The Mithril Series Hobb-5s

A Stereo Sound System for Home Theater Usage

Built by: Gabe Harrmann

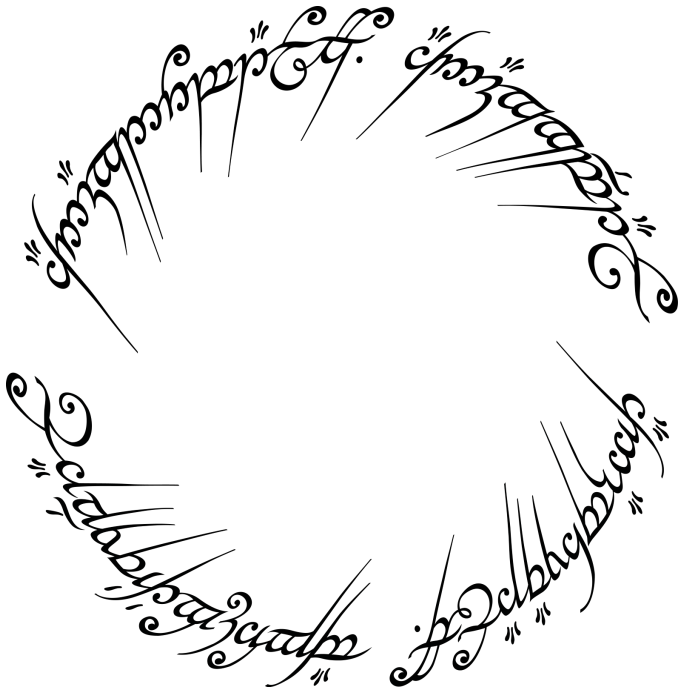


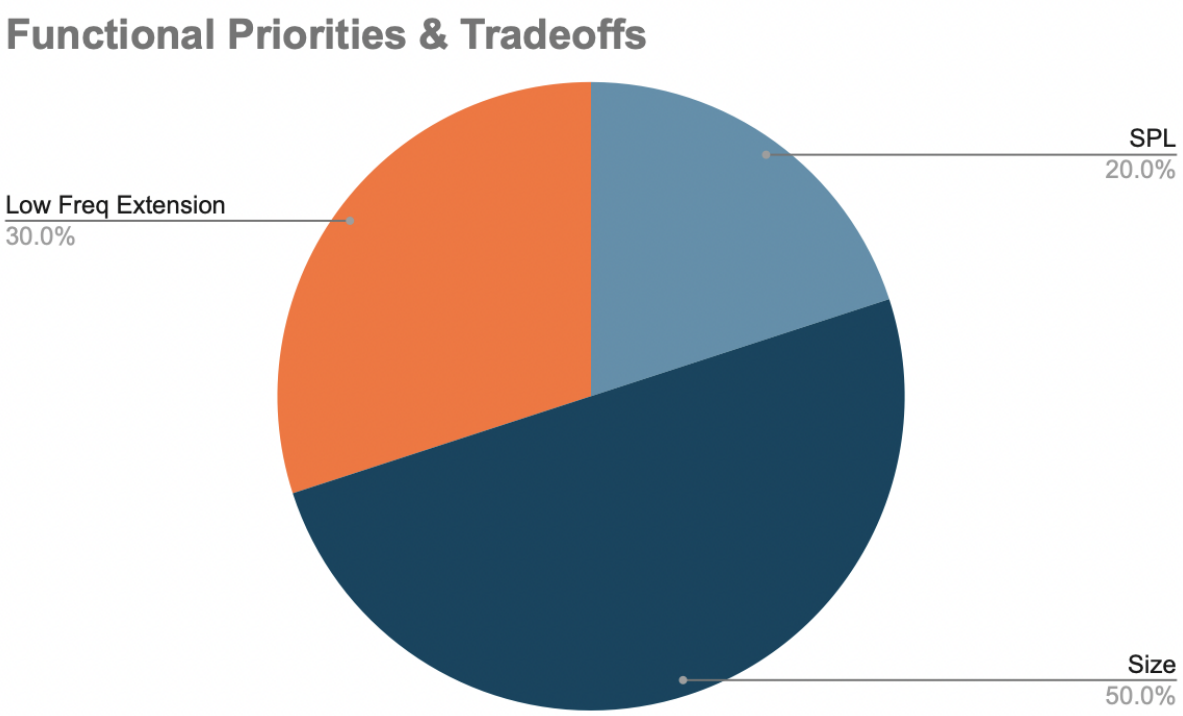
Table of Contents

1.0 Functional Description

The focus behind the design of this system will be for Home Theatre use and as a set of studio reference speakers to listen forward to. It will be comprised of a pair of stereo monitors each with 6.5” woofers and a 1” tweeter. The stereo monitors shall be designed with overall clarity in mind and will also need to support the lower frequencies. The largest space these speakers will have to accommodate would be a large living room space approximately 16’ x 20’ or an area of 320 square feet. With this space in mind, this system will be designed with low frequency extension and high SPL output as a primary design goal (obviously size and clarity will be considered but will not be focal point).

The monitors will ideally be placed on an entertainment center or console on either side of the television. The cabinet design will be minimalistic black or wood veneer boxes with nice black grills on the front to keep things sleek and ‘homey’. Rubber feet will possibly be added to the cabinets to reduce wear and tear on the cabinet or furniture it may rest on. I wish to create a beefy speaker that looks proportional to a large television and draws attention to itself. The maximum size will be set for transportation in my mid-sized SUV.

