Engin. 100: Music Signal Processing
Introduction and Lab #1

• **Overview of Engin 100:** What’s coming? What’s in store for you in this course?

• **Technical part:** Digital Signal Processing. What is it and why is it worth doing?

• **Tech Comm part:** Significance to Engineers. Introduction to Tech Comm next lecture.

Lab and Lecture Materials Location:

• Canvas website: [http://canvas.umich.edu](http://canvas.umich.edu)
• Log on with UM ID and Kerberos password.
• Labs, lectures, *assignments* all online 24/7.
• Also: Lab .mat files, Course Notes, etc.
• May wish to *print out lectures ahead of time.*

Course Overview

• 50% of course is technical (signal processing).
• 50% of course is technical communication.
• BOTH are equally important to your grade and to your future career in engineering (more later).

• 4 labs and 3 projects (2 small, 1 large).
• **Large:** simple music synthesizer and transcriber.
• **2 exams:** memos, oral & written presentations.

Engin 100 Lab Schedule

• **GOAL:** To learn skills for use in projects;
• **#1:** Introduction to Matlab and sinusoids.
• **#2:** Measure frequencies of music tones with DSP; visualization using semilog and log-log plots.
• **#3:** Compute spectra of signals using Matlab; filtering noisy signals, separate two signals.
• **#4:** Spectrogram: Depict time-varying spectra

Engin 100 Project Schedule

• **GOAL:** (1) To design & build simple music systems; (2) To apply tech comm principles to present results.

• **#1:** Build music tone synthesizer and transcriber.
• **#2:** Reverse-engineer touch-tone phone signal:
  • (a) Compute freqs; (b) Build synthesizer; (c) Build transcriber; (d) Study transcriber behavior in noise.
• **#3:** Build simple music synthesizer and transcriber:
  • (a) Generate musical staff-like notation from signal;
  • (b) Study transcriber behavior in noise
  • (c) Report results using tech comm principles.

Project #1: Tone Synthesizer GUI

Mimics single octave of a piano keyboard: black keys above (for accidental notes); white keys below (for whole notes).

You can jazz this up (add colors & labels) if you desire to do so.

Clicking on key with mouse plays that note.
Project #1: Tone Transcriber Output

Crude musical staff notation of “The Victors.”
Musical notes: uses stems instead of ♫ or ♪.
No interval info.-all notes have same duration.

But heights against 5-line background correct.
Computing these heights from sampled signal from your synthesizer is the point of project.

Project #2: Touch-Tone Synthesizer GUI

Touch-Tone Phone:
Synthetic keyboard.
Click on key with mouse makes tones.
Transcriber Output
like: “8 6 7 5 3 0 9”
Computing this from sampled sound from keyboard is point of this project. Also:
performance in noise.

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Introduction to Tech Comm next lecture.

Plotted below is a signal-plus-noise.
Can you figure out what the signal is?

This is the signal without noise.
How to get it? Wait for Lab #3.

Applications of Digital Signal Processing (DSP)

- Digital storage of real-world analog signals.
  Analog storage: vinyl, cassette tapes, wire.
  Digital storage: hard drive, CD, DVD, ipod.
  Allows compression (digital vs. analog TV).

- Analysis of signals: What is frequency of note?
What is its spectrum? What type of instrument?

- Filtering of signals: Removing noise (previous);
  removing interference (known undesired signal).

- Lab #3: Denoise signal; separate 2 trumpets.
- Lab #4: Spectrogram: Use to interpret signals.
What IS DSP? How do we do it?

**Sampling:** Convert analog to digital

Analog (continuous-time) $x(t)$

Digital (discrete-time) $x[n]$

Once have sampled signal $x[n]$, can process it on a digital computer!

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$5$ Hz Sinusoid Sampled $50$ Samples/Second

$x(t) = 2\cos(10\pi t - \pi /5)$. Substitute $t = n/50 = 0.02n$:

$x[n] = 2\cos(0.2\pi n - \pi /5)$. Sampling rate = $50$ “Hertz.”

<table>
<thead>
<tr>
<th>$n$</th>
<th>$x[n]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.62</td>
</tr>
<tr>
<td>1</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>1.62</td>
</tr>
<tr>
<td>3</td>
<td>0.62</td>
</tr>
</tbody>
</table>

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A $500$-Hz sinusoid is sampled at $450$ samples/second. Samples = red circles. Are samples from $450$ or $50$ Hz?

Appears samples came from $50$ Hz. $50$ Hz is reconstructed by D/A. D/A assumes all frequencies $< 450/2 = 225$ Hz, to avoid any aliasing.

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Issue: Can we recover $x(t)$ from $x[n]$? Can we convert digital back to analog? How do we interpolate $x[n]$ to $x(t)$?

You do need an analog signal output for your speakers or earphones! If we can’t interpolate, then we are just playing with numbers here!

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**WARNING!**

- How you report results is just as important as the technical merit of results themselves!
- A technically good transcriber that is poorly presented will NOT get a good grade!
- A technically inferior transcriber that is well presented MAY still get a good grade!
- A technically good transcriber that is well presented will get a REALLY good grade.
Why is Presentation so Important?

• This is absolutely how the real world works.
• True in both industry and academia (oh yes!)
• Only difference: grades in Eng. 100 become salary, jobs and careers in the real world.

• But you don’t have to take my word for it.
• Take the word of UM engineering alumni:

So you want to be an EE...
(same holds for any other type)

• Most important: To know math & physics.
• Employers look for: Technical competence (good grades in your engineering courses).
• What you will do: Apply directly what you learned in all of your engineering courses.
• Your job: Electrical Engineer, obviously.
• Which statement/statements is/are wrong?

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(same holds for any other type)

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• Your job: Electrical Engineer, obviously.
• ALL of the above statements are WRONG!

U-M EE Alumni Say That:

• Most important in their professional experience

1 Ability to function on a team

U-M EE Alumni Say That:

• Most important in their professional experience

1 Ability to function on a team
2 Oral communication skills
U-M EE Alumni Say That:

- Most important in their professional experience
  1. Ability to function on a team
  2. Oral communication skills
  3. Written communication skills
  4. Engineering problem-solving ability
  5. Math, science, and engineering skills (yes, 5th)

What U-M EE Alumni Do:

- 62.5%: Engineer
- 14.6%: Manager
- 6.3%: Marketing
- 16.7%: Other

Source: U-M College of Engineering Alumni Surveys for classes 00-01, 01-02, 02-03, 03-04

Conclusions from this data:

- **Nerds can’t be engineers!**
- Team and communication skills are more important on the job than technical competence.
- You’re not smarter than everyone: Someone else is smarter (in India?)