Introduction to Communications Engineering

IT4593E

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ONE LOVE. ONE FUTURE.

Thông tin chung

- Tên học phần: **Nhập môn kỹ thuật truyền thông**
- Mã học phần: **IT4593E**
- Khối lượng: **2 TC (2-1-0-4)**
- Lý thuyết và bài tập: **10 buổi lý thuyết, 5 buổi bài tập**
- Đánh giá học phần:

  30% QT (kiểm tra + bài tập/project + chuyên cần-quiz)

  70% CK (trắc nghiệm + tự luận)
- Tài liệu tham khảo:
  - Lecture slides
  - Lecture notes
  - Textbooks, ví dụ ***Communication Systems Engineering***, 2nd Edition, by John G. Proakis Masoud Salehi
  - Internet

Lec 02: Signals

Contents

- General introduction to signals
- Classification of signals
- Some special types of signals

Signals

- A signal is a collection of information or data.
- Examples:
  - Television signal, telephone signal
  - Monthly sales of a corporation
  - End-of-day stock market price
- In this course, we focus on **signals as functions of time**.
- Questions:
  - How do we measure a signal?
  - How do we distinguish between different signals?

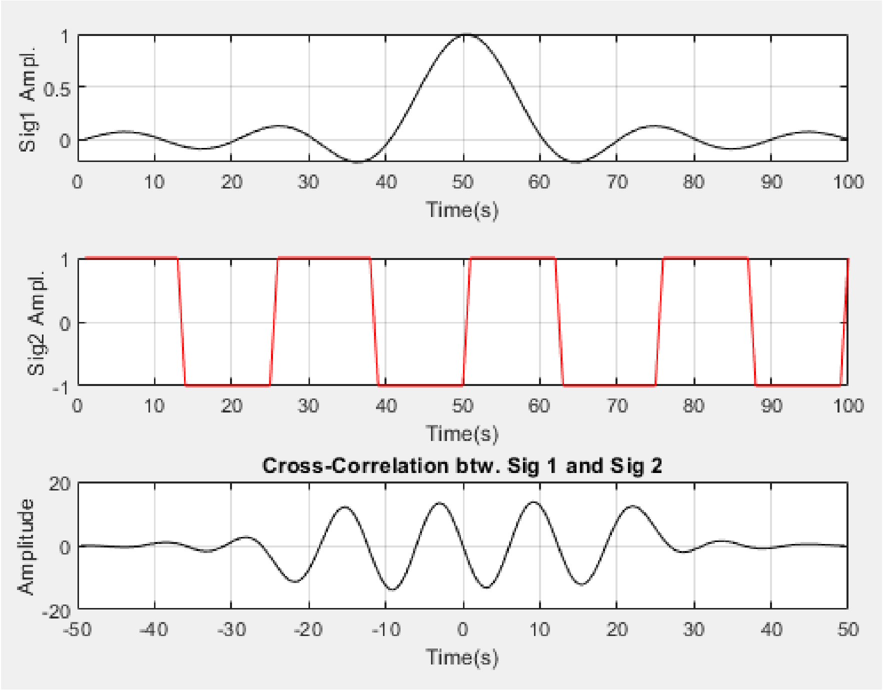
Example: Cross-correlation & Autocorrelation

