

JMWS-1 Studio Monitors  
John Watza

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FA4740 R01  
4/30/14

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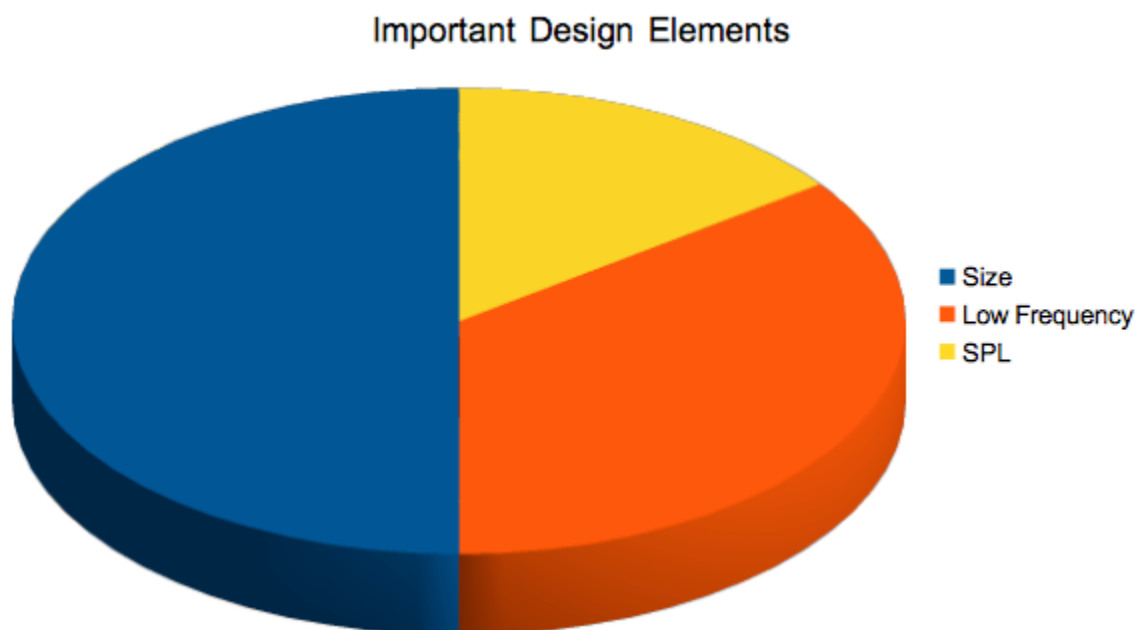
## Functional Description

The primary use intended for these speakers will be for mixing pop and rock styles of music. They are intended to accurately reproduce the sound of a track with no coloration so they will be designed to be listening back<sup>1</sup> speakers. They will need to be small because they will be used on a desk in a small room as near field monitors. They will need to be sturdy and somewhat portable because they will be moved around from time to time as I move. The listening environment will be moderately noisy at times so. They don't need to be able to reproduce the really low bass frequencies but they should be able to produce low enough to not miss too much from typical rock and pop recordings. The visual aesthetic of the speakers is important because they will be prominently displayed and should look professional, so they will be painted black. The general shape of the speakers will be rectangular. A protective lid will be made for safety during transport. Size is the most important factor in these speakers they have to be reasonably small. The second most important design factor is low frequency I want them to get as low as possible within the size and budget constraints. SPL is not a huge issue as these will be used in small rooms in close proximity and they will only be used for mixing so they do not need to get very loud. The adjectives I would like to be attributed to my speakers are, clean, clear, crisp, accurate, and tight. Below is a Pie chart showing the importance of certain design elements showing that size is the biggest determining factor in my design.

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<sup>1</sup> David Moulton, *Total Recording* (Sherman Oaks, CA: KIQ Productions, 2000) 313.

<sup>2</sup> Moulton, *Total Recording*, 216.



## Technical Goals

### Size

The dimensions of the speaker cabinets will be designed using David Moultons ideal room dimension ratios for the Moulton Room<sup>2</sup>. Moultons formula is to use musical intervals expressed as ratios to figure out the dimensions. The dimension ratio between depth and width will be an augmented 4<sup>th</sup>, expressed as a ratio it is 1.414:1. The ratio between height and length will be a minor 7<sup>th</sup>, expressed as a ratio it is 1.782:1. With the drivers that I am planning on using<sup>3</sup> I will want a box with a Q(tc) of 0.65 which will give an F(3) of 67 Hz if my box internal size equals 0.49866 cubic feet.<sup>4</sup> I will also be adding a margin of error to my box dimensions so that it is slightly bigger than necessary. The internal dimensions therefore come out to have a Depth = 6.5" Width = 9." and Height = 15.75". The walls will be ½ inch MDF on the outside then a layer of 1/8 inch vinyl material and then a layer of ½ inch underlayment plywood on the inside. All together adding 1 and 1/8 inch per side for a total of 2 ¼ inches to my internal dimensions. The mini dsp dimensions are height = 8.5" Width = 6" Depth = 3 1/8". I will be creating a sub enclosure for the mini dsp on the back of the speaker which will add 4" to the depth on top of the 2.25". The final exterior dimensions will end up being Height = 18" Width = 11.25" Depth = 12.75".

### Weight

The overall weight of the speakers should be no more than 40 lbs per speaker and if possible less. They are going to be portable speakers and need to be easily moved one at a time by a

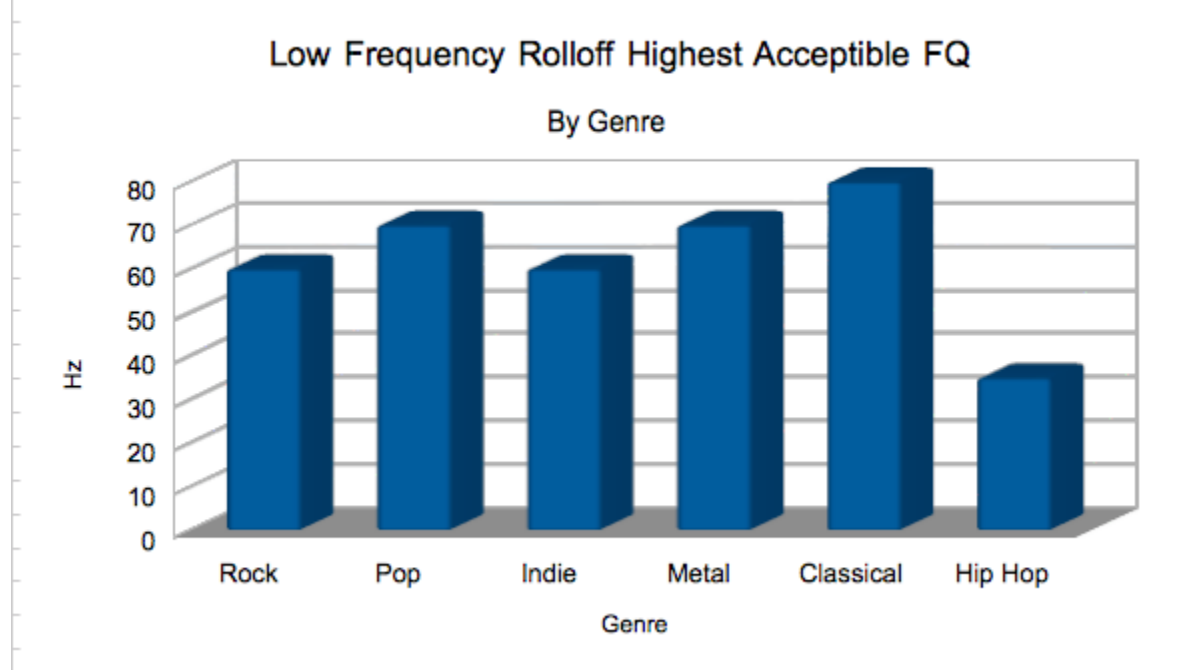
<sup>2</sup> Moulton, Total Recording, 216.

<sup>4</sup> John Watza, WynySpeaker Modeling Lab, (Houghton, MI, 02 2014).

single person. The woofers that I am planning on using weigh 2.64 lbs each. The tweeters that I am planning on using weigh 1.8 lbs each. The mini dsp plate amplifiers do not have a weight listed on the site or on any spec sheets but I will estimate 5 lbs. I will be using mdf, plywood and vinyl and the final weight will come out to be right around 40 lbs.

## Frequency

The frequency requirements are that it can reproduce enough low frequency for typical rock and pop music recordings. It does not need to be able to reproduce down to 20 Hz. My goal is to be able to accurately reproduce down to 60 Hz. The target for frequency range is to go from 60 Hz to at least 20 kHz. With the drivers I have selected and with the designed enclosure I have gotten an F(3) of 67 Hz. The desired frequency response will be as flat as possible. Below is a graph showing what my low frequency preferences are for how low I need to be able to go for different genres of music.



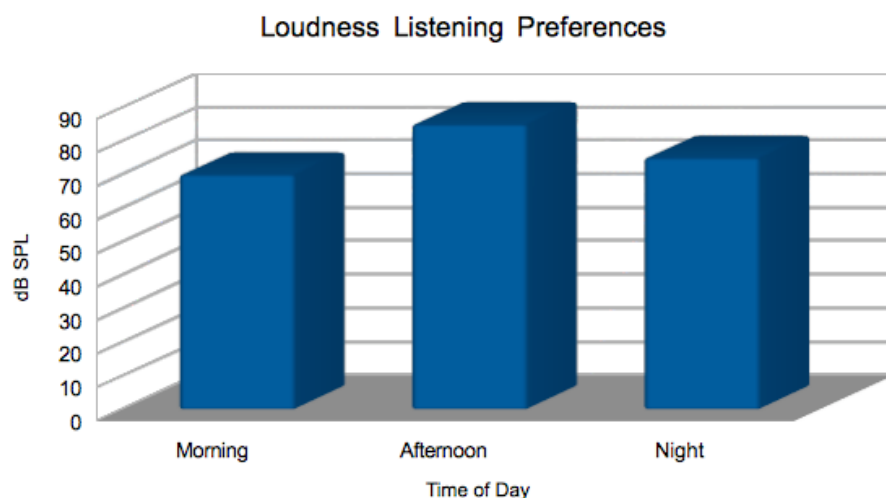
## SPL

I want to be able to mix to the K system<sup>5</sup> standard so the peak SPL will need to be able to ideally go to about 105 dB. My personal preferences for mixing is a bit lower so the lowest acceptable peak volume level will be 100 dB. With the Morel woofers and tweeters that I am planning on using and the mini dsp plate amplifier I will be able to achieve this SPL requirement. The Morel woofers have a sensitivity of 86 dB @ 1 meter. The mini DSP plate amplifiers are 125W and converting that into dBW<sup>6</sup> we get roughly 21 dBW. Adding that 21 dBW to our sensitivity of 86 dB we get a peak volume of 107 dB which is greater than my ideal goal. It will be a sealed box no bass reflex ports I want the transient timing to be crisp and accurately timed. Below is a

<sup>5</sup> Bob Katz, "Level Practices (Part 2) (Includes the K-System)." *Digital Domain* (Digital Domain), 2000.

