ME579: Fourier Methods in Digital Signal Processing

School of Mechanical Engineering, Purdue University, West Lafayette, Indiana , USA.
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[Put ME579 in Subject Line of Email]
Course Web Site: https://engineering.purdue.edu/ME579

Course Syllabus

1. **Introduction to Signal Processing**

2. **Deterministic Signals**
   - 2.1 Classification of deterministic data
   - 2.2 Fourier series
   - 2.3 Fourier integrals
   - 2.4 The effect of filters and windows: multiplication and convolution
   - 2.5 Sampling signals, analog to digital conversion and aliasing
   - 2.6 The Discrete Fourier Transform (DFT)
   - 2.7 Computation of Discrete Fourier Transforms

3. **Introduction to Digital Filtering**
   - 3.1 Review of z transforms
   - 3.2 Digital filter realizations
   - 3.3 Frequency response of digital filters
   - 3.4 Design of IIR filters
   - 3.5 Design of FIR filters

4. **Random Processes**
   - 4.1 Probability, distributions and density functions, expectation: mean, standard deviation, moments
   - 4.2 Stochastic Processes: ensembles, probability density functions, moments of a stochastic process, correlation functions, stationarity, ergodicity, time averaging
   - 4.3 Spectra: power and cross spectral densities
   - 4.4 Input-output relationships for linear systems
   - 4.5 Coherence functions

5. **Estimation Methods**
   - 5.1 Estimator errors and accuracy: bias and variance of estimators
   - 5.2 Estimators for stochastic processes
   - 5.3 Estimation of power spectra
   - 5.4 Estimation of cross spectral densities
   - 5.5 Estimation of the coherence function
   - 5.6 Frequency response function estimates

Lecture Times and Office Hours

Class: Monday, Wednesday, Friday 11:30am-12:20pm.
Office Hours with Prof. Davies: Monday, Wednesday, Friday: 4:00-5:00pm at HLAB 2004 & Zoom
Topic: ME579 Office Hours with Prof. Davies MWF 4-5pm
Join Zoom Meeting
Meeting ID: 979 8848 2750
Passcode: 491657

Office Hours with Reza Ramezanpour, To be determined.

Updates will be announced on https://engineering.purdue.edu/me579.

References for Additional Reading

K. Shin and J. K. Hammond
Fundamentals of Signal Processing for Sound and Vibration Engineers, Wiley, 2010.
Covers most of what we do in the course but not digital filter design. Written from a more Mechanical Engineering perspective than most signal processing books. Many basic undergraduate EE text books that cover digital filtering.

J.G.Proakis and D.G.Manolakis
Introduction to Digital Signal Processing, Macmillan, N.Y., 1988.
Covers most of what we do in the course, and a lot of other things too.

A.V.Oppenheim and R.W.Schafer
(a) Digital Signal Processing, Prentice Hall, N.J., 1985.
My personal favorite signal processing text, treatment is mathematical. or
(b) Discrete-Time Signal Processing, Prentice-Hall, 1989.
Similar to (a) but certain sections are missing. It contains more illustrations and is more user friendly. Sometimes used as a text in undergraduate EE courses. Neither are good texts for an in depth treatment of spectral analysis of random signals nor for transfer function estimation.

J.S.Bendat and A.G.Piersol
Random Data: Analysis and Measurement Procedures, 4th Ed., Wiley Interscience, 2010.
If much of the analysis that you do is with random data (e.g., wind noise, random excitation of structures) this book will be useful; it covers sections 4 and 5 of the course.

Exams, Good Practices and How Grades are Determined

Exams: Exams are closed book, no crib sheets, no calculators nor any other electronic devices with communication capabilities or file storage capabilities. Pencil, eraser, pencil sharpener, and a straight edge (e.g., ruler) are all that are allowed. You are expected to know the formulae that are used in the class.

On campus students will take the exam in person. Off campus students may join the on campus students, if possible, or will join via a simultaneous Zoom room proctored by the instructor and/or the TA, or will be supervised by a local (to the student) pre-approved (by Purdue Instructors and/or Purdue Engineering On-Line's Exam coordinators) site exam proctor.

Class Attendance and Note Taking: On-campus students should attend classes and take their own notes in class. On-campus students will not have access to the class videos.

Off-campus students should take notes when watching the video, and the video should be watched as soon as possible after the class is given. When an off-campus student is unable to attend via live streaming during the scheduled class time, the student should make a three one-hour sessions/week timetable (ideally spread out over the week) that suits their work schedule, and then adhere to that timetable throughout the semester. Stacking up many videos to be watched in one very long session is not a good approach to learning.

Grades: There are three main components in the grade assignment for this class. These are:

1. Final Exam (2 hour comprehensive, closed book, no calculators or electronic devices)
2. Mid-Term Exam (1 hour, in class, on material covered to date, closed book, no calculators or electronic devices)
3. Homework (Typically 6 or 7 assignments spaced across the semester, approximately one every 2 weeks, each assignment 3 to 6 questions). See Homework instructions and expectations on Homework and Exams part of https://engineering.purdue.edu/me579.

The weighting of each part of the graded components of the class may vary depending on various factors, e.g., the difficulty of the different components in a particular semester. Previous ranges: Final: 40-70%, Mid-Term: 15-30%, Homework: 10-40%. I.e., it is important to take all three components very seriously and do your best in each. It is a straight scale, so your grade is not dependent on the performance of other students in the class.
$A \geq 90.00\%$, $89.99\% \geq B \geq 80.00\%$, $79.99\% \geq C \geq 70.00\%$, $69,99 \geq D \geq 60.00\%$, $F \leq 59.99\%$.

In addition to high scores in the different components, completion of ALL homework assignments in a timely manner where "completion" means a substantial attempt at each problem was made, is viewed positively. Significant improvement in exam performance from the mid-term to the final, is also viewed as a positive. Half-hearted attempts at homework, or missing homework assignments are viewed very negatively.

Homework Instructions and Information on Exams

See File posted on Home and Exams part of https://engineering.purdue.edu/me579.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Emergency Plans For On-Campus Students

The complete Wang Hall Building Emergency Plan can be found at:
Wang Hall Building Emergency Plan: https://www.purdue.edu/ehps/emergency-preparedness/emergency-plans/bep/building-beps/wang--bep.html
See also Emergency Warning Notification System: Purdue:
https://purdue.edu/ehps/emergency-preparedness/purduealert/index.php

In summary:

Fire Alarm: leave the building immediately. Use the nearest exit. Do not use the Elevators. Congregate in the Northwestern Parking Garage. Shut doors behind you as you leave rooms and corridors in the building.

Tornados/Extreme Weather Events: Congregate on the 1st Floor Stairwell, Bathrooms or Janitors Closet (Behind the Elevators). If it is possible to be outside for a brief time, go to the corridor that connects the Northwest Parking Garage with the MSEE Basement.

Shelter in Place because of a possible violent attack: Stay in a room that can be locked (and is locked or secured so entry is blocked) and in a place that cannot be seen when viewed through windows or doors (closet, under desks, out of line of sight, etc.). it is preferable to be in a room without windows.

Shelter in Place because it is unsafe to go outdoors for other reasons: Shut doors and windows. Do not use elevators. Do not go outside or attempt to drive unless you are specifically instructed to evacuate.

Use email, web, cell phones, etc. to determine status of emergency.

Call 911 to report any suspicious activity.

Nondiscrimination Statement

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Accessibility

Purdue University is committed to making learning experiences accessible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it relates to COVID-19, students may submit requests for emergency assistance from the Critical Need Fund.