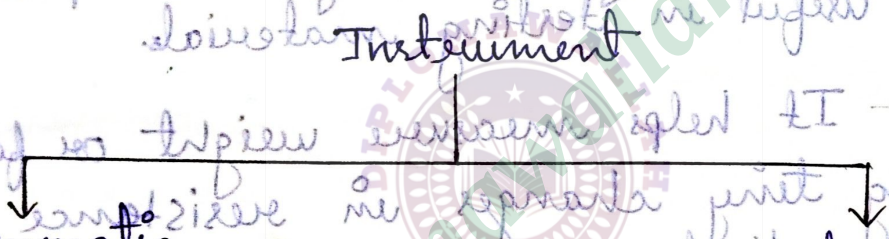
Unit :- 04

Transducers...

1. Basic of Transducer :-

Instrument :- It is a device used for measuring any physical quantity.



Ex :- Air, gas 7-15 Psi

Ex :- Current 4-20 mA

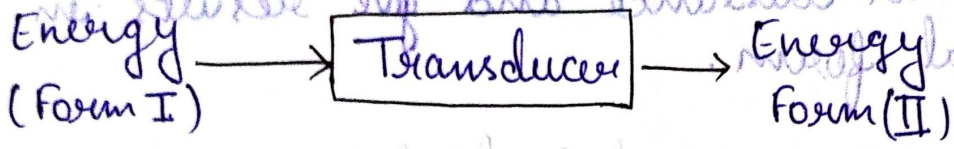
Sensor :- It is the instrument which senses the change and makes it readable.
[output is not generated to be electrical]

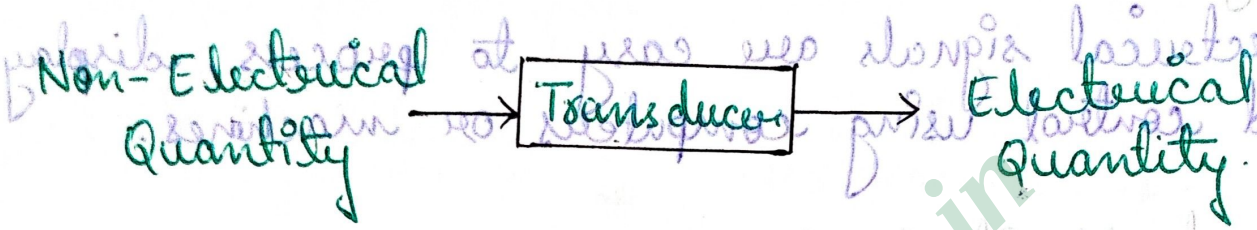
Physical quantity → [sensor] → Electrical / Non-electrical

Ex :- °C → [Thermometer] → x (displacement)

Transducers :-

It is a device which converts non electrical quantity into electrical quantity.





Ex:- 

Displacement
(Non-electrical)

Output Voltage
(Electrical quantity)

» Advantages of Electrical Signal :-

- Easily Recorded
- Transfered.
- Amplified
- Filtered
- Can be converted
- Attenuated.

→ Tranducer consist of two parts :-

i) Sensing element / sensor.

ii) Transduction element.

* All the transducer is the sensor but all the sensor is not transducer.

» NECESSITY of electrical Transducer

1.) To measure Things Accurately :-

They help measure things like temperature, pressure or distance and give results in electrical form.

2.) Easy to process and Control :-

Electrical signals are easy to process, display and control using computers or machines.

3.) Remote Monitoring :-

They allow us to measure and monitor things from far away.

4.) Automation :-

They are crucial for automatic machines and robots to function.

» Selection of electrical Transducer :-

→ To select an electrical Transducer :-

1.) What to Measure? :- Pick one based on the quantity (e.g. temperature, pressure or distance).

2.) Range :- Ensure it covers your measurement range.

3) Accuracy :- Choose higher accuracy for critical task.

4) Environment :- Pick durable options for heat, moisture or dust.

5) Speed :- Go for fast response if needed.

6) Output Type :- Use analog for continous signals, digital for computer use.

7) Budget :- Balance cost and quality.