<sup>6</sup> Christopher Plummer, FA4740 Transducer Theory, (Michigan Technological University. Spring 2014) 1/22/14

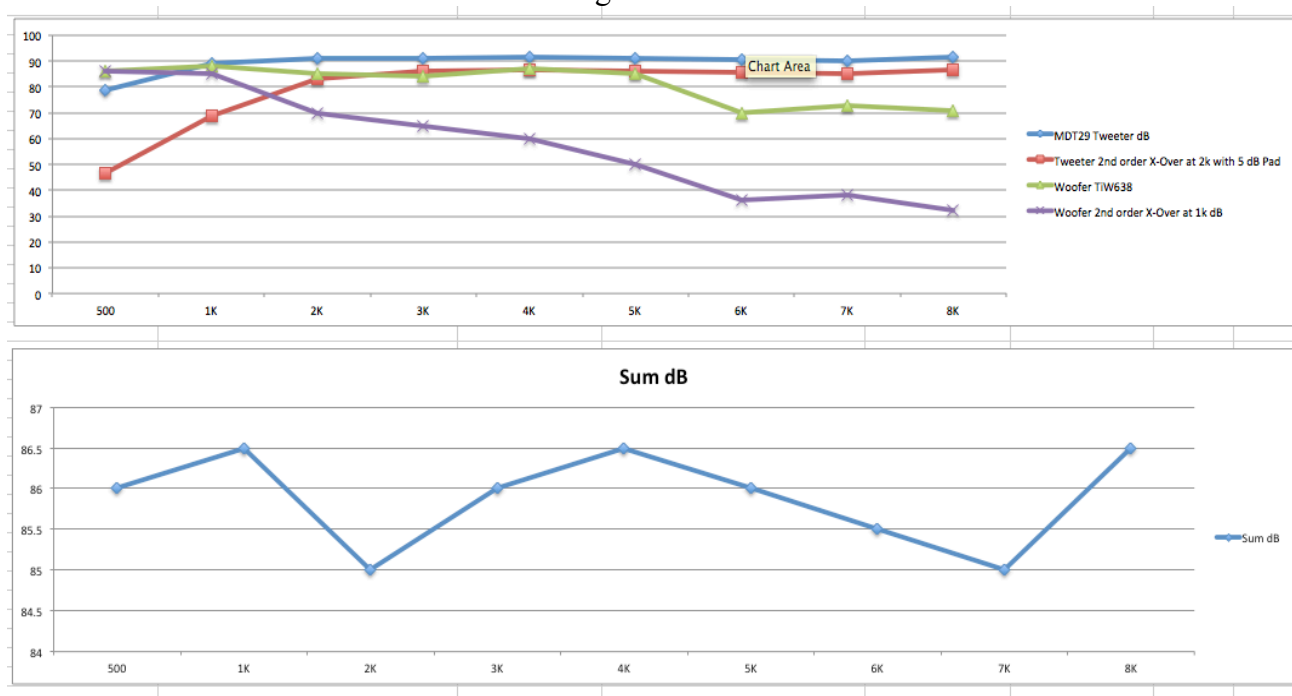
graph showing my preferred decibel listening levels at different times of day. As you can see my speakers will be plenty loud enough for my typical needs and more.



## Design

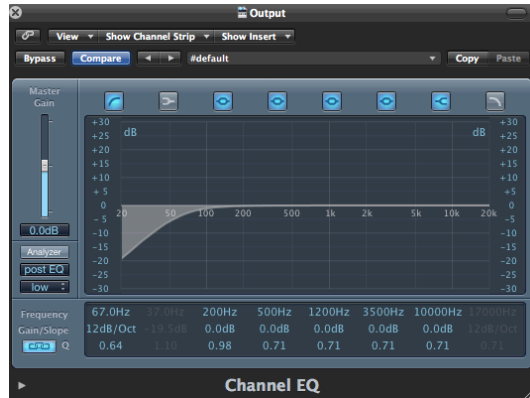
### Crossover

For my crossover I am planning on using 2nd order crossovers at 1 kHz for my woofer and 2kHz for my tweeter. Here is a chart and graph showing my initial crossover plan. I will be able to tweak my crossover because I will be using the mini dsp and will have the capability to adapt to what is needed when the time comes for tuning.

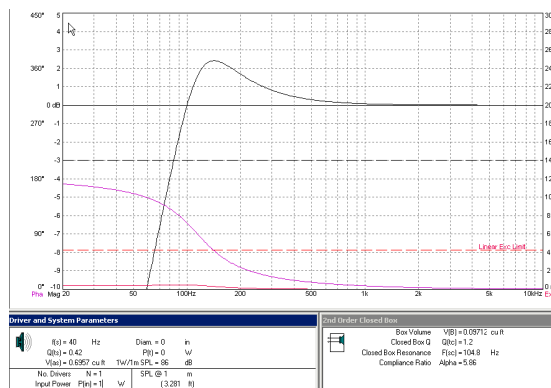


## Woofers

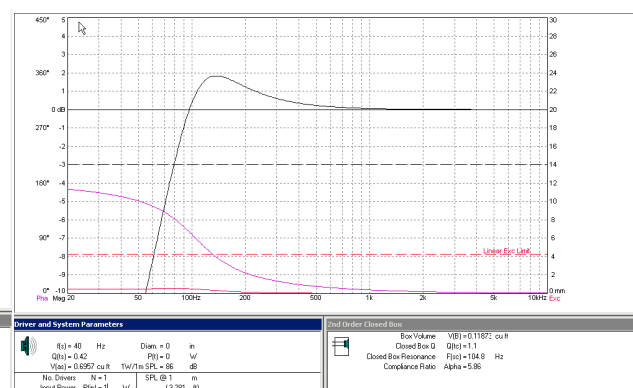
When looking at woofers and tweeters I wanted to find a combination that would work well together with a simple crossover. My goal for these speakers is for them to be as flat as possible so I was looking for very flat frequency responses from the drivers. I decided that I wanted a certain Q when I was doing the low frequency listening tests. I found out that the slope from a Q of 0.65 was an ideal sound for my ears. I found it had plenty of low end for what I will be using it for and I liked the sound of the nice long smooth slope. When I did my Wynspeaker modeling I modeled every driver in a sealed box with a Q of 0.65. I also modeled a number of different Q's to see if there were any that would give me better results as far as low frequency and box size.



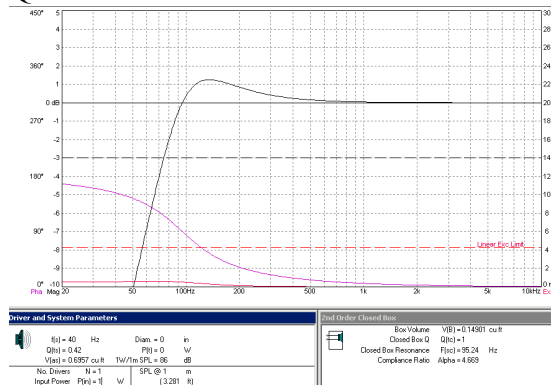
Here is the EQ curve that I found to sound very nice for my purposes. The scale is different than from the Wynspeaker so it doesn't look exactly the same but it is actually very close when using the Q=0.65. These Wynspeaker models were from the TiW638 which is the driver I decided to use for this design.



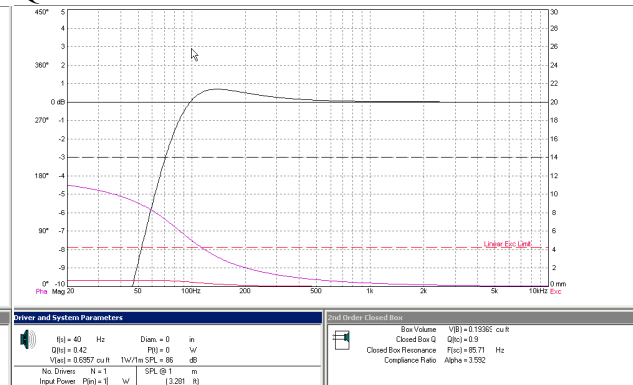
Q=1.2



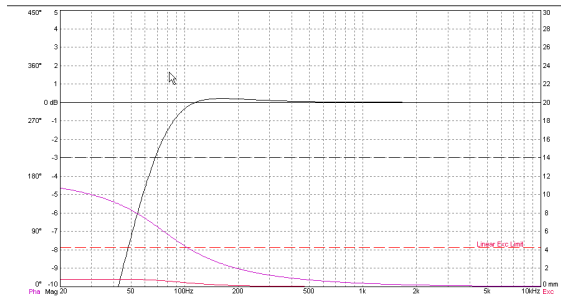
Q=1.1



Q=1



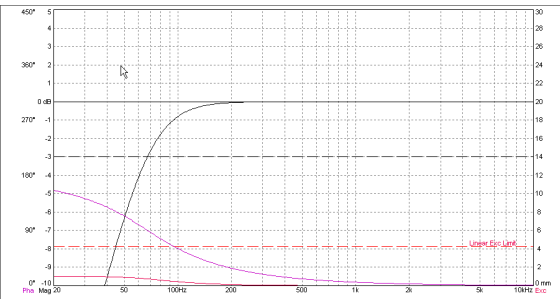
Q=0.9



Driver and System Parameters			
	$f_s = 40$ Hz	Diam = 0 in	
	$Q_{ts} = 0.42$	$P_{PI} = 0$ W	
	$V_{box} = 0.6957$ cu ft	$T_{th}/T_{m} \text{ SPL} = 95$ dB	
No. Drivers	$N = 1$	SPL @ 1 m	(3.281 ft)
Input Power	$P_{in} = 1$ W		

Final Order Closed Box			
	Box Volume	$V_{B1} = 0.25471$ cu ft	
	Closed Box Q	$Q_{B1} = 0.6$	
	Closed Box Resonance	$F_{B1} = 76.19$ Hz	
	Compliance Ratio	Alpha = 2.628	

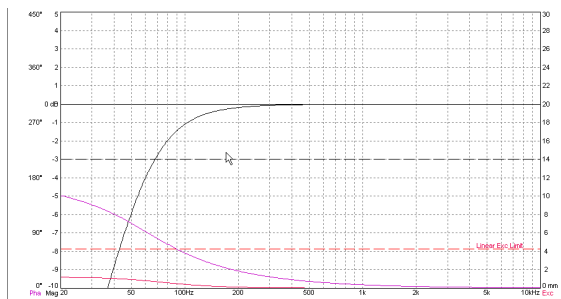
Q=0.8



Driver and System Parameters			
	$f_s = 40$ Hz	Diam = 0 in	
	$Q_{ts} = 0.42$	$P_{PI} = 0$ W	
	$V_{box} = 0.6957$ cu ft	$T_{th}/T_{m} \text{ SPL} = 95$ dB	
No. Drivers	$N = 1$	SPL @ 1 m	(3.281 ft)
Input Power	$P_{in} = 1$ W		

Final Order Closed Box			
	Box Volume	$V_{B1} = 0.37941$ cu ft	
	Closed Box Q	$Q_{B1} = 0.707$	
	Closed Box Resonance	$F_{B1} = 67.34$ Hz	
	Compliance Ratio	Alpha = 1.834	

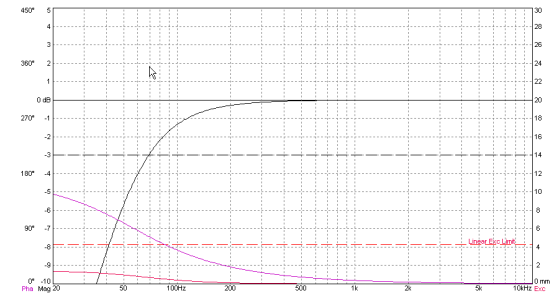
Q=0.707



Driver and System Parameters			
	$f_s = 40$ Hz	Diam = 0 in	
	$Q_{ts} = 0.42$	$P_{PI} = 0$ W	
	$V_{box} = 0.6957$ cu ft	$T_{th}/T_{m} \text{ SPL} = 95$ dB	
No. Drivers	$N = 1$	SPL @ 1 m	(3.281 ft)
Input Power	$P_{in} = 1$ W		

Final Order Closed Box			
	Box Volume	$V_{B1} = 0.43666$ cu ft	
	Closed Box Q	$Q_{B1} = 0.65$	
	Closed Box Resonance	$F_{B1} = 61.91$ Hz	
	Compliance Ratio	Alpha = 1.395	

