THE DG01 SPEAKERS, OR

A TALE OF TWO DRIVERS

Daniel Grayvold

FA4740: Transducer Theory

28 April, 2016

Functional Description

Goals

The DG01 monitors are close-field stereo listening speakers, designed as a jack-of-all-trades solution for my various creative home studio needs. They need to be flexible enough to keep up with my music composition, sound design, and film editing work.

As the pair will most likely spend the entirety of its life in a home environment, they need to be small enough to fit on a large desk with isolation pads. The environment will usually be at a quiet level to little background noise. Portability will not be a major factor as they will only move when I move between living spaces.

The type of room in which I would be using these speakers is a bedroom studio with minimal treating. Foam, hung carpets, and a couple of bass traps at the extreme would be the most extensive treatment for the room. Reflections will not be as big of a deal. As Newell and Holland explain, my goal is "remove the room response from the listening chain."[1] For this, they will be made for close-field (or near-field) use; most of the room reflections will be less important because they are taken out of the equation with the close listening range.

High SPL will not be a priority for these speakers, both as they are for listening at close range while at a workstation and meant only for a single user or two at a time. Flexibility comes from the MiniDSP digital crossovers I am employing; they may include settings for critical and leisure listening.

---

[1] Philip Newell and Keith Holland, *Loudspeakers For Music Recording and Reproduction* (New York: Focal Press, 2007), 252.

Listening Purposes

Tracking will not be a use case for these speakers as any recording of live instruments will be done in higher-quality spaces. If tracking is done in the same room as the monitors, headphones will be employed to avoid feedback. The purpose of the monitors, as stated before, is to be accurate for composition, sound design, and editing purposes, but also for listening purposes.

The DG01 speakers are for listening forward as opposed to listening backward. As I create and craft audio for various uses, I want to make sure what I am hearing is close to what the intended consumer will hear. While accuracy will be a factor, I will need to be thinking ahead and hearing ahead with these speakers.[2] As per the Range Rule, these speakers (particularly when set to the "listening" frequency response) will help me hear the sound in one of the many ways that users will hear what I create: in domestic spaces, with colored playback.[3] When I need them to be colored, I will have that option. The sound can be accurate or unreal, depending on my need.

Aesthetics

Since the speakers will be used in a home, I want them to look pleasing to the eye. They will be crafted from plywood and will be painted black. Professional, but not outmoded.

The monitors will be placed on a large desk as part of my creative workstation, and so they must not be too large or heavy. To approximate the size goal of my speakers, I aimed for the same ballpark dimensions as the JBL LSR308 monitors, about

---

[2] David Moulton, *Total Recording: The Complete Guide to Audio Production*. (Sherman Oaks, CA: KIQ Productions, 2000), 313-314.

[3] Ibid.

16” tall by 10” wide and 12” deep.[4] If the performance of the speakers required a larger size, I could budge a little bit from that. Weight followed size, but was unimportant unless they would be so heavy as to collapse a sturdy desk. It follows that portability would not be of any great concern because the monitors would stay at my home.

The outside would not need any protection other than that which wood should have to stay in good condition inside of a home environment. These are not meant to be taken outside through any elements. Neither will these speakers contain a grill, which would complicate the process of getting the clearest form of the audio to my ears, but a case may be made or bought in the future if and when they need to be moved.

SPL Output

As these monitors will be used for close-field listening with one or up to a few people at most in a home, these do not need to reach a very high output. I will only need to make sure that I hear what I need to hear at close range, and so the dynamic range of the speakers will be of bigger concern than a high maximum SPL. In the future, I may adjust the speakers so that they meet with THX and K20 standards.

Sound Quality Description

Some of the Audio Engineering Society’s terms assist me in explaining what I wanted from my speakers during the planning phase.[5] They needed to have good spectral uniformity—I wanted to hear a wide range of frequencies at a good balance. The stage needed to have good depth and image separation since my composition

---

[4] JBL Professional. *JBL Series 3 Powered Studio Monitors Owner's Manua*l. (Northridge, CA), 19.

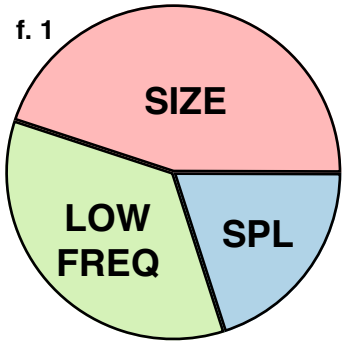
[5] *AES Recommended Practice for Professional Audio — Subjective Evaluation of Loudspeakers*. (New York: Audio Engineering Society, 2007), 16-18.

work will require precise placement of sound within a sonic field. Along with that, I needed appropriate dynamics and pianissimo clarity, since as a pianist my ears are accustomed to soft sounds and the timbre shifts between piano passages need to sound correct in order to achieve good playback. If possible, I also wanted there to be little fatigue with use of these speakers during a long session.

Prioritization Chart

To concisely display my priorities for these monitors, figure 1 is a chart—based on John Murphy's tradeoff charts—showing what I aimed for in the balance in these speakers.[6]

f. 1



As can be seen in figure 1, I deem the size to be the biggest factor in my speaker design, with low frequency coming in as a close second. If necessary, I can couple these speakers with a subwoofer to achieve the goal. SPL output is last on my list as they are close-field monitors and not made for the purpose of full-room listening.

Technical Specifications

Description

In the interest of keeping the design simple, the DG01s were designed as a vented-box speaker pair with two drivers each. After experimenting with a tape measure, I found that I wanted to keep these speakers within the dimensions of

---

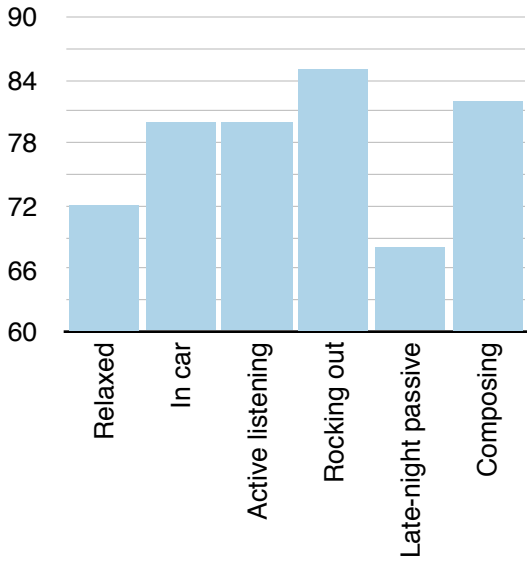
[6] Murphy, John L. *Introduction to Loudspeaker Design*. (Escondido, CA: True Audio, 1998), 78-82.

19”Hx15”W18”D. At this size, there would be plenty of room to place these speakers on most large desks.

For the same reasons, I wanted to keep these speakers under 50 pounds each. I can fairly easily lift that much weight, and it would provide some stability to the cabinet at that weight. Portability is again not a large concern as these speakers will not be moved around often. Once placed, they will likely stay in that same space until I move to a different home. If I decide to create a small studio, these will also fit in easily. Durability will just be a matter of making sure the speakers are able to be moved from one place to another in the back of my car, and since these are relatively small speakers, that should not be a problem.

The dispersion pattern of these speakers was to be fairly narrow horizontally. As they are small monitors meant for only a person or two to use at a time, they do not need to have great width. Additionally, I aim not to have the room’s reflections be an important matter, so a narrower horizontal pattern would help keep the sound away from the walls. Something around a 45-60º horizontal dispersion pattern should do it. Vertically, I will allow these speakers to have a larger dispersion pattern. The reason for this is because I am a fidgety person and will often change the height of whatever chair I am sitting in often during long composition sessions. These speakers will need to be able to give me a similar response no matter how low or high I am, without the

f. 2 Average Listening Level (dBA)



need for changing their position every time I change mine. Something between 30-50º vertical dispersion should accomplish the task.

Loudness

Through some experimentation, I have found some typical levels in decibels at which I typically listen to music and other audio. Figure 2 shows the average levels for certain situations and moods that I measured over time.

I also found that typically the maximum average level at which I listen to speakers is around 85-86 dBA. With that as my base, I can calculate the industry standard measurements. Using the K-20 system (which dictates that I need a 20-decibel crest factor at 83dbSPL)[7], I will need my speakers to be able to put out around 103dB maximum. However, the THX maximum marks nominal 0 to be 85dB C from where I am listening, with 20dB headroom.[8] Using this measurement would mean that I would need 105dB as my maximum level, which would fit in with a crest factor of 20dB above my maximum average listening level.

Through my experimentation, I found that there are a variety of levels at which I listen to music depending on where I am, what I am listening to, and how I am feeling while listening. Throughout all of my tests, I have found that I typically never go above 86 decibels as an average maximum. I do not often go below 65 decibels for any form of active listening either. More averages can be found in figure 2.

Power Handling

---

[7] "Level Practices (Part 2) (Includes the K-System)." Digital Domain (2013): 8, accessed 23 January 2016. http://www.digido.com/how-to-make-better-recordings-part-2.html.

[8] "THX Reference Level Explained." Acoustic Frontiers (2013). Accessed January 23, 2016. http://www.acousticfrontiers.com/2013314thx-reference-level/.

I am using MiniDSP to take care of crossover design and power amplification. The model I am using (the PWR-ICE125) allows for 125 watts of power for each speaker. This allows me to get the full possible range of loudness that I am looking for, which for a 100 watt amp is about 20dB.[9] Given that this amp provides 125 watts or 20.97 dBW of power, this is be perfect for my speakers. It even provides a little bit of wiggle room, which though most likely unnecessary for my drivers still gives some peace of mind in terms of flexibility.

Tone

During the lab work I completed during week 1, I found that I start to notice roll off of 6dB/octave anywhere between 25-40Hz depending on what I am listening to. After experimentation, I discovered that I am willing to put up with that factor of low frequency loss if it started as high as 40-70Hz. Anything above 80Hz is undesirable.

This is important because video editing, composition, and sound design all use low frequencies for effect and depth. Not being able to hear them could result in an inaccurate mix. Also, if I intend to work on music of all genres I need to be sure that my speakers can handle all of the frequencies necessary for accurate reproduction of sound. Some instruments, such as the tuba and the piano, can get quite low in the range, so being able to hear them will be important. The same goes for high frequencies as well; I intend for them to easily be able to reach all the way up to 20kHz.

As for everything in between, the speakers are fairly flat at the critical listening setting. The frequency response when set to listening for pleasure, however, will be less flat and more tuned for listening when I do not care about the accuracy of the speakers.

---

[9] Plummer, Christopher. Lecture, FA4740 Transducer Theory, MI, Houghton, January 20, 2016.

Driver Candidates - DG01 Speakers

WOOFERS												
Brand/Model (*=candidates)	**Size (“)**	**Price**	**Fs (Hz)**	**F3 (Hz, Q@0.7)**	**Qts**	**Passband (+/- dBSPL)**	**Sensitivity (dB)**	**Vb (ft³)**	**Max SPL (w/20dBW)**	**Xmax (mm)**	**Weight (kg)**	**Notes**
ScanSpeak 18W/8545-01	7	173.20	25	90	0.20	3, 100Hz to 1050Hz°	88	0.2151	108	6.5	2.3	°Could be made better with EQ
ScanSpeak Discovery 12W/8524G	4.5	58	52	120	0.32	1, 110Hz to 3100Hz	85.8	0.0766	105.8	3	1	
ScanSpeak Discovery 15W/8434G00*	5.25	64.30	45	140	0.25	1, 102Hz to 3300Hz	86.9	0.0660	106.9	4.2	1.2	
Zaph Audio ZA14W08*	5	39.95	65.84	110	0.44	2, 120Hz to 4000Hz	87	0.1176	107	3.25	1.1	
SB Acoustics SB15NRX 30-C4*	5	51.40	41	100	0.29	2.5, 102Hz to 2000Hz	91	0.1222	111	5	1.48	
ScanSpeak 22W/4534G00	8	79.25	30	64	0.34	1, 90Hz to 900Hz	92.4	1.034	112.4	5.7	2.1	
Fountek FW168	6.5	44.80	45	80	0.40	3.5, 150Hz to 2000Hz	87.3	0.2764	107.3	4.6	1.76	
Dayton Audio PA310-8 Pro	12	66.75	39	95	0.29	1.5, 70Hz to 1000Hz	96.1	0.6713	116.1	5	-	
Dayton Audio PA165-8*	6	17	80.8	140	0.47	3, 80Hz to 1.4kHz	92.9	0.2627	112.9	0	1.91	
PRV Audio 6MB200	6.5	29.99	123.3	70	1.25	1, 100Hz to 1100Hz	93	-0.236	113	3.5	3.34	
Eminence Alpha-8A	8	44.99	73	87	0.59	2, 90Hz to 2000Hz	94	1.546	114	3.2	1.9	
SB Acoustics SB16PFC25-8	6	25.50	38	66	0.4	3.5, 100Hz to 2kHz°	87	0.4621	107	4.5	0.96	°Could be improved to 1.5-2 with EQ

TWEETERS												
Brand/Model	**Size (“)**		**Fs (Hz)**			**Passband (+/- dBSPL)**	**Sensitivity (dB)**		**Max SPL (w/20dBW)**		**Weight (kg)**	**Notes**
ScanSpeak D26069200*	1		1100			1.5, 1kHz to 21kHz	91.4		111.4		0.5	
ScanSpeak D2604/8330*	1		475			2, 1kHz to 20kHz	93		113		0.8	
SB Acoustics SB26STCN-C000-4	1		950			1, 900Hz to 10kHz	92		112		0.1	
SB Acoustics SB Acoustics SB19ST-C000-4	0.75		980			1, 1kHz to 20kHz	88.5		108.5		0.32	
Dayton Audio DC25T-8	1		1468			1, 1.8kHz to 15kHz	93		113		0.45	
Morel CAT 308	1.125		650			2, 2kHz to 15kHz	90		110		0.573	
Tymphany OC25SC65-04	1		1382.2			3.5, 1kHz to 15kHz°	93.18		113.18		0.05	°Could be improved to 1.5-2 with EQ
Dayton Audio ND25TA-4	1		1470			1.5, 1.8kHz to 10kHz	91		111		0.09	
Tymphany XT25SC90-04	1		824.75			4, 1kHz to 15kHz	86.8		106.8		0.07	
SB Acoustics SB26STAC-C000-4*	1		750			1, 800Hz to 30kHz	91		111		0.53	
Tymphany BC25TG15-04	1		1128			1.5, 1kHz to 15kHz	89.8		109.8		0.5	
SEAS Prestige 22TAF/G (H1283)	0.87		1100			1.5, 1.2kHz to 21kHz	92		112		0.5	

f. 3 Driver Selection Chart

∞

A port was used to extend the low range. This caused a loss in transient accuracy which I deem to be an unfortunate but necessary loss in order to be able to actually hear the full range of sound I am looking to get.[10]

I did want inner reflections to color the sound of my speakers, so I will take steps to prevent that from happening. To deaden some of the high frequencies inside of the box, I looked into using acoustic foam or other suitable materials.

Cabinet Design

These were of the vented box design. As I have mentioned previously, my goal dimensions for this pair of speakers was 19”Hx15”W18”D. They cannot be so heavy as to need carrying by multiple people for a single speaker, but since their form factor is relatively small this should not be an issue.

The speakers are rectangular to avoid some of the issues that square boxes can have. The vertical range is meant to be wider than the horizontal range due to my constant movement while sitting. The box itself is made out of 3/4” plywood on the outside and 1/2” MDF on the inside. In the future, the speakers will be painted black.

Driver Research & Selection

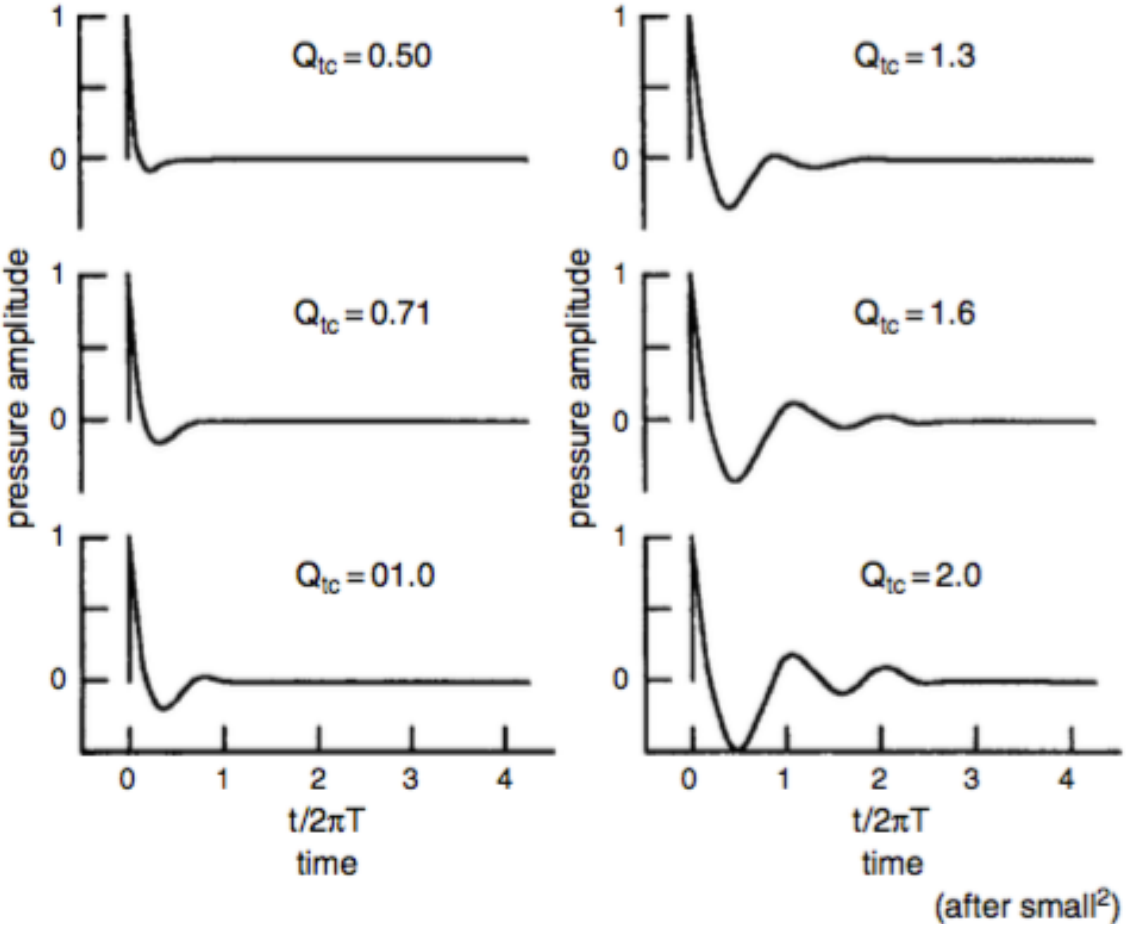
Figure 3 is a chart including the woofers and tweeters I researched. Candidates for final selection are highlighted. Following this chart are the specification sheets for each of the woofers and tweeters that I researched. Modeling is based on a 100-watt power supply.

---

[10] [10] Philip Newell and Keith Holland, *Loudspeakers For Music Recording and Reproduction* (New York: Focal Press, 2007), 327-329.

Based on the research on drivers that I conducted, I found that for a vented box design a good Q to work toward for my goal of low bass reach would be between 0.5 and 0.9. This introduces some time delay in the response. However, if we refer to Newell and Holland's chart measuring the effects that Q has on time (figure 4[11]), we can see that this is not a huge deal since my Q is going to be fairly low anyway. From calculations in Winspeakerz, I find that it could be as good as 0.54.

