

How To Use **Passive Crossover Designer**

To Find The Relative Acoustic Offset

By Jeff Bagby

Introduction

In this article I would like to explain how to use my **Passive Crossover Designer** Excel tool to find the relative acoustic offset between the acoustic centers of two drivers for crossover design.

Finding this value is not difficult if these steps are followed, and once found will allow for very accurate crossover design simulation using my **Passive Crossover Designer**. Without knowing this value phase relationships will not be accurate, and as a consequence, the accuracy of the modeled response will be reduced as well.

This method requires the ability to take loudspeaker measurements using any number of measurement methods such as Soundeasy, LspCad, Praxis, Clio, ATB, OmniMic, or a separate measurement microphone and software such as ARTA, Holm Impulse, or other systems. In this case, I used OmniMic.

As you will see, perfect measurements are not necessary. To make this point my example was done in my family room intentionally to show that you can do this the same way.

My Set-up

To begin with, I am designing a small stand mounted monitor type speaker with a 6.5" woofer and a 1" dome tweeter in a .35 cubic foot sealed enclosure. Both drivers are centered on the baffle with the woofer below in the tweeter is a standard arrangement. The cabinet has been placed on a 28" stand in the middle of my family room and the microphone has been placed on the tweeter axis about 33" away from the speaker. Out of the back of the cabinet are two sets of wires – one set leading to the woofer with no crossover, and one set leading to the tweeter with no crossover as well.

To find the acoustic offset I will need to take three measurements, but for all three, the position of the microphone and the speaker must remain unchanged. This distance and axis must be held constant.

I should add that I have used this method for years in one variation or another. However, I am not the only person to develop this method. David Ralph (dlr on several forums) published an article on this same method over a decade ago in Speaker Builder magazine, and has a version of it available for download on his website (www.speakerdesign.net). I recommend this article for all seeking additional information.

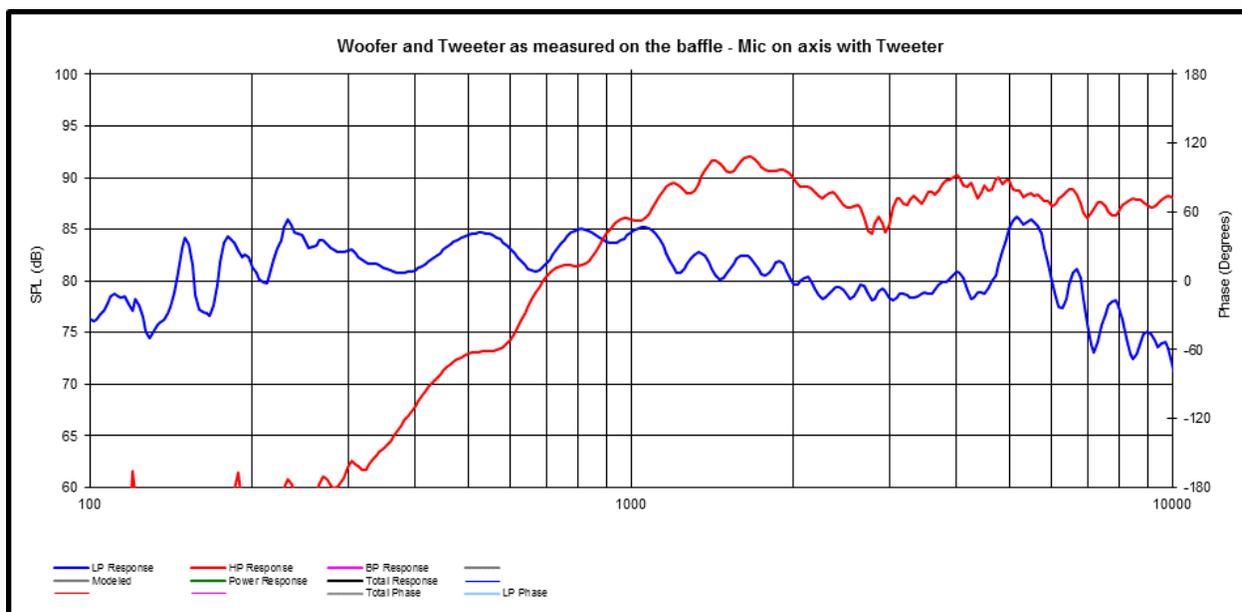
Three Measurements

The first thing I do is take a measurement of the response of both the tweeter and the woofer without changing the speaker position, microphone position, or amplifier setting between takes. As stated above, leaving this

constant is essential. I use alligator clips to connect my speaker wire from the amplifier to the leads for each driver. For these measurements I used an 8 mSec gating on my impulse response. Make sure with whatever software you use that phase data is included in the generated frd file. Without this phase data the file will not import into Passive Crossover Designer. The measured phase data is also important to determine the relative offset.

