Transducer Technical Document

Gust Op. 1

FA4740 Spring 2018

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Function Description

Design Goals

To create a functioning floor-standing 3-way system capable of pleasant response throughout the auditory frequency spectrum. They should be able to provide sufficient low frequency extension without an external subwoofer while maintaining a level of accuracy for critical listening.

Purpose

The purpose of these loudspeakers will be for casual listening in addition to serving as the main left/right channels of a home surround system. A variety of content will be played through these speakers, making it necessary for a solid accurate frequency and transient response.

Usage Environment

The location of these loudspeakers will most likely end up in a small square room of a busy apartment. With that in mind, some level of noise competition will occur between the content being played and the outside noise of the environment. This means that the loudspeakers will need to be able to produce a reasonable amount of sound. The ideal listening position will be across a wide seating area around standard couch height. To improve the response for the intended area, the speakers should be placed near a wall to be in quarter space between the wall and floor. Proximity to the wall also allows for the sound leaving the rear port to reflect more in space creating a sense of fuller bass.

Listening Purpose

The main listening experience of these loudspeakers will be closer to high enjoyment loudspeakers rather than monitoring and mixing loudspeakers. Very little mixing and monitoring will be done on these speakers as they are meant for relaxed listening and casual enjoyment. The design will also allow for extended periods of listening while limiting fatigue due to their coloration. These are also designed with listening backward in mind.[1] Listening backward implies an accurate reproduction of the original source. While these speakers will have some coloration to them, it is still intended for them to play content accurately.

Visual Aesthetics

Designed for living room enjoyment, size was not a limitation for the concept of these loudspeakers. A tall, narrow yet deep rectangular cabinet was the conceived shape of the loudspeaker. Ideally different angles would be used but for ease of manufacturing, regular 90 degree internal corners were designed. To compensate for the rectangular shape of the cabinets, a non-whole number ratio is used. Having each dimension be unique will allow for better control of internal resonances and provide a more consistent listening experience between different content. Made from an inner layer of ½" MDF and an outer layer of ½" Baltic

[1] (Moulton, Total Recording 2000) p 313

Birch Plywood, these loudspeakers will be sturdy without having excess weight when compared with a double MDF design. For improved visual aesthetics, a set of custom stands will be crafted completing the Hi-Fi look inspired design. These stands will be placed directly on the floor with a thin layer of acoustic foam between the stand base and speaker base reducing the amount of mechanical coupling between the two.

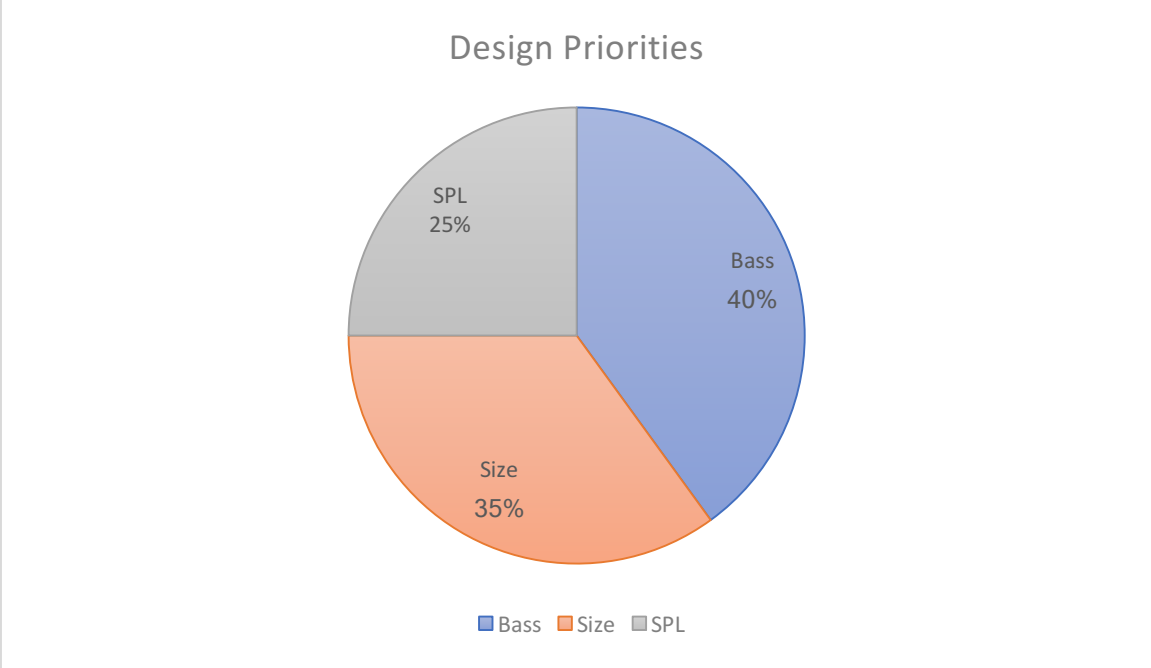
SPL Volume Output

Despite being designed for a busy living area; high SPL output was not considered a top priority for the loudspeakers. More focus was put on the dynamic range of the loudspeaker and the ability to play the full range of the system with equal levels. Ideal home theater levels should approach 85dB with an additional 20dB headroom for the THX standard, which should not be a problem considering cabinet size and location.[2]

Sound Quality Description

Warm, pleasant, and blissful are three words that were repeated in the design stages of these loudspeakers. Some brief critical listening for enjoyment purposes will be supported by these loudspeakers but most of their purpose is for a relaxed setting.

Overall Design Priorities



[2] (FAQ - What is the reference level? 2018)

Technical Specifications

Definition

The object of this next section is to translate the functional design goals into useful technical descriptions for the overall design of the loudspeakers.

Size

While portable small loudspeakers may be convenient, larger cabinet loudspeakers allow for increased low frequency response and improved SPL levels. Both criteria benefit a living room entertainment system when used for a variety of mediums. Therefore, the size of these loudspeakers will only be limited by the difficultly to move them with help a few times a year.

Dimensions

Considering the average couch seating height and personal height, the cabinet height should be around 40”. This should place the center of the tweeter around ear level for a seated individual in the intended environment. The internal measurements are based on a non-whole number ratio to minimize the modes and resonances of the box itself. This ratio is based on Doug Jones’ room measures of 1:1.89:2.56.[3] To improve the response of the bass driver, a two-cavity approach was taken separating the 8” driver from the mid 5” and tweeter. Keeping the width of the boxes as close to the width of the largest driver to limit any baffle steps, the smallest dimension is 10.25". Using this as the 1 dimension, the depth of the lower cabinet comes out to 19.37” with the upper depth at 15.13”. The larger depth of the speakers will improve the soundstage of the stereo pair. The internal height of the lower cabinet then comes out to 26.24” with the upper cabinet at 8”. The outer dimensions of the cabinets are roughly 1’1.25” W x 3’2” H x 1’10.375” D. The front corners will also be rounded, reducing the front dimensions slightly closer to the driver side without reducing the support.

Weight and Portability

Due to their larger size and heavy weight, lifting these loudspeakers will most likely be a two-person job. The goal for weight is to keep them below 75lbs making it possible to move alone in a pinch. These rough estimates for weight make the loudspeakers less practical in terms of portability. The only portability requirement is to keep them at a dimension that is still easily moveable by truck. They will be left alone once in place making the criteria for weight and size less of a priority in the overall design.

SPL

Designed with a reasonable listening level in mind, high SPL output was not the main objective for these loudspeakers. As a person with a preference for quieter listening levels, this limitation should not pose a problem.

[3] (Jones 2008)

Personal SPL Listening Levels

Below is a brief collection of listening data for personal SPL preferences when listening to mild jazz tracks over the course of a week. Times: Morning (before noon), Afternoon (noon-6pm), and Evening (after 6pm).

Date	Morning	Afternoon	Evening
January 21	n/a	67	80
January 22	49	71	60
January 23	55	59	76
January 28	52	66	68
January 29	60	72	83

SPL Standards

Values of known standards were considered for the design of these loudspeakers, but were not deemed a priority. In ideal world, these loudspeakers would be capable of reproducing hi-fidelity jazz and classical records at K-20. The K-20 system is designed to place the reference level, typically 83dB, 20dB below full scale. The 20dB of headroom allow for a more dynamic listening experience. K-20 would make listening more enjoyable for highly dynamic genres and films but can also lower your perceived listening level for less dynamic material. Judging by the data that I collected and the time of day that these loudspeakers would be used, I would estimate a reference SPL level around 77dB.

Sensitivity and Power Handling

The optimal goal for these speakers to produce 77dB at 1 meter. With an ideal headroom of 20dB, the peak SPL would be around 103dB at 1 meter with both speakers playing content. As SPL output is not a major concern, a slightly lower listening level will be acceptable if this value cannot be met without approaching thermal/excursion thresholds for each driver. Matching the loudspeakers with an external amplifier of 40W RMS would result in a dBW value of about 16dBW. Each driver in this 3-way system will be amplified separately allowing for more control over amplification. This method is referred to as tri-amped speakers. Three channels of amplification decrease the strain on each amplifier as they work in a more stable section of their amplification power curve. Ideally a vertical tri-amped setup will be used with the loudspeakers for ease of placement and an equal wear between each amplifier.

Frequency Response

A more in-depth analysis of the loudspeaker design in terms of frequency response and voicing.

Bandwidth

With casual listening and film enjoyment in mind, the design of these speakers is to provide a F3 response around 30Hz to 35Hz. This will most likely result from a ported enclosure tuned to a similar frequency to ensure the low frequencies would be reached. With preferred genres of classical and jazz, having a good low frequency response will aid the reproduction of the upright

basses and low brass. In addition to solid low response, the loudspeakers should also be able to reproduce high frequencies, and everything in-between, with ease.

Shape and Voicing

Warm, pleasant, and blissful are three words that will be repeated throughout this document in regards to describing the sound of the loudspeakers. This description will best be matched using a tuning that is pleasant to our ears. This is a subjective tune, but will originate from the BBC shaping to reduce the upper harshness and "warm up" the sound. A slight bass bump will also add to the shape of the loudspeakers while extending the lower frequency response into the sub bass range.

Coloration and Time Response

The coloration of these loudspeakers should be pleasing to listen to. As previously mentioned, the tuning will start with the BBC curve. This cuts the 2kHz to 4kHz signals down to a more pleasant level resulting in what is obviously not a perfectly flat response curve. The addition of a port will also effect the transient response of the loudspeaker, noticeably in the lower frequencies. Due to having a port, the lower frequencies will decay longer and as the speakers will be placed along a wall, careful tuning will need to done to ensure that the lower frequencies aren't distracting. In combination with Doug Jones' ratio, unique internal bracing and damping will improve this side effect. To reduce the internal reflections unique braces will be placed to create unequal volumes. These braces will also serve to provide better structural support and vibration control. The internal damping from fiberglass will reduce the internal reflections straight from the driver before it reaches the side walls of the cabinet. The internal foam will also serve to limit the sound that escapes through the port in the bass cabinet. To not cause a false surface, a small amount of foam will be used.

Mounting

These loudspeakers are designed to be placed on a set of custom stands to improve the height aspect but to also remove them straight from the floor. This should improve stability as well. The loudspeakers will be placed against a wall in most scenarios bringing the characteristics of a quarter space into play. This will increase the low frequencies by around 6dB. A large concern of the design is the grounding and relationship between the upper and lower cavities. An internal separation will result in a shared volume for resonances to a small degree. Separating the two completely will remove this effect but will increase the number of cabinets. By having the internal boxes separated with a continuous outer box, some separation is maintained while keeping a single cabinet design.

Enclosure Goals

Carpentry Limitations

Carpentry skills were a major influence on the cabinet design. Originally planned with angled faces and fancy joints, these loudspeakers have been heavily changed to reduce the attention and skill needed to craft the loudspeakers. Ideally one would not design a rectangular box to maximize the horizontal listening field, but rectangles are a proven design and are significantly easier to cut.

Internal Acoustic Properties

For the best acoustical response of a cabinet, it is important for the internal modes to be evenly distributed without overlap.[4] If this goal was not met, the cabinet would favor certain harmonic sets making it inconsistent between content. Using different dimensions for width, height, and depth help accomplish this goal. This is the reasoning behind using the ratios described in the Dimensions section above. There are several other methods to accomplish this. A common ratio used is the Golden Ratio (1.62:1:0.62). One reason for not using the Golden Ratio is that although it uses different dimensions, two of the sides are related with a common denominator. This is acceptable but will still contain some slight favoritism to certain harmonic sets. In addition to the unique dimensions, internal bracing and acoustic filling are used to mitigate the internal standing waves by absorbing some internal noise.

Baffle Step

With any loudspeaker, baffle step and edge diffraction were addressed in the enclosure design. Baffle step is the loss of around 6dB when a source is operating in or close to Omni-directionality. This occurs with loudspeaker cabinets as you are mounting an omnidirectional source to a half space allowing it to only produce sound forward resulting in a loss of dB.[5] There are ways to solve this problem. One way is to widen the face of the speaker. While this method is easy, it can pose more problems with the edge diffraction of the speaker. Another fix is to place the speaker in a quarter space or more. While this doesn't fix the problem, it will counteract it with its own +6dB gain.

Time Alignment and Listening Alignment

All three drivers in the enclosure will be placed flush on a flat surface. No curvature will be present on the face making the drivers naturally out of time in alignment. This is because the three different drivers have their voice coils at different depths, therefore sound will be produced at different points within the box. To address this problem, delays will be used within the electronic DSP for the mid-woofer and tweeter to virtually time align all three drivers. Having time aligned drivers not only improves the time aspects of content but it also improves the listening axis of the speaker. Correctly adjusted delays will result in a parallel listening axis to the floor. Ideally this axis will originate from the space between the woofer and the mid-woofer (center of the driver cluster) centering the axis on the front face. This will result in the most consistent listening experience vertically for the intended area if they stay seated. Not as

[4] (Murphy 2014)

[5] (Vanderkooy 1991)

directly affected, the width of the listening area will also be more consistent assuming the floor of the living room is flat and doesn't slope in any way.

Material Reasoning

With a larger enclosure, ¾" material is more common for support reasons. These loudspeakers however use two layers of ½" material to reduce weight. An inner layer or MDF and an outer layer of Baltic Birch Plywood provide two different hardness rated materials. This difference in structure limits the amount of sound that tries to pass through each wall in way of vibration.[6] The two layers will vibrate at different frequencies hopefully reducing the chance for the entire cabinet to vibrate and resonate more. To compensate for the reduced structural support of the material, an internal brace will be used. This brace serves two major purposes. One being the added support while the other is to section off the internal box into essentially two different cavities. Different circles, ovals, or rectangles are used to cut out the brace allowing for sound to travel between each cavity. The position of this brace is recommended at 7/16ths of the length for one brace.[7]

Ported Enclosure versus Seal Enclosure

Great transient response or improved bass response? The design for these loudspeakers were home theater general listening. While a good transient response is never a bad thing, it was not necessary for this design. Having a slightly increased lower frequency response proved to be a better choice for the application, especially when used with an absence of an external sub. There are more negative effects that come with a ported design. The first thing needing to be addressed is the reflections inside the cabinet escaping through the port. While you cannot eliminate this problem, as that would just make a sealed box, there are ways to use this to your advantage. By designing a rear port and knowing that the loudspeakers will be placed near a wall, the sounds escaping through the port will be reflected again by the wall resulting in a more encompassing response. The downside to this design is an even poorer transient response. Being high enjoyment loudspeakers, this wasn't seen as an overly important factor and the rear port was kept.

[6] (Gust 2018)

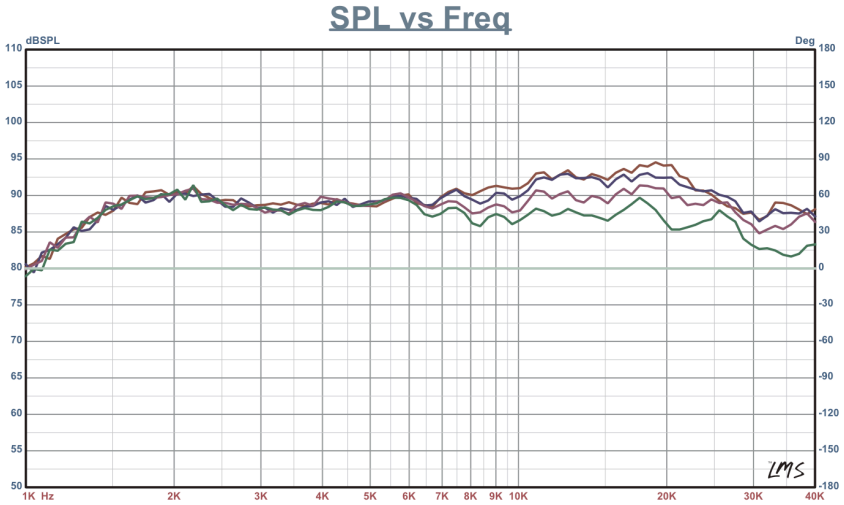
[7] (North Creek Music Systems 1992)

Driver Research

Tweeters

Fountek NeoCD1.0 Ribbon Tweeter[8]

Price: $52.80
Sensitivity: 90dB/1W/2V
Frequency Range: 2,000-40,000Hz
Power Handling: 12W Nominal
Recommended Crossover: 3,500Hz @ -18dB

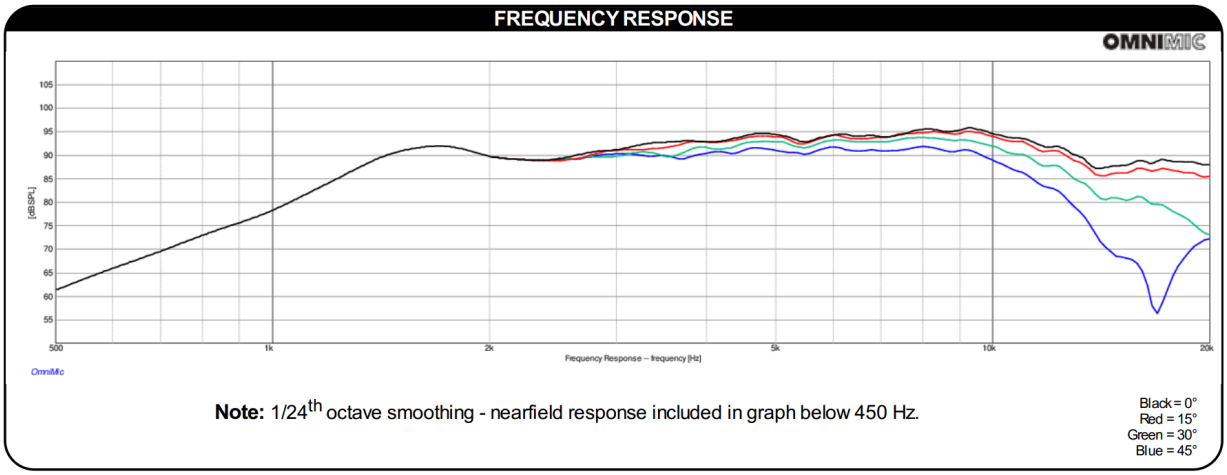


horizontal diffusion: on-axis, 15 degree , 30 degree, 45 degree

As the smallest ribbon tweeter in the list, the NeoCD1.0 has some interesting quirks. To start, it is the only driver with a 5Ω resistance. Strange but not useless. The frequency response is decent with a little boost in the upper registers but manageable. For being a ribbon tweeter, the off-axis response isn't phenomenal with more variations in the upper registers as well. Like the other tweeters in the list, it has a high sensitivity at 90dB. There was no information of thermal handling but the nominal power handling was rated at 12W which could easily be over powered by the amplifier without proper care and attention. The recommended crossover is too high for an 8" driver so a mid-woofer would be necessary to achieve a decent frequency response.

[8] https://www.parts-express.com/fountek-neocd10-ribbon-tweeter--296-701

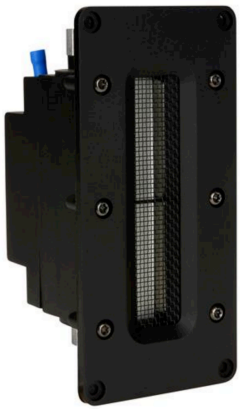
Dayton Audio PT2C-8 Planar Tweeter[9]
Price: $54.98
Sensitivity: 94dB/1W/1m
Frequency Range: 2,000-26,000Hz
Power Handling: 80W RMS
Recommended Crossover: 3,000Hz @ -12dB

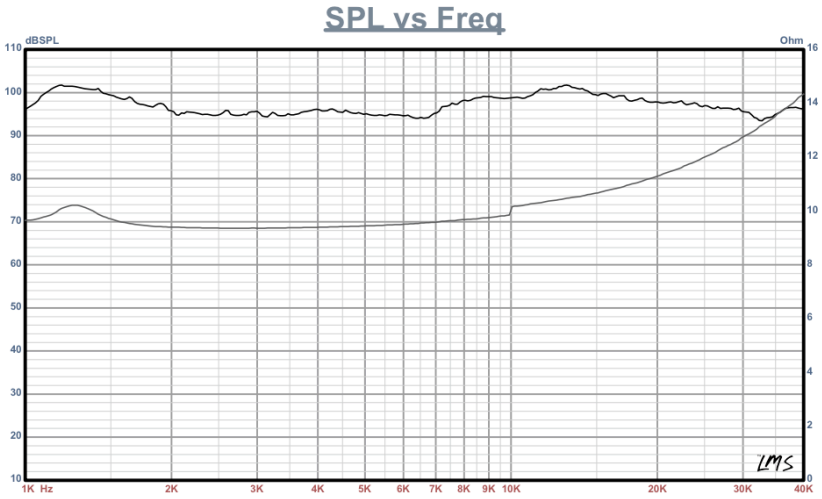


The Dayton Audio PT2C Planar Tweeter has the highest power rating for a tweeter that I reviewed. At 80W, it can take a lot of power, but it doesn't have the highest sensitivity in the group. The off-axis response is more typical for a planar tweeter with minimal differences until 10,000Hz. Unlike the other tweeters in the list, the PT2C has a slight waveguide form on its front plate. While I can imagine this is to improve the off-axis response, I'm not a huge fan of its visual offerings. While there isn't a real negative with the price, frequency range, or recommended crossover point, the overall look of the tweeter turned me away.

[9] https://www.parts-express.com/dayton-audio-pt2c-8-planar-tweeter--275-085

Fountek Neo X 3.0 Ribbon Tweeter Black[10]
Price: $100 (sale price)
Sensitivity: 95dB/1W/2.83V
Frequency Range: 1,200-40,000Hz
Power Handling: 30W Nominal
Recommended Crossover: 2,000Hz @ -12dB

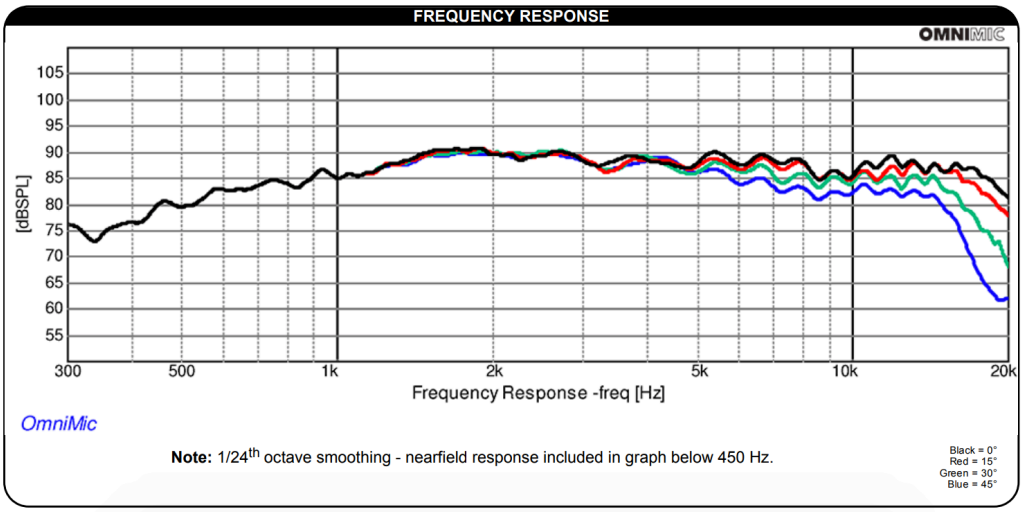




In the same series as the NeoCD1.0's, the Neo X 3.0 Ribbon Tweeter shares the same good looks with improved specifications. Increasing the ribbons physical length has expanded the usable frequency range which improves the crossover point. While it is lower, a mid-woofer would still be recommended to ensure no frequencies aren't represented. The larger size also requires more power which is safe with the increased power handling. The sensitivity isn't all that different but what is interesting is the lack of off-axis response curves. While it is potentially safe to assume it isn't bad considering it is a ribbon, there is a higher risk that there is something Fountek is hiding. Prior to the sale price, these tweeters were a little out of my price range which led to more research.

