Tutorial Overview of Digital Signal Processing (DSP) for Practicing Engineers

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DSP Engineering

Overview of Presentation

- Need for DSP (brief discussion)
- Implementations (brief discussion)
- Applications of DSP (just a list)
- Studying Digital Signal Processing
  - Most of the emphasis of the talk
- Sources of study material
  - Books, SW packages, Web links

Need for DSP

- Real world is analog, not digital: source, sink or medium
  - Analog source: music, voice, pictures, etc
  - Analog sink or sensors: ears, eyes, skin
  - Analog medium: communication channels for digital data – e.g., phone lines, RF, etc.
- Problems with analog processing
  - Cumulative degradation - analog recordings
  - Low accuracy and susceptible analog components – equalizers for radios and modems difficult to build and maintain
  - Not flexible: hardware based

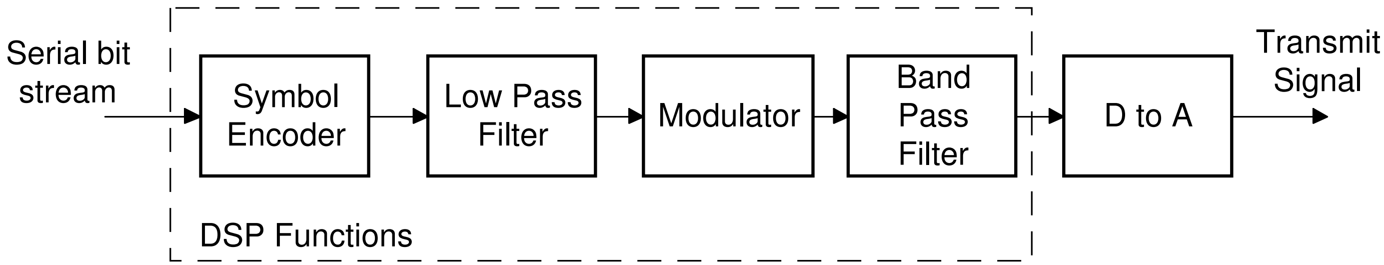
Need for DSP (contd.)

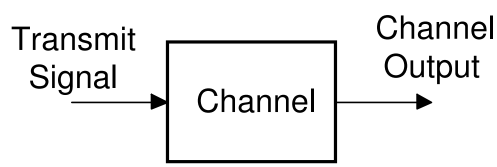
- Analog source sampled (A to D)
  - Requires words of enough bits to represent info. from analog source
- Digital bits end in to analog result (D/A)
  - Requires words of enough bits to yield useable analog result
- Filtering and spectral analysis (analog functions) require processing these words digitally: thus, digital signal processing!

