Loudspeaker Design

Designing The Monochromes

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2 Functional Description

2.1 The Loudspeaker

The Loudspeaker cabinet is small, portable, and capable of producing rich, warm sounds without the use of the sub. Easy listening is intended on this system rather than loud “in your face” type sounds that you hear at a given venue. The idea was to create bookshelf loudspeakers that are pleasing to the ears from a short distance away. Each loudspeaker weighs less than 30 pounds and is easily capable of being transported to any given designation.

3 Design Goals

The main goal I had in mind was to create the most enjoyable listening experience at the cheapest cost possible. This would make the speakers affordable for college students and music hobbyists alike. The budget I used for the speakers is a flat $300.

3.1 Size and Shape

For my design, I decided to create a ported a box as it would yield a lower f3 than sealed boxes of the same size with the same speakers. The speakers are 10” x 14” x 14” (L x W x Depth) with an inner cabinet volume of about 1 cubic foot. The port is about six inches long and located to the left of the left speaker and the right of the right one. 1.5 inches of MDF surrounds the entire enclosure. A standard box shape has been used for the cabinet.

3.2 SPL Output

Each loudspeaker is capable of producing an SPL of 88 dB at 1m away. For me, 88 dB is more than enough sound pressing against my face and because these are speakers that are to be built for sound reproduction at close range, distance does not factor into the equation as much.

Desired Distance = 1m

SPL	Wattage
88	1
91	2
94	4
97	8
100	16

This chart measures the SPL level based on a distance of a meter away in relation to wattage. You can see that an amp with very low wattage could be enough to power my speakers at the potential they need to be at.

3.3 Bandwidth

By playing three different songs and applying a high pass filter to each song to find the highest frequency acceptable to me for the loudspeakers to stop reproducing sound well, I discovered that the speakers need to be able to handle frequencies down to at least 80 Hz. The songs I tested on were Skrillex – Roughneck (Full Flex), BT – Emergency, Dirtyphonics – Dirty (Darth & Vader Remix). So each loudspeaker needs to handle frequencies from **80 Hz to 20 kHz**. The speakers I plan to use are able to handle frequencies of about 30 Hz according to their response chart.

3.4 Directivity

The speakers have an accurate on-axis response that is fairly precise. Off-axis response for these speakers is not as important as they are intended to be about 1m away from the user at most.

3.5 Design Priorities

It is important to keep the bass extension to at least 80 Hz. If the budget allows it, the bass extension should go to 60 Hz. The speakers are not intended to be very loud so the SPL does not have to be very high in the end. The important thing is to make speakers that can accurately reproduce sound from about 100 Hz – 20kHz and that the speakers be as small as possible to make them convenient for travel purposes.

3.6 Design Consequences

The intention is to build speakers that can at least accurately reproduce sounds from about with an f3 of at most 80 Hz.

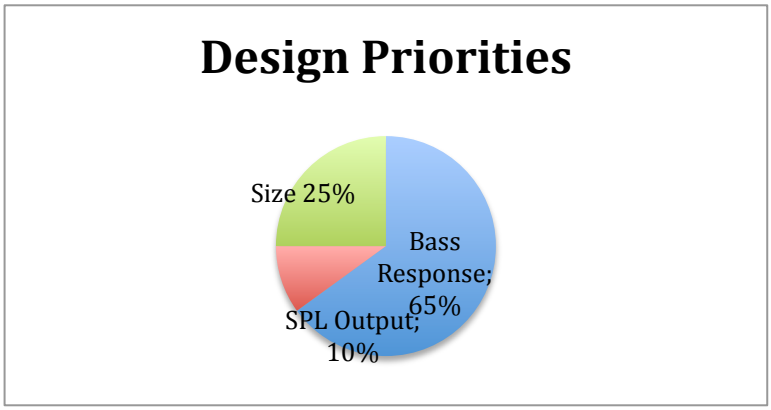


Figure 1 – Design Priorities

As seen in Figure 1, my major priority is bass response. For that reason, I will be using a vented box. Fidelity is also a highly regarded part of loudspeaker design.

By sacrificing some SPL output, I should be able to come up with an affordable and effective system in theory.

4 Technical Details

4.1 SPL Level

The loudspeakers in question are intended to reproduce the sound in a club atmosphere that mimics the "boomy" qualities of a club without being tuned as loud as a club. For this reason, I decided to keep my cap SPL level at around 100 dB. According to a document given to the students on Christopher Plummer's Jan 23, 2012 lecture, that just barely touches the range of medium level music. By doing an experiment out of class, I discovered that my average listening level is about 76 dBA which is way less than what I originally intended the speakers needed to produce.

Figure 2 – Songs vs. Preferred dBa

Songs	Average Listening Level
City and Colour – Day Old Hate	74 dBa
The M Machine - Black	80 dBa
Macklemore – Same Love	78 dBa

Because my own comfortable listening level is not very high and well within the ability of my speakers that I'm choosing, I will not need a very expensive amplifier to improve the SPL of the loudspeakers.

4.2 Driver Size and Spacing

Upon researching ideas for a 2-way passive speaker system, I decided to use a ~1 1/4" Dome Tweeter and an ~6-1/2" woofer. Each box will have a 1" tweeter and an 6 1/2" woofer mounted to its baffle. By calculating length of a wavelength at 1800 Hz and converting it to inches, (331/x where x is the frequency and 331 is the speed of sound in m/s) I discovered that my drivers need to be ~7" apart from each other in order to perform adequately.

