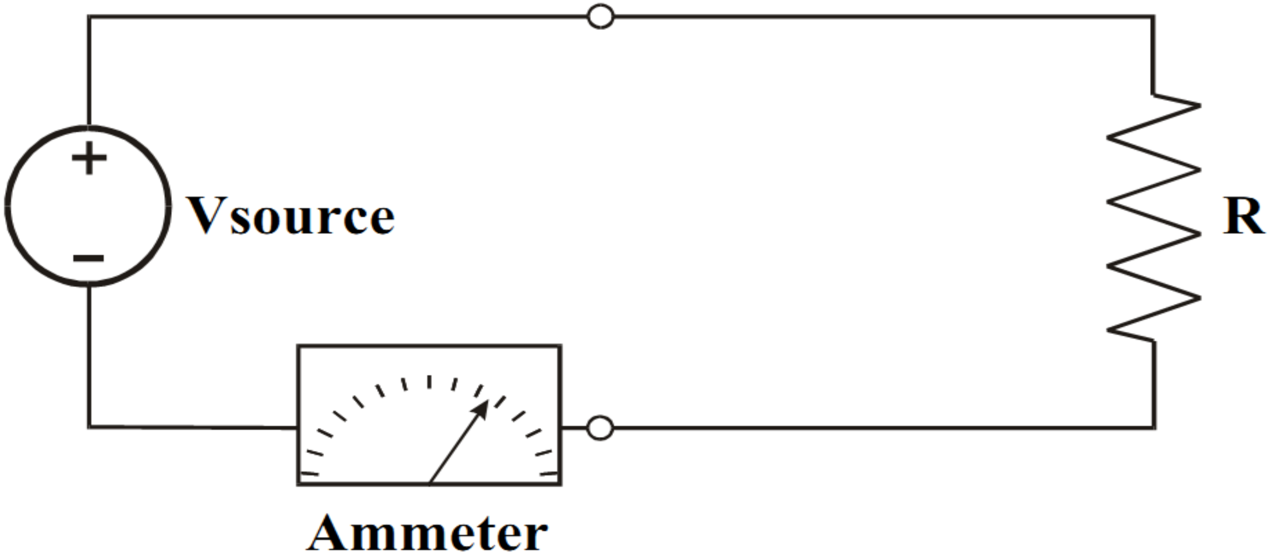
Sensors

- **Capacitive and Resistive sensors.**
- **Piezoelectric Transducers.**
- **Magnetic sensors.**
- **Hall Effect Sensors.**
- **Strain Guages Sensors.**

Resistive Sensors:

- A resistive sensor is a transducer or electromechanical device that converts a mechanical change such as displacement into an electrical signal that can be monitored . Resistive sensors are among the most common in instrumentation.



Major types of Resistive transducers

- . Potentiometers
- Strain Gauges
- Resistance temperature detector (RTD)
- Thermistors
- Light Dependent Resistor (LDR)

Resistivity & Resistance.

- ***Resistance = (Resistivity * Length)/Area***

- The resistance of a material depends on four factors:
    1. Composition
    2. Temperature
    3. Length
    4. Cross Sectional Area

- Changes in composition and temperature do not change the resistivity of a material in such a simple way.

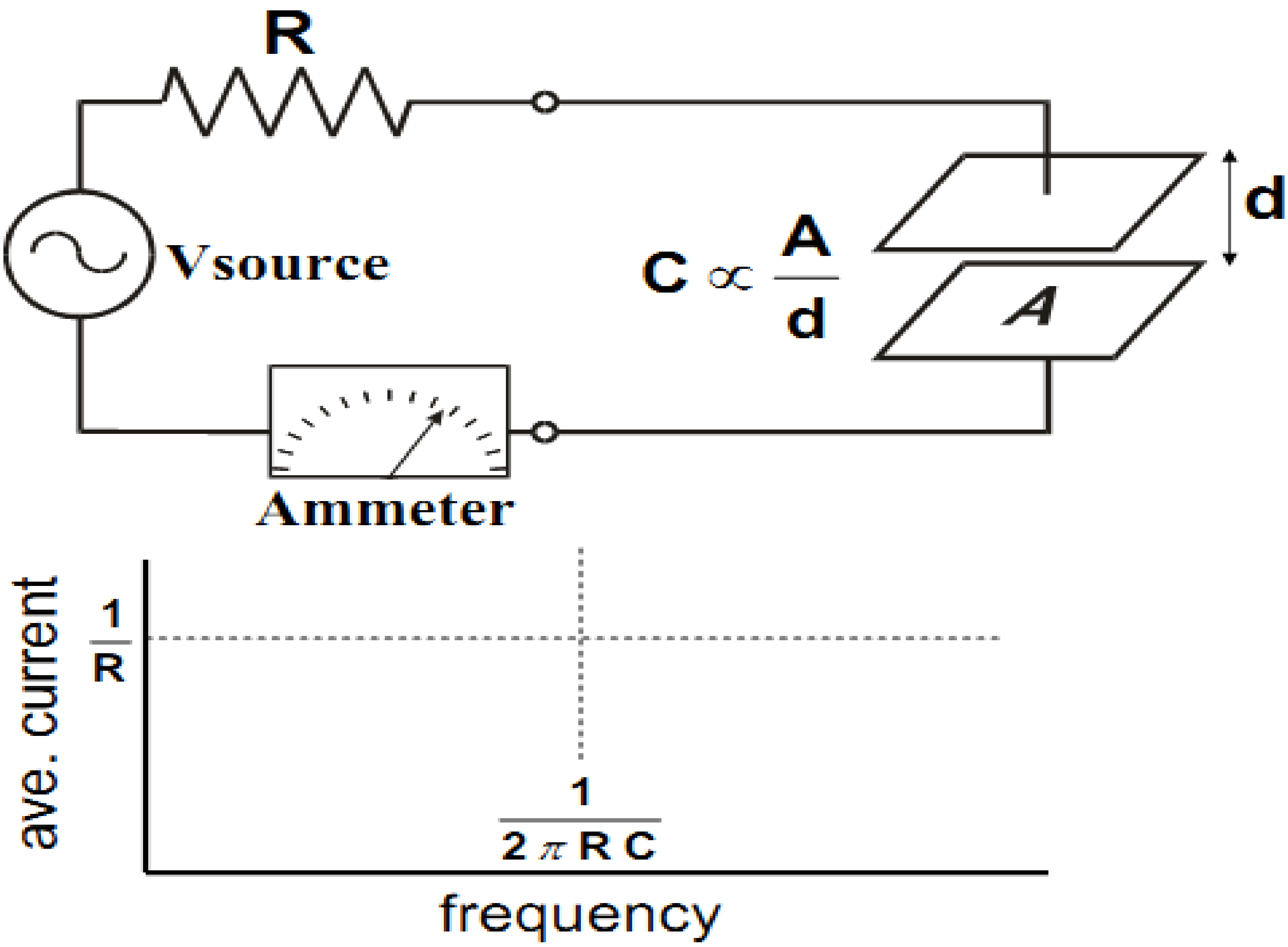
RESISTIVITE POTENTIOMETERS

A resistance element provided with a movable contact.

The contact motion can be,

- Translation.
- Rotation.
- Combination of the two such as helical.

Capacitive Sensors



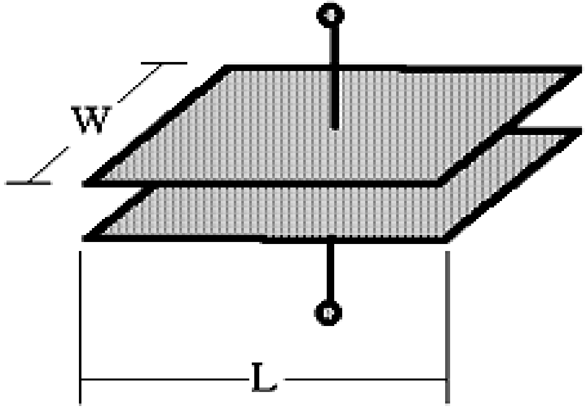
CAPACITIVE SENSORS:

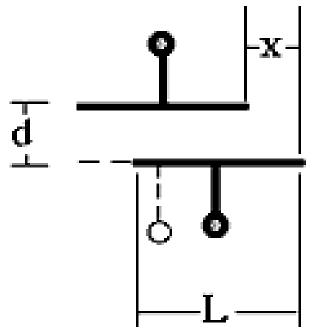
Capacitance C = $\frac{Q}{V}$

- ✓ The capacitance between two parallel metallic plates of area.

