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

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Introduction :

My first open baffle design could only be described as huge. It not only filled the room with great sound, it physically filled the room with a solid wall of plywood when the baffle extending wings were rotated out to be flush with the front baffle. Once positioned in the room, these speakers were so heavy they never moved for almost three years while serving as my reference speaker system. Moving them out of the way to try another set of speakers was out of the question. At some point this arrangement could not continue and this past August they were disassembled and replaced with a new dipole speaker system.

Over the past couple of years, I have learned a lot more about dipole speakers. Typical of the way I work, my first open baffle speaker design was a brute force approach where I threw baffle size at the problem with little thought for optimization of the baffle width and driver Qts to manage the bass extension. Recently, I have added an open baffle theory section to my web site which documents some of the lessons I have learned. The first article in this section describes the trade-offs used to design a fairly compact open baffle speaker system using only passive crossovers. Shortly after the first article was completed, I added a second article focusing on extending the bass response of dipole speakers using appropriate driver selection and a U or H frame baffle without requiring additional low frequency EQ filters. This second article really opened my eyes to the potential for deep bass in a reasonably compact dipole design and is the motivation for this project.

As a result of the most recent work, I decided to challenge myself by attempting to design and build a compact, cost-effective, two-way dipole speaker system that covered as much of the 20 Hz to 20 kHz frequency range as possible. Sticking with what I had recently learned, I elected to use an H frame configuration for the bass below 200 Hz and a smaller diameter full range driver for the frequency range from 200 Hz to 20 kHz. This was the goal and the following pages describe the results.

Driver Selection :

Based on earlier H frame calculations I had done using the Eminence Alpha 15A woofers, it was clear that a full range driver with an efficiency of 95+ dB/W/m was going to force me into using dual woofers per channel or so much boost that driver displacement would start to become a limitation. Starting the design based on one of my Lowther drivers was going to quickly back me into another huge system. Realistically, to meet my goals of simple, cost effective, and small (a relative term for sure) the maximum efficiency for the full range was probably going to be limited to about 90 dB/W/m..

I assembled a list of the available driver candidates in the Fostex line and a few from other manufacturers that I had thought about trying over the years. The six inch and larger drivers appeared to be too efficient so I crossed all of them off the list. I was drawn towards the 4 to 5 inch diameter full range drivers since they would behave well down to 200 Hz and still extend upwards towards 20 kHz. I quickly narrowed the search to two Fostex drivers, the FX120 and the F120A, and the Jordan JX92S driver.

Table 1 lists the Thiele/Small parameters of the three full range drivers that made the final cut. The efficiency of each driver is between 88 and 89 dB/W/m (referenced to 8 ohms) with the most significant differences being the Jordan's fs and Xmax values.

Driver	JX92S	FX120*	F120A*	Units			
fs	49.8	70.0	65.0	Hz			
Re	5.3	7.3	7.0	ohm			
Qed	0.71	0.47	0.51	-			
Qmd	2.03	8.40	3.10	-			
Qtd	0.52	0.45	0.44	-			
Vad	15.53	8.21	9.88	liter			
BL	3.66	-	-	N/amp			
Xmax	9.0	2.0	1.5	mm pk-pk			
SPL	88.2	89	89	dB/W/m			
Unit Cost	180.00	102.60	227.15	US \$'s			

Table	1	Full	Range	Drivers
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* Manufacturer's Specified Thiele/Small Parameters

The Jordan JX92S full range driver had intrigued me for many years and when it went on sale this summer I just could not pass it up for this project. Conveniently, it would also appear that the two Fostex drivers might fit in the same baffle cut-out but with a slightly different bolt hole pattern so driver swapping may be a consideration in the future.

Reviewing the drivers listed in Table 1, and recognizing that a woofer will be used to eliminate the need to produce bass frequencies, the Thiele / Small parameters for the full range drivers are no longer as important in the design process. All three drivers shown in Table 1 have almost the same efficiencies. Each will probably work in this design with minor adjustments that can be accomplished using an active crossover.

