Transducer Theory Final and Complete Paper

“Sno-Cones”

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Functional Description

These speakers will be as small as they can be to fit on the desk in front of video monitors and next to slightly smaller loudspeaker monitors. These larger speakers will be useful for switching from the smaller speakers to test mixes as reference monitors. They will also be used for traveling so they will be a familiar sounding set of speakers for mixing in different environments. In all cases, the tweeter will be above or below the woofer to maximize the time alignment of drivers.

The speakers will be at a desk and close to the listener or used in low SPL installations so SPL requirements are rather small. These speakers will be small enough to not take up too much space on the desk but still be able to fit the SPL requirements. At close listening, they will need to meet the standards for music mixing. Low-frequency extensions should extend low enough for them to work well as mixing monitors by themselves but in most cases, they will have a subwoofer to help out in the low end.

Sound quality will aim for low distortion, a flat response, and a boost in the lows when there isn't any low-frequency extension available. This will create a frequency response that will be pleasant to listen to with an accurate and transparent sound. The goal will be to provide a window into listening forward so mixing can be accurate while also catering to listeners who will be listening on more common loudspeaker setups.[1]

[1] Philip Newell & Keith Holland, Loudspeakers for Music Recording and Reproduction. 2nd Edition, Focal Press, 2007.

Physical protection must be designed into the speakers for travel and portability but it isn’t necessary for being used. Sound quality is more important than physical protection for travel.

Based on John L. Murphy’s recommended three-point design tradeoff this speaker will prioritize size first, low-frequency output second, and SPL output last.[2]

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[2] Murphy, John L. Introduction to Loudspeaker Design. Escondido, CA: True Audio, 1998.

Reference Speakers

A review of medium-sized, mostly powered, two-way monitors with 6” or 6.5” woofers was done to determine the performance guidelines for this segment. I spent some time getting to understand these speakers; what I liked about them and what I didn’t like about them and how I could improve those things in my speakers. The top three speakers that I wanted to model my speaker after are the JBL 306P MkII 6.5-inch Powered Studio Monitor, the Yamaha HS7 6.5-inch Powered Studio Monitor, and the Mackie HR624mk2 6-inch Powered Studio Monitor.

The JBL 306P MkII 6.5-inch Powered Studio Monitor is the size up from the monitors that I already have. I’ve been using them for years and I’ve been very happy with them so I wanted to use them as a reference speaker when coming up with my speaker design. The JBL 306P’s have a horn design on their tweeter but it isn’t exactly a horn so that’s where I wanted to turn it more into the “wave-guide” design that I added with my tweeter on my speakers. They also have a similar low-frequency goal that I have with a response that reaches down to 39Hz.

The Yamaha HS7 has another example of a “wave-guide”, but one that is less like a horn tweeter and more of a circular “wave-guide” like the tweeter that I chose. Now that I have my speakers finished, the white cone woofer and the tweeter make my speakers look a lot like this model but with a little more separation from the woofer and tweeter on the baffle. The low end of my speakers will also go lower than the HS7’s do as the HS7's only reaches 43Hz and I'm hoping that my speakers will be capable of going lower than that.

The Mackie HR624mk2 6-inch Powered Studio Monitor has another similar look to the “wave-guide” tweeter. The low-end also doesn't reach as far down as I hope for my speaker to reach as the Mackie's only reach down to 43Hz. One thing that did catch my attention was their “zero edge” baffle. I plan to sand down all of the edges on my speaker so that I minimize the outside corner reflections as much as possible.

I think using the look of these three monitors and following the idea of the “wave-guide” can contribute to my goal of having a directional off-axis high-frequency response. Using the “zero edge” baffle idea to minimize reflections outside of my speaker will also be a goal of mine. I would like for my speaker frequency range to reach lower than these speakers but if it's something similar I wouldn't be upset about it. I would also like for my speaker to have the same or higher sensitivity than these other speakers because they're in the 98-100 dB SPL range and I would be happy with that but a little more would be better so I had enough headroom to not have to worry about playing them too loud.

SPL Analysis

After doing a lot of testing of what my preferred listening levels were at certain times of the day with certain genres, I was able to conclude some average levels as well as the loudest that I casually listen to my speakers and the quietest I casually listen to my speakers. I discovered that most of the time, listening in the morning was when I listened to music at the quietest SPL level. I listen to my speakers the loudest during the afternoon when everyone in my house is still awake and I listen just in between during the evening.

My average listening SPL for these three times of the day is as follows; in the mornings, my average listening SPL is 36.5 dBA @ -14LUFS with a peak of 46.4 dBA @ -14 LUFS, and the dynamic range is 16.9 dBA Min to 45.8 dBA Max @ -14 LUFS. In the afternoons, my average listening SPL is 55.5 dBA @ -14LUFS with a peak of 69.3 dBA @ -14LUFS, with a dynamic range of 1.0 dBA Min to 62.8 dBA Max @ -14 LUFS. In the evenings, my average listening is 52.0 dBA @ -14LUFS with a peak of 63.5 dBA @ -14LUFS, and the dynamic range is 12.7 dBA Min to 59.8 dBA Max @ -14LUFS.

