Sensors and Transducers

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Sensors for displacement, proximity, motion, sound, light, temperature, fluid Level and flow, force, etc.

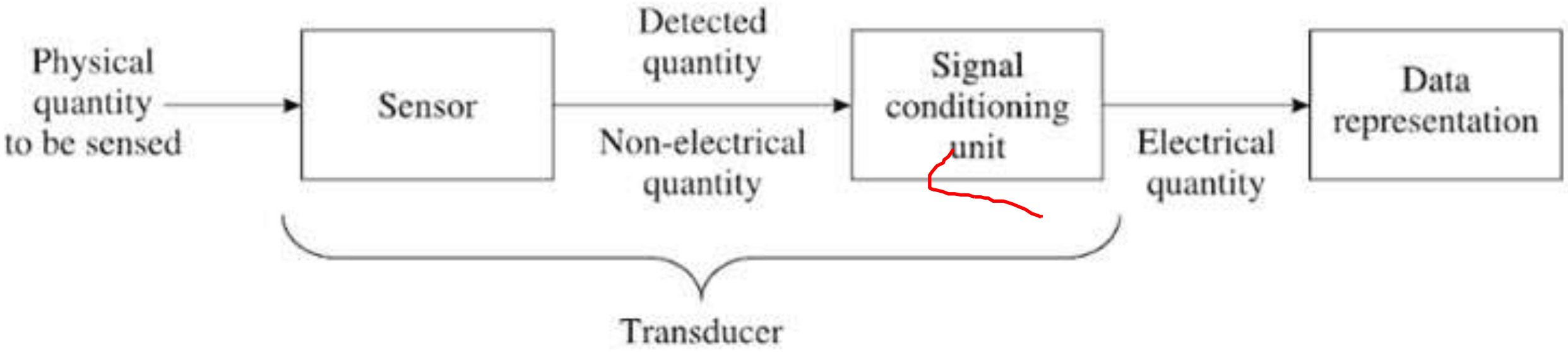
Transducer

- A **transducer** is a device that converts energy from one form to another.
- Transducers are often employed in automation, measurement, and control systems.
- It converts electrical signals to and from other physical quantities (energy, force, torque, light, motion, position, etc.).
- The process of converting one form of energy to another is known as transduction.
- **Types:** 1. Mechanical transducers
  2. Electrical transducers

Block Diagram

In this block diagram of a simple measuring system, there are three basic elements:

- Sensor
- Signal Conditioning Unit
- Data Representing Device



Classification of Transducers

- There are several ways in which we can classify transducers.
- It is easy to classify transducers as **Input Transducers** or **Output Transducers.**
- Input Transducers measure non-electrical quantities and convert them into electrical quantities.
- Output Transducers, work in the opposite way, their input signals are electrical and their output signals are non-electrical or physical.
- Depending on the principle of operation, transducers can also be classified into **mechanical, thermal, electrical**, etc.
- The classification of transducers based on the following three ways:

  Physical Effect, Physical Quantity and Source of Energy

1. Classification based on Physical Effect

- The first classification of Transducers is based on the physical effect engaged to convert the physical quantity to electrical quantity.
- The following physical effects are generally used:
    - Variation in Resistance
    - Variation in Inductance
    - Variation in Capacitance
    - Hall Effect
    - Piezoelectric Effect

Hall effect:
the production of a potential difference across an electrical conductor when a magnetic field is applied in a direction perpendicular to that of the flow of current.

2. Classification based on Physical Quantity

Classification of transducers based on physical quantity and corresponding examples:

- Temperature Transducer – Thermocouple
- Pressure Transducer – Bourdon Gauge
- Displacement Transducer – LVDT (Linear Variable Differential Transformer)
- Level Transducer – Torque Tube
- Flow Transducer – Flow Meter
- Force Transducer – Dynamometer
- Acceleration Transducer – accelerometer

For example, a Pressure Transducer is a transducer that converts pressure into electrical signal.

