Signal and System Models

KEEE343 Communication Theory

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Summary

- Signal Classification
- Basic Continuous-Time Signals
- System and Classification of Systems

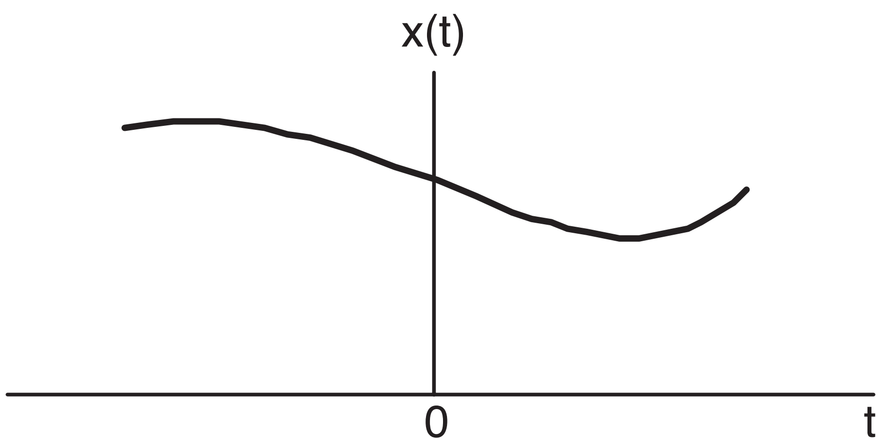
Signal Classification

- Continuous-Time and Discrete-Time signals
- Analog and Digital signals
- Real and Complex signals
- Deterministic and Random signals
- Even and Odd signals
- Periodic and Nonperiodic signals
- Energy and Power signals

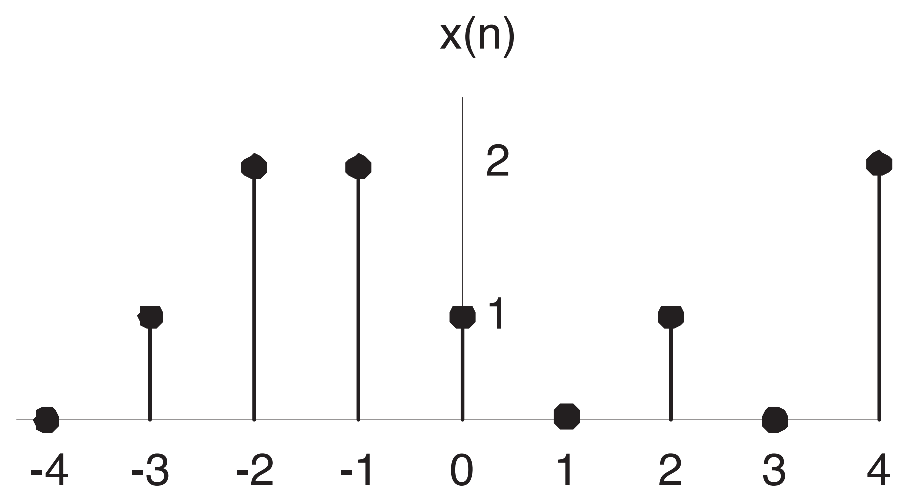
Continuous-Time and Discrete-Time Signals

- Continuous-time signals
  - A signal $x(t)$ is continuous-time if t is a continuous variable.
- Discrete-time signals
  - 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 is defined at discrete times such as $t = nT$, a discrete-time signal is often identified as a sequence of numbers, denoted by $\{x_n\}$ or $x[n]$

Continuous-Time and Discrete-Time Signals



(a)



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Analog and Digital Signals

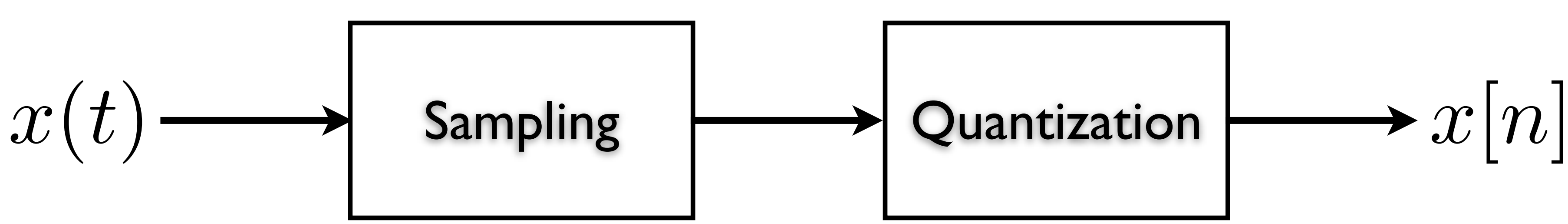
- Analog signals

$$-\infty < x(t) < \infty$$

- Digital signals

$$x[n] \in \{q_1, q_2, \cdots, q_n\}$$

- Analog signals to Digital signals



Real and Complex Signals

- Real signal
  - If $x(t)$ takes real number, it is a real signal
- Complex signal

$$x(t) = x_1(t) + jx_2(t)$$

  - Dumb Questions:
    - Is the complex signal real?
    - Does there really exist an imaginary part?
  - Example of Quadrature Components (or generally orthogonal signals)

