INTRODUCTION

- A wide variety of measuring gadgets is accessible for gathering data from the manufacturing process for use in feedback control. In popular, a measuring device is made out of two segments: a sensor and a transducer.
- The **sensor detects the physical variable of interest** (such as temperature, force, or pressure). The **transducer converts the physical variable into an alternative form** (commonly electrical voltage), quantifying the variable in the conversion. The quantified signal can be interpreted as the value of the measured variable.
- In some cases, the sensor and transducer are the same device; for example, a limit switch that converts the mechanical movement of a lever to close an electrical contact.
- To use any measuring device, a calibration procedure is required. Calibration is a process by which the relationship between the measured variable and the converted output signal (such as voltage) is established.

SENSORS

- **Definition:**
  - Sensor is a device that detects the presence or absence of an object, or certain properties of that object, and provides feedback. Robots use sensors to interact with their environment.
  - Actually, the use of sensors in a machine changes it from a dumb machine to an intelligent machine. A robot needs sensing to be an active participant in the environment. Thus, sensors constitute robot's window to the environment.
- **Functions of a sensor:**
  - *Component location:* determines identity, position, and orientation of parts.
  - *Operation monitoring:* confirms progress status of components and machines, checks for jamming, missing parts, successful grasping.
  - *Inspection:* examine completed work for blemishes.

CHARACTERISTICS OF A SENSOR

A sensor device should possess the following characteristics:

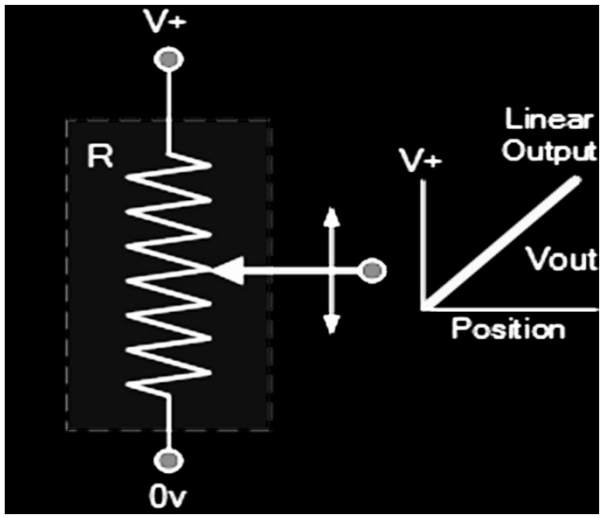
- **Accuracy:** As high as possible; closeness to true value of variable
- **Precision**: little or no random variability in measured variable
- **Operating range:** wide operating range; accurate and precise over entire sensing range
- **Reliability**: no failure
- **Repeatability**: repeat a measurement when put back in the same environment
- **Response time:** as quick as possible
- **Calibration:** easy to calibrate; no drift (tendency to lose accuracy over time)
- **Operation & installation:** easy and simple
- **Cost :** as low as possible

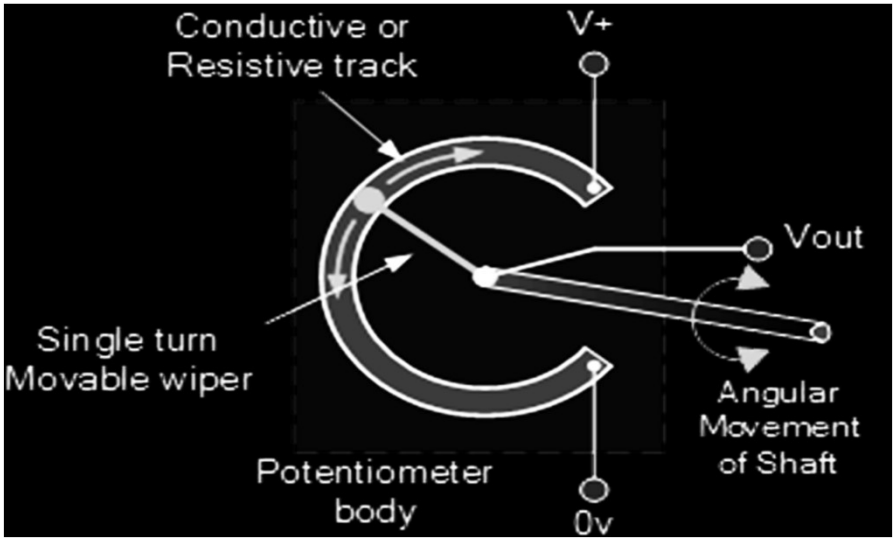
TYPES OF SENSORS

- Sensors used in industrial robotics can be classified into two categories:
  1. **Internal sensors:** Internal sensors are used for controlling position and velocity of the various joints of the robot. These sensors form a feedback control loop with the robot controller. Typical sensors used to control the position of the robot arm include:
     - Position sensors: potentiometers, resolvers, encoders, synchro, LVDT
     - Velocity sensors: DC tachometer, AC tachometer
  2. **External sensors:** External sensors are used for interacting with the environment. In manufacturing, these are used to coordinate the operation of the robot with other equipment in the cell. Theses are:
     - Tactile sensors
     - Proximity and range sensors
     - Machine vision

POTENTIOMETERS

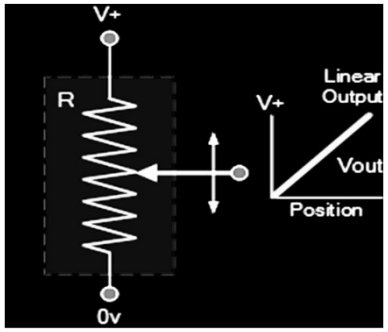
- The most commonly used of all the "Position Sensors", is the *potentiometer* because it is an inexpensive and easy to use position sensor.
- It has a wiper contact linked to a mechanical shaft that can be either angular (rotational) or linear (slider type) in its movement, and which causes the resistance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

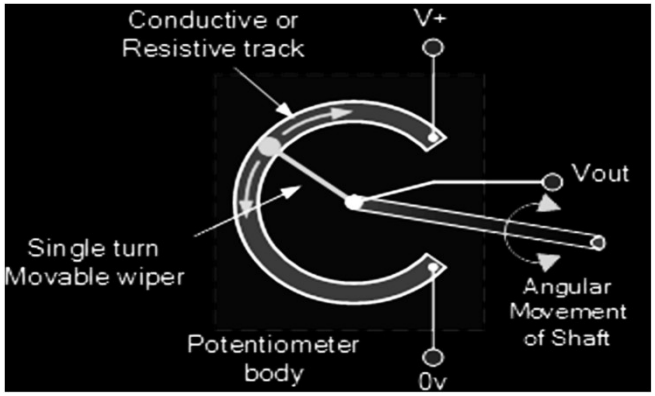




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- The main disadvantage of using the potentiometer as a positional sensor is the range of movement of its wiper or slider (and hence the output signal obtained) is limited to the physical Size of the potentiometer being used.

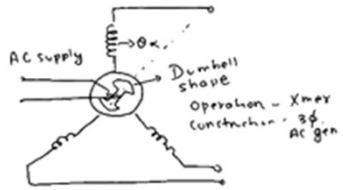


SYNCHRO

- Synchro's are typically used to feedback angular position of rotating equipment.
- A synchro is essentially a transformer whose primary-to-secondary coupling may be varied by physically changing the relative orientation of the two windings.
- The general physical construction of a synchro is much like that of an electric motor.
- The primary winding of the transformer, fixed to the rotor, is excited by an alternating current.
- Due to electromagnetic induction, this causes currents to flow in three secondary windings fixed at 120 degrees to each other on the stator.
- The relative magnitudes of the secondary currents are measured and used to determine the angle of the rotor relative to the stator.
- The secondary currents can also be used to directly drive a receiver synchro that will rotate in unison with the transmitter synchro.

SYNCHRO

Commercially known as
SELSYN OR AUTOSYN

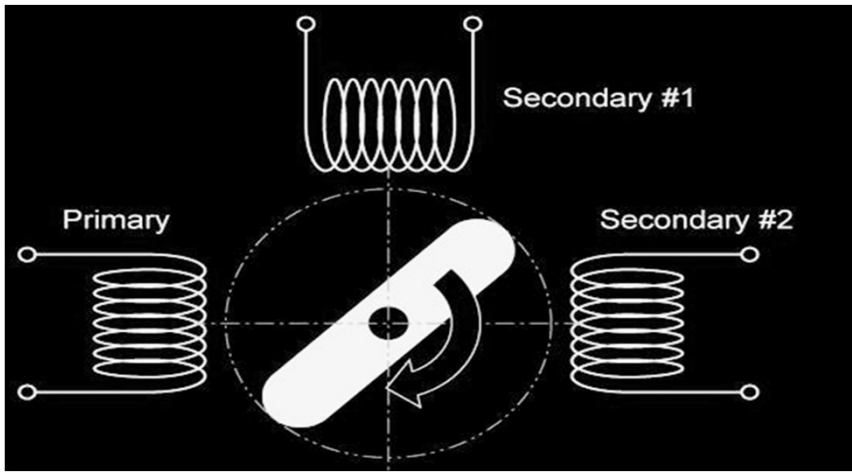


Operation - Xmer
Construction - 3ϕ AC gen

RESOLVERS

- A resolver is an electrical transformer used to measure angle of rotation.
- Most resolvers look rather like an electric motor – with copper windings on the stator and a machined metal rotor.
- The inductive coupling between the transformer's windings varies according to angle.
- So, if we energize the resolver with an AC signal and measure the output from the transformer's windings, we get an AC electrical signal whose amplitude is proportional to angle.

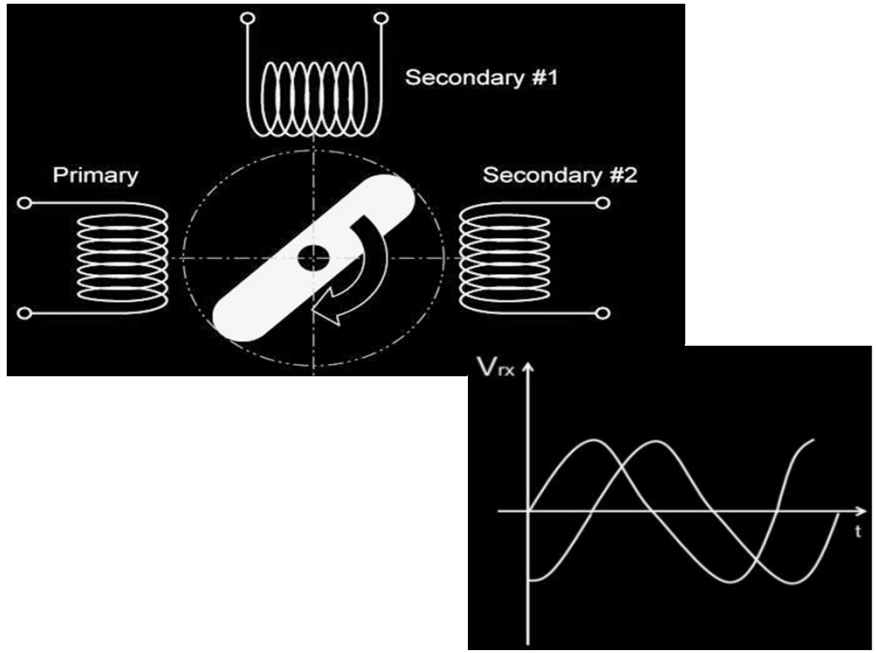
- A typical resolver has three windings – a primary winding and two secondary windings.
- These windings are made using copper wire and are usually formed on the resolver's stationary element – the stator.
- The primary winding is used as the input for an AC drive signal and each secondary is used as pick up or receive winding.



