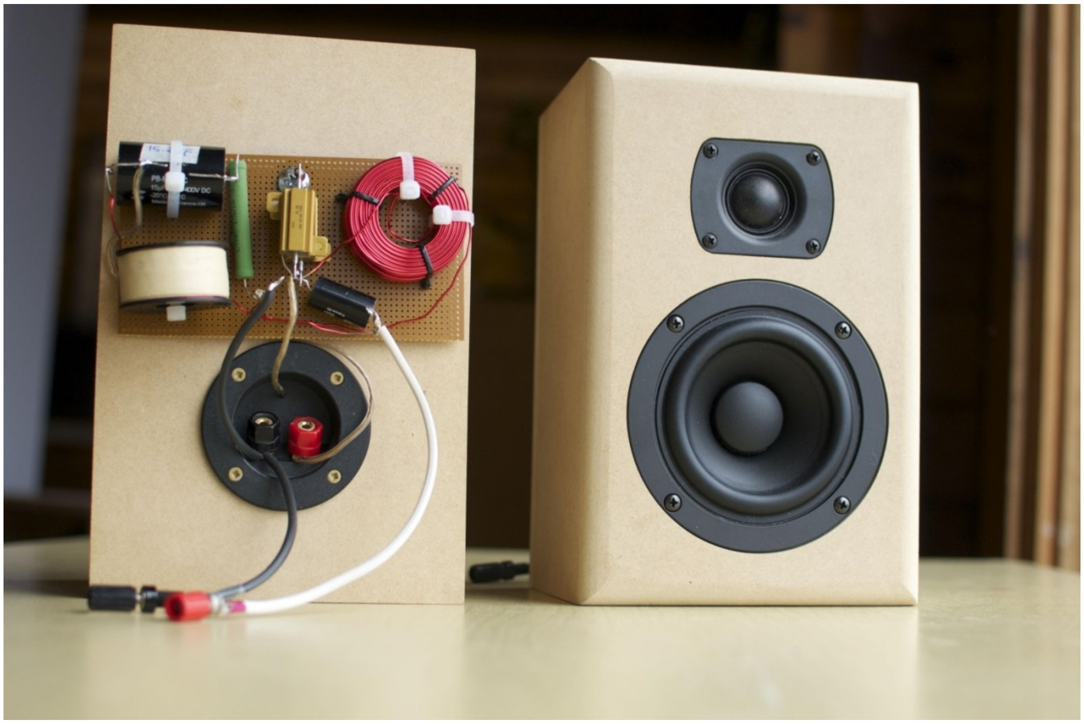
The Napoleons

Small Speakers that punch above their weight



The Napoleons are a small DIY loudspeaker designed to deliver a natural tonal balance and clean loud playback from of a small box suited to both small and large rooms, at a reasonable price. This write up was in response to requests from the 2013 Ottawa DIY fest, where the speaker was first shown http://www.diyaudio.com/forums/clubs-events/223294-diy-ottawa-winter-2013-a-17.html

Driver Selection

Off axis response irregularities will detract from speaker tonal balance more in a small room than in a large room due to the greater relative strength of indirect sound, compared to direct sound. To help combat this, a tweeter was chosen with some mild horn loading, and a woofer with a well-controlled extended higher frequency response that could take advantage of it.

The Tang band W4-1720 (http://www.parts-express.com/pe/showdetl.cfm?partnumber=264-872) provides powerful and clean mid to upper bass from a very small sealed box. A vented design was avoided to keep the box small and to avoid box/vent unloading which would compromise the high sound pressure levels desired for larger rooms. The mighty little W4-1720 plays ridiculously loud and clean in this application, and mid to upper bass is rich enough to give a pleasant tonal balance. It's smooth mid treble allows a higher crossover point so the tweeter can play loud without strain. This is a good sounding driver, but it can still be made to bottom when over driven by drum test discs. Still, it plays clean and loud enough to pass the "I didn't realize it was playing that loud" test.