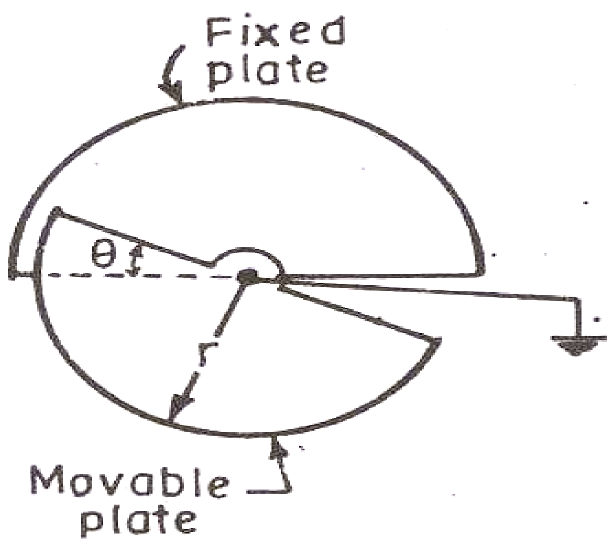
$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \qquad \left(\varepsilon_0 = 8.85 \times 10^{-12} \frac{F}{m} \right)$$

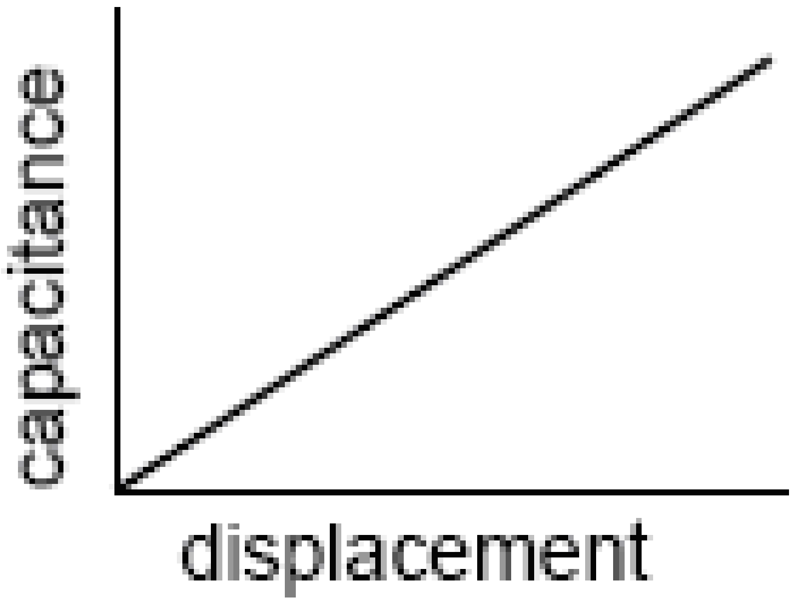
PLATE AREA CHANGE:





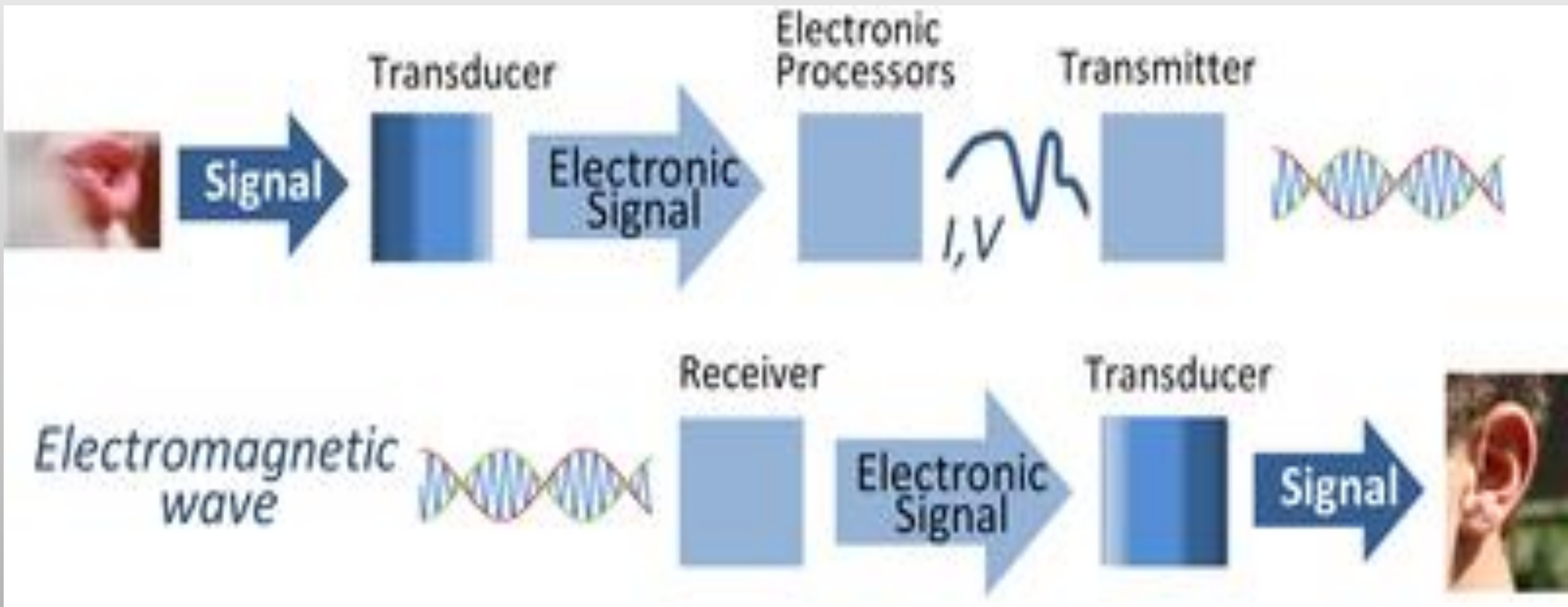
$$C = \frac{\varepsilon_0 \varepsilon_r w(L - x)}{d}$$





Piezoelectric Transducers

Example

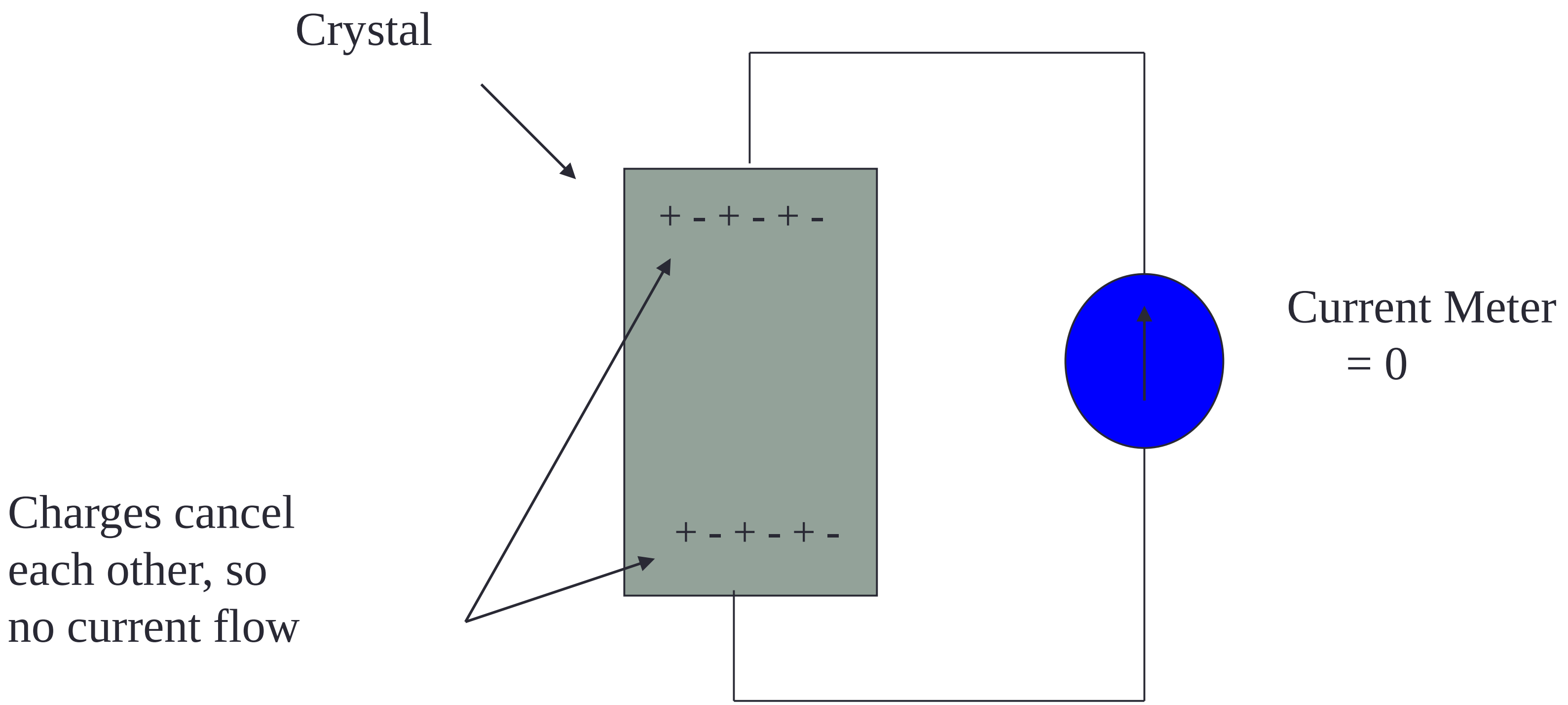


The Piezoelectric Effect:

- **How the Piezoelectric Effect Works.**
- **Uses.**
- **Applications.**
- **What are Typical Piezo Transducer Materials?**

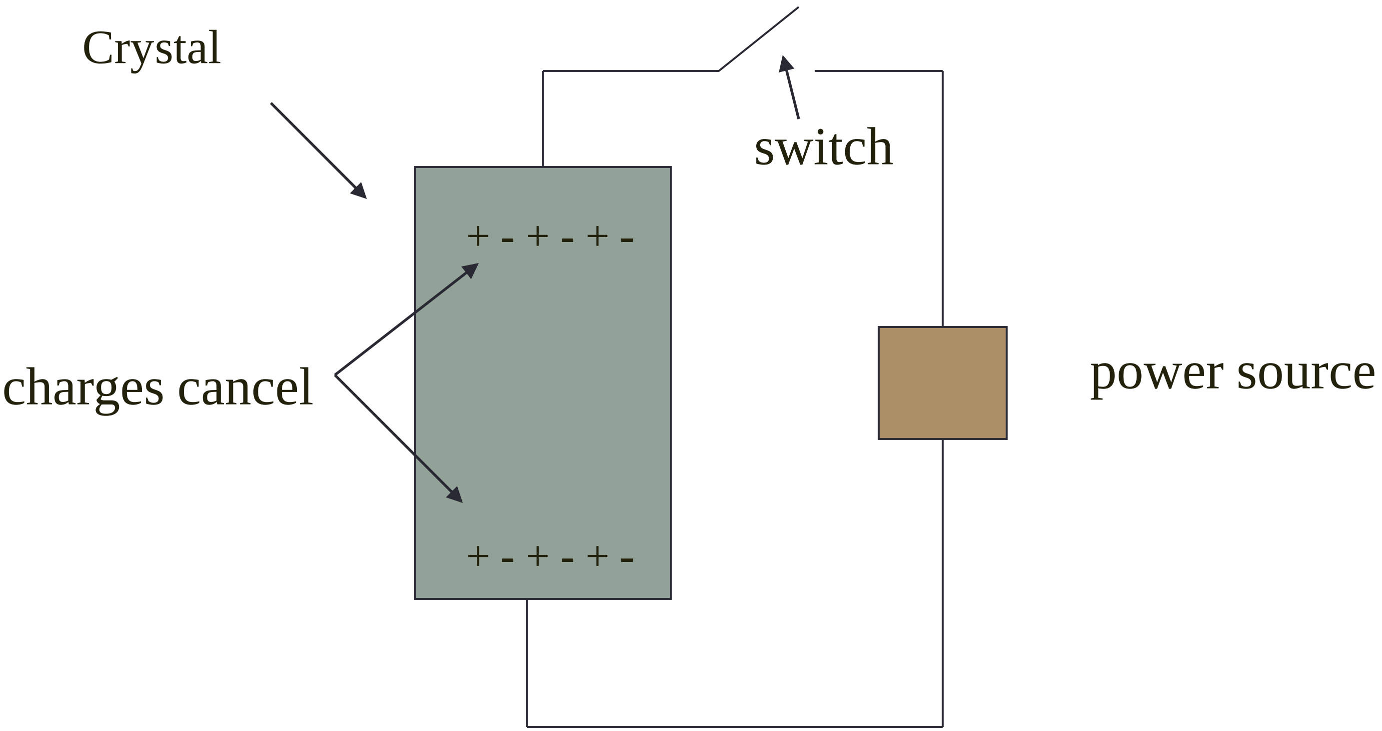
The Piezoelectric Effect

Crystal material at rest: No forces applied, so net current flow is 0

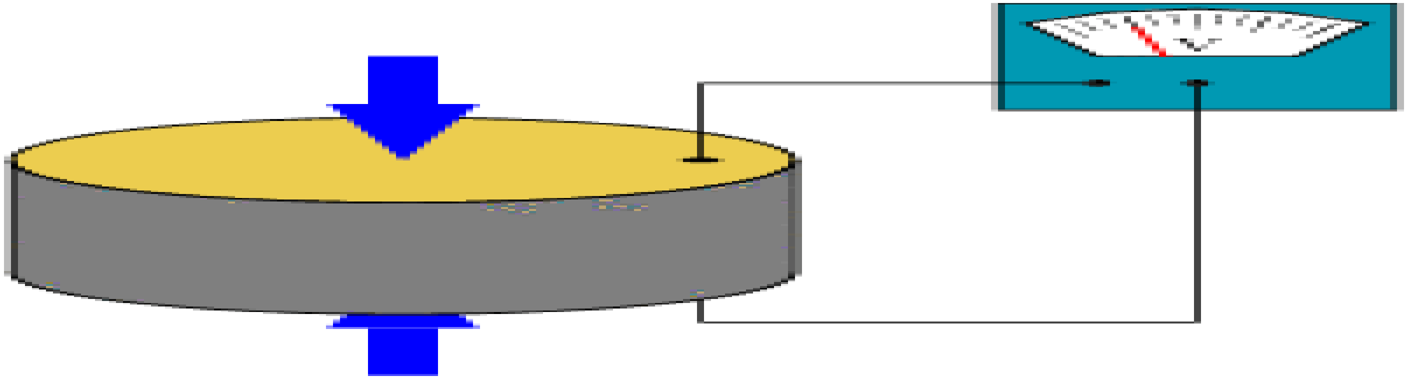


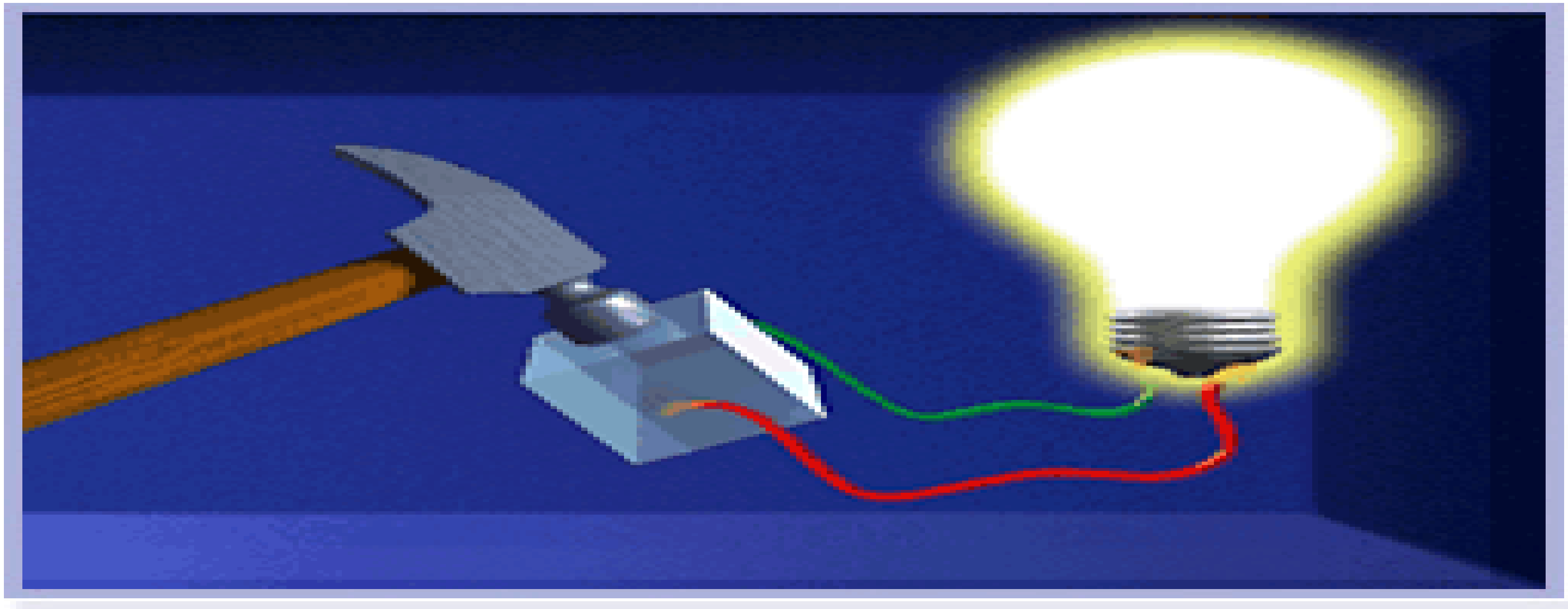
The electromechanical effect

Now, replace the current meter with a power source capable of supplying the same current indicated by the meter….



…. With the switch open, the crystal material is now at rest again: the positive charges cancel the negative charges.





What is Magnetic Sensor?

- The Sensors, transducers which uses the changes in magnetic field for their operations.
- Used to measure the currents, speed, position and Displacement.
- As the conventional sensors, Magnetic sensor does not give output parameters directly.
- Signal processing is required for desired output.

