NUS
National University
of Singapore

Department of Electrical and Computer Engineering

CG2023: Signal and Systems

Course Instructor

Sahoo SK
Senior Lecturer
Office: E4 08-09
Email: elesahoo@nus.edu.sg

AIMS & OBJECTIVES

This is a fundamental course in signals and systems, specially developed for computer engineering students. Signals play an important role in carrying information. In particular, the idea of frequency domain analysis of signals and systems are important concepts for all computer engineers. The concepts that will be covered include time and frequency domain representations, Fourier transform, spectrum and bandwidth of a signal, frequency response of systems (Bode diagrams), sampling theorem, aliasing, signal reconstruction, and filtering.

In this course, students will learn things like:

- How to: classify signals based on their properties; apply Fourier techniques to transform signals between their time-domain (waveform) and frequency domain (spectrum) representations; evaluate the energy, power and bandwidth of signals
- How to: apply the concepts of impulse response, frequency response and transfer function to characterize linear time-invariant (LTI) systems; use frequency selective LTI systems (or filters) to shape the spectrum of a signal.
- How to model the sampling process leading to the Nyquist sampling theorem and its application for perfect signal reconstruction.

LEARNING OUTCOMES

- Describe a signal in time and frequency domains
- Compute the Fourier Transforms of simple signals : Spectrum of Periodic and Aperiodic Signals
- Calculate the bandwidth, power and energy spectra of signals
- Describe and identify the characteristics of linear time invariant systems
- Construct the frequency response of systems via Bode plots
- Explain aliasing and evaluate the impact of the Nyquist sampling theorem

ASSESSMENT TASKS

Assignment	(5%)
Midterm Quiz	(20%)
Lab	(10%)
Mini Project	(15%)
Examination	(50%)

PRE-REQUISITE

MA1506: Mathematics II or MA1512 : Differential Equations for Engineering

CG2023 TIMETABLE (2021/22-II)

DAY		TUESDAY	THURSDAY	REMARKS
TIME		16:00 – 18:00	14:00 – 16:00	
VENUE		zoom	zoom	
DATES	Week			
	01	11 Jan 2022	13 Jan 2022	
	02	18 Jan 2022	20 Jan 2022	
	03	25 Jan 2022	27 Jan 2022	
	04	01 Feb 2022	03 Feb 2022	
	05	08 Feb 2022	10 Feb 2022	
	06	15 Feb 2022	17 Feb 2022	
	RECESS WEEK (19 Feb 2022 – 27 Feb 2022)			
	07	01 Mar 2022	03 Mar 2022	Midterm : 3rd March 2021
	08	08 Mar 2022	10 Mar 2022	
	09	15 Mar 2022	17 Mar 2022	
	10	22 Mar 2022	24 Mar 2022	
	11	29 Mar 2022	31 Mar 2022	
	12	05 Apr 2022	07 Apr 2022	
	13	12 Apr 2022	No classes	
	READING WEEK (16 Apr 2022 – 22 Apr 2022)			

EXAMINATION →	Date: 27 April 2022 (Wednesday) Time: 13:00 – 15:00 (120 minutes)

TABLE OF CONTENTS

TOPICS	Page
1. Signals and Classification of Signals	1-1
1.1 Signals	1-1
1.1.1 Classification of Signals	1-2
1.2 Basic Signals	1-14
1.3 Time-Scaling, -Reversal and -Shifting of Signals	1-19
End of Chapter	1-21
2. Discrete-Frequency Spectrum (Fourier Series)	2-1
2.1 What is a Spectrum in the Context of Signals?	2-1
2.2 Spectrum of a Sinusoid	2-2
2.2.1 Complex Exponentials and Phasors (The concept of negative frequency)	2-6
2.3 Fourier Series	2-7
2.3.1 Complex Exponential Fourier Series	2-7
2.3.2 Trigonometric Fourier Series	2-9
End of Chapter	2-14
3. Continuous-Frequency Spectrum (Fourier Transform)	3-1
3.1 Fourier Transform	3-1
3.2 Properties of Fourier Transform	3-8
3.3 Spectral Properties of a REAL Signal	3-19
3.4 The Dirac-δ and Spectrum of Periodic Signals	3-23
3.4.1 The Continuous-time Unit Impulse (Dirac-δ function)	3-23

TOPICS	Page
3.4.2 Spectrum of Periodic Signals	3-26
End of Chapter	3-31
4. ESD, PSD and Bandwidth	4-1
4.1 Energy Spectral Density (ESD) - - - a.k.a. Energy Spectrum	4-1
4.2 Power Spectral Density (PSD) - - - a.k.a. Power Spectrum	4-4
4.2.1 PSD of Periodic Signals	4-7
4.3 Bandwidth	4-10
4.3.1 Bandlimited Signals	4-10
4.3.2 Signals with Unrestricted Band	4-13
End of Chapter	4-17
5. Systems and Classification of Systems	5-1
5.1 Systems	5-1
5.1.1 Classification of Systems	5-2
5.2 Remarks	5-7
End of Chapter	5-7
6. Linear Time-Invariant Systems	6-1
6.1 Impulse Response	6-2
6.2 Frequency Response	6-5
6.2.1 Notation for Expressing Fourier Transfrom in ω-domain	6-7
6.3 Bode Diagram	6-10
6.3.1 Transfer Function	6-11
6.3.2 Construction of Straight-line Bode Plots	6-14

TOPICS	Page
6.3.3 Resonance in Second Order Systems	6-29
6.3.4 Asymptotic Behavior of Bode Straight-line Plots	6-32
End of Chapter	6-34
7. Sampling Theorem	7-1
7.1 Idealized Filters	7-2
7.2 Continuous-time Sampling and Reconstruction of Signals	7-4
7.3 Sampling Band-limited Bandpass Signal below Nyquist Rate	7-10
End of Chapter	7-13

REFERENCES

1. Hwei Hsu, Schaum's Outline of Signals and Systems, McGraw Hill.

2. Erhan Kudeki and David C. Munson, Jr, Analog Signals and Systems, Pearson Prentice Hall.

PRE-REQUISITE KNOWLEDGE

- Calculus

- Complex number arithmetic and Complex functions
  - Cartesian form $\left(z = \mathrm{Re}\left[z\right] + j\,\mathrm{Im}\left[z\right]\right)$
  - Polar form $\left(z = \left|z\right|\exp\left(j\angle z\right)\right)$
  - Relationship between Polar and Cartesian form $\left[\begin{array}{c}\exp\left(j\theta\right) = \cos\left(\theta\right) + j\sin\left(\theta\right) \\ \cdots\cdots\ Euler's\ Formula\ \cdots\cdots\end{array}\right]$

- Sinusoids: $A\sin\left(\omega t + \phi\right)$, $A\cos\left(\omega t + \phi\right)$ and $A\exp\left[j\left(\omega t + \phi\right)\right]$
  - Converting between cyclic frequency and angular frequency
  - Converting between period and frequency