## Analog and Digital Data

Data can be analog or digital.

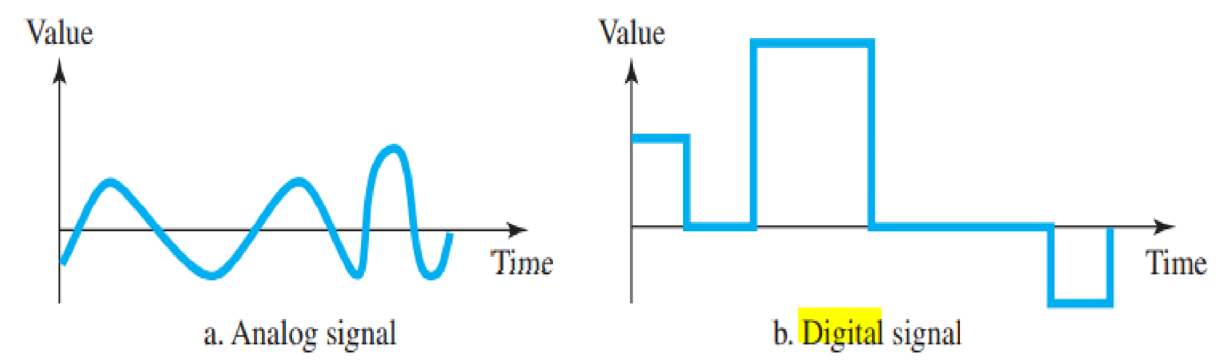
- The term analog data refers to information that is continuous;
- Digital data refers to information that has discrete states.
- For example, an analog clock that has hour, minute, and second hands gives information in a continuous form;
- The movements of the hands are continuous.
- On the other hand, a digital clock that reports the hours and the minutes will change suddenly from 8:05 to 8:06.

## Analog and digital signals

Similarly signals can be either analog or digital.

- ❖ An analog signal has **infinitely many levels of intensity over a period of time**. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.
- ❖ A digital signal, on the other hand, **can have only a limited number of defined values**. Although each value can be any number, it is often as simple as 1 and 0.

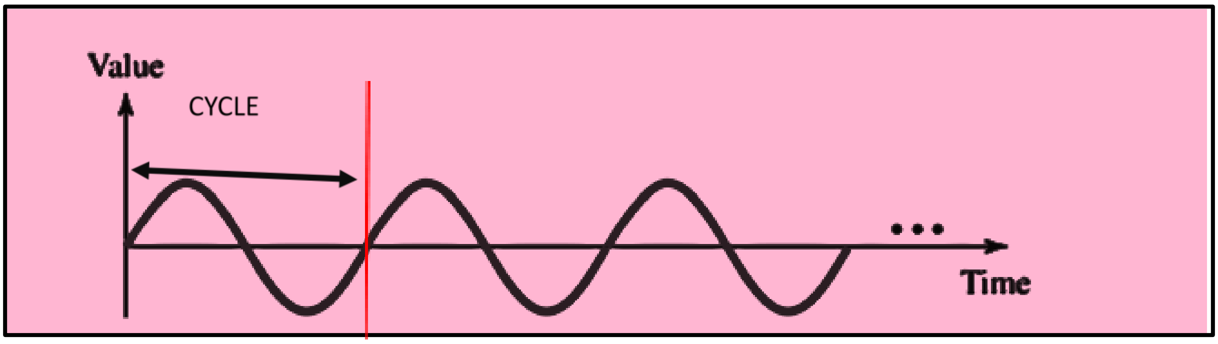
**Figure 3.2** *Comparison of analog and digital signals*




## Periodic and Nonperiodic

Both analog and digital signals can take one of two forms:

- ❖ periodic or nonperiodic
  A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods.
  The completion of one full pattern is called a cycle



