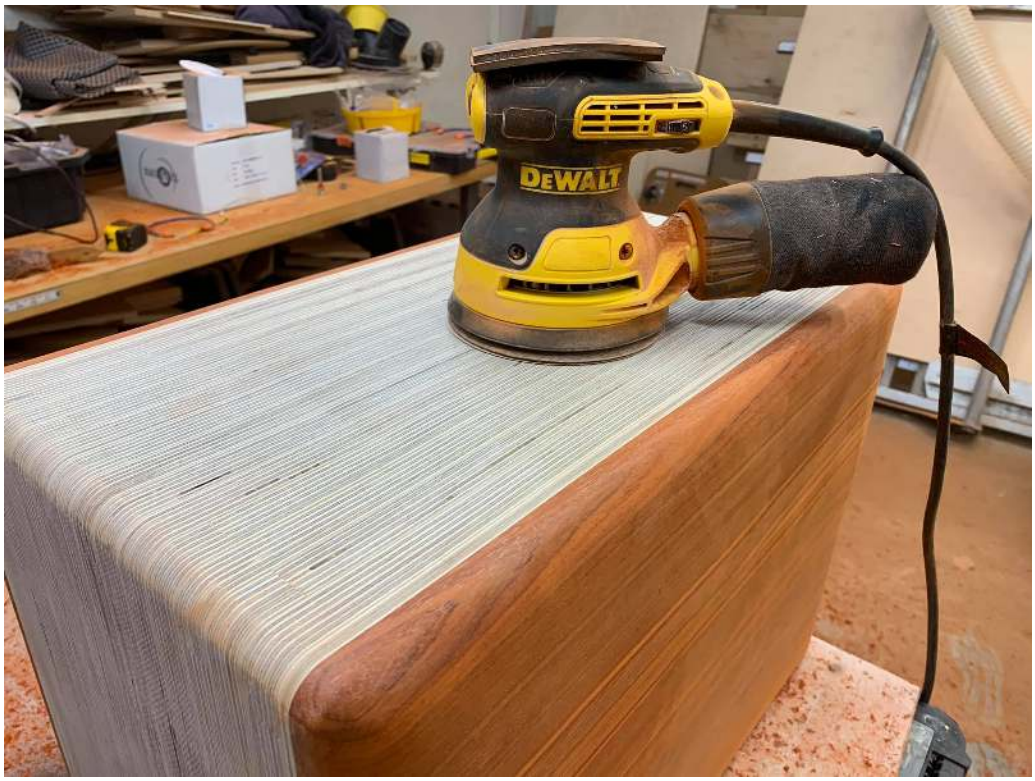

DEWALT

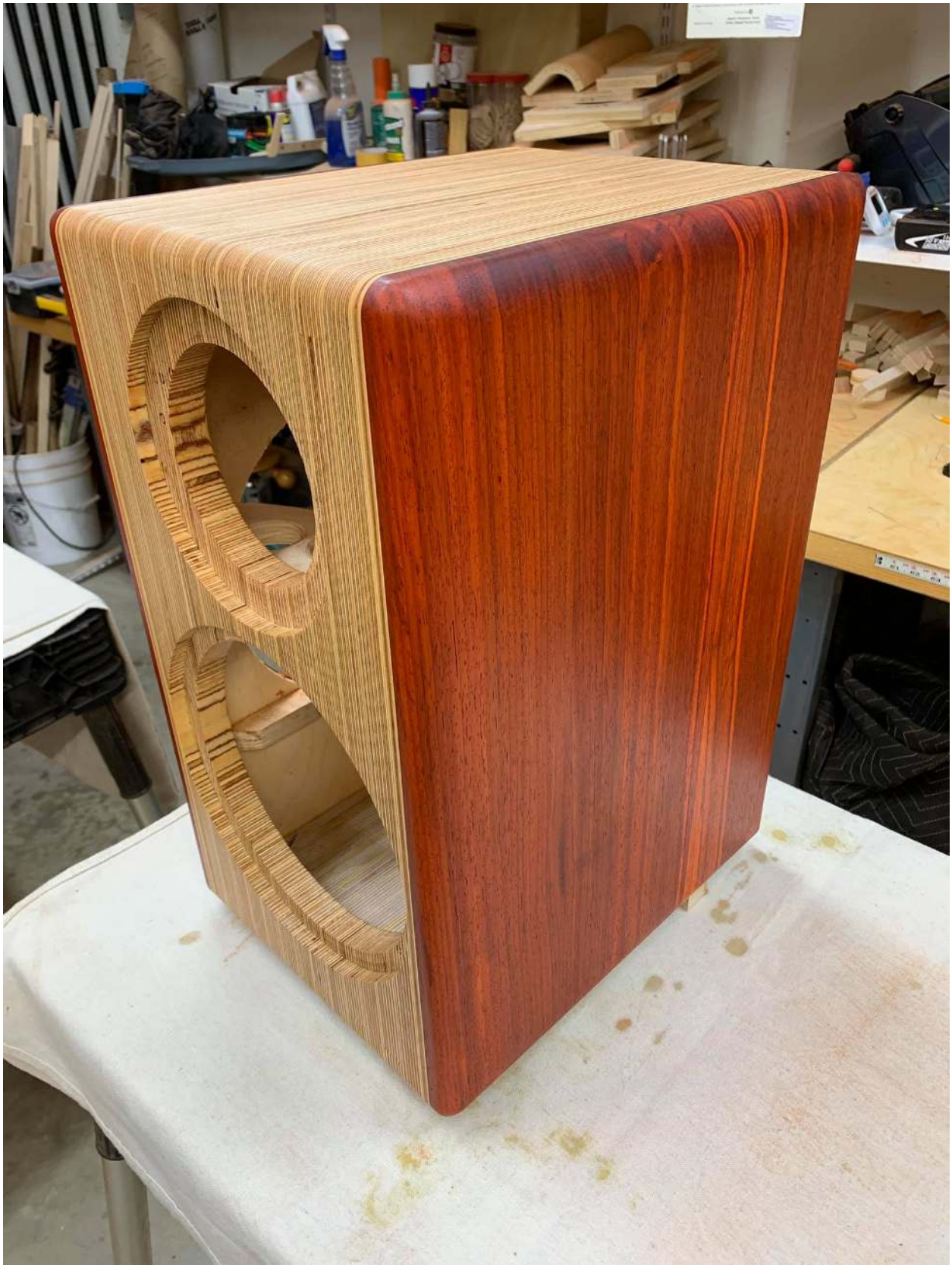
Helios Speaker Project Part 8 - Rubio Monocoat

