Senior Design | ECE 349

Augmented Audio Reality

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Our Vision

- An immersive 3D Audio Experience integrated with your digital footprint i.e. music, soundscape, games
- The user has absolute control over his/her own (augmented) audio reality, with recording and real-time filtering capabilities
- Uses:

(a) **Mixed Virtual Reality:** Virtual reality designers could use such a design to integrate digital sources such as personal Artificial Intelligences (i.e. Siri) or games in a realistic, non-invasive, binaural manner.

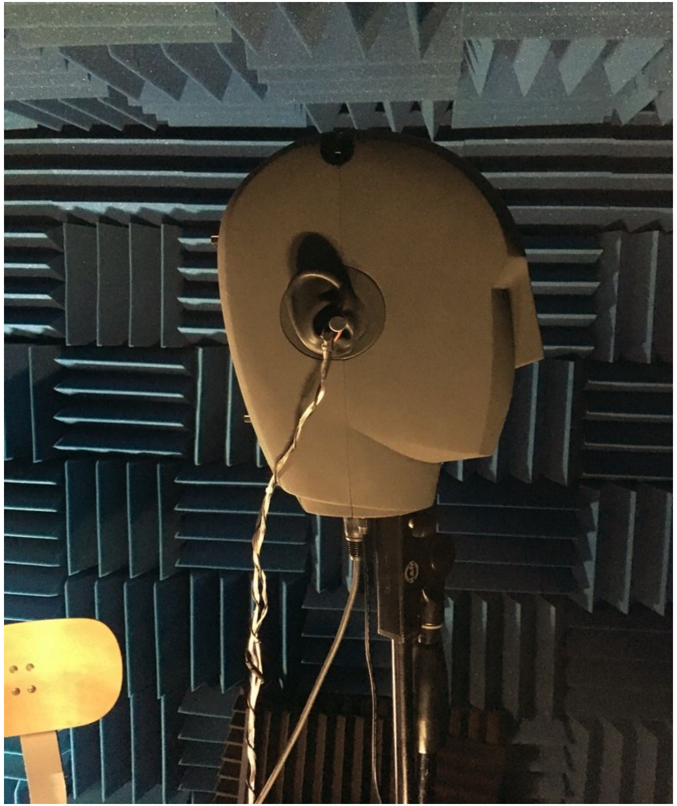
(b) **Social Media:** Social Media users would be able to record their experiences in a hyper-realistic, personalized manner for their audience.

(c) **Hearing Loss:** Patients suffering from hearing loss would have a more socially acceptable and user-friendly design for accurate hearing augmentation.

(d) **Art & Media:** Recreating real-life soundscapes can be an extraordinarily moving art and media tool. This design would allow for such experiences.

Prototype I - Development & Testing

- Experimental set-up:
  - Neumann 9000 Binaural Head directly facing flat-frequency response speakers
  - Pass-through of Mic data to the Headphones via the Bela
- Signal Path:
  - Clio Pocket ➔ output speaker ➔ AMVR design (Mic ➔ Bela ➔ headphone output) ➔ Neumann Head ➔ Clio Pocket

