EE312 Signals and Systems (Summer 2022): Course Introduction

Instructor: Sulaiman Alghunaim
Email: `sulaiman.alghunaim@ku.edu.kw`

Kuwait University
College of Engineering and Petroleum
Electrical Engineering Department

Electrical engineering

electrical engineers study and design of electrical systems using scientific principles (*e.g.*, math and physics)

- *electrical systems* are used in the
  1. storage, transmission, and processing of information
  2. generation, transmission, and consumption of energy
- examples of electrical systems:
  - power systems (power grids)
  - communication systems (telephone, wifi networks)
  - signal processing systems (speech processing, image processing)
  - control systems (airplane autopilot system)
  - hardware systems (calculators, computers)

Signals

a *signal* is a collection of data or information

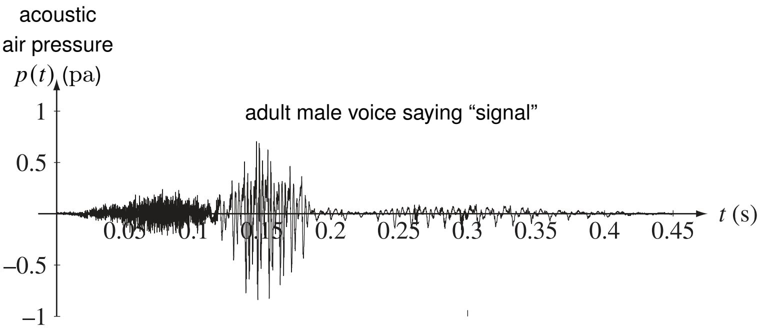
- human voice, telephone/television signal
- monthly sales of a company, daily cash in a bank

Mathematical definition: a signal is a *function* $f(t_1, t_2, \ldots, t_N)$ of *variables* t_i

- *one-dimensional signal* $f(t)$
  - speech over time
  - force on some mass over time
- *multi-dimensional signal* $f(t_1, t_2, \ldots, t_N)$
  - image intensity $f(a, b)$ at pixel (a, b)
  - temperature $f(x, y)$ at location (x, y)
  - charge density over space (human body)

(in this course, we focus on one-dimensional signals)

Voice signal



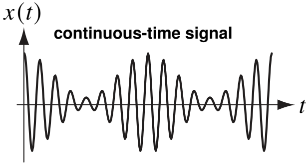
Continuous-time and discrete-time signals

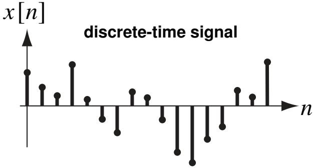
a **continuous-time signal**, $x(t)$, is a function of real time variable t

- voltage, current, audio signals
- position or velocity of moving object

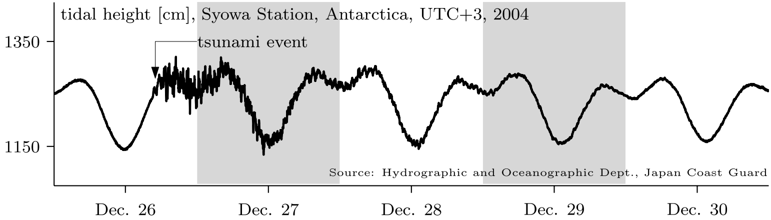
a **discrete-time signal**, $x[n]$ is a function defined over integer variable $n \in \{\ldots, -1, 0, 1, \ldots\}$

- daily average temperature
- stock market daily averages



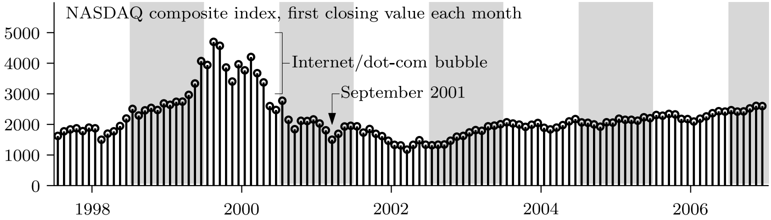


Example



tidal height [cm], Syowa Station, Antarctica, UTC+3, 2004
tsunami event
1350
1150
Source: Hydrographic and Oceanographic Dept., Japan Coast Guard
Dec. 26
Dec. 27
Dec. 28
Dec. 29
Dec. 30

