Lecture (3)
" Data Communication”

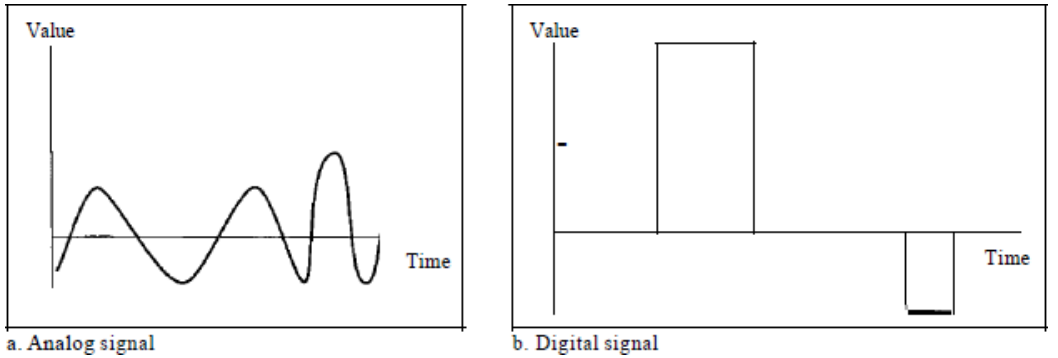
Data and Signals

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ANALOG AND DIGITAL SIGNALS

Definition:

- **Analog Signals**: Continuous signals that vary smoothly over time.
- **Digital Signals**: Discrete signals represented in binary (0s and 1s).



a. Analog signal

b. Digital signal

Examples:

- Analog: Sound waves, temperature variations.
- Digital: Computer data, digital audio.

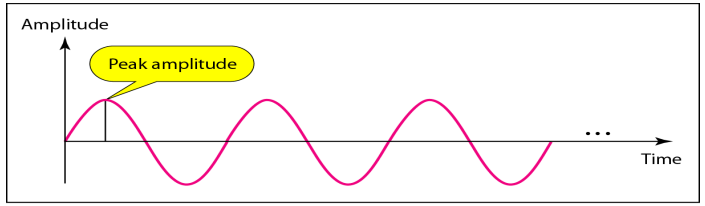
CHARACTERISTICS OF ANALOG SIGNAL

Key Characteristics:

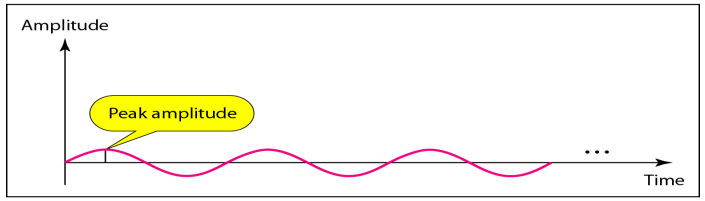
- **Peak Amplitude :** Maximum value or amplitude of the signal.

  For electric signals, peak amplitude is normally measured in *volts*

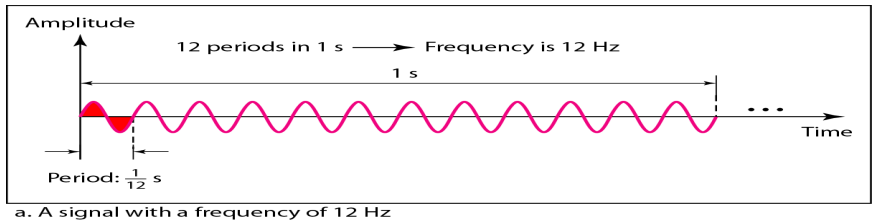
- **Frequency :** Number of cycles per second (Hz), which is cycle per second.
- **Phase :** Position of the waveform relative to time at time 0.