4.3 Diffraction and Speaker Shape

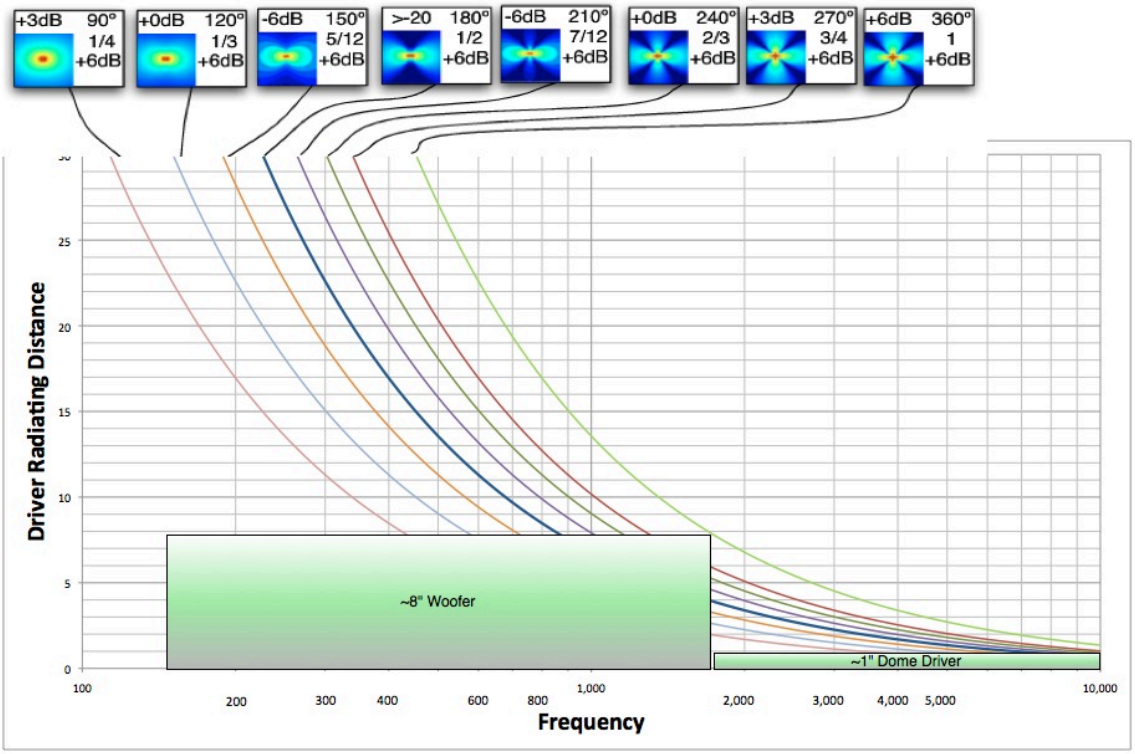


Figure 3 – Dispersion vs. Frequency

This graph roughly shows the way a circular tweeter and woofer will react to each other if the crossover frequency is ~1800 Hz. In theory, the tweeters should

cross over to the woofer frequency at a lower frequency than 1800 Hz to prevent lobing far better than what they will now. But despite the diffraction happening here, I do not want to push the tweeter further down frequency.

5 Driver Selection

As I went down the list of drivers on the list, I also put the drivers through modeling on *WinSpeakerz* to see just how they would react to the vented enclosure. The majority of the woofers had a very similar response to the enclosure. The woofer's frequency response charts are as follows;

5.1 Woofer Selections

Woofers	Price	F3	dB Sensitivity
1. Dayton Audio RS225-8 8" Reference Woofer	$57.42	28 Hz	86 dB
2. Dayton Audio DC160-8 6-1/2" Classic Woofer	$21.78	34 Hz	88 dB
3. Dayton Audio RS180-4 7" Reference Woofer 4 Ohm	$49.60	40 Hz	88 dB
4. Dayton Audio ST210-8 8" Series II Woofer	$69.75	52 Hz	90 dB
5. Dayton Audio DS215-8 8" Designer Series Woofer Speaker	$43.20	37 Hz	90 dB

Figure 4.1 – Woofer Selections

Dayton Audio RS225-8 8" Reference Woofer – This speaker's frequency plot can be found on the next. I really wanted an 8" woofer to go with a set of tweeters because I really wanted that bass response in my set of drivers. I love the response ability of these speakers but they have some significant problems before 1 kHz with a very steep roll-off.

