BACKGROUND

I received a surprise quarterly bonus from work and decided to build a pair of speakers using said bonus. Although these speakers are named "O'Ryan", the working name was initially "The Bonus Babies" – a nod to the days of pre-free agency in baseball, my favorite sport (go Cardinals!).

I enjoy designing and building 8" 3-ways. To date, I have done five of these types of designs and had lately gotten the itch to do another one. While I was pondering which drivers on my shelf would be best suited, I decided to put a couple constraints on the project. First constraint was it should be approximately the same dimensions as a previous 3-way I had recently completed. Second constraint was the design needed to be reproducible. Third constraint – one point source for all components. Of course, if you are building this design you can source your components wherever you can find them.

In this case, I elected to use Parts Express for putting together the BoM – but I *did* source all of my components from a variety of sources including Ebay, Meniscus, Aliexpress, Apex Jr, and others.

DRIVER SELECTION

Tweeter:

When GRS released a "knock off" of the Fountek ribbon line, I purchased a pair of the round faceplate model. It was always me intention to use it in an 8" 3-way design but never got around to doing so. I always came up against finding a mid to blend with it. So they sat on my shelf for a year or so. These are beautiful looking drivers with a nice aluminum face plate. The recessed ribbon element means diffraction concerns will be minimized, and they can cross as low as 3200-3500Hz which is perfect for a 3-way.

Midrange:

HiVi recently released a 3" dome mid – and since it was coincidentally quarterly bonus time at work I ordered a pair. They are an unknown driver and since I enjoy working with stuff no-one else uses I decided these would be my midrange of choice. These are interesting drivers, to say the least. They stand very proud of the baffle – complicating time alignment in a passive crossover. The dome is not sticky (a nice change from so many dome midrange drivers out there). The surround is a larger than expected half roll type and the aluminum faceplate has some slight sculpting around the inside edge.

Although the large diameter (>6") technically requires a lower crossover point than the ribbon can handle I decided that I would not worry about that too much since these are likely never going to be listened to at 1M. The further to a listening position, the less critical the theoretical ideal center-to-center spacing becomes and the more important first arrival and power response become.

Woofer

That left me with needing a woofer. I already knew I was going with an 8", but it had to model well in 1 cubic foot. This constraint was based on a previous 8" 3-way I designed (Le Petite Sarcophage) – this was to be able to re-use the stands I had made for those speakers. After modeling a half dozen different woofers across a range of price points, I settled on the Dayton Audio Designer Series aluminum cone 8".

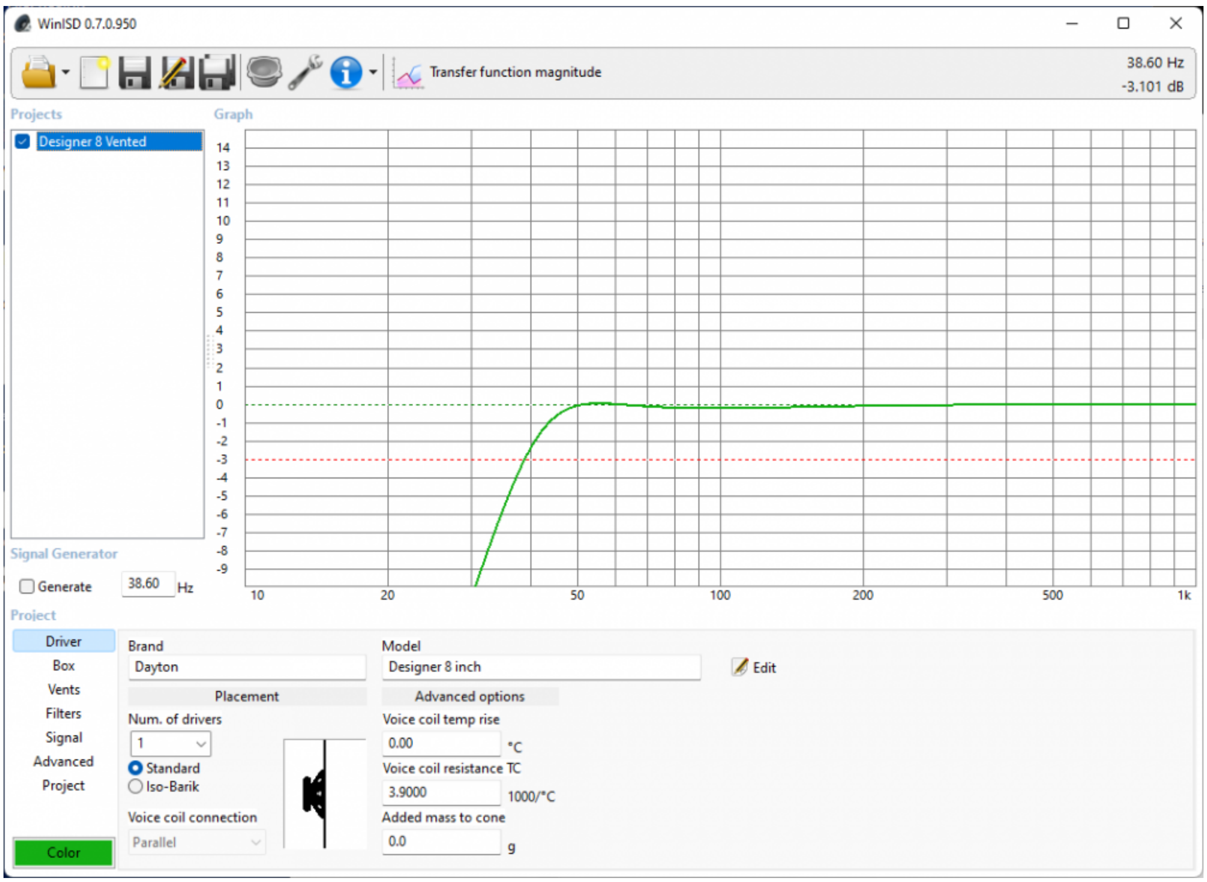
It modeled very well in the enclosure and although not “cheap” it does offer a solid value. They are also a good looking driver, and that matters.

