(ES)

UNIT-3

→ Magnetic Sensors:

- Introduction.
- Sensors & the principles behind.
- Magneto-resistive Sensors.
- Anisotropic Magneto resistive sensing.
- Semiconductor Magneto resistors.
- Hall Effect & Sensors.
- Inductance & Eddy current Sensors.
- Angular / Rotary Movement Transducers
- Synchros

(magnetic field → electric field)

2). Magnetic Sensors & Types → detect & measure magnetic fields

→ It detect magnetic field strength, direction or changes in magnetic flux.

→ Sensors converting magnetic field into electric signal

→ It is a device, detect magnetic fields or changes in them

→ they are widely used in industrial, automotive applications.

Types

- Hall effect Sensors
- Magnetoresistive Sensors
- Fluxgate Sensor
- SQUID
- Inductive Magnetic Sensor
- GMR/AMR Sensors

Applications

- Speed sensing
- Current sensing
- Position detection
- ABS systems
- Compasses
- Proximity detection

Applications

- Automotive
- Industrial
- Medical
- Electronics

Magnetoresistive (MR) Sensors; Resistance will changes with the response of magnetic fields.

- used in compass, hard drivers (storage) & Industrial applications)

Fluxgate Sensors; It detects low magnetic fields with high precision.

- used in geophysics.

Inductive & Eddy Current Sensors: uses Electromagnetic Induction (EMF produced)

- To detect metallic objects
- To measure position

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Magnetic Sensor

ex: ① Google maps
- shows direction
- uses MR sensor

②. Mobile Screen rotation
- when you rotate mbl, MR sensors detect

③. Laptop Screen rotation

④. Bike Speedometer

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* Sensors & the Principles Behind (or) Principles of Magnetic Sensors

→ Magnetic sensors operate / work on different principles depending on the type of sensor & application.

→ Magnetic sensors work on one or more principles :

①. Hall effect principle.

②. Magnetoresistive Principle (MR)

③. Inductive & Eddy current.

④. Change in resistance due to magnetic field

⑤. Change in inductance due to magnetic field

⑥. Lorentz Force

ex:

- Airport suitcase scanning
  - eddy current sensors detect hidden metallic objects.

* Magneto-resistive Sensors (MR Sensors)

→ these sensors work based on the magneto resistance effect

→ Also called as "MR Sensors".

→ these sensors change their resistance when exposed to a magnetic field.

⇒ Resistance will changes with the response of magnetic fields.

used in:

- magnetic field sensing
- navigation
- position tracking
- hard drives

* MR sensors change their resistance when a magnetic field is applied

magnetic field → resistance changes → output

Types

1. AMR - (Anisotropic Magneto-resistance)
2. GMR - (Giant MR)
3. TMR - (Tunnel MR)

1. AMR: Resistance changes with direction of magnetic field

ex: your phone compass

2. GMR: When magnetic layers align or misalign,
 - there is a Big change in resistance

Giant - Big change in resistance.

→ used in hard disk.

3. TMR: Electron tunnel through layer.

* AMR

A = Angle (direction) - AMR cares about direction

AMR - Anisotropic MR

- Anisotropic = different values in different directions.

Def: Resistance of a magnetic material changes when the direction of magnetization changes - due to an external magnetic field.

→ AMR shows different resistance in different directions.

→ Resistance depends on direction of magnetic field

Features

- Simple structure
- Good accuracy
- works with earth's magnetic field
- Low noise

Examples

- Digital compass in mbl
- Digital compass in Google maps (helps your mbl know which direction you are facing)
- Digital compasses in drones
- Navigation watches
  - Smart watch
- AR apps

- used in compasses, navigation, robotics

* Semiconductor Magneto-Resistors

→ These are a special class of MR sensors.

→ It uses semiconductor materials instead of metals.

→ A semiconductor MR sensor is a device
 - made by using semiconductor materials.

→ It is a resistor made of semiconductor material.
 (InSb, GaAs, InAs)

→ They show much larger resistance change than metallic MR sensors.

Why Semiconductors?

→ Semiconductors have:
- High electron mobility
- Strong reaction to magnetic field

⇒ So even a small magnetic field produces a big resistive change.

Working

- Current flows through a semiconductor strip (InSb)
- Apply magnetic field
  → electrons bend due to Lorentz force
- Their path becomes longer
- This makes the resistance increases.

