# Final Design Statement

Transducer Theory

2/17/11

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After much research and revising of goals I have arrived at a plan for my speakers. This speaker design exhibits qualities of simplicity and usability in a midsize box for quality listening.

**General Specifications:**

2-Way vented box
Volume of 20 Liters
Playback of 80 dB with 14 dB headroom
+/- 2 dB response from 45 Hz - 20 kHz

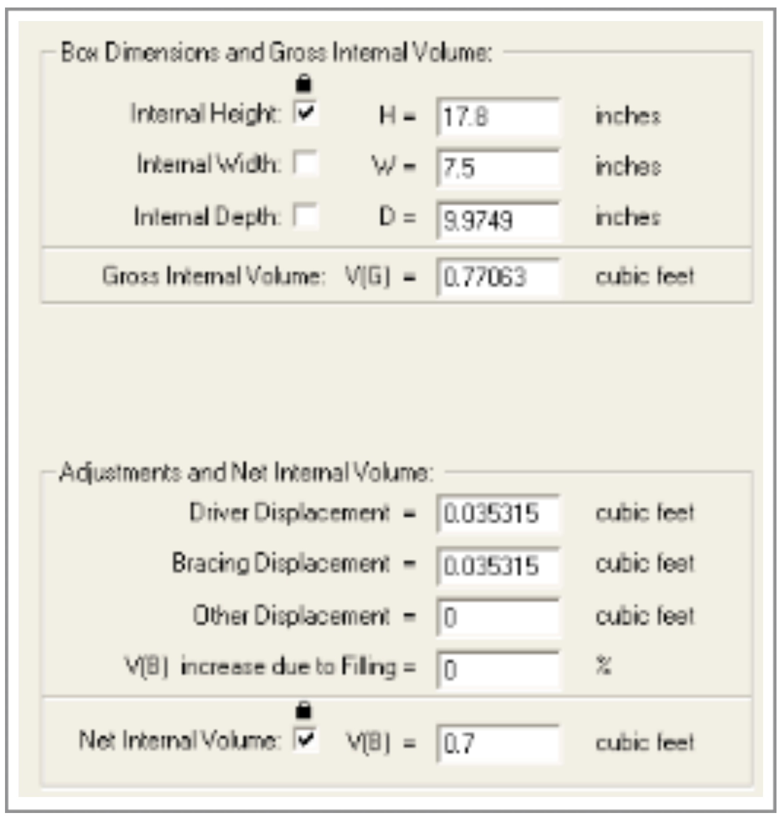
**Internal Dimensions:**

Height: 17.8”

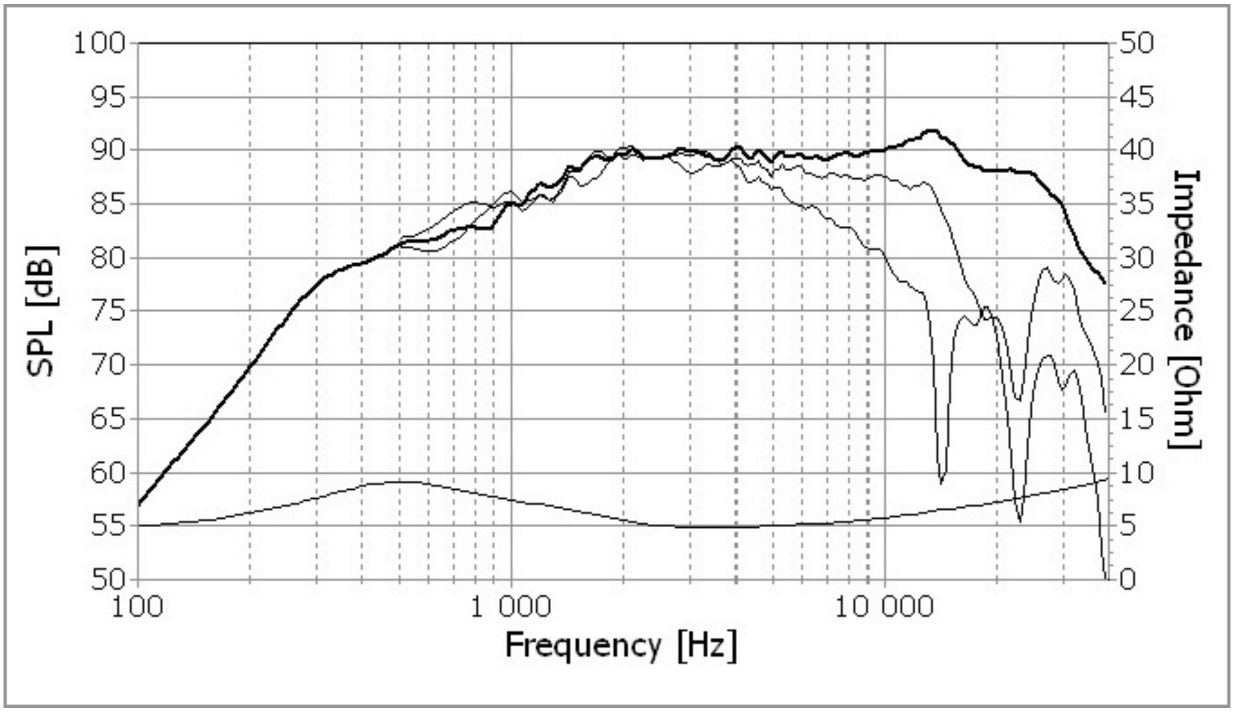
Width: 7.5”

Depth: 10”

These measurements include .07 cubic feet for driver, bracing and crossover displacement. The gross internal volume is .77 cubic feet, the net volume is .7 cubic feet.



