EE213 - Introduction to Signal Processing

Semester1, 2021

Course Outline

- Basic understanding of signals
  - definition, classification, simple mathematical presentation, etc.
- Fundamentals of signal processing
  - sampling, quantization, etc
- Simple filter designs
  - analogue and digital filters
- lectures, tutorials, labs

Assessment Criteria

- **Evaluation**
  - Labs (5x3hr): 20%.
  - Class tests (2x1hr): 20%.
  - Assignments (3x2hr): 10%.
  - Semester exam (2hr): 50%.
- **Pass**
  - Overall 40%
  - CA mark is carried forward to Autumn repeat examination.
- **Lab reports**
  - Corrected within two weeks.
  - Available for viewing upon request.
  - Penalty of 10% of grade for each day overdue.

Suggested Study Methods

- Show up in classes, do NOT miss tutorials.
- Read lecture notes and slides before going to classes.
- Read Lab materials before going to the Labs.
- Try to go over all the examples, tutorials, past exam papers (by yourself first).
- Send emails or drop by my office for further help.

Recommended Textbooks

1. Signals and Systems, Simon Haykin and Barry Van Veen.
2. Structure and Interpretation of Signals and Systems, Edward Ashford Lee and Pravin Varaiya.
3. Signals and Systems, A. Oppenheim and A. Willsky.

Lecture 1: Introduction

- Define a signal
- Give some examples of signals
- Explain the roles of signal processing
- Name some applications of signals processing

What Is a Signal?

- We are all immersed in a sea of signals
  - human voice
  - gestures (sign language, body language)
  - visual of surrounding objects
  - blood pressure, heart rate
  - smoke signals
  - electromagnetic field emanating from a transmitting antenna
  - variation of light intensity in an optical fibre

  .....

- What do all of these examples have in common?

What Is a Signal?...

To define it precisely is a difficult task

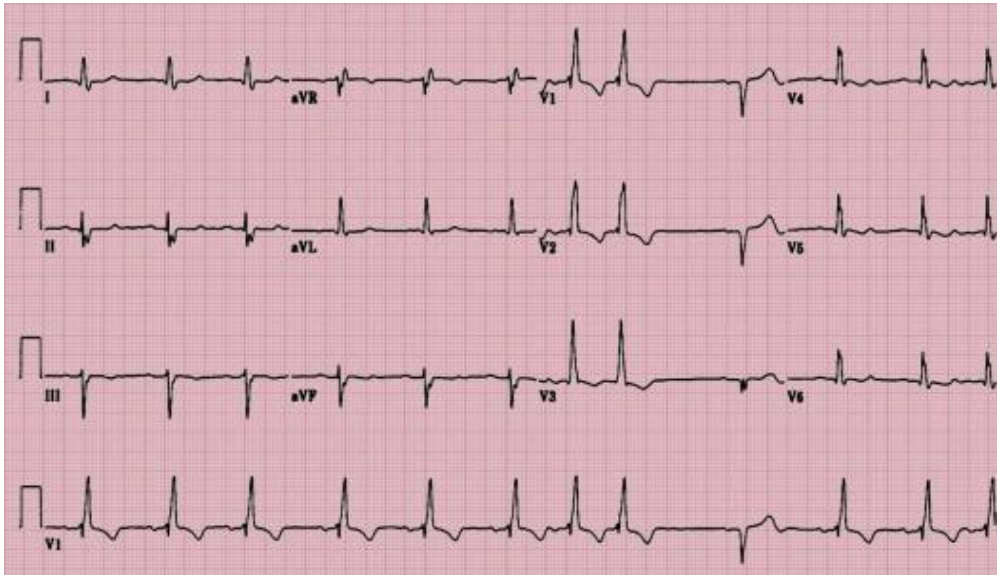
Definition (General definition)

Anything that carries information is a signal

Definition (More mathematical definition)

A signal ***is a function of one or more variables*** which ***conveys information*** on a nature of ***a physical phenomenon or system***

- We are mainly interested in **one-dimensional signals** in this module.
- The independent variable is often referred to as 'time', although in some specific examples it may in fact not represent time



An Audio Signal

Examples of Signal

Example (Sounds)

- can be generated by human beings, animals, machines, etc
- one-dimensional signals

Example (Images)

