0610312-1A
Signals and Systems (Fall 2024)
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 for
  1. storage, transmission, and processing of information
  2. generation, transmission, and consumption of energy
- examples of electrical systems:
  - hardware systems (circuits, electronics)
  - power systems (power grids)
  - communication systems (telephone, wifi networks)
  - control systems (airplane autopilot system)
  - signal processing systems (speech processing, image processing)

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*

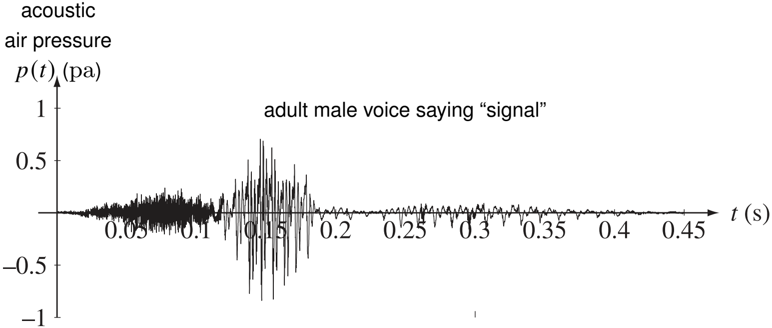
$$f(t_1, t_2, \ldots, t_N)$$

of *variables* $t_1, \ldots, t_N$

- *one-dimensional* or *single-variable* 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)

Example: voice signal



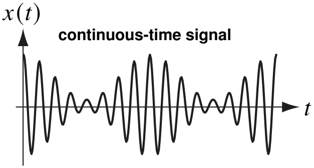
Continuous-time and discrete-time signals

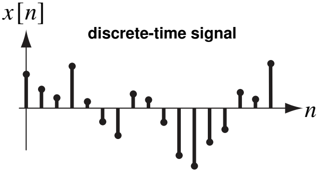
a **continuous-time signal** $x(t)$ is a function of real time variable t

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

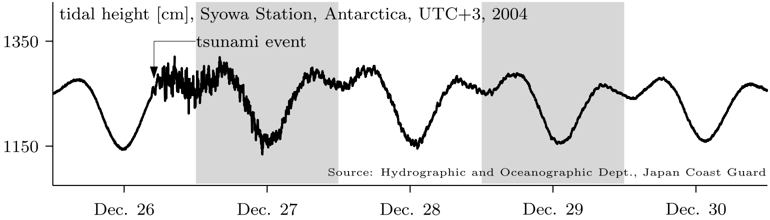
a **discrete-time signal** $x[n]$ is a function of integer variable $n = \ldots, -1, 0, 1, \ldots$

- daily average temperature
- stock market daily averages



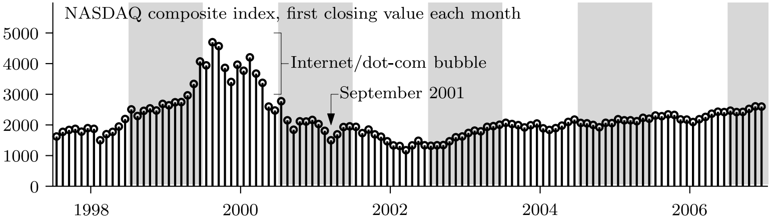


Example



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*

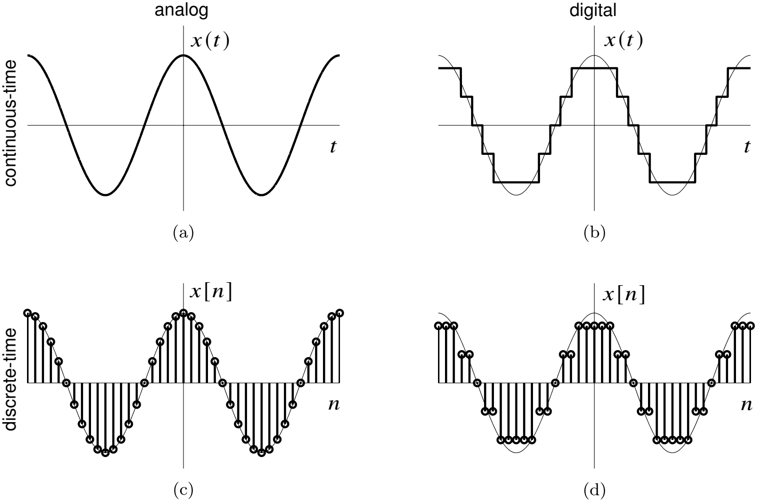
- amplitude can take on an infinite number of values
- analog signal can be discrete-or continuous-time signal

