Politeknik Elektronika Negeri Surabaya

# Data and Signals

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Note

To be transmitted, data must be transformed to electromagnetic signals.

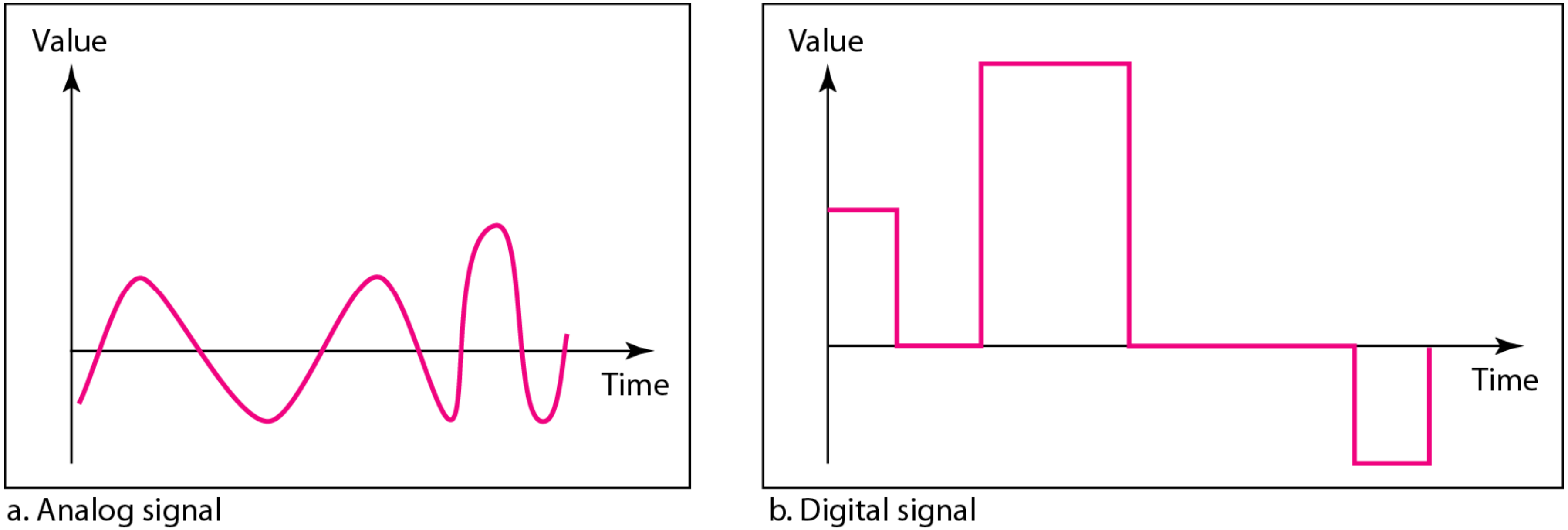
# ANALOG AND DIGITAL

- Data can be **analog** or **digital**. The term **analog data** refers to information that is continuous; **digital data** refers to information that has discrete states. Analog data take on continuous values. Digital data take on discrete values.

- **Topics discussed in this section:**

- Analog and Digital Data
- Analog and Digital Signals
- Periodic and Nonperiodic Signals

