

# **DESIGN PROPOSAL**

**FA 4740 Transducer Theory**

**Loudspeaker Construction Project**

*Prepared By:*  
**Zach Carlson**  
2/11/2009

# I. Introduction and Class Objectives

The part of loudspeaker design that can be both incredibly frustrating, and eventually rewarding, is the constant bombardment of compromises and tradeoffs inherent in every part of your design process. Loudspeaker design can in essence be compared to a juggling act. How can you stick to your original functional goals with so many options staring you in the face? The first and most important part in your design process starts with having a solid understanding of what you want out of your loudspeaker.

## A. Functional Description

My goal is to produce a final product that exceeds the quality of existing consumer speakers in the same price range. At the end of the day, this loudspeaker is going to be used by me for *listening enjoyment*. As a music listener, I don't want to be constrained to one "sweet spot", so off-axis response needs to be good. As an added challenge to create a quality product, this loudspeaker needs to have a controlled polar response, have relatively good bandwidth (intended to be used with a sub), have tight and accurate transient response with the least amount of delay characteristics, and achieve 90 dB SPL with 15 dB headroom (listening levels concluded in 212). Although this may seem daunting, carefully selected drivers, crossover topologies, and cabinet design will allow me to meet these requirements with the least amount of sacrifice.

## B. Volume, SPL, and Bandwidth Relationships

John Murphy presents a massively simplified version of loudspeaker design tradeoffs in his SPL/Size/Bass pie charts.<sup>1</sup> My design will be somewhat of a hybrid of these. These speakers should have good sensitivity (high 80's), yet I don't need these speakers to get incredibly loud. They should also have a fairly low  $f_3$  point so I can rock out without a subwoofer. Box dimensions aren't a huge concern, but I would prefer a mid-sized enclosure. An M-T-M (Mid-Tweeter-Mid) configuration was decided upon because it works the best with the desired SPL output, a low  $f(3)$  point, size limitations, and other important characteristics required in this design.

## C. Overall Design Goals

With the factors of the functional description and loudspeaker design trade-offs in mind, my loudspeaker should be able to:

- 1) Fit the budget. (\$700 with \$100 cushion)
- 2) High Fidelity and Accuracy
- 3) Sustain 90 dB SPL (+15 dB headroom)
- 4) Wide Bandwidth ( $f(3)$  of 60 in sealed enclosure)
- 5) Be good looking
- 6) Luggable

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John, Murphy, *Introduction to Loudspeaker Design* (Andersonville, Tennessee: True Audio, 1998), Pg. 56

## II. Driver Selection

Driver selection was one of the most difficult parts of my design. In order to get a great sound, the drivers need to mesh as closely as possible, and with carefully selected drivers, circuit compensation can also be kept to a minimum. With an overall budget of \$700 dollars, I am allowing the driver budget to be around \$350-\$400 dollars total (about half the cost). A subwoofer has been designed, but will be implemented at a later date.

### A. Mid-Bass Drivers

In order for a subwoofer to mesh coherently with existing speakers and not appear to be outside of the sound field, an  $f(3)$  of around 50 Hz needs to be accomplished<sup>2</sup>. With a sealed box design and mid-bass drivers this can be fairly difficult to accomplish. However, by placing a subwoofer in between a stereo pair of loudspeakers, the  $f(3)$  is allowed to be a little higher, as the subwoofer will be included in the sound field<sup>3</sup>. My goal is to hit around 70 Hz, close to the CM7s in Walker 212. Still, the problem lies in how to get the most bass out of a midrange driver. After some modeling a few drivers in *Winspeakerz*, it was concluded that a driver would not produce the desired  $f(3)$  if its diameter is less than 6.5 inches. Therefore, smaller diameter drivers were not considered. Also the price of four mid-bass drivers (including tweeters) must fall into the budgeting plans. It should be noted that all *Winspeakerz* modeling was done with **two** drivers.

A few drivers were chosen for specific characteristics, along with their rival competitors in the same price range. The drivers that were considered are listed below (see *Appendix A* for driver spec sheets).

#### *Prime Mid-Bass Drivers (\$100 limit per driver)*

- 1) Tang Band W6-1721
- 2) Seas CA18RNX
- 3) Vifa PL18WO
- 4) Peerless HDS

These four drivers were all simulated in the *Winspeakerz* software program in a 2<sup>nd</sup> order sealed box. They were modeled to try and achieve a  $Q(tc)$  of around .7 for a controlled 12 dB/octave roll-off<sup>4</sup>. See *Figure 1*. Also, using a sealed enclosure results in a more controlled and detailed sound (due in part to improved transients)<sup>5</sup>.

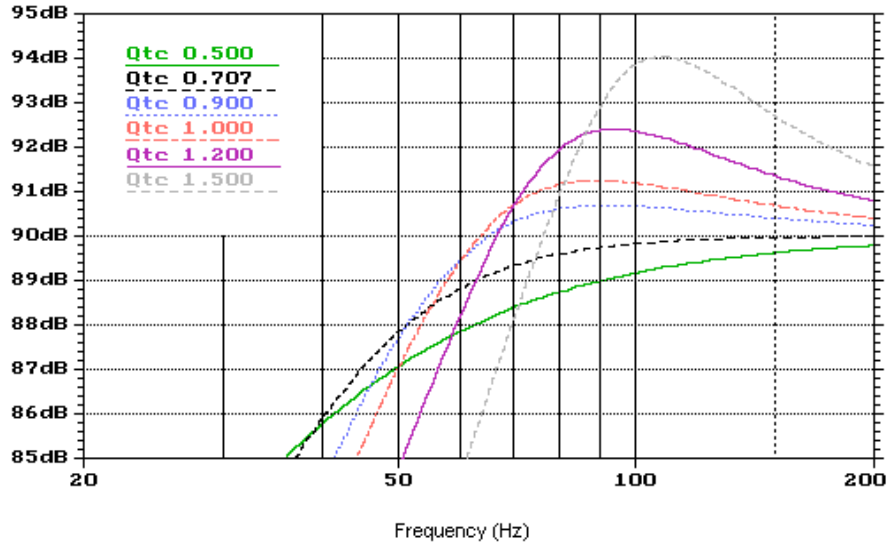
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<sup>2</sup> Plummer, Christopher. Discussion with Professor. Michigan Tech. February 13, 2009.

<sup>3</sup> Plummer, Christopher. Discussion with Professor. Michigan Tech. February 13, 2009.