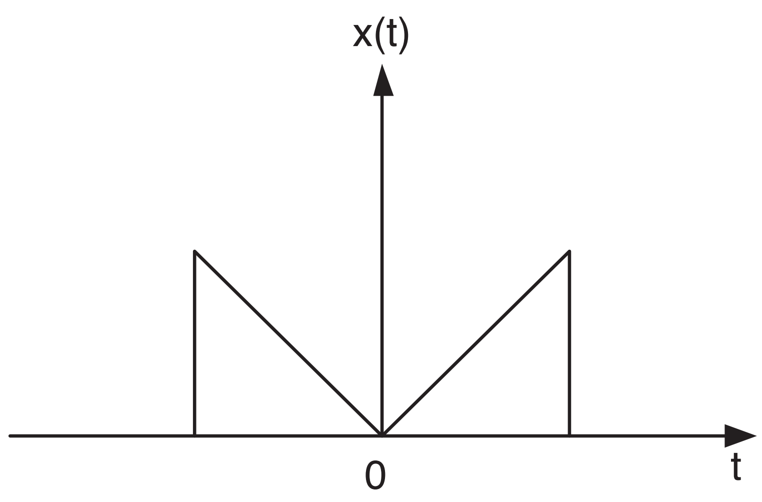
Even and Odd Signals

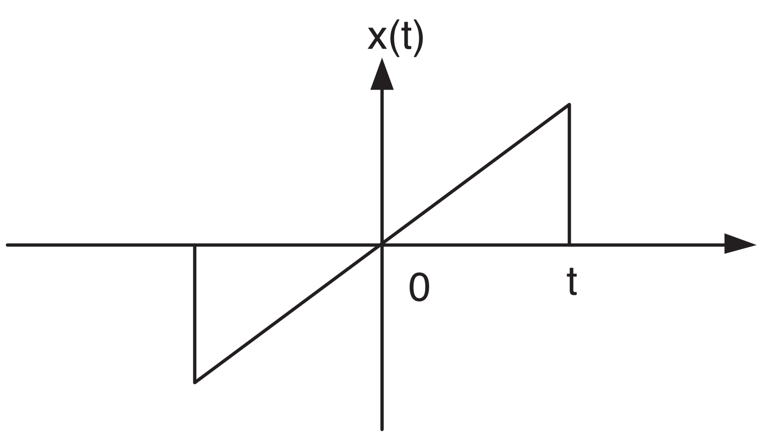
- Even signal if

$$x(-t) = x(t)$$

- Odd signal if

$$x(-t) = -x(t)$$





Even and Odd Signals

- Any signal $x(t)$ can be expressed as a sum of even and odd signals:

$$x(t) = x_e(t) + x_o(t)$$

- Even part and odd part of $x(t)$

$$x_e(t) = \frac{1}{2}\left\{x(t) + x(-t)\right\}$$

$$x_o(t) = \frac{1}{2}\left\{x(t) + x(-t)\right\}$$

Periodic and Nonperiodic Signals

- Periodic signal with period T if

$$x(t+T) = x(t) \quad \text{for all } t$$

- Fundamental period T_0
  - smallest positive value of T

$$T = mT_0 \quad \text{for any integer } m$$

Energy and Power Signals

- Energy of continuous time signal $x(t)$ is defined as

$$E = \int_{-\infty}^{\infty} |x(t)|^2 \, dt$$

- Normalized average power is defined as

$$P = \lim_{T \to \infty} \frac{1}{T} \int_{-\infty}^{\infty} |x(t)|^2 \, dt$$

- $x(t)$ is an energy signal if and only if

$$0 < E < \infty$$

- $x(t)$ is a power signal if and only if

$$0 < P < \infty$$

Basic Continuous-Time Signals

- Unit step function
- Unit impulse function (Dirac delta function)
- Complex exponential signals
  - General complex exponential signals
  - Real exponential signals
- Sinusoidal signals

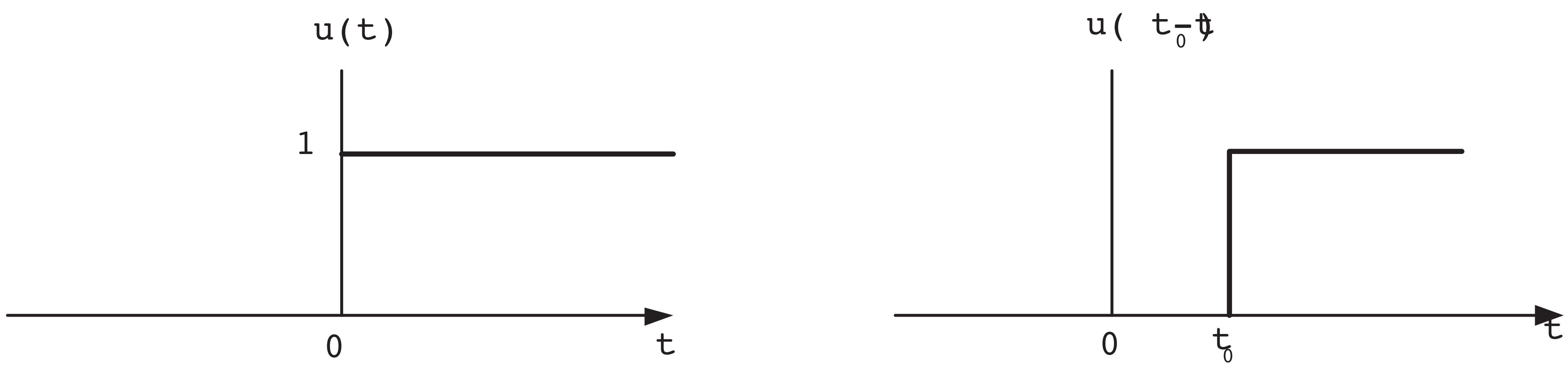
Unit Step Function

- **Definition**

$$u(t) = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$$

- **Shifted unit step function**

$$u(t - t_0) = \begin{cases} 1, & t > t_0 \\ 0, & t < t_0 \end{cases}$$



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