Chapter-1

INTRODUCTION TO INSTRUMENTATION SYSTEM

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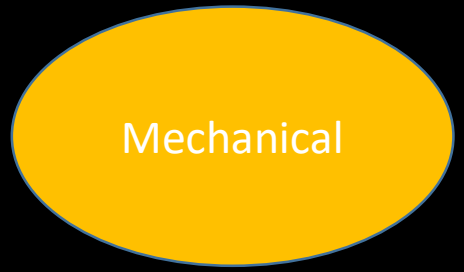
1.1 INTRODUTION

1.1.1 Measurement:

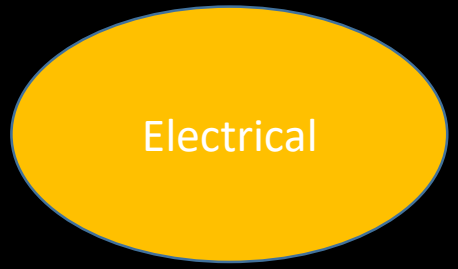
- Measurement of a given quantity is the act of comparision between unknown and predefined standard.
- Result is expressed in numerical value.
- Physical parameters are converted in to meaningful numbers.
- During measurement process:
  - The property of the object under consideration is compared to an accepted standard unit.
  - The number of times the unit standard fits into the quantity being measured gives the numerical value.
  - Numerical value is followed by a unit. It gains the unit of the standard.
- Numerical values are meaningless until it is followed by a unit.
- Methods of measurement may be direct or indirect.

1.1.2 Instrument:

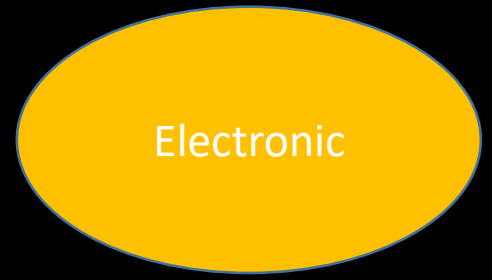
- Device that gives the measurement of any particular physical variable applied to it.
- The assembly of the instruments for measure, update and control the function is called Instrumentation System/ Measurement System.
- Instrument may be:



Eg: Strain gauge



Eg: Galvanometer



Eg: CRO

1.1.3 Accuracy:

- It is the closeness with which an instrument reaing approaches the true value of the quantity being measured.
- Confirmity to the truth.
- Accuracy may be specified in terms of inaccuracy or limits of error.

1.1.4 Precision:

- It is the measure of reproducibilityof the measurement.
- It is the degree og agreement with in a group of measurements.
- Two parts: Confirmity and Significant figure.
- Error caused due to the limitation of scale reading is called precision error.

1.1.5 Sensitivity:

- It is the measure of change in instrument output which occurs due to the change in quantity being measured.
- It is the ratio given by:

$$S = \frac{\text{Scale deflection}}{\text{value of measurand causing deflection}}$$

S= Change in o/p / Change in i/p

1.1.6 Resolution (Discrimination):

- Smallest increment in i/p which can be detected with certainty by an instrument is its resolution.
- If the i/p is slowly increased for some non zero i/p value,it will be found that o/p doesnot change until a certain increment is exceeded. This increment is called resolution.

1.1.7 Error:

- Difference between measured value and true value.

- Shows the deviation of measured value from the true value.

  If measured value=9.8V and true value=10V

  Error=9.8-10=-0.2V Here, –ve sign means measured value is less than true value.

- Types of error: Gross error, Systemic error and Residual error.

Assignment:

“ Precision is necessary but not sufficient condition for accuracy”. Justify your answer with suitable example.

1.2 Instrumentation system:

- Also known as Measurement system.

- The assembly of the instruments for measure, update and control the function is called Instrumentation System/ Measurement System.

