PA 2201 Midfields

Design Statement

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FA 4740: Transducer Theory

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Functional Analysis

These monitors will be used to mix and master in an acoustically treated room. This demands that the monitors be able to listen backwards, which is to say that they will be able to accurate reproduce a recorded signal[1]. The monitors will need to have a high SPL output so that unwanted distortion will not color the sound at high volumes. Yet as a personal preference, a grittier sound in the midrange is preferred which calls for non-linearity in the mid-range driver. This distortion that "sets in at moderate level allows us to derive a sense of edge and intensity that in fact translates into predictable and satisfactory sound quality for a broad range of end users."[2]

The monitors also have to be relatively portable, so one could bring them to a studio. At any given studio, these speakers will have to be mounted in some manner that it will not color the sound. Therefore multiple mounting solutions will be considered. The most common way they would be mounted would be on top of a console desk.

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[1] David Moulton, Total Recording: The Complete Guide to Audio Production and Engineering, (KIQ Productions, Inc., 2000), 313.

[2] David Moulton, Total Recording: The Complete Guide to Audio Production and Engineering, (KIQ Productions, Inc., 2000), 319.

Design Goals

The monitors will be of a sealed 3 way mid-field design to achieve the desired bandwidth, physical design goals, SPL goals. The overall layout of the speakers on the box is seen in Figure 1.[3] Sealed monitors provide the most accurate transient response without time smearing, whereas "ports tend [smear the transient response] since [it is] a resonant system."[4] To give the monitors a grittier sound, a soft dome midrange will be used.

Size & Shape

The configuration of the drivers will be in a modified horizontal Midwoofer-Tweeter-Midwoofer, which calls for adding an actual midrange driver. The traditional design of the horizontal MTM configuration causes "acoustical interference at increasing horizontal angles."[5] This modified MTM configuration allows the midwoofers to be crossed over at lower frequencies therefore decreasing the acoustical interference. The monitor in Figure 1 displays a version of the modified MTM design. Both cabinets will have a rectangular build, and the dimensions that follow are ballpark figures. The three way mid-field will be a maximum of 50 liters. The size will provide the needed functional goals of being able to mount on or under a console with ease, while also still making them portable.

Figure 1:
Adam S3X-H
(Source: www.adam-audio.com)

Bandwidth Goal

The desired bandwidth is 50hz to 20,000hz for these monitors. After tests and researched performed by the designer, he came to the conclusion that in a midfield design the full spectrum is not normally attained, in a sealed box enclosure, in most professional monitoring speakers.

With the desired bandwidth one could easily mix or master on these monitors without any repercussion. One could also easily integrate a subwoofer unit into the monitor chain to fill out the rest of the spectrum, if need be.

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[3] Adam Audio, "S3X-H." http://www.adam-audio.com/en/content/s3x-h.

[4] Philip Newell, and Keith Holland, Loudspeakers: For Music Recording and Reproduction, (Amsterdam: Focal Press, 2007), 327-328.

[5] Floyd Toole, Sound Reproduction: Loudspeakers and Rooms, (Amsterdam: Focal Press, 2008), 401.

Physical Design Goals

The planned mounting of the midfield monitors will be on floor stands, to decouple and reduce coloration of the sound. But when mounted on a mixing or mastering console, small stands will replace the floor stands so the same objective is achieved.

Visual Aesthetics

The three way monitor cabinet will be stained a dark cherry with the tweeter and woofer mounted in a black absorptive material that will be wrapped in a fabric for aesthetic purposes. The visual aesthetic is minimal in the design, so more time is spent on tuning and optimization of the system.

SPL Output

To accurately monitor the sound, a high SPL output on the monitors is needed. The high SPL will allow a lot of headroom, so that no unwanted distortion is caused by driving the monitors too hard.

I conducted an experiment where I measured the loudness of a mix or master I was working on during three specific times of the day. The average decibels per time of day is show in Figure 2. [6]

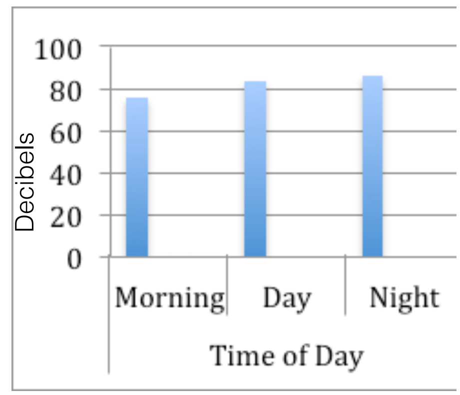

Figure 2:
Average dB (dBA) over time of day. See Appendix 1 for full data.

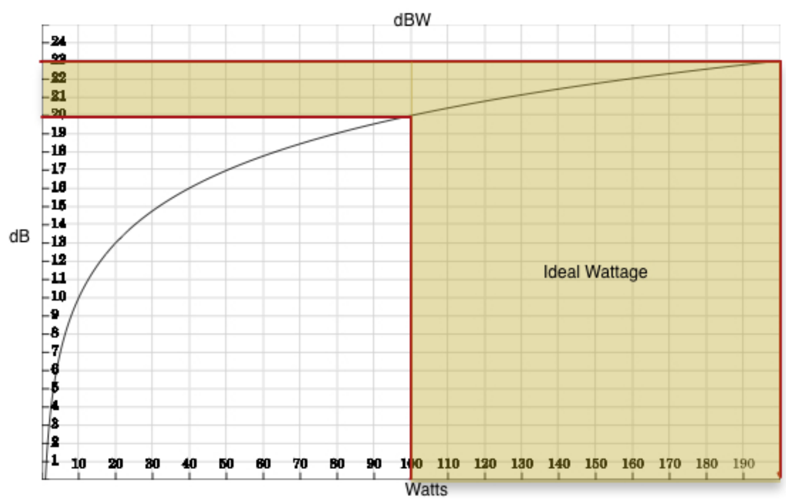

Figure 3:
This graph represents the different amount of Watts to produce decibels. Showing that doubling the wattage (of 100W) produces only a 3db increase.

[6] Thomas Conran, 25 January 2013, Transducer Theory dB level experimentation, Michigan Technological University.

The overall sensitivity of the monitor system needs to be about 88dB/Watt. Coupled with a 100 Watt amplifier, see Figure 3 for dBW rating of amplifer, the monitors will produce up to about 108 dB. This will give the monitors ample amount of headroom so they will not distort at the desired working level, which is from 77dB to 85dB. This also fits the desired crest factor of 20 dB, which gives the crest SPL of 105dB, even when working at 85dB.

Design Consequences

With this design, the monitors will be pushing the extremes of my $1800 budget, therefore the design consequences triangle that will allow one to pick any two of the three options. The two that were focused on for this design was SPL and bass response because size was chosen to be nominal, up to a point. Of course these decisions are all relative to the budget.

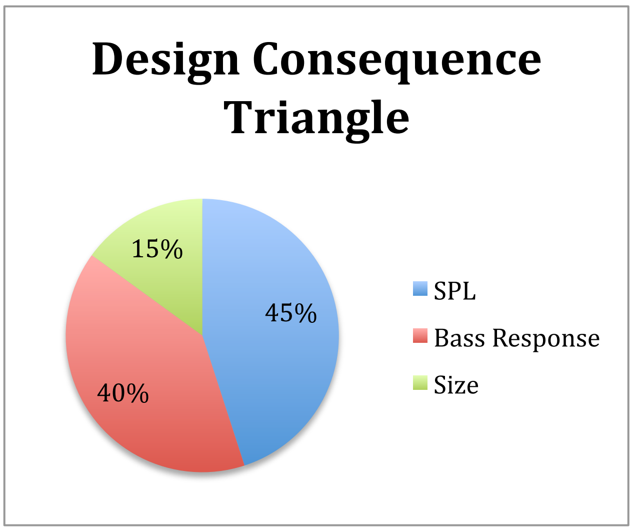

Figure 4:
As shown above, the percentage of size is nominal compared to the others.

The sealed cabinet does give a more accurate transient response, yet the bass response suffers. Therefore the midfields will have to be larger to accommodate the larger drive units need to get to a lower frequency response.

Technical Details

Baffle Step

The width of the box is 27”, and therefore creates a baffle step of 169 Hz. But since these monitors are designed for horizontal mounting the baffle step could accord at 326 Hz because the height of the box is 14”. At that point, the drivers act as if they were in free space (4 pi), whereas above the frequency the drivers are acting as if there were in half space (2 pi). At the point below the baffle step frequency, f_3, a -3dB shelf takes place.

Low Frequency Alignment

To preserve the transients in the monitor and accommodate the design goals, a sealed box was required. Shown below are two waterfall plots of small loudspeakers one of which is ported where the other is sealed. One can see that at lower frequencies the monitor “rings,” whereas the sealed monitor does not. This “blurs” the response, and can mask problems in the recorded audio. Therefore it was a logical decision to make the monitors sealed. The inherent problem with sealed boxes though is that they have to be rather large to reach lower frequencies.

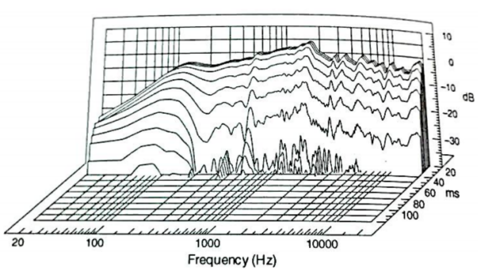

Figure 5:
The response of a small sealed monitor.[7]

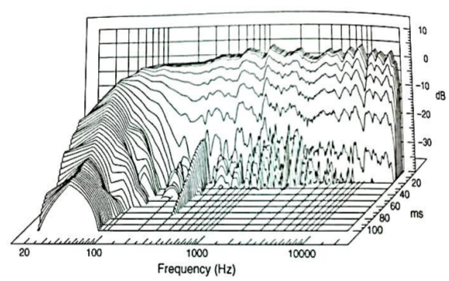

Figure 6:
The response of a small ported monitor.

Diffraction Effects

The tweeter and midrange drivers will be surrounded by a stepped felt profile. That will be removable the effects of the felt can be measured and adjusted to taste of the user. Research that was done by David Ralph showed that imaging improved, as well as frequency response (especially in the 1,500 hertz to 4,000 hertz range). [8]

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[7] Philip Newell, and Keith Holland, *Loudspeakers: For Music Recording and Reproduction*, (Amsterdam: Focal Press, 2007), 320-333.

[8] Ralph, David. "Diffraction Doesn't Have To Be A Problem." 06 , 2005. http://www.speakerdesign.net/audioXpress/diffraction/diffraction.html (accessed March 3, 2013).

Wall Construction & Bracing
The wall construction of the monitors will consist of a dual layer design. The outside of the box will consist of 3/4" 13 plywood Baltic Birch. While the inside, except for the rear will be 1/2” MDF coupled to the outside walls.

The bracing for the monitors will be made out of 3/4” 11 Plywood Pine. The bracing will run from the front face to the rear of the monitor to ensure the rigidity along its longest faces.[9] Each brace will be a 1/2” thick and 1” wide, and one will be placed above the left woofer whereas the other will be placed below the right woofer. Since these two braces are offset from each other this will not cause similar resonances on the walls of the monitor.

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[9] George Short, *North Creek Cabinet Handbook*, (Old Forge: North Creek Music Systems, 1992), 10.

Drivers

The drivers used in monitors were carefully selected to best produce the functional design, and meet the design goals. All of the drivers mentioned below have their respected data sheets in the appendix.

Driver Size and Type

The tweeter will be a ribbon tweeter, which has a frequency response up 40khz. This extended frequency range will allow the user to hear the effects of the ultrasonic frequency information on their recordings, which “can positively affect the perception of sound quality.”[10]

The midrange will be a soft dome midrange. Dome midranges are notorious for tasteful distortion that colors the sound caused by the non-linearity of the dome at different frequencies.

The two woofers should be anywhere from a 6.5”-9” cone midwoofer drivers to provide the low frequency response desired. The two drivers, when wired in series, have the about the same surface area that a 10” woofer would have, which gives the two 7” drivers the advantage of a fast transient response. The downside to using two drivers instead of one to produce the mid-bass range is that the separation causes lobbing, yet if spaced properly there are many advantages to using this technique.

Driver Spacing

The spacing between the woofers is about 6” creating for a total driver separation (measuring from the center of the cones) of 15”. This puts the drivers about a half of a wavelength apart at their upper crossover point (around 500hz). The midrange and tweeter are then aligned on the vertical midpoint axis between the woofers, with spacing between the drivers be about 1” which will make a total distance from center to center of about 5”. On the subwoofer, the driver will be placed in the middle of the front face. Below in Figure 5 and Figure 6, will show graphically show the factors for deciding the spacing.

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[10] Neve, R. Letters: Rupert Neve of Amek replies. Studio Sound and Broadcasting Engineering, (1992), 3:21-22. Quoted in Oohashi, Tsutomu ; Nishina, Emi; Honda, Manabu; Yonekura, Yoshiharu ; Fuwamoto, Yoshitaka; Kawai, Norie; Maekawa, Tadao; Nakamura, Satoshi; Fukuyama, Hidenao; Shibasaki, Hiroshi, *Inaudible High-Frequency Sounds Affect Brain Activity: Hypersonic Effect*, (Journal of Neurophysiology, 2000 June 1), 83:6 3548-3558.

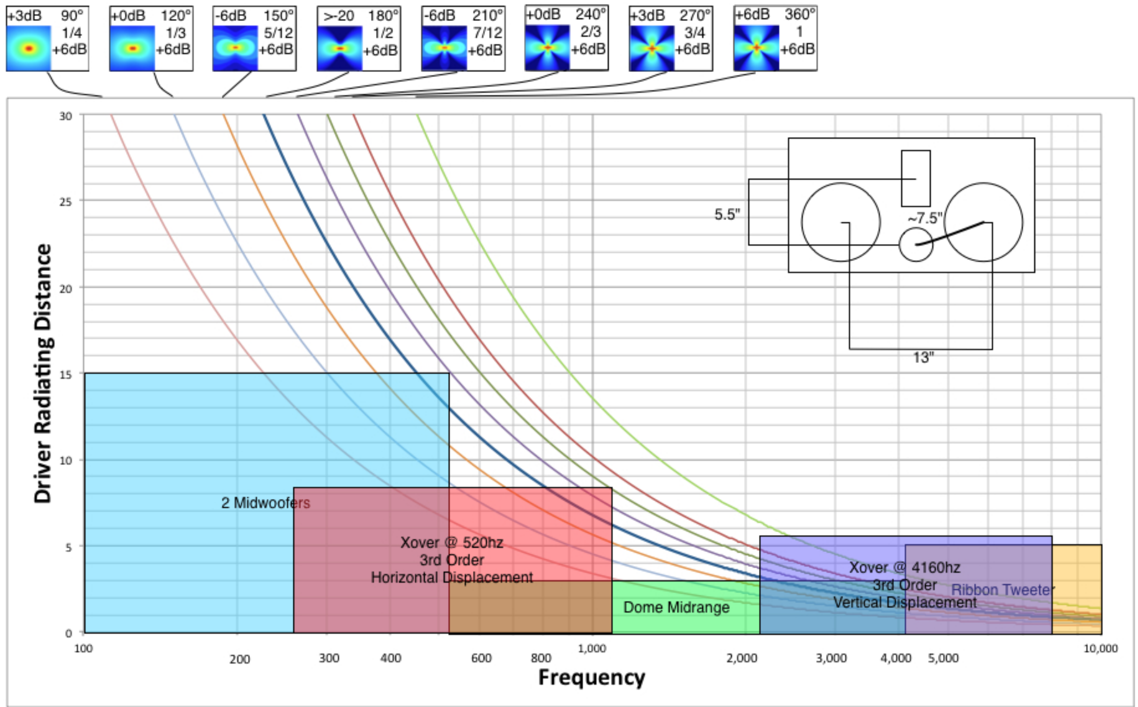


Figure 7:
The lobbing that occurs at different mid to high frequencies relative to the spacing of the drivers.

Tweeter Analysis & Selection

The desired goals of the tweeter are to have a relatively flat, or easily correctable, frequency response from 4000 hertz and up. The sensitivity of the driver is going to be larger than the rest of the system, therefore it does not play a part in my decision process.

Driver Company	Driver Name	Size	Sensitivity (dB)	f3 (Hz)	Power Handling (Watts)	Price ($)
Fountek	NeoCD2.0M	5"	98	300	20	119
Aurum Cantus	G2Si	3-1/4"	96	-	30	139.25
Aurum Cantus	AST2560	3-3/8"	95	-	60	199.49
Tang Band	RT-1516SA	3"	95	-	8	185.37
HiVi	RT1.3WE	2"	92	-	10	99.05

Tweeter #1 Detail

Fountek NeoCD2.0 is a 5” ribbon tweeter that is sealed, and has a very fast and accurate transient response. There is little deviation of the frequency response above the desired crossover frequency of about 4100 hertz after a first order filter is put on around 6500 hertz. The sensitivity of this driver is 98 dB, and will need damping to sound balance with the other drivers. The driver also has excellent horizontal off-axis response, yet the vertical off-axis rolls over drastically above 10,000 hertz. Also the driver is rated to go up to 40,000 hertz, which is a bonus design goal. Even though the power handling is low, the driver will get well above my desired SPL, as well as my desired SPL with crest factor.

Figure 8:
Fountek NeoCD2.0

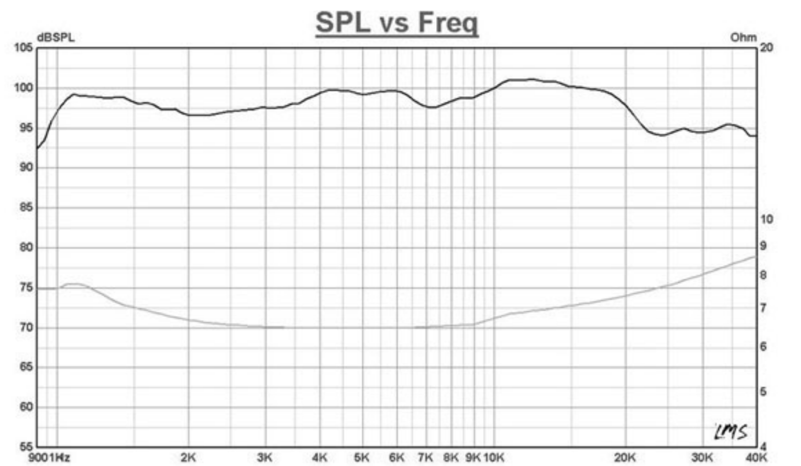


Figure 9:
NeoCD 2.0 frequency response plot, and impedance curve.

