* Signal (Defn):

A signal may be defined as any physical quantity that varies with time, space or any other independent variable(s). Or in other words, any time varying physical phenomenan that is intended to convey information is signal.

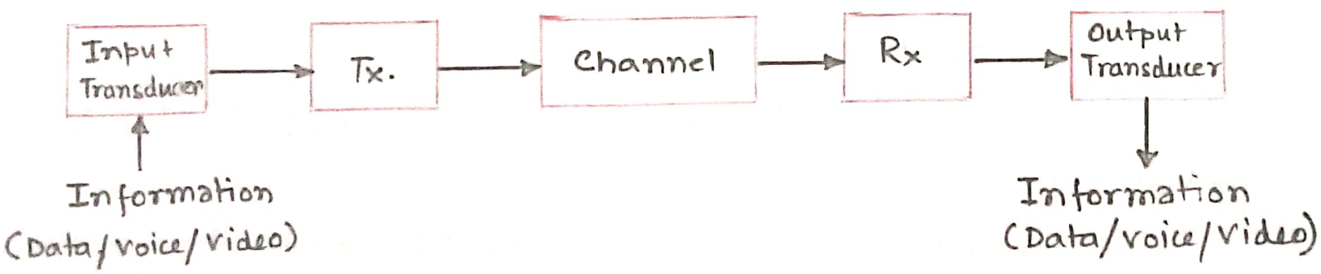
For example - speech signal, sign language, morse code etc. Speech/voice signal can be represented mathematically by acoustic pressure as a function of time.

* Noise

Noise is like a signal. But in noise, the time-varying physical phenomenon usually does not carry any useful information. Generally it is considered undesirable. It is very important to note that, the noise signal term is also relative. For example in a common communicating medium, the signal intended for one user may act as noise signal to the other user(s).

* Elements of an electronic communication system :-

The structure of an electronic communication system is shown below.



From the above block diagram, it is seen that the input of the information may be in electrical signal form or in some other non-electrical format. The input transducer translates the non-electrical signal in to electrical signal suitable for transmitter circuitry. The transmitter then converts the electrical signal (may be analog or digital) into more suitable form for transmission over a particular communication channel. The information may be carried out directly or may be transmitted utilizing a high-frequency signal. The communication channel provides a means of carrying electrical or electromagnetic signals between a transmitter and a receiver. The channel may be wireline or wi

Another electronic device, called receiver, accepts the signals from the communication channel and then converts it back to their original form. It must be noted that the design of the transmitter and receiver must be taken into account the characteristics of the communication channel. The recovered information signal is presented to output transducer device that converts it back into the desired analog or digital form of information.

However, it is important to note that there are primarily four design aspects which one should take care in the design of an electronic communication system. They are listed as,

a. The bandwidth (BW) of the signal and communication channel.

b. The data rate that is used for data transmission.

c. The amount of noise and other impairments

d. The level of acceptable error rate.

* Definition of some common signals :

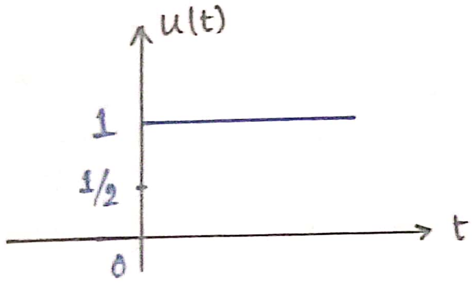
In this section, we shall discuss some of the common signal definitions.

a. **Unit Step Function :**

Continuous time unit step function is defined as,

$$u(t) = \begin{cases} 1, & t > 0 \\ 1/2, & t = 0 \\ 0, & t < 0 \end{cases}$$

This signal is important for analytic studies and it also has many practical signal.



