Speaker Design Statement: Ignis Series 1

FA4740 Transducer Theory

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INTRODUCTION

Bo Bennett once said, "music is what feelings sound like." [1]As a musician, composer, and audio engineer, I could not agree more. To me music is a powerful, emotional force. It can tell stories or inspire the observer to imagine their own. Sweet melodies can enhance the meaning of an eloquent lyrical phrase or describe that phrase in detail without the use of words. Yet all of these beautiful happenings in music mean nothing if the listener cannot hear the music properly from their loudspeakers. As much as a wrong note can diminish a performance, listening to music on unsatisfying speakers can take away or limit the emotion and beauty of a recorded musical piece. David Moulton commented that loudspeakers "do have a sound all their own."[2] The loudspeaker design of the *Ignis Series 1* has a main goal of not subtracting from or limiting the musical recordings that will be played out of them, but to instead enhance the music so those emotions and feelings are not lost but instead fully experienced. *Ignis* is latin for fire. Fire has the power to bring light, warm a weary soul, and spread its blaze across the land. The *Ignis Series 1* loudspeakers will likewise enhance the music that is played on them to bring the listener joy, hope, and a spark of creativity.

[1] Likeablequotes, Accessed January 19, 2013. http://www.likeablequotes.com/expression/music-is-what-feelings-sound-89323.html.

[2] David Moulton, *Total Recording: The Complete Guide to Audio Production and Engineering*, (United States: KIQ Productions, Inc., 2000), 207-210.

FUNCTIONAL DESCRIPTION

The vast majority of the use for this set of loudspeakers will be for personal listening for pleasure and relaxation. There will be some mixing on these speakers, but that will not be their primary use. The design of these speakers is not heavily geared towards mixing, but rather listening for personal enjoyment. David Moulton uses the term "listening backward" to describe listening for the tone and quality of a past recording.[3] As clarity for personal listening is the priority for this design, this set of speakers will be used primarily for listening backward. This set of loudspeakers will be placed on a desk within three feet of where the listener will be seated. These loudspeakers will be designed for the personal use of one listener.

[3] David Moulton, *Total Recording: The Complete Guide to Audio Production and Engineering*, (United States: KIQ Productions, Inc., 2000), 303.

DESIGN GOALS

SIZE & SHAPE

The design of these loudspeakers is to find a good medium and balance between my goals for bass extension and limits of physical size. The speakers will have to be small enough that they can be placed on a desk on either side of a computer monitor. Making a good decision in woofer choice can allow for low frequency extension with compromising the goal of small size. This speaker design is in a conventional box shape. This is the simplest shape cabinet to make but unfortunately results in undesired diffraction effects.[4] Philip Newell explains diffraction effects in his book Loudspeakers for Music Recording and Reproduction. As the wave radiates away from the source on the baffle the wave diffracts when it hits a sharp edge as can be seen in Figure 1 on the left.[5] Fortunately smoothing and rounding the edges of the box is shown to lessen the effects of the loudspeaker shape on the frequency response.[6]

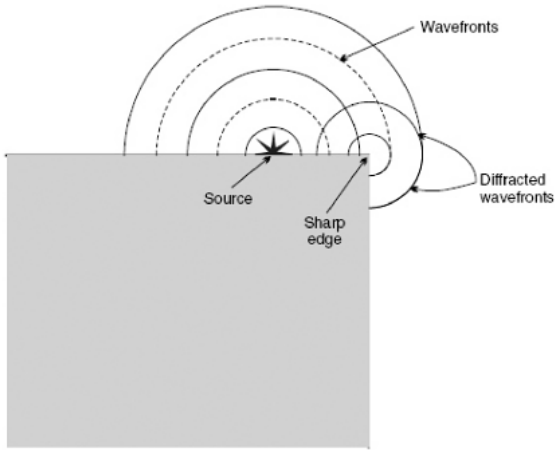


FIGURE 1: WAVE DIFFRACTION ON A FINITE BAFFLE

SPL OUTPUT

The core use for this loudspeaker design is for personal listening, so these loudspeakers do not need to have extremely high SPL. They will not be used to play loud music at a party or any other similar situation where high SPL is desired. The SPL requirements for this system are for the loudspeakers to maintain low distortion at an SPL level above what the maximum expected listening level will be. This will guarantee low distortion at the desired max listening level and all levels below it.

Song	Genre	Comfortable SPL	Uncomfortable SPL
Underoath – In Division	Metal	77 dB	84 dB
Athletics - Why Aren't I Home?	Rock	74 dB	80 dB
Samuel Barber – Adagio for Strings	Orchestral	70 dB	82 dB

Above is a table showing comfortable and uncomfortable listening levels for three different songs in three different genres of music. All of these measurements were taken in a sitting position with a distance of 57 inches

[4] Harry Olson, "Direct Radiator Loudspeaker Enclosures," ***Journal of the Audio Engineering Society***, 17, no. 1 (1969): 34, 38, 64, http://www.aes.org/e-lib/browse.cfm?elib=1609 (accessed February 19, 2013).

[5] Philip Newell, and Keith Holland, ***Loudspeakers For Music Recording and Reproduction***, (Oxford: Focal Press, 2007), 90.

[6] Philip Newell, and Keith Holland, ***Loudspeakers For Music Recording and Reproduction***, (Oxford: Focal Press, 2007), 88-89.

(1.448 m) away from a pair of loudspeakers. It is likely that this design will be placed within 24-40 inches (0.762 - 1.016 m) of the listener.

The table shows that at an average of 82 dB the music becomes uncomfortably loud and fatiguing. The majority of the time I would like my music to be listened to at around the 74 dB mark. Therefore, having this design carry low distortion up to 90 dB at 1m will allow for some buffer room in my SPL output goal while still keeping good sound quality.

BANDWIDTH

To the right is another chart that displays the design preferences for bandwidth.

Song	Genre	FL1	FL2	FH1	FH2
Underoath – In Division	Metal	80 Hz	45 Hz	14 KHz	17 KHz
Athletics - Why Aren't I Home?	Rock	73 Hz	50 Hz	13 KHz	16.8 KHz
Samuel Barber – Adagio for Strings	Orchestral	94 Hz	54 Hz	13.4 KHz	16 KHz

Experimenting was done by placing high-pass and low-pass filters on favorite music tracks and listening to where cuts in frequency range made a difference. FL2 and FH2 represent the high low extremes where no differences was noticed when a sharp drop in frequency was made. FL1 and FH1 represent the frequencies where making any further cuts inward produced a very noticeable and undesired effect. Based upon these findings I would like bandwidth to be flat from at least 73 Hz to 17 KHz if possible. High frequency extension above 17 KHz (but not above 20KHz, which is where the average human hearing range stops) would be desirable if the results were free of strange notches and frequency bumps. Additional low frequency extension down to 45 Hz would also be desired if possible with a smaller enclosure.

DIRECTIVITY

Directivity is not a major concern with this design. These speakers will be set on my desk within three feet of my listening position. If I point them well at myself then I will be able to maintain good sound quality and SPL without worrying about the effects of the directivity (or lack thereof) of my speakers. The use of these loudspeakers will be personal, not in small or large group usage. Any good off-axis response from my speakers will be welcome but it is not important to this particular design.

VISUAL AESTHETICS

For this design the speakers will need to look clean and crisp. A simple coat of orange paint all around the speaker with a small artistic design based on fire or a flame on the sides of the loudspeakers should suffice. Just as fire

warms a person and a spark ignites creativity, I wish for my loudspeakers to invoke inspiration, joy, and passion to the listener through the music that is played across these speakers.

Design Priorities

For this design the number one priority with these speakers is budget. My budget for this speaker design is tight so I am limiting myself to a maximum of $500, but going lower than that is desired. Limiting the physical size of the loudspeakers is another large priority. Maintaining good low frequency extension (despite a small enclosure design) is a secondary priority. High SPL and directionality of the speakers are not high priorities. These speakers will also need to be able to listen backward accurately with minimum distortion. Physical size (or the limiting of), accurate response, and low cost are the three most important design priorities.

TECHNICAL DETAILS

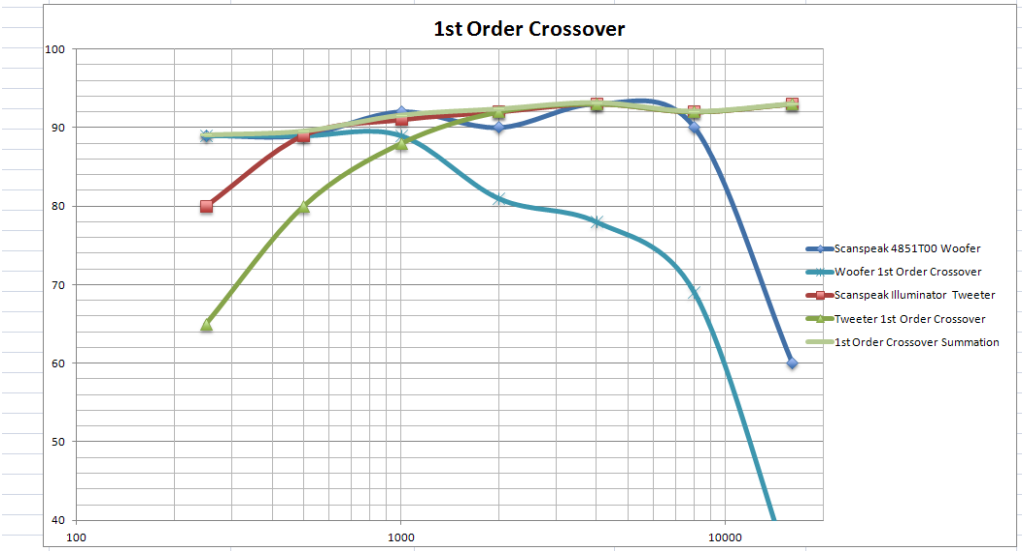
ENCLOSURE DETAILS

Loudspeakers of large size are the best at producing low bass extension. For small speakers such as those in this design, putting a port or vent in the enclosure allows for bass extension despite having small enclosure volume. This occurs because a vent traps a greater mass of air inside the loudspeaker, which lowers the resonant frequency of the loudspeaker allowing for lower bass extension.[7] A sealed box would simply not get the bass extension that is desired without compromising the size design goals needed for this design.

