

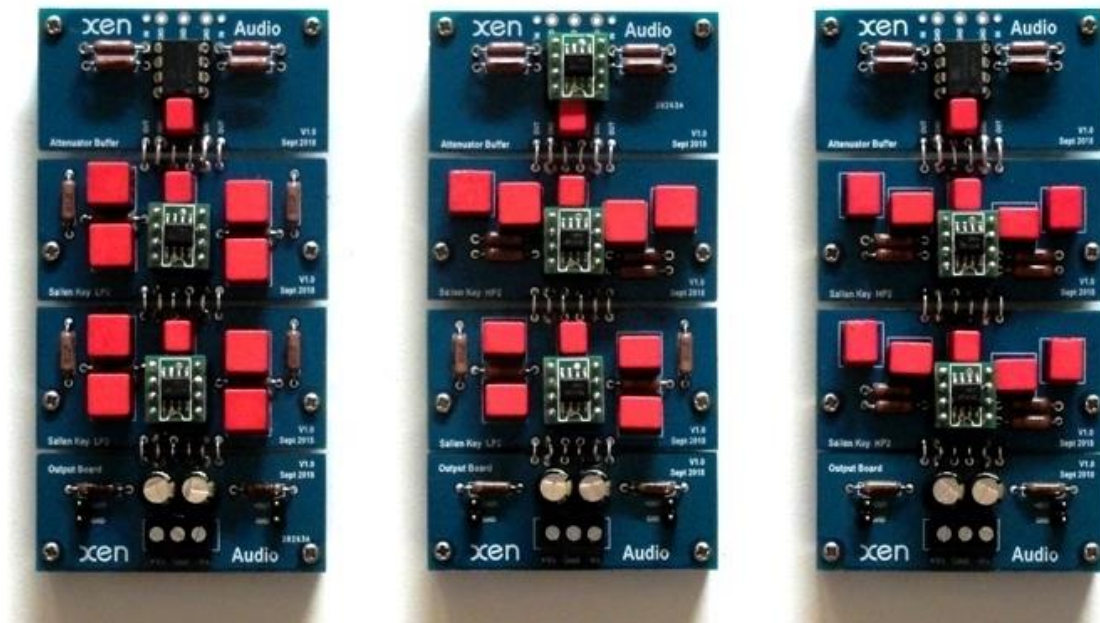
# A Modular System for Line-Level Loudspeaker Active Crossover

XEN Audio

November 2018

## Forward

We wish to dedicate this project to the late Siegfried Linkwitz, from whom many of us have learnt a great deal about loudspeaker design and sound reproduction.



## Background

A few years ago we published a line-level active crossover for our Avalon Clone <sup>[1]</sup> using the latest Accuton Cell series chasses. A dedicated PCB was made for that specific circuit / purpose after testing with a prototyping board. And we were very pleased with the results.

Lately a friend of ours who is into speaker building finished a project called the DUO-DXT <sup>[2]</sup>, a two-way bookshelf with SEAS chasses and a somewhat complex passive crossover. Just for fun, we took on the challenge to come up with an active crossover with essential the same (driving voltage) frequency response at the chassis terminals.

At the same time, we also have a few other speakers around for which we had long wanted to try out active crossovers with. Among them a pair of second-hand B&W CDM1s that is worth very cent we spent on them.

We were looking for something that was totally flexible and modular, so that we could make up any filter system by putting different circuit elements in series and/or parallel. Also we do not want to have any DIP switches to select different values, and prefer soldering instead. Unfortunately nothing readily available appealed to us, so we ended up designing and building our own.

## Design

The basic design consists of a number of small PCBs stackable in a series. Each is approximately 50 x 25mm in size, and can support one filter function for 2 single-ended or one balanced channel(s). Examples of such basic filter functions include <sup>[3]</sup>.

Input Buffer with Passive Attenuator

Sallen Key Low & High Pass (Bessel, Butterworth, Chebeshev, Linkwitz-Riley)

All Pass for Delay Correction, positive and negative

Shelving Filter with Notch, Low & High Pass

Notch filter with optional Gyrator (work in progress)

As much as possible, we only want to use passive filter elements (resistors and capacitors) and unity-gain buffers. The latter can of course be dual JFET opamp's such as OPA2134 in unity gain, but can also be discrete buffers. In some cases, such as the all-pass delay, opamp's cannot be avoided unfortunately.

