CHE 573: Signal Processing for Process Engineers
2012 Winter Term

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Office Hours: Mondays from 11 AM to 12:00 Noon
Course Time Schedule:
Lecture   M W F   10:00–10:50 in ETLE 2-009
Lab time: F   14:00–16:50 MecE 3-3

Course Teaching Assistant: Fari Kiasi (Email: kiasi@ualberta.ca)
Grader: Fari Kiasi
Office hours: Tuesdays 3:00 to 5:00 PM in NREF 4th Floor Lounge

Course Objectives
The main objective of this course is to introduce three commonly used powerful *information processing techniques*, namely, temporal and spectral analysis via (1) **Correlation analysis**, (2) **Fourier transforms** (spectral analysis) and (3) **Filtering methods** (including filter design) for practical data analysis. The focus of this course is on discrete-time signals. A systematic development of the theoretical background will be supplemented with suitable applications to real-life data. The course will also provide the student with a hands-on experience in applying these tools to real-life data from the process industry.
The preliminary part of this course provides an introduction to the theory of sampling, discrete-time systems and convolution. Notions of frequency in continuous-time and discrete-time domains will be provided with suitable examples. MATLAB® & Signal Processing Toolbox (MATLAB) will be the primary software platform for this course.

Who will find this course useful?
This course is aimed at students at the undergraduate and graduate levels, as well as to the practical data analyst. This course is particularly useful to all individuals currently studying/working (or intend to take up employment) in disciplines such as engineering/ medicine/ sciences/ business with particular interests in data analysis. Engineering students will also find it useful to obtain a basic knowledge of Digital Signal Processing (DSP) for future and current research projects in areas such as control theory, process monitoring, vibration monitoring, *etc*. A practical engineer can directly employ the techniques taught in this course to analyze process data with applications to controller performance assessment, plant-wide oscillation detection, time-delay estimation, etc.

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Course Contents

Topics to be covered will include some or all the following. (The required lecture hours given in the brackets are approximate):

Topic	Sub-topics	Duration
Introduction	Introduction to the concepts of signals, systems/filters, and signal processing; Applications of DSP; Course objectives and contents.	1 Lecture
Sinusoidal signals	Introduction to CT and DT signals; Understanding the notion of frequencies in a signal; The relationship with the complex exponential signals using Euler's rule	2 Lecture
Sampling & Aliasing	Introduction to Sampling; Concept of Aliasing; Sampling Theorem; Quantization & Coding; D-to-A conversion.	3 Lectures
Discrete-time (DT) Signals & Systems	Mathematical Representation of DT Signals & Systems; Elementary DT Signals; Classification of DT systems; Convolution Sum & Properties; Impulse & Step Response; Causality & Stability.	3 Lectures
The z-Transform & its Applications	The z-Transform Definition & Properties; Applications of the z-Transform to LTI Systems.	3 Lectures
Time series, Correlation & Covariance Analysis	Concepts of ACF and CCF, Covariance & Correlation: Definitions, Properties, & Calculations; Application of Correlation Analysis in Process Control: Identification of Periodic Signals, Time-delay & Impulse Response Estimation.	8 Lectures
Fourier series & Transforms	Introduction to Spectrum; Fourier Series; Power Spectrum; Magnitude & Phase Spectra; Applications of Power Spectrum; Fourier Transforms; Properties of Fourier Transforms; Discrete Fourier Transform (DFT); Periodogram.	8 Lectures
Frequency Response of DT Systems	The Frequency Response Function; Response to Periodic & Aperiodic Input Signals; Input-Output Covariance Functions and Spectra.	3 Lectures
Filtering & Design of Filters	Introduction to filtering; Low-, High-and Band-pass filters; Median Filter; EWMA Filter; Filter specifications; Design of FIR & IIR Filters.	4 Lectures
Design of Alarm Systems	Introduction to the concept of missed and false alarms. Role of filters in alarm design. Multivariate alarms.	4 Lectures

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Text book

A text book is not required for this course. The lecture notes and class handouts should suffice. For supplementary reading, the following books are recommended.

- Lecture Notes
- J.G. Proakis and D.G. Manolakis, *Digital Signal Processing*: *Principles*, *Algorithms and*
- *Applications*, 4th edition, Prentice Hall, 2007.
  Sanjit Mitra. *Digital Signal Processing*: A *Computer-Based Approach*, *2e with DSP Laboratory using MATLAB*, McGraw-Hill Higher Education, 2001.
- A.V. Oppenheim and R.W. Schafer. *Digital Signal Processing*, Prentice Hall, Eaglewood Cliffs, NJ, 1998.
- There is a lot of material on the web as well as demo toolboxes in Matlab.

