SAMPLE OF THE STUDY MATERIAL

PART OF CHAPTER 1

Classification of Transducers

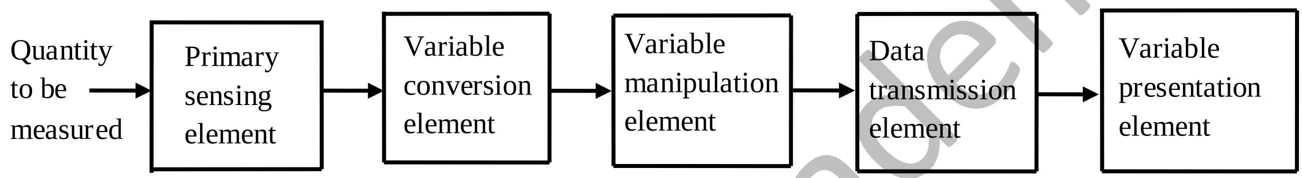
Introduction:

The measuring process is one in which the property of an object or system under consideration is compared to an accepted standard unit, a standard defined for that particular property.

It is important to have a systematic organization and analysis of measurement systems. An instrument may be defined as a device or a system which is designed to maintain a functional relationship between prescribed properties of physical variables and must include ways and means of communication to a human observer.

Generalized Measurement system:

Primary sensing element - The quantity under measurement makes its first contact with the primary sensing element of a measurement system



Variable conversion element - The output of the primary sensing element is converted to some other suitable form for the instrument to perform desired function

Variable manipulation element - The function of this element is to manipulate the signal presented to it preserving the original nature of the signal.

Data preserving element- -This element conveys the information about the quantity under measurement to the personnel handling the instrument or the system for monitoring, control & analysis purposes.

- The measurand in an instrumentation system makes contact with a primary detection element or input device.
- The measurand or the input signal is called an "information" for measurement system.
- The information may be in the form of physical phenomenon or it may be an electrical signal.
- The process of detection and conversion of the information into an acceptable form requires energy.
- The ideal situation is, the energy required for above purpose is supplied from outside, not from measurand
- So that the measurand is not distorted and the analogous output of the detection is a faithful representation of measurand.

Example: A ___________ element is that Part of a Transducer which responds to a physical phenomenon or change in a physical phenomenon.

(A) Sensing
(B) Transduction
(C) Resistive
(D) Inductive

Solution:

[Ans. A]

Primary sensing element →The quantity under measurement (any physical phenomenon) makes its first contact with the sensing element of a measurement system, thus it responds to a physical phenomenon.

Example: Some of the Functional Building Blocks of the measurement System are: **PSE** (Primary sensing element), **VCE** (Variable Conversion Element). **DTE** (Data Transmission Element), **VME** (Variable Manipulation Element), **DPE** (Data Presentation Element).

The Correct Sequential Connection of the functional Building Blocks for an electronic Pressure gauge will be:

(A) PSE, VME, VCE, DPE, DTE.
(B) PSE, VCE, VME, DTE, DPE
(C) DTE, DPE, VCE, PSE, VME
(D) PSE, VCE, DTE, DPE, VME

Solution:

[Ans. B]

A generalized measurement system should have a systematic organization for the measurement of given physical phenomenon. And building blocks should have a correct sequential connections for an electronic pressure gauge.

TRANSDUCERS:

1. The Input Quantity for the most instrumentation System is a Non electrical Quantity. In order to use electrical methods and techniques for measurements, manipulation, or control. Non electrical Quantity is generally converted into an electrical form by a device called **Transducer.**

2. We can define Transducer as a device which, accurately transforms energy from one form to another.

3. Another name for Transducer is 'PICK – UP'.

4. The reason for Transforming a physical phenomenon into an electrical form is that the electrical output can be easily used, transmitted and processed for the purpose of measurement.

5. The Relationship between the physical Parameter and its resulting electrical signal must be a Linear one.

6. Transducers mainly consists of two parts :-
   a) Sensing Element.
   b) Transduction Element
   a) **Sensing Element** → It is that part of a Transducer which responds to a physical phenomenon or a change in a physical phenomenon.
   b) **Transduction Element** → It Transforms the output of a Sensing element to an electrical output.

