# Chapter 2. Signals and Signal Space

## Communication Theory - 2026

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# Definition: Signal and System

## Signal

A signal is a set of information or data.
The signals are functions of the independent variable **time t**.

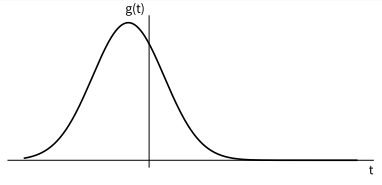
- Examples: Audio signals, video signals, sensor data, etc.

## System

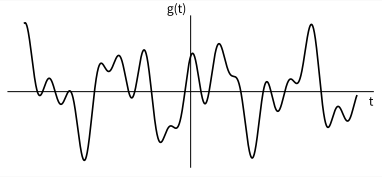
Signals may be processed further by systems, which may modify them or extract additional infromation from them.
Thus, a system is an entity that processes signals (**inputs**) to yield another set of signals (**outputs**).

- 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.

# Energy vs Power Signals




(a) Signal with finite energy




(b) Signal with finite power

**Figure 2.1:** *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.

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

## Power Signal

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

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

# 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,
  $P_{dBm} = -30$ dBm $= 10^{-6}$W.

# Example 2.1

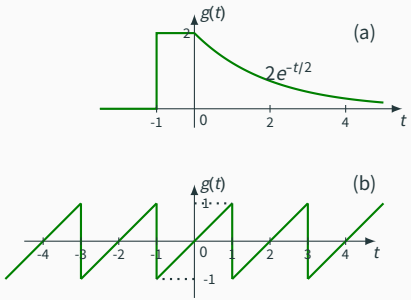



**Figure 2.2:** *Signal for Example*

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

**(a) Energy signal**

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

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

**(b) Power signal**

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

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

# Classification of Signals

1. Continuous time and discrete time signals
2. Analog and digital signals
3. Periodic and aperiodic signals
4. Energy and power signals
5. Deterministic and probabilistic signals

# Figure 2.3 Continuous vs Discrete Time Signals

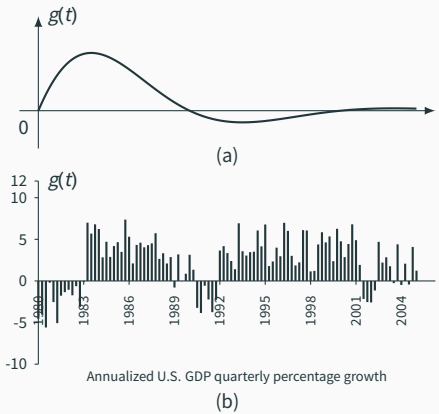



**Figure 2.3:** *Continuous vs Discrete Time Signals*

## (a) Continuous Time Signal

Continous time signals are specified for every value of time *t*. Many examples including:

- Audio recordings in analog media like LP, magnetic cassette, or reel-to-reel tapes.
- Signals received through AM/FM radio channel.

## (b) Discrete Time Signal

Discrete time signals are specified only at discrete points of $t = nT$. Many examples including:

- The quarterly gross domestic product (GDP), stock market daily averages, and monthly sales of a corporation.
- Audio signals formatted by MP3, HE-AAC, FLAC, or ALAC.

# Figure 2.4 Classification of Signals

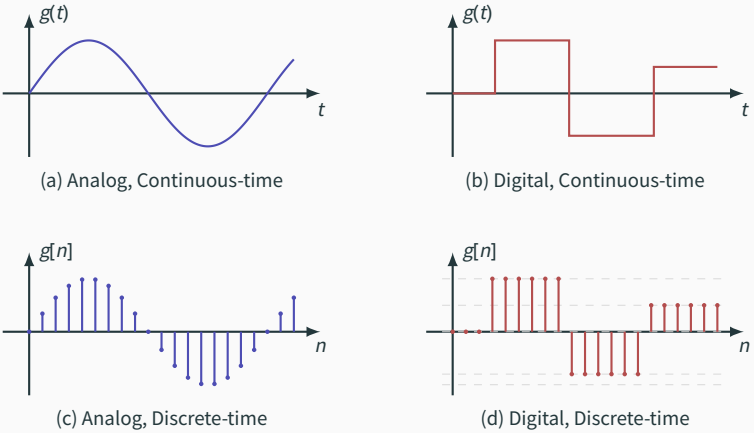



**Figure 2.4:** *Classification of signals based on amplitude and time domains*

# Periodic and Aperiodic Signals

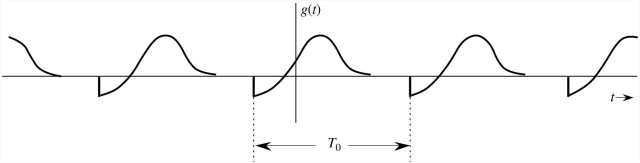



**Figure 2.5:** *Periodic signal of period $T_0$*

A signal $g(t)$ is **periodic** if there exists a positive constant $T_0$.

$$g(t) = g(t + T_0) \quad \text{for all t} \tag{2.5}$$

The smallest value of $T_0$ in Eq. (2.5) is the **period** of $g(t)$.

# 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