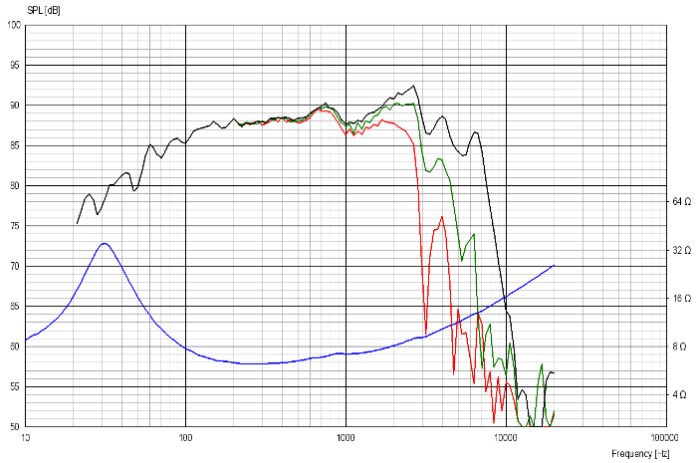
f. 4 Effects of Q on time response



(New

ScanSpeak

Classic 18W/8545-01 New 7" Mid Woofer Paper Cone[12]

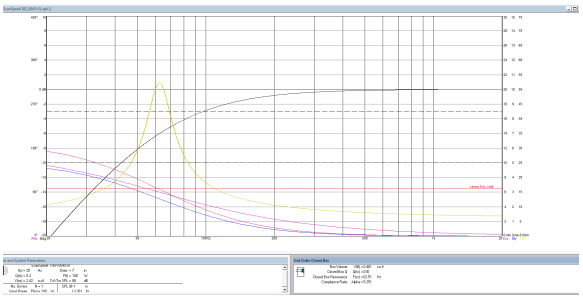


Specifications:

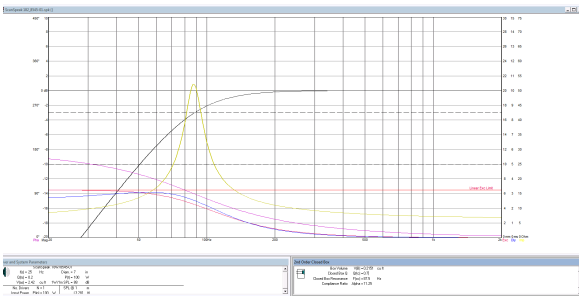
Cost: $173.20
Size: 7”
+/- 3dBSPL in Bandpass 100Hz to 1050Hz
Breakup starts at: 1180Hz
Breakup amplitude peak: 92.5dB
Recommended crossover: 3rd order at 1000Hz
Thermal Power handling: 100 watts

Narrative:

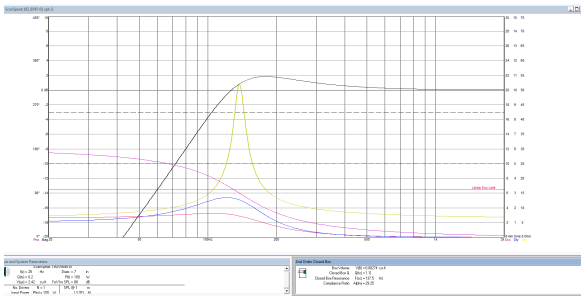
This woofer gets reasonably low frequency coverage for my speakers, and at a 1.1Q could get a bit of a bass boost as well at around 100Hz, although there is a significant spike in impedance as the resonant frequency is reached. At a sensitivity of 88dB, this would be well within the 100-200 watt limit I am aiming for. With a 2nd order crossover, I could get a relatively flat response all the way up to 2kHz.



0.5Q



0.7Q

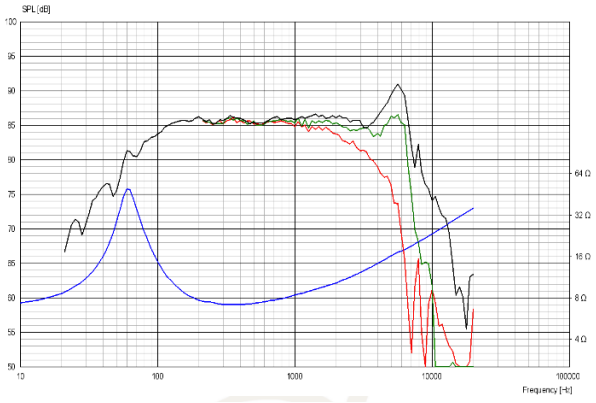


1.1Q

[12] ScanSpeak. *CLASSIC MIDWOOFER 18W/8545-01 Transducer Specification Sheet*. PDF. Middleton, WI: The Madisound Speaker Store. Accessed 29 January 2016

ScanSpeak

Discovery 4.5” 12W/8524G00[13]

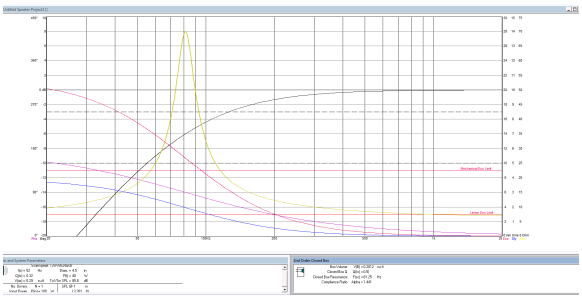


Specifications:

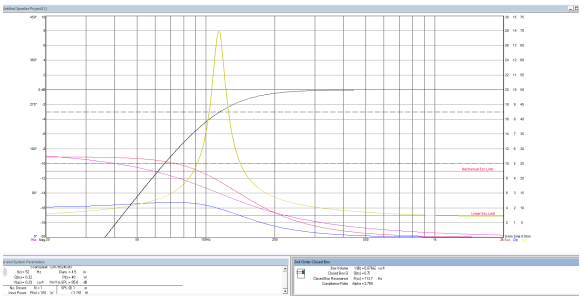
Cost: $58
Size: 4.5”
+/- 1dBSPL in Bandpass 110Hz to 3100Hz
Breakup starts at: 5800Hz
Breakup amplitude peak: 91dB
Recommended crossover: 2nd order at 2kHz
Thermal Power handling: 40 watts

Narrative:

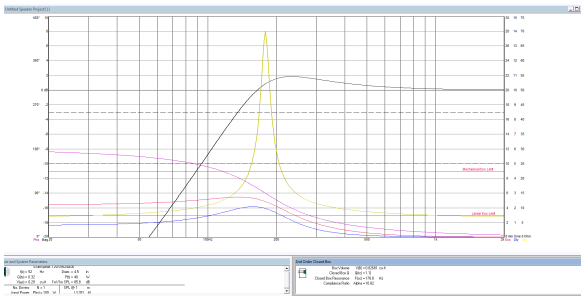
The Discovery woofer has great frequency response flatness with +/-1dB max difference in its usable range. A high breakup frequency would allow me flexibility with crossover placement, and the roll-off seems flat enough to allow me to fix the curve if I so desire, making for a great frequency response in relatively small speakers.



0.5Q



0.7Q

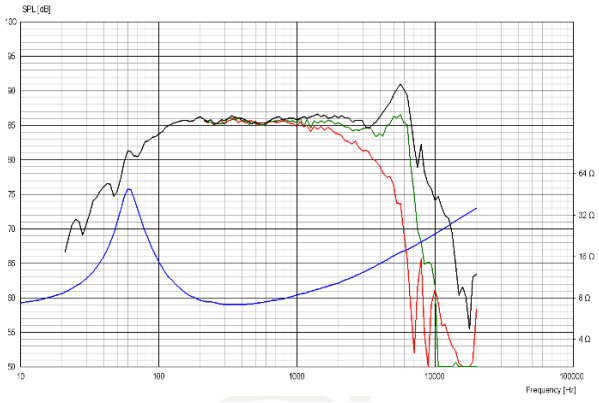


1.1Q

[13] ScanSpeak. *DISCOVERY MIDWOOFER 12W/8524G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 7 February 2016.

ScanSpeak

Discovery 5.25” 15W/8434G00[14]

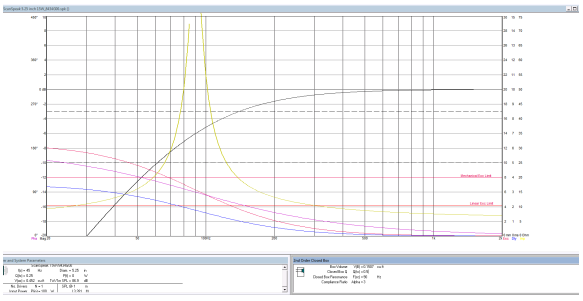


Specifications:

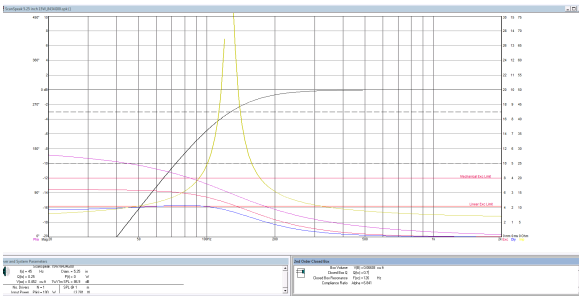
Cost: $64.30
Size: 5.25”
+/- 1dBSPL in Bandpass 102Hz to 3300Hz
Breakup starts at: 5600Hz
Breakup amplitude peak: 91dB
Recommended crossover: 1st order at 2kHz
Thermal Power handling: 60 watts

Narrative:

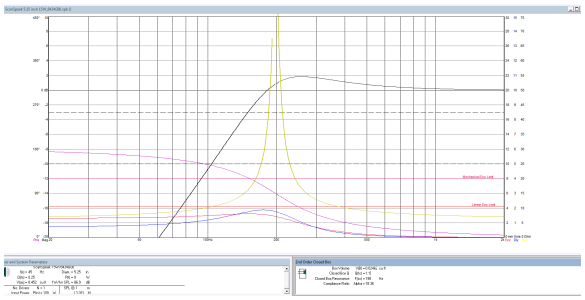
Much like the previous ScanSpeak (the 4.5” model), this Discovery driver has a great flat frequency response in the usable range, as well as a very similar low end roll-off. The breakup frequency is slightly lower at 5.6kHz, but has a higher sensitivity rating. A first-order crossover at 2.8kHz would allow for a longer, still-flat frequency response all the way up to the low high-end frequencies.



0.5Q



0.7Q

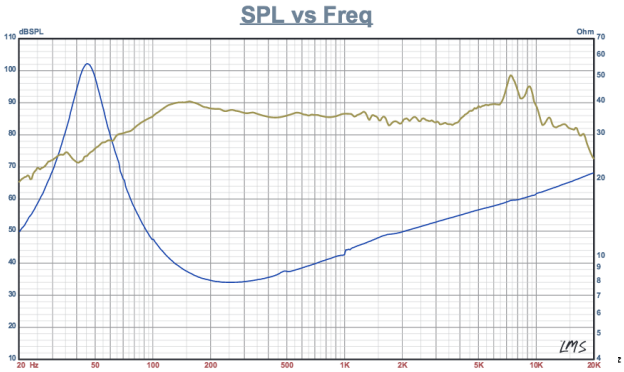


1.1Q

[14] ScanSpeak. *DISCOVERY MIDWOOFER 15W/8434G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 7 February 2016.

Zaph Audio

5” ZA14W08[15]

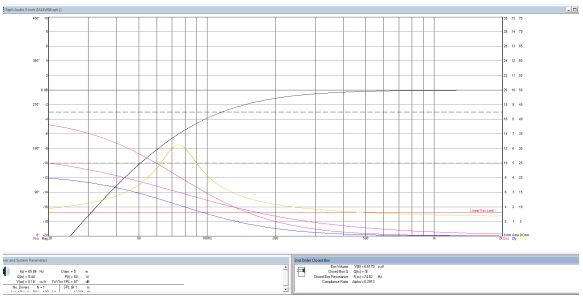


Specifications:

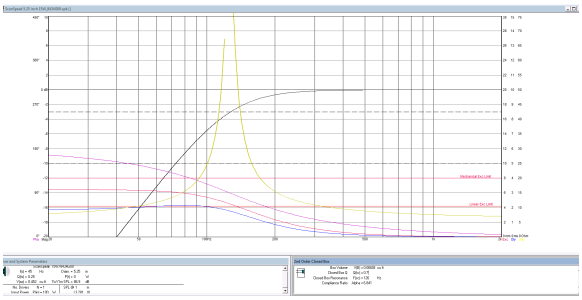
Cost: $39.95
Size: 5”
+/- 2dBSPL in Bandpass 120Hz to 4000Hz
Breakup starts at: 9000Hz
Breakup amplitude peak: 99dB
Recommended crossover: 3rd order at 3kHz
Thermal Power handling: 60 watts

Narrative:

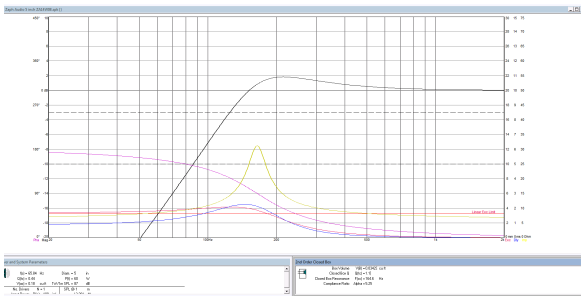
This driver features a smooth roll-off with a relatively low impedance jump at the resonant frequency. The crossover could be a little difficult to manage, but the usable range of the driver is flat enough to more than make up for any problems.



0.5Q



0.7Q

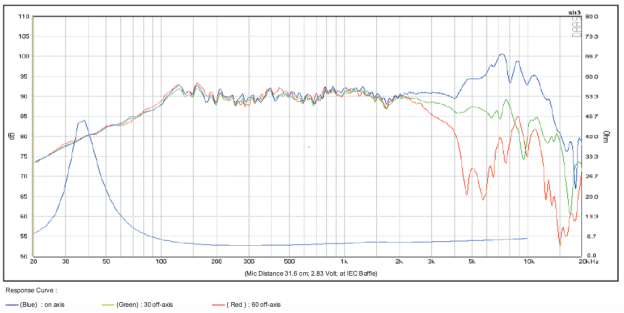


1.1Q

[15] Zaph Audio. *ZA14W08 Transducer Specification Sheet*. PDF. Accessed 7 February 2016.

SB Acoustics

5” SB15NRXC30-4[16]

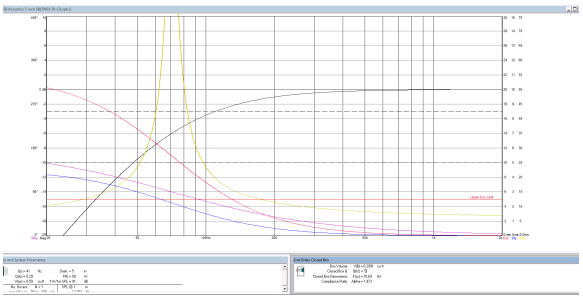


Specifications:

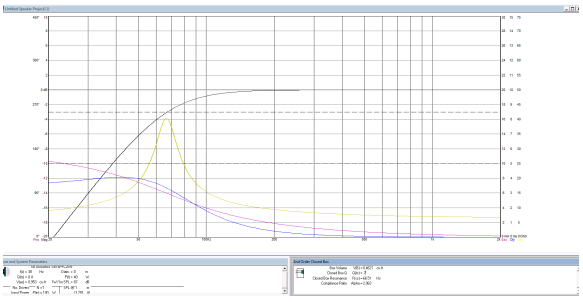
Cost: $51.40
Size: 5”
+/- 2.5dBSPL in Bandpass 102Hz to 2000Hz
Breakup starts at: 7200Hz
Breakup amplitude peak: 100dB
Recommended crossover: 3rd order at 4kHz
Thermal Power handling: 50 watts

Narrative:

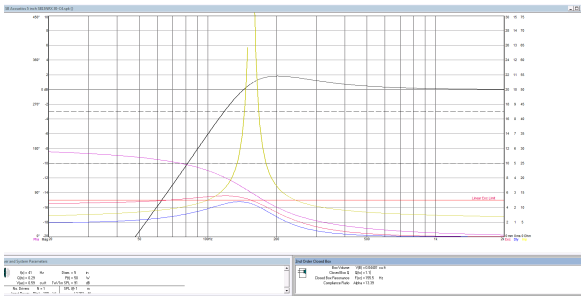
This driver has a bit of a bumpy frequency response at the usable range, but also manages to have a less steep roll-off on the low end. Off-axis response on the high end is largely variable, but this is of little concern to me because I plan to have close-field monitors only to be used by one or two people at a time. The impedance spike ends up being lower than most others. A high sensitivity rating would help to make sure I do not reach the maximum amplitude.



0.5Q



0.7Q



1.1Q

[16] SB Acoustics. *SB15NRX 30-C4 Transducer Specification Sheet*. PDF. Accessed 7 February 2016.

Fountek

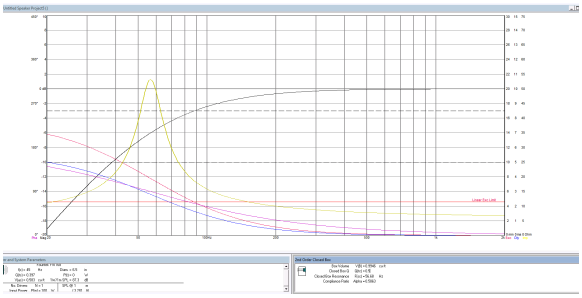
6.5” FW168[17]

Specifications:

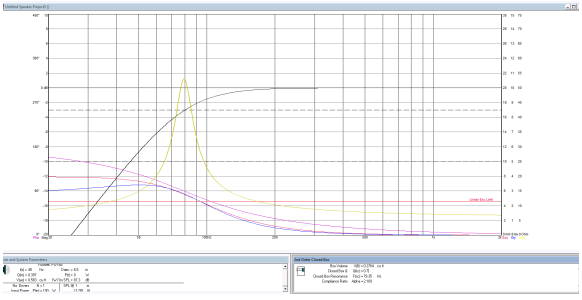
Cost: $44.80
Size: 6.5”
+/- 3.5dBSPL in Bandpass 150Hz to 2000Hz
Breakup starts at: 7400Hz
Breakup amplitude peak: 98dB
Recommended crossover: 1st order at 2kHz
Thermal Power handling: 50 watts

Narrative:

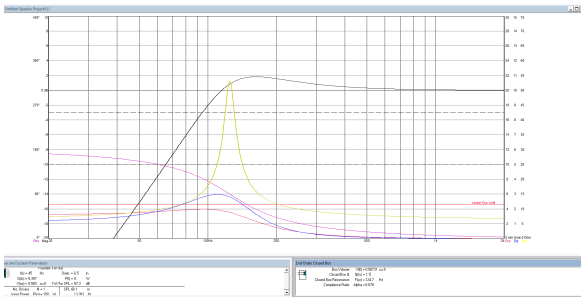
This driver goes low, but an impedance spike makes this a less attractive option. The usable range has somewhat large variability. A crossover at 4kHz would help to smooth out the response at the high end, but for the price it is an alright option, so this could be a feasible option if my budget ends up being lower than expected.



0.5Q



0.7Q

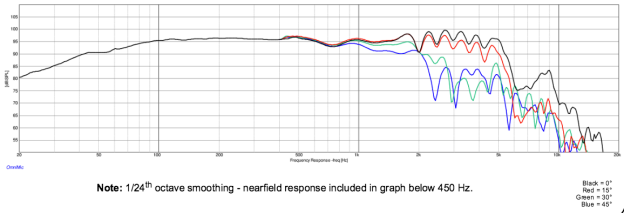


1.1Q

[17] Fountek. *FW168 Transducer Specification Sheet*. PDF. Zhe Jiang, China. Accessed 8 February 2016.

Dayton Audio

12” PA310-8 Pro[18]



Note: 1/24th octave smoothing - nearfield response included in graph below 450 Hz.

