

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

ECE 466: Digital Signal Processing

Fall Semester, 2003

| |
|---|
| ECE 466 WWW HOME PAGE – http://www.egr.msu.edu/classes/ece466/deller |
|---|

..... **INSTRUCTOR CONTACT INFORMATION**

Instructor: J.R. Deller, Jr., Professor of Electrical and Computer Engineering

Office: 3209 Engineering Building
Phone: (517) 353-8840
Internet: deller@msu.edu www.egr.msu.edu/~deller

Office Hours: MWF 1:30-1:40 p.m. (in ECE466 classroom)
MWF 1:45-2:30 p.m. (in EB 3209)
Appt. by email: Send 3 times that you could meet on MWF – 24 hrs. notice, please.
Email response will confirm.

..... **STUDY MATERIALS**

| Resource | Purpose |
|--|---|
| “Lecture” Notes: J.R. Deller, Jr., <i>An Introduction to Signal Processing Through Speech Processing</i> , notes for text in preparation, ©IEEE Press, New York. – Posted on class web site | Primary reading source. Covers all topics to appear on exams. If lectures were given on audio tape (or audio CD), these notes would be texts of the lectures given. |
| Textbook: A. Ambardar, <i>Analog and Digital Signal Processing (2nd edition)</i> , Brooks-Cole Pub., 1999. | Secondary reading source. Different perspective on most topics. Lots of additional topics (not required unless explicitly assigned). Lots of examples! Summaries and “cookbook style” review and presentation. Tables of transform pairs, properties, etc. Homework problems. Software support. |
| Class Periods ⇒ “In-class” Notes | Assimilate and illustrate materials in reading sources. Answer questions on reading. “Mini-lectures” on certain difficult topics. Problem examples and discussion. Application examples and discussion. |
| DSP software package (MATLAB) | Support computer-based homework and application examples. |
| Supplementary references on speech and general signal processing (SP): Appendix 0.A of Lecture Notes - more may be posted on class web site | Independent study and review. Advanced topics. Pursuit of further applications. |

Prerequisites

The student is assumed to have a solid background in continuous-time (CT) linear signal and systems analysis, typical of courses taught in the junior year in most electrical engineering curricula. Of particular importance is the Fourier transform and series, and spectral analysis. At Michigan State, these topics have been covered in ECE 360 until the present semester (more below). The student must also have basic training in the analysis of discrete-time (DT) systems including topics such as discrete convolution and discrete system properties — linearity, time invariance, causality and stability. At Michigan State, these topics were also covered in ECE 360.

Beginning Fall Semester 2003, the prior sequence ECE 200-201-360 has been replaced by ECE 200-202-366, with an additional “bridge course,” ECE 291, offered during the AY 2003 only. Here are the updated prerequisites for ECE 466 with future semesters shown for planning purposes:

| ECE 466 Offering | Prerequisites |
|---------------------------------|---|
| Fall 2003 | ECE 360 |
| Fall 2004 | ECE 200, ECE 291 & ECE 366, or ECE 202 & ECE 366 |
| Fall 2005, 06, . . . , ∞ | ECE 202 & ECE 366 |

The most recently-used text for ECE 360 and the one currently used in ECE 366 is the book by Ambardar, the same as the one we are using as a secondary reading source for ECE 466. The prerequisite material for ECE 466 is found in Ambardar’s text as follows:

- CT concepts: Chapters 2, 4, 6, 8, 9, 11, and 12
- DT concepts: Chapters 5 and 7; basic sampling theory and the concept of “aliasing” from Ch. 14 (including the important notions of “normalized” time and frequency); Sections 17.7–17.9 (one-sided z -transform theory, system analysis, frequency response).

If the material in these sections is unfamiliar to you (particularly the CT material), you should complete the prerequisite courses before attempting ECE 466.

Course Content and Use of Study Materials

- What is covered in the course?

The temporal schedule of coverage of the material, along with correlative reading in Ambardar appears in the *Topic & Reading Schedule* attached to this syllabus. For the sections covered in the Lecture Notes, the corresponding *Table of Contents* (TOC) can be used as an outline of topics to be covered in the course. The initial T& R Schedule attached here contains a plan only through Midterm 1. Updates to the T & R Schedule will be posted on the course web site as needed.

- “What’s on the test?” (Part I)

Let’s make some pretense of being scholars and rephrase this question a bit: How can I best use the study materials to maximize my learning experience, while not becoming overwhelmed with details, advanced topics, etc.?

