UNIT III
MAGNETIC SENSORS

Introduction to Magnetic Sensors

Definition

Magnetic sensors detect magnetic fields and convert them into electrical signals.

Applications

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

Advantages

- Non-contact sensing
- High reliability
- Long life

Image: Various magnetic sensors and their applications.

Magnetoresistance Effect

Principle

Resistance changes due to magnetic field:

$MR = \frac{R(H)-R(0)}{R(0)}$ Where:

- R(H) = Resistance in magnetic field
- R(0) = Resistance without field

Types

- AMR
- GMR
- TMR

Image: Graph of resistance versus magnetic field.

Anisotropic Magnetoresistive (AMR) Sensing

Definition

Resistance depends on the angle between:

- Current flow
- Magnetization direction

Characteristics

- High accuracy
- Low magnetic field detection

Applications

- Electronic compasses
- Vehicle position sensing

Image: AMR sensor operation diagram.

Working of AMR Sensor

Equation

$R = R_{\perp} + (R_{\parallel} - R_{\perp})\cos^2\theta$ Where:

- θ = Angle between current and magnetic field

Advantages

- Excellent sensitivity
- Small size

Image: Angle-dependent resistance illustration.

Semiconductor Magnetoresistors

Definition

Semiconductors whose resistance changes significantly under magnetic fields.

Materials

Indium Antimonite (InSb)
Indium Arsenide (InAs)

Advantages

Very high sensitivity
Compact size

Applications

Speed sensing
Position detection

Image: Semiconductor magneto resistor device.

Hall Effect and Hall Sensors

Hall Effect

When current flows through a conductor in a magnetic field, a voltage develops perpendicular to both.

Hall Voltage

VH=BItnqV_H = \frac{BIt}{nq}VH=nqBIt Where:

- B = Magnetic flux density
- I = Current
- n = Carrier density
- q = Electron charge

Image: Hall effect diagram.

Hall Effect Sensor Construction

Components

Semiconductor plate

Current source

Voltage measurement terminals

Applications

Speed sensing

Proximity detection

Current measurement

Image: Hall sensor internal structure.

Hall Sensor Applications

Automotive

•Wheel speed sensors

•Crankshaft sensors

Industrial

•Position sensing

•Motor control

Consumer Electronics

•Smartphones

•Laptops

Image: Hall sensor applications collage.

Inductance Sensors

Principle

Based on change in inductance due to:

•Position

•Material properties

•Distance

Formula

L=N2μAlL = \frac{N^2\mu A}{l}L=lN2μA **Applications**

•Metal detection

•Displacement measurement

Image: Inductive proximity sensor.

Eddy Current Sensors

Principle

Alternating magnetic field induces eddy currents in conductive objects.

Characteristics

- Non-contact
- High precision
- Fast response

Applications

- Thickness measurement
- Crack detection
- Shaft vibration monitoring

Image: Eddy current formation diagram.

Angular/Rotary Movement Transducers

Purpose

Measure rotational displacement.

Types

- Rotary encoders
- Magnetic angle sensors
- Resolvers

Applications

- Robotics
- CNC machines
- Servo systems

Image: Rotary encoder and magnetic angle sensor.

Principles Behind Magnetic Sensors

Working Principle

Magnetic sensors operate by detecting:

- Magnetic field strength
- Direction of magnetic field
- Changes in magnetic flux

Common Effects Used

- Hall Effect
- Magnetoresistance
- Electromagnetic Induction
- Eddy Current Effect

Image: Block diagram showing magnetic field → sensor → electrical output.

Magneto-Resistive Sensors

Definition

Devices whose electrical resistance changes when exposed to a magnetic field.

Features

- High sensitivity
- Fast response
- Low power consumption

Applications

- Compass modules
- Position sensing
- Current sensing

Image: Magnetoresistive sensor structure.

Rotary Magnetic Sensors

Working

Rotation changes magnetic field orientation.

Output

•Analog voltage

•Digital angle measurement

Advantages

•Contactless operation

•Long lifespan

Image: Rotary magnetic sensor operation.

Synchros

Definition

Electromechanical devices used for angular position transmission.

Main Parts

Rotor

Stator

Function

Transmit shaft position electrically.

Image: Synchro transmitter and receiver.

Working of Synchros

Principle

AC excitation applied to rotor produces voltages in stator windings.

Uses

- Aircraft systems
- Radar systems
- Industrial control

Image: Synchro operation block diagram.

Advantages and Limitations

Advantages

✓ Contactless measurement
✓ High accuracy
✓ Long operating life
✓ High reliability

Limitations

✕ Sensitive to electromagnetic interference
✕ Temperature effects
✕ Higher cost in some applications

Image: Pros and cons infographic.