The Burning Amp NC-434
Or
Newb Cube 4”-3/4”
Or
“The simplest good sounding speaker I know how to make…that actually has a ton of engineering in it.”

By

Scott Hinson

Audio Engineering Society
AUDIO A ES Member

Introduction

When in the course of human events it becomes necessary for DIYers to build a speaker, they sometimes believe it is necessary to keep it simple and use a single full range driver. We the loudspeaker engineers, in order to form a more perfect soundstage, establish clarity and reduce modulation distortion and pesky cone resonances may scoff at this approach…but when we..ppfft…. That was too much work.

Look, I don't like single full range driver speakers. There's just too much audible modulation distortion, the high frequencies beam like crazy and their time domain performance leaves more than a lot to be desired. I've measured expensive ones with 20dB swings in the frequency response above 5kHz and to get them to reproduce 15-20kHz they must resort to very thin cones and/or whizzer cones operating well into their breakup mode. Simply playing pink noise and moving your head side to side leaves you with the tell-tale sign of rapid response changes with position.

But I get told that many of my designs are to big, bulky, complicated or dare I say it….perfect[1] for every day use.

Background

A couple years back SpeakerSpouse threw down a challenge. "SpeakerScott", she said "We need small speakers for the top of this bookshelf, like a little cube".

Well…okay. At the time I had decided to turn it into a DIYRM project, but I never did. Fast forward to a few months ago and all of a sudden I'm agreeing to run Speaker Camp for the Burning Amp folks but we need a speaker project. I offered up the cube…and we decided to go for it.

So it's a super simple 6" box made out of ½" material. The woofer fires upward, the tweeter forward and the "crossover" is a grand total of 3 components. Except…one of the components isn't used for crossover duties, more on that in a bit.

With such a simple design one might assume that not a lot of engineering decisions were made in the design. But that's not true…I can't help myself when it comes to making engineering tradeoffs, I will figure out ways to minimize problems.

[1] No one's actually said that. That's just me being a doofus.

Expectations

Is this the ultimate in ultimate fidelity? No. It's a small form factor two way that relies on some careful engineering to maximize the capabilities of well engineered but budget conscious drivers. Does it have the flattest on-axis response, nope…but as we'll get to later in the document, what does on-axis even mean for a speaker like this.

Is it a really compact, budget conscious, super easy to build speaker with sound quality way above the average smart speaker or portable speaker? Yes. Absolutely. Quite a few decisions were made during the design to get more out of less and minimize the faults induced by trying to keep it simple.

Engineering Decision #1-Reduce distortion, lower F3.

A 6" cube with internal dimensions of 5"x5"x5" (1/2" material on all 6 sides) is a whopping two liters. In most designs to get more bass response there is a ton of EQ applied to boost the low frequency content. This does a couple of things, first it introduces amplitude modulation distortion and compression since the driver has to absorb all that power. Hoffmann's iron law is undefeated and if you apply a ton of voltage a driver in a small box, which means efficiency is low and that power has to go somewhere…and that means it has to heat up.

I picked the SB12PFCR-08 4" woofer for the project. In a 2L sealed box the driver has an F3 of ~100Hz but a relatively high Q with a peak centred at 150Hz. You can get a better F3 in a vented box, but that has to be 10L for the driver…which is way larger than what SpeakerSpouse wanted for the space. Either way you're never going to get tremendous high output at low frequencies…you're limited by the physics of the thing just being a 4" woofer. It's just not going to happen.

Most designers these days would have gone the EQ route, but I wanted this to work with any amplifier I hooked it up to, and I didn't want to build an external EQ box. That was just way too much effort for what I was trying to do in a single weekend.

So, I went back to an old trick. I used a third order capacitor assisted alignment.

????

