

Loudspeaker Research and Design – Final Boss

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Functional Description

Requirements and Goals

The purpose of this paper is to detail and rationalize the design choices made for the loudspeakers I will be designing and building through personal sentiments, classroom and lab discussions, and logical conclusions based on the research I have done this semester.

The primary purpose for these loudspeakers is recreational live performance with a primary focus on karaoke. These speakers should ideally be good for listening to music, as well as TV, movie, and video game sound, along with fulfilling other day to day listening purposes. I want these speakers to function primarily indoors in large living rooms and smaller bedroom or home office spaces, along with the capability of functioning outside in fair weather conditions. Being able to fill the space of an average living room is my number one priority for these speakers. The combined two of them should be able to overpower ambient living room noises such as ventilation, fans, obnoxious clocks, etc. These loudspeakers should be able to function as well from a close range (working as bookshelf speakers) as they would from farther away (an ideal range of 5-8 feet). Another benefit of having two speakers would be to expand upon the listening 'sweet spot', giving more people the opportunity to listen from where the speakers sound best. These speakers should be able to be placed on a stand or pedestal for recreational performance and be able to rest on a bookshelf, entertainment center, or other similar sized structure for day to day listening. Operating as a stereo pair is a must for these speakers with an external subwoofer having the potential to be added for media with very low frequencies.

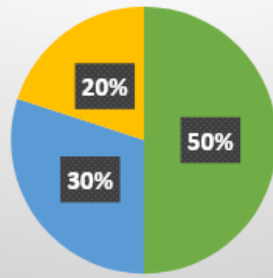
The loudspeakers should be portable enough for the occasional move from one location to another, so keeping the speakers smaller and lighter is a must. I find it ideal to be able to carry both with me, whether that be carrying one in each arm, or finding a bag to pack away the speakers and other essential parts (microphones, small 4 channel mixer, amplifier, and potentially the aforementioned subwoofer). The loudspeakers need to be able to function for multiple hours in each session (family karaoke night, TV/Movie binge watching, long video gaming sessions, etc.). The speakers should be to reproduce sound with little to no alterations, so in cases of critical listening, would function well as testing speakers for mixing. This project should produce a set of speakers that while primarily used for recreational enjoyment, have the capability of being used in critical listening scenarios. These speakers will be designed with backwards listening mentality, meaning that they won't be mixing extraordinary and more emulate an average listening experience.¹

Based on John L. Murphy's recommendation of three-point design tradeoffs, this project will prioritize size first, SPL second, and finally, a \$500 budget.²

¹: John Moulton, p. 313

²: John Murphy

Design Tradeoffs



■ Size ■ SPL ■ Budget

Reference Systems

Overview

A review of other bookshelf speakers with adequate SPL was done to assess the performance guidelines for the speakers I intend to build. The systems are summarized in this table:

Speaker	Sensitivity (dB @ 2.83V/1m)	Weight (lbs.)	Dimensions (inches)	Price (US\$/pair)
RP-600M II	94.5	18.1	7.95*13*15.75	\$462.00
ELIAC Debut 2.0 B6.2	87	16.3	7.69*14.76*10.55	\$299.98
Jamo Concert 9 Series C 93 II	88	6.4	7.9*10.2*13.8	\$299.00
JBL Stage A120	86	8.4	6.7*6.7*11.22	\$500.00
PSB Alpha P5	89	10.15	6.75*9.5*11.35	\$399.00

Looking over the reference speakers, the sensitivity ranges from 86-94.5 with the 94.5 being an outlier. The average sensitivity for this set of speakers seems to be in the 86-90 range.

Specific Loudspeakers

Klipsch RP-600M II ³



The Klipsch RP-600M II is captivating in both its aesthetic and specifications. Boasting a much higher sensitivity than its rivals on the table means that its more energy efficient at higher SPL levels. These speakers seem a bit bigger than an average set of bookshelf speakers and have the weight to show for it, something less than ideal for the speakers I am pursuing.

Jamo C93 II ⁴



Something I enjoy about the C 93 II speakers is despite their significantly lighter weight than the rest of the tabled speakers is that sensitivity isn't compromised. It also makes finding supports for the speakers that much easier. The curved structure in the front makes it immediately that much more eye-catching.

PSB Alpha P5 ⁵



While I appreciate the efforts put into having a magnetic grill on the front of the speaker, a grill will muddy the sound quality from the speaker. Something unique this speaker does is place the tweeter under the woofer,

which seems unconventional, especially with the higher frequencies likely going straight into the shelf the speakers are on.

