1.2 CLASSIFICATION OF SIGNALS

CONTINUOUS TIME AND DISCRETE TIME SIGNAL

Continuous time signal:

A signal that is defined for every instants of time is known as continuous time signal. Continuous time signals are continuous in amplitude and continuous in time. It is denoted by x(t) and shown in Figure 1.2.1

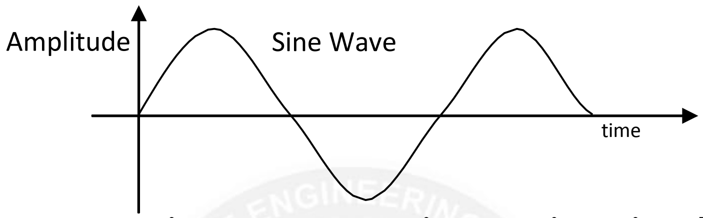


Figure 1.2.1 Continuous time signal

[https://drive.google.com/file/d/1baseARsD-geFLoR-QrEbV5hVsYKKLzGM/view]

Discrete time signal:

A signal that is defined for discrete instants of time is known as discrete time signal. Discrete time signals are continuous in amplitude and discrete in time. It is also obtained by sampling a continuous time signal. It is denoted by x(n) and shown in Figure 1.2.2

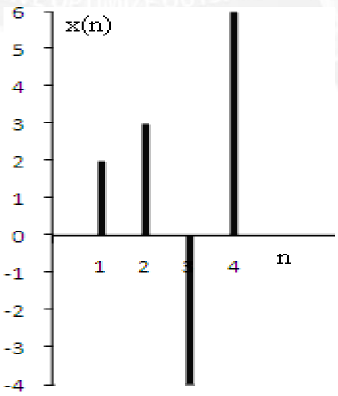


Figure 1.2.2 Discrete time signal

[https://drive.google.com/file/d/1baseARsD-geFLoR-QrEbV5hVsYKKLzGM/view]

EVEN (SYMMETRIC) AND ODD (ANTI-SYMMETRIC) SIGNAL

Continuous domain:

Even signal:

A signal that exhibits symmetry with respect to t=0 is called even signal

Even signal satisfies the condition $x(t) = x(-t)$

Odd signal:

A signal that exhibits anti-symmetry with respect to t=0 is called odd signal

Odd signal satisfies the condition $x(t) = -x(-t)$

Even part $\boldsymbol{x_e(t)}$ and Odd part $\boldsymbol{x_0(t)}$ of continuous time signal $\boldsymbol{x(t)}$:

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

Odd component of $x(t)$ is $x_o(t) = \frac{1}{2}[x(t) - x(-t)]$

Discrete domain:

Even signal:

A signal that exhibits symmetry with respect to n=0 is called even signal

Even signal satisfies the condition $x(n) = x(-n)$.

Odd signal:

A signal that exhibits anti-symmetry with respect to n=0 is called odd signal

Odd signal satisfies the condition $x(n) = -x(-n)$.

Even part $\boldsymbol{x_e(n)}$ and Odd part $\boldsymbol{x_0(n)}$ of discrete time signal $\boldsymbol{x(n)}$:

Even component of $x(n)$ is $x_e(n) = \frac{1}{2}[x(n) + x(-n)]$

Odd component of $x(n)$ is $x_o(n) = \frac{1}{2}[x(n) - x(-n)]$

PERIODIC AND APERIODIC SIGNAL

Periodic signal:

A signal is said to periodic if it repeats again and again over a certain period of time.

Aperiodic signal:

A signal that does not repeat at a definite interval of time is called aperiodic signal.