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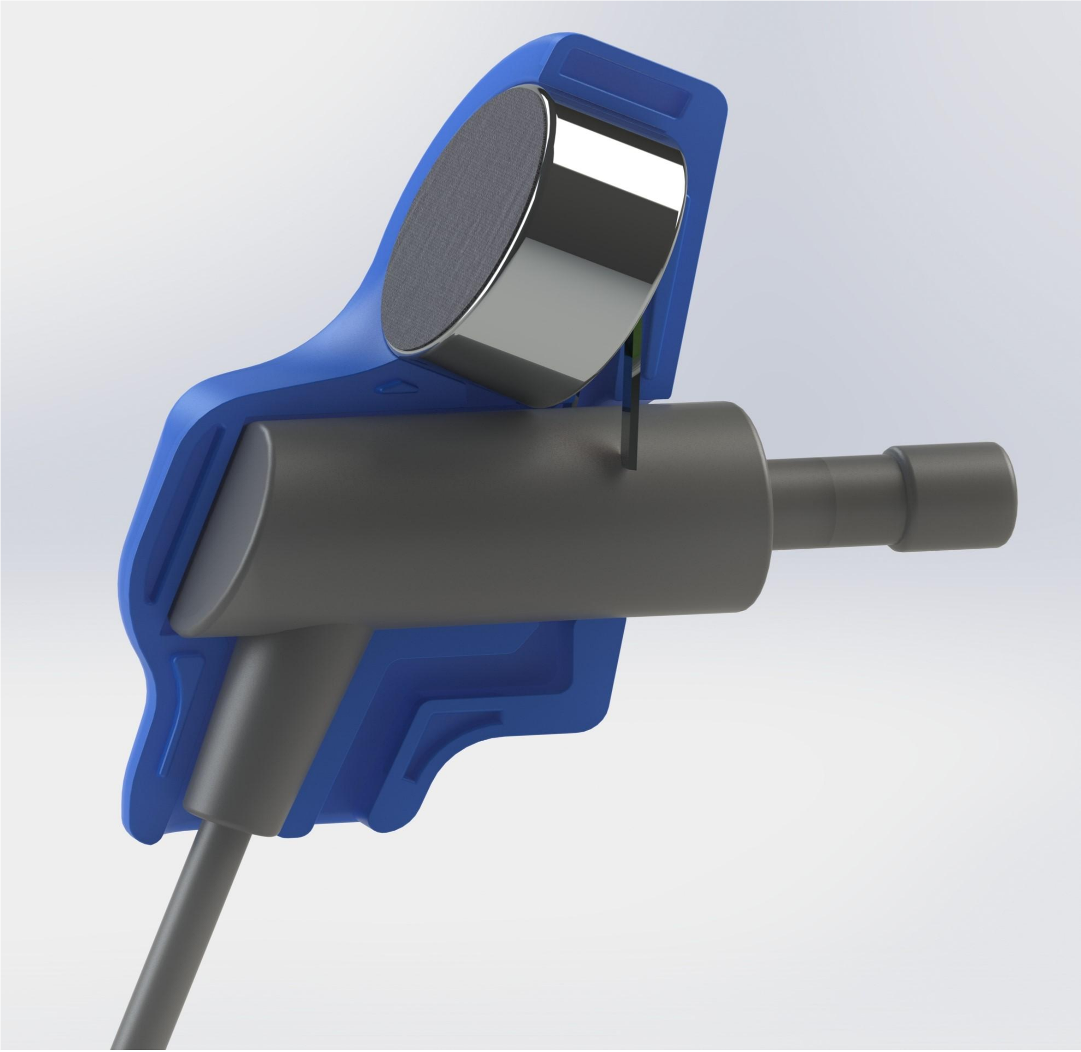
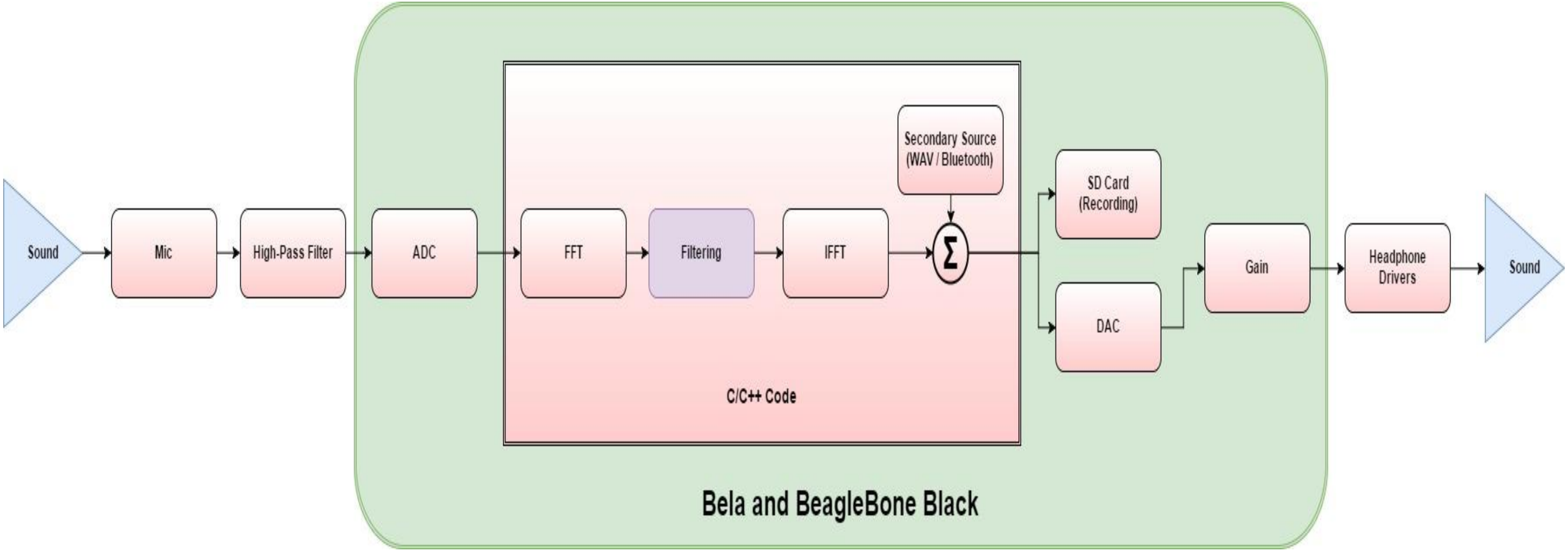


