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
- 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
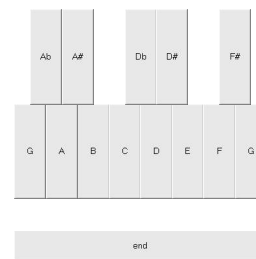
Mimics single octave of a piano keyboard: black keys above (for accidental notes); white keys below (for whole notes).
You can jazz this up (add colors & labels) if you desire to do so.
Clicking on key with mouse plays that note

Project #1: Tone Transcriber Output
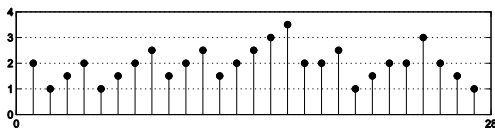
Crude musical staff notation of "The Victors."
Musical notes: uses stems instead of ♫ or ♪.
No interval info.-all notes have same duration.

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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Plotted below is a signal-plus-noise. Can you figure out what the signal is?
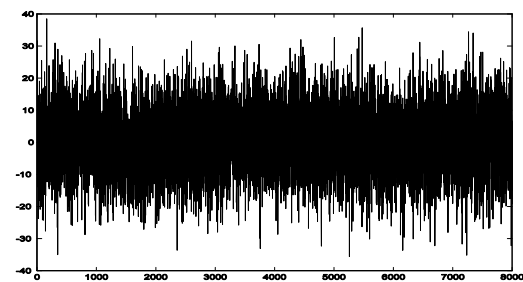
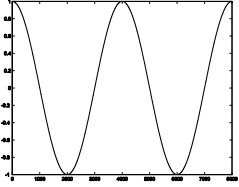## This is the signal without noise. How to get it? Wait for Lab #3.
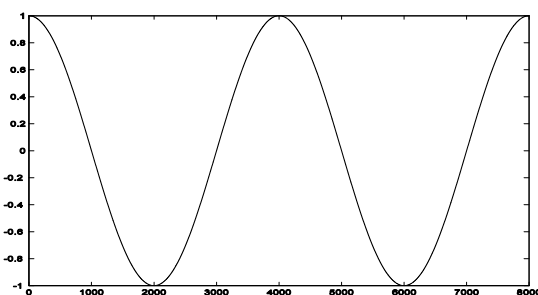
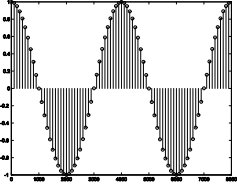Applications of Digital Signal Processing (DSP)

- 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?
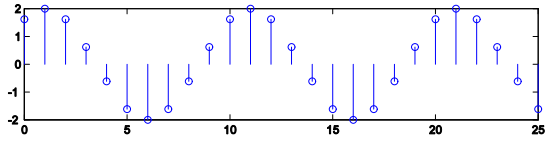## Sampling: Convert analog to digital

SAMPLE analog to get digital (sequence of discrete numbers).

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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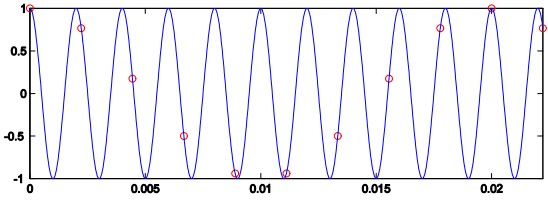
5 Hz Sinusoid Sampled 50 Samples/Second

x(t) =2cos(10πt-π/5). Substitute t=n/50=0.02n:

x[n]=2cos(0.2πn-π/5). Sampling rate=50 "Hertz."

x[n]	x[0]=1.62	x[1]=2.00	x[2]=1.62	x[3]=0.62
x[n]	2cos(0.2π0-π/5)	2cos(0.2π1-π/5)	2cos(0.2π2-π/5)	2cos(0.2π3-π/5)

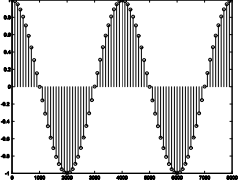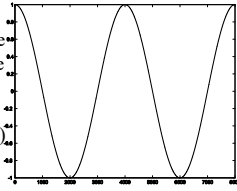**A 500-Hz sinusoid is sampled at 450 samples/second. Samples=red circles. Are samples from 450 or 50 Hz?**

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.

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)?

How do we connect the dots to get the correct smooth 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)

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

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- <u>What you will do</u>: Apply directly what you learned in all of your engineering courses
- <u>Your job</u>: Electrical Engineer, obviously.
- **ALL** of the above statements are **WRONG!**

U-M EE Alumni Say That:

- <u>Most important in their professional experience</u>

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3 Written communication skills

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4 Engineering problem-solving ability

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3 Written communication skills
4 Engineering problem-solving ability
5 Math, science,and engineering skills (yes, 5th)

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- 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)
6 Professional and ethical responsibility

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?)