Magnetic field bends electrons → resistance ↑es

Material used

InSb - Indium Antimonide
InAS - Indium Arsenide
GaAS - Gallium Arsenide

Adv / Features

- High sensitivity
- detect small changes
- Fast response
- low power

ex:
- used in phone sensors
- used in laptop chargers
- used in digital compasses

* Hall Effect & Sensors

→ When current flows through a semiconductor & a magnetic field is applied perpendicular, a voltage is produced.

(Hall → field + current → Vol)

→ that voltage is used to detect magnetic field strength.

→ That voltage called as Hall Voltage

Formula: $V_H = \frac{IB}{qn\cancel{t}}$ (or) $\frac{BI}{nqt}$

V_H – Hall Voltage

I – Current

B – Magnetic field/flux

q – Charge

n – Carrier concentration

t – thickness of conductor

$$\boxed{R_H = \frac{V_H t}{IB}}$$ ⇒ Hall coefficient

Uses:

- Speed Sensors
- Proximity Sensors
- Current Sensors

Examples

Device	Use
Smart Phone	Auto screen rota
Car	Speed sensor
~~B~~ Motor	
Power Supply	
bike Speedometers	

Adv

- Cheap
- No contact
- Long life

Dis

- Low Sensitivity
- affected by temperature
- errors

Features

- Simple
- Cheap

* Inductance and Eddy current Sensors

→ An Inductive Sensor is a transducer

→ It detects metal objects without touching them.

⇒ Inductive Sensor detects a physical quantity by measuring the change in inductance of coil

Working :

→ A coil is excited with AC supply

→ Inductance of the coil depends on:

- no. of turns
- distance of metal object

→ When a metal object comes near the coil

- Magnetic flux changes
- Inductance of coil changes.

→ This change is converted into an electrical signal.

⇒ coil with AC supply → creates a magnetic field.

→ When a metal comes near, the magnetic field changes

→ Bcz of this, the inductance of the coil changes.

→ This change is used to detect the object.

* Metal nearby → inductance changes → detects

⇒ Detects metal by change in inductance

Ex: Uses
- Automatic doors
- Metal detection
- Position sensing

types
- Self-inductance sensors: change in L (single coil)
- Mutual-Inductance sensors: change in inductance b/w (two coils)

Features

Non-contact

$$\boxed{e = \frac{d\phi}{dt}}$$

e = voltage
ϕ = magnetic flux
t = time

e = Included voltage

~~Application~~ Appln
- Proximity sensors
- Metal detection
- Position sensing
- Speed measurement

Eddy Current Sensor

⇒ detects metal properties using eddy currents

→ measures distance, displacement, metal defects
- by generating eddy currents in metal

Working
→ A coil is supplied with AC
→ this produces magnetic field.
→ When a metal object is near the coil,
- eddy currents are induced in it.

→ these eddy currents oppose the magnetic field
→ this changes the coil impedance.
→ the change $\propto$ to distance or defect.

Applications
- Distance measurement
- Displacement measurement
- metal defect measurement

- Highly accurate
- fast
- Non-contact

* Angular/ Rotary Movement Transducers

→ An Angular/ Rotary movement transducer is a device.

→ It converts angular displacement (rotation) into an electrical signal.

* Rotation ⟶ Electric Signal

Angular Displacement :

→ It is the rotation of an object about a fixed axis
- measured in degrees, radians

ex: rotation of knob

→ It is used for robotics, automation & aerospace.

Working :

→ A rotating shaft is connected to the transducer.

→ When the shaft rotates, electrical Parameter changes like :
- voltage
- magnetic field
- resistance.

→ this change is converted into an electrical signal.

Types :

1. Potentiometric type
2. Inductive type
3. Capacitive type
4. Magnetic (Hall effect) type
5. Optical encoder
6. Syncro

* Synchros

→ It is nothing but Synchronous Transducer.

→ It is a device

→ A Synchro is a device that copies rotation.

- Turn a knob at one place → the same angle appears at another place

Main Parts

- Rotor
- Stator

⇒ A Synchro is an electromechanical transducer used to transmit angular position from one place to another.

