Industrial Automation

JANNATUNNAIM HARUN
GWEE CHIOU CHIN
ALIF BAKRI BIN ABDULLAH

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Muhammad Alif Bakri

Preface

The rapid advancement of technology has revolutionized numerous sectors, with industrial automation standing at the forefront of this transformation. Industrial automation involves the use of control systems such as computers, robots, and information technologies to handle different processes and machinery in an industry, substituting manual intervention. This evolution not only enhances efficiency, productivity, and safety but also reshapes the industrial landscape, paving the way for smart factories and Industry 4.0. In this era of unprecedented change, the relevance of industrial automation cannot be overstated. It streamlines operations, reduces human error, and enables real-time monitoring and control of processes, ensuring optimal performance and resource utilization. As industries face increasing competition and pressure to innovate, the adoption of automation technologies becomes not just an advantage but a necessity. This book delves into the intricacies of industrial automation, offering a comprehensive overview of its principles, technologies, and applications. From the basics of control systems to the latest advancements in robotics and artificial intelligence, we explore how these technologies integrate and function to create automated, efficient, and intelligent industrial environments. We also address the challenges and considerations in implementing automation, and need for continuous adaptation and learning. Real-world case studies and examples illustrate the transformative impact of automation across various industries, providing valuable insights into the practical aspects of these technologies. Whether you are a student, engineer, manager, or industry professional, this book aims to equip you with the knowledge and understanding necessary to navigate and thrive in the evolving landscape of industrial automation. By embracing these technologies, we can drive progress, innovation, and sustainability, shaping the future of industry for the better. Welcome to the world of industrial automation—where the future of manufacturing and industry is being built today.

Jannatunnaim Bt Harun
Gwee Chiou Chin
Muhammad Alif Bakri bin Abdullah

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1.0 Industrial Automation

Industrial automation refers to the use of control systems and information technologies to reduce the need for human intervention in industrial processes. It aims to increase productivity, reduce labor costs, and mitigate the effects of labor shortages. However, automation also comes with higher start-up and maintenance costs, as well as the potential for worker displacement. This document explores the concept of industrial automation, its advantages and disadvantages, and the different types of automation systems used in production.

1.1 Advantages of Industrial Automation

- Increases labor productivity by increasing production rate and output per
- hour Reduces of labor input labor costs by substituting machines for human
- labor, Mitigates lowering unit product cost the effects of labor shortages in advanced nations by automating operations as a substitute for labor for labor

- Eliminates routine manual and clerical tasks, improving working conditions

1.3 Disadvantages of Industrial Automation

1. Higher start-up and operating costs for automated equipment sensors, and smart devices

2. Higher maintenance costs for electromechanical devices,

3. Potential for worker displacement and unemployment, especially in the manufacturing industry

1.4 Concept of Automation

Youtube:https://www.youtube.com/watch?v=finl14HJ33g

Automation includes three main steps: input (sensors, keyboards, CD drives, tapes), processing (PLCs, CPUs, software, relays, valves), and output (actuators, monitors, motors, servos, solenoids, valves). These components work together to create an automated system that can operate with minimal human intervention.

Input

1 PLCs, CPUs, software, relays, and valves process the input data and control the automation system.

2 **Processing**
   Sensors, keyboards, CD drives, and tapes provide the necessary inputs to the automation system.

3 **Output**
   Actuators, monitors, motors, servos, solenoids, and valves execute the automated actions and provide the desired output.

1.5 Types of Industrial Automation Systems

Fixed or Hard Automation
This type of automation is used to to perform fixed and repetitive operations, achieving high production rates. It employs special-purpose or dedicated equipment to automate a fixed sequence of assembling or processing operations. It is inflexible in providing product variety variety but increases efficiency and reduces unit cost.

Programmable Automation
This automation system provides the flexibility to make changes in product design and assembly or processing operations through modifications to the control program. It is well-suited for batch production processes with medium to high product volumes, but requires longer setup times for new products or reconfigured operations.

Flexible Automation
This automation system offers a high high degree of flexibility, allowing manufacturers to produce multiple products with different ranges as a combined process, rather than separate processes. It enables quick changes to product design through human-operated commands and codes.

Youtube:https://www.youtube.com/watch?v=PvdYH1bLLLs

1.6 Automation in Production

1 **Assembly Line**
Automation is used in assembly lines to increase efficiency, precision, and speed of the manufacturing process.

2 **Testing and Packaging**
Automated systems are employed for product testing and packaging to ensure consistent quality and reduce manual labor.

3 Haz**ardous Zones**
Automation is used in hazardous or dangerous areas to protect workers and improve safety.

4 **High-Speed and Precision Processes**
Automation is essential for high-speed and precision manufacturing processes, such as those found in computer-integrated manufacturing (CIM) systems.

2.0 The Fundamentals of Automation Systems

Youtube:https://www.youtube.com/watch?v=Gb4xmIT51uI&t=11s

Automation systems are the backbone of modern industry, enabling precise control, increased efficiency, and enhanced safety across a wide range of applications. At the core of these systems are three essential elements: power, programming, and control. This comprehensive guide will explore the inner workings of automation systems, from the sources of power that drive them to the intricate control mechanisms that govern their operation.

2.1 The Power Behind Automation

Electricity: The Lifeblood

Electricity is the most commonly used power source for automated systems, providing the necessary energy to drive processes and control mechanisms. From industrial motors to programmable logic controllers, electricity is the foundation upon which automation is built.

Versatile Power Options

While electricity is the predominant choice, automated automated systems can also be powered by a variety of other sources, including hydraulic, pneumatic, and even renewable energy systems. The selection of the appropriate power source is crucial, as it must match the specific requirements of the of the application.

Safety Considerations

Ensuring the safety of personnel is a paramount concern in automated systems. Robust power systems, emergency shut-off mechanisms, and comprehensive safety protocols are essential to protect workers and maintain the integrity of the automation process.

2.2 Programming the Automation Process

1 **Defining the Process**

The first step in programming an automated system is to clearly define the desired process, including the sequence of actions, the required inputs and outputs, and the desired outcomes. This lays the foundation for the development of the control program.

2 **Developing the Control Program**

The control program is the set of instructions that directs the automated system to perform the desired actions. This program is typically written in a specialized programming language, such as ladder logic or structured text, and is then loaded into the system's control unit.