Frequency Response and Extension

These loudspeakers are designed to have an accurate reproduction of a signal as possible and therefore the flattest frequency response I can get is necessary. That means I'm looking for a frequency response of at least +/- 2 dB with a small boost in the lows to try to extend the low-frequency range as far as possible. I'm also hoping to get the high frequency range flat as close to 20kHz as possible but a small roll-off somewhere after 18kHz is okay too as long as the breakup frequency is above 20kHz. For the low-frequency extension, the size of the enclosure will be a limiting factor but I'm to have a longer port to allow the frequency to extend down to at least 40Hz if possible but 45-50Hz will be acceptable as well.

Target Shape: +/- 2dB with a slight low-frequency boost

High-Frequency Extension: A roll-of somewhere between 18kHz-20kHz

Low-Frequency Extensions: 70Hz minimum, 50Hz Target, 40Hz unlikely but desired

Tech Specifications

For the technical specifications of the speaker, I'm looking to make a cabinet design that is small enough to fit on my desk but has enough volume to extend into the lower frequency range, hopefully reaching as close to 20 as I can get it to. I want the speakers to be small enough that I can carry them easily and set them up in different places because after I graduate college, I will be moving somewhere else and I want them to be portable and fit in a variety of spaces. I would also like the listening axis to be fairly directional but also have some capability to maintain a good frequency response off-axis. Taking all of these into consideration, I'm hoping to be able to get a cabinet somewhere between $0.5ft^3$ and $0.7ft^3$, that weighs enough for me to still be able to carry around on my own, and has a listening axis that is at my ear level. Since I can adjust my sitting height, the ear level isn't as important but would be convenient.

Since my speakers will be on my desk and fairly close to my ears, approximately 28" away from my ears, a high SPL level isn't a very important factor for them. I'm hoping for the speakers to be able to produce an SPL level somewhere between 75 and 85dBA SPL at -14LUFS, since most of the time I only use my speakers to listen to Spotify. I also want to be able to push them somewhat loudly so that I can be assured that they can handle anything unexpected because the dB level I plan to listen to most of the time averages out to about 64.8dB SPL. My target sensitivity for the speakers is 105dB SPL, with the long-term handling being about 110dB SPL and the short-term handling about 115dB SPL.

For my DSP I plan to use the Dayton Audio DSP-408 along with the Bluetooth adapter so I can control the DSP through my phone and the remote so I can change the volume on the remote instead of each amplifier. For the amplifiers, I want to use the Fosi V3 amplifier which is capable of using 300W per channel. I will only be using the 32V package so I won't be able to push my speakers past their limits accidentally. I'm also hoping to be able to get the frequency response as flat as possible by using the DSP and my phone to tune easily at the computer.

Driver Selection

Woofer

When I first started looking for a woofer, I decided I wanted to go a little larger in diameter after I considered the benefits of having a larger speaker and woofer. I decided to go with a 6” or 6.5” diameter woofer. I spent some time searching through websites and I ended up choosing between a few different woofers. I had to decide between the ScanSpeak Classic P17WJ00 6.5” woofer, the Audax HM170Z18 6.5” woofer, the Audax HM170C0 6.5” woofer, the SB Acoustics SB17CRC35-8 6” woofer, the SB Acoustics SB17CAC35-4 6” woofer, and the SEAS Prestige L16RNX 6” woofer.

My first deciding factor was to compare the price to the performance of the speaker. I was willing to pay a little more to ensure that I have a woofer that can perform the way I’m looking for so I wasn’t asking too much for something that didn’t have the performance I needed. That eliminated everything that was an outlier of the average price of the speakers I had picked, which was $116. So I eliminated two woofers, one over $150 and the other $80. The next step of elimination was how well the woofer handled low-frequencies. I decided that anything that had an F3 of over 50 or a resonant frequency over 40 was going to go, that eliminated one other woofer. The last elimination criterion was that the woofer had to have high sensitivity and a high thermal SPL limit, which finally eliminated the final two woofers, leaving me with the SB Acoustics SB17CAC35-4 6” woofer. I was interested in its ceramic cone which promised a density of the cone and a clear sound, which was useful for being woofers in mixing monitors.

