DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester

BM3301 SENSORS AND MEASUREMENTS

UNIT -1

Measurement System – Instrumentation

Measurement is a technique in which the properties of an object are determined by comparing them to a standard quantity. Also, measurement is the essential metric to express any quantity of objects, things and events.

1.1 Measurement System:

A measurement system is a combination of devices, methods, and procedures used to quantify physical quantities or attributes, enabling us to gain insights into the characteristics of objects, systems, or processes. Measurement systems play a crucial role in various fields, including science, engineering, manufacturing, healthcare, and more. Here are the key components and concepts related to measurement systems.

1.1.1 Methods of Measurements:

Methods of measurement are broadly classified into two categories:

(1) Direct Methods (2) Indirect Methods

Direct Methods of Measurement:

In these methods, the. unknown quantity (also called the masurand) is directly compared against standard. The result is expressed as a numerical number and a unit. The standard, in fact, is a physical embodiment of a unit. Direct methods are quite common for the measurement of physical quantities like length, mass and time. Suppose we want to measure the length of a bar. The unit of length is metre. A human being can make direct length comparisons with a preciseness of about 0.25 mm. With

direct measurements, measuring instruments such as Vernier calipers, micrometers, and coordinate measuring machines are used to measure the dimensions of the target directly Therefore, on account of human factors it is not possible to make very accurate measurements. Measurement by direct methods are not always possible, feasible and practicable.

Indirect Methods of Measurement:

Indirect measurement is a method that is used in scenarios where direct measurement is not possible**.** Example, Indirect Method of Level measurement is, Pressure gauge type. Differential pressure type, Ultrasonic type. In engineering applications Measurement Systems are used which require need of indirect methods for measurement purposes.

1.1.2 Classification of Instruments:

There are many ways in which instruments can be classified. Broadly, instruments are classified into two categories :
(i) Absolute Instruments, and
(ii) Secondary Instruments.

Absolute instruments : These instruments give the magnitude of the quantity under measurement in terms of physical constants of the instrument. The examples of this class of instruments are Tangent Galvanometer and Rayleigh's Current Balance.

Secondary instruments: These instruments are so constructed that the quantity being measured can only be measured by observing the output indicated by the instrument. These instruments are calibrated by comparison with an absolute instrument or another secondary instrument which has already been calibrated against an absolute instrument.

secondary instruments are most commonly used. Absolute instruments are seldom used except in standards institutions while secondary instruments find usage almost in every' sphere of measurement. A voltmeter, a glass thermometer and a pressure gauge are typical examples of secondary' instruments.

1.1.3 ELEMENTS OF A GENERALIZED MEASUREMENT SYSTEM :

Figure represents a possible arrangement of functional elements in an instrument and includes all the basic functions considered necessary for a description of any instrument.

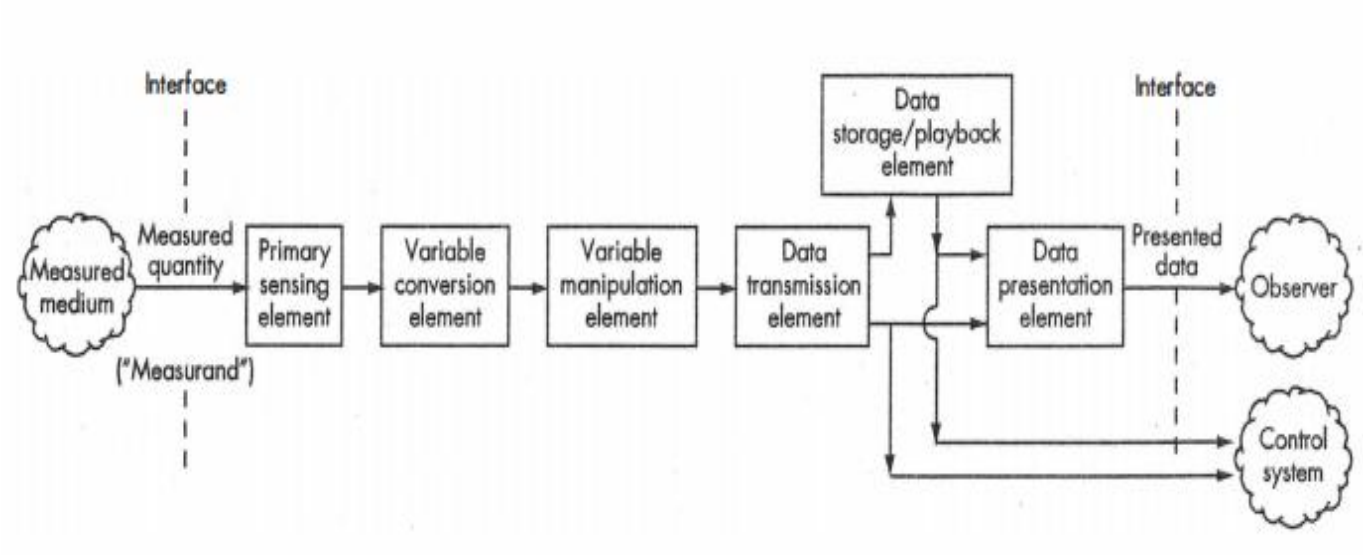

Figure 1.1.1 Functional elements of an instrumentation system.

The whole operation can be described in terms of functional elements. Most of the measurement systems contain three main functional elements. They are :

1. Primary sensing element,
2. Variable conversion element, and
3. Data presentation element

Each functional element is made up of a distinct component or groups of components which perform the required and definite steps in the measurement.

