SB-Audience Passive Open Baffle 3-way

Or

“Have you lost your mind?”

By

Scott Hinson

Introduction

I really didn't set out in October and November of this 2020 to attempt a speaker design I hadn't done in almost 20 years. The opportunity just sort of fell in my lap. The nice folks at Madisound and SB Audience approached me about doing a few designs with the SB Audience drivers, and after a few emails discussing options one design leapt to the top simply because of demand.

Them: "Do you think you can do a passive open baffle design, we get calls and emails about them….a lot."

Me: Madly does a bunch of simulations in Basta and SoundEasy.

Me: "Sure!"

Me: Clicks send.

Me, internal voice: "Wait…what did I just do? "

Background and My Past Experiences with Open Baffle Speakers

The last time I built a passive open baffle speaker was circa 2002 or 2003. Dr. Linkwitz had recently published the Orion active crossover based open baffle speakers and the reviews were glowing. There was a lot of interest all over the web, with people trying versions with lower cost drivers, simpler crossovers, more expensive drivers and fancier crossovers.

At the time I really wasn't that interested in the design. I was much more interested in Dr. Linkwitz work looking at multitone/IMD distortion tone bursts and perceived midrange quality. I had designed quite a few speakers using the usual suspect mids/midwoofers. Designs that on the spec sheets had a quite smooth response, but used older, less advanced motor designs. To a young speaker designer with only a few years of experience under my belt, they seemed like they should be better. I had hoped with my ruler flat frequency response the speakers would be more exciting. But those mica damped poly cones, rubber surrounds and simple motors just sounded….so…boring. And if you turned them up loud…bleh…next.

When I saw Dr. Linkwitz' use of the tone bursts and ETC a light bulb went off in my head…ohh…man….this is important…I need to know more. The drivers I was using performed quite poorly. I was able to replicate most of his results with drivers we both owned, but not all of them. I was getting some different numbers… So I mustered up my courage. And I sent him an email….I assumed I had done it wrong.

I fully expected him to ignore me. I was stunned to get an email back within a few hours. A few emails later he said something to the effect of:

"This discussion will have to take a pause…I've got to pack I'm going to CES in a few days."

Mustering up all of my courage a second time, I immediately wrote back saying I would be at CES too, would you like to meet for lunch, my treat as a way of saying thank you for all the help. He agreed. Again, I was floored.

We ended up meeting early one morning at the Alexis Park, before the exhibits opened…and Dr. Linkwitz and I had a LONG conversation, at least an hour. During the conversation Dr. Joseph D'Appolito walked over and Dr. Linkwitz introduced me. I learned more in that hour from those two men than I care to admit. I never did take Dr. Linkwitz to lunch, our schedules just didn't work out, but I forever owe him a debt of gratitude and have tried to give back to the DIY community following his example. (I did take Dr. D'Appolito to lunch…but that is another story.)

When I got back home, I decided to give this open baffle thing a try. And kind of failed miserably. It was entirely my fault…I had no budget. I used a couple of 12" cheapo drivers with a not high enough QTS and teensy xmax. I didn't understand how to get the total power response of the speaker into balance…it just wasn't good. Over the intervening 18 or so years I'd revisited open baffle speakers, but *always* using DSP for crossovers.

Fast Forward to 2020[1]

In a day and age where DSP and class-D amplifiers are as cheap as they are, the choice to do a passive open baffle speaker might seem a bit odd to some. But as soon as Madisound suggested it, I was like…yeah….I can see the need. My primary amplification is a McIntosh MC2505….if I went DSP I'd have to ditch that, or just use it on one set of drivers. For folks that switch different speakers or amps in and out of the system regularly (guilty) active can be a bit annoying. It's nice to be able to change from tube to solid state, or from lower power to higher power amps without having to multiply the number of channels by 3 to get a functional 3 way system.

There's another reason too…when doing active systems, you have to be very careful about gain structures so that you don't run out headroom, and you minimize noise injection into the system. It's entirely doable…but inexperienced DIYers can struggle. They'll end up with the bass channels clipping due to too much low frequency gain, or a hiss in the tweeters (especially with high efficiency horns.)

So….I decided to give it a try again. This time taking what I had learned doing active versions and substantially better parts….

[1] Did we *have* to?

Parts is Parts.

Except when they aren't. One of these drivers is an obvious choice for an open baffle speaker…the other two aren't. First the woofer…

The SB Audience Bianco 15OB350 is a 15" woofer with a 2.5" voice coil. The woofer has a thick stamped frame, double half roll surround, and a set of T/S parameters that make it perfect for an open baffle speaker. The driver has a generous xmax of 11mm and a maximum mechanical excursion of 25mm one way. In simulations with a passive low pass filter….using a rather narrow 24" width baffle you can expect an F3 in the low 50Hz range. What's impressive is the power handling without running into any excursion issues.