**Tweeter:** SEAS Prestige TDFC [1]



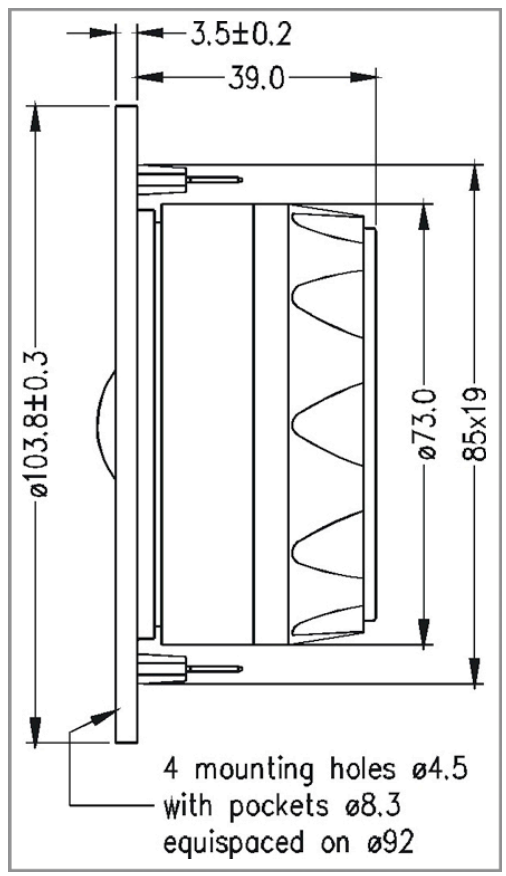

| | | | |
|---|---|---|---|
| Nominal Impedance | 6 Ohms | Voice Coil Resistance | 4.8 Ohms |
| Recommended Frequency Range | 1500 - 25000 Hz | Voice Coil Inductance | 0.05 mH |
| Short Term Power Handling * | 220 W | Force Factor | 3.5 N/A |
| Long Term Power Handling * | 90 W | Free Air Resonance | 550 Hz |
| Characteristic Sensitivity (2.83V, 1m) | 90 dB | Moving Mass | 0.37 g |
| Voice Coil Diameter | 26 mm | Effective Piston Area | 7.5 cm² |
| Voice Coil Height | 1.5 mm | Magnetic Gap Flux Density | 1.8 T |
| Air Gap Height | 2.0 mm | Magnet Weight | 0.25 kg |
| Linear Coil Travel (p-p) | 0.5 mm | Total Weight | 0.50 kg |

[1] https://www.madisound.com/store/product_info.php?products_id=792 Accessed 2/18/11.

The SEAS TDFC is a fabric dome tweeter with a polymer surround. It is fairly smooth up to around 2 kHz and then starts to break up. There is also a slight bump right after 10 kHz of about 3 dB that may need to be padded down to fit into my goal of a +/- 2 dB response. It has a sensitivity of 90 dB. The resonant frequency of this tweeter is around 500 Hz. This should not be a problem as there will not be any power going to these frequencies of the tweeter below 900 Hz after the crossover.

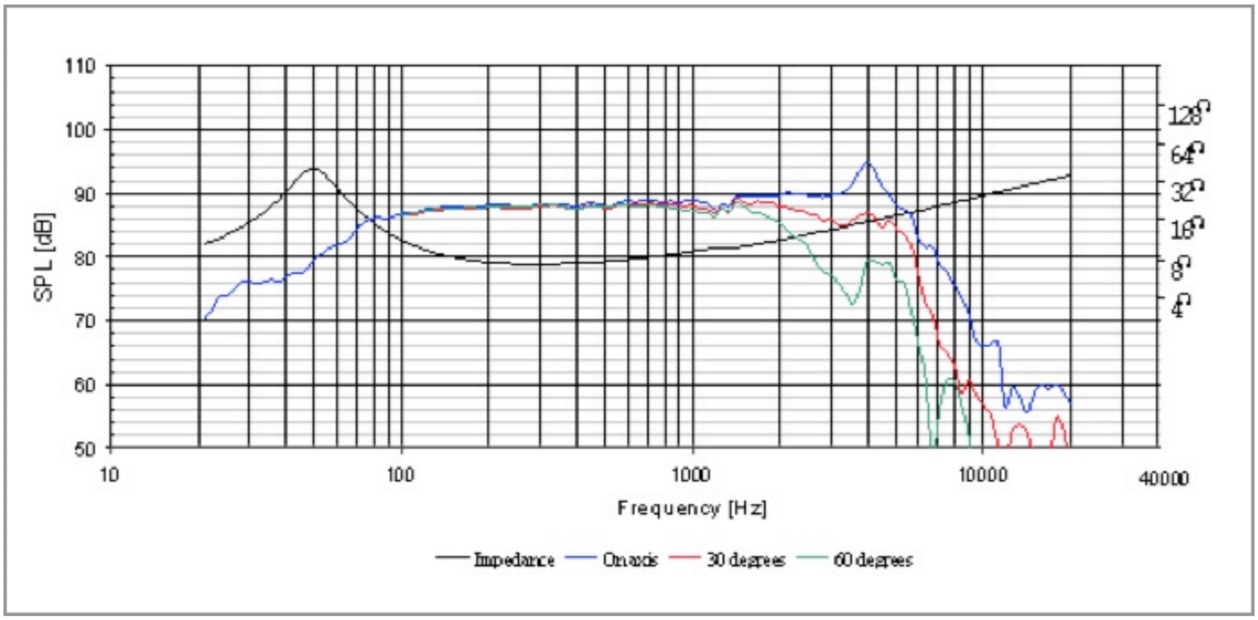
*"Stiff and stable rear chamber with optimal acoustic damping allows the tweeter to be used with moderately low crossover frequencies."* [2]