Difference between Conventional and Magnetic Sensors:

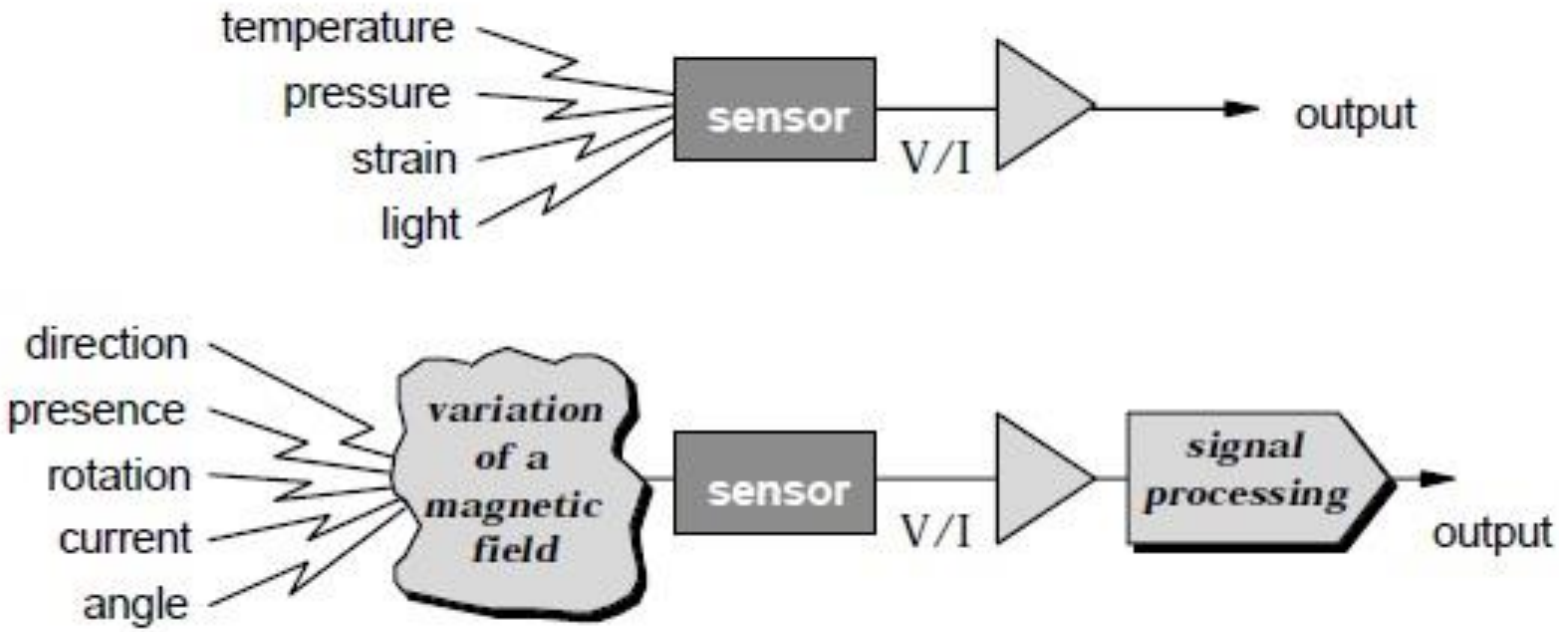


Figure 1. Conventional vs. Magnetic Sensing

Types of Magnetic Sensors:

- On the bases of sensing the variation of magnetic fields, magnetic sensors are of three types,

1) Low field sensors.
2) Earth field sensors.
3) BIAS Magnetic field sensors.

Low Field Sensors:

Can sense very low values of magnetic fields, less then **1μG**

1 Gauss = 10^{-4} Tesla

For Example SQUID, Fiber-Optic , Nuclear Procession

Uses:

In medical and nuclear application.

Earth Field Sensor:

- The magnetic range for the medium field sensors lends 1µGauss to 10 Gauss

- Uses the Earth's magnetic field in many of applications for Example,

Navigation and Vehicle Detection

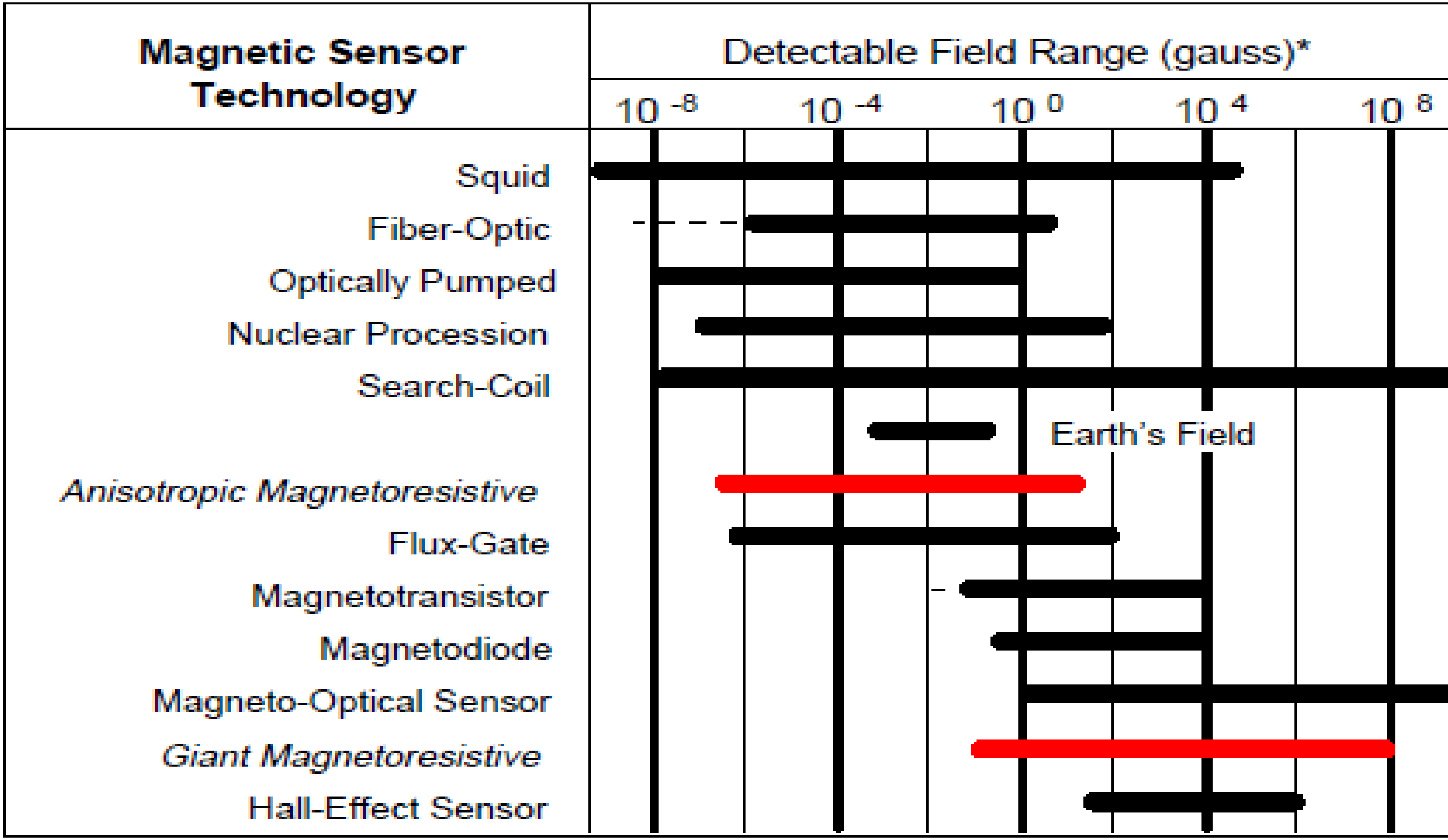
BIAS MAGNET FIELD SENSORS:

- Can Sense the large magnetic fields more then 10 Gauss.

- Most industrial sensors use permanent magnets as a source of the detected magnetic field.

- These permanent magnets magnetize, or bias, ferromagnetic objects close to the sensor.

- Sensors in this category include reed switches, Hall devices, and GMR sensors….



