UNIT – 4
TRANSDUCERS

Prepared By

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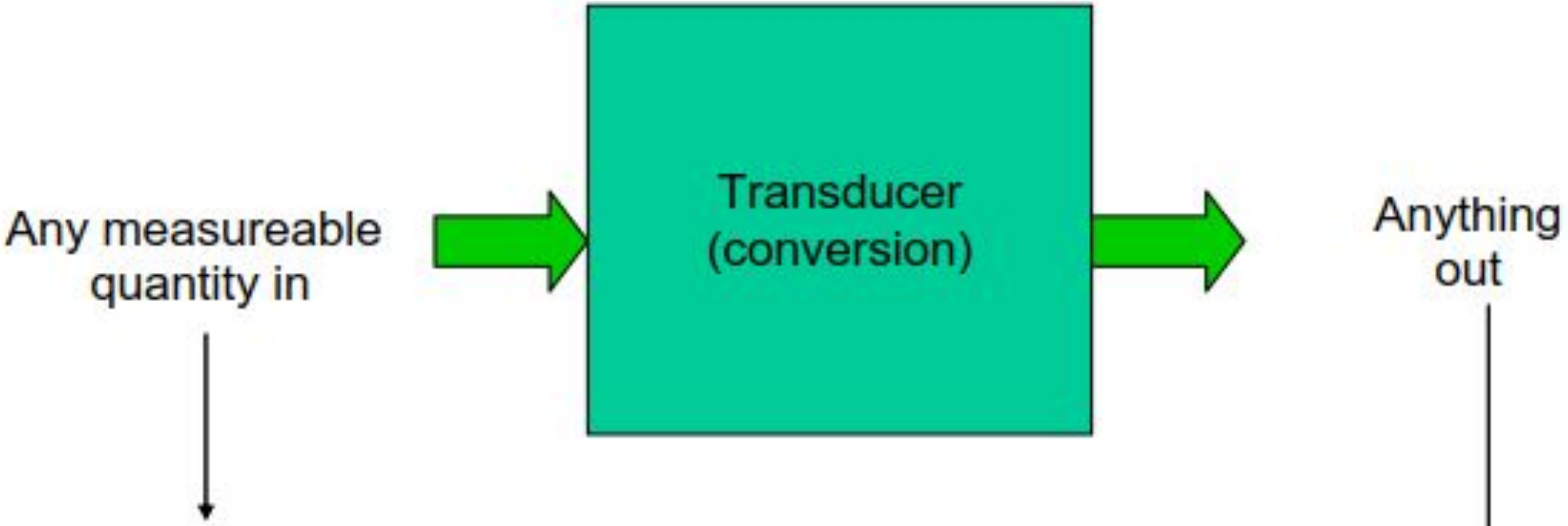
TRANSDUCERS

- A transducer is a device that converts energy from one form to another.
- Any device or component that converts an input signal of one form to an output signal of another form.
- An element or device which receives information in the form of one quantity and converts it to information in the same or an other quantity or form.
- A device for translating the magnitude of one quantity into another quantity.
- Energy forms can be mechanical, visual, aural, electrical, thermal, chemical, etc. (examples to follow).
- Used to change information into a form that can be easily transferred, stored, processed, interpreted, etc.

Transducers (Briefly)



eg. any measurable quantity:

- energy: sound, electrical, mechanical, light, chemical,
- pressure, level, density, temp, pH, flow, temperature
- position, distance, mass, time
- etc, etc.

Basic Requirements of Transducer

- **Linearity:** Linearity of any transducer is the prime requirement. A transducer having linear input output characteristics is a big plus.
- **Repeatability:** A transducer having this quality produces the same result again and again when the same input signal is applied repeatedly under same environmental conditions ex. Temperature, pressure, humidity etc.
- **Ruggedness:** A transducer should be robust in construction. It should be mechanically rugged, so that is capable of withstanding overload.
- **High Signal To Noise Ratio:** The quality of output signal of transducer should be good; it should be free from the internal and external noise.
- **Highly Reliable:** Output of the transducer should be highly reliable and stable it should be precise. It should give minimum error in measurement for temperature variations, humidity vibrations.
- **Good Dynamic Response:** A transducer may be called upon to respond to either slowly varying or dynamic signals. Its output should be faithful to input when taken as a function of time.
- **No Hysteresis:** A good transducer is free from hysteresis. It should not introduce any hysteresis during measurement while input signal is varied from its low value to high value and vice versa.
- **Residual Deformation:** There should be no deformation of testing material after the removal of any pressure after long period of application.

Transducers can be classified as

1. On the basis of transduction form used.
2. Primary and secondary transducers.
3. Passive and active transducers.
4. Analog and digital transducers.
5. As transducers and inverse transducers.

Introduction of Transducers

- Transducers are divided into two types:
  - Active Transducer
  - Passive Transducer

Active Transducers

- An active transducer does not require an external power supply to provide an output signal.
- These transducers usually rely upon magnetic inductance or piezoelectric effects to produce their output signals.
- Ex. Piezoelectric crystal used for acceleration measurement.
- Measurand is converted into output without any other form of energy requirements.
- They are also called self generating type transducers.

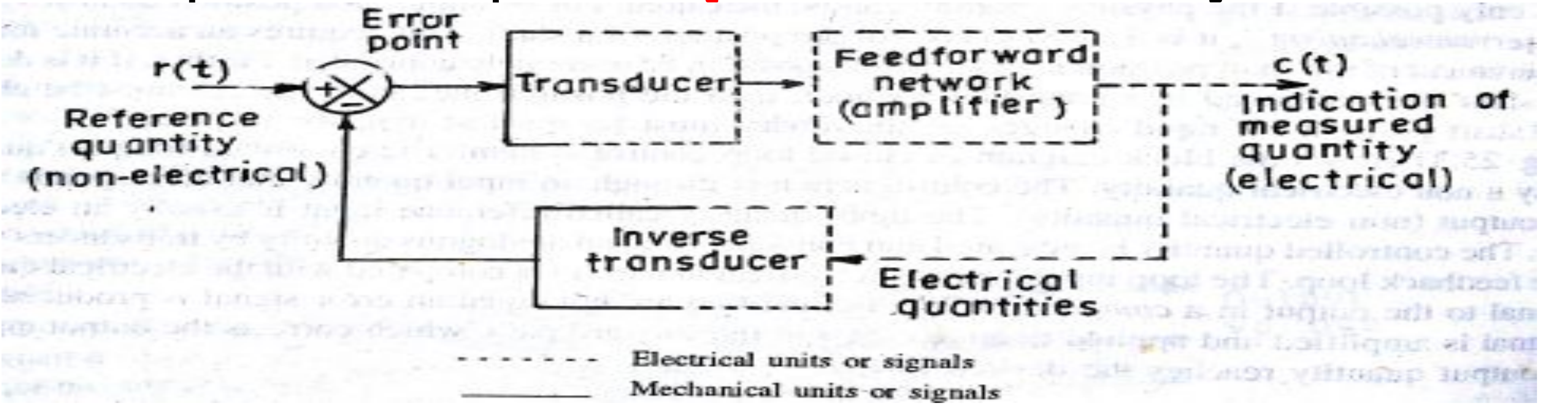
Passive Transducers

- Passive transducers need an external power supply in order to amplifies the input and generate an output signal.
- All passive transducers change one of, or a combination of, the three general circuit parameters; resistance, inductance, or capacitance.
- Ex. Potentiometer is used for measurement of pressure, displacement and position.

Direct and Inverse Transducers

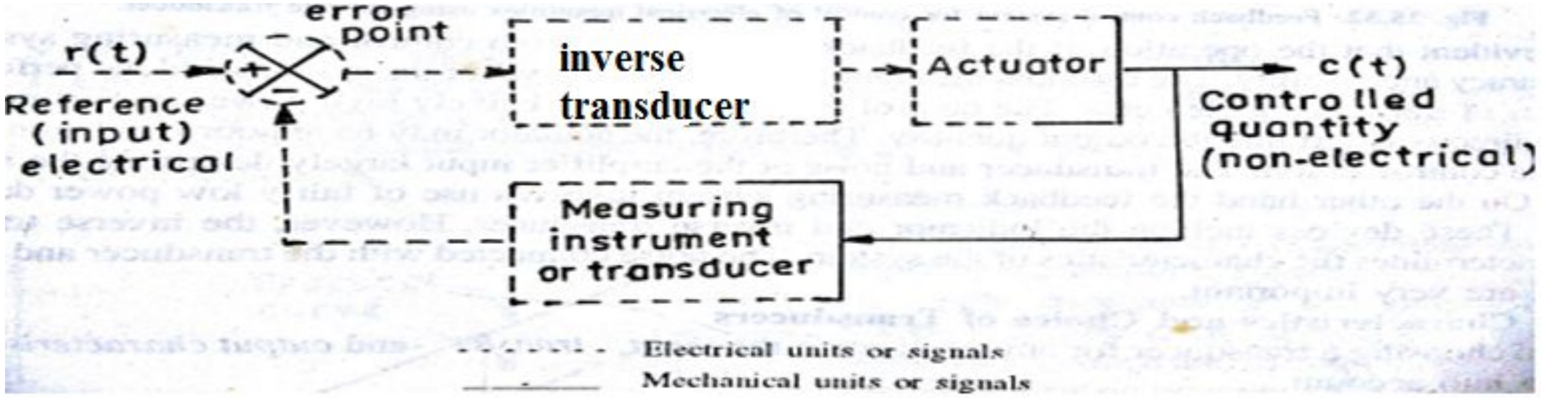
Direct-one form to electrical

Example :microphone [sound-electrical]



Inverse-electrical into non-electrical

Example:loudspeaker[electrical-sound]

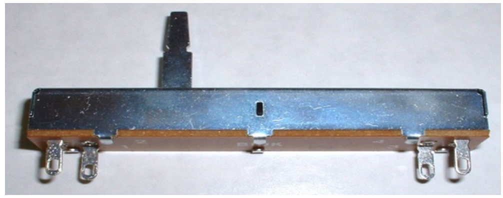


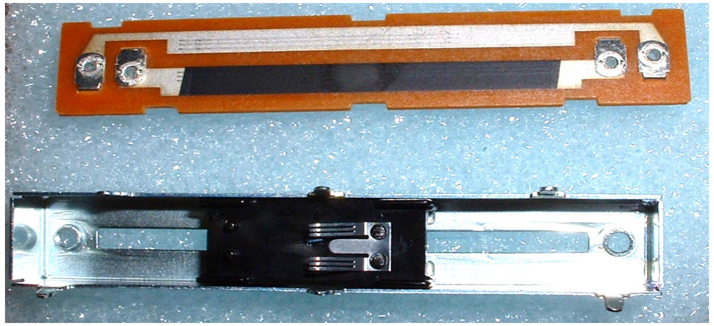
Displacement Transducer

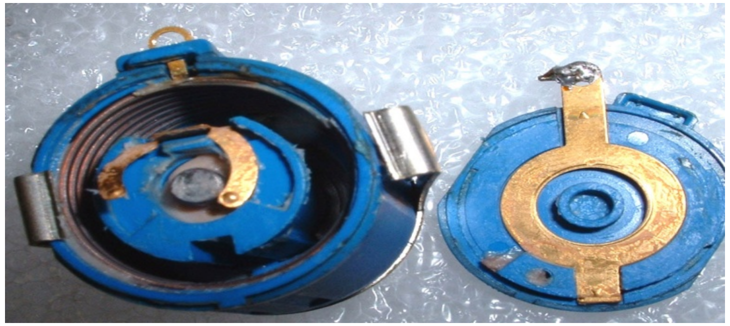
- A Displacement Transducer is an electromechanical device used to convert mechanical motion or vibrations, specifically rectilinear motion, into a variable electrical current, voltage or electric signals, and the reverse.

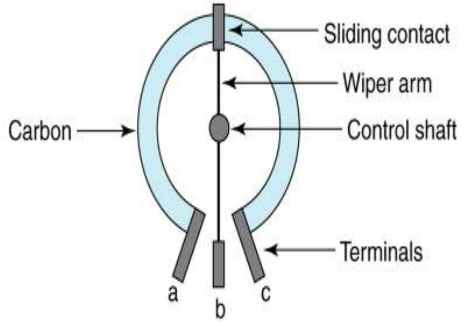
  - Capacitive Transducer
  - Inductive
  - Variable Inductance
  - Linear Variable Differential Transformer

Variation of resistance

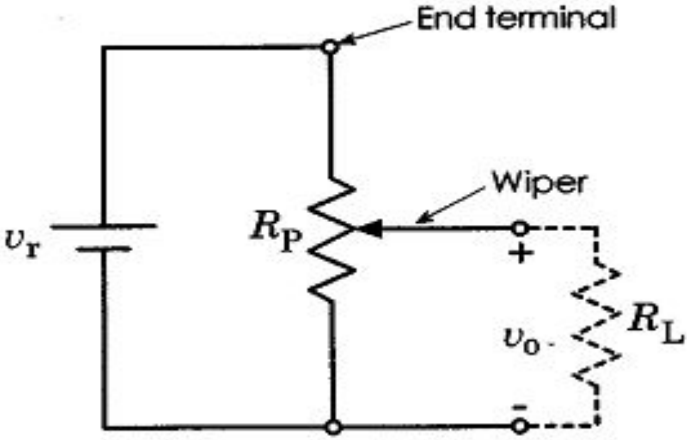








Note: Most potentiometers are constructed so that the moving contact can rotate approximately 350°.



Capacitance Transducers

- Variable capacitance pressure gage –
  - Principle of operation: Distance between two parallel plates is varied by an externally applied force.
  - Applications: Measurement of Displacement, pressure.
- Capacitor microphone
  - Principle of operation: Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.
  - Applications: Speech, music, noise.
- Dielectric gauge
  - Principle of operation: Variation in capacitance by changes in the dielectric.
  - Applications: Liquid level, thickness.

Inductance Transducers

- Magnetic circuit transducer
  - Principle of operation: Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit.
  - Applications: Pressure, displacement.
- Reluctance pickup
  - Principle of operation: Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil.
  - Applications: Pressure, displacement, vibration, position.
- Differential transformer
  - Principle of operation: The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.
  - Applications: Pressure, force, displacement, position.
- Eddy current gage
  - Principle of operation: Inductance of a coil is varied by the proximity of an eddy current plate.
  - Applications: Displacement, thickness.
- Magnetostriction gauge
  - Principle of operation: Magnetic properties are varied by pressure and stress.
  - Applications: Force, pressure, sound.