Core Components

- **Bela + Beaglebone Black**
  - Heart of the audio processing for our project
  - Uses dedicated Linux Kernel to process audio tasks
- **Noise Isolating Earbuds**
- **Binaural Microphones**
  - Encased into the earbuds using 3D printed design
- **Proto-board for I/O and Control Peripherals**
  - Amplification circuit for microphones
  - Control functionality circuitry using Switches, Potentiometers and LED’s
- **Portable 5V Power Bank**
- **Box Casing**
  - Integrated all the above components into a user-friendly portable design product

Block Diagram



Features

- **Real Time Filtering**
  - Successfully implemented FFT algorithm for real-time filtering for a ‘richer and complete’ augmented audio experience.
- **Binaural Recording and Playback**
  - Tested and implemented new microphones into design
    - Electret Condenser Mics - superior audio quality
    - 3D Printed new Prototype casing for Mic
  - Save the binaural recordings in real-time onto the SD card of the Beagleboard:
    - Control Recording functionality with Switch and LED
    - Ability to save the recordings with a timestamp as a regular wav audio file

FFT Considerations for Real-Time Filtering

- **Input Sound Pressure → Microphone → ADC (AD7699)→ DSP on BeagleBone (FFT Filtering)→ DAC(AD5668)/Recorder → Earphone Speaker → Sound pressure**
  - ADC (AD7699) Supports 88.2 kHz x 2 Analog In (Latency <10µs, Throughput 500 kSPS)
  - BeagleBone 1GHz processor takes 1 cycle for multiplication and addition
- **FFT (radix-2) Trade-off between Frequency Resolution and Acquisition Time**
  - ***Bin Size (determines frequency resolution) = B_{Res} = (0.5 f_S/0.5 N)***
  - ***Acquisition Time = T_{Acq} = N/f_S = 1/B_{Res}***

Real-Time: We have $f_{SIGNAL} = 20$ kHz and we sample at $f_S = 44.1$ kHz. $N = 512$. Calculate T_{Acq} and B_{Res}:

$$B_{Res} = \frac{0.5 f_S}{N/2} = \frac{22.05 \text{ kHz}}{256} \approx \boxed{90 \text{ Hz/bin}}$$

