

# EN1020 Circuits, Signals, and Systems: Introduction

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# Section 1

## Introduction to Signals and Systems

## Subsection 1

### Introduction

# Introduction to the Course

- Signals and systems find many applications in communications, and automatic control, and form the basis for signal processing, machine vision, and pattern recognition.
- Electrical signals (voltages and currents in circuits, electromagnetic communication signals), acoustic signals, image and video signals, and biological signals are all examples of signals that we encounter.
- They are functions of independent variables and carry information.

# Introduction to Course Contd.

- We define a system as a mathematical relationship between an input signal and an output signal.
- We can use systems to analyze and modify signals.
- Signals and systems have enabled major advances in communication, control, and information processing technologies.
- In this course we will study the fundamentals of signals and systems.
- Types of signals in continuous time and discrete time, linear time-invariant (LTI) systems, Fourier series, and an introduction to Fourier transforms are the core components of the signals and systems part of this course.
- We will study sampling, discrete-time Fourier series and transform, Laplace transform,  $z$ -transform, and stability of systems in EN2063.

# Learning Outcomes

After completing this course you will be able to do the following:

- Differentiate between continuous-time, discrete-time, and digital signals, and techniques applicable to the analysis of each type.
- Apply appropriate theoretical principles to characterize the behavior of linear time-invariant (LTI) systems.
- Use Fourier techniques to understand frequency-domain characteristics of signals.

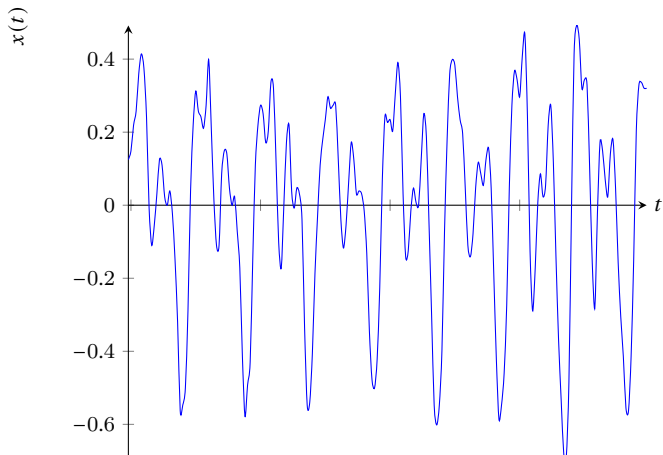
# Categories of Signals

- In this course, we study signals and systems that process these signals.
- Categories of signals:
  - ▶ Continuous-time signals: independent variable is continuous,
  - ▶ Discrete-time signals: independent variable is an integer,
- There are some very strong similarities and also some very important differences between discrete-time signals and systems and continuous-time signals and systems.

# Continuous-Time Signals $x(t)$

- The independent variable is continuous.
- E.g., sound pressure at a microphone as a function of time (one-dimensional signal).
- E.g., image brightness as a function of two spatial variables (two-dimensional signal).
- For convenience, we refer to the independent variable as time.





A function of a continuous variable  
A speech signal: a continuous-time,  
one-dimensional signal



An image on a film: a continuous-time, two-dimensional signal

# Discrete-Time Signals $x[n]$

- A function of an integer variable.
- Takes on values at integer values of the argument of  $x[n]$ .

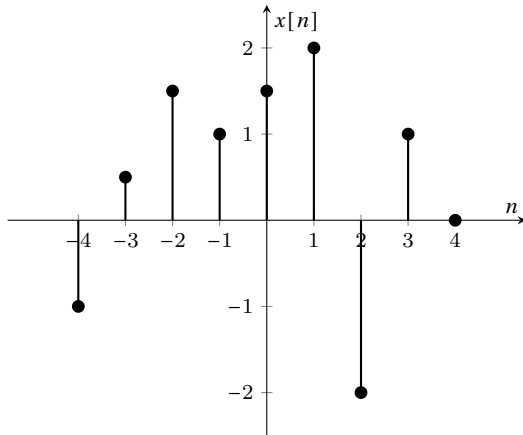


Figure: DT Signal

# Digital Signals

- What is a digital signal?
  - ▶ A quantized discrete-time signal: A digital signal is a discrete-time signal that takes on values from a finite set of distinct, quantized levels.
- What is a digital image?
  - ▶ A two-dimensional, quantized, discrete-time signal.
  - ▶ A  $600 \times 800$  image:  $n \in [0, 599]$ ,  $m \in [0, 799]$ ,  $x[n, m] \in [0, 255]$ . 8-bit image.

## Subsection 2

### Systems

# Systems

- A system processes signals.
- Examples of systems:
  - ▶ Dynamics of an aircraft.
  - ▶ An algorithm for analyzing financial and economic factors to predict bond prices.
  - ▶ An algorithm used in high-frequency trading, where traders use algorithms to analyze financial data and make trades in fractions of a second.
  - ▶ An algorithm for post-flight analysis of a space launch.
  - ▶ An edge detection algorithm for medical images.
  - ▶ A filter used in Electrocardiogram (ECG) signal acquisition, such as a notch filter used to remove 50 Hz power line interference.