[10] https://www.parts-express.com/fountek-neo-x-30-ribbon-tweeter-black--296-713

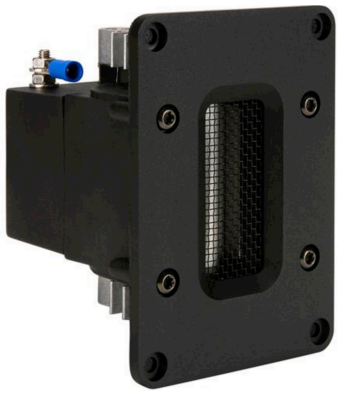
Dayton Audio DC28F-8 1-1/8" Silk Dome[11]
Tweeter
Price: $19.75
Sensitivity: 89dB/1W/1m
Frequency Range: 1,300-20,000Hz
Power Handling: 50W RMS
Recommended Crossover: “as low as 1,800Hz”

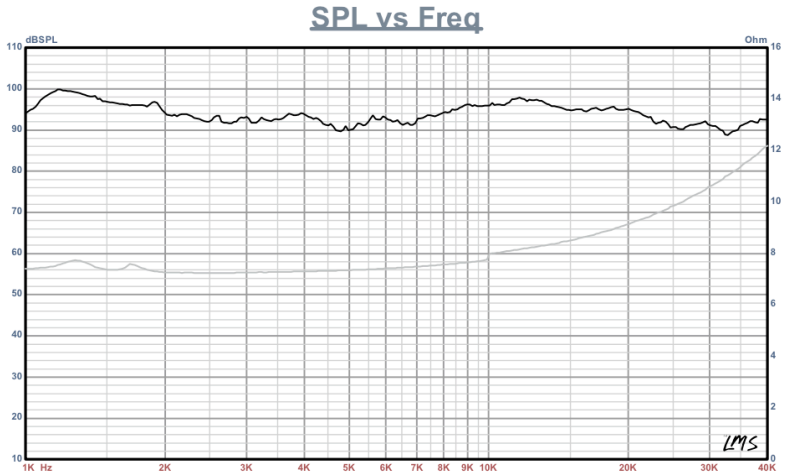


The Dayton Audio DC28F’s were chosen to compare silk dome tweeters to the ribbons that I was more focused on. These specifically had one of the better off-axis responses that I came across. The price and spec comparison made these tweeters very tempting as more time went into planning. Power handling and sensitivity are on par with the list but the DC28F’s are Ferro fluid cooled, not that it is important. While I had settled on designing a ribbon setup, these tweeters made a solid back up decision for a budget option. With a lower possible crossover compared to the ribbons, it would not be necessary to use a mid-woofer significantly reducing costs.

[11] https://www.parts-express.com/dayton-audio-dc28f-8-1-1-8-silk-dome-tweeter--275-070

Fountek Neo X 1.0 Ribbon Tweeter Black[12]
Price: $65.00 (sale price)
Sensitivity: 92dB/1W/2.83V
Frequency Range: 1,200-40,000Hz
Power Handling: 20W Nominal
Recommended Crossover: 2,500Hz @ -12dB



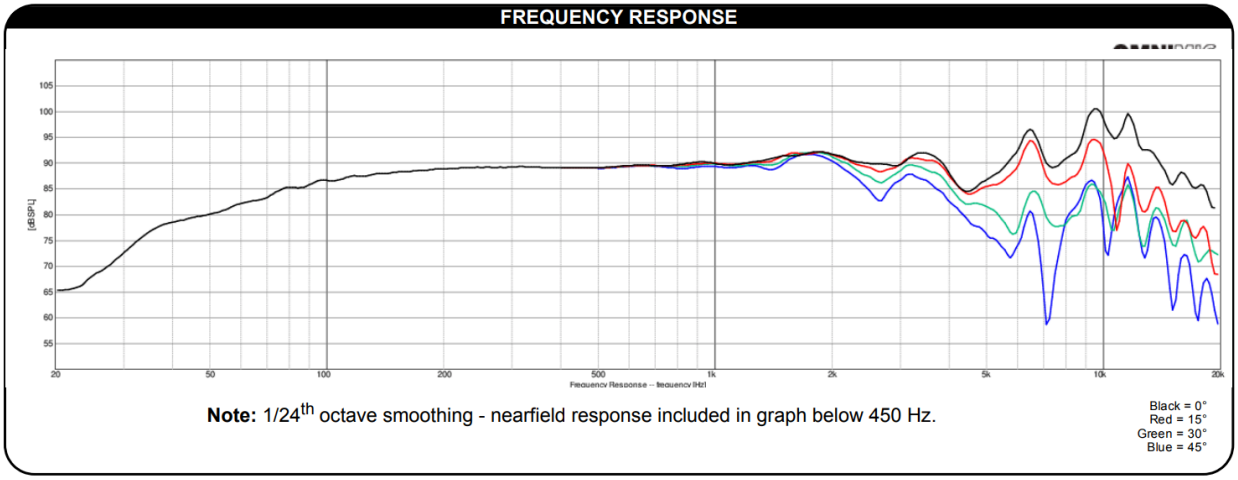


The Neo X 1.0 ribbon tweeters are the option that I ended up choosing for the design. I felt like they had an average sensitivity and range with everything that I considered and the sale price convinced me to make a call. Originally thinking about the NeoCD1.0's, the Neo X 1.0's have a smoother frequency response and slightly extended range. The power handling isn't a major concern as I plan on using a smaller amp for the upper driver regardless of what tweeter I chose. The only major concern with these tweeters are the fact that there is still no off-axis response curve. I have heard these in a design before so I'm not making a blind risk in this decision.

[12] https://www.parts-express.com/fountek-neo-x-10-ribbon-tweeter-black--296-705

Mid-Woofers

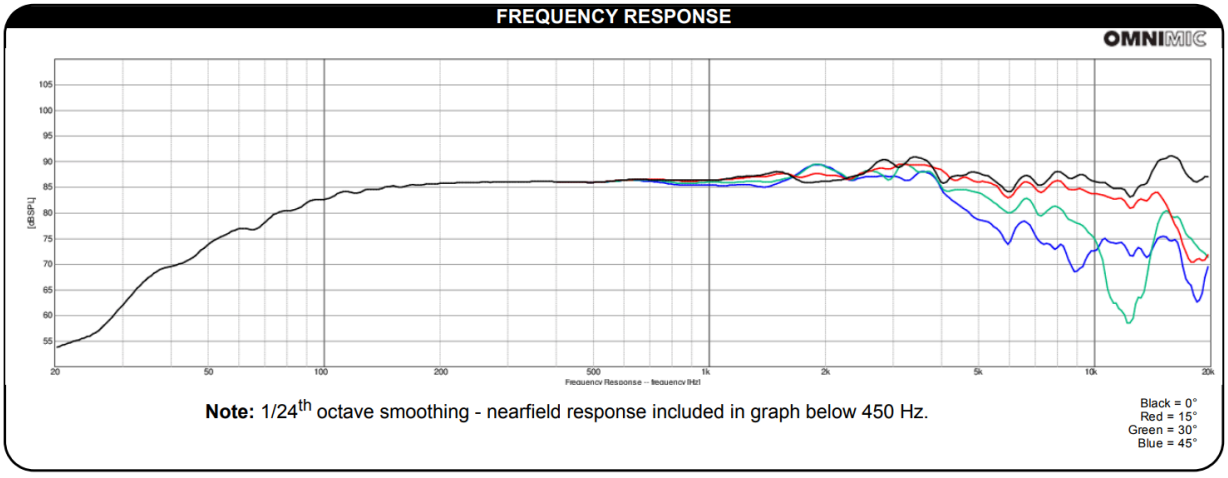
Dayton Audio RS150-8 6" Reference Woofer[13]
Price: $39.45
Sensitivity: 88.7dB/2.83V/1m
Frequency Range: 47-4,200Hz
Power Handling: 40W RMS
Fs: 47.8Hz



Advantages of using a 6” driver as a mid-woofer would allow for a potentially smoother transition between the mid-woofer and woofer itself. The RS150 featured a Fs of about 48Hz and could reach 2,000Hz without major discrepancies. It would have been nicer to have a better high frequency response in terms of off-axis but overall it seemed flat enough for the mid frequencies. The aluminum cone increases stiffness of the cone with the tradeoff of a present breakup region above a certain frequency measure. Using an aluminum cone driver would require more attention to the crossover design to ensure the breakup region is avoided. The final decision not to go with these drivers came down to them being out of stock during the building phase.

[13] https://www.parts-express.com/dayton-audio-rs150-8-6-reference-woofer--295-354

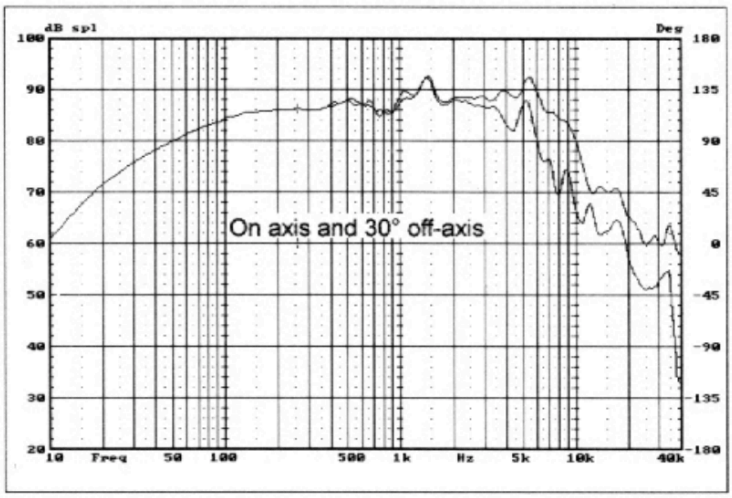
Dayton Audio RS100-4 4" Reference Full-Range Driver[14]
Price: $28.85
Sensitivity: 87.5dB/2.83V/1m
Frequency Range: 80-20,000Hz
Power Handling: 30W RMS
Fs: 84.8Hz



The RS100's are in the same series as the RS150's above and where researched as an alternative if size ever became an issue. The smaller size allowed for an easier crossover point in the 3,000Hz range. Similar construction and material to the RS150's, the RS100's share several specifications with the major difference in the lower frequency responses. This would not be a tradeoff for my design as another woofer would be responsible for the lower frequencies. The RS100 had a very pleasant off-axis curve throughout the useable range which made these a contender. The final decision, like the RS150's, came down to them being out of stock.

[14] https://www.parts-express.com/dayton-audio-rs100-4-4-reference-full-range-driver-4-ohm--295-378

HiVi F5 5" Bass/Midrange[15]
Price: $29.59
Sensitivity: 86dB/1W/1m
Frequency Range:
Power Handling: 35W Nominal
Fs: 52Hz



The HiVi 5 bass/midrange driver features a Kevlar/paper hybrid cone. This is an interesting design that should create a strong cone while keeping it lightweight and able to produce higher SPL ratings. Outside of the Kevlar cone, there wasn't much going for these drivers. The frequency response was small and difficult to read but you can still see a few jumps after 1,000Hz the concerned me. Due to the lack of information, more research was done on other drivers.

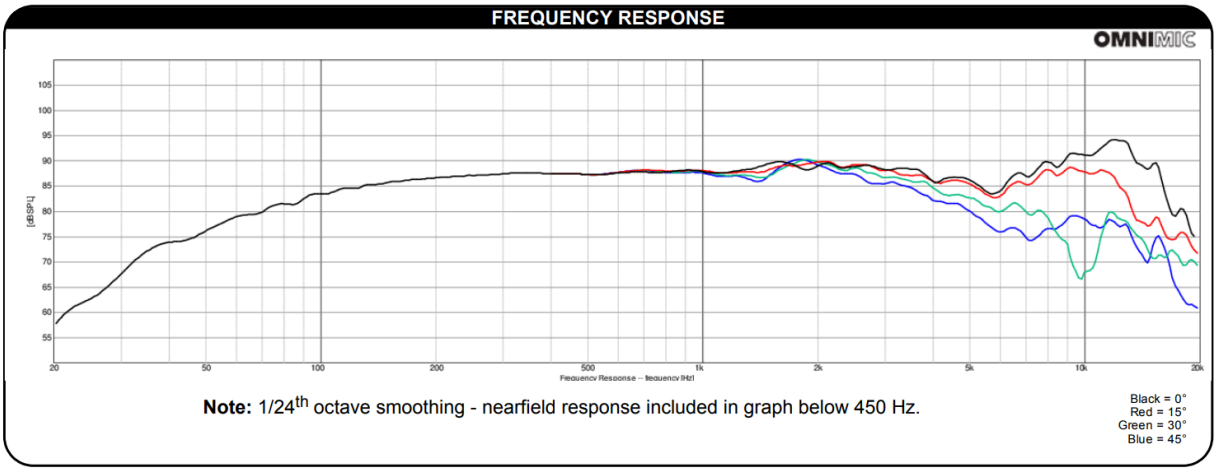
[15] https://www.parts-express.com/hivi-f5-5-bass-midrange--297-435

HiVi M5N 5" Aluminum / Magnesium Midbass[16]
Price: $21.73
Sensitivity: 87dB/2.83V/1m
Frequency Range: 50-6,000Hz
Power Handling: 35W RMS
Fs: 50Hz

The main reason for researching this driver is similar to the previous option. Featuring an aluminum/magnesium cone, it seemed different. Upon further research, major information was missing. The first problem with this drive is the lack of a specifications sheet including a basic frequency response curve. With this missing, I call it off quickly but still interested in the design. Upon more research, the numerical specs seem decent but I doubt it translates to the real-world results. More thought would have gone into this driver if I had chosen to go with the 8" version for my woofer choice.

[16] https://www.parts-express.com/hivi-m5n-5-aluminum---magnesium-midbass--297-436

Dayton Audio RS125-8 5" Reference Woofer[17]
Price: $31.57
Sensitivity: 86.8dB/2.83V/1m
Frequency Range: 65-5,400Hz
Power Handling: 30W RMS
Fs: 59.2Hz

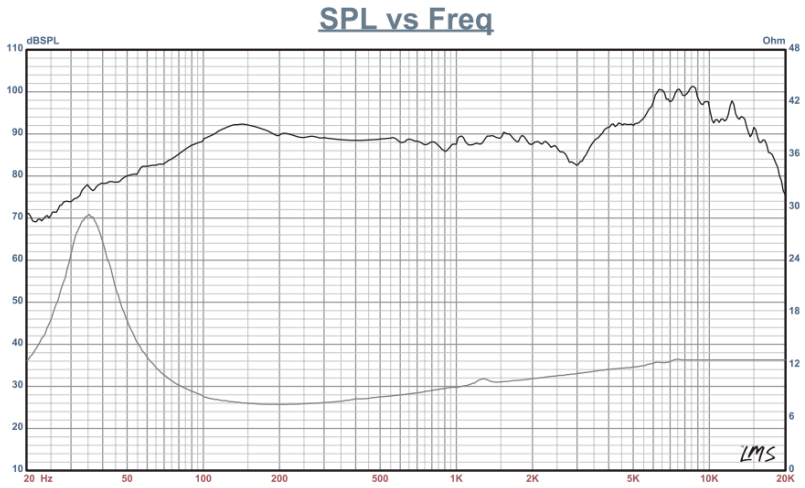


After some initial research, the RS125 seemed like an overall logical choice for my design. Matching the series and aesthetics to my 8” woofer, they look good together. Using similar materials and manufacturing processes, they should sound good together in practice. The RS125 although being called a 5” driver is closer to a 4”. With that being the case, I felt like the RS125 had a better response curve and a significantly lower Fs than the actual 4” in the series, the RS100. After comparing the two further, my final decision was made for me when the RS125 was in stock and on sale while the RS100 was out of stock at the time of purchasing.

[17] https://www.parts-express.com/dayton-audio-rs125-8-5-reference-woofer--295-353

Woofers

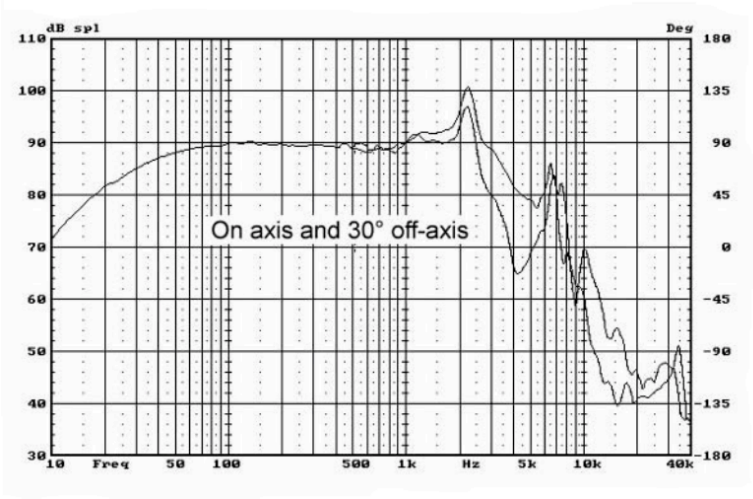
Fountek FW200 8" Aluminum Midwoofer Speaker[18]
Price: $50 (sale price)
Sensitivity: 88dB/1W/1m
Frequency Range: 35-3,000Hz
Power Handling: 75W RMS
Fs: 35.7Hz



The Fountek FW200 was one of the first 8” drivers considered for the design. With a sliver aluminum cone, it looked nice and had the rigidity to power through a life of dedicated low frequencies. One of the concerns with the driver however was the upper frequency response jump. This would have been avoided with the addition of a mid-woofer but that was not considered at that time.

[18] https://www.parts-express.com/fountek-fw200-8-aluminum-midwoofer-speaker--296-731

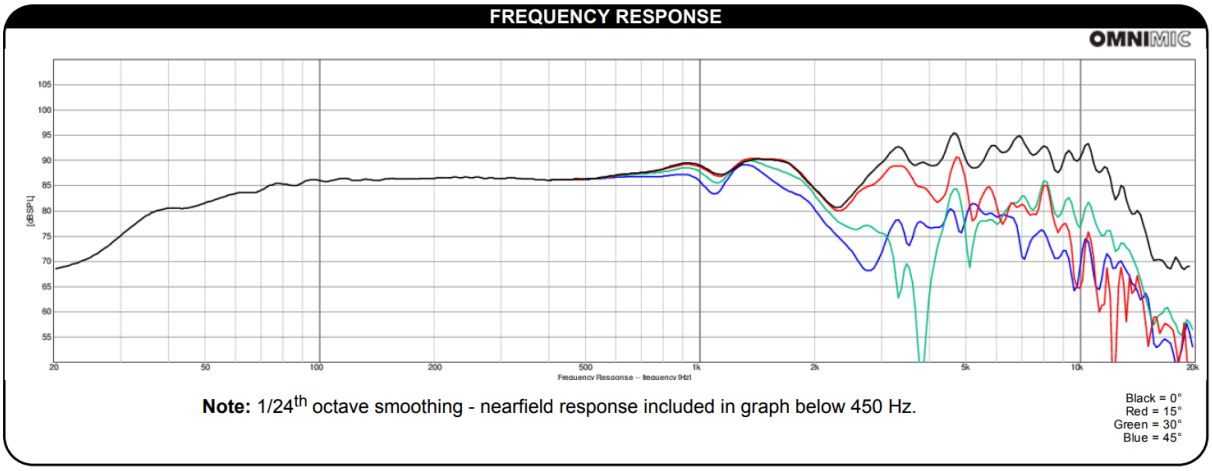
HiVi M8N 8" Aluminum / Magnesium Woofer[19]
Price: $34.86
Sensitivity: 86dB/2.83V/1m
Frequency Range:
Power Handling: 80W Nominal
Fs: 29Hz



The HiVi M8N's were an attractive woofer option with the unique coloration and visual aesthetics. The frequency response, be it small, seemed alright for the lower frequencies making it hard to see any problems. There was no stated frequency response, but the driver itself did have a Fs of 29Hz which is quite low. Another interesting specification was that the Qms of this driver was 5.02. Most of the other drivers researched were closer to 2 which makes this driver have a considerable amount of less mechanical dampening. In the end, the decision to buy a different driver came down to the lack of information and organization of the spec spreadsheet.

[19] https://www.parts-express.com/hivi-m8n-8-aluminum---magnesium-woofer--297-446

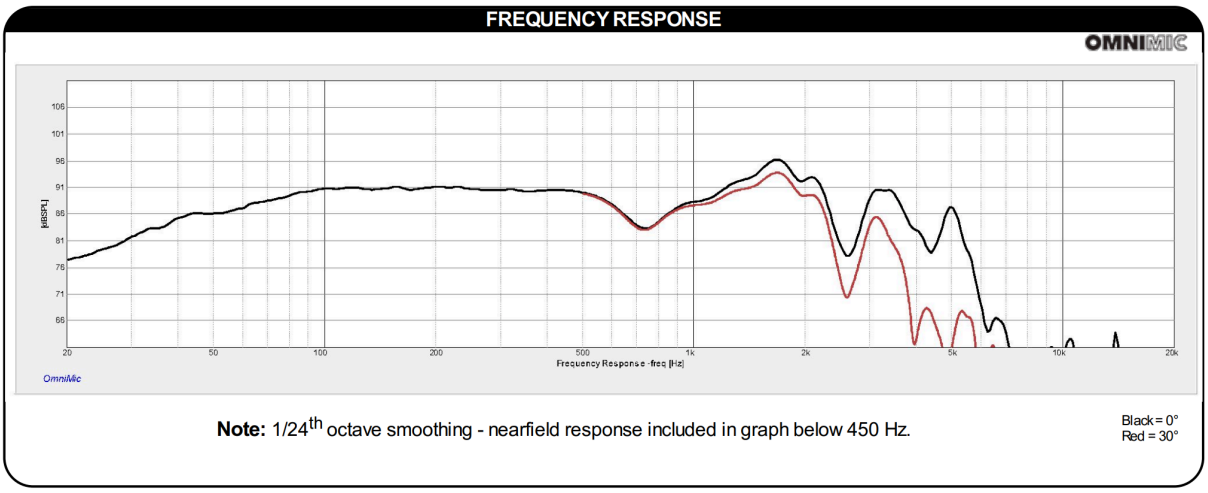
Dayton Audio RS270-8 10" Reference Woofer[20]
Price: $90.94
Sensitivity: 88.7dB/2.83V/1m
Frequency Range: 27-2,040Hz
Power Handling: 100W RMS
Fs: 29.6HZ



The RS270 was researched as an option for a 10” driver. Once a 3-way system was designed, the option for a larger woofer became available. The benefit for going to a 10” woofer included better low frequency response and the greater chance of a sealed cabinet thanks to the lower response. Besides the extra power needed for the operation and the cost of the driver, the amount of space required for the mounting became too much and a small woofer was chosen.

[20] https://www.parts-express.com/dayton-audio-rs270-8-10-reference-woofer--295-357

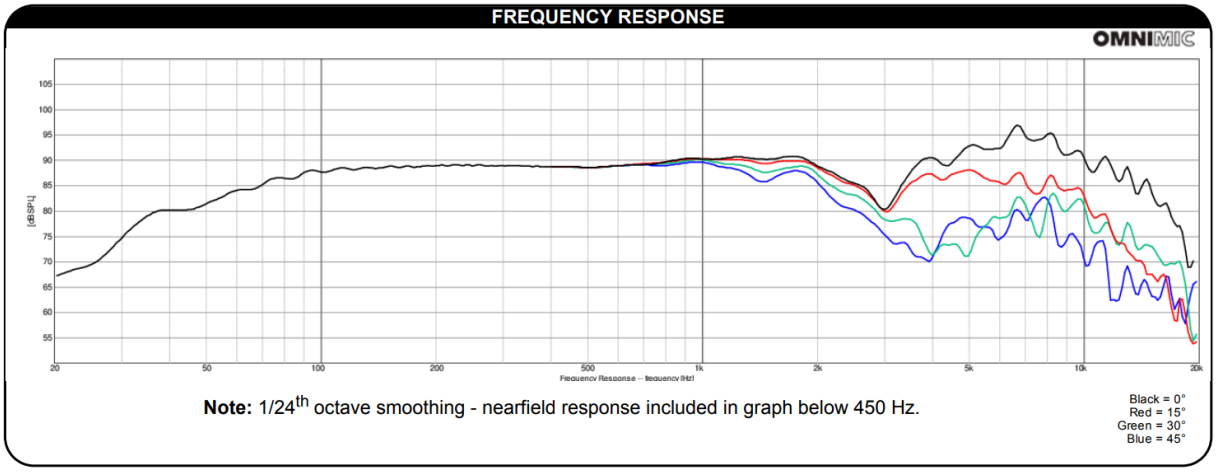
Eminence 8" Paper Cone Professional Woofer[21]
Price: $45 (sale price)
Sensitivity: 91dB/1W/1m
Frequency Range: 50-3,500Hz
Power Handling: 150W RMS
Fs: 37Hz



The Eminence 8” woofer was the most sensitive driver in the 8” category. This was interesting as it is also the only paper cone driver in the list. While the paper cone is more flexible, it is more prone to tear and damage the harder you push it. The Eminence driver is also capable of taking the most power at 150W RMS. While I do not plan on buying that large of an amplifier, it would be nice knowing that I would have to try to overpower this driver. While the price was hard to beat, different divers have better frequency responses and visual aesthetics which ended the journey for the Eminence driver.

[21] https://www.parts-express.com/eminence-8-paper-cone-professional-woofer-8-ohm--290-4007

Dayton Audio RS225-8 8" Reference Woofer[22]
Price: $57.42
Sensitivity: 86.8dB/2.83V/1m
Frequency Range: 28-2,400Hz
Power Handling: 80W RMS
Fs: 28.3Hz



The Dayton Audio RS225 driver was chosen due to its flat frequency response from 100-1,00Hz and its surprisingly controlled low frequency roll off. I have heard these drivers in a variety of different cabinet designs and they have always sounded nice with good coverage which made them hard to beat. The aluminum cone gives it a rigid structure which aids its ability to reach the lower decades as well as being able to produce a decent SPL rating. The excursion is maxed out at 7mm which is larger than the RS270 which surprised me. That will be something I'll have to watch out for but overall it's an almost unbeatable driver for the cost.

