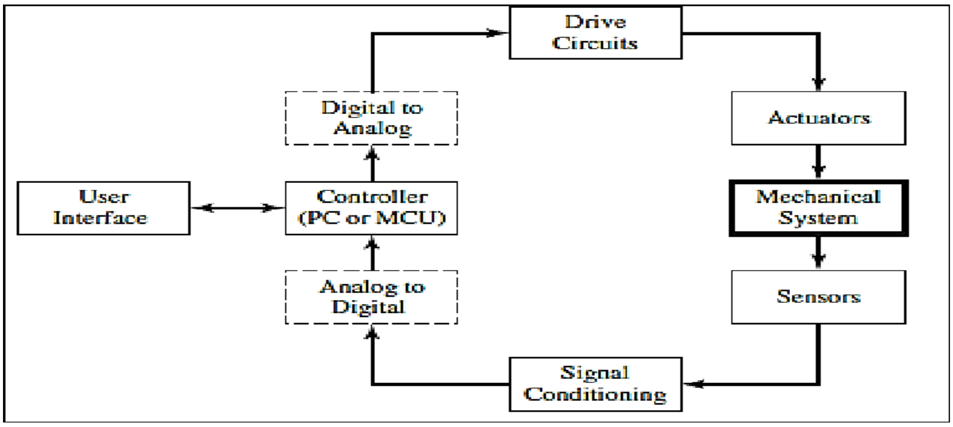
INTRODUCTION TO MECHATRONICS

Q-01: What do you understand by mechatronics? List the components of a mechatronics system and briefly explain each of them. Also show a relationship among them. [NITER_C_01]

Answer:

Mechatronics is a multidisciplinary field that combines principles from mechanical engineering, electronics, computer science, and control engineering to design, create, and operate intelligent systems and products.



Components of a Mechatronics System:

1. Mechanical Components: These include the physical structures, mechanisms, and devices that form the mechanical part of the system. Examples include gears, motors, drive systems, frames, and bodies.

2. Electronics: Electronics refer to the electrical components and systems used in mechatronic systems. This includes sensors, actuators, microcontrollers, power supplies, and electronic circuits.

3. Sensors: Sensors are devices that detect and measure physical parameters such as position, force, temperature, pressure, light, or sound. They convert physical quantities into electrical signals that can be processed and utilized by the control system. Examples of sensors include encoders, temperature sensors, load cells, and proximity sensors.

4. Actuators: Actuators are devices responsible for converting electrical or hydraulic signals into mechanical motion or force. Common types of actuators used in mechatronic systems are electric motors, pneumatic or hydraulic cylinders, solenoids, and relays.

5. Control System: The control system is the brain of the mechatronic system. It consists of a combination of hardware and software components that receive input signals from sensors, process the information, and generate output signals to drive the actuators. The control system ensures the desired behaviour and performance of the mechatronics system through closed-loop or open-loop control techniques.

Relationship Among Components:

1. **Sensors ↔ Control System:**
   - Sensors provide feedback to the control system about the current state of the system. The control system processes this information to make decisions regarding the required actions.
2. **Control System ↔ Actuators:**
   - The control system generates commands based on sensor feedback. These commands are sent to actuators, instructing them to perform specific physical actions or movements.
3. **Mechanical Components ↔ Sensors/Actuators:**
   - Mechanical components interact with sensors by providing the physical variables (position, velocity, etc.) that sensors measure. Actuators, in turn, act upon the mechanical components based on commands received from the control system.

Q-02:Define the sensor and transducer. Explain the working of a thermal sensor. [NITER_C_01]

Answer:

A sensor is a device that detects and measures physical quantities or environmental conditions and converts them into electrical or digital signals that can be processed by other components in a system. Sensors play a crucial role in mechatronics by providing real-time data about the system or the surrounding environment.

A transducer, on the other hand, is a device that converts one form of energy into another. In the context of sensors, a transducer refers to the component that converts a physical input into an electrical or digital signal that can be processed by other components.

Working of a Thermal Sensor:

A thermal sensor, also known as a temperature sensor, is a type of sensor that measures temperature variations. These sensors detect the changes in temperature and convert them into electrical signals that are then utilized for various purposes.

Thermal sensors work based on the principle of temperature-dependent electrical properties of materials. One common type of thermal sensor is the thermocouple, which consists of two conductive wires made of different metals (e.g., copper and constantan) that are joined at one end, forming a junction.

Here are some common types of thermal sensors and their working principles:

1. Thermocouples: Thermocouples consist of two different conductive wires (e.g., copper and constantan) that are joined at one end to form a junction. When there is a temperature difference between the two junctions, it creates an electromotive force (EMF) due to the Seebeck effect. This generated EMF is proportional to the temperature difference and can be measured to determine the temperature.

2. Resistance Temperature Detectors (RTDs): RTDs work on the principle that the electrical resistance of certain materials (such as platinum or nickel) changes with temperature. RTDs have a known resistance-temperature relationship, typically described by a linear or nonlinear equation. By measuring the resistance of the RTD element, the corresponding temperature can be determined using calibration curves or equations.

3. Thermistors: Thermistors are temperature-sensitive resistors made of ceramic materials. They have a highly nonlinear resistance-temperature relationship, with resistance decreasing rapidly as the temperature increases. Thermistors can be either positive temperature coefficient (PTC) or negative temperature coefficient (NTC), depending on how their resistance changes with temperature.

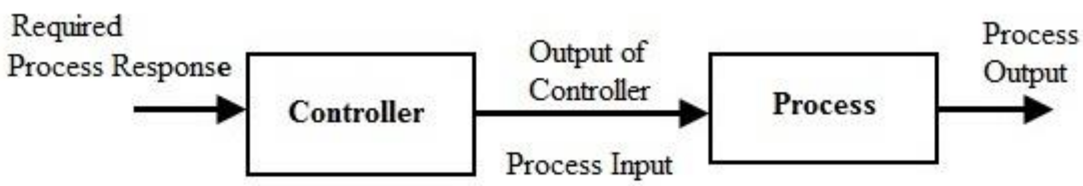
4. Infrared Temperature Sensors: Infrared temperature sensors, also known as pyrometers, detect thermal radiation (infrared radiation) emitted by an object. They have an optical system that focuses the emitted radiation onto a detector element, such as a thermopile or pyroelectric sensor. The thermal radiation is converted into an electrical signal, and based on the intensity of the radiation, the temperature of the object can be determined.

Q-03: Explain the open loop and close loop control system using suitable block diagram. [NITER_C_01]

Answer:

1. **Open-loop Control System:** An open-loop control system is a system where the output has no effect on the control action. In other words, the control actions are predetermined and not adjusted based on the system's response. The system's control action relies solely on the input or setpoint, without any feedback or error correction mechanism. Open-loop control systems are relatively simple but are more susceptible to disturbances and inaccuracies.

Here's a block diagram representing an open-loop control system:

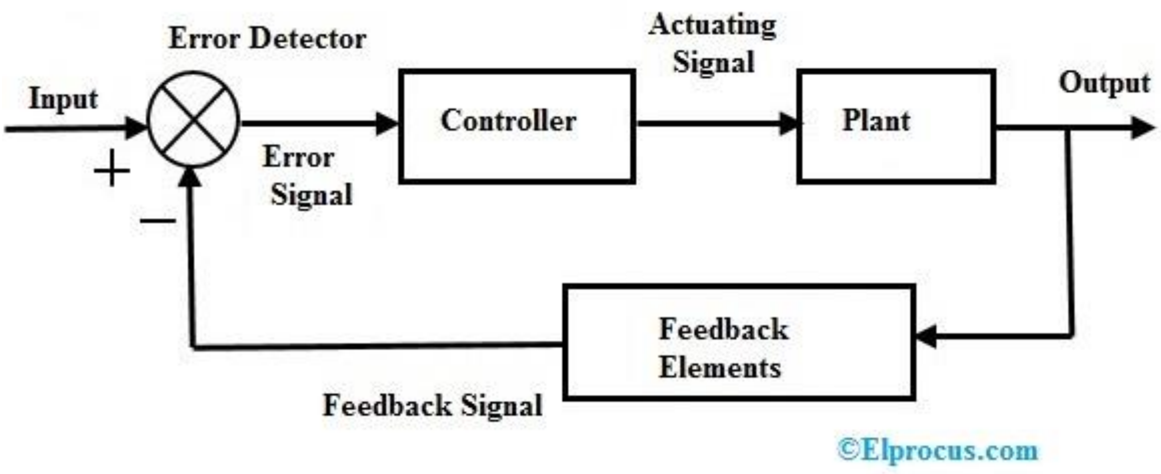


Key Characteristics:

- No Feedback: The controller doesn't receive information about the actual output or any disturbances that might affect it.
- Operates Blindly: Commands are sent to the actuator based solely on the input signal, without considering the actual system response.
- Examples: Toaster, washing machine timer, traffic lights on a fixed cycle.

2. **Closed-loop Control System:** A closed-loop control system, also known as a feedback control system, incorporates feedback from the output to adjust the control action. The system continuously monitors the output and compares it to the desired setpoint, generating an error signal. This error signal is then processed and used to adjust the control action, providing more accurate and stable control compared to open-loop systems.

Here's a block diagram representing a closed-loop control system:



Key Characteristics:

- Feedback Loop: The output is continuously measured and compared with the desired input.
- Correction Mechanism: The controller adjusts its commands based on the feedback to minimize any errors or deviations.
- Self-Correction: Maintains output accuracy even in the presence of disturbances or system changes.
- Examples: Cruise control in a car, thermostat in a room, robotic arm positioning.

Q-04:Why mathematical modeling of electrical and mechanical systems is necessary for mechatronics systems? Explain with an example. [NITER_C_01]

Answer: Mathematical modeling of electrical and mechanical systems is crucial in mechatronics because it allows engineers to analyze, design, and optimize system behavior. It provides a quantitative representation of the system's dynamics under different conditions.

Importance of Mathematical Modeling:

1. **Understanding System Behaviour:**
    - Mathematical models help in understanding the relationships between different variables and components within the mechatronics system. This understanding is crucial for engineers to comprehend how the system will respond to various inputs and conditions.
    - Robotic Arm Design: Simulate different arm configurations and control algorithms to optimize speed, accuracy, and payload capacity.
2. **Analysis and Design:**
    - Models enable engineers to perform analysis and design tasks before the actual system is built. This includes predicting system responses and identifying potential issues that can be addressed during the design phase.
    - Self-Balancing Robot Design: Model the robot's dynamics and control algorithms to ensure it maintains balance even on uneven terrain.
3. **Simulation:**
    - Mathematical models allow for the simulation of system behavior under different scenarios. Simulations help validate design choices and ensure the system meets performance requirements.
    - Wind Turbine Monitoring: Models anticipate component wear and tear, guiding preventive maintenance schedules to minimize downtime.
4. **Control System Design:**
    - Control strategies, such as feedback controllers, are often designed based on mathematical models. These models help in predicting how the system will respond to control inputs and disturbances.
    - Engine Control System: Model engine dynamics and emissions to fine-tune fuel injection and ignition timing for optimal performance and efficiency.
5. **Optimization:**
    - Models facilitate optimization of system parameters to achieve specific objectives, such as maximizing efficiency, minimizing energy consumption, or enhancing overall performance.

    Aircraft Design: Models integrate aerodynamic, structural, and control system aspects for seamless design and evaluation.

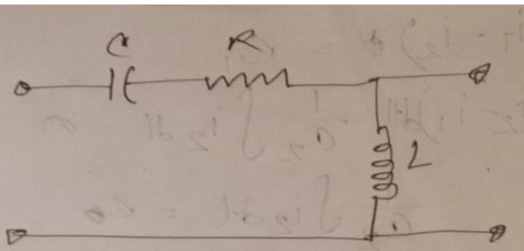
Q-05:Suppose a given system consists of a resistor, an inductor, and a capacitor in series. The output is taken across the inductor. Derive the equation for the transfer function of the system. [NITER_C_01]

Answer:

The system you described, consisting of a resistor (R), an inductor (L), and a capacitor (C) in series, can be represented by an electrical circuit. The transfer function (TF) is a mathematical expression that relates the Laplace transform of the output to the Laplace transform of the input. The transfer function (H(s)) for the given system can be derived using Kirchhoff's voltage law and Ohm's law.

Let's denote:

- $V_{in}(s)$: Laplace transform of the input voltage.
- $I(s)$: Laplace transform of the current flowing through the circuit.
- $V_{out}(s)$: Laplace transform of the output voltage (taken across the inductor).



$$\frac{1}{C}\int i\,dt + Ri + L\frac{di}{dt} = e_i$$

$$L\frac{di}{dt} = e_o$$

Laplace transform,

$$\frac{1}{C}\cdot\frac{1}{s}I(s) + RI(s) + LsI(s) = E_i(s)$$

$$LsI(s) = E_o(s)$$

$$\therefore \text{T.F.} = \frac{E_o(s)}{E_i(s)}$$

$$= \frac{Ls}{\frac{1}{Cs} + R + Ls}$$

$$= \frac{Ls}{\frac{1+RCs+LCs^2}{Cs}}$$

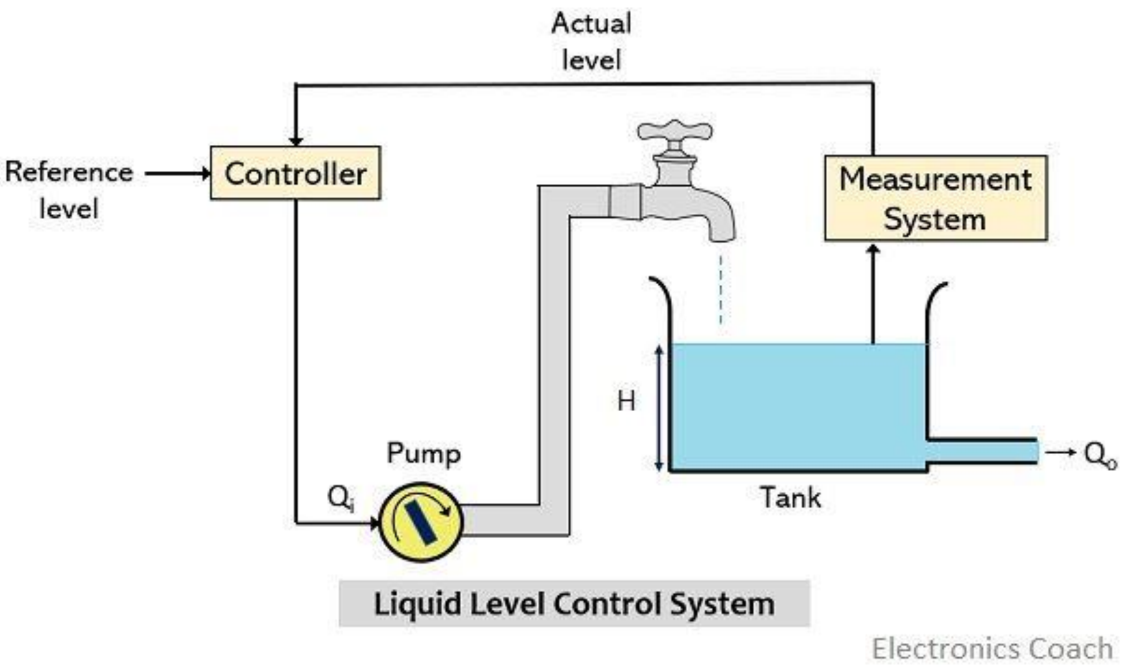
$$= \frac{LCs^2}{LCs^2+RCs+1}$$

Q-06:Define a liquid-level system. Derive the equation for capacitance of a liquid- level system. [NITER_C_02]

Answer:

A liquid-level system refers to a setup or device used to measure or control the level of a liquid in a vessel or container. It typically consists of a sensor or probe that detects the height of the liquid and provides a corresponding output signal.

The capacitance-based liquid-level system is one common type of level measurement technique.. The conductive plates act as electrodes, and the liquid serves as the dielectric material.



For liquid level system, the equation of capacitance is given as:

$$C\frac{dh}{dt} = q_i - q_o$$

$$C\,dh = (q_i - q_o)\,dt$$

Also,

$$R = \frac{h}{q_o}$$

$$q_o = \frac{h}{R}$$

On substituting the value of q_o, we will get,

$$C\,dh = (q_i - \frac{h}{R})\,dt$$

Further,

$$RC\,dh = (Rq_i - h)\,dt$$

On transforming

$$RC\frac{dh}{dt} = Rq_i - h$$

Therefore,

$$RC\,\frac{dh}{dt} + h = Rq_i$$

Extra: For laplace transform

Now, taking Laplace transform, we will get,

$$RC\,sH(s) + H(s) = RQ_i(s)$$

$$H(s)(sRC + 1) = RQ_i(s)$$

Thus, the transfer function of the system for input q_i and output h, we will have,

$$\frac{H(s)}{Q_i(s)} = \frac{R}{1 + s\,RC}$$

While if q_o is considered as the output for input q_i, then the Laplace transform of the equation shown above i.e.,

$$q_o = \frac{h}{R}$$

Will be

$$Q_o(s) = \frac{H(s)}{R}$$

So, on substituting, H(s) from the transfer function obtained above, we will get,

$$Q_o(s) = \frac{Q_i(s)}{1 + s\,RC}$$

Therefore,

$$\frac{Q_o(s)}{Q_i(s)} = \frac{1}{1 + s\,RC}$$

: RC corresponds the time constant i.e., τ, of the liquid level control system.

Q-07:Define a pneumatic system. Derive the equation for the resistance of a pneumatic system. [NITER_C_02]

A pneumatic system is a system that utilizes compressed air or gas to perform various tasks and functions. It consists of components such as compressors, air lines, valves, actuators, and pneumatic cylinders. The compressed air or gas is stored in a reservoir or tank and is used to create mechanical motion, operate machinery, control valves, and perform other types of work. Pneumatic systems are commonly used in industries for tasks such as powering pneumatic tools, controlling automated machines, operating pneumatic actuators in robotics, and more.

The Hagen–Poiseuille equation is given by:

$\Delta P = \pi r 4 8 \mu L Q$

Now, let's derive this equation step by step.

Where:

- $\Delta\Delta P$ is the pressure drop across the pipe,
- μ is the dynamic viscosity of the gas,
- L is the length of the pipe,
- Q is the volumetric flow rate of the gas, and
- r is the radius of the pipe.

1. **Start with the definition of the pressure drop (ΔP):**

$$\Delta P = -\frac{\Delta P}{\Delta x} \cdot \Delta x$$

1. **Use the Poiseuille's Law for laminar flow:**

$$-\frac{\Delta P}{\Delta x} = \frac{8\mu Q}{\pi r^4}$$

1. **Multiply both sides by the length of the pipe (L):**

$$-\Delta P = \frac{8\mu L Q}{\pi r^4} \cdot \Delta x$$

1. **Take the absolute value of both sides (pressure drop is a positive quantity):**

$$\Delta P = \frac{8\mu L Q}{\pi r^4} \cdot \Delta x$$

1. **Recognize that $\frac{\Delta x}{\Delta t}$ is the velocity (V) of the gas:**

$$\Delta P = \frac{8\mu L Q}{\pi r^4} \cdot V$$

1. **Now, express the volumetric flow rate (Q) in terms of the cross-sectional area (A) and velocity (V):**

$$Q = A \cdot V$$

1. **Substitute $Q = A \cdot V$ back into the equation:**

$$\Delta P = \frac{8\mu L A V}{\pi r^4}$$

Q-08:Make comparison Between Pneumatic Systems and Hydraulic Systems. [NITER_C_01]

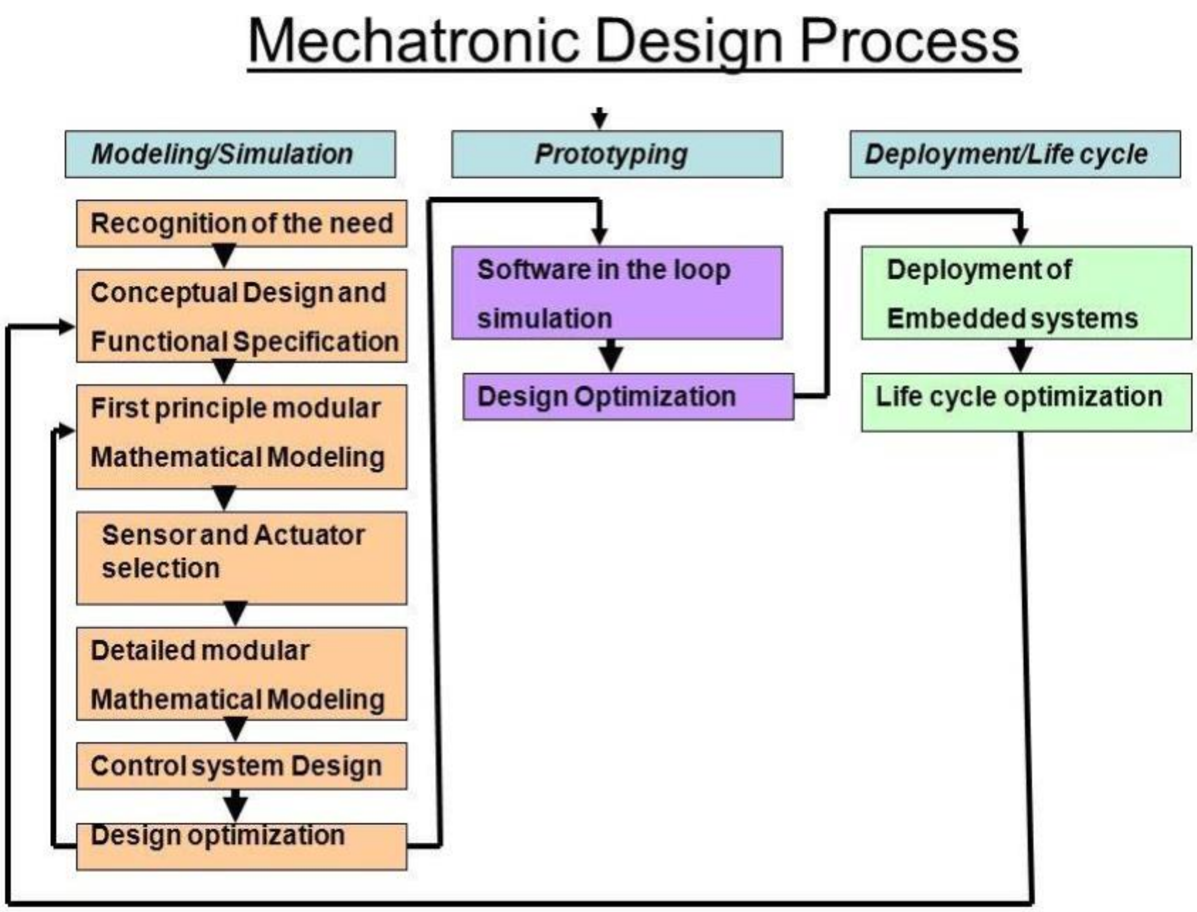
Answer:

Hydraulic System	Pneumatic System
A hydraulic system is a closed-loop system.	Pneumatic System is an open-loop system.
It is robust in construction and maintenance cost is high.	It is simple in construction and maintenance cost is less.
The working fluid is hydraulic oil.	The working fluid is air.
As oil is incompressible, it can be pressurized to very high pressure.	Air is compressible and hence air can be pressurized to lesser pressure.
The system is bulky due to high pressure.	The system is less bulky as compared to a hydraulic system.
The accuracy of the system is high.	The accuracy of the system is not high.
Hydraulic oil is flammable.	Air is inflammable.
To protect against rust, the system needs special attention.	This system does not require any special attention.
Contamination control is required in this system.	Contamination control is not required in this system.
The power to size ratio is more.	The power to size ratio is small.

Q-09:Describe the life cycle for the mechatronics design system. [NITER_C_01]

Or, Draw the block diagram of Mechatronics Engineering design process with a brief discussion.

Answer:



Several important life cycle factors are described below.

1. Delivery: Time, cost, and medium

2. Reliability: Failure rate, materials, and tolerances.

3. Maintainability: Modular design.

4. Serviceability: On board diagnostics, prognostics, and modular design.

5. Upgradeability: Future compatibility with current designs. Disposability: Recycling and disposal of hazardous materials

Q-10:Briefly describe the stages of mechatronics system design. [NITER_C_01]

Answer:

1. The Need:

➢The design process starts with the need of a customer.

2. Analysis of the Problem:

➢This is the first stage and also the critical stage in the design process.

➢After knowing the customer need, analysis should be done to know the true nature of the problem.

3. Preparation of a Specification:

➢The second stage of the mechatronic process involves in the preparation of a specification.

➢The specification must be given to understand everyone the requirements and functions to be met.

4. Conceptualization:

➢In this stage, possible solutions should be generated for each of the functions required. Such as shape, size, material cost etc.

➢It should be possible to think of at least six solutions for realizing each function.

5. Optimization:

➢This stage involves in a selection of a best solution for the problem.

➢Optimization is defined as a technique in which a best solution is selected among a group of solutions to solve a problem.

6. Detail Design:

➢Once optimizing a solution is completed, the detail design of that solution is developed.

➢This may require a production of prototype etc., Mechanical layout is to be made whether physically all components can be accommodated.

7. Production of working Drawings:

➢The selected design or translated into working solution Drawings is then circuit diagrams, etc.

Q-11: Define Mechatronics & mechatronics model.[FEC_C_01]

Answer:

🤖 **Mechatronics** is a type of engineering that combines different areas like mechanical engineering, electrical engineering, computer science, and control systems. It's all about making smart machines and systems that can do things automatically.

Here are some of the key benefits of using mechatronics:

- Improved performance: Mechatronics systems can be more accurate, efficient.
- Reduced costs: Mechatronics can help to reduce development and manufacturing costs.
- Increased functionality: Mechatronics can add new features and capabilities to products.
- Greater user experience: Mechatronics can make products easier and more enjoyable to use.

A **mechatronics model** is like a virtual version of a mechatronic system. Engineers use these models to test how the real system will work before actually building it. They can simulate different scenarios, check if everything fits and works well together, and fix any problems they find. 🛠️ 🔌 💻

Here are some of the different types of mechatronics models:

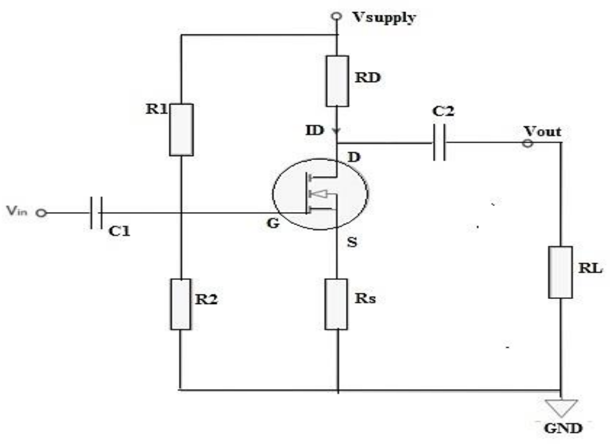
- Physical models: These are models that are built using real-world components.
- Computer models: These are models that are created using software.
- Hybrid models: These are models that combine physical and computer models.

Q-12: How MOSFET act as an Amplifier. [FEC_C_01]

Answer:MOSFET amplifiers work by controlling the flow of current between the source and drain terminals based on the voltage applied to the gate. By amplifying small input signals into larger output signals, MOSFETs serve as amplifiers in various electronic devices like audio systems and radios.

Basic Principle:

A MOSFET has three terminals: Source (S), Drain (D), and Gate (G).



Here's how it works:

Amplification Process:

1. **Biasing**: The MOSFET is biased such that it operates in the active region. A small input signal is applied to the gate terminal.
2. **Controlled Resistance**: The input signal applied to the gate controls the resistance between the source and drain terminals. This varying resistance modulates the output current flowing through the MOSFET.
3. **Amplification**: As the input signal changes, the output current also changes proportionally. This amplification is achieved by the MOSFET acting as a voltage-controlled current source.
4. **Load**: The output current from the MOSFET can then be fed into a load (like a speaker or another circuit) to drive it with an amplified version of the input signal.

Remember, MOSFETs can be used in both analog and digital circuits with appropriate biasing and configurations. 🚀

Q-13: Short note: i). RMS Value ii) Resistance iii) Impedance . [FEC_C_01]

Answer:

i) **RMS Value**:

- Stands for Root Mean Square
- Represents the effective (equivalent) value of an alternating current or voltage
- Used to calculate the equivalent DC value of an AC signal

ii) **Resistance**:

- Property that opposes the flow of electric current
- Measured in Ohms (Ω)
- Determines how easily a current can flow through a material

iii) **Impedance**:

- Overall opposition to the flow of alternating current in a circuit
- Combination of resistance and reactance (due to inductance or capacitance)
- Measured in Ohms (Ω) and represented as a complex number

Q-14: Define displacement sensor. Write the Applications of gauge strain. [FEC_C_01]

Answer:

A displacement sensor is a device that measures and detects the linear or angular displacement (movement) of an object or surface. It can determine the change in position or distance and provide an output signal that corresponds to the amount of displacement. Displacement sensors come in various types, including contact-based sensors (e.g., linear potentiometers) and non-contact sensors (e.g., optical, capacitive, inductive sensors).

Applications of gauge strain, also known as strain gauges, include:

1. Load and Force Measurement: Strain gauges are widely used to measure the strain or deformation in mechanical structures or components when subjected to external loads or forces. They can be applied to measure force in load cells, weigh scales, and structural testing.

2. Pressure and Torque Measurement: Strain gauges can be employed to measure the strain or deformation caused by pressure or torque. They are used in pressure transducers, torque sensors for rotating machinery, and automotive components like engine and transmission systems.

3. Structural Health Monitoring: Strain gauges play a crucial role in monitoring the structural health of buildings, bridges, dams, and other civil engineering structures. They help detect any structural deformations or stresses and provide valuable data for maintenance and safety purposes.

4. Aerospace Industry: Strain gauges are extensively used in the aerospace industry for monitoring the structural integrity of aircraft wings, fuselages, and other critical components. They aid in assessing the performance and response of structural elements under different flight conditions.

5. Robotics and Automation: Strain gauges find applications in robotics and automation systems where they can measure the forces and strains exerted by robotic arms, manipulators, and grippers. This data enables accurate control and feedback for precise movement and manipulation.

6. Geotechnical Engineering: Strain gauges are utilized in geotechnical engineering to measure soil pressure, settlement, and deformation in earth structures such as embankments, retaining walls, and tunnels. This helps assess the stability of structures and monitor potential hazards.

7. Biomechanics and Biomedical Engineering: In biomechanics and biomedical applications, strain gauges are used to measure joint movements, muscle contractions, and forces exerted during physical activities. This data assists in analyzing human movements, assessing athletic performance, and designing prosthetics.

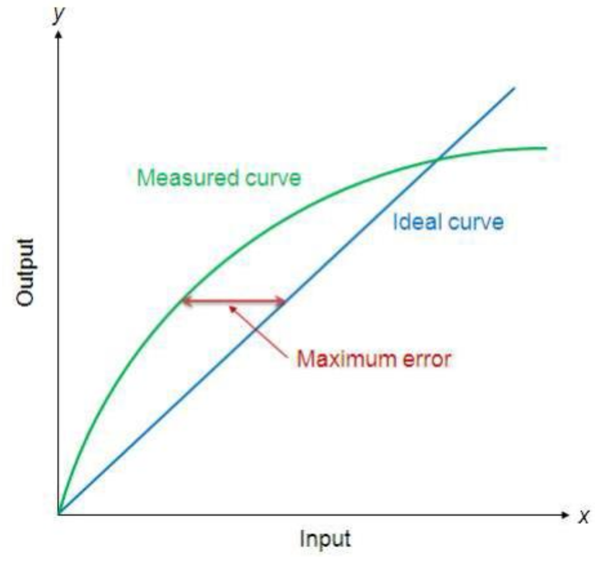
Q-15: Define Sensor with examples. Sketch and show the non-linearity and hysteresis properties of it. [FEC_C_02]

Answer:A sensor is a device that detects and responds to a signal , physical input and converts it into an electrical signal or output.

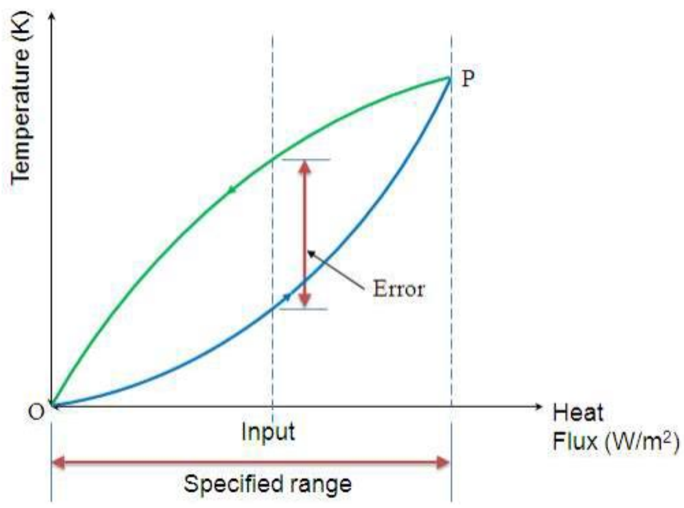
1. Temperature Sensor (e.g., Thermocouples, Resistance Temperature Detectors)
2. Pressure Sensor (e.g., Piezoresistive, Capacitive, Piezoelectric)
3. Light Sensor (e.g., Photodiodes, Phototransistors, Light-dependent resistors)
4. Acceleration Sensor (e.g., Accelerometers)
5. Proximity Sensor (e.g., Inductive Proximity Sensors, Capacitive Proximity Sensors)
6. Gas Sensor (e.g., Carbon Monoxide Sensor, Oxygen Sensor, Gas Chromatography Sensors)

Non-linearity: Not a straight line 📈

Hysteresis: Output depends on history 🔄



Non-linearity



Hysteresis

1. Non-linearity:
   - Output of the system is not directly proportional to the input.
   - Relationship between input and output is not a straight line.
   - Commonly observed in various systems and components.
   - Can lead to complex responses and behaviors.
2. Hysteresis:
   - System's state depends on its history.
   - Response at a given time is influenced by the path it took to reach that state.

- Commonly observed in materials, circuits, and mechanical systems.
- Presence of memory effect in the system's behavior.

Q-16:What is electrical strain gauge? A potentiometer displacement sensor is to be used to position measurement of 10 cm linear displacement. The resistance changes linearly over this range from 0 τo 240Ω. The above sensor is incorporated in 0.87A current. For an output motion of 210V the sensitivity of the potentiometer is? [FEC_C_02]

Answer:

A strain gauge is a type of sensor that measures strain or deformation in an object by detecting changes in electrical resistance. An electrical strain gauge typically consists of a thin wire or a metal foil, which acts as the sensing element. As strain is applied to the gauge, it stretches or compresses, causing a change in its resistance. This change in resistance is proportional to the strain experienced by the object, allowing for strain measurement.

$$V_{out} = K V_{in}\, x$$

$$K = \frac{V_{out}}{V_{in} \cdot x}$$

$$\text{or } K = \frac{210}{208.8 \times 0.1}$$

$$\therefore K = 10.05 \quad \text{Ans.}$$

$x = 10$ cm $= 0.1$ m

$V_{in} = I \times R = 0.87 \times 240 = 208.8$

$K = ?$

$V_{out} = 210$ ✓

Q-17: Notes on- i) LVDT ii) Thermocouple iii) Electrical Actuation system [FEC_C_02]

Answer:

Notes on:

i) LVDT (Linear Variable Differential Transformer):

- ✓ **Principle:** Uses transformer coupling to convert linear displacement into an electrical signal. An AC current is applied to a primary coil, inducing voltages in two secondary coils positioned symmetrically around the primary.
- ✓ **Advantages:** Highly accurate and sensitive, excellent linearity, non-contact operation, immune to external magnetic fields.
- ✓ **Disadvantages:** Requires AC excitation, bulky and expensive compared to some sensors, limited frequency response.
- ✓ **Applications:** Precision measurement in machine tools, robotics, aircraft control systems, vibration monitoring.

ii) Thermocouple:

- ✓ **Principle:** Converts temperature differences into voltage based on the See beck effect, where dissimilar metals in contact produce a voltage proportional to the temperature difference between their junctions.
- ✓ **Advantages**: Wide temperature range measurement, fast response time, rugged and versatile.
- ✓ **Disadvantages:** Non-linear output, requires reference junction compensation, susceptible to corrosion and contamination.
- ✓ **Applications:** Temperature measurement in furnaces, engines, power plants, chemical processing, medical equipment.

iii) Electrical Actuation System:

- ✓ Principle: Uses electrical energy to generate mechanical force or motion. Commonly employs electric motors, solenoids, or piezoelectric actuators.
- ✓ Types: Electric motors, Solenoids, Piezoelectric actuators
- ✓ Advantages: Precise control, clean and efficient operation, quiet and smooth motion.
- ✓ Disadvantages: Can be complex and expensive, power consumption can be high depending on application, may require feedback control for accurate positioning.
- ✓ Applications: Robotics, industrial automation, medical devices, aerospace systems, consumer electronics.

Q-18:Difference between Pneumatic and Hydraulic System[FEC_C_02]

Answer:
[Before]

Q-19:What is sensor? When a sensor is in operation mode, what phenomenon occurs? [FEC_Pre_02]

Answer:

When a sensor is in operation mode, there's a broad range of phenomena that could occur, depending on the type of sensor and what it's designed to detect or measure.

Here are a few general phenomena and principles that are common to many sensors during operation:

1. **Transduction**: The core function of a sensor is to convert one form of energy into another. This process is known as transduction. For instance, a thermocouple converts thermal energy into electrical energy.
2. **Signal Processing**: After energy conversion, the signal typically needs to be processed. This can include amplification, filtering, or digitization. This processing allows the signal to be read or recorded for further analysis.
3. **Response Time**: When a sensor detects its target, there will be a response time, which is the time taken for a sensor to react to a stimulus.
4. **Sensitivity and Selectivity**: These are crucial properties where sensitivity refers to how much the sensor's output changes when the quantity being measured changes. Selectivity refers to how well a sensor can differentiate between different stimuli.
5. **Drift**: Over time, the measurement a sensor provides might drift away from the true value. This can be due to changes in the sensor itself or its environment (like temperature or humidity).
6. **Noise**: All sensors have some level of noise, which is any unwanted variation in the output. Noise can come from electronic components or environmental factors.
7. **Range**: The sensor will have a specified range of values it can measure. Any stimulus beyond this range may not be accurately detected or could potentially damage the sensor.
8. **Hysteresis**: This is when the current output of the sensor depends not only on its current input but also on the history of its input. In other words, if you increase the stimulus and then decrease it, the path of the output will not be the same, showing a lag.
9. **Linearity and Non-Linearity**: Some sensors exhibit a linear relationship between the sensor input and output; others display non-linearity, where the relationship is not a straight line and is instead more complex.
10. **Saturation**: If the stimulus exceeds the sensor’s maximum range, the sensor may enter a state known as saturation, where the output no longer increases despite increases in the input.
11. **Environmental Effects**: How a sensor operates can be affected by its environment. For example, a sensor could be sensitive to temperatures, humidity, pressure, electromagnetic interference, or other factors that aren’t being measured.

Q-20: Write down the selection criteria of a Transducer? [FEC_Pre_02]

Answer:

When selecting a transducer, there are several key criteria to consider: 🤔

1. **Measurement Range:** 📏 The transducer should be able to cover the desired range of measurements accurately.

2. **Accuracy:** ✅ The transducer should provide precise and reliable measurements, with minimal errors or deviations.

3. **Sensitivity:** 🎚️ The transducer's sensitivity determines its ability to detect small changes in the measured quantity. Higher sensitivity is preferred in cases where fine resolution is needed.

4. **Response Time:** ⏱️ The transducer's response time refers to the speed at which it can detect and deliver a measurement after a change in the input. Fast response times are crucial in dynamic applications.

5. **Linearity:** 📈 A transducer with good linearity ensures that its output is directly proportional to the input. Linearity minimizes distortion and simplifies calibration.

6. **Signal-to-Noise Ratio (SNR):** 📶 An optimal transducer should have a high signal-to-noise ratio, which means the desired signal is stronger than any interference or noise present.

7. **Environmental Factors:** 🌧️ Consider the operating environment, such as temperature, humidity, pressure, or presence of corrosive substances, and select a transducer that can withstand those conditions.

8. **Power Requirements:** 🔋 Determine the power supply available and choose a transducer that is compatible with it.

9. **Size and Mounting:** 💪 Consider the physical dimensions and mounting requirements of the transducer to ensure it can be installed properly in the intended application.

10. **Cost:** 💰 Evaluate the cost of the transducer in relation to its performance and suitability for the specific application.

By considering these criteria, you can select a transducer that best meets your measurement needs.

Q-21: Draw the block diagram of Mechatronics Engineering design process with a brief discussion. [FEC_Pre_02]

Solve: [NITER_C_01]

Q-22: What is measurement device loading errors? [FEC_Pre_02]

Answer:

📏 Measurement device loading errors refer to inaccuracies or biases introduced during the measurement process due to factors related to the device or instrument used. These errors can affect the reliability and validity of the measurements obtained.

Q-23: Define Mechatronics with its application in Engineering [FEC_Pre_02]

Answer:

🤖 Mechatronics is an interdisciplinary field combining mechanical engineering, electrical engineering, and computer science. It focuses on integrating mechanics, electronics, and control systems to design and create intelligent and automated systems. The aim is to develop efficient and reliable products and processes.

🔧 Mechatronics finds applications in various engineering domains, such as:

1️⃣ **Manufacturing:** Mechatronics is used in automated assembly lines, robotics, and computer-controlled manufacturing processes to improve productivity and precision.

2️⃣ **Automotive:** Mechatronics plays a significant role in the automotive industry, enabling the development of advanced features like anti-lock braking systems (ABS), active suspension systems, and adaptive cruise control.

3️⃣ **Aerospace:** Mechatronics contributes to the design and operation of autonomous aircraft, control systems for stabilization and navigation, as well as communication and data recording systems.

4️⃣ **Biomedical Engineering:** Mechatronics is utilized in medical equipment and devices, such as robotic-assisted surgery systems, prosthetics, and diagnostic instruments.

5️⃣ **Robotics:** Mechatronics forms the foundation of the field of robotics, enabling the design and development of intelligent robots used in various industries, including healthcare, manufacturing, and space exploration.

6️⃣ **Consumer Electronics:** Mechatronics is incorporated into consumer products like smart appliances, wearable devices, and home automation systems, enhancing their functionality and interconnectivity.

In summary, mechatronics combines multiple engineering disciplines to create innovative systems and technologies that enhance automation, efficiency, and functionality across diverse industries.

🚀 🤖 🔌

EXTRA:

Q-01: Explain how mechatronic components and systems contribute to robot functionality and autonomy.

Mechatronics plays a crucial role in making robots functional and autonomous. It's the synergy between **mechanics, electronics, and software** that breathes life into robots, allowing them to sense, move, and interact with the world. Here's how each component contributes:

Mechanics:

- **Structure and movement:** Provides the robot's physical body, joints, and actuators (motors, etc.) that enable locomotion and manipulation.
- **Sensors:** Integrates various sensors (e.g., cameras, LiDAR, touch sensors) for gathering information about the environment.

Electronics:

- **Control systems:** Microcontrollers and computers process sensor data, run control algorithms, and send commands to actuators.
- **Power systems:** Batteries, fuel cells, or other sources provide energy for robot operation.

Software:

- **Control algorithms:** Defines how the robot interprets sensor data, makes decisions, and controls its actions.
- **Artificial intelligence (AI):** In advanced robots, AI algorithms provide capabilities like learning, adaptation, and planning for greater autonomy.

Together, these elements work in concert:

- **Sensors** perceive the environment, feeding data to **electronics**.
- **Electronics** process data and send commands to **mechanics** through **software algorithms**.
- **Mechanics** then execute actions like movement, based on the commands.

Examples of mechatronics in action:

- **Industrial robots:** Assemble cars, weld parts, and perform repetitive tasks with high precision.
- **Service robots:** Vacuum homes, deliver packages, and even provide companionship.
- **Surgical robots:** Assist surgeons with minimally invasive procedures, improving accuracy and control.

Q-02: what is pick and place robot. write it application.

A pick-and-place robot is a type of robotic system designed to pick up objects from one location and place them in another. These robots are widely used in industrial automation and manufacturing processes to handle repetitive tasks efficiently and with high precision.

Applications of Pick and Place Robots:

1. **Assembly Line Automation**: Pick-and-place robots are commonly used in assembly lines to pick up components and assemble products like electronics, automobiles, and appliances.
2. **Packaging**: These robots are employed in packaging industries to pick up items from a conveyor belt and place them in packaging containers such as boxes, bags, or trays.
3. **Material Handling**: Pick-and-place robots help in moving materials between different stages of production, warehouses, or logistics centers.
4. **High-Speed Sorting**: They are utilized in sorting applications to pick up items from a random array and place them in specific locations based on predefined criteria.
5. **3D Printing**: In additive manufacturing processes, pick-and-place robots assist in handling parts and materials for 3D printing tasks.
6. **Food and Beverage Industry**: Pick-and-place robots are used for tasks such as food packaging, palletizing, and sorting in food processing and beverage industries.
7. **Pharmaceutical Industry**: These robots play a crucial role in pharmaceutical production by handling delicate components, vials, and packaging materials.

Q-03: Briefly explain the components and operations of a typical pick-and-place system used in automation.

A typical pick-and-place system used in automation consists of the following components and operations:

Here are the main parts of a typical pick-and-place robot:

1. **Manipulator**: The manipulator is the mechanical arm of the robot responsible for picking up and placing objects.

2. **End Effector (Gripper)**: The end effector, or gripper, is the tool attached to the end of the manipulator that physically picks up and releases objects.
3. **Actuators**: Actuators provide the necessary motion to the robot's joints and end-effector.

4. **Sensors**: Sensors are essential for providing feedback to the robot about its position,

5. **Controller**: The controller is the brain of the robot that receives input from sensors, processes data, and sends commands to the actuators to perform the desired tasks.

6. **Programming Interface**: Pick-and-place robots can be programmed using various methods, such as teach pendant programming, graphical user interfaces, or programming languages like C++ or Python.

7. **Safety Features**: Pick-and-place robots are equipped with safety features such as emergency stop buttons, protective barriers, motion sensors, and safety protocols to ensure a safe working environment for humans and prevent accidents.

Operations:

- **Picking**: The robotic arm uses the end effector to grip the object from a specified location. This requires precise movement and control.
- **Transportation**: The robot moves the object to the desired location while ensuring stability and avoiding collisions with other objects.
- **Placing**: The robot releases the object with precision at the target location. It needs to be accurate to ensure correct positioning.
- **Repeat**: The system repeats these operations continuously and with high speed, making it suitable for automation tasks in industries like manufacturing and packaging.

Overall, pick-and-place systems improve efficiency and accuracy in production processes by automating repetitive tasks that involve moving objects from one place to another. 🤖 🏗️

Relation Between Robort and Mechatronics

1. **Design and Development**: Mechatronics principles are used in the design and development of robotic systems.
2. **Sensing and Actuation**: Robots rely on sensors to perceive the environment and actuators to physically interact with it.
3. **Control Systems**: Mechatronics plays a significant role in designing control systems for robots.
4. **Integration of Technologies**: Mechatronics facilitates the integration of various technologies essential for robotic systems.
5. **Interdisciplinary Approach**: Mechatronics brings together knowledge from multiple disciplines to address challenges in robotics.
6. **Sustainability and Optimization**: Mechatronics principles are used to enhance the efficiency, functionality, and sustainability of robotic systems. Optimization techniques are applied to improve energy efficiency, reduce costs, and enhance performance.

##Light Sensor, proximity Sensor.

Light sensor: Light sensors are devices that are used to convert light energy into electrical energy. The commonly used sensors are

➢ Light Dependent Resister (LDR)

➢ Photo Diode

➢ Photo transistor

proximity Sensor: A proximity sensor is sensor able to detect the presence of nearby objects without any physical contact. Proximity sensors often emits an electromagnetic field or beam of electromagnetic radiation(infrared) and looks for change in the field or return signal. The object being sensed is often referred to the proximity sensor target. Types of proximity sensors

➢ Inductive

➢ Capacitive

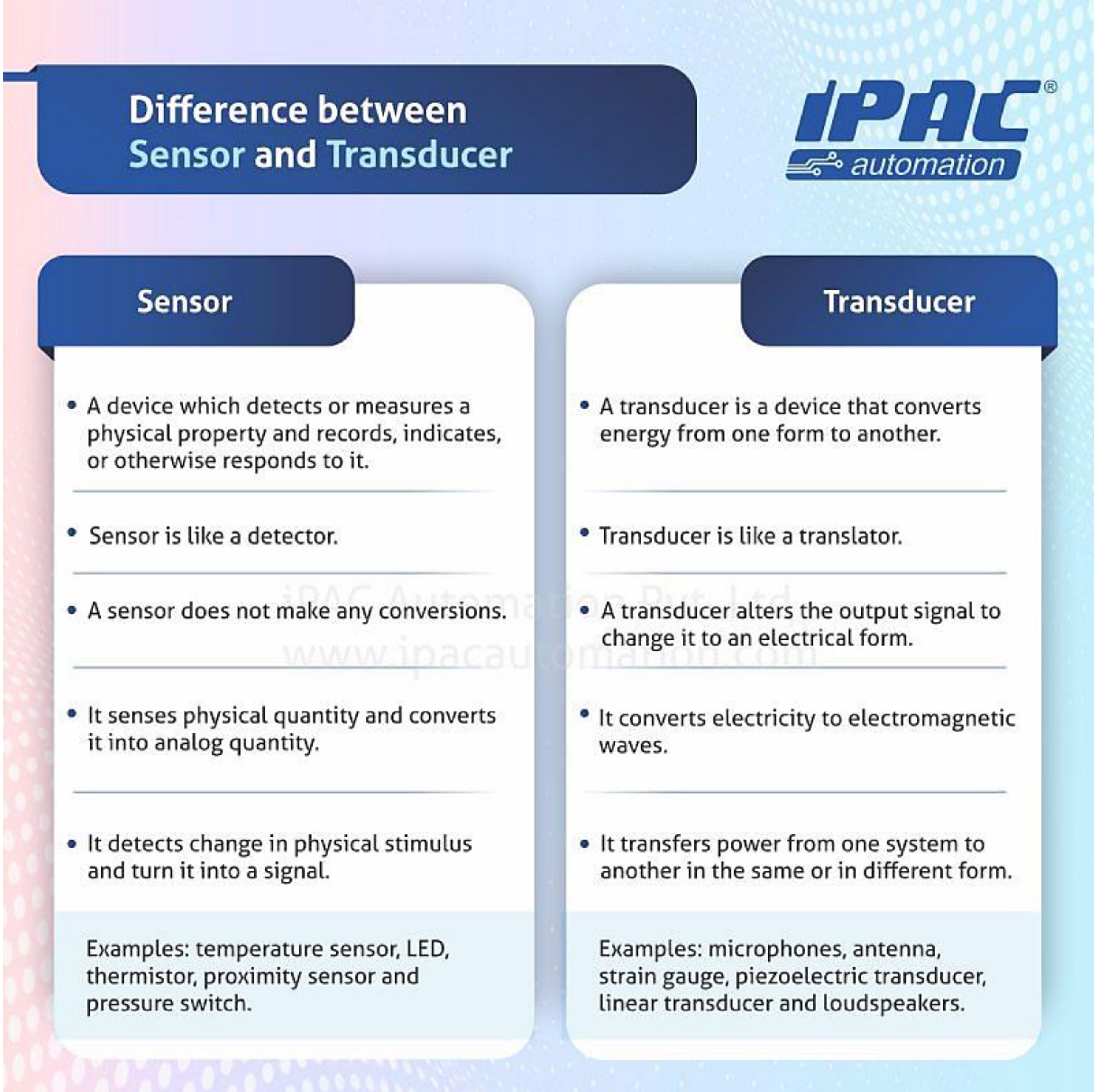
➢ Optical

➢ Ultrasonic

Q-04: Automatic vs. Manual Control Systems

Compare and contrast the features of automatic and manual control systems.

Feature	Automatic	Manual
Operation	Self-driven	Human-controlled
Flexibility	Limited	High
Efficiency	High	Variable
Reliability	Technical errors	Human errors
Cost	High upfront	Lower upfront, higher labor
Safety	Removes human error risks	Requires trained operators
Best for	Repetitive tasks, precise control	Judgement, adaptability



Q-05:Describe how control engineering principles form the foundation of mechatronic system behaviour and how feedback mechanisms contribute to accurate operation.

Or,

Write to the feedback of control engineering.

Feedback in Control Engineering: Feedback in control engineering is a fundamental concept that involves comparing the actual output of a system with a desired reference value and using the difference (error signal) to adjust the system's behavior to achieve the desired output. By providing information about the system's performance and making real-time adjustments, feedback mechanisms ensure accurate operation and stability. Feedback can be positive (reinforcing) or negative (corrective) depending on its impact on the system.

Q-06: Describe the behaviour of damped RLC circuits and their mathematical representation.

These sensors are used in applications such as robotics, autonomous vehicles, quality control in manufacturing, security systems, medical imaging, and more.

Behaviour of Damped RLC Circuits: Damped RLC circuits consist of a resistor (R), an inductor (L), and a capacitor (C) connected in series or parallel.

Primary Function of a Transformer: In a mechatronic system, a transformer is used to transfer electrical energy between circuits at different voltage levels

Mathematical Model of a Transformer: It involves equations that describe the relationship between the primary and secondary voltages, currents, turns ratio, and power transfer efficiency.

Operation of Hydraulic Systems and Applications: Hydraulic systems utilize fluid (usually oil) under pressure to generate, control, and transmit power.

Q-07: What is the primary function of a transformer in a mechatronic system?

The primary function of a transformer in a mechatronic system is to transfer electrical energy between two circuits through electromagnetic induction. Transformers are commonly used in mechatronic systems to:
Step-up or step-down voltage: Transformers can be used to increase or decrease the voltage of an electrical signal, which is useful in mechatronic systems where different components require different voltage levels.
Isolate circuits: Transformers can be used to isolate two circuits from each other, providing electrical insulation and preventing the flow of current or signals between the two circuits.
Provide power supply isolation: Transformers can be used to isolate the power supply of a mechatronic system from the load, reducing the risk of damage to the system or injury to people.
Implement electronic filtering: Transformers can be used to implement electronic filtering in mechatronic systems, such as low-pass, high-pass, band-pass, and remove-pass filters.
Provide electromagnetic field control: Transformers can be used to control the electromagnetic field in mechatronic systems, such as in the control of inductive loads or in the generation of magnetic fields.

Q-08: Can you describe the mathematical model that represents the behaviour of a transformer?

A transformer is a device that helps transfer electrical energy between two circuits through electromagnetic induction. It works by using electromagnetic fields to transform the voltage and current levels of the primary circuit to the secondary circuit.

1. Ideal Transformer:

This simplified model assumes perfect conditions with no losses or leakage, making it great for grasping the core concept. Think of it as a "thought experiment" transformer:

Voltage Ratio: $V_1/V_2 = N_1/N_2$ (Primary to secondary winding turns ratio)
Current Ratio: $I_2/I_1 = N_2/N_1$ (Assuming constant power transfer)
Impedance Ratio: $Z_2/Z_1 = (N_2/N_1)^2$

2. Equivalent Circuit Model:

This model gets more realistic by incorporating losses and leakage. It's similar to building a simplified circuit using ideal components to represent the actual behavior:

- Ideal Transformers
- Resistors
- Inductors

Different levels of detail exist in equivalent circuits, depending on the desired accuracy:

- Single-phase equivalent circuit
- Three-phase equivalent circuit
- Efficiency
- Frequency response Note

Q-09: Applications of both hydraulic and pneumatic systems

Hydraulic Systems:

1. **Construction Machinery**: Hydraulic systems are widely used in excavators, bulldozers, cranes, and loaders for lifting heavy loads, moving earth, and various construction tasks.
2. **Manufacturing Machinery**: Hydraulic systems are employed in presses, injection molding machines, metal forming equipment, and other machinery for bending.
3. **Aerospace Industry**: Hydraulic systems are crucial in aircraft for controlling landing gear, wing flaps, flight control surfaces, and braking systems due to their power and reliability.
4. **Automotive Industry**: Hydraulic systems are found in applications like braking systems, power steering, suspension systems, and automatic transmissions in vehicles for effective control and power assistance.
5. **Maritime Industry**: Ships and boats utilize hydraulic systems for steering mechanisms, loading and unloading cargo with cranes, and controlling various functions on board.

Pneumatic Systems:

1. **Manufacturing Automation**: Pneumatic systems are popular in automated manufacturing processes for tasks like pick-and-place operations, assembly lines, and packaging applications.
2. **Medical Equipment**: Pneumatic systems are used in devices like ventilators, dental chairs, surgical tools, and blood pressure monitors for precise control and operation.
3. **Air Tools**: Pneumatic systems power a wide range of tools such as impact wrenches, nail guns, paint sprayers, and pneumatic drills used in construction, automotive repair, and maintenance.
4. **HVAC Systems**: Pneumatic actuators are utilized in heating, ventilation, and air conditioning systems for controlling valves, dampers, and airflow regulation.
5. **Food and Beverage Industry**: Pneumatic systems are employed in food processing and packaging equipment for tasks like sorting, filling, sealing, and labeling

##primary vs secondary transducer

Primary Transducer	Secondary Transducer
Converts physical phenomenon into a measurable electrical signal.	Converts the electrical signal from the primary transducer into another form of energy or signal.
Typically the first component in a measurement system.	Receives the output from the primary transducer for further processing or display.
Examples include pressure sensors, temperature sensors, strain gauges, etc.	Examples include analog-to-digital converters (ADCs), digital-to-analog converters (DACs), display units, actuators, etc.
Directly interacts with the physical quantity being measured.	Operates on the electrical signal generated by the primary transducer.
Accuracy and reliability of measurement are crucial in primary transducers.	The secondary transducer may amplify, filter, or convert the signal for specific purposes.
Critical in ensuring the fidelity of data acquisition in a measurement system.	Plays a role in signal processing, control, or actuation based on the converted signal.

##**Flow:** In hydraulic and pneumatic systems, "flow" refers to the movement of fluid (either liquid in hydraulic systems or gas in pneumatic systems) within the system. The flow rate determines how quickly the actuator moves or how fast a device is operated. Flow is typically measured in liters per minute (l/min) for hydraulic systems and in cubic feet per minute (CFM) for pneumatic systems.

##**Forces:** Forces play a significant role in hydraulic and pneumatic systems. Pressure is the force exerted on a certain area, and it is essential for transmitting power in these systems. The force produced by hydraulic or pneumatic actuators is a result of the pressure applied to the fluid within the system. Understanding forces allows engineers to design systems that can lift heavy loads or perform specific tasks effectively.

##**System Model:** A system model in the context of hydraulic and pneumatic systems involves creating a mathematical representation of the system's behavior. Engineers develop models to predict how the system will respond under different operating conditions. These models consider factors like fluid properties, components, flow rates, pressures, forces, and control mechanisms. By analyzing the system model, engineers can optimize performance, troubleshoot issues, and design improvements.

Q-10: Define: Current, Ac Current. Dc current, Voltage Average valve, peak Value, Rms Value, Resistance, Impedance, Ac & Dc Circuit, Series and parallel Circuit, ADC,DAC, velocity.

Current: Current refers to the flow of electricity in the electronic circuit, and to the amount of electricity flowing through a circuit. It is measured in ampere(A)

AC current: Alternating Current (AC) is a type of electrical current, in which the direction of flow of electrons switches back and forward at regular intervals or cycles.

DC current: Direct Current is one directional flow of electric harge

Voltage: Voltage is the pressure from an electrical circuit power source that pushes charged electrons (current) through a conducting loops. enabling them to do works such as illuminating a light.

Average Value: The average value is defined as the average of all the instantances values of an alternating quantity such as current or voltage over one complete cycle.

Peak value: Peak value is defined as the maximum value that the alternating quantity (current or voltage) reaches in one cycle (either positive or Neg)

RMS Value: Root means the square root of means of squares of instantaneous values.

Resistance: Resistance is a measure of the opposition to current flow in an electrical circuit. It's measured in ohms(Ω).

Impedance: Impedance denoted Z, is an expression of the opposition that an electronic components, circuits or system offers to alternating or direct electric circuit.

AC & DC circuit: An Ac to DC converter circuits relies on rectification, where input AC power is connected into an unstable DC output with same residual ripple. The basic components involved in AC to DC converter are: Transformer: This steps up or down the grid power to a value that is useful by the load in the system.

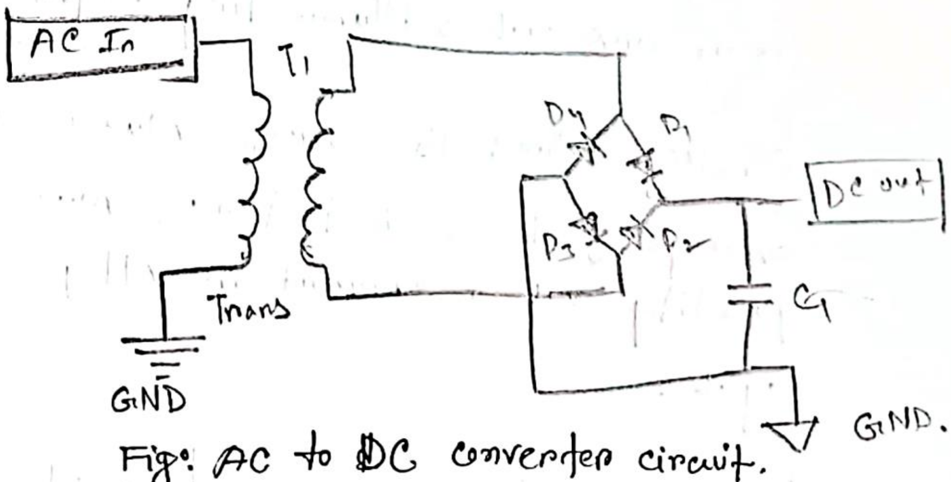
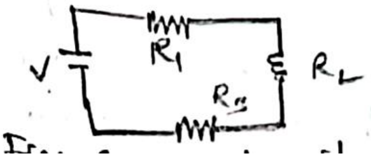


Fig: AC to DC converter circuit.

Series circuit: Series circuit are that circuits where components are connected in series.

Example:



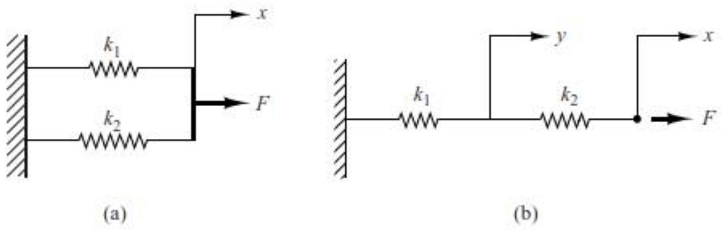


Figure 3–1
(a) System consisting of two springs in parallel;
(b) system consisting of two springs in series.

EXAMPLE 3–1 Let us obtain the equivalent spring constants for the systems shown in Figures 3–1(a) and (b), respectively.

For the springs in parallel [Figure 3–1(a)] the equivalent spring constant k_{eq} is obtained from

$$k_1 x + k_2 x = F = k_{eq} x$$

or

$$k_{eq} = k_1 + k_2$$

For the springs in series [Figure–3–1(b)], the force in each spring is the same. Thus

$$k_1 y = F, \qquad k_2(x - y) = F$$

Elimination of y from these two equations results in

$$k_2\left(x - \frac{F}{k_1}\right) = F$$

or

$$k_2 x = F + \frac{k_2}{k_1} F = \frac{k_1 + k_2}{k_1} F$$

The equivalent spring constant k_{eq} for this case is then found as

$$k_{eq} = \frac{F}{x} = \frac{k_1 k_2}{k_1 + k_2} = \frac{1}{\dfrac{1}{k_1} + \dfrac{1}{k_2}}$$

EXAMPLE 3–2 Let us obtain the equivalent viscous-friction coefficient b_{eq} for each of the damper systems shown in Figures 3–2(a) and (b). An oil-filled damper is often called a dashpot. A dashpot is a device that provides viscous friction, or damping. It consists of a piston and oil-filled cylinder. Any relative motion between the piston rod and the cylinder is resisted by the oil because the oil must flow around the piston (or through orifices provided in the piston) from one side of the piston to the other. The dashpot essentially absorbs energy. This absorbed energy is dissipated as heat, and the dashpot does not store any kinetic or potential energy.

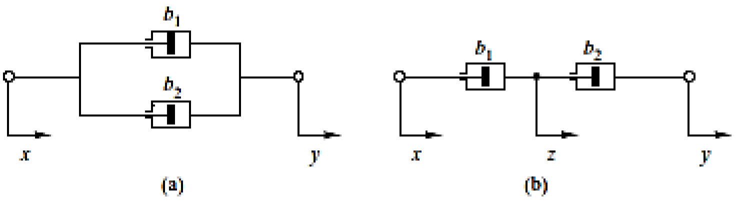


Figure 3–2
(a) Two dampers connected in parallel; (b) two dampers connected in series.