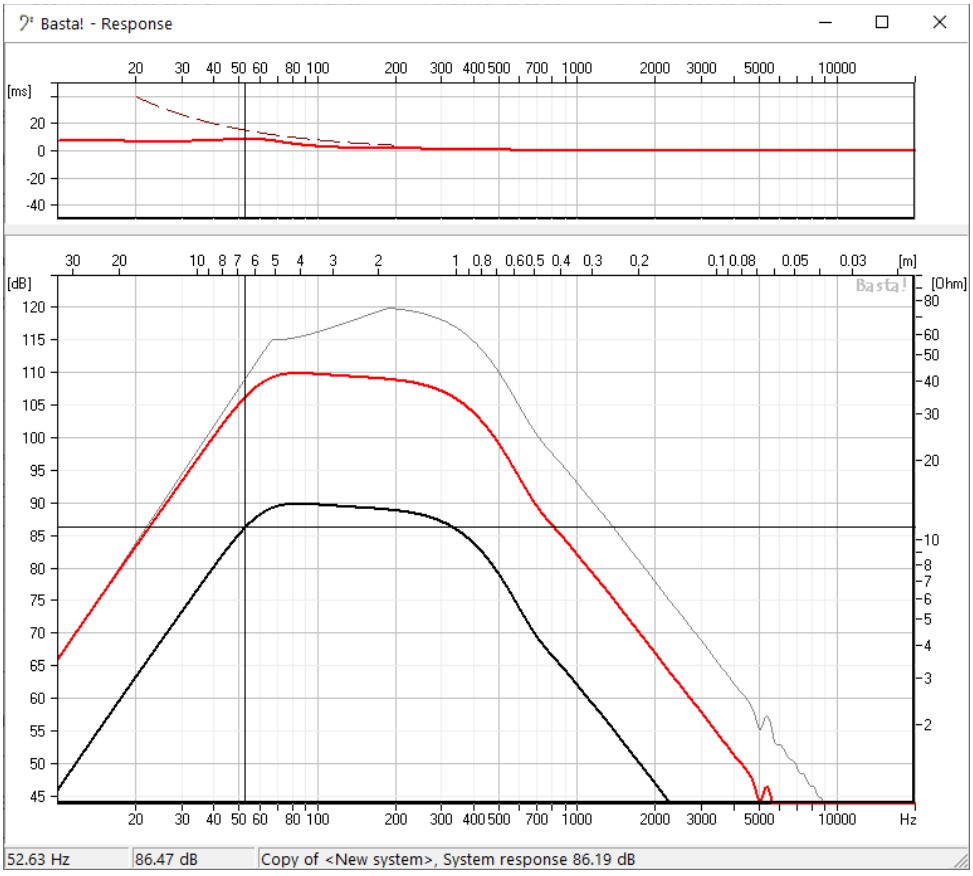

Figure 1 15OB350 response, 2.83V (black), 28.3V (red) and maximum output at linear excursion and AES ratings (light grey).

Figure 1 shows the simulated response of the woofer on a 24" wide baffle, 1 meter tall. What's surprised me is that you can easily use a 100W into 8 ohm amplifier with this driver and the driver will take every bit of voltage swing that the amp can dish out without exceeding the *linear* excursion limits, let alone the mechanical excursion limits. The first time I tried a design

like this if I had tried that power level the drivers I had probably would have had the voice coil hop out of the gap or lock itself into the gap getting crushed against the back plate.

Figure 2 SB Audience Open Baffle 15" Woofer

the speakers into it and I measured it…

Oooh…yeah…that was bad.

With the woofer taken care of, now was the time to pick the midrange and tweeter. In the SB Audience line, there was an immediate winner for the midrange.

The SB Audience Nero 6MRN150D, a cast frame neo magnet driver with venting under the spider, a vented pole piece and a shorting ring in the motor to reduce distortion. For the home audiophile readers, the surround might be a bit weird…it's flat. No rolls…but more on that in a bit.

The trick with open baffle speakers is that the midrange can have some pretty wild suckouts if you're not careful. You can fix that on axis with DSP, but again, this one had to be all passive. I simulated a few baffle placements with Basta, and low and behold when the driver was centered it didn't look that great. But without actually putting a speaker on a test baffle, I wouldn't know for sure if I could deal with any frequency issues without resorting to DSP. So I built a baffle…and I put

