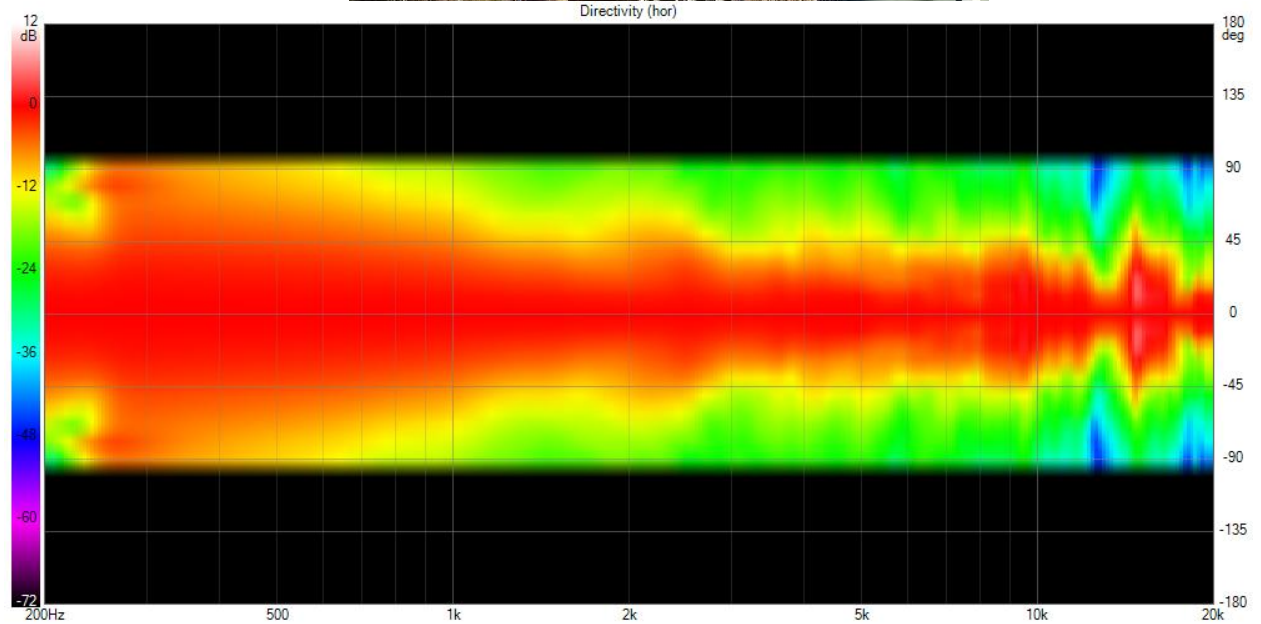


The BR12-1: Passive 2-Way PA Top

By

Scott Hinson



Introduction

For many of the completed designs I do, I'm trying to use the design to talk about particular aspects of loudspeaker design in more detail. For instance...for The RuleBreakers two-way home speaker, I wanted to talk about diffraction, and the marketing aspects around it...and other ways to make the speaker have less audible diffraction ripple.

For this one...well...I wanted to do a reasonably sized, lightweight, good sounding PA top for basic passive applications where you might want to deploy one of those inexpensive injection molded plastic boxes. I decided to use this project to talk about real world sensitivity/power handling specifications.

Design Process

Two way speakers aren't *that* hard to design. Three ways are far more likely to have wild impedance swings caused by too much overlap in the reactive components of the crossover themselves. You can typically avoid that using advanced crossover modeling....but one of the things that can be a challenge for any passive PA speaker is power handling. This is an area where DSP really begins to shine. For this speaker it's still totally doable, and I'd be more worried about the drivers than the crossover components for distortion/compression...but too much more and even I'd give up on passive and go all active. (I have a 15"/1.4" combo on the way that is the absolute limit...and even then, I might consider going active with it.)

For this one I wanted to do a couple of things...one, make it pole mountable. Two, I wanted it to be as light as possible. This was for portable applications as a primary application, not install..so weight is pretty critical. Three I wanted it to sound good and have high sensitivity, so I was willing to give up a bit of bass extension.

