KECUDO

EE FOUNDATIONS · CLASS 4 OF 4





Signals & Systems

From convolution to the z-transform: a visual, practice-first guide

13 Chapters ◆ 78 Practice Problems ◆ 25-Question Quiz

2026 EDITION · ENGINEERING SERIES

Contents

Front matter

About this book 2

Meet the Kecudo Weather Station 3

Part I · Foundations

1 Signals & Their Classification 6

2 Signal Operations & Elementary Signals 9

3 System Properties 12

4 LTI Systems & Impulse Response 15

Part II · Core Methods

5 Continuous Convolution 19

6 Discrete Convolution 22

7 Fourier Series 25

8 Fourier Transform 28

9 Frequency Response & Filtering 31

Part III · Advanced Topics

10 Laplace Transform 35

11 Transfer Functions, Poles & Zeros 38

12 Sampling & Aliasing 41

13 z-Transform & Discrete-Time Systems 44

Back matter

Worked Solutions (78 problems) 47

Self-Assessment (25 questions) 52

Your Result 58

●○○ FOUNDATION

Chapter 1 · What a signal is

Signals & Their Classification

A signal is any quantity that varies with time (or space) and carries information: a voltage, a temperature, a sound. Classifying signals tells you which tools apply.

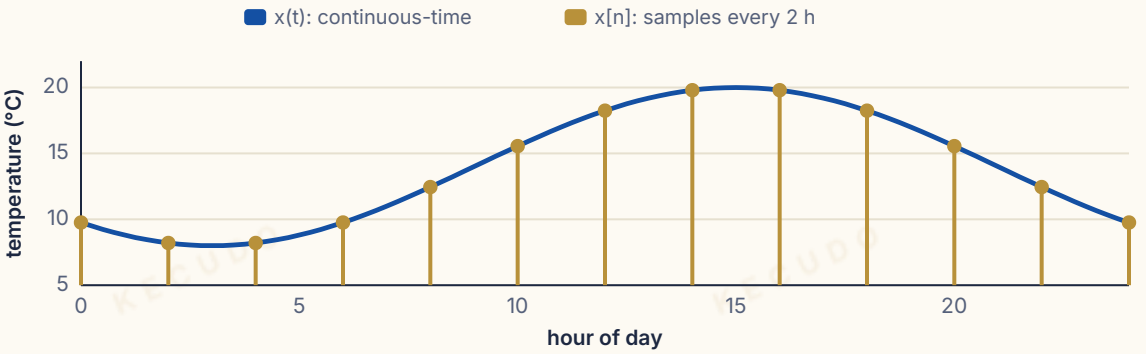


FIG 1.1 · The station's temperature as a continuous-time signal x(t) and as samples x[n] taken every two hours. (Stems start at the axis floor of 5 °C.)

Class	Either…	…or
Time	continuous-time x(t)	discrete-time x[n]
Values	analog (any value)	digital (finite levels)
Repetition	periodic: x(t + T) = x(t)	aperiodic
Symmetry	even: x(−t) = x(t)	odd: x(−t) = −x(t)
Size	energy signal (finite E)	power signal (finite P)

$$E = \int |x(t)|^2\,dt \quad \cdot \quad P = \lim (1/T)\int |x(t)|^2\,dt$$

energy signals have P = 0; power signals have E = ∞

Worked example · energy and power

1. $x(t) = e^{-t}u(t)$: $E = \int_0^{\infty} e^{-2t}\,dt$ = **1/2**. A decaying pulse is an energy signal.
2. $x(t) = 5\cos(\omega t)$: $P = 5^2/2$ = **12.5** (W into 1 Ω). It never ends, so it is a power signal.

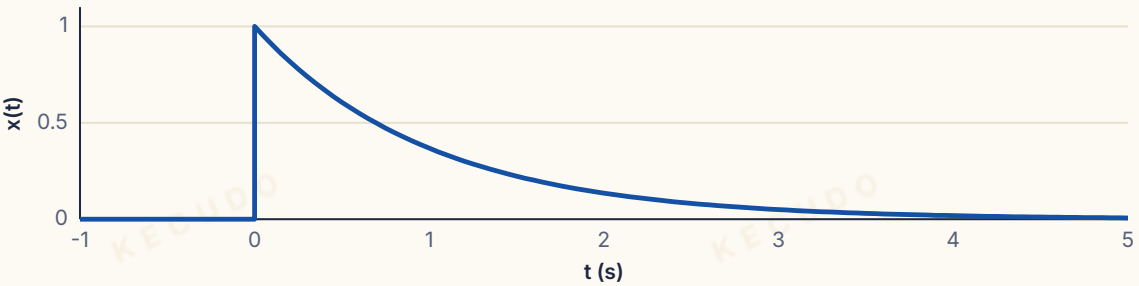


FIG 1.2 · The decaying exponential: most of its energy arrives in the first second.

Worked example · even and odd parts

1. Any signal splits as $x = x_e + x_o$ with $x_e(t) = [x(t) + x(-t)]/2$ and $x_o(t) = [x(t) - x(-t)]/2$.
2. For $x(t) = t^2 + t$: x_e = **t^2**, x_o = **t**.

Periodic sums $\cos(\omega_1 t) + \cos(\omega_2 t)$ is periodic only if ω_1/ω_2 is a ratio of integers. $\cos(2t) + \cos(3t)$ repeats every 2π s; $\cos(t) + \cos(\pi t)$ never repeats.

FOUNDATION

Chapter 2 · Shift, scale, flip

Signal Operations & Elementary Signals

Most signals can be built from a few elementary ones, and most manipulations are three operations on the time axis: shifting, scaling and reversing.