[22] https://www.parts-express.com/dayton-audio-rs225-8-8-reference-woofer--295-356

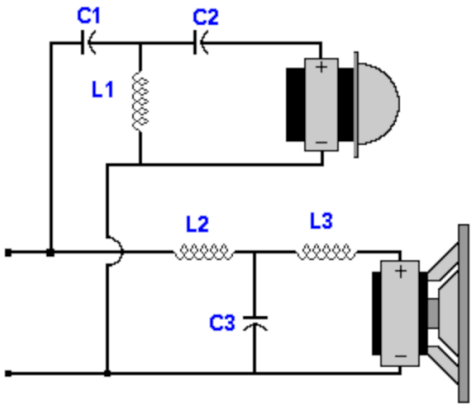
Crossover Design

Orders and Tuning Frequencies

This crossover design combines the utility and flexibility of an active DSP with the cost efficiency of a passive crossover. The crossover diagram can be seen below to ease understanding. The crossover frequency between the woofer and mid is going to start at 400Hz. This part of the tuning will be fully within the DSP software. The order will ideally be a first order Butterworth to ensure a smooth transition (6dB per octave) between the two drivers. This frequency was chosen as it is roughly halfway between the overlap of the two drivers frequency responses. At 400Hz there are 2.5 octaves on either side meaning there shouldn't be any problems with a first order crossover. There is also a high-pass filter @30Hz to limit driver overextension. The crossover frequency between the mid and tweeter is at 2500Hz. This will be a third order Butterworth crossover resulting in a quick transition between the two drivers. At 2500Hz there are about 1.25 octaves on either side which means that a switch to a second order crossover can be made if desired. The crossover between the mid and tweeter will be passive and will include a time delay circuit as well a 6dB attenuator for the tweeter.

Topology

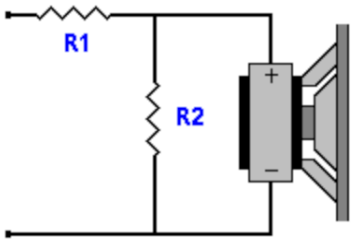
Mid/Tweeter Third Order Butterworth @2500Hz



Parts List

Capacitors
C1 = 5.31 uF
C2 = 15.92 uF
C3 = 10.61 uF
Inductors
L1 = 0.38 mH
L2 = 0.76 mH
L3 = 0.25 mH

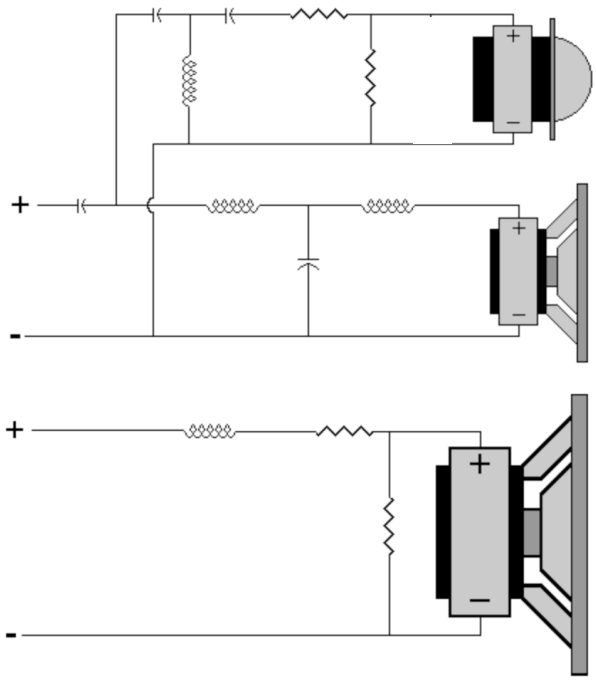
6dB Attenuator for Tweeter rated @20W



Parts List

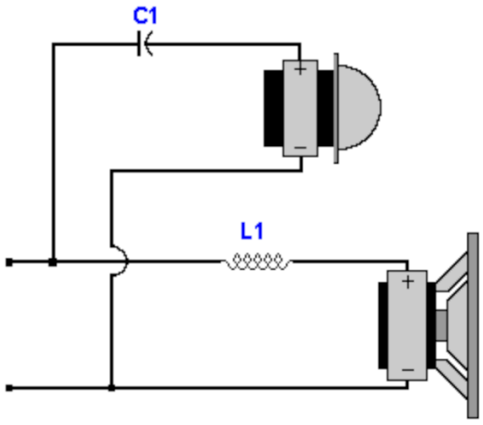
Resistors
R1 = 3.99 Ohms 9.98 Watts
R2 = 8.04 Ohms 5 Watts

Complete Bi-Amped Circuit Design



The complete design shows the woofer with a first order crossover with an attenuator. This will be programed within the DSP resulting in no passive components for the woofer channel. If a fully passive speaker is desired, the values below would work as a substitute to the DSP. Note the tweeter shown in the woofer/mid diagram would be the mid and tweeter combined in parallel as shown in the previous diagram.

Woofer/Mid Passive Frist Order Butterworth Crossover @400Hz



Parts List

Capacitors
C1 = 99.38 uF
Inductors
L1 = 1.59 mH

Baffle Step

While the edges of the cabinet will be rounded over, a loss in output cannot be avoided due to physical nature of the enclosure itself. This loss is referred to as the baffle step and is found in the lower frequencies of your driver as they become more omnidirectional. The correction for the baffle loss typically includes a tuned circuit in series with the bass driver. For a passive speaker, this would be required but as the lower frequencies of this speaker are managed by the DSP, the correction will be programed and tuned through the included software. The frequency in which the loss is expected to start is around 350Hz with respect to the size of driver and width of the cabinet.

Driver Pads

The sensitivity between all three drivers vary. To correct this problem everything will be reduced to the lowest value which is the mid woofer at 86dB. The tweeter has a sensitivity of 92dB which means a 6dB pad is needed. This will be accomplished with the 6dB attenuator described above placed in parallel with the tweeter after the crossover network. The woofer has a rated sensitivity of 91dB and therefore needs a 5dB pad to result in equal sensitivity across each driver. This pad will be done within the DSP software. A passive attenuator can also be designed like the tweeter attenuator if a passive speaker is desired.

Time Alignment

The magnet and voice coil for each driver are similarly different. While a slanted baffle could have been designed to ensure physical time alignment (Coincident), electronic delay can also be used for typical front baffles (Coherence). To ensure a good time response, everything will be delayed to the deepest component. In this case, the woofer voice coil. The tweeter will need a passive time delay circuit to properly align it with the mid woofer. From there, the upper drivers can be delayed together using the DSP to align them with the bass woofer creating a time aligned speaker.

Tuning Goals

Ideally this speaker will be able to produce 35Hz-20kHz with a +/-1.5dB response. This is with a ported enclosure. The sealed estimate will be closer to 45Hz-20kHz. While this goal is attainable, some frequency ranges will contain expect problems due to various reasons. Each crossover point will be subjected to some sort of deviation by nature. 350Hz will experience some attenuation with the baffle loss. A slight dip in the 2000Hz range will be implemented to reduce harshness if present. Finally depending on how well the tweeter attenuator is built, the upper frequencies will have some deviation in either direction until the circuit is tested and changed to the field results.

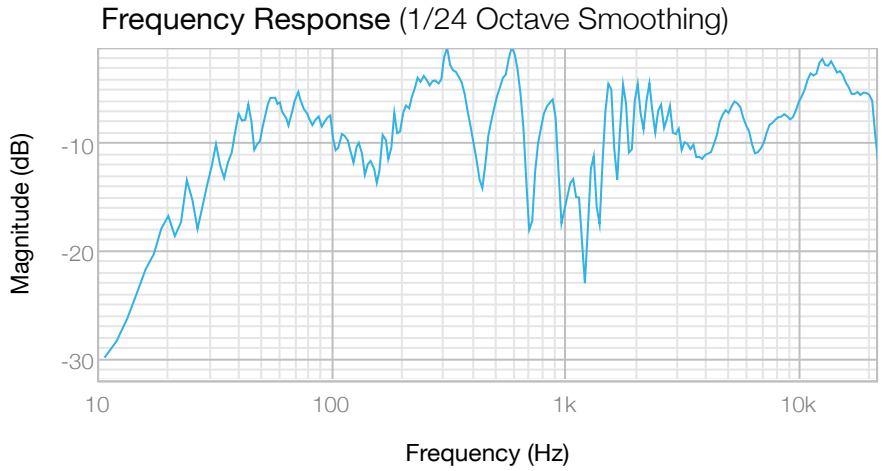
Tuning Plan

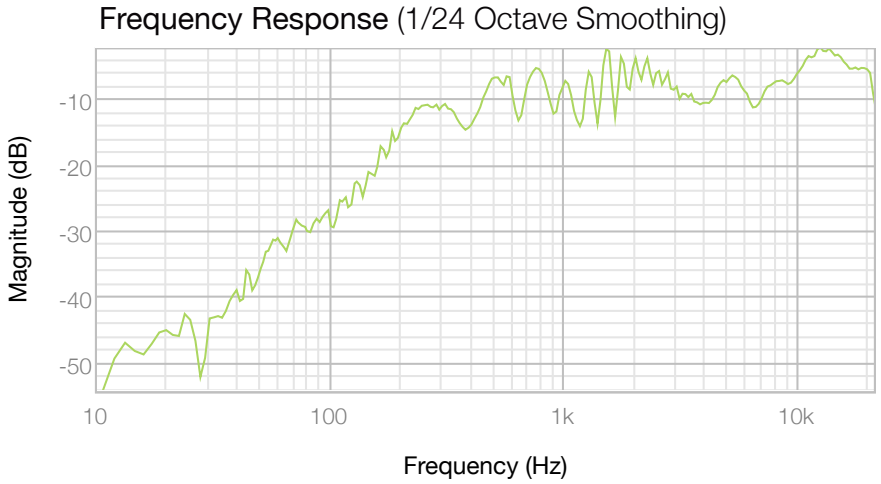
Starting out at the values discussed above, the first move is to set the crossover frequencies. The passive crossover between the mid and tweeter will most likely need some revisions until reasonable. After the higher frequencies have been solved, the crossover between the DSP and passive network will be tested. Some testing on the crossover order will be implemented

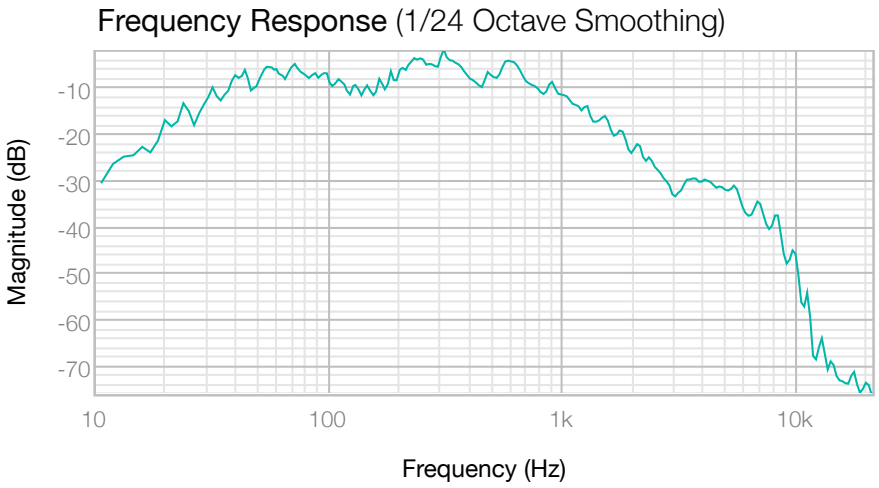
through the DSP in real time. It should also be noted that the speaker will be tested first as a sealed cabinet. This will provide data which will be assessed to determine if a port is truly necessary for the desired tune. If the addition of a port is required, the tuning process will restart after the port is added starting at the final values of the sealed design.

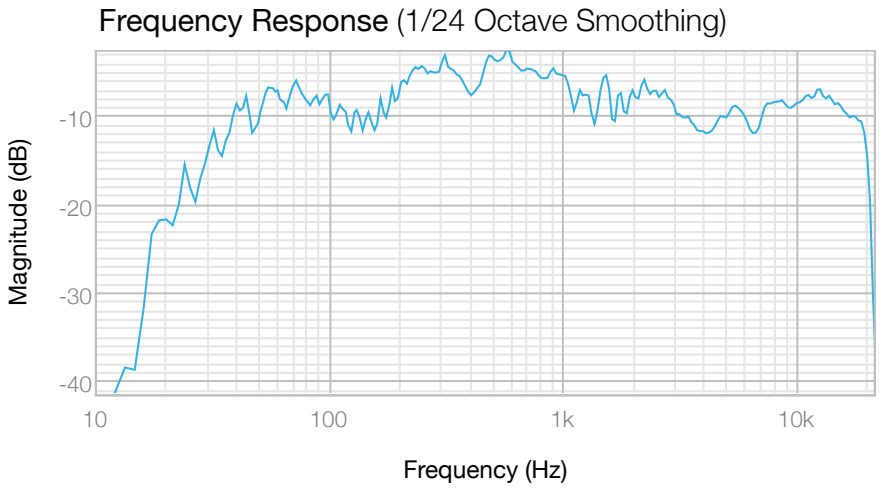
Tuning Sheets

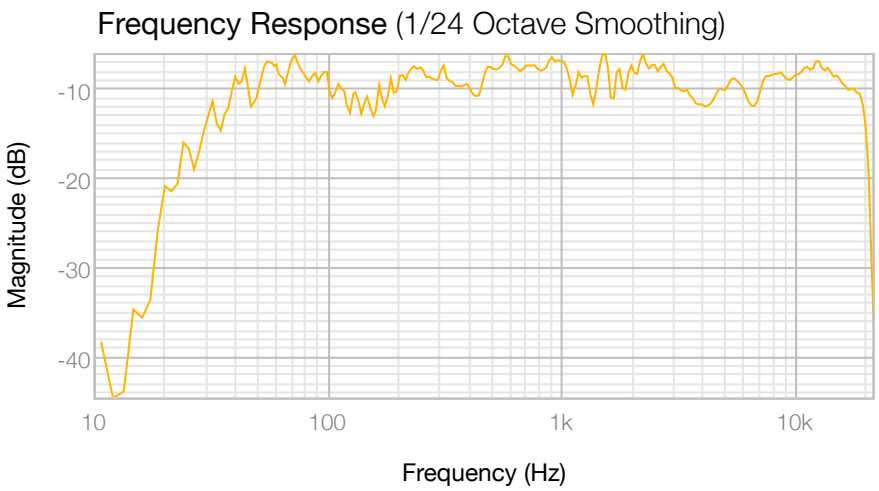
Sealed Enclosure

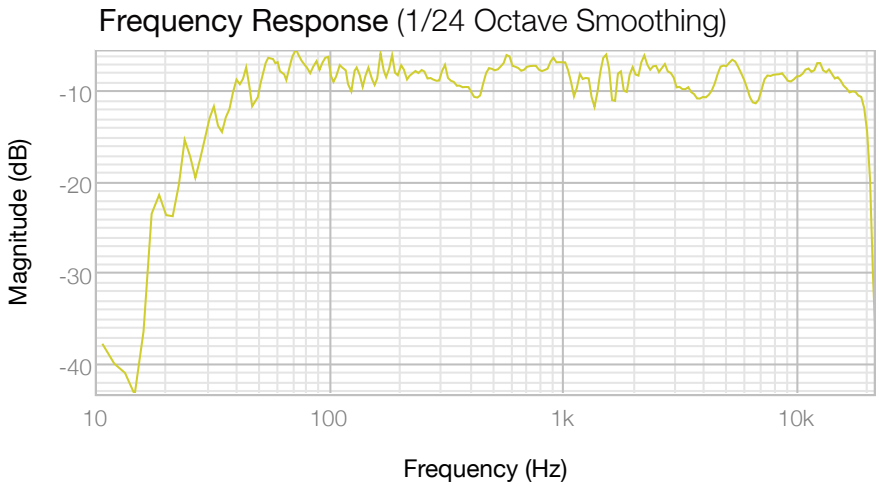


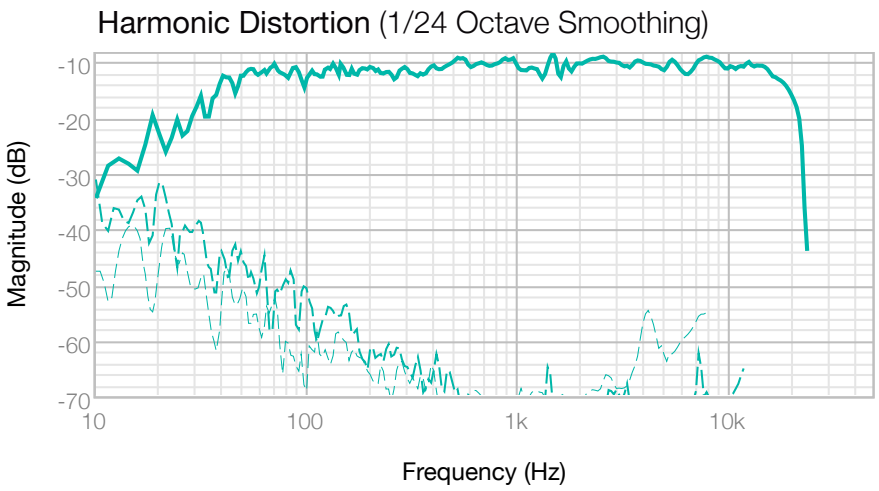



Frequency Response (1/24 Octave Smoothing)
Magnitude (dB)
-10
-20
-30
-40
-50
-60
-70
10
100
1k
10k
Frequency (Hz)

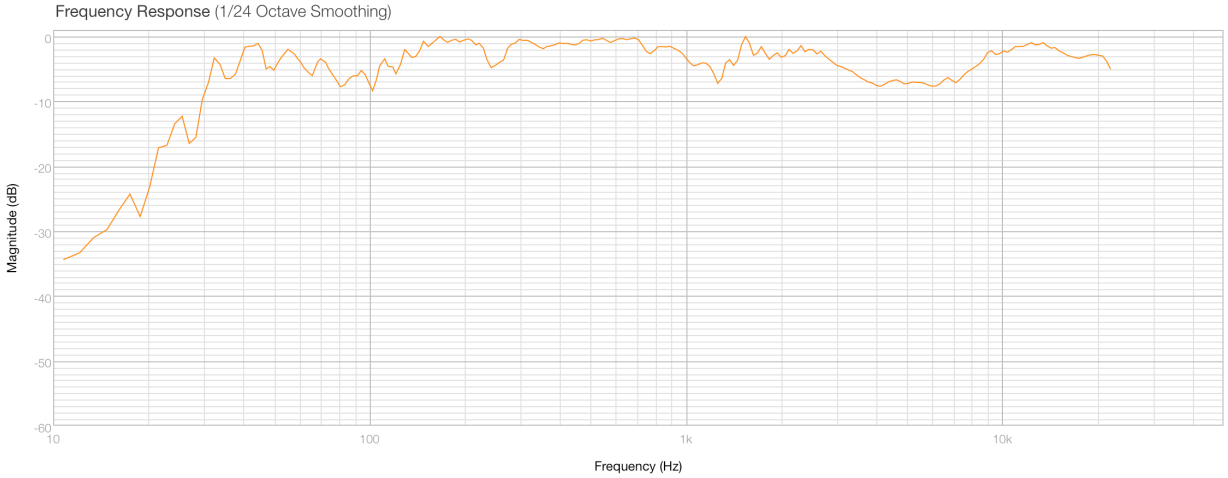

Frequency Response (1/24 Octave Smoothing)
Magnitude (dB)
-10
-20
-30
-40
10
100
1k
10k
Frequency (Hz)


Frequency Response (1/24 Octave Smoothing)
Magnitude (dB)
-10
-20
-30
-40
10
100
1k
10k
Frequency (Hz)

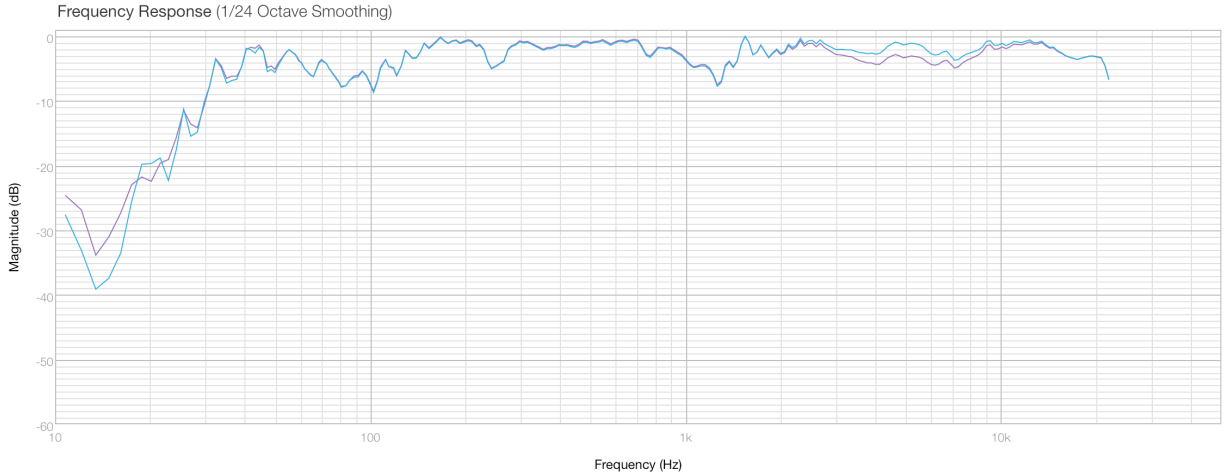

Frequency Response (1/24 Octave Smoothing)
Magnitude (dB)
-10
-20
-30
-40
10
100
1k
10k
Frequency (Hz)


Harmonic Distortion (1/24 Octave Smoothing)
Magnitude (dB)
-10
-20
-30
-40
-50
-60
-70
10
100
1k
10k
Frequency (Hz)

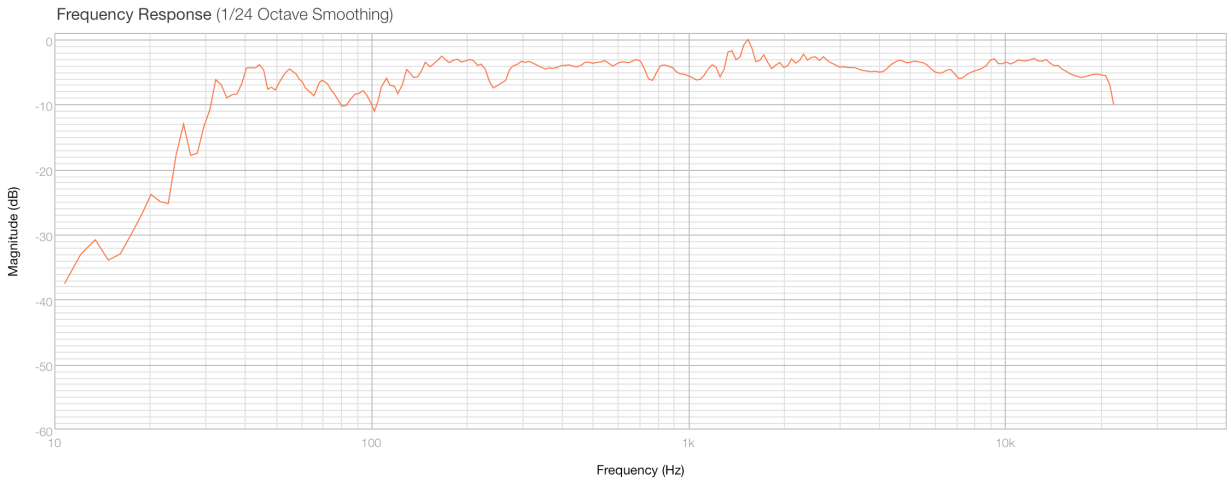
Ported Enclosure



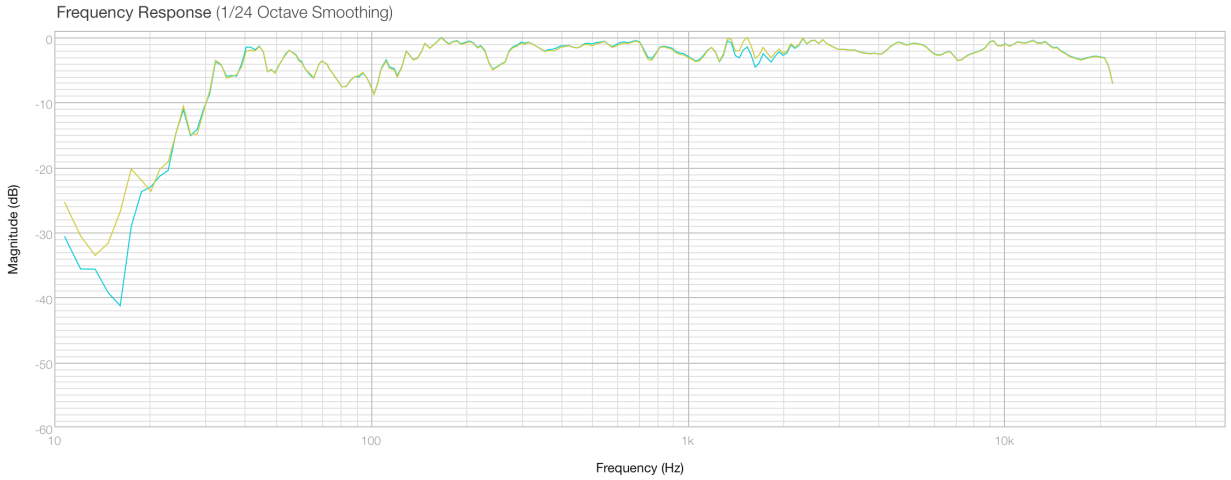
First Test with small port configuration (3x6.5”). No tuning or adjustments.