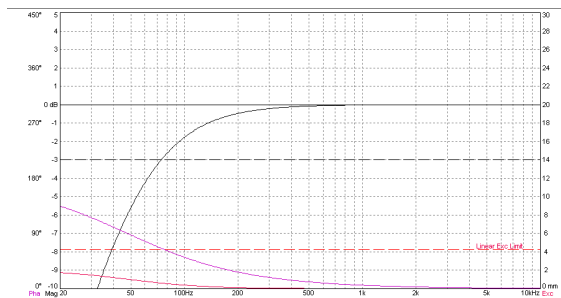
Q=0.65



Driver and System Parameters			
	$f_s = 40$ Hz	Diam = 0 in	
	$Q_{ts} = 0.42$	$P_{PI} = 0$ W	
	$V_{box} = 0.6957$ cu ft	$T_{th}/T_{m} \text{ SPL} = 95$ dB	
No. Drivers	$N = 1$	SPL @ 1 m	(3.281 ft)
Input Power	$P_{in} = 1$ W		

Final Order Closed Box			
	Box Volume	$V_{B1} = 0.56542$ cu ft	
	Closed Box Q	$Q_{B1} = 0.6$	
	Closed Box Resonance	$F_{B1} = 57.14$ Hz	
	Compliance Ratio	Alpha = 1.581	

Q=0.6



Driver and System Parameters			
	$f_s = 40$ Hz	Diam = 0 in	
	$Q_{ts} = 0.42$	$P_{PI} = 0$ W	
	$V_{box} = 0.6957$ cu ft	$T_{th}/T_{m} \text{ SPL} = 95$ dB	
No. Drivers	$N = 1$	SPL @ 1 m	(3.281 ft)
Input Power	$P_{in} = 1$ W		

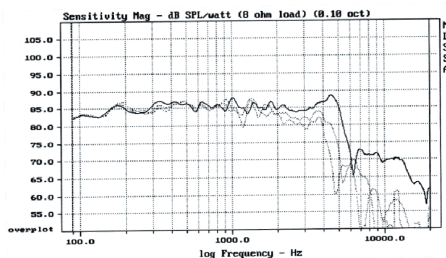
Final Order Closed Box			
	Box Volume	$V_{B1} = 1.5674$ cu ft	
	Closed Box Q	$Q_{B1} = 0.5$	
	Closed Box Resonance	$F_{B1} = 47.62$ Hz	
	Compliance Ratio	Alpha = 0.4172	

Q=0.5



## TiW638

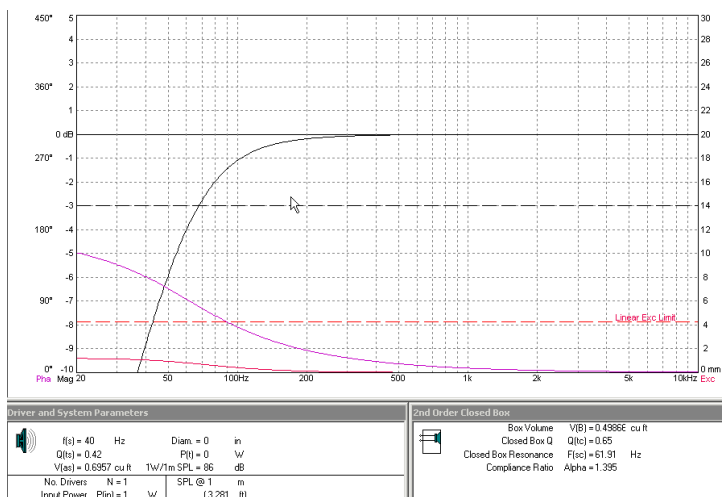
I will be using the TiW638 6" woofer by Morel. This woofer is very comparable to the CAW638 as well as the Tang Band W6 the factor that set this woofer above those others was the smaller box size required.



### Frequency Response

The frequency response of this woofer is flat up to 3 kHz where it has a small peak and then it drops off very quickly. I modeled a 2<sup>nd</sup> order crossover at 1 kHz which would make the break up at 4 kHz be 2 octaves away and 27 dB down.

## 2<sup>nd</sup> Order Sealed Box Modeling

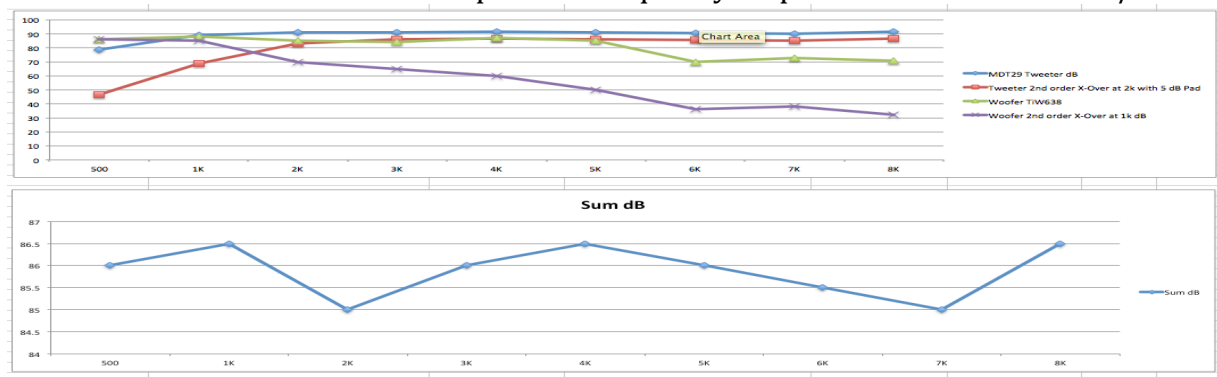


$Q(tc) = 0.65$   
 $F(3) = 67 \text{ Hz}$   
 Box Volume = 0.49866 Cu Ft

When doing the enclosure modeling I liked the Q of 0.65 the best. It gave me a good  $F(3)$  with a nice slope and an  $F10$  of 37 Hz. It also gave me the smallest box size with this slope and  $F(3)$ .

### Crossover

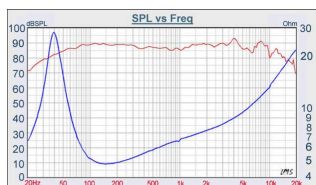
I created a crossover for this woofer with the MDT29 tweeter my crossover points were at 1 kHz for the woofer and 2 kHz for the tweeter. I put a 5 dB pad on the tweeter and used 2<sup>nd</sup> order crossovers and it came up with a frequency response even better than  $\pm 1 \text{ dB}$ .



## W6-1721

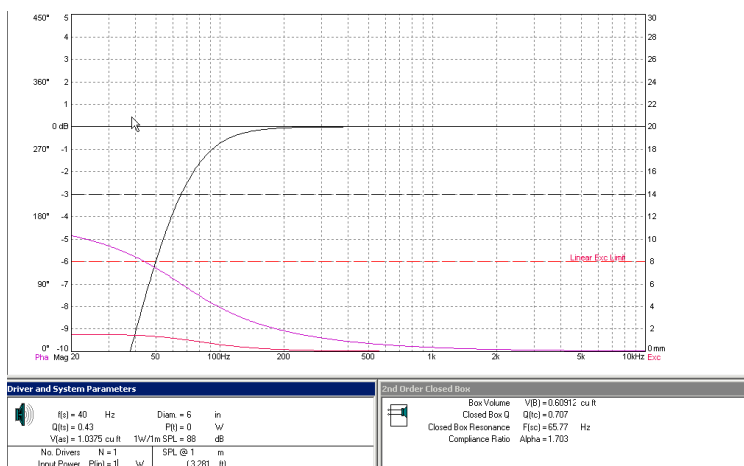
The Tang Band W6 is a good driver and is recommended for a sealed box. It is very comparable to the Morel drivers that I modeled the main differences being box size and excursion. This driver has better excursion characteristics so it can be louder before distortion but it requires a larger box size and it was too large for my goals.

### Frequency Response



The frequency response of this driver is pretty flat up to 4 kHz besides a slight dip between 300 Hz and 1 kHz. This slight dip will actually help with the baffle step. I modeled a 2<sup>nd</sup> order crossover at 1 kHz which would make 4 kHz 2 octaves away making the breakup be about 27 dB down.

### 2<sup>nd</sup> Order Sealed Box Modeling



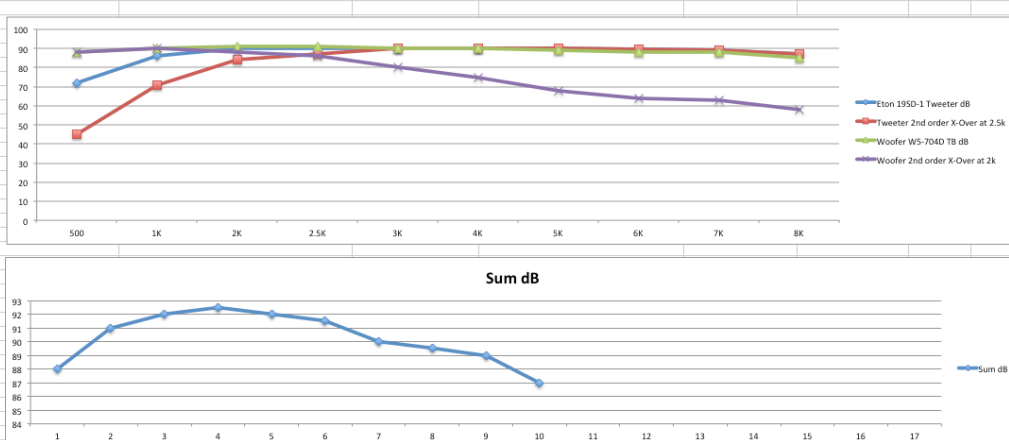
$$Q(tc) = 0.707$$

$$F(3) = 67 \text{ Hz}$$

$$\text{Box Volume} = 0.60912 \text{ Cu Ft}$$

When doing enclosure modeling I liked the Q of 0.707 the best, it gave me a good F3 with a good slope and an F10 of 39. I did not like the internal box volume for the size of speaker that I want. With this slope it is flat down to 200 Hz, down 1 dB at 90 Hz and then 3 dB down at 67.

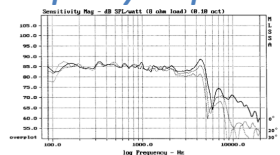
### Crossover



## CAW638

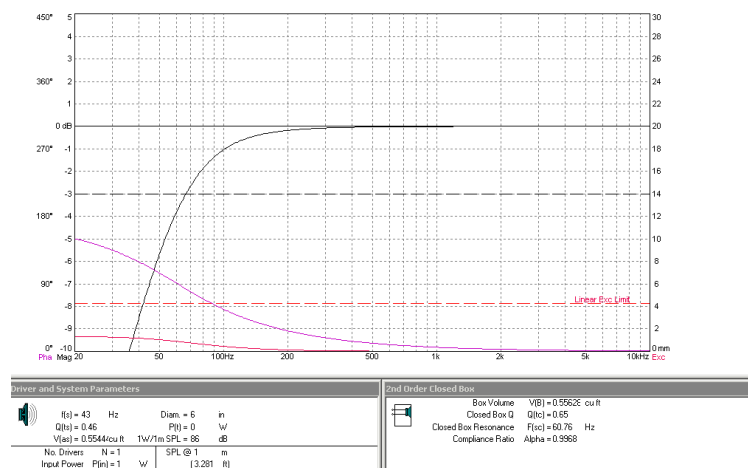
The Morel CAW638 woofer was my first choice for a while. I like these woofers because they have a flat frequency response and will work well with a 2<sup>nd</sup> order crossover at 1 kHz. I like that they do not require a very large box size, which is an important factor in my design. I ultimately did not go with this driver because the TiW638 gave me the same F(3), a slightly flatter frequency response and a smaller box size.

