

Communication Theory - 2026

Chapter 2. Signals and Signal Space

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January 21, 2026

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2.1. Size of A Signal

2.1.1 Energy vs Power Signals

Definition: Signal and System

Signal

A signal is a set of information or data.

The signals are functions of the independent variable **time t** .

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

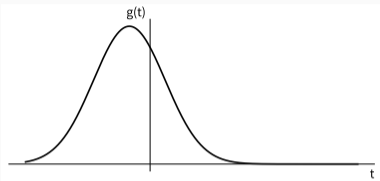
System

Signals may be processed further by systems, which may modify them or extract additional information from them.

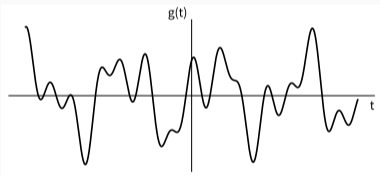
Thus, a system is an entity that processes signals (**inputs**) to yield another set of signals (**outputs**).

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- For example, an anti-aircraft radar system processes the received signals (inputs) to determine the position and velocity of an aircraft (outputs).
 - More examples: Amplifiers, filters, modulators, demodulators, etc.

Energy vs Power Signals



(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 approaches zero.

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

Power Signal

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

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

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

Determine the suitable measures of the signals in the left Figure.

(a) Energy signal

Energy signal. Power approaches 0 as $|t| \rightarrow \infty$.

$$E_g = \int_{-\infty}^{\infty} |g(t)|^2 dt = \int_{-1}^0 (2)^2 dt + \int_0^{\infty} 4e^{-t} dt = 4 + 4 = 8$$

(b) Power signal

Averaging $g^2(t)$ over an infinitely large interval is equivalent to averaging it over one period (2 seconds).

$$\begin{aligned} P_g &= \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T/2}^{T/2} |g(t)|^2 dt = \frac{1}{T} \int_{-T/2}^{T/2} |g(t)|^2 dt \\ &= \frac{1}{2} \int_{-1}^1 t^2 dt = \frac{1}{3} \end{aligned}$$

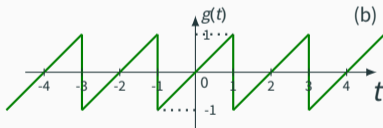
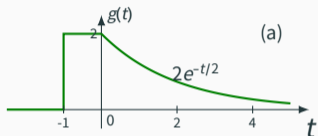
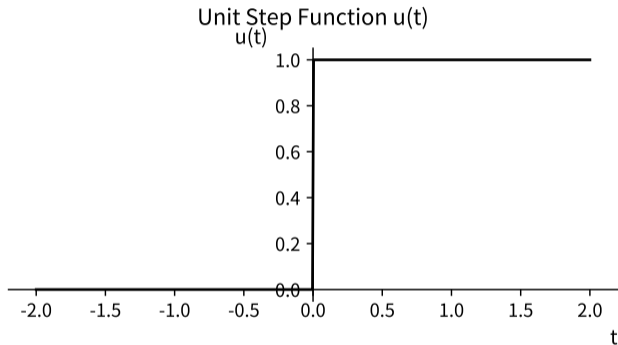


Figure 2. Signal for Example

1. Basic Signals: Unit Step Function



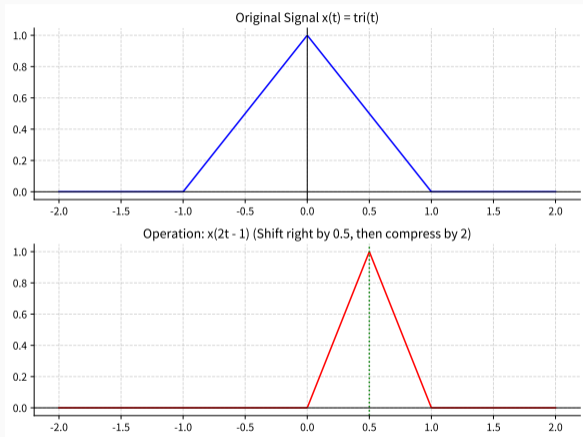
Definition

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

Key Property:

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

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



해석 순서 (Order of Operations):

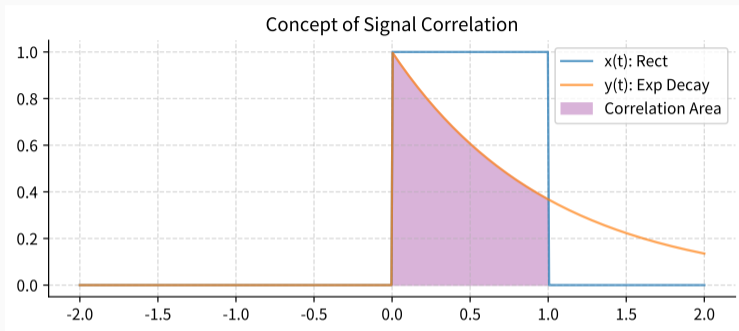
1. **Shifting:** $t \rightarrow t - t_0$
(Right if $t_0 > 0$)
2. **Scaling:** $t \rightarrow at$
(Compression if $a > 1$)

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)

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

- **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