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BASIC STUDY OF WORKING MECHANISM OF ELECTRO-PASSIVE TRANSDUCER BASED ON TRANSDUCTION PHENOMENON

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Abstract
In this review, we mainly focus the novel understanding categories of transducer. Today's manufacturing sector uses analytical and managerial techniques in increasing quantities to increase productivity and minimise costs on all areas; economic, ecological, and energy-related. Additionally, industries frequently require energy conversion from a particular type to a different one. Especially, when it comes to long distance and mass communication, we need conversion of sound energy to electrical energy. Transducer is very helpful in this process. The aim of this paper is to perform a basic but systematic review of the electro-passive transducer based on transduction and the classification including the working mechanism. The systems reviewed based on their operational principle, primary introduction, classification based on numerous activities, the identical parameters, and specific features, provides the various taxonomy about the subdivision of the transducer based on their operational and transduction phenomena including their sensing mechanism. Through signal input is required for changes of physical to electrical transducer based on transduction, e.g., resistive, capacitive, inductive. This review focuses on an electro-passive phase having different mechanism based on the transduction principle. Technologies that have been in use for a while as well as those that are still in the early stages of development are all featured together. Lastly, the readily available. An outlook for prospective future developments is presented, along with a summary of the instruments.
Key words: Transducers, Electro-passive Transducer, Modulator, Resistive, Capacitive, Inductive.

Introduction

First, we understand the basic operation of the sensor by the help of example of human body. A Human body have different body parts like skin, eyes, ear etc. Eyes detect the colour or shapes of objects, Ears senses the voice signal, when we touch the hot body then we get the information about the temperature of an object. In this way all information goes to the brain so eyes, skin, and ear act as a sensor in human body. In our daily life, we use different types of sensors for different purposes. Such as oxygen detector, temperature checker etc. In many technical and scientific applications, sensors or transducers play a crucial role in changing one type of energy into another for

measurement or control. Transducers can be classified into two main categories: active and passive. [1] Passive electrical transducer are those which converts mechanical signal into electrical signal. They are commonly used in sensing applications that require the measurement of pressure, acceleration, and vibration. Passive transducer includes a wide range of transducers and classified into various types. Types of passive transducers include resistive sensors, capacitive sensors, and inductive sensors. Resistive sensors are used to measure changes in resistance due to physical or chemical stimuli, such as strain or gas concentration. [2]Capacitive sensors measure changes in capacitance due to physical stimuli, such as pressure or humidity.[3] Presence of a magnetic field, inductive sensors are utilised.[4] Advances in material science and nanotechnology have enabled the development of new types of passive transducers with improved sensitivity and performance. For example, ionic polymer-metal composites (IPMCs) are a type of smart material that can be used as an artificial muscle or sensor due to their unique combination of mechanical and electrical properties[5]. The development of new sensing and actuation technologies with greater performance and lower power consumption may be facilitated by developments in the field of passive transducers.[6]. Passive transducer is widely used in various applications such as temperature measurement, pressure measurement, displacement measurement, etc. The precision and dependability of the measurement are significantly influenced by the sensing mechanism of passive transducers. The idea behind how passive transducers operate is the transformation of physical properties into electrical signals. In most cases, a change in the physical parameter being measured causes a change in the electrical property of the transducer material. The electrical signal is then measured using an appropriate measuring instrument such as a voltmeter or an oscilloscope. The precision and dependability of the measurement are dependent upon the mechanism for sensing utilised in the passive transducer, which is a critical factor in the assessment of both precision and dependability.[7] In this study, we will explore the sensing mechanism and classification of electro-passive transducers.