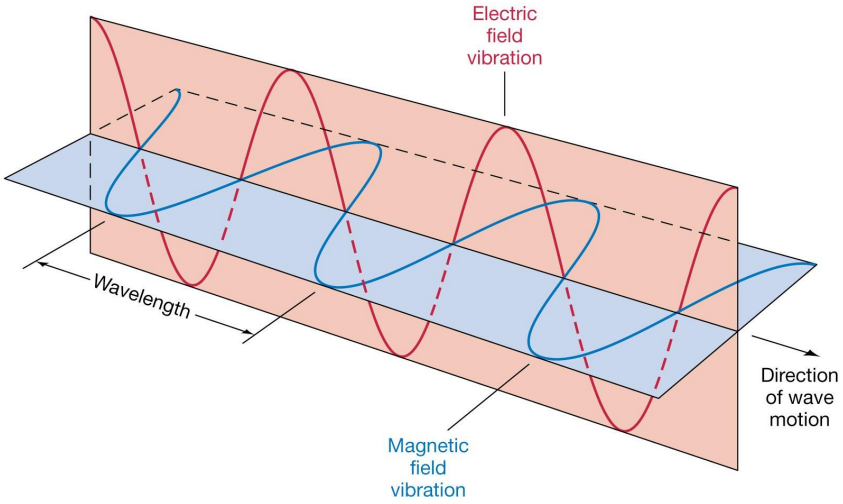
- a function of 2 spatial variables

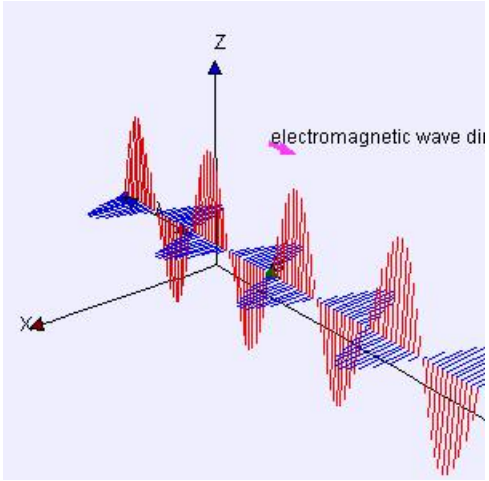
Example (Videos)

- a function of 3 variables

Electromagnetic Waves

- Electromagnetic waves are created by the vibration of an electric charge, which then creates a wave which has both an electric and a magnetic component.
- The oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation.
- Electromagnetic waves are characterised by
  - Wavelength: measured between the distances of either crests or troughs
  - Amplitude: the distance from the maximum vertical displacement of the wave to the middle of the wave. Larger amplitude means higher energy and lower amplitude means lower energy.





Electromagnetic Waves

- Electromagnetic waves make wireless communications possible.
- A baseband signal is attached to another electrical signal, a radio frequency carrier wave from a signal generator.
- The baseband signal modulates some properties of the carrier signal such as amplitude or frequency: modulation.
- Carrier signals are usually generated from a resonant crystal oscillator.
- Modulated radio frequency signal is then amplified, and then goes into an antenna, and some of it leaks out, thus it's transmitted.

What is Signal Processing?

- Operations on or analysis of signals
  - to extract some useful information or to change their characteristics

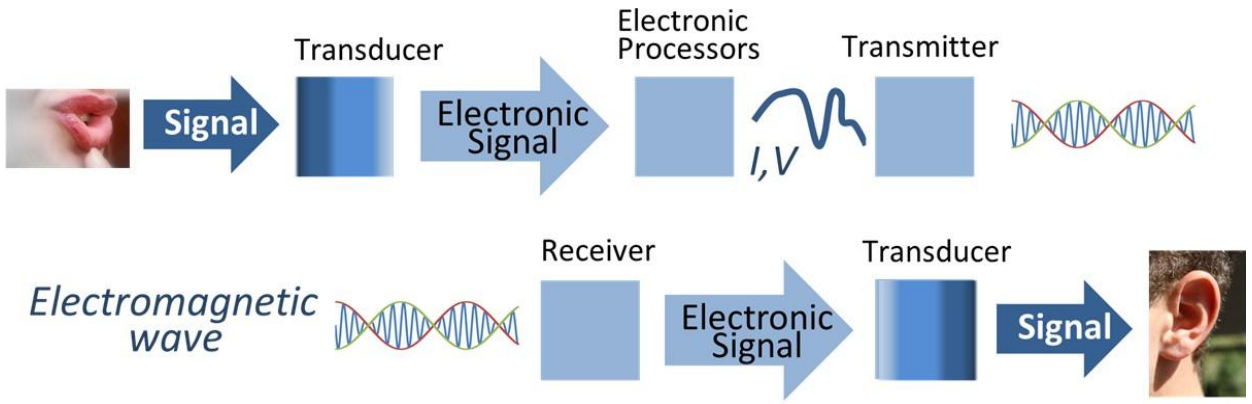
biological example: hear some thing then extract the information in the brain

