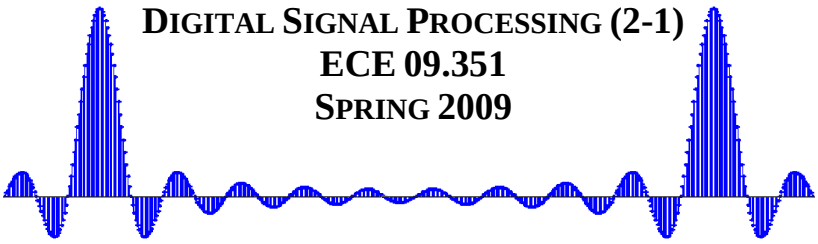
ECE 09.351.01
DIGITAL SIGNAL PROCESSING
POLIKAR

Spring 2009



DIGITAL SIGNAL PROCESSING (2-1)
ECE 09.351
SPRING 2009

Class Homepage: http://engineering.rowan.edu/~polikar/CLASSES/ECE351

Instructor: Dr. Robi Polikar
Office& Phone: 136 Rowan, 256-5372 (voice-mail available)
E-mail: polikar@rowan.edu

Class Meeting: Mondays 1215-1330 (Rowan 239), Wednesdays 0925-1015 (Rowan 204), Fridays 1050 – 1330 (Rowan 204/206)

Office Hours: Mondays 1500 – 1630, or by appointment, or according to open door policy: you may come in at any time if and when the office door is open.

Required Text: Analog and Digital Signal Processing (using Matlab), Kronenburger & Sebeson, Thomson 2008

Reference Texts: Digital Signal Processing 3/e, Mitra, McGraw Hill, 2006
Digital Signal Processing using Matlab, Ingler & Proakis, Thomson, 2007
Signal Processing First, McClellan, Schafer and Yoder, Prentice Hall, 2004
Digital Signal Processing Using Matlab, Ingle and Proakis, PWS, 2002.

ABOUT THIS CLASS & OBJECTIVES

This class is concerned primarily with signals and systems, specifically, processing of digital and/or discrete time signals using linear time invariant systems, hence digital signal processing - DSP. The tools and techniques developed to process signals span several hundred years; however, it was not until recently with the advance of microprocessor technology that such techniques became practically feasible. In fact, *practically feasible* is a rather understatement, since our daily lives depend so much on DSP techniques and devices that implement these techniques. It is DSP that makes communication systems, medical diagnosis and monitoring systems, engine diagnostics, seismic / tectonic / oceanographic analysis systems, all of audio-visual entertainment systems and many other countless systems possible.

All DSP techniques and algorithms use sophisticated mathematical tools, and it is this requirement that made traditional DSP classes very theoretical in nature, to the extend that at the end of a semester of struggling with complex mathematical analysis techniques, students often forget what these techniques were supposed to achieve in the first place. It is rather unfortunate that DSP has traditionally turned into a course so theoretical when in fact the practical applications of its topics are so vital to our daily life.

This course has been designed to keep the real-world perspective at the forefront in each topic discussed, without sacrificing any of the elegant mathematics that underlie all DSP techniques. The primary goals of this course are to

1. Introduce signals, systems, time and frequency domain concepts and the associated mathematical tools that are fundamental to all DSP techniques;
2. Provide a thorough understanding and working knowledge of design, implementation, analysis and comparison of digital filters for processing of discrete time signals.

There are a set of instructional objectives for each topic we are going to discuss in this class. These objectives, provided on the class web page and described in considerable detail, explain exactly what you need to be able to do if you understand the concepts. My expectations of you will therefore be limited to these objectives. All student performance evaluation modalities that will be used in this course (homeworks, exams, projects) will be geared towards testing whether you have achieved these course objectives.

Upon successful completion of this class, you will be able to propose, design, implement and validate appropriate DSP techniques for a broad spectrum of real-world applications.

COURSE PREREQUISITES

This course builds upon concepts that you have learned in Calculus, Math for Engineering Analysis, Networks, and Systems and Control I (with a minimum passing grade of C). It is your responsibility to come to class equipped with the knowledge provided in those courses. The following is a brief list of topics that are of utmost importance and hence need your particular attention before you come to this class.