Primary illustration of Transducer

Both the terms “sensor” and “transducer” are frequently used when describing measurement systems. The words “sensor” and “transducer” come from the Latin verb sentire, transducer, which means "to lead through, and the transducer, that means, “a sensor is a device that observes a change in a physical stimulus and changes that change into an electrical signal which can be measured or recorded”. [8] The processing device attenuates, filters, and modulates the output signal after the transducer gets the measurement.[9]

1. Identical Parameters of Transducer

2.1 Accuracy: The accuracy of a transducers is the difference between the actual value and observed value, which is typically given as a percentage of full scale, and the measured value. [10]

2.2 Transducer sensitivity: A measurement is accomplished by contrasting a product quantity with a source quantity. Sensitivity is primarily what introduces the transducers' efficiency. [11]

2.3 Time Response: The expression "responsivity" (R) refers to a transducer's reaction to a signal that is input and has been defined as [12]

$$R = \frac{output\ signal\ in\ response\ to\ input}{input\ signal}$$

2.4 Transducer efficiency: is known as the ratio of the power output in the preferred type to the total power input. [13]

2.5 Repeatability: The term "repeatability" refers to a sensor's capacity to produce the same result when subjected to the same input value repeatedly. It is represented by as following:

$$Repeatability\ = \frac{Maximum - Minimum}{Full\ Range} * 100$$

2.6 Nonlinearity: The largest deviation of a sensor's actual observed curve from its ideal curve is indicated by nonlinearity, which is defined as:

$$Non - linearity(\%) = \frac{(maximum\ deviation\ in\ input)}{(maximum\ scale\ input)}$$

2. Classification of Transducer based on numerous activities

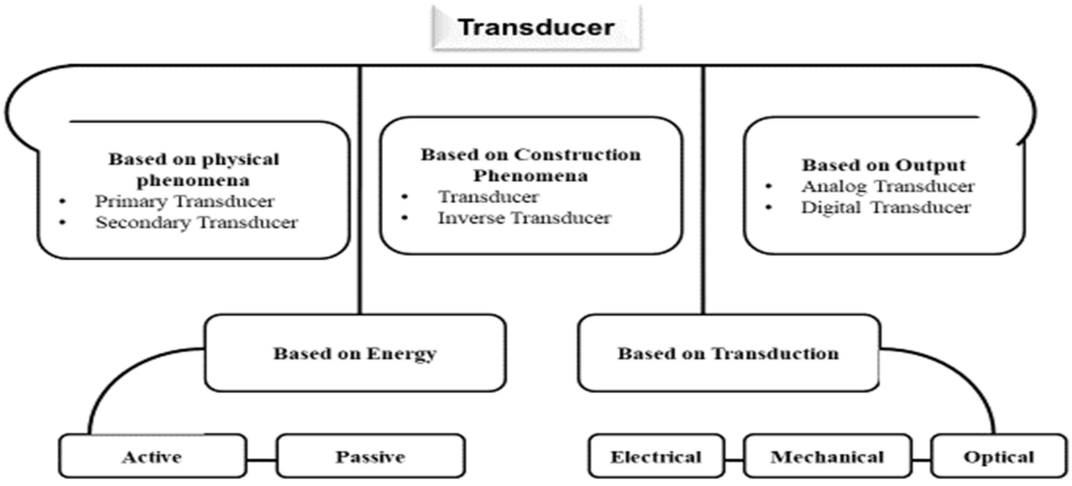
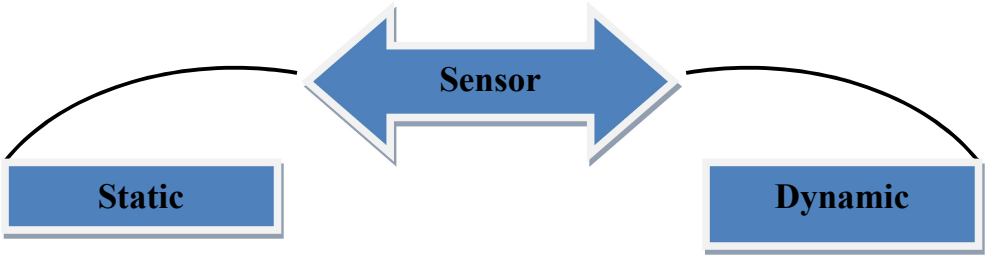