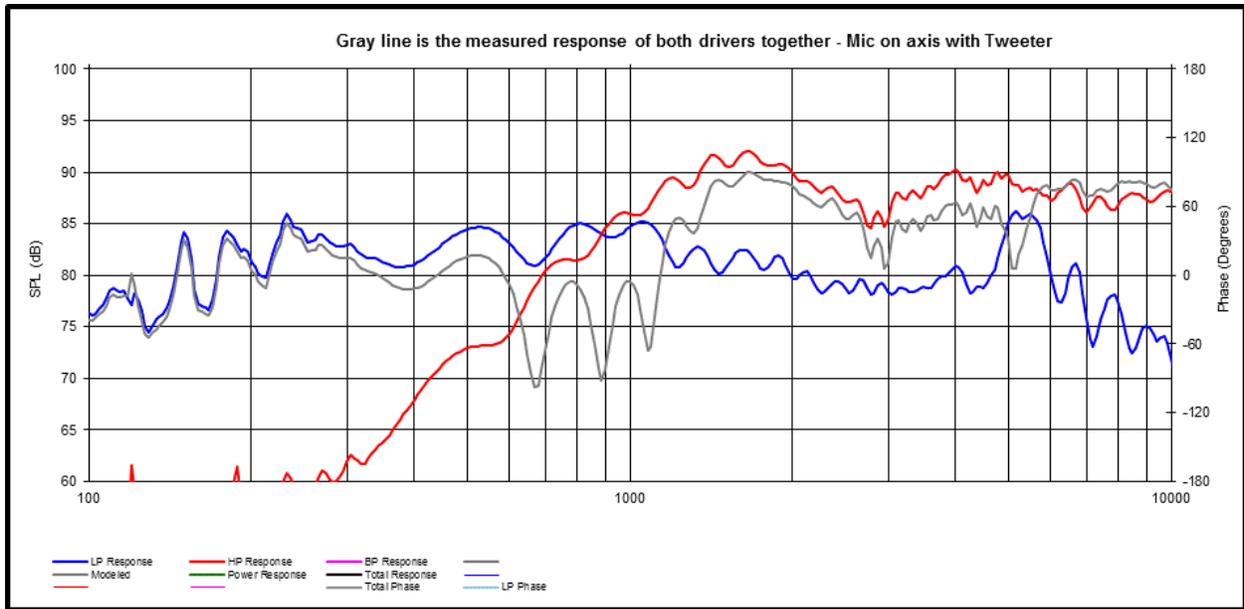
I have used the OmniMic from Parts Express for this article. OmniMic normalizes the measured phase data from the spike of the impulse response, leaving a form of Quasi- minimum phase response. If you have pure measured phase with all of the time-of-flight included you may need to adjust that out, or extract the minimum phase from the data before importing the files into Passive Crossover Designer. However, these steps are not necessary with the OmniMic, its data can be used directly.

The chart below shows the frequency response of the tweeter (Red line) and the woofer (Blue line) taken under the conditions listed above.