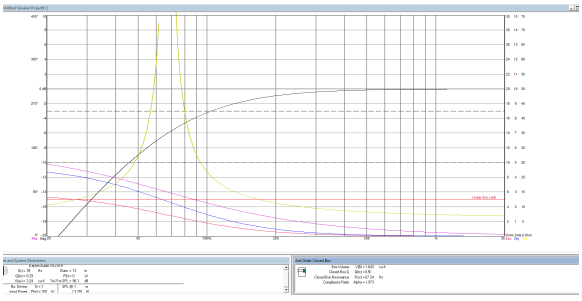
Black = 0°
Red = 15°
Green = 30°
Blue = 45°

Specifications:

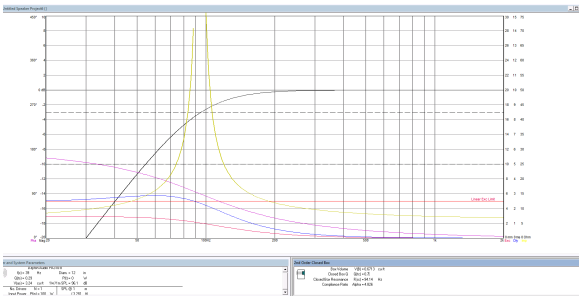
Cost: $66.75
Size: 12”
+/- 1.5dBSPL in Bandpass 70Hz to 1000Hz
Breakup starts at: 1800Hz
Breakup amplitude peak: 100dB
Recommended crossover: 2nd order at 1kHz
Thermal Power handling: 450 watts

Narrative:

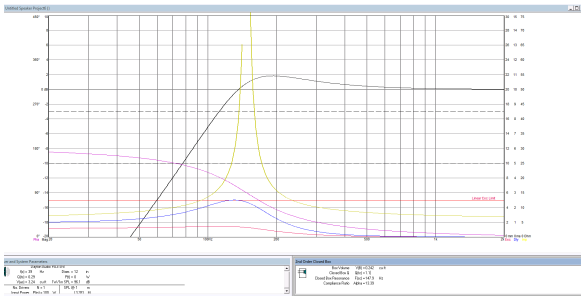
This large driver would just fit in the higher end of my speakers’ size estimate. With its size comes the lower-shifted usable range, which goes low but also does not go very high. The crossover should be able to manage the breakup but the tweeter would have to go low to make up for the low high frequencies. The driver also has an impedance of around 150 ohms at 40 Hz, so that would be trouble to work with. This seems to need too much power to be plausible for use with
my speaker design.



0.5Q



0.7Q



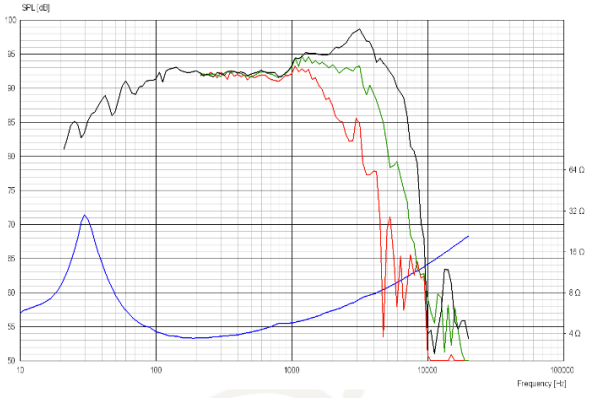
1.1Q

---

[18] Dayton Audio. *Dayton Audio PA310-8 12" Pro Woofer 8 ohm Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 8 February 2016.

ScanSpeak

Discovery 8” 22W/4534G00[19]

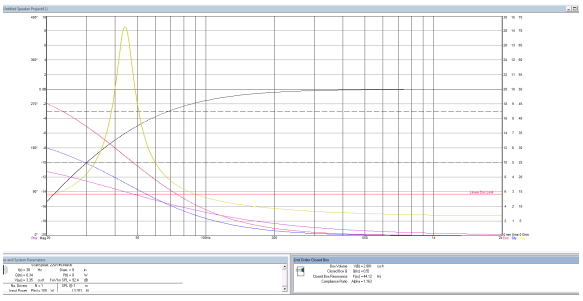


Specifications:

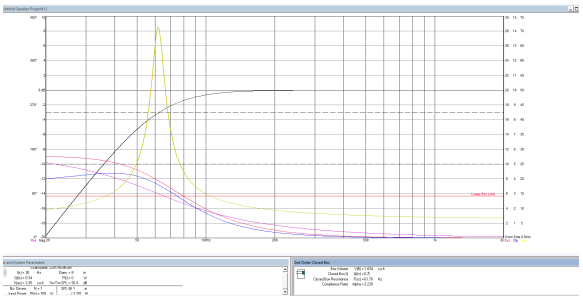
Cost: $79.20
Size: 8”
+/- 1dBSPL in Bandpass 90Hz to 900Hz
Breakup starts at: 3100Hz
Breakup amplitude peak: 98.9dB
Recommended crossover: 4th order at 1kHz
Thermal Power handling: 70 watts

Narrative:

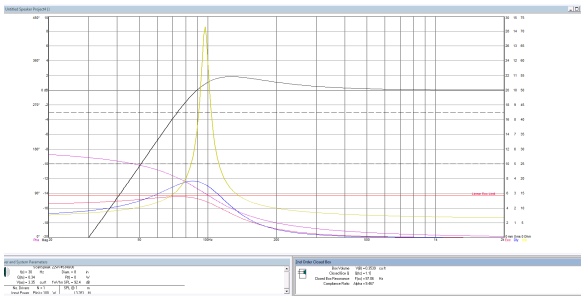
This driver has a fairly narrow range but again comes with the ability to go loser. The impedance of this driver is good and it can get loud, so if I end up wanting more power, this may work if I can find a tweeter that can take care of the low high frequencies.



0.5Q



0.7Q

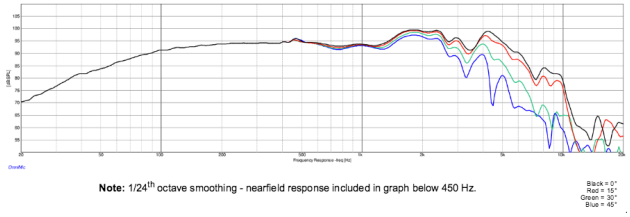


1.1Q

[19] ScanSpeak. *DISCOVERY WOOFER 22W/4534G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 8 February 2016.

Dayton Audio

6” PA165-8[20]

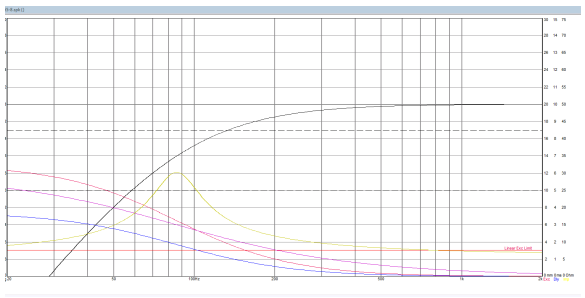


Specifications:

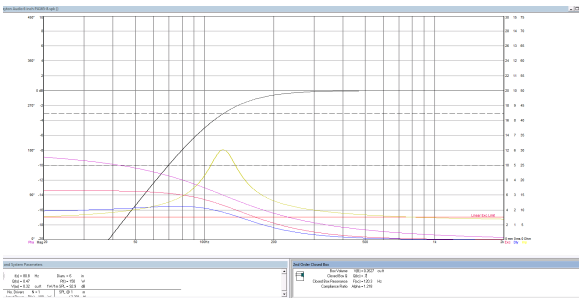
Cost: $17
Size: 6”
+/- 3dBSPL in Bandpass 80Hz to 1.4kHz
Breakup starts at: 1.8kHz
Breakup amplitude peak: 99dB
Recommended crossover: 2nd order at 1.3kHz
Thermal Power handling: 75 watts

Narrative:

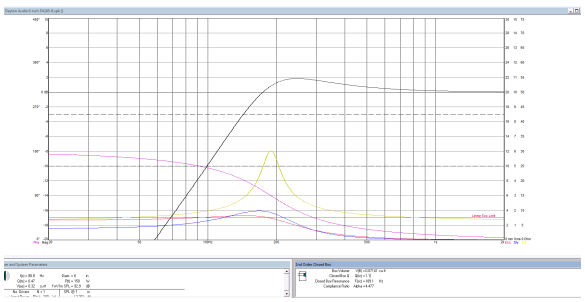
For such a cheap driver, this seems to have a surprisingly good set of specifications. The manufacturer claims that it was made “with the goal of the producing the highest possible output from a driver its size.” It seems to live up to that goal with a high output and a good roll-off at the low end. It may be tricky to make the crossover work, though.



0.5Q



0.7Q

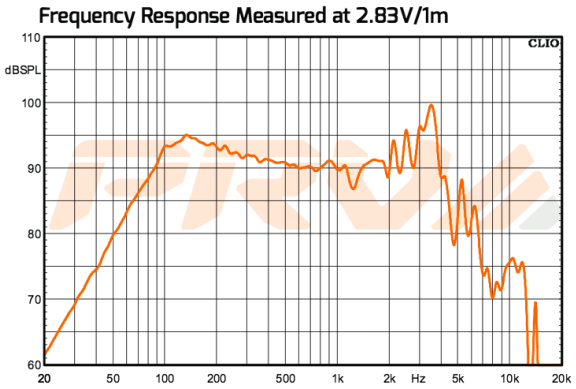


1.1Q

[20] Dayton Audio. *Dayton Audio PA310-8 12" Pro Woofer 8 ohm Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 8 February 2016.

PRV Audio

6.5” 6MB200[21]

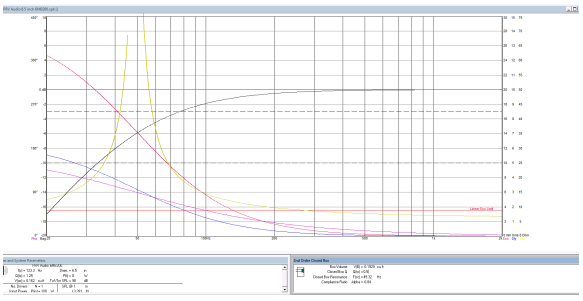


Specifications:

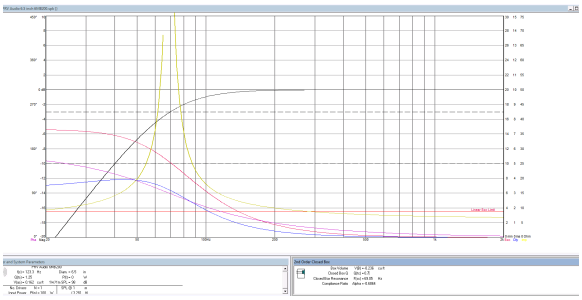
Cost: $29.99
Size: 6.5”
+/- 1dBSPL in Bandpass 100Hz to 1100Hz
Breakup starts at: 2100Hz
Breakup amplitude peak: 99dB
Recommended crossover: 4th order at 1.3kHz
Thermal Power handling: 100 watts

Narrative:

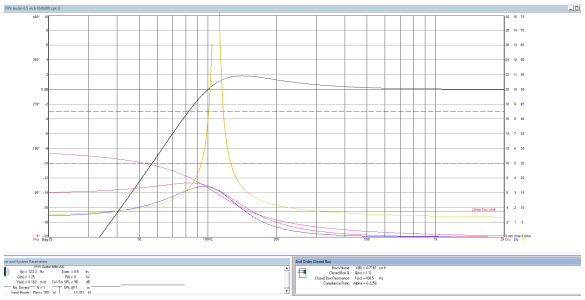
This is a cheap driver, and it shows. The usable frequency range is narrow, and once we reach the breakup of the driver, everything goes south. The bass is not that great either. In fact, the only thing really going for it is its price to loudness. This may work for a 3-way system or greater, but may not be the best choice for my speakers.



0.5Q



0.7Q

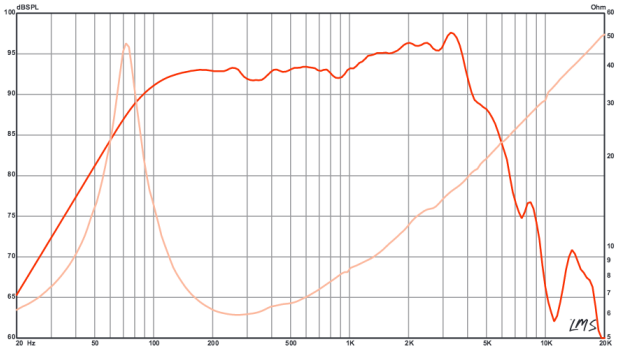


1.1Q

[21] PRV Audio. *6MB200 Transducer Specification Sheet*. PDF. Sao Leopoldo, Brazil. Accessed 8 February 2016.

Eminence

8” Alpha-8A[22]

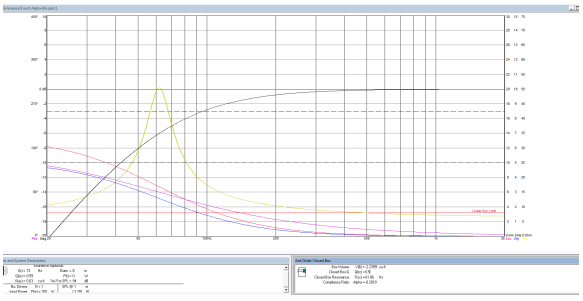


Specifications:

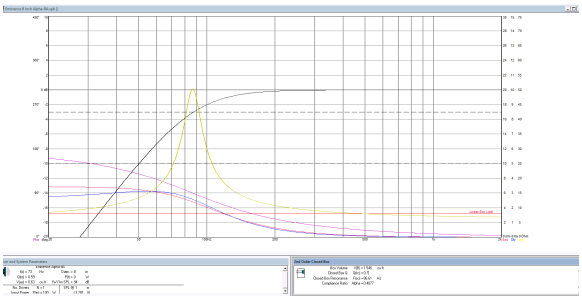
Cost: $44.99
Size: 8”
+/- 2dBSPL in Bandpass 90Hz to 2000Hz
Breakup starts at: 1200Hz
Breakup amplitude peak: 97dB
Recommended crossover: 2nd order at 1kHz
Thermal Power handling: 125 watts

Narrative:

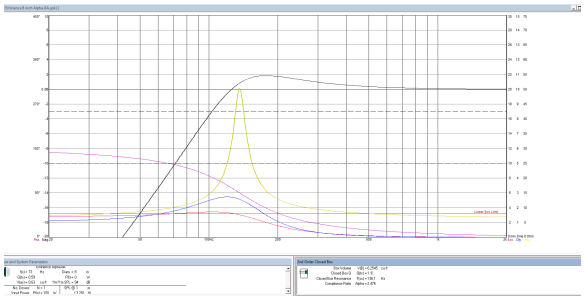
For its price, this seems to be a fairly sensible choice for a woofer because of its wider usable frequency range. Its impedance is quite high at the low end, but it seems to be quite loud enough for my speakers’ purposes. The crossover should be a simple matter; with a first-order crossover at 1kHz, the tweeter would have to go low but I would not have to fight the response of this woofer.



0.5Q



0.7Q

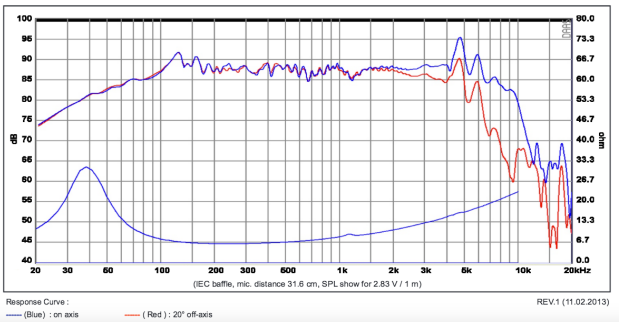


1.1Q

[22] Eminence. *Eminence American Standard Series Alpha-8A Transducer Specification Sheet*. PDF. Eminence, Kentucky: Eminence Speaker LLC. Accessed 8 February 2016.

SB Acoustics

6” SB16PFC25-8[23]

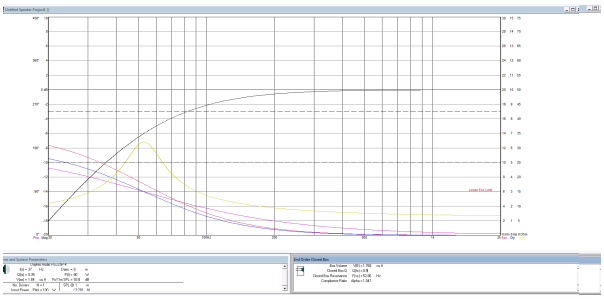


Specifications:

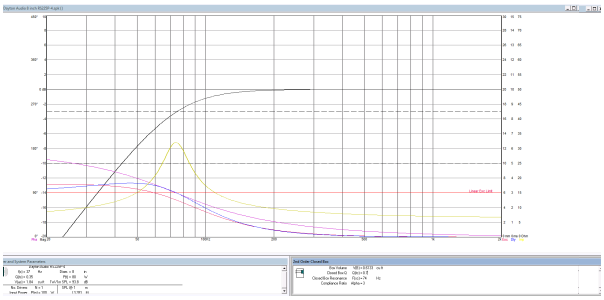
Cost: $25.50
Size: 6”
+/- 3.5 dBSPL in Bandpass 100Hz to 2000Hz
Breakup starts at: 4.6kHz
Breakup amplitude peak: 95.2dB
Recommended crossover: 3rd order at 2kHz
Thermal Power handling: 40 watts

Narrative:

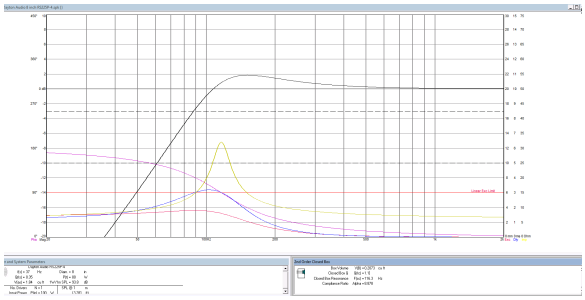
This seems at first glance to be a quite flat driver (given a little EQ) with a fairly good roll-off at the low end. Another plus is that the breakup frequency is fairly high, which would give me flexibility with the tweeter. However, the power handling also seems quite low, a little too low for what I need.



0.5Q



0.7Q



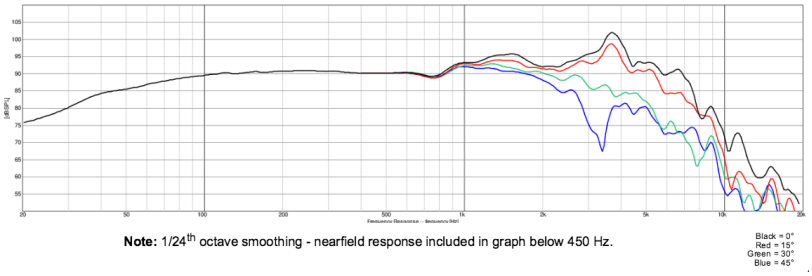
1.1Q

---

[23] SB Acoustics. *SB16PFC25-8 Transducer Specification Sheet*. PDF. Accessed 14 February 2016.

Dayton Audio

8” RS225P-4[24]

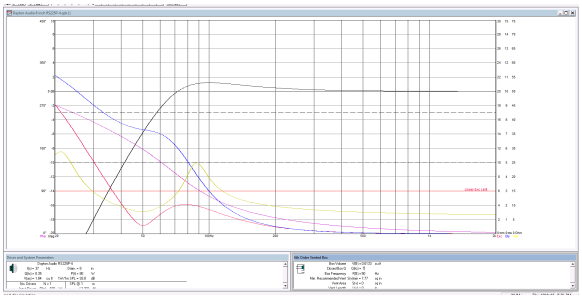


Specifications:

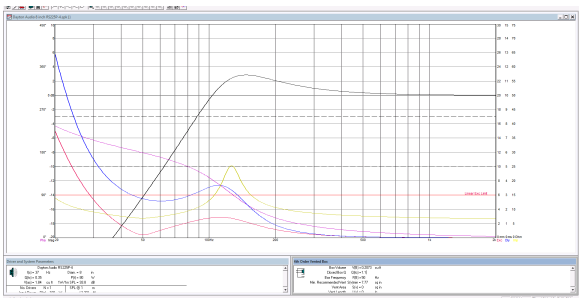
Cost: $61.85
Size: 8”
+/- 2.5dBSPL in Bandpass 90Hz to 2000Hz
Breakup starts at: 1Hz
Breakup amplitude peak: 102dB
Thermal Power handling: watts

Narrative:

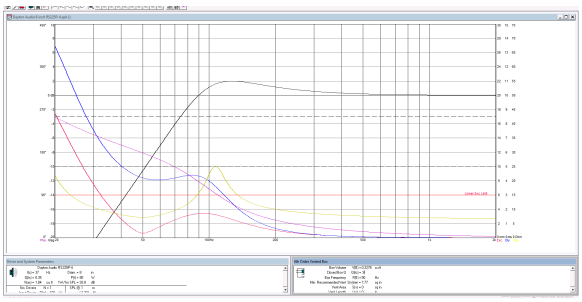
This driver seems to have enough power for all of my applications and can get quite far down into the low end. This would help achieve my goal of getting the low frequencies while remaining relatively low-cost.



