



# Proteus

The Proteus - To D'Appolito or not to D' Appolito, that is the question



An exercise in trying to use the series network for two different configurations using the same loudspeakers. The guinea pig is a classic MTM configuration using two Seas 7-inch mid-woofers and a 1-inch soft dome tweeter in a stand mounted symmetrical reflex loaded cabinet. Furthermore the drivers are physically time aligned.

## Introduction

A lot had happened in the year after I finished the Andromeda's. On the loudspeaker side of life I have built three more pairs, of which two could already be seen in the Andromeda article, the third pair I would like to explain in more detail in this article. What do you do when you have finished a pair of Andromeda's? You sell them! Or at least I did. Not because they are bad, according to the many e-mails I received they are one of the best speakers you could build (he said modestly). No, I sold them because the designer in me is never satisfied, he wants to conquer new frontiers and boldly go where no loudspeaker designer has gone before (and some friendly Danes offered me enough money). After such a complex exercise I thought it was time to build something a little easier. It had been a few years since I had built a D' Appolito system and I happened to have some 7 inch mid-woofers and a couple of burnt out tweeters laying around and some left over pieces of mdf. I thought it would be fun to see what would happen if I mixed them all together. I didn't want to put much effort into designing the cabinet seeing as this would be a temporary design that needed to be built quickly as I was speakerless (not a situation you want to be in for too long). I had always found the Wilson Audio Cub a very nice example of form-follows-function design so the decision was easily made. The Series-I, where I had found my inspiration, has now been discontinued. I find the follow-up Series-II not as attractive because it is less basic in form and a little more (over) styled.

## The tweeter

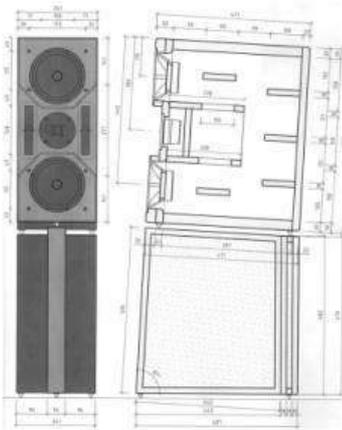
The Seas Excel T25-001. I had by accident fried a pair due to a faulty filter so I bought some replacement domes. While I had the massive aluminium front plate off for repair I thought why don't I take out the ferrofluid? You never know, they might sound better. It comes out rather easily if you pour a little turpentine into the air-gap and carefully absorb it out by using a piece of kitchen roll or toilet paper (preferably the pale pink type with the little blue flowers printed on it). Repeat this several times until all the dark brown liquid has gone. The cavity inside the magnet and rear volume is filled with mineral wool to dampen resonances, remove this first so that it doesn't get wet. Leave the speaker to dry for a few hours before you replace the mineral wool. The Seas replacement domes are self-centring, so putting in new one's shouldn't be too difficult.

## The mid-woofers

The Seas CB17RCY/P. I had originally bought some to use in the Andromeda. I had noticed that several commercial designs use similar units in their systems so they couldn't be that bad. They are not as good as the Scanspeak 18W8545 but considering they are much less than half the price they perform very well. They have a very lightweight coated paper cone; the moving mass is only 10 grams as compared to 15 grams for the Seas Excel units. The magnet is reasonably large and in combination with the lightweight cone it should give a quick reacting driver. A nice detail is that the basket has four more half-depth mounting holes on the rear side. It is therefore easy to drill them through so that the driver can be mounted with eight screws instead of the standard four. I believe it is better to divide the pressure as evenly as possible around the frame to give maximum contact between the driver and the cabinet - and it looks rather cool. This unit is also sold by Intertechnik under the name Seas W17PPI.

## The cabinet

If you have been designing and building loudspeakers for more than seventeen years, then by now you would probably have rather a lot of pieces of MDF left over. Seeing as I didn't want to build a very large cabinet I thought it was time to use some of these left-overs. All external walls are made of 22mm MDF except the top and bottom panel, which are made of 30mm MDF.



