CONTENTS

CHAPTER 1

INTRODUCTION TO INSTRUMENTATION SYSTEM

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1.1 COMPONENTS OF INSTRUMENTATION AND THEIR FUNCTION

Instrumentation is a collective term for measuring instruments used for indicating, measuring and recording physical quantities and has its origins in the art and scientific instrument-making. The main functional element of a measurement are:

i) Primary sensing element
ii) Variable conversion element
iii) Variable manipulation element
iv) Signal conditioning element.
v) Data transmission element
vi) Data presentation element

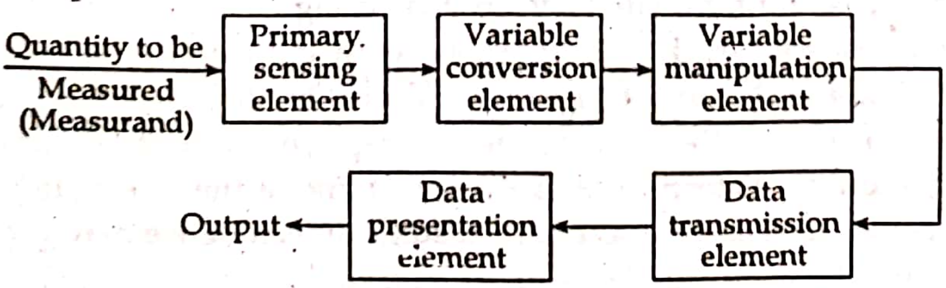

Figure: Generalized or functional block diagram of an instrumentation system.

i) **Primary sensing element**

The quantity or the variable which is being measured makes it first contact with the primary sensing element of a measurement system. The measurement is thus first detected by primary sensor or detector. The measurement is then immediately converted by transducer. Transducer is defined as a device which converts a physical quantity into an electrical quantity. The output of the sensor and detector element employed for measuring a quantity could be in different analogous form. This output is then converted into an electrical signal by a transducer. In many cases, the physical quantity is directly converted into an electrical quantity by a detector transducer.

For example: LDR, microphone etc

ii) **Variable conversion element**

The output signal of the variable sensing element may be any kind. It could be a mechanical or electrical signal. It may be a deflection of some electrical parameter such as voltage, frequency etc. Sometimes the output from the sensor is not suited to the measurement system. For the instrument to perform the desired function, it may be necessary to convert this output signal from the sensor to some other suitable form while preserving the information content of the original signal.

For example: Analog to digital conversion and vice-versa etc.

iii) **Variable manipulation element**

Variable manipulation means a change in numerical value of the signal. The function of a variable manipulation element is to manipulate the signal presented to this element while preserving the origin nature of the signal. The variable manipulation element could be either placed after the variable conversion element or it may precede the variable conversion element. *For example;* a voltage amplifier acts as a variable manipulation element. The amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude.

iv) **Signal conditioning element**

The output signal of transducers contain information which is further processed by the system. Many transducers develop usually a voltage or some other kind of electrical signal and quite often the signal developed is of very low voltages, may be of the order of mV and some even μV. This signal could be contaminated by unwanted signals like noise due to an extraneous source which may interface with the original output signal. Another problem is that the signal could also be distorted by processing equipment itself. If the signal after being sensed contains unwanted contamination or distortion, it is need to remove the interfering noise/ sources before its transmission to next stage otherwise we may get highly distorted results which are far from its true value.

The solution of these problems is to prevent or remove the signal contamination or distortion. The operations performed on the signal to remove the signal contamination or distortion is called signal conditioning. Many signal conditioning processes may be linear, such as amplification, attenuation, integration, differentiation, addition and subtraction. Some may be non-linear processes, such as modulation, filtering, clipping etc.

For example: filter circuit, clamper, clipper etc.

v) **Data transmission element**

There are several situations where the elements of an instrument are actually physically separated. In such situations it become necessary to transmit data from one element to another. The element that performs this function is called data transmission element. The signal conditioning and transmission stage is commonly known as intermediate stage.

For example: electrical cable, pneumatic pipe etc

vi) **Data presentation element**

The function of data presentation element is to convey the information about the quantity under measurement to the personnel handling the instrument or the system for monitoring, control or analysis purposes. The information conveyed must be in a convenient form. In case data is to be monitored, visual display devices are needed. These device may be analog or digital indicating instruments like ammeter, voltmeters etc. In case the data is to be recorded, recorders like magnetic tapes, high speed camera and TV equipment, storage type CRT, printers, analog and digital computers may be used. The final stage in a measurement system is known as terminating stage.

