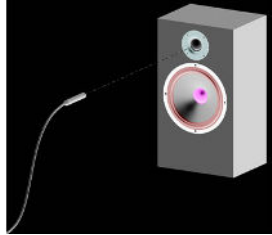


# MANUAL



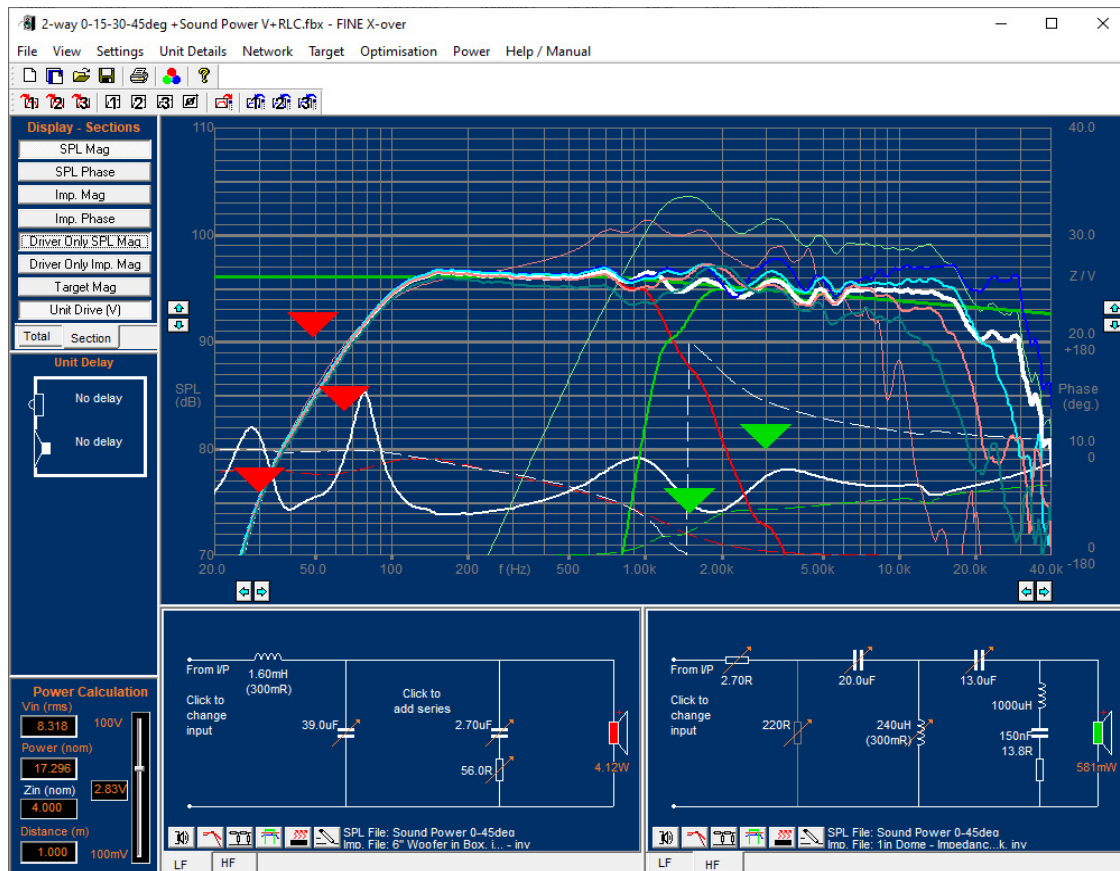
## FINE X-over™

X-over Design with Power Control



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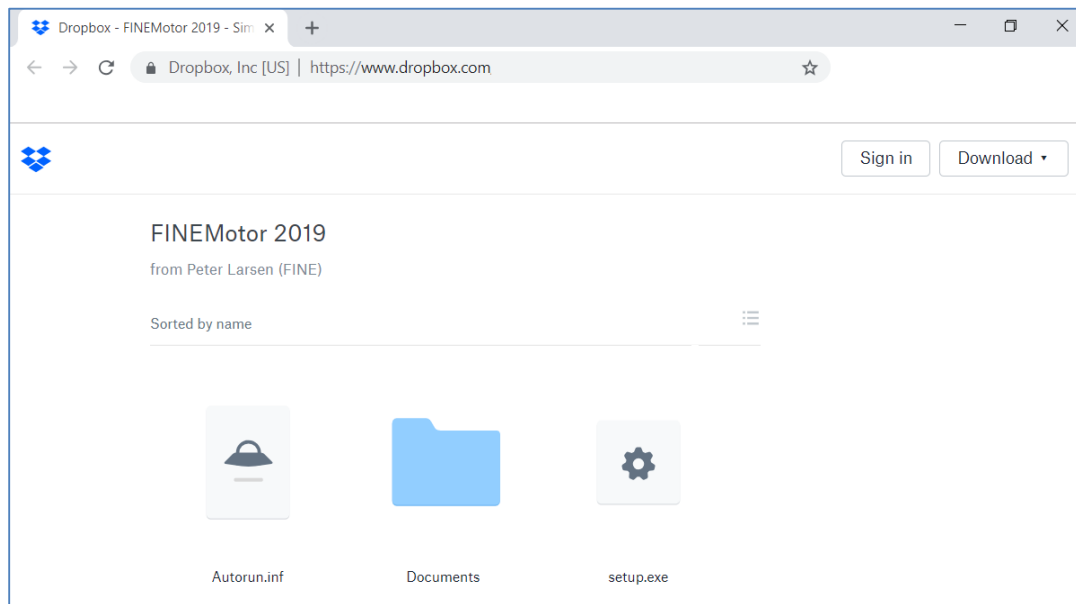
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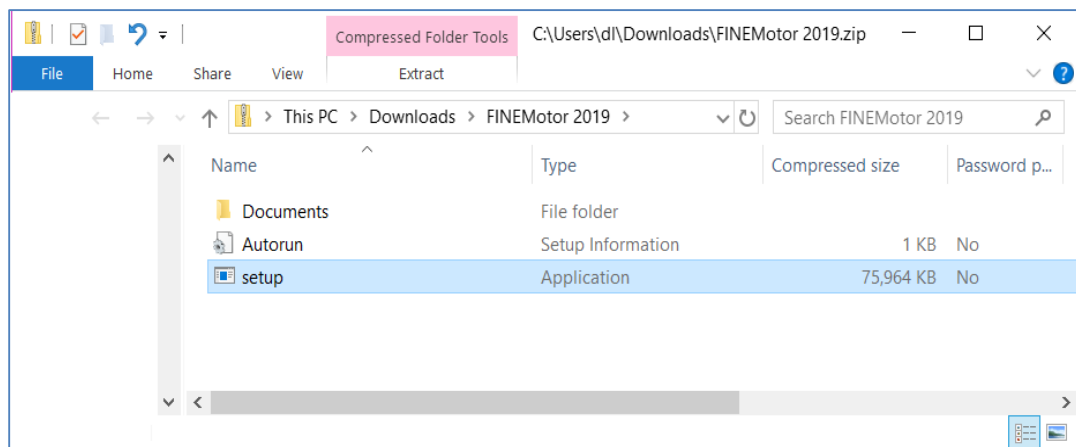
## 1. How to install the LOUDSOFT programs from a link

**The computer must be connected to internet during installation.  
You can't move the program after installation, so make sure to install on the right computer.**

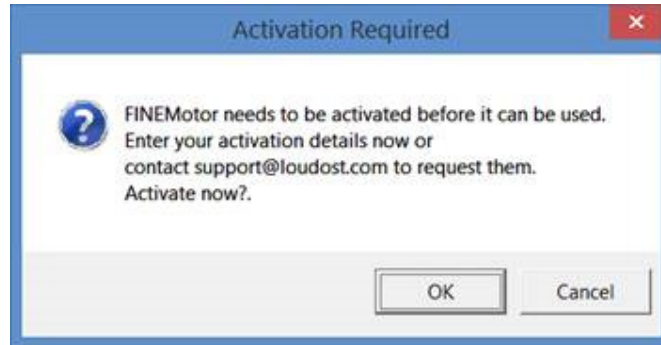
- When you click on the license link, you must download the program. Click on “Download” at the top right corner of your screen. Make sure to save it, you might need it later. We change the links from time to time for security.



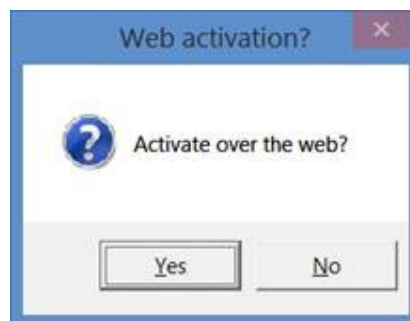
- Now find the downloaded file at the left bottom of your screen. Click on it and you will see the picture below. Click on “Setup” and follow the instructions to install the program.



- Once the installation has finished you have to activate (and not later, because it will cause problems). The software will be usable once the activation has been completed.
- Click OK on the first dialog



- Click YES on the second dialog



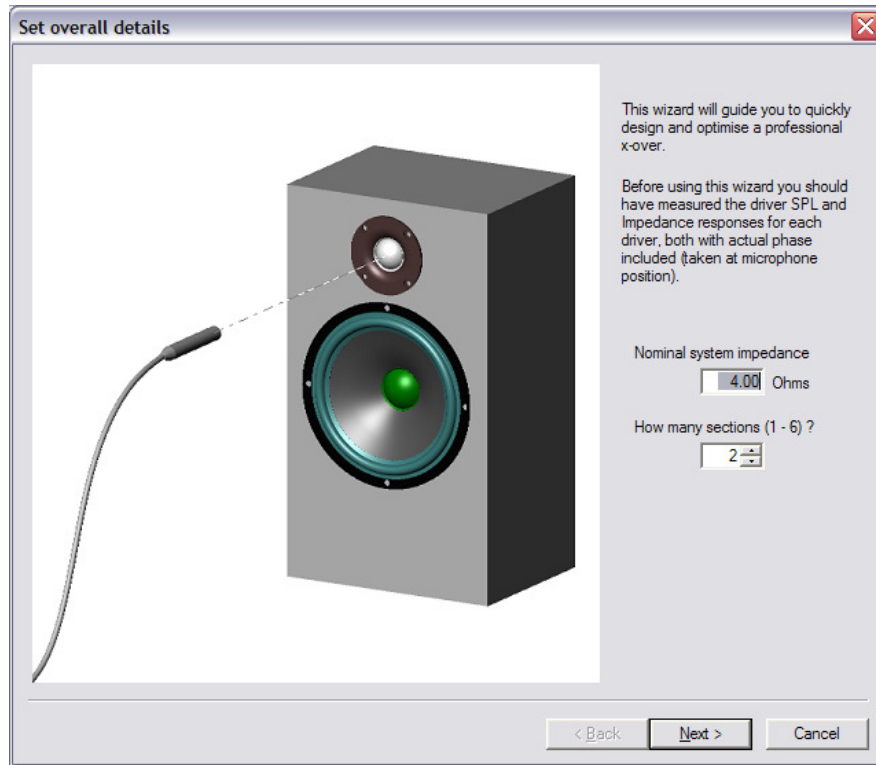
- Fill in your license ID and password in next dialog. Your License ID is XXXXXXXX, and your password is P P P P P P P P



- Click OK. It is all done!

## 2. X-over for 2-way design

In the first example we create the x-over for two drivers we have previously measured in our cabinet. Press New to get the Wizard, which will guide you to design the best possible x-over for your system.



**Figure 1 - Initial design wizard**

We have the option to import measured files from FINELab (.lab) and FINECone (.FSIM) and several systems like MLSSA, LMS, Sound-check, Klippel etc. Here we start with MLSSA files as \*.FRQ and \*.TXT.

You can drag and drop both on- and off-axis responses directly from FINE R+D by keeping both programs open, see Figure 3.

The two drivers are measured in the cabinet as shown on the sketch. We have placed the microphone ideally in the listening position (usually in line with the tweeter). However 1m or shorter distance is used in normal rooms. Then we have measured the woofer response and exported as \*.txt files (Actual + BODE Plot in MLSSA). The tweeter is done the same way, with the microphone in the SAME position. Finally, we measured the impedance from 20-20kHz for both drivers

Choose the nominal system impedance, normally 4 or 8 ohms (mostly determined by the woofer) even 1 ohm or 0.5 ohm is possible. This is used for initial x-over calculations and for minimum impedance calculation. We will set the nominal impedance to 4 ohms (min impedance is therefore  $4 \text{ ohms} \cdot 20\% = 3.2 \text{ ohms}$ ). We choose 2 sections (2-way) as we have two drivers.

Press Next. Open SPL to load the file you had previously measured: SKO130-SPL.txt, and Open Imp. to load the impedance file SKO130-Imp.FRQ. You can click the file to preview and check that you have selected the correct curve as shown in Figure 2.

Note the vertical line —Target level, Figure 3. This is the level we want to optimise the system to. You can drag the line up/down by the left mouse button or overwrite the number (90.3 dB). We have chosen the flat level above 200Hz for the woofer because this is close to the maximum level we expect to get out of the total system. We will consider off-axis SPL files later.