3. Classification based on Source of Energy

- Under this category, there usually two types of transducers:

  Active Transducers

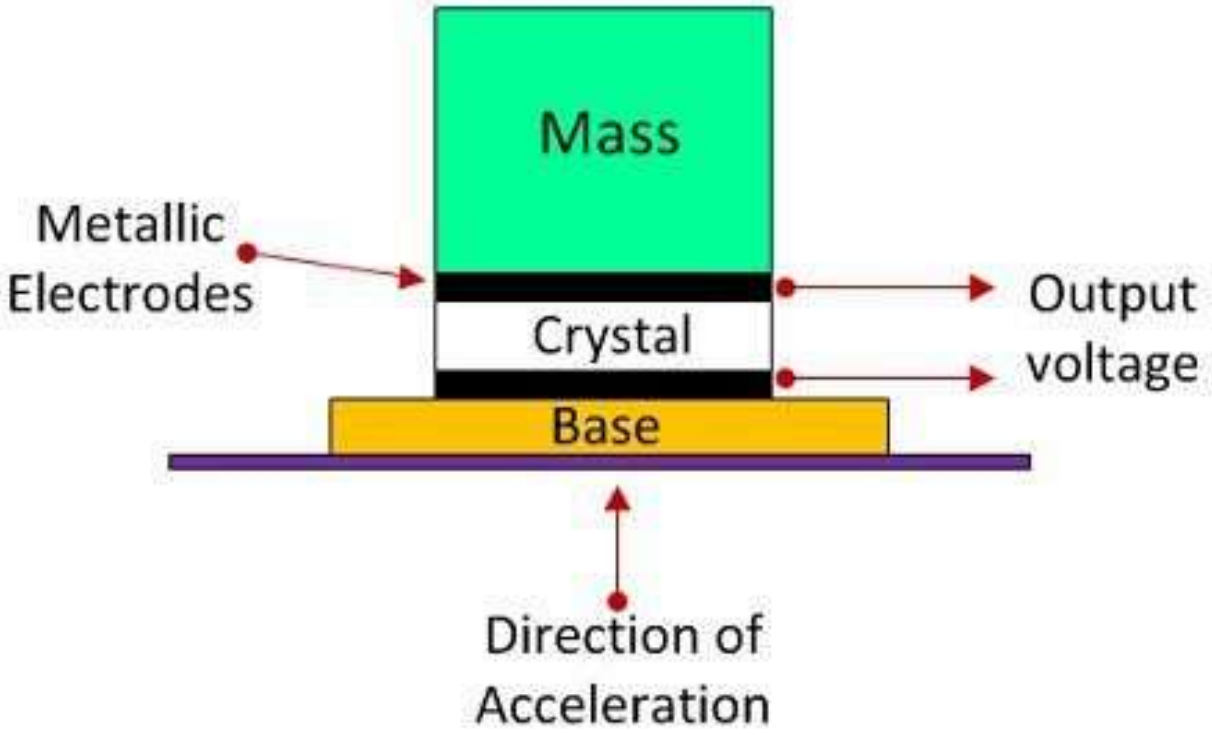
  Passive Transducers

Active Transducers

- The transducer whose output is obtained in the form of voltage or current without any additional auxiliary source is known as the active transducer.
- It works on the principle of conversion of energy from one form to another.
- The active transducer is also known as the self-generating transducer because they self-develop their electrical output signal.
- The energy requires for generating the output signals are obtained from the physical quantity which is to be measured.

Example:

- The Piezo electrical crystal is the example of the natural active transducer.
- The crystal has the property of producing the output voltage when the external force applied to them.
- The piezoelectric crystal is placed between the two metallic electrodes.
- When the force applied to the crystal, the voltage induces across it.