# Comparison of analog and digital signals



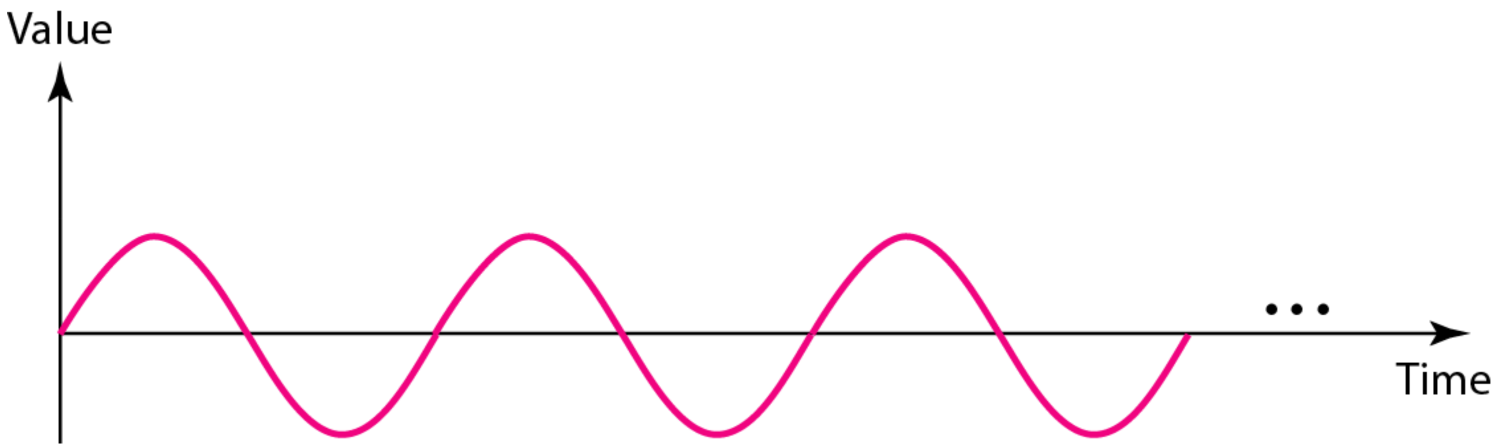
# PERIODIC ANALOG SIGNALS

- In data communications, we commonly use periodic analog signals and non-periodic digital signals. Periodic analog signals can be classified as simple or composite. A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals. A composite periodic analog signal is composed of multiple sine waves.

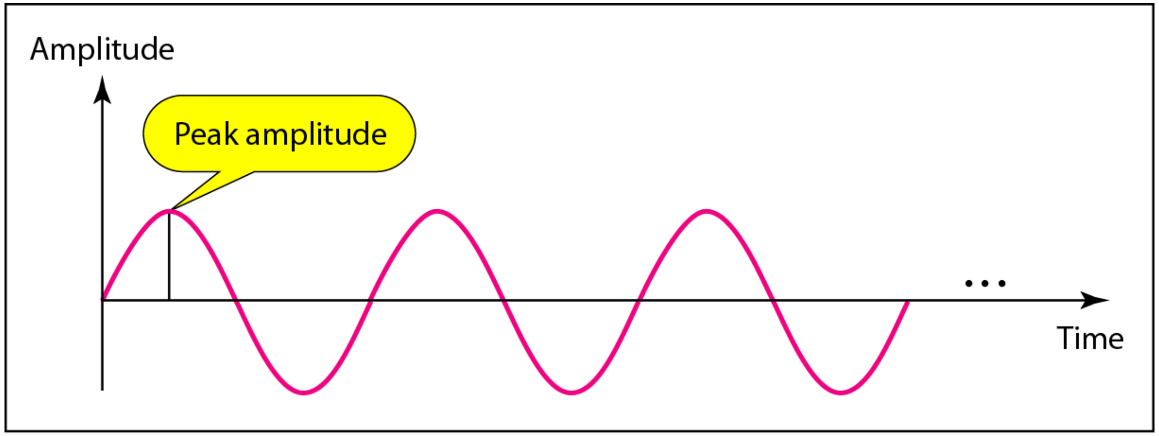
- **Topics discussed in this section:**

- Sine Wave
- Wavelength
- Time and Frequency Domain
- Composite Signals
- Bandwidth

