765PA

Public Address System for Electronic Music with Indoor and Outdoor functionality

Designed by: Cole Puertas

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1.0 Functional Description

This PA System will consist of two distinct parts, the top boxes, and the subwoofer. Each Top Box (of two) will contain a compression driver for high frequencies, and a midrange driver for midrange frequencies. The subwoofer will consist of one subwoofer driver for the lowest frequencies.

The SPL of the PA System must be loud. The goal is low distortion at high levels across the whole frequency spectrum. The PA system will be tuned specifically for electronic music and club music, but should sound good for all forms of musical playback

Low Frequency Extension is important for the system. Lots of electronic music and club music is bass heavy, so representing those low frequencies is a must. While the subwoofer is necessary, a nice, fine-tuned punch from the low frequencies of the midrange driver will help kick drums and bass stand out without feeling too muddy. These Speakers should provide similar specifications to most mid-range PA solutions, providing not only entertainment usage, but the ability to listen ahead to how mixes may sound over PAs in Club Settings.[1]

The size of the system is a concern when it comes to portability, as the PA system should be able to be moved to different venues. The entire PA system should be able to fit into most vehicles larger than a sedan. The system should be compatible with a standard tripod pole mount, as well as subwoofer pole mount, so the speakers can be no heavier than the standard pole mount can support.

The speakers should be able to withstand being outdoors and feature some weather/water resistance. The speakers should also feature some standard DSP controls on the back so they can be easily adjusted based on different locations (Indoor, outdoor, etc…)

Based on John L. Murphy's recommended design tradeoffs, this PA system will first prioritize SPL level, then Low Frequency Extension, then Size.[2]

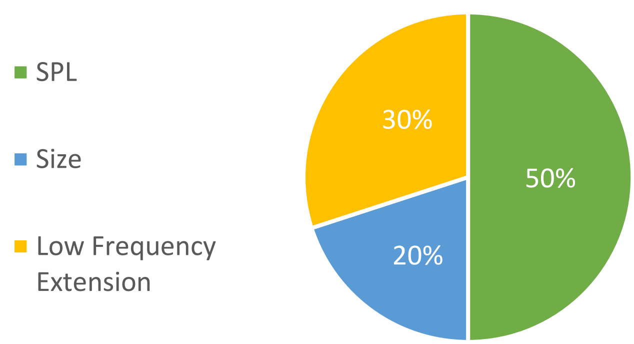

Figure 1: Pie Chart based on John L. Murphy's recommended design tradeoffs

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[1] Moulton, David

[2] Murphy, John

2.0 Reference Systems

2.1 Overview (Top Box)

Below is a review of a number of Top Boxes for standard PA Systems. These PAs are all two-way active speakers to grant a close comparison to my PA system.

Speaker	Lowest Frequency	Coverage Angle	SPL Peak	Weight	Watts	Dimensions	Price
QSC K12.2	50 Hz (12” -6dB)	75°	132dB @ 1M	39 lbs.	2000 W Peak	23.7 × 14 × 13.8 in (2.65 ft^3)	$999.99
JBL SRX835P	41Hz (15” -3dB)	60°	137dB @1M	85 lbs.	2000 W Peak	18.74” x 21.4” x 38.74” (8.99 ft^3)	$2039.00
Electro-Voice EKX-15P	55Hz (15” -3dB)	90°	134dB @ 1M	54 lbs.	1500 W Peak	27 in x 17 in x 17 in (4.5 ft^3)	$1099
QSC K10.2	56Hz (10” -6dB)	90°	130dB @ 1M	32 lbs.	2000 W Peak	20.4 × 12.6 × 11.8 in (1.76ft^3)	$899
Turbosound iQ12	52Hz (12” -3dB)	80°	130dB @ 1M	32 lbs.	2500 W Peak	24.0 x 14.5 x 14.5" (2.9ft^3)	$809
JBL PRX912	65Hz (12” -3dB)	90°	132dB @ 1M	43 lbs.	2000 W Peak	25 x 15.5 x 13.1 in (2.94ft^3)	$999

Based on the example above, the woofer size for top boxes can vary greatly, but 12” to 10” woofers are ideal for my system based on dimensions and total cost. While the 15” speakers have their benefits, examples like the JBL SRX954P goes all the way down to 41Hz (-3dB) which is lower than I would need since this system will integrate a subwoofer. The QSC K10.2 lists a nice frequency response but offers a bit less low frequency extension than its 12” counterpart for a very similar price. The speakers offer a wide range of dispersion angles, with 90° being the max and 60° being the min. Based on these standards, I would like to achieve a coverage angle between 75° and 90°.

2.2 Overview (Subwoofer)

Below is a review of a number of Subwoofers for standard PA Systems. These Subwoofers are all active speakers with driver’s ranging from 12-18” to grant a close comparison to my PA system.

Speaker	Lowest Frequency	Highest Frequency	SPL Peak	Weight	Dimensions	Watts	Price
JBL SRX818SP	35 Hz (-3dB)	120 Hz	135dB @ 1 m	87 lbs.	26.89in x 26.92in x 22.62in ($9.48\ ft^3$)	1000W (peak)	$2039
Electro-Voice ELX200-18SP	47 Hz (-3dB)	105 Hz	132dB @ 1 m	64 lbs.	23.7 in x 20.0 in x 22.6 in ($6.2\ ft^3$)	1200W (peak)	$1199
QSC KS118	41 Hz (-6dB)	98 Hz	136dB @ 1 m	104 lbs.	25.2 × 20.5 × 30.9 in ($9.24\ ft^3$)	3600W (peak)	$1999.99
QSC KS112	41 Hz (-6dB)	108 Hz	128dB @ 1 m	62.6 lbs.	24.5 × 15.5 × 24.25 in ($5.33\ ft^3$)	2000W (peak)	$1199.99
JBL-EON718S	40 Hz (-3dB)	120 Hz	131dB @ 1m	81.5 lbs.	26.3 x 24 x 25.1 in ($9.17\ ft^3$)	1500W (peak)	$1239

Based on the examples above, most modern Subwoofers seem to use Class D Amplifiers. The price of the subwoofer seems to correlate directly with its size. Price can also be affected by additional features like DSP options, many of these subwoofers contain lcd displays and presets for customization. In most cases, the larger the driver, the lower it can output. While this info is not 100% consistent throughout the chart, this may have to do with manufacturers reporting different frequency response at different levels, (-3dB vs -6dB). Both QSC's (regardless of driver size) have the same lowest frequency, though the larger driver outputs at a greater SPL.

3.0 Technical Specifications

3.1 Size

My main goal for the size of the box is to have a large enough internal cubic feet measurement to achieve a satisfactory low frequency extension, but not get large enough that I am unable to move the box or lift it up onto a monitor stand alone. I also drive a Compact SUV, so I would like this system to be able to fit in the trunk of my vehicle for transport. When comparing to the cubic feet of my reference speakers, the QSC K12's size of 2.65 cubic ft is ideal. The other Top Boxes with 12" woofers are a similar size, being slightly larger, but no bigger than 3 cubic ft. Based on my experience handling QSC K12's, I think this goal of no larger than 3 cubic ft is ideal for the size of my PA speakers.

3.2 SPL and Listening Distance

These speakers must be capable of reaching listening level of 85dB SPL across a large distance. The dynamic range of the content played will vary, but these speakers will typically be used for DJing or Live Music Reinforcement. Based on an assessment of integrated LUFS throughout different genres of club music, most electronic music falls into the range of -6 to -4 LUFS Integrated. For this purpose, large headroom is not required, but to still adhere to some standard, a headroom of 12dB, as proposed by Bob Katz K-12 System[3], will be imposed.

The system will be mainly used in large environments, typically outdoors. Because of this, they will need to be able to provide loud levels at a far distance. One common place these speakers will be used is in my backyard. Based on Google Maps Satellite Image measuring tool, the distance of my backyard is around 22 Meters. To account for this space, and slightly larger venues, a maximum listening distance of 30 Meters will be designated as the location for optimal listening.

By using the inverse square law, 20Log10(R2/R1), we can see that at a distance of 30 Meters, results in a loss of 29.5dB SPL. Based on this, an additional 29.5dB SPL is needed at the source to allow for the optimal listening level at 30 Meters. This will be rounded up to 30dB SPL for convenience

After calculations, this speaker will require the following SPL in order to produce a listening level of 85dB SPL continuous at 30 Meters.

Target SPL: 115dB SPL continuous, 127dB SPL peak

Flexibility: minimum acceptable is 109dB SPL continuous, 123 dB SPL peak

This level of headroom will not match K-20 standards, 20dB headroom with 85dB continuous and 105dB peak[3], at its maximum listening distance. Though, this actually can still be met by this system if it is not used at its maximum listening distance. If this system were to be used for wide dynamic range material like theatrical playback, I would not expect it to require the same

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[3] Katz, Bob

30 Meter listening distance that will be expected for music playback. In this case, as the system will require 129dB SPL @ 1W 1M, the 27dB headroom expected by platforms like Netflix, can still be achieved at a constant listening level of 85dB SPL up to 7 Meters.

3.3 Frequency Response

This speaker will be mainly used for the playback of club music. Because of this, low frequency extension is a must. Without a subwoofer, the system should extend down to 60Hz, seeing a boost in the 60Hz to 100Hz range to increase the low-end feeling when being used standalone. With the subwoofer, these speakers must be able to reproduce down to 35Hz accurately. While a flat response is not required of this system, a target of +/- 3dB across the frequency spectrum would be ideal. A flat response to 20Khz is ideal to ensure the system sounds even and is not perceived as too bass heavy. Above 20Khz is unnecessary, as mp3 format is common for DJing and most commonly cuts off at 20Khz.

Target Shape: +/- 3dB with a slight boost between 60-100Hz..

High Frequency Extension: Ideally even till 20Khz.

Low Frequency Extension: 45Hz minimum, 35Hz target.

4.0 Driver Selection

4.01 Addendum

From this point on in the process, I decided the Subwoofer was not a project I would be able to tackle during this semester, and it was scrapped from the design. The system is still designed to be paired with a Subwoofer, but one will not be built during the span of this project.

4.1 Tweeter Selection

For my Tweeter Selection, I looked at compression drivers and compared their Peak SPL limits, Coverage Angles (with paired horns), and cost. I weighed all these options against each other to make my final choice for my Tweeters. That comparison is shown below in Figure 2

	Nominal Size	Design	Horizontal Coverage	Vertical Coverage	Price	Sensitivity	Short Term Power	Long Term Power	Thermal SPL Limit	Peak SPL Limit	Notes
SB Audience Bianco 44CD-T Compression Driver	1"	Compression Driver (Use SB Audience Horn H225/H250)	90	60 or 70	$53.5 (+30-40 for horn)	105	100	50	122.0	125.0	
SB Audience Bianco 25CD-P Compression Driver- 1"	1"	Compression Driver (Use SB Audience Horn H225/H250)	90	60 or 70	$21.4 (+30-40 for horn)	107	40	20	120.0	123.0	
SB Audience Bianco 44CD-PK Compression Driver- 1"	1"	Compression Driver (Use SB Audience Horn H225/H250)	90	60 or 70	$64.8 (+30-40 for horn)	107	100	50	124.0	127.0	
SB Audience Rosso-44CD-PK 44mm PEEK dome	1.73228"	Compression Driver (Use SB Audience Horn H225/H250)	90	60 or 70	$86.2 (+30-40 for horn)	107	120	60	124.8	127.8	
DS18 PRO-D1 2" Professional Compression Driver 8 Ohm	2"	Compression Driver (use Goldwood GM-450PB 2" Horn)	90	40	$69.95 (+40 with horn)	110	450	150	131.8	136.5	

Figure 2: Tweeter Comparison

4.2 Woofer Selection

When looking at Woofers to purchase for my top box, I decided to look at 10-12" woofers and compare their F3, Peak SPL, and Cost against each other. This graph is shown below in Figure 3.

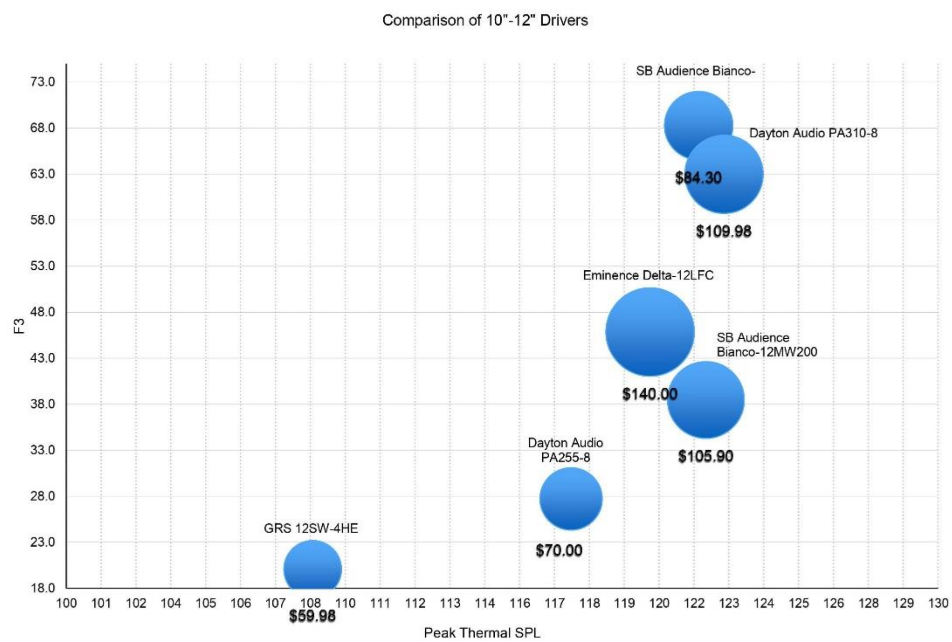

Figure 3: Woofer Comparison

I also completed modeling for these drivers in WinSpeakerz to help decide which would provide appropriate frequency response and power handling for my system. The modeling for my selected driver can be found in Figure 7.

4.3 Final Driver Choices

Based on the performance shown in Figure 1 and Figure 2, I decided to chose the SB Audience Bianco 44CD-PK 1" Compression Driver as my Tweeter, and the SB Audience Bianco -12MW200 as my Woofer. I prioritized the selection of the Woofer, and then chose the Tweeter. The Bianco 12MW200 was selected for its low f3 (38.5hz), high Thermal SPL Limit (122dB SPL) and fair price point ($105.90). Once I chose to use the SB Audience Bianco series, I looked at the SB Audience Bianco Compression Drivers, and the Bianco 44CD-PK stood out to me. It had a comparable Thermal SPL Limit of (124dB SPL), good coverage (when paired with an SB Audience Horn) at 90* Horizontal and 60* Vertical, and a high sensitivity (107dB SPL @ 1W 1M). The spec sheets for both the SB Audience Bianco 12MW200, SB Audience Bianco 44CD-PK, and SB Audience H225 Horn in Figures 4, 5 and 6 respectively.

