Initial Design Statement
FA 4740

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Concept

I am building a pair of general-purpose speakers that will mostly be used for media, such as watching movies and television, and listening to music from multiple sources, including my computer, a tape deck, and a turntable. On some occasions, I will be using these speakers for mixing audio recordings and projects, so they need to be good enough to function well as a pair of studio monitors.

The speakers will need to be relatively small for two reasons. They will be set up on top of a corner desk, so they will need to fit comfortably with desk space left over. They will also need to be small to be transported easily, as they won't be permanently installed in any one room, or building for that matter.

I listen to a wide variety of music genres. These speakers will need to be versatile enough for any type of music played through them. The speakers should have a good depth-of-field to accurately give space to well-mastered records. It would be preferable to use these speakers without a sub-woofer, but I have one that I can use to fill out any deficiency in the lower frequency ranges. These speakers will be used for hours on end at times, and should not fatigue the ears quickly. Most importantly, these speakers must fit within a budget of $500.

Technical Requirements

To insure my speakers perform the way I want them to I needed to determine a number of factors. Because I don't want to require a subwoofer for these speakers, I needed to determine an acceptable F3 will be for my woofer. I also needed to determine how loud my speakers would need to be capable of playing. They need to be loud enough to acceptably mix by.

To determine the specific allowable roll-off in the bass frequencies, I loaded several of my favorite songs, from multiple genres and mastering levels, into Logic Pro Studio and played them on the overhead stereo system in Walker 212. I applied a high-pass filter with a roll-off of 24dB/octave and determined the locations where the roll-off became noticeable and the highest frequencies where the roll-off was tolerable.

Song	Noticeable Roll-off Frequencies (Hz)	Acceptable Roll-off Frequencies (Hz)
I'm Looking Forward to Joining You Finally – Nine Inch Nails	32	60
Forget Me - BT	35	62
Falling Away From Me - Korn	36	65
Tron Legacy (End Titles) – Daft Punk	50	75
Give You Love - thenewno2	50	76
Long Way Down (Look What the Cat Drug In) – Michael Penn	51	87
One Nation Under a Groove - Funkadelic	55	85
All the Love in the World – Nine Inch Nails	61	75
Berlioz: Symphonie Fantastique Movement 5 – The San Francisco Symphony Orchestra	61	87
Apache Rose Peacock – Red Hot Chili Peppers	66	100
Mean Average	49.7	77.2

Fig. 1: A selection of songs from a wide variety of genres with their noticeable and acceptable roll-off frequencies.

By looking at the lowest noticeable frequency with the lowest acceptable frequency, I determined that the F_3 point of my driver should fall between 32Hz and 60Hz, as it would still be an acceptable point for the biggest outlier on the low-end, being “I'm Looking Forward to Joining You Finally” by Nine Inch Nails.

I measured various SPL levels under different listening conditions of my speakers ranging from quiet, ambient music to being able to hear it while doing dishes. After running measurements over a period of a few days, listening to music at morning, evening, during peaceful, and somewhat angry moods, I determined the loudest volume, measured from an average listening distance of one foot was a maximum of 93.3 dB SPL, giving an estimated RMS of approximately 84 dB SPL.

Fig. 2: Screenshot of the loudest max SPL recorded while listening to music while doing dishes in the kitchen.

Drivers

The speakers will be a 2-way system, meaning they will consist of one woofer and one tweeter each. I didn't really know what I was looking for in terms of a woofer, so I researched a wide variety of types and sizes, paying attention to how smooth the frequency responses were, how large the X_{max} was, and what the power rating was.

Woofer	Size	Material	Impedance	Q_{ts}
SEAS Prestige L15RLY/P (H1141)*	**5.5"**	**Aluminum**	**8 ohm**	**0.35**
SEAS Prestige L12RCV/P (H1207)	4.5"	Aluminum	8 ohm	0.29
SEAS Prestige CA15RLY (H1216)	5.5"	Coated Paper	8 ohm	0.34
Dayton RS125	4.5"	Aluminum	4 ohm	0.63
Tang Band W5-1138SMF	5.25"	Paper	4 ohm	0.49
Dayton RS180-8*	**7"**	**Aluminum**	**8 ohm**	**0.37**
Fountek FW146*	**5.5"**	**Aluminum**	**8 ohm**	**0.4**
Fountek FW168	6.5"	Aluminum	8 ohm	0.4
HiVi L6-4R*	**6.5"**	**Kevlar**	**8 ohm**	**0.4**
Scan-Speak 15W/8434G-00 Discovery*	**5.25"**	**Fiber Glass**	**8 ohm**	**0.25**
SEAS CA12RCY (H1152)	4.5"	Coated Paper	8 ohm	0.31

	Power	Price
SEAS Prestige L15RLY/P (H1141)*	**80/200W**	**$85.18**
SEAS Prestige L12RCV/P (H1207)	70/200W	$72.60
SEAS Prestige CA15RLY (H1216)	60/250W	$69.00
Dayton RS125	30/45W	$31.96
Tang Band W5-1138SMF	40/80W	$32.20
Dayton RS180-8*	**60W**	**$48.99**
Fountek FW146*	**35W**	**$38.70**
Fountek FW168	50W	$46.00
HiVi L6-4R*	**30/60W**	**$39.27**
Scan-Speak 15W/8434G-00 Discovery*	**60/120W**	**$70.70**
SEAS CA12RCY (H1152)	60/200W	$66.67

Figure 3: Research Data for multiple woofers.

I looked at multiple factors, paying closest attention to the frequency response. I was looking for a driver that kept a steady frequency response without deviating more than plus or minus 3dB from its SPL over the total pass band of the speaker. I also paid close attention to power ratings and Xmax. I was able to eliminate many of them immediately due to inferiority in these factors. The ones that made it to the final selection round stood out the most in these categories. Using the spec sheet, with data provided from the Loudspeaker Design Cookbook I calculated the necessary data required for modeling the low frequency extension using the software WinSpeakerz.

Woofer	**Sensitivity**	**Power**	**Xmax**	**V_{as} (ft³)**	**Q_{ts}**	**F_s (Hz)**
SEAS Prestige L15RLY/P (H1141)	86 dB	80/200 W	20 mm	0.4238	0.35	44
Dayton RS180-8	87 dB	60 W	6 mm	0.7275	0.37	42
Fountek FW146	86 dB	35 W	3.6 mm	0.3461	0.4	50
HiVi L6-4R	88 dB	30/60 W	4.3 mm	0.5191	0.4	50
Scan-Speak 15W/8434G-00 Discovery	86.9 dB	60/120 W	8 mm	0.452	0.25	45
Analysis (Assumed Loss of Q_L=15)						
SEAS Prestige L15RLY/P (H1141)	**H**	**α**	**F_3/F_s**	**Peak dB**	**V_B (ft³)**	**f_B (Hz)**
SBB_4	1	1.9467	1.3146	0	0.2177	44
SC_4	1.0769	1.8896	1.2342	0	0.2243	47.3836
QB_3	1.1052	1.8629	1.1251	0	0.2275	48.6288
Dayton RS180-8	**H**	**α**	**F_3/F_s**	**Peak dB**	**V_B (ft³)**	**f_B (Hz)**
SBB_4	1	1.7372	1.2071	0.01	0.4188	42
SC_4	1.0456	1.5567	1.1146	0	0.4673	43.9152
QB_3	1.0526	1.5468	1.1099	0	0.4703	44.2092
Fountek FW146	**H**	**α**	**F_3/F_s**	**Peak dB**	**V_B (ft³)**	**f_B (Hz)**
SBB_4	1	1.4803	1.0886	0.27	0.2338	50
SC_4	0.984	1.1591	0.9675	0	0.2986	49.2
QB_3	0.9845	1.1579	0.9672	0	0.2989	49.225
HiVi L6-4R	**H**	**α**	**F_3/F_s**	**Peak dB**	**V_B (ft³)**	**f_B (Hz)**
SBB_4	1	1.4803	1.0886	0.27	0.3507	50
SC_4	0.984	1.1591	0.9675	0	0.4478	49.2
QB_3	0.9845	1.1579	0.9672	0	0.4483	49.225
Scan-Speak 15W/8434G-00 Discovery	**H**	**α**	**F_3/F_s**	**Peak dB**	**V_B (ft³)**	**f_B (Hz)**
SBB_4	1	3.8678	2.3033	0	0.1169	45
SC_4	1.042	4.089	2.3097	0	0.1105	46.89
QB_3	1.5058	4.7375	1.9023	0	0.0954	67.761

