Signals and Systems

Signals and their classifications-I

Signals and Systems Defined

- A **signal** is any physical phenomenon which conveys information
- **Systems** respond to signals and produce new signals
- A **signal** is a function representing a physical quantity or variable, and typically it contains information about the behavior or nature of the phenomenon. For instance, in a RC circuit the signal may represent the voltage across the capacitor or the current flowing in the resistor. Mathematically, a signal is represented as a function of an independent variable t. Usually t represents time. Thus, a signal is denoted by x(t).

CLASSIFICATION OF SIGNALS

- Continuous-time & Discrete-time Signals
- Analog & Digital Signals
- Real and Complex Signals
- Deterministic & Random Signals
- Even and Odd Signals
- Periodic & Aperiodic Signals
- Energy & Power Signals

Continuous-time & Discrete-time Signals

A signal x(t) is a continuous-time signal if t is a continuous variable. If t is a discrete variable, that is, x(t) is defined at discrete times, then x(t) is a discrete-time signal. Since a discrete-time signal is defined at discrete times, a discrete-time signal is often identified as a sequence of numbers, denoted by $\{x_n\}$ or x[n], where n = integer. Illustrations of a continuous-time signal x(t) and of a discrete-time signal x[n] are shown in Fig. 1-1.

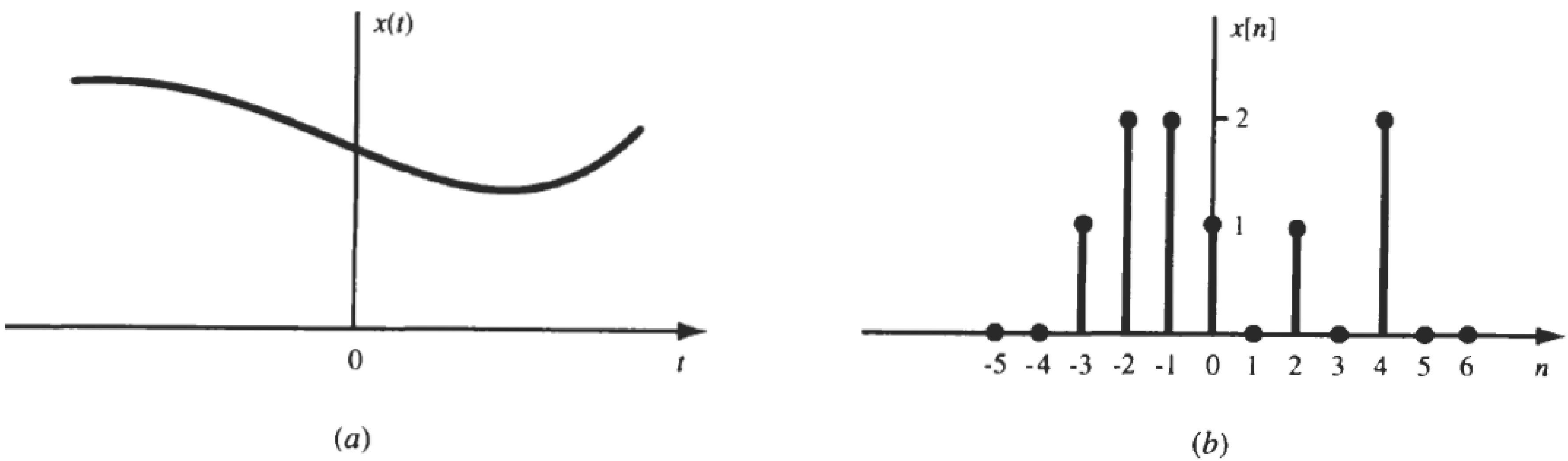

Fig. 1-1 Graphical representation of (*a*) continuous-time and (*b*) discrete-time signals.

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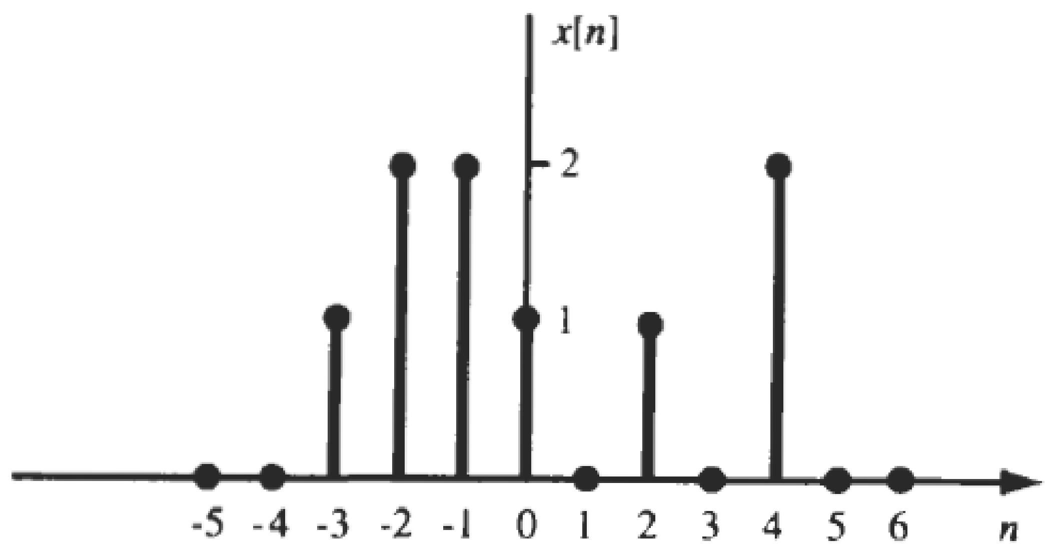
A discrete-time signal x[n] may represent a phenomenon for which the independent variable is inherently discrete. For instance, the daily closing stock market average is by its nature a signal that evolves at discrete points in time (that is, at the close of each day). On the other hand a discrete-time signal x[n] may be obtained by sampling a continuous-time signal x(t) such as