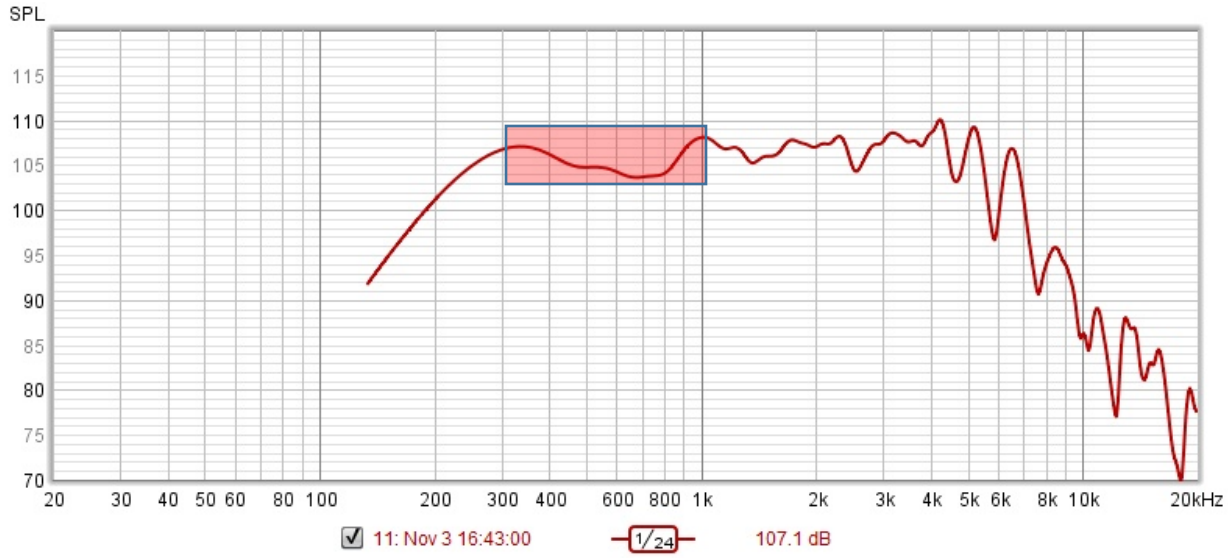

Figure 3 Midrange Measurement, Centered on Baffle

Any of my regular readers know I'm not necessarily afraid of any particular response of any particular speaker….I can usually deal with things that some designers might not attempt. This one though…this gave me pause. Here's why…the red box in Figure 3 shows the suckout of the midrange driver from being centered on the baffle, nearly equidistant from the sides and the top and the typical loss added because it's an open baffle. (A lot of that cleared up when I just put a test enclosure (PVC end cap) over the back of the midrange.

The problem with that kind of frequency deviation is that the shape will be difficult to deal with, the relatively fast rise in frequency back to the nominal level at 800Hz and the fact that it starts to drop off right when it would probably be coming out of the crossover in the 300Hz range is problematic. Plus it's about an octave wide. If it was only one of those two problems I'd probably have been willing to forge ahead at that point, but with both of those issues…nope. Gotta pause and re-evaluate. (FWIW, I tried all sorts of things to keep that driver centered, felt absorption, add on wings, and really never got it where I felt I needed it to move forward with crossover design.)

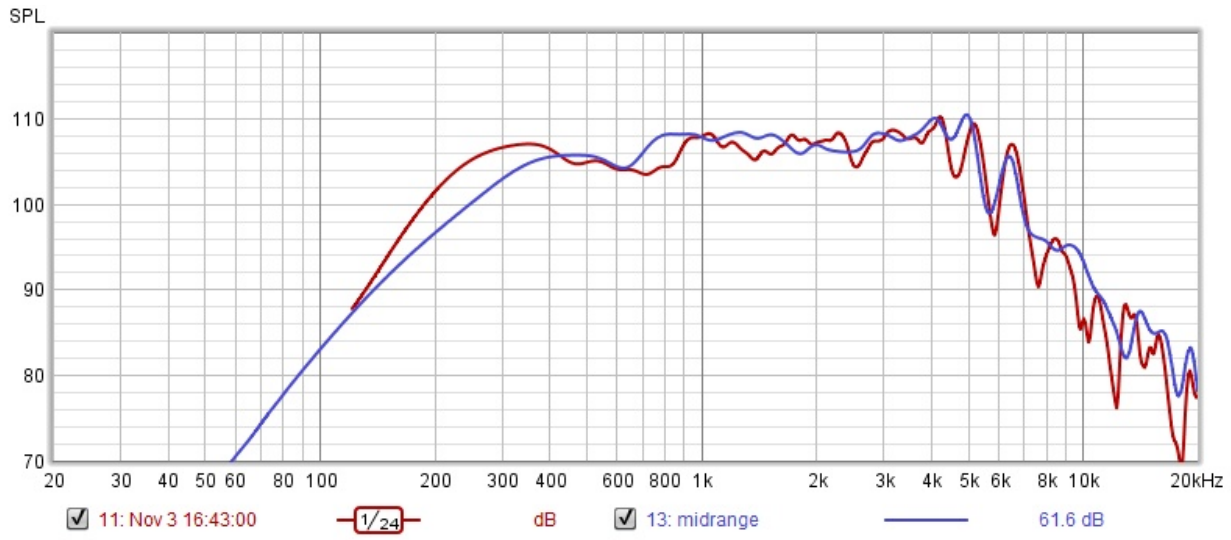

Figure 4 Offset Improvement.

By offsetting the driver the improvement is pretty dramatic. There's still a dip, but it's much narrower (read less audible) and it gets out of the crossover range so I don't have to deal with two things moving on me in the frequency domain at the same time.