Yup…sealed is second order, vented is 4'th order and by putting a capacitor in series with a sealed box driver, and sizing it right you can get a 3'rd order system. This used to be more popular in the late 60's and early 70's but as driver power levels and amplifiers got bigger it fell out of favor. You need an expensive capacitor in many applications where you're trying to get a low F3, but as this thing clocks in at >100Hz and I'm not trying to get it down to 30Hz, the

capacitor can be a reasonable value and size. I would not use this in a home theatre subwoofer for instance you'd have a tough time finding capacitors with the current handling capacity to survive the application, and they'd cost a fortune.

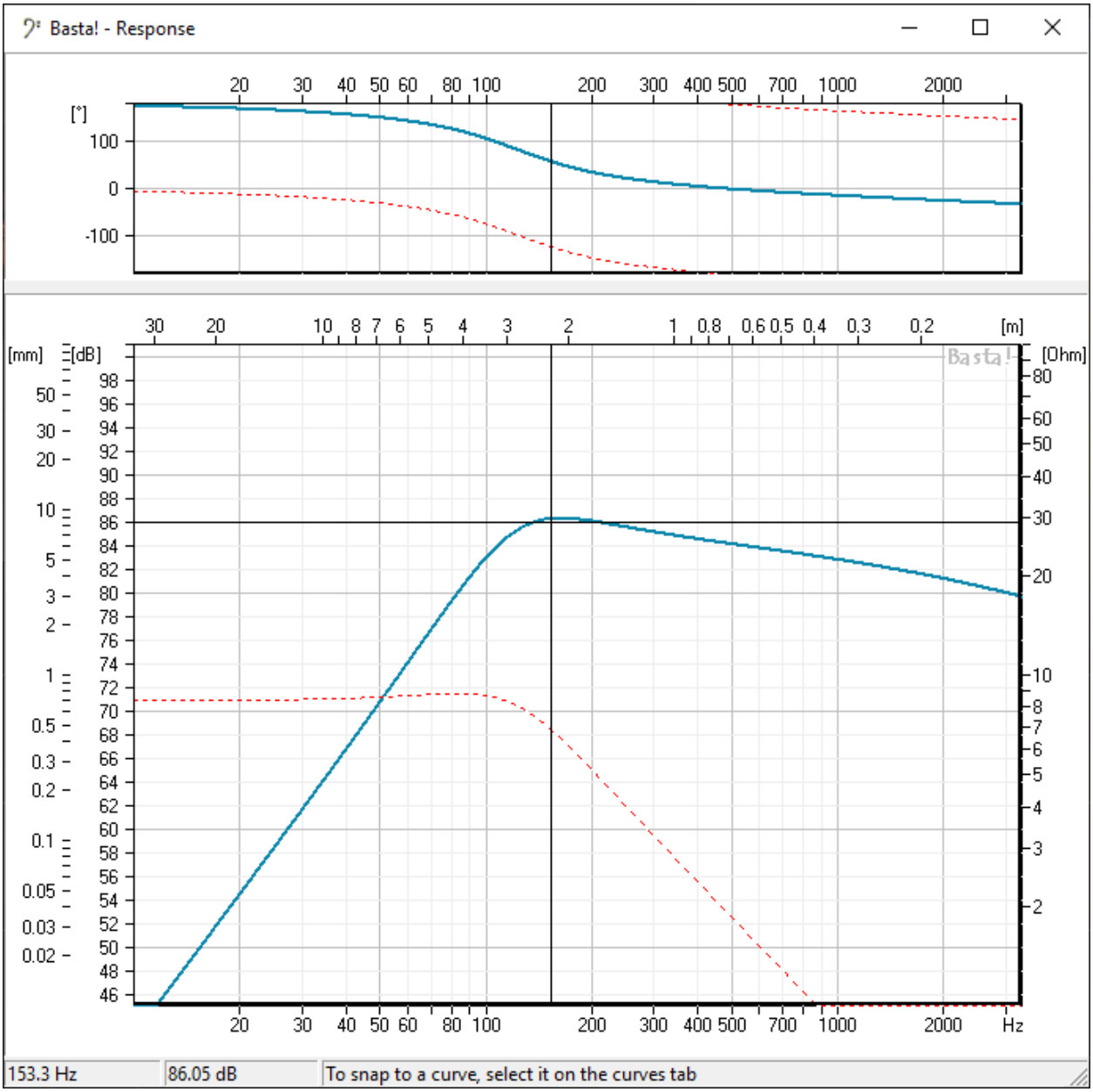

Figure 1 2L Sealed Box Response

You can see in the sealed box alignment that there is a pretty good peak, and the excursion levels off below F3, indicating that the air in the box itself is providing a substantial portion of the restoring force. The box is roughly ½ of the VAS of the driver so that makes sense.

