Automation and Robotics

Module -1

Introduction to Robotics: Definition and origin of robotics – different types of robotics – various generations of robots – degrees of freedom – Asimov's laws of robotics .

Sensors; Sensors, analog to digital converters, digital to analog converters, input/output devices for discrete data

Introduction to Robot;

Word robot was coined by a Czech novelist Karel Capek in a 1920 play titled Rassum's Universal Robots (RUR). Robot in Czech is a word for worker or servant

Definition

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks

Types of Robot;

- Industrial robots
- Domestic or household robots
- Medical robots
- Service robots
- Military robots
- Entertainment robots
- Space robots
- Hobby and competition robots

Advantages

- Perform each task with speed and accuracy
- Give us information that we can't
- Don't get bored

- Can work in dangerous and hazardous environment
- Multitasking
- Don't need experience

Disadvantages

- Replacement of human labor
- Greater unemployment
- Significant retraining costs for both unemployed and users of new technology
- Advertised technology does not always disclose some of the hidden disadvantages
- Hidden costs because of the associated technology that must be purchased and integrated into a functioning cell. Typically, a functioning cell will cost 3-10 times the cost of the robot.

Robot Anatomy and Related Attributes

Robot anatomy is concerned with the types and sizes of these joints and links and other aspects of the manipulator's physical construction. The robot's anatomy affects its capabilities and the tasks for which it is best suited.

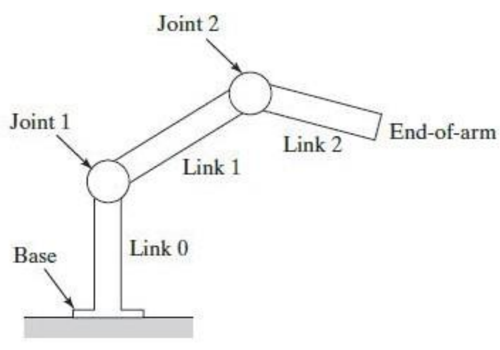


Figure 8.1 Diagram of robot construction showing robot is made up of a series of joint-link combinations.

Joints and Links

A robot's joint, or *axis* as it is also called in robotics, is similar to a joint in the human body: It provides relative motion between two parts of the body. Robots are often classified according to the total number of axes they possess. Connected to each joint are two links, an input link and an output link. Links are the rigid components of the robot manipulator. The purpose of the joint is to provide controlled relative movement between the input link and the output link.

Nearly all industrial robots have mechanical joints that can be classified into one of five types: two types that provide translational motion and three types that provide rotary motion.

1. Linear joint (type L joint). The relative movement between the input link and the output link is a translational telescoping motion, with the axes of the two links being parallel.

2. Orthogonal joint (type O joint). This is also a translational sliding motion, but the input and output links are perpendicular to each other.

3. Rotational joint (type R joint). This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

4. Twisting joint (type T joint). This joint also involves rotary motion, but the axis of rotation is parallel to the axes of the two links.

5. Revolving joint (type V joint, V from the “v” in revolving). In this joint type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.

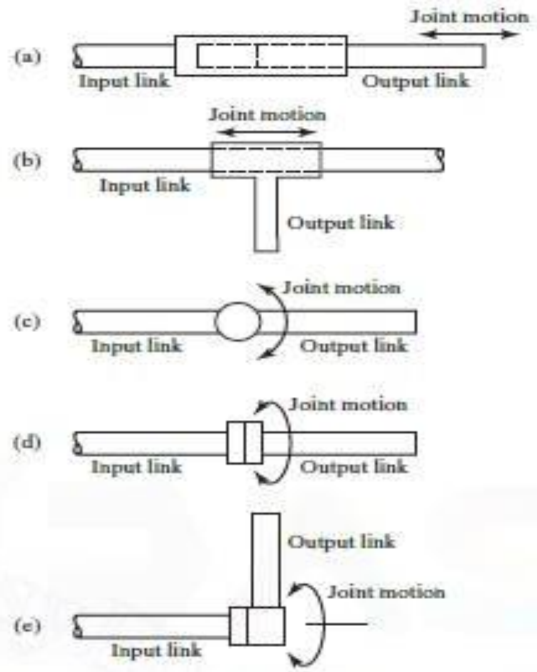


Figure 8.2 Five types of joints commonly used in industrial robot construction: (a) linear joint (type L joint), (b) orthogonal joint (type O joint), (c) rotational joint (type R joint), (d) twisting joint (type T joint), and (e) revolving joint (type V joint).

Common Robot Configurations

A robot manipulator can be divided into two sections: a body-and-arm assembly and a wrist assembly. There are usually three axes associated with the body-and-arm, and either two or three axes associated with the wrist. At the end of the manipulator's wrist is a device related to the task that must be accomplished by the robot. The device, called an end effector (Section 8.3), is usually either (1) a gripper for holding a work part or (2) a tool for performing some process. The body-and-arm of the robot is used to position the end effector, and the robot's wrist is used to orient the end effector.

Articulated robot. Also known as a jointed-arm robot (Figure), it has the general configuration of a human shoulder and arm. It consists of an upright body that swivels about the base using a T joint. At the top of the body is a shoulder joint (shown as an R joint in the figure), who's output link connects to an elbow joint (another R joint).

Polar configuration. This configuration (Figure) consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and a horizontal axis (R joint).

SCARA. SCARA is an acronym for Selectively Compliant Arm for Robotic Assembly. This configuration (Figure 8.5) is similar to the jointed-arm robot except that the shoulder and elbow rotational axes are vertical, which means that the arm is very rigid in the vertical direction, but compliant in the horizontal direction. This permits the robot to perform insertion tasks (for assembly) in a vertical direction, where some side-to-side alignment may be needed to mate the two parts properly.

Cartesian coordinate robot. Other names for this configuration include gantry robot, rectilinear robot, and x–y–z robot. As shown in Figure 8.6, it consists of three orthogonal joints (type O) to achieve linear motions in a three-dimensional rectangular work space. It is commonly used for overhead access to load and unload production machines.

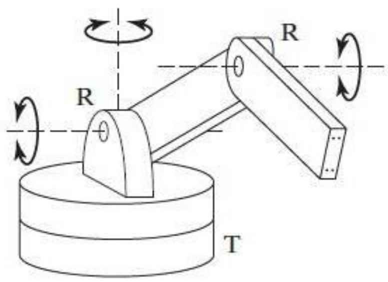


Figure 8.3 Articulated robot (jointed-arm robot).

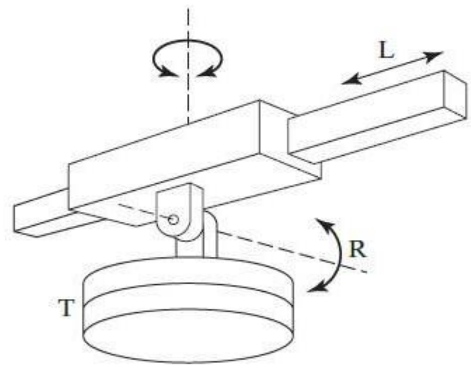


Figure 8.4 Polar configuration.

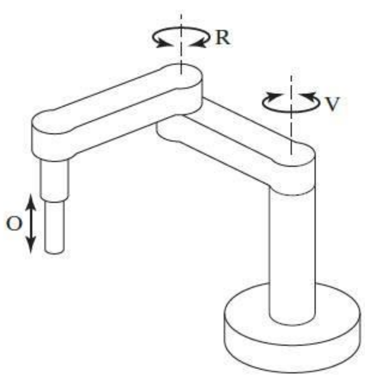
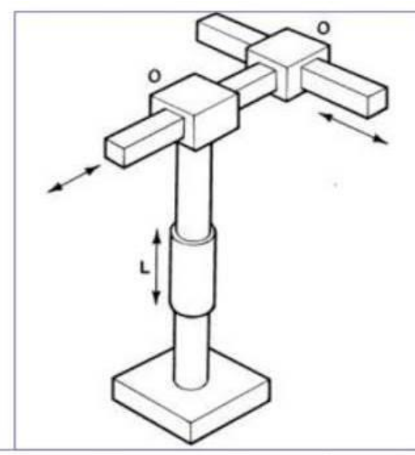
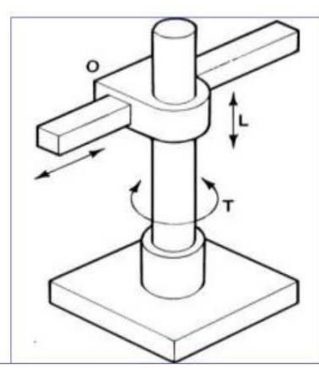


Figure 8.5 SCARA configuration.



:sian coordinate body-and-arm as



Cylindrical body-and-arm assembly (TLO)

Key components

- **Power Supply** ;The working power to the robot is provided by batteries, hydraulic, solar power, or pneumatic power sources.
- **Actuators**; Actuators are the energy conversion device used inside a robot. The major function of actuators is to convert energy into movement.

- **Electric motors (DC/AC)-** Motors are electromechanical component used for converting electrical energy into its equivalent mechanical energy. In robots motors are used for providing rotational movement.

- **Manipulator;** To fulfill their purposes, many robots are required to interact with their environment, and the world around them. Sometimes they are required to move or reorient objects from their environments without direct contact by human operators. Unlike the Body/frame and the Control System, manipulators are not integral to a robot, i.e. a robot can exist without a manipulator

- **End effecter;** The effectors are the parts of the robot that actually do the work. Effectors can be any sort of tool that you can mount on your robot and control with the robot's computer.

  End effecter the tools at the end of robotic arms and other robotic appendiges that directly interact with objects in the world. A "gripper" at the end of a robotic arm is a common end-effecter. Others include spikes, lights, hammers and screw-drivers.

- **Controller;** Controller is a part of robot that coordinates all motion of the mechanical system. It also receives an input from immediate environment through various sensors. The heart of robot's controller is a microprocessor linked with the input/output and monitoring device.

- **Sensors -** Sensors provide real time information on the task environment. Robots are equipped with tactile sensor it imitates the mechanical properties of touch receptors of human fingerprints and a vision sensor is used for computing the depth in the environment

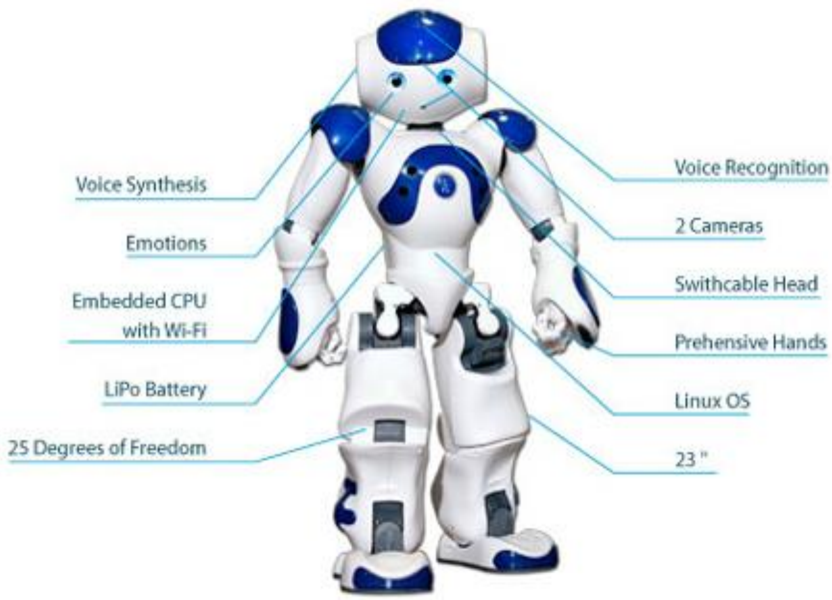


Fig.1 ; Robot

Application of Industrial Robots

1. Material Transfer
2. Machine loading
3. Processing Operations
4. Spray coating
5. Assembly
6. Inspection

But, there is a major disadvantage, if robots are used in Arc Welding. Arc Welding is used in case of low volume production. So, if robots are used, the cost of investment will be very high.

4. Spray Coating:

Many industries will be having some form of spray coating application. Initially, human workers used to do spray coating, which may lead to health hazards.

- Spray coating/painting creates toxic atmosphere.
- Noise is produced.
- May result in fire hazard.

So, in this regard, workers are replaced by robots in spray painting.

Advantage, by using robots in spray painting:

1. Safe in operation.
2. Coating consistency
3. Lower material usage.
4. Less verification requirements.
5. Greater productivity.

5. Processing Operations:

These are performed by a specialized tools attached to the robots arm. These tools can do lot of operations like drilling, Riveting, Grinding, Polishing etc.

6. Assembly:

Robots are widely used for assembly operations in industries, which may result in increased productivity.

Also, robots can do repetitive tasks continuously, in case of assembly operations.

7. Inspection:

This is the new application area of robot.

Previously the inspection process was difficult and very slow and tedious. Workers usually perform sampling techniques rather than 100% inspection. Now a days, as the quality of products became very important, each and every product must be inspected, and this can be accomplished by a robot.

Here, robots are equipped with mechanical probes, sensors and other measuring devices to perform inspection process.

In general, robot picks the work parts from the conveyor and loads on the machine. But in some cases, robots holds the parts in position during processing.

When processing is finished, robot unloads the part and places in another conveyor.

Machine loading application will be very useful in case of Die casting, Injection Molding, Hot forging, and in Machining Operation such as Turning, Milling etc.

3. **Welding:**

Welding is one of the important application area in case of Robotic applications. The applications in welding basically is divided into two categories.

- Spot Welding
- Arc Welding

- **Spot Welding:**

It is a process where metal parts are fused together at localized points by passing electric current through the two parts.

This is done with the help of two electrodes.

Robot is used to hold the electrodes in such applications, and through these electrodes electric current is made to pass into the metal parts.

This application is widely used in Automobile Industry.

- **Arc Welding:**

Different types of Arc Welding can be performed by using Robots like

GMAW - Gas Metal Arc Welding

MIG - Metal Inert Gas Welding

TIG - Tungsten Inert Gas Welding

Most of the times, Arc Welding is performed by Human Workers (Welders), who must often work under hot, uncomfortable and dangerous conditions.

So, in order to improve workers safety robots are used.

Advantages due to robots in Arc Welding:

1. High productivity, i.e., operations can be done at faster rate.
2. Improved safety.
3. More consistent welds can be obtained.

Various generations of Robots(Evaluation of Robot)

The industrial robot, its image having been widely promulgated in the print mediaandontelevision,almostinvariablycomestomindtodayatthementionof the word robot. It has largely displaced the bipedal tin men of early science fiction.

First-generation

The typically squat, one-armed, occasionally mobile **first-generation robot** originated in the 1960s. Usually, it was single purpose and was used in such occupations as welding, painting, and machining. Today such robots are in wide use, having matriculated through the early stages of laboratory development and technical feasibility to economic feasibility in the early 1980s.

A first-generation robot is a simple mechanical arm. These machines have the ability to make precise motions at high speed, many times, for a long time. Such robots find widespread industrial use today. First-generation robots can work in groups, such as in an automated integrated manufacturing system (AIMS), if their actions are synchronized. The operation of these machines must be constantly supervised, because if they get out of alignment and are allowed to keep working, the result can be a series of bad production units.

Second generation

A**Secondgeneration**ofadaptive,sensor-basedrobots,atthelaboratorystage in the 1970s, are just arriving at the stage of technical feasibility. These are diverse robots, with some intelligence, but still largely single function. Like first-generation robots, they are used primarily inmanufacturing.

A second-generation robot has rudimentary machine intelligence. Such a robot is equipped with sensors that tell it things about the outside world. These devices include pressure sensors, proximity sensors, tactile sensors, radar, sonar, ladar, and vision systems. A controller processes the data from these sensors and adjusts the operation of the robot accordingly. These devices came into common use around 1980. Second-generation robots can stay synchronized with each other, without having to be overseen constantly by a human operator. Of course, periodic checking is needed with any machine, because things can always go wrong; the more complex the system, the more ways it can malfunction

Third generation

A **third generation** of robots is needed to work outside the factory. The industrial robots employed in manufacturing operate in highly structured environments. Often the manufacturing environment is altered to accommodate them. Altering to any great extent the environments that service robots will be called upon to operate in (e.g., undersea and construction environments, space, mines, nuclear power plants, hospitals, offices, homes) is inconceivable. To function in such unstructured environments, robots must come to resemble humans more than machines, including possession of certain human like faculties. Communication functions will be essential in these third-generation “intelligent” robots.

The concept of a third-generation robot encompasses two major avenues of evolving smart robot technology: the autonomous robot and the insect robot. An autonomous robot can work on its own. It contains a controller, and it can do things largely without supervision, either by an outside computer or by a human being. A good example of this type of third generation robot is the personal robot about which some people dream. There are some situations in which autonomous robots do not perform efficiently. In these cases, a fleet of simple insect robots, all under the control of one central computer, can be used. These machines work like ants in an anthill, or like bees in a hive. While the individual machines lack artificial intelligence (AI), the group as a whole is intelligent.

Fourth generation

Any robot of a sort yet to be seriously put into operation is a fourth generation robot. Examples of these might be robots that reproduce and evolve, or that incorporate biological as well as mechanical components. Past that, we might say that a fifth-generation robot is something no one has yet designed or conceived.

Degrees of freedom;

Degrees of freedom refers to Number of independent parameters that define the configuration or state of a mechanical system.

The individual joint motions associated with the performance of a task are Called as Degree of freedom.(DOF)

Degrees of freedom, in a mechanics context, are specific, defined modes in which a mechanical device or system can move. The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion.

Degree of Freedom (D.O.F) - 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 2or 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 D.O.F requires a restriction to 2D space, or else it limits orientations

Industrial robot is equipped with **Four to Six degree** of freedom.

The robot's motions are accomplished by means of powered joints. Three joints are normally associated with the action of the arm and body, and two or threee joints are generally used to actuate the wrist.Connecting various joints Called Links.The links are connected to form **Serial Chain or Parallel Chain.**

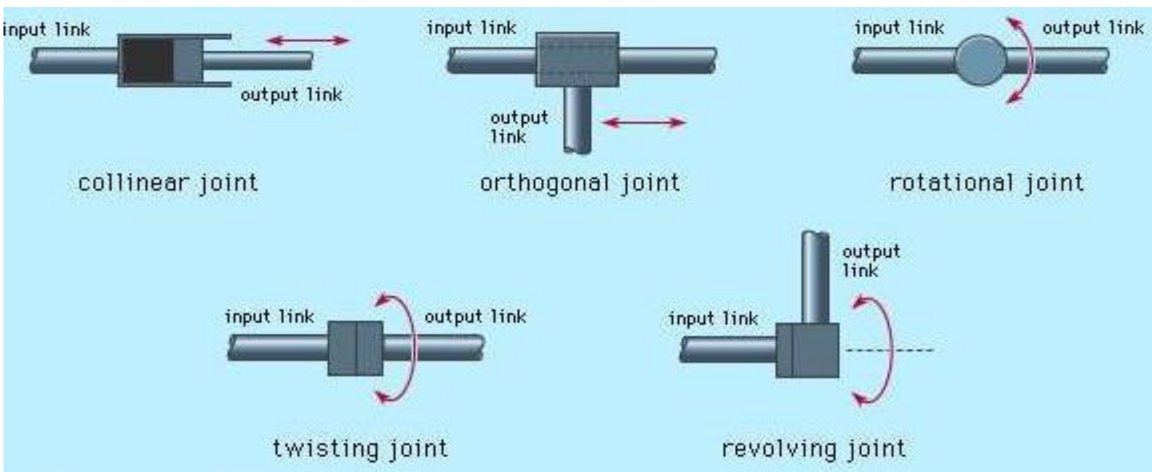


Fig.2 . Types of Joints

1. **Vertical traverse**; It is the capability to move the wrist up or down to provide the desired vertical attitude.
2. **Radial traverse**: It is the extension or retraction (in or out movement) of the arm from the vertical centre of the robot.
3. **Rotational traverse**; It is the rotation of the arm about the vertical axis.

