EE-2200 Fall-98

Lecture 18

DIGITAL FILTERING of ANALOG SIGNALS

4-Dec-98

Info: Web-CT, Lab, HW

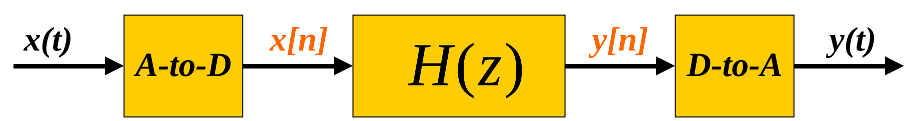
- Final Exam is Period 15
- Review Sessions planned (EE Aud)
  - Tuesday 6–7 PM
  - Wednesday 6–7:30 PM
  - Thursday 6:30–8 PM (tentative)
- Prob Set #7 is due Today
- Lab #9 due Today

READING ASSIGNMENTS

- This Lecture:
  - Chapter 8, all
- Other Reading:
  - Ch. 8, that's all

LECTURE OBJECTIVES

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



THREE DOMAINS

$$H(z)=\frac{\sum b_k z^{-k}}{1-\sum a_\ell z^{-\ell}}$$

$$z=e^{j\hat{\omega}}$$

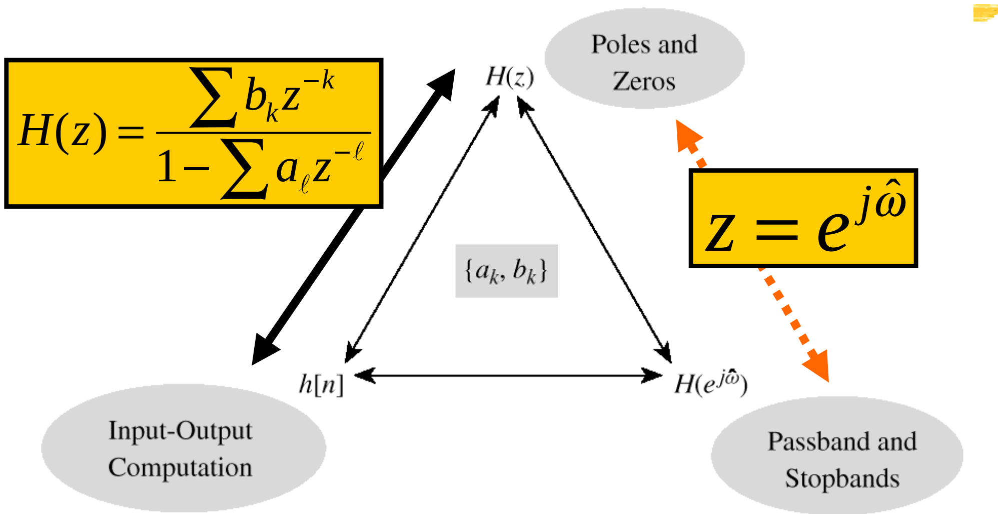
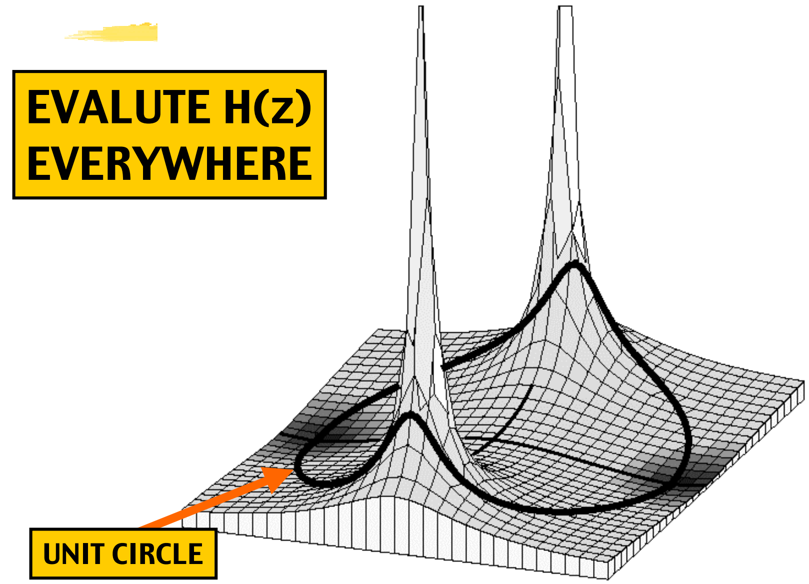