Transducer Types

- Electromagnetic Transducer
- Electrochemical Transducer
- Electromechanical Transducer
- Electro acoustic Transducer
- Photoelectric Transducer
- Electrostatic Transducer
- Thermoelectric Transducer
- Radio acoustic Transducer

Types and applications

Some common transducers and common uses

• Thermistor/thermocouple	temperature eg;motors
• LDRs/LEDs	flame or smoke
• Opto-coupler	data transfer
• Speaker/microphone	acoustic/sound
• Magnetic pickup	stylus/vibration
• Strain guage	tension
• Hall effect	magnetism
• Peltier effect device	temperature
• Piezzo	stress/pressure

Transducer	*Input*	*Output*
Thermistor	heat	change in resistance
Torch battery	chemical	emf
Piezo effect device	change in applied force	emf
Hall-effect device	magnetic field	emf
Thermocouple	heat	emf
Magnetic pick-up cartridge	change in displacement	emf
Speaker	current	sound wave
LED	current	light
Opto-coupler	current	current
Strain gauge	physical force	change in resistance
Photo-transistor	change in light intensity	change in current
LDR	change in light intensity	change in resistance
Microphone	sound wave	emf
Peltier effect device	change in current	change in temperature
Seebeck effect device	change in temperature	change in emf

Principles of Energy Transformation

Capacitive Transducers

Voltage between plates: $V_{ab} = Ed$

$$C = \frac{Q}{V} = \frac{Q}{Ed} = \frac{\varepsilon A}{d}$$

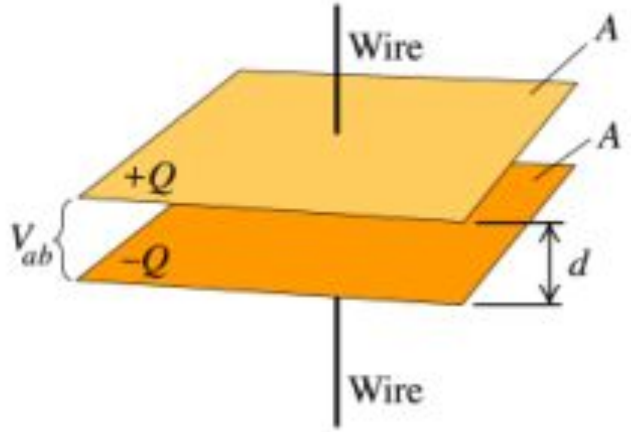
where:

Q = plate charge

ε = permittivity of dielectric

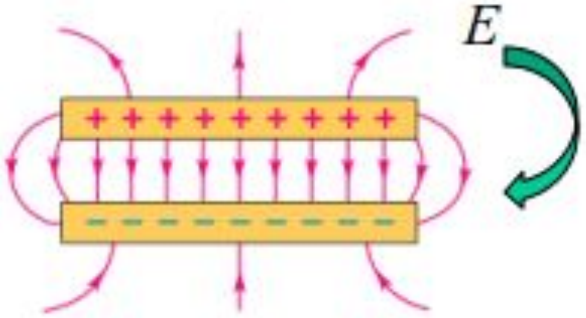
A = area of plates

d = distance between plates



(a)

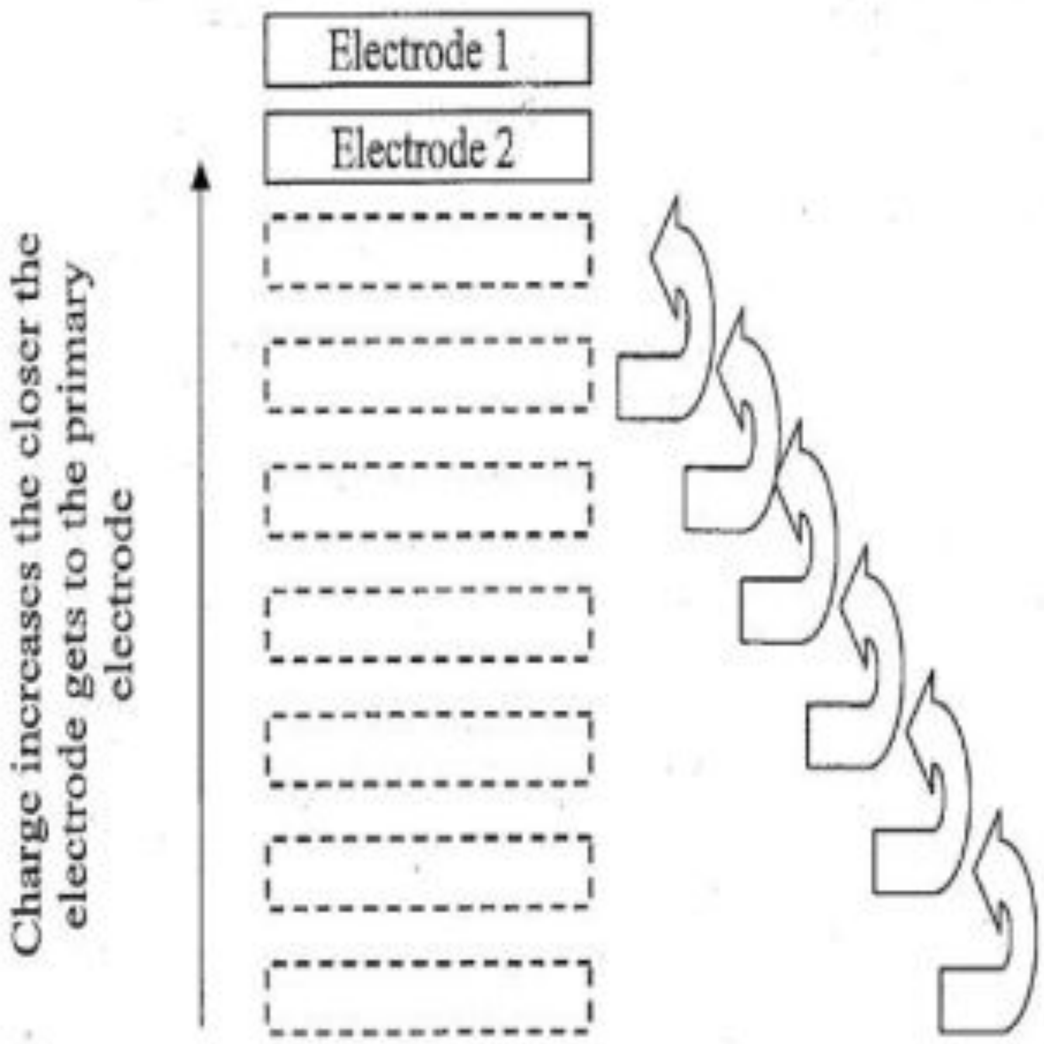
Electric Field



(b)

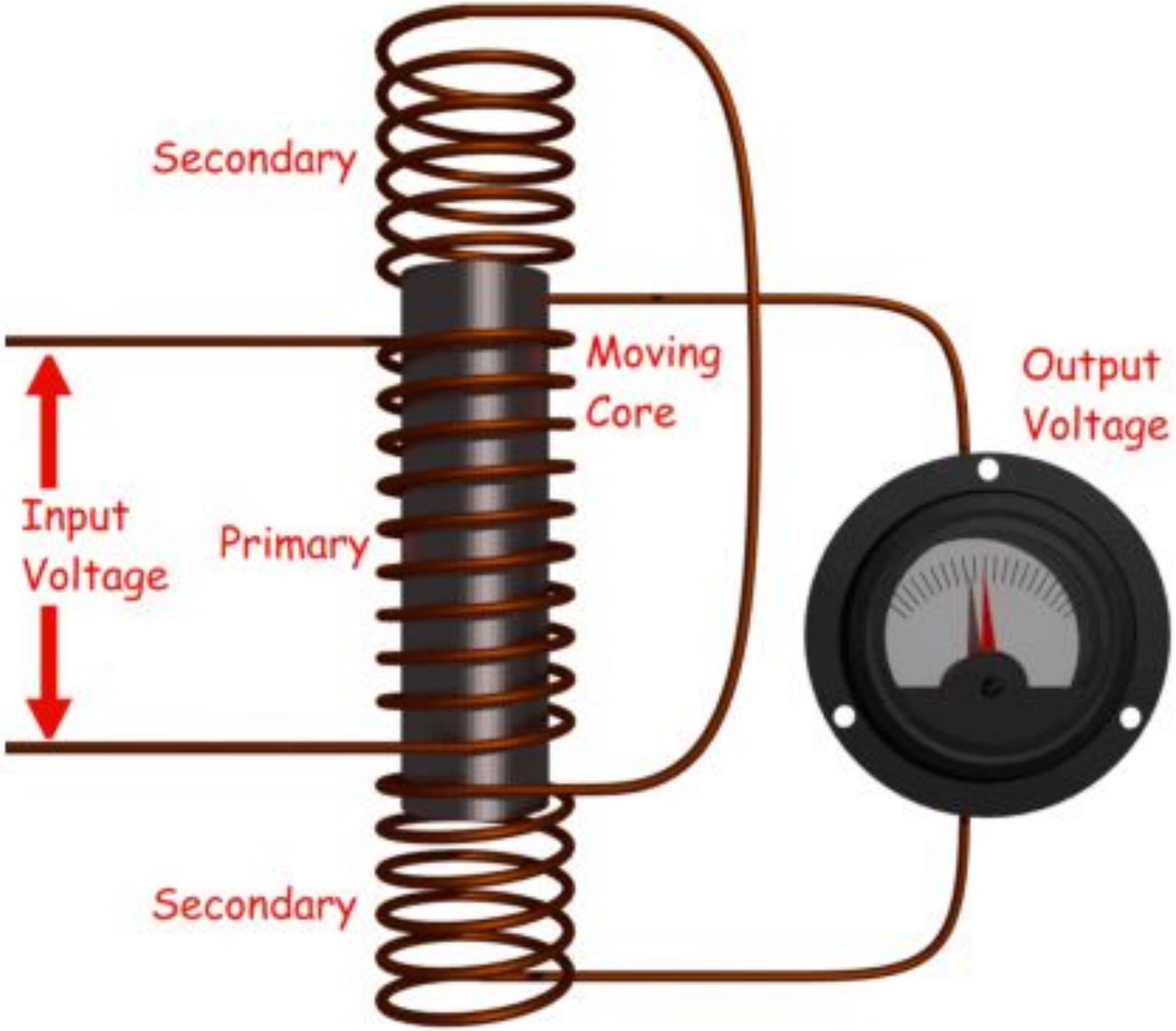
Capacitive Transducers

- Capacitive transducers use a changing capacitive reactance within the transducer to produce a proportional output. The typical capacitive transducer. is used as a proximity device with one electrode charged and the other affected as it approaches in close proximity. The surrounding air is used as a dielectric to produce a reactance that is proportional to the distance between the to electrodes of the capacitor.



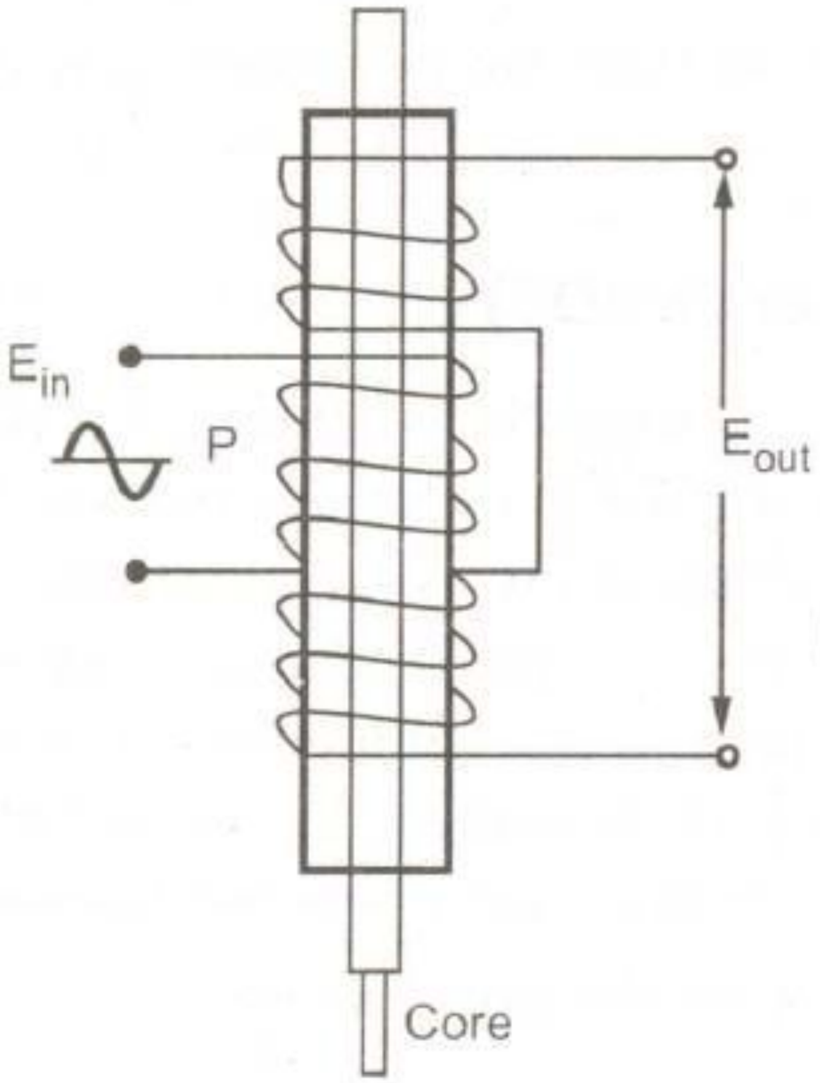
Inductive Transducers

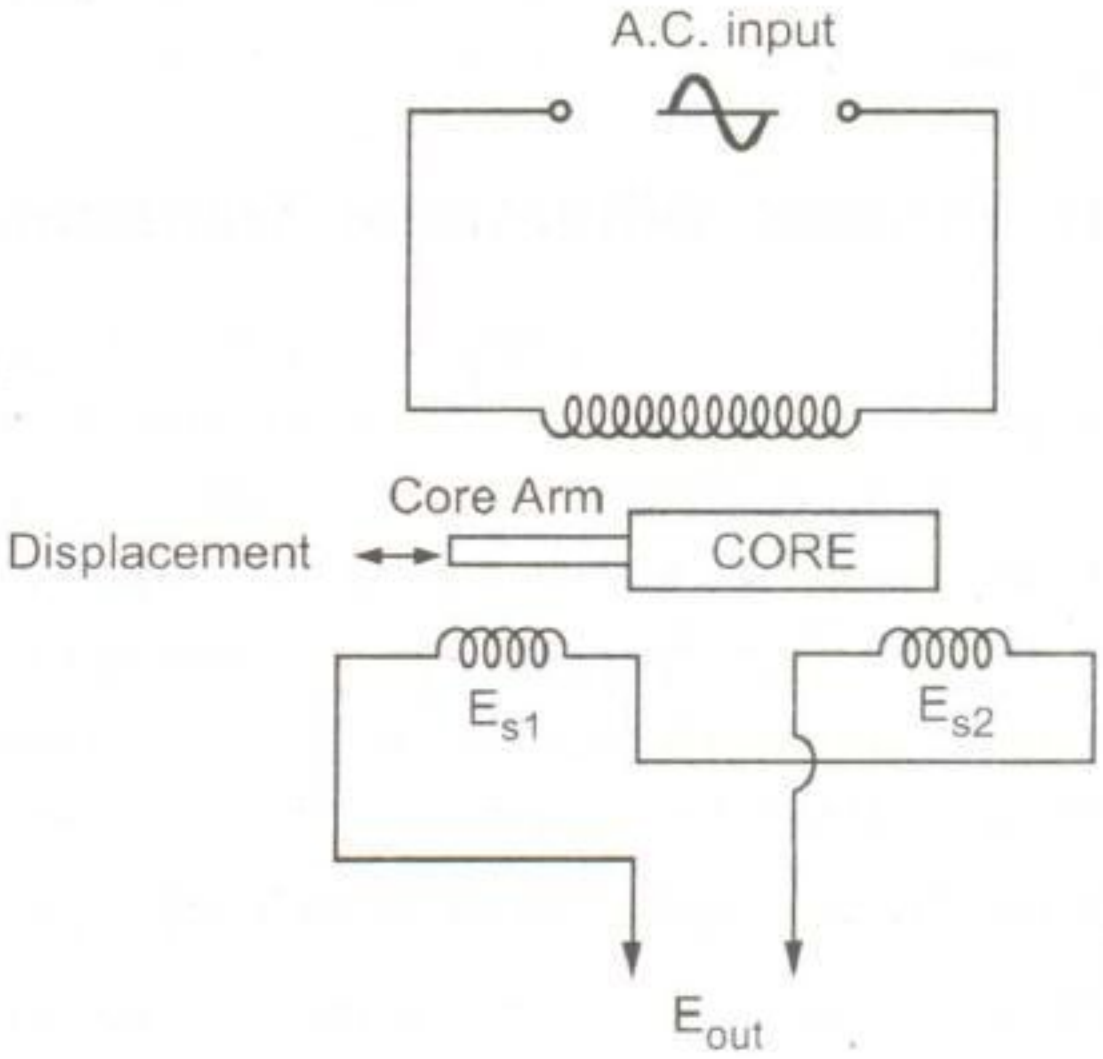
- **Inductive transducers** work on the principle of inductance change due to any appreciable change in the quantity to be measured i.e. measured.
- For example, LVDT, a kind of inductive transducers, measures displacement in terms of voltage difference between its two secondary voltages.
- Secondary voltages are nothing but the result of induction due to the flux change in the secondary coil with the displacement of the iron bar.
- Anyway, LVDT is discussed here briefly to explain the **principle of inductive transducer**.