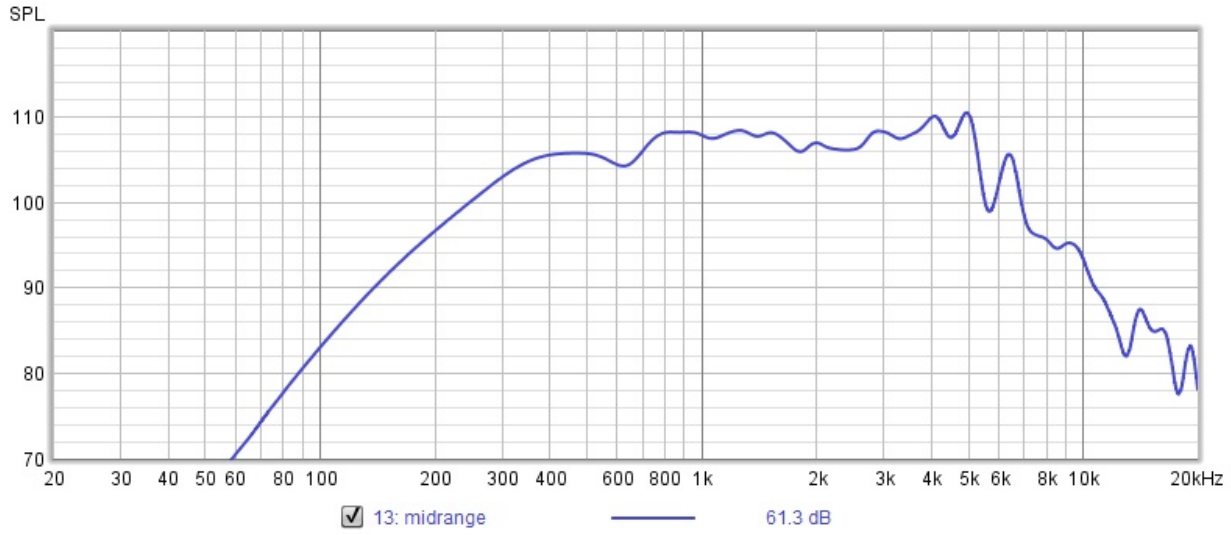

Figure 5 That's Pretty Special....just saying...

Let's go back to that flat surround….for midrange frequencies there can be problematic frequency response ripple and re-radiation from a half roll surround with any height to it at all. There's this juggling driver designers have to do between excursion, mechanical termination of resonances, etc. A flat surround solves a lot of this, but you have to pay special attention to get the crossover high enough so that there's no real excursion on the driver even at high volumes.

Figure 6 44CD-PK Tweeter

The tweeter and horn….I picked the Bianco 44CD-PK and H250 horn. Together they have a smooth response, wide bandwidth and like the midrange…stupid output. I mean…stupid. Since these were originally designed for PA use, they will handle abuse that home audio drivers would not survive.

With the efficiency that both the midrange and tweeter have, in a home environment in this speaker….if they are distorting either your clipping the amp badly or…you're going deaf. And quickly. In normal use they are coasting, literally not even trying. Distortion will be vanishingly low, less than a typical tube amp. Soft dome tweeters can't hope to keep up.

The compression driver has a 107dB sensitivity and 50W AES power handling….in a home environment *LOUD* peaks will be around a watt total to the driver. 1/50'th the capacity of the driver.

Horns get a bad rap in a home environment. I used to be in this camp, I was a soft domes forever kind of guy. But to be honest…at the time I hadn't measured a PA speaker...and didn't realize how badly they typically cover the crossover region. Swings of ~2-3dB + through the crossover region are not uncommon in even moderately expensive PA designs. They're meant to be used with external equalization, and often the crossover is designed to get the tweeter to survive hours of likely abuse, and not much else. Inexpensive designs are horrible in the frequency domain and can have tremendous issues with cabinet/horn resonances in the time domain. It is more than possible to get them to sound GREAT. You must juggle the total power response, on axis response, time domain and distortion…but it can be done.

CAUTION:
The magnet on the Nero midrange is strong. Like super strong…like Scott knows to watch out for pro-sound neo magnets and Scott still got his fingers smooshed REAL GOOD. Scott set the tweeter too close to the midrange and Scott's fingers and phalanx's were the only thing keeping them apart. Keep them off the cast iron top of a power tool. Use caution. Scott's not kidding.

Crossover….

To design the crossover, I first had to get good measurements. It's tough on a speaker with a baffle this size….I used a ground plane technique and measured at both 2 and 4 meters on and off axis….to check how the diffraction would sum on the final response. I also wanted to make

sure that the decision I made to not flush mount the drivers (making construction easy) wasn't a poor choice. What I was looking for in the measurements was the tell-tale frequency response ripple that comes from diffraction. I was quite pleased…on and off axis it was smooth. Diffraction ripple tends to be bad on axis and smooths out off axis….so I knew that hurdle had been cleared.

Figure 7 Raw and Crossover Responses, Tweeter (Red), Midrange (Green), Woofer (Tan), System (Blue).

Open baffle speakers can be a bit challenging to balance tonally….I've found that if you make them measure flat on axis, in room they have always sounded really thin and anaemic. Since I can't know the in-room response of this speaker in every builder's room, I defaulted to the overall tonal response that sounded best to me. The crossover points and overall frequency response was checked regularly with a combination of ground plane and in-room during crossover optimization. This ensured that I wasn't adding too much EQ through the crossover or introducing narrow band frequency response issues that easily escape the ear on any given song, but can really come back to bite you on others.