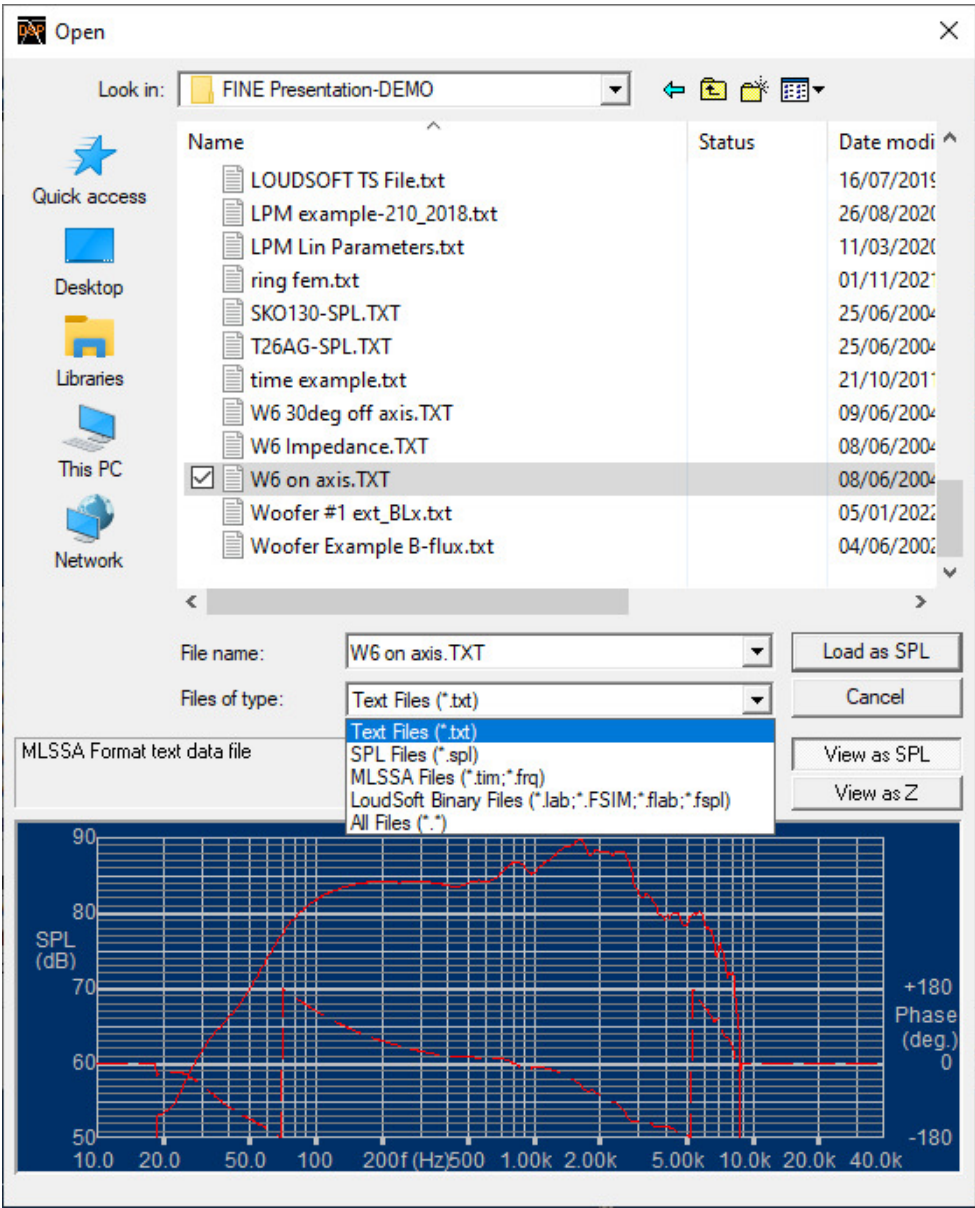
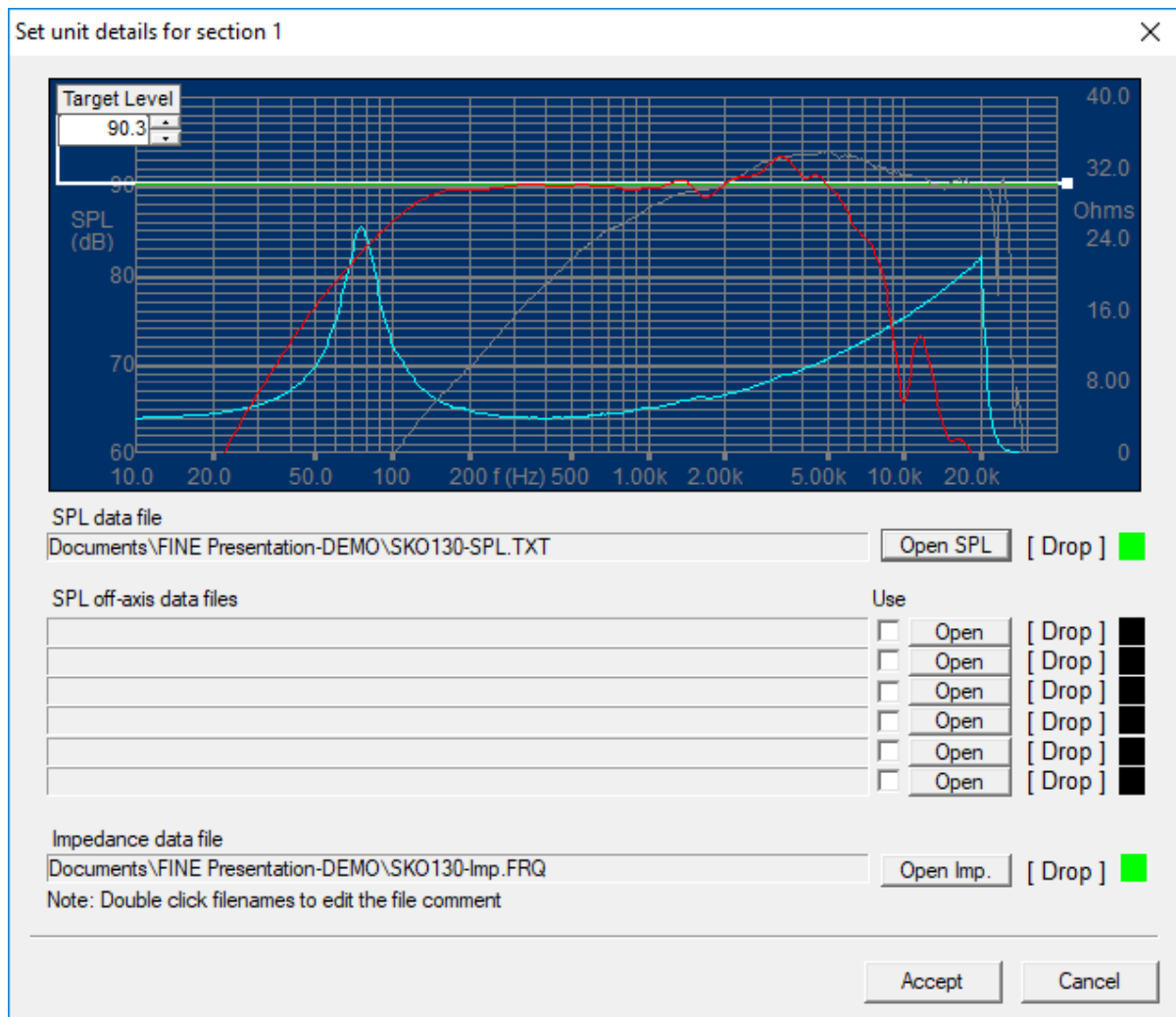


Figure 2 - File preview

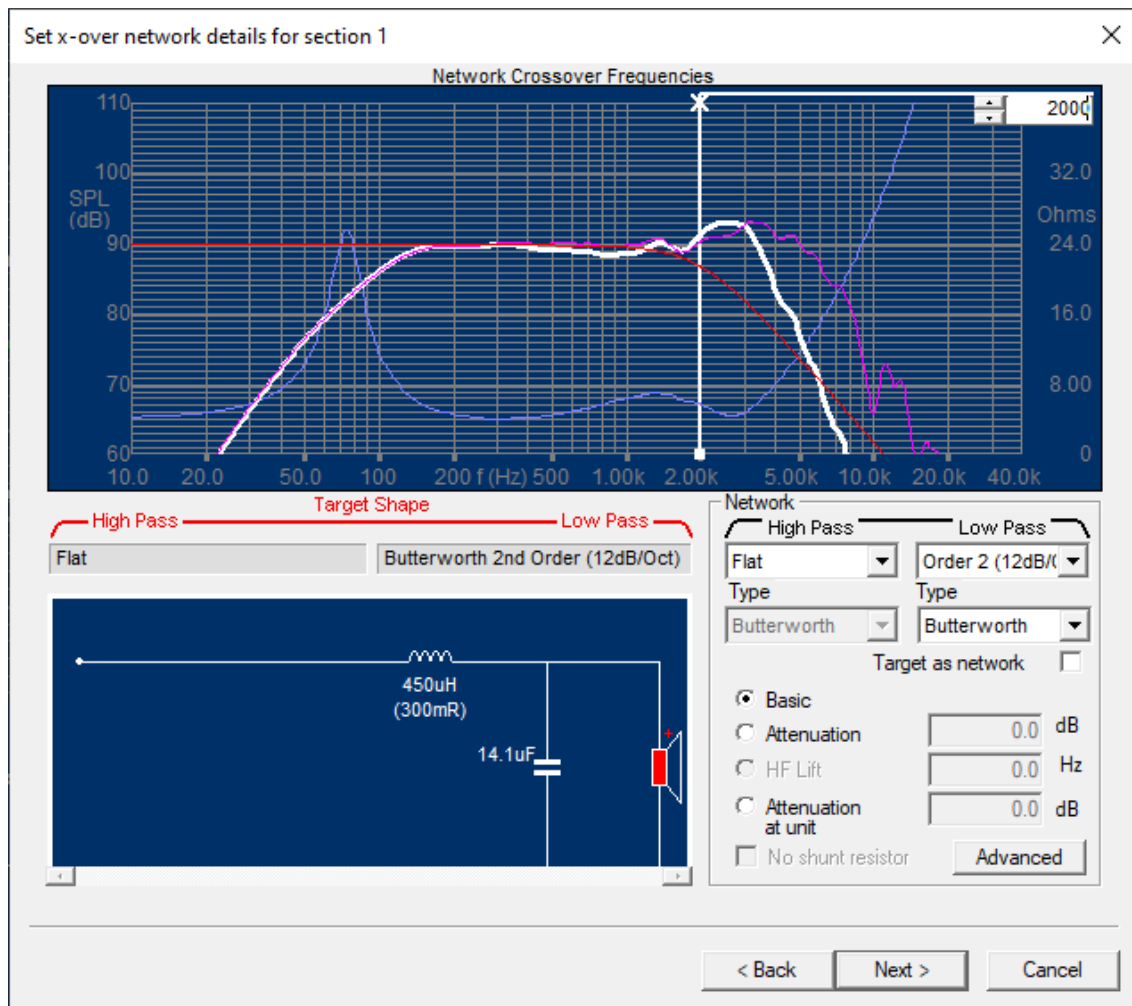


**Figure 3 - Drag / Drop responses directly from FINE R+D**

Press next to load the tweeter the same way. This time we use the measured T26AG.frq file directly without exporting to txt-format. Let us keep the 90.3dB target level also for the tweeter.

Figure 3 shows files dragged from FINE R+D.



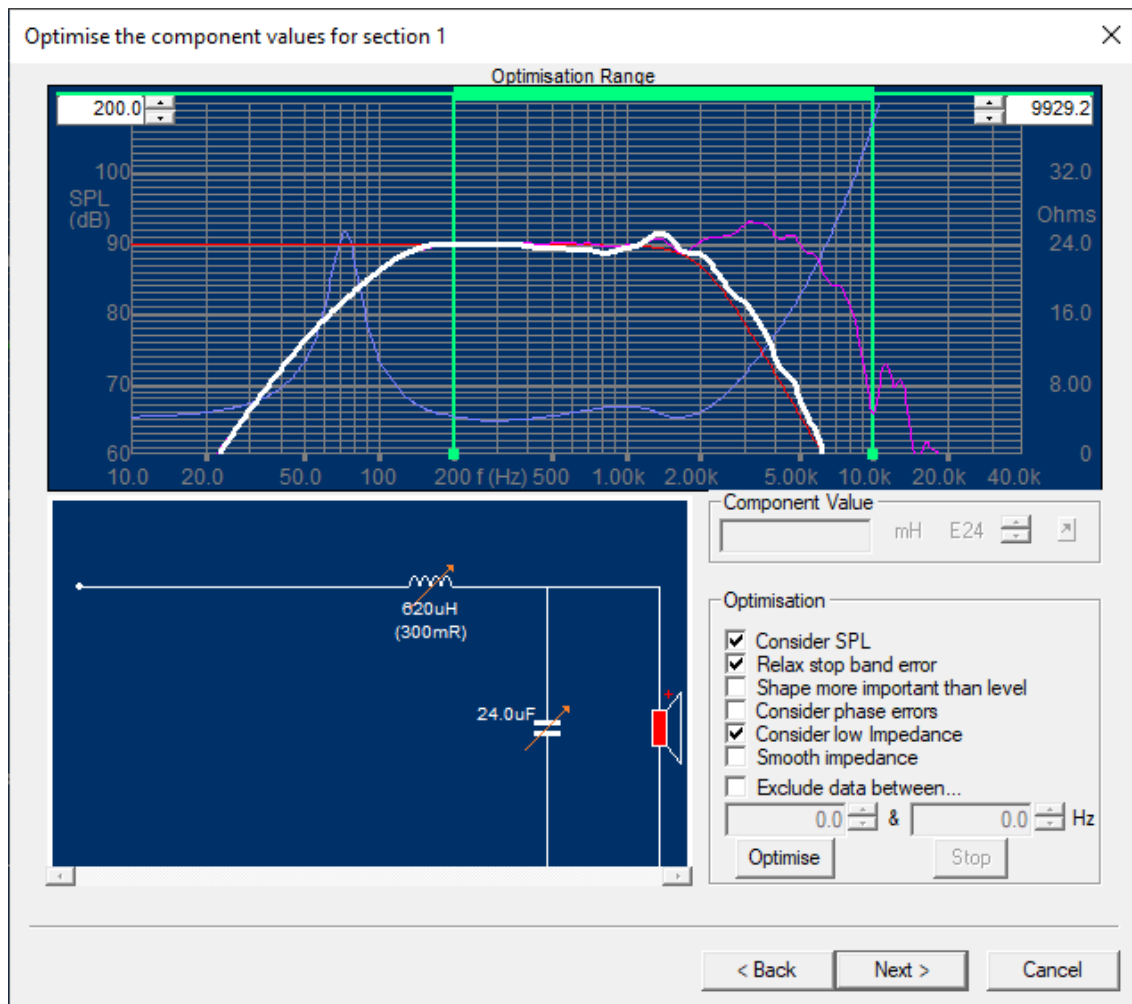


**Figure 4 - Target response**

Now is the time to select the x-over type and Target frequency response. Figure 4 shows the first section - woofer (LF). We may choose Butterworth (Linkwitz-Riley, Chebyshev and Bessel are also possible) type and 1<sup>st</sup> Order (6dB/Oct) up to 4<sup>th</sup> Order (24dB/Oct). The black vertical x-line shows the chosen x-over frequency, and we have selected 2<sup>nd</sup> order (12dB/Oct) Butterworth at 2000Hz.

You can drag the X-line by the left mouse button, while observing the filtered section response change.





**Figure 5 – Optimisation of section 1**

The next screen is the 1<sup>st</sup> (woofer) section Optimiser, see Figure 5. Let us optimise the x-over components to the target 2<sup>nd</sup> order Low Pass response (red line), while keeping a minimum impedance of 4 ohms -20%=3.2 ohms (according to the common IEC 60268-5 standard). We observe that the inductor (L) and capacitor (C) already are marked for optimisation by the red arrows.

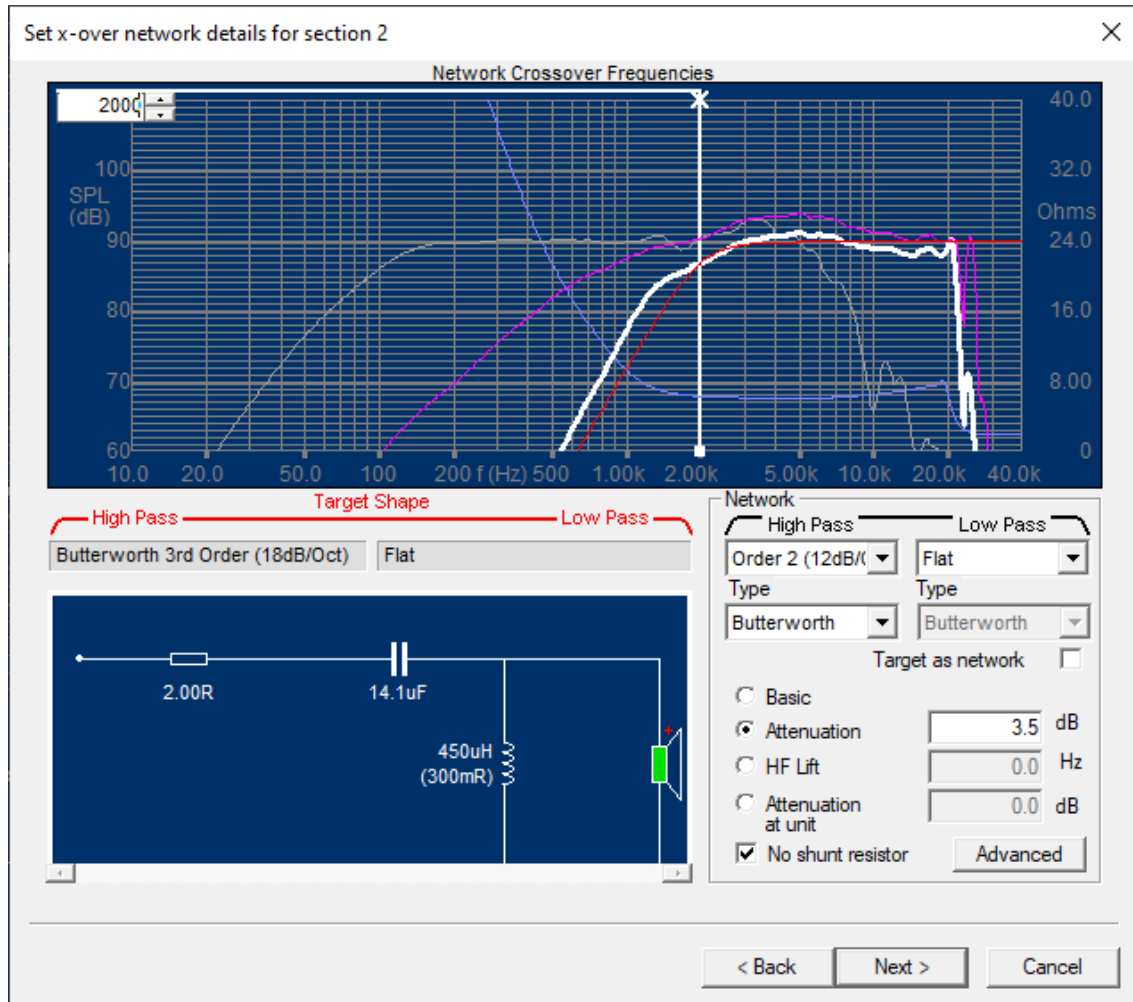
The chosen optimising range is shown between the two green lines, which can be dragged as before. It is important select the start at 200 Hz above the woofer resonance where the response is almost flat (if the first green line is too low the optimisation does not work). The upper limit is set by default to two times the x-over frequency (=4000 Hz), which we drag to 6082.2 Hz to include the top end.

Observe the Optimisation settings on the right side: “Consider SPL” and “Relax stop band error” are selected by default. We could select “Shape more important than level” because that may help the optimiser to find a good response at a higher SPL level. Further “Consider low impedance” is set to avoid getting lower than minimum impedance.

Now we press “Optimise” and see the optimised response in a few seconds.