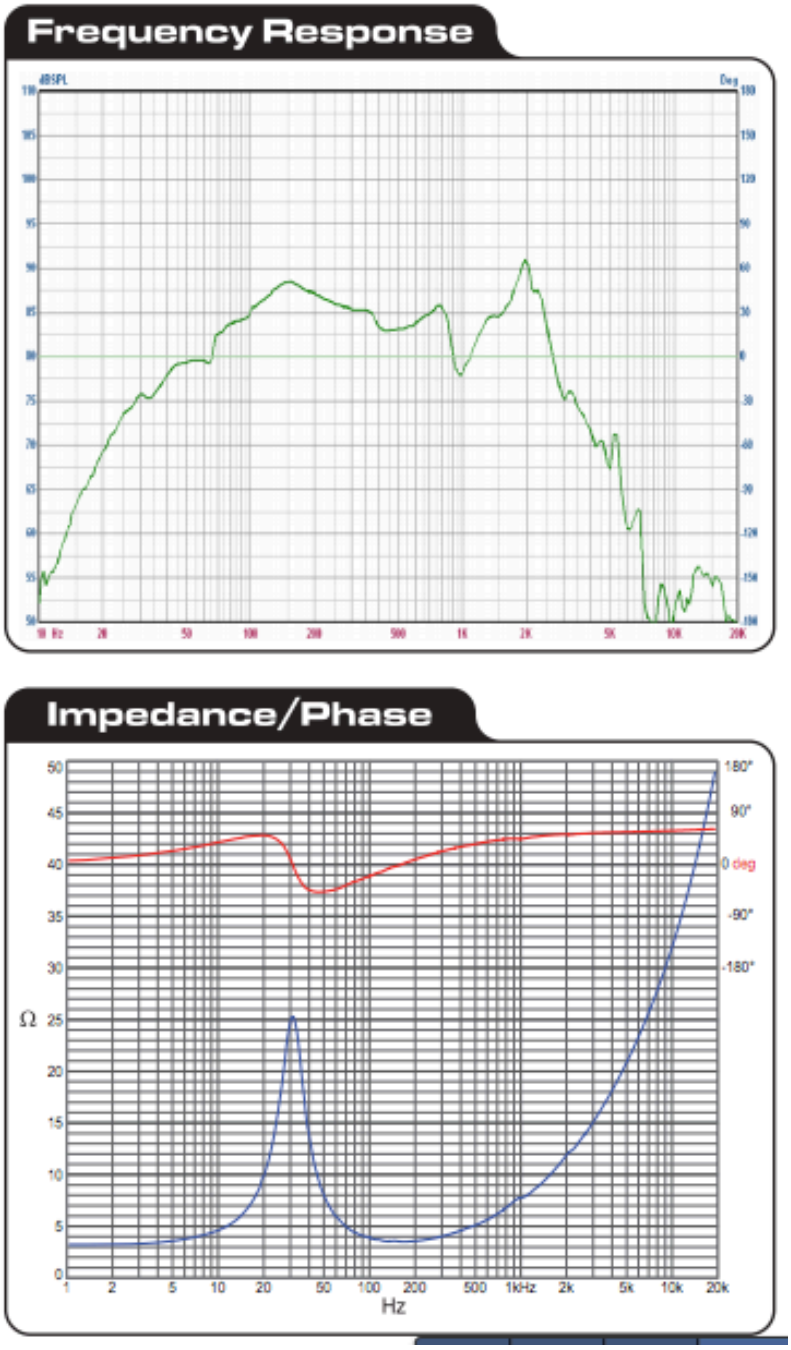


Figure 4.2 - Dayton Audio RS225-8 8" Reference Woofer

The next drivers I chose were from Dayton Audio just like all the other drivers in this paper will be. This woofer is the Dayton Audio DC160-8 6-1/2" Classic Woofer. I wanted to push myself to stick with a particular brand of speaker in order to build loud

speakers that had drivers that were meant for each other, so to speak. This speaker is smaller than the speaker I intended to have.

