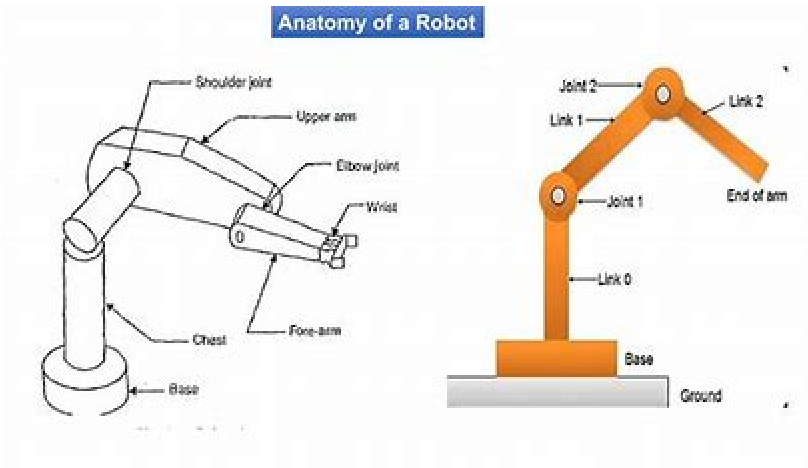
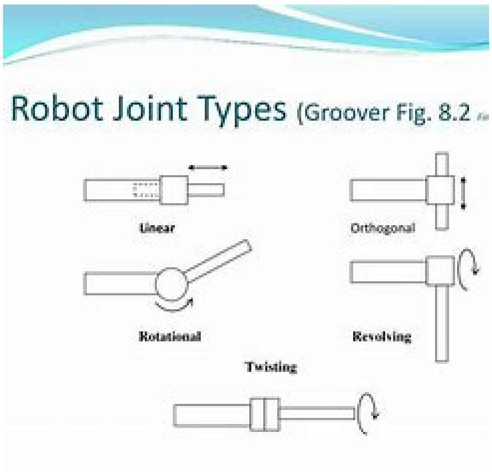
ROBOT ANATOMY

Joints and Links:

The manipulator of an industrial robot consists of a series of joints and links. Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion. In most of the cases, only one degree-of freedom is associated with each joint. Therefore the robot's complexity can be classified according to the total number of degrees-of-freedom they possess. Each joint is connected to two links, an input link and an output link. Joint provides controlled relative movement between the input link and output link. A robotic link is the rigid component of the robot manipulator. Most of the robots are mounted upon a stationary base, such as the floor. From this base, a joint-link numbering scheme may be recognized as shown in Figure 1. The robotic base and its connection to the first joint are termed as link-0. The first joint in the sequence is joint-1. Link-0 is the input link for joint-1, while the output link from joint-1 is link-1—which leads to joint-2. Thus link 1 is, simultaneously, the output link for joint-1 and the input link for joint-2. This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.



Nearly all industrial robots have mechanical joints that can be classified into following five types as shown in Figure 2.



Types of Joints

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

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

c) 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.

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

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

CLASSIFICATION OF ROBOT

The ways of classifying a robot as follows

1) According to the structural capability of robot –

i) mobile or ii) fixed robot.

i) Mobile robot: A mobile robot is an automatic machine that is capable of locomotion. . Example: spying robot. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. Mobile robots can be "autonomous" (AMR - autonomous mobile robot) which means they are capable of navigating an uncontrolled environment without the need for physical or electro-mechanical guidance devices. Alternatively, mobile robots can rely on guidance devices that allow them to travel a pre-defined navigation route in relatively controlled space (AGV - autonomous guided vehicle). By contrast, industrial robots are usually more-or-less stationary, consisting of a jointed arm (multi-linked manipulator) and gripper assembly (or end effector), attached to a fixed surface

ii) Fixed Robot: Most industrial robots are fixed with the base but the arms are moving.