Extended Shelf



Bass Boost

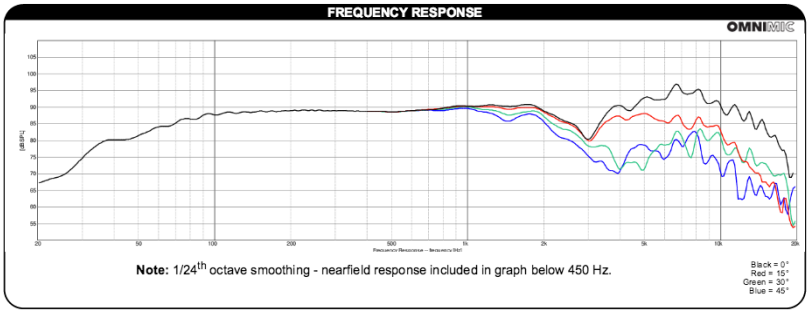


Critically Damped (almost)

[24] Dayton Audio. *Dayton Audio RS225P-4 Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 20 February 2016.

Dayton Audio

8” RS225-8[25]

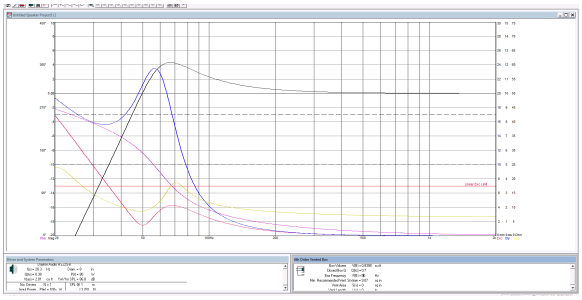


Specifications:

Cost: $53
Size: 8”
+/- 2.5dBSPL in Bandpass 90Hz to 2000Hz
Breakup starts at: 2kHz
Breakup amplitude peak: 97dB
Thermal Power handling: 80 watts

Narrative:

This appears to be the ideal woofer for my needs. It goes low enough for what I need and is inexpensive for what it delivers.

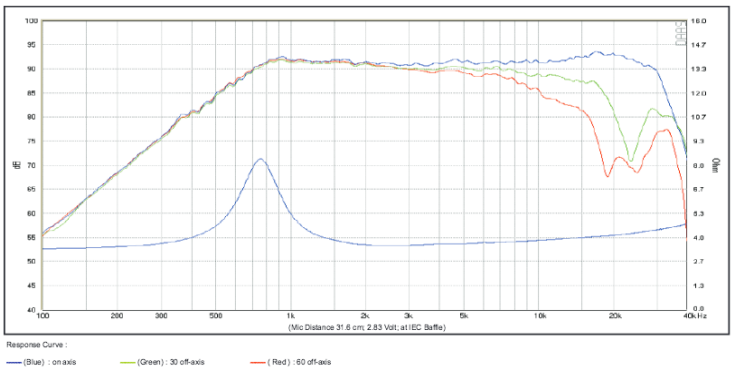


Bass Boost

[25] Dayton Audio. *Dayton Audio RS225P-4 Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 20 February 2016.

SB Acoustics

SB26STAC-C000-4[26]



Specifications:

Cost: $41.60
Size: 1”
+/- 1 dBSPL in Bandpass 800Hz to 30,000Hz
Breakup starts at: 17kHz
Breakup amplitude peak: 93dB
Recommended crossover: 4th order at 18kHz
Thermal Power handling: 120 watts

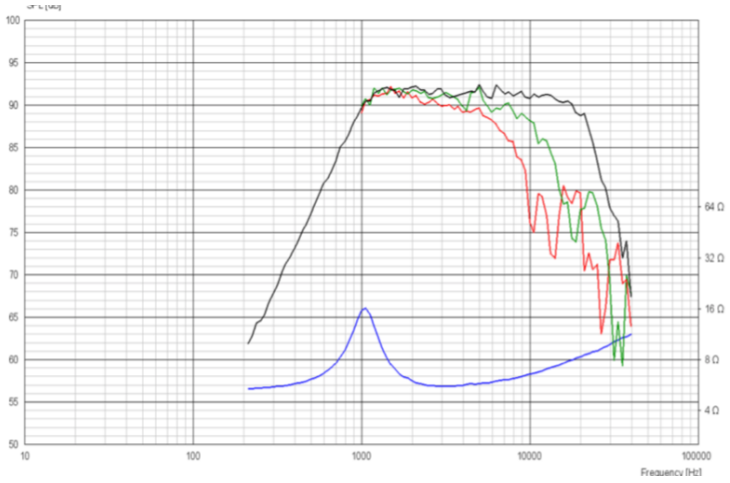
Narrative:

This tweeter has an excellent reach in frequency range with a relatively low cost. It fits with my planned woofer in terms of crossover and has plenty of power handling for my needs. This driver would be a great fit for my speakers.

[26] SB Acoustics. *SB26STAC-C000-4 Transducer Specification Sheet*. PDF. Accessed 14 February 2016.

ScanSpeak

D2606/9200[27]



Specifications:

Cost: $47.50
Size: 1”
+/- 1 dBSPL in Bandpass
1000Hz to 18,000Hz
Breakup starts at: 10kHz
Breakup amplitude peak: 92dB
Recommended crossover: 4th order at 1.7kHz
Thermal Power handling: 100 watts

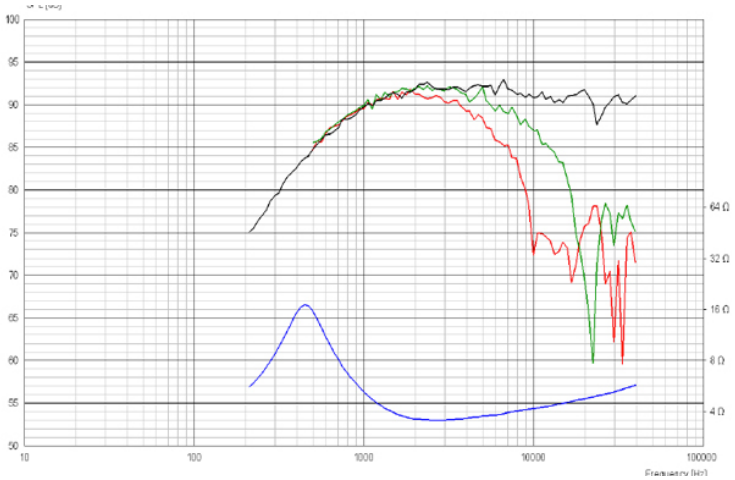
Narrative:

This tweeter has an alright response, not too wide but also not too narrow for the price. The power handling amount is just right and is not too expensive. However, the response range may be slightly limiting for my speaker plans.

[27] ScanSpeak. *D2606/9200 Transducer Specification Sheet*. PDF. Accessed 14 February 2016.

ScanSpeak

D2604/8330[28]



Specifications:

Cost: $59.60
Size: 1”
+/- 1 dBSPL in Bandpass
1000Hz to 20,000Hz
Breakup starts at: 5kHz
Breakup amplitude peak: 93dB
Recommended crossover: 4th order at 1.5kHz
Thermal Power handling: 100 watts

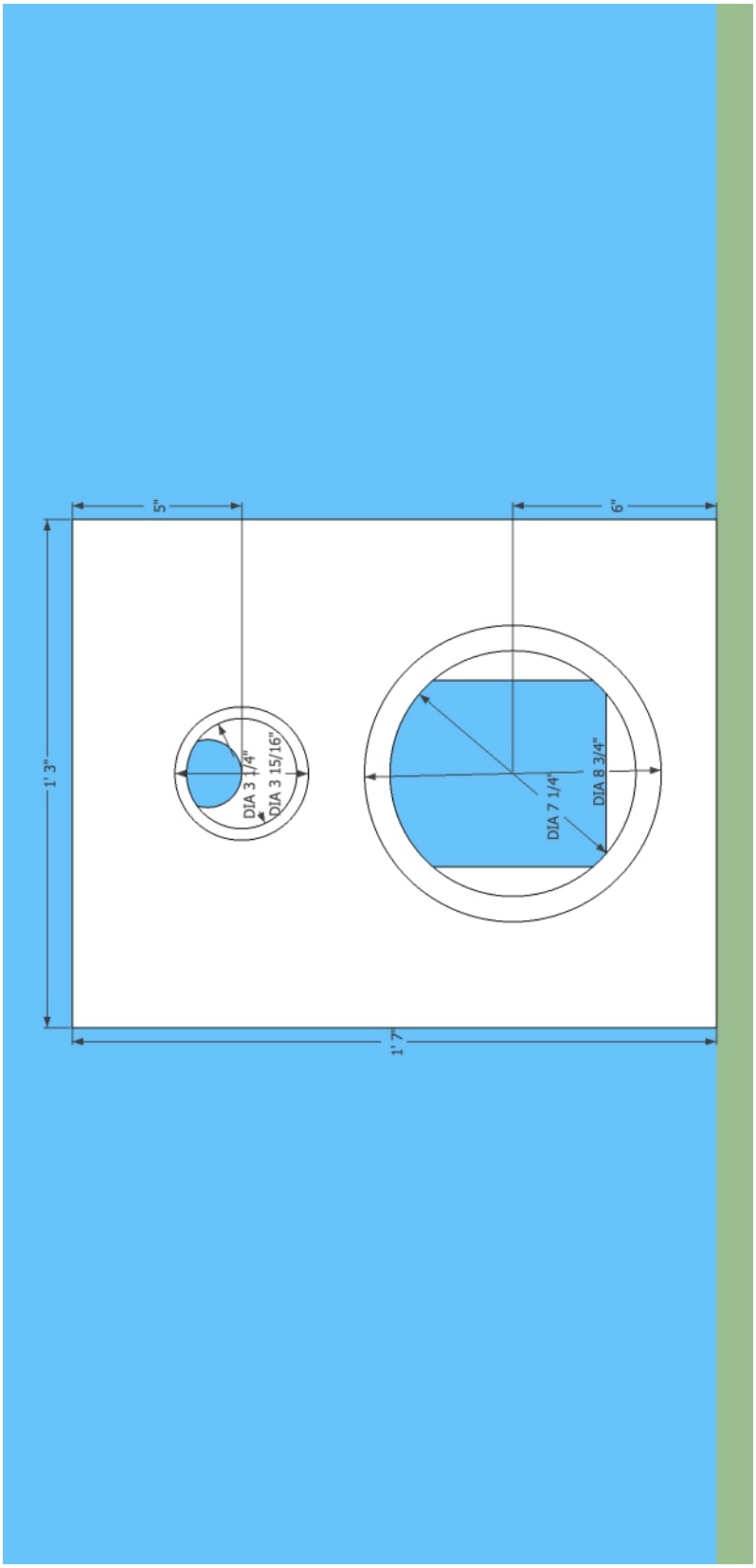
Narrative:

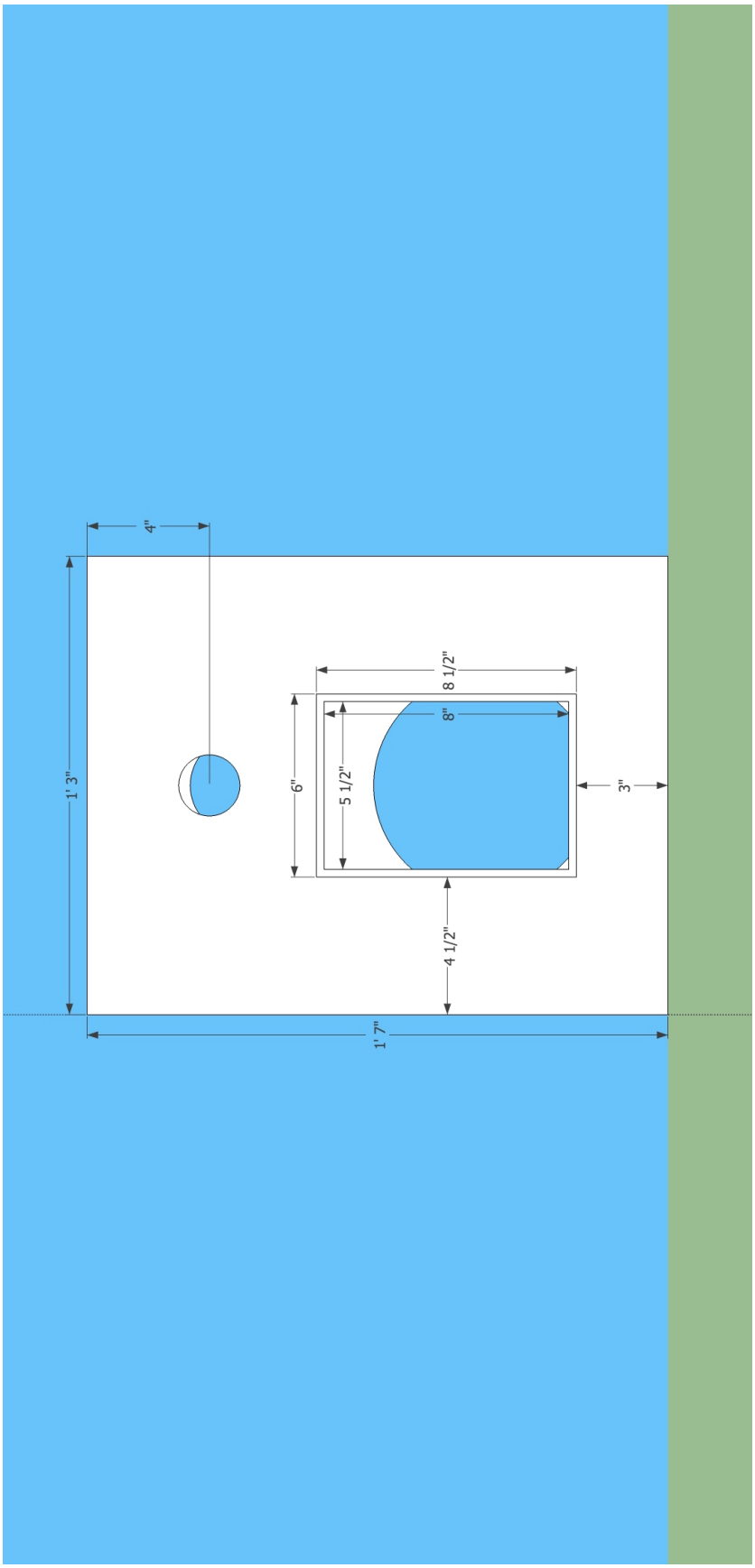
This driver was in the upper range of costs for my plans but had a fairly good frequency response for the price. The resonant frequency was shockingly low (440Hz!) but as my woofer goes much higher than that, I do not deem it to be as important as other factors. This would be a good secondary choice for a tweeter. Based on my research of drivers, I have found that the Dayton Audio RS225-8 would best fit my needs for a woofer. It has a good amount of low end and loudness without a very high price. To go along with it, I believe that the SB Acoustics SB26STAC-C000-4 tweeter would work well.

---

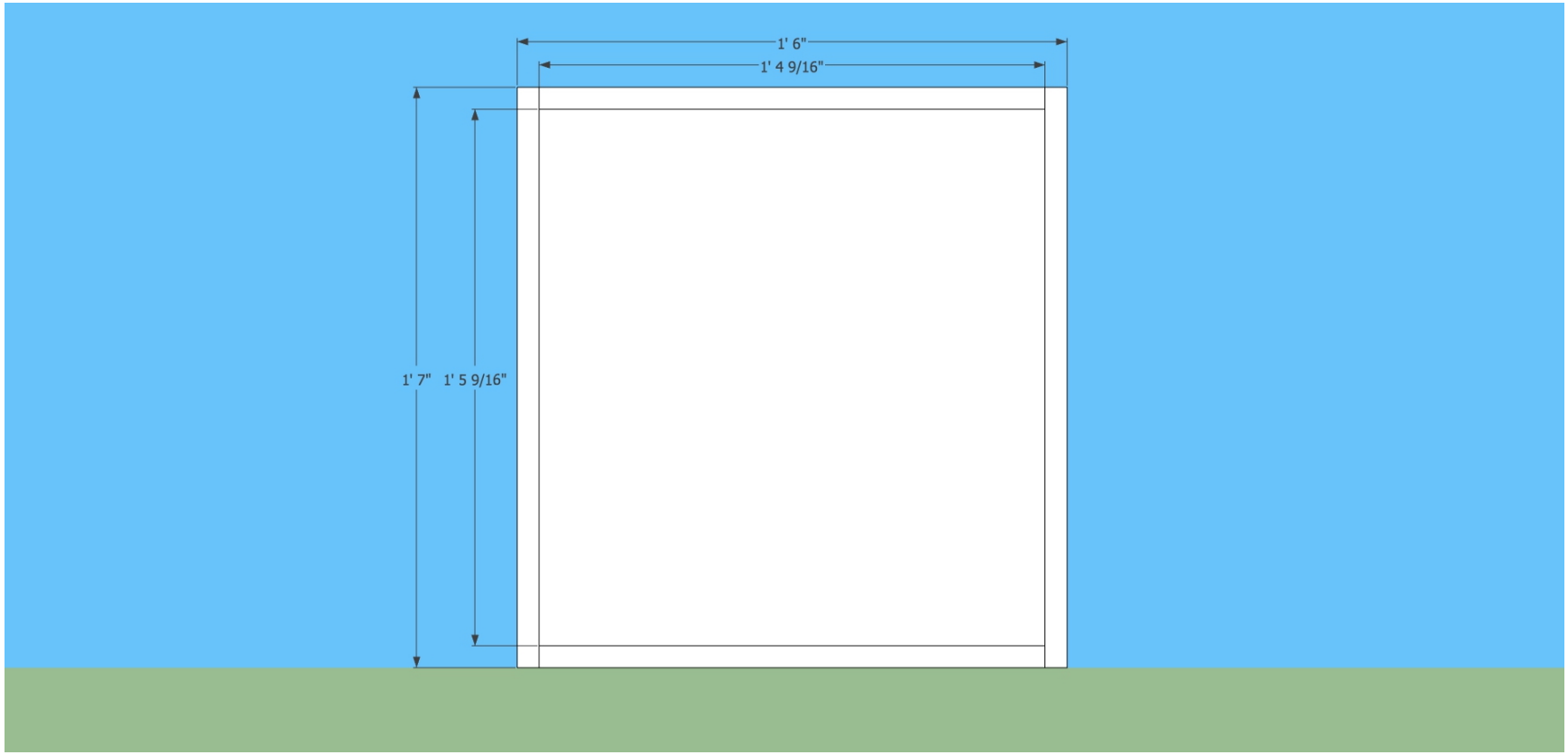
[28] ScanSpeak. *D2604/8330 Transducer Specification Sheet*. PDF. Accessed 14 February 2016.