   The wrist movement is designed to enable the robot to orient the end effector properly with respect to the task being performed.

1. **Wrist roll (Wrist swivel):** It involves rotation of the wrist mechanism about the arm axis.
2. **Wrist Pitch**; It is the up and down rotation of the wrist
3. **Wrist yaw**; Wrist swivel is in the centre position of its range, wrist yaw would involve the right or left rotaion of the wrist.

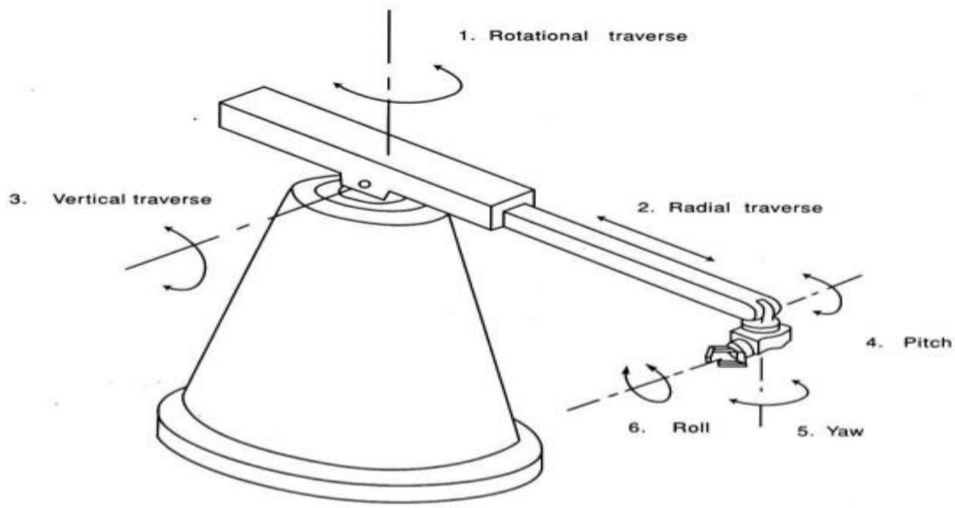


Fig.3; Various degrees of freedom

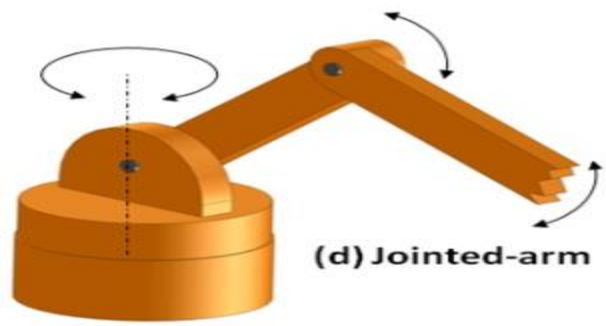


Fig.4; Three degrres of freedom

Six degrees of freedom (**6 DOF**) refers to the freedom of movement of a rigid body in three-dimensional space. Specifically, the body is free to change position as forward/backward (surge), up/down (heave), left/right (sway) translation in three perpendicular axes, combined with changes in orientation through rotation about three perpendicular axes, often termed yaw (normal axis), pitch (transverse axis), and roll (longitudinal axis).

A few robot that are commonly used in the industry are **PUMA** (Programmable Universal Machine for Assembly)

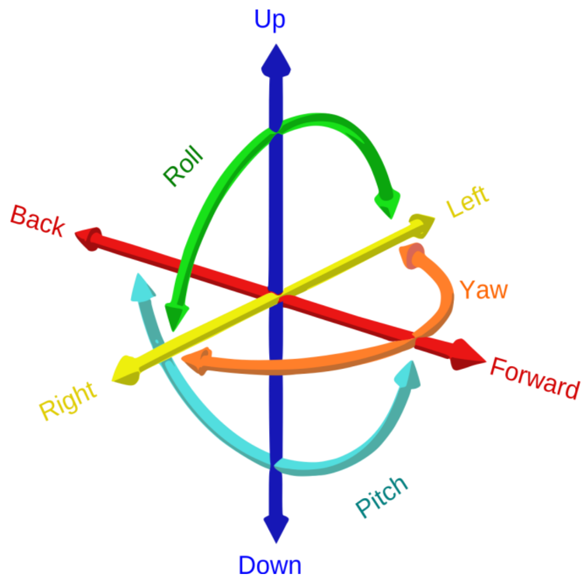


Fig.5 ; Six Degrees of Freedom used in PUMA robot.

Laws of Robotics;

Asimov proposedthree "Laws of Robotics " and later added the "zeroth law "

• **Law 0:** A robot may not injure humanity or through inaction, allow humanity to come to harm

• **Law 1:** A robot may not injure a human being or through inaction, allow a human being to come to harm, unless this would violate a higher order law

• **Law 2:** A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law

• **Law 3:** A robot must protect its own existence as long as such protection does not conflict with a higher order law

Sensor;

Sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor.

Robot sensors: measure robot configuration/condition and its environment and send such information to robot controller as electronic signals (e.g., arm position, presence of toxic gas).

Robots often need information that is beyond 5 human senses (e.g., ability to: see in the dark, detect tiny amounts of invisible radiation, measure movement that is too small or fast for the human eye to see)

Vision Sensor: e.g., to pick bins, perform inspection, etc

Part-Picking: Robot can handle In-Sight Vision Sensors work pieces that are randomly piled by using 3-D vision sensor. Since alignment operation, a special parts feeder, and an alignment pallete are not required, an automatic system can be constructed at low cost.

Force Sensors; e.g., parts fitting and insertion, force feedback in robotic surgery.

Parts fitting and insertion: Robots can do precise fitting and insertion of machine parts by using force sensor. A robot can insert parts that have the phases after matching their phases in addition to simply inserting them. It can automate high skill jobs.

Tilt Sensors; e.g., to balance a robot

Sensors and Transducers (15)

* Sensors are devices which produce a proportional output signal (mechanical, electrical, magnetic, etc.) when exposed to a physical phenomenon (pressure, temperature, displacement, force, etc.)

* Sensor is a device which detects (or) measures a physical property and records, indicates, (or) otherwise responds to it

* Transducers are devices which converts an input of one form of energy into an output of another form of energy.

Classification of sensors:

* Based on its power requirement

i. Passive sensor: * passive sensors require external power source. [Ex: differential transformers, strain gauge, resistance thermometers, etc.]

* Passive sensors work based on one of the following principles: resistance, inductance, and capacitance.

ii. Active sensor: * In active sensors, the power required to produce the output is provided by the sensed physical phenomenon itself.

[Ex: thermocouples, thermometer, piezoelectric transducers]

* The active sensors are also called as "self-generating transducers.

* Based on the type of output signal

i. Analog sensors: [Ex: potentiometers, LVDT]

Primary Sensor:

* Primary sensors produce the output which is the direct measure of the input phenomenon.

Secondary sensor:

* secondary sensorsy on the other hand produce output which is not the direct representation of the physical phenomenon.

Active → Primary Sensor
Passive → Secondary Sensor

Performance Terminology:

1. Static characteristics:

Range:

* Every sensor is designed to work a specified range. (i.e) certain maximum and minimum value.

Ex: Thermocouple range of −100 to 1260°C

Span:

* It is the difference between maximum and minimum values of the quantity to be measured.

Span = Maximum Value of the input − Minimum Value of the input

Error:

Error = Measured value − True input value.

Accuracy:

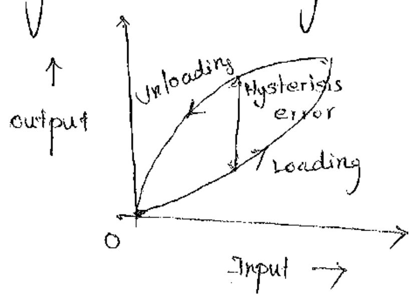
* The accuracy of a sensor is inversly proportional

Sensitivity :

$$\text{Sensitivity} = \frac{\text{change in output}}{\text{change in input}} = \frac{\Delta \theta_o}{\Delta \theta_i}$$

Hysteresis :

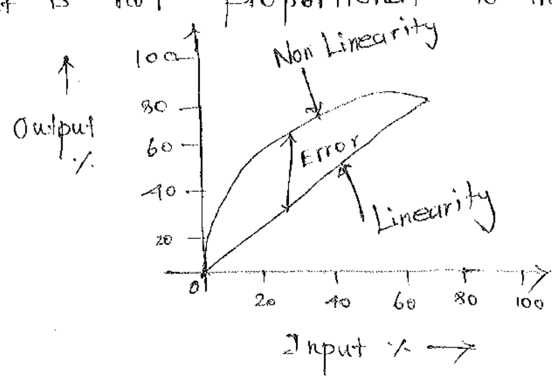
* Hysteresis is defined as the maximum differences in output for a given input when this value is approached from the opposite direction.
* It is a phenomenon which shows different outputs when loading and unloading.



Linearity : * Linearity of a sensor refers to the output that is directly proportional to input over its entire range.

Non Linearity :

* Non linearity of a sensor refers to the output that is not proportional to input over its entire range.



Sensor specifications

Transducers or measurement systems are not perfect systems. Mechatronics design engineer must know the capability and shortcoming of a transducer or measurement system to properly assess its performance. There are a number of performance related parameters of a transducer or measurement system. These parameters are called as sensor specifications.

Sensor specifications inform the user to the about deviations from the ideal behavior of the sensors. Following are the various specifications of a sensor/transducersystem.

1. **Range**

The range of a sensor indicates the limits between which the input can vary. For example, a thermocouple for the measurement of temperature might have a range of 25-225 °C.

2. **Span**

The span is difference between the maximum and minimum values of the input. Thus, the above-mentioned thermocouple will have a span of 200 °C.

3. **Error**

Error is the difference between the result of the measurement and the true value of the quantity being measured. A sensor might give a displacement reading of 29.8 mm, when the actual displacement had been 30 mm, then the error is –0.2 mm.

4. **Sensitivity**

Sensitivity of a sensor is defined as the ratio of change in output value of a sensor to the per unit change in input value that causes the output change. For example, a general purpose thermocouple may have a sensitivity of 41 μV/°C.

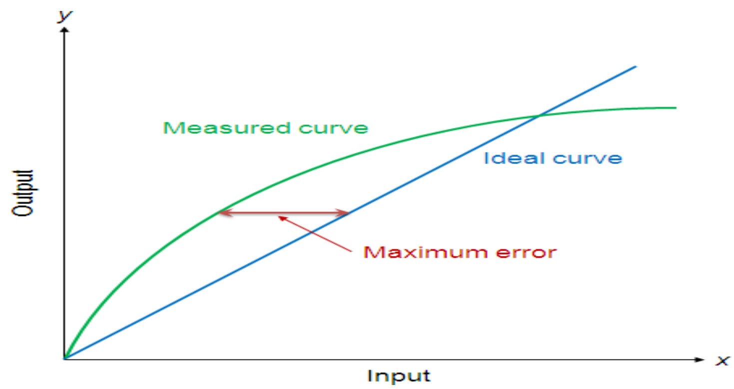


Fig.6 ; Graph

4. Nonlinearity

The nonlinearity indicates the maximum deviation of the actual measured curve of a sensor from the ideal curve. Figure 2.1.1 shows a somewhat exaggerated relationship between the ideal, or least squares fit, line and the actual measured or calibration line. Linearity is often specified in terms of percentage of non linearity, which is defined as:

Nonlinearity (%) = Maximum deviation in input ⁄ Maximum full scale input (2.1.1).The static nonlinearity defined by Equation 2.1.1 is dependent upon environmental factors, including temperature, vibration, acoustic noise level, and humidity. Therefore it is important to know under what conditions the specification isvalid.

5. Hysteresis

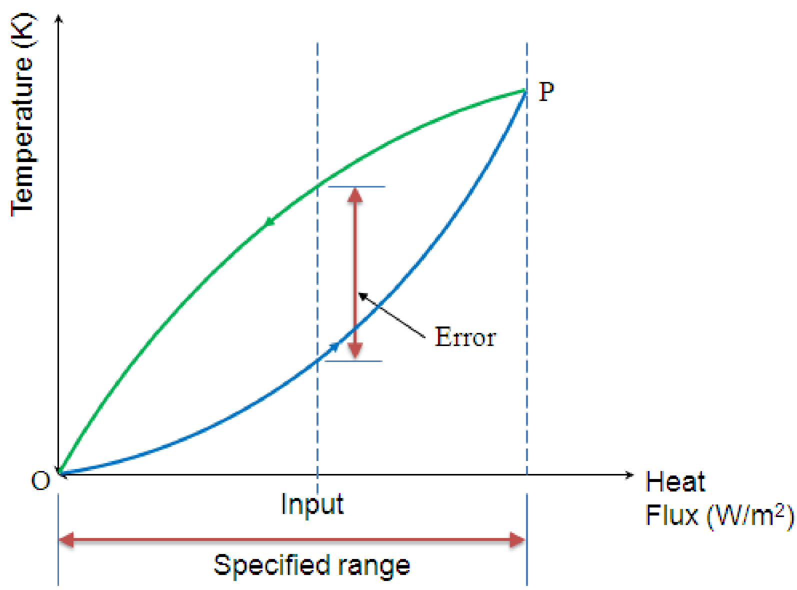


Figure 2.1.2 Hysteresis error curve

The hysteresis is an error of a sensor, which is defined as the maximum difference in output at any measurement value within the sensor's specified range when approaching the point first with increasing and then with decreasing the input parameter. Figure 2.1.2 shows the hysteresis error might have occurred during measurement of temperature using a thermocouple. The hysteresis error value is normally specified as a positive or negative percentage of the specified input range.

6. Resolution

Resolution is the smallest detectable incremental change of input parameter that can be detected in the output signal. Resolution can be expressed either as a proportion of the full-scale reading or in absolute terms. For example, if a LVDT sensor measures a displacement up to 20 mm and it provides an output as a number between 1 and 100 then the resolution of the sensor device is 0.2mm.

7. Stability

Stability is the ability of a sensor device to give same output when used to measure a constant input over a period of time. The term ‘drift’ is used to indicate the change in output that occurs over a period of time. It is expressed as the percentage of full range output.

8. Dead and time

The dead band or dead space of a transducer is the range of input values for which there is no output. The dead time of a sensor device is the time duration from the application of an input until the output begins to respond or change.

9. Repeatability

It specifies the ability of a sensor to give same output for repeated applications of same input value. It is usually expressed as a percentage of the full rangeoutput:

Repeatability = (maximum – minimum values given) X 100 ⁄ full range (2.1.2)

10. Response time

Response time describes the speed of change in the output on a step-wise change of the measurand. It is always specified with an indication of input step and the output range for which the response time is defined.

Analog to digital converters;

The procedure for converting an analog signal from the process into digital form typically consists of the following steps and hardware devices, as illustrated in Figure.

Sensor and transducer; This is the measuring device that generates the analog signal.

Signal conditioning; The continuous analog signal from the transducer may require conditioning to render it into more suitable form.

Multiplexer; The multiplexer is a switching device connected in series with each input channel from the process; it is used to time-share the analog-to-digital converter (ADC) among the input channels.

Amplifier; Amplifiers are used to scale the incoming signal up or down to be compatible with therange of the analog-to-digital converter.

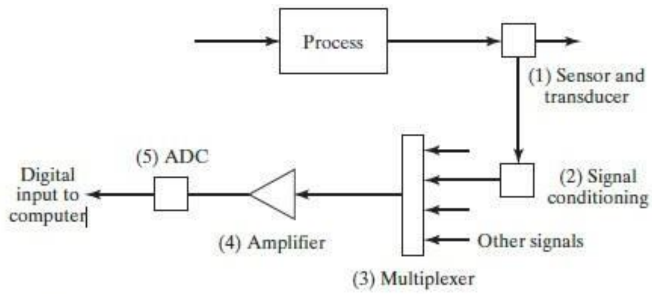


Figure 6.9 Steps in analog-to-digital conversion of continuous analog signals from process.

Analog-to-digital converter; As its name indicates, the function of the ADC is to convert the incoming analog signal into its digital counterpart

Analog ;

Real world signal that contains noise

Continuous in time

Digital;

Discrete in time and value

Binary digits that contains 0 and 1

Advantages

All microcontrollers store information using digital logic.

Compress information to digital form for efficient storage

Medium for storing digital data is more robust

Digital data transfer is more efficient

Digital data is easily reproducible

Provides a link between real worls signals and data storage.

Digital to analog converters;

D**igital-to-analog converter** is a system that converts a digital signal into an analog signal.

The process performed by a digital-to-analog converter (DAC) is the reverse of the ADC process. The DAC transforms the digital output of the computer into a continuous signal to drive an analog actuator or the analog device. Digital-to-analog conversion consists of two steps:

(1) decoding, in which the digital output of the computer is converted into

a series of analog values at discrete moments in time, and (2) data holding, in which each successive value is changed into a continuous signal (usually electrical voltage) used to drive the analog actuator during the sampling interval. Decoding is accomplished by transferring the digital value from the computer to a binary register that controls a reference voltage source. Eachsuccessive bit in the register controls half the voltage of the preceding bit, so that the level of the output voltage is determined by the status of the bits in the register.

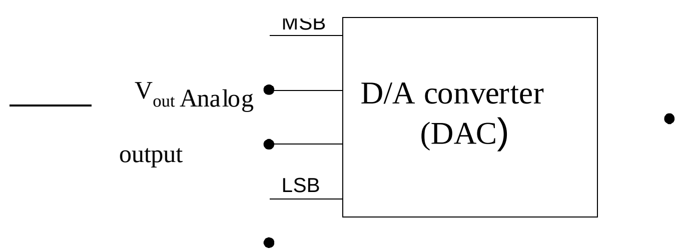


Fig. : Four bit DAC with voltage output.

Input/ Output Devices for Discrete Data

Discrete data can be processed by a digital computer without the kinds of conversion procedures required for continuous analog signals. As indicated earlier, discrete data divide into three categories: (a) binary data, (b) discrete data other than binary, and(c) pulse data.

Contact interfaces are of two types, input and output. These interfaces read binary data from the process into the computer and send binary signals from the computer to the process, respectively.

The terms input and output are relative to the computer**.**

A E R module - 02

Sensors :- sensors used in Robotics mainly for interaction with the environment.

the sensors are divided into the following general categories

i) tactile sensors.

ii) Proximity and Range sensors.

iii) miscelleneous sensors.

iv) machine vision system.