Figure 4: Tuning Data for driver finalists.[1]

By calculating the values for the drivers in QB3, SBB4, and SC4 vented box tunings, I determined that the average lowest F3s occurred in QB3 tuning. It was for this reason that I decided to

1 Dickason, Vance. *Loudspeaker Design Cookbook 7th Ed.* Peterborough, NH Amateur Audio Press, 2006. 62-69.

use QBB4 tuning in my speakers, as I'm searching for a low frequency extension.

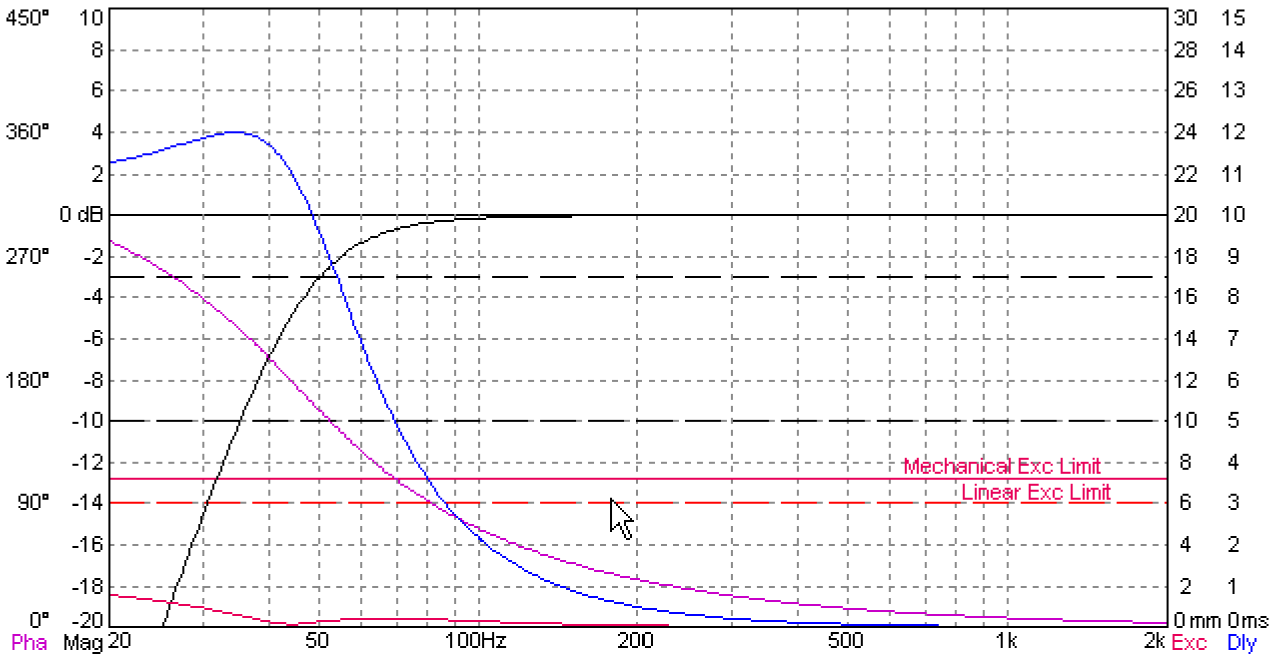


Fig. 5: Low Frequency Extension, Excursion, Phase and Delay of the Dayton RS180-8 in QB3 tuning

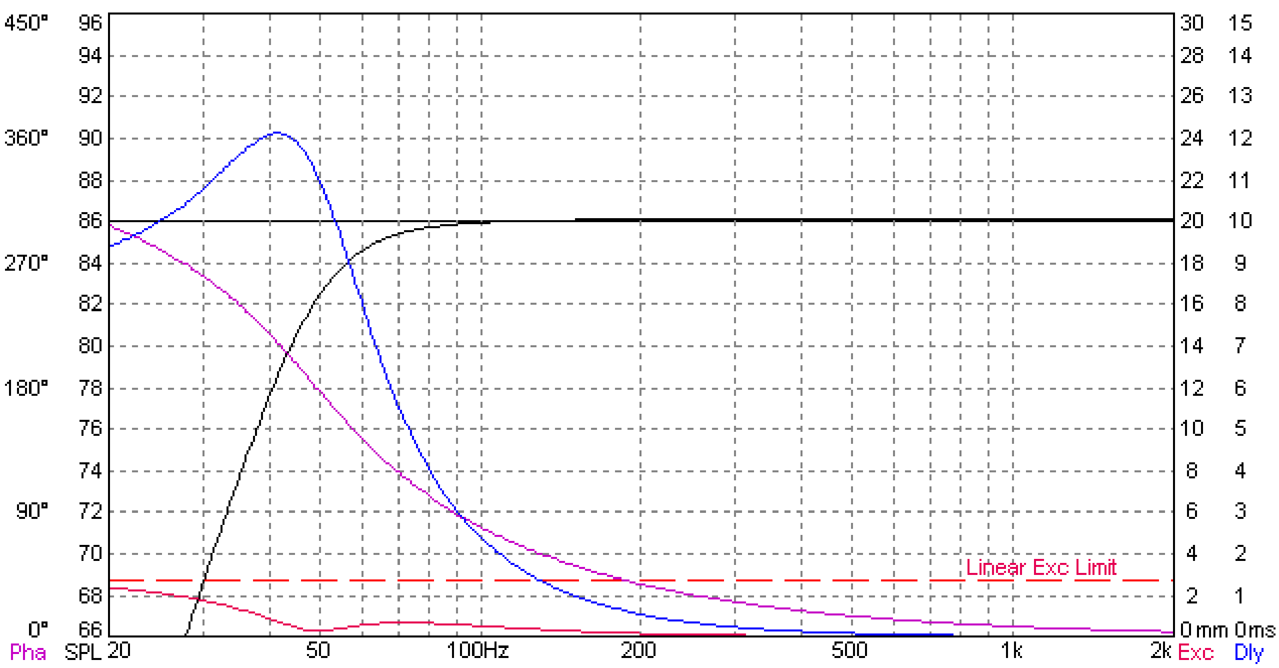


Fig. 6: Low Frequency Extension, Excursion, Phase and Delay of the Fountek FW146 in QB3 tuning