- Basic knowledge of differential and integral calculus, derivatives, finite and infinite sums, series expansion, and most importantly **Fourier series**;
- Complex numbers, representation of signals / numbers in polar and Cartesian coordinates, phasor notation;
- Basic network concepts of sinusoidal signals, amplitude, frequency and obtaining system transfer function;
- Basic systems and control concepts of linear systems, properties of linear systems, convolution integral, frequency response, system transfer function, filtering;
- Basic concepts of probability, random variables, and probability distributions;
- Working knowledge and competency of **MATLAB** and **SIMULINK**

You will be tested at the beginning of the semester on these concepts.

CLASS MECHANICS

This class will meet three times a week, where the Monday & Wednesday meetings will be lectures, whereas Friday meetings will be primarily laboratory sessions. We will have regularly scheduled homework assignments, and occasional quizzes, daily "oral reviews", laboratory exercises, midterm(s), one final exam and a final project. The oral review is a new concept where every day one or more randomly selected class participants will be asked to review the previous lecture and answer questions from the class. Your performance on these reviews will constitute a meaningful component of your final grade. These oral reviews will ensure that everyone comes to class prepared, having reviewed the previous lecture.

ATTENDANCE POLICY & ESTIMATED AMOUNT OF WORK

Attendance is **absolutely mandatory** for success in this class, and therefore it is required. Random attendance will be taken, which will also contribute to your final grade. If you are absent on the day you are randomly called for oral review, or for a quiz (or for roll call) you will get a zero for that activity – unless you have an excused absence or an extenuating circumstance. Quizzes / oral reviews missed due to excused absences may be retaken; those missed due to unexcused absences may not. A missed exam may not be retaken with the exception of most serious and extenuating circumstances that require official and written proof of such circumstances.

Excused absence is one where you have given me at least 48 hours of written notice (e-mail is acceptable) of your absence. You may have one (1) excused absence for any reason during the semester.

Extenuating Circumstances are those that are truly beyond your control, such as sudden illness, or death of family member. Written documentation must be provided for an extenuating circumstance to be valid (such as a letter from a physician, or an obituary / funeral house notice). Undocumented cases will not be honored.

Tardiness: You will be considered present if you are in class during the first 10 minutes of the class, and remain in class during the entire (remaining) duration of the class. One quiz or oral review missed due to tardiness will be counted towards your excused absence. Any additional absences / tardiness will result in a zero grade for the missed activity.

Note that DSP is a fast paced and mathematically intensive course with a rich set of novel topics and concepts that need to be mastered to gain sufficient appreciation and expertise. Successful completion of this course will therefore demand significant amount of time commitment from you, a good portion of which should be spend on implementing the techniques on real world signals. **As a rule of thumb, expect to spend three - four hours for each hour we spend in class, i.e. 9 – 12 hours a week on top of class meetings**. Please budget your time accordingly. The course material will be challenging but ultimately rewarding. It will require hard work from everyone, including myself.

HOMEWORK & LABORATORY ASSIGNMENTS

There will be occasional homework but regular laboratory assignments, which will challenge you; however, you will realize that working on the assignments will allow you to have a much deeper and solid understanding of the concepts. As an added bonus, you will notice that your analytical thinking and problem solving skills will also improve significantly, not to mention your math skills. Assignments must be neatly and professionally prepared. All assignments will be due one week (168 hours) from the day they are assigned, unless indicated otherwise. Late Policy: Late submissions are not accepted unless there are extenuating circumstances, which will be handled on a case-by-case basis.

TEAM POLICY FOR CLASS RELATED WORK

You may – and in fact encouraged to – work with your class mates on homework assignments, however**, your lab work and all submissions must be your own work**. You may not use someone else's solution or code and present them as yours, even if they have no problem with you using their intellectual property. This is considered academic dishonesty, and will not be tolerated.

COURSE PROJECT

A final project to help you put all course-developed skills to work will be assigned. You will be working in teams for the project as well, as described above. You will have the opportunity to select your own project. More information on the final project will be available after the midterm.

CLASS ETHICS:

- No eating /drinking in class (except bottled water)
- Cell phones must be kept outside of class or shut-off during class. No exceptions! If your cell-phone rings during class / lab (or you use it in any way), you will be asked to leave and counted as unexcused absent. It will also cause difficult-to-repair damage to "professionalism" part of your grade (see below).
- No web surfing, instant messaging, and / or unrelated use of computers, when we use computers in class / labs.
- In-class discussions are welcome, and in fact encouraged, within the limits of mutual respect and courtesy.
- You are responsible for checking the class web page often for announcements, homework / exam solutions. See below for the e-mail policy.
- You are encouraged to work with other students for all exercises, except exams and quizzes.
- Although I do not anticipate, and certainly hope that it will never be an issue, it is my responsibility to remind you that academic dishonesty – in any form, shape or manner – will not be tolerated, and will be dealt with according to university rules and regulations. In general, presenting any work, or a portion thereof, that does not belong to you, as if it does – or even attempting to do so – is considered academic dishonesty.