*Note: you may select a Target slope to match the actual measured curve, i.e., 3<sup>rd</sup> order here*

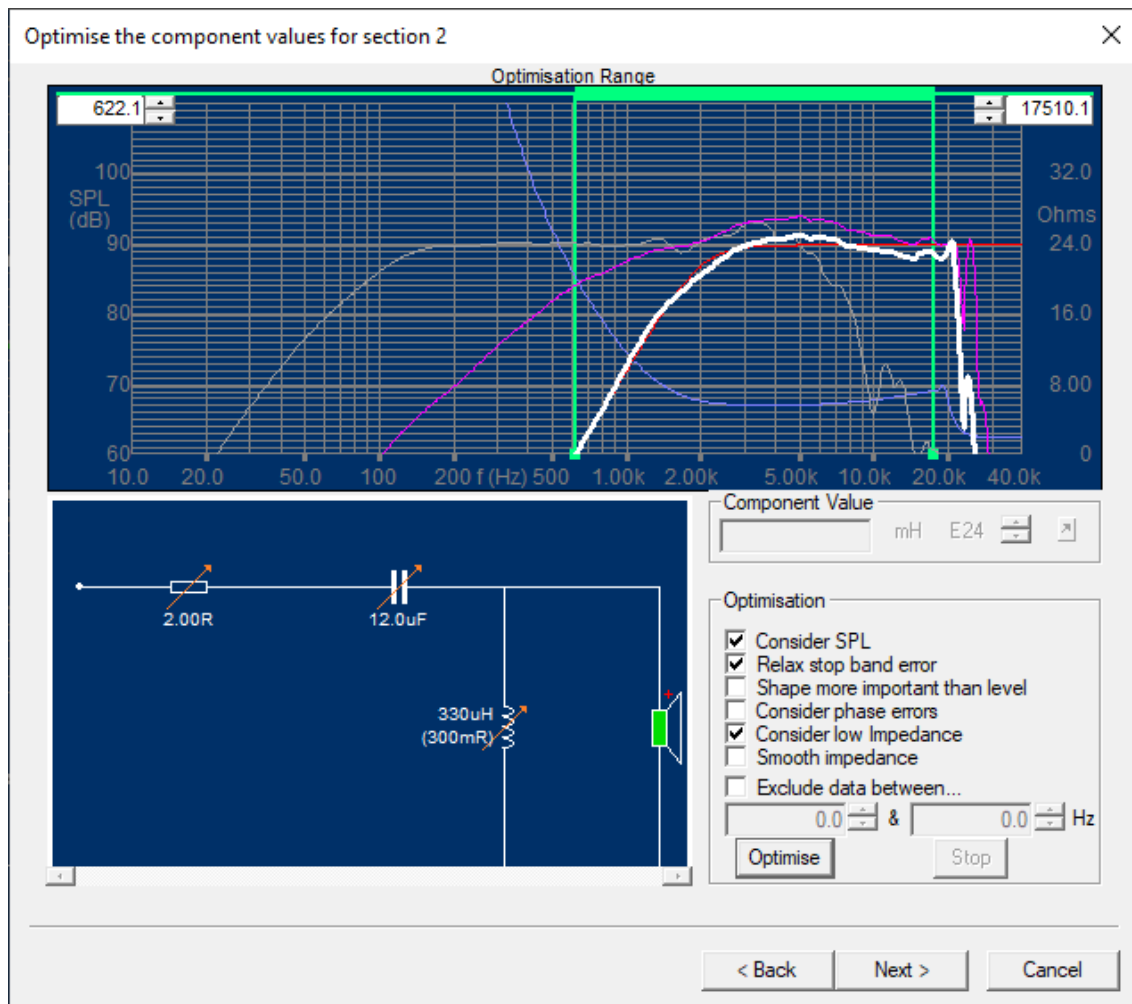
The next screen, shown in Figure 6, shows the target response for the 2nd (tweeter) section with the already chosen x-over frequency (2000 Hz) marked. We have chosen attenuation by one resistor only, because the tweeter sensitivity is above the target. 2 resistor attenuation is also possible, and may control impedance better.



**Figure 6 - Tweeter target response**

Figure 7 shows the HF (Tweeter) optimising range is set from 1000 to almost 20 kHz, because we want to include the top end response without exceeding the limit in the impedance response at 20 kHz. If you want to keep any of the components as a fixed value, just double click and the red arrow (=variable) is removed.

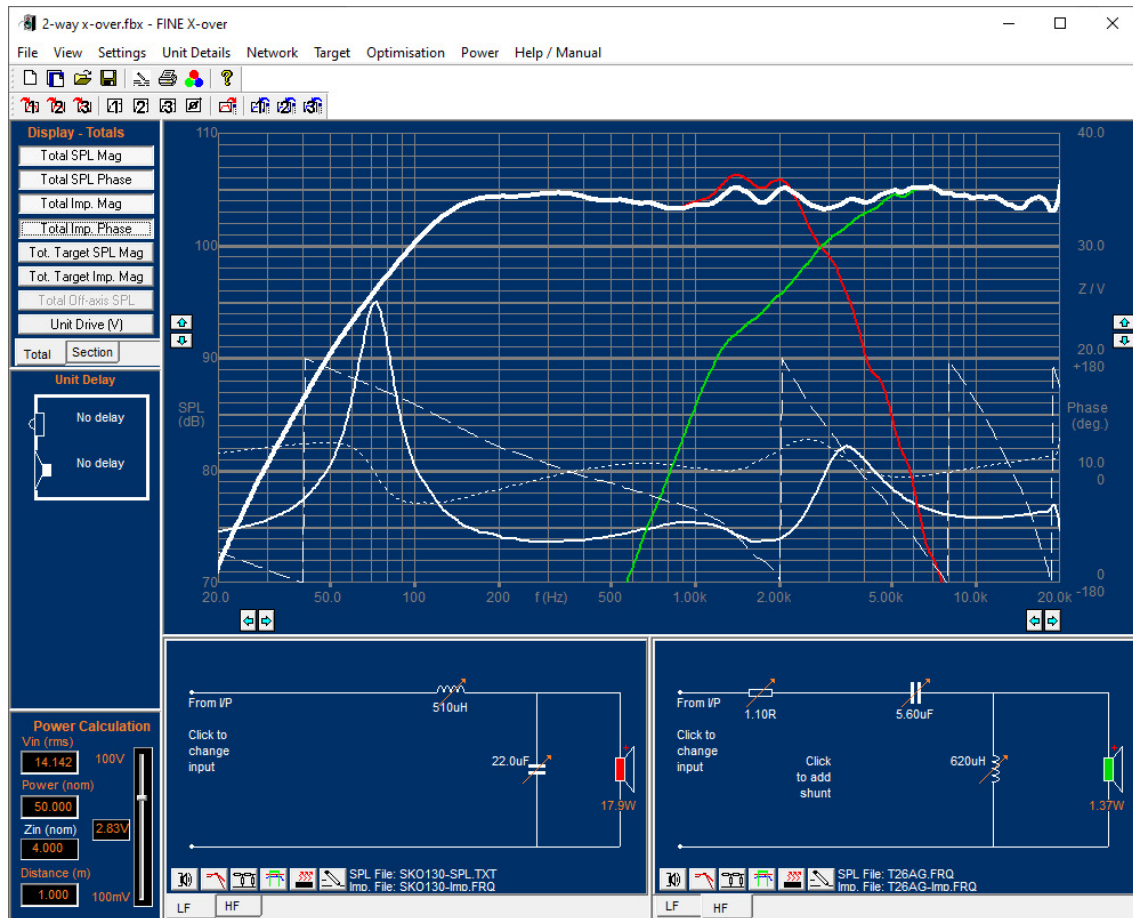
After pressing "Optimise" we see the optimised HF/ Tweeter response is quite close to the target. The Wizard is now finished. See the total response in the main window with the optimised sections. This response is quite flat already; however, we should use the System Optimisation to obtain an even better total response.



**Figure 7 - Optimised HF section**

The optimisation range is set as the “flat” part of the total response. However, we have deselected “Shape more important than level” because we are interested in the absolute best and flattest response.

The final optimised response in Figure 8 is flat within +/-1.0 dB from 150-20kHz. The minimum impedance is above the limit (3.2 ohms) 20-20kHz.



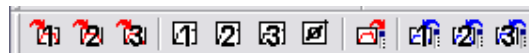
**Figure 8 - Final optimised response w/ acoustical and electrical phase**

The power in the woofer (LF) and tweeter (HF) is shown under the driver symbols with red numbers, 17.9W and 1.37W respectively, for 50W RMS input (IEC 60268-1: Simulated Music).

Note you can always change component values by clicking (left mouse button), and you will get the edit menu shown in the lower right corner. Change (standard E24/E12...) values by rolling the mouse wheel up/down or use the arrow keys in menu or keyboard.

Press Total SPL Phase and Total Imp Phase to view the acoustical and electrical phase responses, see Figure 8. The acoustical phase (-----) is quite linear and the electrical phase (.....) is well behaved within +/- 45deg up to 20 kHz.

You may save the total response for later in user memory or as a file using the button bar:



### 3. SPL scaled with Power Input

When you select a frequency response file for import you will be asked if it should be scaled according to the current power settings in FINE X-over. The scaling is automatic when importing from the latest FINEBox and FINE R+D programs.

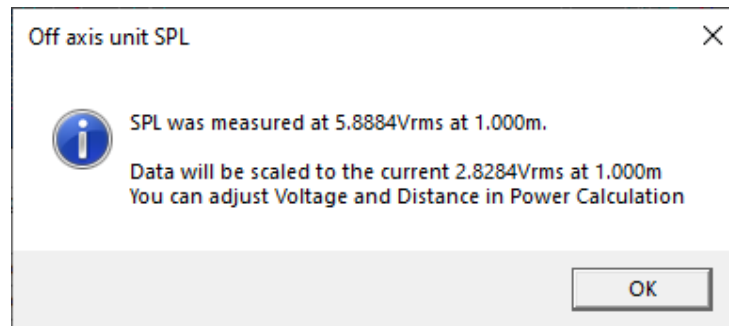


Figure 9 - Imported FINE- responses are automatically scaled to correct SPL

If the measurements come from other systems, you will get this message Fig.7, where you can set the voltage and distance used for that specific measurement.

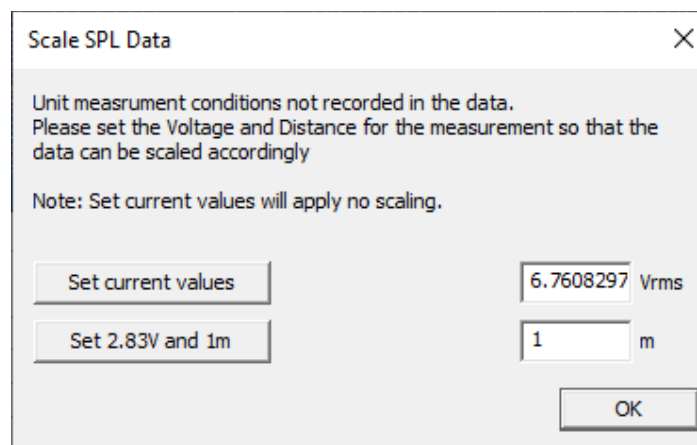


Figure 10 - Scaling of unspecified responses

## 4. Import of FSIM files from FINECone etc.

The new versions of FINE programs can both export and import responses in the new compressed FSIM format. In other words, it is possible to simulate and solve response problems without having to build any samples.

Figure 11 shows the imported woofer simulation from FINECone of a bad 165mm woofer with a big dip at 1300Hz. This dip cannot be avoided with the x-over, also because the tweeter cannot go so low without getting too high power. (>2.26W)

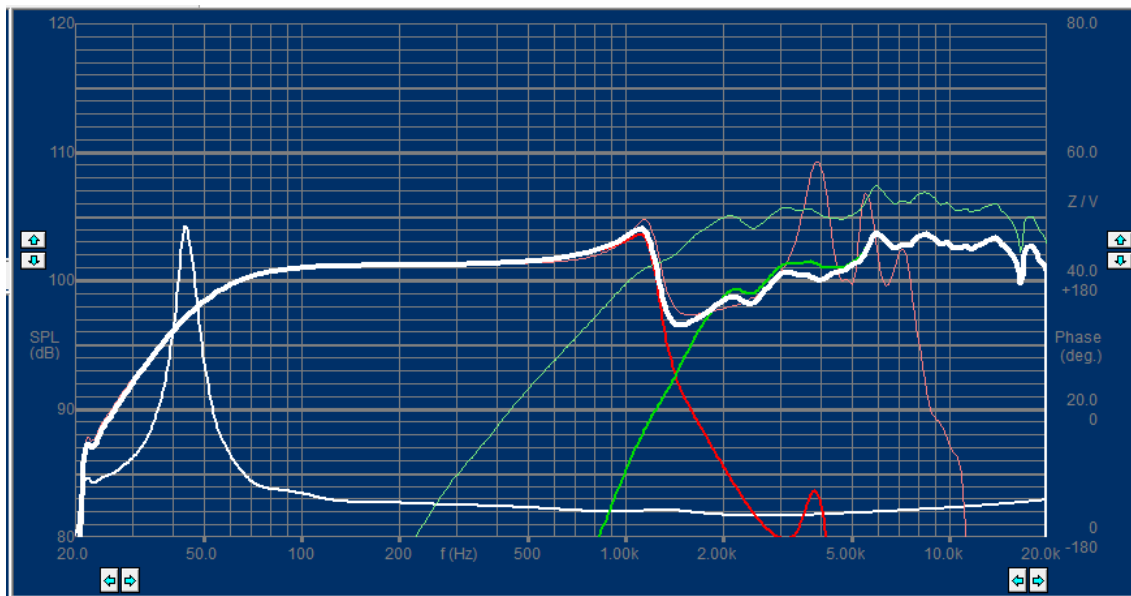


Figure 11 - FINECone 165woofer response imported into FINE X-over as FSIM

FINECone was used to simulate a solution to the bad woofer response, and the improved woofer response was imported into FINE X-over, see Figure 12. Now a good response can be achieved with a suitable X-over.

In addition, we have simulated the effect of the **Baffle** on the response by the 72.1uF//2.2 ohms in series. The cabinet front baffle will lower the response level up to the actual frequency (1004 Hz), indicated by the grey pointer. (The grey response is without baffle simulation)

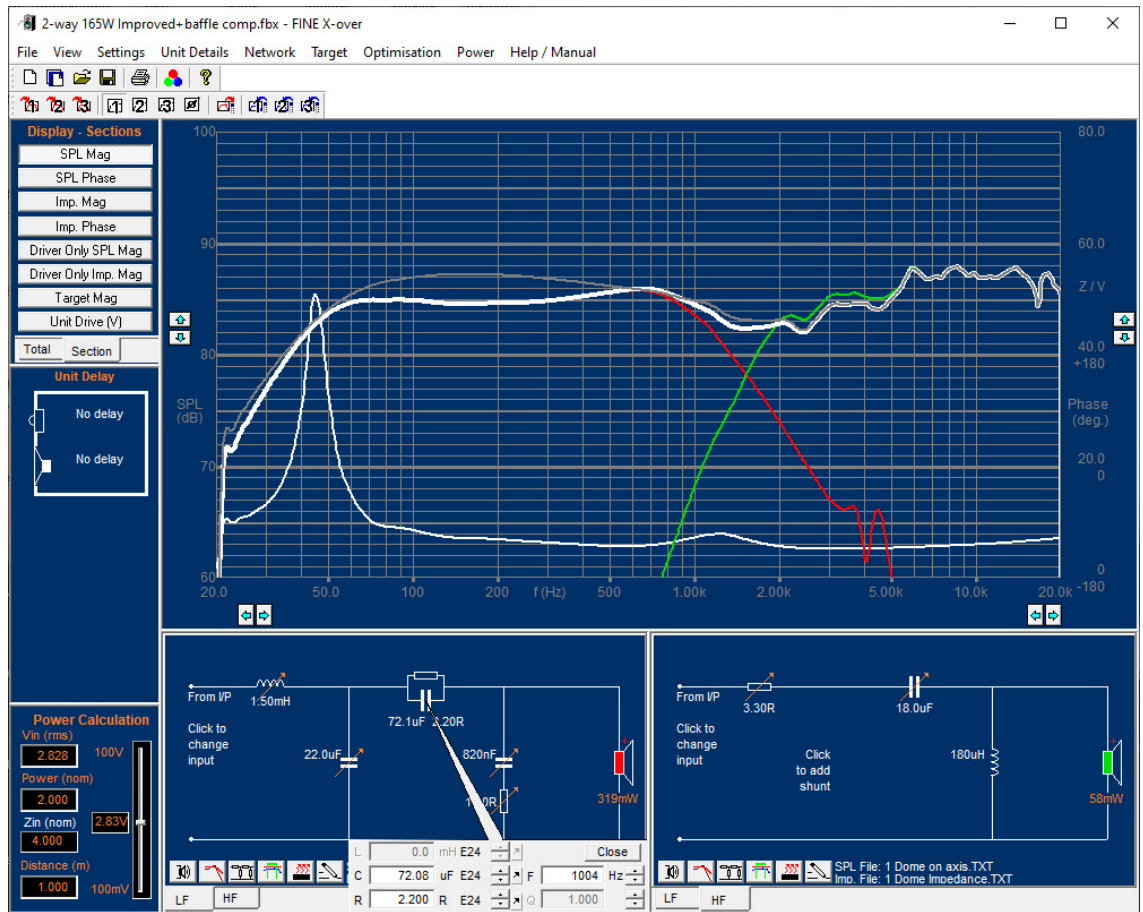
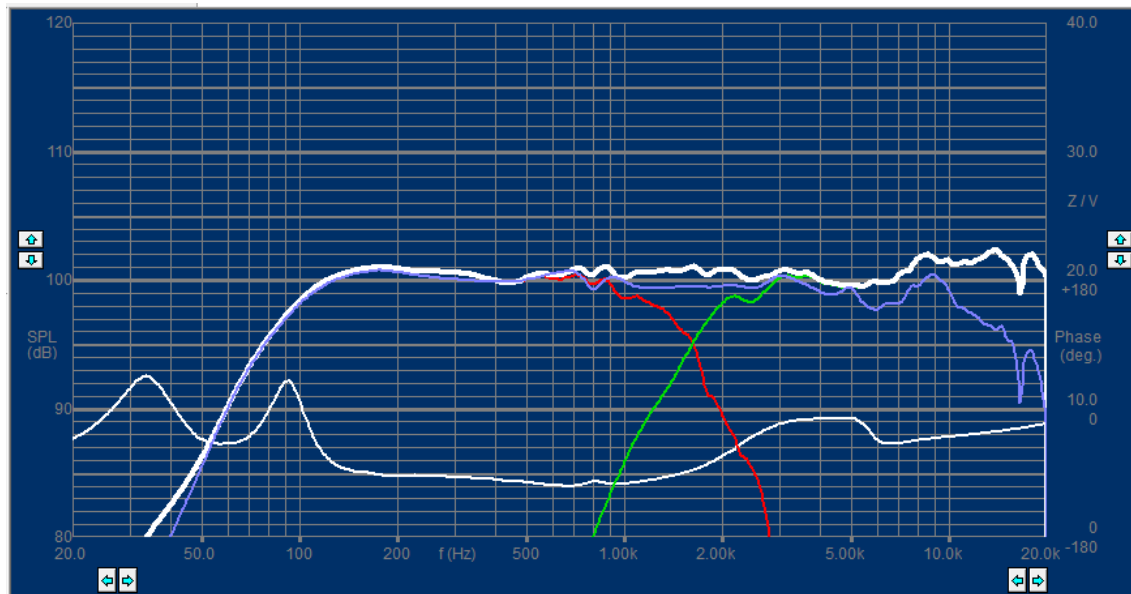