RESOLVERS

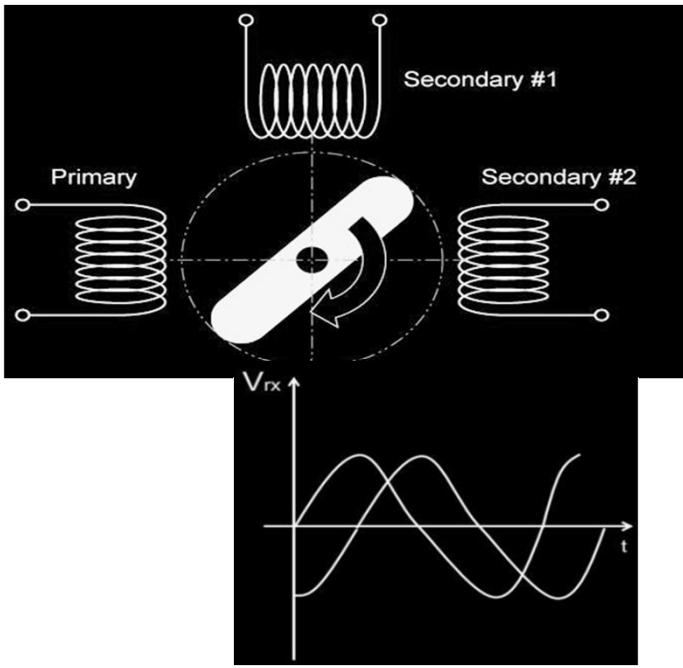
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- In the diagram below, the rotor is made from a material such as iron or steel and is arranged such that it will couple varying amounts of energy in to the secondaries depending on its angle of rotation.
- The output from the secondaries will be in the form of a sinusoid and cosinusoid. Accordingly, the ratio of signals varies in proportion to angle.



RESOLVERS

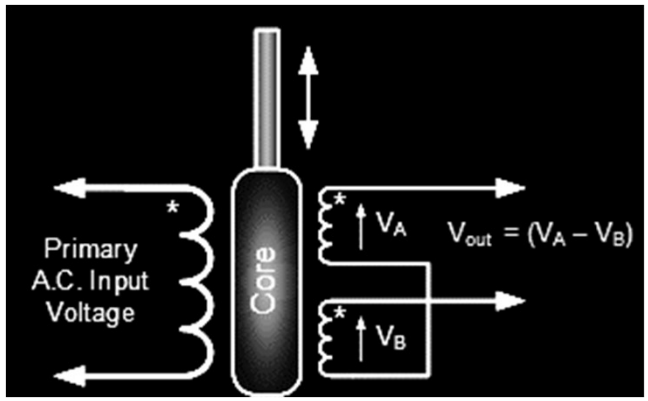
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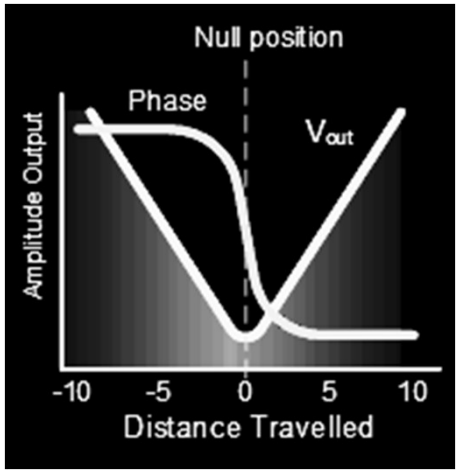
- Resolvers have a solid reputation for reliability and are often the automatic choice for high-reliability and safety related applications.
- A common pitfall is that many resolver data sheets specify infinite resolution. Whilst this is theoretically true, in practice, it is not – because most modern control systems will be converted to a digital signal of finite resolution. The actual resolution will be determined by the quality of the analogue to digital conversion circuit.

LINEAR VARIBLE DIFFERENTIAL TRANSFORMERS

- This is an inductive type position sensor which works on the same principle as the AC transformer that is used to measure movement.
- It is a very accurate device for measuring linear displacement and whose output is proportional to the position of its moveable core.

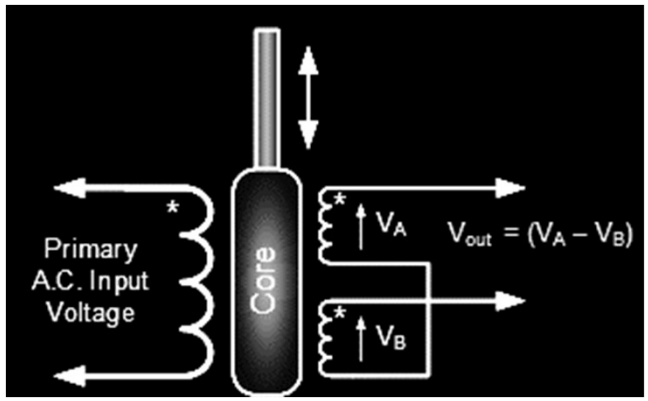


- It basically consists of three coils wound on a hollow tube former, one forming the primary coil and the other two coils forming identical secondaries connected electrically together in series but 180^o out of phase either side of the primary coil.
- A moveable soft iron ferromagnetic core which is connected to the object being measured, slides or moves up and down inside the tubular body of the LVDT.
- A small AC reference voltage called the "excitation signal" (2 – 20V rms, 2 – 20kHz) is applied to the primary winding which in turn induces an EMF signal into the two adjacent secondary windings (transformer principles).

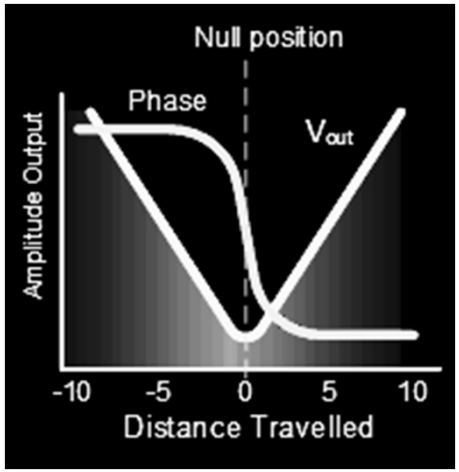


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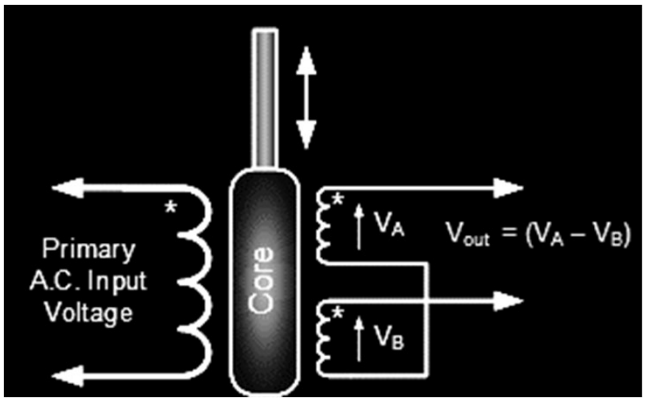


- If the soft iron magnetic core armature is exactly in the centre of the tube and the windings, "null position", the two induced emf's in the two secondary windings cancel each other out as they are 180^o out of phase, so the resultant output voltage is zero.
- As the core is displaced slightly to one side or the other from this null or zero position, the induced voltage in one of the secondaries will be become greater than that of the other secondary and an output will be produced.
- The polarity of the output signal depends upon the direction and displacement of the moving core.

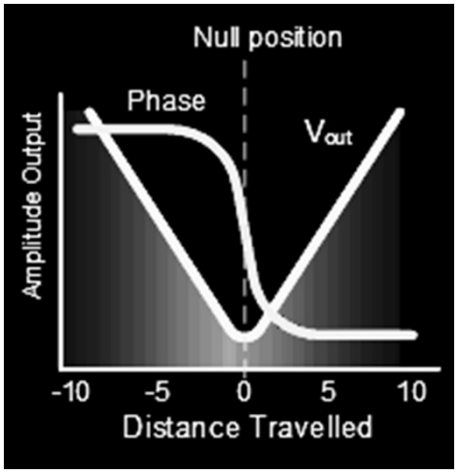


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- The greater the movement of the soft iron core from its central null position the greater will be the resulting output signal.
- The result is a differential voltage output which varies linearly with the cores position.
- Therefore, the output signal from this type of position sensor has both an amplitude that is a linear function of the cores displacement and a polarity that indicates direction of movement.
- The phase of the output signal can be compared to the primary coil excitation phase enabling suitable electronic circuits such as the AD592 LVDT Sensor Amplifier to know which half of the coil the magnetic core is in and thereby know the direction of travel.