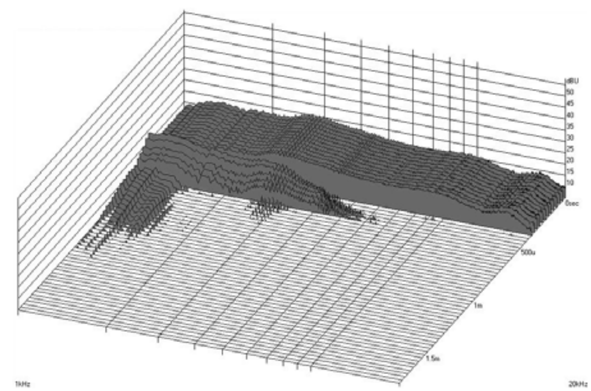


Figure 11:
NeoCD 2.0 waterfall plot

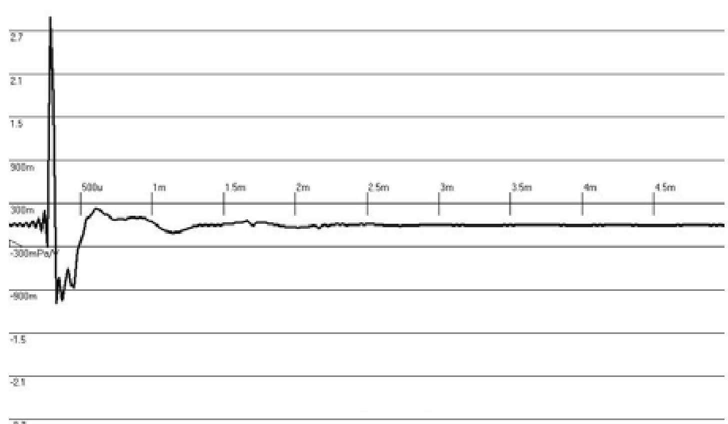
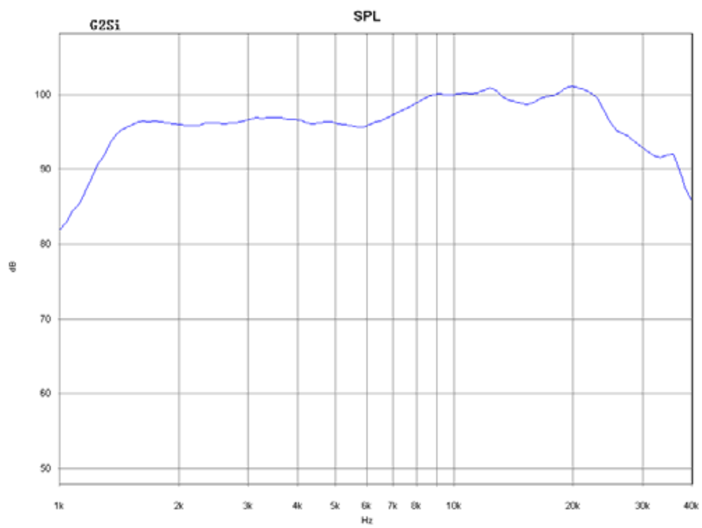
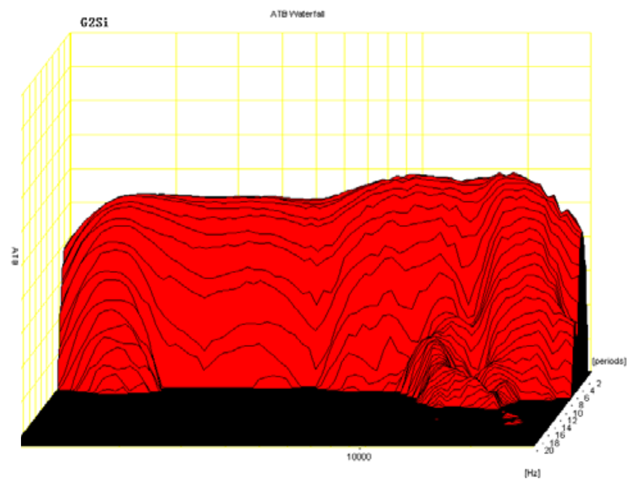


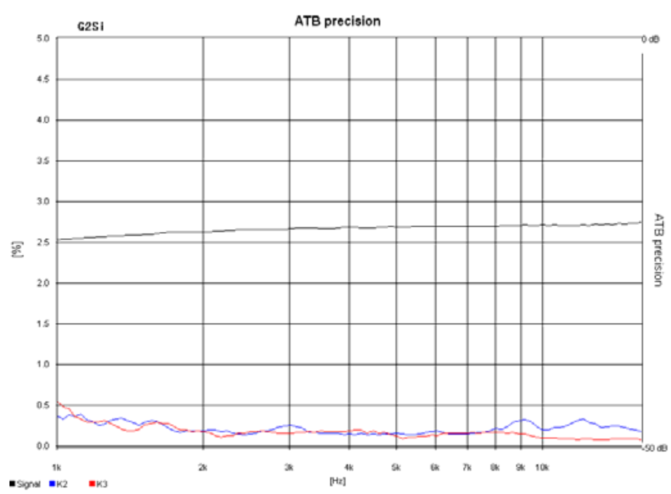
Figure 10:
NeoCD 2.0 transient response

Tweeter #2 Detail

Aurum Cantus G2Si is a 3.5" aluminum ribbon tweeter that is sealed, and has very low distortion characteristics at and above the desired frequency response of 4160 hertz. The frequency response of the driver is not as accurate as the Fountek, and has resonance at 16,000 hertz. The sensitivity of this driver is 96dB, and will need damping to sound balance with the other drivers. The driver has low distortion, and has a graph posted while most other drivers do not both to show that information. The driver said it is rated up to 40,000 hertz, but the frequency response goes only slightly above 20,000 hertz. This raises some speculation about the listed range.

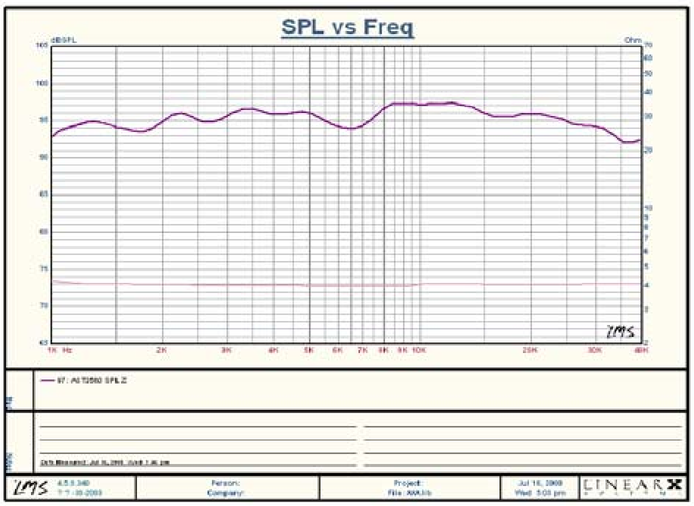


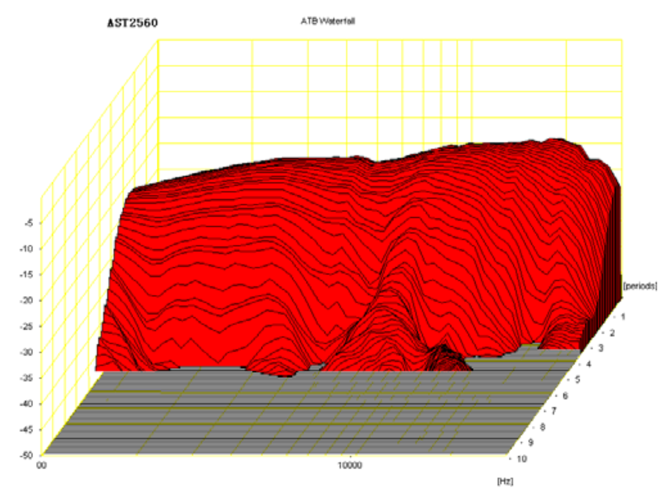


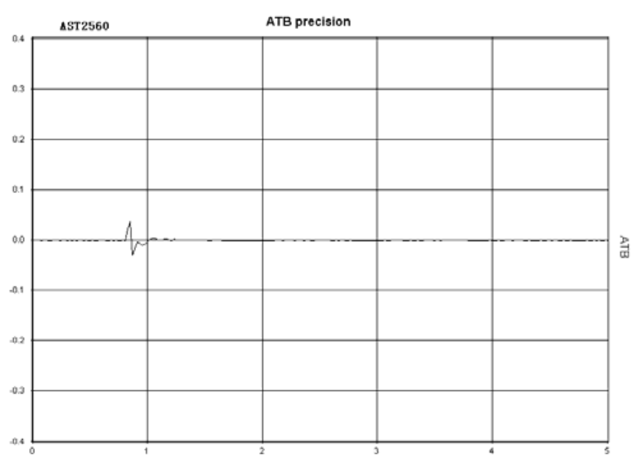


Tweeter #3 Detail

Aurum Cantus AST2560 is a 3 3/8” pneumatic tweeter that is sealed, and has a very fast transient response. The frequency response is fairly accurate, yet there are bumps throughout the upper midrange (5000-8000 hertz). This driver also produces very low distortion. The sensitivity of this driver is 95dB, and will need damping to sound balance with the other drivers. The driver is rated up to 35,000 hertz, but appears to extend well above that, which is a positive.

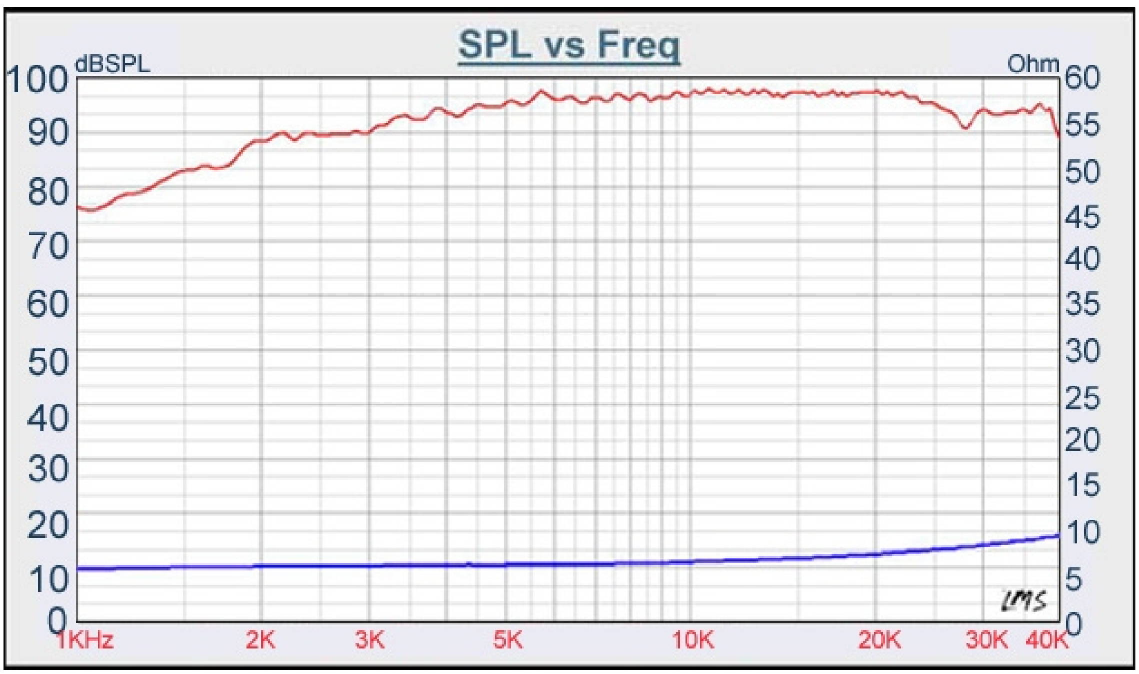






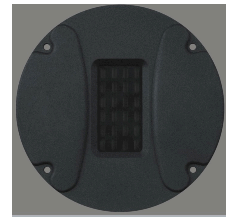
Tweeter #4 Detail

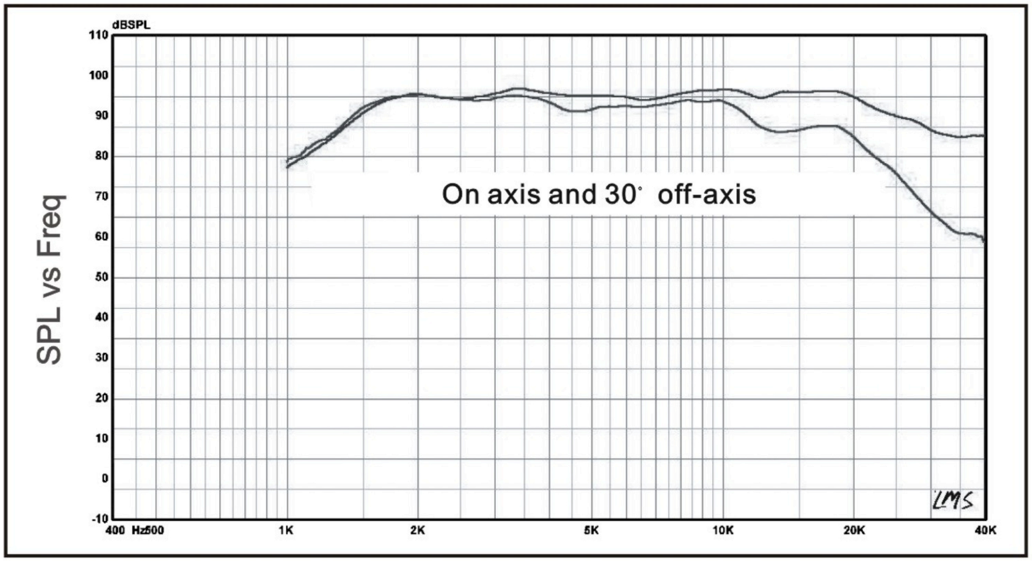
Tang Band RT-1516SA is a 3” ribbon tweeter that is sealed and have a very fast and accurate transient response. The frequency response is very similar in shape to the Fountek NeoCD2.0, yet the boosted in the high end starts to at to low of a frequency to easily compensate it. The driver has a sensitivity of 95 dB, so it will need to be damped to sound balance with the other drivers. As with all ribbon tweeters it extends well above 20,000 hertz. Yet the one this driver lacks in the amount of information in it’s specification sheet, only a frequency response plot and impedance curve was found. Which is always a red flag for me, but from the reviews on Parts Express it is quite good.

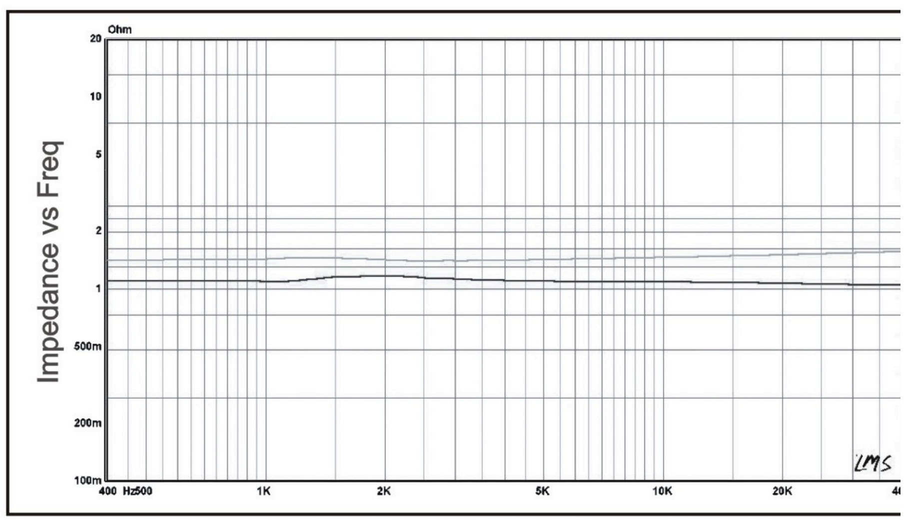


Tweeter #5 Detail

HiVi RT1.3WE is about a 2” ribbon tweeter that is sealed. The frequency response is relatively flat all the way up to 20,000 hertz. The off-axis response up to 10,000 hertz is very good as well. Given that this driver is very cheap and has little to no information on it concerns me. The driver has a low sensitivity, given that it is a ribbon, of 92 dB.







Midrange Analysis & Selection

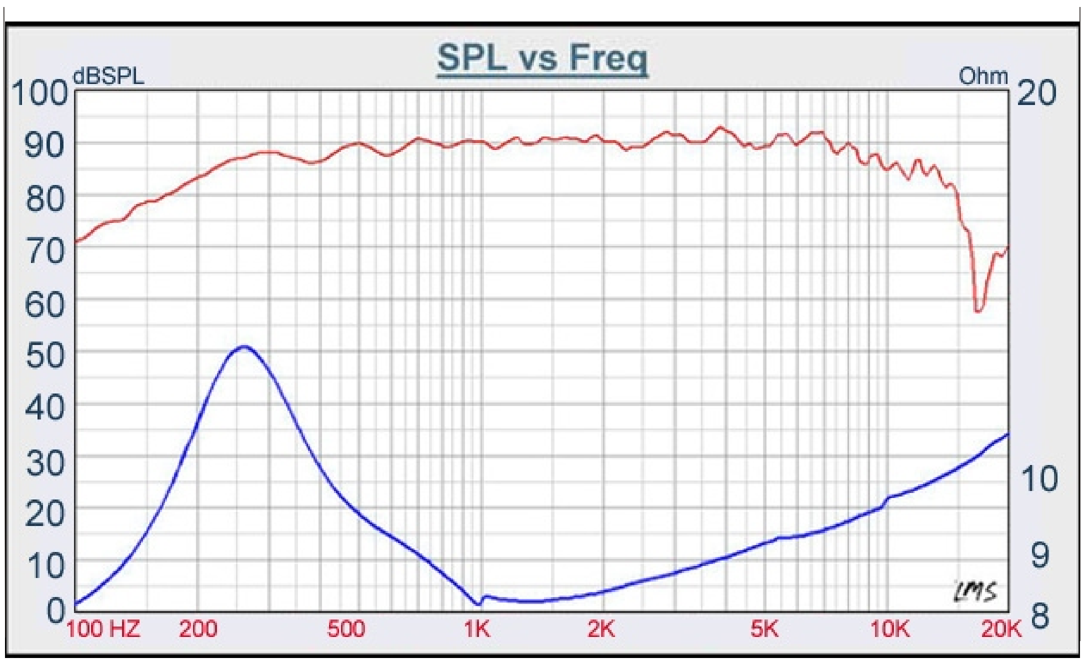
The desired goals of the midrange are to have a ±1.5 dB frequency response from 500 hertz up to 4100 hertz. The sensitivity of the driver has to be above 89dB 1W/1m, so that the sensitivity can be roughly the same throughout most of the system.

Driver Company	Driver Name	Size	Sensitivity (dB)	fs (Hz)	Power Handling (Watts)	Price ($)
Tang Band	75-1558SE	3"	90	260	25	135.26
Morel	MDM 55	2.1"	89.5	380	200	90.1
HiVi	DMN-A	2"	93	800	60	92.69
Scanspeak	Discovery D7608/92000-10	3"	92	300	80	103.1
Dynaudio	Esotec MD 142	2"	90	475	100	234.99

Midrange #1 Detail

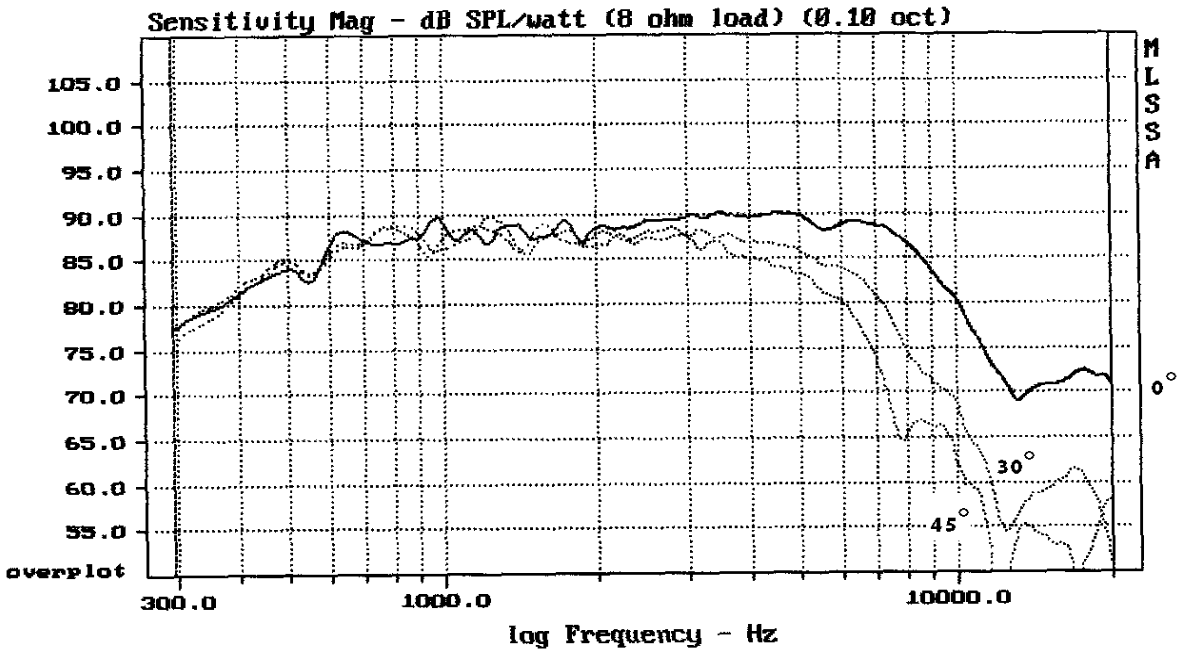
Tang Band 75-1558SE is a 3" soft dome midrange. It is a sealed midrange, which has a flat extended high frequency response because of being optimally damped. The sensitivity of this is 90dB, and has a power rating of 20 Watts that means that this driver cannot handle a high average level, but the peak wattage is 200 Watts so the peaks are not a problem. The inherent dome quality will provide the design goal of grittiness, and the loudness of the driver will meet the SPL goal. From my desired two crossover points this driver has a $\pm$1 dB, which is acceptable since I want to have a $\pm$1.5 dB throughout the frequency spectrum.