It ended up being tilted downward a bit more than my typical "house curve" but not excessively so. The default crossover for this speaker is tuned to the slightly darker side of a strict neutral tonal balance. I did this because that's my preferred tonal balance, it's helpful for avoiding fatigue in longer listening sessions, it can be a nice hedge against the classic "the speaker was soooo...revealing…it made bad recordings unlistenable…" phenomenon. To be honest these tonal adjustments are minor, but important to get that last bit of resolution/listenability out of a speaker. I've noted some parts you can swap to change the overall tonal balance without impacting the crossover summation/target tracking to the point where I think it "breaks" the crossover.

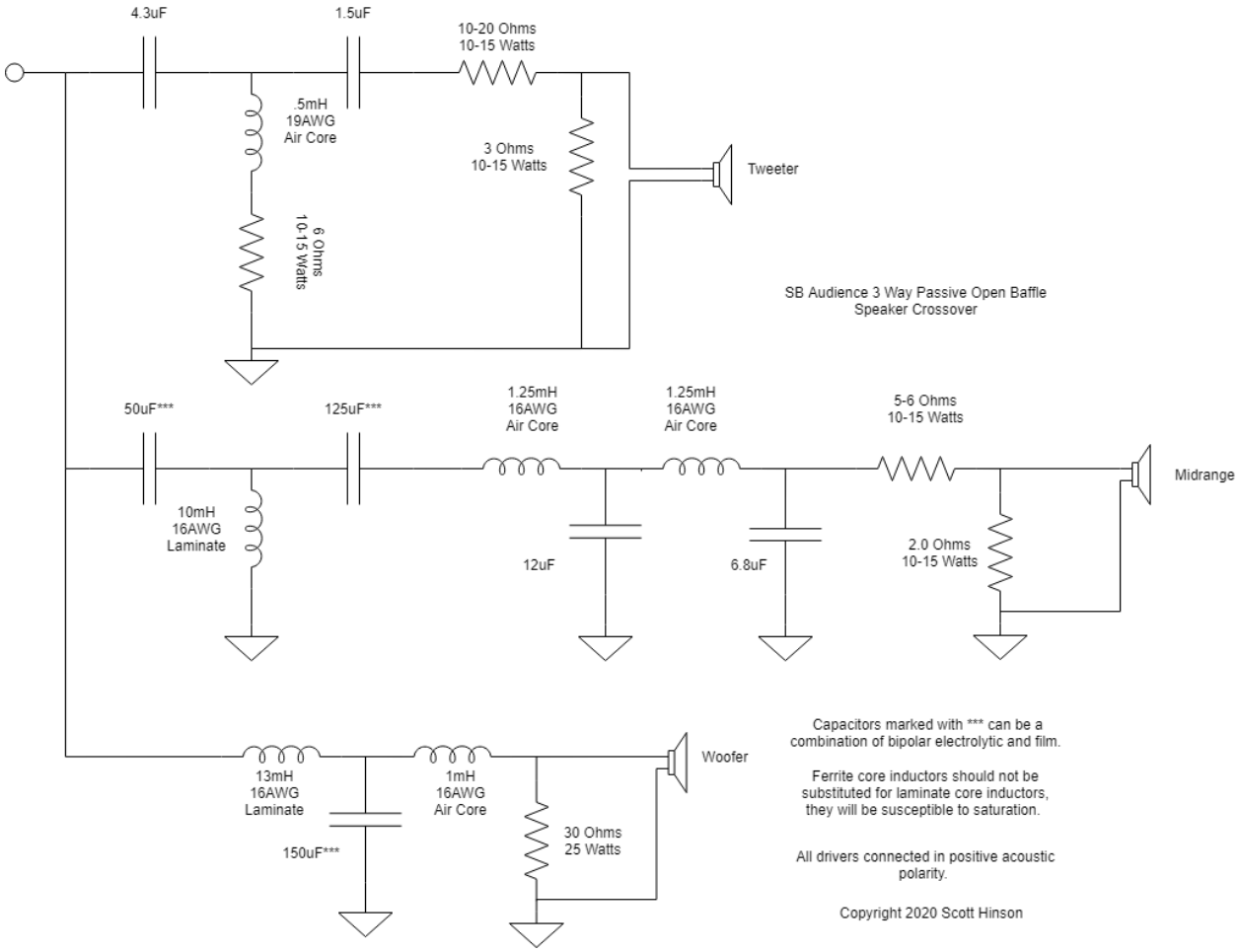

Figure 8 Full Schematic

The crossover has a couple of options to it…you can put anywhere from 10-20 ohms in series with the tweeter. I liked 20 ohms for most of my listening, but it could get a tad mellow on classical music. The midrange series resistor can be anywhere from 5-6 ohms, I liked 6 ohms the best. Much more change than that and you can start to run into bigger shifts around the crossover frequencies than I'd like. One thing to note is that the design is pretty sensitive to the value of the 2 ohm resistor in parallel with the midrange, make sure you use a 5% tolerance part or better there, and don't substitute one value up/down because it'll be "close enough". Listening results with a 1.8 or 2.2 ohm resistor there weren't bad, but definitely not my preferred sound.