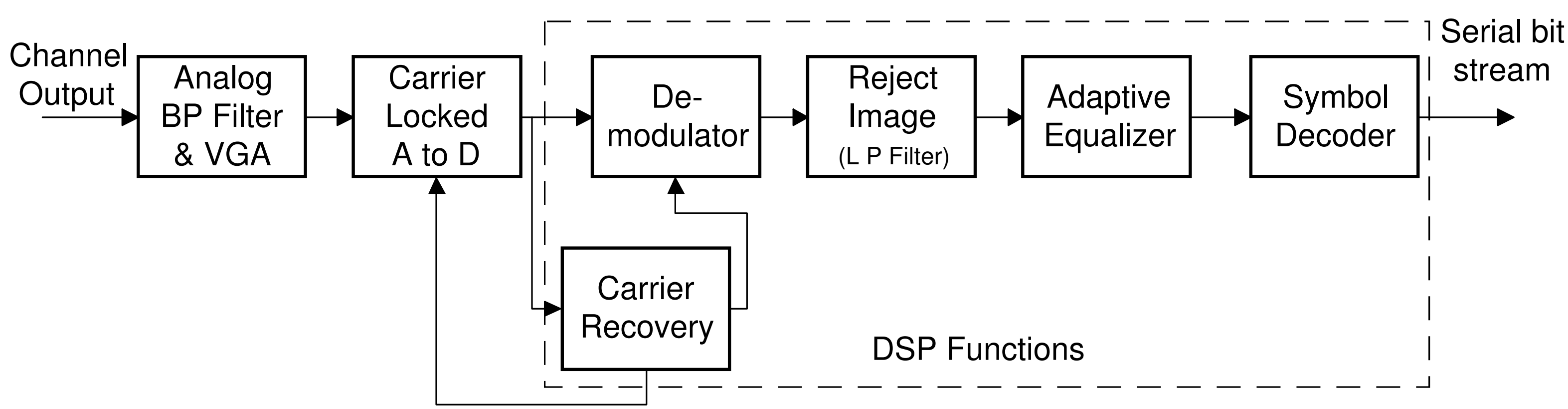
Notes on Need for DSP

- uP w data & coefficient bus architecture (Harvard) & MAC (multiply-accumulate) has proliferated DSP
  - made it cheaper & efficient
- For real-time operation with one MAC DSP, need instruction execution rate at least 100 times the sampling rate
  - e.g., 5 MHz BW signal needs 1G inst./sec processor

Carrier Based Data Communication System







DSP Implementations & Trends

- DSP uP (w Harvard architecture)
- General uP with special instructions and dual bus (Intel's MMX extension)
- Application Specific Functional Blocks or ASIC
- Gate array or FPGAs
- Trends: 1) multiple processors (TI 6XXX)
2) low power (cell phones, PDA)
3) SOC: ADC, PWM - ADI 21992
4) RF on same chip - WLAN

Applications of DSP Techniques

- Communication systems
  - Wireline modems
  - Wireless systems
  - Cellular
  - xDSL
  - Adaptive antenna

Applications (contd.)

- Audio
  - Psycho Acoustic enhancements
  - Room acoustic compensation
  - Distortion amelioration in speakers
  - Noise reduction

Applications (contd.)

- Image enhancement
  - Filtering for smoothing
  - Noise reduction
  - Video
    - motion compensation
  - Medical applications
    - MRI

Applications (contd.)

- Spectral Analysis
  - Oil exploration

Learning DSP - Avenues

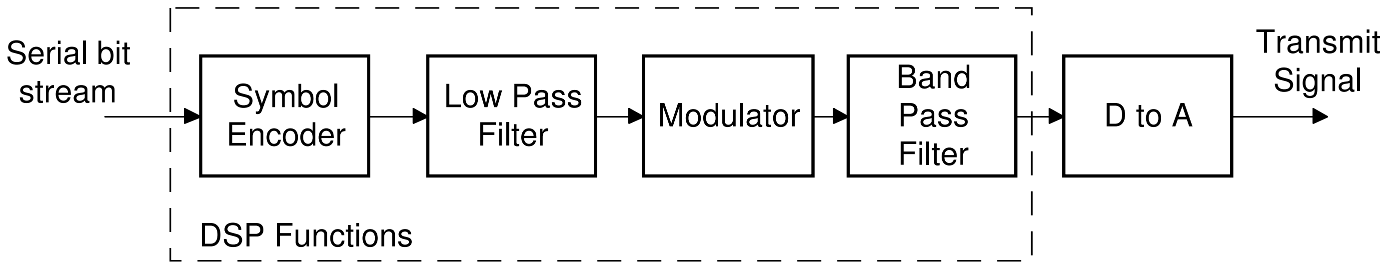
- Courses in a university and college extension classes
- Self study

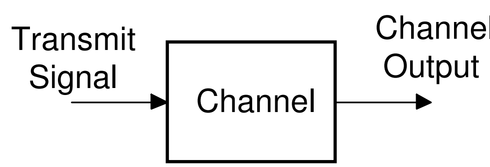
Self Study Approach (SSA)