CLASSIFICATION OF TRANSDUCERS:

The transducers can be classified as:
(i) Based upon transduction principle
(ii) As primary and secondary transducers
(iii) As passive and active transducers
(iv) As analog and digital transducers
(v) As transducers and inverse transducers

(i) Based upon transduction principle:

The transducers can be classified on the basis of principle of transduction as resistive, inductive, capacitive etc., depending upon how they convert the input quantity into resistance, inductance or capacitance respectively.

(ii) Primary and secondary Transducers:

- The first transducer which converts physical phenomenon into displacement, pressure, velocity etc. which is to be accepted by next stage is known as "**Primary Transducer**".
- The output of the primary transducer is converted subsequently into a usable output by a device called "**Secondary Transducer**"

(iii) Passive and Active Transducers:

Passive transducers: They derive the power required for transduction from an auxillary power source.
Eg: Resistive, inductive and capacitive transducers.

Active transducers: They do not require an auxillary power source to produce their output. They are also known as self – generating type since they develop their own voltage or current output.

Eg: piezoelectric, photovoltaic etc.

(iv)Analog and digital Transducers:

Analog transducers: These Transducers convert the input quantity into an analog output which is a continuous function of time.

Eg: LVDT, thermocouple etc.

Digital Transducers: These transducers convert the input quantity into an electrical output which is in the form of pulses.

(v) Transducers & Inverse Transducers:

Transducer: A transducer can be broadly defined as a device which converts a non – electrical quantity into an electrical quantity.

Example: L.V.D.T, Resistive and Capacitive Transducers as well.

Inverse transducer: An inverse transducer is defined as a device which converts an electrical quantity into a non – electrical quantity.

NOTE: Generally a Inverse Transducer is a output transducer.

Example: Indicating Instruments, Pen Recorders, Oscilloscope.

MECHANICAL DEVICES AS PRIMARY DETECTORS:

Type	Operation
A. Contacting spindle, pin or finger	Displacement to displacement
B. Elastic member	
1. Prooving ring	Force to displacement
2. Bourdon tube	Pressure to displacement
3. Bellows	Pressure to displacement
4. Diaphragm	Pressure to displacement
5. Spring	Force to displacement
C. Mass	
1. Seismic mass	Forcing function to displacement
2. Pendulum scale	Force to displacement
3. Manometer	Pressure to displacement
D. Thermal	
1. Thermocouple	Temperature to electric current
2. Bimetallic	Temperature to displacement
3. Temp – slik	Temperature to phase
E. Hydropneumatic	
1. Static	
(a) Float	Fluid level to displacement
(b) Hydrometer	Specific gravity to displacement
2. Dynamic	
(a) Orifice	Velocity to pressure
(b) Venturi	Velocity to pressure
(c) Pitot tube	Velocity to pressure
(d) Vanes	Velocity to force
(e) Turbines	Linear to angular velocity

TYPES OF ELECTRICAL TRANSDUCERS:

Electrical parameter And class of transducer	Principle of Operation	Typical application
A. RESISTANCE		

Potentiometer device	Positioning of the slider by an external force varies the resistance in a potentiometer or a bridge circuit.	Pressure, displacement
Resistance strain gauge	Resistance of a wire or semiconductor is changed by elongation or compression due to externally applied stress.	Force, torque, displacement
Pirani gauge or hot wire meter	Resistance of a heating element is varied by convection cooling of a stream of gas.	Gas flow, gas pressure
Resistance thermometer	Resistance of pure metal wire with a large positive temperature co-efficient of resistance varies with temperature	Temperature, radiant heat
Thermistor	Resistance of certain metal oxides with negative temperature coefficient of resistance varies with temperature	Temperature, flow
Resistance Hydrometer	Resistance of a conductive strip changes with moisture content.	Relative humidity
Photoconductive cell	Resistance of the cell as a circuit element varies with incident light.	Photo-sensitive relay.
B. CAPACITANCE		
Variable capacitance pressure gauge	Distance between two parallel plates is varied by an externally applied force.	Displacement, pressure
Capacitor microphone	Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.	Speech, music, noise
Dielectric gauge	Variation in capacitance by changes in the dielectric or dielectric constant	Liquid level, thickness
C. INDUCTANCE		
Magnetic circuit transducer	Self – inductance or mutual inductance of a.c. excited coil is varied by changes in the magnetic circuit.	Pressure, displacement
Reluctance pick up	Reluctance of the magnetic circuits is varied by changing the position of the iron core of coil.	Pressure, displacement, vibrations, position