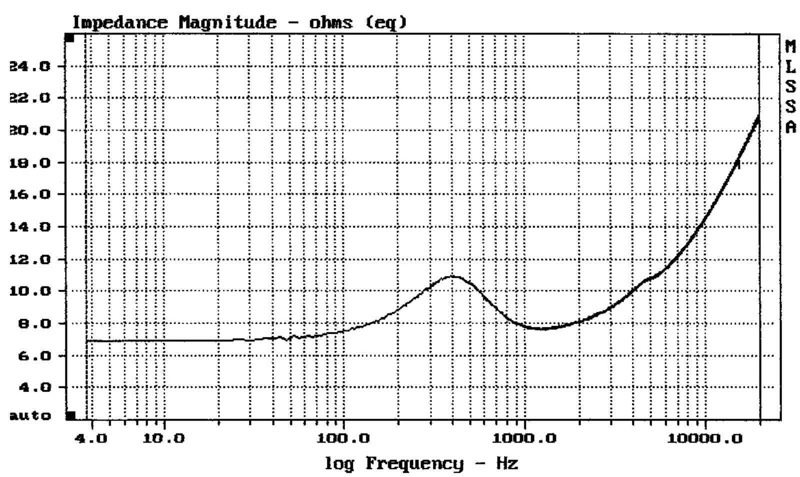
The driver would be crossed over around 500 hertz and 4100 hertz, so a flat frequency response is a must to meet the design goals, which this driver provides.



Midrange #2 Detail

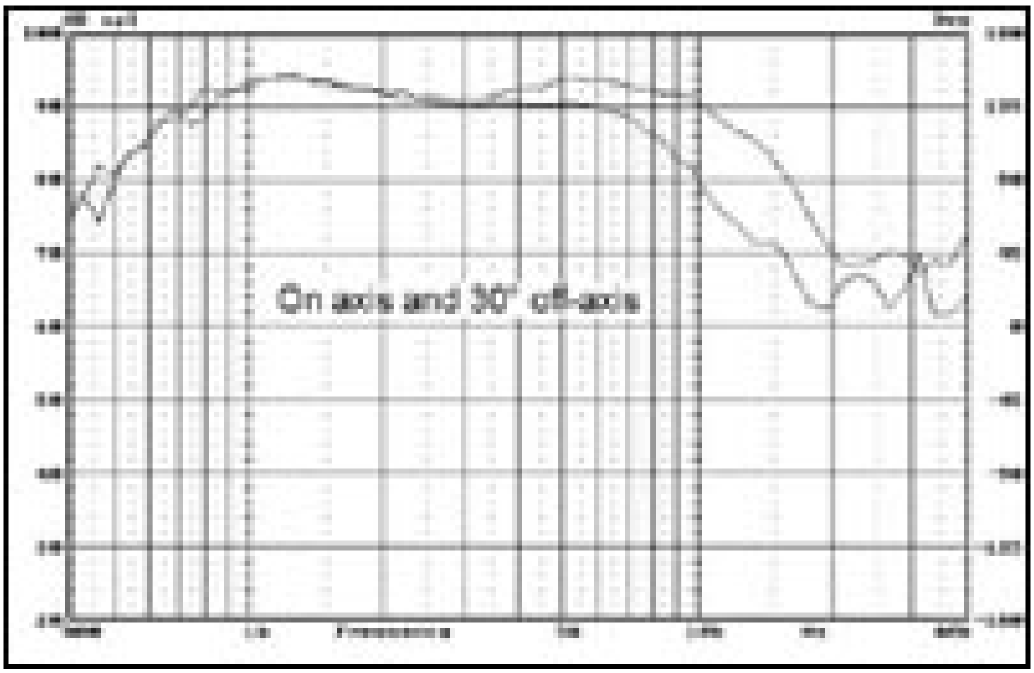
Morel MDM 55 is a 2.1" soft dome midrange. It is a sealed midrange that is highly appraised. The sensitivity of this driver is 89.5dB, and has a power rating of 200
Watts, so it can hand a lot of Watts and get loud. The dome quality does give this driver the grittiness, but the resonant frequency is around 800 hertz, and is really only useful from 1000 hertz up to the tweeter crossover of around 4100 hertz. Therefore in my design, this midrange would not work.

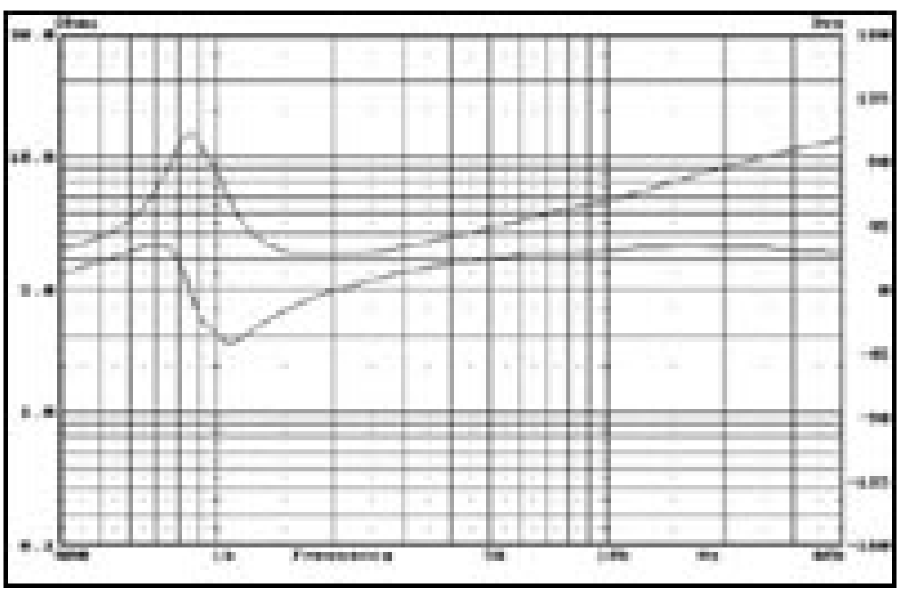




Midrange #3 Detail

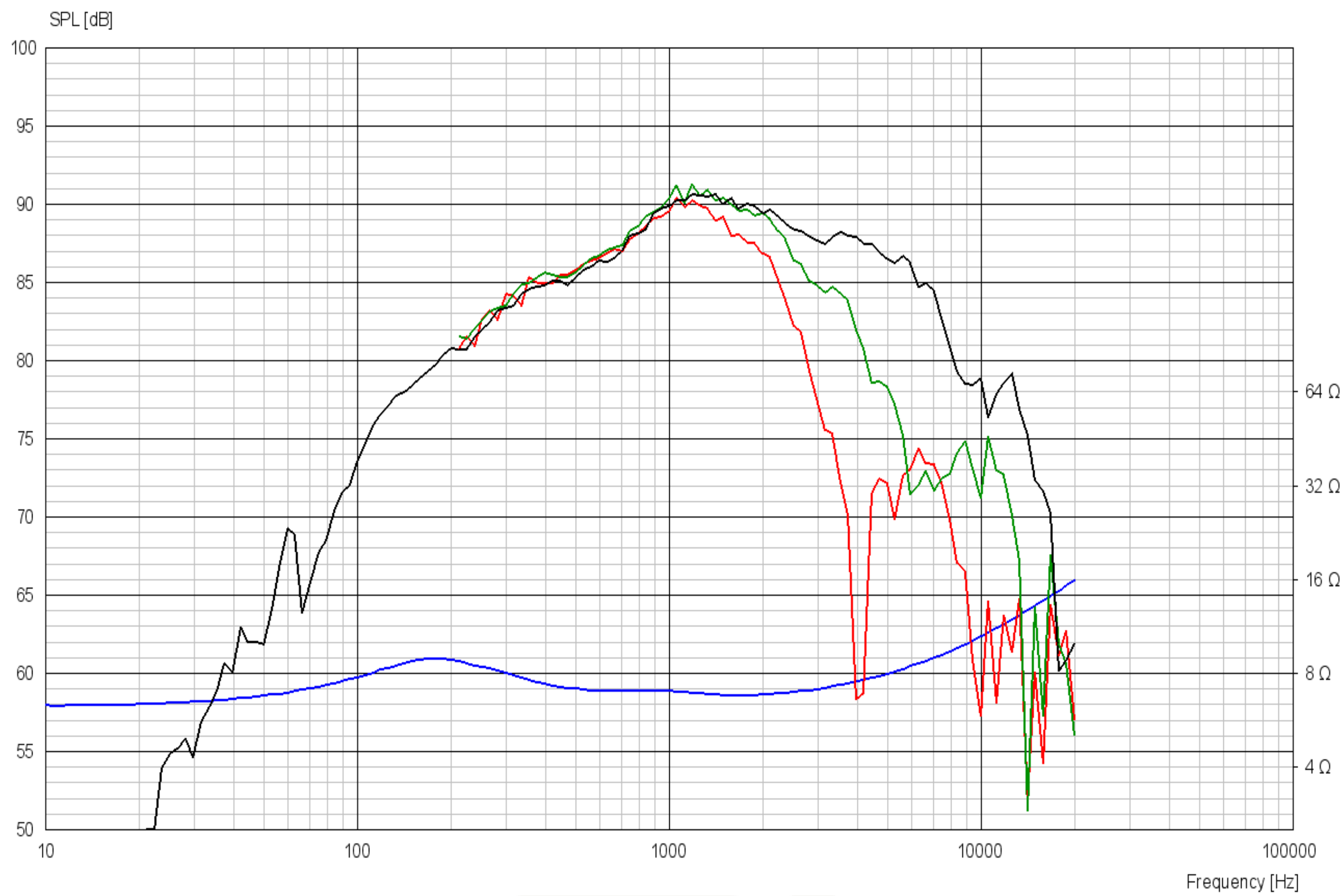
HiVi DMN-A is 2” soft dome midrange. It is a sealed midrange that has a sensitivity of 93 dB. The power rating is 60 watts over time. The dome quality does give this driver the grittiness, but since it is so small the f3 is 360 hertz, and is very inconsistent from 300 hertz to 1000 hertz. So this driver would not suit the design goal of crossover points for my midrange driver.





Midrange #4 Detail

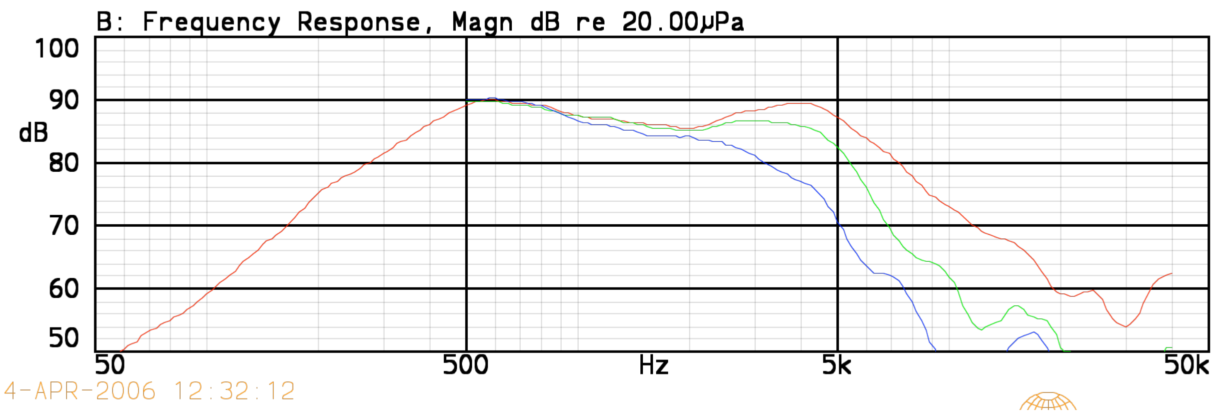
Scanspeak Discovery D7608/9200-10 is a 3" dome midrange that is not sealed. This would call for an enclosure to be built. The driver has a sensitivity of 92dB, and provides wide dispersion. The power handling over time is 80 Watts so this driver can get loud. From my desired two crossover points this driver has a ±1.5 dB, which is acceptable since I want to have a ±1.5 dB throughout the frequency spectrum.



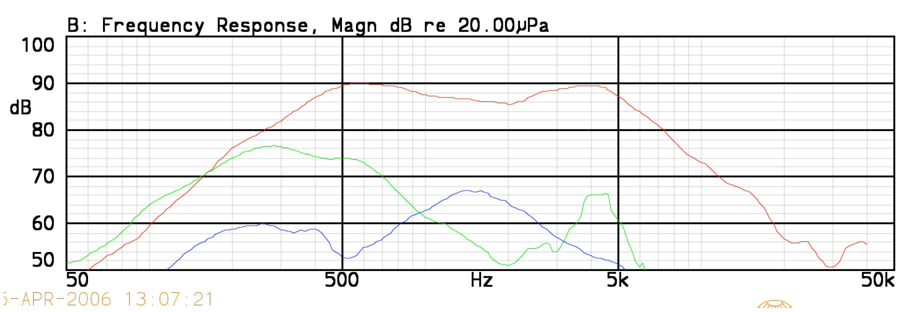
Midrange #5 Detail

Dynaudio Esotec MD 142 is a 3" dome midrange It is a sealed midrange that has a sensitivity of 90 dB. The power rating is 100 Watts, and has a transient power handing of 1000 Watts, which is an enormous load. From my desired two crossover points this driver has a +2 dB, which is acceptable since I want to have a +1.5 dB throughout the frequency spectrum. This driver is specifically made for the midrange application so at each of the end of the useful spectrum it is transducing it employs about a 3rd order roll off, naturally. Unfortunately, this driver is out of the price range so it will not be employed in this design.

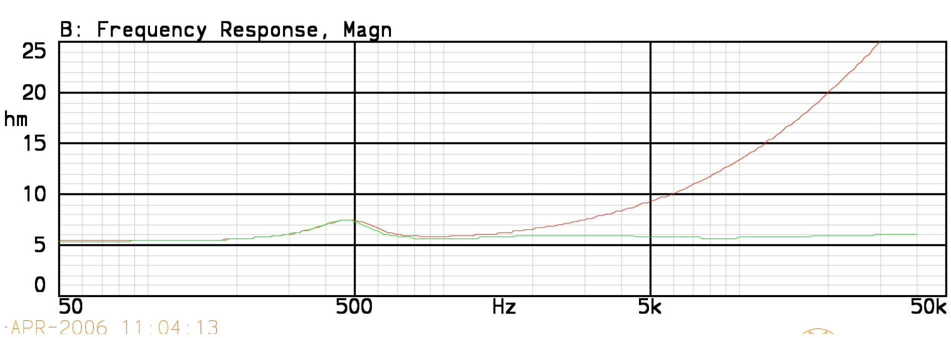
Frequency response • on-axis, 30° and 60° off-axis



Frequency response • 2nd and 3rd harmonic distortion



Impedance • with and without impedance correction circuit



Woofer Analysis & Selection

The desired goals of the woofer are to have a low Q in a 50 or less liter box, as well as not exceeding the excursion (X_{max}). The sensitivity of the driver has to be above 86 dB 1W/1m, and have an f3 point anywhere from 50 hertz to 55 hertz. Also the woofers should have a fairly flat frequency response up to 500 hertz, and from there either continue with the linearity up the frequency spectrum or begin to roll off. Yet below 200 hertz, the testing that was performed by the company of the driver is slightly irrelevant because of the size of the companies' testing baffle.

Each woofer has four WinSpeakerz graphs attached, in order they list the optimal size to fit the design goals, the resulting SPL from the optimal size, overly-damped, followed by optimally damped.

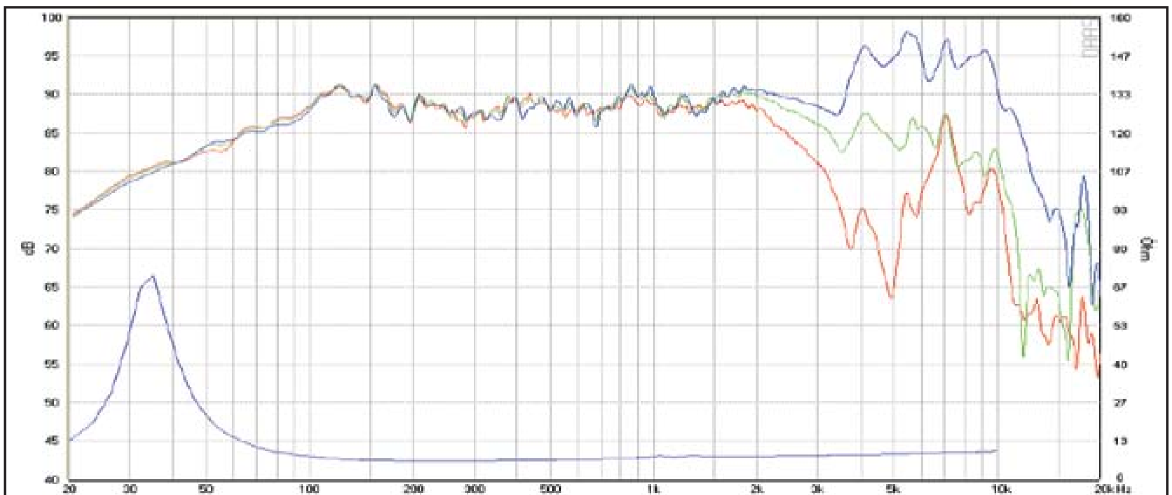
Driver Name	Size	Vas (liters)	Fs (hertz)	Xmax (mm)	Pt (watts)	Qts	Sensitivity (dB)	Price ($)
SB17NRXC35-8-UC	6.5"	44.5	32	5.5	60	0.34	89	62.4
Discovery 18W/4434G-00	7"	19.5	50	4.2	55	0.43	90.8	73.75
Prestige CD22RN4X H1192	8"	108	20	7	100	0.24	87	118.4
CAW938	9"	51	31	4.25	150	0.6	87	145.1
SB23NRXS45-8	8"	94	27	6.5	60	0.38	88.5	99.05

Woofer #1 Detail

SB Acoustics SB17NRXC35-8-UC is a 6.5" woofer that would be mounted in a sealed box with a high crossover around 500 hertz. The box is about 46 liters and has a Q of .55. The f3 of this monitor is 73 hertz, and an f10 of 38 hertz. The sensitivity of this driver meets the requirements, which is 90 dB 1W/1m.

In this enclosure, the driver had a very high resonant peak, which is not desirable in this design. These drivers have a low X_{max}, and this hinders this driver from being used in this design. The X_{max} is hit before the f3 point, so there would be distortion in driver while it is rolling off.

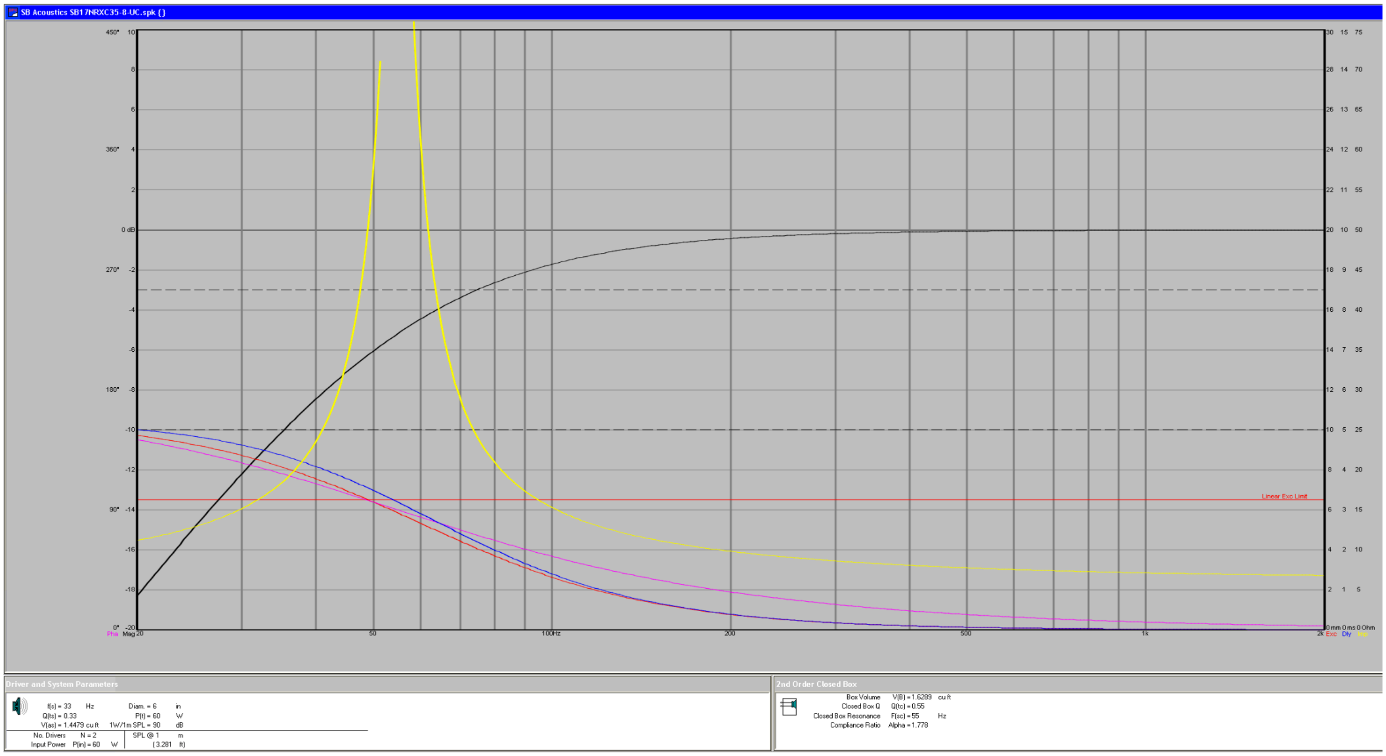
One of the positives of this driver is that the impedance already is flattened through the rest of the frequency spectrum. This driver would be ideal if a subwoofer was in use to extend the frequency response lower.