1) Tactile sensor :- Tactile sensor are devices which indicate contact b/w themselves and some other solid of object.

tactile sensing device can be divided into two classes a) Touch sensor

b) Force sensor

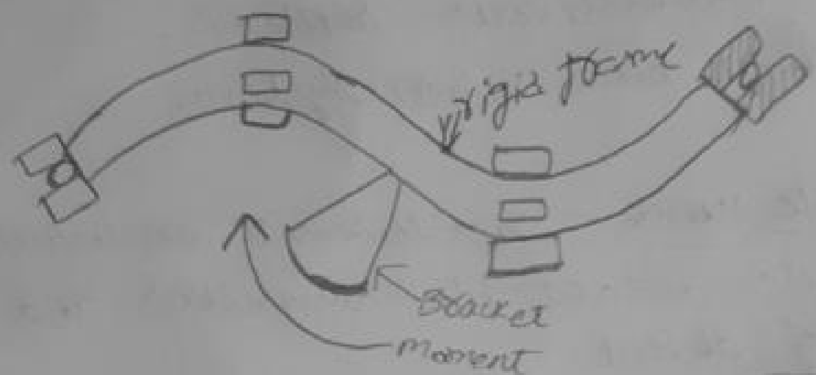
i) Touch sensor :- Touch sensor are devices which provide a binary output signal which indicate whether or not contact has been made with the object.

Touch sensor are used to indicate that contact has been made b/w two objects without regard to the magnitude of the contacting force.

for example Touch sensor are used to indicate the presence or absence of parts in a fixture or at the pickup point along a conveyor.

b) Force sensor:- ~~The Capacity to measure~~ it is a device which is used to indicate the contact has been made with the object but also the magnitude of the contact force b/w the two object.

Force sensor will measure the force required to grasp parts of different sizes in material handling, machine loading & assembly works applying the appropriate level for the given path



The force sensing wrist is a device consists of a metal bracket fasteners to a rigid frame. The frame is mounted to the wrist of the robot. when tool is mounted to the centre of the bracket. The above figure shows how the sensor might react to a moment applied to the bracket due to forces & moments on the tool.

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The purpose of force sensing wrist is to provide information about the three components of along x, y & z direction. The three movements along x, y, & z direction, being applied at the end effector.

The procedure could begin by deciding on the desired force to be applied in each axis direction. Measure to force at ~~[illegible]~~ wrist in each axis direction

2) Calculate the force offset required. The force offset in each direction is determined by subtracting the desired force from the measuring force.
3) Calculate the torque to be applied by each axis to generate the desired force offset at the wrist.
4) There are movement calculation which take into account the combined effects of the various joint & links of the robot.

Robot must provide the torque, so that the desired forces are applied in each direction.

2) Joint sensing

① If the robot uses DC-servomotor then the torque being created by the motor is proportional through the current flowing through the armature. a simple way to measure this current is to measure the voltage drop across a small precision resistor in series with the motor and power amplifier.

② Drawback / Disadvantages

a) If the joint friction is relatively high it will mask out the small forces being applied, at the tool team.

③ Tactile array sensor:-

→ A tactile array sensor is a special type of force sensor composed of a matrix of 4 sensing elements.

→ The device is typically composed of an array of conductive elastomer pads. an each pads is squeezed it's electrical resistance changes in response to the amount of deflection in the pan which is proportional to the applied force by measuring the resistance of each pan information about the shape of the object can be determined.

→ No of characteristics that can be determined

1) the presence of an object.
2) the object contact area shape, location ⓡ orientation
3) the pressure and pressure distribution
4) force magnitude & location.

Proximity sensor & Range sensor

Proximity sensor:- These are devices which indicates presence ⓞ absence of an object in a work space.

Range sensor:- these are devices which is used to measure the distance b/w the object & the sensor.

→ A variety of technologies used for designing proximity & range sensor. these technology used optical devices, acoustic & electric field technique.

Optical technique) :- optical proximity sensor canbe designed using either visible (or) invisible light ...

→ The optical proximity sensor categorized into ① active sensor ② Passive sensor.

① active sensor :- the active sensor send out an infrared beam on respond to the reflection of the beam against a target. The infrared reflection sensor using an incandiscent light source, will indicate the presence (or) absence of an object, but also the position of the object. the measuring of distance b/w the object & the sensor can be made with the help of infrared reflection of light source from the object.

② Passive sensor :- Passive sensor / devices which detect the presence of object by knowing the radiation in wavelength of light due to the heat desipated by the presence of object within the range of sensor.

③ Accoustic sensor :-

→ there are devices which uses ultrasonic frequencies sound in a open ended cylindrical chamber with an accoustic emitter of sound at the close end of the chamber.

→ The emitter set of patter of wave in the cavity which is alter by the presence of an object near the opend end. A sensor located in the wall of the chamber is used to sense the change in the same factor.

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Electric field ~~Eddy Current~~ technique

proximity & range sensor based on the use of electric field, is called as eddy current sensor.

eddy current devices create a primary alternating magnetic field in the small region near the prop. this field induces eddy current in an object placed in the region so long as the object is made of a conducting material. These eddy current produce their own magnetic field which interacts with the primary field. to change it's flux density the prop detects the change in the flux density & this indicates the presence of the object.

---

magnetic field Sensors :-

magnetic field sensor are relatively simple & can be made using a Reed switch (or) & a permanent magnet. the magnet can be a part of the object, being detected (or) it can be part of the sensor device. the device can be designated so that the presence of the object in the region of the sensor complete the magnetic circuit & activates the read switch.

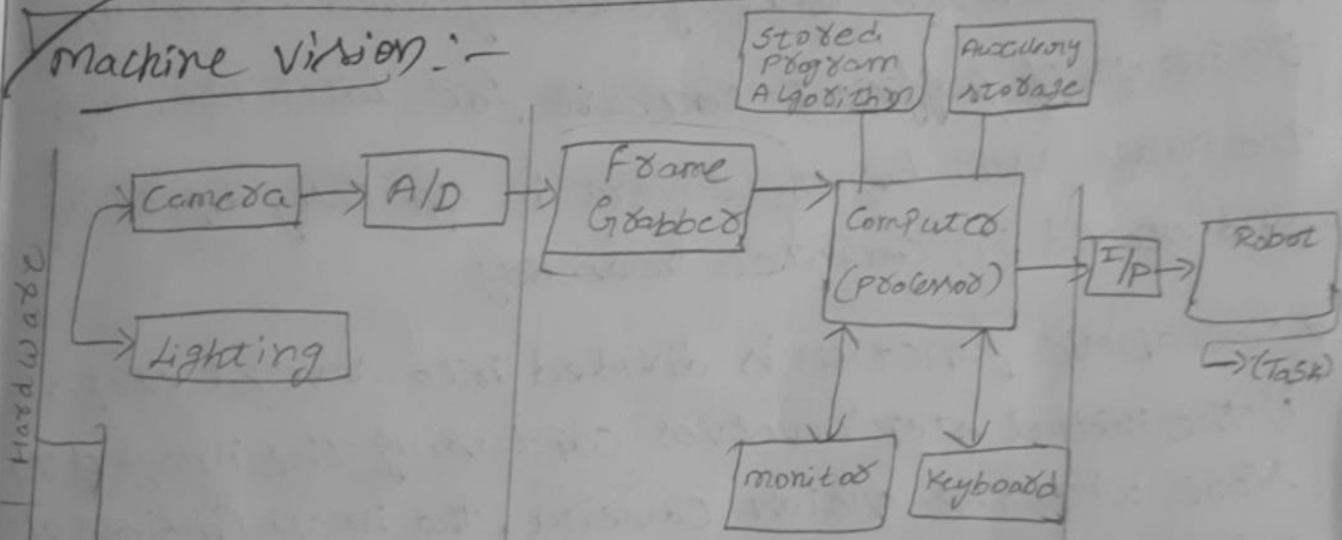
& The change in magnetic field will gives information about the object.

uses of sensor in robot:-

* the uses of sensor in industrial robot & other automated manufacturing system can be listed out into

* safety monitoring
* Parts inspection for quality control
* interlocks in work cell control.
* determining Position & related information about the object.

Machine vision:-



Functions	Sensing and Digitizing Image Data	2) Image Processing and Analysis	3) Applications
Techniques & applications	Signal Conversions Image storage / Image grabber. Lighting.	Data Reduction segmentation Feature extraction object recognition other Algorithm	Inspection Identification visual serving & navigation.

* machine vision is concert with the sensing of vision data & it interpretation by a computer.
* the machine vision system consists of the Camera, digitizing Hardware, computer and necessary software to interspace them.

* The operation of the machine vision system consists of 3 functions.
i) Sensing & Digitizing Image data
ii) Image processing & analysis
iii) application.

a) Sensing & Digitizing image data:- The sensing & digitizing function involve the input of vision data by means of camera focused on the scene of interest. special lighting technique are frequently used to obtain the image of sufficient contrast for later processing. The image view by the camera is typically digitized and stored in computer memory.

* The above function is divided into several steps
i) The initial step involves capturing the image of the scene with the vision camera. The image consists of relative light intensities corresponding to the various portion of the scene. this light intensities are continuous analog value which must be sampled & converted into a digital form.

* In the second step digitizing is achieved by an analog to digital converter. the analog to digital converter is either a part of a digital video camera (or) the front end of a frame grabber.

* In the 3rd step the frame grabber representing an image storage at computation device which stores a given pixel array.

the stored image (or) than subsequently processed and analyzed by the Combination of the frame grabber and the Vision Controller.

Note:- the elements of the matrix are called Picture elements (or) pixels.

(b) Image processing and Analysis:-

→ In the image processing & analysis; the stored image in the Computer must be program to operate on the digitally stored image. this is a substantial task considering the large amount of data that must be analyzed.

→ the Various techniques involve to reduce the magnitude of the image processing problem

i) image data Reduction

In image data reduction; the object is to reduce the Volume of data.

ii) Segmentation:- segmentation is used to groove area of an image have in similar charatteristics (or) feature into distinct entitys representing Parts of the images.

iii) Feature extraction:- Feature extraction in the Context of vision system is a single Parameter, that Permits ease of Comparision & identification.

iv) object Recognition:- In the object recognition the recognition algorithm must be Powerful enof to uniquely identify the object

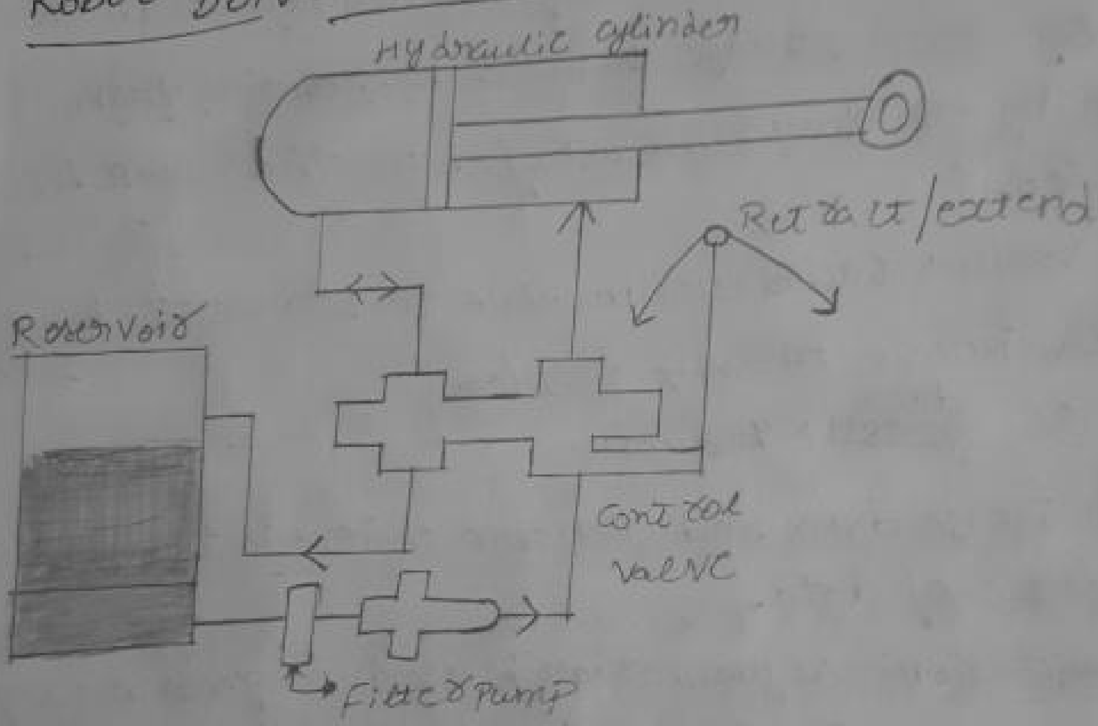
③ Application :-

* The 3rd function of a machine vision system is the application of will be categorized into 3 broad groups

1) inspection :-
2) Identification.
3) Visual serving & navigation.

Hydraulic Drive system

Robot Drive system :-



* The Robot capacity to move it's body, arm and wrist is provided by the drive system used to power the robot.

* Types of drive system :-

Basically there are 3 types of drive system

1) Hydraulic drive system.
2) Pneumatic drive system.
3) electric drive system.

Hydraulic Drive System:

* A hydraulic drive is a method of providing movement to a robot manipulator.
* the main components of a hydraulic system are

1) Reservoir: The reservoir holds the hydraulic liquid such as water and oil based liquid etc.

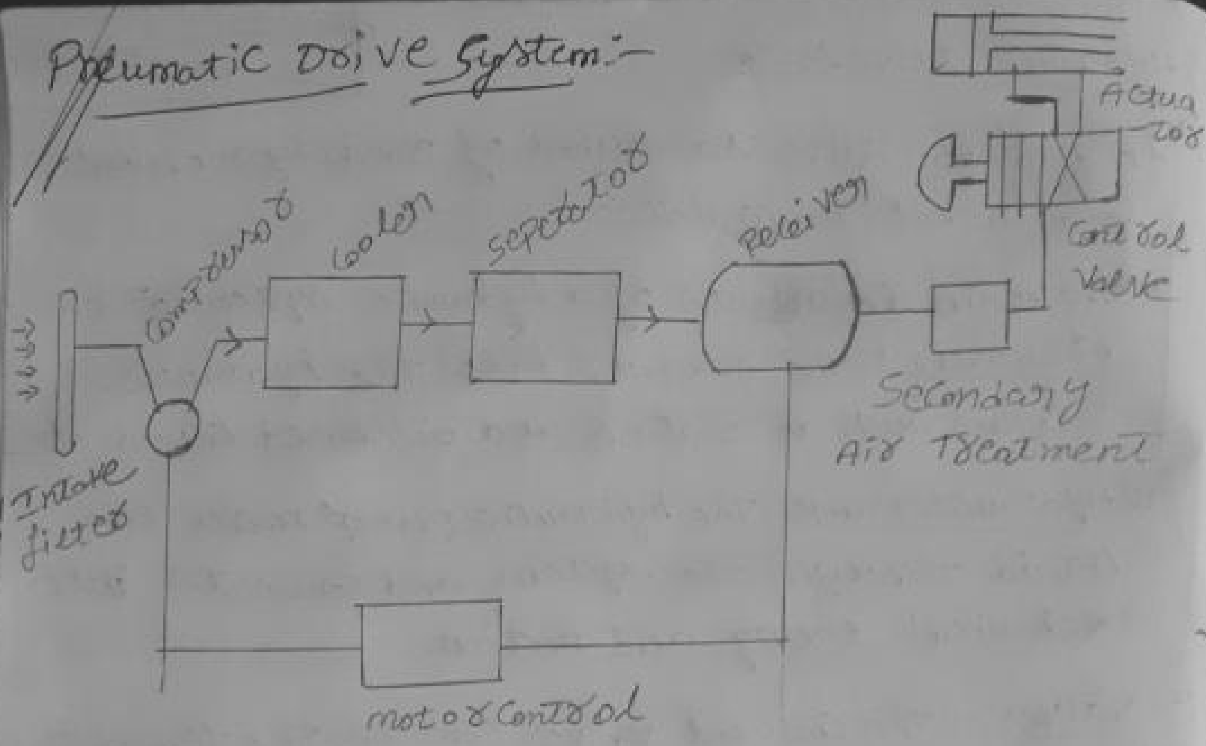
2) Hydraulic Pump:- The hydraulic pump moves the liquid through the system and converts into mechanical energy and motion.

3) Valves:- the control valve controls the flow of the liquid and releases excessive pressure from the system if needed.

4) Hydraulic Cylinder:- The hydraulic cylinder converts hydraulic energy into mechanical energy.

* Hydraulic system use the pump to push hydraulic fluid through the system to create fluid power. the fluid passes through the valve & flow to the cylinder. where the hydraulic energy converts back into mechanical energy. the valve help to direct the flow of the liquid & relief when pressure needed.

Pneumatic Drive System:-



* The main components of a pneumatic system are

1) Air filter → The Air filter are used to filter out the contaminents from the air.

2) Compressor:- the compressed air is generated by using air compressor. based on the requirement of compressed air suitable capacity compressors may be used.

3) Air cooler:- During compression operation air temperature increases. ∴ Coolers are used to reduce the temperature of the compressed air.

4) Separator:- The water vapour (or) moisture in the air is seperated from the air by using a separator (or) drier.

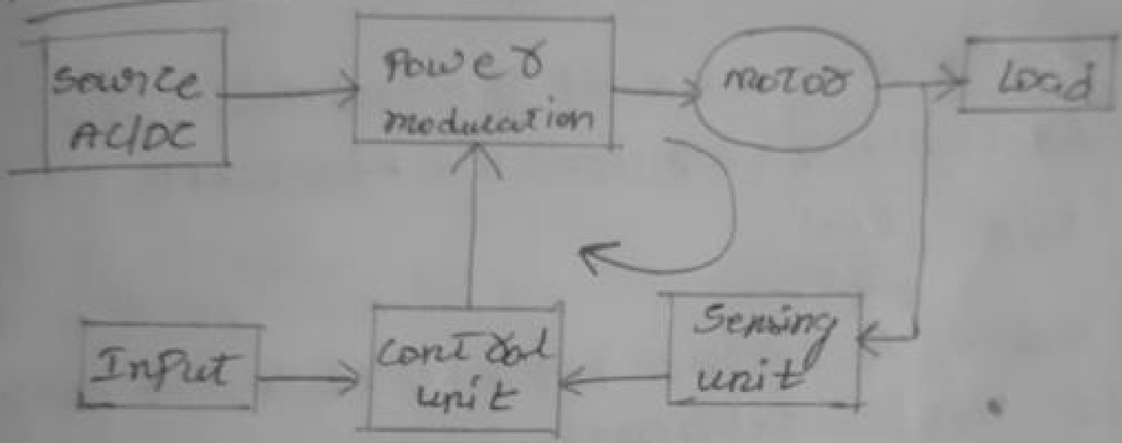
5) Receiver tank:- The compressed air coming from the compressor is stored in the air receiver.

6) Control valve:- Control valve (is) used to regulate, control and monitor for control of flow of air

7) Actuator:- Actuators are piston and cylinder arrangement are used to obtain the moments of mechanical elements of Pneumatic system by converting higher pressure gauge into mechanical form of energy

8) Electric motor:- Electric motor are used to drive the compressor and other components of a pneumatic system.