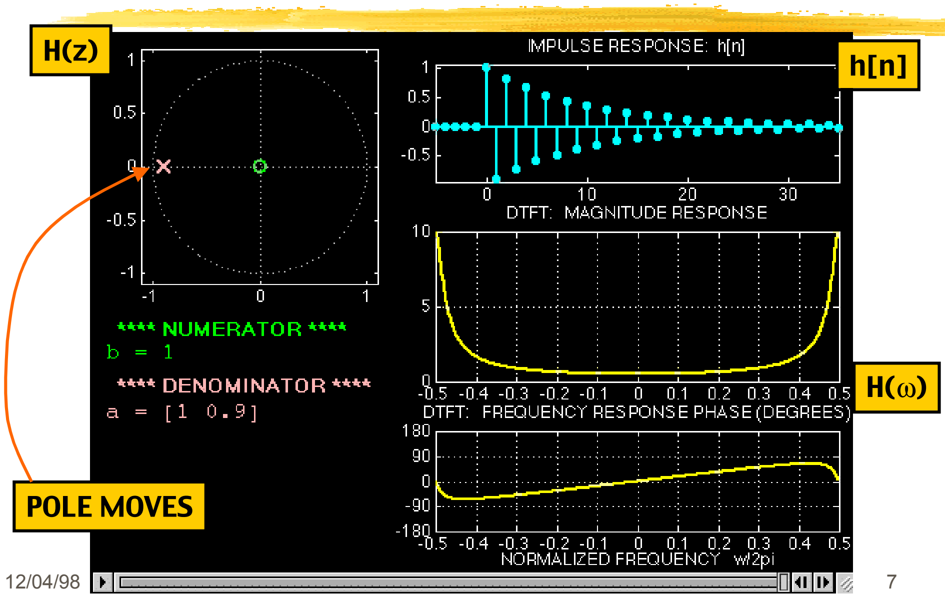
Figure 8.13 Relationship among the n-, z-, and $\hat{\omega}$-domains. The filter coefficients $\{a_k,\ b_k\}$ play a central role.

3-D VIEW



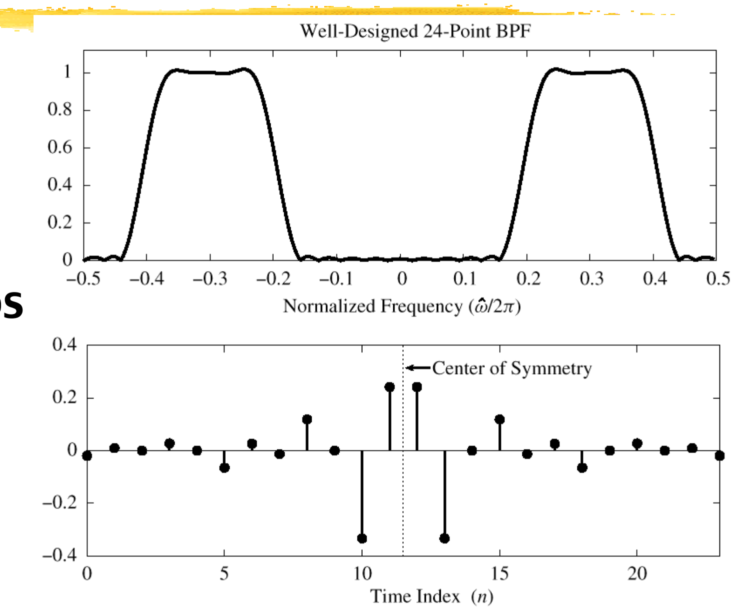
The poles are at $z = 0.85e^{\pm j\pi/2}$ and the zeros at $z = \pm 1$.