Speaker Design Drafting (Build Copy)

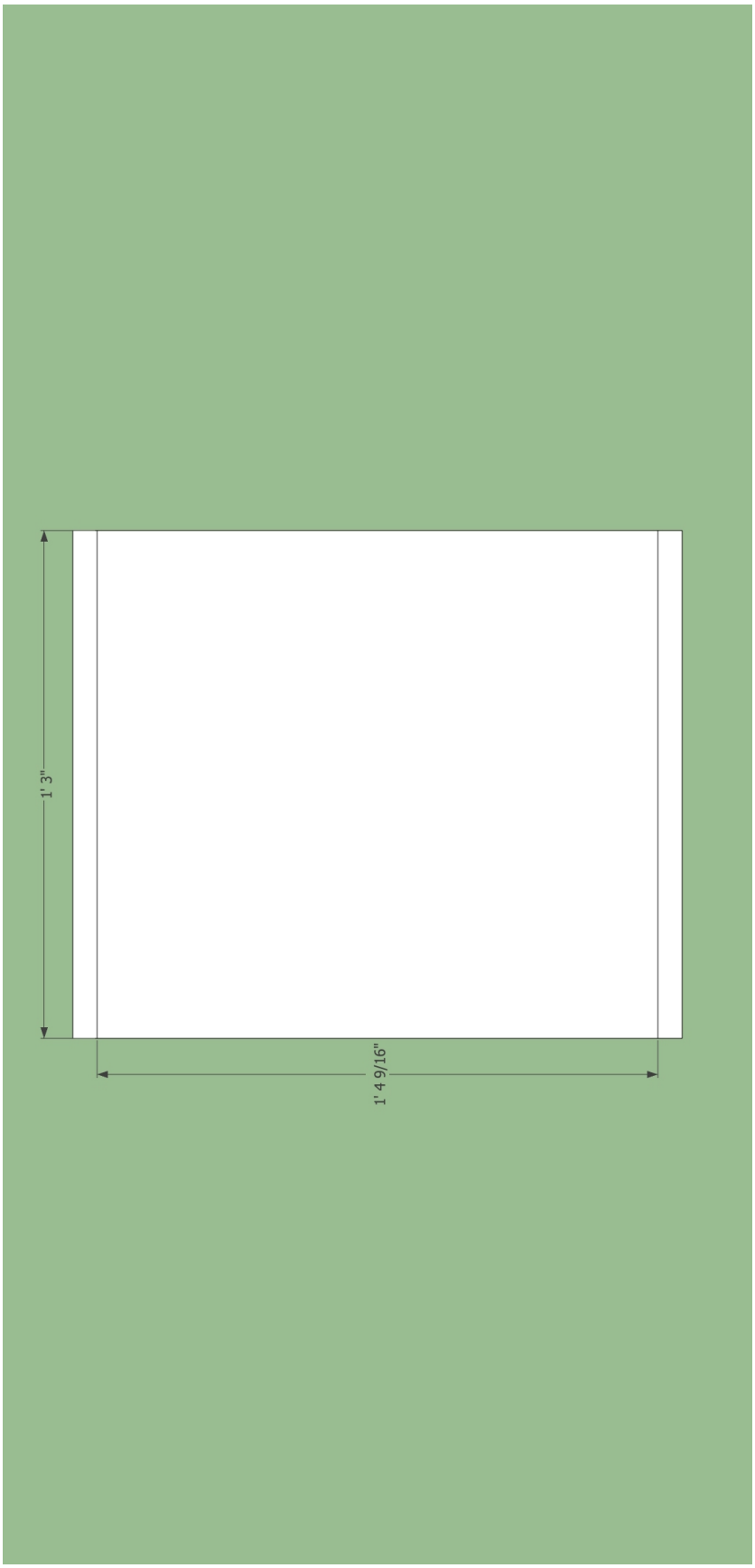




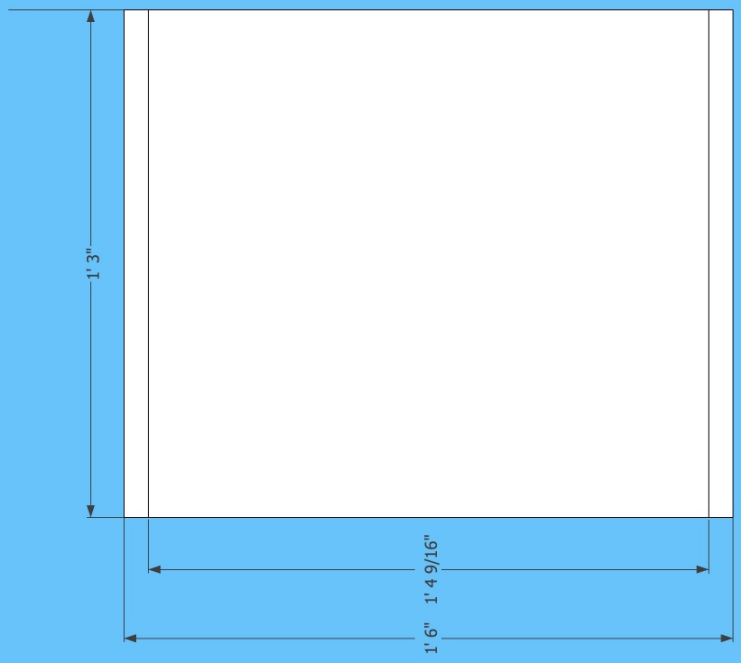
BACK VIEW



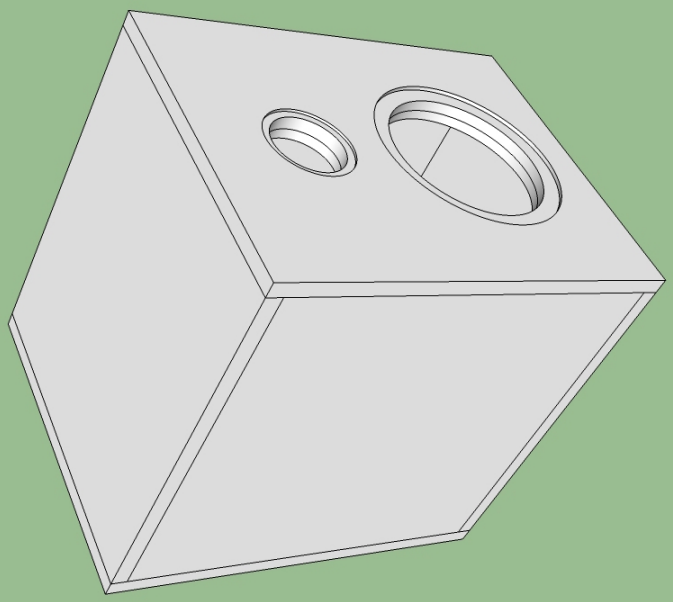
LEFT & RIGHT SIDE VIEW



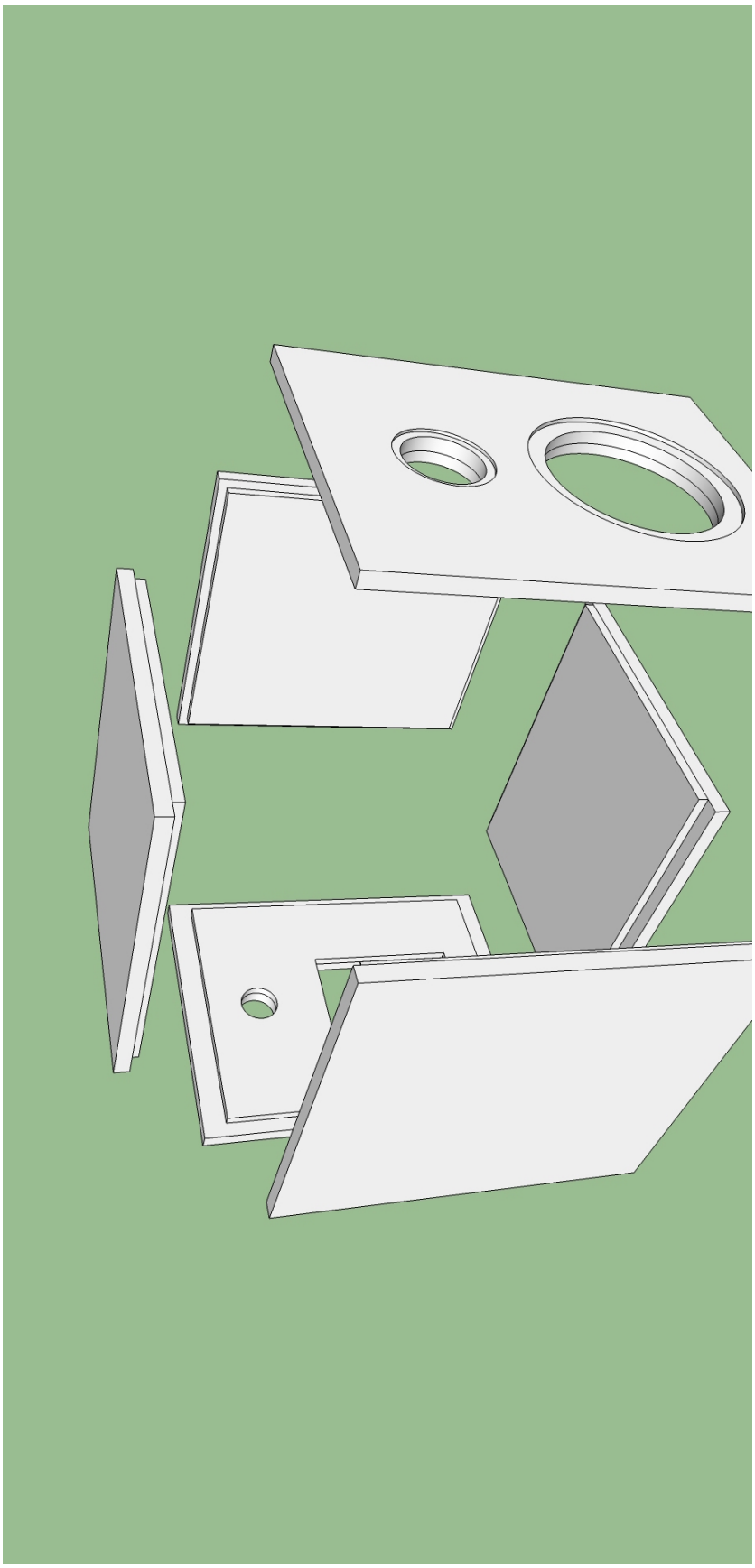
TOP VIEW



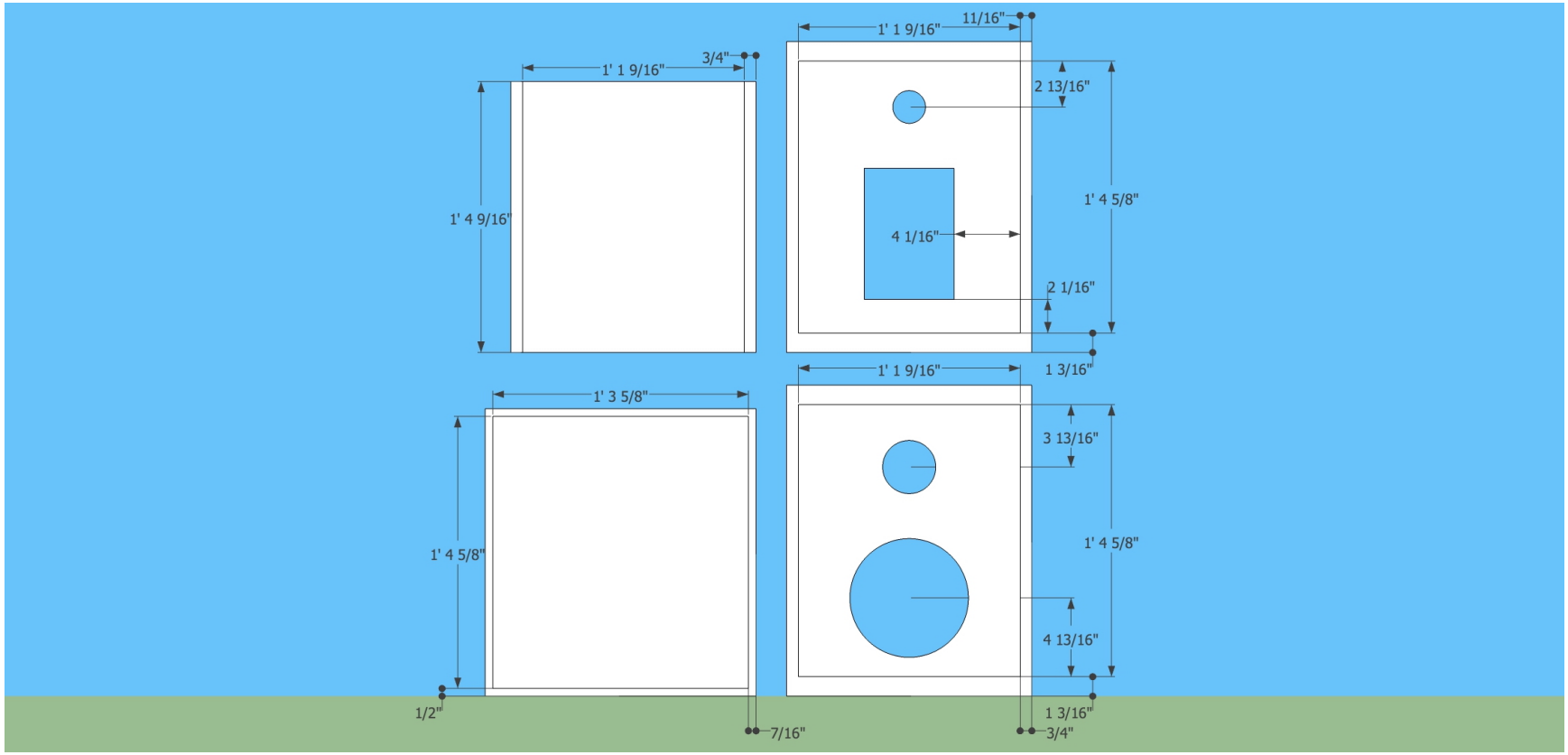
UNDER VIEW



ISO VIEW



ISO EXPLODED VIEW


11/16"
1' 1 9/16"
3/4"
1' 1 9/16"
2 13/16"
1' 4 9/16"
1' 4 5/8"
4 1/16"
2 1/16"
1 3/16"
1' 1 9/16"
1' 3 5/8"
3 13/16"
1' 4 5/8"
1' 4 5/8"
4 13/16"
1/2"
7/16"
1 3/16"
3/4"

Notes On Building

Multiple small changes were made during the building of the speakers. The biggest change made during this time was to the size of the port hole - though I originally drafted a 2” hole for the 2” port, I quickly realized that I would need a bigger hole, and so the port hole became 4”. Small adjustments were made to cut sizes to make the boards fit together.

Crossover Design

Given that the woofer really begins to break up starting at 2k after EQ'ing the roughness out of the 1k-2k region, I found that a 4th-order crossover at 1.8k would likely get rid of everything ugly in it. This brings the 4kHz region of the woofer's breakup pattern from 90dB down to 66dB, a significant improvement. This is also greater than twice the resonant frequency of the tweeter (which is 750Hz), and so it should work nicely; at 900 Hz the level will go from 92dB all the way down to 68dB. With the MiniDSP units, creating this crossover is simple.

System Tuning

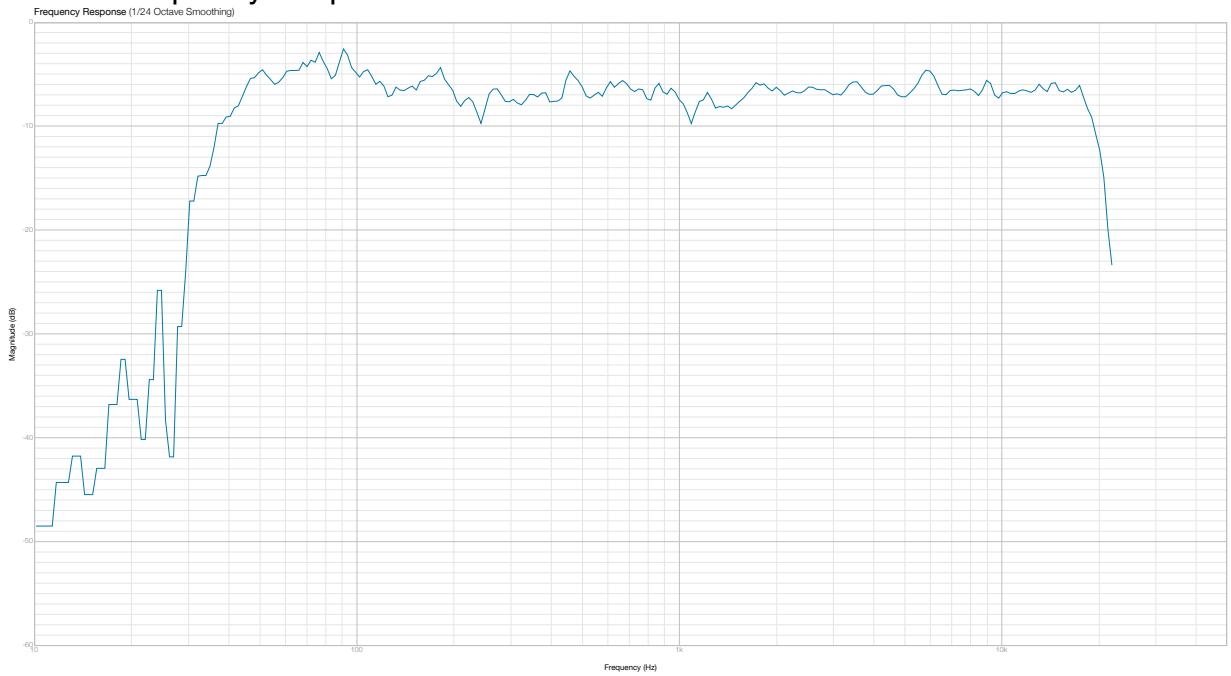
Right from the beginning, I realized that my original plan for the crossover would not make the drivers quite play as well as I thought they would. With some experimentation, I found that an uneven crossover—with the tweeter at 2kHz and the woofer at 2.2kHz—made for the best crossing. With some EQ, I ended up with a great, flat response with an F3 of 38Hz.

I experimented with adding dampening to the inside of the speakers, but found that it affected the sound in two ways: it deadened the sound and quieted the speaker overall. It did both of these things by too great a degree, and in the end I opted for the live sound with no dampening added.

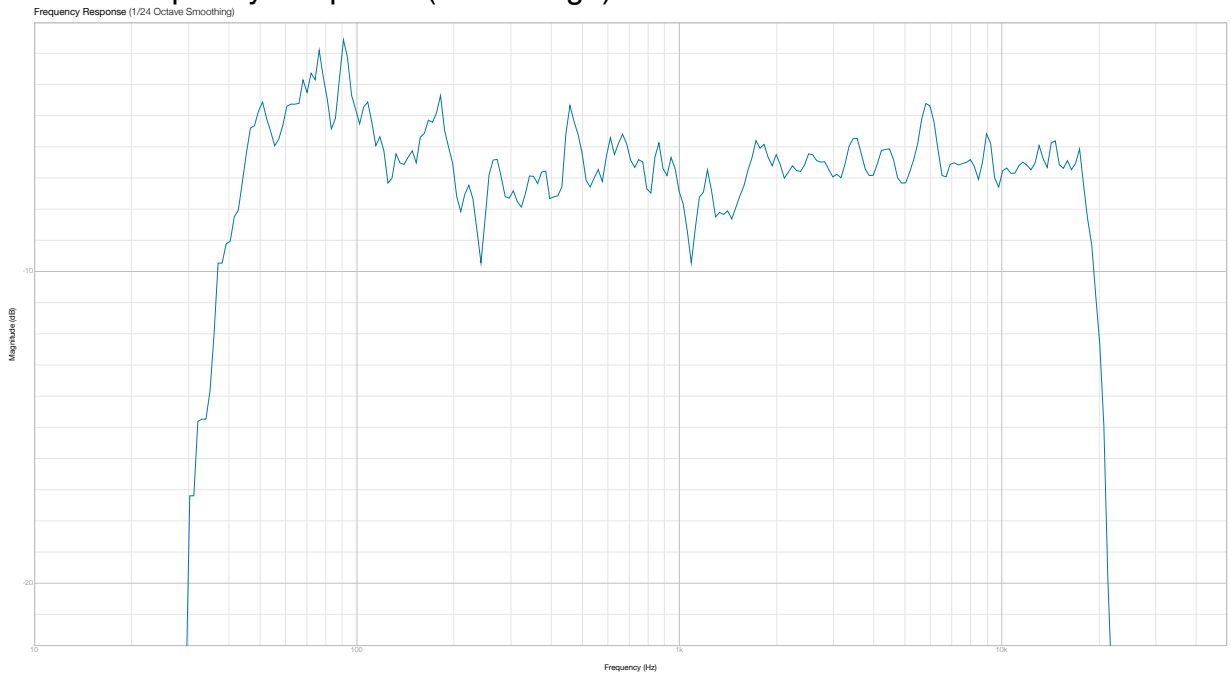
Time alignment was simple. I wanted the biggest sound stage possible, and so I aligned the beginning of the tweeter impulse with the woofer impulse by delaying the tweeter by about 3.7ms.

