Multi-way Speaker Design 101

A Beginner’s How-To Guide For Building 2-Way & 3-Way Speakers

Tim Murphy

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1. Introduction

This "How-To" is intended to be used as guide for DIY enthusiasts to design and build the best possible audio speakers possible. It is simply how I did it starting with nothing, knowing nothing. I still know only a little, but I now have my dream speakers in my living room. The fact is that most anybody can build their dream speakers. Today, there are too many kits and plans available to count. All you need to do is determine the size and shape you want.

One thing that has made this hobby so accessible is the development of software tools that guide us through much of the arcane process. Of course, it helps to have a background in electrical engineering and physics. But those are no longer prerequisites to diving in and having some fun with it.

In this guide we are going to walk through my process from beginning to end. I started a project a couple of years ago and shelved it. When I got back into DIY speaker making, I realized how much I had forgotten. The idea to re-learn everything and documenting it was born.

I learned much of what I know from the forums, videos, and reading. The truth was that there was no substitute for just rolling up my sleeves and trying it out. There were plenty of mistakes along the way. Read it, then try it. Youtube it, then try it. There was nothing fancy about it.

Some of the techniques employed were learned from others and I will provide attribution. I'm not claiming this is 100% the right way to do it. I actually believe there is no such thing in DIY speaker making. It just worked for me.

Have you ever looked at a pair of speakers and thought, "I'd love to have those in my home!!" Me too. Speakers hold a special place in the home audio environment. They look cool. It's where the sound comes out. They are pieces of fine furniture. For me it is the B&W Nautilus. I love those things. I just don't have $50K laying around right now to spend on them. So, I set out to build something that kind of cool.

My website is: www.kayasound.com and there is information regarding all of the tools we talk about below. Some areas will refer you to the site for more details. There will be "How-To" Guides or Youtube videos related to specific topics.

2. Goals & Guardrails

Vision

I encourage you not to have any self-limiting beliefs. Whether you think you can or think you can't…you're right. I saw in my mind's eye a 3-way tubular beast in metallic dark forest green. There had to be a way to do it while overcoming the obstacles of the enclosure challenges. Dream big. Not size-wise, but design-wise. When I had this vision, I had no idea what the difference between an inductor and a capacitor was.

Goals

Let's get a little more focused. Do you want a 2-way? 3-way? Bluetooth? High efficiency? Certain crossover topology? Large floor stander? Thin? Wide? Bookshelf? The list goes on.

List your goals:

1. ____
2. ____
3. ____
4. ____
5. ____

Limitations

We all have them. Spousal Acceptance Factor (SAF), Budget, and Space are a few of the obvious ones. I'm sure you can think of more. These will help you get honest with yourself about how much you can bite off right now. List them out:

1. ____
2. ____
3. ____
4. ____
5. ____

3. Tooling

Shop Tools

Having the right tools is critical in order to make a start. The good news is that there are varying levels of investment required depending on whether you plan to assemble a kit, build from a plan, or design from scratch. Here's a matrix to reference:

	Assembling		Building		Designing	
	Minimal	Optimal	Minimal	Optimal	Minimal	Optimal
Measurement:						
Tape measure	X	X	X	X	X	X
Rulers	X	X	X		X	
Vernier Caliper (6 inch)				X		X
Steel Rule (fractions and decimal - 24")						
Saws:						
Circular saw (with fine tooth cross cut and rip blades)			X	X	X	X
Sabre saw			X	X	X	X
Table saw				X		X
Band saw				X		X
Drill press				X		X
Router:						
Plunge router (2 HP Min)	X	X	X	X	X	X
Trim router (1 HP)				X		X
Router table (with micro fence)				X		X
Miscellaneous:						
Sand paper (120, 150 and 220 grits)	X	X	X	X	X	X
Glue (Yellow -Tite-Bond)	X	X	X	X	X	X
Clamps	X	X	X	X	X	X
Random ordit sander		X		X		X
Hand drill	X	X	X	X	X	X
Soldering iron	X	X	X	X	X	X
Heat gun		X		X		X
Wire strippers/cutters	X	X	X	X	X	X
Closed cell foam tape		X		X		X
Damping material	X	X	X	X	X	X
Heat shrink		X		X		X
Hand rasp		X		X		X
Jasper Jig		X		X		X
Hook up wire		X		X		X
Measurement:						
Measurement microphone				X	X	X
Measurement software				X	X	X
Test amp				X	X	X
ASIO Soundcard				X	X	X
Mic stand with boom				X		X
Infinite Test Baffle				X		X
Testing:						
Multimeter						X
LCR Meter						X
SPL Meter						X

IEC Test Baffle

This requires some serious commitment. Not in terms of money, but certainly in terms of space. I built mine according to the IEC 268-5 spec for 10" drivers. It's the biggest one I could get away with that would fit. There is a "How-To" guide for how I built it on the website by clicking **HERE**.

I have used this more than I thought I would, which is a good thing. I even use it to test larger drivers and it suffices. Here's a pic:

Testing Environment

There are several things that you are going to need up front in order to follow this guide:

- Windows laptop
- DATS ($100)
- Xsim (free)
- Omnimic ($298 w/ microphone)
- WinISD (free)
- Jeff Bagby Diffraction & Boundary Simulator (free)
- Xdir (free)
- Amplifiers
  - 40W
  - 100W
- Microphone Stand w/ Boom (telescoping)
- Accessories (speaker cable, alligator clips, capacitors, etc.)

Your laptop will need an optical drive. The amps don't need to be anything special. I got mine from Parts Express. The mic stand doesn't need to be anything special either, although a telescoping version is recommended.