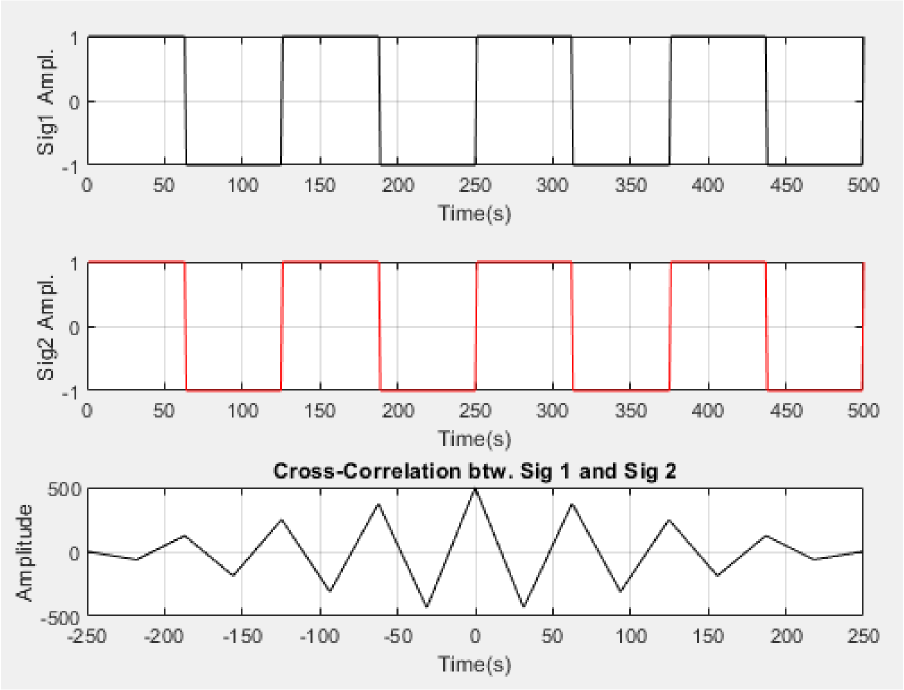
- For continuous signals:

$$(f * g)(\tau) = \int_{-\infty}^{\infty} f(t)\, g^*(t-\tau)dt = \int_{-\infty}^{\infty} f(t)\, g(t+\tau)dt$$

- For discrete signals:

$$(x * y)[m] = \sum_{n=-\infty}^{\infty} x[n].\, y^*[n-m]$$





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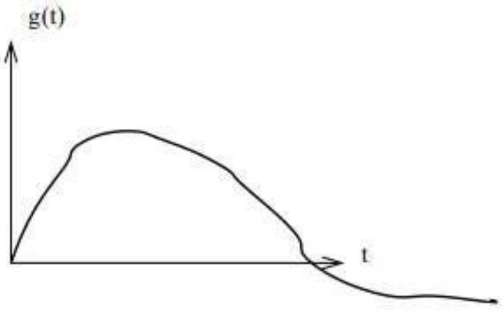
Classification of Signals

- Continuous-time signals vs. Discrete-time signals
- Analog signals vs. Digital signals
- Periodic signals vs. Aperiodic signals
- Power signals vs. Energy signals
- Random (stochastic) signals vs. Deterministic signals

Continuous-time vs. Discrete-time Signals

- A continuous-time signal has values defined for every time ***t***.
- A discrete-time signal has values defined only at discrete time instants.



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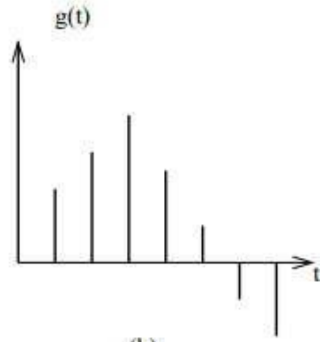


(b)

Continuous-time vs. Discrete-time Signals

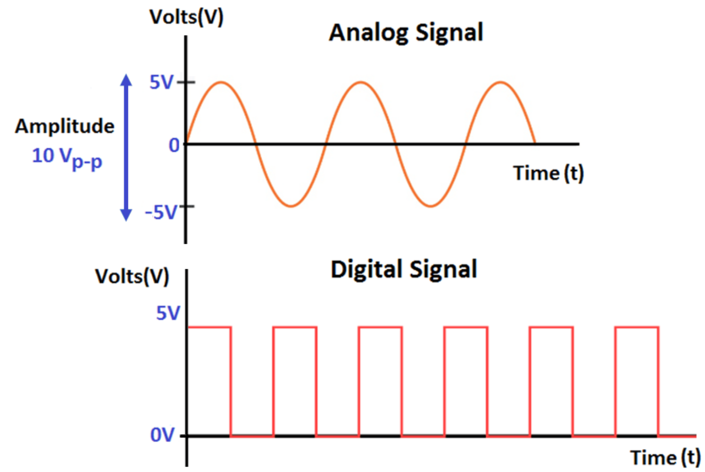
- A discrete-time signal can be obtained by sampling a continuous-time signal.
- In some cases, the sampling process can be "undone," meaning the continuous-time signal can be reconstructed.