The tweeter is the Vifa D26NC55-06. It's well-controlled off axis response near crossover and its drooping high frequencies off axis reduce "splatter" in a small reflective room. Its distortion is also very low. While this driver is officially NLA, examples can often still be purchased from on-line suppliers.

Box Dimensions

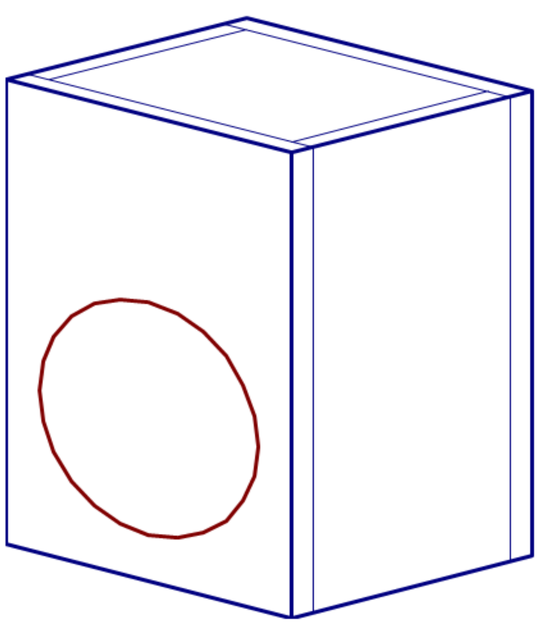
The sealed box is simple and was built using hand tools and a flush trim bit. Half inch mdf kept the box small which in turn keeps panel vibration under control. The box was made shallow to allow true shelf mounting. Woofer center is 3.5" from bottom, tweeter 7.5". Drivers are centered horizontally.

A different baffle shape (for example due to thicker wood) would change diffraction and affect the response. This could require a crossover change and this design is expressed for 0.5" wood only.

Bracing						Wall Thickness (Inches)			
Width	Length	Depth	Qty/spkr			Front	Rear	Top/Bottom	Sides
5 1/2	9	0.5	0	Full length		0.5	0.5	0.5	0.5
5 1/2	4 1/2	0.5	0	Shelf					

Outside Box Dimensions (Inches)			Internal Volume		Driver Height		Relief
Width	Height	Depth					drv - drv
6 1/2	10	5 1/2	3.65	liters	Drv 1	3 1/2	4

Bill of Materials	For 2 Speakers			
	Width	Height	Thickness	Qty
Front/Rear Baffles	6 1/2	10	0.5	4
Side Panels	4 1/2	10	0.5	4
Top/Bottom Panels	4 1/2	5 1/2	0.5	4
Bracing	9	5 1/2	0.50	-
Total Sq.ft	3.7	(5x8 Sheet is 40sq ft - 60"x96")		



The prototype shown has an externally mounted crossover, but of course this can be mounted in the box behind the tweeter. There is no room behind the woofer for the crossover. You can increase the depth by about a quarter inch to compensate for the crossover part volume, but it's not critical.

Bass Alignment

The measured W4-1720 parameters (closed box method) were:

SN034			SN 103	
55.325 "Fs Hz"			59.776 "Fs Hz"	
4.100 "Re Ohms"			3.900 "Re Ohms"	
18.323 "Res Ohms"			17.782 "Res Ohms"	
2.308 "Qms "			2.454 "Qms "	
0.516 "Qes "			0.538 "Qes "	
0.422 "Qts "			0.441 "Qts "	
0.149 "L1 mH"			0.142 "L1 mH"	
1.007 "L2 mH"			1.111 "L2 mH"	
1.515 "R2 Ohms"			1.742 "R2 Ohms"	
0.227 "RMSE-load Ohms"			0.218 "RMSE-load Ohms"	
57.00 "Area (Sd)"			57.00 "Area (Sd)"	
4.222 "Vas liters"			3.430 "Vas liters"	
8.944 "Mms(Sd) grams"			9.431 "Mms(Sd) grams"	
925.213 "Cms(Sd) æM/Newton"			751.665 "Cms(Sd) æM/Newton"	
4.969 "Bl(Sd) Tesla-M"			5.066 "Bl(Sd) Tesla-M"	
83.242 "SPLref dB "			83.167 "SPLref dB "	

These measurements were taken with several watts input power and are therefore not true "Thiele-Small" parameters, but I find this is a better representation of perceived box tuning at real playback levels.