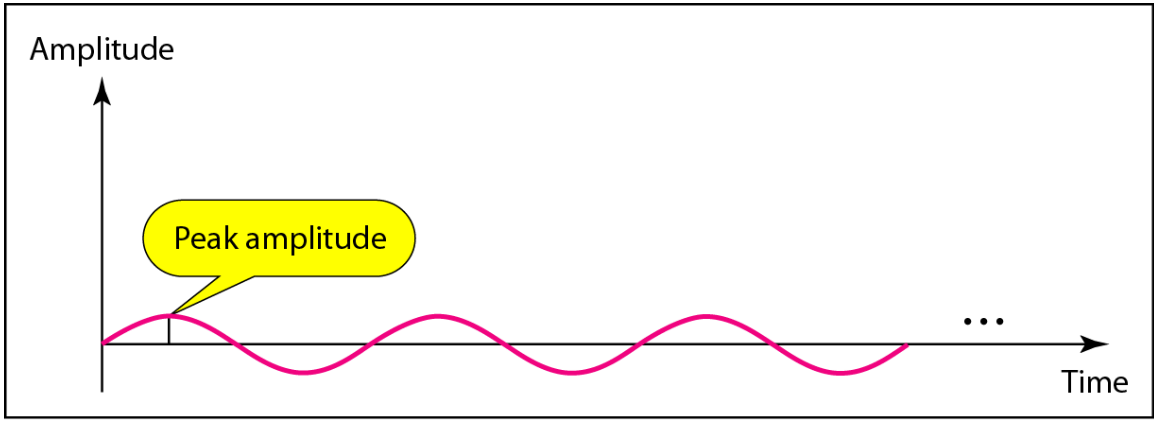
# A sine wave



# Two signals with the same phase and frequency, but different amplitudes




a. A signal with high peak amplitude



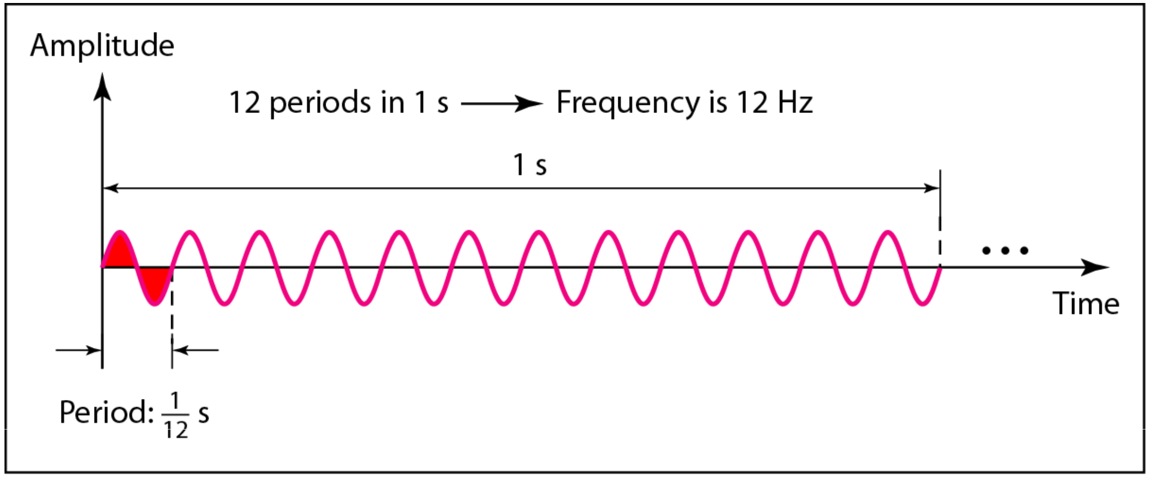

b. A signal with low peak amplitude

Note

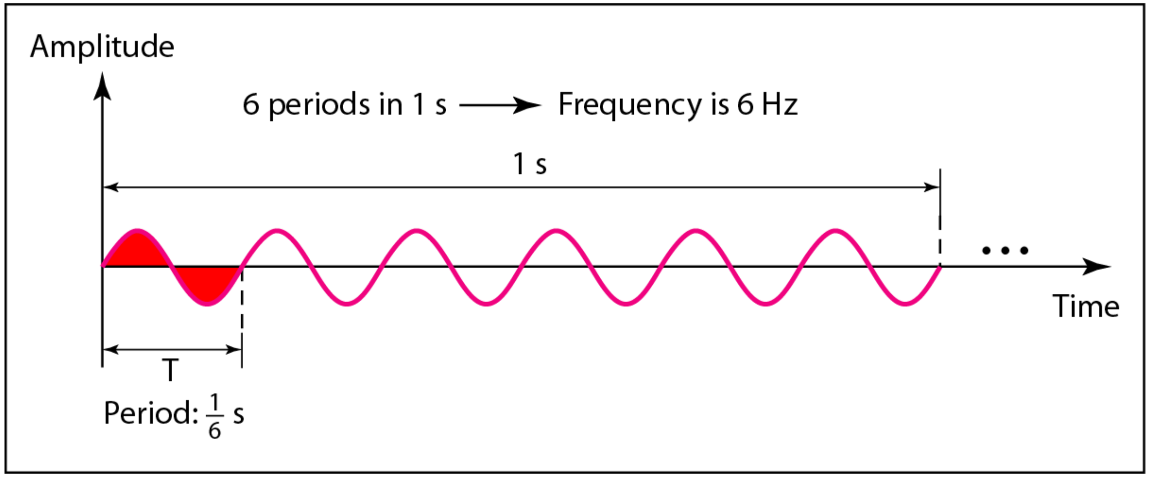
Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \qquad \text{and} \qquad T = \frac{1}{f}$$