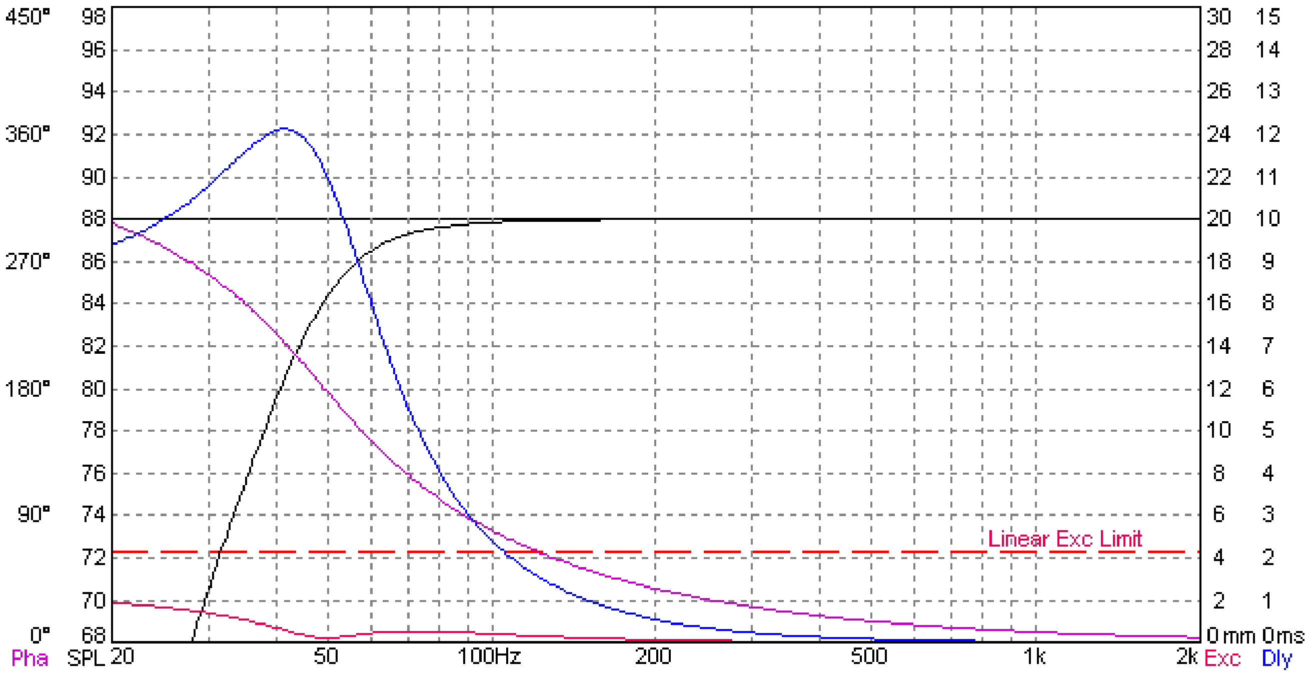


Fig. 7: Low Frequency Extension, Excursion, Phase and Delay of the HiVi L6-4R in QB3 tuning

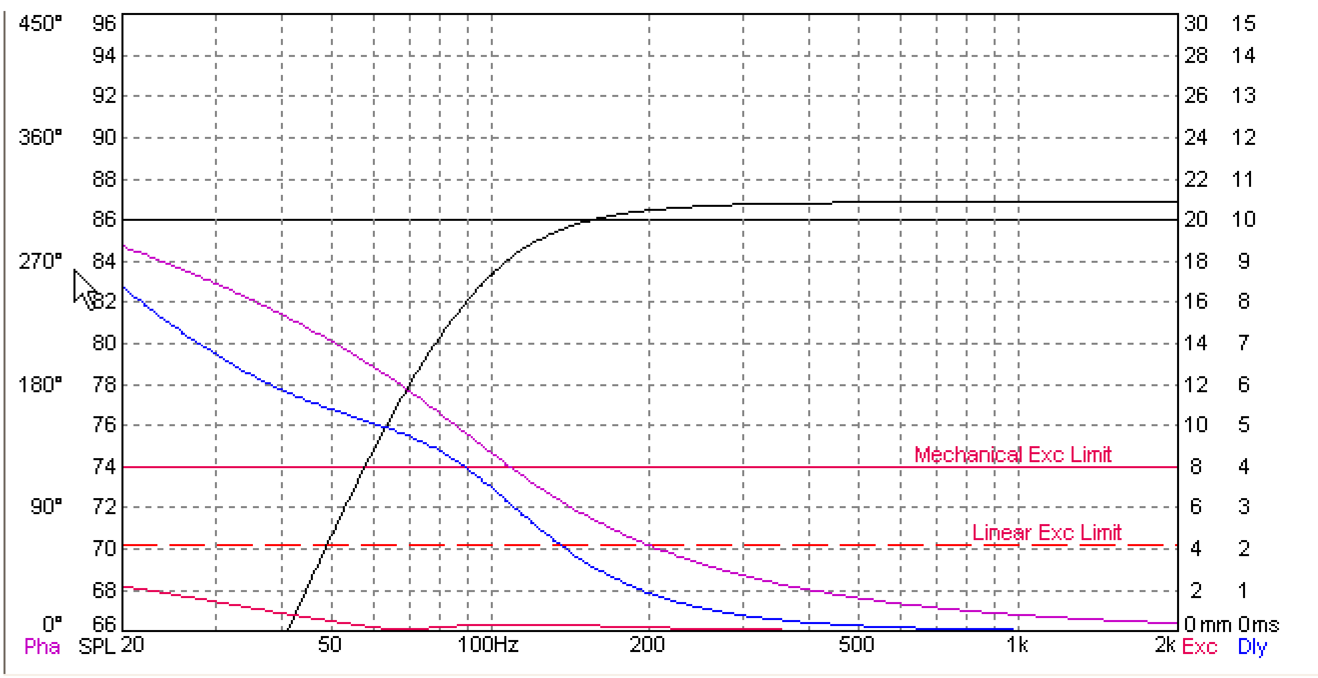


Fig. 8: Low Frequency Extension, Excursion, Phase and Delay of the Scanspeak in QB3 tuning

