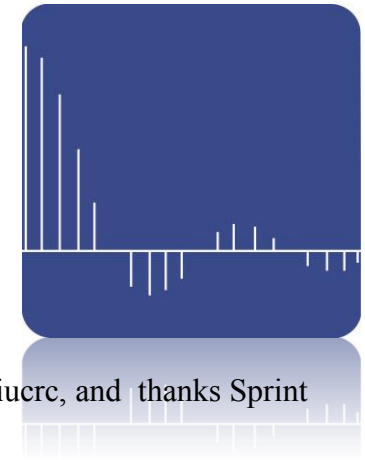
DSP Algorithm and Software Development on the iPad/ iPhone Platform

Prof. Andreas Spanias



Acknowledgment:
Project supported in part by the nsf jdsp phase 3 grant and the sensip center and NCSS iucrc, and thanks Sprint Communicationsand Debbie Vogel, Sprint SW Manager for providing devices.

ASU

Outline

- Motivation
- iJDSP Background
- Design Architecture
- New iJDSP Functions

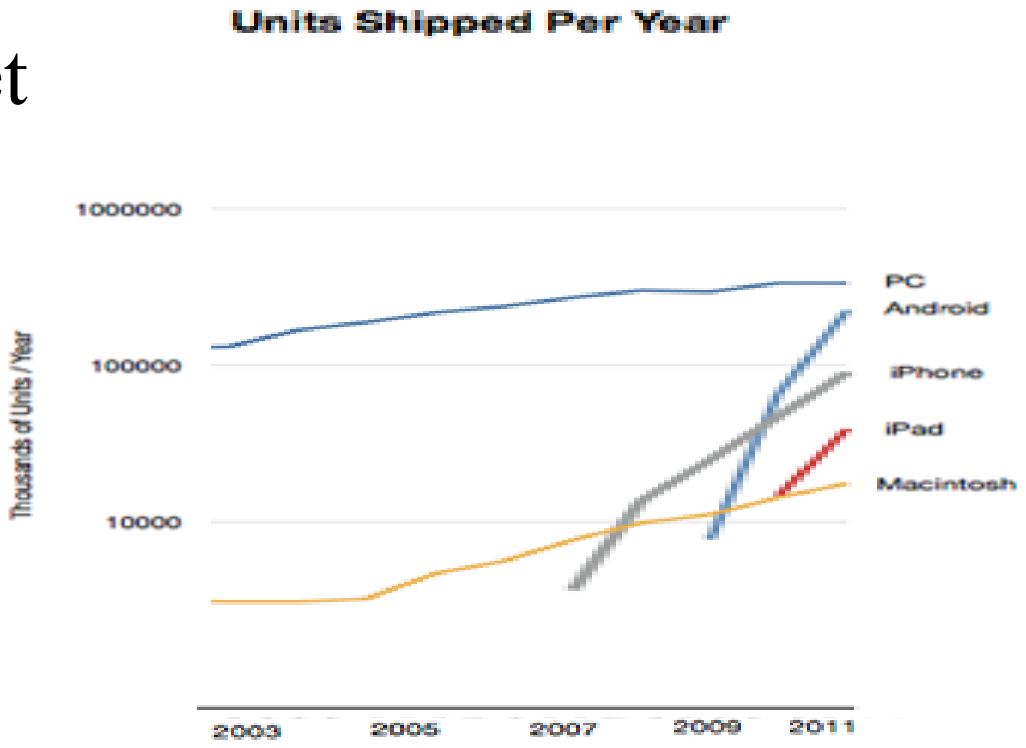
  Convolution Demo

  FIR Filter Design
  IIR Filter Design
  Hardware Interface iJDSP with WSN
- Assessments
- Future Work

Motivation

- Mobile Market

Huge growth of Smartphones and Tablet PC from 2007 to 2011



Acquired from the online source:
http://i-stuff.org/will-android-and-ios-take-over-the-pc-market/

Statistic acquired at March 2011

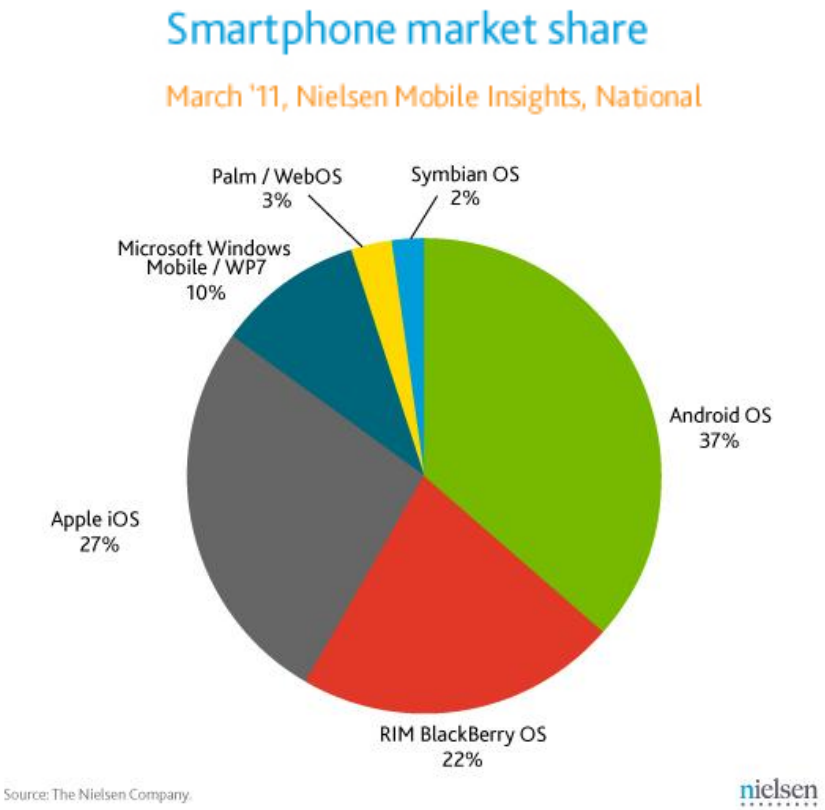
- Apple iOS : *27%*

  iPhone

- Android OS: *37%*

  Samsumg Galaxy, LG, HTC, etc.

- RIM BlackBerry OS: *22%*
- Windows Mobile: *10%*
- Web OS: 3%
- Symbian OS: 2%



Acquired from the online source:
http://blog.nielsen.com/nielsenwire/?p=27418

- # Mobile Educational Tools

- Star Walk

  Astronomy
  $2.99

- HP 12c Financial Calculator

  Bussiness
  $14.99

- Spectrogram

  Music: Visualize frequency over time
  $9.99

- MATLAB Mobile

  Computing & Simulation
  $0.00
  Command line only
  Lightweight mobile version
  Heavily relies on the Internet

- Need for DSP Mobile Tool

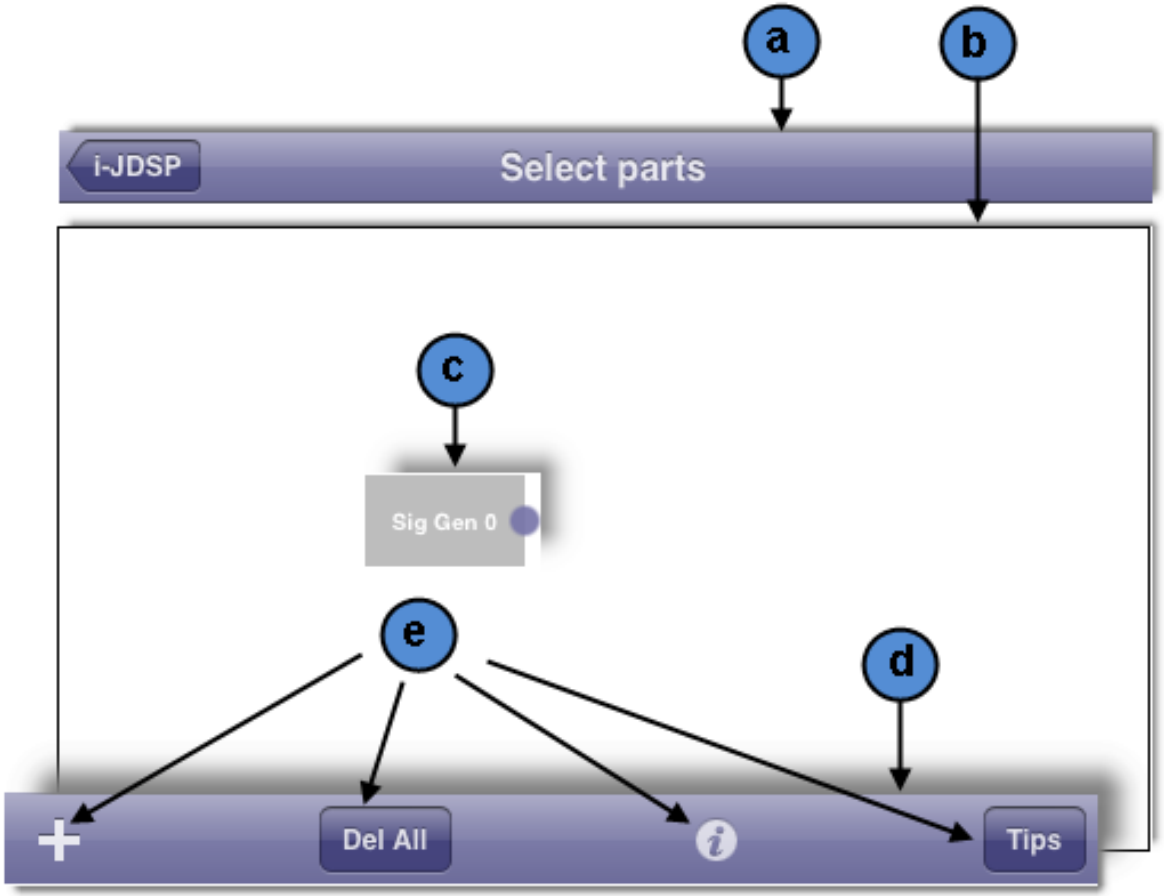
- Standalone mobile application with intuitive graphical user interface.
- Rich user interactions stimulate students interest.
- Provide multi-touch experience to undergraduate/ graduate DSP students and distance learners.
- Demonstrate signal processing concepts
- Undergraduate labs on iPhone/ iPad
- Infrastructure for research in sensor networks