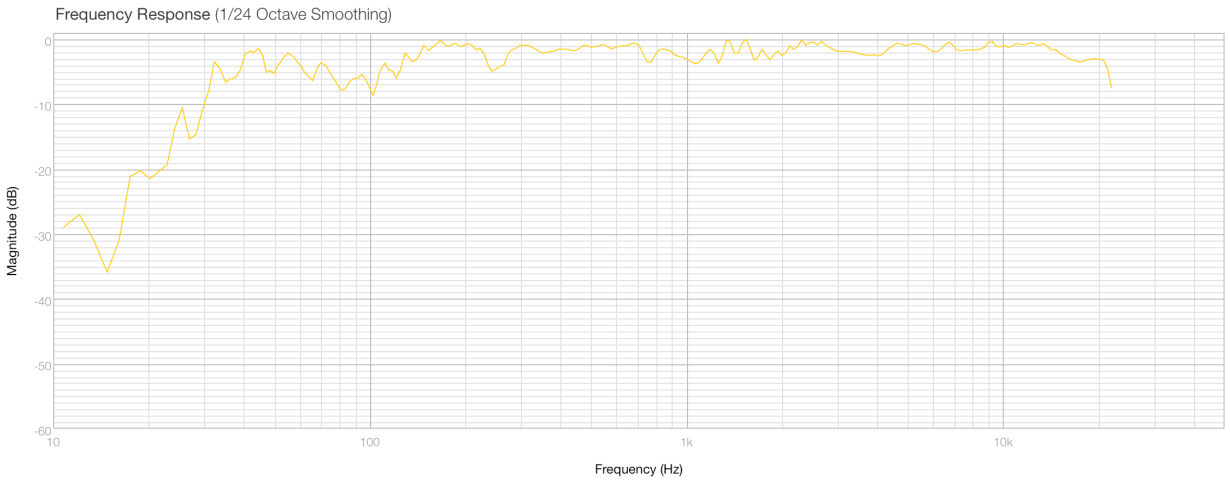
Purple: F=5kHz Gain=4dB Q=1 Blue: F=5kHz Gain=6 Q=1



F=1250Hz Gain=6dB Q=3

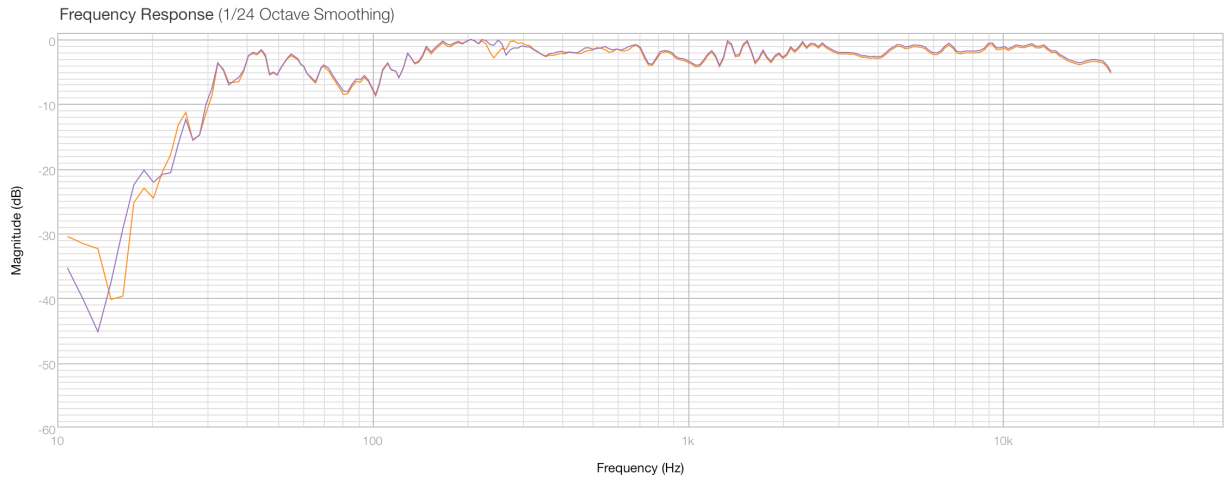


Blue: F=1550Hz Gain=-5dB Q=4 Green: F=1550Hz Gain=-4dB Q=4



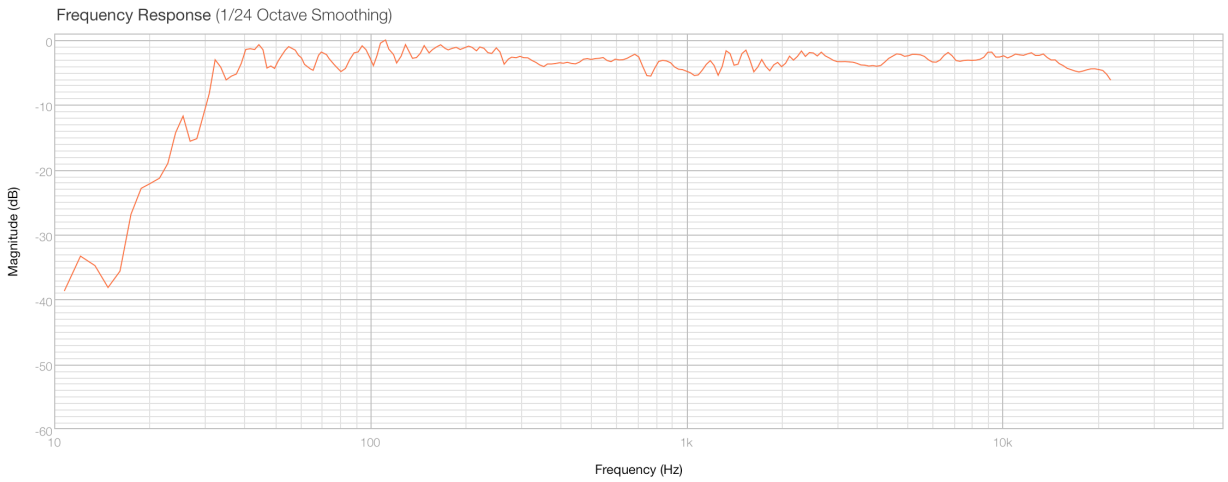
F=7000Hz Gain=2dB Q=4

Purple: F=250Hz Gain=4dB Q=2 Teal: F=250Hz Gain=4dB Q=8

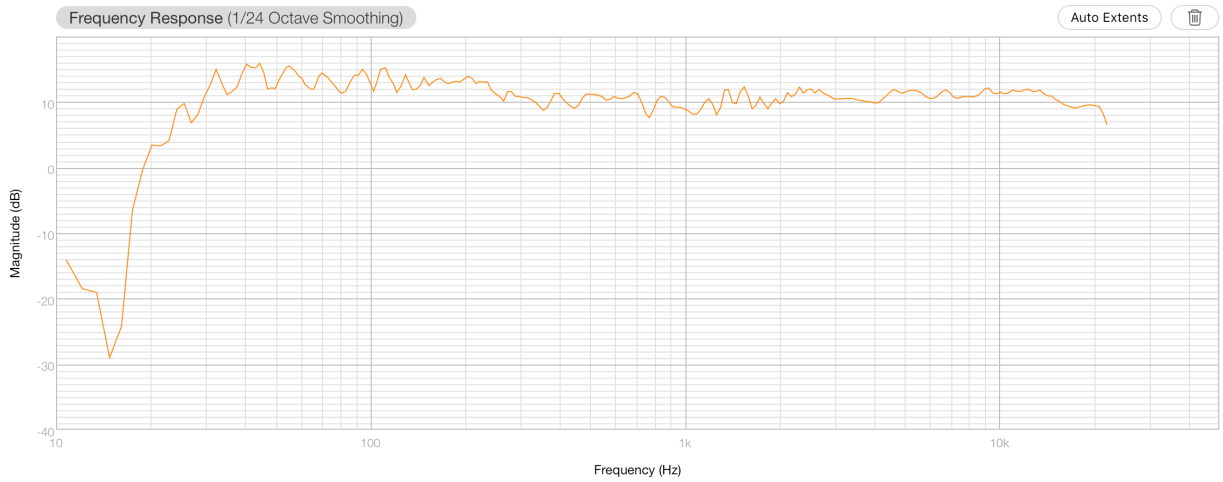


Orange: F=260Hz Gain=4dB Q=5 Purple: F=250Hz Gain=6dB Q=9

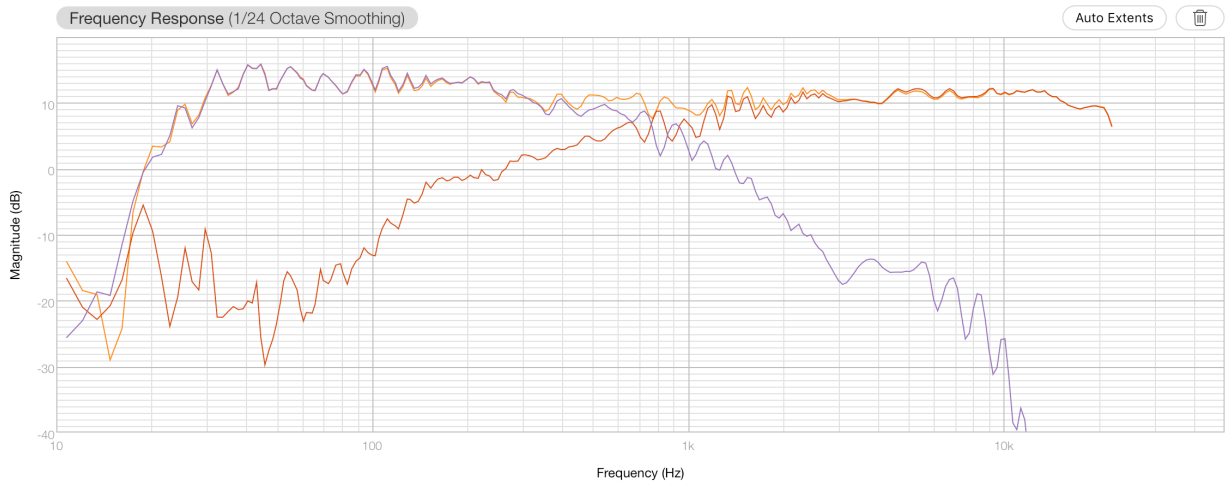
Green: F=100Hz Gain=2dB Q=2 Low Shelf Orange: F=100Hz Gain=5dB Q=2 Bandpass



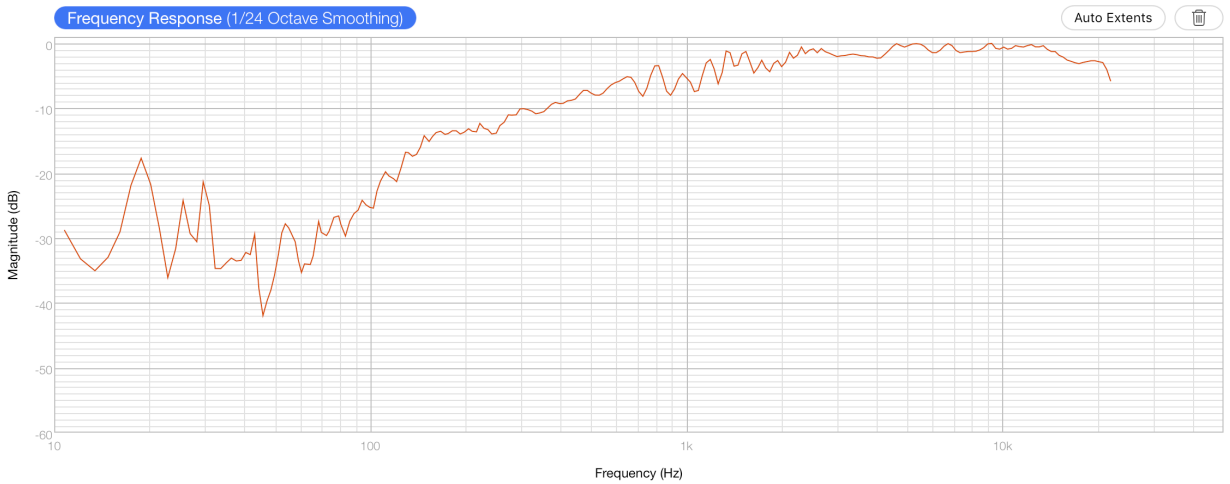
F=50Hz Gain=2dB Q=0.5



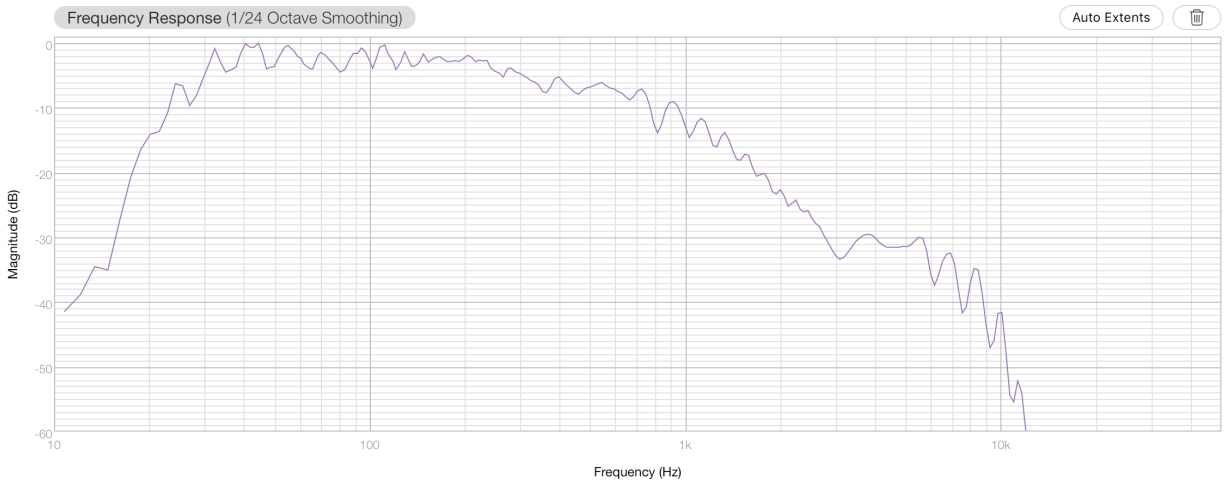
Final Result with foam on bottom and back walls. Small port (3x6.5”).



Integrated Final Result. Red: Tweeter/Mid Purple: Woofer Orange: Full



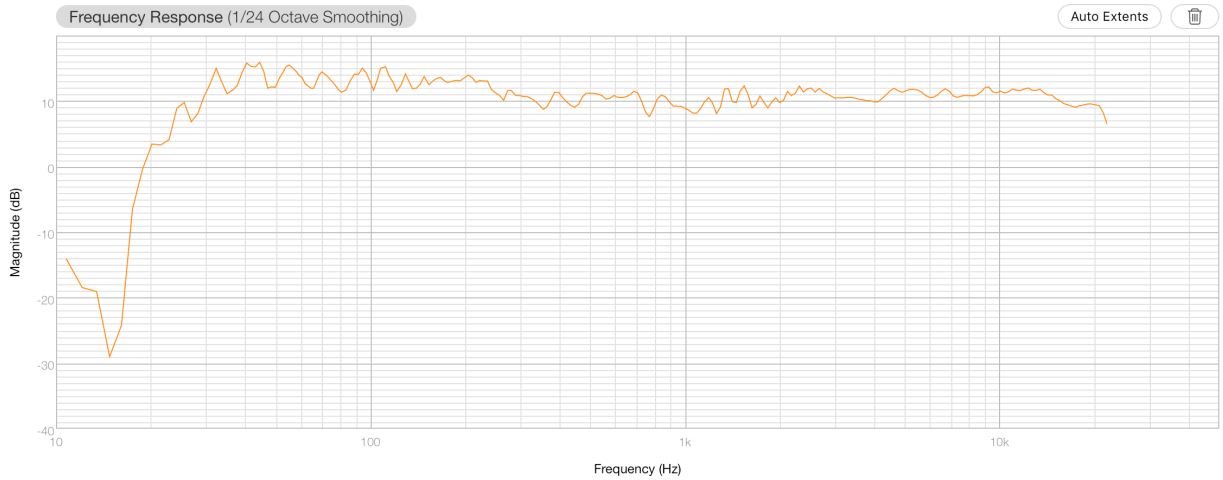
Tweeter & Mid Response



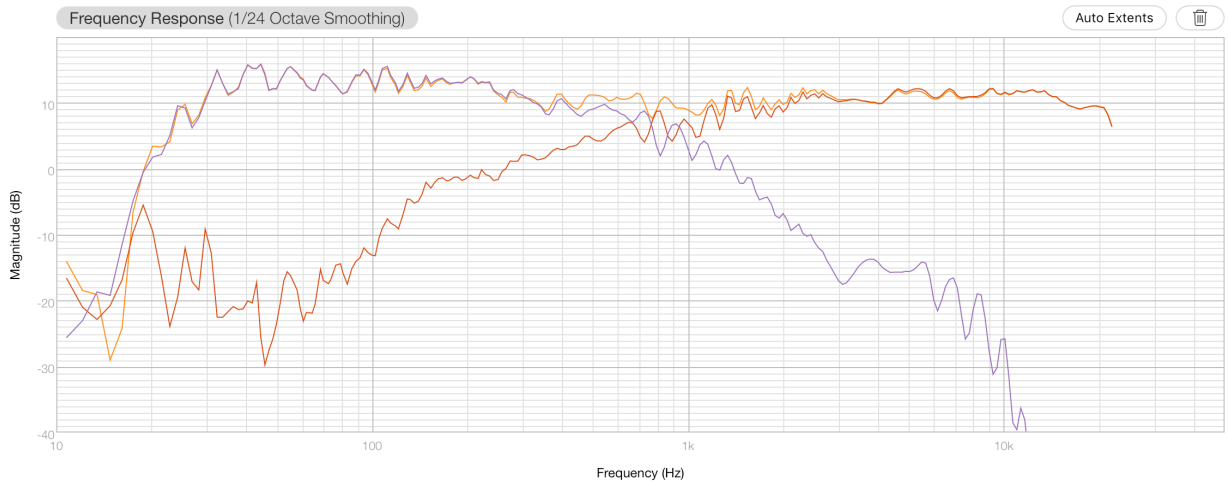
Woofer Response

Final Speaker Specification Sheet

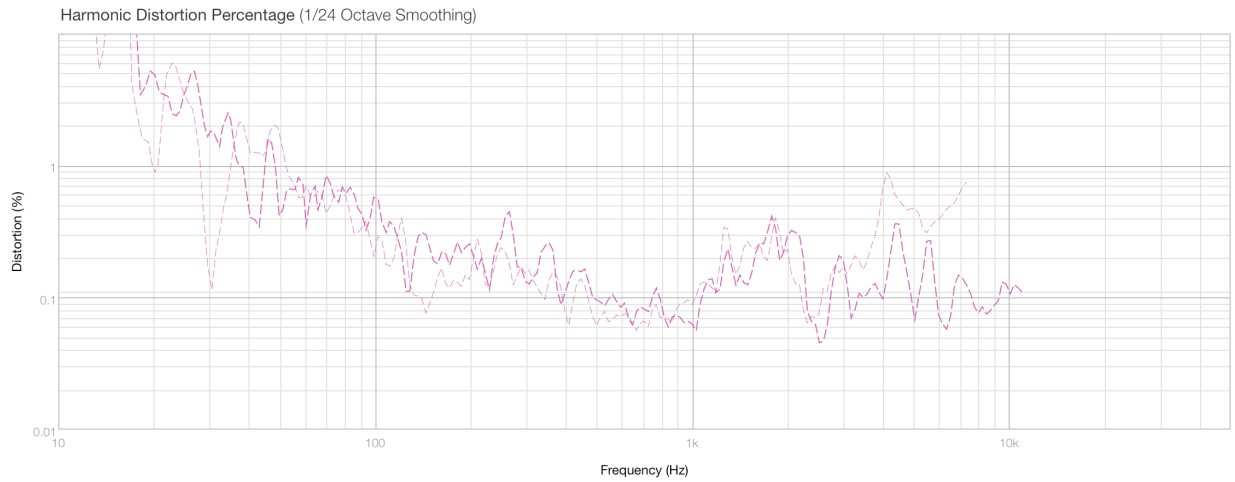
Full Speaker



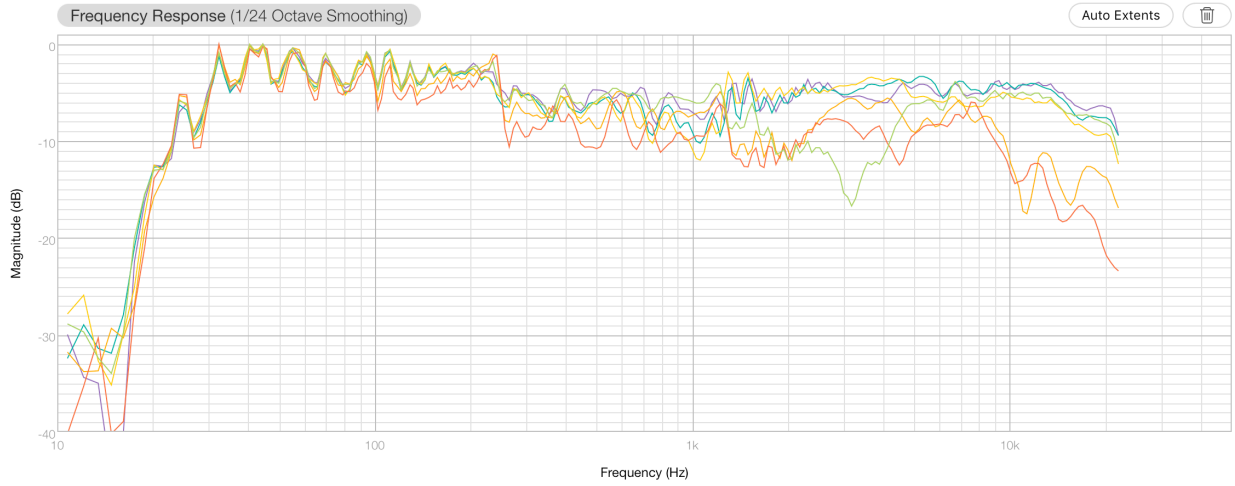
Frequency Response 10Hz-50kHz



Integrated Frequency Response 10Hz-50kHz

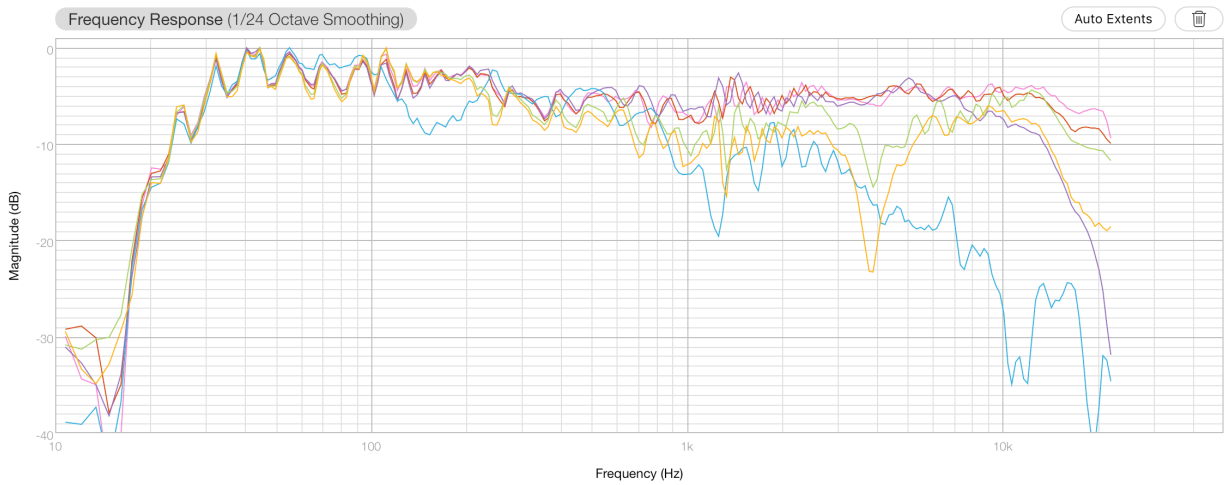


Harmonic Distortion 10Hz-50kHz



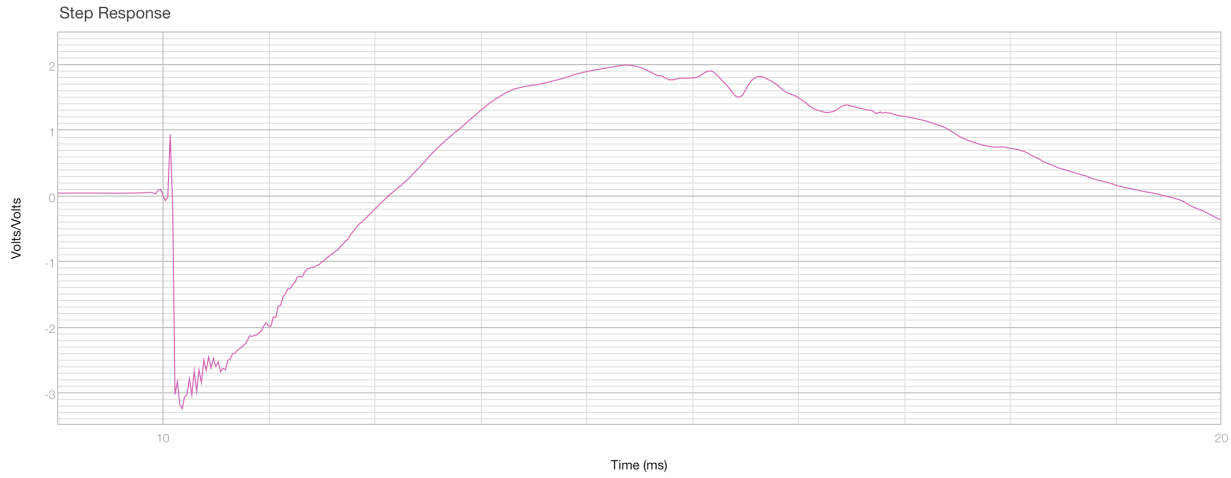
Horizontal Off Axis Response

- 0 Degrees: Purple
- 9 Degrees: Teal
- 15 Degrees: Yellow
- 30 Degrees: Orange
- 45 Degrees: Green
- 60 Degrees: Red