Now, what happens if you put 330uF in series with the woofer?

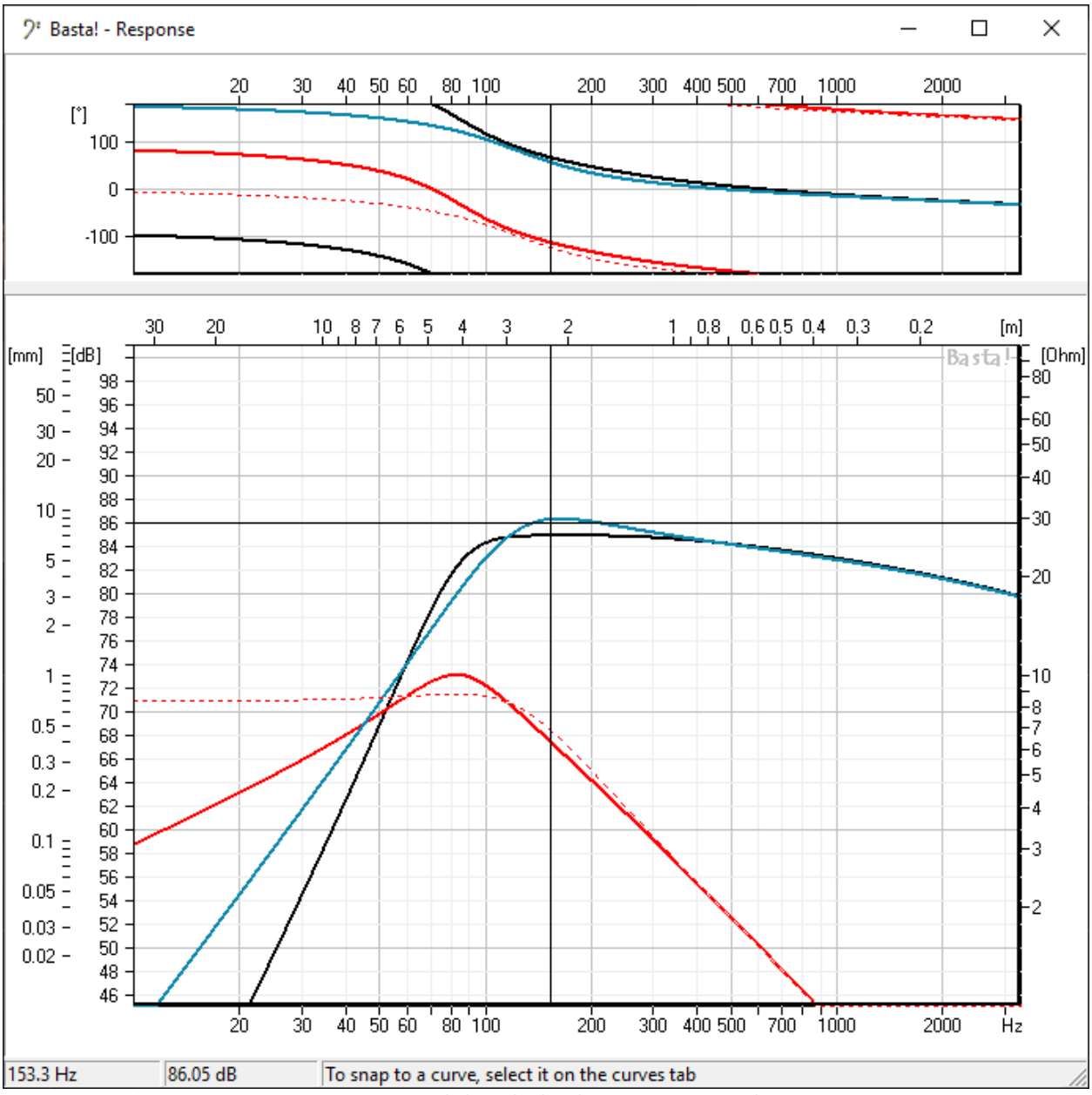

Figure 2 Sealed vs. Third Order Capacitor Assisted

All of a sudden you can see the advantage with this design. The peak at 150Hz is flattened out and the F3 dropes to ~78-~79Hz. That's a lot more palatable in my book. Not only that…but you have a slight peak in excursion at F3, but at low frequencies the capacitor reduces the excursion of the driver. That means using this in a system without a high pass filter isn't going to be as detrimental to modulation distortion. You're simply going to have less low frequency

rumble moving the woofer coil out of its linear range.

That's pretty cool.

Engineering Decision #2-Point that woofer away, minimize breakup audibility.

When you have a 6" cube for a box and you're trying to cram two drivers onto it you have some choices to make. At 2 litres if any face is sized large enough to hold both drivers the speaker is so shallow the woofer won't fit. So that means by definition that they have to be on different sides of the box.

Allison Acoustics, years ago, used to sell a speaker called the Model 6 that had an 8" up firing woofer and a 1" forward firing tweeter. At those sizes I struggle with the idea of how far the acoustic centers of the two drivers will be from each other…but in a 6" cube that distance is greatly reduced.

This also helps with the woofer crossover, well…helps eliminate the woofer crossover. One of the things I do not like about full range speakers is that the breakup mode of the driver is used to extend the frequency response out to high frequency. This is always audible to me, and I don't like the way it sounds. In a normal two way design I spend an inordinate amount of time getting the low pass on the woofer right to minimize the audibility of any breakup on axis with the woofer.

The thing is that breakup tends to be directional, go 30-60 degrees off axis and it is largely gone. So, in this design by pointing the woofer upward the audibility of the breakup is minimized without having to spend money on crossover components…which…given the size of the box probably wouldn't fit.

