

# Introduction to Signals and Systems

David W. Graham

EE 327

# Definitions

## Signal

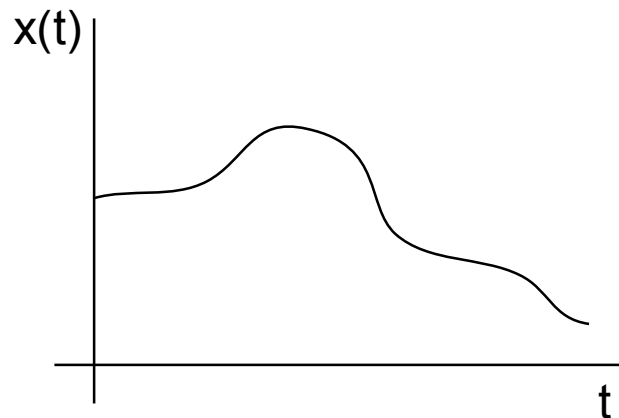
- Conveys information
- Function of time
- The way it evolves in time is what encodes the information
- Examples
  - Voltage or current in an electronic circuit
  - Speech and music
  - Bioelectric signals (e.g. ECG)

# Two Types of Signals

1. Continuous-time signals
2. Discrete-time signals

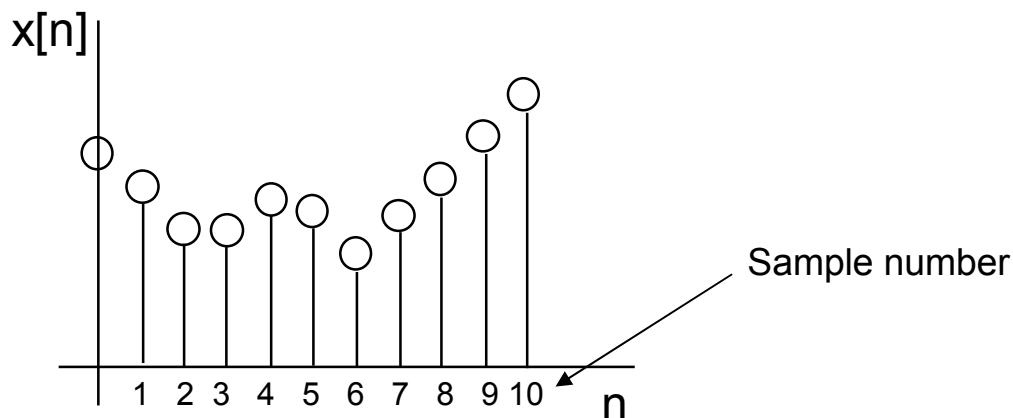
# 1. Continuous-Time Signals

- Signal that has a value for all points in time
- Function of time
  - Written as  $x(t)$  because the signal “ $x$ ” is a function of time
- Commonly found in the physical world
  - ex. Human speech
- Displayed graphically as a line



# 2. Discrete-Time Signals

- Signal that has a value for only specific points in time
- Typically formed by “sampling” a continuous-time signal
  - Taking the value of the original waveform at specific intervals in time
- Function of the sample value,  $n$ 
  - Write as  $x[n]$
  - Often called a sequence
- Commonly found in the digital world
  - ex. wav file or mp3
- Displayed graphically as individual values
  - Called a “stem” plot



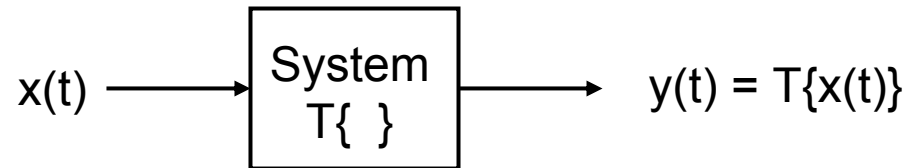
# Discrete-Time $\neq$ Digital

- Discrete-time sequences are continuous in values, but discrete only in time
- Digital signals are discrete in values and discrete in time (they can only take on specific values)