Figure a: Classification of Transducer

Depending on the role play, their structure, or the fundamental phenomena on which they are based, transducers can be categorised in a variety of ways when used as signal converters. They can be simply categorised as input and output transducers. The purpose of input transducers is to measure non-electrical quantities. Transducers can be classified as mechanical, electrical, thermal, or radiation type transducers based on how they function. Schematic representation of transducers where we consider basic physical processes available for use in a transducer. (Figure a)

3. Specific Features

An extensive and specialised data and information is needed to explain and categorise a sensor's capability. Johnson, J. M et al. explain how a sensor is characterised. [14]



The accuracy of the transducer depends on its dynamic properties when the quantity being measured is a function of time, that is, when it varies significantly with respect to time. [15] [16]

Table 1 ; Dynamic and Static Features

Quality	responses that are dynamic for error
Time – dependent	Hysteresis
Distortion	Instability and drift
A minimum frequency to be detected	turbulence
Non – linearity	Functioning range
Selectivity	Precision
Liability	Step response
Uncertainty	

From the above table better understand some of the principle characteristics which are necessary for describing a sensor and its static and dynamic appearance.

4. Categorisation of Transducer based on Transduction

Transducers, has divided into two parts; which includes-

- An input transducer which is known as a sensor,

- And another one is output transducer which defines as an actuator.[17],[18] Based on processes, the transducers further divided in three categories including self-generated, modulate and modifiers.

a schematic illustration of the transducer group based on the transduction phenomenon. [19] The active transducer converts the energy without taking the auxiliary energy supply.

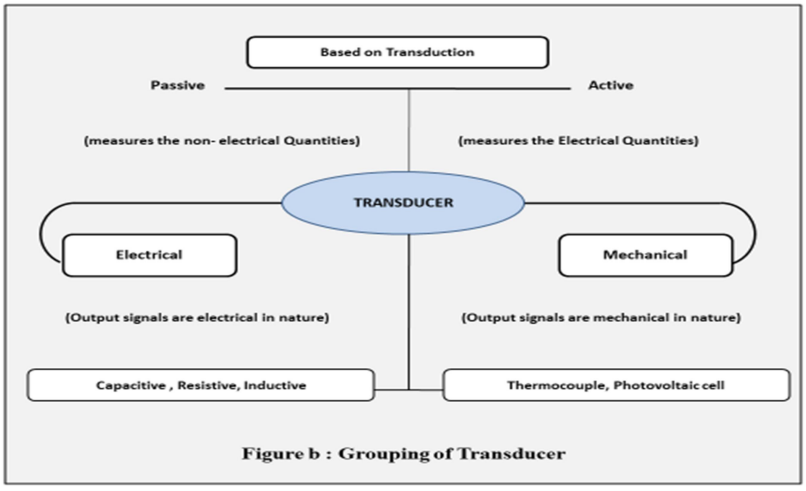


Figure b : Grouping of Transducer

5. Electro-Passive Transducer (sensor)

Devices that convert the measurand (a physical quantity such as light, sound, temperature, etc.) are known as passive transducers or sensors. into a quantifiable electrical signal. With a passive transducer, the output is increased by altering the material's physical properties (resistance, inductance, and capacitance). The passive transducer, on the other hand, is also referred to as a modulated transducer because it depends on an external energy source for transduction. Example - microphone, one more example of an passive transducer or sensor that transforms a physical property, such as sound waves, into an electrical signal that can be transmitted by wires is a microphone.[20]

However, these transducers and circuitry may absorb some energy during measurement and detection of change in process variable. For understanding the passive Transducer or Sensor by following the descriptive Diagram mention as below. (Figure c)[21]