  - Signals are processed by systems

examples:computers

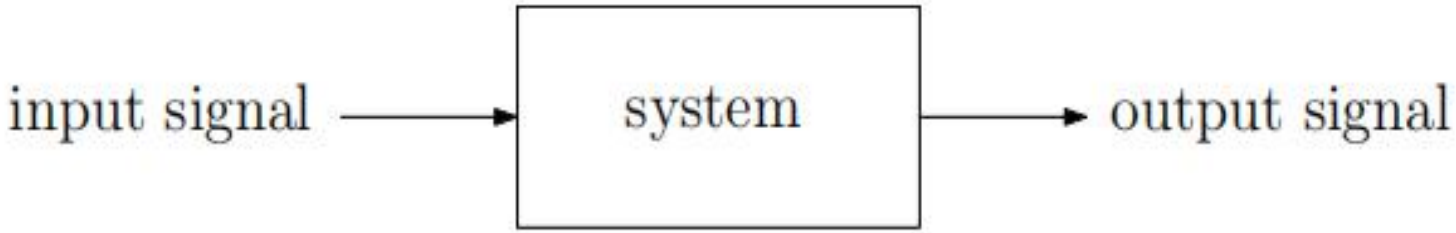
specific purposed ICs

analogue electrical circuits



What is Signal Processing?

- A signal processing system

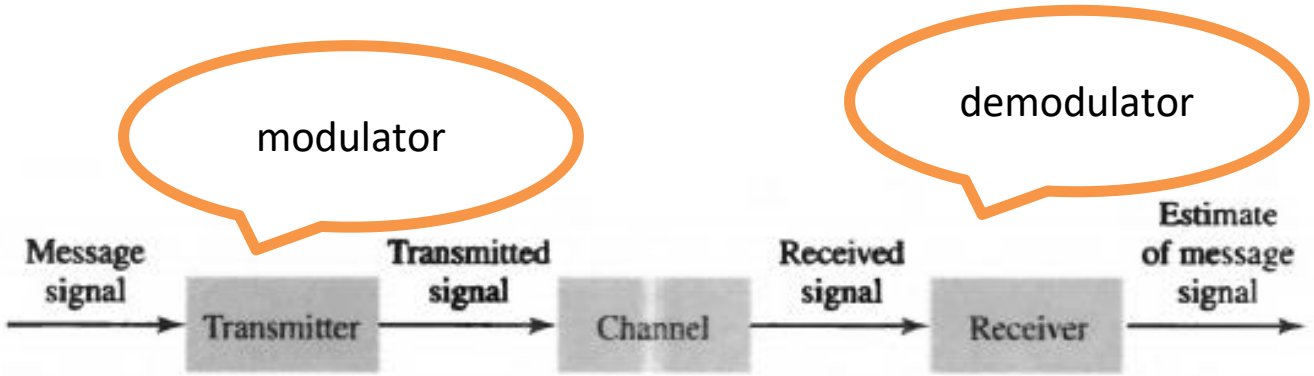


This abstract model may be used to represent a range of physical processess:

- Electrical circuits
- Mechanical devices
- Computer algorithm

Popular Systems

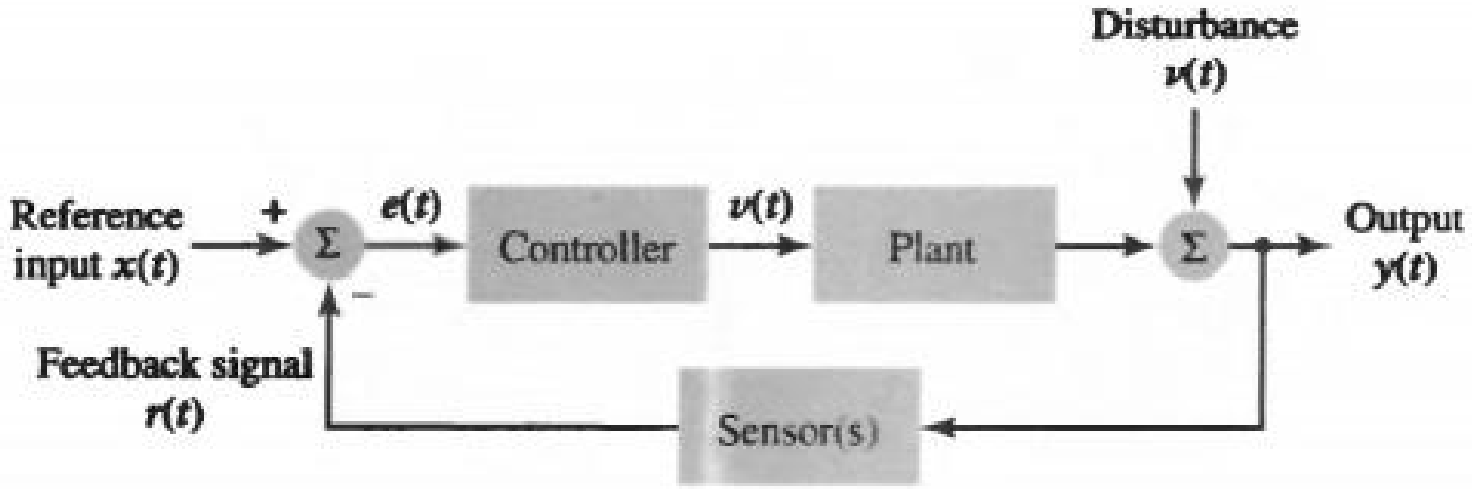
- **Communication systems**:sending data from one point to another.
  - Component:transmitter, channel, and receiver



  - Classification: analogue and digital; wired and wireless ……

Popular Systems

- **Control systems**: control some physical quantity or object on the specified value.
  - Broad applications: aircraft autopilot, mass-transitvehicle, automobile engines, machine tools, oilrefineries, paper mills, nuclear reactors, power plants, and robots ect.
  - Two main reasons for using control systems: satisfactory response and robustness
  - Block diagram of a feedback control system:



Popular Systems

- **Remote Sensing**: obtain information about an object without physically contacting it by detecting and measuring the changes that the object impose on the field surrounding it.

  - Sensor: devices to detect events or changes in its environment and send the information to other electronics.

  - Remote Sensing: without being in physical contact, and it make it possible to collect data of dangerous or inaccessible areas.

Sensor Network

Internet of Things

Analogue versus Digital Signal Processing

- Analogue signal processing
  - works on continuous signals (commonly known as analogue signals): voltage, electric current, or electric charge
  - relies on the use of analogue circuit elements (i.e., by analogue means): resistors, capacitors, amplifiers
  - responses in real time
  - examples: “bass”, “treble” and “volume” controls on stereos

- Digital Signal Processing
  - works on discrete signals
  - basic elements: adders, multipliers, and memory
  - relies on numerical approaches
  - real-time solutions are not always guaranteed

Analogue versus Digital Signal Processing

- Digital communication may require a considerable amount of electronic circuitry, and cost more bandwidth resource. But digital communications are often more cost effective than analog communication.

- Analogue Signal convert into Digital Signal
  - Sampling: Converts the message signal into a sequence of numbers, with each number representing the amplitude of the message signal at a particular instant of time.
  - Quantization: Involves representing each number produced by the sampler to the nearest level selected from a finite number of discrete amplitude levels.
  - Coding: The purpose of which is to represent each quantized sample by a code word made up of a finite number of symbols.

Analogue versus Digital Signal Processing

- DSP has the following important advantages
  - **flexibility**:The property simply means that we can use the same digital machine(hardware) to implement different versions of a signal processing operation of interest by making changes to the software loaded to the machine.
  - **repeatability**: refers to the fact that digital signal processing operations can be repeated exactly over and over gain.
  - **robustness to errors**:This property has a quite broad meaning. For example, the operation of digital circuits are more tolerant to electronic noise, compared to analogue circuits. Because DSP deals with digital signals, coding can be applied to provide more resilience against noise.

Applications of Signal Processing

- Audio signal processing
- Speech signal processing
- Image processing
- Video signal processing
- Biomedical signal processing
- Financial signal processing
- Control systems
- Wireless communications

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