3 : <https://www.klipsch.com/products/rp-600m-ii-bookshelf-speakers> 8/31/2023

4 : <https://www.jamo.com/speakers/bookshelf-speakers/c93-ii> 8/31/2023

5 : <https://www.psbSpeakers.com/product/alpha-p5-bookshelf-speaker/> 8/31/2023

Technical Specifications

Cabinet Design

The design of the cabinet determines many factors regarding how big, portable, and intrusive a set of speakers may be. Ideally, I would like to be able to wrap my arms around or under a speaker and carry it. I am not looking to exceed a cubic foot in volume and would like to have more height in the speaker as opposed to width and depth. This will make the speaker feed into my needs for portability and. I would like to be able to transport my speakers via my car and still be able to have room to carry other things whether that be for taking the sound system somewhere to perform with (mics, board, stands, amps, guitars) or taking them home with everything else I'd want for winter break, the less I have to worry about how much room my speakers are taking up, the better. I would ideally be able to carry them without needing help. Testing with lifting boulders and concrete bags, I can pick up 80 lbs. in concentrated weight, so I think I would be able to competently carry 60 lbs. with better distribution and somewhere with good grip.

Listening Axis

Something neat about the Final Boss pair is that there are mid woofers above and under the tweeter. Many speakers have a tweeter with one woofer under them, and this will influence the listening axis of the tweeter more upward. Because there is another mid woofer above the tweeter, this evens out the listening axis and would put my ideal listening axis at ear level to the tweeters. The horizontal offset of the two tweeters provides an inward focus and narrower listening space.

SPL

SPL has many different factors that need to be weighed in for the various purposes the speaker will serve. My ideal sensitivity (SPL with no additional power supplied to the speakers from 1 meter away) lies in the 87-90 range. Primarily, I want something that could be used for performing music via either backing track or via adding instruments to the system. In that context, I would like to prioritize around 100dB so that I could fill my backyard with sound but also be able to start lower (around 90dB) for enjoying the speakers in a smaller, more intimate space. My secondary priority is for entertainment listening (streaming or playing video games), and I would like to be able to listen from the same distance at a lower volume.

Something very important to consider in these wants are the various methods of SPL calibration. The LUFS System is used in the context of streaming backing tracks or movies. LUFS stands for Loudness Units Relative to Full Scale and is one of the most accurate ways of measuring the loudness of audio played on streaming services, film, and TV.⁶ While the sites I'd run through for music (YouTube, Spotify) run at an average of -14 LUFS, Video games run at an average -23⁷, and Netflix runs at a whopping -27.⁸ LUFS is useful for keeping things consistent across a platform and making sure that a change in tracks or a sudden sound effect is not the reason someone damages their speakers or even worse, their hearing.

Amplifiers

A choice in amplifier can be the difference in reaching one's desired SPL. I intend on using a 100w output amp as the 100w of extra power will result in a 20dB net gain, bringing my speakers output to 107-110 dB. My ideal is to have a long time maximum of 100dB, short term or peak maximum at 110, and an average that rests at 95 but would be willing to go lower. I believe that this is beyond capable of filling any room I'd place my speakers in with the desired sound

Frequency Response

The best thing a frequency response can be is flat as this means any pitch isn't over amplified or under represented. Considering that these speakers are meant to be for casual listening, I want to be able to capture everything that a program has to offer, without the risk of any unwelcome surprises.