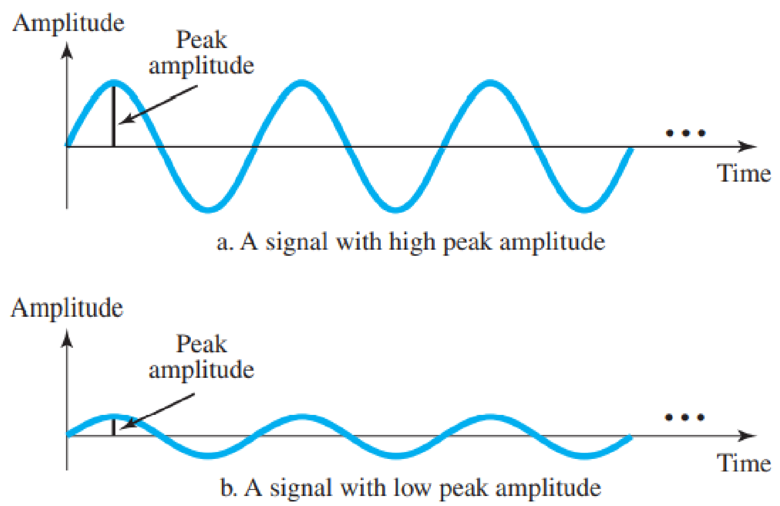

. A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time.
Both analog and digital signals can be periodic or non periodic.
In data communications, we commonly use periodic analog signals and nonperiodic digital signals

**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.**

## Peak Amplitude

The peak amplitude of a signal is the absolute value of its highest intensity, proportional to the energy it carries.
For electric signals, peak amplitude is normally measured in volts.

**Figure 3.4** *Two signals with the same phase and frequency, but different amplitudes*



## Period and Frequency

**Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.**

Frequency refers to the number of periods in 1 s.

Period is the inverse of frequency, and frequency is the inverse of period, as the following formulas show.

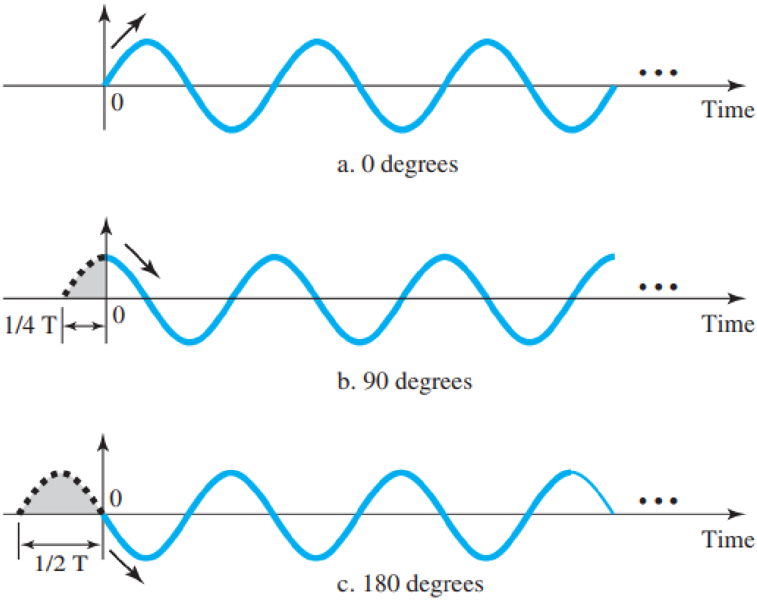
$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

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

### Phase

**The term phase, or phase shift, describes the position of the waveform relative to time 0. If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of the first cycle.**

**Figure 3.6** *Three sine waves with the same amplitude and frequency, but different phases*




A composite signal can be periodic or nonperiodic.

A periodic composite signal can be decomposed into a series of simple sine waves with discrete frequencies— frequencies that have integer values (1, 2, 3, and so on).

