SAND2015-9018R

Earzin NMSBA Final Review

Subtitle 28 pt

August 6th, 2015

Pawel Cieslewski, Bill O'rourke and Jason Krein

The acknowledgement statement MUST be used on the title slide of all presentation material distributed outside of Sandia.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Problem Statement

- Earzin produces an listening amplifier product that provides hearing correction for age-related hearing loss.
- Earzin's product is based on Analog filters
  - Large foot print is required for the low-frequencies filter components
  - Changes to filter characteristics requires component changes and is difficult to do

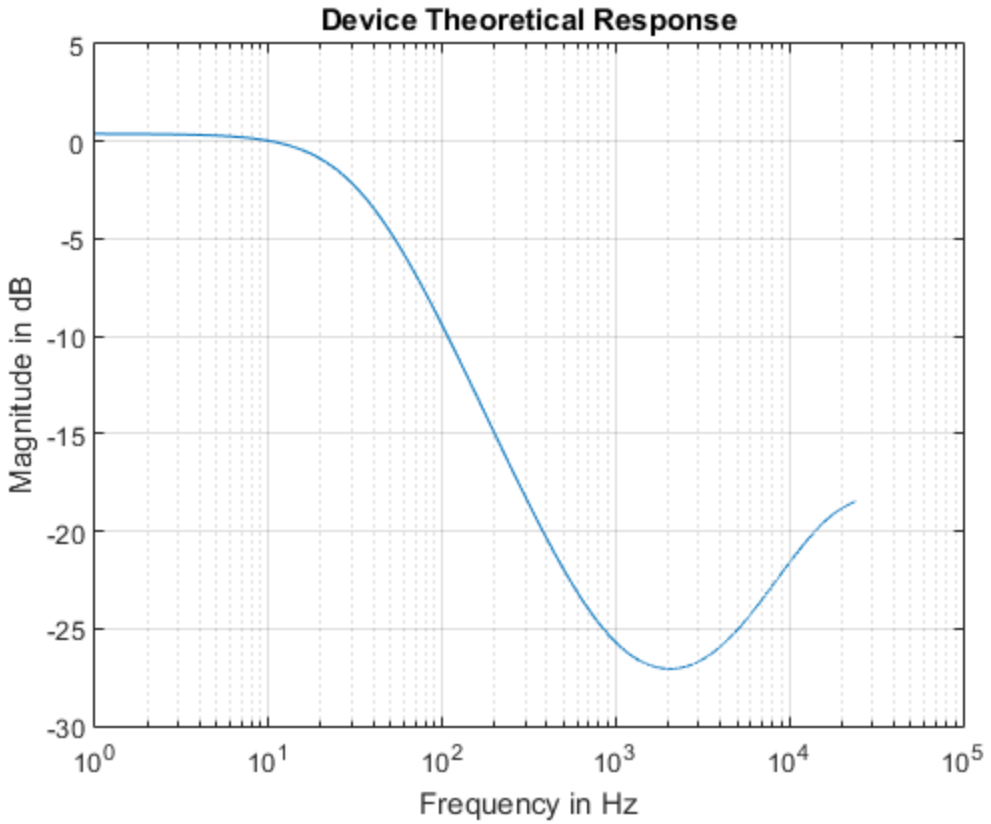
Statement of Work

- **Sandia National Laboratories will provide consulting to the Requestor in the technical area of signal processing including the conversion of analog circuits to digital realization, perform a trade study on available digital signal processors (DSP), and initial code implementation on the chosen DSP platform. Sandia National Laboratories will investigate ways to assist the Requestor in his proprietary design and offer recommendations for improvements.**

