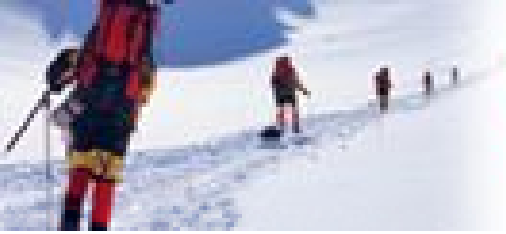


Data Communications and Networking Fourth Edition

Forouzan

Chapter 3

Data and Signals

Note

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

3-1 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**

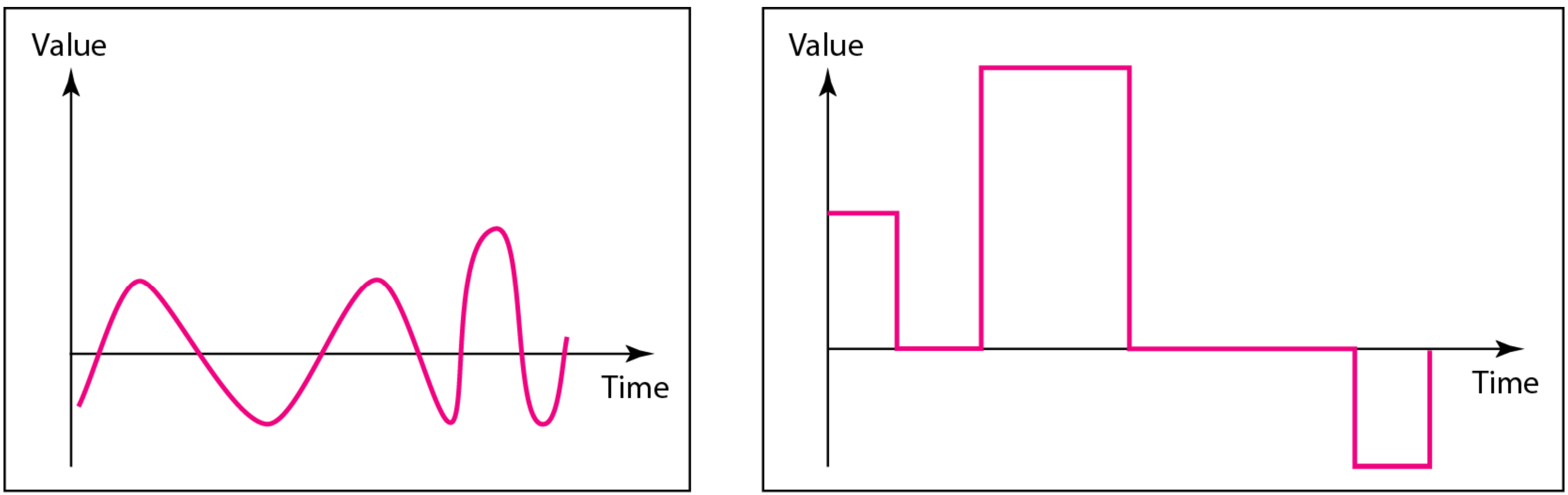
Analog and Digital Data

- ***Data can be analog or digital.***
- ***Analog data are continuous and take continuous values.***
- ***Digital data have discrete states and take discrete values.***

Analog and Digital Signals

- ***Signals can be analog or digital.***
- ***Analog signals can have an infinite number of values in a range.***
- ***Digital signals can have only a limited number of values.***

Figure 3.1 *Comparison of analog and digital signals*



a. Analog signal

b. Digital signal

•*The simplest way to show signals is by plotting them on a pair of perpendicular axes.*

•*The **vertical axis** represents the value or strength of a signal.*

•*The **horizontal axis** represents time.*

•*The **curve** representing the analog signal passes through an **infinite number of points**.*

•*The **vertical lines** of the digital signal, however, demonstrate the **sudden jump** that the signal makes from value to value.*

Periodic and Nonperiodic Signals

•Both analog and digital signals can take one of two forms: periodic or nonperiodic (sometimes refer to as aperiodic, because the prefix a in Greek means "non").

