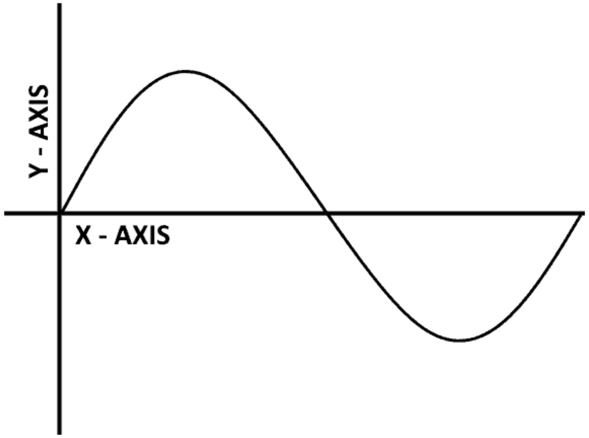
Introduction to Signals

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

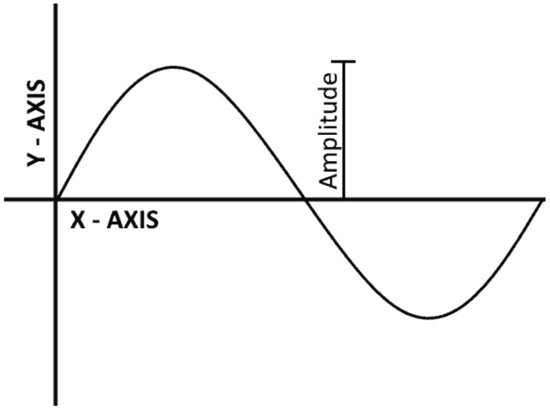
- Naturally occurring signals can be converted to electronic signals by various sensors (a device that produces an output signal for the purpose of detecting a physical phenomenon)

Examples

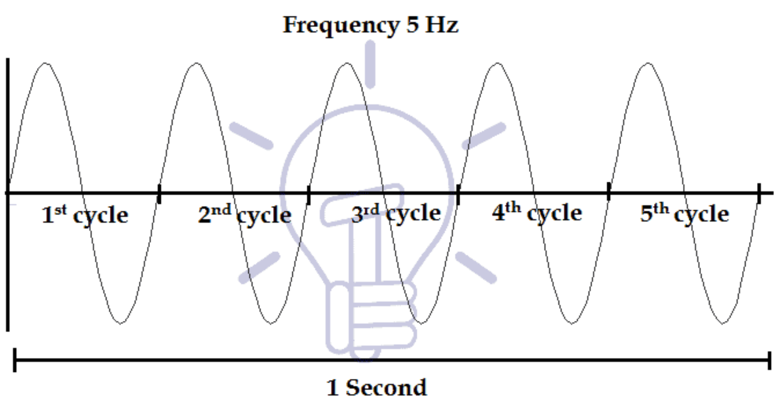
- *Motion*. The motion of an object can be considered to be a signal and can be monitored by various sensors to provide electrical signals. For example, radar can provide an electromagnetic signal for following aircraft motion. A motion signal is one-dimensional (time),
- *Sound*. a sound is a vibration 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

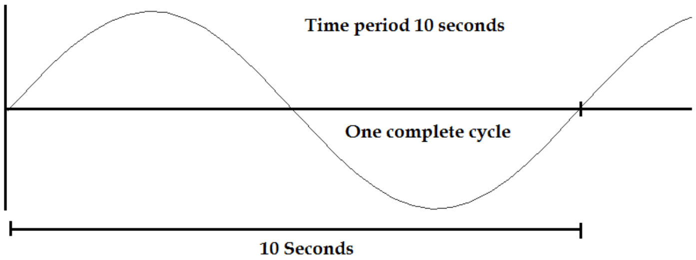
- **Amplitude**
  - the maximum displacement of wave (current or voltage) from the time axis.
  - It determines the strength of a signal.