Intro To DATS

DATS is a very useful and affordable tool. For the purposes of this method, it does something critical to success. It generates .ZMA files in a snap. I also use it for real-world speaker parameters to be used in WinISD. Here's what else it does:

- Measure Speaker Parameters Quickly and Accurately (FS, QTS, QMS, QES, RE, VAS, etc.)
- Perform Rub and Buzz Testing (with Continuous Mode for Production Testing)
- Measure Values of Resistors, Capacitors (also ESR and DF) and Inductors (also RE)
- Generate Audio Waveforms at Any Frequency or Level up to 20 kHz and +5 dBu
- Generate Sine, Square, Triangle, Saw Tooth and Impulse Waveforms
- Generate Pink Noise, White Noise and Three Different Log Sweeps
- Monitor Generator Output Waveforms On The Dual Channel Oscilloscope
- Design and Verify Impedance Compensation Networks
- Extract Parameters from Imported Driver Impedance Data
- Characterize Complete Loudspeaker Systems (FSC, FB, etc.)
- Diagnose Loudspeaker Fault Conditions (open or shorted drivers, cables or components)
- Perform General Purpose Impedance Measurements (1Hz to 20k Hz, and 1 Ohm to 10k Ohms)
- Measure Real and Imaginary Parts of the Impedance in Addition to Magnitude and Phase

For more information, click here. Intro video at: https://kayasound.com/design/

Intro To OmniMic

Omnimic is a power and simple to use acoustic measurement system written by Bill Waslo. There's way too much to go into here, but it is worth pointing out that if has a cool feature that I use all the time…you can directly export your test curves into .FRD files. This file is needed for Xsim to perform accurate simulations.

Measurements:

- SPL meter with A, B, C, or no weighting
- Spectrum analyzer, FFT, or RTA
- Frequency response with phase and impulse response
- Oscilloscope function to view complex waveforms
- Harmonic distortion: 2nd, 3rd, 4th, 5th harmonics plus THD
- RT60 reverberation: measures sound reflection
- Bass decay function identifies room modes and helps determine proper subwoofer placement
- Polar Plotting, in flat or 3D radar format
- Wavelet Spectrogram (color) to the Waterfall group
- Curve Math for live or added curves
- Auto-naming of repeated FRD measurements; updated
- Snapshots to PNG, BMP, JPG or WMF formats
- Measurement down to 5 Hz
- Energy-Time Curves, with configurable band limiting

For more information, click here. Intro video at: https://kayasound.com/design/

Intro To Xsim

Xsim is a freeform passive crossover designer and simulator also written by Bill Waslo. It is available here. This is one of my favorite tools…and it is FREE. Intro video at: https://kayasound.com/design/

From Bill Waslo:

> Experimenting with "ideal" driver data (the default for each driver) can also be fun and helpful in understanding the effects of various circuit types. Some built-in multi-part "Circuit Blocks" also provide for basic pre-configured circuits to be tuned per their overall parameters (Q, corner frequency, attenuation, etc). There are "Example" files included in the XSim download (currently less than 1.5MB) as well.

XSim allows you to see simultaneous multiple graphs of your choice, including impedances, voltages, power consumptions, group delay, and frequency, impulse, step, and square wave responses. You can watch the performance and/or stress on any part vary as you tune structure or component values in real-time. The circuit network is re-solved automatically with every change you make.

The "free-form" aspect of XSim is that crossover designs are unrestricted, no particular circuit structure need be used. Essentially any R-L-C passive network you can think of can be easily entered using graphical schematic entry, with results calculated as you design. A common "ground" node is provided, but its use isn't required.

Intro To WinISD

WinISD is freeware speaker designing software for Windows environment. You can design Closed, Vented and Bandpass boxes with this program.

This tool is fantastic for modeling out what the size of your cabinet should be as well as aiding in figuring out the vent specifics and tuning of the enclosure.

Another very useful and FREE tool. Available here. Intro video at: https://kayasound.com/design/

4. Driver Selection

Re-visit Goals & Guardrails

Take a look again at what you are trying to accomplish and what stands in your way. Perhaps you have made a decision to build a 2-way speaker. You have to buy four drivers. And all the crossover componentry…potentially big money. Maybe you have a particular driver that you really want to use. There are a lot of combinations of things here that may stop you dead in your tracks and cause reconsideration. This isn’t necessarily a bad thing. You may have to make some trade-offs. For example, maybe you don’t use Mundorf inductors and you use Sidewinders from Madisound instead. Your project will still come out just fine. Fear not, you are not alone.

Study Data Sheets

I confess, I get a kick out of these things. Sure, they might be tainted by the marketing department but it’s all we’ve got for now. I print them out to read versus reading online. I find them easier to read and I can write notes on them. I’m looking for a few things in particular…frequency range, Thiele/Small parameters, frequency response graphs, and other key specs (sensitivity, moving mass, BL, dimensions, etc.).

I really pay attention to the frequency response graph information. I’m looking for a more realistic view of the range of frequencies that the driver might perform well in. Many graphs will give you a clue about whether a driver is delivering certain frequencies at a desired SPL level. They can also give you some clues about whether there is a potential breakup of a driver at particular frequencies. I've found that this is helpful in identifying potential crossover points.

A final benefit is that you can eyeball where there is overlap between two (or more) drivers. This is also important in determining whether two drivers will play nice in the sandbox. For example, if a midrange driver goes wonky at 5,000Hz, you might look to cross it over somewhere lower than that. This will be more evident when you build the Frequency Response Model spreadsheet.

Sensitivity Matching

This one is really pretty straight forward. You have to have drivers with a sensitivity level that can be configured via the crossover to deliver as flat of a frequency response as possible. For a 3-way, I try to look for a woofer that is a few dB lower sensitivity than the midrange. Then, I try to have the tweeter similar to the mid as it can also be attenuated down to the correct level. The same sort of theory goes for 2-ways.

Power Rating

What you are looking for here is the continuous or 'RMS' power rating. The peak power handling may be much higher, but you can't run your speaker at that level for a long period of time. High power rating does not mean louder! It can work against you through reduced sensitivity which may require the speakers to play at loud levels to really get them to blossom.

