1 Module A: Signals and Systems

This module introduces you to the fundamental concepts of *signal* and *system*. The module aims to provide both an intuitive understanding of these concepts, and to provide a simple yet formal foundation for discussing them. In particular, the important distinction between *declarative* and *imperative* descriptions of signals and systems is emphasized by the tutorial and laboratory exercises.

1.1 Readings and other resources

The following readings are taken from the textbook by Lee and Varaiya. You can use the questions in the following section to help you find your way through these readings.

Readings

- Lee and Varaiya, Chapter 1 introduction
- Lee and Varaiya, Section 1.1, *Signals*
- Lee and Varaiya, Section 1.2, *Systems*
- Lee and Varaiya, Section 11.1, *Sampling*
- Lee and Varaiya, Section 11.2, *Reconstruction*
- Lee and Varaiya, Chapter 2 introduction
- Lee and Varaiya, Section 2.1, *Defining functions*
- Lee and Varaiya, Section 2.2, *Defining signals*
- Lee and Varaiya, Section 2.3.4, *Composing systems by using block diagrams*
- Lee and Varaiya, Appendix B, *Complex numbers*

On-line resources

- EECS20 topic notes (click on "Topic Notes" link in left margin)
  http://ptolemy.eecs.berkeley.edu/eecs20/
- Sound
  http://ptolemy.eecs.berkeley.edu/eecs20/week1/audio.html

1.2 Text-reading questions

The "answers" to these questions are obtained readily from the required readings listed above, in the section indicated in parentheses. The purpose of working through these question is to ensure that you have read the important parts of the text, and also to serve as a useful reference for you for later study.

1. What is a *system*? (1.intro)

2. What is the difference between a *declarative* and an *imperative* description of a system? (1.intro)

3. Give some examples of signals. (1.intro)

4. What is the purpose of a mathematical model? (1.intro)

5. Explain the difference between continuous-time and discrete-time signals. Give an example with diagrams. (1.1)

6. Give the equation for the voltage waveform of (single-phase) household power in Australia. (1.1)

7. Write the function for an image as stored in a computer. (1.1)

8. Write the function for a video signal. (1.1)

9. Write the function for the position of an airplane. (1.1)

10. Write two short traces that represent the sequence of events that one might observe when cooking an egg. (1.1)

11. Can a continuous signal be stored in finite memory? If not, what two operations are typically needed to be able to store an approximation?

12. List a number of ways in which a system might transform a signal. (1.2)

13. What, in essence, is a modem? (1.2)

14. Draw a diagram of a heating system, showing the signals present in the system. (1.2)

15. What is an *assignment rule*? (2.intro)

16. Give two examples of different types of assignment rule. (2.intro)

17. What is a function? (2.1)

18. Give the declarative version of the function that computes the volume of a sphere from its radius. (2.1)

19. What is a graph? Give it's general form. (2.1)

20. When is a graph a function? (2.1)

21. Write a procedure to compute the volume of a sphere. (2.1)

22. Sketch the graph of $sin(x)/x$ for $x \in [-\pi, \pi]$ (2.1)

1.3 Tutorial exercises

Use the space provided to note the most important elements of your work during the tutorial session. You may be required to show this working to a tutor or submit it to obtain marks for an assignment.

Begin by forming into groups of four of five students. Work on the following problems as a team, and try to arrive at answers that are complete and that everybody on the team agrees to be a suitable answer.

1. Describe the following signals. For each, a) draw a labeled graph showing a typical or possible example of this signal, and b) give the signals name, domain, and range, written using the notation

$$\text{SignalName} : \text{Domain} \rightarrow \text{Range}$$

   (a) The sound of music.

   (b) The distance of Halley's comment from the sun.

   (c) The voltage across the terminals of a car battery.[1]

   (d) The location of your car on your drive from home to work/Uni/the train station.

   (e) The price of Microsoft stock at the close of each day's trading.

   (f) The cricket score.

   (This question is originally based on Exercise 2 of Chapter 1 of the Lee and Varaiya textbook.)