Specs :

Nominal Impedance	8 Ohm
Minimum Impedance	5.2 Ohm
AES Power Handling (1)	200 W
Maximum Power Handling (2)	400 W
Sensitivity (1W/1m)	99 dB
Frequency Range	51 - 5350 Hz
Voice Coil Diameter	60.5 mm (2.4 in)
Winding Material	Copper
Former Material	Till
Winding Depth	16.6 mm
Magnetic Gap Depth	8 mm (0.31 in)
Flux Density	1.23 T
Magnet	Ferrite
Basket Material	Stamped steel
Demodulation	-
Cone Surround	Double half roll with damping glue
NET Air Volume filled by driver	3.33 liters
Spider Profile	Single constant height waves
Weather Resistant	Yes

Thiele Small Parameters

Fs	51 Hz
Re	5.3 Ohm
Qes	0.51
Qms	14.33
Qts	0.49
Vas	62.9 liters
Sd	543.3 cm^2
Xmax (3)	6.97 mm
Xdamage (4)	20 mm
Mms	65.2 gr
Bl	14.7 Tm
Le	0.83 mH
Cms	0.15 mm/N
Rms	1.45 Kg/s
Eta Zero	1.56 %
EBP	100

Figure 4: BIANCO 12MW200

Specs :

Nominal coverage	
Horizontal	90 degrees
Vertical	70 degrees
Directivity	
Directivity factor (Q)	8
Directivity index (Di)	9 dB
Sensitivity	
On driver.1W@1m, on axis[1]	109 dB
Frequency response @-10dB[2]	600 Hz - 20 kHz
Throat diameter	25.4 mm (1 in)
Minimum recommended crossover[3]	700 Hz

Figure 5: BIANCO 44CD-PK

Specs :

Nominal Impedance	8 Ohm
RDC	6.2 Ohm
AES Power Handling (1)	50 W
Maximum Power Handling (2)	100 W
Sensitivity (1W/1m)(3)	107 dB
Frequency Range	700 - 20000 Hz
Recommended Crossover Frequency	1.8 kHz
Voice Coil Diameter	44 mm (1.73 in)
Winding Material	Flat copper clad aluminium
Former Material	Kapton
Winding Depth	2.25 mm (0.089 in)
Magnetic Gap Depth	2.5 mm (0.10 in)
Diaphragm Material	Polyether ether ketone (PEEK)
Flux Density	1.6 T
Magnet	Ferrite
Demodulation	-
Phase Plug Design	Annular
Exit Angle	10.86° conical
NET Air Volume filled by HF Driver	0.59 liters

Figure 6: H225

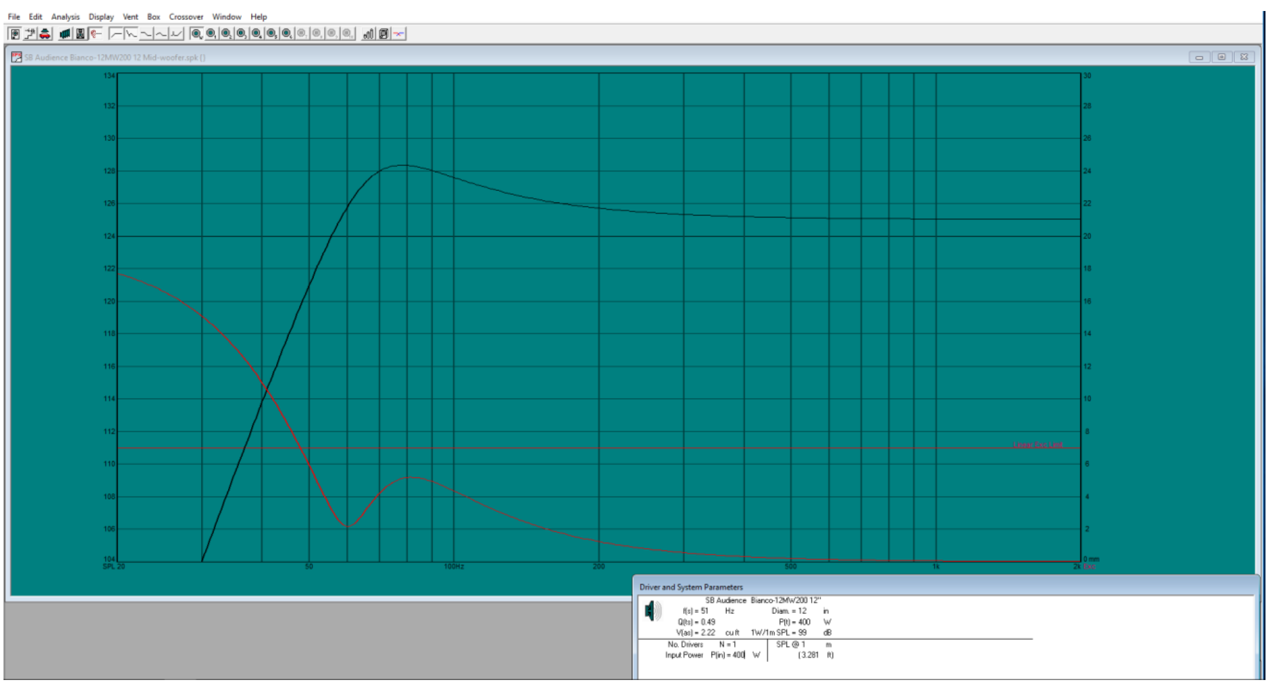

Figure 7: : BIANCO 12MW200 WinSpeakerz Modeling

5.0 Amplifier/DSP Selection

When deciding on the method of Amplification for my system, my concern first and foremost was convince. The benefit of most PA's I looked at, was the fact that they were powered loudspeakers, all of which came with built in plate amps and featured a variety of DSP features right on the back of the speaker. A plate amp was the number 1 consideration for the amplification of my speaker, and one with a built in DSP was an added bonus. The amp I decided on was the PPA800DSP 2-Way Plate Amplifier from Dayton Audio. This amplifies provides 800W split into two bands, 200W for the Tweeter, and 600W for the Woofer. Based on my calculations seen in Figure 7, the SB Audience Bianco 12MW200 when powered at 400W can hit a peak SPL of 128dB. This amplifier provides more wattage than the 12MW200's peak, and with that wattage, also allows the 12MW200 to hit its thermal SPL Limit. The amplifier not only provides sufficient power, but also features a dual ¼"/XLR input method, a built in DSP, and True Wireless Stereo Bluetooth functionality. Costing at $316, the PPA800 was a competitively priced option which featured even more convenience features than I originally expected to have. Its specifications can be seen in Figure 8.

Specifications

- Amplifier type: ....Class D
- Low frequency power rating: .....600W RMS (4 ohms/1 kHz @ THD+N 1%)
- High frequency power rating: ....200W RMS (4 ohms/8 kHz @ THD+N 0.1%)
- Input sensitivity:..........................LINE, 0 dBu; MIC, -24 dBu
- Bluetooth version: 5.0
- Power: ....120~240 VAC, 50/60 Hz, auto-sensing
- Dimensions: ....15" L x 6-5/16" W x 2-3/4" D
- Cutout dimensions: ....14" x 5-1/2" • Weight: 5.0 lbs.

Figure 8: PPA800 DSP Specifications

6.0 Cabinet Design

6.1 Size Calculation

The first consideration when beginning my cabinet design was the overall size of the speakers. Based on my calculations from WinSpeakerz, I determined that a vented box of 3 cubic ft would allow me to surpass my target peak SPL of 127dB and place me at an F3 of around 50hz. My initial goal was an f3 of 45hz, but after some calculations in WinSpeakerz, I opted for a bass boost from 60-80 SPL with a higher f3, than a more flat bass response, and a lower f3. This bass boost calculation can be seen in Figure 7.

WinSpeakerz calculations recommended a minimum vent size of 28.2 sq in, and based on the port calculator, I opted for a 6" diameter port with a length of 4.472" (Figure 9).

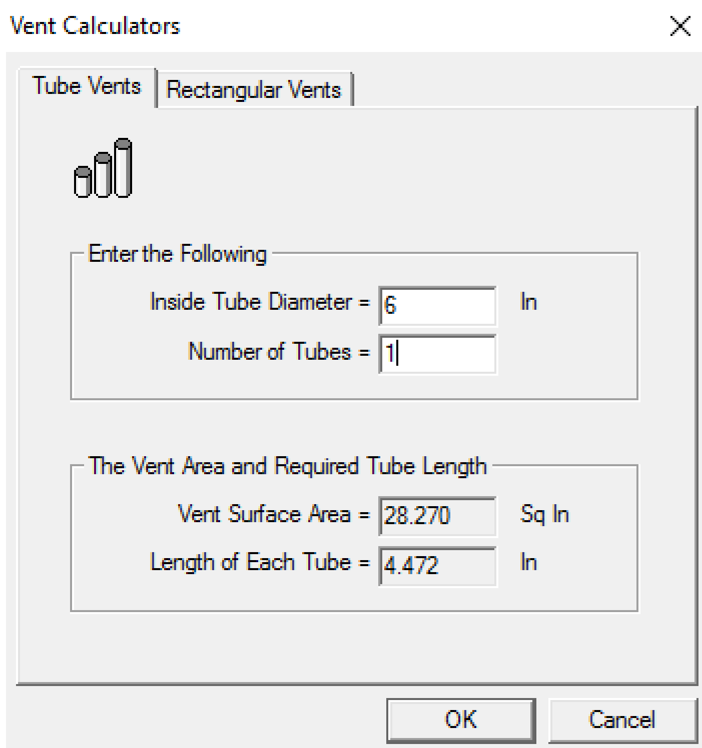

Figure 9: Port Calculations

6.2 Modeling

With the cubic ft I was shooting for decided, I then used WinSpeakerz box calculator to decide on the individual measurements of each side. The box size calculations and displacement calculations can be seen in Figure 10. The overall cubic ft of my box is slightly larger than 3, and this was done to preserve dissonant ratios between the sides of my box.

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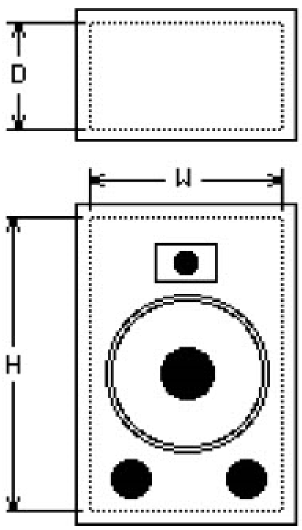

Box Dimensions and Gross Internal Volume

Internal Height:	H =	24.75	inches
Internal Width:	W =	13	inches
Internal Depth:	D =	17	inches
Gross Internal Volume:		3.165	cubic feet

Adjustments and Net Internal Volume

Driver Displacement =	0.4436	cubic feet
Bracing Displacement =	0.1695	cubic feet
Other Displacement =	0.167	cubic feet
V(B) increase due to filling =	0	%
Net Internal Volume: V(B) =	2.385	cubic feet

Notes

S(v) = 0 square inches (Vent Surface Area)
L(v) = 0 inches (Vent Length)

MTU

2485716772

System Name:

4th Order Vented Box

Designer: Cole Puertas
Title: 765PA Woofer Test

Rev Date: Rev:

Figure 10: WinSpeakerz Box Calculation

Once these dimensions were locked, I used Autodesk Inventor to create a 3d model of my speakers. I determined I would need a 3D Model to insure all my pieces would fit together properly and prepare me more accurately for the build. Pictures of the model are shown in Figures 11-15.

The box consist of 4 main walls, 7 holes (1 for the woofer, 1 for the horn, 1 for the port, 1 for the plate amp, 2 for handles, and 1 for a tripod stand mount), as well as an internal seal to separate the plate amp from the main resonant area of the box, and horizontal bracing which provides support for the compression driver.