* Note: 1gauss = 10^{-4} Tesla = 10^{5} gamma

Table 1. Magnetic Sensor Technology Field Ranges

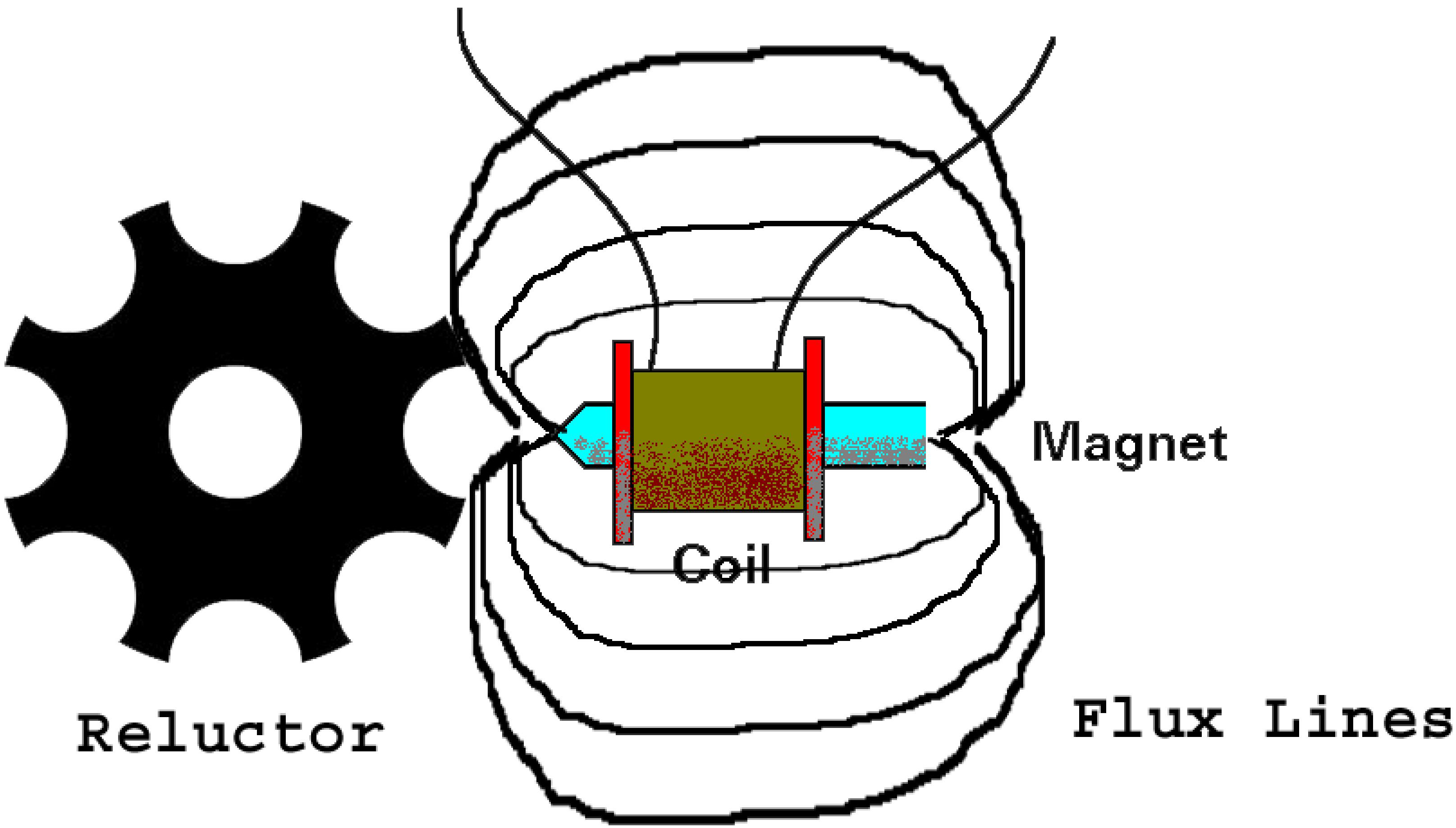
Variable Reluctance Sensors:

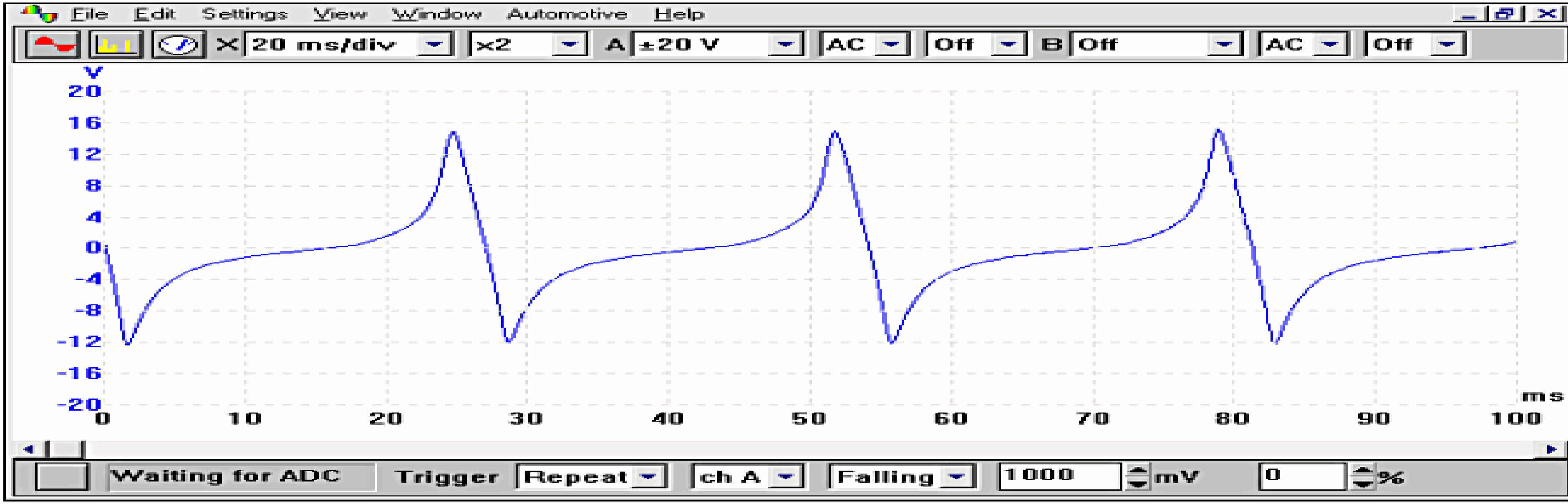
- These sensors often measure Rotation.
- They create their own A/C voltage.
- Senses speed and position of rotating objects.
- Have many applications as:

    i) Magnetic Pulse Generators.
    ii) Pickup Coils.
    iii) Reluctor Sensors.

Working:

- Consist of a permanent Magnet and a Fixed coil on it.
- As the ferromagnetic wheel having tooth rotates, It changes the flux in the coil and in result the AC voltage is induced
- The frequency of this voltage depends on the speed of wheel
- The Output of the sensor is measured digitally using Signal processing techniques