Final Performance Documentation

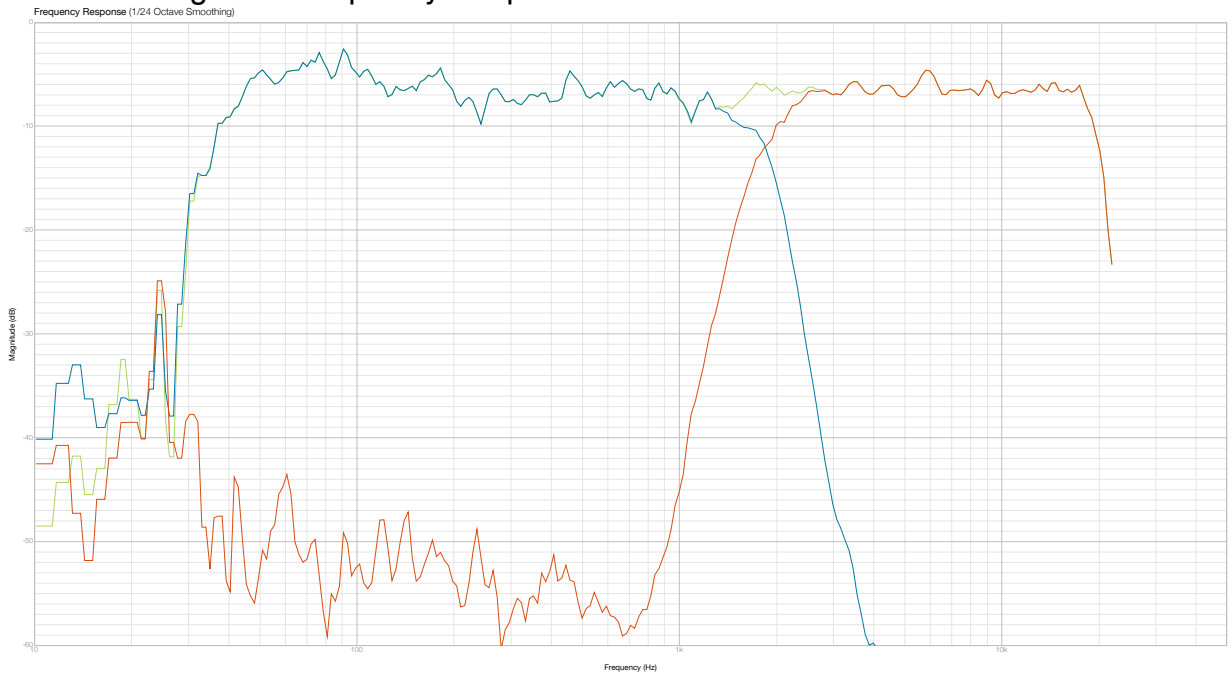
Overall Frequency Response



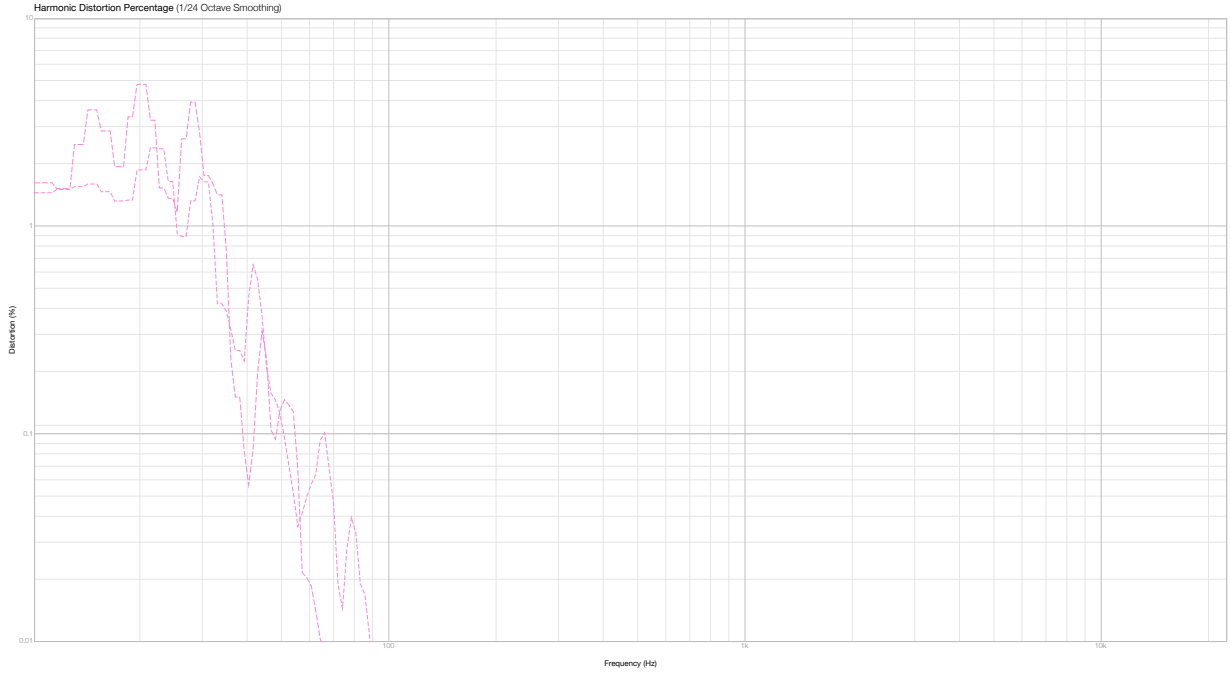
Overall Frequency Response (20dB range)