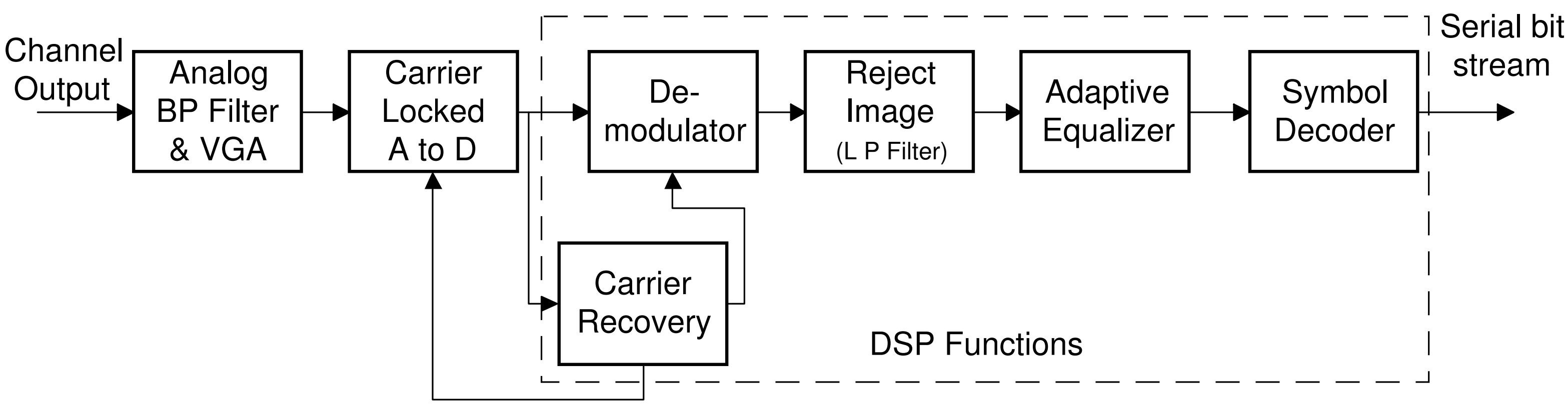
Overview:

- Practice with 1st and 2nd order filters
- Experiment with commonly used circuits
- Play with high order filter design SW
- Use root locus to study stability of feedback system
- Use pictorial approach for spectral analysis
- Understand sampling and multi-rate processing (Topics such as PLL, adaptive systems skimmed)

Carrier Based Data Communication System





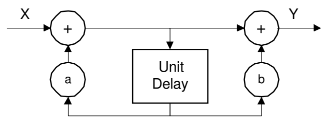


SSA – 1st & 2nd Ord. Filters

Practice with 1st and 2nd order filter configurations

- Use z plane for placement of poles and zeros
  - Poles provide control of peaks of freq. response
  - Zeros provide control of notches or rejection
  - Use vectors in complex plane to estimate trends in amplitude response with frequency – 1st order example
- Try 1st order filters: low pass & high pass – understand step response by stepping through sample by sample
- Try 2nd order filters: low & high pass, band pass & band reject – use direct form II
- Higher order filters can be constructed as cascades of 2nd and 1st order filters

Analysis of First Order Filter

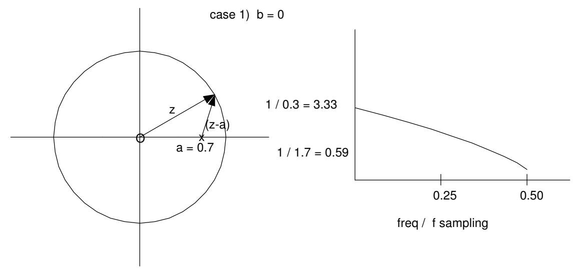


Transfer function given by :

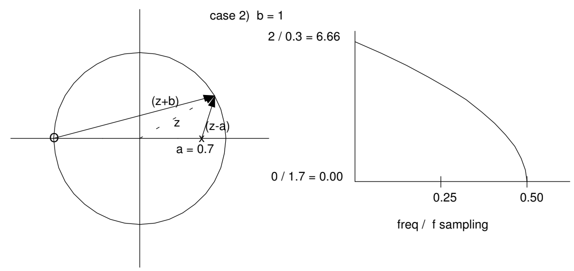
Y / X = (z + b) / (z - a)

1st Order Filter

case 1) b = 0



case 2) b = 1



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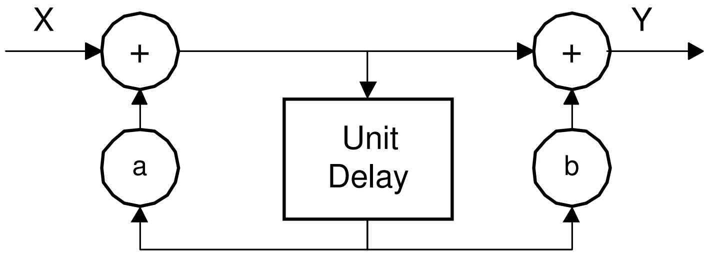