•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 nonperiodic.*

•*In data communications, we commonly use periodic analog signals (because they need less bandwidth) and nonperiodic digital signals (because they can represent variation in data).*

3-2 PERIODIC ANALOG SIGNALS

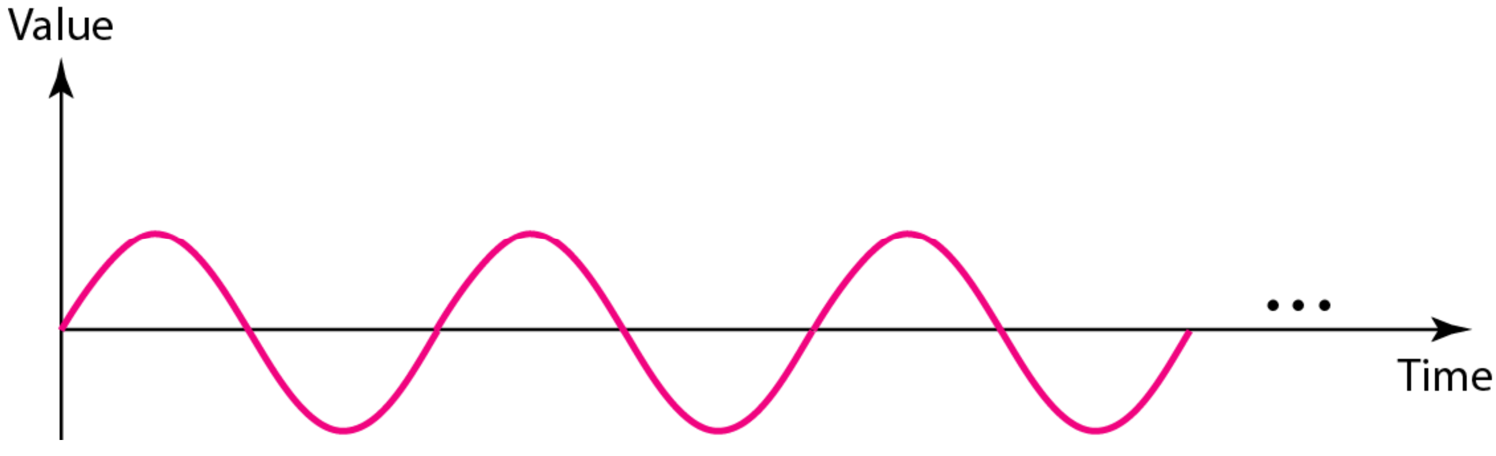
In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

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.

Figure 3.2 *A sine wave*



Sine Wave

•*The sine wave is the most fundamental form of a periodic analog signal.*

•*It is a simple oscillating curve, its change over the course of a cycle is smooth and consistent, a continuous, rolling flow.*

•*Each cycle consists of a single arc above the time axis followed by a single arc below it.*

•*A sine wave can be represented by three parameters: the peak amplitude, the frequency, and the phase.*

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.*

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.*

• ***Note that period and frequency are just one characteristic defined in two ways.***

