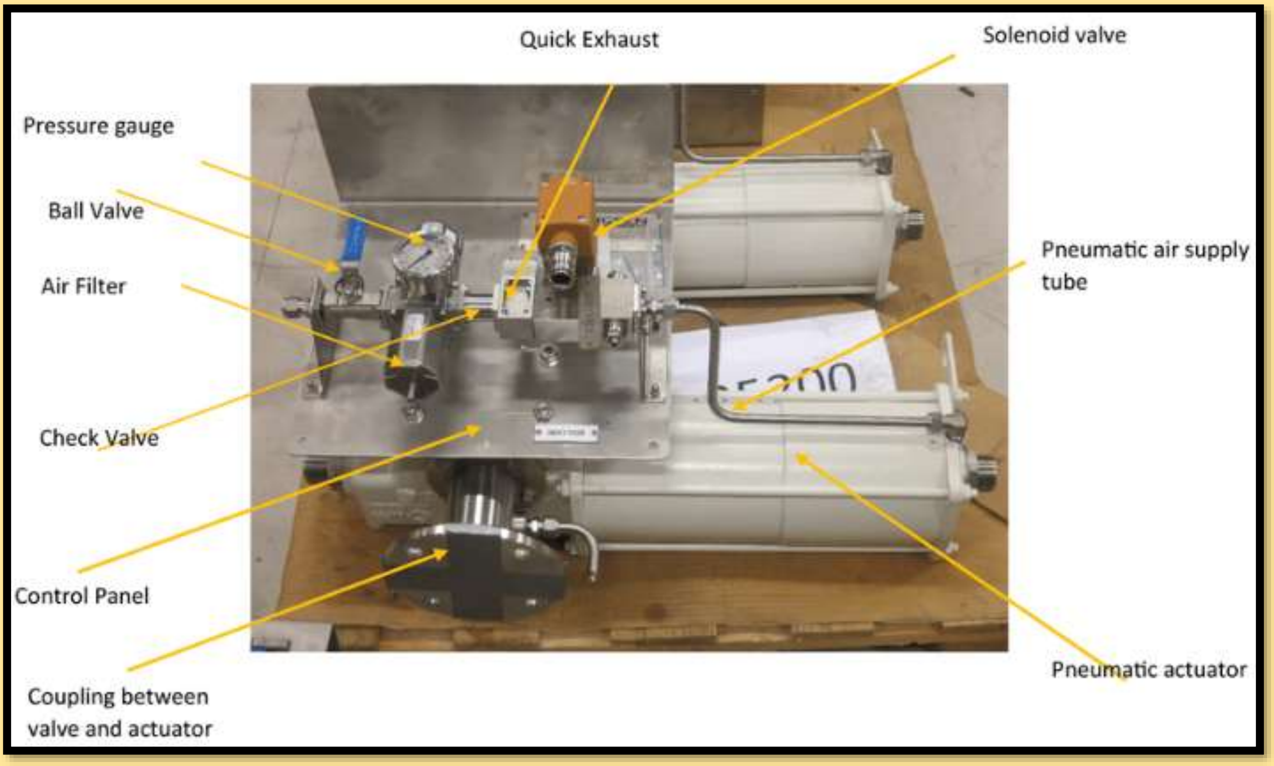
4.2.3 Apply control method for Hydraulic Actuator



The components of a hydraulic actuation system are:

- Pump, that is, the hydraulic power generation system;
- Actuator, that is, the element which converts hydraulic power into mechanical power;
- Valve, that is, the hydraulic power regulator;
- Pipes for connecting the various components of the actuation system;
- Filters, accumulators, and reservoirs;
- Fluid, which transfers the power between the various circuit elements;
- Sensors and Transducers;
- The system display, measurement, and control devices.

4.2.4 Apply control method for Pneumatic Actuator



The components of a pneumatic actuation system are:

- Compressed air generation system, consisting of the compressor, the cooler, possibly a dryer,
- Storage tank, and the intake and output filters;
- Air treatment unit, usually consisting of the FRL assembly (filter, pressure regulator, possibly a lubricant, which permits filtration and local regulation of the supply pressure
- Actuator valve;
- The valve, that is, the regulator of the pneumatic power;
- the actuator, which converts the pneumatic power into mechanical power;
- The piping;
- The sensors and transducers;
- The system display, physical magnitude measurement, and control devices.

END OF THIS CHAPTER

- ACTUATOR IN AUTOMATION
  - CONTROL OF ACTUATOR
  - STEPPER MOTOR
  - BRUSHLESS DC MOTORS
  - DIRECT DRIVES
  - HYDRAULIC
  - PNEUMATIC

EXERCISE

1. Indicate the correct answer:
   a. The major advantage of a permanent magnet step motor is that it can provide holding torque (True/ False).
   b. The torque generated in a step motor under start-stop mode is more than under slewing mode (True/ False).
   c. A variable reluctance type step motor requires less number of switches than of permanent magnet type (True/ False).
   d. Damping of a step motor refers to slow acceleration during starting (True/ False).
   e. 3-phase a.c. excitation is needed to drive a 3-phase step motor (True/ False).
2. What stepper motor has to offer in the field of engineering?
3. Explain how can we identify a stepper motor through physical outlook?
4. Explain the operation principles of a stepper motor.
5. Why are the step positions likely to be less well defined when a motor is operated in 'two-phase-on' mode as compared with one-phase-on mode?
6. Explain how rotation is achieved in a stepper motor.
7. A stepper motor cannot be bench-checked directly from a power source. Why?
8. What is meant by detent torque, and in what type of motors does detent torque occur?
9. What is meant by the 'holding torque' of a stepping motor?
10. Find the step angle of the following stepping motors:
    (a) 3-phase, VR, 12 stator teeth and 8 rotor teeth;
    (b) 3-phase, VR, three-stack, 16 rotor teeth;
    (c) 4-phase unipolar, hybrid, 50 rotor teeth.

EXERCISE

11. Named two methods of Damping Rotor Oscillations and explain one method of damping.
12. Explain briefly about linear stepper motor.
13. A step motor has 130 steps per revolution. Find the input digital pulse rate that produces continuous rotation at a speed of 10.5 revolutions/ sec.
14. Explain the operation principles of a Brushless DC motor.
15. Named three types of direct drive actuator.
16. Explain how solenoid actuator works.
17. Draw a schematic diagram for fluid power actuation system.
18. Draw a schematic of fluid power servo system.
19. Draw symbol for hydraulic rotary actuator.
20. Draw symbol for double acting, single ended actuator.
21. List three advantages and three disadvantages of using fluid power for power transfer mechanism.
22. Name several pumps that used hydraulic fluid.
23. Draw a schematic diagram pneumatic actuation system.
24. Given three advantages and three disadvantages for pneumatic system.
25. How proportional regulator valve works for a pneumatic system?

CHAPTER 5

Automation Sensory Devices

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.

CHAPTER 5

Automation Sensory Devices

5.1 Describe the General Characteristics of sensor

- 5.1.1 Explain the following sensor characteristics:
  - a. Classification of sensors (internal, external etc.)
  - b. Sensor generalities (absolute, incremental, etc)

5.2 Explain the Angular and Linear Position Sensors

- 5.2.1 Explain methods of angular position measurement (resistive, capacitive, inductive, optical)
- 5.2.2 Explain encoding schemes (incremental, absolute)

5.3 Explain the Velocity and Acceleration Sensors

- 5.3.1 Explain tacho generator, optical incremental encoder, Sagnac interferometer, micromechanical angular velocity and acceleration sensor

5.4 Explain the Contact Sensors

- 5.4.1 Explain piezoresistive and capacitive tactile sensors, optical tactile sensors, force measurement by deformation of contact sensors: principle and applications of strain gage sensors.

5.5 Apply the distance and velocity sensor

- 5.5.1 Explain triangle sensor, Time-Of-Flight Sensors, Laser-Range Radar, Laser interferometric distance meter, Laser-Doppler Velocimeter

5.1 Describe the General Characteristics of sensor

- In simple terms, Industrial Automation Sensors are input devices which provide an output (signal) with respect to a specific physical quantity (input).
- Sensors used in Automation: In the industrial automation, sensors play a vital part to make the products intellectual and exceptionally automatic.

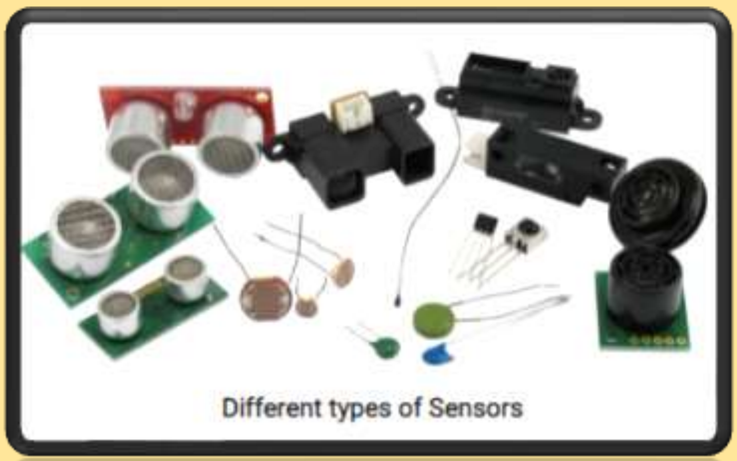
Characteristic	Description
Accuracy/Precision	The correctness of the measured absolute value or event
Drift	The degree to which the measured value shifts away from the correct value over time
Dynamic range	The allowed lower and upper limits of the instruments' input or output given the required level of accuracy
Reliability	The ability to consistently return correct measures
Resolution	The finest measurable change in input value
Repeatability	The ability to consistently return the same measure for the same input conditions
Update rate	The rate at which a new signal value is collected

What is a Sensor?

A device that detects the changes in electrical or physical or other quantities and thereby produces an output as an acknowledgement of change in the quantity is called as a Sensor. Generally, this sensor output will be in the form of electrical or optical signal.

The most frequently used different types of sensors are classified based on the quantities such as Electric current or Potential or Magnetic or Radio sensors, Humidity sensor, Fluid velocity or Flow sensors, Pressure sensors, Thermal or Heat or Temperature sensors, Proximity sensors, Optical sensors, Position sensors, Chemical sensor, Environment sensor, Magnetic switch sensor , etc.

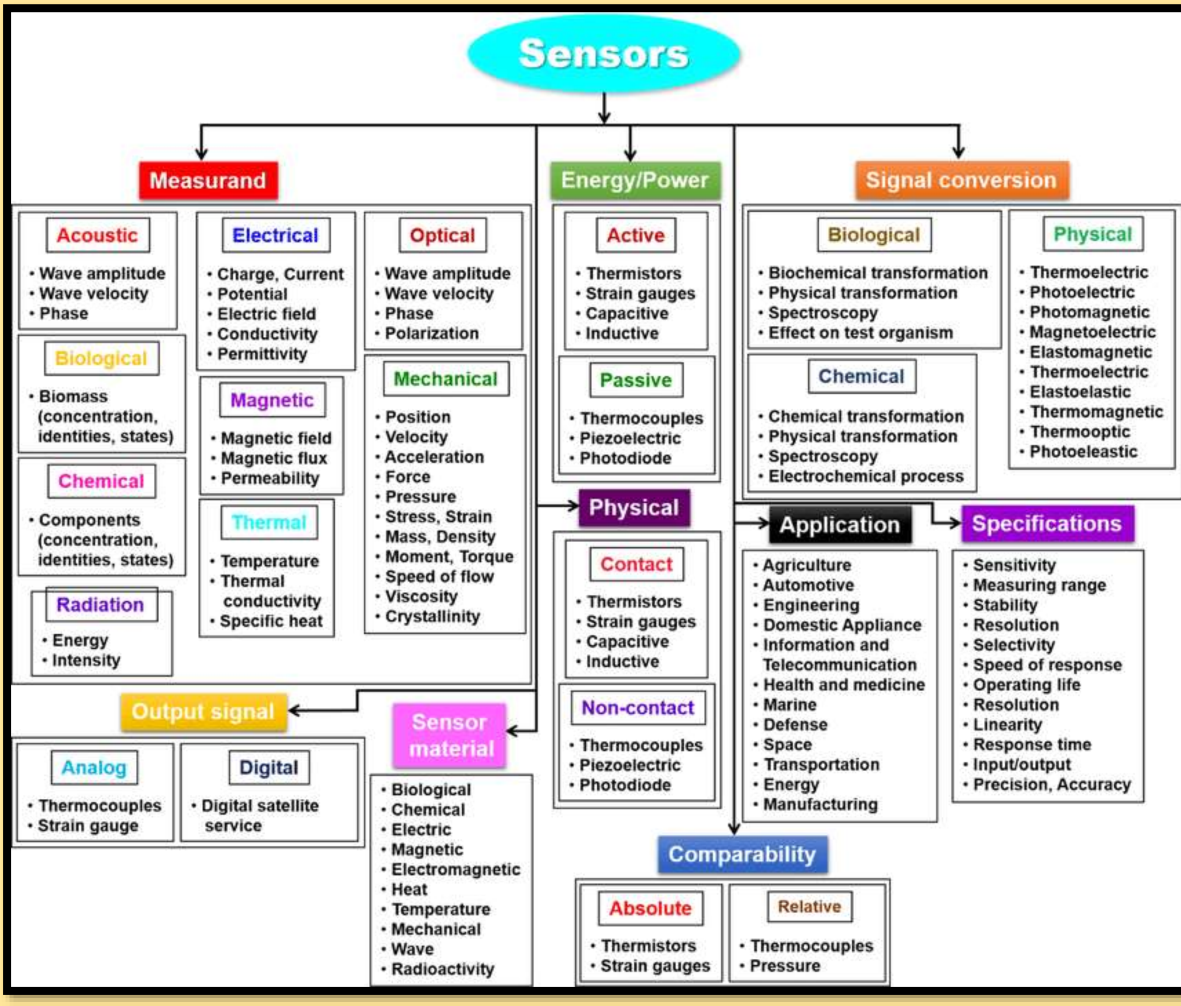
Different Types of Sensors

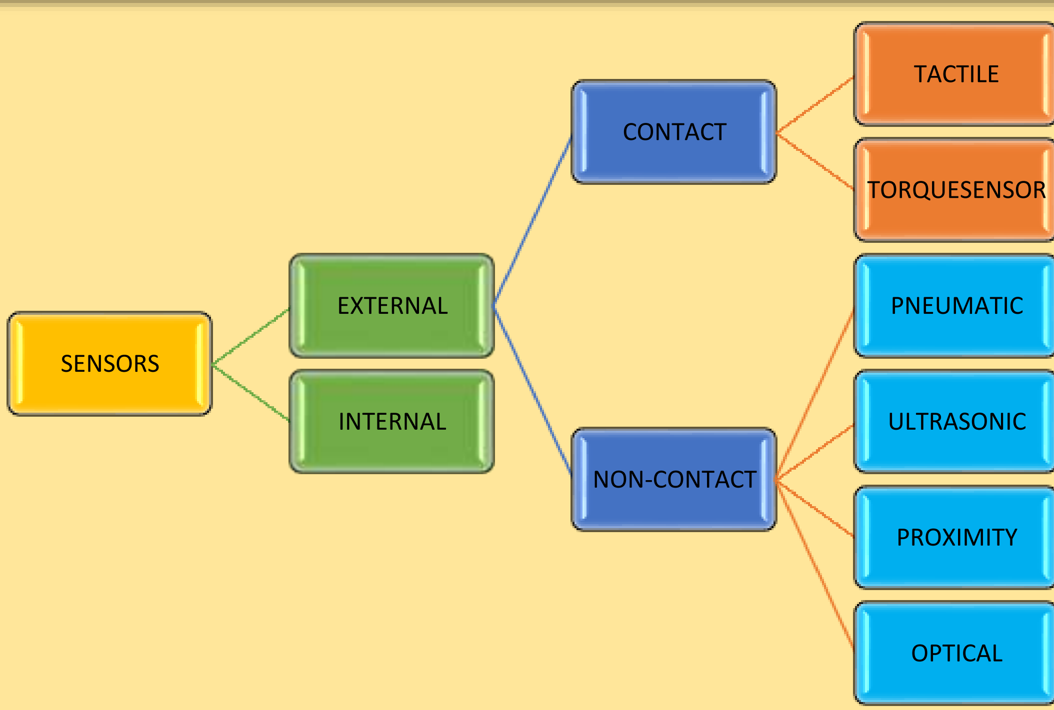


Different Types Of Sensors With Their Applications

- Speed sensor for synchronizing the speed of multiple motors
- Temperature sensor application for industrial temperature control
- PIR sensor for automatic-door-opening system
- Ultrasonic sensor application for distance measurement

5.1.1 Explain the following sensor characteristics:





External Contact sensor

- A tactile sensor is a device that measures information arising from physical interaction with its environment. Tactile sensors are generally modeled after the biological sense of cutaneous touch which is capable of detecting stimuli resulting from mechanical stimulation, temperature, and pain.