Well by now you may have noticed I love this stuff 😊 For these 2 projects it was critical as time was tight and I really couldn't afford a week or two of time to do finish on both of these projects.

RMC gives a really uniform matte finish, it makes the grain pop and gives a surprising amount of build for a quick one coat application.

I sanded to a 220 grit finish, vacuumed and cleaned any left over dust off the wood and applied the finish in a clean shop. Mix the two parts, wipe it on with a rag, let it soak in for about 10 min then buff off. W/in 24-36hrs it's ok to handle and fully cured in 3 weeks.

After this fully cured I applied a furniture wax finish with UV inhibitors built in to help protect the wood and finish, the wax adds a nice sheeen and really makes the surface more uniform. Johnson's furniture was works well too with RMC.



Helios Speaker Project Part 9 - Final Waveguide Assembly, Driver Installation

Getting close to making some noise with these! After the RMC cured for about 36 hours I started to assemble the cabinet and drivers so we could start doing some test measurements and designing the crossover.

One new thing I tried on these cabinets that I haven't done before, I made the driver recess is over sized in the outside diameter, then I filled the space with neoprene gasketing tape with adhesive on one side. This allowed a tight gap free installation to prevent any type of the fraction issues for many camp around any of the drivers, visually looks really nice and allows the driver to be removed in the future without any fear of a binding with what expansion. I really like how it turned out as something I think I'll be doing more in the future.

Since the Satori waveguide is a prototype first article, I had the pleasure of disassembling this very expensive tweeter and installing it in the waveguide. Also since this was a prototype, there ended up being some fitment issues that I was able to correct, fortunately I have a good lathe and great engineers at work and they were able to make some tweaks so that the tweeter fit tightly into the housing without any gaps around the dome. My understanding is that in the future Satori will offer the tweeter with the waveguide already installed in the future, it sounds like they'll release information about that sometime this year.

Be very careful with any stray metal near the tweeter with the faceplate off, good idea to be careful even with the faceplate on, but the neo magnets on this tweeter are very powerful and will pull screws, tools and other metal right into the dome, and if that happens it would likely permanently damage the dome.

I used black metal oxide coated Phillips wood screws for all the drivers, the tweeter waveguide got -#6 screws, the woofer frame got #10 as well as the passive radiator. Threading into the maple Appleply is very secure with high torque and no worry about stripping threads.

At this stage I don't install the binding post yet, but I run the wires for the drivers through the binding post holes in the back plate, and then seal those holes from the inside with some black sealing putty.

Helios Speaker Project Part 10 - Crossover design

We've now reached the time for the big reveal on the Helios loudspeaker – the crossover and measurements and the explanations of the design intent. To back up just a little, after AXPONA last year when I did the Revolutions and then Javad and I did the Ceramicos, Bo Albrechtsen, Marketing Director for SB Acoustics asked if I wanted to do a set for 2019. During our discussion I commented that we should try something a little different and make a larger than normal two-way Satori using the WO24P 9.5" woofer with Satori motor and Papyrus/paper cone and SB's top tweeter the TW29BN, Beryllium dome / neo motor tweeter. Bo said he loved the idea and that SB was in the development of a waveguide designed specifically for this tweeter. This conversation launched the speaker we have today – The Helios. Helios is the Greek word for the sun, and I expect this speaker to really shine.

I began some preliminary design work. I wanted the speaker to be a stand mounted model of reasonable size, this presented some problems with the bass alignment, but I resolved those by using a novel bass loading system that I used on the Testarossas several years ago. I can't say that no one has ever done this before, but I have not seen anyone else do this before, at least not in the way I am. So, in my next post I will explain this bass loading alignment and what we gain from it. In some ways it may sound counter-intuitive, but you will see how it works to give us some of the best bass you will hear in a stand mounted speaker like this. For a speaker just over one cubit foot of volume to reach into the low 30's with very low distortion at the same time is really quite remarkable.

Once ready to build I gave Javad basic cabinet dimensions and volume, each with a little room for adjustment, and then gave Javad complete freedom in cabinet design and construction. I wanted the cabinet to showcase his talents, and I believe he has done a wonderful job of taking advantage of the opportunity, as you have seen from previous installments on the cabinet construction. He has built a magnificent enclosure. Likewise, I wanted the system design, frequency response, and crossover design to reflect my talents, so on with the story. I will try to let you in to my thought process as I go, and this make be beneficial for some wanting to know how my design process works.