2) According to the control To perform as per the program instructions, the joint movements an industrial robot must accurately be controlled. Micro-processor-based controllers are used to control the robots. Different types of control that are being used in robotics are given as follows

. a. Limited Sequence Control: It is an elementary control type. It is used for simple motion cycles, such as pick-and-place operations. It is implemented by fixing limits or mechanical stops for each joint and sequencing the movement of joints to accomplish operation. Feedback loops may be used to inform the controller that the action has been performed, so that the program can move to the next step. Precision of such control system is less. It is generally used in pneumatically driven robots.

b. Playback with Point-to-Point Control Playback control uses a controller with memory to record motion sequences in a work cycle, as well as associated locations and other parameters, and then plays back the work cycle during program execution. Point-to-point control means individual robot positions are recorded in the memory. These positions include both mechanical stops for each joint, and the set of values that represent locations in the range of each joint. Feedback control is used to confirm that the individual joints achieve the specified locations in the program.

c. Playback with Continuous Path Control Continuous path control refers to a control system capable of continuous simultaneous control of two or more axes. The following advantages are noted with this type of playback control: greater storage capacity—the number of locations that can be stored is greater than in point-to-point; and interpolation calculations may be used, especially linear and circular interpolations.

d. Intelligent Control An intelligent robot exhibits behavior that makes it seems to be intelligent. For example, it may have capacity to interact with its ambient surroundings; decision-making capability; ability to communicate with humans; ability to carry out computational analysis during the work cycle; and responsiveness to advanced sensor inputs. They may also possess the playback facilities. However, it requires a high level of computer control, an advanced programming language for decision-making logic and other ‗intelligence' into the memory.

Degree of freedom:

In mechanics, the degree of freedom (DOF) of a mechanical system is the number of independent parameters that define its configuration. It is the number of parameters that determine the state of a physical system and is important to the analysis of systems of bodies in mechanical engineering, aeronautical engineering, robotics, and structural engineering. The position and orientation of a rigid body in space is defined by three components of translation and three components of rotation, which means that it has six degrees of freedom. The six degrees of freedom of movement of a ship The motion of a ship at sea has the six degrees of freedom of a rigid body.

The load carrying capacity of a robot:

often referred to as its payload capacity, is the maximum weight it can lift and manipulate during operation, influenced by various design factors.

Payload capacity refers to the maximum weight a robot can safely lift and mov e. This includes not only the weight of the objects being handled but also any a dditional equipment or tools attached to the robot's end effector. It is typically expressed in kilograms (kg) or pounds (lbs) and is a critical specification when s electing a robot for specific task.

Application of robots in industrial and commercial sectors.

Industrial robotics applications are the use of robots to automate repetitive, dangerous, or high-precision tasks in manufacturing and other industries. Common applications include **welding, painting, assembly, material handling, machine tending, and packaging**.

some of the key applications of robots in commercial settings:

- Security: Autonomous security robots are being developed to protect businesses and prevent crime. These robots can provide real-time intelligence and assist human security personnel
  Manufacturing: Robots are used in assembly, inspection, and material handling to perform tasks with precision and speed, improving production efficiency
  Healthcare: Robotic assistance in surgeries and other medical procedures is becoming more common, offering specialized care and reducing the workload on human staff.
  Entertainment: Robots are used in theme parks and movie sets to manage operations and provide entertainment, enhancing the overall experience for customers.

Direct Kinematics for Three Degrees of Freedom

The direct kinematics problem for a three-degree-of-freedom (DOF) mechanism involves determining the joint displacements required to achieve a specific end-effecter position and orientation. This problem is crucial for the design and control of robot mechanisms, as it ensures that the end-effecter can perform desired tasks with precision. The kinematic equations must be solved for joint displacements given the end-effecter position and orientation, and the desired end-effecter motion can be achieved by moving each joint to the determined value

For a three-degree-of-freedom parallel mechanism, the architecture consists of a mobile platform attached to a base through three identical prismatic-revolute-spherical jointed serial linkages. The prismatic joints are considered to be actuated, and the mechanism's inverse displacement solution is obtained. Constraint equations describing the inter-relationship between the six motion coordinates are derived, allowing for the definition of parasitic motions.