Based on John L. Murphey’s recommended three-point design tradeoffs this system will strive strongly for Speaker Size along with Low Frequency Output and prioritize SPL output last. Graph shown below:



2.0 Reference Systems

2.1 Overview

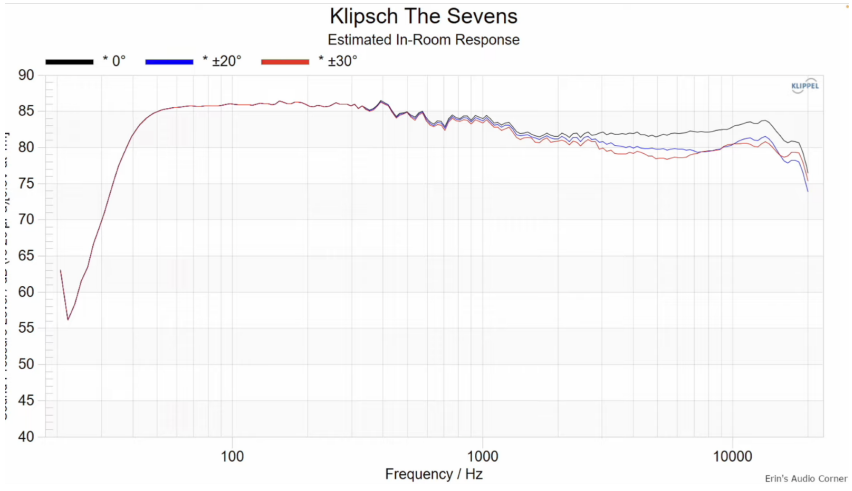
The table below lists several loudspeaker systems to determine general guidelines & references for speaker performance:

Speaker	F3	SPL Peak	Weight	Dimensions	Price
Klipsch "The Sevens"		112	22.3lbs	8.13w x 10.88d x 16.38h	$1,300
QSC CP8		124	21lbs	10.7w x 10.1 x 16.2	$1,000 (pair)
Yamaha NS-6490 3-WAY 8"		90	13.2lbs	10.5w x 13.1d x 16.1h	$170
Klipsch The Fives		109	11.8lbs	6.5w x 9.25d x 12h	$970
Focal Aria 906		89.5	19lbs	8w x 11d x 15h	$1,400

2.2 Specific Loudspeakers

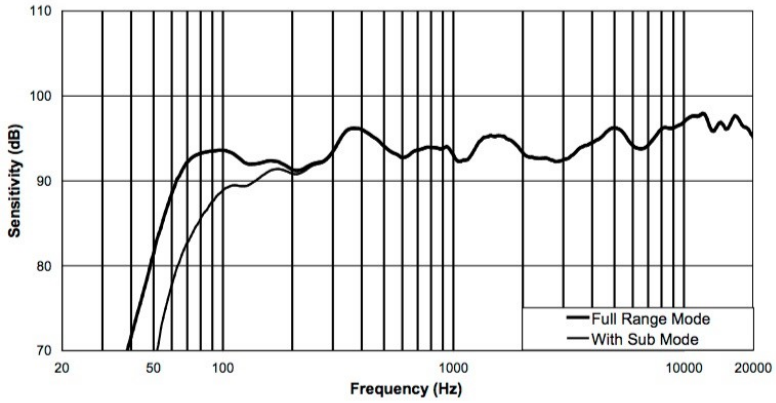
The Sevens by Klipsch

These speakers serve as the main inspiration for this design project. They are straightforward, sleek, and yet large enough to handle lower frequencies with its 6.5” woofer. The cab is made of MDF but is either painted black or covered in a vinyl walnut wrap as shown. The horn placed in front of the 1” titanium tweeter as an efficient transfer of acoustic energy and looks very stylish as well. With a frequency response of 39-25kHz at +/- 3dB, it also offers a very consistent listening experience with a mild emphasis of the mid-range frequencies (can tell from the mild “frown” shape of the frequency response itself). This is something I hope to emulate. The Sevens also utilize a digital DSP which can be configured using an app. This is an expensive but attractive route. I do not wish to have to keep opening my speakers up in my living room when I want to make changes to their sound. If I take anything away from these speakers it will most likely be the visuals and the size/dimensions of the cabinet itself. It perfectly replicates what I want next to my television in my future home.



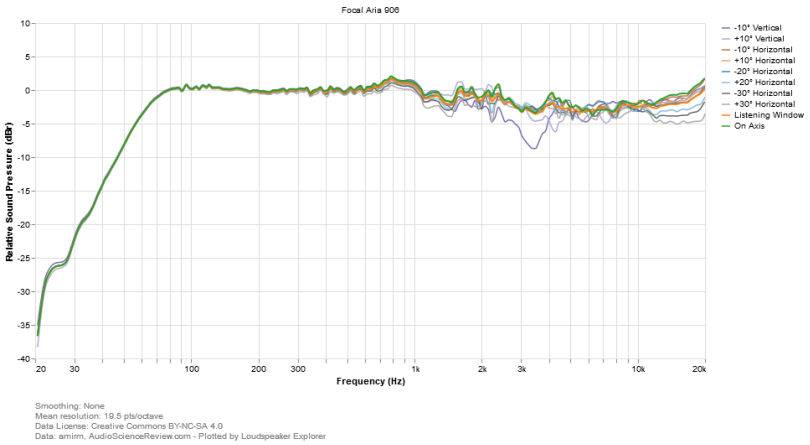
QSC CP8's

I chose these speakers as a heavy-duty option. Boasting an 8" woofer, the QSC CP8 handles lower frequencies like a champ, especially considering its almost 2lbs lighter than The Sevens. I used QSC quite often in my internship this last summer, so it made sense to find a reference speaker with which I had some personal experience with. This is the result of researching the possibility of utilizing 8" woofers instead of 6.5" woofers to see if there were any major disadvantages to either. I concluded that a 6.5" will be quite sufficient and that adding a subwoofer later in life is an option as well. It also pushes an extra 12dB in max SPL when compared to the Klipsch's. But for an average living room this difference will not be utilized. Lastly, I prefer the metal grill on these speakers a lot more than the foam grill on The Sevens.



