UNIVERSITY OF UTAH
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINIEERING

ECE 5530 **DIGITAL SIGNAL PROCESSING** **Spring 2010**
ECE 6530

Instructor:	V. John Mathews MEB 3264 801-581-7869, mathews@ece.utah.edu. *E-mail is the easiest way of contacting me at times other than office hours.*
Classroom:	WEB 1230
Meeting Time:	TH 10.45 a.m. - 12.05 p.m.
Teaching assistant:	Olakunle Eso MEB 3305 kunleeso@yahoo.com
Office Hours:	Instructor : T 12:05 - 1:00 p.m, H 9:00 - 10:00 a.m. TA : M 2:00 - 3:00 p.m., W 1:00 - 2:00 p.m. These are tentative times. We may change them after hearing from the students about how convenient these times are for them. If you are not able to meet with the instructor or the TAs during the scheduled office hours, please send an e-mail to make an appointment.
Text:	A. V. Oppenheim and R. G. Schafer, *Discrete-Time Signal Processing* , Third Edition, Prentice Hall, 2010
Course Website:	Go to the course webct page for information about the course.
Homework:	Several homework problems will be assigned during the semester. These problems will try to illustrate certain concepts taught in the class, familiarize the students with certain applications that are not discussed in the class, and/or extend some of the ideas discussed in the class. Your solutions will be collected on the dates specified in the handouts. No extensions to the due dates will be given. The solutions to the problems will be posted the working day after they are due. You can get individual help from the TA or the instructor

for solving these problems. You are also encouraged to work together in groups if necessary to solve the problems. *However, each of you must understand the principles behind solving each problem, and the solutions you submit must be your own. If you understand the principles behind solving each homework problem, you will do very well in the class.*

Computer Projects: Three projects of two to three weeks duration will be assigned during the semester. These projects will involve detailed derivations, computer implementations of the solutions and submission of formal reports. The goal of the project is to develop a digital communications systems through implementation of several digital signal processing components.

Term Paper: The students in the graduate section are required to write a term paper not exceeding 15 typed pages. More information will be provided later. Students in the undergraduate section may also do the project to replace one of their midterm scores or up to half of their final exam scores.

Examinations: There will be two midterm examinations during the semester. The tentative dates for the midterms are February 11, 2010 and March 16, 2010. The final exam will be comprehensive. The exam will be on May 6, 2010, from 10:30 a.m. to 12:30 p.m.

The objective of the examinations will be to test your knowledge of fundamentals and your ability to apply the concepts learned in class in situations that you may not have come across before. You may bring the text book to the exams along with one sheet of formulas for the first exam, two sheets of formulas for the second midterm and three sheets of formulas to the final exam. Use of calculators are not allowed during the exams.

Grading Policy: I will grade on a curve, and therefore there are no preselected cut off points for letter grade. One exception to this rule is that you will need to score least least fifty percent of the maximum possible total score for all components to pass the course. The weights assigned to each component of the course is as follows:

	ECE 5530	ECE 6530
Your best midterm:	25%	20%
Your worst midterm:	20%	15%
Homeworks:	15%	15%
Computer Projects:	15%	15%
Term Paper		15%
Final Exam:	25	20%

Policy on Cheating: Integrity in all your activities inside and outside the class is of extreme importance to each one of us. While we will work on an honor system, and expect each of you to do your own work in the class, I have had to occasionally deal with issues of cheating in the past. Cheating of any form will not be tolerated. Examples of cheating include, but are not limited to:

1. Copying someone else's work.
2. Allowing someone else to copy your work.
3. Using published work from the literature or the web without referring to the source.

If caught, students are subject to disciplinary action. The mildest form of punishment for cheating in my classes is a mandatory zero score in the homework, exam or project involved.

THINGS I EXPECT YOU TO KNOW FROM PRIOR COURSES

Note: These are the absolute minimum number of things I would expect you to know. Most of you would have done a lot of additional things. Please take the self test at the end of this handout to see if you need to brush up the materials.

1. Definitions of linearity and time-invariance. An ability to determine if a system is linear and or time-invariant given its input-output relationship.

2. Convolution integral for continuous-time linear, time-invariant systems.

3. Convolution sum for discrete-time linear, time-invariant systems.

4. Laplace transform and its properties. In particular, you should be thorough in your understanding of the linearity, delay, convolution, differentiation and integration properties.

5. Fourier series expansion of periodic, continuous-time signals. Basic properties of Fourier series expansion. You should be comfortable with the Fourier series expansion using complex exponentials.

6. Fourier transform of continuous-time signals. Linearity, delay, convolution and modulation properties of Fourier transform. Relationship between the Fourier transform and the Laplace transform.