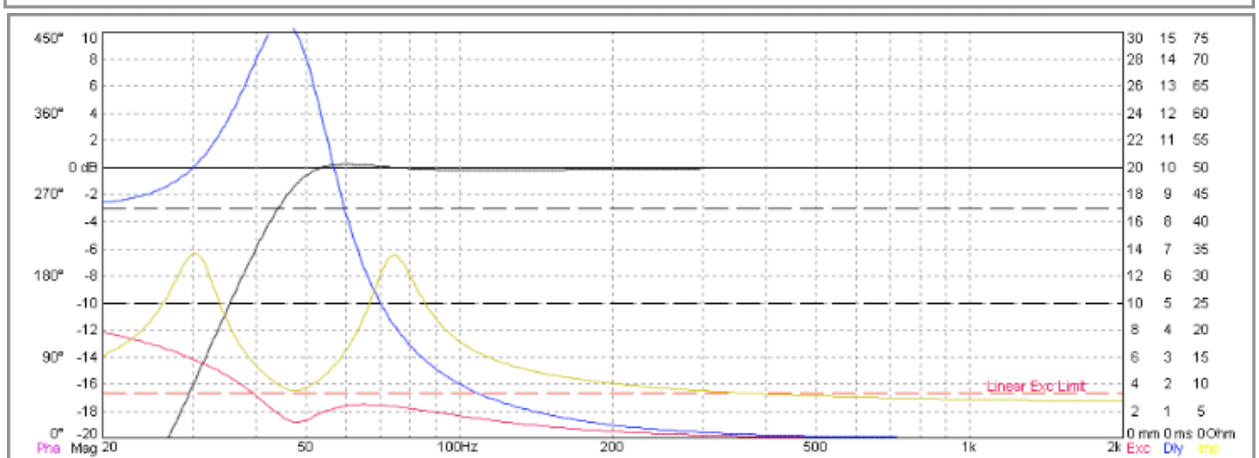
At the right is a side view of the SEAS TDFC. The front plate will be flush-mounted to the baffle to avoid the diffraction of the higher frequencies. A smooth baffle surface is crucial to keeping the sound waves radiating undisturbed from the speaker.




[2] https://www.madisound.com/store/product_info.php?products_id=792 Accessed 2/18/11.

**Driver:** Peerless PPB 830874 Cone Woofer




**...er and System Parameters**

| | | | | | |
|---|---|---|---|---|---|
| f(s) = 47.3 | Hz | Diam. = 6.5 | in | | |
| Q(ts) = 0.4 | | P(t) = 18 | W | | |
| V(as) = 0.56 | cu ft | 1W/1m SPL = 87.8 | dB | | |
| No. Drivers | N = 1 | SPL @ 1 | m | | |
| Input Power | P(in) = 18 | W | (3.281 | ft) | |

**4th Order Vented Box**

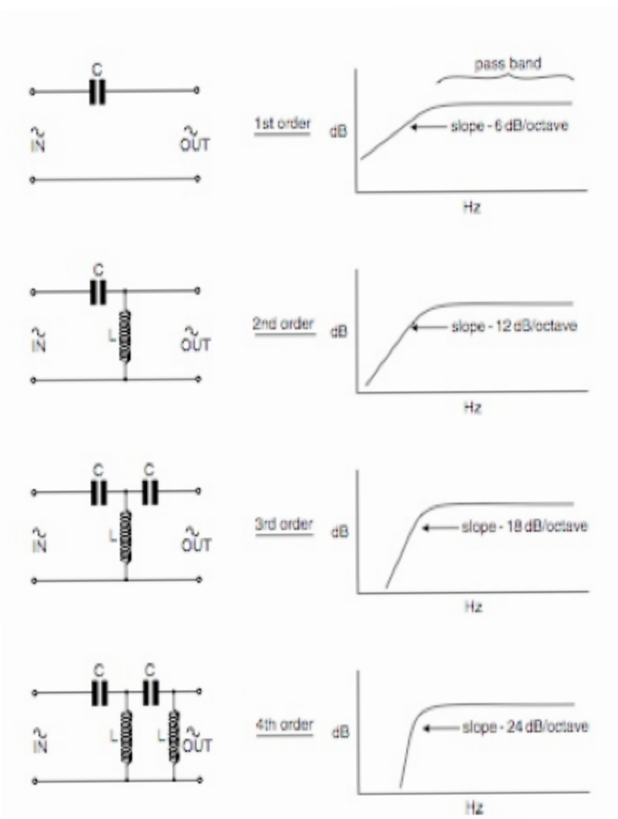
| | | |
|---|---|---|
| Box Volume | V(B) = 0.6808 | cu ft |
| Closed Box Q | Q(tc) = 0.54 | |
| Box Frequency | F(B) = 47.7 | Hz |
| Min. Recommended Vent | S(v)min = 2.4 | sq in |
| Vent Area | S(v) = 2.457 | sq in |
| Vent Length | L(v) = 3 | in |