CROSSOVER ORDER CHOICE

This set of loudspeakers will feature a passive third order crossover. A passive crossover is cheaper to make but is harder to implement into a loudspeaker system than an active crossover. A lower order crossover is desired because adding extra components creates more resonance in the loudspeaker circuit. Some brief number-crunching on the differences between first, second, and third order crossovers, reveals that a second order crossover has significantly more drop-off than a first order crossover. A third order crossover provides even more roll-off by giving a 21 dB rolloff at the first octave beyond the crossover frequency. A fourth order crossover adds an unnecessary level of complexity to the circuit without providing significant benefit, so a second or third order crossover is the best choice. Initial analysis of tweeters and woofers that were considered for use in this design revealed that many of the drivers considered would have quite a bit of interference if only a second order crossover was used. A third order crossover would provide the necessary roll off while allowing for the maximum use of the flat response of the drivers before rolling

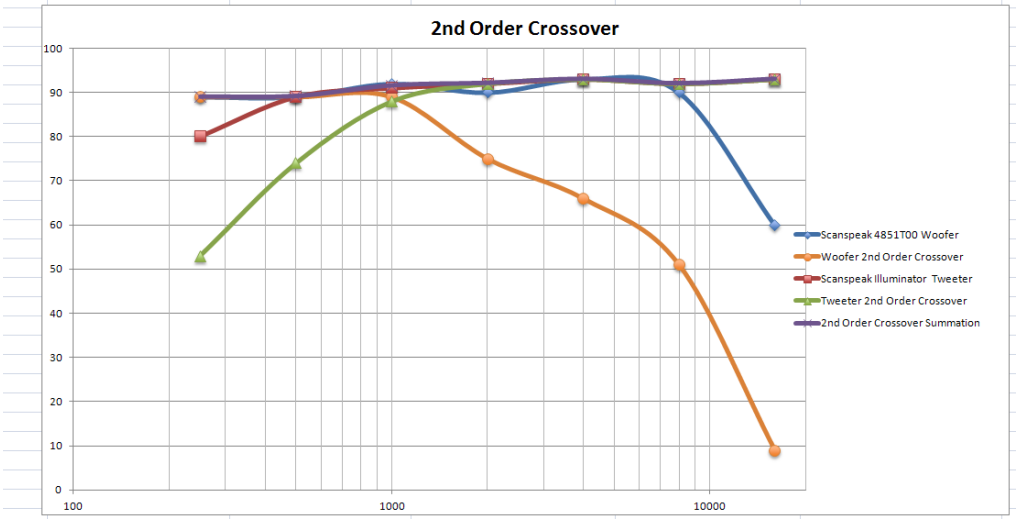
	Scanspeak 4851T00 Woofer	Woofer 1st Order Crossover	Scanspeak Illuminator Tweeter	Tweeter 1st Order Crossover	1st Order Crossover Summation
250	89	89	80	65	89.01725525
500	89	89	89	80	89.51496942
1000	92	89	91	88	91.53901891
2000	90	81	92	92	92.3319562
4000	93	78	93	93	93.13520922
8000	90	69	92	92	92.02171192
16000	60	33	93	93	93.00000434



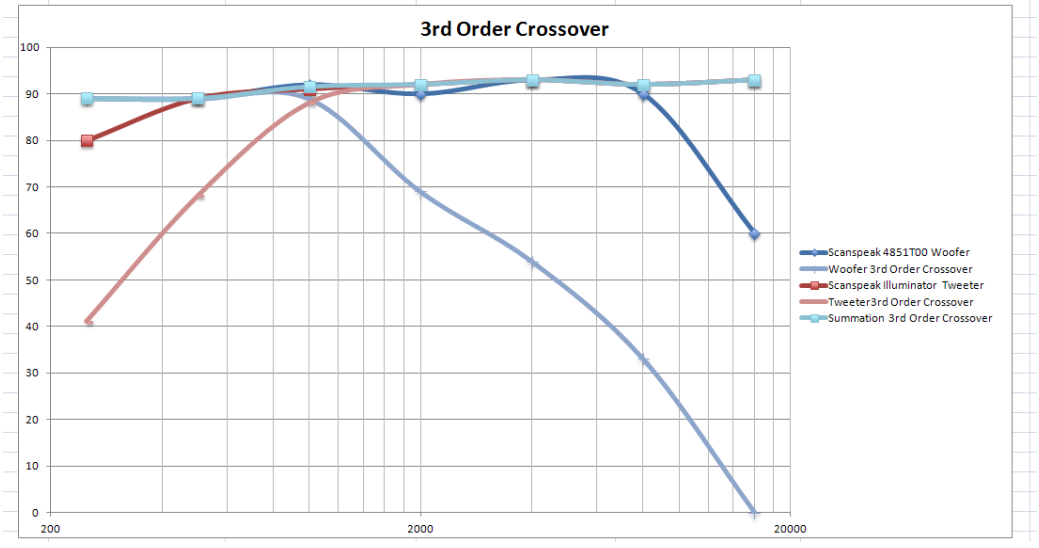
[7] Philip Newell, and Keith Holland, ***Loudspeakers For Music Recording and Reproduction***, (Oxford: Focal Press, 2007), 71-73.

off the response with the crossover. On this and the previous page are graphs showing the estimated responses of a Scanspeak Tweeter and Woofer, their responses when using a first, second, and third crossover with those drivers, and the summations of those drivers with the crossovers implemented. After deciding on drivers for this loudspeaker design, it was concluded that crossing over at 2 KHz with a third order crossover would have the best result in averaging a flat response from the loudspeakers over the crossover design.

	Scanspeak 4851T00 Woofer	Woofer 2nd Order Crossover	Scanspeak Illuminator Tweeter	Tweeter 2nd Order Crossover	2nd Order Crossover Summation
250	89	89	80	53	89.00109076
500	89	89	89	74	89.13520922
1000	92	89	91	88	91.53901891
2000	90	75	92	92	92.08579999
4000	93	66	93	93	93.00865668
8000	90	51	92	92	92.00034496
16000	60	9	93	93	93.00000002



	Scanspeak 4851T00 Woofer	Woofer 3rd Order Crossover	Scanspeak Illuminator Tweeter	Tweeter3rd Order Crossover	Summation 3rd Order Crossover
250	89	89	80	41	89.00006883
500	89	89	89	68	89.03436095
1000	92	89	91	88	91.53901891
2000	90	69	92	92	92.02171192
4000	93	54	93	93	93.00054671
8000	90	33	92	92	92.00000547
16000	60	0	93	93	93



Baffle Step

There is a certain point in the frequency response of a driver in a baffle where the response begins to dip down 6 dB. This is because the wavelength of the frequency is now the same length as the width of the baffle, and so the sound radiates in all directions instead of just forward from the baffle. This midpoint can be approximated by the equation f = 4560/W_B , where W_B is the width of the baffle in inches and f is the frequency where the dip is estimated.[8] This would mean for a 10" wide loudspeaker the midpoint would be about 456 Hz. Ten inches wide is the maximum width considered for this loudspeaker design will eight inches is the minimum width. A baffle of eight inches produces a mid-point frequency of 570 Hz. This means the baffle diffraction step will likely be below the crossover point no matter what the width of the baffle is.

Construction Materials

Hard dome drivers composed of metals have lower distortion than soft domes and tend to be used in high-fidelity audio systems for that purpose. They are also generally only used for higher frequencies. Beyond their intended frequency range and also when radiating a higher SPL than their intended use, these hard drivers will distort in a very distasteful way that is not satisfying to the ear. Soft dome drivers do not have the low distortion in their intended frequency range as the hard dome drivers but their break-up outside of their recommended frequency range is much more smooth with less distortion that the harder drivers. [9] For this design soft dome drivers will most likely be used but I am not impartial to hard dome tweeters if they will not cause problems at the crossover or extreme frequencies.

For the materials in this loudspeaker design I would like to use a wood that will be fairly sturdy, cheap, and easy to use. Medium density fiberboard (MDF) is one of the most common loudspeaker materials. It is not part of this design goal to spend a lot of the budget on the enclosure materials.

[8] "Simple Sizing of the Components in a Baffle Step Correction Circuit." Last modified 2005. http://www.quarter-wave.com/General/BSC_Sizing.pdf.

[9] Philip Newell, and Keith Holland, ***Loudspeakers For Music Recording and Reproduction***, (Oxford: Focal Press, 2007), 43-44.