iJDSP Background

- Features:
  - Intuitive Graphic User Interface
  - Free DSP Mobile App trough iTunes App Store
  - Multitouch Experience
  - Visualize DSP Functions
- Platform: *Compatible with iOS 3.2 or later*
- Development Environment: *Xcode*

- Hybrid Programming: *Objective C/C*

- Graphical User Interface



a Navigation Bar

b Main Canvas

c Block Diagram

d Tool Bar

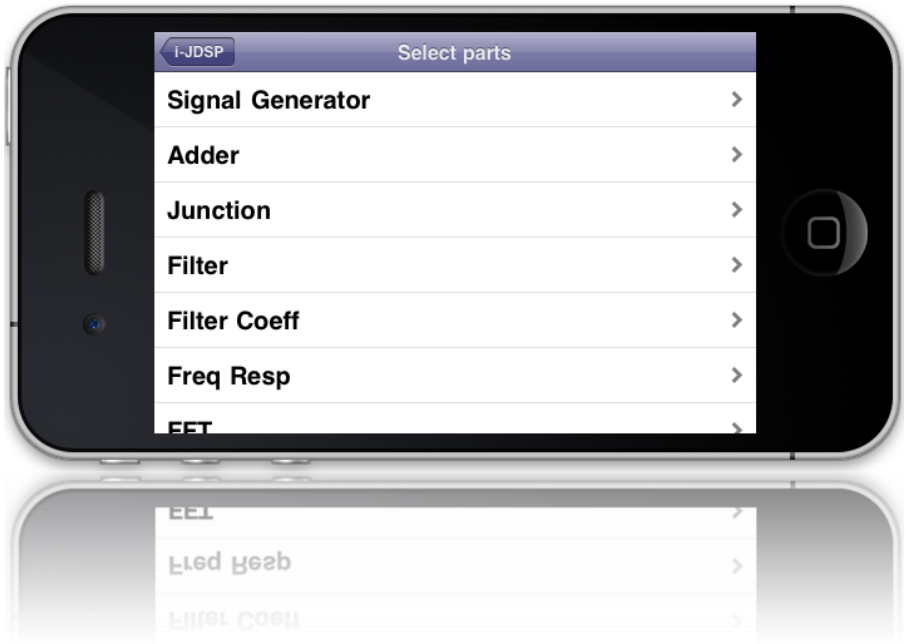
e Tool Bar Items
- Add button
- Delete button
- Info button
- Tips button

- User Gesture Recognition

Gesture Recognition	Operation
Double tap on a block	Open a block
Long hold on a block	Delete the block
Single tap on a pin	Make a connection
Single tap on a connection	Delete a connection
Hold and drag on a block	Move blocks
Swipe down/up on main canvas	Hide/show tool bar

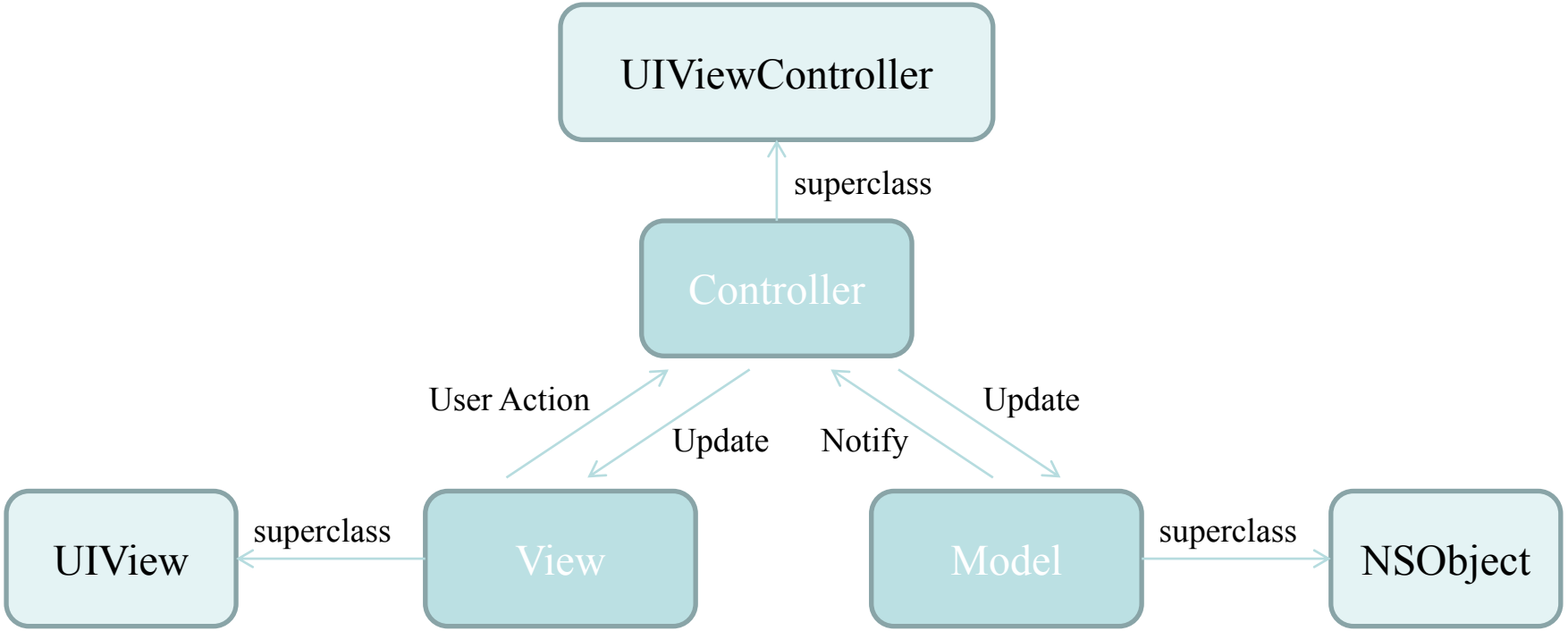
- DSP Functions

1. Signal Generator
2. Digital Filter
4. Frequency Response
5. PZ Computation
6. FFT
7. Plot
8. Sound Recorder/ Player
9. Convolution Demo (new)
10. FIR Filter Design (new)
11. IIR Filter Design (new)
…