Sandia's Goals

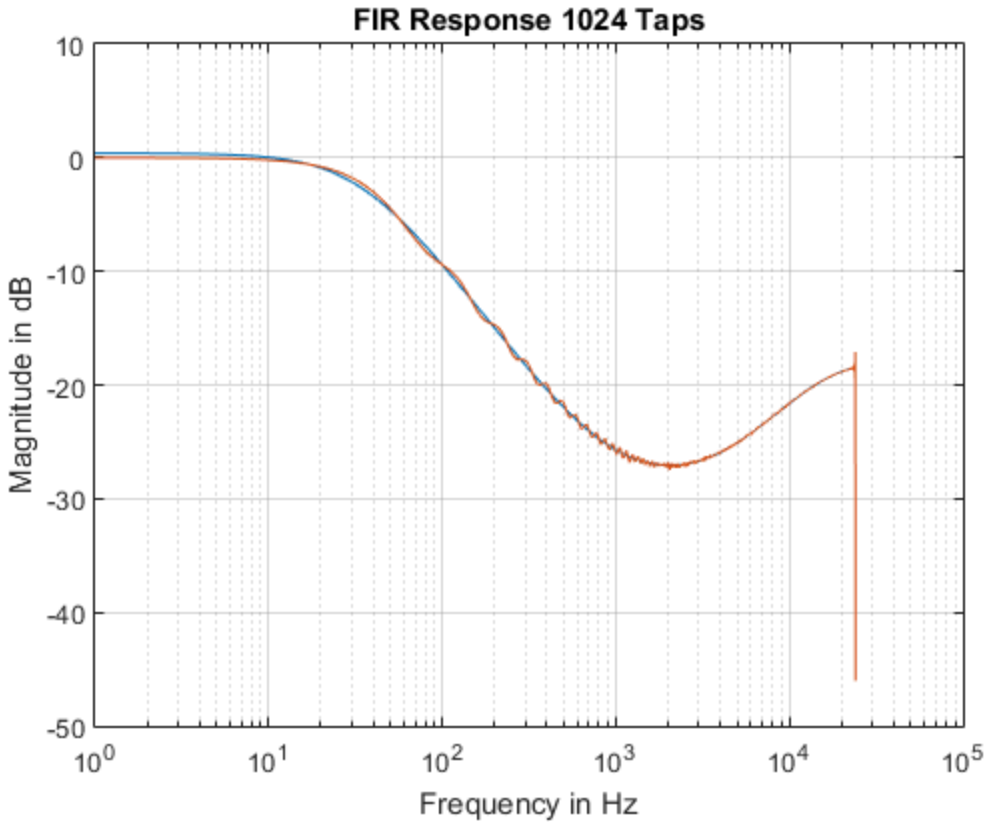
- Characterize Existing Unit's performance
  - Circuit Analysis to generate filter transform
  - ~~Measurement of actual filter performance~~ ← Denied access to device
- Create corresponding Digital Filter
  - Modifiable
  - Finite Impulse response
  - Infinite Impulse response
- Recommend digital design to implement filter
- Provide example code running on development board