3 DOMAINS MOVIE: IIR

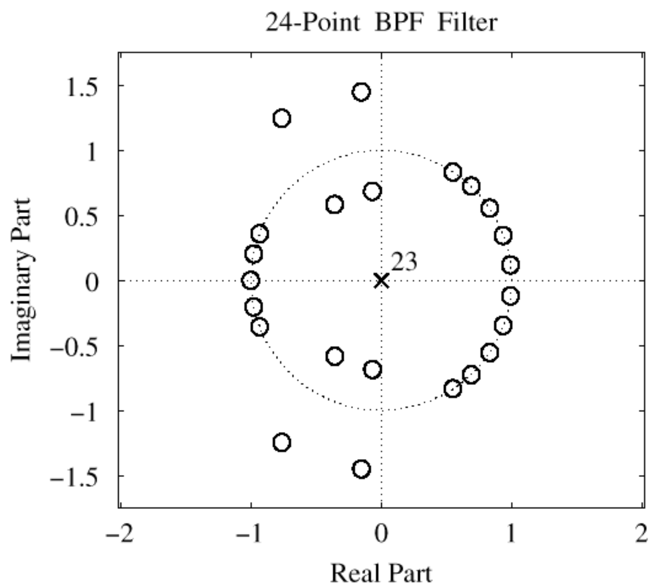


REALISTIC FIR BANDPASS

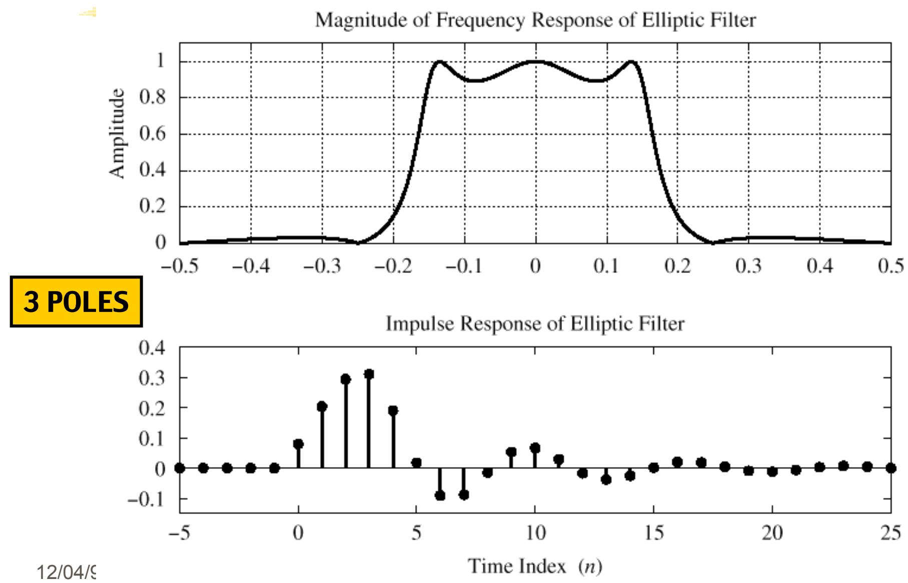
- FIR
- L = 24
- M=23
- 23 zeros



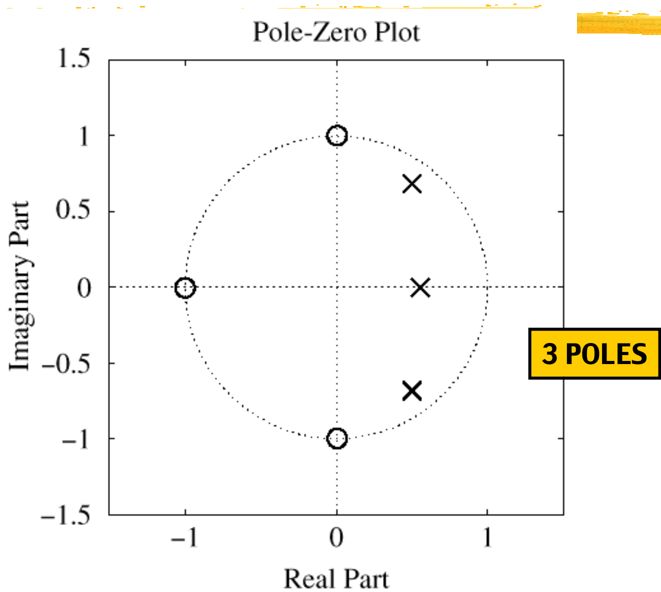
FIR BPF: 23 ZEROS



IIR Elliptic LPF (N=3)