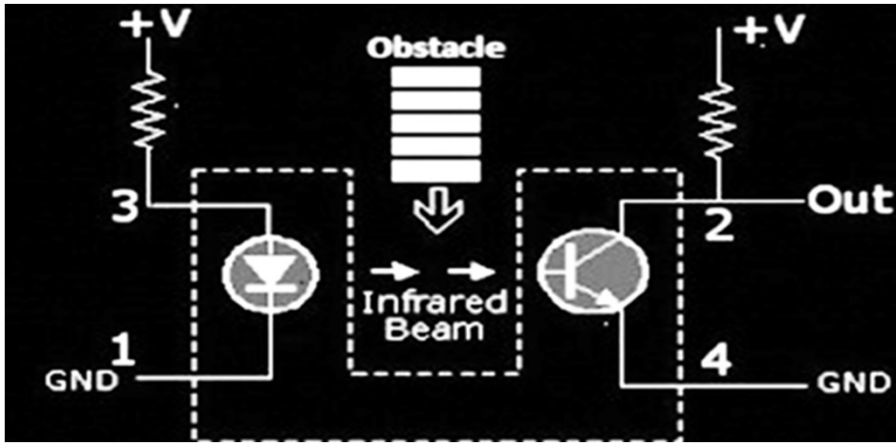


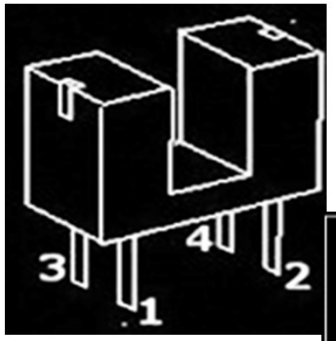
OPTICAL POSITION SENSORS

- OPTO-INTERRUPTERS
- OPTICAL ENCODERS
  - ROTARY ABSOLUTE ENCODERS
  - OPTICAL INCREMENTAL ENCODERS

OPTO-INTERRUPTERS

- The Opto switch or interrupter is a small U shaped black plastic package which has four legs-2 for infra red LED on one side of the U and 2 for light sensitive transistor on the other.
- Both are inbuilt, no external connection is required .
- With both the infrared light source and the photo diode in a single package, the photo-interrupter employs trans missive technology to sense obstacles existence , acts as on / off switchers or even to sense low resolution rotary or linear motions .i.e The principle states that objects opaque to infrared will interrupt the transmission of light between an infrared emitting diode and a photo sensor switching the output from an "ON" state to an "OFF" state .
- The photo interrupter is specified for operation over -25 °C to +85°C temperature range.





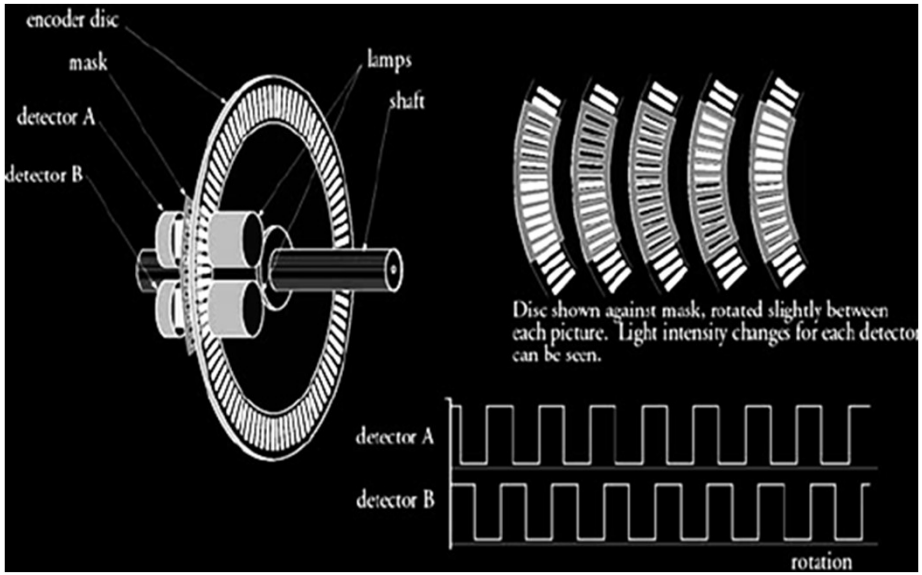


OPTICAL ENCODERS

- Optical rotary encoders are most commonly found in motion control systems while linear encoders are used more specifically for linear-positioning applications such as piston or actuator monitoring systems.
- A rotary encoder using optical sensing technology relies on the rotation of an internal code disc that has opaque lines and patterns on it.
- The disc is rotated (hence the name rotary encoder) in a beam of light such as an LED and the markings on the disc act as shutters blocking and unblocking the light.
- An internal photo detector senses the alternating light beam and the encoder's electronics convert the pattern into an electrical signal that is then passed on to an external control system through the encoder's output.
- Absolute optical encoders naturally have a more complicated signal structure. These encoders provide a "whole word" output with a unique code pattern that is derived from independent tracks on the encoder disc which correspond to individual photo-detectors and represents each position. The output from these detectors is HI or LO depending on the code disc pattern for that particular position.

OPTICAL INCREMENTAL ENCODERS

- Incremental optical encoder of a type often used for measuring the motor shaft position and speed in low cost servos.
- The two detectors produce pulses as the shaft rotates and the light intensity changes.
- The mask has two sets of slots arranged such that pulses from the detectors are 90^{o} out of phase (see sequence at top left).
- The detectors incorporate threshold logic to convert light intensity changes to an on/off electrical signal. Many encoders also provide an additional detector to provide a reference pulse once per revolution.



PROXIMITY SENSORS

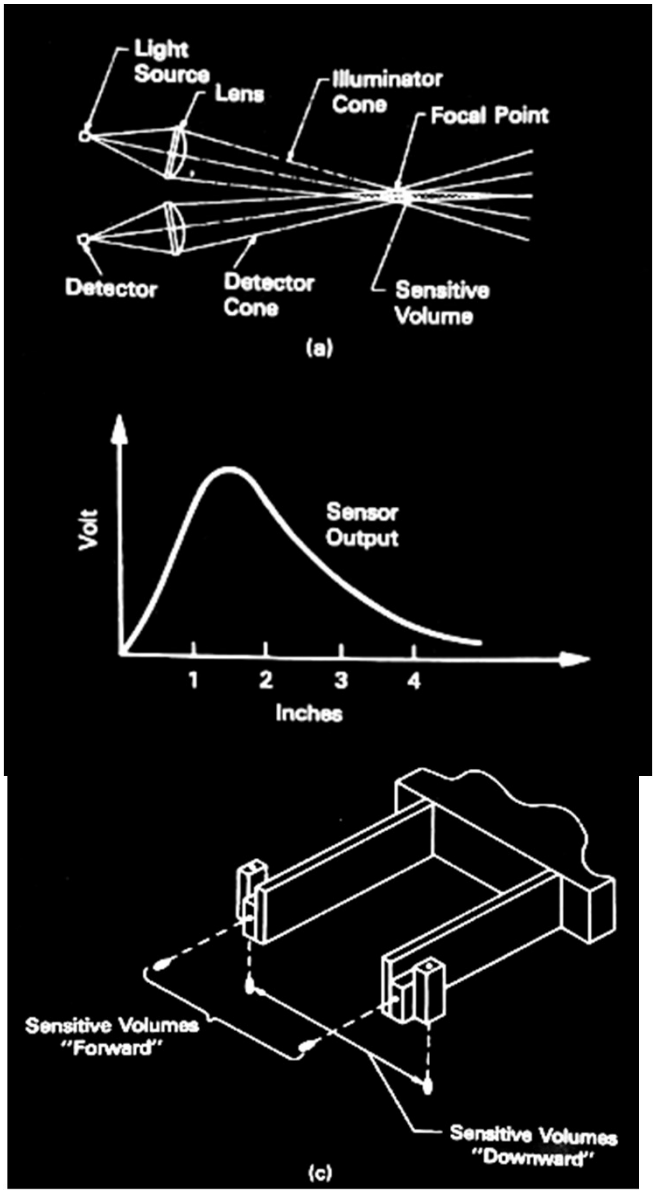
- CONTACT PROXIMITY SENSORS
- NONCONTACT PROXIMITY SENSORS
  - REFLECTED LIGHT SENSORS
  - FIBRE OPTIC SCANNING SENSORS
  - SCANNING LASER SENSORS
  - ULTRA SONIC SENSORS
  - EDDY CURRENT SENSOR
  - RESISTIVESENSING

PROXIMITY SENSORS

- A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal.
- The object being sensed is often referred to as the proximity sensor's target.
- Different proximity sensor targets demand different sensors.
- For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.
- The maximum distance that this sensor can detect is defined "nominal range".
- Some sensors have adjustments of the nominal range or means to report a graduated detection distance.
- Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

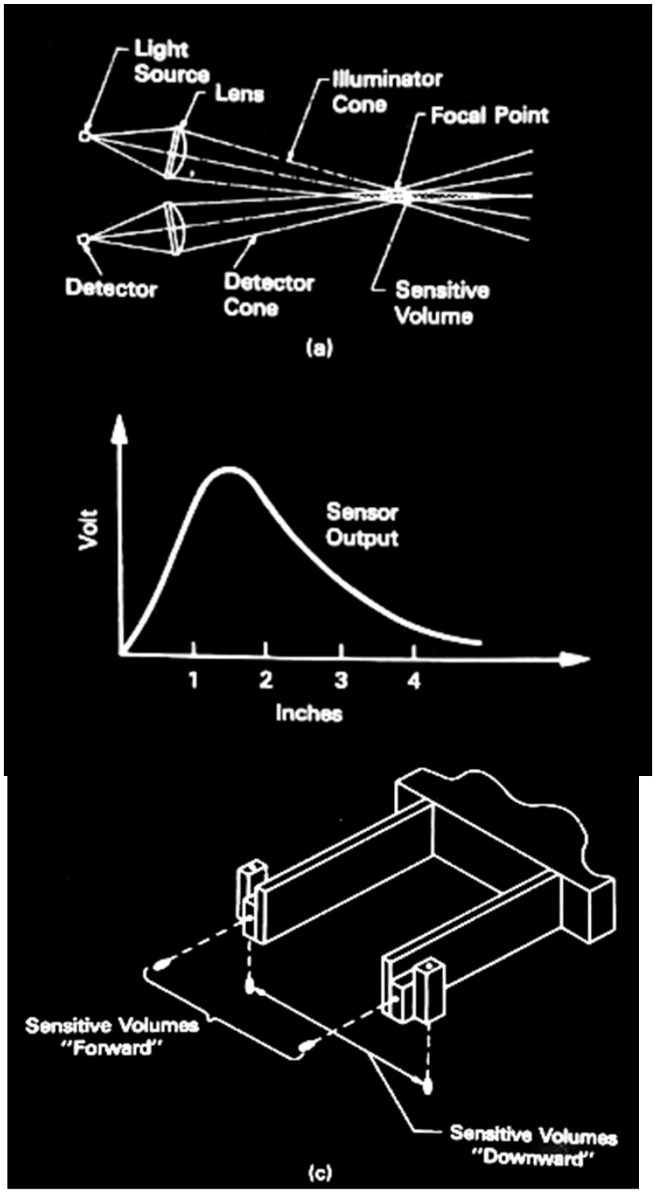
Reflected light Sensor

- One of the simplest types of proximity sensors that uses light reflected from an object and has been used experimentally on a robot gripper is shown in Figure
- The sensor consists of a source of light and a photodetector separated by about 8 mm and tilted symmetrically toward one another.
- This, together with lenses mounted in front of the assembly, produces focused incident and reflected beams.
- Figure.b shows the photodetector voltage as a function of object distance from the (detector) lens.
- Figure.c indicates that several of these sensors can be placed on a robotic gripper this way, proximity in several directions can be monitored simultaneously (e.g., ahead and below the robot's hand).