Figure 12 - Simulated solution imported from FINECone + baffle simulation



## 5. Off-axis Response / Examples

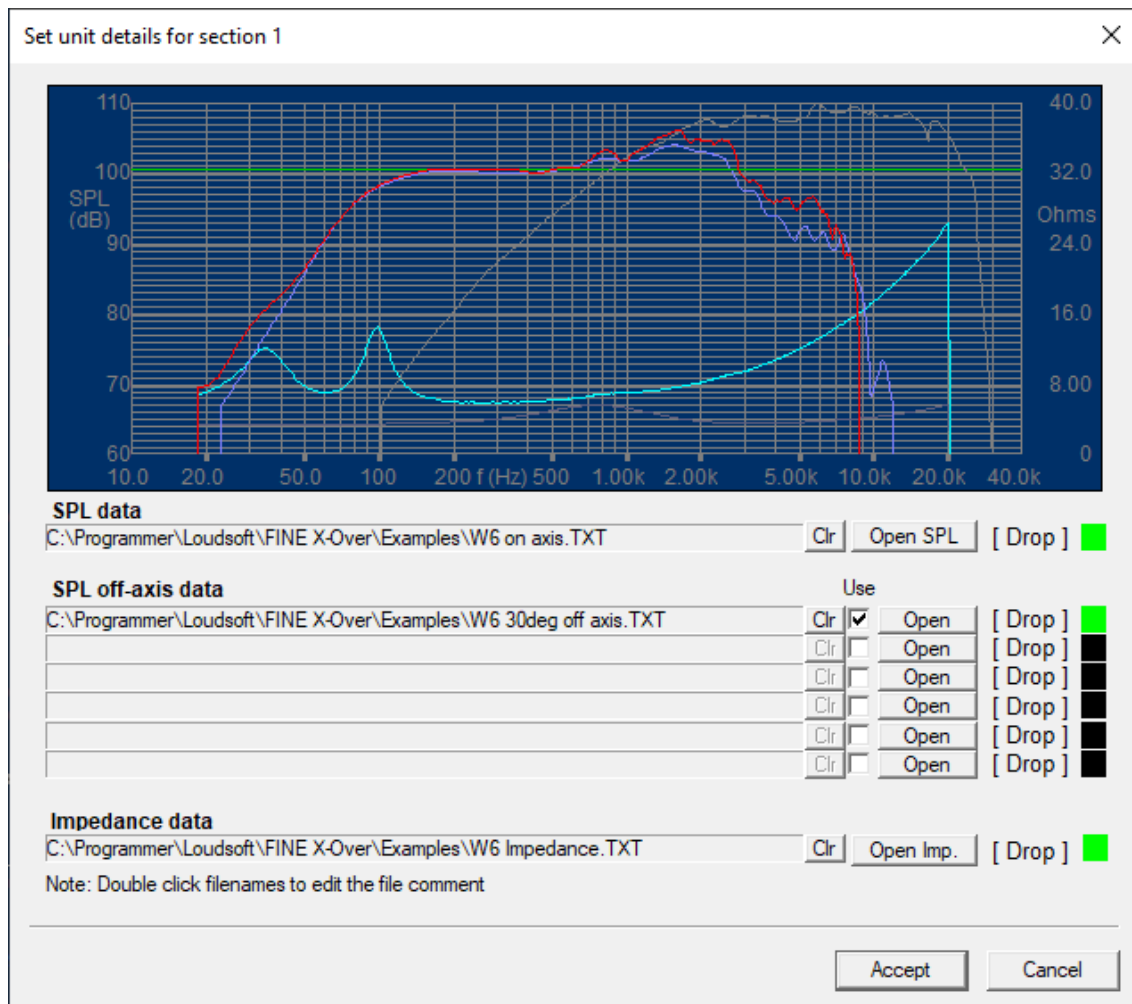
To achieve the highest quality speaker system design, it is recommended to measure and optimise both the on-axis as well as off-axis responses. That is best done using Sound Power responses from FINE R+D.



**Figure 13 - On- and off-axis curves calculated in FINE X-over**

The blue curve is the 30 degree off-axis response calculated with the same filter components as the on-axis response.

Recent research in acoustics has shown that it is most important to keep the off-axis responses smooth and controlled. Therefore, it is interesting to optimise the Sound Power while keeping the off-axis curve(s) in control. That is what we will do in the next example.



**Figure 14 - On- and off-axis curve import**

In the curve import screen, shown in Figure 14, we do a little trick and import the OFF-axis curve first and secondly the on-axis response (which is normally used for the off-axis). We may even import up to 6 off-axis responses

However, the off-axis response should not be flat as normal, but rather sloping gently downwards towards the high frequencies.

Go to the main menu and find "Target" and "System Target" in the drop-down box. Here we will modify the target to have a -0.5dB/oct slope starting at 1000 Hz, see Figure 15.

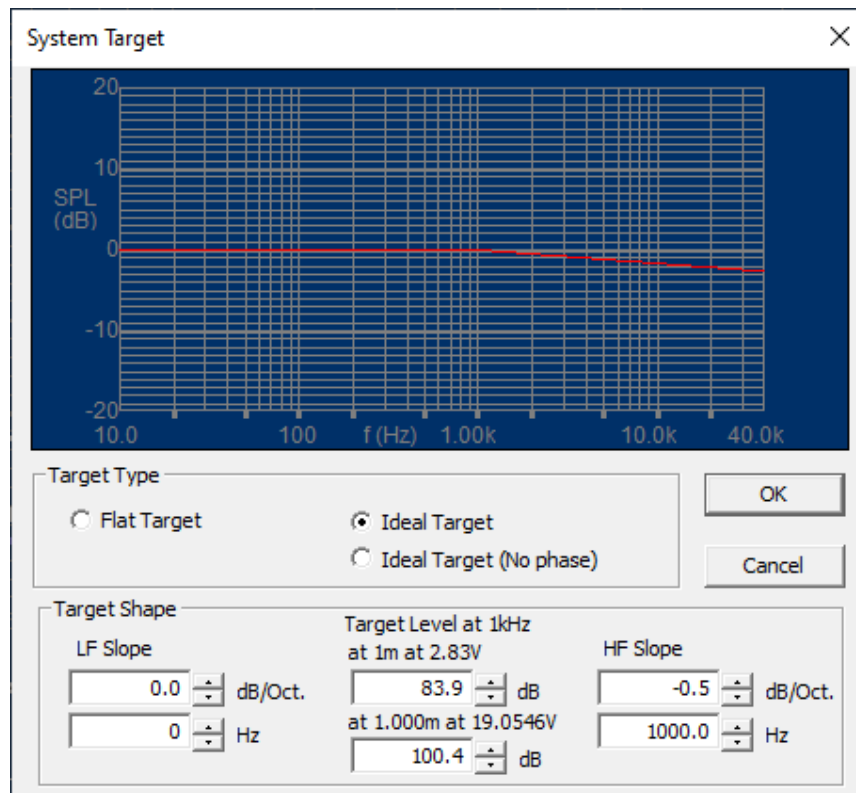


Figure 15 - Sloping Target settings

Now we can optimise the **off-axis** response to the new sloping target, see Figure 16. The off-axis response is now smooth and well-controlled

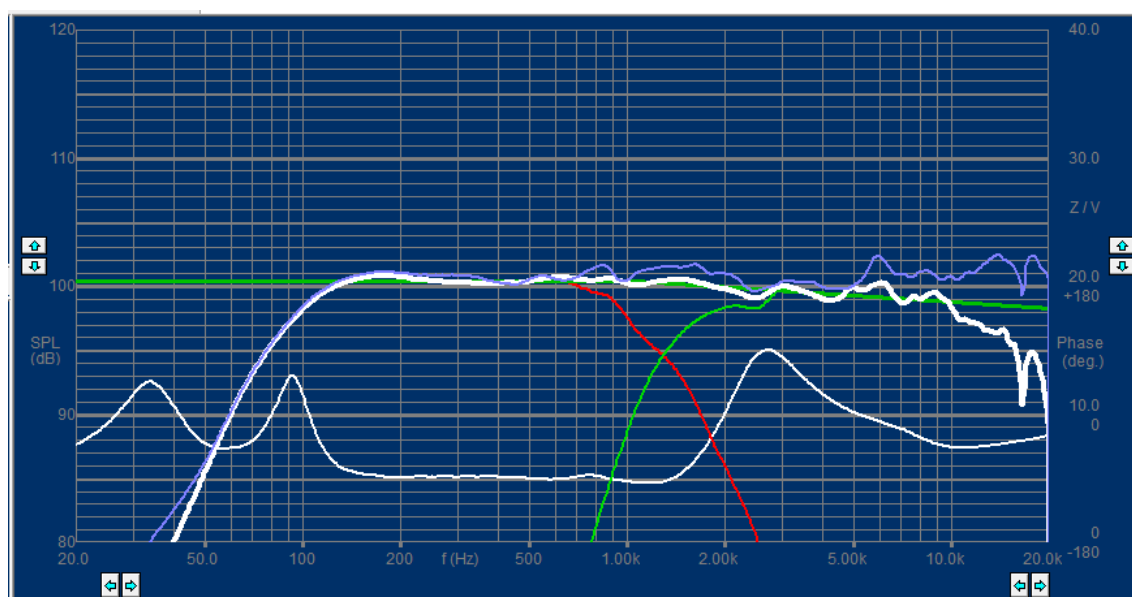


Figure 16 - X-over optimised to the sloping off-axis target

## 6. Sound Power Control

Figure 17. shows part of an optimized Sound Power curve (white). This curve was optimized for the green target response, which is gently sloping down.

At the same time the on- and off-axis response can be seen in other colours. Ideally all these responses should be smooth, and the off-axis responses should gently slope down towards the high frequencies, which is the case here. We may accept small variations on axis.

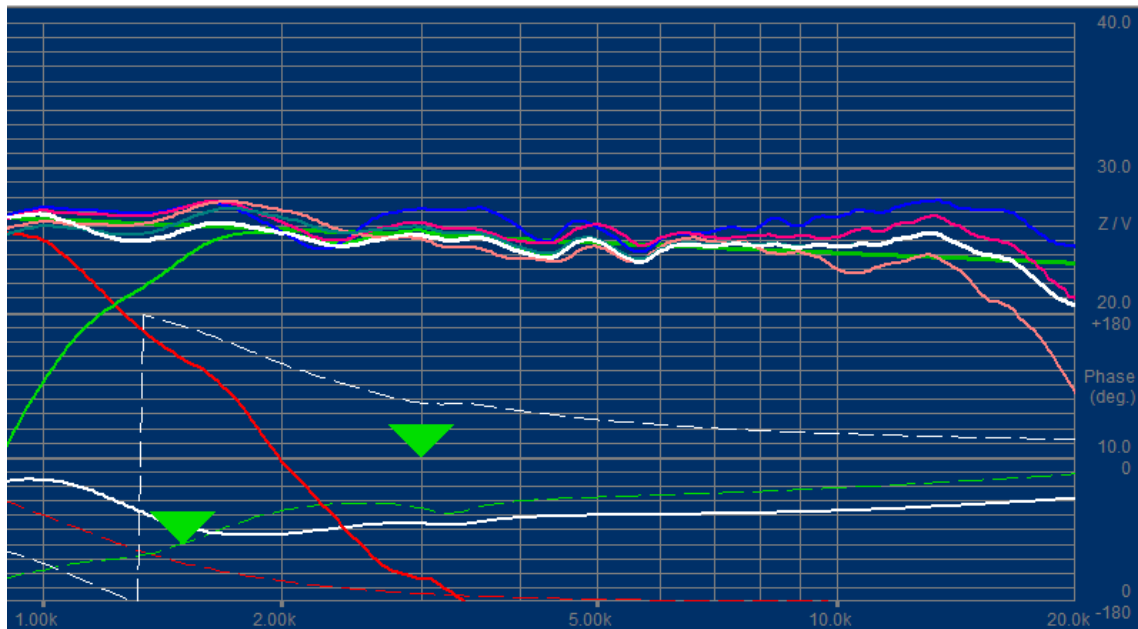


Figure 17 - Optimized Sound Power (white) + Off-axis responses

## 7.3-way X-over

In the next example we will design a more advanced 3-way x-over using the two previous drivers as midrange and tweeter and add a new driver as woofer. The new woofer is 8 ohms impedance, but the two others are 4- and 6-ohms impedance. We will therefore aim at a nominal 4 ohms impedance system. We want to design our system with minimum impedance of 3.2 ohms to protect the amplifier.