SYN = SAMe

Same angle here → Same angle in another place

Adv	Dis
- High accuracy	- Uses AC Supply
- Reliable	- Slower
- Simple	- Costly

Construction

Synchros consists of ② Parts:

~~①. Rotor~~ - As Synchros

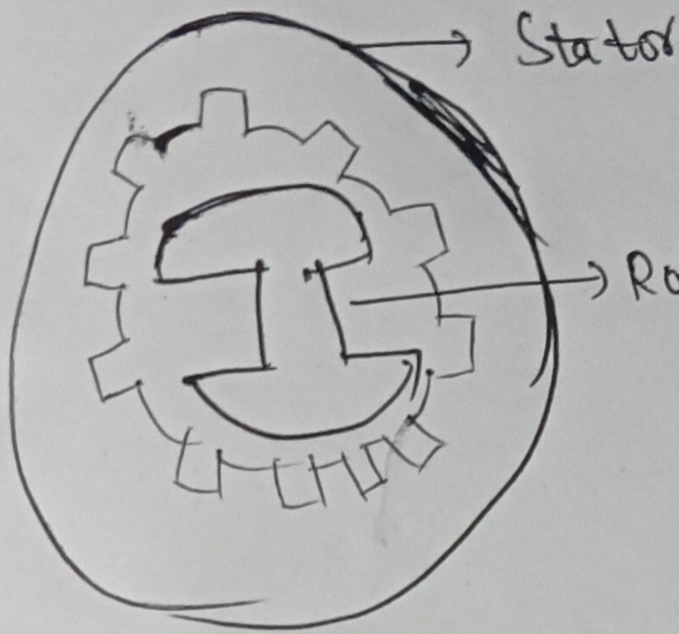
(made of Silicon)

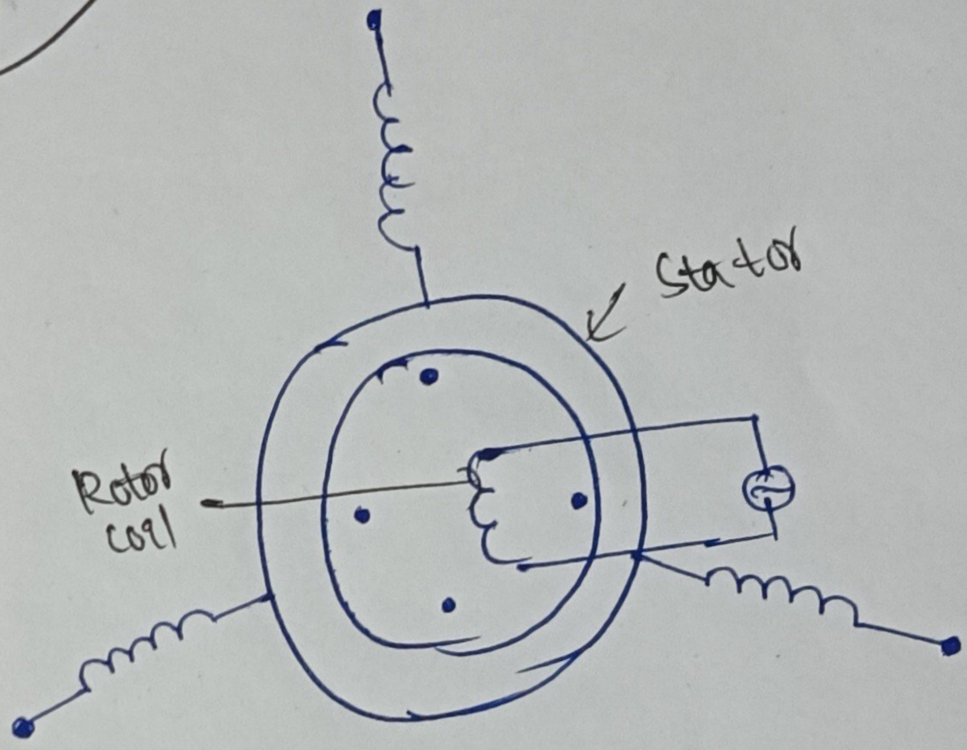
①. **Rotor**: Rotating part

- receives AC excitation voltage

②. **Stator** (iron): Stationary part with 3 winding

- arranged at 120° apart


Stator
Rotor


Stator
Rotor
coil