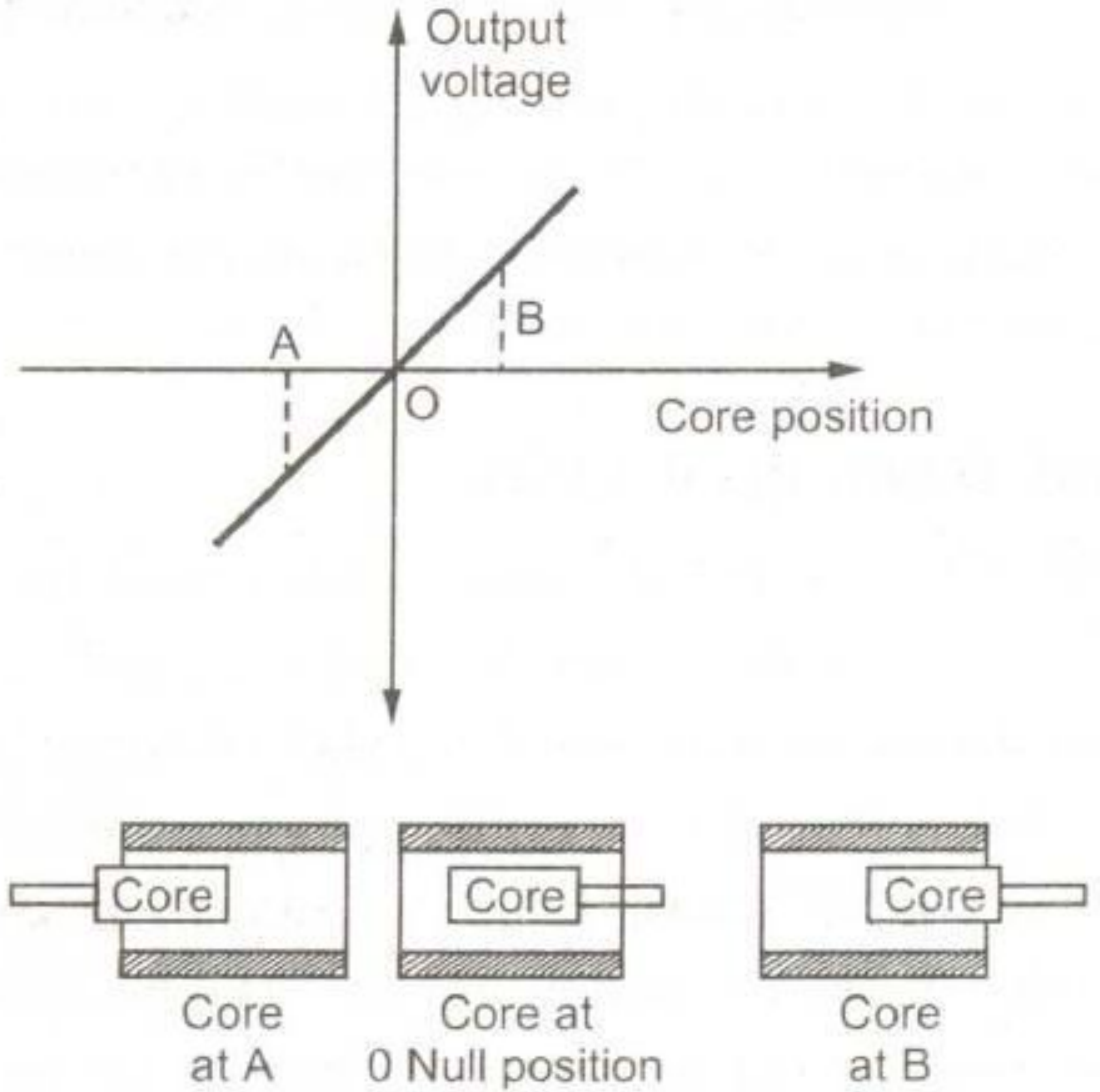

Secondary
Moving
Core
Output
Voltage
Input
Voltage
Primary
Secondary

Linear variable differential transformer (LVDT)

- When an externally applied force moves the core to the left-hand position, more magnetic flux links the left-hand coil than the right hand coil.
- The emf induced in the left-hand coil [Es1], is therefore larger than the induced emf of the right-hand coil [Es2].
- The magnitude of the output voltage is then equal to the difference between the two secondary voltages and it is in phase with the voltage of the left-hand coil.


E_in
P
E_out
Core


A.C. input
Core Arm
Displacement
CORE
E_s1
E_s2
E_out


Output voltage
B
A
O
Core position
Core
Core
Core
Core at A
Core at 0 Null position
Core at B

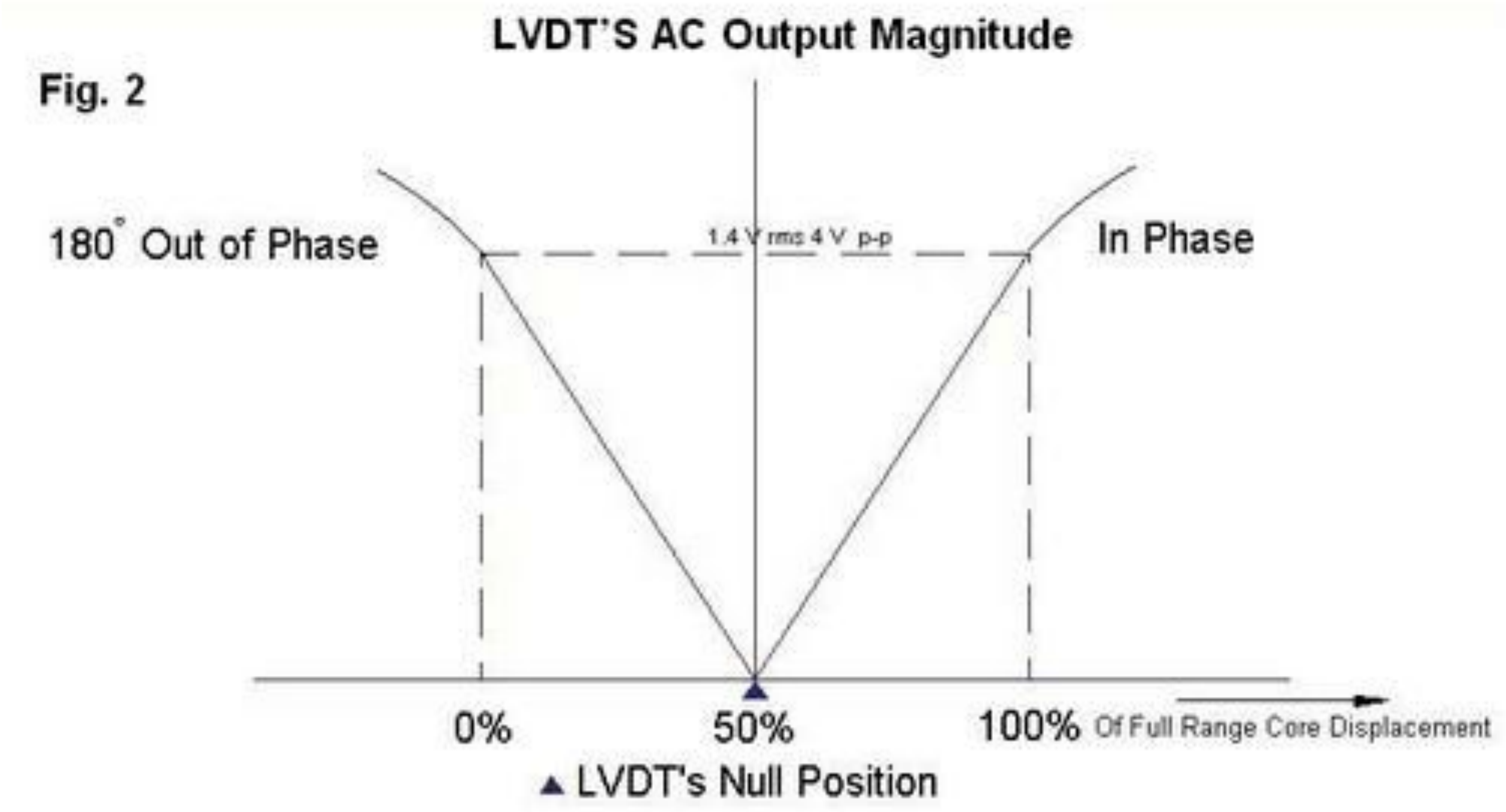
Construction of LVDT

- The transformer consists of a primary winding P and two secondary winding S1 and S2 wound on a cylindrical former(which is hollow in nature and will contain core).
- Both the secondary windings have equal number of turns and are identically placed on the either side of primary winding.
- The primary winding is connected to an AC source which produces a flux in the air gap and voltages are induced in secondary windings.
- A movable soft iron core is placed inside the former and displacement to be measured is connected to the iron core.
- The iron core is generally of high permeability which helps in reducing harmonics and high sensitivity of LVDT.
- The LVDT is placed inside a stainless steel housing because it will provide electrostatic and electromagnetic shielding.
- The both the secondary windings are connected in such a way that resulted output is the difference of the voltages of two windings.

Principle of Operation and Working

- As the primary is connected to an AC source so alternating current and voltages are produced in the secondary of the LVDT. The output in secondary S_1 is e_1 and in the secondary S_2 is e_2. So the differential output is, $e_{out} = e_1 - e_2$ This equation explains the principle of Operation of LVDT.
- Now three cases arise according to the locations of core which explains the working of LVDT are discussed below as,
    - CASE I When the core is at null position (for no displacement) When the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. So for no displacement the value of output e_{out} is zero as e_1 and e_2 both are equal. So it shows that no displacement took place.
    - CASE II When the core is moved to upward of null position (For displacement to the upward of reference point) In the this case the flux linking with secondary winding S_1 is more as compared to flux linking with S_2. Due to this e_1 will be more as that of e_2. Due to this output voltage e_{out} is positive.
    - CASE III When the core is moved to downward of Null position (for displacement to the downward of reference point) In this case magnitude of e_2 will be more as that of e_1. Due to this output e_{out} will be negative and shows the output to downward of reference point.

Output Vs Core Displacement: A linear curve shows that output voltage varies linearly with displacement of core.



AC Output of Conventional LVDT Versus Core Displacement

Some important points about magnitude and sign of voltage induced in LVDT:

- The amount of change in voltage either negative or positive is proportional to the amount of movement of core and indicates amount of linear motion.
- By noting the output voltage increasing or decreasing the direction of motion can be determined.
- The output voltage of an LVDT is linear function of core displacement.

Advantages of LVDT

- High Range - The LVDTs have a very high range for measurement of displacement. They can used for measurement of displacements ranging from 1.25mm to 250mm.
- No Frictional Losses - As the core moves inside a hollow former so there is no loss of displacement input as frictional loss so it makes LVDT as very accurate device.
- High Input and High Sensitivity - The output of LVDT is so high that it doesn't need any amplification. The transducer possesses a high sensitivity which is typically about 40V/mm.
- Low Hysteresis - LVDTs show a low hysteresis and hence repeatability is excellent under all conditions.
- Low Power Consumption - The power is about 1W which is very as compared to other transducers.
- Direct Conversion to Electrical Signals - They convert the linear displacement to electrical voltage which are easy to process.

Disadvantages of LVDT

- LVDT is sensitive to stray magnetic fields so they always require a setup to protect them from stray magnetic fields.
- They are affected by vibrations and temperature.

Applications of LVDT

- They are used in applications where displacements ranging from fraction of mm to few cm are to be measured. The LVDT acting as a primary Transducer converts the displacement to electrical signal directly.
- They can also acts as the secondary transducers. E.g. the Bourbon tube which acts as a primary transducer and covert pressure into linear displacement. Then LVDT coverts this displacement into electrical signal which after calibration gives the ideas of the pressure of fluid.

Electromechanical Transducers

- Galvanometer-an instrument for detecting and measuring electric current. It is an analog electromechanical transducer that produces a rotary deflection, through a limited arc, in response to electric current flowing through its coil.
- Accelerometer- a device for measuring acceleration and gravity induced reaction forces.
- Rotary motor, linear motor , Vibration powered generator are some examples of this type.

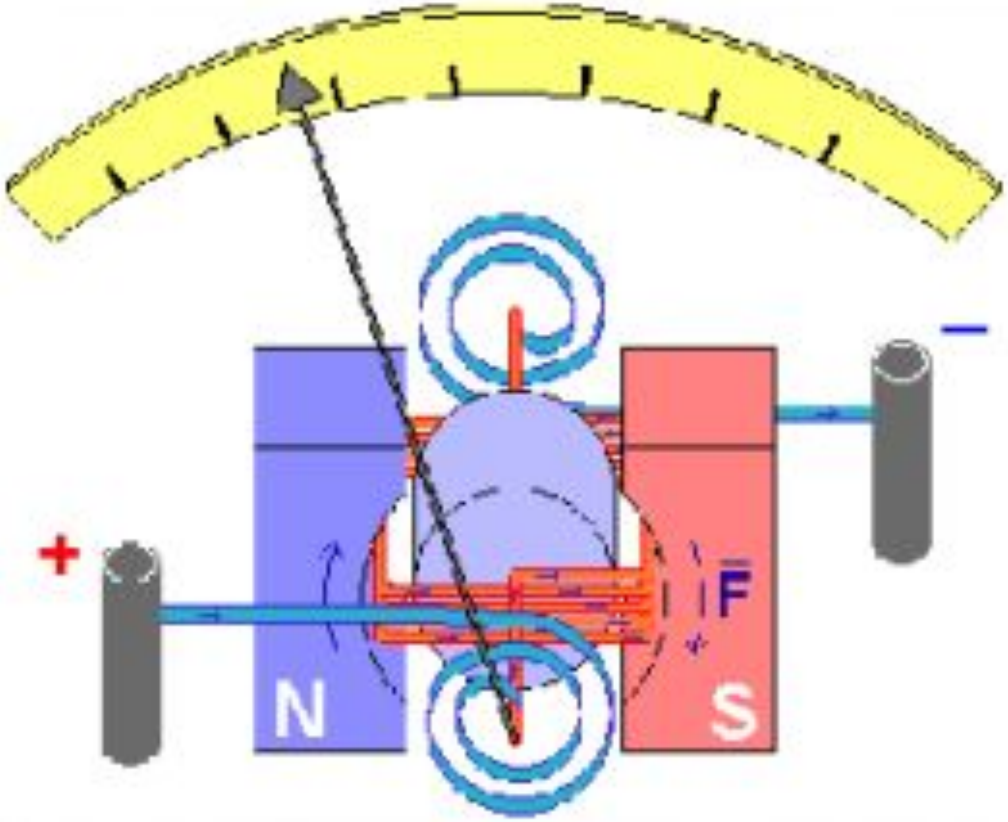
Types of Energy Transformations

- Electromechanical - movement ⟺ voltage

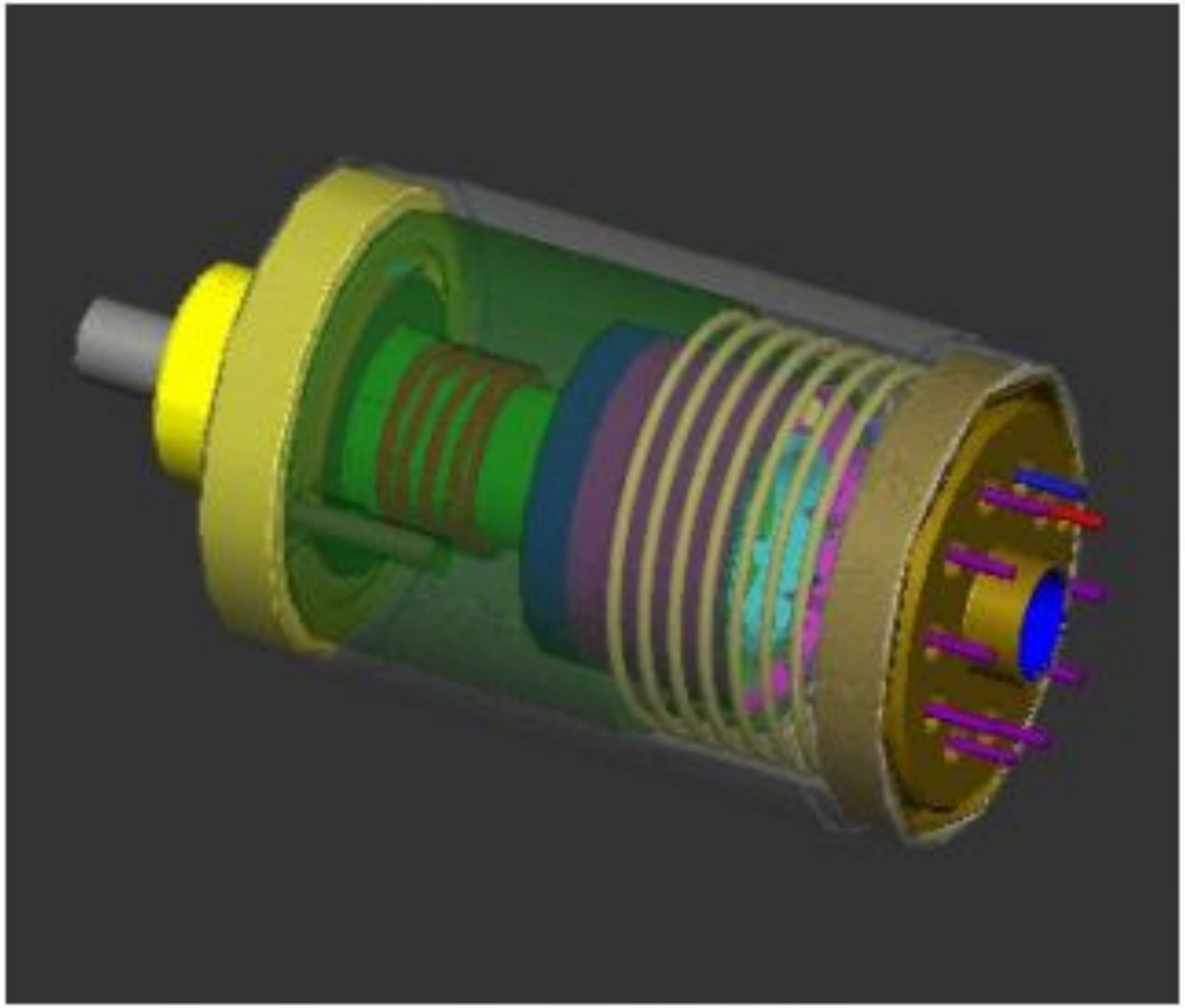
Examples:

Motor/Generator

Phonograph Cartridge



GALVANOMETER


ACCELEROMETER

Principles of Energy Transformation

Electromechanical Transducers

- Some type of mechanical contact

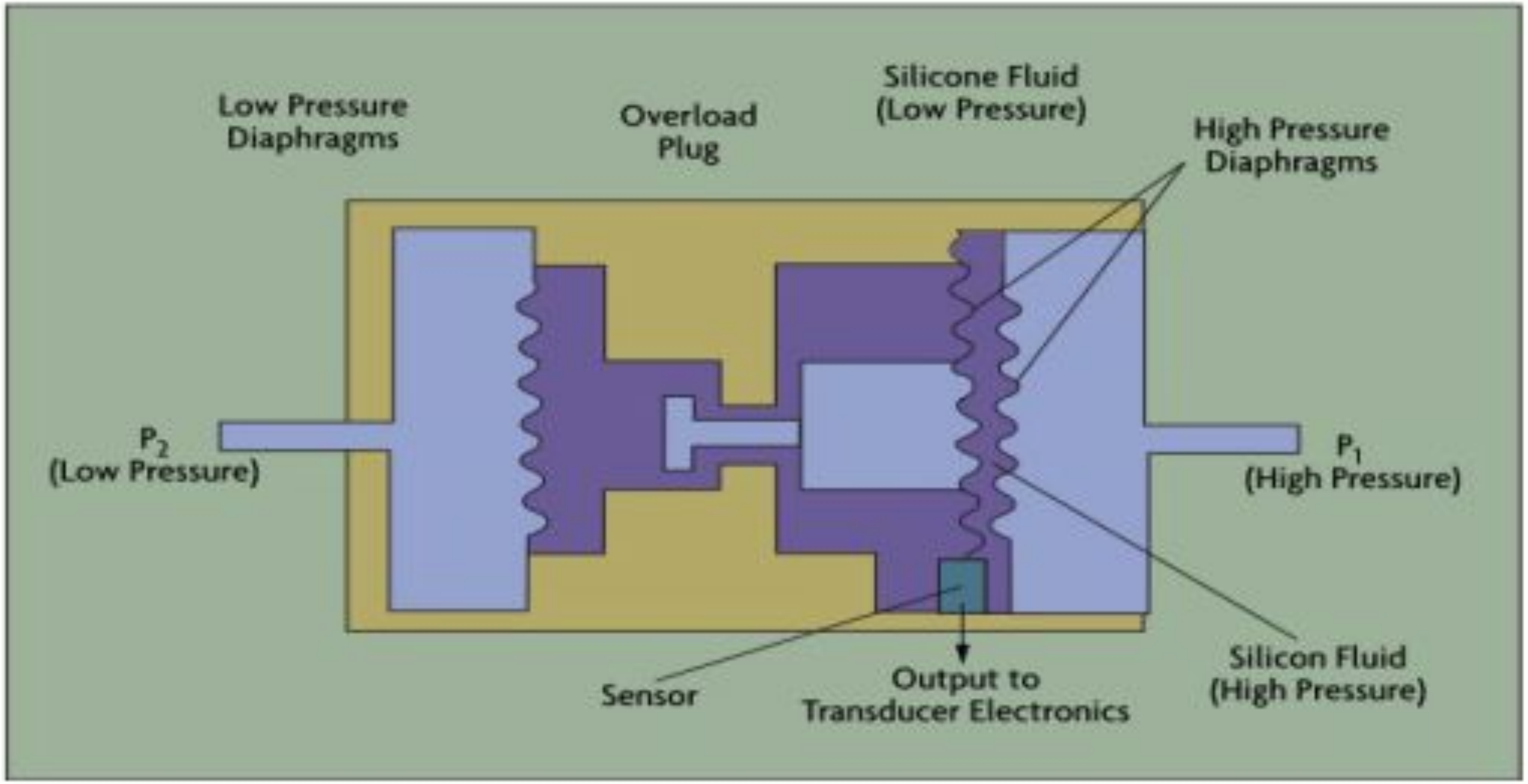
- Convert physical change (movement, distance, etc.) to electrical signal (or *vice-versa*)

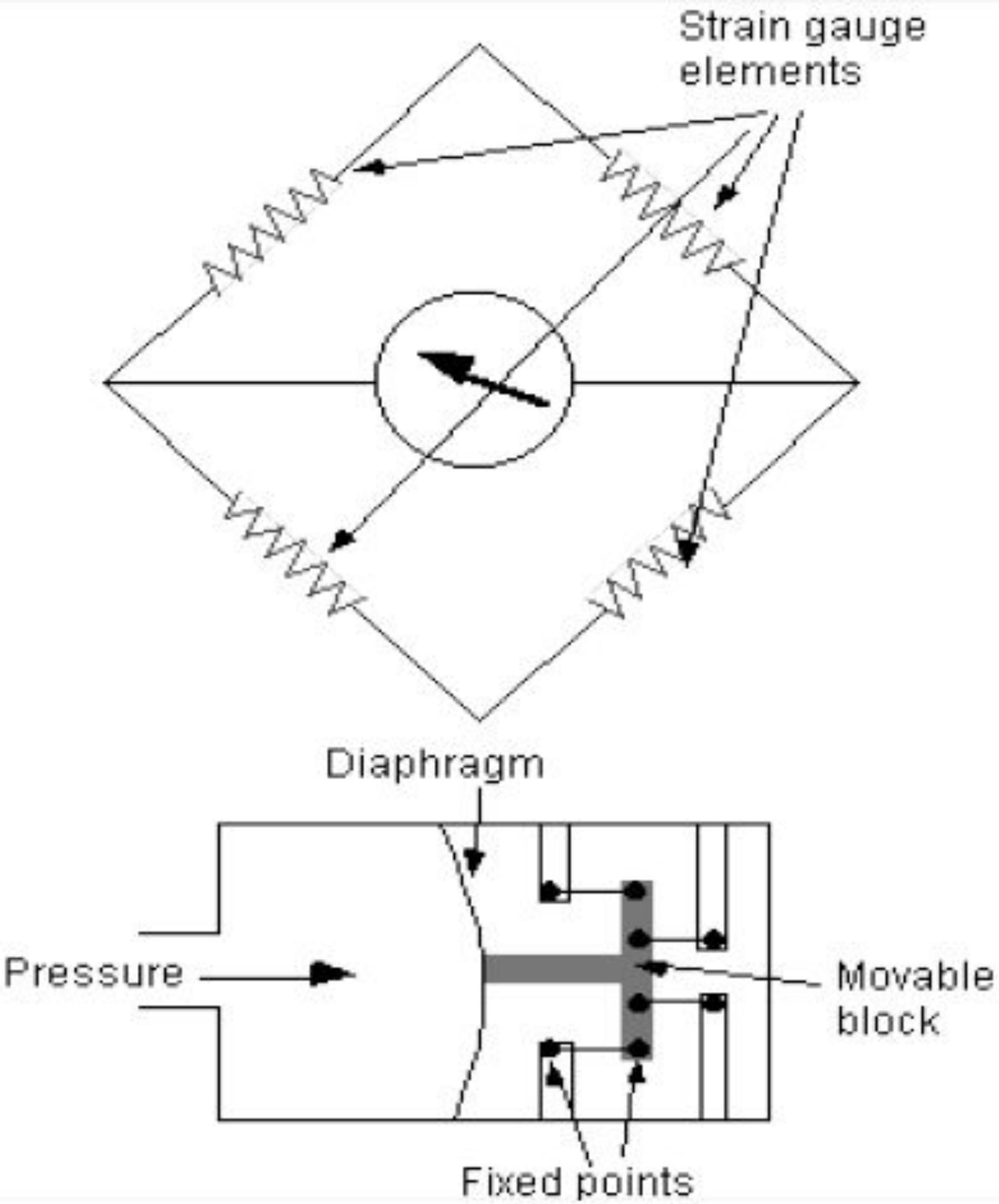
- Mouse - Movement of track ball causes electric signal

Strain Gauge Pressure Transducer

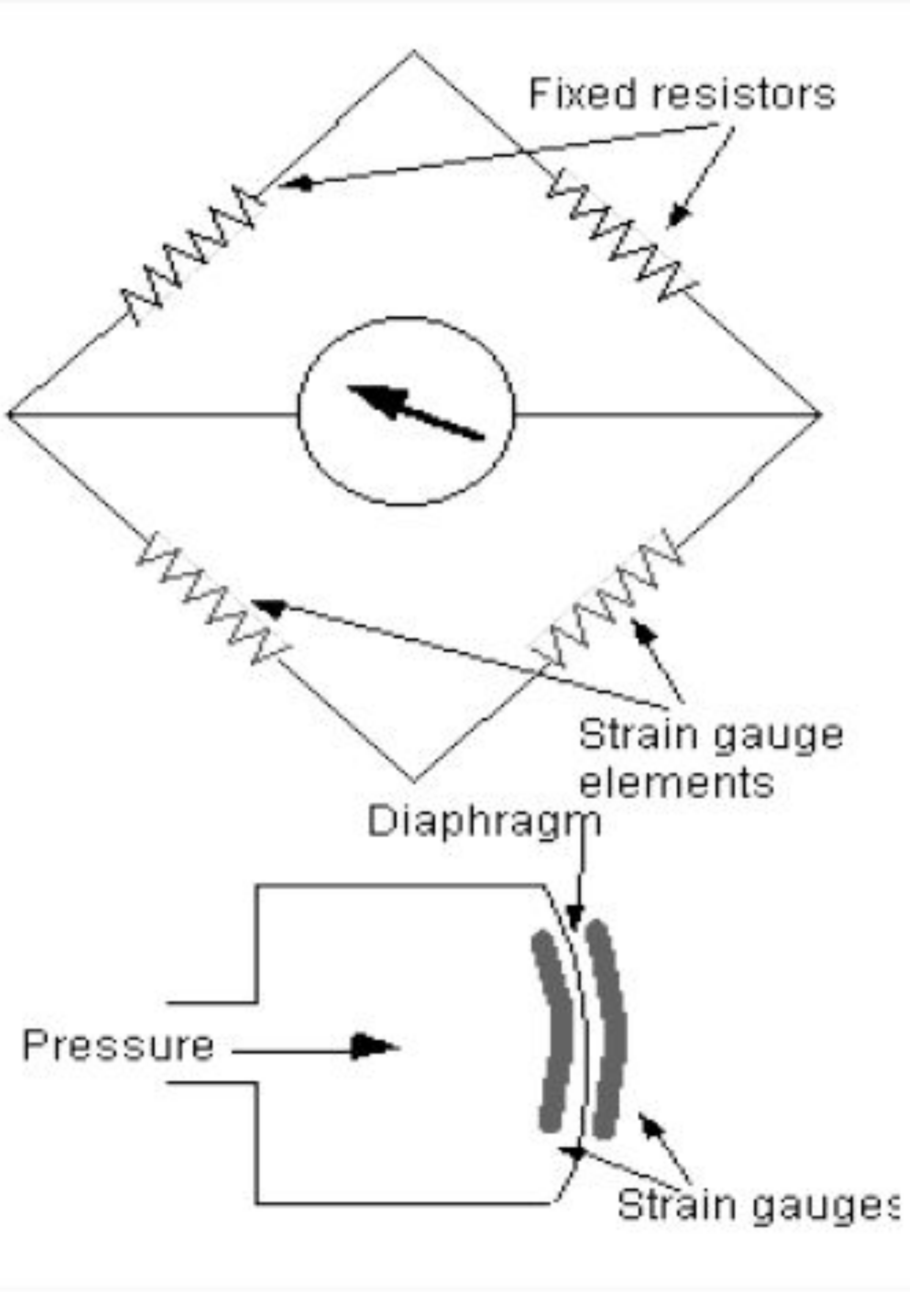
- When the tension is applied to the electrical conductor, its length increases while the cross section area decreases.
- So its resistance changes.
- This change can be measured to measured.
- Used for the measurement of force, stress and strain.
- A strain gauge is a passive type resistance pressure transducer whose electrical resistance changes when it is stretched or compressed.
- A pressure transducer contains a diaphragm which is deformed by the pressure which can cause a strain gauge to stretch or compress. This deformation of the strain gauge causes the variation in length and cross sectional area due to which its resistance changes.

- The wire filament is attached to a structure under strain and the resistance in the strained wire is measured.

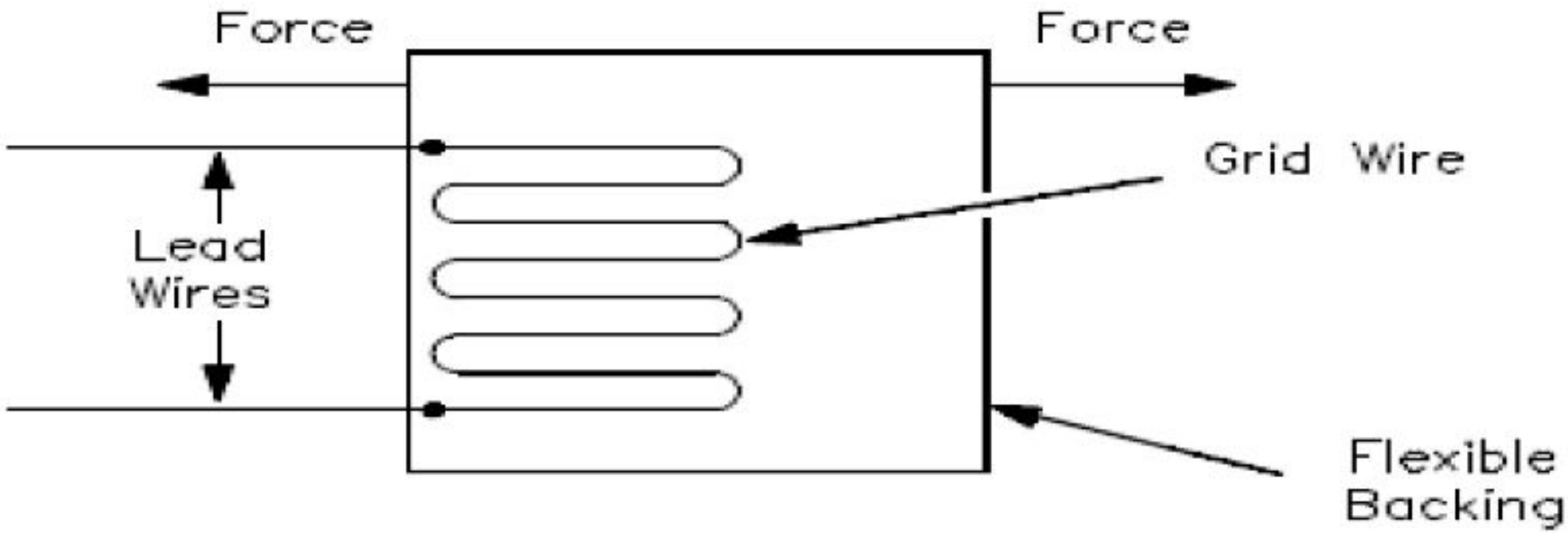




WIRE RESISTANCE STRAIN GAUGE



DOUBLE BONDED STRAIN GAUGE



- Strain gauge pressure transducers are used for narrow pressure span and for differential pressure measurements.
- Available for pressure ranges as low as 3 inches of water to as high as 200,000 psig.
- Inaccuracy ranges from 0.1 % of span to 0.25 % of full scale.

Thermoelectric Transducers

- RTD(Resistance Temperature Detector)-To predict change in electrical resistance of some materials with changing temperature.
- Thermocouple-to convert thermal potential difference into electric potential difference.
- Thermistor are some of the examples of this type of transducers.