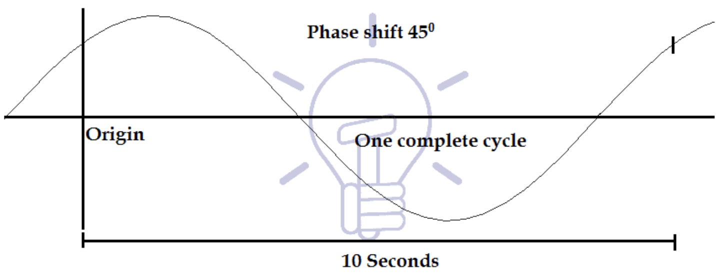
- **Frequency**
  - Frequency is the rate of repetitions of a signal's waveform in a second.
  - Periodic signals repeat its cycle after some time.
  - The number of cycles in a second is known as **Frequency**.
  - The unit of Frequency is **hertz (Hz)**
  - **one hertz** is equal to **one cycle** per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



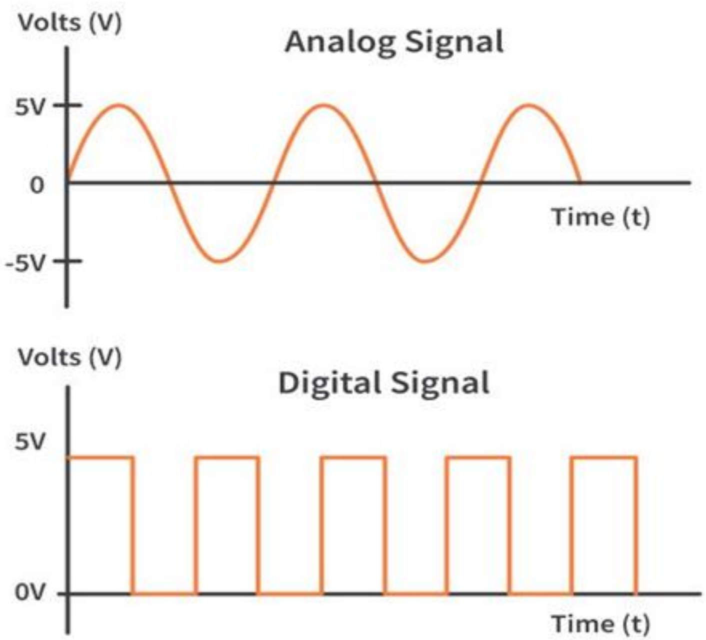
Signal Operations

- **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

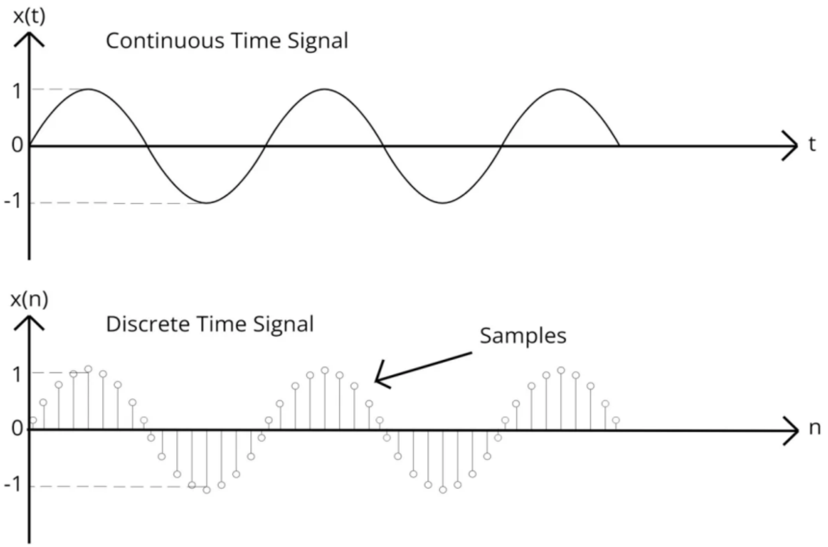
- The amplitude of an **analog signal** can have **any value** (including fractions) at any point in time (analog signal have **infinite values).**
- **digital signal's** amplitude can only have **finite** and **discrete** values.
- The **special case** of Digital signal having **two discrete** values 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



