ELEG-212 Signal Processing and Communications

LECTURE #1
Introduction and Sinusoids

INFORMATION

- LABS – Every other Week
  - DSP Lab: 134 Evans Hall
  - DSP board and MATLAB based projects
- DISCUSSION
  - Mondays: 10:10-11:00
  - eCALC II Room: 146 Dupont Laboratory
  - EMPHASIS on Laboratories and Problem Solving
- GRADING: (3) tests (37.5%), final (20%), homework (20%), labs (20%), quizzes (2.5%)

COMPUTER ACTIVITIES

- MyCourses (WebCT)
  - www.udel.edu/mycourses
  - Composer username/password
  - All course information is centralized here
- ECE Computer Account
  - Account request form: www.eecis.udel.edu
  - Useful for lab and Matlab assignments
### ECE-212 Signals and Communications: Fall 2006 Course Schedule

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<tr>
<th>Date</th>
<th>Topic</th>
<th>Chapters</th>
<th>Lectures</th>
<th>Laboratory - Section Meetings</th>
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<tr>
<td>28-Aug</td>
<td>Lab 1: Intro. to MATLAB</td>
<td>1</td>
<td>Monday</td>
<td>Lab 0: Intro. to MATLAB</td>
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<tr>
<td>2-Sep</td>
<td>Lab 1: Sinusoids</td>
<td>1, 2</td>
<td>Tuesday</td>
<td>Lab 1: Sinusoids in MATLAB and VAB</td>
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<tr>
<td>3-Sep</td>
<td>Lab 1: Platonic solids, Harmonics</td>
<td>1, 2</td>
<td>Wednesday</td>
<td>Lab 1: Platonic solids, Harmonics in MATLAB</td>
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<td>4-Sep</td>
<td>Lab 1: Phase &amp; time shift</td>
<td>2</td>
<td>Thursday</td>
<td>Lab 1: Phase &amp; time shift</td>
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<tr>
<td>11-Sep</td>
<td>Lab 1: Phasor Addition Theorem</td>
<td>2</td>
<td>Monday</td>
<td>Lab 1: Phasor Addition Theorem</td>
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<tr>
<td>12-Sep</td>
<td>Lab 1: Spectrum &amp; Spectrum</td>
<td>2</td>
<td>Tuesday</td>
<td>Lab 1: Spectrum &amp; Spectrum</td>
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<tr>
<td>13-Sep</td>
<td>Lab 1: Sampling &amp; aliasing</td>
<td>2</td>
<td>Wednesday</td>
<td>Lab 1: Sampling &amp; aliasing</td>
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<tr>
<td>14-Sep</td>
<td>Lab 1: D-to-A conversion</td>
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<td>Thursday</td>
<td>Lab 1: D-to-A conversion</td>
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<td>18-Sep</td>
<td>Lab 2: FIR Filtering</td>
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<td>Monday</td>
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<td>19-Sep</td>
<td>Lab 2: Zeros of H(z) and Frequency domain</td>
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<td>Tuesday</td>
<td>Lab 2: Zeros of H(z) and Frequency domain</td>
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<tr>
<td>25-Sep</td>
<td>Lab 3: Digital Filters</td>
<td>7</td>
<td>Wednesday</td>
<td>Lab 3: Digital Filters</td>
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<td>26-Sep</td>
<td>Lab 3: Continuous-Time Filters</td>
<td>7</td>
<td>Thursday</td>
<td>Lab 3: Continuous-Time Filters</td>
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### Reading Assignments

- **This Lecture:**
  - Chapter 2, pp. 9-17
  - Appendix A: Complex Numbers
  - Appendix B: MATLAB
  - Chapter 1: Introduction

- **Homework #1:** Due next Wednesday
  - Engineering paper mandatory
  - Assignments turned in @ 310 Evans (by 5 p.m.)