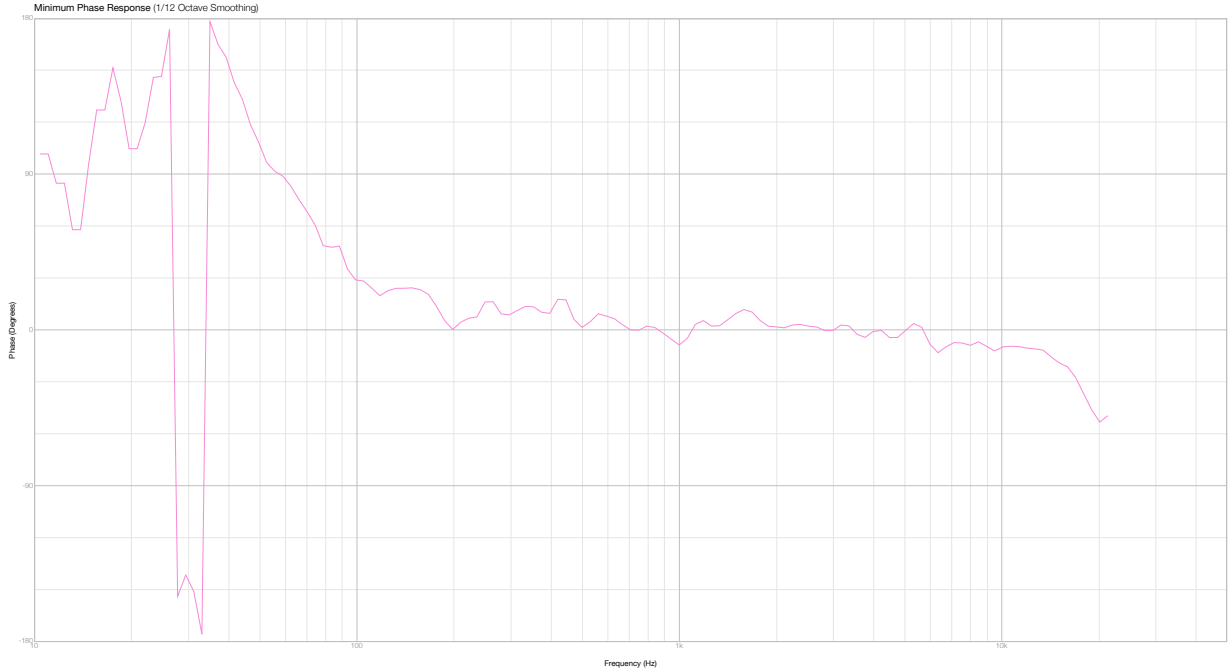
Overall Integrated Frequency Response



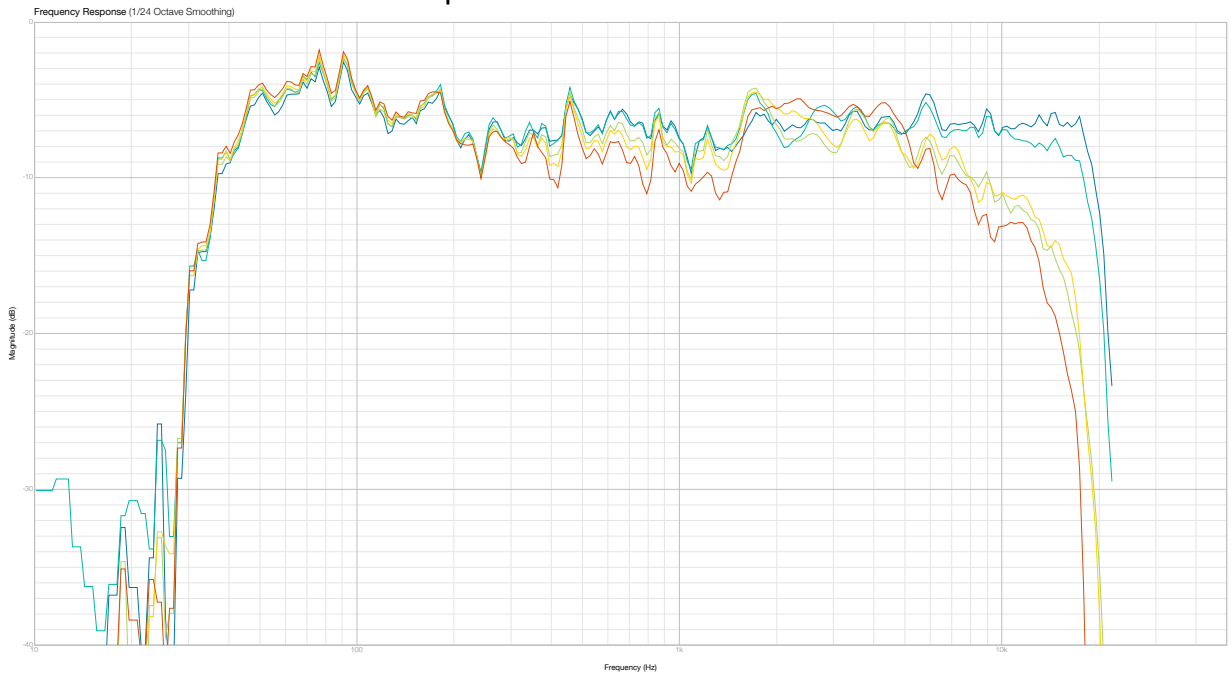
Overall Harmonic Distortion



Overall Minimum Phase



Overall Horizontal Off-Axis Response

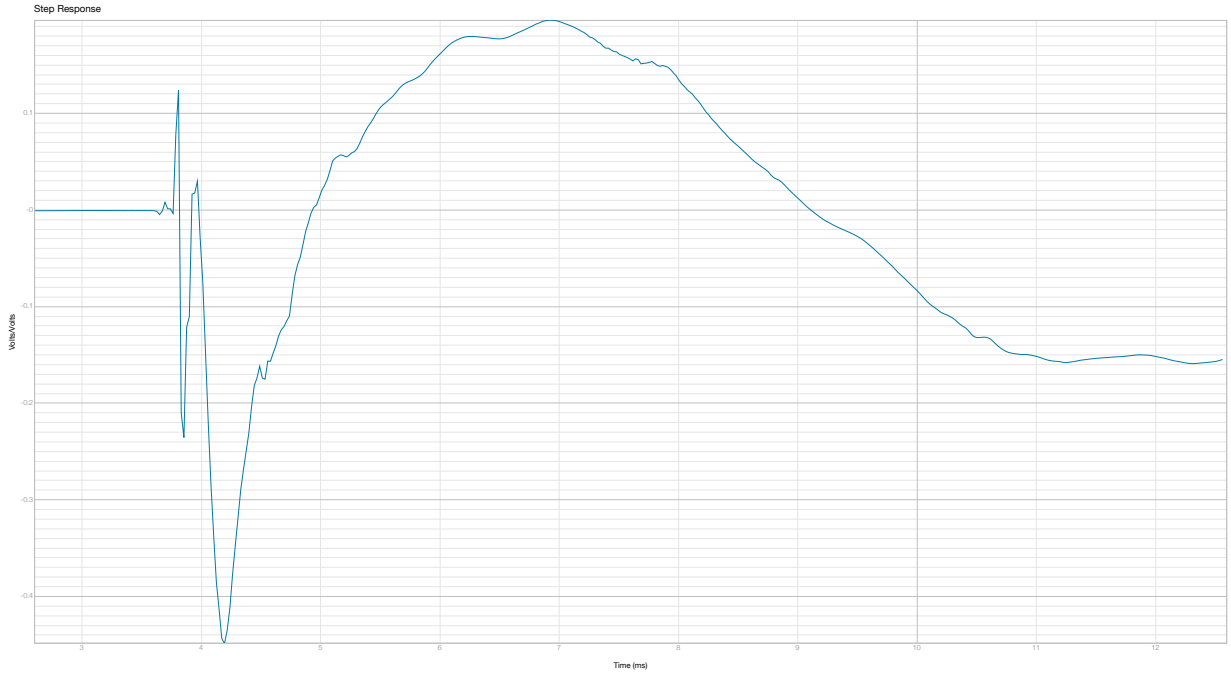


Blue-on axis; Cyan-15º; Green-30º; Yellow-45º; Red-60º

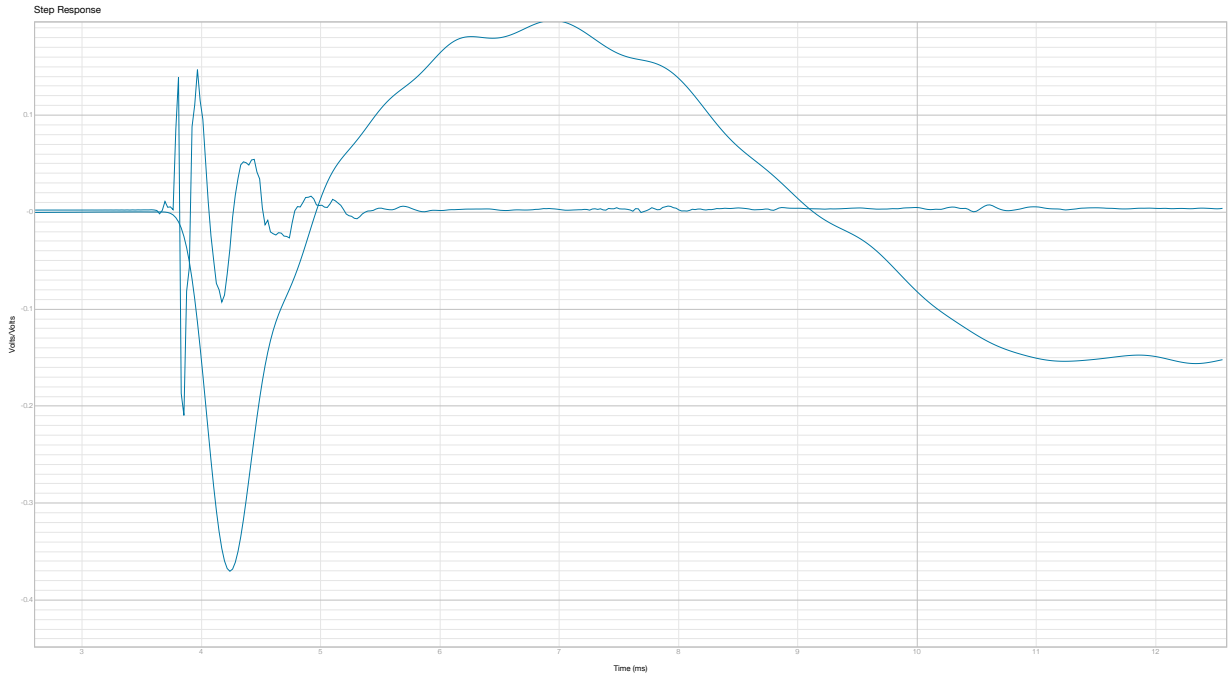
Overall Vertical Off-Axis Response

Blue-on axis; Cyan-15º; Green-30º; Yellow-45º; Red-60º

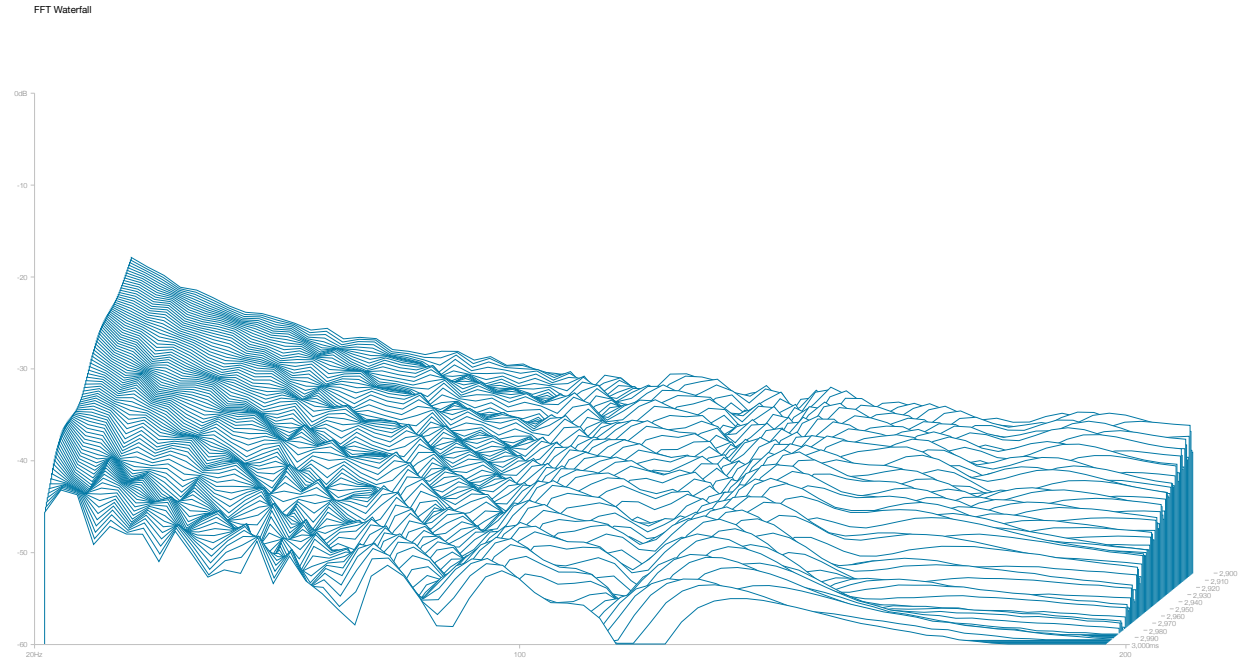
Overall Step Response



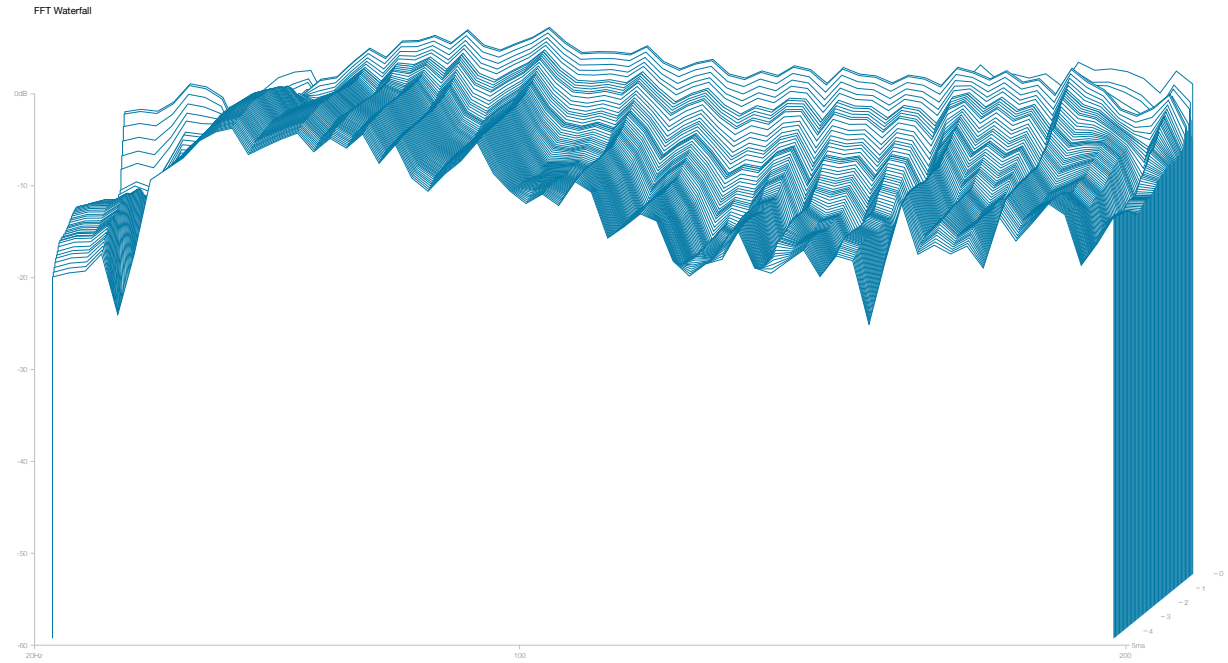
Integrated Step Response



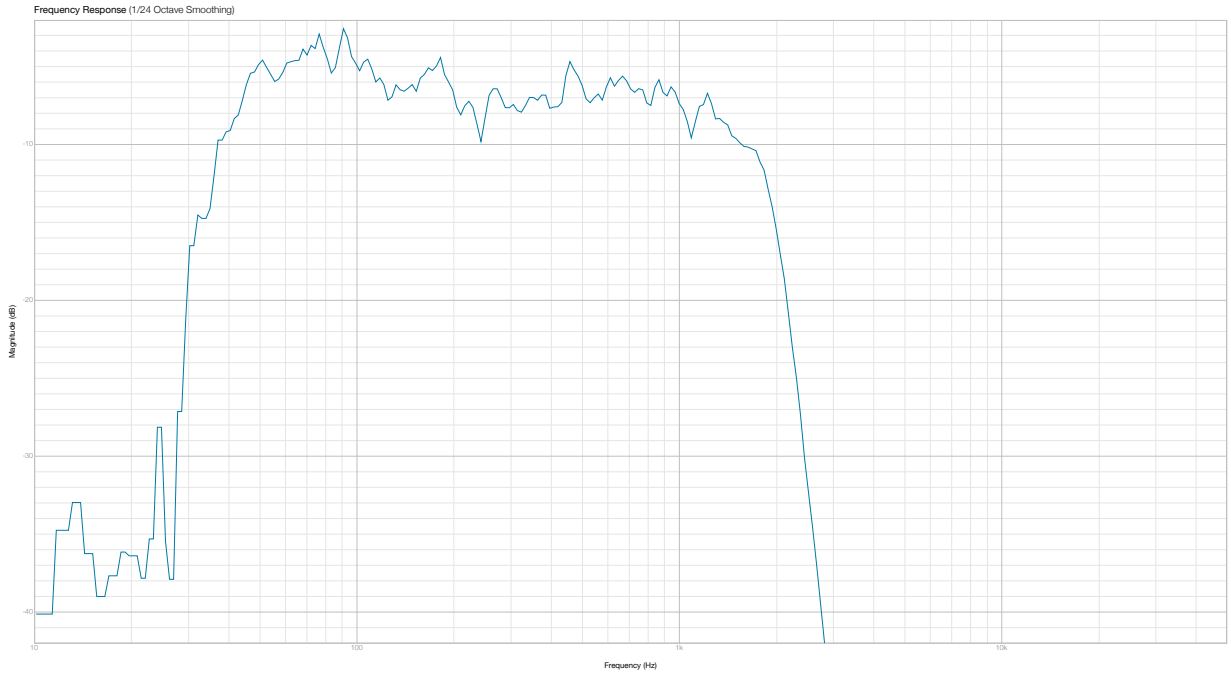
Waterfall Plot - Full



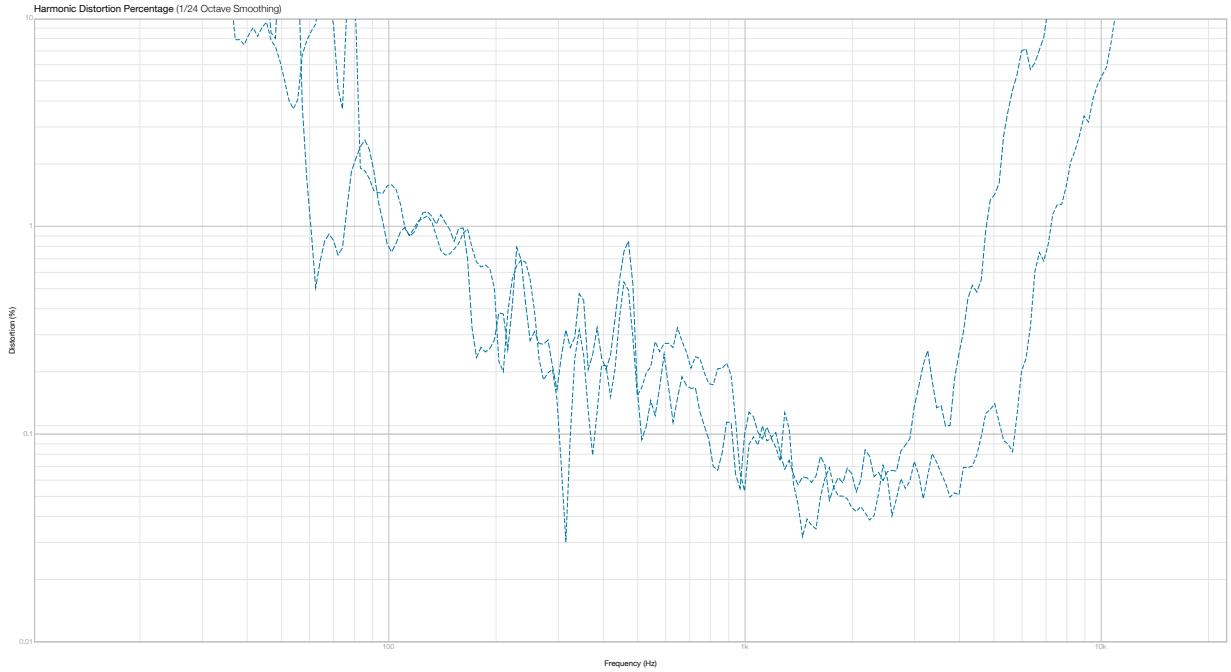
Waterfall Plot - High Frequency



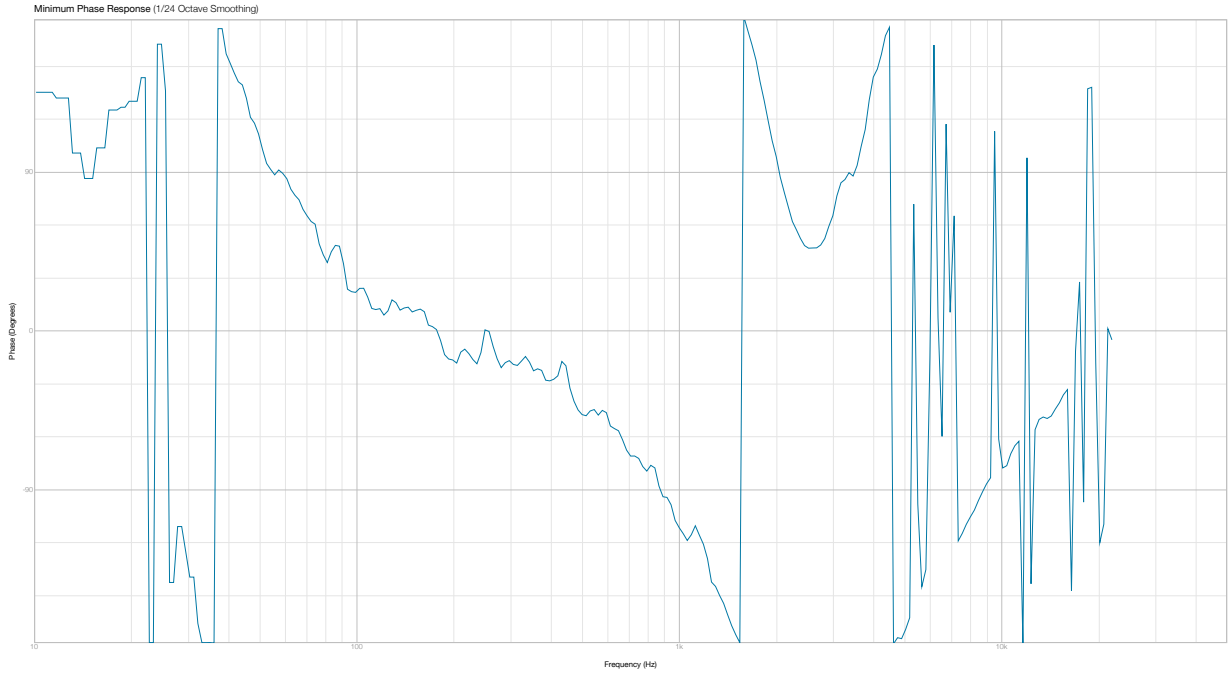
Woofer Frequency Response



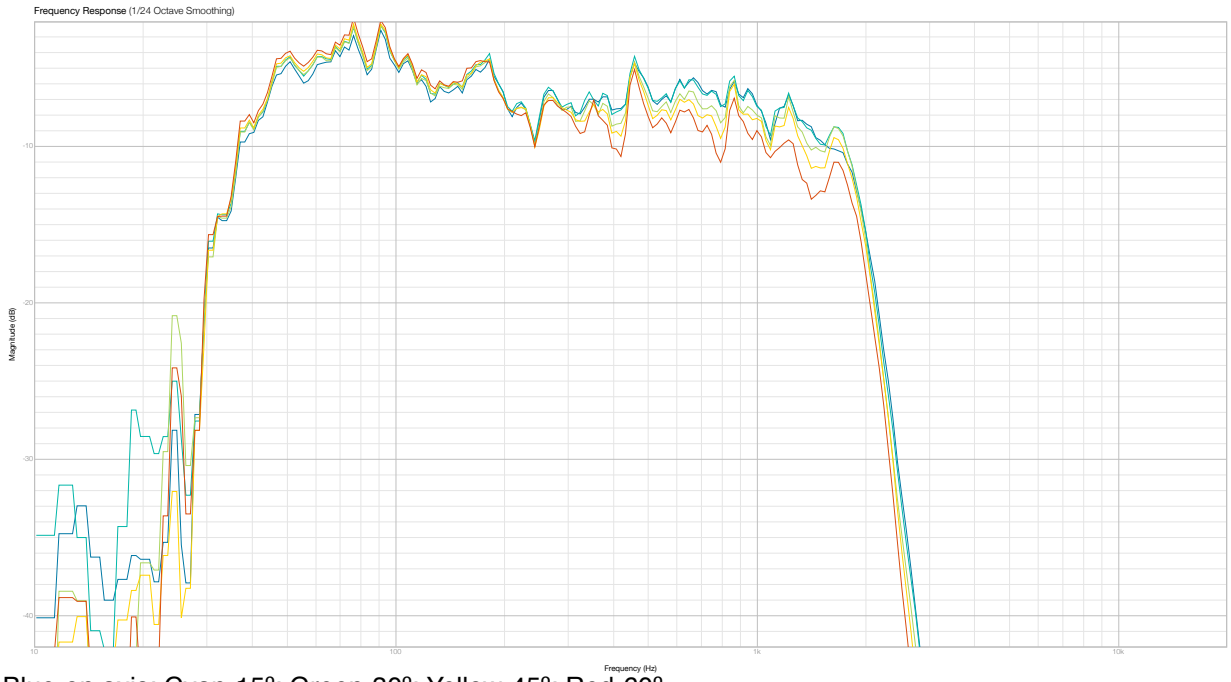
Woofer Harmonic Distortion



Woofer Minimum Phase



Woofer Horizontal Off-Axis Frequency Response

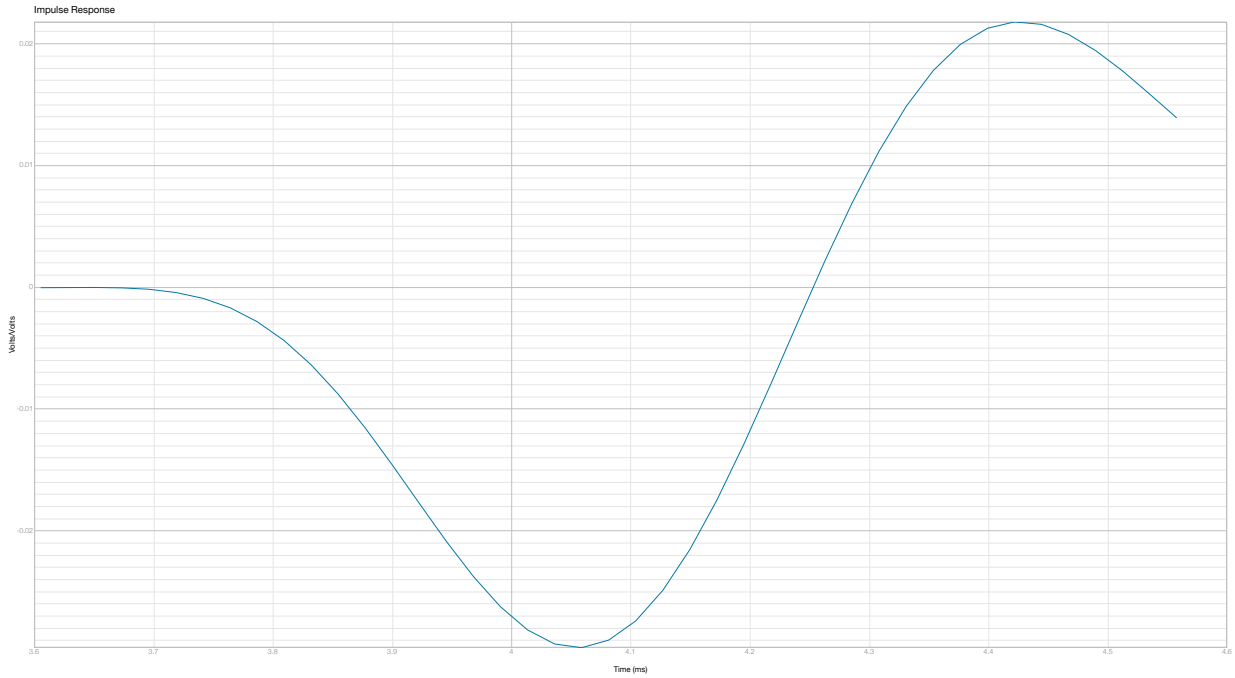


Blue-on axis; Cyan-15º; Green-30º; Yellow-45º; Red-60º

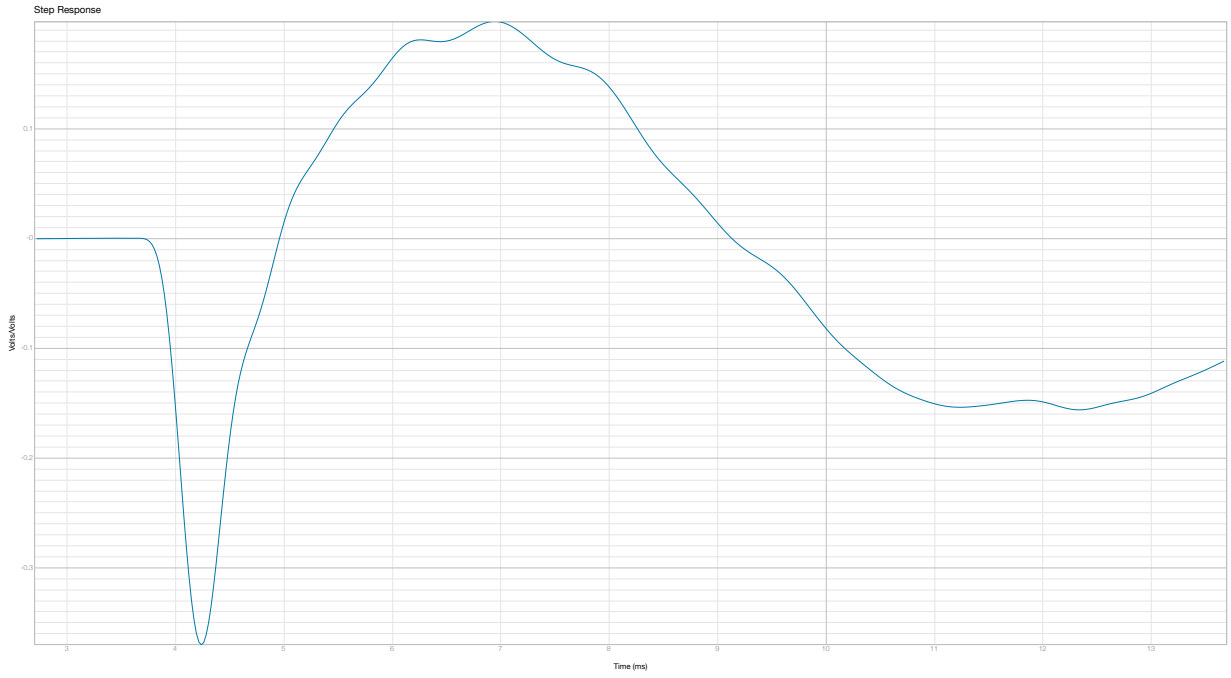
Woofer Vertical Off-Axis Frequency Response