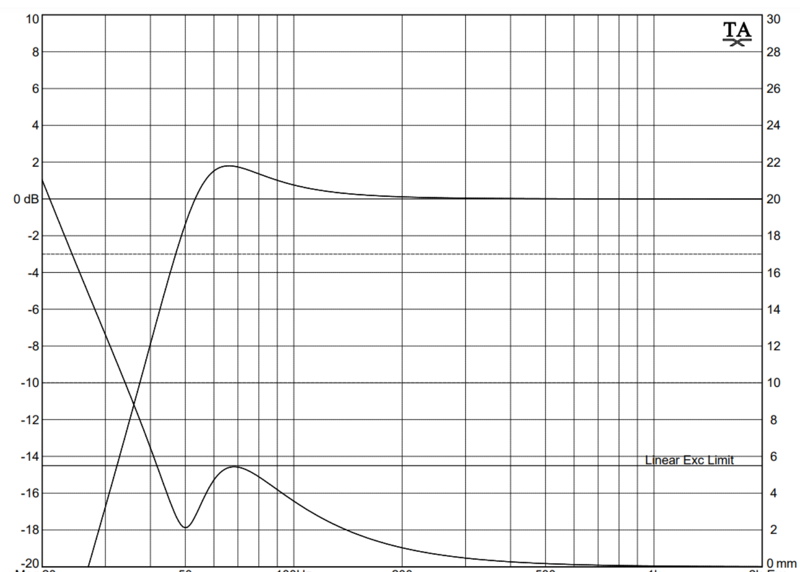
Tweeter

When I was looking for tweeters, my main goal was to have a tweeter that had a flat frequency response that carried over into the off-axis response because when I'm mixing I usually have others with me and I want them to be getting an accurate sound as well if they're sitting off-axis. I was looking at other tweeters for a while but I ended up finding the Dayton Audio ND25FW-4 tweeter which had a built-in "wave-guide" that I wasn't able to find anywhere else. It was a little on the cheap side but I was happy with the sensitivity and the thermal SPL limit. The resonant frequency was higher than the other tweeters but I was willing to overlook those downsides for the use of the "wave-guide" because the directionality of my high-frequencies is important to me.

Sunday, December 17, 2023

Cabinet Design and Drafting

I decided that with the money and time that I had available to me, it would be easier for me to cave in and get a speaker-building kit. I was hoping that I could find a kit that would be somewhere between 0.5ft^3 and 0.7ft^3 and I would also be able to fit the woofer and tweeter that I had selected. I was able to find a speaker kit that was 0.56ft^3 and had a blank front baffle. I was unable to find anything bigger that would be able to fit the drivers that I selected so it seemed like my only choice was the 0.56ft^3. Because the front baffle was blank, I was able to cut the proper-sized holes into the baffle for the drivers to fit. I also added a 2-inch wide flared port on the back of each enclosure and the port was about 6.5” long. I went back and checked out the resonant frequency and how my woofer would react with a slightly smaller enclosure that I already had saved and the enclosure gave the frequency response a very small low-frequency boost which was what I was looking for.



Driver Parameters

Driver:

Nominal Diameter	D = 0	in
Nominal Power	P = 0	Watts
Sensitivity (1W/1m)	SPL = 90	dB SPL
Free Air Resonance	f(s) = 29.5	Hz
Total Q	Q(ts) = 0.29	
Electrical Q	Q(es) = 0.31	
Mechanical Q	Q(ms) = 4.7	
Equivalent Volume	V(as) = 1.335	cu ft
Nominal Impedance	Z = 0	Ohms
DC Resistance	R(e) = 0	Ohms
Max Thermal Power	P(t) = 60	Watts
Max Linear Excursion	X(max) = 5.5	mm
Max Excursion	X(lim) = 0	mm
Voice Coil Diam.	D(vc) = 0	mm

Driver Notes:

NOTE: Reference Efficiency was calculated based on the 1W/1m sensitivity.

Box Parameters

System Type: 4th Order Vented Box

Box Volume	V(B) = 0.53	cu ft
Closed Box Q	Q(tc) = 0.544	
Box Frequency	F(B) = 50	Hz
Min Rec Vent Area	S(vMin) = 40.2	sq in
Vent Surface Area	S(v) = 0	sq in
Vent Length	L(v) = 0	in
Compliance Ratio	alpha = 2.519	
Box Loss Q	Q(B) = 7	

System Parameters

No. of Drivers	N = 1	
Isobaric Factor	I = 1	(1=normal, 2=iso)
Input Power	P(in) = 7400	Watts
SPL Distance	D = 1	m

