

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:

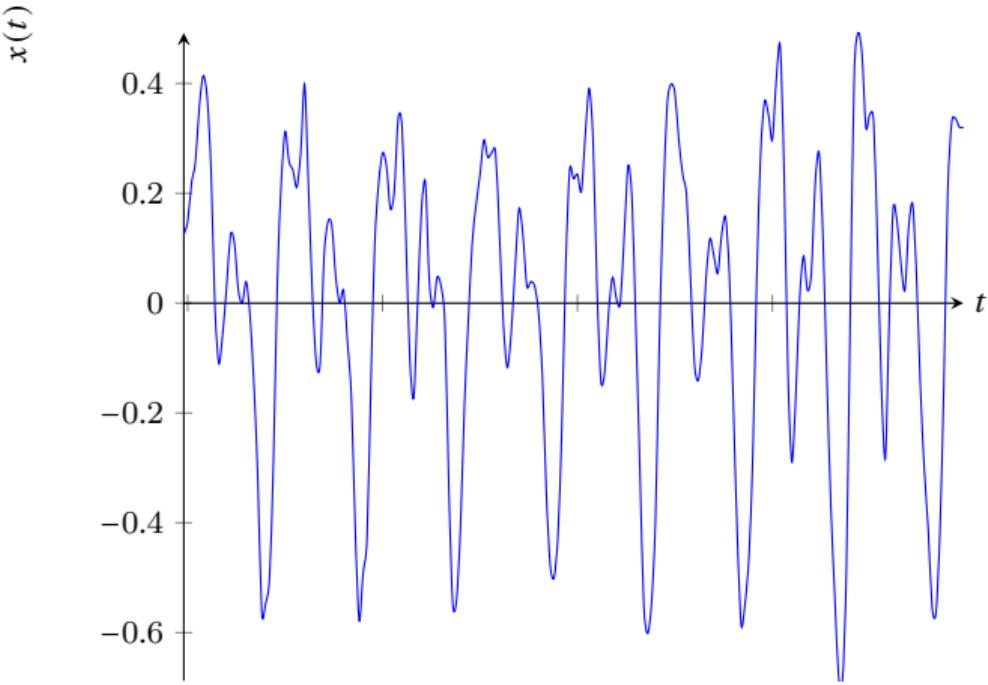
- Differentiate between continuous-time, discrete-time, and digital signals, and techniques applicable to the analysis of each type.
- Apply appropriate theoretical principles to characterize the behavior of linear time-invariant (LTI) systems.
- Use Fourier techniques to understand frequency-domain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

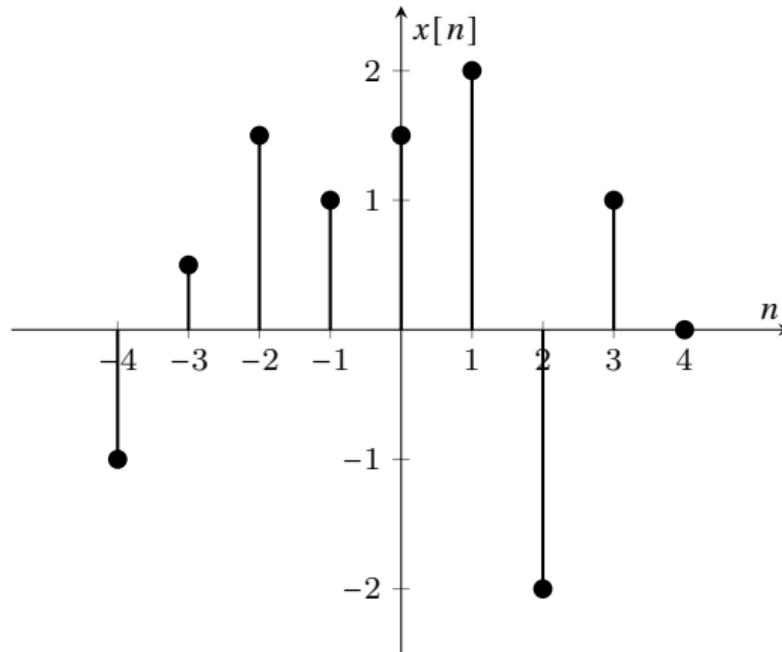


Figure: DT Signal

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 600×800 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.