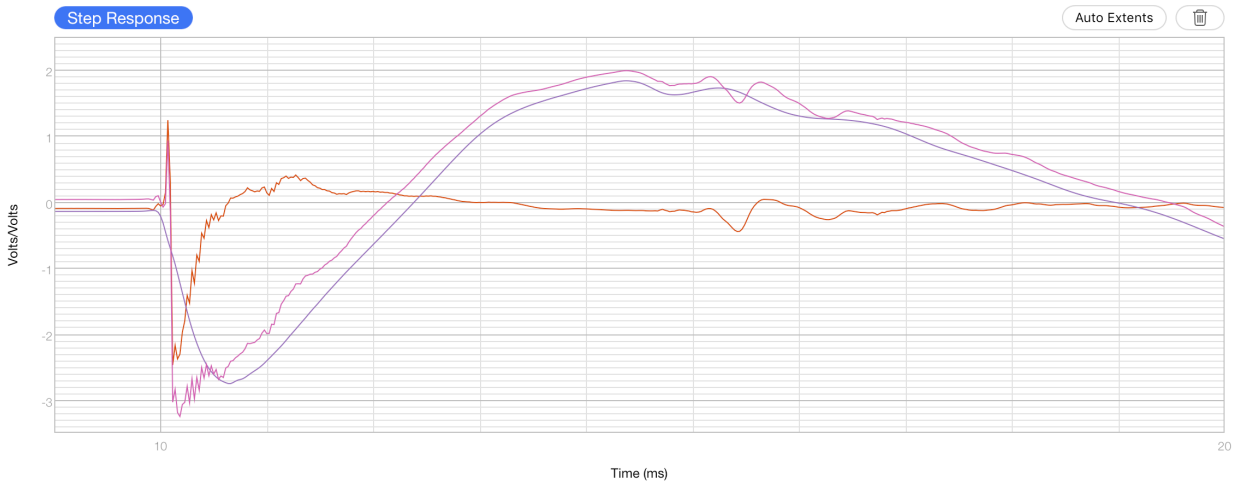


Vertical Off Axis Response

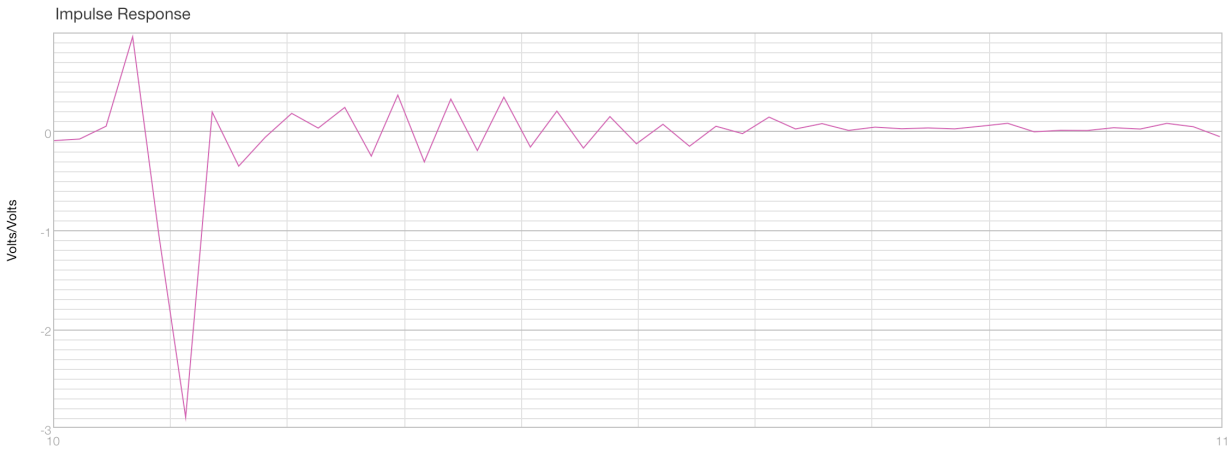
- 0 Degrees: Pink
- 9 Degrees Up: Red
- 15 Degrees Up: Purple
- 30 Degrees Up: Green
- 45 Degrees Up: Orange
- 60 Degrees Up: Blue



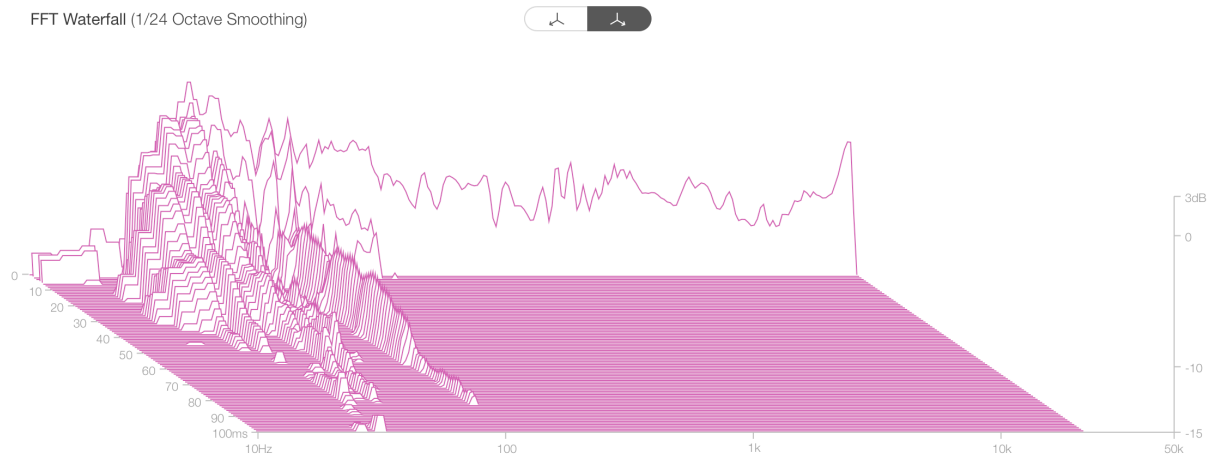
Step Response



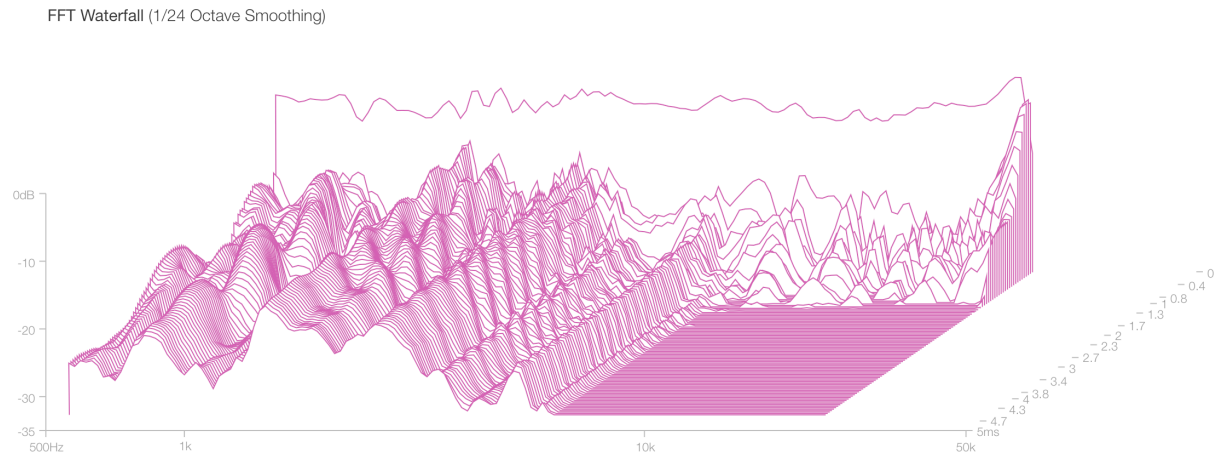
Integrated Step Response Red: Tweeter/Mid Blue: Woofer Purple: Full



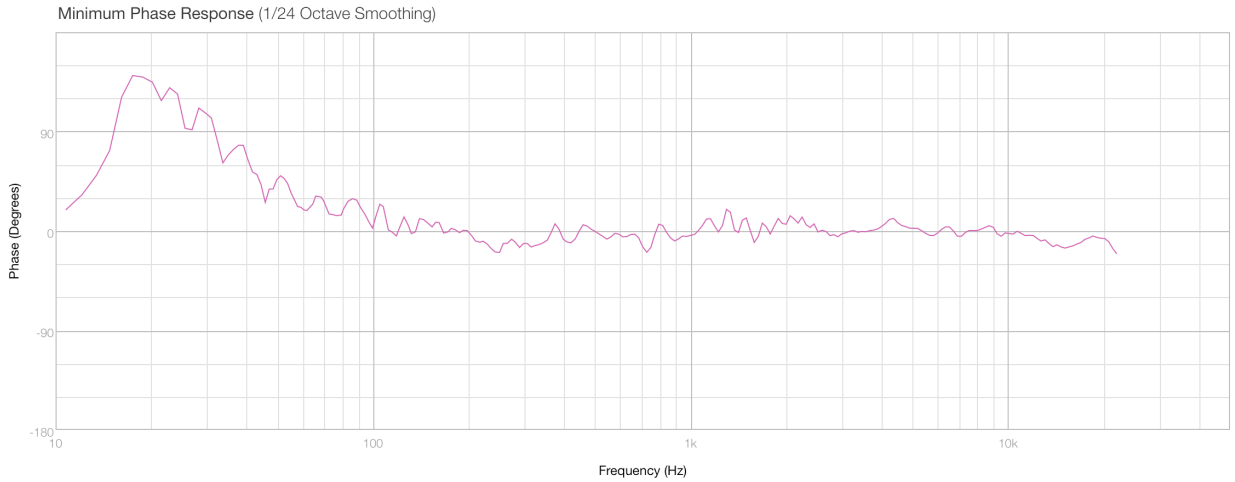
Impulse Response (1ms)



Full Frequency Waterfall Plot

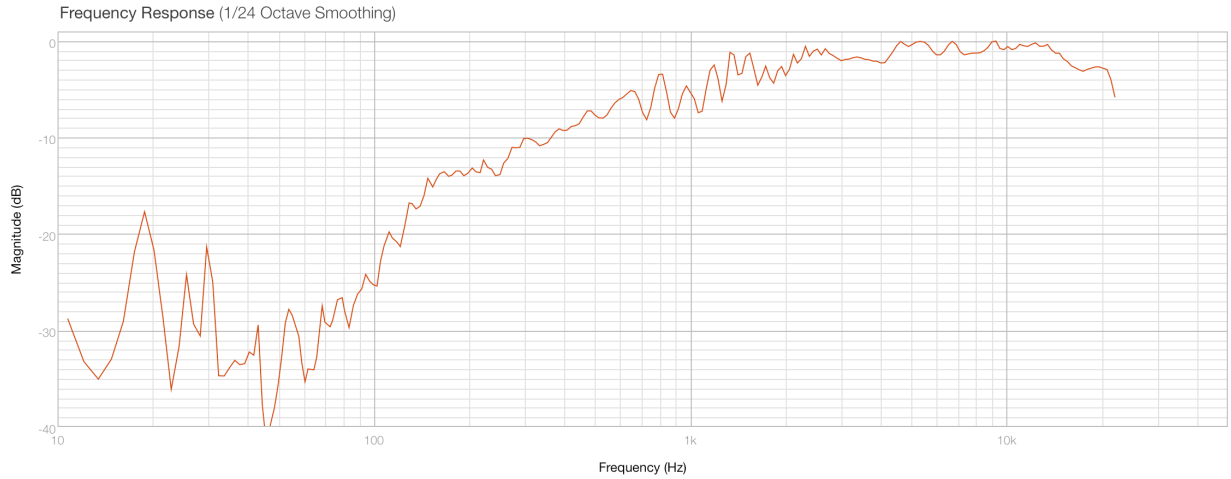


High Frequency Waterfall Plot

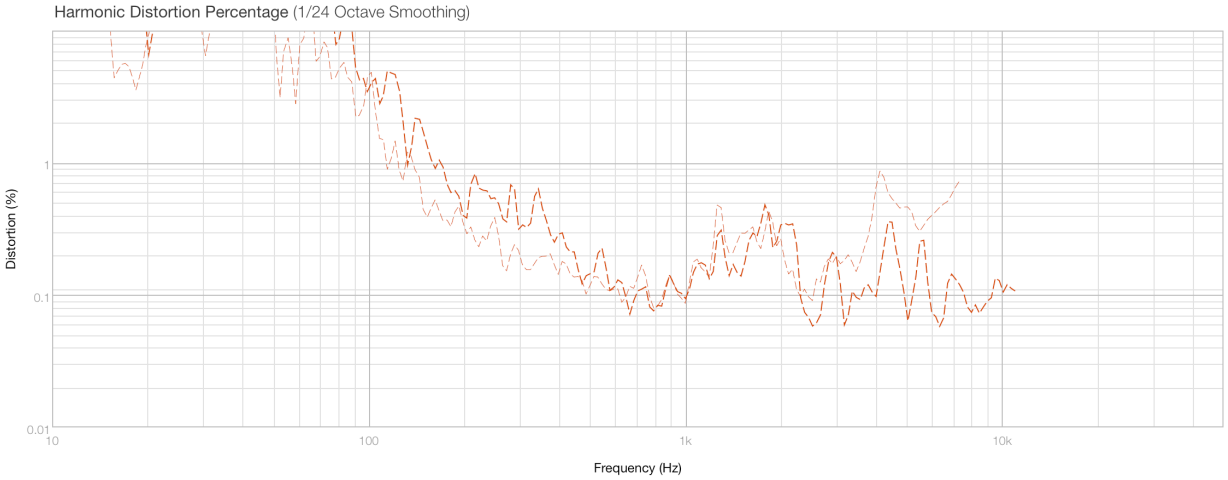


Minimum Phase Response

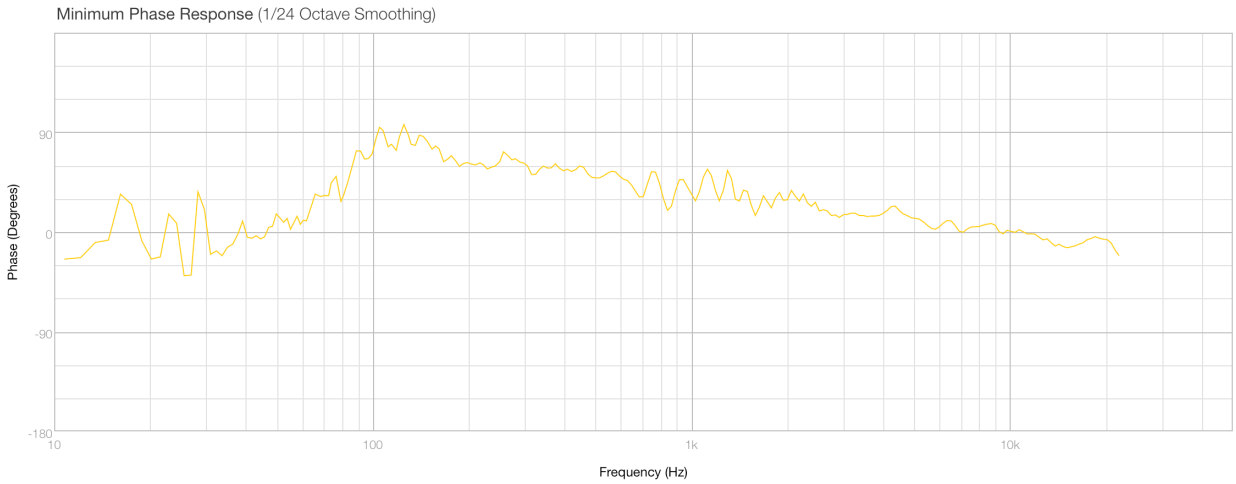
Tweeter/Mid Responses



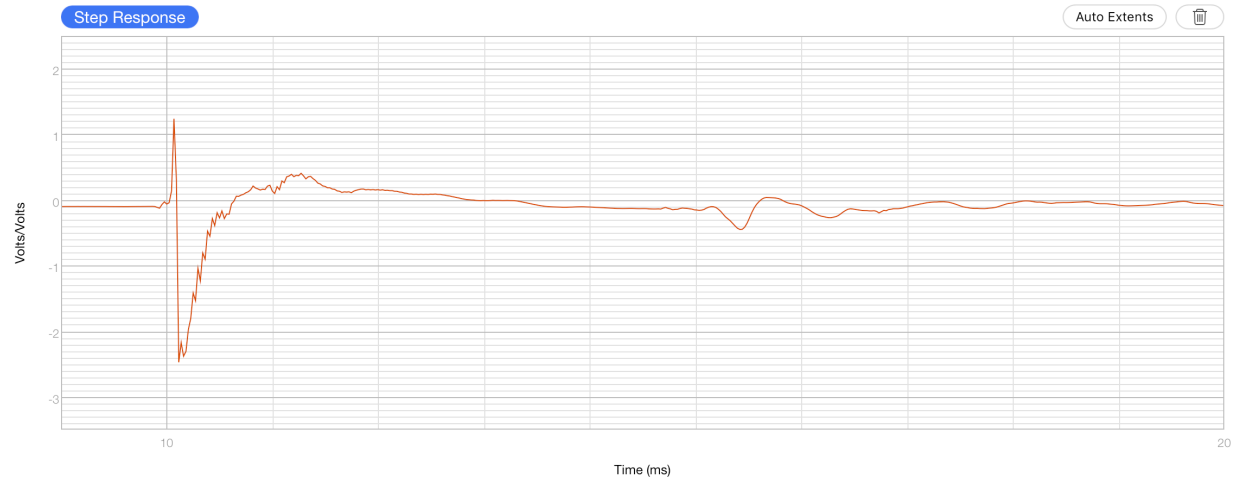
Tweeter/Mid Frequency Response 10Hz-50kHz



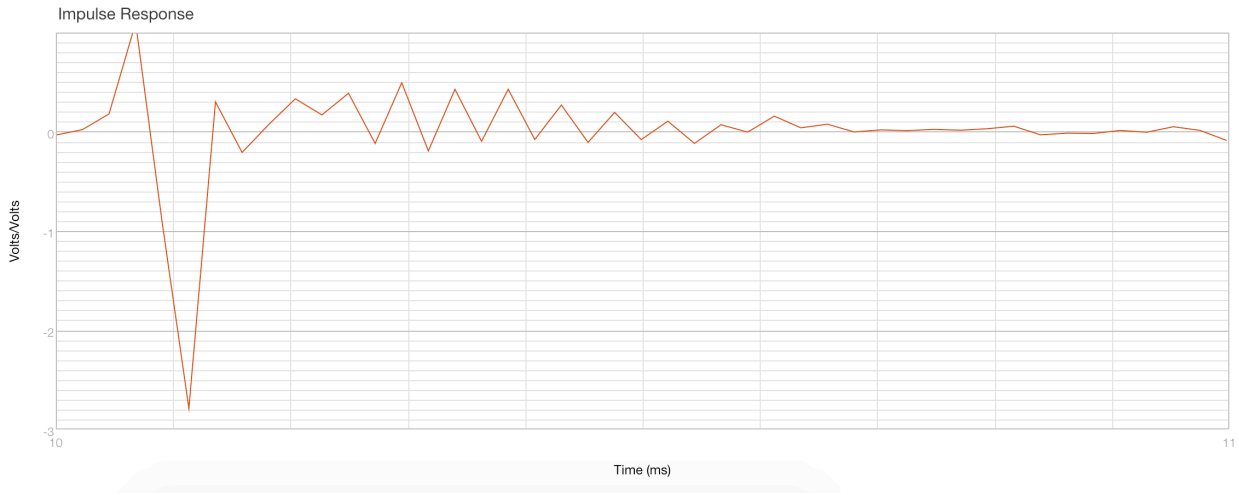
Harmonic Distortion High Frequencies



Minimum Phase Response Tweeter/Mid

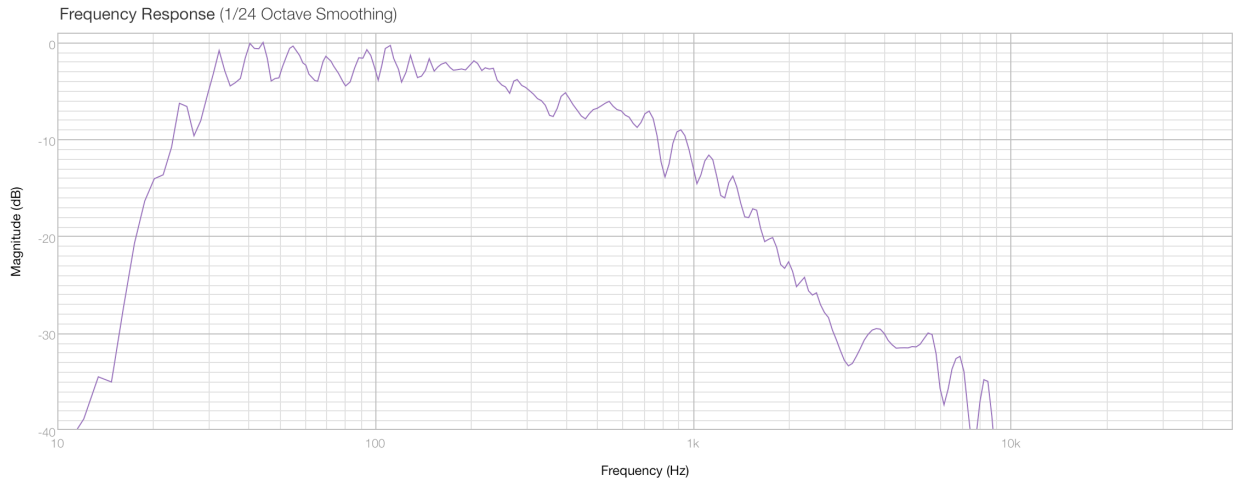


Tweeter/Mid Step Response

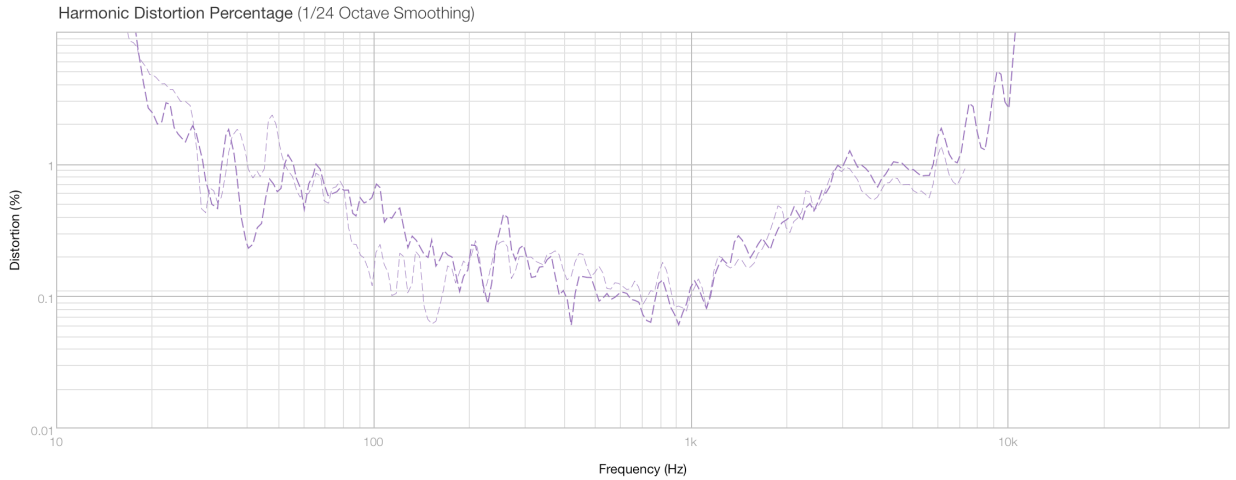


Tweeter/Mid Impulse Response (1ms)

