UNIT IV
MAGNETIC SENSORS

SESSION 1: SLO-1

Introduction to Magnetic Sensors

- A magnetic sensor is a sensor that detects the magnitude of magnetism and geomagnetism generated by a magnet or current.
- It serves a strong impact in changing properties of certain materials.
- It produces effects which are mechanical or electrical in nature.
- There are many different types of magnetic sensors

DIFFERENT TYPES

1. Magnetic field sensor
2. Magneto elastic sensors
3. Magnetic elastic sensor
4. Torque/force sensors
5. Magneto resistive sensors
6. Hall effect sensors or magneto galvanic sensors
7. Distance or proximity sensors
8. Wiegand and pulse wire sensors
9. Superconducting Quantum Interference Devices (SQUIDs)
10. Magnetostriction

1. Magnetic field sensor

- The Magnetic Field Sensor can be used to study the field around permanent magnets, coils, and electrical devices.
- It features a rotating sensor tip to measure both transverse and longitudinal magnetic fields.
- Developed following ‘Δy effect’ which is observed as change in Young’s modulus with magnetization.
- The sensors are often termed as Acoustic Delay Line Components (ADLC).

- *Note: Young’s modulus - the modulus of elasticity in tension or compression (i.e., negative tension), is a mechanical property that measures the tensile or compressive stiffness of a solid material when the force is applied lengthwise. It quantifies the relationship between tensile/compressive stress*

Example:

- Coils are the simplest magnetic sensors which can detect changes of the magnetic flux density