Some alternative description of the unit step function are,

$$u(t) = \begin{cases} 1, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

$$u(t) = \begin{cases} 1, & t > 0 \\ 0, & t \leq 0 \end{cases}$$

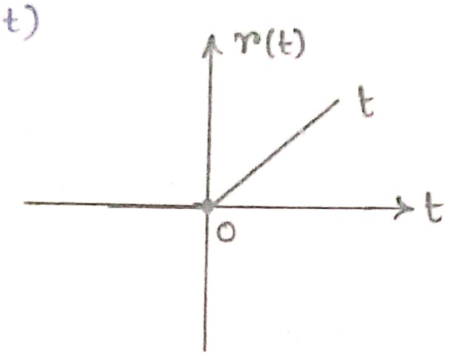
b. **Unit Ramp Function**

Unit ramp functions are defined as,

$$r(t) = \begin{cases} t ; & t \geq 0 \\ 0 ; & t < 0 \end{cases}$$

Unit step function are related to as the ramp function as,

$$r(t) = \int_{-\infty}^{t} u(\lambda)\, d\lambda = t\,u(t)$$



c. <u>Impulse Function</u>

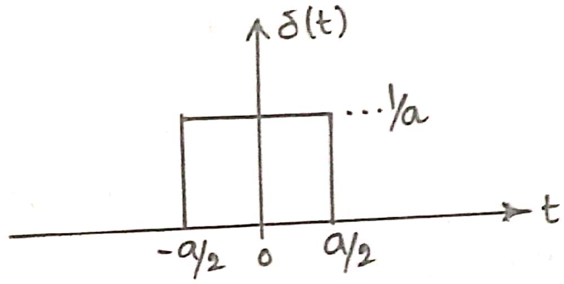
Continuous-time unit impulse function, also known as Dirac delta function $\delta(t)$ was defined by P.A.M Dirac as,

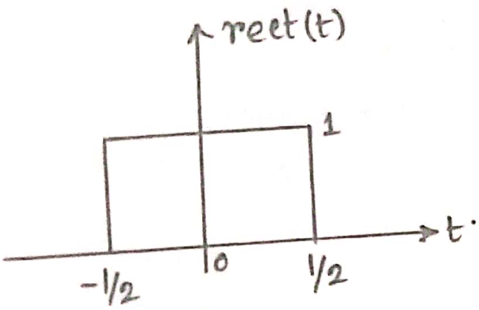
$$\delta(t) = 0 \; ; \quad t \neq 0$$

and, $$\int_{-\infty}^{+\infty} \delta(t)\, dt = 1$$ (Area under unit impulse function is one)

Alternatively, the unit impulse function can be defined as,

$$\delta(t) = \begin{cases} 1/a \; ; & |t| \leq a/2 \\ 0 \; ; & |t| > a/2 . \end{cases}$$





d. <u>Rectangular Function</u>

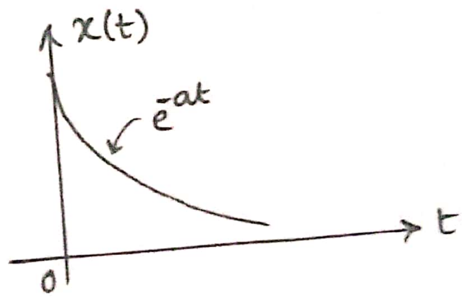
Rectangular function can be defined as,

$$\text{rect}(t) = \begin{cases} 1 \; ; & |t| < 1/2 \\ 1/2 \; ; & |t| = 1/2 \\ 0 \; ; & |t| > 1/2 \end{cases}$$

e. <u>Exponentially Decaying Signal</u>

The exponentially decaying signal can be defined as,

$$x(t) = \begin{cases} e^{-at} \; ; & t \geq 0 \quad (\text{where } a > 0) \\ 0 \; ; & t < 0 \end{cases}$$



Such kind of the signal has wide applications of the Fourier Transform.

* Classification of the signal :-

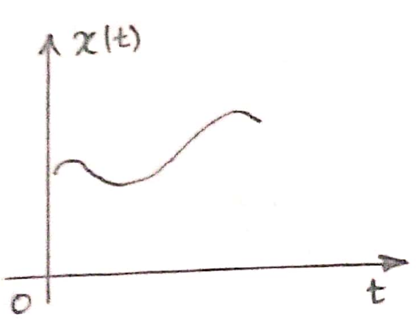
Depending on the independent variables and the value of the function defining the signal, various types of signals can be defined. We shall list some of them. Detailed discussion about these signals classification is beyond the scope and its brief discussion will be placed as per the requirement.

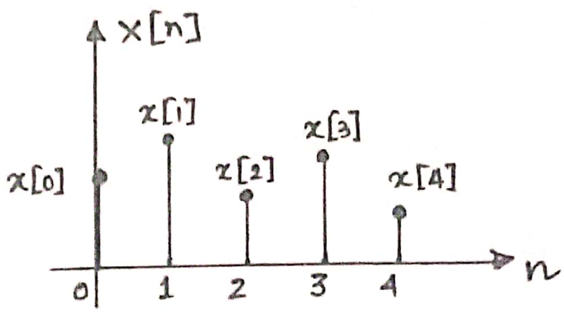
Signal
- → Continuous Time and Discrete Time Signal.
- → Continuous Value and Discrete Value Signal.
- → Random and Deterministic Signal.
- → Odd Signal and Even Signal.
- → Periodic Signal and Aperiodic Signal.
- → Causal Signal and Anti-causal Signal.

a. Continuous Time and Discrete Time Signal

A continuous time/analog signal is defined for a continuum of values of the independent variable 't'. A discrete-time signal is defined only at discrete-time instants 'n', and consequently for discrete-time signals, the independent variables takes only at a discrete-set of values. The amplitude of the discrete-time signal between two time instants is just not defined.