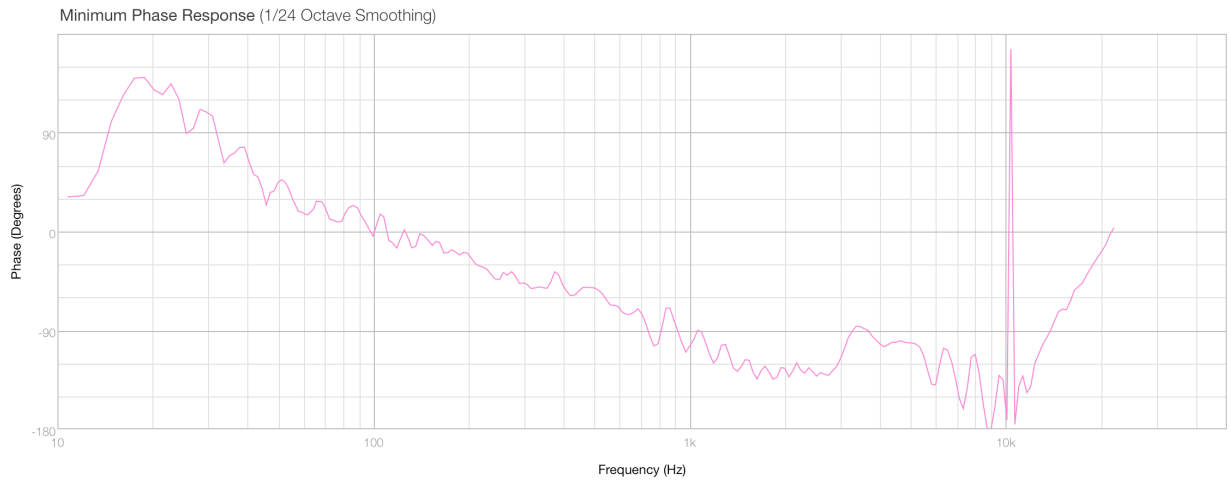
Woofer Responses



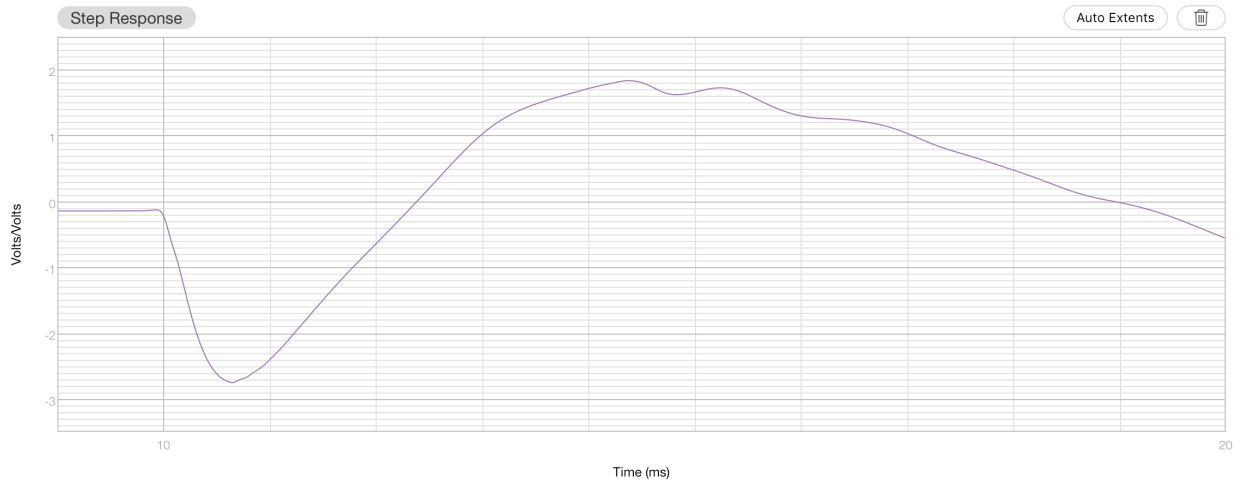
Woofer Frequency Response 10Hz-50kHz



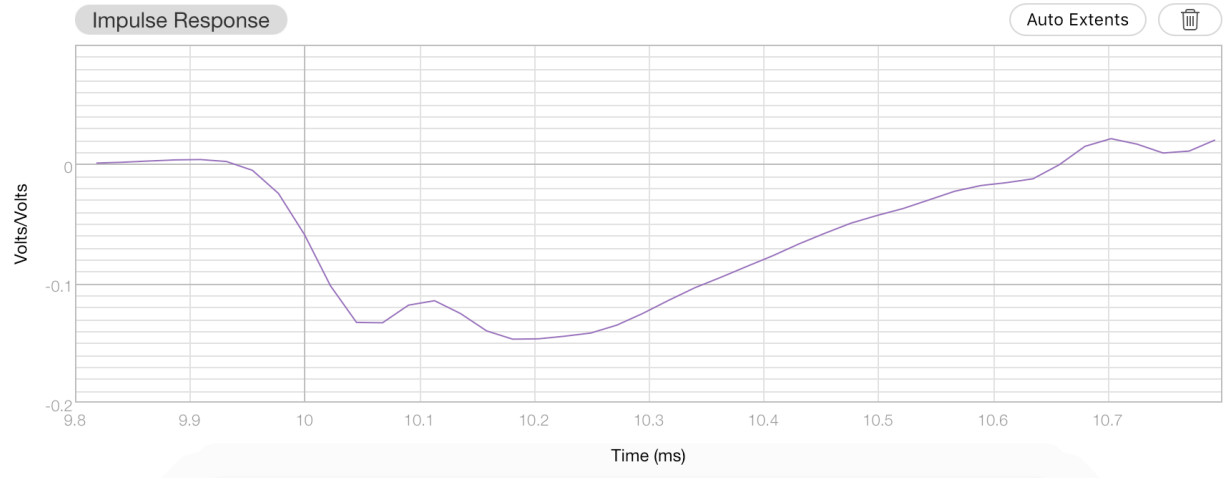
Woofer Harmonic Distortion



Woofer Minimal Phase Response



Woofer Step Response



Woofer Impulse Response (1ms)

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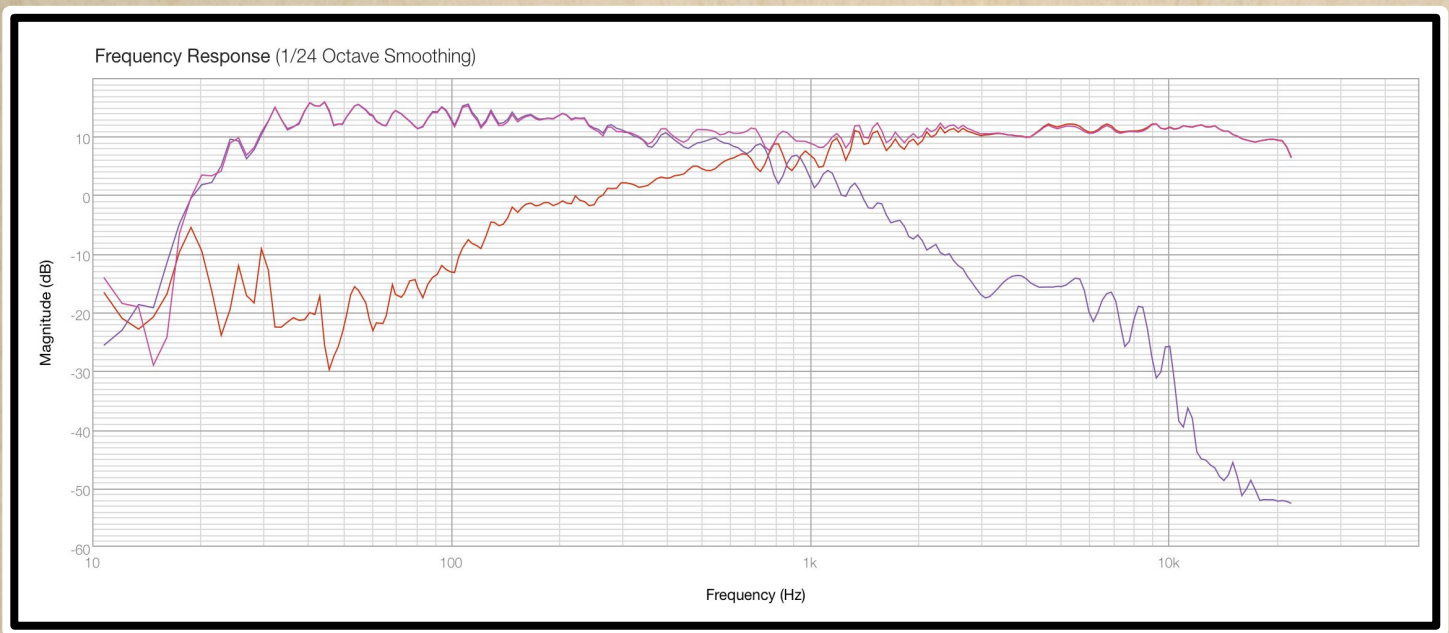
Gust Op. 1

Design Goals

- Active Home Theater Loudspeakers
- Warm & Unique Sound
- Extended Low Range
- Even Off Axis Listening

Specifications

- Fountek NeoX1.0 Ribbon Tweeter
- Dayton Audio RS125-8 5" Mid
- Dayton Audio RS225-4 8" Woofer
- Passive 3kHz Crossover



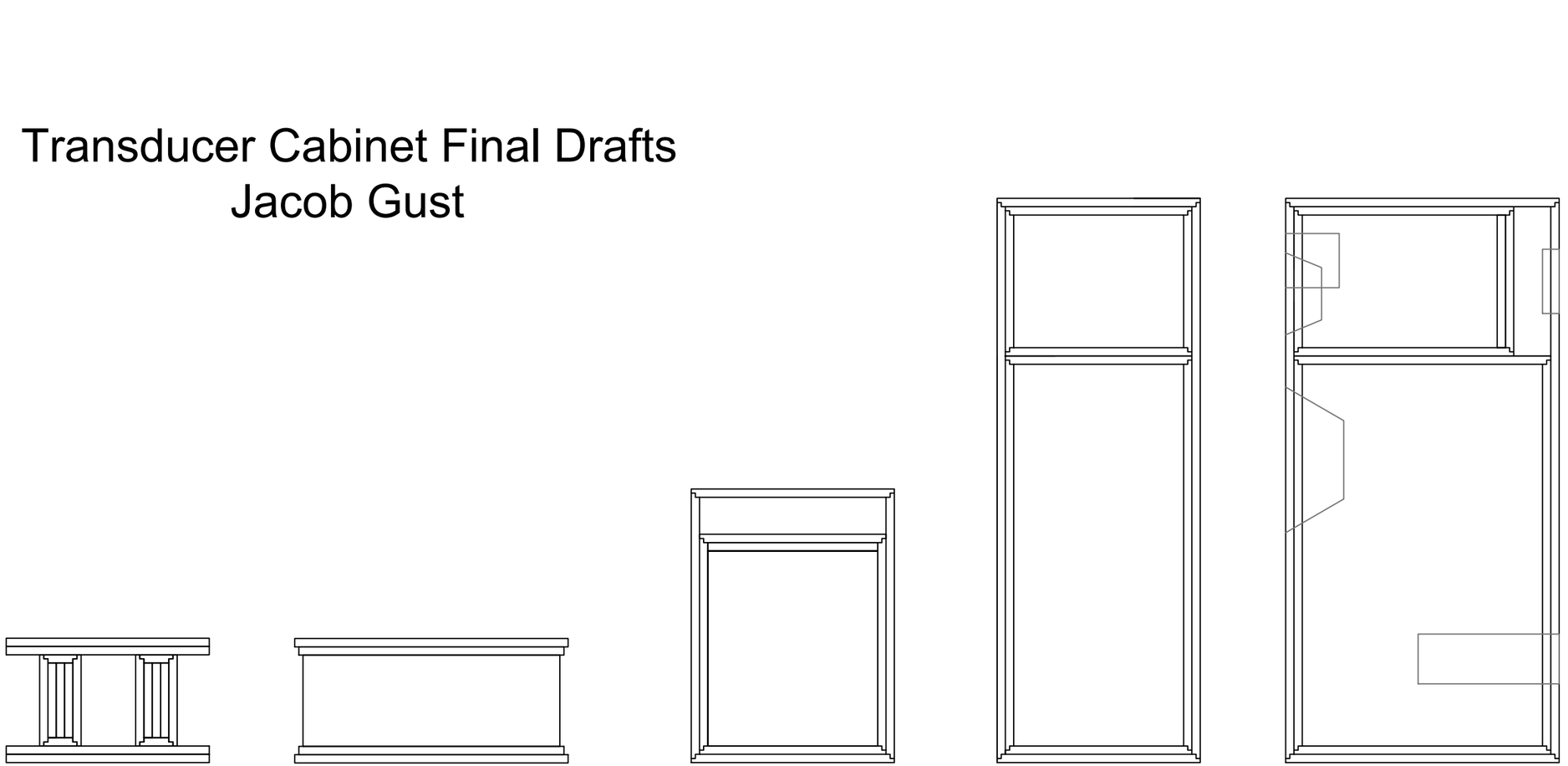
F3 of 30Hz

+/- 3dB 30Hz-20kHz

3" x 7" Port @ 30Hz

Transducer Budget Sheet					
Jacob Gust					
Quantity	Item	Link	Price	Total	Shipped?
2	4'x8' MDF	McGann's	$33.50	$67.00	Yes
2	4'x8' Baltic Birch Plywood	McGann's	$67.00	$134.00	Yes
2	Fountek Neo1.0 Ribbon Tweeter	https://www.p	$65.00	$130.00	Yes
2	Dayton Audio RS125-8 5" Driver	https://www.p	$31.57	$63.14	Yes
2	Dayton Audio RS225-8 8" Driver	https://www.p	$57.42	$57.42	Yes
2	Terminal Plates	https://www.p	$6.50	$13.00	Yes
2	3" Tube Port	https://www.p	$12.20	$24.40	Yes
1	MiniDSP	https://www.a	$149.00	$149.00	Yes
1	Lepai lp 2020ti	https://www.p	$20.00	$20.00	Yes
1	Lepai lp 7498e	https://www.p	$84.98	$84.98	Yes
1	100ft Speaker Wire	https://www.a	$10.99	$10.99	Yes
4	Binding Posts	https://www.p	$7.78	$31.12	Yes
2	Dayton Audio RS225-4 8" Driver	https://www.p	$58.66	$117.32	Yes
1	Stain		$23.68	$23.68	Yes
1	Paint		$15.77	$15.77	Yes
			Sub Total	$941.82	
	Contingency		5%	$47.09	
			Total	$988.91	
	Goal		Under	$1,000.00	
			Success?	$11.09	So Far

Transducer Cabinet Final Drafts
Jacob Gust

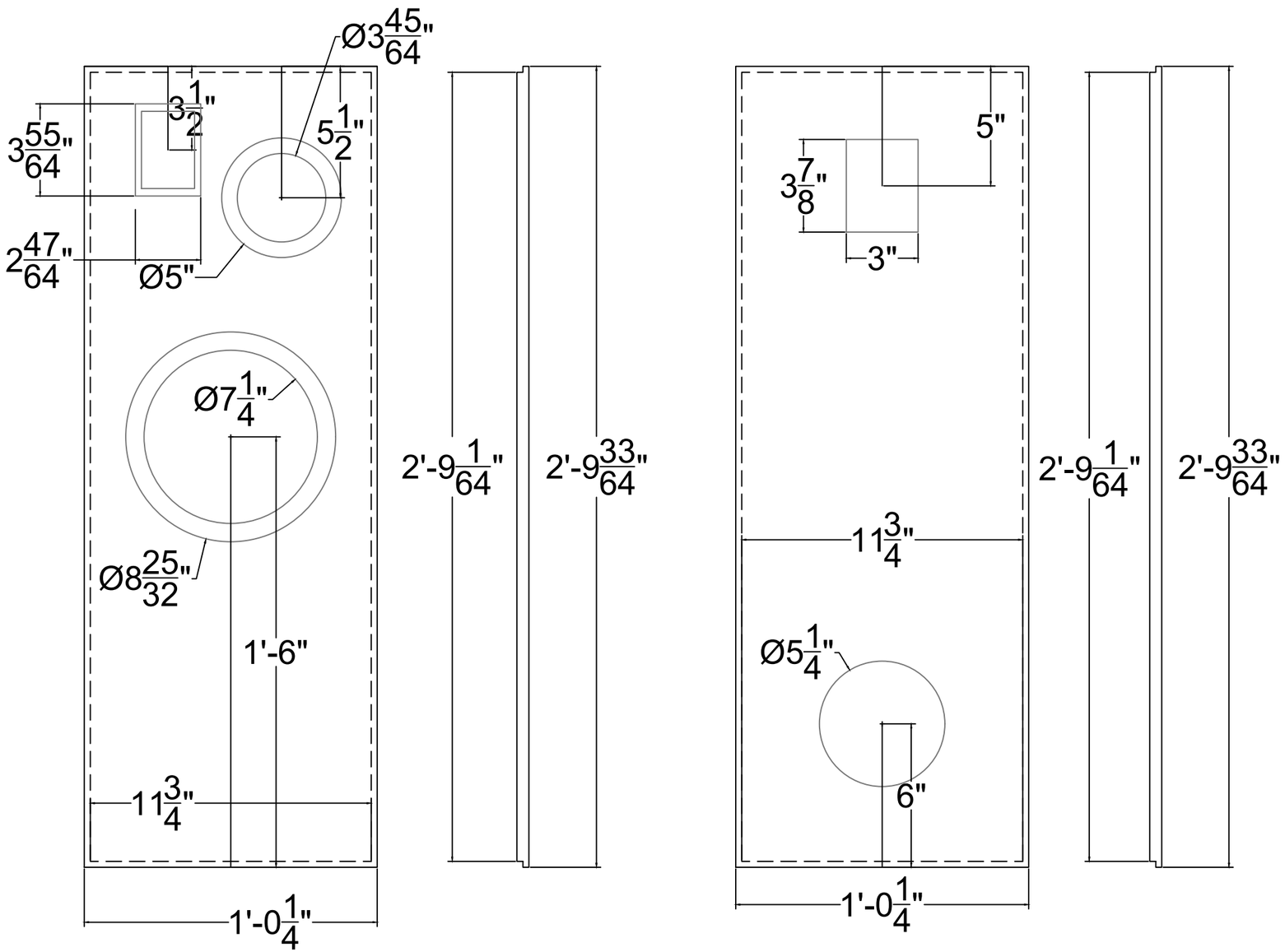


Top/Bottom | Front/Back | Left/Right

JtGust Audio

Jacob Gust

Final Drafts



Outer Front

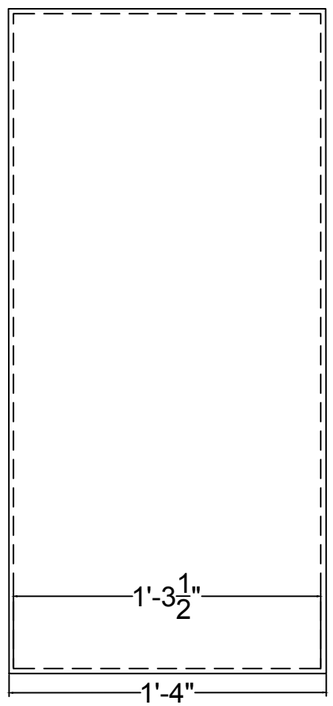
Outer Back

JtGust Audio

Jacob Gust

Final Drafts

Outer Front & Back



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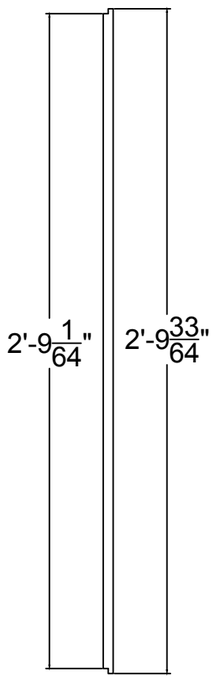

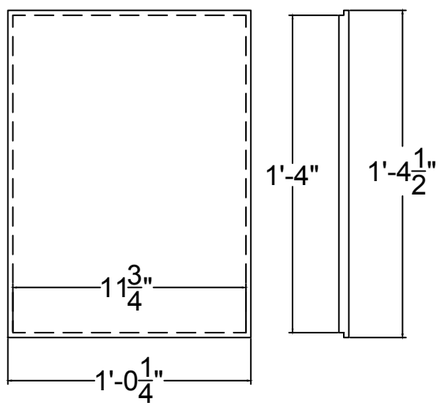

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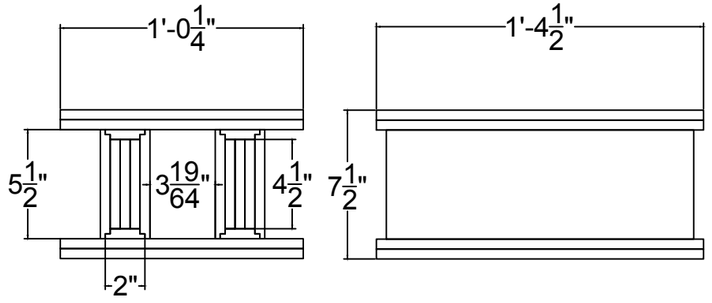
Top/Bottom



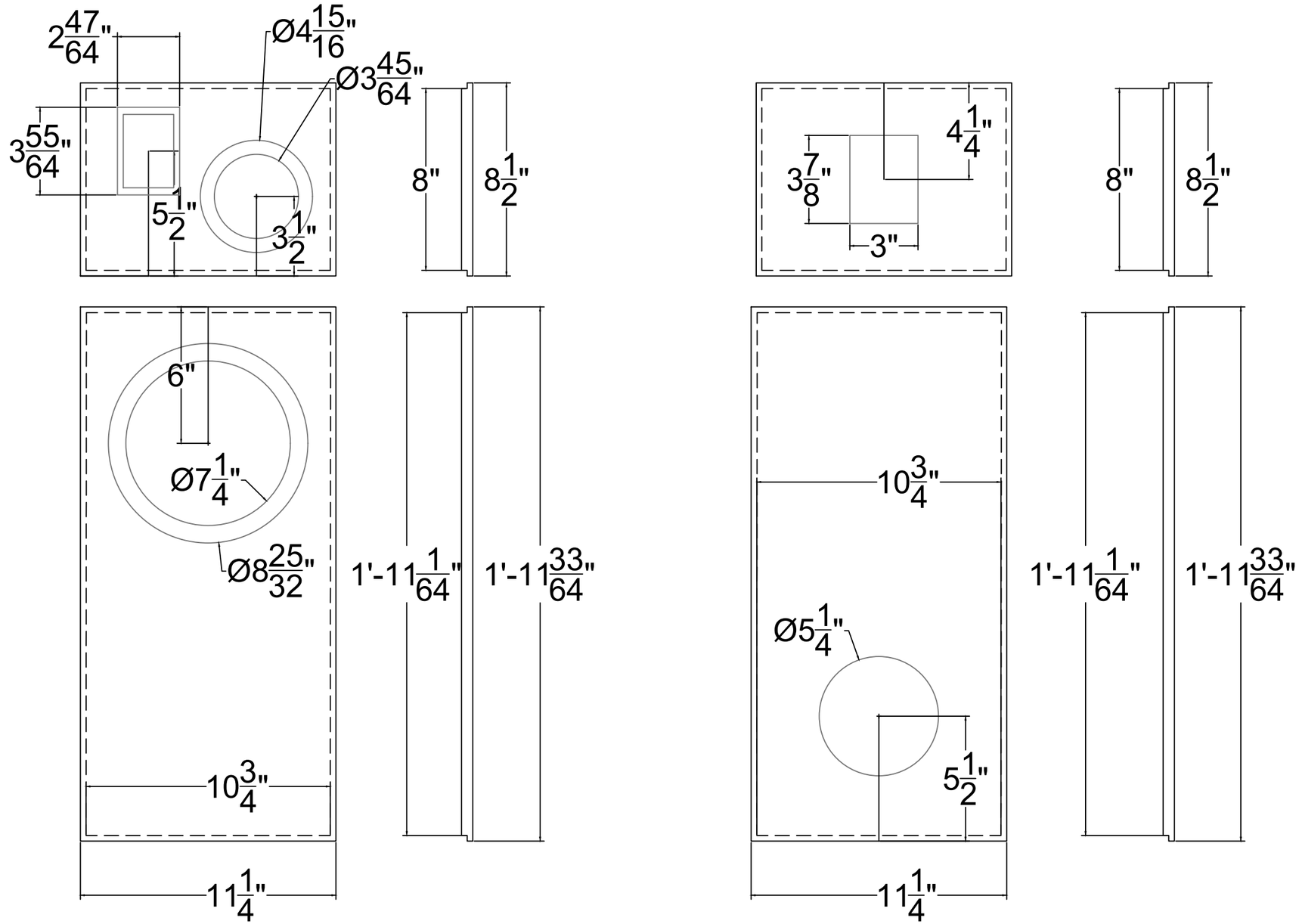
Stand

JtGust Audio

Jacob Gust

Final Drafts

Outer Left/Right/Top/Bottom



Inner Front

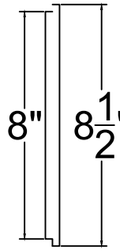
Inner Back

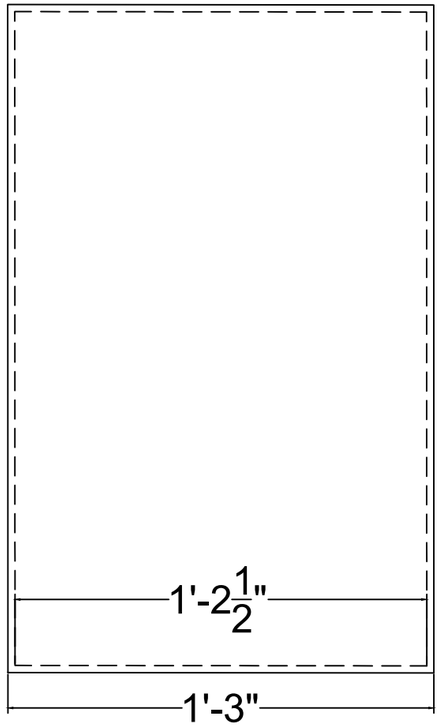
JtGust Audio

Jacob Gust

Final Drafts

Inner Front & Back





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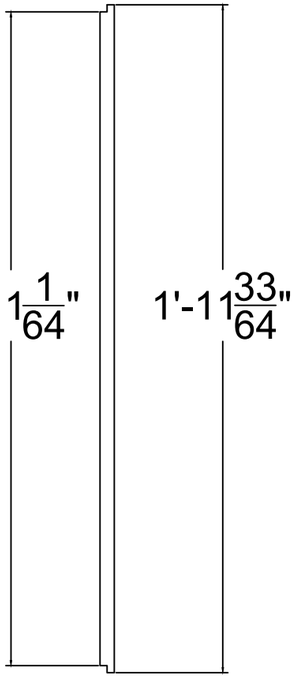
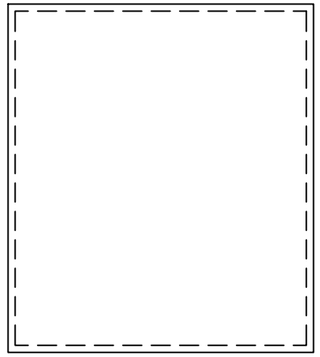
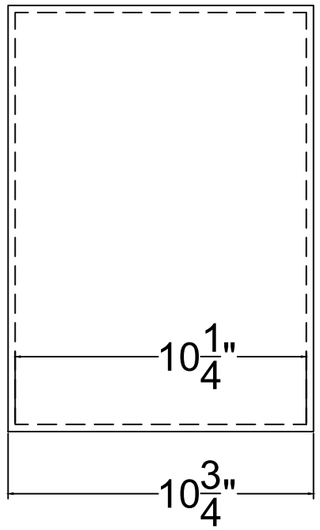
Left/Right







