Jordan JX92S Open Baffle and Goldwood GW-1858 H Frame Two Way Passive Crossover Speaker System

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Introduction :

My first article about this project documented the design and build of a compact, cost-effective, two-way dipole speaker system that covered as much of the 20 Hz to 20 kHz frequency range as possible. Figures 1 and 2 show the resulting combination of a Goldwood GW-1858 18" woofer in an H frame and a Jordan JX92S full range driver mounted on an open baffle. I drove this speaker using an active crossover, and a pair of 200 watt SS amps, to handle the frequency filtering and any required SPL leveling between the two drivers. The intent was to relieve the full range driver of the lowest bass frequencies and allow it to do what it does best with the remainder of the audio spectrum. I have been listening to this speaker for the past six months and have learned a lot and enjoyed the performance as it has evolved into today's version.

When I first configured the active crossover, I programmed a 2nd order Linkwitz-Riley low pass crossover at 100 Hz with 2.5 dB of boost for the Goldwood woofer and programmed a 2nd order Linkwitz-Riley high pass crossover at 250 Hz for the Jordan full range driver. I played with the crossover points and slopes for a while but eventually ended up returning to this configuration as my preferred set-up.

The next thing I tried adjusting was the amount of bass boost. Starting with +2.5 dB yielded bass you could hear and feel in sufficient quantities and was very satisfying and entertaining. But the +2.5 dB setting sometimes left the speaker with a slightly darker sound. Adjusted the boost down to +1 or +1.5 dB voiced the system to have more of the midrange magic, typically associated with full range drivers, while still retained most of the bass presence. All three of these boost settings worked well and different personal tastes or styles of music might lead one to prefer one over the others. Based on this experience I started to think about exploring the possibility of a completely passive crossover.

Seeing the document's title, it should be obvious that I have a passive crossover option to present for the Goldwood woofer and Jordan full range driver design shown in Figures 1 and 2. A passive design should be much more attractive to DIYers since the expense of an additional amp is avoided. In addition, I am also going to use this opportunity to demonstrate a new MathCad based method of calculation that includes room effects. I will present correlations of calculated SPL responses with SPL measurements made in my listening room. These are the two goals of this document and the following pages provide the details.

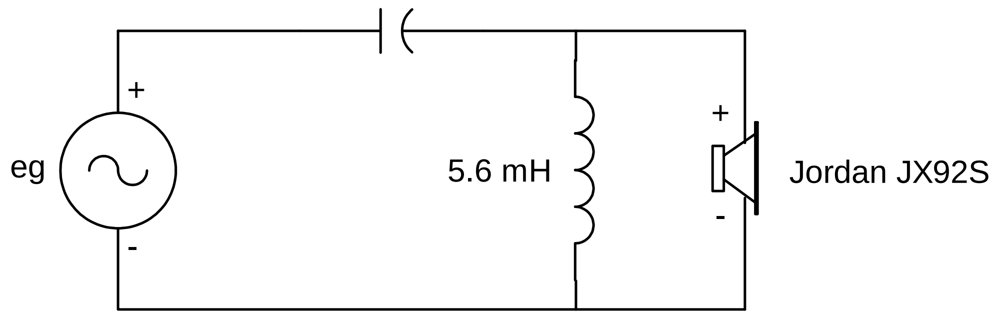
Passive Crossover Design :

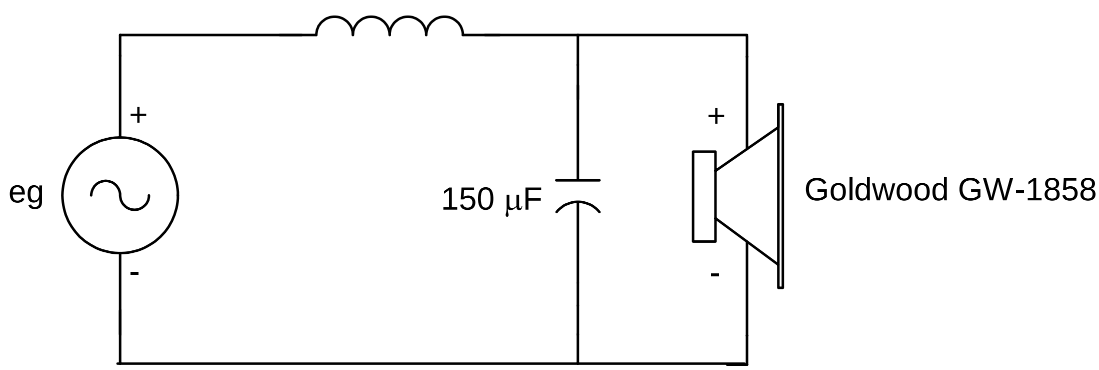
I started sizing the passive crossover using text book equations to calculate component values using the voice coil DC resistances. Clearly this is only a starting point to get ballpark inputs for a MathCad worksheet that handles passive crossovers in the calculation of the system SPL response. The calculations included the interaction between the passive crossovers and the actual voice coil complex impedances. Then by iterating component values, and watching the summed SPL response, I worked my way towards a set of component values that produced an on axis SPL response that tracked the goal function used in the earlier active crossover design article. Figure 3 shows the schematic of the final crossovers and a parts list with component prices. The actual crossovers are shown in Figure 4 just prior to installation.