Tuning

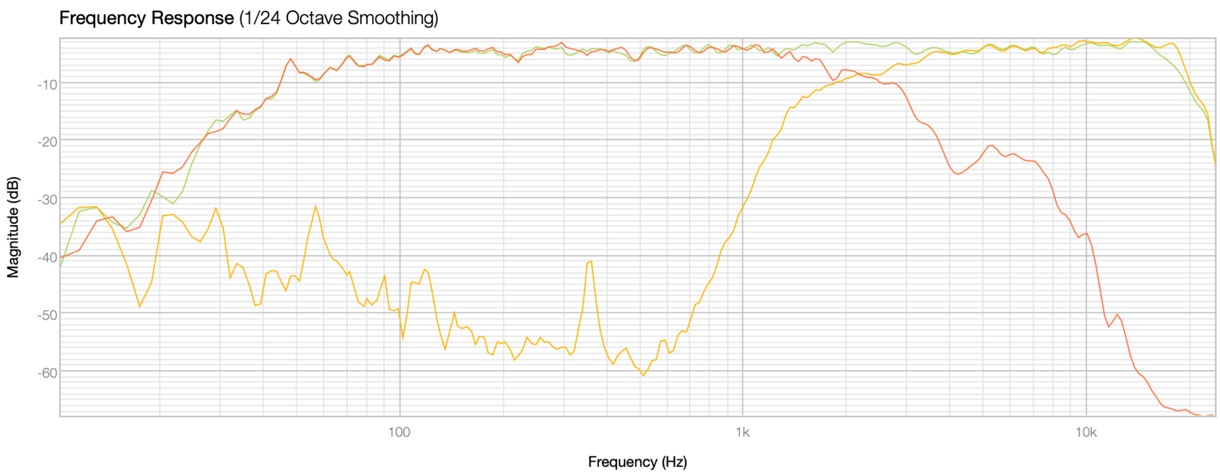
I wanted the tuning of my speakers to go as efficiently as possible and luckily I could set myself up for that with the Dayton Audio DSP-408 that I got. The first thing I did was work on the crossover frequency and figure out the point that would be best for the crossover. I noticed that initially the tweeter was creating a little distortion or noise in the enclosure and I knew that the resonant frequency of the tweeter was around 1300Hz so I tho. Hence, the tweeter was having a difficult time with some of the lower frequencies so I decided to shift the crossover frequency from 2500Hz to 2750Hz and it seemed to get rid of the sound that was happening in the enclosure. I then set my woofer from 20Hz to the crossover frequency of 2750Hz and made them both 4th-order crossovers with a Butterworth filter to make the passband as flat as possible.

Because I had my phone connected to my DSP I was able to control the EQ and Q from where I was sitting at the computer with Smaart running and the signal generator generating pink noise out of the speaker. I spent some time testing the frequencies and working on getting the response as flat as possible for the crossover point first because the summation caused a +5-7dB mound at the crossover frequency so I first got that tamed out by lowering the level of the frequencies of both the tweeter and the woofer around the crossover frequency as evenly as possible. Then I worked on flattening out the woofer frequency response and extending some of the low frequencies so it could reach down as far as possible. I then worked on flattening the tweeter out and I was starting to get into the understanding of what to do in the DSP to get the result on the Smaart graph and the frequency response that I wanted. I noticed that there was a steep roll-off after 18kHz and I tried to see if I could extend it a little further so that the roll-off started as close to 20kHz as possible. I noticed that as I was flattening out the frequency response, the output on one of my tweeters was louder than the output on my woofer so the frequency response slightly sloped upward on the crossword frequency. All I had to do was lower the level by 1 dB and it matched the same SPL level as the woofer.

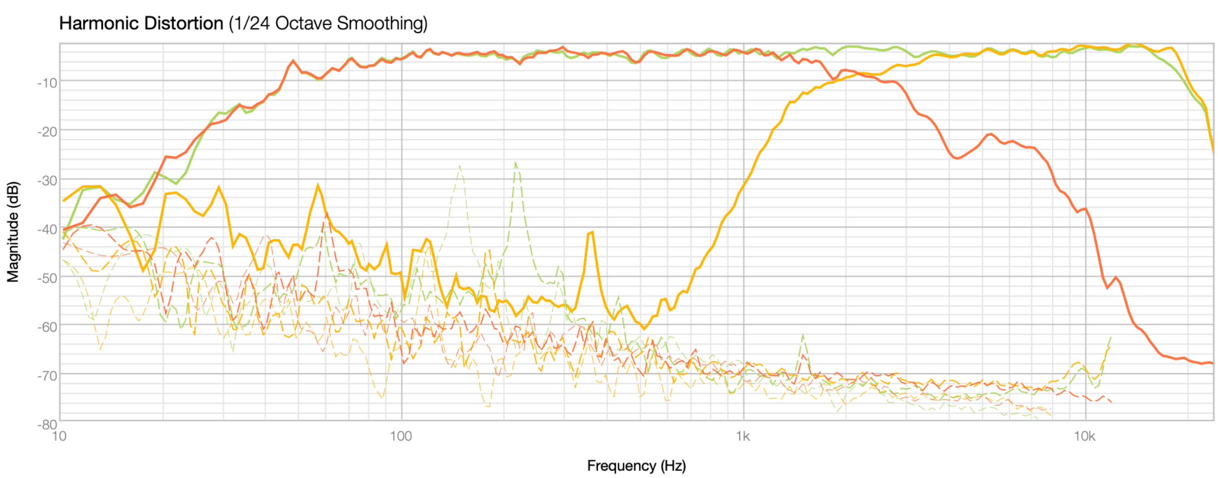
Once I had gotten my speakers to be as flat as I possibly could, I checked the phase alignment between the drivers and found that they were actually in phase and that I didn't need to add any delay to the tweeter which was very nice to see and saved me some time.