The dual buffer or opamp is to be mounted on DIP8 IC sockets. That means one can also use single / dual SOIC8 opamp's (such as 2x OPA627) on adaptor PCBs, or in case of unity gain, dual discrete JFET buffers with a quad of matched low-noise N-JFETs (2SK170, 2SK369, 2SK117, .....). Each filter module has its own local power-supply-decoupling capacitor. While MKS-02 1 $\mu$ F were used in ours, you can also freely pick any electrolytic caps with 2.5mm pitch and 5mm diameter with >30V rating.



**Figure 1**      **Dual Source Follower with TO92 N-JFETs on DIP8 header**

To allow for a wide choice of components, capacitors are on 5mm pin pitch with additional 0805 SMD pads, and resistors on 5 & 10mm pitches. For our prototype build, we used WIMA MKP2, FKP2 and Panasonic ECHU SMD extensively for capacitors. For resistors, anything from Vishay S102, Caddock MK132, Nikkohm RP44, to Dale RN55, PRP9372, Welwyn RC55Y will all fit.

The connections at both input and output edges of the boards are all on 2.54mm pitch. One can then choose between hard wiring (as we did) or DIL header / sockets. Each set of connections (common on all boards) consists of Signal left, Gnd, -Vs, +Vs, Gnd, & Signal right (from left to right).