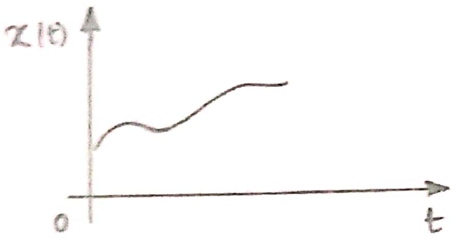
Example of discrete time signal is stock market daily averages. Similarly, speech signal as a function of time is an example of continuous-time signals.

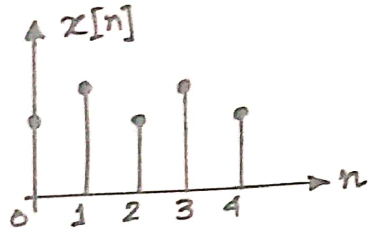




b. Continuous-valued and Discrete-valued Signals

The value of continuous-time or discrete-time signal can be continuous or discrete. If an any signal takes on all possible values on a finite or on infinite range, it is said to be a continuous-valued signal. Alternatively, if the signal takes on values from a finite set of possible values, it is said to be discrete-time signal. Remember, a discrete-time signal having a set of discrete values is called a digital signal.





c. Deterministic and Random Signals

A signal whose compete physical description is known, either in a mathematical form or in a graphical form, is a deterministic signal. The nature and amplitude of such a signal at any time can be predicted. The pattern of such a signal is regular. A signal whose values cannot be predicted precisely but are known only in terms of probablistic description, such as mean value or mean-square value, is a random signal. A typical example of a random signal is thermal noise in an electrical circuit.

d. Even and Odd Signals

A signal $x(t)$ is referred to as an even signal if it is identical with its reflection about the origin. In continuous time, a signal is even if,

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

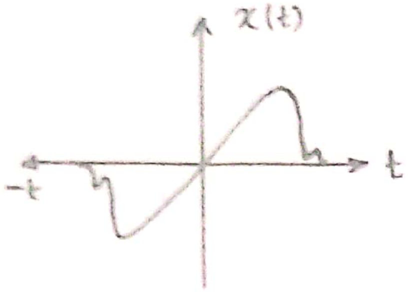
Clearly, an even signal is symmetrical about the vertical axis.

Similarly, a signal is refferred to as odd if,

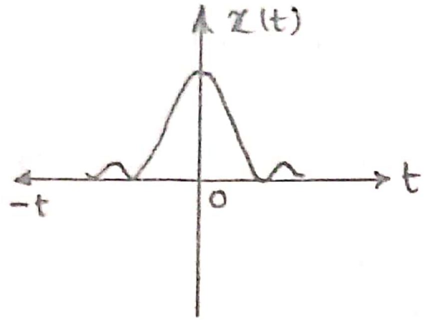
$$x(t) = -x(-t)$$

or, $x(-t) = -x(t)$

From the property, we can say that, any odd signal must necessarily be 0 at $t=0$.



Even Signal



Odd Signal

* Representation of arbitary signal in odd and even signal

Every signal can be represented as a sum of odd and even signal. Mathematically,

$$x(t) = \underbrace{x_o(t)}_{\text{Odd Signal}} + \underbrace{x_e(t)}_{\text{Even Signal}}$$

Let, $E(\ )$ and $O(\ )$ operators identifies the even and odd part of the signal, respectively. Then,

$$\left.\begin{aligned} E(x(t)) &= x_e(t) = \frac{2x(t)}{2} = \frac{x(t)+x(-t)}{2} \\ O(x(t)) &= x_o(t) = \frac{2x(t)}{2} = \frac{x(t)-x(-t)}{2} \end{aligned}\right\}$$

* Properties

Assume, $x_1(t)$ is an odd signal, and $x_2(t)$ is an even signal then,

(i) $x_1(t)\, x_2(t) \Rightarrow$ odd signal

(ii) $x_1(t)\, x_1(t) \Rightarrow$ even signal

(iii) $x_1(t) \pm x_2(t) \Rightarrow$ Even signal (Both $x_1(t)$, $x_2(t)$ are even signal)

(iv) $x_1(t) \pm x_2(t) \Rightarrow$ Odd signal (Both $x_1(t)$, $x_2(t)$ are odd signal)

(v) $x_1(t) \pm x_2(t) \Rightarrow$ Cannot be directly estimated if $x_1(t)$ is odd and $x_2(t)$ is even signal.