I used the three measurement method to find the relative acoustic offset from the OmniMic data. I won't bother sharing what the value is, because it is only valid for this set of data. (in other words it may not be the real offset, but it is the one that works). However, I will show the graph of the measurement of both drivers together (gray) overlaid with the simulation in PCD (black) using the individual driver data and the dimensional offset on the tweeter axis that I arrived at. This is how well your measurement and your simulation should match. When it matches like this then you have very high confidence that your crossover will produce very predictable results. You must go through this process when using Omnimic or your driver phase will not match with reality and you will not get the summation you think you are going to get.

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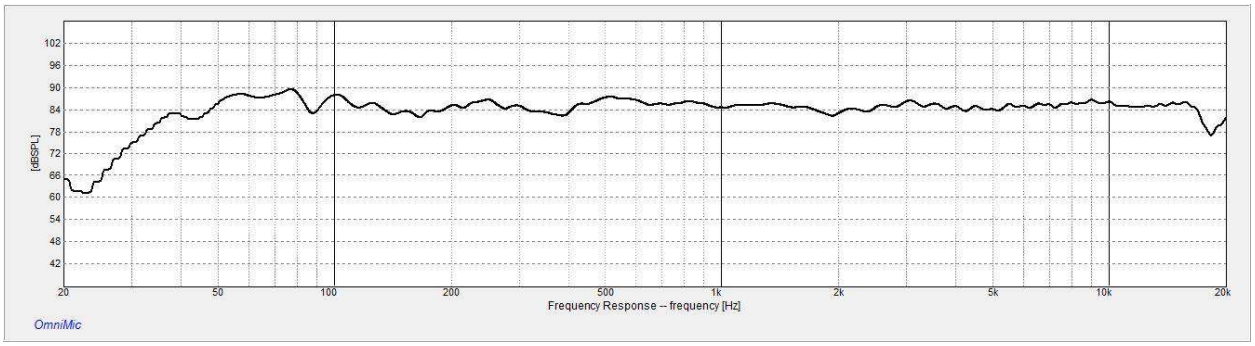
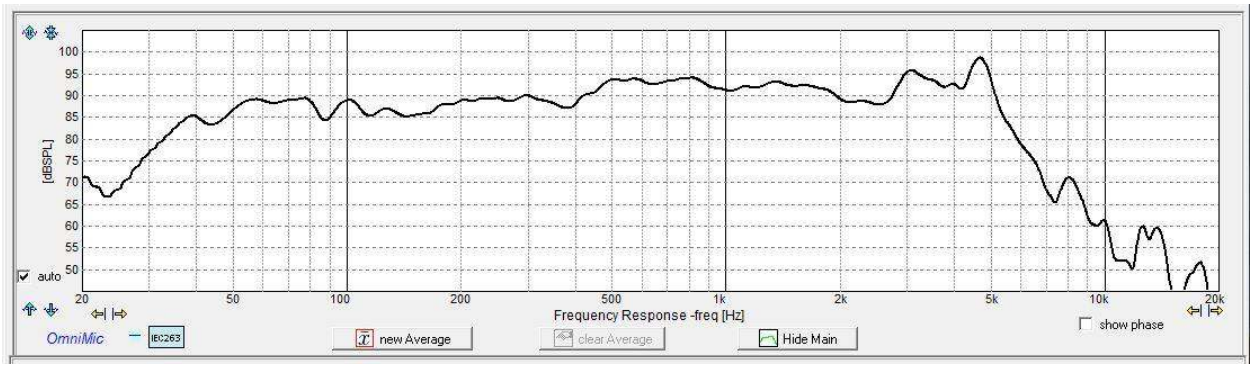
process when using OmniMic or your driver phase will not match with reality and you will not get the summation you think you are going to get.

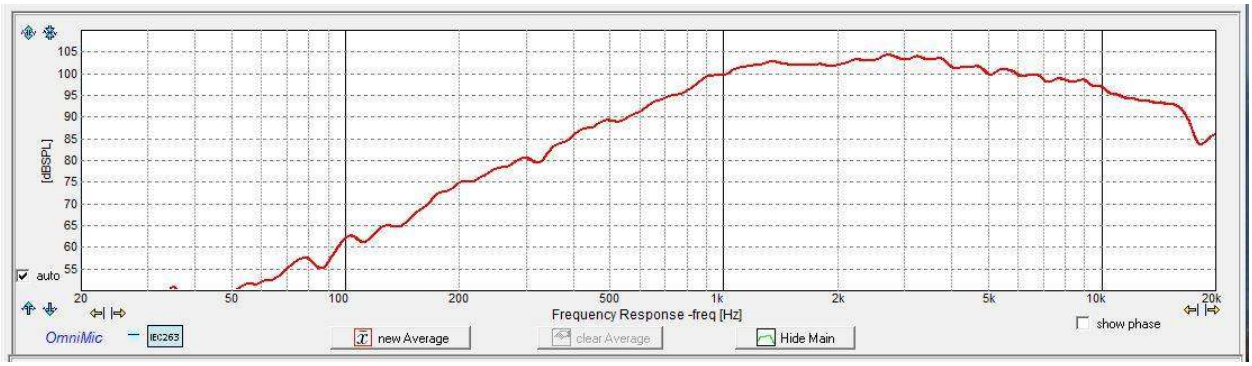
In the design process, the first thing I always do is work on the woofer's crossover to level it out and give it an initial low pass in the region I expect to end up in, knowing that this will change some when I begin to dial things in. I use the response at around 200 Hz as a reference, this establishes the overall sensitivity of the speaker. I don't concern myself with things like baffle step compensation, I simply target a level frequency response, all of the rest is taken care of in this process.