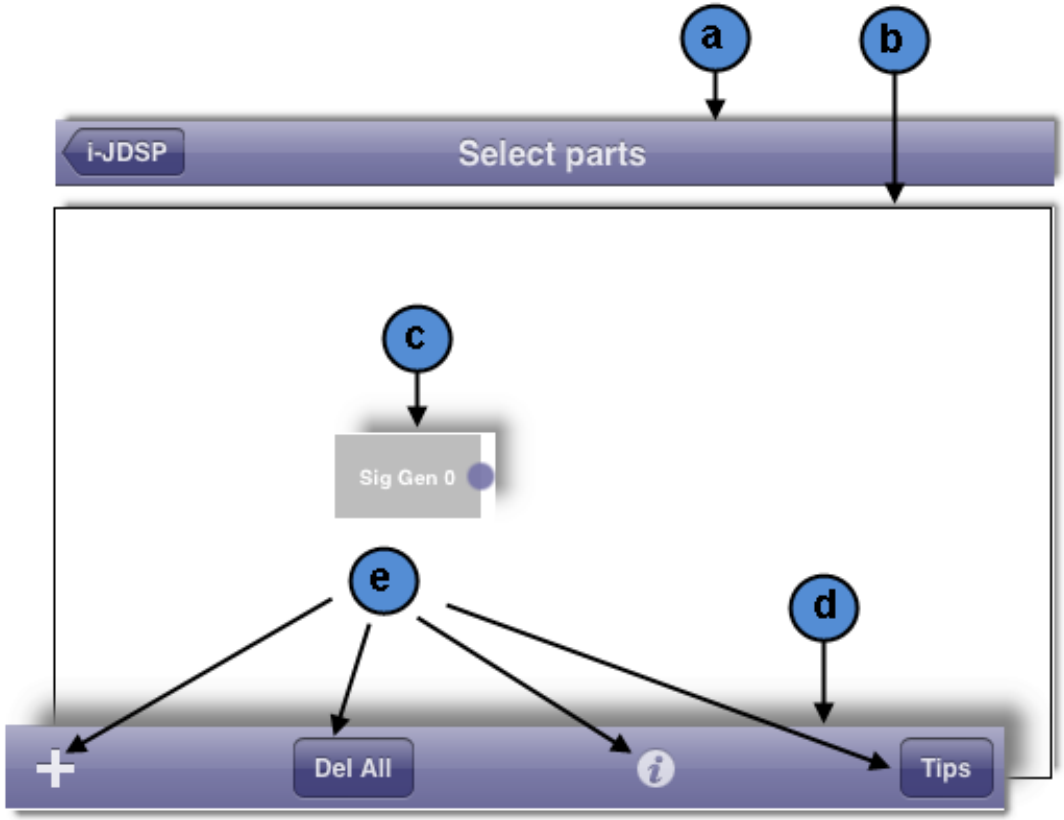


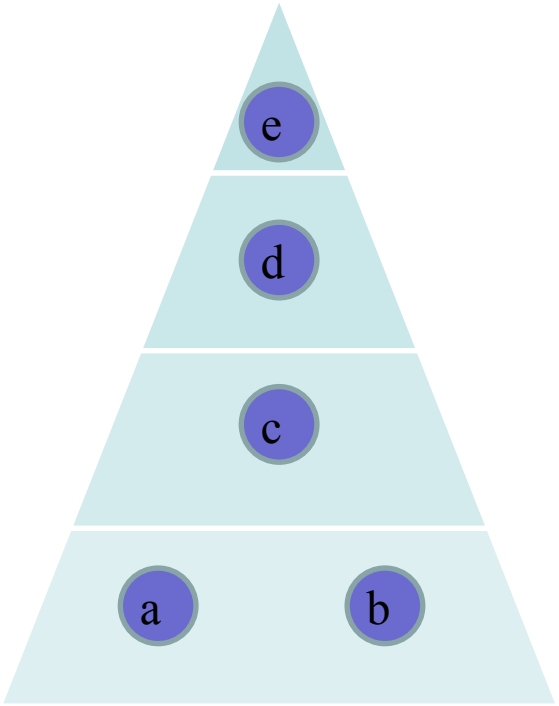
Design Architecture

- Model -View-Controller Paradigm[1]



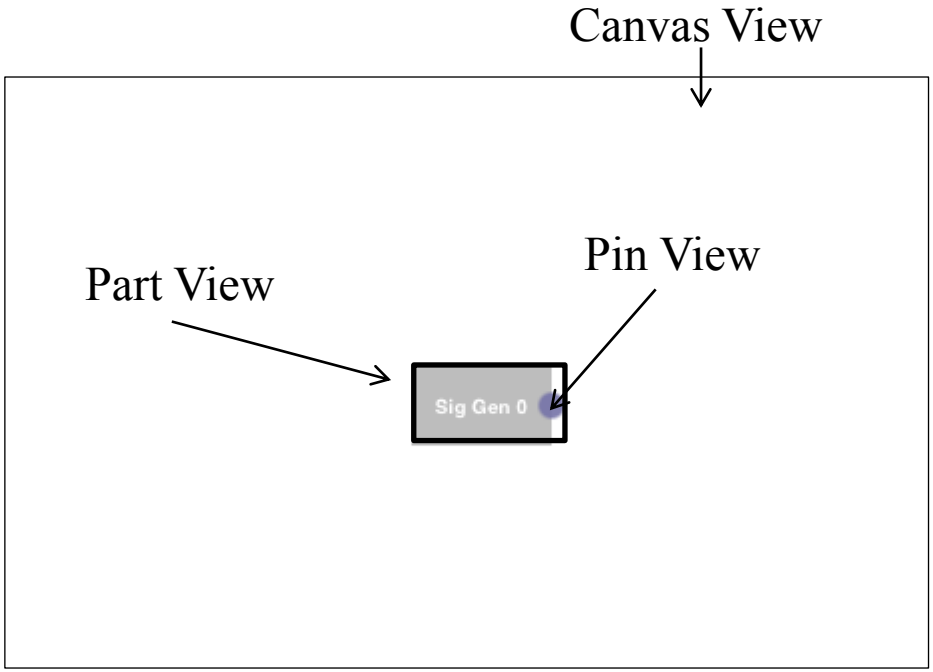
- View Layers



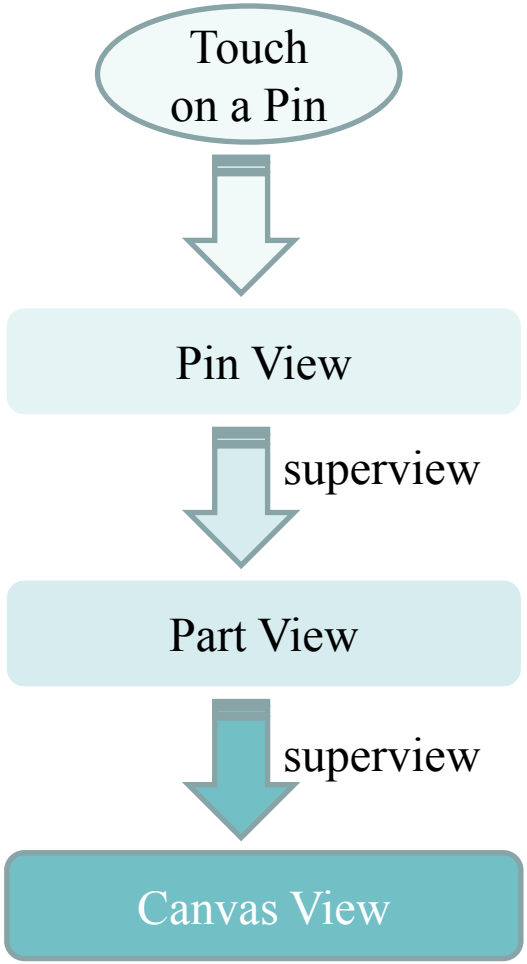


- Touch Event Handling

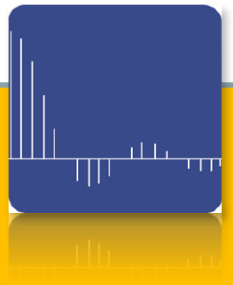
The Responder Chain



Make a connection on canvas



iJDSP Functions

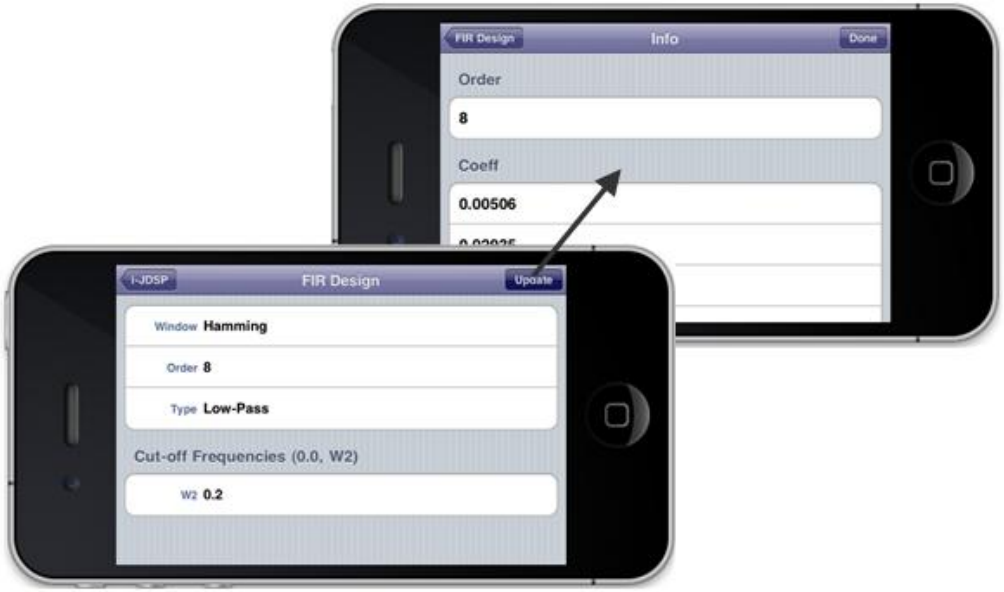


New Added Functionalities in iJDSP

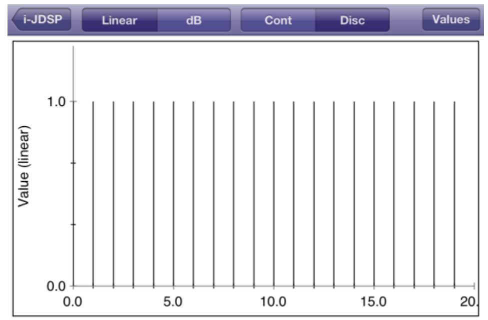
- Convolution Demo: Animated continuous / discrete convolution
- Filter Design: FIR /IIR filter design
- Collaborative Sensor Signal Processing Enabled by iJDSP:
  - Wireless connection between sensors and iPad
  - GUI for sensor motes on iPad
  - Inputs from multiple sensors: photometer, microphone, thermometer and accelerometer
  - Real-time plot of sensor data
  - Frame-by-frame process with DSP functions in iJDSP