Differential transformer	The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.	Pressure, force, displacement, position.
Eddy current gauge	Inductance of a coil is varied by the proximity of an eddy current plate.	Displacement, thickness
Magnetostriction gauge	Magnetic properties are varied by pressure and stress	Force, pressure, sound.
VOLTAGE AND CURRENT		
Hall effect pick up	A potential difference is generated across a semiconductor plate (germanium) when magnetic flux interacts with an applied current	Magnetic flux, current, power
Ionization chamber	Electron flow induced by ionization of gas due to radio – active radiation.	Particle counting, radiation
Photoemissive cell	Electron emission due to incident radiation upon photoemissive surface.	Light and radiation.
Photomultiplier tube	Secondary electron emission due to incident radiation on photosensitive cathode	Light and radiation, photosensitive relays.
SELF – GENERATING TRANSDUCERS		
Thermocouple and thermopile	An emf is generated across the junction of two dissimilar metals or semiconductors when that junction is heated.	Temperature, heat flow, radiation
Moving coil generator	Motion of coil in a magnetic field generates a voltage.	Velocity, vibrations.
Piezoelectric pickup	An emf is generated when an external force is applied to certain crystalline materials such as quartz.	Sound, vibrations, acceleration, pressure changes.
Photovoltaic	A voltage is generated in a semiconductor junction device when radiant energy stimulates the cell	Light meter, solar cell

Example: Consider the following Statement: A transducer converts

(a) Mechanical Energy into electrical energy.

(b) Mechanical Displacement into Electrical Signal.

(c) One form of energy into another form.
(d) Electrical energy into Mechanical form.
Which of the following Statement is / are correct?
(A) → a and d
(B) → a and b
(C) → c alone
(D) → a alone.

Solution:
[Ans. C]
In general if one wants to define the word transducer precisely then it is a device which converts one form of energy into another form.

Example: Which one of the following transducer requires Power Supply for its Operation?
(A) Thermocouple.
(B) Photo Voltaic Cell.
(C) Piezoelectric.
(D) Thermistor.
Solution:
[Ans. D]
Thermistor, is a Passive transducer, Hence requites Power Supply for its operation, Rest all are Active Transducers.

Example: The Pair of Active Transducer is
(A) Thermistor, Solar Cell
(B) Thermocouple, Thermistor
(C) Thermocouple, Solar Cell
(D) Solar Cell, L.V.D.T.
Solution:
[Ans. C]
Thermocouple and solar cell both of them are the pair of active transducer because they do not require an auxiliary power source to produce their output. They are also known as self-generating type since they develop their own voltage or current output.

Example: A S trip Chart Recorder is a:
(A) Active Transducer
(B) Inverse Transducer
(C) Output Transducer
(D) B and C both.
Solution:
[Ans. D]
A strip chart recorder is generally used to measure output of a dynamic quantity, & hence is a output transducer, and because of this factor it convert electrical signal/quantity to mechanical vibrational form, so a inverse transducer also.

Characteristics and Choice of Transducers:
1. In the vast field of Engineering, there are Various Applications of Transducers in different fields.

2. Depending upon the application the choice of Transducer is to be made, and which in turn ultimately depends upon the Input, Transfer and output characteristics.

3. Input, Transfer and output characteristics are taken into account one by one as follows :-

1. INPUT CHARACTERISTICS:

1.A Type of Input and operating Range:
1. The type of input, which can be any physical Quantity, is generally determined in advanced A physical Quantity may be measured through use of a number of Transducers.

2. However the choice of a Particular Transducer that is selected for the Purpose, depends upon the useful range of Selected Quantity over which the Transducer Can be used.
3. The useful operating range of the transducer may be a decisive factor in Selection of a transducer for a Particular application.
4. The upper limit is decided by the transducer Capabilities, while the lower limit of range is normally determined by the transducer error or by the unavoidable noise originating in the transducer.
5. The Transducer should maintain a good Resolution throughout its operating range.

1.B Loading Effects:

1. The transducer, that is selected for a Particular application should ideally extract no force, Power or energy from the Quantity Under measurement in Order that the latter is measured accurately.
2. Ideally a transducer should have no loading effect on the input Quantity being measured.
3. The magnitude of the loading effect can be expressed in terms of force, Power or energy extracted from the quantity under measurement for working of the transducers.