Construction

Cabinet

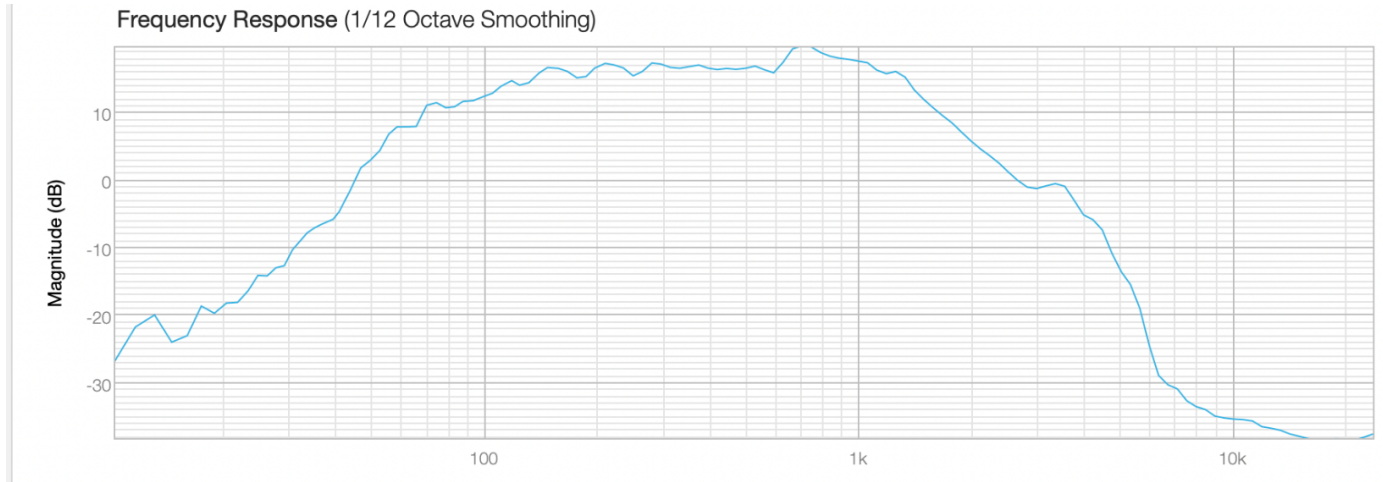
I purchased the TriTrix MTM Bookshelf Speaker kit from Parts Express, so my cabinets, drivers, and electrical components all arrived in the same box. I elected to purchase a kit as it was more budget friendly and time efficient. The MDF material is light and very transportable, which makes the completed speakers much easier for me to take from place to place. These are meant to travel from place to place as I see fit, so having them be lightweight for me to carry on my own is great, even if I need to make one trip for each speaker.

Crossover

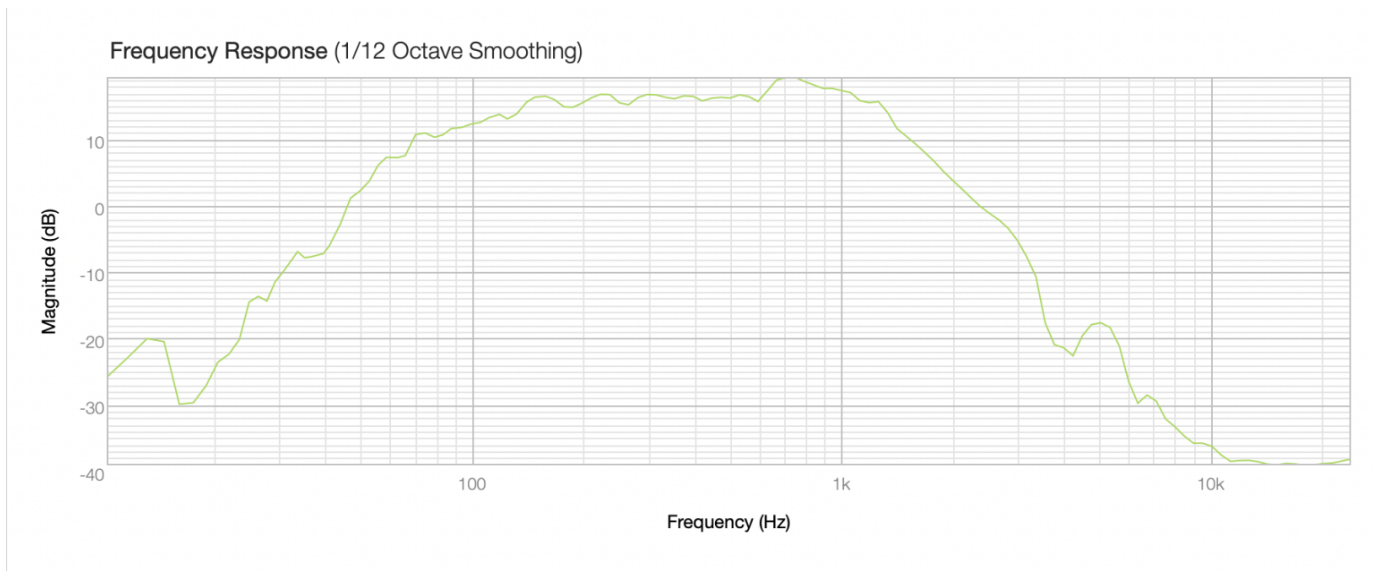
With the cabinet complete, all that needed to be done was to wire the electricals. Although I had my crossover layout available in a picture, it did not stop me from making mistakes along the way. Something that I would heavily recommend to anybody looking to build their speakers is to wire their crossover board first and leave extra length for any component that needs to be connected to a driver or binding post. That way, if adjustments need to be made, one can do such without having to overly disassemble their speakers. I ran into a lot of troubleshooting issues after first listening to my empty speakers that I would have loved to have extra wire for and not worry about my crimp connectors falling off due to my wires pulling too far. In the end, I built a pair of speakers that had every driver working properly, with my woofers running in series and my tweeter having its own routing.

