Signal Processing

Classification of signals

Introduction to Signals and Systems

Definition of Signals and Systems

Signal:

A function of one or more independent variables which contain some information is called signal.

Examples of Signal:

- **Electric voltage and current, such as radio signal, TV signal, telephone signal, computer signals, etc.**
- **Pressure signal , sound signal, etc are non electric signals.**

Introduction to Signals and Systems

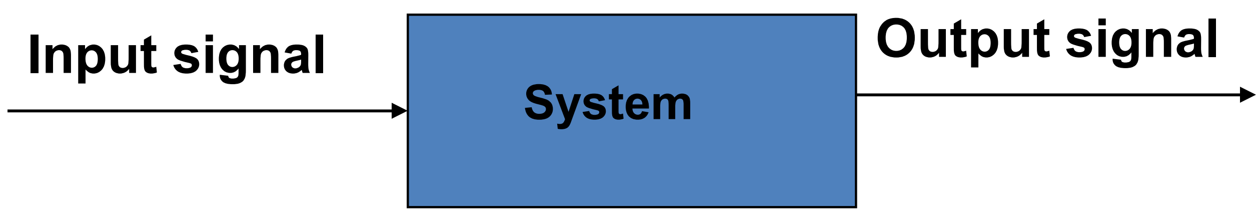
Definition of Signals and Systems

System:

A system is a set of elements or functional block that is connected together and produces an output in response to an input signal.

Examples of System:

- An audio amplifier , attenuator, TV set, communications systems , etc are systems.
- Any machine or engine are also systems.



Classification of Signals

The signals can be classified into two parts depending upon independent variable (time).

- Continuous Time (CT) Signals.
- Discrete Time (DT) Signals.
- Both the CT and DT signals can be classified into following parts:
- periodic and non periodic signals.
- Even and odd signals.
- Energy and power signals.
- Deterministic and random signals.

CT and DT signals

Definition: A CT signal is defined continuously with respect to time. A DT signal is defined only at specific or regular time instants.

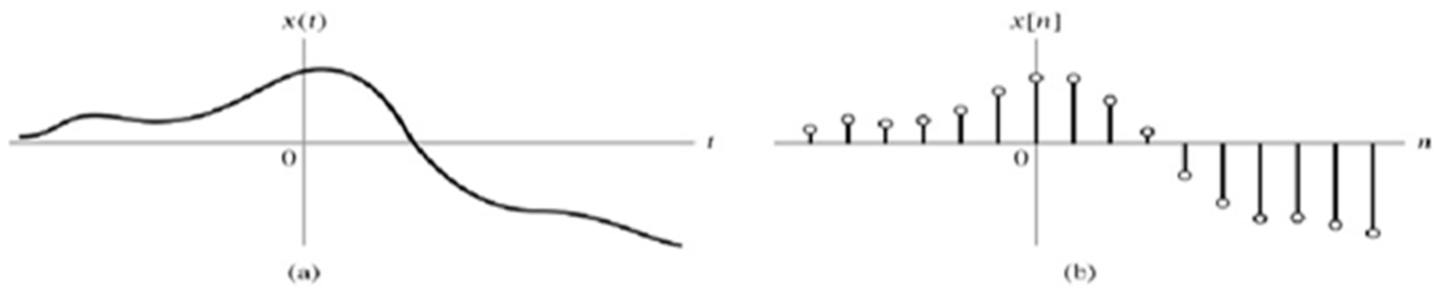


Figure
(a) Continuous-time signal $x(t)$. (b) Representation of $x(t)$ as a discrete-time signal $x[n]$.

For many cases, x[n] is obtained by sampling x(t) as:

$x[n] = x(nT)$, $n = 0, \pm 1, \pm 2, \ldots$

Analog and digital signals:

❖ When amplitude of CT signals varies continuously, it is called analog signal. In other words amplitude and time both are continuous for analog signal.

❖ When amplitude of DT signal takes only finite values, it is called digital signal. In other words amplitude and time are discrete for digital signal.