Tactile sensor applications are used in

- Robotics
- Computer hardware
- Security system
- Touch screen devices on mobile phone
- Computing

- Torque sensors are a device used to measure twisting or turning forces. They can be either static or dynamic and are able to measure turning forces in either clockwise or anti-clockwise directions.

Torque sensors are used in the following industries;

Motorsport

Test and Measurement

Renewable Energy (especially wind power)

Engine and Plant

Construction

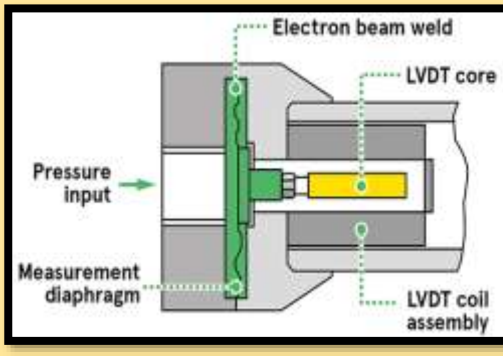
Aerospace

Railway

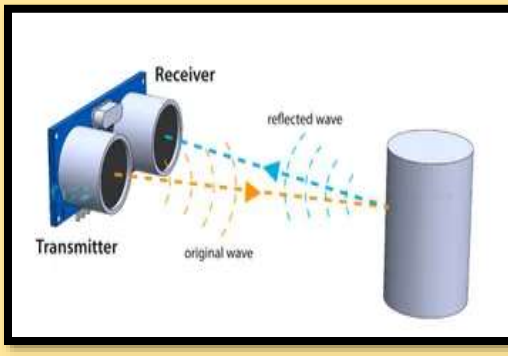
Plant and Construction

Internal Non-Contact sensor

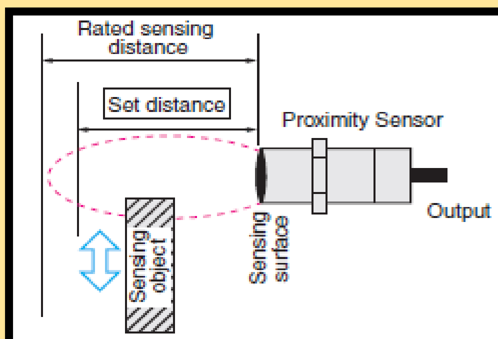
- A pneumatic pressure sensor is used to measure the compressed air/ gas pressure levels in a system by allowing them to be measured and monitored through a range of electronic devices.



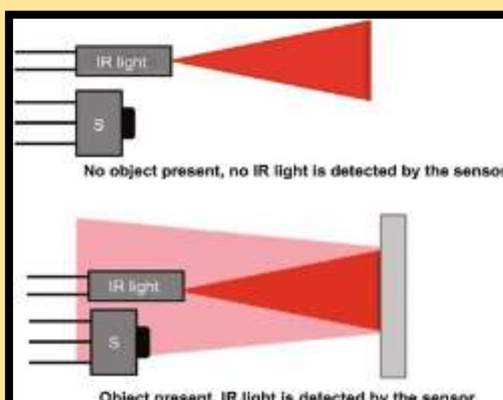
- An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal.



- A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal.



- An optical sensor converts light rays into electronic signals. It measures the physical quantity of light and then translates it into a form that is readable by an instrument.



Sensor generalities (absolute, incremental, etc)

Absolute Optical Rotary Encoder

- Absolute optical or magnetic encoders are position sensors that use optical signals to identify an absolute angular position.
- Optical encoders use a glass disk with a pattern of lines deposited on it, a metal or plastic disk with slots (in a rotary encoder), or a glass or metal strip (in a linear encoder).
- Light from a LED shines through the disk or strip onto one or more photodetectors, which produce the encoder's output.

Incremental Optical Rotary Encoder

- An incremental encoder is a linear or rotary electromechanical device that has two output signals, A and B, which issue pulses when the device is moved. Together, the A and B signals indicate both the occurrence of and direction of movement.
- Many incremental encoders have an additional output signal, typically designated index or Z, which indicates the encoder is located at a particular reference position.
- Also, some encoders provide a status output (typically designated alarm) that indicates internal fault conditions such as a bearing failure or sensor malfunction.
- Position changes nearly instantaneously, which allows them to monitor the movements of high speed mechanisms in near real-time. Because of this, incremental encoders are commonly used in applications that require precise measurement and control of position and velocity.

5.2 Explain The Angular and Linear Position Sensor

Industrial automation uses control systems and equipment, such as computer software and robots, to perform tasks that were historically done manually.

These systems operate industrial equipment automatically, significantly reducing the level of operator involvement and oversight required.

Automation systems typically consist of feedback loops and sensory programs that automatically adjust operating conditions to meet the desired values based on real-time data.

5.2.1 Explain Method of Angular and Linear position measurement (resistive, capacitive, inductive, optical)

Mechanical → Sensors measure such quantities as position, shape, velocity, force, torque, pressure, vibration, strain and mass.

Electrical → Sensors measure voltage, current, charge and conductivity.

Magnetic → Sensors measure magnetic field, flux and permeability.

Thermal → Sensors measure temperature, flux, conductivity
and specific heat.

Position Sensors : detect the position of something which means that they are referenced either to or from some fixed point or position. These types of sensors provide a "positional" feedback.

Angular and linear position sensors : are electronic devices used to simultaneously measure both angular and linear position changes relative to a reference position.

CONTACT SENSOR

↓

Strain gage, LVDT, RVDT, tachometer, etc

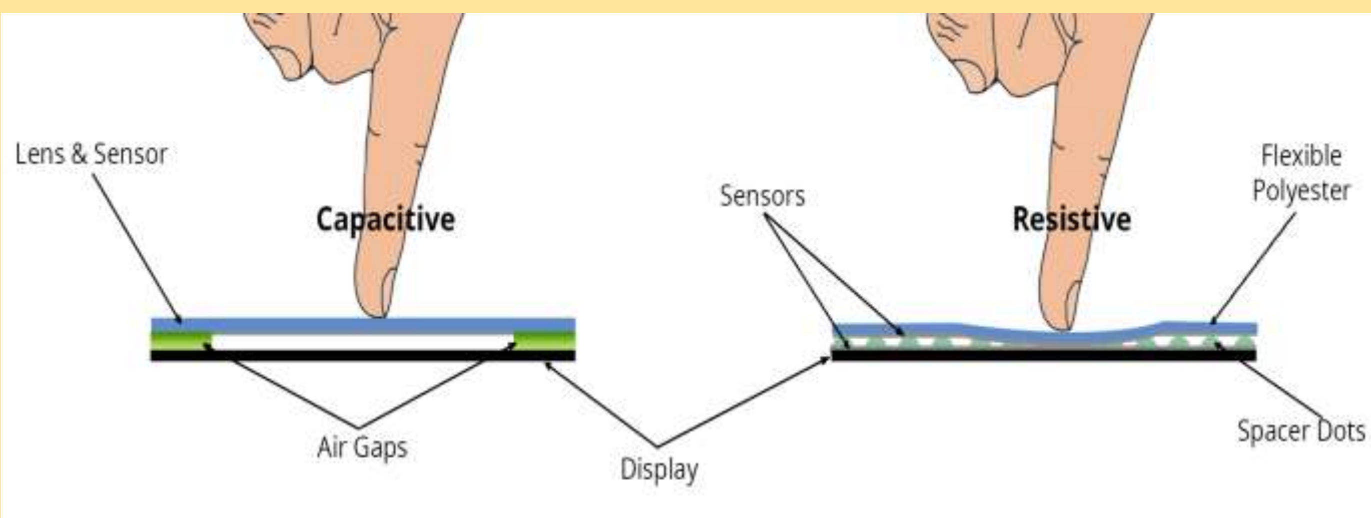
NON - CONTACT SENSOR

↓

Encoders, hall effect, capacitance, inductance, and interferometer type

TOUCH SENSORS: CAPACITIVE VS. RESISTIVE

A resistive touchscreen operates by pressure because you actually need to close the gap between the two circuit sides of the touchscreen



A capacitive touch screen uses your finger as a method to produce a capacitive shift in the system and hence sense a touch

The Potentiometer

The most commonly used of all the "Position Sensors", is the potentiometer because it is an inexpensive and easy to use position sensor. It has a wiper contact linked to a mechanical shaft that can be either angular (rotational) or linear (slider type) in its movement, and which causes the resistance value between the wiper/slider and the two end connections to change giving an electrical signal output that has a proportional relationship between the actual wiper position on the resistive track and its resistance value. In other words, resistance is proportional to position.

Potentiometers come in a wide range of designs and sizes such as the commonly available round rotational type or the longer and flat linear slider types. When used as a position sensor the moveable object is connected directly to the rotational shaft or slider of the potentiometer.

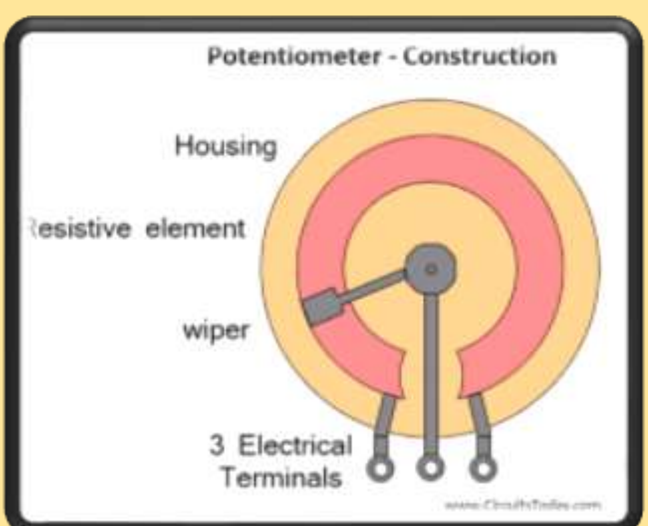
Characteristic of Potentiometers

TAPER: The law of pots or the taper of pots is one such characteristic of potentiometer in which one needs a prior knowledge, to pick the right device for the desired application.

MARKING CODES: While selecting a potentiometer, you need to know the maximum value of resistance it can attain.

RESOLUTION: As we vary the resistance in the pot, there is a minimum amount of resistance that can be changed. This is known as the resolution of the pot.

HOP ON HOP OFF RESISTANCE: Like we have seen in the construction part of this article that the resistive element is connected in between the two terminals. These terminals are made of very low resistance metal.



Application of Potentiometers

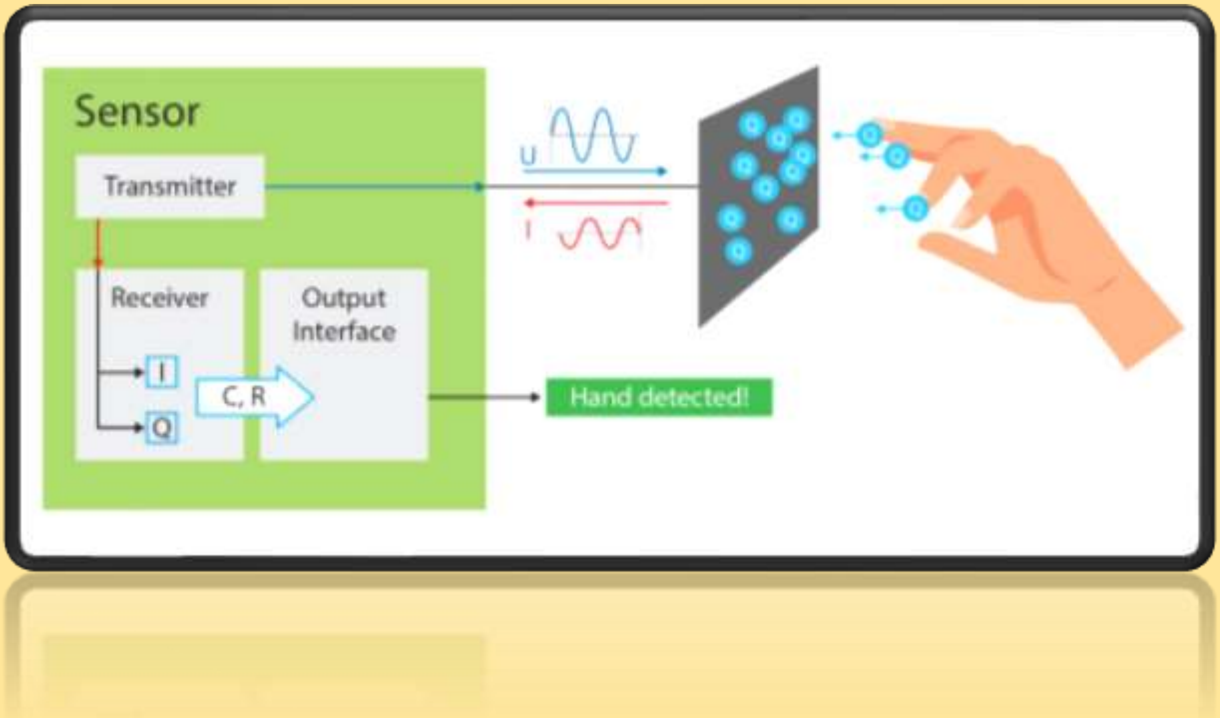
- Mobile vehicle
- Medical applications
- Test and lab applications
- Robotics
- Agricultural machinery
- Industrial machinery
- Motorsport applications

Capacitive

Capacitive proximity sensors are **non-contact devices** that **can detect the presence or absence of virtually any object regardless of material**. They utilize the electrical property of capacitance and the change of capacitance based on a change in the electrical field around the active face of the sensor.

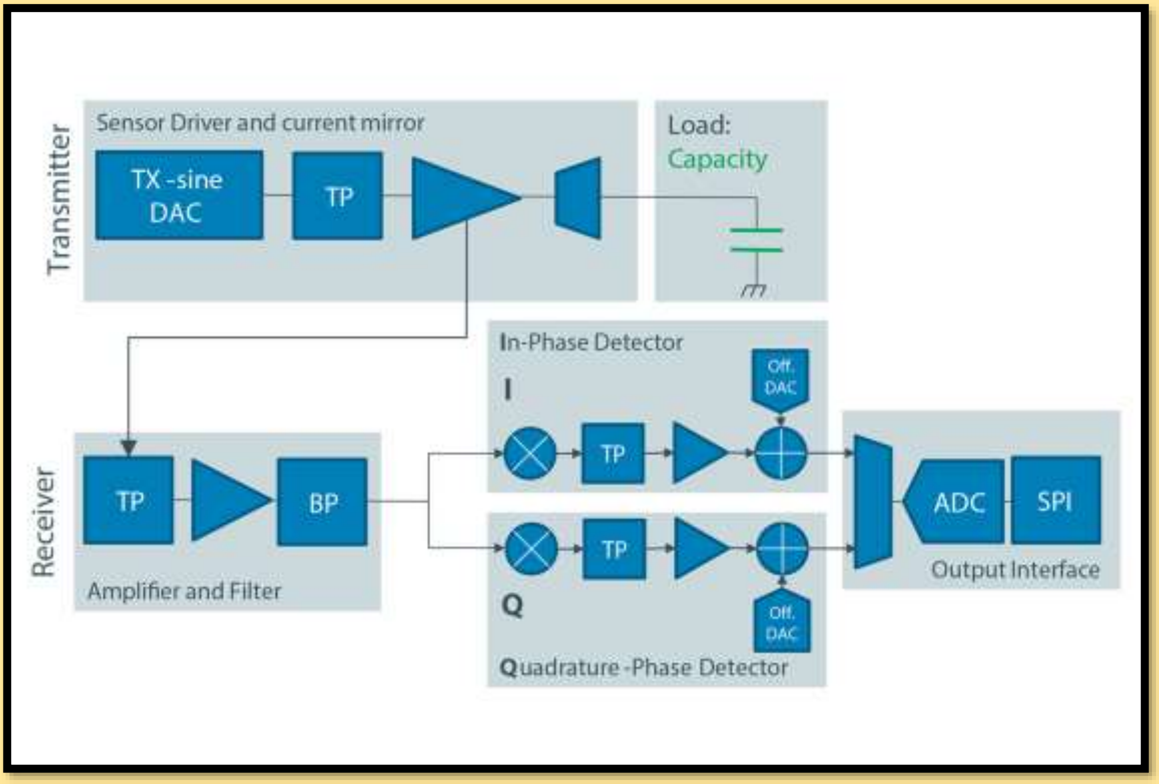
Capacitive sensing technology is often used in other sensing technologies such as:

- Flow
- Pressure
- Liquid Level
- Spacing
- Thickness
- Ice Detection
- Shaft Angle Or Linear Position
- Dimmer Switches
- Key Switches
- X-y Tablet
- Accelerometers



What is the working principle of capacitive sensor?

Transmitter block forces a sine wave voltage across the load - Receiver block detects the current response of the load - Current response is converted to a voltage and demodulated into in- phase (I) and quadrature (Q) components.