Electric Drive System



~~the above~~
An electric drive can be defined as an electromechanical device for converting electrical energy to mechanical energy to impart motion to different machines and mechanisms for various kinds of process control.

The above block diagram for electrical drives used for the motion control is as shown in above figure.

The basic components of electric drive

1) Power modulator:- Power modulator regulate the power flow from source to the motor to enable the motor to develop the torque speed required by the load

(2) motor :- motor is a device which converts electrical energy supply by the source to mechanical energy.

(3) Source :- The energy require for the operation of the system. is supply by the AC/DC source.

(4) Control unit :- The control unit adjust motor & load characteristics for the optimal load.

(5) load :- It is usually a machinary to accomplish a given task.

(6) Horse power :- it is a unit of measurement that calculates power. one Horsepower = 735.5 watt.

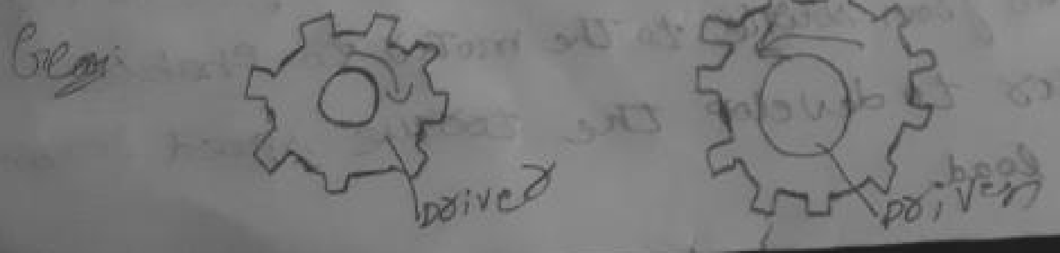
$$1HP = \frac{T \times N}{5252}$$

by knowing the torque & speed of the engine horse power can be calculated.

Variable speed Arrangement :-

In most of the practical system it is require to operate the motor at different speeds as per the requirements. this is achieved by the implementation of gear.

Gears :- A gear (or) cogwheel is a rotating machine part having the cut teeth (or) inserted teeth which mesh with another tooth part to transmit torque.



A gear train is a mechanical system formed by mounting gears on a frame so the teeth of gear engage.

Path Determination:-

* Path determination is a Path Planning for industrial robot is an essential aspects of the overall Performance of automation system.
* Path planning determine how an industrial robot arm should approach a Path. how it should probes a Path and how it should orient itself for optimal Productivity & to avoid collission.

Types of motion

a) Limited Sequence:-
b) Point to Point
c) Continuous Path
d) intelligent Control.

a) Limited sequence:- In limited sequence control each link can only stop at a few limited Position controlled by sensor, mechanical stops.

b) Point to Point:- In Point to point control each axis or Joint as many stoppable Position. however trajectory is not controllable at will roughly deterministic.

Types of motion in Point to point:-

a) one Joint at a time:- In one Joint at a time Joint cannot move simultaneously. rather one move after another in some sequences.

b) Slew motion:- In slew motion all Joint that require motion start simultaneously & deformed Joint speed

c) Joint interpolation:- In this all Joint that require movement start simultaneously & stop simultaneously

3) Continuous Path Control:- In Continuous Path Control several Joint Can move simultaneously in some user specified trajectory. the most useful ones are linear & circular interpolation.

a) Linear interpolation:- In linear interpolation the robot attempts to achieve a linear line while maintaining the tool orientations

b) circular interpolation:- In circular interpolation the robot will achieve a circular motion while maintaining the tool orientation.

4) Intelligent Control:- In Intelligent Control motion are flexible based on sensor & intelligent to cope with various situation.

Role of proper Robot Path Planning

a) Robot Accuracy:- A Robot Path needs to be Plan in order to productively process a path with little (or) no error.

b) Task Repeatability:- once a robot path is well defined it can repeat the same task 1000 of times without variation.

Module-3

Manipulators, Grippers: Construction of manipulators – manipulator dynamics and force control – electronic and pneumatic manipulator control circuits – end effectors –various types of grippers.

Robot Actuators: Position sensors – Potentiometers, resolvers, encoders, velocity sensors. Actuators - Pneumatic and Hydraulic Actuators, Electric Motors, Stepper motors, Servomotors, Power Transmission systems.

A robot manipulator is an electronically controlled mechanism, consisting of multiple segments, that performs tasks by interacting with its environment. They are also commonly referred to as robotic arms. Robot manipulators are extensively used in the industrial manufacturing sector.

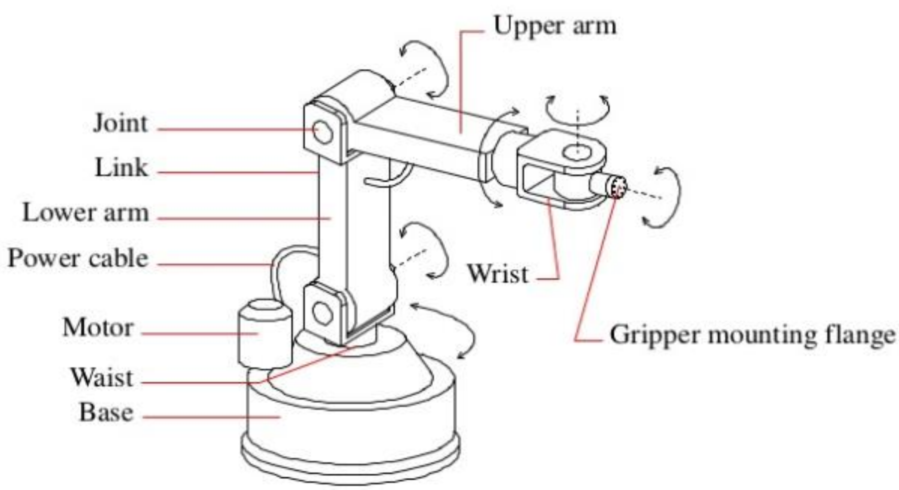


Fig Robot Manipulator

The manipulator can be divided into two parts each having different functions,

Arm and Body- The arm and body of the robot consist of three joints connected by large links. They can be used to move and place objects or tools within the workspace.

Wrist- The function of the wrist is to arrange the objects or tools at the workspace. The structural characteristics of a robotic wrist consist of two or three compact joints.

Joints and Links

A robot's joint, or *axis* as it is also called in robotics, is similar to a joint in the human body: It provides relative motion between two parts of the body. Robots are often classified according to the total number of axes they possess. Connected to each joint are two links, an input link and an output link. Links are the rigid components of the robot manipulator. The purpose of the joint is to provide controlled relative movement between the input link and the output link.

Nearly all industrial robots have mechanical joints that can be classified into one of five types: two types that provide translational motion and three types that provide rotary motion.

1. **Linear joint (type L joint).** The relative movement between the input link and the output link is a translational telescoping motion, with the axes of the two links being parallel.

2. **Orthogonal joint (type O joint).** This is also a translational sliding motion, but the input and output links are perpendicular to each other.

3. **Rotational joint (type R joint).** This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

4. **Twisting joint (type T joint).** This joint also involves rotary motion, but the axis of rotation is parallel to the axes of the two links.

5. **Revolving joint** (type V joint, V from the "v" in revolving). In this joint type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.

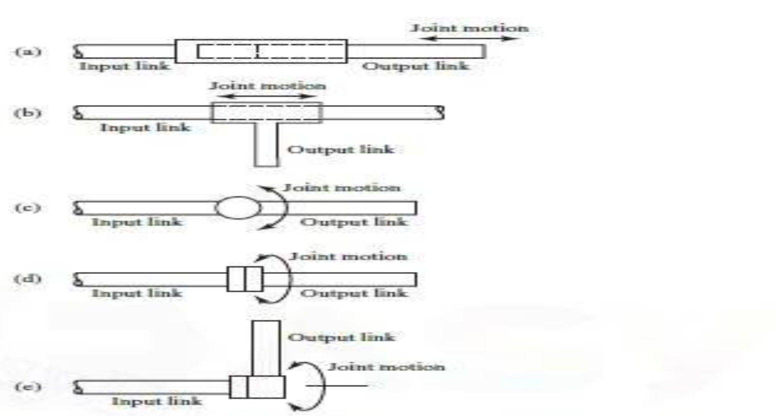


Figure 8.2 Five types of joints commonly used in industrial robot construction: (a) linear joint (type L joint), (b) orthogonal joint (type O joint), (c) rotational joint (type R joint), (d) twisting joint (type T joint), and (e) revolving joint (type V joint).

Application;

- Motion planning
- Remote handling
- Teleoperation
- Micro-robots
- Humanoid robots
- Machine tools
- Space shuttle operations
- Military EOD
- Medical applications, such as surgery

Kinematic Chain • Robotic Manipulators are composed of an assembly of links and joints. Links are defined as the rigid sections that make up the mechanism and joints are defined as the connection between two links. The device attached to the manipulator which interacts with its environment to perform tasks is called the end-effector. • "Robotic manipulator is a set of links connected by joints to form a kinematic chain."

Kinematic Chain

• Kinematic pair – two links connected by joint (mobile connection)

• Kinematic chain of manipulator is a combination of a couple of kinematic pairs

Force control: Manipulators do not always move through space; sometimes they are also required to touch a work piece or work surface and apply a static force. In this case the problem arises: Given a desired contact force and moment, what set of joint torques is required to generate them? Once again, the Jacobian matrix of the manipulator arises quite naturally in the solution of this problem.

Manipulator Dynamics:

• In order to accelerate a manipulator from rest, slide at a constant end effectors velocity, and finally decelerate to a stop, a complex set of torque functions must be applied by the joint actuators.

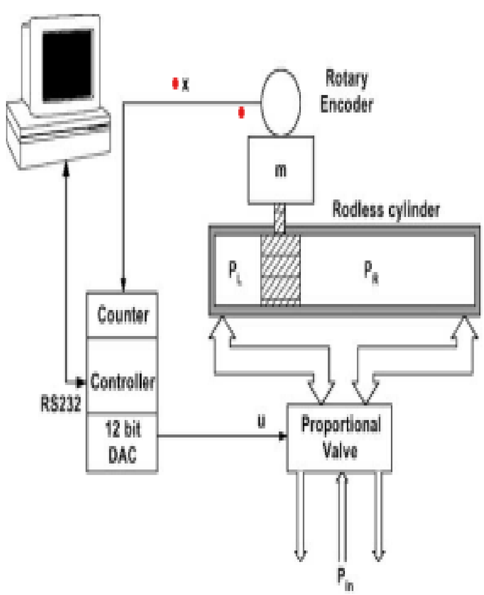
• The exact form of the required functions of actuator torque depend on the spatial and temporal attributes of the path taken by the end-effectors and on the mass properties of the links and payload, friction in the joints, and so on.

• One method of controlling a manipulator to follow a desired path involves calculating these actuator torque functions by using the dynamic equations of motion of the manipulator

Robot Manipulator Classifications • According to power source, the robot manipulators are:

- Electrically powered: Robots driven by DC- or AC-servo motors are increasingly popular since they are cheap, clean and quiet.
- Hydraulically powered: Hydraulic actuators are unrivalled in their speed response and torque, and usually used to lift heavy loads. However, the hydraulic robots tend to leak hydraulic fluid, require much more peripheral equipment and maintenance, and they are noisy.
- Pneumatically powered: Pneumatic robots are inexpensive and simple, but cannot be controlled precisely. As a result, pneumatic robots are limited in their range of applications and popularity

Pneumatic Control Circuit



Some building inspection operations require working along long linear trajectories with good positional accuracy. This may be carried out by means of long cylinders with necessary technological equipment connected to the end-effector. The main difficulties in this case are to combine velocity during the motion with high accuracy at the desired positioning. A rodless pneumatic manipulator can be applied to fulfill the described task. A diagram of the manipulator is shown in Fig. 3.

The manipulator has a rodless pneumatic cylinder with the piston connected to the tool of the mass *M* to be moved. The tool position is measured by an incremental optical encoder. A current-commanded proportional valve controls the airflow in the cylinder chambers. The control algorithm is run by means of a microcontroller that interfaces to the encoder and to the valve through a 12-bit digital-to-analog converter (DAC). A PC connected by an RS232 serial interface to the controller monitors the system.

Fig. Pneumatic Control Circuit

End Effectors;

In robotics, an end effectors 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

The end effectors 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

Mechanism of gripping

Generally, the gripping mechanism is done by the grippers or mechanical fingers. Though in the industrial robotics due to less complications, two finger grippers are used. The fingers are also replaceable. Due to gradual wearing, the fingers can be replaced without actually replacing the grippers.

Shape of the gripping surface

The shape of the gripping surface on the fingers can be chosen according to the shape of the objects that are lifted by the grippers. **For example**, if the robot is designated a task to lift a round object, the gripper surface shape can be a negative impression of the object to make the grip efficient, or for a square shape the surface can be plane.

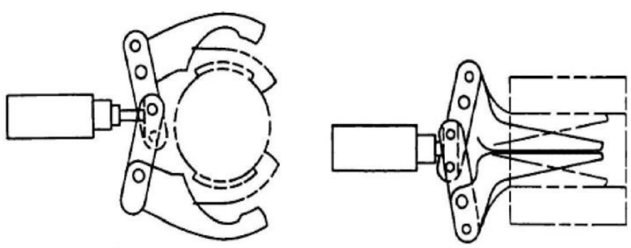


Figure 1 External gripper.   Figure 2 Internal gripper.

Fig. Examples of Gripper

End effectors may consist of a gripper or a tool. When referring to robotic prehension (the action of grasping) there are four general categories of robot grippers, these are:

Types:

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

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

3. Astrictive – Suction forces applied to the objects surface (whether by vacuum, magneto– or electro adhesion).

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

freezing).

Mechanical Grippers

A mechanical gripper is used as an end effectors in a robot for grasping the objects with its mechanically operated fingers. In industries, two fingers are enough for holding purposes. As most of the fingers are of replaceable type, it can be easily removed and replaced.

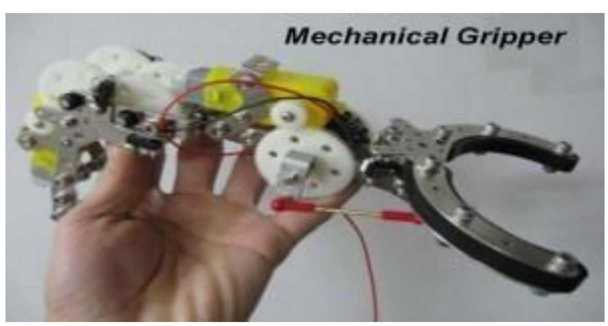
A robot requires either hydraulic, electric, or pneumatic drive system to create the input power. The power produced is sent to the gripper for making the fingers react. It also allows the fingers to perform open and close actions. Most importantly, a sufficient force must be given to hold the object.

In a mechanical gripper, the holding of an object can be done by two different methods such as: Using the finger pads as like the shape of the work part.

- Using soft material finger pads.

In the first method, the contact surfaces of the fingers are designed according to the work part for achieving the estimated shape. It will help the fingers to hold the work part for some extent.

In the second method, the fingers must be capable of supplying sufficient force to hold the work part. To avoid scratches on the work part, soft type pads are fabricated on the fingers. As a result, the contact surface of the finger and co – efficient of friction are improved. This method is very simple and as well as less expensive. It may cause slippage if the force applied against the work part is in the parallel direction. The slippage can be avoided by designing the gripper based on the force exerted.



Pneumatic gripper A pneumatic gripper is a specific type of pneumatic actuator that typically involves either parallel or angular motion of surfaces, A.K.A. “tooling jaws or fingers” that will grip an object. When combined with other pneumatic, electric, or hydraulic components, the gripper can be used as part of a "pick and place" system that will allow a component to be picked up and placed somewhere else as part of a manufacturing system.

Types of Pneumatic Grippers: The most popular types of pneumatic grippers are the 2 jaw parallel and 2 jaw angular gripper styles. Parallel grippers open and close parallel to the object that it will be holding, these are the most widely used grippers. They are the simplest to tool and can compensate for some dimensional variation. Angular grippers move the jaws in a radial manner to rotate the jaws away from the object and therefore require more space.

Adhesive grippers; A type of end effector that uses a continuously fed ribbon covered with an adhesive that sticks to the objects the robot manipulates. Adhesive grippers are commonly used for lightweight materials where other gripper types would be less effective. An adhesion gripper is a robot end effector that grasps objects by literally sticking to them. In its most primitive form, this type of gripper consists of a rod, sphere, or other solid object covered with two sided tape.

A major asset of the adhesive gripper is the fact that it is simple. As long as the adhesive keeps its “stickiness,” it will continue to function without maintenance. However, there are certain limitations. The most significant is the fact that the adhesive cannot readily be disabled in order to release the grasp on an object. Some other means, such as devices that lock the gripped object into place, must be used.

Magnetic grippers; Magnetic grippers are most commonly used in a robot as an end effector for grasping the ferrous materials. It is another type of handling the work parts other than the mechanical grippers and vacuum grippers.

Robot with magnetic gripper

Types of magnetic grippers: The magnetic grippers can be classified into two common types, namely: Magnetic grippers with

Electromagnets:

Electromagnetic grippers include a controller unit and a DC power for handling the materials. This type of grippers is easy to control, and very effective in releasing the part at the end of the operation than the permanent magnets. If the work part gripped is to be released, the polarity level is minimized by the controller unit before the electromagnet is turned off. This process will certainly help in removing the magnetism on the work parts. As a result, a best way of releasing the materials is possible in this gripper.

Permanent magnets: The permanent magnets do not require any sort of external power as like the electromagnets for handling the materials. After this gripper grasps a work part, an additional device called as stripper push – off pin will be required to separate the work part from the magnet. This device is incorporated at the sides of the gripper. The advantage of this permanent magnet gripper is that it can be used in hazardous applications like explosion-proof apparatus because of no electrical circuit. Moreover, there is no possibility of spark production as well. Benefits: This gripper only requires one surface to grasp the materials.• The grasping of materials is done very quickly.• It does not require separate designs for handling different size of materials.• It is capable of grasping materials with holes, which is unfeasible in the vacuum grippers.• Importance: The end effectors that can be used as tools serves 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. The end effector of an assembly line robot would typically be a welding head, or a paint spray gun. A surgica robot's end effector could be a scalpel or others tools used in surgery. Other possible end effectors are machine tools, like a drill or milling cutters. The end effector on the space shuttle's robotic arm uses a pattern of wires which close like the aperture of a camera around a handle or other grasping point.

Encoders As microprocessors have become cheaper and with a move towards digital electronics, the encoder is virtually used everywhere for position measurement. Almost all industrial robots, NC machines, etc., use encoders to measure the position and velocity of motion. Encoders are available as two basic types: incremental and absolute. There are various categories of encoding devices, but we will limit our discussion to those that are most commonly used in robots, i.e., optical encoders. A simple incremental encoder is illustrated in Fig. 3.13.