Tuning

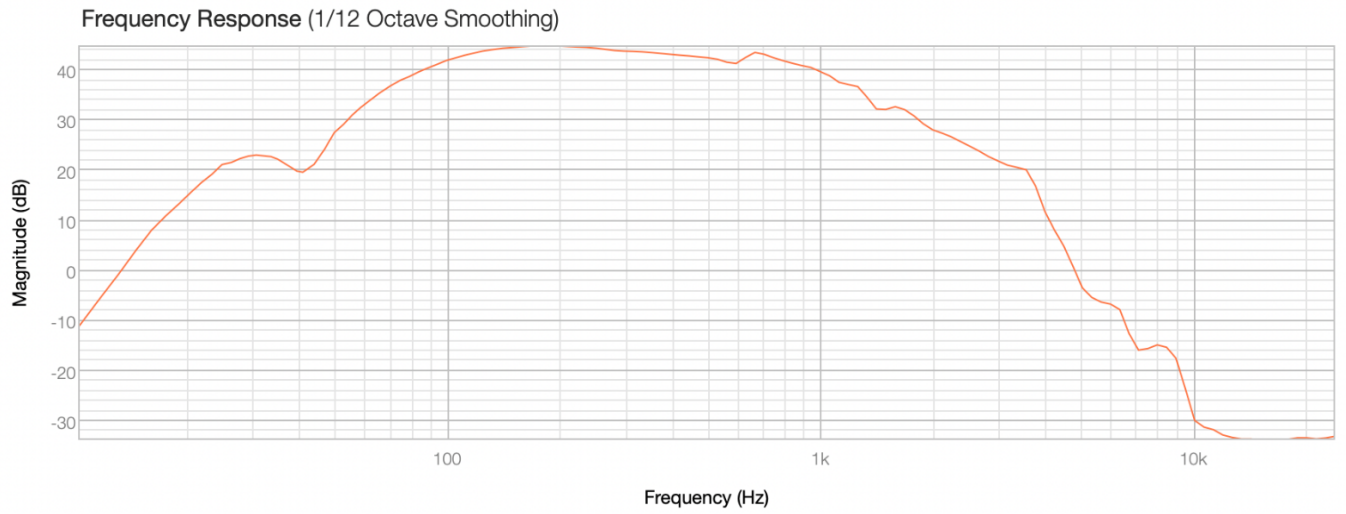
Undampened



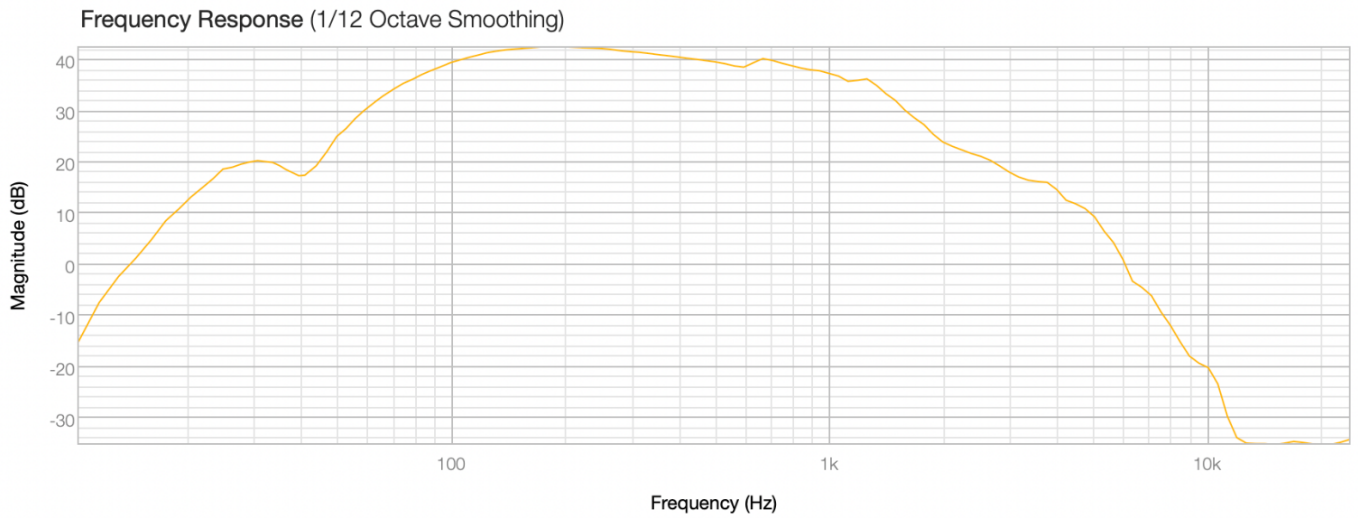
Top Woofer from 1 meter away



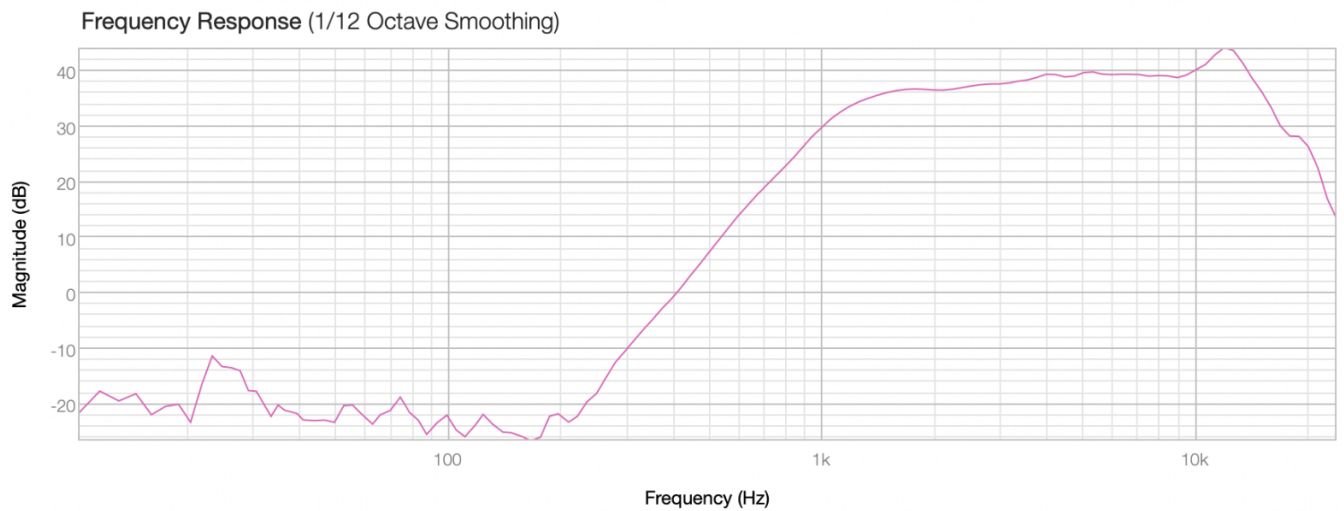
Bottom Woofer from 1 meter away



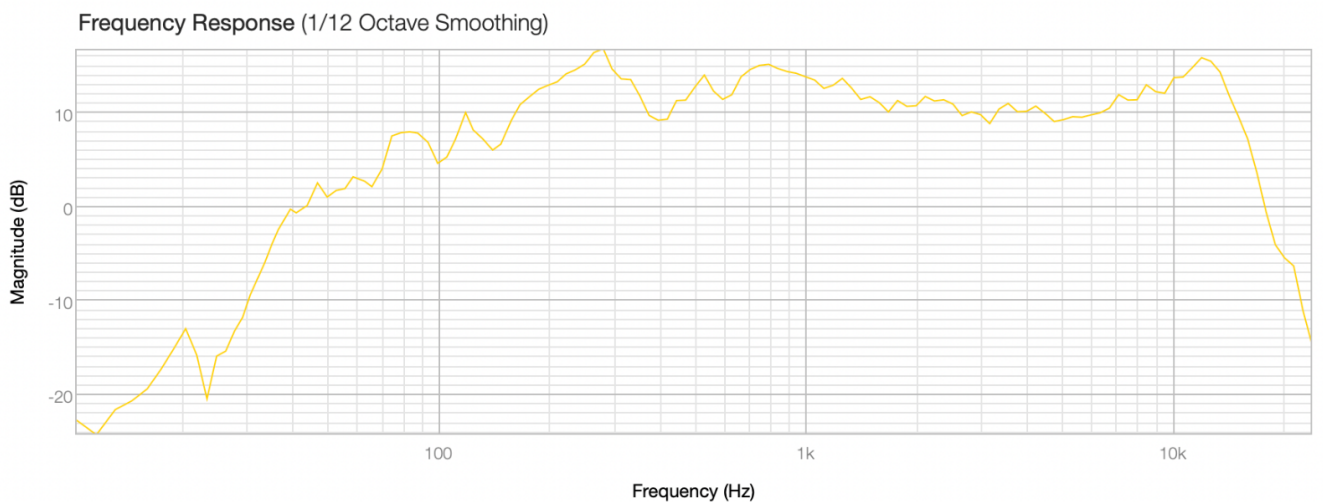
Top Woofer from 1 inch away