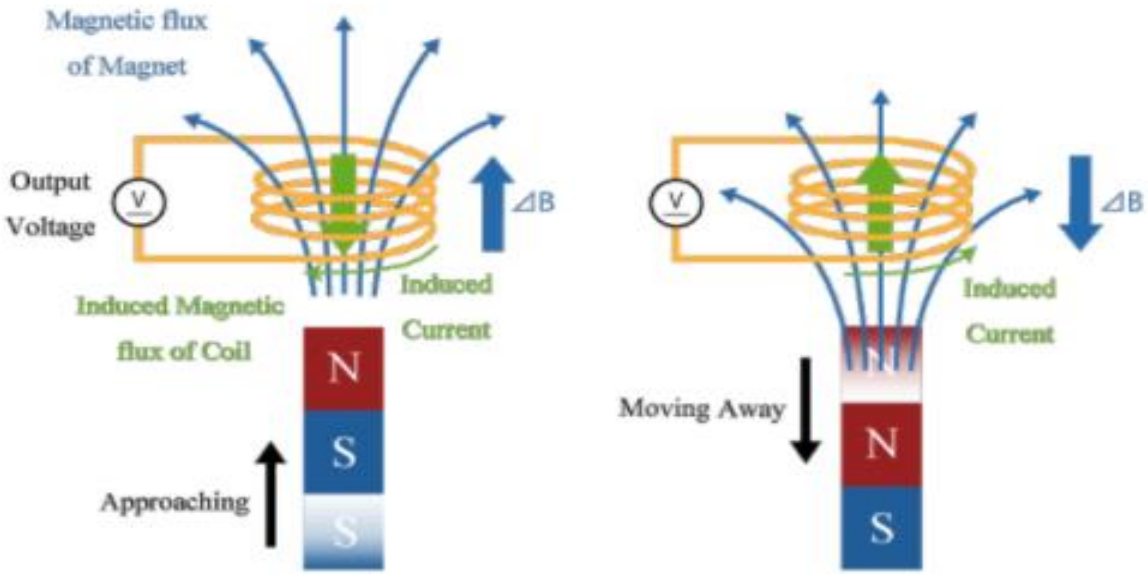

Figure 1. Principle Diagram of Coil

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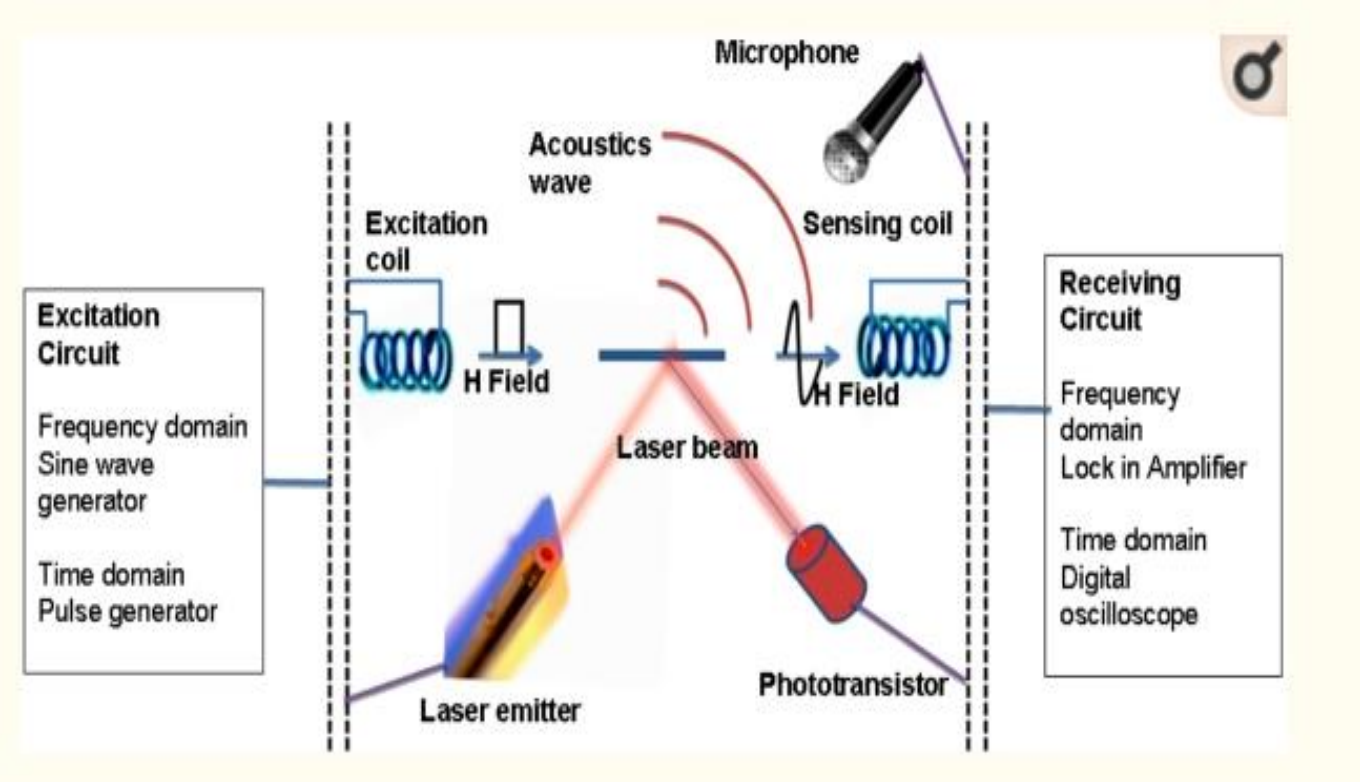
- When a magnet is brought close to the coil, the magnetic flux density in the coil increases by ΔB.
- Then an induced current will be generated in the direction of magnetic flux .
- Conversely, moving the magnet away from the coil reduces the magnetic flux density in the coil, so an electromotive force is induced and also an induced current will be generated in the coil to increase the magnetic flux density.

2. Magneto - Elastic sensor

- Magnetoelastic sensors are **amorphous ferromagnetic ribbons** that exhibit a magneto-mechanical resonance when excited by a time varying magnetic field.

- Magnetoelastic sensors have successfully been used for stress, pressure, liquid viscosity and density, fluid flow velocity, elasticity, and temperature monitoring.



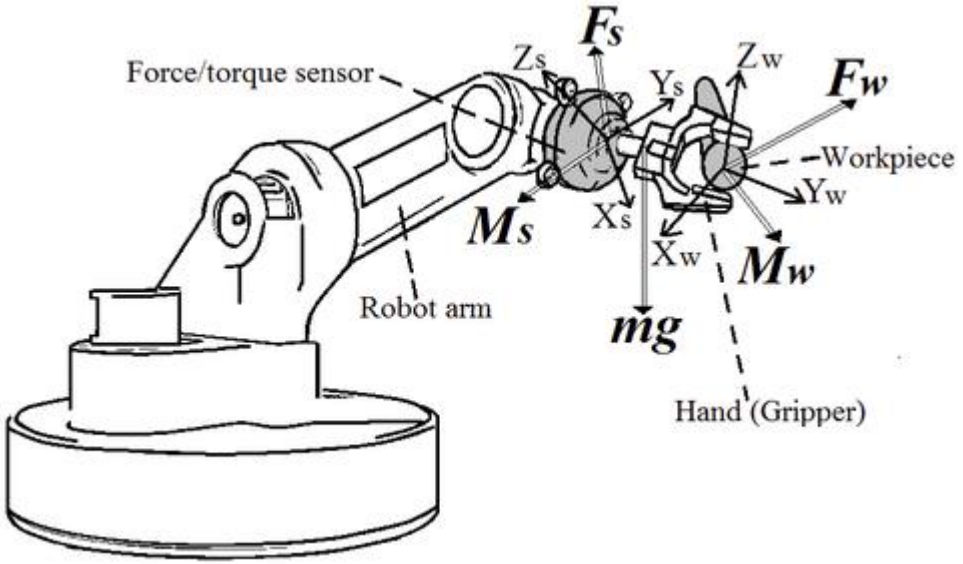
- Based on the fact that, in a longitudinal field, torsion given in a ferromagnetic rod changes its magnetization – Matteucci effect –(Voltage generating property of a twisted ferro-magnetic wire depends upon change of magnetization).