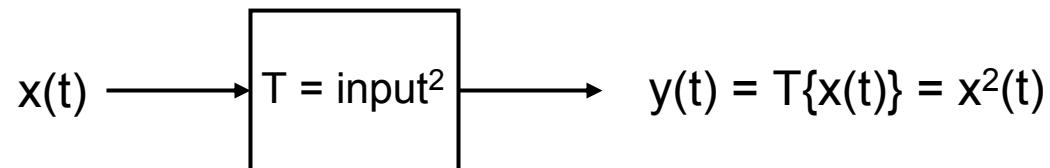
# Systems

## System

- A collection of items that together performs a function
- Modifies / transforms an input to give an output
- Represented by



ex. A squaring system



# System Examples

## Real-World Examples of Systems

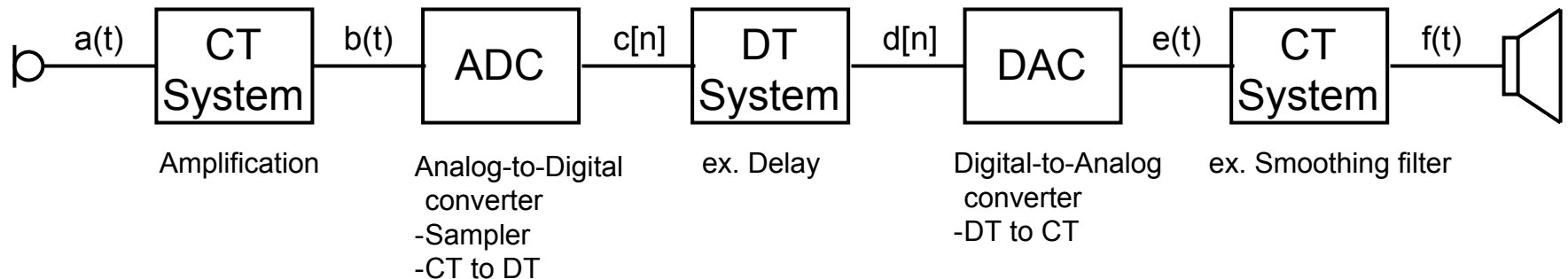
- Circuits
- Car
  - Inputs → Steering wheel, force on accelerometer and brakes
  - Outputs → Position of car, velocity
- Chemical processes
- Electromechanical systems (motors)
- Economics, stock market
- Biological processes (heart)