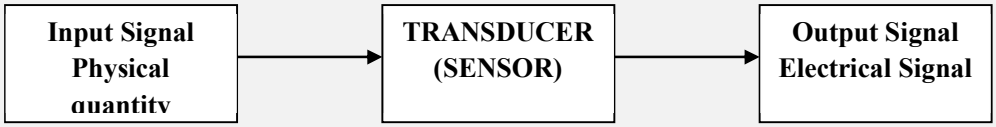


Figure c: Descriptive of Passive Transducer

6. Subgrouping of electro-passive transducers

Electrical circuits consist of combinations of the three passive elements: resistor, inductor and capacitor. The primary parameters that describe them are respectively resistance, self or mutual inductance and capacitance. Transducers that are based on the variation of the parameters due to application of any external stimulus are known as passive transducers. Another classification of transducers is based on the end product or the end use of the transducer after the energy conversion. For example, transducers used to convert pressure into electrical signal are termed as pressure transducers. Some of the transducers under this classification are listed below and presenting the short summary of the Sub – Division of the Electro-passive Transducer. (figure d).

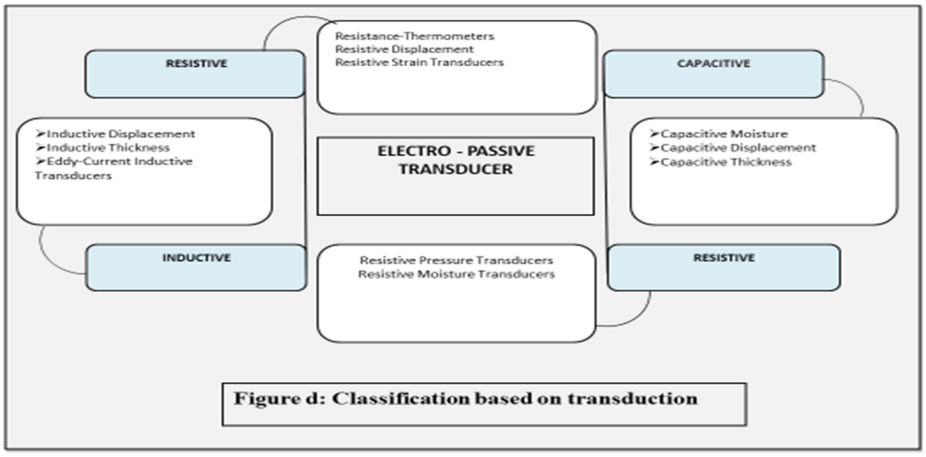


Figure d: Classification based on transduction

7.a. Resistive Transducer

Transducers based on the principle of variation in resistance are generally termed as resistance transducers. They are nowadays most common in many measurements and instrumentation fields. Most of the variables like displacement, acceleration, vibration, force, pressure, temperature. etc. are transduced using this kind of transducers. For instance, a copper wire's resistance varies as a function of temperature, and this effect might be utilised to translate temperature into an electrical output. As the passive transducer needs a power supply or energy from external energy sources for transduction and transduces the physical quantities like displacement, acceleration, force, pressure, temperature etc. Resistance transducer is one of the simplest forms of passive transducers. These are transducers whose electrical resistance is varied in accordance to the input quantity (measurand)[22]
Potentiometer is the example of electro-resistive Transducer as it measures the displacement which is a non-electrical or physical quantity. [23], Some of the Another Example of Resistive Transducer are

Strain gauge: Resistance is changed when applying strain and this property is used for measuring pressure, force etc. [24], [25].
Thermistors (Resistance thermometers): Resistance changes with change in temperature and is used as thermometers.

7.b. Sensing-mechanism

When exposed to an external stimuli like temperature, pressure, or strain, a resistive transducer alters its resistance value. The

stimulus's intensity can then be determined by comparing the change in resistance. In a typical resistive transducer, a sensing element made of a resistive material is used to convert the physical stimulus into a change in resistance. A Wheatstone bridge circuit, a kind of electrical circuit designed to gauge minute changes in resistance, is attached to the sensing device. [26] The Wheatstone bridge circuit becomes unbalanced as a result of the sensing element's resistance changing in response to the stimulus. The circuit detects and measures this imbalance, and depending on the change in resistance, it determines the size of the stimulus.[27] The ratio between the strain produced to the device and the quantity of resistance change in a strain gauge. Therefore, it is feasible to calculate how much strain or deformation the object has experienced by measuring the resistance change.[28].