- The block diagram consists of following major blocks:
  - Primary sensing element
  - Variable conversion element
  - Variable manipulation element
  - Data transmission element
  - Data Presentation element

Block diagram:

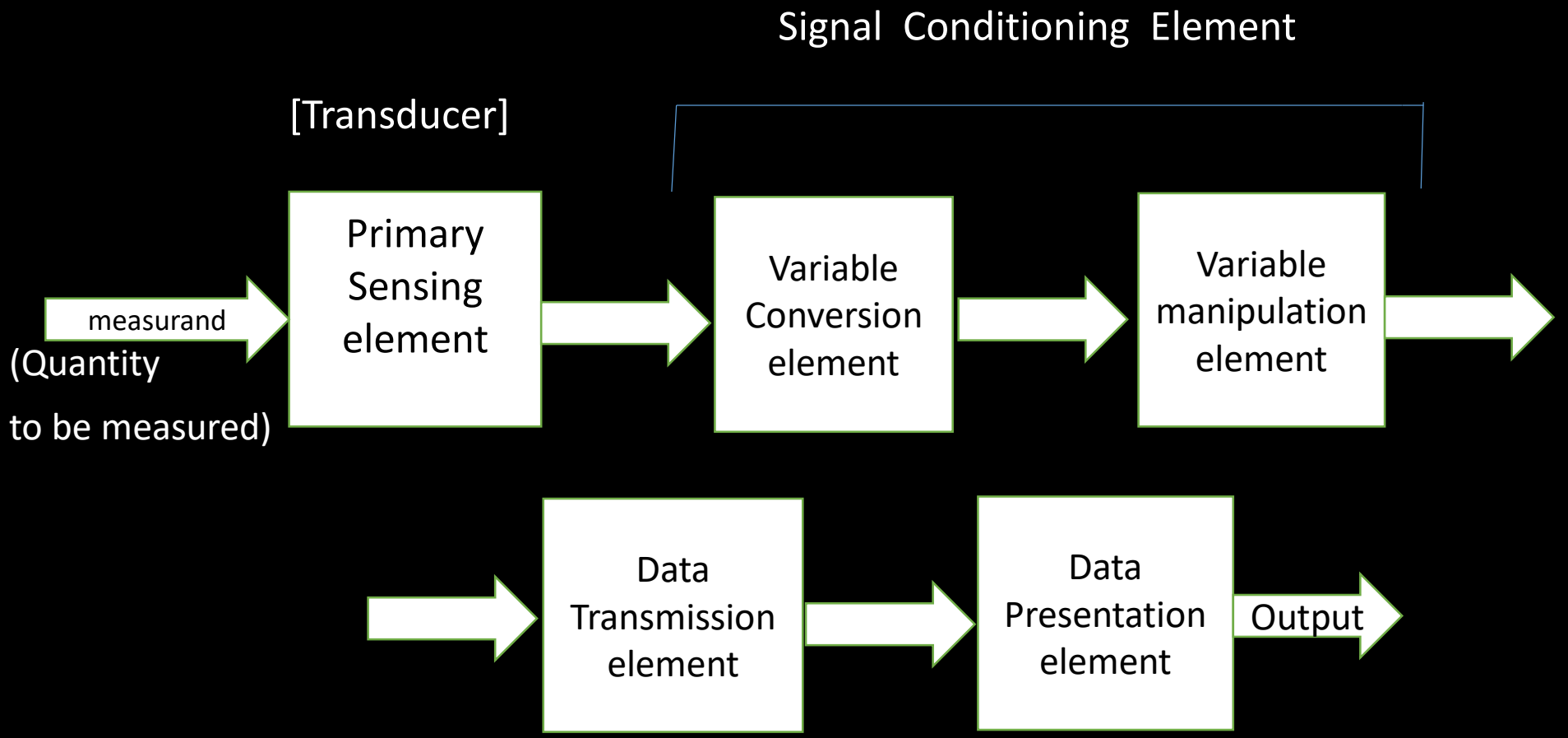


Fig: Block diagram of Instrumentation system

Primary sensing element:

- Measurand is first detected by primary sensing element.
- Transducer then converts it into electrical form.
- Transducer is a device which converts energy from one form to another.
- An electrical transducer converts any physical quantity into corresponding electrical quantity.
- The physical quantity to be measured is first sensed and detected by an element which gives the o/p in different analysis form. Then the o/p signal is converted into an electrical form by a transducer.
- Eg: microphone, loudspeaker, strain gauge.
- Detector-transducer stage.