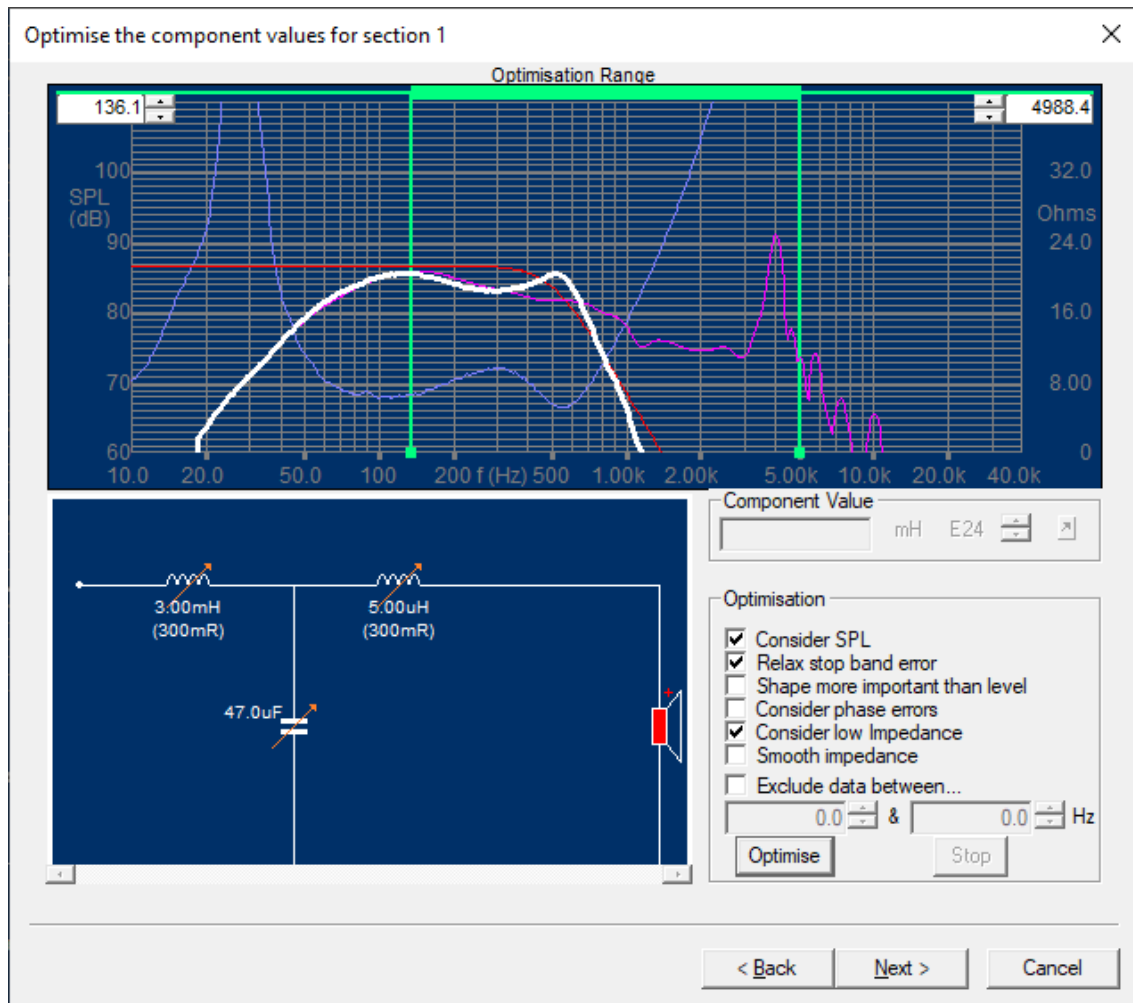
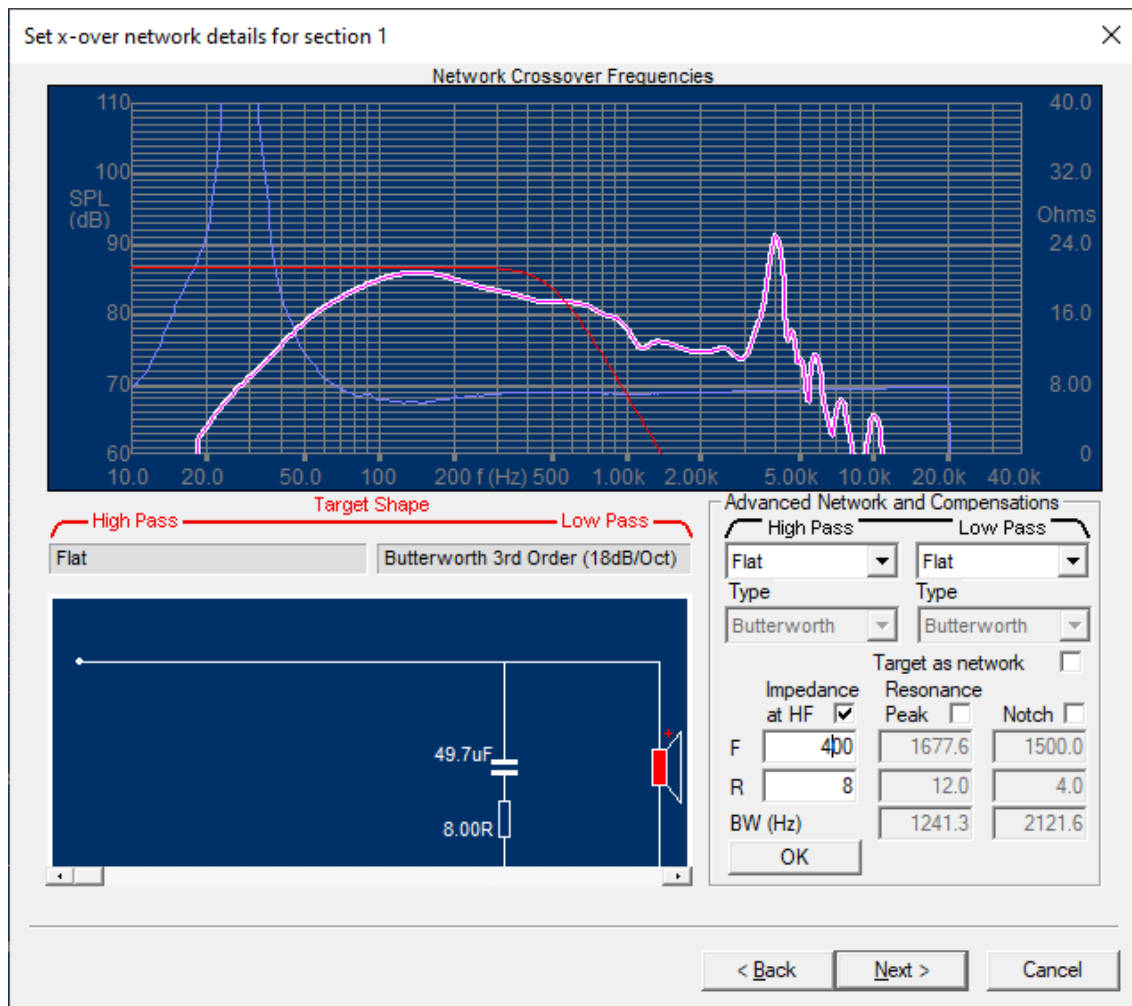


Figure 18 - Woofer response without compensation

Figure 18 shows the response (—) of the woofer (SEAS L22RN4X/P), having a downward slope and a large peak at 4 kHz. We have chosen the target SPL at 86 dB due to the lower sensitivity, and x-over frequency of 500 Hz. The optimised response with a 3<sup>rd</sup> order-18dB/oct Butterworth filter is also shown (note that we have dragged the optimisation range to include the large peak).

However, the optimised section response is far from the red target (—), and we need to do something to improve this x-over. We could select a 4<sup>th</sup> order (24dB/oct) or special x-over but let us instead investigate the cause of the bad response.



**Figure 19 - Woofer impedance compensation**

The SEAS L22RN4X/P woofer has a long voice coil and very high impedance above 500 Hz. This is the reason why the three x-over components are not effective. Luckily, we have another option, namely, to compensate for the impedance rise with a capacitor and a resistor, see Figure 19.

To view the driver impedance without x-over components, we can select a flat target (= no x-over). Press the “Advanced” button.

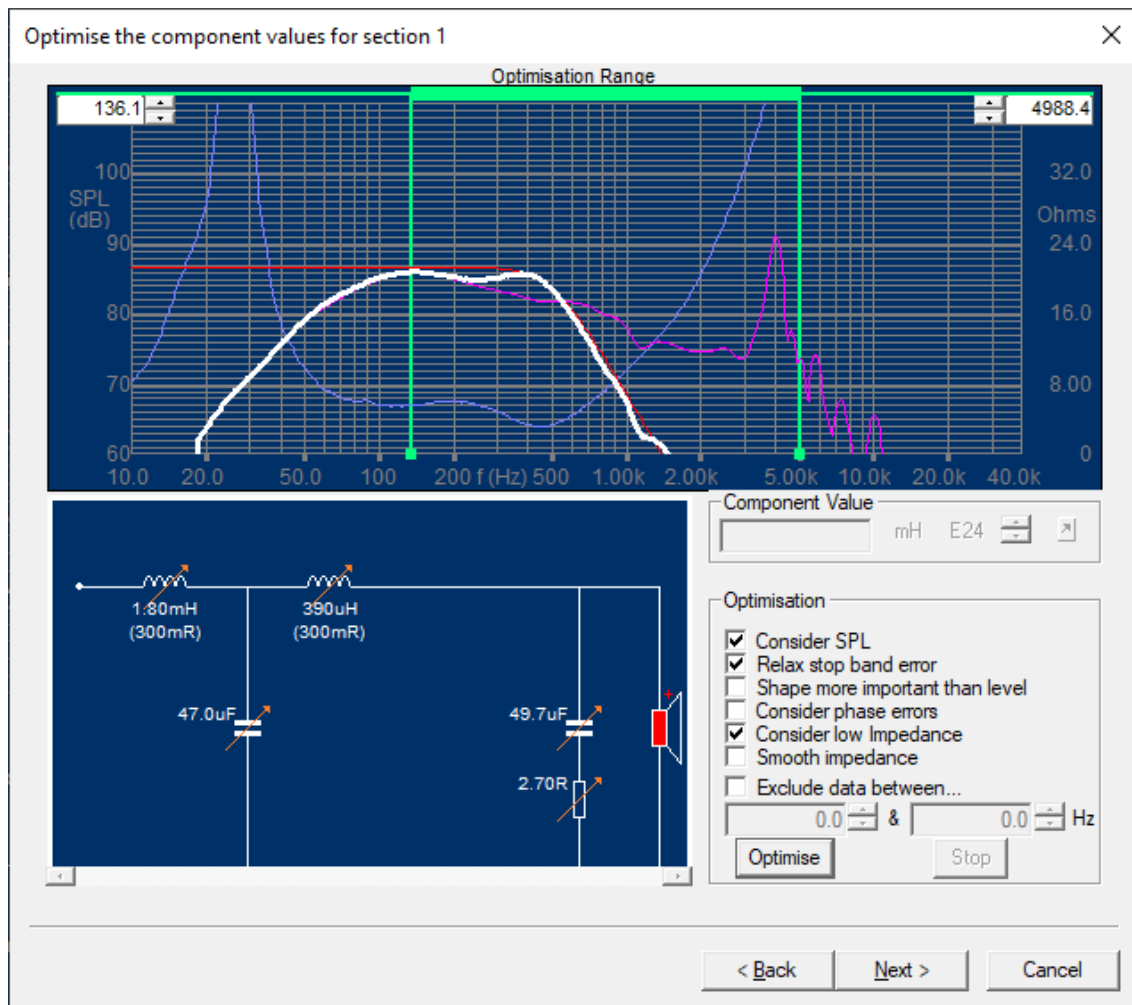
Here we can choose 3 kinds of compensations:

- 1) Impedance at HF
- 2) Resonance peak
- 3) Notch (filter)

All indicated by the small sketches. The first will compensate for the impedance rise towards high frequencies, the second will compensate for the woofer resonance  $F_s$  and the last is a tuneable notch filter.

For this application we can use both the first and last, but we have chosen the first impedance compensation, because it only needs two components. We have initially set F to 300 Hz (frequency where the imp has increased by about 3 dB), after trying a couple of other values we set R to 8 ohms and get the nice flat impedance curve, which is shown in blue (Fig. 19).

The new optimised woofer response is shown in Figure 20 and is now following the red target well while keeping above minimum impedance.



**Figure 20 - Optimised woofer section with compensation**

Moving to the next driver section, we want to use the SKO130 now as midrange. Therefore, we need to choose two x-over frequencies to form the necessary band-pass filter, see Figure 21.

The lower X-over frequency is already chosen at 500 Hz, and we select the upper above 4000 Hz to relieve the tweeter for the low frequencies.



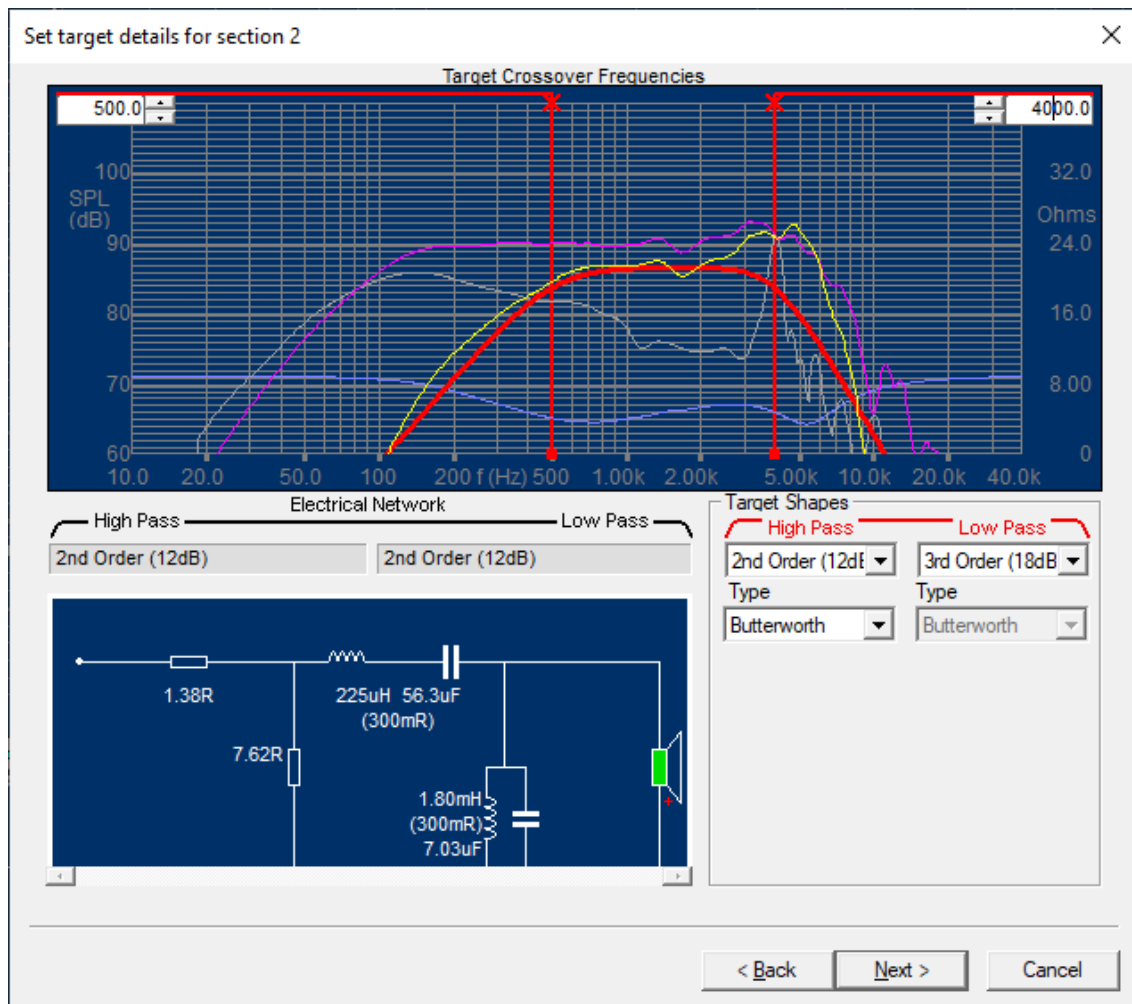


Figure 21 - Midrange variable target setup

This time the attenuator option has been selected as we need to lower the output from the more sensitive midrange to match the target SPL of the woofer (86dB). The attenuation is set to 5 dB, but this is not so important, because the optimiser will find the best setting also for the attenuator component. We also have the option to set [v] No shunt resistor, which helps keeping the minimum impedance.

Figure 21 also shows that it is possible to specify for instance a **3<sup>rd</sup> order target** with a 2<sup>nd</sup> order network because “Target as Network” has been deselected. This may be used to match the acoustical slope.

After extending the optimisation range to 6000 Hz, we get the optimised band-pass response, see Figure 22. We have used the default optimise settings, however we have deselected “Shape more important than level” to aim for the best absolute band-pass response.