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

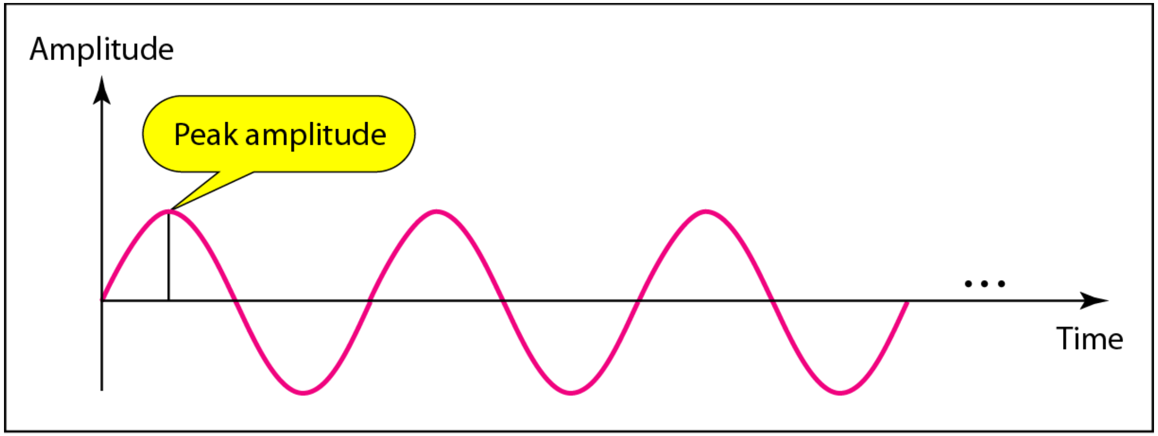
$$\boxed{f = \frac{1}{T} \qquad \text{and} \qquad T = \frac{1}{f}}$$

Note

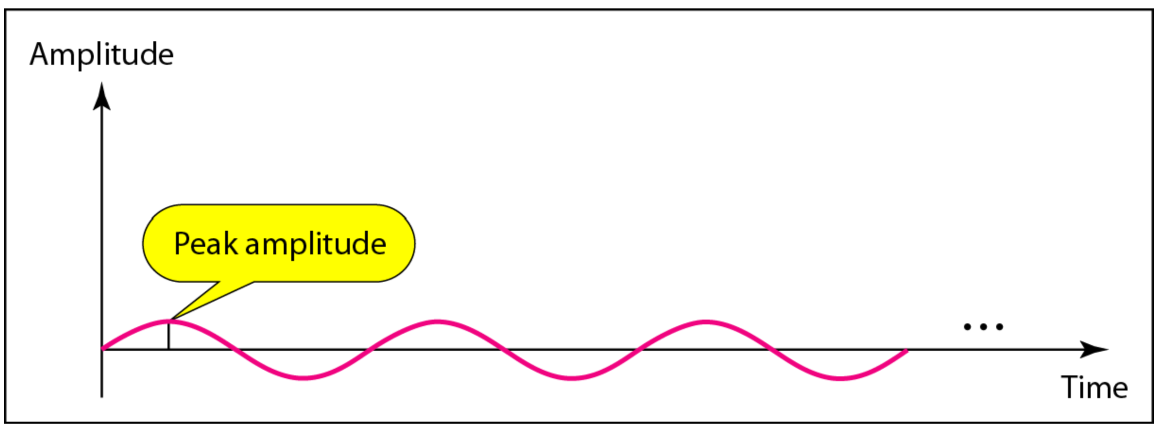
Frequency and period are the inverse of each other.

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

Figure 3.3 *Two signals with the same phase and frequency, but different amplitudes*