The compliance and Fs differed for the two woofers. This may be due to batch to batch variation given the difference in serial numbers. By using a sealed design, the differences in the final system response are immaterial due to these driver production differences. The design is also insensitive to small changes in box depth. For example, adding 1" greater depth has no impact on F3.

	SN034	SN103	SN103	
Physical Vb	3.3	3.3	4.3	l
Absorption, Qa	20	20	20	
Leakage, Ql	30	30	30	
Alpha, a	1.206	0.971	0.745	
Vb	3.5	3.5	4.6	l
Fb	82.06	83.89	78.94	Hz
F3	85.51	85.51	85.51	Hz
Qtc	0.664	0.688	0.648	
Response peak	0.00	0.00	0.00	dB
Peak at	none	none	none	

The above alignments are with an 18 gauge air core low pass inductor. A 20 gauge inductor would reduce woofer sensitivity by 0.3 dB and F3 by 4 Hz. Larger gauges give slightly (0.3 dB) more woofer sensitivity. Neither has been auditioned and there is no inherent value to a larger gauge inductor in this application. 18 gauge is recommended.

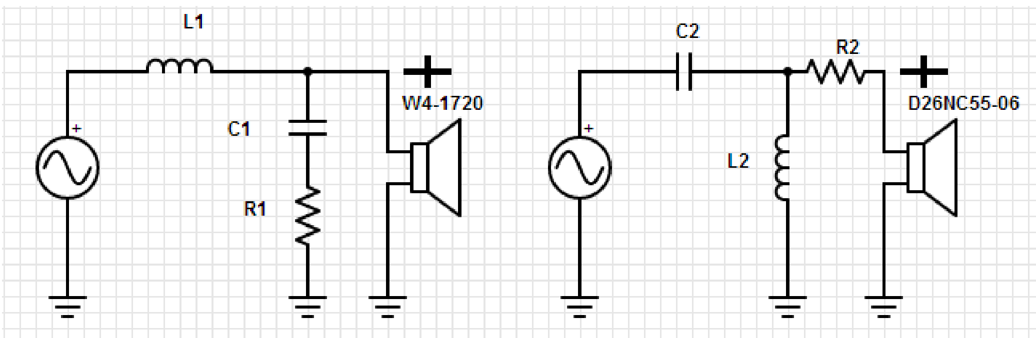
The box was lightly stuffed with audio poly.

Crossover and Frequency Responses

The crossover is a 6 element second order electrical, in phase driver connection. Special attention was placed on smooth on and off axis response, and a smooth response when standing while listening.

Low pass
L1: 1.5 mH inductor, 0.7 ohms dc resistance (18 gauge air core).
C1: 15 uF cap (not electrolytic)
R1: 1 ohm power resistor (10W or greater)

High Pass
C2: 2 uF cap (not electrolytic)
L2: 1.1 mH inductor, 0.5 ohms dc resistance (18 gauge air core)
R2: 15 ohm resistor, high power (25W or greater)