Figure 1 : Front View

Figure 2 : Rear View

Figure 3 : Crossover Schematics and Parts List

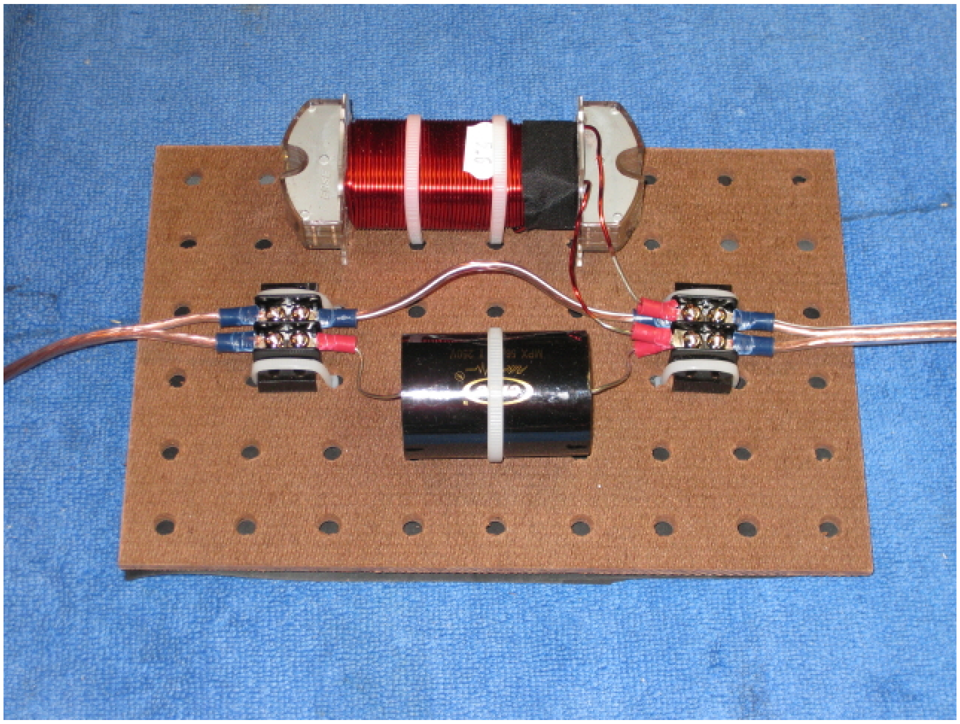




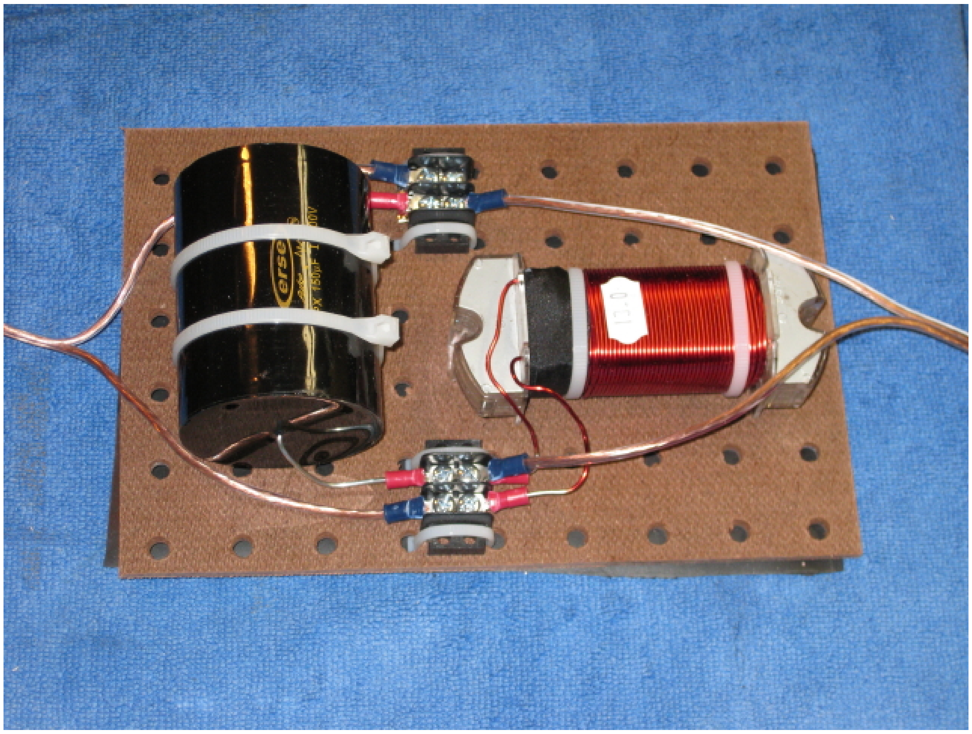
Crossover Cost Calculation				
Low Pass for Goldwood GW-1858				Unit Cost
L1 =	13 mH	ERSE Super Q 16 AWG		$ 25.05
C2 =	150 uF	ERSE 400V		$ 32.60
High Pass for JX92S				
C1 =	51 uF	ERSE 250V		$ 11.36
L2 =	5.6 mH	ERSE Super Q 16 AWG		$ 19.70
http://www.erseaudio.com/			Total Cost =	**$ 177.42**

Figure 4 : As-Built Crossovers

High Pass : Jordan Full Range Driver



Low Pass : Goldwood Woofer

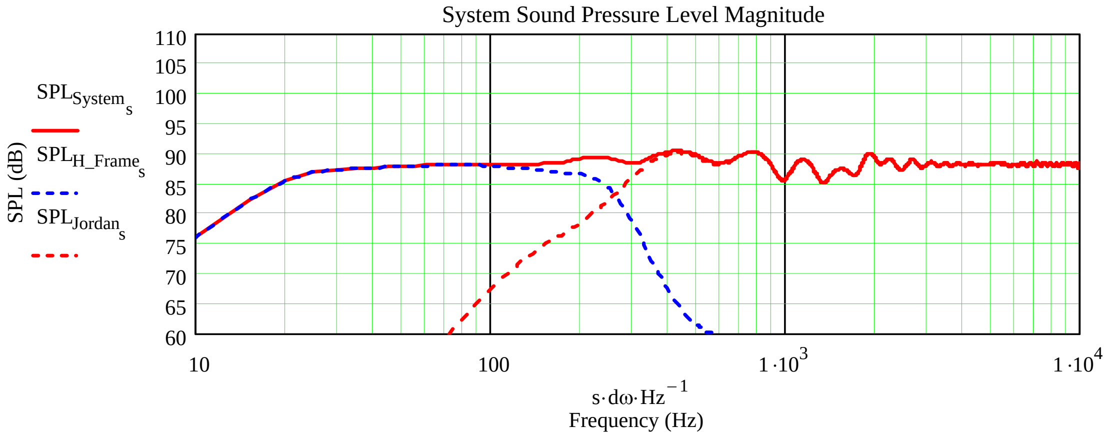


The simulation results for the active crossover, copied from the previous article, and for the new passive crossover are shown below in Figure 5. Comparing the two curves you can see the similarity of the SPL response results. I was surprised at first because the active crossover simulation still had +2.5 dB of bass boost applied. There is no possibility of applying bass boost to a passive system and yet it appears to produce equivalent levels of bass output. I had to think about this for a while to convince myself that the calculations were accurate.