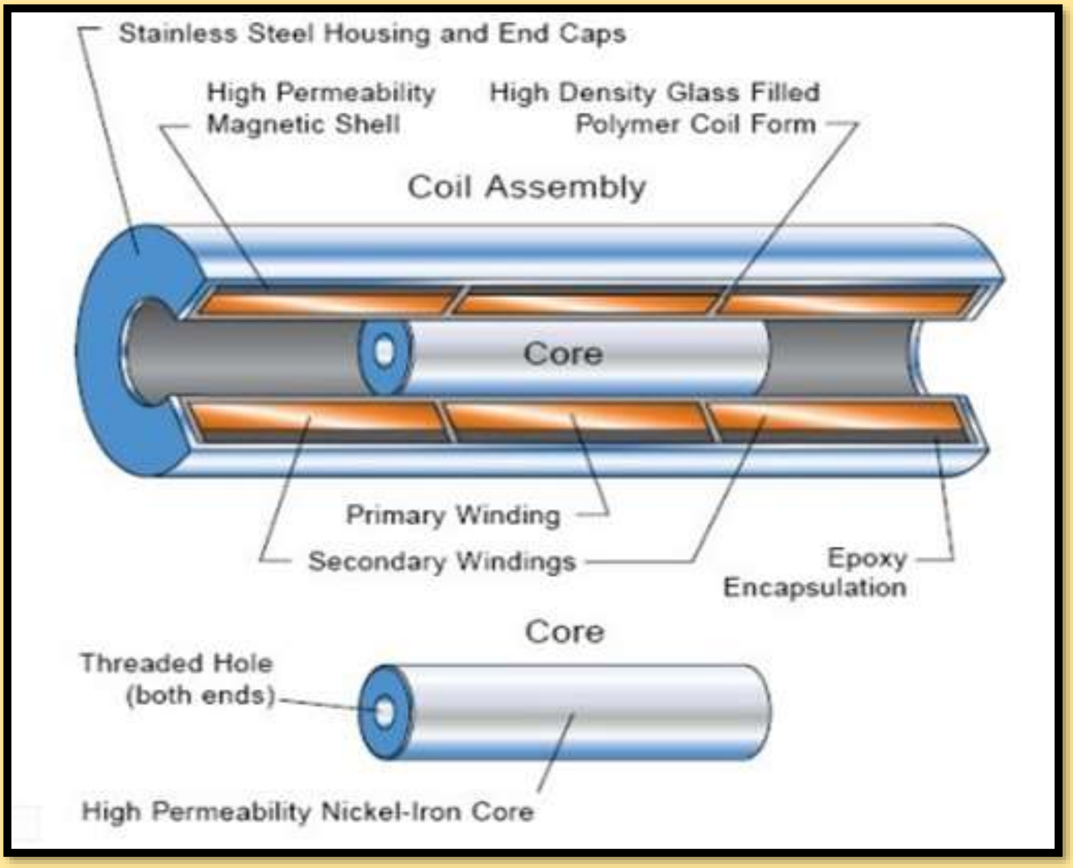


AC INDUCTIVE- LVDT
Linear Variable Differential Transformer

- Used to measure displacement. LVDTs operate on the principle of a transformer.
- Uses a trio of transformer-like windings and magnetic coupling to provide a highly accurate, absolute readout of linear position.

- The internal structure consists of a primary winding centered between a pair of identically wound secondary windings, symmetrically spaced on either side of the primary coil. This entire multiple-winding assembly is considered as the stationary element of the position sensor.
- Mechanically, the coils are wound on a one-piece hollow form, often on a thermally stable glass-reinforced polymer, encapsulated against moisture, wrapped in a high permeability magnetic shield, and then sealed in an aluminum or stainless steel cylindrical housing.

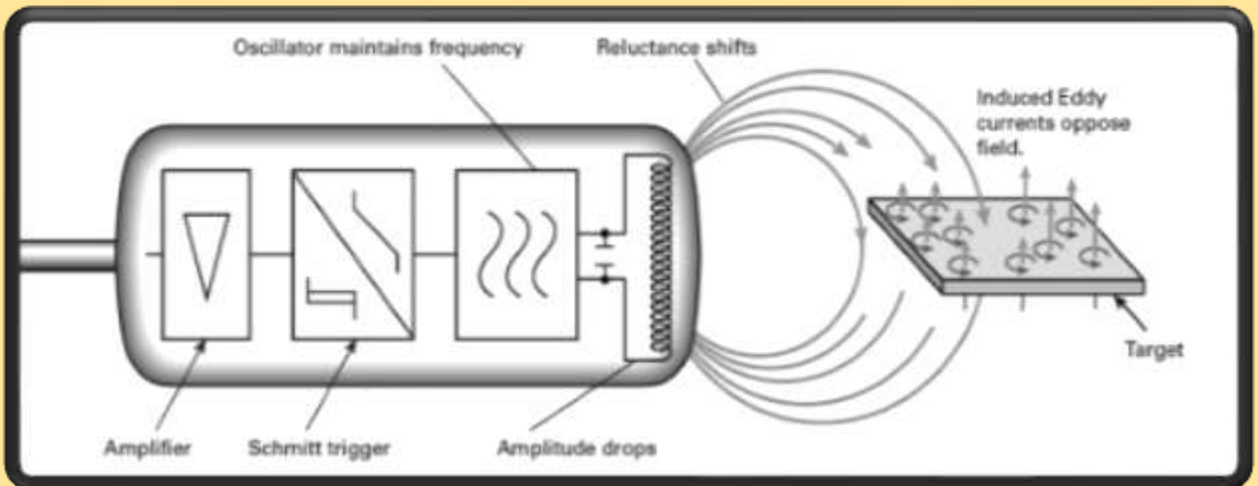
The moving part of the LVDT is its core, which is a basic rod or tube of magnetically permeable material. The core is usually threaded at one or both ends for convenience for mechanical connection to the object whose position is being measured and moves freely through the coil's hollow bore. This bore of the LVDT body has a large-enough diameter so that the fit between the hole and the core is not tight; instead, there is substantial clearance between the coil bore and core, and thus there is no physical contact between the two.



- Inductive Proximity Sensor

Proximity Sensor includes all sensors that perform non-contact detection in comparison to sensors, such as limit switches, that detect objects by physically contacting them.

Proximity sensors convert information on the movement or presence of an object into an electrical signal.

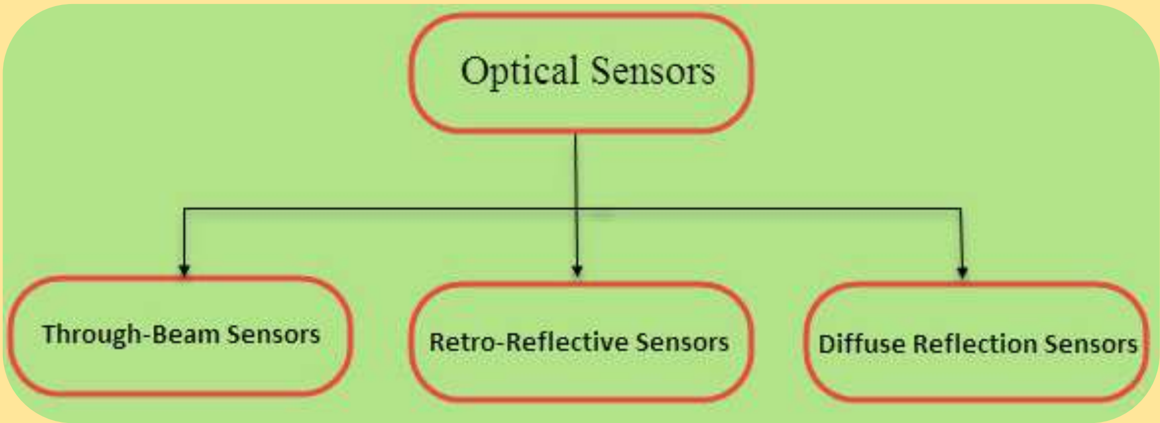


Since the output voltage (and current) of an inductive sensor is directly proportional to the distance between the sensor and the target (the voltage and current represent the absolute measured values corresponding to the distance), inductive proximity sensors are widely used in numerous applications.

Application of Inductive Sensor

- Parking sensors - systems mounted on car bumper that sense distance to nearby cars for parking.
- Mobile devices - touch screens that come in close proximity to the face
- Roller coasters
- Automatic faucets
- Beverage and food can making lines
- Sheet break sensing in paper machine

Optical Sensor

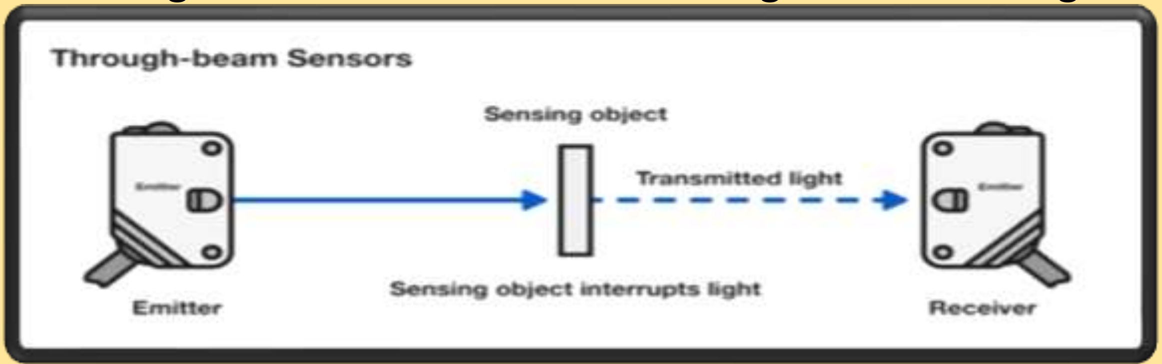


Different Light Sources For Optical Sensors:

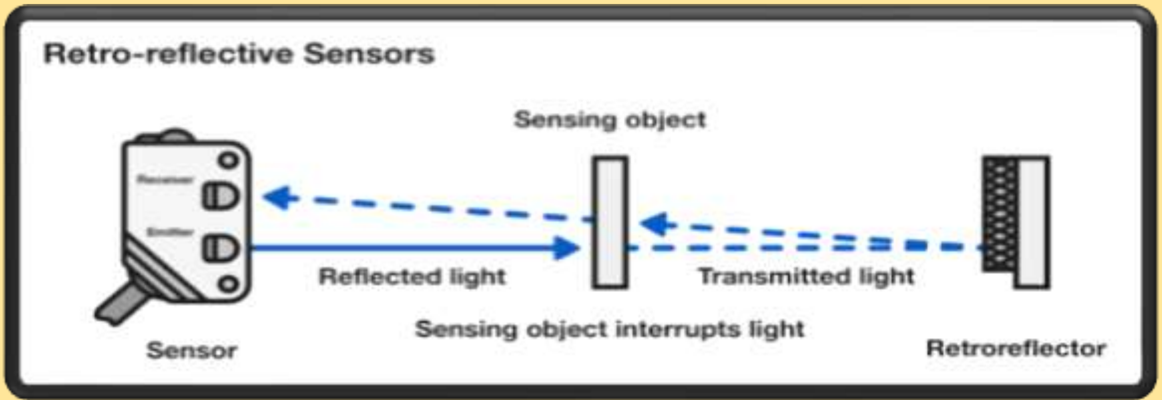
1. LED (Light Emitting Diode)
2. LASER (Light Amplification by Stimulated Emission Radiation)

Photoelectric sensor: a device that detects a difference in the light level received from the light source. The sensor is made up of a light source, an amplifier, signal converter, and an output.

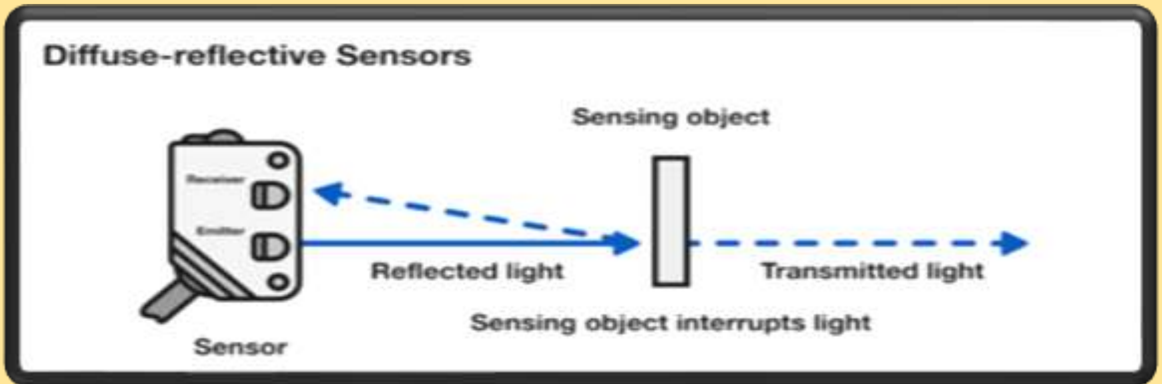
Through-beam sensors: Through beam optical sensor has transmitter and receiver as a separate device and work on the principle that whenever a object comes between transmitter and receiver a signal is sent. Used when sensing distance is large.



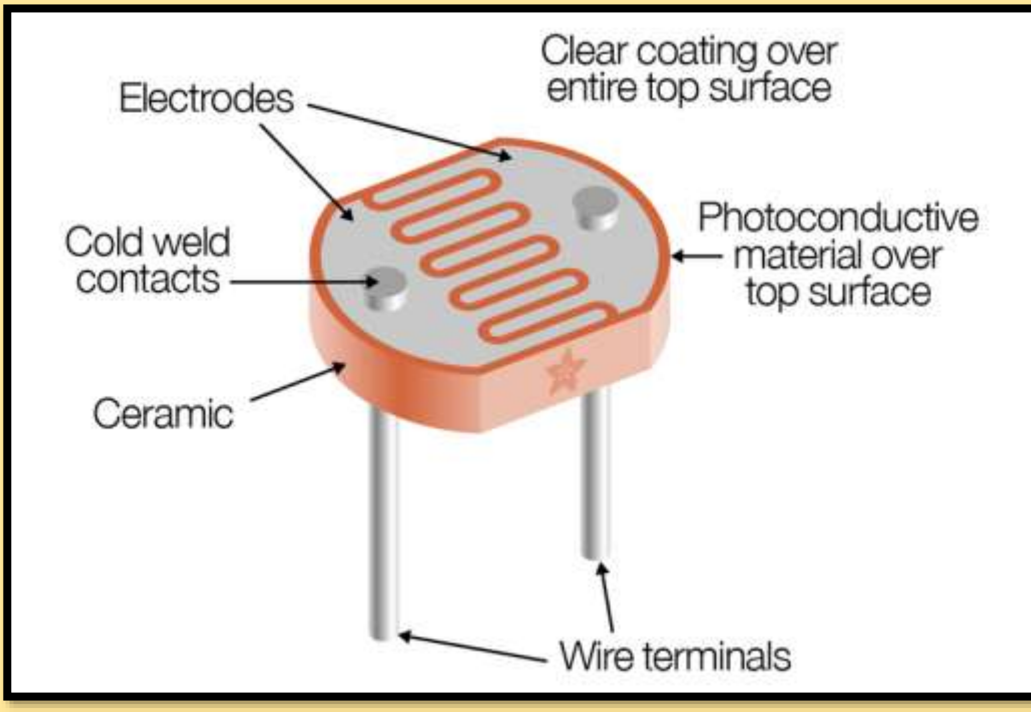
Retroreflective sensors: Has transmitter and receiver on same housing and they require a reflective surface called reflector for there working.



Diffuse -reflective sensors: Has transmitter and receiver on same housing but they do not require any reflector for there working. Object to detected itself work as a reflector.

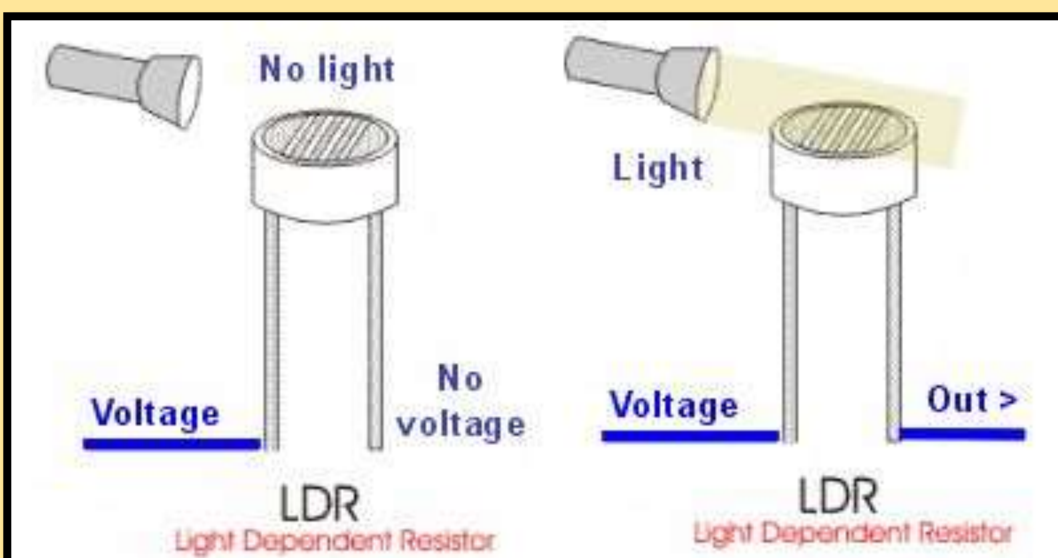


Photocell or Photoresistor is a light-controlled variable resistor.