Magnet
Coil
Reluctor
Flux Lines


File Edit Settings View Window Automotive Help
20 ms/div
x2
A ±20 V
AC
Off
B Off
AC
Off
V
20
16
12
8
4
0
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-8
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0 10 20 30 40 50 60 70 80 90 100
ms
Waiting for ADC
Trigger
Repeat
ch A
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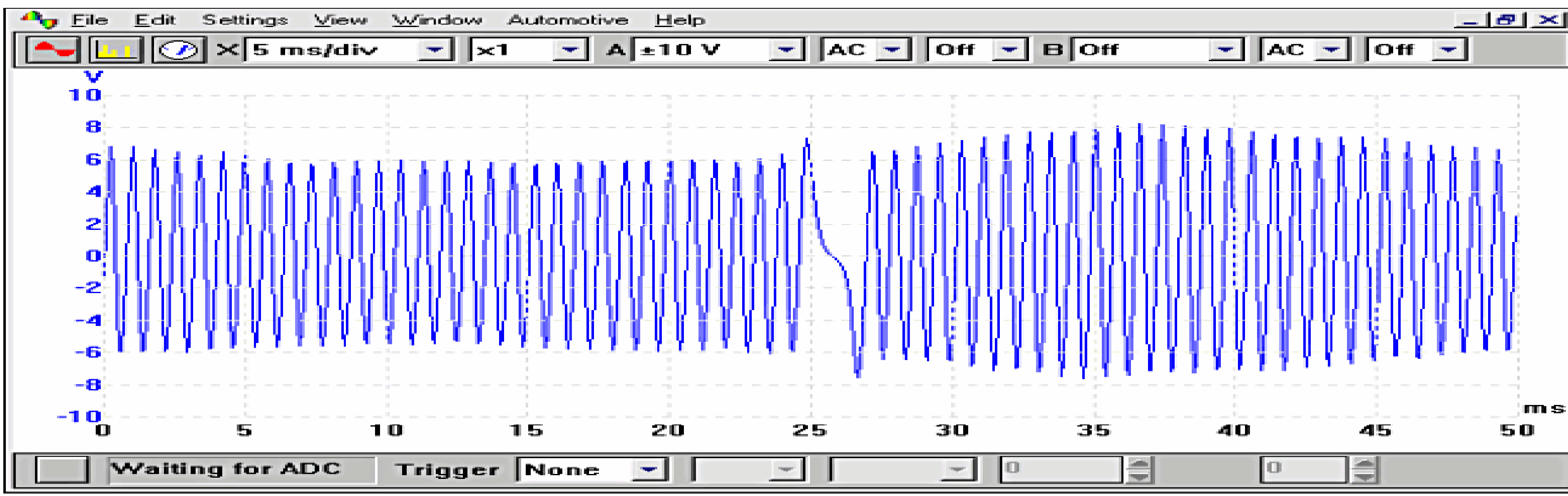
File Edit Settings View Window Automotive Help
5 ms/div
x1
A ±10 V
AC
Off
B Off
AC
Off
V
10
8
6
4
2
0
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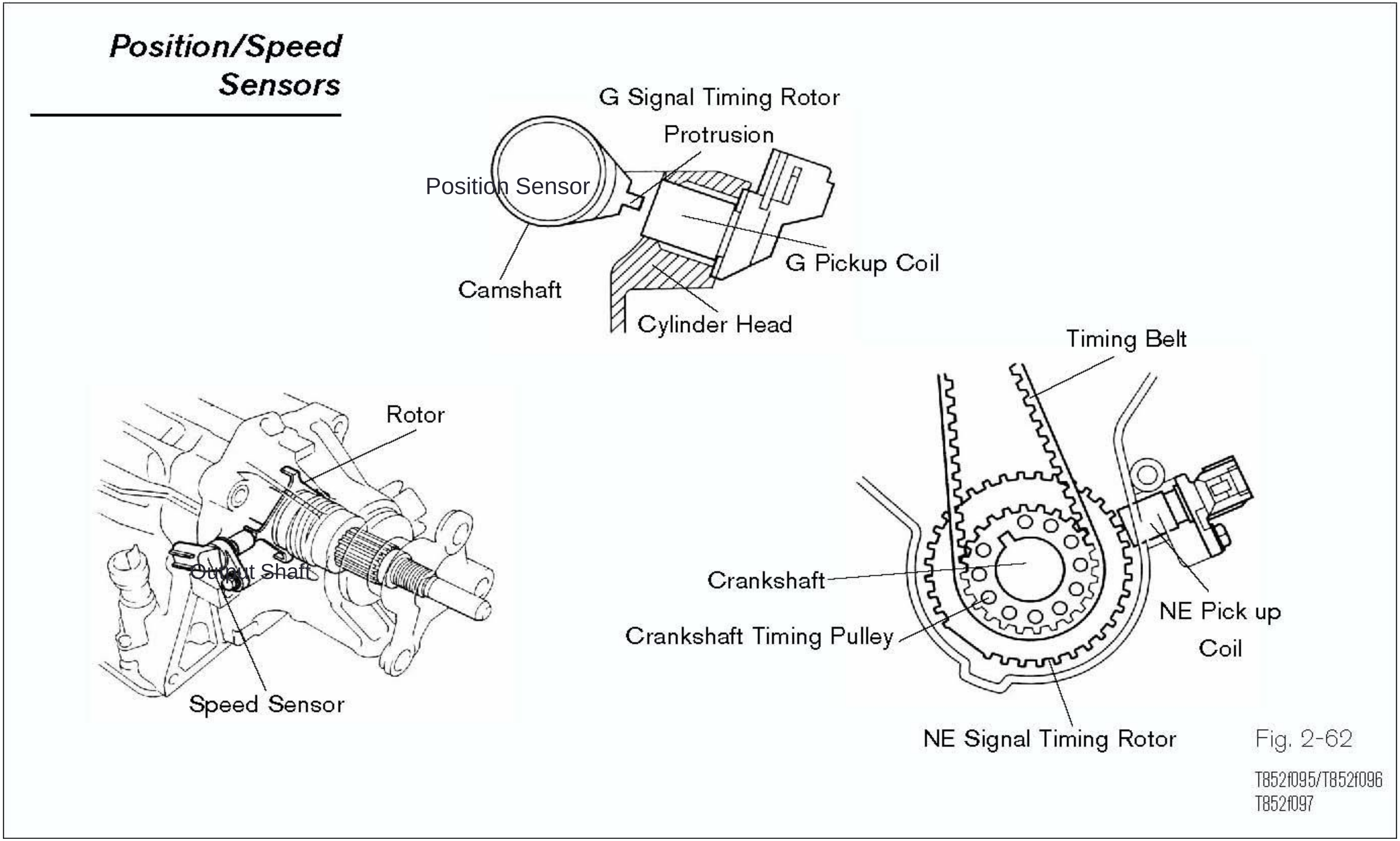
-4
-6
-8
-10
0 5 10 15 20 25 30 35 40 45 50
ms
Waiting for ADC
Trigger
None

Applications:



Inductive Sensors:

- Translate movement into a change in the inductance between magnetically coupled parts.

- The inductance principle is also used in differential transformers to measure translational and rotational displacements.

For Example,

inductive displacement transducer ,LVDT.

Working:

- The single winding on the central limb of a **‘E’-shaped** ferromagnetic body is excited with an alternating voltage.
- The displacement to be measured is applied to a ferromagnetic plate in close proximity to the ‘E’ piece as

$$\mathbf{I = V/\omega L.}$$

- For the fixed values of **V** and **ω** the relationship **I** and **L** can be used to find the displacement.

Inductive Displacement Sensor:

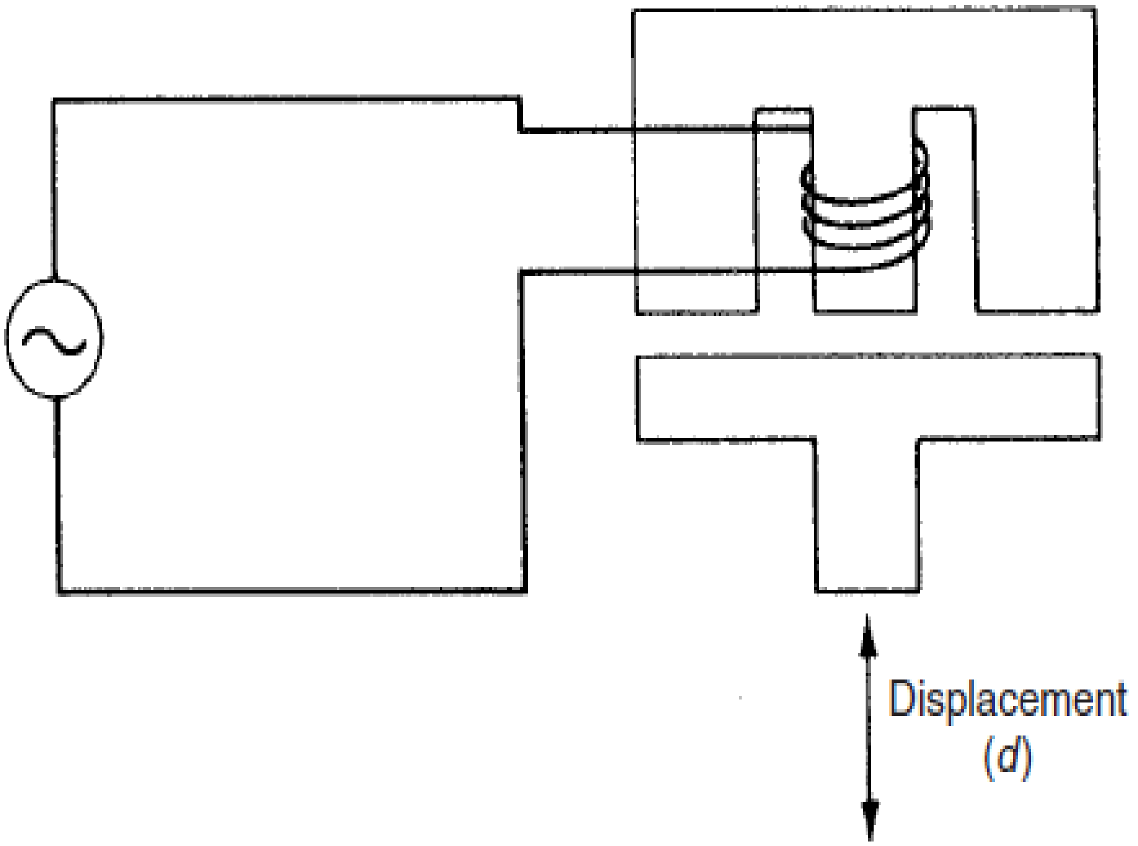


Fig. 13.1 Inductive displacement sensor.

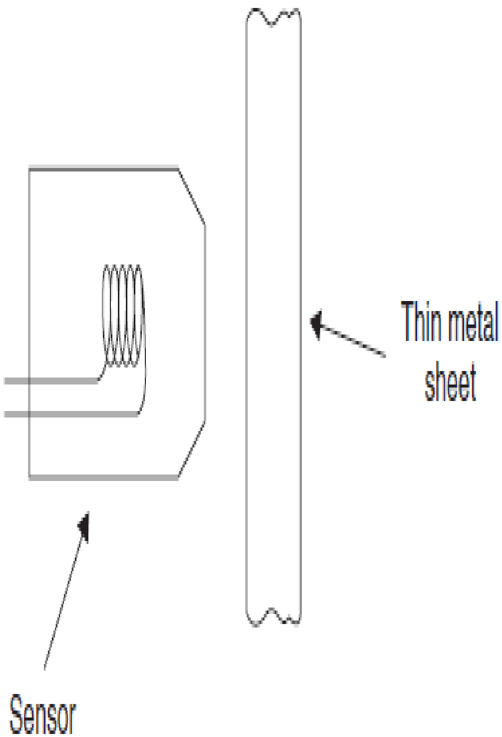
Eddy Current Sensor:

- Consist a probe containing coil excited at high frequency (1Mhz).