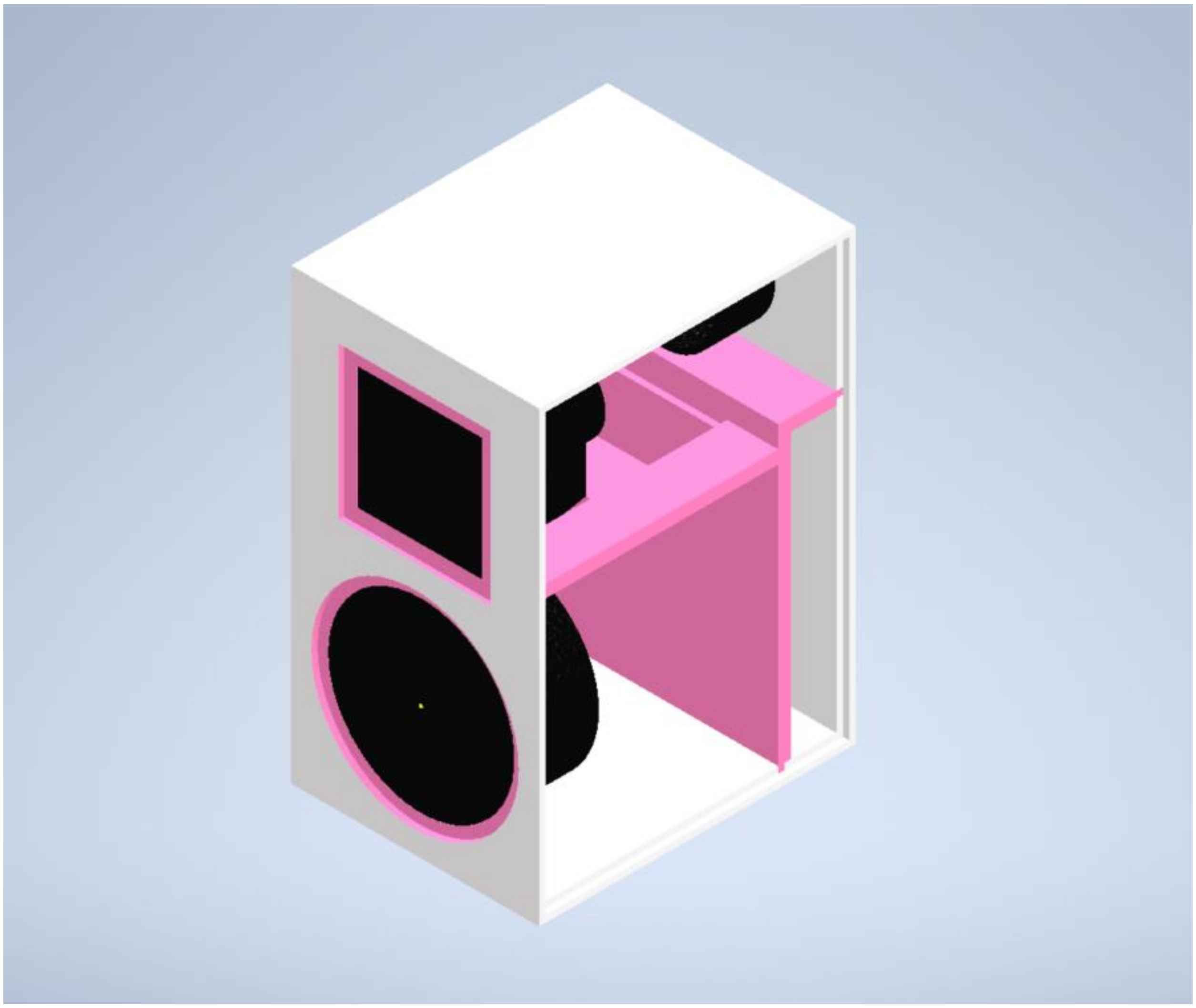

Figure 11: 765PA Model Angled Side View

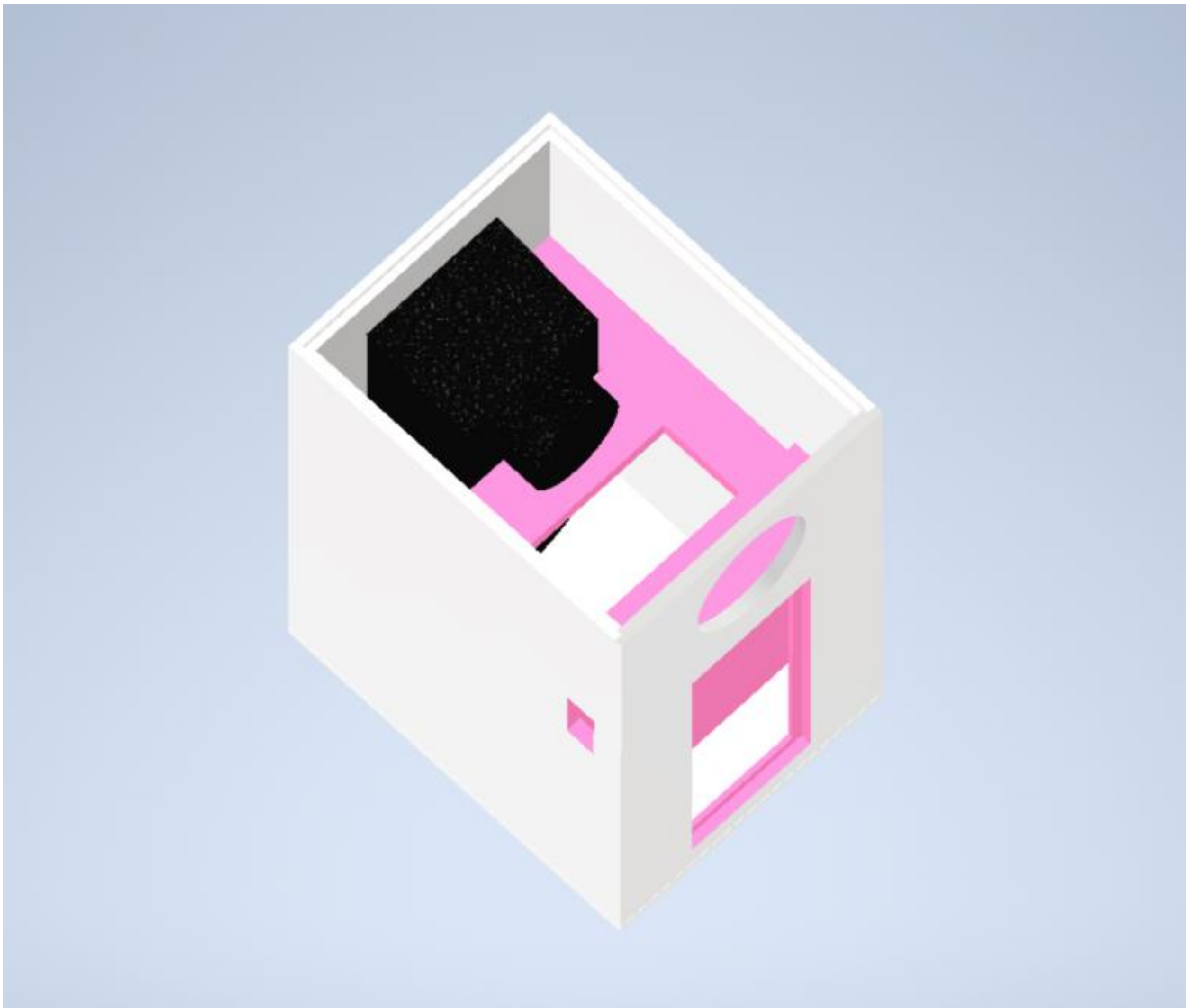

Figure 12: 765PA Model Top View

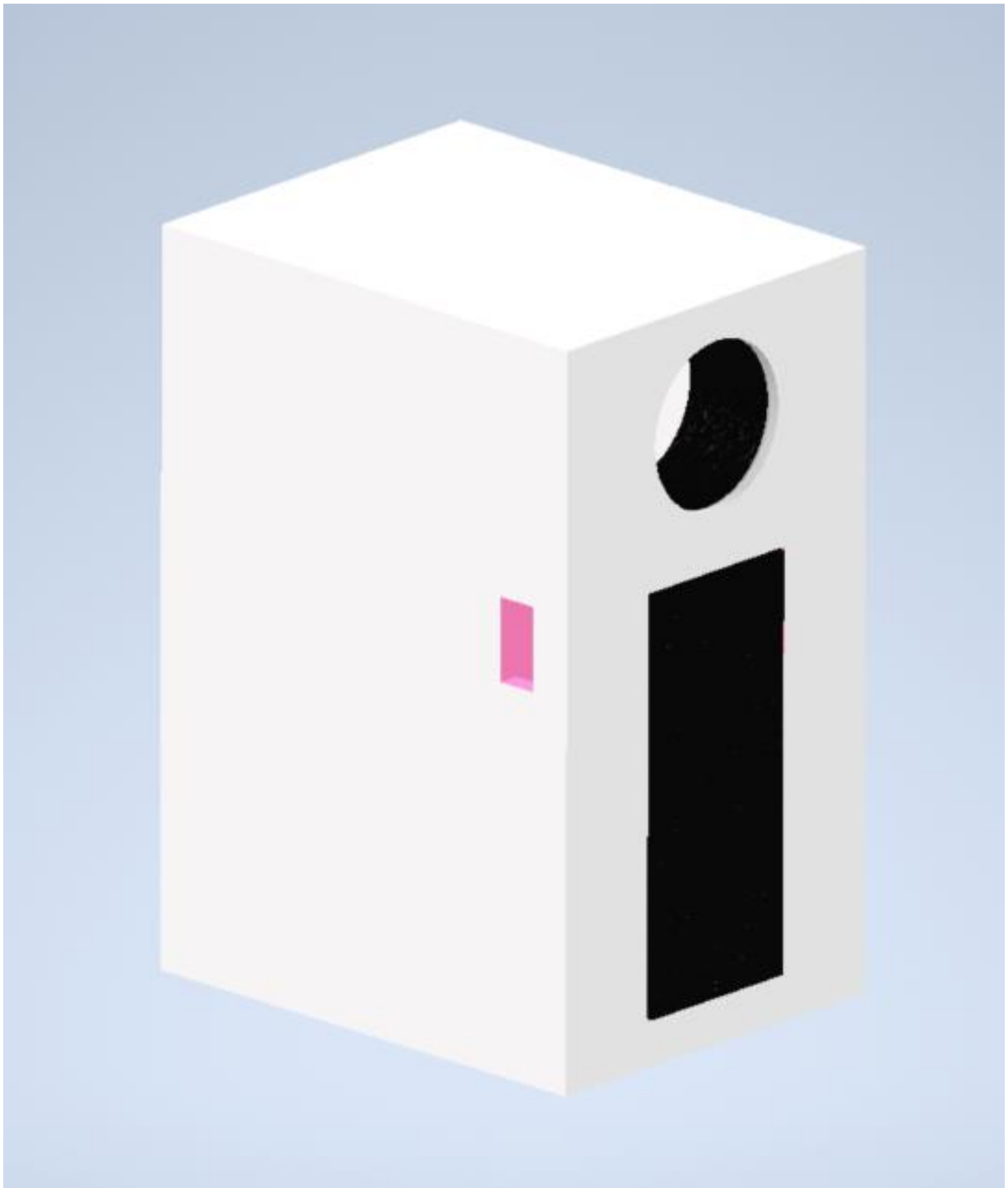

Figure 13: 765PA Model Back View

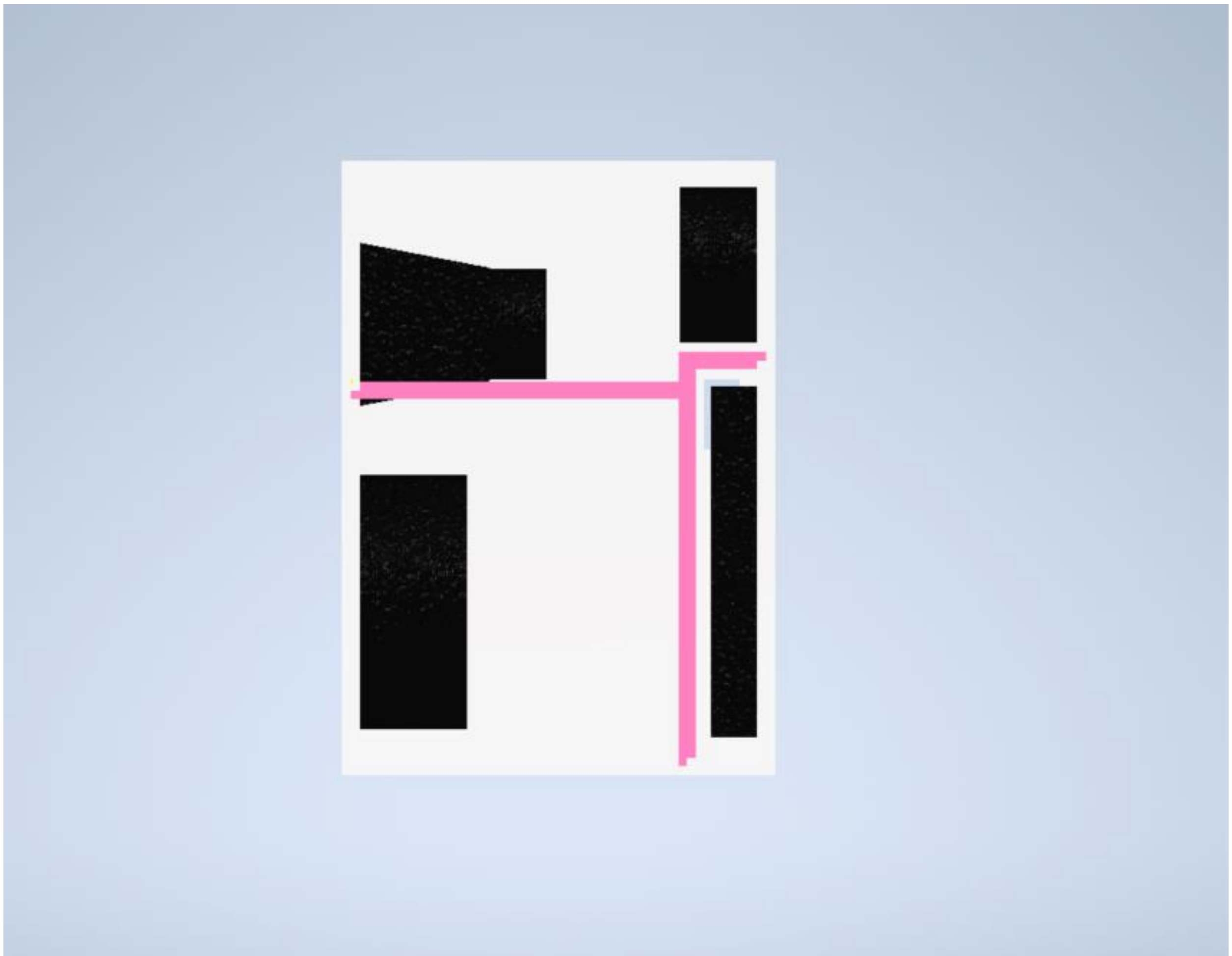

Figure 14: 765PA Model Section View

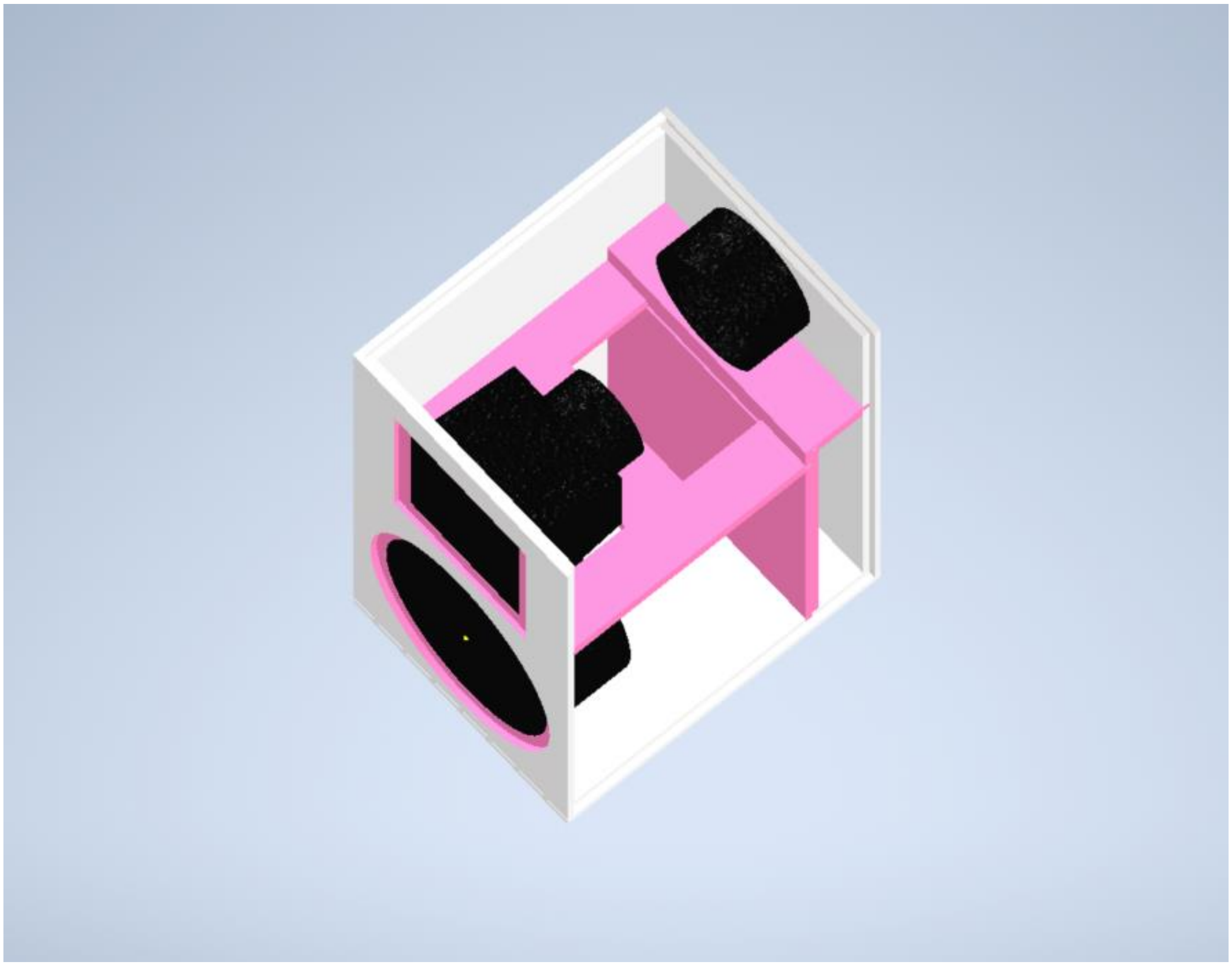

Figure 15: 765PA Model Overhead/Internal View

6.3 Final Drafts

Final Drafts of each piece can be found in Figures 16-24. Each was dimensioned to build. 9 pieces total are used to assemble each individual cabinet.