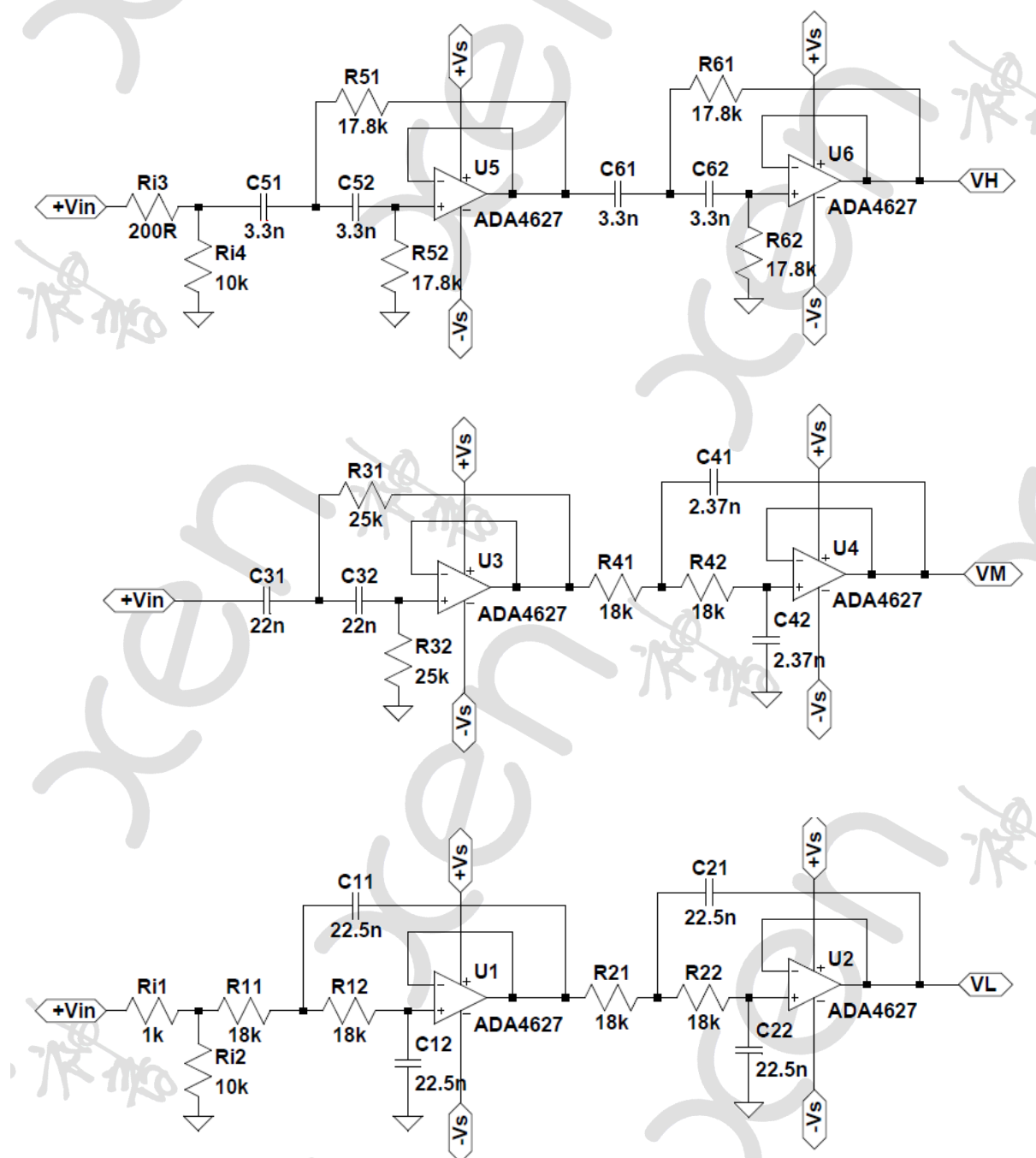
## Application Examples

### 1) Linkwitz approximated Duelund 3-way (see front page photo)

In one of his webpages <sup>[4]</sup>, Siegfried Linkwitz discussed the Duelund 3-Way crossover <sup>[5]</sup> in some detail, and proposed an approximated version at the end. This differs from the traditional LR-4 3-way

in that the mid-range HP and LP are only 2<sup>nd</sup> order, instead of 4<sup>th</sup>. Not only does the latter see less phase shift around the crossover frequencies, but there is also less active devices (3 buffers instead of 5) in the signal chain. So we decided to build one, just for fun. Note that both the tweeter and the bass driver has to be connected in reverse polarity.

The circuits are as follows.



**Figure 2** Schematics of the Linkwitz Approximated Duelund 3-Way Active Crossover

The simulated frequency response is shown below :