A nonperiodic composite signal can be decomposed into a combination of an infinite number of simple sine waves with continuous frequencies, frequencies that have real values

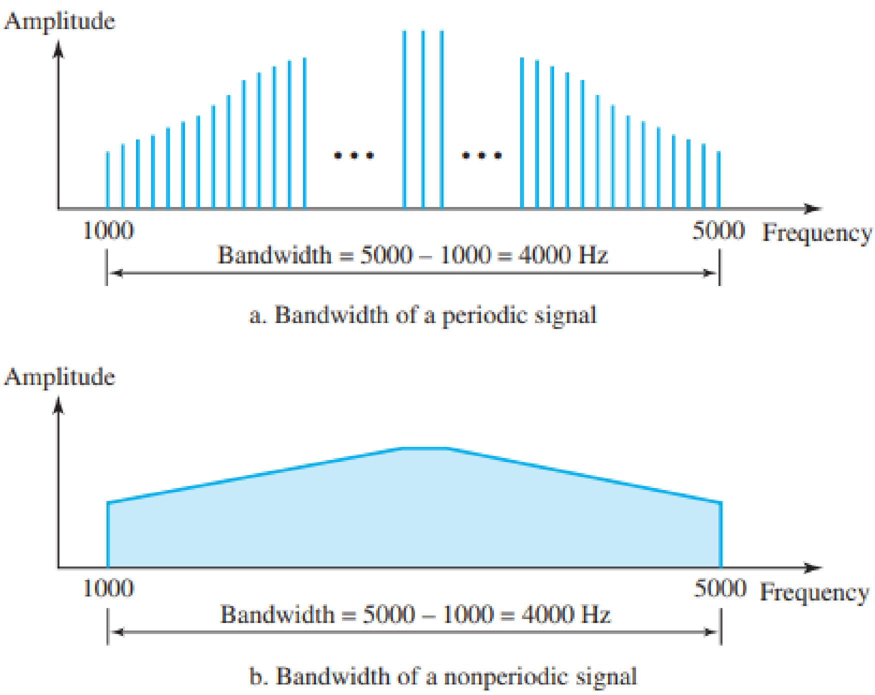
## Bandwidth

The range of frequencies contained in a composite signal is its bandwidth.

The bandwidth is normally a difference between two numbers

. For example, if a composite signal contains frequencies between 1000 and 5000, its bandwidth is 5000 − 1000, or 4000.

**Figure 3.13** *The bandwidth of periodic and nonperiodic composite signals*




## TRANSMISSION IMPAIRMENT

**Signals travel through transmission media, which are not perfect.**

**The imperfection causes signal impairment.**

**This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium. What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise**

## Attenuation

Attenuation means a loss of energy.

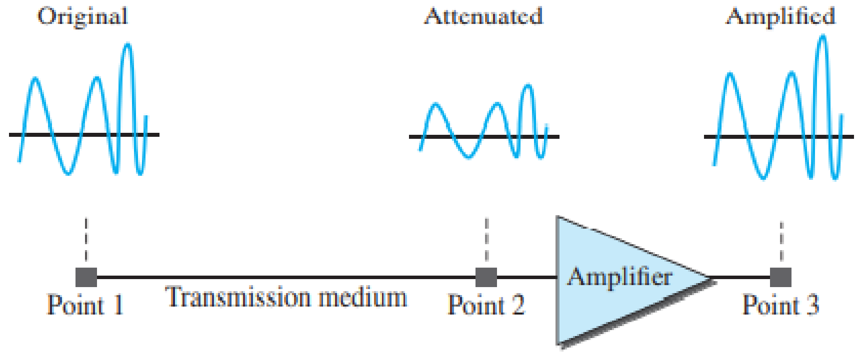
When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium.

That is why a wire carrying electric signals gets warm

Some of the electrical energy in the signal is converted to heat.