Driver Selection

Preliminary Tweeter Analysis & Selection

Manufacturer	Model	F(s)	Frequency Range	Price	Power Handling	Sensitivity
Seas	27TDFC	550 Hz	1500 - 25000 Hz	$50.70	90 W	90 dB
ScanSpeak	Discovery R2604/8320	500 Hz	1500 - 35000 Hz	$54.45	N/A	90 dB
Seas	27TBC/G	600 Hz	2000 - 25000 Hz	$50.50	55 W	92 dB
SB Acoustics	SB26ADC-C000-4 Metal	680 Hz	1500 - 20000 Hz	$52.90	120 W	91 dB
SB Acoustics	SB26STAC-C000-4 Textile	750 Hz	2000 - 25000 Hz	$43.85	120 W	91 dB

Listed above are the different tweeters considered for this loudspeaker design and some of their important specifications.

Seas Prestige 27TDFC (H1189) Textile Dome Tweeter

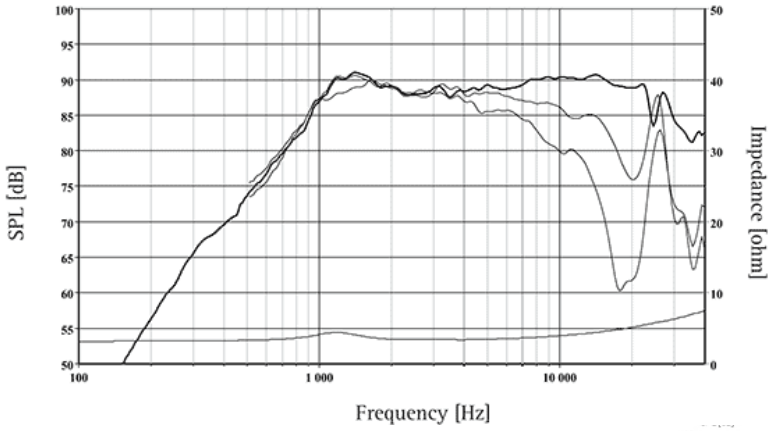


FIGURE 2: RESPONSE OF SEAS PRESTIGE 27TDFC TWEETER

The Seas Prestige 27TDFC tweeter is a widely enjoyed tweeter that has gained popularity with many loudspeaker builders. The price is very affordable and attractive for this design. This tweeter has relatively flat frequency response above 2 kHz and reaches and SPL of 90 dB, which is more than my maximum SPL output goal.[10] It also has a very low resonant frequency of 550 Hz which would allow for a low crossover point of 1.5 KHz. Beyond 10 KHz the off-axis response deteriorates a bit. When paired with certain woofers a lower crossover point is desired.

ScanSpeak Discovery R2604/8320

One of the desirable qualities in this tweeter is that the 30 degrees off-axis response does not deteriorate as badly as some of the other tweeters

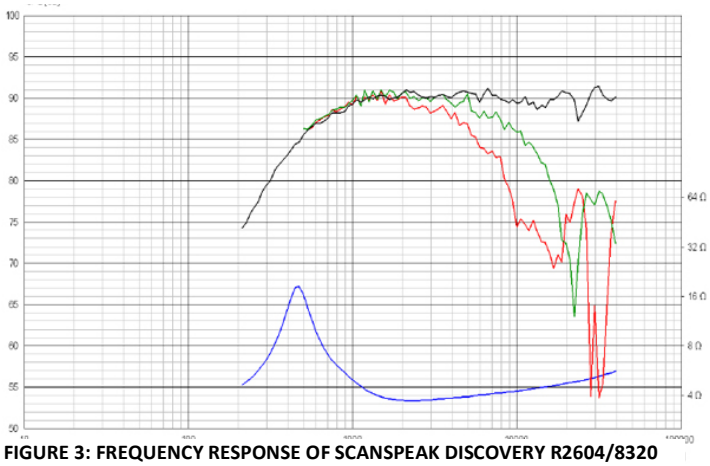


FIGURE 3: FREQUENCY RESPONSE OF SCANSPEAK DISCOVERY R2604/8320

[10] "SEAS, "h1189_27tdfc_datasheet.pdf." Last modified 2007. Accessed February 19, 2013. http://www.seas.no/images/stories/prestige/pdfdatasheet/h1189_27tdfc_datasheet.pdf.

considered. This driver also has a low resonant frequency of 500 Hz.[11] The tweeter has a waveguide to help rescind phase cancelations. The manufacturer does not provide the long term power handling though and that is a bit uncomforting.

SEAS PRESTIGE 27TBC/G (H1147) ALUMINUM DOME TWEETER

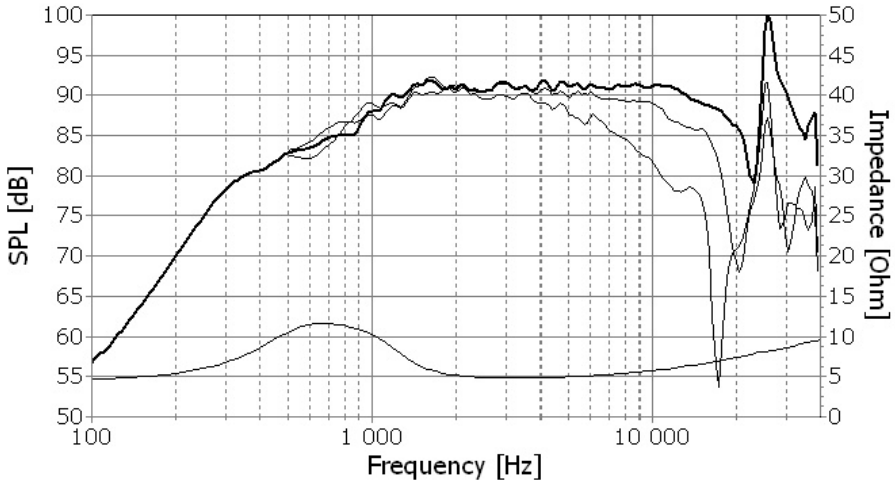


FIGURE 4: FREQUENCY RESPONSE OF SEAS PRESTIGE 27TBC/G

This driver also has a low resonant frequency of 600 Hz.[12] The aluminum dome allows for lower distortion overall. However, the frequency response does get very funky at 20 KHz so I will likely need a shelving filter there. The cost is average and the frequency response is fairly flat, but dips slightly at 12 KHz.

SB ACOUSTICS SB26ADC-C000-4 METAL DOME TWEETER

This tweeter appears to have really good off axis response when compared with the previously mentioned drivers. The difference between the on-axis and 60 degrees off axis response stays within a 10 dB difference of each other until about 19 KHz.[13] This is also a metallic tweeter so it will have lower distortion than a soft

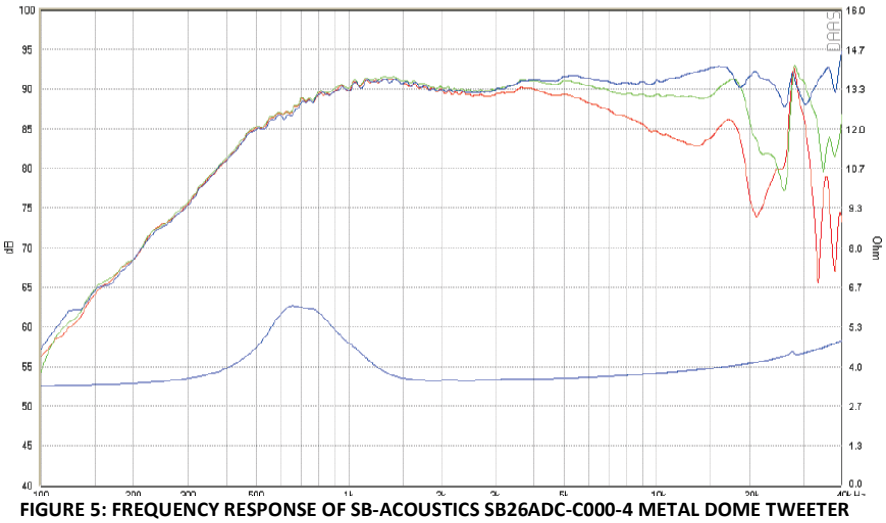


FIGURE 5: FREQUENCY RESPONSE OF SB-ACOUSTICS SB26ADC-C000-4 METAL DOME TWEETER

[11] ScanSpeak, "r2604-832000." Last modified 2011. Accessed February 19, 2013. http://www.scan-speak.dk/datasheet/pdf/r2604-832000.pdf.

[12] SEAS, "h1147_27tbc_g_datasheet.pdf." Last modified 2007. Accessed February 19, 2013. http://www.seas.no/images/stories/prestige/pdfdatasheet/h1147_27tbc_g_datasheet.pdf.

[13] SB Acoustics, "SB25AC-C000-4.PDF." Accessed February 19, 2013. http://www.madisound.com/store/manuals/SB25AC-C000-4.pdf.

dome tweeter. It does have a higher resonance frequency which means a crossover at 1.5 KHz is not as feasible as with other tweeters. The power handling for this driver is rated pretty high. This driver does have a 1 db dip from about 1.5 KHz to 4 KHz and it also appears that this driver is no longer being manufactured.

SB Acoustics SB26STAC-C000-4 Textile Dome Tweeter

This driver has a fairly high resonant frequency compared to the other considered tweeters at 750 Hz. This means a crossover at 1.5 KHz is not going to be good, so crossing over at 2 KHz. One retailer suggested that the driver would only be used from 2 KHz up despite the driver having a very flat response from 900 Hz up to nearly 30 KHz. The off-axis response is pretty good up until about 17 KHz and the power handling is high at 120 W. The most unattractive characteristic of this driver is the high resonant frequency, which may not work well with the desired crossover frequency.