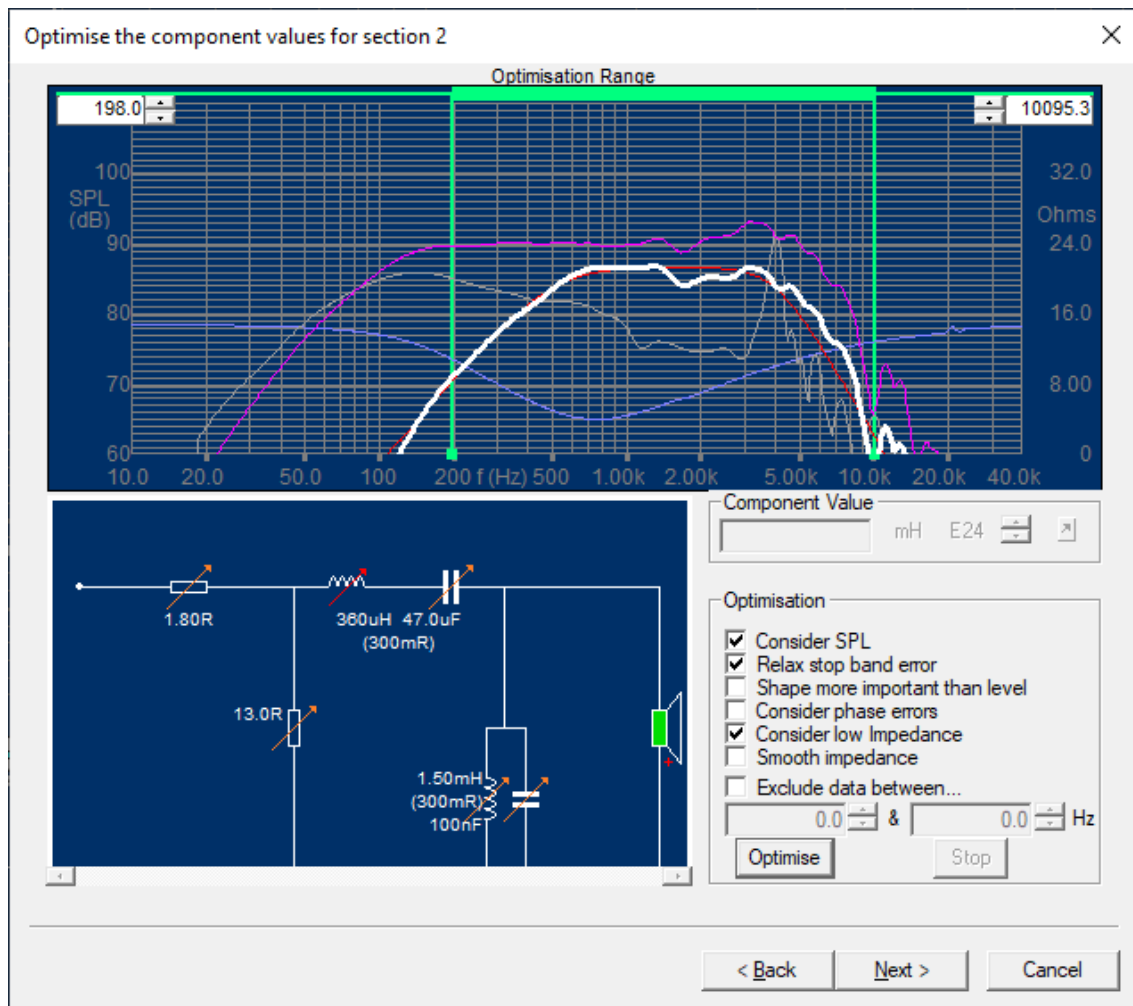


Figure 22 - Optimised band-pass for midrange

The tweeter section is optimised like the first 2-way x-over, except that we have chosen a 3<sup>rd</sup> order target. We need an attenuator like in the midrange case due to the lower sensitivity of the woofer. We use 6 dB attenuation using only one resistor and optimise without “Shape more important than level” set. The optimised tweeter section is shown in Figure 23.

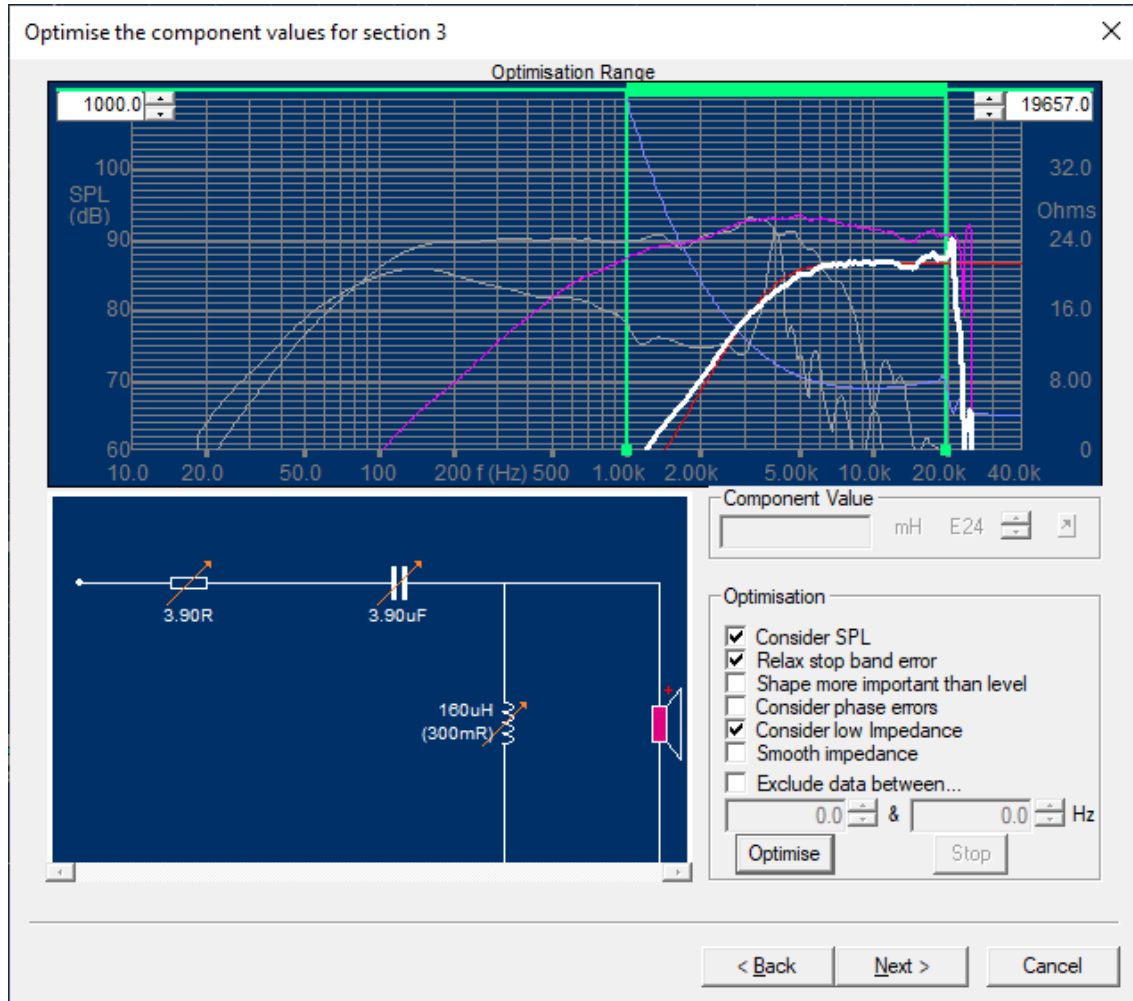
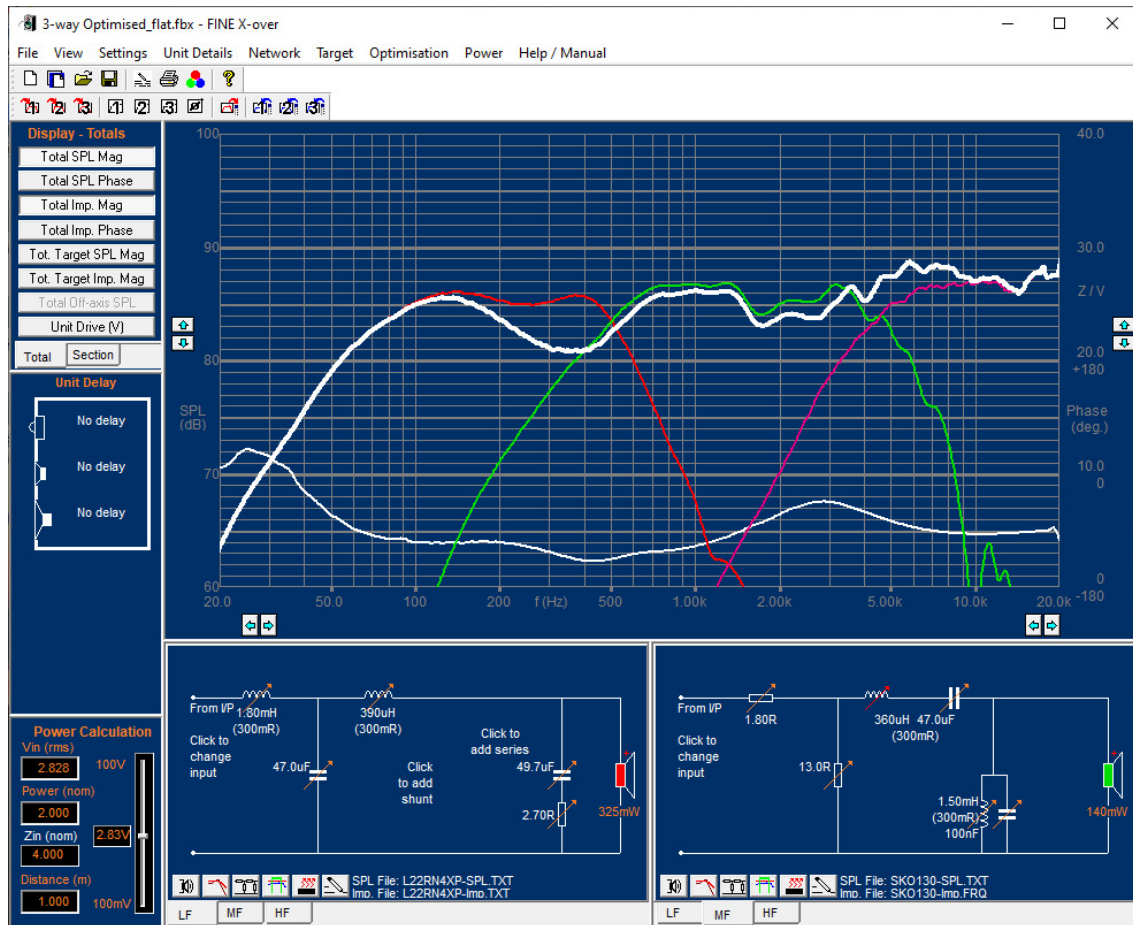


Figure 23 - Optimised tweeter section

We have now finished the Wizard and it is time to view the total response, see Figure 24.



**Figure 24 - Total system response with problem**

This response is not that good, maybe to our surprise. Optimizing the total response does not really help.

But when we check the driver responses, we see the woofer and midrange are reaching well together. The reason for the two drivers not summing together is that they are acoustically out of phase.

There are basically two ways to change the acoustical phase between drivers: A) To invert the + and - terminals or B) Move the drivers physically (delay).

## 7.1. Midrange inverted

We can easily change the electrical phase of the midrange (+ and – terminals) by clicking on the midrange driver symbol and set a mark for “Phase Invert” for the midrange, see Figure 25.



Figure 25 - Driver phase settings

The response is now without the dips, but still not flat. We may optimise the total system response at once, however there is a big risk for the optimiser to end up with a strange X-over, because there may be too many components to optimise.

Therefore, we need to guide the optimiser by selecting only few components to optimise. The rule is “better few than many”. In the 1<sup>st</sup> woofer section, we have fixed the impedance compensation circuit (capacitor + resistor across the woofer) by double-clicking to remove the red variable arrow.

The capacitor in the tweeter section was increased, to obtain a lower crossover to the tweeter. Finally, we select “System Optimisation” from 150-15 kHz with “Consider Low Impedance” checked, to get the flattest response while keeping the impedance above the minimum 3.2 ohms.

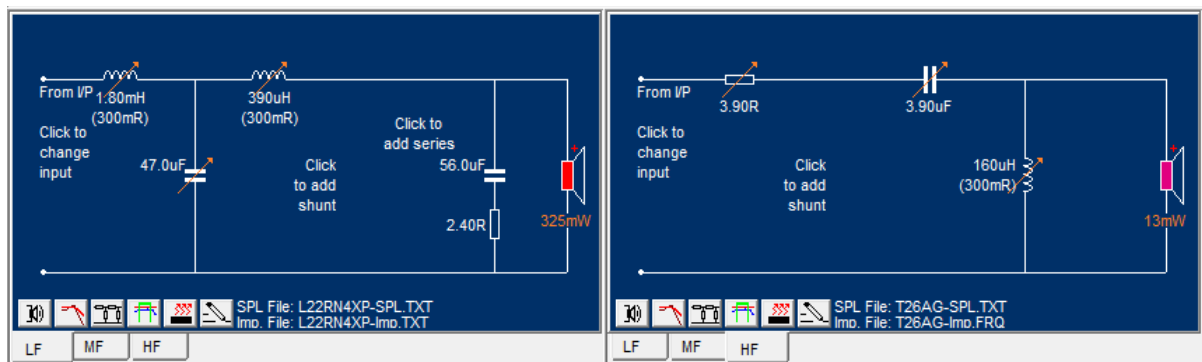
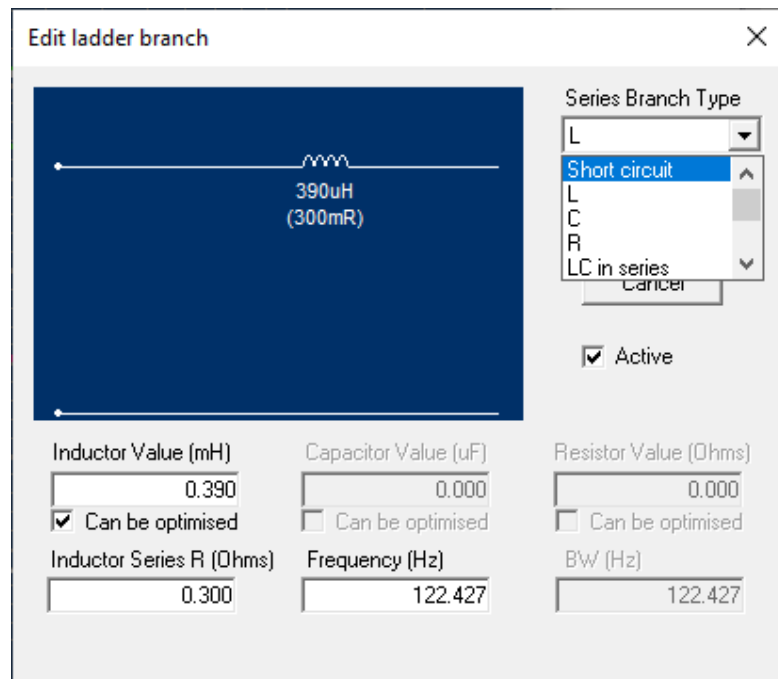


Figure 26 - Component adjustment before final optimisation

The final response is quite flat, and the total impedance is above the required minimum impedance of 3.2 Ohms (10-20000 Hz).

But here is an interesting observation: The second inductance in section 1 (woofer) is just 390uH and may be omitted. By right-clicking on the component we get a menu where we can de-activate the inductor, see Figure 27.



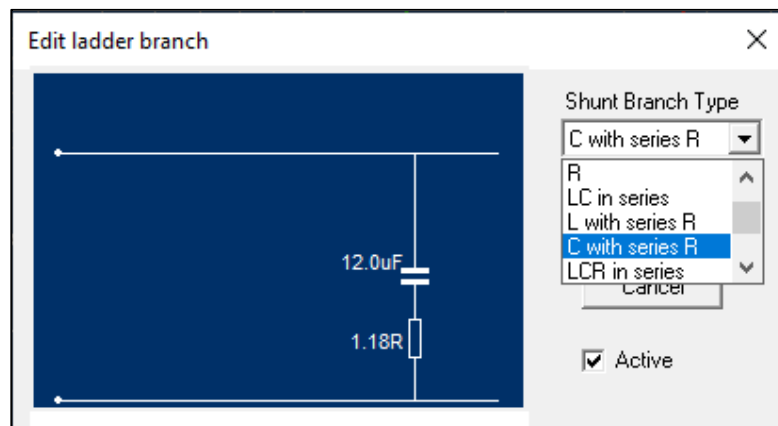
**Figure 27 - X-over component settings**

We see that the change is small, so we select “Short circuit” under “Series Branch Type” Fig.27. Likewise, we decide to omit the parallel resistors in section 2 and 3 (Mid + TW).

Interestingly we began with a 3<sup>rd</sup> order (18dB/oct) filter for the woofer but left out a component, so 2<sup>nd</sup> order (12dB/Oct) was enough.

All the above changes were done and fine-tuned in Figure 29, using System Optimisation again.

## 7.2. Capacitor Loss Resistance



**Figure 28 - Capacitor with loss resistance**

Large (Electrolytic) capacitors have loss (factors), which can be included as a resistor, see Fig. 28.

