LECTURE #1 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

LECTURE #2 OBJECTIVES

- Relate TIME-SHIFT to PHASE
- Introduce an ABSTRACTION:
  - Complex Numbers represent Sinusoids
  - Complex Exponential Signal

$$z(t) = Ze^{j\omega t}$$

LECTURE #3 OBJECTIVES

- Phasors = Complex Amplitude
  - Add Sinusoids = Complex Addition
  - PHASOR ADDITION THEOREM

$$z(t) = Ze^{j\omega t} = (Ae^{j\varphi})e^{j\omega t}$$

- Develop the ABSTRACTION:
  - Complex Numbers represent Sinusoids

LECTURE #4 OBJECTIVES

- Sinusoids with DIFFERENT Frequencies
  - Add Sinusoids

$$x(t) = \sum_{k=1}^{N} A_k \cos(2\pi f_k t + \varphi_k)$$

- SPECTRUM Representation
  - Graphical Form shows Different Freqs

LECTURE #5 OBJECTIVES

- Signals with HARMONIC Frequencies
  - Add Sinusoids with $f_k = kf_0$

$$x(t) = A_0 + \sum_{k=1}^{N} A_k \cos(2\pi k f_0 t + \varphi_k)$$

- ANALYSIS via Fourier Series
  - For PERIODIC signals: x(t+T) = x(t)

LECTURE #6 OBJECTIVES

- Frequency can change vs. time
  - Basis of Frequency Modulation (FM)
  - Define "instantaneous frequency"
- Chirp Signals (LFM)
  - Quadratic phase

$$x(t) = A\cos(\alpha t^2 + 2\pi f_0 t + \varphi)$$

LECTURE #7 OBJECTIVES

- SAMPLING can cause ALIASING
  - Sampling Theorem
  - Sampling Rate > 2(Highest Frequency)
- Spectrum for digital signals, x[n]
  - Normalized Frequency

$$\hat{\omega} = \omega T_s = \frac{2\pi f}{f_s}$$

LECTURE #8 OBJECTIVES

- DIGITAL–to–ANALOG CONVERSION is
  - Reconstructing x(t) from its samples
    - SAMPLING THEOREM applies
  - Smooth Interpolation
- Mathematical Model of D–to–A
  - SUM of SHIFTED PULSES
    - Linear Interpolation example

LECTURE #9 OBJECTIVES

- INTRODUCE FILTERING IDEA
  - Weighted Average
  - Running Average
- FINITE IMPULSE RESPONSE FILTERS
  - FIR Filters $y[n] = \sum_{k=0}^{M} b_k x[n-k]$
  - Show how to compute the output y[n] from the input signal, x[n]

LECTURE #10

- BLOCK DIAGRAM REPRESENTATION
  - Components for Hardware
  - Connect Simple Filters Together to Build More Complicated Systems
- GENERAL PROPERTIES of FILTERS
  - LINEARITY
  - TIME–INVARIANCE
  - ==> CONVOLUTION

LTI SYSTEMS

LECTURE #11

- SINUSOIDAL INPUT SIGNAL
  - DETERMINE FIR OUTPUT
- FREQUENCY RESPONSE of FIR
  - MAGNITUDE vs. Frequency
  - PHASE vs. Freq
  - PLOTTING:

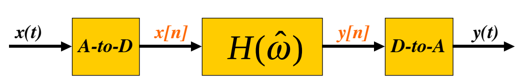
MAG

PHASE

$$H(\hat{\omega}) = |H(\hat{\omega})| e^{j\varphi(\hat{\omega})}$$

LECTURE #12

- DIGITAL PROCESSING of ANALOG SIGNALS
- UNIFICATION:
  - How does Frequency Response affect x(t) to produce y(t) ?



LECTURE #13

- INTRODUCE the Z-TRANSFORM
  - Give Mathematical Definition
  - Show how H(z) POLYNOMIAL simplifies analysis
    - CASCADE EXAMPLE
- Z-Transform can be applied to
  - FIR Filter: h[n] --> H(z)
  - Signals: x[n] --> X(z)

$$H(z)=\sum_{n} h[n]z^{-n}$$

11/19/98 EE-2200 Fall-98 jMc 14

LECTURE #14

- Relate H(z) to FREQUENCY RESPONSE

$$H(\hat{\omega}) = H(z)\big|_{z=e^{j\hat{\omega}}}$$

- Zeros of H(z)
- THREE DOMAINS:
  - Show Relationship for FIR:

$$h[n] \leftrightarrow H(z) \leftrightarrow H(e^{j\hat{\omega}})$$

11/19/98 EE-2200 Fall-98 jMc 15

LECTURE #15

- INFINITE IMPULSE RESPONSE FILTERS
  - IIR Filters
  - Have FEEDBACK: PREVIOUS OUTPUTS

$$y[n]=\sum_{\ell=1}^{N} a_\ell y[n-\ell]+\sum_{k=0}^{M} b_k x[n-k]$$

  - Show how to compute the output y[n]
    - FIRST-ORDER CASE (N=1)
    - h[n] <--> H(z)

11/19/98 EE-2200 Fall-98 jMc 16

LECTURE #16

- FREQUENCY RESPONSE of IIR
  - Get H(z) first

$$H(e^{j\hat{\omega}}) = H(z)\big|_{z=e^{j\hat{\omega}}}$$

- H(z) has POLES and ZEROS
- THREE-DOMAIN APPROACH
  - Get h[n] from H(z)
  - Get STRUCTURES from H(z)

11/19/98 EE-2200 Fall-98 jMc 17

LECTURE #17

- SECOND-ORDER IIR FILTERS
  - TWO FEEDBACK TERMS

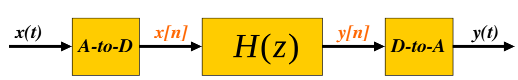
$$y[n]=a_1 y[n-1]+a_2 y[n-2]+\sum_{k=0}^{2} b_k x[n-k]$$

- H(z) can have COMPLEX POLES & ZEROS
- THREE-DOMAIN APPROACH
  - UNIFIES h[n] & FREQUENCY RESPONSE in terms of POLES and ZEROS

11/19/98 EE-2200 Fall-98 jMc 18

LECTURE #18

- THREE-DOMAIN APPROACH
  - EXHIBIT BANDPASS FILTERS
- RE-UNIFICATION:
  - How does Frequency Response affect x(t) to produce y(t) ?



11/19/98 EE-2200 Fall-98 jMc 19