The Peerless 830874 is a 6 1/2”, 8 Ohm driver. It has a sensitivity of 87.8 dB. The cone of this driver is polypropylene with a rubber surround. The frequency response of the driver is shown as well as the modeled response in a ported box in *WinSpeakers*. The vent is a 3 inches long with an area of 2.53 square inches. I modeled the driver with the excursion, showing that it will cross the excursion limit below the F(3) of 45 Hz. Below are the specifications of the woofer: [3]

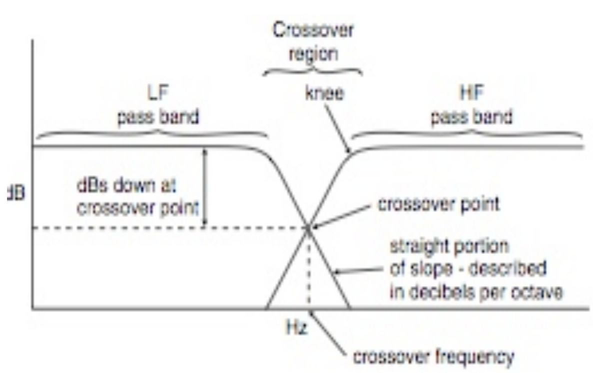
| | | |
|---|---|---|
| **Electrical data** | | |
| Nominal impedance | Zn | 8 (ohm) |
| Minimum imp./at freq. | Zmin | 7.0/290 (ohm/Hz) |
| Maximum impedance | Zo | 43 (ohm) |
| Dc resistance | Re | 6.4 (ohm) |
| Voice coil inductance | Le | 1.2 (mH) |
| | | |
| **TS Parameters** | | |
| Resonance Frequency | fs | 47.3 (Hz) |
| Mechanical Q factor | Qms | 2.73 |
| Electrical Q factor | Qes | 0.47 |
| Total Q factor | Qts | 0.40 |
| | | |
| Force factor | Bl | 8.5 (Tm) |
| Mechanical resistance | Rms | 1.97 (Kg/s) |
| Moving mass | Mms | 18.1 (g) |
| Suspens. compliance | Cms | 0.63 (mm/N) |
| Effective cone diam. | D | 13.3 (cm) |
| Effective piston area | Sd | 139 ($cm^2$) |
| Equivalent volume | Vas | 16.7 (ltrs) |
| SPL 2.83V/1m at fmin | | 87.8 (dB) |

[3] https://www.madisound.com/store/product_info.php?products_id=1609products_id1609, Accessed 2/18/11.

I chose this driver over others for it's smooth response and adequate low frequency extension in a vented box. This driver has a relatively smooth response up to 3kHz. I am planning on doing a 3rd order crossover on both the woofer and tweeter at 2 kHz. Because the tweeter already has a natural 1st order slope starting at 2 kHz I can hopefully accomplish a 3rd order slope with only two components. My crossover will be a passive crossover housed in the box itself. In the pictures at the left and below show crossover slopes, and an overall visual of a crossover with terminology.[4] I will possibly need to pad the high end to get the smooth response that I have as one of my goals.

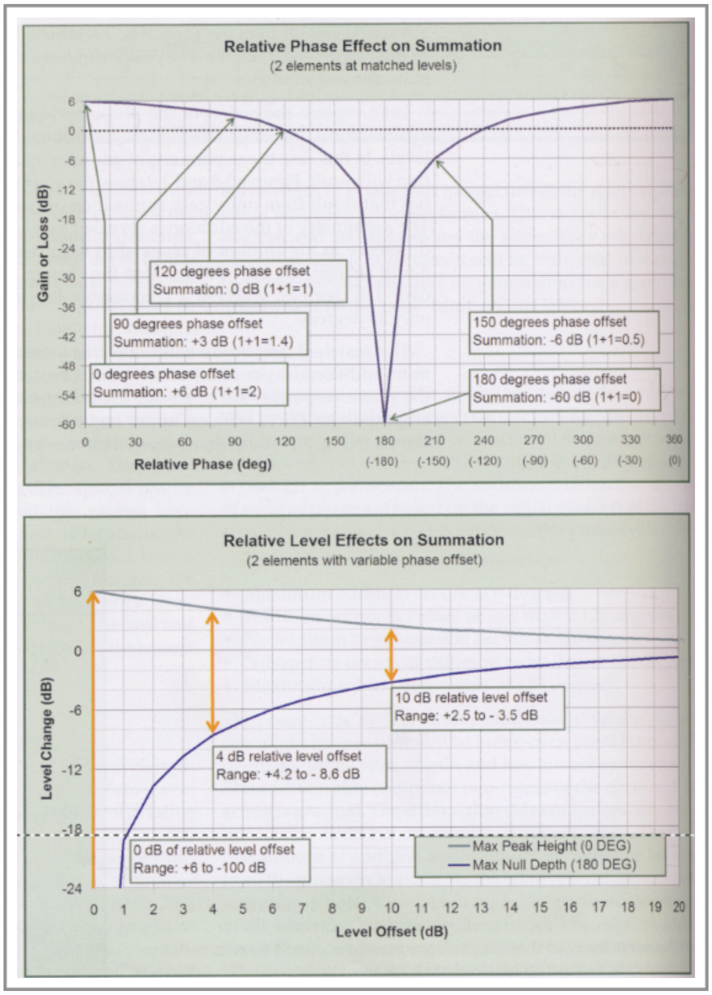



A 3rd order on the tweeter will roll the high end off before sending any power the resonant frequency which is around 500 Hz. This will also cut the driver off well before its breakup mode around 3 kHz.