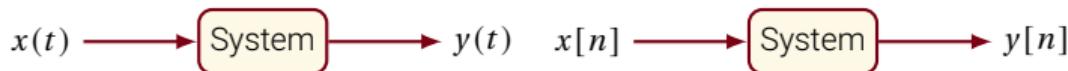


Figure: CT and DT Systems.

Types of Systems

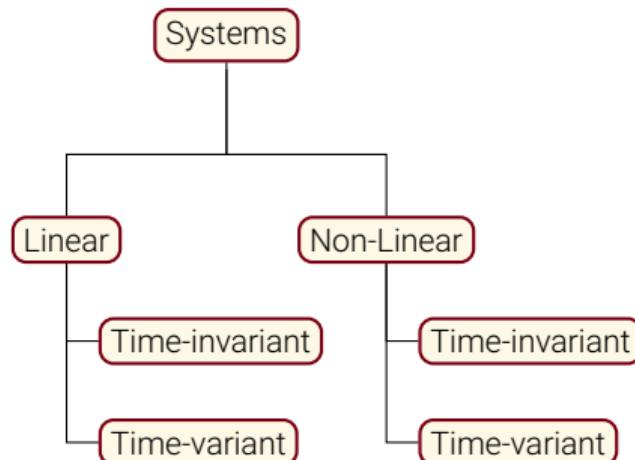


Figure: System types.

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

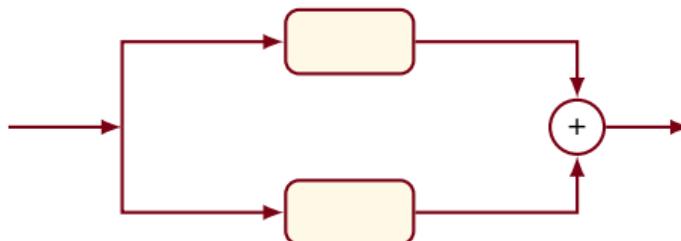
Systems Interconnections

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

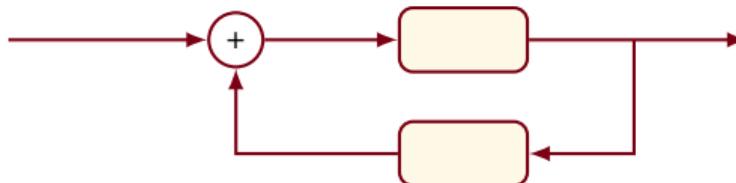
Signal-Flow (Block) Diagrams



Series (Cascade)