(a)



NASDAQ composite index, first closing value each month
Internet/dot-com bubble
September 2001
5000
4000
3000
2000
1000
0
1998
2000
2002
2004
2006

(b)

Analog and digital signals

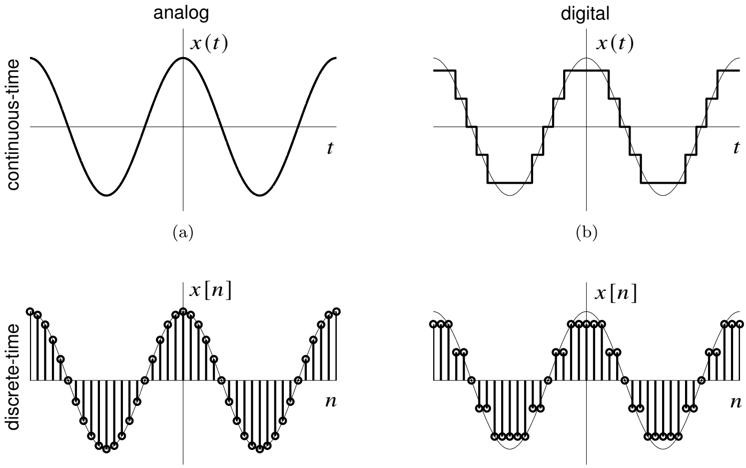
Analog signal: a signal with continuous range values is an *analog signal*

- amplitude can take on an infinite number of values
- analog may not be continuous-time

Digital signal: a signal with a finite number of values is a *digital signal*

- digital computer signals: binary signals (amplitude 0 or 1)
- digital may not be discrete-time
- analog signal can be converted into a digital signal (analog-to-digital (A/D) conversion) through quantization (rounding off)

continuous/discrete time determine the signal nature along the *time (horizontal) axis*; analog/digital determine the nature of signal *amplitude*


analog
digital
continuous-time
discrete-time
$x(t)$
t
$x(t)$
t
$x[n]$
n
$x[n]$
n

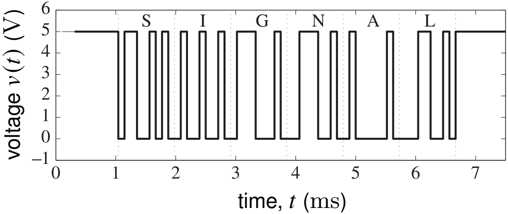
(a) (b) (c) (d)

Example

binary digital signals are commonly used to send text messages using the American Standard Code for Information Interchange (ASCII)

- a total of 128 characters (alphabets, digits 0-9, etc), are all encoded into a sequence of 7 binary bits characters
- in direct-wired connections between digital equipment, the bits are represented by a higher voltage (2 to 5 V) for a 1 and a lower voltage level (around 0 V) for a 0
- the 7 bits are sent sequentially, preceded by a *start* bit and followed by 1 or 2 *stop* bits for synchronization purposes

example: serial binary voltage signal for the ASCII message “SIGNAL”



Deterministic and random signals

Deterministic signals: a signal that can be mathematically described is a *deterministic signal*

Random signals: a *random signal* or *stochastic signal* is a signal whose values cannot be predicted precisely but are known only in terms of probabilistic description (*e.g.*, mean and variance)

- example:

$$x(t) = \cos(t) + n(t)$$

  where $n(t)$ is an unknown random noise with known mean and variance

- random signals are beyond the scope of this course

Systems

Systems: a *system* is is an entity that processes a set of *input* signals to provide a set of *output* signals, which can provide additional useful information

- example: a radar can estimate the future location (output) of a moving target by processing the past radar signal (input), which provides the past location and velocity of the target
- a system may be made up of physical components (hardware), such as electrical or mechanical systems, or it may be an algorithm (software) that computes an output from an input signal
- scientific instruments are systems that measure a physical phenomenon (temperature, pressure, speed) and convert it to a voltage/current, or a signal
- the term system even encompasses things such as the stock market, government, weather, the human body, ...etc