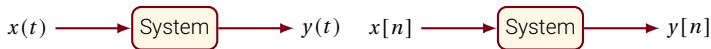


Figure: CT and DT Systems.

# Types of Systems

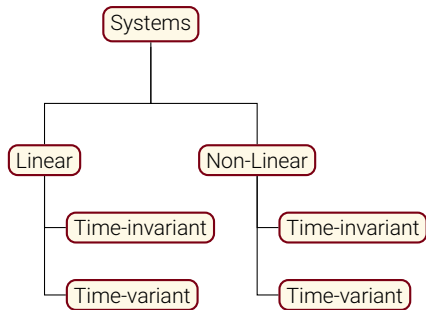


Figure: System types.

This classification applies to both continuous-time and discrete-time systems. This course is focused on the class of linear, time-invariant (LTI) systems.

# Systems Interconnections

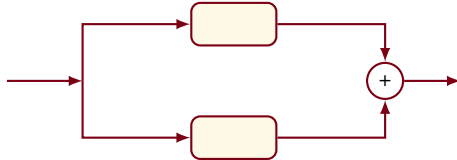
- To build more complex systems by interconnecting simpler subsystems.
- To modify the response of a system.
- E.g.: amplifier design, stabilizing unstable systems.



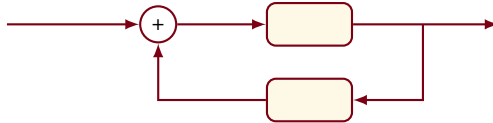
# Signal-Flow (Block) Diagrams



Series (Cascade)



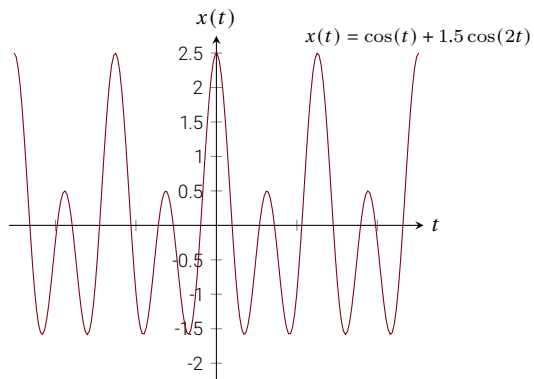
Parallel



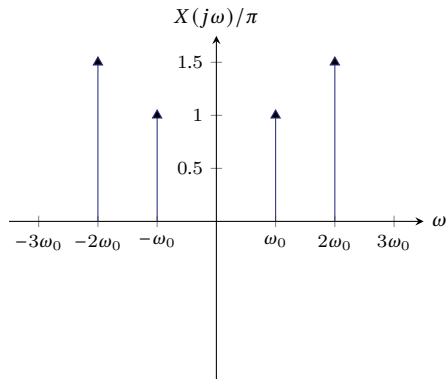
Feedback

Figure: System interconnections.

# Domains



Time domain representation.



Frequency domain representation,  $\omega_0 = 1$ .

Figure: Domains. The spectrum is shown normalized by  $\pi$  for visualization.

# Domains

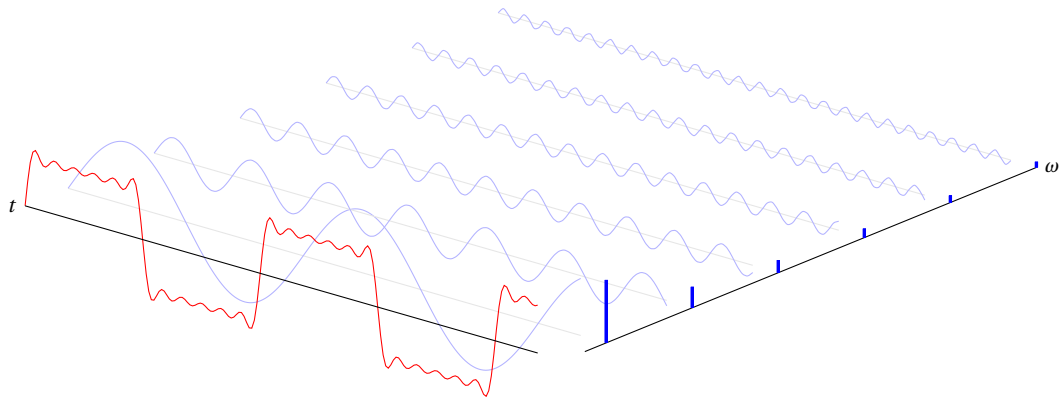


Figure: Square wave: time and frequency domains.

# Summary

- Signals represent information as functions of time, space, or other independent variables.
- We classify signals as continuous-time, discrete-time, or digital based on their domain and amplitude.
- A system defines a mathematical relationship that transforms an input signal into an output signal.
- We interconnect systems to build complex signal-processing and control applications.
- This course focuses primarily on linear, time-invariant (LTI) systems.
- We analyze signals in both the time domain and the frequency domain.