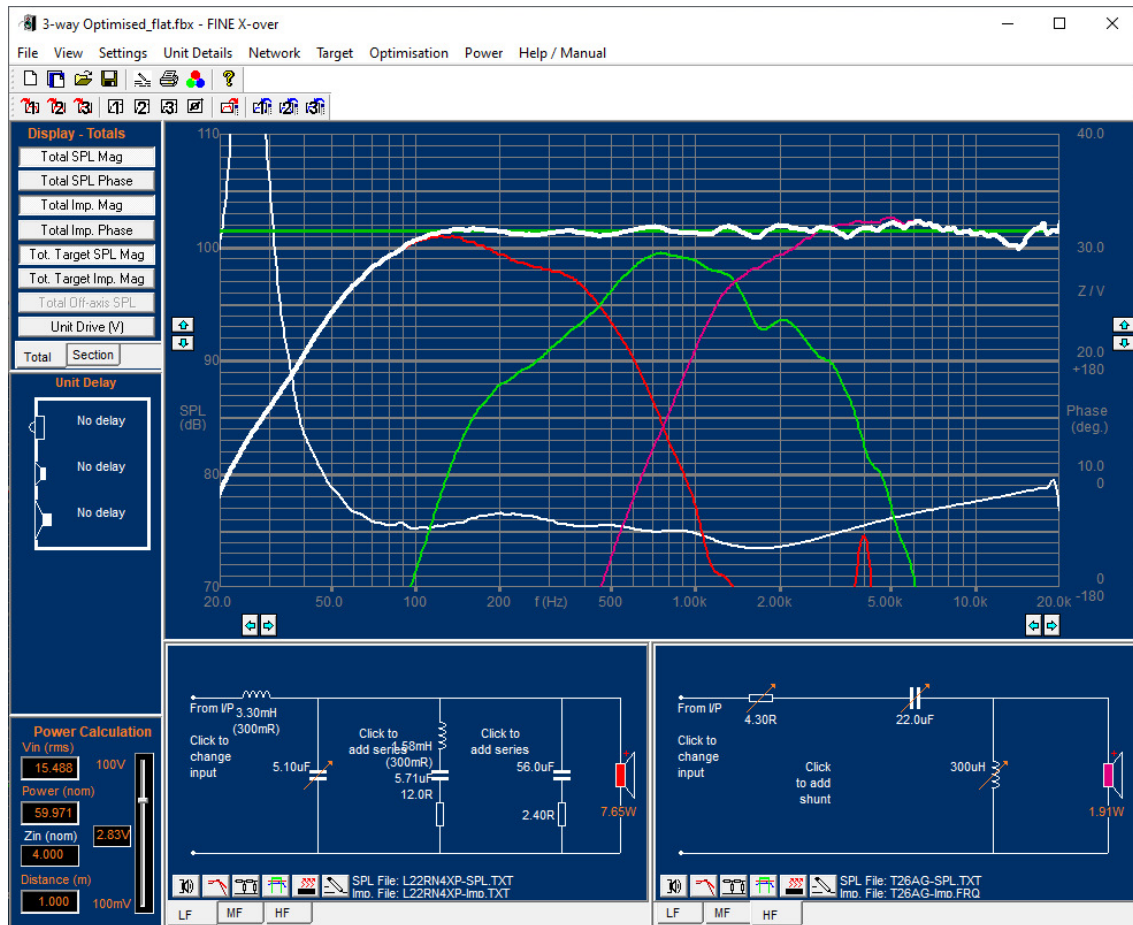


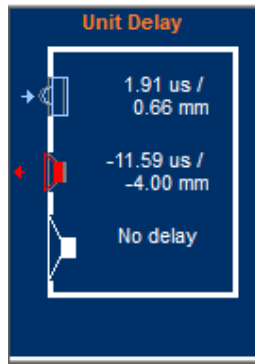
Figure 29 - Final optimised 3-way X-over

### 7.3. Midrange and Tweeter with Delay

Instead of inverting the terminal of the midrange we can simulate changes to the driver positions by introducing delay, see Figure 30. By clicking and rolling with the mouse wheel the user can simulate +/- movements of the driver recessed in or protruding from the baffle.

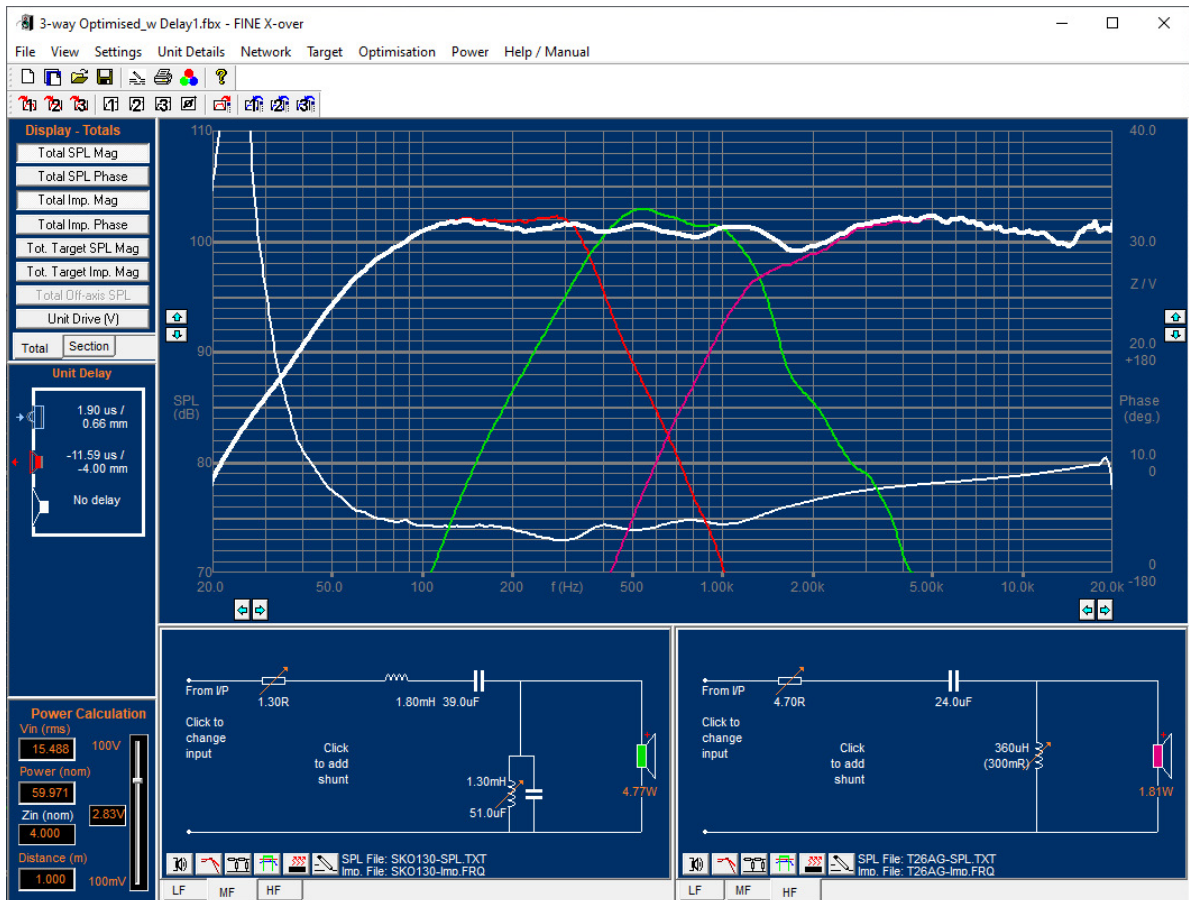
It is possible to find the best position by observing the acoustical phase of the individual drivers.





**Figure 30 - Driver delay**

The resulting response with delay and all drivers in (electrical) phase is shown in Figure 31. The driver responses are OK, and the midrange is working better.



**Figure 31 - 3-way X-over with midrange and tweeter delay**

## 8.2.5-way X-over

In a multiple woofer design the engineer often wants to have all woofers working together at low frequencies but only use one of the drivers to extend up to the midrange or tweeter.

The following example is exactly that, which we call a 2.5-way system design. We have used L22RN4XP woofer in the first section. The second woofer SKO130 input is taken from the first woofer terminals, see Figure 32, where you select the LF input by one click.

The frequency response shows that the two woofers work nicely together at low frequencies and the second (purple) woofer response extend well up to the tweeter.

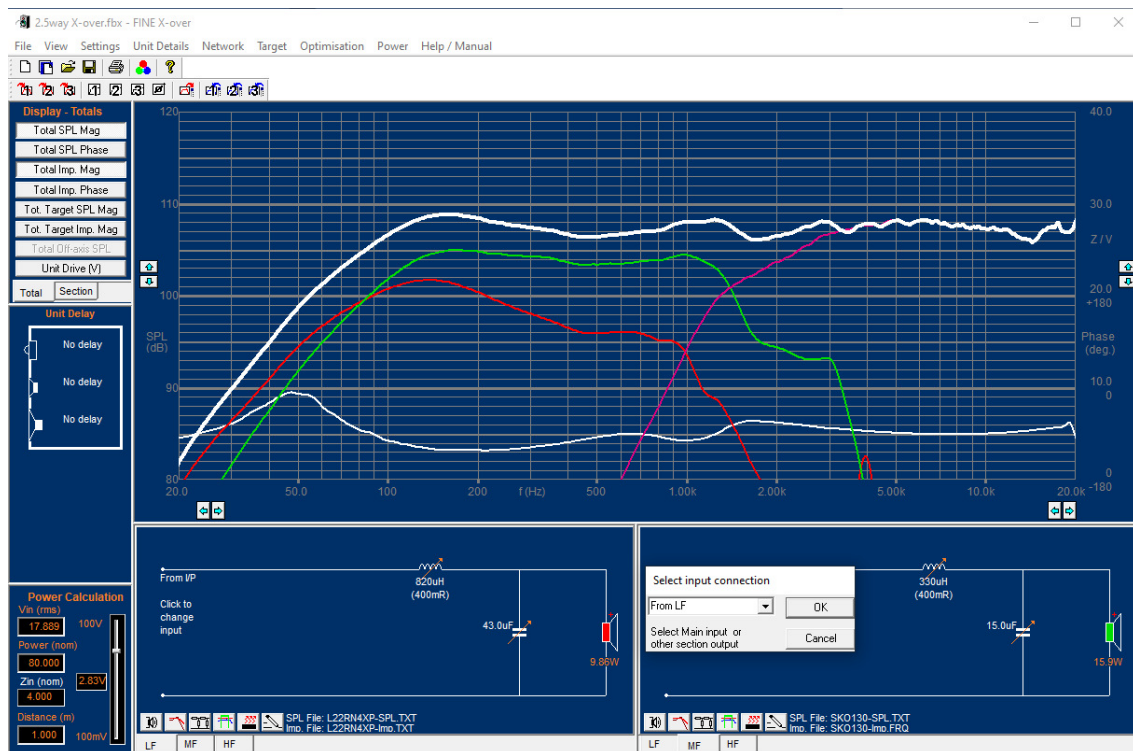



Figure 32 - 2.5-way X-over (tapped woofer)

## 9. Power in Drivers and Components

Finally, we may inspect the component and driver power in all the x-over sections. Press the button  to display the Power in section 2 (Midrange) of the 3-way X-over as shown in Figure 33.

Here is the real power calculated for the resistive components and the driver. The input is 100W (RMS) in nominal 4 ohms, with a power spectrum per IEC 60268-1, to simulate “normal” music. The power for the driver is 3.58W, which seems low. However, the impedance of the driver is higher than 4 ohms over most of the spectrum, the x-over frequency is 500 Hz, and the power is reduced due to the IEC 60268-1 spectrum.

Note that the power in the serial inductor is only 253mW, which is due to the 0.3 ohms RL.

However, the power in the attenuation resistor is 6.25W! The power in the resistors and coils can be rather high and is therefore quite important!

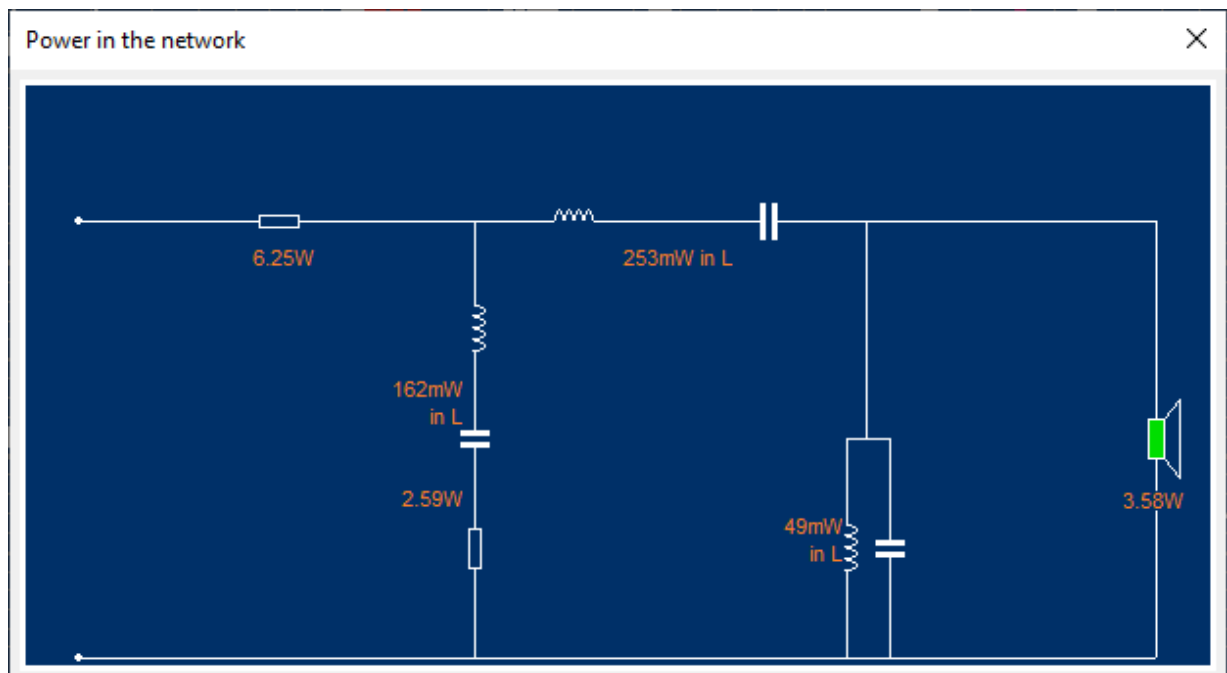
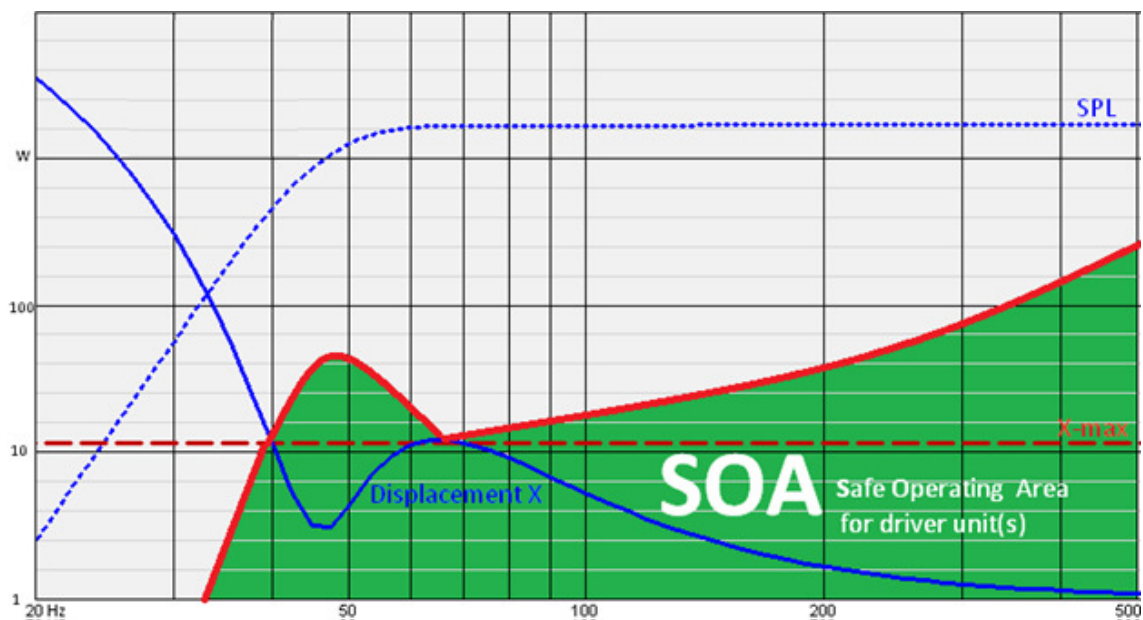


Figure 33 - Real power in 3-way (midrange shown)

## 8. Power (V, A) and Xmax in Drivers

When considering the maximum power input into the system we need to know how much each driver moves. This is called Voice Coil Displacement or Excursion, and the normal maximum is called Xmax.