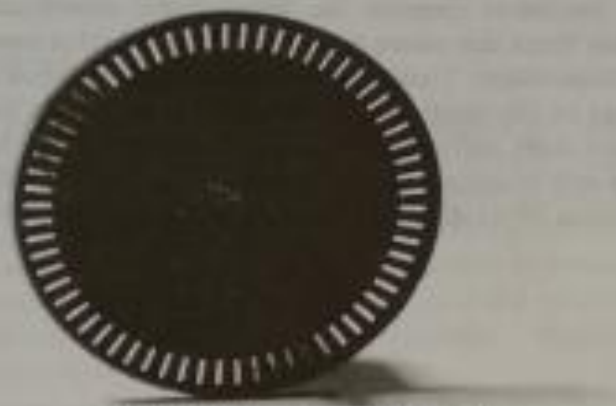


Fig. 3.13 *Incremental encoder*

An incremental encoder consists of a disk marked with alternating transparent and opaque stripes aligned radially. A phototransmitter (a light source) is located on one side of the disk and a photo receiver is on the other Fig. 3.14. As the disk rotates, the light beam is alternately completed and broken. The output from the photoreceiver is a pulse train whose frequency is proportional to the speed of rotation of the disk. In a typical encoder, there are two sets of phototransmitters and receivers aligned 90° out of phase. This phasing provides direction information, that is, if signal A leads to signal B by 90° the encoder disk is rotating in one direction, if B leads A then it is going in the other direction. By counting the pulses and by adding or subtracting based on the sign, it is possible to use the encoder to provide position information with respect to a known starting location. Normally, two incremental encoders are used in parallel so that the resolution of measurement is increased. These two signals are passed through an XOR gate. It can be seen that the resolution of the resulting

Fig. 3.14 *Photo transmitter and receiver place on a incremental encoder.*

signal is now increased two times, as we now have two pulses in place of only one pulse from each encoder. Most modern position control systems have two or more encoders in parallel to increase the resolution of the systems. The rate at which the pulses are generated by the encoder can also be counted to get an estimate of the velocity of the rotating shaft. Hence, an encoder can also be used as a velocity sensor. In some cases, it is desirable to know the, position of an object in absolute terms, that is, not with respect to a starting position. For this an absolute encoder could be used. Absolute encoders employ the same basic construction as incremental encoders except that there are more tracks of stripes and a corresponding number of receivers and transmitters. Usually the stripes are arranged to provide a binary number proportional to the shaft angle. The first track might have two stripes, the second four, the third eight and so on. In this way the angle can be read directly from the encoder without any counting being necessary. Figure 3.15 illustrates an absolute encoder. The resolution of an absolute encoder is dependent on the number of tracks and is given by

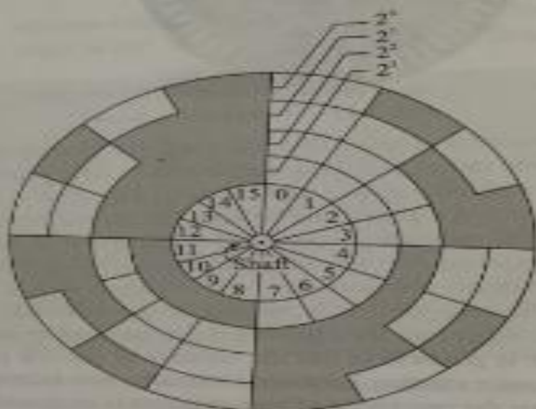


Fig. 3.15 *Absolute optical encoder.*

$$\text{resolution} = 2^n \tag{3.32}$$

where n is the number of tracks on the disk.

Resolvers A resolver is another type of analog device whose output is proportional to the angle of a rotating element with respect to a fixed element. In its simplest form, a resolver has a single winding on its rotor and a pair of windings on its stator. The stator windings are 90° apart as shown in Fig. 3.12. If the rotor is excited with a signal of the type $A \sin(\omega t)$ the voltage across the two pairs of stator terminals will be

$$V_{s1}(t) = A \sin(\omega t) \sin \theta \tag{3.30}$$

and

$$V_{s2}(t) = A \sin(\omega t) \sin \theta \tag{3.31}$$

where θ is the angle of the rotor with respect to the stator. This signal may be used directly, or it may be converted into a digital representation using a device known as a 'resolver-to-digital' converter. Since a resolver is essentially a rotating transformer, it is important to remember that an ac signal must be used for excitation. If a dc signal were used there would be no output signal

3.4.1 Position and velocity sensors

Potentiometers Potentiometers are analog devices whose output voltage is proportional to the position of a wiper. Fig. 3.11 illustrates a typical pot. A voltage is applied across the resistive element. The voltage between the wiper and ground is proportional to the ratio of the resistance on one side of the wiper to the total resistance of the resistive element. Essentially the pot acts as a voltage divider network. That is, the voltage across the resistive element is divided into two parts by a wiper. Measuring this voltage gives the position of the wiper. The function of the potentiometer can be represented by the following function:

$$V_o(t) = K_p\theta(t) \tag{3.28}$$

where $V_o(t)$ is the output voltage, K_p is the voltage constant of the pot in volts per radian (or volts per inch in the case of a linear pot) and $\theta(t)$ is the position of the pot in radians (or inches). Since a pot requires an excitation voltage, in order to calculate V_o, we can use

$$V_o = V_{ex}\frac{\theta_{act}}{\theta_{tot}} \tag{3.29}$$

where V_{ex} is the excitation voltage, θ_{tot} is the total travel available of the wiper, and θ_{act} is the actual position of the wiper.

Potentiometers can be single turn in which the rotating wiper can move only by 360° or they can also be multi turn in which the rotating wiper can move by several 360° turns. Potentiometers suffer from disadvantages like non-linearity and low life due to the continuous friction between the wiper and the variations in the resistive element. In addition, the variation in wiper contact between the coil and the wiper can lead to noise in position measurement.

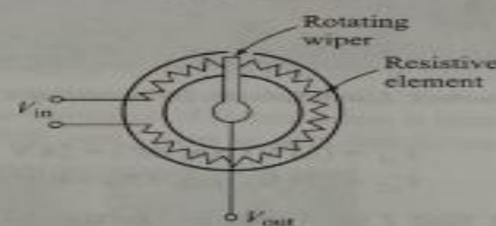


Fig. 3.11 *Potentiometer*

Position, Velocity, and Acceleration Sensors. Linear position-measuring devices include linear potentiometers and the sonar and laser rangefinders just discussed. Linear velocity sensors may be laser- or sonar-based Doppler-effect devices.

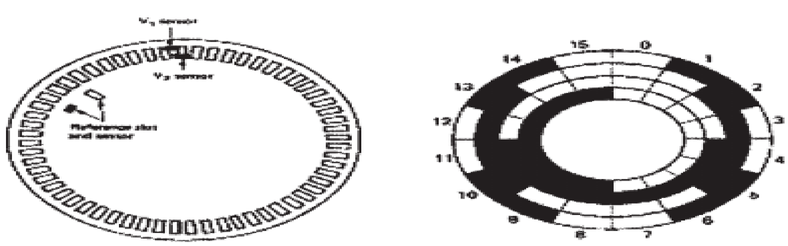


Figure 1.4.1: Optical Encoders, (a) Incremental optical encoder, (b) Absolute optical encoder with n=4 using Grey code. (Snyder, W.E., 1985. Industrial Robots, Prentice-Hall, NJ, with permission.)

Joint-angle position and velocity proprioceptors are an important part of the robot arm servocontrol drive axis. Angular position sensors include potentiometers, which use dc voltage, and resolvers, which use ac voltage and have accuracies of 15 min. Optical encoders can provide extreme accuracy using digital techniques. Incremental optical encoders use three optical sensors and a single ring of alternating opaque/clear areas, Figure 1.4.1(a), to provide angular position relative to a reference point and angular velocity information; commercial devices may have 1200 slots per turn. More expensive absolute optical encoders, Figure 1.4.1(b), have *n* concentric rings of alternating opaque/clear areas and require n optical sensors. They offer increased accuracy and minimize errors associated with data reading and transmission, particularly if they employ the Grey code, where only one bit changes between two consecutive sectors. Accuracy is $360^o/2^n$ with commercial devices having n=12 or so.

Gyros have good accuracy if repeatability problems associated with drift are compensated for. Directional gyros have accuracies of about 1.5 deg. Vertical gyros have accuracies of 0.5 deg and are available to measure multiaxis motion (e.g. pitch and roll). Rate gyros measure velocities directly with thresholds of 0.05 deg/sec or so.

Various sorts of accelerometers are available based on strain gauges (next paragraph), gyros, or crystal properties. Commercial devices are available to measure accelerations along three axes. A popular new technology involves microelectromechanical systems (MEMS), which are either surface or bulk micromachined devices. MEMS accelerometers are very small, inexpensive, robust, and accurate. MEMS sensors have especially been used in the automotive industry [Eddy 1998].

Actuator :

By themselves, valves cannot control a process. Manual valves require an operator to position them to control a process variable. Valves that must be operated remotely and automatically require special devices to move them. These devices are called actuators.

Actuators may be pneumatic, hydraulic, or electric solenoids or motors.

The actions of the individual joints must be controlled in order for the manipulator to perform a desired motion. The robot's capacity to move its body, arm, and wrist is provided by the drive system used to power the robot.

The joints are moved by actuators powered by a particular form of drive system. Common drive systems used in robotics are electric drive, hydraulic drive, and pneumatic drive.

Pneumatic Actuators :

A simplified diagram of a pneumatic actuator is shown in Figure 1. It operates by a combination of force created by air and spring force. The actuator positions a control valve by transmitting its motion through the stem.

A rubber diaphragm separates the actuator housing into two air chambers. The upper chamber receives supply air through an opening in the top of the housing.

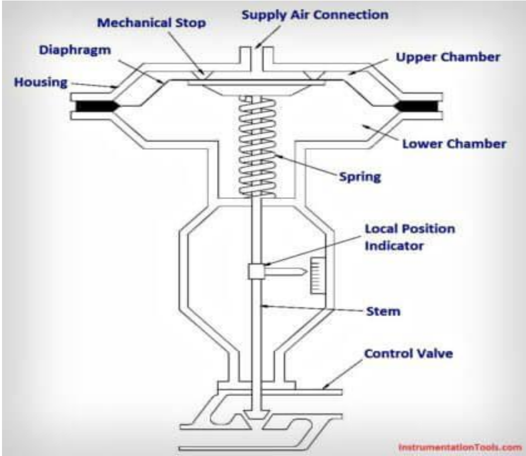


Fig. Pneumatic Actuator

The bottom chamber contains a spring that forces the diaphragm against mechanical stops in the upper chamber. Finally, a local indicator is connected to the stem to indicate the position of the valve.

The position of the valve is controlled by varying supply air pressure in the upper chamber. This results in a varying force on the top of the diaphragm. Initially, with no supply air, the spring forces the diaphragm upward against the mechanical stops and holds the valve fully open.

As supply air pressure is increased from zero, its force on top of the diaphragm begins to overcome the opposing force of the spring. This causes the diaphragm to move downward and the control valve to close. With increasing supply air pressure, the diaphragm will continue to move downward and compress the spring until the control valve is fully closed.

Conversely, if supply air pressure is decreased, the spring will begin to force the diaphragm upward and open the control valve. Additionally, if supply pressure is held constant at some value between zero and maximum, the valve will position at an intermediate position. Therefore, the valve can be positioned anywhere between fully open and fully closed in response to changes in supply air pressure.

Hydraulic Actuator

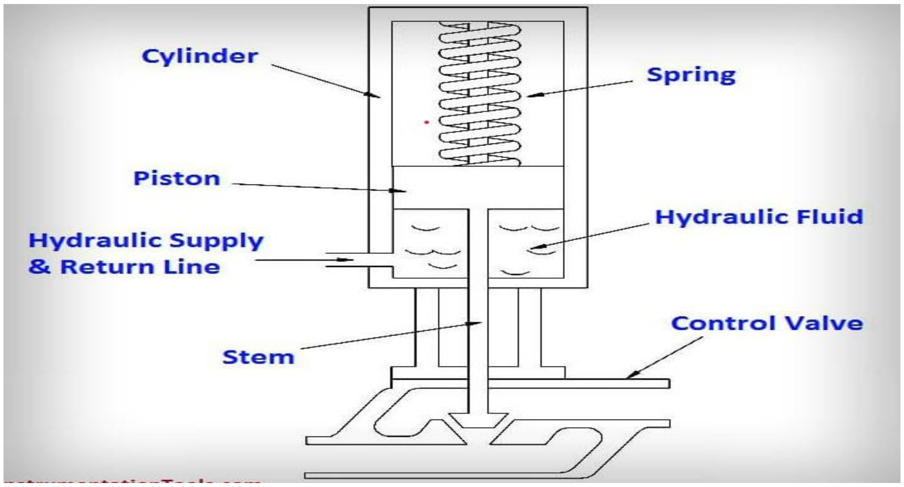


Fig. Hydraulic Actuator

The hydraulic supply and return line is connected to the lower chamber and allows hydraulic fluid to flow to and from the lower chamber of the actuator. The stem transmits the motion of the piston to a valve.

Initially, with no hydraulic fluid pressure, the spring force holds the valve in the closed position. As fluid enters the lower chamber, pressure in the chamber increases.

This pressure results in a force on the bottom of the piston opposite to the force caused by the spring. When the hydraulic force is greater than the spring force, the piston begins to move upward, the spring compresses, and the valve begins to open.

As the hydraulic pressure increases, the valve continues to open. Conversely, as hydraulic oil is drained from the cylinder, the hydraulic force becomes less than the spring force, the piston moves downward, and the valve closes. By regulating amount of oil supplied or drained from the actuator, the valve can be positioned between fully open and fully closed.

The principles of operation of a hydraulic actuator are like those of the pneumatic actuator. Each uses some motive force to overcome spring force to move the valve. Also, hydraulic actuators can be designed to fail-open or fail-closed to provide a fail-safe feature.

Advantages of Hydraulic Actuator

1. Hydraulic actuators are rugged and suited for high force applications. They can produce forces 25 times greater than pneumatic cylinders of equal size. They also operate in pressures of up to 4,000 psi.
2. A hydraulic actuator can hold force and torque constant without the pump supplying more fluid or pressure due to the incompressibility of fluids.
3. Hydraulic actuators can have their pumps and motors located a considerable distance away with minimal loss of power.

Disadvantages of Hydraulic Actuator

Hydraulics will leak fluid. Like pneumatic actuators, loss of fluid leads to less efficiency and cleanliness problems resulting in potential damage to surrounding components and areas.

Hydraulic actuators require many complementary parts, including a fluid reservoir, motor, pump, release valves, and heat exchangers, along with noise reduction equipment.

Electrical Motor

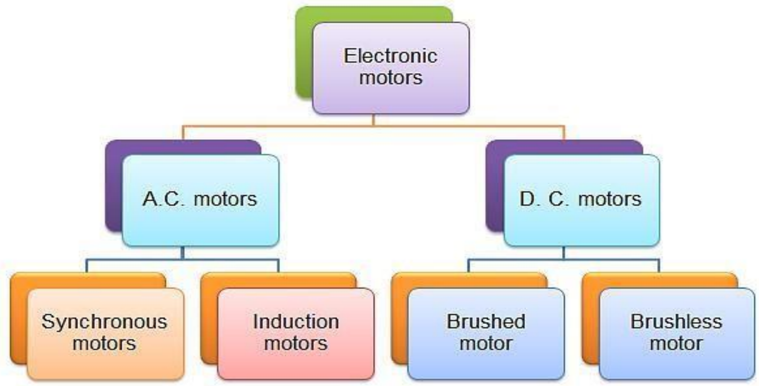
DC Servo Motors | Stepper Motor

As we know that any electrical motor can be utilized as servo motor if it is controlled by servomechanism. Likewise, if we control a DC motor by means of servomechanism, it would be referred as **DC servo motor**. There are different types of DC motor, such **shunt wound DC motor, series DC motor, Separately excited DC motor, permanent magnet DC motor, Brushless DC motor** etc. Among all mainly separately excited DC motor, permanent magnet DC motor and brush less DC motor are used as servo.

It is an automatic closed loop control system. Here instead of controlling a device by applying the variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

When reference input signal or command signal is applied to the system, it is compared with output reference signal of the system produced by output sensor, and a third signal produced by a feedback system. This third signal acts as an input signal of controlled device

DC/AC Motors



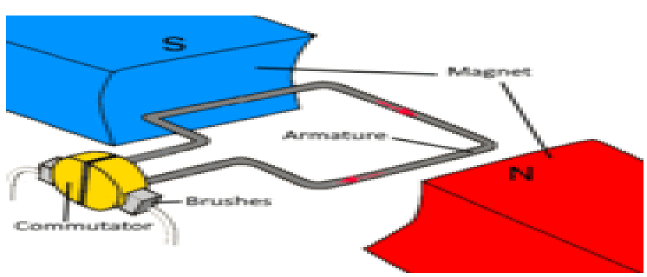
Electric drives are mostly used in position and speed control systems. The motors can be classified into two groups namely DC motors and AC motors (above fig 1). In this session we shall study the operation, construction, advantages and limitations of DC and AC motors.

DC motors

A DC motor is a device that converts direct current (electrical energy) into rotation of an element (mechanical energy). These motors can further be classified into brushed DC motor and brushless DC motors.

1. **Brush type DC motor**

A typical brushed motor consists of an armature coil, slip rings divided into two parts, a pair of brushes and horse shoes electromagnet as shown in Fig. 2. A simple DC motor has two field poles namely a north pole and a south pole. The magnetic lines of force extend across the opening between the poles from north to south. The coil is wound around a soft iron core and is placed in between the magnet poles. These electromagnets receive electricity from an outside power source. The coil ends are connected to split rings. The carbon brushes are in contact with the split rings. The brushes are connected to a DC source. Here the split rings rotate with the coil while the brushes remain stationary.



The working is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming's left-hand rule. The magnitude of the force is given by

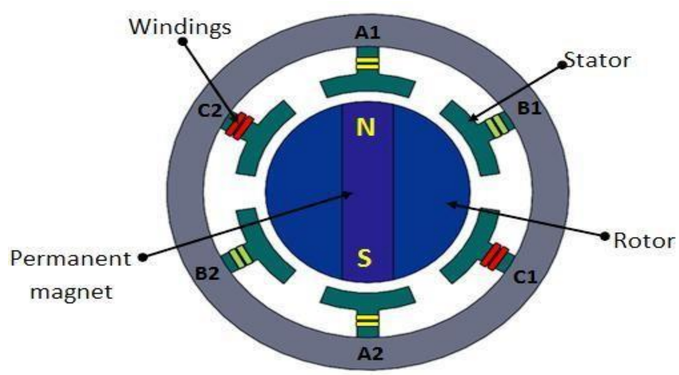
Advantages of brushed DC motor:

- The design of the brushed DC motor is quite simple
- Controlling the speed of a Brush DC Motor is easy
- Very cost effective

Disadvantages of brushed DC motor:

- High maintenance
- Performance decreases with dust particles
- Less reliable in control at lower speeds
- The brushes wear off with usage

2. **Brushless DC motor**



A brushless DC motor has a rotor with permanent magnets and a stator with windings. The rotor can be of ceramic permanent magnet type. The brushes and commutator are eliminated and the windings are connected to the control electronics. The control electronics replace the commutator and brushes and energize the stator sequentially. Here the conductor is fixed and the magnet moves (Fig 3).

