DSP EXERCISE

Objectives

The objective of this exercise is to provide hands-on experiences with AJDSP, a DSP simulation application built for the Android platform. The exercise problems are directed towards providing a basic understanding of signals and the role of DSP in mobile health monitoring. Signals such as Speech, Video, Accelerometer, Photoplethysmogram (PPG), and Electrocardiogram (ECG) are introduced.

Part 1: Overview of ECG signals

In this part, normal and abnormal ECG signals are visualized using the *Biosignal Generator* block. A brief overview of the various signal characteristics in relation to bio-physical conditions are provided.

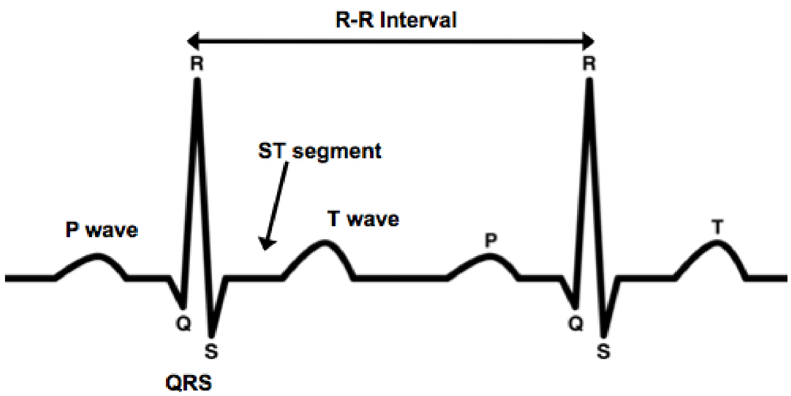

Fig. 1.1 (a)

1. Fig. 1.1 (a) shows a sample ECG recording with its several wave segments annotated.
2. An ECG is a signal obtained by placing electrodes on the surface of the skin to observe the electrical activity of the heart over a period of time.
3. Select the *Biosignal Generator* block from the part list, and choose the 'On-board' option.
4. Set the 'Raw Signal' to **Synthetic ECG.**
5. Carefully observe this artificially simulated ECG record in correspondence with the signal in the above figure and identify the P-wave, the QRS-complex and the T-wave which together comprise an ECG waveform for a single heart beat.
    - **P-wave** corresponds to wave of **depolarization** starting in the **atria.**
    - **QRS-complex** corresponds to electrical excitation of the two **ventricles** and its **depolarization**.

- **T-wave** corresponds to **repolarization of ventricles**, which is the recovery stage of the ventricles restoring it to the rest state.

6. Set the 'Raw Signal' to **Normal Sinus Rhythm**, this corresponds to a normal clinical ECG recording.
7. To navigate through the different frames of the signal, do a swipe action over the plot or use the forward (>>) and backward (<<) frame buttons. Hit the '>' button to automatically scroll through the frames and '||' to pause.
8. Observe the various wave segments discussed above.
9. Set signal to **AFB – Atrial Fibrillation** and notice the P-wave segment.
10. Observe how the QRS-complex and the T-wave follow a regular pattern, while the P-wave is either lost or multiple waves occur.
11. These will in-turn cause a loss in the **Atrioventricular (AV)** conduction ratio, which is the ratio of number of P-waves to the QRS-complexes. A normal ECG waveform will have AV ratio as 1:1
12. Set signal to **VT – Ventricular Tachycardia** and pay close attention to the T-wave from frames 11 through 13 and frames 27 and 28.
13. Observe the deviation of the T-wave segment from its ideal case.

Part 2: Speech Signal Processing

The primary objective of this exercise is to design a **band-stop** filter to remove a noise signal from the input speech signal using the frame-by-frame processing feature of AJDSP.