3.Magnetic elastic sensor

- Produced using villari effect in which a tensile or compressive stress changes magnetization or affects magnetization in some way.
- The **inverse magnetostrictive effect**, **magnetoelastic effect** or **Villari effect** is the change of the magnetization of a material when subjected to a mechanical stress.

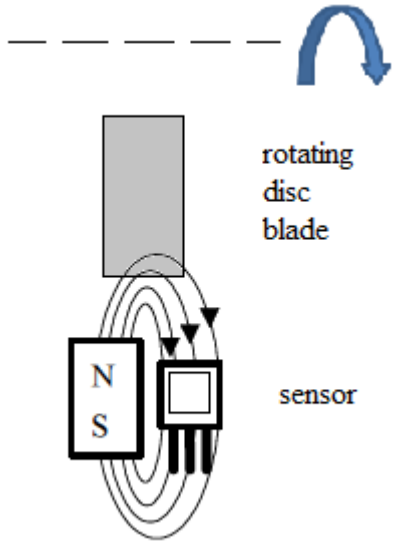
Torque/force sensors

- Wiedemann effect is used to develop the torque/force sensors.
- In such sensors, The twisting of a ferromagnetic rod through which an electric current is flowing when the rod is placed in a longitudinal magnetic field.
- A force torque (FT) sensor is an **electronic device that is designed to monitor, detect, record and regulate linear and rotational forces exerted upon it**.



5. Magneto resistive sensors

- Becoming increasingly popular, are developed on the basis of 'Thomson effect' which is basically a change in resistance of specified materials with magnetic field impressed.
- A magneto resistive sensor **uses the fact that the electrical resistance in a ferromagnetic thin film alloy is changed through an external magnetic field**



6. Hall effect sensors or magneto galvanic sensors

- Most common and widely used type magnetic sensors.
- It works based on the principle that a crystal carrying a current when subjected to a magnetic field perpendicular to the direction of the current, produces a traverse voltage.
- detects the presence and magnitude of a magnetic field using the Hall effect.
- The output voltage of a Hall sensor is directly proportional to the strength of the field
- Hall sensors are used for proximity sensing, positioning, speed detection, and current sensing applications.

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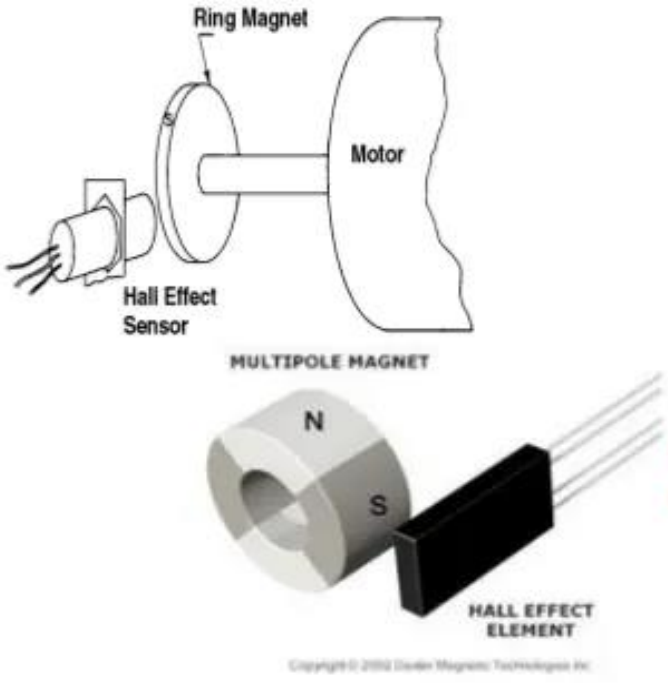
Applications of Hall Field Sensors

Response to South or North Polarity



Motor-Tachometer application where each rotation of the motor shaft is to be detected

When ring magnet rotates w/ motor, South Pole passes the sensing face of the Hall sensor after each revolution.