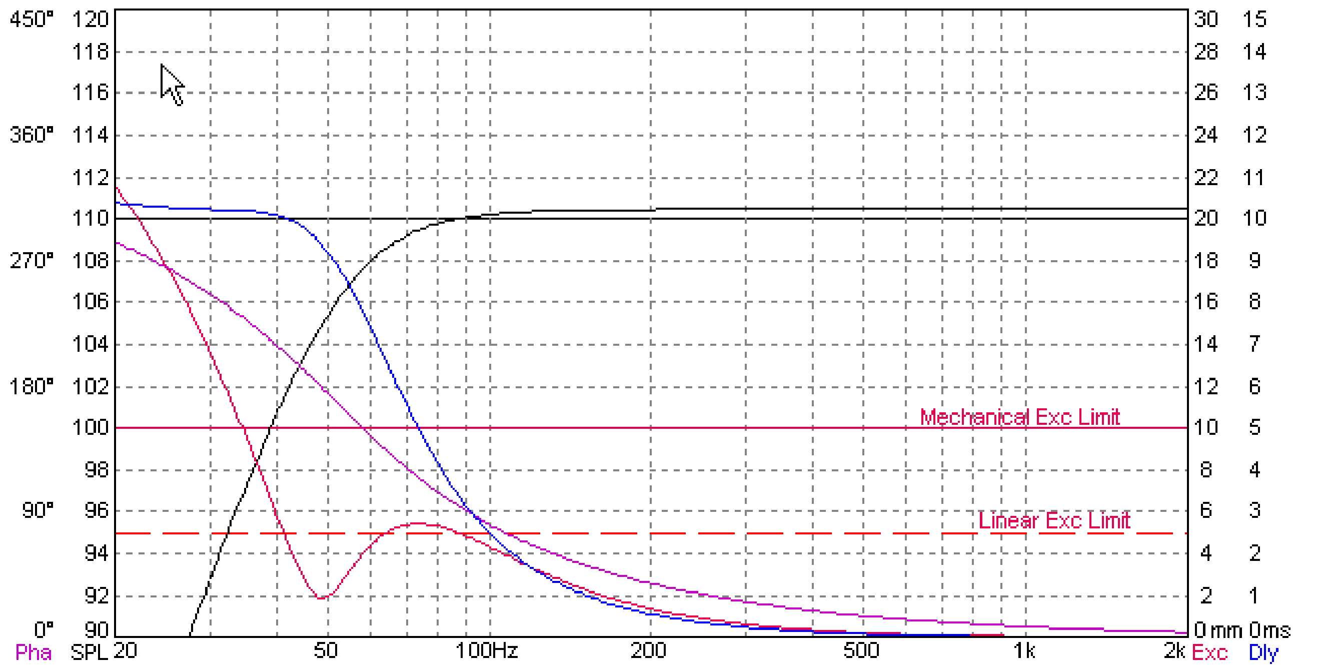


Fig. 9: Low Frequency Extension, Excursion, Phase and Delay of the SEAS H1141 in QB3 tuning.

I ultimately chose the SEAS Prestige H1141. It is a 5.5" aluminum cone woofer with a power rating of 80/200W and an Xmax of 5mm. In QB3 tuning. the F_3 of this woofer falls at about 55 Hz, within my acceptable limit of 60 Hz. With 70W of power at an SPL of 90dB, the maximum volume I will use, there will be only a slight distortion around 70-80Hz due to the excursion passing the linear limit of 5mm.

I looked at a wide variety of tweeters to try to determine what type would be most suitable for my design. As with the woofers, I paid close attention to how smooth the frequency response was, and power ratings. I also looked at the estimated F_3 to see how well they would crossover with the woofer. I also eliminated many of the tweeters due to poor frequency curves and low power ratings. Some of them, like Dynavox TD2801XL had an F_3 that was much too high, and would not likely crossover efficiently. This runs the risk of blowing the tweeter.

Tweeters	Material	Style	Impedance	F_s (Hz)
SEAS Prestige 29TAF/W (H1322)	**Aluminum/Magnesium**	**Dome**	**6 Ohms**	**950**
SEAS Prestige 22TAF/G (H1283)	Aluminum/Magnesium	Dome	6 Ohms	1100
SEAS Prestige 27TDF (H1211)	**Textile**	**Dome**	**6 Ohms**	**900**
Dayton RS281-4	**Aluminum**	**Dome**	**4 Ohms**	**592.2**
HiVi RT1.3WE	Kaptio/Copper	Ribbon	6 Ohms	-
Fountek NeoCd3.5H	Neodymium magnet	Ribbon/Horn	7 Ohms	-
Fostex FT17H	?	Super/Horn	8 Ohms	5000
Vifa XT25TG30-04	?	Ring Radiator	3.5 Ohms	436
Dynavox TD2801XL	**Silk**	**Dome**	**5.3 Ohms**	**900**
Tang Band 25-1719S	**Ceramic**	**Dome**	**4 Ohms**	**800**

	Sensitivity	F_3 (Hz)	Power	Xmax
SEAS Prestige 29TAF/W (H1322)	**91.5**	**900**	**100/220W**	**0.5 mm**
SEAS Prestige 22TAF/G (H1283)	92	1250	80/180W	0.5 mm
SEAS Prestige 27TDF (H1211)	**91**	**900**	**90/220W**	**0.5 mm**
Dayton RS281-4	**88**	**750**	**100W**	**-**
HiVi RT1.3WE	92	1500	10/30 W	-
Fountek NeoCd3.5H	95.5	1100	12/25W	-
Fostex FT17H	98.5	2600	30W	-
Vifa XT25TG30-04	90.8	500	100W	0.65
Dynavox TD2801XL	**92**	**1500**	**100/150W**	**-**
Tang Band 25-1719S	**90**	**700**	**8/80W**	**-**

	Price
SEAS Prestige 29TAF/W (H1322)	**$48.55**
SEAS Prestige 22TAF/G (H1283)	$35.85
SEAS Prestige 27TDF (H1211)	**$40.05**
Dayton RS281-4	**$54.77**
HiVi RT1.3WE	$37.87
Fountek NeoCd3.5H	(sale) $59.00
Fostex FT17H	$42.40
Vifa XT25TG30-04	$34.25
Dynavox TD2801XL	**$42.55**
Tang Band 25-1719S	**$35.50**

Figure 10: Research Data for multiple tweeters.

Crossovers

To help with my tweeter decision, I modeled the summation curve of a 2nd order crossover starting at 1kHz for the SEAS woofer, and 2kHz for the tweeters. I used the summation table from

Sound Systems: Design and Optimization[2]

Freq	Woofer	-12dB/Oct	Tweeter	-12dB/Oct	Woof Signal	Tweet Signal	Sum
250	-3	0	-22	-36	-3	-58	-3
500	0	0	-13	-24	0	-37	0
1000	1	0	-7	-12	1	-19	1
2000	-2	-12	-4	0	-14	-4	2
4000	-6	-24	-1	0	-30	-1	-1
8000	10	-36	-2	0	-26	-2	-2
16000	-6	-48	-3	0	-54	-3	-3