Signal conditioning element:

a. Variable conver:sion element:

- O/p of transducer may be of an electrical signal of any form.
- It may be voltage, current, frequency or any other.
- May not be suited for system.
- To perform the desired function, it is necessary to convert the o/p in to suitable form.
- Eg: ADC, DAC.

b. Variable manipulation element:

- It manipulates the signal presented for preserving the original nature.
- Change in numerical value only.
- But preserves the original nature of the signal.
- Eg.: Amplifier.

Data transmission element:

- Instrumentation system consists of several instruments/ components which may be far apart.
- Communication/ data transmission is necessary between components or systems.
- The result is to be transmitted from a system to another system.
- This action is done with the help of data transmission element.
- Data transmission is done either thru wire (eg; twisted pair cable, co-axial cable, optical fibre or wave guide) or it may be wireless (eg; microwave, Bluetooth, infra red).
- Eg: Land line data transmission, RF data transmission.

Data presentation element:

- The information about the quantity under measurement has to be conveyed to the person who is handling the instrument.
- The final result/output is presented either thru visual devices, indicators or recorders.
- Eg: CRO, LED, strip chart recorder, magnetic tape recorder, X-Y recorder.

- Signal conditioning and transmission stage → Intermediate stage.
- Data presentation stage → Terminating stage.

1.3 Signal and its types:

1.3.1 Signal:

- A signal is a function representing a physical quantity, and typically it contains information about the behavior or nature of the phenomenon.
- A signal is any function that carries some information.

1.3.2 Types of signals:

- Continuous time and discrete time signals
- Periodic and aperiodic signals
- Deterministic and non deterministic signals
- Even and odd signals

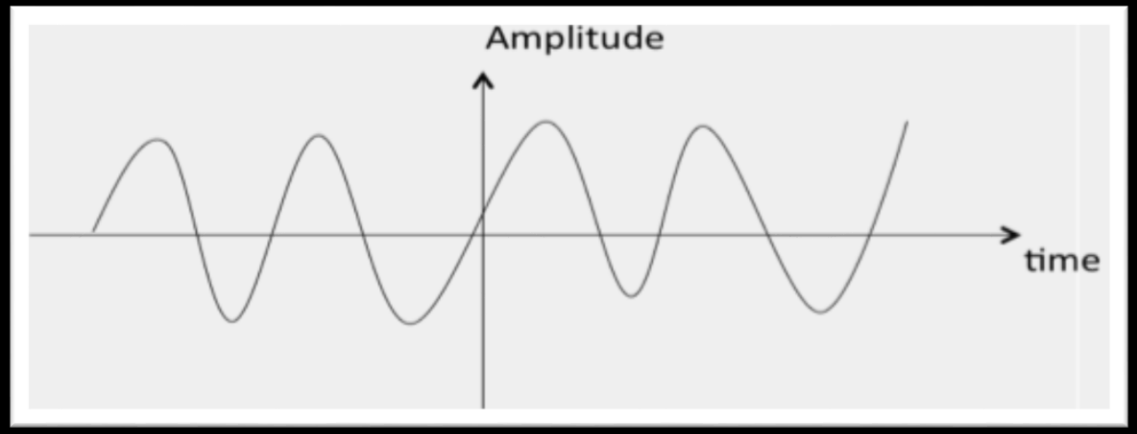
Types of signals continue…

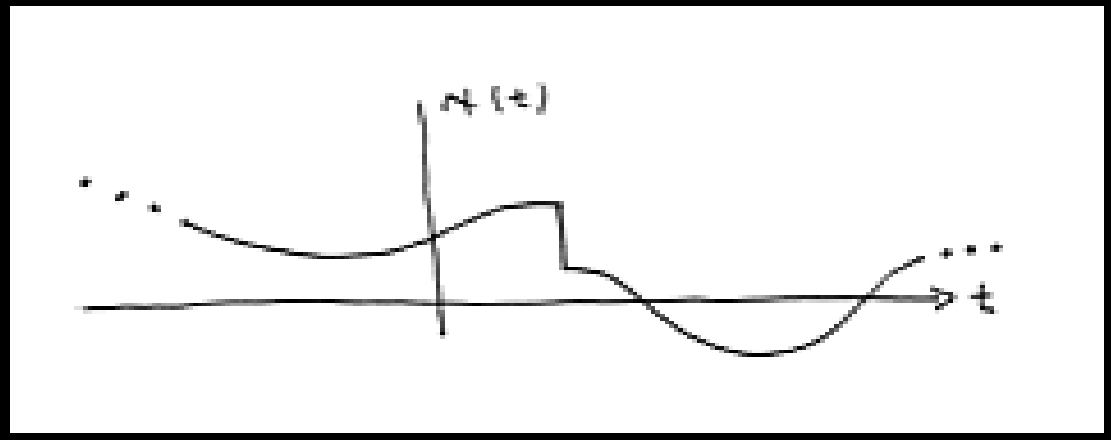
- Energy and power signals
- Unit step function
- Rectangular pulse
- Triangular pulse
- Sinc signal
- Impulse function/ Delta function
- Signum function

Continuous time and discrete time signal:

<u>Continuous time signal:</u>

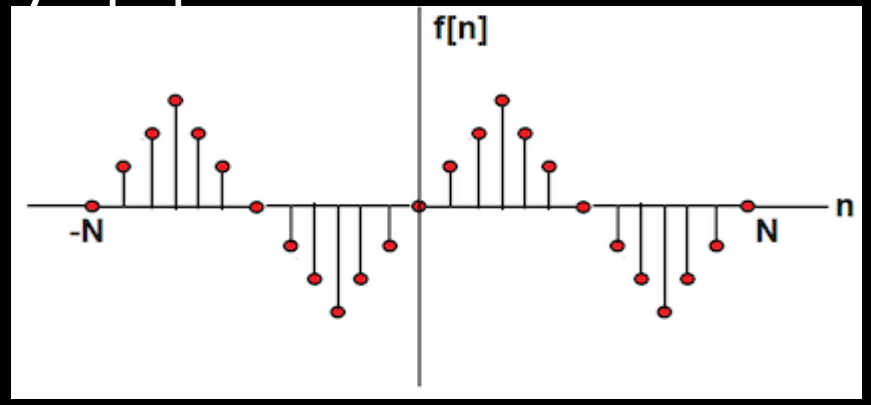
- A signal is said to be continuous when it is defined for all instants of time.
- It is defined as a mathematical continuous function.
- Independent variable is continuous time ‘t’ and the signal represented by x(t).
- It is a function $x(t)$ of the real variable ‘t’ defined for $-\infty < t < \infty$.

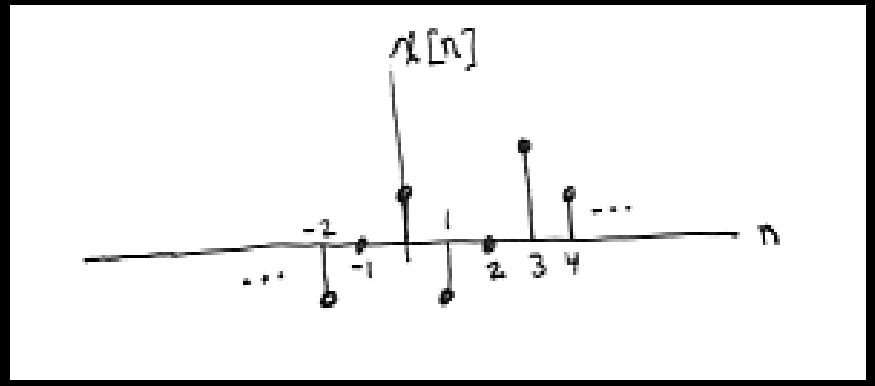




Discrete time signal:

- Defined only at certain time intervals.
- Amplitude between two time intervals is not defined.
- Independent variable is discrete time ‘n’ and the signal is represented by x[n].



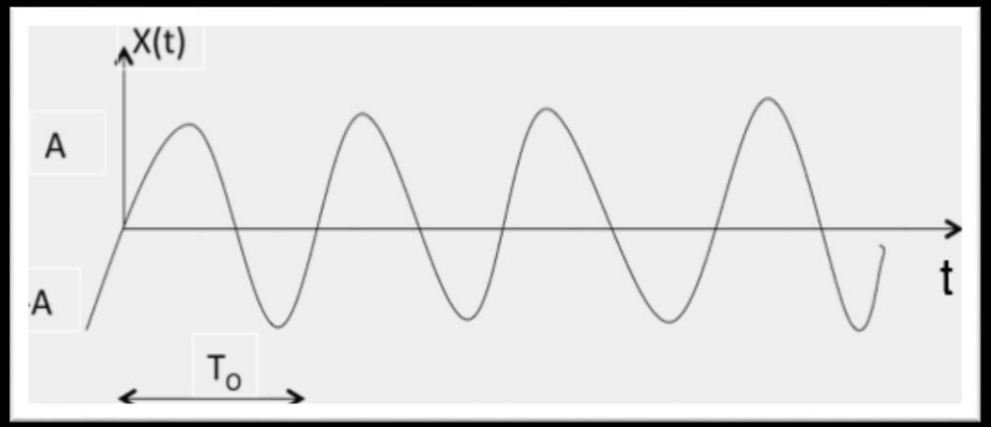


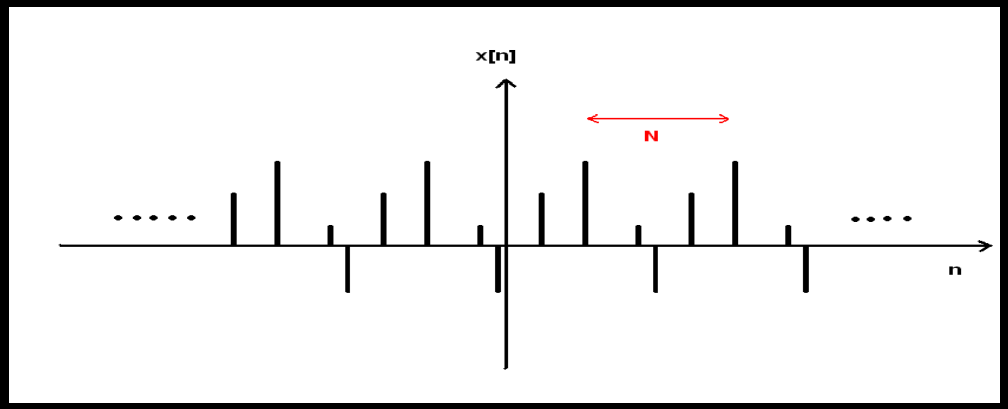
- A *discrete-time signal* is a sequence $x[n]$defined for all integers $-\infty < n < \infty$.