Figure 9 Crossover Options

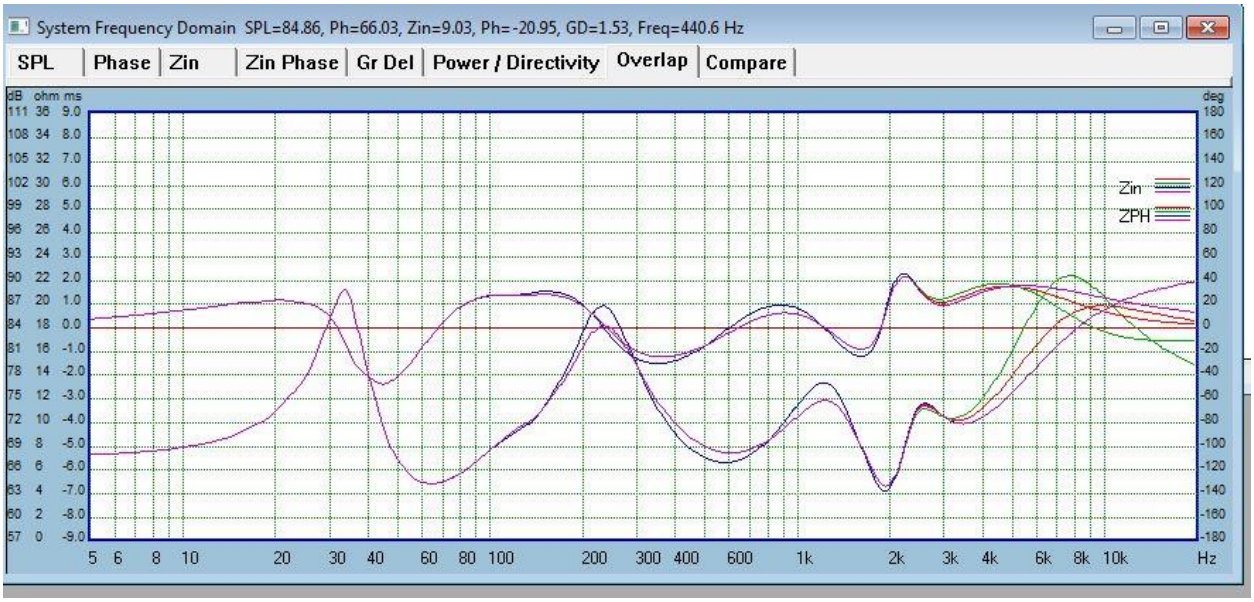

Figure 10 Impedance

While the speaker has a couple of relatively narrow band dips to just over 4 ohms…I would easily call this an 8 ohm speaker. It should be an easy load for most amps to drive.

One important note….the woofer crossover has a 30 ohm resistor in parallel with it…do not leave that out. Without it the high QTS woofer impedance peak shows an impedance swing wide enough that amplifiers with a marginal grasp on stability may have some issues with the completed speaker. The magnitude isn't the issue…but the phase of the electrical impedance swings more than 45 degrees negative without it. (Competent amplifiers with a firm grasp on stability won't have an issue, but you never know what amp is going to get hooked up and better safe then sorry with that cheap insurance.

"Cabinet"

This is a major advantage of open baffles…the cabinets are pretty easy to make. I designed these to be built with easy to get materials. I made mine out of Baltic Birch 18mm ply, but you could make these out of the 2'x4' project panels at the big box home improvement stores. The baffle is 24" x 39" and the minimum level of bracing can be made out of 1x4's or even ¾" project panels with a rip cut. If you get the panels cut to size at the hardware store, you could make this speaker with a jig saw (being super careful on mounting hole tolerance), chop saw and a drill for some pocket hole screws.

Minimum Tool Set:

- Jig Saw
- Chop saw or miter box/miter saw.
- Drill
- Pocket hole jig.
- Clamps

Nice to Have Tool Set:

- Table Saw
- Router with circle cutting jig.
- Transfer Punches.
- MORE CLAMPS

Makes it Super Easy[2]:

- CNC Machine.
- MORE MORE CLAMPS

The drivers are surface mounted onto the baffle. Based on the crossover frequencies, and directivity of the drivers there is no advantage to be had by flush mounting them. The drivers don't paint the baffles with enough energy to cause diffraction ripple bad enough to be detrimental to the sound. You can if you'd like for looks, but keep in mind that the frames of the woofer and horn are thick enough where you'll have to double up on the baffle material to have enough wood for mounting screws to attach to.

[2] Cheater cheater, pumpkin eater….also…what I did.