## Frequency Response



The frequency response of this driver is pretty flat up to 3 kHz and then starts breaking up at 4 kHz. At the breakup you can see a large spike and then a large drop, I modeled a 2<sup>nd</sup> order crossover at 1 kHz which would make 4 kHz 2 octaves away so the spike would be down by 27 dB.

## 2<sup>nd</sup> Order Sealed Box Modeling

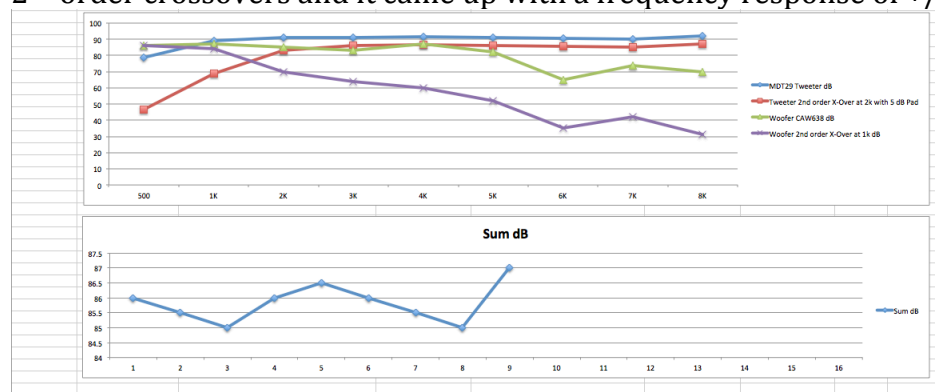


$Q(tc) = 0.65$   
 $F(3) = 67 \text{ Hz}$   
 Box Volume = 0.55625 Cu Ft

When doing enclosure modeling I liked the Q of 6.5 the best, it gave me a good F3 with a good slope and an F10 of 36. It also gave me a decent internal box volume for the size of speaker that I want. With this slope it is flat down to 200 Hz, down 1 dB at 100 Hz and then 3 dB down at 67.

## Crossover

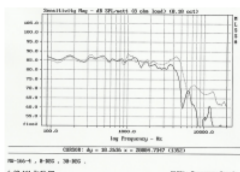
I created a crossover for this woofer with the MDT29 tweeter my crossover points were at 1 kHz for the woofer and 2 kHz for the tweeter. I put a 5 dB pad on the tweeter and used 2<sup>nd</sup> order crossovers and it came up with a frequency response of +/- 1 dB.



## MW166-4

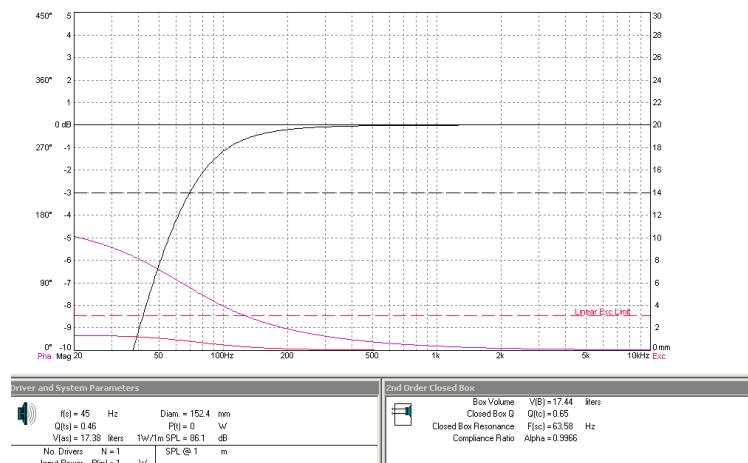
The Morel MW166-4 is another 6" woofer that I looked into. One of the first things I did not like about this driver is that on Zaph Audio he reviewed this driver and said that there was a lot of distortion in the midrange. The frequency response looks pretty good.

## Frequency Response



The frequency response of this driver is pretty flat up to 3 kHz and then starts breaking up at 4 kHz. At the breakup you can see a large spike and then a large drop, I modeled a 2<sup>nd</sup> order crossover at 1 kHz which would make 4 kHz 2 octaves away so the spike would be down by 27 dB.

## 2<sup>nd</sup> Order Sealed Box Modeling



$$Q(tc) = 0.65$$

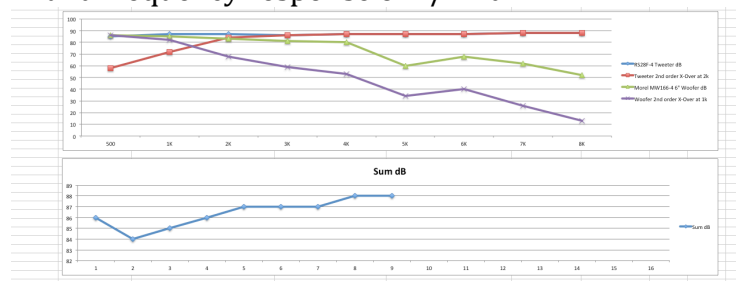
$$F(3) = 70 \text{ Hz}$$

$$\text{Box Volume} = 0.61589 \text{ Cu Ft}$$

When doing enclosure modeling I liked the Q of 6.5 the best, it gave me a good F3 with a good slope and an F10 of 39. It gave me a bit to big of an internal box volume for the size of speaker that I want. With this slope it is flat down to 300 Hz, down 1 dB at 100 Hz and then 3 dB down at 70 Hz.

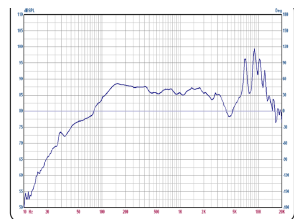
## Crossover

I created a crossover for this woofer with the RS28F tweeter my crossover points were at 1 kHz for the woofer and 2 kHz for the tweeter. I used a 2<sup>nd</sup> order crossovers and it came up with a frequency response of +/- 2 dB.



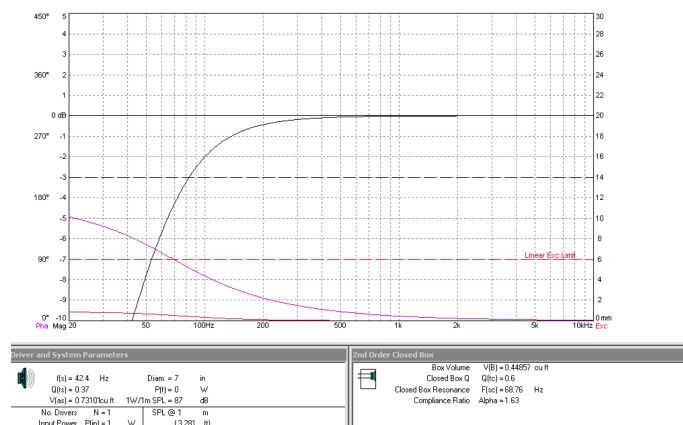
## RS180-8

The Dayton Audio RS180 is a very good driver and was one of my front runners for while. It has good flat frequency response up to 2.5 kHz. This woofer would be a solid choice but I wanted the lower  $F(3)$  and the higher break up frequency that the TiW638 offered.



### Frequency Response

The frequency response of this driver is pretty flat up to 2.5 kHz and then it breaks up pretty bad with a dip at 4 kHz and a lot of spikes starting at 6 kHz.



### 2<sup>nd</sup> Order Sealed Box Modeling

$$Q(tc) = 0.6$$

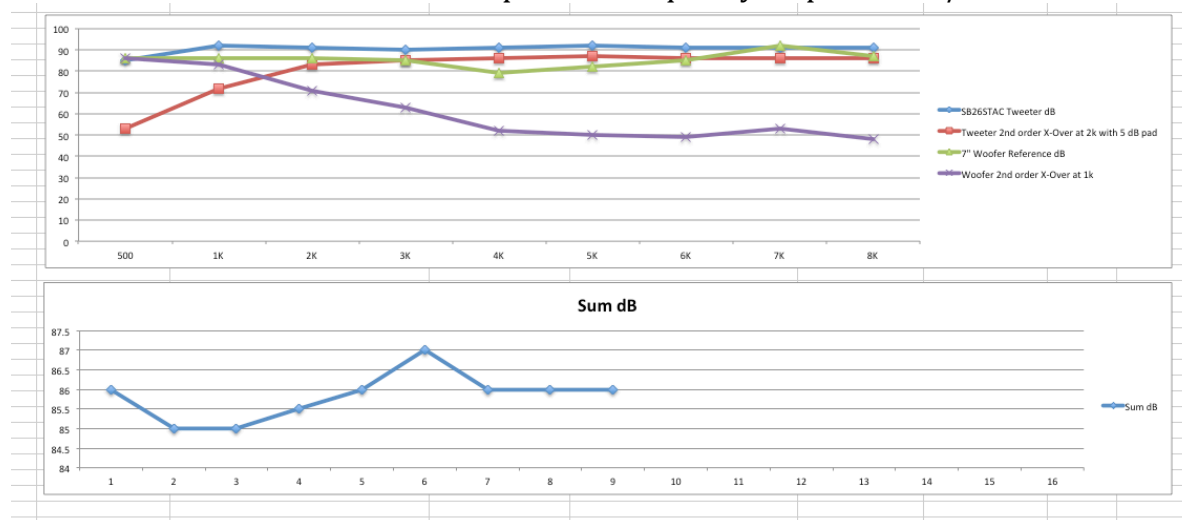
$$F(3) = 83$$

$$\text{Box Volume} = 0.44857 \text{ Cu Ft}$$

This woofer is good but it doesn't quite give me the  $F(3)$  I want. It also has a harsh breakup which would make it a bit more difficult to crossover smoothly.

## Crossover

I created a crossover for this woofer with the SB26STAC tweeter my crossover points were at 1 kHz for the woofer and 2 kHz for the tweeter. I put a 5 dB pad on the tweeter and used a 2<sup>nd</sup> order crossovers and it came up with a frequency response of  $\pm 1 \text{ dB}$ .



### Woofer Comparison Chart

Model	Morel TiW638	Morel CAW638	Morel MW166	Tang Band W6-1721	Dayton Audio RS180-8
F(3)	67 Hz	67 Hz	70 Hz	66 Hz	83 Hz
Sensitivity	86 dB	86 dB	86 dB	88 dB	87 dB
Q	0.65	0.65	0.65	0.707	0.6
Size	6"	6"	6"	6"	7"
Price	\$143	\$134	\$98	\$92	\$49

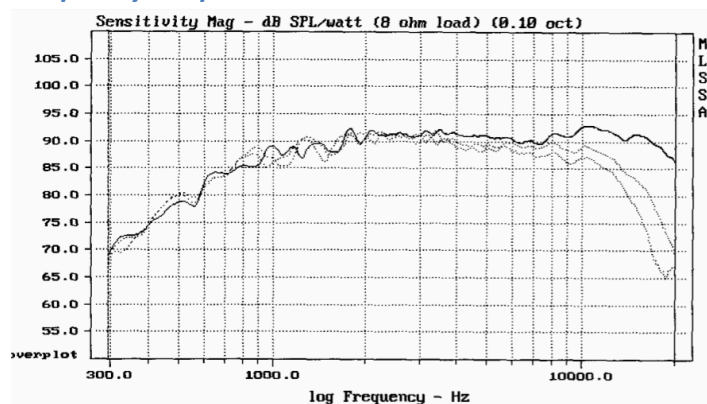
### Tweeters

What I was looking for in my tweeter selections was flat frequency response from at least 2 to 20 kHz. I wanted to be able to cross over at around 2 kHz so I wanted to make sure the  $F_s$  was no higher than 1 kHz and preferably lower so that I can crossover at least an octave higher than the  $F_s$ .