# Two Types of Systems

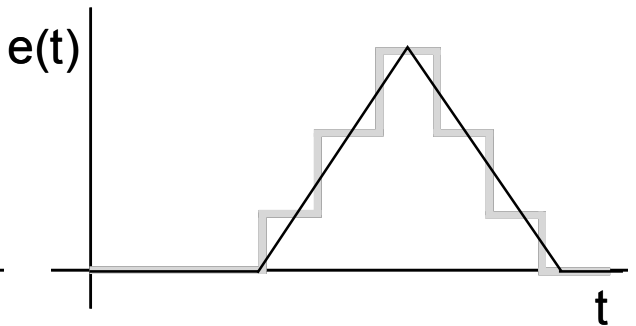
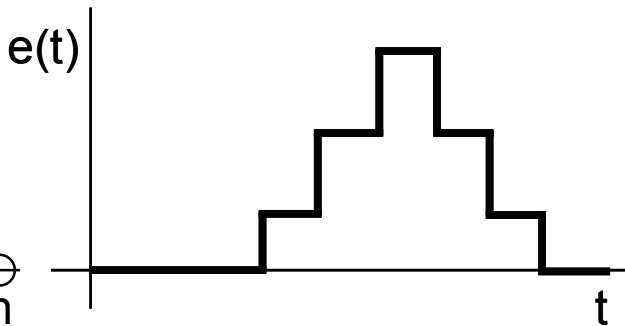
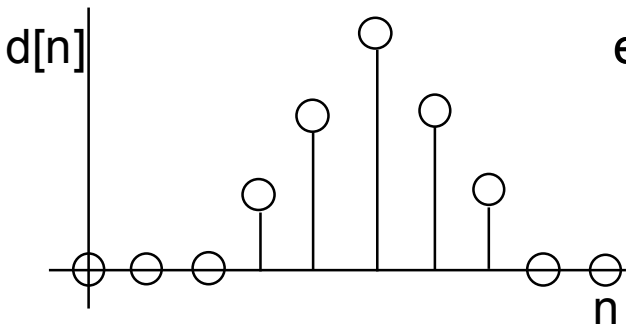
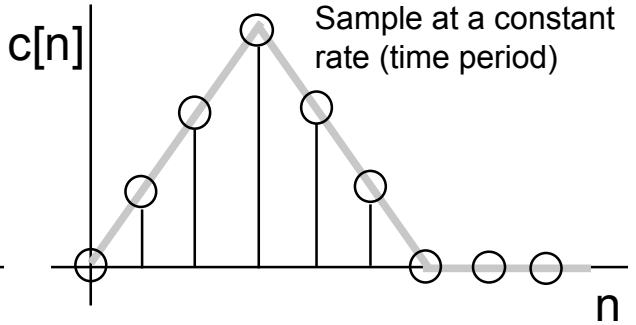
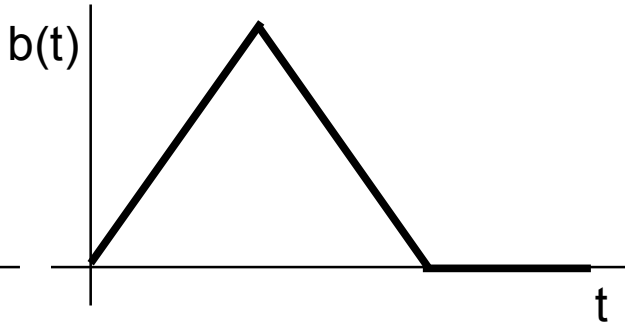
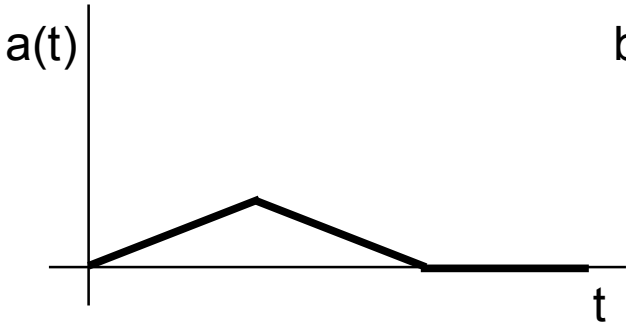
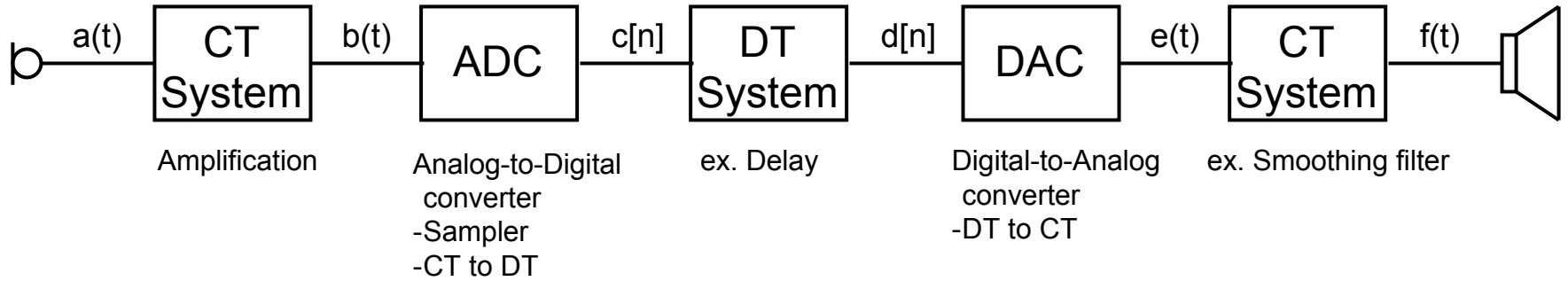
- Continuous-time systems
  - Operate on continuous-time signals
  - Commonly found in the physical world
  - Represented mathematically using differential equations
  - System parameters are defined on a continuum of time
- Discrete-time systems
  - Operate on discrete-time signals
  - ex. Computer algorithms
  - Represented mathematically by difference equations
  - System parameters are defined only at discrete points in time

