**Avalon Clone with Accuton CELL Series (Part 2)**

XEN Audio
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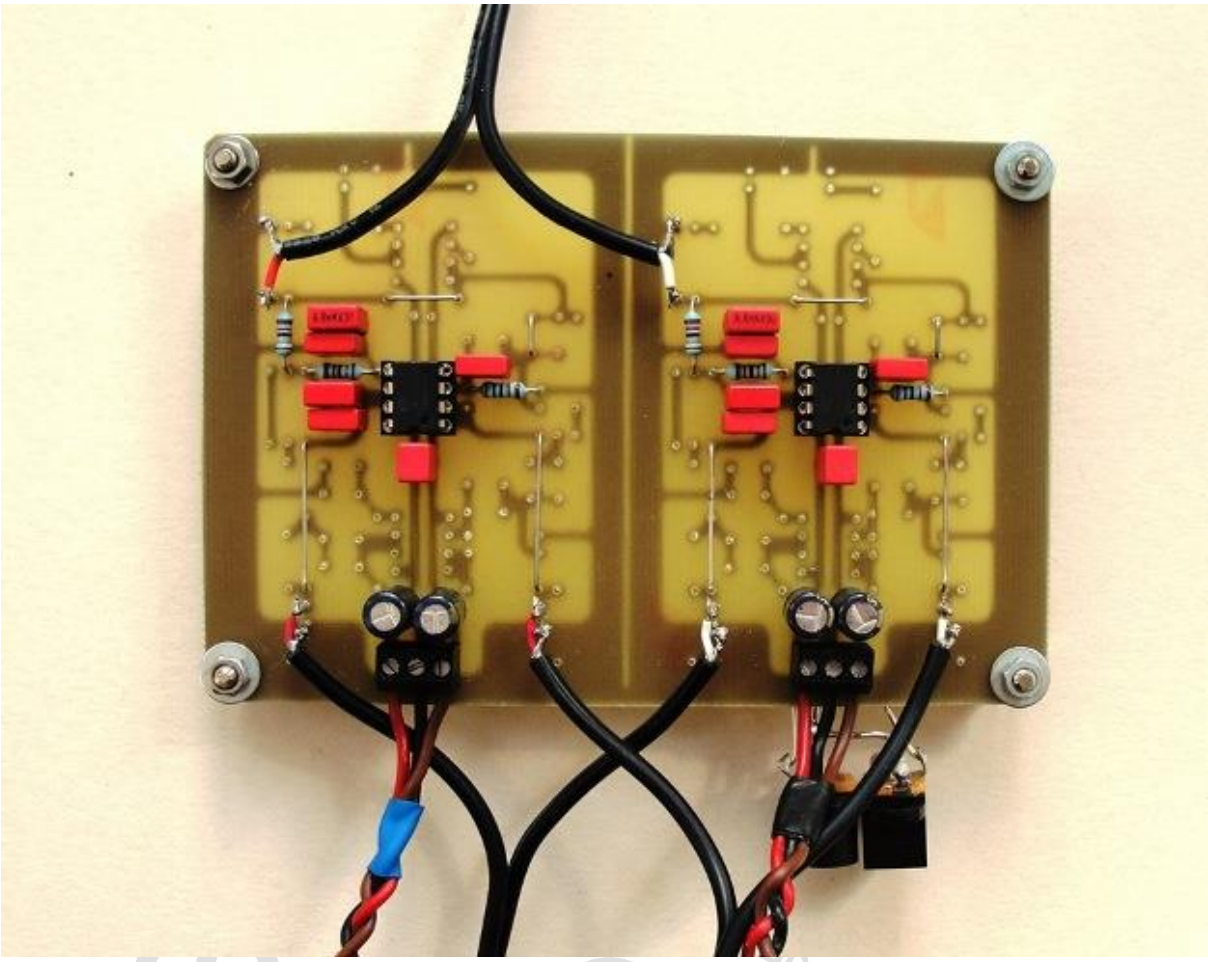
## Crossover Building

Separate doubled-sided PCBs with 70µm copper were designed for the tweeter and mid-range drivers. I personally do not like long copper foils dangling around the foil coils, so I placed them facing down, directly above the PCB. The 75µH coil was modified from a normal Mundorf 0.1mH air coil with 0.5mm wires. This was unwounded to 75µH with the help of an LCR meter set at 1kHz. After that, the coil was impregnated with epoxy in vacuum, then baked at 70°C for curing, taped, excess flange of the coil carrier trimmed off on a lath, and then finally covered with a transparent heat shrink of the appropriate size. By lucky coincidence, it happened to have an internal resistance of 0.32 ohm, so no extra series resistor was necessary for the 10kHz notch. The air coil was then placed at 90° orientation to the high-pass filter foil coil of the tweeter. Both of the foil coils were bolted onto their respective PCBs using M6 nylon screws and nuts. The small air coil was glued with silicon instead. This also applied to all the capacitors. I managed to get some NOS Siemens 18nF Polystyrene film capacitors, and use them to parallel all of the Mundorf EVO Oil. Other than that, the building of the passive part of the crossover was pretty straight forward.