<sup>4</sup> Vance, Dickason. *Loudspeaker Design Cookbook*. (Peterborough, New Hampshire: Audio Amateur Press, 2006), Pg. 29

<sup>5</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 30



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Figure 1: Q(tc) curves

The Peerless HDS was the first driver to be discarded because of its relatively low  $X_{max}$  compared to the other drivers. Because sealed box drivers excursion further than vented designs<sup>7</sup>, I found this is a pretty important aspect. When modeled at the long-term power handling in *Winspeakerz*, this driver showed the worst excursion characteristics of the four. There is also a large a cone breakup peak around 4k. This would require a steeper order crossover to counteract (See *Figure 2*). The *Efficiency Bandwidth Product (EBP)* also suggests this driver would work better in a vented enclosure<sup>8</sup>. The formula for calculating the *EBP* is shown below.

$$EBP = f(s)/Q(es)$$

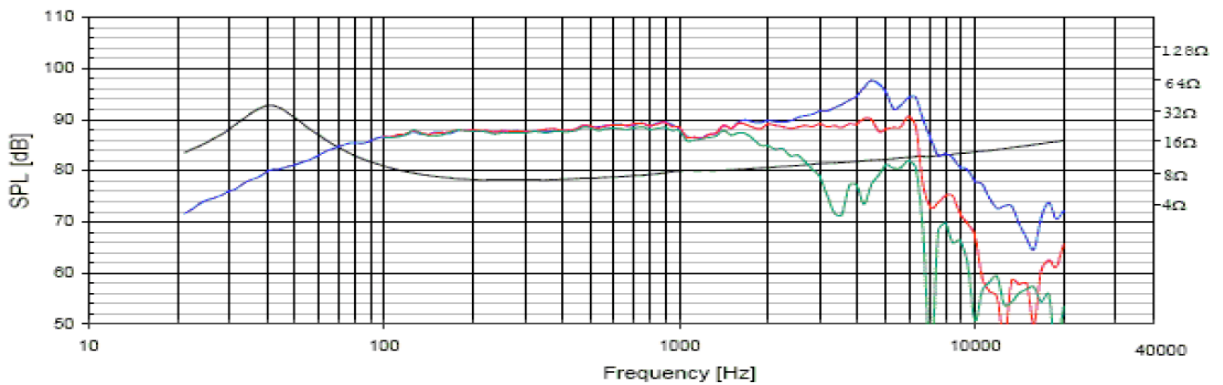


Figure 2: Peerless HDS

<sup>6</sup> Loudspeaker Builder. <<http://www.members.shaw.ca/LoudspeakerBuilder.ca/thiele-small.html>> (accessed February 21, 2009).

<sup>7</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 34

<sup>8</sup> Dickason, *Loudspeaker Design Cookbook*, Pg.34

The Vifa PL18WO and the Seas CA18RNX are almost the exact same driver. However, the Vifa PL18WO had inconsistently advertised  $X_{max}$  measurements. The final  $X_{max}$  was modeled at 4.5mm. The Vifa PL18WO has a commendably flat frequency response. The only issue is a slight 4 dB peak at 4k (See Figure 3). One interesting point in this driver is that after the peak there is a nice controlled 24 dB/octave slope without any breakup, making it easy to crossover. The  $EBP$  of this driver also suggests a vented enclosure.

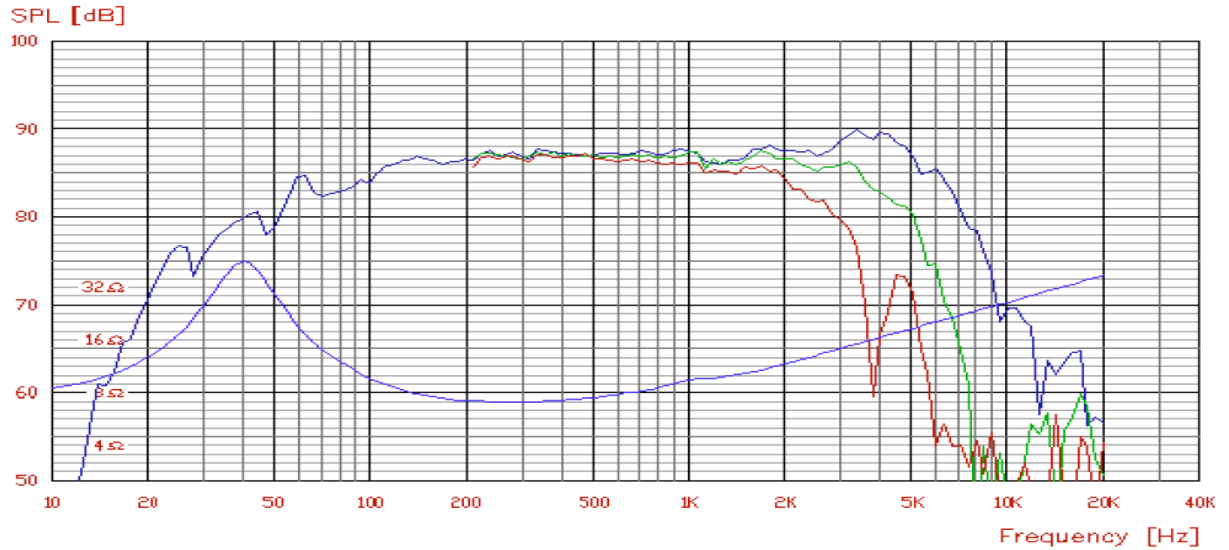
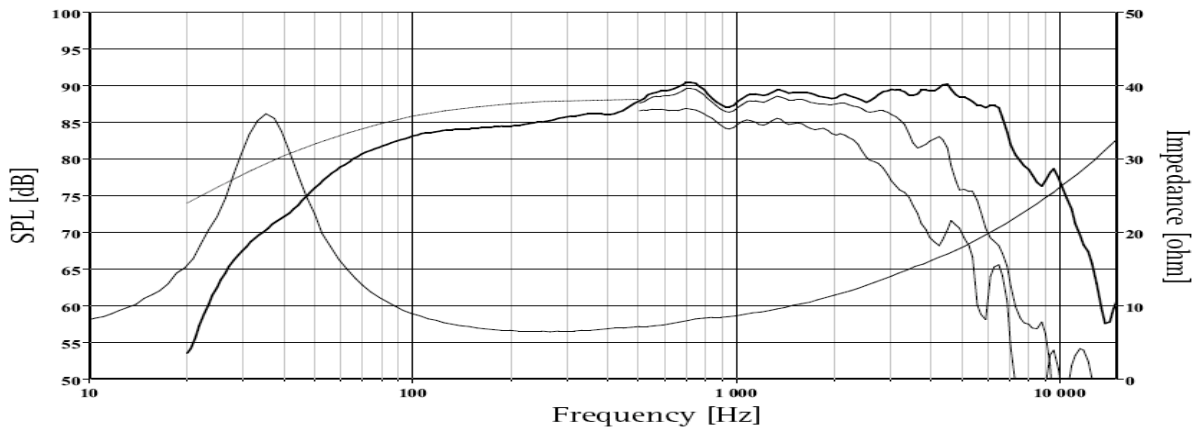


Figure 3: Vifa PL18WO

The Seas CA18RNX, although remarkably similar to the Vifa PL18WO, has one of the flattest and most extended frequency responses in the 6.5" driver grouping. It is also recommended on Zaph Audio's<sup>9</sup> website. This was the original mid-bass I had planned for use in my design. The Seas CA18RNX also exhibits a controlled roll-off without breakup (See frequency response below). With an  $f(3)$  of 80Hz this is my second choice.