7.c. Capacitive Transducer

The electrical transducer known as a capacitive transducer is passive. It operates by taking advantage of the capacitor's phenomenon of changing capacitances. A dielectric (a non-conductor) separates the two conductors (plates) which make form a capacitor's structure from one another electrically. The system has the capacity to store an electric charge when the two conductors are at different potentials. Farads are a unit used to express a capacitor's storing capacity. The capacitance of a parallel plate capacitor's equation serves as the foundation for the functioning of capacitive transducers. Changes in the plates' overlapping area, the distance between them, or the dielectric constant could all contribute to this shift in capacitance.[29]

$$\boldsymbol{Capacitance, C = \frac{\varepsilon A}{D}}$$

Where A defines as the Overlapping area of plates (m^2), Distance measures in D and ε define as the Dielectric constant F/m.

The sensor system of an accelerometer is built for identifying the presence of forces of inertia on the foundation of a decreased spring mass structure, and capacitive MEMS transducers are one of the types that are commonly employed in the sensing area.[30].

7.d. Inductive Transducers

Inductive transducers are devices that convert mechanical motion into electrical signals. Devices function according to the electromagnetic induction theory, which holds that a magnetic field that changes causes a voltage to be induced in a coil of wire. An inductive transducer's moving magnetic core and wire coil are required for its basic operation. A change in the magnetic field brought on by the mechanical action results in a voltage being produced in the coil. It is possible to determine velocity, displacement, or velocity with an inductive transducer. [31] The output of the transducer can be processed and displayed to provide information about the physical quantity being measured. Some common examples of inductive transducers include linear variable differential transformers (LVDTs), rotary transformers, and inductive proximity sensors. Such devices are employed in various fields, including as robotics, automobile engineering, aerospace, and industrial automation. [32], [33].

Future Scope

A technological advancement is the century's future. An easy-to-use modern technology in new technologies is the transducer. Using an electrical device or transduction, energy is changed from one type to another. Transducers are required

to transform a physical force into an electronic signal so that it may be more easily recognised and controlled. The two crucial components of a transducer are the sensing element and the transduction element. The connection among the entire power input and the desired output power is known as transducer efficiency. The effectiveness of the transducer oscillates between 0 and 1. No transducer is 100% efficient; some power is continuously lost during the conversion process. In future by the use of eco-friendly nanoparticles we can form sensing devices and its uses in various field. (Srivastava, R., Agrawal, M., & Bano, S., 2022).[34], (Bano S.,2022).[35] (Upadhyay, R., & Bano, S.,2023).[36] , (Banoa, S., Agrawal, M., & Palc, D.,2020).[37] , (Naga, S., & Bano, S. 2023).[38], (Rakesh, & Bano, S., 2023).[39] , (Lakra, A., & Bano, S. 2023).[40], Bano, S.,2023).[41] , (Dubey, P., Nimbalkar, T., Sahu, V., & Bano, S.,2023).[42], (Nag, M., & Bano, S.,2023).[43], (Sarangi, A., Bano, S. 2022).[44].

Conclusion

This paper is focus on working mechanism of all type of transducer. Transducers are divided into three groups based on the transduction process: electrical, mechanical, and optical. Electrical transducers are defined as transducers that produce electrical energy. Active and passive transducers are additional categories for electrical transducers. The passive transducer is unable to perform transduction without an electrical source from external sources of energy. and converts physical quantities such as pressure, temperature, force, acceleration, and displacement. One of the most basic types of passive transducers is the resistance transducer. The electrical resistance of these transducers varies depending on the input quantity. The features produced by the transducers and their varied operating theories include sensitivity, sample consumption, and multiplexing capability. Although the sensitivities for all transducers were provided, it should be remembered that for successful commercialization, the perceived sensitivity of an operator in everyday life would be very crucial. Usability, ease of use, repeatability, and resilience are essential components in addition to sensitivity. The type of technical advancement must also be taken into consideration.

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