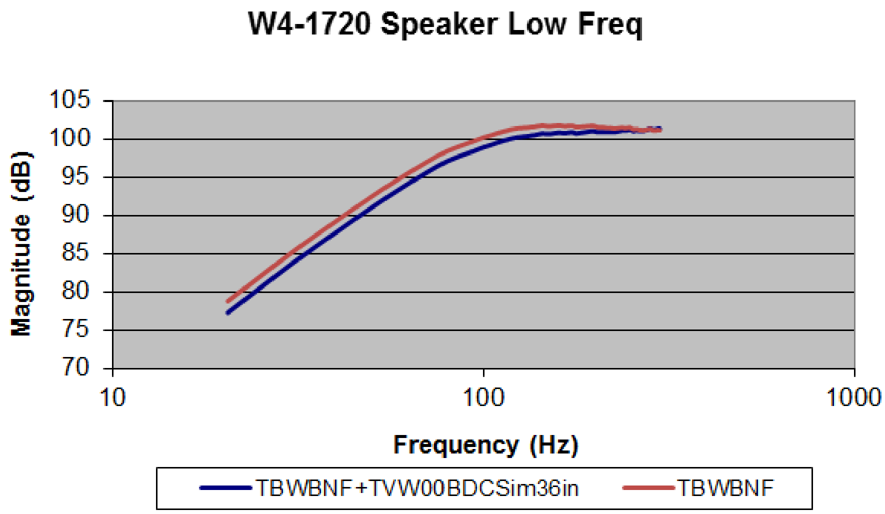
To help make this an easy load to drive, only a series resistor was used on the tweeter. Low cost air cores were chosen for their small size without iron core's potential for saturation induced distortion.

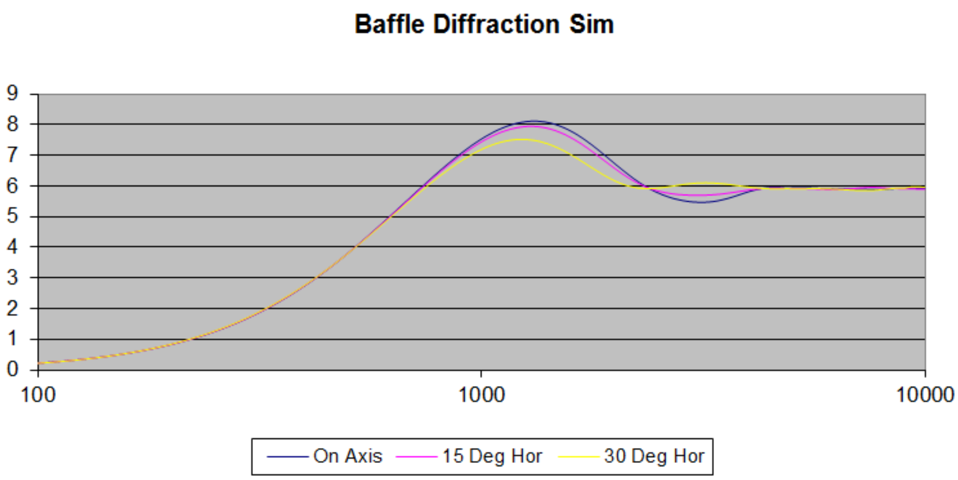
Anechoic Low Frequency Response: Diffraction and Near Field Splice

The reflection-free response is found by splicing the low frequency near field woofer measurement to the windowed in-room response after adjusting the near field measurement to the windowed in-room measurement mic position using a model of the box diffraction. See my tutorial at http://audio.claub.net/software.html for details.

I haven't seen on-line designs (or Stereophile) adjust the near field response for diffraction when splicing but the following graph illustrates the error that results. Without adjusting for diffraction, the predicted response would have been about 1.4 dB in error too high at frequencies below 100Hz.

The actual system tonal balance would be very different than predicted by the composite curve because the curve would have been inaccurate.