Maximum Output

One of the most common lies is bandwidth and maximum output. I've said it before in other writeups there are a lot of claims in loudspeaker marketing...and some of them don't hold up to the slightest examination under the laws of physics. I've seen some rather stupendous claims over the years. Let's look at a completely made up example.¹

¹ Wink.

PantsOnFire 120000 SpeakerZZZZ

Power Rating: 1000W Continuous/2000W Peak

Frequency Range: 45Hz to 20kHz.

Sensitivity: 101dB

Maximum Output: 135dB

Size: 26"x14"x8"

At first glance these specifications don't seem too bad...but lets' take a closer look.

The example speaker has a sensitivity of 101dB and a maximum input power of 2000W. If that spec is at the 2.83V nominal level (1W into 8 ohms) then the speaker can handle 33dB more power ($10 \cdot \log(2000/1)$) for a short term peak. 101dB plus 33dB = 134dB...but the spec says 35???

Yup I've seen this. Even if the spec was 134dB as implied by the peak power I still wouldn't believe it....for a couple of reasons....one the speaker would have to handle all 2000W without any compression and the sensitivity of the speaker would have to actually have 101dB 2.83V sensitivity. The first is impossible, compression will set in...the second is just really...really...really difficult.

Let's look at that sensitivity figure a bit closer....if they don't give you a frequency response with some nominal window and a sensitivity...something like 45Hz to 20kHz +/- 3dB then the sensitivity rating and the frequency response rating are meaningless. I've seen speakers rated at a particular sensitivity where that happened to be a high Q peak in midrange response from a poor crossover design. The rest of the speaker was a good 3dB lower.

Next up....is the bandwidth...Hofmann's Iron Law is a thing...and to get into the mid/high nineties either requires a HUGE box or major sacrifices to the F3 of the speaker. There's no way around it. Any manufacturer claiming novel ways around that is just flat out lying...physics isn't a good idea...it's the law.

All of this is to say...to keep sensitivity and maximum output high, you have to give up on bass extension without equalization. Which I did...but more on that later.

Enclosure Construction

Given my background in audiophile speaker designer, my first instinct is to start adding heroic levels of bracing inside a speaker design. I mean, every panel gets a brace, top, bottom, sides, baffle, back...etc. I also tend to use heavy duty lumber...18mm/3/4". But I wanted to make this liftable....that was not going to work. I did use 18mm on the baffle and grill mounting strips...but most everything else is 12mm. Combined with the neo woofer that keeps the total weight of the speaker reasonable. 4 strips are used for side panel bracing, and to maximize



wood usage, some of the additional pieces are cut out of the pieces left over from the baffle holes for tweeter and woofer cutouts. This means a CNC would be super useful for the baffle, but it could be done without one using pattern jigs and a router table.

I put a brace on the tweeter, something I don't typically do for cast aluminum horns and lighter neodymium based compression drivers....but this horn, although a very strong injection molded plastic, concerned me a bit for really heavy duty portable use. It might be fine...I have just seen too many speakers take a tumble off a cart or out of the SUV/van. The brace is a bit challenging to get lined up right...but if you install it with the tweeter installed then you can get it glued into the sides perfectly. Basically...mount the tweeter/horn to the cabinet..put glue on the pieces that contact the sides and slip the brace over the tweeter magnet. The tweeter itself is your alignment jig.

Lastly the port is at the top of the speaker just over the tweeter because if I put it on the bottom it would interfere with the pole mount location. Putting them in the sides would have increased complexity greatly...and although this isn't a super simple build I didn't want to make it more complicated than it needed to be. (For the 15"/1.4" I am going to make it that complicated...but for other reasons....which I'll explain in that writeup, if I remember.)

I recommend high quality marine grade birch plywood, especially with the thinner walls/top/bottom/back. Anything less won't hold up to the use and abuse.

Woofer

The woofer is the SB Audience Nero-12MWN400D woofer. It's a cast frame 12" Neo magnet driver with a bunch of cool features. Inside/outside voice coil, distortion reducing shorting rings and a total weight of 9 pounds. It's pretty cool looking too...