### MDT29

I chose to go with the MDT 29 by Morel it goes well with the woofer that I have chosen and the crossover will be pretty easy especially with the Mini DSP.

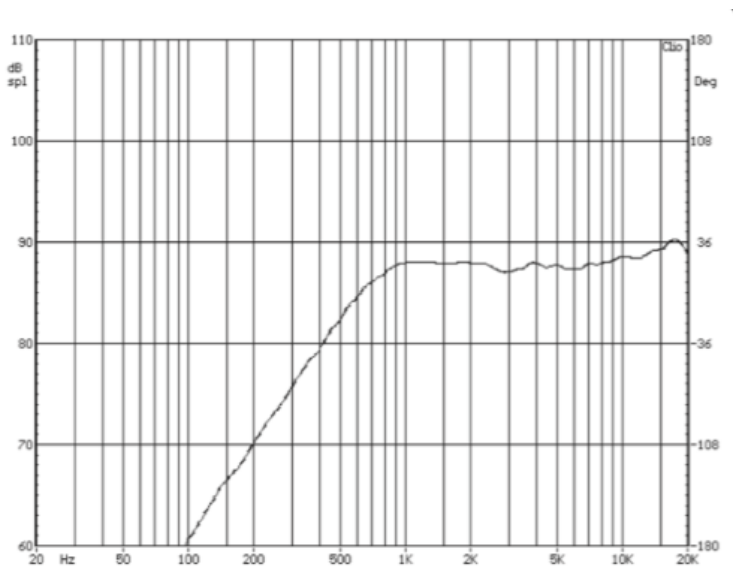
### Frequency Response



This tweeter was recommended by many users who were happy with the sound whether they were building their own speakers or replacing a blown tweeter in an already built speaker. This tweeter has a flat frequency response and will work well with the TiW638 woofer that I have chosen.

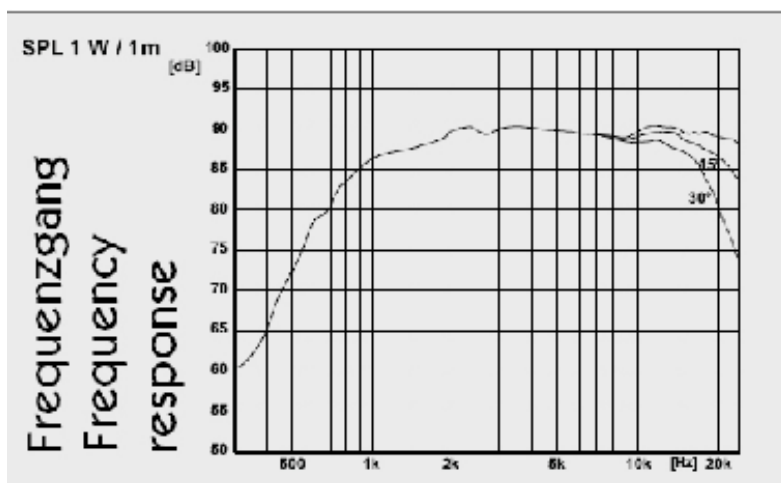
### RS28F-4

The RS28F-4 is made by Dayton Audio and would be a fine choice it has flat frequency response and its in the price range I was looking at which was between \$40 and \$60.



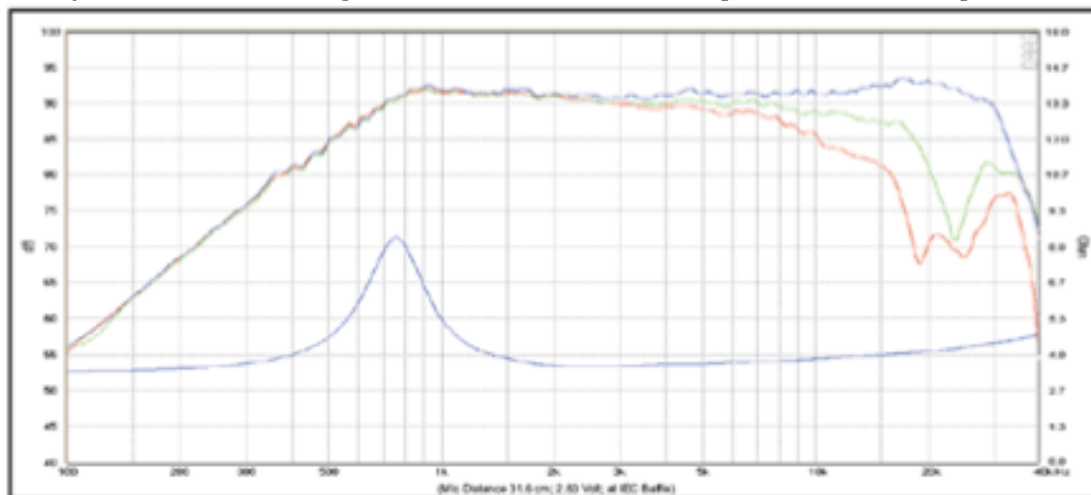
### Eton 19SD-1

This tweeter is very good but was out of my price range with the woofers I wanted to use.



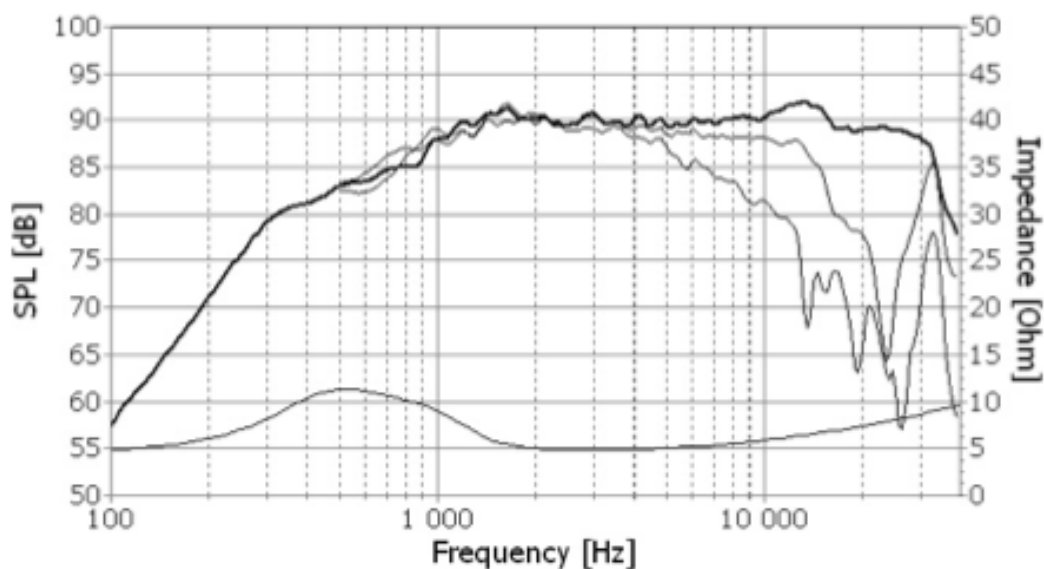
### SB26STAC-C000-4

This tweeter looks real nice but it worries me when a frequency response graph is quite blurry and hard to distinguish on the manufacturers pdf for their own product.



### Seas Prestige 27TDC

This tweeter looks pretty good but it is not quite as flat as some of the other options it also doesn't go as low, it starts to roll off at a higher frequency.



### Construction Materials

I will be using ½ inch underlayment plywood for the inside of my cabinet with a layer of 1/8 inch vinyl material in between the inner and outer layer. The outer layer will be ½ inch mdf.

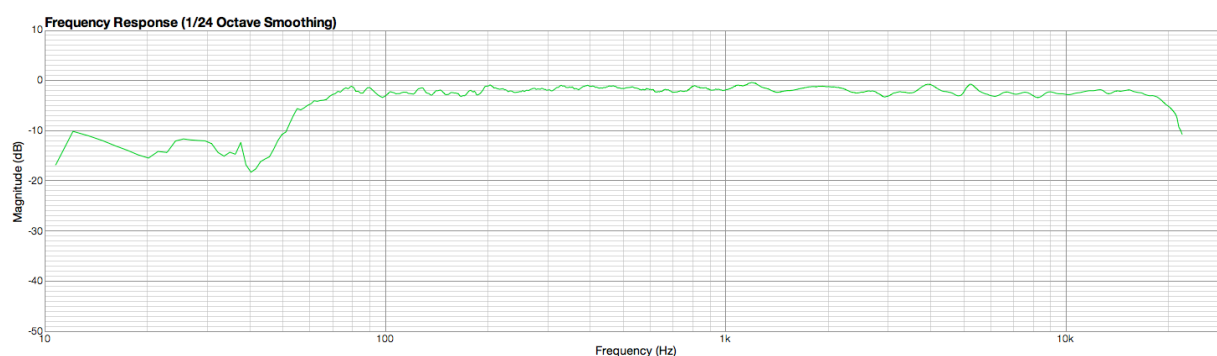


## Testing

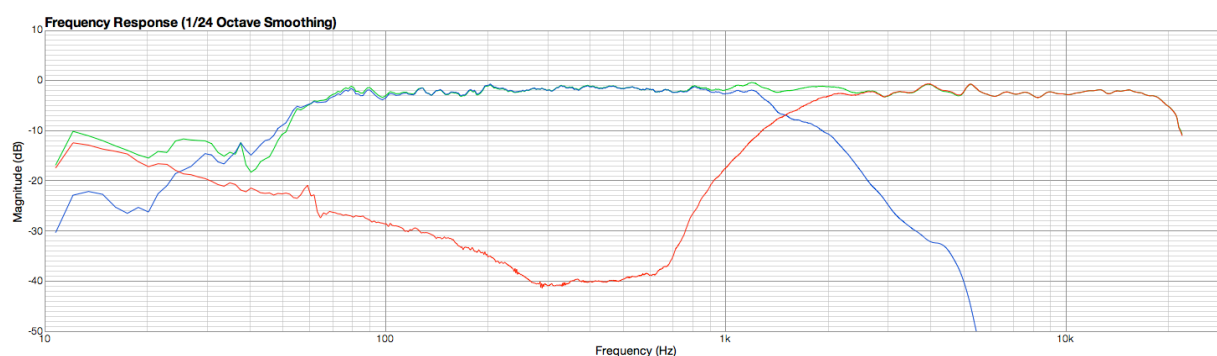
My initial testing showed that I had a box resonance at 1 kHz, which I remedied with fiberglass insulation inside my box for absorption. I tweaked my DSP crossover points to get better response in the midrange because I initially had a dip between 900 Hz and 2 kHz. I ended up setting my woofers crossover point to 1.5 kHz and my tweeter to 2 kHz. I found that my initial calculation of a 5 dB pad on the tweeter was too much and I ended up using a 4 dB pad. I then used the eq on the DSP to adjust some minor fluctuations. All of these tests were conducted in Mcardle Theater. The microphone was 18 Inches from the speaker.