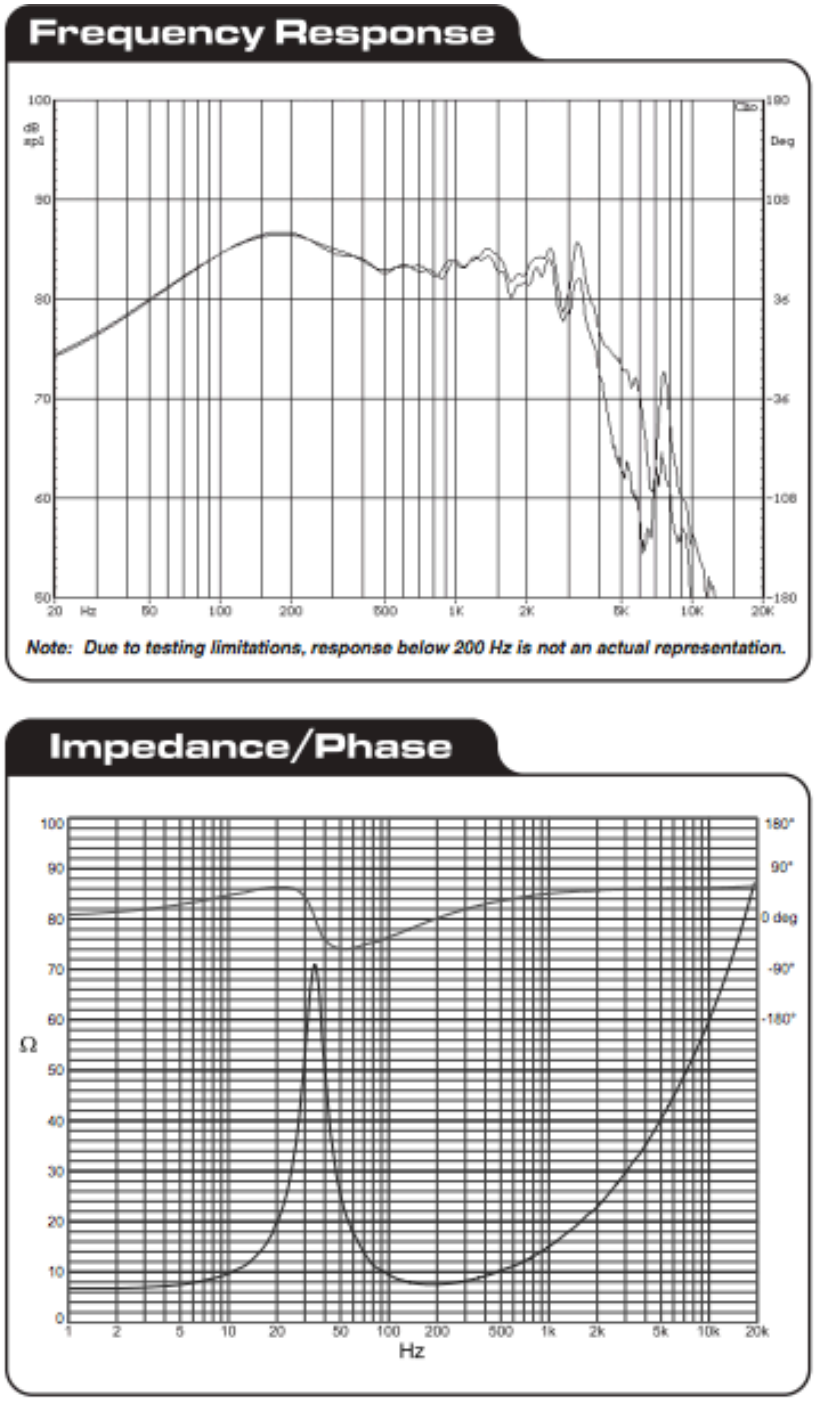


Figure 4.3 - Dayton Audio DC160-8 6-1/2" Classic Woofer

The speakers I got really excited to get my hands on were the Dayton Audio ST210-8 8" Series II Woofers. Amazingly, these ones also have the dip similar to the first 8".

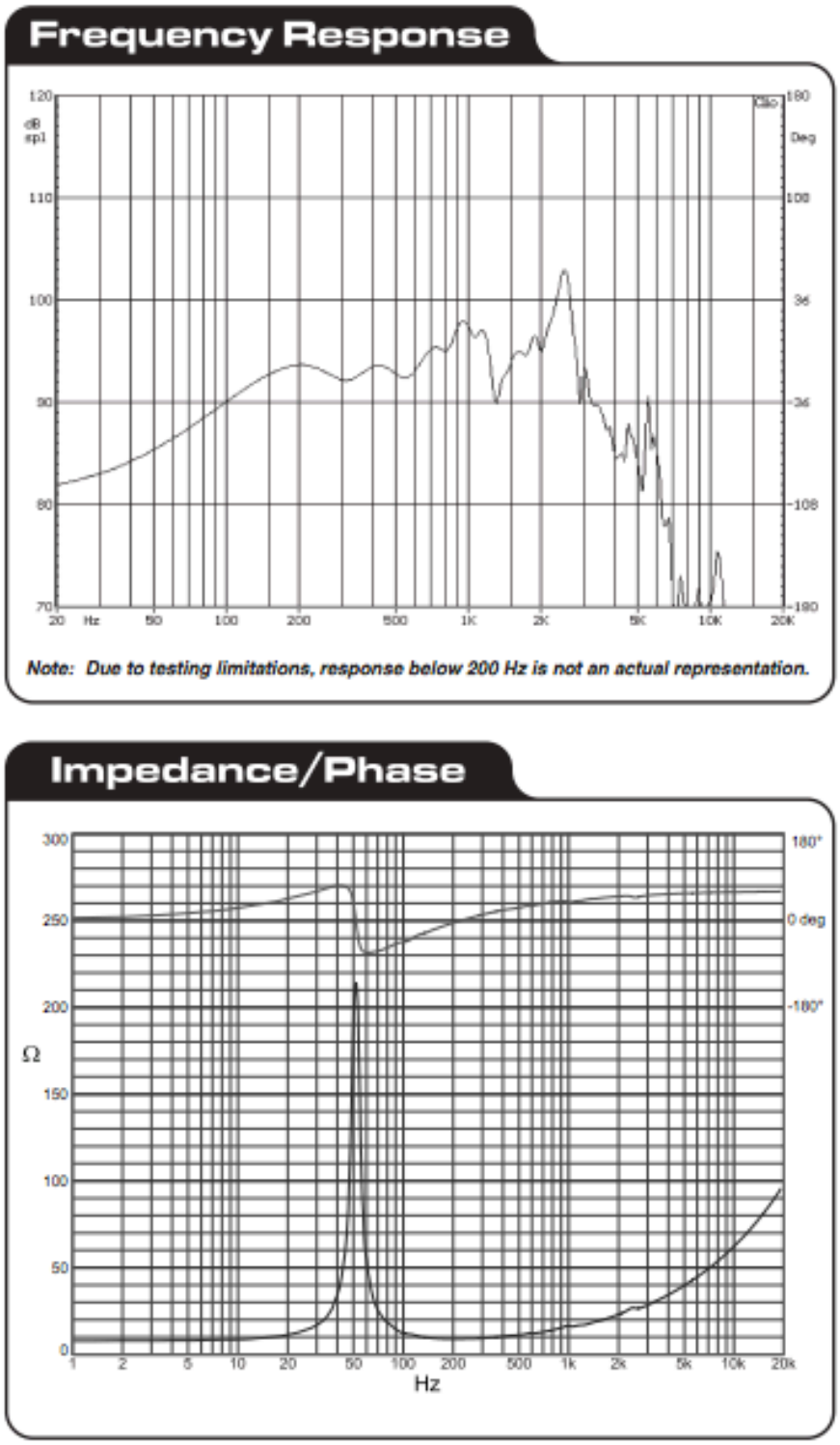


Figure 4.4 - Dayton Audio ST210-8 8" Series II Woofers

After all the debate, I decided to go with the next set of drivers which are the Dayton Audio DS215-8 8" Designer Series Woofer Speaker. The frequency response plot looks a bit easier to work with when it comes to a cross-over at about 1800 Hz. The f3 of the driver is fairly impressive as well at 36 Hz.