Original Device Filter Response



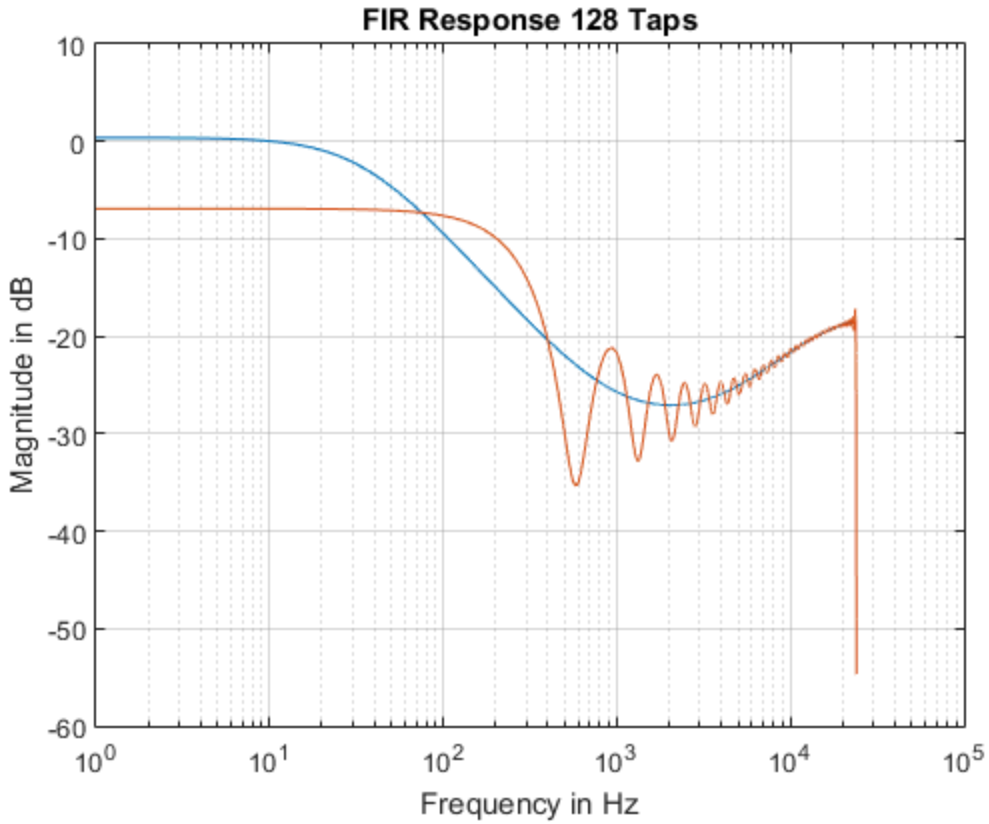
Sandia National Laboratories

Digital Filter Design (FIR 1024 Taps)



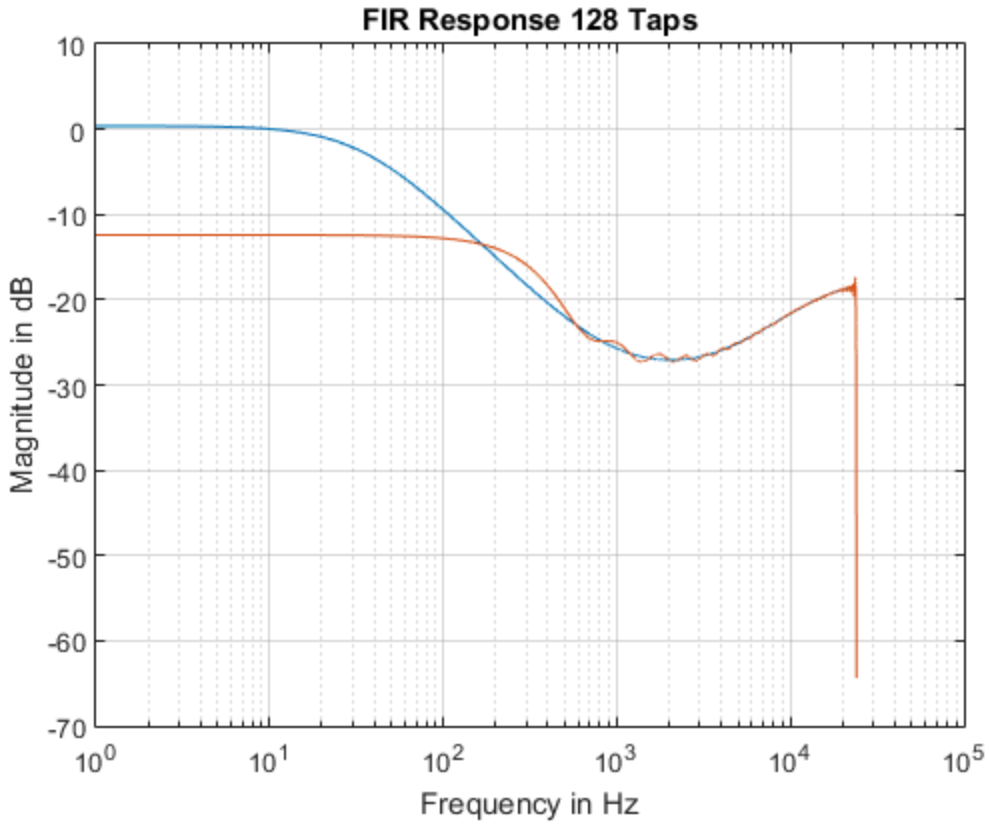
Sandia National Laboratories

Digital Filter Design (FIR 128 Taps)



- Filter generated attempting to match the entirety of the response including the low frequencies.
- Difficulty matching the filter with low amount of taps.

Digital Filter Design (FIR 128 Taps)



- Filter generated attempting to match only from ~120 Hz.
- Removing requirement to match low frequencies significantly improves FIR filter over the rest of the spectrum.