Focal Aria 906's

These were chosen for their amazing mid-range response and their striking visuals. The 906's have an amazingly level frequency response. The Walnut look is something I think I have a taste for.



3.0 Technical Goals

3.1 Cabinet Design: Size & Portability

My speaker's external design will be heavily inspired by Klipsch *The Nines* which are very sleek boxes will a black or wood finish. They are also nice and tall and would look presentable when placed in an entertainment center or on stands beside a mounted television. My ideal dimensions will be approximately **20" x 10" x 14"** (height, width, and depth). This is large enough to hold my 8" woofer and also small enough to be transported in my mid-sized Honda CR-V. I do not plan to install any type of carry handle or brackets for wall mounting capability. I will design these with the purpose of resting on a surface or on a custom stand (which I may build next summer).

3.2 Listening Axis & Internal Volume

To determine the listening axis for my speaker design I measured my ear height on several different couches and chairs. On my home couch, I measured 42”. In a kitchen chair I measured 46”, and on a couch in the Alcove at Walker, I measured 38”. If we take the average of these measurements we get 42”. This shall be my target listening axis when designing and tuning my speakers.

When calculating the internal volume of my speaker cabinet, the thickness of the wall materials (¾”) must be subtracted from the external dimensions and then solved as usual. With the dimensions of **20” x 10” x 14”** (height, width, and depth), my box will have a volume of **2,800 cubic inches** or 1.62 cubic feet.

3.3 Experimental and Reference SPL Levels

I must set target SPL levels for my design before I begin woofer and tweeter selection to make sure my speakers perform perfectly in the situations I need them to. Below are listed the comfortable and max dB SPL levels I have collected from different audio mediums in the Michigan Tech Mixing Studio in Walker 212.

Input	Max dB SPL	Comfort dB SPL	*data is average of early morning and mid evening recordings
Action FIlm	97dB	85dB	
Dramatic FIlm	93dB	64dB	
Rock Music	98dB	76dB	
Jazz	93dB	78dB	

The highest peak SPL I hit was 98dB when listening to a rock song called *For Billy* by Highly Suspect which is a song I know sounds good hot in the monitors. While the lowest I was

comfortable listening to was 64dB during the final courtroom scene of *A Few Good Men.* If we take the normalized dB limit of -14dB used by Spotify, Amazon Prime, and YouTube AND we take the AES Streaming recommendation dB limit of -16 dB, my speaker must be capable of performing a peak SPL range of 112-114dB.

The same headroom math can be applied to the comfort listening level. My speakers must be tuned and have a good frequency response when listening at 78-80dB comfortably.

3.4 Listening Distance

The average living room is approximately 180-380 ft2 in size. So the ideal listening distance from the speaker will be 5-25 ft. The “sweet spot” will be set at 11ft because the furthest listening plane in MY living room is a chair that is approximately 11ft away from the television.

3.5 Amplifiers

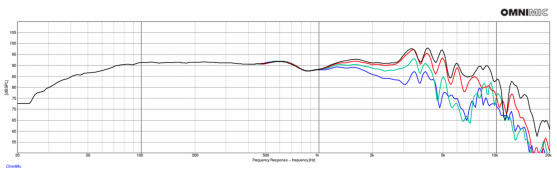
I shall assume a sensitivity of 89dB and that my crossover shall affect this sensitivity level by approximately -3dB. Based on this I will need approximately 360W of power or 180W per speaker. Whether I will supply this is individual amp for each woofer and tweeter is yet to be decided.

4.0 Loudspeaker Design

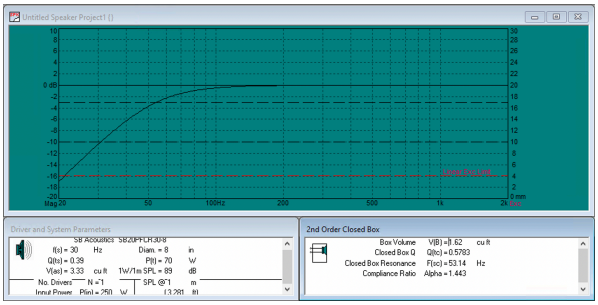
4.1 Woofer Analysis

Model	Nominal Size	Cone	Price	Sensitivity (dB)	RMS Power (Watts)	Thermal SPL Limit	Peak SPL Limit	X-Max	Sd cm2	Vas (litres)	Qts	Fs	Vb (Litres)	Vb (cu feet)	Vd	F3 in Hz (Vented)	X-Max SPL	K1
Dayton Audio PA200-8	8"	Paper/Kevlar	$60	94.2	250	118.18	254.24	3mm	210.4	28.32	0.48	55.2Hz				61		
Dayton Audio MB820-8	8"	Paper	$45	94	200	117.01	244.59	4mm	208.9	15.86	0.46	69Hz				61		
Eminence Alpha-8A	8"	Paper	$80	94	125	114.97	225.41	3.2mm	210	17.84	0.59	73Hz				50		
PRV Audio 8MR500-4 BULLET	8"	Treated Paper	$55	95	250	118.98	256.40	3.25mm	241	20.67	0.46	78.2Hz				70.4		
Eminence Beta 8	8"	Paper Cone	$30	95.1	225	118.62	252.32	3mm	210	23.3	0.38	65Hz				90		
SB Acoustics SB20PFCR30-8 (8 Ohm)	8"	Paper Cone	$54	90.5	50	107.49	153.76	5mm	216	66.2	0.37	34Hz				42		
Sanspeak 8534G00 Discovery	8"	Fibre Glass	$130	89	70	107.45	185.05	5.8mm	235	94.2	0.39	30Hz				35		