2. TRANSFER CHARACTERISTICS:

2.A Transfer Function:

1. The transfer function of a transducer defines a relationship between the input quantity and the output.

2. The **Sensitivity** of a transducer is defined as the differential Quotient,

$$S = \frac{dq_o}{dq_i}$$

3. The **Scale Factor** is defined as the inverse of Sensitivity,

$$= \frac{1}{S} = \frac{dq_i}{dq_o}$$

2.B ERROR:

1. The errors in transducers occur because they do not follow, in many situations the input – output relationship given by $q_o = f(q_i)$. Any deviation from above mentioned relationship results in errors.

2. Classification of error :-
   a) Scale error
   b) Dynamic error
   c) Error on account of Noise and Drift.

2.C Transducer Response:

1. The performance of the transducer is fully defined by its Transfer function and errors, Provided that the transducer is in constant environments and not subjected to any disturbances like stray electrostatic and electromagnetic fields, mechanical shocks and vibrations, temperature changes, Pressure and Humidity changes, changes in Supply voltage and improper mechanical mountings.
2. If transducers are subjected to the above environmental disturbances then precautions are to be taken, So that change in transfer function and resulting errors thereform do not occur.

3. OUTPUT CHARACTERISTICS:

3.A Type of Electrical output:

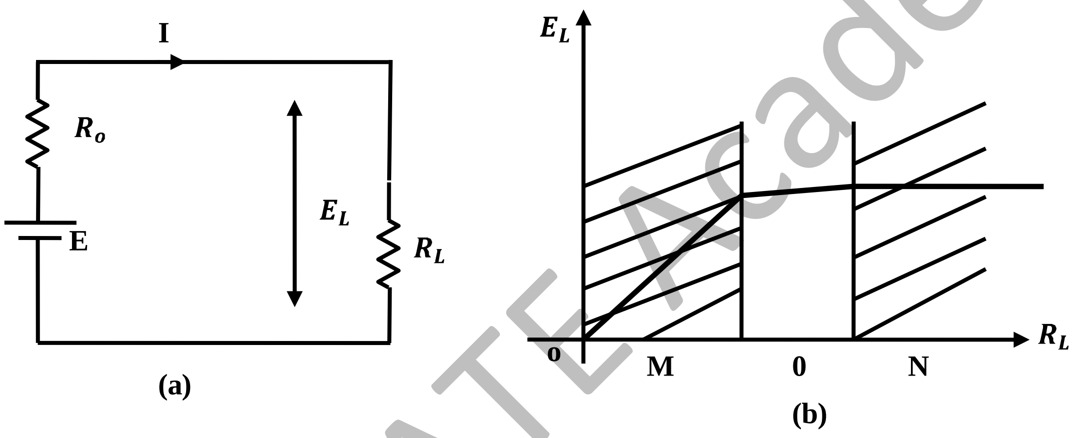
1. The types of outputs which may be available from the transducers may be a voltage, current, impedance or a time function of these amplitudes.
2. These output quantities mentioned above may or may not be acceptable to the latter stages of the Instrumentation System. They may have to be manipulated.

3.B Output Impedance:

1. The output Impedance Z_o of a transducer determines to the extent the Subsequent Stages of Instrumentation is loaded.
2. Ideally, the value of output impedance should be Zero, if no loading effects are there on Subsequent Stages.

CONSTANT VOLTAGE SOURCE:

(1) If the output Impedance is low compared to the forward Impedance of the System, then the transducer has the characteristics of a constant voltage Source. Provided the output of the transducer is a voltage.



Above figure (a) Shows a practical voltage Source, which Consists of a voltage Source E in Series with a internal resistance R_o and a Load Resistance R_L.

The current in this Circuit is given by,

$$I = \frac{E}{R_o + R_L}$$

and voltage across load $E_L = \frac{E . R_L}{R_o + R_L}$

$$= \frac{E}{1 + R_o/R_L}$$

In Case the Internal Resistance (output Resistance) R_o of the Source is much smaller than load resistance (for instance R_o = 1 KΩ and R_L =1MΩ) then ratio R_o/R_L is very small as compared with Unity.