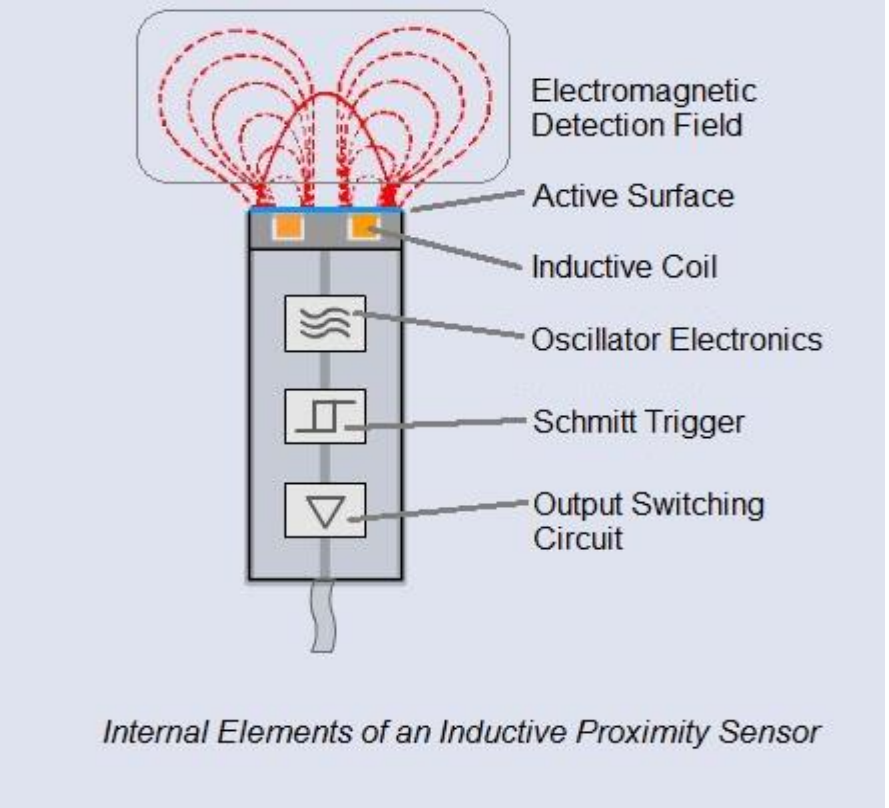
Sensor
- Actuated when the South Pole approaches sensor
- Deactuated when South Pole moves away from sensor

Single digital pulse produced for each revolution.

7. Distance or proximity sensors

- Developed based on ‘skin effect’ in which eddy current forces the current flowing through the interior of a material to move to its surface level.

- Proximity (nearness in space) of the object is detected by a change in capacitance.



Internal Elements of an Inductive Proximity Sensor

The sensor can also be used to detect a wide variety of non-metallic and metallic objects and typically operate over a range of **3 to 30 mm**.

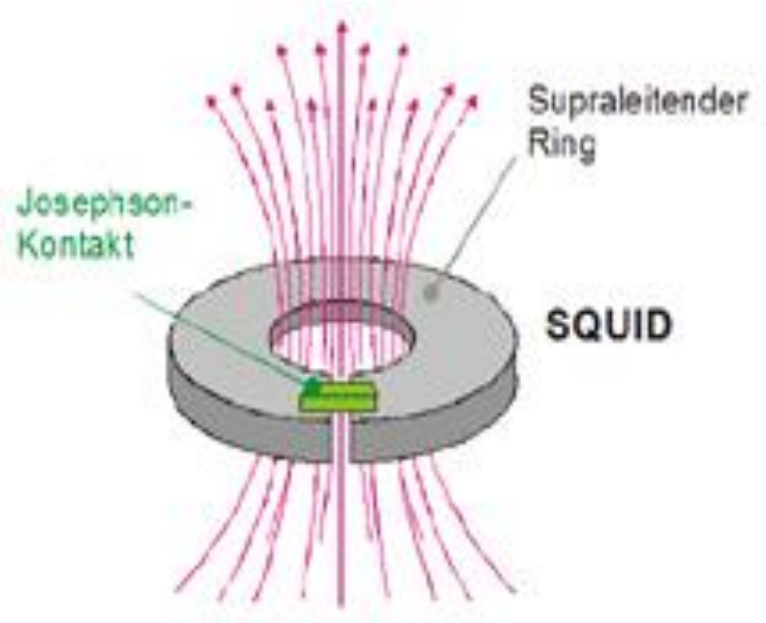
8. Wiegand and Pulse Wire Sensors

- Tiny devices that use variations in an external magnetic field to generate electrical signals and energy

- A specific type of material when subjected to pulse voltages under stress shows switching effect which occurs due to Barkhausen jump.