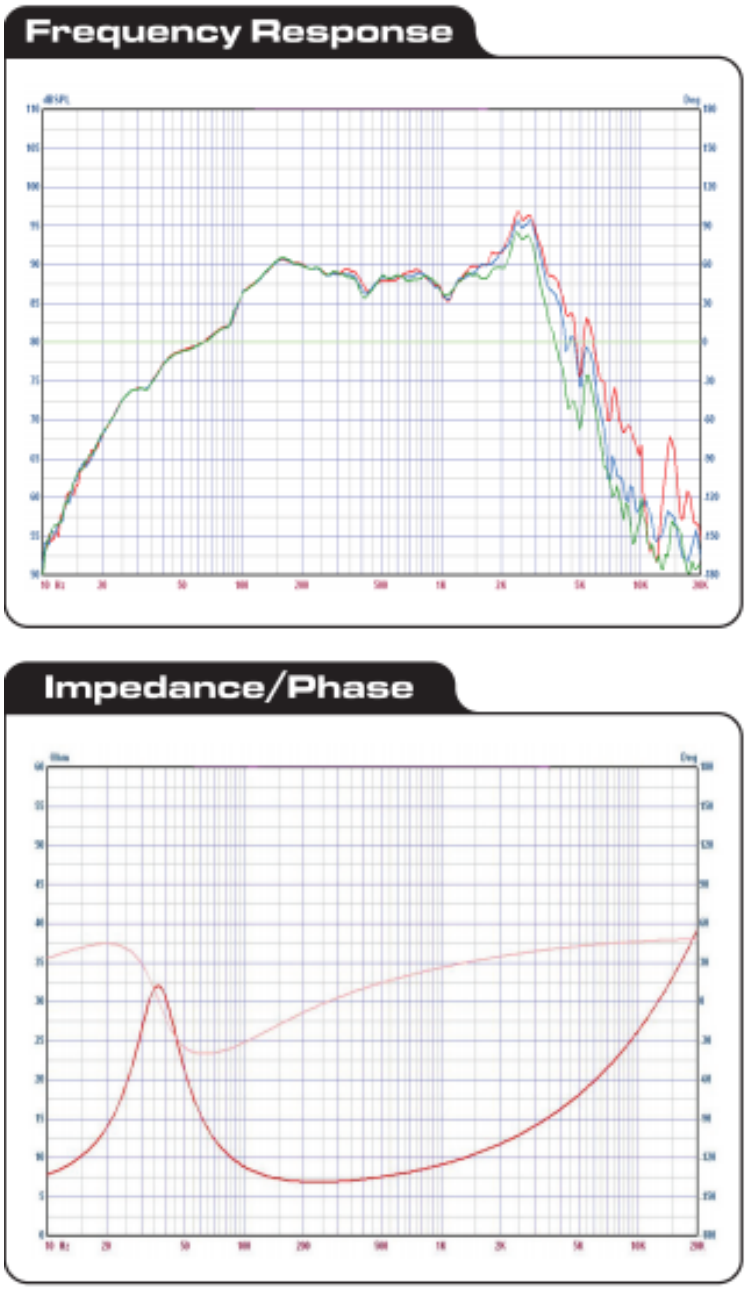


Figure 4.5 - Dayton Audio DS215-8 8" Designer Series Woofer Speaker

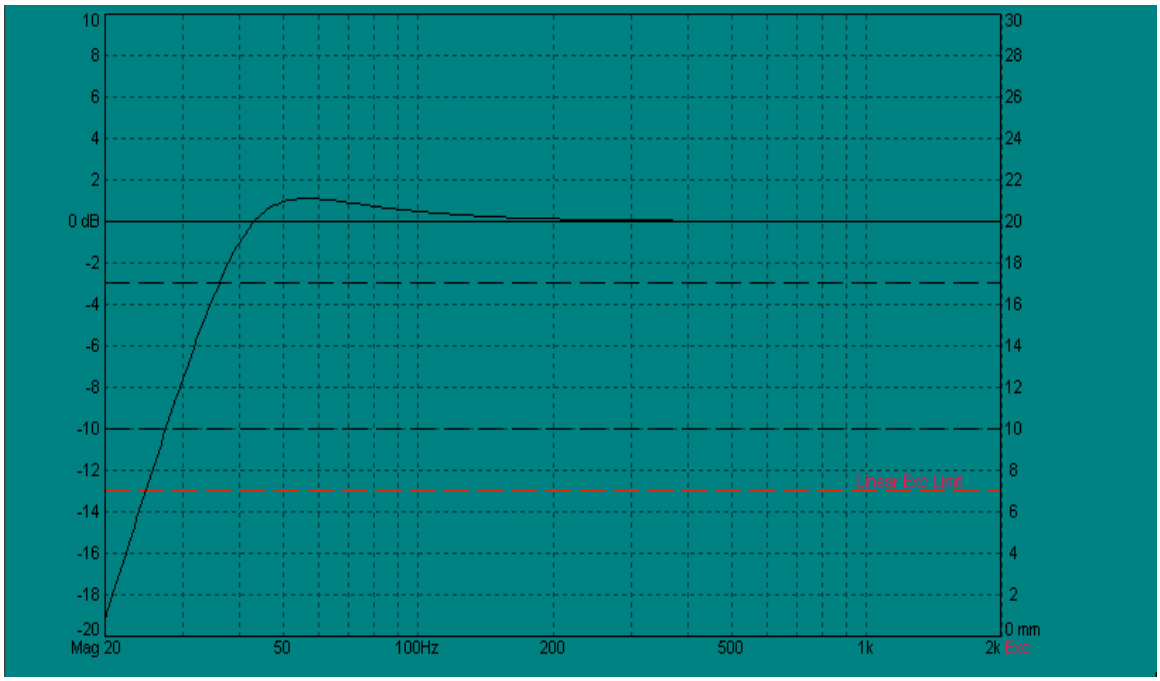


Figure 4.6 – A Modeled Dayton Audio DS175-8 6 1/2" Designer Series Woofer Speaker

That driver looks like this when modeled in a 18" x 14" x 14" (H x W x D) enclosure with a 1.5 inch diameter/ 2.18 circular vent. The bass boost is what I want in order to achieve a big, warm sound. And by dropping the diameter of the speaker from 8" to 6 - 1/2", the price dropped along with the sensitivity. This ended up with my woofer and tweeter both having the same sensitivity.