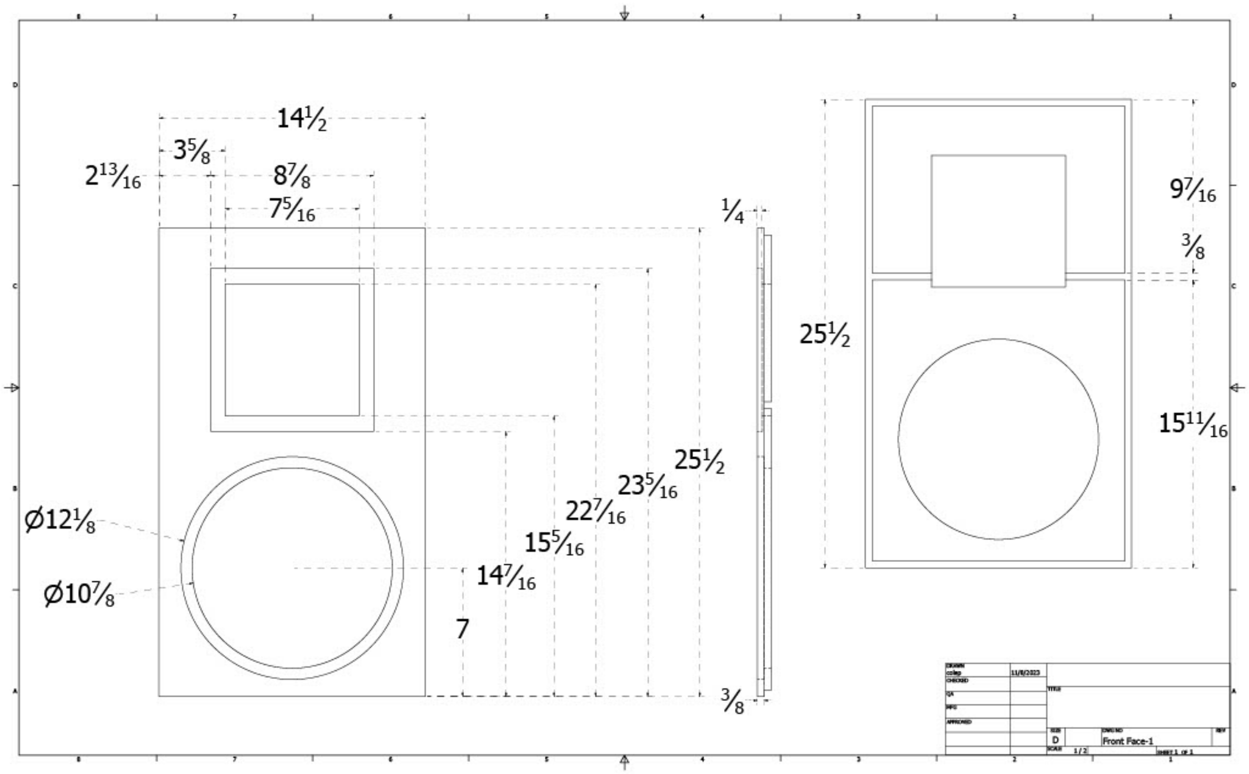

Figure 16: 765PA Front Draft

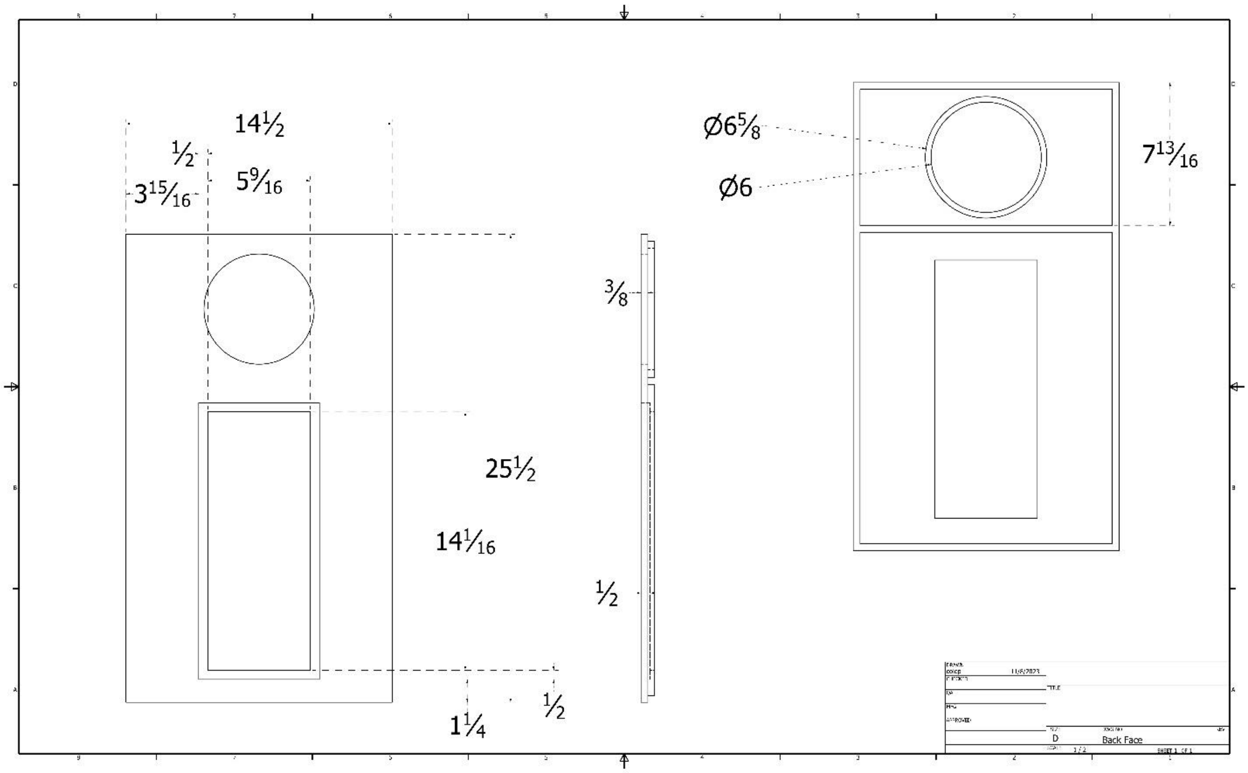

Figure 17: 765PA Back Draft

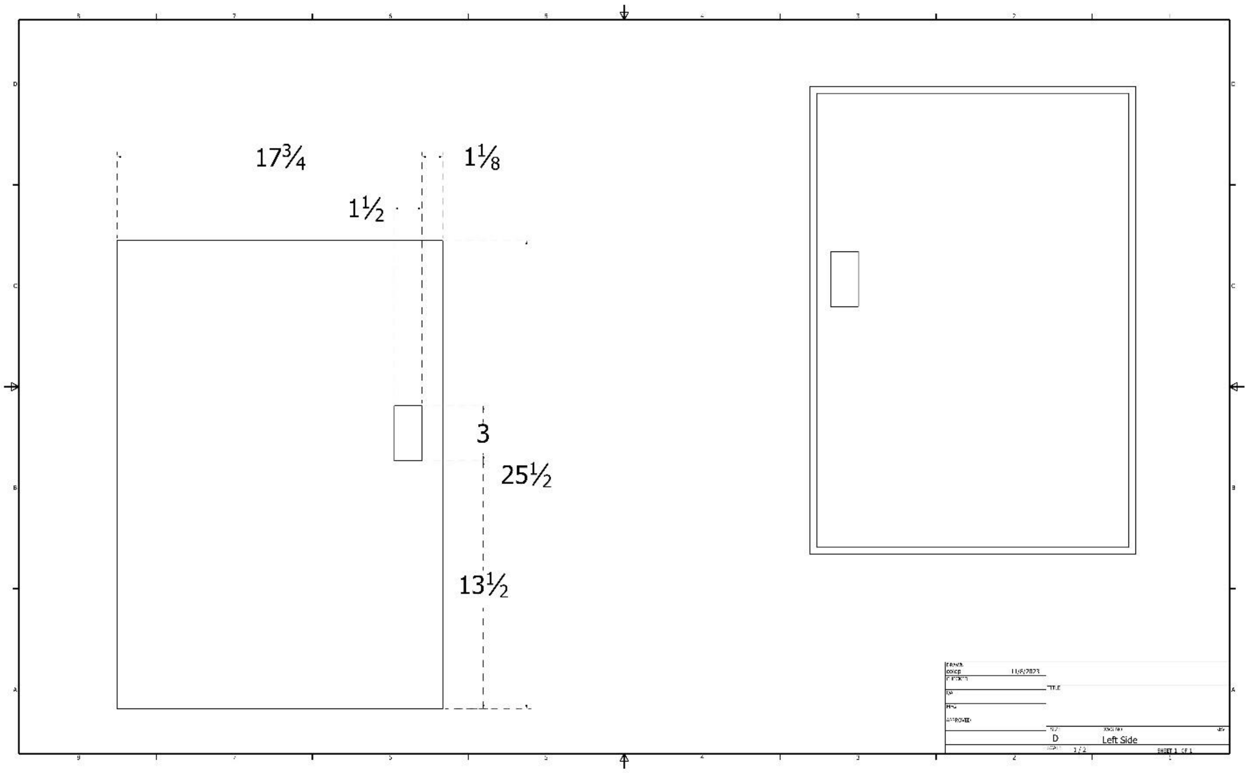

Figure 18: 765PA Left Draft

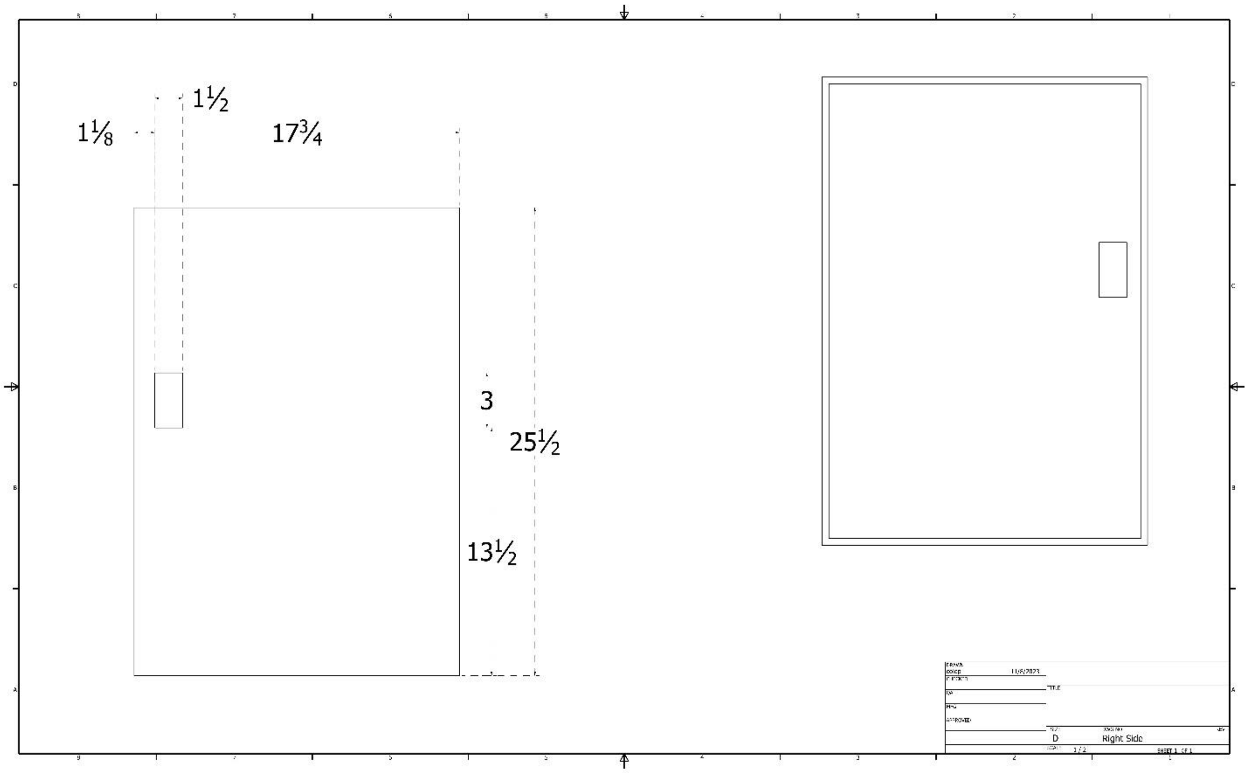

Figure 19: 765PA Right Draft

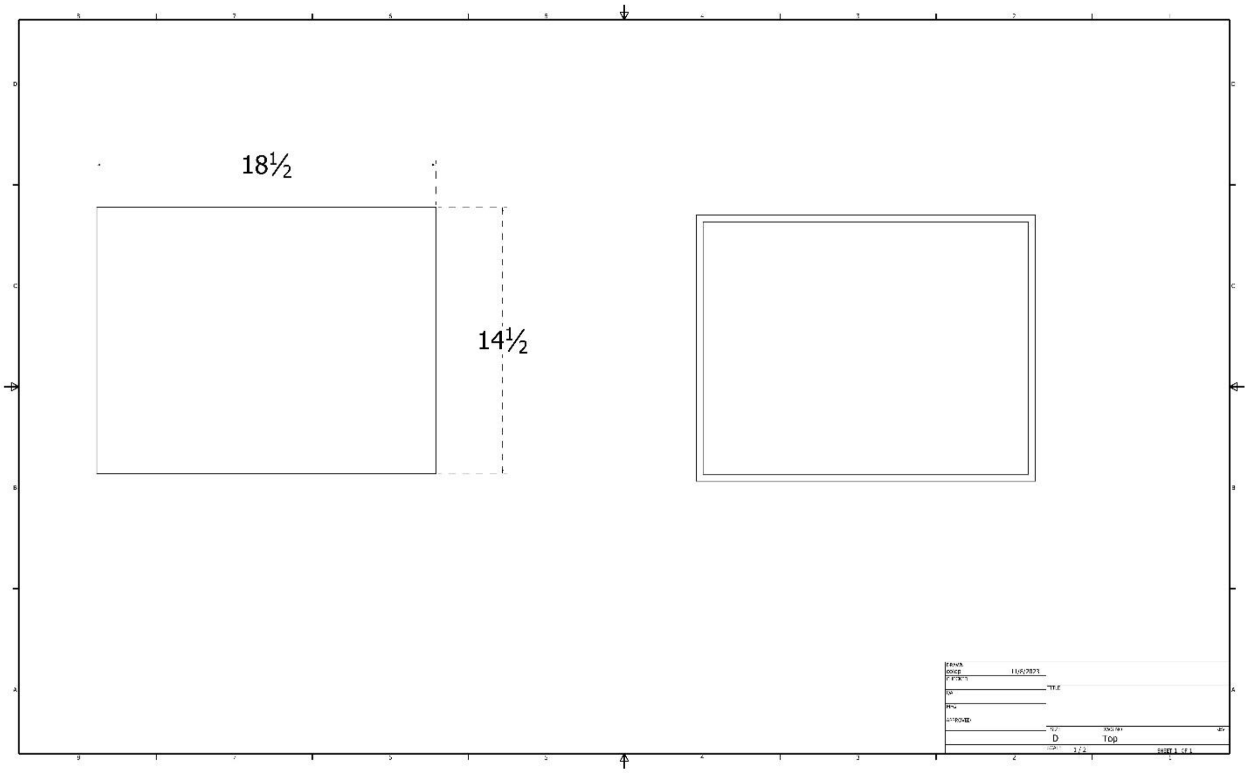

Figure 20: 765PA Top Draft

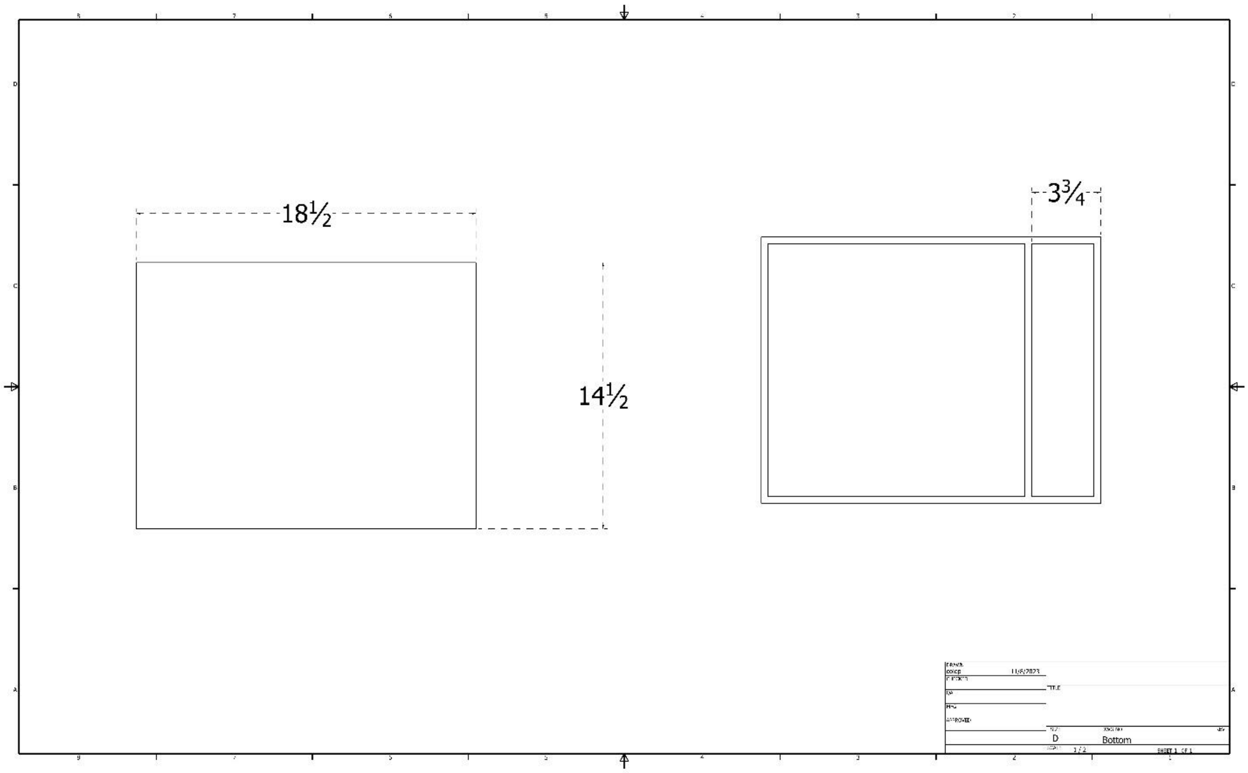

Figure 21: 765PA Bottom Draft

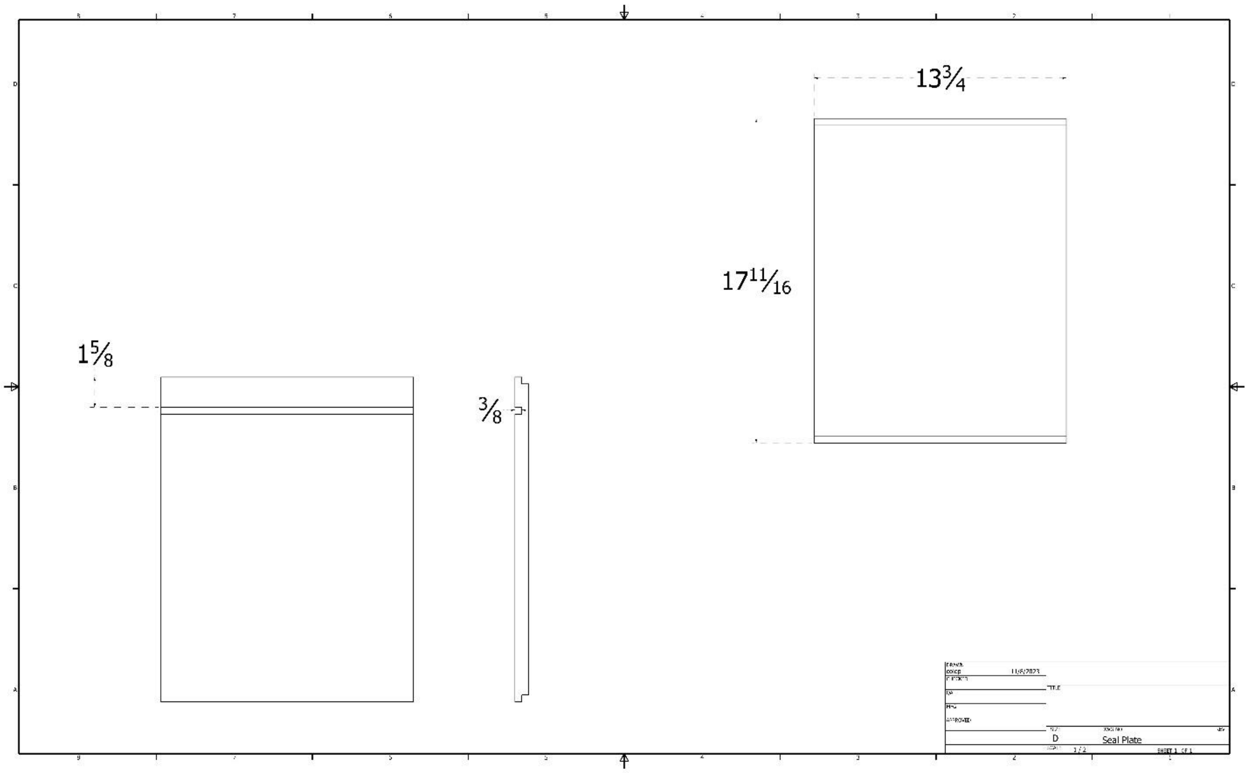

Figure 22: 765PA Seal Front Draft

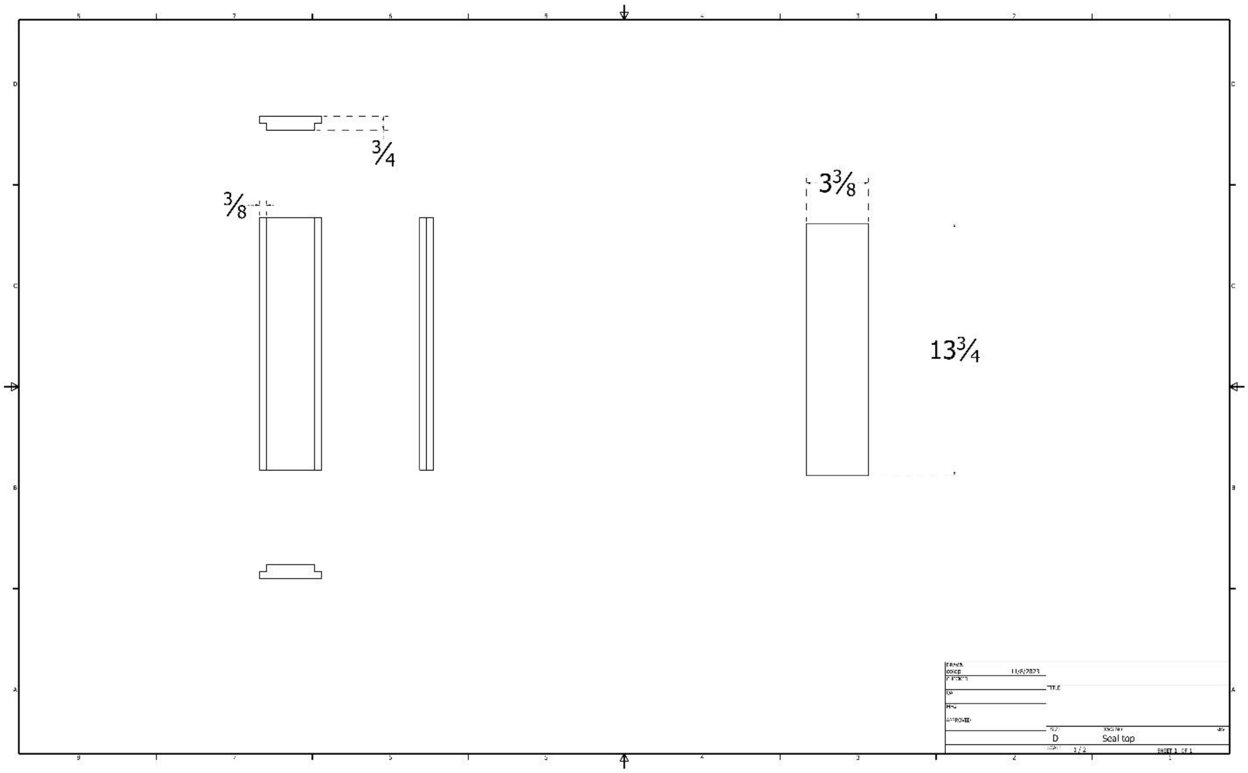

Figure 23: 765PA Seal Top Draft

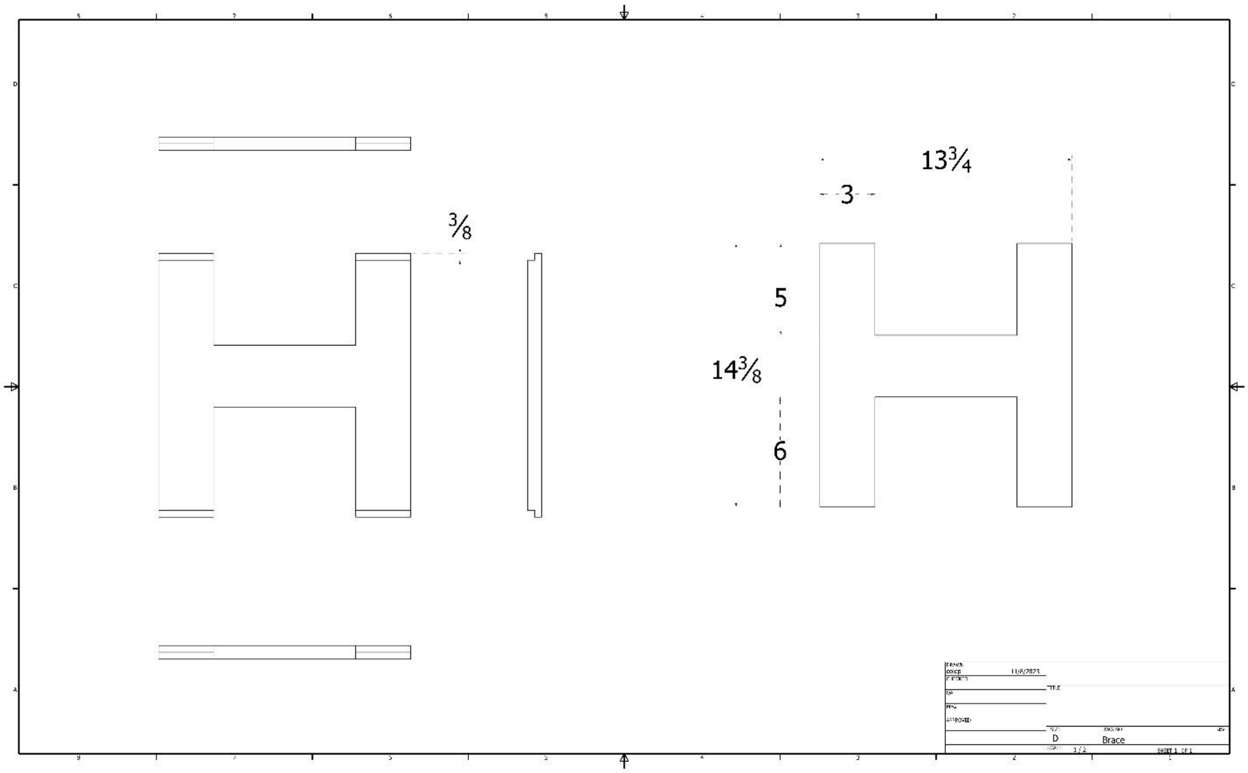

Figure 24: 765PA Bracing Draft

6.4 Materials and Build

The Speakers were built out of Plywood. I purchased the highest ply plywood that was available in Houghton MI, which was 7-Ply AC Plywood. The cabinets were constructed in the Rozsa Center for Performing Arts Scene Shop under the supervision of Mat Moore and Christopher Treviño, both of whom I owe a great deal of gratitude. Pictures of the construction process are shown in Figures 25-29

Figure 25: Initial Cuts

Figure 26: Woofer Routing

Figure 27: Woofer Test Fit

Figure 28: Horn Test Fit

Figure 29: Clamping and Gluing

After construction was complete, the cabinets were coated with White Duratex. Duratex was used to give the cabinets more weather protection. I went with white as it allows for more colors to be painted over it, if I decide to pain the cabinets in the future. The Duratex coating is thick and coarse, which gives the speakers a unique look, but I think it turned out nice, and enjoy the look of the cabinets. Pictures of the completed speakers can be seen below in Figures 30-33

Figure 30: Front View of Completed System

Figure 31: Back View of Completed System

Figure 32: 765PA's (Photo Credit: Christopher Plummer)

Figure 33: Cole Puertas with 765PA's (Photo Credit: Christopher Plummer)

7.0 Tuning

7.1 Crossover

The tuning process began with an initial measurement of the woofer and tweeter in isolation at 1M both on axis and 30* off axis. These initial measurements are shown in figures 34-37