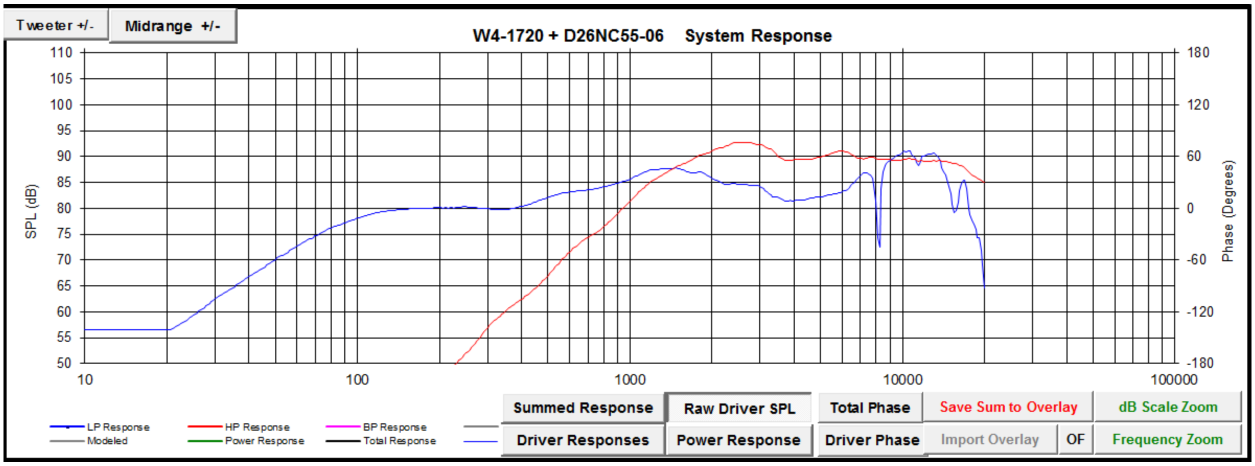


For all the graphs following, diffraction was modeled for each measurement point and the near-field measurement was adjusted to the windowed in-room measurement mic position using the diffraction model, before splicing to the in room measurement. Phase was corrected as well.

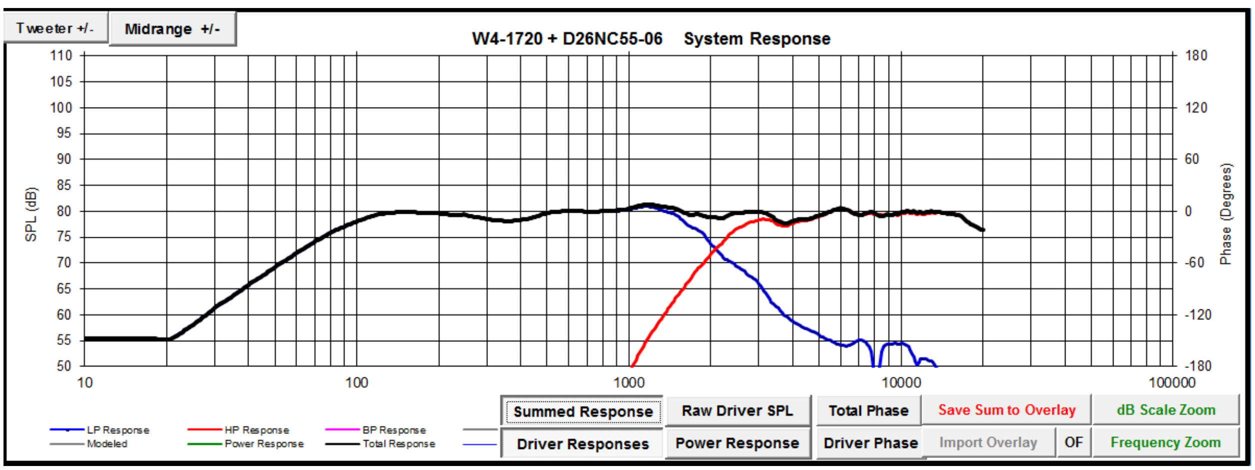
These can be considered highly accurate reflection-free responses.

All sensitivities are at 1 meter.