$$x(t_o), x(t_1), \ldots\ldots, x(t_n), \ldots$$



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or in a shorter form as

$$x[0], x[1], \dots, x[n], \dots$$

or

$$x_0, x_1, \dots, x_n, \dots$$

where we understand that

$$x_n = x[n] = x(t_n)$$

and x_n's are called *samples* and the time interval between them is called the *sampling interval*. When the sampling intervals are equal (uniform sampling), then

$$x_n = x[n] = x(nT_s)$$

where the constant T_s is the sampling interval.

A discrete-time signal $x[n]$ can be defined in two ways:

1. We can specify a rule for calculating the nth value of the sequence. For example,

$$x[n] = x_n = \begin{cases} \left(\frac{1}{2}\right)^n & n \geq 0 \\ 0 & n < 0 \end{cases}$$

or

$$\{x_n\} = \left\{1, \tfrac{1}{2}, \tfrac{1}{4}, \dots, \left(\tfrac{1}{2}\right)^n, \dots\right\}$$

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2. We can also explicitly list the values of the sequence. For example, the sequence shown in Fig. 1-1(b) can be written as

$$\{x_n\} = \{\ldots, 0, 0, 1, 2, 2, \underset{\uparrow}{1}, 0, 1, 0, 2, 0, 0, \ldots\}$$

or

$$\{x_n\} = \{1, 2, 2, \underset{\uparrow}{1}, 0, 1, 0, 2\}$$

We use the arrow to denote the $n = 0$ term. We shall use the convention that if no arrow is indicated, then the first term corresponds to $n = 0$ and all the values of the sequence are zero for $n < 0$.

The sum and product of two sequences are defined as follows:

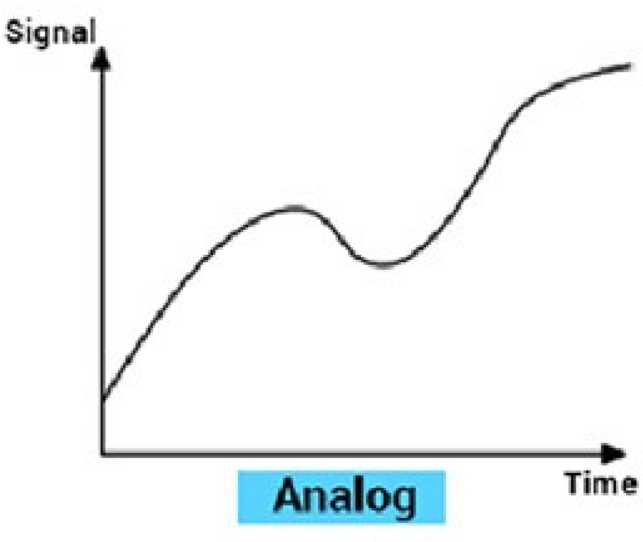
$$\{c_n\} = \{a_n\} + \{b_n\} \longrightarrow c_n = a_n + b_n$$

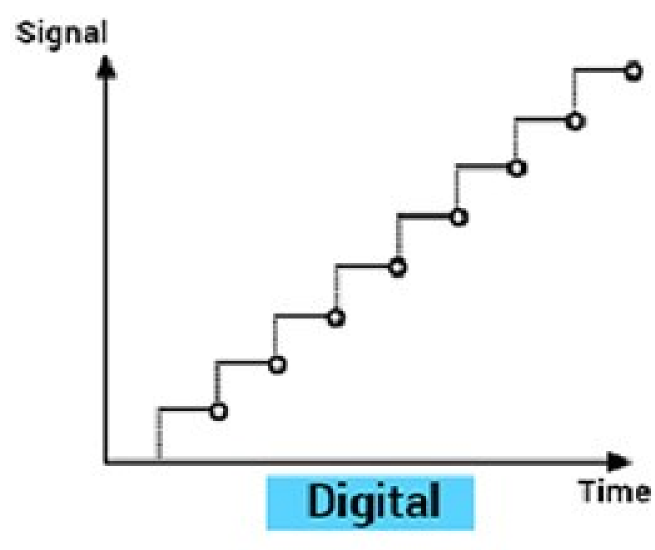
$$\{c_n\} = \{a_n\}\{b_n\} \qquad \longrightarrow c_n = a_n b_n$$

$$\{c_n\} = \alpha\{a_n\} \qquad \longrightarrow c_n = \alpha a_n \qquad \alpha = \text{constant}$$

Analog & Digital Signals

If a continuous-time signal $x(t)$ can take on any value in the continuous interval (a, b), where a may be $-\infty$ and b may be $+\infty$, then the continuous-time signal $x(t)$ is called an *analog* signal. If a discrete-time signal $x[n]$ can take on only a finite number of distinct values, then we call this signal a *digital* signal.





Real and Complex Signals

A signal $x(t)$ is a *real* signal if its value is a real number, and a signal $x(t)$ is a *complex* signal if its value is a complex number. A general complex signal $x(t)$ is a function of the form

$$x(t) = x_1(t) + jx_2(t) \tag{1.1}$$

where $x_1(t)$ and $x_2(t)$ are real signals and $j = \sqrt{-1}$.

Note that in Eq. (1.1) t represents either a continuous or a discrete variable.

Thank You