One of the most attractive features to me was the impressive inductance reduction of the shorting rings...for a 12" woofer with a 3" voice coil a total L_e of .19mH is spectacular. You typically only see that in high end home drivers with much smaller voice coils. An overall smooth response bodes well for crossover design too...the cone breakup is well behaved.



Tweeter

The tweeter is the Bianco 44CD-PK, a 1" exit compression driver with a 1.75" voice coil, 50W AES power handling and a recommended 1.8kHz crossover frequency. I put the tweeter on the H250 horn. I've written more on this tweeter and horn in my open-baffle writeup...go check it out there.

Crossover

The crossover ended up being relatively simple to design...and in a pretty major stroke of luck requires relatively few discrete values.

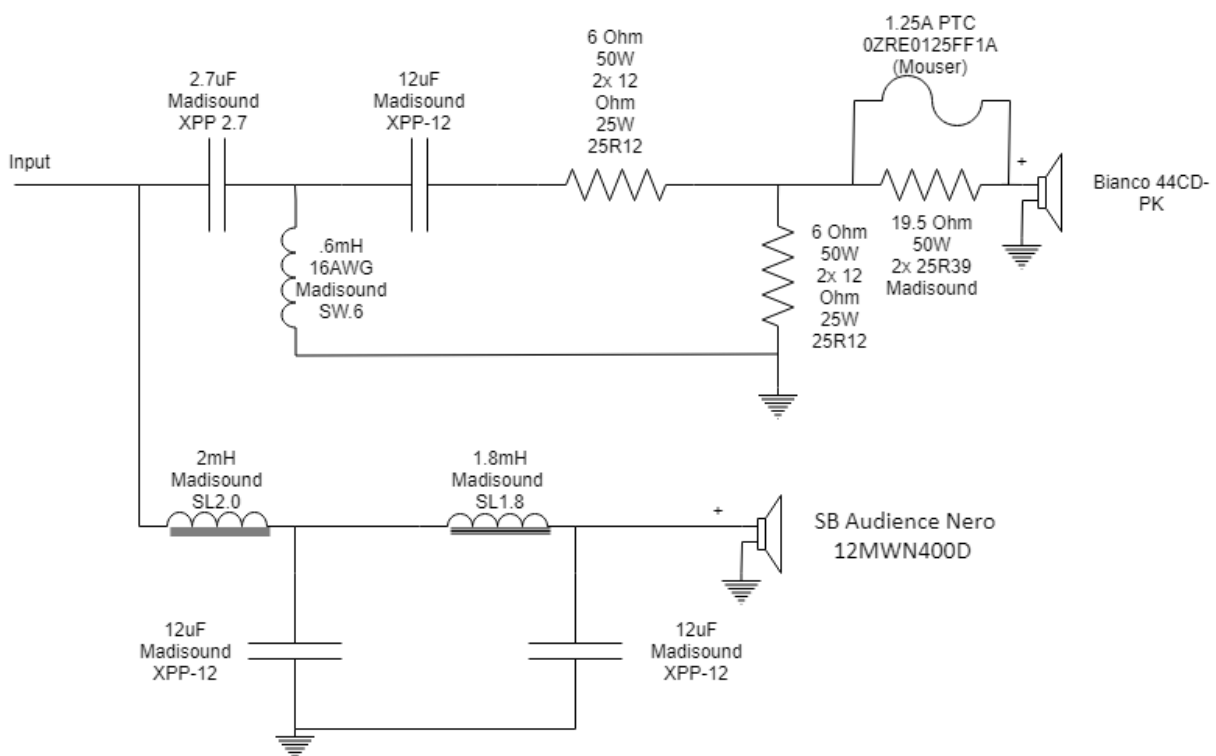


Figure 1 Crossover Diagram

Give the PA application I put a positive temperature coefficient polymer fuse in line with the tweeter. In pink noise testing 1.25A worked out to be a good value. I tested this by running the pair of speakers out of phase and facing each other with pink noise at high volume for 2 hours. What is high volume? Well...I had a 500W RMS amplifier flickering the clip light the entire time. At the end of the two hours I did a sweep of one of the speakers and the PTC fuse hadn't tripped, and compression was very very low. In theory the PTC will trip at 2.5A, protecting the driver before AES limits are hit.