At the crossover point the combination of the two levels will sum to keep a smooth response over the crossover region. At the crossover point both slopes should cross around 82 dB.

[4] Newell, Phillip & Keith Holland, 132.




The phase effect on summation and the level adjustments with summation are shown to left. One of the problems with some of the drivers looked at below were odd peaks, that when summed with tweeter, would give me large peaks in my response, even with 4th order slopes on the crossover. It took time to go through and see which driver would ideally sum with my tweeter for a smooth response.

I looked at numerous other drivers before arriving at the Peerless 830874. The HiVi M8a[5] 8" woofer was another serious consideration. When modeled for my box volume, I was able to get an f(3) of 40 Hz. I really liked the appearance of it and thought it would go well with the finished look of my speakers, not to mention it would fit well in my budget. The problem with this driver was the 10 dB peak at 2 kHz, shown below, which would have shown up in my response however I chose to approach the crossover point. Below are some comparisons of the other drivers I looked at. It gives the size, cost and f(3) of each one.

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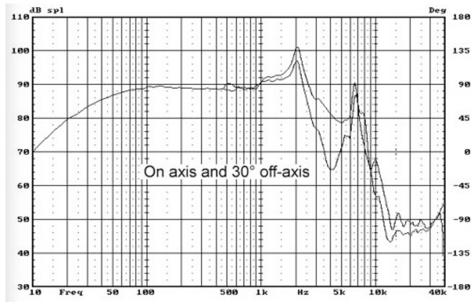
[5] http://www.parts-express.com/pe/showdetl.cfm?Partnumber=297-447 Accessed 2/18/11.