# Two signals with the same amplitude and phase, but different frequencies




a. A signal with a frequency of 12 Hz




b. A signal with a frequency of 6 Hz

# Units of period and frequency

| *Unit* | *Equivalent* | *Unit* | *Equivalent* |
|---|---|---|---|
| Seconds (s) | 1 s | Hertz (Hz) | 1 Hz |
| Milliseconds (ms) | $10^{-3}$ s | Kilohertz (kHz) | $10^{3}$ Hz |
| Microseconds (μs) | $10^{-6}$ s | Megahertz (MHz) | $10^{6}$ Hz |
| Nanoseconds (ns) | $10^{-9}$ s | Gigahertz (GHz) | $10^{9}$ Hz |
| Picoseconds (ps) | $10^{-12}$ s | Terahertz (THz) | $10^{12}$ Hz |

# Example

- The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166\ \text{s} = 0.0166 \times 10^{3}\ \text{ms} = 16.6\ \text{ms}$$

# Example

- The period of a signal is 100 ms. What is its frequency in kilohertz?

**Solution**

- First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10−3 kHz).

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

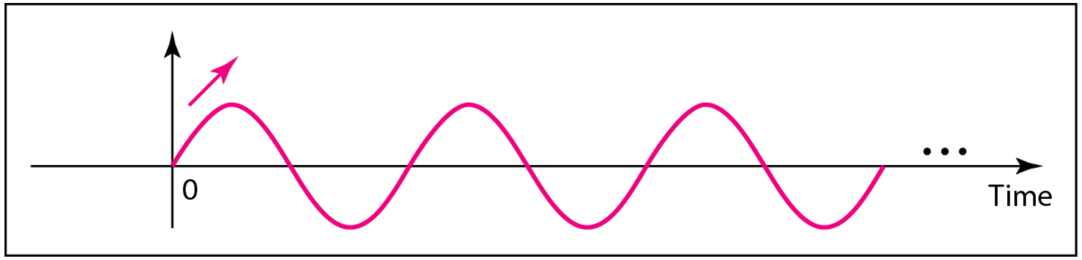
# Frequency

- Frequency is the rate of change with respect to time.
- Change in a short span of time means high frequency.
- Change over a long span of time means low frequency

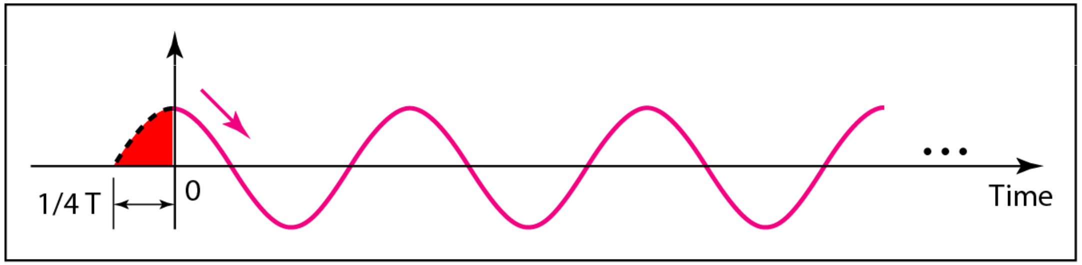
Note

Phase describes the position of the waveform relative to time 0.

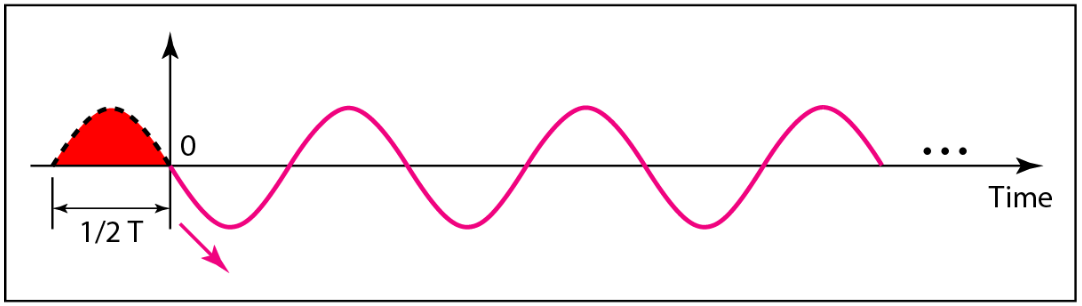
# Three sine waves with the same amplitude and frequency, but different phases