These also came out of my work bonus.

BASS ALIGNMENT

Having constrained myself to a more or less specific form factor, coming up with a bass alignment was straightforward. I had chosen the woofer based on the cabinet I had already designed in my mind. This is backwards from what the normal approach is – which is to grab a woofer, measure it and then design the cabinet around those measurements.

Here is the modeled response of the woofer:

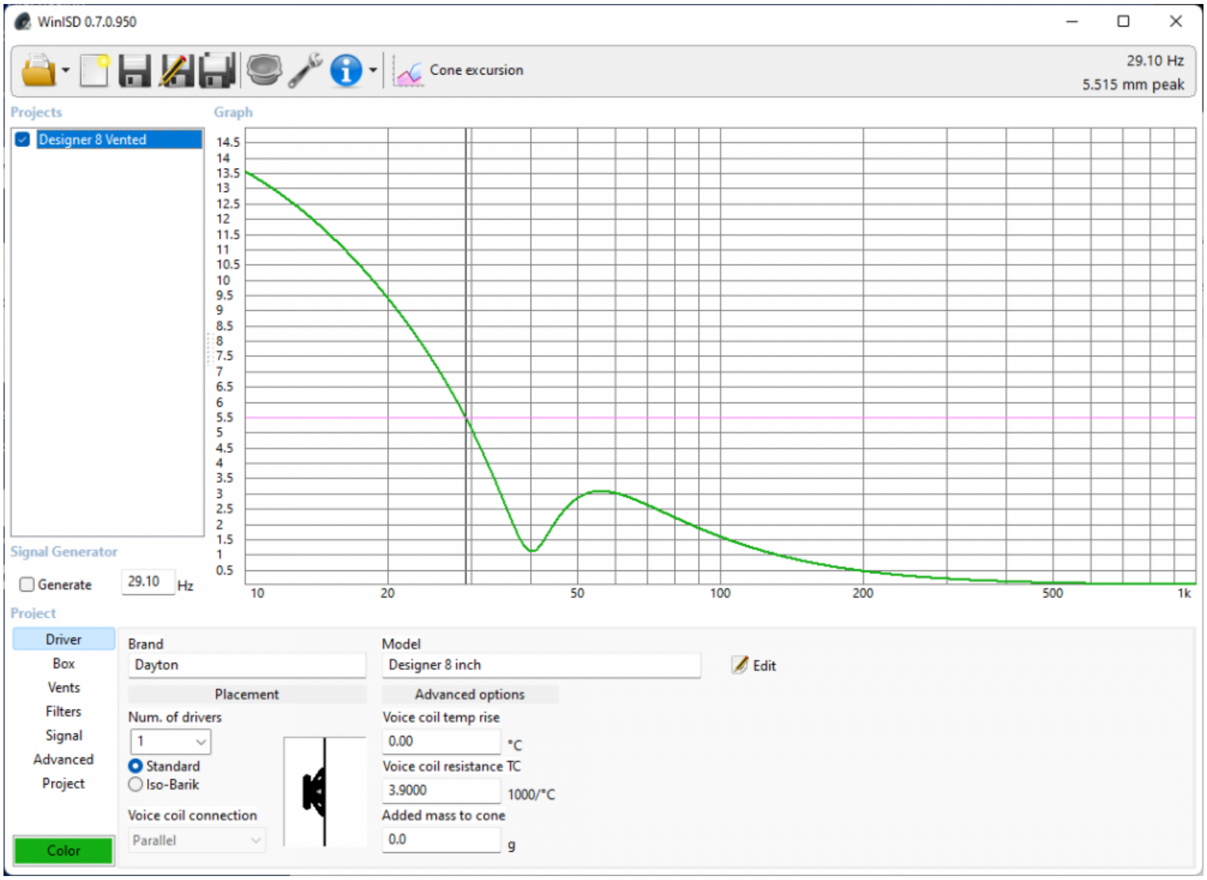


One minor mistake a lot of beginners will make when designing their bass alignments is forgetting the impact series resistance will have on a woofers behavior in a given enclosure. While we cannot know for certain how much series resistance we will have until we finalize a crossover, we *can* make reasonable assumptions. In this case, my initial model utilized 0.5ohm of series resistance. However, the final iteration of the crossover ended up with 1.2 ohm of series resistance. The model above is with the 1.2ohm.

The woofer models very well, from both an extension and mechanical power handling perspective. The modeled response indicates a F3/6/10 of 39/34/30. The models were done with an input of 20W –

which yields anechoic SPL of 100db. At these levels, cone excursion is kept below advertised Xmax to 29Hz – which is well below the content of most music.

Below you can see the excursion behavior:



In addition to superb mechanical power handling, these woofers will handle quite a bit of thermal power. These can be considered “crankers” – do not be afraid of the volume knob, especially if high-passing around 40Hz to a subwoofer.

CABINET DESIGN

As indicated above, I constrained myself to a specific size of cabinet. I like to target a certain aesthetic, based loosely on the golden ratio as well as ratio of driver to baffle size. The dimensions I chose for my last build ended up very appealing to me so I chose to come very close to that on this build.

I also wanted the cabinets to be easily reproducible by potential builders. To that end, they use all ¾” MDF with two simple internal braces. The drivers are flush mounted and there is a ¾” round-over on the baffle so the cabinets are of an intermediate difficulty to duplicate as it requires some specialized tools or techniques.

In this particular case, I hired a local company to build these cabinets based on my design. They were also coated by them, and they turned out very nice.

The braces attach to the rear baffle and the two sides and are evenly spaced out on the vertical plane. Generally I do quite extensive bracing, but again – reproducibility was one of the design goals.

The overall dimensions are (WxHxD) 11-1/4” x 22” x 14”. They are not super heavy, nor particularly clumsy to carry so they are easy to move around – important during crossover design phase.

There is a 2” Precision Port that is mounted directly behind the tweeter, and 1/2lb of Acoustastuff behind the woofer and the midrange. I am not sure what effect it has on the bass alignment, but it is likely to have some - I have not measured before and after the fill.