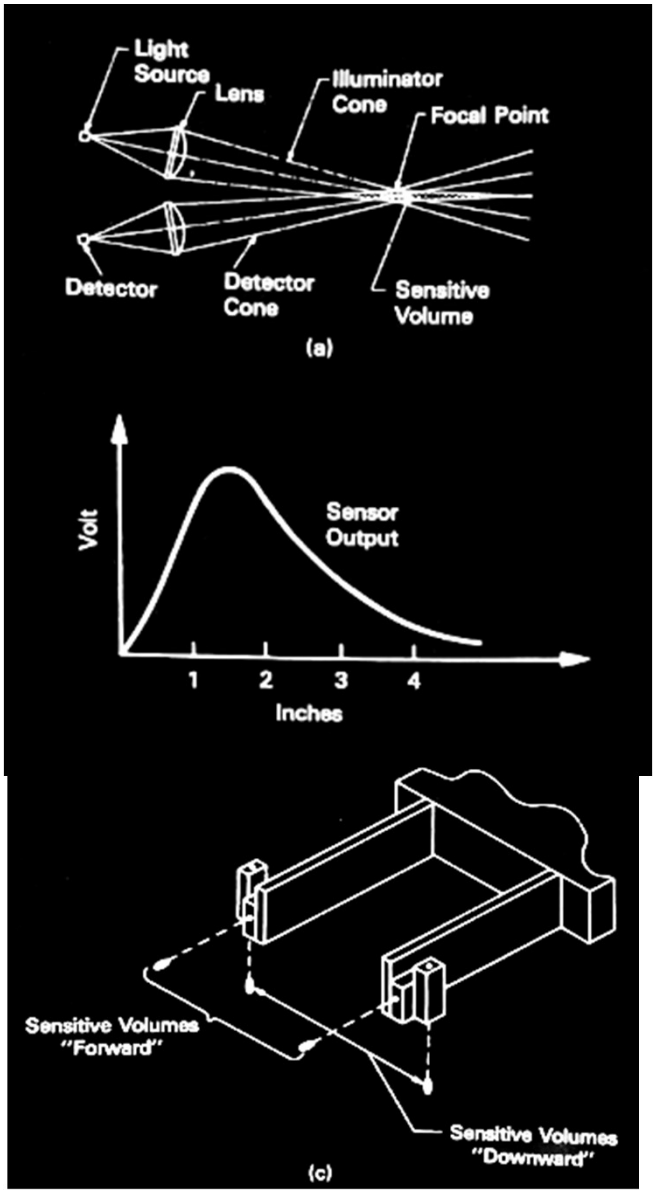
Reflected light Sensor

- Although the maximum sensor output will occur when an object (or obstacle) is at the focal point, Figure.b reveals a basic difficulty with this device.
- That is, two different object positions produce the same voltage except when the object is located exactly at the focal point. Since a one-to-one correspondence between the position and detector voltage does not exist, additional logic or hardware is required to eliminate the ambiguity.
- For example, if the robot is moving and the sensor signal is increasing, it is clear that the object is on the far side of the focal point (i.e., has yet to reach this point, and so the output corresponds to the larger of the two position values).
- If, however, the signal is decreasing, the focal point has been passed and the smaller distance should be used.
- Several sensors placed at can also be utilized to eliminate this ambiguity.

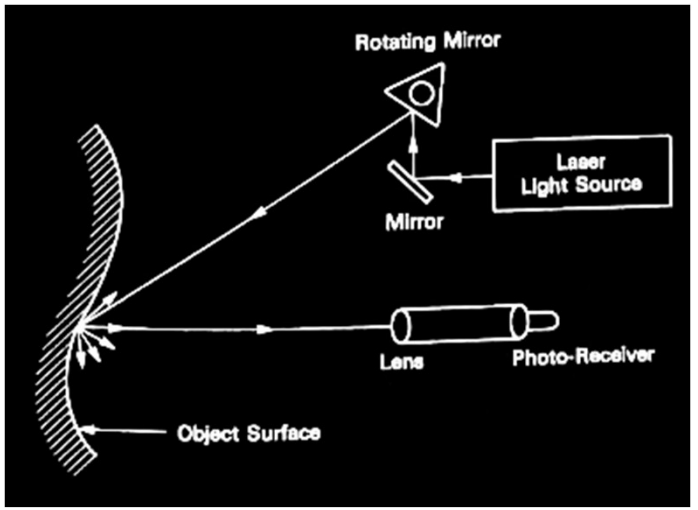


Reflected light Sensor

- Besides this difficulty, other problems with the sensor exist. For example, ambient light will shift the curve in Figure.b up or down depending on the intensity.
- A more difficult and perhaps impossible problem to overcome that the sensor is sensitive to the reflectivity of the object or obstacle. A highly reflective surface will obviously produce a larger output voltage than one that is less reflective.
- Thus it might be necessary to "calibrate" the sensor to each object So that the maximum output voltage could be found. Then, knowing the characteristic of the detector, position could be determined relative to this maximum value.
- Even with these measures implemented, it would still be difficult to use the sensor for absolute position monitoring.



Scanning laser sensors



- A considerably more involved and costly proximity sensor is shown in Figure
- Consisting of a laser light source, two mirrors, one of which is rotated by an ac motor, and a lens-photo-receiver assembly.
- This scanning laser device has been used to permit an industrial robot to arc-weld curved objects.
- The incident light beam from the laser (helium-neon) is "swept" across the object surface by the action of the motor-driven triangular mirror. Note that this occurs three times for each motor revolution.
- A lens mounted in front of a photodetector (e.g., a phototransistor) permits light reflected from only one point on the object's surface to be acquired.
- Distance from the sensor to this point is determined by synchronizing the ac motor voltage with a high-frequency clock.
- The number of clock pulses from the time this voltage is zero until the photodetector receives reflected light is a measure of the distance.

TACTILE SENSORS

- **Tactile sensor** is a device which **detects the physical contact between themselves and another object or surface.** Tactile sensor can be divided into two categories:
  1. **Touch sensors:** Touch sensor **indicates whether or not contact has been made with the object**. It **does not provide the magnitude** of the contacting force. Some of the commonly used simple devices as touch sensors are micro-switches, limit switches, etc. These sensors can be used to indicate the presence or absence of a part in a fixture or on a conveyer belt. In addition, these devices can also be used as inspection devices, which have a probe to measure the size of a component.
  2. **Force sensors:** Force sensor, also known as stress sensor, **indicates not only the contact** has been made with the object **but also the contact force** between the two objects. The force sensor is used for calculating the forces of several functions like machine loading & unloading, material handling, and so on. This sensor can also be used in the assembly process for checking the problems.

FORCE SENSING TECHNIQUES

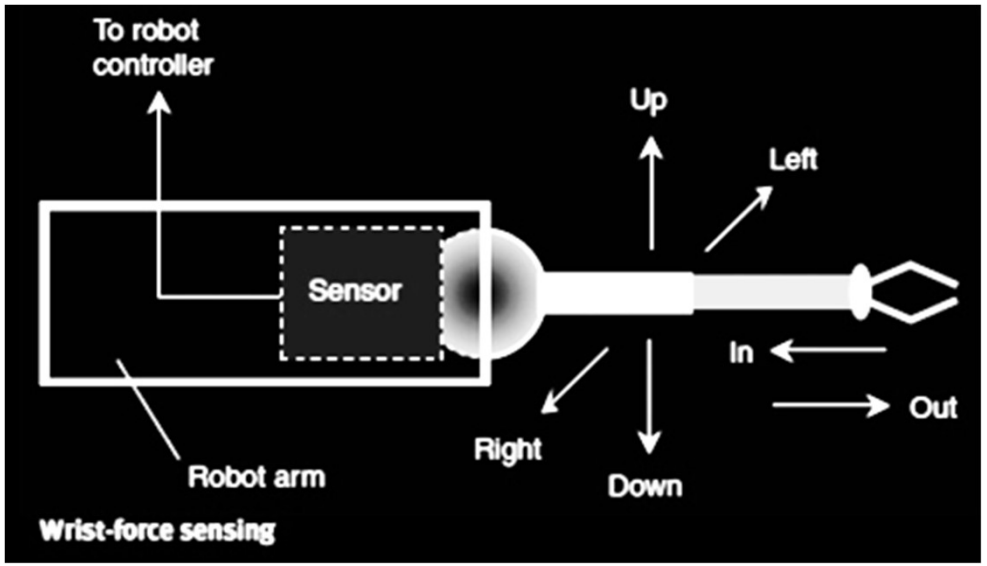
- Force sensing in robotics can be done in several ways. These techniques are as follows:

1. Force-sensing wrist
2. Joint sensing
3. Tactile array sensors

FORCE-SENSING WRIST

- Several different forces exist at the point where a robot arm joins the end effector. This point is called the wrist. A wrist-force sensor can detect and measure these forces. It consists of specialized pressure sensors known as strain gauges. The strain gauges convert the wrist forces into electric signals, which go to the robot controller. Thus the machine can determine what is happening at the wrist, and act accordingly. Wrist force is complex. Several dimensions are required to represent all the possible motions that can take place.

  - The illustration shows a hypothetical robot wrist, and the forces that can occur there. The orientations are right/left, in/out, and up/down. Rotation is possible along all three axes. These forces are called pitch, roll, and yaw. A wrist-force sensor must detect, and translate, each of the forces independently.