What is the working principle of LDR?

When the light is absorbed by the material then the conductivity of the material reduces.
When the light falls on the LDR, then the electrons in the valence band of the material are eager to the conduction band.

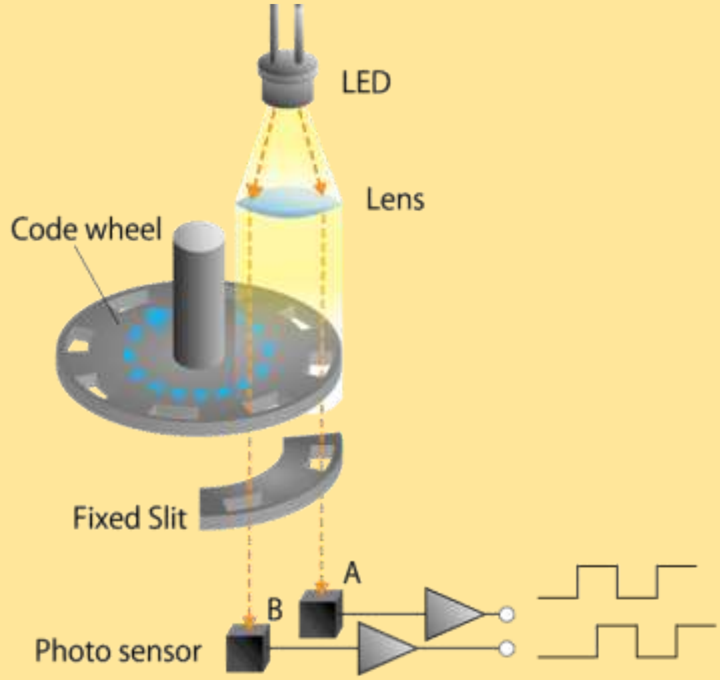


Rotary Encoders

Rotary Encoders are another type of position sensor which resemble potentiometers mentioned earlier but are non-contact optical devices used for converting the angular position of a rotating shaft into an analogue or digital data code. In other words, they convert mechanical movement into an electrical signal (preferably digital).

All optical encoders work on the same basic principle. Light from an LED or infra-red light source is passed through a rotating high-resolution encoded disk that contains the required code patterns, either binary, grey code or BCD. Photo detectors scan the disk as it rotates and an electronic circuit processes the information into a digital form as a stream of binary output pulses that are fed to counters or controllers which determine the actual angular position of the shaft.

There are two basic types of rotary optical encoders, **Incremental Encoders** and **Absolute Position Encoders**.

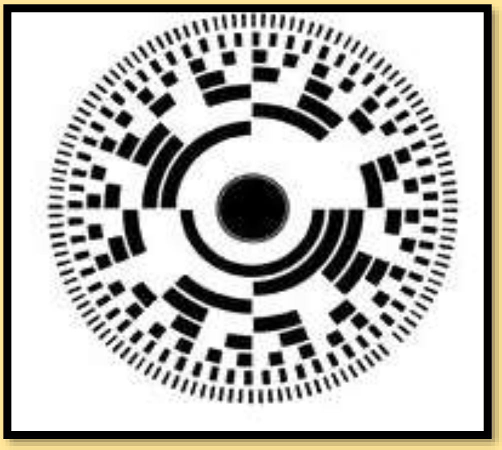


5.2.2 Explain encoding schemes (Incremental, absolute)

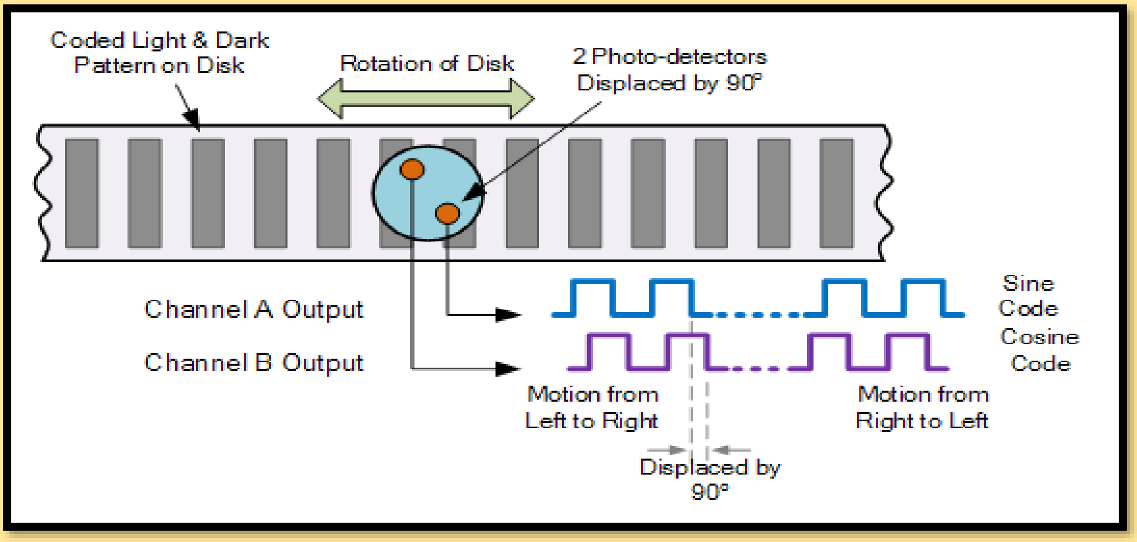
Incremental Encoders, also known as quadrature encoders or relative rotary encoder, are the simplest of the two position sensors. Their output is a series of square wave pulses generated by a photocell arrangement as the coded disk, with evenly spaced transparent and dark lines called segments on its surface, moves or rotates past the light source. The encoder produces a stream of square wave pulses which, when counted, indicates the angular position of the rotating shaft.

Incremental encoders have two separate outputs called "quadrature outputs". These two outputs are displaced at 90' out of phase from each other with the direction of rotation of the shaft being determined from the output sequence.

The number of transparent and dark segments or slots on the disk determines the resolution of the device and increasing the number of lines in the pattern increases the resolution per degree of rotation. Typical encoded discs have a resolution of up to 256 pulses or 8-bits per rotation.



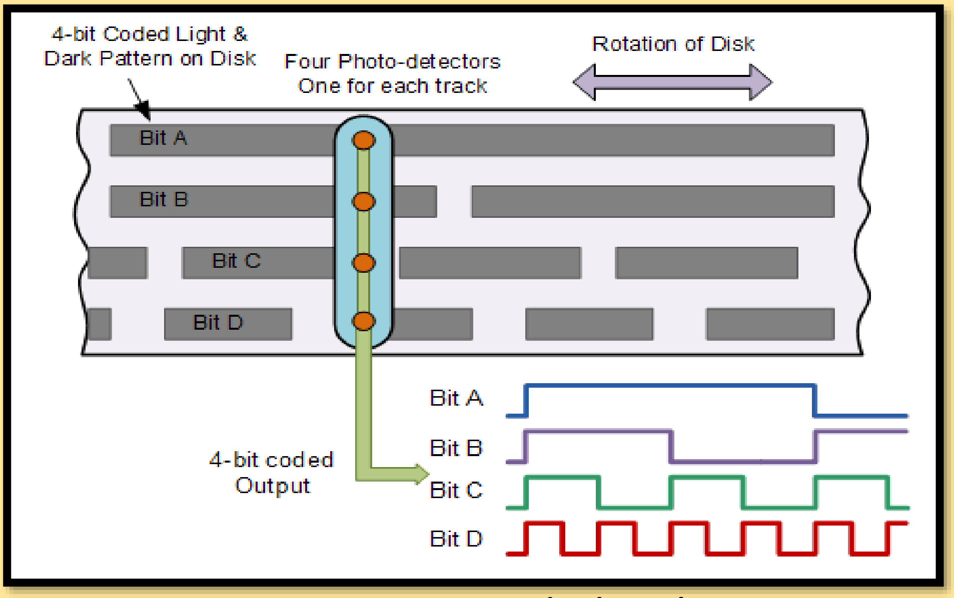
Encoder disk



Simple incremental Encoder

One main disadvantage of incremental encoders when used as a position sensor, is that they require external counters to determine the absolute angle of the shaft within a given rotation. If the power is momentarily shut off, or if the encoder misses a pulse due to noise or a dirty disc, the resulting angular information will produce an error. One way of overcoming this disadvantage is to use absolute position encoders.

Absolute Position Encoders are more complex than quadrature encoders. They provide a unique output code for every single position of rotation indicating both position and direction. Their coded disk consists of multiple concentric "tracks" of light and dark segments. Each track is independent with its own photo detector to simultaneously read a unique coded position value for each angle of movement. The number of tracks on the disk corresponds to the binary "bit"-resolution of the encoder so a 12-bit absolute encoder would have 12 tracks and the same coded value only appears once per revolution.



4-Bit Binary Coded Disk

Typical application of absolute position encoders are in computer hard drives and CD/DVD drives were the absolute position of the drives read/write heads are monitored or in printers/plotters to accurately position the printing heads over the paper.

5.3 Explain Velocity and Acceleration Sensor

5.3.1 Explain tacho generator, optical incremental encoder, Sagnac interferometer, micromechanical angular velocity and acceleration sensor

Tachometer (Tachogenerator)

Measurement of rotary speed using a DC generator

Essentially a motor running in reverse

Used to be common to have these attached to motors to enable direct analog feedback

Much less common now with digital control (use incremental encoders)

Measure engine and motor speed

Application of Tachogenerator

As feedback components in speed control circuits

Measure corresponding speed of powered equipment as conveyors, mixers, fans, and machine tools

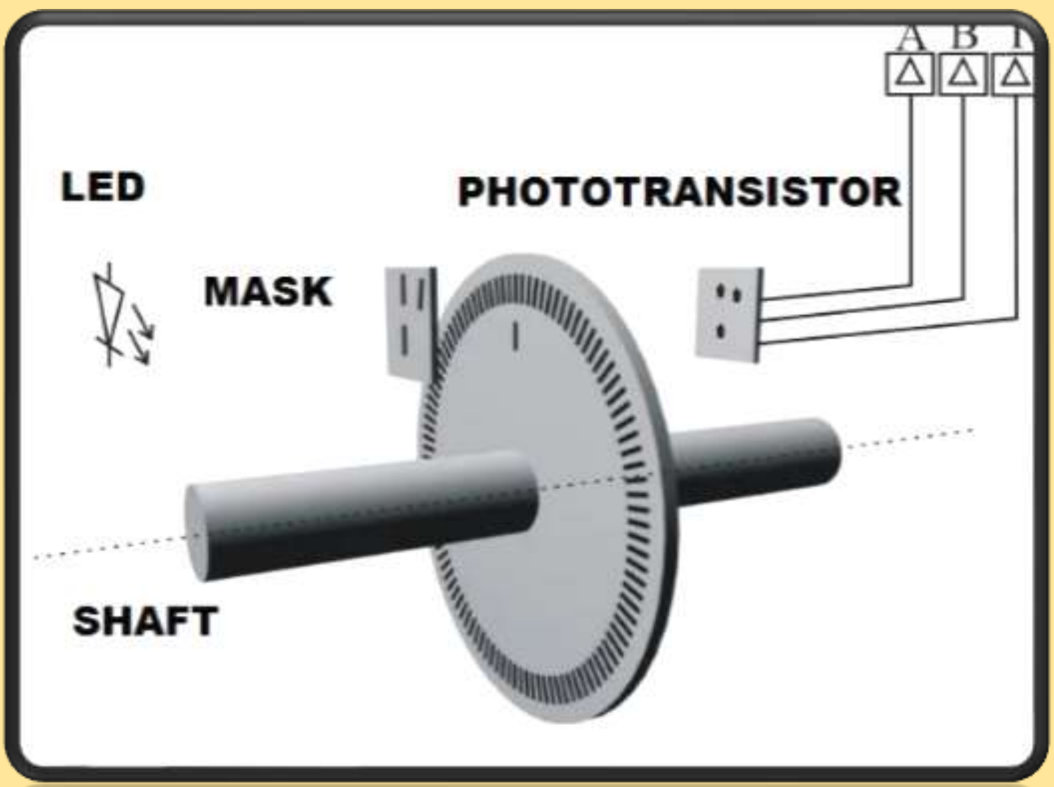
Optical Incremental Encoder

An optical encoder uses photo-interrupters to convert motion into an electrical pulse train.

These electrical pulses “encode” the motion, and the pulses are counted or “decoded” by circuitry to produce the displacement measurement.

By counting the number of pulses and knowing the number of radial lines in the disk, the rotation of the shaft can be measured.

The direction of rotation is determined by the phase relationship of the A and B pulse trains, i.e., which signal leads the other.



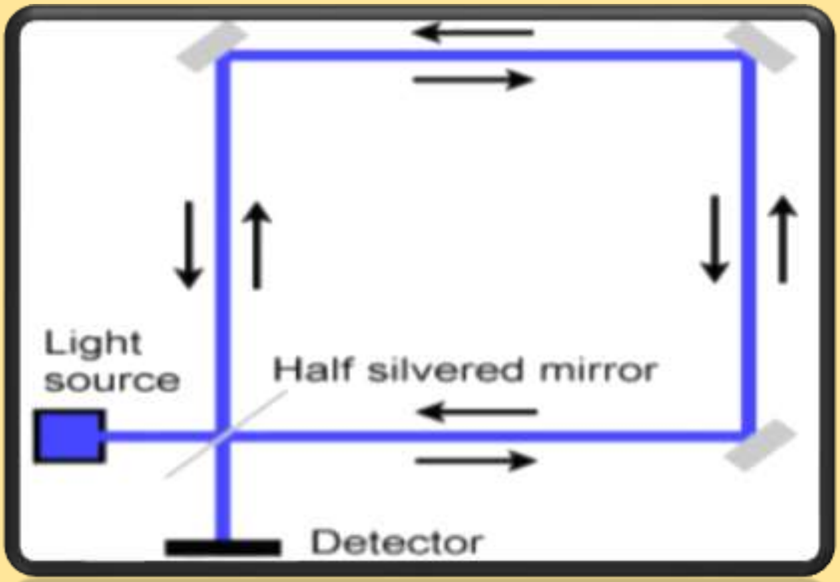
Sagnac Interferometer

The Sagnac effect (also called Sagnac interference), named after French physicist Georges Sagnac, is a phenomenon encountered in interferometry that is elicited by rotation.

A beam of light is split and the two beams are made to follow a trajectory in opposite directions.

To act as a ring the trajectory must enclose an area.

On return to the point of entry the light is allowed to exit the apparatus in such a way that an interference pattern is obtained.



Micromechanical Angular Velocity (Gyroscopes)

Structural arrangement of silicon which records centrifugal acceleration and thus angular speed

Multiple component elements to calibrate other accelerations

Use strain-gauge bridges and/or piezo structure to record deformations

Acceleration Sensor

Acceleration is also measured via the force exerted by an accelerating mass

Distortion of a piezo

Motion of a cantilever

Strain on mass restraints

Accelerometers mainly used to measure vibration

Shielded for Severe environment

Single Axis, 10,000g

EMI shielded

5.4 Explain The Contact Sensor

5.4.1 Explain piezoresistive and capacitive tactile sensor, optical tactile sensor, force measurement by deformation of contact sensor: principle and application of strain gage sensor

Contact Sensors (Force & Pressure)

Contact Sensor (Force and Pressure) generally measured indirectly through deflection of an alternate surface

Mechanism include:

– **Piezoresistive** materials that generate changes in resistance when deformed

Piezoresistive force sensor

– **Optical Tactile Sensors** –force applied will change the amount of light reflected to the receiver.