That’s a good question, now that you have rephrased it. To answer it, we need to discuss the course materials and their relationships to the use of class time. There are three primary sources of “delivered” information in this class. The first two are the “formal” (reading) sources – the textbook and the “formal” lecture notes posted on the class web site. The third source is the discussion and other proceedings in the three weekly class meetings. To a large extent, the “formal” lecture notes represent the (expanded) texts of “lectures” that would be delivered in class under the more traditional (European) academic system. These should be used as a primary reading source, with the Ambardar text used, if desired, to summarize, fill in gaps, present practice problems and examples. Think of the Ambardar text as a sort of “handbook.”

The third source of “delivered” information is the content of the class time. This time will be used to (1) assimilate and illustrate materials in reading sources, (2) answer questions on the reading, (3) present “mini-lectures” on certain difficult topics, and (4) work problem examples, and (5) to present application examples. You’ll probably want to have a notebook to take informal notes on all of the above. (A pen or pencil will also be useful for this purpose.)

- What’s on the test? (Part II)

Oh, I think you mean: There’s a lot of reading material! What should I concentrate on?

Material in “Lecture” Notes, plus those sections in the Ambardar text that you are specifically asked to read to fill in points, will be emphasized on examinations. If it’s not in the lecture notes, and you haven’t been specifically asked to study a textbook topic “on your own,” then it won’t be “on the test.” The class experience will assimilate the reading material, develop related problems skills, and help pare down the content to salient topics.

- What’s all this speech processing stuff appearing in the syllabus?

This course will use speech processing as a motivating application for the learning of general (one-dimensional) SP. Speech processing provides an interesting and very important current application of the theories and techniques of SP, and considerable expertise in the speech field exists in the ECE Department at MSU. In previous semesters, students have appreciated having the application integrated into the material to illustrate the use of the theory. Being able to talk with job recruiters about this “hot” area has also been cited as a benefit of this approach.

ECE 466 is *not* a course in speech processing *per se*. (If you want to formally study modern speech processing, consider enrolling in ECE 966A.) However, it will be necessary to cover some material about the speech application area that might not appear in a “conventional” SP course. To do so, we need to deviate a bit from the “classical” syllabus of topics for a SP course. Historically, “filter design” was the ultimate goal and application area of such a course. Although we will briefly examine this classical design area, most related SP tasks are accomplished using widely-available software packages, so we will shorten this area of study considerably to make room for the more modern application.

Homework (HW)

- When and how are HW assignments made?

HW assignments with due dates will be posted on the class web site approximately every two weeks. New postings will always be announced in class and announced by email. Collection and grading of HW is explained below. *Note: “I didn’t get the email announcing the HW assignment” is not a valid excuse for not submitting an assignment on time.*

- Is HW important?

You will not succeed in this course unless you diligently work the assigned problems. These problems force you to struggle with the concepts, and to learn the important analytical tricks necessary to solve exam problems. It is important to *try the problems and exercises as soon as possible after the relevant class*. Doing so will strongly reinforce the new concepts.

- Are solutions to HW problems provided?

HW will be discussed in and outside of class to the extent that students have questions, and to the extent that certain problems might be particularly illustrative of some points. Solutions will be posted on the class web site as soon as they are available – sometimes even before the due date.

- Is late HW submission permitted?

In a word, NO. HW solutions must be submitted at the beginning of the class period on the due date unless prior permission (rare! – very rare!) has been granted to submit later. Late (or early) HW must be turned in at 3209 EB (or as otherwise arranged). Any other submission (mailbox, fax, carrier pigeon, telepathy, etc.) will probably not be graded.

- Are all HW problem taken from the text?

In addition to problems from the Ambardar text, special *Web Problems* (WPs) will be assigned. Almost all ECE 466 exam problems from recent (3+) semesters are included (and clearly marked) in the list of WPs.

- Do I need to use a computer to solve HW problems?

Problems labeled “MATLAB” involve the use of the MATLAB software package for their solutions. These problems will be part of a regular HW assignment and will be subject to the due date for that assignment.

- How can I get help with MATLAB? Help using computers?

Students are expected to take some initiative, just as you would in an engineering job setting, in seeking out and learning to use the appropriate computing resources (e.g., software, plotters, printers) for completion of assignments. No computer instruction or assistance with such details are available in this course. If you are unfamiliar with MATLAB (or even if you are familiar with it), it is strongly recommended that you attend one of the DECS MATLAB Workshops for valuable training. For information, see

<http://www.egr.msu.edu/decs/facilities/software/matlab.php>

and especially note item 17.

- Do I have to use MATLAB, or may I use another software package?