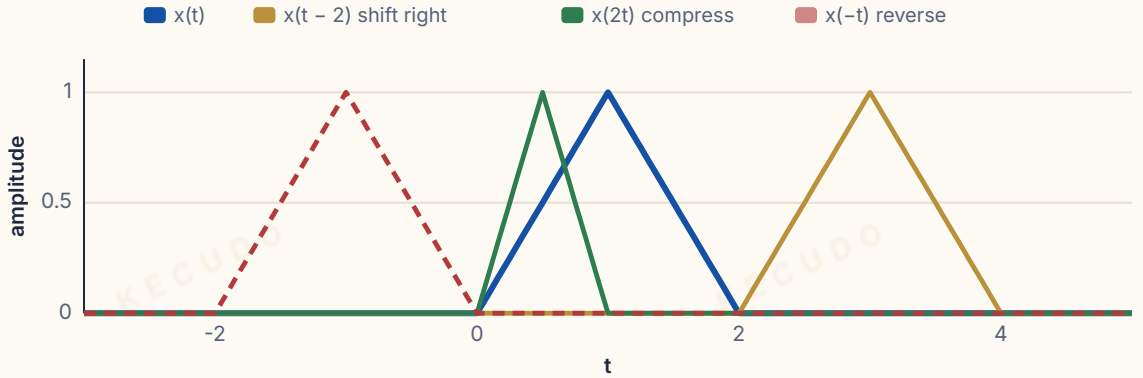


FIG 2.1 · A triangle pulse x(t) on 0 ≤ t ≤ 2 and three operations on it.

Operation	Formula	Effect
Time shift	$x(t - t_o)$	delays by t_o (right if $t_o > 0$)
Time scale	$x(at)$	compresses if $a > 1$, stretches if $a < 1$
Reversal	$x(-t)$	mirror about $t = 0$
Combined	$x(at - b) = x(a(t - b/a))$	shift by b/a after scaling

Tip For $x(at - b)$, find the new start and end by solving $at - b$ = (old start) and $at - b$ = (old end). It avoids sign mistakes.

● ○ ○ FOUNDATION

Chapter 3 · What a system does

System Properties

A system turns an input signal into an output signal. Six yes-or-no properties tell you which analysis tools you may use; the most important pair is linearity and time invariance.

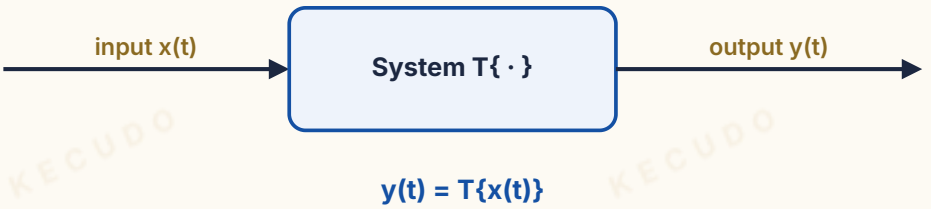


FIG 3.1 · A system as a block: input in, output out.

Property	Test
Linear	$T\{ax_1 + bx_2\} = aT\{x_1\} + bT\{x_2\}$
Time-invariant	delaying the input only delays the output
Causal	output never depends on future inputs
Stable (BIBO)	every bounded input gives a bounded output
Memoryless	y(t) depends only on x at the same instant
Invertible	the input can be recovered from the output

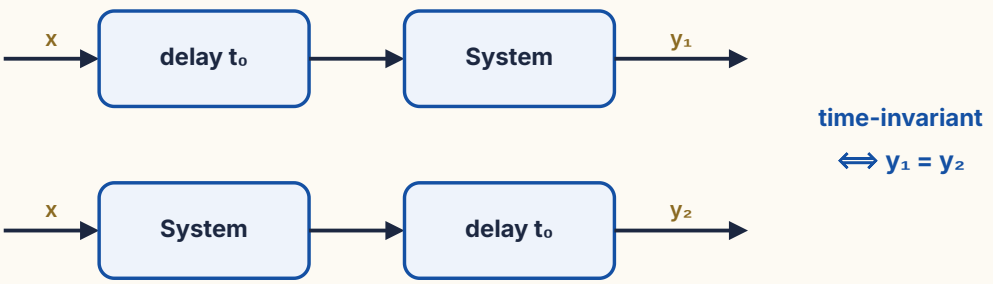


FIG 3.3 · The time-invariance test: delay then process, or process then delay. If the two outputs always match, the system is time-invariant.

Part A · Basics

1. A signal defined only at integer n is...

A. continuous-time

B. discrete-time

C. analog

D. periodic

2. The impulse response h(t) fully describes a system that is...

A. nonlinear

B. time-varying

C. LTI

D. unstable

3. Convolution in time corresponds in frequency to...

A. multiplication

B. addition

C. differentiation

D. division

4. A continuous LTI system is BIBO stable when its poles are...

A. on the jω axis

B. at the origin

C. in the right half-plane

D. in the left half-plane

5. The Nyquist rate for a signal band-limited to B Hz is...

A. B

B. 2B

K

KECUDO

Thank you for learning with Kecudo.

SERIES COMPLETE

You've finished EE Foundations

DC circuits · AC circuits · digital logic · signals and systems. Revisit any class at kecudo.com, and keep the formula pages close.

Class 1 DC Circuits · Class 2 AC Circuits · Class 3 Digital Logic · Class 4 Signals & Systems

kecudo.com