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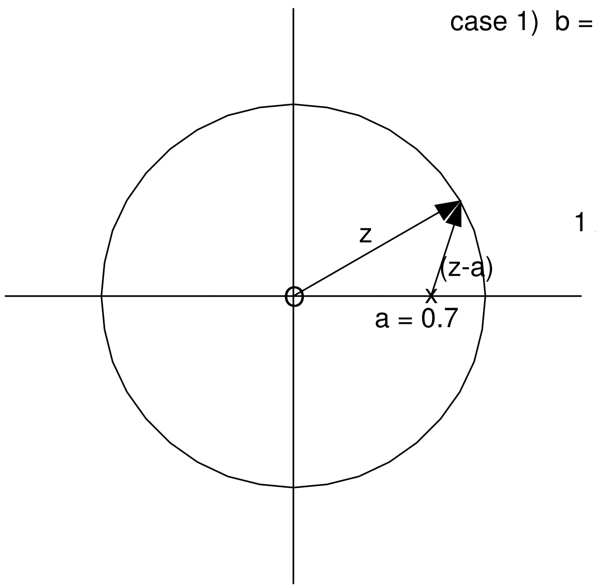
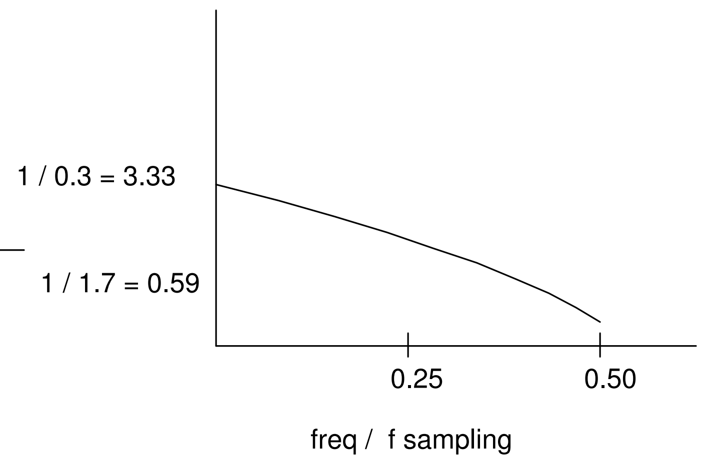
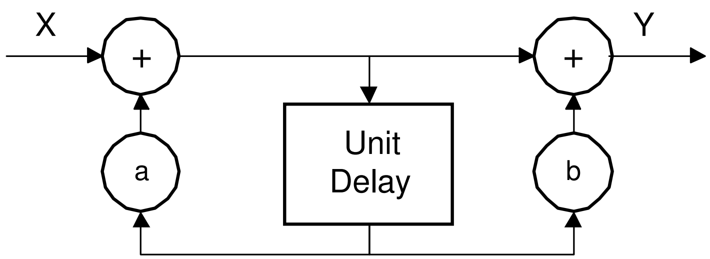




Analysis of First Order Filter (contd.)