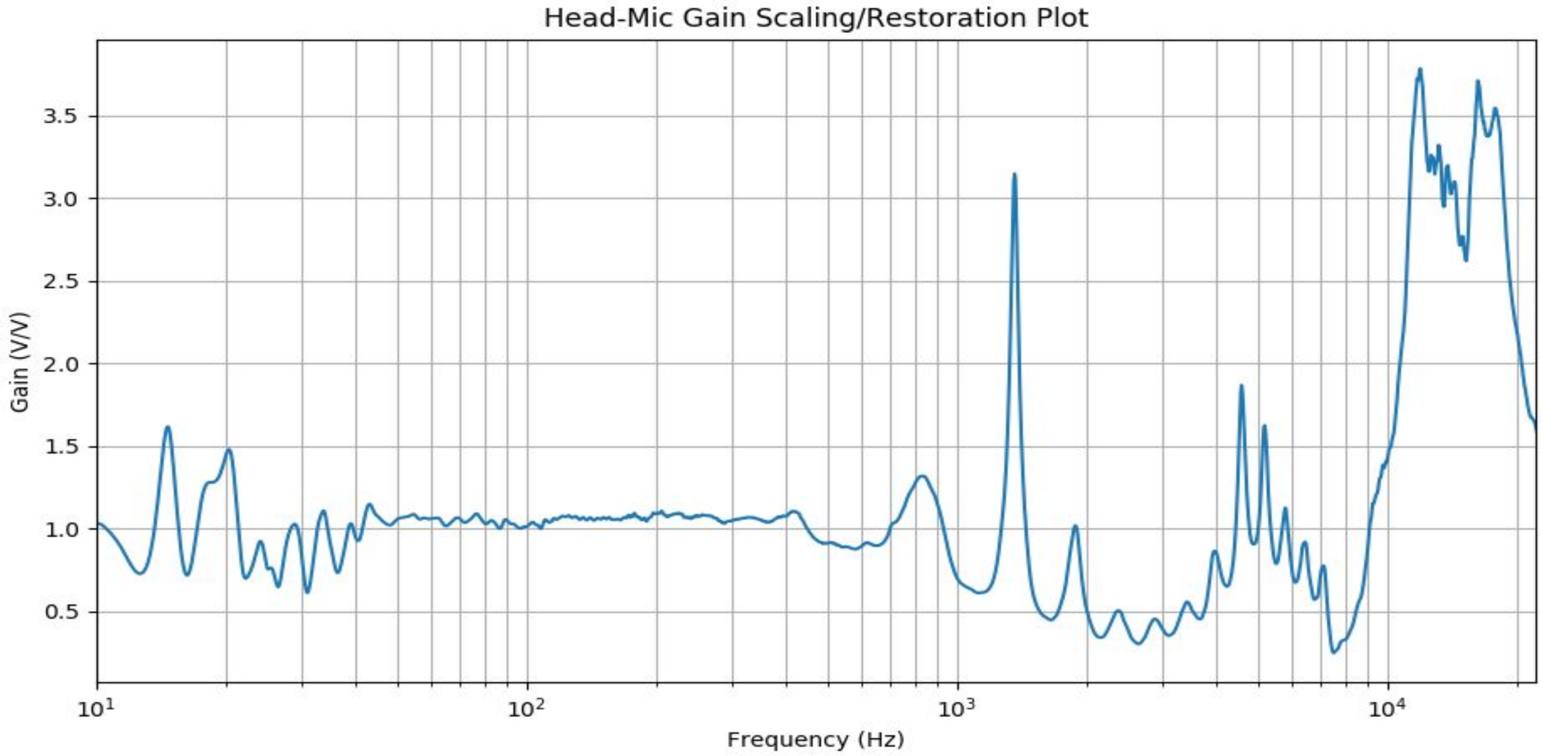
$$T_{Acq} = \frac{N}{f_S} = \frac{512}{44100} \approx \boxed{11.6 \text{ ms}}$$