For a woofer I had two constraints, no EQ and affordably priced. I still wanted to use an H frame acoustic solution for the low bass so I started looking for efficient high Qts woofers, fortunately this is also the direction of lower cost. I also decided not to disassemble my Lowther OB to reuse my Eminence Alpha 15A drivers. Even though my Alpha 15A drivers would be perfect for the H frame design, I did not want be without music for a number of weeks during construction and testing. This limited the number of other candidates to a handful.

The Goldwood line of drivers from Parts Express contained a pair of 15" woofers and an 18" woofer that all met my needs. After running a number of simulations, the Goldwood GW-1858 18" diameter woofer was selected. A comparison of the Goldwood GW-1858 and the Eminence Alpha 15A measured Thiele/Small parameters is provided in Table 2.

In my opinion, any of the drivers mentioned above would work very well in an H frame design and could be substituted into this type of system. In fact, one of the 15 inch woofers would lead to a further reduction in the external size of the H frame. You would be trading a few Hz of low frequency output for a 3 or 4 inch reduction in the width and height of the H frame.

Table 2. Wooler Companson					
Driver	Alpha 15A	GW-1858	Units		
fs	41.0	30.0	Hz		
Re	5.88	5.50	ohm		
Qed	1.53	1.15	-		
Qmd	7.23	4.24	-		
Qtd	1.26	0.91	-		
Vad	260.5	497.2	liter		
BL	7.7	10.8	N-amp		
Xmax	3.8	3.5	mm pk-pk		
SPL	94.2	94.4	dB/W/m		
Unit Cost	58.19	67.89	US \$'s		

Table 2 : Wasfer Comparison

Design Simulations :

My plan was to build an H frame for the Goldwood GW-1858 woofer and a smaller OB for the Jordan JX92S that would sit on top of the H frame and place the Jordan at ear level. The OB would not be physically attached and could be positioned to provide the best performance. An active crossover and a pair of identical SS amps would independently power the two sources and allow easy adjustment of the output levels and crossover configuration to provide the best SPL response curve.

At this time, I do not have a MathCad worksheet that will simulate a two way system composed of an H frame and an OB. So I designed each independently and calculated the SPL response at a 1 m distance on the axis of the Jordan full range driver. Then I saved the output from each into a file (unfortunately this cannot be done with the MathCad Explorer 8 program) and used another MathCad worksheet to read in the two results and combine them, taking into account the phase of each, at the reference position. Then by adjusting the low pass crossover and boost applied to the H frame and the high pass crossover applied to the OB, I iterated to find a SPL response that matched a specified goal function. This is the same process I used in the passive two way OB design study documented on the OB Theory page of this site.

The MathCad model for the Goldwood woofer in an H frame is shown in Figure 1. The H frame's external dimensions are 21" wide, 21" tall, and 16" deep. The open area is a 20" by 20" square. The calculated SPL response, assuming a 2nd order Linkwitz-Riley low pass crossover at 100 Hz and applying 2.5 dB of boost, is shown in Figure 2. Copyright © 2008 by Martin J. King. All Rights Reserved.

Figure 1 : MathCad Model of the Goldwood GW-1858 Woofer in an H Frame Dimensions are Meters

H Frame Simple Source Pattern with Baffle Edge Outline







To model the Jordan full range driver on an OB, the OB was assumed to include the H frame and treat it as the lower portion of a floor standing OB. In reality, the OB is a 20" square with the Jordan off-set to help control ripple typically associated with a driver centered on a baffle. Figure 3 shows the MathCad OB model. The calculated SPL response, assuming a 2nd order Linkwitz-Riley high pass crossover at 250 Hz, is shown in Figure 4.

Since both of the SPL responses were calculated at the same location, the sum will yield the combined system SPL response. When combining the two SPL results, the SPL was converted back to a pressure and the phase was used to split the pressure into real and imaginary components. After adding these complex pressures the sum was converted back to SPL and the result is shown in Figure 5.