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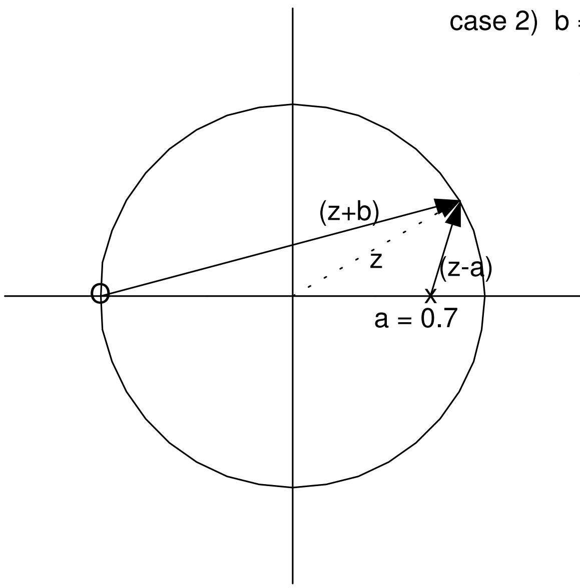
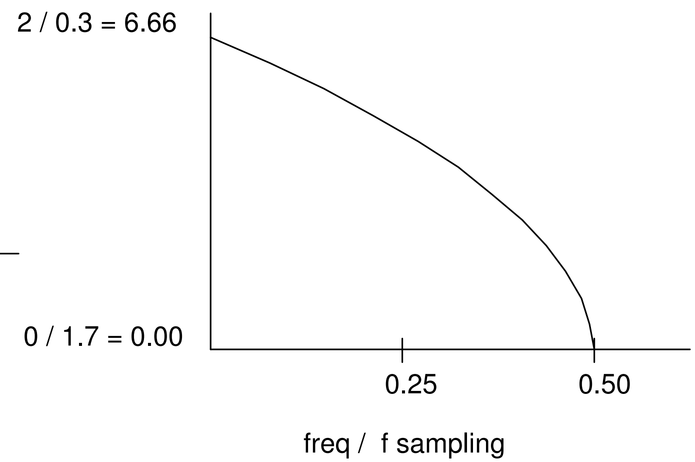
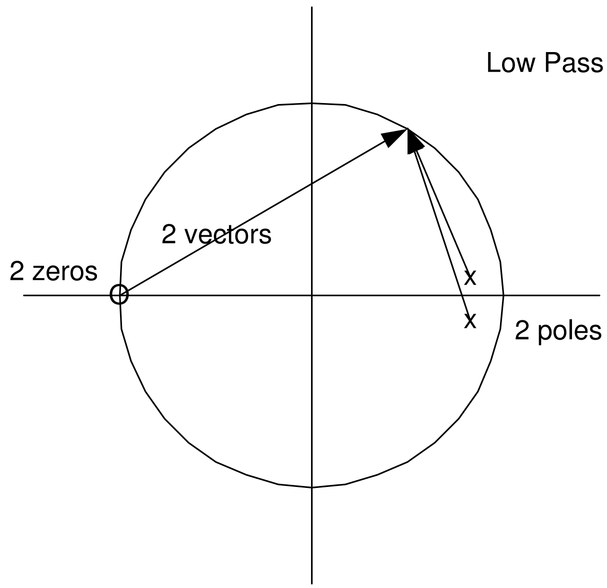
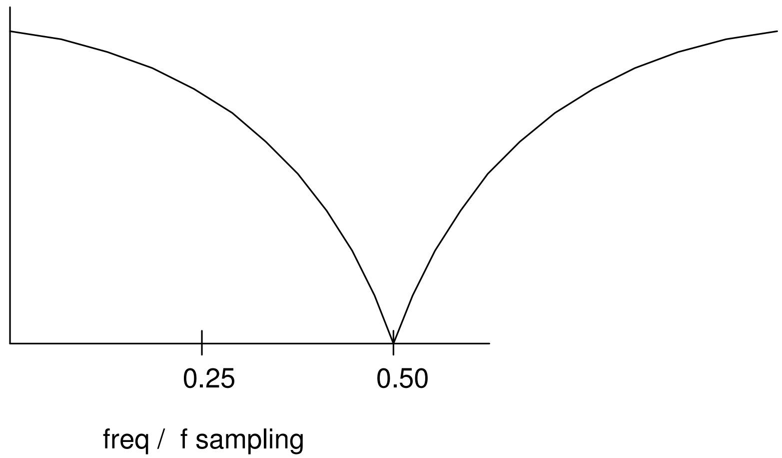