<sup>9</sup> Zaph Audio. <<http://zaphaudio.com/6.5test/>> (accessed February 23, 2009).

The Tang Band WF-1721 is a remarkable and unique 6.5" driver. It has a massive under hung voice coil and exhibits high excursion capabilities. With an  $X_{max}$  of 8mm I found that this speaker exhibited the best excursion response when modeled in *Winspeakerz* (See *Appendix B*). When run at the long-term power rating, the Tang Band has a generous amount of room (almost 2mm) before it even hits the linear excursion line. This fact alone will drastically reduce the amount of distortion in output. Furthermore, Zaph Audio's tests show that because of the large magnet, there is a lack of harmonic distortion, and is quoted to be a "...nice sounding and certainly unique driver"<sup>10</sup>. Also, by looking at the frequency response of this driver (See *Figure 4*), there is a slight dip in the midrange. I consider this to be an interesting point, because the midrange droop could be utilized in *baffle step reduction*. *Baffle step reduction* theoretically happens when the driver switches from radiating from half space to whole space. *Baffle step reduction* can be calculated by:

$$\text{Baffle Step Reduction} = 4560/\text{Baffle Width in Inches}^{11}$$

An estimation of where this will occur in my box design happens at 4560/9.5 inches, which results in a baffle step loss of around 480 Hz. In order to utilize the droop in the frequency response I would need a baffle of 15 inches to achieve a baffle step loss of 300 Hz. This is not feasible, but the slight rise in bass will give these loudspeakers a little extra beef in their lower end.

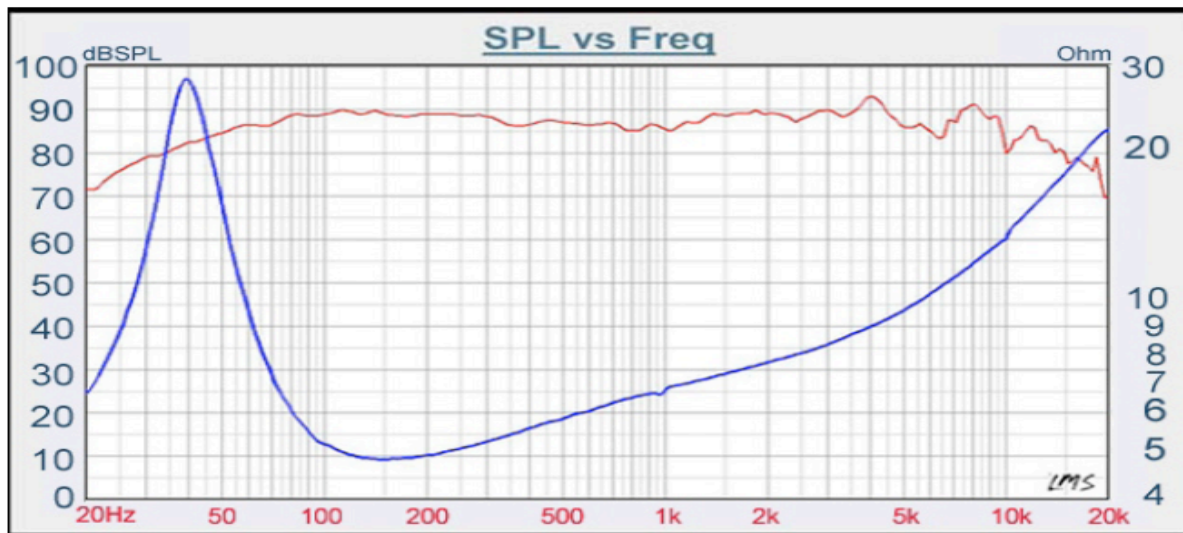


Figure 4: Tang Band W6-1721

<sup>10</sup> Zaph Audio. <<http://zaphaudio.com/6.5test/>> (accessed February 23, 2009).

<sup>11</sup> Martin J. King. *Simple Sizing of the Components in a Baffle Step Correction Circuit*. (Martin J. King, 2005), Pg. 3

The Tang Band W6 is also able to achieve the lowest  $f(3)$ , coming out to be around 65 Hz (See *Appendix B*). This will mate nicely with a subwoofer, and will still be able to hold its own when operating by itself. At 65Hz I will still be able to get most of the lower bass, this is where most of the bass energy is located, and Low C resides exactly at 65Hz<sup>12</sup>.

### **My Mid-Bass Driver is the Tang Band WF-1721**

#### **B. Tweeter**

In this design, the tweeter needs to have a relatively flat frequency response and be able to handle a decent amount of power. Off-axis response is also a key point in tweeter selection. In other words, how do I get my loudspeaker to sound good at a variety of different listening locations? Also, to try and minimize extraneous crossover parts and unneeded amplifier stress, a tweeter with a lower impedance peak is also something to be considered.

Tweeter frequency plots, power handling, off-axis response, and sensitivity were considered. The standout tweeters are listed below (See *Appendix A* for tweeter spec sheets).

#### *Prime Tweeters (\$50 limit per tweeter)*

- 1) Seas 27TFFC
- 2) Vifa D27TG
- 3) Seas 27TDC
- 4) Vifa XT25TG30

The Vifa XT25TG30 received rave reviews and is used in a few big time designs such as the Von Schweikert VR-4 SR MKII<sup>13</sup>. The dual-ring design was interesting and supposedly has great off-axis response and a quality similar in sound to planar and electrostatic transducers. However, after consulting LDSG<sup>14</sup> and reading other forum reviews, it was made clear that it likes a high crossover, which just isn't feasible in my two-way design.

The Seas 27TDC has an incredibly flat response, a nice roll-off at 1k, and a fairly flat impedance curve (See *Figure 5*). Considering the fact that I want to have headroom of 15 dB, and after calculating the power required to get this (See *Figure 6*), I found that to achieve around 105 dB would require a slightly higher power handling ability. To get

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<sup>12</sup> David, Moulton. *Total Recording: The Complete Guide to Audio Production*. (KIQ Productions, 2000), Pg. 32

<sup>13</sup> Dagogo Review. <<http://www.dagogo.com/VonSchweikertVR4SRMKII.html>> (accessed February 16, 2009).

<sup>14</sup> LDSG. <<http://ldsg.snippets.org/vendors/vifa.php>> (accessed January 23, 2009).

105 dB (with attenuation considered) would require about 64 Watts, which is slightly over the long-term power handling of this driver.