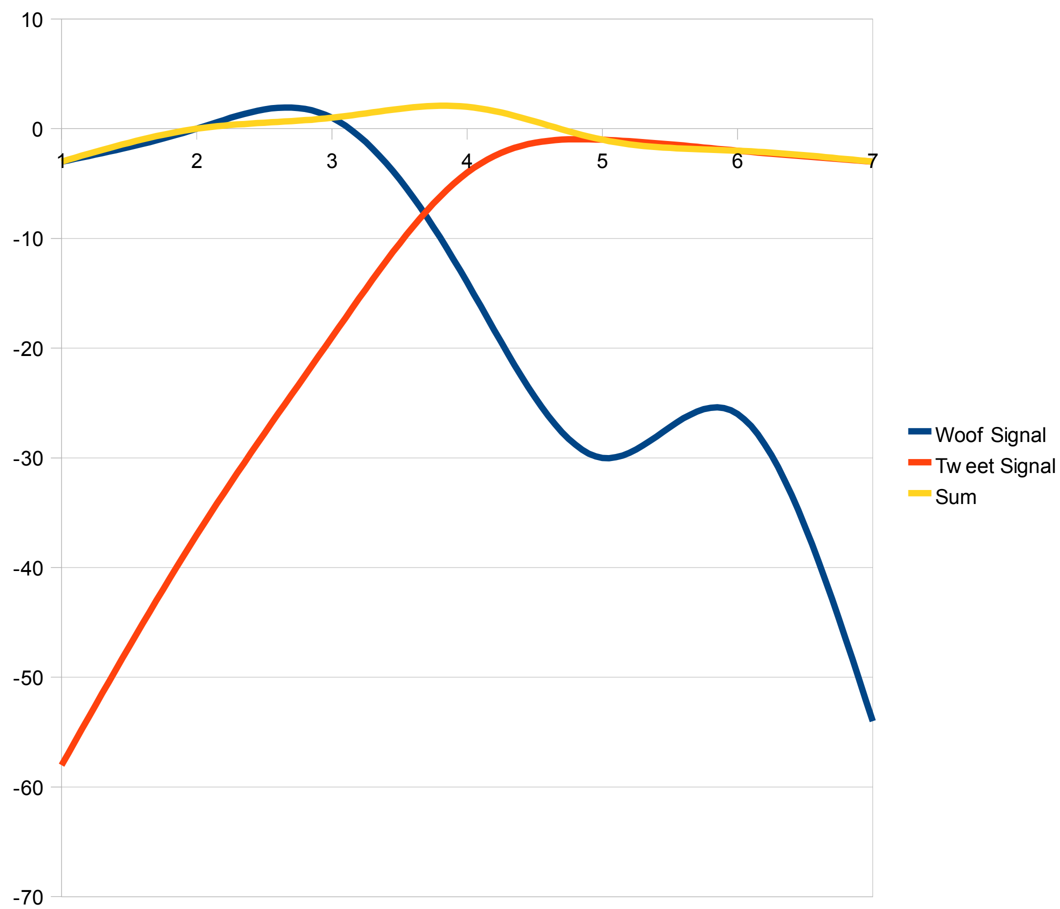


Fig. 11: Summation for the SEAS h1141 and Dynavox TD2801XL

2 McCarthy, Bob. *Sound Systems: Design and Optimization. Second Edition.* Burlington, MA. Focal Press. 2010. 66

Freq	Woofer	-12dB/Oct	Tweeter	-12dB/Oct	Woof Signal	Tweet Signal	Sum
250	-3	0	-22	-36	-3	-58	-3
500	0	0	-11	-24	0	-35	0
1000	1	0	-1	-12	1	-13	2
2000	-2	-12	0	0	-14	0	2
4000	-6	-24	0	0	-30	0	0
8000	10	-36	-1	0	-26	-1	-1
16000	-6	-48	0	0	-54	0	0

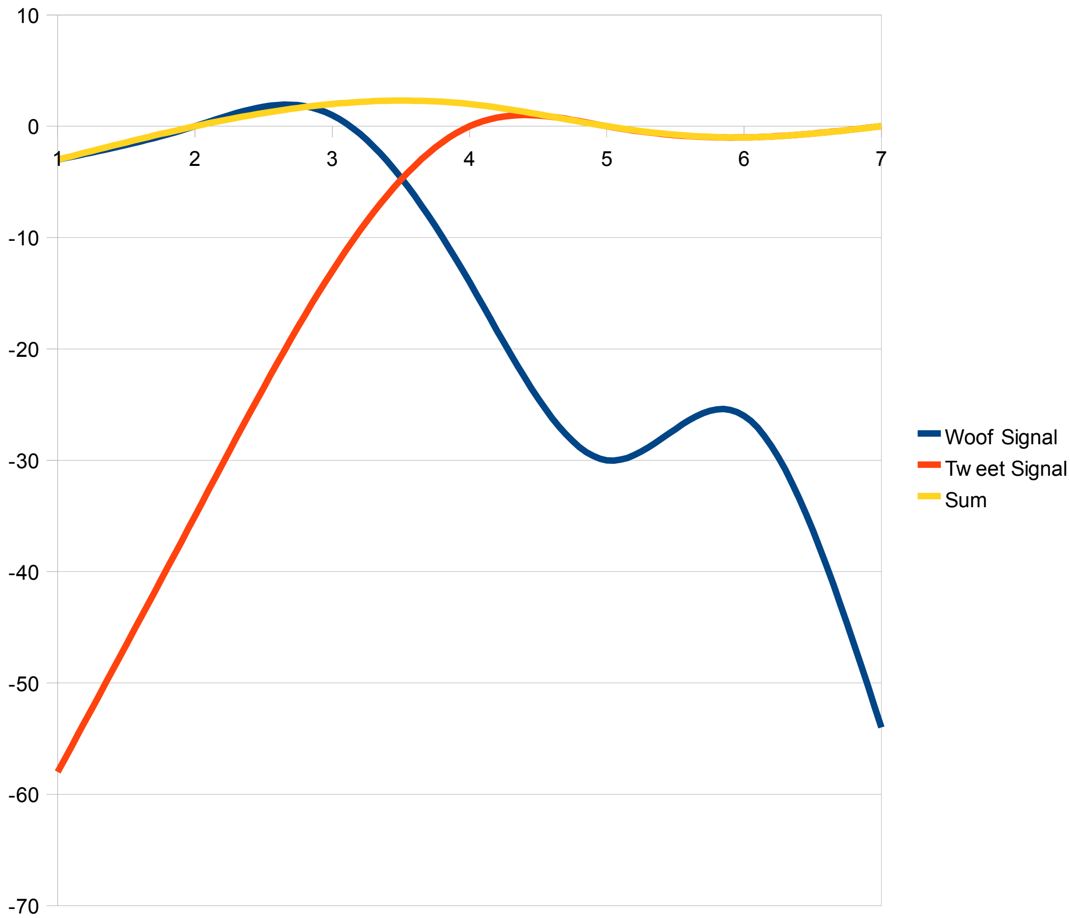


Fig. 12: Summation for the SEAS h1141 and Tang Band 25-1719S

Freq	Woofer	-12dB/Oct	Tweeter	-12dB/Oct	Woof Signal	Tweet Signal	Sum
250	-3	0	-24	-36	-3	-60	-3
500	0	0	-11	-24	0	-35	0
1000	1	0	-1	-12	1	-13	2
2000	-2	-12	0	0	-14	0	2
4000	-6	-24	0	0	-30	0	0
8000	10	-36	-1	0	-26	-1	-1
16000	-6	-48	3	0	-54	3	3

