Nebular Monitor

Nebular Monitor - A small loudspeaker big sound

Among other things, the Humble Homemade Hifi website features numerous stand-mount loudspeakers ranging from micro-monitors based on small 12cm woofers to larger models that use 18cm woofers as a starting point. Until now there was nothing in between. The Nebular Monitor with it's 15cm woofer fills in that gap. On the rear it gets some extra support from a pair of passive radiators.

The tweeter

The Seas Prestige 27TBCD/GB-DXT (H1499) tweeter works according to the so-called Constant Directivity principle. This is often found in the PA world but not so often in the Hi-Fi scene. The goal is to create an off-axis response that is identical to the on-axis response, only a few decibels lower in level. The main advantage of such a radiation pattern is a more even in room energy response resulting in a more stable image. Also diffraction on the cabinet edges is less of an issue. To obtain such Constant Directivity the tweeter has a short horn (a.k.a. Wave-Guide) mounted in front of the dome. The lower the frequency, the more the energy is concentrated by the Wave-Guide onto the main axis. The higher the frequency, less less the frequency response is altered in comparison to a normal dome tweeter. The overall result is a gain in output level as the frequency drops. Another advantage of the horn is that its large area gives a better coupling to that of the woofer, also resulting in a more even radiation pattern.

For such a Wave-Guide to work properly, the contour of the horn must be as smooth as possible. With this Seas tweeter the screws that fix the face-plate to the magnet assembly form small obstacles that create irregularities in the output level around 10kHz. Covering the screws with small pieces of foam-rubber or similar solve this problem. The audible difference when the screws are covered is a fractionally less "nervous" image.

The woofer

The Seas Prestige L16RNX (H1488-04) used in the Nebular Monitor is something quite special. The designers of Seas from Norway have managed to squeeze a cone that is nearly the size that you normally find in 18cm woofers, into a basket with a diameter of

only 146 millimetres! This cone is joined to the basket via a large rubber front suspension that allows a liniear excursion of 12mm peak-peak and a maximum excursion before damage of 22mm peak-peak. The only downside of this large cone / small basket construction is that there isn't much space left to mount the driver to the cabinet. So you will have to work rather precise when making the driver cut-outs otherwise the six mounting screws may not have enough "meat" to grip to. In the centre of the cone we find a relatively large dust-cap that covers the large 39mm diameter voice-coil. On the rear of the driver there is a large magnet of 10cm diameter. Seeing as the driver cut-out is only 126mm it is very important to chamfer the inside of the driver cut-out so that the woofer has enough space the breathe. All these parts are held together by a stiff and light-weight basket that has ventilation openings everywhere. The four ohm voice-coil can be seen through the openings between the rear suspension and the front pole-piece. The magnet is also ventilated to the rear to minimize compression inside the motor system.

The passive radiators

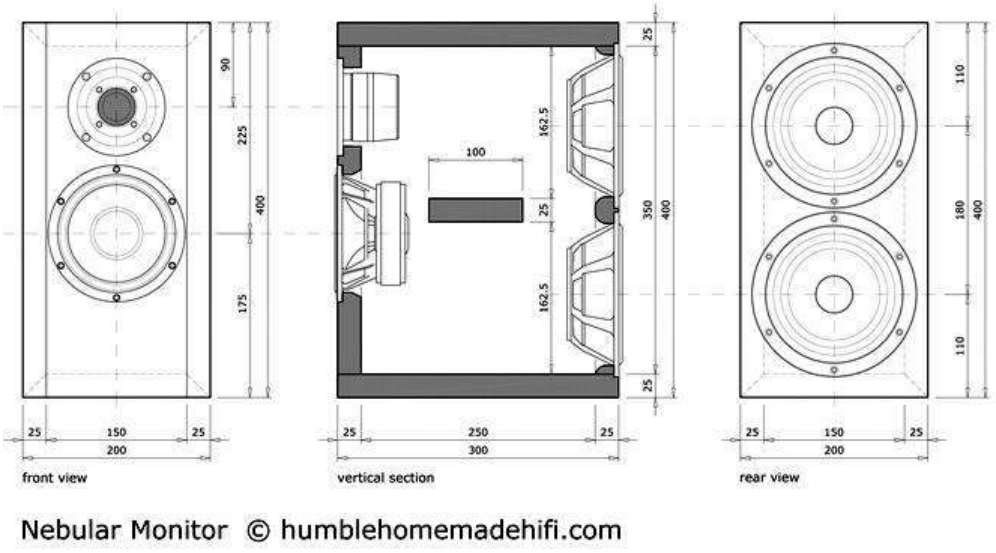
Most compact loudspeakers use a bass-reflex port to give a bit of extra bass in the lower octaves. An efficient and cost effective way to obtain deeper bass, but ports also have a few disadvantages. Especially when compact loudspeakers need to be tuned to relatively low frequencies it goes "wrong". In this case the Nebular Monitor, with it's long-throw woofer, would create port noise at higher volume levels. Even if trumpet ports are used with their large rounded off ends. Port noise is not only measurable as increased harmonic distortion but also audible as a sort of "pof" sound that coincides with a bass-drum for example. Rather irritating! One way to minimize these losses is to increase the diameter of the port so that the air can flow more easily. But when the port area get bigger, the port length also increases. In one of the first prototypes I built, I used a standard flared port with a diameter of 39mm and a length of 139mm. It produced lots of chuffing and the quality and amount of bass lagged behind that of the rest of the frequency spectrum. Enlarging the port to one of 70mm in diameter would have resulted in a length of 490mm for the same tuning frequency and would not have been able to fit into the cabinet.