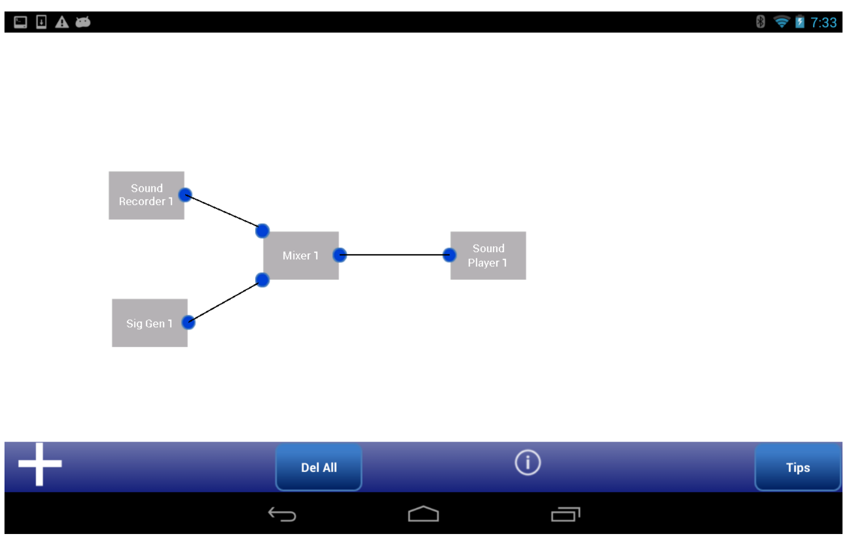

Fig. 2.1

1. Select the *Sound Recorder* block from the part list and tap the 'Add' button.
2. To add a noise signal choose the *Signal Generator* and set signal type as **Sinusoid** with a pulsewidth of **256 samples**, gain **0.04** and frequency **0.6 π**, and press the 'Add' button.

3. Next, choose the *Adder* block followed by the *Sound Player* block and tap 'Add' to add the two blocks to the workspace.
4. Make connections between them to set up the simulation as shown in figure 2.1.
5. Double tap the *Sound Recorder* block to open a view and press the 'Record' button to record your voice up to 10 seconds using the device microphone.
6. Use the 'Stop' button to stop the recording.
7. Press 'Parse' to transfer the data and 'Update' to confirm the change. Frame Size is set to the default **256 samples**.
8. Now double tap on the *Sound Player* block to listen to the noisy signal. (**Ensure that the device is not set on mute**).

<u>Denoising using Band-stop Filter</u>

1. Delete the connection between the *Adder* and the *Sound Player* block.
2. Select the *Junction, Filter*, *FIR Design*, and *Frequency Response* blocks from the part list and add them to the workspace.
3. Set up another simulation as shown in figure 2.2. using the above added blocks.