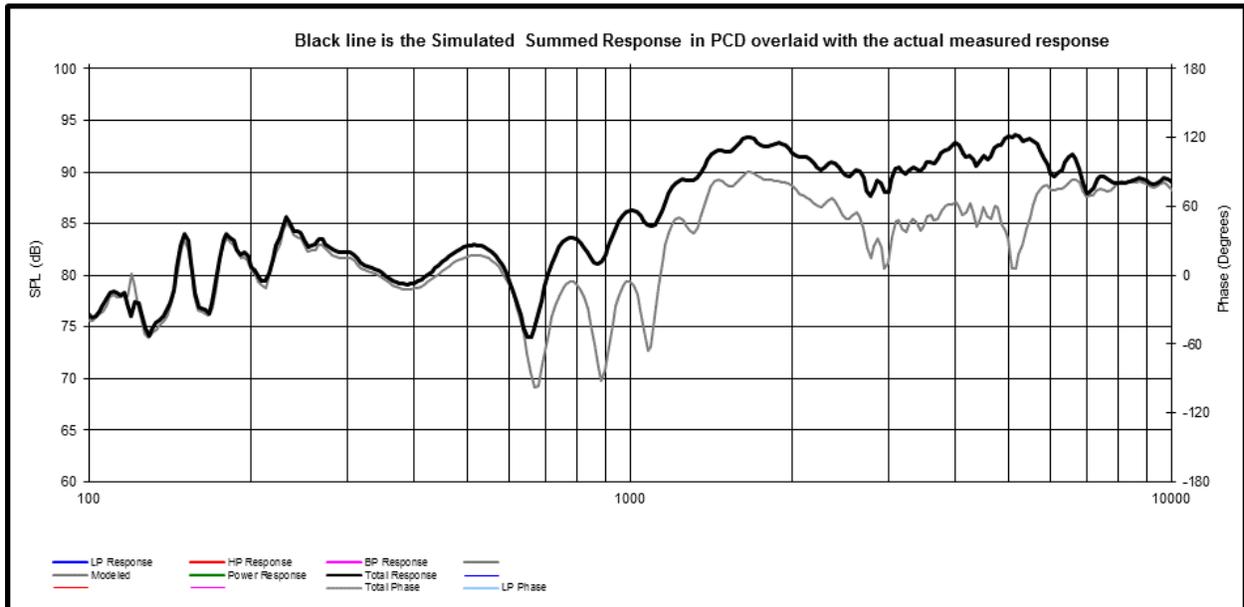
After taking each individual driver's frequency response, using the alligator clips, I connect both drivers together in parallel observing the same polarity, and take a summed response measurement. This summed response will not be flat, in fact, it may have very severe peaks and dips. As we will see, this does not change our ability to determine the relative acoustic offset.

The next chart includes the measured response of both drivers connected together (Gray line). This line has been imported into Passive Crossover Designer as the "imported overlay" line.



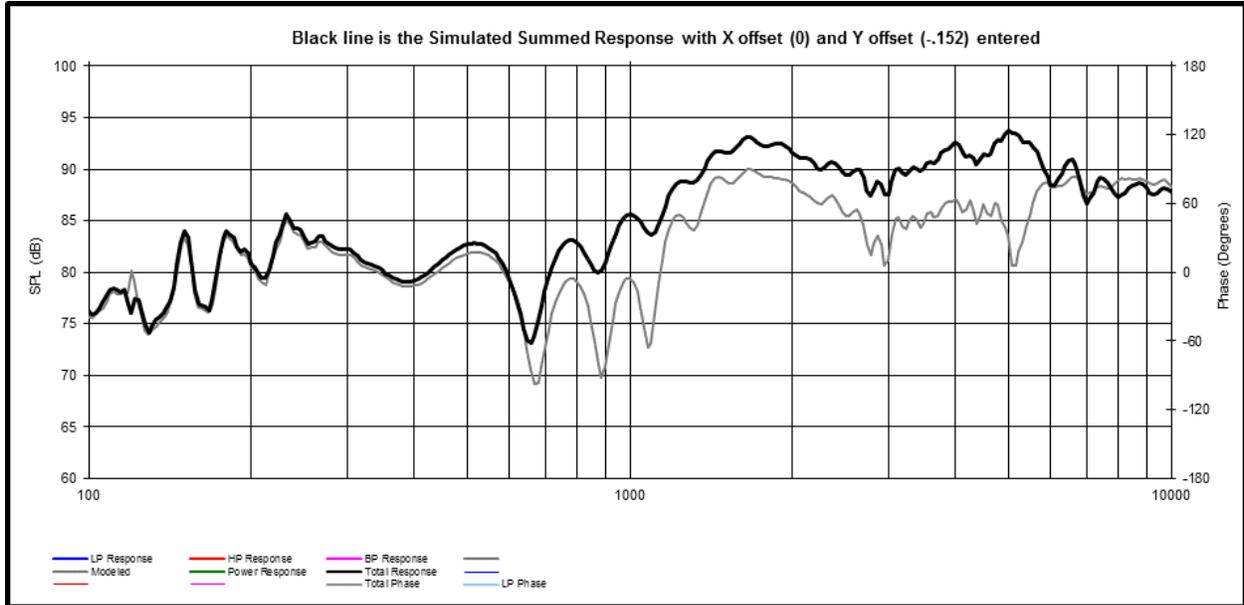
The Simulation

Now that these three measured responses have been imported into Passive Crossover Designer, it is time to let PCD calculate the summed response. That line is shown in black below, overlaid with the actual measured combined response. Keep in mind that in PCD the offsets are all set at 0.000 Meters and the listening distance is set to the default distance of 2.0 Meters.