Blue-on axis; Cyan-15º; Green-30º; Yellow-45º; Red-60º

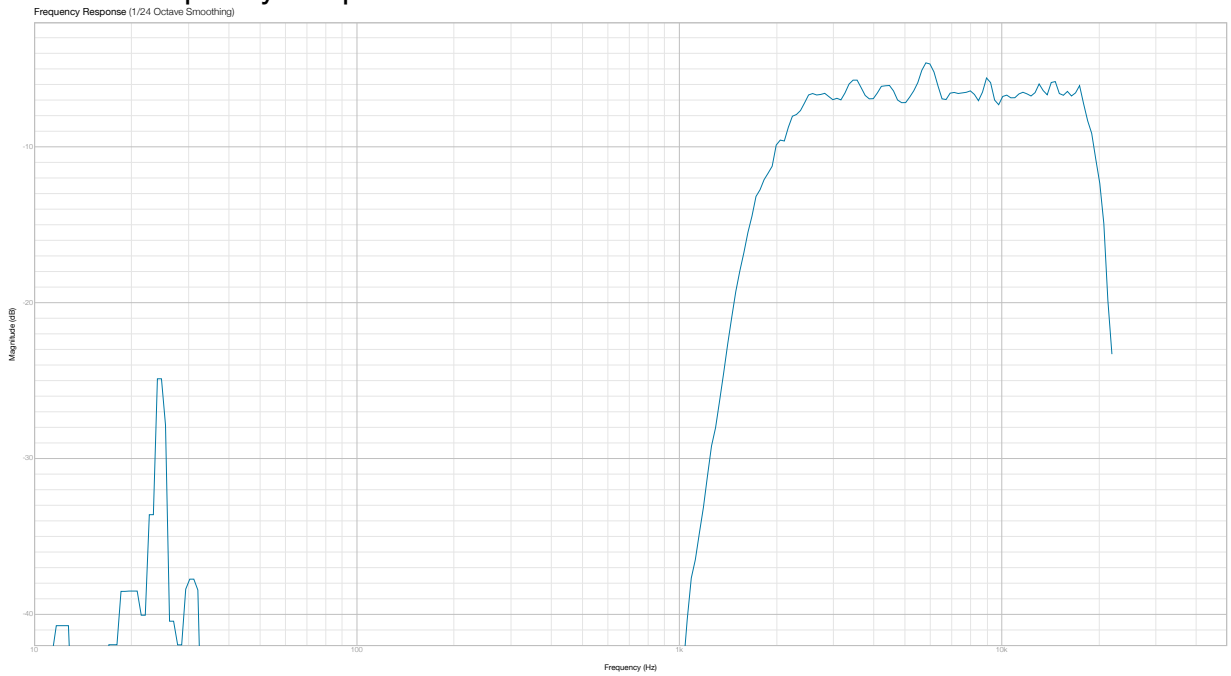
Woofer Step Response



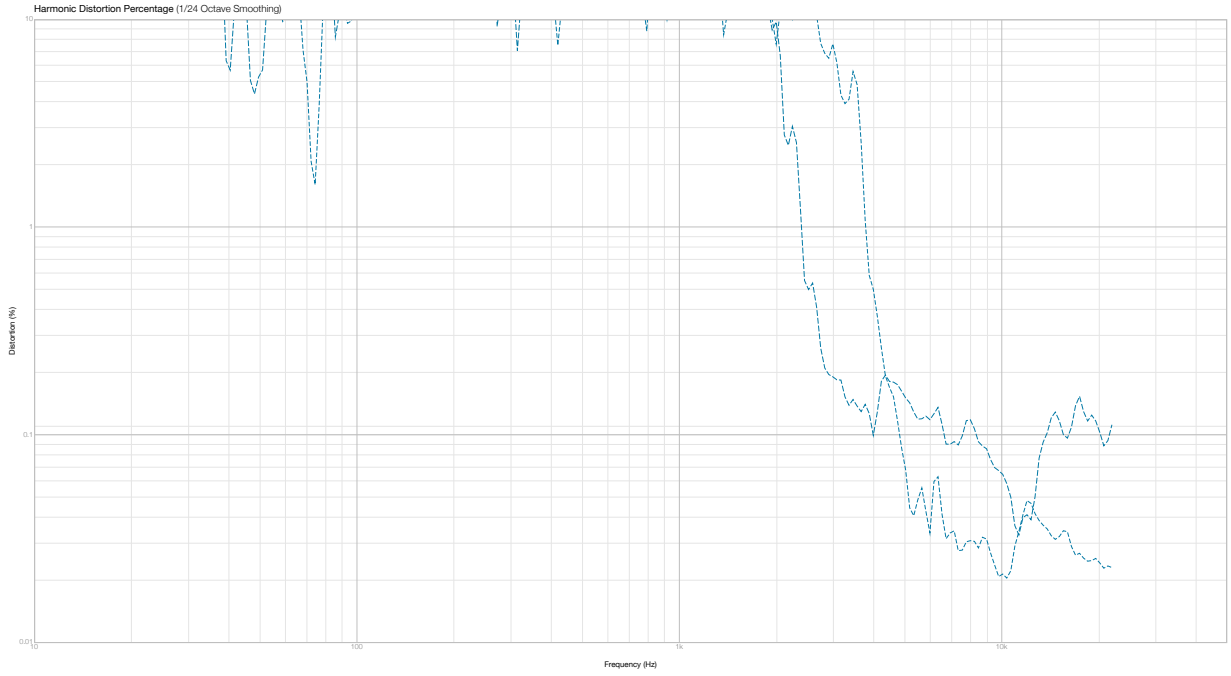
Woofer Impulse Response



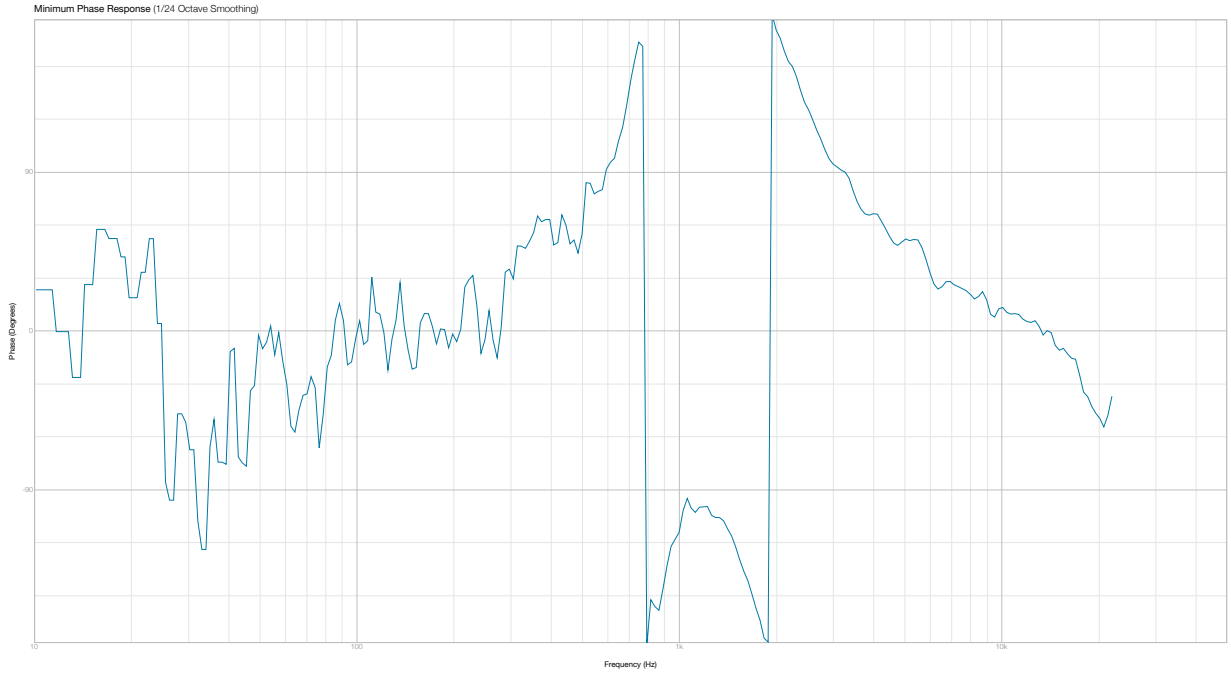
Tweeter Frequency Response



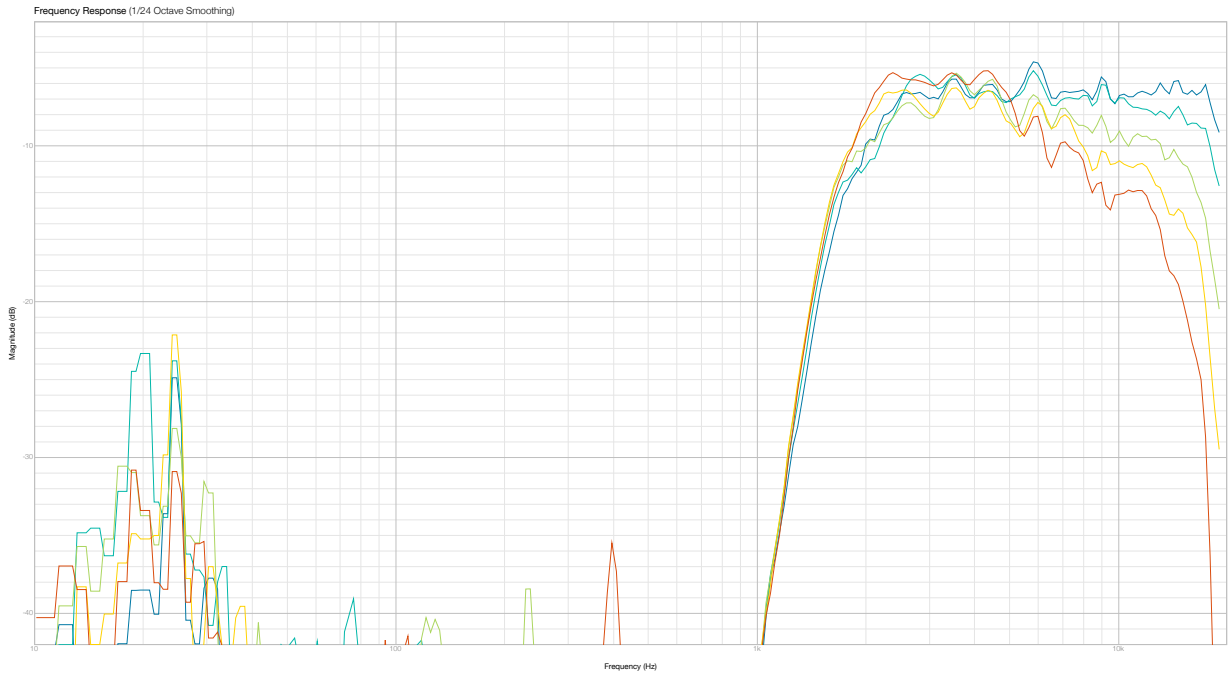
Tweeter Harmonic Distortion



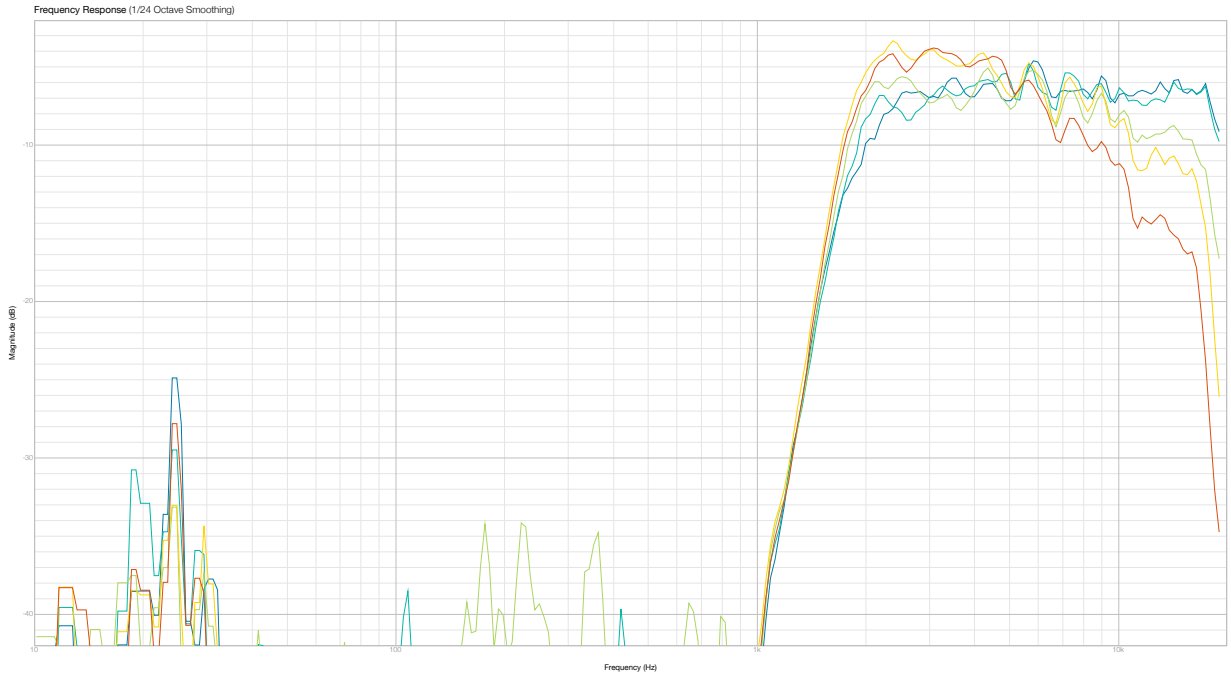
Tweeter Minimum Phase Response



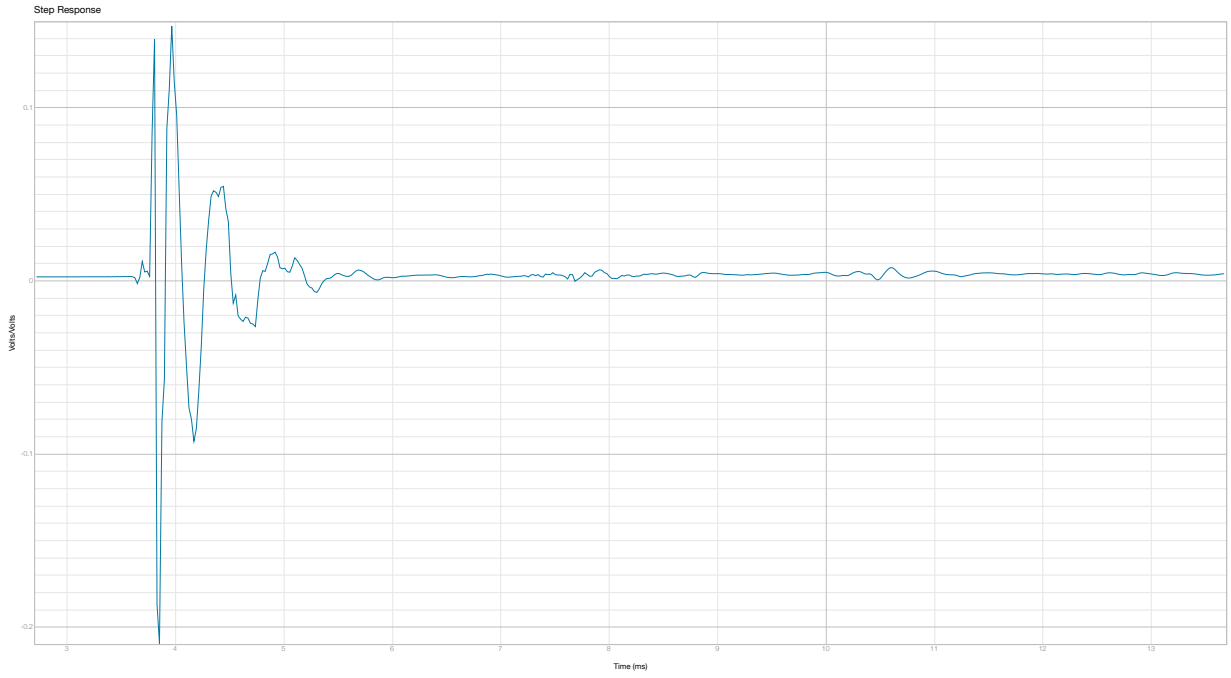
Tweeter Horizontal Off-Axis Frequency Response



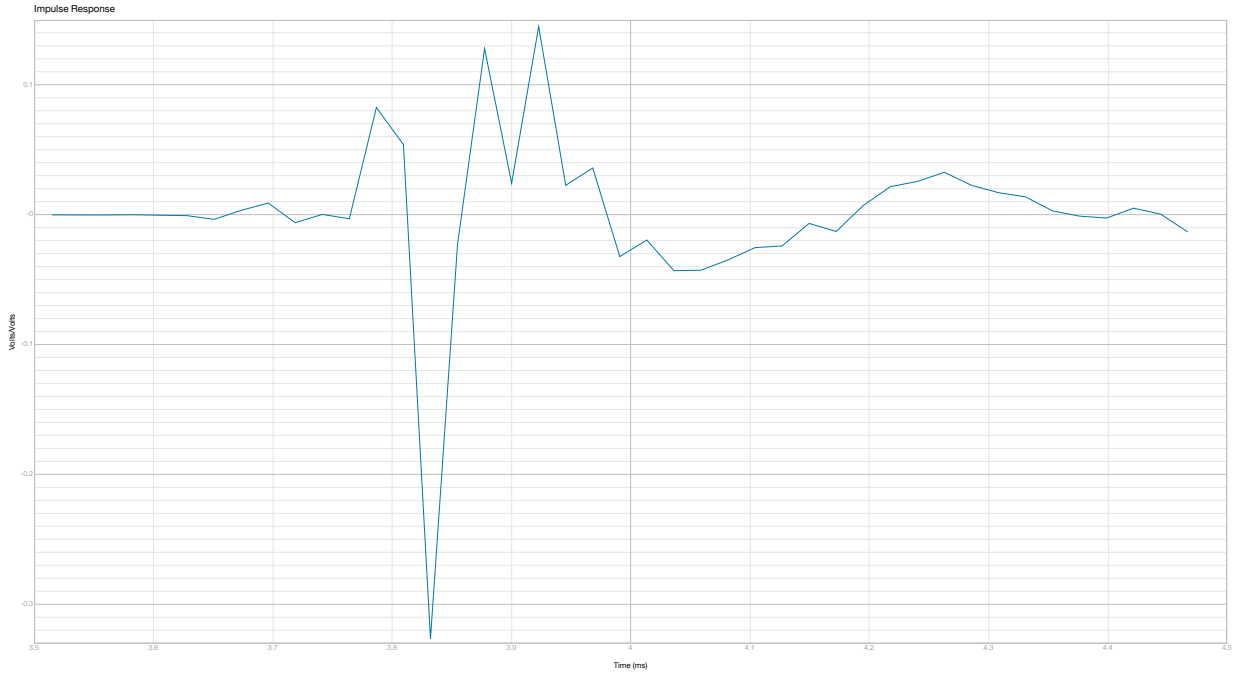
Tweeter Vertical Off-Axis Frequency Response



Tweeter Step Response



Tweeter Impulse Response



Bibliography

AES Recommended Practice for Professional Audio — Subjective Evaluation of Loudspeakers. PDF. New York, NY: Audio Engineering Society, 2007.

Dayton Audio. *Dayton Audio PA310-8 12" Pro Woofer 8 ohm Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 8 February 2016.

Dayton Audio. *Dayton Audio PA310-8 12" Pro Woofer 8 ohm Transducer Specification Sheet*. PDF. Springboro, Ohio: Parts Express. Accessed 8 February 2016.

Eminence. *Eminence American Standard Series Alpha-8A Transducer Specification Sheet*. PDF. Eminence, Kentucky: Eminence Speaker LLC. Accessed 8 February 2016.

Fountek. *FW168 Transducer Specification Sheet*. PDF. Zhe Jiang, China. Accessed 8 February 2016.

JBL Professional. *JBL Series 3 Powered Studio Monitors Owner's Manual*. Northridge, CA.

“Level Practices (Part 2) (Includes the K-System)." Digital Domain. 2013. Accessed January 23, 2016. http://www.digido.com/how-to-make-better-recordings-part-2.html.

Moulton, David. *Total Recording: The Complete Guide to Audio Production.* Sherman Oaks, CA: KIQ Productions, 2000.

Murphy, John L. *Introduction to Loudspeaker Design*. Escondido, CA: True Audio, 1998.

Newell, Philip Richard., and K. R. Holland. *Loudspeakers For Music Recording and Reproduction*. 2013 ed. Oxford: Focal, 2007.

North Creek Music Systems Cabinet Handbook. Old Forge, New York: North Creek Music Systems, 1992.

Plummer, Christopher. Lecture, FA4740 Transducer Theory, MI, Houghton, January 20, 2016.

PRV Audio. *6MB200 Transducer Specification Sheet*. PDF. Sao Leopoldo, Brazil. Accessed 8 February 2016.

SB Acoustics. *SB15NRX 30-C4 Transducer Specification Sheet*. PDF. Accessed 7 February 2016.

SB Acoustics. *SB16PFC25-8 Transducer Specification Sheet*. PDF. Accessed 14 February 2016.

ScanSpeak. *CLASSIC MIDWOOFER 18W/8545-01 Transducer Specification Sheet*. PDF. Middleton, WI: The Madisound Speaker Store. Accessed 29 January 2016

ScanSpeak. *DISCOVERY MIDWOOFER 12W/8524G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 7 February 2016.

ScanSpeak. *DISCOVERY MIDWOOFER 15W/8434G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 7 February 2016.

ScanSpeak. *DISCOVERY WOOFER 22W/4534G00 Transducer Specification Sheet*. PDF. Videbæk, Denmark. Accessed 8 February 2016.

“THX Reference Level Explained." Acoustic Frontiers. March 18, 2013. Accessed January 23, 2016. http://www.acousticfrontiers.com/2013314thx-reference-level/.

Zaph Audio. *ZA14W08 Transducer Specification Sheet*. PDF. Accessed 7 February 2016.