Impedance

This is the load that you are putting on your amp to deliver power to your speakers. Many speakers are rated at 8 ohms, but the truth is that you may see dips in the curve down approaching 4 ohms. That's okay for short periods and you certainly don't want to see anything under that unless the amp is specifically rated for it. But, my suggestion is that you check the specs of you amp to determine if it can handle a 4 ohm load.

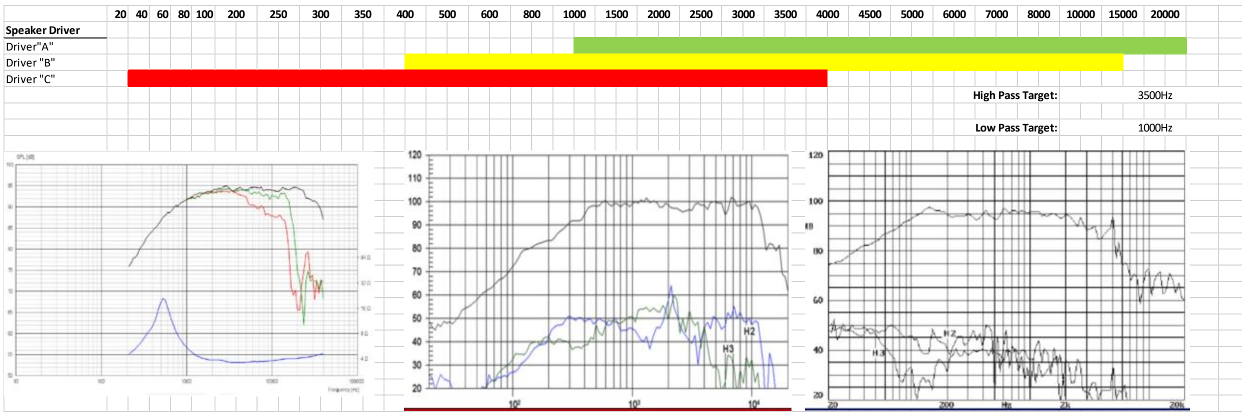
Initial Driver Selection

Had enough of pouring through data sheets? Hopefully by now you have selected the drivers that you would like to use. But…will they allow you to meet your goals? Are they within the guardrails? Do the FR graphs and Thiele/Small parameters match up. This probably took WAY longer than you thought it was going to. Let's take a deeper look.

Build A Frequency Response Model

I needed more than just looking at FR graphs to help me identify if the drivers would work together and to narrow down potential crossover points. I had been taught that it was desirable to have at least two octaves of overlap between drivers so that there was enough headroom to adjust the crossover point. So, I built this little simple tool to help me. Across the top are frequencies. I plot the claimed range of performance from the datasheet for each driver I intend to use and color code it. Now I can see a visual representation of the overlap. Is it more than two octaves? What will my roll-offs look like?

Below is the model for a project I'm working on.   I feel very confident now that I can use the drivers I want to, and they are going to blend nicely. If this chart showed that the midrange really only went down to, say 1000Hz, it might be a different story with that driver.



Make A Commitment

I'm not sure how this is going to go over, but it's how I roll. Once I have as much confidence in my driver choice as possible, I buy one of each. Why only one? Because I want to get into some live testing to see how they are going to react in the real world. If I go through the testing/modeling procedure described below and all is cool, I can go ahead and buy the matching drivers. If it goes sideways, I'm not out as much money.

5. Attribution

I need to call out here a couple of people whose research and techniques are a huge part of what's to come in the following steps. The first is Nigel Tufnel and he has a blog titled "A Speakermaker's Journey". In it he very eloquently lays out how he uses some of these tools to design crossovers. I encourage you to read his blog at: https://speakermakersjourney.blogspot.com/

The other is Jeff Bagby, whose whitepaper titled "How To Use PCD To Find The Relative Acoustic Offset" might be the basis for a lot of the technique below. Nigel gives Jeff credit as possibly being the father of this technique. Jeff calls out a white paper by David Ralph that documents this procedure some 10 years before Jeff expanded on it.

6. Driver Modeling

DATS

This is where I hook up the drivers to DATS and let it do its thing. I do this for one simple reason. It produces .ZMA files quickly and easily. You're going to use these in the Xsim sandbox. You can also compare the T/S parameters to what's on the spec sheet, which is nice. And, you can use these T/S parameters in WinISD.

There is a Quick Start Guide and other documentation on how to operate DATS, so I'm not going to detail it here. It's straight-forward and the docs are sufficient.

Remember, all you want to accomplish right now is to create the .ZMA file for our purposes. Once you done that, you are done with DATS for now.

Test Baffle

I am going to mount the drivers in my test baffle and run it through the paces with OmniMic. My main goal here is to create .FRD files.

Here are the steps:

1. Cut a ¼”x 15”x 15” square of plywood.
2. Mark center of each panel.
3. Route an appropriate hole in the plywood for your woofer using a Jasper Jig.
4. Mount plywood to baffle.
5. Mount woofer driver to baffle.
6. Connect driver to test/measurement environment.
7. Position microphone on-axis at 0-degrees at 1 meter from woofer. In other words, put it dead center in front of the woofer 1 meter away.
8. Generate pink noise signal in Omnimic to measure SPL at microphone (~70dB is fine).
9. **Make sure “Show Phase” button is checked in Omnimic.**
10. Generate short sweep sine wave in Omnimic.
11. Once your FR curve has settled down, you can hit the ‘pause’ button in the upper left corner to freeze the measurement.
12. Generate a .FRD file by:
    a. Click “File”
    b. “Save FRD Curve”
    c. Name & save file
13. Repeat for midrange
14. Repeat for tweeter (be sure to protect it with a 10-20uF cap).

Now you have your .FRD and .ZMA files all in one place. At this time, we are not looking to measure them all at the same time for a ‘combined’ .FRD file. That comes a little later. Time for Xsim.