Bottom Woofer from 1 inch away



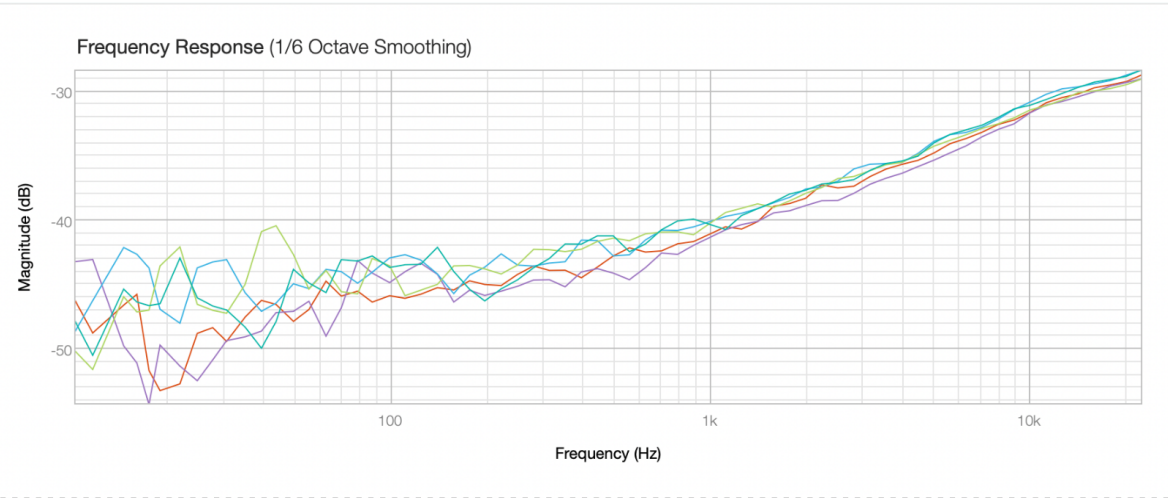
Tweeter from 1 inch away



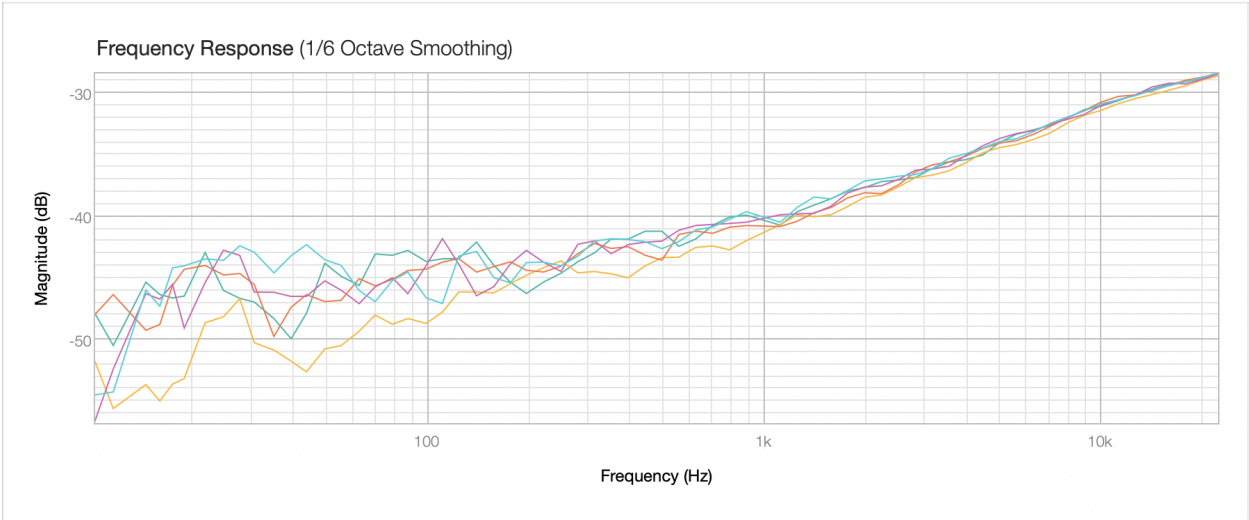
The whole speaker from 1 meter away

Dampened

When I tested these speakers for the final tuning, I used a cheaper Sound Reference microphone as it was more readily available. This resulted in a set of measurements that aren't quite as accurate as they would've been had I used one of the Earthworks microphone. It also may be worth noting that my Tweeters could have been damaged in the process of gluing the backs of my speakers on (resting them face down is a bad idea).