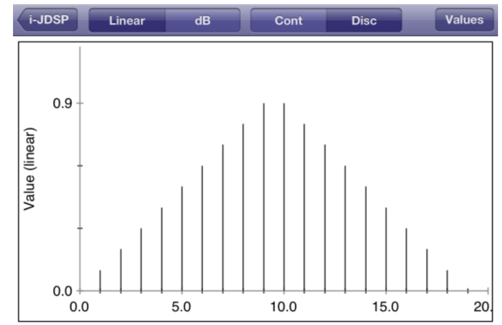
- Convolution Demo

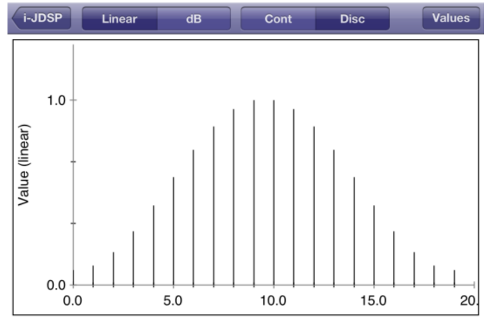
- FIR Filter Design
  - Windowing Method
  - Parks-McClellan Algorithm

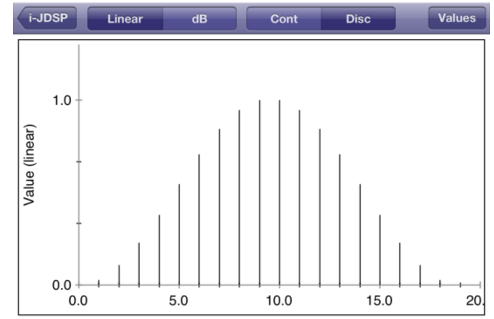


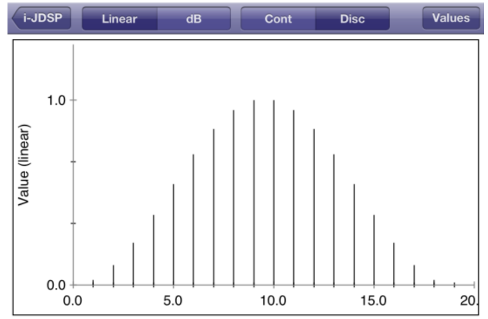
Window Type
Rectangular
Triangular
Hamming
Hanning
Blackmann
Kaiser

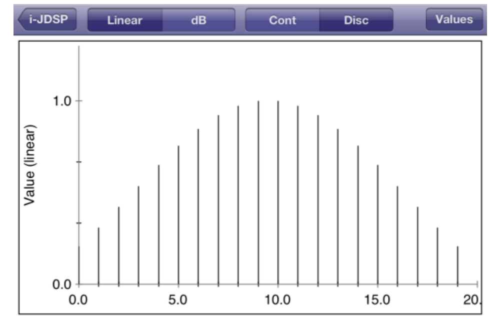










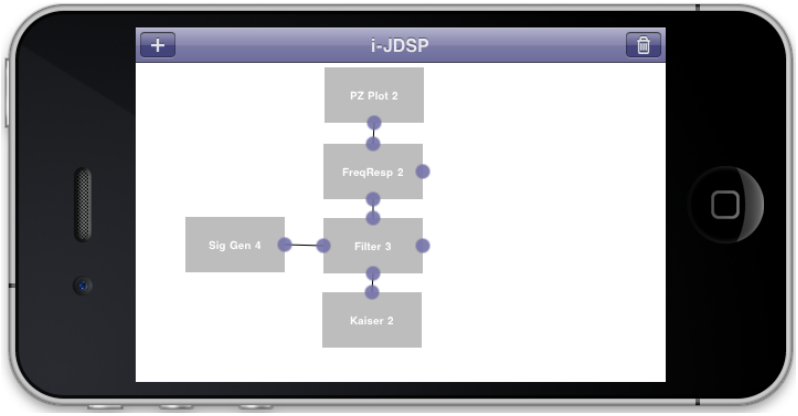


-Example:

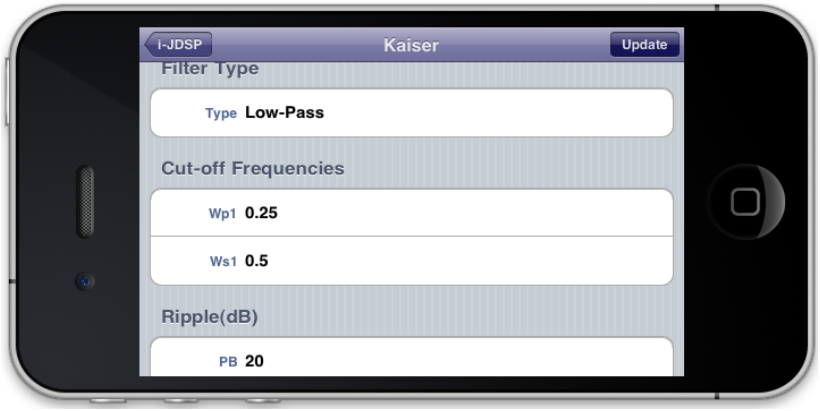
Design a lowpass filter using Kaiser window method with following specifications,

$$0.9 \le \left|H(e^{j\Omega})\right| \le 1.1, \qquad 0 \le \Omega \le 0.25\pi$$

$$\left|H(e^{j\Omega})\right| \le 0.056, \qquad 0.5 \le \Omega \le \pi$$



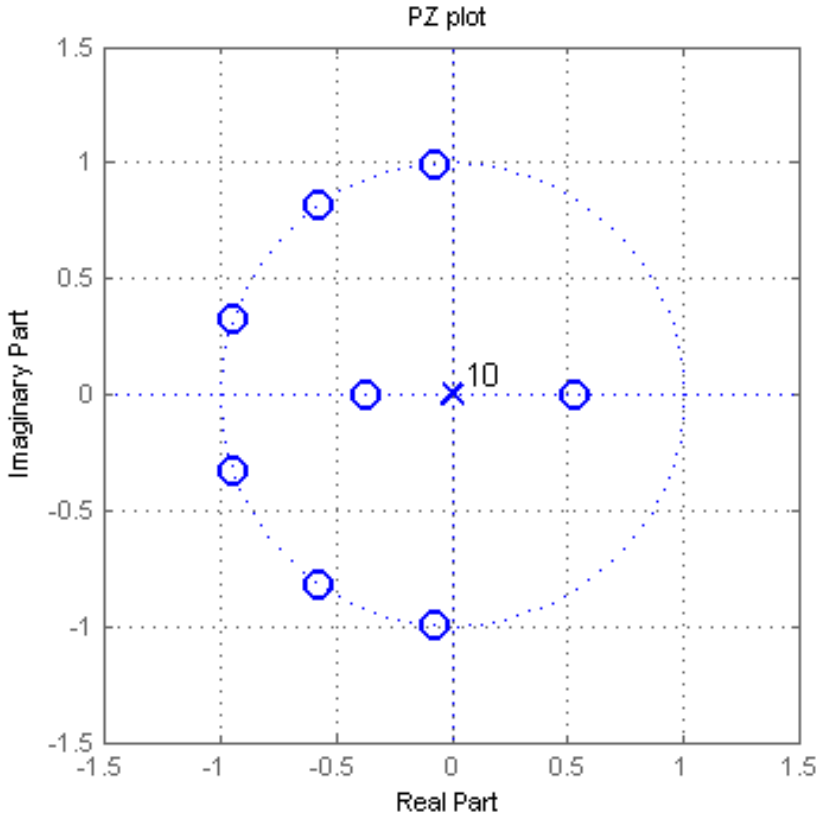
(a)Set up for Kaiser Filter Design



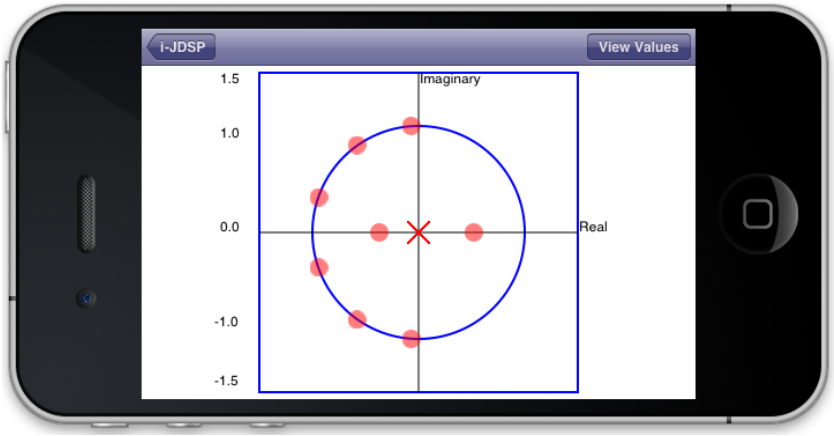
(b)Main Menu of Kaiser FIR Filter Design