Final Performance Documentation

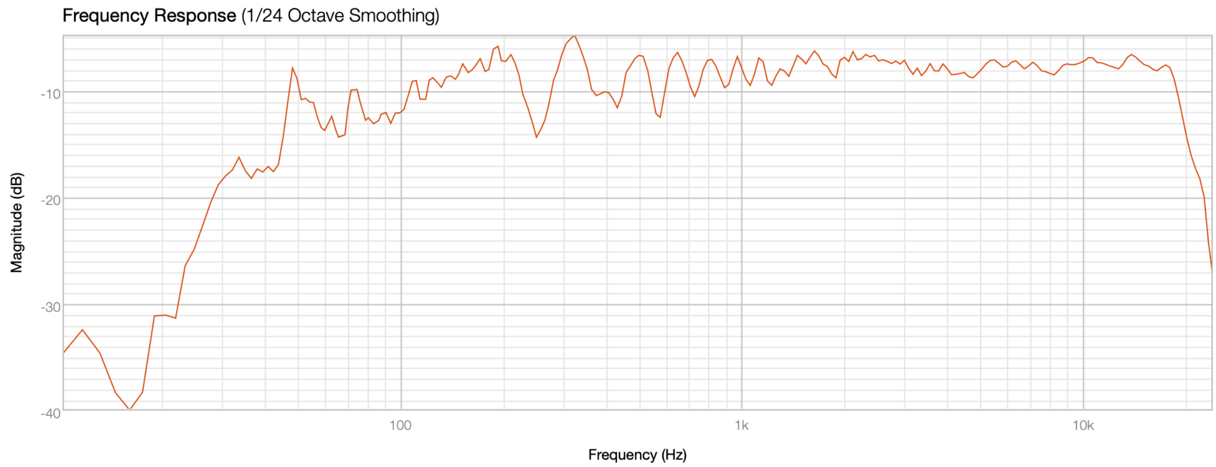
1m Full Frequency Response @83dB SPL (Plus Tweeter and Woofer Response)



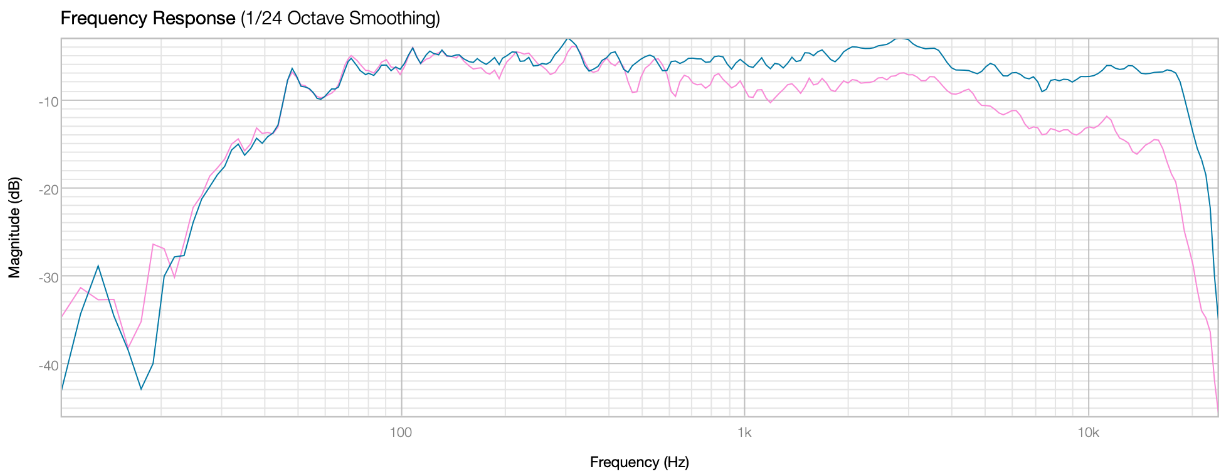
1m Full Frequency Harmonic Distortion @83dB SPL