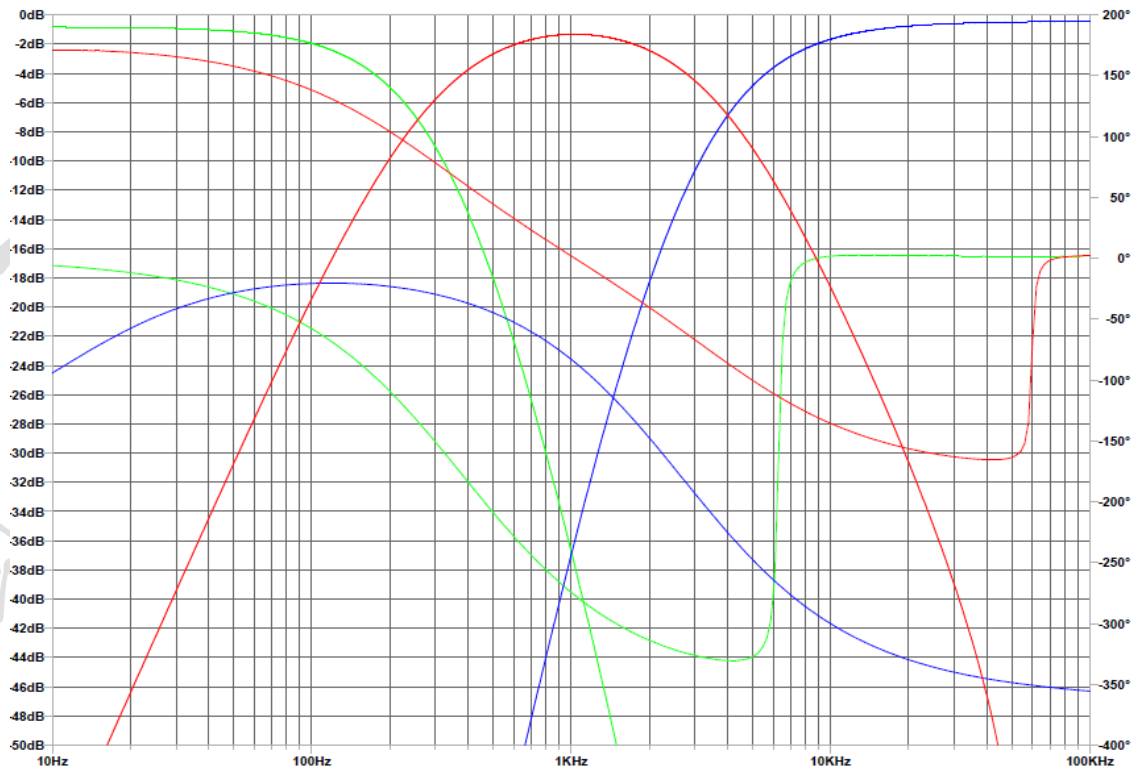
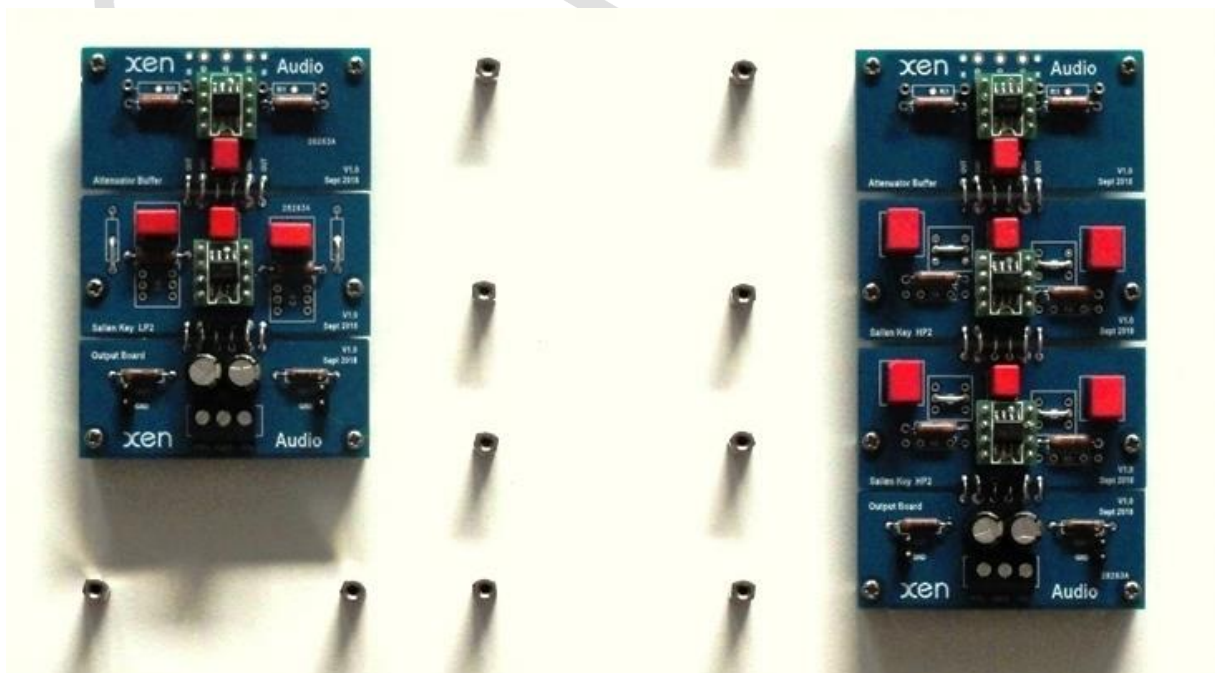


Figure 3 Linkwitz Approximated Duelund 3-Way Active Crossover - Frequency Response

## 2) B&W CDM1



The B&W CDM1 is Loudspeaker of the Year 1995 [6]. They are still popular on the second hand market, and prices have been holding steady for the last 10 years. For a bit more than 300 USD, they are a real bargain.

The components used in the original B&W crossover are not particularly high end. So an active crossover can be a good upgrade. In order to determine the required driving frequency response of each chassis, the simplest way is to power the loudspeaker with a sweep sine of constant amplitude via a power amplifier of sufficient bandwidth, and measure the AC voltage of each chassis as a function of frequency. Once this is known, one can try to emulate this with line level filters.