Types of Energy Transformations

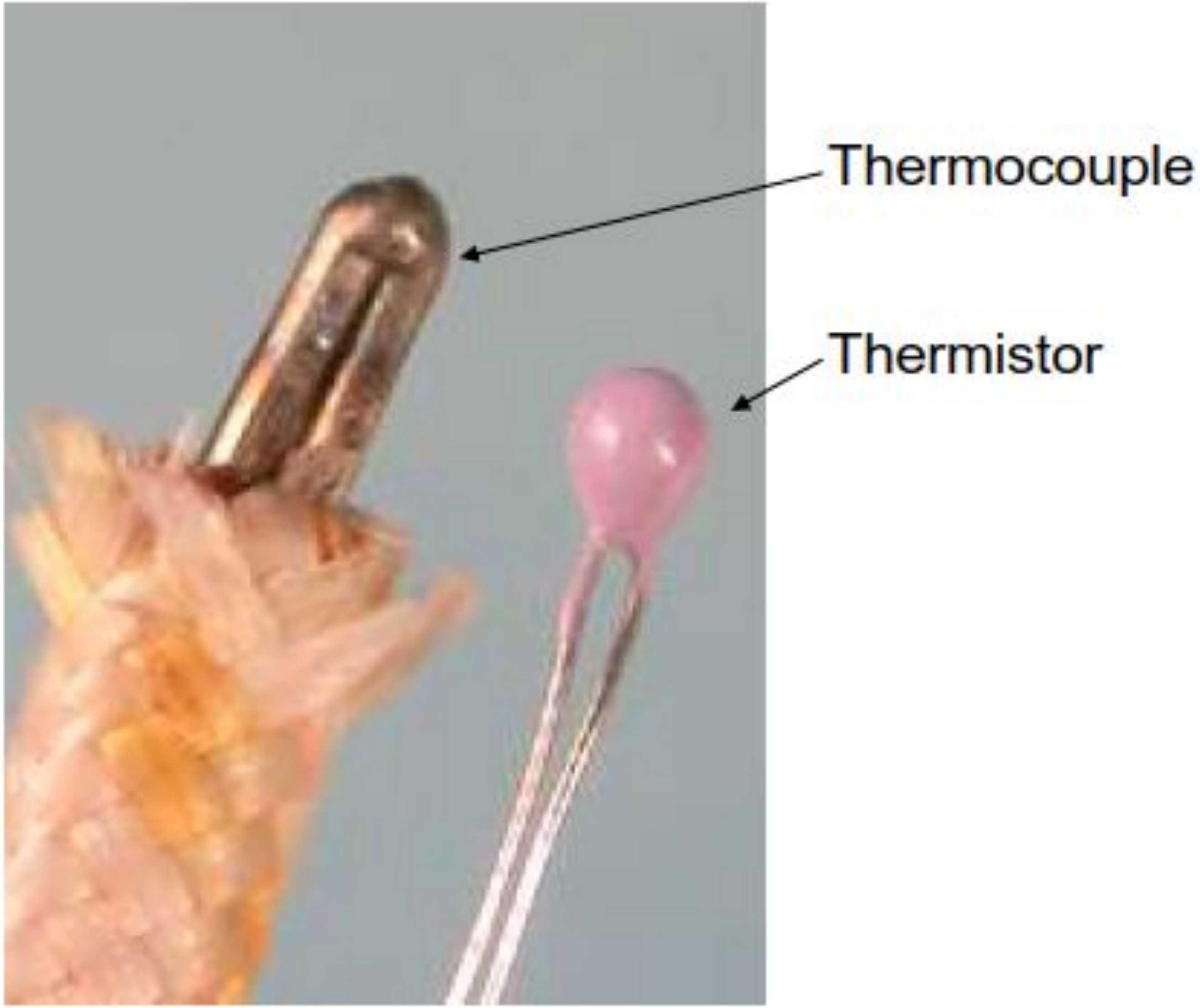
- Thermoelectric - temperature ⟷ voltage

Examples:

Hotplate

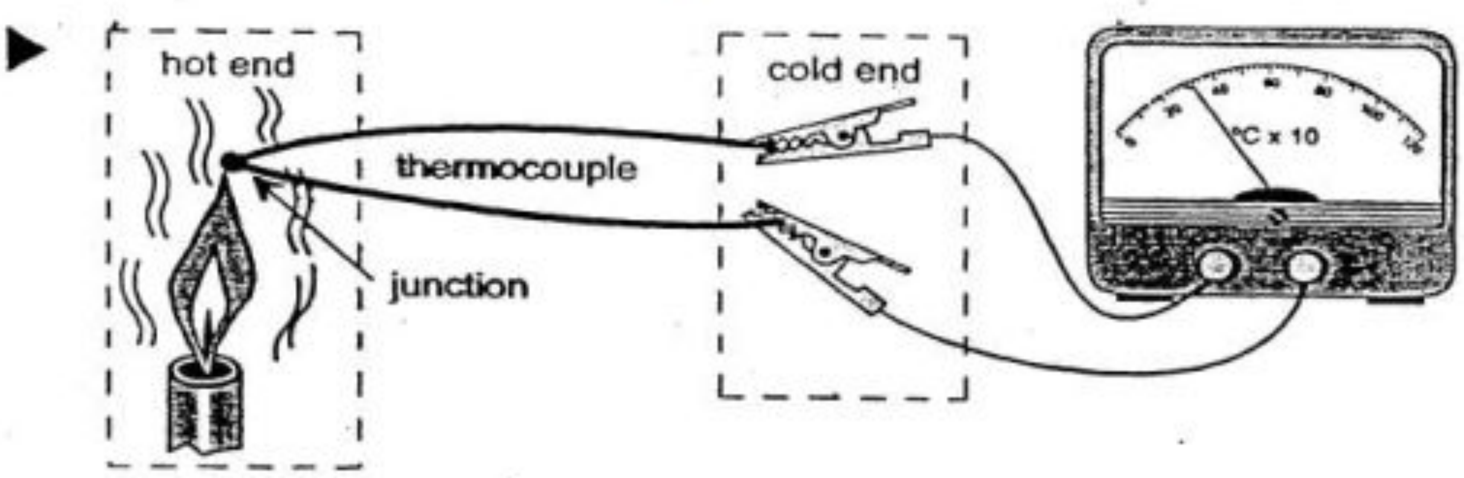
Thermistor

Measuring temperature



Thermocouples

A thermocouple is formed by two different metals joined at one point



As the junction temperature increases a small voltage is created in the loop. The voltage produced at the junction of the dissimilar metals is due to a phenomenon called the "Seebeck Effect".

- The higher the temperature at the junction, the greater the voltage produced by that junction.

- The relationship between voltage and temperature is constant and therefore will graph as a linear line.

Temperature Transducer (cont'd):-

2. Thermocouples:-

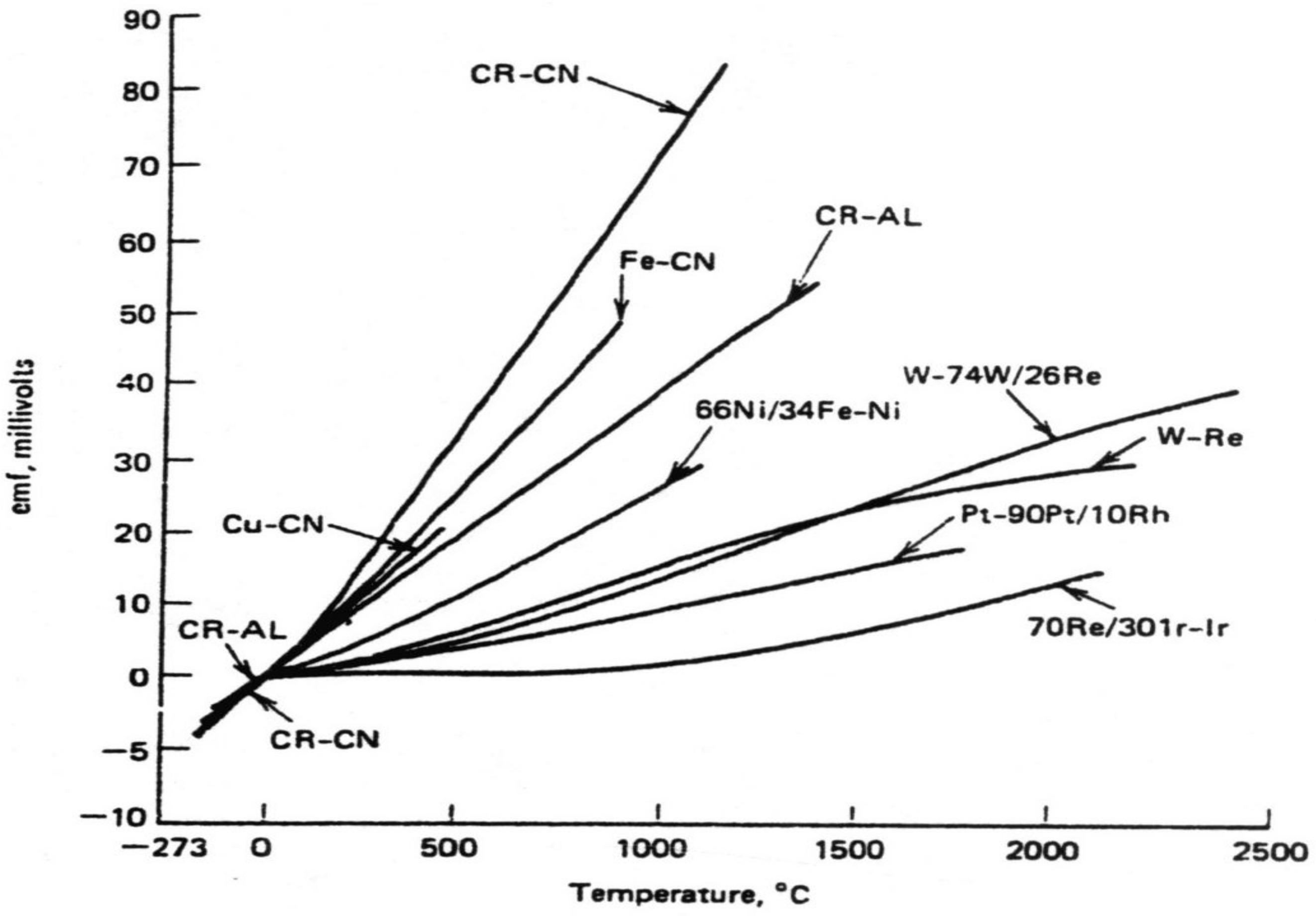
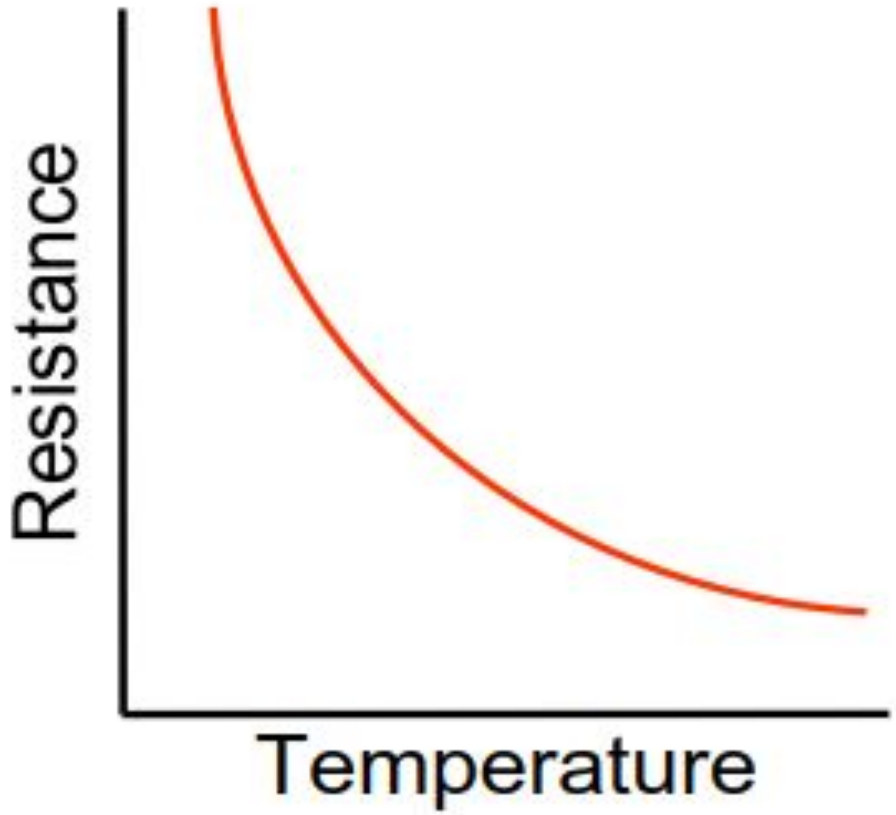


Fig (11) Calibration curves for several thermocouple combinations.

Thermistors

- Thermistors are made from semi-conductor materials.
- Semi-conductor thermistors have a Negative Temperature Coefficient (NTC). i.e. as temperature increases, the resistance decreases.



Thermistor construction

- Thermistors come in a variety of sizes and shapes.
- Beads, disks, rods and probes are some of the more common styles.

Thermistors (Cont)

Like RTDs, thermistors are often enclosed in a housing suitable for either contact or non-contact applications in industry.

RESISTANCE TEMPERATURE DETECTOR (RTD)

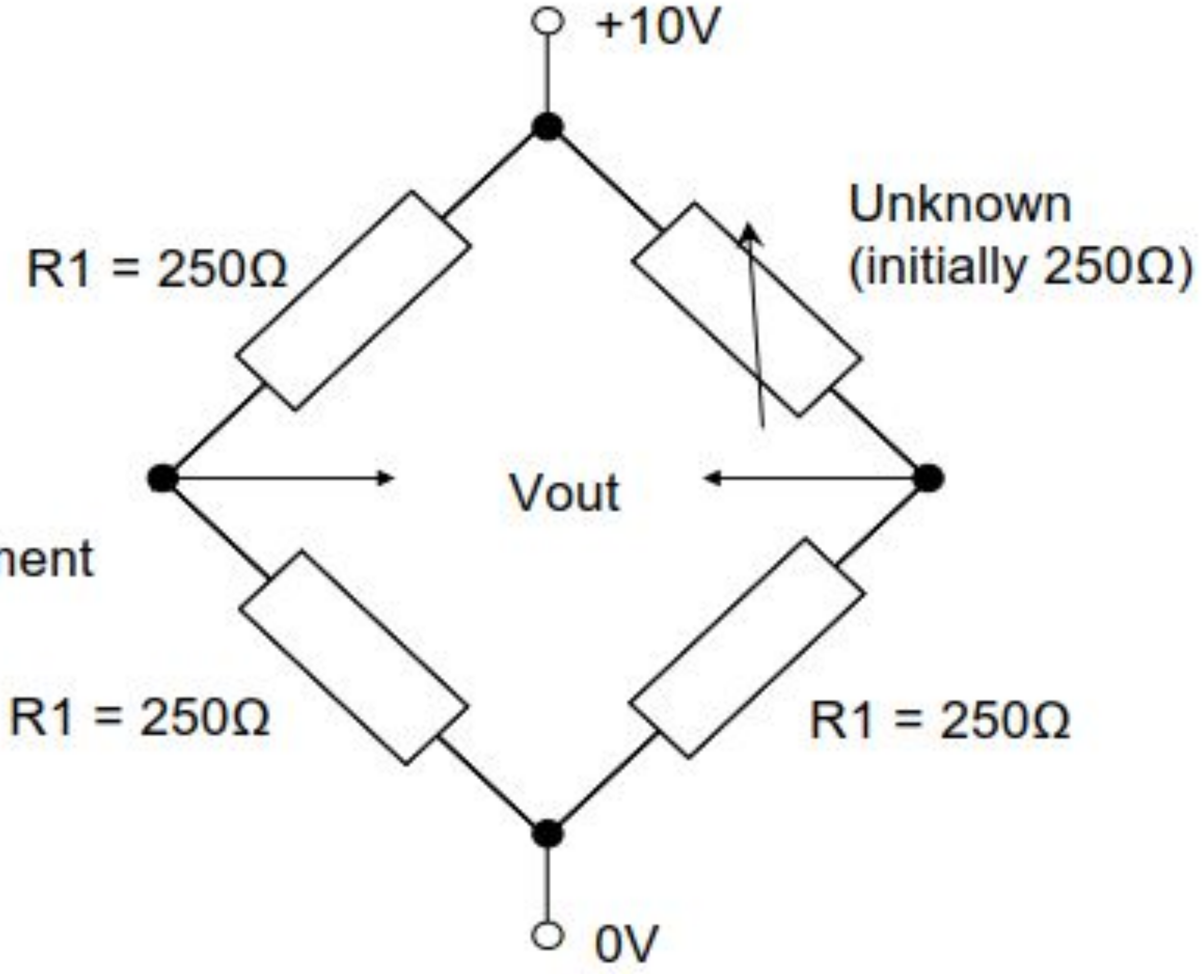
- Resistance temperature detector (RTD) devices are conductors used for temperature sensing.
- They can be used in bridge method as well as ohmmeter method to take the output.
- The change in resistance of material per unit change in temperature should be as large as possible.
- The material should have high value of resistivity to get required value in less space.
- Resistance and temperature relation should be continuous and stable.
- Platinum, nickel and copper are the most commonly used.
- Tungsten and nickel alloy are also used.
- APPLICATIONS OF RTD:
    - They can be used in average and differential temp. measurement.
    - Differential temp. sensing to an accuracy of 0.05° have been accomplished in a nuclear reactor coolant heat rise application.