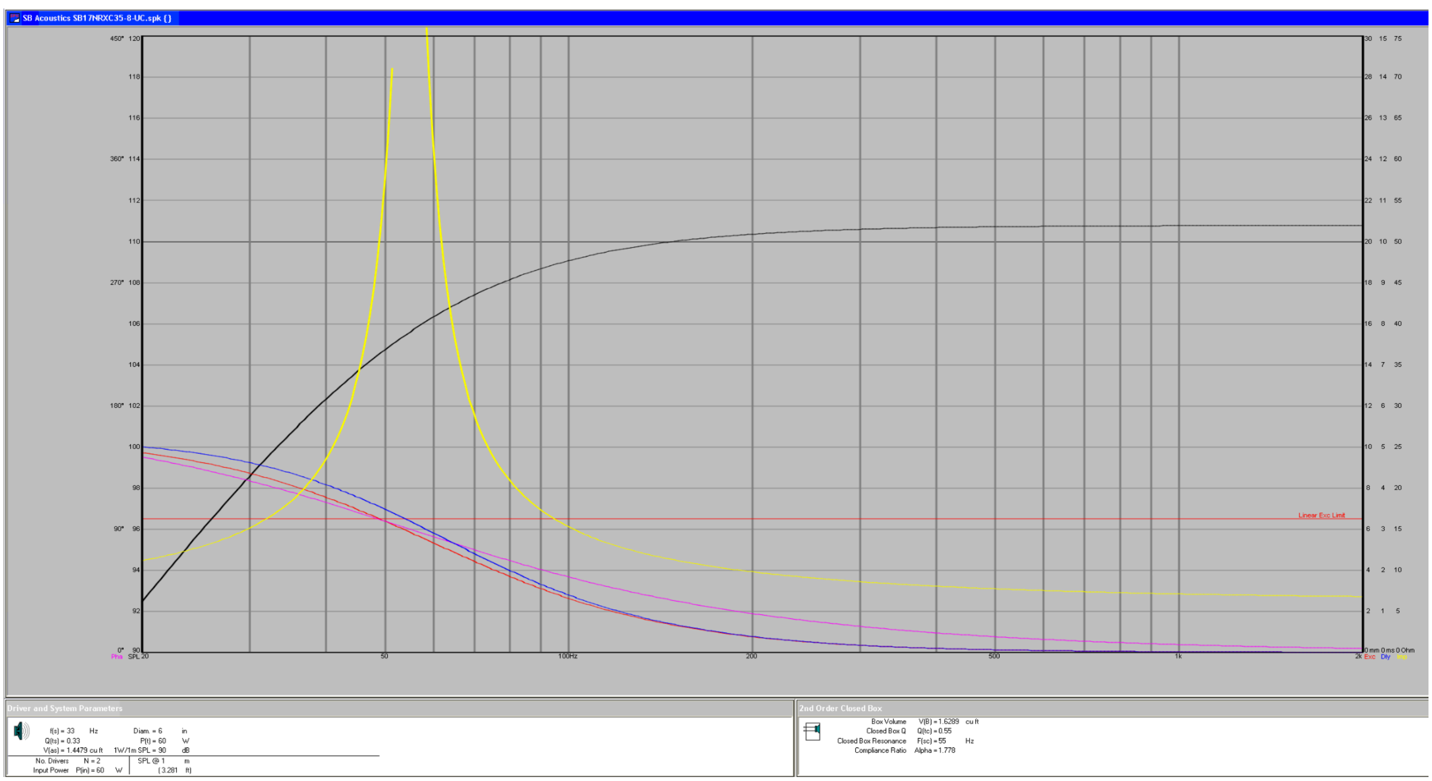


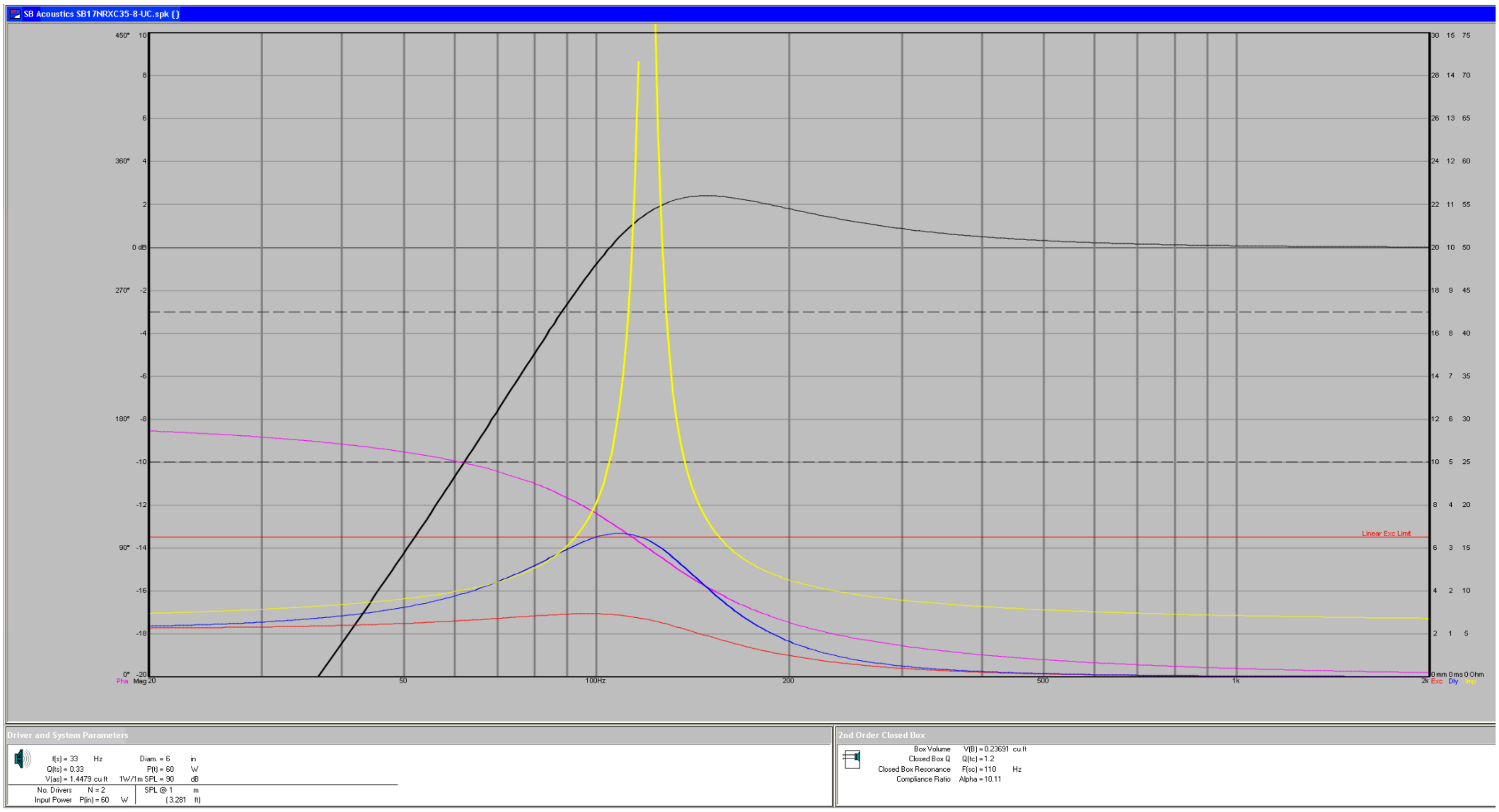
(Mic Distance 31.6 cm; 2.83 Volt; at IEC Baffle)

Response Curve :

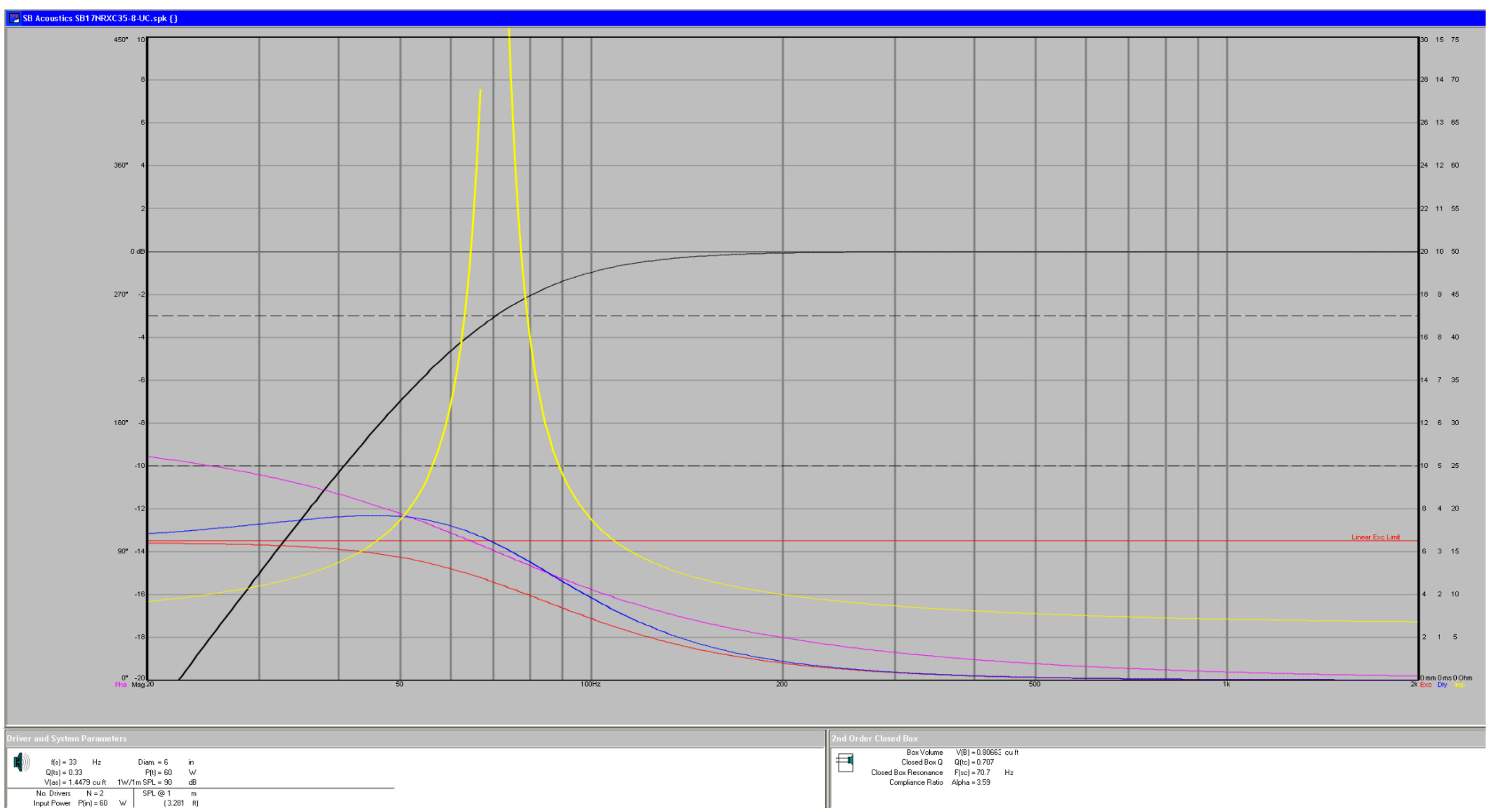
—— (Blue) : on axis —— (Green) : 30 off-axis —— (Red) : 60 off-axis


SB Acoustics SB17NRXC35-8-UC.spk {}
Linear Exc Limit
Pha Mag
Exc Dly Imp
Driver and System Parameters
f(s) = 33 Hz
Q(ts) = 0.33
V(as) = 1.4479 cu ft
Diam. = 6 in
P(t) = 60 W
1W/1m SPL = 90 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.6289 cu ft
Closed Box Q Q(tc) = 0.55
Closed Box Resonance F(sc) = 55 Hz
Compliance Ratio Alpha = 1.778


SB Acoustics SB17NRXC35-8-UC.spk {}
Linear Exc Limit
Pha SPL
Exc Dly Imp
Driver and System Parameters
f(s) = 33 Hz
Q(ts) = 0.33
V(as) = 1.4479 cu ft
Diam. = 6 in
P(t) = 60 W
1W/1m SPL = 90 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.6289 cu ft
Closed Box Q Q(tc) = 0.55
Closed Box Resonance F(sc) = 55 Hz
Compliance Ratio Alpha = 1.778



SB Acoustics SB17NRXC35-8-UC.spk ()
Linear Exc Limit
100Hz
Driver and System Parameters
f(s) = 33 Hz
Q(ts) = 0.33
V(as) = 1.4479 cu ft
Diam. = 6 in
P(t) = 60 W
1W/1m SPL = 90 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.23691 cu ft
Closed Box Q Q(tc) = 1.2
Closed Box Resonance F(sc) = 110 Hz
Compliance Ratio Alpha = 10.11

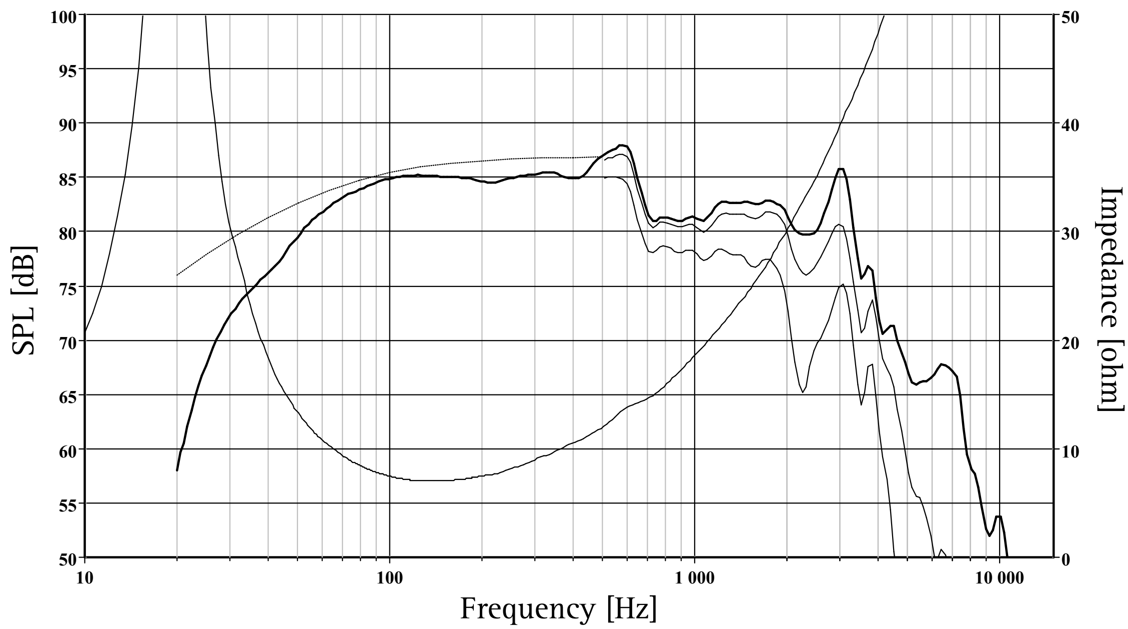


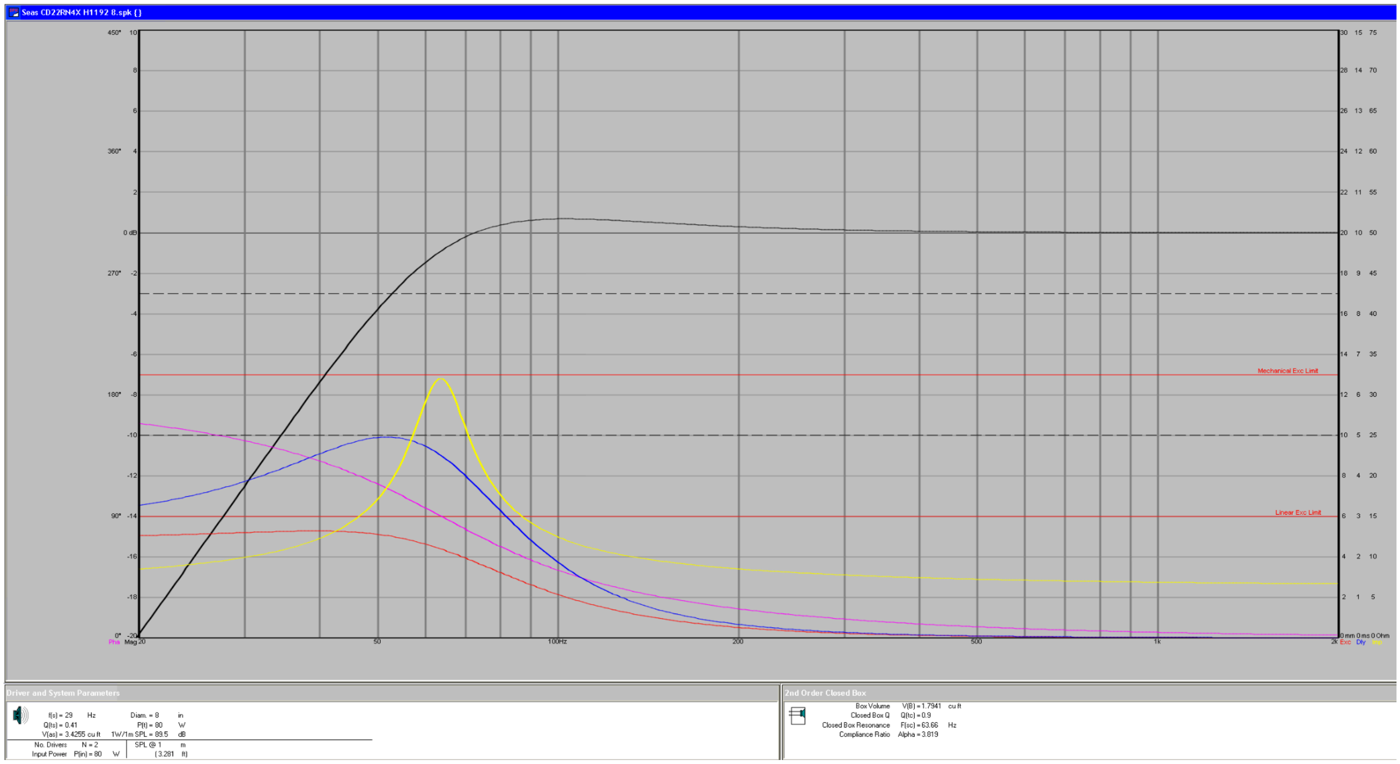
SB Acoustics SB17NRXC35-8-UC.spk ()
Linear Exc Limit
100Hz
Driver and System Parameters
f(s) = 33 Hz
Q(ts) = 0.33
V(as) = 1.4479 cu ft
Diam. = 6 in
P(t) = 60 W
1W/1m SPL = 90 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Closed Box Q Q(tc) = 0.707
Closed Box Resonance F(sc) = 70.7 Hz
Compliance Ratio Alpha = 3.59

Woofer #2 Detail

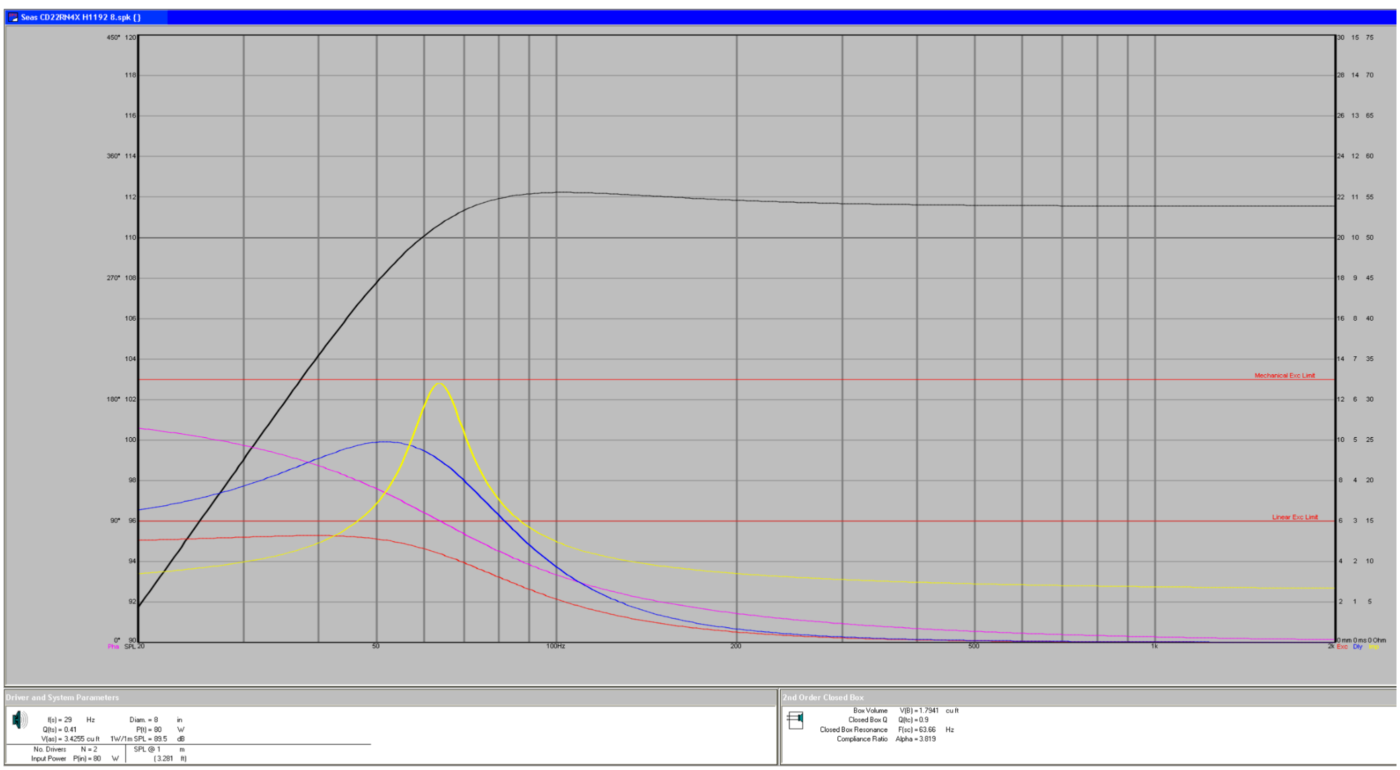
Seas Prestige CD22RN4X H1192 is an 8” woofer that would be mounted in a sealed box with a high crossover around 500 hertz. The sensitivity of this driver meets the requirements, which is 87 dB 1W/1m. In the optimal size box, an f3 of 53 hertz was achieved and a f10 of 35 hertz, yet the Q was .9.

