Communication Theory - 2026

Chapter 2. Signals and Signal Space

이 경 근

infosec@knu.ac.kr Kenny-0633-Lee

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EE / KNU

Definitions: Signals and Systems

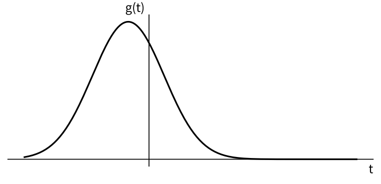
Signals

- A signal is a set of information or data.
- Examples: Audio signals, video signals, sensor data, etc.
- In all these examples, the signals are functions of the independent variable **time** t.

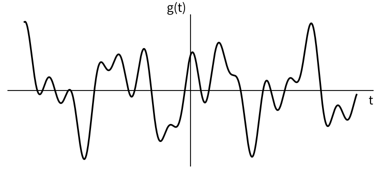
Systems

- Signals may be processed further by systems, which may modify them or extract additional infromation from them.
- For example, an antiaircraft radar system processes the received signals (inputs) to determine the position and velocity of an aircraft (outputs).
- Thus, a system is an entity that processes signals (**inputs**) to yield another set of signals (**outputs**).
- More examples: Amplifiers, filters, modulators, demodulators, etc.

Energy Signal vs Power Signal



(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.

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

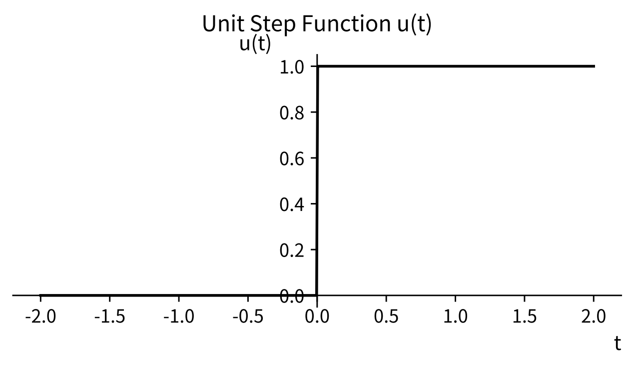
Power Signal
A signal is said to be a power signal if its average power is finite and its energy is infinite.

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

Overview

- **Basic Signals:** 단위 계단 함수 $u(t)$와 델타 함수 $\delta(t)$
- **Signal Operations:** 시간 이동(Shifting)과 스케일링(Scaling)
- **Correlation:** 신호의 유사도(Similarity) 측정

1. Basic Signals: Unit Step Function



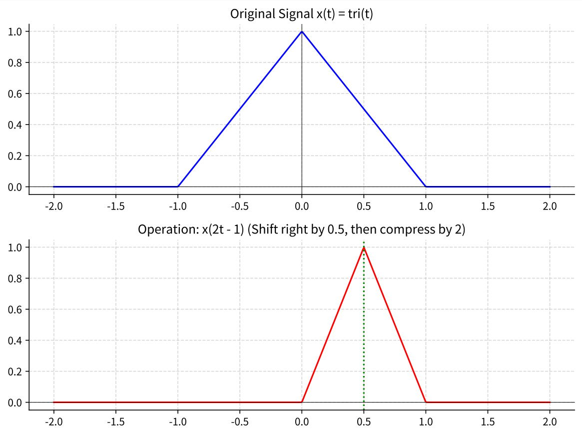
Definition

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

Key Property:

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

2. Signal Operations: $x(at - b)$



해석 순서 (Order of Operations):

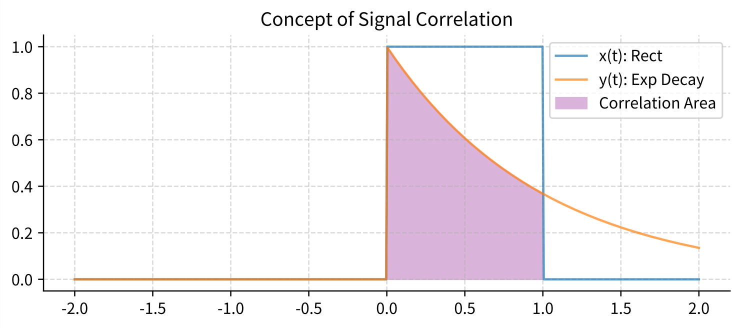
1. **Shifting:** $t \rightarrow t - t_0$
   (Right if $t_0 > 0$)
2. **Scaling:** $t \rightarrow at$
   (Compression if $a > 1$)

Caution

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

→ $x(2(t - 0.5))$로 생각해야 함.

3. 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