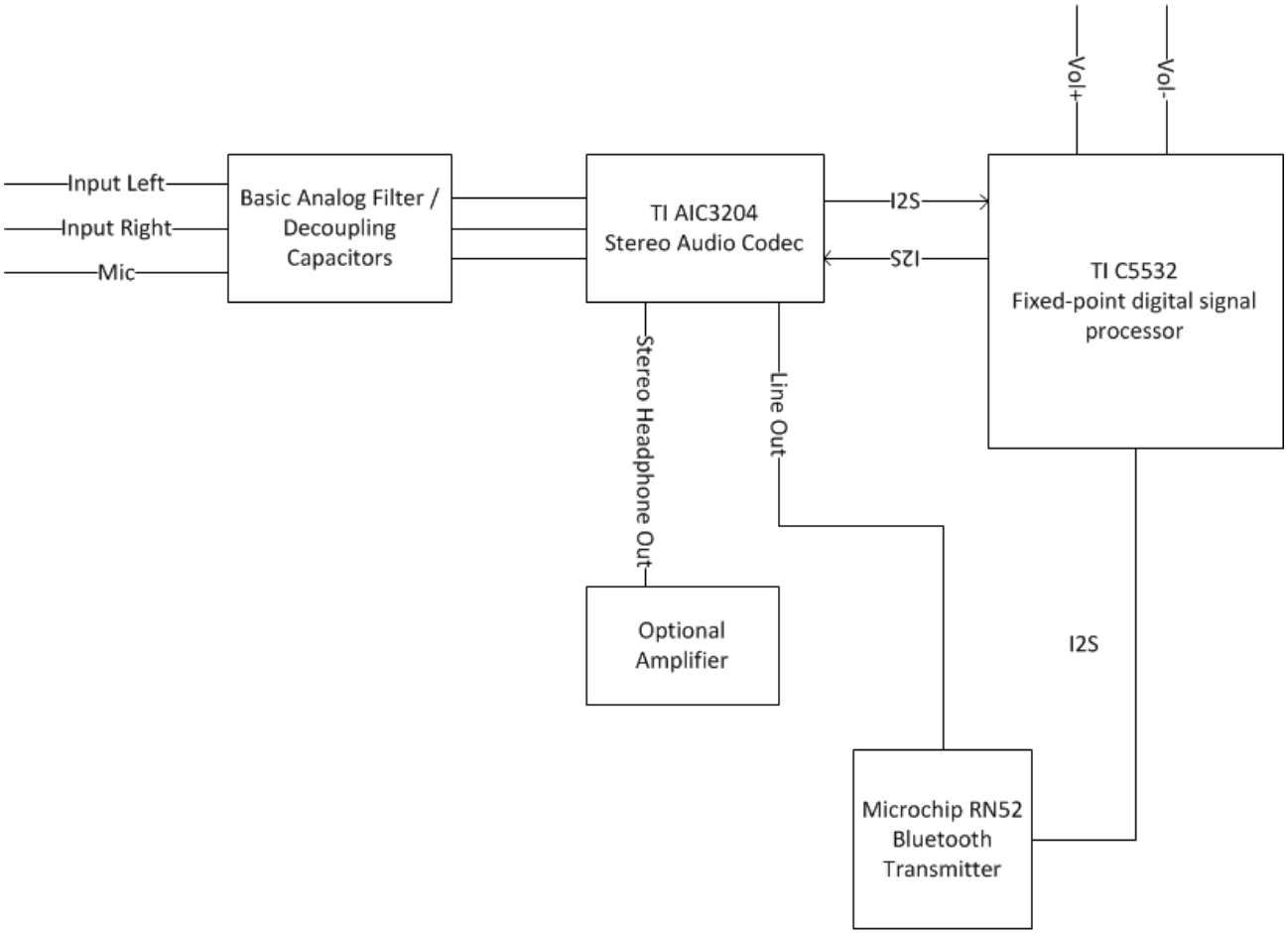
Digital Signal Processors

- Microchip DsPic
  - High Performance
  - Eliminated due to high power
- TI C550x Fixed-Point DSP
  - Successfully evaluated with low-power
  - Slow wakeup times might add latency
  - Tested this processor. Have the most experience with this processor
- Atmel SAM4E Arm Cortex M4
  - Power generally best in class
  - DSP processing capability may be lower.
  - Did not have time / money to test this processor. Previous experience with processor is favorable.