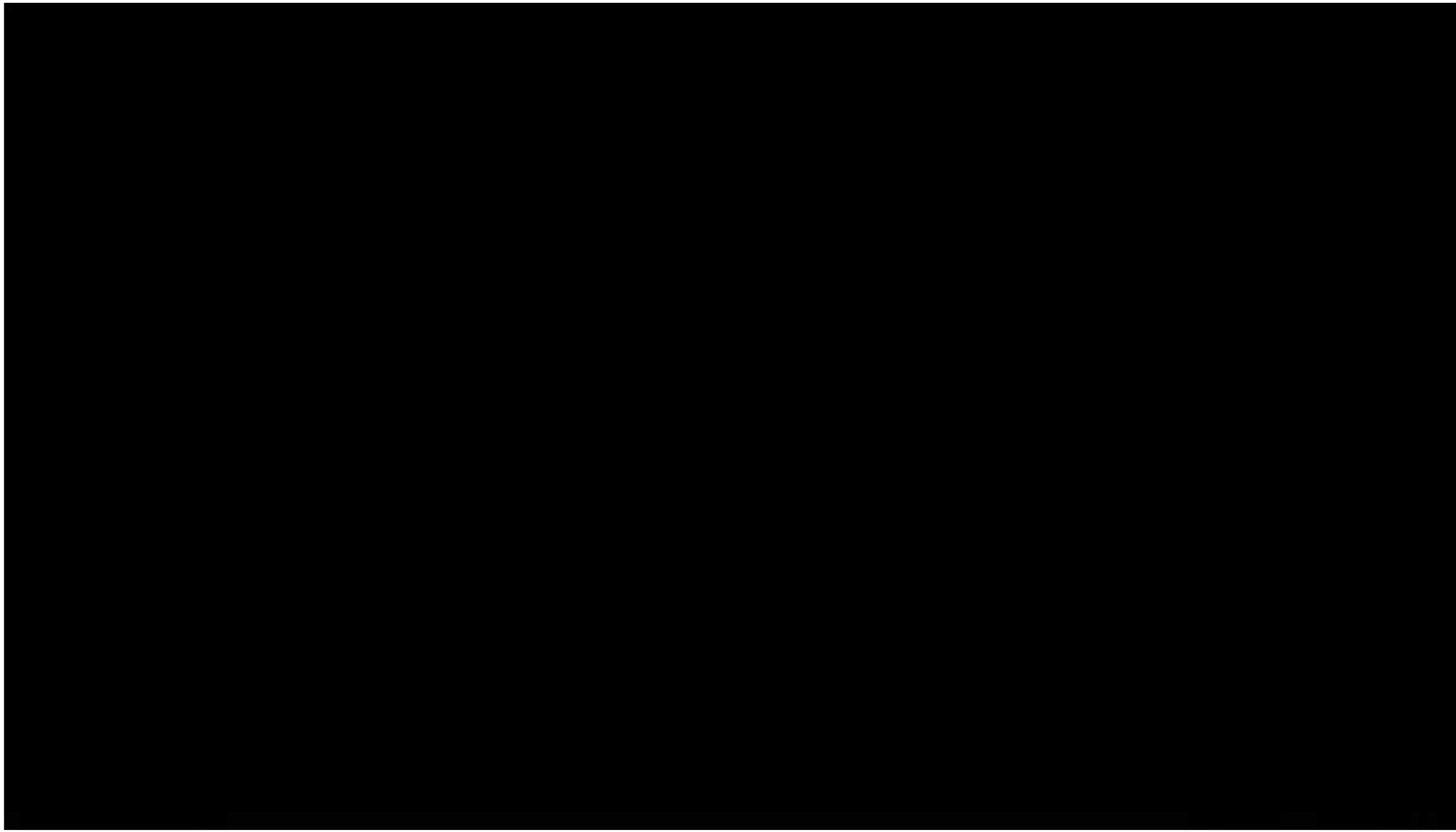


JOINT SENSING

- Joint sensing is, a very simple and attractive technique, used for the robots which use DC servomotors. In these types of robots, the torque exerted by the motors is proportional to the current flowing through the armature. To measure the current, it is simple to measure the voltage drop across a small precision resistor in series with the motor and power amplifier.
- As the forces of interest are applied by the tool, the measurements would be more useful if done in tool space. But here, the measurements are done in joint space which is the main disadvantage of this technique.

TACTILE ARRAY SENSORS

- Tactile array sensors are special types of force sensors composed of a matrix of force-sensing elements. These devices provide force data which may be combined with pattern recognition techniques to identify a number of characteristics about the object contacting the array sensor surface.
- The characteristics are: 1. the presence of the object, 2. the object's contact area, shape, location, and orientation, 3. the pressure and pressure distribution, 4. force magnitude and location.
- The device is typically composed of an array of conductive elastomer pads. By measuring the resistance of each pad, information, all the above cited characteristics can be determined.
- These sensors can be mounted in the fingers of the robot gripper or attached to a work table as a flat touch surface.



PROXIMITY AND RANGE SENSORS

- **Proximity sensor** is a device that **indicates when an object is close to the sensor**. It **uses an electronic sensing field to detect the presence** of an object. When some of these **sensors** are **used to indicate the actual distance** between the object and the sensor, they are called **range sensors.**
- Generally, the proximity and range **sensors are mounted on the robot's wrist or end effector** since these are the moving part.
- These types of sensors are **capable of pointing out the presence or absence of an object**. They may also be used for **detecting the presence of a human being** in the work volume so that the accidents can be reduced.
- **Optical proximity sensors, photoelectric proximity sensors, acoustic proximity sensors, capacitive proximity sensors** are few examples of proximity and range sensors.

PROXIMITY & RANGE SENSORS TECHNIQUES

- A variety of techniques are available for designing proximity and range sensors. These techniques include optical devices, acoustics, electrical field techniques, etc.
- **Optical proximity sensors:** It works on either visible or invisible (infrared) light sources. These sensors may be active or passive.
  - The **active sensors** send out an infrared beam and respond to the reflection of the beam against the target. The active sensor can be used to indicate not only the presence but also the position of the object. By measuring the time taken by the signal in travelling the to and fro distance between the sensor and the object, the position of the object can be calculated. This feature is useful in locomotion and guiding systems.
  - The **passive sensors** are simply devices used to detect the presence of infrared radiation in the environment. These sensors are very useful from securities point of view as they used to detect the presence of the bodies releasing heat with in the range of the sensor.

PROXIMITY & RANGE SENSORS TECHNIQUES

- Another useful **optical technique for proximity sensing involves the use of a collimated light beam and the linear array of light sensors**. By reflecting the light beam off the surface of the object, the location of the object can be determined from the position of its reflected beam on the sensor array.

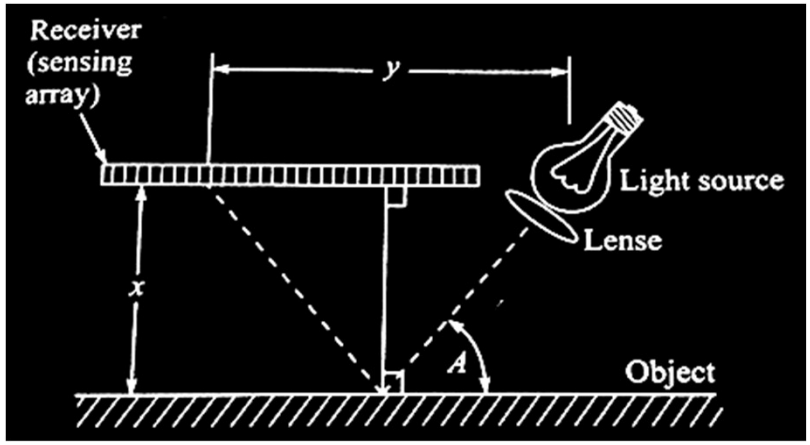
- The formula for the distance between the object an the sensor is given as follows:

$$x = 0.5\, y\, \mathrm{Tan}(A)$$

where x = the distance of the object from the sensor

y = the lateral distance between the light source and the reflected light beam

A = the angle between the object and the sensor array as shown in the figure.



PROXIMITY & RANGE SENSORS TECHNIQUES

Acoustic proximity sensors:

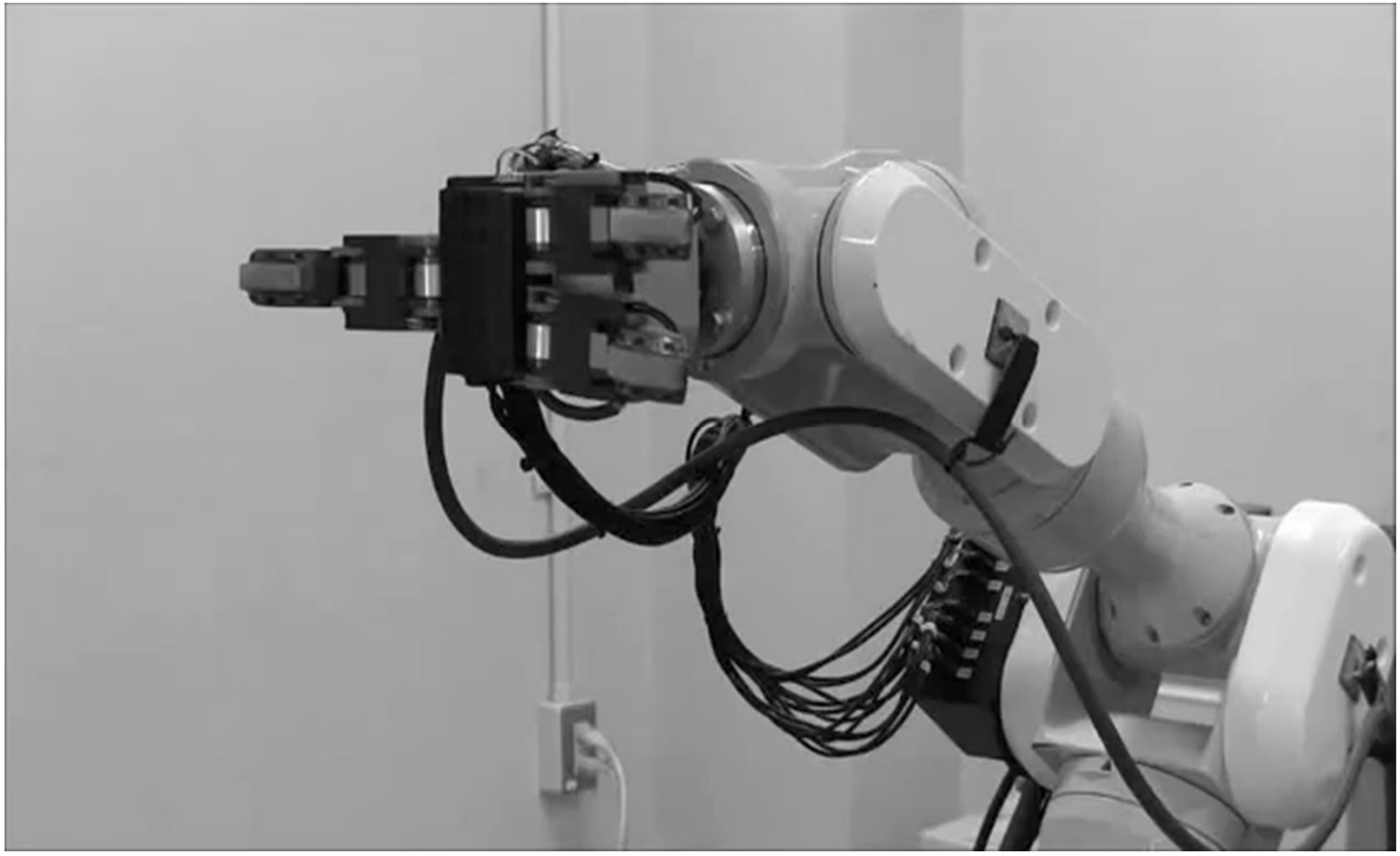
- It works on the same principle as sonar.
- An oscillator generates a pulsed signal, having a frequency somewhat above the range of human hearing.
- This signal is fed to transducer that emits ultrasound pulses at various frequencies in a coded sequence.
- These pulses reflect from the near by objects and are returned to another transducer, which converts the ultrasound back into high-frequency pulses.
- The return pulses are amplified and sent to the robot controller. The delay between the transmitted and received pulses is timed, which gives an indication of the distance to the object.