-Verified using MATLAB Code

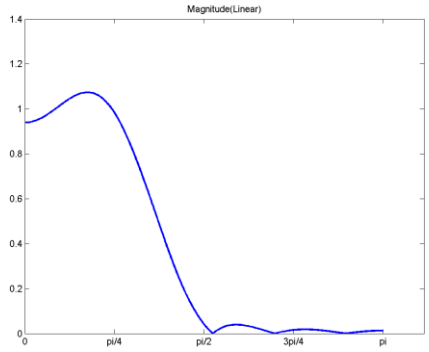
• *PZ plot in MATLAB*



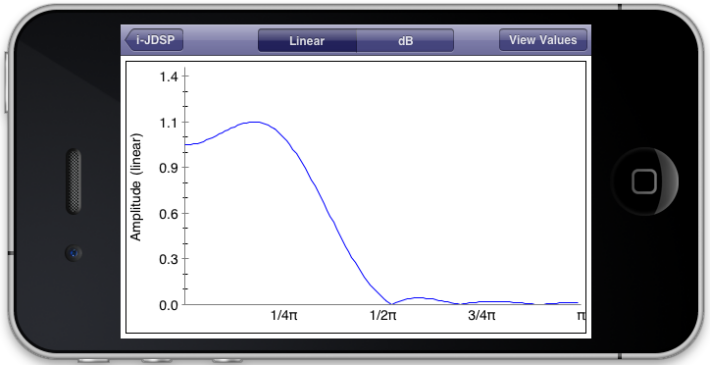
• *PZ plot in iJDSP*



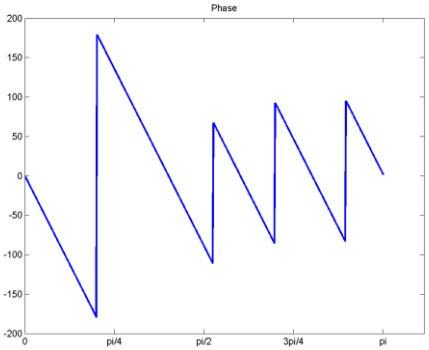
- *Magnitude of Frequency Response in MATLAB*



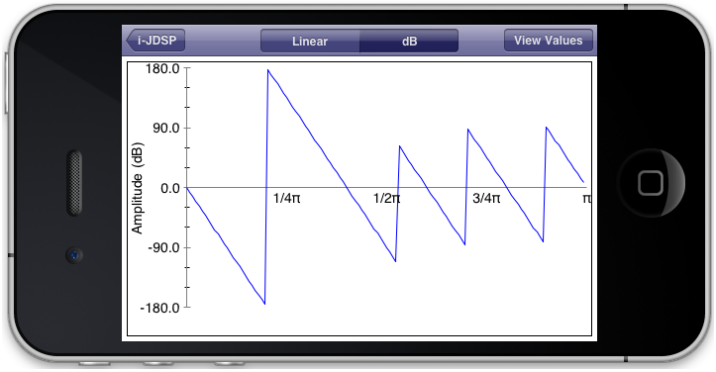
- *Magnitude of Frequency Response in iJDSP*



- *Linear Phase Constraint in MATLAB*

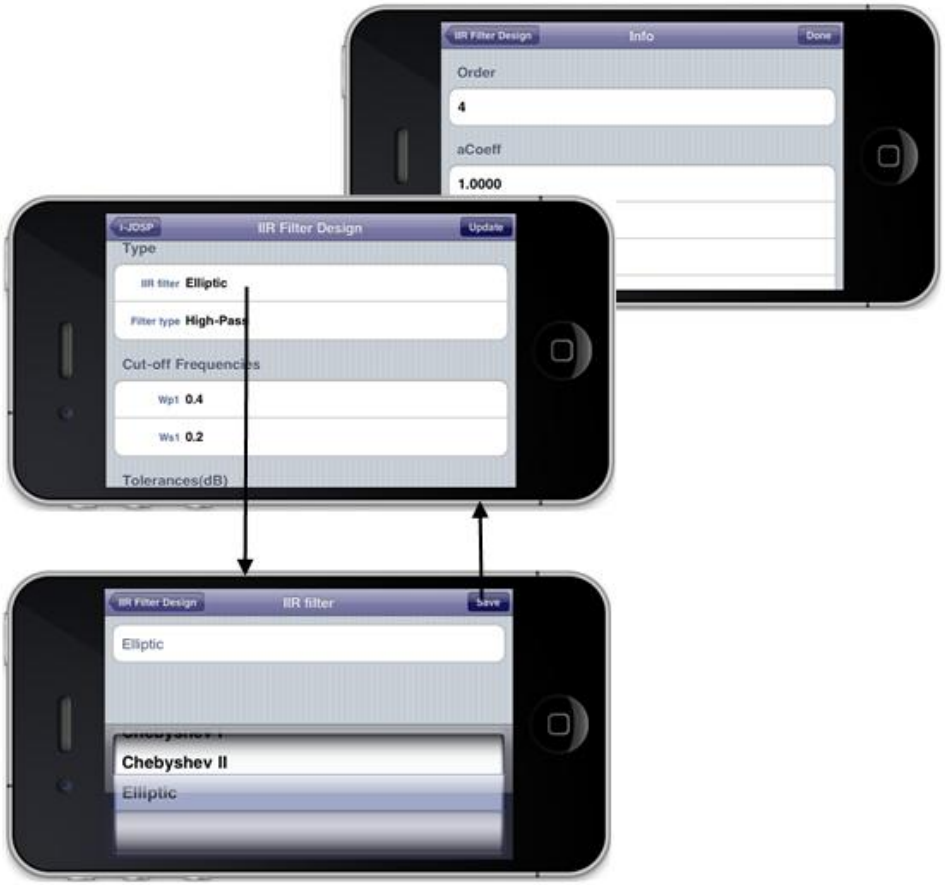


- *Linear Phase Constraint in iJDSP*



- IIR Filter Design

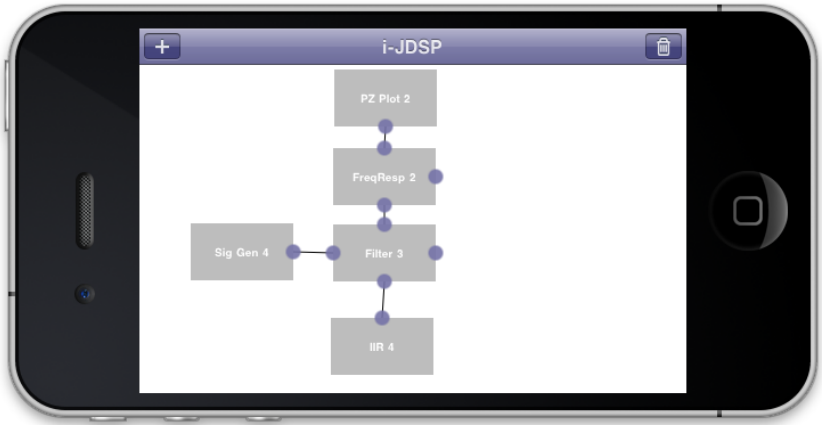
Analog Approximation
Butterworth
Chebyshev I
Chebyshev II
Elliptic



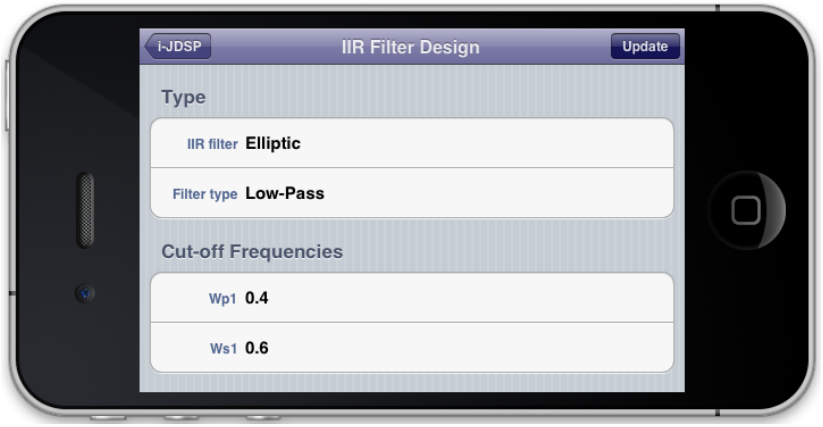
-Example:

Design a lowpass Elliptic IIR filter with following specifications,

- *Passband Cutoff frequency: 0.4π ; Stopband Cutoff frequency: 0.6π*
- *Tolerance in passband: 1dB; Tolerance in stopband: 45dB*



