Signals and classifications

Signal: A signal is a function representing a physical quantity or variable, and typically contains information about the behavior or nature of the phenomenon.

Ex:

In an RC circuit, the signal can be the voltage across the capacitor or the current flowing through the register.

Mathematically, a signal is represented as a function of an independent variable ***t*** and is denoted by ***x(t)***.

System: It is a collection of components wherein individual components are constrained by the connecting inter-relationships such that the system as a whole fulfills some specific functions in response to varying demands.

Varying demand is a function of one or more parameters and is called the **signal**.

Ex: RC circuit as integrator or differentiator.

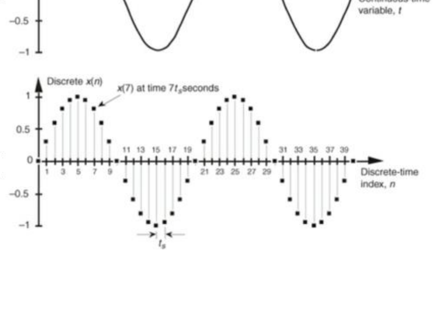
Continuous Time and Discrete Time signals

Continuous/Analog signal: A signal continuous in time taking continuous range of amplitude values, defined for all times.

Discrete/Digital signal: A discrete signal for which we only know values of the signal at discrete points in time.

A 1-dimensional **continuous** signal could for example be: $x(t) = \sin(2\pi f_0 t)$ where t represents the time.

A 1-dimensional **discrete** signal could for example be: $x[n] = \sin(2\pi f_0 n)$ where n represents the index 0, 1, 2, 3, ...



Representation of Signal

Mathematical/Functional

$$x[n]=\begin{cases}-3 & n=-2\\ 2 & n=-1\\ 0 & n=0\\ 3 & n=1\end{cases} \qquad \text{or} \qquad x[n]=\begin{cases}2^n & n\geq 0\\ 0 & otherwise\end{cases}$$

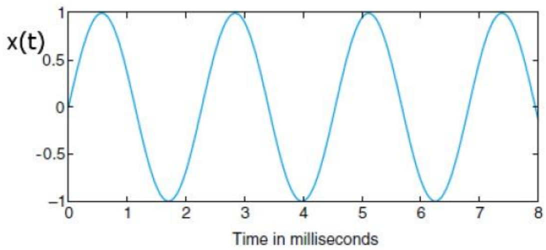
- Sequence

$$x[n]=\left\{-3 \quad -2 \quad \underset{\uparrow}{5} \quad 0 \quad -6\right\} \qquad \text{or} \qquad x[n]=\left\{2 \quad \underset{\uparrow}{3} \quad -1 \quad 2\right\}$$

- Tabular

n	-3	-2	-1	0	1
X[n]	-5	0	2	-2	9

- Graphical



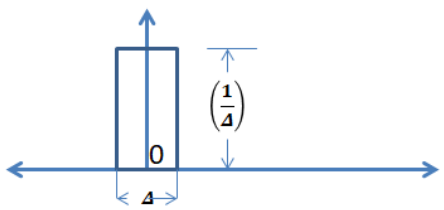
<u>Types of signal</u>

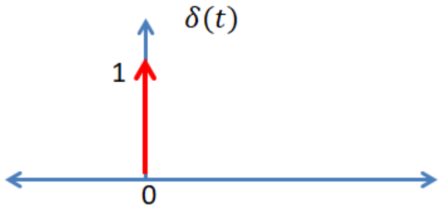
Elementary Signals:

1. Unit Impulse or Impulse Signal
2. Unit Step or Step signal
3. Ramp
4. Signum Function
5. Exponential

1. Unit Impulse or Impulse Signal

The unit impulse function, $\delta(t)$, is also known as Dirac Delta function. Consider a pulse occurring at *t=0* of height $\frac{1}{\Delta}$ and duration *Δ* as shown below





- $\delta(t)$ is defined as the limit of a suitably chosen conventional function having unity area over an small time interval.
- Mathematical Expression:
- $\delta(t) = \begin{cases} 0\,, & t \neq 0 \\ 1\,, & t = 0 \end{cases}$
- $\delta[n] = \begin{cases} 0\,, & n \neq 0 \\ 1\,, & n = 0 \end{cases}$
- $\int_{-\infty}^{\infty} \delta(t)dt = 1$

2. Unit Step or Step signal

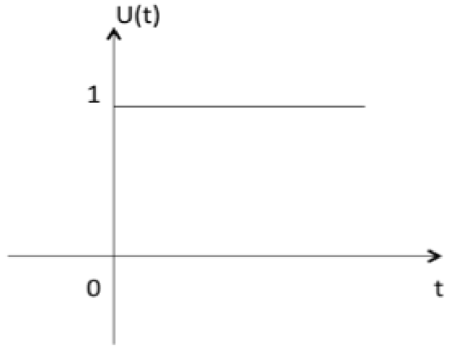
A unit step function, $u(t)$, is also known as Heaviside unit function.