Next it's time to work on the tweeter. The initial goal is similar; to flatten its response and level it out with the woofer's response. Most of the time, this isn't a big deal because the tweeter is usually fairly flat to begin with and all you have to do is pad it down to the correct level first, but with a waveguide loaded tweeter quite a bit of response shaping may be required. My first step here comes by recognizing that the tweeter's roll-off is going to have to begin at a very high frequency if I want a flat frequency response. I played around a little and settled on a small capacitor to get things started. Next, I work the two networks back and forth until I arrive at a fairly good crossover point between the two flat responses. Simple right?

My goal with a crossover network is to make every part accomplish as much as possible, sometimes multiple things. I look at a crossover holistically, with every part working together, so that I can reduce the parts count as much as possible. I am not a minimalist where crossovers go, but I don't like the idea of throwing a load of parts at the speaker either if I can accomplish all of my goals with fewer parts. Since this is an open source design, in part 2 I will describe how I do this with the woofer circuit so you can see what each component's role is in the crossover.







Helios Speaker Project Part 11 - Crossover design Continued and measurements

As I mentioned in my last post, my goal with a crossover network is to make every part accomplish as much as possible, sometimes multiple things, so that I can reduce the parts count as much as possible. I am not a minimalist where crossovers go, but I don't like the idea of throwing a load of parts at the speaker either if I can accomplish all of my goals with fewer parts. Since this is an open source design, I will describe how I do this with the woofer circuit so you can see what each component's role: The first 2.0 mH inductor levels out the response, the 25 uF cap combines with the inductor to set the corner frequency. The 3 ohm resistor in series with the cap controls the Q or the shape of the knee. The resistor is also very useful in adjusting the phase response of the woofer. When there is a physical offset between drivers then the slopes must be asymmetrical in order to arrive at a point where the phase tracks as desired, so you have to adjust the slope of one driver or the other to accomplish this. Moving on, the parallel small inductor and capacitor is tuned for both notching out the woofer's cone break-up at 4.6 kHz and providing the acoustic 4th order roll off.

I decided to pursue a fourth order L-R acoustic crossover, because 4th order roll-offs are the natural result with these drivers and crossovers, anything less leads to too shallow of circuit, and an L-R crossover with good phase tracking tells us that the highest summation point is directly on the tweeter axis, so there is no risk of any peak in the response above this level on any other axis, above or below the tweeter. Allowing the two drivers to talk to me, it was apparent that the best crossover was going to be in the 1100-1400 Hz range. I started on the lower side of this range, but the best phase tracking was in the 1250-1300 Hz range. After adjusting the top octave balance the crossover point ultimately came in right at 1300 Hz. Remember, crossovers are acoustic. They have nothing to do with textbook circuit shapes. Circuits, whether passive or active are there to optimized to acoustic responses when combined with the driver.

Now, this may seem like a low crossover point for a 29mm dome tweeter, but keep in mind the tweeter's crossover transfer function is down 23 dB at this point. This is how the waveguide enables us to reach a lower crossover point.

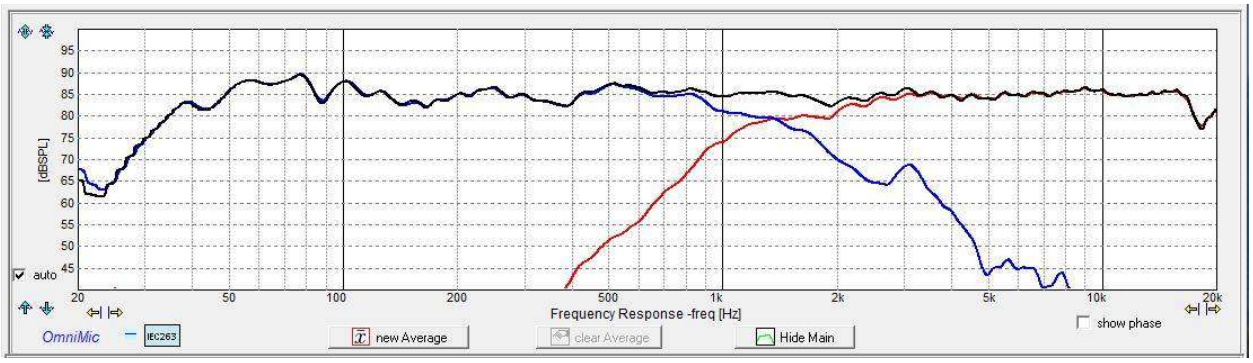
I have provided graphs of the actual final measured response on the tweeter axis, the actual measured (not simulated) response of each driver with their crossover circuit, the acoustic crossover point, and a graph of actual measured reverse null that shows a null -35 dB, and a plot of the measured phase response show the exceptional phase tracking between the woofer and the tweeter from around 100 Hz to 3 kHz. This range of phase tracking is ideal for an L-R Crossover type.

