Communication Theory - 2026

Chapter 2. Signals and Signal Space

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Table of Contents

Signal

A signal is a set of information or data.
In all these examples, the signals are functions of the independent variable **time** t.

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- Examples: Audio signals, video signals, sensor data, etc.

System

Signals may be processed further by systems, which may modify them or extract additional infromation from them.
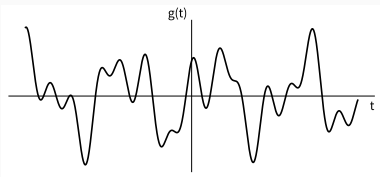Thus, a system is an entity that processes signals (**inputs**) to yield another set of signals (**outputs**).

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- For example, an antiaircraft radar system processes the received signals (inputs) to determine the position and velocity of an aircraft (outputs).

- More examples: Amplifiers, filters, modulators, demodulators, etc.
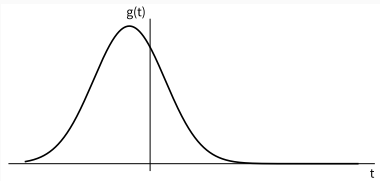
(a) Signal with finite energy

(b) Signal with finite power

Figure 1. Examples of signals.

Energy Signal
A signal is said to be an energy signal if its energy is finite and its average power is zero.

$$E = \int_{-\infty}^{\infty} |g(t)|^2 dt < \infty, \quad P = 0$$

Power Signal
A signal is said to be a power signal if its average power is finite and its energy is infinite.

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

Units of Signal Power

- The standard units of signal energy and power are the "joule" and the "watt".
- However, in practice, it is often customary to use logarithmic scales to describe signal power.
- A signal with average power of P watts has power of either P_{dBw} or P_{dBm}.

$$P_{dBw} = [10 \cdot \log_{10} P] \text{ dBw}$$

$$P_{dBm} = [30 + 10 \cdot \log_{10} P] \text{ dBm}$$

- For example,
  $P_{dBm} = -30 \text{ dBm} = 10^{-6} \text{W}.$
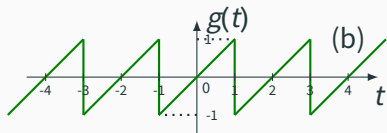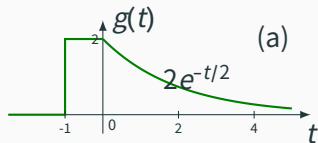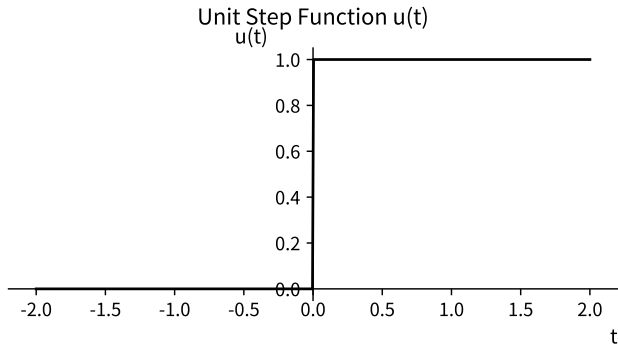
Example 2.1

Figure 2. Signal for Example

Problem: Determine whether each of the following signals is an energy signal, a power signal, or neither.

Solution:

(a) $g(t) = \begin{cases} 2e^{-t/2}, & t \geq 0 \\ 0, & t < 0 \end{cases}$

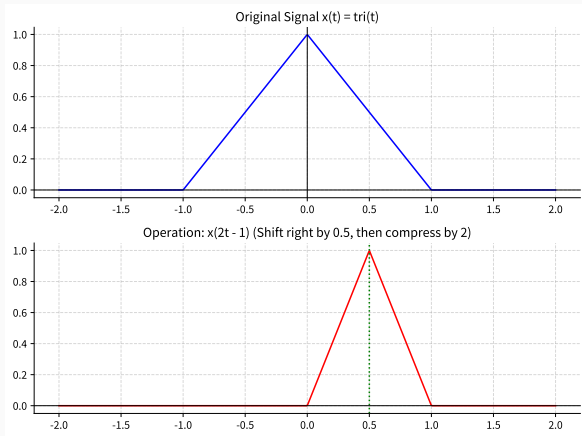Energy:

1. Basic Signals: Unit Step Function

Unit Step Function u(t)

Definition

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

Key Property:
시스템의 스위칭 동작(Switching)을 수학적으로 모델링할 때 사용됨.

Original Signal x(t) = tri(t)

Operation: x(2t - 1) (Shift right by 0.5, then compress by 2)
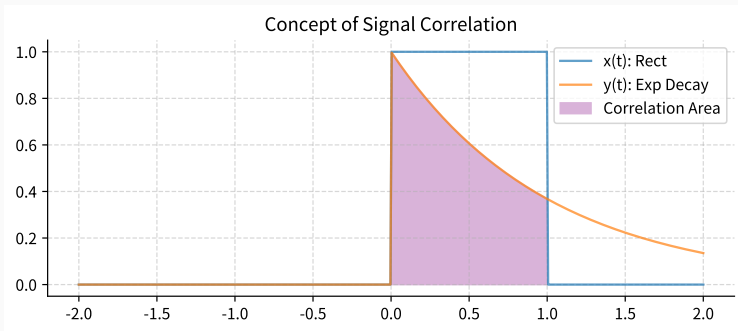
해석 순서 (Order of Operations):

1. **Shifting:** $t \rightarrow t - t_0$
   (Right if $t_0 > 0$)

2. **Scaling:** $t \rightarrow at$
   (Compression if $a > 1$)

Caution

$x(2t - 1)$은 $x(t)$를 1만큼 이동 후 2배 압축하는 것이 아님!

→ $x(2(t - 0.5))$로 생각해야 함.

Concept of Signal Correlation

Correlation Coefficient (C_n)
두 신호가 얼마나 닮았는가? (Measure of Similarity)

$$\rho = \frac{\int x(t)y^*(t)dt}{\sqrt{E_x E_y}}$$

Summary

- **Unit Step** $u(t)$**:** 인과성(Causality) 표현의 핵심
- **Operations:** $x(at - b)$ 꼴의 변환을 자유자재로 다뤄야 함
- **Correlation:** 통신 시스템에서 수신 신호를 검출(Detection)하는 기본 원리