The PTC is in parallel with a 19.5 Ohm 50W (total, made up by two resistors in parallel) load. In



normal operation the PTC shunts the resistor with a total resistance under .3 Ohms...when the current exceeds the maximum guaranteed break current for long enough it opens up (greater than 2.5A and 100s) and the resistor drastically drops power into the driver. I wasn't able to get the PTC to trip without annoying EVERYONE, even driving the two speakers out of phase against each other to cancel as much sound as possible. It may be possible to drop that current rating a bit and give the tweeter more protection...but I feel pretty comfortable with the value as it sits.

Enclosure and Port Tuning

I chose a 40L enclosure with a 50Hz tuning frequency set by a port with $\sim 76\text{cm}^2$ area...roughly equal to a 4" diameter pipe. Length of the port is 14cm, yielding a $\sim 95\text{dB}$ 2.83V system with a whopping F3 of?

Sit. Down. I'm warning you....you're going to want to sit down.

Roughly 100Hz.

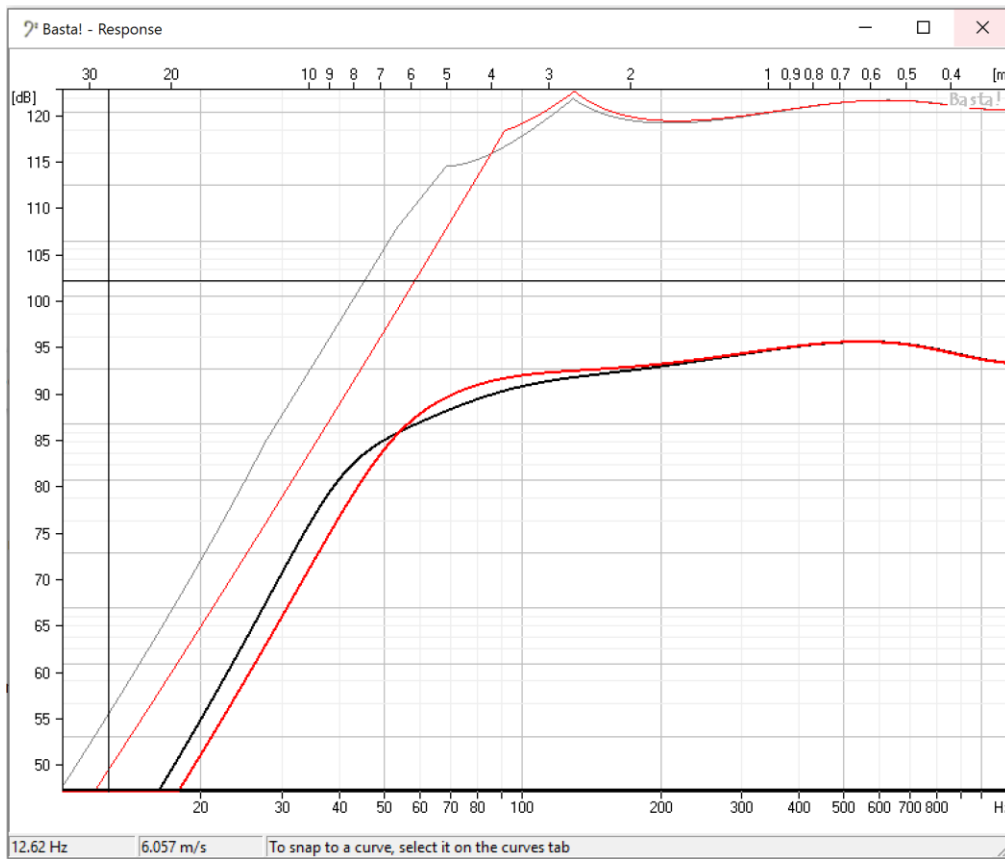


Figure 2 Black = 40L, 50Hz Fb, Full Space Simulation With Baffle Step, Red = 40L, 60Hz Fb, Full Space With Baffle Step



Before you close this PDF and walk away...I've got news for you...if you see a system with a box roughly this size and vastly different claims either they are using lots of EQ or they are fibbing. Physics isn't just a good idea it's the law. (If they are way different they aren't fibbing..they're lying.)