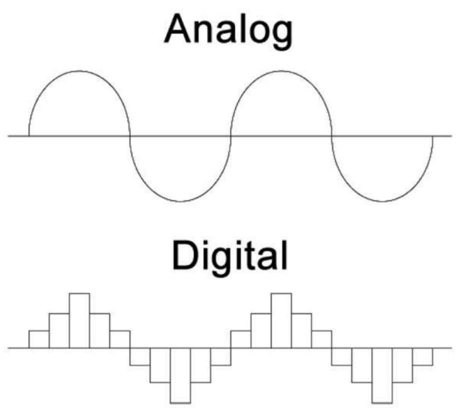
Sampling Theorem:

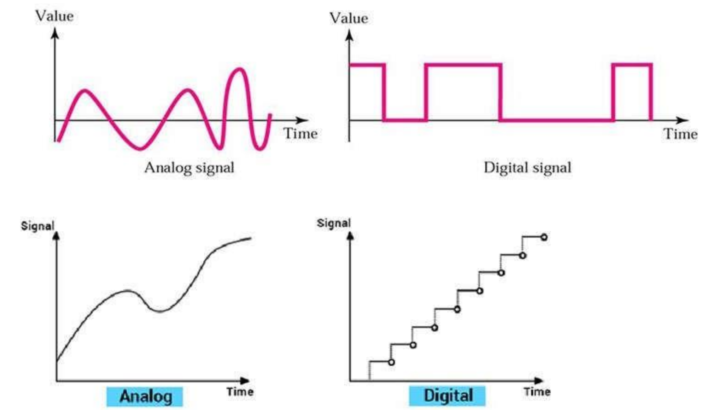
*If the highest frequency in a signal's spectrum is **B**, the signal can be reconstructed from its samples taken at a rate not less than **2B** samples per second.*

Analog vs. Digital Signals

- An **analog signal** can take any value in a continuous range.
- This concept differs from continuous-time vs. discrete-time signals.







Analog vs. Digital Signals

- Digital signals can be obtained from analog signals using **quantization**.
  - The amplitude of an analog signal is divided into **L** intervals. Each sample is mapped to the nearest quantization level.
- Quantization is a lossy process.
- Note: A **discrete-time digital signal** can be obtained by sampling and quantizing a continuous-time analog signal.

Periodic vs. Aperiodic Signals

- A signal ***g(t)*** is **periodic** if there exists a positive constant $\mathbf{T_0}$ such that:

$$g(t) = g(t+T_0) \text{ for every } t.$$

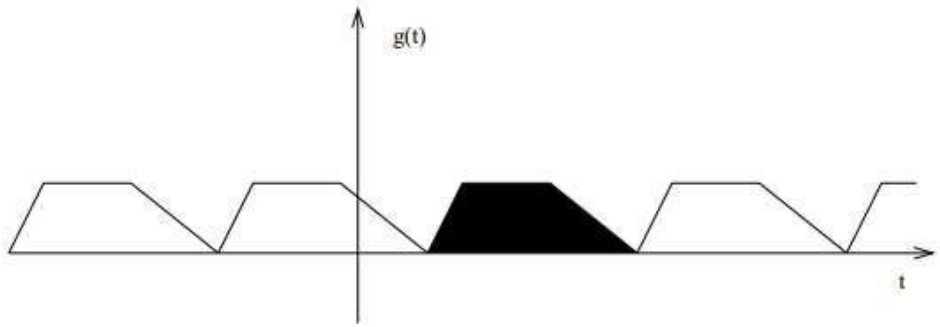
- Otherwise, it is **aperiodic**.
- Common periodic functions:

$$\sin(\omega_0 t)\,, cos\ (\omega_0 t), e^{j\omega_0 t} \quad \text{where } \omega_0 = \frac{2\pi}{T_0}.$$

Note: $e^{j\omega_0 t} = cos(\omega_0 t) + jsin(\omega_0 t)$ (Euler's formula)

Periodic Signals

- A periodic signal ***g(t)*** can be generated by periodically extending any segment of ***g(t)*** over the time interval $\mathbf{T_0}$.