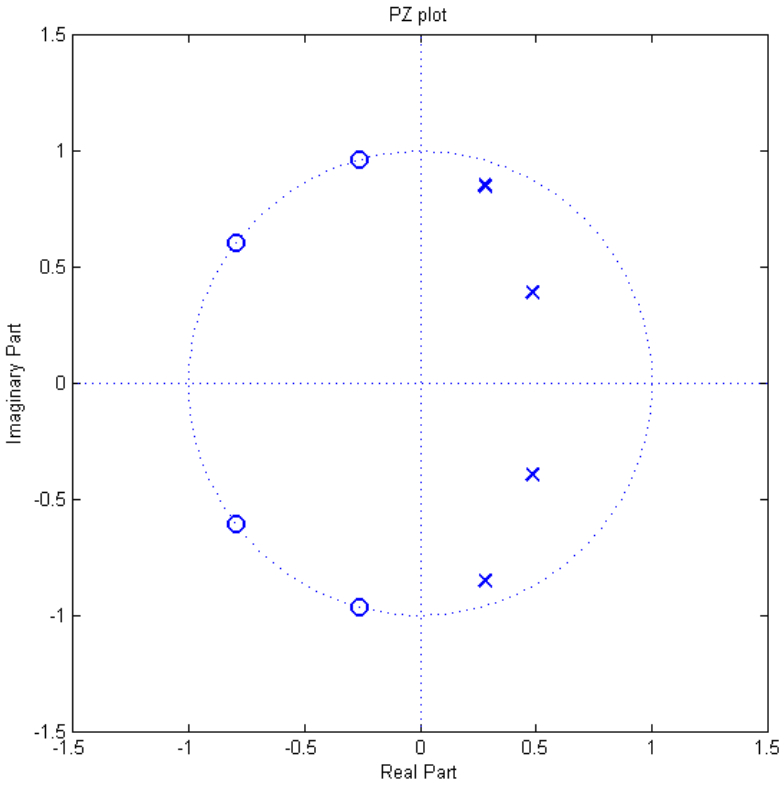
(a)Set up for IIR Filter Design



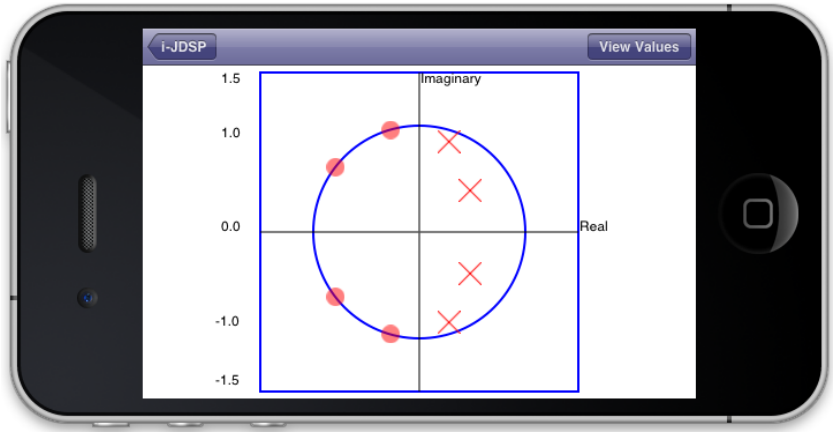
(b)Main Menu of IIR Filter Design

-Verified using MATLAB Code

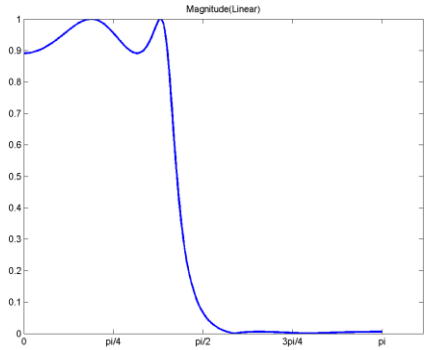
- *PZ plot in MATLAB*



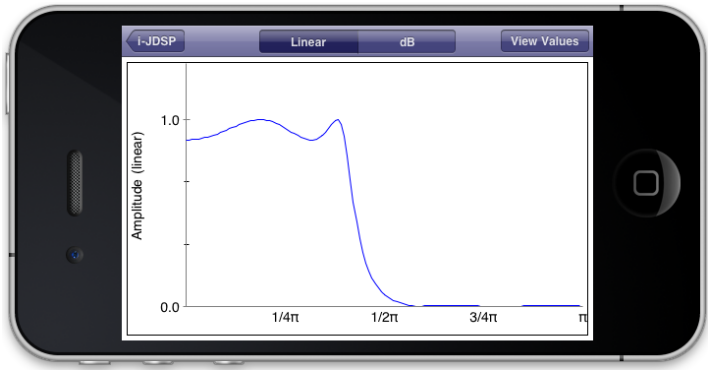
- *PZ plot in iJDSP*



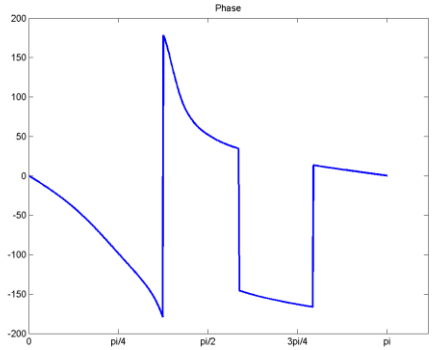
- *Magnitude of Frequency Response in MATLAB*



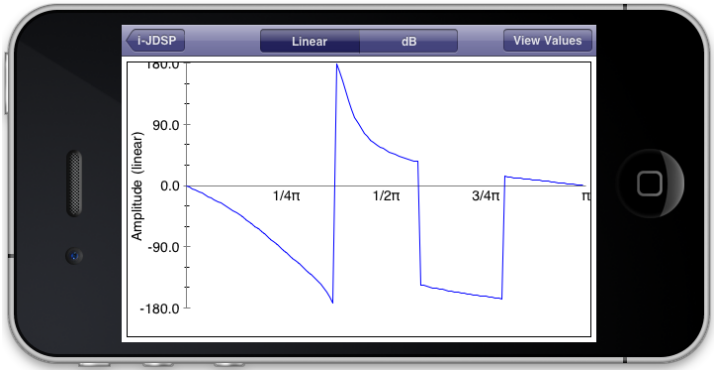
- *Magnitude of Frequency Response in iJDSP*