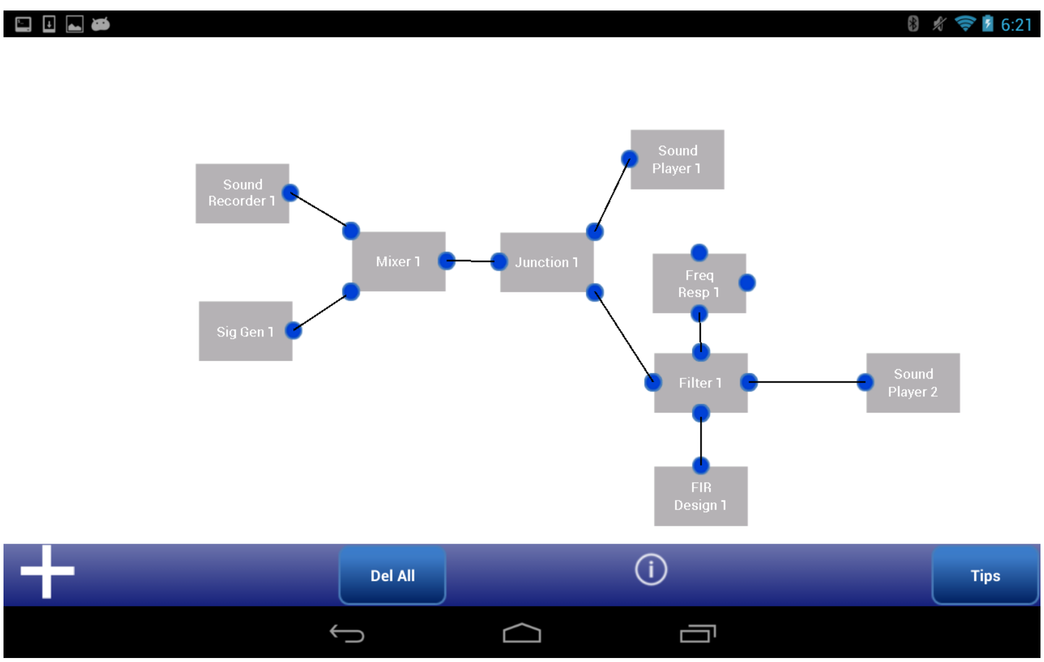

Fig. 2.2

4. Double tap the *FIR Design* block and design a Band-Stop (notch) filter to remove the noisy tone using the following specifications:

Window	Order	Filter-Type	W_1	W_2
Hanning	**32**	**Band-Stop**	**0.5π**	**0.7π**

5. Press 'Add' and 'Done' in the *FIR Design* menu.
6. To process the signal using the filter, double tap the *Sound Recorder* block and press the 'Parse' button followed by the 'Update' button to go back to the workspace.
7. Double tap the *Frequency Response* block and select 'Magnitude' to observe the notch at the frequency of the noisy tone.
8. Double tap the player block and listen to the filtered signal.

Fast Fourier Transform

1. To observe the signals in the frequency domain, we need to compute the Fourier Transform of the signal.
2. To do so, delete both the *Sound Player* blocks and replace them with an *FFT* and a *Plot* block as shown in figure 2.3.
3. Double tap *Plot 1* block and select the 'Magnitude' option to observe the FFT of the noise sinusoid. Observe the amplitude of this FFT peak.
4. Similarly, double tap *Plot 2* block and select 'Magnitude' and observe the amplitude of the sinusoid's FFT peak.

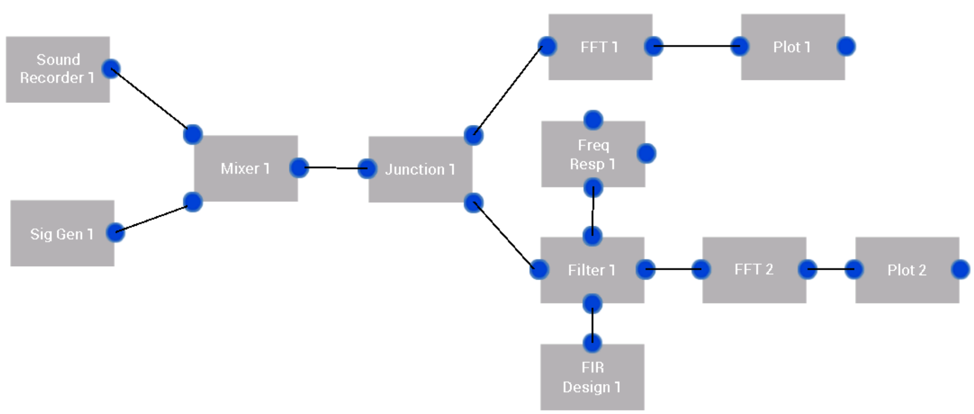

Fig. 2.3

Do the amplitudes of the FFT peaks change after the de-noising operation? (Y/N)_________

How does this correspond to what you heard?