So what's the deal? Well..I designed for maximum output. In use I suspect these speakers will be used two different ways. One...as a fast setup PA speaker by themselves....and two as tops for a larger system with dedicated 2x18 or 1x18" subwoofers filling out the bottom end. In the second scenario there will be a high pass filter applied and so the F3 of the speakers themselves isn't as critical.

In the first scenario where these are a quick deploy of some tripod mounts and speaker cables to an amp rack away from making sound I designed for maximum output. The red line is a slightly higher tuning (60 Hz) which drops the F3 to a whopping ~80Hz....but notice the maximum output lines...determined by AES power handling, linear excursion and 17m/s vent velocity. The higher F3 speaker has significantly more maximum bass output in the 60Hz range. With a little EQ applied (used all the time in PA settings) this would be a punchier box. So...instead of handicapping the speaker for the sake of the specification goodness...I was willing to sacrifice the numbers for performance where it counted. You'll still want to high-pass it...probably in the 50Hz range at a 4'th order Butterworth...but in spite of that F3 number, in listening tests with that EQ applied it's a box that really rocks.



Figure 3 Driver Integration, 2khz. Crossover.

The frequency response shows the 2kHz acoustic crossover. Impedance is an easy load...with well behaved magnitude and phase. ...



Figure 4 Impedance Phase and Magnitude

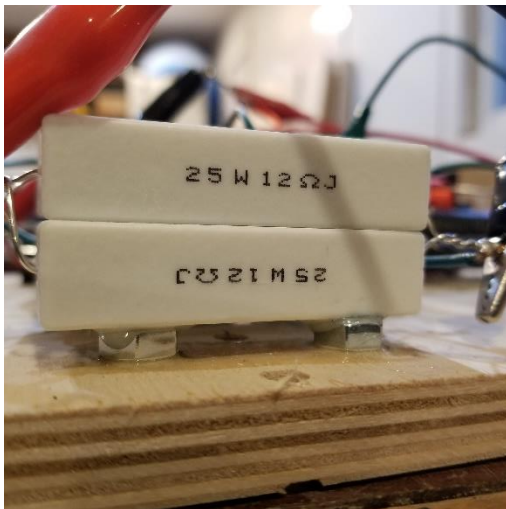


Figure 5 Resistor Spacers

Crossovers for PA speakers need to be built to handle more current than hi-fi home speakers. A lot more. 50W resistors...large laminate core inductors. Even then you still need to pay attention to how those parts are mounted. If you're going to put these on wood you're going to want to space the resistors off the board. I've done this in the past by spacing the resistors off the board by epoxying them to ¼-20 nuts on the board...

I could have gotten a bit more power out of the resistors by having space all the way around both of them...but in testing the configuration pictured seemed to work pretty well.