OFFICE HOURS & CONTACTING THE PROFESSOR

The official office hours are on Mondays right after the class. However, you may always make appointments (for example, if you need my uninterrupted attention for an extended period of time), or you can also come in at any time to ask questions if my office door is open (which it usually is). A couple things to note however: Please do not come in if the door is closed, even if my light is on or you know that I am, in fact, inside. My door is typically open, but if it is closed, that means either I am not in, or I am working on something and prefer – and request – not to be interrupted.

E-MAIL POLICY:

In general, I prefer that class related questions be asked in the class, so that everyone can benefit from the answer. If your answer requires a longer time to answer, then please ask in person. Use e-mail as a last resort only. If you do use e-mail, I expect you to follow proper business etiquette for electronic communications, including a formal greeting, formal language and formal signature line. E-mails that do not follow proper etiquette will not be answered, and will affect the professionalism portion of your grade. Also, and this in very important: make sure that your Rowan e-mail account is active and not over quota. I will use your Rowan e-mail address exclusively, and cannot / will not follow up with messages that bounce back for over quota issues. All e-mails sent to me **MUST come from your Rowan e-mail address**, preferably with a subject line starting with "DSP". My e-mail software is configured to recognize all e-mails coming from Rowan addresses as legitimate. Any other e-mail address may – and probably will – be automatically classified as spam and I may not notice it in a timely manner.

GRADING SCALE

An absolute grading scheme will be used to assess your final grade:

Midterm(s):	20%
HW & Labs	25%
Quizzes/Reviews:	15%
Final Exam + Projects:	30-35%
Professionalism:	5-10%

100-95: A, 95-90: A-
89-87: B+, 86-83: B, 82-80: B-
79-77: C+, 76-73: C, 72-70: C-
69-67: D+, 66-63: D, 62-60: D-
59-0: F

Professionalism will include, but is not limited to, good academic citizenship, professional conduct, and active class participation. Depending on the actual number of quizzes, their weights may be shifted to other categories.

ACCOMMODATION FOR DISABILITY

If you have a documented physical and/or learning disability, please feel free to inform me or the Academic Success Center (ACS, director, Dr. Melissa Arnott– cox@rowan.edu, or 256-4260) regarding what kind of accommodation you need to help you succeed in this class. While you are not required to disclose your disability to me, you must provide appropriate documentation to the ACS to receive official university assistance. All such requests will be held confidential to the extent possible.

CLASS BONUS:

Here is the deal: For those of you who would like to participate, there will be a paper competition at the end of the semester. If you wish to participate, you will write a four page paper based on your project, and this paper will compete against other papers for technical merit, organization, oral and written presentation. The winning paper will then be submitted to an appropriate signal processing conference, such as IEEE's ICASSP (Int. Conf. on Acoustics, Speech and Signal Processing). If your paper is accepted, you will then have the opportunity to present your work at this conference. All (domestic) air travel and conference registration expenses will be paid for by the instructor or by the department.

INSTRUCTOR EVALUATION, QUESTIONS, COMMENTS, SUGGESTIONS

Questions, constructive criticisms, comments, and suggestions are always welcome. Please feel free to share your opinions about all aspects of the class: content, math level, workload, instructor's communication skills, etc. There will be a box outside of my office for anonymous comments. Also, you may use the "I've got something to say! ©" form, available at class homepage for your comments. A copy is attached to this syllabus.