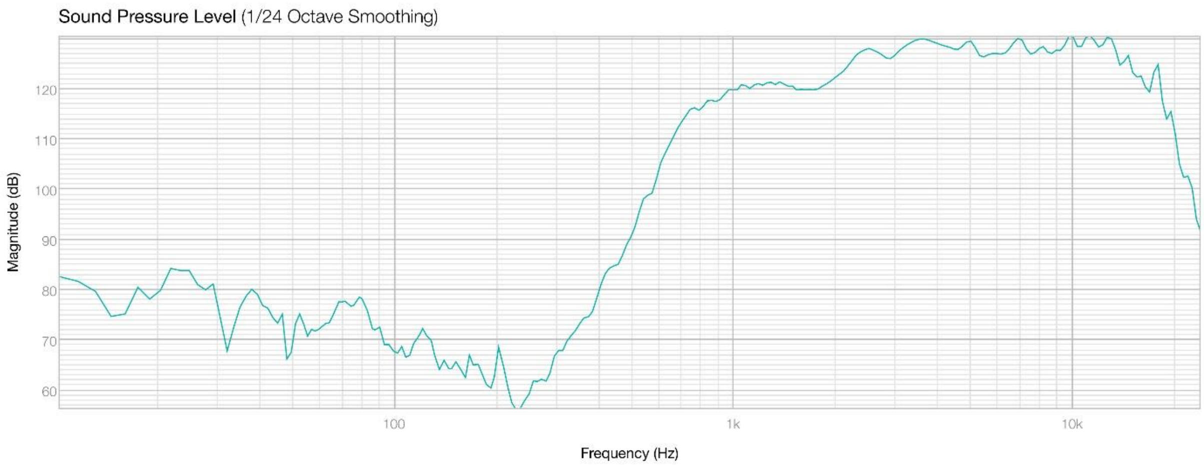

Figure 34: Tweeter Frequency Response @ 1M On Axis

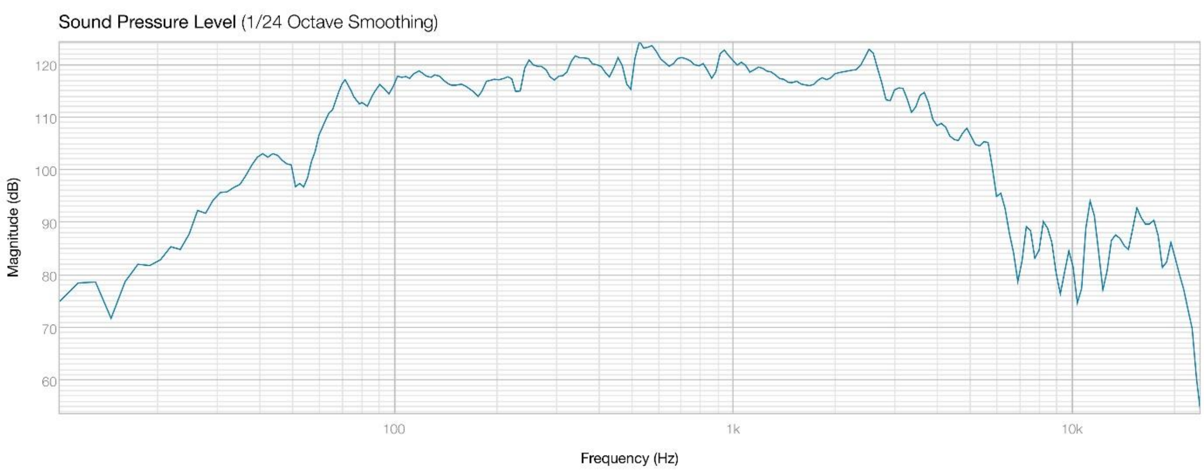

Figure 35 Woofer Frequency Response @ 1M On Axis

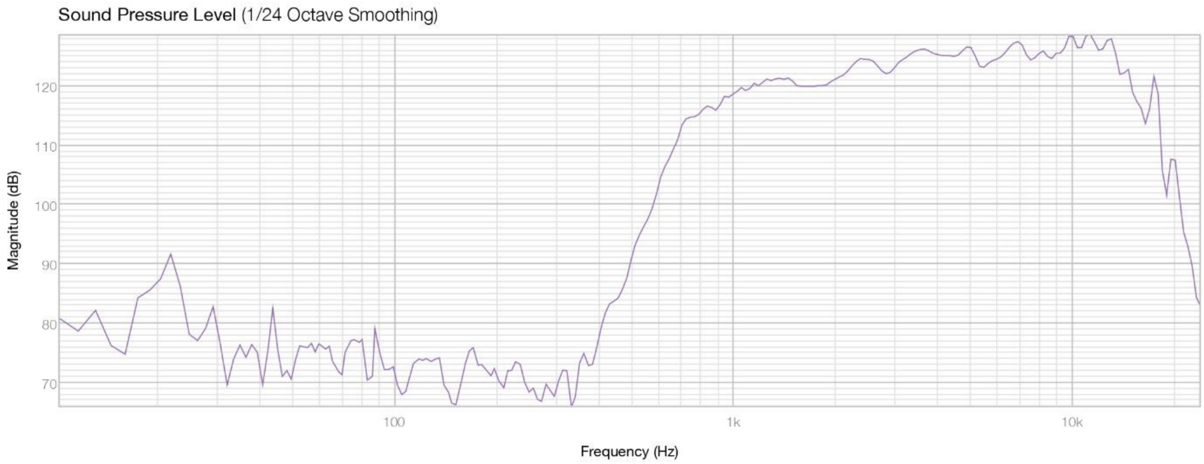

Figure 36: Tweeter Frequency Response @ 1M Off Axis

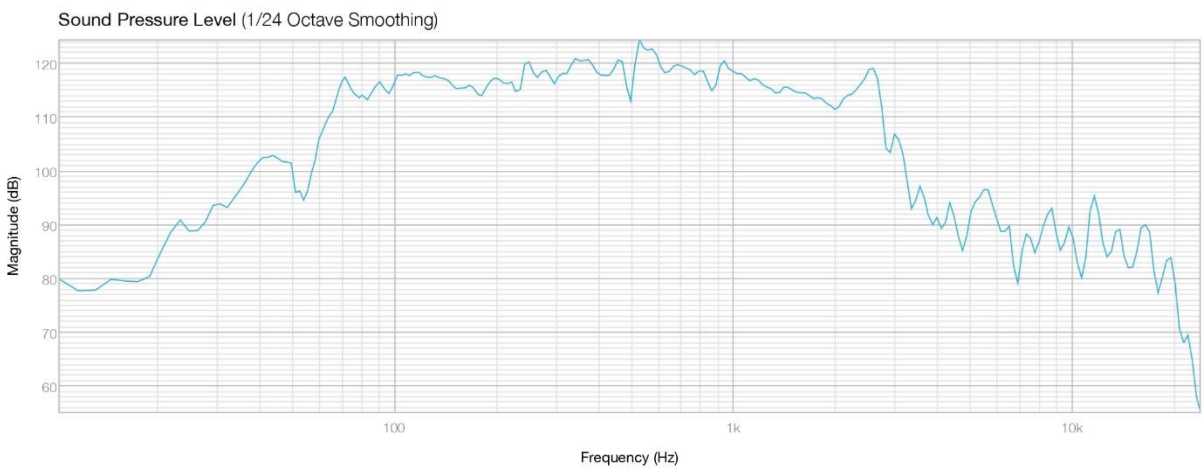

Figure 37: Woofer Frequency Response @ 1M Off Axis

Based on the roll off frequencies of each driver, a steep 48dB/Octave Butterworth Filter at 1.8khz was used. The results of the crossover on the Woofer and Tweeter can be seen in Figures 38 and 39

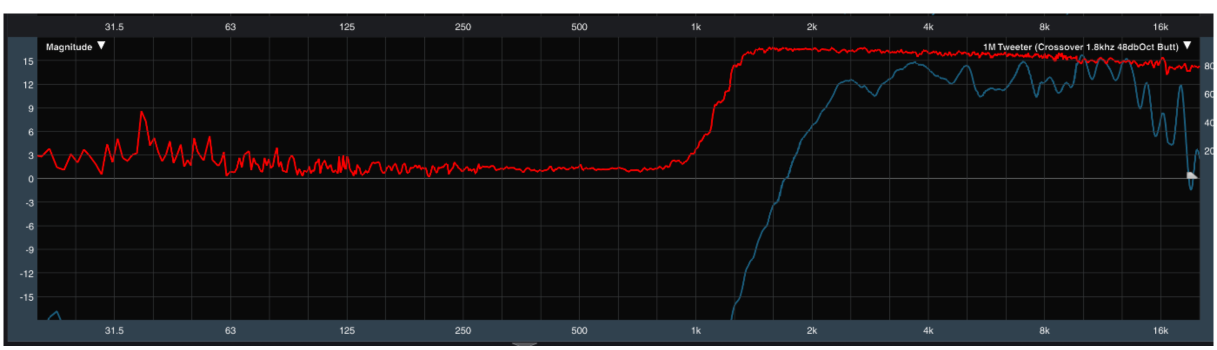

Figure 38: Tweeter with Crossover

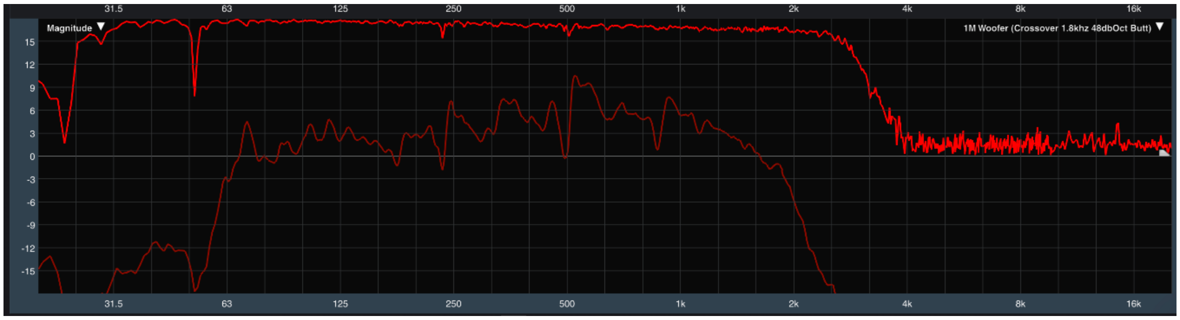

Figure 39: Woofer with Crossover

The volume of the Tweeter was then lowered by -10dB to align it with the Woofer

7.2 Delay

After the crossover was set, the phase response of the drivers was aligned using delay. As my Compression Driver sits further behind the Woofer in the cabinet, delay was applied to the Woofer. Adding .3ms of delay aligned my Woofer and Tweeter, as shown in Figure 40.

Figure 40: Drivers in phase at 1.8kHz

7.3 EQ

Once the drivers were phase aligned, I used a Pink Noise output from Smaart to EQ to speakers to be as close to +/-3dB across their frequency spectrum. The Woofer was showing an f3 of ~65Hz, while the Tweeter began to drop off around 16kHz. Everything between 65Hz-16kHz was eq'd to be within the +/3dB range. This response can be seen in Figure 41

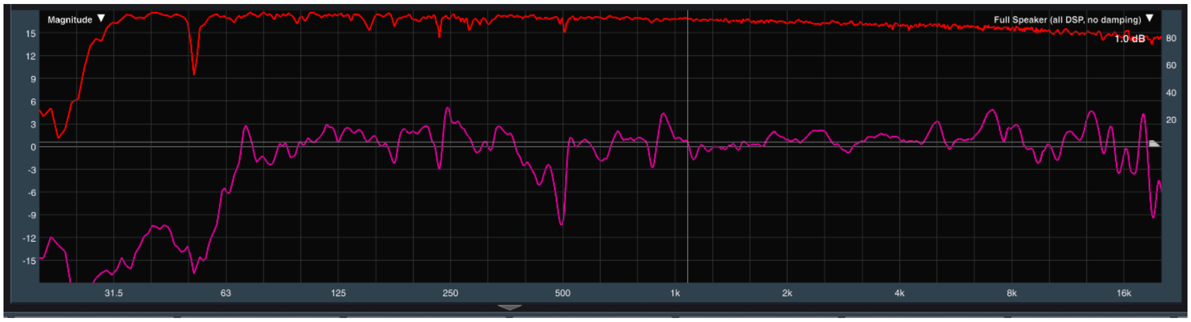

Figure 41: Initial EQ'd Speaker

7.4 Damping

As seen in Figure 41, the speaker showed a box resonance around 500Hz. 500Hz corresponded to the distance of the back seal from the woofer. Damping was placed around the back and side walls of the speaker, which reduced this dip at 500hz. The damping also cleaned up the low end of the woofer but reduced its SPL levels quite substantially. For the final tests, I removed the damping as I prioritized the extra low end over the 500hz resonant dip.