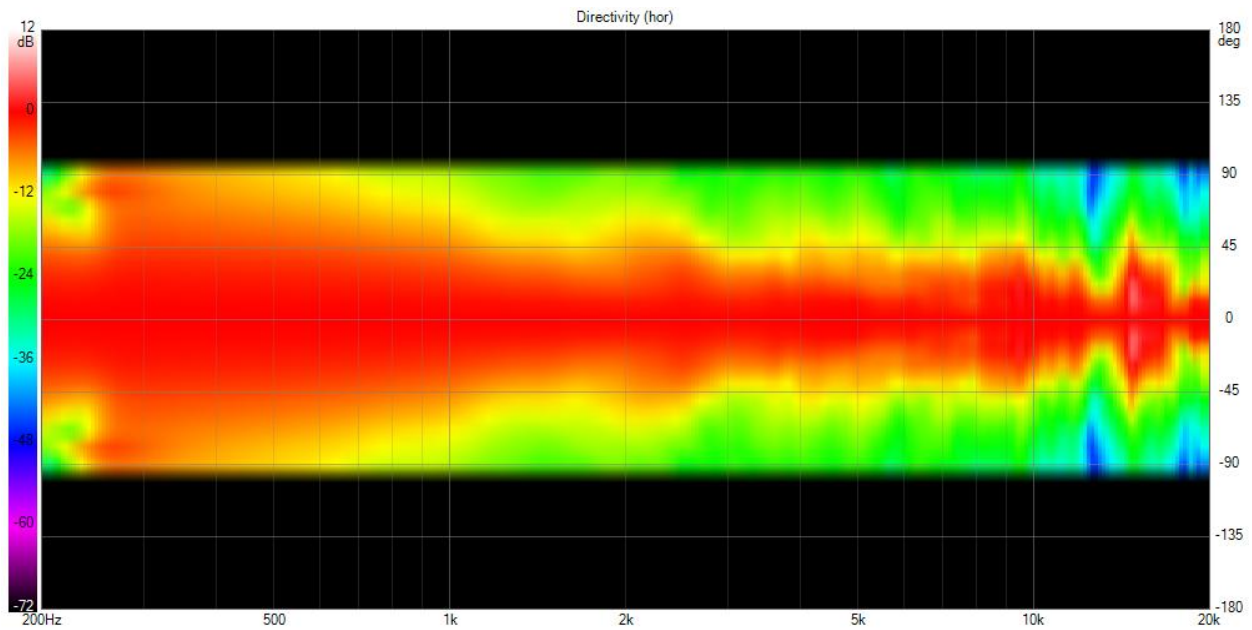


Figure 6 Horizontal Directivity Plot

Enclosure Design and Construction

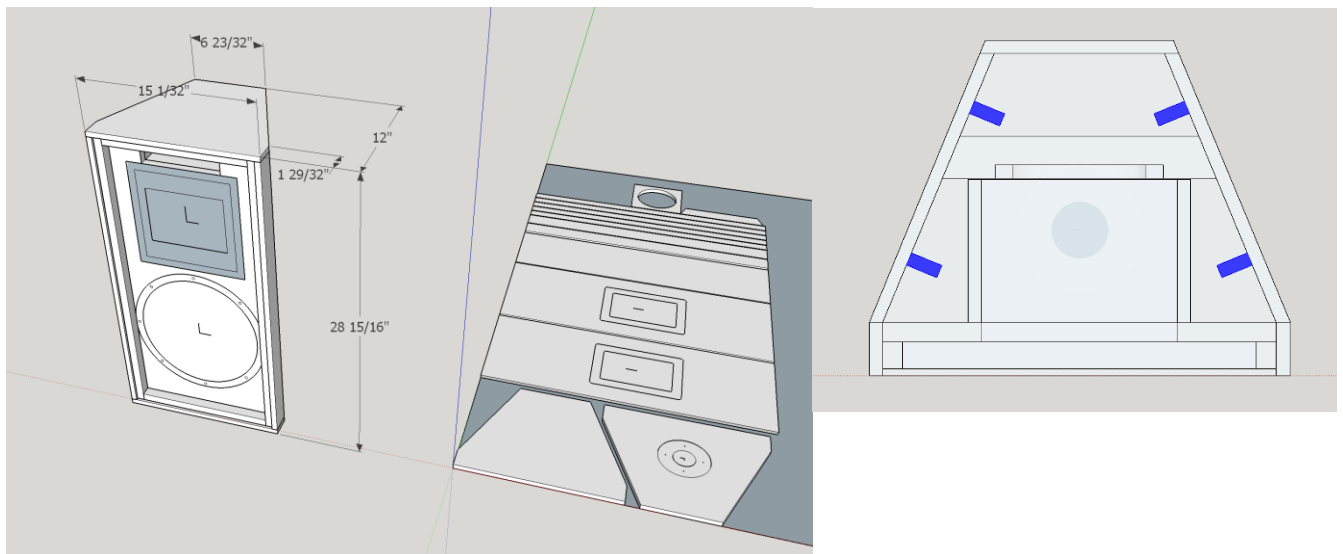


Figure 7 Enclosure Dimensions and 12mm BB Cut Locations, Side Panel Bracing

The enclosure is designed so that you can get all the 12mm pieces out of $\frac{1}{2}$ of a sheet of 5'x5' Baltic birch plywood.