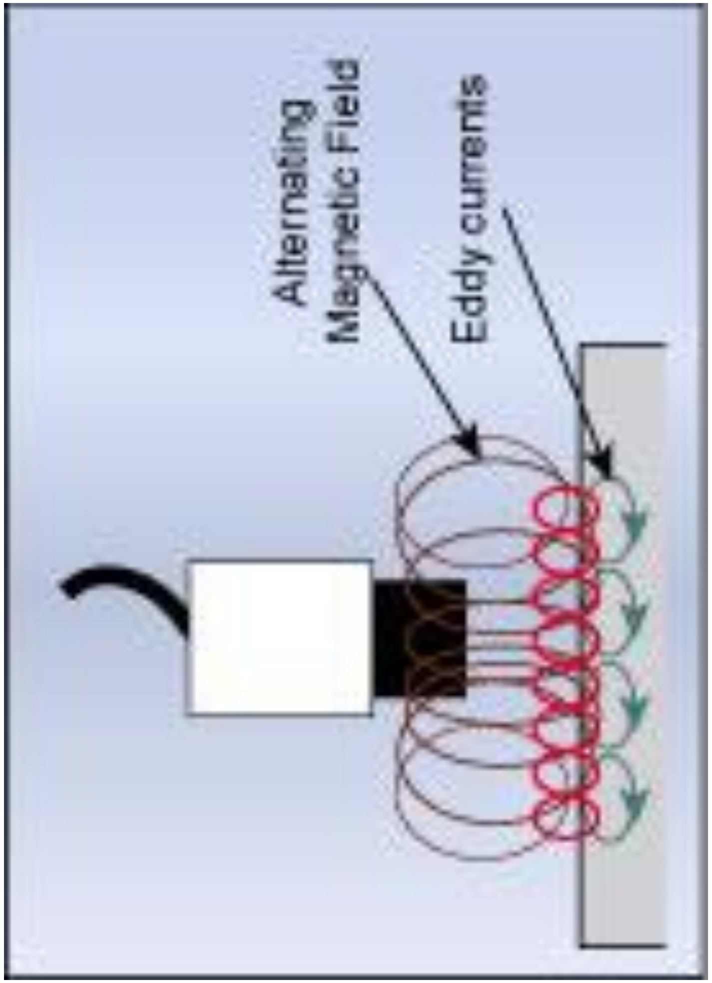
- Because of the high frequency of excitation, eddy currents are induced only in the surface of the target and the current magnitude reduces to almost zero a short distance inside the target.

- Eddy currents alter the inductance of the probe, this change can be translated into a d.c. voltage output that is proportional to the distance between the probe and the target.

Eddy Current Sensor



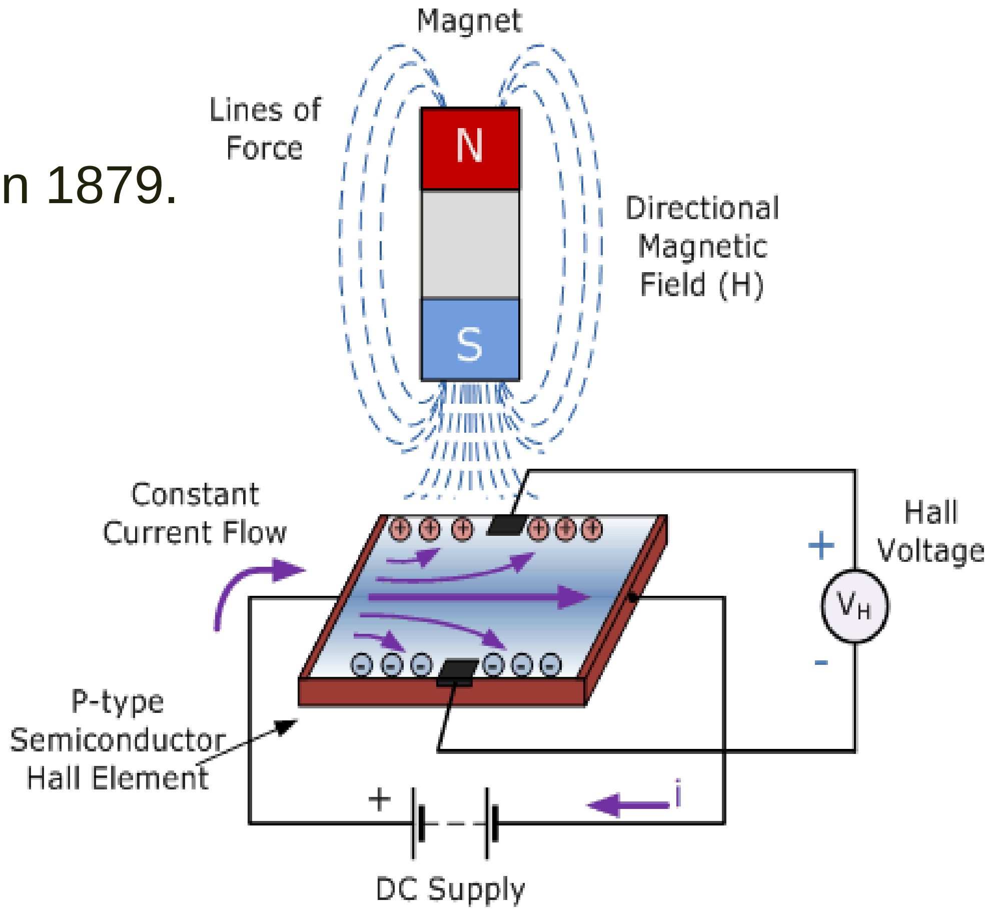
Eddy current sensor.



Hall Effect.

- ❖ The production of a potential difference across a conductor carrying an electric current when a magnetic field is applied in the direction perpendicular to the that of current flowing.

- ❖ It was discovered by **Edwin Hall** in 1879.



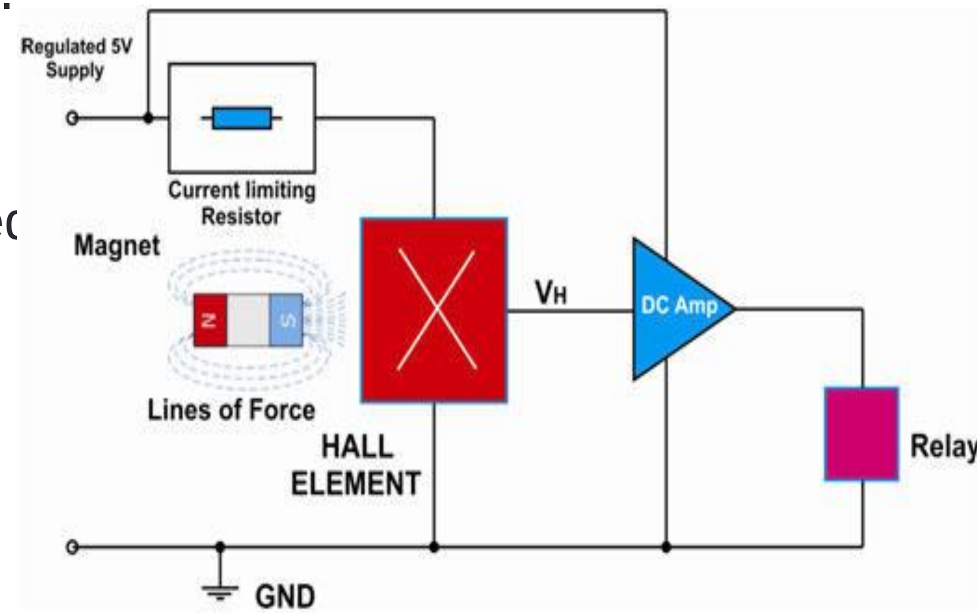
Hall Effect Sensor.

- **Hall Effect Sensors** are devices which are activated by an external magnetic field

- The output voltage, called the **Hall voltage**, (V_H) of the basic Hall Element is directly proportional to the strength of the magnetic field passing through the semiconductor material (output $\propto$ H).

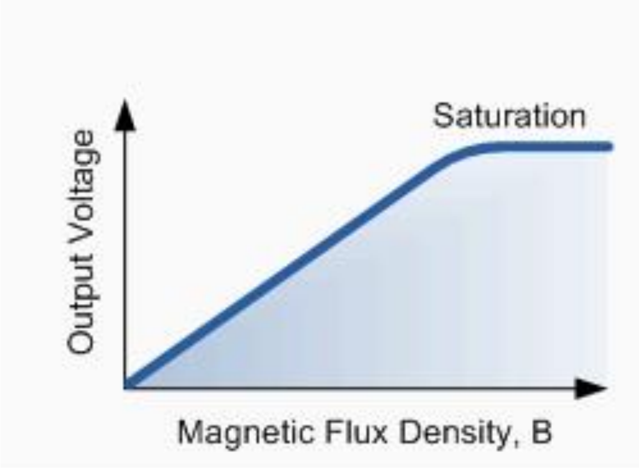
- Output voltage can be quite small, only a few microvolts even when subjected to strong magnetic fields.