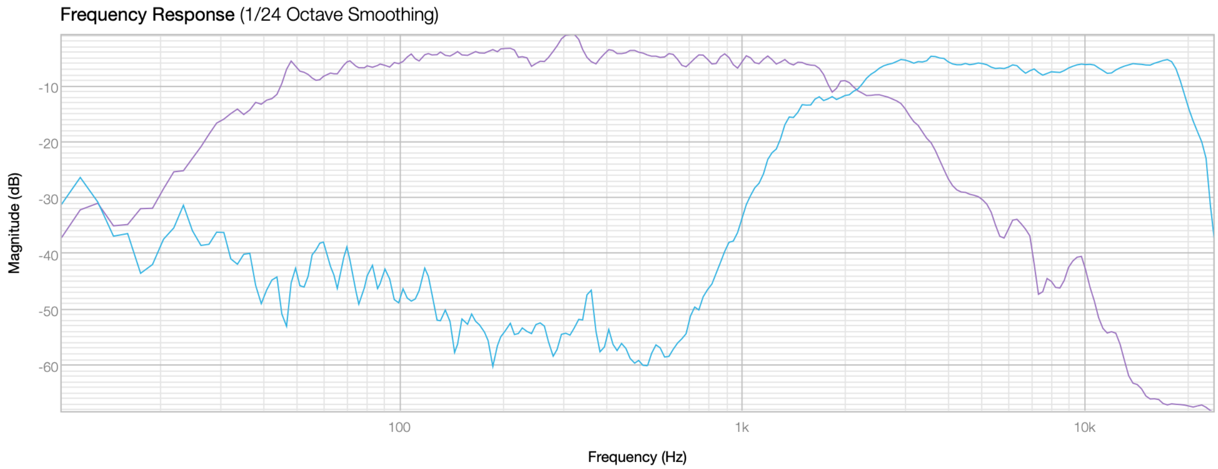
1.5m Full Frequency Response @83dB SPL



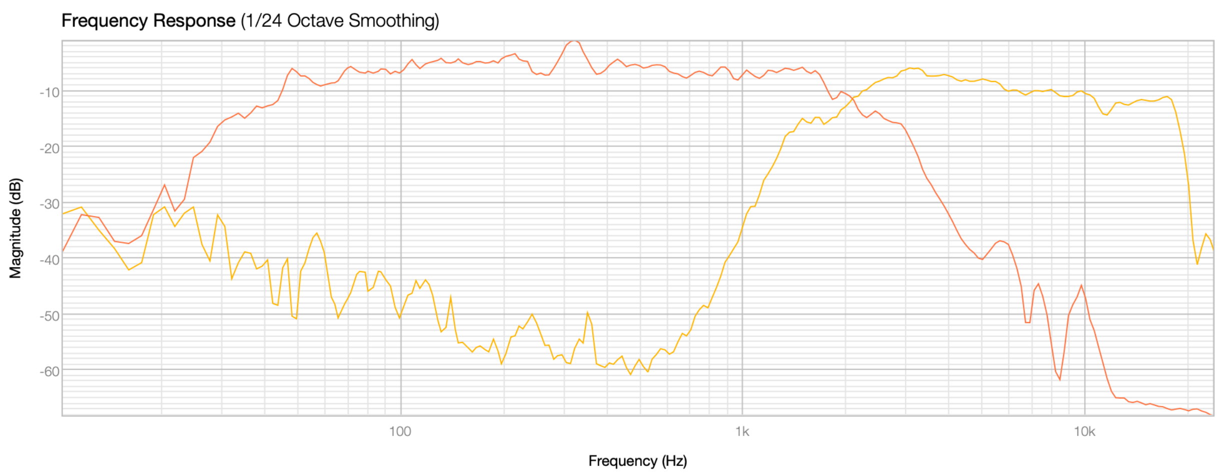
1m Off-Axis Full Frequency Response @83dB SPL (30 degrees and 60 degrees)



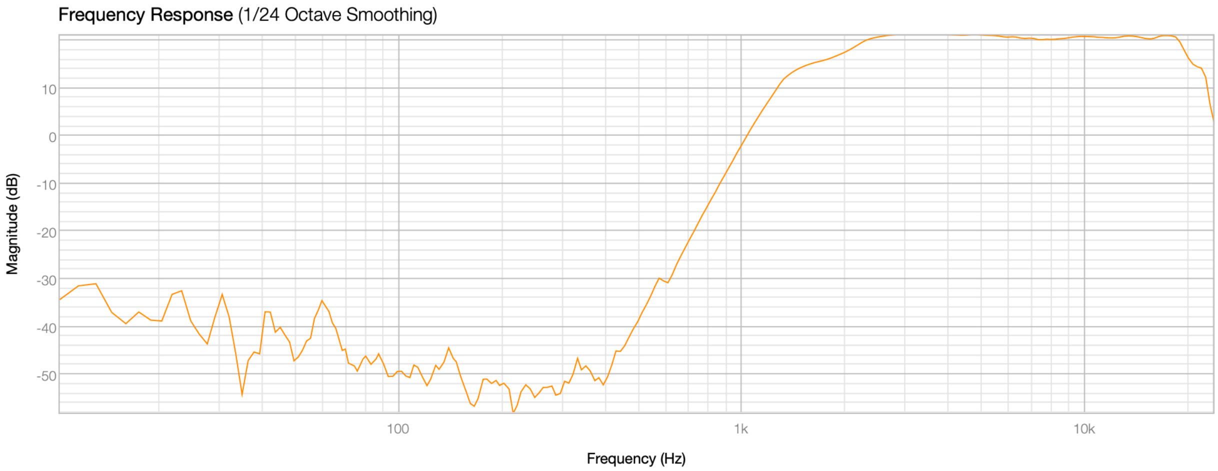
1m Vertical Off-Axis Full Frequency Response @83dB SPL (30 degrees)