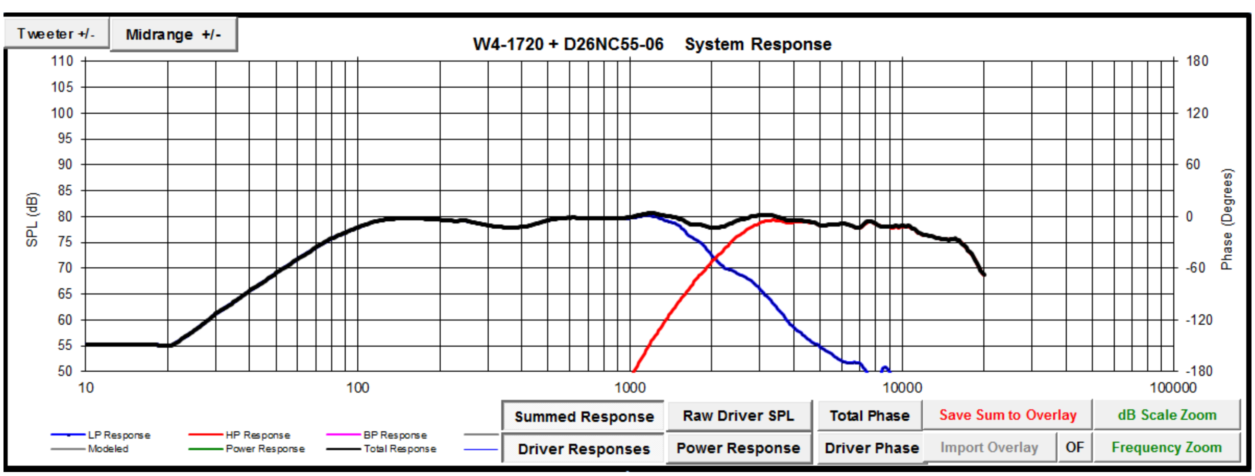
Driver Responses in Box, Unfiltered, On Axis