The solution to these problems is to use a passive radiator or two. A PR is no more than a normal woofer with it's magnet-system and voice-coil removed. A passive radiator is, like a reflex-port, a mass-spring-system that can be tuned to a certain frequency by adding mass. The only difference is that a PR has one frequency at which it doesn't radiate any energy and just sits still. As long as this frequency is below the usable frequency range of the loudspeaker, then there is no problem. In the case of the Nebular Monitor it is at about 16Hz. Beside the advantages of no port chuffing and no standing waves in the port, the PR has another great advantage: that of the large increase in radiating area in the bass. This loudspeaker uses two PR's per cabinet resulting in a radiating area of 260cm2 - compare that to the area of a normal reflex-port!

Not every passive-radiator is suitable for use in a two-way system. Types with stiff suspension, often found in subwoofers, are a no-no here. That type of PR has rather high mechanical losses, the active woofer has to sort of "push through" this stiffness and that is why they often don't seem to come alive until higher sound pressure levels. A good Hi-Fi speaker should also have enough body and low frequency definition at lower sound pressure levels. This calls for PR's with a relatively soft suspension with low mechanical losses. The Seas Prestige SP18R (H9944) that is used here has a compliance of 1,74mm/N so soft enough for this situation. To obtain a tuning frequency of 42Hz, the SP18R's both need some extra added mass. On the rear of the PR's there is a mounting bolt and nut to fix the extra mass to. They both needed 35 grammes of mass on the back which I found in the form of a stainless steel M16 bolt and an M6 mudguard washer (see the photo below).

The cabinet

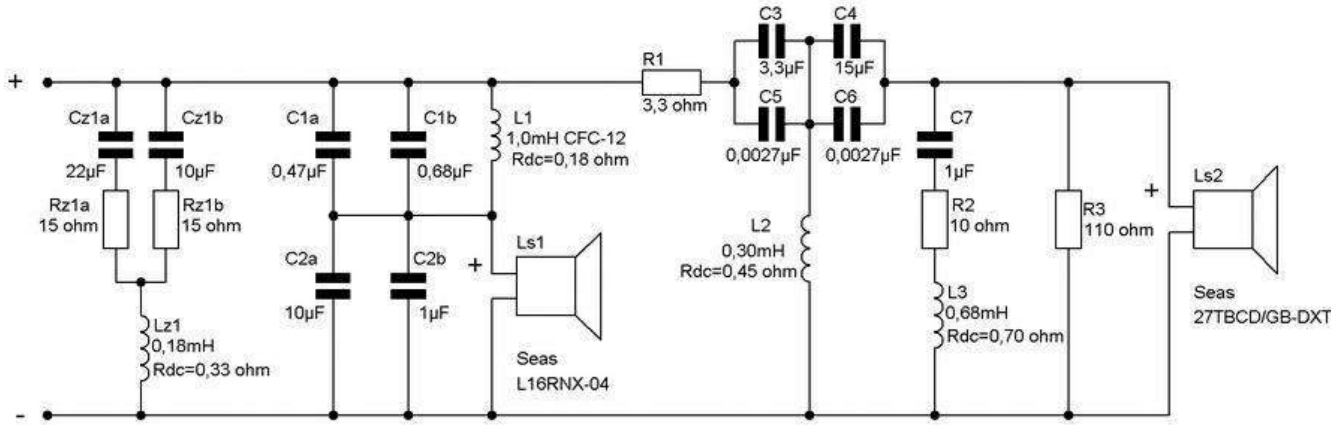
The size of the this speaker is determined by the two passive radiators on the back. The height and width are chosen that the two PR's just about cover the whole rear of the cabinet. There is even such little spare space that the binding posts had to be placed near the corners of the cabinet. The depth was then a result of the 12 litres nett volume the little woofer needs to work in. The front of the cabinet has bevelled edges to make the cabinet look even slender. All the drivers are flush-mounted. The cabinets are made of 25mm mdf that has a black Hammerite finish usually found on metal tools, etc. It gives a high-gloss finish with a sort of "orange peel" texture. Looking at the drawing you can see that the woofer opening has been widened on the inside so that the magnet doesn't close off the woofer on the rear. It's best to make this edge before you assemble the cabinet. The rest is very basic, just your standard six planks and one centre brace. A higher resolution drawing is available on request.