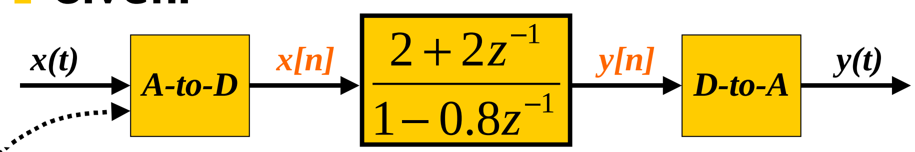


POLES & ZEROS of IIR



POP QUIZ

- **Given:**



- **Find the output, y(t)**
  - **When** $x(t) = \cos(2000\pi t)$

$f_s = 5000\,\text{Hz}$

POP QUIZ BECOMES

- **Given:** $H(z) = \dfrac{2+2z^{-1}}{1-0.8z^{-1}}$
- **Find the output, y[n]**
  - **When** $x[n] = \cos(0.4\pi n)$
  - **Because** $\omega T_s = 2000\pi / 5000 = 0.4\pi$

NO Aliasing

SINUSOIDAL RESPONSE

- **x[n] = SINUSOID => y[n] is SINUSOID**
- **Get MAGNITUDE & PHASE from H(z)**

$$\text{if } x[n] = e^{j\hat{\omega}n}, \text{ then}$$

$$y[n] = \mathcal{H}(\hat{\omega})e^{j\hat{\omega}n}$$

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

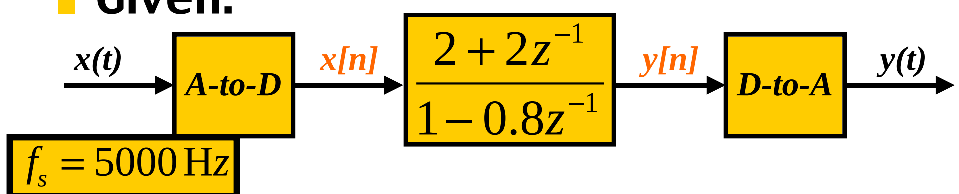
POP QUIZ INSIDE ANSWER

- **Given:** $H(z) = \dfrac{2+2z^{-1}}{1-0.8z^{-1}}$
- **The input:** $x[n] = \cos(0.4\pi n)$
- **Then y[n]** $y[n] = M\cos(0.4\pi n + \psi)$

$$H(e^{j0.4\pi}) = \frac{2+2e^{-j0.4\pi}}{1-0.8e^{-j0.4\pi}} = 3.02e^{-j0.452\pi}$$

POP QUIZ ANSWER

- **Given:**

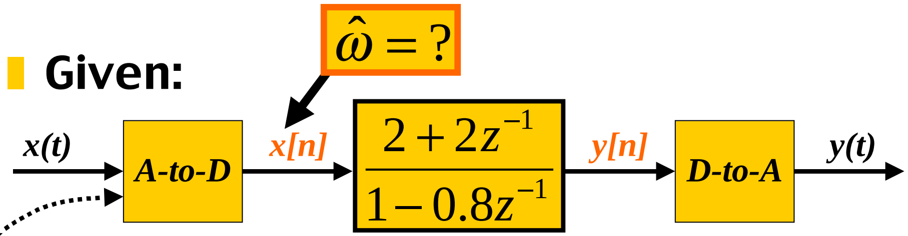


- **When** $x(t) = \cos(2000\pi t)$
- **The output is**

$$y(t) = 3.02\cos(2000\pi t - 0.452\pi)$$

ANOTHER POP QUIZ

- **Given:**



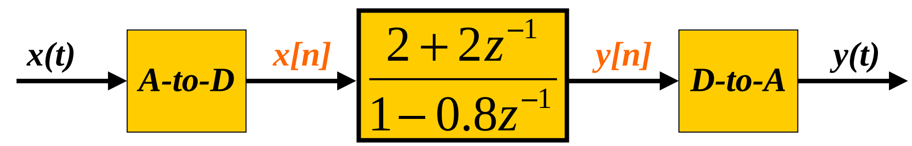
- **Find the output, y(t)**
  - **When** $x(t) = \cos(2\pi(7500)t)$

$f_s = 5000\,\text{Hz}$

$\hat{\omega} = ?$

2nd POP QUIZ ANSWER

- **Given:**



- **When** $x(t) = \cos(2\pi(7500)t)$

$f_s = 5000\,\text{Hz}$ → $\hat{\omega} = 3\pi$ → $y(t) = 0$

IMPORTANT CONCEPTS

- **ALL Signals have Frequency Content**
  - **Sum of Sinusoids**
  - **Complex Exponentials**
- **FILTERS alter the Frequency Content**
  - **Image Processing Example: Blur**
  - **Linear Time–Invariant Processing**
- **3 Domains for Analysis**

THE FUTURE

- **Circuits & Laplace Transforms**