Subtractive Crossovers by Bansuri

1st Order BW

A **subtractive** crossover doesn't introduce additional phase change or delay, a square wave is perfectly reproduced, the drivers have to be wired in phase.

It has a flat impedance and power curve, perfect for tubes; but what happens when speakers and enclosures are added?

Each speaker has a low and high frequency -3dB point. The low end is well defined of at least second order and easily measurable. The upper limit has to be guessed from a frequency plot.

Several effects like cone break-up, cone shape, resonances and reflections on small obstacles (screws, gaps) and baffle/waveguide superimpose with the inductive impedance rise. Generally a 2nd order low-pass plus a notch filter can approximate radiation sufficiently.

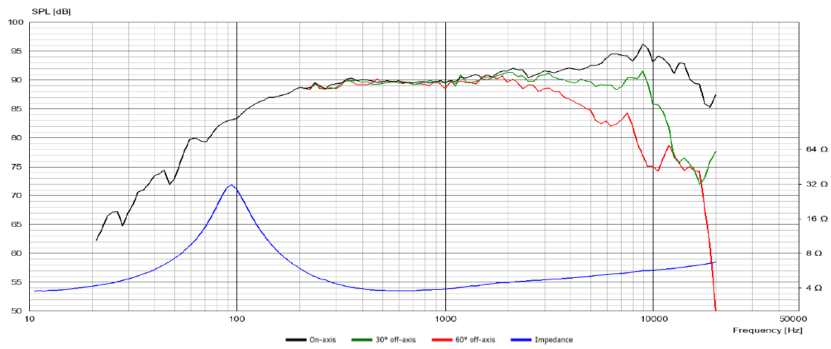
Driver Selection

Tweeter: Scan-Speak 10F4424-01 one of the finest fullrange drivers

With a notch at 9kHz a very linear response.

2L closed with 20g Angle-Hair damping

125Hz, Q= 0.48



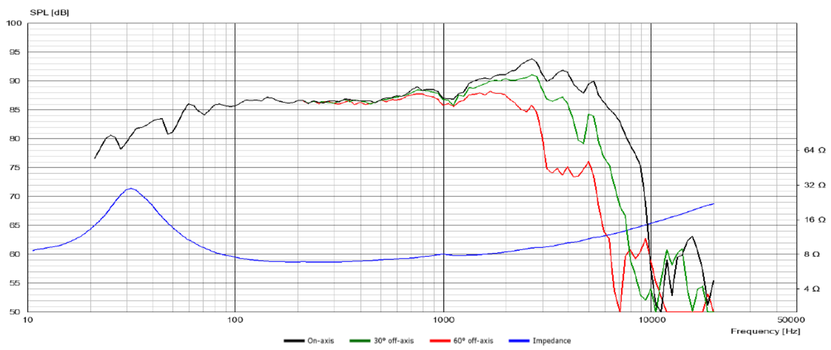
Woofer: Scan-Speak 18W8535-01 wideband and linear, 2 in parallel

2x28L vented f-3= 38Hz

2x20L closed f-3= 50Hz

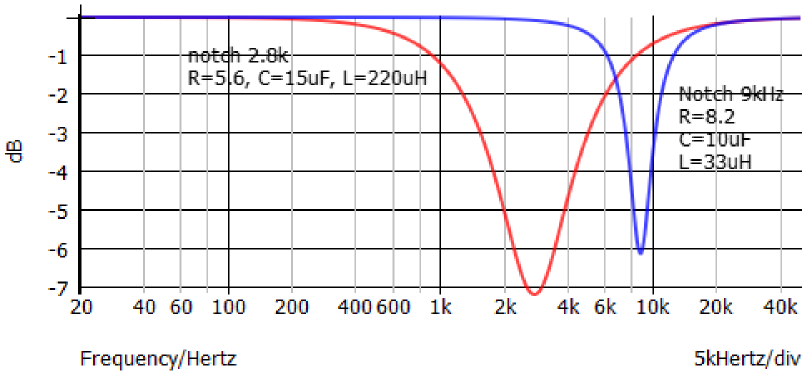
2x11L closed + serial C f-3= 48Hz, 1200uF