These drivers meet all of the design requirements, but the size constraint. These drivers need a very larger box to work in a sealed enclosure. To be optimally damped, they would have to be in a 100 liter box.

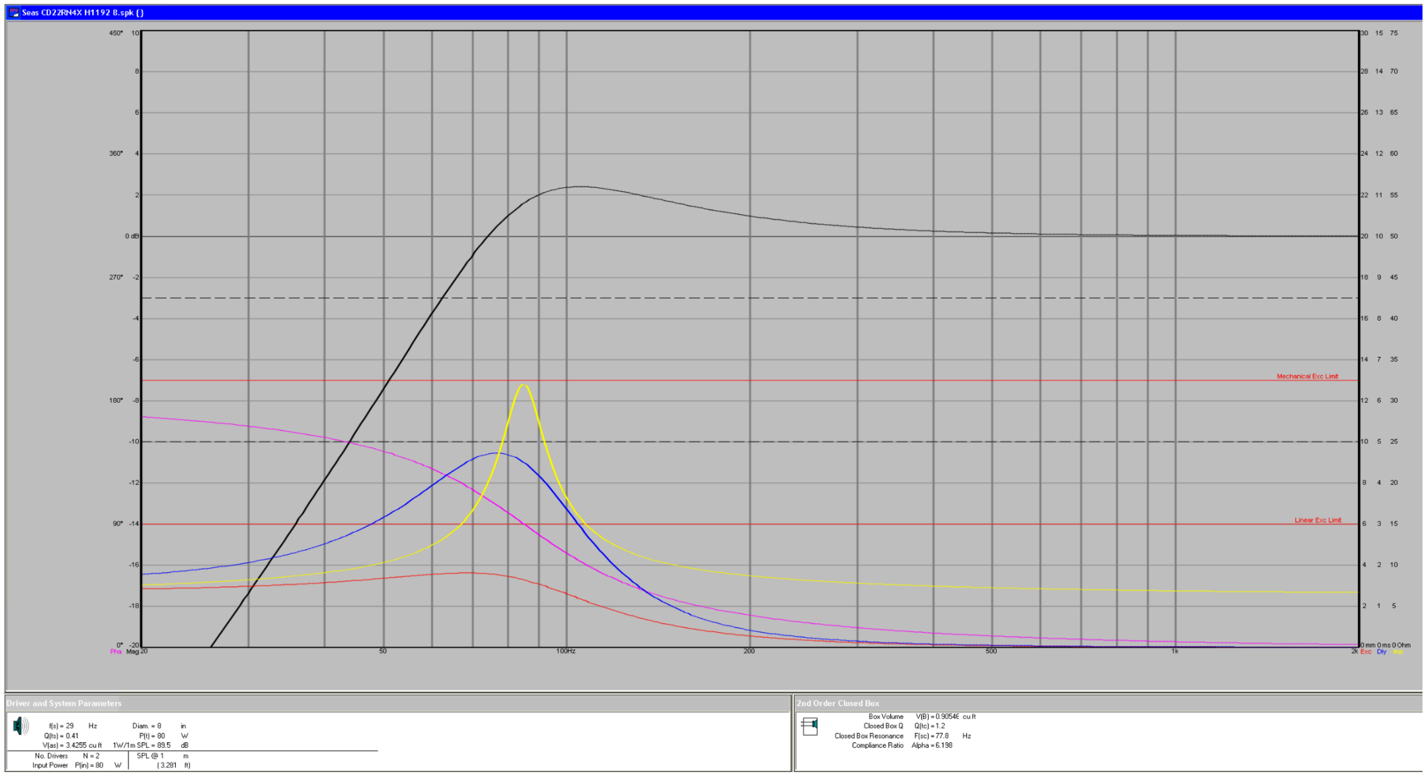


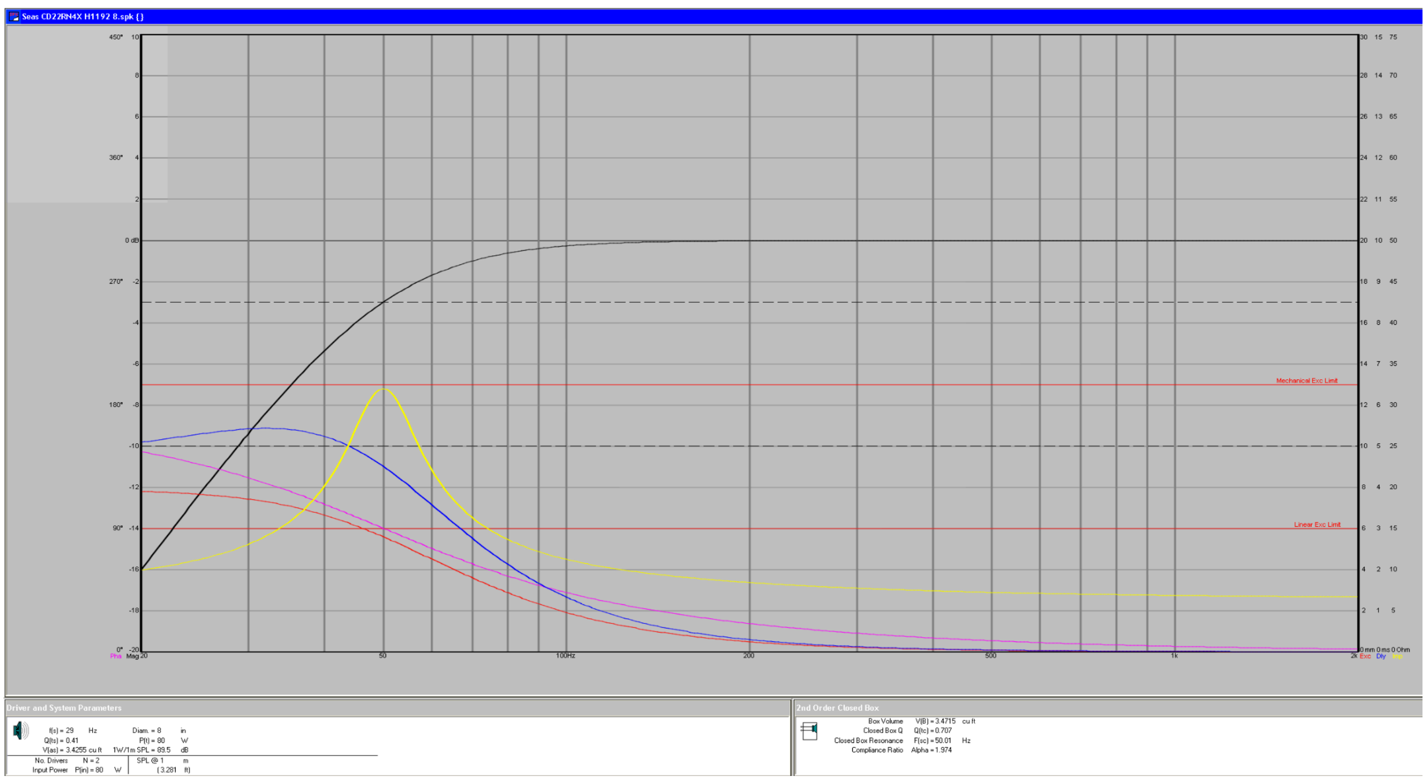


Seas CD22RN4X H1192 8.spk {}
Mechanical Exc Limit
Linear Exc Limit
Driver and System Parameters
f(s) = 29 Hz
Q(ts) = 0.41
V(as) = 3.4255 cu ft
Diam. = 8 in
P(t) = 80 W
1W/1m SPL = 89.5 dB
No. Drivers N = 2
Input Power P(in) = 80 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.7941 cu ft
Closed Box Q Q(tc) = 0.9
Closed Box Resonance F(sc) = 63.66 Hz
Compliance Ratio Alpha = 3.819



Seas CD22RN4X H1192 8.spk {}
Mechanical Exc Limit
Linear Exc Limit
Driver and System Parameters
f(s) = 29 Hz
Q(ts) = 0.41
V(as) = 3.4255 cu ft
Diam. = 8 in
P(t) = 80 W
1W/1m SPL = 89.5 dB
No. Drivers N = 2
Input Power P(in) = 80 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.7941 cu ft
Closed Box Q Q(tc) = 0.9
Closed Box Resonance F(sc) = 63.66 Hz
Compliance Ratio Alpha = 3.819

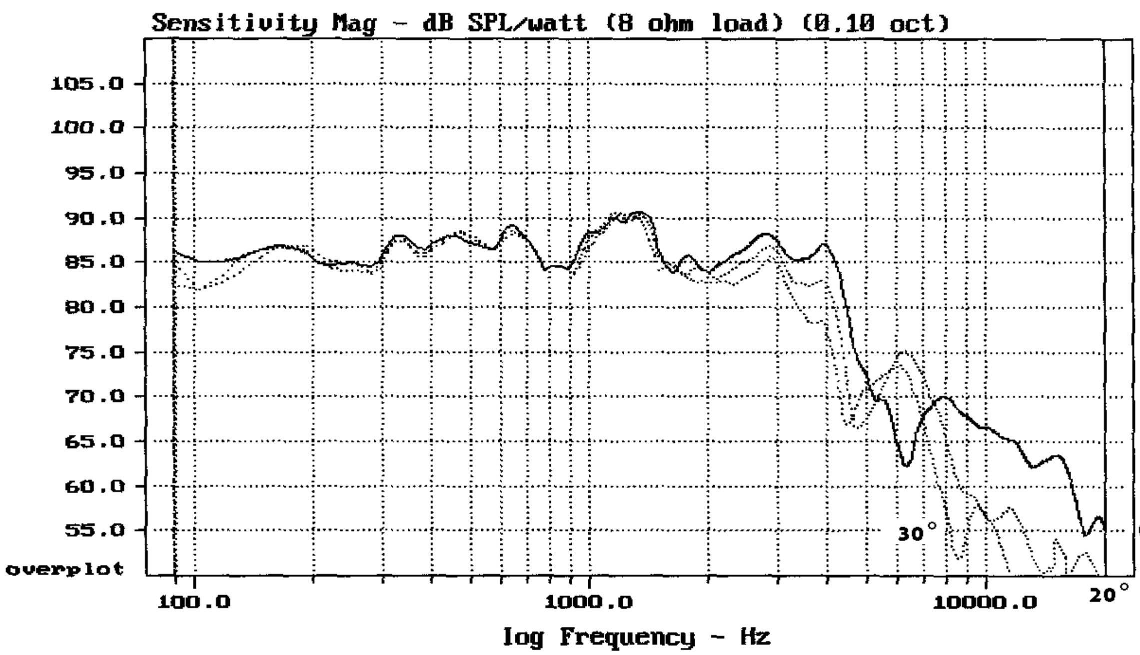

Seas CD22RN4X H1192 8.spk {}
Mechanical Exc Limit
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 29 Hz
Q(ts) = 0.41
V(as) = 3.4255 cu ft
Diam. = 8 in
P(t) = 80 W
1W/1m SPL = 89.5 dB
No. Drivers N = 2
Input Power P(in) = 80 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.9054€ cu ft
Closed Box Q Q(tc) = 1.2
Closed Box Resonance F(sc) = 77.8 Hz
Compliance Ratio Alpha = 6.198

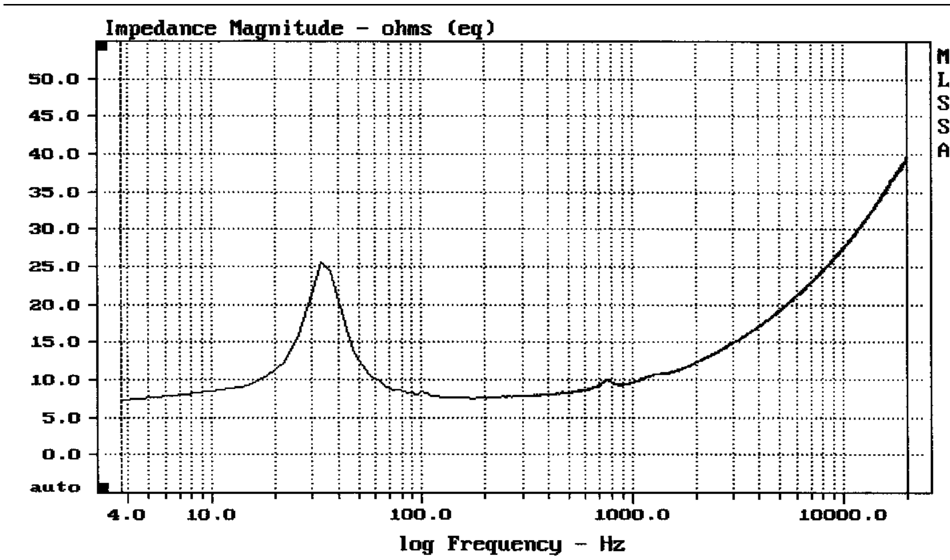

Seas CD22RN4X H1192 8.spk {}
Mechanical Exc Limit
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 29 Hz
Q(ts) = 0.41
V(as) = 3.4255 cu ft
Diam. = 8 in
P(t) = 80 W
1W/1m SPL = 89.5 dB
No. Drivers N = 2
Input Power P(in) = 80 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 3.4715 cu ft
Closed Box Q Q(tc) = 0.707
Closed Box Resonance F(sc) = 50.01 Hz
Compliance Ratio Alpha = 1.974

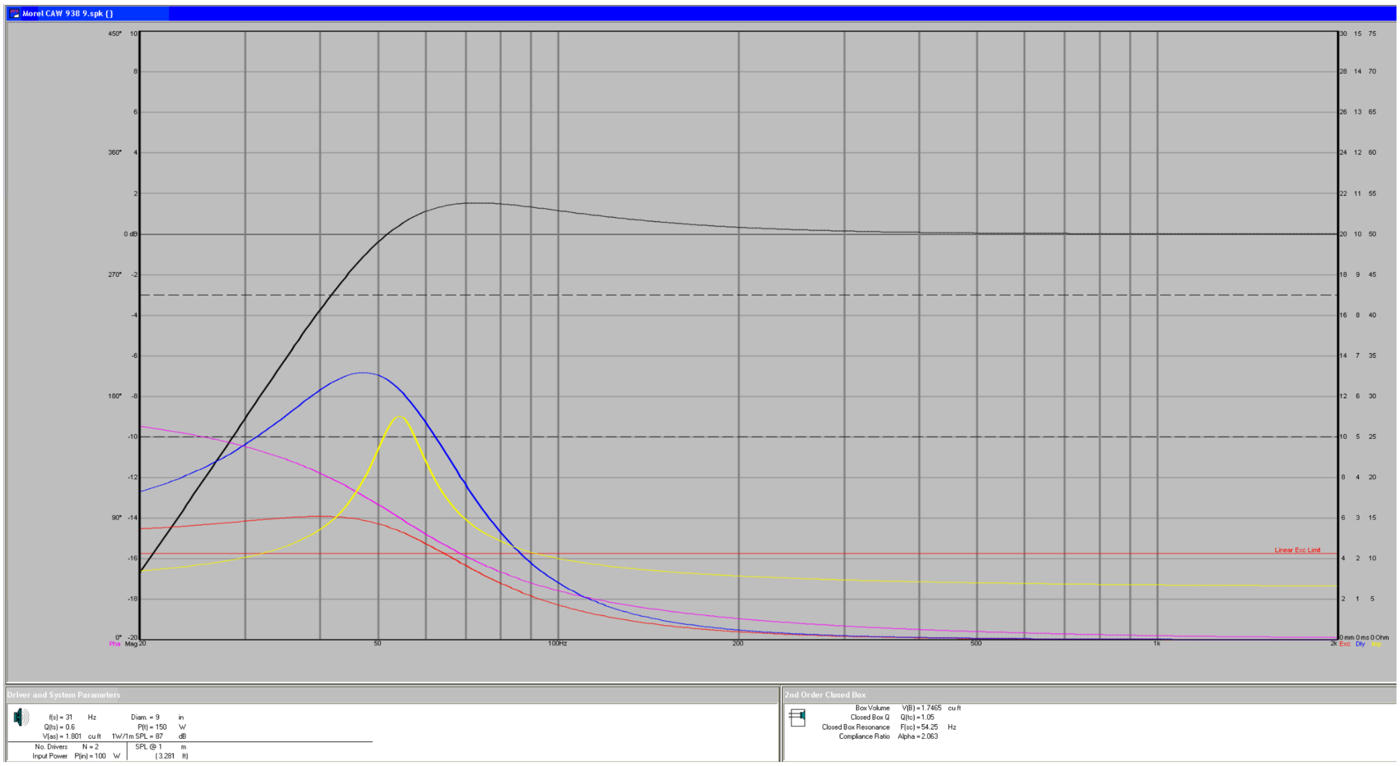
Woofer #3 Detail

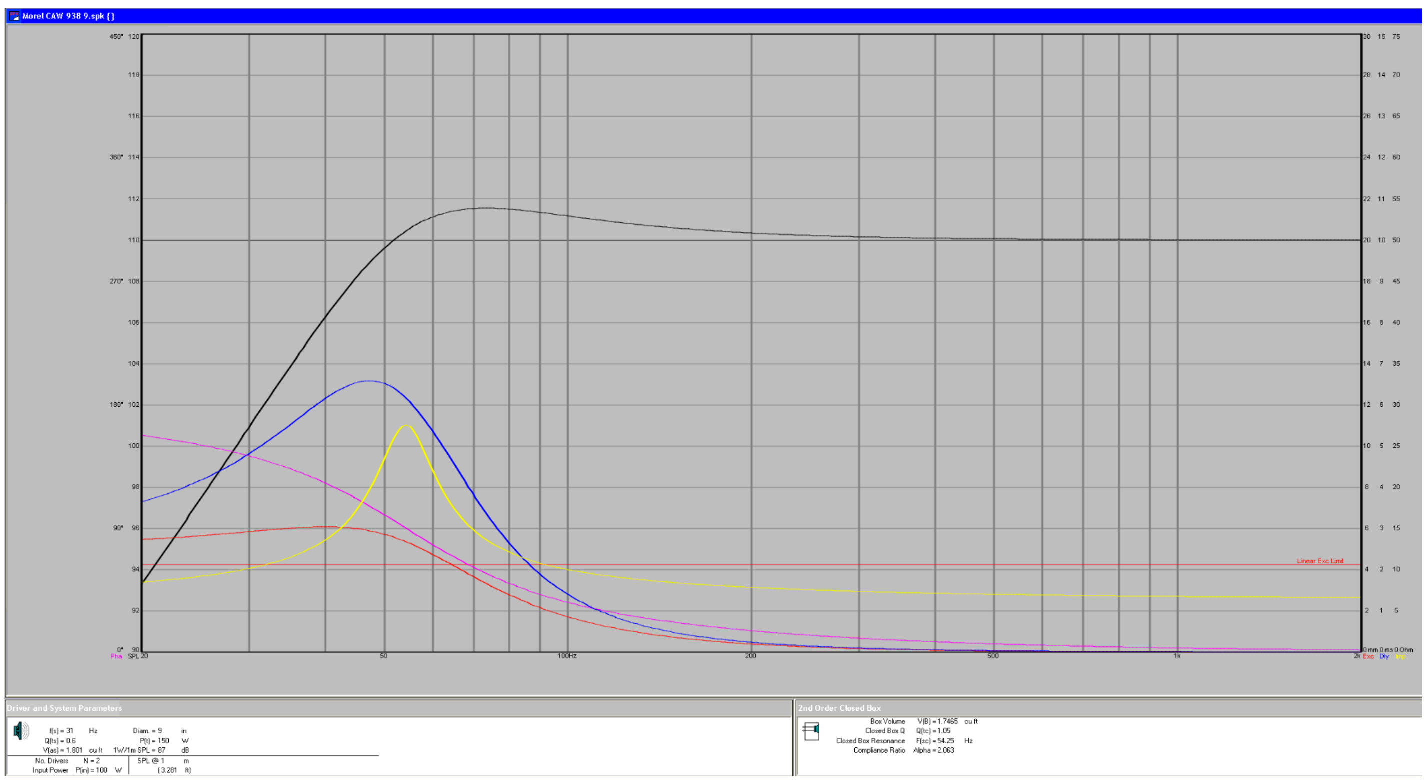
Morel CAW938 is a 9” woofer that would be mounted in a sealed box, and high crossover around 500 hertz. The sensitivity of this driver meets the requirements, which is 87 dB 1W/1m.