DAC / ADC Codec

- Low Power (6.1mW Record, 4.1mW Playback)
- 15mW to 40mW per channel output
- 25 tap FIR filter
- First Order IIR
- Beep Effect
- 6 Inputs, 2 outputs

System Block Diagram



Sandia National Laboratories

iPod Shuffle Comparison

- **Battery: .19 Whr**
- **15 hours of playback**
- **Power: 13mW**
- **Size: 29mm x 31mm**

Power / Battery Life Analysis

Power Estimation

	Low mW	High mW
Codec A/D Power (Record)	4.1	4.1
DSP Processing (10% duty cycle)	6	12
Codec D/A Power (Playback)	6.1	6.1
Amplifier Power	2	40
Total Power	18.2	62.2

Battery Life

	Low (Hr)	High (Hr)
iPod Touch Battery (.19WHr)	10.4	3.1
.5wHr	27.5	8.0
1wHr	54.9	16.1

Bluetooth Options

- Option 1
  - Use a complete bluetooth system on a chip
  - Microchip RN52
  - Will transmit stereo audio and supports bluetooth audio profiles/compression standards like: A2DP
- Cons
  - Large Footprint (13mm x 26mm x 2mm)
  - High Power (~100mW)

Bluetooth Options

- Option 2
  - Use a bluetooth baseband chip (Toshiba TC35654, for example)
  - Bluetooth stack will reside on DSP
  - Must perform all profile / compression on DSP
- Cons
  - Design complexity goes up
  - Software complexity goes up
  - Board / Layout complexity goes up
  - Power Estimation Difficult

Power / Battery Life Analysis with Bluetooth RN52

Power Estimation

	Low mW	High mW
Codec A/D Power (Record)	4.1	4.1
DSP Processing (10% duty cycle)	6	12
Bluetooth Radio power	100	150
Total Power	110.1	166.1

Battery Life

	Low (Hr)	High (Hr)
iPod Touch Battery (.19WHr)	1.7	1.1
.5wHr	4.5	3.0
1wHr	9.1	6.0

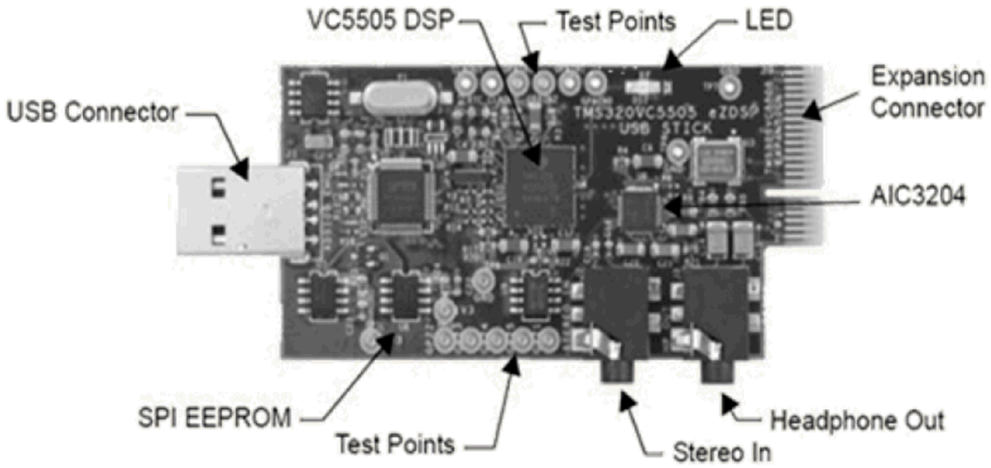
Component Cost Estimate

- **Rough estimate on component costs**

	Low Volume	High Volume
AIC3204	5.67	2.53
C5532	7.35	3.99
Connectors / Buttons	3	1.5
Support Circuitry	2	1
Bluetooth RN52	20.64	?
Component Cost w/o BT	18.02	9.02

Demo

- **Uses ezUSB (c5505) development board to demonstrate digital filter capabilities and end-to-end running.**



Sandia National Laboratories

Final Words

- Using