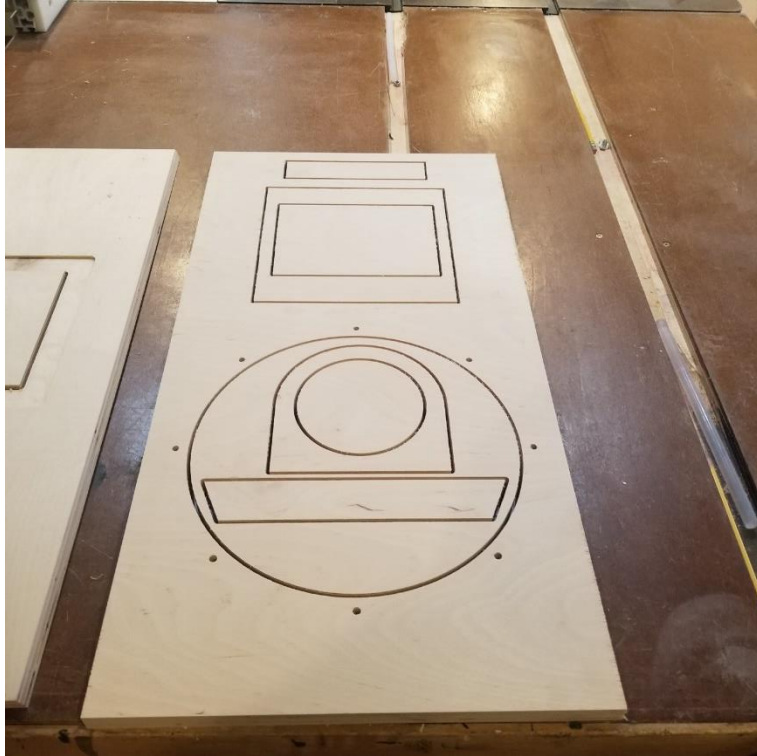


Figure 8 Nested Parts, ports and horn/compression driver support.



Figure 9 Pole Mount and Foot Detail



Figure 10 Completed Cabinets

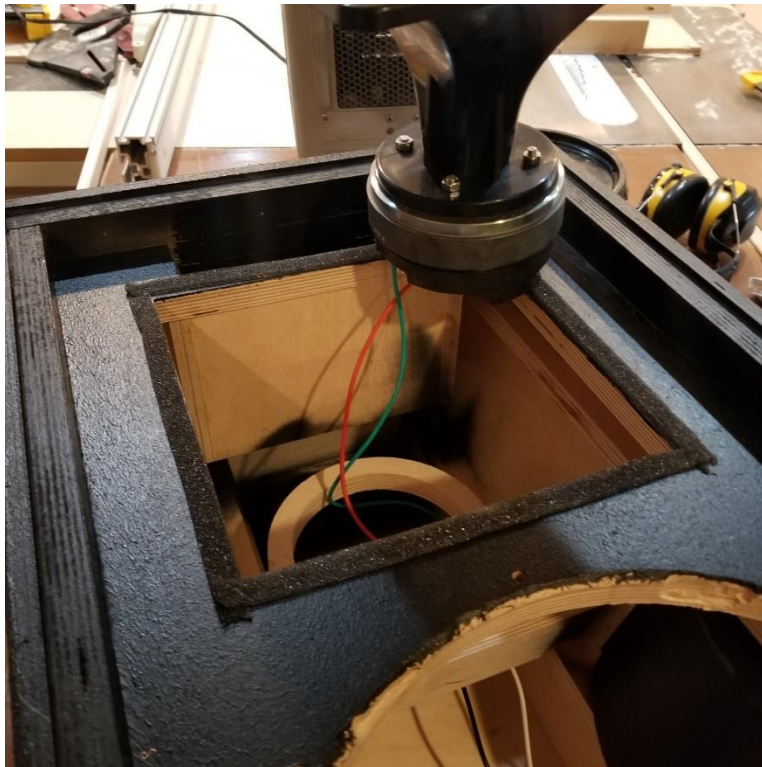


Figure 11 Foam Strip for Sealing Horn To Cabinet



Figure 12 Inset Speakon Connector



Figure 13 Parts Ready for Assembly





Figure 14 Tweeter Crossover Location (note, I keep them away from stuffing material)