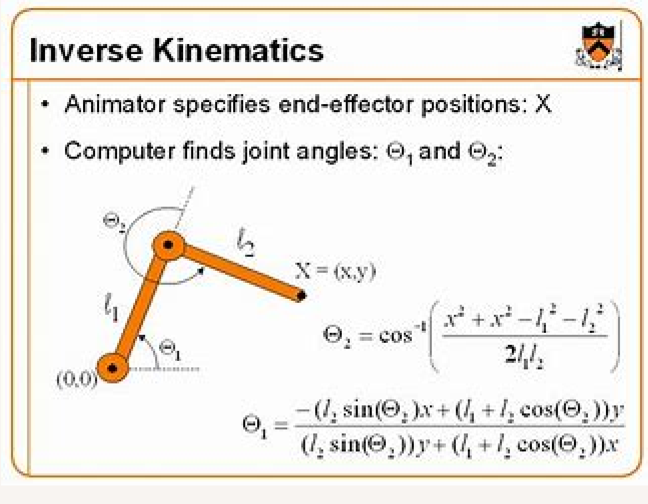
The kinematic design of a spherical three-degree-of-freedom parallel manipulator has been studied in detail, but the direct kinematic problem has not been addressed in the context of manipulators with noncoplanar gripper axes. However, the structure of these manipulators has been shown to lead to a polynomial of degree 8, which can be used to support the direct kinematic problem. The translational three-degree-of-freedom parallel mechanism has been studied for its potential in industrial production lines, where process operations require only pure translational motions. This mechanism consists of three fixed actuated prismatic joints and has analytic solutions to the direct and inverse kinematic problems.

In summary, the direct kinematics for three degrees of freedom involves solving the kinematic equations for joint displacements given the end-effecter position and orientation, ensuring that the end-effecter can perform desired tasks with precision. This problem is central to the design and control of robot mechanisms and has been addressed in various studies and research papers.

Inverse kinematics for a 3-DOF robotic system involves calculating the joint angles required to position the end effector at a desired location in space.

Understanding Inverse Kinematics

Inverse kinematics (IK) is a mathematical process used in robotics to determine the joint parameters that achieve a specific position and orientation of the end effector (e.g., a robotic hand or tool). For a 3DOF manipulator, which typically consists of three rotational joints, the goal is to find the angles of these joints that will place the end effector at a desired point in a three-dimensional space.



Key Concepts

1. **Degrees of Freedom**: A 3-DOF manipulator can move in three independent directions, allowing it to reach various positions and orientations. Each joint contributes to the overall movement capability of the manipulator.
2. **Mathematical Modeling**: The kinematic equations are derived using transformation matrices, often employing the Denavit-Hartenberg (DH) convention to systematically describe the relationship between joint parameters and the end effector's position.
3. **Algorithms**: Various algorithms can be used to solve the inverse kinematics problem, including:

- **Geometric Methods**: These involve visualizing the manipulator's configuration and using geometric relationships to derive joint angles.
- **Analytical Methods**: These use algebraic equations to directly compute joint angles based on the desired end effector position.
- **Numerical Methods**: These iterative approaches, such as the Jacobian method, are used when analytical solutions are difficult to obtain.

Different types of driver and actuator system

The driver and actuator system is a crucial component in various applications, from robotics to industrial automation. Here are the different types of driver and actuator systems:

- **Electrical Actuators**: These actuators use electrical energy to produce motion and are widely used in various applications due to their precision and reliability. They are available in two main types: Linear Actuators and Rotary Actuators.
- **Pneumatic Actuators**: Utilizing compressed air, these actuators are known for their speed and efficiency, making them ideal for applications requiring quick movements.
- **Hydraulic Actuators**: Operating using pressurized hydraulic fluid, these actuators are capable of generating high force and are commonly used in heavy machinery and industrial applications.

Mechanical Actuators: These actuators convert mechanical energy into motion and are often simpler in design. They are used in various applications, including robotics and conveyor systems.

Each type of actuator has its own set of advantages and applications, making it essential to choose the right one for a specific project.

Hydraulic Driver and Actuator System Working Principle

The hydraulic driver and actuator system operates on the principle of Pascal's Law, which states that pressure applied to a confined fluid is transmitted undiminished in all directions. This principle is utilized in hydraulic actuators to convert hydraulic energy into mechanical motion. The system consists of several key components:

- **Hydraulic Fluid**: Typically mineral oil or synthetic fluids, responsible for transferring force.
- **Cylinder/Actuator Body**: Encloses the fluid and houses the piston.
- **Piston/Rod Assembly**: Converts fluid pressure into linear or rotary motion.
- **Valves**: Control fluid flow direction, pressure, and speed.