5.2 Tweeter Selections

Tweeters	Price	dB Sensitivity
1. Dayton Audio ND28F-6 1-1/8" Neodymium Dome Tweeter	$23.29	88 dB
2. Dayton Audio DC28F-8 1-1/8" Silk Dome Tweeter	$19.75	89 dB
3. Dayton Audio DC28FT-8 1-1/8" Silk Dome Truncated Tweeter	$20.45	89 dB
4. Dayton Audio RS28F-4 1-1/8" Silk Dome Tweeter	$54.75	88 dB
5. Dayton Audio RS28A-4 1-1/8" Aluminum Dome Tweeter	$54.75	88 dB

Figure 5.1 Tweeter Selections Table

I ended up narrowing down my tweeter selections to the two silk tweeters based on price and quality. The first of the two is this tweeter, the Dayton Audio DC28F-8 1-1/8" Silk

Dome Tweeter. The tweeter looks to have some problems as the frequencies enter the very high ranges.

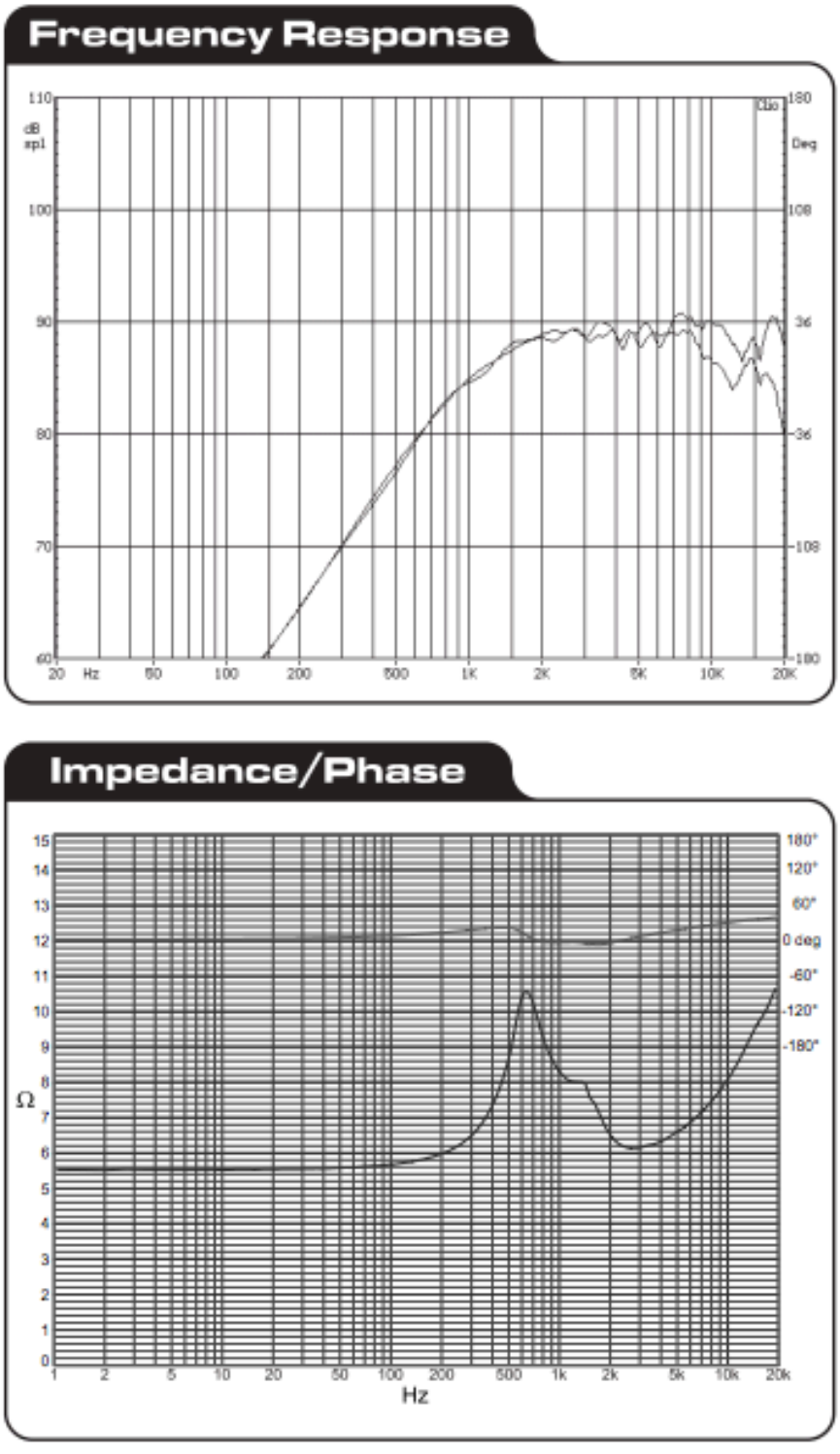


Figure 5.2 - Dayton Audio DC28F-8 1-1/8" Silk Dome Tweeter

As it turns out, the Dayton Audio RS28F-4 1-1/8" Silk Dome Tweeter may cost roughly 30 more dollars but may be very worth it in the end due to the flat response they give.