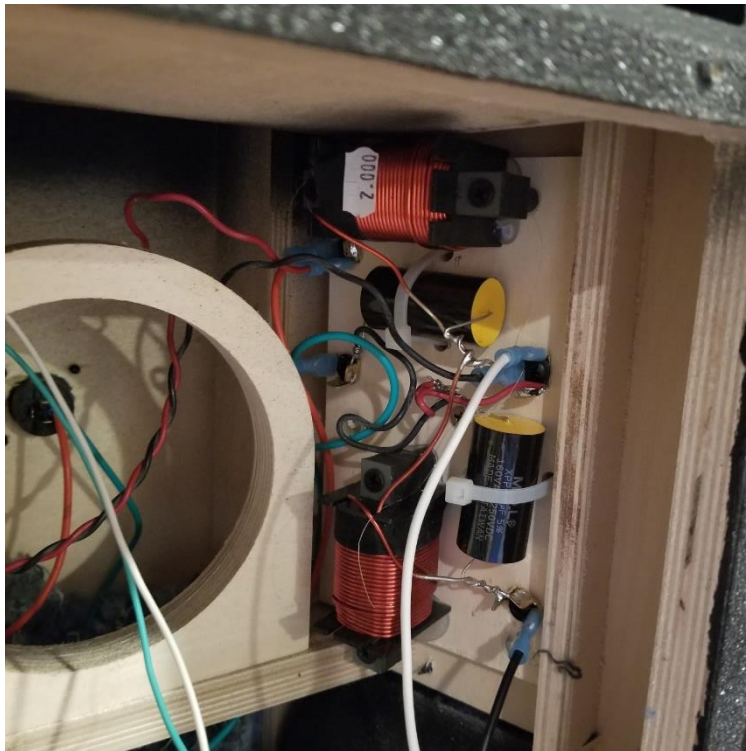


Figure 15 Woofer Crossover Location



Conclusion

So...how do I like these? Let me tell you all the ways...they are a light, easily portable speaker that sounds detailed without ranging into harshness. In my effort to get every last bit of midband sensitivity out of them, they'd be a tad too forward for home hi-fi use (though there's nothing stopping you from making great hi-fi speakers out of either of these drivers...that's just not the tonal balance of this speaker) but they completely avoid that wonky harshness of a lot of PA speakers in this size/price range. Perfect for back yard parties, smaller acoustical events and even as fill for larger bar/club spaces where high output is needed.

Specifications

Sensitivity: 95dB/2.83V/1m

Frequency Response: 100Hz to 15kHz, +/- 3dB, 80Hz to 18kHz +/-6dB.

Dimensions: 29"x15"x12" (HxWxD)

Amplifier Compatibility: ~500W 8 Ohm, probably more if you can set your limiters and high pass correctly.

Nominal Impedance: 8 Ohms.

Authors Note: Power Handling/Compression

I made a valiant effort to determine the actual maximum continuous power handling for these speakers. At some point in the future I may try again....and update this document. The first thing I tried was using the two speakers, facing each other but out of phase with bandwidth limited pink noise, high pass filter at 60Hz low pass at 20kHz. I used a Crown CDi 2000 and turned up the volume until the clip lights were just flickering. With this test signal the peak power was the amplifier rating of 475W and the continuous power was ~12dB lower because of the crest factor. What does this mean? I put a *WHOPPING* ~25W continuous into these speakers. So...I'm not surprised I wasn't able measure compression when I quickly moved to measure just one speakers' frequency response.

So...this weekend I made a second attempt. This time I BRIDGED the CDi-2000 and attempted to run the test using the M-noise protocol specified by Meyer Sound and SMAART². Without going into too much detail, it is a better representation of typical live music crest factor, and bandwidth then filtered Pink noise...even then I tapped out of the testing before I could hit the ~2dB of compression specified as the limit. With ear plugs in, and over ear protection the output was SO loud that you could feel it. I was afraid of getting an amplified noise ordinance violation because my garage isn't insulated well enough to contain it.

² This is a spectacular test...future writeup...once I get a successful completion. I may have to build a smaller PA speaker to do it. I wonder how home speakers would do? Hmmmm.....