  When pressurized fluid enters the actuator, it pushes the piston, generating linear thrust (for cylinders) or rotational torque (for motors). This mechanism enables hydraulic actuators to produce forces ranging from hundreds to millions of Newtons, making them suitable for heavy-duty applications. The system's strength, accuracy, and reliability make it indispensable across numerous industries.
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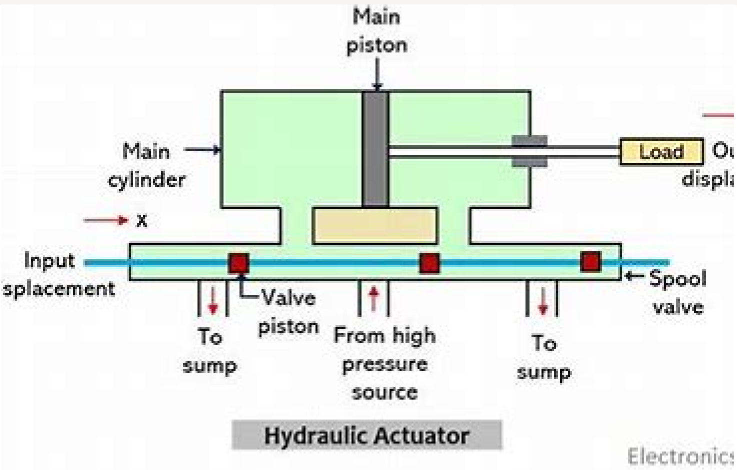
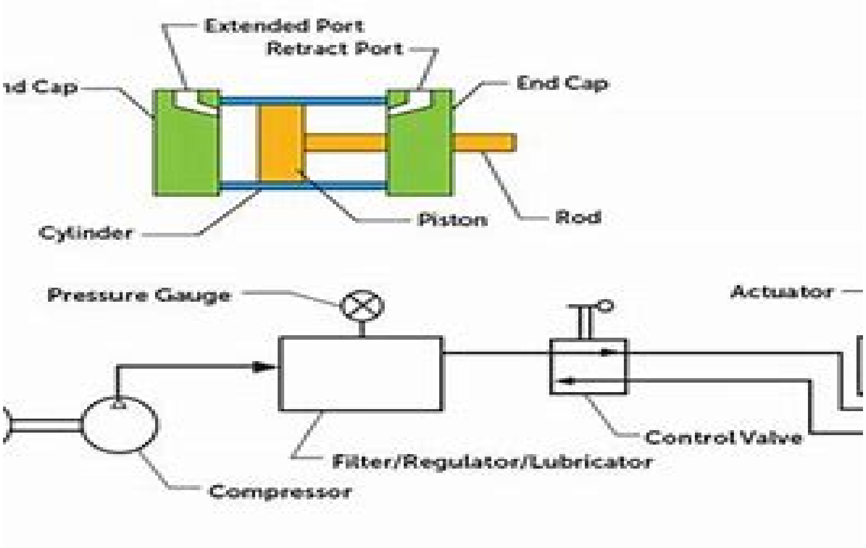