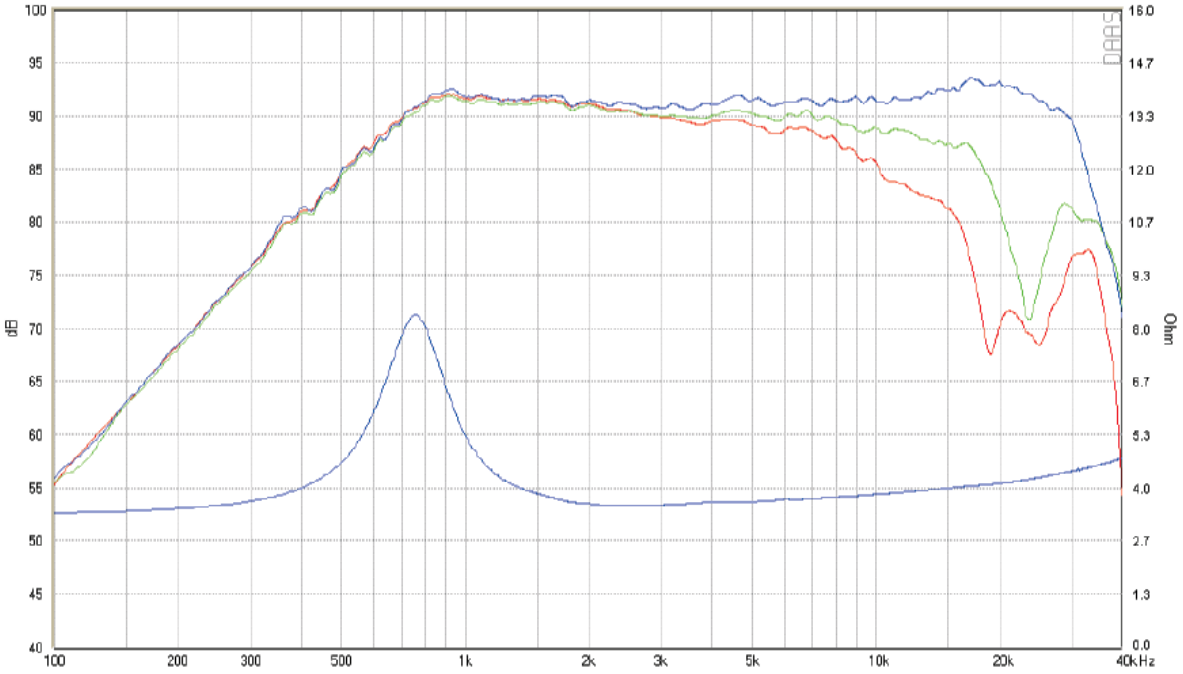


FIGURE 6: FREQUENCY RESPONSE OF SB26STAC-C000-4 TWEETER[14]

[14] SB Acoustics, "SB26STAC-C000-4." Last modified 2010. Accessed February 19, 2013. http://www.sbacoustics.com/index.php/products/tweeters/sb26stac-c000-4/.

Preliminary Woofer Analysis & Selection

Manufacturer	Model	Diameter	Fs	Power Handling	Sensitivity	Q(ts)
ScanSpeak	18W/8434G00 Discovery	6.5”	50 Hz	170 W	88.7 dB	0.43
ScanSpeak	22W/4534G00 Discovery	8.0”	30 Hz	120 W	92.4 dB	0.34
SB Acoustics	SB17NRXC35-8	6.5”	32 Hz	60 W	89 dB	0.34
SB Acoustics	SB17MFC35-4	6.0”	31 Hz	60 W	90.0 dB	0.29
Seas	Prestige CA15RLY (H1216)	5.5”	44 Hz	60 W	87.5 dB	0.34

Above is a set of characteristics about the next five woofers that will be compared as possible woofer selections for this design.

ScanSpeak 18W/8434G00 Discovery 6.5” Midwoofer

One of the tendencies that I really like about this woofer is that from 100 Hz to 1 KHz the frequency is response is both very flat at about 88 dB but also has very good off-axis response. There is a bit of a bump response at about 1200 Hz that goes up about 3 dB. At 2 KHz the off-axis response decreases sharply. Lower than 100 Hz the response dips quickly and does not have a smooth pattern in anymore.[15] The driver price is listed at $73 which is within my price range for woofers. Modeling these drivers within the software program WinSpeakerz produced interesting results. A flat response was achieved with a box volume of .49 cubic feet (14 liters) which is the recommended box size given by one retailer. With a box tuned to 40 Hz, the modeled loudspeaker had an F3 just below 60 Hz, which is good for the design goals. I also

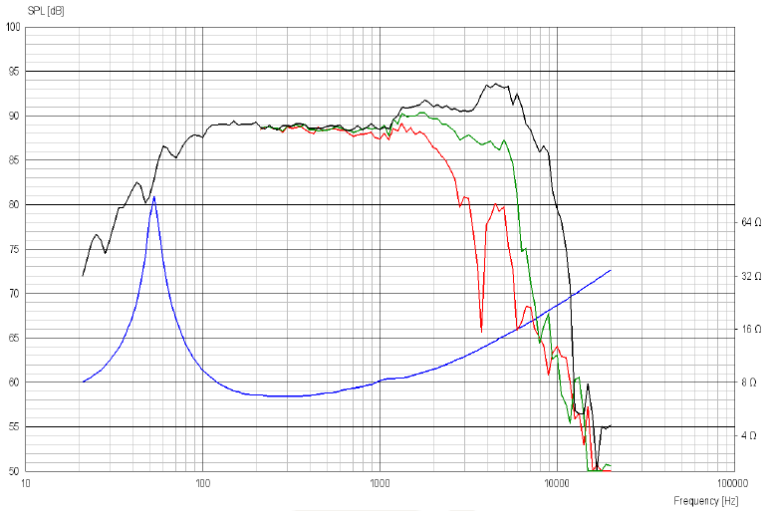


FIGURE 7: FREQUENCY RESPONSE OF SCANSPEAK 18W/8434G-00

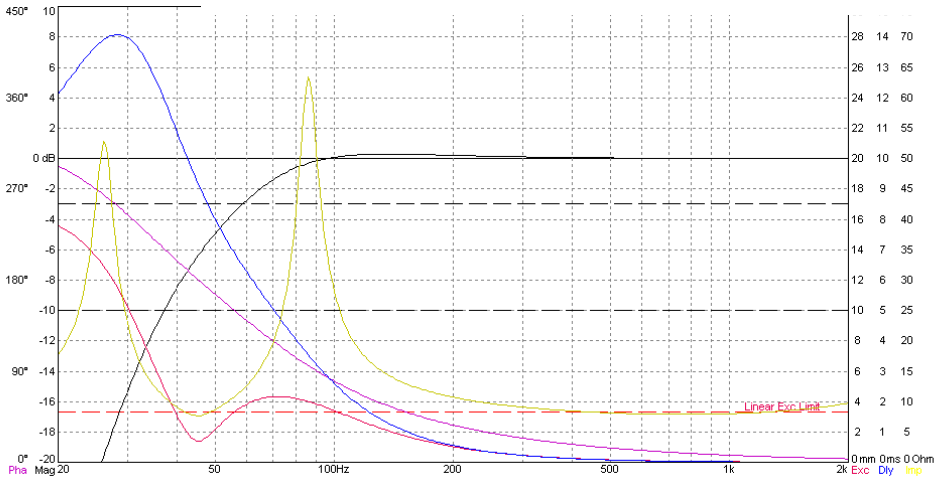


FIGURE 8: MODELED FLAT RESPONSE OF SCANSPEAK 18W/8434G-00

[15] Scan-Speak, "18w-8434g00.pdf." Accessed February 10, 2013. http://www.scan-speak.dk/datasheet/pdf/18w-8434g00.pdf.

really liked how the box volume became so small and the inner dimensions would work at 9” wide, 12” tall and about 7” deep. I feel this driver gets fairly good frequency extension while being in a very small enclosure. The one thing I still don’t like about the driver is the boost in frequency response both at 1.2 KHz and also 3.5 KHz. I don’t think the crossover can completely mask these abnormalities. In another modeled simulation a flat response down to nearly 60 Hz was obtained for very good frequency extension with an F3 of 45 Hz (Figure 7). However this makes the enclosure quite a bit larger at 9” wide, 10” deep, and 16.32” tall which is not ideal for the size design goals. It also increases a large amount of delay in frequencies below 60 Hz. By keeping the box volume at half of a liter but tuning the box up to 65 Hz, considerable bass boost was achieved (3 dB was gained at 90 Hz). The modeled designs were all used with a single port 1” wide.