[1] Don't forget that a car battery has a non-zero internal impedance. It is also discharged (such as when starting the car) and charged (when the engine is running).

2. A CD player, while a common piece of technology, is remarkably reliable and robust considering the fragility of the medium on which the data is stored. Describe how the sound-pressure waves created by a musician end up being played through speakers in your living room, by:

   (a) Drawing two block diagrams, one for recording and one for playback

   (b) Labeling the diagram clearly with signals, showing for each the name, domain, and range.

   You will need to consider the following kinds of operation: conversion between sound and electrical signals; voltage amplification; digital-to-analog and analog-to-digital conversion; error encoding and correction; byte-stream to bit-stream conversion.

Instructor Verification

Instructor name	Date/time

1.4 Laboratory exercises

The Lab for this week is selected portions from Lab 1 of the Lee and Varaiya Laboratory Manual.

- In-lab section

  Do the following items in Section L.1.1:

  - 1a
  - 2a, 2b, 2c, 2d
  - 3b, 3c, 3d, 3e, 3f

  Use the rest of this page for making notes during the lab session. Your tutor may ask to see your working to verify completion of the in-lab section.

- Self-work section

  Do items 1, 2, and 3 from Section L.1.2.

  You are expected to complete the at-home part of the lab in your own time. Keep notes, program code, and plots of your work. You may be required to show these to a tutor, or deliver them as part of an assignment.

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1.5 Drill questions

This is a series of questions related to this module, the answers to which should be "automatic" to you. Work through these, and if you cannot get answers in a short period of time, seek help.

1. What is the frequency of each of the following signals?

   (a) $x(t) = cos(2\pi 100t)$
   (b) $x(t) = cos(2\pi 1000t)$
   (c) $x(t) = 1 + cos(2\pi 100t)$
   (d) $x(t) = sin(2\pi 440t)$
   (e) $x(t) = sin(2\pi 440t + \pi/4)$
   (f) $x(t) = sin(1000t)$

2. What is the period, in seconds, of each of the following signals?

   (a) $x(t) = cos(2\pi 100t)$
   (b) $x(t) = cos(2\pi 1000t)$
   (c) $x(t) = 1 + cos(2\pi 100t)$
   (d) $x(t) = sin(2\pi 440t)$
   (e) $x(t) = sin(2\pi 440t + \pi/4)$
   (f) $x(t) = sin(1000t)$

3. What is the *angular frequency* of each of the following signals?

   (a) $x(t) = cos(2\pi 100t)$
   (b) $x(t) = cos(2\pi 1000t)$
   (c) $x(t) = 1 + cos(2\pi 100t)$
   (d) $x(t) = sin(2\pi 440t)$
   (e) $x(t) = sin(2\pi 440t + \pi/4)$
   (f) $x(t) = sin(1000t)$

4. Assume that each of the following signals is sampled at 8 kHz. How many samples are there in one period?

   (a) $x(t) = cos(2\pi 100t)$
   (b) $x(t) = cos(2\pi 1000t)$
   (c) $x(t) = 1 + cos(2\pi 100t)$
   (d) $x(t) = sin(2\pi 440t)$
   (e) $x(t) = sin(2\pi 440t + \pi/4)$
   (f) $x(t) = sin(1000t)$

1.6 Self-study questions

The instructor will provide you with exercises and drill questions that you will need to work on. The following questions are a representative sample of questions that you can try in your own time.

1. Lee and Varaiya, Chapter 1, Exercise 1
2. Lee and Varaiya, Chapter 1, Exercise 3
3. Lee and Varaiya, Chapter 1, Exercise 4
4. Lee and Varaiya, Chapter 1, Exercise 7
5. Lee and Varaiya, Chapter 1, Exercise 12
6. Lee and Varaiya, Chapter 2, Exercise 1
7. Lee and Varaiya, Chapter 2, Exercise 2
8. Lee and Varaiya, Chapter 2, Exercise 4
9. Lee and Varaiya, Chapter 2, Exercise 11
10. Describe an automated flight control system in terms of the key system components and the signals present in the system.