The circuit is shown below. As in the original passive crossover, the main driver gets a 1<sup>st</sup> order low-pass, whereas that for the tweeter is 2<sup>nd</sup> order. The beauty with the modular system is that one can use the same breadboard to make up different combinations, as shown in the photos.

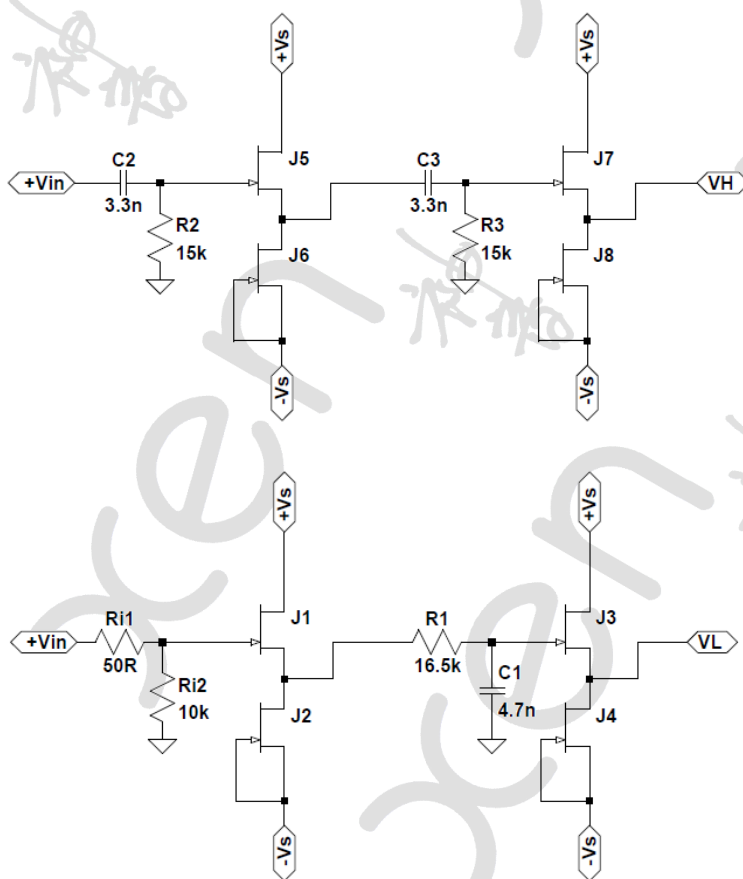


Figure 4 Schematics of B&W CDM1 Active Crossover



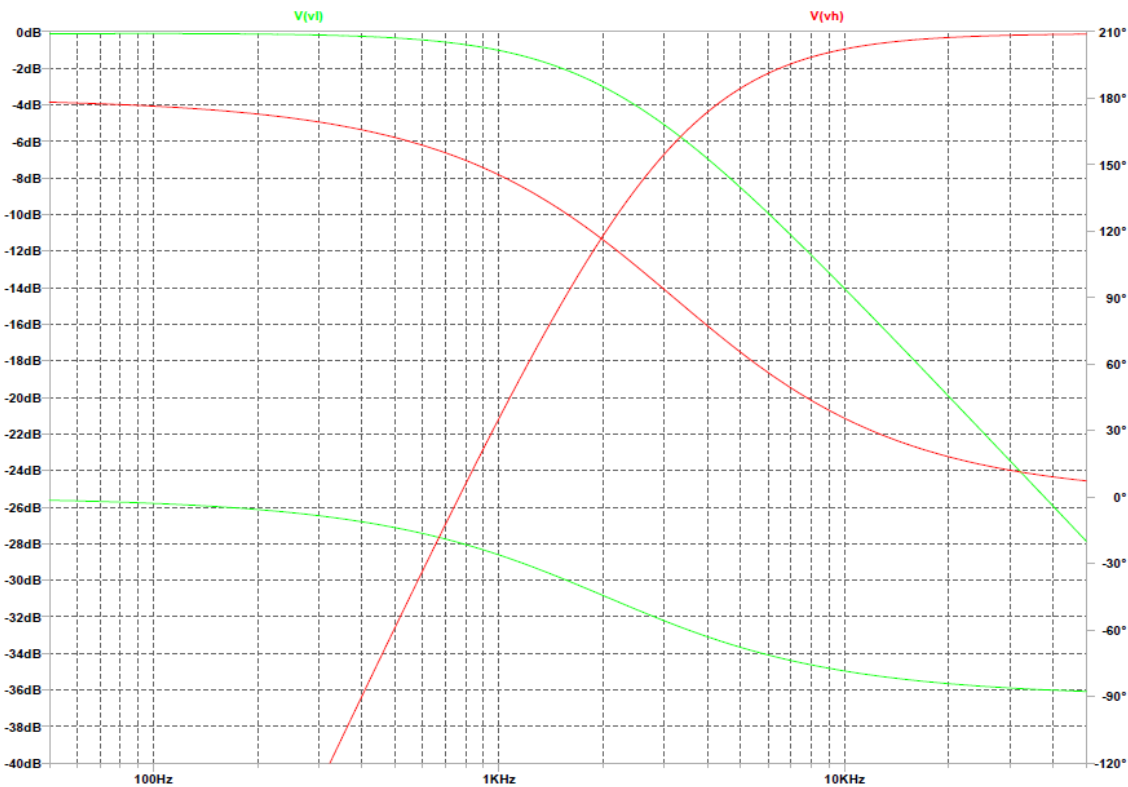