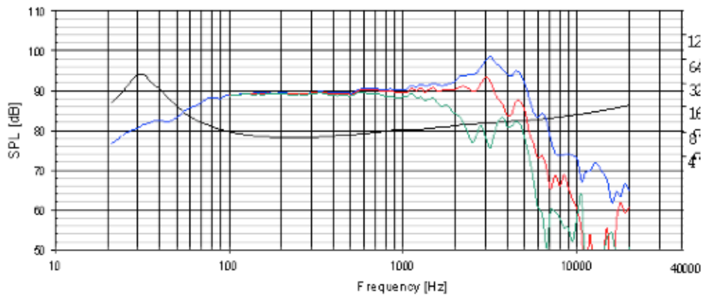
Hivi M8a

Size: 8"
Cost: $42
F(3): 45 Hz



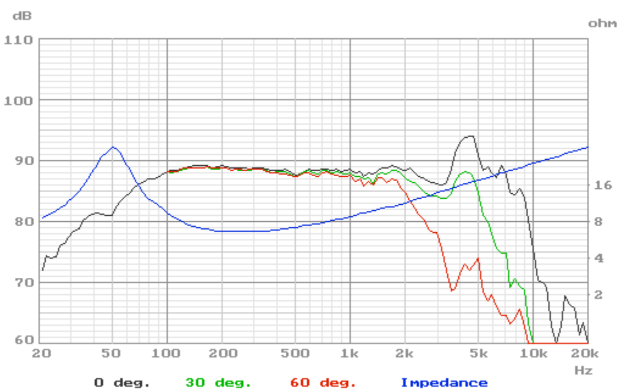

Peerless 830884

Size: 8"
Cost: $81
F(3): 50 Hz



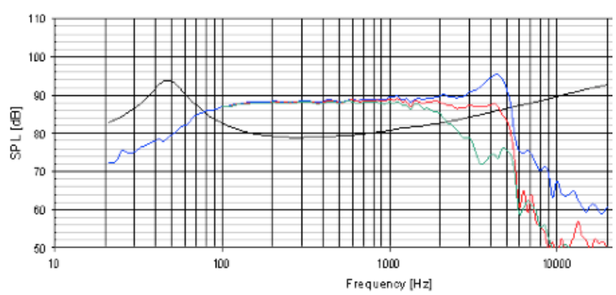

SDS 830657

Size: 6.5"
Cost: $18.50
F(3): 55 Hz



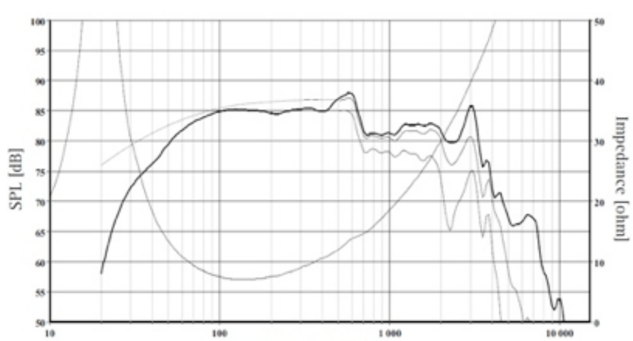

Peerless Nomex

Size: 6.5"
Cost: $50
F(3): 45 Hz




SEAS Prestige

Size: 8"
Cost: $96
F(3): 40 Hz

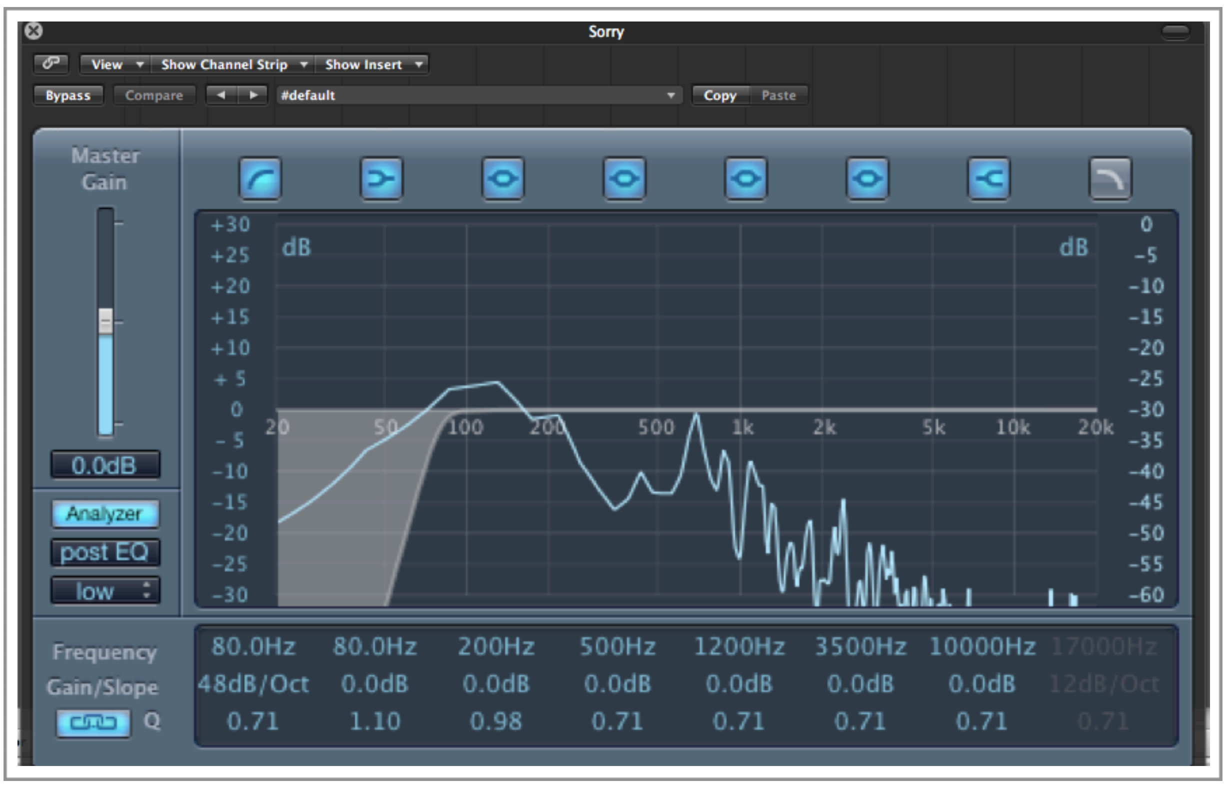


The general purpose of my speakers is to have an accurate pair of portable speakers that I can mix and master on, as well as casually listen to music at an enjoyable volume. I found my normal listening level through testing different systems I listen on regularly. I found that right around 80 dB is comfortable listing level and over 95 dB was too loud. For this reason I have been designing these speakers to play at an average level of 80 dB with 14 dB for headroom. This means my speakers must be able to handle clips up to 94 dB. At 1 Watt and 1 Meter the SPL of my speakers would be around 88 dB. Using the inverse square law I found that I will need 18 Watts to get 94 dB at two meters. Two meters is how far away I would be if I were mixing. The table below shows the conversion of Watts to Decibels.[6] My calculations were done using the fact that for every doubling of distance, six decibels is lost, and every doubling of power adds three decibels.