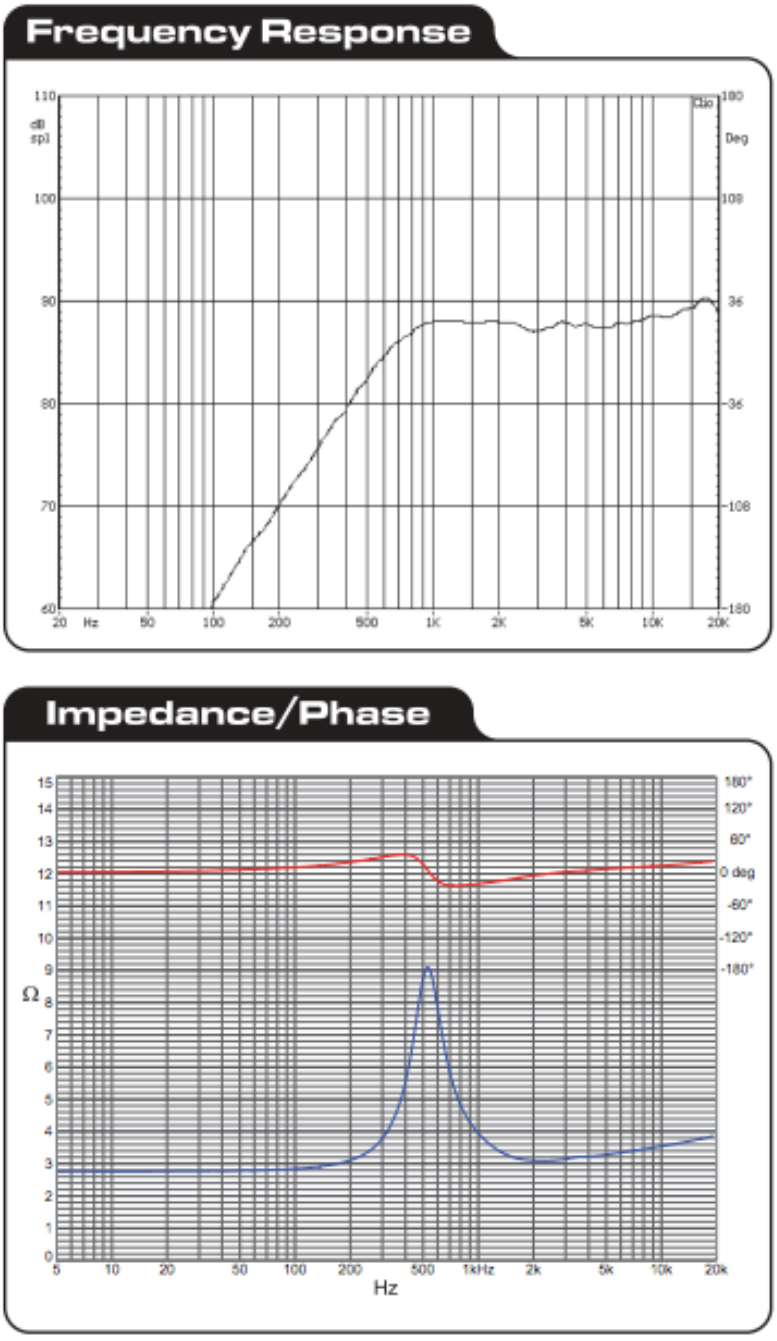


Figure 5.3 - Dayton Audio RS28F-4 1-1/8" Silk Dome Tweeter

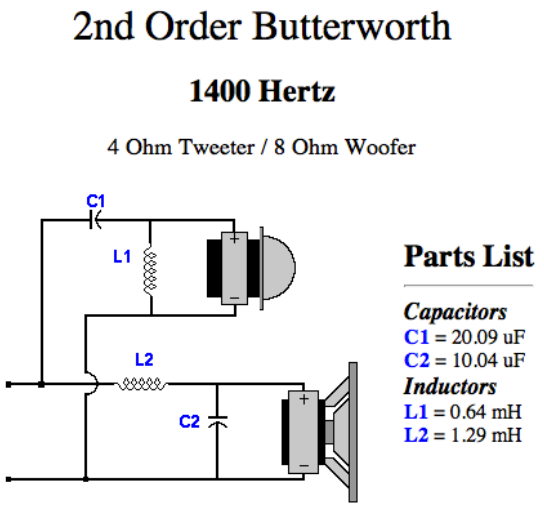
6 Baffle Step Correction

I used an online calculator to generate the baffle step correction in my given speaker enclosure. The equation took in my speaker sensitivity of 90 dB along with the width of my baffle in inches and my driver's resistance. This calculator generates what is needed in my circuit in order to shift from 2pi space to 4pi space effectively.

[1]

7 Crossover

A 2nd Order Butterworth Crossover will be added to the circuit for a smooth pass around 1400 Hz between the tweeter and woofer.



[2]

[1] http://diyaudioprojects.com/Technical/Baffle-Step-Correction-Circuit-Calculator/ (Accessed February 25th, 2013)

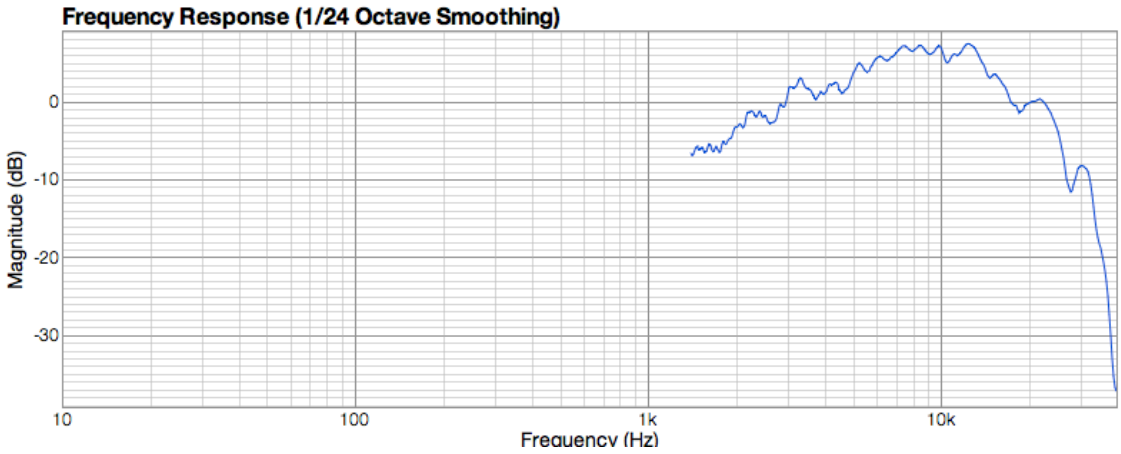
1. [2] 2 way crossover designer/calculator Accessed April 10, 2013