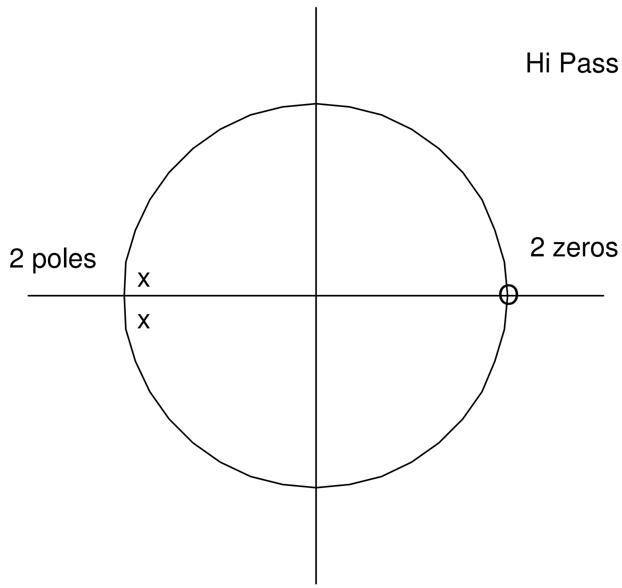
Poles and Zeros for 2nd Order Filters

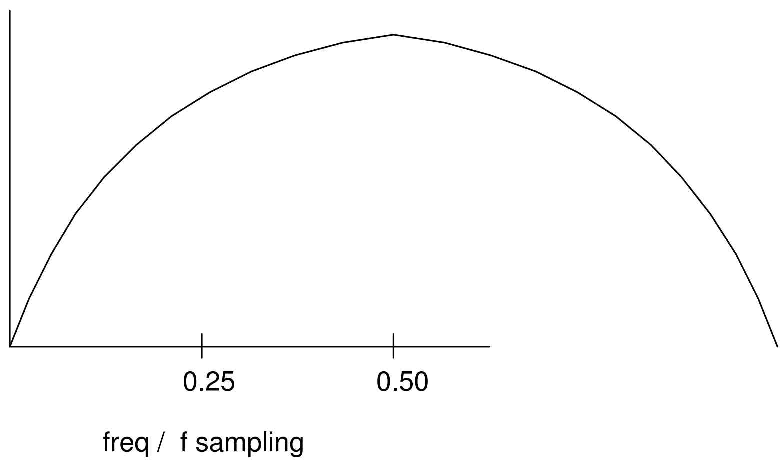
Low Pass Filter