Periodic and aperiodic signal:

Periodic signal:

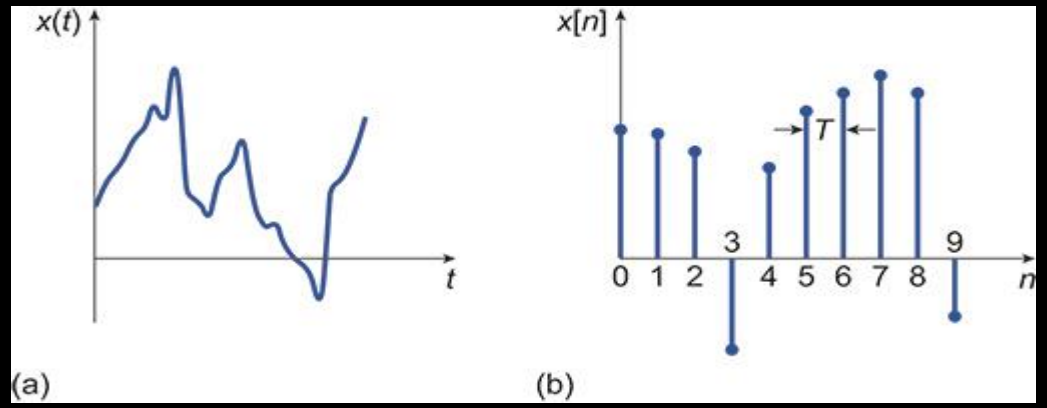
- Signal that has a definite pattern and repeats over a certain period T
- For continuous time signal, it is periodic if $x(t+T)=x(t)$ for $-\infty<t<\infty$, where T is its period.
- For discrete time signal, it is periodic if $x[n+N]=x[n]$ for $-\infty<n<\infty$, where N is its sampling period.

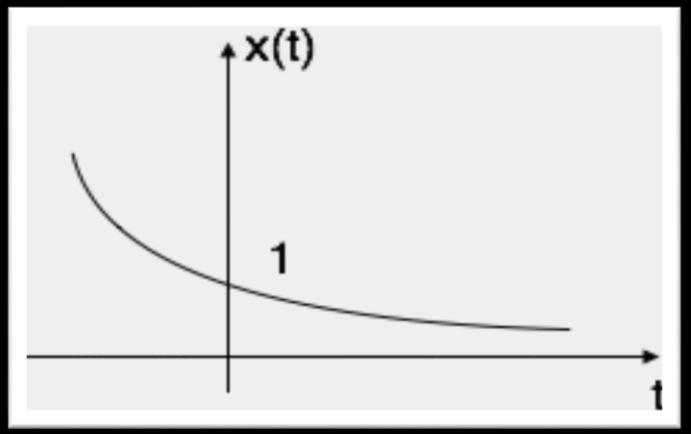




Aperiodic signal:

- Signal is said to be aperiodic if it does not repeat.
- They are said to have time period equal to infinity.





Deterministic and non deterministic signals:

Deterministic signals:

- Signals can be completely specified in time.
- Pattern of these signals are regular and can be characterised mathematically.
- At any time, nature and amplitude can be predicted.

Non deterministic signals:

- Occurrence is always random in nature.
- Pattern is quite irregular.
- Also known as random or stocastic signal.
- Eg: thermal noise generated in electric ckt.

Even and odd signal:

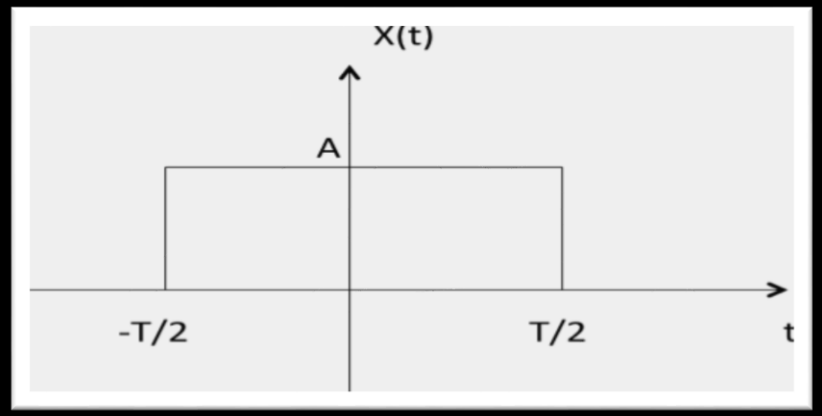
Even signal:

- A signal x(t) or x[n] is said to be even if

  x(t) = x(-t) for continuous time signal

  x[n] = x[-n] for discrete time signal.