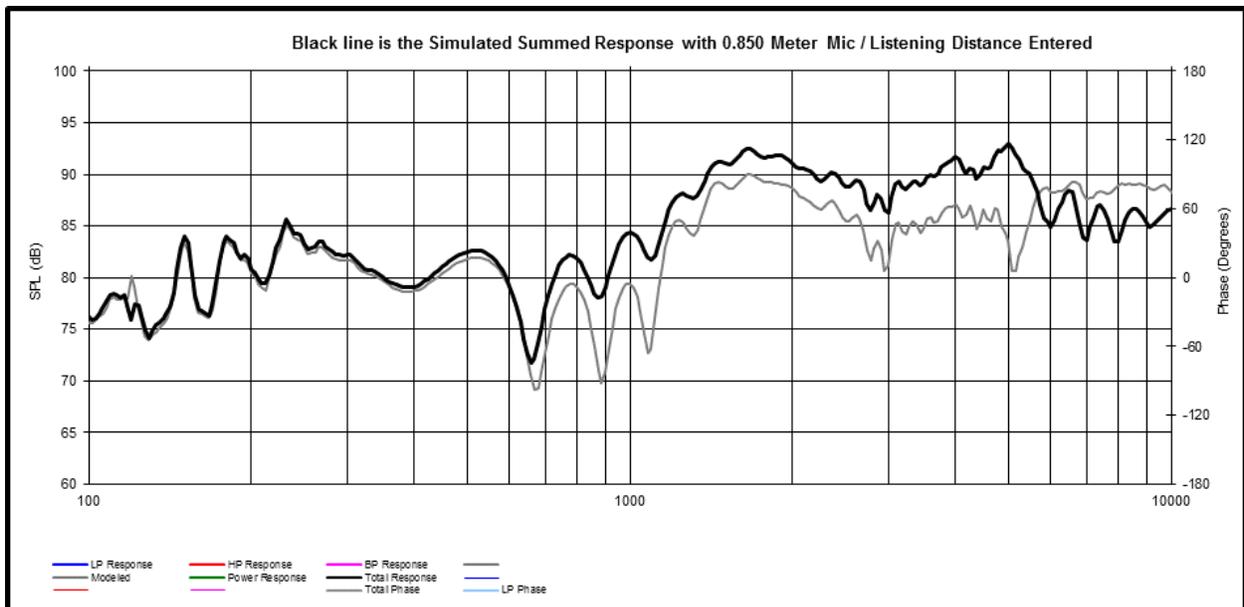


Setting The Offsets You Know

The next step is to set the offsets that you can physically measure. In this case, the center of the woofer is exactly 6" below the center of the tweeter on the same vertical line. Leaving the tweeter's offsets all at zero I enter 0.000 for woofer's horizontal offset and (-.152) Meters for its vertical offset.



Next I have to adjust the microphone distance / Listening distance in Passive Crossover Designer to match the actual distance the measurement microphone was from the tweeter. This distance measured just a little over 33 inches with a tape measure. This equates to approximately 0.850 Meters. If this is not adjusted and the setting is left at the default of 2.0 Meters then the relative offset will not be arrived at with the highest degree of certainty, because the other phase relationships will be slightly off. The next chart shows the change in the simulation's summed response with this distance entered.