The damping-material inside the cabinet is 4mm thick Intertechnik Bitumex FG4 self-adhesive anti-resonance material constructed from bitumen foil and 10mm thick self-adhesive Intertechnik Damping-10 wool-felt that covers the top, bottom and side panels completely. There is no other wool or fibre material in the middle of the volume so that the energy transferred from the woofer to the PR's is done as efficiently as possible.

The crossover

The drivers in the Nebular Monitor are not the easiest to work with when designing the crossover. The aluminium woofer has severe cone breakup at high frequencies and the tweeter also has a slightly odd looking frequency curve. This means the crossover will need a few extra correction networks to get an end result that sounds neutral and measures flat. The basis of this crossover is a second-order low-pass network on the woofer and a third-order high-pass on the tweeter.



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Starting with the woofer, the capacitors C1a+C1b form together with inductor L1 a resonance trap that is tuned to the cone break-up at 5kHz. Furthermore L1 acts as a low-pass together with capacitors C2a+C2b. For optimum bass response inductor L1 should have low Rdc, the 12AWG copper-foil inductor used here has an Rdc of 0,18 ohms. The tweeter section is a little more complicated. First resistor R1 lowers the tweeter output level to match that of the woofer. The high-pass function is formed by the combination C3+L2+C4 (C5 and C6 are small bypass caps to add some micro detail). C3 and C4 are in the direct signal-path of the tweeter so determine the perceived quality of the high frequencies quite a lot. To keep costs down I chose Clarity Cap SA, a good standard quality capacitor that scores points for being neutral and smooth which matches well with the detailed qualities of the metal dome tweeter. The Clarity Cap SA does have a slightly rounded-off character at the top but I compensated that with two 2700pF Styroflex bypass capacitors C5 and C6. They give the treble a fraction more "bite" and subjectively more "speed". Inductor L2 is a standard vacuum impregnated air-core type with 0,70mm wire - nothing fancy. The next section is a series LCR-network connected parallel across the tweeter. This network flattens a 3dB hump in the tweeters output between 4kHz to 8kHz. Without this network the treble would sound harsh. Here also I used good standard quality components, an MKP capacitor, a vacuum impregnated air-core inductor and an metal-oxide resistor. Finally resistor R3 is used to fine-tune the treble to match ones personal taste and / or system-matching. It can be anywhere between 56 ohms to 270 ohms. In my system two 220 ohm / 2 watt carbon types wired parallel did the job just nicely. There is an optional LCR-network Cz1 / Lz1 / Rz1 that flattens the speakers impedance in the midrange to a nearly flat 5 ohms average. Some amplifiers with a low damping-factor gain smoothness and depth when such a network is added. You can see what works out best for your situation because the network can be connected directly across the speaker's input terminals even after the speaker is finished.