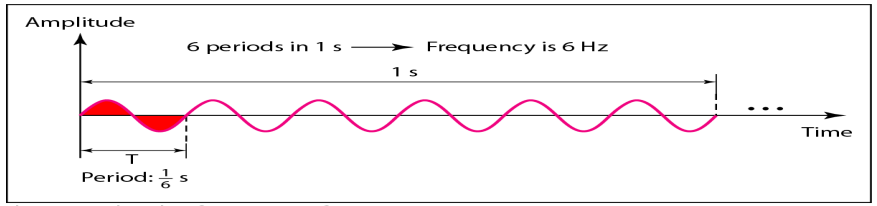
a. A signal with high peak amplitude



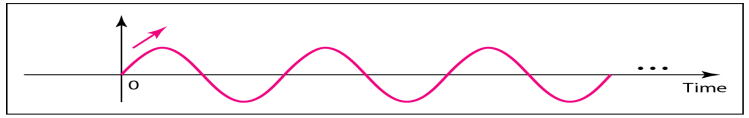
b. A signal with low peak amplitude



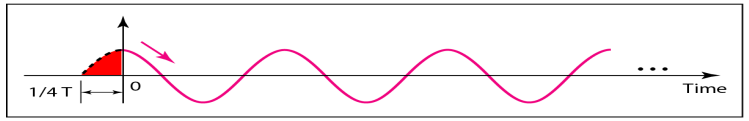
a. A signal with a frequency of 12 Hz



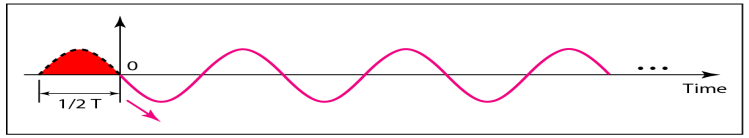
b. A signal with a frequency of 6 Hz



a. 0 degrees



b. 90 degrees



c. 180 degrees

FREQUENCY & PERIOD RELATION

- **Formula:**
  - Frequency (f) = 1 / Period (T)
- **Example:**
  - If a signal has a frequency of 2 Hz, its period is 0.5 seconds.

WAVELENGTH

- **Definition:**
  - Distance over which the wave's shape repeats.
- **Formula:**
  - Wavelength (λ) = Speed (v) / Frequency (f)
- **Example:**
  - In radio waves, longer wavelengths correspond to lower frequencies.

If a wave travels at a speed of 300 m/s and has a frequency of 60 Hz, the wavelength would be:

$$\lambda = \frac{300\,\mathrm{m/s}}{60\,\mathrm{Hz}} = 5\,\mathrm{m}$$

an example where a wave travels at a speed of =340 m/s (which is the speed of sound in air at room temperature) and has a frequency of f=680 Hz

Step 1: Use the formula for wavelength

$$\lambda = \frac{v}{f}$$

Step 2: Substitute the values

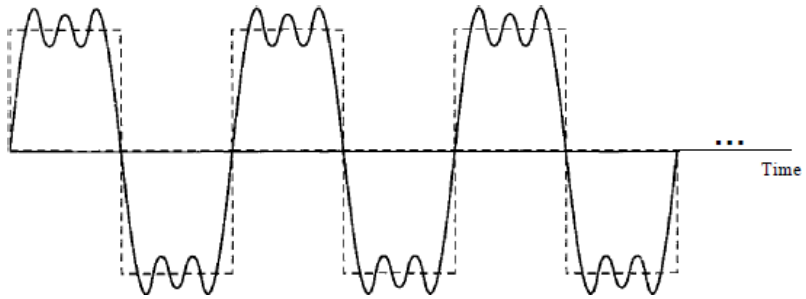
$$\lambda = \frac{340\,\mathrm{m/s}}{680\,\mathrm{Hz}}$$

Step 3: Calculate the wavelength

$$\lambda = \frac{340}{680} = 0.5\,\mathrm{m}$$

COMPOSITE ANALOG SIGNALS

- **Definition:** Signals that combine multiple simple analog signals.
- **Applications:** Used in broadcasting (e.g., TV signals that combine audio and video).
- **Example:** Musical notes combine various frequencies.