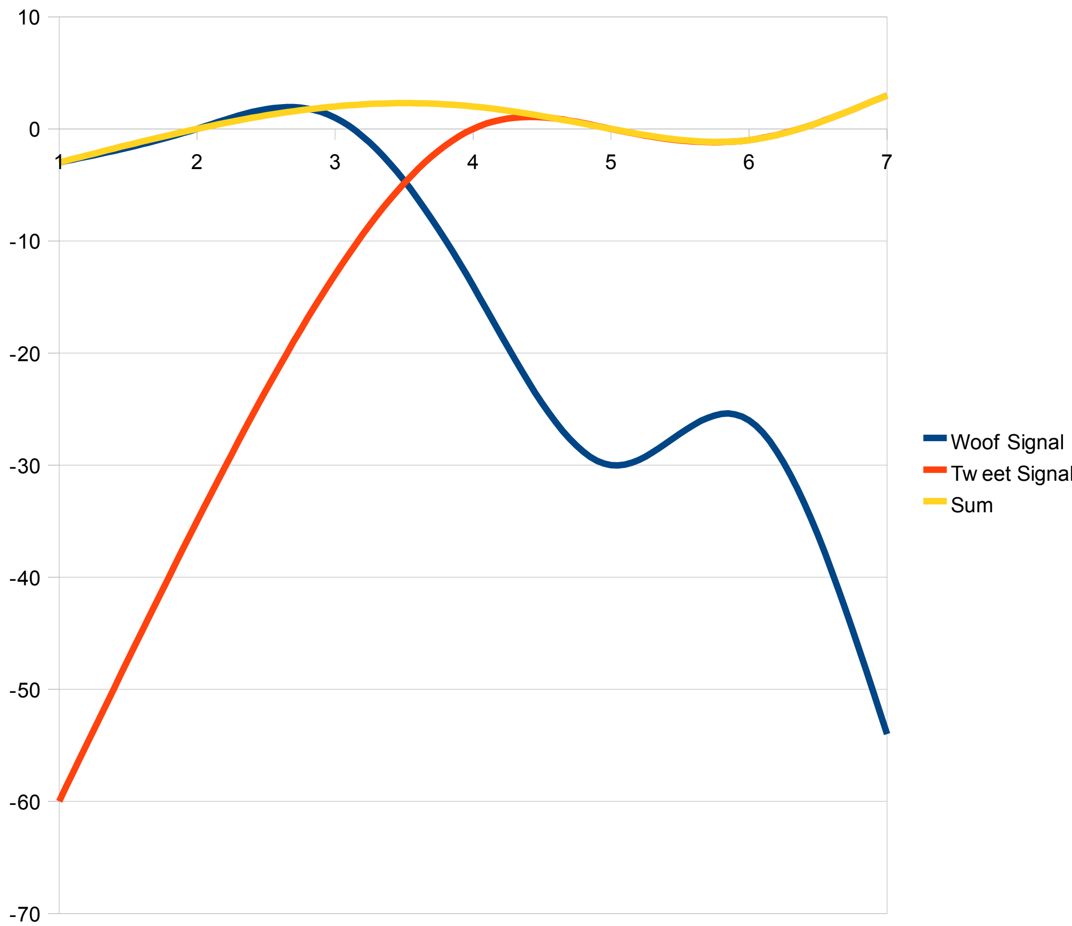


Fig. 13: Summation for the SEAS h1141 and SEAS Prestige 29TAF/W (H1322)

Freq	Woofer	-12dB/Oct	Tweeter	-12dB/Oct	Woof Signal	Tweet Signal	Sum
250	-3	0	-13	-36	-3	-49	-3
500	0	0	-3	-24	0	-27	0
1000	1	0	0	-12	1	-12	3
2000	-2	-12	2	0	-14	2	4
4000	-6	-24	2	0	-30	2	2
8000	10	-36	4	0	-26	4	4
16000	-6	-48	0	0	-54	0	0

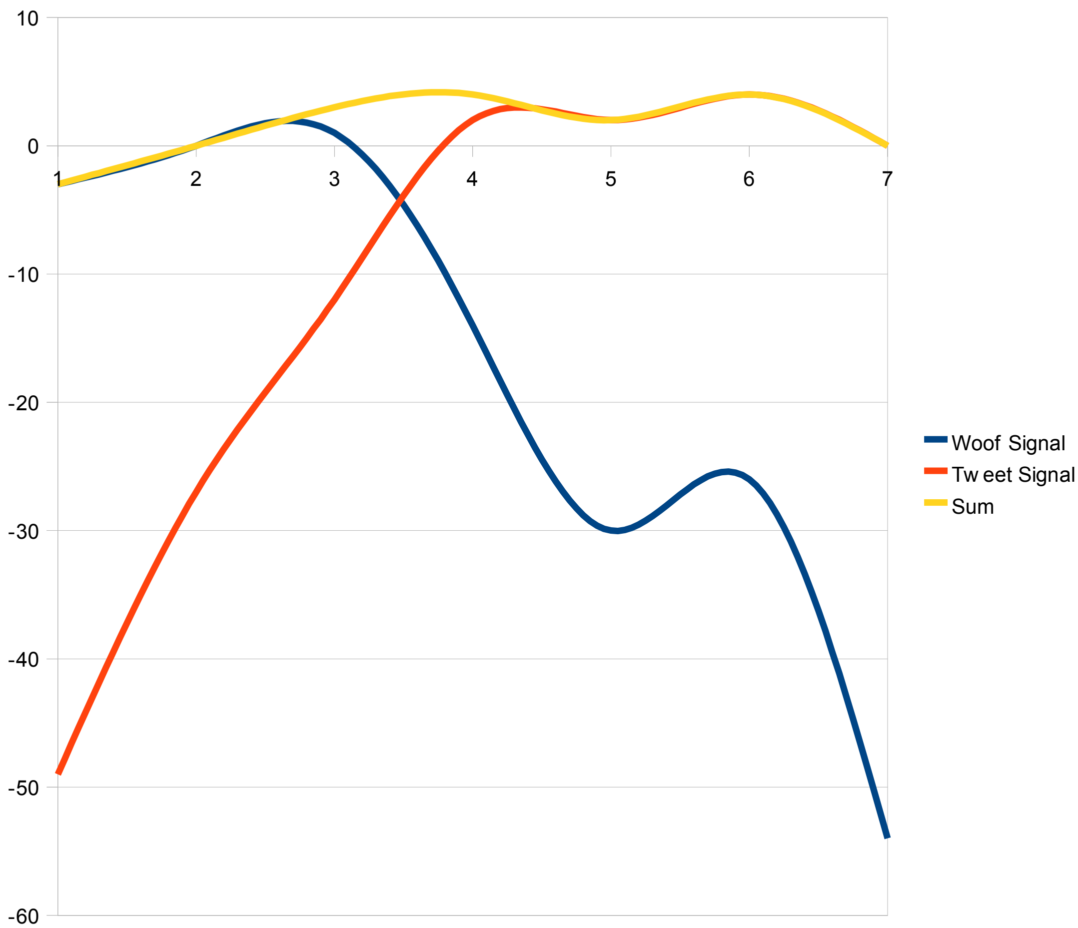


Fig. 14: Summation for the SEAS h1141 and Dayton RS28A-4

Freq (Hz)	SEAS H1141	-12dB/Oct	SEAS H1211	-12dB/Oct	Woof Signal	Tweet Signal	Sum
250	-3	0	-24	-36	-3	-60	-3
500	0	0	-11	-24	0	-35	0
1000	1	0	-3	-12	1	-15	2
2000	-2	-12	0	0	-14	0	1.8
4000	-6	-24	-1	0	-30	-1	0
8000	10	-36	-1	0	-26	-1	0
16000	-6	-48	2	0	-54	2	0

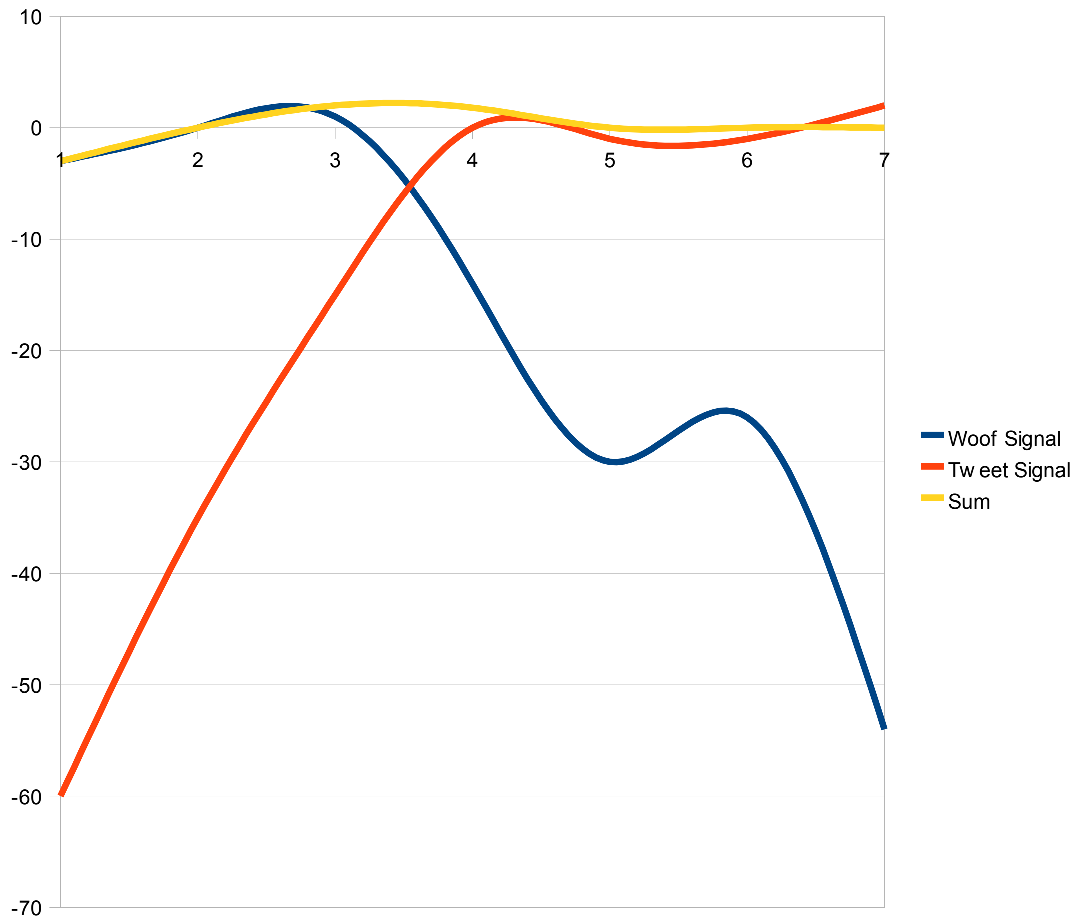


Fig. 15: Summation of SEAS H1141 and SEAS H1211 with 2nd order crossovers.

I chose the SEAS Prestige H1211 textile dome tweeter. With a roll-off of 12dB/octave, starting at 1kHz for the woofer and 2kHz for the tweeter, the crossover summation stays within a variance of ±3dB, as seen in Fig. 15. In addition to its smooth estimated summation, I picked it for its flat frequency curve, high breakdown frequency, and its very high roll-off allowing me to roll it off for my system via crossover if need be.

SEAS PRESTIGE

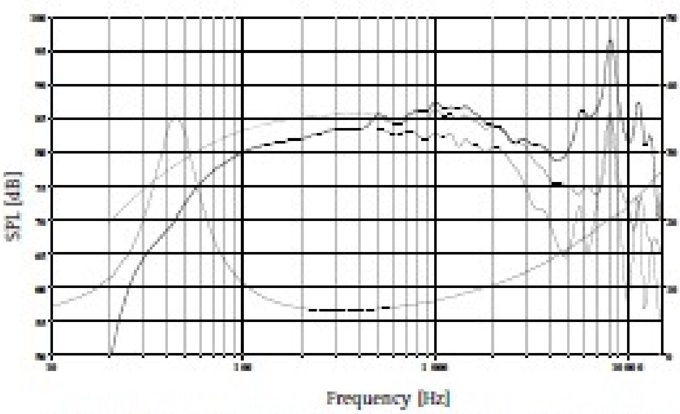
L15RLY/P H1141

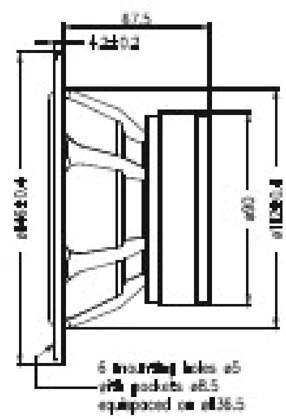
L15RLY/P is a 15 cm (5") cone driver, developed for use as a long throw high fidelity woofer or woofer/midrange unit.

Stiff, yet light aluminium cone and low loss rubber surround show no sign of the familiar 500-1500 Hz cone edge resonance and distortion associated with soft cones.

Large magnet system , together with very long, and light weight copper clad aluminium voice coil allow for extreme coil excursion with low distortion and good transient response.

Extremely stiff and stable injection moulded metal basket, keeps the critical components in perfect alignment. Large windows in the basket both above and below the spider reduce sound reflection, air flow noise and cavity resonances to a minimum.





Nominal Impedance	8 Ohms	Voice Coil Resistance	5.5 Ohms
Recommended Frequency Range	45 - 3000 Hz	Voice Coil Inductance	0.84 mH
Short Term Power Handling *	200 W	Force Factor	5.7 N/A
Long Term Power Handling *	80 W	Free Air Resonance	44 Hz
Characteristic Sensitivity (2,83V, 1m)	86 dB	Moving Mass	8.1 g
Voice Coil Diameter	26 mm	Air Load Mass In IEC Baffle	0.38 g
Voice Coil Height	16 mm	Suspension Compliance	1.6 mm/N
Air Gap Height	6 mm	Suspension Mechanical Resistance	1.12 Ns/m
Linear Coil Travel (p-p)	10 mm	Effective Piston Area	75 cm²
Maximum Coil Travel (p-p)	20 mm	VAS	12 Litres
Magnetic Gap Flux Density	1.1 T	QMS	2.10
Magnet Weight	0.42 kg	QES	0.43
Total Weight	1.28 kg	QTS	0.35

Jul 2007-1 *IEC 268-5 W15-411

SEAS reserves the right to change technical data

RoHS compliant product www.seas.no

Fig. 16: Data sheet for SEAS Prestige H1141

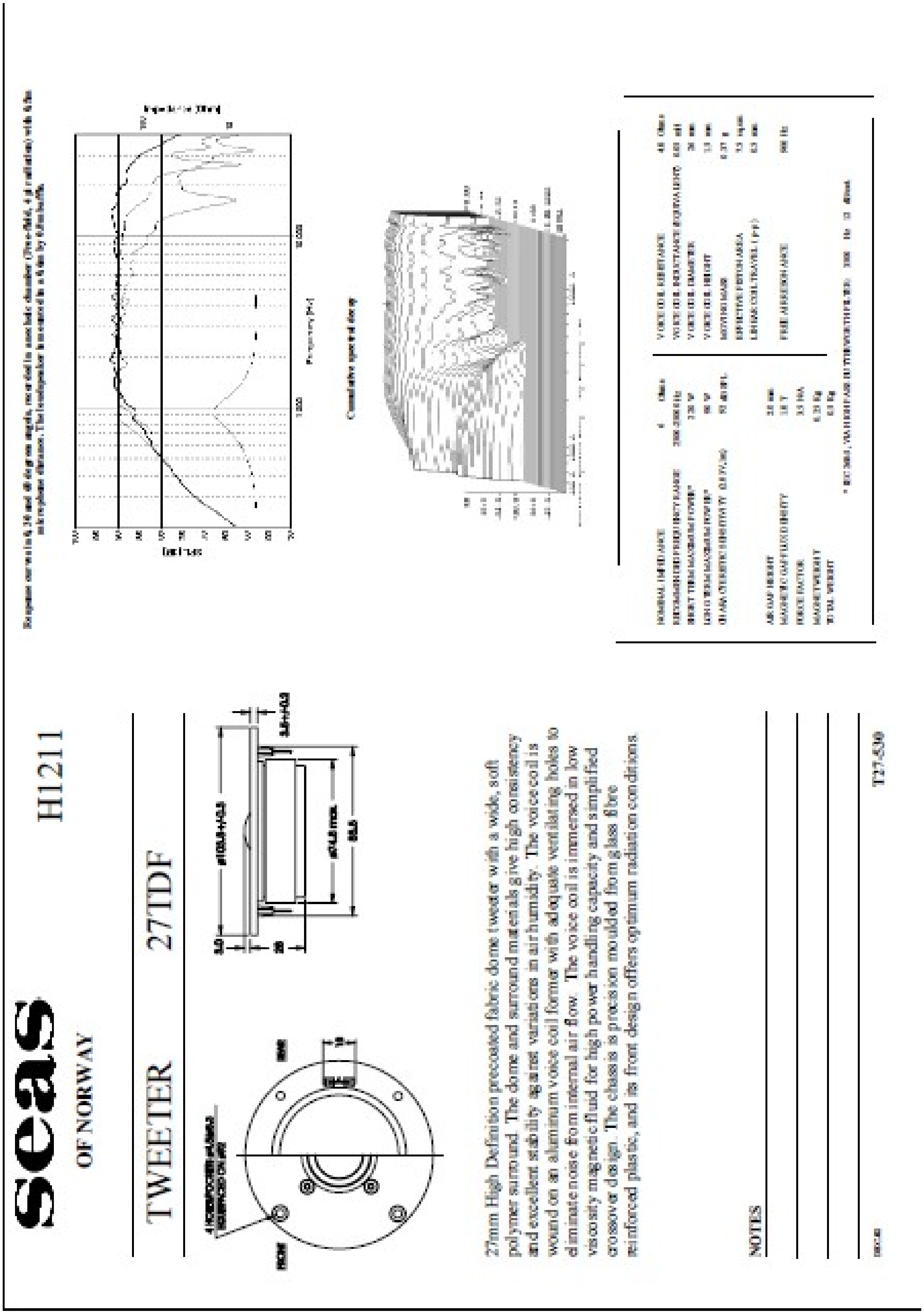


Fig. 17: Data sheet for TB 25-1719S

Enclosures

These speakers must be able to fit on my desk, and will therefore be a size of 10" wide x 12" deep x 18" high. Based on the size of my drivers, and the predicted ideal box volume in Fig. 1, this should not be an issue. The enclosures will be vented to provide a larger depth of field, and to be less fatiguing for extended mixing sessions. The vents will be located on the sides of the speakers in order to avoid unpleasant frequency coloration from reverberant sound. The enclosures themselves will be made from 3/4" 11-ply birch, with an interior of 1/2" MDF.

The placement of the drivers on the baffle will be off-center vertically, and also off-center horizontally for the tweeter. This will allow for a smoother diffraction loss.[3]

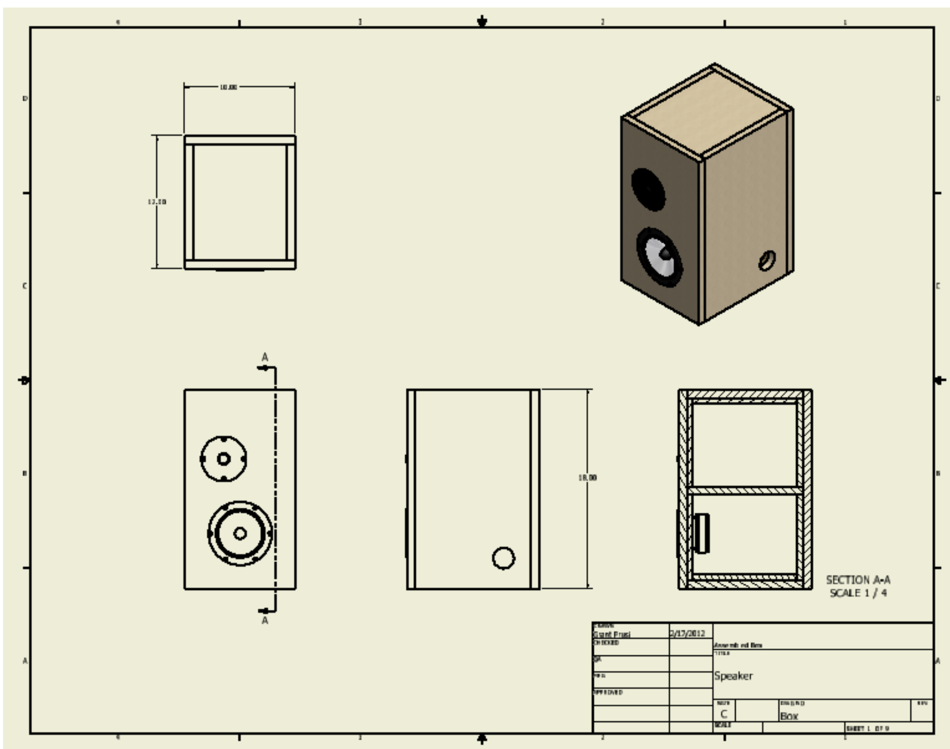


Fig. 18: Isometric, Orthographic, and cross-cut views of the speaker..

3 Murphy, John L. *Introduction to Loudspeaker Design*. Andersonville, TN:True Audio 1998. 71

Budget

2x SEAS H1141 + Shipping (Madisound)	$189.00
2x SEAS H1211 (Madisound)	$81.00
Crossover Components	$92.00
Enclosure and Dampening Materials	$90.00
Ports and Terminal Cups	$26.00
Paint and Finishing	$15.00
Total	**$493.00**

With the drivers taking up $270 of my budget and $92 including shipping for my crossover components, that left me plenty $138 to spend on enclosure materials, including ports, terminals, and paint. That turned out to be enough to build a set of nice sounding speakers to last for years of audio enjoyment.