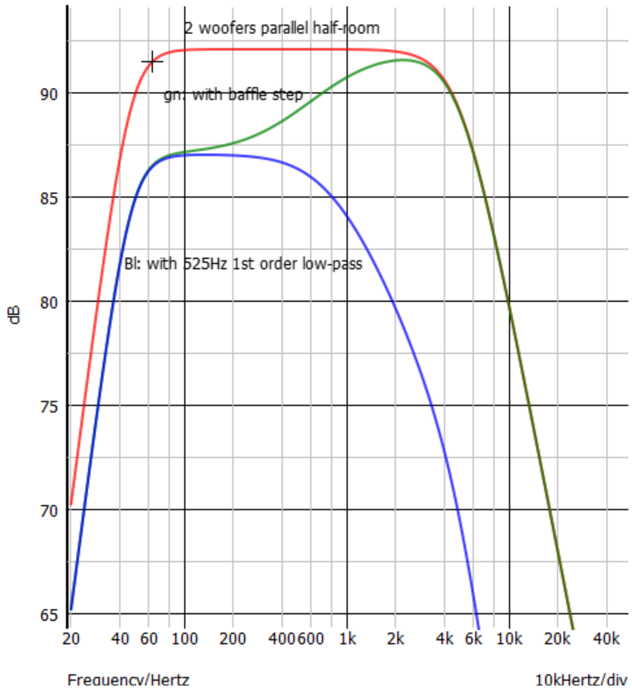
With 5mm excursion only 96dB SPL @45Hz can be reached in a closed enclosure ⇒ dual.

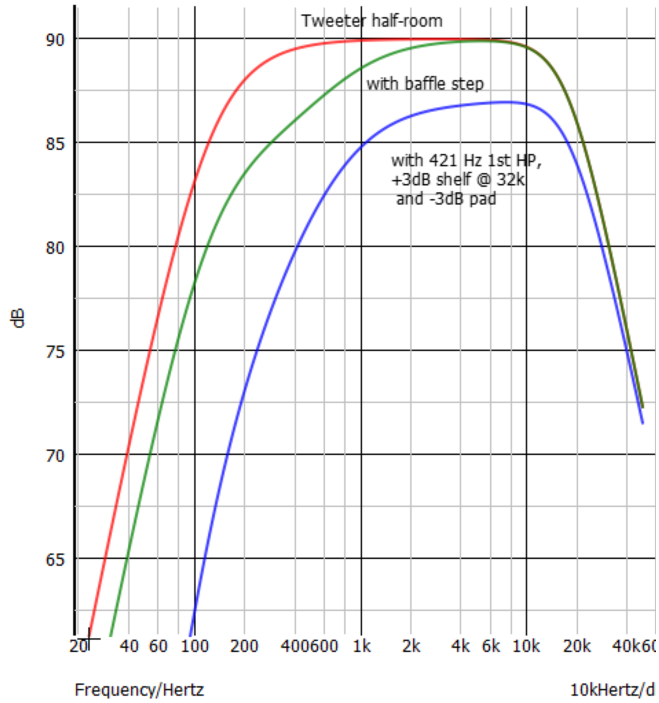


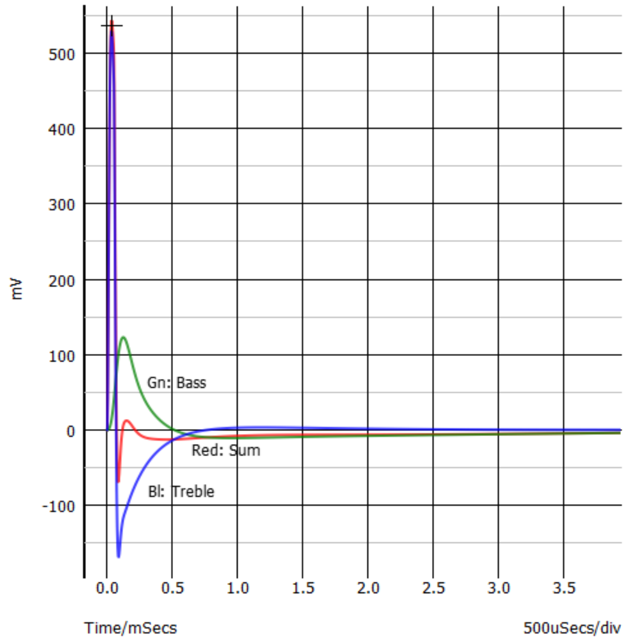
Notch filters, better all active to avoid interaction with XO components.