System model

a *system model* is the mathematical equations relating the outputs to the inputs

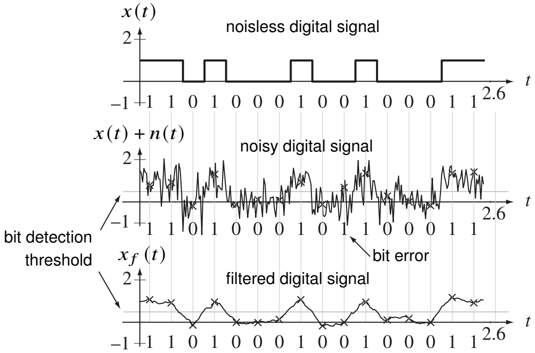
- example: voltages/currents of an electrical circuit can be described using the voltage-current relations of resistors, capacitors, inductors, transformers, transistors, and so on, and laws of interconnection (*i.e.*, Kirchhoff's laws)
- the study of systems consists of three major areas:
  - *mathematical modeling*
  - *analysis*: how to find the system outputs for the given inputs and mathematical model of the system
  - *design (synthesis)*: how to construct a system that will produce a desired set of outputs for the given inputs

Outline

- signals and systems
- **practical examples**
- course information

Example: bit detection

in binary signal communication system, the detection of bit values is usually done by comparing the signal value at a predetermined bit time with a threshold: if it is above threshold it is declared a 1 and if it is below threshold it is declared a 0



the bits can be detected with a very low probability of error even though the filtered signal does not look very clean; this is the basic reason that digital signals can have better noise immunity than analog signals

Example: image processing

- on the left is an unprocessed X-ray image of a carry-on bag
- on the right is the same image after being processed by some image-filtering operations to reveal the presence of a weapon

Feedback systems

in a *feedback system*, something in the system observes its outputs and may modify the input signal to the system to improve the response

AC thermostat control

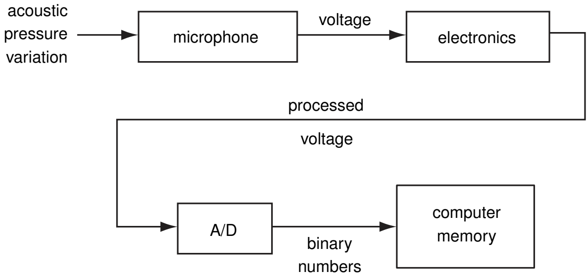
- when the temperature inside the thermostat exceeds the desired level, a switch closes and turns on the air conditioner
- when the temperature inside the thermostat drops below the desired level, the switch opens, turning off the air conditioner

Aircraft autopilot

- computer system senses/measures the velocity, altitude, roll, pitch and yaw of the aircraft
- based on these measurements, the system adjusts the control surfaces to maintain the desired flight path

Sound recording system

sound systems typically consist of a microphone that converts air-pressure variation into a continuous-time voltage signal, electronic circuitry that processes the continuous-time voltage signal, and an analog-to-digital (A/D) conversion that changes the continuous-time voltage signal to a digital signal in the form of a sequence of binary numbers that are then stored in computer memory



Outline

- signals and systems
- practical examples
- **course information**

Course information

Course objective

- learn math descriptions of signals and systems
- learn techniques for the analysis of signals processed by systems
- learn how to handle signals and systems using MATLAB

Textbook

B.P. Lathi and R. Green, *Linear Systems and Signals*, Oxford University Press

Grading policy: 5% hw, 10% quizzes, 25% exam I, 20% exam II, 40% final exam

- lowest homework grade will be dropped when finalizing grades
- lowest two quizzes grades will be dropped when finalizing grades

- course material (syllabus, lecture slides, homework,...) will posted on Moodle course webpage
- expect around 10-12 quizzes (no make-up quizzes)
- book examples, exercises, and homework problems serve as a good practice for quizzes and exams

this course is more of an applied mathematics course rather than a course covering the design of useful devices, but an understanding of this course is very important for later courses where you need to actually design stuff...