Dayton Audio PA200-8



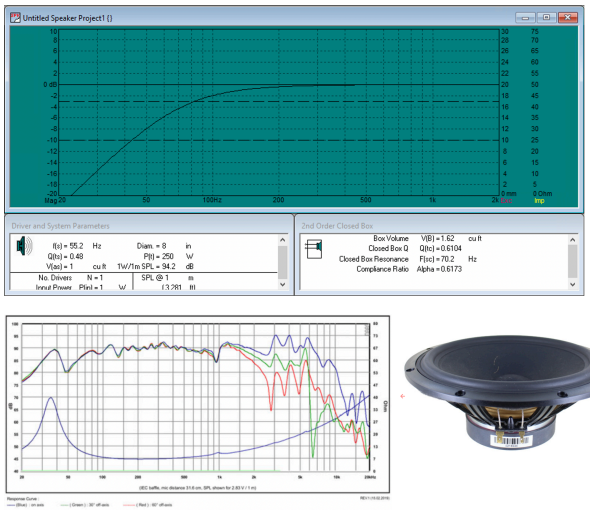
This 8” Dayton Audio driver is $60 and has an extremely solid sensitivity level at 94.2dB. One thing that really peaks my interest with this particular driver is the kevlar reinforced paper cone. This will help stiffen the cone and promote higher efficiency. The resonant frequency sits at approximately 55Hz which is just barely low enough for my target bass frequency of 50Hz. This is an average option for my design.



SB Acoustics SB20PFCR30-8 (8 Ohm)

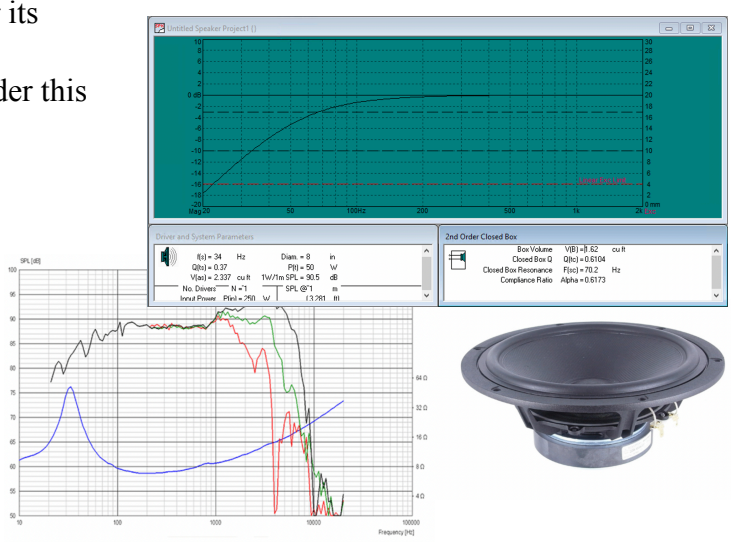
The SB20PF…blah blah blah is my favorite option by far. I have loved what I’ve seen from the SB Acoustic drivers in class, so I made sure to have at least one of them on my final woofer and tweeter lists. We don’t see any major breakup frequencies until about 3kHz which is perfect for

meeting my tweeter at the ideal crossover frequency at approximately 2kHz. The resonant frequency is also a whopping 34Hz which leaves plenty of room to comfortably set my bass floor at around 50Hz. The only issue I see with this driver is the +-4dB bump at 1kHz that coincides with a hiccup in the impedance but that can always be remedied with EQ. This is my favorite choice on this list.



ScanSpeak 8534G00 Discovery

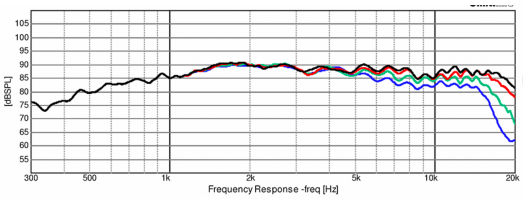
The ScanSpeak is more of a visual inspiration. The textured fiberglass cone looks much nicer to my eyes. Also this woofer has a resonant frequency of 30Hz! That is very ideal for my design. If it weren't for its jagged frequency response I might consider this driver more seriously.



4.2 Tweeter Analysis

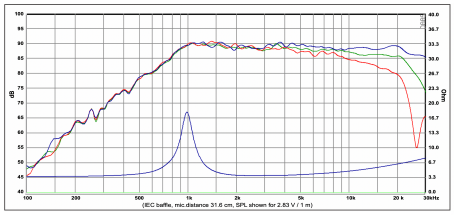
Model	Nominal Size	Design	Price	Fs (Hz)	Sensitivity (dB)	RMS Power (Watts)	Peak Power (Watts)	Thermal SPL Limit	Peak SPL Limit
Dayton Audio DC28F-8	**1.125"**	**Silk (soft) Dome**	**$23**	**834**	**89**	**50**		**151.21**	**#NUM!**
Dayton Audio ND25FW-4	1"	Soft Dome	$22	1350	91	20		118.39	#NUM!
SB Acoustics SB26STCN-C000-4	1"	Soft Fabirc Dome	$38	960	92.5	120		192.32	#NUM!
SB Acoustics SB19ST-C000-4	**3/4"**	**Textile (soft) Dome**	**$24**	**980**	**88.5**	**30**		**130.73**	**#NUM!**
ScanSpeak Discovery D2606/9200	1"	Textile (soft) Dome	$45	1100	91.5	100	200	183.00	210.54

Dayton Audio DC28F-8



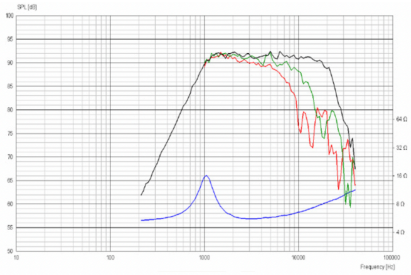
This 1-1/8th Silk Dome Tweeter is very attractive to me and my design because of its low resonant frequency of 834Hz. An 8” woofer is great at carrying the low-mids and I need a tweeter that can meet it in the mid range and not struggle to move air. In addition, the off-axis response is almost identical in shape to the on axis response until it drops at about 15kHz! Priced at about $23 this tweeter has the most bang for the buck out of the options on my list.