a. 0 degrees

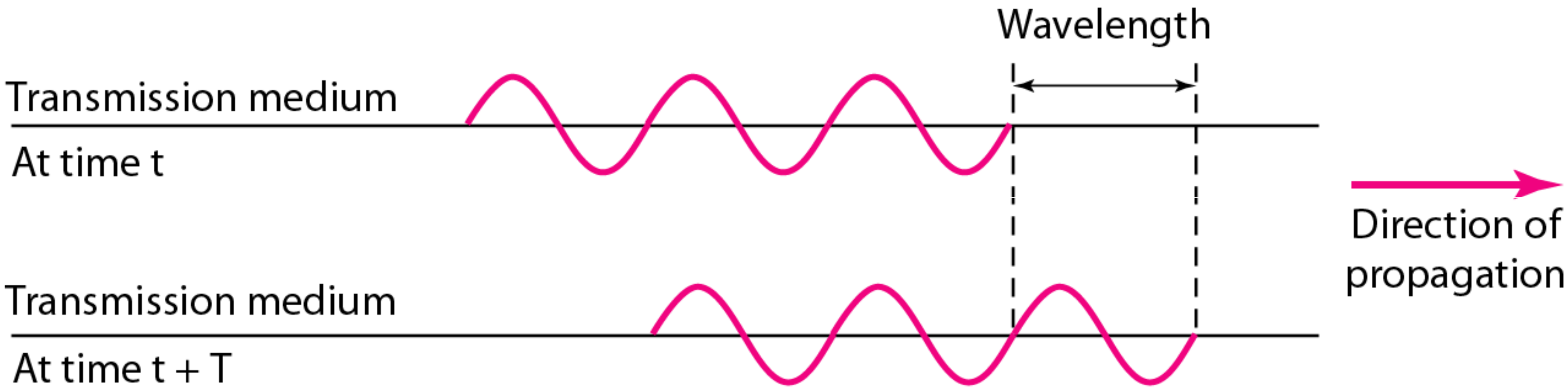



b. 90 degrees

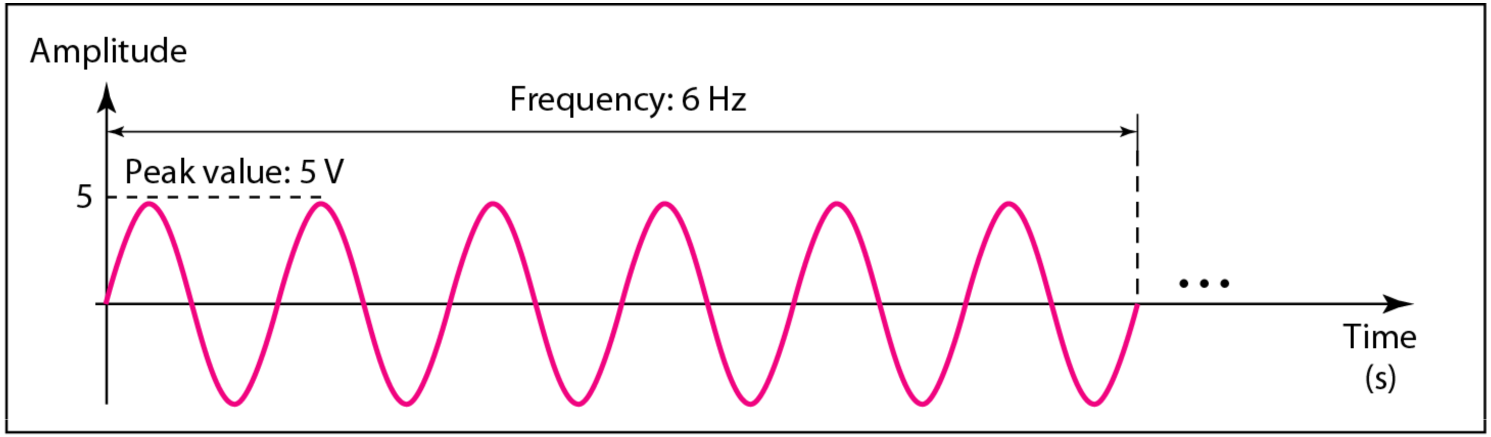



c. 180 degrees

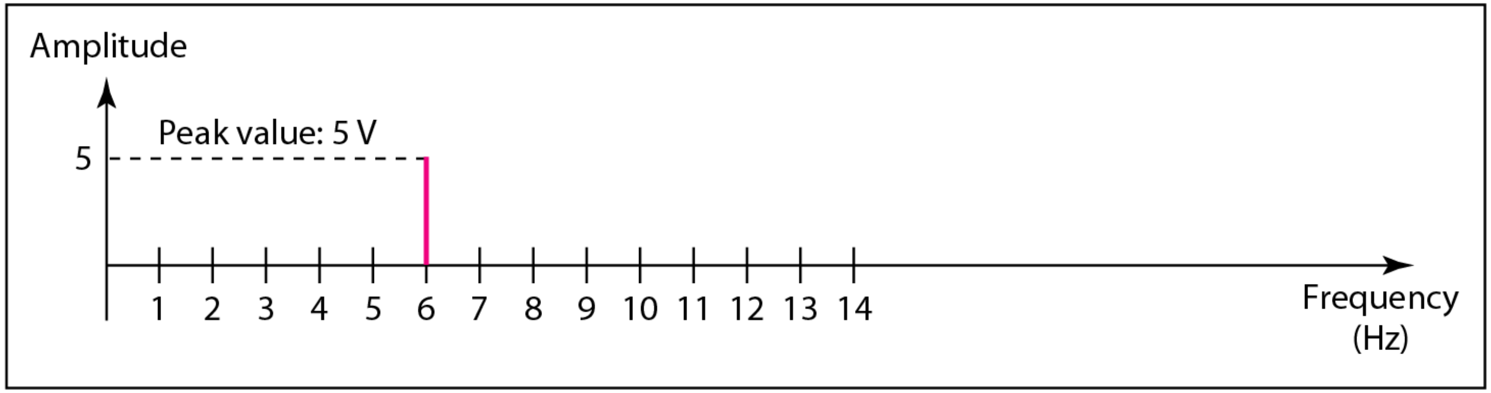