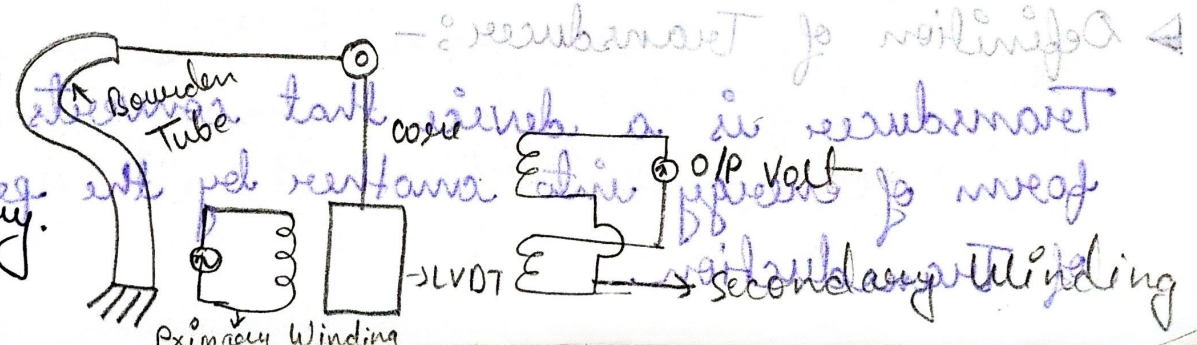
Classification of Transducer :-

- Primary and secondary Transducer.
- Active and Passive Transducer.
- Analog and Digital Transducer.
  - ↳ Stepper motor.
- Electrical and Mechanical Transducer.

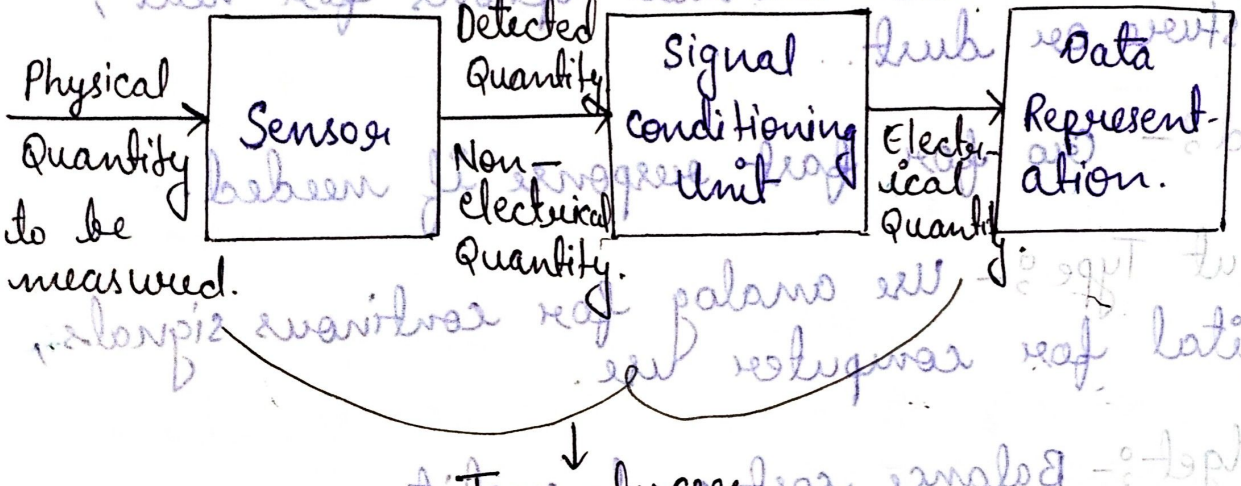
» Based on Principle of Operation :-

→ Resistive — ex strain gauge
→ Inductive — LVDT
→ Capacitive

→ Primary and Secondary.



» Introduction of different types of Tran



→ Signal Conditioning Unit are :-

- ADC → Analoge to Digital Converter.
- Amplifiers
- Eilters
- Rectifiers
- Modulator.

» Data Representation Device :-

- A Scale
- An LCD Display
- A signal recorder.

▶ Definition of Transducer :-

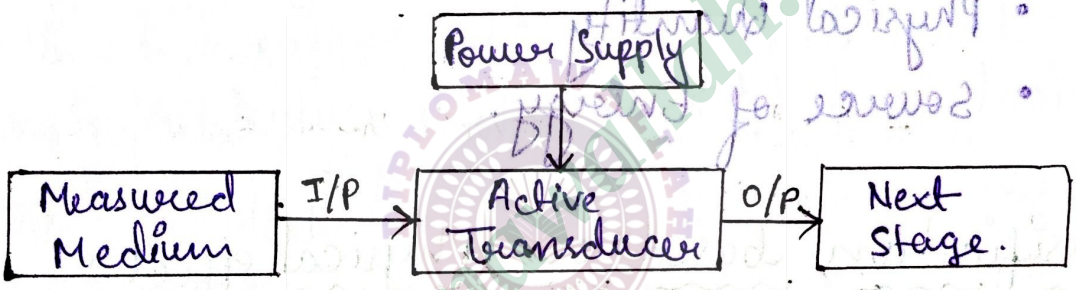
Transducer is a device that converts one form of energy into another by the principle of Transduction.