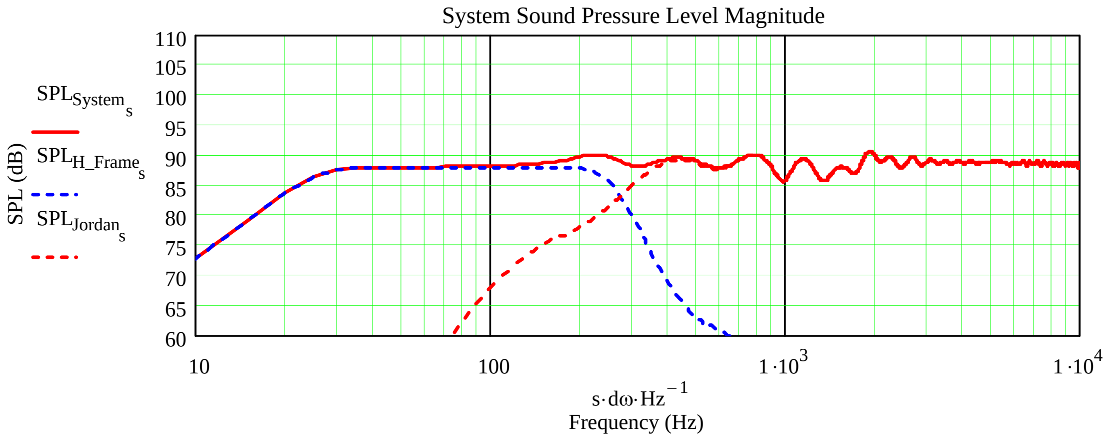
The elevated bass output produced by the passive crossover can be explained after recognizing that in the passive system the large impedance peak associated with the Goldwood driver's resonance interacts with the crossover pushing the initial roll-off of the 100 Hz low pass filter higher in frequency. In an active system the filter is isolated from the driver by the amp, the impedance of the driver does not interact with the crossover filter, so the roll off is predictable and consistent with an ideal filter. The passive crossover's attenuation starts higher in frequency compared to the active crossover resulting in elevated bass output at low frequencies. This is a real advantage of the passive crossover design.

Figure 5 : Simulations of Free Field SPL Response at 1 meter for 1 Watt Input

Active Crossover Response



Passive Crossover Response



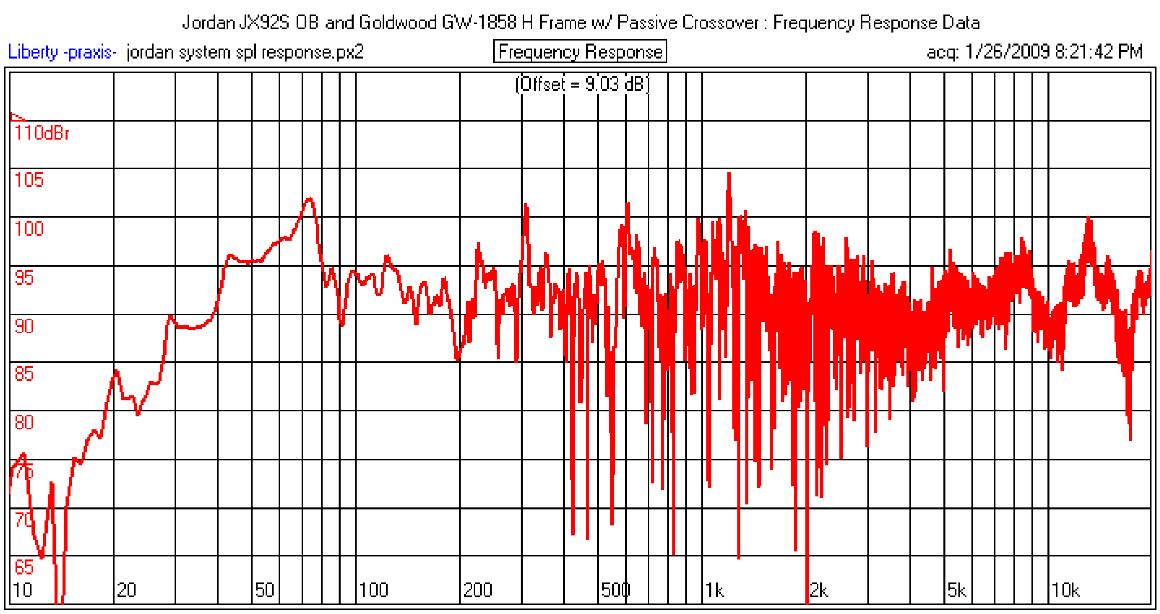
Measurement Results and MathCad Correlations :

Originally, I measured the response of the finished speaker systems using my two car garage since it is a fairly large open space. That was last summer and now it is winter in upstate New York which precludes me from performing the same set of measurements with the passive crossover system. So the measurements needed to be conducted with the speakers located in my listening room.

In parallel with designing and building the passive crossover, I had also been working on upgrading my MathCad worksheets to allow modeling a speaker system located in a rectangular room. Conveniently, these two efforts came together at the same time so I was very interested in taking the SPL measurements and seeing how well the new MathCad calculations correlated.

Real world measurements are never as clean as the plotted results we get from the various Thiele/Small based speaker modeling programs. As frequency increases the measurements start to exhibit a lot of hash that is associated with the different time delays between the sounds emanated from different points on the driver's cone, different baffle edge sources, and reflections from nearby room surfaces such as walls. Figure 6 is a typical example of an untreated SPL response curve taken at 1 m on the axis of the Jordan full range driver. To clean up the SPL plots, 1/6 octave averaging is applied to all SPL measurements and SPL calculations presented on the following pages.