Transducers (Briefly)

Bridge circuits

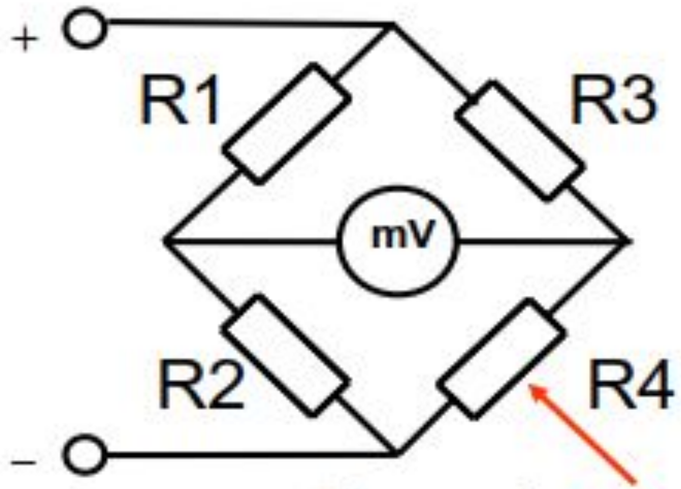
<u>Use</u>:

Weighers
Conveyors (Tonnes/Hr)
Pressure
RTD Temperature measurement



Wheatstone bridge

A circuit invented by Sir Charles Wheatstone in the mid-1800s. It is essentially two matched voltage dividers with a galvanometer across the network to sense any difference in potential.



Transducers (e.g. Thermistors or RTDs) can replace the resistors.

Photoelectric Transducers

- Laser diode, light-emitting diode - convert electrical power into forms of light.
- Photodiode, photo resistor, phototransistor, photomultiplier tube - converts changing light levels into electrical form.

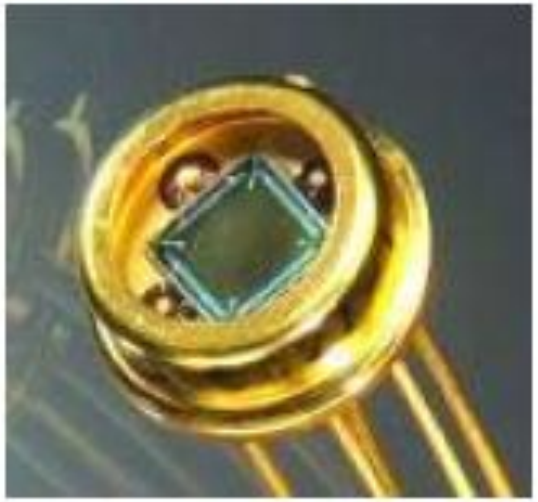
Types of Energy Transformations

- Photoelectric - light $\longleftrightarrow$ voltage

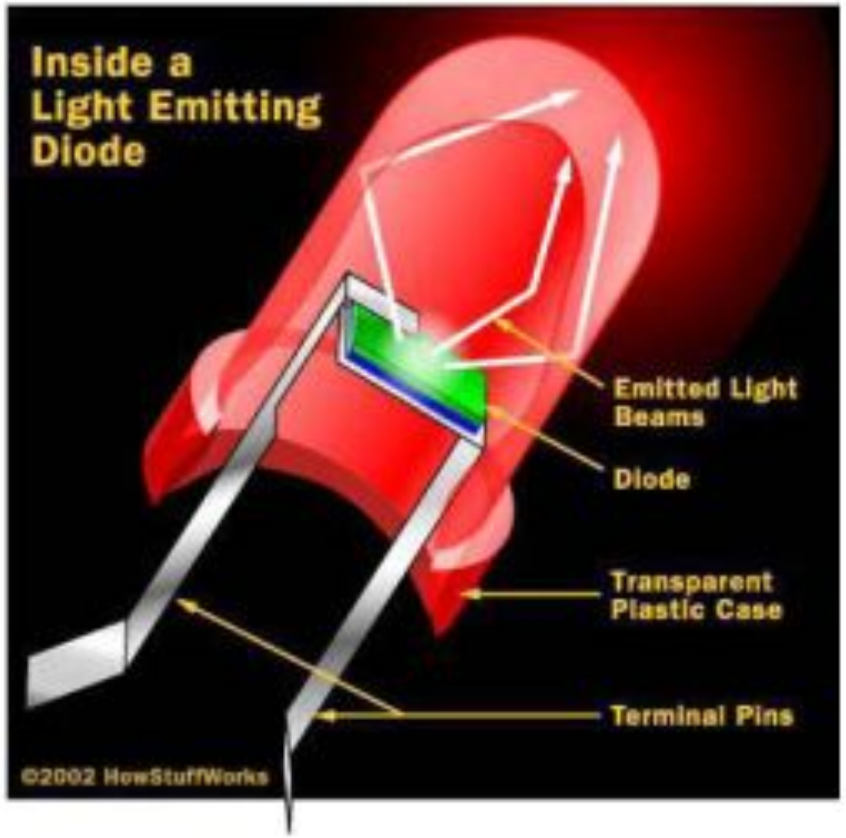
Examples:

Light Bulb

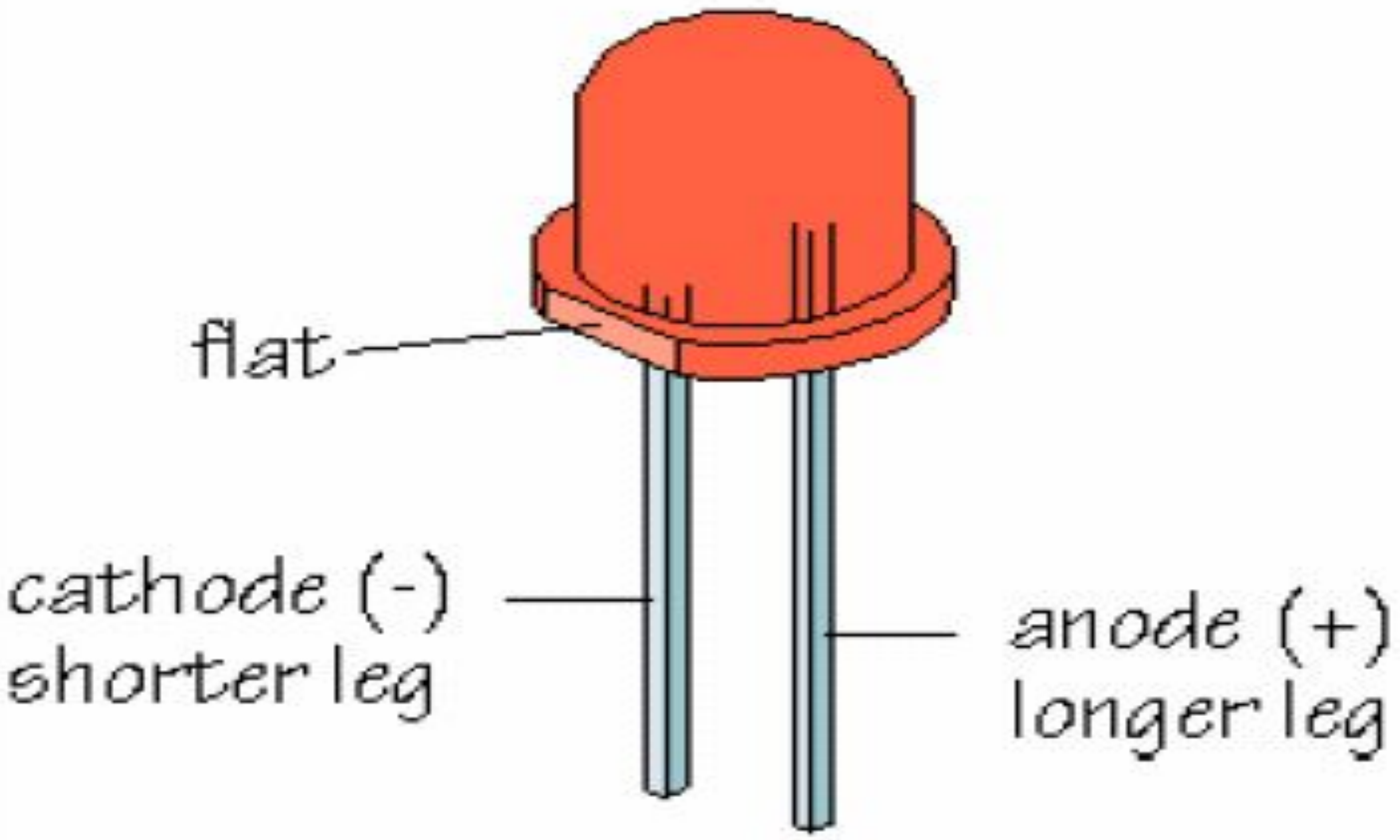
Photodiode

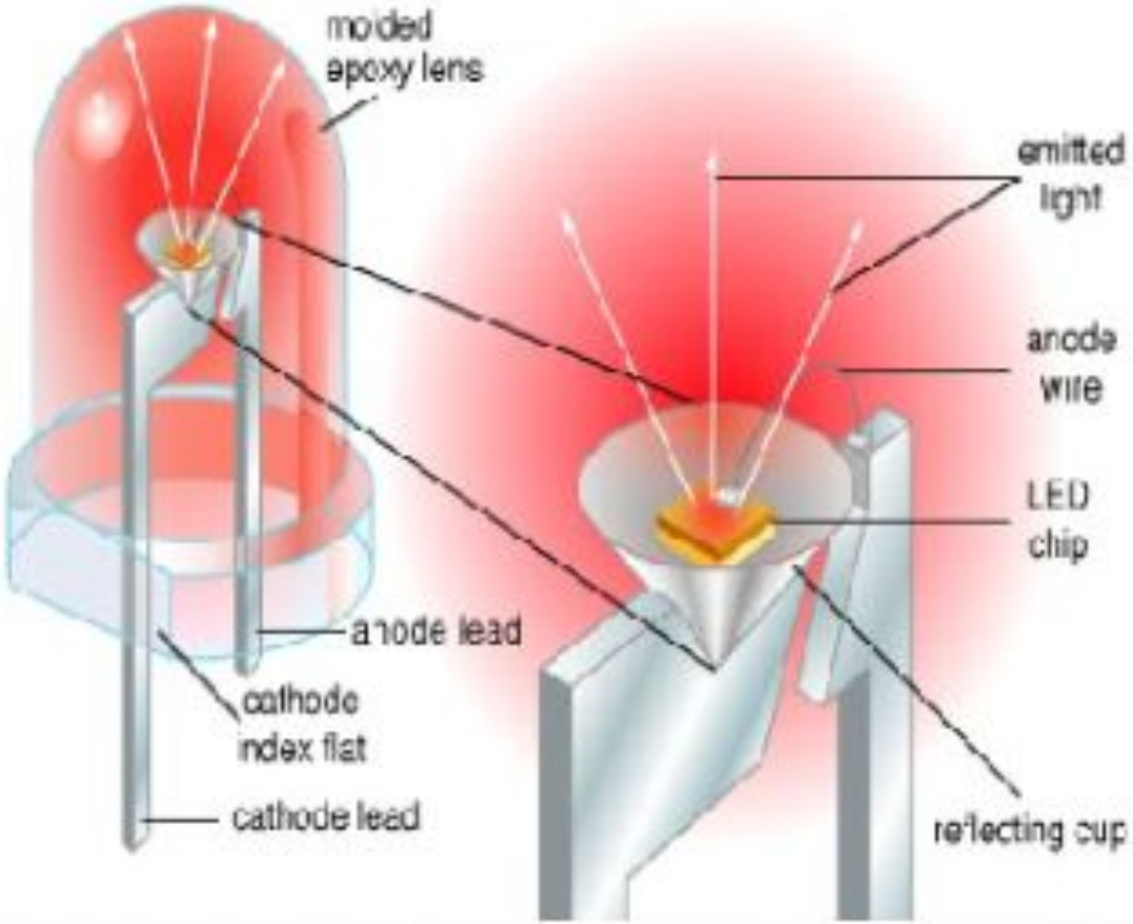


Light Emitting Diode



- This LED is a semi conductive P-N junction enclosed in a coloured case to enhance the colour of the light output. Silicon is not used as it produces mainly heat rather than light.
- The semi conductive materials used in the manufacture of LED's determines the colour of the emitted light. By using different materials, such colours as red, yellow, green, and even invisible light spectrums such as infra-red can be produced.


flat
cathode (-)
shorter leg
anode (+)
longer leg



LIGHT EMITTING DIODE

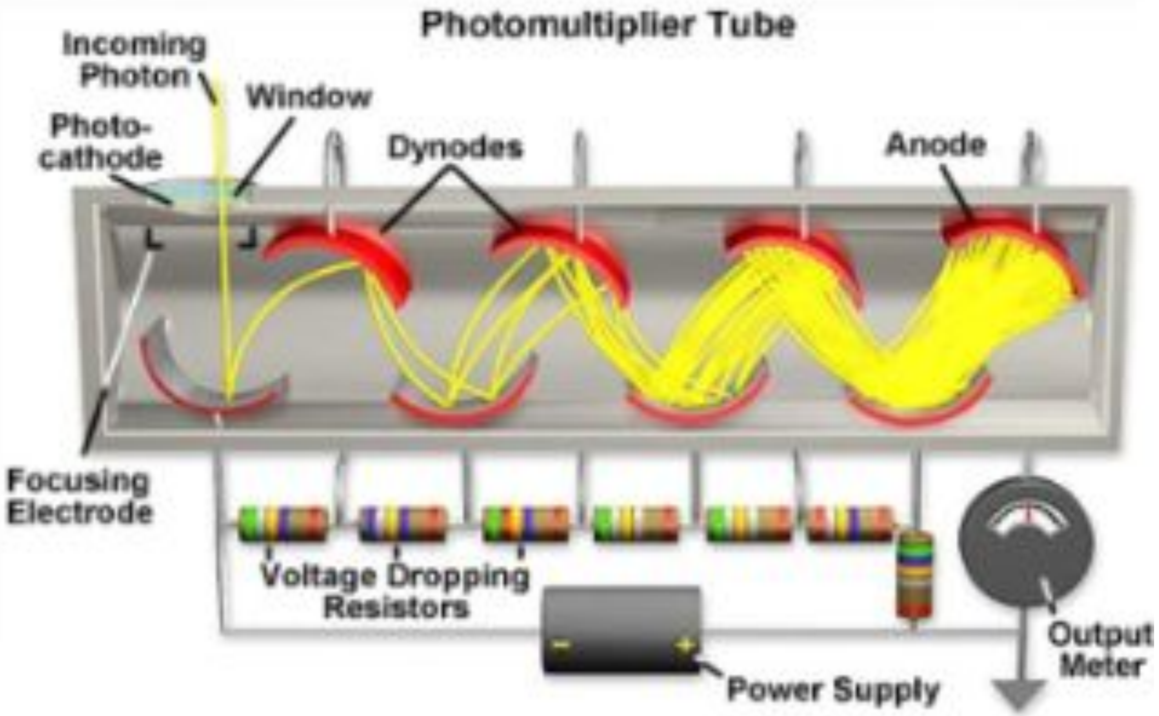


PHOTO MULTIPLIER TUBE

Photoelectric Transducers

Photoelectric transducers are devices that produce an electrical variation in response to a change in light intensity, or produce a light intensity variation due to a change in applied electrical energy. Photoelectric transducers operate in three classifications, they are:

- **Photoconductive,**
- **Photovoltaic,**
- **Photoemissive.**

Photoconductive

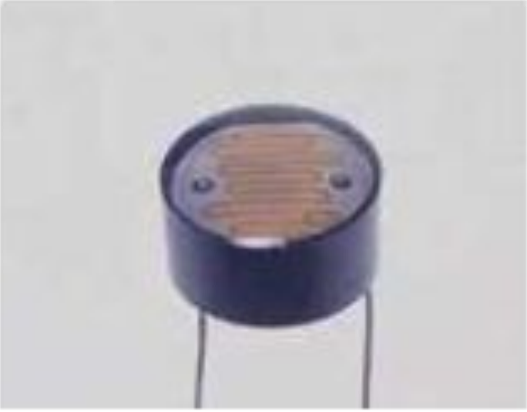
The photoconductive device is a semiconductor cell which produces a change in it’s resistance in response to a change in light intensity.