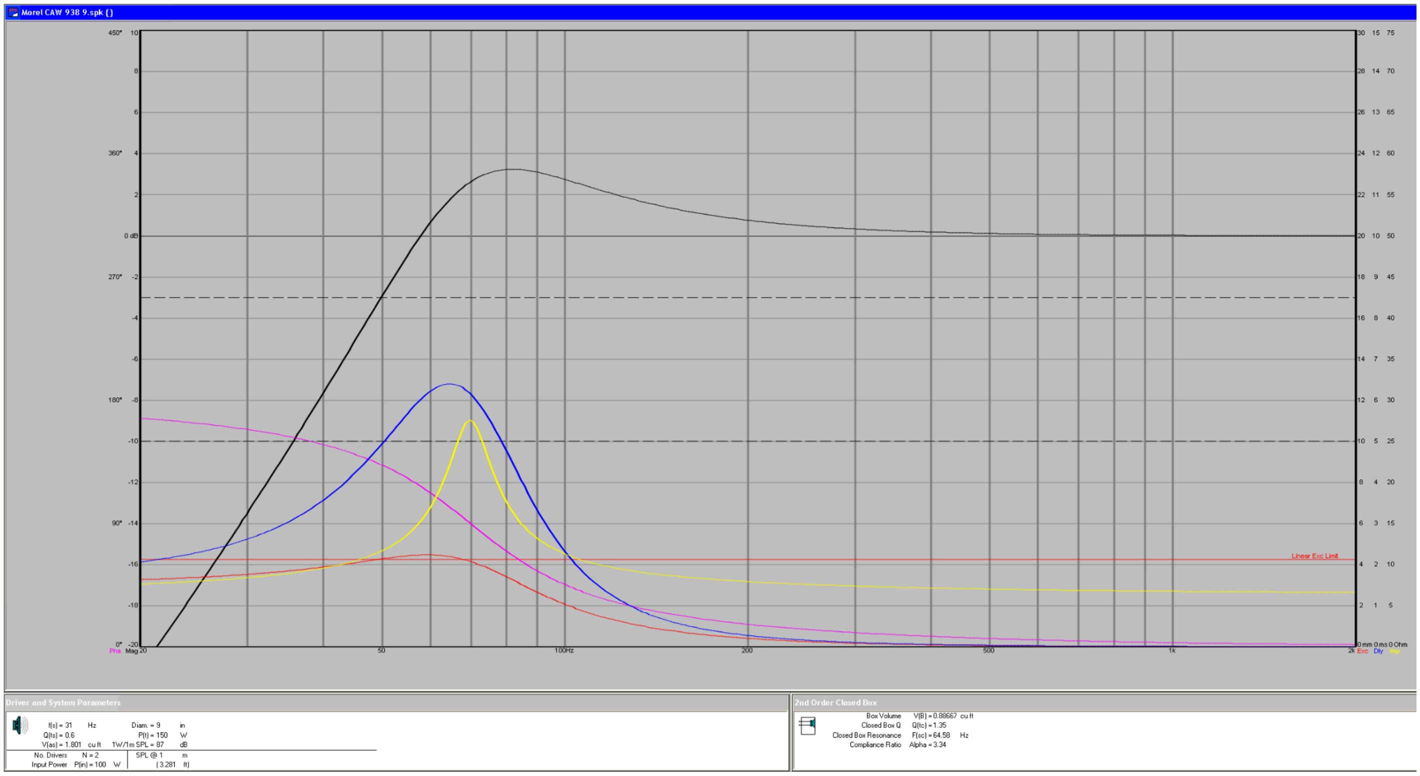
These drivers meet all of the design requirements, but the size constraint. These drivers need a very larger box to work in a sealed enclosure. To be optimally damped, they would have to be in about a 280 liter box. Also at this optimally damping, the drivers cross their X_{max} around 55 hertz, so there would be distortion in driver below the crossing point. There could also be potential damage to this driver when it crosses these frequencies because it is not known what the X_{Lim} of the driver is, which is when it breaks.

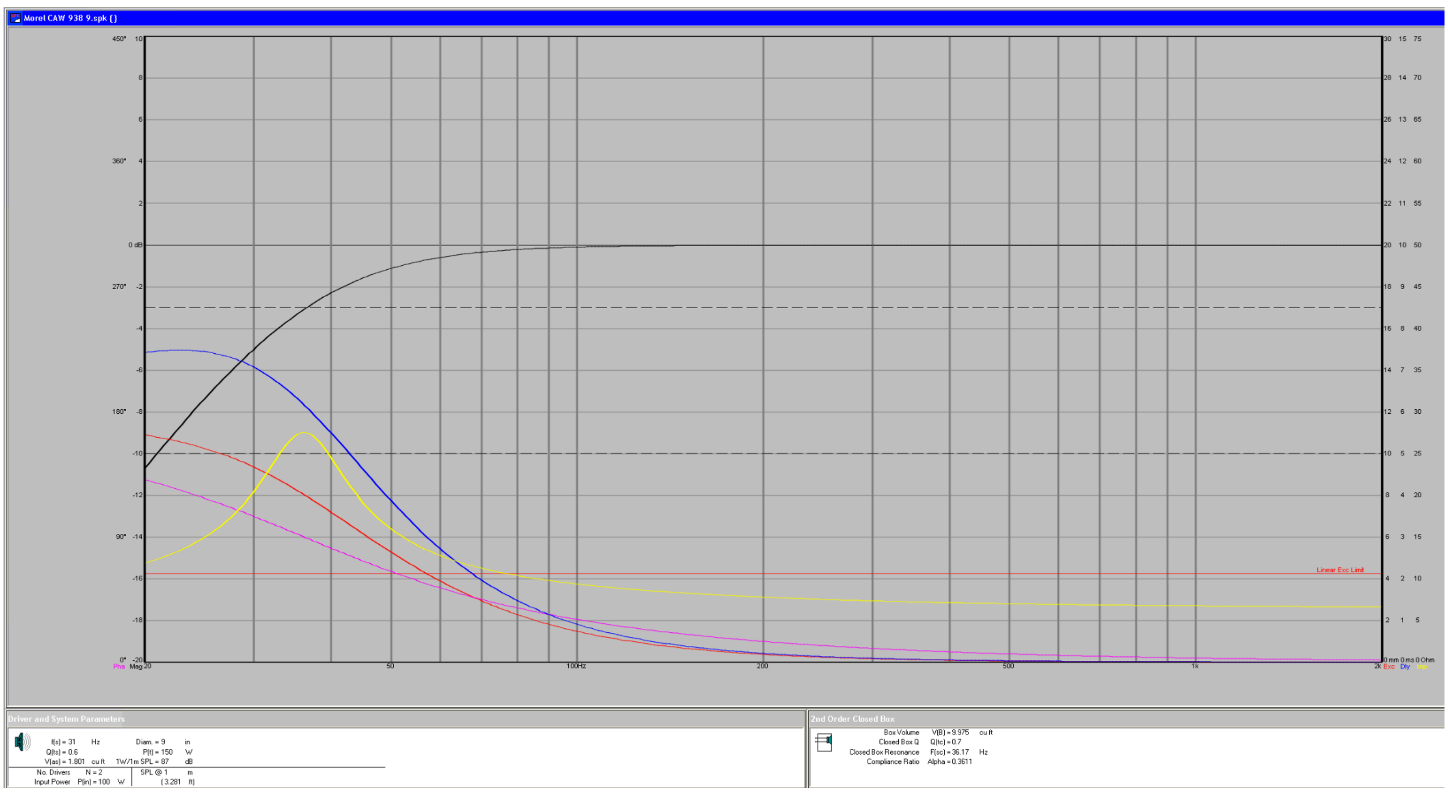





Morel CAW 938 9.spk {}
Linear Exc Limit
Pha Mag
100Hz
Driver and System Parameters
f(s) = 31 Hz
Q(ts) = 0.6
V(as) = 1.801 cu ft
Diam. = 9 in
P(t) = 150 W
1W/1m SPL = 87 dB
No. Drivers N = 2
Input Power P(in) = 100 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.7465 cu ft
Closed Box Q Q(tc) = 1.05
Closed Box Resonance F(sc) = 54.25 Hz
Compliance Ratio Alpha = 2.063


Morel CAW 938 9.spk {}
Linear Exc Limit
Pha SPL
100Hz
Driver and System Parameters
f(s) = 31 Hz
Q(ts) = 0.6
V(as) = 1.801 cu ft
Diam. = 9 in
P(t) = 150 W
1W/1m SPL = 87 dB
No. Drivers N = 2
Input Power P(in) = 100 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.7465 cu ft
Closed Box Q Q(tc) = 1.05
Closed Box Resonance F(sc) = 54.25 Hz
Compliance Ratio Alpha = 2.063

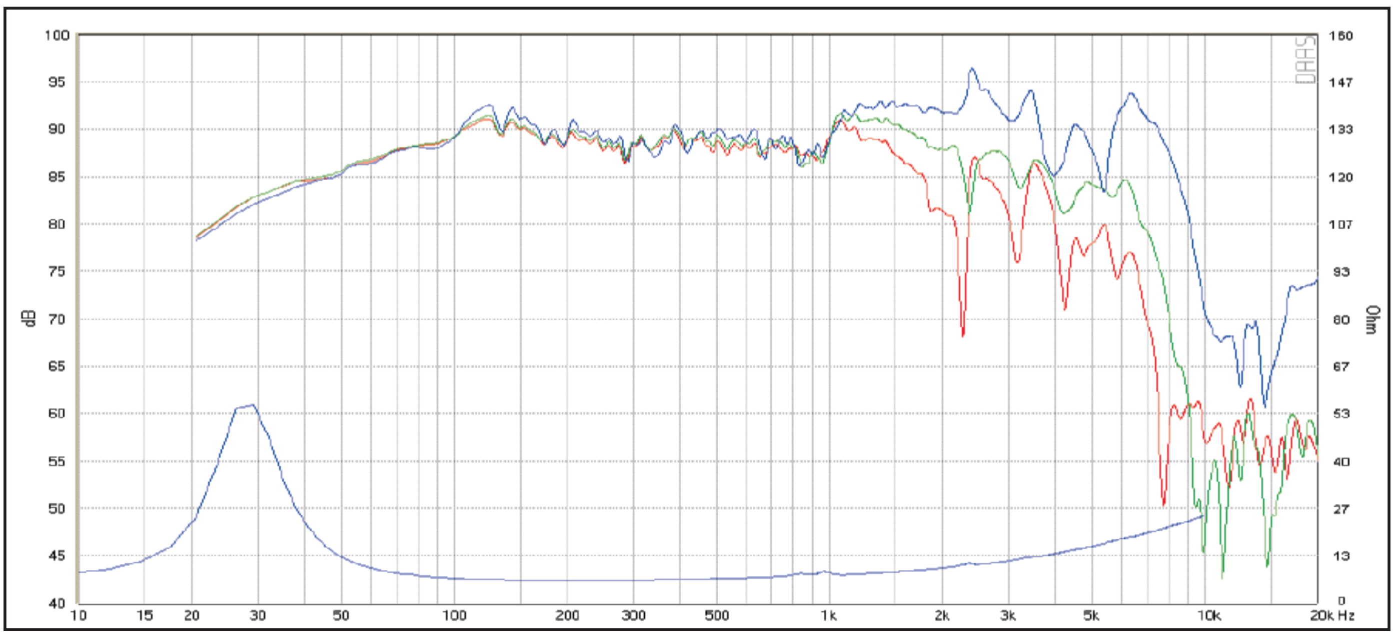

Morel CAW 938 9.spk {}
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 31 Hz
Q(ts) = 0.6
V(as) = 1.801 cu ft
Diam. = 9 in
P(t) = 150 W
1W/1m SPL = 87 dB
No. Drivers N = 2
Input Power P(in) = 100 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.88667 cu ft
Closed Box Q Q(tc) = 1.35
Closed Box Resonance F(sc) = 64.58 Hz
Compliance Ratio Alpha = 3.34


Morel CAW 938 9.spk {}
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 31 Hz
Q(ts) = 0.6
V(as) = 1.801 cu ft
Diam. = 9 in
P(t) = 150 W
1W/1m SPL = 87 dB
No. Drivers N = 2
Input Power P(in) = 100 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 9.975 cu ft
Closed Box Q Q(tc) = 0.7
Closed Box Resonance F(sc) = 36.17 Hz
Compliance Ratio Alpha = 0.3611

Woofer #4 Detail

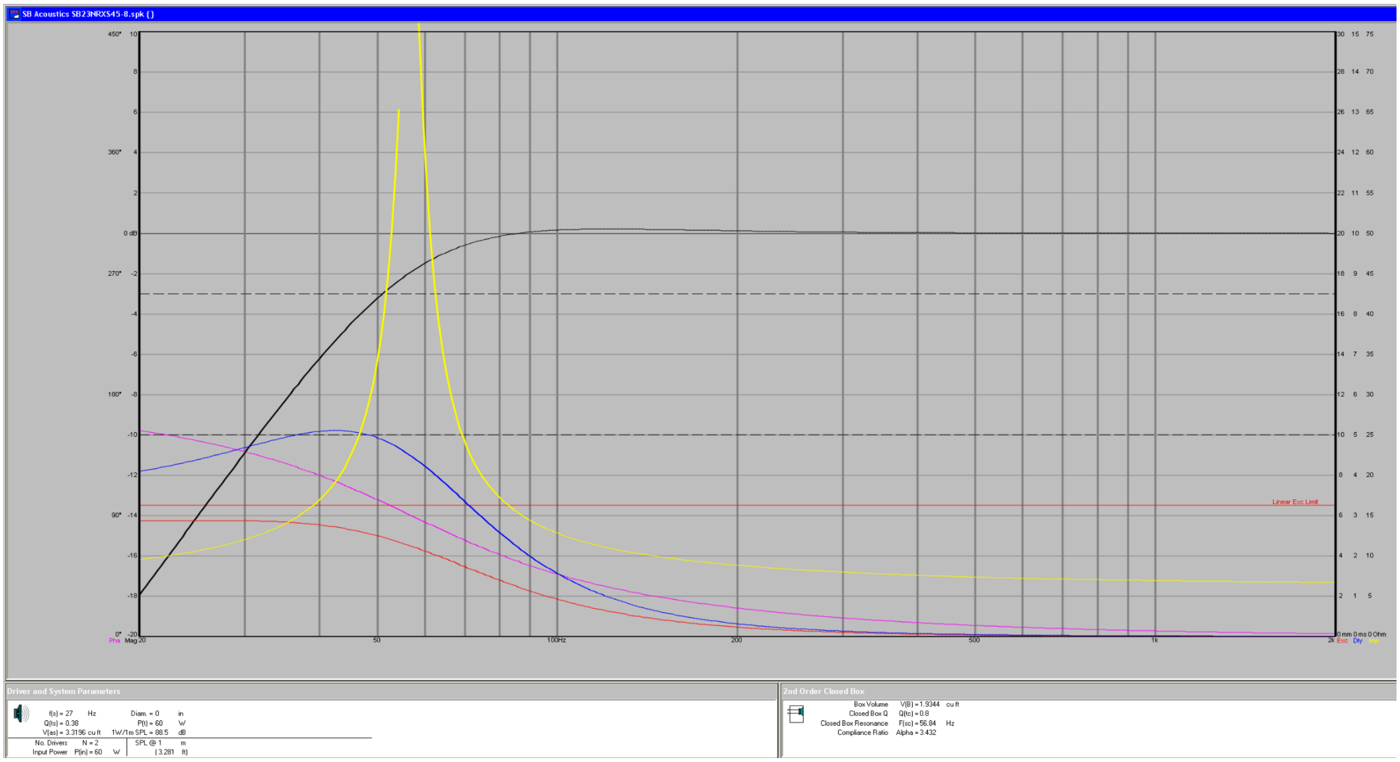
SB Acoustics SB23NRXS45-8 is an 8” woofer that would be mounted in a sealed box, and high crossover around 500 hertz. The sensitivity of this driver meets the requirements, which is 88.5 dB 1W/1m.

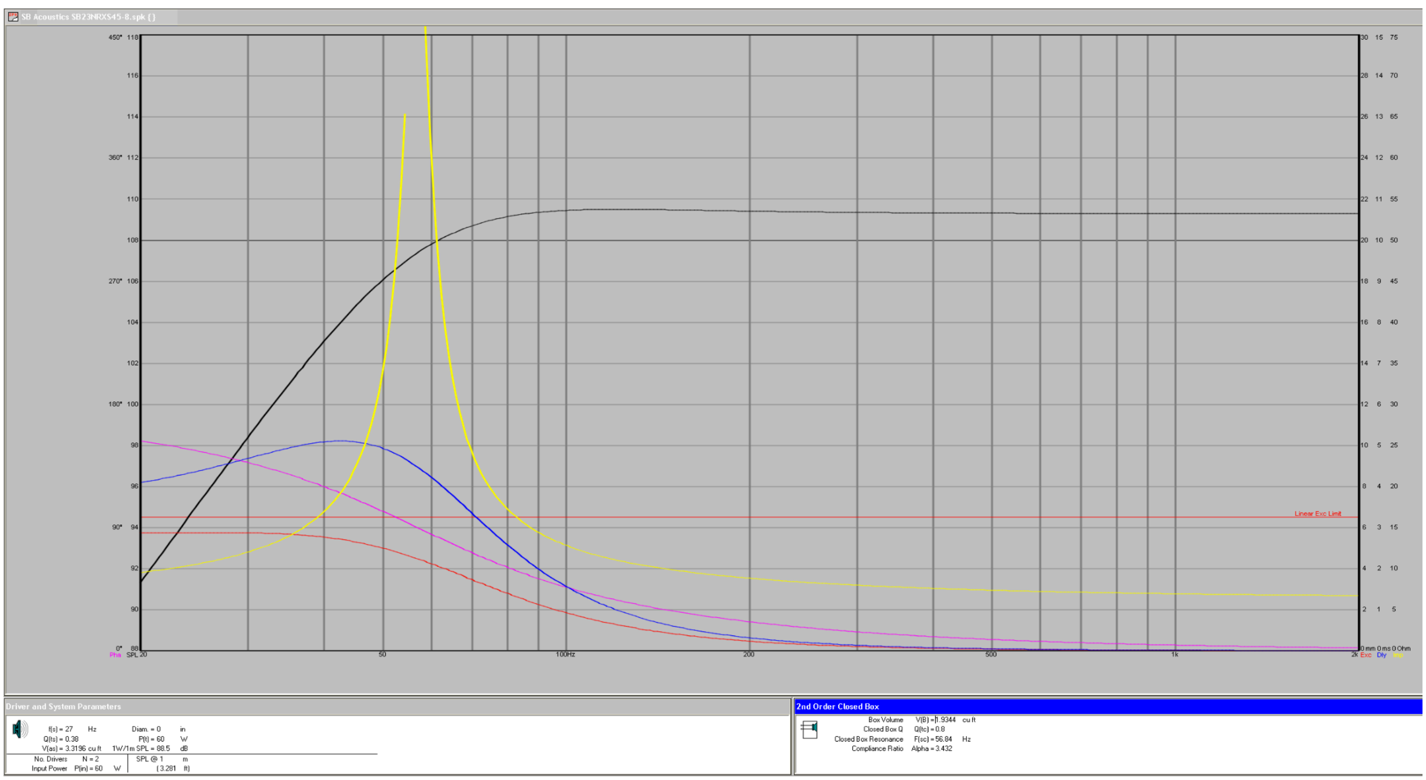
This driver meets all of the requirements that the design goals set out. The desired size was under 56 liters (or 2 cubic feet), and this give the monitors a .8 Q, which was acceptable in the design. Also with the Q being .8 it holds the excursion under the X_{max}. Also the impedance is equalized, so there would be no need for a correction circuit for an easy crossover.