### Converging Fields

- Math
- Physics
- Computer Science
- Applications

### Course Objective

- Students will be able to:
  - Understand mathematical descriptions of signal processing algorithms and express those algorithms as computer implementations (MATLAB, DSP chips)
  - What are your objectives?
WHY USE DSP?

- Mathematical abstractions lead to generalization and discovery of new processing techniques
- Computer implementations are flexible
- Applications provide a physical context

LECTURE OBJECTIVES

- Write general formula for a “sinusoidal” waveform, or signal
- From the formula, plot the sinusoid versus time
- What’s a signal?
  - It’s a function of time, x(t)
  - In the mathematical sense

TUNING FORK EXAMPLE

- “A” is at 440 Hertz (Hz)
- Waveform is a sinusoidal signal
- Computer plot looks like a sine wave
- Here is a mathematical formula:

\[ A \cos(2\pi(440)t + \varphi) \]
TUNING FORK PLOT

SPEECH EXAMPLE

More complicated signal (BAT.MAT)
- Waveform $x(t)$ is NOT a Sinusoid
- Theory will tell us
  - $x(t)$ is approximately a sum of sinusoids
  - FOURIER ANALYSIS
    - Break $x(t)$ into its sinusoidal components
    - Called the FREQUENCY SPECTRUM

Speech Signal: BAT

- Nearly Periodic in Vowel Region

DIGITIZE the WAVEFORM

- $x[n]$ is a SAMPLED SINUSOID
  - A list of numbers stored in memory
- Sample at 11,025 samples per second
  - Called the SAMPLING RATE of the A/D
  - Time between samples is
    - $1/11025 = 90.7$ microsec
- Output via D/A hardware (at $F_{\text{amp}}$)
STORING DIGITAL SOUND

- $x[n]$ is a SAMPLED SINUSOID
- A list of numbers stored in memory
- CD rate is 44,100 samples per second
- 16-bit samples
- Stereo uses 2 channels
- Number of bytes for 1 minute is
  - $2 \times (16/8) \times 60 \times 44100 = 10.584$ Mbytes

TRIG FUNCTIONS

- Circular Functions
- Common Values
  - $\sin(k\pi) = 0$
  - $\cos(0) = 1$
  - $\cos(2k\pi) = 1$ and $\cos((2k+1)\pi) = -1$
  - $\cos((k+0.5)\pi) = 0$

SINES and COSINES

- Always use the COSINE FORM
  - $A\cos(2\pi(440)t + \phi)$
- Sine is a special case:
  - $\sin(\omega t) = \cos(\omega t - \frac{\pi}{2})$

SINUSOIDAL SIGNAL

- $A\cos(\omega t + \phi)$
- Frequency $\omega$
  - Radians/sec
  - Hertz (cycles/sec)
- Amplitude $A$
- Magnitude
- Period (in sec)
  - $T = \frac{1}{f} = \frac{2\pi}{\omega}$
- Phase $\phi$
EXAMPLE of SINUSOID

Given the Formula

\[ 5\cos(0.3\pi t + 1.2\pi) \]

Make a plot

PLOT COSINE SIGNAL

\[ 5\cos(0.3\pi t + 1.2\pi) \]

Formula defines \( A, \omega, \) and \( \phi \)

\[ A = 5 \]
\[ \omega = 0.3\pi \]
\[ \phi = 1.2\pi \]

PLOTTING COSINE SIGNAL from the FORMULA

\[ 5\cos(0.3\pi t + 1.2\pi) \]

Determine **period**:

\[ T = \frac{2\pi}{\omega} = \frac{2\pi}{0.3\pi} = \frac{20}{3} \]

Determine a **peak** location by solving

\[ (\omega t + \phi) = 0 \]

**Zero** crossing is \( T/4 \) before or after

Positive & Negative peaks spaced by \( T/2 \)

PLOT the SINUSOID

\[ 5\cos(0.3\pi t + 1.2\pi) \]

**Use** \( T=20/3 \) and the peak location at \( t=-4 \)