Hence, Voltage across load is,

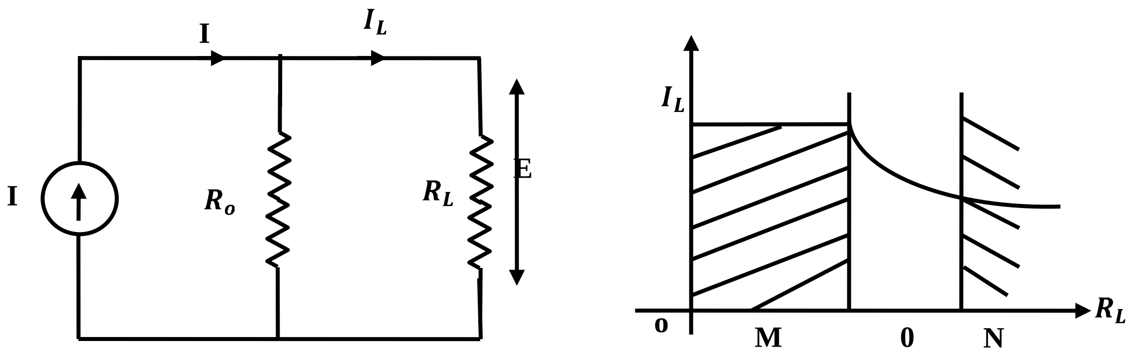
$$E_L = E$$

and the Current is $I = E/R_L$

Thus, the voltage across the load is constant and the Current is independent of the Internal Resistance R_o of the Source. Thus the Source behaves as the Constant voltage Source as indicated in Region N of the above figure.

CONSTANT CURRENT SOURCE:

(1) If the forward Impedance is High as compared with the output impedance of the transducer, it then behaves as a Constant Current Source.



(a) (b)

→ A Practical Current Source Contains a Voltage Source E which causes the current.

→ A Constant Current Source has an internal resistance R_o, which is Connected in Parallel with the Current Source, and is very large as compared with the load resistance R.

→ The Current in Such a System is determined primarily by magnitudes of E and R_L.

From above figure, The Current through Load Resistance is,

$$I_L = \frac{IR_o}{R_o + R_L} = \frac{I}{1 + R_L/R_o}$$

If, the Internal Resistance R_o is very large as Compared to load Resistance (for instance R_o = 1KΩ and R_L = 1Ω) the Ratio R_L/R_o is very small So compared with I and therefore, Load Current

$$I_L = I$$

→ Therefore, the source behaves as a Constant Current Source as depicted in region M.

→ There is a region 0, between regions M and N where the Source neither behaves as a constant voltage source or a constant current source.

3.C Useful Output Range:

1. The output range of a Transducer is limited at a lower end by noise Signals which may shroud the desired input Signals.
2. The upper limit is set by the maximum useful input level. The output range can be increased, in Some Cases, by the inclusion of amplifier in the Transducer.

Example: In a Transducer, the experimentally obtained Transfer function is different from theoretical transfer function, the error results from these difference are called.

(A) Zero Errors
(B) Sensitivity errors.
(C) Non-Conformity Errors
(D) Dynamic errors.

Solution:

[Ans. C]

Non conformity errors → This pertains to a case in which the experimentally obtained transfer function deviates from theoretical transfer function for almost every input.

In the special case of a theoretical linear relationship between input and output quantities, this error is called non-linearity or non linear distortion.

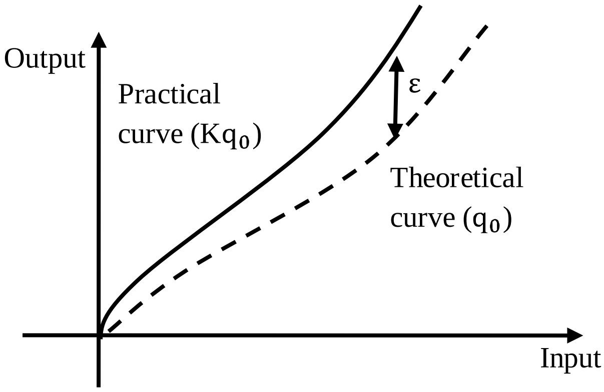
Example: In a transducer, the observed output deviates from the correct value by a constant factor the resulting error is called.

(A) Zero error
(B) Sensitivity error
(C) Non-conformity error
(D) Hysteresis error

Solution:

[Ans. B]

Sensitivity error → Sensitivity error occurs where the observed output deviates from the correct value by a constant value. Suppose the correct output is q_0, the output would be Kq_0 over the entire range of the transducer where K is a constant.



Transducer sensitivity error.