The three most common photoconductive transducers are the

- **Light Dependant Resistor (LDR),**
- **Phototransistor**
- **Photodiode.**

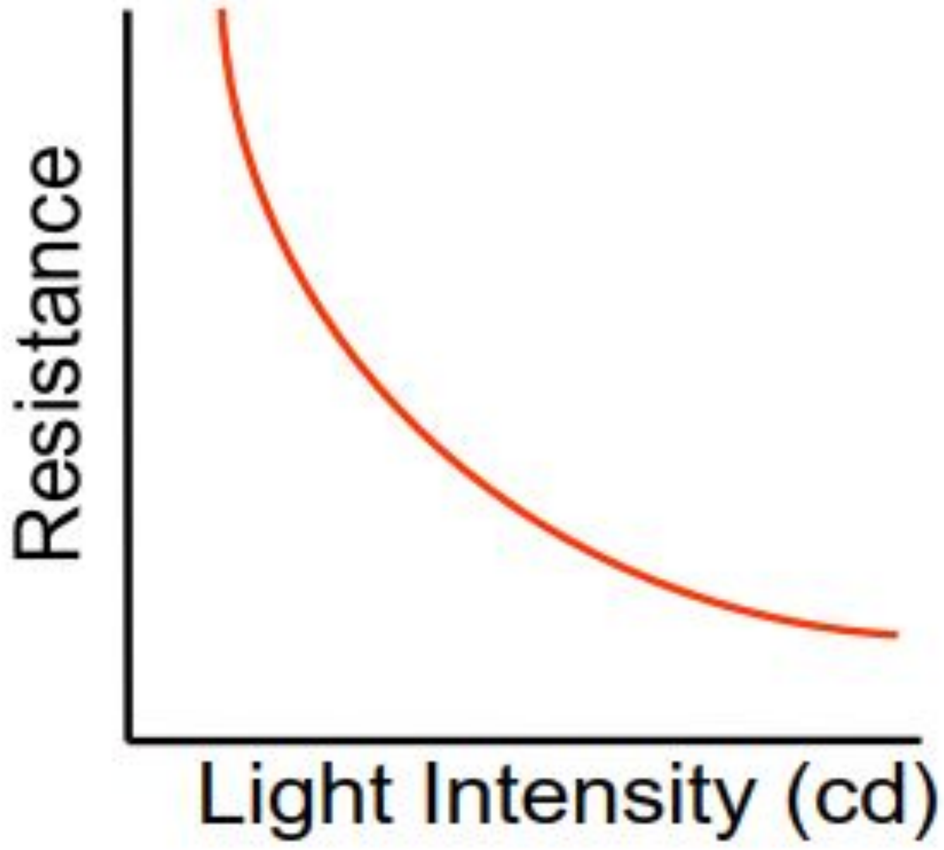
Light dependant resistors LDRS

- The LDR is a semiconductor device.
- Its resistance is dependant on the light intensity that falls on the device.



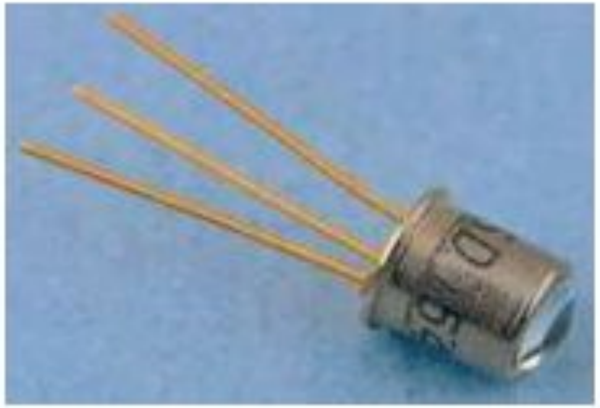
Light dependant resistors

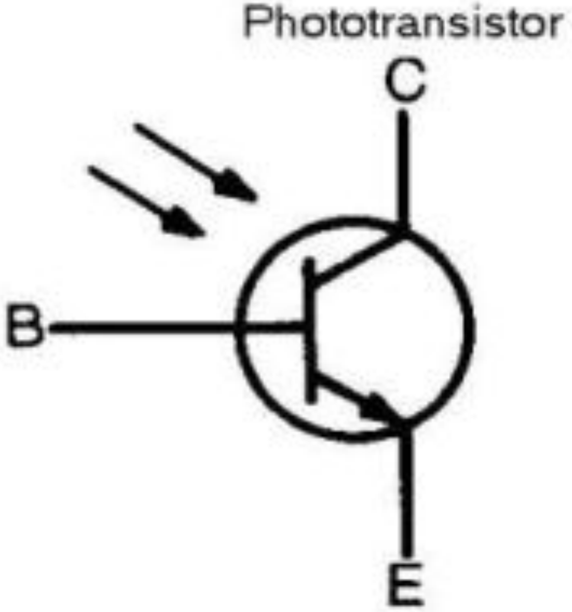
- As the light intensity increases, the resistance of the LDR decreases.
- The LDR is a non-linear device with resistance ranging from about 10 MΩ in complete darkness to 100Ω in full sunlight.



Phototransistor

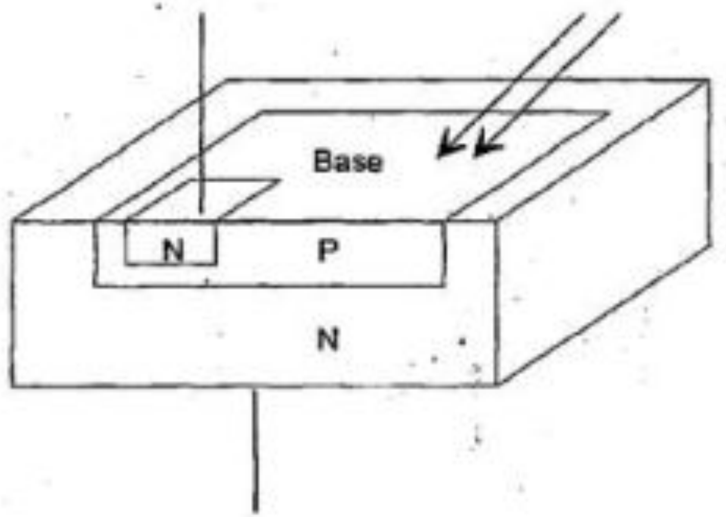
- The phototransistor is a three-layer semiconductor device with a light-sensitive collector-base p-n junction.
- The current flowing through the collector emitter circuit will be controlled by the amount of light falling on the collector-base junction.

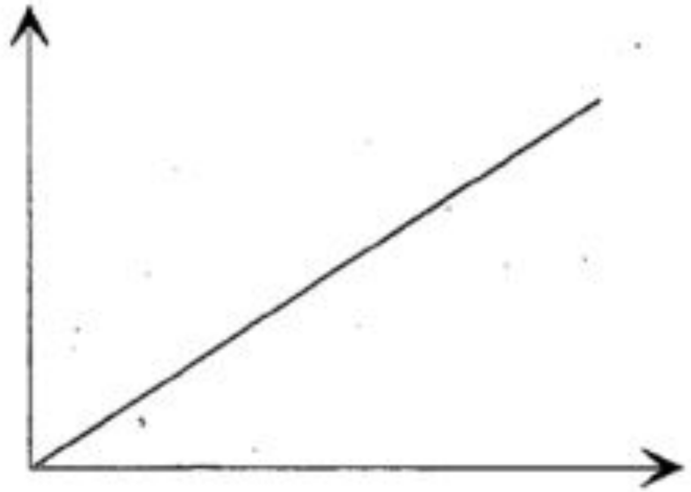




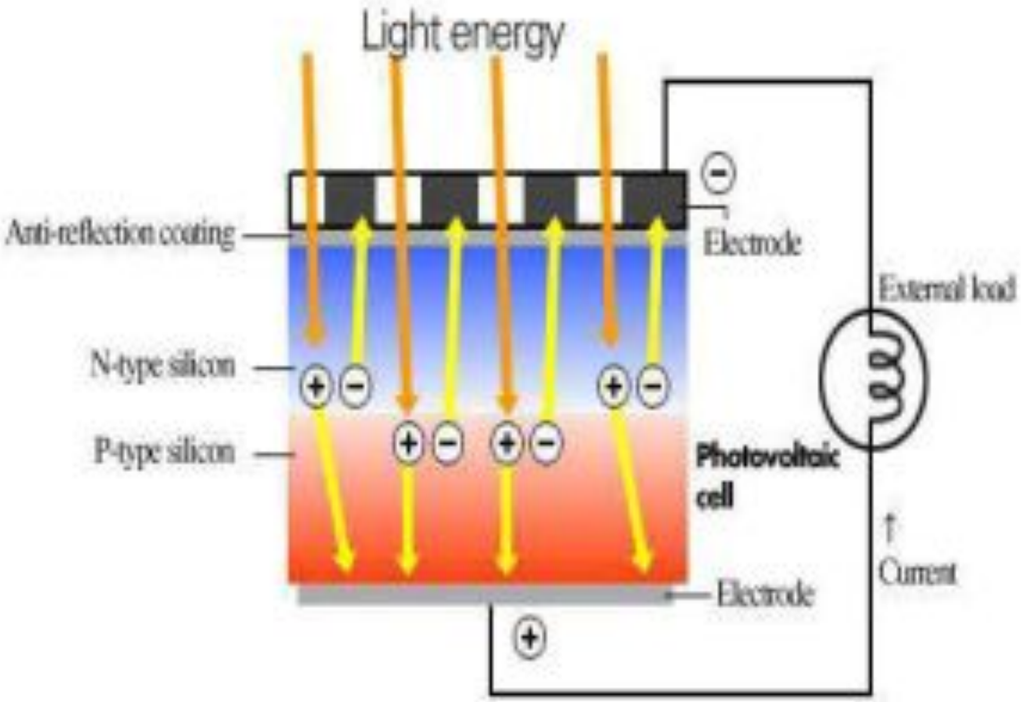
As light intensity increases, the base-collector junction resistance of the phototransistor decreases. This decrease in resistance increases the base current that in turn increases the flow of collector current.

The relationship between light intensity and current flow is generally constant and therefore will graph as a linear line. These linear transfer characteristics are shown below.





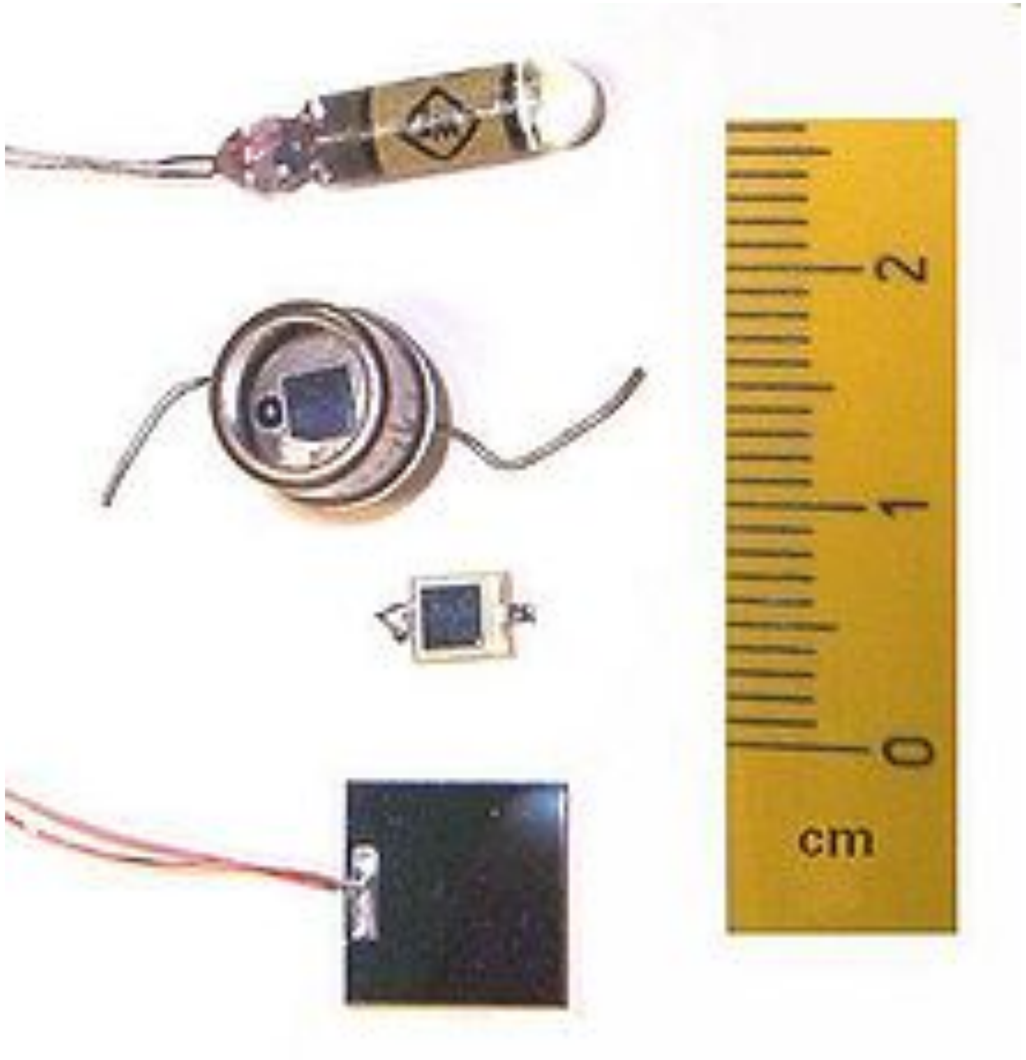
Solar cell



- As the light (protons) intensity increases, an imbalance of electrons and holes are created, which gives an increase to the open circuit potential voltage difference and therefore a current flow within a circuit. The relationship between light intensity and open circuit voltage is not constant and therefore will not graph as a linear line

Photodiode

- A **photodiode** is a semiconductor device that converts light into an electrical current. The current is generated when photons are absorbed in the photodiode.
- Photodiodes may contain optical filters, built-in lenses, and may have large or small surface areas.
- Photodiodes usually have a slower response time as their surface area increases.



Principle of operation

- A photodiode is a p–n junction or PIN structure. When a photon of sufficient energy strikes the diode, it creates an electron–hole pair. This mechanism is also known as the inner photoelectric effect.
- If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in electric field of the depletion region.
- Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced.
- The total current through the photodiode is the sum of the dark current (current that is generated in the absence of light) and the photocurrent, so the dark current must be minimized to maximize the sensitivity of the device.

- **Photovoltaic mode:**
  - When used in zero bias or ***photovoltaic mode***, photocurrent flows out of the anode through a short circuit to the cathode.
  - If the circuit is opened or has a load impedance, restricting the photocurrent out of the device, a voltage builds up in the direction that forward biases the diode, that is, anode positive with respect to cathode.
  - If the circuit is shorted or the impedance is low, a forward current will consume all or some of the photocurrent. This mode exploits the photovoltaic effect, which is the basis for solar cells – a traditional solar cell is just a large area photodiode.
  - For optimum power output, the photovoltaic cell will be operated at a voltage that causes only a small forward current compared to the photocurrent.
- **Photoconductive mode:**
  - In this mode the diode is reverse biased (with the cathode driven positive with respect to the anode). This reduces the response time because the additional reverse bias increases the width of the depletion layer, which decreases the junction's capacitance and increases the region with an electric field that will cause electrons to be quickly collected. The reverse bias also reduces the dark current without much change in the photocurrent.
  - Although this mode is faster, the photoconductive mode can exhibit more electronic noise due to dark current or avalanche effects.[4] The leakage current of a good PIN diode is so low (<1 nA) that the Johnson–Nyquist noise of the load resistance in a typical circuit often dominates.

Laser diode

- A **laser diode**, (**LD**), **injection laser diode** (**ILD**), or **diode laser** is a semiconductor device similar to a light-emitting diode in which a diode pumped directly with electrical current can create lasing conditions at the diode's junction.
- Laser diodes can directly convert electrical energy into light. Driven by voltage, the doped p-n-transition allows for recombination of an electron with a hole. Due to the drop of the electron from a higher energy level to a lower one, radiation, in the form of an emitted photon is generated.
- This is spontaneous emission. Stimulated emission can be produced when the process is continued and further generate light with the same phase, coherence and wavelength.

Principle of operation

- A laser diode is electrically a PIN diode. The active region of the laser diode is in the intrinsic (I) region, and the carriers (electrons and holes) are pumped into that region from the N and P regions respectively.
- While initial diode laser research was conducted on simple P-N diodes, all modern lasers use the double-hetero-structure implementation, where the carriers and the photons are confined in order to maximize their chances for recombination and light generation.
- Unlike a regular diode, the goal for a laser diode is to recombine all carriers in the I region, and produce light. Thus, laser diodes are fabricated using direct band-gap semiconductors.
- The laser diode epitaxial structure is grown using one of the crystal growth techniques, usually starting from an N doped substrate, and growing the I doped active layer, followed by the P doped cladding, and a contact layer.
- The active layer most often consists of quantum wells, which provide lower threshold current and higher efficiency.