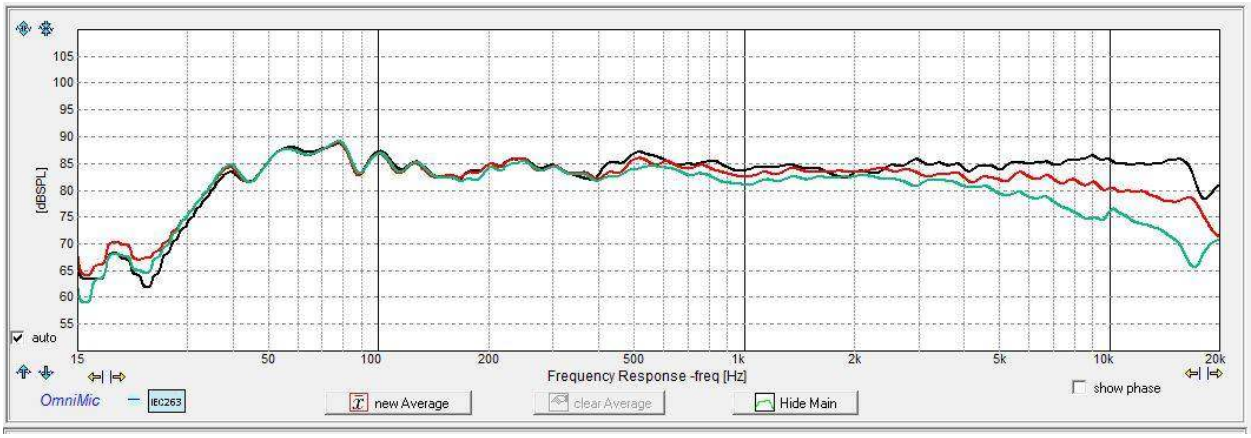
In addition to these graphs, we have included a couple of different graphs showing the horizontal polar response at 0, 22, and 45 degrees off axis. As you can see, off axis response is nearly ideal within this 90 degree window. This is the beauty of matching directivity.

I have provided a distortion plot, but it deserves some explanation. Many people do not realize that you cannot compare distortion plots if they are measured under different circumstances. Distortion is dependent on output level, which is dependent on input power and measurement distance. You cannot compare distortion at 100 dB taken 6” from a driver with distortion measured at 100 dB taken at one meter away. The stress on the driver is very different. This graph represents the latter situation. The woofer if being driven to slightly beyond its Xmax in this graph and the speaker is very loud. Given this, the non-linear distortion is remarkably low. Second order distortion runs at -50 dB in a fairly linear line. This translates to distortion of 0.3%. Third order distortion remains lower than second order everywhere except in the low bass where the woofer is being pushed hard. However, third order does rise around 1 kHz but only to a level of 0.1% and is much lower across the board otherwise. This is a VERY low distortion loudspeaker.

Regarding the impedance, the minimum measured impedance is at 4.5 ohm at 114 Hz, and the impedance runs above this over the rest of the spectrum. Most manufacturers would still call this an 8 ohm speaker. You may call it whatever you wish, because that single designation means very little. The tweeter’s crossover is very capacitive in nature due to the very high roll-off. As a result, it should be noted that the maximum phase angle occurs at 9.7 kHz at 12.5 ohms and -63 degrees. At 20 kHz it is 6.5 ohms and still has a capacitive phase angle of -54 degrees. I think most any decent amp should be OK with this. Javad ran them pretty hard on a Technics receiver and his big Adcom, at very high levels, and everybody seemed happy. But, to be fair, I want to make sure this was disclosed in case you have an amp that doesn’t like capacitive phase angles.

Given the linear response, the controlled directivity, the precision of the acoustic crossover, the phase tracking, the bass extension, and the low distortion, even at high output levels, it may be hard for me to design a better stand-mounted speaker.





Helios Part 12 – Bass Alignment with Passive Radiator

The target for the Helios was a slightly larger than normal stand mounted monitor. The front baffle is just barely larger than the woofer is wide and just taller than the woofer and waveguide together are tall. The depth ended up being slightly deeper than the width of the SB29 passive radiator. So, there really isn't a lot of excess size here. The internal volume is approximately 35 liters.

When working with a speaker this size with a larger woofer like the Satori WO24 the bass alignment becomes tricky. To compound the situation, the Qts of the woofer with wiring comes in at .42, and a Qts this high pushes up the required volume of the cabinet quite a bit from low Qts drivers. The 35 liters works out to sealed Qtc right at .7, which is maximally flat with the lowest F3 for a sealed alignment. Of course we might be able to get deeper bass from the speaker vented, but there's two problems with that – First, the volume is too small for a bass alignment that does not possess some level of peaking. The peaking however, might not be considered objectionable by most people since it would be a broad smooth rise, but it's still not flat. And second, the required port diameter for the WO24 would result in a port too long to work with this enclosure effectively.

This brings us to using a passive radiator. While it is possible to use a passive radiator to tune this enclosure to the optimum target of 25 Hz, there are still two issues that I didn't like. First, there is still the hump in the midbass due to the small volume alignment, and second, the Fs of the radiator is higher resulting in a response that is dropping faster than 24 dB/oct below 40 Hz, despite this we have an F3 of 40 Hz and an F6 of 32. Also, with this alignment the cone is reaching an excursion of 17.5 mm at 20 Hz with 100 Watts of power.

My solution was to do something I came up with on the Testarossas that proved to be more successful than I expected. I called it at the time a Quasi-Transmission Line loading. I called it this because both the impedance curve and the box response curve were nearly identical to what you get with a heavily damped transmission line. This was accomplished by using a passive radiator that tunes the enclosure to a very low frequency, even below 20 Hz. The reason it worked really well on the Testarossa was because I found that this type of tuning worked miracles on controlling cone travel, and the MW16P woofers have a very compliant suspension and this additional control was a great benefit, as the cones stayed under control instead of bouncing around excessively.

Now, the more advanced guys are saying – But sealed will control the cone travel too by using the closed box air compliance to push back against the cone. True, but this passive radiator hybrid beats sealed. Here's the comparison.