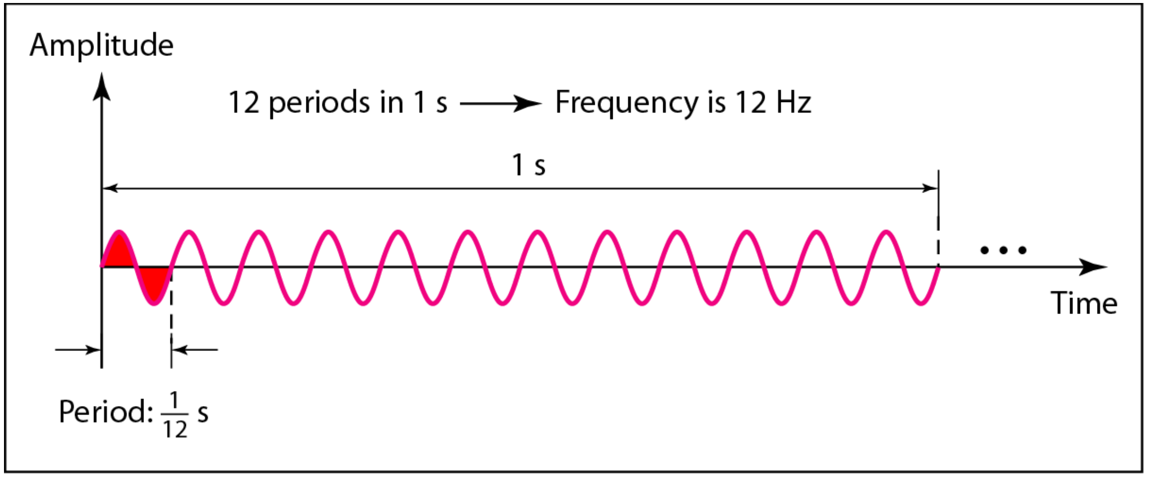


a. A signal with high peak amplitude

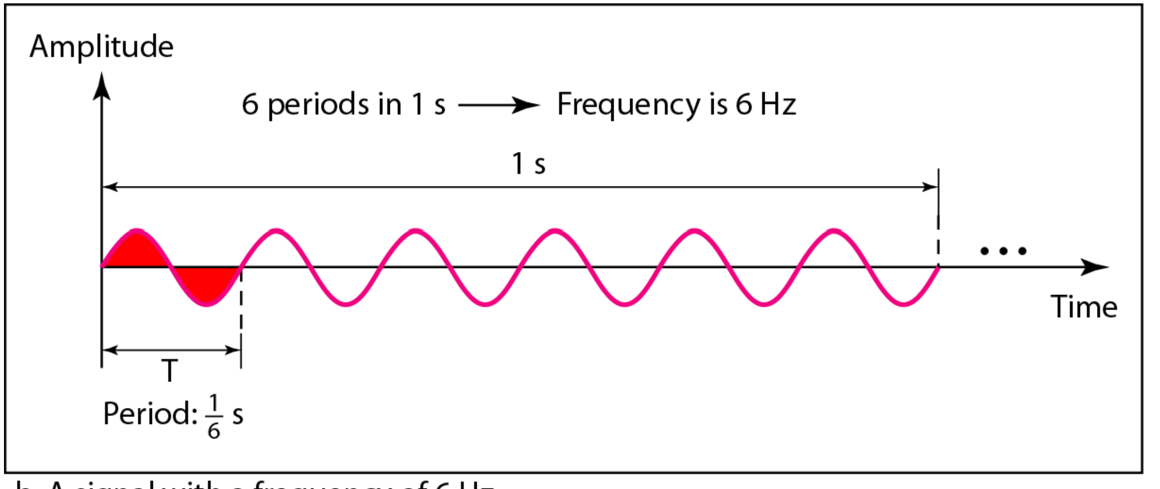


b. A signal with low peak amplitude

Figure 3.4 *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

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

If a signal does not change at all, its frequency is zero.
If a signal changes instantaneously, its frequency is infinite.