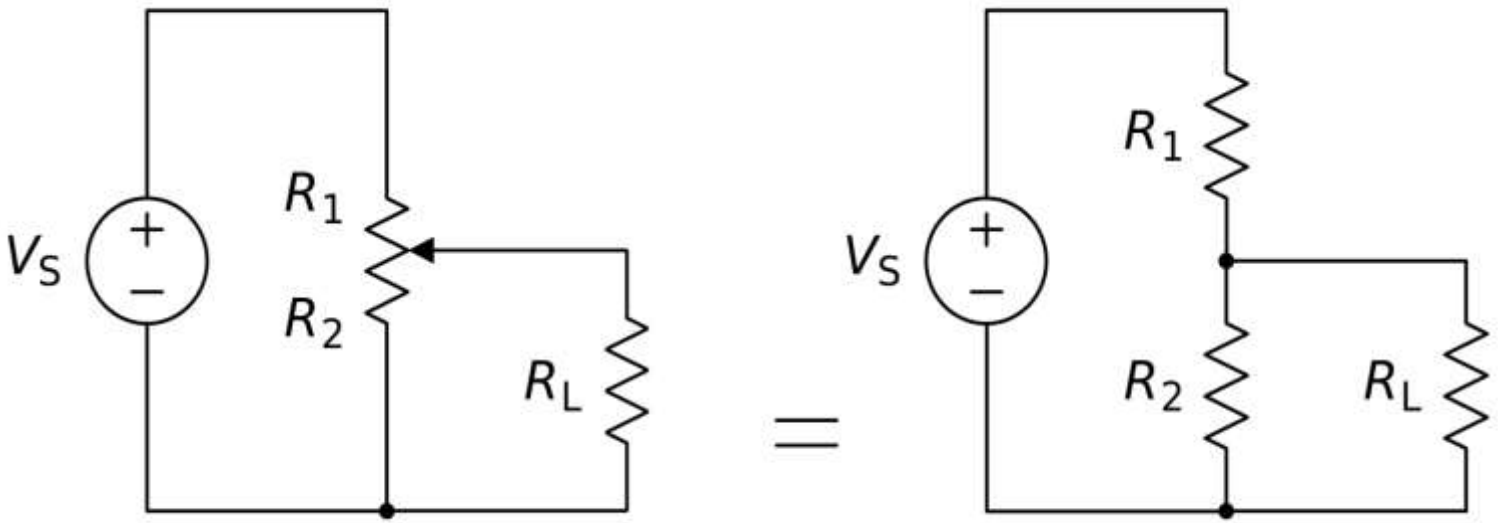
Passive Transducers

- In passive transducer, the output is obtained by changing the physical properties (resistance, inductance, and capacitance) of the material.
- In other words, the passive transducer takes power from the external energy source for transduction.

Example: Potentiometer.

- A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.
- Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment.

Potentiometer



A potentiometer with a resistive load, showing equivalent fixed resistors for clarity.

- The potentiometer can be used as a voltage divider to obtain a manually adjustable output voltage at the slider (wiper) from a fixed input voltage applied across the two ends of the potentiometer.
- The voltage across RL can be calculated by:

$$V_{\mathrm{L}} = \frac{R_2 R_{\mathrm{L}}}{R_1 R_{\mathrm{L}} + R_2 R_{\mathrm{L}} + R_1 R_2} \cdot V_s.$$

If R_L is large compared to the other resistances, the output voltage can be approximated by the simpler equation:

$$V_{\mathrm{L}} = \frac{R_2}{R_1 + R_2} \cdot V_s.$$

(dividing throughout by RL and cancelling terms with RL as denominator)

As an example, assume

$$V_{\mathrm{S}} = 10\ \mathrm{V} \quad R_1 = 1\ \mathrm{k\Omega} \quad R_2 = 2\ \mathrm{k\Omega} \quad R_{\mathrm{L}} = 100\ \mathrm{k\Omega}.$$

Since the load resistance is large compared to the other resistances, the output voltage V_L will be approximately:

$$\frac{2\ \mathrm{k\Omega}}{1\ \mathrm{k\Omega} + 2\ \mathrm{k\Omega}} \cdot 10\ \mathrm{V} = \frac{2}{3} \cdot 10\ \mathrm{V} \approx 6.667\ \mathrm{V}.$$

Because of the load resistance, however, it will actually be slightly lower: ≈ 6.623 V.

Key Differences between Active and Passive Transducer

1. The transducer which gives the electrical output (in the form of voltage and current) without any external energy source is known as the active transducer. The transducer whose physical properties varies because of the input or measurand signal is known as the passive transducer.
2. The active transducer does not require any additional source while the passive transducer requires the additional energy source.
3. Active transducer draws energy from the measurand source and gives the electrical output while in passive transducer the transduction can be done by changing the physical property of the material.

Key Differences between Active and Passive Transducer

4. The design of active transducer is simple as compared to the passive transducer.
5. The resolution of an active transducer is low while that of the passive transducer is high.
6. The active transducer produces the output signal of very low amplitude. Thus, their output signal needs to be amplified. Whereas, the amplification is not required in the output signal of the passive transducer.

Mechanical Transducer

- Mechanical transducers are a set of primary sensing elements that respond to changes in a physical quantity with a mechanical output.
- Examples:

Quantity to be Measured	Mechanical Transducer	Type of Output Signal (Mechanical)
Pressure	Ring Balance Manometer	Displacement
Force	Spring Balance	Displacement and Strain
	Hydraulic Load Cell	Pressure
Flow Rate	Flow Obstruction Element	Strain and Pressure
	Pitot Tube	Pressure
Temperature	Bimetallic Strip	Displacement and Force
	Fluid Expansion	Displacement and Force

Electrical Transducer

Electrical transducers are those that respond to changes in physical quantities with electrical outputs. These are divided into Passive and Active Electrical Transducers.