Mathematical expression:

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

- $u[n] = \begin{cases} 0\,, & n < 0 \\ 1\,, & n > 0 \end{cases}$

- The signal is discontinuous at t=0.



  - $\int_{-\infty}^{\infty} \delta(t)dt = u(t)$
  - $\delta(t) = \frac{du(t)}{dt}$
  - $\boldsymbol{Area\ under\ unit\ step\ is\ unity}$

3. Ramp

Ramp signal is denoted by r(t) or r[n].

Mathematical expression:

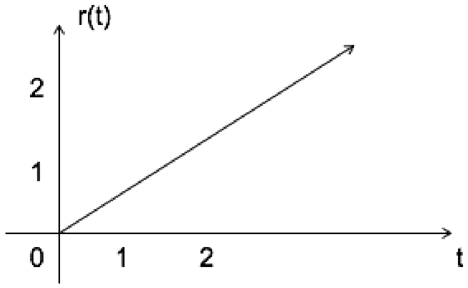
- $r(t) = \begin{cases} 0\,, & t < 0 \\ t\,, & t \geq 0 \end{cases}$

- $r[n] = \begin{cases} 0\,, & n < 0 \\ n\,, & n \geq 0 \end{cases}$

- Area under unity ramp is unity

- $\int_{-\infty}^{\infty} u(t)dt = \int_{0}^{\infty} 1\, dt = t = r(t)$

- $u(t) = \frac{dr(t)}{dt}$

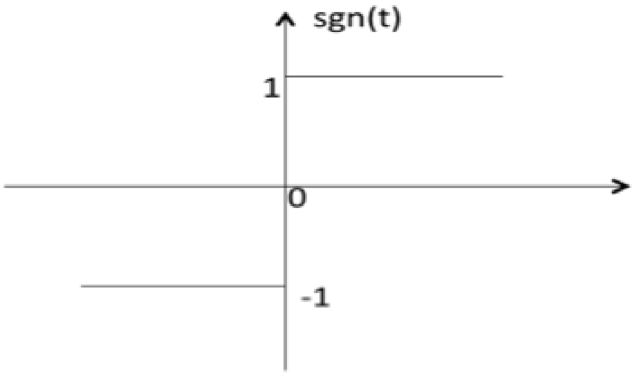


4. Signum Function

Signum function is denoted as sgn(t).

Mathematical expression:

- $sgn(t) = \begin{cases} 1, & t > 0 \\ 0, & t = 0 \\ -1, & t < 0 \end{cases}$
- $sgn(n) = \begin{cases} 1, & n > 0 \\ 0, & n = 0 \\ -1, & n < 0 \end{cases}$
- $\boldsymbol{sgn(t) = 2u(t) - 1}$

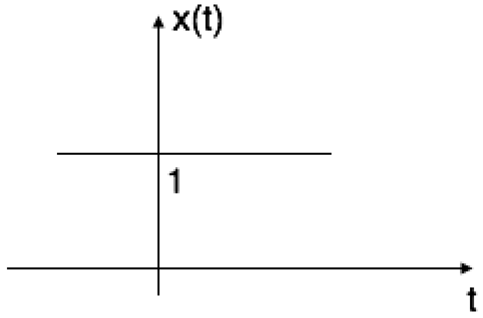


5. Exponential

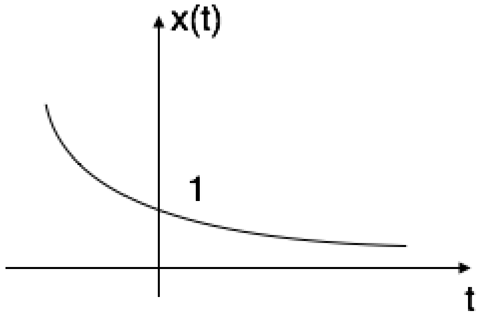
Exponential signal is in the form of $x(t) = e^{\alpha t}$

The shape of exponential can be defined by α.

Case i: If $\alpha = 0$ -> x(t)=e^0 = 1



Case ii: If $\alpha < 0$ -> $x(t) = e^{-t}$. It is known as **decaying exponential**.



Case ii: If $\alpha > 0$ -> $(t) = e^{t}$. It is known as **rising exponential**.