- These signals are identical about the origin and exhibit symmetry in the time domain.



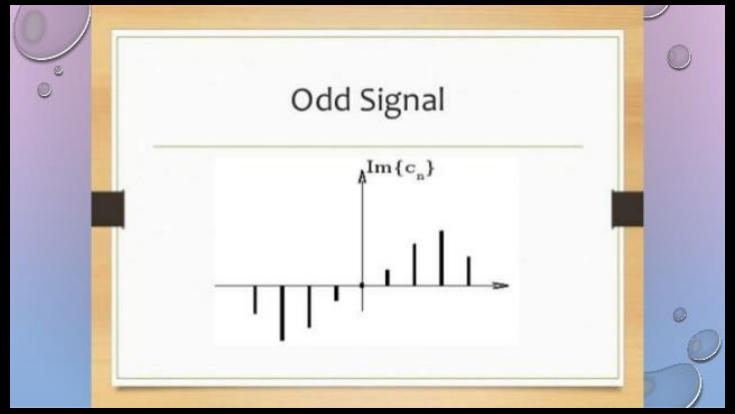
Odd signal:

- A signal is said to be odd if:

  x(t) = -x(-t) for continuous time signal

  x[n] = -x[-n] for discrete time signal.

- These signals exhibit anti symmetry and is not identical about the origin.
- The signal is identical to its negative. Eg: Sine wave .



Energy and power signal:

Energy signal:

- Energy signal has finite energy and zero signal power.
- X(t) is an energy signal if 0<E<∞ and P = 0.
- Eg: single rectangular pulse.
- The *total energy* of a continuous-time signal $x(t)$, where $x(t)$ is defined for $-\infty < t < \infty$, is

$$E_x \triangleq \lim_{T\to\infty} \int_{-T}^{T} |x(t)|^2\, dt = \int_{-\infty}^{+\infty} |x(t)|^2\, dt,$$

Power signal:

- Power signal has finite average power and infinite energy.
- X(t) is a power signal if 0<P<∞ and E = ∞.
- Eg: rectangular pulse train
- The power of a signal is calculated as:

$$P_\infty \triangleq \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 \, dt$$

Unit step function:

- A signal is said to be unit step if

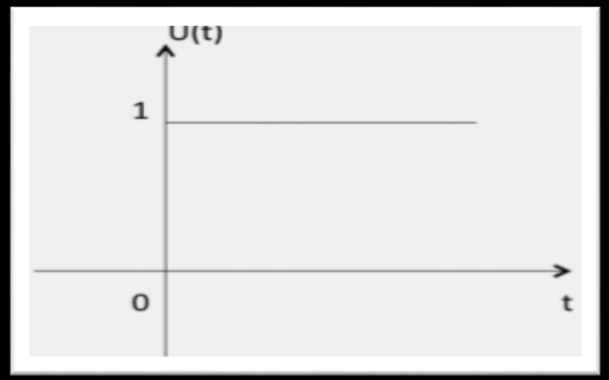
  u(t) = 0 for t < 0

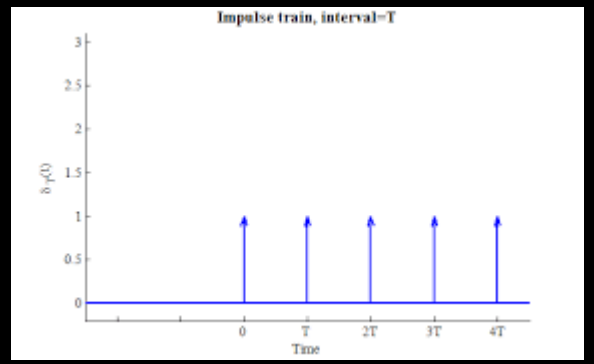
  = 1 for t ≥ 0 for continuous time signal.