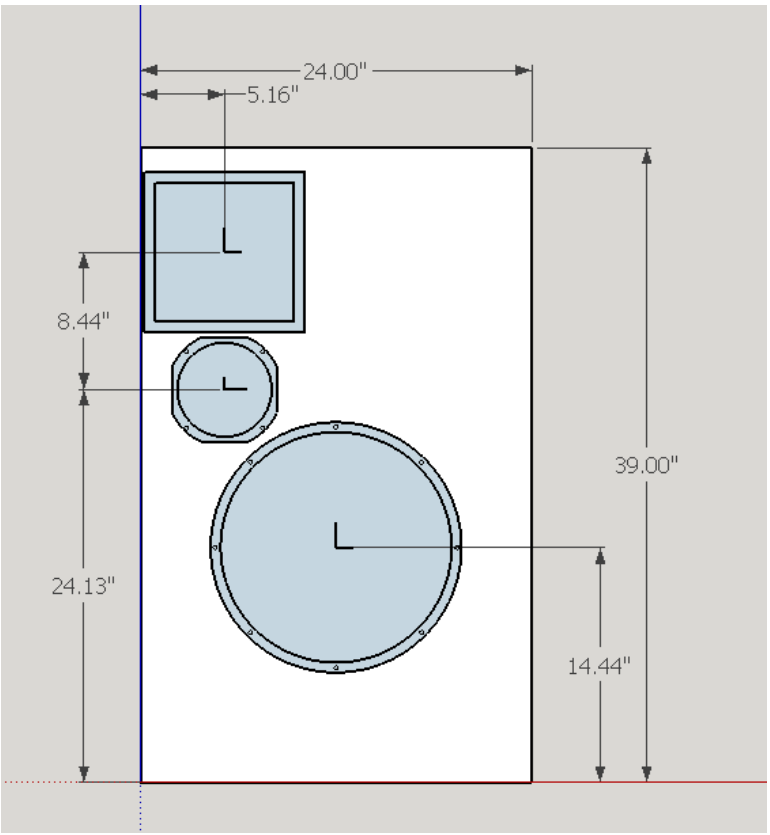

Figure 11 Driver Locations

The woofer cutout is 14.18”, midrange is 5.78” and the tweeter cutout is an 8.5” square. To do the cutout on the tweeter, I would drill holes large enough for a jig-saw blade to fit in at all 4 corners and then cut the straight sides with the jig saw. (I cheated and used my CNC for the pair I built.)

My minimum level of baffle bracing is shown in Figure 12…that’s the baffle/bracing I designed the crossover with…but there is certainly room for improvement. **Error! Reference source not found.** shows an optional brace design that improves overall baffle rigidity. There’s certainly some room for improvement and experimentation. Do make sure you keep the braces open/small enough to not form a substantial H-frame type open baffle…that would require adjustments to the crossover.

You may also wish to experiment with constrained layer damping on the back of the baffle or even the horn body itself…there could be some room for improvement, but from experience these types of modifications will quickly run into a point of diminishing returns. I’ve performed some rather heroic damping experiments with horns like this only to A/B with a stock horn and think….hmmmm….not sure it’s worth it. A bit of bitumen damping pad wouldn’t be a bad idea, adding 2” of cast plaster all the way around probably isn’t worth your time. Don’t ask me how I know.

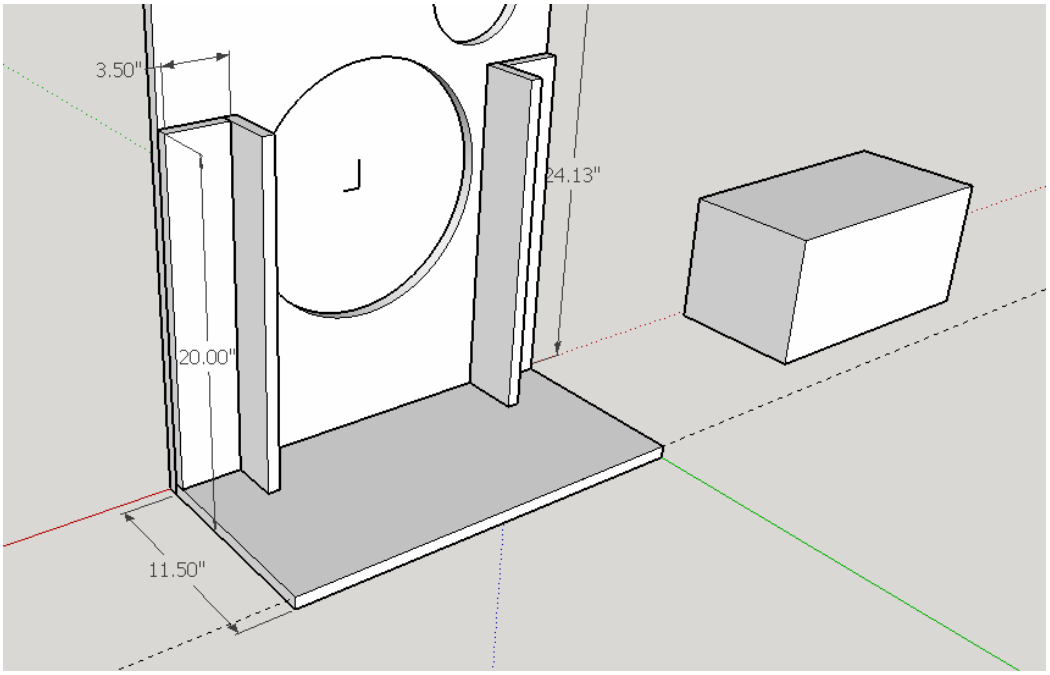

Figure 12 Baffle bracing and base dimensions.

The base is designed so that you can use a cinder block as ballast, again I was trying to make this as easy to build with common hardware store pieces. This makes the cabinet less prone to tipping forward.