Engineering Decision #3-Use a tweeter even if it's just to add a bit of sparkle.

The little SB19ST-C000-4 dome tweeter should get more love in the speaker world. Low cost, lovely sound, low distortion, wide dispersion. Normally I aim for a flat frequency response with a Toole/NRC like off axis power response.

In the case of this speaker, what's the design axis? This speaker was designed to be placed on surface near a wall boundary to help out that bass response, what is my listening axis? My desk would place me about 30 degrees horizontally off axis and a good 20 degrees vertically below the tweeter axis. My wife's desk is better…but it's just not a priority.

The final design (graph later) ended up being +/-5dB from 80Hz to 18kHz. Many DIYers for their first project end up with full rangers that are far worse, and have very poor high frequency off axis behavior. They'll be lucky if those speakers are +/-10dB in the same frequency range and as I said in the intro I've measured expensive full rangers that swing 20dB or more. Sure the manufacturer of those drivers publish ruler flat frequency responses on stickers on the back of the magnet or in a spec sheet, but those responses are, just…not realistic.

It also means that you can easily assemble the speaker…I glued the resistor/cap used on the tweeter to the back of the tweeter.

Engineering Decision #4. The box, make it simple, make it tiny.

The box is made from 12mm or ½" plywood. I used marine grade ply but even the big box store stuff would work. If you have reasonable glue joints on this thing it's not going to need any bracing. Two ounces of polyfil/fiberfill kill any standing waves that might try to form in there and you really don't have to worry after that.

The woofer is centred on the top and the tweeter is mounted 2" down on the center of the front baffle. Both drivers are flush mounted…mostly for looks, though it will help a bit on tweeter diffraction ripple.