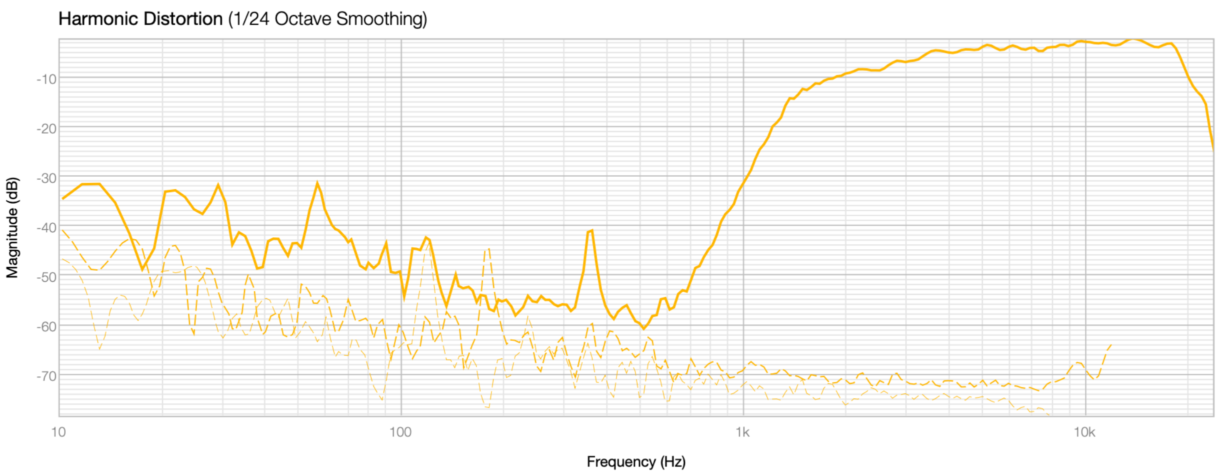
1m Vertical Off-Axis Full Frequency Response @83dB SPL (60 degrees)



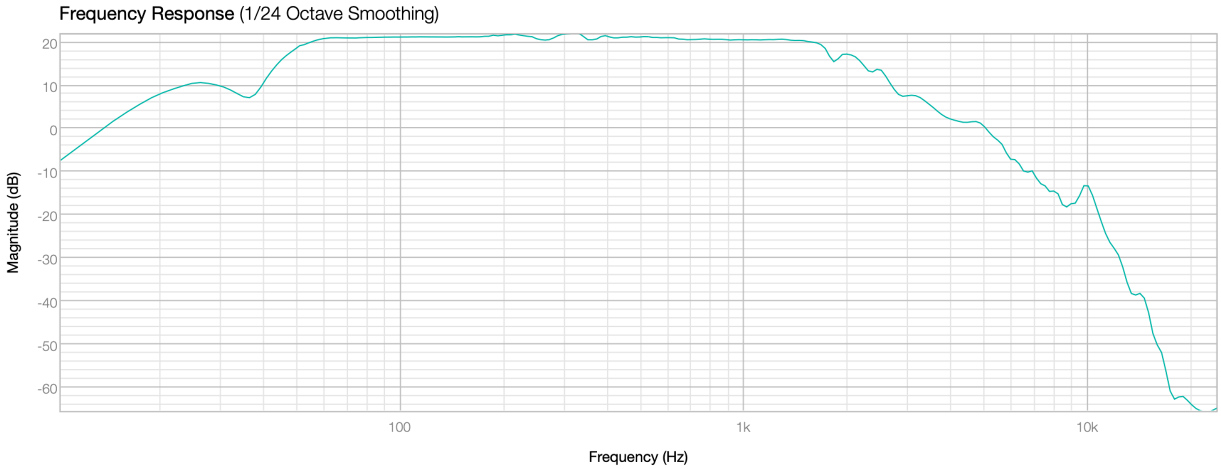
1in Tweeter Frequency Response @83dB SPL @ 1m



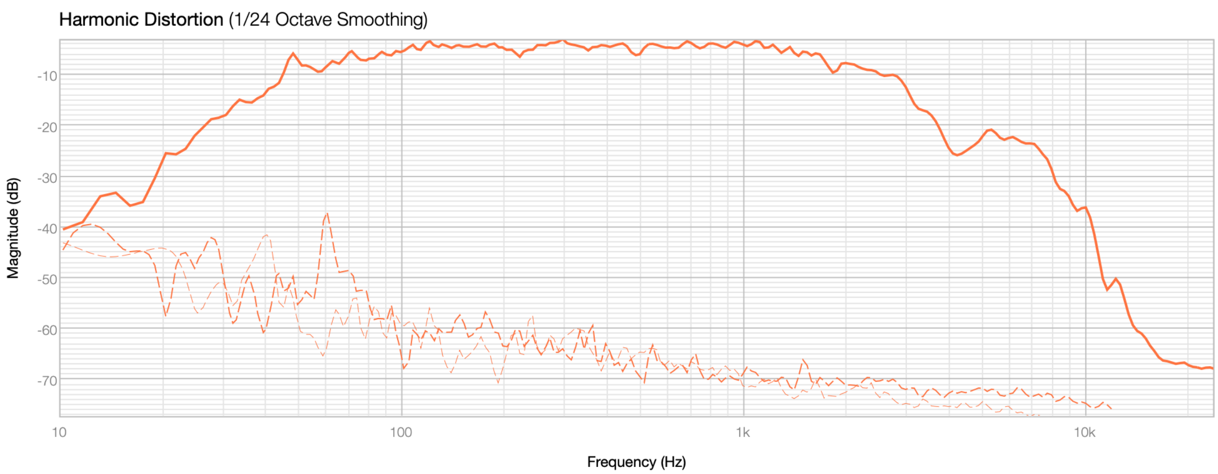
1m Tweeter Harmonic Distortion @83dB SPL