Energy vs. Power Signals

Signal Energy E_g is defined as the integral (or sum in discrete case) of squared magnitude:

$$E_g = \int_{-\infty}^{+\infty} g^2(t)dt$$

- In the case where **g(t)** is represented in complex form, its signal energy is calculated by:

$$E_g = \int_{-\infty}^{+\infty} g^*(t)g(t)dt = \int_{-\infty}^{+\infty} |g(t)|^2 dt$$

- A signal **g(t)** is an energy signal if its total energy is finite, i.e. $E_g < \infty$.

Signal Power

- If energy is not finite (e.g., periodic signals), **average power** is a better measure:

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

- A signal is a power signal if its average power is finite and nonzero:

$$0 < \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |g(t)|^2 \, dt < \infty$$

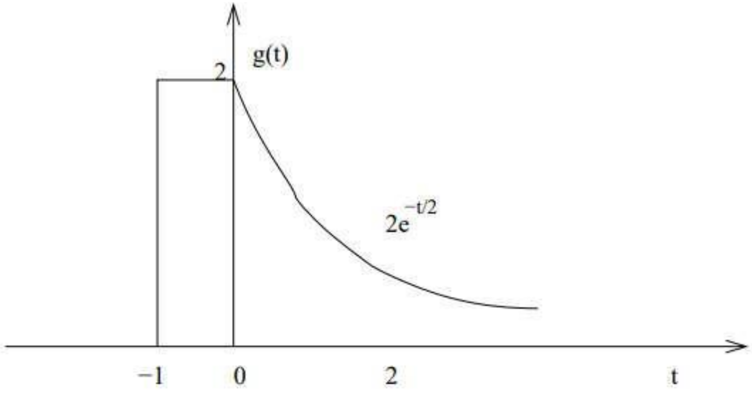
- A signal cannot be both an energy signal and a power signal.

Periodic Signal Power

- The power of a periodic signal ***g(t)*** with period T_0 is:

$$P_g = \frac{1}{T_0}\int_{-T_0/2}^{T_0/2} |g(t)|^2 dt$$

An example of energy signal



Signal Energy calculation

$$E_g = \int_{-\infty}^{\infty} g^2(t)dt = \int_{-1}^{0} (2)^2 dt + \int_{0}^{\infty} 4e^{-t} dt = 4 + 4 = 8.$$

An example of power signal

Assume $g(t) = Acos(\omega_0 t + \theta)$, its power is given by

$$
\begin{aligned}
P_g &= \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} A^2 cos^2(\omega_0 t + \theta) dt \\
&= \lim_{T\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} \frac{A^2}{2}[1 + cos(2\omega_0 t + 2\theta)] dt \\
&= \lim_{T\to\infty} \frac{A^2}{2T}\int_{-T/2}^{T/2} dt + \lim_{T\to\infty} \frac{A^2}{2T}\int_{-T/2}^{T/2} cos(2\omega_0 t + 2\theta)] dt \\
&= A^2/2
\end{aligned}
$$