PROXIMITY & RANGE SENSORS TECHNIQUES

- Based on the use of electric fields, there are two types of proximity and range sensors available in the market:

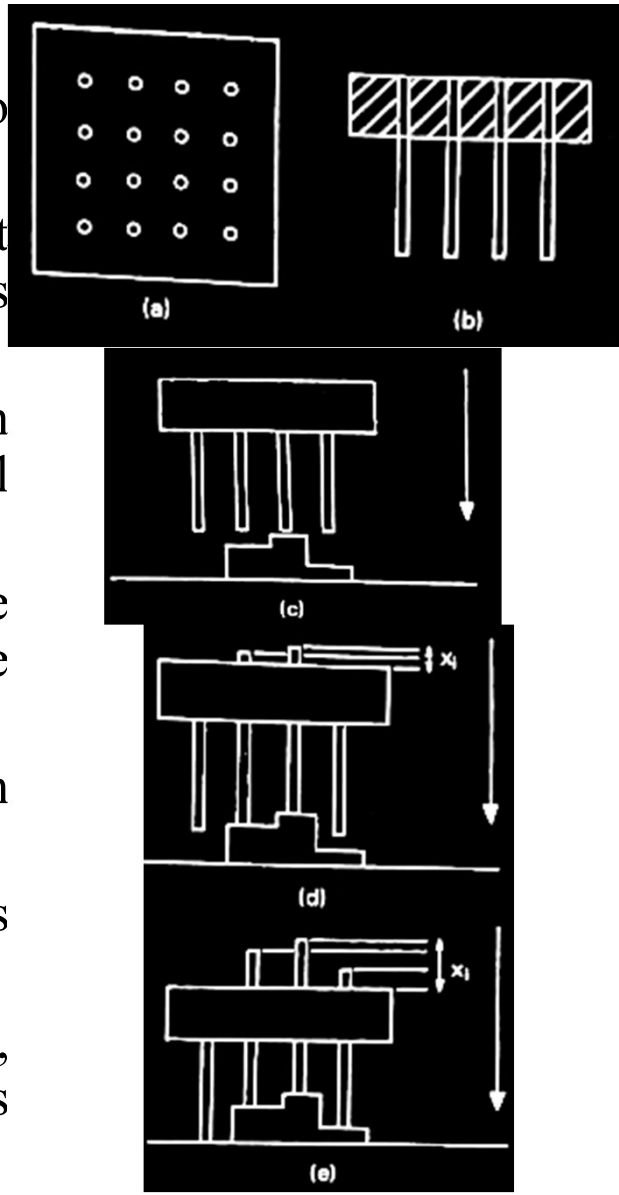
1. **Eddy-current sensors:** Eddy-current devices create a primary alternating magnetic field in the small region near the probe. This magnetic field induces eddy currents in an object placed in the region so long as the object is made of a conductive material. This eddy currents produce their own magnetic field which interacts with the primary field to change its flux density. The probe detects the change in the flux density and this indicates the presence of the object.
2. **Magnetic field sensors:** These sensors are very attractive because of their relative simplicity. One of their best feature is that they do not require any external power supply for their operation. They can be made using a reed switch and a permanent magnet. The magnet can be a part of the object being detected or it can be a part of the sensor device. In either case, the device can be designated so that the presence of the object in the region of the sensor completes the magnetic circuit and activates the reed switch.

PROXIMITY AND RANGE SENSORS



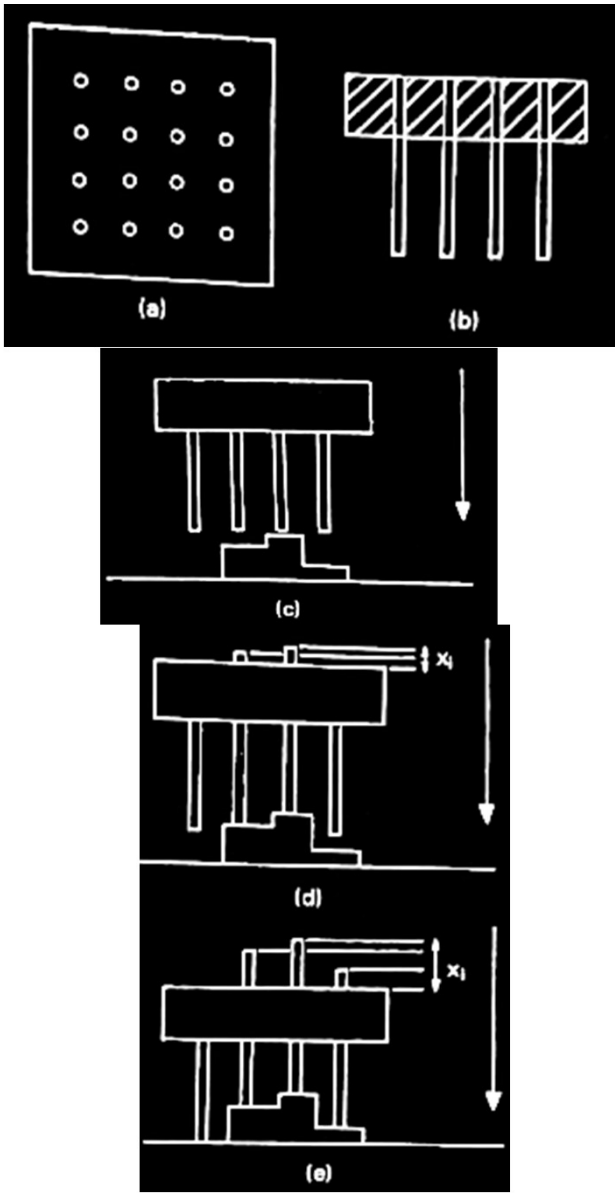
Proximity rod tactile sensors

- Certain simple proximity-sensing techniques can be extended to produce a robotic tactile sensor.
- An example of this is shown in Figure, where the single-contact rod proximity sensor has been replaced by an array of such sensors (i.e., 4 x 4 = 16).
- A possible mode of operation requires that the robot wrist on which the device is mounted be moved down toward and parallel to the table or other surface on which an object is resting.
- Descent continues until the base of the sensor is at a distance approximately equal to the length of the sensing rods above the table top
- At this point, mechanical or electrical switches connected to each of the sensor rods are checked for closure (i.e., contact).
- In this manner, a two-dimensional or binary pattern of the object is obtained.
- An appropriate set of actions can then be performed by the robot, [e.g., reorientation of the gripper (necessary) and closing of its jaws].



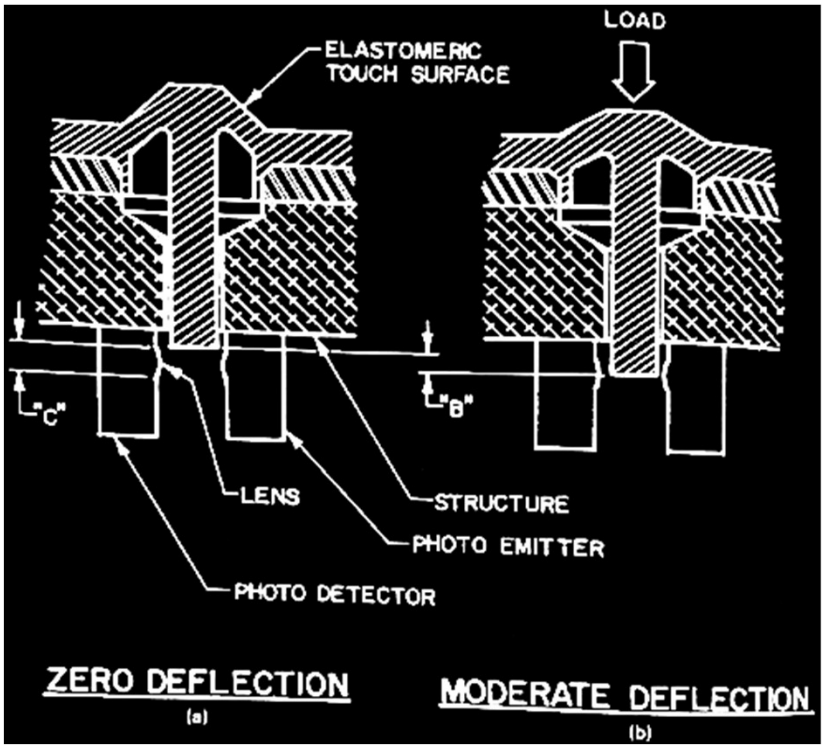
Proximity rod tactile sensors

- A major difficulty with this technique is that the robot must know exactly how far to descend toward the table surface.
- If it does not go far enough, 1t possible that not all of the sensing rods will come in contact with the object.
- it goes too far, the table will appear as part of the object.
- One method of over coming this problem is to replace the (binary) switches with elements that measuring actual distance
- With such a modification, as the sensor moves toward the object, the rods are once again pushed back into the body of the device
- (Figure.d). However, in this case, the robot stops descent when all rods have moved a minimum (or threshold) distance, there by indicating that the sensor's elements have come in contact with either the object or the table top (Figure.e). Measuring the distance moved by each these rods (relative to their starting position) yields a three-dimensional image of the object being scanned.