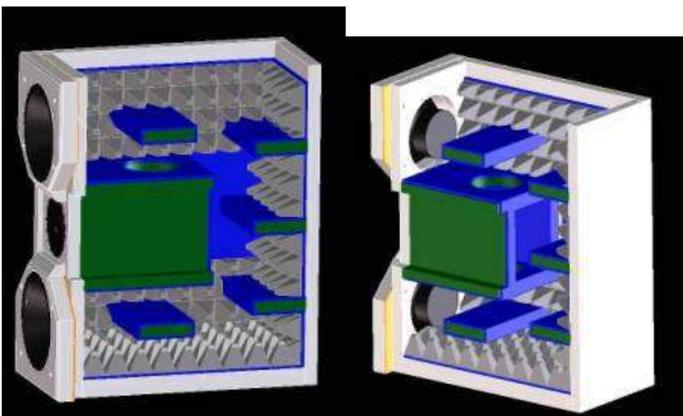
*A higher resolution drawing is available on request.*

The central construction is formed by the reflex-port/tweeter cabinet combination. It can best be described as the capital letter "H" with two horizontal bars. The area between the two bars is closed off on one side. This forms a separate sub-enclosure for the tweeter to stop unwanted vibrations in the box reaching the rear of this unit, 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 cabinet is internally strengthened with this "H"-part and by planks all made of 18mm MDF. There is no voodoo behind the different widths of the planks used in the photo; this is what you get when you use leftovers.



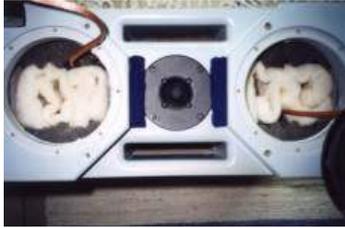
*The internals.*

Placing the reflex ports symmetrically to the left and right of the tweeter is a very wise thing to do. Seeing as it is a two-way system a lot of midrange energy will be coming out of the ports. If you place the ports in the rear panel then this energy will arrive delayed compared to the midrange energy coming from the drivers. This will result in some blurring of the stereo image. As this would be a D' Appolito design there are two ports placed centrally around the tweeter as the woofers are. All internal walls except near the ports are covered with heavy-duty carpet tiles and wedge moulded foam to minimise vibrations and standing waves. The carpet tiles have a nice heavy backing that adds mass to the enclosure and they come in all kinds of lovely colours and patterns. Glue them to the MDF using lots of carpet glue. Adding a few screws or nails helps hold them in place and stop them curling up while the glue dries. Bonded acetate fibre damping material is rolled up and placed directly behind each woofer.



3D-model showing the positioning of the carpet tiles (blue) and Pritex damping (gray). The felt is shown as yellow.

Depending on the positioning of the speakers in the room and personal taste this fibre can be rolled up densely or loosely to give a tighter and dryer or a fuller and warmer sounding bass. I used Monacor MDM-3 damping pads that consist of 2/3 sheep's wool and 1/3 polyester fibre and found that one bag per speaker was okay. If you have a small listening room or your speakers have to stand close to a wall then maybe some extra fibre placed in the middle of the cabinet will be necessary.



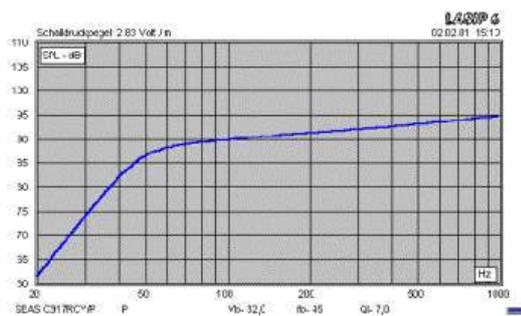
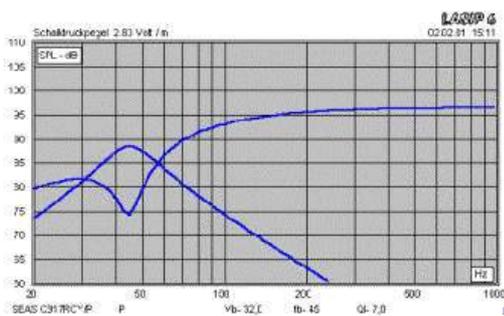
The damping material in place.

The baffle has two extra pieces of 30mm thick MDF mounted on it. The edges are routed with 4mm's at 45 degrees for looks and to remove the sharp edges that would cause baffle diffraction problems. The ends closest to the tweeter are covered with thick soft felt (the blue things) to stop reflections so close to the tweeter. The add-on parts have two main reasons. First of all they time-align the two woofers with the tweeter, the acoustic centres of the drivers are all in line with each other. Later on you will see that this only works for first-order networks. Higher-order networks give steeper phase shifts and therefore the thickness should ideally be changed. Secondly they reduce the amount of vibrations caused by the woofers reaching the tweeter.



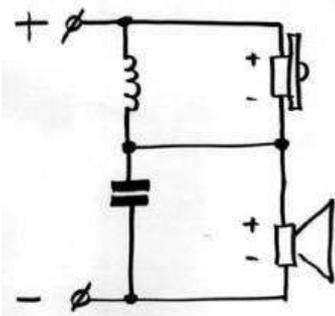
The felt absorbers and "add-ons".