- This is utilized to produce such sensors. The effect is called ‘Sixtus - Tonks effect’ after the experimenter who demonstrated the effect.

9. Superconducting Quantum Interference Devices (SQUIDs)



- A SQUID (for superconducting quantum interference device) is **a very sensitive magnetometer used to measure extremely subtle magnetic fields**, based on superconducting loops containing Josephson junctions. SQUIDs are sensitive enough to measure fields as low as 5×10^{-14} T

- Used for varying application areas, are based on the superconducting state specifically, 'flux quantization and Josephson effect'.

- These types of sensors have a resolution of the order of a few femto Tesla(fT).

10. Magnetostriction

- Magnetostriction is **a property of ferromagnetic materials that causes them to change their shape when subjected to a magnetic field**.

- It has been used in combination with piezoelectric elements for field measurements.

- This effect is known as ‘Joule effect’ in which magnetization changes the shape of ferromagnetic material body.

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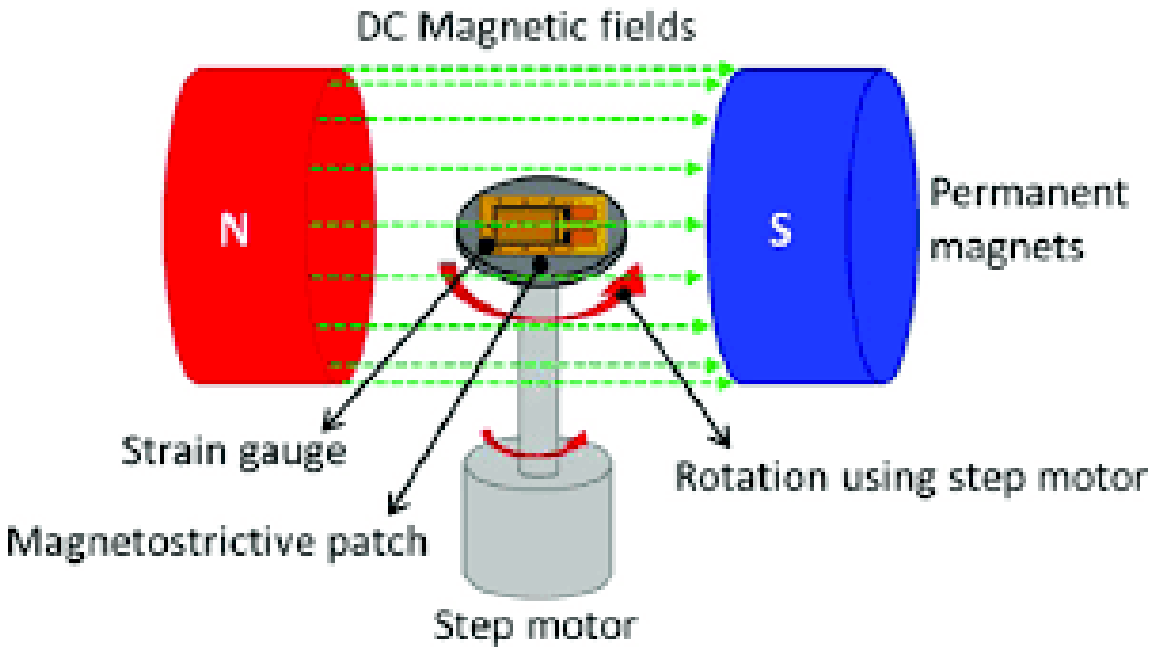

- Magnetostrictive materials are used to **convert electromagnetic energy into mechanical energy and vice versa**. This effect can be used to create sensors that measure a magnetic field or detect a force.
- The magnetic field or force applied would create a strain in the material, which can be measured.
- Its **magnetic field magnetises the** wire axially. Since the two magnetic fields are superimposed, around the float magnet a torsion wave is generated which runs in both directions along the wire.