$h[n] \Leftrightarrow H(e^{j\omega})$

Frequency

Gain - dB

0 0.5

-45

0

Re

Im

z-plane

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Chapter 1

Course Introduction/Overview

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1.1 Introduction to Modern Digital Signal Processing

- Contemporary DSP
  - Theory
  - Technology
  - Applications

- Course perspective
  - Expected background
  - Where to go from here

- What is this course about?

- The role of computer analysis/simulation tools in and outside this course

- The computer simulation project

- Instructor policies
1.2 Contemporary DSP

- The theoretical foundation for Modern signal processing got it’s start back in the late 1960s and early 1970s

- Two key texts which started this era are *Digital Signal Processing* by Oppenheim and Schafer and *Theory and Application of Digital Signal Processing* by Rabiner and Gold, both published in 1975


- A good source of recent theoretical developments is the *IEEE Journal on Signal Processing* (formerly Acoustics Speech and Signal Processing) and the annual *Proceedings of the International Conference on Acoustics Speech and Signal Processing* (ICASSP)

- Other applied digital signal processing conferences exist and are usually associated with trade shows

1.2.1 The Technology

- DSP chips/architectures
  - Integer/Fixed point implementations
  - Floating point implementations
  - FPGA based implementations

- DSP software and tools
1.2.2 Key Applications Areas

- Computers/Internet
  - Broadband access
  - Voice over IP
  - MP3 and related high quality audio formats
  - Multimedia in general: data, voice, music, & video

- Wireless Communications
  - Mobile communications (over 200 million phones/yr over the world)
  - High-speed modems and xDSL
  - Real-time data compression for voice and video
  - Wireless and telecommunication infrastructure

- Industrial
  - Real-time processing of industrial and medical signals
  - PC with DSP for virtual instruments for test and analysis

- Digital Control Systems
  - DSP vs microprocessors and microcontrollers

- Audio
  - MP3 players
  - Home audio and theatre systems
  - Noise cancelling, e.g., quieting a car interior using adaptive noise cancellation or headphones
• Video Imaging
  – HDTV
  – Special purpose image processing in instrumentation and medical

• Biomedical
  – Many possibilities
  – Hearing aids
  – Diagnostic imaging

• Military/Aerospace
  – An active DSP area for over 40 years
  – Many consumer DSP applications had their start here
  – Sophisticated surveillance systems and smart weapons
  – Specialty technologies include:
    * Frequency domain processing
    * Parallel processing
    * Radar signal processing
    * Software defined radio (SDR)
1.3 Course Perspective in Comm/DSP Area ECE

Undergraduate Engineering Curriculum

Senior/1st Year Graduate Signals & Systems Courses

Other Graduate Signals & Systems Courses Offered on Demand/Indep. Study

Signals & Systems Lab
Comm Lab
Satellite Comm
Identical
Comm Sys II (even)
Inform/Coding

Comm Sys I (odd)
Statistical Signal Process

Real-Time DSP
Random Signals

Spectral Estimation

ECE 5650/4650 Modern DSP
1.4 What is this course about?

- This course has as its focus the \textit{nuts and bolts} of one-dimensional discrete-time signals and systems analysis
  - Developing analytical skills is of primary importance
  - Introducing specialized applications is secondary

- Most all of the theoretical developments will parallel those of a traditional continuous-time signals and systems course
  - Here at UCCS, we now introduce discrete-time signal and systems in ECE 2610 (Intro to Sig & Sys), and more DSP topics are covered in ECE 3205 (Ckts & Sys II)
  - This course pushes the math well beyond the introduction in those courses

- Unique aspects of discrete-time signals and systems include:
  - Analog-to-digital and digital-to-analog interfaces
  - Multi-rate processing systems, i.e., more than one sampling rate in the signal input/output path
  - Software reconfigurability of systems

- Discrete random signals will be introduced
  - This will allow analysis of quantization affects
  - Key to follow-on courses involving statistical signal processing
  - Building simulation models that include \textit{noise}
1.5 Software Analysis/Simulation Tools