The current supplied to the stator is based on the position of rotor. It is switched in sequence using transistors. The position of the rotor is sensed by Hall effect sensors. Thus a continuous rotation is obtained

Advantages of brushless DC motor:

- More precise due to computer control

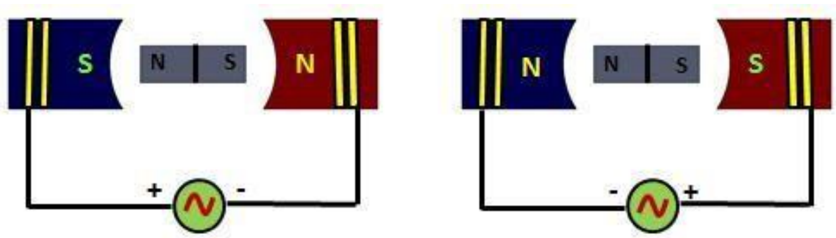
- More efficient
- No sparking due to absence of brushes
- Less electrical noise
- No brushes to wear out
- Electromagnets are situated on the stator hence easy to cool
- Motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions
- Responsiveness and quick acceleration due to low rotor inertia

Disadvantages of brushless DC motor:

- Higher initial cost
- Complex due to presence of computer controller
- Brushless DC motor also requires additional system wiring in order to power the electronic commutation circuitry

AC motors

AC motors convert AC current into the rotation of a mechanical element (mechanical energy). As in the case of DC motor, a current is passed through the coil, generating a torque on the coil. Typical components include a stator and a rotor. The armature of rotor is a magnet unlike DC motors and the stator is formed by electromagnets similar to DC motors. The main limitation of AC motors over DC motors is that speed is more difficult to control in AC motors. To overcome this limitation, AC motors are equipped with variable frequency drives but the improved speed control comes together with a reduced power quality.



The working principle of AC motor is shown in fig. 4.1.6. Consider the rotor to be a permanent magnet. Current flowing through conductors energizes the magnets and develops N and S poles. The strength of electromagnets depends on current. First half cycle current flows in one direction and in the second half cycle it flows in opposite direction. As AC voltage changes the poles alternate.

AC motors can be classified into synchronous motors and induction motors.

Synchronous motor

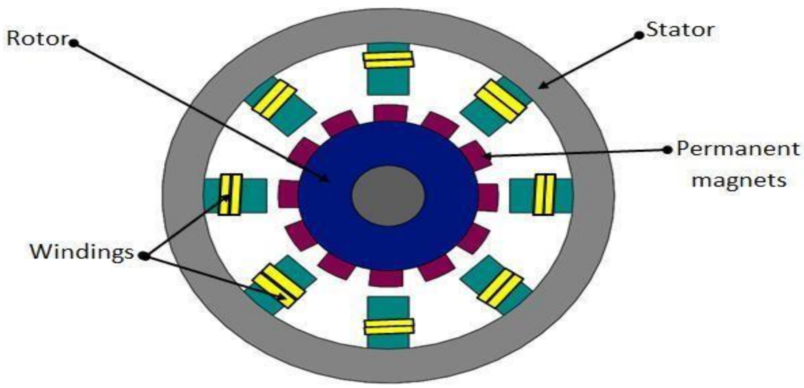


Fig. 4.1.7 Synchronous AC motor

A synchronous motor is an AC motor which runs at constant speed fixed by frequency of the system. It requires direct current (DC) for excitation and has low starting torque, and hence is suited for applications that start with a low load. It has two basic electrical parts namely stator and rotor as shown in fig. 4.1.7. The stator consists of a group of individual wounded electro-magnets arranged in such a way that they form a hollow cylinder. The stator produces a rotating magnetic field that is proportional to the frequency supplied. The rotor is the rotating electrical component. It also consists of a group of permanent magnets arranged around a cylinder, with the poles facing toward the stator poles. The rotor is mounted on the motor shaft. The main difference between the synchronous motor and the induction motor is that the rotor of the synchronous motor travels at the same speed as the rotating magnet.

The stator is given a three phase supply and as the polarity of the stator progressively change the magnetic field rotates, the rotor will follow and rotate with the magnetic field of the stator. If a synchronous motor loses lock with the line frequency it will stall. It cannot start by itself, hence has to be started by an auxiliary motor.

Induction motor

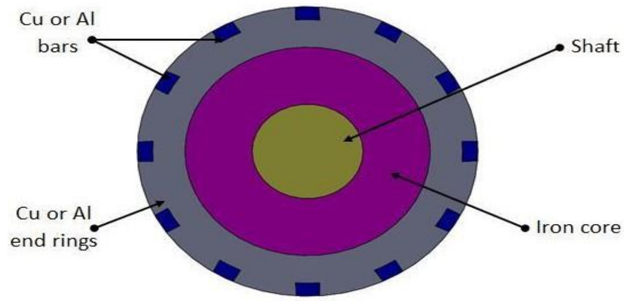


Fig. 4.1.8 Induction motor rotor

Induction motors are quite commonly used in industrial automation. In the synchronous motor the stator poles are wound with coils and rotor is permanent magnet and is supplied with current to create fixed polarity poles. In case of induction motor, the stator is similar to synchronous motor with windings but the rotors' construction is different

Rotor of an induction motor can be of two types:

- A squirrel-cage rotor consists of thick conducting bars embedded in parallel slots. The bars can be of copper or aluminum. These bars are fitted at both ends by means end rings as shown in above figure
- A wound rotor has a three-phase, double-layer, distributed winding. The rotor is wound for as many numbers of poles as the stator. The three phases are wired internally and the other ends are connected to slip-rings mounted on a shaft with brushes resting on them.

Induction motors can be classified into two types:

- Single-phase induction motor: It has one stator winding and a squirrel cage rotor. It operates with a single-phase power supply and requires a device to start the motor.
- Three-phase induction motor: The rotating magnetic field is produced by the balanced three-phase power supply. These motors can have squirrel cage or wound rotors and are self-starting.

In an induction motor there is no external power supply to rotor. It works on the principle of induction. When a conductor is moved through an existing magnetic field the relative motion of the two causes an electric current to flow in the conductor. In an induction motor the current flow in the rotor is not caused by any direct connection of the conductors to a voltage source, but rather by the influence of the rotor conductors cutting across the lines of flux produced by the stator magnetic fields. The induced current which is produced in the rotor results in a magnetic field around the rotor. The magnetic field around each rotor conductor will cause the rotor conductor to act like the permanent

Advantages of AC induction motors

- It has a simple design, low initial cost, rugged construction almost unbreakable

- The operation is simple with less maintenance (as there are no brushes)
- The efficiency of these motors is very high, as there are no frictional losses, with reasonably good power factor
- The control gear for the starting purpose of these motors is minimum and thus simple and reliable operation

Disadvantages of AC induction motors

- The speed control of these motors is at the expense of their efficiency
- As the load on the motor increases, the speed decreases
- The starting torque is inferior when compared to DC motors

Principle of Stepper Motors & servomotors

Stepper motor

A stepper motor is a **pulse-driven motor that changes the angular position of the rotor in steps**. Due to this nature of a stepper motor, it is widely used in low cost, **open loop position control systems.**

Types of stepper motors:

- Permanent Magnet
  - ❖ Employ permanent magnet
  - ❖ Low speed, relatively high torque
- Variable Reluctance
  - ❖ Does not have permanent magnet
  - ❖ Low torque

Variable Reluctance Motor

Figure 4.2.1 shows the construction of Variable Reluctance motor. The cylindrical rotor is made of soft steel and has four poles as shown in Fig.4.2.1. It **has four rotor teeth, 90^0 apart and six stator poles, 60^0 apart**. Electromagnetic field is produced by activating the stator coils in sequence. It attracts the metal rotor. When the windings are energized in a reoccurring sequence of 2, 3, 1, and so on, the motor **will rotate in a 30^0 step angle**. In the non-energized condition, there is no magnetic flux in the air gap, as the **stator is an electromagnet** and the **rotor is a piece of soft iron**; hence, there is no detent torque. This type of stepper motor is called a variable reluctance stepper

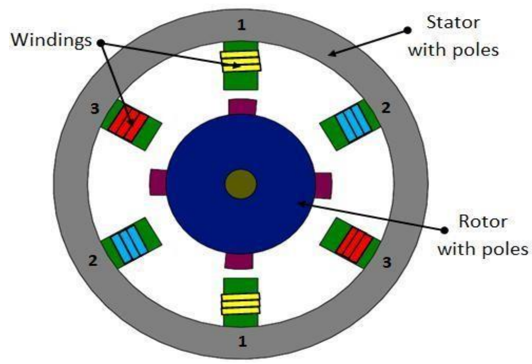


Fig. 4.2.1 Variable reluctance stepper motor

Permanent magnet (PM) stepper motor

In this type of motor, the **rotor is a permanent magnet**. Unlike the other stepping motors, the **PM motor rotor has no teeth** and is designed to be magnetized at a right angle to its axis. Figure 4.2.2 shows a simple, **90º PM motor with four phases (A-D).** Applying current to each phase in sequence will cause the **rotor to rotate by adjusting to the changing magnetic fields**. Although it operates at fairly low speed, the PM motor has a relatively high torque characteristic. These are low cost motors with typical step angle ranging between 7.5º to 15º.

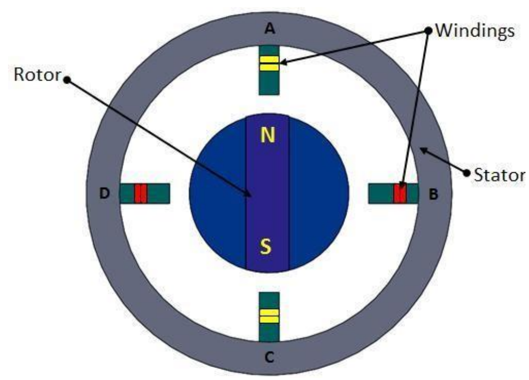


Fig. Permanent magnet stepper

Hybrid stepper motor

Hybrid stepping motors combine a **permanent magnet** and a **rotor with metal teeth** to provide features of the variable reluctance and permanent magnet motors together. The number of rotor pole pairs is equal to the number of teeth on one of the rotor's parts. The hybrid motor stator has teeth creating more poles than the main poles windings (Fig. 4.2.3).

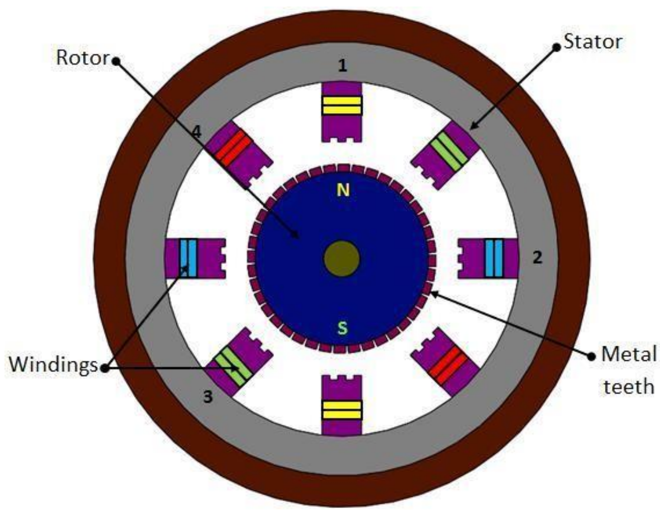
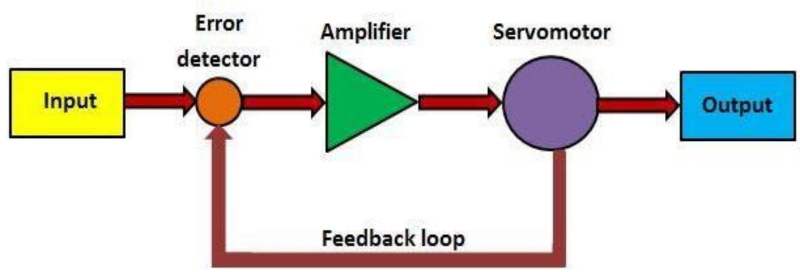


Fig. 3 Hybrid stepper motor

Rotation of a hybrid stepping motor is produced in the similar fashion as a permanent magnet stepping motor, by energizing individual windings in a positive or negative direction. When a winding is energized, north and south poles are created, depending on the polarity of the current flowing. These generated poles attract the permanent poles of the rotor and also the finer metal teeth present on rotor. The rotor moves one step to align the offset magnetized rotor teeth to the corresponding energized windings. Hybrid motors are more expensive than motors with permanent magnets, but they use smaller steps, have greater torque and maximum speed.

Servomotor

Servomotors are special electromechanical devices that produce precise degrees of rotation. A servo motor is a DC or AC or brushless DC motor combined with a **position sensing device**. Servomotors are also called **control motors** as they are involved in controlling a mechanical system. The servomotors are used in a **closed-loop servo system** as shown in Figure 4.2.4. A reference **input is sent to the servo amplifier**, which controls the **speed of the servomotor**. A feedback device is mounted on the machine, which is either an encoder or resolver. This device changes **mechanical motion into electrical signals** and is used as a feedback. This feedback is sent to the error detector, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which will be used to make necessary corrections in control action. In many servo systems, both velocity and position are monitored. **Servomotors provide accurate speed, torque, and have ability of direction control.**



DC Servomotor

DC operated servomotors are usually respond to error signal abruptly and accelerate the load quickly. A DC servo motor is actually an assembly of four separate components, namely

- DC Motor
- Gear Assembly
- Control Circuit
- Position sensing device

,

AC servo motor

In this type of motor, the magnetic force is generated by a permanent magnet and current which further produce the torque. It has no brushes so there is little noise/vibration. This motor provides high precision control with the help of high resolution encoder. The stator is composed of a core and a winding. The rotor part comprises of shaft, rotor core and a permanent magnet.

Digital encoder can be of optical or magnetic type. It gives digital signals, which are in proportion of rotation of the shaft. The details about optical encoder have already discussed in Lecture 3 of Module 2.

Advantages of servo motors

- Provides high intermittent torque, high torque to inertia ratio, and high speeds
- Work well for velocity control
- Available in all sizes
- Quiet in operation
- Smoother rotation at lower speeds

Disadvantages of servo motors

- More expensive than stepper motors
- Require tuning of control loop parameters
- Not suitable for hazardous environments or in vacuum
- Excessive current can result in partial demagnetization of DC type servo motor

3.8 POWER TRANSMISSIONS SYSTEMS

In many cases, it is not possible to find an actuator with the exact speed-force or speed-torque characteristics to perform the desired tasks. In other cases it is necessary to locate the actuator away from the intended joint of the manipulator. For these reasons it becomes necessary to use some type of power transmission. Power transmissions perform two functions: transmit power at a distance and act as a power transformer. There are a number of ways to perform mechanical power transmission. These include belts and pulleys, chains and sprockets, gears, transmission shafts, and screws. In this section, we will discuss a number of power transmission devices that are used for industrial robots.

3.8.1 Gears

The use of gears for power transmission in robots is very common. Gears are used to transmit rotary motion from one shaft to another. This transfer may be between parallel shafts, intersecting shafts, or skewed shafts. The simplest types of gears are for transmission between parallel shafts and are known as *spur gears*.

Figure 3.23 illustrates a simple two-gear spur gear train. The driving gear, in this case the smaller one, is known as the *pinion* and the other gear is the *driven gear*. For example, if the pinion is one-fourth the size of the gear, for every revolution made by the pinion the driven gear turns only one-fourth of a revolution. This gear train is referred to as a *speed reducer*. The torque applied by the pinion however is multiplied by four times at the gear shaft. Since the speed is quartered and the torque is quadrupled the power out of the gear train equals the power into it.

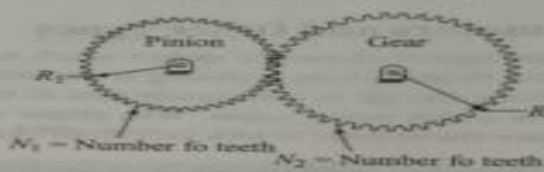


Fig. 3.23 *Spur gear train.*

The number of teeth in a gear is proportional to its diameter. If we let the number of teeth in a pinion be N_1 and the teeth in the gear equal N_2 then the gear ratio is given by

$$n = \frac{N_1}{N_2} \tag{3.43}$$

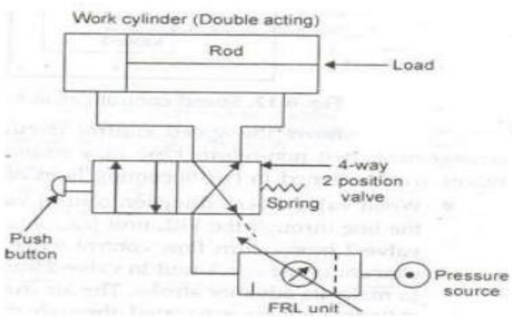
and the speed of the output with respect to the input is

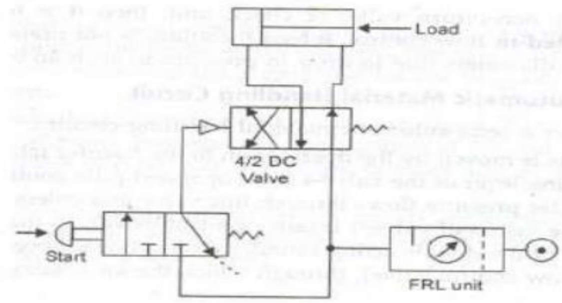
$$\omega_o = n\omega_{in} \tag{3.44}$$

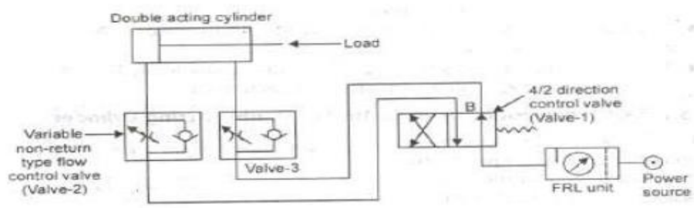
where ω_o is the output speed and ω_{in} is the input speed. The output torque is

$$T_o = \frac{T_{in}}{n}$$

,


Work cylinder (Double acting)
Rod
Load
4-way
2 position
valve
Spring
Push
button
Pressure
source
FRL unit


Load
4/2 DC
Valve
Start
FRL unit


Double acting cylinder
Load
4/2 direction
control valve
(Valve-1)
B
Variable
non-return
type flow
control valve
(Valve-2)
Valve-3
FRL unit
Power
source

Module 4

Introduction to Automation

Basic elements of an automated system, advanced automation functions, levels of automation, process industries versus discrete manufacturing industries.

Industrial Automation: List basic Devices in Automated Systems • Distinguish Different Controllers Employed In Automated Systems. Identify Safety in Industrial Automation.

Introduction – Automation

Automation can be defined as the technology by which a process or procedure is accomplished without human assistance. It is implemented using a program of instructions combined with a control system that executes the instructions. To automate a process, power is required, both to drive the process itself and to operate the program and control system.