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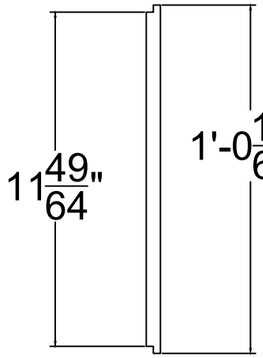
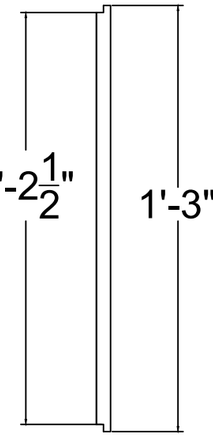
Top/Bottom



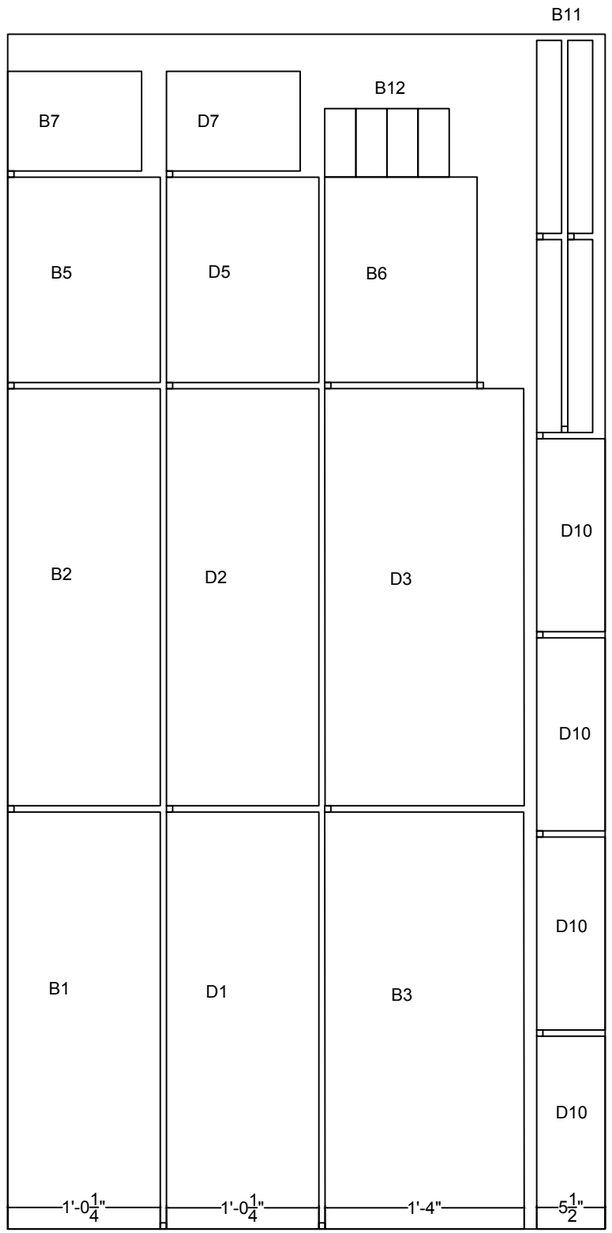


JtGust Audio

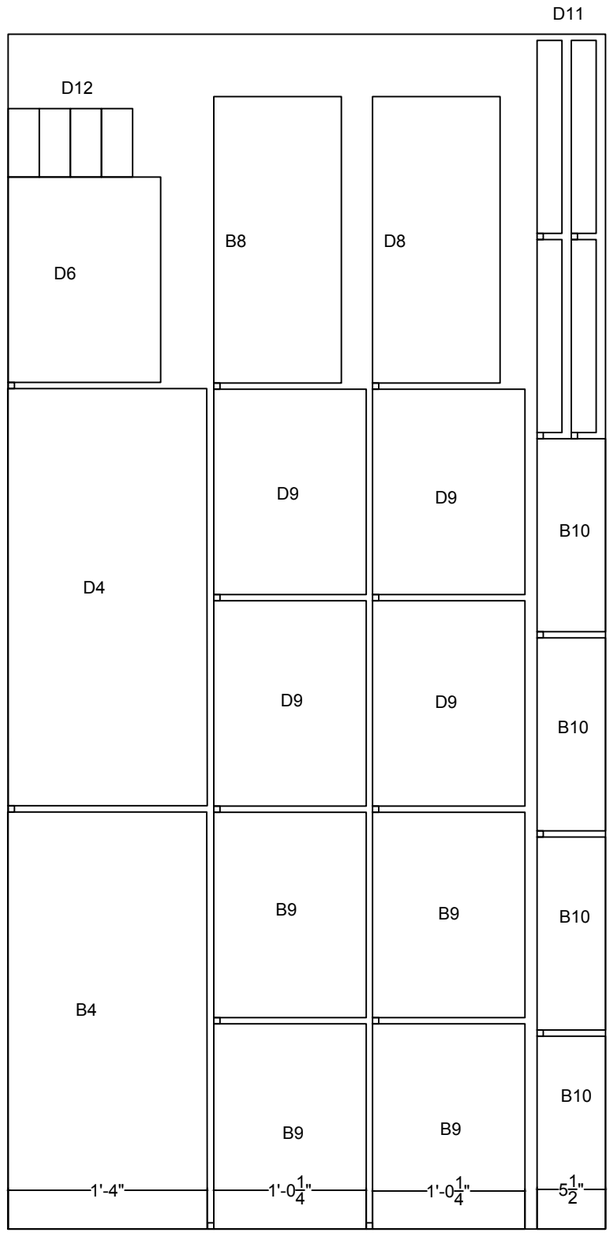
Jacob Gust

Final Drafts

Inner Left/Right/Top/Bottom



Birch - 1



Birch - 2

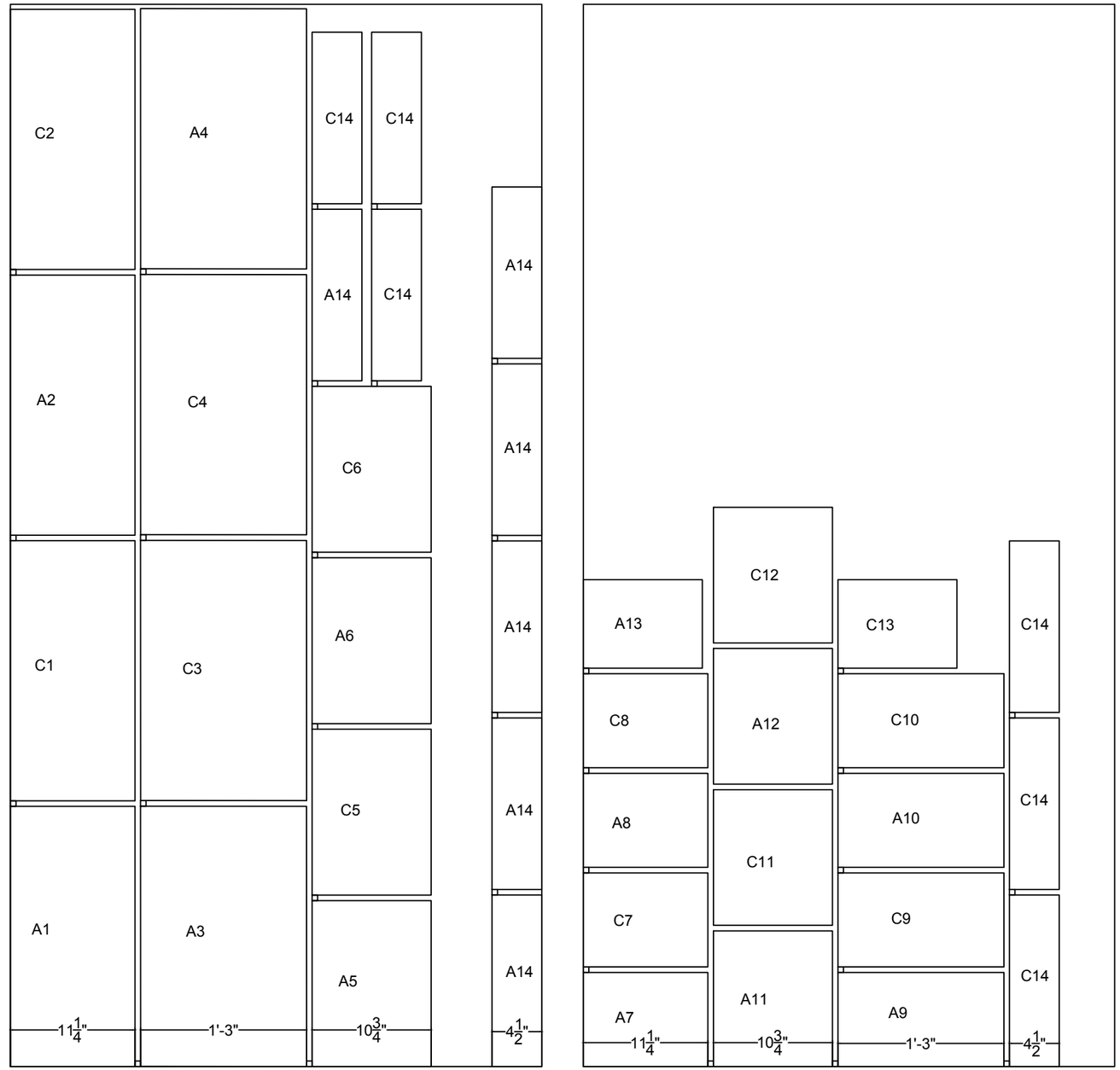
$\frac{1}{2}$" Baltic Birch Plywood

JtGust Audio

Jacob Gust

Final Drafts

Baltic Birch Cut Sheet



MDF - 1

MDF - 2

$\frac{1}{2}$" MDF

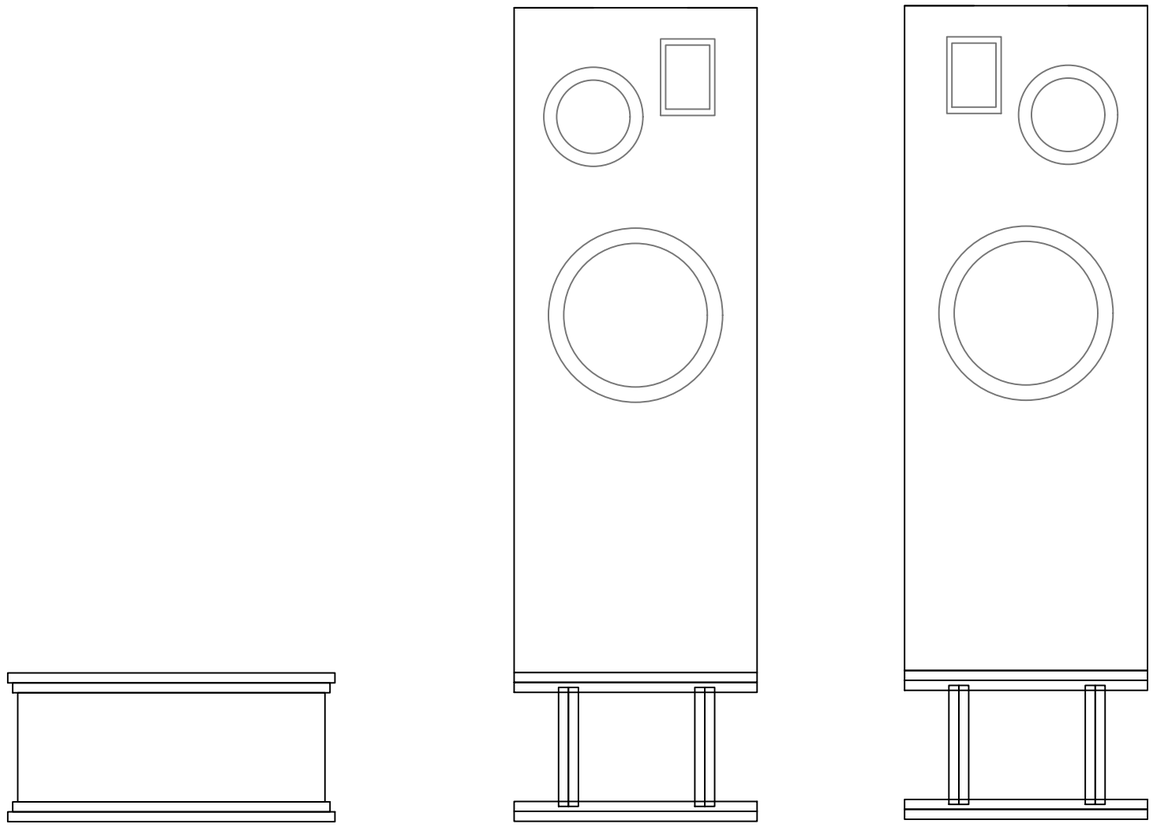
JtGust Audio

Jacob Gust

Final Drafts

MDF Cut Sheet

Transducer Cabinet As Builts
Gust Op. 1

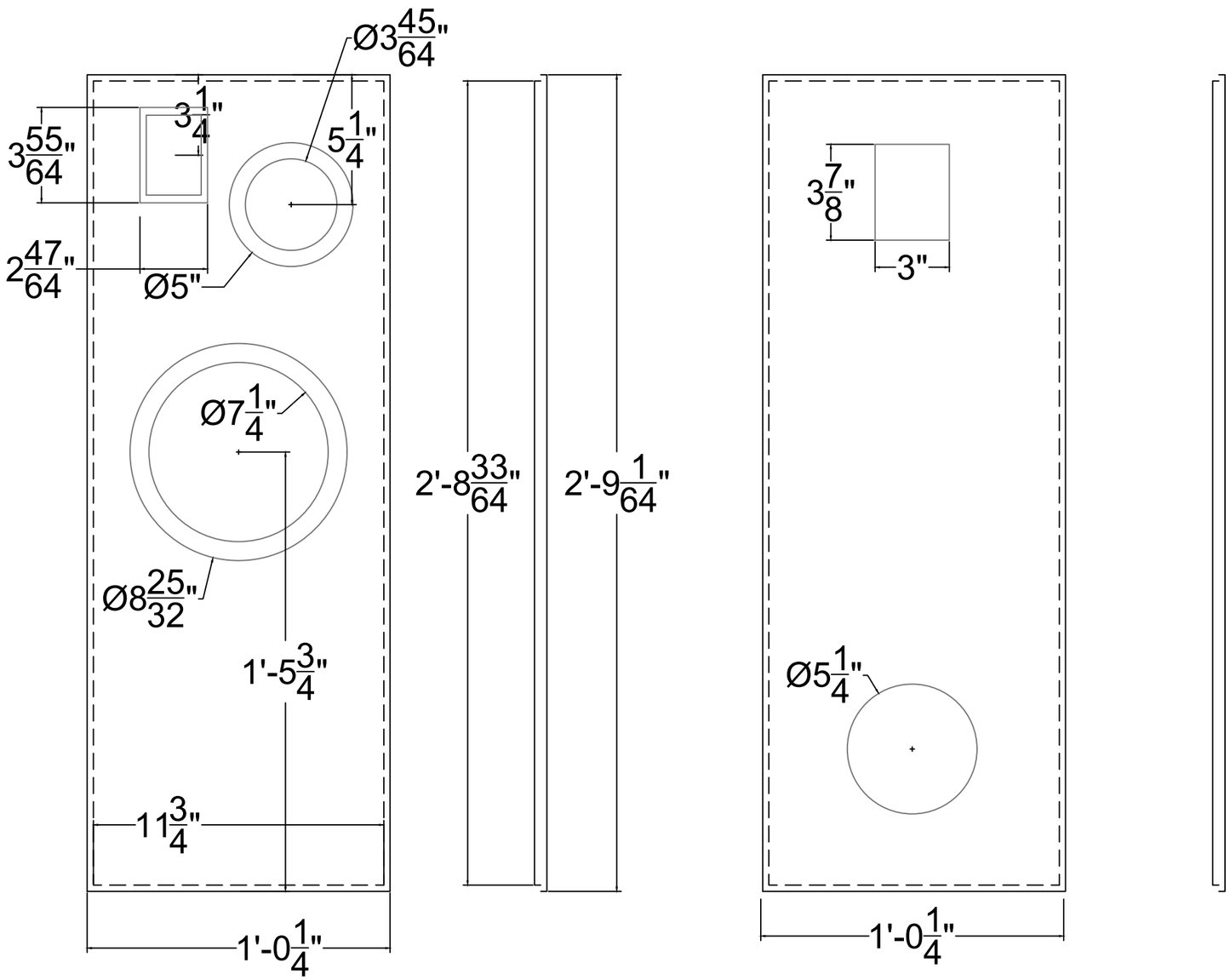


JtGust Audio

Gust Op. 1

As Built Drafts

Designed By Jacob Gust



Outer Front

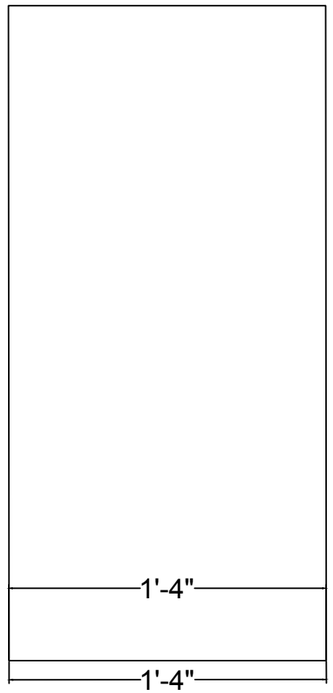
Outer Back

JtGust Audio

Gust Op. 1

As Built Drafts

Outer Front & Back



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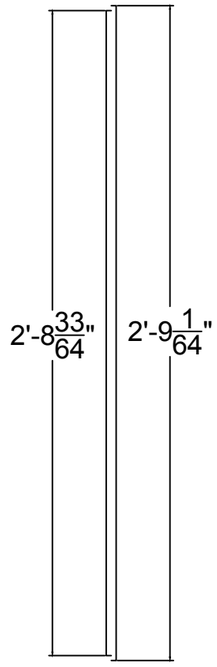
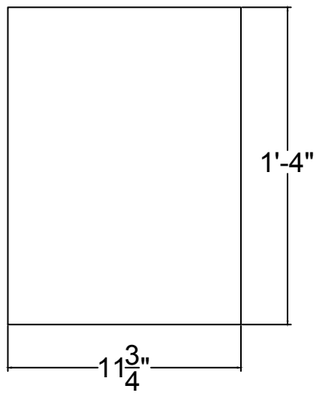
Left/Right





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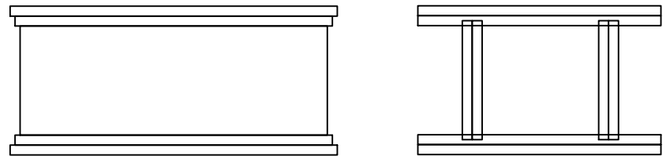
Top/Bottom



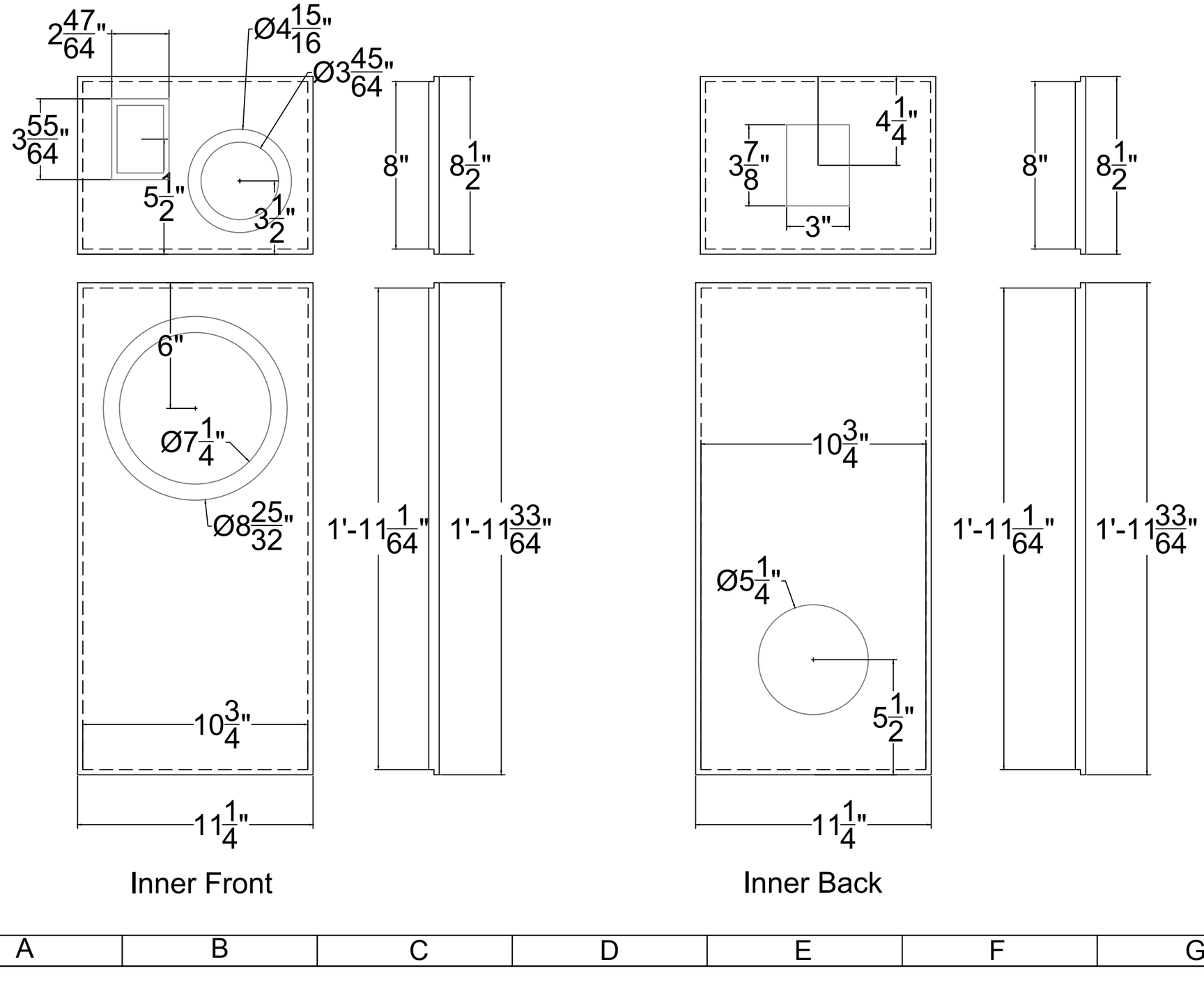
Stand

JtGust
Audio

Gust Op. 1

As Built Drafts

Outer Left/Right/Top/Bottom



Inner Front

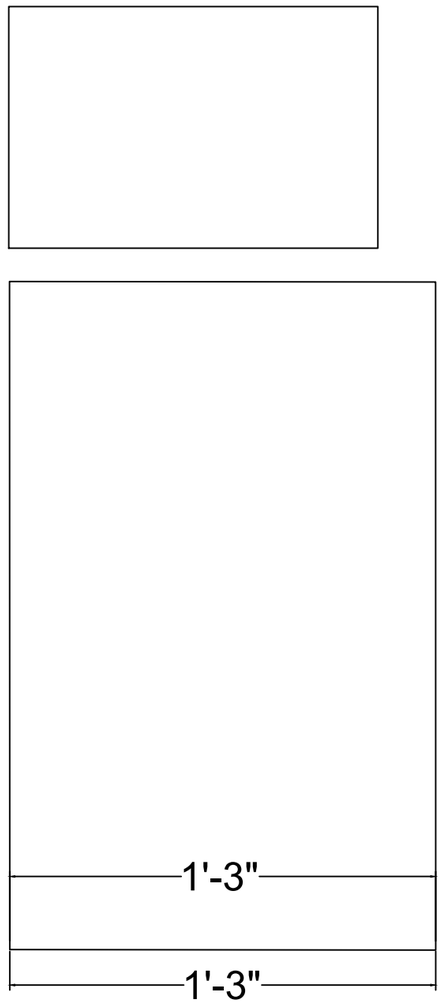
Inner Back

JtGust Audio

Gust Op. 1

As Built Drafts

Inner Front & Back



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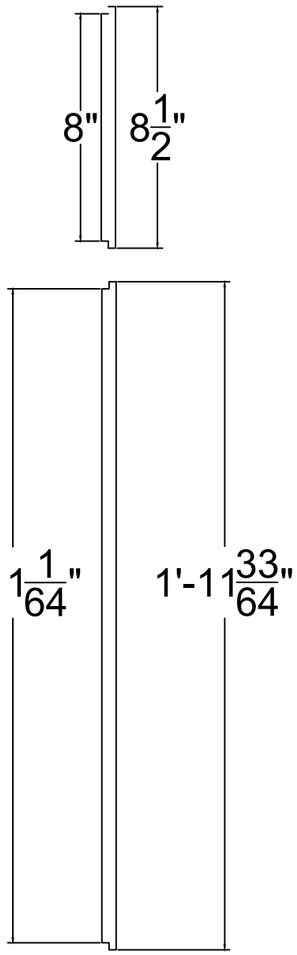
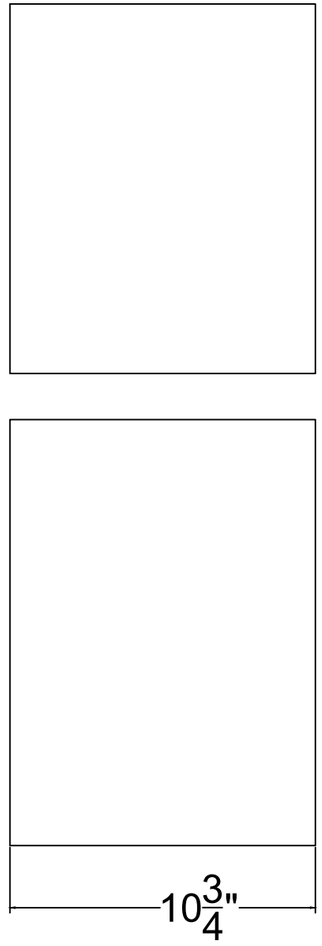
Left/Right





