Speaker Design Proposal

Alex Palma

Transducer Theory

Christopher Plummer

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Design Goals

The main goal for the loudspeakers is to function as two-way bookshelf mixing monitors for music and film. These speakers must therefore meet all the necessary requirements that enable professional mixing, but at the same time meet some of my personal preferences. Listed below are the needs they speakers have for mixing:

- Have a flat frequency response (+/-2 dB range)
- Maintain clear and detailed sound
- Have good low extension (an f3 at least at 50 Hz)
- Produce 103 dB SPL to meet the K-20 system standard (83 dB +20 dB of headroom)[1]

When it comes to my personal needs, the speakers need to fit my mixing practices and practical preferences. These include:

- SPL requirements only necessary for 1w/1meter
- Portable enough to travel easily (small enough to carry one at a time)
- Have proper frequency response for sitting level
- Cost less than $500

In addition, the dB SPL level of my mixing does not exceed the standard of 83 dB, so those requirements are unaffected by this. The off axis response of the speakers should not be two bad because the speakers will also be used for casual listening, but mixing is the priority.

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[1] Katz, Bob. "Level 2 Practices (Part 2) (Includes the K-System)." http://www.digido.com/level-practices-part-2-includes-the-k-system.html (accessed 01/15/2011).

Drivers

To start, this speaker design is 2-way, so just a woofer and a tweeter will be used, no midrange. For this particular design, I plan to use a waveguide the tweeter. The waveguide, which is a smooth circular shaped horn, has many advantages that improve a tweeter's sound. The benefit of waveguides in relation to the woofer is that the voice coils can be lined up closer, which decreases time delay between the two drivers output.[2] This will be addressed further on.

Woofer

When it comes to choosing a woofer there are a few initial requirements. Budget is biggest constraint. Since the budget limit for these speakers is $500, I decided that no more than $100 should be spent on a woofer. As for the size of the woofer, I generally looked at woofer's that have diameter between 5 ½" – 8". I felt these sizes would be appropriate for the size of speaker, which will be sized like a bookshelf speaker and be relatively portable. These woofers need provide a good low end, and be able to handle enough power to produce up to 103 dB SPL cleanly. This means that the excursion limit (Xmax) of the woofer needs to be somewhat high for the woofer size, so that the woofer provides a clean clear low end at higher levels. If the excursion limit is how far the cone can travel before it exceeds its limits and distortion arises.[3]

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[2] Newell, Philip. *Loudspeakers: For Music Recording and Reproduction.* 1st ed. Burlington, MA: Elsevier Ltd., 2007. Pg 149.

[3] Murphy, John. True Audio.http://www.trueaudio.com/about_3.htm (accessed 02/20/11)

The woofer's sensitivity must be at least above 88 dB at 1w/1m, so that it can handle a good amount of power without having problems and produce up to 103 dB SPL without it costing too much. The higher the sensitivity, the less amplification is needed. As you can see in figure 4.1, this is very important because the amount of watts needed increases exponentially while the SPL increase stays constant.

Amplifier power (Watts)	Increase in speaker output (dB) created by given wattage (at 1 meter or 3.3 feet)
1	Rated Speaker Sensitivity
1.25	+1
1.6	+2
2.	+3
2.5	+4
3.1	+5
4.0	+6
5.0	+7
6.3	+8
8.0	+9
10	+10
12.5	+11
16	+12
20	+13
25	+14
31	+15
40	+16
50	+17
63	+18
80	+19
100	+20
125	+21
163	+22
200	+23
250	+24
310	+25

Figure 4.1 The SPL level only increases by 3 dB for every doubling in wattage.[4]

With this in mind, higher sensitivity drivers need less wattage to produce higher levels. This saves money because a less powerful amplifier can work.

[4] Applegate, Bob. "The Importance of Loudspeaker Sensitivity *Integrated Audio Systems, Inc.*".2, http://www.integratedaudio.com/help/sensitivity (accessed 01/19/1011).

The last few big requirements for the woofer are to have a flat frequency response, good low extension, and a smooth high break-up. These last few needs are very important, and easy to find. These are critical for deciding if a woofer is worth looking further into. After looking through a large variety of woofers, I found a few that stuck out. Over the next few pages there are specifications, modeling in *Winspeakerz*, and analyses of each of the top choice woofers. The initial modeling shown for each driver is set up with a Quasi-third order alignment. I used this to calculate the suggested box size and tuning that would give the driver a good performance.[5] The in models further down on the page the size and frequency is tweaked to get better low-end extension.

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[5] Dickason, Vance. The Loudspeaker Design Cookbook. 7 ed. Peterborough, NH: Audio Amateur Press, 2006. p. 62-69.

SCAN-SPEAK DISCOVERY 22W/4534

8" WOOFER ($82)

Electrical Data

Nominal impedance	Zn	4	ohm
Minimum impedance	Zmin	3,7 / 188	ohm
Maximum impedance	Zo	29,9	ohm
DC resistance	Re	3,0	ohm
Voice coil inductance	Le	0,42	mH

T-S Parameters

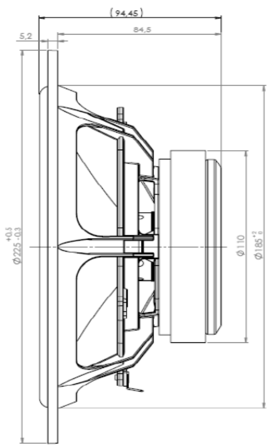
Resonance Frequency	fs	25,0	Hz
Mechanical Q factor	Qms	5,07	
Electrical Q factor	Qes	0,30	
Total Q factor	Qts	0,28	
Force factor	Bl	6,40	Tm
Mechanical resistance	Rms	0,80	Kg/s
Moving mass	Mms	25,8	g
Suspension compliance	Cms	1,57	mm/N
Effective cone diameter	D	17,3	cm
Effective piston area	Sd	235	cm2
Equivalent volume	Vas	122,5	ltrs
Sensitivity (2.83V/1m)		92,4	dB