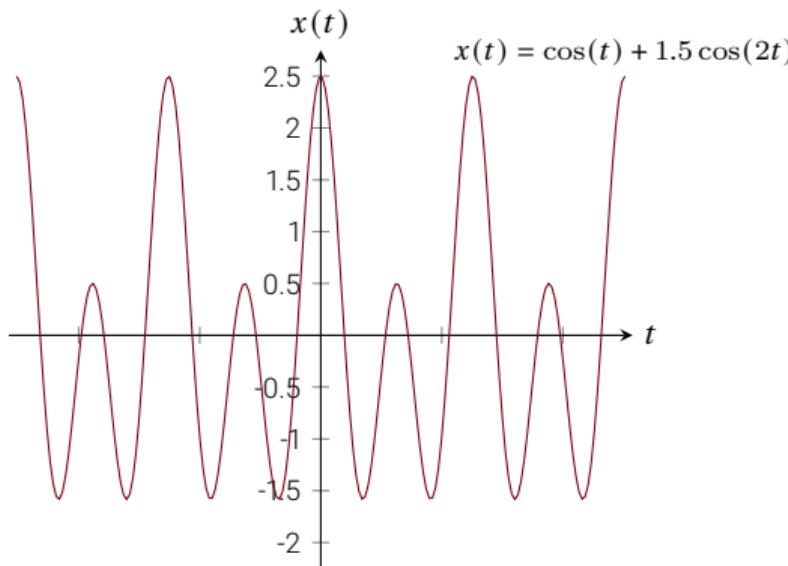
Parallel



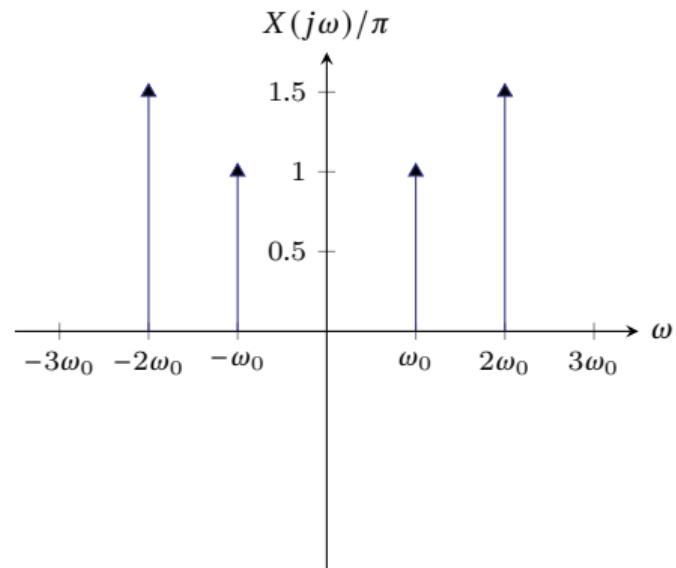
Feedback

Figure: System interconnections.

Domains



Time domain representation.



Frequency domain representation, $\omega_0 = 1$.

Figure: Domains. The spectrum is shown normalized by π for visualization.

Domains

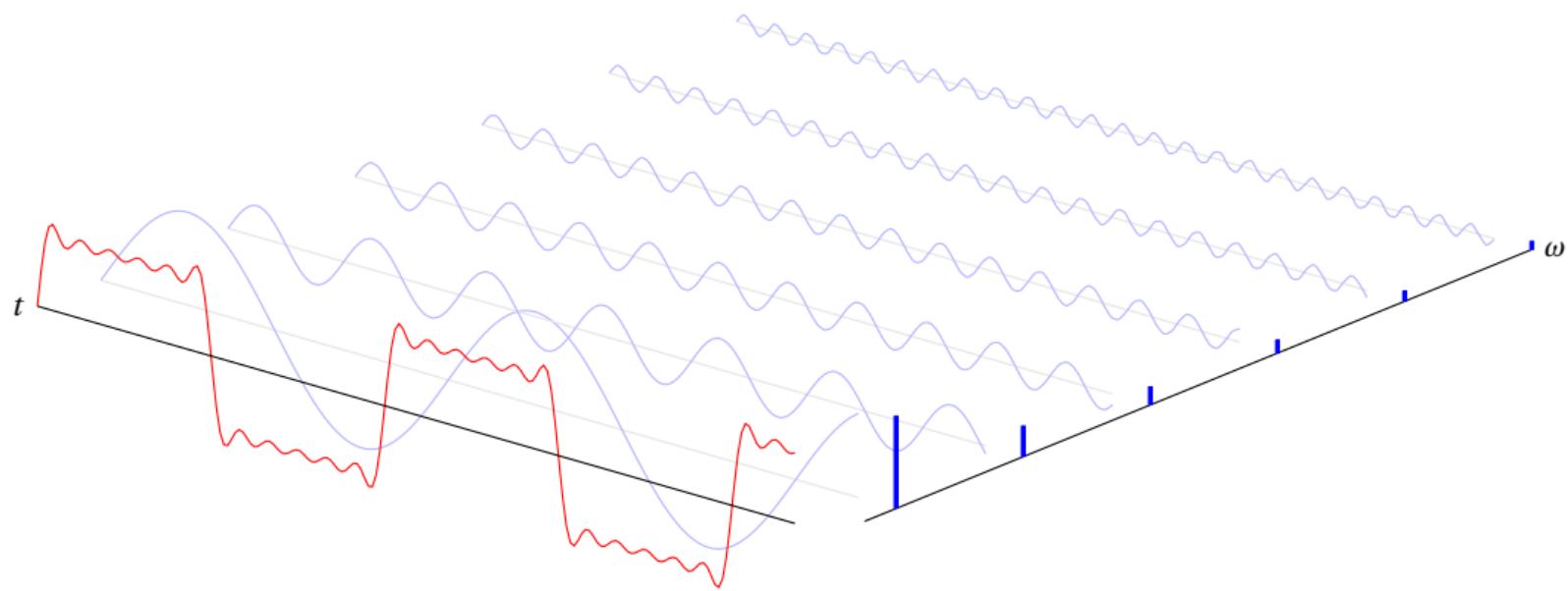


Figure: Square wave: time and frequency domains.

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.