Figure 6 : Untreated SPL Response Measurement



Figures 7, 8, and 9 present the speaker impedance, the H frame and system SPL response at 1 m, and the H frame and system SPL response at the listening position. The SPL measurements are all taken in my listening room with the speakers located in their preferred positions. The measured results extending from 10 Hz to 20 kHz and are 1/6 octave smoothed without any gating or windowing applied.

Figure 7 : Speaker System Impedance

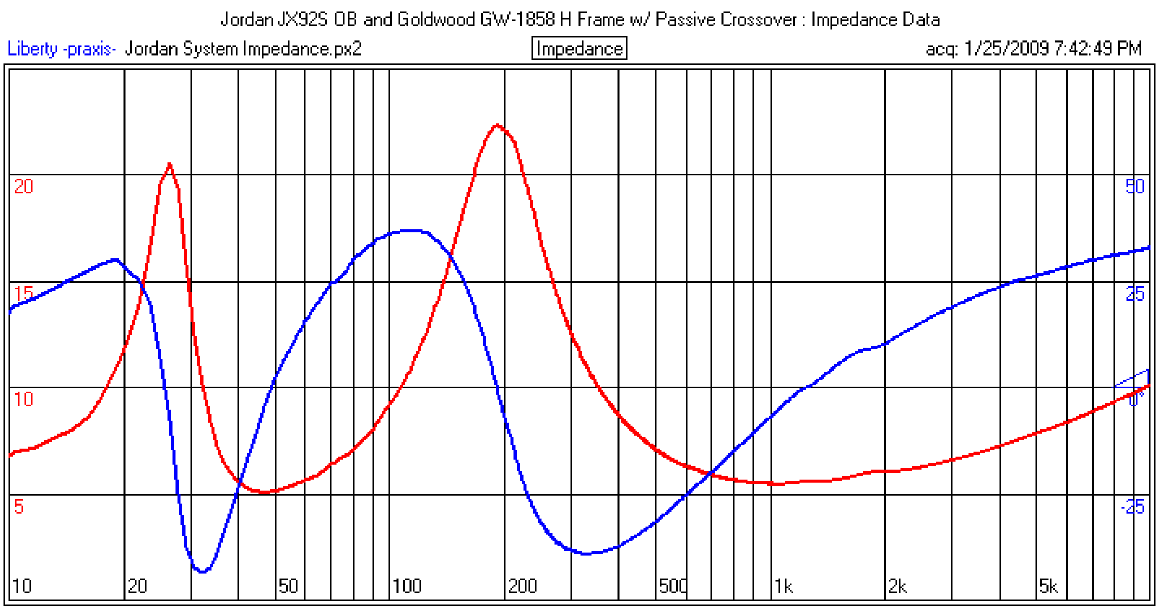
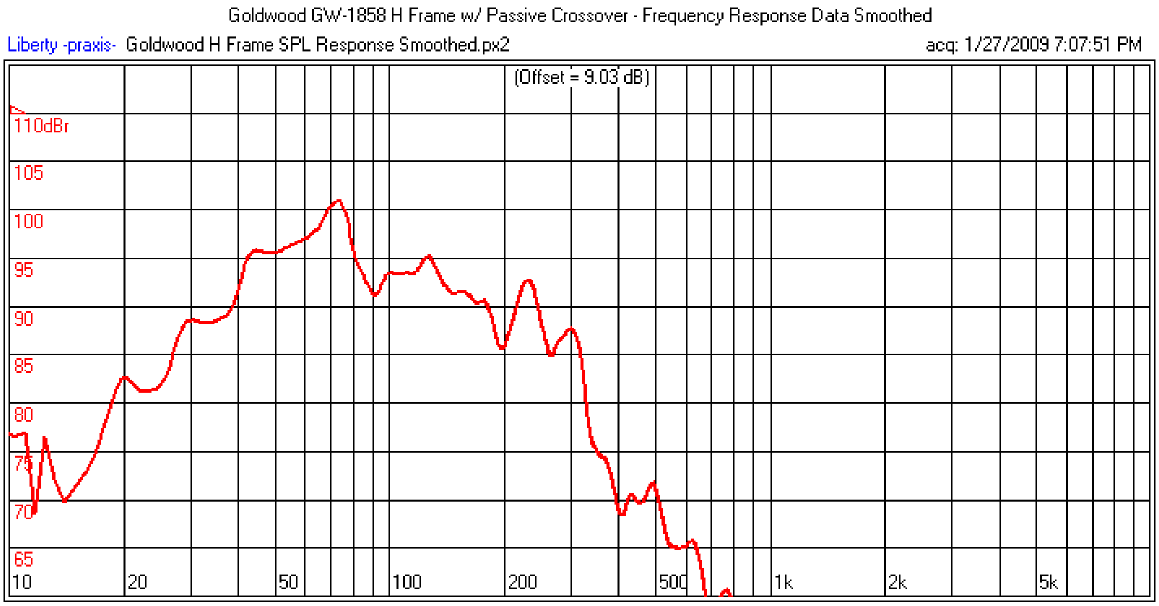


Figure 8 : H Frame and System SPL at 1 m on the Axis of the Jordan Full Range Driver