Prerequisites

CHE 358 Process Data Analysis; CHE 446 Process Dynamics and Control

Assignments

There will be five (more or less) assignments in this course. Please drop your completed assignments in the CHE 573 Assignment Box located on the South corridor of the 3rd floor of the CME buidling.

Please note that late assignments will not be accepted unless a legitimate reason (illness, etc.) exists and is discussed with the instructor.

Software

The software platform for this course is MATLAB and the associated toolboxes. MATLAB is a popular scientific computation and visualization software package that closely incorporates the theory taught in this course. The Signal Processing Toolbox along with the MATLAB contains the necessary tools for the analysis and design of control systems. It is highly recommended that students familiarize themselves with the basic functionalities of MATLAB as the text and the course frequently refer to MATLAB codes for implementation purposes.

The best way to learn MATLAB is by going through some of the popular tutorials first and then trying it out for oneself. A good site that contains links to a few educational web sites is: http://www.ee.ucr.edu/EESystems/docs/Matlab/index.html. Students can also utilize several other resources to learn MATLAB, links to which are given in the useful links section.

MATLAB is available on all departmental Unix workstations as well as several PC labs. You may want to consider buying the Student Edition of MATLAB for Windows XP, available in the U of A Bookstore, for your own PC; this software will be useful later for several other courses.

MATLAB is a registered trademark of the Mathworks Inc.

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Course webpage

All handouts, assignments and other pertinent information will be posted on UofA's eclass portal for this course < https://eclass.srv.ualberta.ca/portal/ >. Other important announcements and information will also appear on this webpage.

Useful Links

http://www.mathworks.com
The official site of Mathworks, the makers of MATLAB.

http://www.math.siu.edu/matlab/tutorials.html
MATLAB Tutorial at the Southern Illinois University at Carbondale.

http://math.uc.edu/~kingjt/matlab_lnk.html
Useful MATLAB links at the website of Prof. J.T. King, Dept. of Mathematical Sciences, University of Cincinnati.

http://spicerack.sr.unh.edu/~mathadm/tutorial/software/matlab/
The MATLAB Tutorial Information website at the Department of Mathematics, University of New Hampshire.

http://fairway.ecn.purdue.edu/v1/asee/fie95/4c5/4c54/4c54.htm
A web-enabled approach using MATLAB to teach a course on the theory of digital audio and video.

http://www.eng.auburn.edu/~sjreeves/Classes/DSP/DSP.html
An introduction to using MATLAB for Digital Signal Processing.

Computer Labs

The objective of the computer labs is to enable the students to apply the concepts learnt in the classroom to computer-aided data analysis. This exercise allows the student to (1) obtain more insights into the theory and (2) obtain an experience of combining the theory with a powerful tools that MATLAB and the associated toolboxes offer for data processing.

Several labs will be carried out and the exact time schedules will be announced later. The venue for the labs will be announced in the class room and on the web page.

Handouts will be given at the beginning of each lab. The students are expected to go through the handout carefully prior to performing the lab work.

Individual lab reports are due by 4:00 pm on the due date for each lab (to be announced then), and should be deposited in the CHE 573 assignment box. Lab reports should be legible and clear. They should be stapled or contained in a standard lab book.

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Examinations and Grading

Assignments   25%
Midterm exam   25%   (2 March, 2012 during regular class time)
Final exam   50%   (23 April 2012 at 9 AM)

The conversion of the percentage grade into a final grade will be performed using a combination of relative and absolute measures taking into account the quality of work submitted and University policy on the distribution of grades. Grades are unofficial until confirmed by Faculty Council or its representative. Re-examination requests for a missed midterm examination will not be entertained. The weight for any deferred midterm exam will be carried onto the final exam.

All examinations are closed book and closed notes; calculators are required. Policy regarding the use of calculators will be declared. Formulae sheets, if required, will be provided with each examination.

Penalty for late assignments and lab reports

Unless you have an acceptable excuse, there will be a penalty on late assignments or lab reports according to the following rules:

- Late by 24 hours or less, the grade will be reduced by 25%
- Late by more than 24 hours, a zero grade will be assigned

Plagiarism, Cheating, Misrepresentation of Facts and Participation in an Offence:

The University of Alberta is committed to the highest standards of academic integrity and honesty.

Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the Code of Student Behaviour (online at http://www.uofaweb.ualberta.ca/secretariat/) and avoid any behaviour which could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University.

The following behaviours constitute academic misconduct in this course (in addition to those specified on the Code):

1. Looking at another student's exam during a midterm or final.
2. Copying any part of an assignment or lab report from another student, or from an assignment or lab report from previous offerings for CHE358.
3. Permitting any other class member to copy any part of your assignment or project report.
4. Presenting laboratory data from any other student or former student of CHE358 as your own.
5. Using a programmable calculator in the exams.