7.5 Tuning Frequency

I also measured the tuning frequency of my port, Shown in Figure 42, which was at 63Hz. Since this was below the f3 of my Woofer, it was not helping my low-end response, so the port was removed before the final tests in order to raise the resonant frequency of the box. The damping being removed also helped to slightly raise the resonant frequency and get a greater low-end response.

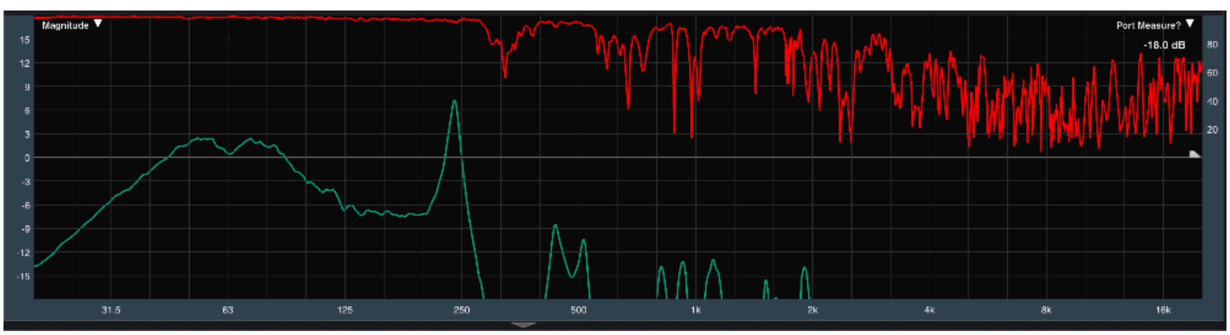

Figure 42: Tuning Frequency with Port

8.0 Final Performance Tests

After removing my port and damping material, the steps shown in tuning were gone through once again to recalibrate my EQ and Delay. The final performance tests of the 765PA's can be seen in Figures 43-