For the active crossover between bass and mid-range drivers, there was already an active crossover PCB from our Sisters' series, which was ideal for the purpose of the test. As mentioned earlier, the bass filter was a unity-gain Sallen Key, whereas the mid-range has a first-order C-R followed by a unity-gain buffer. For now, the buffers were just OPA2604s. They would eventually be replaced by discrete JFET followers, without saying.



**Fine Adjustments**

All of the above worked first time, and I left the speaker with this baseline crossover running for a few weeks, just to make sure everything was properly burnt-in. The excellent details, dynamic and sound stage were immediately there, as one would expect. But it was a touch on the bright side, and bass was not quite balanced.

After some weeks of listening, I went back to do some enclosure simulation, using the proper T&S parameters that were set to me by the manufacturer of the C220-6-227. It turned out that these were different from those of the C220-6-221, and the resulting bass reflex box needed to be much smaller at 39litre and a somewhat higher tuning frequency. But as I already have a 51-litre box, I used the simulator to get a close-enough-to-optimum response by changing the pipe length alone. This turned out to be 12cm according to the simulator. A 38-litre box should have a pipe length of 18.5cm, just for comparison.

A few lengths of pipes of 12cm, 15cm, and 19cm were cut and tested on the box by listening. At least in my listening environment, 12cm gave the best balance, so I stayed with that. Good to know that the simulator gave results close to listening optimum. Eventually, the enclosure will be redesigned to give the proper 38 litres.

The slight touch of brightness was still bothering me. Instead of just adding more resistance to trim down the entire tweeter SPL, I wanted to understand what was happening. So I went to set up equivalent electrical models of the driver impedances, and used them to simulate the response of the filter and driver combined. There are many such equivalent circuits on the internet. I tried quite a few of them, and picked the one that gave closest results to the measurements. Then the component values were further fine-tuned for even better matching.

Once that was done, LT Spice was used to simulate the original all-passive crossover design of Joachim Gerhard, as well as the actual filter used in the prototype. Both the active and passive parts of the latter, as well as the drivers, were included in the simulation. The driver responses were them summed in both cases for direct comparison.

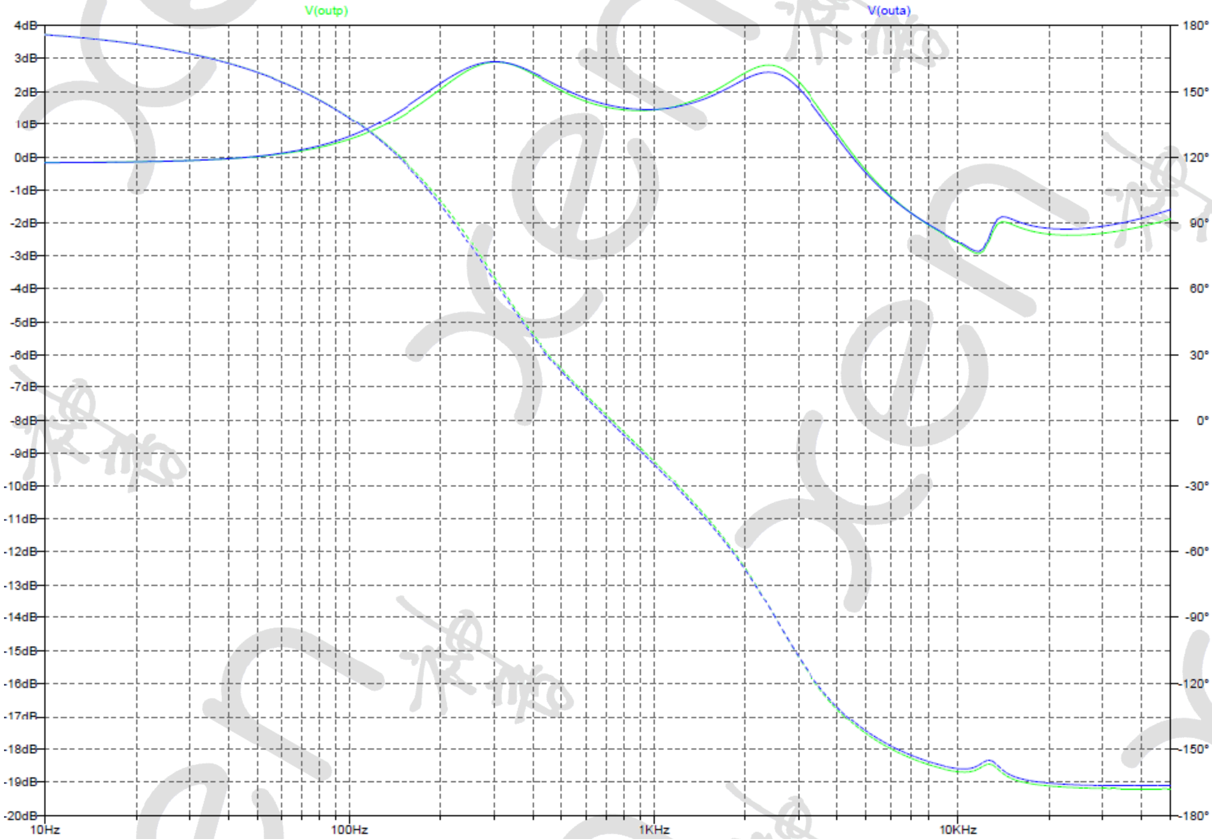
This happened to be a very revealing exercise, even without professional crossover design software such as LSPCAD. It demonstrated, for example, that the 14AWG foil coil used in the mid-range crossover caused a 1dB lower electrical input to the mid-range chassis. In addition to that, because I left out the 150Hz impedance compensation network, a small hump of 1dB around the same frequency could also be observed.

Since the active crossover of the mid-range was a simple first-order C-R without much room for fine adjustments, these deviations from the original design had to be compensated by adjustments in the tweeter and the bass driver instead. After many iterations of optimisation, the final solution gave very similar response (to within 0.3dB) of the original.

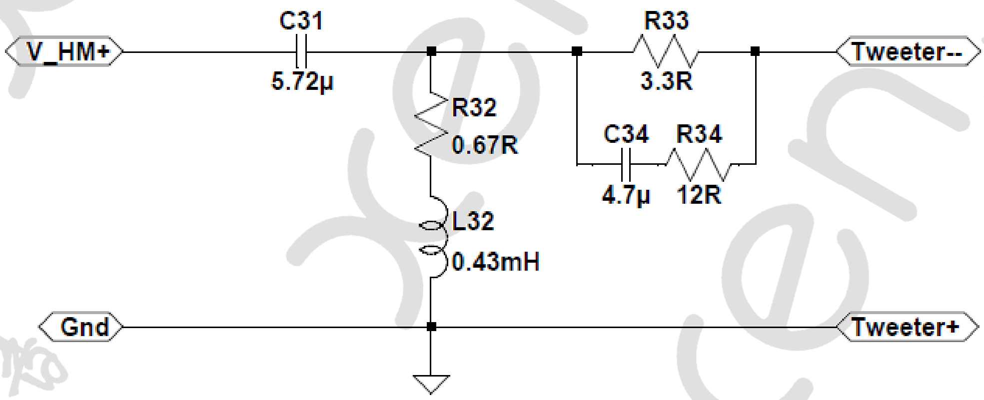
The 2.2R series resistor for the tweeter was increased to 3.3R. And an additional resistor of 0.5R was added in series with the 0.39mH foil coil. To make up for a slight drop at upper treble, an additional R-C of 12R (PRP 1W) and 4.7µF (MKT1822 paralleled by 10nF Polystyrene) was wired in parallel to the 3.3R.

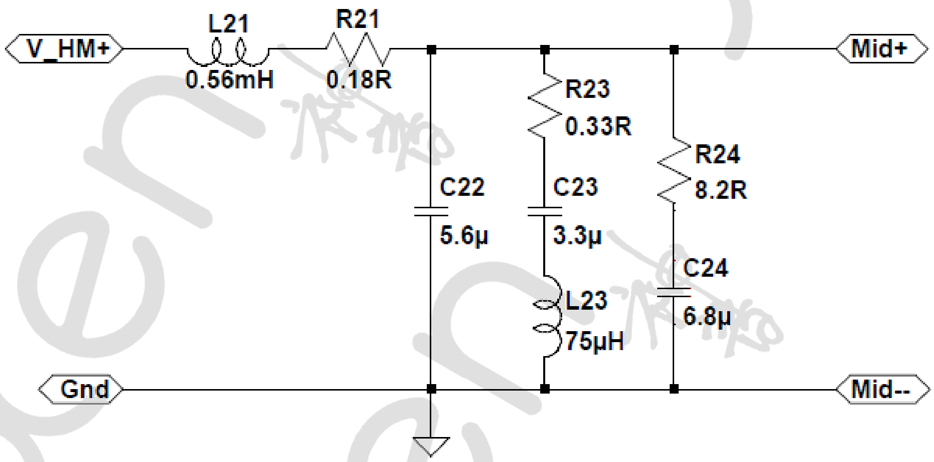
Level adjustment for the bass units was simple, as they were driven by separate power amplifiers. The 1dB hump at 150Hz was ironed out by adapting the Sallen Key filter of the bass units. The capacitors of 27n / 80n were replaced by 30n / 78n, and the 11.5k replaced by 11k.

The revised overall response is shown below. The original passive crossover is represented by the green line, and the revised crossover the blue. The two match to better than 0.3dB over the entire spectrum.

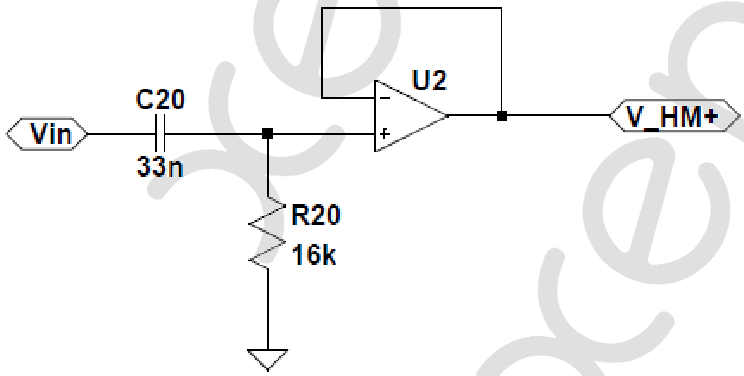


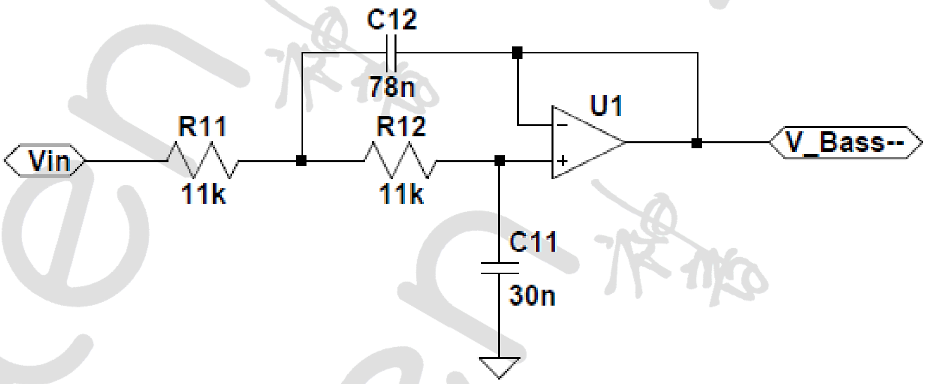
**The Revised Crossover Schematics**
(Tweeter – Mid-Range   Passive)



**The Revised Crossover Schematics**
(Bass – Mid-Range   Active)



**Listening Impressions**

The changes in tonal balance due to the new crossover are subtle. Nevertheless, it is noticeable, especially in fast A-B test using jumpers to short out added resistances. Listening tests over a couple of weeks confirm that the revised tweeter crossover gives more balanced, natural highs than before. It is a difficult choice between having C34 / R34 or not. In the end I chose to leave them out. It resulted in a touch more silkiness at the expense of some brilliance. But it was a real hard call.

And the bass is now proper and full with the shortened bass reflex pipe. The revised Sallen Key gave tight and fast bass, but for some music, I also liked the fullness of the previous values (11.5k / 27n-80n). It will take a lot more listening before I can make up my mind.

There will undoubtedly be some further fine tuning in the coming months or perhaps years. And there is no absolute measure of perfection, but rather an adjustment to individual preferences and listening circumstances (room acoustic, music type, …., etc.) But I do believe that the baseline crossover presented here is a good basis to work on.

All in all a very enlightening DIY exercise and money well spent. Apart from a new pair of reference loudspeakers of the highest sonic quality, I have learnt a tremendous lot about chassis, enclosures, damping, and above all crossover design and fine tuning.

Highly recommended.

Patrick