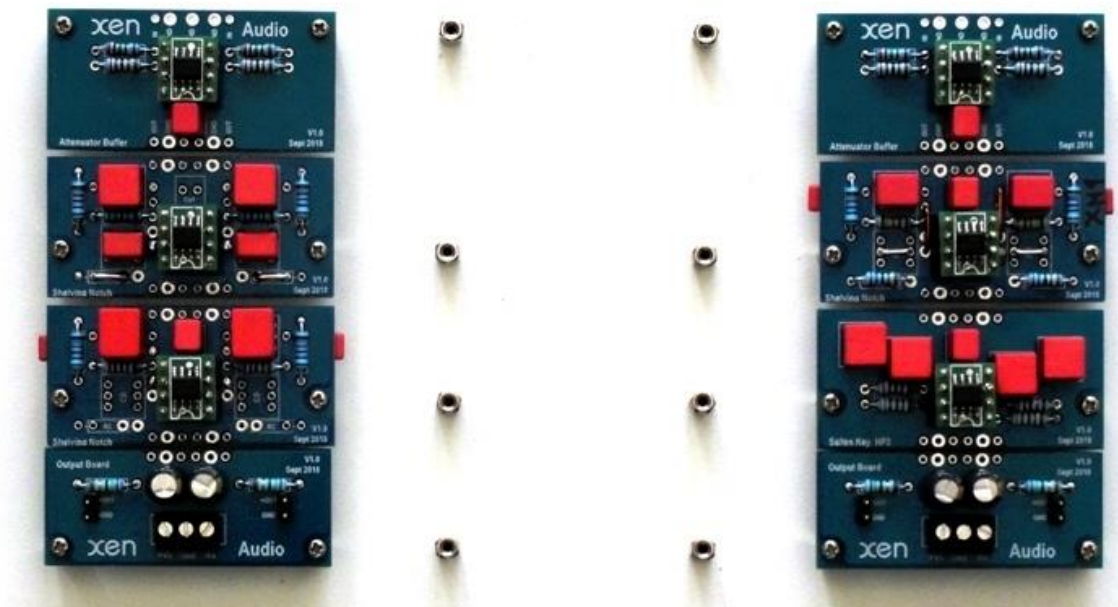


Figure 5 B&W CDM1 Active Crossover - Frequency Response

### 3) DUO-DXT Reference Bookshelf



The original passive crossover of the DUO-DXT is rather complex. Thus, the same approach as in the CDM1 was used to determine the desired filter characteristics. After some iterations, the active filter circuits shown here were arrived at, which resembles the original passive counterpart to within 2dB from 10 to 25kHz.