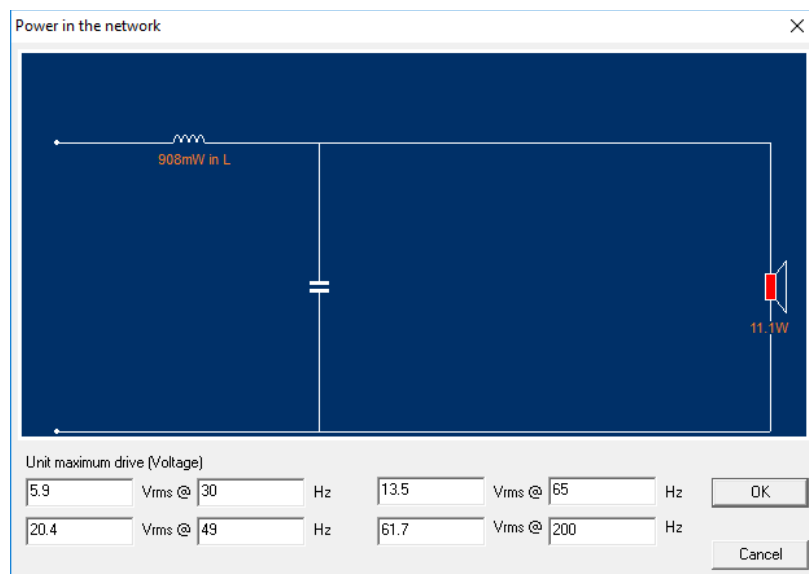
Unfortunately, the voltage to obtain Xmax for each driver depends very much on the frequency, see Figure 34.



**Figure 34- SOA (Safe Operating Area) for driver control with DSP**

Figure 34 shows the typical Voice Coil (VC) Displacement for a woofer in a bass reflex box or ABR system. The upper dotted blue curve is the bass frequency response, and the full blue curve is the typical (VC) Displacement of the woofer. Note that the Displacement is quite high at very low frequencies (<40 Hz), has a minimum around 45 Hz, shows a local maximum at 55 Hz, and decreases towards higher frequencies.

The bass reflex system was tuned to 45Hz (=Fb) in this example, which means that the woofer cone and VC is moving less at this frequency compared to 55 Hz.



**Figure 35 - Driver Voltages for getting Xmax at various frequencies**

Using the Power button, we can now input the voltage giving Xmax at various frequencies, see Figure 34.

Pressing the Unit Drive (V) button will display the red and green arrows, indicating the maximum voltages for getting Xmax. The voltage scale is shown at right in Figure 35, which also shows the optimized Sound Power response (white), as well as the corresponding off-axis curves.

The total input was set as 45W at the lower left. The dashed red and green curves are the voltages over the terminals for woofer and tweeter. The voltages are below the arrows, except at 30Hz, which may be OK considering that most music has less power content below 50 Hz.

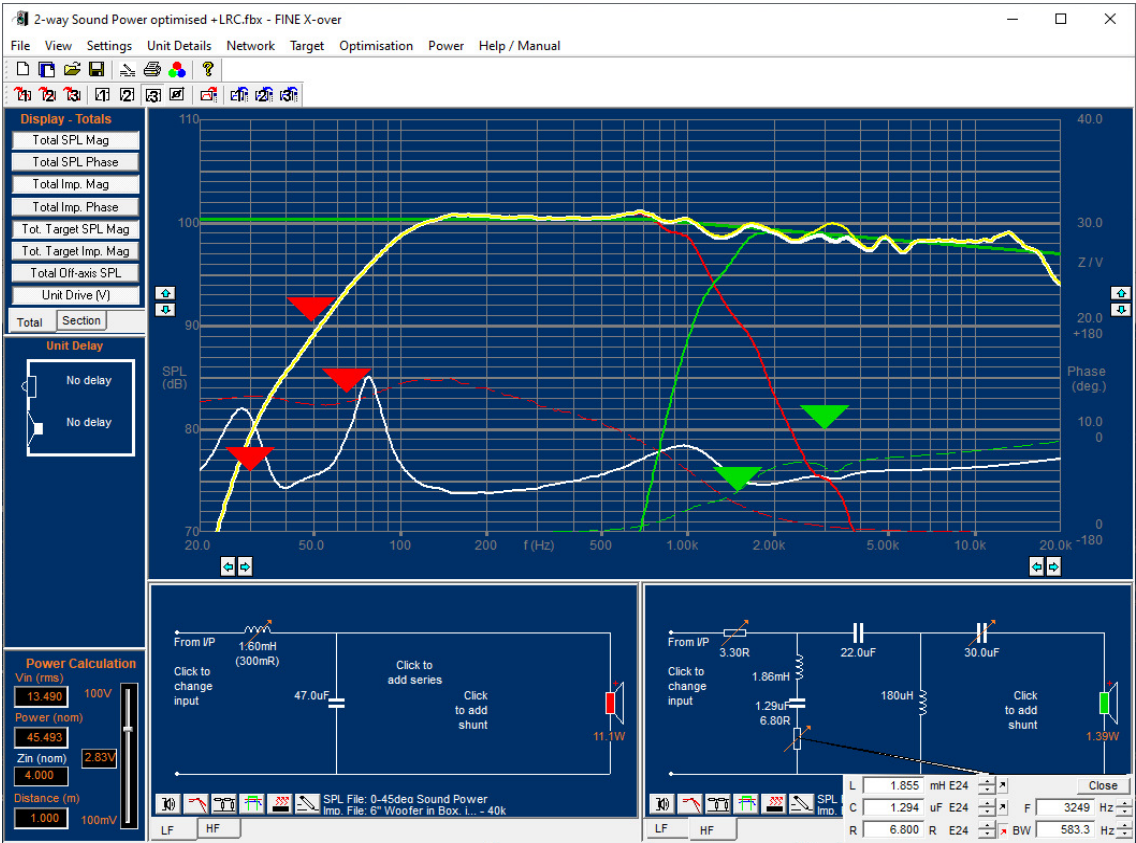


Figure 36 - 2-way Speaker Sound Power optimized + Xmax Voltages

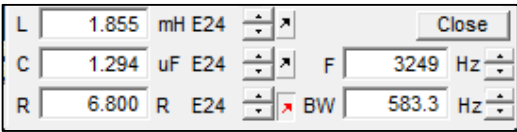


Figure 37 - Tuning of RLC series circuit using Bandwidth (BW) control in HF section

## 9. RLC series Tuning

Fig. 36 shows the tuning parameters of the RLC circuit for the tweeter. Now you can tune both frequency, level using R, and Bandwidth BW. This is a quite powerful feature for minimising peaks. By applying thin wire of the inductor, most of the series resistance can be included in L.

Parallel RLC circuits are also possible from the drop-down menu.

## 10. Printing

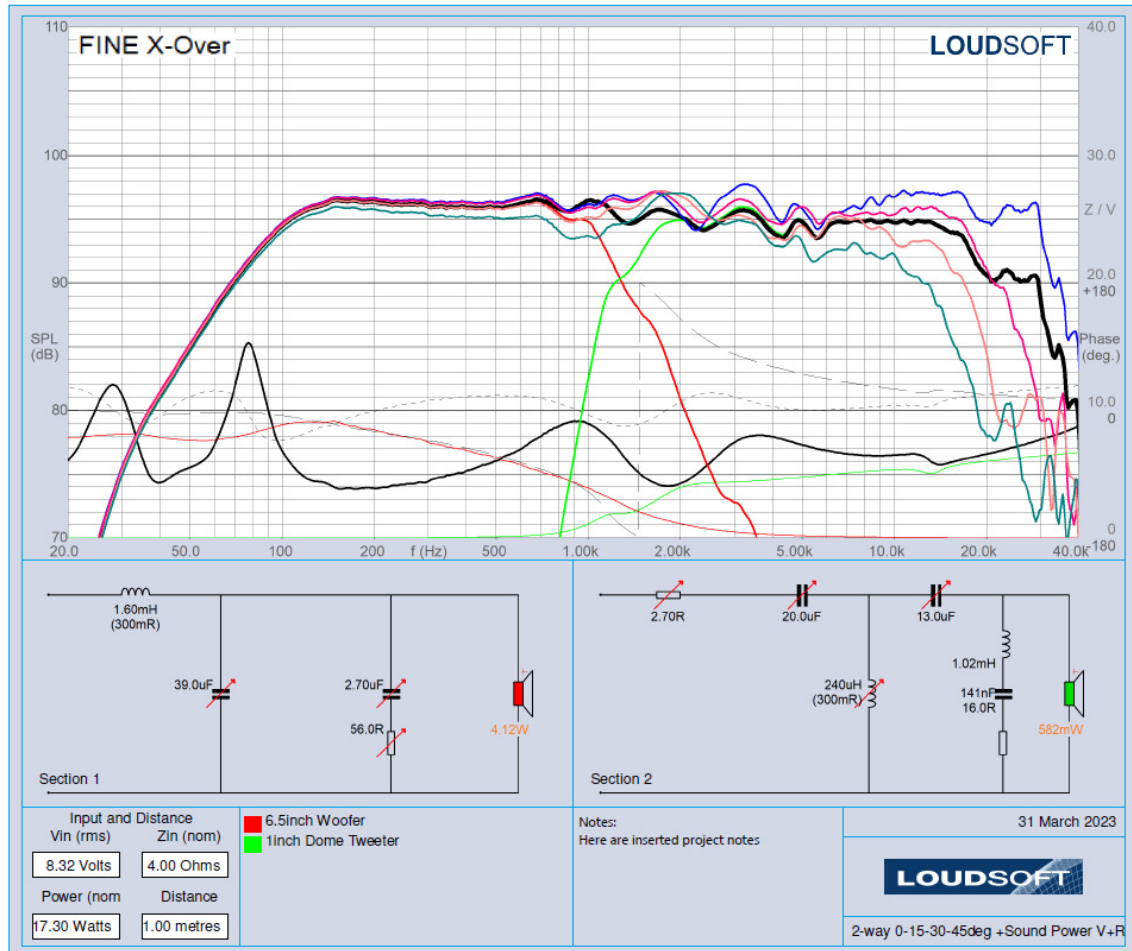


Figure 38 - Print. Section 3-4 on 2nd page

You can insert notes including the sections, and they will be shown in the print. You may also print to PDF, to send measurements to customers etc.

## 11. Cursor

Click anywhere on the main curve (White) and the cursor is shown for that frequency point, see figure below:

Right-click to enable the relative cursor from the point where you clicked. Right-click to go back (ABS).

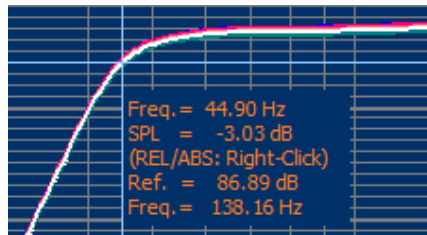


Figure 39 - Cursor by click. Relative by Right-Click

## 12. Buttons and Settings

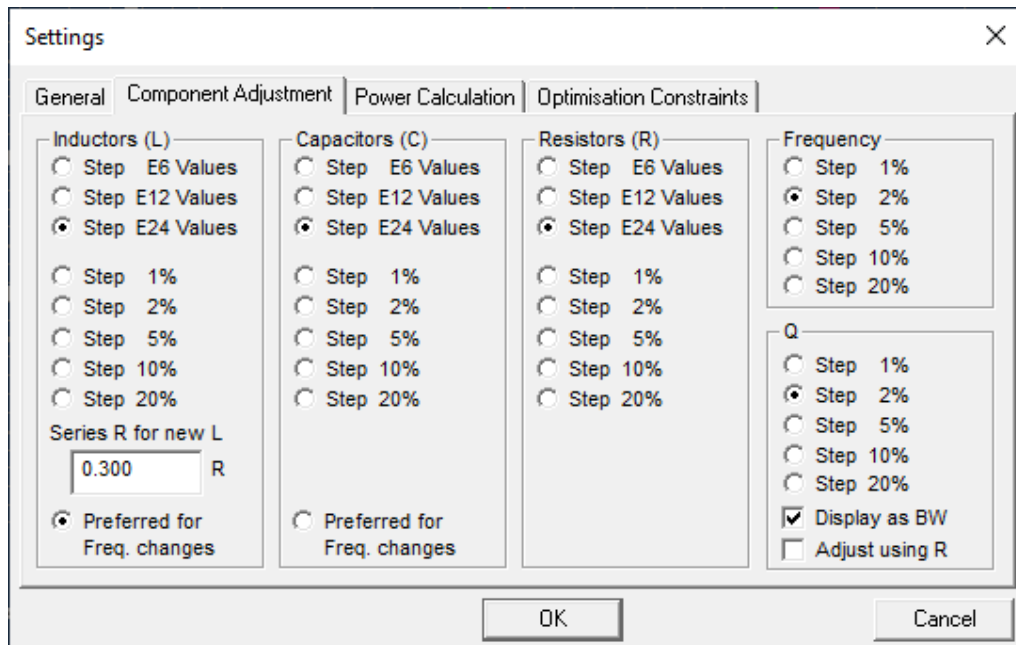


The above section buttons provide fast access to:

1. Response Input
2. Target
3. Network
4. Optimise
5. Power Analysis

Finally, we may go into “Settings” to enter the tab: Component Adjustments, see Figure 40. Here we can set which range of standard components we want. First was used the E24 range, which is the most accurate. Selecting E12 or maybe 5% will use less accurate and therefore less expensive components. However new simulations may be necessary to optimise for the best response.

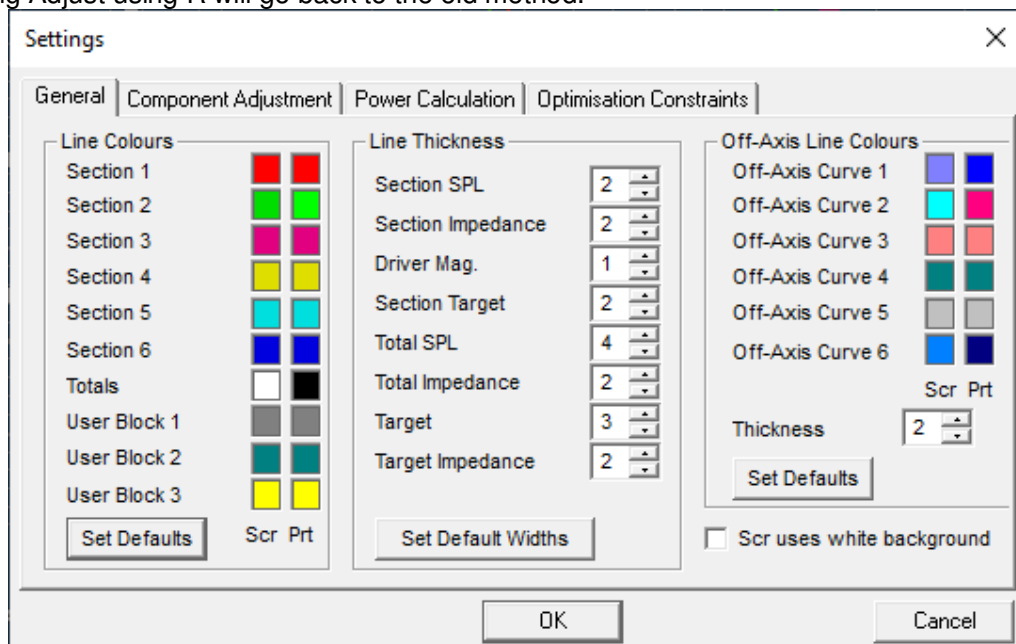




**Figure 40 - Component adjustment settings**

Regarding tuning of series RLC circuits the new default is tuning by bandwidth, see Fig. 38 and Fig.36. This allows you to adjust the bandwidth independent of the level and frequency.

Selecting Adjust using R will go back to the old method.



**Figure 41 - Colour settings. Select white background (Scr uses white background)**

## 13. Optimization Constraints

The screenshot shows a software window titled "Settings" with a close button (X) in the top right corner. It has four tabs: "General", "Component Adjustment", "Power Calculation", and "Optimisation Constraints". The "Optimisation Constraints" tab is selected. Inside this tab, there are three columns for different component types: "Inductors (L)", "Capacitors (C)", and "Resistors (R)". Each column has a "Constrain" checkbox which is checked. Below each checkbox are two input fields: "Max" and "Min", followed by a unit label. For Inductors (L), the units are "mH". For Capacitors (C), the units are "uF". For Resistors (R), the units are "R". To the right of these columns is a "Set Defaults" button. At the bottom of the dialog are "OK" and "Cancel" buttons.

Component Type	Constrain	Max Value	Max Unit	Min Value	Min Unit
Inductors (L)	<input checked="" type="checkbox"/>	200.0	mH	0.005000	mH
Capacitors (C)	<input checked="" type="checkbox"/>	2000	uF	0.10000	uF
Resistors (R)	<input checked="" type="checkbox"/>	10000	R	0.05000	R

**Figure 42 - Component Constraints / Limits**

The maximum component values for optimisation are defined in Fig. 41. Having limited ranges makes the optimizer faster.