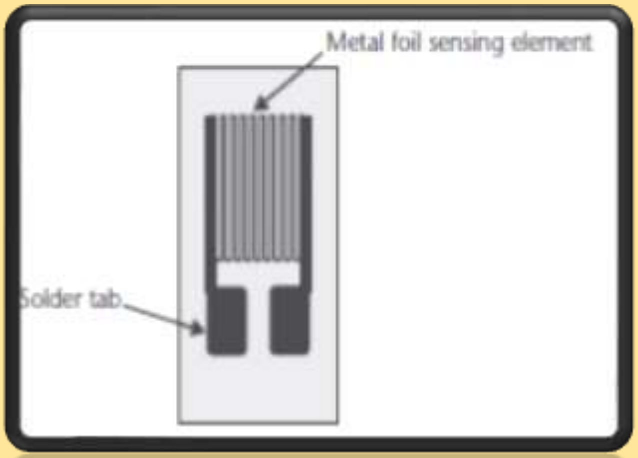
Tactile sensor

– **Strain gauges** (metal that changes resistance when stressed)

Strain gauges

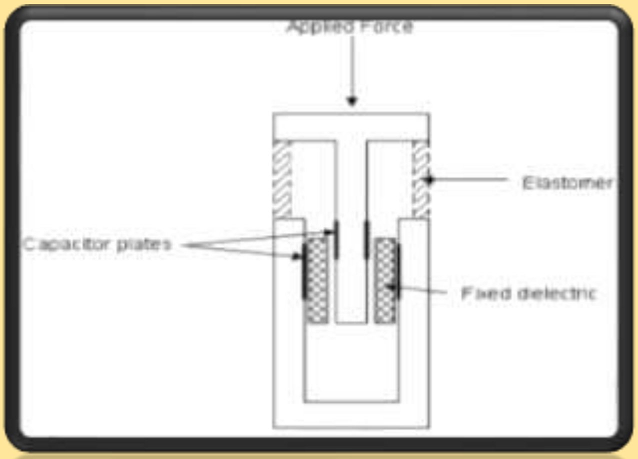
Piezoresistive

- Piezoresistive sensor, the magnitude of a mechanical displacement is measured by the amount of stress it induces in a mechanical member.
- A stress-sensitive resistor (called a piezoresistor) located strategically on the mechanical member experiences a change of resistance as a result of the applied stress.



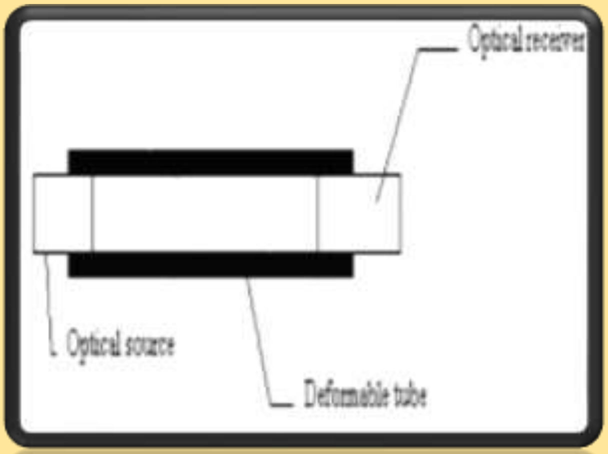
Capacitive Tactile Sensors

- Transducer that uses capacitance variation can be used to measure force.
- The force is directed onto a membrane whose elastic deflection is detected by a capacitance variation.
- A highly sensitive force transducer can be constructed because the capacitive transducer senses very small deflections accurately.
- An electronic circuit converts the capacitance variations into DC-voltage variations.



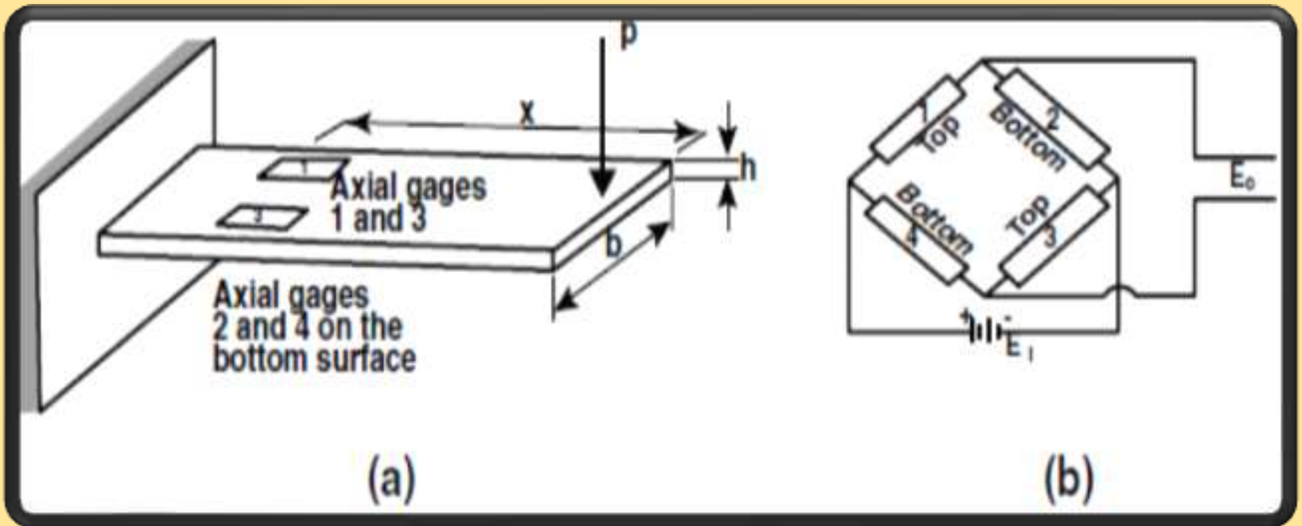
Optical Tactile Sensor

- Force applied will change the amount of light reflected to the receiver.
- In the reflective touch sensor below, the distance between the reflector and the plane of source and the detector is the variable.
- The intensity of the received light is a function of distance, and hence the applied force.



Strain Gage

- The strain gage load cell consists of a structure that elastically deforms when subjected to a force and a strain gage network that produces an electrical signal proportional to this deformation.



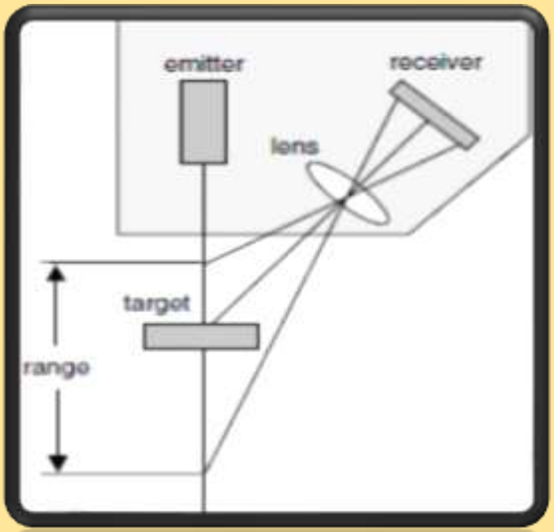
Beam-type load cells; (a) a selection of beam-type load cells (elastic element with strain gages) and (b) gage position in the Wheatstone bridge

5.5 Apply The Distance and Velocity Sensor

5.5.1 Explain triangle sensor, Time-Off-Flight Sensor, Laser Range Radar, Laser Interferometric Distance Meter, Laser Doppler Velocimeter

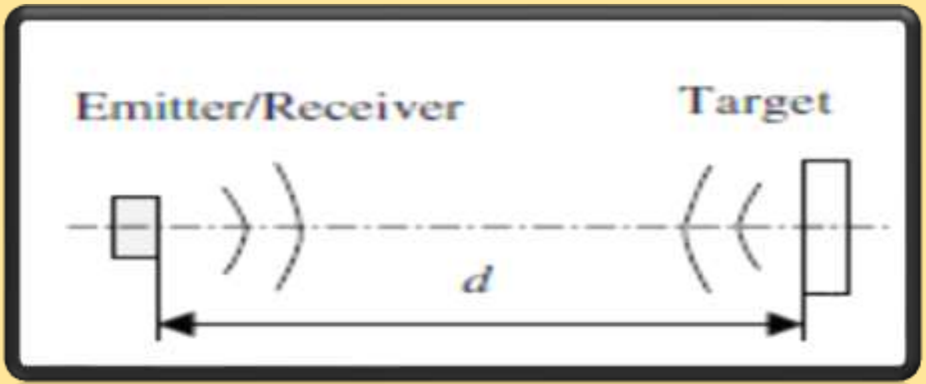
Triangle sensor

- Optical triangulation sensors use a light emitter, either a laser or an LED, in combination with a light receiver to sense the position of objects. Both the emitter and receiver are contained in the same housing.



Time-Of-Flight Sensors

- Optical time-of-flight sensors detect the position of objects by measuring the time it takes for light to travel to the object and back.
- As in the case of optical triangulation sensors, time-of-flight sensors also contain an emitter and a receiver.
- The emitter is a laser or an LED while the receiver is a photodiode.



A wave is emitted and bounced from a target object.

Laser-Range Radar

- Laser Range Radar (Laser-based TOF ranging systems), also known as laser radar or lidar.
- Laser energy is emitted in a rapid sequence of short bursts aimed directly at the object being ranged.

- The TOF of a given pulse reflecting off the object is used to calculate distance to the target based on the speed of light
- Accuracies for early sensors of this type could approach a few centimeters over the range of 1–5 m.

Laser Interferometric Distance Meter

- *Laser interferometers* are capable of measuring incremental linear motions with resolution on the order of nanometers.
- In an interferometer, collimated laser light passes through a beam-splitter, sending the light energy on two different paths.
- One path is directly reflected to the detector, such as an optical sensing array, giving a flight path of fixed length.
- The other path reflects back to the detector from a retroreflector (mirror) attached to the target to be measured.

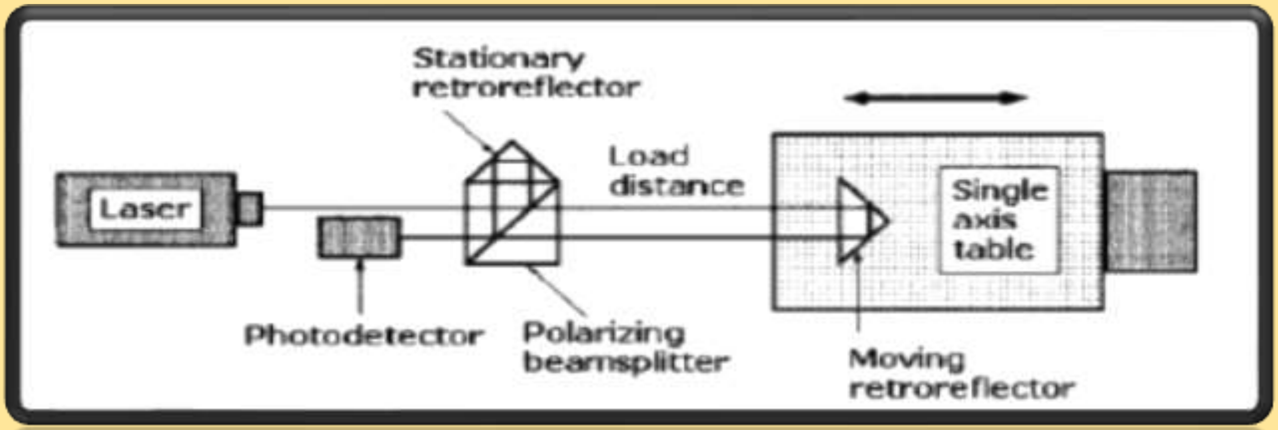
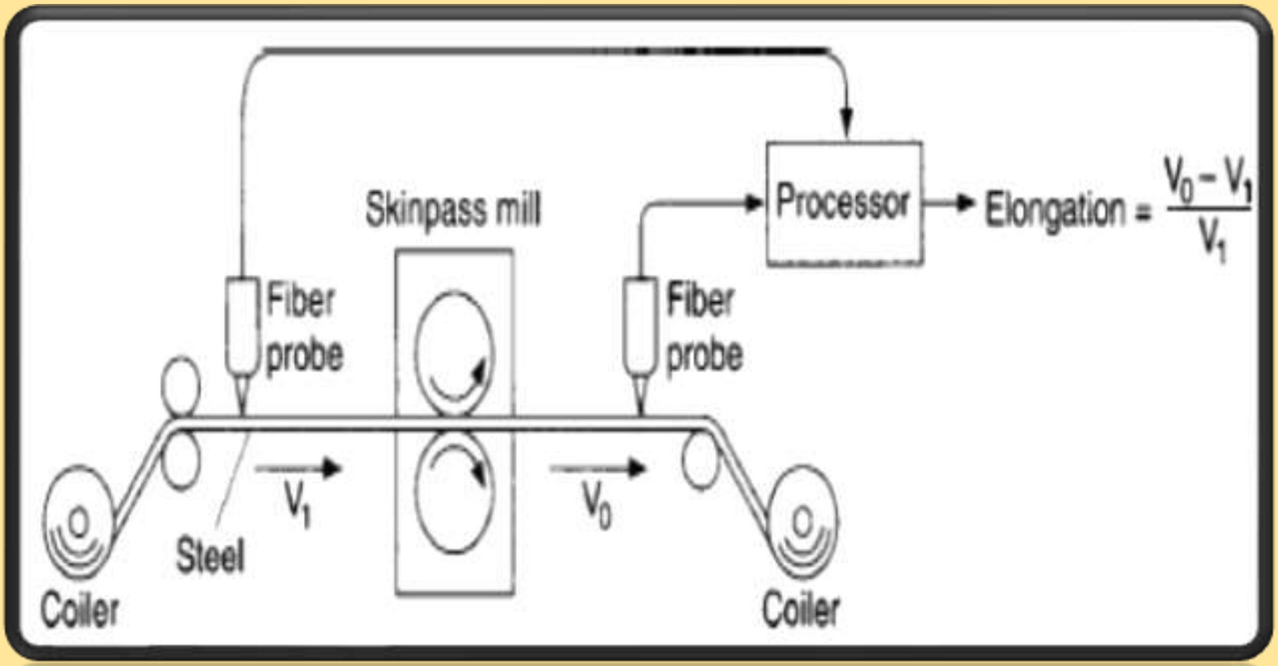


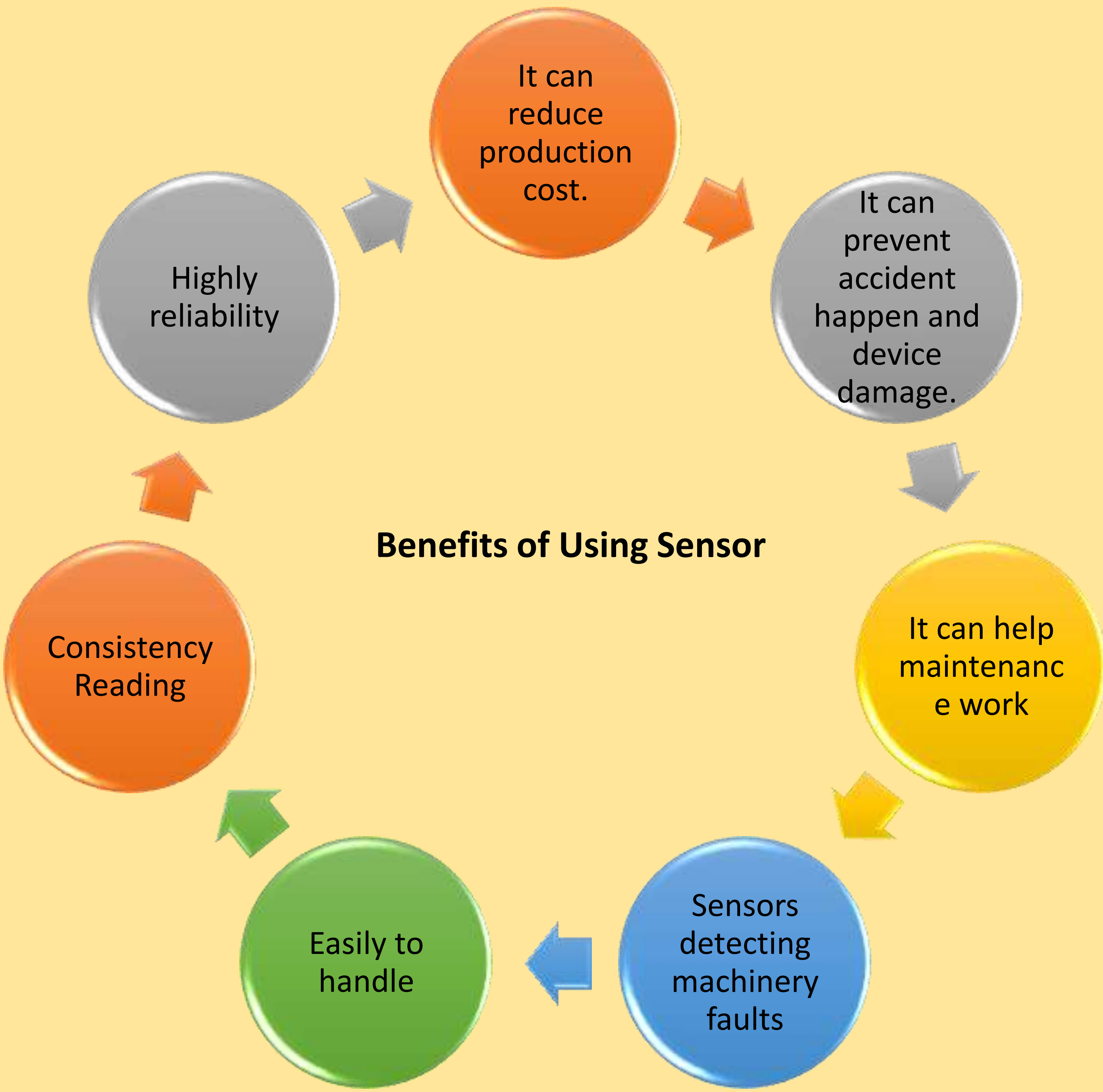
Diagram of a laser interferometer for position feedback that combines high resolution

Laser-Doppler Velocimeter

- Laser Doppler velocimetry (LDV) , also known as laser Doppler anemometry (LDA), is the technique of using the Doppler shift in a laser beam to measure the velocity in transparent or semi-transparent fluid flows, or the linear or vibratory motion of opaque, reflecting, surfaces.