Between these add-on parts and the box there is a 2mm layer of felt that forms a sort of barrier for vibrations. These together with the internal bracing and the carpet tiles form a very rigid cabinet. For a single walled box the vibrations that can be felt on the outside, when playing them loudly, are minimal. The total weight of each cabinet is 27 kg (61 pounds). To stand this firmly and level on the ground you need spikes. The cabinet rests on three spikes so that there is always optimum contact. I used three gold-plated SPS-10/GO spikes and protectors by Monacor. To bring the speaker to ear height it stands on a T-shaped stand, which is also spiked to the floor. This stand is made of three layers of Finnish birch plywood of which the middle layer has a large cut-out. This hollow space is filled with dry silver-sand to add mass and form a sturdy base for the speaker to stand on; the total weight of each stand is 14 kg (31,5 pounds). So that the speakers are in line at the listening spot the stand is angled 3 degrees upwards. You can of course build a straight stand but then it should be taller so that the tweeter is exactly at ear height. The internal volume is about 32 litres and the bass-reflex ports are tuned to 45Hz. The images show the separate output for the parallel woofers and the reflex port as also the summed output.



### The crossover network

Here it all boils down to the question: To D' Appolito or not to D' Appolito. Both have their advantages and disadvantages so I designed two series-filters, one for each. With a series-filter the electrical signal 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 wiring etc of course).

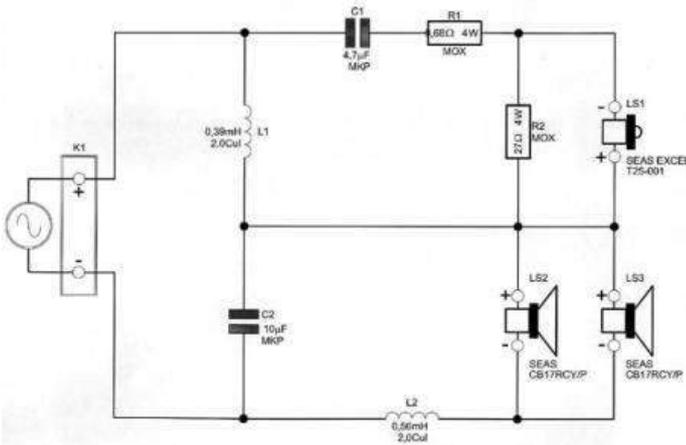


A basic 2-way series filter.

For example if you take a basic first-order two-way 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.

### The D' Appolito version

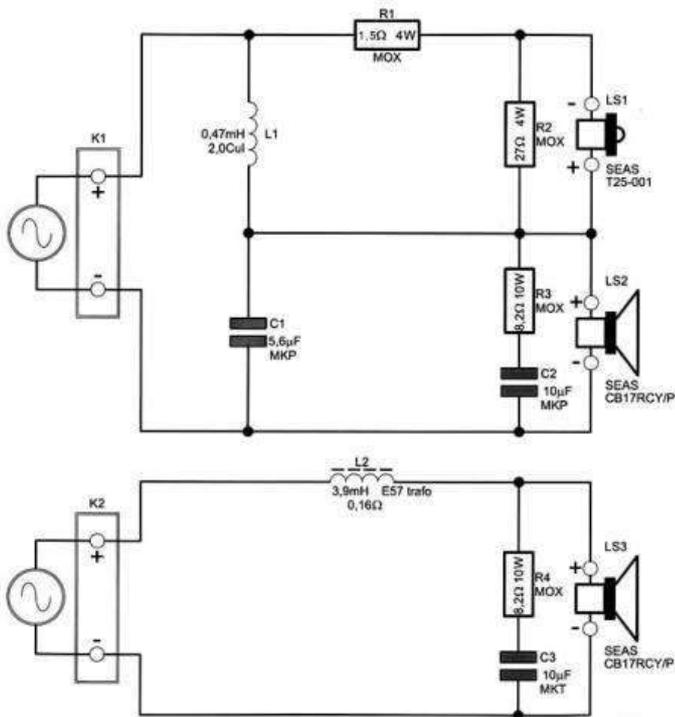
This uses a second-order series-filter, this isn't what Joseph D' Appolito originally specified but it seems to work. This must be a world premier, if anybody can find information about D' Appolito systems using series filters please let me know I would be very grateful. The whole filter is nice and simple using only four active components for three drivers but still giving a crossover with electrical slopes of 15dB's per octave. The only extra components are the resistors to tame the tweeter slightly. Depending on your equipment and taste the series resistor can be anything from 1,5 ohms to no resistor at all. The inductors are air-core type using thick wire for low Rdc and no saturation and are matched within 1/100 of a millihenry using a LCR meter. The capacitors use metallized polypropylene foil and the metal film resistors are also matched for minimum tolerance. The tweeter is connected in reverse polarity.