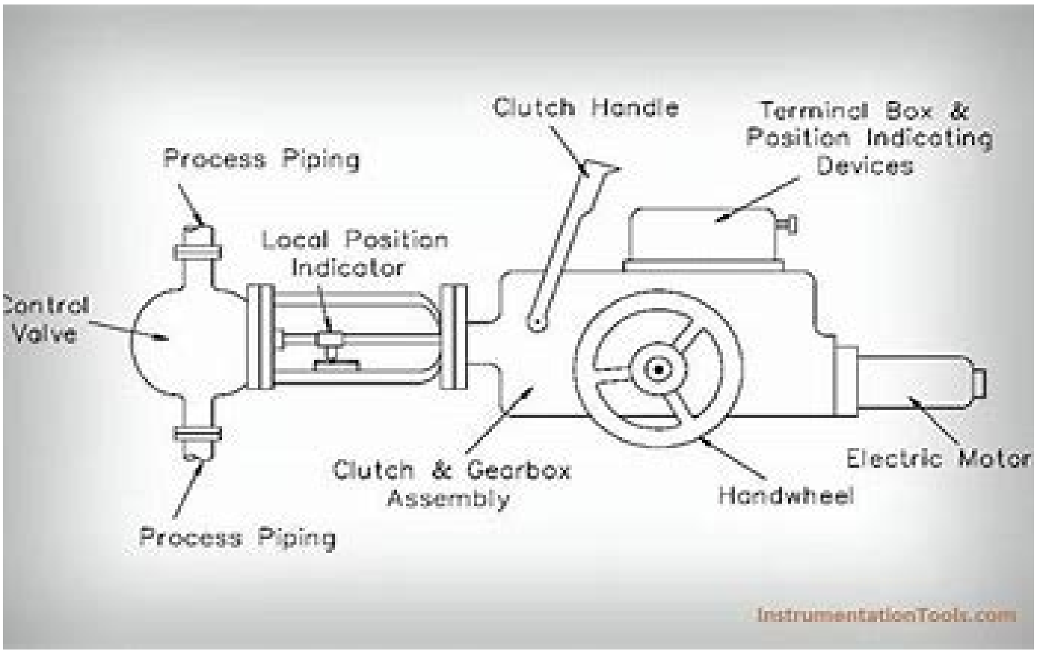
Pneumatic Driver and Actuator System Working Principle
The working principle of a pneumatic driver and actuator system involves using compressed air to move a piston inside a cylinder. The pressure forces the piston to move, generating linear or rotary motion. This movement can be controlled for precise movement in automation systems. Compressed air entering one side of the cylinder pushes the piston forward, generating linear motion. The expelled air exits through an exhaust port. In double-acting actuators, compressed air is supplied alternately to both sides of the piston, allowing controlled back-and-forth movement for greater precision. For rotary pneumatic actuators, the piston inside is connected to a rack-and-pinion mechanism or a vane-style design, which converts the linear motion into rotational motion. These are commonly used in applications requiring controlled rotary motion, such as butterfly valves and robotic automation. The efficiency of a pneumatic actuator depends on the air pressure supplied, the quality of seals, and the design of the cylinder. Regular maintenance, such as checking for leaks and ensuring proper lubrication, helps maintain optimal performance and extends the lifespan of the actuator.



Electrical Driver and Actuator System Working Principle
The working principle of an electrical driver and actuator system involves the conversion of electrical signals into mechanical motion. This process typically includes the following steps:

1. **Power Source**: The system is powered by electricity, which is the energy source for the actuators.

2. **Motor**: The electric motor converts electrical energy into mechanical force, which is essential for the actuator's operation.
3. **Gear Mechanism**: The gear mechanism reduces the motor's speed while increasing the torque output, allowing the actuator to move the load.
4. **Lead Screw/Ball Screw**: These components convert the rotational motion into linear motion, providing the necessary movement for the actuator.
5. **Position Sensor**: This feedback system provides continuous information about the actuator's position, ensuring precise control.
6. **Limit Switches**: These prevent over-travel and protect the actuator from mechanical damage.
7. **Control Electronics**: This includes motor drivers, controllers, and communication interfaces for system integration.
   The control system sends an electrical signal to the actuator's control electronics, which generates appropriate power signals for the electric motor. The motor then converts electrical energy into mechanical energy, which is further modified by the gear mechanism and lead screw/ball screw to achieve the desired motion. Position sensors and limit switches ensure that the actuator operates within defined limits, maintaining accuracy and safety in its operation



Classification of end effectors,

End effectors are classified into various types based on their design and functionality, including grippers, vacuum grippers, and specialized tools, each serving distinct roles in robotic applications.

Overview of End Effectors

End effectors are devices attached to the end of a robotic arm, enabling robots to interact with their environment. They are crucial for performing tasks such as gripping, cutting, welding, and sensing. The classification of end effectors can be broadly categorized based on their design, construction, and application.