For example: LCD, voltmeters ammeter etc

1.2 BASIC CONCEPTS OF TRANSDUCER

Transducer is a device that converts one type of energy into other type of energy for the purpose of measurement or transfer of information. *For example;* a microphone as an input device converts sound waves into electrical signals for the amplifier to amplify and a loudspeaker as an output device converts the electrical signals back into sound waves.

Following are the factors which need to be considered while selecting a transducer;

i) High input impedance and low output impedance to avoid loading effect.
ii) Preferafly small in size.
iii) High degree of accuracy and repeatability.
iv) Selected transducer must be free from errors.

v) Good resolution over entire selected range.

vi) Highly sensitive to desired signal and insensitive to unwanted signal.

The transducer consists of two main parts:

I) Sensing or detector element

It is the part of the transducer which give the response to the physical sensation. The response of the sensing element depends on the physical phenomenon.

II) Transduction element

The transduction element converts the output of the sensing element into an electrical signal. This element is also called the secondary transducer.

1.3 TYPES OF SIGNAL IN INSTRUMENTATION

A signal is defined as a function of one or more independent variables that contains information about the nature of some phenomenon. Voltages and currents as a function of time in an electrical circuit are examples of signals.

Classification of Signal

a) Continuous-time and discrete-time signals

A signal x(t) is said to be continuous-time signal if it is defined for all time t. A speech signal as a function of time is an example of a continuous-time signal.

A discrete time signal is defined only at discrete time. The weekly stock market index is an example of a discrete-time signal.

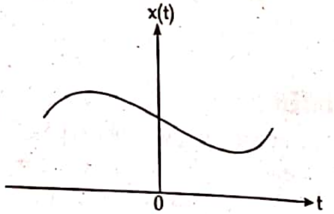

Figure: Example of continuous time signal

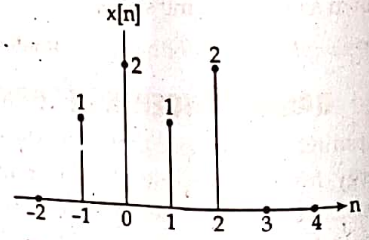

Figure: Example of discrete-time signal

Continuous time signal is denoted by x(t), where the time interval may be bounded (finite) or infinite and discrete-time signal is denoted by x[n], where n is an integer value that varies discretely.

b) Even and odd signals

A signal x(t) or x[n] is defined as an even signal if it is identical to its time-reversed counterpart.

i.e., $x(-t) = x(t)$

$x[-n] = x[n]$

For example: cosine wave series

A signal x(t) or x[n] is said to be an odd signal

If $x(-t) = -x(t)$

$x[-n] = -x[n]$

For example: sine wave series

Any signal can be decomposed into even and odd parts

That is,

$$x(t) = x_e(t) + x_o(t) \qquad (1)$$

Substituting t by – t,

$$x(-t) = x_e(-t) + x_o(-t)$$

or, $$x(-t) = x_e(t) - x_o(t) \qquad (2)$$

Solving equation (1) and (2);

$$x_e(t) = \frac{1}{2}[x(t) + x(-t)]$$

and, $$x_o(t) = \frac{1}{2}[x(t) - x(-t)]$$

Similarly for discrete time signal x[n],

$$x_e[n] = \frac{1}{2}[x[n] + x[-n]]$$

and, $$x_o[n] = \frac{1}{2}[x[n] - x[-n]]$$

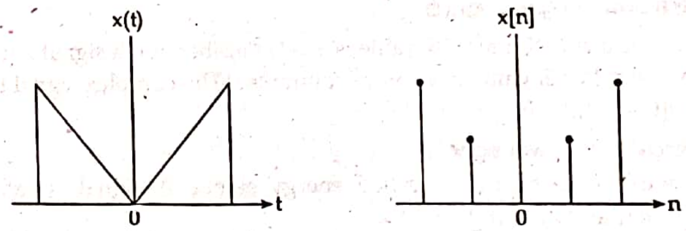

Figure: Continuous-time and discrete-time even signal.

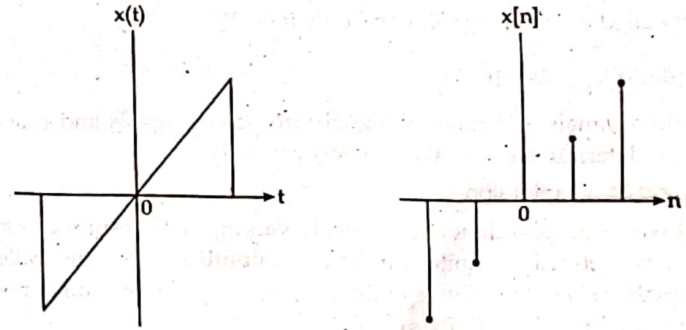

Figure: Continuous-time and discrete-time odd signal

c) Periodic and non-periodic signals

A continuous time signal x(t) is said to be periodic with period T if there is a positive non zero value of T for which $x(t + T) = x(t)$, for all values of t. Also, $x(t + mT) = x(t)$, where m is an integer.