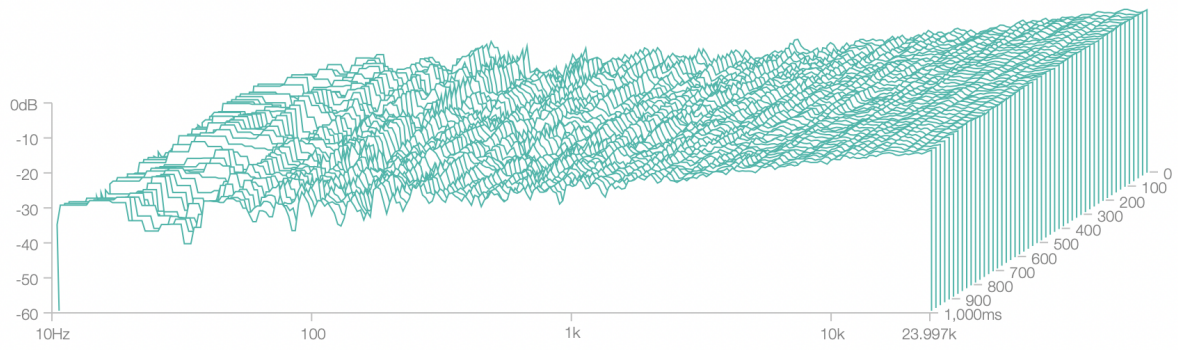


Horizontal Off-Axis Testing

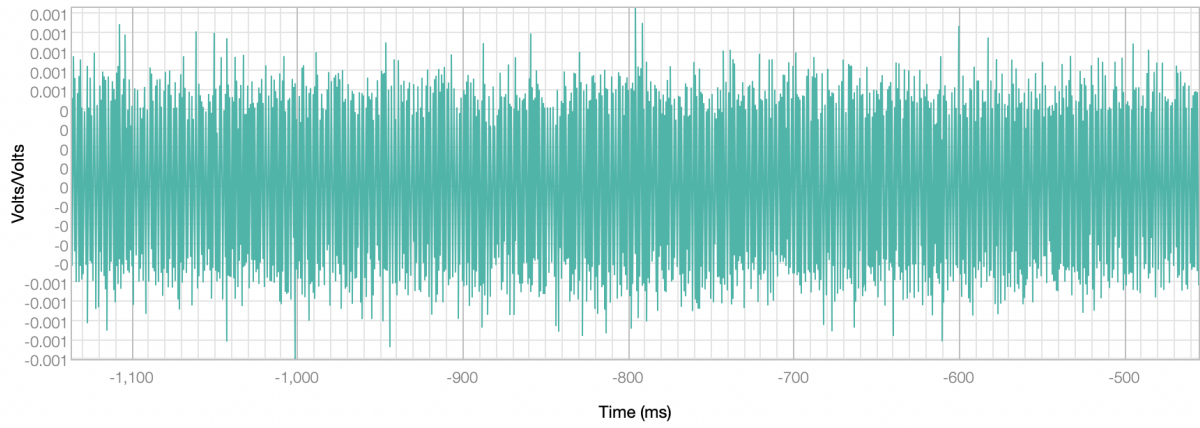


Vertical Off-Axis Testing

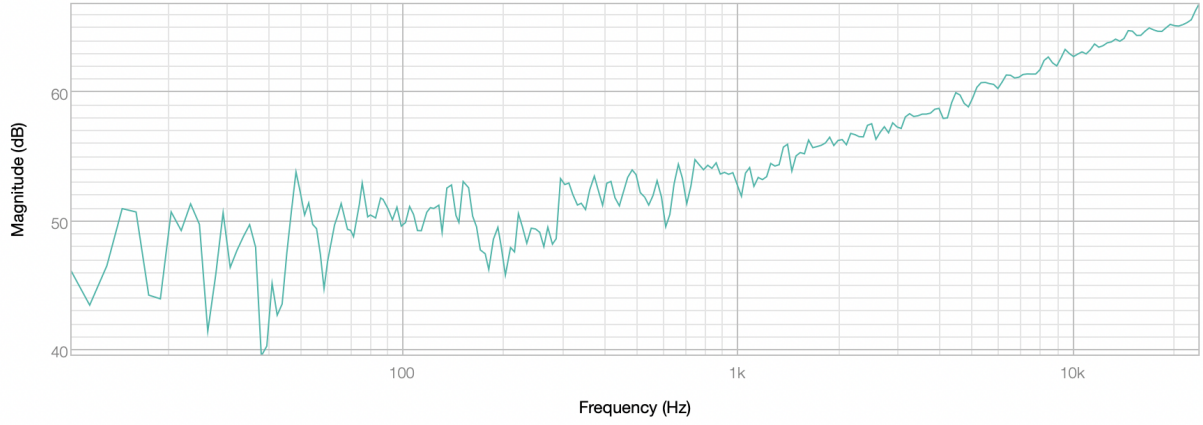
FFT Waterfall (1/24 Octave Smoothing)



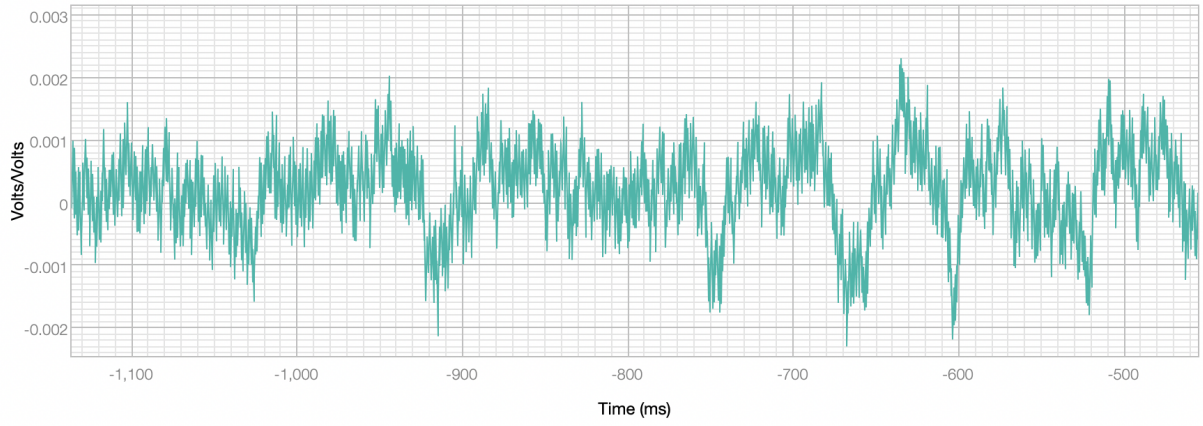
Impulse Response



Sound Pressure Level (1/24 Octave Smoothing)



Step Response



Reflection and Conclusion

Now that I am at the end of this project, not only do I realize that there were things I could have done better, but there are also things that I'd do differently given another chance. Firstly, I would opt to go through the design process and build something more original. There were a lot of amazing self designs and it definitely felt like there was more to be learned in starting from square one. Secondly, I'd opt to incorporate a subwoofer into this system. A sub is great for adding low-end and more thump to any set, but I could've especially appreciated it knowing that my mid woofers are higher than the average woofer. Finally, I would avoid many of the technical errors made along the way. This build was a learning process, and after small oversights like not ordering binding posts, cutting myself short on wire, and resting my tweeters face down, I could make improvements that would save time and result in higher quality listening.

In conclusion, however, I am very thankful to have built the Final Boss pair. I love the way they sound and can't wait to paint them, show them off, and listen to them with many people when they travel with me.

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