Types of End Effectors

1. **Grippers**:

- **Mechanical Grippers**: Utilize jaws or fingers to grasp objects. They are versatile and can handle various shapes and sizes, making them suitable for tasks like pick-and-place operations.
- **Pneumatic Grippers**: Operate using compressed air to create movement. They are effective for tasks requiring quick and powerful gripping.
- **Electric Grippers**: Use motors to control the gripping action, allowing for precise handling of objects.

2. **Vacuum Grippers**:

- These employ suction cups to pick up and hold smooth or flat objects, such as glass or metal sheets. They are widely used in packaging and manufacturing due to their efficiency and ability to handle delicate items without damage.

3. **Magnetic Grippers**:

- Designed for handling ferromagnetic materials, these grippers use magnetic force to lift and move objects. They are particularly useful in metal fabrication and construction.

4. **Adhesive Grippers**:

- Utilize sticky surfaces to pick up items, making them ideal for delicate applications like handling fabrics or electronics.

5. **Tool-Based End Effectors**:

- These are specialized tools attached to robotic arms for specific tasks, such as welding torches for precise welding operations or cutting tools for material processing.

6. **Sensors**:

- Some end effectors are equipped with sensors that provide feedback about the environment, enhancing the robot's ability to perform tasks accurately.

Applications of End Effectors

End effectors are employed across various industries, including manufacturing, healthcare, automotive, and electronics. Their ability to perform precise and repetitive tasks makes them essential for improving efficiency and safety in automated systems. In summary, end effectors play a vital role in robotics, enabling machines to perform a wide range of tasks effectively. Understanding their classifications and functionalities is crucial for selecting the right end effector for specific applications.

A **drive system for grippers** is essential for enabling robotic arms to grasp and manipulate objects. Here are the key components and types of drive systems used in grippers:

Types of Drive Systems:

- **Hydraulic Drive Systems**: Convert hydraulic energy into mechanical energy, providing high torque and speed.
- **Pneumatic Drive Systems**: Utilize compressed air to control power, suitable for fast, repetitive tasks.
- **Electric Drive Systems**: Convert electrical energy into mechanical energy, offering precise control and speed.
- **Actuators**: These devices convert energy from the drive system into mechanical energy for gripper movement. Common types include:
- **Hydraulic Actuators**: Used for high-torque applications.
- **Pneumatic Actuators**: Ideal for quick, lightweight movements.
- **Electric Actuators**: Provide fine position and force control, essential for precision tasks.

- **Applications**: Grippers can be designed for various applications, includi ng:
- **High-speed tasks**: Utilizing pneumatic systems for rapid response.
- **Precision tasks**: Electric grippers offer better control and accuracy.

Understanding these components and their applications is crucial for sel ecting the right drive system for specific robotic gripper needs.

Analog sensors are devices that produce a continuous output sign al, typically voltage, proportional to the physical quantity being me asured.

Common Types of Analog Sensors

1. **Temperature Sensors**:

- **Thermocouples** and **thermistors** are common examples. They measur e temperature changes and provide a voltage output that corresponds to the temperature level. For instance, the LM35 is a classic analog tempe rature sensor.

2. **Pressure Sensors**:

- These sensors measure the pressure of gases or liquids. They convert t he pressure into an analog voltage signal, which can be used in various applications, including weather monitoring and industrial processes.

3. **Light Sensors**:

- Also known as photoresistors or photodiodes, these sensors detect light intensity. They are used in applications like automatic lighting systems a nd cameras. The resistance of light sensors changes with light levels, all owing them to produce an analog output.

4. **Accelerometers**:

- These sensors measure acceleration forces and can detect changes in motion, orientation, and vibration. They provide analog voltage outputs t hat correspond to the acceleration applied to the sensor.

5. **Sound Sensors**:

- Sound sensors convert sound waves into an electrical signal. They are often used in applications like audio recording and environmental monitoring to measure sound levels.

6. **Gas Sensors**:

- These sensors detect the presence and concentration of various gases in the environment. They are commonly used in safety applications, such as detecting harmful gases in industrial settings.

7. **Position Sensors**:

- Position sensors detect the position of an object and provide an analog output based on its location. They are used in robotics, automotive applications, and industrial automation.

8. **Torque Sensors**:

- These sensors measure the torque applied to a rotating object. They are used in various applications, including automotive and industrial machinery.