## Testing Graphs

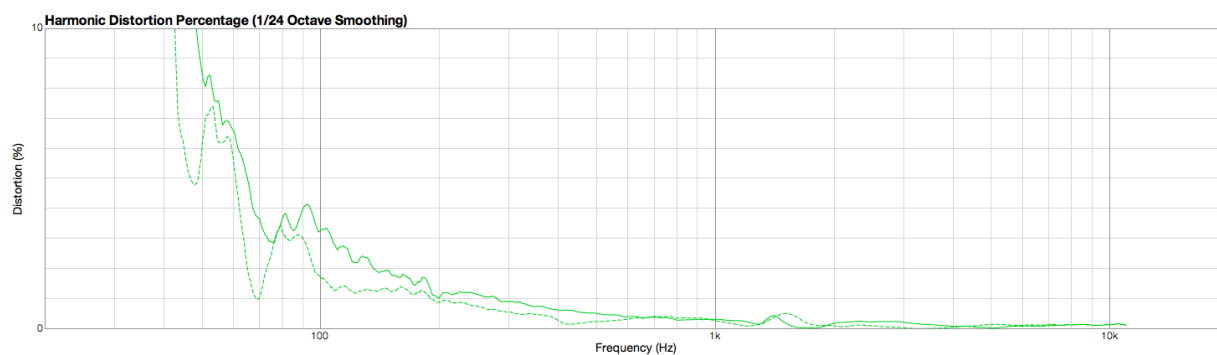
### Overall Frequency Response



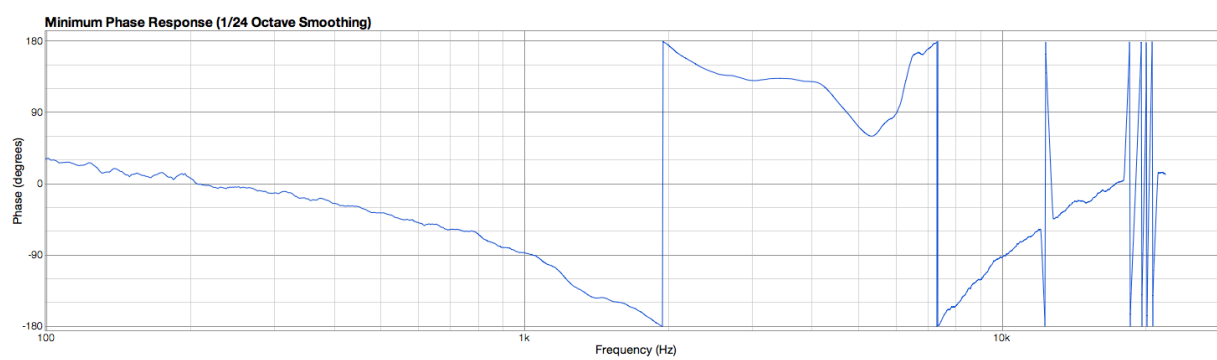
### Integrated Frequency Response



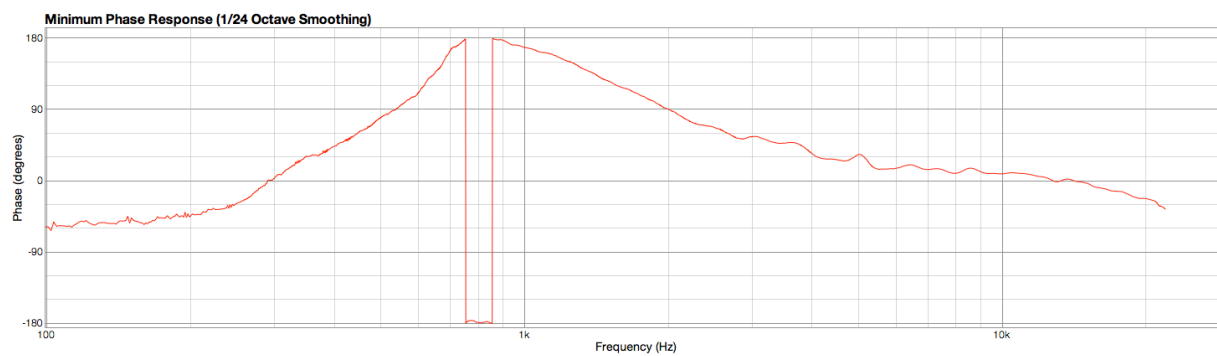
## Harmonic Distortion %



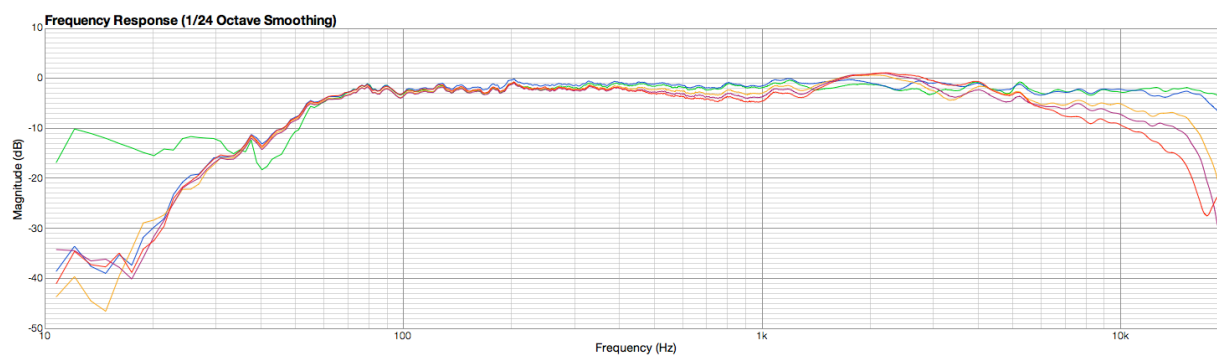
## Minimum Phase Graph of Woofer



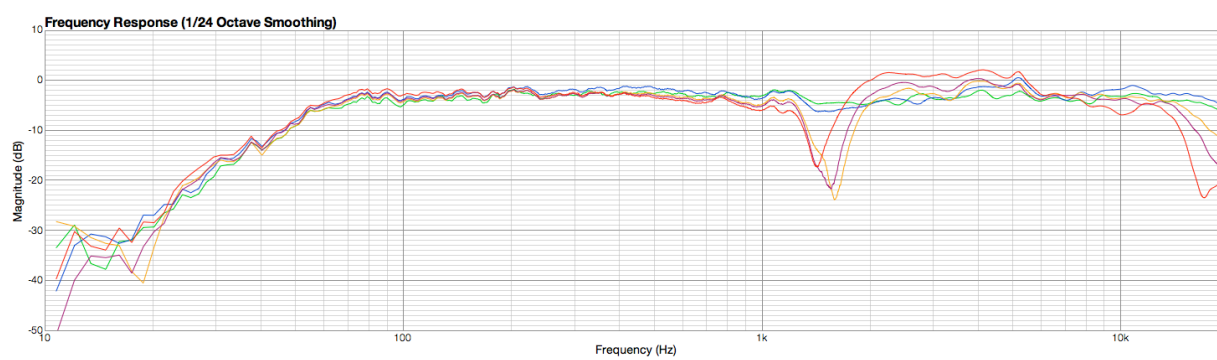
## Minimum Phase Graph of Tweeter



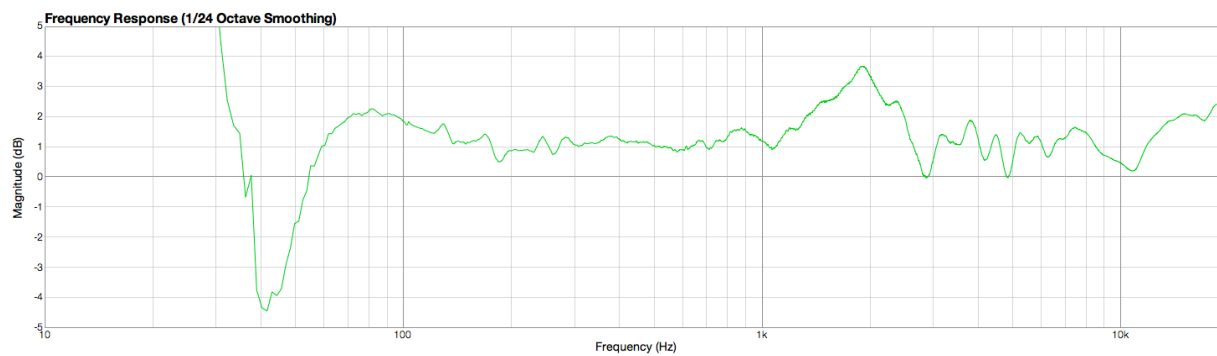
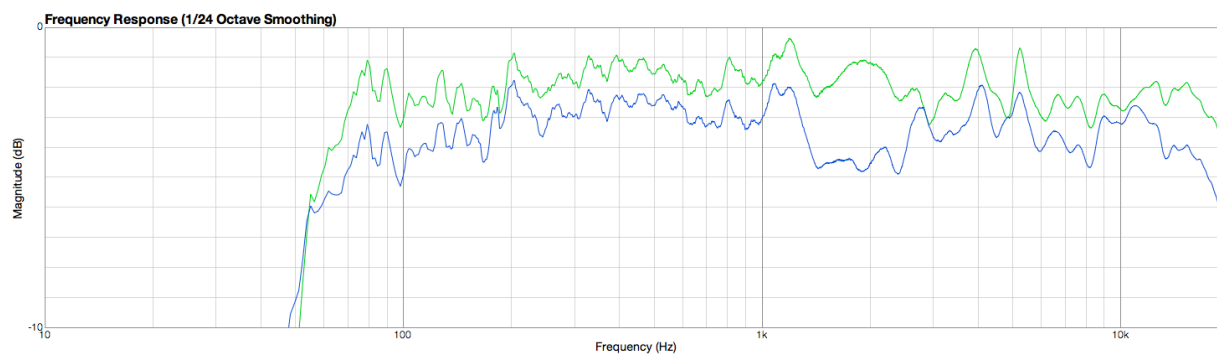
## Horizontal Off Axis Response



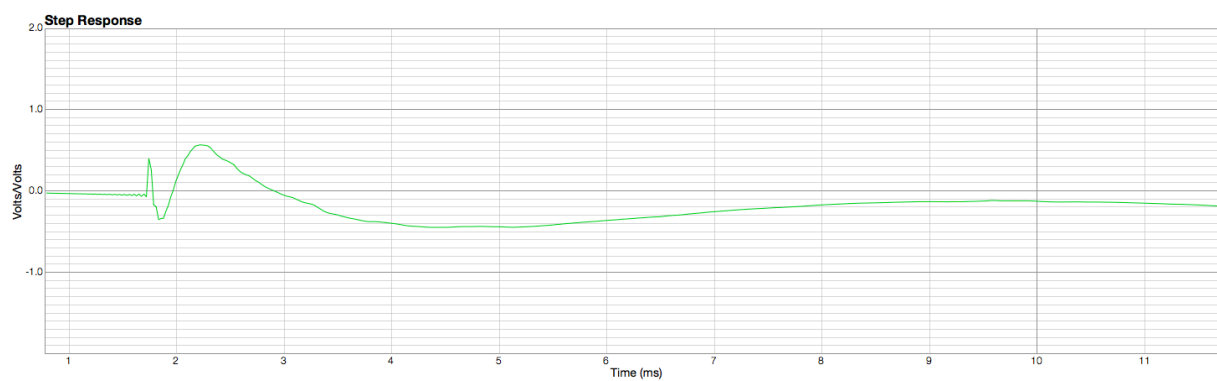
## Vertical Off Axis Response



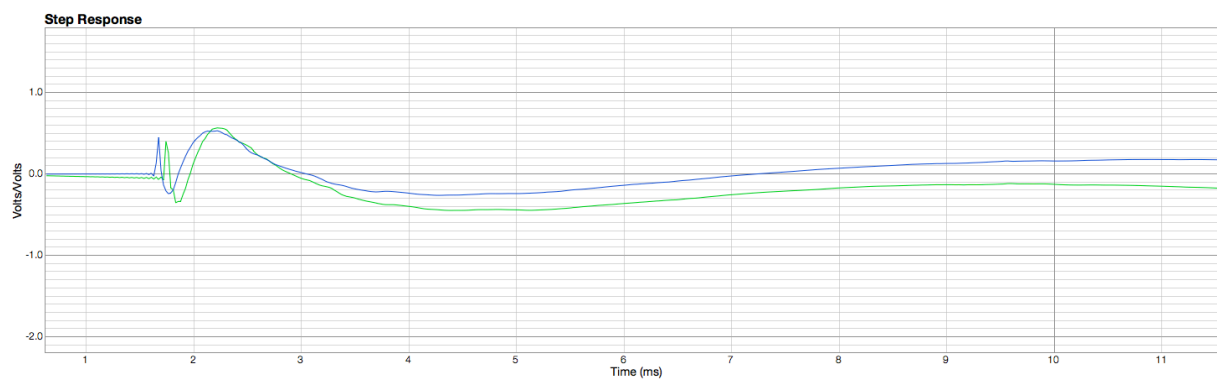
## Difference Between Left and Right Speakers