Figure 43: Final Woofer Frequency Response in Smaart

Figure 44 Final Tweeter Frequency Response in Smaart

Figure 45: Final Phase Response in Smaart

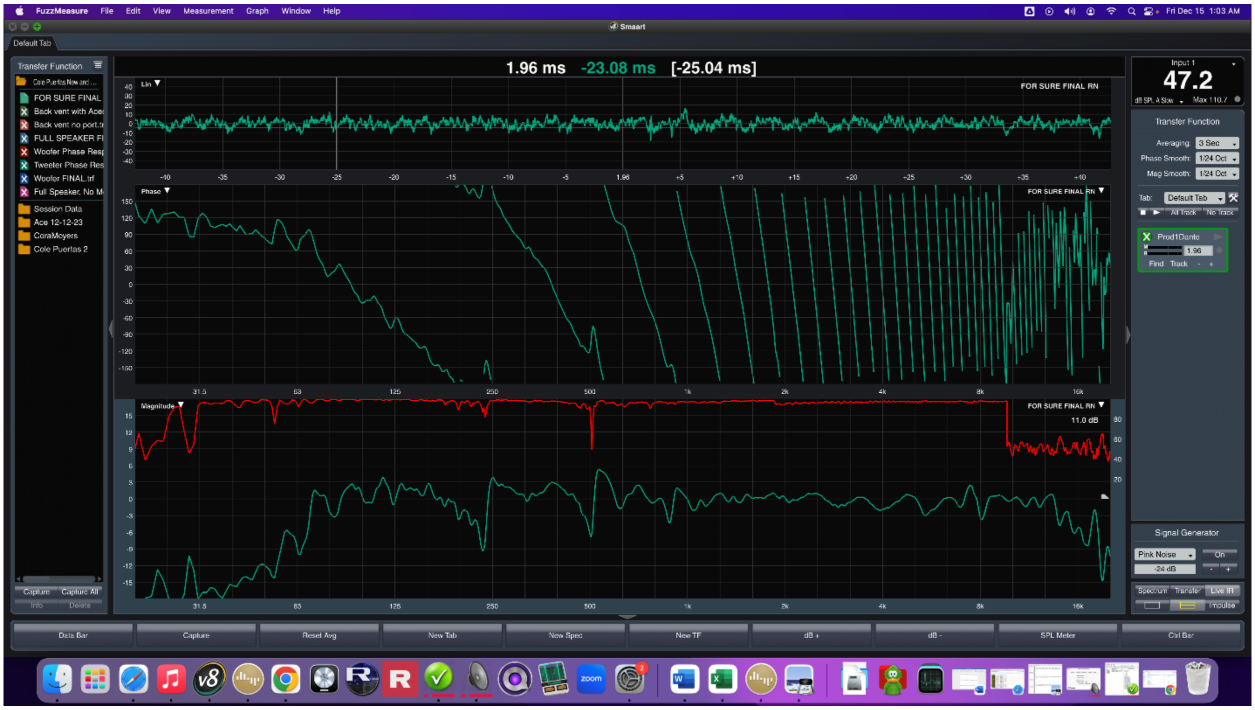

Figure 46: Final Frequency Response in Smaart

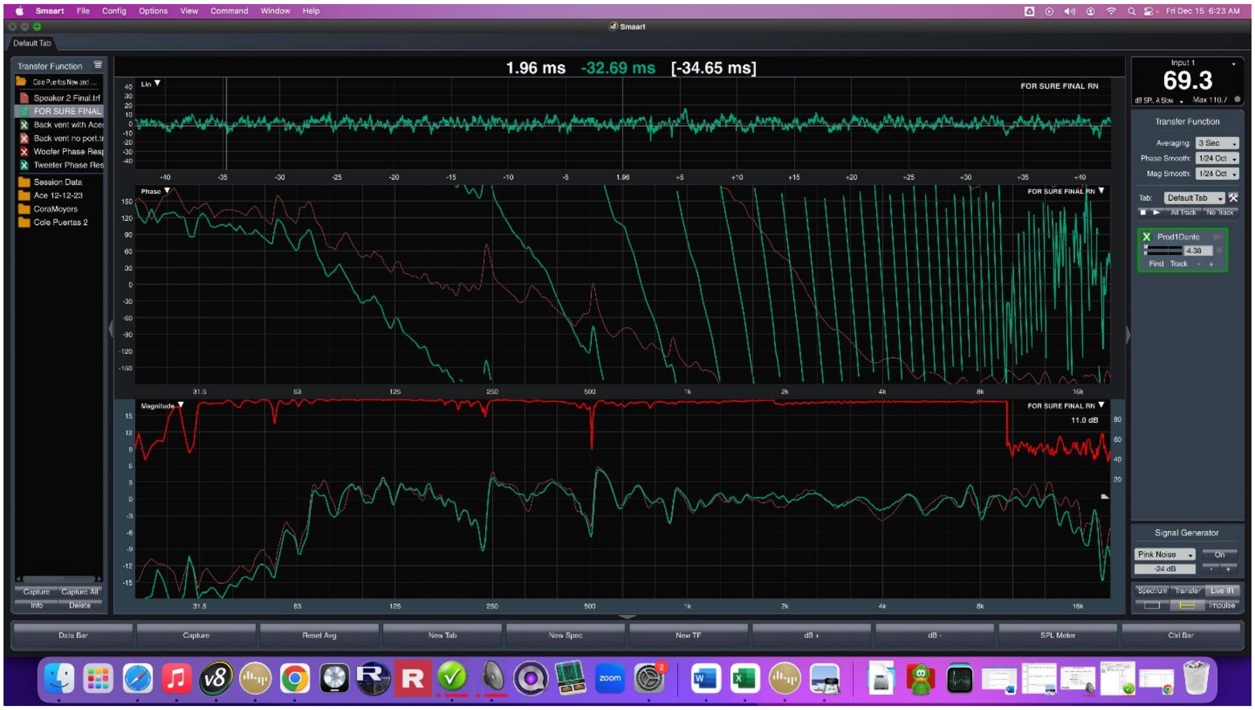

Figure 47: Integrated Frequency Response (Speakers) in Smaart

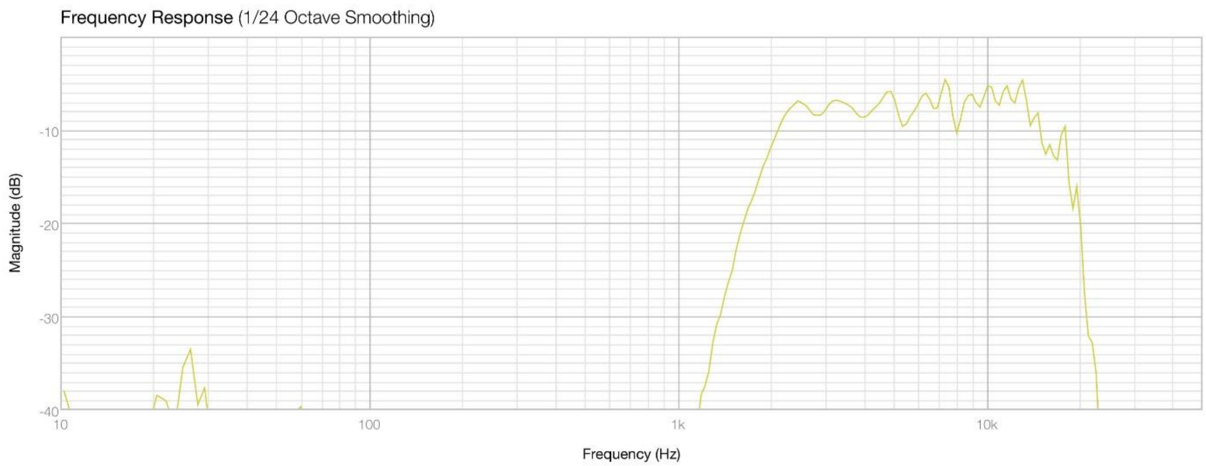

Figure 48: Tweeter Frequency Response

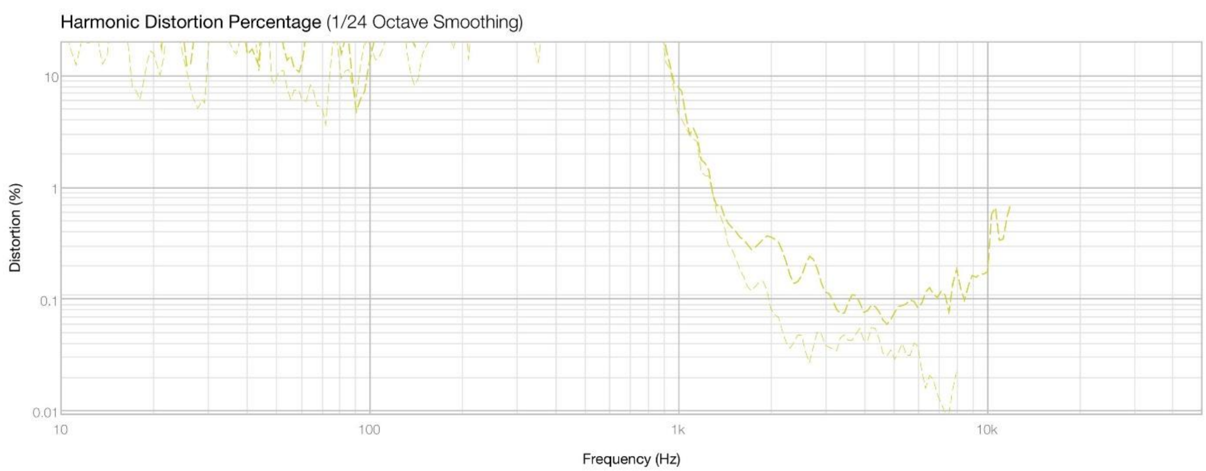

Figure 49: Tweeter Harmonic Distortion

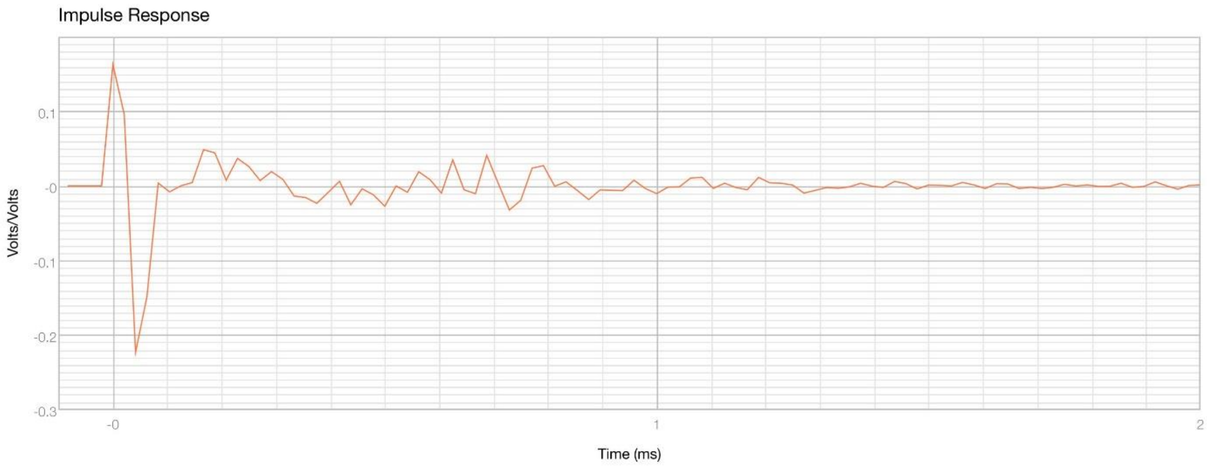

Figure 50: Tweeter Impulse Response

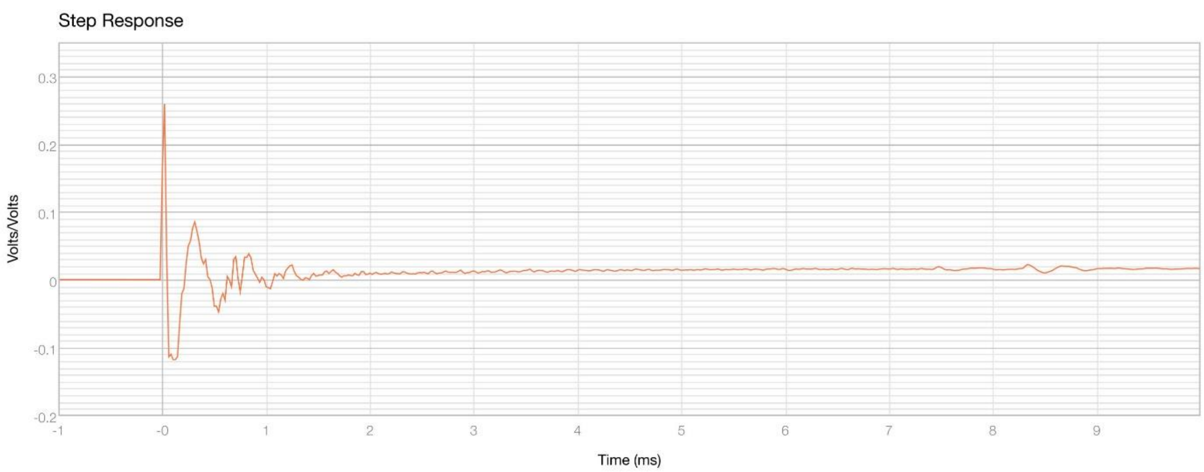

Figure 51: Tweeter Step Response

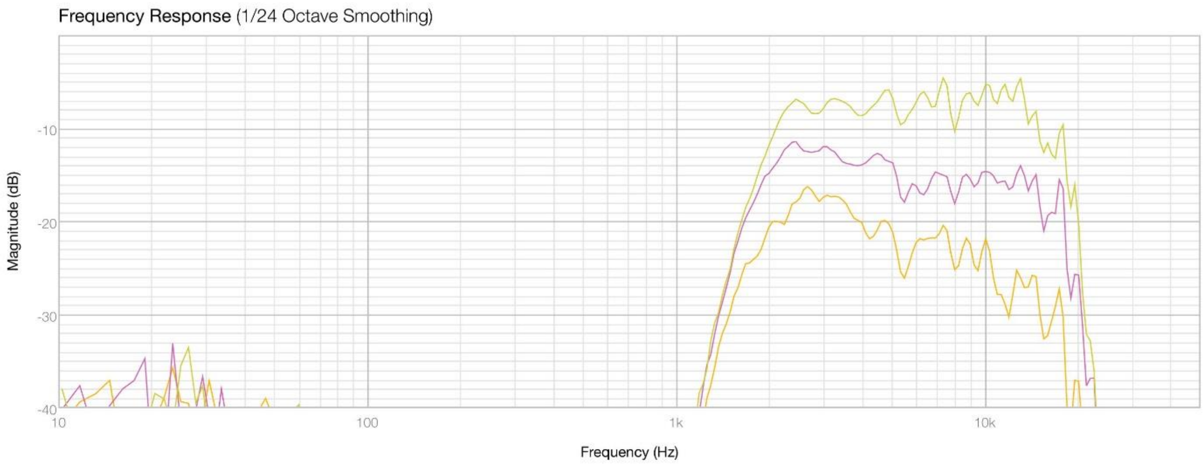

Figure 52: Tweeter Vertical Off Axis

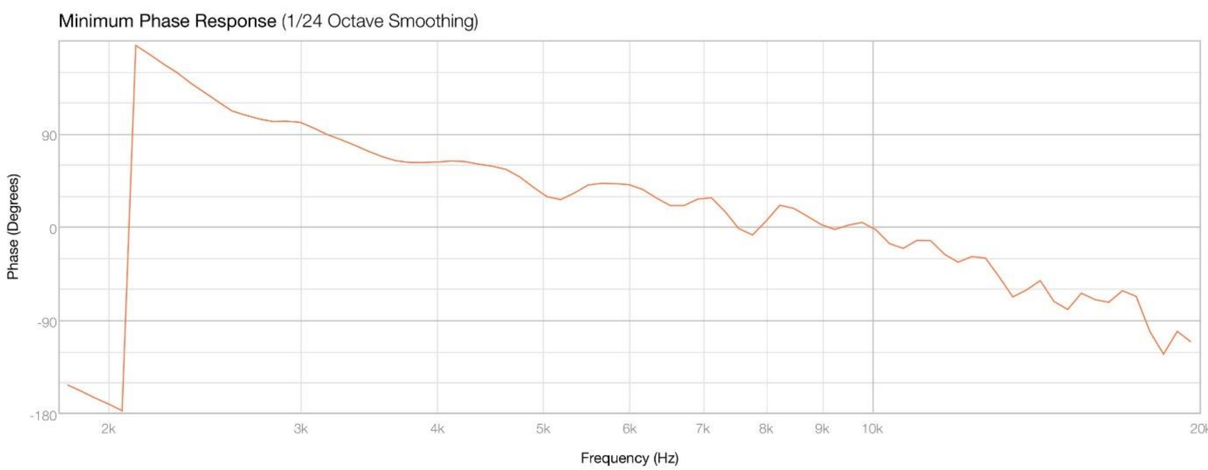

Figure 53: Tweeter Minimum Phase Response

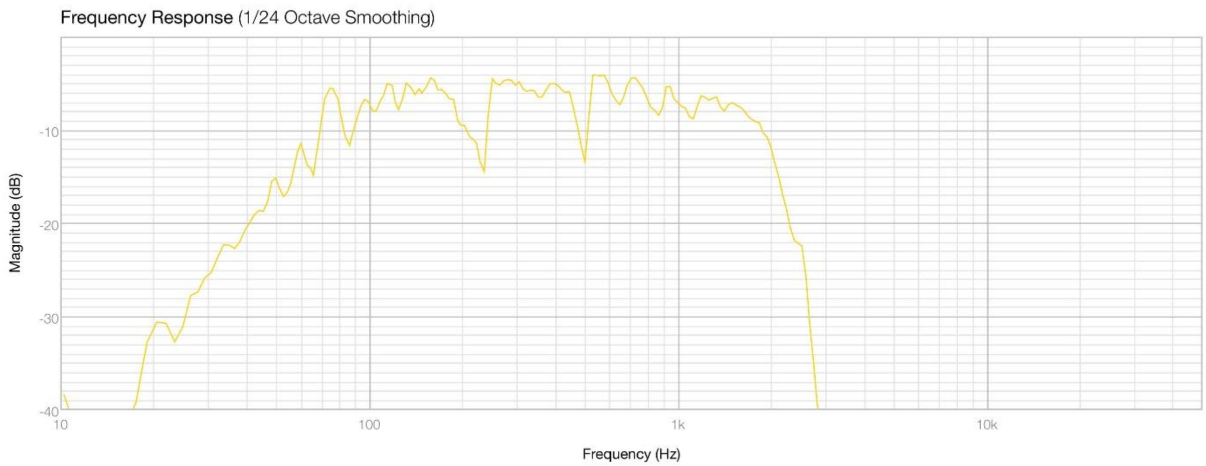

Figure 54: Woofer Frequency Response

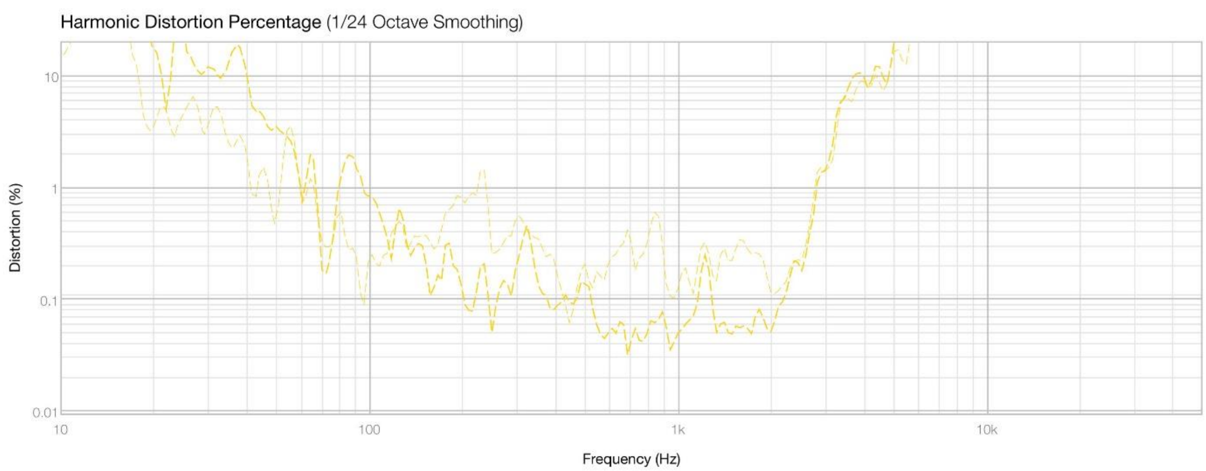

Figure 55: Woofer Harmonic Distortion

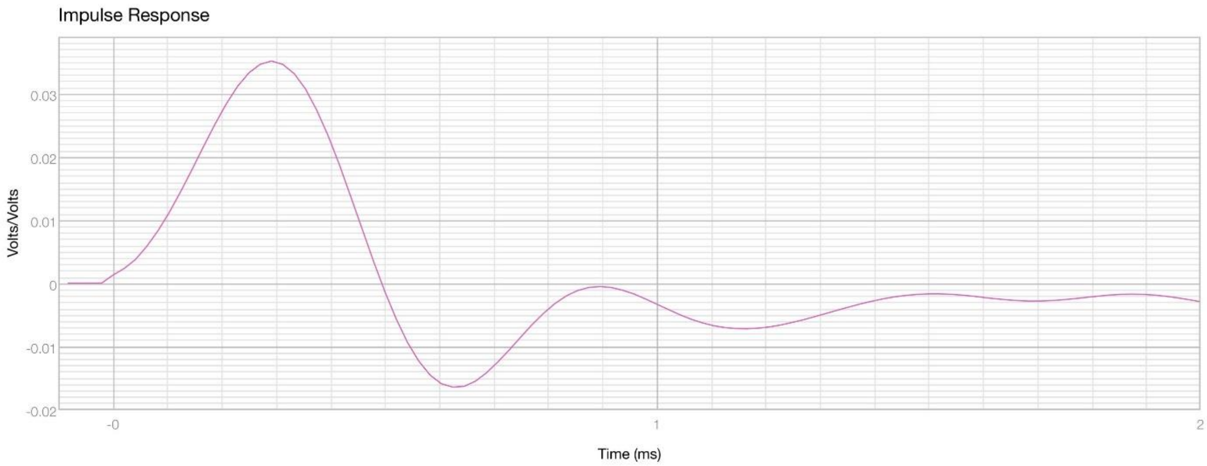

Figure 56: Woofer Impulse Response

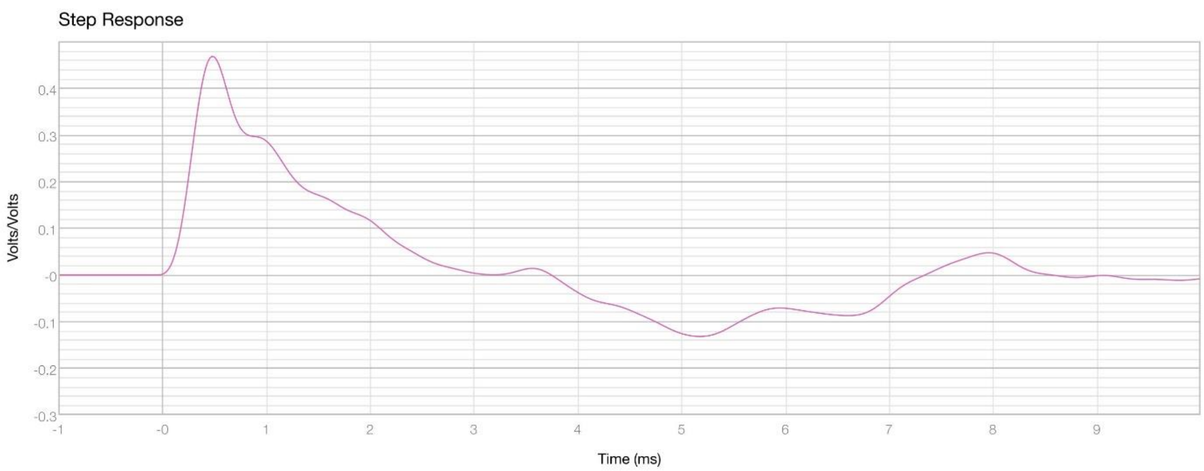

Figure 57: Woofer Step Response

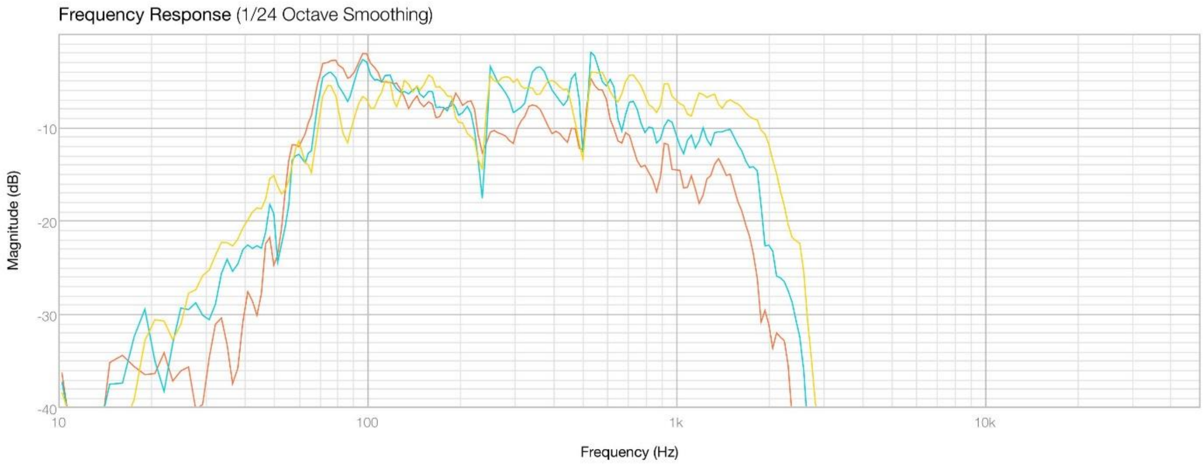

Figure 58: Woofer Vertical Off Axis

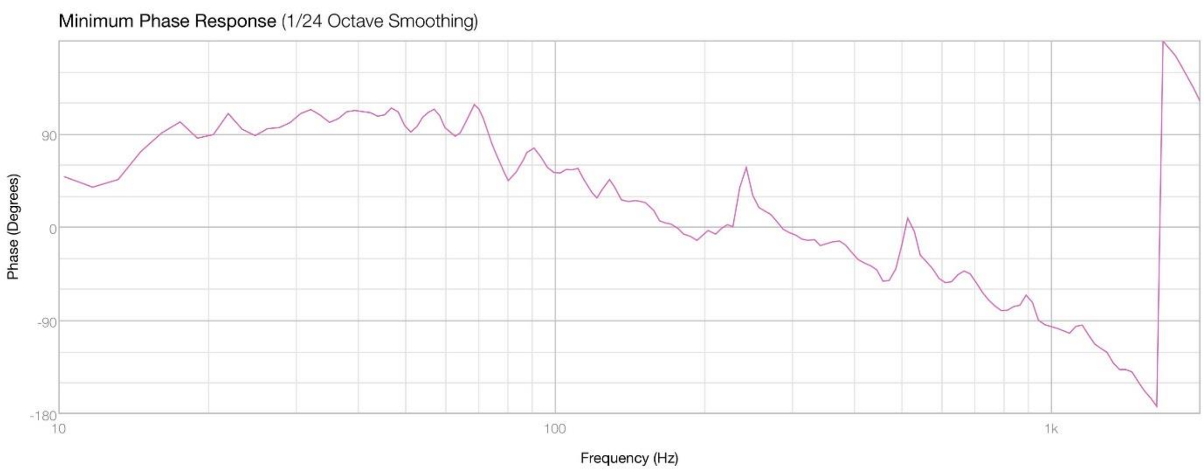

Figure 59: Woofer Minimum Phase Response

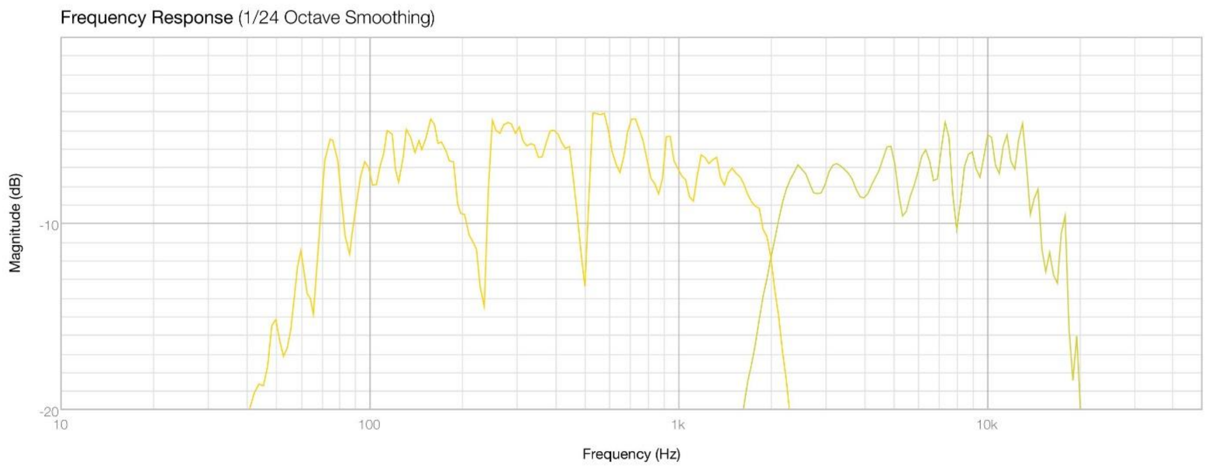

Figure 60: Integrated Frequency Response (Drivers)