Continuous domain:

A Continuous time signal is said to periodic if it satisfies the condition

$$x(t) = x(t + T) \text{ where } T \text{ is fundamental time period}$$

If the above condition is not satisfied, then the signal is said to be aperiodic

Fundamental time period

$$T = 2\pi/\Omega$$

where Ω is fundamental angular frequency in rad/sec

Discrete domain:

A Discrete time signal is said to periodic if it satisfies the condition

$$x(n) = x(n + N) \text{ where } N \text{ is fundamental time period}$$

If the above condition is not satisfied, then the signal is said to be aperiodic

Fundamental time period

$$N = 2\pi m/\omega$$

where ω is fundamental angular frequency in rad/sec,

m is smallest positive integer that makes N as positive integer.

ENERGY AND POWER SIGNAL

Energy signal:

The signal which has finite energy and zero average power is called energy signal. The non-periodic signals like exponential signals will have constant energy and so non periodic signals are energy signals.

i.e., For energy signal, $0 < E < \infty$ *and* $P = 0$

For Continuous time signals,

$$Energy\ E = \lim_{T \to \infty} \int_{-T}^{T} |x(t)|^2 dt$$

For Discrete time signals,

$$Energy\ E = \lim_{N\to\infty} \sum_{n=-N}^{N} |x(n)|^2$$

Power signal:

The signal which has finite average power and infinite energy is called power signal. The periodic signals like sinusoidal complex exponential signals will have constant power and so periodic signals are power signals.

i.e., For power signal, $0 < P < \infty \quad and \quad E = \infty$

For Continuous time signals,

$$Average\ power\ P = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 dt$$

For Discrete time signals,

$$Average\ power\ P = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} |x(n)|^2$$

DETERMINISTIC AND RANDOM SIGNALS

Deterministic signal:

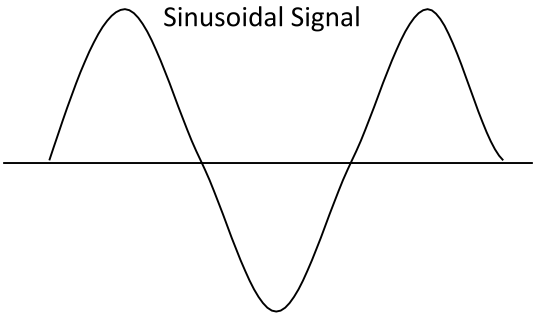
A signal is said to be deterministic if there is no uncertainty over the signal at any instant of time i.e., its instantaneous value can be predicted. It can be represented by mathematical equation.

Example: sinusoidal signal

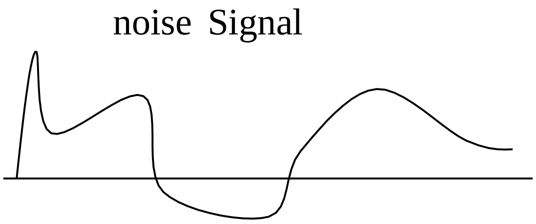
Random signal (Non-Deterministic signal):

A signal is said to be random if there is uncertainty over the signal at any instant of time i.e., its instantaneous value cannot be predicted. It cannot be represented by mathematical equation.

Example: noise signal



Deterministic signal



Random signal

CAUSAL AND NON-CAUSAL SIGNAL

Continuous domain:

Causal signal:

A signal is said to be causal if it is defined for $t \geq 0$.

$$i.e., \quad x(t) = 0 \quad for\ t < 0$$

Non-causal signal:

A signal is said to be non-causal, if it is defined for $t < 0$ or for both $t < 0$ and $t \geq 0$

$$i.e., \quad x(t) \neq 0 \quad for\ t < 0$$

When a non-causal signal is defined only for $t<0$, it is called as anti-causal signal

Discrete domain:

Causal signal:

A signal is said to be causal, if it is defined for $n \geq 0$.

$$i.e., \quad x(n) = 0 \quad for\ n < 0$$

Non-causal signal:

A signal is said to be non-causal, if it is defined, for $n < 0$ or for both $n < 0$ $and\ n \geq 0$

$$i.e., \quad x(n) \neq 0 \quad for\ n < 0$$

When a non-causal signal is defined only for $n<0$, it is called as anti-causal signal.