Xsim Sandbox

This is where you’ll need to learn Xsim. It is pretty simple to use and if you just fool around with it then you’ll pick it up pretty quickly. There is a good video at: https://kayasound.com/design/

Here are the steps:

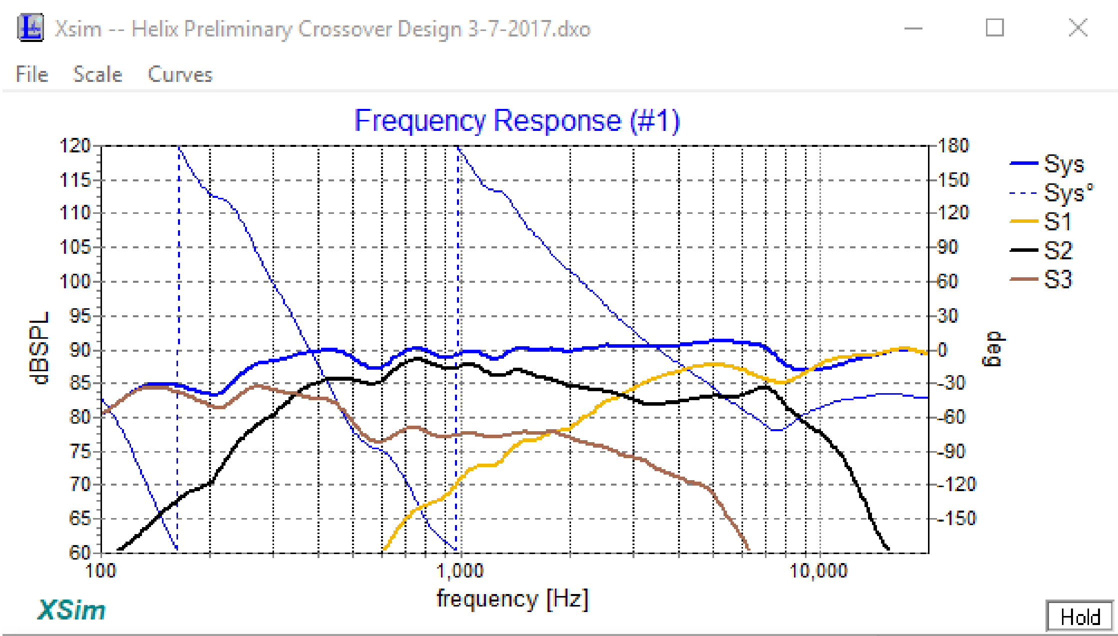
1. Create a new project in Xsim and drag your drivers to the palette.
2. Double-click the ‘woofer’ driver to open the “Tuning” dialogue box.
3. Click the FRD Response File ‘folder’ icon and load the appropriate file.
4. Do the same for the ZMA Impedance File ‘folder’ icon.
5. Repeat for your other drivers.
6. Connect positive amp leads to your drivers and add the grounds to all.
7. In the upper-right window you can display the Sys, S1, S2…curves.

8. I set the smoothing to 1/6th on each curve (1/24th is going to be ugly at this point).
9. Experiment with building a crossover network to see what you can come up with that smooths out the 'Sys' curve. This is NOT your final crossover. It's just a glimpse into whether the driver should work well together or not.
10. There is a deeper dive coming and things are going to get much better, so don't freak out when it looks ugly. However, you should be pleasantly surprised at how flat you can make it look!

Sandbox Results

The goal here is to simply determine our confidence level that if we go forward that a crossover can be built that will deliver the best possible outcome of an acceptable FR curve as well as having it be at the right impedance levels. This is by no means the final crossover design, but it gives us a clue as to what it will look like. Once we can see if this looks feasible, we can move on to the cabinet design phase.

Here is the sandbox for a sample project. I'm feeling pretty good. Again, at this point it's a little ugly and that is expected. I think we'll end up at about 95dB sensitivity, which is a goal for this project. I also make note of where the crossover points ended up.