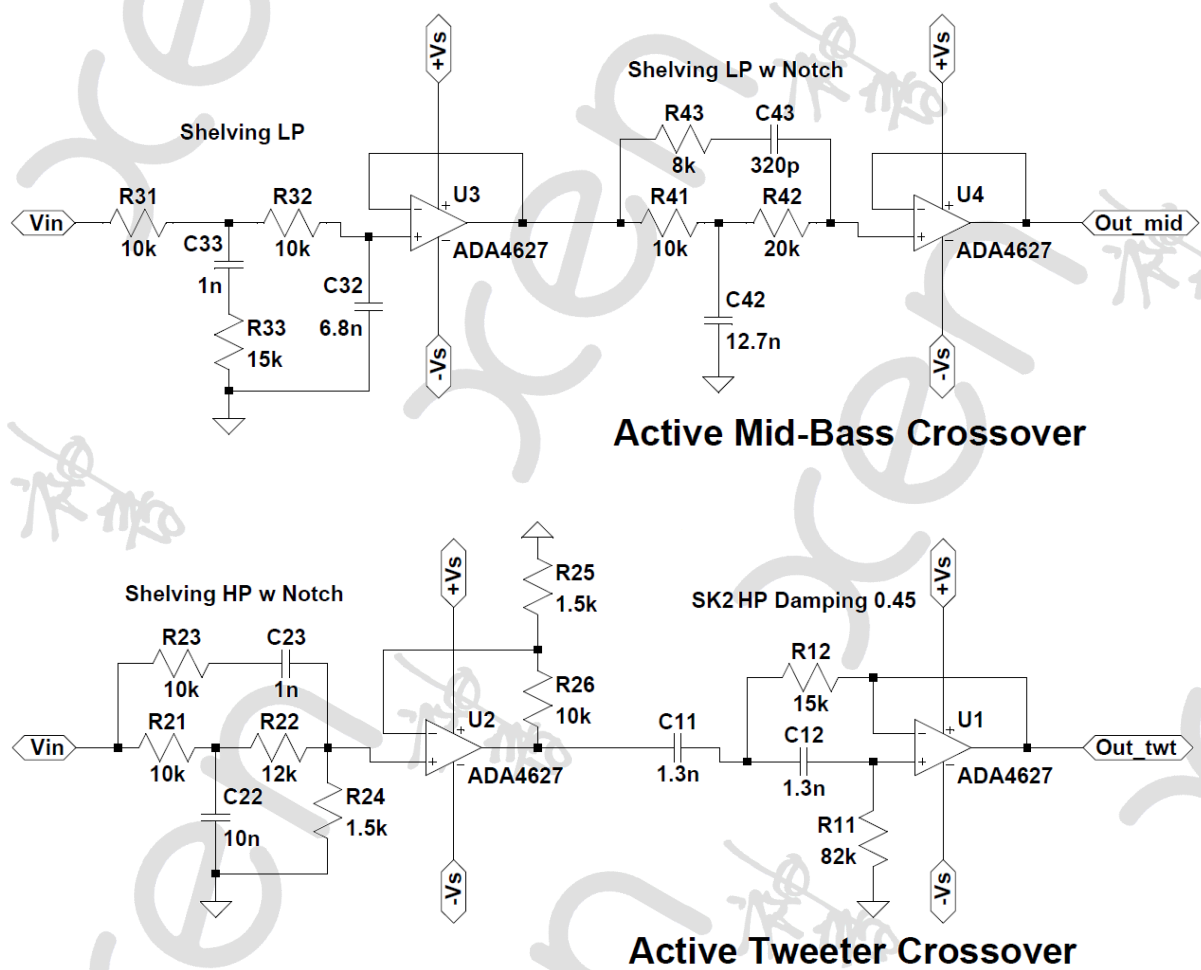
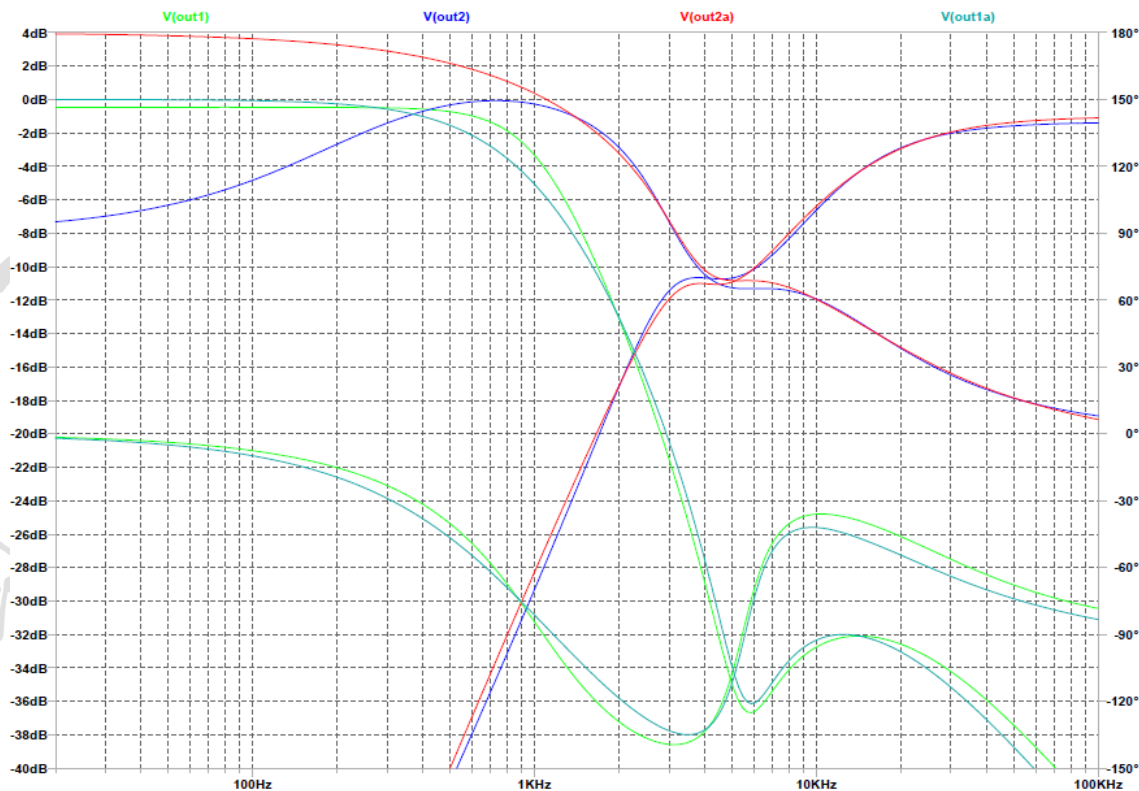