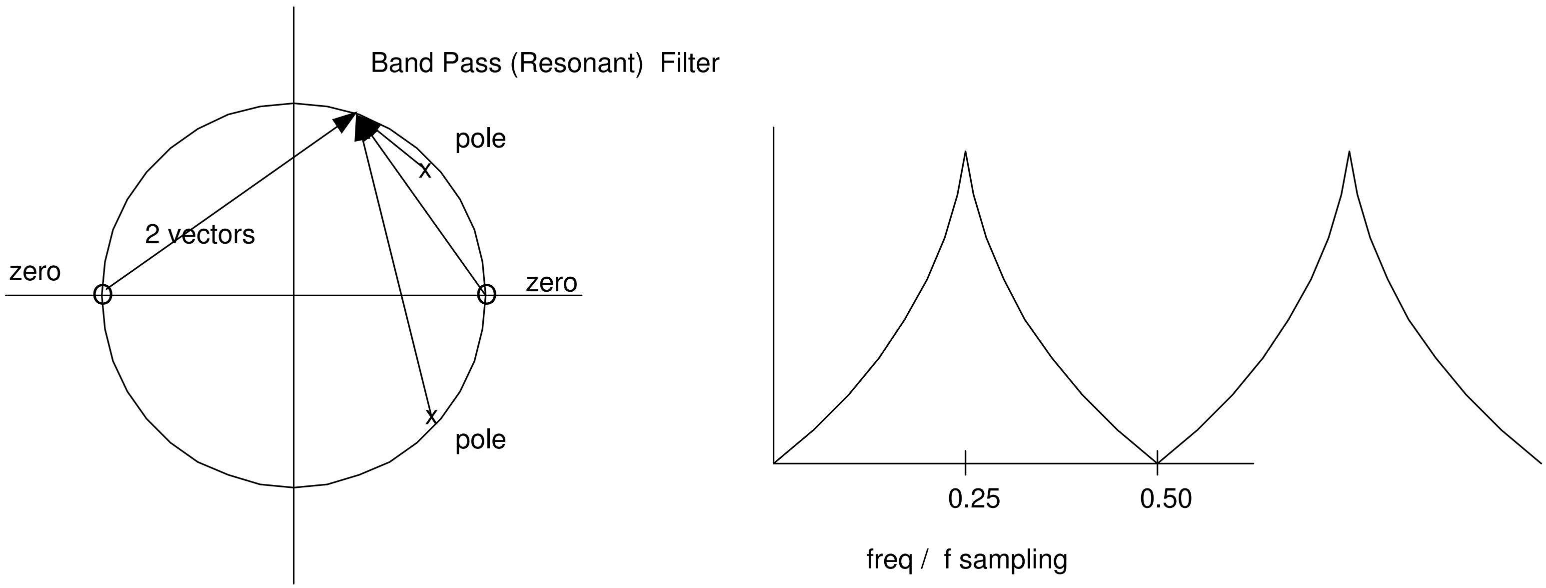


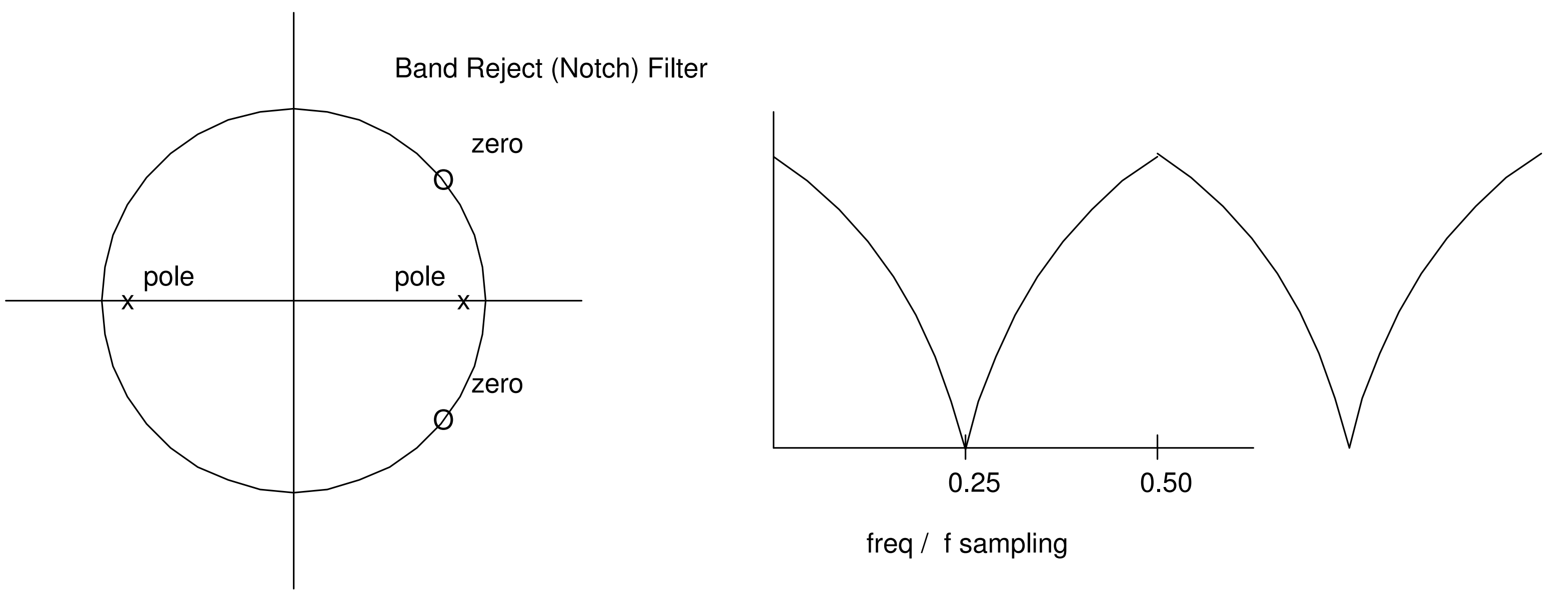
Hi Pass Filter





Poles and Zeros for 2nd Order Filters (contd)