The 2-way D' Appolito series filter.

### The non-D' Appolito' Appolito version

This is designed as a 2-and-a-half-way system. The upper Seas CB17RCY/P and the Seas Excel T25-001 are wired together using a first-order series-filter giving electrical slopes of 9dB's per octave. The lower Seas CB17RCY/P is connected using a first-order parallel network. Both woofers have an extra parallel RC-network to compensate for the rising impedance due to the voice-coil inductance. The lower woofer is filtered using an E-core transformer type inductor for low Rdc and high power handling. The other inductor is an 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 metallized polyester foil all the others use metallized polypropylene foil. The resistors use metal film with 1-% tolerance. Depending on your equipment and taste the series resistor can vary from 1,2 ohms to 2,2 ohms. I had the best results with 1,5 ohms. In the earlier published version there was a mistake in the filter schematic due to connectors being labeled the wrong way, this is the correct schematic:



The 2,5-way filter schematic.

L1 = 0,47 mH air-core inductor 2,0 mm wire, R = 0,11 ohms

L2 = 3,9 mH transformer inductor, R = max 0,16 ohms

C1 = 5,6uF MKP polypropylene foil capacitor - Audyn Cap Plus, Mundorf Supreme Cap, etc.

C2 = 10uF MKP polypropylene foil capacitor - Audyn Cap, Mundorf M-Cap or LeClanché

C3 = 10 uF MKT polyester foil capacitor - or better

R1 = 1,5 ohms, 10 watts MOX resistor

R2 = 27 ohms, 10 watts MOX resistor

R3 = 8,2 ohms, 10 watts MOX resistor

R4 = 8,2 ohms, 10 watts MOX resistor

### Wiring and connectors

I decided to place the filters outside the cabinets in separate enclosures to keep them away from the woofer magnets so that the inductors will function properly. 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 though 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. Each driver has separate connectors on the rear of the cabinet. I used the BP-500G by Monacor. They are gold plated and can take up to 6mm<sup>2</sup> cable, spades or banana plugs.

### To D' Appolito or not to D' Appolito? That is the question.

#### Version nr. 1 - The D' Appolito version

It sounds smooth and sweet with a nice wide sound stage but the sweet spot is a little narrow. The sound stage is more forward than deep. Bass is tight and deep considering the modest size of the speakers. A surprising thing is that the bass is tighter than with the 2-and-a-half-way system. If you listen a lot to jazz trio's and classical quartets you will be amazed by the amount of detail, but if you like Top 40 pop and rock you will probably find this filter a bit on the bright side. It is not at all harsh just very revealing. Efficiency is high at about 92,5dB's for 2,83V/m, so it won't need much power to get loud. The impedance varies around 4 ohms.

#### Version nr. 2 - The non-D' Appolito version

This version has a very 3-dimensional sound, not only very wide but also with more depth than the other version; very enveloping. The sound is very open and warm, bass is full and deep. Basically it is an all-round speaker with no preferences for any type of music. The tonal balance seems more neutral than the D' Appolito version partly because of the extra warmth and forwardness in the midrange. Maybe the ideal phase characteristics contribute to this. Efficiency is about 91,5dB's for 2,83V/m and the impedance a very smooth 5 ohms.

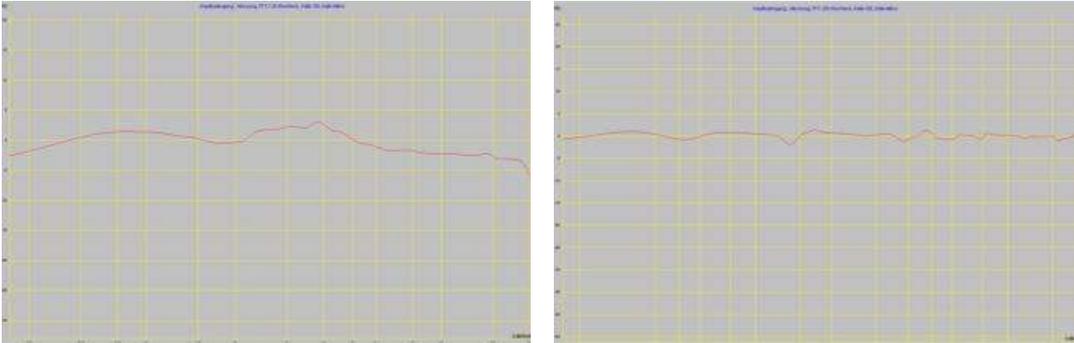
Of course there is nothing to stop you building both filters and trying out which one you prefer. Or to have both so that you can switch filters depending on what kind of music you are playing.