Note

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

Phase

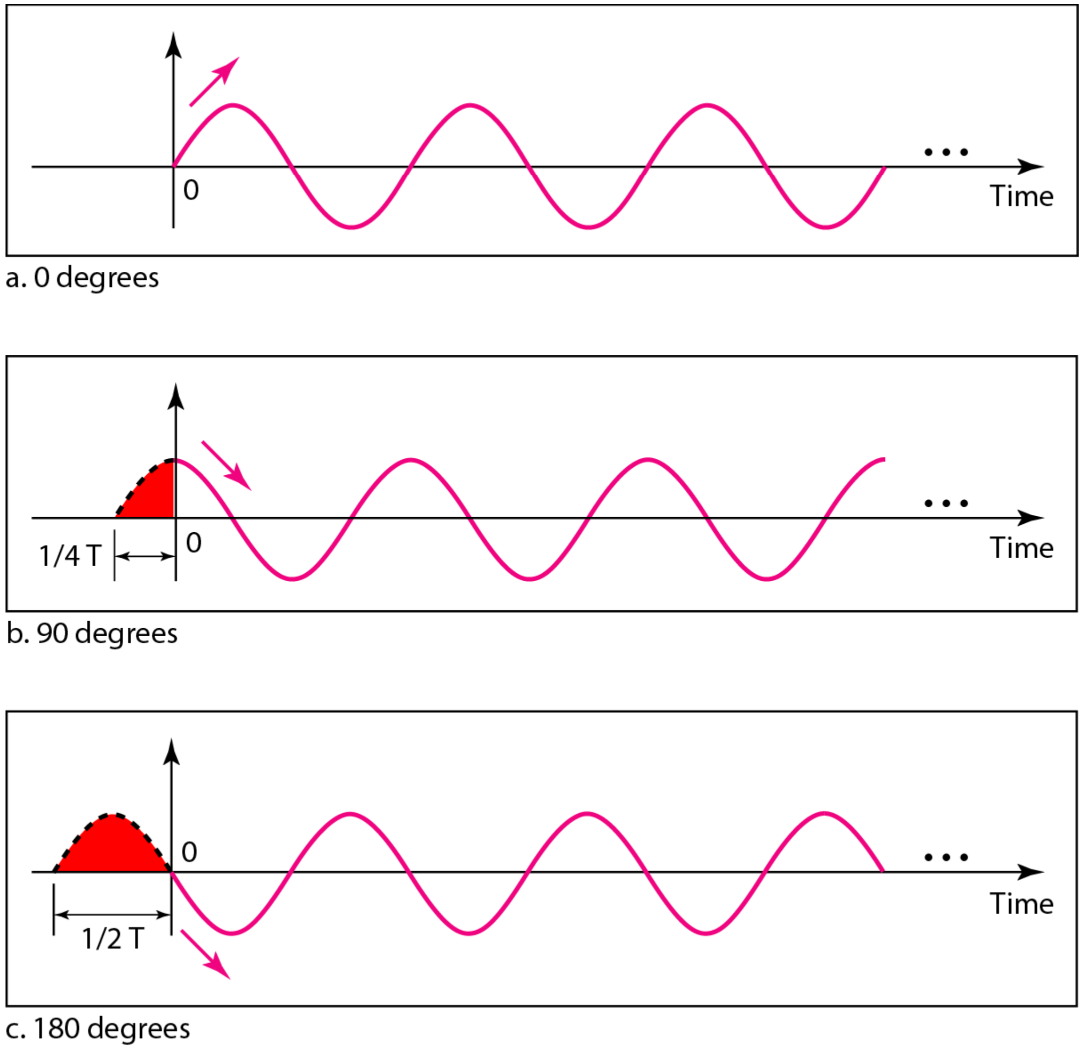
- ***The term phase describes the position of the waveform relative to time O.***

- ***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.***

- ***Phase is measured in degrees or radians***

Figure 3.5 *Three sine waves with the same amplitude and frequency, but different phases*