SB Acoustics SB19ST-C000-4



This 3/4” SB Acoustics tweeter is very similar to the Dayton tweeter in that it is cheap ($24) and has a “low” resonant frequency (980Hz), BUT the frequency response is much smoother (+-2.5dB) and does not experience any major drop in on axis performance below 20kHz. This is my personal favorite option at the time of this research stage.

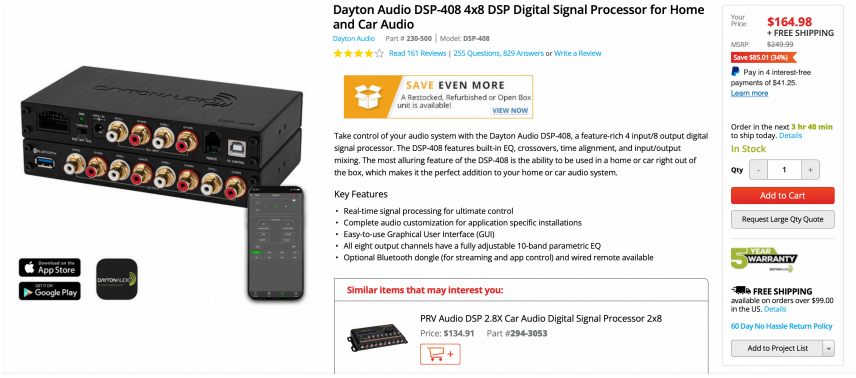
ScanSpeak Discovery D2606/9200



The ScanSpeak Discovery 1” Textile Dome Tweeter is a bit of a wild card for me. It is the most expensive tweeter on this list and its off axis response is not very good (extremely directional). But the visual aesthetic as well as the max SPL are what impressed me the most. Note: I really like the idea of getting gold or silver hardware when installing drivers to contrast the black/wood veneer cabinets.

4.3 Final Build Selections

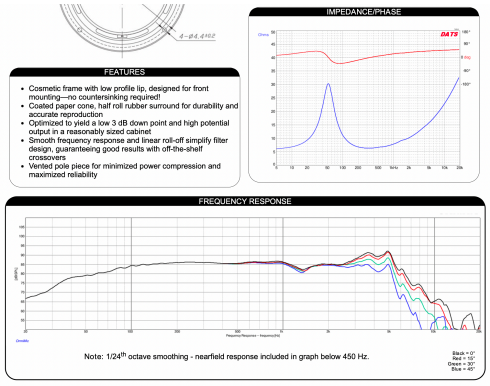
For my final build I have selected the SB Acoustics SB19ST-C000-4 3/4” Tweeter and the SB Acoustics SB20PFCR30-8 8” Woofer. They shall be connected to RCA input jacks and controlled by the Dayton Audio DSP-408 Digital Signal Processor which was the recommended DSP from my Transducer Theory class due to it’s price and reliability. The crossover points shall be at approximately 2.5kHz but shall be fine tuned during the testing stage.

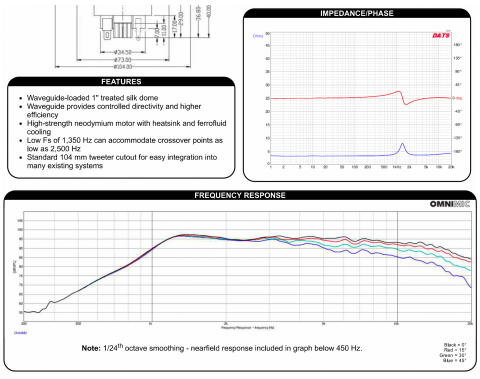


I hope to design the cabinets out of 3/4” MDF with standard foam insulation on the inside. I will sand and finish the MDF with a dark wood veneer on all sides except the front which shall be painted black.

4.4 Decision Making Processes

After careful consideration in developing my own speaker design, I ended up selecting the C-Sharp Active Speaker kit from PartsExpress.com. This decision was largely made due to money constraints. These speakers fit the size profile I desired (next to a television) and still have great frequency response. They utilize Dayton Audio Designer Series 5” Aluminum Cone Woofers and Dayton Audio ND Series 1” Neo Soft Dome Tweeter with Waveguide. The frequency response and specs for these drivers shall be shown below. The designed crossover for this kit is set as a 2nd order at approximately 2.5kHz. This kit includes pre-drilled but disassembled cabinets built from 3/4” MDF and comes with an amp that uses bluetooth and 3.5mm aux inputs which is the only negative aspect I can find about this kit but it fulfills my needs for TV/Bookshelf speakers perfectly as I will never need to use any more complex input jacks other than RCA to my television. Otherwise these match most of my previous design hopes as well as saving me significant money. I will also still be able to finish the cabinets in a black/ wood veneer and I hope to add a subwoofer to this system once I am more financially stable.





5.0 Construction

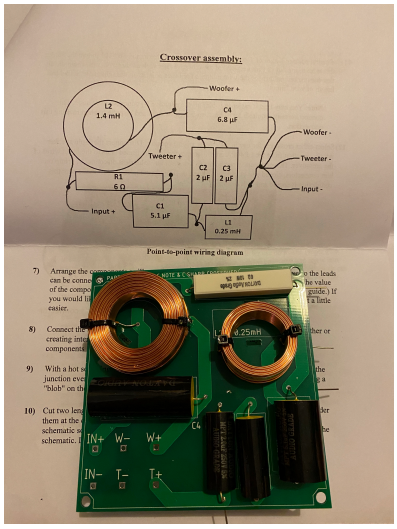
5.1 Cabinets

Cabinet construction was comprised out of three stages. The first being initial installation via wood glue and clamps. Every wall besides the front baffle of each speaker were mounted to the base plate and set to rest for approximately 30 mins before removing the clamps and setting heavy books on top for another 30 minutes. The front was left open for ease of access as my hands somewhat struggle to fit through the port hole.