- *Nonlinear Phase in MATLAB*



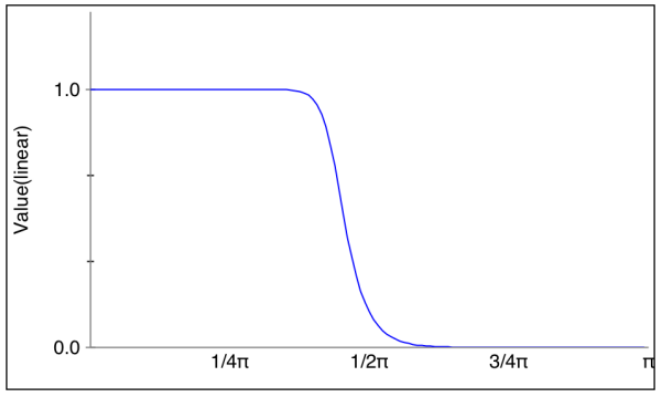
- *Nonlinear Phase in iJDSP*



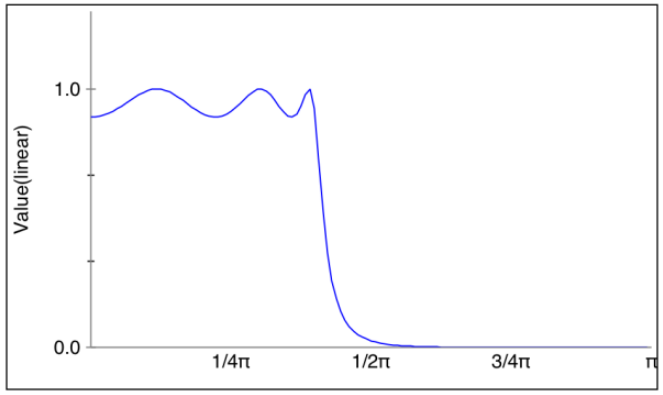
- Comparison between four types IIR

Use same filter parameters

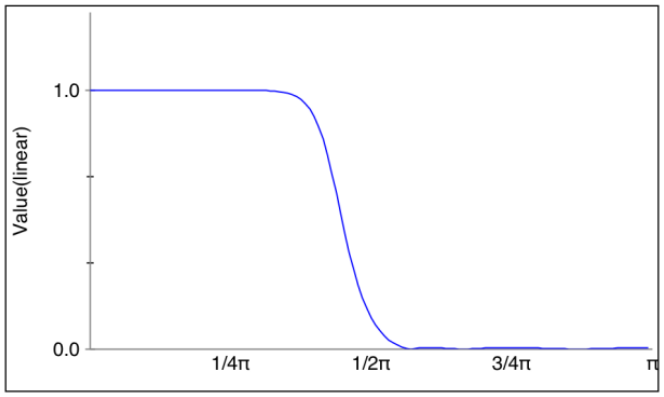
•*Butterworth(Order = 10)*



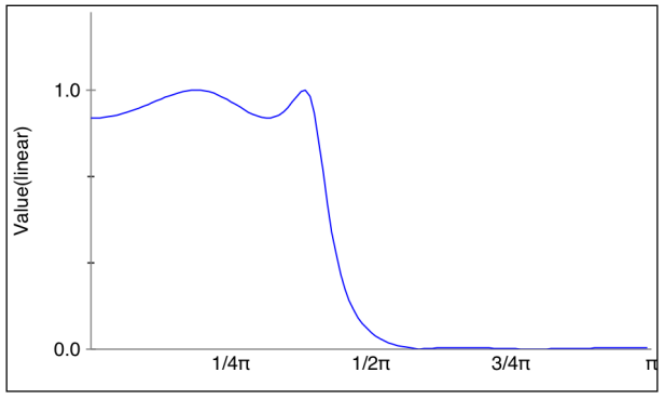
•*Chebyshev I(Order = 6)*

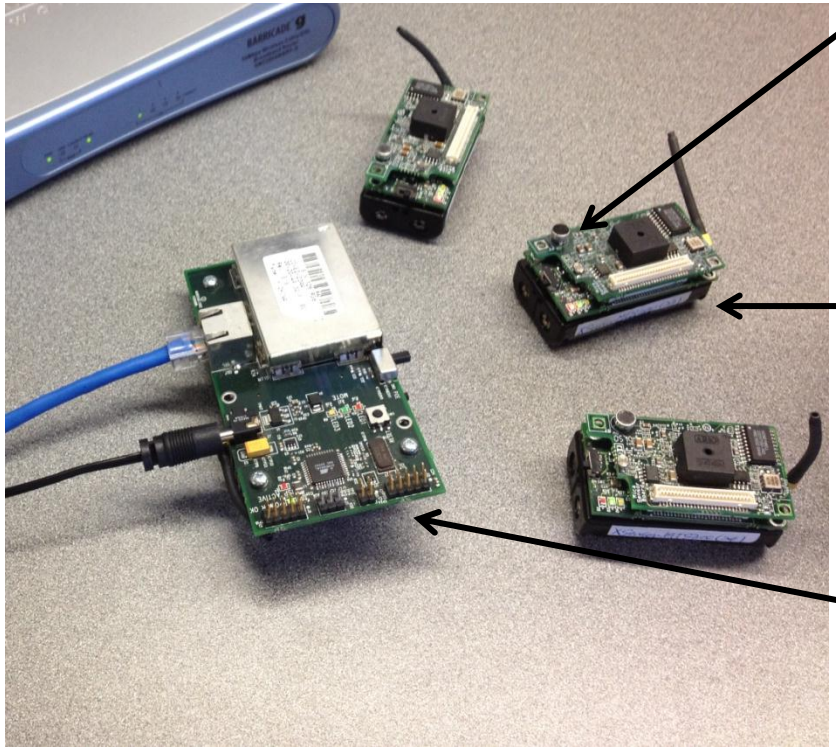


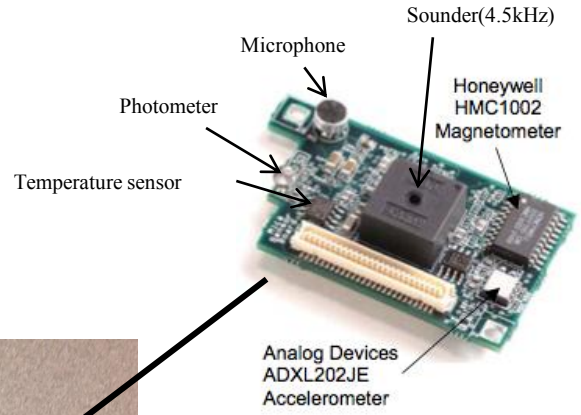
•*Chebyshev II(Order = 6)*



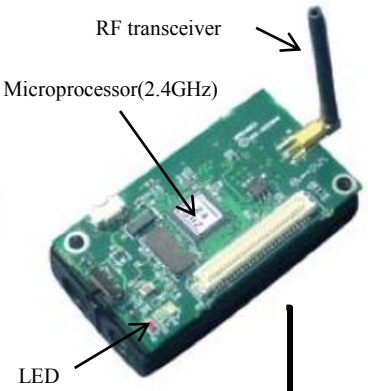
•*Elliptic(Order = 4)*





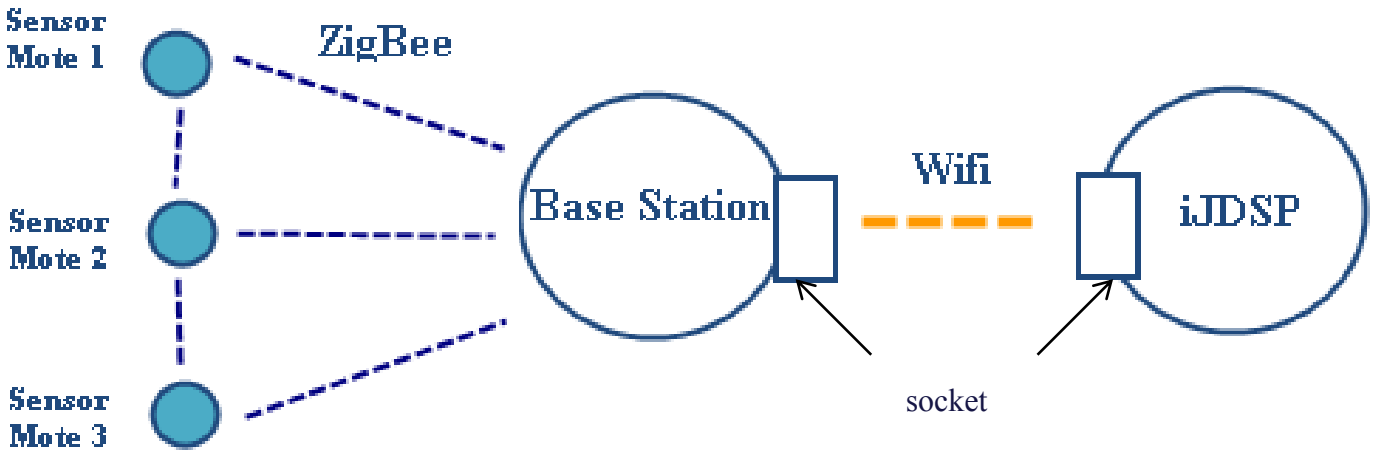


MTS310CA Sensor Board



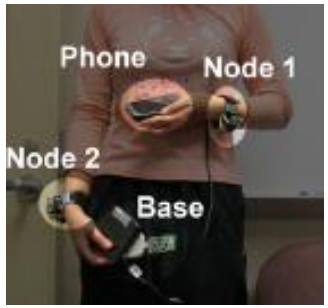
MICAz Mote

MIB600 Ethernet Interface Board

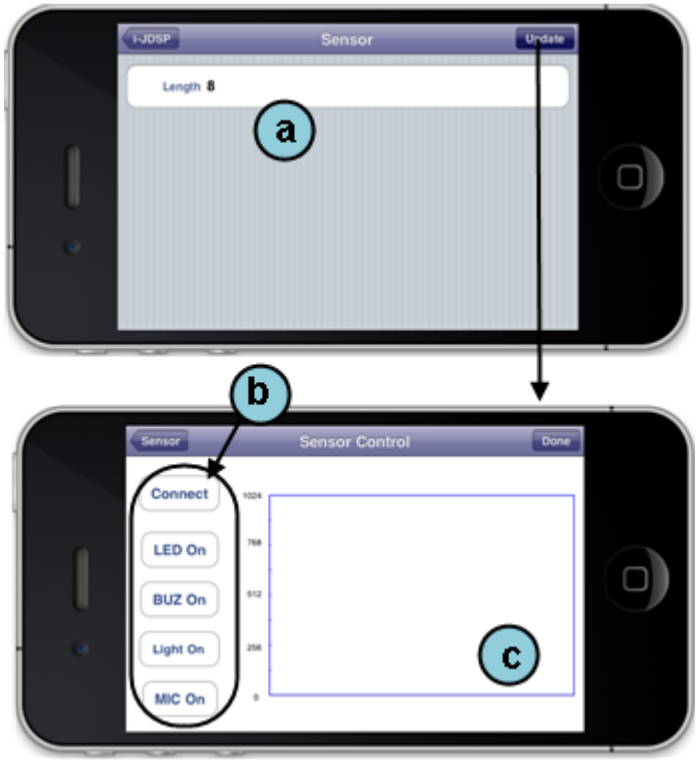


Targeted Applications:

- Environmental Monitoring[2]
- Security[3]
- Gesture Recognition[4]
- Tracking[5]
- Localization