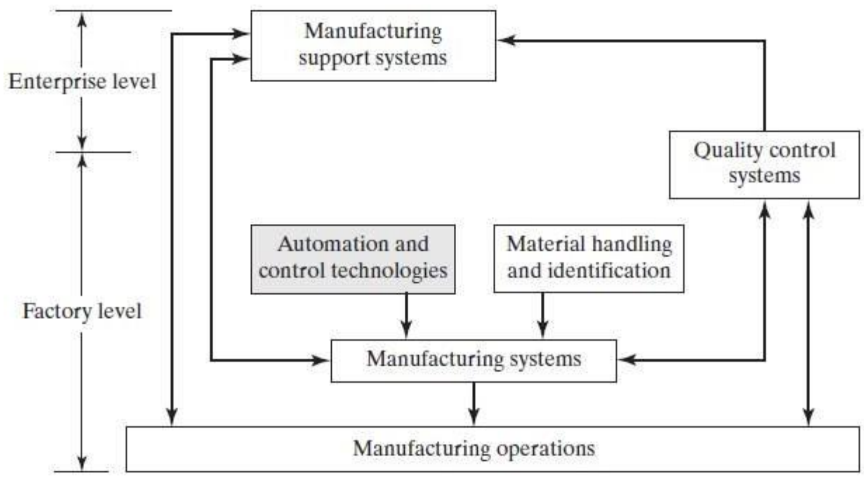
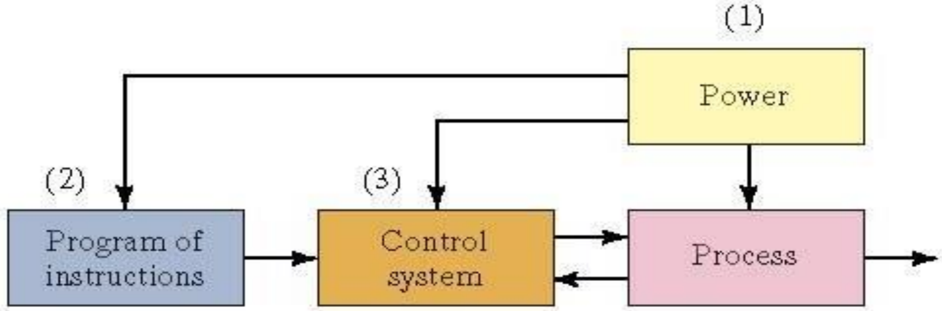


Figure 4.1 Automation and control technologies in the production system.

Basic Elements of an Automated System



Power to Accomplish the Automated Process

- Power for the process
    - To drive the process itself
    - To load and unload the work unit
    - Transport between operations
- Power for automation
    - Controller unit
    - Power to actuate the control signals
    - Data acquisition and information processing

Program of Instructions

Set of commands that specify the sequence of steps in the work cycle and the details of each step

Example: CNC part program

- During each step, there are one or more activities involving changes in one or more process parameters

Examples:

- Temperature setting of a furnace
- Axis position in a positioning system
- Motor on or off
- ATM
- Starting of the vehicle
- Automatic filling machines

Control System – Two Types

1. **Closed-loop (feedback) control system** – a system in which the output variable is compared with an input parameter, and any difference between the two is used to drivethe output into agreement with the input
2. **Open-loop control system –** operates without the feedback loop

➢ Simpler and less expensive

➢ Risk that the actuator will not have the intended effect Feedback Control System and (Open and close loop Control System)

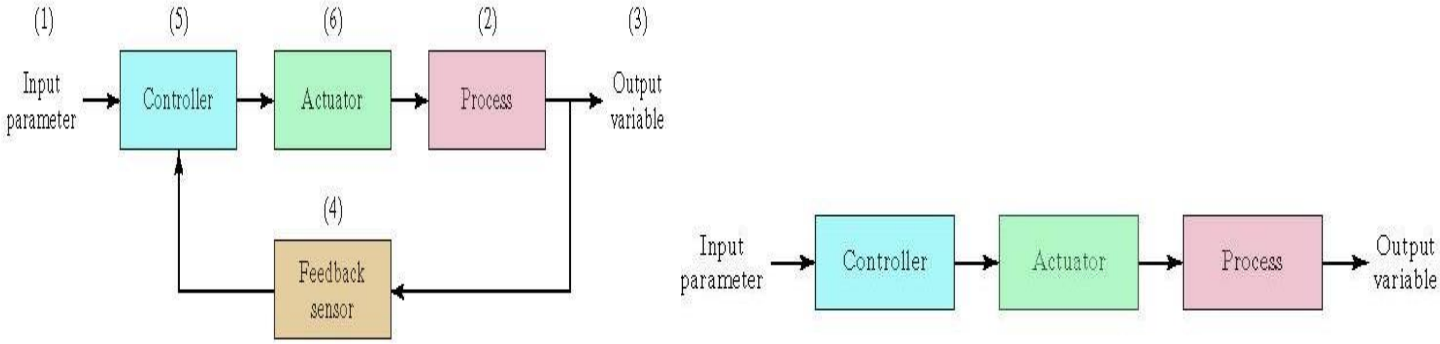
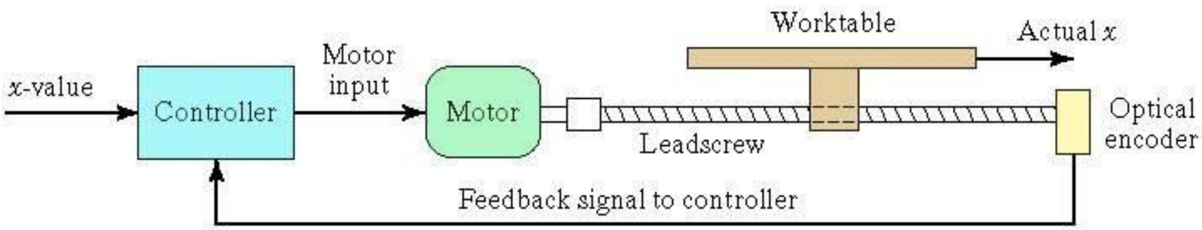


Fig. Closed and Open loop control system

Examples



Advanced Automation Functions

1. Safety monitoring
2. Maintenance and repair diagnostics
3. 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

Maintenance and Repair Diagnostics

- Status monitoring
    - Monitors and records status of key sensors and parameters during system operation
- Failure diagnostics
    - Invoked when a malfunction occurs
    - Purpose: analyze recorded values so the cause of the malfunction can be identified
- Recommendation of repair procedure
    - Provides recommended procedure for the repair crew to effect repairs

Error Detection and Recovery

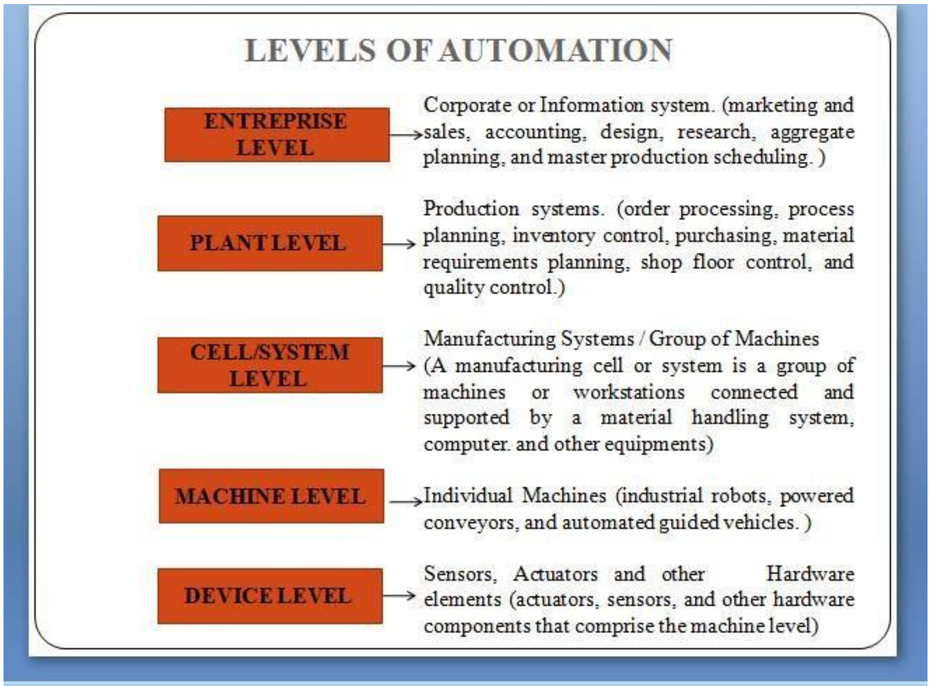
1. **Error detection – functions:**
    - Use the system's available sensors to determine when a deviation or malfunction has occurred
    - Correctly interpret the sensor signal
    - Classify the error

- Error recovery – possible strategies:
    - Make adjustments at end of work cycle
    - Make adjustments during current work cycle
    - Stop the process to invoke corrective action
    - Stop the process and call for help

Table; Advanced automated function

Function	Description
Safety Monitoring	Automation systems can be designed to operate safely when human operators are in attendance. The automation system must also work in a way that is not self-destructive. It therefore must protect the human operator, and its own equipment. Safety monitoring involves the use of sensors to track the system's operation and to spot potentially unsafe working conditions. Based upon this monitoring, the system is programmed to take necessary measures to counteract the hazards met. Possible responses vary, from stopping the system, to warning operators, or taking corrective actions to remove the risk involved.
Maintenance and Repair Diagnostics	Complex equipment is generally harder to repair and maintain. Maintenance and repair diagnostics uses the system itself to participate in the identification and sourcing of malfunctions and failures of the system. There are three modes: status monitoring—key sensors and parameters are continually examined during system operation, to detect malfunctions as they might occur; failure diagnostics—this is invoked so that the cause of a failure can be identified; and recommendation of repair procedure—suggestions for repair procedures are supplied to the repair crew.
Error Detection and Recovery	An error detection and recovery system uses an interrupt subroutine: this allows the main programme to be interrupted, upon the detection of an error, so that a recovery subroutine may be run instead. In error detection the system's sensors determine, interpret and classify an error when it occurs. Three types of errors may occur: random errors—which result from the normal stochastic nature of the process; systematic errors—which result from an assignable cause in material or equipment; and aberrations—which result from human mistakes or equipment failure. Collecting and classifying all possible errors is the largest problem in error detection.

Levels of Automation



PROCESS INDUSTRIES VERSUS DISCRETE MANUFACTURING INDUSTRIES

Industries and their production operations were divided into two basic categories: (1) process industries and (2) discrete manufacturing industries. Process industries perform their production operations on amounts of materials, because the materials tend to be liquids, gases, powders, and similar materials, whereas discrete manufacturing industries perform their operations on quantities of materials, because the materials tend to be discrete parts and products. The kinds of unit operations performed on the materials are different in the two industry categories

Typical Unit Operations in the Process Industries and Discrete Manufacturing Industries

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Process Industries	**Discrete Manufacturing industries**
Chemical reactions	Casting
Comminution	Forging
Chemical vapor deposition	Extrusion
Distillation	Machining
Mixing and blending of ingredients	Plastic molding
Separation of ingredients	Sheet metal stamping

TABLE 5.2 Levels of Automation in the Process Industries and Discrete Manufacturing Industries

Level	Process Industries	Discrete Manufacturing Industries
5	Enterprise level—management information system, strategic planning, high-level management of enterprise	Enterprise level—management information system, strategic planning, high-level management of enterprise
4	Plant level—scheduling, tracking materials, equipment monitoring	Plant or factory level—scheduling, tracking work-in-process, routing parts through machines, machine utilization
3	Supervisory control level—control and coordination of several interconnected unit operations that make up the total process	Manufacturing cell or system level—control and coordination of groups of machines and supporting equipment working in coordination, including material handling equipment
2	Regulatory control level—control of unit operations	Machine level—production machines and workstations for discrete product manufacture
1	Device level—sensors and actuators comprising the basic control loops for unit operations	Device level—sensors and actuators to accomplish control of machine actions

Continuous Versus Discrete Control

Industrial control systems used in the process industries tend to emphasize the control of continuous variables and parameters. By contrast, the manufacturing industries produce discrete parts and products, and their controllers tend to emphasize discrete variables and parameters. Just as there are two basic types of variables and parameters that characterize production operations, there are also two basic types of control: (1) **Continuous control**, in which the variables and parameters are continuous and analog; and (2) **Discrete** control, in which the variables and parameters are discrete, mostly binary discrete. Some of the differences between continuous control and discrete control are summarized in Table 5.3. In reality, most operations in the process and discrete manufacturing industries include both continuous and discrete variables and parameters. Consequently, many industrial controllers are designed with the capability to receive, operate on, and transmit both types of signals and data. Chapter 6 covers the various types of signals and data in industrial control systems and how the data are convertedfor use by digital computers.

TABLE 5.3 Comparison Between Continuous Control and Discrete Control

Comparison Factor	Continuous Control in Process Industries	Discrete Control in Discrete Manufacturing Industries
Typical measures of product output	Weight measures, liquid volume measures, solid volume measures	Number of parts, number of products
Typical quality measures	Consistency, concentration of solution, absence of contaminants, conformance to specification	Dimensions, surface finish, appearance, absence of defects, product reliability
Typical variables and parameters	Temperature, volume flow rate, pressure	Position, velocity, acceleration, force
Typical sensors	Flow meters, thermocouples, pressure sensors	Limit switches, photoelectric sensors, strain gages, piezoelectric sensors
Typical actuators	Valves, heaters, pumps	Switches, motors, pistons
Typical process time constants	Seconds, minutes, hours	Less than a second

Basic Devices in Automated Systems

- power distribution
- motor control and drives
- safety system
- programmable controllers
- discrete and analog I/O
- communication systems
- human-machine interface (HMI)

Control System

Industrial Control System (ICS) is a collective term used to describe different types of control systems and related instrumentation, which include the devices, systems, networks, and controls used to operate and/or automate industrial processes.

Each ICS functions differently depending on the industry and is designed to handle tasks efficiently electronically. In almost every industrial sector and critical infrastructures such as the production, transportation, power and water treatments, the devices and protocols used in an ICS are currently used

Types of Industrial Control Systems

Industrial Control Systems are distinguished into several kinds depending on the functionality and complexity of the control action. Here’s a list of the most common control system used:

1. **Programmable Logic Controllers (PLCs)** - A Solid state control system that has a user-programmable memory for storing instructions to implement specific functions such as I/O control, logic, timing, counting, three modes (PID) control, communication, arithmetic, and data and file processing.
2. **Distributed Control Systems (DCS) -** An industrial control system deployed and controlled in a distributed manner, such that various distributed control systems or processes are controlled individually. In a control system, refers to control achieved by intelligence that is distributed about the process to be controlled rather than by a centrally located single unit.
3. **Supervisory control and Data Acquisition (SCADA) -** A generic name for a computerized system that is capable of gathering and processing data and applying operational controls over long distances. Typical uses include power transmission and distribution and pipeline systems. SCADA was designed for the unique communication challenges (e.g., delays, data integrity) posed by the various media that must be used, such as phone lines, microwave, and satellite. Usually shared rather than dedicated.

4. **Remote Terminal Units (RTUs) :** A remote terminal unit (RTU) is a microprocessor-based electronic device used in industrial control systems (ICS) to connect different hardware to distributed control systems (DCS) or SCADA. RTUs are also known as remote units of telemetry or remote units of telecontrol. RTUs pass sensor data from input streams in the control loop to an output stream to be transmitted to ICS centralized command. RTUs negotiate links to local or remote controls.
5. **Industrial Automation and Control Systems (IACS) :** Industrial automation control system solutions involve safe infrastructure to allow information transfers and communications as well as smart devices for information collection. Sensors on machines and machinery usually achieve this. Industrial automation control systems also involve hardware, software and communication alternatives to transform sensor information into information.
6. **Programmable Automation Controllers (PACs):** Programmable Automation Controller (PAC) is a term that is used loosely to define any automation controller that comprises of higher-level instructions. The systems are used for equipment in a broad spectrum of sectors, including those engaged in critical infrastructure, in industrial control systems (ICS).
7. **Intelligent Electronic Devices (IEDs):** An intelligent electronic device is an electronic component (such as a regulator and circuit control) that has a microprocessor and can communicate, typically digitally using Field bus, real time Ethernet, or other industrial protocols

Module-5

Material handling: Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems,

Identification Technologies: Overview of Automatic Identification Methods.

Material handling;

13.1 GENERAL CONSIDERATIONS IN ROBOT MATERIAL HANDLING

In planning an application in which the robot will be used to transfer parts, load a machine, or other similar operation, there are several considerations that must be reviewed. Most of these considerations have been discussed in previous chapters of the book, and we itemize them below as a reference checklist.

1. Part positioning and orientation In most parts-handling applications the parts must be presented to the robot in a known position and orientation. Robots used in these applications do not generally possess highly sophisticated sensors (e.g., machine vision) that would enable them to seek out a part and identify its orientation before picking it up.

2. Gripper design Special end effectors must be designed for the robot to grasp and hold the workpart during the handling operation. Design considerations for these grippers were discussed in Chap. 5.

3. Minimum distances moved The material-handling application should be planned so as to minimize the distances that the parts must be moved. This can be accomplished by proper design of the workcell layout (e.g., keeping the equipment in the cell close together), by proper gripper design (e.g., using a double gripper in a machine loading/unloading operation), and by careful study of the robot motion cycle.

4. Robot work volume The cell layout must be designed with proper consideration given to the robot's capability to reach the required extreme locations in the cell and still allow room to maneuver the gripper.

5. Robot weight capacity There is an obvious limitation on the materialhandling operation that the load capacity of the robot must not be exceeded. A robot with sufficient weight-carrying capacity must be specified for the application.

6. Accuracy and repeatability Some applications require the materials to be handled with very high precision. Other applications are less demanding in this respect. The robot must be specified accordingly.

7. Robot configuration, degrees of freedom, and control Many parts transfer operations are simple enough that they can be accomplished by a robot with two to four joints of motion. Machine-loading applications often require more degrees of freedom. Robot control requirements are unsophisticated for most material-handling operations. Palletizing operations, and picking parts from a moving conveyor are examples where the control requirements are more demanding.

8. Machine utilization problems It is important for the application to effectively utilize all pieces of equipment in the cell. In a machine loading/unloading operation, it is common for the robot to be idle while the machine is working, and the machine to be idle while the robot is working. In cases where a long machine cycle is involved, the robot is idle a high proportion of the time. To increase the utilization of the robot, consideration should be given to the possibility for the robot to service more than a single machine. One of the problems arising in the multi machine cell is machine interference, discussed in Chap. 11.

We now proceed to deal with the specific cases of material transfer and machine loading/unloading applications in the following two sections.

1. **PLANNING PRINCIPLE**;

All material handling should be the result of a deliberate plan where the needs, performance objectives and functional specification of the proposed methods are completely defined at the outset.

Definition: A plan is a prescribed course of action that is defined in advance of implementation. In its simplest form a material handing plan defines the mate- rial (what) and the moves (when and where); together they define the method (how and who).

