EECE 301
Signals & Systems

Note Set #1

• What is “Signals & Systems” all about??
• See also Section 1.1 of textbook by Kamen and Heck
Do All EE’s & CoE’s Design Circuits?

• No!!!! Someone has to figure out what function those circuits need to do

• Someone also needs to figure out the “algorithms” needed (i.e., mathematical computer processing)

• Someone also needs to figure out what the whole system needs to do

So… lots of EEs/CoEs don’t design circuits at all…
What they do instead is design the **systems & algorithms** that are needed to accomplish certain needed tasks

Rely Heavily on Mathematical Models
Signals & Systems

• Because most “systems” are driven by “signals” EEs & CoEs study what is called “Signals & Systems”

• “Signal” = a time-varying voltage (or other quantity) that generally carries some information

• The job of the “System” is often to extract, modify, transform, or manipulate that carried information

• So… a big part of “Signals & Systems” is using math models to see what a system “does” to a signal
Beyond “Signals & Systems”
### Application Areas

<table>
<thead>
<tr>
<th>Field of Application</th>
<th>Specific Uses of DSP Systems</th>
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<tbody>
<tr>
<td>Telecommunications</td>
<td>Answering machines, modems, fax machines, cellular telephones, speaker phones</td>
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<tr>
<td>Voice and Speech</td>
<td>Voice mail, speaker verification, speech synthesis, speech digitization and compression</td>
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<tr>
<td>Automotive</td>
<td>Engine control, antilock braking systems, active suspension, airbag control, system diagnosis</td>
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<tr>
<td>Medical</td>
<td>Hearing aids, patient monitoring, ultrasound imaging, magnetic resonance imaging (MRI)</td>
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<tr>
<td>Image Processing</td>
<td>3D rotation and animation, image enhancement, image compression and transmission, high-definition television (HDTV), pattern recognition</td>
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<tr>
<td>Control Systems</td>
<td>Head positioning in disk drives, laser printer control, engine and motor control, robot control, numerical control of automatic machine tools</td>
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<tr>
<td>Instrumentation</td>
<td>Signal generators, spectrum analysis, transient analysis</td>
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<tr>
<td>Military</td>
<td>Radar and sonar signal processing, navigation systems, high-frequency modems, secure radios and voice systems, missile guidance</td>
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</tbody>
</table>

In each of these areas you can’t build the electronics until your math models tell you what you need to build.

**Table 32.1 from Electrical Engineering Uncovered, 2nd Ed. by White & Doering**

DSP = Digital Signal Processing
Signal Models (1)

• Engineers think of signals as being functions of time
  – Thus, one “math model” for a signal is simply the idea of “mathematical function”

• Engineers also use other mathematical models such as:
  – Fourier Series
  – Fourier Transform
  – Laplace Transform
Signal Models: Fourier (1)

- Engineers think of signals as being made as a sum of a whole bunch of sinusoids at various frequencies and various amplitudes

Add these sines & a bunch of others to get the signal $x(t)$

Simplification Warning
Signal Models: Fourier (2)

• We use a thing called the signal’s Fourier Transform $X(f)$, which as a function of $f$, shows how much of each frequency $f$ is in the signal $x(t)$:

$$|X(f)|$$

**Signal Bandwidth (BW)**

Frequency Range over which a signal has significant components

Simplification Warning
System Models (1)

• Many physical systems are modeled w/ **Differential Eqs**
  – Because physics shows that electrical (& mechanical!) components often have “V-I Rules” that depend on derivatives

• However, engineers use **Other Math Models** to help solve and analyze differential eqs
  – The concept of **“Frequency Response”** and the related concept of **“Transfer Function”** are the most widely used such math models
    > **“Fourier Transform”** is the math tool underlying Frequency Response
  – Another helpful math model is called **“Convolution”**
System Models (2)

- These 4 models all are equivalent
- …but one or another may be easier to apply to a given problem
• **Five Common Signals & Systems Scenarios:**
  – Given a system, determine a signal that will pass through it well
    ▶ e.g., Communication Transmitter
  – Given a type of signal, design a system that will pass it well
    ▶ e.g., Audio Amplifier
  – Design a system that will make a desired change to a signal
    ▶ e.g., Audio Equalizer
  – Design a system that will extract desired info from a signal
    ▶ e.g., Radar System or Communication Receiver
  – Design a system (and maybe signal) that gives a desired output
    ▶ e.g., Control System…. such as cruise control for a car
Digital Signal Processing (1)

- Modern electronic systems generally process signals using what is known as Digital Signal Processing (DSP)
  - Instead of using only analog electronics to manipulate an “analog” signal we convert the signal into a stream of bits and use a computer to manipulate those bits
  - Once the bits have been manipulated we can convert that stream of bits back into an “analog” signal
- However, in some applications we simply stay in the digital domain (e.g., using DSP to analyze underwater sound to determine if a submarine is nearby or not)
Digital Signal Processing (2)

- Example: Digitized music on a Compact Disc
- Analog music signal is “Sampled” and “Digitized”
  - Sample how fast? Digitize with how many bits?

Record

Time

Signal Value

Amp

Sample & Digitize

Code

“Burn” bits into CD

Microphone

Play

Laser

Sensor

Decode

“Undigitize”

Amp

Speaker

= Original?

Creates a sequence of samples (i.e., a sequence of numbers)
Digital Signal Processing (3)

- Systems that use DSP generally
  - get a **continuous-time signal** from a sensor
  - a **cont.-time system** modifies the signal
  - an “analog-to-digital converter” (ADC or A-to-D) sample the signal to create a **discrete-time signal**
  - A **discrete-time system** (digital electronics and/or computer) to do the Digital Signal Processing
  - and then (if desired) convert back to analog (not shown here)
C-T vs. D-T Signals & Systems

- We’ll need the same KINDS of math models
  - There will be some SIMILARITIES… and DIFFERENCES
Our Studies

- Because there are many similarities between C-T and D-T signals and systems…
  - We will present many ideas “side-by-side”
  - You’ll need to recognize the differences/similarities