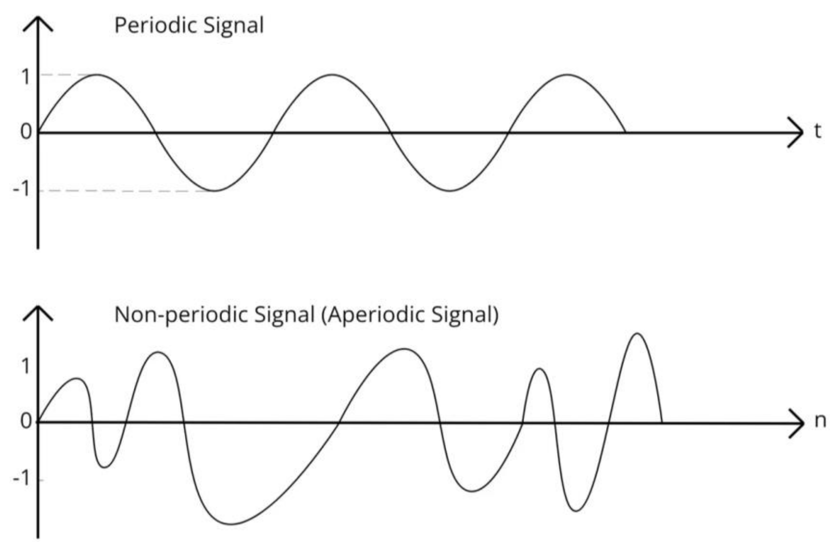
Classification of Signals

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:

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

T_o is the Time period of signal **g(t)**.

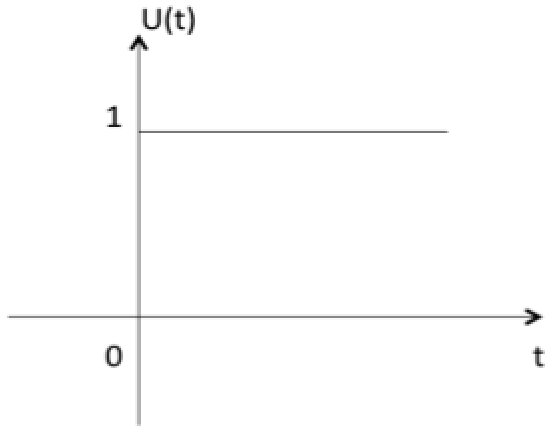


- **Aperiodic Signals**
  - The **aperiodic** or **non-periodic** signal is a signal which does **not repeat** itself after a specific time. These signals have **no repetitions** of any pattern.
  - Examples : impulse signals, transient signals

Some Elementary signals

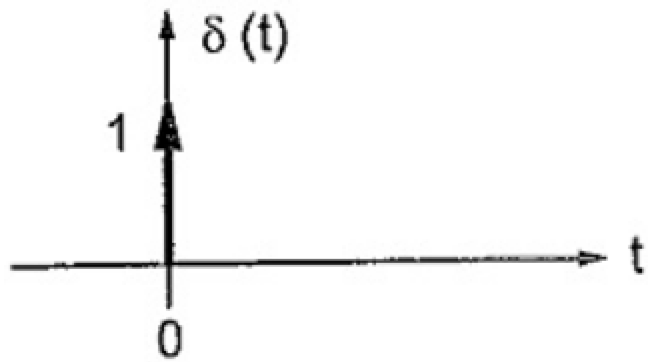
- Unit Step Signal, u(t)

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



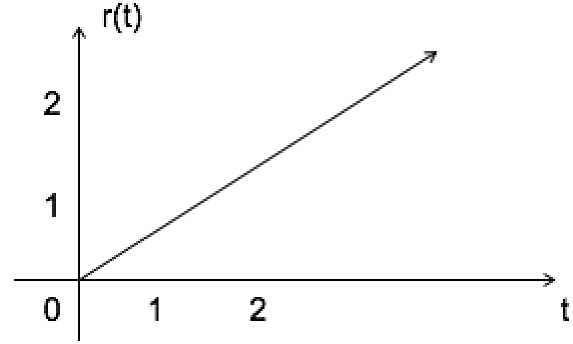
- Unit Impulse Function, δ(t)