I used the standard Dayton Audio “heavy duty” binding posts in the satin nickel. I like them, and they take the spades that I terminate my cables with just fine. They also look nice – not gaudy, they just look like they get the job done.

Overall, cabinet construction will be straightforward for anyone with experience building boxes. The round-over and counter-sunk drivers are the only aspects that need special tools.

DRIVER MEASUREMENTS/CROSSOVER DESIGN

I initially consider writing a lengthy description of how the crossover evolved, but decided to just link to a thread I started on my forum (ask me for invite):

https://diy.midwestaudio.club/discussion/2120/8-3-way-coming-soon/p1

Quite a bit of the journey these speakers took is included on that thread, so this section will just be a summary of the crossover work.

It is not a cheap nor simple crossover. There are three notch filters – one to control some off-axis issues in the midrange and one each to suppress the impedance peak at Fs on the mid and tweeter. All three are necessary in my opinion. Otherwise, the crossover is actually pretty typical.

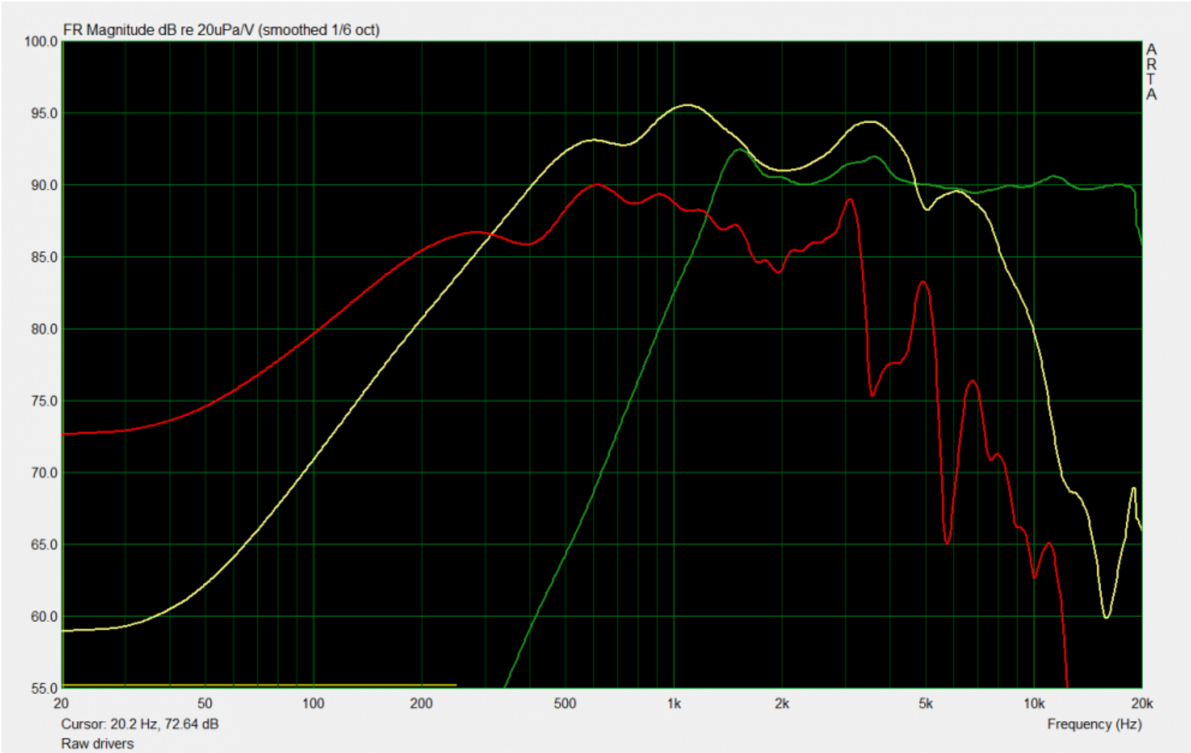
The tweeter distortion is somewhat higher than the other two drivers, and the distortion is largely 3^{rd} order dominant. This can lead to a false impression of detail that over time *might* become fatiguing.

What surprised me the most was the on-baffle response of the tweeter. It shows almost zero diffraction related linear distortion, this is likely due to the mounting depth of the ribbon element.

The midrange has decent on-baffle response and sensitivity, as well. Not perfect by any means, but usable. It surprised me at how capable it is on the bottom end. Clean across the entire usable response, and the distortion that is present is 2^{nd} order dominant. A lot of people consider 2^{nd} order distortion to be euphonic in nature. Given the larger radiating surface of the driver and the clean performance on the bottom end I would imagine it could be used as low as 350Hz with few issues.

The woofer is excellent, as well. The only drawback is the complex breakup starting around 2K. The distortion is low – especially on the bottom end – and response is fairly linear out to 2K before the breakup gets in the way. I can definitely recommend this woofer – especially in a 3-way, although it could be used in a 2-way with a robust tweeter and special attention to the break-up.

Here is a picture of all three drivers on-baffle:



The tweeter exhibits twin peaks around 1500 and again around 3500. Not ideal frequencies to have excess energy; it can be compensated for in the crossover.

The midrange has a bit of linear distortion on-baffle. This is somewhat more difficult to deal with. It also has an off-axis issue around 1200-1500K that seems to radiate at the same power regardless of what axis I took the measurement. It necessitated one of the notch filters to knock that energy back a bit.

The terrible break-up on the woofer is much more obvious on this graph. Due to the lower crossover point I am using on the woofer to mid transition, I did not worry about it. I shoot for 30-40db down for break-ups to become inaudible and I hit that target.

I take all of my measurements at 1M on the tweeter axis. They are SPL accurate as verified by my calibrated Extech SPL meter. I display 1/6 octave for visualization, but export my FRD files in 1/24 octave smoothing. I understand that the dips and peaks are greater in magnitude than my measurements above show.

My approximate method for taking measurements is as follows:

1. Start with tweeter and target 90db/1M. This is my personal baseline.
2. Then do the midrange (or woofer if a 2-way) without touching the amp volume knob.