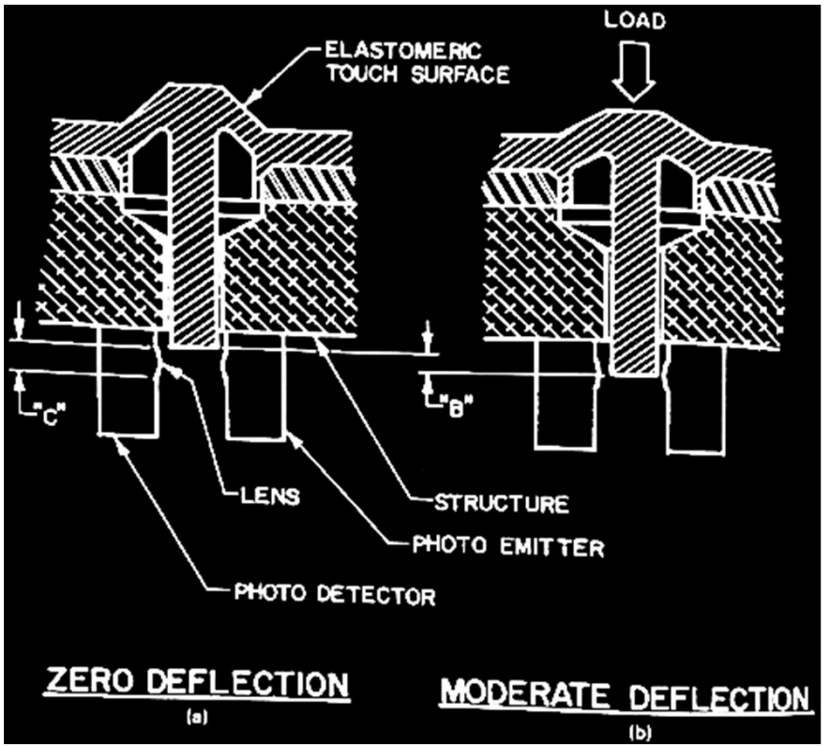


Photodetector Tactile Sensors

- Among the noncontact proximity sensors will be recalled that one used the "beam break principle."
- In 1983 the Lord Corporation described a commercial device |24] shown in Figure
- Actually, only one sensor element is indicated. In reality the sensor would, of course, consist of an array of such elements, (e.g., 8 x 8 for the Lord LTS 100)
- It can be seen that the portion of the sensor that comes in contact with the object to be sensed is covered with an elastomer (a rubber-like material). In addition, a piece of this material extends through the sensor structure. Mounted on the back of the body of the device is a photo emitter-detector assembly (see Figure).

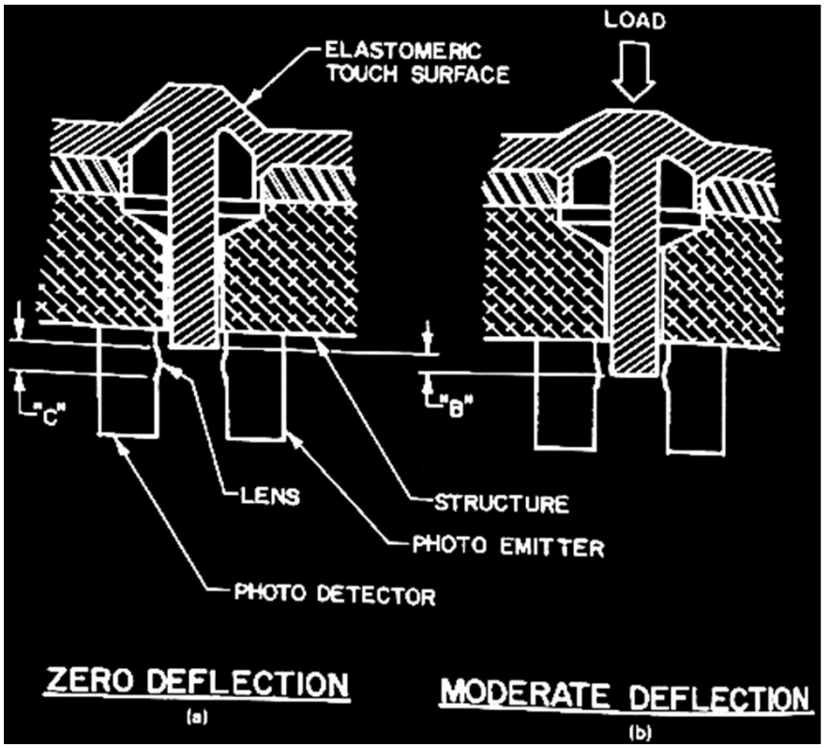


Photodetector Tactile Sensors



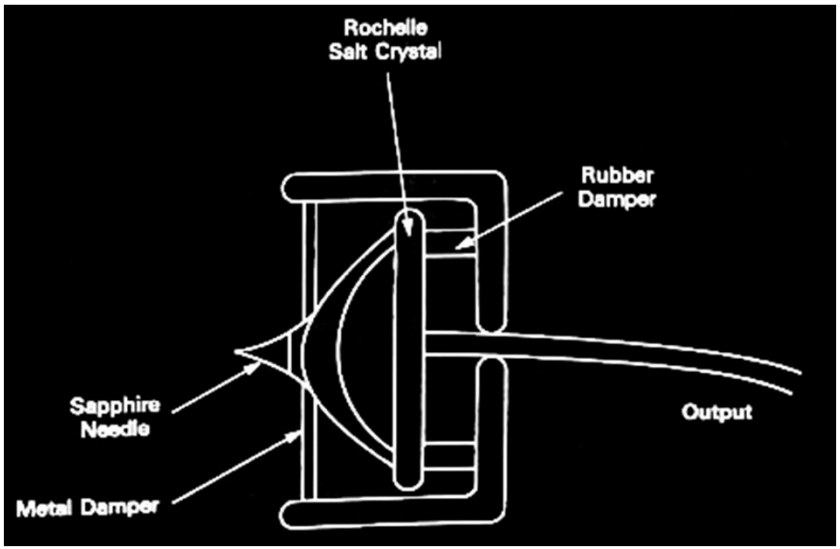
- When the object comes in contact with the touch surface, if the elastomer is compressed a minimum distance, the material extending through the body breaks the beam of the photosensor (see Figure)
- Obviously, a thresholding circuit can be used to provide binary information about the object, that is, whether or not each element of a sensor composed of such devices is in contact with in a manner similar to that described for the proximity rod contact sensor, two- dimensional information about size, shape, and part orientation can be obtained.
- It is also possible to determine information about the relative deflection at each array point.
- The voltage output from a photodetector varies with the incident light intensity. Thus, by monitoring the actual signal from the individual photo-detectors, the voltage level can be related to distance travelled by the element. Depth (e.g., three-dimensional) information is limited since the overall sensing distance is quite small.

Photodetector Tactile Sensors



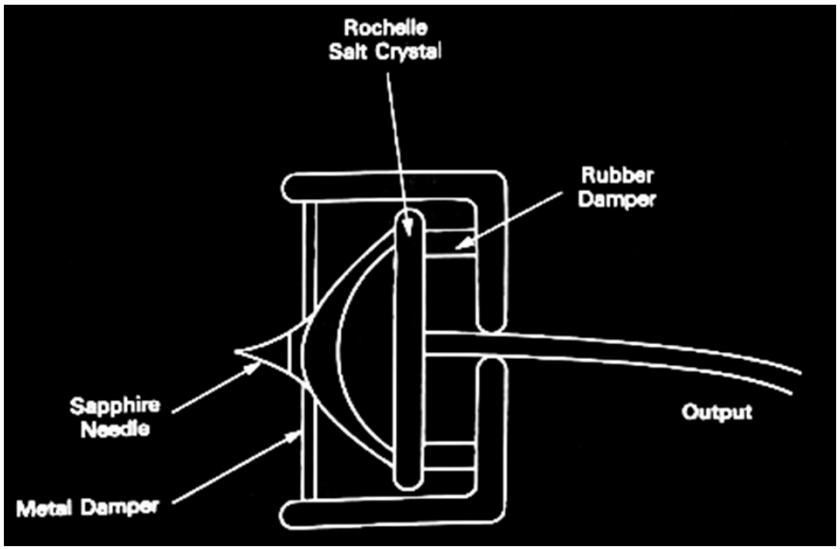
- At least two potential difficulties occur with such a sensor. The first has to do with mechanical hysteresis in the elastomer. This implies that the rubber will not return to its original position after it has been compressed.
- For a binary device, proper thresholding of photodetector signal level will probably minimize the problem.
- However, this effect will create severe problems with a sensor that is suppose to provide absolute voltage-level information
- The second problem with using this type of tactile sensor has to do with ruggedness in a manufacturing environment. Since the elastomeric surface actually must come in contact with the object being grasped by the robot, it is quite likely that significant wear will take place. This means that unless the rubber is carefully protected, it will have to be replaced quite frequently. Depending on the actual application, this may or may not be an acceptable solution.

Forced oscillation slip sensors



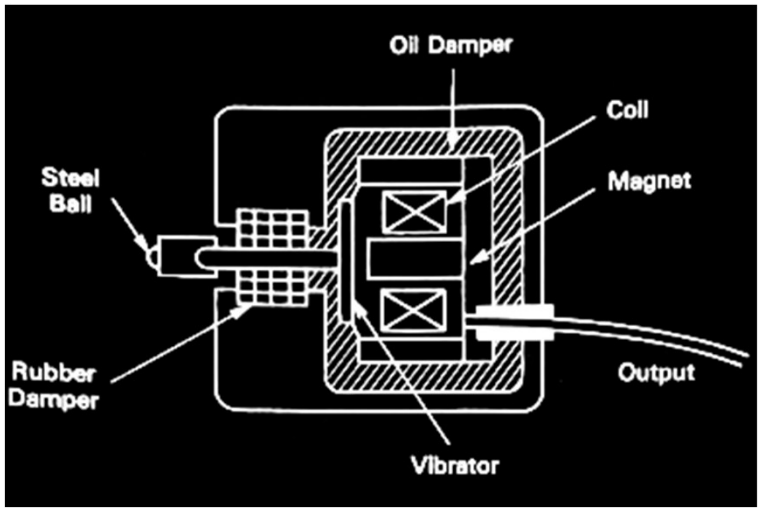
- In 1972 a group of researchers working at the Nagoya University in Japan reported on a number of experimental devices that were developed for detecting the slippage of an object being held by a robotic gripper.
- A variety of sensing techniques were employed. For example, "forced oscillation" was used whereby any translation of the part in a direction tangential to the surface of the grippe jaws (i.e., orthogonal to the direction of the applied gripping force) caused a short burst of voltage (i.e., a "spike") to be generated.
- One method of accomplishing this is shown in Figure and is very much like that used to play back signals recorded on a (analog) phonograph record.
- Here a sapphire needle protrudes from the surface of the sensor and is in contact with the object being grasped. If the part begins to slip, the needle will be displaced and will produce mechanical deformation in a piezoelectric crystal.