L1 = 1,00mH copper-foil 12AWG; Rdc = 0,18 ohms

L2 = 0,30mH air-core 0,70mm wire; Rdc = 0,45 ohms

L3 = 0,68mH air-core 0,70mm wire; Rdc = 0,70 ohms

C5 = 2700pF Styroflex 500VDC

C6 = 2700pF Styroflex 500VDC

C7 = 1,0uF standard quality MKP

Lz1 = 0,18mH air-core 0,70mm wire; Rdc = 0,33 ohms

C1a = 0,47uF standard quality MKP

C1b = 0,68uF standard quality MKP

C2a = 10uF standard quality MKP

C2b = 1,0uF standard quality MKP

C3 = 3,3uF Clarity Cap SA 630VDC

C4 = 15uF Clarity Cap SA 630VDC

Cz1a = 22uF MKT or bipolar electrolytic

Cz1b = 10uF standard quality MKP

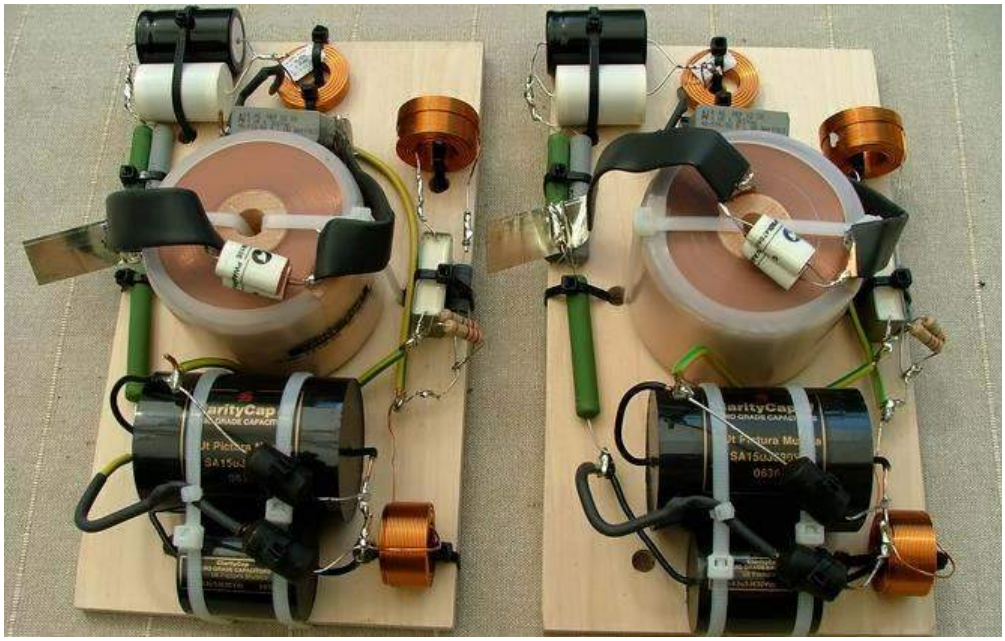
R1 = 3,3 ohms / 10 watts high quality resistor

R2 = 10 ohms / 10 watts MOX

R3 = 110 ohms / 4 watts (2x 220 ohms / 2 watts parallel)

Rz1a = 15 ohms / 10 watts MOX

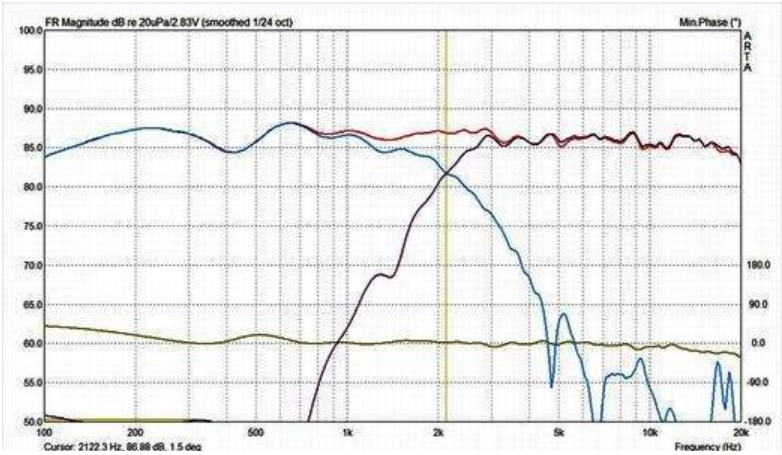
Rz1b = 15 ohms / 10 watts MOX



One tip about mounting these crossovers inside the cabinets: they take up the whole bottom of the enclosure so make sure you position the components in such a way that they don't touch the back of the passive radiators.