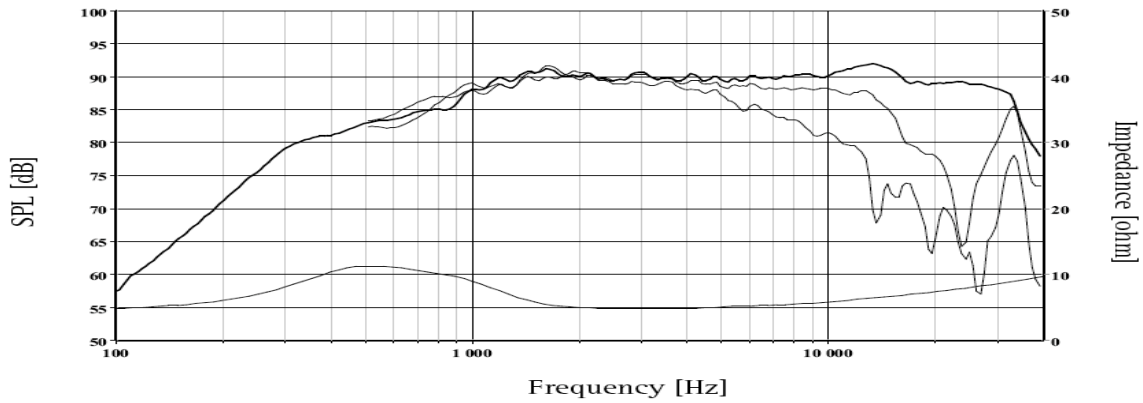


Figure 5: Seas 27TDC

**Power Requirement**

dB	Watts
87	1
90	2
93	4
96	8
99	16
102	32
105	64

Figure 6: For every 3 dB extra, the power must double.

This requirement led me to look at the Vifa D27TG and Seas 27TFFC. The Vifa D27 features a beautiful frequency response with a slight dip at 12k (See *Figure 7*). The Seas 27TFFC has a very nice frequency response that fluctuates a bit at the higher end (See *Figure 8*). Both are recommended on the LDSG website. However, the deciding factor was the lower impedance curve of the Seas 27TFFC. Also, if you match this tweeter with the two Tang Band drivers you will get a close match in sensitivity. For example, at 1Watt/1 meter, the two Tang Band drivers wired in series will reach 88 dB sensitivity. Because the Seas 27TFFC's sensitivity is 91 dB at 1W/1 meter, less tweeter attenuation is required. With Diffraction taken into account the final SPL level should be around 85 dB. I am going with this estimate because with room interaction, the actual diffraction

loss is around 3 to 4 dB<sup>15</sup>. Also, the Sea 27TFC has a nice 6 dB/octave roll-off around 2k I can utilize in my crossover design (explained in *Section II-A*).

**My tweeter will be the Seas 27TFC**

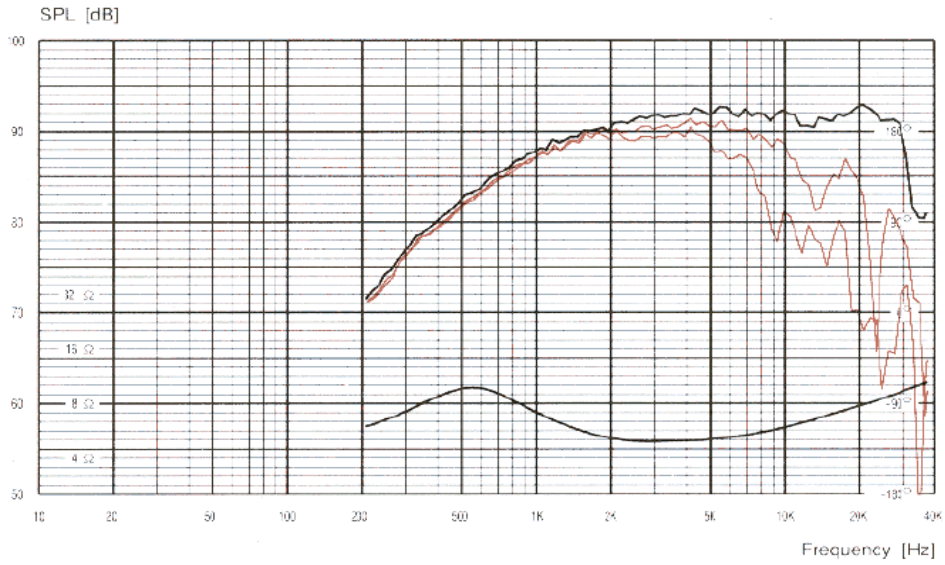


Figure 7: Vifa D27TG

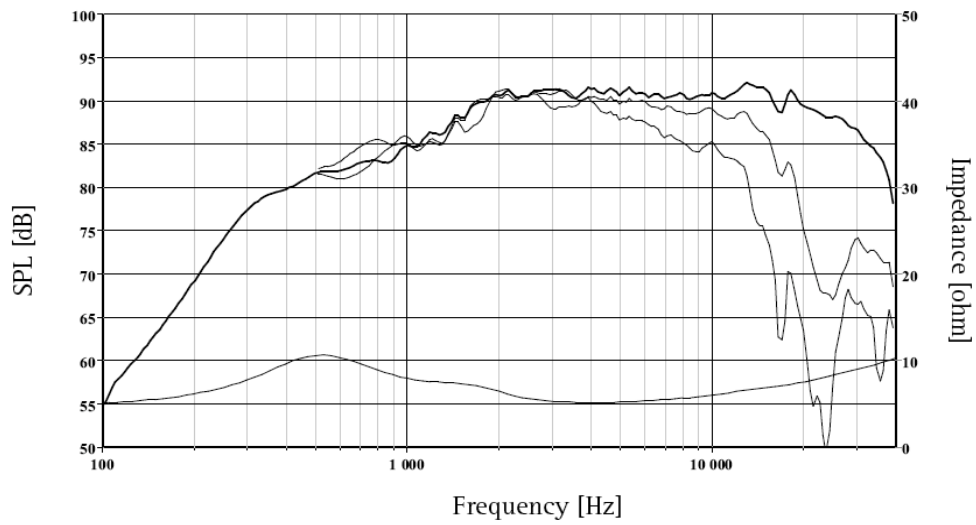


Figure 8: Seas 27TFC

<sup>15</sup> Murphy, *Introduction to Loudspeaker Design*, Pg. 68

For side by side comparison see: *Appendix A: Driver Specs, Appendix B: Winspeakerz plots*)

### III. Crossover Design

A single driver cannot reproduce the entire frequency spectrum with accuracy and detail because the characteristics that make a driver suitable for reproducing one frequency extreme make it unsuitable for the other<sup>16</sup>. Therefore, the implementation of crossovers is needed to effectively distribute frequencies to the correct driver. Crossovers are incredibly important, because they effect polar radiation, delay, phase, roll-off slope, and can even add their own distinct coloration to your sound.

#### A. Topology Considerations

Crossover design was considered mainly in regards to how I can utilize the existing slopes of the drivers I selected, and for the roll-off rates. Although Newell compares the benefits of an active crossover by about 6 to 1<sup>17</sup>, the price of individual channels of amplification is just too much. Therefore, a passive crossover will be used.