Random vs. Deterministic Signals

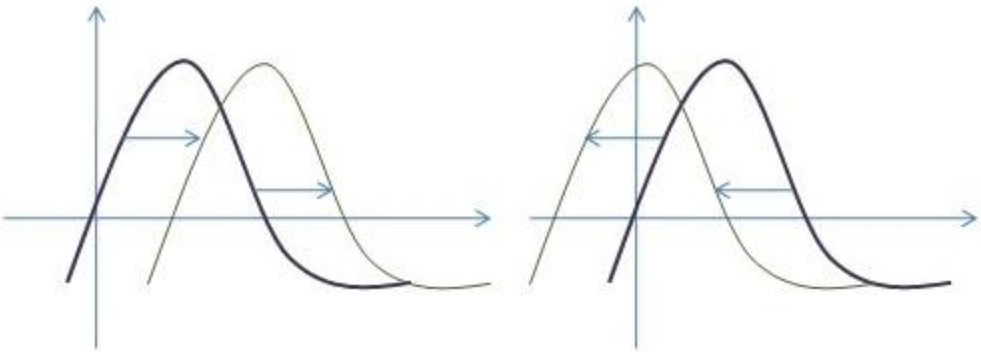
- A signal whose physical description is fully known is **deterministic**.
- A signal described in terms of probability is **random (stochastic)**.

Operations on Signals

Time shifting:

If $y(t) = x(t - T)$, then

- $T > 0$: delayed version (shift right)
- $T < 0$: advanced version (shift left)

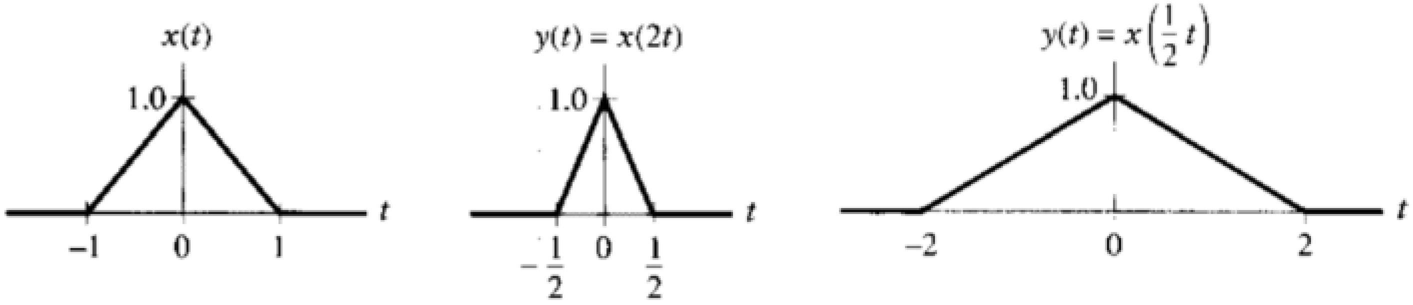


Operations on Signals

Time scaling:

If $y(t) = x(kt)$, then:

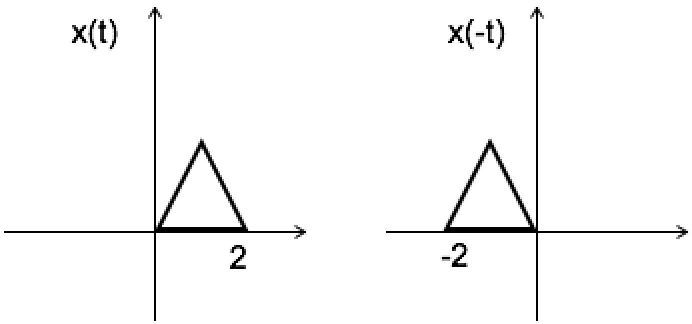
- $k > 1$: compressed version
- $0 < k < 1$: expanded version



Operations on Signals

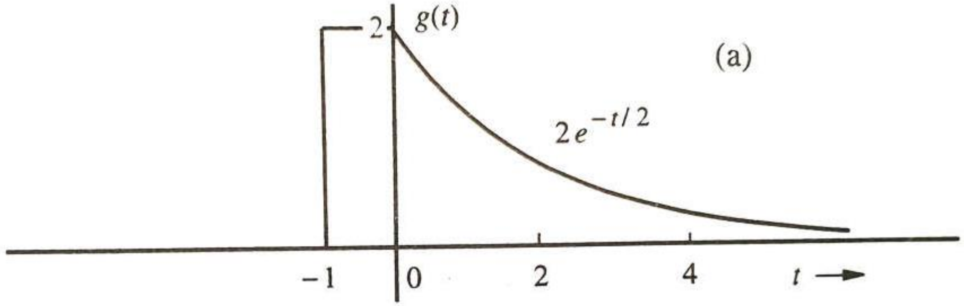
Time inversion:

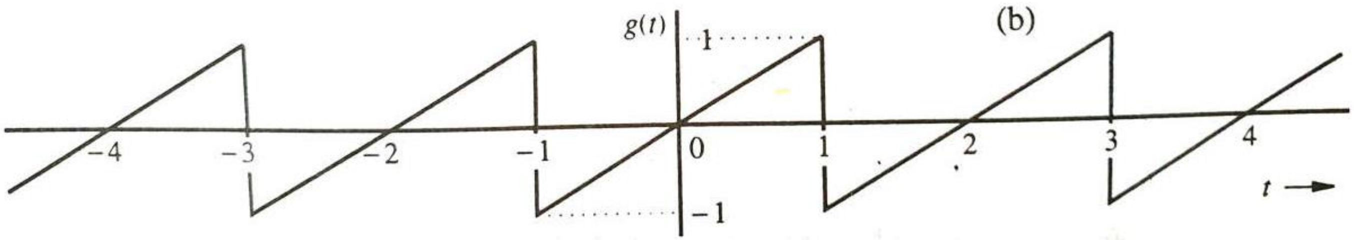
- Special case of time scaling with $k = -1$.



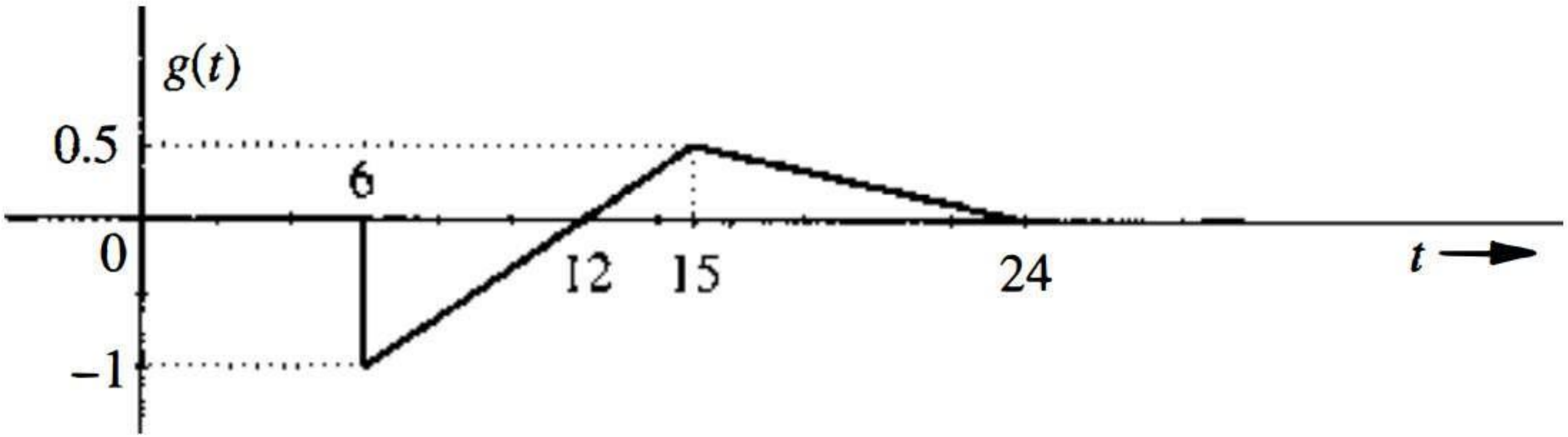
Exercises

- Determine the appropriate measure (energy or power) for given signals:





Exercises



- Given a signal g(t), draw the following transformed versions:

  a) g(t-4)
  b) g(t+6)
  c) g(3t)
  d) g(6-t)