Occasionally students ask about using an alternative to MATLAB, e.g. MATHCAD, to complete “MATLAB” assignments. This is strongly discouraged, but acceptable as long as you achieve the expected results.

MATLAB will be employed in class demonstrations. The package is available on all Windows and Unix-based computers in the college and probably elsewhere on campus. Student (PC) versions are available for very reasonable prices (maybe even free). Most students prefer to use MATLAB to be “in synch” with the majority and with the class demos.

Note: Most employers of DSP engineers expect job applicants to be proficient users of MATLAB.

Examinations

- How many exams will there be, and when are they scheduled?

There will be *two Midterm Exams*, and a *Final Exam*. Dates for these exams are shown on the course schedule. The two midterms cover roughly the first and second thirds of the course, respectively, and the final is comprehensive (with some emphasis on later topics as announced). Although the material might have to be adjusted, the EXAM DATES WILL NOT CHANGE, so you can plan accordingly.

- Are sample exams available?

See “Web Problems” above.

- What if I miss an exam?

A **single makeup exam** will be given to students who miss *either* regularly-scheduled midterm, and who are excused from the missed examination. This exam will take place during the last regular class week of the semester and will cover all material that was covered on Midterms 1 and 2. A student may take the makeup exam only if a legitimate case of illness or personal emergency arises which is documented by a physician or other appropriate official. A student who finds it necessary to miss a midterm should contact the professor *before* the exam to explain the circumstances.

Figure 1: EXAMPLE FINAL GRADE COMPUTATION

Joe Digital receives the following “percentage” scores on the exams: MT1 80, MT2 43, Final 106. His homework score (when normalized to 100 points) is 78. The test scores correspond to “report card” of 3.5, 1.5, 3.0, respectively, and the homework is awarded a 3.0.

Method 1 (“Subjective”). At the end of the semester the “percentage” scores are averaged to give a course percentage of

$$\frac{80 + 43 + 106 + 78}{450} \times 100\% = 68.2\% \rightarrow 2.5 \quad (1)$$

The instructor decides that this is a 2.5 for the course after considering the overall class performance.

Method 2 (“Objective”). Then the “report card” scores are averaged

$$\frac{(3.5 \times 100) + (1.5 \times 100) + (3.0 \times 150) + (3.0 \times 100)}{450} = 2.78 \text{ round to } \rightarrow 3.0 \quad (2)$$

The Verdict. Joe receives a 3.0 in ECE 466.

Grading

- How is HW graded?

HW will be collected on due dates posted on the course web site. Selected problems will be scored. If the *average* HW submission is worth N points, then $2N$ points will be added to everyone’s HW total at the end of the semester *before* computing the overall HW averages for each person. The approximately means that each student may miss two (average-sized) submissions without penalty. In other words, you can fail to submit two average HW assignments and still achieve a perfect 100% on the HW part of the final grade.

- How is the final grade determined? How will I know where I stand in the course after the first, second midterm, etc.?

Examinations and homework will be weighted, and grades determined, as follows:

| | |
|-----------------------|----------------------|
| 2 Midterm Exams | 100 points each |
| Final Exam | 150 points |
| Homework | Scaled to 100 points |
| TOTAL possible points | 450 |

On each exam you will receive a “report card” (or “quality point”) grade: 4.0, 3.5, 3.0, . . . , 0.0 [sometimes a finer quantization used], as well as a usual point (percentage) score. At the end of the semester, the professor will determine a grade for each person based on a curve of the total 450 points. A second grade will also be based on your individual “report card” scores, including one to be determined for the total homework. Let

$$\begin{aligned} n_{\text{mt1}} &= \text{“report card” grade on midterm 1} \\ n_{\text{mt2}} &= \text{“report card” grade on midterm 2} \\ n_{\text{fin}} &= \text{“report card” grade on the final} \\ n_{\text{hw}} &= \text{“report card” grade on the homework} \\ g &= \text{grade determined in usual way using percentage scores} \end{aligned}$$

Then your final course grade will be

$$\max \left\{ g, \left[\frac{100n_{\text{mt1}} + 100n_{\text{mt2}} + 150n_{\text{fin}} + 100n_{\text{hw}}}{450} \right] \right\}. \quad (3)$$

where, $[\cdot]$ indicates rounding to the nearest half integer. See Fig. 1 for an example grade computation.

- Are “Incompletes” possible?

INCOMPLETE grades will be given only in unusual cases of illness or other personal emergency which causes the student to miss a significant amount of the course. This grade will NOT be given for any other reason. A student who misses the final exam without satisfactory explanation will receive a failing grade in the course.