7. Fourier transform of discrete-time signals. Linearity, delay, convolution and modulation properties of Fourier transform.

8. Sampling theorem.

9. Relationship between the discrete-time Fourier transform of a signal and the continuous-time Fourier transform of the signal that was uniformly sampled to obtain the discrete-time signal.

10. Causality and stability of systems.

11. Given a differential equation representation of a continuous-time, linear, time-invariant system or a difference equation representation of a discrete-time, linear, time-invariant system, you should know how to efficiently implement the system using the basic components, and also to analyze the system for its frequency response.

12. Basics of differential and integral calculus and linear algebra.

SYLLABUS

Topic	Reading Material
Overview of course and course policies. What I expect you to learn from the course. What I expect you to know from prior courses. Notation and terminology.	
Overview of material I expect you to know from prior courses.	Any text book on Signals and Systems
Sampling Theorem; Relationship between the Fourier transform of a continuous-time signal and the Fourier transform of the discrete-time signal obtained by uniformly sampling the continuous-time signal; Practical issues in sampling.	Ch. 4
Definitions of discrete-time Fourier transform (DtFT) and z-transform; Relationship between the two transforms; Region of convergence of the z-transform.	Ch. 2, 3
Properties of the z-transform; Linearity, Time-shifting and Convolution; Transfer function of discrete-time linear time-invariant systems.	Ch. 3
Rational transfer functions; Interconnection of linear, time-invariant systems; Structures for implementing discrete-time, linear, time-invariant filters; Direct form structures, cascade and parallel structures.	Ch. 2, 6
Poles and zeros of linear, time-invariant systems; Effects of poles and zeros on the frequency response of the system; Design of linear, time-invariant filters using pole-zero placement.	Ch. 5
Inverse z-transform using power series expansion, partial fraction expansion, and look-up table methods.	Ch . 3
Discrete Fourier transform (DFT); Relationship between DFT, DtFT and the z-transform.	Ch. 7
Properties of DFT; Periodicity, linearity and symmetry; Multiplication of two DFTs and circular convolution.	Ch. 8
Implementation of finite impulse response filters using DFT.	Ch. 8
Fast Fourier transform (FFT) algorithms.	Ch. 9
Design of FIR filters using the window method.	Ch. 7
Design of optimum equiripple FIR linear phase filters.	Ch. 7
Design of discrete-time IIR filters from analog filters; Examples of commonly used analog lowpass filters.	Ch. 7
Transformation of analog filters to discrete-time filters – impulse invariant technique; bilinear transform; Examples of IIR filter design. Frequency transformations.	Ch. 7 7

SELF TEST

1. Determine if the systems with the following input-output relationships are linear and/or time-invariant. In each of the cases, y is the output signal and x is the input signal.

   (a) $y(t) = \text{real}\{x(t)\}$,
   where $x(t)$ can take complex values.

   (b) $y[n] = \sin(3x[n])$

   (c) $y[n] = 3x[n] + 3$

   (d) $y(t) = \int_{-\infty}^{t} x(t-\tau)d\tau$

2. Suppose that the unit impulse response of a continuous-time, linear, time-invariant system is

$$h(t) = e^{-t}u(t),$$

   where $u(t)$ represent the unit step function. Find the output of the system when its input is

   (a) $x(t) = u(t) - u(t-10)$

   (b) $x(t) = e^{-(t-5)}u(t-5)$

3. Consider the system in the previous problem:

   (a) Find the frequency response and transfer function of the system.

   (b) Find a realization of the system using integrators, adders and multipliers only.

4. Suppose that the unit impulse response function of a discrete-time, linear, time-invariant system is given by

$$h[n] = \begin{cases} 1 & ; \quad n = 6, 7, \cdots, 13 \\ 0 & ; \quad \text{otherwise} \end{cases}$$

   Find the output of this system when its input is

$$x[n] = u[n-7].$$

5. Find the discrete-time Fourier transform of

$$h[n] = 0.5^{n+3}\cos(0.2\pi n + (\pi/6))\,u[n].$$

   Is the discrete-time, linear, time-invariant system with unit impulse response function as given above stable in the bounded-input, bounded-output sense? Is it causal?

6. The Fourier transform of a continuous-time signal $x(t)$ is given by

$$X(\Omega) = \begin{cases} 1 & ; \quad |\Omega| < 2000\pi \\ 0 & ; \quad \text{Otherwise.} \end{cases}$$

   The discrete-time signal $x[n]$ is obtained by uniformly sampling $x(t)$ at the rate of 4000 samples/second. Find $X(\omega)$, the discrete-time Fourier transform of $x[n]$.