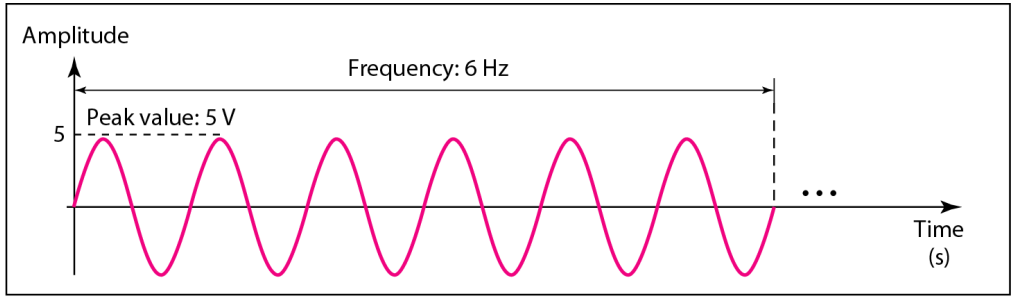


- **Analysis:** Can be analyzed using Fourier analysis to understand frequency components

TIMEAND FREQUENCY DOMAIN REPRESENTATION OF SIGNALS

Time Domain:

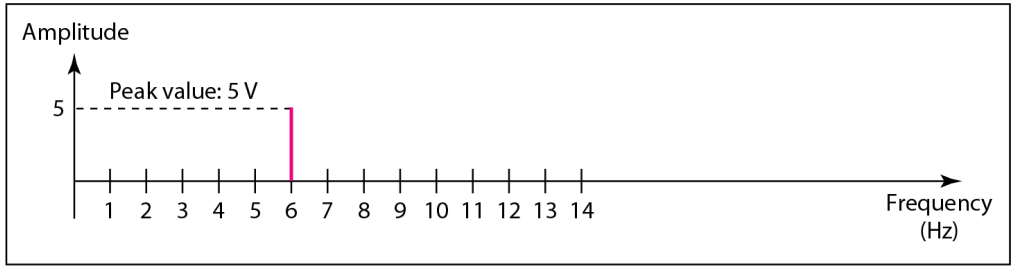
- Definition:Shows how a signal varies over time (amplitude vs.time).
- Importance:Provides insight into the signal's behavior at any moment.



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)

Frequency Domain:

- Definition:Shows the distribution of frequency components (amplitude vs. frequency).
- Tools:Utilizes FourierTransform to convert time-domain signals into frequency-domain.



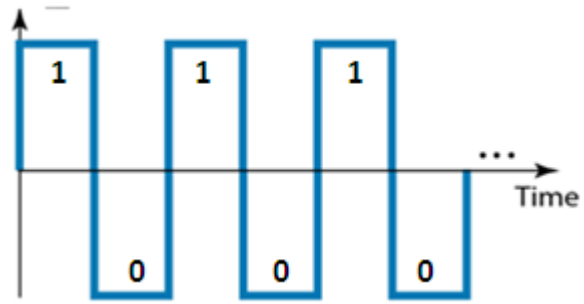
b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

PERIODIC & NON-PERIODIC SIGNALS

- **Periodic Signals:** Repeat at regular intervals.
  - Example:Sine wave.
- **Non-Periodic Signals:** Do not repeat regularly.
  - Example:Speech signal.

DIGITAL SIGNAL

Definition:-



- A digital is a signal that has discrete values.
- The signal will have value that is not continuous.
- **Example:** Digital audio files.

LEVEL

- Information in a digital signal can be represented in the form of voltage levels.
- Ex. In the signal shown below, a _1‘ is represented by a positive voltage and a _0‘ is represented by a Zero voltage.

CHARACTERISTICS OF DIGITAL SIGNAL

- **Levels :**Distinct values (high and low).
- **Bit Length or Bit Interval :**Time taken to send one bit.
- **Bit Rate :**Number of bits transmitted per second.