Passive Electrical Transducers:

- Resistive Transducers
- Capacitive Transducers
- Inductive Transducer

Active Electrical Transducers:

- Photoelectric Transducers
- Piezoelectric Transducers
- Magnetostrictive Transducers
- Electromechanical Transducers
- Ionization Transducers
- Electrochemical Transducers
- Hall-Effect Transducers
- Thermoelectric Transducers

Applications

Electromagnetic

- **Antennae** – converts propagating electromagnetic waves to and from conducted electrical signals.
- **Magnetic cartridges** – converts physical motion to and from electrical signals

Electromechanical

- **Accelerometers, Air flow sensors, Rotary and linear motors, Galvanometers** etc.

Electroacoustic

- **Loudspeakers, earphones**– converts electrical signals into sound
- **Microphones** – converts sound into an electrical signal
- **Tactile transducers** – converts electrical signal into vibration

Applications

Electro-optical: also known as photoelectric

- **Fluorescent lamps, LEDs** – converts electrical power into incoherent light
- **Laser diodes** – converts electrical power into coherent light
- **Photodiodes, photoresistors, phototransistors, photomultipliers** – converts changing light levels into electrical signals.

Thermoelectric

- **Thermocouples, Thermistors**

  – converts relative temperatures of metallic junctions to electrical voltage

Radioacoustic

- **Radio receivers** converts electromagnetic transmissions to electrical signals.
- Radio transmitters converts electrical signals to electromagnetic transmissions.

What is Sensor?

- A device that gives an output by detecting the changes in quantities or events can be defined as a sensor.
- In general, sensors are termed as the devices that generate an electrical signal or optical output signal corresponding to the variations in the level of inputs.
- There are different types of sensors, for example, consider a thermocouple which can be considered as a temperature sensor that produces an output voltage based on the input temperature changes.

Different Types of Sensors in Electronics

- Temperature Sensor
- IR Sensor
- Ultrasonic Sensor
- Touch Sensor
- Proximity Sensors
- Pressure Sensor
- Level Sensors
- Smoke and Gas Sensors

Temperature Sensor

- Temperature is one of the most commonly measured environmental quantities.
- Different types of temperature sensors are thermocouple, semiconductor temperature sensors, thermistors, resistance temperature detectors (RTDs) etc.

Practical Application of Temperature Sensor

- The programmable digital temperature controller is a practical embedded system based electronic project it is designed, that is used for controlling the temperature of any device based on the requirement of industrial applications.

IR Sensor

- The small photo chips having a photocell which are used to emit and detect the infrared light are called as IR sensors.
- Different types of sensors are used for detecting infrared lights.

Practical Application of IR Sensor

- IR sensors are generally used for designing remote control technology.
- IR sensors can be used for detecting obstacles of the robotic vehicle and thus control the direction.

Ultrasonic Sensor

- A transducer that works on the principle similar to the sonar or radar and estimate attributes of the target by interpreting is called an ultrasonic sensors or transceivers.

Practical Application of Ultrasonic Sensor

- The high-frequency sound waves generated by active ultrasonic sensors are received back by the ultrasonic sensor for evaluating the echo.
- Thus, the time interval taken for transmitting and receiving the echo is used for determining the distance to an object.
- Passive ultrasonic sensors are just used for detecting ultrasonic noise which is present under specific conditions.
- This method is used, where we cannot implement the conventional methods to measure like inaccessible areas such as high temperature or pressure zones, etc.

Touch Sensor

- Touch sensors can be defined as switches that are activated by the touch.
- There are different types of touch sensors such as capacitance touch switch, resistance touch switch, and piezo touch switch.

Practical Application of Touch Sensor

- A touch-sensitive sensor is designed for controlling the load.
- Similarly, we can develop simple and innovative electrical and electronics projects using more advanced sensors such as a PIR sensor-based automatic door opening system.

Proximity Sensors

- This a type of IoT sensor where it identifies the existence or non-existence of the surrounding object or finds the object properties.
- Then it converts the detected signal into the form that is clearly understood by the user or might be a simple electronic device that gets in no contact with them.

Practical Application of Proximity Sensor

- The application of proximity sensors is mainly in the retail domain where they can find out the movement and association that exists between the product and the consumer.
- With this users can receive quick notifications of discount updates and exclusive offers of interesting products.

Chemical Sensor

- These sensors are implemented in various industries.
- The main objective of these sensors is to signify any kind of changes in the liquid or to detect any air chemical variations.

Practical Application of Chemical Sensor

- The essential implementation of chemical sensors can be seen in commercial atmospherically observation and to process management which can be either intentionally or fortuitously evolved chemicals, dangerous or radioactive exposure, reusable operations in space stations, pharmaceutical industries etc.