Primary Sensing Element:

The quantity under measurement makes its first contact with the primary sensing element of a measurement system. In other words, the measurand is first detected by primary sensor.

This act is then immediately followed by the conversion of measurand into an analogous electrical signal. This is done by a transducer.

A transducer in general, is defined as a device which converts energy from one form to another. But in Electrical measurement systems, this definition is limited in scope. A transducer is defined as a device which converts a physical quantity into an electrical quantity.

The physical quantity to be measured, in the first place is sensed and detected by an element which gives the output in a different analogous form. This output is then converted into an electrical signal by a transducer.

Variable Conversion Element:

The output of the primary sensing element may be electrical signal of any form. It may be a voltage, a frequency or some other electrical parameter. Sometimes this output is not suited to the system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while preserving the information content of the original signal.

Example, Suppose output is.in analog form and the next stage of the system accepts input signals only in digital form and therefore, an A/D converter will have to be used for converting signals from analog to digital form for them to be acceptable for the next stage of the system.

Variable Manipulation Element:

Manipulation here means only a change in numerical value of the signal. **Example**, an electronic amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude. Thus voltage amplifier acts as a variable manipulation element.

In case, the voltage is too high, attenuators are used which lower the voltage or power for the subsequent stages of the system.

These processes may be linear like amplification, attenuation, integration, differentiation, addition and subtraction.

This process of conversion is called Signal Conditioning. The term signal conditioning includes many other functions in addition to variable conversion and variable manipulation.

Data Transmission Element:

When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function is called a ***Data Transmission Element***.

For example, space-crafts are physically separated from the earth where the control stations guiding their movements are located. Therefore, control signals are sent from these stations to space-crafts by a complicated telemetry system using radio signals.

The signal conditioning and transmission stage is commonly known as Intermediate Stage.

Data Presentation Element:

The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes.

This function is done by data presentation element. In case data is to be monitored, visual display devices are needed. These devices may be analog or digital indicating instruments like ammeters, voltmeters etc. In case the data is to be recorded, recorders like magnetic tapes, high speed camera and T.V. equipment, storage type C.R.T., printers, analog and digital computers or microprocessors may be used.

The final stage in a measurement system is known as ***terminating stage.***

Example of a measurement System:

consider the simple bourdon tube pressure gauge as shown in Figure. The Bourdon tube is the basis of many mechanical pressure gages. The tube is open to atmosphere at one end and sealed closed at the other. Any increase in system pressure within the tube causes the tube to expand and straighten.

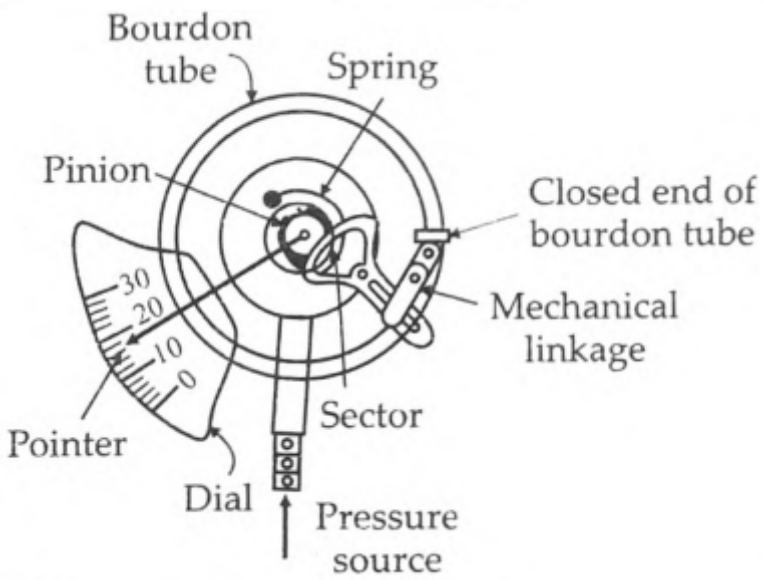

Figure 1.1.2 Bourdon tube pressure gauge.

- This gauge offers a good example of a measurement system. In this case the bourdon tube acts as the ***primary sensing element*** and a variable conversion element.
- It senses the input quantity (pressure in this case). On account of the pressure the closed end of the bourdon tube is displaced.
- Thus the pressure is converted into a small displacement.
- The closed end of the bourdon tube is connected through mechanical linkage to a gearing arrangement.
- The gearing arrangement amplifies the small displacement and makes the pointer to rotate through a large angle.
- The mechanical linkage thus acts as a ***data transmission element*** while the gearing arrangement acts as a ***data manipulation element***.

The final data presentation stage consists of the pointer and dial arrangement, which when calibrated with known pressure inputs, gives an indication of the pressure signal applied to the bourdon tube.

The schematic diagram of this measurement system example is given in Figure.

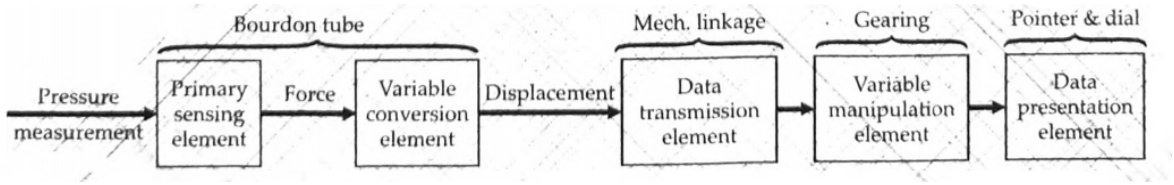

Figure 1.1.3 Schematic diagram of a Bourdon tube pressure gauge