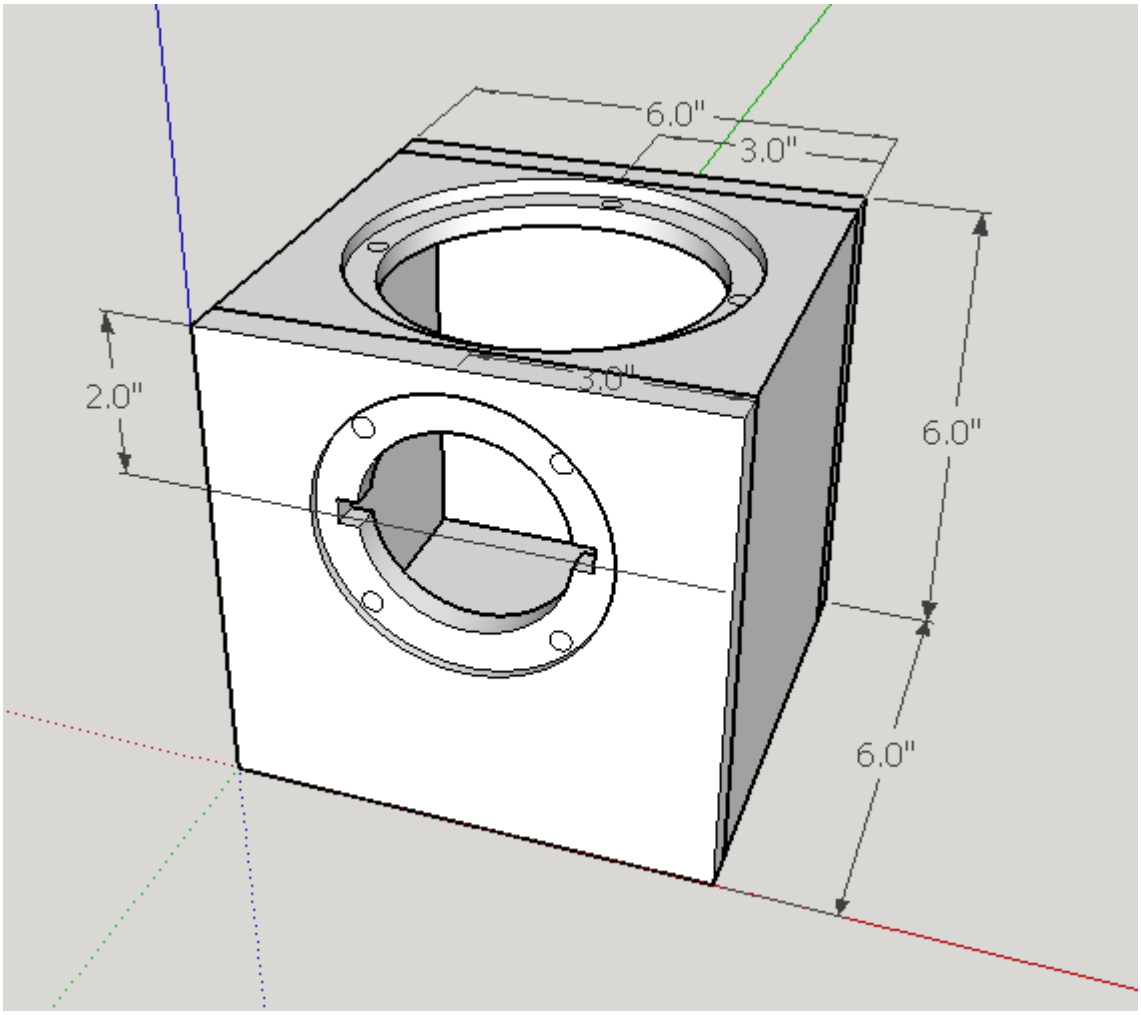

Figure 3 Enclosure

The Crossover, Frequency Response, Impedance and Conclusion

It really does not get much simpler than this.