- **Example:**
- A bit rate of 1000 bps (bits per second).

CHARACTERISTICS OF A DIGITAL SIGNAL

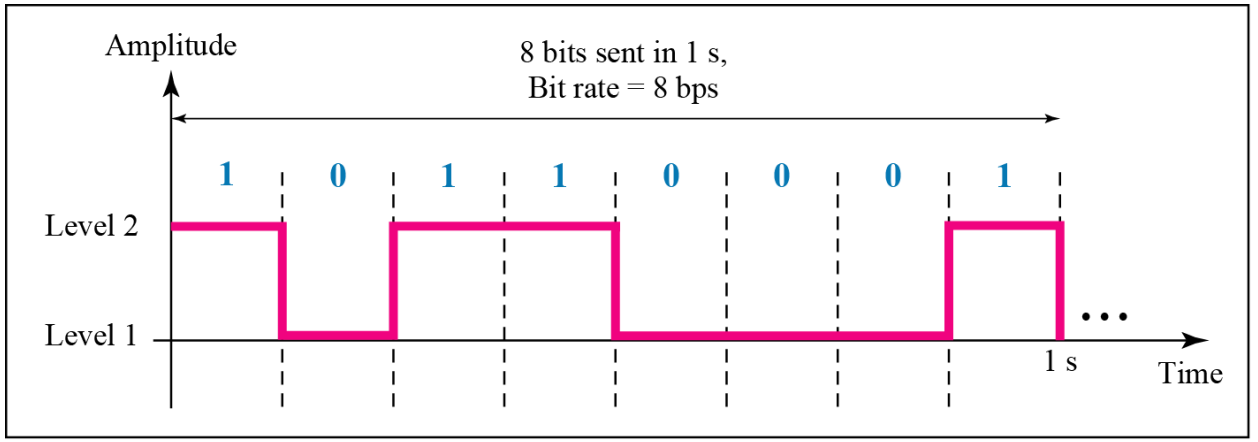
- **Discrete Levels**: Composed of distinct values (0s and 1s).
- **Noise Immunity**: More resilient to noise and distortion.
- **Limited Resolution**: Finite number of levels to represent values.
- **Ease of Processing**: Can be easily manipulated and compressed.

DIGITAL SIGNAL

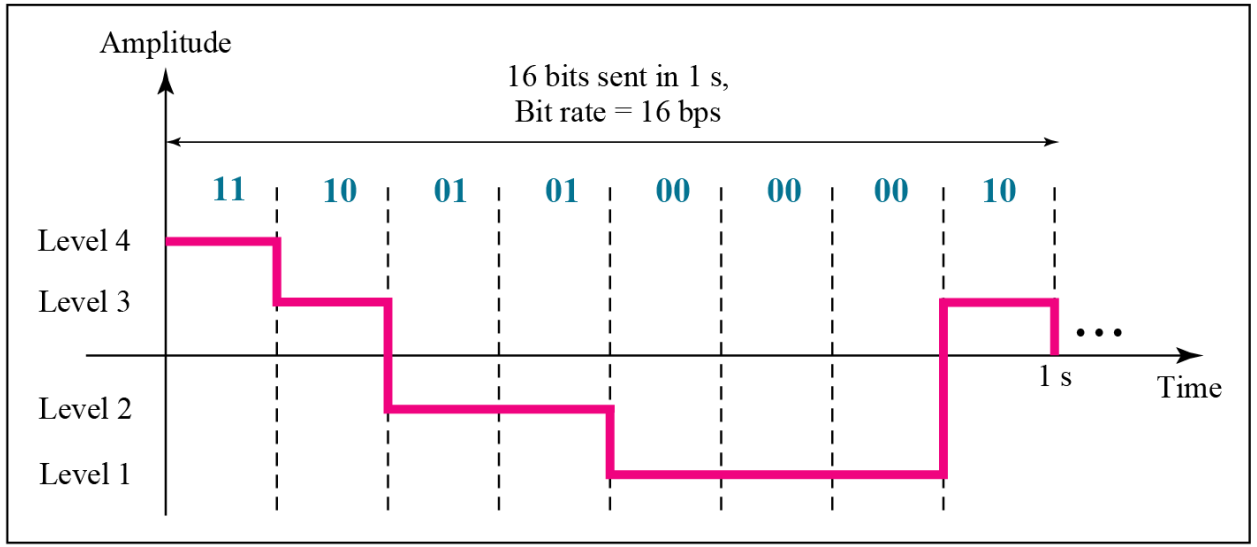
A digital signal can have more than two levels.