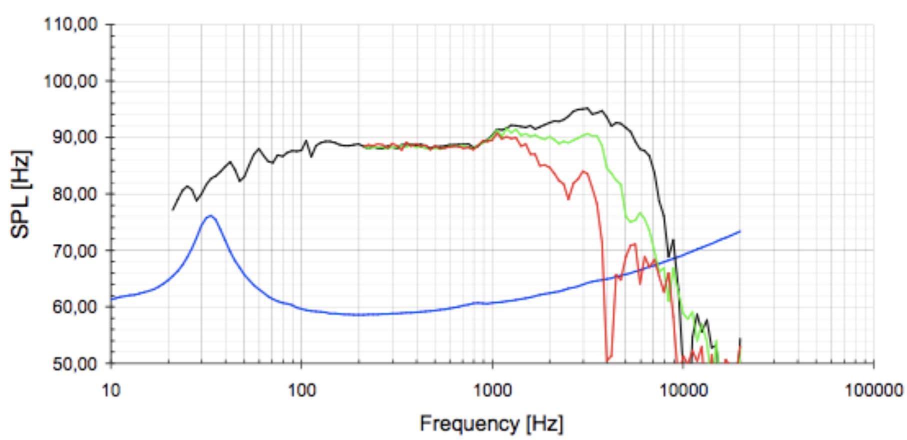
Power Handling

100h RMS noice test (IEC)	70	W
Long-term Max Power (IEC18.3)	120	W

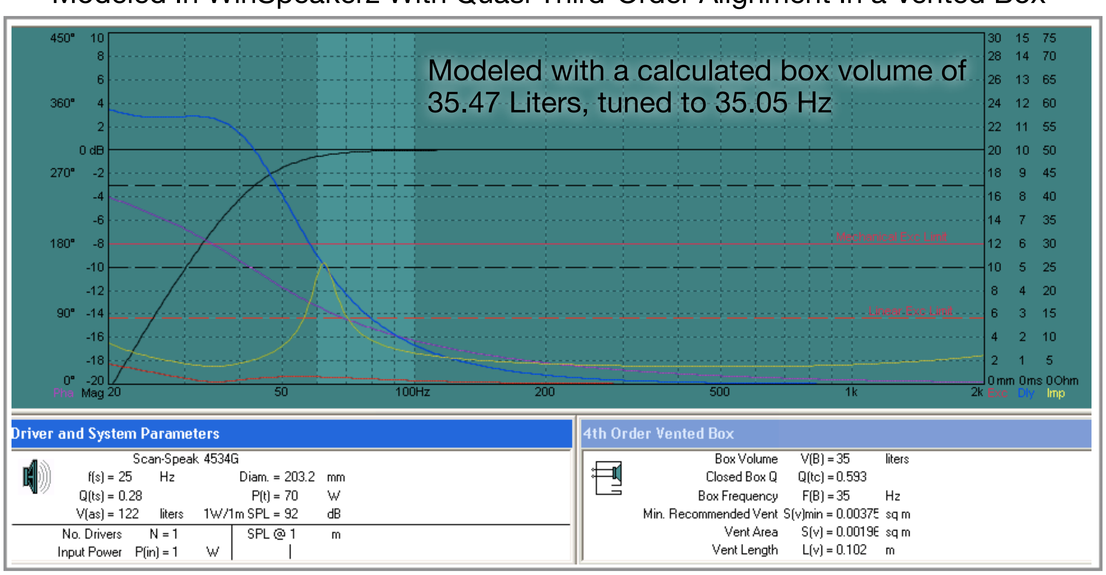
Voice Coil and Magnet Parametres

Voice coil diameter	38,0	mm
Voice coil height	17,3	mm
Voice coil layers	2	
Height of gap	6,0	mm
Linear excursion +/-	5,7	mm
Max mech. Excursion +/-	12,0	mm
Diameter of magnet	110,0	mm
Height of magnet	18,0	mm
Weight of magnet	0,70	Kg
Unit net weight	2,1	Kg