I also do the usual stuff like taking a measurement of all three simultaneously and using that measurement to derive acoustic off-set. Since I design around the tweeter axis using simple on-baffle measurements I derive that information purely out of inquisitiveness.

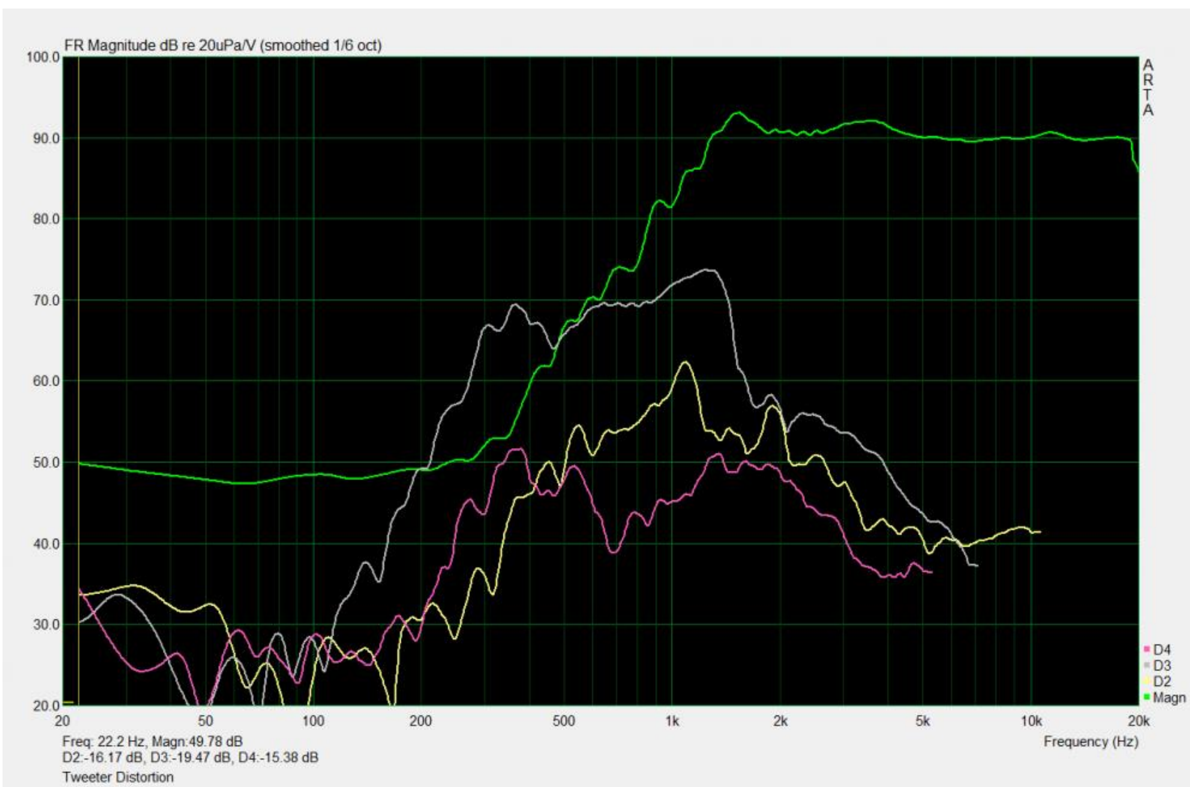
Let's talk briefly about DIY measurements. All of us use gated measurements, some of us take nearfield and splice (you have to extract minimum phase and go through the exercise of calculating acoustic off-sets if you do that), but to my knowledge no DIY'er has access to an anechoic chamber. That being said, for design work I believe the DIY approach to be perfectly acceptable.

Another thing to consider is DIY'ers all vary slightly in their approach to measuring. Most of us, myself included, probably don't spend near enough time taking initial measurements and too much time spent clipping and un-clipping components in and out of a rat's nest. I take many secondary (on and off-axis) measurements during the LMT (listen, measure, tweak) phase and tertiary measurements - which are the simple measurements I publish of the on-axis response after a design is buttoned up.

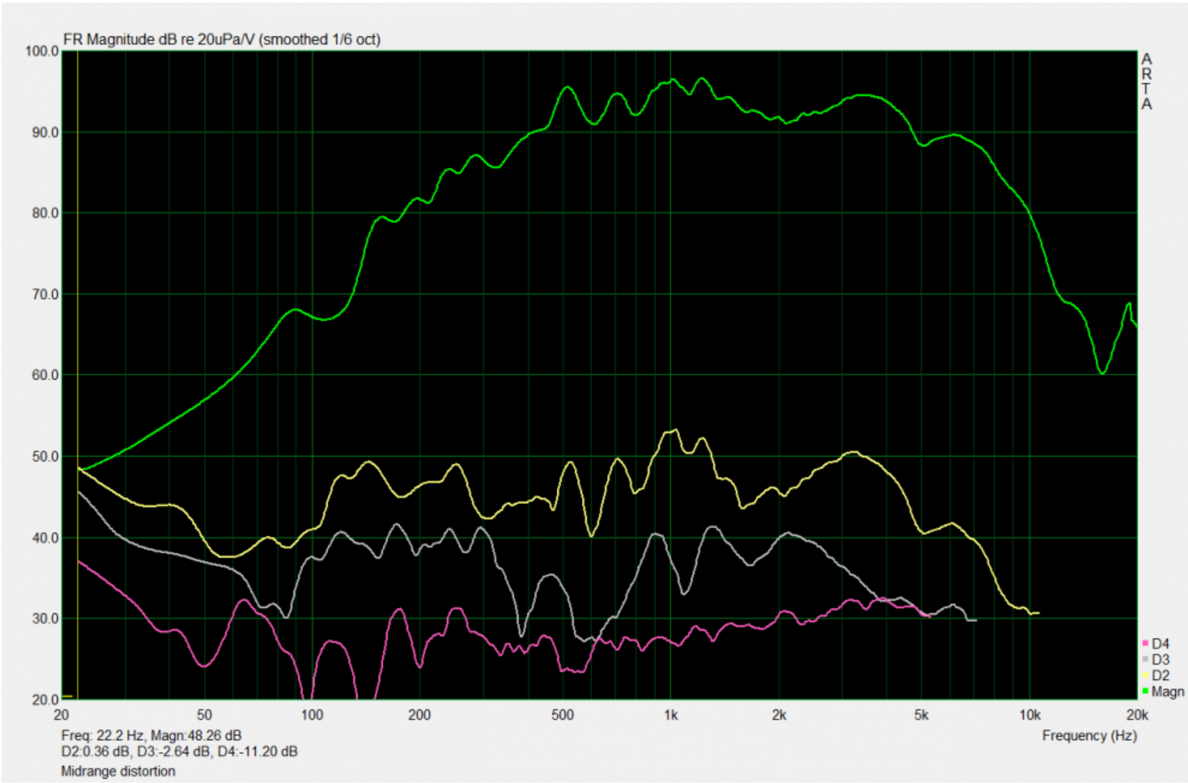
My measurements should not be used as gospel – they are just another tool for me to try and nail a design. Do not use them for tracing purposes, and I do not share my FRD files since they are only useful to me. I very often find myself tweaking padding resistors way more than I thought I would and that is because of my methodology vis-à-vis my amp volume knob.