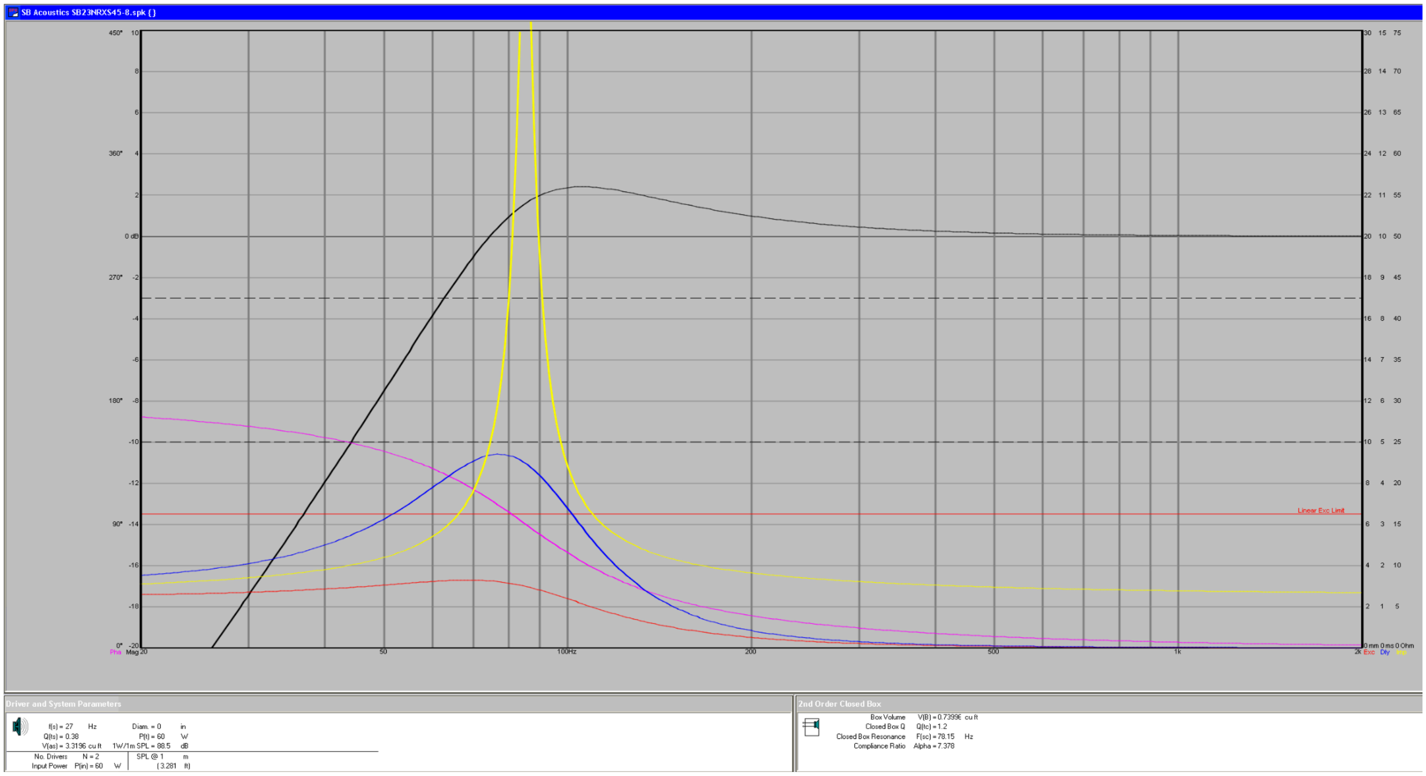


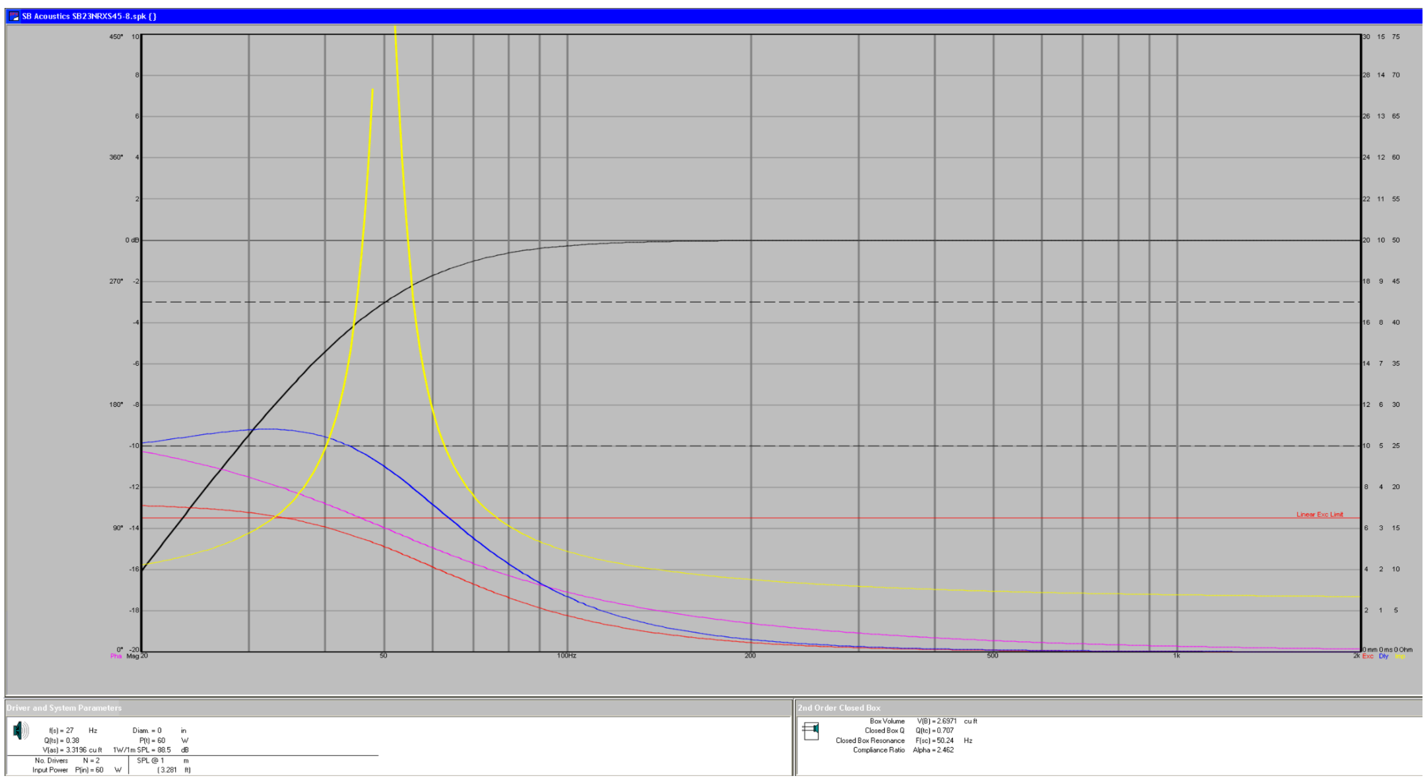
Response Curve :

—— (Blue) : on axis —— (Green) : 30 off-axis —— (Red) : 60 off-axis


SB Acoustics SB23NRXS45-8.spk {}
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k
Driver and System Parameters
f(s) = 27 Hz
Q(ts) = 0.38
V(as) = 3.3196 cu ft
Diam. = 0 in
P(t) = 60 W
1W/1m SPL = 88.5 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.9344 cu ft
Closed Box Q Q(tc) = 0.8
Closed Box Resonance F(sc) = 56.84 Hz
Compliance Ratio Alpha = 3.432


SB Acoustics SB23NRXS45-8.spk {}
Linear Exc Limit
Pha SPL 20
50
100Hz
200
500
1k
2k
Driver and System Parameters
f(s) = 27 Hz
Q(ts) = 0.38
V(as) = 3.3196 cu ft
Diam. = 0 in
P(t) = 60 W
1W/1m SPL = 88.5 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.9344 cu ft
Closed Box Q Q(tc) = 0.8
Closed Box Resonance F(sc) = 56.84 Hz
Compliance Ratio Alpha = 3.432

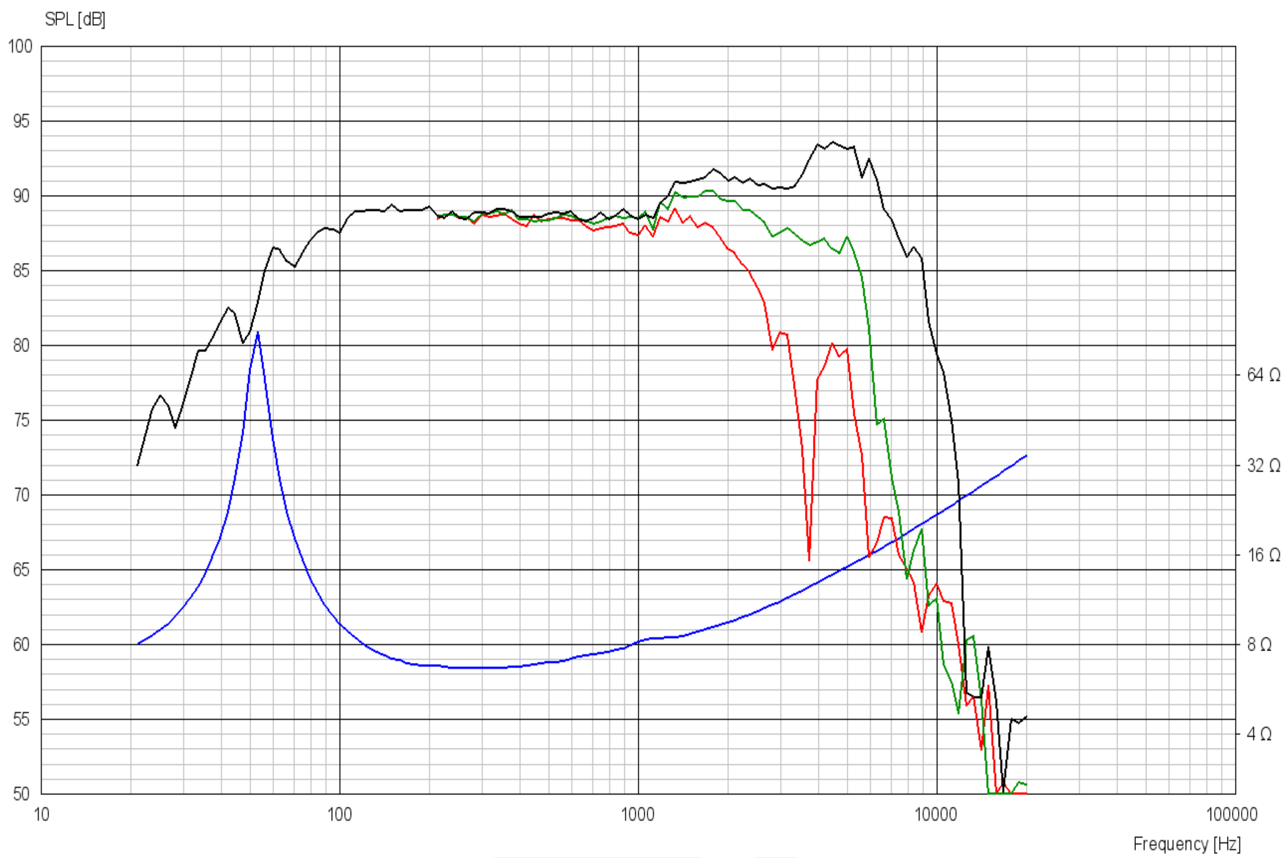

SB Acoustics SB23NRXS45-8.spk {}
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 27 Hz
Q(ts) = 0.38
V(as) = 3.3196 cu ft
Diam. = 0 in
P(t) = 60 W
1W/1m SPL = 88.5 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.7399€ cu ft
Closed Box Q Q(tc) = 1.2
Closed Box Resonance F(sc) = 78.15 Hz
Compliance Ratio Alpha = 7.378

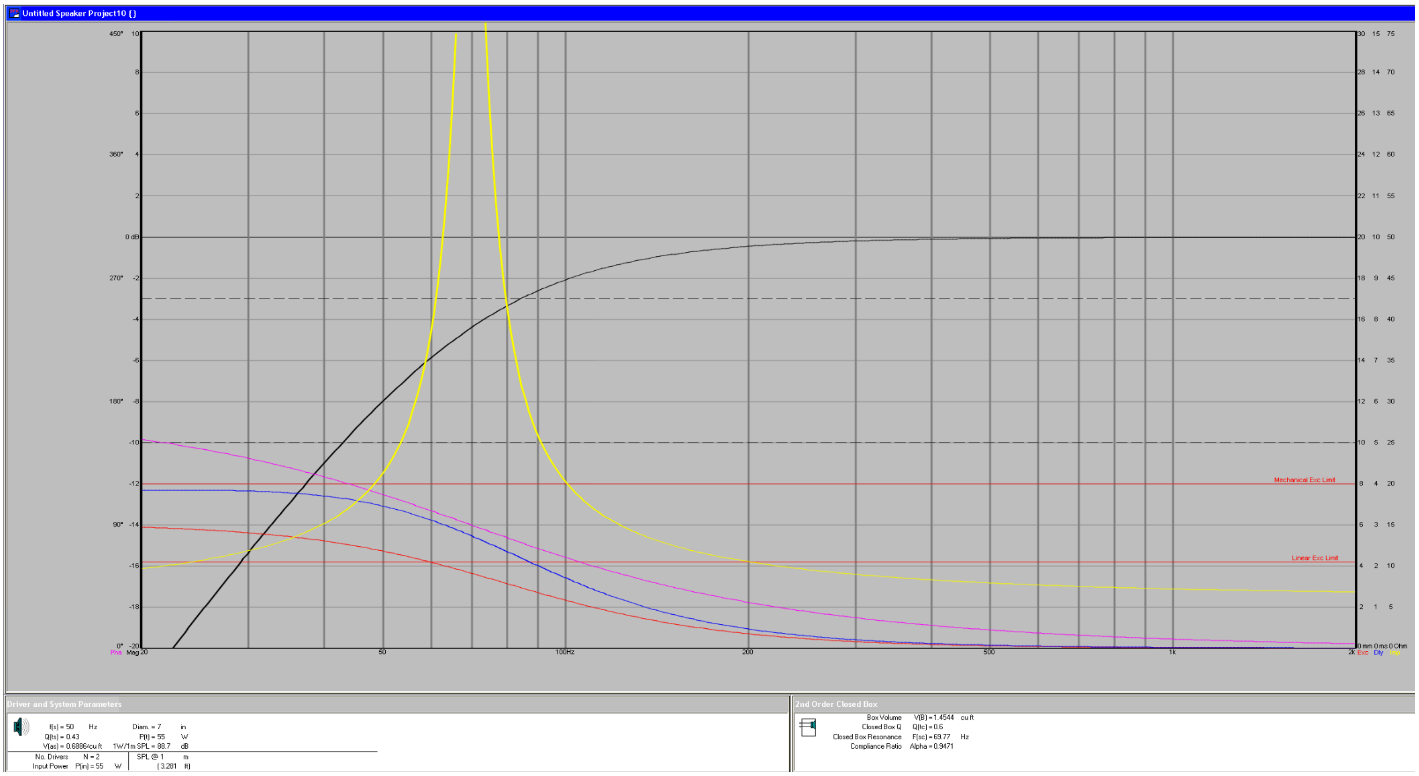

SB Acoustics SB23NRXS45-8.spk {}
Linear Exc Limit
Pha Mag 20
50
100Hz
200
500
1k
2k Exc Dly Imp
Driver and System Parameters
f(s) = 27 Hz
Q(ts) = 0.38
V(as) = 3.3196 cu ft
Diam. = 0 in
P(t) = 60 W
1W/1m SPL = 88.5 dB
No. Drivers N = 2
Input Power P(in) = 60 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 2.6971 cu ft
Closed Box Q Q(tc) = 0.707
Closed Box Resonance F(sc) = 50.24 Hz
Compliance Ratio Alpha = 2.462