Fig. 6 Schematics of Active Crossover for the DUO DXT



**Figure 7 DUO-DXT Active Crossover - Frequency Response**  
 Out1 = passive Mid-bass      Out1a = active Mid-bass  
 Out2 = passive tweeter      Out2a = active tweeter

### But why Analogue and not DSP ?

People will say, why bother these days with analogue crossover when you can do everything (and more) digitally. Which has of course been made easy by nice, inexpensive products from the like of mini-DSP. But our own experience, and perhaps also that of others, suggests that analogue might still be subjectively the preferred solution in the end [7, 8].



## References

1. <http://xen-audio.com/documents/accuton/130701%20Accuton%20CELL%20Public.pdf>  
<http://xen-audio.com/documents/accuton/130818%20Accuton%20CELL%20Public%202.pdf>
2. <https://www.hifi-selbstbau.de/bauvorschl-mainmenu-36/2-wege-lautsprecher-mainmenu-75/416-duo-dxt>
3. <http://www.linkwitzlab.com/filters.htm>
4. <http://www.linkwitzlab.com/crossovers.htm>
5. [http://www.musicanddesign.com/Duelund\\_and\\_Beyond.html](http://www.musicanddesign.com/Duelund_and_Beyond.html)
6. <https://www.stereophile.com/standloudspeakers/630/index.html>
7. <http://www.diyaudio.com/forums/the-lounge/146693-john-curls-blowtorch-preamplifier-ii-9870.html#post5285486>
8. <http://www.diyaudio.com/forums/the-lounge/146693-john-curls-blowtorch-preamplifier-ii-9870.html#post5285509>