Long story short, big grains of salt should be taken with my measurements. They are repeatable and consistent on my end but no way of guaranteeing they will provide identical results to someone else performing measurements on the same driver(s).

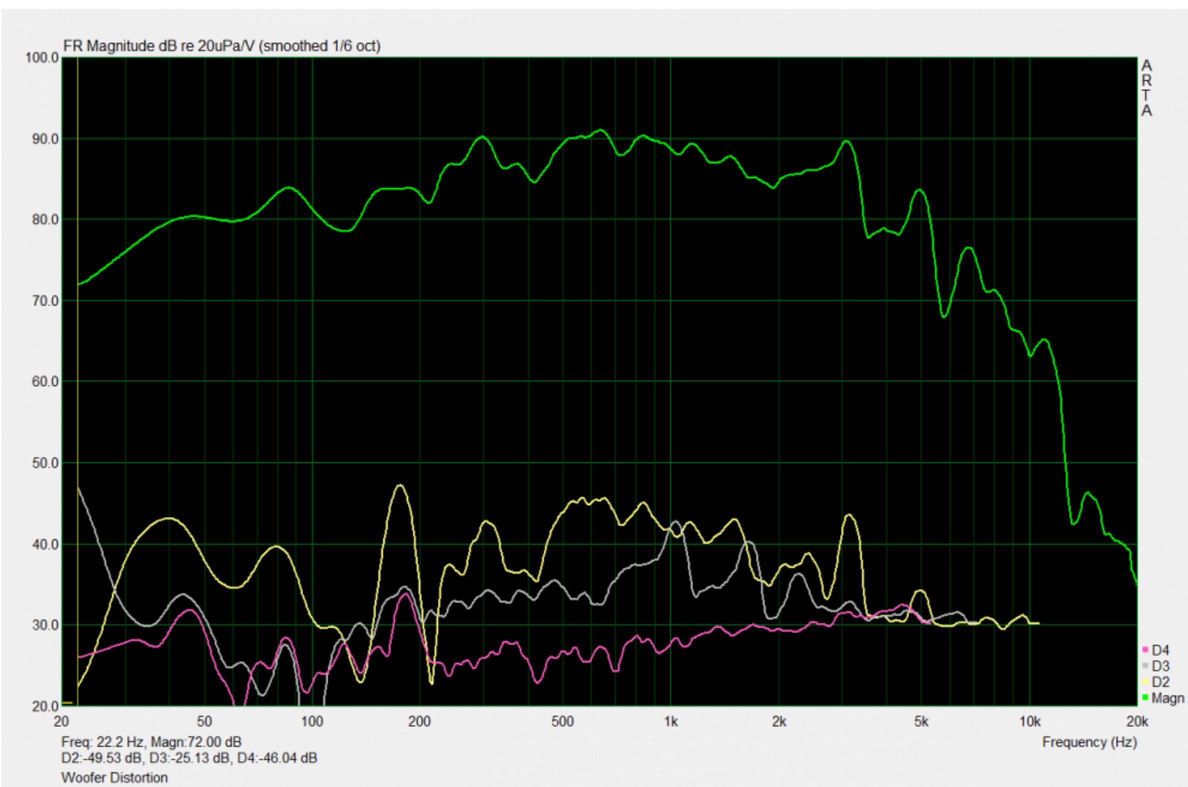
Here is my distortion measurement of the tweeter:



Here is the midrange:

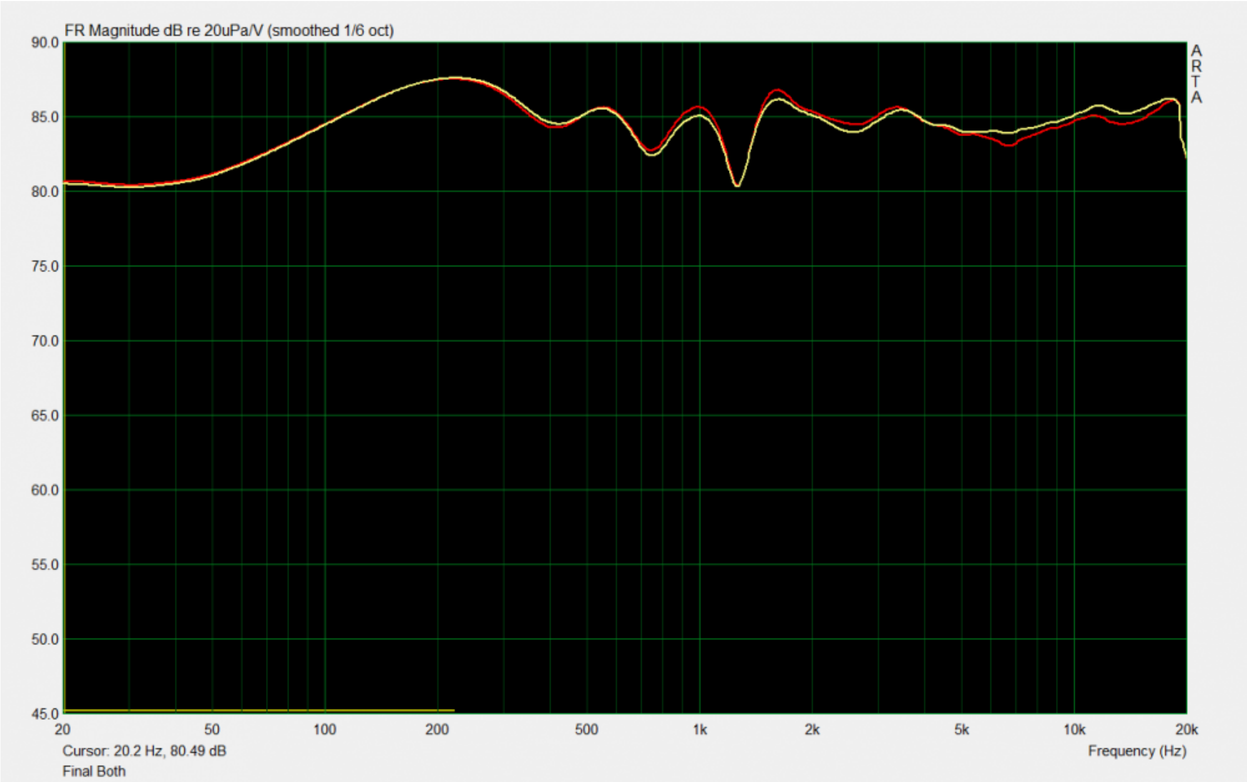


Here is the woofer:



All in all, other than the linear distortion of the midrange the drivers measure very well. The tweeter is smooth on and off-axis and as long as care is taken on the bottom end (keep in mind the posted measurement is done with a 20uF cap in series – necessary with true ribbons) it is very usable. The midrange is very low distortion and very sensitive so you can definitely address the peaks in the crossover and still have some overhead to play with padding options.

Here are the final measurements:

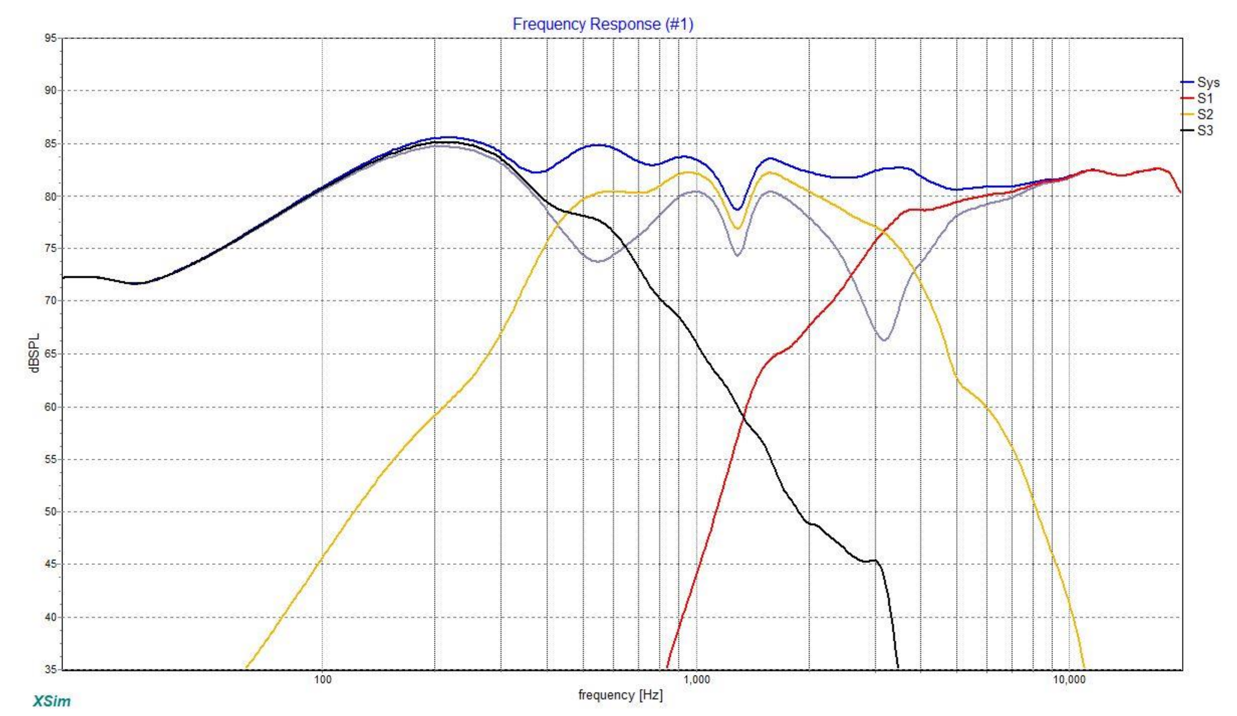


You can see the notch I put in at 1300 to help with excess off-axis energy. I may have slightly missed the mark on the notch, but even getting "close" was an audible improvement. There is a slight sensitivity mis-match between the pair – enough to probably color the sound slightly and smear the imaging a bit. Unfortunately, one channel the mid is more sensitive and the other channel the tweeter is. I used the speaker in yellow for my final LMT session.