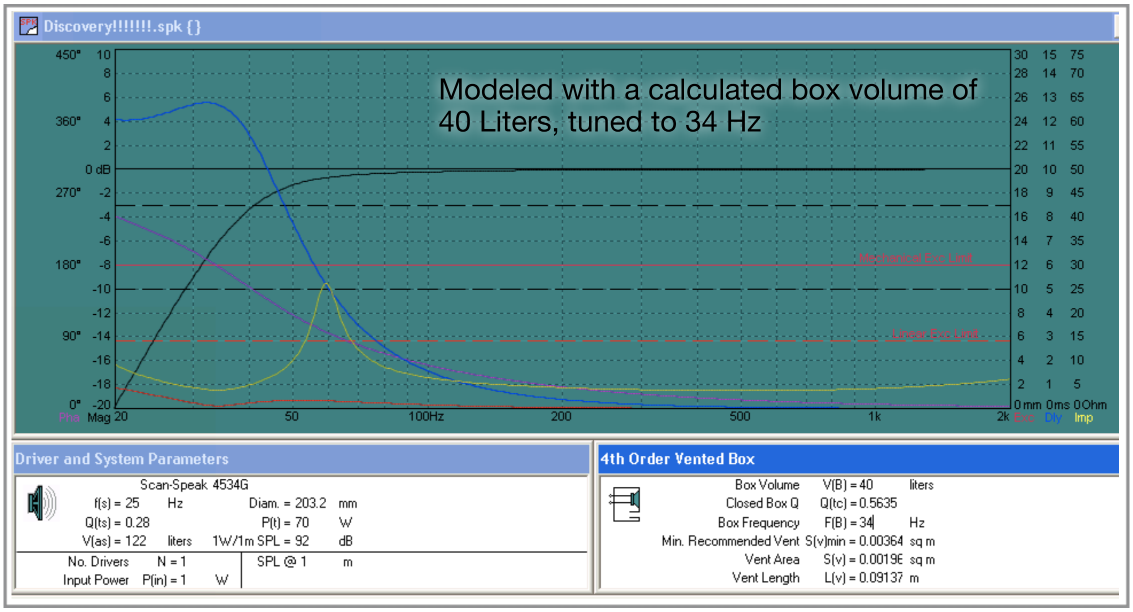


Modeled In WinSpeakerz With Quasi Third-Order Alignment In a Vented Box

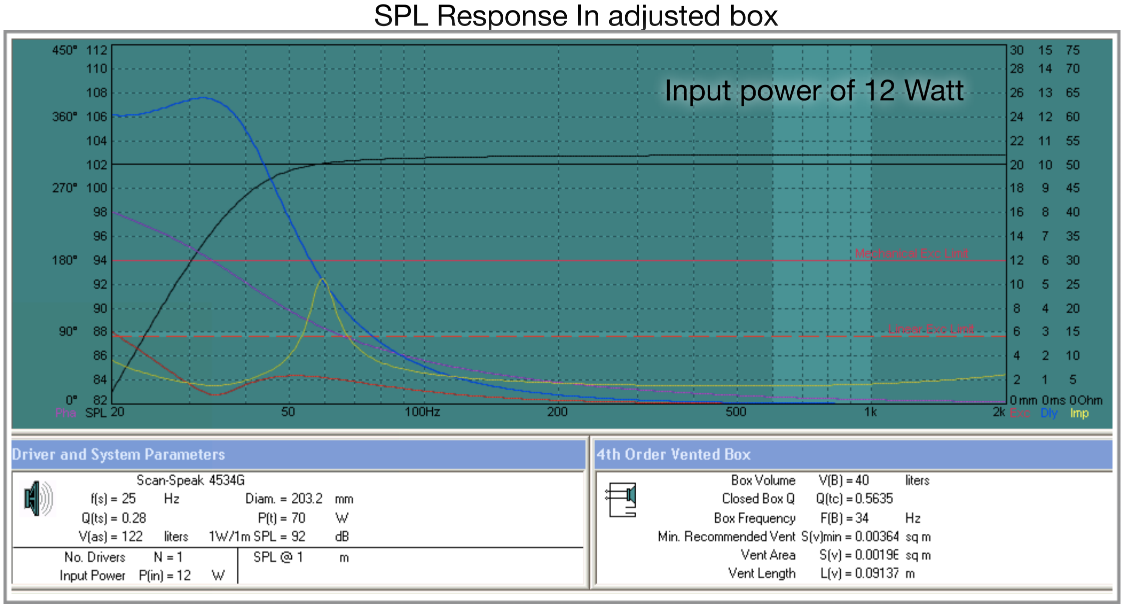


https://www.madisound.com/store/product_info.php?products_id=8771

Modeled With adjustments in box size and tuning



SPL Response In adjusted box

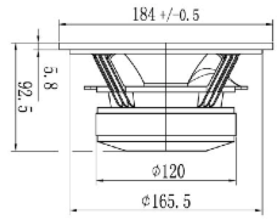


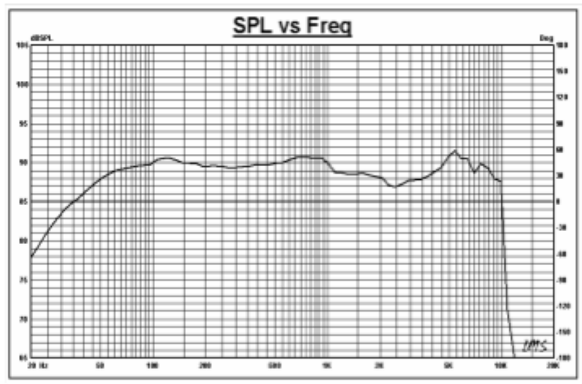
PROS	CONS
This woofer's strengths lie in its power handling ability and low extension. As we can see in the SPL response it can handle 12 watts with no excursion problems. This is very good because the speaker can reach the desired SPL level of 103dB at 1 meter while still having 3 mm of room for the woofer's excursion. The modeled performance of the low end is good because it has an F3 at about 41 Hz and rolls off at about 14dB/octave. The response is flat up to 1K, which is good because the crossover will probably be a little above this. The woofer's on axis break up is relatively smooth. Other pros include an acceptable box size, good sensitivity, and high extension for a good crossover. Also, the impedance bump is nice and low.	This woofer is on the upper end of the budget (costing $82). The off axis responses don't have very smooth break ups, the group delay is at around 11 ms at the F3, which could be better. If the box size is increased further than 40 Liters the quality of the low end starts to decrease quickly.

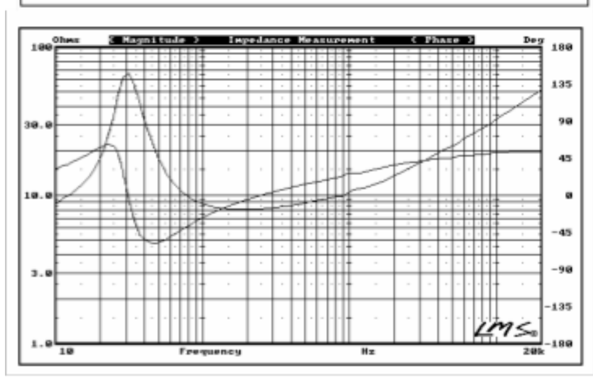
https://www.madisound.com/store/product_info.php?products_id=8771

AURUM CANTUS-180F1

7" MID/WOOFER ($82)

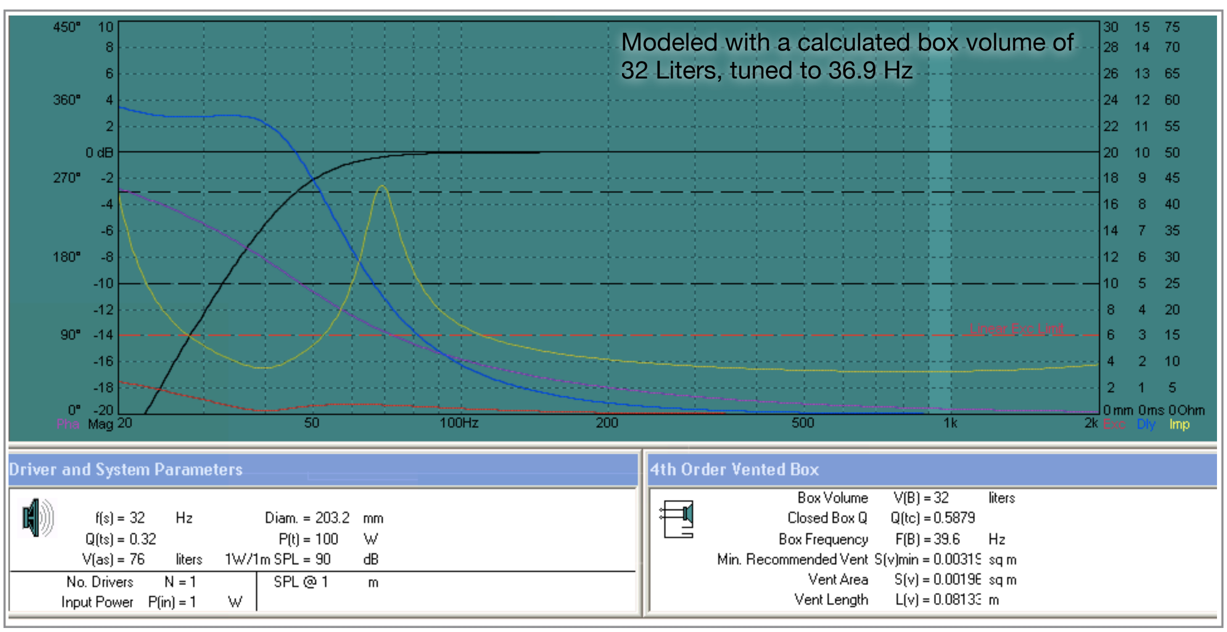






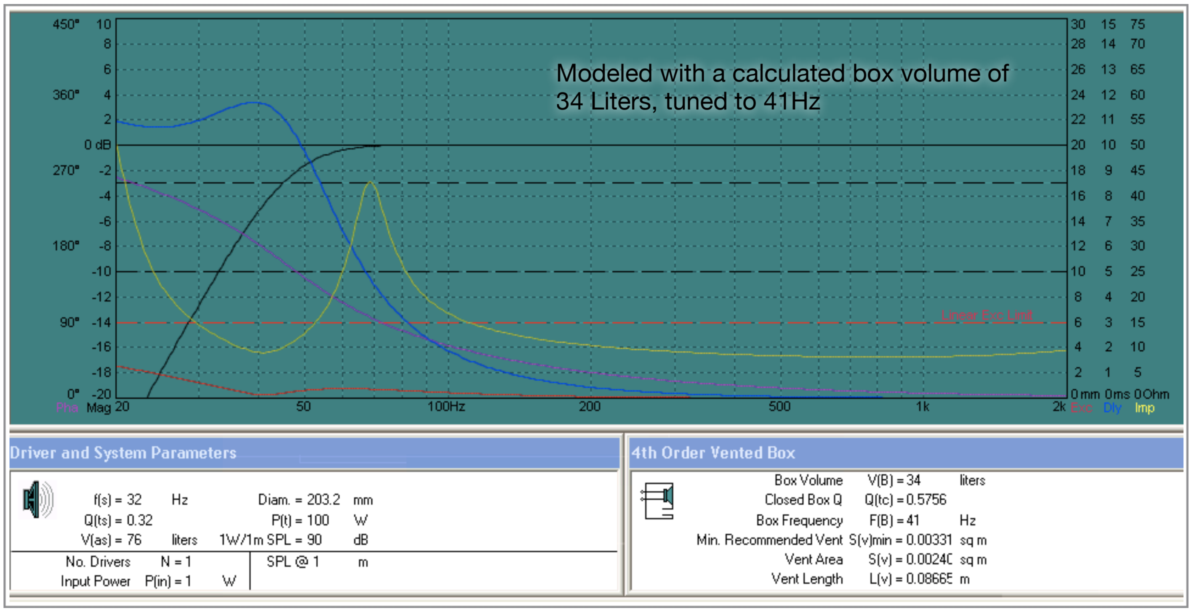
Nominal power	P	100	W
Sensitivity 1W/1m	SPL	90	dB
Nominal impedance	Z	8	Ω
Frequency range	–	32~5000	Hz
Resonance frequency	F0	32	Hz
DC resistance	Re	7.0	Ω
Mechanical quality factor	Qms	3.05	–
Electrical quality factor	Qes	0.36	–
Total quality factor	Qts	0.32	–
Equivalent volume of air	Vas	76	L
Moving mass	Mms	15.4	g
Effective piston area	S	168	cm^2
Mechanical suspension compliance	Cms	1.89	mm/N
BL product	BL	7.2	N/A
Flux density	B	1.13	T
Voice coil diameter	Φ	35	mm
Voice coil height	H	15	mm
Voice coil inductance	Lbm	0.48	mH
Linear excursion	Xmax	±6	mm
Magnet diameter	Φ	120	mm
Magnet height	H	20	mm
Frame	–	Aluminum	–
Net weight	M	2.20	kg
Outer dimensions	–	184×184/Φ204	mm
Cutout dimensions	Φ	169	mm
Flange thickness	T	5.8	mm
Overall depth	D	92.5	mm

Modeled In WinSpeakerz With Quasi Third-Order Alignment In a Vented Box

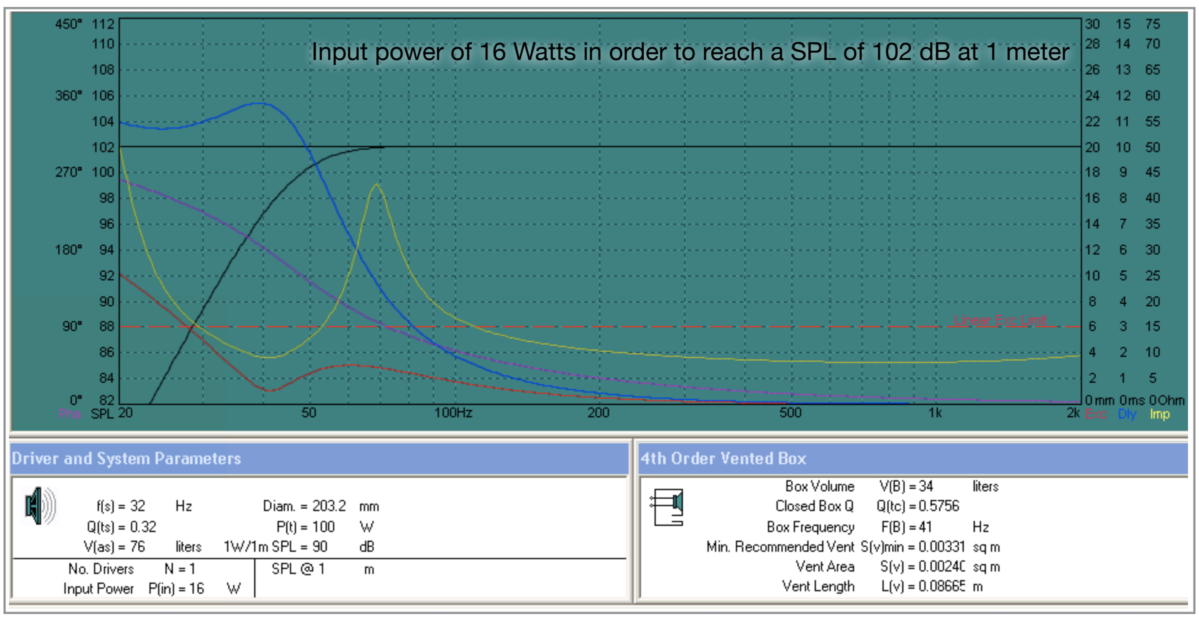


http://www.parts-express.com/1/1/9055-aurum-cantus-ac180-50c2c-7-woofer.html

Modeled With adjustments in box size and tuning



SPL Response In adjusted box



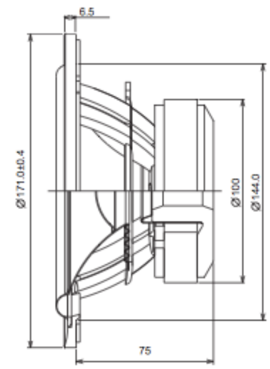
PROS	CONS
The frequency response to this driver is decent as it is very flat up to about 1K. The box size is an acceptable size and smaller than the Discovery. The break up of this driver is very smooth and cuts off abruptly, which would make it easy to crossover. Also, the group delay is sort of low compared to the other drivers.	There is a dip in the frequency response centered around 2K which could present difficulties if the crossover is above that frequency. The impedance bump is not small around 700 Hz. The modeled F3 of the driver is at 45Hz, which could be lower.

http://www.parts-express.com/1/1/9055-aurum-cantus-ac180-50c2c-7-woofer.html

SB ACOUSTIC SB17NRXC35-8-UC

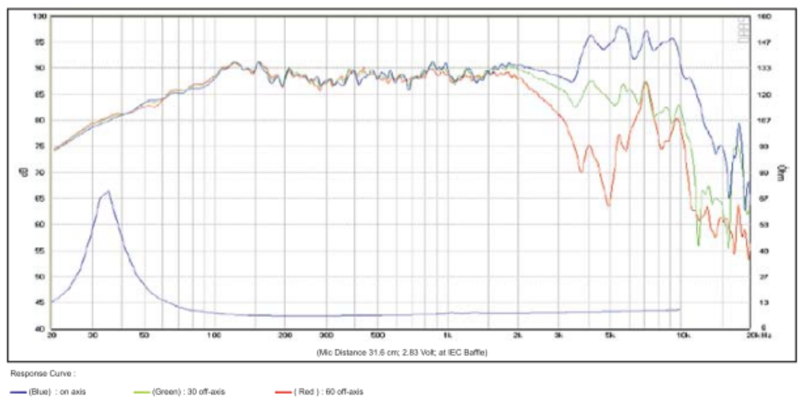
6.5" WOOFER ($61)

Free air resonance, Fs	32 Hz
Sensitivity (2.83 V/1m)	89 dB
Mechanical Q-factor, Qms	5.0
Electrical Q-factor, Qes	0.36
Total Q-factor, Qts	0.34
Moving mass incl.air, md	11.0 g
Force factor, Bl	5.9 Tm
Equivalent volume, Vas	44.5 liters
Compliance, Cms	2.25 mm/N
Mechanical loss, Rm	0.44 kg/s
Rated power handling	60 watt

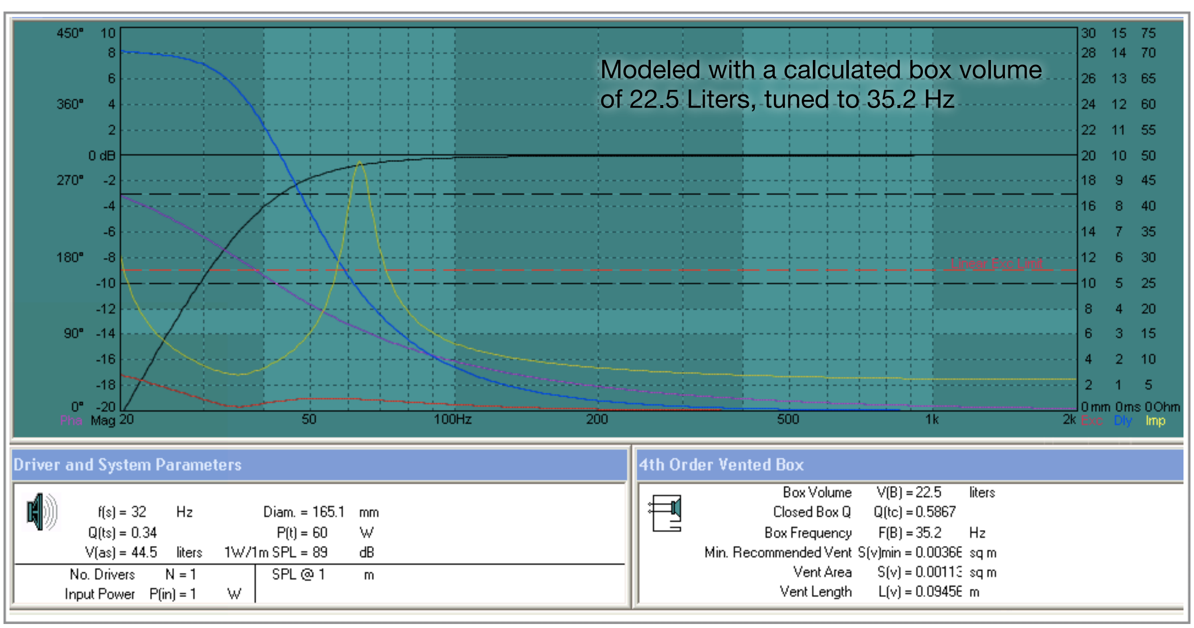


Nominal Impedance	8 Ω
DC resistance, Re	5.7 Ω
Voice coil inductance, Le	0.15 mH
Effective piston area, Sd	118 cm^2
Voice coil diameter	35.5 mm
Voice coil height	16 mm
Air gap height	5 mm
Linear coil travel (p-p)	11 mm
Magnetic flux density	1.0 T
Magnet weight	0.54 kg
Net weight	1.56 kg

The parameter are measured on drive units that are broken in



Modeled In WinSpeakerz With Quasi Third-Order Alignment In a Vented Box



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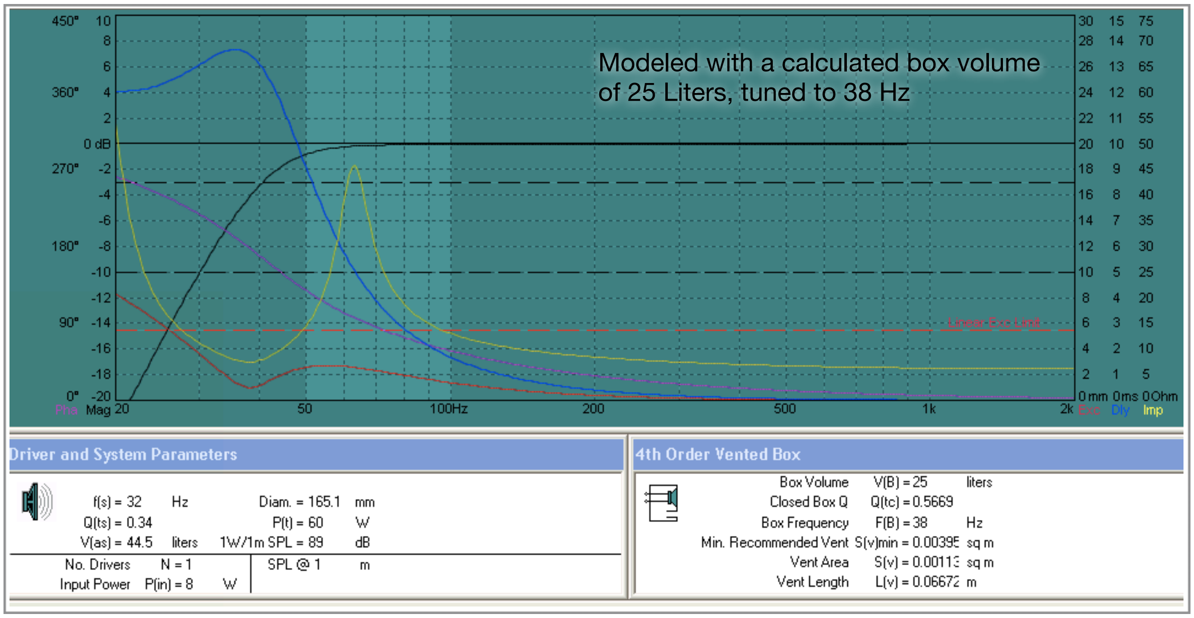
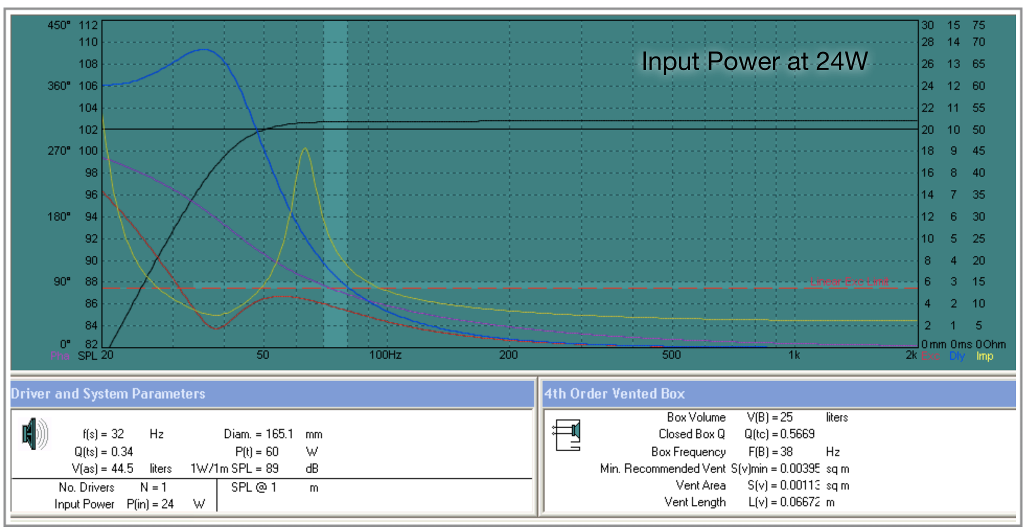
Modeled With Adjustments



SPL In Adjusted Box



PROS	CONS
This woofer has an excellent frequency response that is fairly flat all the way up to 3k. The box volume modeled for this driver is only 25 liters, which would provide a very portable box size. The F3 is modeled to be at about 40 Hz, which is very good especially for the box size. The impedance peak on the spec sheet is very low, although the modeling shows different. This woofer's price of $62 is a very affordable for its performance.	The low end roll-off could be down to 35Hz if the the box size is made larger, but the impedance, group delay, and phase start to go out of control. With these pushed too far, the low end would start to smear and become boomy. In seeing this, the driver seems to be made for a small enclosure. With this in mind, in order for the driver to reach a peak level of 103dB at 1m, it would need 24 watts. This brings the excursion around 50 Hz up too high, within 1 mm of the linear excursion limit. The break up on this woofer is particularly unusual, especially since the off axis break up is smoother than the on axis response. Also, the impedance bump at around 60 Hz is somewhat large.

https://www.madisound.com/store/manuals/SB17NRX35-8-UC.pdf

After going through the analysis of these three I decided to go with the Scan-Speak Discovery 22W/4534 8” woofer. Compared to the others, as you can see in the pros and cons sections, this driver has the best power handling of the three, has a solid f3 at 41Hz. For the least amount of wattage input, the best results are received. In addition, the impedance bump for the Scan-Speak was much lower than the impedance bumps on the other drivers. Although the bass extension that the SB Acoustic has is greater than the Scan-Speak, I found when adjusting the Scan-Speak’s enclosure that the driver is meant for a small box. Whenever I tried to make the box bigger the group delay, impedance, and phase would start to get drastically worse. The f3 is therefore only 40Hz instead of the tempting 36Hz that could jeopardize the low end’s integrity. The drives all read decent, but the Scan-Speak really showed through with the sensitivity, freedom of excursion issues, power handling, and loudness. This driver dictates the size of the box for the most part. The best alignment found using *Winspeakerz* would give us the volume of the box for the best results with that driver. The volume found to work best is 40 Liters, and addressed further on.

Tweeters

The goals for the tweeter consist of a flat response, be under $60 to fit the budget, and that it has to be a dome tweeter in order to work with a waveguide. The tweeter also has to roll off lower than 5k in order crossover well with the selected woofer. After much searching, I narrowed it down to two tweeters: the Vifa D27TG, and the SEAS Prestige 27TDFC. The two tweeters have very good flat responses, and they roll off low enough to work with the woofer. Going with the Vifa's would saver $20, and the tweeter has a very similar sensitivity to the woofer of 91 dB 1w/1m. The SEAS Prestige has a slightly better impedance and shallower low roll off. One of the big factors is that Zaph Audio's demo with the waveguide uses the SEAS Prestige 27TDFC, and it is very successful[6]. This tweeter works well with the waveguide, and his design proves effective. This will also give me a peace of mind that the tweeter will not utterly fail with the waveguide like another tweeter might. The frequency responses are shown below.

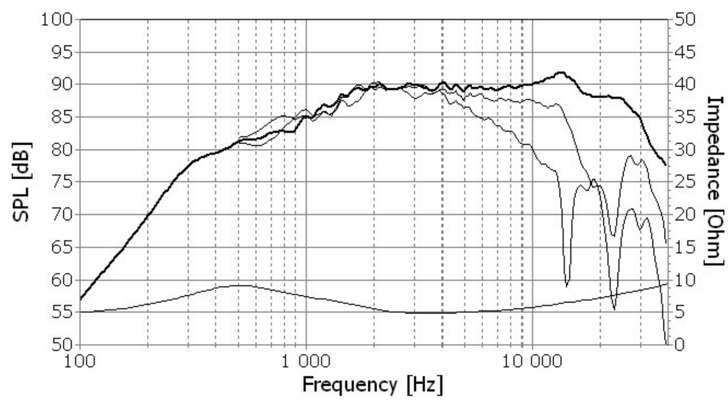


Figure 13.1 Seas Prestige 27TDFC ($42) frequency response[7]

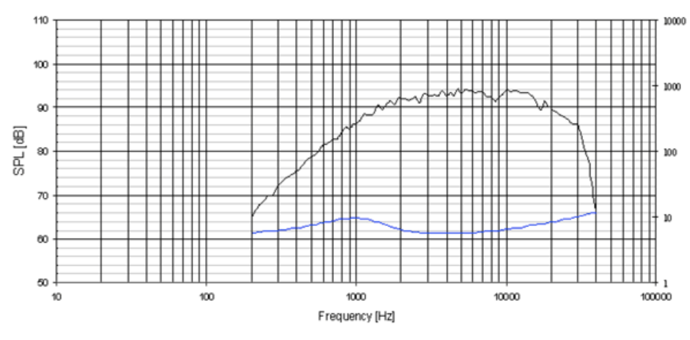


Figure 13.2 Vifa D27TG35 ($32) frequency response[8]

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[6] Krutke, John "Zaph". *Waveguide TTM*. http://www.zaphaudio.com/Waveguidetmm.html (accessed February 19, 2011)
[7] Madisound. https://www.madisound.com/store/product_info.php?products_id=792 (accessed February 19, 2011)

Waveguide

For understanding how the waveguide can work and what its benefits are, I closely monitored John "Zaph" Krutke's design of the 3-way speakers called Waveguide TTM. The waveguide in this case provided a variety of benefits such as a better off-axis response, better voice coil alignment with the woofer, boosts the power handling, boosts the frequency response, and less circuitry for a steeper tweeter roll off.[9] The improved voice coil alignment means that the woofer and the tweeters' coils would be closer together, thus providing a better transient response. The waveguide disperses the sound and also helps reduce diffraction because it has an enlarged smooth exit from the baffle.

Waveguides are very cheap, around eleven dollars, but there are not very many of the right kinds available. The type desired, as you can see in figure 16.1, is circular and shaped nothing like a horn. When looking for waveguides I could only find two that were usable: a Dayton 8" and the MCM "Threaded horn lens".

[8] Madisound https://www.madisound.com/store/product_info.php?products_id=1086 (accessed February 19, 2011)
[9] Krutke Waveguide, 10.

Figure 14.1 MCM 6 1/2" diameter x 2 3/16" depth[10]

With a waveguide mounted, by calculating the displacement between the woofer and the tweeter one can predict a sharp dip in the response. The difference between the two voice coils predicts where this dip is along the response. For example, the depth of the voice coil on the Discovery is .094 m. Now, when dividing 340 (speed of sound) by this we get a wavelength of 3,6k. Adding the MCM to the system changes this displacement of .094 m to .040 m. clears up the phase issues and moves the dip up to 9.6k. The 8" Dayton waveguide would line up the tweeter and the woofer even closer, about .020 m, but it is a narrower waveguide so it might have a slightly cupped horn type to its sound. Zaph Audio discourages people from using either or the 8" or 10" Dayton waveguides because they lose some of the advantages that the 6 ½" like flatter response and wider dispersion of sound.[11]

With these in mind, I decided to go with the 6 ½" MCM waveguide. If the delay is still an issue the speakers could just be raised off the ground the appropriate the level, or a delay network could be set up. Although, it would be preferable not to set up a delay network.

Crossover

One of the most important parts of speaker design is the crossover. It consists of a network of resistors, capacitors, and/or inductors to filter the high

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[10] MCM electronics. http://www.mcmelectronics.com/product/DISTRIBUTED-BY-MCM-H-65-/54-580 (accessed February 19, 2011)

[11] Krutke, John "Zaph". *Home Conversion*. http://www.zaphaudio.com/hornconversion.html (accessed February 19, 2011)

end of the woofer and the low end of the tweeter so that they can mesh together seamlessly.[12] Even though I can plan how my crossover will be constructed now, the contents in it are subject to change during the tuning phase in order to get the best response out of my speakers.

The crossover I plan on using will be a slight variation on Zaph Audio's *Perfectionist* crossover that he used with his speakers that utilize waveguides. According to his tests, when a 3.3uF Capacitor is added to the tweeter with the waveguide it creates a 2nd order roll off slope, even though only one capacitor is being used.[13] This is good because it means fewer filters are needed, which in turn gives you a cleaner and stronger signal. You can see the responses with or without the capacitor below for the SEAS Prestige 27TDFC.

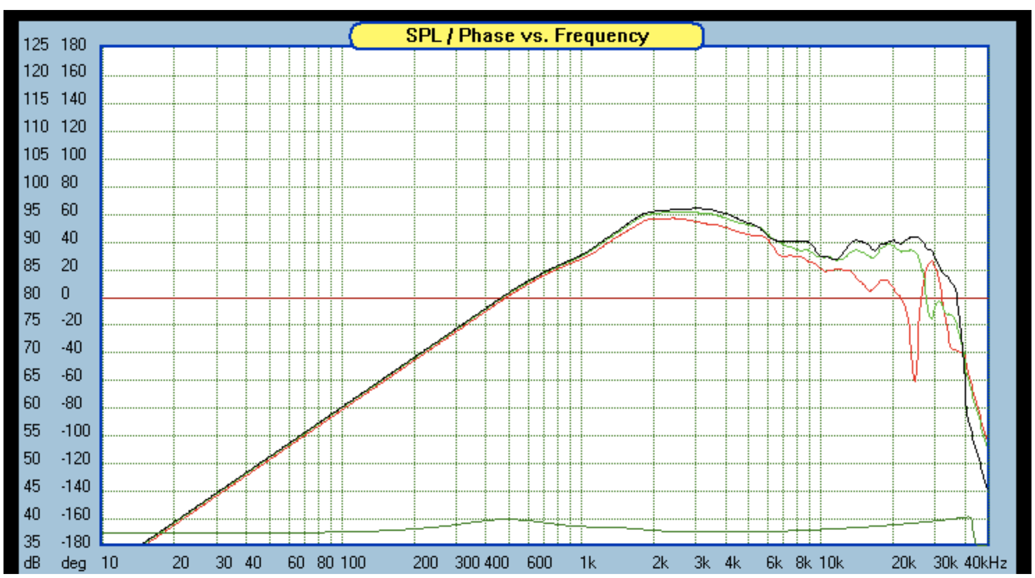

Figure 15.1 Frequency response of tweeter with waveguide[14]

[12] Newell, Philip. *Loudspeakers: For Music Recording and Reproduction.* 1st ed. Burlington, MA: Elsevier Ltd., 2007.
[13] Krutke, 3. *Home Conversion.*
[14] Krutke, 3. *Home Conversion.*

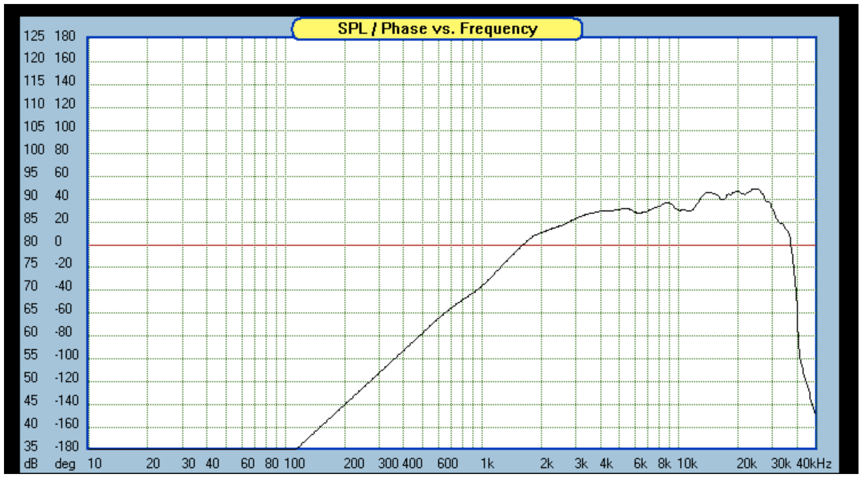

Figure 16.1 Frequency response of tweeter with waveguide and 3.3uF capacitor[15]

This convenient 2nd order roll off, with a slope at about 1.9k, is very smooth and will be very simple to construct.

As for the woofer's roll off I plan to use a 2nd or 3rd order crossover. I plan at crossing the drivers over at about 2k, since it is higher than the tweeter's impedance and seems appropriate. This will be tested during the tuning phase and I will see which tuning and crossover frequency works best. As of now, a 2nd order slope looks like the type of slope that Zaph Audio uses in his design. As one can see in figure 17.1, when loosely plotted, the summation does not have a noticeable bump in the frequency response at all. *The Perfectionist* crossover that Zaph Audio uses, as you can see in figure 17.2, works very well to create a clean crossover and a flatter frequency response than other crossovers.[16] During tuning I will look into making a version of this that works with a 2-way system instead of a 3-way. If this is causing too many problems, I

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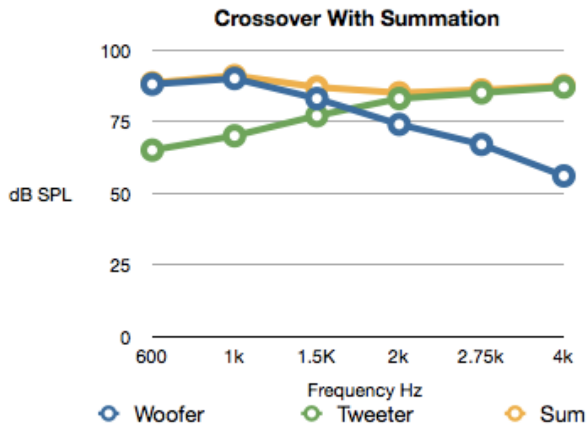
[15] Krutke, 4. *Home Conversion.*
[16] Krutke, 6. *Home Conversion.*

will fall back on a simple 2nd order crossover for the woofer and go from there (see figure 17.3).



	600	1K	1.5K	2K	2.75K	4K
Woofer	88	90	83	74	67	56
Tweeter	65	70	77	83	85	87
Sum	88.5	91	87	85	86	87.5

Figure 17.1 The woofer and tweeter with 2nd order crossovers

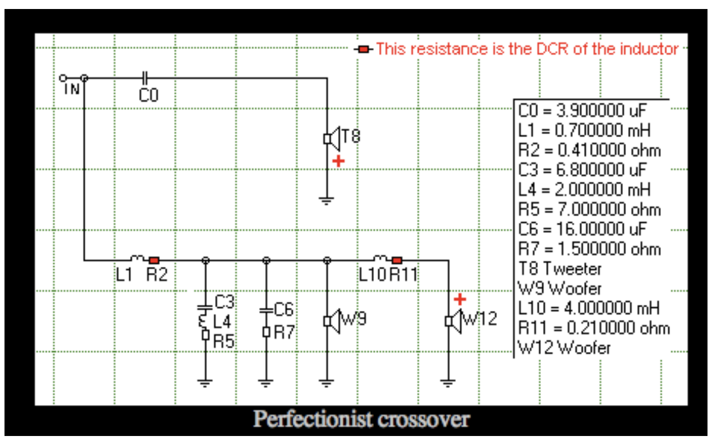


Figure 17.2 Zaph Audio's perfectionist crossover for his 3-way waveguide design[17]

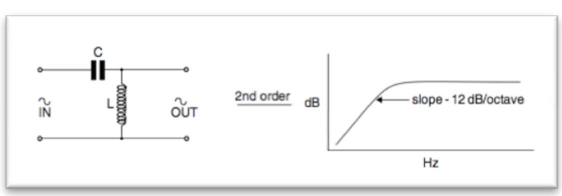


Figure 17.3 2nd order crossover with slope[18]

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[17] Krutke, 6. *Waveguide TTM.*

Enclosure

One of the biggest decisions when building a pair of loudspeakers is whether it is going to be a vented box or a sealed box. Below is an analysis of the tradeoffs.

	Vented/Ported Box	Sealed Box
Pros	Can increase the bass extension with adjusting the box size, adjustable box frequency.	Superior transient response, tighter phase, less delay, smooth low-end roll off.
Cons	Vent leakage, more phase shift, more group delay, more complex impedance curve, and more complex excursion response.	Box size has to increase to improve bass extension High Fs in smaller enclosures, may have issues with pressure change and durability over time.

Figure 18.1 These are the basic tradeoffs of the two enclosure types[19]

After understanding the pros and cons of the two types I decided to go with the vented box type. I did this because I need to have the extra low end since I am designing mixing monitors, yet I also need them to be somewhat portable. This bass extension is the most important deciding factor; although another benefit will be that I will be able to adjust the tuning frequency of the box. This is important to me, as I want to have as much room for correction because this is the first set of loudspeakers I am building.

When addressing loudspeaker enclosures the shape is very critical. A well-known study shown in figure 18.1 shows the responses of different enclosure shapes.

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[18] Newell, 155

[19] Murphy, John L. *Introduction to Loudspeaker Design.* 2nd edition. True Audio, 1998 p. 27

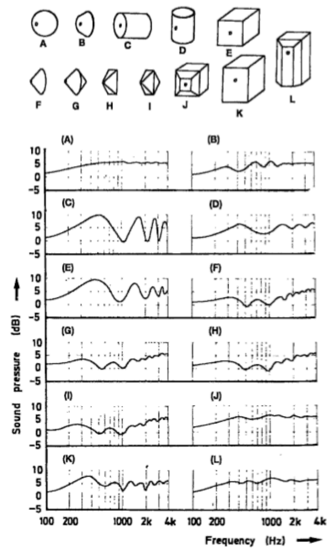

Figure 18.1 Response of different enclosures[20]

As one can see, the spherical enclosure produces the best response, but this would be very difficult and expensive to construct. Based on the box's responses I decided to go with a rectangular enclosure. In addition, most loudspeakers are built in this shape, which provides a sense of security for my design. Although, the rectangular box with the angled edges has an even flatter response than the simple rectangle. With this in mind, I plan on at contouring the front edges of the rectangle. This will hopefully improve the response and help with midrange diffusion, which can be a problem.

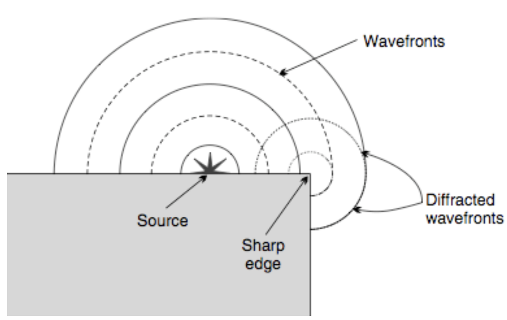

Figure 19.1 Sharp edges cause problems as diffracted waveforms clutter the sound source

[20] Newell, 89.

Based on what enclosure volume best supports my woofer choice, I need a volume of 40 liters. When it comes to rectangle enclosures, there is a mathematical way of obtaining dimensions. The goal is to avoid creating a rectangle that is very close to a cube, as many standing waves will be present. The tool to use is the Golden Ratio of 1.62 : 1 : .62.[21] To calculate the internal dimensions I addressed a table that provides dimensions based on an appointed volume.[22] I found that the internal dimensions of the enclosure should be 22.23” (H) x 8.49” (W) x 13.74” (D). An extra inch to the internal width will be added to help compensate for the volume of the contents in the box.

For the vent, I planned on going with a short pvc tube with a diameter of 1.5”. The tube must be fairly small as to stay out of the way of any dampening placed in the enclosure, and I wanted to avoid having the tube be too short to cut properly. I plan on starting out with 4” ports, and I will cut them down as needed to improve the low end extension.

Driver Placement

Since I am trying to align the voice coils of the woofer and tweeter very close so I can mix with the speakers at ear level the drivers need to be placed evenly on the baffle too. The tweeter and woofer will be vertically aligned to promote a balanced amount of both drivers at a centered ear level position. Having the drivers placed different distances from each edge can help reduce diffraction because different frequencies reflect if there are a variety of distances

[21] Murphy, 87-89.
[22] Murphy, 89.

from the edge of the woofer to the edge of the baffle. The incentive to avoid placing them centrally is that if all of the distances were the same, then they would reflect the same frequencies making it more noticeable. Due to the baffle shape of speaker, even though the woofer will be centrally aligned the only dimensions that will be the same are the distances to the two sides. I plan on contouring the side edges to deal with this. Some other reasons for my decision are that I feel it is more visually pleasing if they are placed centrally, there is better time alignment, and since I am using a waveguide I really won't have to worry about diffraction anywhere above the crossover point.

Bracing and Dampening

To improve the loudspeaker's structure and stability I plan on using two sheets with cut bout areas that will be placed in the box. The basic goals for these two bracing pieces are that they do not restrict airflow to the woofer or port, and that they don't take up too much volume (that would decrease the low end extension). One of the braces would be placed horizontally with a large area cut out of the middle. It will be placed in between the woofer and the edge of the waveguide. In addition for supplying extra support it can help keep various dampening material by the tweeter and away from directly behind the woofer. The other one of the braces would be as wide as the enclosure and be placed parallel to the baffle in the middle of the enclosure. This would have a large area cut out directly behind the woofer to promote good airflow.[23] This is very important because I plan on placing the vent at the bottom rear area of my

[23] *Cabinet Handbook*. 2nd edition. Old Forge, NY: North Creek Music Systems, 1992. 10. Print.

box. The braces will be ¾" thick plywood and glued into place. The thickness is not particularly important, but plywood provides good structural integrity.[24] As for dampening, I plan on surrounding the tweeter, the port, and most of the walls with fiberglass. I plan on setting the fiberglass about a half an inch from touching the back wall. Therefore the sound has to travel through the fiberglass twice, once to get through it and once to get back.

As for the wood used for cabinet, I plan on using two layers. Each side will have ¾" inches of plywood, then a layer of loaded vinyl, and then on the outside a ¾" layer of MDF. This style of layering is highly absorptive because the sound transfers very poorly through the three very different types of material. This type of layering is highly recommended.[25]

The reason the MDF is on the outside is because I plan on painting the box, and MDF is easy to paint. I plan on painting the enclosure solid white, and eventually get artistic stencils or designs painted on to them.

Baffle Step Correction

High and low frequencies do not radiate the same in a given space. The high end is projected more directionally foreword in half space, but the low end less directionally radiates into full space. This produces a shift in the response of about -6 dB from the highs to the lows. This loss of bass can be compensated for through Baffle Correction Circuit.[26] This circuit will be added

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[24] North Creek, 9.
[25] North Creek, 7.
[26] Murphy, John L. (2000, June). Loudspeaker diffraction loss and compensation. Retrieved from http://www.trueaudio.com/st_diff1.htm

before all other components related to the woofer. I used an online Baffle Step calculator to determine the values of the circuit's components (R_{bsc} and L_{bsc}). The schematic of the circuit is shown in figure 23.2

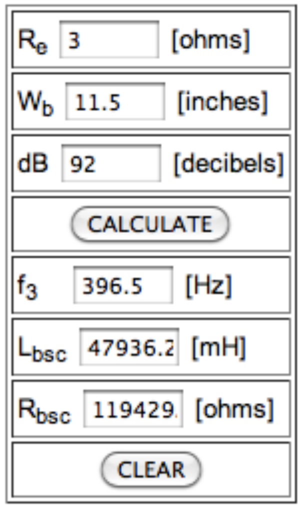

Figure 23.1 Baffle step calculator[27]

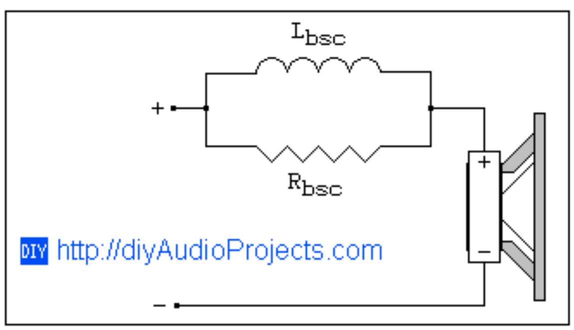

Figure 23.2 Baffle Step Correction circuit.

[27] Difraction loss / baffle step compensation. (2008, March 29). Retrieved from http://diyaudioprojects.com/Technical/Baffle-Step-Correction-Circuit-Calculator/ (accessed February 21, 2011)

Costs:

Here is an overview of expenses. Keep in mind some of these values are estimated.

Item	Quantity	Price	Total
Scan-speak Discovery 8" Woofer	2	81.60	$163.20
Seas Prestige TDFC Dome Tweeter	2	42.40	$84.40
MCM Waveguide	2	11.99	$23.98
Crossover			$100
Wood			$80
Extra materials			$50
		Total	$501.50

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