# Hybrid Systems

- Most real systems are hybrid systems
  - Use both CT and DT systems
- ex. Audio delay system

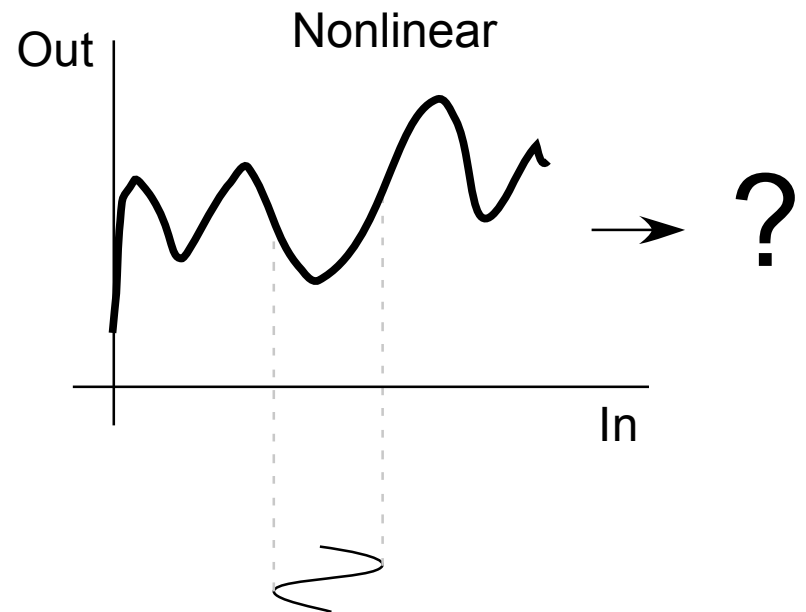
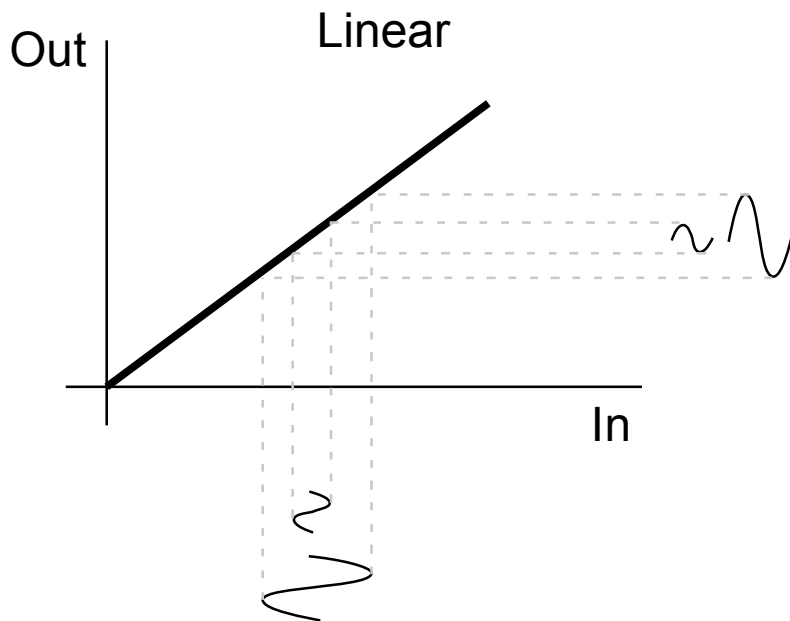


# Audio Delay System Example



# Creating Useable Systems

- Purpose of system design
  - To create an I/O relationship that is predictable
- The system I/O relationship must be the same every time ... the same today as it was yesterday and will be tomorrow
  - Time Invariant
- Given any type of input, the output follows a reasonable relationship
  - Easiest is Linear



# LTI System

- Most engineering systems are designed to be linear and time invariant (LTI) so that they are predictable
- The rest of this course focuses on LTI systems
  - How to analyze
  - How to use
  - How to design