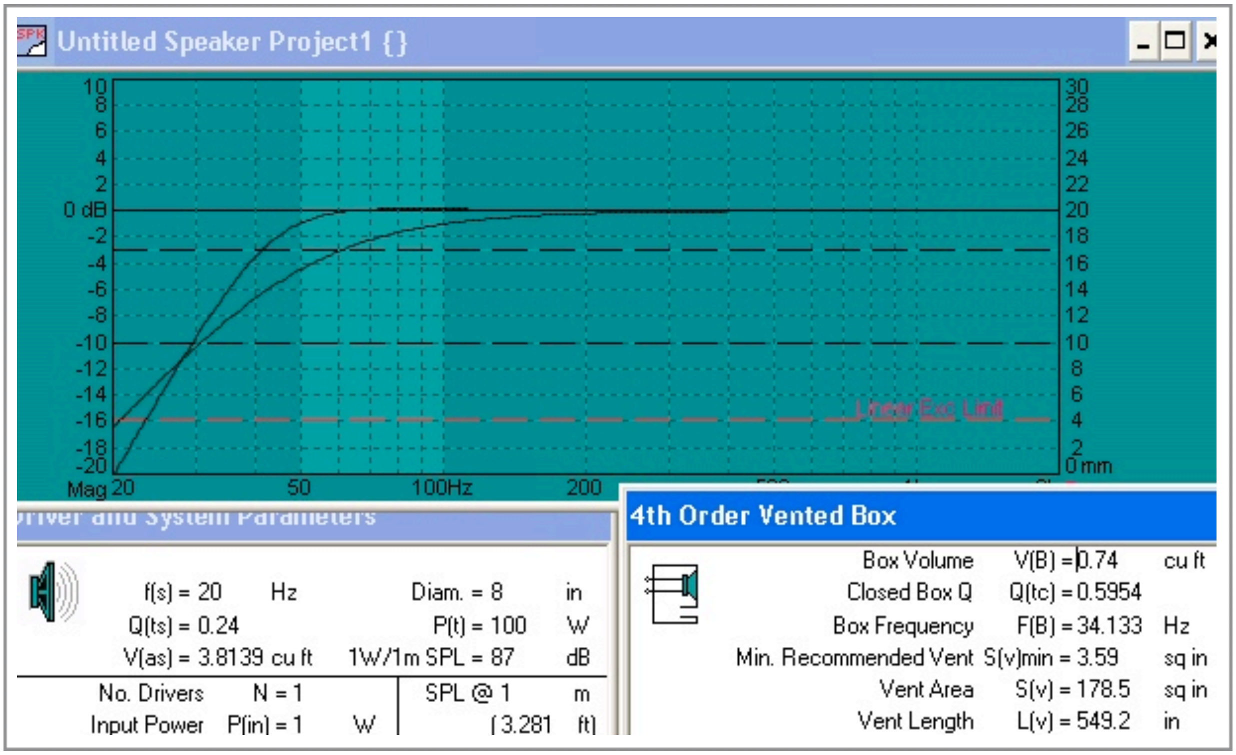
| DBM | DBW | WATTS | TERMINOLOGY |
|---|---|---|---|
| +100 | +70 | 10 000 000 | 10 Megawatts |
| +90 | +60 | 1 000 000 | 1 Megawatt |
| +80 | +50 | 100 000 | 100 kilowatts |
| +70 | +40 | 10 000 | 10 kilowatts |
| +60 | +30 | 1 000 | 1 kilowatt |
| +50 | +20 | 100 | 100 watts |
| +40 | +10 | 10 | 10 watts |
| +30 | 0 | 1 | 1 watt |
| +20 | -10 | 0.1 | 100 milliwatts |
| +10 | -20 | 0.01 | 10 milliwatts |
| 0 | -30 | 0.001 | 1 milliwatt |
| -10 | -40 | 0.0001 | 100 microwatts |
| -20 | -50 | 0.00001 | 10 microwatts |
| -30 | -60 | 0.000001 | 1 microwatt |
| -40 | -70 | 0.0000001 | 100 nanowatts |
| -50 | -80 | 0.00000001 | 10 nanowatts |
| -60 | -90 | 0.000000001 | 1 nanowatt |

6 “dBm-dBw Watts conversion Chart” Radio Electronics.com. Accessed 2/19/11.

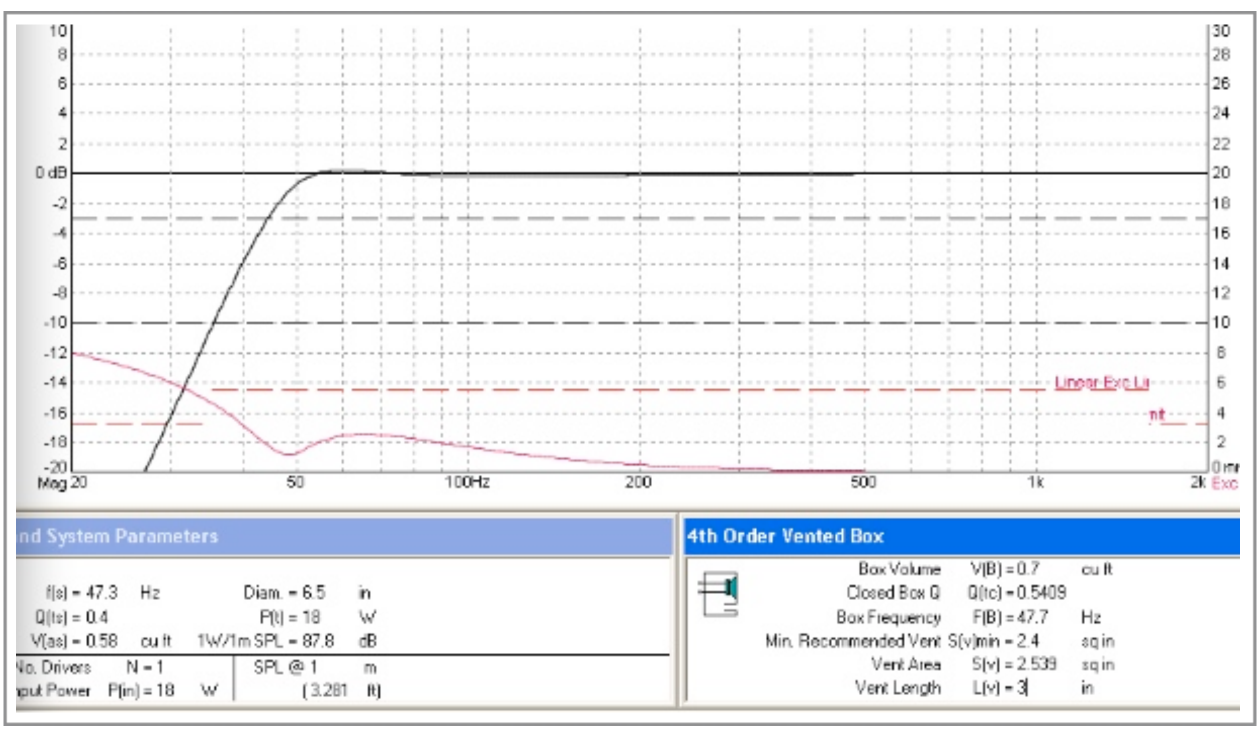
At first my goal was to have a sealed box that was slightly larger to get the low end I wanted. As I began testing in *WinSpeakers*, I found that with a port I was able to go far lower with most drivers. When I was listening to music on different speakers to get a rough idea of listening level, I was also listening to how much low end was an acceptable amount for my speakers. My original goal was to hit at least 60 Hz. With a vent, most of the speakers I modeled easily met this limit. Usually I could make it down between 40 and 50 Hz, which is a much more satisfactory amount of low end. Below is a shot of the equalizer I used to find the right low end extension, the F(3) in this shot is around 80 Hz, which was not enough low end at all.