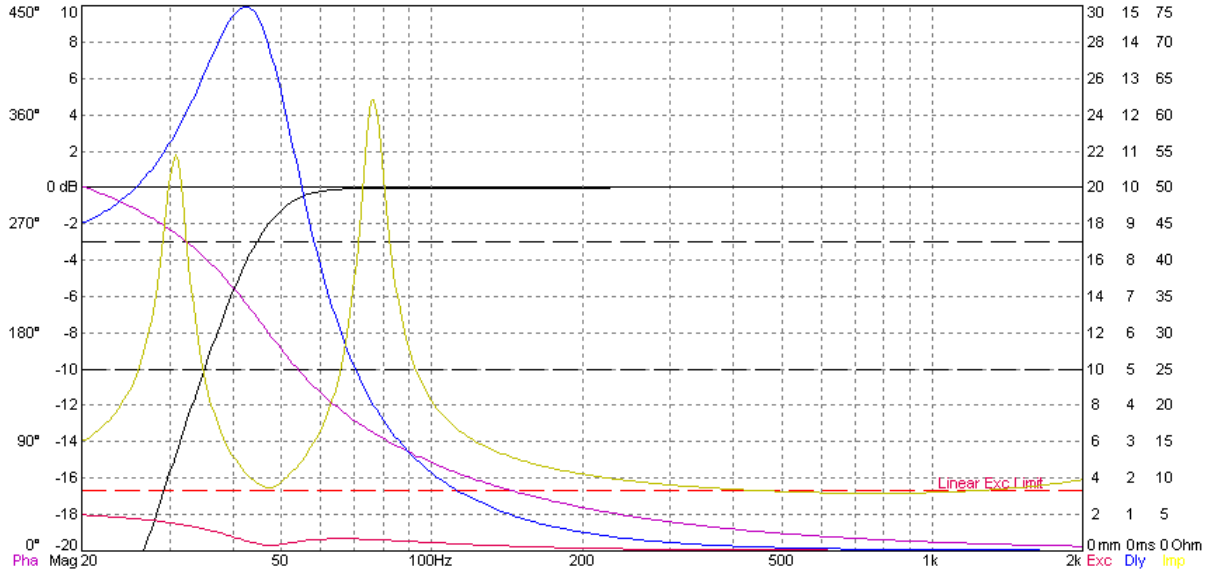


FIGURE 7: MODELED BASS EXTENSION RESPONSE OF SCANSPEAK 18W/8434G-00

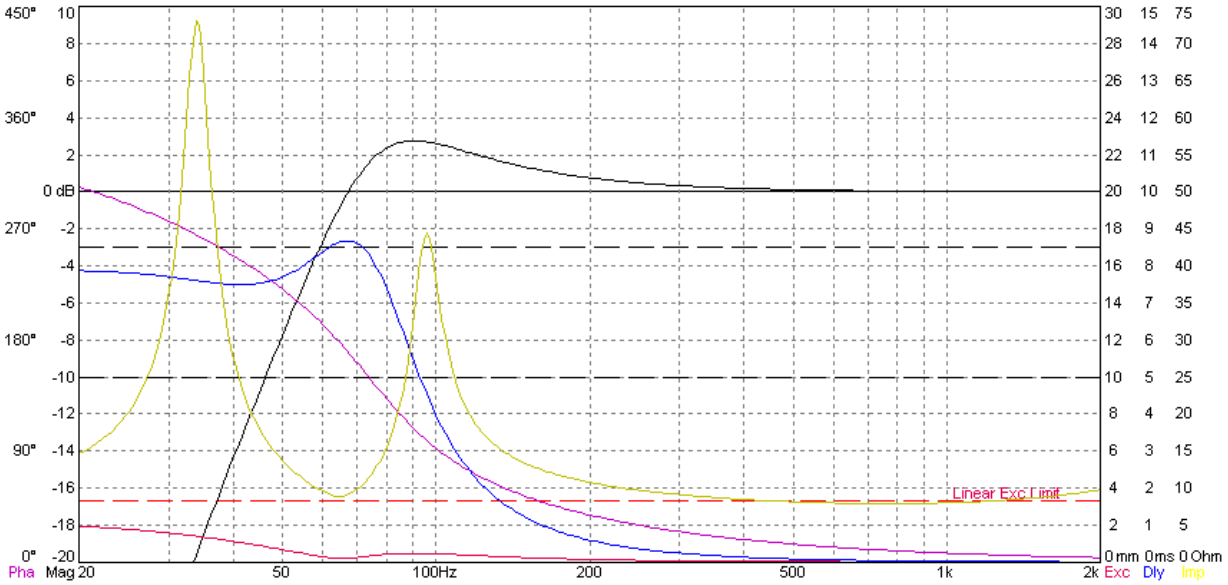


FIGURE 8: MODELED BASS BOOST RESPONSE OF SCANSPEAK 18W/8434G-00

SCANSPEAK 22W/4534G00 DISCOVERY 8" WOOFER

One characteristic of this driver that is appealing is the good directivity from 100 – 1000 Hz. This driver also has an F3 of about 55 Hz. The resonant frequency is very low at 30 Hz and the driver has a very low extension, getting down to 25 Hz at 85 dB. The sensitivity of the driver is also pretty high SPL. Unfortunately the low frequency extension is not very smooth and is about 8 dB below the average frequency. There is also some unwanted boost at 1000 and 3000 Hz. These boosts would likely result in undesirable summation with a 2nd order crossover centered at 1.5 KHz. From 1050 Hz and downward the off axis response deteriorates greatly. This can be seen in Figure 9 on the left.[16] Compared to the other ScanSpeak woofer, this driver has a louder response at lower frequencies.

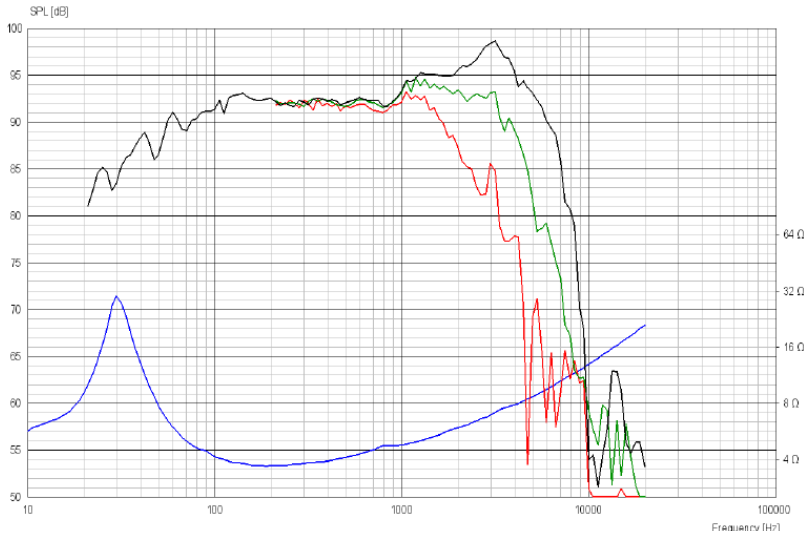


FIGURE 9: FREQUENCY RESPONSE OF SCANSPEAK 22W/4534G00 8" WOOFER

Modeling this driver using the recommended enclosure size of 1 cubic foot produced a flat frequency response down to 80 Hz with an f3 of 53 Hz (this was not quite the expected f3 of 49 Hz as given by the retailer). The delay effects were somewhat minimal down to frequencies of 30 Hz. In order to achieve a bass boost, the box volume had to be increased by half a cubic foot and a 2nd port was needed. In the end the response only stayed flat for another 10 Hz down despite a big increase in box volume. This can be seen on the next page in Figure 11. The bass extension plot in Figure 12 shows that using 1 cubic foot as an enclosure volume good bass boost can be obtained at with a 4 dB increase at 80 Hz. This also causes an increase in delay at 70 Hz and a large peak in the middle of the delay curve.

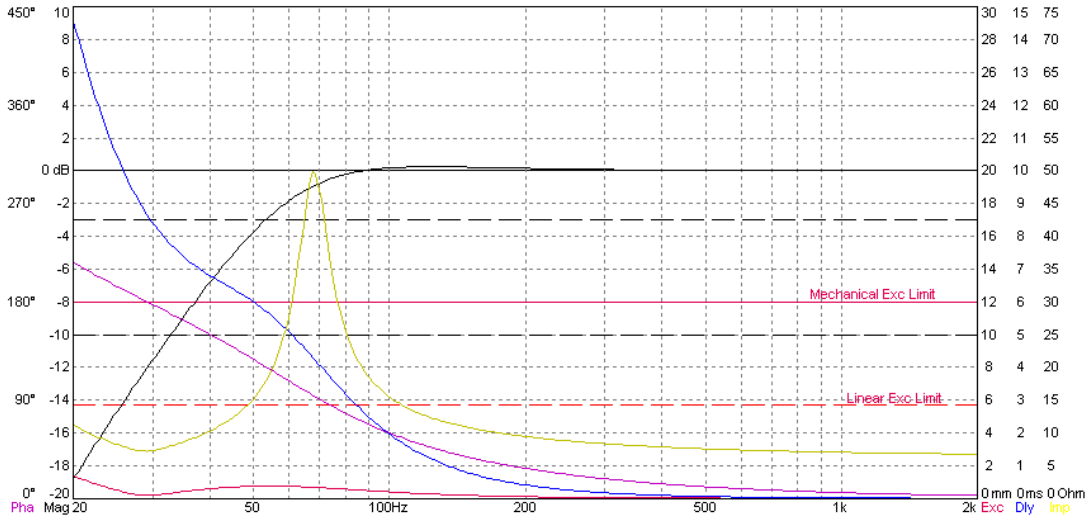


FIGURE 10: FLAT RESPONSE OF SCANSPEAK 22W/4534G00 8" WOOFER

[16] ScanSpeak, "22w-4534-g00.pdf." Last modified 2011. Accessed February 20, 2013. http://www.scan-speak.dk/datasheet/pdf/22w-4534g00.pdf.

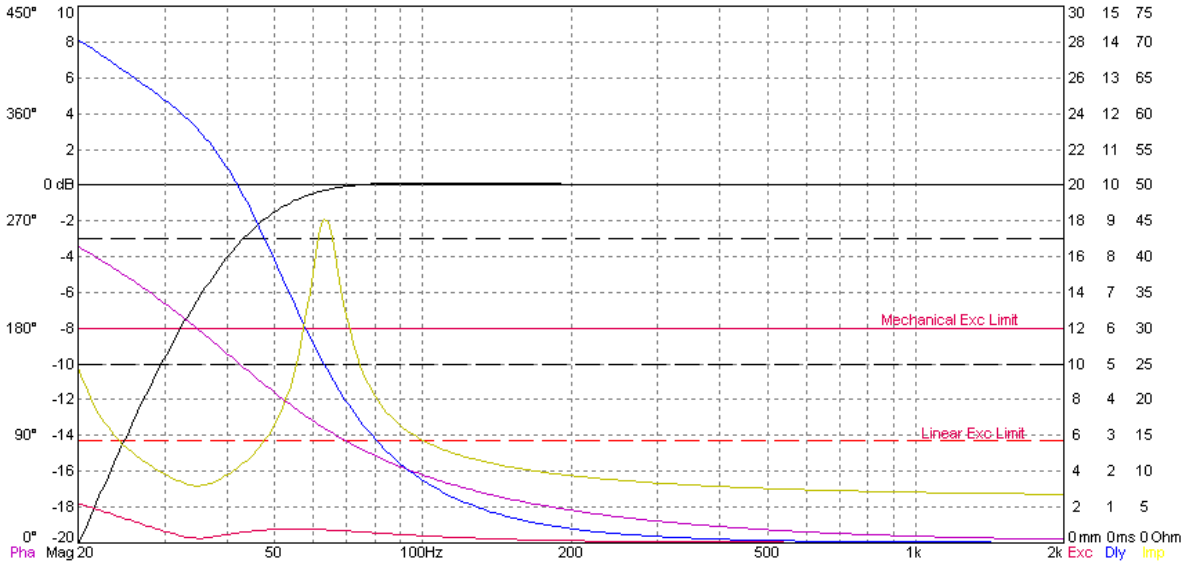


FIGURE 11: BASS EXTENSION FOR SCANSPEAK 22W/4534G00 8" WOOFER

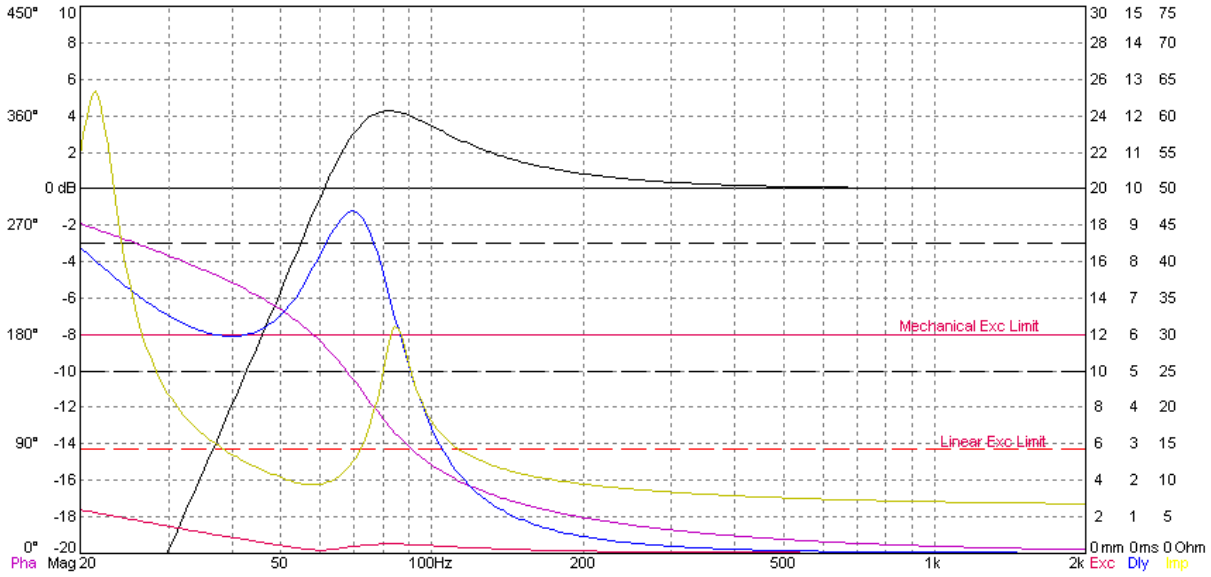
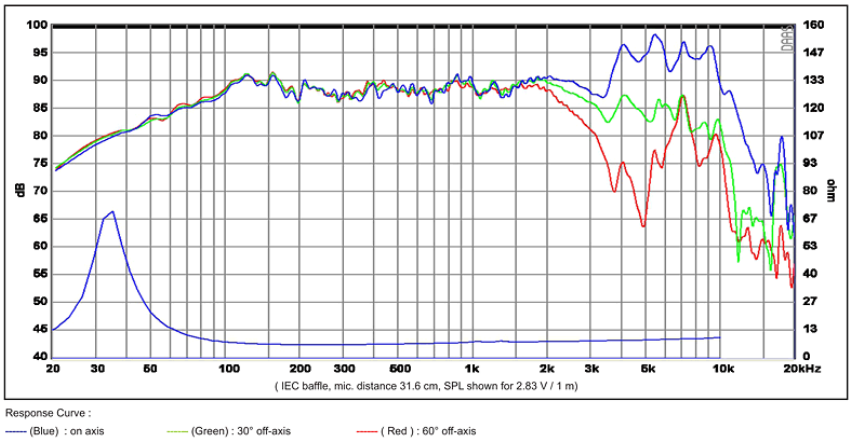


FIGURE 12: BASS BOOST FOR SCANSPEAK 22W/4534G00 8" WOOFER

SB ACOUSTICS SB17NRXC35-8, 6.5" WOOFER

This woofer also has a flat and very good off-axis response from the range of 100 Hz to 2 KHz. Past 3 KHz the response breaks up and becomes terrible.[17] The listed frequency range lists 3.5 KHz as the end of range and it does appear to break up beyond that point. It seems that at minimum a second order crossover would be able to cancel out the breakup frequencies if it was centered at 1.5 KHz. The response does not seem to be as flat as the Scan-Speak Discovery drivers mentioned above but it is still very good. It can be seen in Figure 13 that this driver has a

[17] SB Acoustics, " SB17NRXC35-8.PDF." Accessed February 19, 2013. www.sbacoustics.com/index.php/download_file/-/view/415/.



flatter response for longer but has more variance (about 4-5 dB difference) in its frequency response plot. The response also seems to be a bit smoother below 100 Hz when compared to the Scan-Speak woofers. Like the Scan-Speak 18W/8434G00 woofer, this driver reaches down to 50 Hz at about 80 dB. A flat response was modeled down to 70 dB with an enclosure volume of 0.7 cubic feet. When modeled with a bass boost there was a very large peak in the delay at about 65 Hz that did not look good.

FIGURE 13: FREQUENCY RESPONSE FOR SB ACOUSTICS 6" SB17NRXC35-8

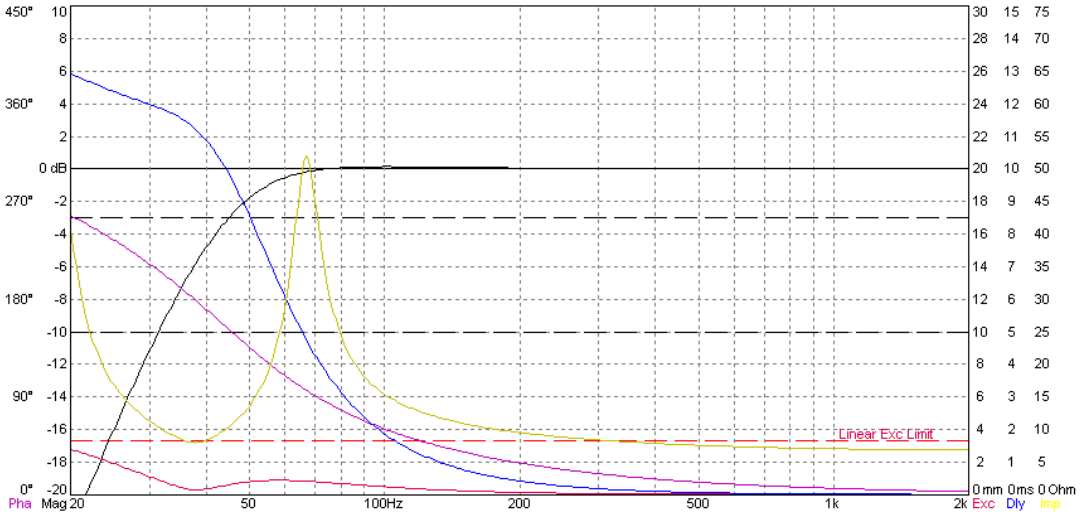


FIGURE 14: FLAT FREQUENCY RESPONSE FOR SB ACOUSTICS 6" SB17NRXC35-8

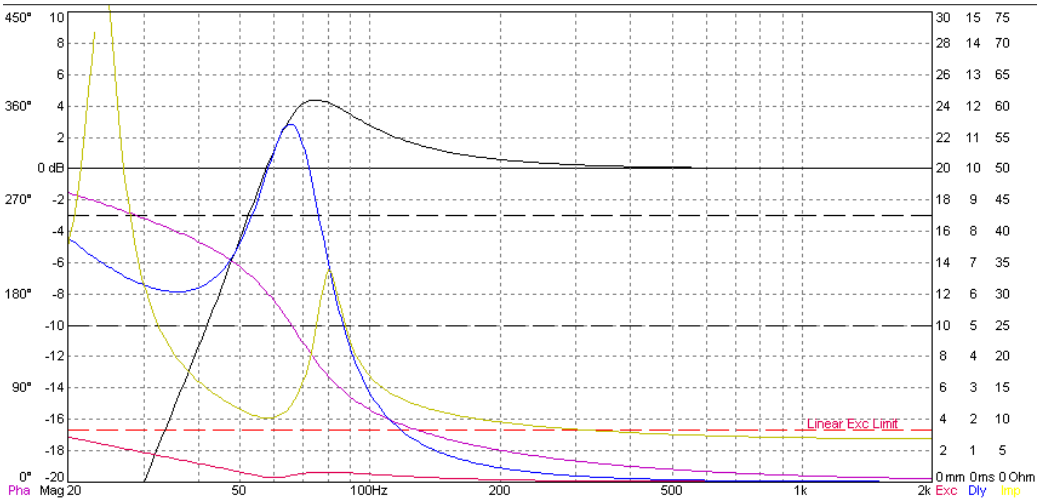


FIGURE 15: BASS BOOST RESPONSE FOR SB ACOUSTICS 6" SB17NRXC35-8

SB Acoustics SB17MFC35 6" Poly Cone Woofer

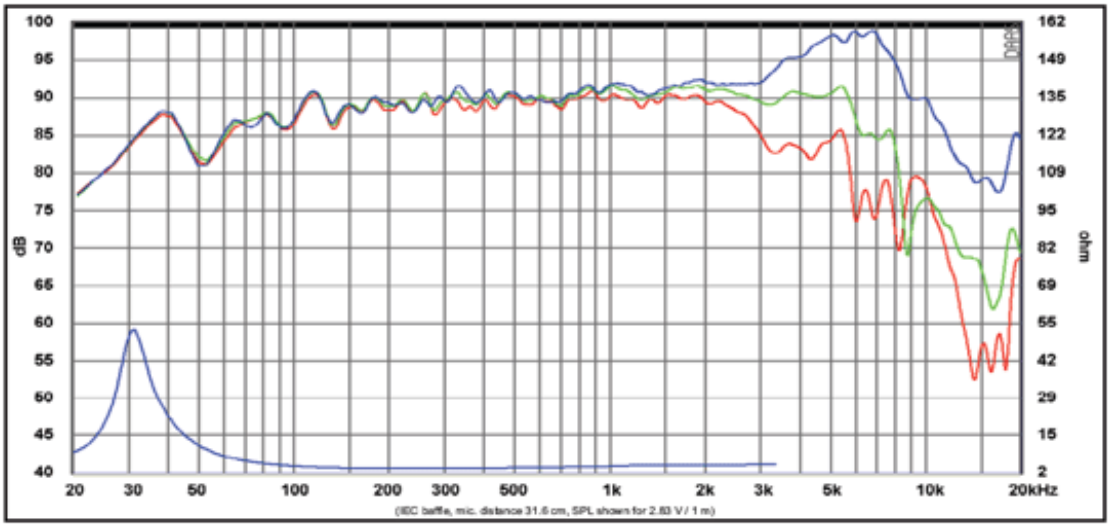


FIGURE 16: FREQUENCY RESPONSE OF SB ACOUSTICS SB17MFC35-4

This driver is recommended by one retailer for a vented box that is of 0.45 cubic feet in volume. Modeling the driver in a box at this volume and using a box frequency of 43 Hz produced a very flat response with an f3 of just above 50 Hz. The frequency response of the driver is also fairly flat from 100 Hz to 3.5 KHz.[18] The f3 (3 db drop in volume point) is at about 70 Hz on the driver. The low-end roll off is rather slow and doesn't reach a -10 dB difference from the average volume until 35 Hz. The frequency response is also very directive up until 2 KHz and doesn't break up until 3.5 KHz. The price for what appears to be a good quality driver is also very nice. By raising the box frequency to 62 Hz, the modeling produced a result that had a 3 dB gain of bass boost at 83 Hz, however this bumped up the f3 about 5 Hz and the roll off after it was much steeper. This can be seen in Figure 18. In Figure

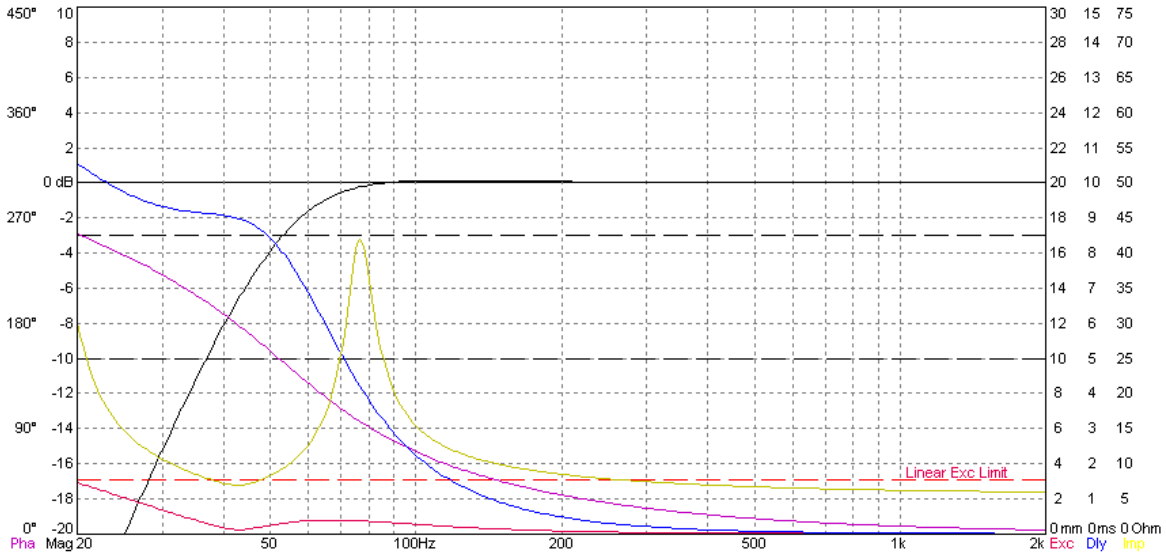


FIGURE 17: MODELED FLAT FREQUENCY RESPONSE OF SB ACOUSTICS SB17MFC35-4

[18] SB Acoustics, "6" SB17MFC35-4." Last modified 2010. Accessed February 24, 2013. http://www.sbacoustics.com/index.php/products/midwoofers/sb17mfc35-4/.

19, increasing the inner box volume to be 0.75 cubic feet allowed for flat response down to 55 Hz and an f3 of 43 Hz. However, this requires over a 50% larger box and is not worth it when compared with the importance of the size design goals.

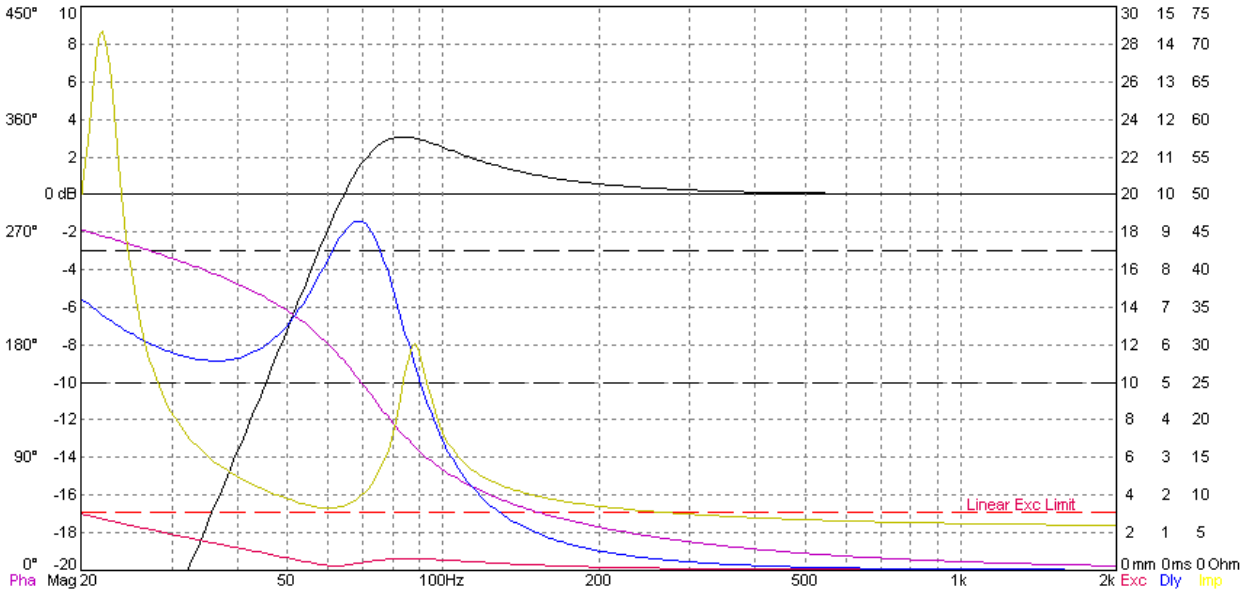


FIGURE 18: MODELED BASS BOOST RESPONSE FOR SB ACOUSTICS SB17MFC35-4

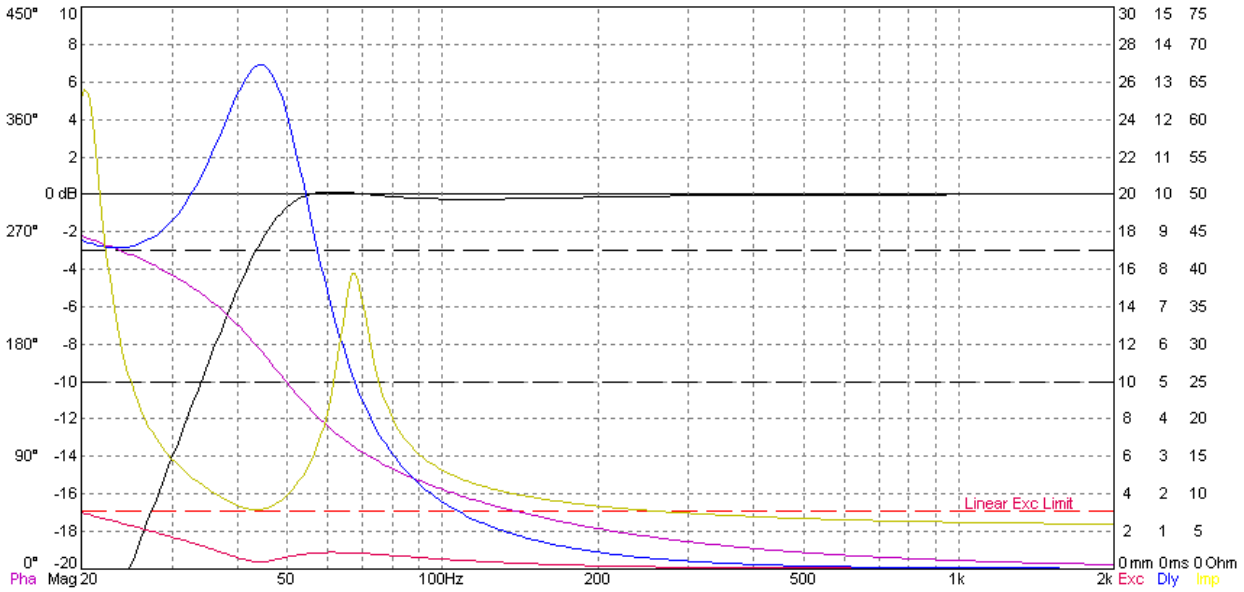


FIGURE 19: MODELED BASS EXTENSION RESPONSE FOR SB ACOUSTICS SB17MFC35-4

SEAS PRESTIGE CA15RLY 5.5" COATED PAPER CONE WOOFER

The Seas Prestige CA15RLY Driver is a 5.5”driver recommended for a very small sealed box enclosure. The frequency response of this driver is not very flat for most of it, but it is from about 1.5 to 4.0 KHz.[19] There is a 3 dB gain from 400 Hz to 500 Hz and a 5 dB drop from 300 Hz to 80 Hz. However, the recommended internal enclosure volume for this driver is only 0.25 cubic feet, which is very small. Modeling showed that with a box frequency of 52 Hz, the f3 point in the flat frequency response was 58 Hz. Doubling the internal volume resulted in a bass extension of f3 by 13 Hz down to 45 Hz, but with a small 1 dB dip at 100 Hz.

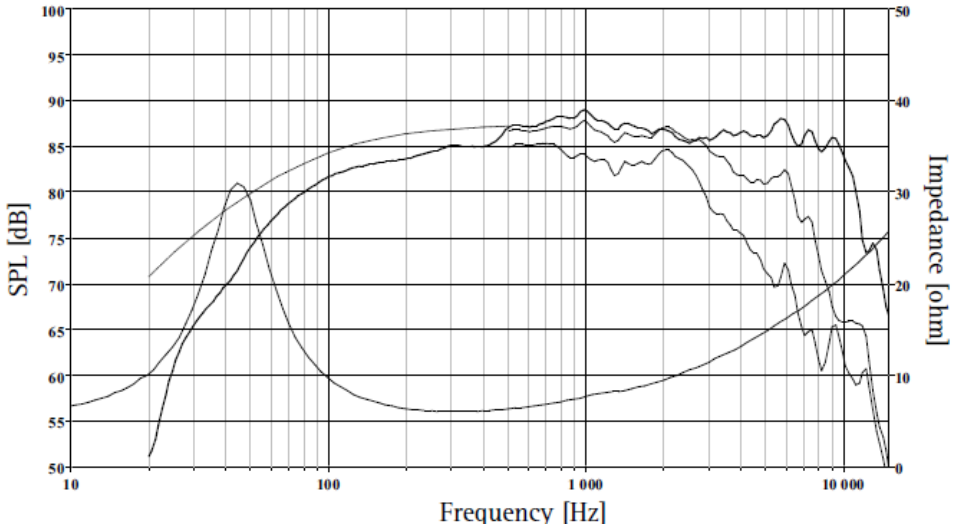


FIGURE 20: SEAS PRESTIGE CA15RLY FREQUENCY RESPONSE

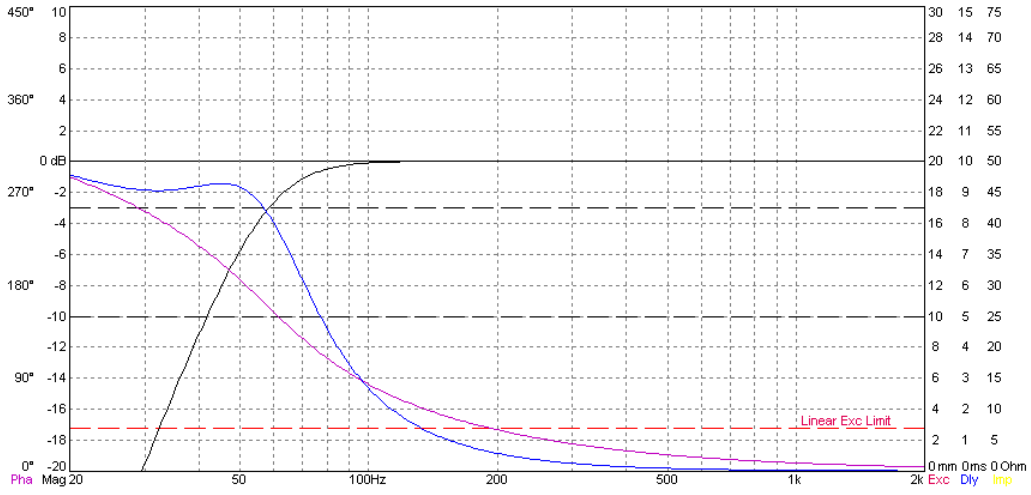


FIGURE 21: MODELED FLAT RESPONSE FOR SEAS PRESTIGE CA15RLY

[19] SEAS, "H1216-08_CA15RLY_datasheet.pdf." Last modified 2011. Accessed February 25, 2013. http://www.seas.no/images/stories/prestige/pdfdatasheet/H1216_CA15RLY_Datasheet.pdf.

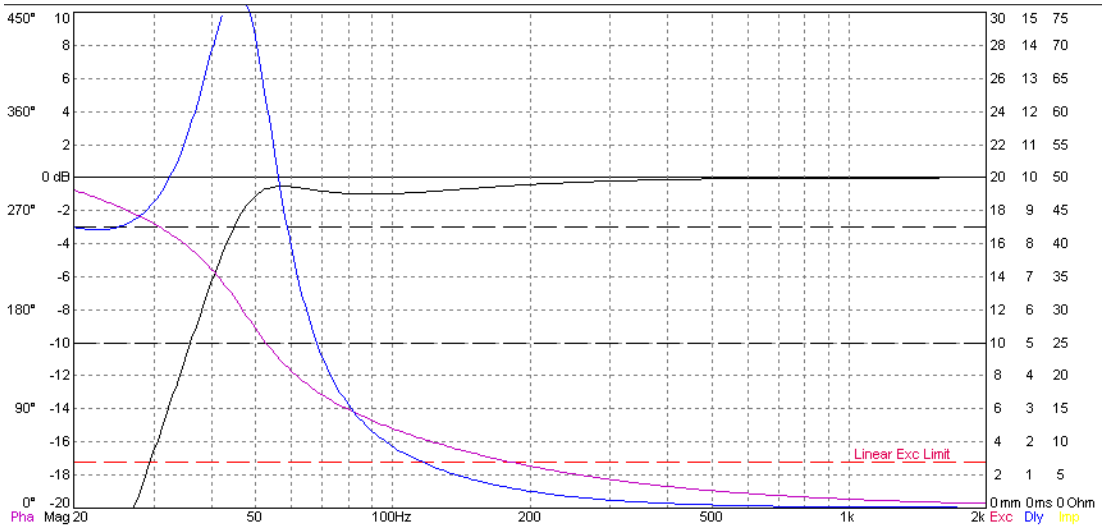


FIGURE 22: MODELED BASS EXTENSION FOR SEAS PRESTIGE CA15RLY

FINAL DRIVER SELECTION

When selecting a woofer for this design one of the most important factors was flat response from 1 KHz to above. Most of the drivers were pretty flat from 100 Hz to 1 KHz, but many of the drivers had quite a bump in volume or a breakup in their response beyond 2 KHz. The SB Acoustics drivers had flat responses above 2 KHz, but specifically the SB17MFC35 had a flatter response and a less unattractive break up. It also was slightly less wide than the other SB Acoustics woofer and had a higher sensitivity.

For choosing a tweeter, the desired driver would have to match well with the chosen woofer. It must have a flat response and have close dB sensitivity. It must be able to crossover well and not have hideous response past 20 KHz. The SB Acoustics SB26ADC-C000-4 had a flat frequency response and very wide dispersion. It was also a metal dome and worked well with the chosen SB Acoustics woofer. A crossover at 2 KHz was very possible.

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