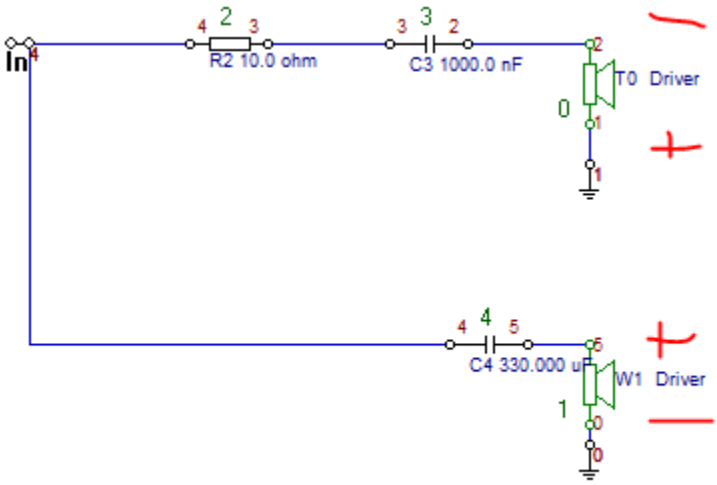

Figure 4 Crossover T0= Tweeter, W1 = Woofer

Could I have done one of my 9-18 element crossovers and gotten this speaker to +/-2dB or better? Probably. Would that have ruined the whole point of making this thing easy to build and a quick and dirty DIY speaker that sounds better than the vast majority of "lifestyle" or streaming speaker solutions out there? Absolutely. Plus honestly, you wouldn't have been able to fit the crossover in the box…it's not exactly roomy in there.

The impedance above 200Hz stays between 7 and 18 ohms making this a trivially easy speaker to drive with any amp. In it's native format both drivers have a capacitor in series with them…so at DC it's an open circuit and at low frequencies it's capacitive. Most solid state amps will be just fine with this…tubes…you might want to put a 30 ohm resistor in parallel with the entire speaker.