Secondly, installing the port and amplifier in the back of the right speaker. The left slave speaker only required the port and does not have it's own amplifier. This amplifier has bluetooth and 3.5mm inputs which make it perfect for a casual living room setting. The C-Sharp Kit came with pre cut holes for the ports and amplifiers so they fit very snug upon installation. Only a few screws were needed for the port. Which leads into the final steps regarding the cabinet.

Finally, the cabinet used many screws to hold the port and drivers in place. These required pilot holes which were drilled with my hand drill using a 5/64" drill bit. Having the front panel detached from the cabinet itself lended to the ease of drilling these holes. All that was left to do is glue and clamp the front baffle on to the cabinet after inserting the crossover inside.

5.2 Crossover



The crossover assembly was simple enough. I had the option of either setting the components on a rebuild circuit board, solder and trim, or I could simply set the components on a piece of wood, twist the connections together according to the diagram, solder and trim. I decided to use the circuit board because it was more organized. The only issue that was encountered when soldering the cross over, was that's the plastic near to the solder points started to bubble in some places but I had my work double checked by Chris Trevino.

I then placed the crossover inside the speaker and connected all the corresponding wires to their places. I attempted to glue the crossover to the floor of the cabinet, but my tube of gorilla glue exploded all over my arm so they are not yet secure.

5.3 Final Product

The final product came out great! My initial signal test was in my living room from a 3.5mm jack coming from my MacBook Air playing rock music on Spotify.

My initial notes:

- Surprisingly good sounding bass
- Tad bit of hardware vibration (probably crossover loose inside the cabinet)

- I don’t like the look of bare MDF

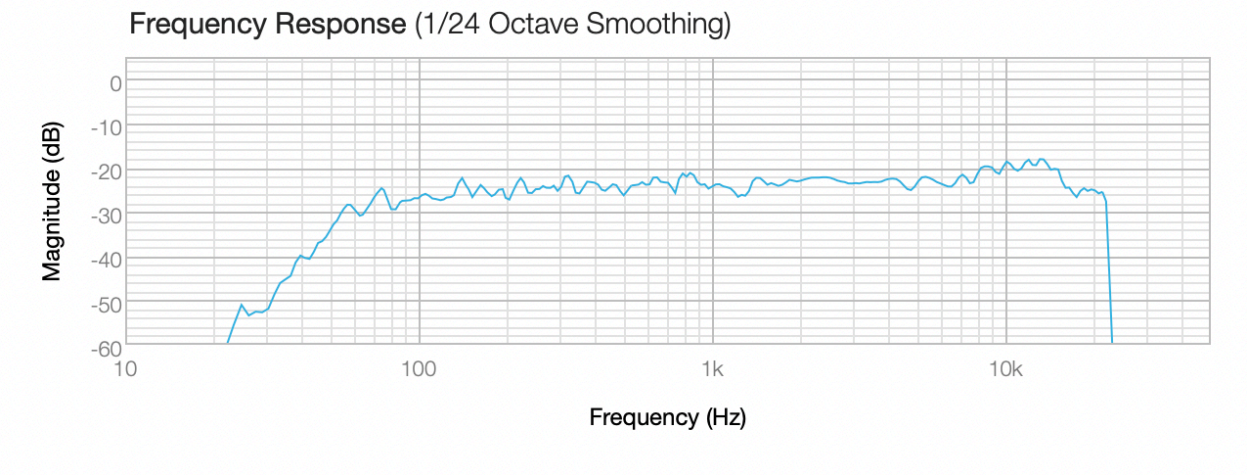
I am very happy with how these speakers have come along. Now on to testing and tuning!

6.0 Speaker Testing/Tuning

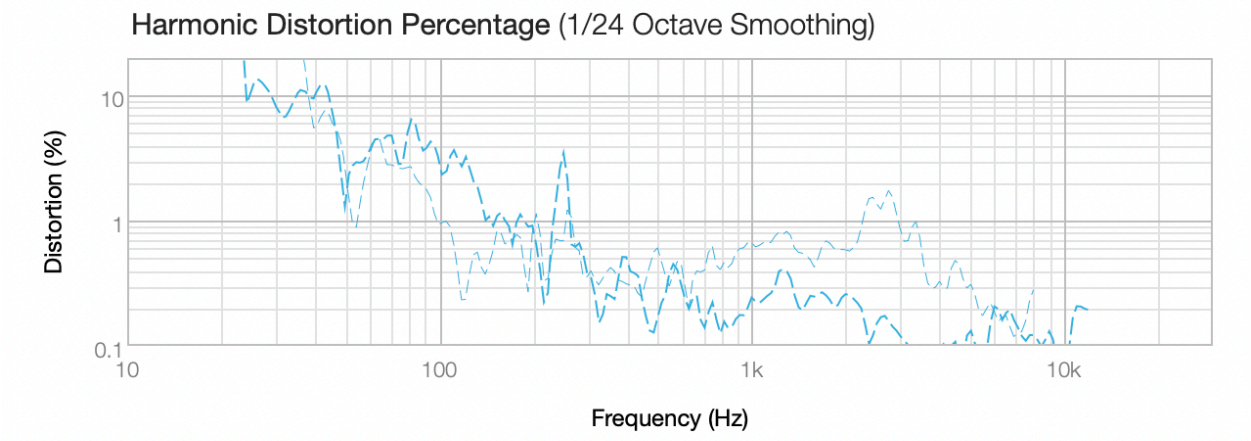
6.1 Final Testing Documentation

Once the speakers were built, it was time to run tests and see how they respond statistically. These tests were taken using a Earthworks M50 Omnidirectional Microphone that was calibrated to 94dB. Each speaker was measured 83dB @ 1 meter away pointed directly between the tweeter and woofer. All tests were taken on a 10 foot tall stand in a blackbox theatre to avoid reflections.