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

- digital computer signals: binary signals (amplitude 0 or 1)
- digital signal can be discrete-or continuous-time signal
- 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*



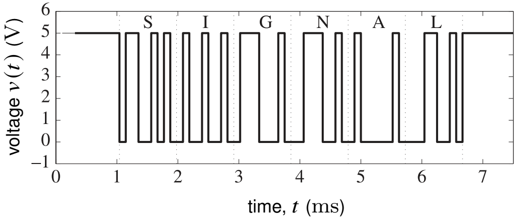
analog
digital
continuous-time
discrete-time
$x(t)$
t
$x(t)$
t
(a)
(b)
$x[n]$
n
$x[n]$
n
(c)
(d)

Example: binary signal

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

- 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 $5\ \mathrm{V}$) for a 1 and a lower voltage level (around $0\ \mathrm{V}$) 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

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

- 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 hardware, such as electrical or mechanical systems, or it may be a software that computes an output from an input signal
- sensors 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

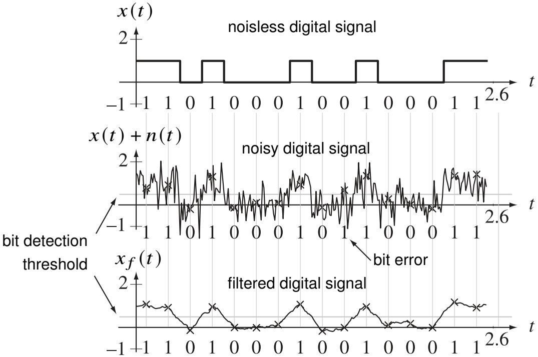
- example: voltages/currents of an electrical circuit can be described using the voltage-current relations of resistors, capacitors, inductors, transformers, transistors, and so on, and laws of interconnection (*i.e.*, Kirchhoff's laws)
- the study of systems consists of three major areas:
  - *mathematical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



bits can be detected with low probability of error even though the filtered signal is noisy; this is why digital signals can have better noise immunity than analog signals

Example: image processing

- left: unprocessed X-ray image of a carry-on bag
- right: processed image by some image-filtering system to reveal the presence of a weapon

Feedback systems

in a *feedback system*, the output is observed and used to modify the input signal 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

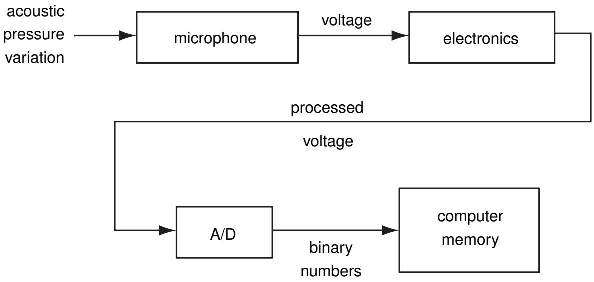
Aircraft autopilot

- computer system 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 CT voltage signal
- electronic circuitry that processes the continuous-time voltage signal
- analog-to-digital (A/D) conversion that converts the CT voltage signal to a digital signal 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

- teach the students about signals, systems, including their basic classifications
- teach students to analyze *linear time-invariant (LTI)* systems through convolution
- learn how to analyze LTI systems using the Laplace and z-transforms
- introduce students to state-space representations of LTI systems
- acquaint students with MATLAB software for analyzing signals/systems

Textbook

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

Grading policy

- hw (5%+2%bonus)
- quizzes (7%+3%bonus)
- two midterm exams (48%)
- final exam (40%)

Class Policy on AI use

- use of AI tools, such as ChatGPT, unless explicitly permitted, is viewed as receiving help from another individual
- AI should augment, not replace, genuine understanding and effort
- students suspected of unpermitted AI use may undergo additional assessments to prove comprehension

- 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 systems, but an understanding of this course is very important for later courses where you need to actually design stuff...