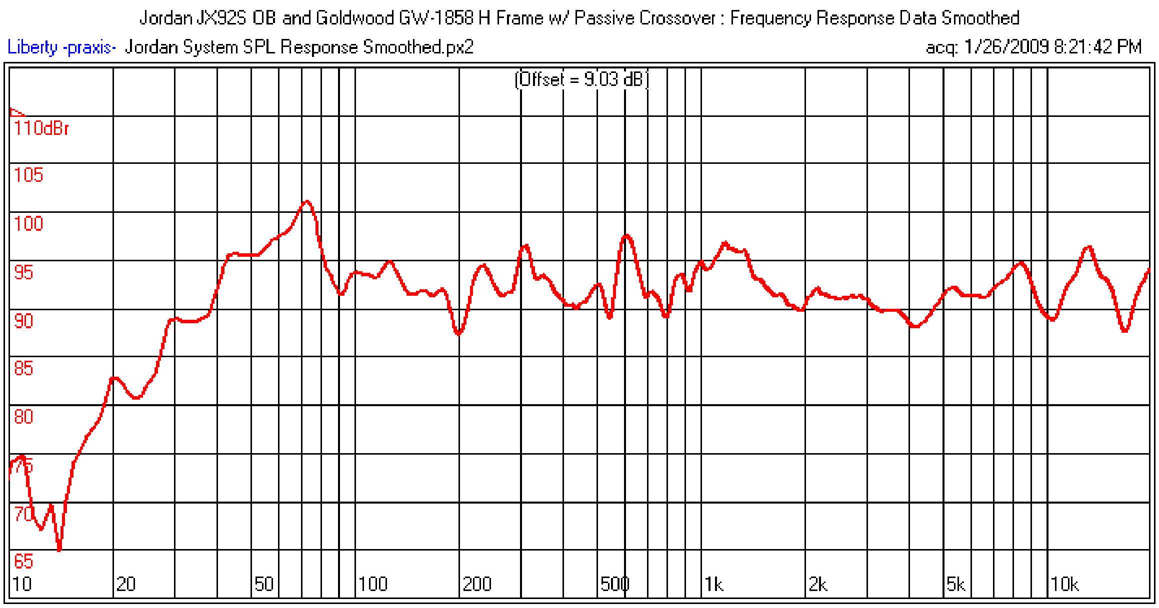
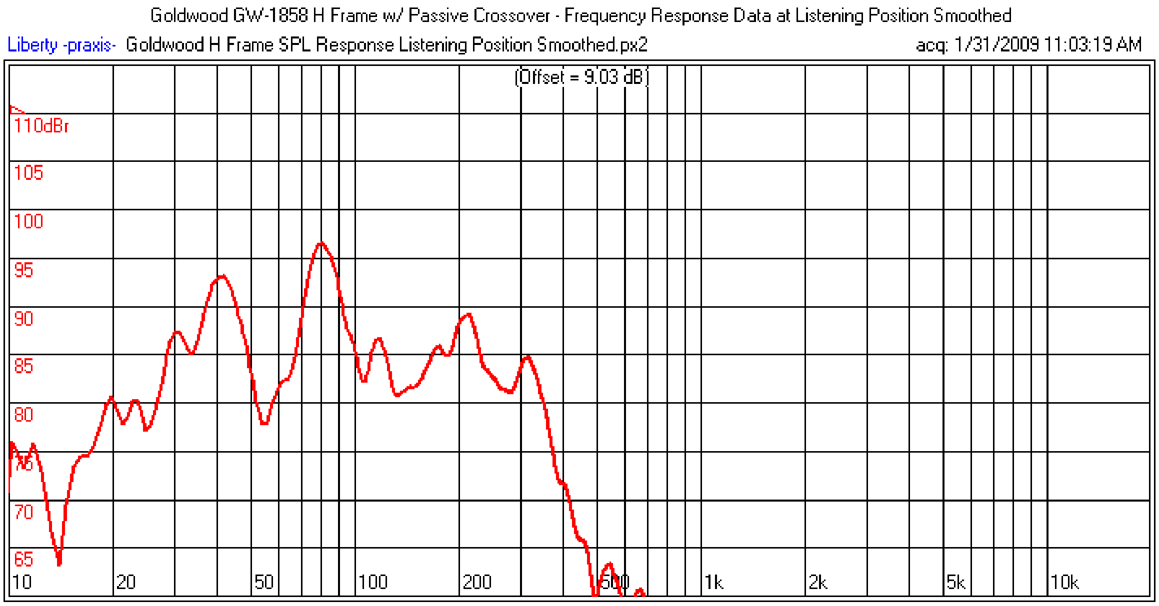
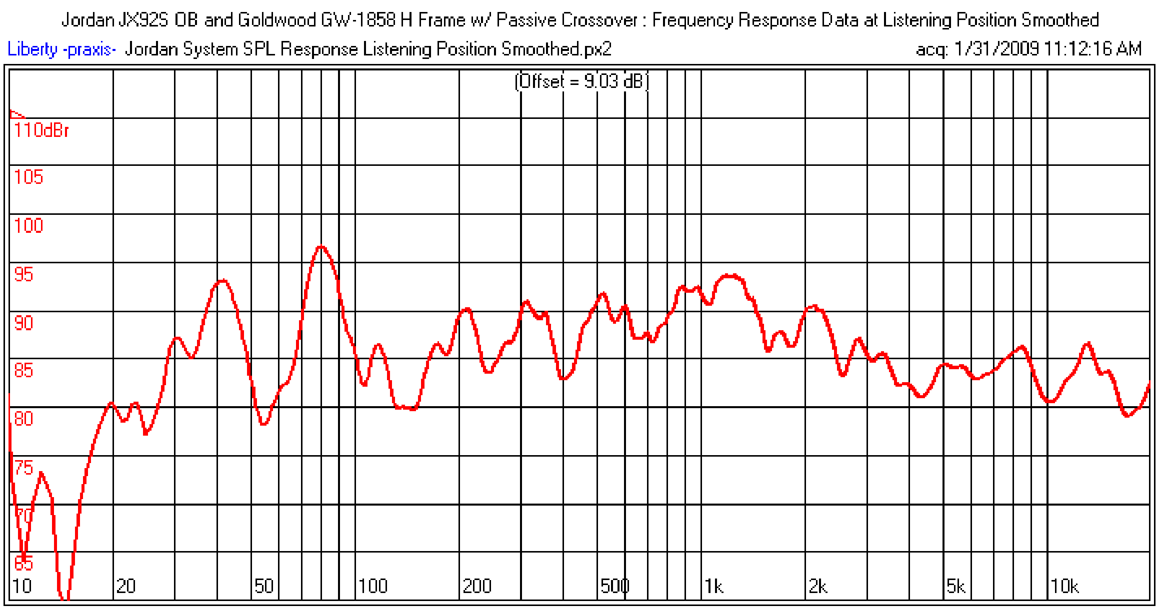


Figure 9 : H Frame and System SPL at the Listening Position





The data shown in Figures 7, 8, and 9 was exported into text files and read into MathCad for correlation with the calculated results. The MathCad model I have been developing superimposes the results from the H frame and the single driver OB worksheets after applying a passive crossover. The worksheets have been upgraded to allow the speaker to be placed in an empty rectangular room. The speaker is located with respect to one of the corners and can be rotated so that it is not parallel to any of the walls.