» Classified based on the source of energy:

- Active Transducer
- Passive Transducer.

① Active Transducer :-

In active transducer the energy from the input is used as a control signal in the process of transferring energy from power supply to proportional output.

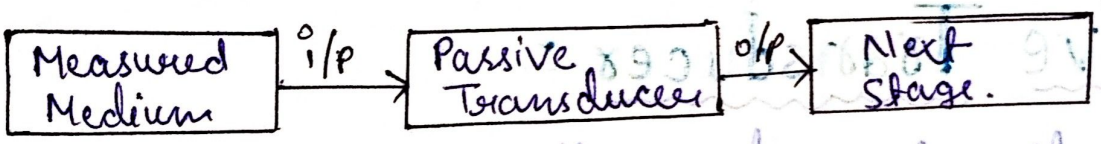


Ex:- A strain gauge is an active Tranducer in which the strain Transducer is converted into resistance. But since the energy form the strained element is very small, the energy for the output is provided by an external power supply.

② Passive Transducer :-

In passive Transducers the energy from the input is directly converted into the output.

Ex:- Thermocouple is a passive transducer where the heat energy, which is absorbed from input is converted into electrical signals (voltages).



▶ Classification of transducers based on the following three ways:-

- Physical effect
- Physical Quantity
- Source of Energy.

→ Classification based on Physical effect:-

Current Physical quantity to electrical quantity.

ex:- Change in resistance (Physical quantity of a copper element in proportion to the change in temperature.

- Variation in resistance
- Variation in inductance
- Variation in capacitance
- Hall effect
- Piezoelectric effect

→ classification based on Physical Quantity

- Pressure transducer is that converts pressure into electrical signal.
  ex:- Temperature transducer
  → Thermocouple
- Pressure transducer
  →Bourdon Gauge.
- Displacement Transducer
  → LVDT
- Level Transducer
  →Torque Tube.
- Flow Transducer
  →Flow Meter.
- Force Transducer
  → Dynamometer
- Acceleration Transducer
  →Accelerometer

» Analog or Digital Transducer:—

① Analog Transducer:—

These transducer provide continous output signals that vary proportionally with the measured physical quantity.

Ex:- • Thermistor (Temperature to resistance).
• Strain guage (strain to resistance).

② Digital Transducer :-

These transducer provides a discrete, typically binary output (e.g 0 or 1) that corresponding to the physical quantity being measured.

Ex:- • Rotatary encoder (rotation to digital).
• Digital temperature sensor (eg. DS18B20).

» Primary and Secondary Transducers :-

① Primary Transducer :-

These transducer directly respond to the physical quantity being measured and convert it into a corresponding electrical signal.

Ex:- • Thermocouple (temperature to voltage).
• Photocell (light to electrical signal).

② Secondary Transducer :-

These transducer convert the electrical signal produced by a primary transducer into a more usable or processable form often enhancing the signal or provide an output in the desired format.

Ex:- • Amplifier (boosting the output signal).
• Signal Conditioners
• Analog to Digital converters (ADC).

2) Strain Gauge :—

→ A strain gauge operator based on the principle a material electrical resistance change when it is stretched (Tensile strain) or compressed (compressive strain.)

Key Principle :—

when a strain is applied to the material to when the strain guage is attached.

(i) Change in length :— The material elongates or contracts causing the strain guage to change in length.

(ii) Change in cross section area :— The cross sectional area of the strain guage ~~to change in~~ may also change.

(iii) Change on Resistance :— The resistance of the strain gauge wire changes due to these dimensional change, following the formula.

$$R = \rho (L/A).$$

where,

R is the resistance

ρ is the resistivity of the material.

L is the length.

A is the cross sectional area.

Resistance increase (when the gauge and stretched (length ↑, & cross sectional).

- Resistance increase (when the gauge and is compress length, cross-sectional, area).

* Gauge Factor :-

The sensitivity of the strain gauge is expressed as the guage factor (GF).