Forced oscillation slip sensors



- The resultant generated voltage spike can be sensed using a threshold detector and the gripping force increased incrementally until the part stops slipping.
- There are a number of difficulties with this type of slip sensor. The Major one is that, although the rubber damper shown in the figure makes the device less sensitive to non-slip-related motions, the unit still tends to respond to mechanical vibrations of the robot manipulator itself. It is important to note that such a detector must be able to sense slippage accurately while a part is being moved.
- Thus it is necessary to reduce as much as possible this sensitivity to non-slip-related motions.
- Another obvious disadvantage of the sensor described above is that the needle must move against the surface of a part in order to detect slip. This will cause eventual wear, meaning that periodic replacement of the needle will be required.
- Finally, the entire device tends to be easily damaged if it is dropped or rapidly decelerated

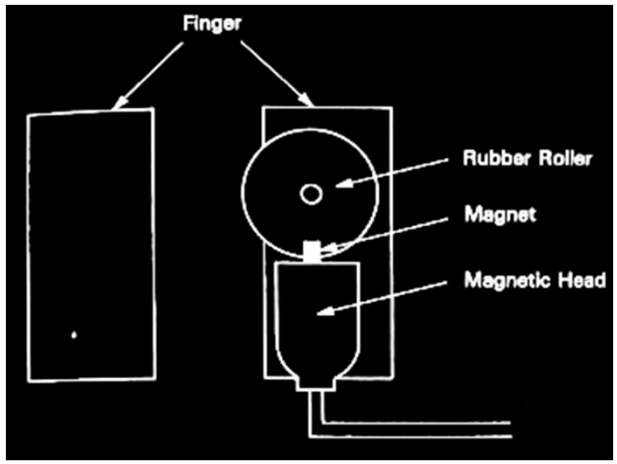
Forced oscillation slip sensors



- The unit shown in Figure incorporates a number of improvements which eliminate most of the difficulties described above .
- In particular, the sapphire needle has been replaced by a more robust steel ball (0.5 mm in diameter).
- The fragile crystal transducer has also been eliminated and in its place a permanent magnet-coil arrangement is used.
- Any motion of a part along the gripper's jaws will cause a mechanical displacement of the coil which will, in turn, produce a voltage output.
- Again, the use of dampers (both rubber and oil) and thresholding circuitry will reduce the sensitivity of the sensor to manipulator vibrations.

Interrupter-type slip sensors

- The same Japanese research group also developed additional prototype slip sensors using two techniques borrowed from other types of sensors [e.g.optical (or magnetic) encoders or interrupters].



- One such detector is shown in Figure. This device consists of a rubber roller that protrudes above the sensors surface and contains a small permanent magnet.
- Any slip of the part in the gripper's jaws will cause roller rotation. As the permanent magnet passes over the magnetic sense head (e.g., one used in a tape recorder can be employed) a pulse is generated and the gripping force can be increased accordingly.
- A major disadvantage of this technique is that the slip "resolution" is not good.
- It can be seen from Figure that if the sensor is not placed initially in a "reset" position (e.g., magnetic section of the roller over the read head), it will take some fraction of an entire rotation before any slip is detected.
- Even if the reset position is used to begin with, so that slip will then be detected as soon as almost any rotation occurs, further slip will not be sensed until one additional roller revolution occurs.

ROBOT PROGRAMMING

- **Programming** is the *identification* and *specification* of a series of *basic actions* which, when executed in the specified order, achieve some specific task or realize some specific process.
- **Robot Programming** is the defining of desired motions so that the robot may perform them without human intervention.

- According to the consistent performance by the robots in industries, the robot programming can be divided in two common types such as:
  - Lead through Programming Method (online Programming)
  - Off-line Programming

Lead through Programming Method:

- During this programming method, the traveling of robots is based on the desired movements, and it is stored in the external controller memory. There are two modes of a control system in this method such as a run mode and teach mode. The program is taught in the teach mode, and it is executed in the run mode.

Leadthrough Programming Method
- Textual Robot Languages

ROBOT PROGRAMMING

- The lead through programming method can be done by two methods.

- Powered Lead through Method**:**

  The powered lead through is the common programming method in the industries. A teach pendant is incorporated in this method for controlling the motors available in the joints. It is also used to operate the robot wrist and arm through a sequence of points. The playback of an operation is done by recording these points. The control of complex geometric moves is difficult to perform in the teach pendant. As a result, this method is good for point to point movements. Some of the key applications are spot welding, machine loading & unloading, and part transfer process.

- Manual Lead through Method

  In this method, the robot's end effector is moved physically by the programmer at the desired movements. Sometimes, it may be difficult to move large robot arm manually. To get rid of it a teach button is implemented in the wrist for special programming. The manual lead through method is also known as Walk Through method. It is mainly used to perform continuous path movements. This method is best for spray painting and arc welding operations.

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

- Lead through programming is not readily compatible with modern computer based technology.

Advantages:

- Easy
- No special programming skills or training

Disadvantages:

- Robot cannot be used in production, while it is being programmed.
- not practical for large or heavy robots
- High accuracy and straight-line movements are difficult to achieve, as are any other kind of geometrically defined trajectory, such as circular arcs, etc.
- difficult to edit out unwanted operator moves
- difficult to incorporate external sensor data
- Synchronization with other machines or equipment in the work cell is difficult
- A large amount of memory is required

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

➢ Off-line Programming:

- ➢ Similar to the way in which CAD systems are being used to generate NC programs for milling machines it is also possible to program robots from CAD data. The CAD models of the components are used along with models of the robots being used and the fixturing required.
- ➢ The program structure is built up in much the same way as for teach programming but intelligent tools are available which allow the CAD data to be used to generate sequences of location and process information.
- ➢ At present there are only a few companies using this technology as it is still in its infancy but its use is increasing each year.
- ➢ The benefits of this form of programming are:-
  - Reduced down time for programming.
  - Programming tools make programming easier.
  - Simplification of complex tasks
  - Optimization of robot programs
  - Access control
  - Reduction of the robot operating time
  - Single robot programming system
  - Integration of CAD / CAM systems
  - Cycle time analysis
  - Verification of robot programs

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

Programming Languages for Robotics:

- There are many programming languages which we use while building Robots, we have a few programming languages which we always prefer to use in designing.
- Actually the programming languages which can be used mainly depend on the hardware used to the building robots.
- URBI : URBI stands for Universal Real-time Behavior Interface.
- It is a client/server based interpreted language in which Robot works as a client and controller as a server.
- It makes us to learn about the commands which we give to Robots and receive messages from them.
- The interpreter and wrapped server are called as "URBI Engine". The URBI Engine uses commands from Client and receives messages to it.
- This language allows user to work on basic Perception-action principle. The users just have to write some simple loops on the basis of this principle directly in URBI.

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

Programming Languages for Robotics:

- PYTHON : There is another language which is used in designing Robots.
- Python is an object-oriented language which is used to access and control Robots.
- Python is an interpreted language; this language has an application in working with mobile robots, particularly those manufactured by different companies.
- With python it is possible to use a single program for controlling many different robots. However Python is slower than C++ but it has some good sides as well as it proved very easy to interact with robots using this language, it is highly portable and can be run in windows and MAC OSX plus it can easily be extendable using C and C++ language.
- Python is a very reliable language for string manipulation and text processing.
- ROBOTC is another programming language which is C-based.
- It is actually a text based programming language.
- The commands which we want to give to our Robot, first written on the screen in the form of simple text, now as we know that Robot is a kind of machine and a machine only understands machine language. So these commands need to be converted in machine language so that robot can easily understand and do whatever it is instructed to do.

Leadthrough Programming Method
- Textual Robot Languages

ROBOT PROGRAMMING

Programming Languages for Robotics:

- Microsoft Robotics Developer Studio is an environment given for simulation purpose of Robots.
- It is based on a .net library concurrent implementation. This environment has support so that we can add other services as well.
- It has features which not only include creating and debugging Robot Applications but also it becomes easy to interact with sensors directly.
- C programming language is used as a primary language in it.
- If we want to graphics and visual effects in our programming, we use VPL.
- Visual Programming language is a programming language which allows us to create programs by doing manipulations in programming languages graphically.
- We use boxes and arrows in this kind of programming while we want to show dataflow kind of things.

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

Textual Robot Languages:

- In 1973, WAVE language was developed, and it is the first textual robot language as well. It is used to interface the machine vision system with the robot.
- Trajectory calculations through coordination of joint movements, end-effector positions and touch sensing were some of the new features of WAVE. But the algorithm was too complex and not user-friendly.
- Then AL language was introduced in 1974 for controlling multiple robot arms during arm coordination.
- VAL was invented in 1979, and it is the common textual robot language. Later, this language was dated in 1984, and called as VAL II.
- The IBM Corporation has established their two own languages such as AML and AUTOPASS, which is used for the assembly operations.
- AML is very useful for assembly operations as different user—robot programming interfaces are possible. The programming language AML is also used in other automated manufacturing systems.
- Other important textual robot languages are Manufacturing Control Language (MCL), RAIL, and Automatic Programmed Tooling (APT) languages.

Leadthrough Programming Method

- Textual Robot Languages

ROBOT PROGRAMMING

➢ Textual Robot Languages:

- ➢ Other important textual robot languages are Manufacturing Control Language (MCL), RAIL, and Automatic Programmed Tooling (APT) languages.
- ➢ US Air force ICAM project led to the development of another manufacturing control language known as MCL by McDonnel—Douglas. This is a modification of the popular APT (Automatically Programmed Tooling) language used in CNC machine tools as many similar commands are used to control
- ➢ RAIL Was developed by Automatic for robotic assembly, inspection, arc Welding and machine vision.
- ➢ A variety of data types as used in PASCAL can be used. It uses Motorola 68000 type microcomputer system; It supports many commands and control of the vision system.
- ➢ HELP was developed by General Electric Company. It acts more or less like RAIL. It has the capability to control two robot arms at the same time. The structure of the language is like PASCAL.
- ➢ JARS was developed by NASA JPL. The base of the language is PASCAL. JARS can be interfaced with PUMA 6000 robot for running robotic programs.

ROBOT PROGRAMMING

Textual Robot Languages:

- RPL was developed at SRI International. A compiler is used to convert a program into the codes that can be interpreted by an interpreter. Unimation PUMA 500 can be controlled with the help of RPL. The basic ideas of LISP (an Al language) have been organized into a FORTRAN-like syntax in RPL. It is modular and flexible.
- Besides these, there are some other languages like PAL, ADA etc. PAL has been written by Richard Paul by modifying WAVE and incorporating features of PASCAL. But the representations of syntaxes used in the program are difficult to handle. ADA developed by the Department of Defense (DOD) in USA is a real-time system that can be run on several microcomputers like Zilog, VAX, Motorola 68000, etc. ADA is convenient for controlling the robots used in a manufacturing cell.
- Different textual robot languages have different attributes. Far example, VAL, HELP and MC though powerful for many simple tasks, do not have the same structured modular programming capability like AL, AML, JARS and ADA or VAL II. In a manufacturing cell, multiple robots or robotic equipment work in unison. Control of two or more operations done by the robots in a coordinated manner is complex .