Figure 10 shows three views of the modeled geometry for the Goldwood H frame and Jordan OB speaker system. The dark black lines outline the speaker geometry, the red circles represent the driven sources, and the blue circles represent the edge diffraction sources.

Starting with the third image in Figure 10, this is a view looking down on the speaker system (looking along the Z axis). The reference corner is located at the origin of the coordinate system and the X and Y axes have units of meters. In the third image the speaker system is seen rotated approximately 30 degrees towards the listening position with respect to the side and rear walls. Recognizing that the speaker system is rotated about 30 degrees, in the first and second image the front and rear openings of the H frame are offset in the two views.

The room being modeled is 14 feet square (4.267 m square) and assumed to be empty. Multiple reflections off of all four walls, the floor, and the ceiling are included with independent absorption coefficients defined as functions of frequency for each reflecting surface. The top two images in Figure 10 are the front view (looking along the X axis) and the side view (looking along the Y axis).

Two listening positions were evaluated. First, a point 1 m along the axis of the Jordan driver was used to assess the influences that are predominantly from corner loading. Second, a position consistent with the my location while I am sitting and listening to music was evaluated to assess the overall room influences on the sound field.

The same sets of plots that were shown in Figures 7, 8, and 9 were produced including the MathCad predictions and they are shown in Figures 11, 12, and 13. In each plot the solid red curve represents the MathCad calculated results while the dashed blue curve represents the Praxis tested results.