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



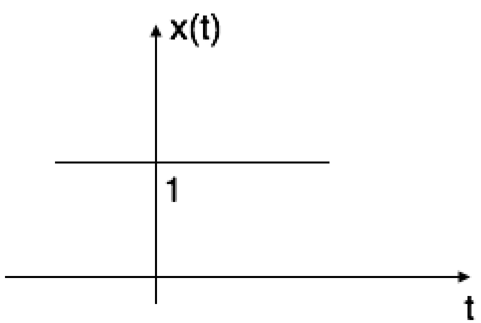
- # Ramp Signal, r(t)

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

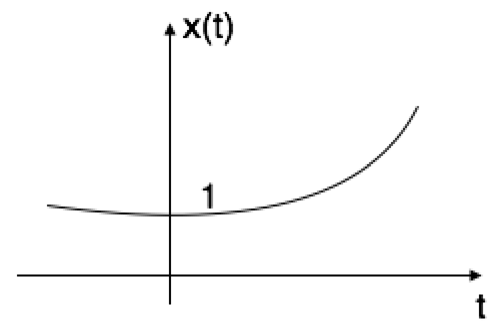


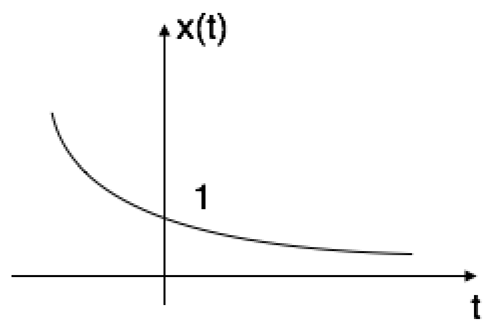
- # Exponential Signal $x(t) = e^{\alpha t}$.

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.

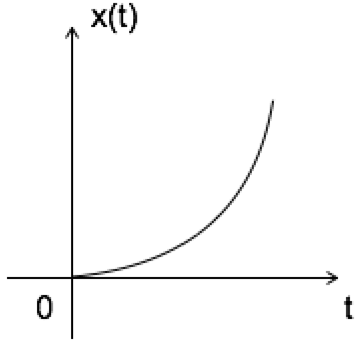




Case ii: if $\alpha < 0$ i.e. -ve then $x(t) = e^{-\alpha t}$. The shape is called decaying exponential.

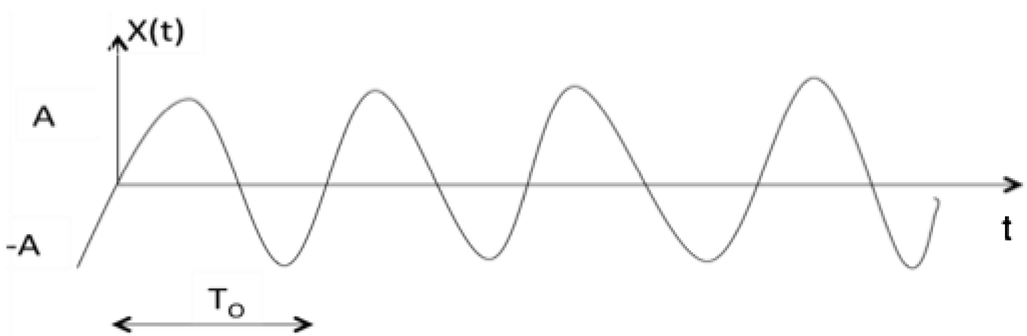
- Parabolic Signal

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



- Sinusoidal Signal

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



Nyquist Sampling Theorem

- Established the principle of using sampling to convert a continuous analog signal to a digital signal.
- Ensures the accuracy of the digital representation of analog signals.
- Explains the relationship between the sample rate and the frequency of the measured signal. i.e. the sampling rate must be twice the highest frequency in the signal.

$$\boxed{f_S \geq 2 f_m}$$

- It is used to reconstruct any signal from samples.

[A sample is basically the number of times an analog signal is measured per value of time (typically seconds)]

Summary

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