Fiber-optic Doppler velocimeter at a rolling mill controls pressure by measuring inputs speeds


Benefits of Using Sensor
It can reduce production cost.
It can prevent accident happen and device damage.
It can help maintenanc e work
Sensors detecting machinery faults
Easily to handle
Consistency Reading
Highly reliability

EXERCISE

1. Describe meaning of sensor.
2. Explain the functions of a sensor.
3. List three types of internal sensor and three types of external sensor.
4. How does Range sensor work?
5. Explain about analog displacement sensor and digital sensor.
6. Name two types of inputs that would be analog input values (versus a digital value).
7. What is the resolution of an absolute optical encoder that has six tracks? nine tracks? Twelve tracks?
8. What are the following: Shaft encoder, Incremental encoder and Absolute encoder.
9. Define the following term for sensor
   i. Range
   ii. Sensitivity
   iii. Error iv. Dynamic response
   v. Resolution
10. In general, how do sensor pilot devices operate?
11. What is the main feature of a proximity sensor?
12. List the main components of an inductive proximity sensor.
13. Explain the term hysteresis as it applies to a proximity sensor.
14. How a two-wire sensor is connected relative to the load it controls?
15. In what way is the sensing field of a capacitive proximity sensor different from that of the inductive proximity sensor? For what type of target would a capacitive proximity sensor be selected over an inductive type?
16. Outline the principle of operation of a photoelectric sensor.

EXERCISE

17. Name the three most common scan techniques for photoelectric sensors.
18. What are the advantages of fiber optic sensing systems?
19. Outline the principle of operation of a Laser Range radar sensor.
20. Compare the way in which a tachometer and magnetic pickup are used in speed measurement.
21. Named 4 types of sensor for used in angular position measurement.
22. Explain how linear variable differential transformer (LVDT) operates?
23. Explain about the principles of optical sensor and named three examples of optical sensor?
24. Explain about the principles of encoder scheme.
25. Explain how velocity sensors work and named three examples of velocity sensor.
26. Explain how the strain gages sensor works.
27. What is a strain gauge?
28. What are the types of strain gauges?
29. Give other classification of strain gauges
30. What is a Resistance Strain Gauge?
31. What is a semiconductor strain gauge?
32. Give Gauge Factor for few materials.
33. What are the points to be considered for selecting sensor?
34. What are the different types of strain gauges? Name four resistance materials used in wire and foil gauges.
35. Mention desirable characteristics of strain gauges.
36. Name two light sensitive sensor
37. What is Tachogenerator?

EXERCISE

38. Mention major applications of L.V.D.T.s?
39. Enlist advantages’ of LVDT.
40. Mention one disadvantage of LVDT.
41. Explain the main functions for micromechanical angular velocity.
42. Explain the concept of contact sensor and named three types of contact sensor.
43. Explain about the Lesser Doppler Velocimeter.
44. Give comparison between Active and Passive transducers.

CHAPTER 6

DESIGN AN EXAMPLE FOR INDUSTRIAL AUTOMATION SYSTEM

CLO1

Apply the fundamental concept of industrial automation including the mechanical system, actuator control and sensory devices.

CHAPTER 6

Design An Example For Industrial Automation System

6.1 Explain the Automation Design and process specifications

6.1.1 Explain the characteristics of the industrial automation system

a. System Specifications
b. Mechanical Description of the automation
c. Motion Sequence
d. Motor and Drive Mechanism Selection

6.2 Describe the Encoder Selection

6.3 Construct the Control Structure: Programmable Logic Controller used for Industrial Automation

6.1 Explain the Automation Design and process specifications

What Is An Industrial Automation System 

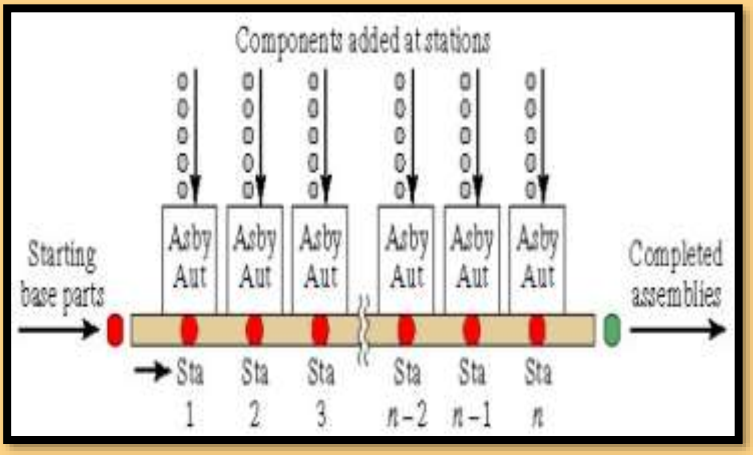
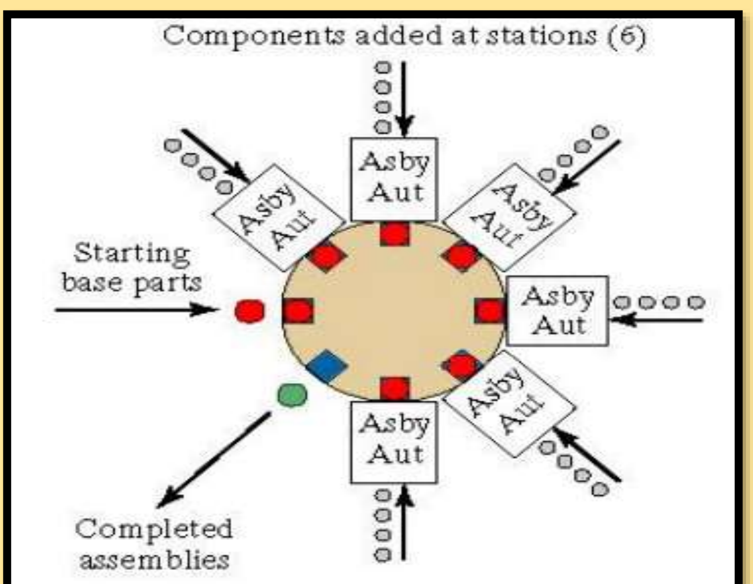
Industrial automation systems are systems used to control and monitor a process, machine or device in a computerized manner that usually fulfills repetitive functions or tasks. It intended to operate automatically in order to reduce and improve human work in the industry.

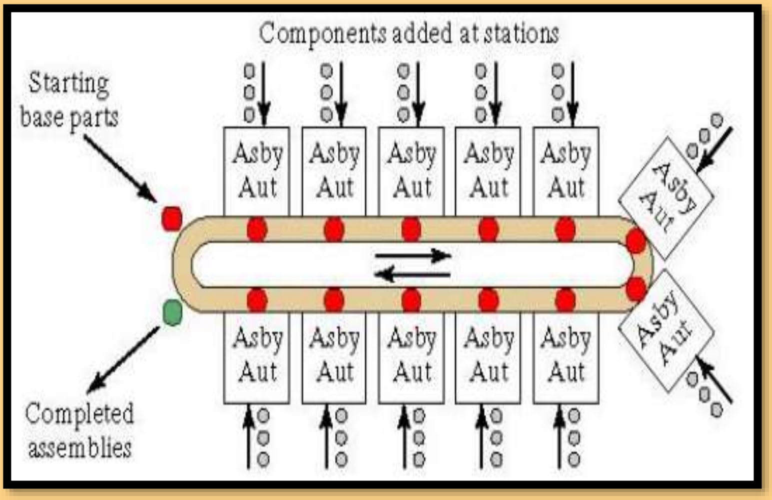
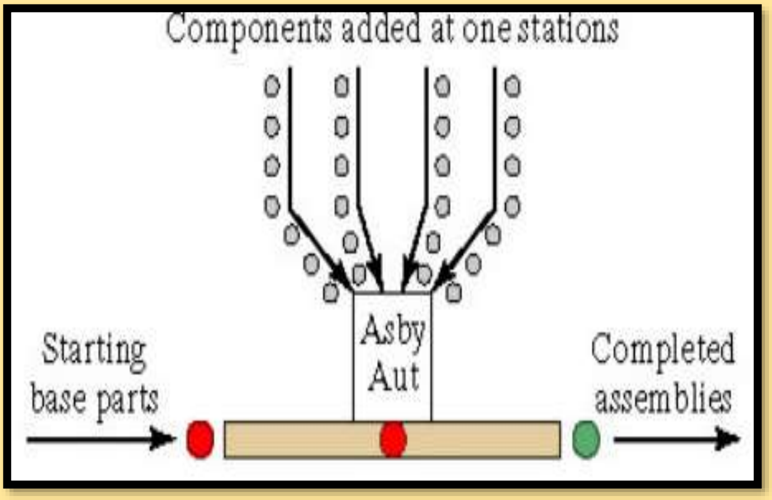
6.1.1 Explain the characteristics of the industrial automation system

An automated assembly system performs a sequence of automated assembly operations to combine multiple components into a single entity. The single entity can be a final product or a subassembly in a larger product. In many cases, the assembled entity consists of a base part to which other components are attached.

Automated assembly systems can be classified according to physical configuration.
The principal configurations:
(a) in-line assembly machine
(b) dial-type assembly machine
(c) carousel assembly system
(d) single station assembly machine

System configurations for Automated Assembly Systems

<table>
<tr><th>Configuration</th><th>Description</th></tr>
<tr><td>In-line

</td><td>A series of automatic workstations located along an in-line transfer system—the assembly version of the machining transfer line. Synchronous and asynchronous transfer systems may be used to transport parts from workstation to workstation.</td></tr>
<tr><td>Dial-type

</td><td>Base parts loaded onto fixtures or nests around the periphery of the circular dial, and—as the dial table turns—components are assembled sequentially onto the base part. Synchronous transfer system in operation, as all nests move at the same time, sometimes through continuous motion, but more often intermittently.</td></tr>
</table>

Configuration	Description
Carousel Assembly System 	Represents a hybrid between the circular work flow of the dial-type assembly machine, and the straight work flow of the in-line system. Carousels can be operated with continuous, synchronous, or asynchronous transfer mechanisms.
Single-station Assembly 	Consists of one workstation where components are assembled, successively, onto a base part that has entered the system. Once all the components have been assembled onto the base part, the base part leaves the system. Inherently slower than the other three system configurations, as only one base part is processed at a time.

Mechanical Description of the Automation

In each of the configurations described, a workstation accomplishes one or both of the following tasks:

1. A part is delivered to the assembly work head and added to the existing base part in front of the work head (in the case of the first station in the system, the base part is often deposited into the work carrier)

2. Fastening or joining operation is performed at the station in which parts added at the workstation or at previous workstations are permanently attached to the existing base part.

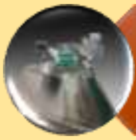
Hopper and parts feeder

The parts delivery system typically consists of the following hardware:

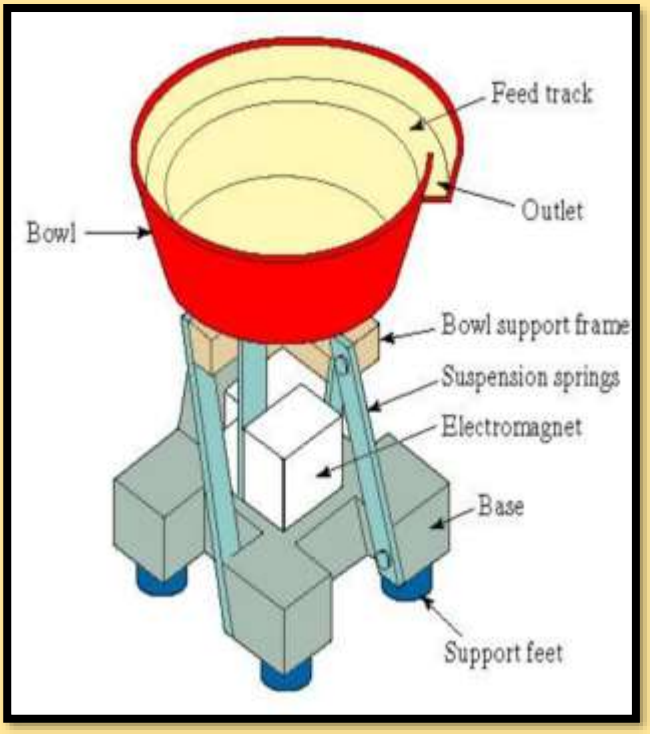

Hopper

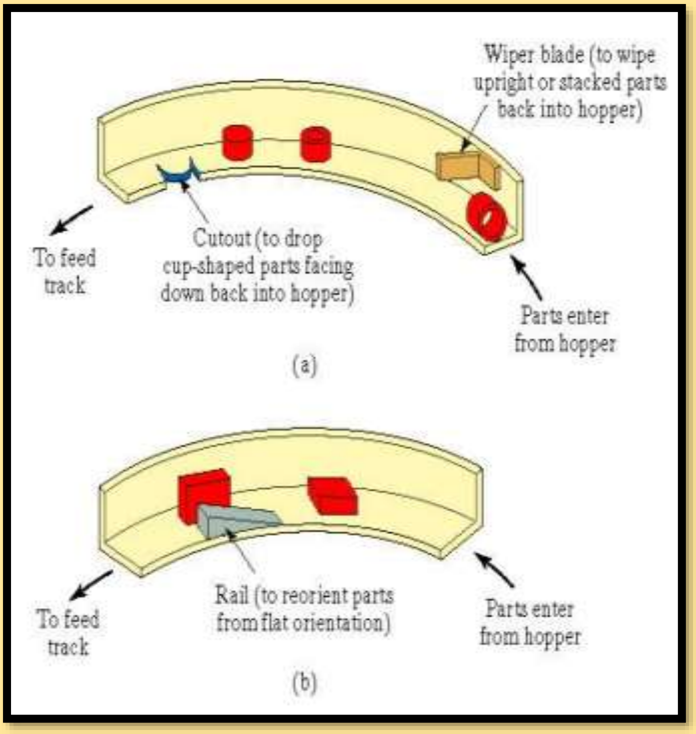

Parts feeder


Selector and/or orientor


Feed back

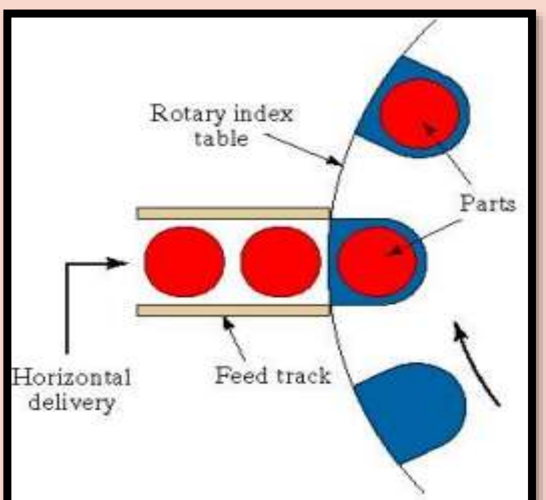
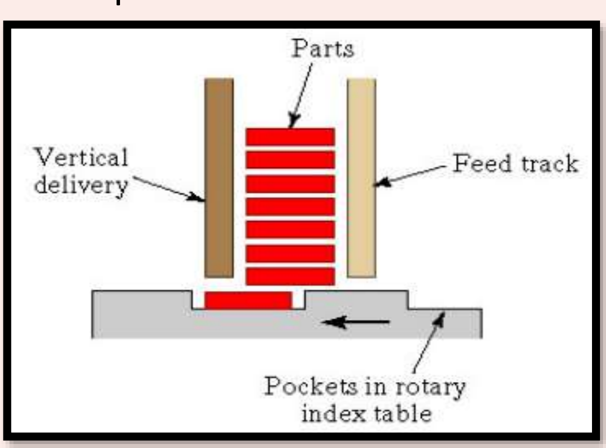

