



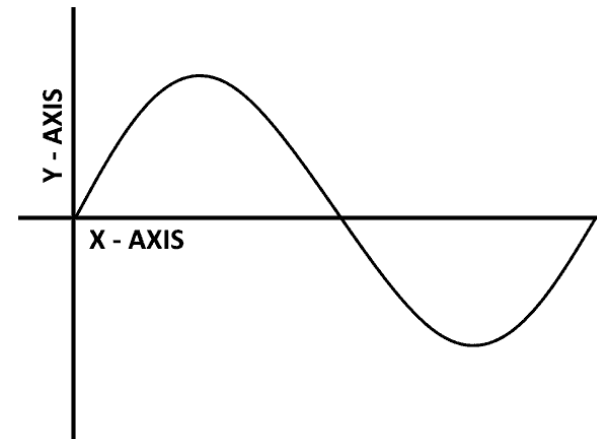
Introduction to Signals

22AIE211 Introduction To Communication & IoT

Signals

- To be transmitted, data must be transformed to electromagnetic signals
- A Signal is a function that conveys information about a phenomenon.
- Signal is defined as any physical or virtual quantity that varies with time or space or any other independent variable or variables.

Graphically, the **independent variable** is represented along the **horizontal axis** or x-axis and the **dependent variable** along the **vertical axis** or y-axis.



- examples of signals : audio, video, speech, image, sonar, radar etc.
- Noise is also a signal, but the information conveyed by noise is unwanted hence it is considered as undesirable

Examples of signals

- Naturally occurring signals can be converted to electronic signals by various sensors (a device that produces an output signal for the purpose of detecting a physical phenomenon)

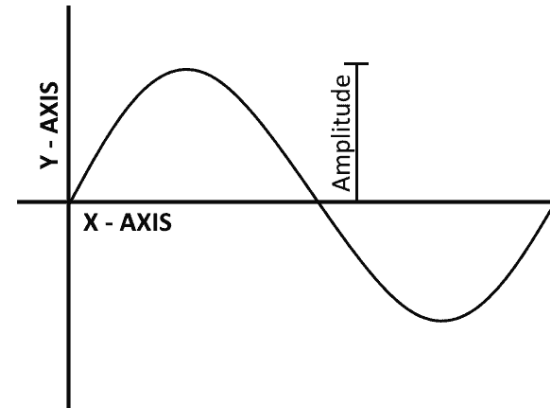
Examples

- [Motion](#). The motion of an object can be considered to be a signal and can be monitored by various sensors to provide electrical signals. For example, radar can provide an electromagnetic signal for following aircraft motion. A motion signal is one-dimensional (time),
- [Sound](#). a sound is a vibration of a medium (such as air). A sound signal is converted to an electrical signal by a microphone, generating a voltage signal as an analog of the sound signal.
- [Images](#). A picture or image consists of a brightness or color signal, a function of a two-dimensional location. It can be converted to voltage or current waveforms using devices such as the charge-coupled device.
- [Videos](#). A video signal is a sequence of images. A point in a video is identified by its two-dimensional position in the image and by the time at which it occurs, so a video signal has a three-dimensional domain.

Characteristics of Signals

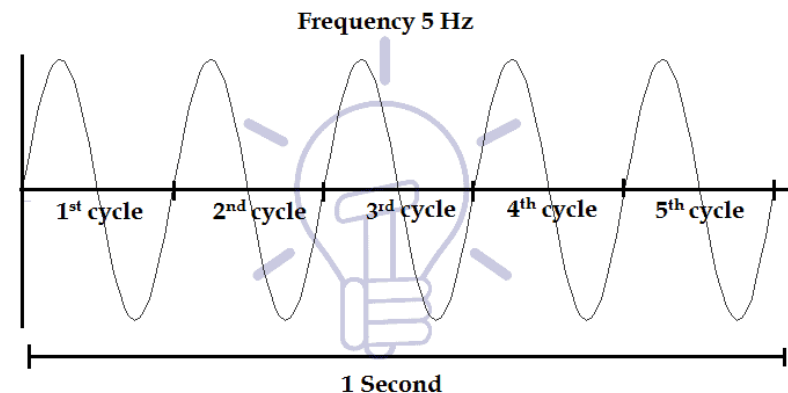
- **Amplitude**

- the maximum displacement of wave (current or voltage) from the time axis.
- It determines the strength of a signal.