Gas Sensor

- These are almost the same as chemical sensors but are exclusively implemented to observe modifications of the quality of the air and to find out the existence of different types of gases.

Practical Application of Gas Sensor

- These are employed in multiple domains like agriculture, health, manufacturing
- These are utilized for air quality observation, recognition of toxic or flammable gas, dangerous gas supervision in coal industries, oil & gas businesses, chemical laboratory investigation etc.
- Engineering – paints, plastics, rubber, medicinal & petrochemical, and others.

Humidity Sensors

With the measurement of humidity, one can make sure that the entire procedure goes easily and when there occurs abrupt modification, then they go with immediate action as these sensors identify the variation more quickly.

Practical Application of Humidity Sensor

- Residential and commercial domains use these humidity sensors for the purposes of heating, ventilation, and cooling purposes.
- These sensors are observed in many other domains such as painting, hospitals, pharmaceutical, meteorology, automobile, greenhouses, and coating industries.

Flow Sensor:

- A flow meter (or a flow sensor) is type of flow instrument that is used to indicate the amount of liquid, gas, or vapor moving through a pipe or conduit by measuring linear, non-linear, mass, or volumetric flow rates.
- Flow sensors typically output a series of pulses proportional to the instantaneous flow rate.

Practical Application of Flow Sensor

- They are commonly used in HVAC systems, medical devices, chemical factories, and septic systems.
- Flow sensors are able to detect leaks, blockages, pipe bursts, and changes in liquid concentration due to contamination or pollution.

Liquid Level Sensor:

- Liquid level sensors, also called liquid level switches, are designed to change state when immersed in a liquid.
- They are used to determine if a liquid or oil exists at a particular level in a container.

Practical Application of Level Sensor

- Cars and other vehicles use liquid level sensors to monitor a variety of liquids, including fuel, oil and occasionally also specialist liquids such as power steering fluid.
- Level sensors can also be found in industrial storage tanks, slurries, and at water treatment plants.

Sensors in Robotics

- Sensors hold more importance in the robotics industry as they allow the robot to be informed of the surrounding environment and so facilitate it to go with the necessary operations.
- Without the implementation of these sensors, robots can perform only a few monotonous activities that restrict robot capability.
- With all these abilities, robots can perform many high-level operations..

Various types of sensors in robotics

Acceleration Sensor

- This type of sensor is employed to calculate angular and acceleration values.
- This calculation is helpful for robotic balancing, or to know either the robot has a driving motion on uphill or on a flat edge.

Sound Sensor

- These sensors are usually microphone devices that are used to know the sound and deliver the corresponding level of voltage based on the detected sound level.
- With the implementation of a sound sensor, a small robot can be manufactured to navigate depending on the level of the received sound.

Light Sensor

- Light sensors are kind of transducer devices that are used for identifying light and generates a voltage change which is the same as the intensity of light that comes under the light sensors.
- There exist mainly two types of sensors in the robotics industry and those are photoresistor and photovoltaic.
- Even there are other types of light sensors those are not much implemented like phototransistor and phototubes.

Light Sensor

- **Photo Resistor**
- This is a kind of resistor mainly employed for the purpose of light detection.
- In this, the resistance value gets changed in correspondence to the intensity level of light.
- **Photovoltaic Cells**
- Photovoltaic cells are the energy transformation devices that are employed for the purpose of converting solar radiation into an electrical energy form.
- These are mainly used in the manufacturing process of solar robots.

Tactile Sensors

- This is a type of sensor that states the contact that is in between the sensor and object.
- Tactile sensors are implemented in everyday scenarios such as in the lamps those dim or enhance brightness by touching their base and in lift buttons.

Force Sensor

- This is utilized for measuring the force values of multiple operations such as machine unloading and loading, material carrying, and others that are operated by a robot.

Apart from these, there are many types of sensors used in many industries.

Types of Sensors used in Building Industry

- Temperature sensors
- Motion Detection Sensors
- Electric voltage and current sensors
- Smoke and fire detection sensors
- Camera sensors
- Gas sensors

Types of Sensors in Remote Sensing: mainly two types

Active Sensors

- These generate energy to scan the things and locations and then identifies and calculates the amount of backscattered or reflected radiation from the target object.
- The examples of active sensors are RADAR where the time difference that is in between the emission process and return process is calculated by determining the area, speed, and object direction.

Passive Sensors

- These sensors collect radiation which is either radiated or reflected by the surrounding locations or object.
- The most crucial example of a passive sensor is reflected sunlight collector.