Applications of Analog Sensors

Analog sensors are widely used across various industries, including:

- **Automotive**: For monitoring engine temperature, pressure, and other critical parameters.
- **Industrial Automation**: In process control systems to monitor and control manufacturing processes.
- **Environmental Monitoring**: To measure temperature, humidity, and air quality in various settings.
- **Consumer Electronics**: In devices like cameras and smartphones for light and motion detection.

Analog sensors play a crucial role in providing continuous data for monitoring and control systems, making them essential in many technological applications.

Type of Sensor	**Used For**

Temperature Sensor	Controlling HVAC systems in h
Proximity Sensor	Detecting objects in automatic
Accelerometer Sensor	Screen orientation in smartpho
IR Sensor (Infrared Sensor)	Remote controls for TVs and c
Pressure Sensor	Monitoring tire pressure in veh
Light Sensor	Adjusting screen brightness or
Ultrasonic Sensor	Parking assistance in cars
Flow and Level Sensor	Managing water levels in tanks
Smoke, Gas and Alcohol Sensor	Detecting smoke and gas leak
Microphone (Sound Sensor)	Voice recognition in smart spe
Touch Sensor	Touchscreens on smartphones
Color Sensor	Color detection in industrial so
Humidity Sensor	Controlling humidity levels in g
Magnetic Sensor (Hall Effect Sensor)	Detecting the position of a rota
Position Sensor	Tracking the position of machi
Tilt Sensor	Detecting the tilt of gaming con
PIR Sensor	Motion detection in security sy

Strain and Weight Sensor	Weighing items on digital scale
Gyroscope Sensor	Stabilizing drones during flight
Optical Sensor	Adjusting lighting in smart hom
Capacitive Sensor	Touchpads on laptops
Piezoelectric Sensor	Detecting vibrations in musical
Thermal Sensor	Temperature control in ovens
RFID Sensor	Tracking inventory in warehou
Chemical Sensor	Monitoring air quality

Sensor signal conditioning is the process of manipulating an analog signal from a sensor to make it suitable for further processing, ensuring accurate and reliable data acquisition.

What is Signal Conditioning?

Signal conditioning refers to the manipulation of an analog signal to meet the requirements of the next stage in a data acquisition system. This process is crucial for ensuring that the signals from sensors are in a form that can be effectively processed, analyzed, and converted into digital data. Signal conditioning can involve various operations, including amplification, filtering, isolation, and conversion.

Importance of Signal Conditioning

1. **Enhances Signal Quality**: Sensors often produce weak signals that can be easily affected by noise. Signal conditioning amplifies these signals, improving their resolution and sensitivity.
2. **Prepares for Data Acquisition**: Before signals can be digitized by an Analog-to-

Digital Converter (ADC), they must be conditioned to ensure they are within acceptable voltage or current ranges.

3. **Protects Equipment**: Signal conditioning can isolate sensitive equipment from potentially damaging signals, preventing issues like ground loops and electrical noise.

Common Signal Conditioning Techniques

- **Amplification**: Increases the magnitude of the signal, making it easier to detect and process. For example, converting a 0-10mV signal to a 0-10V signal.
- **Filtering**: Removes unwanted noise from the signal, ensuring that only the relevant data is processed. This can include low-pass, high-pass, or band-pass filters.
- **Isolation**: Breaks the electrical connection between the input and output to prevent interference and protect sensitive components.
- **Linearization**: Adjusts the output of a sensor to ensure a linear relationship between the input and output, which is particularly important for sensors with non-linear characteristics.

Applications of Signal Conditioning

Signal conditioning is widely used in various fields, including:

- **Temperature Measurement**: Thermocouples and RTDs often require signal conditioning to amplify and convert their outputs for accurate readings.
- **Mechanical Measurements**: Strain gauges and accelerometers need conditioning to ensure their signals are suitable for data acquisition systems.
- **Industrial Automation**: Signal conditioning is essential in control systems to ensure reliable operation and monitoring of processes.

In summary, sensor signal conditioning is a vital process that enhances the quality and reliability of sensor data, making it essential for effective data acquisition and analysis in various applications.