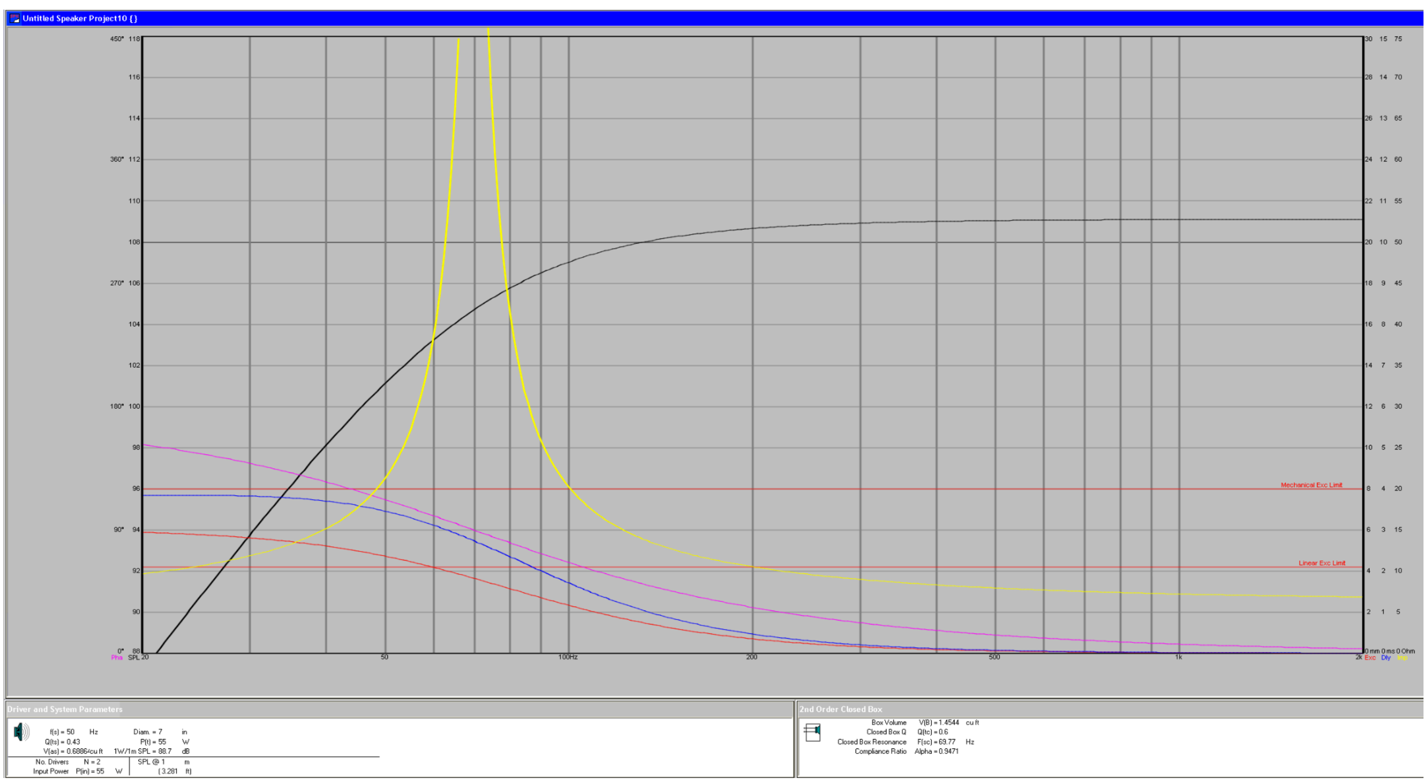
Woofer #5 Detail

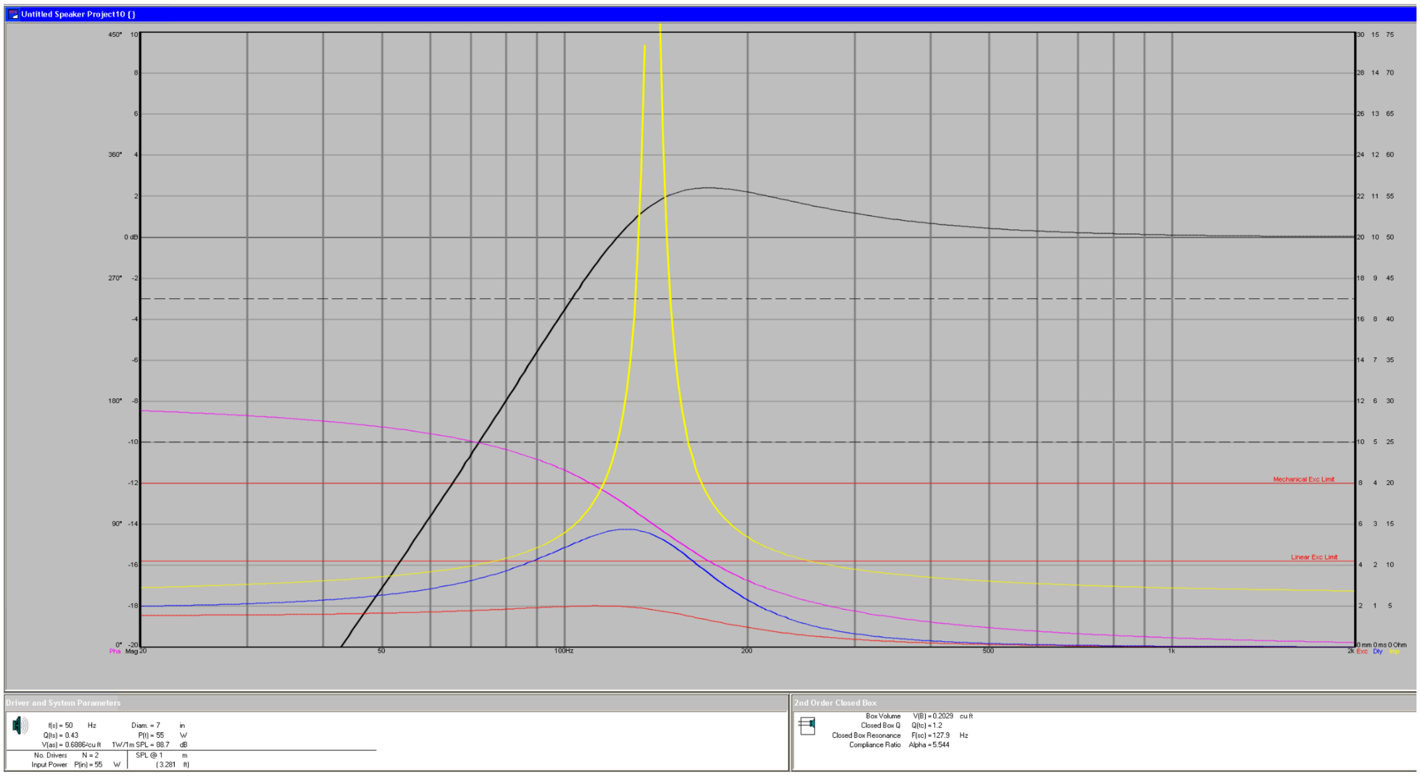
Scanspeak Discovery is a 7” woofer that would be mounted in a sealed box with a high crossover around 500 hertz. The box would be 40 liters and have a Q of .6. The driver has a sensitivity of 88.7db at 1W/1m that matches my specifications.

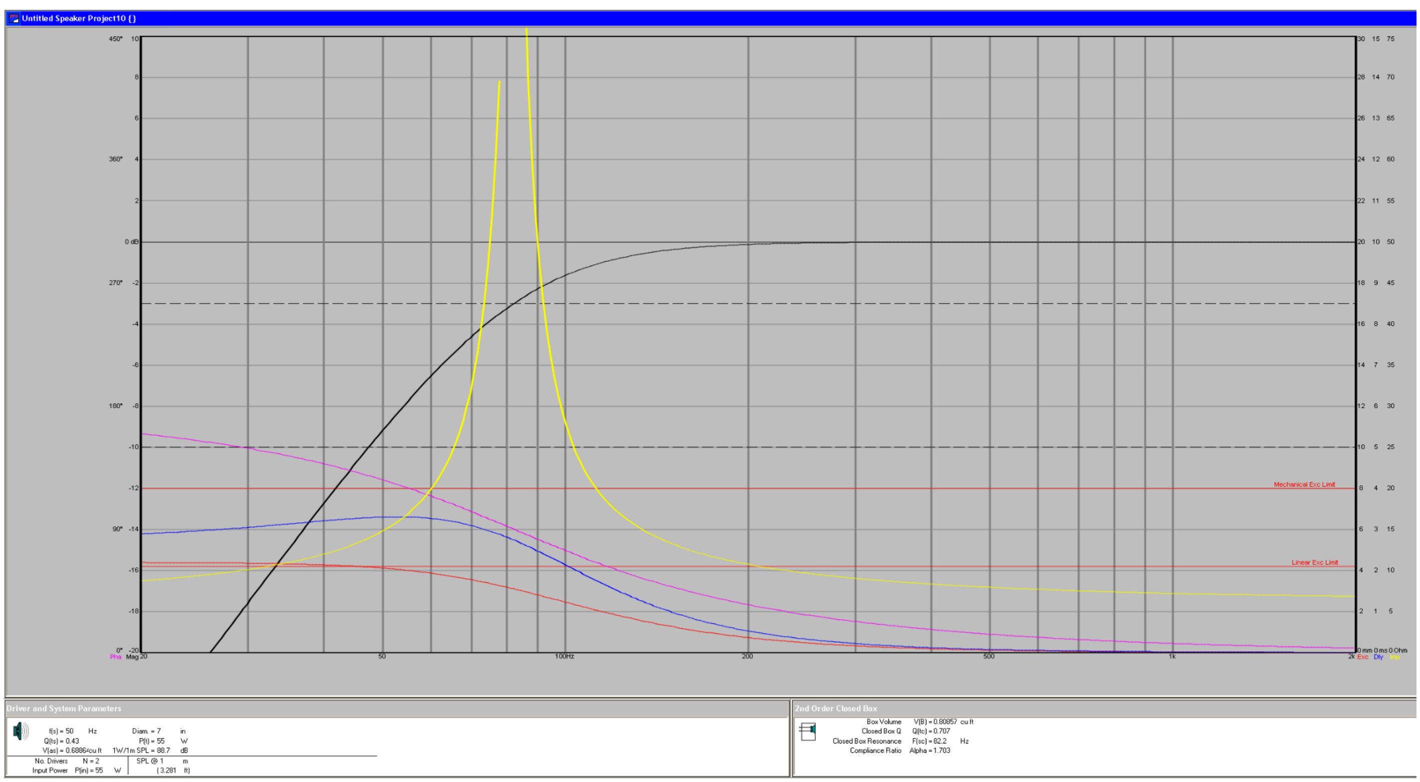
The f3 of this monitor would be 83 hertz, and an f10 of 43 hertz. If this driver was paired with a subwoofer it would fit the design requirements, but unfortunately it does not go as low as desired. The X_{max} of this driver is very low for the application that I plan to use it in. The Xmax is reached at about 60 hertz.




Untitled Speaker Project10 {}
Mechanical Exc Limit
Linear Exc Limit
Driver and System Parameters
f(s) = 50 Hz
Q(ts) = 0.43
V(as) = 0.6886 cu ft
Diam. = 7 in
P(t) = 55 W
1W/1m SPL = 88.7 dB
No. Drivers N = 2
Input Power P(in) = 55 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.4544 cu ft
Closed Box Q Q(tc) = 0.6
Closed Box Resonance F(sc) = 69.77 Hz
Compliance Ratio Alpha = 0.9471


Untitled Speaker Project10 {}
Mechanical Exc Limit
Linear Exc Limit
Driver and System Parameters
f(s) = 50 Hz
Q(ts) = 0.43
V(as) = 0.6886 cu ft
Diam. = 7 in
P(t) = 55 W
1W/1m SPL = 88.7 dB
No. Drivers N = 2
Input Power P(in) = 55 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 1.4544 cu ft
Closed Box Q Q(tc) = 0.6
Closed Box Resonance F(sc) = 69.77 Hz
Compliance Ratio Alpha = 0.9471

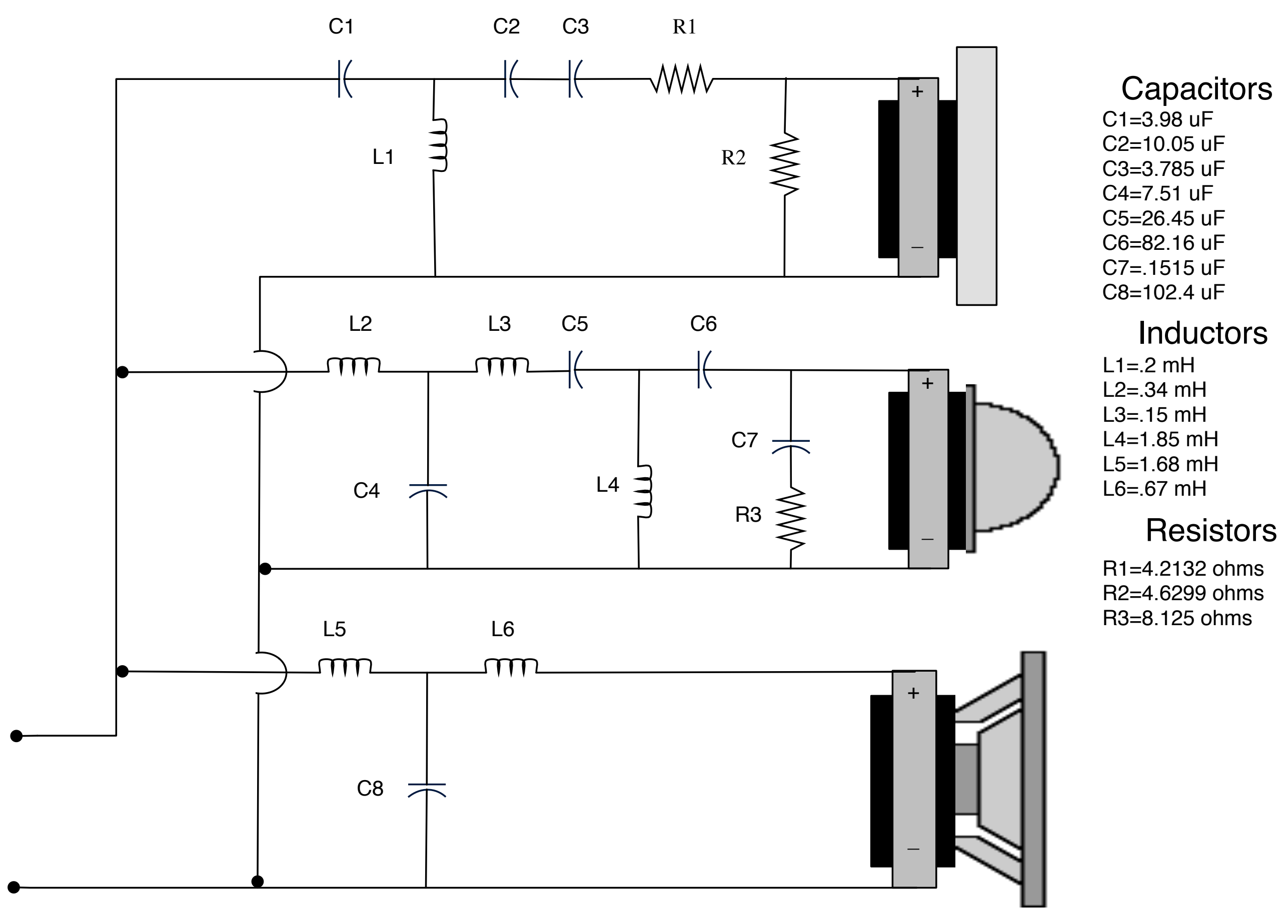

Untitled Speaker Project10 {}
Mechanical Exc Limit
Linear Exc Limit
100Hz
Driver and System Parameters
f(s) = 50 Hz
Q(ts) = 0.43
V(as) = 0.6886 cu ft
Diam. = 7 in
P(t) = 55 W
1W/1m SPL = 88.7 dB
No. Drivers N = 2
Input Power P(in) = 55 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.2029 cu ft
Closed Box Q Q(tc) = 1.2
Closed Box Resonance F(sc) = 127.9 Hz
Compliance Ratio Alpha = 5.544


Untitled Speaker Project10 {}
Mechanical Exc Limit
Linear Exc Limit
100Hz
Driver and System Parameters
f(s) = 50 Hz
Q(ts) = 0.43
V(as) = 0.6886 cu ft
Diam. = 7 in
P(t) = 55 W
1W/1m SPL = 88.7 dB
No. Drivers N = 2
Input Power P(in) = 55 W
SPL @ 1 m
(3.281 ft)
2nd Order Closed Box
Box Volume V(B) = 0.80857 cu ft
Closed Box Q Q(tc) = 0.707
Closed Box Resonance F(sc) = 82.2 Hz
Compliance Ratio Alpha = 1.703

Crossover

The design of these monitors call for two 3rd Order Butterworth filters with the crossover points at 520 hertz, and 4160 hertz. The Butterworth filter provides maximally flat frequency response in the passband and rolls off towards zero in the stopband.[11] Also in the crossover there is an impedance equalization (Zobel) circuit on the midrange driver to flatten the impedance response so the crossover will work smoother

Crossover Schematic



[11] Bianchi, Giovanni, and Roberto Sorrentino. Electronic filter simulation & design. McGraw-Hill Professional, 2007.

Testing & Tuning

Driver Performance

The drivers performed exactly as expected, and even better in some cases. If a set in stone crossover points and extensive testing was done prior to purchasing the drivers a more “dedicated” midrange would have required less parts.

Enclosure Optimization

Since the enclosure was made slightly smaller than expected, to optimize the enclosure it was stuffed, about 25% full, with fiberglass to deaden the sound. Also the edges that connected to the removable back were gasket taped to create an airtight seal.

Cross-over Tuning

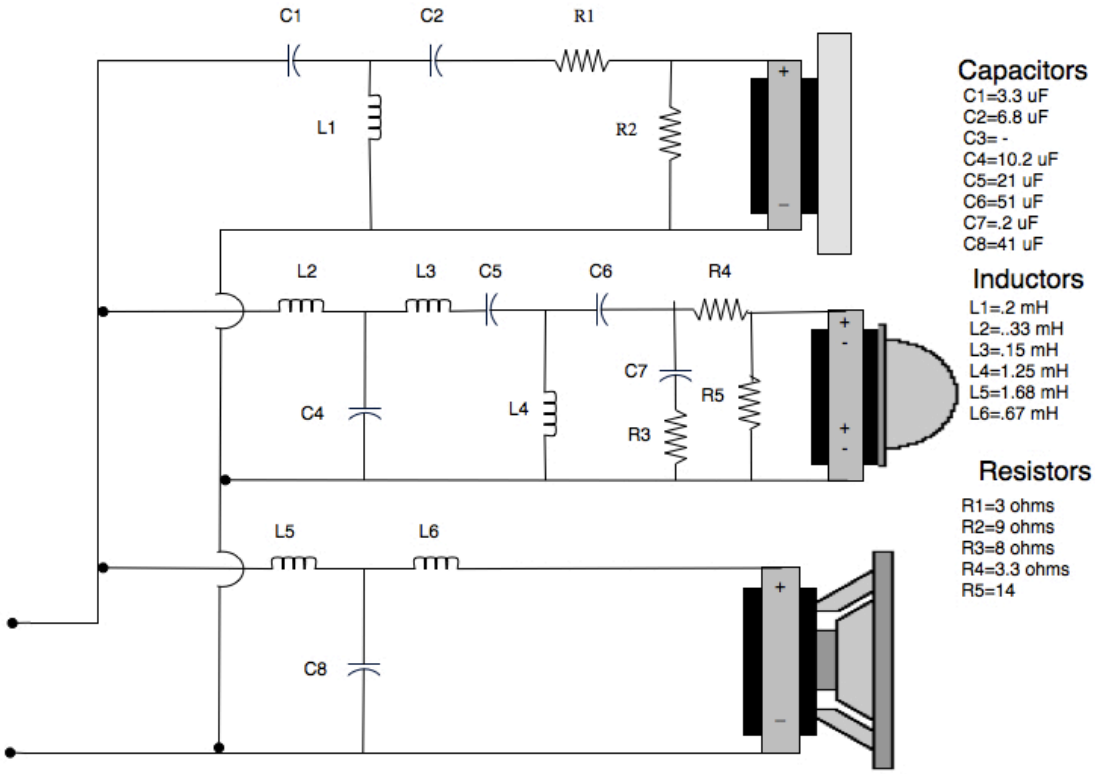
During tuning I found that at the crossover points I was getting too much summation, inherent in Butterworth designs, yet I enjoyed sound of the filters from listening tests. So at the crossover points, I decided to spread the upper and lower points. This allowed me to work with the driver’s frequency response as well as the box response on the woofers to get a flatter response.

Final System Documentation

Final Testing Results

Overall, the monitor has a +/- 2 dB response from 56hz to 24,000hz, with about 3% harmonic distortion in that range as well. See *PA 2201 Midfield Final Testing* for detailed results.

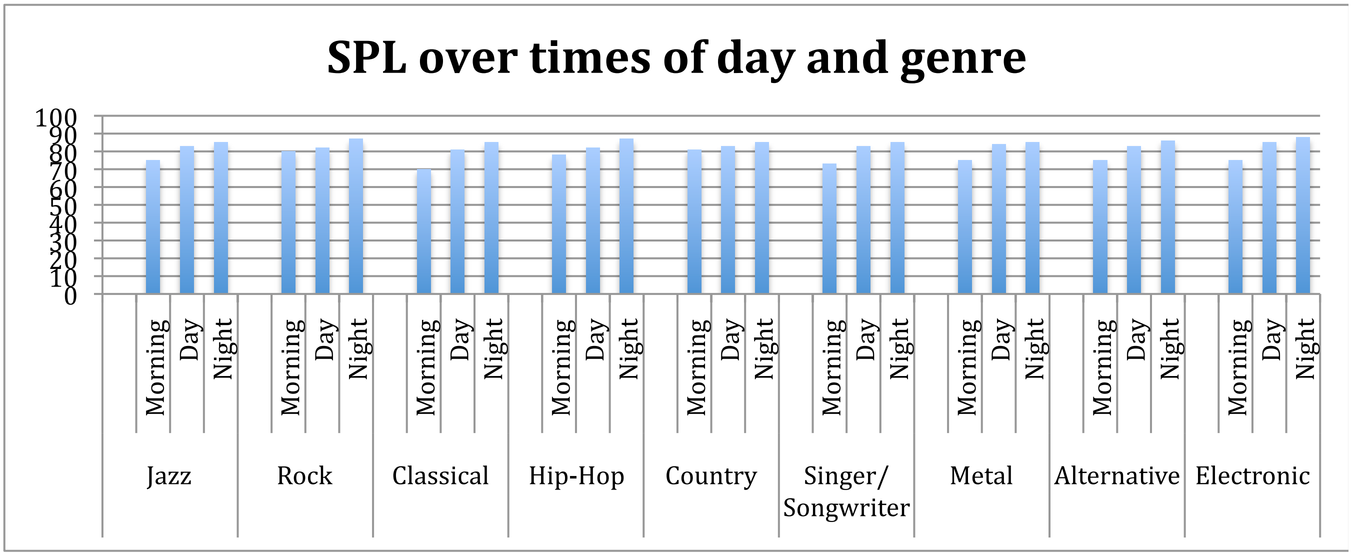
Cross-over Schematic



As-built Drafting

See *Drafting for PA 2201 Midfields* for as built drafting.

Appendix



Appendix 1:
This is the full data for SPL vs. Time of day graph in Figure 2.

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