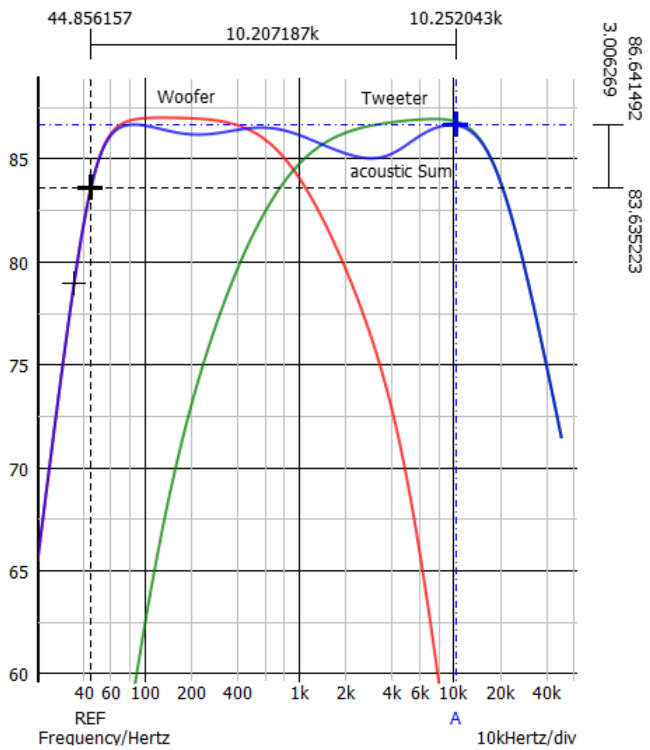
Some simulations with the smallest enclosure.