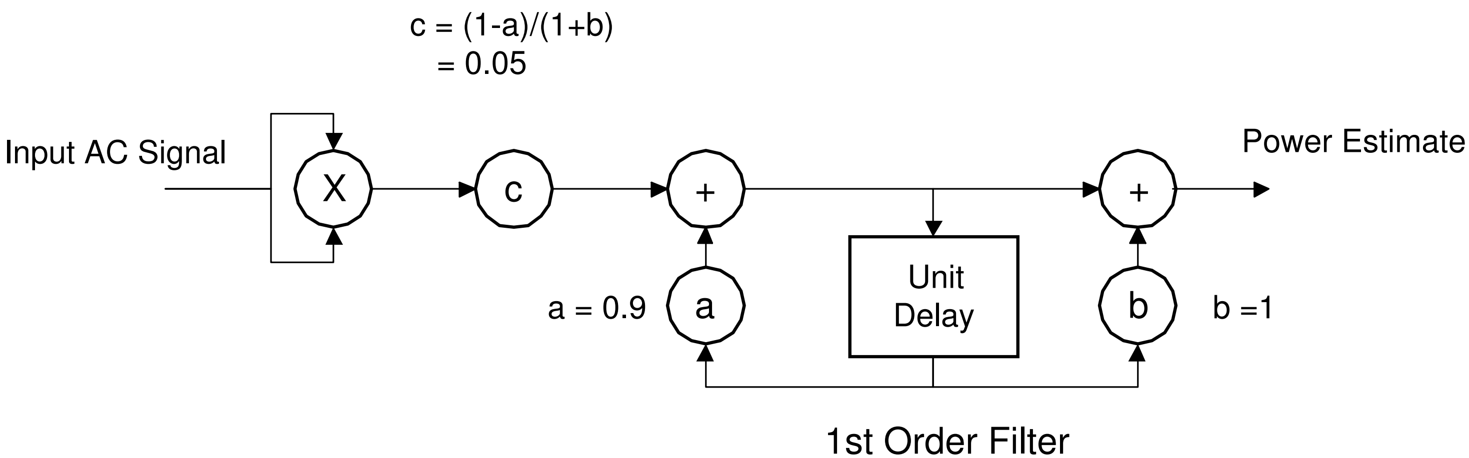




SSA – Common Circuits

- Create common circuits with 1st and 2nd order filters and study their time domain response
  - Examples: Averaging, DC estimation, DC rejection, power estimation, rectification, peak detection, envelope detection, etc.
- Above circuits provides insight and efficient implementation
  - e.g, a 2nd order resonant DC estimation system with properly placed poles & zeros yields low overshoot and has minimum rise time – elliptical has greater overshoot

Power Estimator (Using 1st order Filter)



SSA – Hi Ord. Filter Design

- Play with various methods of filter design for different types of filters:
  - Each method has advantages and disadvantages:
  - IIR – low order filter yields needed amplitude specs but yields non linear phase
    - Methods: 1) Filters similar to analog filters: Butterworth, Chebychev and Elliptical 2) Direct design or synthesis
      - Elliptical for standard filters – has steepest transition band
      - Direct design for arbitrary filters
  - FIR : Can assure linear phase but uses high order filters
    - Methods: 1) Windowing for standard filters 2) Remez and 3) Least squares (2 & 3 for arbitrary filters)

SSA – Other Topics

- **Stability of feedback system:** Use root locus method for determining path of poles with change in a gain parameter
- **Spectral Analysis:** analyze spectra of signals using pictorial approach: (see ch. 6 E. Oran Brigham 'The FFT & it's appl.' or Bracewell)
- **Sampling:** understand sampling well, especially spectrum resulting from it (see Brigham above)
  - study the effect of low pass filtering after sampling – see how it results into interpolation and high rate sampling

Sources of Material (SOM) - Books

- C. Britton Rorabaugh, 'DSP Primer'
  - Covers fundamentals well ; CD ROM provides modules for various techniques
- Bateman & Paterson-Stephans 'The DSP Handbook'
  - Practice oriented; includes a CD ROM
- Proakis & Manolakis 'DSP Principles, Algorithms and Applications'
  - Comprehensive treatment of subject
- Embree & Danieli 'C++ Algos. for DSP'
  - Mostly DSP algos.; CD ROM w source code

SOM – Key Web Sites

- **Signal Processing Information Base (SPIB)**
  - **http://spib.rice.edu/spib.html**
- **DSP Sites to Check Out (by Jinno Magno)**
  - **http://www.mrccos.com/~jmagno/dsplinks.html#gendsp**
- **DSP category from Google**
  - **http://directory.google.com/Top/Science/Technology/Electronics/Signal_Processing/Digital_Signal_Processing_-_DSP/**

SOM – Software Packages

- University based - free or at nominal cost
  - http://www.octave.org/ - Wisconsin
    - Similar to Matlab
  - http://ptolemy.eecs.berkeley.edu/
    - difficult user interface
- Commercial
  - Mathworks: Matlab with Sig. Processing TBox
  - Momentum Data System: Filter design and signal analysis package
  - Hyperception: Block diagram based DSP simulation software

SOM – Chip Vendors

- Vendors such as TI and ADI sell kits and development system around their DSP chip:
  - focused on using their DSP device
  - SW development system about $2K to $3k
  - Kit offered as part of course about $300 or so

Summary & Epilog

- Covered why DSP is needed
- Touched on implementation & trends
- Described approach to teaching yourself DSP
- Listed source of material for learning DSP
- Proverb: I hear, I forget; I see, I remember; I do, I understand! So PLAY & ENJOY!