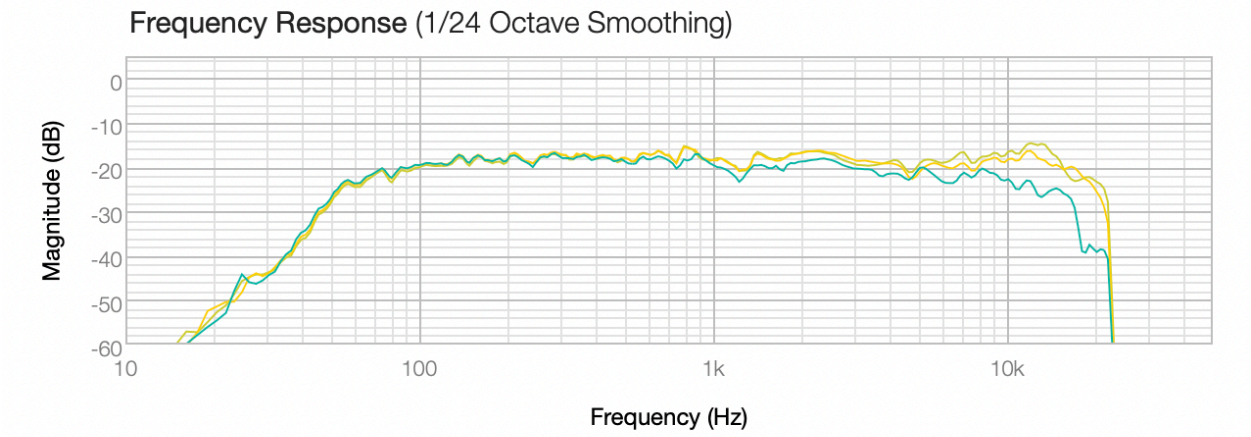
6.2 Speaker Results



Right Speaker Frequency Response at 83dB @ 1m

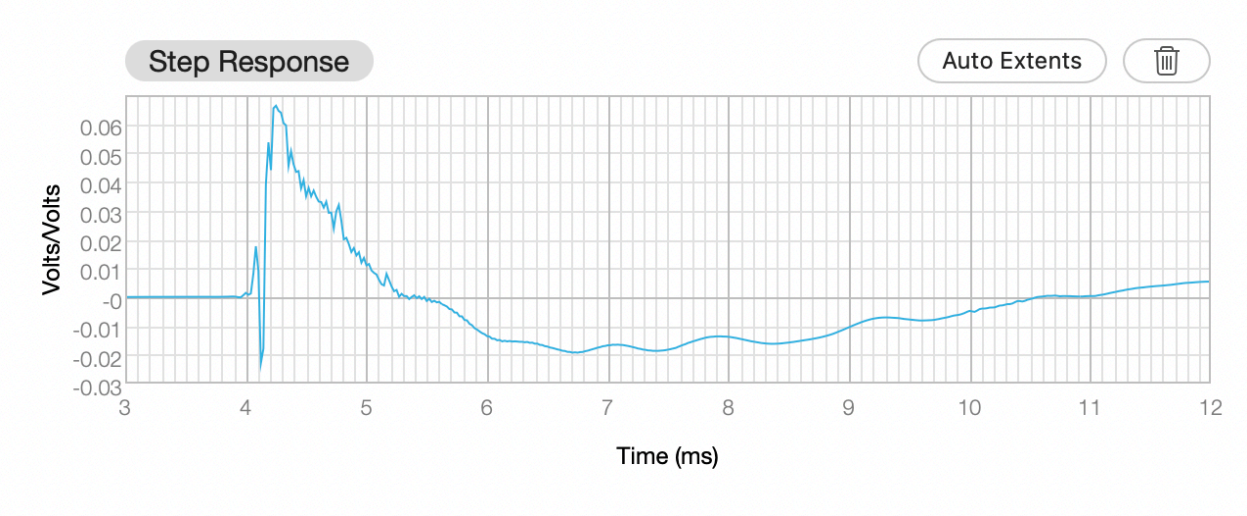


Right Speaker Harmonic Distortion Percentage at 83 db @ 1m

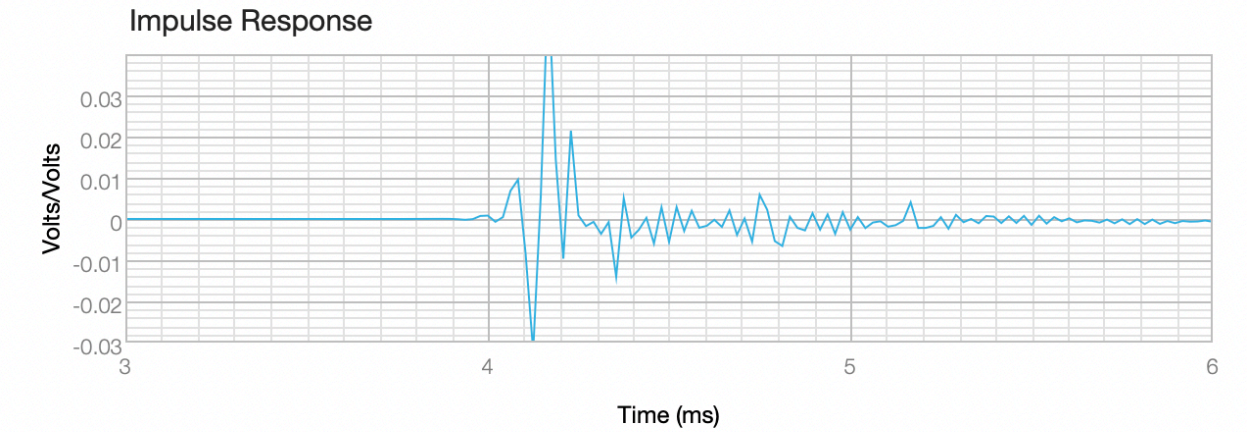


Right Speaker Horizontal Off-Axis Frequency Response at 83dB @ 1m

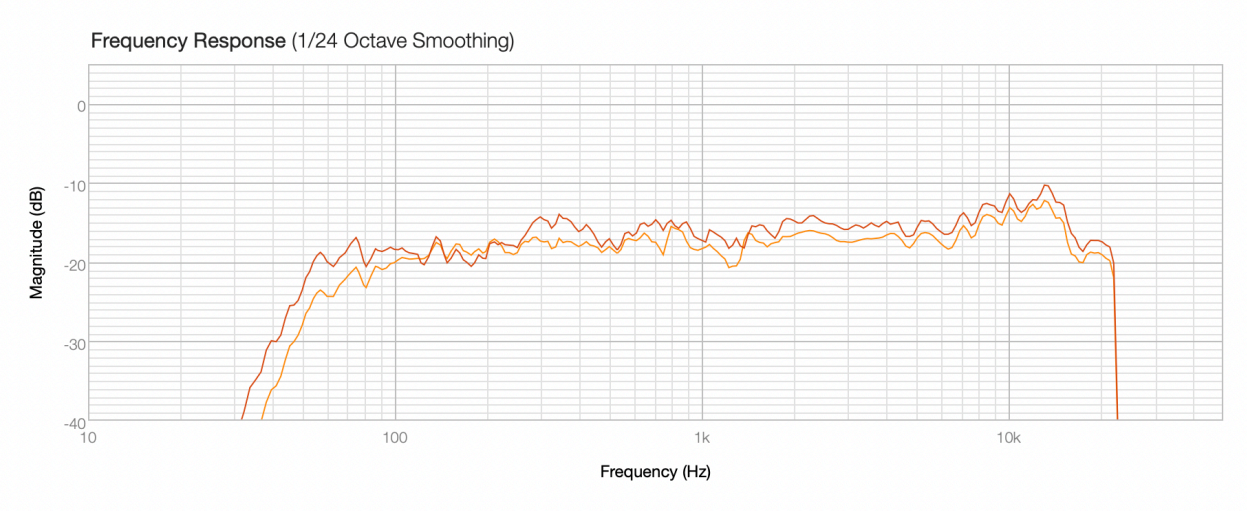
BLUE=0º, YELLOW=30º, GREEN=60º



Right Speaker Step Response at 83dB @1m

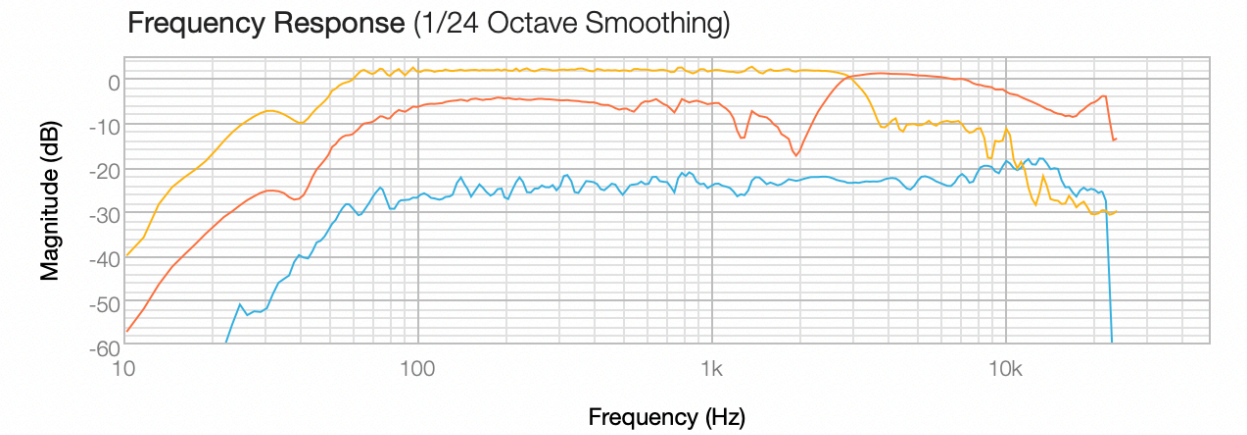


Right Speaker Impulse Response at 83dB @1m



Right(orange) & Left(red) Speaker Frequency Response Comparison at 83dB @1m

NOTE: Slight SPL difference but general shape remains the same.



Tweeter & Woofer at 1inch compared to overall frequency response at 83dB @1m

This graph visually illustrates the crossover frequency of 2.5kHz

NOTE: dB difference due to distance of measurements. Other drivers were not disconnected to isolate each driver

7.0 Conclusion

In conclusion, I am VERY happy with how this speakers performed. They show a smooth bass response and relatively late frequency response up until a small dip at about 17kHz. Due to the end of the semester and other time constraints I was unable to add dampening or any major component changes on the passive crossover. Those would be the first two things I would adjust if I were to get picky but I am happy with where these speakers sit performance-wise. They will fulfill their purpose as bookshelf speakers/TV speakers perfectly. I've learned so much during this class' process and I can't wait to apply it in future practicums or future job.

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