ECE 444/644: Applied DSP and Filtering (3 Credits)
Fall 2020 Course Information and Policies

COVID-19 may necessitate changes to the course syllabus/format throughout the semester.

Instructor

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ECE 215B, 231-1024 (office)

Office Hours

11:00–11:50 am MWF or by appointment.

Description

Digital signal processing theory balanced with practical application. Includes design of FIR, IIR, and adaptive filters; Fast Fourier transforms; sampling theory; implementation techniques; multi-rate processing. Emphasizes system implementation using development tools and DSP hardware: Keil uVision5 IDE and the Freescale FRDM-K22F. Student projects, implemented in hardware, are required to pass the course.

Prerequisites

ECE 173 (C-programming) and ECE 343 (Signals and Systems) OR course equivalents OR prior instructor approval.

Required Text

- Lathi and Green, *Essentials of Digital Signal Processing,* Cambridge University Press, 2014.

Supplemental Texts

- Porat, *A Course in Digital Signal Processing,* Wiley, 1997.
- Proakis and Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications,* 4th ed., Pearson, 2007.
- Van Valkenburg, *Analog Filter Design,* HRW Inc., 1982.
- Welch, Wright, and Morrow, *Real-Time Digital Signal Processing from MATLAB to C with the TMS320C6x DSK,* CRC Press, 2006.
- Freescale technical data sheets also provide valuable information.

Lectures

MWF 12:00-12:50, ECE 237. Lecture material is derived from class and supplemental texts, personal notes, etc. Attendance is expected and excused only through prior written approval from the instructor.

Grading

40%	Pretest, homework, and labs: weekly
10%	Mini Exam 1: Mon., Sept. 28
10%	Mini Exam 2: Mon., Nov. 9
20%	Projects: proposal Wed., Oct. 14; progress report Wed., Nov. 4, final report & presentation by Fri., Dec. 11
20%	Comprehensive final exam: Thur., Dec. 17, 3:30 pm – 5:30 pm

Thresholds: 90–100 = A; 80–90$^-$ = B; 70–80$^-$ = C; 60–70$^-$ = D; <60 = F
Grade thresholds may be lowered at the discretion of the instructor.

Homework

Homework is due at the beginning of class on the due date. Neatly present homework solutions on engineering paper. Staple multiple sheets together. Do not fold your homework. A random selection of problems will be graded. Late, illegible, or improperly formatted homework will not be given credit. Some homework will require the use of Freescale tools (both software and hardware) as well as MATLAB. Frequently, demonstration of working hardware is required to receive assignment credit; thus, portions of homework and project grades are based on oral examination.

Exams and Quizzes

While exams will emphasize class material, homework, and laboratories, students are expected to apply concepts and techniques to new situations. During exams, books, notes, and homework are normally not allowed; calculators and crib sheets normally are permitted.

ECE 444/644 Course Information and Policies (Continued)

Projects

Individual projects represent a major and important component of this course. Each student is required to implement a DSP-based project in hardware to pass the course. All student projects must satisfy the following requirements:

1. Projects must be in an area of personal interest to the student. Project topics require instructor approval. A formal memorandum that proposes a project topic is due by Wednesday, October 14.
2. A progress report must be submitted by Wednesday, November 4. This report should indicate project progress and what remains to be completed. Algorithm validation, in MATLAB or C, is highly recommended.
3. Projects must be implemented in hardware. Each student must demonstrate working hardware to the course instructor before 5:00 p.m., Friday December 11. A portion of each student's project grade will be based on hardware operability as well as oral questioning that occurs during project demonstration.
4. A formal report documenting each project is due on December 11. Although length minimums are not specified, the report should be complete, professional, and reflective of the 20% grade weight (10 or more pages are likely necessary). The report needs to include at least one (recent) reference that is a professional journal article or reputable conference article. If you have any question whether your article qualifies, ask!

Graduate Credit

While grading percentages are the same, students seeking graduate credit are required to:

1. complete supplemental graduate-level questions on each assignment and exam,
2. complete projects reflective of the graduate level, and
3. read supplemental journal literature and apply it to course work.

Graduate students are subject to a few additional project constraints:

4. Ideally, project topic should apply to the student's thesis interests, and project efforts should directly benefit the student's research.
5. Graduate students must formally present their projects in a "lecture style" to the class. Presentation schedules and times will be provided later during the semester but will likely occur during the last week of class.
6. Project reports must be written in a style that is consistent with a journal or conference paper submission. Additionally, graduate students are expected to utilize at least three separate references to professional journal or reputable conference articles; at least one reference must be from a significant journal article and at least one reference must have a publication date of 2019 or later.

Academic Honesty

All work in this course must be completed in a manner consistent with the CEA Honor Code (*https://www.ndsu.edu/coe/current_students/honor_code/*) and NDSU Policy 335: Code of Academic Responsibility and Conduct (*https://www.ndsu.edu/fileadmin/policy/335.pdf*). Any use of solutions manuals is strictly prohibited and grounds for failing the course.

Special Needs

Students with disabilities or special needs who need special accommodations should share their concerns or requests with the instructor as soon as possible.

Session	Topic
1	DSP introduction
2	CT signals and systems (review)
3	FS, FT, and Laplace transforms (review)
4	Frequency response and distortionless transmission
5	Ideal filters and data truncation by windows
6	Practical filter specification and analog filter transforms
7	Butterworth filter design
8	Chebyshev filter design
9	Inverse Chebyshev filter design
10	Elliptic and Bessel-Thomson filters
11	Feature overview of the Freescale FRDM-K22F and/or TI DSPs
12	Impulse sampling and practical sampling
13	Ideal and ZOH signal reconstruction
14	Sampling bandpass signals, spectral sampling
15	Quantization, coding, and ADC characteristics
16	Static and dynamic ADC errors, clock jitter
17	ADC implementations, sample-and-hold considerations
18	DAC implementations
19	Architecture overview of Cortex M4 and/or TI processors
20	Overview FRDM-K22F and/or TI DSK peripherals, constraints
21	DT signals and systems (review), resampling
22	DT analysis of DT systems (review)
23	Discrete-time Fourier transform (DTFT)
24	DTFT: system analysis and CTFT connection
25	Digital processing of analog signals
26	Resampling: frequency-domain perspective
27	z-transforms
28	System realizations: DFI, DFII, TDFI, TDFII, parallel, cascade
29	Frequency response of discrete-time systems
30	Fixed-point considerations and Q format
31	Introduction to digital filtering
32	Digital IIR filter design: impulse invariance method
33	Digital IIR filter design: bilinear transform
34	Realization of digital IIR filters
35	Linear-phase digital FIR filters, constraints
36	Digital FIR filter design: window design method
37	Digital FIR filter design: frequency-sampling method
38	Review linear vector spaces, orthogonality principle
39	Digital FIR filter design: frequency-weighted least squares
40	Equiripple FIR filters: Remez-exchange algorithm, Parks-McClellan algorithm
41	Discrete Fourier transform (DFT) and properties
42	Zero-padding and the DFT
43	Circular convolution, DFT-based linear convolution
44	Linear convolution: overlap-and-add method
45	Linear convolution: overlap-and-save method
46	Goertzel's algorithm
47	Polyphase decompositions and the fast Fourier transform (FFT)
48	Decimation-in-time (DIT), decimation-in-frequency (DIF) FFTs
49	Chirp FFT, discrete-cosine transform (DCT)
50	Spectral analysis and advanced topics

ECE 444/644 Course Objectives:

Upon successful completion of the course, students will be able to...

1 Perform time-domain, transform-domain, and frequency-domain analysis of continuous-time and discrete-time signals and systems, which includes use of the Laplace transform, the Fourier series, the Fourier transform, the z-transform, and the discrete-time Fourier transform.

2 Design and digitally realize Butterworth, Chebyshev, inverse-Chebyshev, elliptic, and Bessel-Thomson IIR lowpass, highpass, bandpass, and bandstop filters, which includes the use of frequency response, pole/zero plots, frequency transformations, the impulse invariance method, the bilinear transform with prewarping, and block representations.

3 Utilize sampling theory to perform signal resampling and to properly convert continuous-time lowpass, bandpass, and non-bandlimited signals to their discrete-time counterparts and vice-versa, which includes utilizing analog-to-digital and digital-to-analog converter technologies.

4 Explain common DSP architectures, peripherals, hardware limitations and constraints and use the Freescale FRDM-K22F to realize digital signal processing systems.

5 Design and digitally realize FIR lowpass, highpass, bandpass, and bandstop filters using the window design method, the frequency-sampling method, frequency-weighted least squares, and the Parks-McClellan algorithm, which includes an emphasis on the design and realization of linear phase FIR filter as well as block representations.

6 Compute the discrete Fourier transform using Goerzel's algorithm and the fast Fourier transform and utilize the DFT for linear convolution and filtering, which includes the application and use of zero-padding and circular convolution.

7 Use modern computer-aided design and analysis tools such as MATLAB to solve digital signal processing problems.

8 Identify, design, simulate, and hardware realize a digital signal processing system, which includes preparation and presentation of written and oral reports.