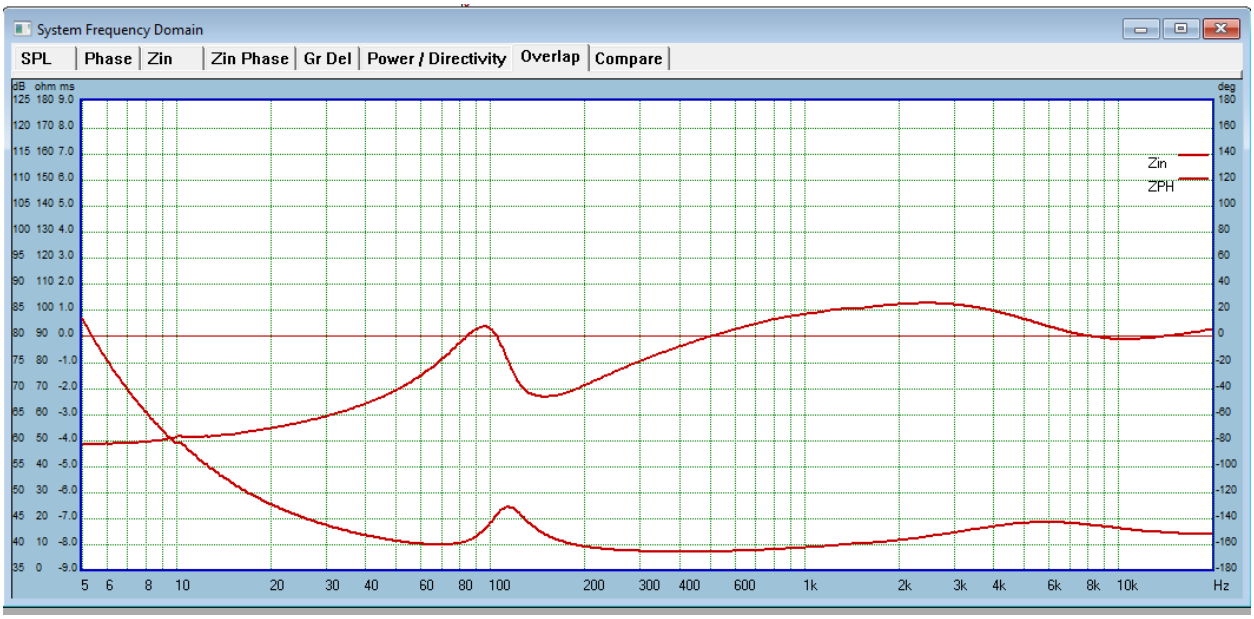

Figure 5 Impedance

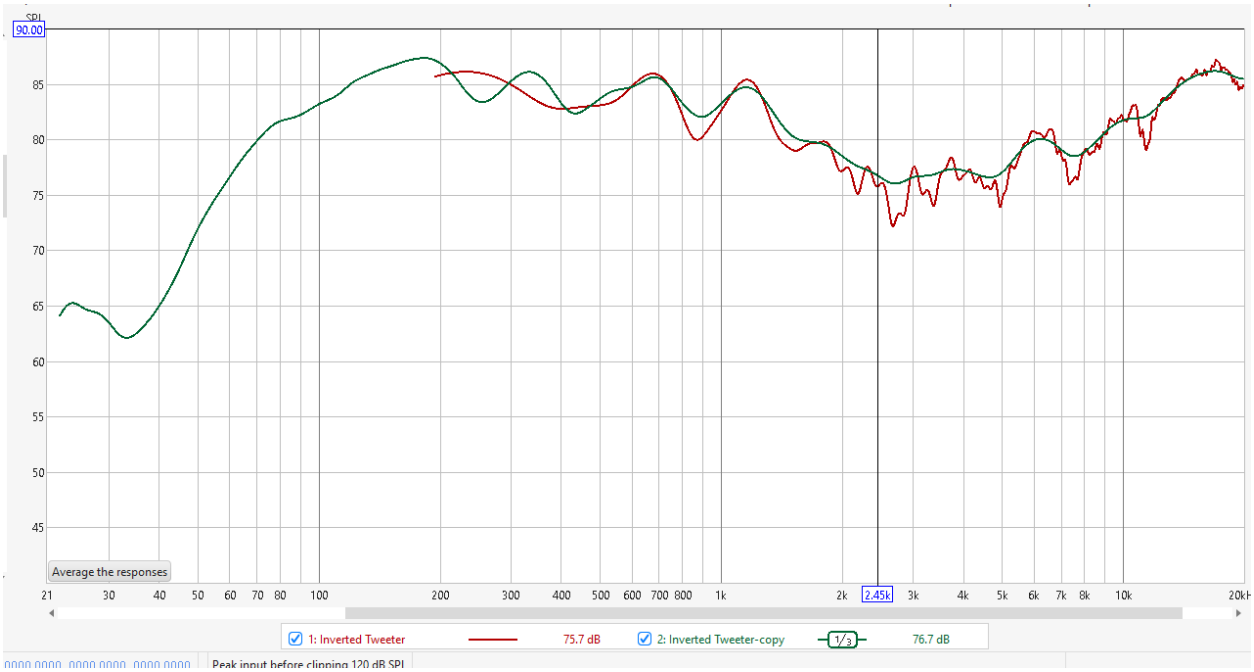

Figure 6 Frequency Response, free/space and against a single boundary

The frequency response is plotted both in free space on the tweeter axis (red, unsmoothed, gated to 5ms) and against a boundary green, 1/3 octave smoothed and gated at 500ms to show the overall frequency response. I suspect I'll have some criticism for this response and it's apparent roughness…that's fine. I'll be happily listening to them day in/day out during my

work day…or as is the case right now…as I type up this writeup. This is a great little speaker, I've used it for whole room sound and as desktop audio and it's way better than it has any right to be given the cost. They would also work well as home theatre surround speakers. Great on vocals, classical music, and pop music at reasonable/conversational volumes they are a fantastic way to get into speaker building.