(a) The force f due to the dampers is

$$f = b_1(\dot{y} - \dot{x}) + b_2(\dot{y} - \dot{x}) = (b_1 + b_2)(\dot{y} - \dot{x})$$

In terms of the equivalent viscous-friction coefficient b_{eq}, force f is given by

$$f = b_{eq}(\dot{y} - \dot{x})$$

Hence

$$b_{eq} = b_1 + b_2$$

(b) The force f due to the dampers is

$$f = b_1(\dot{z} - \dot{x}) = b_2(\dot{y} - \dot{z}) \tag{3–1}$$

where z is the displacement of a point between damper b_1 and damper b_2. (Note that the same force is transmitted through the shaft.) From Equation (3–1), we have

$$(b_1 + b_2)\dot{z} = b_2\dot{y} + b_1\dot{x}$$

or

$$\dot{z} = \frac{1}{b_1 + b_2}(b_2\dot{y} + b_1\dot{x}) \tag{3–2}$$

In terms of the equivalent viscous-friction coefficient b_{eq}, force f is given by

$$f = b_{eq}(\dot{y} - \dot{x})$$

By substituting Equation (3–2) into Equation (3–1), we have

$$f = b_2(\dot{y} - \dot{z}) = b_2\left[\dot{y} - \frac{1}{b_1 + b_2}(b_2\dot{y} + b_1\dot{x})\right]$$

$$= \frac{b_1 b_2}{b_1 + b_2}(\dot{y} - \dot{x})$$

Thus,

$$f = b_{eq}(\dot{y} - \dot{x}) = \frac{b_1 b_2}{b_1 + b_2}(\dot{y} - \dot{x})$$

Hence,

$$b_{eq} = \frac{b_1 b_2}{b_1 + b_2} = \frac{1}{\dfrac{1}{b_1} + \dfrac{1}{b_2}}$$

Example 7.2 If a pipe goes from a 9-cm diameter to 6-cm diameter and the velocity in the 9-cm section is 2.21 m/s, what is the average velocity in the 6-cm section?

$$Q = V_1 A_1 = V_2 A_2$$

$$V_2 = \frac{2.21\ \text{m}^3/\text{s} \times \pi \times 4.5^2}{\pi \times 3^2} = 4.97\ \text{m/s}$$

Mass flow rate F is related to volume flow rate Q by

$$F = \rho Q \tag{7.4}$$

where F is the mass of liquid flowing and ρ is the density of the liquid.

As a gas is compressible, Eq. (7.3) must be modified for gas flow to

$$\gamma_1 V_1 A_1 = \gamma_2 V_2 A_2 \tag{7.5}$$

where γ_1 and γ_2 are specific weights of the gas in the two sections of pipe.

Equation (7.3) is the rate of weight flow in the case of a gas. However, this could also apply to liquid flow in Eq. (7.3) by multiplying both sides of the equation by the specific weight γ.

Problem 4. An ideal transformer, connected to a 240 V mains, supplies a 12 V, 150 W lamp. Calculate the transformer turns ratio and the current taken from the supply.

$V_1 = 240$ V, $V_2 = 12$ V, $I_2 = \dfrac{P}{V_2} = \dfrac{150}{12} = 12.5$ A

Turns ratio $= \dfrac{N_1}{N_2} = \dfrac{V_1}{V_2} = \dfrac{240}{12} = \mathbf{20}$

$\dfrac{V_1}{V_2} = \dfrac{I_2}{I_1}$, from which, $I_1 = I_2\left(\dfrac{V_2}{V_1}\right) = 12.5\left(\dfrac{12}{240}\right)$

Hence current taken from the supply, $I_1 = \dfrac{12.5}{20} = \mathbf{0.625\ A}$

Problem 5. A 5 kVA single-phase transformer has a turns ratio of 10:1 and is fed from a 2.5 kV supply. Neglecting losses, determine (a) the full load secondary current, (b) the minimum load resistance which can be connected across the secondary winding to give full load kVA, (c) the primary current at full load kVA.

(a) $\frac{N_1}{N_2} = \frac{10}{1}$ and $V_1 = 2.5\,\text{kV} = 2500\,\text{V}$

Since $\frac{N_1}{N_2} = \frac{V_1}{V_2}$, secondary voltage

$$V_2 = V_1\left(\frac{N_2}{N_1}\right) = 2500\left(\frac{1}{10}\right) = 250\,\text{V}$$

The transformer rating in volt-amperes $= V_2 I_2$ (at full load), i.e. $5000 = 250 I_2$

Hence full load secondary current $I_2 = \frac{5000}{250} = \mathbf{20\,A}$

(b) Minimum value of load resistance, $R_L = \frac{V_2}{I_2}$

$$= \frac{250}{20}$$

$$= \mathbf{12.5\,\Omega}$$

(c) $\frac{N_1}{N_2} = \frac{I_2}{I_1}$, from which primary current $I_1 = I_2\left(\frac{N_2}{N_1}\right)$

$$= 20\left(\frac{1}{10}\right)$$

$$= \mathbf{2\,A}$$

##Development of PLC ladder programming and implementation of real life system

Developing a Programmable Logic Controller (PLC) ladder program for a real-life system involves creating a series of logical steps represented in ladder diagram format to control industrial processes or machines. Here's a general outline of how you can approach this:

1. **Understand the System**: Begin by understanding the real-life system you want to control using the PLC. Identify the input signals (sensors), output signals (actuators), control requirements, safety measures, and any interlocks.
2. **Design the Control Logic**: Create a detailed control logic diagram that represents the desired behavior of the system. Identify the conditions under which inputs should trigger specific actions on the outputs.
3. **Create the Ladder Logic**: Translate the control logic into ladder logic programming language supported by the PLC.
4. **Test and Debug**: Test the PLC program with simulated inputs and outputs before deploying it in the actual system.
5. **Implement in the Real System**: Once the program is thoroughly tested, deploy it in the real system and monitor its performance.

Application of PLC controller.

A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic operation.

Industrial Automation: PLCs are extensively used in industrial automation to control manufacturing processes such as assembly lines, packaging, and material handling.

Process Control Systems: They help maintain optimal conditions and ensure safety.

Manufacturing Machinery Control: PLCs control a variety of manufacturing machinery, including CNC machines, robotic arms, and stamping machines.

Traffic Light Control Systems: PLCs are employed in traffic light control systems to manage traffic flow efficiently. They help regulate signal timings, coordinate intersections, and respond to changes in traffic patterns.

Building Automation: They enable energy-efficient operations and provide centralized control for various building functions.

Power Plant Control: PLCs are used in power plants to control and monitor the generation, distribution, and consumption of electrical power. They help manage equipment such as generators, turbines, and switchgear.

Automated Testing Systems: PLCs are utilized in automated testing systems for quality control and inspection processes. They can control testing equipment, monitor parameters, and make real-time decisions based on test results.

##Understand control actions such as Proportional, derivative and integral and study its significance in industrial applications.

1. **Proportional (P) Control**:
   - **Significance**: Proportional control adjusts the output based on the current error between the desired setpoint and the actual process value.
   - **Industrial Applications**: Proportional control is essential in systems requiring responsiveness to changes, such as temperature control in ovens, pH control in chemical processes, or flow control in pipelines.
2. **Integral (I) Control**:
   - **Significance**: Integral control integrates the error over time and eliminates any steady-state error.
   - **Industrial Applications**: Integral control is crucial in systems where precise and stable control is required, such as level control in tanks, pressure control in hydraulic systems, or speed control in motors.

3. **Derivative (D) Control**:
    - **Significance**: Derivative control anticipates future trends by considering the rate of change of the error.
    - **Industrial Applications**: Derivative control is used in systems where predictive control is necessary, like in cruise control systems

#A resistance wire strain gauge with a gauge factor of 2 is bonded to a steel structure member subjected to a stress of 100 MN/m2. The modulus of elasticity of steel is 200 GN/ m2. Calculate the percentage change in value of the gauge resistance due to the applied stress.

Solution

$$\text{Strain} = \varepsilon = \frac{S}{E} = \frac{100(10)^6}{200(10)^9} = 0.5(10)^{-3}\,\text{m/m}$$

$$\text{Gauge factor} = \frac{\frac{\Delta R}{R}}{\varepsilon}$$

Thus,

$$\frac{\Delta R}{R} = G_f \cdot \varepsilon = (2)(0.5)(10)^{-3} = 0.001$$

$$\text{Percentage change in}\,\frac{\Delta R}{R} = 0.1\,\%$$

A compressive force is applied to a structure causing the strain, $\varepsilon = -5(10)^{-6}$ Two separate strain gauges are attached to the structures, where one is a nickel wire stain gauge of gauge factor of -12.1 and another is a nicrome wire strain gauge of gauge factor of 2. Calculate the value of resistance of the gauges after they are strained. The resistance of strain gauge is 120 Ω.

Solution

Let us consider tensile strain as positive and compressive strain as negative.

$$Strain,\ \varepsilon = -5(10)^{-6}$$

$$\frac{\Delta R}{R} = G_f.\varepsilon;\ \Delta R = RG_f.\varepsilon$$

Change in resis tan *ce for Nickel strain gauge,*

$$\Delta R = (120)(-12.1)(-5)(10)^{-6} = 7.26(10)^{-3}\Omega$$

Change in resis tan *ce for Nichrome strain gauge,*

$$\Delta R = (120)(2)(-5)(10)^{-6} = -1.2(10)^{-3}\Omega$$

The value of resistance of nickel strain gauge increases, whereas, the value of resistance of nichrome strain gauge decreases.

RAIHAN's idea