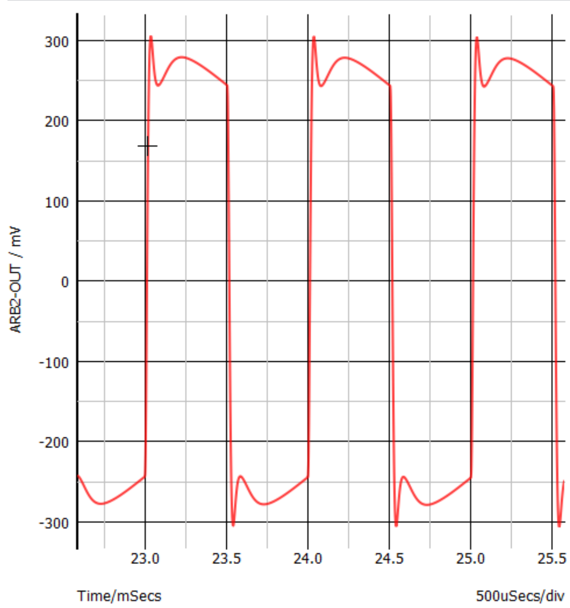












Baffle 25cm wide

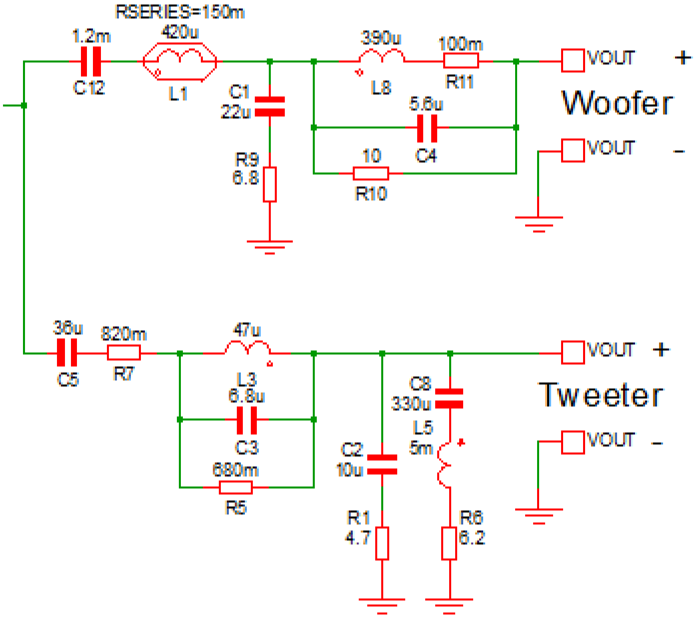
Pulse response and 1k Square show the advantage of subtractive X-overs. No pre-echo or additional delay.

The effect of the low end resonance of the tweeter and f_high of the woofer is visible as (small) dips in the response.

It can be realized with passive components.

Just a rough estimate of values for a passive implementation.

With a 100W amp 103dB SPL is reached.



2^{nd} Order modified Gauss

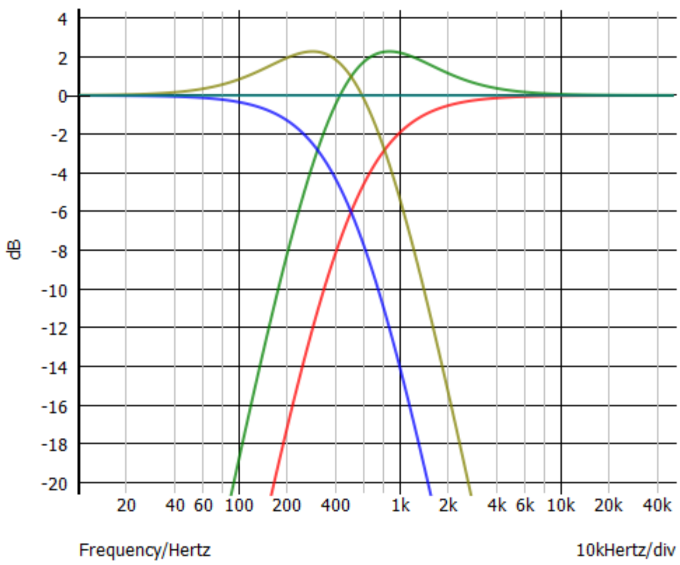
Laplace: $1 = (1+s)^4/(1+s)^4 = (1+4s+6s^2+4s^3+s^4)/(1+s)^4$
cutting: $(1+4s+3s^2)/(1+s)^4 + (3s^2+4s^3+s^4)/(1+s)^4$

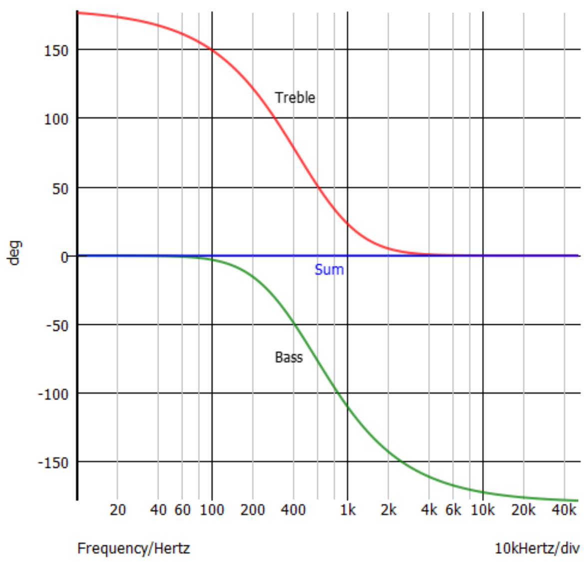
1^{st} part = Woofer $(1+4s+3s^2)/(1+s)^4 = (1+s)+3s(1+s)/(1+s)^4$