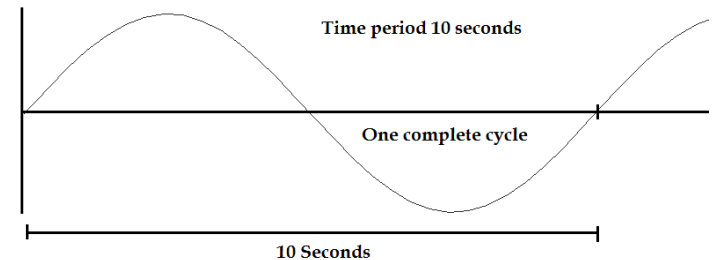
- **Frequency**

- Frequency is the rate of repetitions of a signal's waveform in a second.
- Periodic signals repeat its cycle after some time.
- The number of cycles in a second is known as **Frequency**.
- The unit of Frequency is **hertz (Hz)**
- **one hertz** is equal to **one cycle** per second.



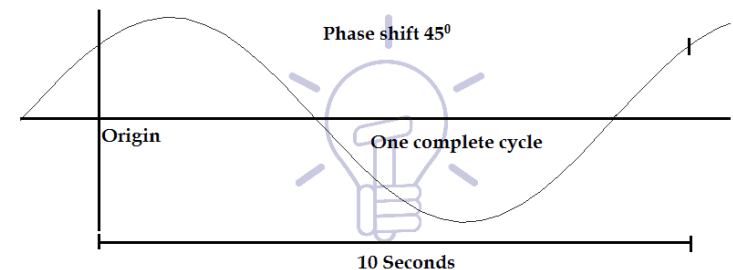
- **Time period**

- the time taken by a signal to complete one full cycle.
- The unit is **Second**.
- Time period, $T=1/F$ (F is the frequency)
- Example: a sine wave of time period **10 sec** will complete its **one full cycle** in **10 seconds**.



- **Phase Shift**

- It is the **shift** or **offset** in its origin or starting point.
- The phase shift can be **lagging** or **leading**.
- the **original** sinusoidal signals have **0°** degree phase and start at 0 amplitude but an offset in phase will shift its starting amplitude to other than 0.
- An example of **45°** phase shift is shown in figure. The signal remains the same but its origin is shifted to **45°**. The phase shift can be from **0° to 360°** in **degrees** or **0 to 2π** in **radians**. 360° degree or 2π radians is one complete period.



Signal Operations

- **Amplification**

- process in which amplitude or strength of a signal is increased.
- Amplifier is used to perform amplification.
- used for effective transmission of a signal because intensity of a signal decreases during transmission, so to regain that amplitude amplification is required.

- **Attenuation**

- process in which there is decrease in amplitude or strength of a signal.
- During transmission, a signal may be subjected to various disturbances like noise, echo or dispersion which results in decrease in amplitude and thus, attenuation takes place.

- **Modulation**

- technique which is performed on a signal in which various characteristics of a signal is changed so that it could be transmitted to a longer distance without any loss of information which is to be carried by a signal.

- **Encoding**

- technique in which a special code is applied on any signal's information, and it gets converted to a particular format so as to shield it from noise and distortion and to provide privacy and security during transmission of a signal.