Figure 10 : Composite MathCad Model

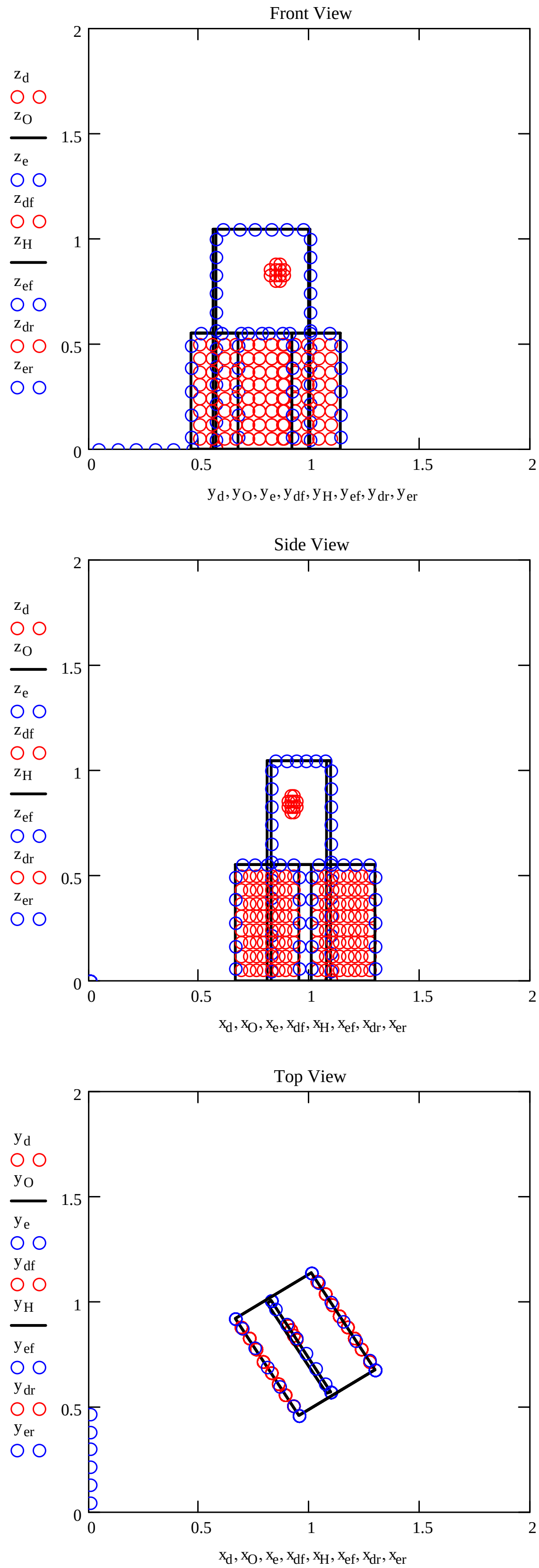


Figure 11 : Speaker System Impedance

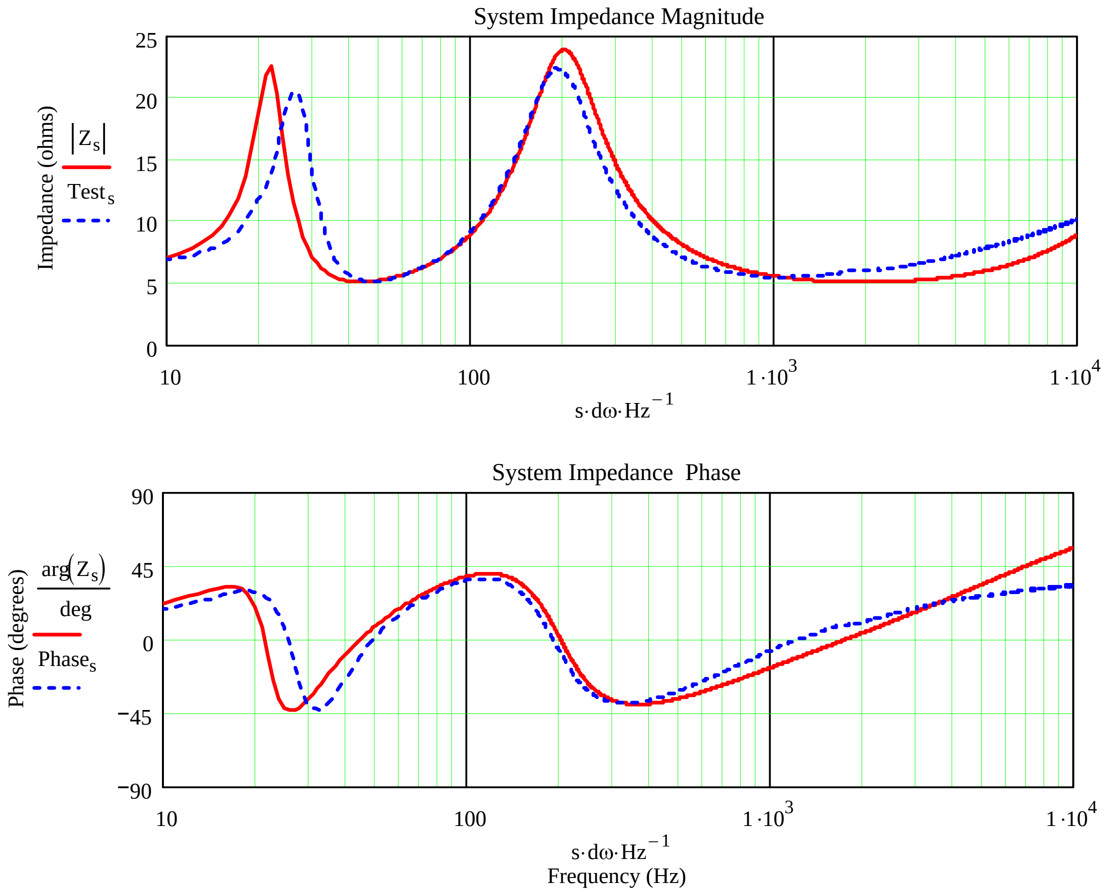
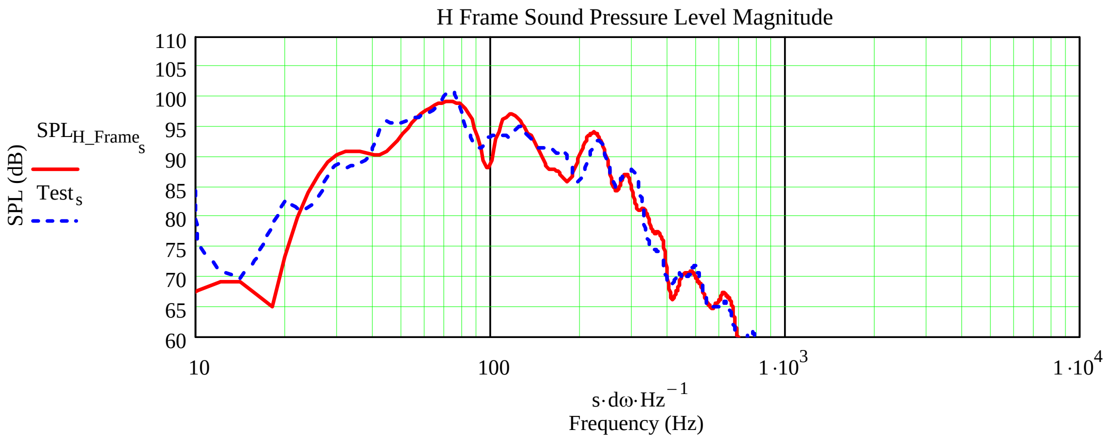


Figure 12 : H Frame and System SPL at 1 m on the Axis of the Jordan Full Range Driver



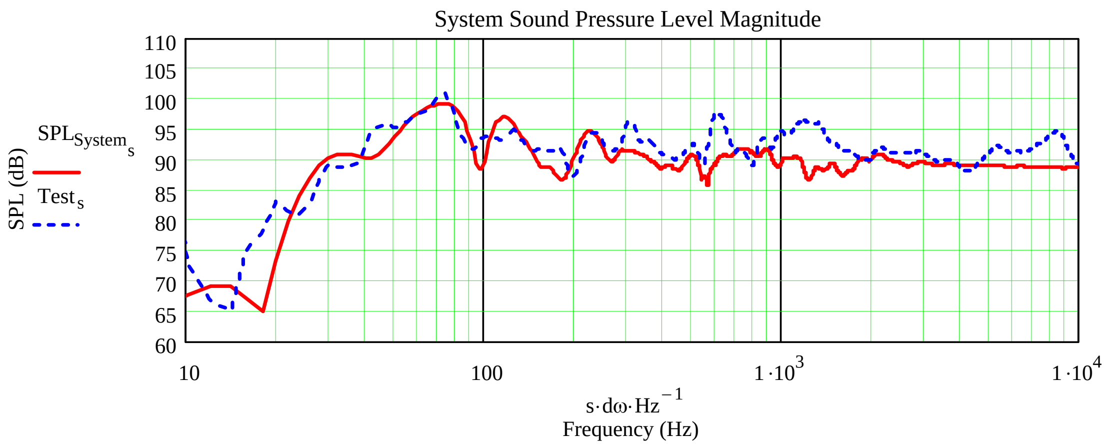
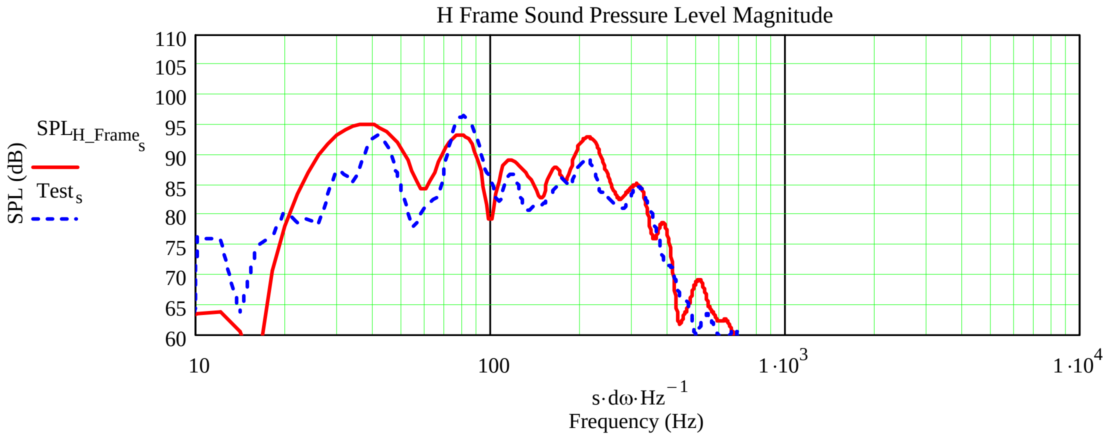