John Murphy preaches “less is more<sup>18</sup>” in his book Introduction to Loudspeaker Design; with the M-T-M layout and driver interactions in mind, I decided to go for a higher rate of roll-off. There are multiple reasons behind this. Lesser slope rates provide more driver interaction. This can be a great thing, as the transition between drivers is more gradual and there isn't a noticeable jump between the different driver characteristics of a woofer and a tweeter. However, this slow rate of change also has its downfall. Because the rate of fall-off is less, more signal is allowed to cross-over into the next driver. Therefore, with slower fall-off rates, more low frequency signal is sent to the tweeter and vice versus. With the need to play music at relatively loud levels (to rock out to household chores), sending unneeded low frequency signals to the tweeter could be damaging.

A third order crossover was chosen for the reasonable 18 dB/ octave fall-off, providing adequate speaker protection. Crossover parts are also decreased and the polar response will not suffer, as the M-T-M configuration keeps the axis from being tilted due to the horizontal driver offsets<sup>19</sup>.

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<sup>16</sup> Murphy, *Introduction to Loudspeaker Design*, Pg. 95

<sup>17</sup> Philip, Newell, *Loudspeakers for Music Recording and Production*. (New York: Focal Press, 2007), Pg. 142

<sup>18</sup> Murphy, *Introduction to Loudspeaker Design*, Pg. 108

<sup>19</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 163

## B. Actual Crossover Orders To Be Used

By looking at the Seas 27TFFC (*Figure 8* on previous page) there is a noticeable 6 dB acoustical roll-off starting at 2k. In order to achieve the 18 dB/octave roll-off I desire, a 2<sup>nd</sup> order Butterworth with an additional 12 dB/octave roll-off will be added. A third order Butterworth electrical roll-off will be applied to the mid-bass. This will take care of any peaking that is shown around 4k with the Tang Band drivers. By inverting one of the drivers, I should also get better group delay characteristics, and an equal summation of the acoustic output<sup>20</sup>. Circuit components were calculated in *Winspeakerz*, and are shown in *Figures 9 and 10*. The final circuit will be shown in *Figure 11*.

Enter the Following:

Tweeter Impedance =	<input type="text" value="6"/>	Ohms
Woofer Impedance =	<input type="text" value="4"/>	Ohms
Crossover Frequency =	<input type="text" value="1700"/>	Hz

The Component Values are:

C1 =	<input type="text" value="11.03"/>	microfarads
C2 =	<input type="text" value="16.55"/>	microfarads
L1 =	<input type="text" value="0.5296"/>	millihenrys
L2 =	<input type="text" value="0.7944"/>	millihenrys

*Figure 9: 2<sup>nd</sup> Order High Pass*

<sup>20</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 163 ( graph on 156)

Enter the Following:

Tweeter Impedance =  Ohms

Woofer Impedance =  Ohms

Crossover Frequency =  Hz

The Component Values are:

C1 =  microfarads

C2 =  microfarads

C3 =  microfarads

L1 =  millihenrys

L2 =  millihenrys

L3 =  millihenrys

*Figure 10: Third Order Low-Pass*

### C. Crossover Point

The crossover point of this loudspeaker design was picked for two specific reasons. The first reason was to utilize the characteristics of the tweeter roll-off. The second was to keep the transition in an area that would be least noticeable. The crossover point is going to be **1700 Hz**. The roll-off of the Seas 27TFFC is 3 dB down at about 1700 Hz, and this will allow the easiest implementation of a second order high-pass crossover.

Furthermore, a crossover point of 1700 Hz would be right outside the strongest consonant frequency range of 1800 to 2500 Hz<sup>21</sup>. A 1700Hz crossover would create a less noticeable transition between drivers, as it is slightly outside of the frequency range of important voice consonances. Furthermore, a lower crossover point would increase the clarity and would unmask the sound as the tweeter is working in its intended frequency range. The only downfall would be the increased power handling pressures on the tweeter. But, because this tweeter was chosen for its increased power handling abilities, and a lower impedance peak at resonance, this should be no problem.

<sup>21</sup> Meyer Sound. < <http://www.meyersound.com/support/papers/speech/section2.htm>> (accessed February 23, 2009).

## D. Circuit Compensation

A few other circuit compensators were designed to allow for the best possible final sound, and for ease of operation in conjunction with an amp.

### *Zobel (Impedance) Correction Circuit*

In order to level out the rising impedance of the Tang Bands' voice coil (which is rather significant), a Zobel Impedance network is going to be used. By using this correction circuit there should be a noticeable reduction in the high frequency output of the woofer<sup>22</sup>. This, in combination with my crossover point, should provide a smooth transition between my mid-bass drivers and the tweeter. The resistor and capacitors values are determined by<sup>23</sup>:

$$R(\text{zobel}) = 1.25 \times R(e) \quad \text{Ohms}$$

$$C(\text{zobel}) = L(\text{vc})/[1.25 \times R(e)]^2 \quad \text{Farads}$$

Where  $R(e)$  = Driver's DC resistance in Ohms

$L(\text{vc})$  = Driver's voice coil impedance in Henries

**The values to be used are  $R(\text{zobel}) = 4.25$  Ohms, and  $C(\text{zobel}) = 4.63$  mH**

### *Baffle Step Correction Circuit:*

In order to achieve equal SPL levels throughout the frequency spectrum, a baffle step correction circuit was designed. Because of the slight rise in the low end of the Tang Band drivers, there could be less dB of attenuation required. This attenuation circuit is also designed to be used with the Zobel network explained above. To find the required components for this circuit you need to find the correct frequency at which baffle step loss occurs. This is calculated by<sup>24</sup>:

$$f(b) = 4560/\text{Baffle Width (in inches)}$$

**The estimated baffle width will be around 9.5 inches giving a baffle step reduction at 480 Hz**

$$R(\text{parallel}) = R(e) \times (10^{(dB/20)} - 1) \quad \text{Ohms}$$

$$L(\text{BSC}) = R(\text{parallel})/[2 \times \text{Pi} \times f(b)] \quad \text{Henries}$$

**The values to be used are  $R(\text{parallel}) = 2$  Ohms, and  $L(\text{BSC}) = .558$  mH**

**(Note: These are all approximations and will be adjusted to real component values)**

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<sup>22</sup> Murphy, *Introduction to Loudspeaker Design*, Pg. 117

<sup>23</sup> King, *Simple Sizing of the Components in a Baffle Step Correction Circuit*, Pg. 4

<sup>24</sup> King, *Simple Sizing of the Components in a Baffle Step Correction Circuit*, Pg. 4

The use of a resonance compensator will not be used because of the relatively low impedance peak of the Seas 27TFFC.

### E. Crossover Placement

The crossovers will be located outside of the loudspeaker cabinet. This is for easy access in case any changes need to be made. A separate enclosure will be built if needed.