1. A sine wave with a phase of 0° starts at time 0 with a zero amplitude. The amplitude is increasing.

2. A sine wave with a phase of 90° starts at time 0 with a peak amplitude. The amplitude is decreasing.

3. A sine wave with a phase of 180° starts at time 0 with a zero amplitude. The amplitude is decreasing.

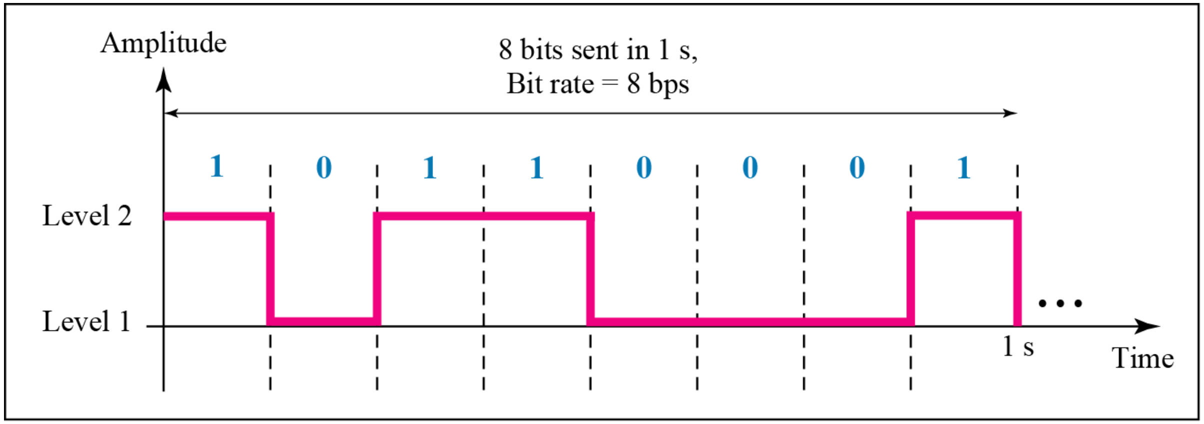
DIGITAL SIGNALS

- ***In addition to being represented by an analog signal, information can also be represented by a digital signal.***

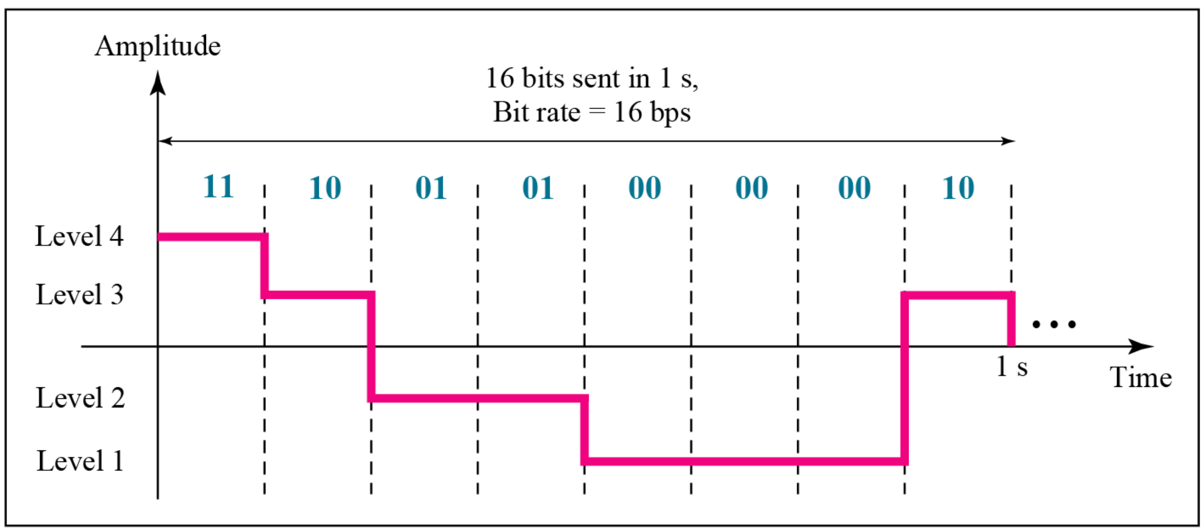
- ***For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.***

- ***A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.***

Figure 3.16 *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

Bit Rate

- *Most digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics.*

- *Another term-bit rate (instead of frequency)-is used to describe digital signals.*

- *The bit rate is the number of bits sent in 1 s, expressed in bits per second (bps).*