- How can I do well in this course?

- Come to class regularly. (The Sampling Theorem does not apply to class attendance.) If you need to miss class, find out what you missed (especially whether there were any important announcements), but **please don’t ask** “Did we do anything important in class last week?”!
- Work hard on the HW (seek help when needed). Make sure you understand the theory behind each HW problem (*never* memorize a solution - this is a waste of time!). Exam problems test theoretical concepts usually with easier problems than those in the HW.
- Preview the material to be covered in class.
- Stay organized and check the course web page regularly. (Even though no “surprises” will appear on the web, there are updates, handouts, etc. that you might miss if you don’t check.)

- How can I fail this course?

There are many good ways, but the following techniques have been very successful in previous semesters:

- Enroll in the class without the appropriate background.
- Skip class.
- Don’t submit HW, or, if you do, think of HW problems as isolated pieces of information to be memorized.
- Don’t keep up with the class schedule. Do all your studying the nights before the exams.

| WEEK | LEC. NOTES & TEXTBOOK ASSIGNMENTS | NOTES |
|--------------------------------|---|--|
| Week of 8/25 | Topics: Introduction, Signal Concepts Lec. Notes: Chs. 0,1 Textbook: [review material] Chs. 1-3 (esp. 3) , Secs. 14.1-14.2 | Class discuss'n based in part on: WPs 2,3 |
| Weeks of 9/01 and 9/08 | Topics: Fourier Techniques - DTFT, Pf. of Sampling Theorem Lec. Notes: Secs. 2.1-2.3 Textbook: Chs. 8,9 [review as needed], Ch. 15 (not Sec. 15.10) Special events: No class Mon. 9/01 (Labor Day) | Class discuss'n based in part on: WPs 88,89,73 |
| Week of 9/15 | Topics: Practical Issues DTFT – Windows, Frames, stDTFT Lec. Notes: Sec. 2.4 Textbook: None | |
| Weeks of 9/22 and 9/29 | Topic: DFT / FFT Lec. Notes: Secs. 2.5 – 2.7 Textbook: Ch. 16 thru Sec. 16.8.2 | Class discuss'n based in part on: WPs 19,31(c),74 WPs 18,20 |
| Week of 10/06 | Topic: Elementary Concepts Speech Science Lec. Notes: Ch. 3 Textbook: None | Class discuss'n based in part on: WPs 25(a,b),79, 23 Handout lecture “slides” |
| ***Midterm 1 | Special event: <i>Midterm Exam 1, in class, Mon. 10/06</i> | Format, content of exam described on web site |
| Week of 10/13 | Topic: z-Transform Lec. Notes: Secs. 4.1 – 4.4 Textbook: Secs. 17.0 – 17.3, 17.5, Review Chs. 5,7 | Class discuss'n based in part on: WPs 32,33,41; LN Ex 4.17-4.21,4.26-4.28 |
| Week of 10/20 | Topic: z-Transform (cont'd) Lec. Notes: Secs. 4.5, 4.6, 5.1, 5.2 Textbook: Sec. 17.5, Review Chs. 5,7 | |
| Weeks of 10/27 and 11/03 | Topic: DT System Concepts Lec. Notes: Sec. 5.3 Textbook: Secs. 15.4-15.7, 15.9, 17.7-17.9, 18.0-18.4 | Class discuss'n based in part on: WPs 5-7, 76-78; |
| Week of 11/10 | Topic: Linear Prediction Analysis of Speech Lec. Notes: Section 10.1-10.3 Textbook: Sec. 18.5.5 | Class discuss'n based in part on: WPs 67,68,70 |
| Week of 11/17 | Topic: Linear Prediction (cont'd) Lec. Notes: 10.4-10.5 Textbook: None | Class discuss'n based in part on: WPs 70,71 |
| Week of 11/24 ***Midterm 2 | Review, Catch-up, Take exam, Eat turkey Special event: <i>Midterm 2, TUES., 11/25 EVENING;</i> | Format, content of exam – web site No class Wed. 11/26 & Fri. 11/28 |
| Week of 12/01 | Topic: Filter Design Lec. Notes: Section 8.1-8.3 Textbook: Secs. 20.0-20.5.1 Special events: Fri. 12/05 Review | Class discuss'n based in part on: WPs 38,51,60,65(d), LN Ex 8.?? (Freq. sampling design) |
| Week of 12/08 ***Final Exam | Final Exam Week Special events: <i>Final Exam, Wed. 12/10, 12:45-2:45 p.m.</i> | Format, content of exam described on web site |