- New graphical user interface for WSN

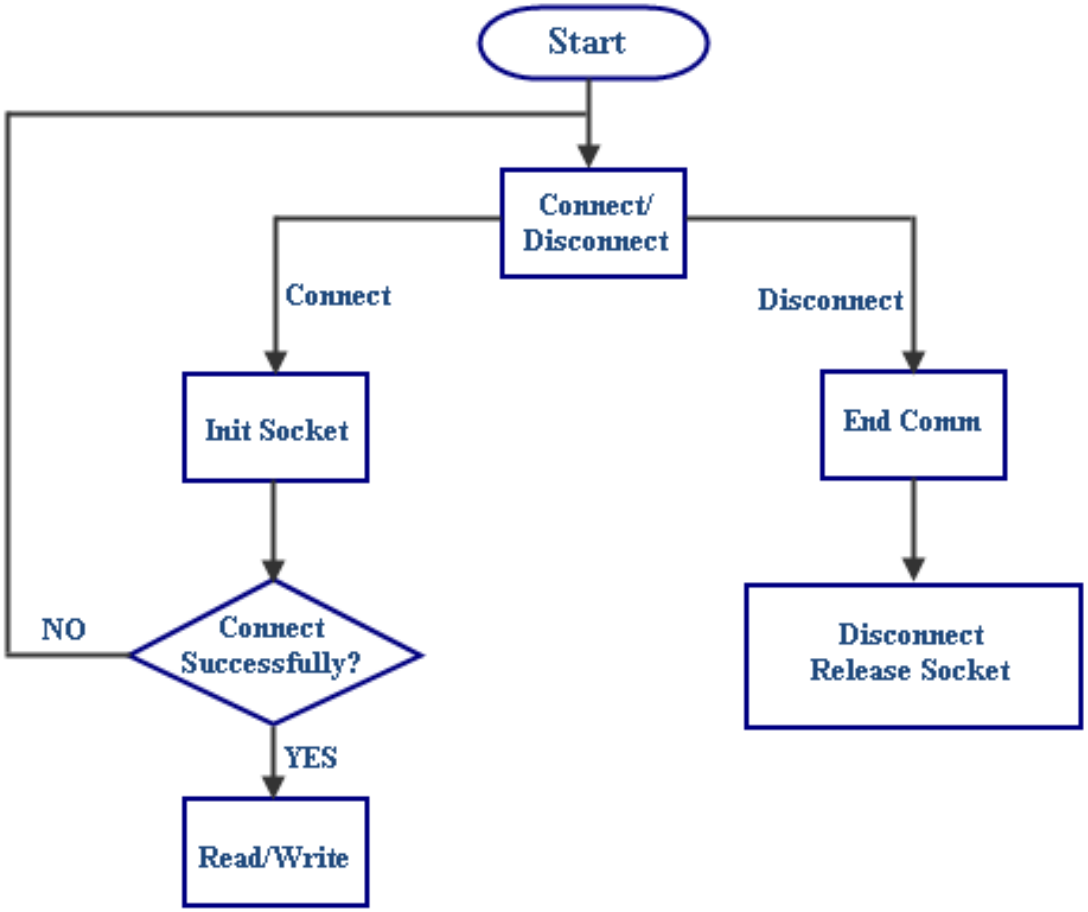


a Buffering panel

b Control panel

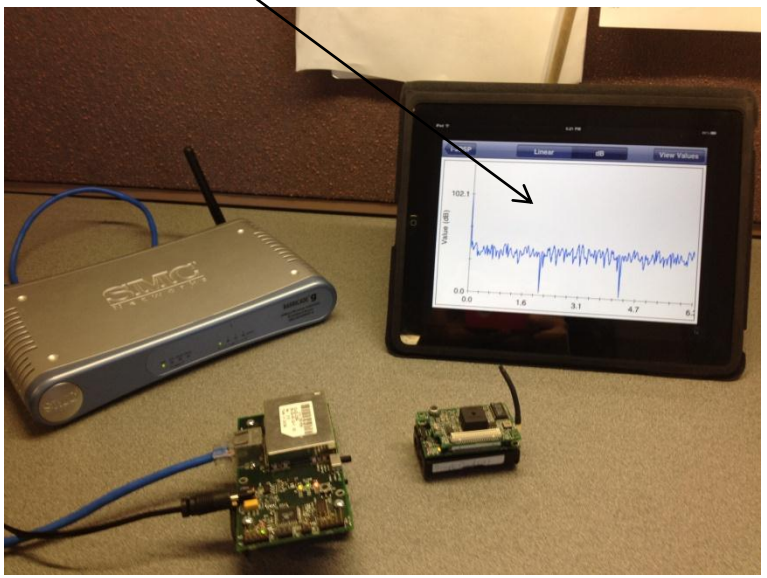
c Real-time plot area

- Workflow Chart



- DSP Functions with Sensor Data

Frame-by-frame processing with DSP functions in iJDSP



Assessments

- 34 students including 19 undergraduates from EEE407 class and 15 graduates from SenSIP Center participated.
- Over 75% students would recommend this application to their friends.

The pedagogy adopted in iJDSP workshop includes:

(a) Lecture on the pertinent signal processing concepts
(b) A pre-lab on the concepts involved in the laboratory exercise
(c) A simulation exercise using iJDSP
(d) A Post-lab to test student understanding of the concepts
(e) Assessments involve students in the evaluation of the exercises and the software.

Statistics Based on the Assessment from Undergraduates in EEE407 .
Total Number of Students = 19.

Evaluation Questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
• Performing this exercise, you learned the concept of cascaded and parallel configuration of systems.	21.1%	31.6%	31.6%	15.7%	
• Do you now understand more clearly the relationship of the frequency response with the poles and zeros?	89.5%	10.5%			
• The contents of this exercise helped you understand the concepts of FIR and IIR filter design.	36.9%	52.6%	10.5%		
• After the lab, you know which of the IIR filters have ripple characteristic in both stopband and passband.	47.4%	31.6%	15.8%		5.2%

- ✓ **Concept of pole and zero was improved by using iJDSP .**
- ✓ **89.5% students felt iJDSP helped them to understand FIR and IIR filter design.**

Statistics Based on the Assessment from Undergraduates from EEE407 .
Total Number of Students = 19.

Evaluation Questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
• How long did it take to get used to the simulation environment on iJDSP?	*(t< 5min)* *73.7%*	*(5min<t<10min)* *21.1%*	*(10min<t<20min)* *5.2%*	*(20min<t<30min)*	*(t>30min)*
• Does the graphic user interface of iJDSP appeal to you?	26.4%	63.2%	5.2%	5.2%	
• It is easy to set up the lab simulations.	68.4%	31.6%			
• You feel comfortable performing simulations with the size of the screen.	31.6%	36.8%	10.5%	21.1%	
• Did you feel comfortable with the processing speed of the device for all the exercises?	73.7%	26.3%			

- ✓ **95% students got used to the environment within 10 min.**
- ✓ **89.6% students liked user interface of iJDSP.**

Statistics Based on the Assessment from Graduates from SenSIP Center.
Total Number of Students = 15.

Evaluation Questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
• Performing this exercise, you learned the concept of cascaded and parallel configuration of systems.	53.4%	33.3%	13.3%		
• Do you now understand more clearly the relationship of the frequency response with the poles and zeros?	100%				
• The contents of this exercise helped you understand the concepts of FIR and IIR filter design.	40.0%	46.7%	13.3%		
• After the lab, you know which of the IIR filters have ripple characteristic in both stopband and passband.	46.7%	46.7%	6.6%		
• The contents of this exercise helped you understand the introductory spectral analysis concepts of the Fast Fourier Transform.	46.7%	40.0%	13.3%		

- ✓ **Concept of pole and zero was improved by using iJDSP .**
- ✓ **93.4% students felt iJDSP helped them to understand concept of filter design.**
- ✓ **86.7% students understood FFT better after exercises.**

Statistics Based on the Assessment from Graduates from SenSIP Center.
Total Number of Students = 15.

Evaluation Questions	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
• How long did it take to get used to the simulation environment on iJDSP?	*(t< 5min)* *60.0%*	*(5min<t<10min)* *20.0%*	*(10min<t<20min)* *6.7%*	*(20min<t<30min)* *6.7%*	*(t>30min)* *6.7%*
• Does the graphic user interface of iJDSP appeal to you?	40.0%	53.3%	6.7%		
• It is easy to set up the lab simulations.	53.3%	46.7%			
• You feel comfortable performing simulations with the size of the screen.	40.0%	40.0%	13.3%	6.7%	
• Did you feel comfortable with the processing speed of the device for all the exercises?	80.0%	20.0%			

- ✓ **80.0% graduates get used to iJDSP within 10min.**
- ✓ **93.3% students felt GUI of iJDSP appeal to them.**
- ✓ **Users liked larger screen size**
- ✓ **iJDSP users preferred to perform simulation on iPad.**

Publications

[1] S. Hu, "Interactive DSP mobile laboratories on iPhone/ iPad", Journal paper in preparation

[2] J. Liu, S. Hu, J. Thiagarajan, X. Zhang, S. Ranganath, M. Banavar, A. Spanias. " Interactive DSP laboratories on mobile phones and tablets." *ICASSP*, Kyoto, Japan, March 2012.

[3] S. Hu, J. Liu, A. Spanias, J. Thiagarajan, K. Ramamurthy, X. Zhang, M. Banavar, S. Ranganath, "Mobile DSP simulation app for design, testing, and education", *ESPA*, Las Vegas, Jan. 2012.

[4] J. Liu, J. Thiagarajan, A. Spanias, K. Ramamurthy, S. Hu, M. Banavar. "iPhone/iPad based interactive laboratory for signal processing in mobile devices". *ASEE*, Vancouver, BC, June 2011.

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[1] Dave Mark and Jeff LaMarche, *Beginning iPhone Development: Exploring the iPhone SDK. Apress, 2008.*

[2] G.W. Allen, K. Lorincz, and M.Welsh, "Deploying a wireless sensor network on an active volcano." IEEE Internet Computing, March/April 2006.

[3] H. Kwon, V. Berisha, and A. Spanias, "Real-time sensing and acoustic scene characterization for security application." IEEE, 2008.

[4] J. Chen, K. Kwong, D. Change, J. Luk, and R. Bajcsy, "Wearable sensors for reliable fall detection." IEEE-EMBS'05, 2005, pp. 3551–3554.

[5] A. Swain, "Characterization of acoustic sensor motes for target tracking in wireless sensor networks," Master's thesis, Arizona State University, December 2006.