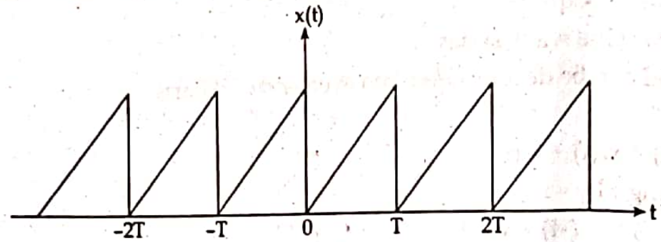

Figure: Continuous time periodic signals

The fundamental period T_0 of x(t) is the smallest positive value of T for which $x(t + T) = x(t)$ holds. A signal which is not periodic or does not hold the above condition is called the non-periodic or a periodic signal.

d) Deterministic and Random signals

The signals whose values are completely specified for any given time are deterministic signals. A deterministic signal is therefore a known function of time. *For example;* sin (ωt) is the deterministic signal.

Random signals are those signals that take random values at any given time and must be characterized statistically. Thermal noise generated in an electronic device is the random signal.

e) Real and complex signals

A signal x(t) is a real signal if its value is a real number and a signal x (t) is a complex signal if its value is a complex number. The complex signal has the form $x(t) = x_1(t) + jx_2(t)$

f) Energy and power signals

A signal with finite energy is called energy signal. A signal is called energy signal if and only if $0 < E_x < \infty$

where, $E_x = \int_{-\infty}^{\infty} x^2(t)\,dt$

A signal is called a power signal if and only if $0 < P_x < \infty$.

where, $P_x = \lim_{T \to 0} \int_{-T/2}^{T/2} x^2(t)\,dt$

Most periodic signals and random signals are power signals and most a periodic and deterministic signals are energy signals.

g) Analog and digital signals

The signal whose amplitude is continuously varying with respect to time and cannot be defined by finite number of amplitude levels are called analog signals where as the signals having only finite number of amplitude levels are called digital signals.

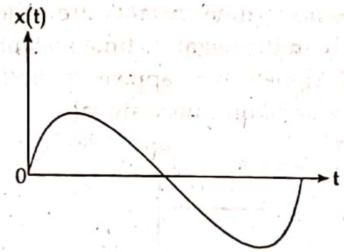

Figure: Analog signal

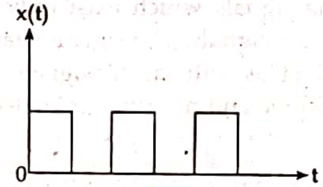

Figure: Digital signal

h) Unit step signal

A continuous time unit step signal is defined by $U(t) = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$

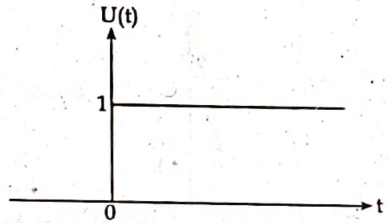

Figure: Continuous time unit step signal

i) Ramp signal

A continuous time ramp signal is defined by $r(t) = \begin{cases} t, & t \geq 0 \\ 0, & t < 0 \end{cases}$

Similarly, a discrete time ramp function is defined by $r[n] = \begin{cases} n, & n \geq 0 \\ 0, & n < 0 \end{cases}$

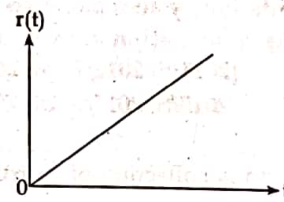

Figure: Continuous-time ramp signal

j) Unit Impulse signal

A continuous time unit impulse signal is defined by $\delta(t) = 0$ for $t \neq 0$

and, $\int_{-\infty}^{\infty} \delta(t)\,dt = 1$

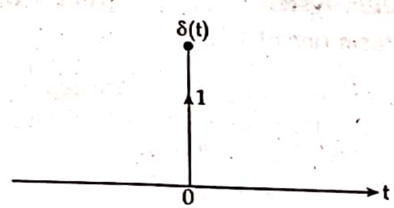

Figure: Continuous time unit impulse signal