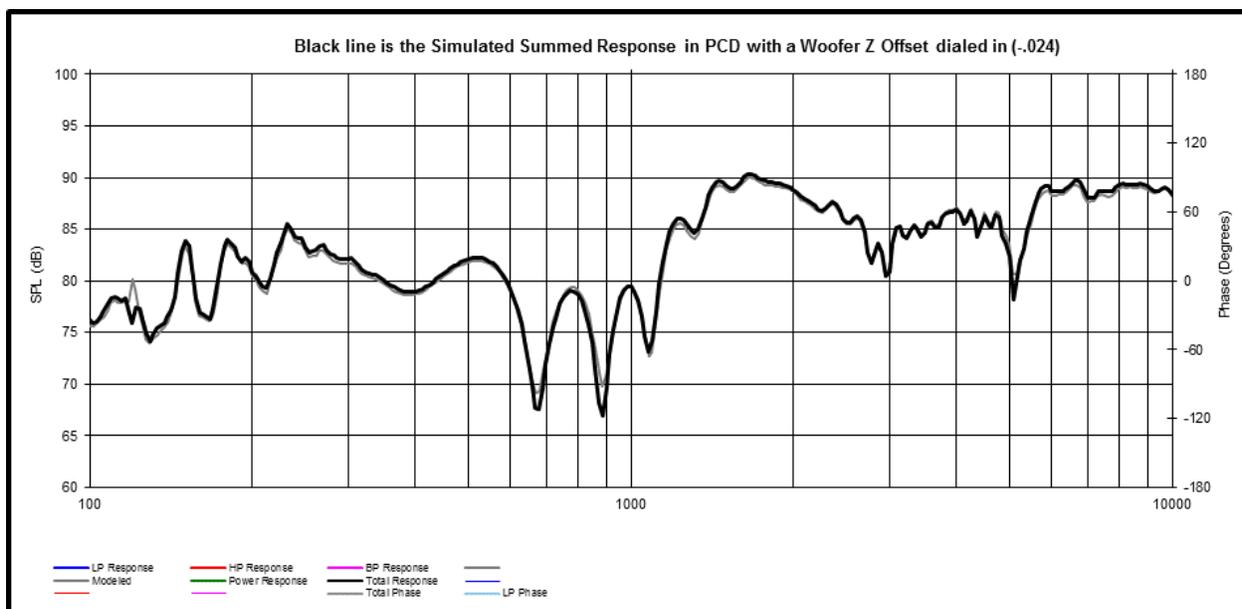


We now see that the two response curves are beginning to come together. At very low frequencies where the wavelengths are long we are already beginning to overlay the two lines – the simulation with the actual measured frequency response. At 650Hz they slightly begin to move apart and the difference increases as the frequency increases. Our next step is to find the relative Z offset of the woofer.

Dialing In the Z Offset

The only offset left is the Z offset of the woofer. This is the difference in distance between the Tweeter's acoustic center and the Woofer's acoustic center to the microphone. For a 5" or 6" woofer I would start with a value of around (-.020) Meters, or 25 mm for the offset. The negative sign is necessary as this has become the standard convention for expressing that the woofer is farther back behind the tweeter's acoustic center. This extra time-of-flight induces delay in the woofer's response and creates additional phase roll.

At this point I simply begin to manually enter values for the woofer's Z offset until I find a value that causes these two lines to overlay each other as closely as possible. In this case that value was (-.024) Meters, which is a very typical value for a 6.5" woofer and a 1" dome tweeter when both drivers are flush mounted. As you will see in the next graph this offset causes both of these lines – the simulation in Passive Crossover Designer and the actual measured response of both drivers at the same time - to overlay so closely it is difficult to even tell that there are two different lines here except for a couple of places.



Summing It Up

As you can see, perfect data is not required. Testing outside or in an anechoic chamber is not required, and a flat frequency response is not required either. You can test with a gated response in your family room like I did and still arrive at the relative acoustic offsets with a very high degree of certainty. For these two lines to match the way they do, your geometry must be correct. The complex interactions between X,Y,Z offsets and the Mic Distance makes it impossible to hit this type of agreement between a simulation using the individual driver responses and the actual measured response without being correct in your offsets. The key is again to not change the position of

the microphone, speaker, or the volume control when taking the three measurements. If you are diligent in your set-up and execution, you will achieve reliable results.

The Next Steps

The next step would be to do any post-processing to the frequency response of the individual drivers that is required (ie, extending the response, splicing near-field bass response, etc.) and then extract the minimum phase data from the final frequency response. Once this is done import the new frequency response files into Passive Crossove Designer along with in-box impedance measurements, and use the offsets that you have already found for your crossover design work. You may change the listening distance to 2.0 Meters or any other distance you desire now, and begin to work on your crossover design. **Passive Crossover Designer** will accurately calculate the summed frequency response on any axis you choose based on the offsets that have been entered, and you will find that the final response in your Passive Crossover Designer Model will match your final measured response exceptionally well. Having good data from the start will take much of the guess-work out of the design process, and give you a much better shot at a successful design.

Jeff Bagby, 9/30/2011