## Measurements

For both versions I have made three measurements.

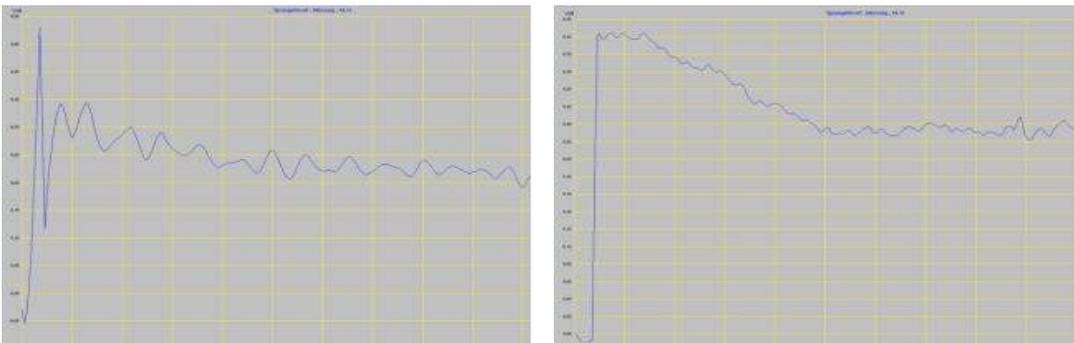
### The relative output level

The horizontal scale is 5dB's. Both have a relatively flat response with version nr.1 +/-2,5dB over the whole range with a gradual roll-off towards the top end. This is measured with a 1-ohm resistor in series with the tweeter. The peak at about 2500 and 3800Hz is due to cone break-up of the CB17RCY/P. Version nr.2 is even smoother with +/-1,5dB over the whole range and completely flat right up to the top end. I must modestly say that I was positively surprised when I first saw these readings. This is measured with a 1,5 ohm resistor in series with the tweeter.



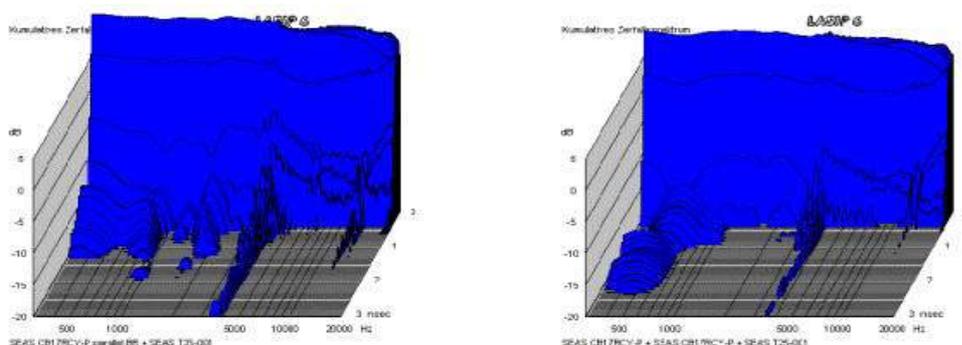
### The step response

Here you can clearly see the differences in phase. Version nr.1 spikes up and down at the beginning showing that the signal from the tweeter arrives first and then about 0,2ms later in opposite polarity the signal from the two woofers. It then continues with fluctuations of about 0,05 Volts. But don't worry, it all looks more serious than it is, many commercial loudspeakers spike up and down for several milliseconds before starting on the decent. But how about version nr.2 Wow! The rise time is practically vertical with no up and downs. It then continues with nearly no fluctuations at all. This shows that the 30mm thick additions on the baffle are doing their work.



### The waterfall response

The waterfall spectra show some interesting results. The tighter sounding bass with the D' Appolito version can be seen in a shorter decay in the bass and low midrange up to about 1000Hz the only difference here is the filter. The cone break-up at 3800Hz can easily be seen being less prominent in version nr.2 because only one of the woofers is active in this region.



*"Waterfall, nothing will change at all" (© Jimi Hendrix).*

NOTE: This design is strictly for the home DIY enthusiast and not to be used professionally without my permission!

Tony Gee, The Netherlands

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