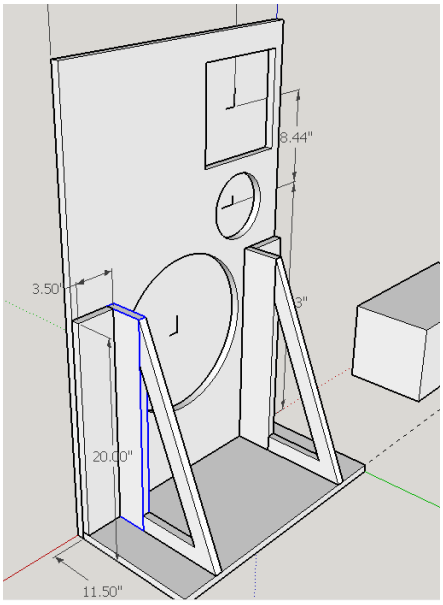

Figure 13 Optional Bracing

Other Modifications

Please do not change baffle size, driver locations, driver models or wholesale crossover changes. Any of these changes mean wholesale revisions to the crossover and it's a whole new speaker…I won't be able assist with any issues you may have in construction/sound.

Sound?

How does this speaker sound? Fantastic, open airy, yet with proper room placement bass is good and punchy. All of the typical benefits of open baffle bass are present, less room interaction means less chance for room node bloom and boom…

Because of the low distortion nature of the speaker and the near unlimited output of the mid and tweeter, I must issue a word of caution. Distortion is one of the ways your ear/brain mechanism determines if a sound is loud…since the speaker is so effortless you can easily be louder than you think. I've been known to listen with an SPL meter by my side to make sure I'm

not exceeding long term limits and damaging my hearing without realizing it. When you first start listening with this speaker I suggest you do the same.

With all of the pro-sound PA speakers I've developed over the years…I did have a odd bias when I was doing the crossover design. With my eyes open I kept expecting to hear that larger than life, big PA trap box sound coming out of these speakers…after all the baffle size and driver compliment look like that. But that is not what you get. When I close my eyes and imagined a smaller tower speaker or mid-size stand mount speaker that's when things snapped into focus for me. That is the sound I was getting, except more focused and far less room interaction blurring the mids and bass. Imaging is fantastic with diffuse recordings having a more diffused soundstage and focused recordings having a rather good pinpoint image, you can point to the spot in space where the vocalist is standing.

For those wanting *really* high output bass (or *really* deep bass) you'll probably want to add a subwoofer. As they stand the woofer displacement capabilities create a lot of bass. You can get kick drum bass/bass guitar bass you can feel without having to add a subwoofer. While open baffles minimize room interaction, they still have some, so play with positioning a bit too. I think a lot of folks will find they do not end up needing a subwoofer...especially if it's a music only system.

Enjoy these, play with them….check out those crossover variations and have fun!

And do watch those fingers. (shakes smooshed puffy sore pointer finger)

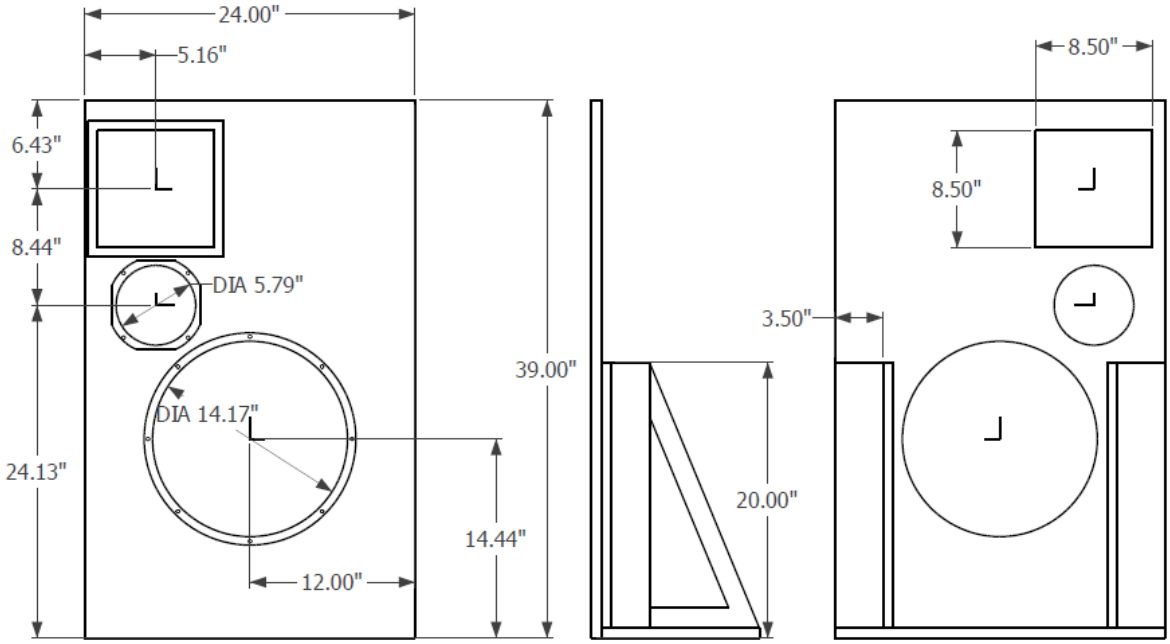

Figure 14 Full Drawing