In the sealed box with the Qtc of .7 the system has an F6 of 36.7 Hz and an F10 28.0 Hz. Using our 100 watts of input power the driver excursion rises to 14 mm at about 20 Hz and below, against an Xmax of 9 mm. And typical to sealed systems with a Q of .7 the response is flat with a 12 dB/oct roll-off beginning at just below 50 Hz.

Using the SB29NRX-00 radiator right out of the box tunes the enclosure to 17.8 Hz. The cone response exactly follows that of the sealed system with a flat response with no peaking and a 12 dB/oct roll-off until we begin to approach the tuning frequency. The radiator output is not really high, but it does sum with the cone to produce an F6 of 33.5 Hz and an F10 of 25.4 Hz. System response is now rolling off at 8-9 dB/octave (you read that right) giving the system 4 dB more output at 20 Hz compared to sealed with no peaking. The more gradual roll-off matches very well with the rising room response of most rooms in this range yielding a system whose in-room response is very flat and extended to 30 Hz and below (for a stand mounted monitor just over one cubic foot in volume). Excursions? With the passive radiator and low tuning, the woofer's excursions peak at 11.9 mm at 35 Hz with 100 Watts, but then below that begin to drop off to only 3.5mm at 17 Hz and doesn't exceed Xmax again until 14 Hz and below. And for those wondering, Group Delay with this passive radiator and the low tuning is only 11 mSec at 20 Hz, which is very low as well.

Using the mass loaded passive radiator to control the cone motion of the woofer to very low frequencies not only adds a few dB of output in the deep bass, helping to extend it, and match the room curve better, it is also keeps the voice coil better centered in the gap to much higher power levels, resulting in even lower distortion from the woofer at low frequencies.

I attempted to make the Helios a very unique, near state of the art loudspeaker in the category of a stand mounted monitor, combining flat response, matched and controlled directivity, smooth extended bass, and low distortion – combined with fairly high output level. I wanted it to be as accurate of a reproducer as was possible to make using passive components, and I believe it will be tough to beat this one overall.

Helios Part 13 - Crossover Assembly

Now that Jeff has outlined the crossover and enclosure modeling, it's time to assemble the crossover.

After 3 builds together now Jeff and I have developed a good process for remotely developing the crossover. I do measurements and send them to him, he models what he feels is optimal, I do more measurements to confirm the model and then listen. From there I give feedback, Jeff makes changes to the crossover, I retest, listen and we optimize. With Jintani we tested two completely different designs but with Helios the initial model Jeff did was very close and then it just came down to my feedback on tweeter level. IME and opinion, getting the tweeter level right separates many bad sounding speakers from great sounding ones, and even a half dB here or there can make a very large difference.

Based on feedback from quite a few others and Jeff himself, we seem to get it right, which is always a big relief for me since usually I'm the only one that's heard the speaker before it's revealed ☺

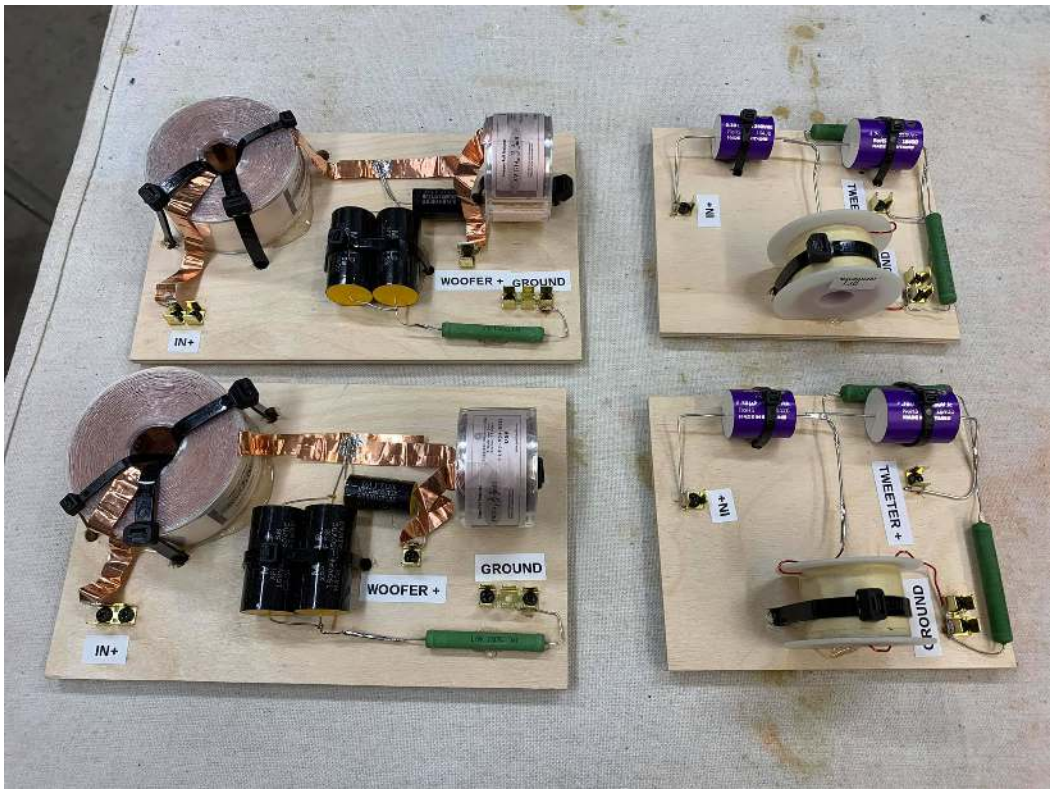
Once we finalize the crossover design it's time to build it and finalize it. Here the key is that the finalized crossover matches the optimized response of the test board crossover. I have a good process, with good test leads and ways to make temporary connections that I have little concern they'll match in the final design.

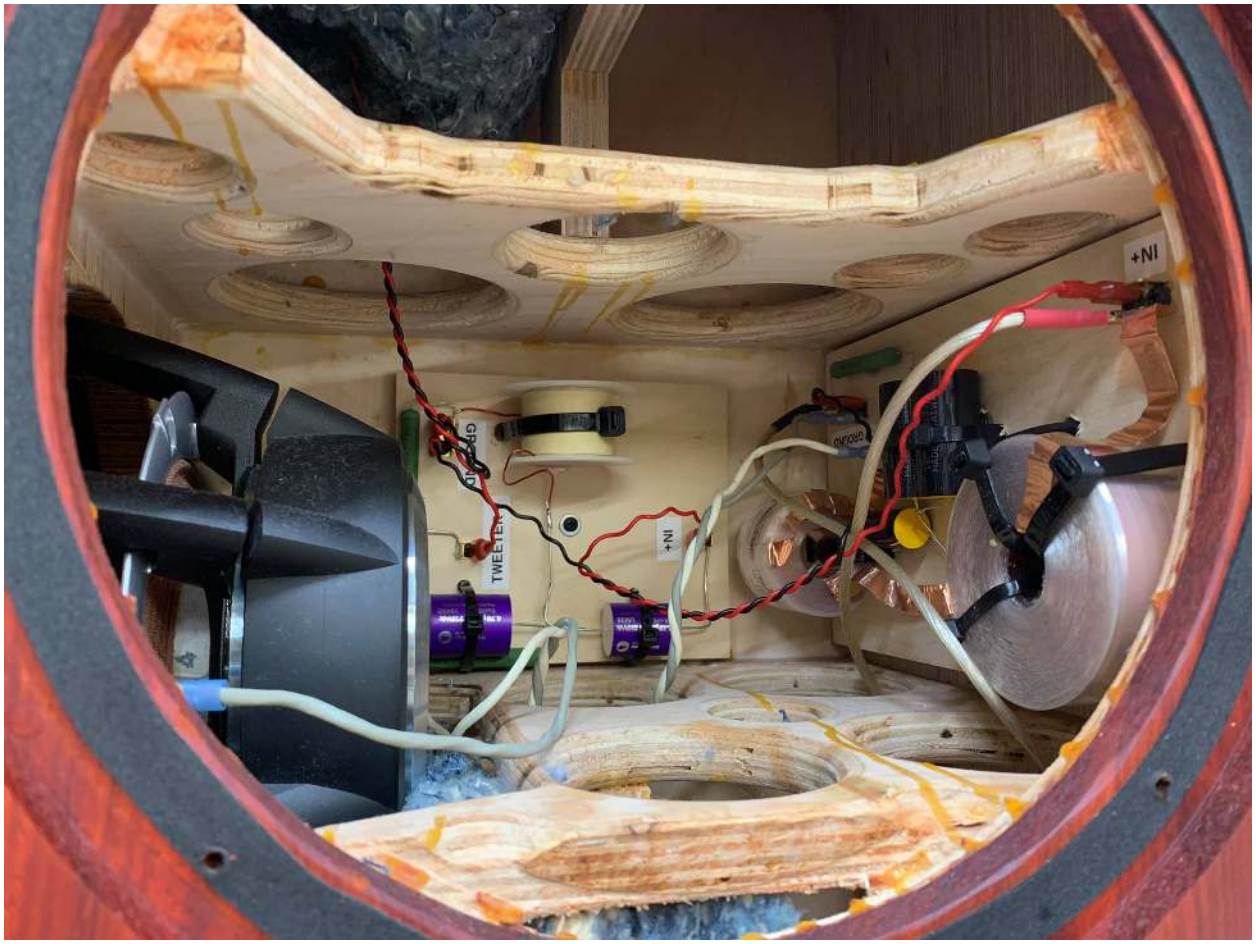
I sent all the values needed to Adam at Madisound and he sent me a nice box of parts. I had never used foil inductors so I wanted to give them a try too. I split the crossover into two boards one for each driver and mounted them in the cabinet.

I attached each board with 4 or 5 pieces of Scotch brand "Extremely Strong" hook fasteners, I like this stuff as its grip is not only extremely strong but the adhesive on the back is really grippy too. Then one #8 screw in the middle of the board permanently attaches it to the enclosure.

I like doing point to point connections whenever possible as I find them neat and simple, it also allows me to quickly look at and evaluate each board if I need to troubleshoot it or make changes. I avoid running connections under the board, I suppose in a production crossover that could be done but in a one off the slightly aesthetic benefit isn't worth the potential complications.

All parts are held down with E6000 glue and heavy duty 100lb test wire wraps. This crossover easily survived the shipment out to Axpona, I think I finally have the crossover mounting shipping thing figured out after a couple issues that I've since corrected.





I did not get to actually hear the Helios speakers until I got to AXPONA. I felt they sounded great in the SB room but it was still not in my own system where I could make some direct comparisons to what I am used to. So, once I got them home I placed them on the stands where the Spiritwinds normally sit, fired them up, and really listened to them.

Now, I know that the first question I am going to get is - how do they compare to the Spiritwinds? I will get to that. I often get asked to compare two speakers, sometimes with long periods of time between listening to each one. I understand what people are looking for, but sometimes this is just impossible to do, especially when you are splitting hairs at a certain level. Anyway, back to the session.

I played a number of songs that I use for voicing speakers to see if I would change anything. It all sounded fabulous: vocals were perfect, the treble was balanced, the bass was beautiful - articulate, deep, honest, without bloom, just as intended. This is the first time that I have used a waveguide of this type - a large round one with a dome tweeter. Even though I normally toe-in my Spiritwinds and Continuums, I found I liked the way the Helios covered the room best when they were aimed straight ahead. Despite the size of the drivers, this set-up spread a beautiful panoramic power response.

My hybrid bass alignment does everything I wanted but may not be what everyone else wants. Most people are used to the bloom, or boom that can come from some vented systems working within the typical room when its room gain is factored in. These speakers are designed to work with the room.

Sometimes it seems like the bass isn't that powerful or extended, until you come across some real bass in the recording, and then there it is! deep, clean, detailed. And at times, much more impressive than I expected.

I got out my mic and decided to take some measurements of my own. My response measurements matched up with Javad's. I took a Cumulative Spectral Decay, and it was very clean, nothing to really talk about. The Energy Storage plot only showed the reflection of my coffee table and was otherwise very clean. I tried to take a distortion sweep using the method and level I normally use and found that the distortion was not separating itself from the noise floor. That is unusual. I began increasing the volume. You can't even measure this speaker's distortion until it is really freaking loud. THAT was truly impressive.

So how do they compare with the Spiritwinds? Well, first of all they are twice the size with a larger woofer and my measurements showed that they are flat to 30 Hz when taking close-mic measurements of the cone and passive radiator. The smaller Spiritwind is flat to 40Hz, and this difference is enough to get your attention when playing music. They can play louder than the Spiritwinds too. Their distortion is lower, but the Spiritwind distortion is very low and both are probably inaudible except under extreme conditions. The directivity and the power response is is smoother than the Spiritwinds too. So, in these areas I would give the nod to the Helios, and probably give it the nod overall as well. The spiritwinds still do some very special things, especially the near perfect timbre in the high end when listening to hats or a ride being played softly. The Helios may do this too, but I haven;t got there yet. But remember, both these speakers use expensive top-of-the-line drivers and both have very flat response, so in some areas, like I said above, I am splitting hairs. The Helios are bigger, more extended, with higher output, and excellent directivity, but for many people they may be too large, in which case the Spiritwind may be the better choice. And, when I have the sub dialed in, these speakers can sound more alike then different. Again splitting hairs.

Helios Speakers Finale!

This Finale is long overdue!

The Helios was an incredible project with Jeff earlier this year, leading up to the madness of Axpona! In about 2 months Jeff and I designed and I built both Jintani and Helios, not to mention developing the crossovers for both as well. Both projects were very successful and certainly set a new standard for me, and Jeff as well as you can read below. It's tough to know what to tackle after you have a number of projects like this under your belt, the designs and drivers lend themselves so well to accurate, dynamic and detailed sound, that you really have to split hairs to find the next level.

The goal with Helios was a compact "stand mount" speaker with full range sound of a much larger speaker, while they aren't small, for the sound they put out they are quite compact. I was able to easily record 115dB c-weighted SPL's in my listening room at about 2.5 meters for both speakers playing, and that's full range sound with no high pass on the woofer.

I chose a construction technique that I used on my Rivalries build which I call Interlocking Strip Translamination Enclosure Construction. The method here was simple due to the fact that Helios have square corners, the technique is a little more complicated when corners aren't square (as in Rivalries) but still very doable. The advantage here is almost zero waste compared to

Translamination where you have big pockets of material in the middle that get wasted. The technique also makes it easy to create interesting enclosure shapes, is very strong with the interlocking corners and creates a neat and unique visual signature. I was pleased to see Tyler Mestas use this technique recently on his Continuum's MTM build!

I wanted these to really pop and the Padauk really was the right choice here, what a cool and beautiful wood, despite being much more messy to work with compared to other more common woods. The wood has an oil that makes it more sticky and the orange sawdust really sticks out around the shop!

The enclosure is solid and non-resonant, each speaker weighs about 45lbs, the solid maple Appleply plywood is very dense and non-resonant, the bracing ties together all sides to raise the resonant frequency and drop the amplitude so they are inaudible.

Jeff contributed the below statement so please take a moment to read his take, also please see all the Helios posts below, enjoy and let us know if you have any questions!

Jeff Bagby:

"My thoughts on the Helios now after living with them for a bit, for this wrap up post. The speaker was an idea that I had about six months earlier. Bo from SB Acoustics liked the idea, so we decided to give it try, but I had to wait on the development of the waveguide. I kinda figured the tweeter would be really special with the Satori Be mounted in a custom waveguide, and I already knew the Satori woofers were excellent, but I was still not prepared for how fantastic the WO24 Satori woofer really was. This driver really raised the bar and made this speaker possible. So, what do I think of the Helios? Well, from a technical perspective it is the best measuring and least flawed of any speaker I have designed. There are some speakers that keep up in some areas, but not in all of the areas that the Helios hit is out of the park. Besides the flat response, and amazing polar response, this speaker has distortion so low I found it difficult to measure. And then there’s the bass response. Wow, such purity and power at the same time. So, if this the best speaker I have designed? Yes, I believe it is. After listening to it in my home for a few weeks I became more convinced of that than ever. And when I put the Spiritwinds back on and they left me wishing for the Helios, I knew for sure then. I would put these speakers up against anything, and I would hold my head high. I just have to find a way to out-do them now. Boy, I can set the bar really high for myself at times."