Given by

$$GF = \frac{\Delta R/R}{\varepsilon}$$

when, ΔR = Change in resistance.

R = Original resistance.

ε = Strain applied.

The change in resistance is deteted and converted into a measurable electrical signal allowing precise measurement of strain in materials.

» Features of bonded foil type Strain gauge :-

- A bonded foil strain gauge is a widely used type of strain gauge due to its reliability and accuracy.

* Construction :- Made from a thin foil pattern on a flexible backing material, such as

Polyester or polyimide.

- High Sensitivity :- Capable of detecting minute change in strain with high precision.
- Temperature Stability :- Designed to minimize thermal effects ensuring consistent performance over a wide temperature range.
- Compact Size :- A small and light weight making it suitable for compare confined application.
- linear resonse :- Provide a linear output proportional to the strain applied.

» Unbonded Foil type strain gauage :-

An unbonded foil type strain gauage is a type of strain sensor where the sensing element (usually a thin metal foil) is not directly attached (bonded) to the surface of the structure being measured.

Construction :-

- Sensing Foil :- A thin metallic foil serves as the sensing element.
- Frame or Supports :- Right mechanical support hold the foil element. These frames are mainted on the structure being tested.
- Mounting Mechanism :- Mechanical fixtures are used to attack the strain gauge to the structure without bonding it directly.

Working Principle :-

- The strain on the structure causes a relative movement between the supports holding the sensing foil.
- The movement stretched or compress the foil causing a change in electrical signal.
- The output signal is proportional to the strain applied the structure.

* Advantage :-

- Non-Bonded design :- Ideal for temporary and non-invasive measurement.
- Revsability :- can be reversed in different applications unlike bonded gauge.
- Durability :- Less affected by environment factor like surface irregularities or adhesive.

* Disadvantage :-

- Complex Installation :- Require precise mechanical setup for accurate reading.
- External Noise Sensitivity :- Susceptible to vibration alignment issues.
- Lower accuracy :- Reduced accuracy compared to bonded strain gauge.

» Load Cell :-

A load cell is a type of sensor or transducer that convert force such a weight or load, into an electrical signal. This signal can then be measured and processed to determine the amount of force being applied, load cell are commonly used in weighting scales, industrial equipment and testing machines.

* Basic Principle :-

Most load cell work on the principle of the strain gauge, which measure the deformation (strain) of an object when a force is applied.

When a load is applied to the load cell, it causes a slight change in the shape of the load cell.

- The deformation changed the electrical resistance of the strain gauge.
- The resistance change is proportional to the applied force and is converted into an electrical signal.

Types of load Cell :-

- Compression load Cell :- Measure force applied in compression.
- Tension load Cell :- Measured force applied on tension.

- Beam load cell :- Measure force applied as bending on a beam.
- Hydraulic and Pneumatic cell :- Cell build pressure to measure force.

Application :-

- Weighting System (e.g :- in digital scale truck weigh bridges).
- Industrial automation and machinery.
- Material testing to measures tensile and compression strength.
- Robotics for force feedback system.

* Advantage :-

High accuracy and precision compact and durable design can measure both small and large load effectively.

Capacitive Transducer :-

A Capacitive transducer is a device that uses change in capacitance to measure physical quantities like displacement, Pressure, humidity or level. It based on the principle of capacitor changes. It is widely used to measure physical quantity like displacement pressure

and humidity by converting them into an electrical signal.

Principle of a Capacitive Transducer :-

The operation is based on the formula for capacitance in a parallel-plate capacitor.

$$C = \frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{d}$$

where,

C = Capacitor

ε_0 = Permittivity of free space.

ε_r = Relative permittivity of the electric material.

A = area of the plates.

d = Distance between the plates.

Working Principle :-

A capacitive transducer measure the change in capacitor caused by

i) Variation in plate area (A) for example in angular displacement measurement.

ii) Variation in distance (d) - used in linear displacement measurement.

iii) Variation in dielectric constant (ε_r) :- Applied in humidity or liquid level sensor.

Features of Capacitive Transducer :-

* High Sensitivity :- capable of detecting small change in the measured parameter.
* Wide frequency range :- Operates effectively across a broad frequency spectrum.
* low power consumption.
* Good linearity.
* Non-Contact Measurement.
* Miniturization :- Suitable for compact and small scale application.
* Environmental Dependency :- Sensitivity to environmental factor such as temperature and humidity.
* High Resolution :- Offers precise and accurate measure of for small scale changes.