Escapement and placement device



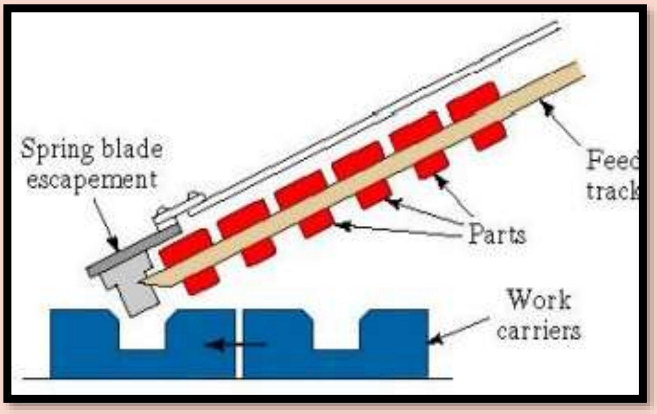


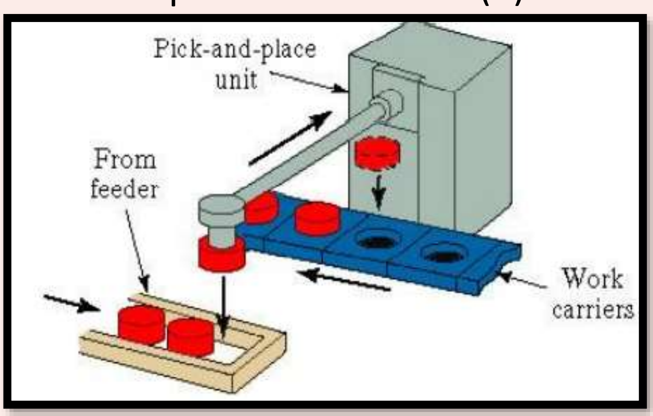
(a) Selector and (b) orientor devices used upon the feedtrack

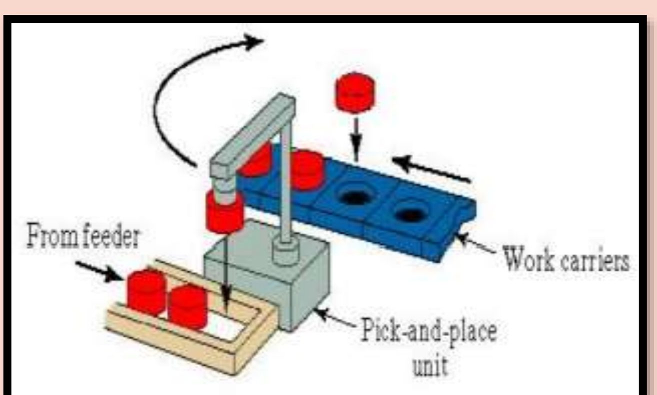
Automated assembly systems are used to produce a wide variety of products and subassemblies. It should be noted that certain assembly processes are more suitable for automation than are others.
For example, threaded fasteners (e.g., screws, bolts, and nuts), although common in manual assembly, are a challenging assembly method to automate.
This issue, along with some guidelines for designing products for automated assembly, is discussed in the following section.

Escapement and placement devices	
Horizontal placement device 	Device used on dial-type assembly machines: parts move via horizontal delivery into vacant nests on the dial, as they appear, from the feed track; meanwhile the circular motion of the dial table means that the nests are revolved away from the feed track, permitting the next component in the feed track to move into the next vacant nest, and so forth.
Vertical placement device 	Device used on dial-type assembly machines: here, the parts feeder is arranged vertically above the dial table, so that when the table turns, to reveal an empty nest, the component can fall by gravity from the feed track into the empty nest. Successive parts fall by gravity to take up their position at the mouth of the feed track in turn.

<table>
<tr><th colspan="2">Escapement and placement devices</th></tr>
<tr><td>Escapement device


</td><td>This device is actuated by the top of the carrier contacting the lower surface of the rivet-shaped part, causing its upper surface to press against the spring blade, which releases the part so that it falls into the work carrier nest. The work carriers are moved horizontally to cause the release of the part, and—after the first part has escaped—the work carrier and released part move off, to be replaced by the next work carrier, and so forth.</td></tr>
<tr><td>Pick-and-place mechanism (1)


</td><td>This mechanism uses a pick-and-place unit with a horizontal arm that may be extended and retracted as necessary, so that parts may be removed from the feed track, and placed into work carriers.</td></tr>
<tr><td>Pick-and-place mechanism (2)


</td><td>This mechanism uses a pick-and-place unit with a revolving arm, so that parts may be removed from the feed track, and placed into work carriers.</td></tr>
</table>

Motion Sequence

One of the obstacles to automated assembly is that many of the traditional assembly method evolved when humans were the only available means of assembling a product. Many of the mechanical fasteners commonly used in industry today require the special anatomical and sensory capabilities of human beings.

This kind of manual operation has been used commonly and successfully in industry for many years to assemble products. The hardware required is inexpensive, the sheet metal is readily perforated to provide the matching clearance holes, and the method lends itself to field service, what is becoming very expensive is the manual labor at the assembly workstation required to accomplish the initial fastening. The high cost of manual labor has resulted in a reexamination of assembly technology with a view toward automation.

Humans are the most dexterous and intelligent machines, able to move to different positions in the workstation, adapt to unexpected problems and new situations during the work cycle, manipulate and coordinate multiple objects simultaneously and make use of a wide range of senses in performing work.

For assembly automation to be achieved, fastening procedures must be devised and specified during product design that does not require all of these human capabilities.

The following are some recommendations and principles that can be applied in product design to facilitate automated assembly:

Reduce the amount of assembly required	This principle can be realized during design by combining functions within the, same part that were previously accomplished by separate components in the product.
Use of modular design	Each module requiring a maximum of 12 or so parts to be assembled on a single assembly system. Also, the subassembly should be designed around a base part to which other components are added.
Reduce the number of fasteners required	Instead of using separate screws, nuts and similar fasteners, design tile fastening mechanism into the component design using snap fits and similar features.
Reduce the need for multiple components to be handled at once	For the case of the single station assembly system, this principle must be interpreted to mean that the handling of multiple components must be minimized in each assembly work clement
Limit the required direction of access	This principle simply means that the number of directions in which new components are added to the existing subassembly should be minimized.
High quality required in components	High performance of the automated assembly system requires consistently good quality of the components added at each workstation.
Hopper ability	One of the major costs in the development of an automated assembly system is the engineering time to devise the means of feeding the components in the correct orientation for the assembly operation.

Motor

Electric motors and drives are important components of industrial automation. Their selection therefore is an important step in the process of building an automated system. You as a buyer must know what types of motors and drives are available and suitable for your application.

AC motors

Synchronous AC motors. These motors are used when load keeps changing and speed is critical. These are mainly used in constant-speed applications. With inverters and cycle converters, these can be in used in variable-speed applications.

Single-phase AC motors. These are small-size motors used in domestic applications like fans, hair dryers, washing machines, vacuum cleaners, kitchen equipment, blowers, small power tools, dairy machinery, small farming equipment and so on.

DC motors

Servo motors. Servo motors are generally an assembly of four things: DC motor, gearing set, control circuit and position sensor (usually a potentiometer).

Stepper motors. These are digital motors whose rotation is in steps defined by the step angle. Stepper motors, unlike traditional AC or DC motors, do not rotate smoothly.

Universal motors

These are a special type of motors designed to run on either DC or single-phase AC supply. These produce high starting torque. Most universal motors are designed to operate at higher speeds, exceeding 3500rpm.

Drive Mechanism Selection

Power range for motor and drives.

Maximum speed and speed range

- As a general rule, for a given power the higher the base speed the smaller the motor. In practice, there are only a few applications where motors with base speeds below a few hundred rev/ min are attractive, and it is usually best to obtain low speeds by means of the appropriate mechanical speed reduction

Load requirements –Torque – Speed Characteristics

- The most important things we need to know about the load are the steady-state torque–speed characteristic, and the effective inertia as seen by the motor.

Constant-torque load

- A constant torque load implies that the torque required to keep the load running is the same at all speeds.

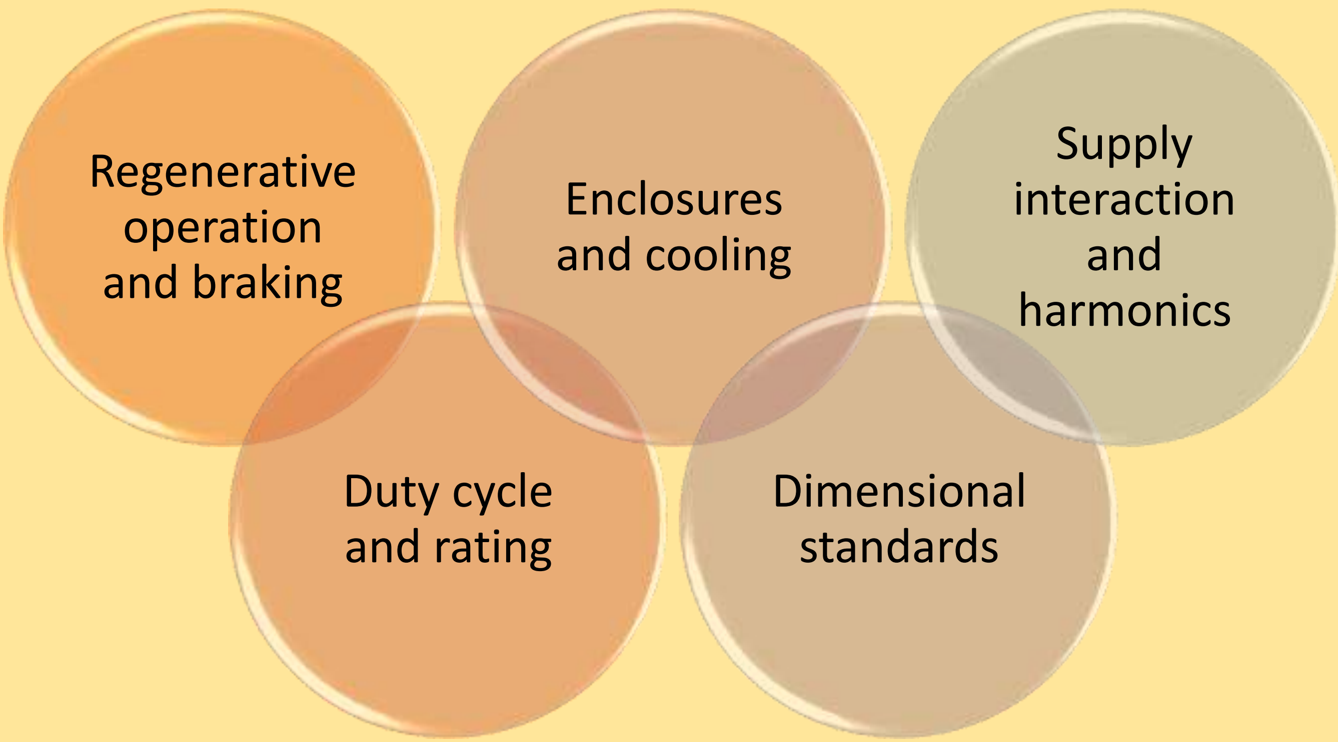
Inertia matching

- There are some applications where the inertia dominates the torque requirement

Fan and pump loads

- Fan-type loads which require speed control can therefore be handled by drives which can only allow reduced power at such low speeds, such as the inverter-fed cage induction motor without additional cooling, or the voltage-controlled cage motor.

General Application Considerations



6.2 Describe The Encoder Selection

A number of static and dynamic factors must be considered in selecting a suitable sensor to measure then desired physical parameter.

Following is a list of typical factors:

- **Range** —Difference between the maximum and minimum value of the sensed parameter
- **Resolution** —The smallest change the sensor can differentiate
- **Accuracy** —Difference between the measured value and the true value
- **Precision** —Ability to reproduce repeatedly with a given accuracy
- **Sensitivity** —Ratio of change in output to a unit change of the input
- **Zero offset** —A nonzero value output for no input
- **Linearity** —Percentage of deviation from the best-fit linear calibration curve
- **Zero Drift** —The departure of output from zero value over a period of time for no input
- **Response time** —The time lag between the input and output
- **Bandwidth**—Frequency at which the output magnitude drops by 3 dB
- **Resonance** —The frequency at which the output magnitude peak occurs
- **Operating temperature** —The range in which the sensor performs as specified
- **Deadband** —The range of input for which there is no output
- **Signal-to-noise ratio** —Ratio between the magnitudes of the signal and the noise at the output

Factors Affecting The Selection Of Position Sensors

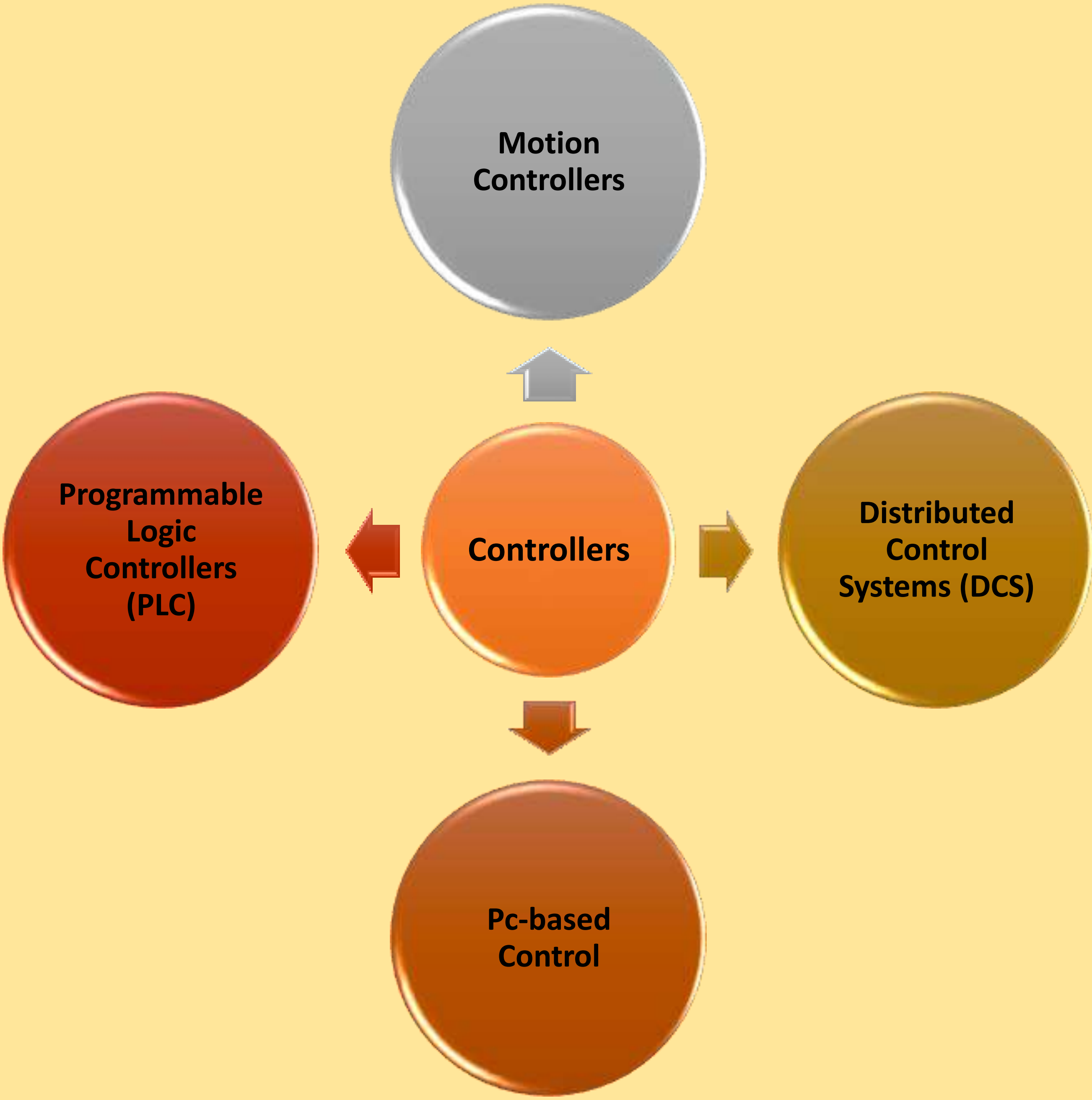
In selecting a position sensor, several key factors should be considered:

- **Cost**. Both initial purchase price and life-cycle cost must be considered.
- **Sensing distance**. Photoelectric sensors are often the best selection when sensing distances are longer than 25 mm. Photoelectric sensors can have sensing ranges as long as 300,000 mm for outdoor or extremely dirty applications, down to 25 mm for extremely small parts or for ignoring background.
- **Type of material**. Inductive proximity sensors can sense only ferrous and nonferrous materials, whereas photoelectric and limit switches can detect the presence of any solid material. Photoelectric sensors, however, may require a polarizer if the target's surface is shiny.
- **Speed**. Electronic devices using DC power are the fastest—as fast as 2000 cycles per second for inductive proximity models. The fastest-acting limit switches can sense and reset in 4 m/s or about 300 times per second.
- **Environment**. Proximity sensors can best handle dirty, gritty environments, but they can be fooled by metal chips and other metallic debris. Photoelectric sensors will also be fooled or left inoperable if they are fogged or blinded by debris.
- **Types of voltages, connections, and requirements of the device are housing**. All three types can accommodate varying requirements, but the proper selection must be made in light of the power supplies, wiring schemes, and environments.
- **Third-party certification**. The organizations impose requirements for safety, often based on the type of application. The certification will ensure the device has been tested and approved for certain uses.
- **Intangibles**. These can include the availability of application support and service, the supplier's reputation, local availability, and quality testing statements from the manufacturer

6.3 Construct The Control Structure: Programmable Logic Controller Used For Industrial Automation

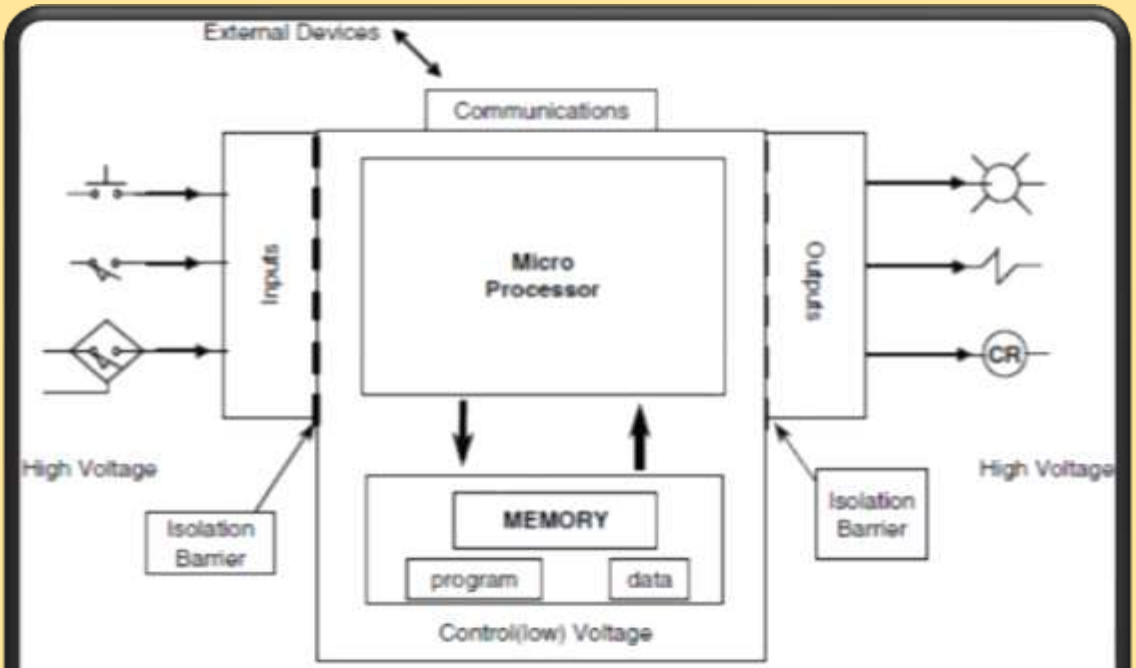
Controllers

There are many different distinctions in the area of industrial automation controllers. The most widely used controllers are:



PLC: Programmable Logic Controller

The programmable logic controller (PLC) has been part of manufacturing automation forever two decades, replacing the hard-wired relay logic controllers. For smaller-scale, event-driven processes and machines with limited I/O points, stand-alone PLCs are the controller of choice. PLCs are rugged, relatively fast, and low cost with excellent sequential control performance.



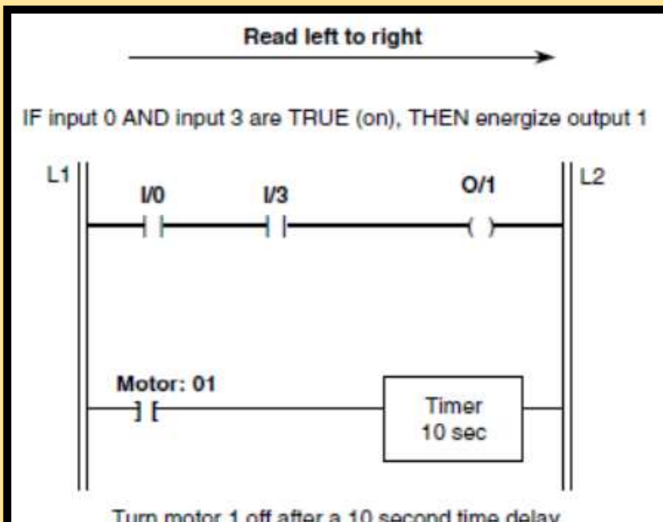
PLC-I/O structure

Ladder Logic Diagrams

- The ladder logic diagram (LLD) is the most common programming language used in PLC applications. LLD is a graphical language resembling wiring diagrams.
- Each instruction set is a rung on the ladder.
- Each rung is executed in sequential order for every control cycle.
- A rung is a logic statement, reading from left to right
- Rungs can have more than one branch.

Structured Text

- Structured text (ST) is a high-level programming language similar to BASIC, Fortran, Pascal, or C. Most engineers are familiar with structured programming languages.
- Structured text has standard program flow control command statements such as If/Then, Case, Do/While, Do/Until, and For/Next constructs.
- Most LLD, SFC, and FBD instructions are supported in ST.



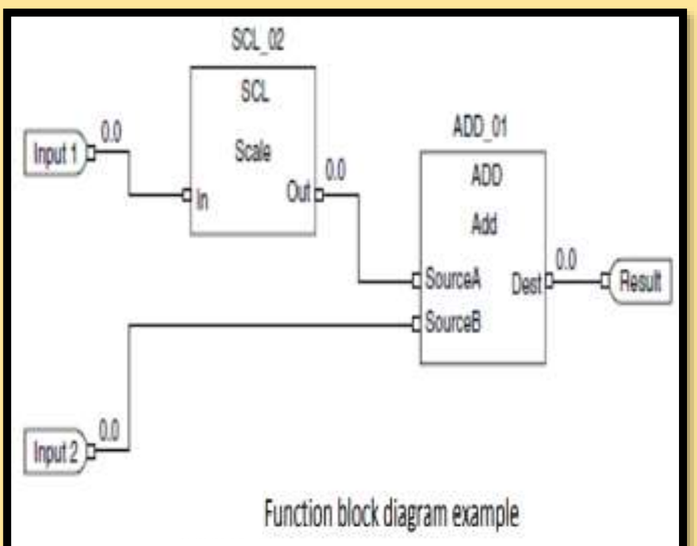
Reading ladder logic diagrams

```
;************* force control loop *****************
WHILE (M362>Q5 AND M362<Q4)          ;begin loop
        P6 = (M156*Q2)               ;DESIRED FORCE (N * force bits/N)
        P15 = M1001                  ;GET WEIGHT
        P8 = P15-P14                 ;TARED FORCE
        P7 = P8-P6                   ;FORCE ERROR
        P9 = P9+P7                   ;INTEGRAL ERROR

        IF (P9>Q8)
                P9 = Q8              ;LIMIT INTEGRATION
        ENDIF
        IF (P9 < (-Q8))
                P9 = -Q8
        ENDIF
                                     ; UPDATE GAINS
        Q6 = M153*P20                ;40 nom PROPORTIONAL GAIN
        Q7 = M154*P20                ;80 nom INTEGRAL GAIN
        X0Y0Z ((P7*Q6+P9*Q7))        ;COMMAND MOVE

ENDWHILE                             ;end of loop
```

Structure text example

Function Block Diagram

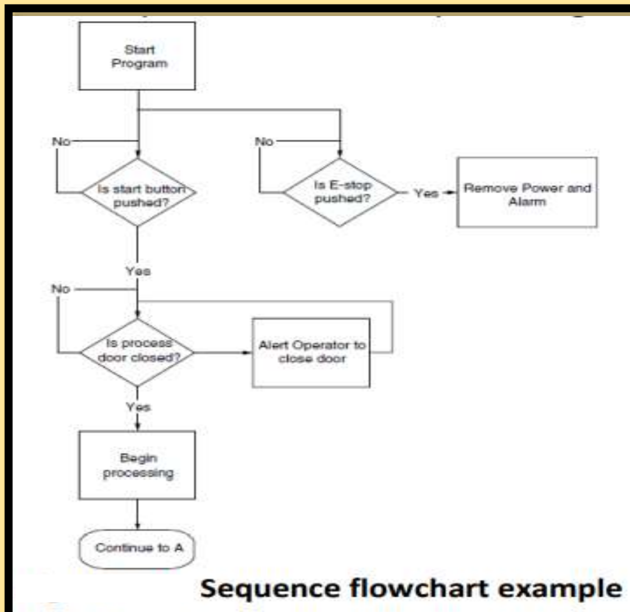
- Function block diagram (FBD) is a highly visual language and is easy to understand because it resembles circuit diagrams.
- The graphical free-form programming environment is easy for manipulating process variables and control.
- The foundation of the FBD program is a set of instruction blocks with predefined structures of inputs and outputs from each block. Different blocks are placed and connections are drawn to pass parameters or variables between blocks.



Function block diagram example

Sequential Flow Chart

- Sequential flow chart (SFC) is another highly visual programming language yielding applications that are easy to create and read.
- SFC is a graphical flowchart-based programming environment. Logical steps (blocks) are placed on the visual layout in an organized manner.



Sequence flowchart example

IL: Instruction List

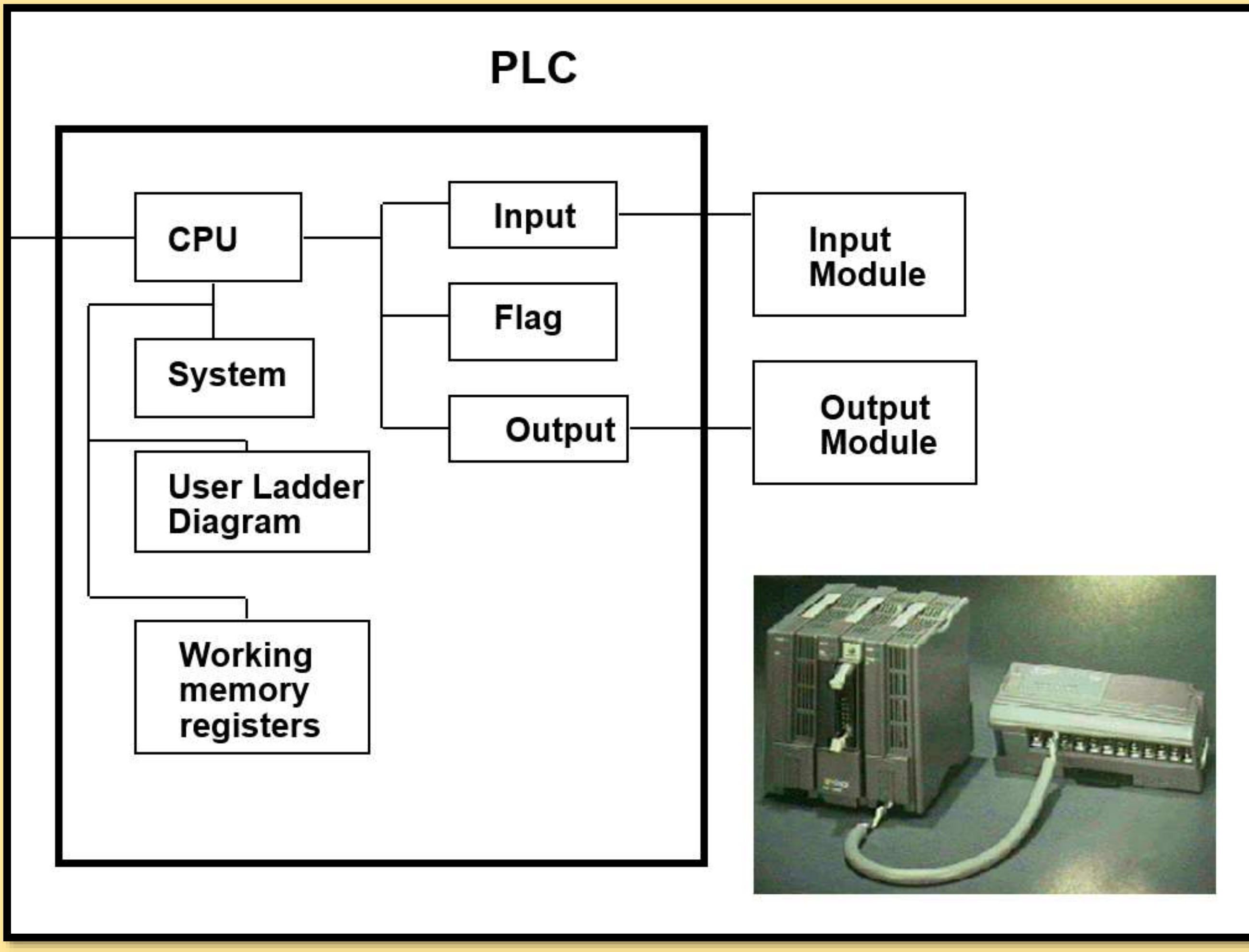
- Instruction list (IL) is the most basic-level programming language for PLCs. All languages can be converted to IL, although it is most often used with LLD.

Functions Of Controllers

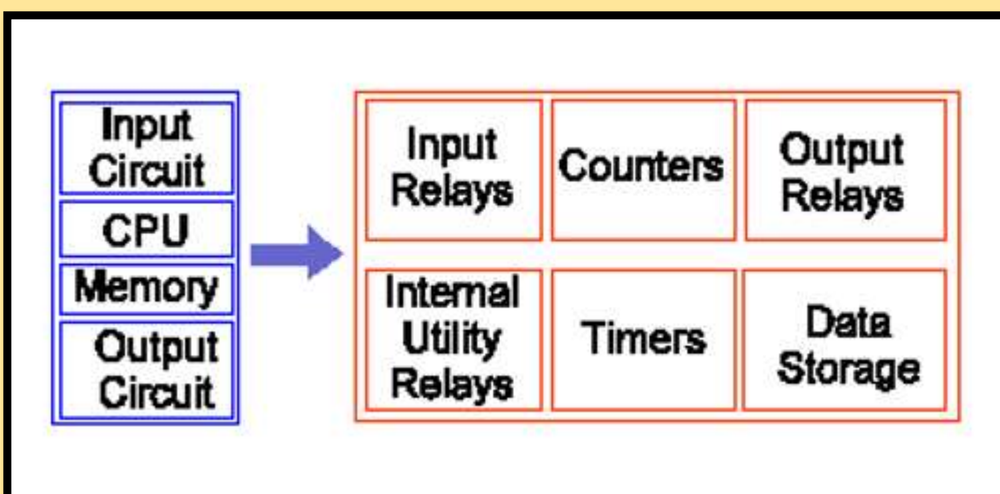
1) On-off Control
2) Sequential Control
3) Feedback Control
4) Motion Control

Control Devices

1) Mechanical control - cam, governor, etc.,
2) Pneumatic control - compressed air, valves, etc.
3) Electromechanical control - switches, relays, a timer, counters, etc,
4) Electronics control - similar to electromechanical control, except uses electronic switches.
5) Computer control.



PLC Configuration



What devices does a PLC interact with

INPUT RELAYS-(contacts) These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc.

INTERNAL UTILITY RELAYS-(contacts) These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task.

COUNTERS-These again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed. Some manufacturers also include high-speed counters that are hardware based.

TIMERS -These also do not physically exist. They come in many varieties and increments. The most common type is an on-delay type. Others include off-delay and both retentive and non-retentive types. Increments vary from 1ms through 1s.

OUTPUT RELAYS-(coils) These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc. They can be transistors, relays, or triacs depending upon the model chosen.

DATA STORAGE -Typically there are registers assigned to simply store data. They are usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC.

EXERCISE

1. What are automated assembly systems? What system configurations can automated assembly systems take?
2. List the hardware components used for parts delivery at workstations.
3. What would generally be seen as typical automated assembly processes?
4. How do the high level sensor and the low level sensor in parts delivery at workstations function?
5. What are the recommendations and principles that can be applied in product design to facilitate automated assembly?
6. Criteria to be consider for motor selection.
7. Factor to be consider for sensor encoder selection.
8. Give an example of where a PLC could be used.
9. A PLC can effectively replace a number of components. Give examples and discuss some good and bad applications of PLCs.
10. What is PLC?
11. List the PLC components.
12. Give five types of PLC language.
13. Develop a simple ladder logic program that will turn on an output X if inputs A and B, or input C is on.

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