Electroacoustic Transducers

- Geophone - convert a ground movement (displacement) into voltage .
- Hydrophone - converts changes in water pressure into an electrical form.
- Loudspeaker, earphone - converts changes in electrical signals into acoustic form.
- Microphone - converts changes in air pressure into an electrical signal.

Types of Energy Transformations

- Electroacoustic - vibration ⟷ voltage

Examples:

Loudspeaker

Microphone

GEOPHONES

LOUDSPEAKERS

EARPHONES

Electromagnetic Transducers

- Antenna - converts electromagnetic waves into electric current and vice versa.
- Cathode ray tube (CRT) - converts electrical signals into visual form
- Fluorescent lamp, light bulb - converts electrical power into visible light
- Tape head - converts changing magnetic fields into electrical form

Types of Energy Transformations

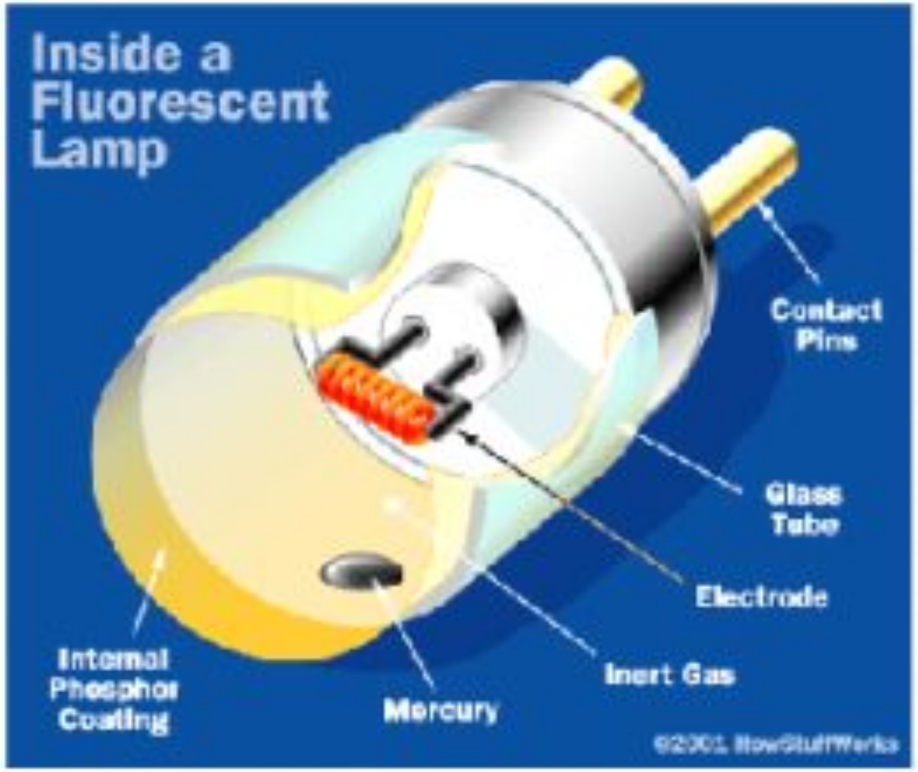
- Electromagnetic - EM fields $\Longleftrightarrow$ current

Examples:

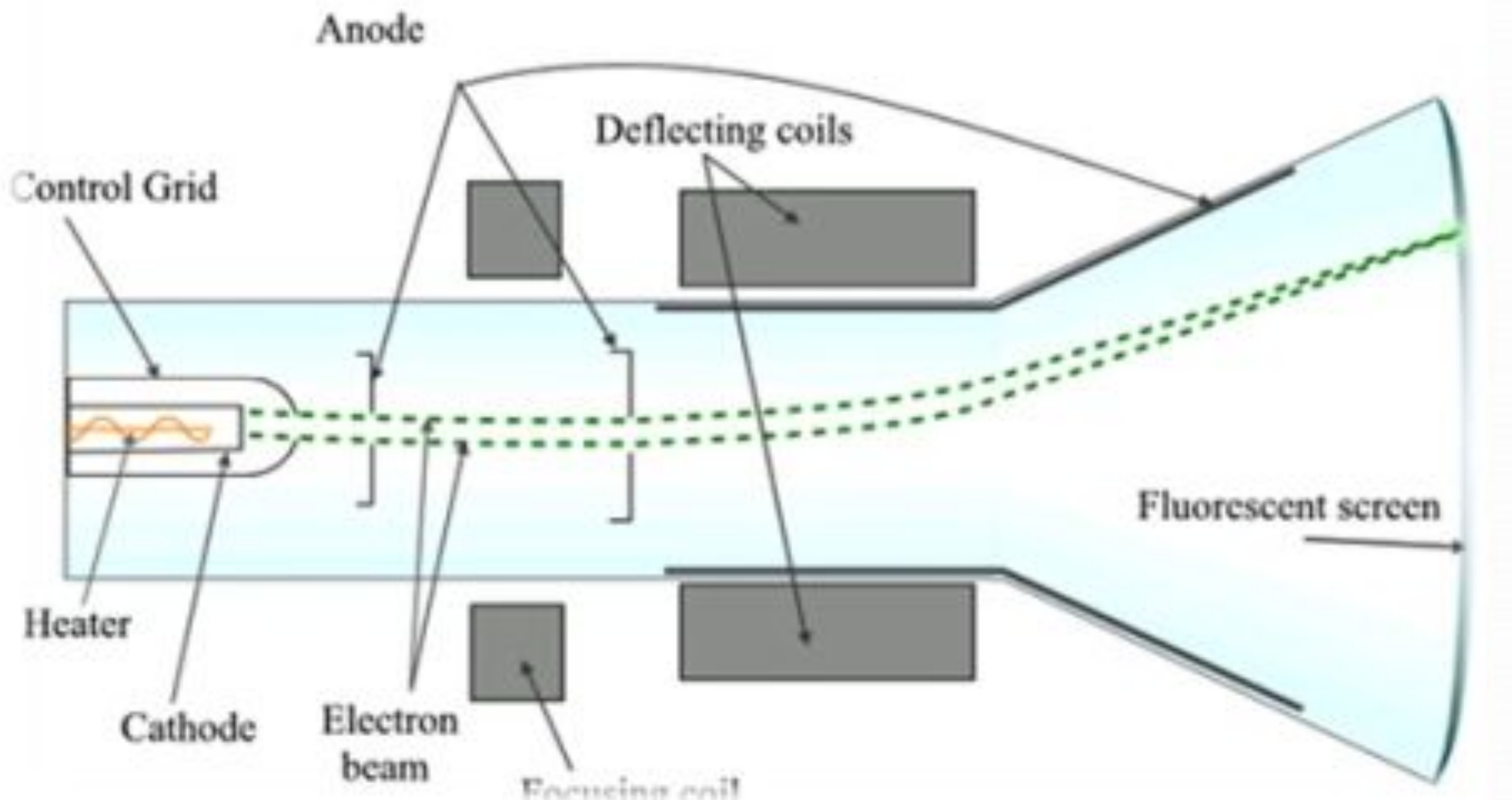
Receiving Antennas

Transmitting Antennas

ANTENNA



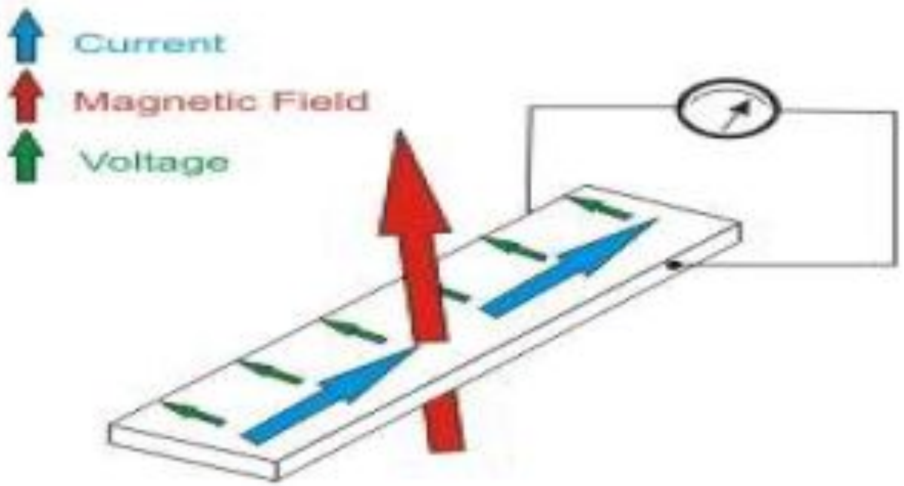
Fluorescent lamp



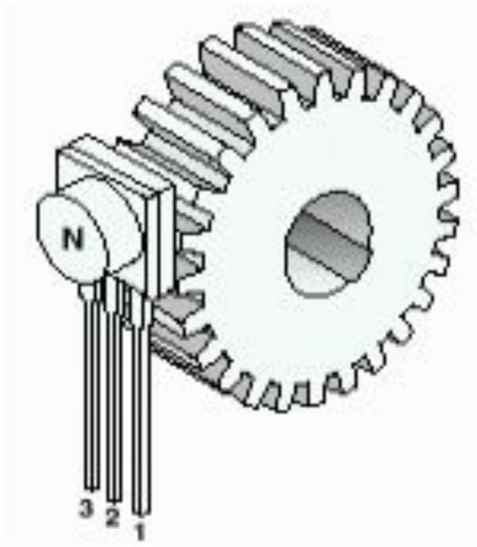
CATHODE RAY TUBE

Hall Effect Transducers

The Hall Effect describes a condition if current flow in a conductor being affected by the presence of a magnetic field If an electric current flows through a conductor in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor. This is most evident in a thin flat conductor. A build up of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall effect after E. H. Hall who discovered it in 1879.



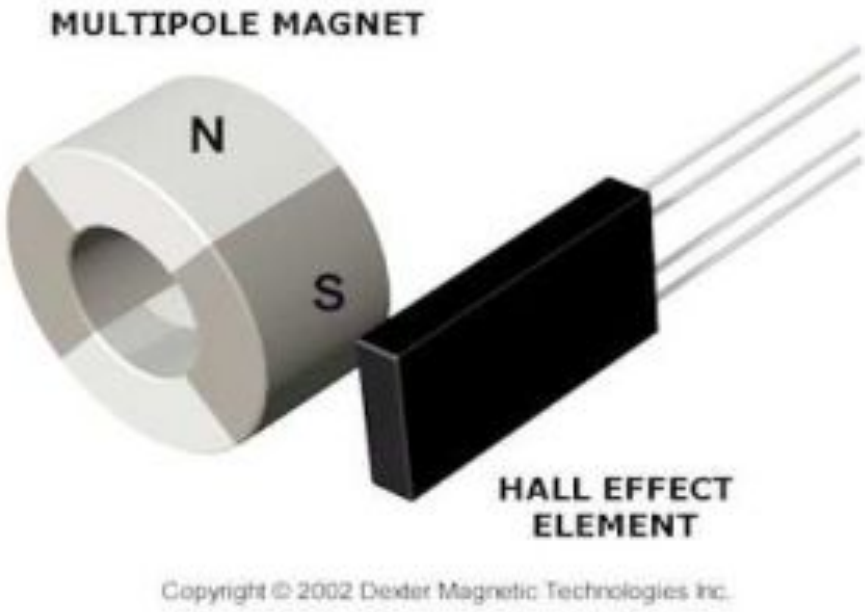
Hall effect
Magnetic reed

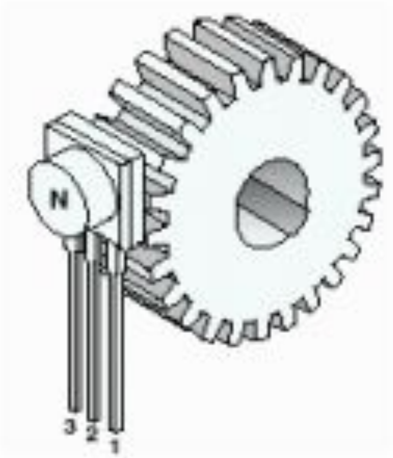


Hall effect devices

Hall effect devices can be used to:

- Measure the velocity of charged particles in a magnetic field (flow meter)
- Measure the proximity of magnetic materials (Linear displacement)
- Detect pulses of magnetism e.g. as in a tachometer





Electrochemical Transducers

- pH probes-an electronic instrument used to measure the pH (acidity or basicity) of a liquid.
- An electro galvanic fuel cell- an electrical device used to measure the concentration of oxygen gas in medical equipment.

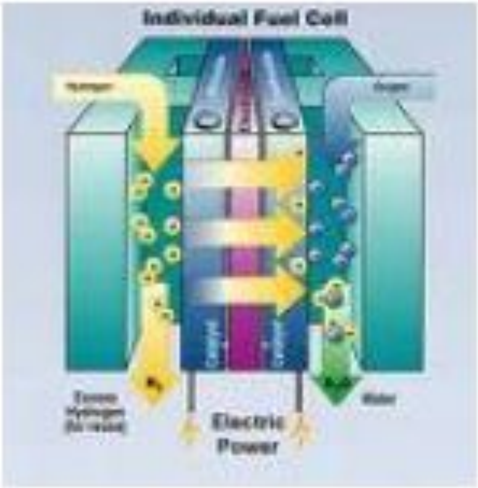
Types of Energy Transformations

- Electrochemical - substance → voltage

Examples:

pH Probe

Fuel Cell



pH probes

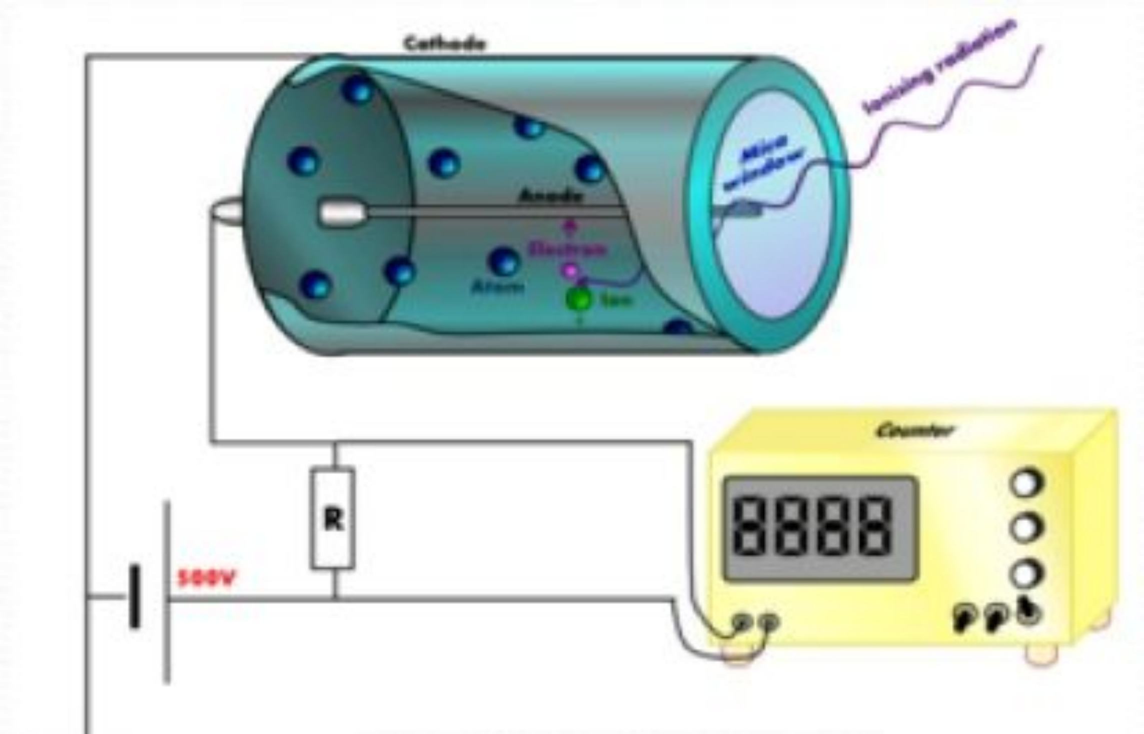
Electro galvanic fuel cells

Electrostatic Transducers

- Electrometer-an electrical instrument for measuring electric charge or electrical potential difference.

Radioacoustic Transducers

- Geiger-Muller tube used for measuring radioactivity.
- Radio Receiver.



GM COUNTER

THANK YOU