   http://www.diyaudioandvideo.com/Calculator/XOver/

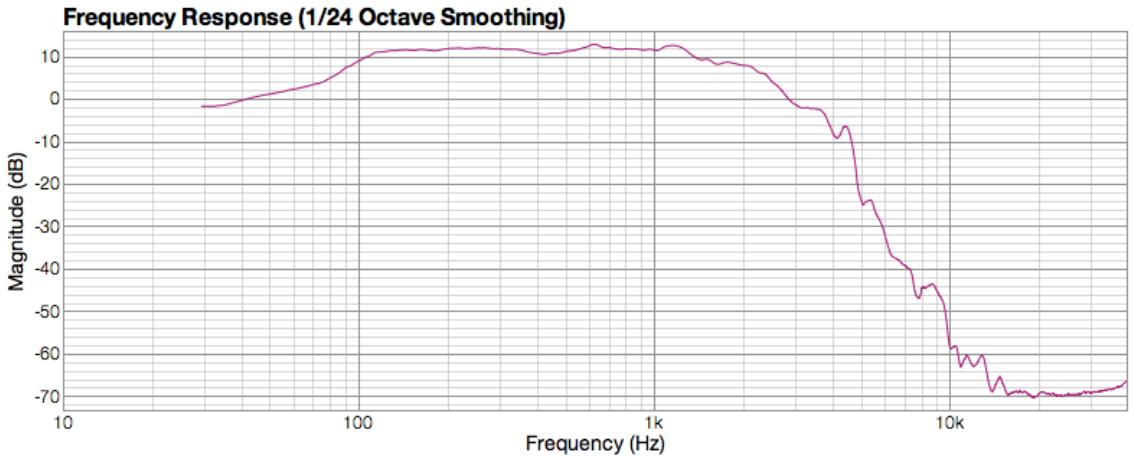
The crossover was designed in hopes that a pad would not be needed in order to lower the harshness of either the lows or the highs and that the two speakers would hopefully have combined signals in a comfortable way.

8 Final System Documentation

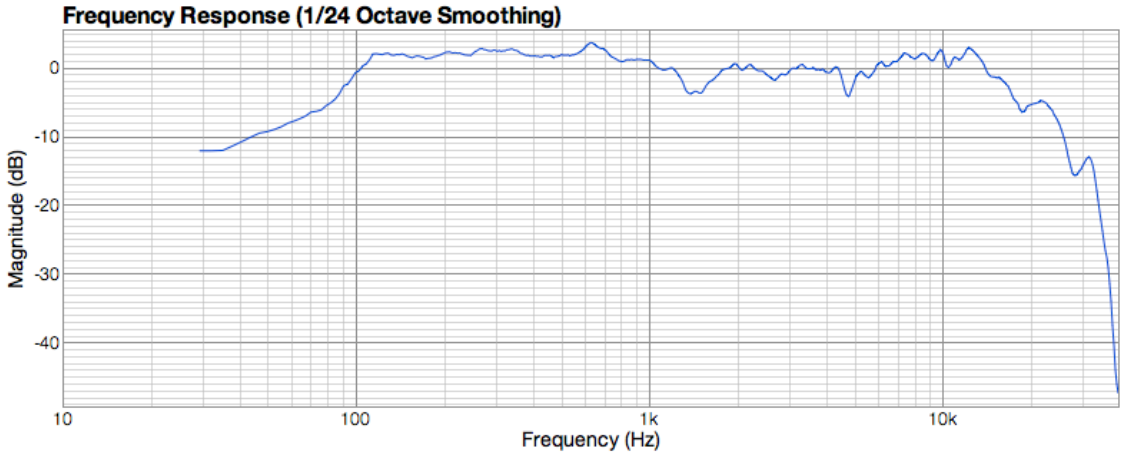
In the end, the response from the woofer and tweeter landed at about plus or minus 3.5 dB from 100 Hz to 10 kHz. After looking at some response charts from some KRK Rokit 6 (Which is what the box is modeled after) I saw some distinct differences in bass extension and high extension but the response overall is not all that different without smoothing.



This is the tweeter's overall response as depicted by FuzzMeasure from around 1400 to 30 kHz.



This is the woofer's response without the tweeter being a part of the overall response.



This final graph gives the overall system response of the woofer and tweeter combined. The f3 of the system is about 80 Hz. I think with a stronger crossover set at a higher frequency (2000 Hz) the response will become much more clear as this response seemed to be formed from a distorted tweeter found after presentation day. The goal was to be able to have usable speakers at the end of the semester with the cheapest cost possible. I originally sought out to build the speakers with only $300 and managed to save $40 of that with this speaker design totaling out to about $260. Now with that being said, I

expect to pay at least $60 extra on a new crossover in the future. This would total the loudspeaker cost at around $320.

9 Bibliography

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