A goal function has been added to the system SPL response plot and is shown as the solid black curve. The magnitude of the goal function is 88 dB and the tuning frequency is 18 Hz. Comparing the calculated SPL response curve to the goal function, the result indicates that the calculated SPL response of this two way design is 88dB +/-3dB from 18 Hz to 20 kHz. Could this be for real? To answer this question, I went ahead and built then tested the system.

Figure 3 : MathCad Model of the Jordan JX92S Full Range Driver Woofer in an OB Dimensions are Meters



OB Simple Source Pattern with Baffle Edge Outline







Plans and Construction :

This was probably the easiest design I have built to date. Not too big, not too many parts, and no real critical dimensions. Rather then a detailed drawing I have included pictures that show the few significant construction details. Figures 6 and 7 show the front and rear views respectively.

Starting with the H frame, the outer dimensions are 21" wide, 21" tall, and 16" deep. The baffle is made from a 20" square of $\frac{3}{4}$ " thick (or whatever the metric equivalent is to $\frac{3}{4}$ ") plywood with the Goldwood woofer cut-out centered. The top, bottom, and sides are all cut from $\frac{1}{2}$ " thick plywood. I did not use any special plywood, just the inexpensive birch plywood found at the local Lowes. I offset the baffle 1" forward in the H frame for two reasons, first I did not want the woofer's magnet to extend past the back of the enclosure and second the acoustic center of the cone is probably about 1" behind the mounting flange. The distance from the front surface of the baffle to the front edge of the H frame is 7".

Some of the H frame construction details can be seen in Figures 8 and 9. Two longer pieces of plywood were first attached to the sides to position and secure the front baffle at the correct distance from the front of the enclosure, then the top and bottom pieces were added. Once the top, bottom, and sides were assembled small reinforcing strips were glued into the corners to align and stiffen the joints. And finally, a block for the binding posts was attached to the center of the bottom panel at the rear of the speaker.

The OB was also made from a 20" square and ³/₄" thick (or whatever the metric equivalent is to ³/₄") piece of plywood. The hole for the driver was offset and is 7" from the inside edge and 11 inches from the bottom. I built a bracket that attached to the bottom of the OB, as can be seen in Figure 9, and the binding posts were located on the rear piece of this bracket. The OB is not physically attached to the H frame so the position and toe in can be adjusted to produce the best performance at the listening position. With the c.g. location of the driver behind the baffle, and the additional weight of the bracket, the OB sits on top of the H frame and there is no tendency to wobble or tip forward. The exact details of my bracket are not important and any other method for supporting the baffle would probably work just as well.

Both the H frame and the OB were primed and painted flat black. Cabinetry and finishing work are not really a strong skill for me so simple and quick is preferred. Overall they are not furniture quality but they look fairly decent until you get real close, then they look like plywood painted black.

The only thing I would like to add to the system set-up is a couple of pieces of heavy stone or countertop to provide more mass for the enclosure. I hope to find a 21" by 16" piece of 1" or 3/4" thick heavy finished stone to serve as the top surface of the H frame. A second smaller piece would also be nice to have sitting on the top of the OB bracket. These are finishing details I need to chase down when I find some free time.



Figure 7 : Rear View







Measured Results :

To measure the response of the finished speakers, I used my two car garage since it is a fairly large open space. I opened both doors and set the speakers so that one side of the dipole faced out towards the neighbor across the street and the other side faced almost diagonally across the garage. I placed the microphone 1 m inside the garage aligned on the axis of the Jordan full range driver, I am not sure if it would have been better placed 1 m outside the garage, and proceeded to make electrical and acoustic measurements using my recently acquired Praxis system. The microphone and speaker system set-up were intended to match the MathCad simulations of each driver without the crossover filters connected. This is the first system were I have attempted to make a full set of measurements with Praxis so I am still on a learning curve. All of the SPL measurements have a 9.03 dB amplitude correction applied in an attempt to simulate 2.83 volts (1 watt into 8 ohms) applied at the driver terminals. One third octave smoothing was applied to each SPL response eliminating the hash.