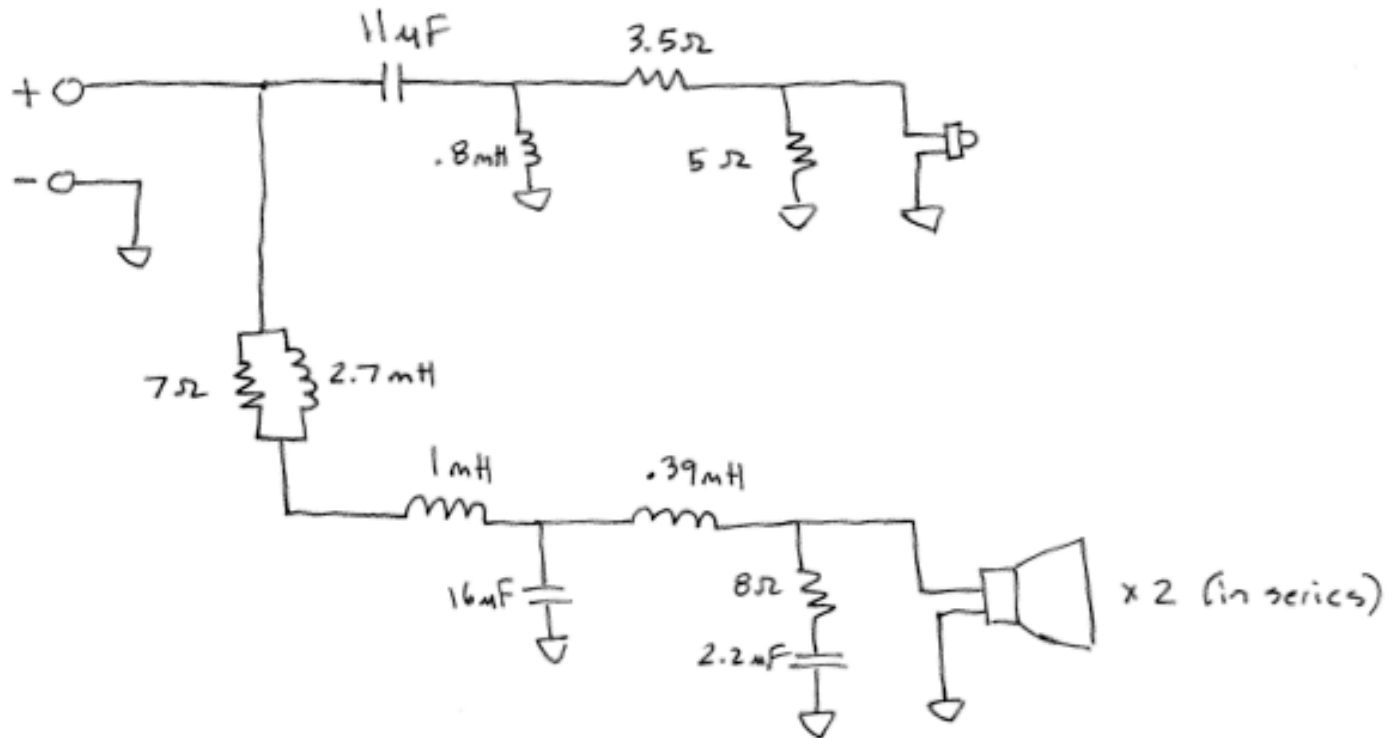


Figure 11: Final Circuit

## IV. Cabinet Construction

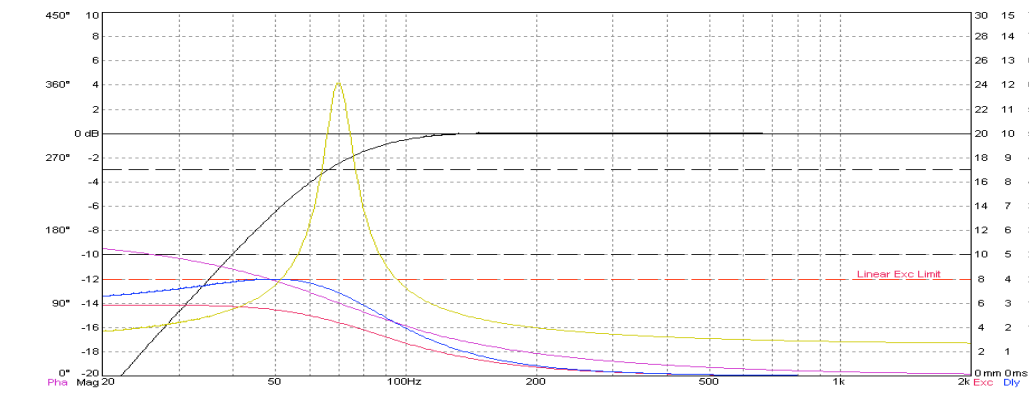
Cabinet construction and damping has an effect on the way your loudspeaker sounds more than you'd think. You can't just slap together some boards and call it good. There are a plethora of different box designs that each add their own unique attributes to the final functionality of your loudspeaker. Also, because a driver radiates sound in both directions, a box requires the proper amount of internal damping and bracing.

### A. Cabinet Types

The two main box designs considered were the ported reflex and the sealed air suspension. A combination of the two that was considered is an aperiodically tuned box. The benefits of a reflex enclosure mainly reside in the extended low end. In accordance to the goals of this design, an air suspension model is better, as it provides quick transient accuracy with a moderately low  $f(3)$ . Also, because this design is intended for use with a sub, the extended low end is unneeded. Because of this, all drivers were tested in a closed box.

#### The cabinet design will be an air suspension model

The benefits of a sealed enclosure are the transient accuracy and controlled group delay characteristics. For verification of this fact, you need to merely compare the superior transient response of vented enclosures to closed enclosures in respect of their  $Q(tc)^{25}$ . All drivers were modeled in a box with a  $Q(tc)$  of around .7 to achieve a controlled roll-off response (See section II A). An air suspension model was also chosen because of the large  $V(as)$  and loose suspension of the Tang Band W6s<sup>26</sup>. Because air suspensions act as a spring behind the driver, lower levels of distortion and a controlled excursion response are achieved. See *Figure 12*.



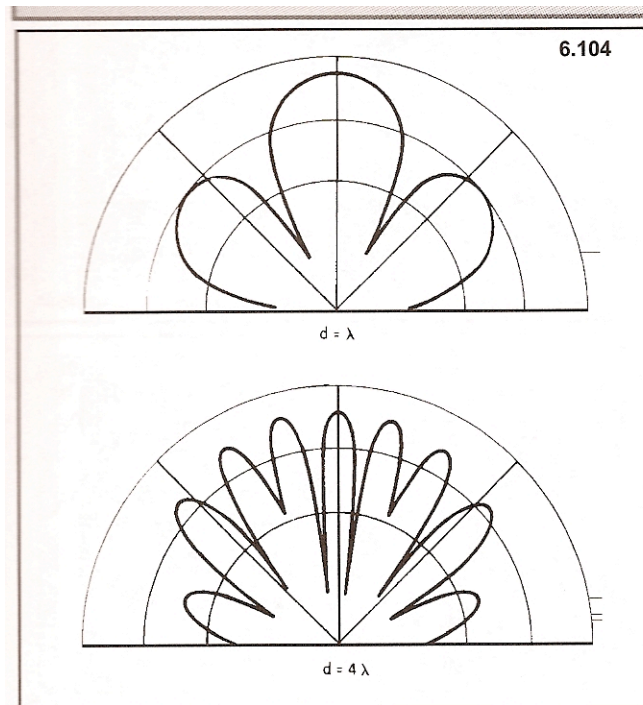
*Figure 12: Air suspension characteristics (note: impedance peak around box resonance)*

<sup>25</sup> Newell, *Loudspeakers for Music Recording and Production*, Pg. 69

<sup>26</sup> Murphy, *Introduction to Loudspeaker Design*, Pg. 25

## B. Driver Placement

Driver placement in an M-T-M configuration is incredibly important. The resulting polar response will vary as drivers are spaced further and further apart. The general rule of thumb is to keep your outside woofers within in one wavelength of the frequencies it needs to produce. Otherwise, extra lobe cancellation will result (See *Figure 13*).