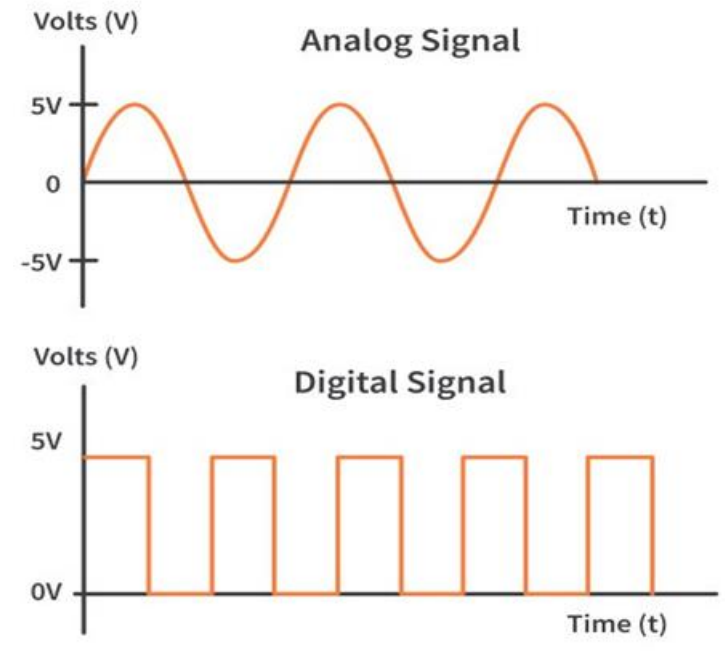
- **Decoding**

- process in which encoded signal is converted back into its original form.
- provide receiver the original data which was transmitted by the sender.

Classification of Signals

Analog Vs. Digital Signal

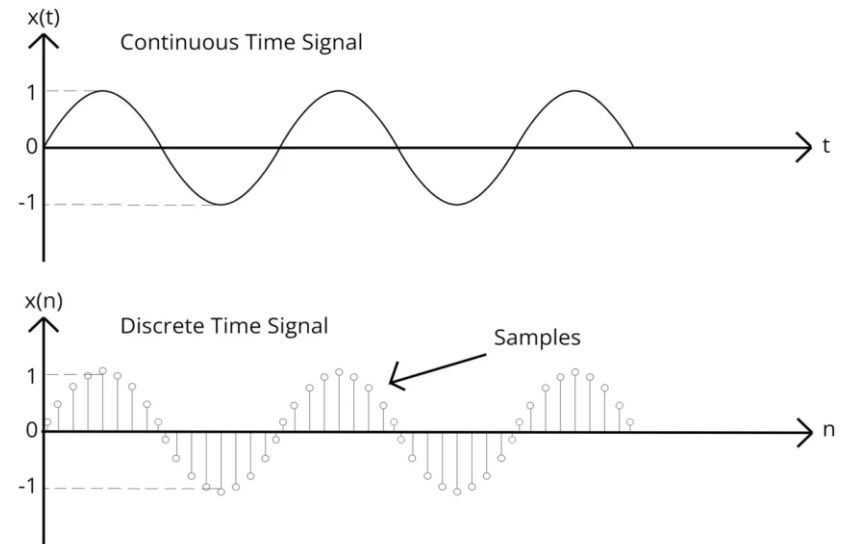
- The amplitude of an **analog signal** can have **any value** (including fractions) at any point in time (analog signal have **infinite values**).
- **digital signal's** amplitude can only have **finite** and **discrete** values.
- The **special case** of Digital signal having **two discrete** values is known as **Binary signal**.
- Analog signal is converted into Digital signal using **A to D converter (ADC)**.



Classification of Signals

Continuous-Time And Discrete-Time Signal

- A **continuous time** signal is a signal whose value (amplitude) exists for **every fraction** of time t .
- A **discrete time** signal exists only for a **discrete value** of time t .
- there is **no limitation** on the **amplitude** of the signal