The measured results for the Goldwood GW-1858 are shown in Figures 10, 11, and 12. Comparing impedance plots shown in Figures 10 and 11 the shift in the driver's resonant frequency can be seen clearly. The original 30 Hz fs has dropped to just under 28 Hz while the Qts has risen from 0.905 to 1.040 when the Goldwood woofer was taken from the test baffle and mounted in the H frame. The SPL response plots presented in Figure 12 indicate bass extension below 30 Hz and the first H frame resonance at approximately 250 Hz.

The measured results for the Jordan JX92S are shown in Figures 13, 14, and 15. Comparing the impedance plots shown in Figures 13 and 14, as expected the driver's resonant frequency and the impedance peak are almost identical for the test bench and OB measurements. The SPL response plot shown in Figure 15 exhibits a significant ripple with peaks at approximately 370 Hz, 650 Hz, and 1100 Hz which are primarily generated by floor bounce reinforcement. The SPL response above 2 kHz also appears to be about 3 dB too high compared to the Thiele/Small based value shown in Table 1. I believe I have a scale factor mistake in my test setup and the SPL test results are all 3 dB too high.

Figure 10 : Goldwood GW-1858 Impedance











Figure 13 : Jordan JX92S Impedance Jordan JX92S Full Range Driver Impedance Data - Driver #1 Liberty -praxis- Jordan Impedance 1.px2 Impedance acq: 7/22/2008 8:26:58 PM 120 25 20 60 15 0. 4 10 -60 -120 20 50 100 200 500 10 Mkr 2 Mkr 1 49.8Hz 500.2Hz 20.070 hm 5.4790hm -1.731° 929.1m°





Figure 15 : Jordan JX92S OB SPL Response





MathCad Model Correlation :

The measured impedance and SPL response curves were saved in text format and read into MathCad to correlate against the simulation results. The levels of the measured SPL were reduced by 3 dB to bring them into line with the calculations. In the following figures, the blue curve is the measured response and the red curve is the calculated response.

Figure 16 shows the measured and calculated impedance of the H frame. It is clear that the measured tuning frequency of 28 Hz is a couple of Hz higher then the calculated value of 24 Hz. I have tried to find a reason for this but have not been able to produce a defendable physics based explanation. I will continue to look harder at the MathCad model and the measurements to see if I can get the two converged.

Figure 17 shows the comparison between the measured and calculated SPL response of the H frame. The roll-off at 30 Hz seems to correlate well. The peak due to the first standing quarter wave resonance is seen in both the test and calculated SPL curve at approximately 250 Hz. The results above 250 Hz are not in as close agreement but are also not as important since the crossover will effectively remove them from the summed system SPL response.

Figure 18 shows the SPL response for the Jordan driver in the OB portion of the speaker. The first couple of floor bounce peaks seem to line up fairly closely but the measured results show more ripple amplitude then the calculated curves. In the past, I have found that the test data typically did not produce as much ripple as the MathCad models so this result is a little puzzling.

Reading the tested SPL response curves into MathCad, I could apply different active crossover settings to see which produced the best system SPL response. Figure 19 shows the response for the original crossover design and also for an alternative that seems to improve the +/- dB variations. This second crossover is the one I am using now to evaluate the sound of the speakers. In Figure 19, the goal function has been fit to the data and is set to the same magnitude of 88 dB but the tuning frequency has been raised to 22 Hz.

Overall, I am happy with the correlation between the test and the calculated SPL response curves. 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 MathCad OB and H frame worksheets, and by extension the U frame worksheet, are valuable tools in the design of dipole speaker systems.