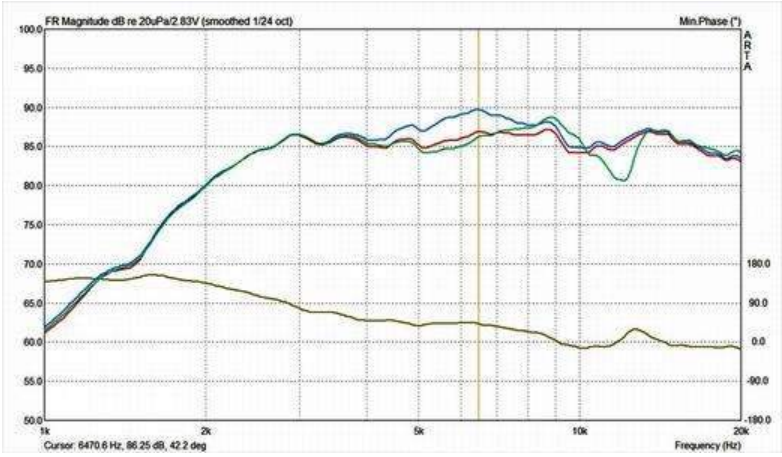
Measuring and listening

The Nebular Monitor is designed to be used on some decent stands free-standing in the room. Ear height should be somewhere between the tweeter and the midwoofer. Positioned as stated they project a surprisingly large image, they sound larger than they look partly because the weight and punch they produce in the bass is not what you would expect from a compact loudspeaker. The overall character can be described as a nice balance between warmth and detail. On the one hand they are very neutral and calm and, positively speaking, nothing in particular jumps out. On the other hand they don't hide anything, so they don't make recordings prettier than they are. It is a speaker for involved listening sessions, not for background "Muzak". I tried the Nebular Monitor on several tube-amps and a few transistor amplifiers, in all cases the loudspeakers were predictable and the characters of the different amplifiers could easily be distinguished - a good sign. They performed well with low-priced tube-amps like the Yarland FV-34B and just grew with higher grade types.

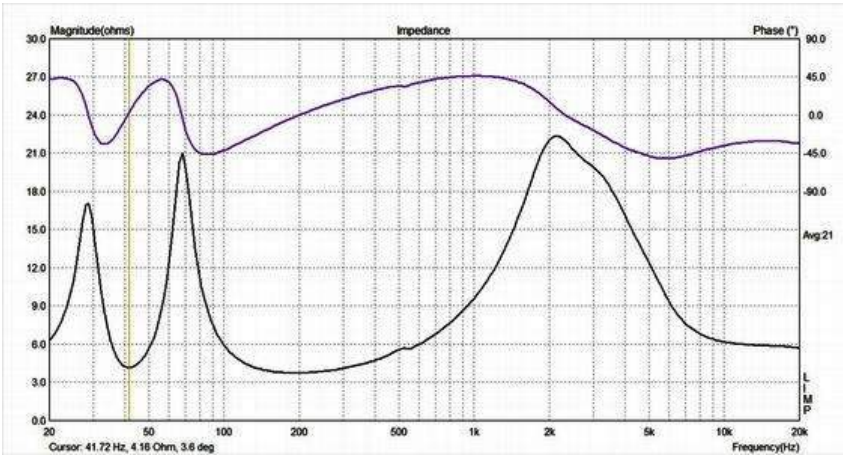


The overall frequency response is very smooth with an output level of about 87dB for 2,83V at 1 meter distance. The critical

mid-band and treble stay within +/- 1dB which corresponds with a very smooth minimum phase. The crossover-point is at about 2100Hz.



These measurements show the tweeter output at various stages. The red curve is the final version with the foam-rubber pads covering the face-plate mounting screws and with correction network C7+R2+L3 in place. The blue curve is the same but with the correction network disconnected. Finally, the green curve is with the correction network in place but the foam pads removed.



The impedance curve shows the port tuning frequency at about 42Hz. The overall load is 4 ohms with an impedance minimum of 4 ohms at 200Hz. The electrical phase stays within +/- 45 degrees, so that shouldn't form any problem for most amplifiers.

Tony Gee, The Netherlands, September 2010

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