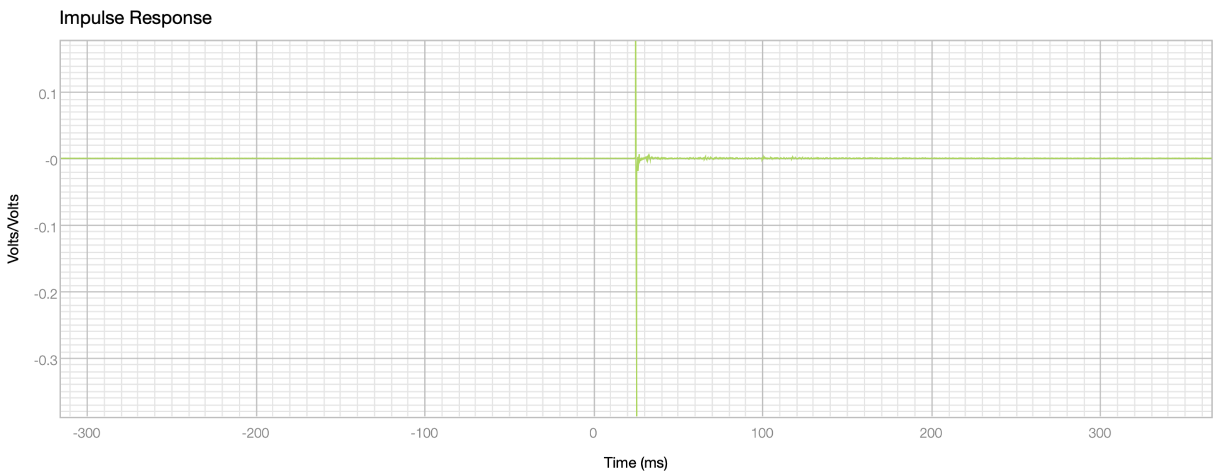
1in Woofer Frequency Response @83dB SPL



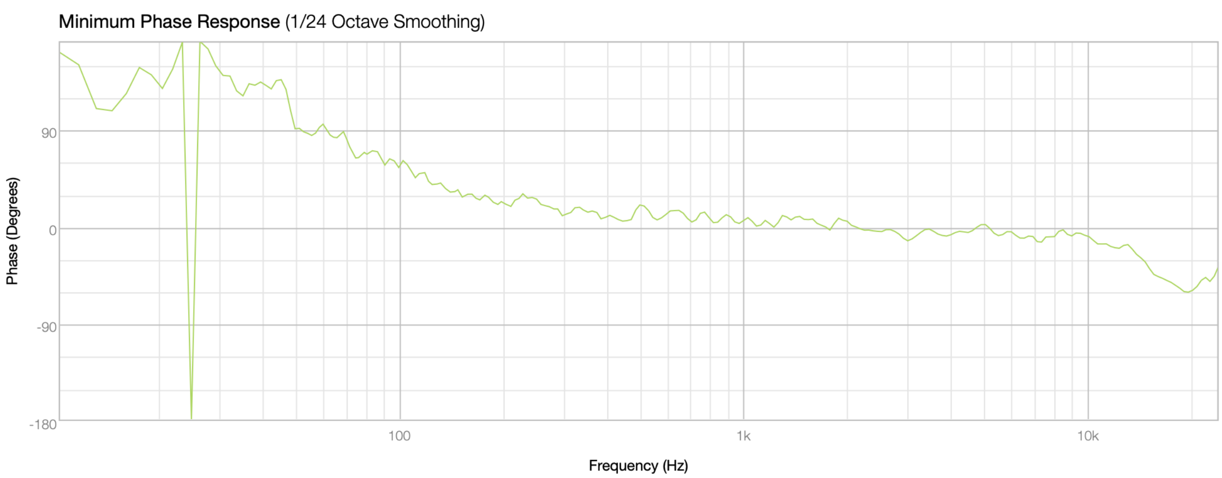
1m Woofer Harmonic Distortion @83dB SPL



1m Speaker Impulse Response



1m Speaker Minimum Phase Response



Bibliography

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