TENTATIVE COURSE CONTENT

(Chapter numbers in parentheses refer to Mitra's book, since that is the more comprehensive book)

- **Introduction, Components of a DSP System, DSP Applications, Concepts of Frequency and Filtering**
- **Signals and Systems / Review (Chapters 1 &2)**
  - Commonly used signals in DSP – unit step and impulse, sinusoids, complex exponentials, classification of signals, periodicity, energy vs. power signals
  - Discrete time systems – classification of discrete systems (linearity, causality, time invariance, memory, stability), characterization of LTI systems – impulse response, convolution, difference equations, finite and infinite impulse response (FIR/IIR) systems
- **Representation of Signals in Frequency Domain (Chapter 3 ~ 4)**
  - Concept of spectrum / frequency (Chapter 3)
  - Frequency representation of continuous time signals - Fourier series and Fourier transform (review)
  - Sampling theorem – aliasing, Nyquist criterion, interpretation of spectrum in discrete time domain (Ch. 4)
  - Frequency representation of discrete time signals
    - Discrete time Fourier transform (DTFT) , (Chapter 3)
    - Discrete Fourier transform (DFT) and Fast Fourier transform (FFT), (Chapter 5)
    - Properties of and relationships between various Fourier transforms,
    - Concepts of circular shift and convolution, decimation and interpolation of discrete signals.
- **The z-transform (Chapter 6)**
  - Definition and properties, relation to DTFT/DFT
  - Concepts of zeros and poles of a system, region of convergence (ROC) of z-transform
  - Inverse z-transform (to be covered in CC Module - Complex Systems)
- **Linear Time Invariant (LTI) Systems in Transform Domain (Chapter 7)**
  - Concept of filtering – revisited, lowpass, bandpass and highpass filters
  - The frequency response and transfer function of a system
  - Types of transfer functions
    - FIR filters, ideal filters, linear phase filters, zero locations of linear phase FIR filters,
    - IIR filters, pole and zero locations of IIR filters, all pass filters, comb filters, stability issues for IIR filters
- **Filter Design and Implementation (Chapters 9 & 10)**
  - Digital filter specifications, selection of filter type, estimation of filter order
  - FIR filter design using windows
  - IIR filter design using bilinear transformation
  - Spectral transformations for designing a filter with new characteristics based on a previously designed filter
- **Filter Structures (Chapter 8)**
  - FIR filter structures – direct and cascade form
  - IIR filter structures, Lattice form
- **Random Signal Analysis & Spectral Estimation**
  - Autocorrelation, cross correlation and power spectral density
  - Spectral estimation using periodogram, Welch's method, Bartlett's method
- **Advanced Topics** (time permitting)
  - Short time Fourier transform / Continuous wavelet transform
  - Discrete wavelet transform and its applications
  - Adaptive filtering
    - **Finite Wordlength Effects (Chapter 12)**
      - Analog to digital and digital to analog conversion,
      - Quantization of fixed and floating point numbers, coefficient quantization
      - Quantization noise analysis, Overflow effects

Date: ___ / ___ / 2009 ***Course: Digital Signal Processing*** ***I am*** _____ *(optional)*

I'VE GOT SOMETHING TO SAY!®

I am having difficulty in understanding the following concepts:

This class has so far been informative / interesting / entertaining /_____ (circle all that apply) because:

This class has so far been confusing / boring / too fast / too slow / _____ (circle all that apply) because:

It would have been much better / beneficial if you could…:

Please continue the following activities as I find them useful in_____

While you are at it, please provide your feedback on the following **on a scale of 1 – 5**,

1: Poor / Strong disagreement with the phrase, 5: Excellent / strongly agree with the phrase

1. The professor's ability to communicate in a clear and understandable manner: _____
2. The professor's responsiveness to student's needs, questions and ideas:_____
3. The professor treat students in a professional manner:_____
4. The professor is enthusiastic about the subject and genuinely believes in its importance:____
5. The professor's knowledge of the subject material is thorough:_____
6. The professor is well prepared for the classes:_____
7. The professor's ability to impart knowledge about the subject is:_____
8. The professor encourages questions and comments during the class session:_____
9. The professor's use of the class time is:_____
10. The professor actively involves students in the teaching / learning process:_____
11. The professor's availability outside of class hours is:_____
12. The professor satisfactorily answers students' questions in class and in the office:_____
13. Professor clarifies /repeats material that is difficult to understand:_____
14. Professor makes use of the latest technology to improve student's learning experience:_____
15. Lecture materials (e.g. slide) are helpful for the understanding of the subject material:_____
16. The professor is genuinely concerned that students take valuable experience from the class:_____
17. Considering everything, how would you rate this teacher: _____

What do you not like about Dr. Polikar's teaching, if any, and what would you suggest that he can do improve?

What do you enjoy about Dr. Polikar's teaching, if any, that he should continue in this and future classes?

Other comments?