- The experimental investigation of discrete-time signals and systems does not require a lab full of test equipment
- What is available from the academic perspective:
  - Basic mathematical analysis tools include
    * Python (Scipy stack), MATLAB, & Mathematica
  - DSP specific tools include
    * Python using the `scipy.signal` package and `ssd.py`
    * MATLAB using the signal processing toolbox
  - Starting from scratch
    * The C/C++ programming language
  - Real-time DSP Development
    * For ARM Cortex M4 – Keil
    * Verilog/VHDL hardware description languages
    * For DSP TI devices Code Composer Studio
    * For Analog Devices DSPs – Visual DSP
    * Other tools that have code generation capability
- Inexpensive hardware evaluation is also a reality, e.g.,
  - ARM Cortex M4 and M7 with CMSIS DSP library, e.g., Cypress Pioneer Kit $50 (ECE 4680 & ECE 4655/5655)
  - TI LCDK at $195 using the OMAP L138
  - Others from Analog Devices and Motorola
1.6 The Computer Projects

- Computer based exercises using Python will be assigned during the semester (Jupyter Notebook & Python 2.7)
  
  - These projects first familiarize you with Python, then work through the many details of DSP in the time and frequency domains
  
  - Python examples are also embedded in the notes and will be used for in-class examples and demos

- A larger computer simulation project, will be assigned during the second-half of the semester, in place of additional computer based exercises
  
  - Past simulation projects have focused on software defined radio concepts, e.g., IF sampling, adaptive filters, or a DSP based modem

- In the Spring Semester ECE 5655, Real-Time DSP is offered as a complement to Modern DSP
  
  - In this course we currently use the ARM Cortex M4 via the Cypress Pioneer Kit and the Keil MDK IDE

- Another follow-on path is ECE 5615, Statistical Signal Processing, which builds upon the theory side of DSP and introduces random signals
  
  - Beyond ECE 5650, an undergraduate background in probability and random variables is required
1.7 Course Syllabus

ECE 5650/4650
Modern Digital Signal Processing
Fall Semester 2017

Instructor: Dr. Mark Wickert  
Office: EB-292  
Phone: 255-3500  
Fax: 255-3589  
http://www.eas.uccs.edu/~mwickert/ece5650/

Office Hrs: Wed. 10:40–11:15 am & Mon/Wed 1:30–2:15 pm, others by appointment.


Notes: Course lecture notes will be posted on the course Web Site as password required PDF files. Students are encouraged to download and print them.

Optional Software: Open source Python 3.6 using the Jupyter Notebook (Lab available soon). I suggest Anaconda then install the package scikit-dsp-comm using pip or conda see SP-Comm-Tutorial-using-scikit-dsp-comm. For typeset notebook output use add Pandoc, and MikTeX will are also available in the PC lab.

Grading: 1.) Graded homework assignments, including use of Python with the scipy-stack + Python project 1, assignments 25%  
2.) Final Python computer project worth 20%/15%. Grade option with final.  
3.) Two “Hour” exams at 15% each, 30% total.  
4.) Final exam worth 25%/30%.

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The expected learning outcomes of this course are a more in-depth treatment of discrete-time signals and systems as first started in the UCCS course ECE2610 or similar from another university. As a discipline within electrical engineering this known as digital signal processing (DSP). Specifically the student will learn how to model discrete-time signals and systems in the time domain; extend the time domain modeling to the frequency domain using the discrete-time Fourier transform (DTFT); working signals and linear time invariant (LTI) systems using z-transform (ZT) techniques; sampling theory and multirate sampling theory as found in modern DSP; discrete-time random processes and modeling quantization/fixed-point arithmetic; DSP problem solving using time, frequency, and z-domains effectively; properties of LTI systems having minimum phase and linear phase; choice of various DSP implementation topologies; the value and power of the discrete Fourier transform (DFT) and its efficient implemention via fast Fourier transform (FFT) algorithms; Simulation of DSP algorithms and subsystems using Python with the Scipy stack.

1.8 Instructor Policies

- Homework papers are due at the start of class

- If business travel or similar activities prevent you from attending class and turning in your homework, please inform me beforehand

- Grading is done on a straight 90, 80, 70, ... scale with curving below these thresholds if needed

- Screencasts of the lectures will be made available as soon as possible after each lecture; this may be of help to those of you that travel and to others for review purposes

- Homework solutions will be posted on the course Web site as PDF documents with password protection

- Old exams will be posted on the Web site prior to the hour exams