- Most commercially available Hall effect devices are manufactured with built-in **DC amplifiers.**



Types:

- **Linear or Analogue Hall Effect Sensor :** These sensors give a continuous voltage output that increases with a strong magnetic field and decreases with a weak magnetic field.

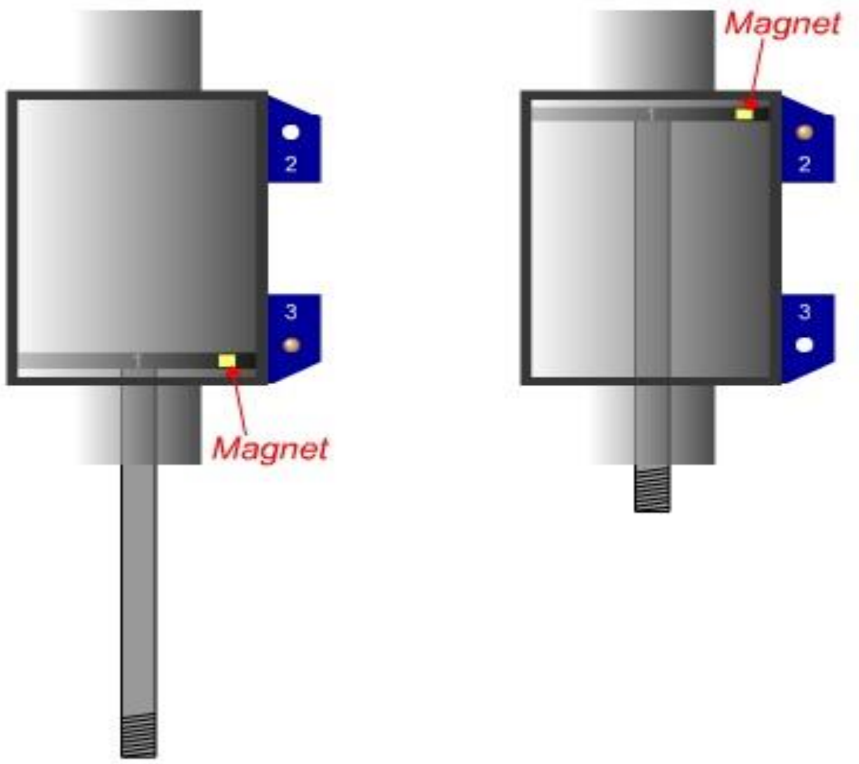


- **Digital Hall Effect Sensor:** These sensors gives the output in the form of “ON” and “OFF”.

Applications:

Magnetic Pistons.

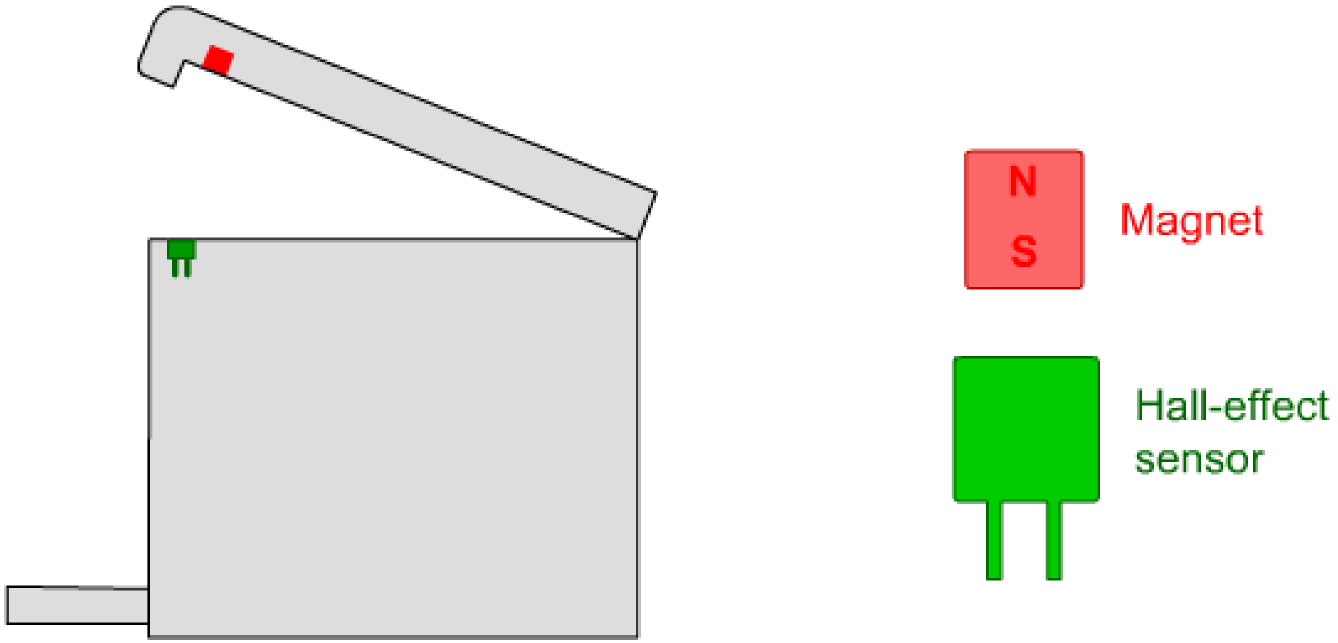
- To indicate that a pneumatic piston has fully extended or retracted , two Hall Effect sensors are mounted on the outer wall of the cylinder.
- Sensors detects small magnets that are embedded on the piston head.



Applications:

Print Cover.

Some computer use Hall Effect device to detect if the cover is open or close.



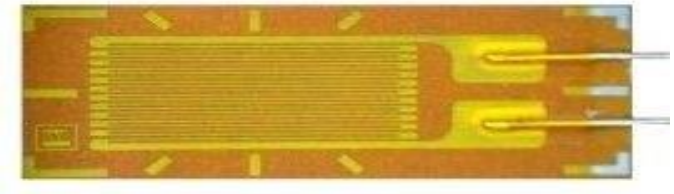
Strain Gauge

Strain: A strain is a normalized measure of deformation representing the displacement between particles in the body relative to a reference length.

A **strain gauge** is a device used to measure the strain of an object.

Working:

It consist of a length of metal resistance wire formed in zigzag pattern. As the object is deformed, the foil is deformed, causing its electrical resistance to change.



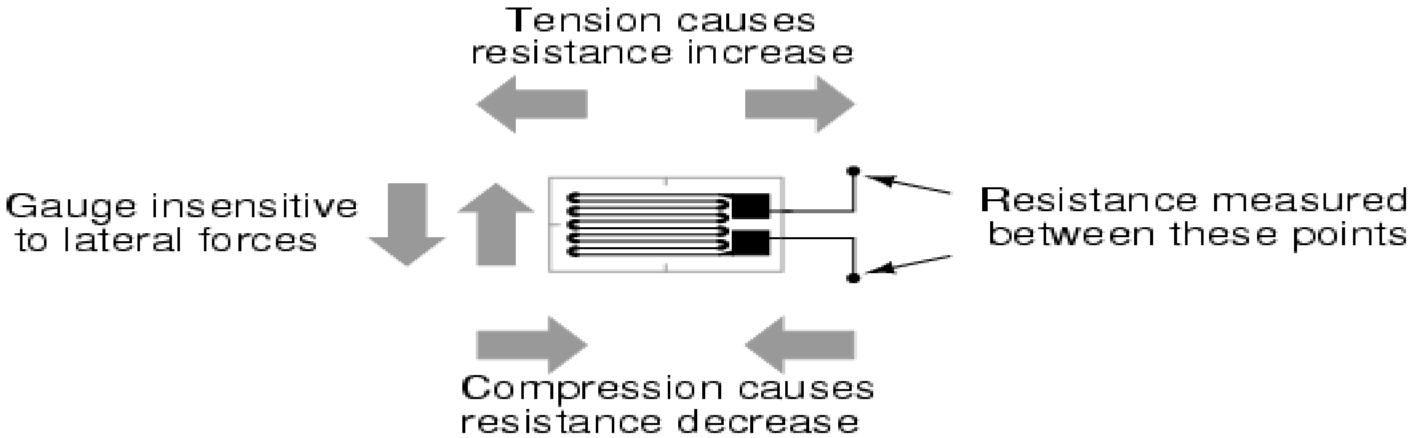
Working (cont.)

- When a strain gauge is bounded to an object, and the object changes in size, the resistance of the strain gauge will be change.

$$R = \rho L/A$$

Gauge Factor: Change in resistance (R) for given value of strain (S).

- **gauge factor = ∆R/∆S**



Application:

Axial Strain

Measure the change in the length of the object.

Important Factor:

i) Direction.

ii) Shape.

Pipe pressure

- Measure the deformation in the pipe.


Thank you