Classification of Signals

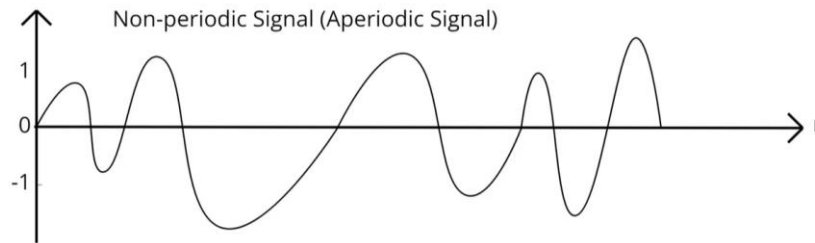
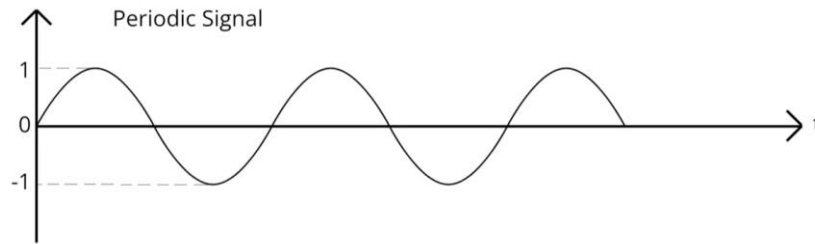
Periodic and Aperiodic Signals

- **Periodic Signals:**

- These signals repeat their pattern at regular intervals over time.
- Examples : sine waves, square waves, and periodic sequences.
- The mathematical expression for periodic signal $g(t)$ is:

$$g(t) = g(t + T_0) \quad \text{for all } t$$

T_0 is the Time period of signal $g(t)$.



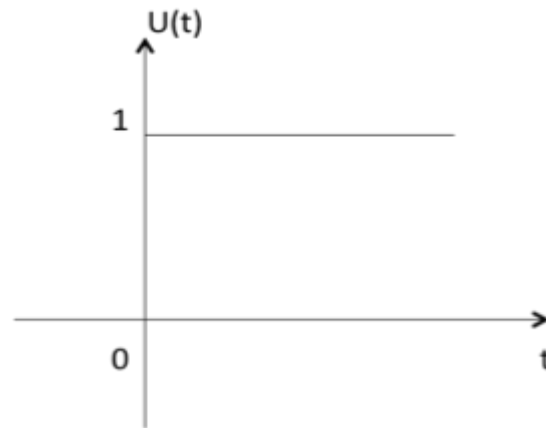
- **Aperiodic Signals**

- The **aperiodic** or **non-periodic** signal is a signal which does **not repeat** itself after a specific time. These signals have **no repetitions** of any pattern.
- Examples : impulse signals, transient signals

Some Elementary signals

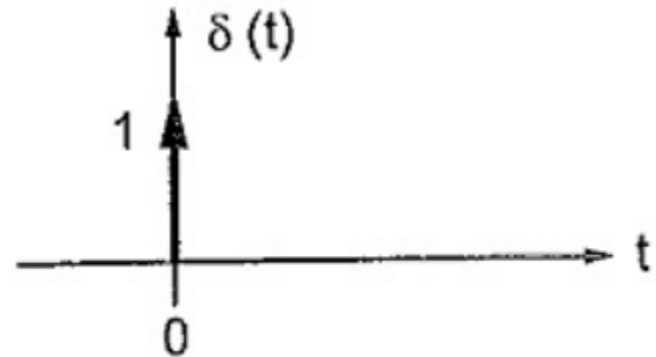
- Unit Step Signal, $u(t)$

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



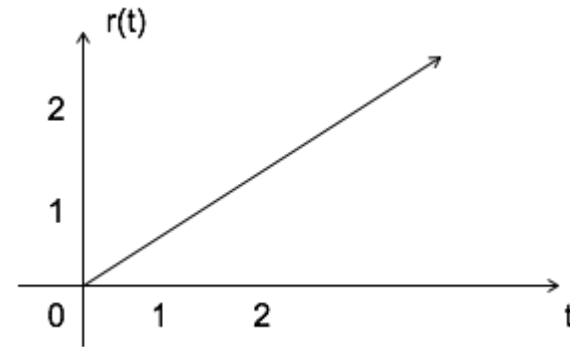
- Unit Impulse Function, $\delta(t)$

$$\delta(t) = \begin{cases} 1 & t = 0 \\ 0 & t \neq 0 \end{cases}$$



- Ramp Signal, $r(t)$

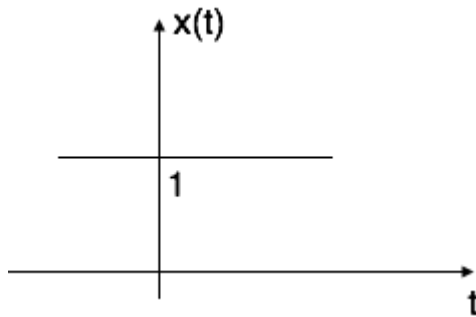
$$r(t) = \begin{cases} t & t \geq 0 \\ 0 & t < 0 \end{cases}$$