Figure 13 : H Frame and System SPL at the Listening Position



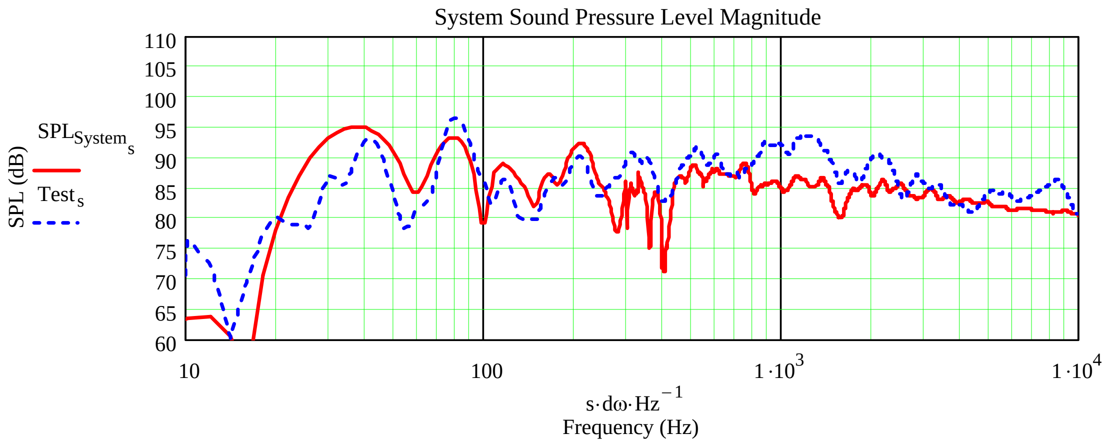


Figure 11 shows the measured and calculated impedance of the passive crossover system. It is clear again that the measured tuning frequency of 28 Hz is a couple of Hz higher then the calculated value of 24 Hz. This was also observed in the earlier article; I still have not been able to produce a defendable physics based explanation leading to a correction in the MathCad H frame model. The second major feature of this plot is the impedance peak at 200 Hz generated by the crossover. Although this might resemble a driver produced resonance impedance peak, this peak is produced by the rising impedance of the low pass filter merging in parallel with the falling impedance of the high pass filter.

Figure 12 shows the comparison between the measured and calculated SPL response at a 1 m distance along the axis of the Jordan full range driver. At low frequencies this plot is dominated by the nearby corner and the resulting rear wave reflections. The correlation between the calculated and measured low frequency response produced by the H frame, shown in the upper plot, is extremely good. In the lower of the two plots, as you move higher in frequency the Jordan driver's SPL response plays more of a role and generates additional peaks and dips. For the higher frequencies, there are frequency ranges where the calculations miss some of the peaks and valleys as a result of the driver being modeled as a piston source without including cone break-up modes. But overall the correlation is not too bad.

Figure 13 shows the comparison between the measured and calculated SPL response at the listening position which is approximately 9 feet away and just off the axis of the Jordan driver. Again, the correlation between the calculated and measured low frequency response produced by the H frame, shown in the upper plot, is good. As you move higher in frequency, the room and the Jordan driver SPL response play more of a role which can be seen in the lower of the two plots. For the higher frequencies, similar frequency ranges where the 1 meter distance calculations missed some of the peaks and dips are still apparent but overall it still is not too bad. One new trouble spot in the correlation can be seen between 300 and 400 Hz, I have not yet determined the cause of these ragged dips in the calculated response.

Overall, I am happy with the correlation between the test and the calculated SPL response curves. In fact, it is quite surprising how well the correlation works for a calculation based on a completely empty room while the measurements were made of a room with furniture, doors, windows, a large equipment rack, and all of the other hardware and software typically associated with an audio set-up. I do have a couple of things to work on to improve the correlation and at this time it is not clear if the math or the test set-up needs further investigation. Based on these results, I believe that the room modeling now built into the MathCad OB and H frame worksheets is a valuable tool in the design of dipole speaker systems. This same room modeling has also been added to all of the other MathCad worksheets and I am looking forward to doing some back loaded horn design simulations, but that is something for another day.

Updated Cost Breakdown :

Item	Quantity	US $'s
Jordan JX92S	2	360.00
Goldwood GW-1858	2	140.00
Binding Posts	4	40.00
1" Rubber Feet	8	8.00
4' x 8' Sheet of ¾ " Plywood	1	40.00
4' x 4' Sheet of ½" Plywood	3	75.00
Passive Crossover	2	177.42
T-Nuts, Bolts, Speaker Wire, Spades, Primer, Paint	–	–
Total Cost	-	840.42

Conclusions :

The use of an active crossover got me started with this type of speaker design and helped me quickly investigate different crossover options to find the one I liked best. Then changing over to a passive crossover implementation has been fairly easy and I have not noticed any significant change in the system's performance. A passive crossover option will definitely make this design much more interesting to a larger group of DIYers.

A second benefit of this update is the correlation of the recent advances in my MathCad worksheets to include the impact of a room corner loading and also the reflections generated in an entire room. I am pleased with this first application of the newer worksheets and have been pleasantly surprised at how well some of the correlations turned out. I believe that this recent worksheet upgrade is a step forward and anticipate using it in all of my future design work.

So in conclusion, I have learned some more and am still learning a lot about dipoles and also MathCad modeling of speaker systems and rooms. I hope that the reader has also found something that increases their understanding after reading this narrative. As always any feedback, comments, corrections, or direction for future study would be appreciated and taken into consideration. Thanks for taking the time to read about this updated speaker project and if you decide to build something based on this design concept please remember to send a picture for my gallery so everybody can see the results of your hard work.