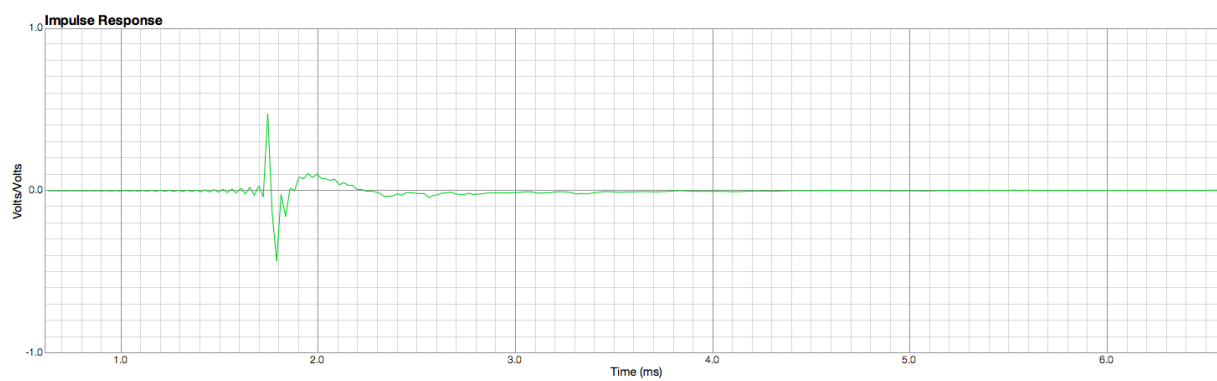
## Step Response



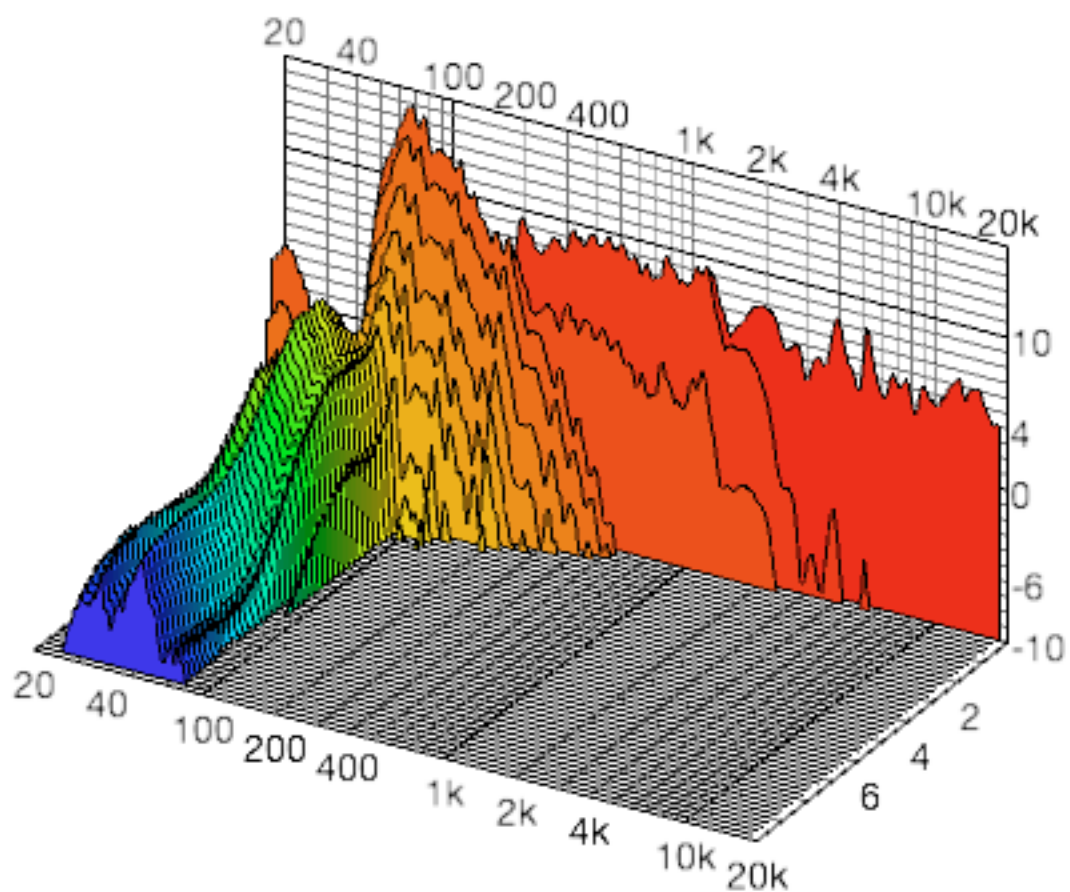
## Integrated Step Response



## Impulse Response

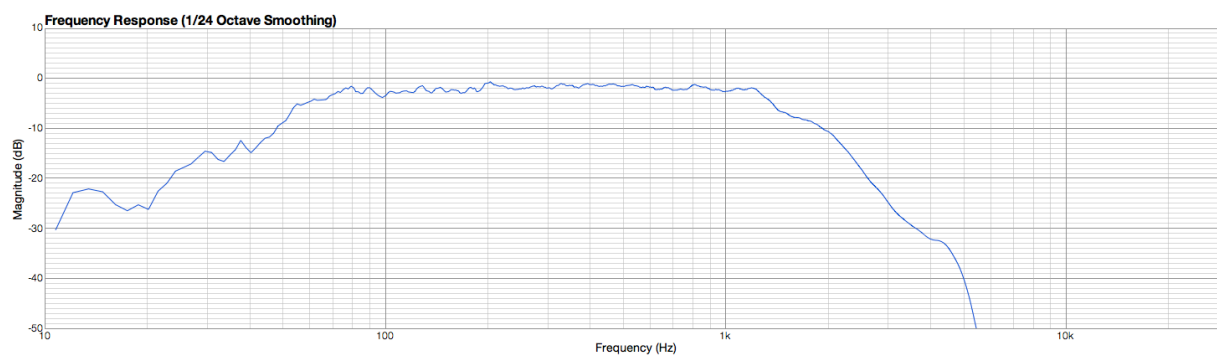


## Waterfall Plot

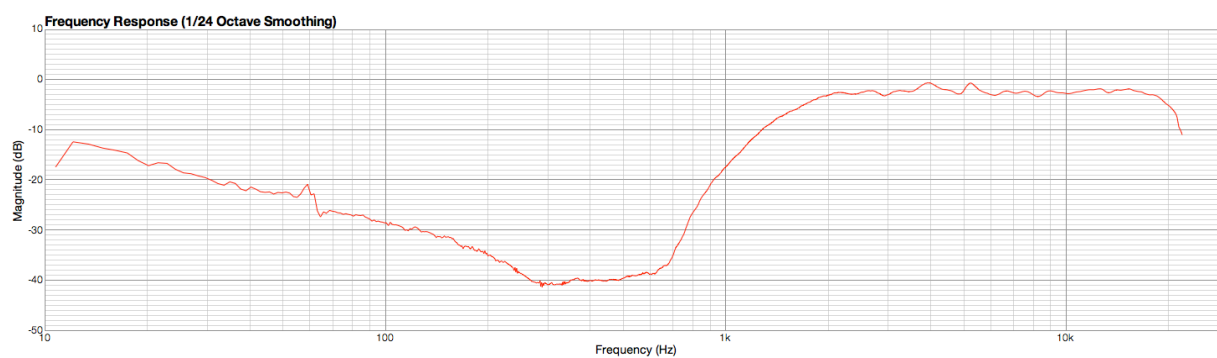


## Individual Frequency Response

### Woofer

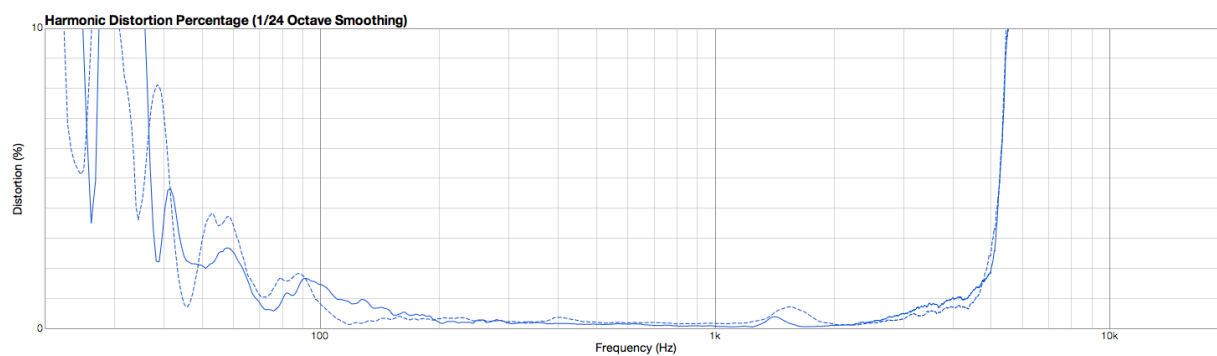


## Tweeter

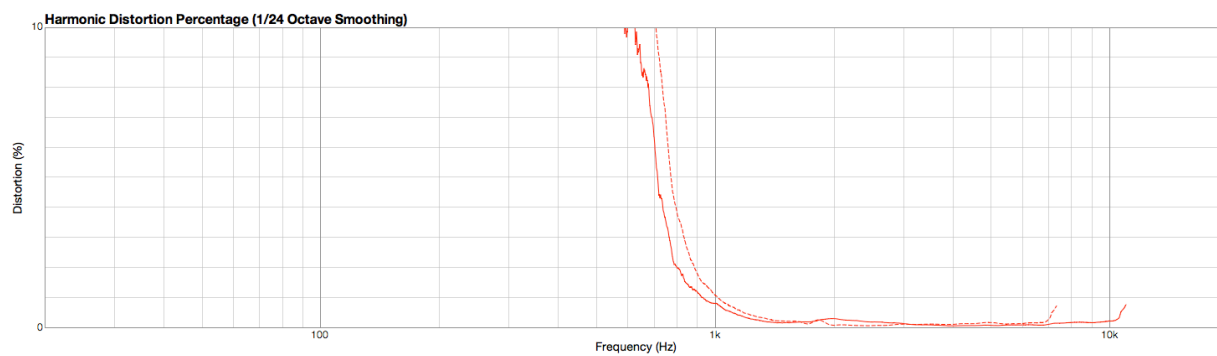


## Individual Harmonic Distortion %

### Woofers

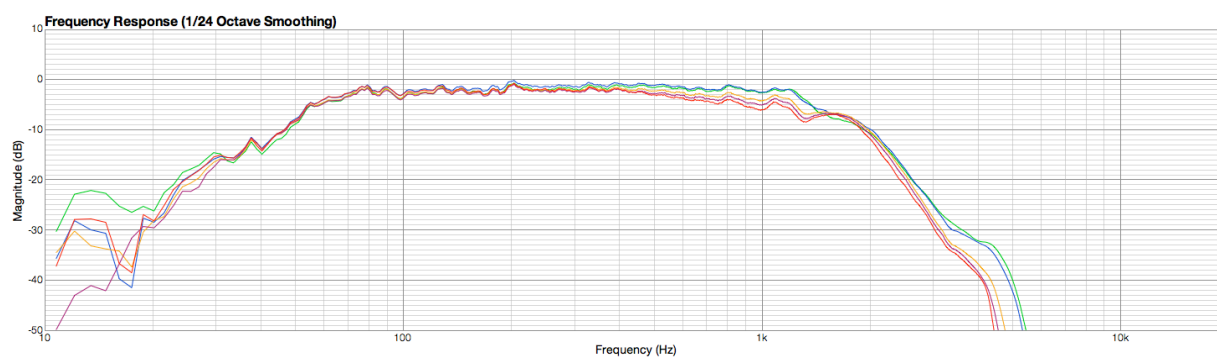


### Tweeters

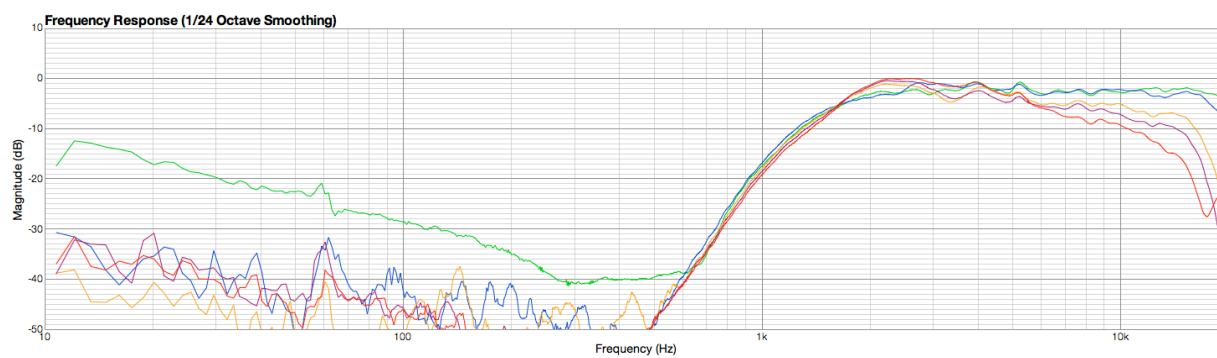


## Individual Horizontal Off Axis Response

### Woofer

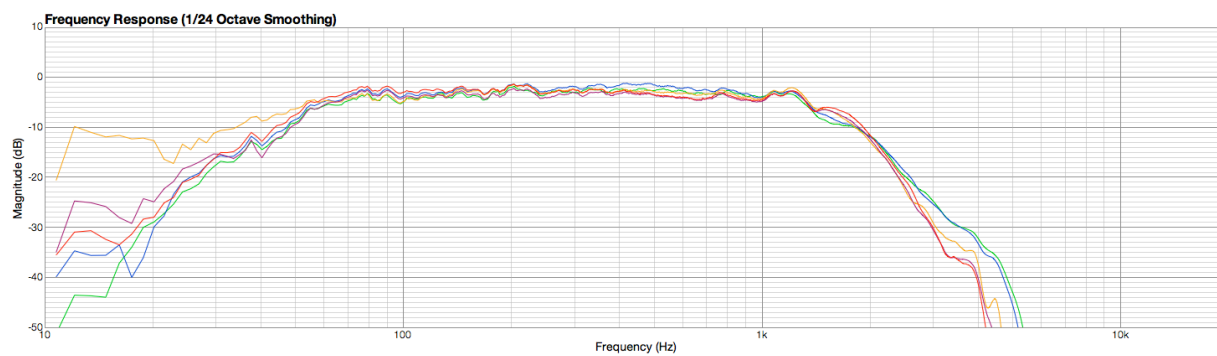


### Tweeter

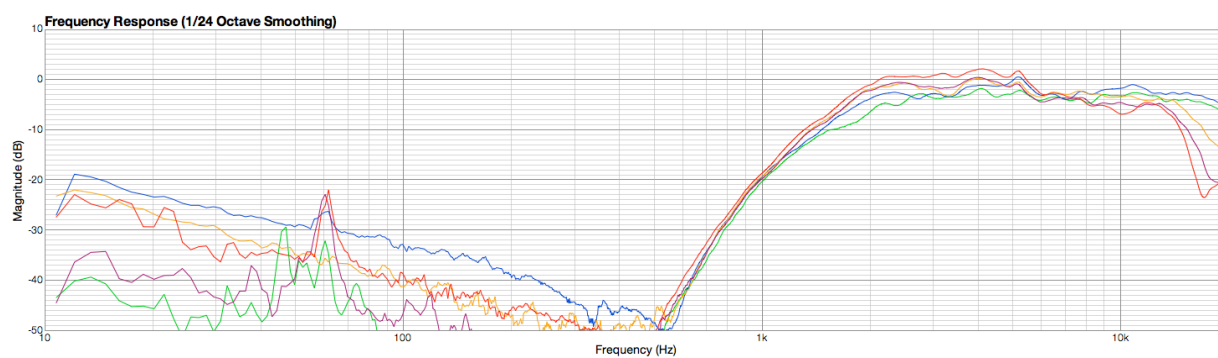