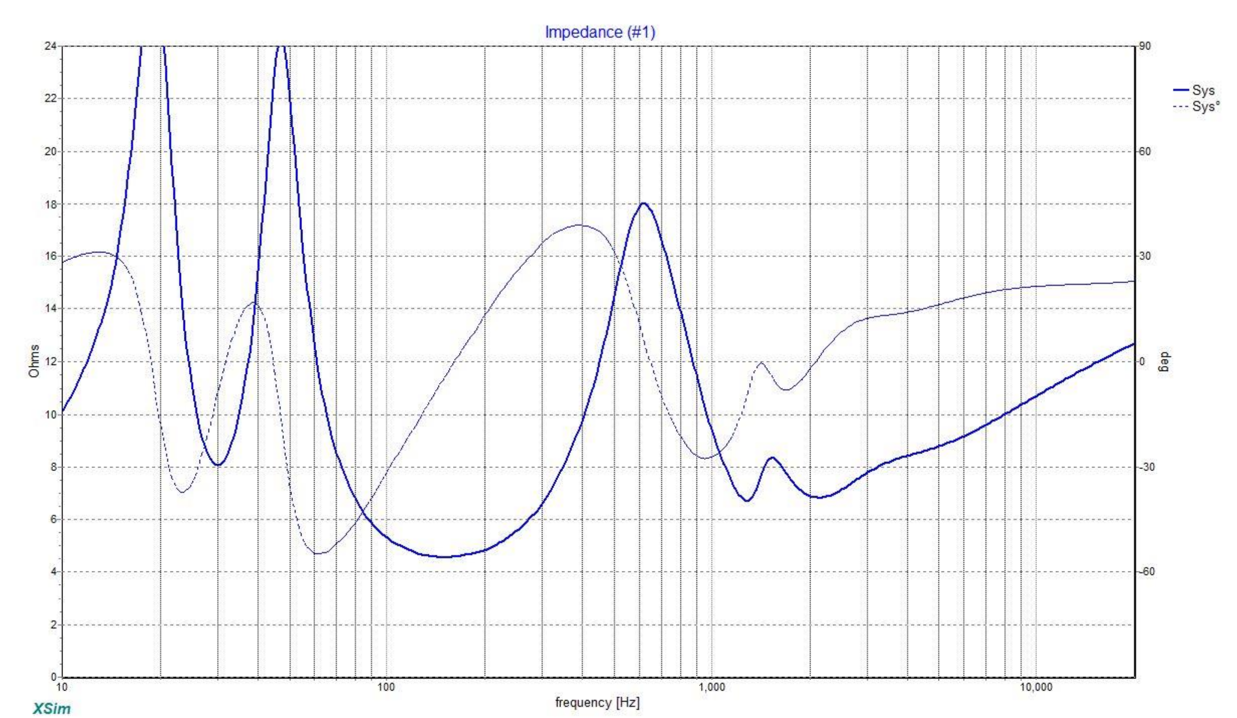
Imaging is largely a function of symmetry between pairs of speakers in both response and level matching. However, this pair has only about a 1db or less variation from one to the other so impact will be minimal.

It is a full baffle step loss corrected design, which was necessary since the bass is surprisingly lean on this. I am not sure where the modeling went wrong but things ended up tuned lower than expected so the roll-off is more similar to a sealed speaker than a ported. Not at all bad sounding – just expected a little more slam out of it. If I care enough about it, I will re-visit the alignment and try to figure out where I went wrong. As it is, I have dual 12" subs in my listening space covering the visceral side of things so it isn't a drawback for me.

Here is the modeled response, and (of questionable value) reverse null:



Here is the modeled impedance:



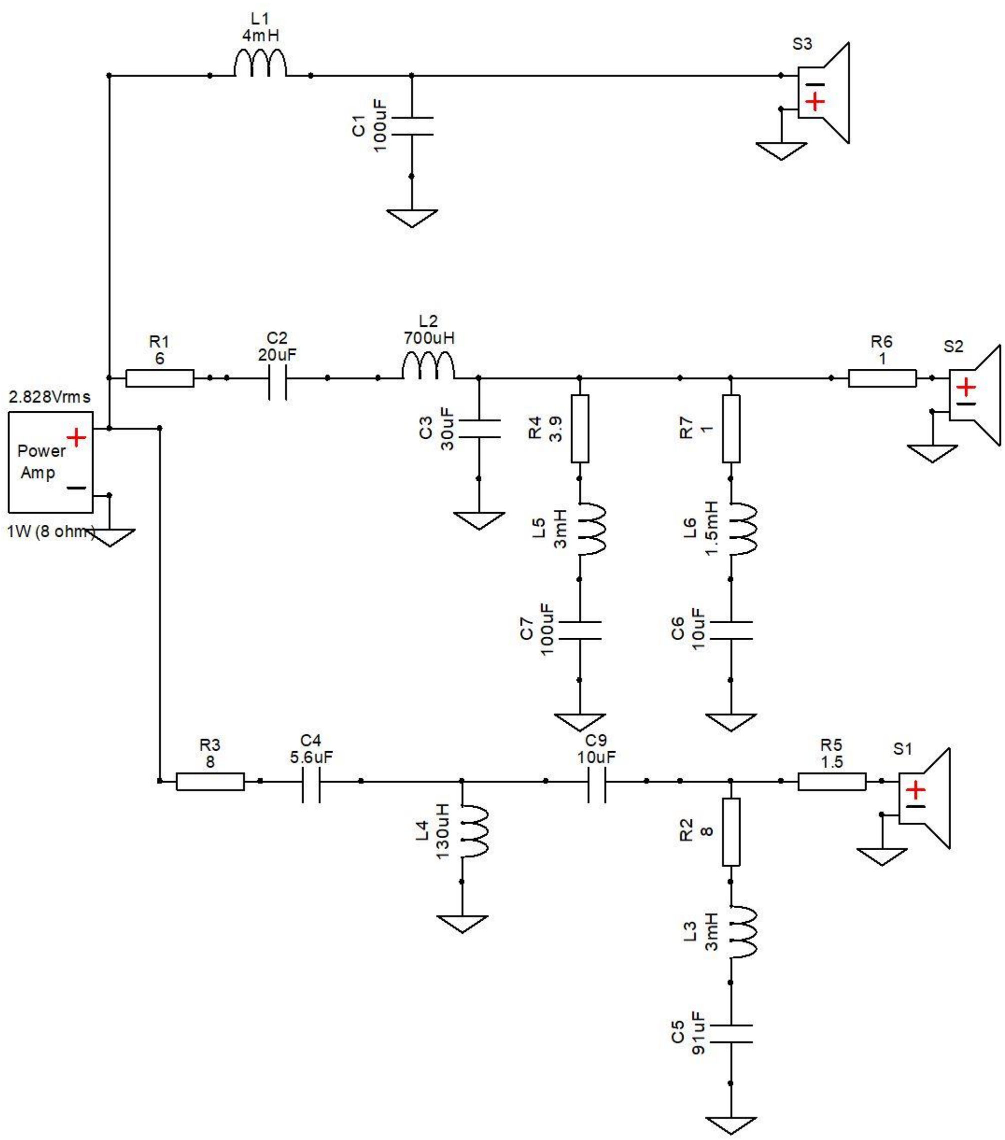
Nominally a 5 or 6 ohm design.