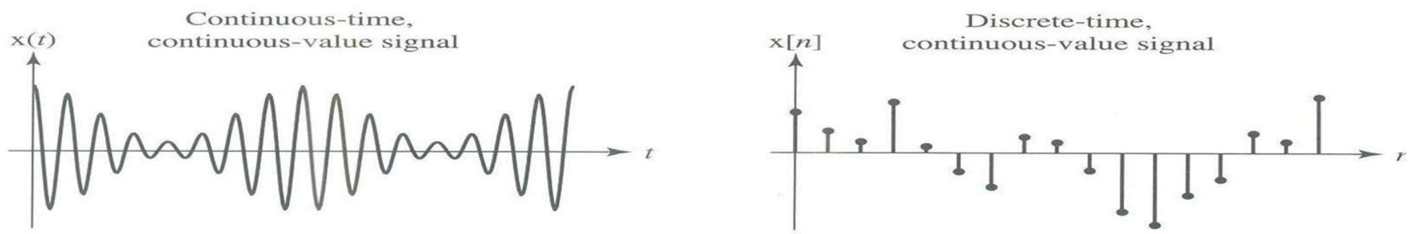


Figure
Examples of continuous-time and discrete-time signals.

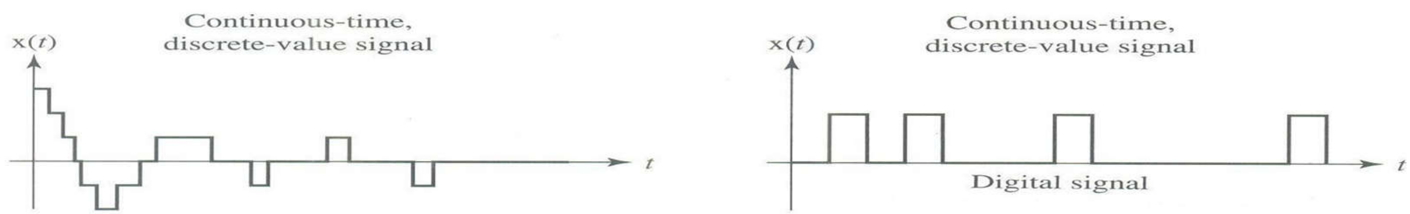


Figure
Examples of continuous-time and digital signals.

Periodic and Non- Periodic Signals

Definition: A signal is said to be periodic if it repeats at regular intervals. Non – periodic signal do not repeats at regular intervals.

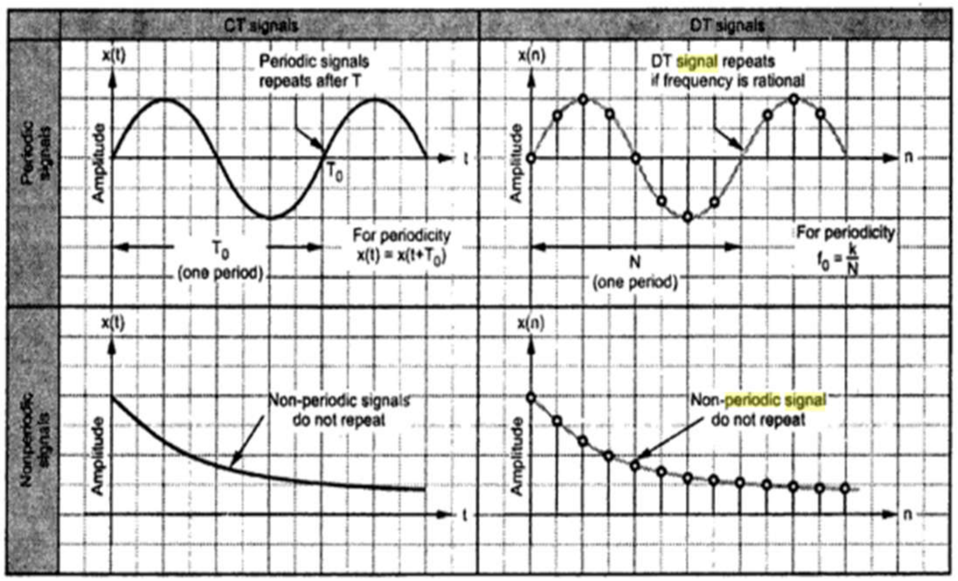


Fig (3): Example of periodic & non- periodic signals

Condition for periodicity of signal

$$x(t) = x(t + T_0)$$
$$x(n) = x(n + N)$$

Periodic and Non- Periodic Signals

Condition for periodicity of signal

- **CT signal:** if x(t) = x(t + T), then x(t) is periodic.

❖ Smallest T=Fundamental period

❖ Fundamental frequency fo = 1/To (Hz or cycles/second)

❖ Angular frequency: $\omega o = 2\pi$ /To (rad/seconds)

- **DT signal:** if x[n] = x[n + N], then x[n] is periodic.

