UNIT-III:

Magnetic sensors

1. INTRODUCTION TO MAGNETIC SENSORS

Definition

Magnetic sensors are devices used to detect magnetic fields and convert them into electrical signals.

Purpose

They are used to measure:

- Magnetic field strength
- Position
- Speed
- Direction
- Current
- Angular displacement

Advantages

- Non-contact sensing
- High reliability
- Long life
- Fast response

Applications

- Automotive systems
- Robotics
- Industrial automation
- Navigation systems
- Consumer electronics

2. SENSORS AND THE PRINCIPLES BEHIND

Magnetic sensors operate based on changes in magnetic properties caused by magnetic fields.

Common Principles

1. Hall Effect

Voltage is generated when current-carrying material is placed in a magnetic field.

2. Magnetoresistance

Resistance changes with magnetic field.

3. Electromagnetic Induction

Voltage is induced by changing magnetic flux.

4. Eddy Current Effect

Magnetic field induces circulating currents in conductors.

5. Magnetic Permeability Change

Magnetic field changes inductance.

3. MAGNETO-RESISTIVE (MR) SENSORS

Definition

Sensors whose electrical resistance changes in the presence of a magnetic field.

Principle

Magnetic field alters electron movement, causing resistance variation.

Characteristics

- High sensitivity
- Fast response
- Small size

Advantages

- Accurate detection
- Low power consumption

Applications

- Position sensing
- Compass systems
- Automotive sensor

4. ANISOTROPIC MAGNETORESISTIVE (AMR) SENSORS

Definition

A type of magnetoresistive sensor based on anisotropic magnetoresistance effect.

Principle

Electrical resistance depends on the angle between:

- Current direction
- Magnetic field direction

Features

- High sensitivity
- Good linearity
- Small size

Advantages

- Precise magnetic field measurement
- Low power consumption

Applications

- Electronic compasses
- Navigation systems
- Position sensors

5. SEMICONDUCTOR MAGNETORESISTORS

Definition

Magnetoresistive devices made using semiconductor materials.

Principle

Magnetic field changes carrier mobility, altering resistance.

Characteristics

- Very high sensitivity
- Fast response
- Compact size

Advantages

- High accuracy
- Suitable for weak magnetic fields

Applications

- Magnetic field measurement
- Current sensing
- Position detection

6. HALL EFFECT AND HALL EFFECT SENSORS

Hall Effect

When a current-carrying conductor or semiconductor is placed in a magnetic field, a voltage is generated perpendicular to both current and magnetic field.

Hall Voltage

$$V_H = \frac{BIt}{nq}$$

Where:

- VH = Hall Voltage
- B = Magnetic Flux Density
- I = Current
- n = Charge Carrier Density
- q = Electron Charge
- t = Thickness

Hall Effect Sensor

A sensor that uses Hall Effect to measure magnetic field.

Advantages

- Non-contact operation
- Long life
- High reliability

Applications

- Speed sensing
- Position sensing
- Current measurement
- Brushless DC motors

7. INDUCTANCE SENSORS

Definition

Sensors that work by varying inductance.

Principle

Inductance depends on:

$$L = \frac{N^2 \mu A}{l}$$

Where:

- L = Inductance
- N = Number of turns
- μ = Permeability
- A = Area
- l = Length of magnetic path

Working

Movement of magnetic material changes inductance.

Applications

- Displacement measurement
- Position sensing
- Metal detection

8. EDDY CURRENT SENSORS

Definition

Sensors based on eddy currents generated in conductive materials.

Principle

Alternating magnetic field induces eddy currents in nearby conductor.

Working

Eddy currents alter coil impedance.

Advantages

- Non-contact sensing

- High accuracy
- High speed

Applications

- Thickness measurement
- Crack detection
- Metal identification
- Position sensing

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9. ANGULAR / ROTARY MOVEMENT TRANSDUCERS

Definition

Devices used to convert angular displacement into electrical output.

Purpose

Measure:

- Angular position
- Angular velocity
- Shaft rotation

Types

Potentiometric Rotary Sensor

Uses variable resistance.

Optical Encoder

Uses light pulses.

Magnetic Encoder

Uses magnetic field variation.

Synchro

Uses electromagnetic induction.

Applications

- Robotics
- CNC Machines
- Industrial Drives

- Servo Systems

10. SYNCHRO

Definition

An electromechanical transducer used to measure and transmit angular position.

Construction

Consists of:

- Rotor
- Three stator windings

Principle

Works on electromagnetic induction.

Working

Rotor position changes magnetic coupling between rotor and stator.

Output voltages vary according to shaft angle.

Advantages

- High accuracy
- Rugged construction
- Reliable operation

Disadvantages

- Complex circuitry
- Higher cost

Applications

- Radar systems
- Aircraft control systems
- Navigation systems
- Position control systems

COMPARISON OF MAGNETIC SENSORS

Sensor Type	Principle	Application
Hall Sensor	Hall Effect	Speed & Position

Sensor Type	Principle	Application
AMR Sensor	Magnetoresistance	Compass Systems
Eddy Current Sensor	Eddy Current Effect	Metal Detection
Inductive Sensor	Inductance Change	Displacement
Synchro	Electromagnetic Induction	Angular Position

IMPORTANT EXAM POINTS

Definitions

Magnetic Sensor: Detects magnetic field and converts it into electrical signal.

Hall Sensor: Uses Hall Effect to measure magnetic field.

AMR Sensor: Resistance changes with magnetic field direction.

Eddy Current Sensor: Uses induced eddy currents in conductors.

Synchro: Measures and transmits angular position.

IMPORTANT FORMULAS

Hall Voltage

$$V_H = \frac{BIt}{nq}$$

Inductance

$$L = \frac{N^2 \mu A}{l}$$

FREQUENTLY ASKED 5-MARK QUESTIONS

1. Hall Effect and Hall Effect Sensor

2. Magnetoresistive Sensors
3. AMR Sensors
4. Eddy Current Sensors
5. Inductive Sensors
6. Angular Movement Transducers

FREQUENTLY ASKED 10-MARK QUESTIONS

1. Hall Effect Sensors – Construction and Working
2. Magnetoresistive and AMR Sensors
3. Eddy Current Sensors – Principle and Applications
4. Angular/Rotary Movement Transducers
5. Synchro – Construction, Working and Applications
6. Inductance Sensors and Magnetic Sensing Principles

QUICK REVISION

✓ Hall Sensor → Hall Effect

✓ MR Sensor → Resistance changes with magnetic field

✓ AMR Sensor → Resistance depends on field direction

✓ Eddy Current Sensor → Induced currents in conductor

✓ Inductive Sensor → Change in inductance

✓ Synchro → Angular position transducer

✓ Magnetic Sensors → Non-contact, reliable, fast response