In this case, we can send more than I bit for each level.

Two digital signals: one with two signal levels and the other with four signal levels.



a. A digital signal with two levels

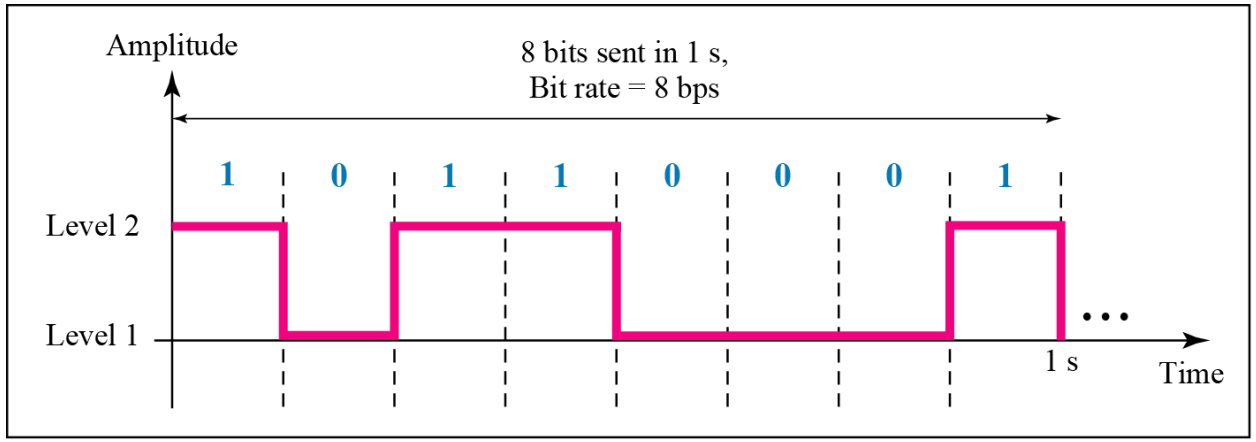


b. A digital signal with four levels

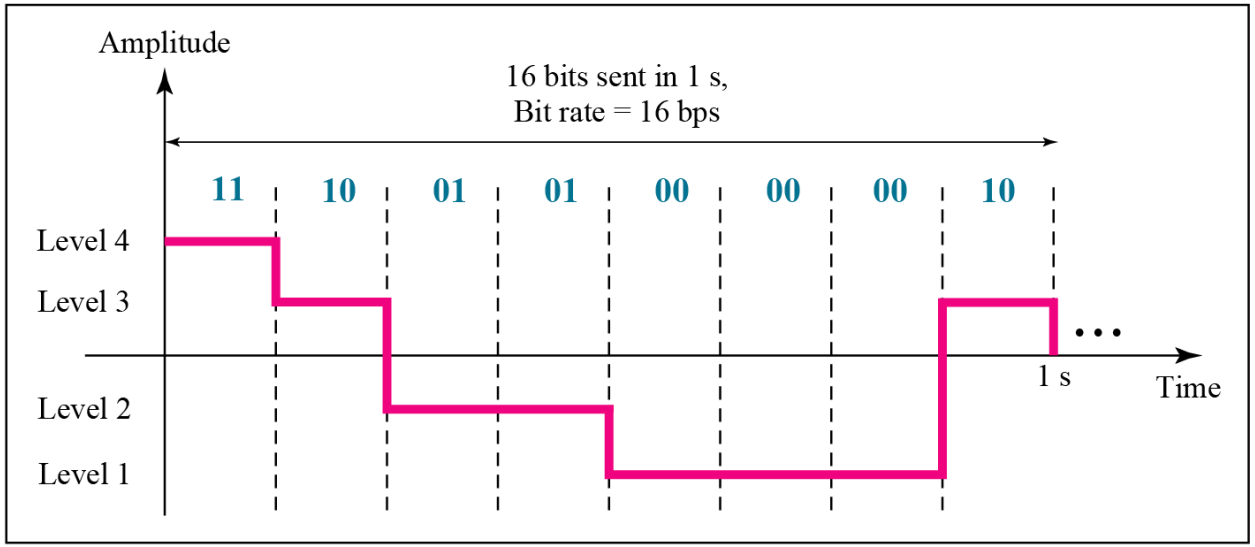
NUMBER OF BITS PER LEVEL

In general, if a signal has L levels

then, each level need $Log_2 L$ bits.



a. A digital signal with two levels



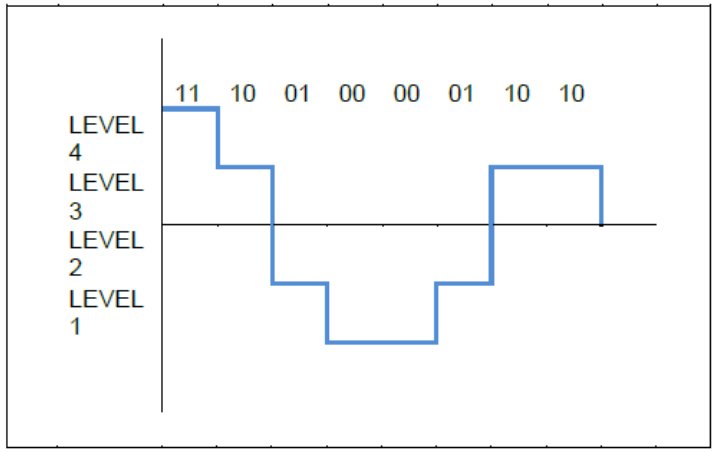
b. A digital signal with four levels

EXAMPLE I

Example: Consider a digital Signal with four levels, how many bits are required per level?

Answer: Number of bits per level = $Log_2L = Log_24 = 2$ Hence, 2 bits are required per level for a signal with four levels

Each signal level is represented by 2 bits.



EXAMPLE 2

A digital signal has eight levels. How many bits are needed per level? We calculate the number of bits from the formula

$$\text{Number of bits per level} = \log_2 8 = 3$$

Each signal level is represented by 3 bits.

WHAT IS BITRATE?

- **Definition**:
  - Bitrate is the amount of data processed per unit of time, typically measured in bits per second (bps).
- **Significance**:
  - Indicates the quality of audio or video files; higher bitrates usually mean better quality.

RELATIONSHIP BETWEEN BANDWIDTH AND BITRATE

- **Bandwidth vs. Bitrate**:
  - Bandwidth is the capacity of the channel,while bitrate is the actual data being transmitted.
- **Analogy**:
  - Think of bandwidth as the size of a pipe (maximum capacity) and bitrate as the flow of water (actual data).

TYPES OF BANDWIDTH

- **Theoretical Bandwidth**:
  - Maximum potential data transfer rate, often calculated based on the medium.
- **Effective Bandwidth**:
  - Actual data transfer rate considering overhead,network conditions, and protocols.
- **Use Cases**:
  - Video streaming,online gaming,and large file transfers require high bandwidth.

Question Of the Lecture!! Think!!

Briefly discuss the following?
You are downloading:
(a) A movie
(b) Attending an online class
(c) Playing an online game.

How do bit rate and bandwidth affect the quality and speed of these activities? Give a real-life example of each.

Thank you!