As I noted above, the crossover is not exactly simple. I normally target more of a “minimalist” approach whenever I can – but due to some of the issues each driver faced I felt obligated to ratchet up complexity a bit.

The woofer and tweeter are both straightforward consisting of 2nd order electrical on woofer and 3rd order on tweeter. The tweeter has a “split” padding set up, consisting of one resistor before and one after the LC components. The midrange uses the same arrangement. I targeted 550 and 3500Hz and got reasonably close to that. Drivers will tell you where they need to play when using basic networks.

The midrange was a different story – it kicked my *** for quite a while. I ended up with a notch at Fs and that notch to reduce energy in the off-axis. Otherwise it is quite normal – 1st order high-pass and 2nd order low pass.

Quite a bit of what I went through to get to that point on the crossover is covered in that thread I posted above. Here is the final network:



As you can see there are 21 components per side – quite a few. This is a physically large crossover as well - I used all poly caps. This is only due to having them all in stock in the "Nerdery". Under normal circumstances all of the shunt caps I would have used the NPE type. This would result in a considerably smaller crossover, not to mention lower cost. I provide a BoM using relatively premium parts as well as some cost-saving options. The difference is considerable.

Assembling the crossover was pretty simple. I put the woofer network on its own board and the midrange and tweeter networks are on a different board. However, since crossover design is iterative in nature and sometimes we button things up too soon – I added the Fs notches on both mid and tweet after I thought I had it buttoned up. So those are on dedicated boards, as well. Literally on boards – I use 1/8" x 4" bass wood from Menards as XO boards these days. They take hot glue like a champ – and glue to the inside walls of speaker boxes in a permanent fashion. Be sure you are done before gluing them in – unlike me.

The series resistor after the crossover is also separate – I added it inline after everything else and some extended listening told me I was still a little hot across the mids and top end. These are spliced in to the driver leads and are twisted and taped – leaving me the option to swap resistors in and out. If I am happy with where these are, and I have no reason to believe I should change anything, I will solder the connections.

I wish I had taken pictures of the finished crossovers – they turned out pretty cool looking with all those big poly caps!

I used air core on everything but the three notch filters (the 4.0mH job on the woofer drives cost up!). Laminate core on the notches. For the two 3mH coils I used some old small form factor buyout laminates that PE was selling years ago that I bought a pile of. The 1.5 is a Dayton out of my hoard.

Resistors are all NOS Dale or equivalent. They look cool since they are usually charcoal colored and "fat" in comparison to the modern green ones. I snapped up a pile of them across many values years ago for a fraction of what even the inexpensive Dayton sandcast cost.

I hope you enjoyed this journey. Between the thread I linked to and this document, it should be a pretty decent glimpse in to my design philosophy and methodology. Nothing magical here, and it should be noted that most of us have "finished" a design too soon and have to go back and rework it a bit. Don't believe otherwise – most of us generally do not publish our failures. I definitely have been secretive about the failures I have experienced – but this particular design I wanted to demonstrate that it is iterative and it is ok to get it wrong. We learn from it.

Read the thread I linked to above for more information including construction pictures.

Note: I recommend Jule Fidelity (JFComponents) for component needs.

Note: I do not know if the GRS is a drop-in for the Fountek. Feel free to send me a pair and I will compare them.

Note: I do not do subjective reviews. I will provide personal feedback – but only on request and only in private.

BoM

Desc	Brand	Qty	Price	Total
4mH 18AWG Air Core	Dayton	2	$17.98	$35.96
0.7mH 20AWG Air Core	Dayton	2	$4.98	$9.96
1.5mH 18AWG Laminate Core	Dayton	2	$6.39	$12.78
3.0mH 18AWG Laminate Core	Dayton	4	$8.59	$34.36
0.13mH 18AWG Air Core	Dayton	2	$3.69	$7.38
5.6uF Poly	Dayton	2	$3.51	$7.02
10uF Poly	Dayton	4	$5.48	$21.92
20uF Poly	Dayton	2	$8.46	$16.92
30uF	Dayton	2	$11.65	$23.30
25uF	Dayton	6	$9.23	$55.38
100uF	Dayton	4	$38.27	$153.08
1ohm Resistor	Dayton	2	$1.79	$3.58
4ohm Resistor	Dayton	2	$1.79	$3.58
6ohm Resistor	Dayton	2	$1.79	$3.58
8ohm Resistor	Dayton	4	$1.79	$7.16
8" Woofer DSA215-8	Dayton	2	$69.98	$139.96
3" Midrange DM-7500	HiVi	2	$99.98	$199.96
Ribbon Tweeter RT1.R-8	GRS	2	$84.98	$169.96
Binding Posts BPA-38SN	Dayton	2	$8.49	$16.98
2" Port	Precision Port	2	$10.49	$20.98
Cabinet fill	Acoustastuff (UoM = lbs)	1	$14.98	$14.98
Misc wire, terminals, glues, solder	Various	1	$25.00	$25.00
Cabinet material	Various	1	$50.00	$50.00
Total cost*				$1,033.78

*Cost Saving Measures

The six 25uF can be substituted with surplus 75uF from Apex, Jr. or 80uF NPE (-$48 for NPE)

Substitute the 100uF poly caps for NPE (-$145 for NPE)

You can try substituting the 30uF poly for 33uF NPE. Voicing is not guaranteed (-$20)

Sandcast resistors are also an option to drive costs down. (-$3)

Use PVC pipe or the Parts Express 2" adjustable port. (-$10)

Contact me: jr@midwestaudioclub.com