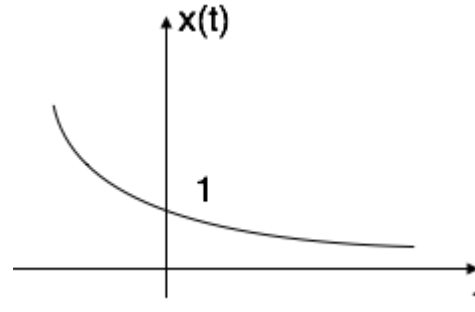
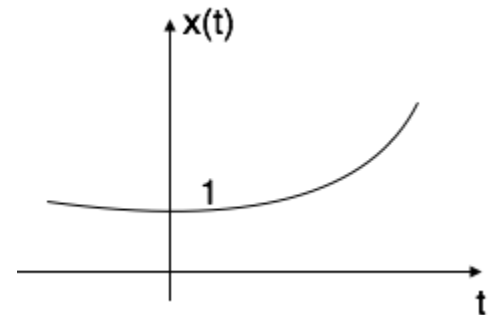
- Exponential Signal

$$x(t) = e^{\alpha t}.$$

Case i: if $\alpha = 0 \rightarrow x(t) = e^0 = 1$



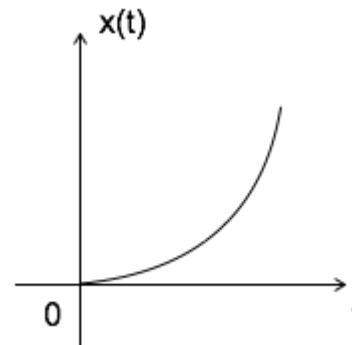
Case iii: if $\alpha > 0$ i.e. +ve then $x(t) = e^{\alpha t}$. The shape is called raising exponential.



Case ii: if $\alpha < 0$ i.e. -ve then $x(t) = e^{-\alpha t}$. The shape is called decaying exponential.

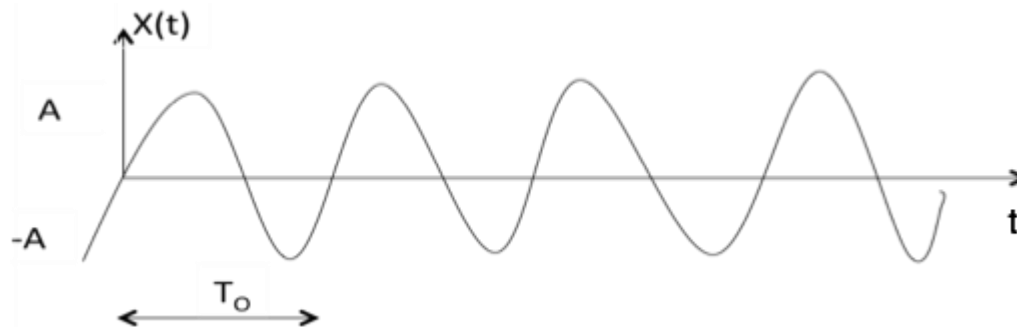
- Parabolic Signal

$$x(t) = \begin{cases} t^2/2 & t \geq 0 \\ 0 & t < 0 \end{cases}$$



- Sinusoidal Signal

$$x(t) = A \cos(w_0 t \pm \phi) \text{ or } A \sin(w_0 t \pm \phi) \quad \text{Where } T_0 = \frac{2\pi}{w_0}$$



Summary

- Signals
- Characteristics
- Signal Operations
- Classification
- Elementary signals