# Wavelength and period



# The time-domain and frequency-domain plots of a sine wave

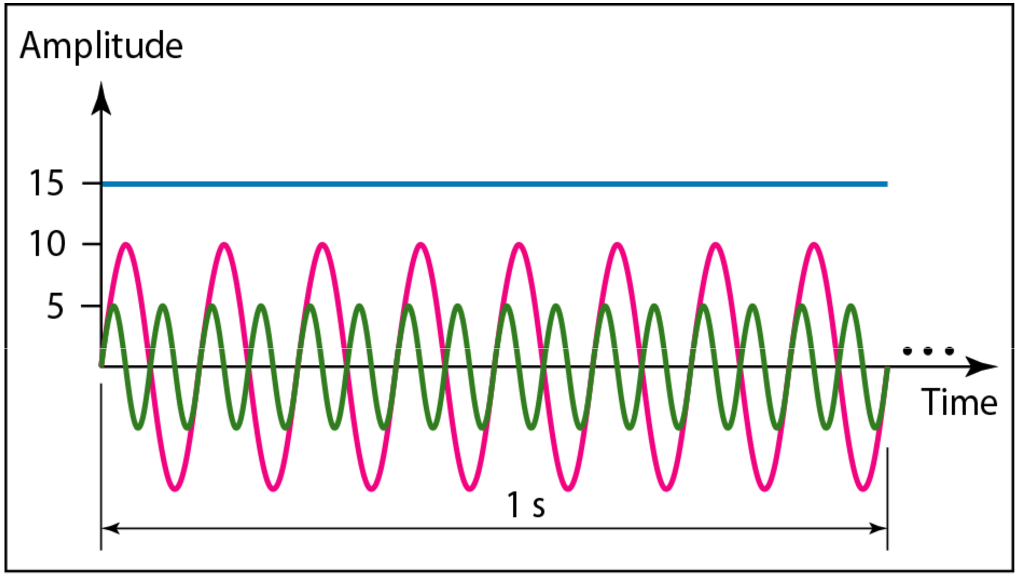



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)

