EN1020 Circuits, Signals, and Systems: Introduction

Ranga Rodrigo
ranga@uom.lk

Department of Electronic and Telecommunication Engineering, The University of Moratuwa, Sri Lanka

January 25, 2026

Section 1

Introduction to Signals and Systems

Outline

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.

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.

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.

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.

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.

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.

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.

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.

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.

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

- In this course, we study signals and systems that process these signals.
- Categories 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, $x(t)$

Categories of Signals

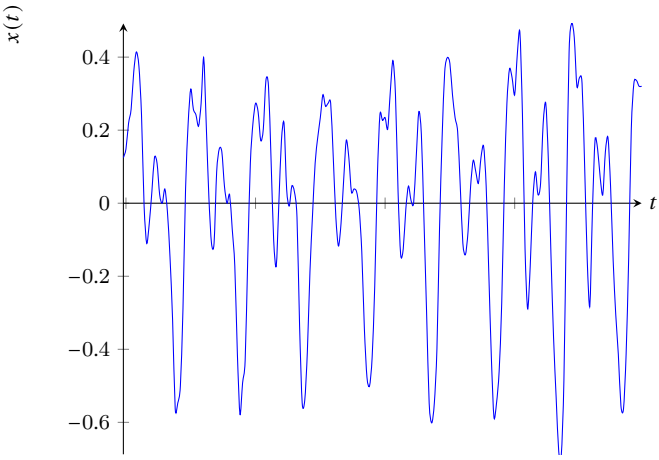
- In this course, we study signals and systems that process these signals.
- Categories of signals:
  - Continuous-time signals: independent variable is continuous, $x(t)$
  - Discrete-time signals:independent variable is an integer, $x[n]$

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, $x(t)$
  - Discrete-time signals:independent variable is an integer, $x[n]$
- 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 $x[n]$.

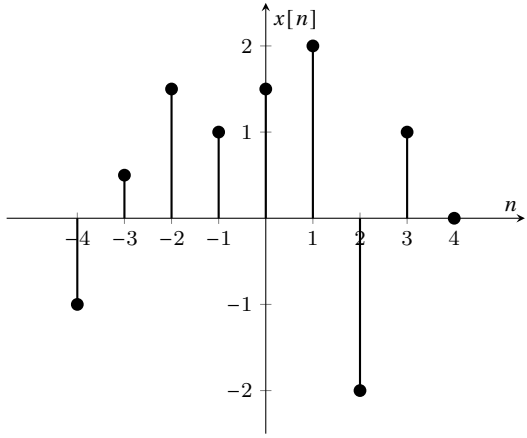


Figure: DT Signal

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.

Outline

Systems

- A system processes signals.

Systems

- A system processes signals.
- Examples of systems:

Systems

- A system processes signals.
- Examples of systems:
  - Dynamics of an aircraft.

Systems

- A system processes signals.
- Examples of systems:
  - Dynamics of an aircraft.
  - An algorithm for analyzing financial and economic factors to predict bond prices.

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.

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.

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.

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 $50\ \mathrm{Hz}$ power line interference.

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 $50\ \mathrm{Hz}$ power line interference.

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.

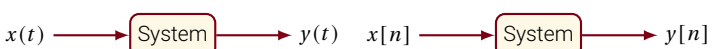


Figure: CT and DT Systems.

Types of Systems

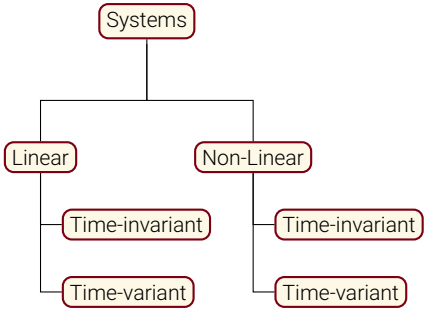


Figure: System types.

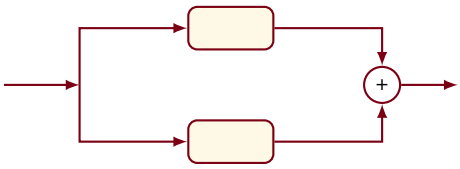
This classification applies to both continuous-time and discrete-time systems. This course is focused on the class of linear, time-invariant (LTI) systems.

Systems Interconnections

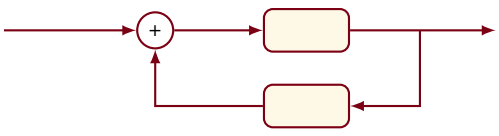
- To build more complex systems by interconnecting simpler subsystems.
- To modify the response of a system.
- E.g.: amplifier design, stabilizing unstable systems.

Signal-Flow (Block) Diagrams

Series (Cascade)



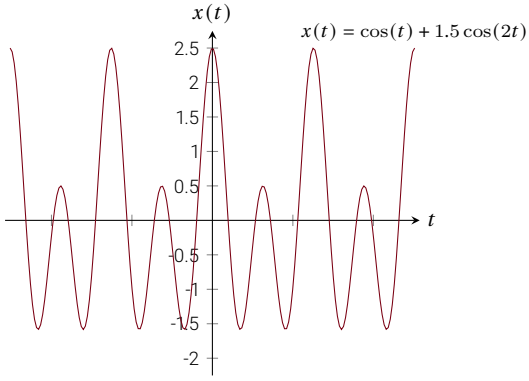
Parallel



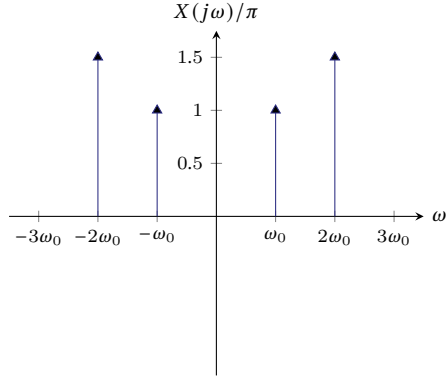
Feedback

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

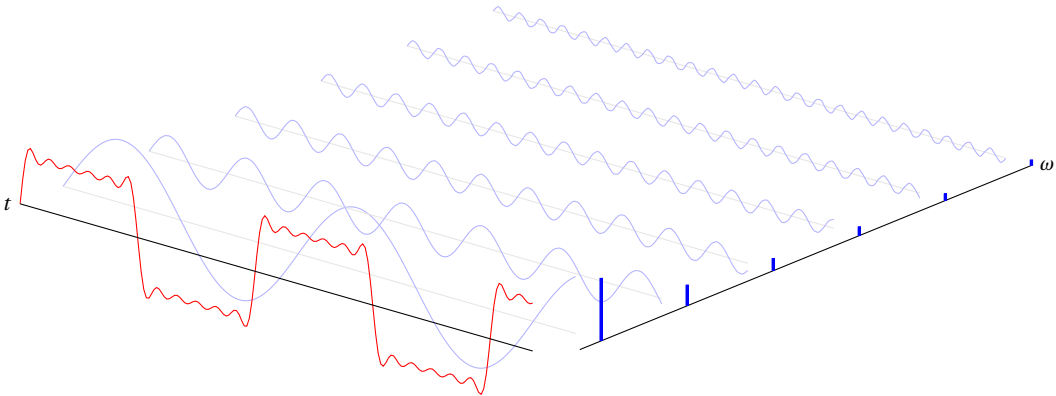


Figure: Square wave: time and frequency domains.

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.