3 **Implementing and Optimizing**

Once the control program is in place, the automated system is implemented and tested. Adjustments and optimizations may be made to the program to ensure that the system operates efficiently and reliably, meeting the desired performance objectives.
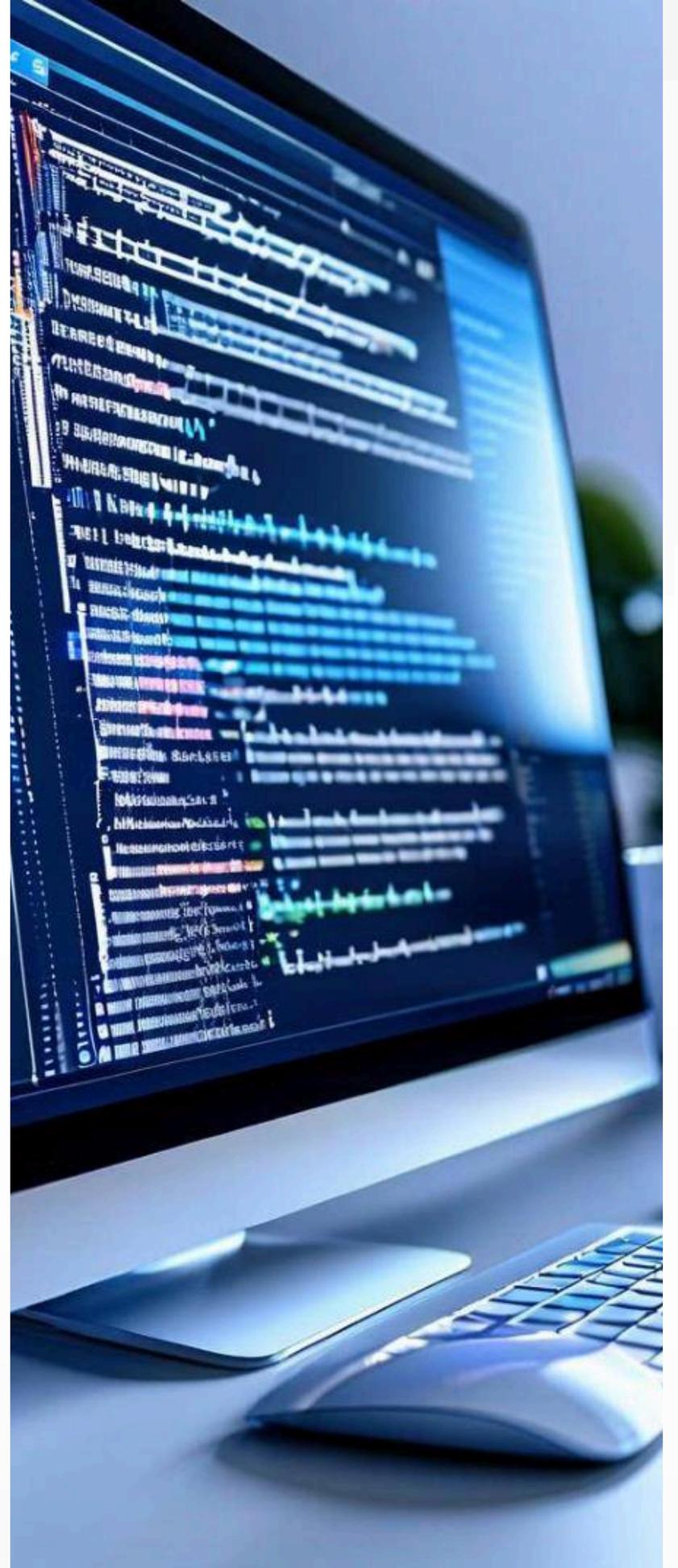
2.3 The Control System: The Brain of Automation

Open-Loop Control

In an open-loop control system, the control actions are independent of the output. The system operates based on a predetermined set of instructions, without any feedback from the process. While simple and cost-effective, open-loop systems are susceptible to disturbances and may not achieve the desired level of precision.

Closed-Loop Control

Closed-loop control systems, also known as feedback control systems, continuously monitor the output and adjust the control actions accordingly. This allows for greater accuracy, stability, and responsiveness, as the system can adapt to changes in the process or external factors. Closed-loop control is widely used in automated systems to ensure consistent and reliable performance.

Hybrid Approaches

In some cases, a combination of open- loop and closed-loop control may be employed, leveraging the strengths of both approaches. This hybrid approach can provide the benefits of precise control while maintaining the simplicity and cost-effectiveness of open-loop systems.

2.5 Maintenance and Diagnostics: Ensuring Reliable Performance

Status Monitoring

Automated systems continuously monitor their own status, providing real-time data on system performance and alerting operators to any potential issues.

Failure Diagnostics

When a failure occurs, advanced diagnostic systems can quickly identify the root cause and recommend appropriate repair procedures, minimizing downtime and ensuring prompt resolution.

Preventive Maintenance

Proactive maintenance strategies, such as scheduled inspections and component replacements, help to ensure the long-term reliability and efficiency of automated systems.

2.6 Safety and Security: Protecting Automated Systems

Safety Protocols

1 Comprehensive safety protocols, including emergency stop mechanisms, sensor-based safety systems, and worker training, are essential to protect personnel and maintain the integrity of automated processes.

Cybersecurity Measures

2 As automated systems become increasingly connected, robust cybersecurity measures are necessary to safeguard against unauthorized access, data breaches, and malicious attacks that could disrupt critical operations.

Regulatory Compliance

3 Automated systems must adhere to a range of industry regulations and safety standards to ensure the protection of workers, the environment, and the public at large.

2.7 The Future of Automation: Trends and Innovations

Artificial Intelligence

The decision-making capabilities of automated systems, enabling them to adapt to changing conditions and optimize their performance.

Internet of Things (IoT)

The seamless connectivity of automated systems with a network of sensors, devices, and cloud- based platforms, allowing for real-time data analysis, remote monitoring, and predictive maintenance.

Collaborative Robotics

The development of advanced robotic systems that can safely work alongside human operators, leveraging their complementary strengths to improve efficiency, flexibility, and productivity.

Sustainable Automation

The design and implementation of automated systems that prioritize energy efficiency, resource conservation, and environmental sustainability, contributing to the broader goals

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3.0 Mechanical Systems: Components, Dynamics, and Modeling

This chapter explores the fundamental concepts of mechanical systems, including the various components, their dynamics, and techniques for modeling these complex systems. From linear and rotational motion to power transfer and linkages, we'll dive deep into the mechanics that underpin a wide range of engineering applications.

3.1 Linear Motion: Translating Along a Straight Line

Uniform Linear Motion

Linear motion with constant velocity and zero acceleration, such as an athlete running at a steady pace.

1

Describing Linear Motion

The position x of a particle along a line can be described mathematically as a function of time t, capturing the dynamics of linear motion.

3

2

Non-Uniform Linear Motion

Linear motion with variable velocity and non-zero acceleration, like a car accelerating or decelerating.

3.2 Rotational Motion: Spinning Around an Axis

Rotational Motion

1 An object rotating about a fixed axis, a common scenario in engineering analysis.

2 **Wheel Example**
The rotation of a wheel is a classic example of rotational motion that is often studied.

3 **Describing Rotation**
Rotational motion can be described mathematically using angular position, position, velocity, and acceleration.

3.3 Mechanical Work and Power

Work

The product of force and distance, representing the transfer of energy from one place to another.

Power

The rate of doing work, measuring the amount of work performed per unit of time.

Units

The SI unit of work is the joule (J), while power is measured in watts (W). (W).

3.5 Motion Conversion: Rotary to Linear

Rotary to Rotary

Conversion between rotational motions, such as in gear trains, belts belts and pulleys, or harmonic drives.

Rotary to Linear

Conversion of rotational motion into into linear motion, as in a slider- crank mechanism.

Mechanical Advantages

The ratio of output force to input input force, and the ratio of input input speed to output speed.

3.6 Mechanical Linkages: Connecting the Connecting the Pieces

Reverse-Motion
Linkages that move objects or forces in opposite directions.

Push-Pull
Linkages that move objects or forces in the same direction.

Parallel-Motion
Linkages that move objects or forces in the same direction, at a set distance.

3.7 Couplings: Connecting Rotating Shafts

Purpose of Couplings

Couplings connect rotating shafts, allowing for some degree of misalignment or end movement while transmitting power.

Maintenance Considerations

Proper selection, installation, and and maintenance of couplings can lead to reduced downtime and and cost savings.

Types of Couplings

Couplings can be rigid, flexible, or torque-limiting, each with their own advantages and applications.

3.8 Power Transmission: Gears and Gearboxes

1

Power Source

The rotating power source, such as an engine or motor, provides the input to the transmission.

2

Gearbox

The transmission, or gearbox, uses gears and gear trains to provide controlled speed and torque conversions.

3

Output Device

The transmission delivers the transformed power to the output device, such as a wheel or mechanism.

3.9 End Effectors: The Robot's Hands

In robotics, an end effector is a device or tool connected to the end of a robot arm, serving as the "hand" that interacts with the environment. The choice of end effector is critical, as it determines the specific tasks a robot can perform. Grippers, for example, are a common end effector used for picking up and manipulating objects, while specialized tools like welding guns or cutting blades allow robots to carry out more complex manufacturing operations.

3.9.1 Challenges with Vacuum Grippers

1 **Surface Compatibility**

Vacuum grippers may leave marks on delicate surfaces or struggle with varied material types.

Compliance Issues

2 Vacuum grippers are inherently compliant, which can introduce challenges during precise positioning and handling.

Customization Needs

3 Vacuum grippers often require custom end-of-arm tooling to support their use, adding complexity to the robotic system.

3.9.2 Remote Center Compliance: Enabling Automated Assembly

Peg-in-Hole Challenge

Without a Remote Center Compliance (RCC) device, a robot's gripper may cause a
peg to jam when trying to insert it into a tight-fitting hole due
to misalignment and lateral forces.

RCC Mechanism

The RCC allows the gripper assembly to move in the plane perpendicular to the
peg's axis, effectively shifting the center of compliance from the
gripper to the hole itself, enabling the peg to rotate and self-align.

Benefits of RCC

RCC devices reduce contact forces, prevent galling and jamming,
and enable the assembly of components that would otherwise be
impossible, making them a crucial technology for automated
manufacturing.

Advantages

- Preventing galling and reducing contact forces
- jamming
- Accommodating lateral and rotational misalignment

Applications

RCC technology is particularly valuable in industries like automotive, where it allows for the assembly of complex components that require precise alignment and positioning.

Benefits

RCC sensors help reduce damage to materials during the assembly process, enabling the completion of tasks that would otherwise be impossible with traditional robotic systems.

3.9.4 Modeling Mechanical Systems

Kinematics

Kinematics is the study of the motion of mechanical systems, focusing on the geometry of movement without considering the forces that cause it.

Dynamics

Dynamics is the study of the forces that cause motion, including the relationships between an object's mass, the forces acting on it, and its resulting acceleration.

Statics

Statics is the study of the forces acting on a mechanical system that is in equilibrium, where the net force and net torque on the system are zero.

Vibration Analysis

Vibration analysis is the study of the oscillatory motion of mechanical systems, which is crucial for understanding and mitigating issues like resonance and fatigue.

3.9.5 Simulation and Optimization

Simulation

Computer simulations allow engineers to model and analyze the behavior of mechanical systems without the need for physical prototypes, saving time and resources.

Optimization

Optimization techniques are used to identify the best design parameters and operating conditions for a mechanical system, improving its efficiency, performance, and reliability.

Data Analysis

Analyzing data from sensors and monitoring systems helps engineers understand the real-world performance of mechanical systems and identify areas for improvement.
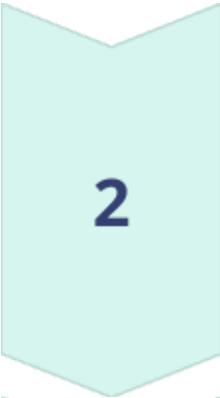
3.9.6 The Future of Mechanical Systems
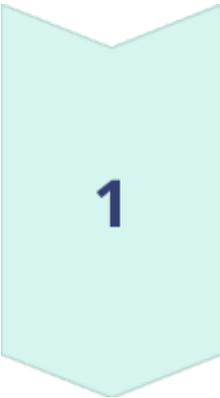
1

Automation
Advancements in robotics and control systems are driving increased automation in manufacturing and other industries, transforming the way mechanical systems are designed and operated.

2

Sustainability
Sustainable design principles, such as the use of renewable materials and energy-efficient technologies, are becoming increasingly important in the development of mechanical systems.

3

Digitalization
The integration of digital technologies, like the Internet of Things and cloud computing, is enabling new approaches to monitoring, maintenance, and optimization of mechanical systems.

4.0 Controlling Actuators in Automation Mechanisms

Automation mechanisms rely on a variety of actuators to precisely control and position mechanical components. From stepping motors that translate electrical signals into incremental movements, to solenoids and hydraulic/pneumatic systems that provide linear or rotary motion, these actuators are the backbone of modern automation. Understanding the capabilities and control methods for different actuator types are crucial for designing efficient and reliable automation systems.
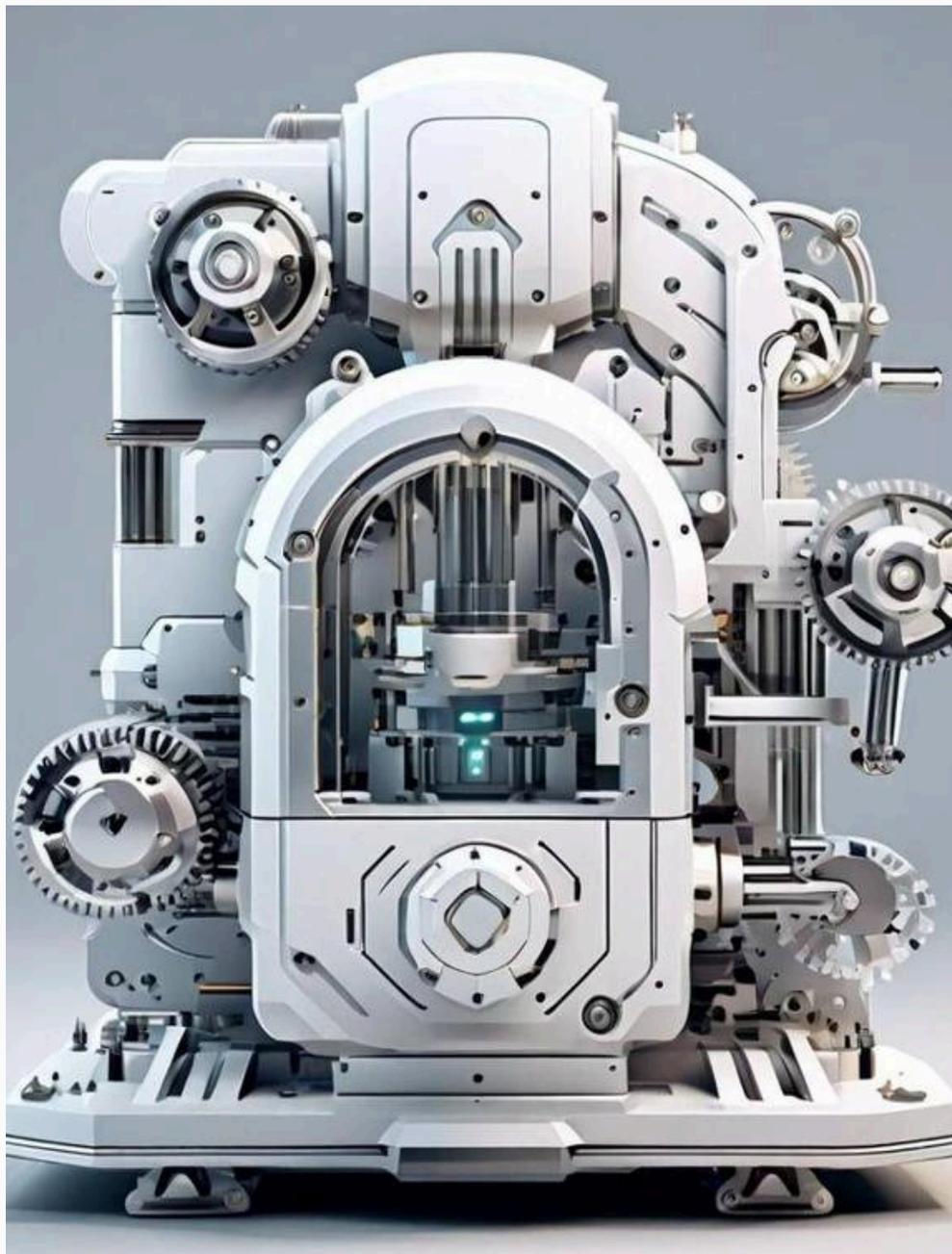
4.1 Stepping Motors: Precise Position Control

Full Step

Stepping motors are energized one phase at a time, providing the simplest control but lower torque.

Half Step

Alternating between one and two phase energization, providing higher resolution and smoother motion.

Microstepping

Using sinusoidal current waveforms to divide steps into hundreds of microsteps, enabling ultra-precise positioning.

Electromagnetic Principle

Solenoids use an energized coil to generate a magnetic field, pulling a ferromagnetic plunger inward and creating linear motion.

Rotary Solenoids

Rotary solenoids convert the linear motion into rotary motion using inclined raceways and ball bearings.

Relay Applications

Solenoids are commonly used in electromechanical relays to switch high-power electrical circuits with low-power control signals.

4.3 Electric Motors: Versatile Power Sources

DC Motors

DC motors use permanent magnets or electromagnets to generate the stator field, and a commutator to control the armature current.

Brushless DC

Brushless DC motors use electronic commutation to control the stator field, eliminating the mechanical commutator and brushes.

AC Motors

AC motors rely on the interaction between the stator and rotor magnetic fields to produce torque, without the need for a commutator.

4.4 Hydraulic Actuation: Powerful Linear Motion

1

Power Generation

Hydraulic pumps generate the pressurized fluid power that drives the system.

2

Fluid Regulation

Valves and other components control the flow and pressure of the hydraulic fluid.

3

Mechanical Actuation

Hydraulic cylinders and motors convert the fluid power into linear or rotary motion.

4.5 Pneumatic Actuation: Clean, Efficient Motion

1 **Air Compression**

Compressors generate the pressurized air that powers the pneumatic system.

2 **Air Treatment**

Filters, regulators, and lubricators condition the air for optimal performance.

3 **Pneumatic Actuators**

Cylinders and rotary actuators convert the air pressure into mechanical motion.

4 **Control Valves**

Valves regulate the flow and direction of the compressed air to the actuators.

4.6 Continuous vs. Discrete Actuation

Discrete Actuators
Stepping motors, solenoids, and relays provide precise, incremental motion control.
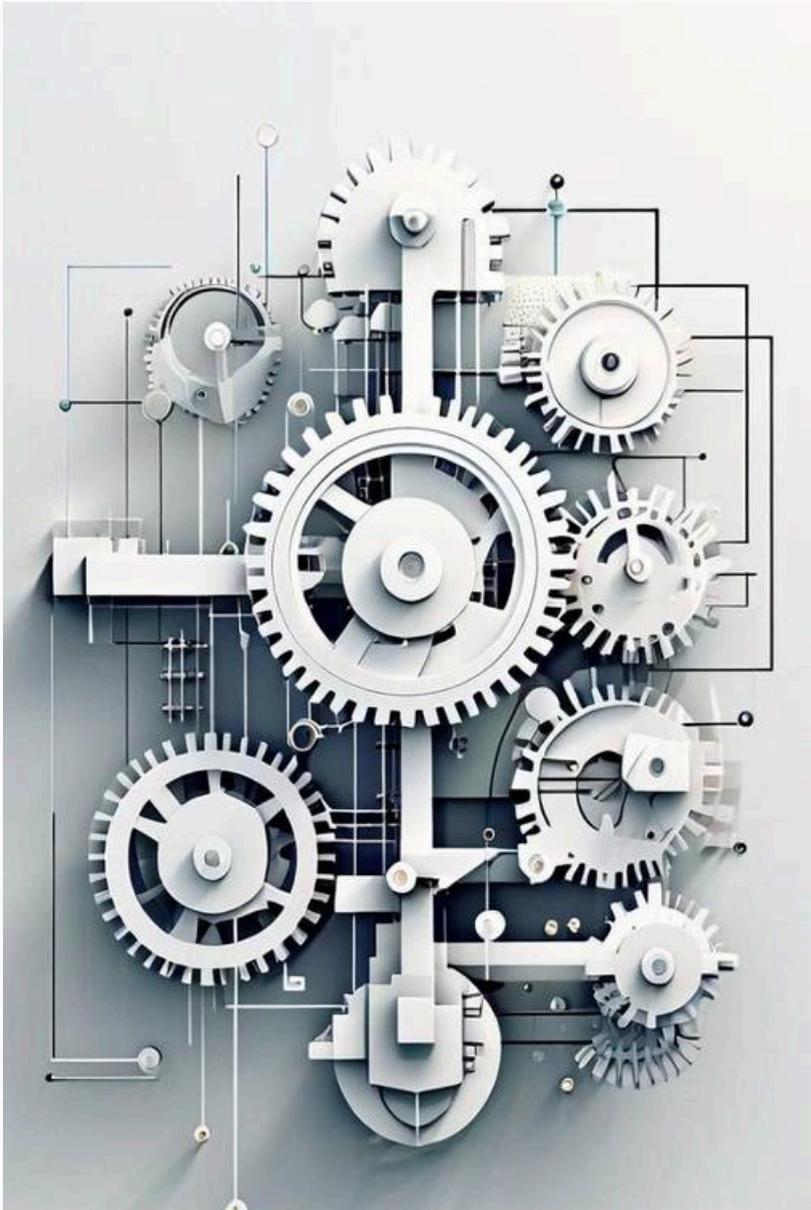
Continuous Actuators
Servomotors, hydraulic, and pneumatic systems offer smooth, variable positioning.

System Complexity
Discrete actuators are generally simpler and more cost-effective, while continuous actuators require more sophisticated control.

4.7 Choosing the Right Actuator

Actuator Type	Advantages	Disadvantages
Stepping Motors	Precise positioning, open-loop control, low cost	Limited torque and speed
Solenoids	Simple, low-cost actuation	Require feedback for precise control
DC Motors	High torque, wide speed range	Limited stroke and force
Hydraulic	Powerful, high force-to-size ratio	Complex, high maintenance
Pneumatic	Clean, efficient, low cost	Limited force and precision

4.8 Stepper Motors: Precise and Versatile

Precise Control

Stepper motors are renowned for their ability to provide precise speed control and positioning, making them ideal for automation systems that require accurate movements. The step-by-step rotation of the motor shaft allows for precise

Versatile Stepping Modes

Stepper motors can be driven in various modes, such as wave step, full step, half step, and microstepping, allowing for fine-tuned control and optimization of motor

Open-Loop Operation

Unlike other electric motors, stepper motors can operate in an open-loop control system, simplifying the overall system design and reducing costs.

4.9 Permanent Magnet Stepper Motors: Efficient and Cost-Effective

Permanent Magnet Design

Permanent magnet stepper motors, also known as can-stack or tin-can motors, feature a rotor made of permanent magnet material, such as ferrite. This design provides a low-cost and efficient solution for many industrial and automation applications.

Principle of Operation

The interaction between the stator's magnetic poles and the permanent magnet rotor poles drives the motor's step-by-step rotation. By energizing the stator windings in a specific sequence, the rotor aligns with the magnetic fields, enabling precise control over the motor's position and speed.

Advantages

Permanent magnet stepper motors offer several benefits, including low manufacturing cost, high torque-to-size ratio, and the ability to operate in open-loop control systems, making them a popular choice for a wide range of industrial and robotic applications.

4.10 Linear Stepper Motors: Precision in a Straight Line

Linear Motion

1 Unlike their rotary counterparts, linear stepper motors convert electrical pulses directly into linear motion, making them well-suited for applications that require precise linear positioning and control.

Hybrid Design

2 Linear stepper motors typically employ a hybrid design, with a forcer (containing the windings and permanent magnets) and a passive platen (the linear track), allowing for high-resolution and high-speed linear motion.

Microstepping Capabilities

3 By utilizing microstepping techniques, linear stepper motors can achieve extremely fine positioning resolution, making them ideal for applications that require high-precision linear movement, such as in CNC machines and robotic systems.

4.11 Brushless DC Motors: Efficient and Maintenance-Free

Electronic Commutation

Brushless DC motors, also known as BLDC motors, use electronic commutation to control the motor's speed and torque, eliminating the need for mechanical brushes and commutators found in traditional DC motors.

High Power Density

Brushless DC motors offer a high power-to-weight ratio, making them well-suited for applications that require compact and efficient actuators, such as in computer peripherals, power tools, and electric vehicles.

Low Maintenance

The absence of brushes and commutators in brushless DC motors results in reduced wear and tear, leading to lower maintenance requirements and increased reliability compared to traditional DC motors.

4.12 Direct Drive Actuators: Precision without Gears

⚙️ **No Backlash**

Direct drive actuators eliminate the need for gearboxes, resulting in a significant reduction in backlash and improved positioning accuracy.

Reduced Weight

By removing the gearbox, direct drive actuators are lighter and more compact, leading to cost savings and easier integration into robotic systems.

Improved Safety

The lack of a gearbox in direct drive actuators reduces the overall system inertia, allowing for faster response times and improved safety in collaborative robotics and exoskeletons.

4.13 Hydraulic and Pneumatic Actuators:
Actuators: Power and Precision

Hydraulic Actuators

Hydraulic actuators are commonly used in applications that require high force and torque, such as in industrial valves and heavy machinery. They utilize pressurized hydraulic fluid to generate the necessary force to operate the system.

Fail-Safe Operation

Both hydraulic and pneumatic actuators can be designed to fail in a specific state, either open or closed, providing a valuable safety feature in critical applications.

Pneumatic Actuators

Pneumatic actuators, on the other hand, use compressed air to generate the motive force. They are often used in applications that require quick and accurate response, such as in control valves and automation systems.

4.14 Choosing the Right Actuator for Your Application

Performance Requirements

When selecting the appropriate actuator for a robotic system, it's essential to consider the specific performance requirements, such as speed, torque, precision, and power density, to ensure the chosen actuator can meet the application's demands.

System Integration

The integration of the actuator into the overall robotic system is also a crucial factor, as the actuator must be compatible with the control system, power supply, and other components to ensure seamless operation.

Cost and Maintenance

Additionally, considerations such as the initial cost, ongoing maintenance requirements, and the overall system complexity can help guide the selection of the most appropriate actuator technology for a given robotic application.

5.0 Sensors: The Backbone of Industrial Automation

Sensors are the critical components that enable industrial robots and automation systems to function effectively. They provide the necessary feedback and control to ensure accurate, safe, and efficient operations in a wide range of manufacturing and production environments.
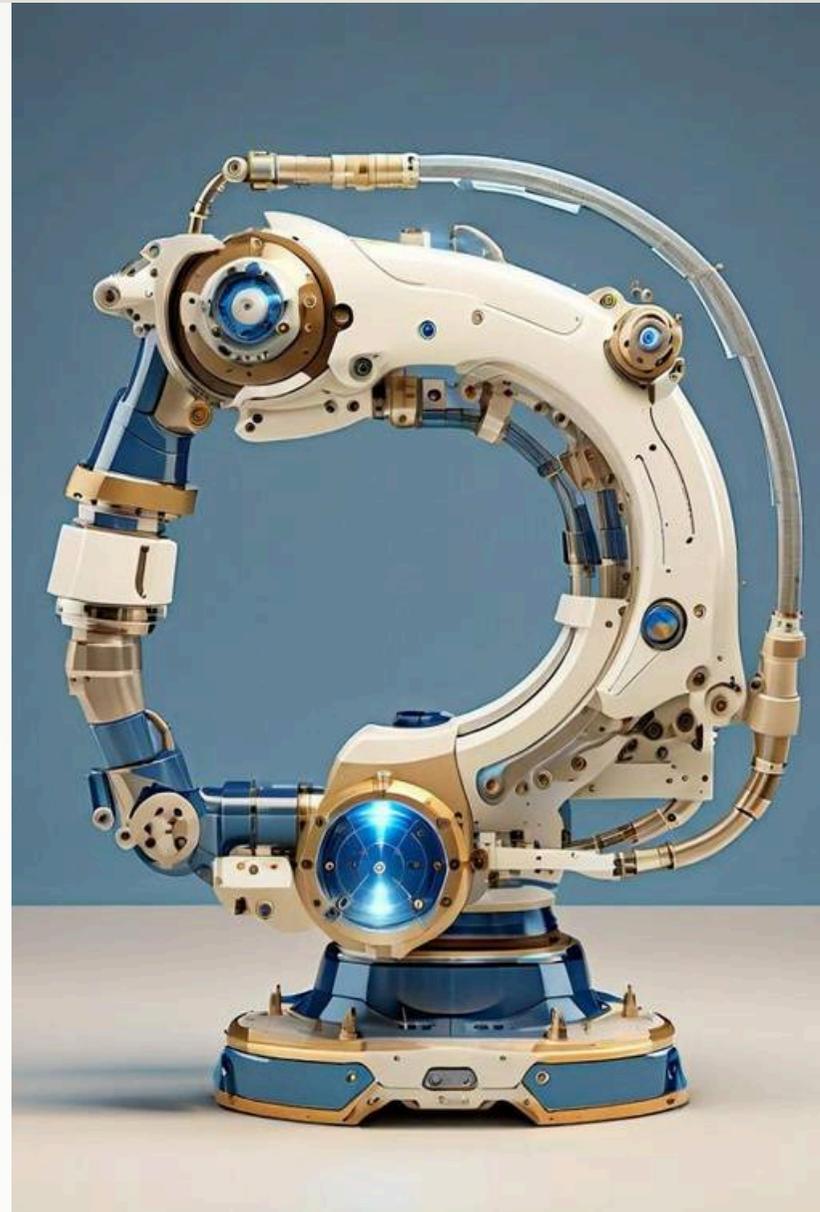
5.1 Definition and Function of Sensors

Sensor Definition

A sensor is an element that provides information about the status of a process or system to a controller. This information can be in the form of analog, digital, or a combination of both, and is used by regulators to ensure accurate and precise control of the system.

Sensor Functions

Sensors serve critical functions in industrial settings, such as detecting hazards to protect operators, monitoring processes to maintain quality, and providing feedback to control and optimize the entire system.
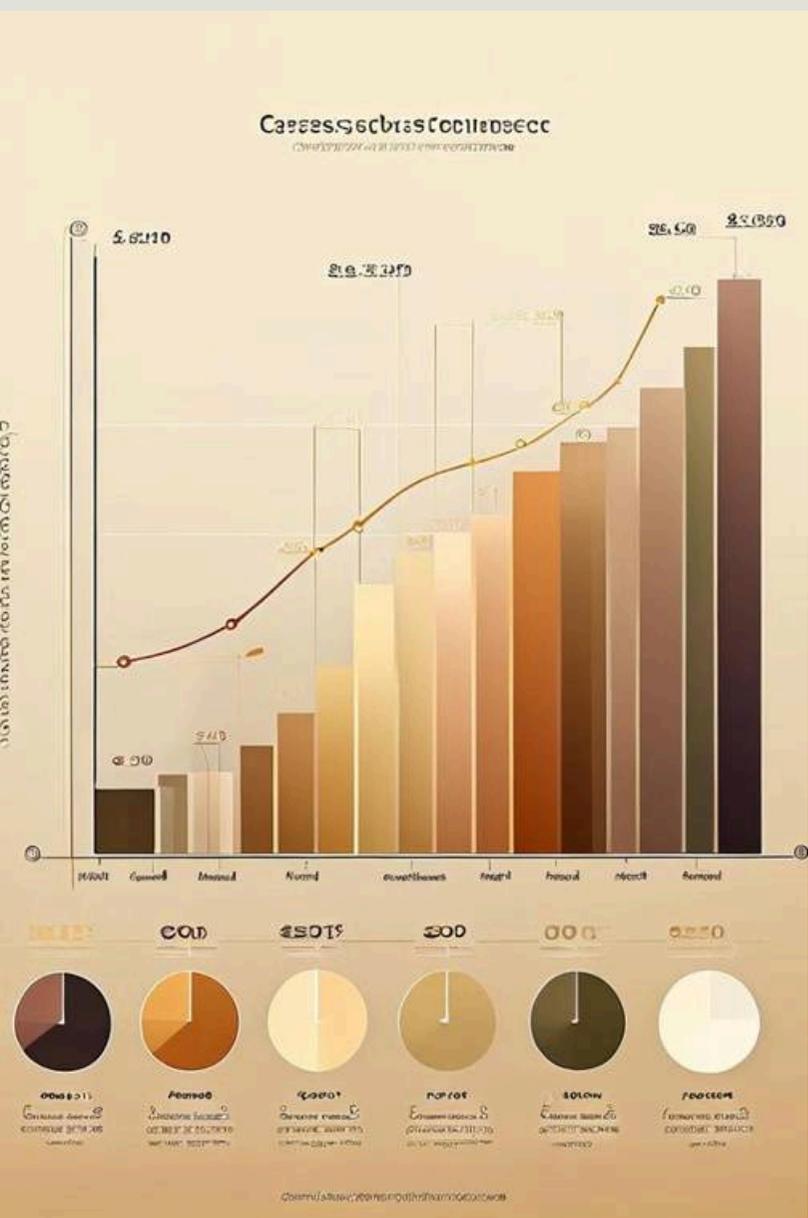
5.2 Advantages of Using Sensors

1 Key Sensor Characteristics
Sensors offer a range of important characteristics, including range, precision, sensitivity, error, accuracy, resolution, repeatability, linearity, dynamic response, and environmental tolerance.

2 Calibration and Cost
Sensors often require calibration to establish the relationship between the input and output. The cost of sensors can vary, with more precise sensors generally being more expensive.

3 Enabling Automation
Sensors are essential for enabling the precise control and automation required in modern industrial processes, allowing for improved efficiency, quality, and safety.

5.3 Industrial Sensing Needs

Sensor Types
Industrial robots and automation systems require a variety of sensing devices, including transducers, contact sensors, non- contact sensors, proximity sensors, range sensors, tactile sensors, displacement sensors, speed sensors, and torque sensors.

Vision Sensors
Vision sensors, such as cameras and image processing systems, enable robots to perceive and manipulate objects, generating adjustments for precise object handling and control.

Optical Sensing
Optical sensing techniques, including intrinsic and extrinsic methods, are widely used in industrial applications, particularly for tactile sensing and velocity measurement.

5.4 Tactile and Proximity Sensing

[1] **Tactile Sensors**
Tactile sensors are used to measure force distributions, providing a more comprehensive touch-based perception compared to simple binary touch detection.
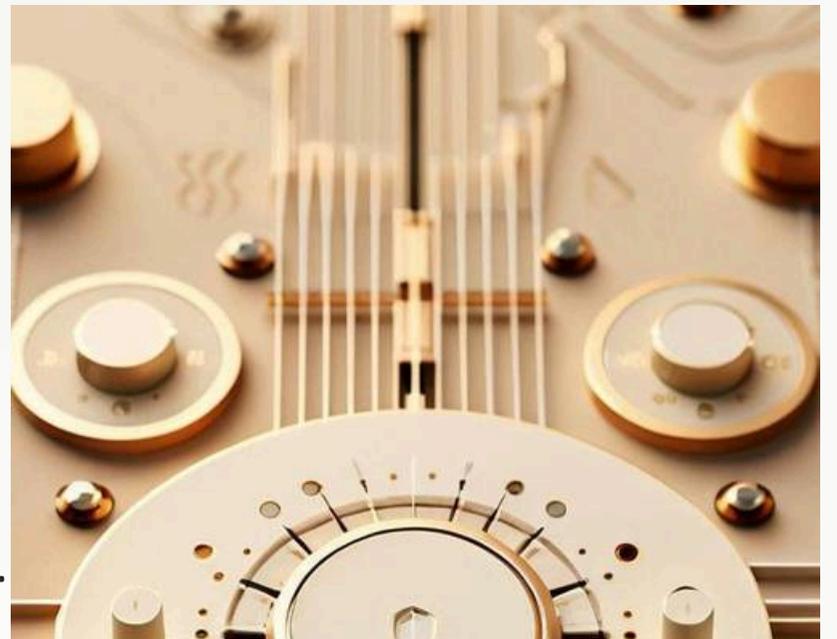
[2] **Proximity Sensors**
Proximity sensors detect the presence of nearby objects, often using

inductive, capacitive, photoelectric, or Hall effect principles to provide

on/off signals for object detection.

[3] **Laser Doppler Velocimetry**
Laser Doppler velocimetry (LDV) is a non-contact technique that uses the Doppler shift in a laser beam to measure the velocity of transparent or semi-transparent fluid flows, as well as the motion of opaque, reflecting surfaces.

5.5 Tachogenerators and Servo Systems

Tachogenerators

Tachogenerators are DC generators that provide velocity feedback for servo systems, with their output voltage directly proportional to the rotational speed of the armature shaft.

Servo Systems

Servo systems use tachogenerators and other sensors to provide precise control of motor speed and position, enabling accurate and responsive industrial automation.
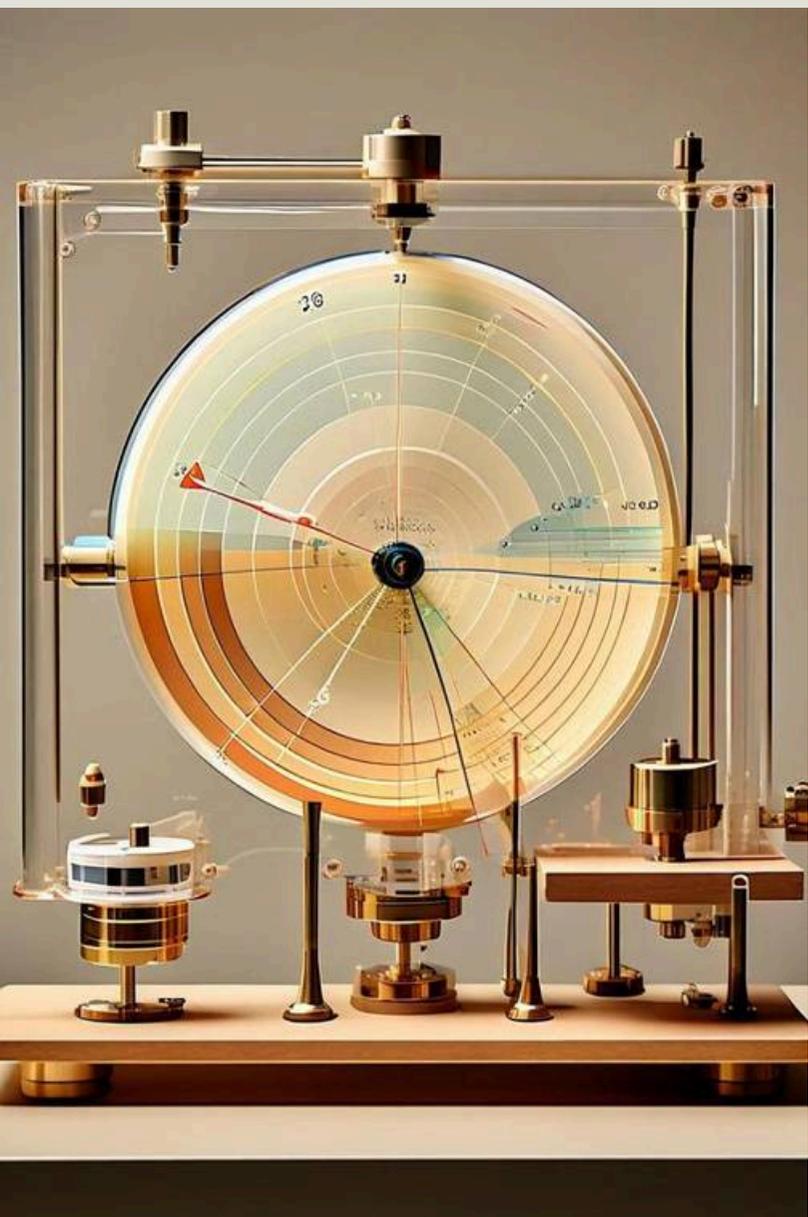
5.6 The Evolution of Laser Doppler Velocimetry

Laser Development

The development of the helium-neon laser in 1962 provided a highly concentrated source of red-spectrum electromagnetic radiation, enabling the use of the Doppler effect for fluid flow measurement.

Fluid Flow Measurement

Laser Doppler velocimetry (LDV) was soon shown to be effective for measuring the velocity of fluid flows by detecting the Doppler shift of the laser beam scattered by small particles entrained in the fluid.

Industrial Applications

LDV has become a widely used non-contact technique for measuring the velocity of transparent or semi-transparent fluids, as well as the motion of opaque ,reflecting surfaces in industrial settings.

5.7 Strain Gauges and Their Role

Strain Gauge Construction	Strain gauges consist of a length of gauge wire formed into a flat coil and bonded between thin insulating sheets. They are used to measure deflection and deformation by detecting changes in electrical resistance.
Sensor Integration	Strain gauges cannot be used directly to measure deflection; they must be properly fixed to a member that will be strained in order to provide the desired measurement.
Industrial Applications	Strain gauges are widely used in industrial automation and control systems to provide feedback on forces, torques, and other mechanical parameters that are critical for process monitoring and optimization.

5.8 Sensor Diversity and Specialization

Sensor Specialization
Industrial automation requires a diverse range of specialized sensors, each designed to measure and provide feedback on specific parameters, such as position, speed, force, and more.

Sensor Integration
The integration of these specialized sensors is crucial for enabling the precise control and optimization of complex industrial processes and robotic systems.

Sensor Innovation
Ongoing advancements in sensor technology, including the development of new sensing principles and materials, continue to drive improvements in industrial automation and control.

Sensor Ecosystem
The ecosystem of industrial sensors, along with the associated signal conditioning, processing, and control systems, forms the backbone of modern industrial automation and robotics.

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This book explores the revolutionary impact of industrial automation, a technological advancement at the forefront of modern industry. Industrial automation refers to the use of control systems like computers, robotics, and information technology to automate industrial processes, replacing the need for manual intervention. This transition to automation has drastically improved efficiency, productivity, and safety while setting the stage for the development of smart factories and Industry 4.0.

Jannatunnaim Binti Harun
Gwee Chiou Chin
Alif Bakri Bin Abdullah

Politeknik Merlimau