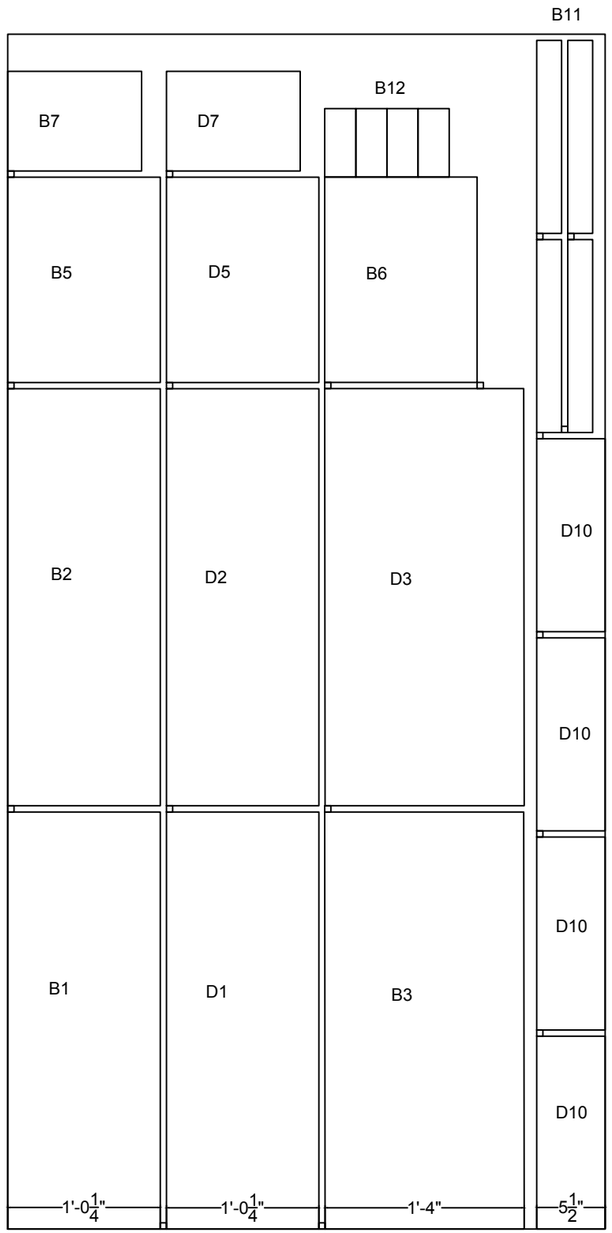
Inner
Top/Bottom

JtGust
Audio

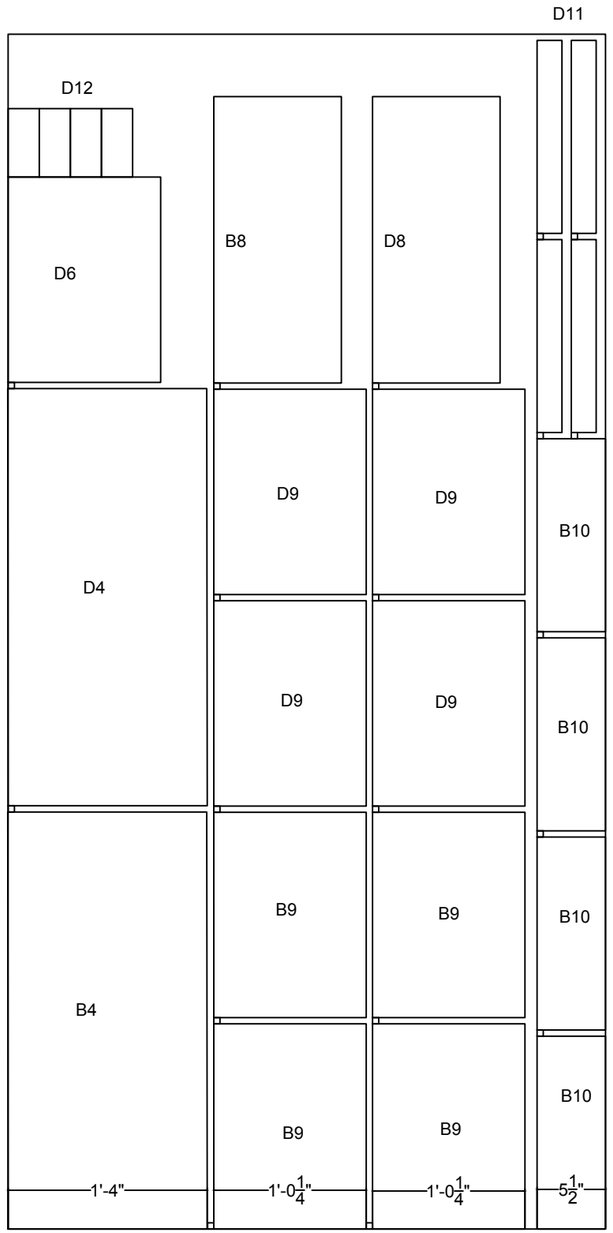
Gust Op. 1

As Built Drafts

Inner Left/Right/Top/Bottom



Birch - 1



Birch - 2

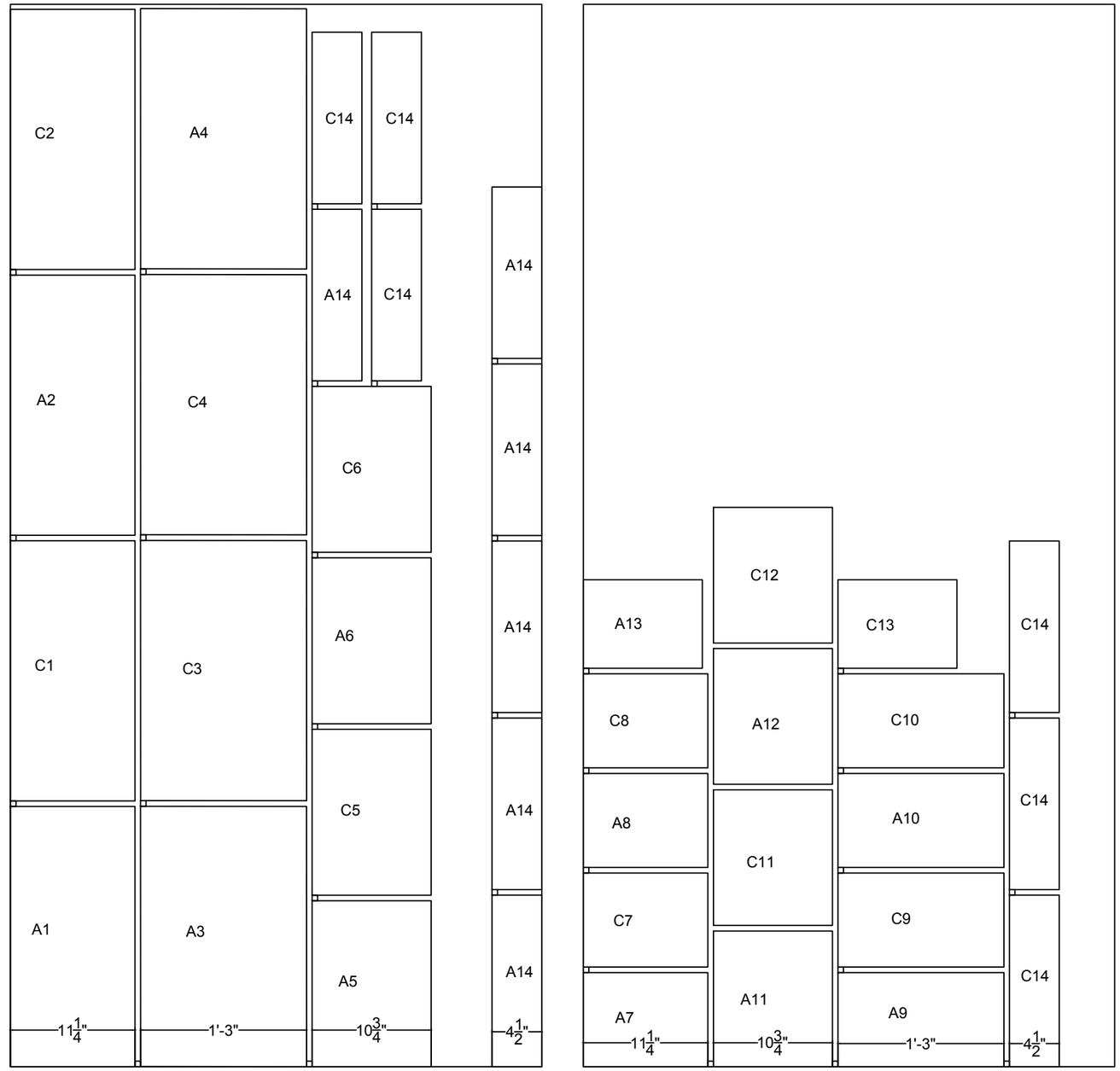
$\frac{1}{2}$" Baltic Birch Plywood

JtGust Audio

Gust Op. 1

As Built Drafts

Baltic Birch Cut Sheet



MDF - 1

MDF - 2

$\frac{1}{2}$" MDF

JtGust Audio

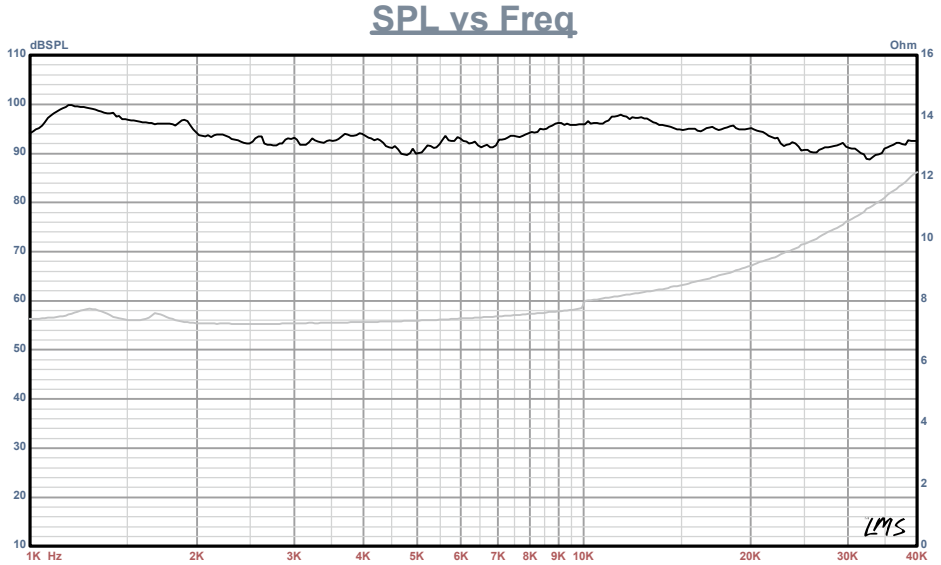
Gust Op. 1

As Built Drafts

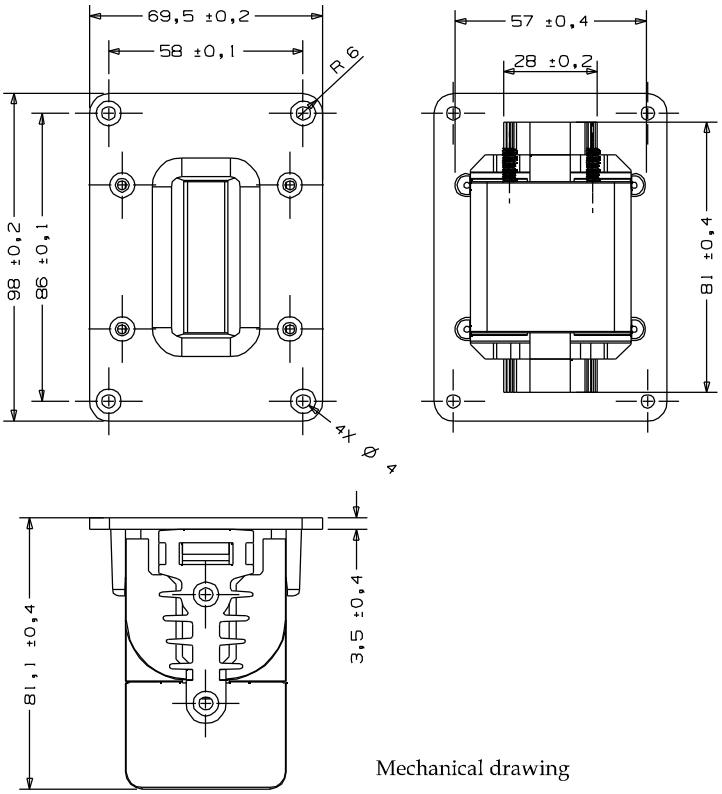
MDF Cut Sheet

NeoX1.0 ribbon tweeter

- Fountek's 3rd generation ribbon driver technology
- 12mm wide reinforced sandwiched ribbon diaphragm
- High power handling, low distortion, very fast response
- Strong Neodymium magnet
- Built-in impedance converting transformer



on-axis frequency response

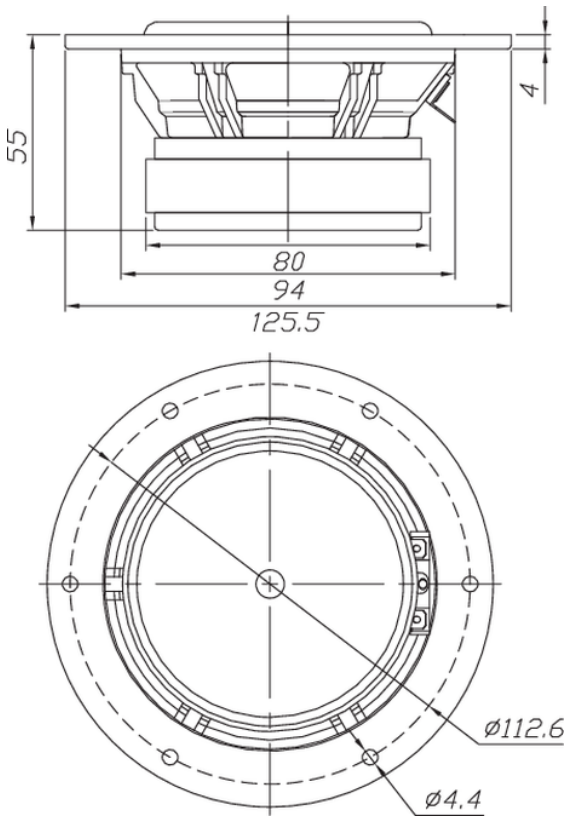


Mechanical drawing

Parameter	
Sensitivity	92dB/1m/2.83v
Power handling	20W nominal, 38W max
Frequency range	1,200-40,000Hz
Nominal impedance	8 ohm
DCR	0.02 ohm
Ribbon dimension	12x45x0.015mm
Effective ribbon area	720 square millimeter
Ribbon weight	20 milligram
Gap flux	0.4 Telsa average
Gap height	13 millimeter
Recommend crossover frequency	2,500Hz with 2-order
Net. Weight	630 gram

RS125-8 5" Reference Woofer 8 Ohm

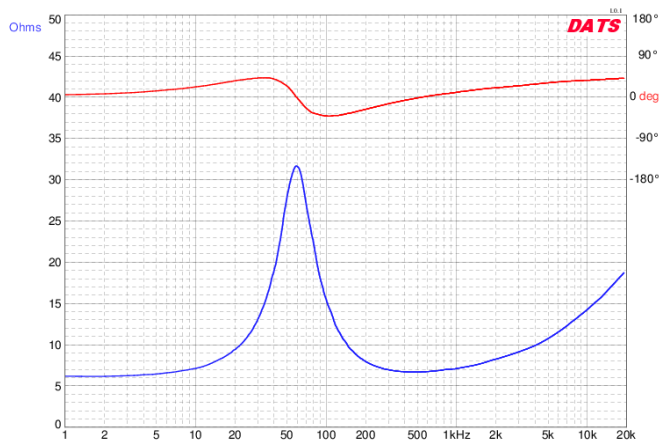
RS125-8



PARAMETERS

Impedance	8 ohms
Re	6.2 ohms
Le	0.57 mH @ 1 kHz
Fs	59.2 Hz
Qms	1.74
Qes	0.42
Qts	0.34
Mms	5.9g
Cms	1.22 mm/N
Sd	52.8 cm²
Vd	21.1 cm³
BL	5.69 Tm
Vas	4.77 liters
Xmax	4.0 mm
VC Diameter	25 mm
SPL	86.8 dB @ 2.83V/1m
RMS Power Handling	30 watts
Usable Frequency Range (Hz)	65 - 5,400 Hz

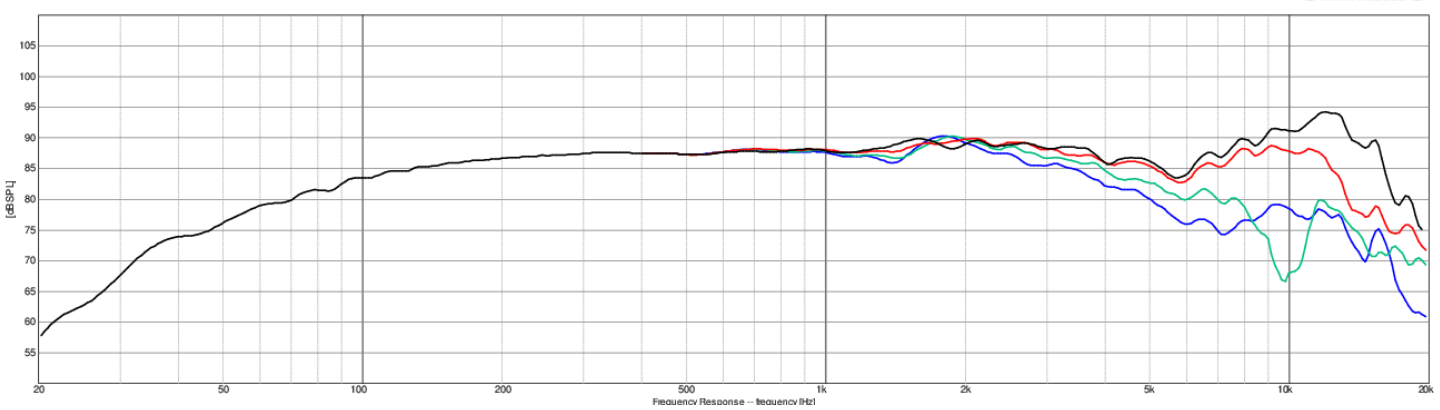
IMPEDANCE/PHASE



FEATURES

- One of the lowest distortion, highest resolution driver series available
- Low-distortion high-excursion motor system with two short-circuit paths
- Compliant suspension and rigid black anodized aluminum cone for strong bass performance
- Heavy-duty 6-hole cast frame, low-loss rubber surround, and solid aluminum phase plug
- Designed and engineered in the USA

FREQUENCY RESPONSE

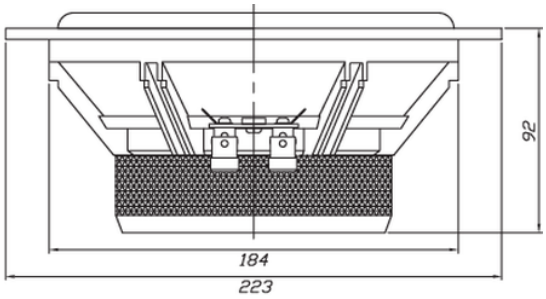


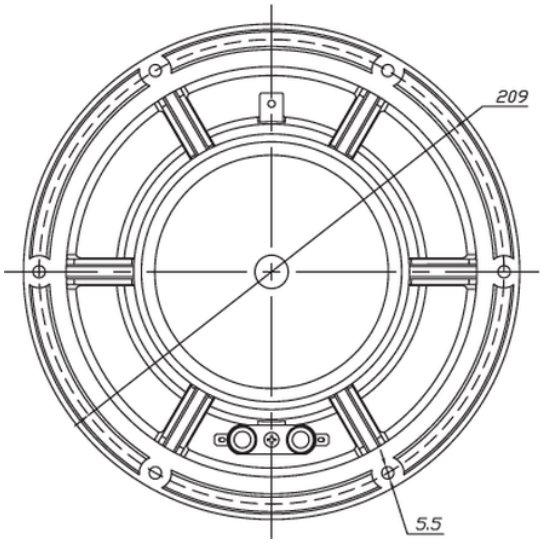
Note: 1/24th octave smoothing - nearfield response included in graph below 450 Hz.

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

RS225-4 8" Reference Woofer 4 Ohm

RS225-4





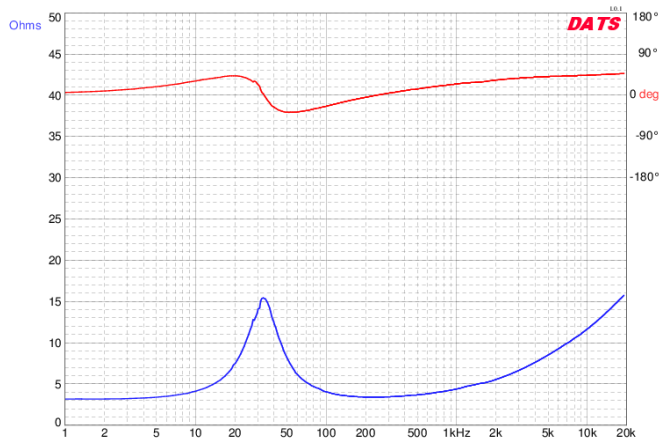
PARAMETERS

Impedance	4 ohms
Re	3.2 ohms
Le	0.49 mH @ 1 kHz
Fs	33 Hz
Qms	2.02
Qes	0.52
Qts	0.41
Mms	32.2g
Cms	0.72 mm/N
Sd	213.8 cm²
Vd	128.2 cm³
BL	6.38 Tm
Vas	46.4 liters
Xmax	6.0 mm
VC Diameter	38 mm
SPL	91 dB @ 2.83V/1m
RMS Power Handling	80 watts
Usable Frequency Range (Hz)	35 - 2,300 Hz

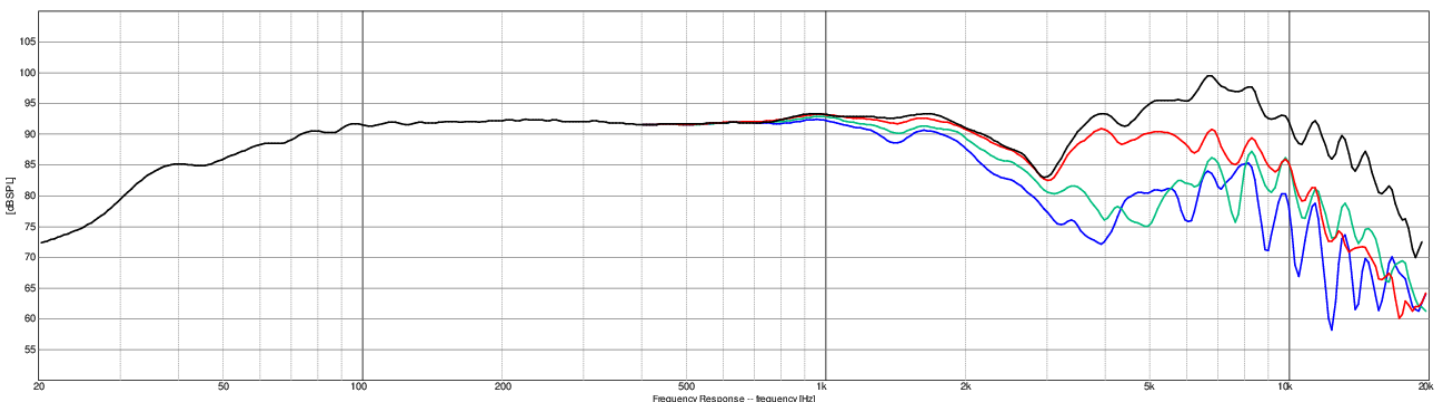
FEATURES

- 4 ohm impedance is perfect for series pairs in MTMs and center channel speakers
- Excellent car audio midrange/midbass
- High-end low-distortion motor with two shorting paths to reduce inductance

IMPEDANCE/PHASE



FREQUENCY RESPONSE



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

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