- For discrete time signal,

  u[n] = 0 for n < 0

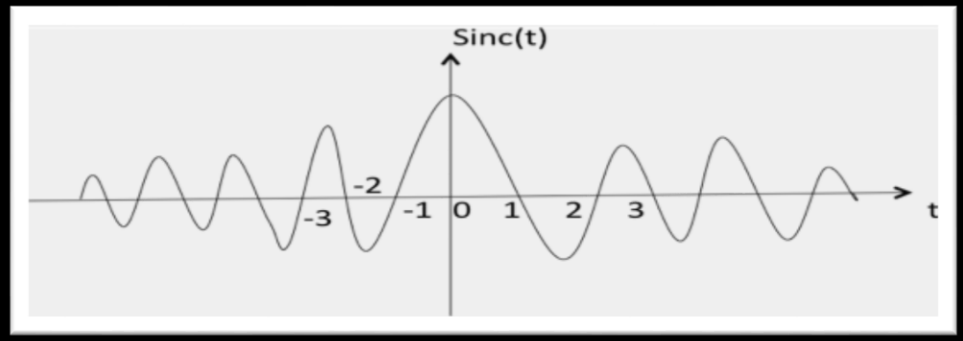
  = 1 for n ≥ 0





Sinc function:

- A signal is said to be a Sinc function if x(t) = Sinc(t) = Sint/t.



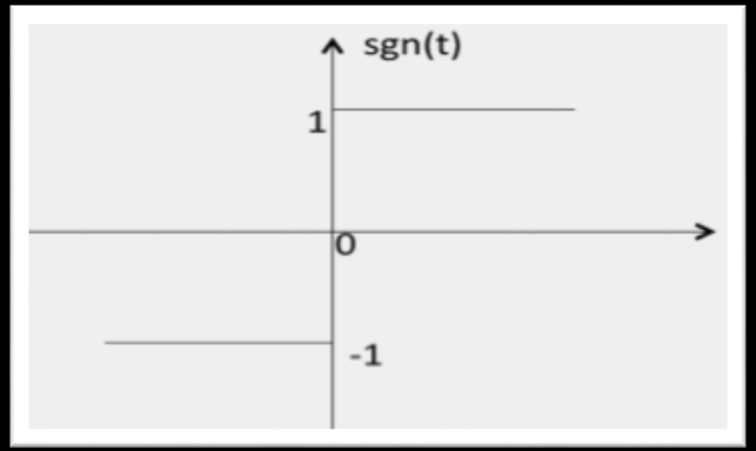
It is the inverse fourier transform of rectangular function.

Signum function:

X(t) = 1 for t > 0

= -1 for t < 0

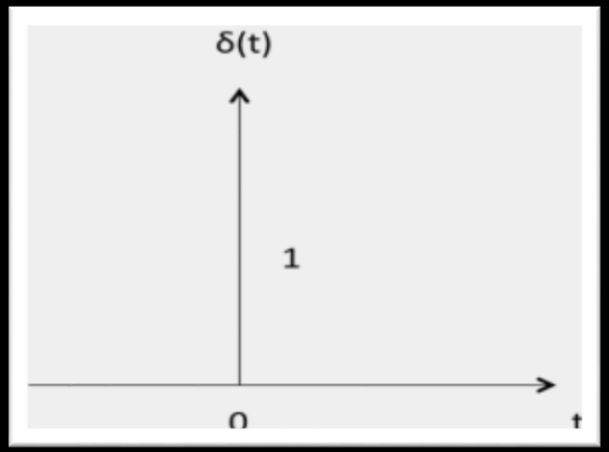
= 0 for t = 0



Delta function/ Impulse function

- Signal is said to be a delta function if

$\delta(t) = 0$ for $t \neq 0$.



Triangular and rectangular pulses