$= (1+s)(1+3s)/(1+s)^4 = 1/(1+s)^2 * (1+3s)/(1+s)$

So the 2^{nd}Gauss $1/(1+2s+s^2)$ multiplied with a shelf $(1+3s)/(1+s)$

2^{nd} part = Tweeter $s^2/(1+2s+s^2)*(3+s)/(1+s)$

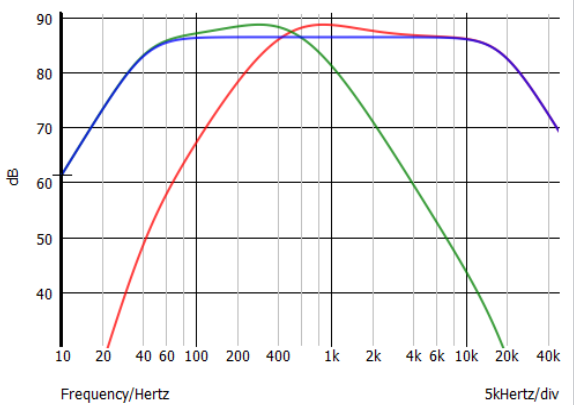




Theoretically 100% flat frequency- and phase-response. XO=500Hz

When we add the drivers low and high ends need to be perfectly matched, to avoid a boost or dip at the xover frequency.

The drivers overlap from 100Hz to 2kHz, the boost is +2.2dB near the XO frequency.



The woofers were limited by the excursion, there is no problem to boost the treble with a bigger amp, but the tweeter would not allow the boost because of thermal limit.

It is easy to add a midrange which could work together with the tweeter:

$s^2/(1+2s+s^2)*(3+s)/(1+s)=$

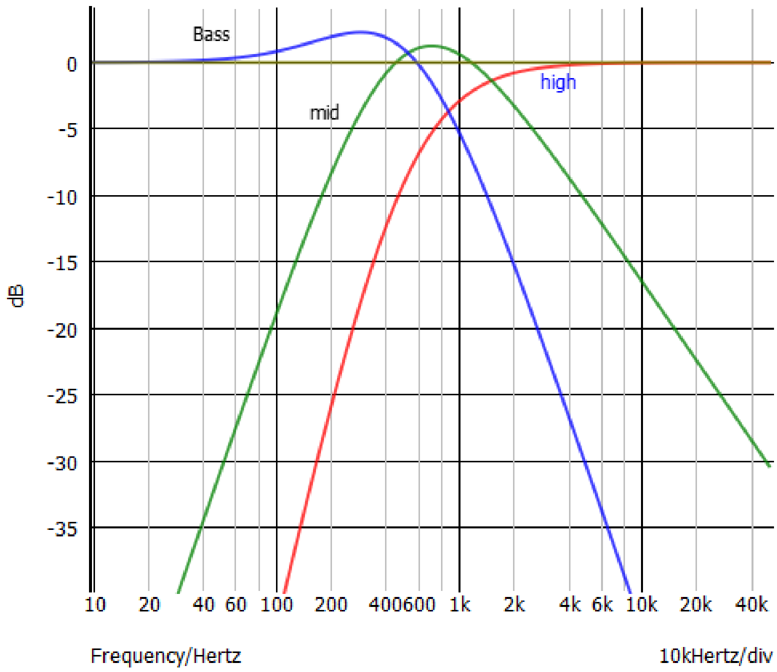
$s^2/(1+2s+s^2)*s/(1+s) + s^2/(1+2s+s^2)*3/(1+s)$

tweeter midrange

This solution is very convenient, the tweeter can output a higher level 105dB.

The mid should be very broadband, as the slope to the tweeter is only 6dB/oct

We could do the same with the bass and have a 4-way XO with a single 500Hz crossover frequency.



A perfect pulse response: