Andromeda

The Andromeda, or how to build a no-compromise loudspeaker

An extensive description of building a no-compromise loudspeaker system and what you bump into along the way. Drivers used are a Focal Audiom 13KX, a Scanspeak 18W8545 and a Focal TC120Tdx2. Joined together by the less common series-filter.

A fresh start

I had moved to a new house and had sold my previous seven pairs of loudspeakers before moving. My new living room was big enough for a large loudspeaker system and I wanted to build something that was the best I had built yet – so no compromises.

What did I want?

The bass: I believe that you can only produce "real" bass by moving a large area of air gently and not by moving a small area of air violently. This means that anything smaller than a 10-inch woofer would simply not do. I wanted to play it safe so I went for a 13-inch woofer. The midrange: This was the most difficult part, there are so many possibilities: 4-inch, 5-inch, 6-inch or 7-inch? Split it into lower-midrange and upper-midrange? Use cone or dome units? Crossover at 2kHz or anywhere up to 6kHz? In the end I decided to go for the simplest solution (is there a simplest solution?) and look at it as a 2-way system with a sub-woofer added. That meant I needed a 6 or 7-inch unit with a smooth response and a large bandwidth. The treble: I like the treble to sound clear and detailed without getting harsh, so no cheap aluminium dome tweeters. I was going to use a 6 or 7-inch unit for the mid, so the tweeter should be able to go low enough – that meant a 25 to 30mm dome. Good dispersion up into the high treble is also important for a nice clear and wide stereo-image. In the end I chose for Focal's TC120Tdx2, an inverse dome tweeter with a titaniumdioxide coated titanium membraneand a cone-shaped diffuser mount on the front. This diffuser gives very wide dispersion right up to 20kHz - 30 degrees' of axis at 20kHz is only down 4,5dB's. It has a double magnet to create a very strong magnetic field in the air-gap and it is also shielded. The cavity inside the magnets is filled with mineral wool to dampen resonance's. For the midrange: nothing but the best here: Scanspeak's 18W8545. The perfect 18cm mid-woofer! It has a low resonance frequency of 28Hz, a large long throw 42x19millimeter voice-coil and a very large magnet to give a strong driving force. The cone is made of carbon fibre filled paper and heavily coated. All this should result in a nice dry, warm and detailed sound. I also considered the 18W8545K, basically the same speaker but with a kapton voice-coil former. It's bass was more detailed and seemed a little stronger, but I preferred the standard 18W8545's mid-range in being clearer. For a long time I had been wanting to use a Focal woofer from their Audiom-series and now I had the financial means:-) A 15-inch one would be a little too big seeing as it needs about 200 to 250 litres to work in – the Audiom 13KX only needs about 90 litres! I chose the Audiom 13KX because it has a rubber surround, as apposed to the foam surround of the Audiom 13VX. Efficiency is high enough at 91dB's and fs low enough at 28,8Hz. The magnet is not what you see every day: It's made up of twelve 72mm standard magnets painted bright red mounted between two chrome-plated pole-plates with a total diameter of 232mm! The cone is made of so-called Poly-Kevlar: two layers of finely woven kevlar sandwiching a layer of polystyrene.

A loudspeakerbox is more than just a box

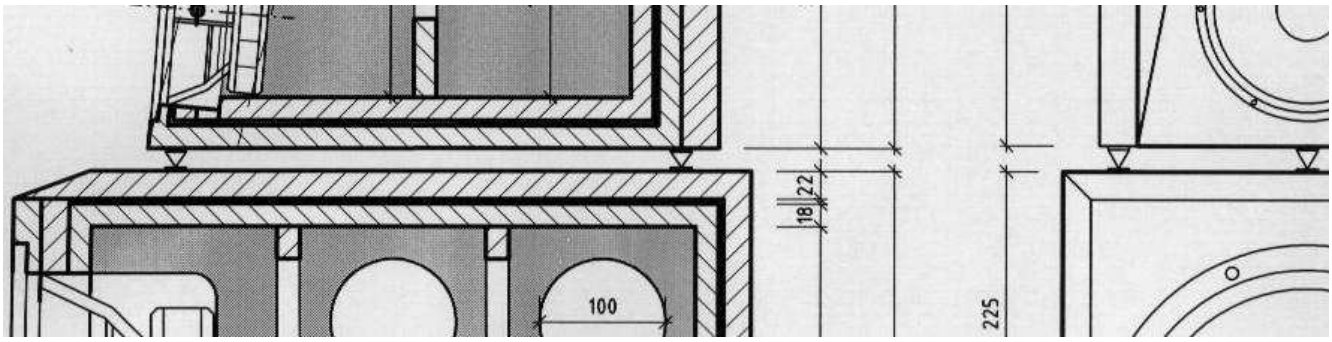
Once you've got these very nice drivers, what do you put them in? It would be a total waste just to build a simple rectangular MDF box of the correct volume and mount them in it. In the past I have done several experiments on cabinet constructions and have

come to the conclusion that the quality of sound produced by a loudspeaker can simply be divided into three equal parts:

1. The quality of the drivers. 2. The quality of the crossover. 3. The quality of the cabinet.

It is amazing how much of what is heard from a loudspeaker is produced by the cabinet. Vibrating cabinet walls, standing waves inside the cabinet, diffraction interference due to sharp edges on the outside of the cabinet, the baffle transferring vibrations from one driver to the other, and so on. As you might of guessed I wanted to build a cabinet of which you could only hear the positive things. So that vibrations of the woofer couldn't interfere with the other drivers, the woofer would be mounted in a separate cabinet.

The woofer cabinet



The basic construction for the cabinet walls is a sandwich of two layers of MDF of different thickness' with a layer of lead-bitumen in between. Lead-bitumen comes in flexible sheets of 1x1 meters and weighs 8 kg/m2. From the outside in you have 22mm's of MDF, 4mm's of lead-bitumen and 18mm's of MDF. All three are glued together using a paste made for glueing parquet floors. No screw's are used otherwise vibrations from the inner panel may be transferred to the outer panel. The cabinet is internally strengthened with a sort of matrix made of 18mm MDF with circular cutouts to let the airflow freely. A higher resolution drawing is available on request.

To minimise vibrations of the bass-driver, its magnet is supported buy a cutout in the internal bracing. All internal walls are covered with Pritex foam to minimise standing waves. The front baffle has two outer layers of MDF and therefore has a total thickness of 62mm. The front edges are angled just for looks. The total weight of the woofer + cabinet is 95 kg (209 pounds). To stand this firmly and level on the ground you need spikes. A very cheap and easy way to make spikes for something this heavy is to use four lengths of M10 bolt-thread mounted in the bottom of the cabinet. Place a large washer over the thread and then fix it with a M10 nut. There should be about 30mm of thread left sticking out onto which you screw a M10 capped-nut (a nut with one closed by a round shaped cap) - being a nut it is very easily height adjustable using a spanner. The cabinet will now have minimal contact with the floor as it is resting on four little metal ball-shaped "spikes".

The internal volume is about 100 litres and the bass-reflex ports are tuned to a low 25Hz. I had originally designed it as a closed box with a Qtc of about 0,5 but I wanted a little more deep bass so I added the ports. This makes it sound more exciting when listening to low synthesizers or Jurassic Park, but for normal listening I just fill the ports with old socks to get a nice tight sounding bass. Don't misunderstand me, even with the ports open it produces about the tightest bass I've ever heard, but with the acoustic air-flow resistors in place it's simply incredible.

The other cabinet

The cabinet for the mid-woofer and the tweeter is built as a closed cabinet using the same principles as the woofer cabinet except for the damping material, which is a 100% fill of glass wool and bonded acetate fibre.

The tweeter is housed in it's own separate sub-enclosure to stop unwanted vibrations in the box reaching the rear of the tweeter, a piece of foam-rubber is pressed between the back of the tweeter and the rear of the sub-enclosure to stop any vibrations in the tweeters rear cover. The "collar" around the sides and rear of the cabinet is made of 30mm thick MDF making the total wall thickness here 74mm's. The front baffle has angled edges to cut down diffraction interference. The total weight of the drivers + cabinet is 30 kg (66 pounds). This cabinet is placed on the woofer cabinet using three gold-plated SPS-10/GO spikes and protectors by Monacor.

Surface finishing

Always a personal part of the design. When speakers get this big I feel they blend into the interior better if there have a real wood finish like a piece of furniture. I chose to cover both cabinets with cherry veneer and 6 layers of clear durable floor varnish, sanded between each layer.

Time alignment

Time alignment is one of those things that until recently was rather under-estimated. But it's all so logical (as Spock would say). If two drivers placed at different positions vertically are producing the same tone (what happens around the crossover point) but one is further away from the listener than the other, they will interfere. The tone from one speaker will reach your ear before the other one does. In a standard flat baffle the horizontal offset between a dome tweeter and say a 7-inch woofer can be 2 to 3 centimetres. Of course it is all-dependent on how high the units are placed in comparison to the listening height, but the principle stays the same. In this case the baffle of the top cabinet slants backward at 5 degrees to time align the tweeter with the mid-woofer. The whole top cabinet is set back 106mm to time-align the mid-woofer with the woofer, this seems a lot but the depth of the Focal 13KX cone is 66mm.

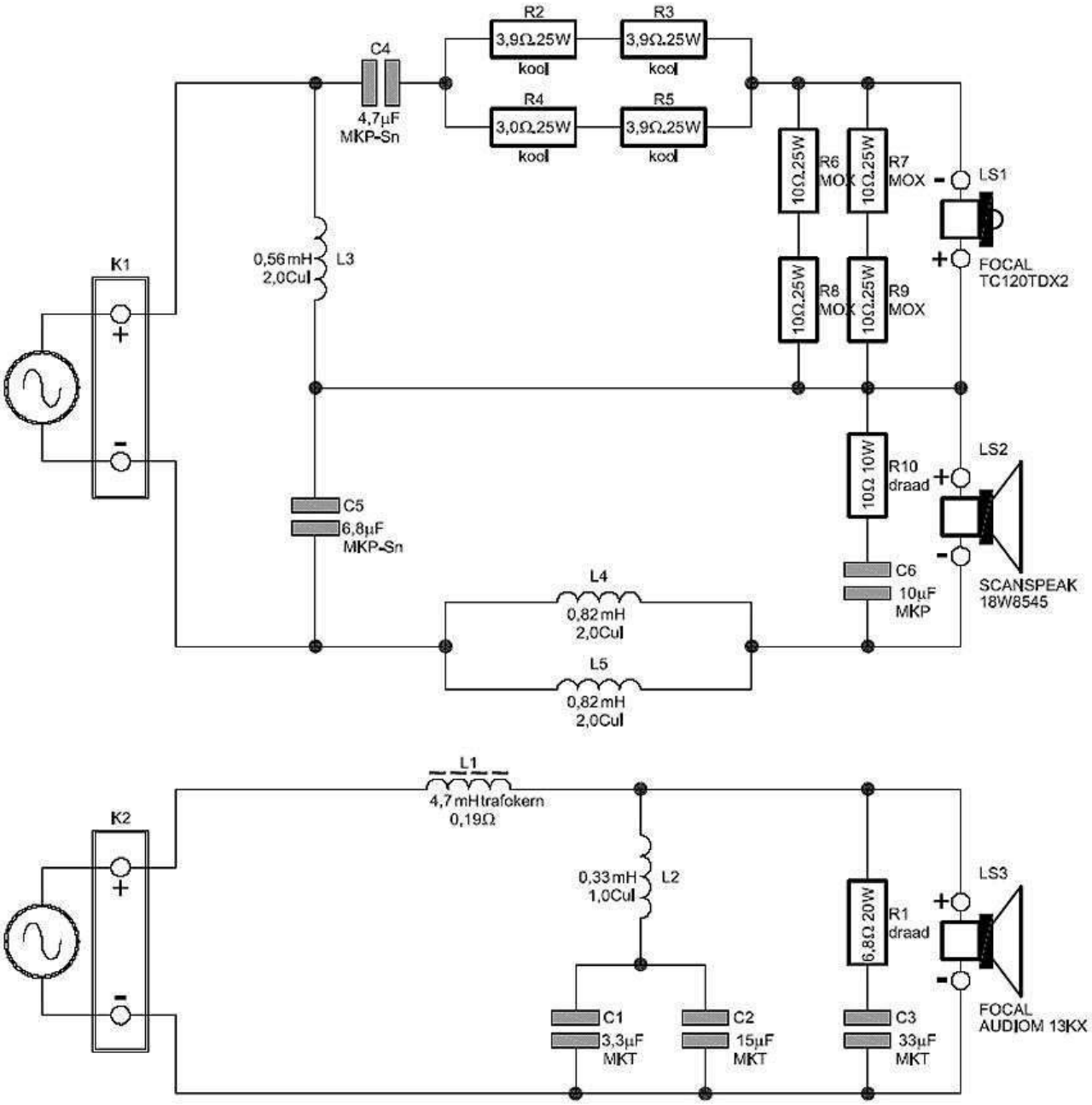
The crossover network

Once you've got these very nice drivers in a very nice box, how do you blend them together electrically? The standard way would be to design a parallel-network and then tweak it until it sounded the most satisfactory, but a parallel filter has one very big problem: Most of the time the signal going in is not evenly divided across the drivers. There will be electrical overlaps or "underlaps" between drivers that will cause unwanted phase shifts even if the acoustic amplitude is flat. The only way to get around this problem is to use a series-filter. The electrical signal sent in is evenly divided across the drivers because the drivers and filter are wired together in series as one total system. The pass- function of the components is an exact mirror image of the stop-function. The total voltage measured across the drivers is identical to the voltage measured across the amplifier outputs (minus the losses in cabling etc of course). For example if you take a basic first-order series-filter consisting of a capacitor, an inductor, a woofer and a tweeter and you shift the cross-over point of the tweeter upwards by choosing a smaller value capacitor the cross-over point of the woofer will go up with it as the capacitor runs parallel to the woofer.

As I designed my system as a 2.5-way system, I combined both types of filter: The Scanspeak 18W8545 and the Focal 120Tdx2 are wired together using a second-order series-filter and the Focal Audiom 13KX is connected parallel using a first-order network. The Focal Audiom 13KX has two extra parallel compensation networks consisting of a LC-network to cut out the cone break-up peak at 2kHz and a RC-network to compensate for the rising impedance due to the voice-coil inductance. The Scanspeak 18W8545 also has a RC-network to compensate for the rising impedance. My personal findings of the series-filter is that in most cases a series-filter sounds more homogeneous, more open and more natural than a parallel-filter.

The shopping-list

The quality of the crossover components used is very high. The Focal Audiom 13KX is filtered using an E-core transformer type inductor for low Rdc and high power handling. All other inductors are air-core type using thick wire for low Rdc and no saturation and are matched using a LCR meter. The capacitors parallel to the woofer use metalled polyester foil all the others use metalled polypropylene foil with tin-foil anodes. All resistors are matched for minimum tolerance.



L1 = 4,7 mH transformer inductor, R = 0,14 ohms (tolerance 5% - matched pair 1%)

L2 = 0,33 mH air-core inductor 1,0 mm wire, R = 0,30 ohms (tolerance 5% - matched pair less than 1%)

L3 = 0,56 mH air-core inductor 2,0 mm wire, R = 0,12 ohms (tolerance 5% - matched pair less than 1%)

L4 = 0,82 mH air-core inductor 2,0 mm wire, R = 0,15 ohms (tolerance 5% - matched pair less than 1%)

L5 = 0,82 mH air-core inductor 2,0 mm wire, R = 0,15 ohms (tolerance 5% - matched pair less than 1%)

C1 = 3,3uF MKT polyester foil capacitor (tolerance 5%)

C2 = 15uF MKT polyester foil capacitor (tolerance 5%)

C3 = 33uF MKT polyester foil capacitor (tolerance 5%)

C4 = 4,7uF MKP-Sn polypropylene-tin foil capacitor (tolerance 2%)

C5 = 6,8uF MKP-Sn polypropylene-tin foil capacitor (tolerance 2%)

C6 = 10uF MKP polypropylene foil capacitor (tolerance 5%)

R1 = 6,8 ohms, 20 watts cemented resistor (tolerance 5%)

R2, R3, R4, R5 = 3,9 ohms, 0,25 watts carbon film resistor (tolerance1%)

R6, R7, R8, R9 = 10 ohms, 0,25 watts metal film resistor (tolerance 1%)

R10 = 10 ohms, 10 watts cemented resistor (tolerance 5%)

Wiring and connectors

On my quest of minimalizing vibrations I decided to place the filters outside the cabinets in separate sand-filled enclosures. This also has the advantage that you can choose the right cable to run from the loudspeakers to the filters that are placed near to the amplifier. Even thou you can't bi-wire a series-filter, this way you can still have the advantage of bi-wiring – a long section of wire from the speaker to the filter and a short little bit from the filter to the amp.

One of the important things for a well defined bass is the ability of the amplifier to be able to use its damping factor as well as possible, therefore the resistance between the speaker and the amp must be as low as possible. The internal wiring for the Focal Audiom 13KX is made of double 2x4,0mm2 oxygen free copper (so 8,0mm2 for the plus and 8,0mm2 for the minus). The sub-woofer cabinet is connected to the amplifier with 2x 20mm2 oxygen free copper. This cable is designed to take up to 100A normally used in the high-end car hi-fi where high currents flow. Compared to a standard 2x4,0mm2 cable there is slightly more definition in the bass. The Scanspeak 18W8545 and the Focal 120Tdx2 are wired directly to the connectors with Teflon insulated silver wire. This type of wire sounds more detailed than standard OFC, but you should only use it in combination with a smooth sounding amplifier. If used with a "bright" sounding amp the sound can get a little too clean some times. Using thick cables means using large connectors. I used the ST-975GM by Monacor for each driver. They are gold plated and can take up to 20mm2 cable and have nice strong screw terminals. If necessary they can also take banana plugs.

Positioning

These loudspeakers where not designed to stand on a bookshelf or in a corner, they need some space. Placing any loudspeaker close to a wall or furniture will alter the tonal balance. I have a listening-room of 36 square metres where my favourite listening seat is placed in the middle. The front of the loudspeakers is 120cm from the rear wall and the outer corners are 110cm from the sidewalls. In this position there are hardly any noticeable room resonances in the bass.

Was it worth it?

I suppose by now you are wondering what they sound like. Well, everyone who has heard them so far is left speechless! Usually when people listen to a new set of loudspeakers they say things while they are listening like: "Wow, that is impressive bass" or "I never knew that was on the CD". But when they hear these loudspeakers for the first time they say nothing until after listening to about three tracks of various CD's they finally come back to earth. Of course I am biased, but there are very good! They radiate a sort of authority and calmness. At first you might think there is not much bass, but the sound is totally free from the boom and boxiness that you are used to with ordinary designs. But when the T-Rex from Jurassic Park breathes, the doors and windows rattle! Stereo imaging is excellent. The sound stage is wide and deep. You can pinpoint the players in an orchestra, not only in depth but also in height. The sound doesn't come from two loudspeakers; it's just there. Hearing the differences between cables or between CD-players is easy. The amount of detail is amazing. Not only in the treble but also all the way down to the low bass. There is no preference for bass, mid or treble, it all melts into one. The total impression is one of a very natural and neutral sounding loudspeaker with a large bandwidth, a big sound stage and excellent dynamics. There is just one big problem! I will have to trade-in my Denon PMA-860 amplifier / Marantz CD-67 SE CD player for a Mark Levinson set to be able to hear what these speakers really can do!

Epilogue

All in all it has taken me more than a year to build these loudspeakers and I am very pleased with the result. They are the best loudspeakers I have ever built and I would love to be able to compare them with a Wilson Audio Watt/Puppy or a JM Lab Utopia. But for me loudspeaker building is a never-ending story in which you keep asking yourself, can I make something even better than last time? So I am going to sell these loudspeakers and start all over again. How about two Focal Audiom 13KX's, or maybe an Audiom 15KX? Then I would need an 8-inch mid-woofer, the Eton 8-472/32HEX looks interesting, then I could use a separate upper-mid driver, maybe something from Thiel or what about the Dynaudio M-560D Esotar? If I used a dome for th…….……

Tony Gee, The Netherlands, April 2000

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