Here are a few responses taken from *WinSpeakers* showing the difference in low end extension between vented, and unvented boxes.




Above, the F(3) with the sealed box is 60 Hz. The same driver in a vented box is 40 Hz. It was much more practical to vent the box for this extension than making the box much larger to get the same response. This was a model for the SEAS Prestige woofer I was looking at before I decided on the Peerless 830874.



The last response on the previous page is again for the Peerless driver I am using. This is the response in a vented box and it has an f(3) of 45 Hz. When modeled with a sealed enclosure the f(3) was only 65 Hz.

As far a appearance goes I am going for a glossy, yet natural finish. The exterior layer of wood will be baltic birch. The speaker below[7] is made of Walnut, which is a much more distinguished type of wood. I am going to stain mine with a similar type of stain, possibly slightly darker. After this the speaker will get a few coats of clear seal to give it the glossy look I want.

All walls and baffle will be 11/2" thick. 3/4" MDF and 3/4" Baltic Birch. The top and bottom will be the same. The rear panel will house my vent, which will probably by 2 inches wide. The back panel will also be removable for easy assess to the crossover components.

There are certain things to keep in mind with the front baffle. I want as smooth a surface as possible to tame the diffraction issues which can throw off how the sound radiates from the speaker. All for edges of the baffle will be rounded so the sound waves gently change, rather than getting a jump when the waves reach the edge of the

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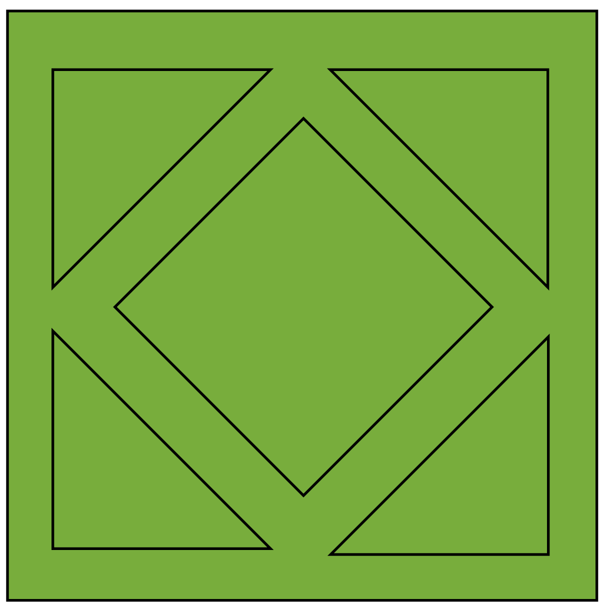
[7] http://www.garagehobbies.com/1801.aspx, Accessed 2/19/11.

speaker. Both the driver and the tweeter will be receded flush to the baffle, again to keep the radiation from the speaker smooth.

Internally there are a few design choices to be made as well. As previously mentioned my port will be on the back panel of the speaker. For padding inside I am going primarily with fiberglass coating the inner walls. There will be clear air flow between the driver and the port. As for as bracing goes I will have one vertical panel parallel to the baffle and rear panel. The very rough diagram below gives an idea of the the structure of the panel. With this design the diamond shaped hole in the middle will be behind the driver, this gives space for the air to move from the back of the woofer.



## Budget

My goal for the cost of these speakers is $500. It is possible I will come out below this number. I plan to buy the amp later on.

- 2 Peerless PPB 830874 = $90
- 2 SEAS TDFC's = $85
- Wood ~ $100
- Crossover ~ $50
- Other ~ $175

These are the design elements for a pair of bookshelf speakers for home and professional use.

**Bibliography:**


1. Murphy, John L. Introduction to Loudspeaker Design. Tennessee: True Audio, 1998.

2. Newell, Phillip & Keith Holland. Loudspeakers: For music recording and reproduction. Focal Press, 2006.

3. “Level Practices (Part 2)” http://www.digido.com/level-practices-part-2-includes-the-k-system.html

4. “dBm-dBw Watts Conversion Chart” http://www.radio-electronics.com/info/formulae/decibels/dBm_dBW_table.php

5. “Garage Hobbies- Ellis Audio 1801 in Figured Walnut” http://www.garagehobbies.com/1801.aspx

6. Dickason, Vance. *The Loudspeaker Design Cookbook*. Audio Amateur Press, 2005.

7. Stuntz,Stephen E. “The Effect of Sound Intensity Level on Judgement of “Tonal Range” and “Volume Level”” http://www.aes.org/aeshc/pdf/how.the.aes.began/stuntz_effect-of-sound-intensity-level.pdf, Accessed 1/29/11.

8. https://www.madisound.com/store/product_info.php?products_id=1609products_id1609, Accessed 2/18/11.

9. https://www.madisound.com/store/product_info.php?products_id=792, Accessed 2/18/11.

10. http://www.parts-express.com/pe/showdetl.cfm?Partnumber=297-447, Accessed 2/18/11.

11. McCarthy, Bob. Sound Systems: Design and Optimization. Elsevier, 2007.