## Individual Vertical Off Axis Response

### Woofer

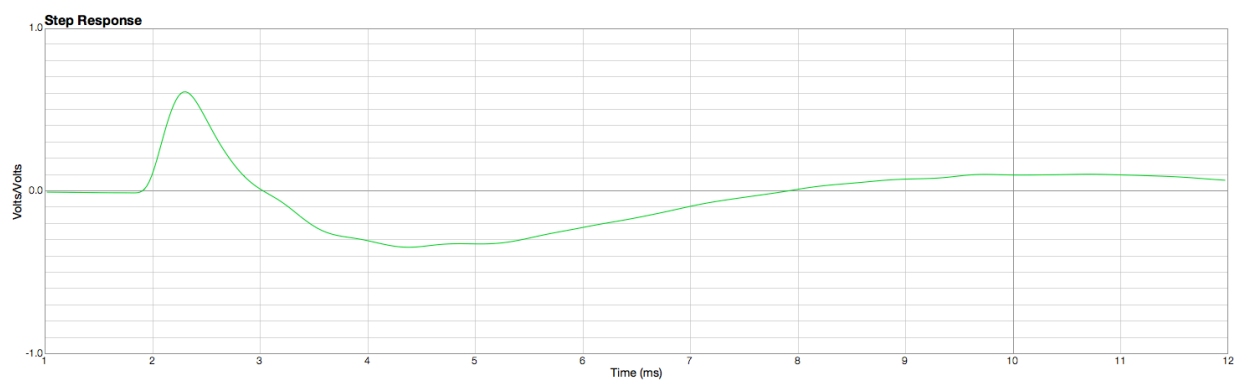


## Tweeter

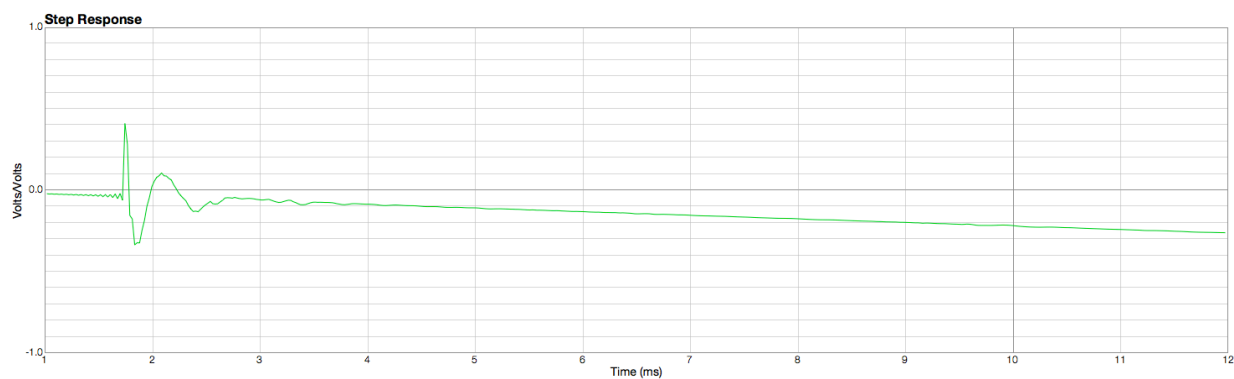


## Individual Step Response

### Woofers



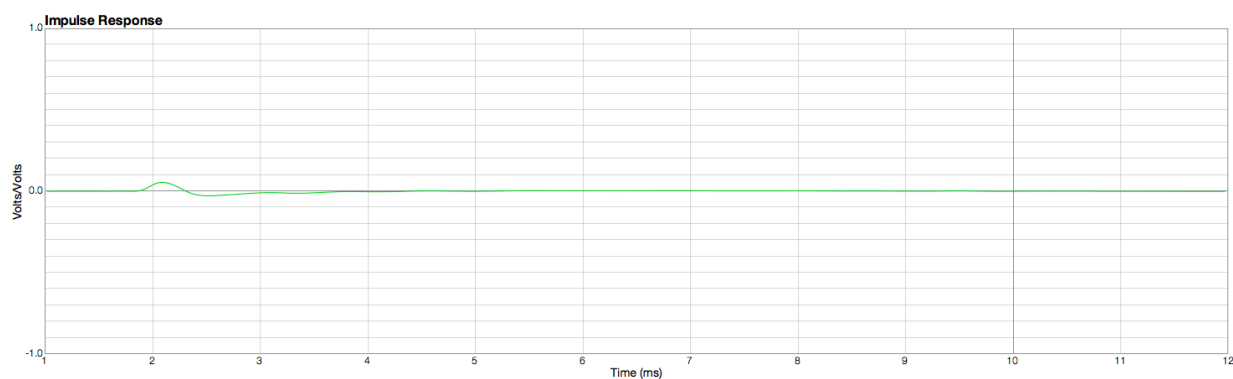
## Tweeter



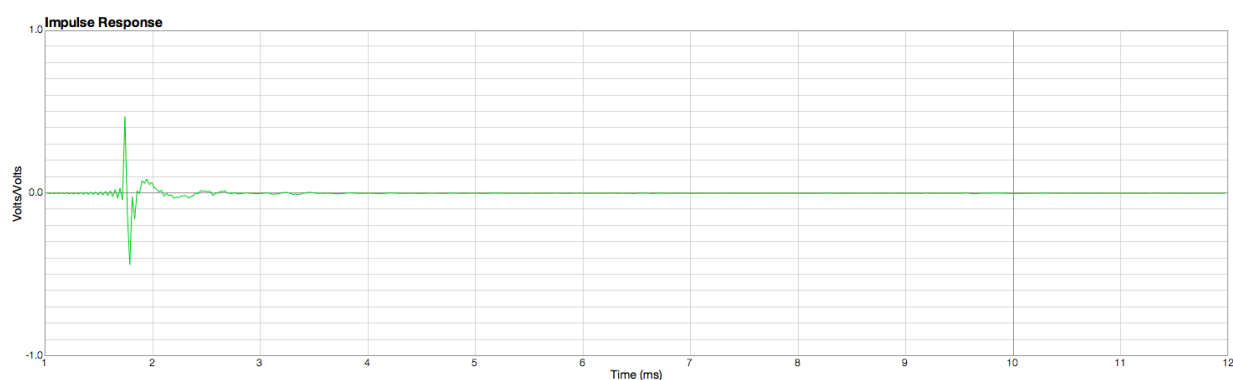


## Individual Impulse Response

### Woofer



### Tweeter



## Final Performance

The final performance of the JMWS-1's is very good they are  $\pm 1.5$  in the range that I desired and have the accurate transient response in the low end that was desired. They do not have good off axis response but are meant as near field mixing monitors for myself and only need to have one sweet spot for the mixing position which they do and it works out very well.

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