KEY POINTS:

- The plan should be developed in consultation between the planner(s) and all who will use and benefit from the equipment to be employed.
- Success in planning large scale material handling projects generally requires a team approach involving suppliers, consultants when appropriate, and end user specialists from management, engineering, computer and information systems, finance and operations.
- The material handling plan should reflect the strategic objectives of the organization as well as the more immediate needs.
- The plan should document existing methods and problems, physical and economic constraints, and future requirements and goals.
- The plan should promote concurrent engineering of product, process design, process layout, and material handling methods, as opposed to independent and sequential design practices.

2. **STANDARDIZATION PRINCIPLE**

Material handling methods, equipment, controls and software should be standardized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity and through put. anticipation of changing future requirements.

Definition: Standardization means less variety and customization in the methods and equipment employed.

KEY POINTS:

- The planner should select methods and equipment that can perform a variety of tasks under a variety of operating conditions and in
- Standardization applies to sizes of containers and other load forming components as well as

operating procedures and equipment.

- Standardization, flexibility and modularity must not be incompatible.

3. WORK PRINCIPLE

Material handling work should be minimized without sacrificing productivity or the level of service required of the operation.

Definition: The measure of work is material handling flow (volume, weight or count per unit of time) multiplied by the distance moved.

KEY POINTS:

- Simplifying processes by reducing, combining, shortening or eliminating unnecessary moves will reduce work.
- Consider each pickup and set-down, or placing material in and out of storage, as distinct moves and components of the distance moved.
- Process methods, operation sequences and process/equipment layouts should be prepared that support the work minimization objective.
- Where possible, gravity should be used to move materials or to assist in their movement while respecting consideration of safety and the potential for product damage
- The shortest distance between two points is a straight line

4. **ERGONOMIC PRINCIPLE** Human capabilities and limitations must be recognized and respected in the design of material handling tasks and equipment to ensure safe and effective operations.

Definition: Ergonomics is the science that seeks to adapt work or working conditions to suit the abilities of the worker.

KEY POINTS:

- Equipment should be selected that eliminates repetitive and strenuous manual labor and which effectively interacts with human operators and users.
- The ergonomic principle embraces both physical and mental tasks.
- The material handling workplace and the equipment employed to assist in that work must be

designed so they are safe for people

5. **UNIT LOAD PRINCIPLE** Unit loads shall be appropriately sized and configured in a way which achieves the material flow and inventory objectives at each stage in the supply chain.

   Definition: A unit load is one that can be stored or moved as a single entity atone time, such as a pallet, container ortote, regardless of the number of individual items that make up the load.

KEY POINTS:

- Less effort and work is required to collect and move many individual items as single load than to move many items one at a time.
- Load size and composition may change as material and product moves through stages of manufacturing and the resulting distribution channels.
- Large unit loads are common both pre and post manufacturing in the form of raw materials and finished goods.
- During manufacturing, smaller unit loads, including as few as one item, yield less in-process inventory and shorter item through-put times.
- Smaller unit loads are consistent with manufacturing strategies that embrace 4operating objectives such as flexibility, continuous flow and just-in-time delivery.
- Unit loads composed of a mix of different items are consistent with just-in-time and/or customized supply strategies so long as item selectivity is not compromised.

6. **SPACE UTILIZATIONPRINCIPLE** Effective and efficient use must be made of all available space.

   Definition: Space in material handling is three dimensional and therefore is counted as cubic space.

KEY POINTS:

- In work areas, cluttered and unorganized spaces and blocked aisles should be eliminated.
- In storage areas, the objective of maximizing storage density must be balanced against accessibility and selectivity.
- When transporting loads within a facility the use of overhead space should be considered

as an option.

7. **SYSTEM PRINCIPLE** Material movement and storage activities should be fully integrated to form a coordinated, operational system which spans receiving, inspection, storage, production, assembly, packaging, unitizing, order selection, shipping, transportation and the handling of returns.

   Definition: A system is a collection of interacting and/or interdependent entities that form a unified whole.

KEY POINTS:

- Systems integration should encompass the entire supply chain including reverse logistics. It should include suppliers, manufacturers, distributors and customers.
- Inventory levels should be minimized at all stages of production and distribution while respecting considerations of process variability and customer service. 6 7
- Information flow and physical material flow should be integrated and treated as concurrent activities
- Methods should be provided for easily identifying materials and products, for determining their location and status within facilities and within the supply chain and for controlling their movement. Customer requirements and regarding regarding quantity, quality, and on-time delivery should be met without exception. Consistency and predictability, regarding quantity, quality, and on-time delivery should be met without exception.

8. **AUTOMATION PRINCIPLE** Material handling operations should be mechanized and/or automated where feasible to improve operational efficiency, increase responsiveness, improve consistency and predictability,

KEY POINTS:

- Pre-existing processes and methods should be simplified and/or re-engineered before any efforts at installing mechanized or automated systems.
- Computerized material handling systems should be considered where appropriate for effective integration of material flow and information management.
- Treat all interface issues as critical to successful automation, including equipment to

equipment, equipment to load, equipment to operator, and control communications.

- All items expected to be handled automatically must have features that accommodate mechanized and automated handling.

9. **ENVIRONMENTAL PRINCIPLE** Environmental impact and energy consumption should be considered as criteria when designing or selecting alter- native equipment and material handling systems.

   Definition: Environmental consciousness stems from a desire not to waste natural resources and to predict and eliminate the possible negative effects of our daily actions on the environment.

KEY POINTS:

- Containers, pallets and other products used to form and protect unit loads should be designed for reusability when possible and/or biodegradability as appropriate.
- Systems design should accommodate the handling of spent dunnage, empty containers and other by-products of material handling.
- Materials specified as hazardous have special needs with regard to spill protection, combustibility and other risks.

10. **LIFE CYCLE COSTPRINCIPLE** A thorough economic analysis should account for the entire life cycle of all material handling equipment and resulting system

    Definition: Life cycle costs include all cash flows that will occur between the time the first dollar is spent to plan or procure a new piece of equipment, or to put in place a new method, until that method and/or equipment is totally replaced.

KEY POINTS:

- Life cycle costs include capital investment, installation, setup and equipment programming, training, system testing and acceptance, operating (labor, utilities, etc.), maintenance and repair, reuse value, and ultimate disposal.
- A plan for preventive and predictive maintenance should be prepared for the equipment, and the estimated cost of maintenance and spare parts should be included in the economic analysis.

- ➢ A long-range plan for replacement of the equipment when it becomes obsolete should be prepared. Although measurable cost is a primary factor, it is certainly not the only factor in selecting among alternatives. Other factors of a strategic nature to the organization and which form the basis for competition in the market place should be considered and quantified whenever possible.

Material transport system

> "Efficient short-distance movement of goods that usually takes place within the confines of a building such as a plant or a warehouse or between a building and a transportation agency."

Advantages of Material handling

- improves efficiency
- Improves productivity
- Maximize profits
- Competitive edge

Applications

- Warehouses
- Manufacturing Plants
- Ports
- Airports

Types of Material Handling Equipment

- Transport Equipment
- Positioning Equipment
- Unit Load Formation Equipment
- Storage Equipment
- Identification and Control Equipment

Transport Equipment

The equipments used to move materials from one location to another.

Conveyors

Equipment used to move materials over a fixed path between specific points

Cranes

Equipment used to move materials over variable paths within a restricted area.

Industrial Trucks

Equipment used to move materials over variable paths, with no restrictions on the area covered by the movement

Types of truck

- Hand truck
- Pallet jack
- Walkie stacker

Unit load formation equipment

Unit load formation equipment used to restrict materials so that they maintain their integrity when handled a single load during transport and for storage

Storage system

Push back rack

Flow through rack

Drive in rack

Identification Methods

Automatic identification systems are being used increasingly to collect data in material handling and manufacturing applications. In material handling, the applications include shipping and receiving, storage, sortation, order picking, and kitting of parts for assembly. In manufacturing, the applications include monitoring the status of order processing, work-in-process, machine utilization, worker attendance, and other measures of factory operations and performance.

AIDC has many important applications outside the factory, including retail sales and inventory control, warehousing and distribution center operations, mail and parcel handling, patient identification in hospitals, check processing in banks, and security systems. This chapter emphasizes material handling and manufacturing applications. There are several drawbacks to this method:

1. **Errors** occur in both data collection and keyboard entry of the data when it is accomplished manually. The average error rate of manual keyboard entry is one error per 300 characters.

2. **Time factor**. Manual methods are inherently more time consuming than automated methods. Also, when manual methods are used, there is a time delay between when the activities and events occur and when the data on status are entered into the computer.

3. **Labor cost.** The full attention of human workers is required in manual data collection and entry, with the associated labor cost.

AIDC technologies

AIDC technologies can be divided into the following six categories.

1. **Optical.** Most of these technologies use high-contrast graphical symbols that can be interpreted by an optical scanner. They include linear (one-dimensional) and two dimensional bar codes, optical character recognition, and machine vision.

2. **Electromagnetic.** The important AIDC technology in this group is radio frequency identification (RFID), which uses a small electronic tag capable of holding more data than a bar code. Its applications are gaining on bar codes due to several mandates from companies like Walmart and from the U.S. Department of Defense.

3. **Magnetic.** These technologies encode data magnetically, similar to recording tape. The two important techniques in this category are (a) magnetic stripe, widely used in plastic credit cards

and bank access cards, and (b) magnetic ink character recognition, widely used in the banking industry for check processing.

4. **Smart card**. This term refers to small plastic cards (the size of a credit card) imbedded with microchips capable of containing large amounts of information. Other terms used for this technology include *chip card* and *integrated circuit card*.

5. **Touch techniques.** These include touch screens and button memory.

6. **Biometric.** These technologies are utilized to identify humans or to interpret vocal commands of humans. They include voice recognition, fingerprint analysis, and retinal eye scans.

Bar Code Technology

bar codes divide into two basic types: (1) linear, in which the encoded data are read using a linear sweep of the scanner, and (2) two-dimensional, in which the encoded data must be read in both directions.

Figure 12.1 Two forms of linear bar codes are (a) width-modulated, exemplified here by the Universal Product Code, and (b) height-modulated, exemplified here by Postnet, used by the U.S. Postal Service.

Linear (One-Dimensional) Bar Codes

Linear bar codes are the most widely used automatic identification and data capture technique. There are actually two forms of linear bar code symbologies, shown in Figure width-modulated, in which the symbol consists of bars and spaces of varying width; and (b) height-modulated, in which the symbol consists of evenly spaced bars of varying height.

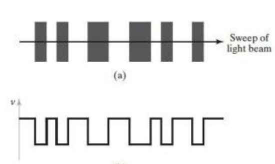

Figure 12.3 Conversion of bar code into a pulse train of electrical signals, (a) bar code and (b) corresponding electrical signal.

TABLE 12.2 Some Widely Used Linear Bar Codes

Bar Code	Description	Applications
Codabar	Only 16 characters: 0–9, $, :, /, ., +, −	Used in libraries, blood banks, and some parcel freight applications
UPC*	Numeric only, length = 12 digits	Widely used in the United States and Canada, in grocery and other retail stores
Code 39	Alphanumeric (see text for description)	Adopted by Department of Defense, automotive, and other manufacturing industries
Postnet	Numeric only**	U.S. Postal Service code for ZIP code numbers
Code 128	Alphanumeric, but higher density	Substitutes in some Code 39 applications
Code 93	Similar to Code 39 but higher density	Same applications as Code 39

The Bar Code Symbol. The bar code standard adopted by the automotive industry, the Department of Defense, the General Services Administration, and many other manufacturing industries is Code 39, also known as AIM USD–2 (Automatic Identification Manufacturers Uniform Symbol Description-2). Code 39 uses a series of wide and narrow elements (bars and spaces) to represent alphanumeric and other characters.

Bar Code Readers. Bar code readers come in a variety of configurations; some require a human to operate them and others are stand-alone automatic units. They are usually classified as contact or noncontact readers. Contact bar code readers are handheld wands or light pens operated by moving the tip of the wand quickly past the bar code on the object or document.

Contact bar code readers are also available as portable units that can be carried around the factory or warehouse by a worker. They are battery-powered and include a solid-state memory device capable of storing data acquired during operation. The data can be transferred to the computer system subsequently. Portable bar code readers often include a keypad that can be used by the operator to input data that cannot be entered via bar code. These portable units are used for order picking in a warehouse and similar applications that require a worker to move significant distances in a building.

Noncontact bar code readers focus a light beam on the bar code, and a photodetector reads the reflected signal to interpret the code. The reader probe is located a certain distance from the bar code (several inches to several feet) during the read procedure. Noncontact readers are classified as fixed beam and moving beam scanners. Fixed beam readers are stationary units that use a fixed beam of light. They are usually mounted beside a conveyor and depend on the movement of the bar code past the light beam for their operation.

Two-Dimensional Bar Codes

The first two-dimensional (2-D) bar code was introduced in 1987. Since then, more than a dozen 2-D symbol schemes have been developed, and the number is expected to increase. The advantage of 2-D codes is their capacity to store much greater amounts of data at higher area densities. Their disadvantage is that special scanning equipment is required to read the codes, and the equipment is more expensive than scanners used for conventional bar codes. Two-dimensional symbologies divide into two basic types: (1) stacked bar codes and (2) matrix symbologies.

Matrix Symbologies. A matrix symbology consists of 2-D patterns of data cells that are usually square and are colored dark (usually black) or white. The 2-D matrix symbologies were introduced around 1990. Applications of the matrix symbologies are found in part and product identification during manufacturing and assembly. These kinds of applications are expected to grow as computer-integrated manufacturing becomes more pervasive throughout industry.

Radio Frequency Identification

In radio frequency identification, an identification tag or label containing electronically encoded data is attached to the subject item, which can be a part, product, or container (e.g., carton, tote pan, pallet). The identification tag consists of an integrated circuit chip and a small antenna, as pictured in Figure below. These components are usually enclosed in a protective plastic container or are imbedded in an adhesive-backed label that is attached to item.

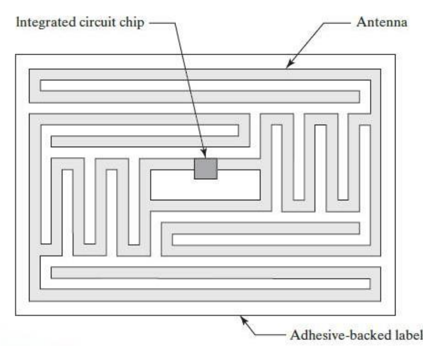

Figure 12.8 RFID label. Approximate size is 20 mm by 30 mm (0.8 in by 1.2 in).

Although the RF signals are similar to those used in wireless radio and television transmission, there are differences in how RF technology is used in product identification. One difference is that the communication is in two directions rather than in one direction as in commercial radio and TV. The identification tag is a ***transponder***, a device that emits a signal of its own when it receives a signal from an external source.

RF identification tags are available in two general types: (1) passive and (2) active. Passive tags have no internal power source; they derive their electrical power for transmitting a signal from radio waves generated by the reader when in close proximity. Active tags include their own battery power packs. Passive tags are smaller, less expensive, longer lasting, and have a shorter radio communication range. Active tags generally possess a larger memory capacity and a longer communication range (typically 10 m and more). Applications of active tags tend to be associated with higher value items due to the higher cost per tag.

Advantages of RFID include the following: (1) identification does not depend on physical contact or direct line of sight observation by the reader, (2) much more data can be contained in the identification tag than with most AIDC technologies, and (3) data in the read/write tags can be altered for historical usage purposes or reuse of the tag.

- **Product Tracking** – RFID tags are increasingly used as a cost-effective way to track inventory and as a substitute for barcodes. For instance, bookstores such as Barnes & Noble use RFID to identify books to be removed from shelves and returned to publishing houses.
- **Toll Road Payments** – Highway toll payment systems, such as E-Z Pass in the eastern states, uses RFID technology to electronically collect tolls from passing cars. Instead of stopping at the toll booth, cars pass directly through in the E-Z Pass lane and the toll is automatically deducted from a pre-paid card.

- **Passports** – A number of countries, including Japan, the United States, Norway, and Spain incorporate RFID tags into passports to store information (such as a photograph) about the passport holder and to track visitors entering and exiting the country.

- **Identification** – RFID chips can be implanted into animals and people to track their movements, provide access to secure locations, or help find lost pets.

- **Libraries** – Libraries use RFID tags in books and other materials to track circulation and inventory, store product information (such as titles and authors), and to provide security from theft. Because RFID tags can be scanned without physically touching the item, checking books in and out, plus doing laborious tasks such as shelf inventory, can be accomplished quickly and efficiently using RFID technology.

- **Shipping** – Large shipments of materials, such as retail goods, often utilize RFID tags to identify location, contents, and movement of goods. Wal-mart is one of the largest consumers of this technology to assist in tracking shipments of merchandise.

- **Other uses** – RFID tags are employed in numerous other ways, including implantation in Saguaro cacti to discourage black-market traders, placement in car tires to transmit road condition information to the onboard computer, and placement around cities (such as Tokyo) to transmit tourist information to visitor cell phones.

TABLE 12.3 Bar Codes versus Radio Frequency Identification

Comparison	Bar Codes	RFID
Technology	Optical	Radio frequency
Read-write capability	Read only	Read-write available
Storage capacity	14–16 digits (linear bar codes)	96–256 digits
Line-of-sight reading	Required	Not required
Reusability	One-time use	Reusable
Cost per label	Very low	About 10 times the cost of bar code for passive tag
Durability	Susceptible to dirt and scratches	More durable in plant environment

Source: Based mostly on Weber [17].

Other AIDC technologies

The other automated identification and data collection techniques are either used in special applications in factory operations, or they are widely applied outside the factory.

Magnetic Stripes

Magnetic stripes attached to a product or container are sometimes used for item identification in factory and warehouse applications. A magnetic stripe is a thin plastic film containing small magnetic particles whose pole orientations can be used to encode bits of data into the film.

Two advantages of magnetic stripes are their large data storage capacity and the ability to alter the data contained in them.

Although they are widely used in the financial community, their use seems to be declining in shop floor control applications for the following reasons:

(1) the magnetic stripe must be in contact with the scanning equipment for reading to be accomplished,

(2) there are no convenient shop floor encoding methods to write data into the stripe, and

(3) the magnetic stripe labels are more expensive than bar code labels.

Optical Character Recognition

Optical character recognition (OCR) is the use of specially designed alphanumeric characters that are machine readable by an optical reading device. Optical character recognition is a 2-D symbology, and scanning involves interpretation of both the vertical and horizontal features of each character during decoding. For factory and warehouse applications, the list of disadvantages includes (1) the requirement for near-contact scanning, (2) lower scanning rates, and (3) higher error rates compared to bar code scanning.

Optical character recognition use cases

OCR can be used for a variety of applications, including:

- Scanning printed documents into versions that can be edited with word processors, like Microsoft Word or Google Docs.
- Indexing print material for search engines.
- Automating data entry, extraction and processing.
- Deciphering documents into text that can be read aloud to visually-impaired or blind users.
- Archiving historic information, such as newspapers, magazines or phonebooks, into searchable formats.
- Electronically depositing checks without the need for a bank teller.

- Placing important, signed legal documents into an electronic database.
- Recognizing text, such as license plates, with a camera or software.
- Sorting letters for mail delivery.
- Translating words within an image into a specified language.