To compensate for this loss, amplifiers are used to amplify the signal. Figure 3.27 shows the effect of attenuation and amplification

**Figure 3.27** *Attenuation*




Distortion

Distortion means that the signal changes its form or shape. Distortion can occur in a composite signal made of different frequencies.

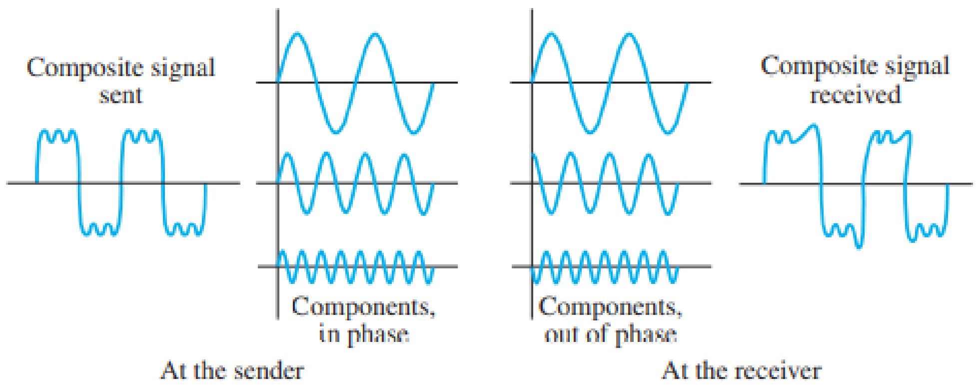
Each signal component has its own propagation speed through a medium and, therefore, its own delay in arriving at the final destination.

Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.

In other words, signal components at the receiver have phases different from what they had at the sender.

The shape of the composite signal is therefore not the same. Figure 3.29 shows the effect of distortion on a composite signal

**Figure 3.29** *Distortion*




**Noise**

**Noise is another cause of impairment.**

**Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.**

**Thermal noise is the random motion of electrons in a wire, which creates an extra signal not originally sent by the transmitter.**

Induced noise comes from sources such as motors and appliancses.

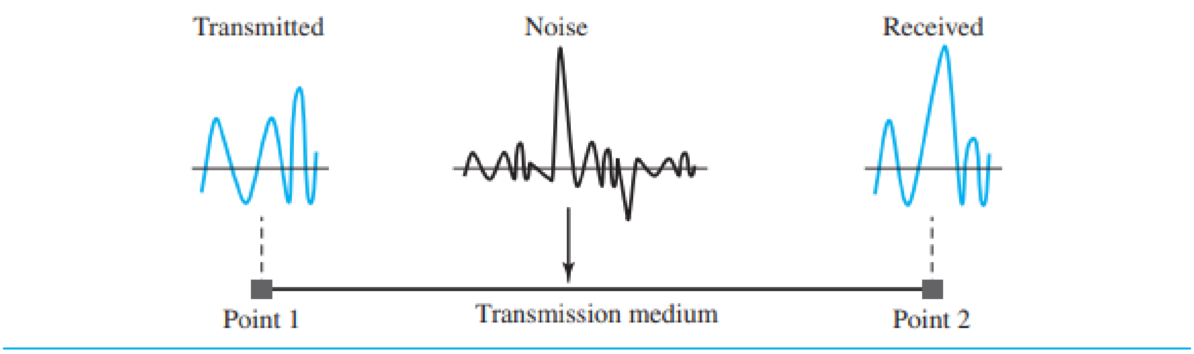
These devices act as a sending antenna, and the transmission medium acts as the receiving antenna.

Crosstalk is the effect of one wire on the other.

One wire acts as a sending antenna and the other as the receiving antenna.

Impulse noise is a spike (a signal with high energy in a very short time) that comes from power lines, lightning, and so on.

**Figure 3.30** *Noise*




Propagation Time

Propagation time measures the time required for a bit to travel from the source to the destination.

The propagation time is calculated by dividing the distance by the propagation speed.

Propagation time = Distance / (Propagation Speed)