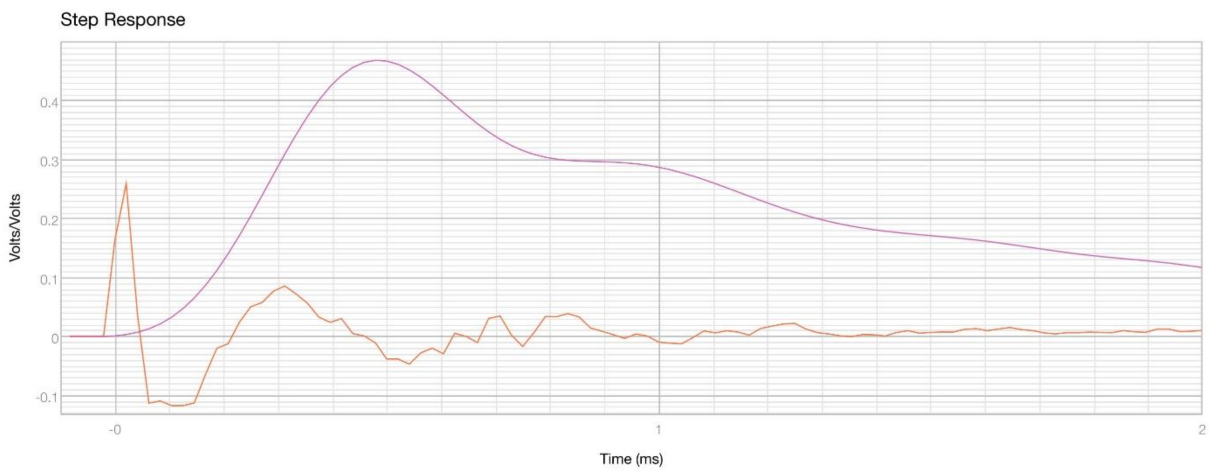

Figure 61: Integrated Step Response

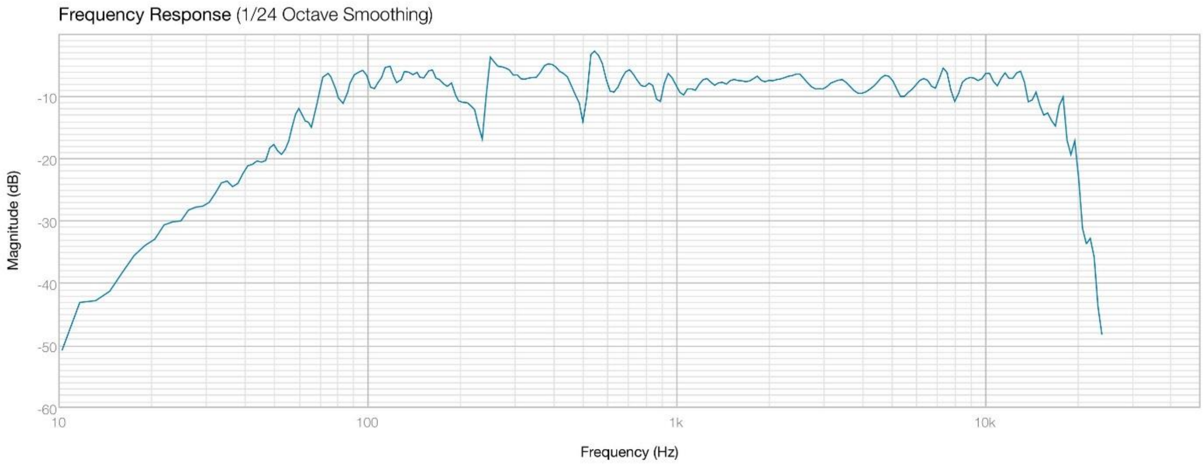

Figure 62: Final Frequency Response 60dB Range

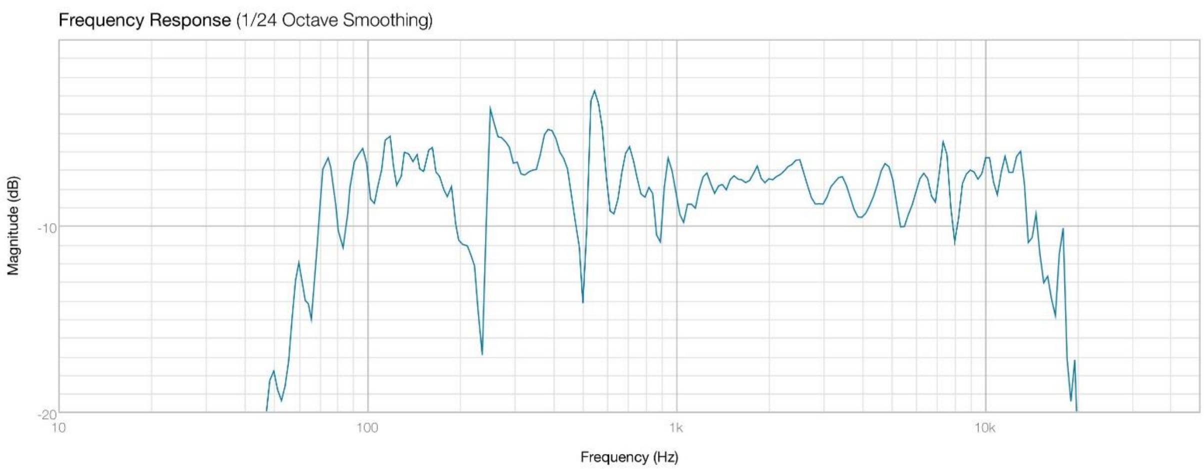

Figure 63: Final Frequency Response 20dB Range

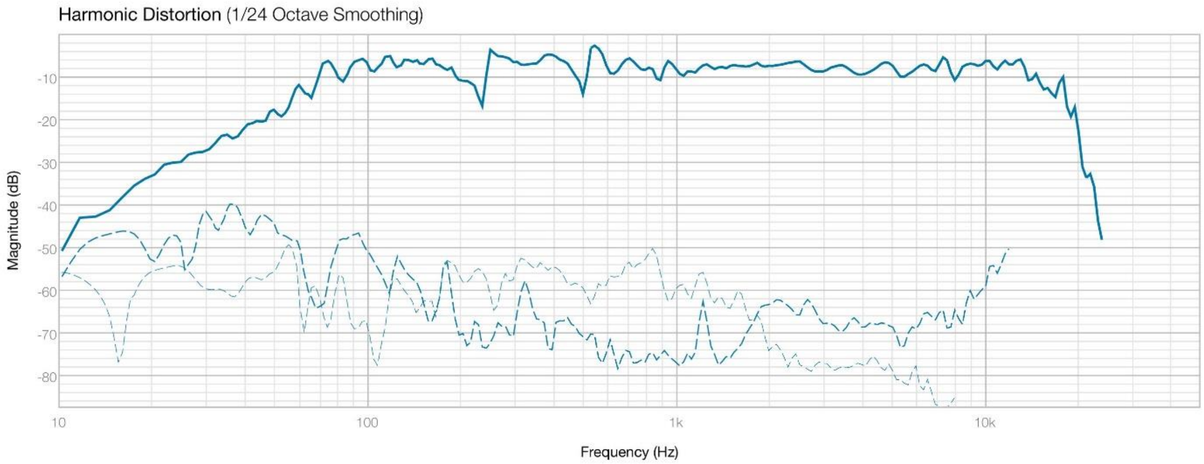

Figure 64: System Harmonic Distortion

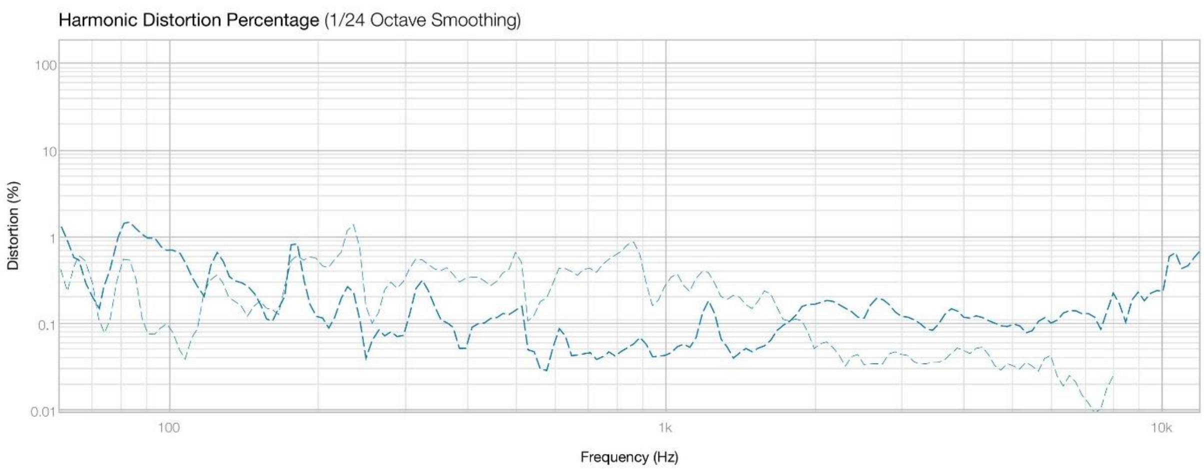

Figure 65: System Harmonic Distortion Percentage

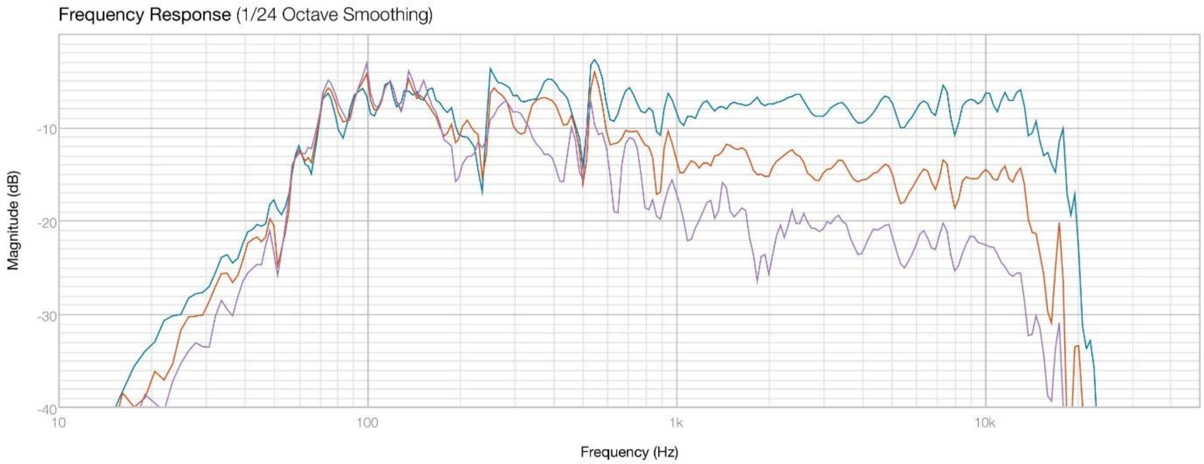

Figure 66: System Horizontal Off Axis

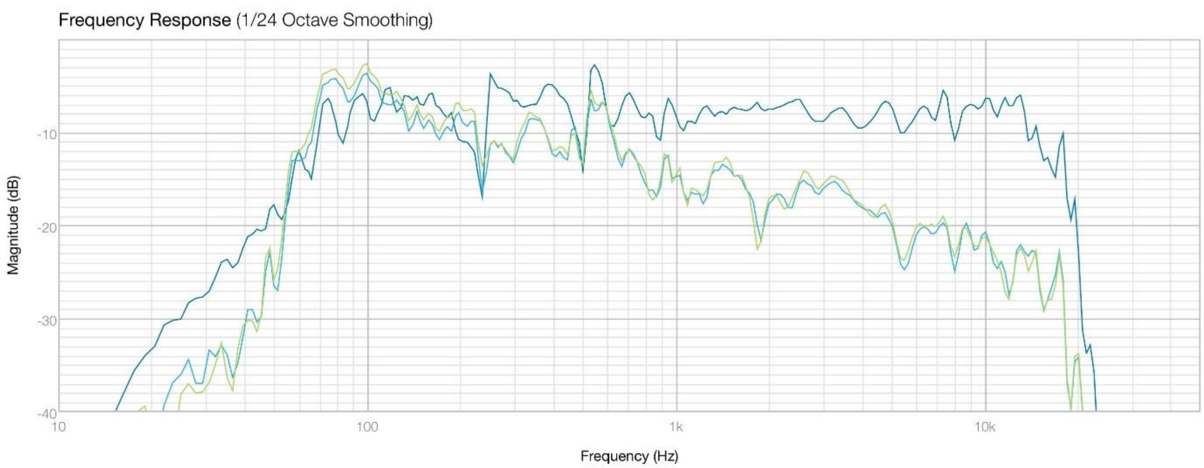

Figure 67: System Vertical Off Axis

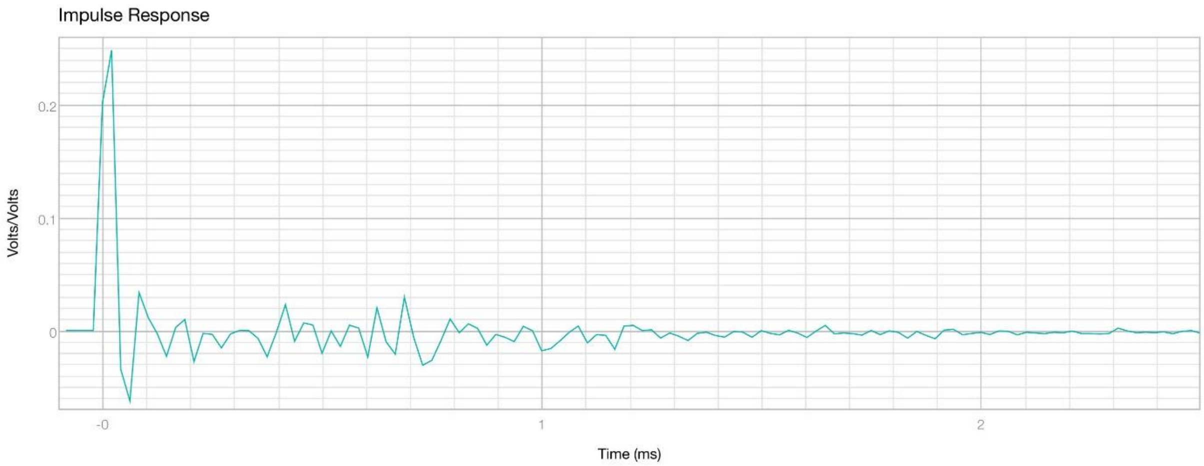

Figure 68: System Impulse Response

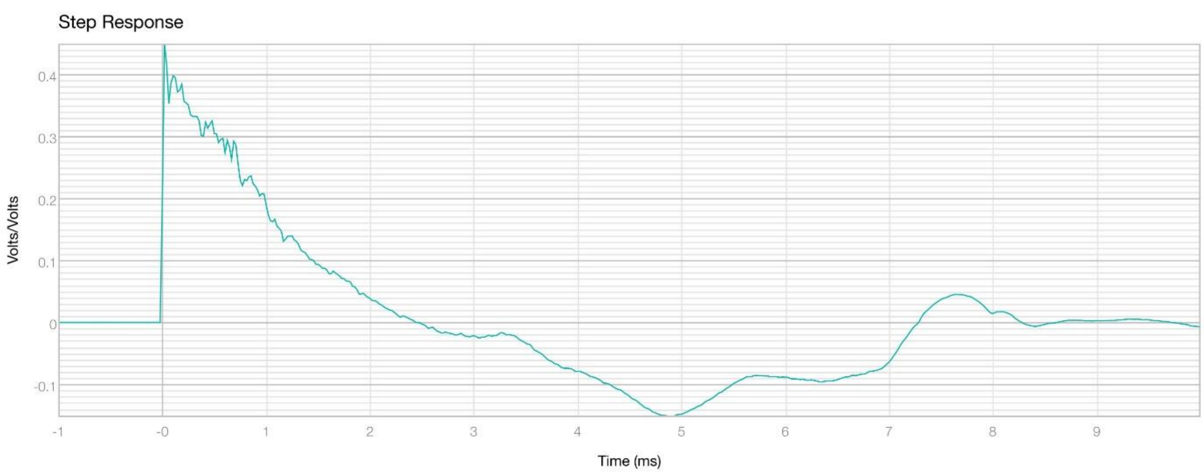

Figure 69: System Step Response

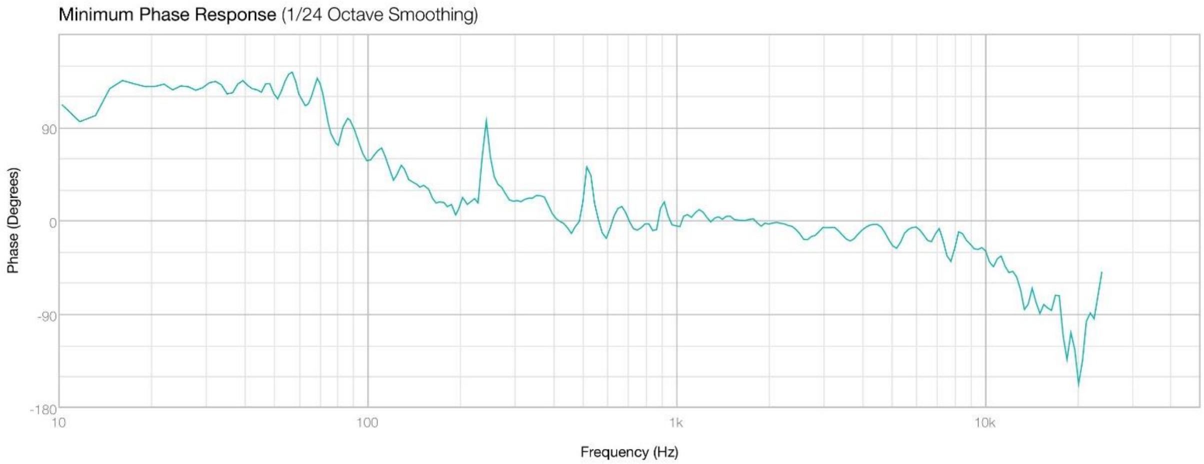

Figure 70: System Minimum Phase Response

9.0 Reflection

There are still many unknowns about my system and kinks I would like to work out. I was unable to properly calculate my max SPL, which is something I feel is really important to know for a PA system. I also ended up with a far less accurate Frequency Response compared to the specs of each individual driver. Based on my technical specification goals I did not achieve my ideal frequency response goals, and with my SPL unknown, I am unsure if I achieved that goal either. Without considering the paper, I am not very satisfied with the low end of my speaker, especially, the transient response of the Woofer. Based on WinSpeakerz calculations, I was aiming for a nice bass boost around 60-80Hz. While that would not provide the boom I am missing without the Subwoofer, it would have provided a nice punch, which I feel is greatly missing from my speakers at the moment. Based on my functional description, I do not think these speakers work great for electronic music or DJing, which makes me feel like I really failed to achieve my goal with this system.

On the positive side, I think my speakers look really nice, and have a ton of really practical and convenient features in real world use. The plate amp makes a big difference, as being able to just move around the two cabinets and have everything I need to get the system up and running is extremely convenient. The cabinets also sit nicely on tripod mounts, and while large, can still be transported and handled by one person. The speakers also sound good compared to typical PA's with relatively low distortion and a low noise floor. Vocals and elements in the mids of music can stand out well without getting too crunchy, even at a high SPL.

While this system has its ups and downs, it unfortunately, do not feel like the fill the gap in my equipment selection that I was looking for. As I continue to use these speakers casually, my opinion may change, but for now, I would hope to continue working on them to be able to get the sound I am looking for.

10.0 Bibliography

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