*Figure 13: As the distance between drivers increases beyond 1 wavelength, polar lobe cancellation occurs*

In order to calculate how much lobe cancellation will occur, a simple formula can be used:

$$\text{Wavelength} = \text{Speed of Sound} / \text{Frequency}$$

Therefore

$$1,032 \text{ ft/sec} / 1700 \text{ Hz} = .6 \text{ feet}$$

.6 feet comes out to be about 7.2 inches. This isn't enough room to fit two woofers and a tweeter without some degree of lobe cancellation. 1700Hz was chosen because it is the location of the crossover point in this design.

### C. Combating Diffraction

Diffraction happens when the outside edges of a loudspeaker enclosure, or any other edge for that matter, act as another radiating source. Because of the energy produced by the drivers, the box resonates and each edge acts as a secondary radiating source, resulting in a smeared and inaccurate final sound. In order to discourage any type of diffraction, the drivers will be flush mounted. Also, by placing the drivers outside of the centerline, as shown in *Figure 14*<sup>27</sup>, the distance from the speaker to the outside edges of the box won't be the same. This helps with the overall flatness of your frequency response. For example, when a speaker is located directly in the center, the equal distances to either side result in a summation of the diffraction sources, causing peaks and dips in the frequency response.



*Figure 14: North Creek CM7*

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<sup>27</sup> North Creek Music. < [http://www.northcreekmusic.com/CM-7/CM-7\\_Loudspeaker\\_System.htm](http://www.northcreekmusic.com/CM-7/CM-7_Loudspeaker_System.htm) > (accessed February 23, 2009).

Rounding or beveling the edges will also be done to discourage diffraction that is often caused by sharp edges. Because a rectangle is within my building abilities, more complex box geometries that combat diffraction (sphere) will not be used.

### D. Box Size

The box dimensions were determined in *Winspeakerz*. Although the golden ratio is preferred, they were altered to be more aesthetically pleasing and space productive. In any case, the internal dimensions must be equal to 1 cubic foot. These box dimensions are only a rough estimate and don't take the internal bracing, damping material, and driver magnets into account. This will be modified and finalized before drafting begins. See *Figure 15*.

Box Dimensions and Gross Internal Volume:

Internal Height:  H = 20 inches

Internal Width:  W = 7 inches

Internal Depth:  D = 12.343 inches

Gross Internal Volume: V(G) = 1 cubic feet

Adjustments and Net Internal Volume:

Driver Displacement = 0 cubic feet

Bracing Displacement = 0 cubic feet

Other Displacement = 0 cubic feet

V(B) increase due to Filling = 0 %

Net Internal Volume:  V(B) = 1 cubic feet

Notes:

*Figure 15: Rough Box Dimension*

### E. Bracing and Damping

Box resonances can be particularly tough on the cabinet walls, and will result in unwanted colorations in the loudspeaker. In order to limit the amount of wall resonance, a bracing technique will be employed, and a shelf brace was decided upon because it can support all four walls and won't hinder airflow<sup>28</sup>. Furthermore, a box within a box design employing an inner layer of 3/4" MDF and an outer layer of 3/4" Baltic Birch plywood will be used to vary wall density. Not only will the layers of plywood provide more

<sup>28</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 114

resonance control because of differently aligned layers, but it will also finish nicely. The correct damping will be largely experimental. Because my box will adhere to the brute-force technique<sup>29</sup>, i.e. thick walls and internal bracing, the use of fiberglass or poly-fill will be used to dampen unwanted internal reflections causing coloration to the sound. The correct amount will be determined by listening tests.

## V. Price

The final price was calculated to be about **\$750** total. The final price, in accordance with the prices listed below, may vary as actual construction takes place.

### Drivers

4 x \$76 Midrange

2 x \$40 Tweeters

\$180 Quality crossover components

\$150 Wood and finishes

\$50 Miscellaneous

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<sup>29</sup> Dickason, *Loudspeaker Design Cookbook*, Pg. 113

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- Zaph Audio. < <http://www.zaphaudio.com/> >

## **Appendix A**

### **Tweeters:**

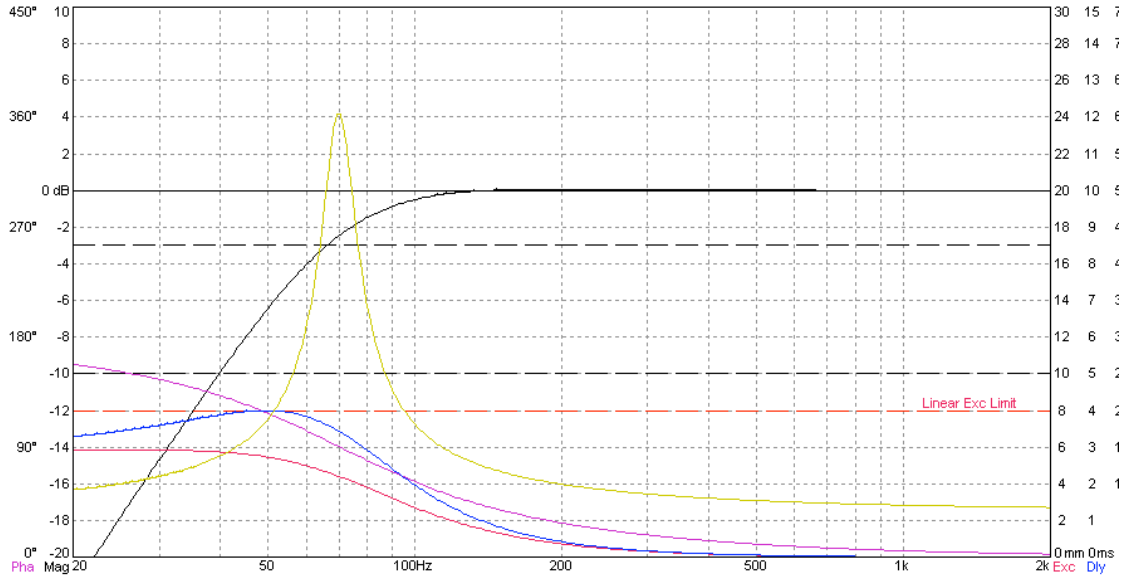
Seas 27TFFC  
Seas 27TDC  
Vifa D27TG  
Vifa XT25TG30