Jordan JX92S Open Baffle and Goldwood GW-1858 H Frame Two Way Speaker System By Martin J. King, 09/18/08

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Figure 19 : Measurement Based System SPL Response

High Pass Crossover – 250 Hz 2nd Order Linkwitz-Riley Low Pass Crossover – 100 Hz 2nd Order Linkwitz-Riley Low Pass Boost – 2.5 dB



High Pass Crossover – 350 Hz 4th Order Linkwitz-Riley Low Pass Crossover – 100 Hz 2nd Order Linkwitz-Riley Low Pass Boost – 2.5 dB



Approximate 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 1/2" Plywood	3	75.00
T-Nuts, Bolts, Speaker	_	_
Wire, Spades, Primer, Paint		
Total Cost	-	663.00

Conclusions :

Twenty some pages of text, figures, and tables later and the question of how this combination of drivers and dipoles actually sounds has not been addressed. For me this is a three part answer; H frame performance, Jordan JX92S performance, and the combination of the two to produce the system's performance.

The H frame produces the deepest bass I have ever had in my home stereo system. Granted I have never used a dedicated subwoofer, but most of the other speakers I have designed and built have tended to reach down to about 40 Hz which has always produced enough bass for the enjoyment of my acoustic jazz collection. But the Goldwood GW-1858 goes well below 40 Hz without any of the bloat or one note bass some speakers can produce; it is just an even growl into the 20 Hz range. I doubt I get all the way down to the measured 22 Hz since the rear wave reflecting off the back wall probably produces some cancellation of the lowest frequencies. A bigger room allowing placement further from the rear wall would definitely improve this situation.

Taken as an independent woofer system, the stereo pair of Goldwood H frame woofers has the potential to mate with a large number of other types of speakers in the 86 to 92 dB/W/m range. An active crossover can be used to match levels and fine tune the crossover. At some point, I would like to try a few other 4 and 5 inch fill range drivers and even a couple of multi way bookshelf speakers sitting on top of the H frame enclosures. On its own, the Goldwood H frame woofer system can be built for under \$300 which seems like a great deal.

The Jordan OB is a little harder to describe. I have seen the Jordan JX92S described on the DIY speaker forums as being very smooth. That seems to really sum up the performance very well; there are no peaking resonances to address meaning the driver just does its job from the crossover point all the way up to 20 kHz. Compared to the Lowther DX3 ML TL speakers, sitting along side, the Jordan does not seem to have the same airy sound of the Lowther which is probably more a function of the Lowther's high frequency whizzer cone resonances. To be brutally honest, the Lowther is a pleasantly colored driver to my ears. I love the presence and detail but understand that it is mostly an artifact of the Lowther's rising and resonant high frequency response and not necessarily completely accurate.

Does the Jordan need a tweeter for the very high frequencies? Based on the measurements and initial listening my answer would be not necessarily. Listening to the Jordan, when called upon to produce cymbals or crisp twinkling piano notes it does the job. I guess a tweeter could give the allusion of more air and make the system sound closer to the Lowther, but I am not convinced that it is required or would be an improvement in tonal accuracy.

I do have a particular CD that I use as a test disc for my speakers. It will instantly expose any hint of sibilance in a speaker's response. The CD is titled *My Turn* by Linda Eder on the Atlantic label. This is a female vocalist performing in front of an all-star big band and she has a great vocal range in a New York Broadway show style. On the downside, the recording has a tendency to expose sibilance problems with hissing vocals that can become very harsh. On a poorly balanced set of speakers with a rising response, it will drive you from the room. My Lowther DX3 ML TL speakers struggle with this recording but are tolerable. The Jordan drivers have no problem with the female vocals, Linda Eder's voice comes through dynamic and crystal clear with almost no hint of sibilance. The Jordan JX92S really is smooth just as others have described on the various DIY speaker forums

The use of an active crossover really makes the system work. Levels and crossover points can be adjusted to optimize performance. Crossing low maintains the full range driver sound while removing the demand to produce bass from the Jordan. The system comes together really well, deep dynamic bass and clear crisp response from approximately 20 Hz to 20 kHz. But be warned, at 88 dB/W/m it does take some power to make them really sing their best. At the end of an evening of enjoyable listening at decent volume levels, my amps are warm.

So in conclusion, I have learned some more and am still learning a lot about dipoles. 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 speaker project and if you decide to build something based on this design concept, or using my MathCad worksheets, please remember to send a picture for my gallery so everybody can see the results of your hard work.