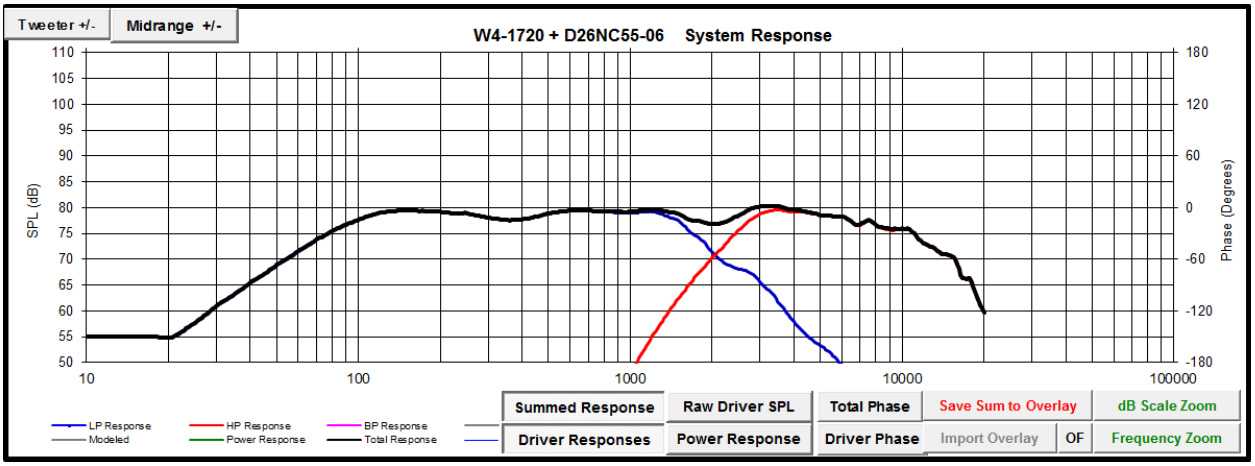
On Axis System Response



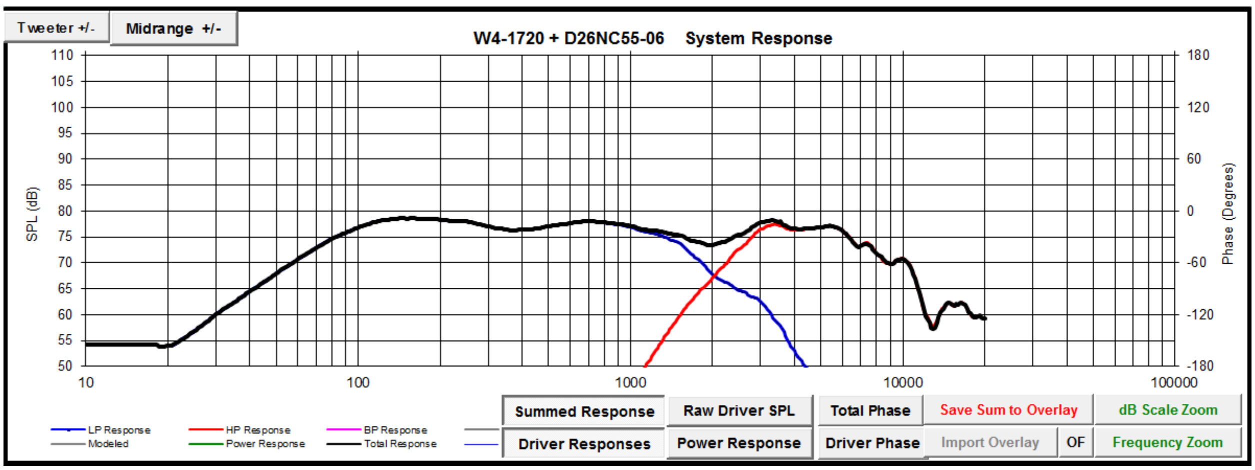
15 Degrees Horizontal System Response



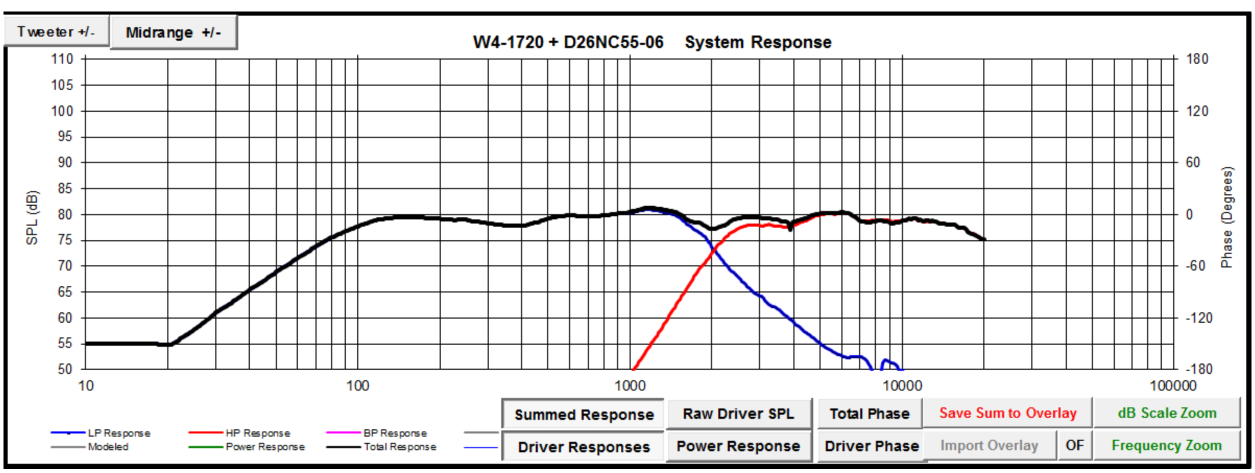
30 Degrees Horizontal System Response



60 Degrees Horizontal System Response



+15 Degrees Vertical (represents "listener standing") System Response



Filter Electrical Response loaded by the drivers and the System Impedance

Filter shapes were chosen for as high a crossover point as possible while maintaining a good off axis response, acceptable rejection of woofer break up and a good tonal balance standing up.

Electrical System Impedance is an easy drive even for chip amps as it never dips below 5 ohms, and never gets too capacitive.