### **Mid-Bass:**

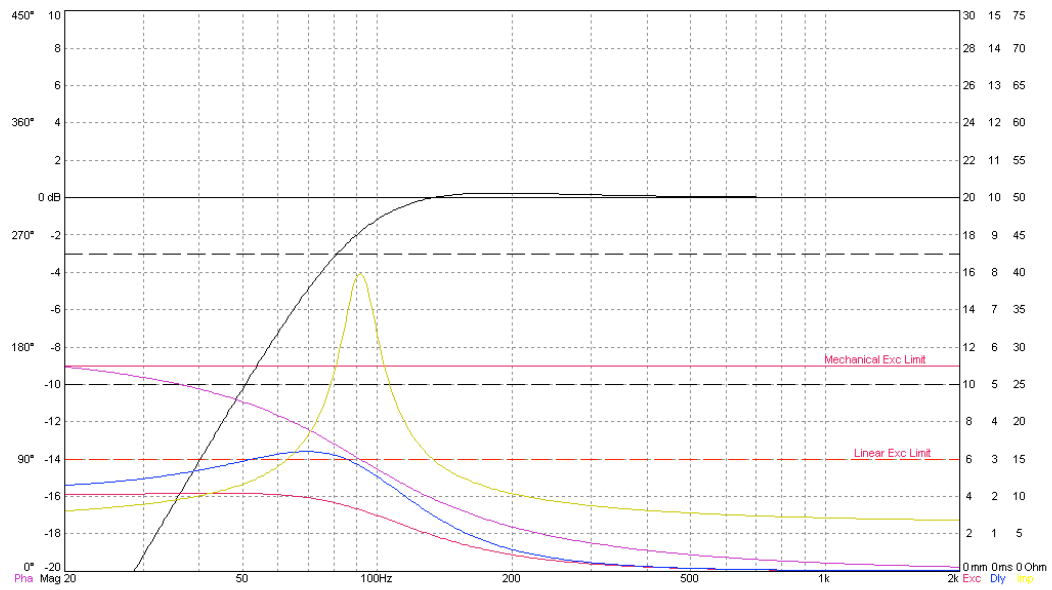
Tang Band W6-1721  
Seas CA18RNX  
Vifa PL18WO  
Peerless HDS

## **Appendix B**

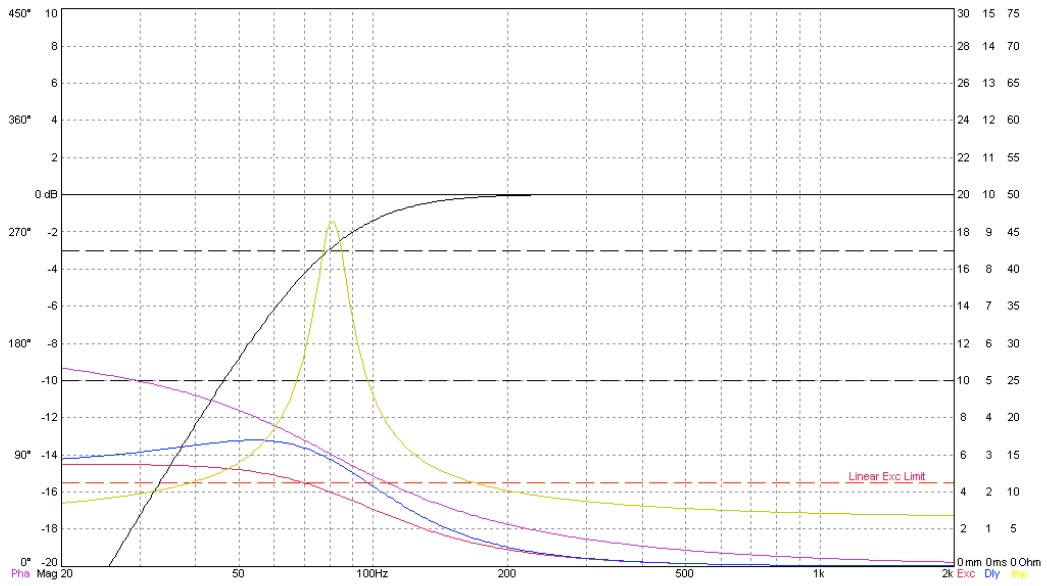
Tang Band W6-1721  
Seas CA18RNX  
Vifa PL18WO  
Peerless HDS



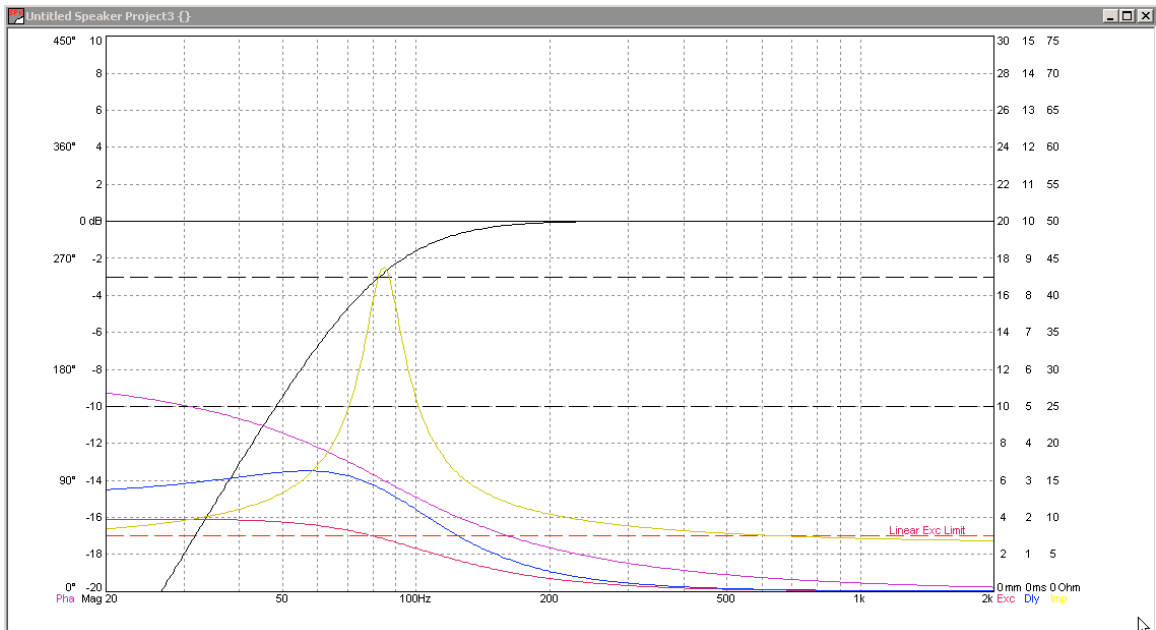
Tang Band W6



Seas CA18RNX



Vifa PL18WO



Peerless HDS