$$T_{FFT|N=512}(\text{41k Computations @1GHz}) \approx \boxed{10\mu s}$$

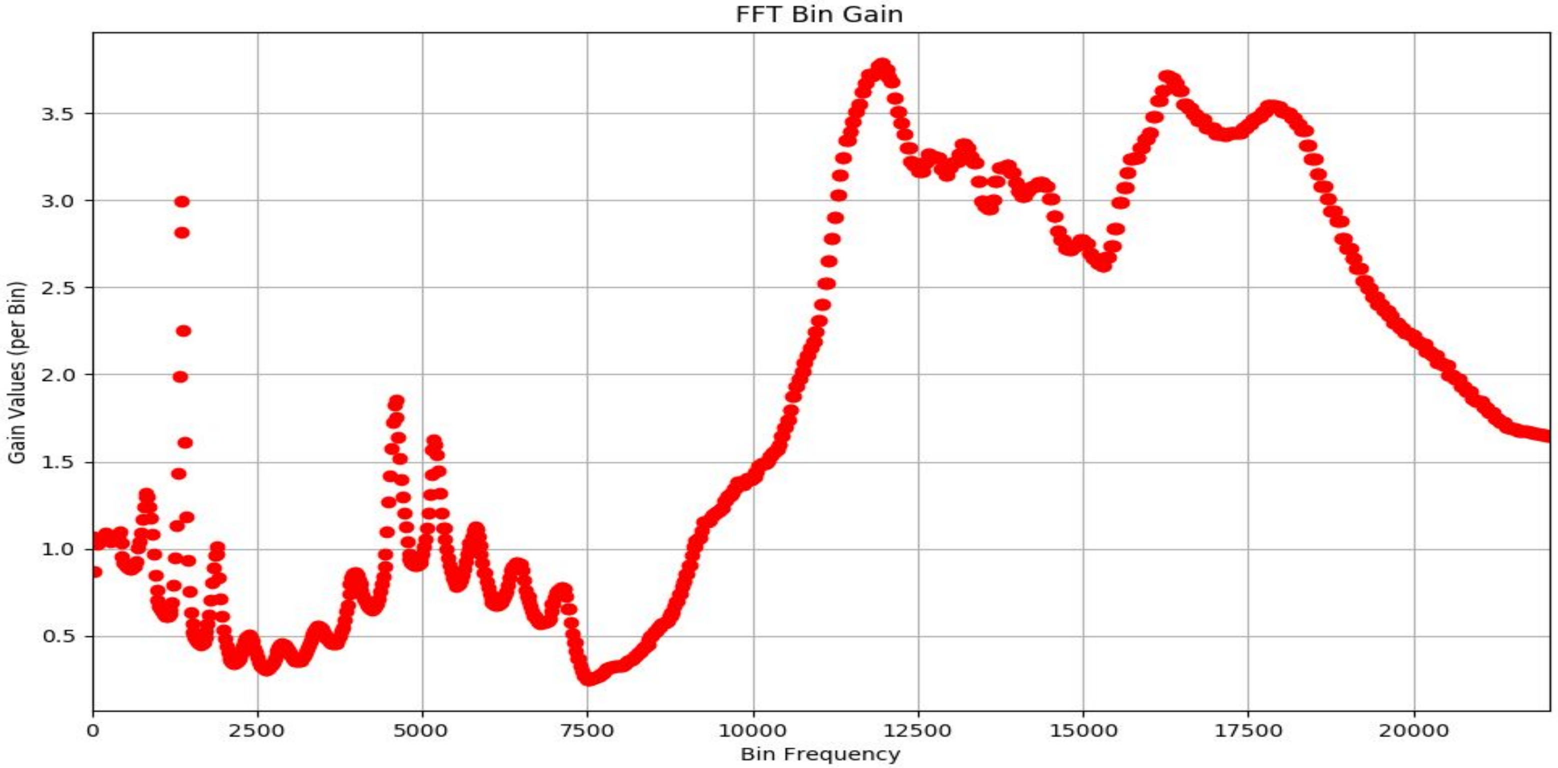
$$T_{I/O} < \boxed{10\mu s}$$

Thus Total Latency = $\boxed{11.6ms + 10\mu s + 10\mu s < 12ms}$

Prototype I - Amplitude Ratio of Binaural Head and AMVR Design Audio Signals



Generated FFT Bin Gain Values for Real-time Filtering



Features

- **Amplification:**
  - On-board amplification for right and left channels
    - Relatively low noise, comparable SNR to off-board amplification
  - Potentiometer Volume control to control amplification on separate channels i.e Binaural Mics, Dual Source and Composite
- **Dual-Source Capability:**
  - Successfully integrated a dual-source in real-time audio
    - Currently implemented using wav file on SD Card
  - Ability to control secondary source gain
- **Casing for portability of design**
  - Integrated all control and processing components into a portable box/case with a 5V Power Bank

I/O and Control

- **I/O and Control Peripherals**
    - Integrated 3 switches to control Board Power, Recording Functionality and Binaural Mic Power
    - Potentiometers to provide dynamic analog control over various audio sources:
        - Overall/Total output gain
        - Secondary Source gain
    - LED's to indicate functionality connected with switches
        - Power - Binaural Mics & Board Power
        - Recording on/off
    - Use 3.5mm Audio Jacks for Audio In/Out

Future Design Considerations

- Further DSP enhancement
  - Z-axis localization Notch filter
  - Otoacoustic Feedback Fix
- Lack of binaural recording support by major players (Facebook, Snapchat, etc.)
- Portability
- Connectability
  - Bluetooth, WIFI Direct
- Cost