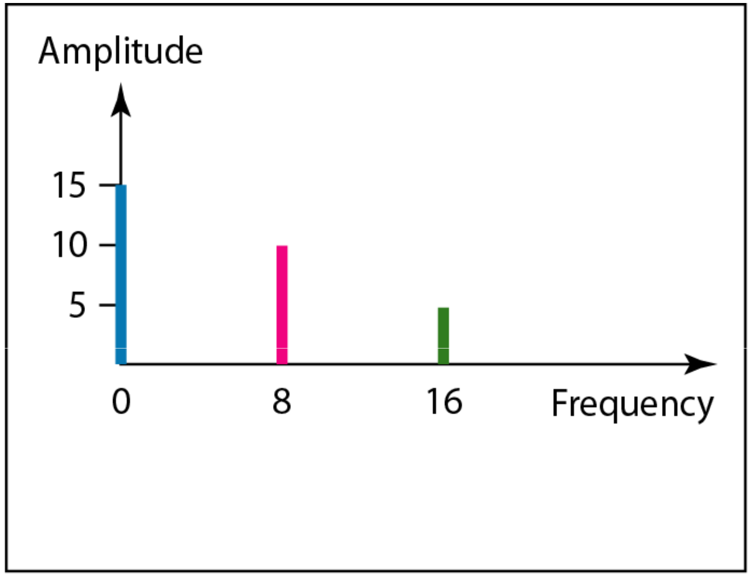



b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

# The time domain and frequency domain of three sine waves




a. Time-domain representation of three sine waves with frequencies 0, 8, and 16

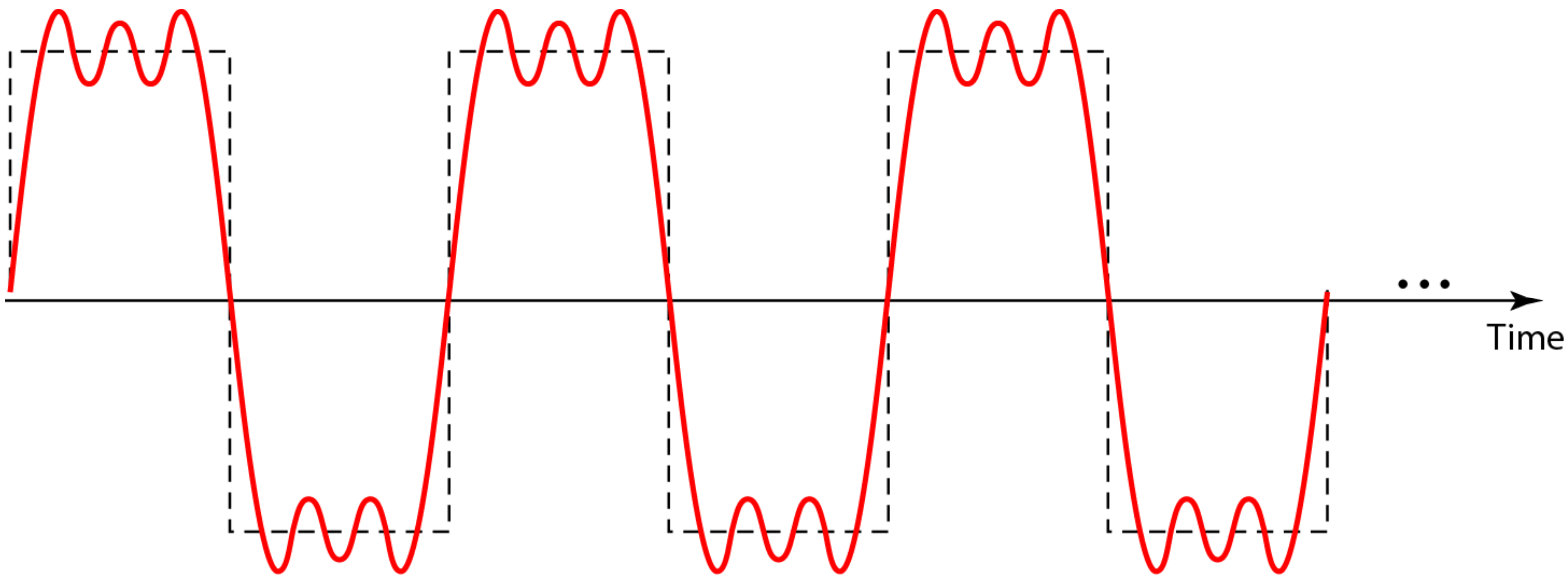



b. Frequency-domain representation of the same three signals

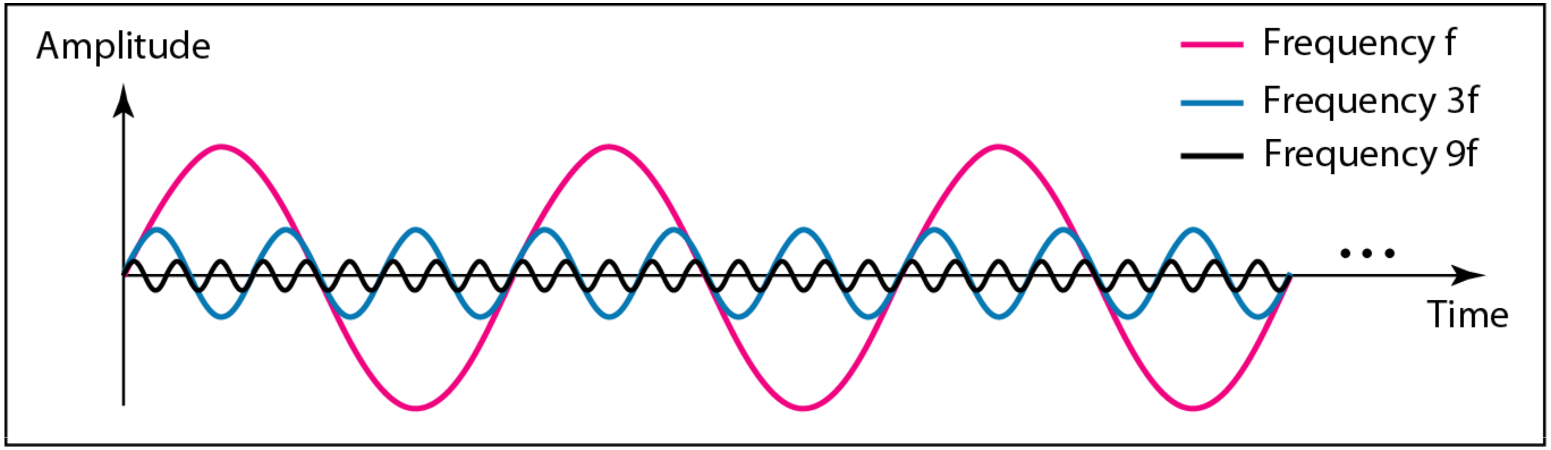
# Signals and Communication

- A single-frequency sine wave is not useful in data communications
- We need to send a composite signal, a signal made of many simple sine waves.
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

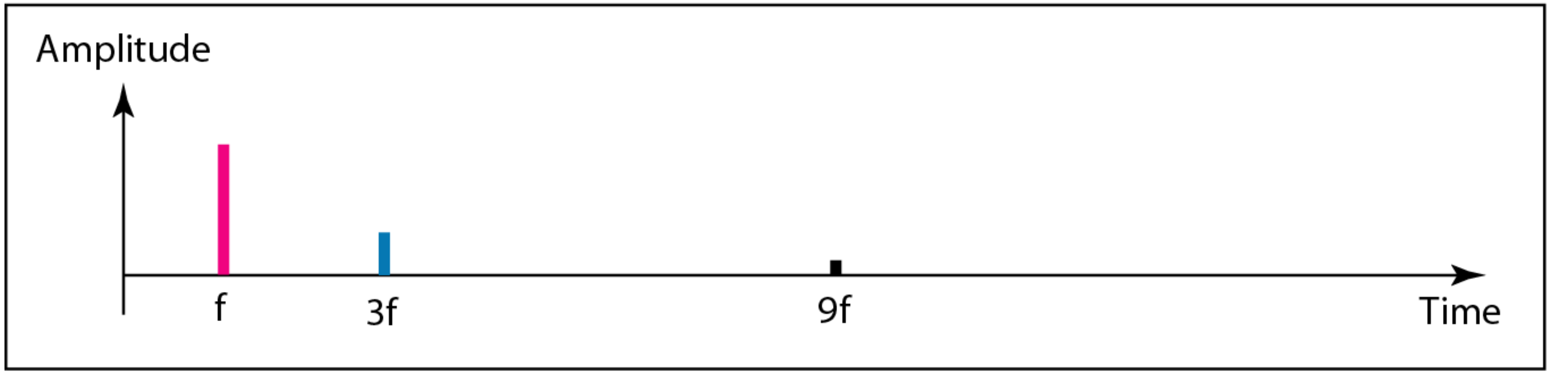
# A composite periodic signal



## Decomposition of a composite periodic signal in the time and frequency domains




a. Time-domain decomposition of a composite signal




b. Frequency-domain decomposition of the composite signal

# Bandwidth and Signal Frequency

- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

# Example

- If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

  Solution
- Let f-h be the highest frequency, fl the lowest frequency, and B the bandwidth. Then

$$B = f_h - f_l = 900 - 100 = 800 \text{ Hz}$$

- The spectrum has only five spikes, at 100, 300, 500, 700, and 900 Hz

# The bandwidth for Example