❖ min(No): fundamental period

❖ Fo = 1/No (cycles/sample)

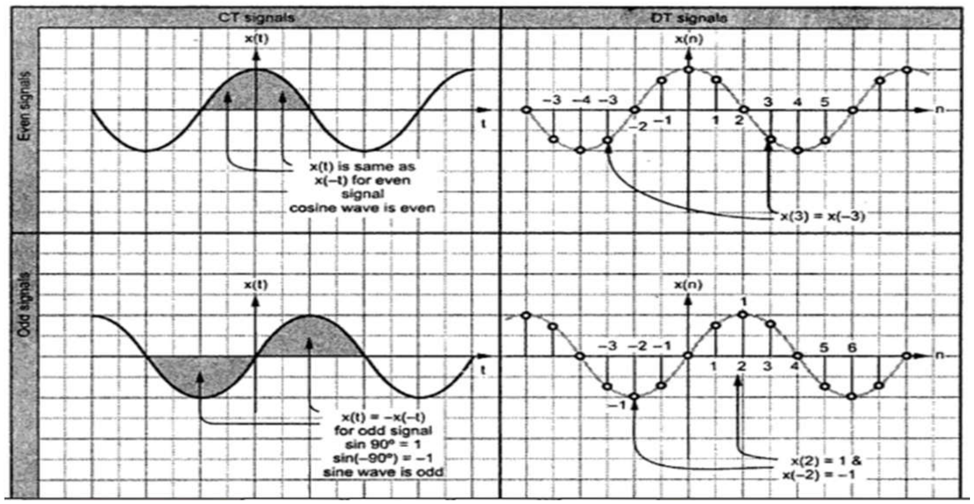
❖ $\Omega = 2\pi$ /N (rads/sample).

Even and Odd Signals

Definition of even signal: A signal is said to be even signal if inversion of time axis does not change the amplitude.

Definition of odd signal: A signal is said to be odd signal if inversion of time axis also inverts amplitude of the signal.

condition for signal to be even $\begin{cases} x(t) = x(-t) \\ x(n) = x(-n) \end{cases}$ condition for signal to be odd $\begin{cases} x(t) = -x(-t) \\ x(n) = -x(-n) \end{cases}$



Energy and power signals

Instantaneous power dissipation

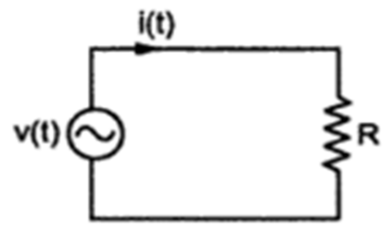


Fig (5)

For circuit of figure (5) , the Instantaneous power dissipated in load resistance "R" Will be given as,

$$p(t) = \frac{v^2(t)}{R} = i^2(t)R$$

Normalized power : it is power dissipated in load. Hence from Normalized power,

$$p(t) = v^2(t) = i^2(t)$$

Let $v(t) = i(t)$ **be denoted by** $x(t)$ **.**

Since power is the rate of energy, the total energy expended over the time interval $t_1 \le t \le t_2$ **is :**

Energy and power signals

$$E = \int_{t_1}^{t_2} p(t)dt = \int_{t_1}^{t_2} x(t)^2 dt$$

and the average power over this interval is:

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} p(t)dt = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} x(t)^2 dt$$

if $t_1 = -T \; and \; t_2 = T$ **then**

$$E = \int_{-T}^{T} x(t)^2 dt \quad and \; P = \frac{1}{2T} \int_{-T}^{T} x(t)^2 dt$$

Energy, $E = \int_{-\infty}^{\infty} |x(t)|^2 dt$ **for CT signal**

And, $E = \sum_{n=-\infty}^{n=\infty} |x(n)|^2$ **for DT signal**

Power, $P = \lim_{T\to\infty} \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} |x(t)|^2 dt$ **for CT signal**

And $P = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{-N}^{N} |x(n)|^2$ **for DT signal**

Energy signal: if $0 < E < \infty$
Power signal: if $0 < P < \infty$

Deterministic and random signals

Definition of deterministic signal : a deterministic signal can be completely represented by mathematical equation at any time.

Example:

Triangular wave, square pulse etc

Definition of random signal : a signal cannot be represented by mathematical equation is called random signal.

Example: noise generated in electronic components , transmission channels, etc.