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Part 3: Accelerometer and Step Counter

a. Understanding the Accelerometer

1. Choose the *Accelerometer* block from the list, and tap the ‘on-board’ option.
2. Hold the mobile device with both hands letting it rest with its screen facing the ceiling.
3. Hit the ‘start’ button and observe the streaming accelerometer signal.
4. Now move the device horizontally along the plane with your hands performing a **left-right** movement. Be careful to keep the device as still as you can in the oriented plane.

Axis	**Movement of the Hand**
X-axis	
Y-axis	
Z-axis	

5. Make a note of which of the three axes signals shows a greater change in its acceleration.
6. Repeat the procedure, now by moving the mobile device **up-down** and observe the signals.
7. Now move the device **forward-back** and again, observe the signals.
8. Use the table above to note down which of the axis corresponds to which of the movements.
9. This should give you an idea of the X, Y, and Z-axis of the mobile device.

b. Data Acquisition and Step Counting

1. Place the mobile device inside your trouser pocket or hold it at the right-side of your waist.
2. You must record a walking movement. To do so, tap the ‘start’ button and take steps of any number between 5 and 10. Tap the ‘stop’ button once you are done walking.
3. Make a note of the number of steps you took, this will be the ground truth data.
4. Make a note of the step count reading on the device.
    - Steps taken (ground truth): _________
    - Device reading: _________

5. Tap the 'save' button; enter the initials of your name followed by the movement. For example, 'DRWalk', and then tap 'OK'. The data is now saved!
    - File name provided: _________
6. Repeat the experiment above by walking a different number of steps between 5 and 10, this time with a slight limp in the gait.
7. Make a note of the steps and save the data with a file name similar to the previous case but, with the word LIMP followed by the initials of your name. (Ex: 'DRLimp')
    - Steps taken (ground truth): _________
    - Device reading: _________
    - File name provided: _________
8. Now scroll through the waveforms by performing a swipe action on the plot and observe the patterns in the signal. View the different signals by selecting different options using the 'Select Signal' pull down menu.
9. Now perform a sit-stand combo in any pace for any number between 3 to 6 times. Make a note of the number of times you performed this action, and save the data. (Ex. 'DRSitStand').
    - Number of sit-stand actions (ground truth): _________
    - File name provided: _________
10. Now record a running movement and save the data accordingly. (Ex. 'DRRun').
    - File name provided: _________

Part 4: Photoplethysmogram (PPG)

Estimation of Heart Rate and Oxygen Saturation (SpO2)

1. Place your **left index finger** on the camera; ensure the camera preview shows a red display.
2. Tap the 'Start' button to record a video with **normal breathing**.
3. Wait until the gauge meter counts down to zero. Then, remove the finger from the lens.
4. Do a swipe action on the gauge to view the signals and estimated parameters.
5. In the table below, make a note of the corresponding readings obtained for each experiment.

6. O Breath Type b	Heart Rate	Oxygen Saturation(SpO2)	Blue DC Value	File Name
s				
e				
r				
v				

Ground Truth from Pulse Oximeter

Breath Type	Heart Rate	Oxygen Saturation	Breathing Rate

Save the data

7. The following is the naming convention to save the files:
    a. Normal Breathing 1 – 'initialsN1'
    b. Fast Breath – 'initialsFB'
    c. Deep Breath – 'initialsDB'
    d. Normal Breathing 2 – 'initialsN2'
8. Now tap the 'Save' button and enter the corresponding file name and hit 'OK'.
9. **Experiment 2 –** Repeat the procedure for the recording, but with **fast breathing** actions.
10. **Experiment 3** – Repeat the procedure for the recording, but with **deep breathing** actions.
11. **Experiment 4 -** Repeat the procedure for the recording, but with **normal breathing** actions, this time pay close attention to how many times you breathe in the 20 seconds and note it down in the ground truth table.
12. Wait for the TA to come and help you record the ground truth using the pulse oximeter for each experiment.
13. Do you observe a relationship between the breathing and the SpO_2 values?