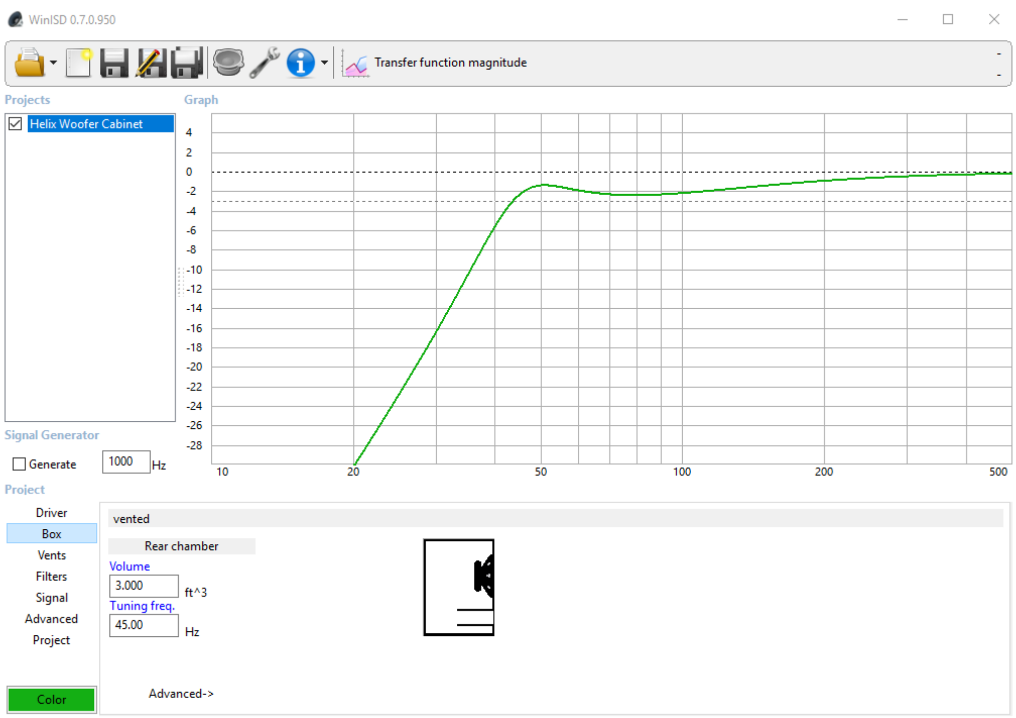
7. Cabinet Design

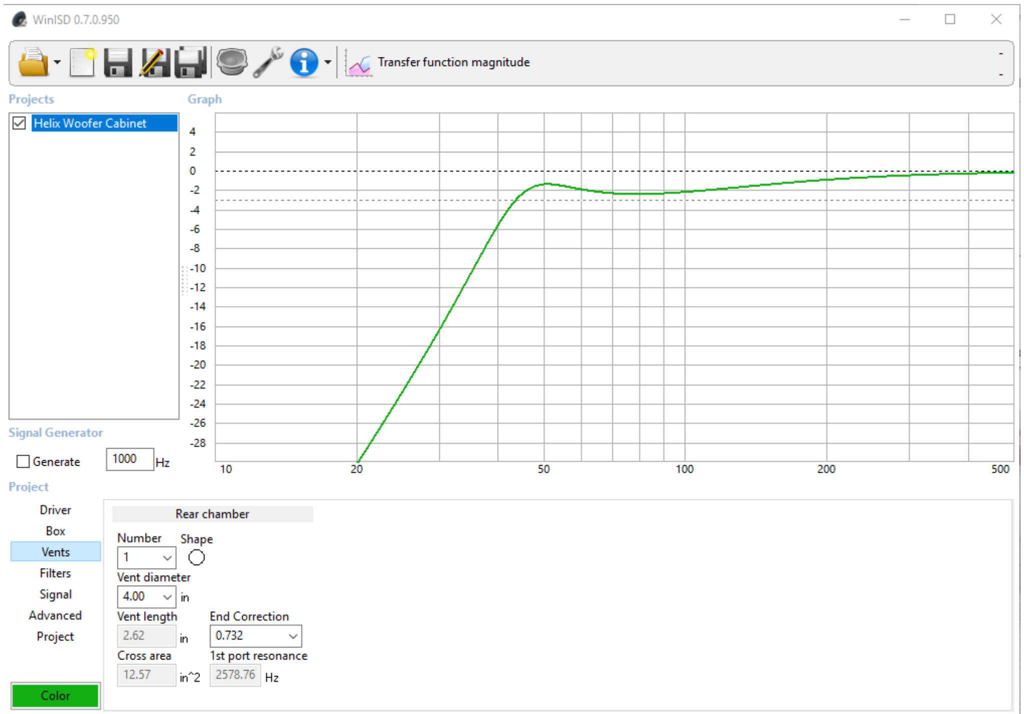
Enclosure Requirements

WinISD is a super useful and FREE tool that will help you determine the volume and type of the cabinet you will need to build. Introductory videos are available at:
https://kayasound.com/design/

The videos are really good and there are plenty more on Youtube. Check out the videos by "123toid"…they're excellent.

Here are a couple of the screenshots from a sample project. It is nice in that you can play around with the parameters to get the tuning optimized. And, you can also model the dimensions of your port. WinISD does a whole bunch of other stuff. Again, watch the videos.





Finally, I got turned onto a website called www.the12volt.com. It's really for car audio but this site has a box calculator that allows you to enter the dimensions of the box you are looking to build, and it will calculate the volume. From there, you can play around with the parameters and zero in on your dimensions. It does cylindrical shaped enclosures too, which was particularly helpful for my current project.

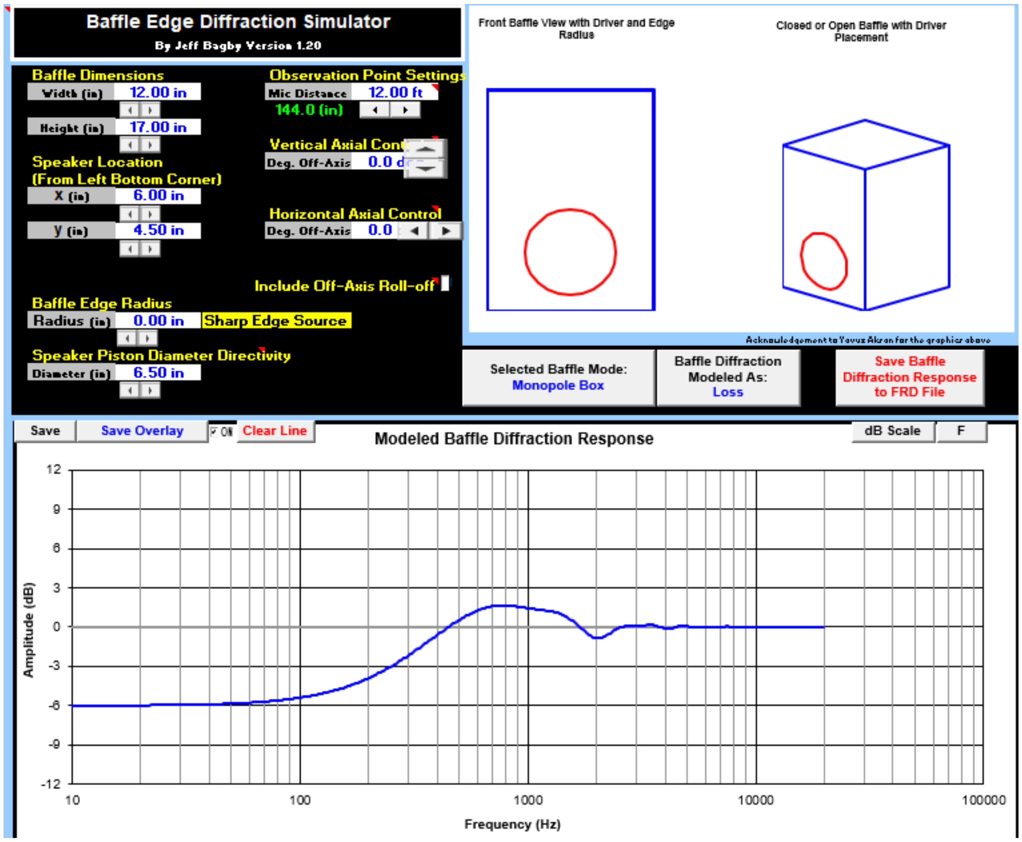
Baffle Step Simulation

This might be a little too far down in this document. I put it here because you need to know the dimensions of the cabinet you just modeled in WinISD. You can do this as soon as you think you know which drivers you want to use and before you buy anything. I chose to locate it here because this can seriously affect the shape and size of your enclosure. The tool I use here is Jeff Bagby's Diffraction & Boundary Simulator. It is another straight-forward, well designed tool.

My recommendation is that you simply enter in your information and play around with it to understand what effect moving the driver around has, keeping in mind that you probably have other drivers to be concerned about as well in the enclosure.

The interface is straight-forward and the fields self-explanatory.

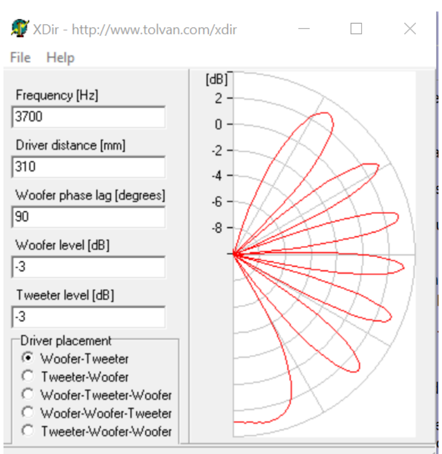
Here's one from a sample project. In this case I found that the lower in the cabinet I could place my midrange, the less diffraction I would experience.



Polar Response Simulation

Xdir is a free product from Tolvan Data that does a couple of things very simply and very well. You can enter the parameters of your proposed design to see how speaker placement will affect directivity.

I just had to experiment with it a little to figure it out. I couldn't find any Youtube videos either. It's pretty easy though. Here's what it looks like:



Cabinet Build

I'm not going into this as part of this document as every enclosure is different. I'm going to trust that the reader has either chosen to buy an existing cabinet or has the tools & skills to build their own. Another option is to have it made. There are some resources on my website, especially the "Build" page, that might be useful.

One topic I will call out here is the bracing of the cabinet. The speakers don't have to be large to need it. I've built 2-way stand-mounted speakers that have bracing. Don't overlook this important step that will make you cabinet more rigid and therefore sound better because of lessened vibration and some wave break up.

Once your cabinet is assembled, you can move onto the next phase. It doesn't need its final finish job (paint, veneer, etc.)…it just needs to be assembled. If you are going to use ½" felt as your dampening material, you'll install it here and that's fine. It is probably better that it is in there for later testing.

8. Driver Testing

In Cabinet Testing Procedure

This is similar to what you did during the Driver Modeling phase. There are two main differences. First, you don't need to do the DATS testing because you've already done it. The second is that you are now going to run the Omnimic tests in the assembled enclosure. We want to see how the drivers will respond to the enclosure itself. This will allow us to capture a new .FRD file based on the enclosure (versus the test baffle). From it we can determine the offset for the drivers through Xsim. Nigel Tufnel calls this Interferometry. He goes on to say, "The goal is to get the correct acoustic distance between the two drivers so when we design the crossover the simulation has the correct phase information to calculate the correct frequency response." Again, you are doing this WITHOUT a crossover.

Here are the steps:

1. Mount all drivers in cabinet with all speaker cable pulled out through the holes you drilled for the binding posts. Be sure to label them for easy identification.
2. Connect your woofer to the test environment.
3. Establish the proper signal strength using your SPL meter (~70dB).
4. **Make sure the "Show Phase" box is checked in Omnimic.**
5. Take your measurements using Omnimic and capture the new .FRD file (with Phase)
6. Do the same for the midrange.
7. Do the same for the tweeter, being sure to protect the driver with a 10-20uF series capacitor.
8. This time, do the same with all three connected (don't forget the capacitor again!!).

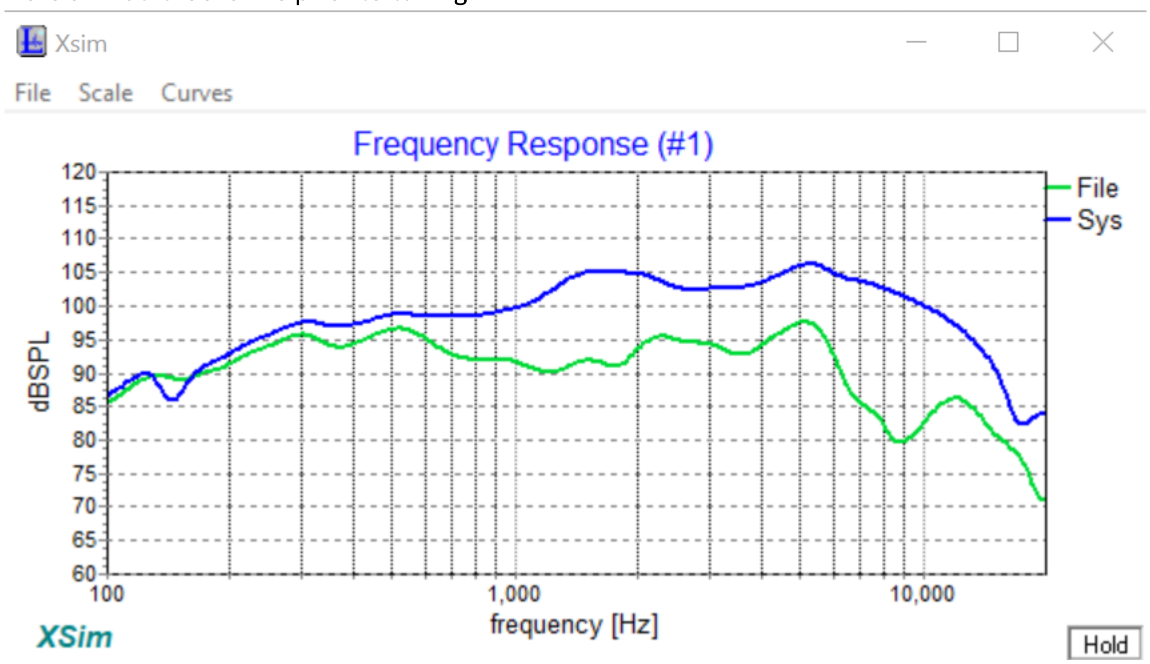
You now have the four new files you need to design your crossover. You have the .ZMA files from DATS and the new .FRD files from Omnimic (seven total). On we go to Xsim again.

9. Crossover Design

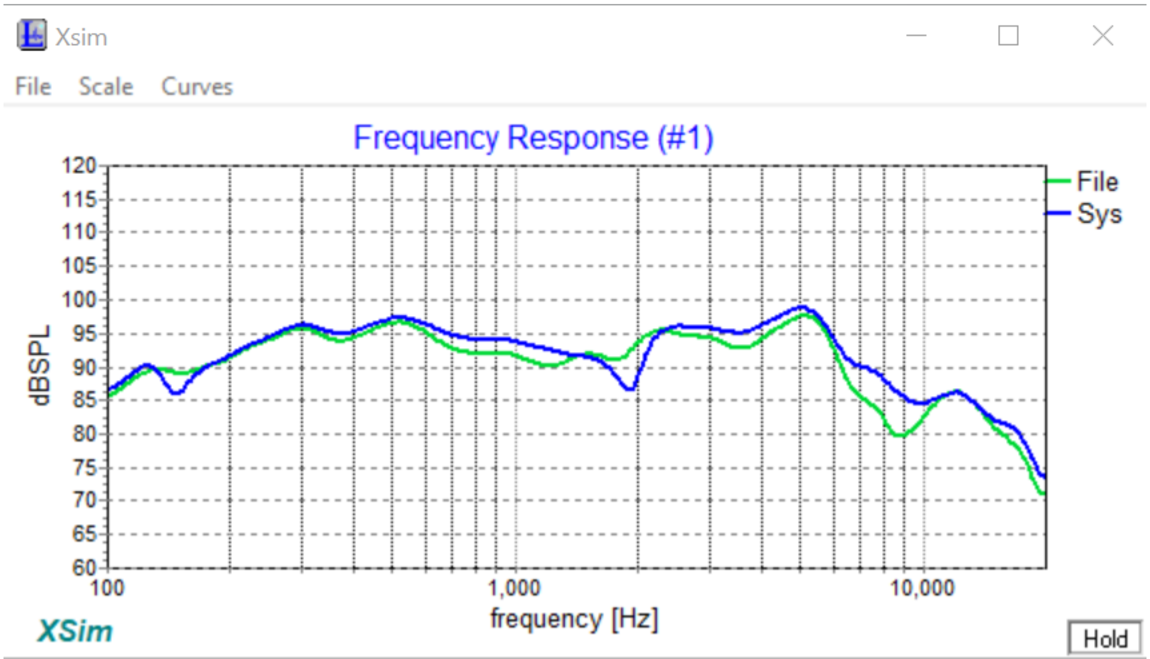
More Xsim

Here we are going to use Interferometry to determine the acoustic offset of our drivers.

1. Create a new network with all drivers represented.
2. Import the file with the combined .FRD file in the window to the right by
    a. Click “Curves”.
    b. Click “Get File”.
    c. Select file from your save location.
3. “Tune” the drivers to add the corresponding ‘new’ .FRD file to them.
4. “Tune” the drivers again to add the .ZMA files.
5. Display the imported curve and the ‘Sys’ curve in the upper right window.
6. Do not freak out at how it looks…they’re not supposed to match yet.
7. Do not display the individual driver curves.
8. Here’s what it looks like prior to tuning:



9. “Tune” the woofer driver by adjusting the delay until the curves come close together.
10. Do the same for the midrange.
11. You now have your delay(s) set. Pretty cool. After tuning:



From here you are going to model out your crossover. My style is to start as simple as possible and go from there. You may start with the model that you created in your test baffle sandbox. I'm assuming that by now you have done your research on different crossover topologies (i.e. Linkwitz, Butterworth, Zobel, L-pads, etc.). This is going to take some serious time, especially for the beginner. Don't get frustrated.

Once my simulation looks acceptable, I can set off to buy the components required. There's not much to fear as far as investment goes. Xsim is really accurate and you'll see that later.

10. Cabinet Finishing

Interior

One important step here is cabinet dampening. There are several ways to go about it. I like ½" felt if the cabinet is rectangular. You would have installed this when you assembled the cabinet. You can also use polyfill or a host of other products. I use the Mundorf Angel Hair. Whatever you use, this is the time to put it in place so that it is there when testing starts below.

Exterior

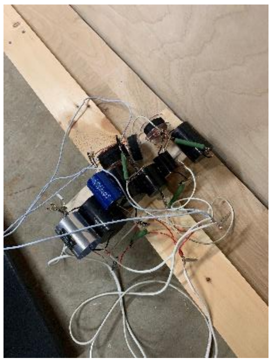
Again, not going to go into this much other than to say this is the time to make sure it is complete. Paint, veneer, stain, natural…you pick.

11. Crossover Assembly

Loose Assembly

This is where I will connect the components using alligator clips. First, I will measure how much space I have for my crossover board and I will cut it to size. Cut a board to the dimensions you determined. I use ¼ plywood…nothing fancy…if nobody is going to see the crossover. If it is going to be exposed, that's a different story. Dry fit it in place to be sure you're correct.

I will also take a first look at how they might actually be laid out on the board that gets mounted in the speaker. It's not final, but it gets me thinking about it. This is very rough, but it works.



You ought to have figured out by now where your binding posts are going to go and where your crossover will reside in the enclosure. That will give you approximate measurements to work with. There's no real secret at this phase, just hook it up so you can see if it performs as expected.

Initial Test

Let it rip!! The first full test with all drivers and crossover. I admit that this can be a little nerve-wracking. You've put a lot of work into it. Relax, it typically works out fine. Using Omnimic again you'll measure out your speakers and produce your FR and Impedance graphs. How do they look? How do they compare with the Xsim simulation? They should be pretty similar.

Crossover Adjustments

Hopefully, there are none. But this is why you used alligator clips. Maybe a slightly different value coil or cap or well placed resistor will be needed to flatten out your FR curve. Better to find out here. The good news is that you can do whatever you want and if they sound good to you then great!

The great thing about Xsim is that you can try out any mods before committing to buying anything. Experimentation is the watchword. I tweak Xsim a lot to zero in on values of components. I found that it is good to 'split hairs here' and even if a small adjustment is called for, make it and re-test.

Secondary Test

If I made any adjustments, I'll run it through Omnimic one more time to see if it achieved the desired effect. Did it make it better, worse or no change? My thought is that you can't do enough testing.

Final Crossover Assembly

We're finally here. We love how our new speakers sound. But, how are we going to put the crossover together? A recommendation here: TAKE YOUR TIME! This can take hours of patient placement and connection making.

Here are the steps:

1. Gather your crossover panel and organize your components by type & value.
2. Have Xsim open and handy to constantly reference your schematic.
3. Place components in a dry run, iterating until your layout works. By 'works' I mean that you must be able to clearly see how you are going to connect the components to each other in the proper order. Caution must be taken here to ensure that components can access the ground and/or speaker wire. You may need hook-up wire to accomplish this. This is the time to figure that out. You also have to be certain that layout rules are followed (i.e. inductors next to each other are not facing the same direction).
4. Are you going to use shrink wrap to cover your connections? Think about that now so that you remember to cut it to length and slide it on BEFORE you make the physical connections and solder. Personal experience speaking here.
5. Make connections and solder those that are a tight fit on the board. You may need the space to get your soldering iron in there…it can pay to solder first before securing to the board…use discretion.
6. Use glue gun to secure components in place. Note: some may have to wait to be glued down until after connecting and soldering. Use your discretion.
7. Place heat shrink, make connections, and solder those components that are easily accessible.
8. Fasten heat shrink in place with heat gun.
9. Consolidate positive and negative wires so that you have the exact number of wires to hook up to your binding posts on one end and the speaker drivers on the other end. Label them (or mark them) so you can identify them.

12.Burn-In

Why?

Burn-in is the belief that the drivers in speakers arrive stiff and inflexible from the factory, which means that they do not sound as good as they possibly could. It's only after continued use that they loosen up and reach their peak performance. The period of time that it takes for these drivers to reach their intended state is known as the burn-in.

Following this line of thought, this means that those brand new DIY Speakers that you only finished building yesterday are but a glimmer of their true selves. And, in order to hear them in their true intended form, you need to pump sound through them for some amount of time. The length of time can be debated. I've read the same for the crossover components.

I don't know if it does or doesn't make a difference, but I do it anyway. I pump pink noise (or music) through them at low levels 24/7 for a few days. I don't have a set amount of time. It's usually a situation where I can't get to it for a couple of days so I just let it go.

Here are the steps (for both crossovers/speakers):

1. Using alligator clips, connect each driver to its corresponding hook-up wires on the crossover.

2. Connect hot/cold wires to your test environment.

3. Play pink noise (or music) at fairly low levels and let it run for a couple of days.

13. Final Assembly

Binding Posts

I've had good luck with both Cardas and WBT. I typically buy long posts if they're available to give me more clearance on the inside of the cabinet. It probably doesn't matter much, but it is my preference.

A word of caution here: be careful that you pick a location for the posts that allows for the installation of the crossover board.

There are several steps to follow for final assembly too:

1. Mount binding posts according to manufacturer directions. I typically solder hook-up wire to them before I mount them in the cabinet. It effectively makes the binding post 'longer' and makes connecting to the crossover easier.
2. Run speaker wire for each driver from its hole in the cabinet down to the crossover, leaving some slack. Sure, you want to minimize the distances, but you need enough wire to reach the crossover.
3. Connect speaker cable to drivers. I use connectors at the driver…no soldering directly to driver tabs unless ABSOLUTELY necessary. I typically use Furutech.
4. Pull all speaker cable from drivers out through woofer hole.
5. Place your heat shrink, connect hot and cold leads of hookup wires to corresponding speaker cable coming from the drivers, and solder.
6. Mount tweeter and midrange drivers in cabinet.
7. Maneuver crossover into cabinet through woofer hole and secure it with Velcro Industrial Strength or whatever method you choose to go with (i.e. screws).
8. Mount woofer in cabinet.
9. Test again.
10. Celebrate!!

14. Final Testing

Frequency Response & Impedance

More Omnimic? You bet!! This is the final product and you're gonna want to show it off online. You just built a set of speakers that would cost several times more to buy and maybe not sound as good. In my experience, DIYers are going to want to see the FR graphs.

15. Conclusion

I hope that this little guide pointed you in the right direction. I'm certain that there may be better/different ways to accomplish this. There are free software packages that can be substituted. I've just tried to use the best 'bang for the buck' products I can find. This is just a process that works for me and I hope it works for you. You are now on your way and you can into as much depth as you want in any area. The forums are great for continuing your education in this fascinating field.