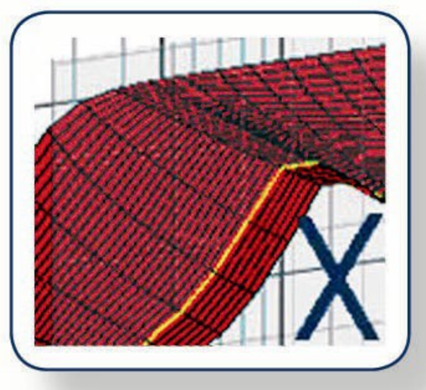
# Manual

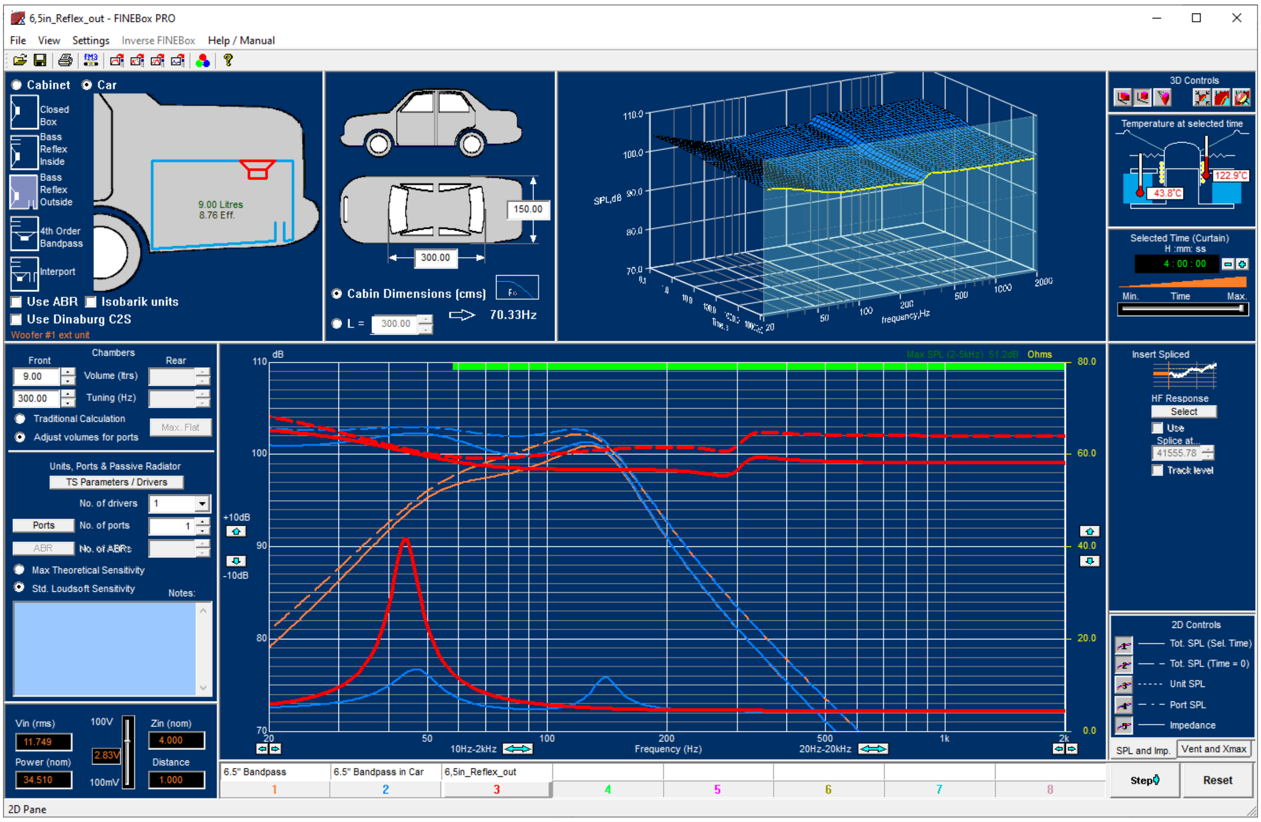


# FINEBox PRO™/ Automotive

## & Inverse FINEBox

**Non-Linear High-Power Box Design Program**
**For Hi-Fi, PRO, Car and Micro loudspeakers**

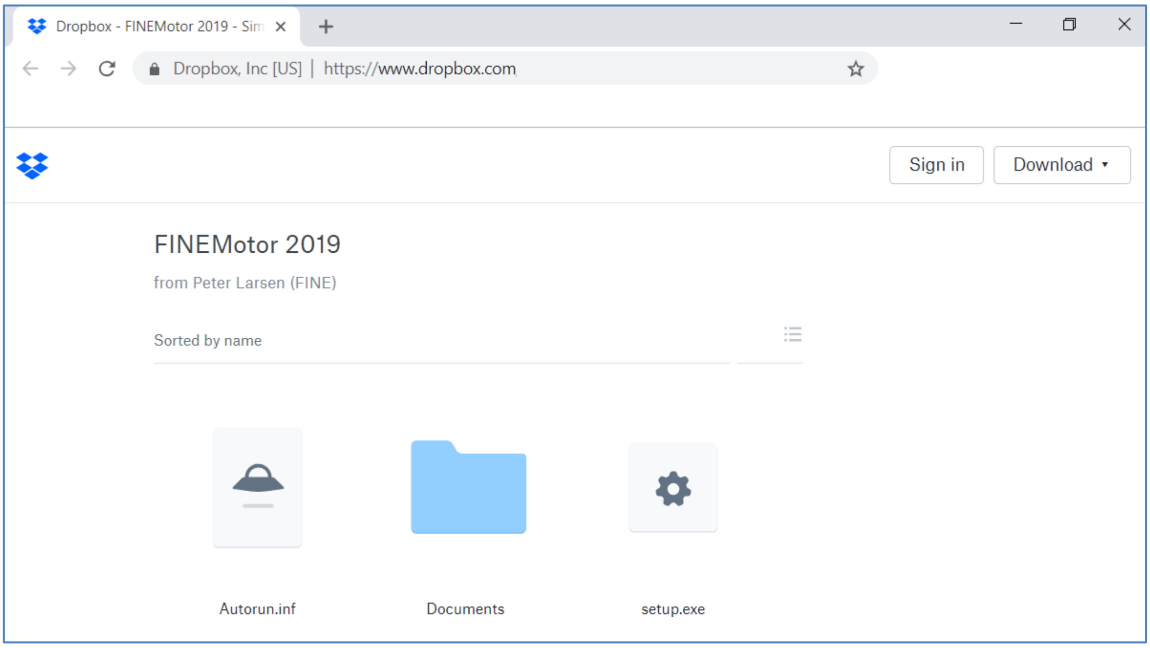
# Contents



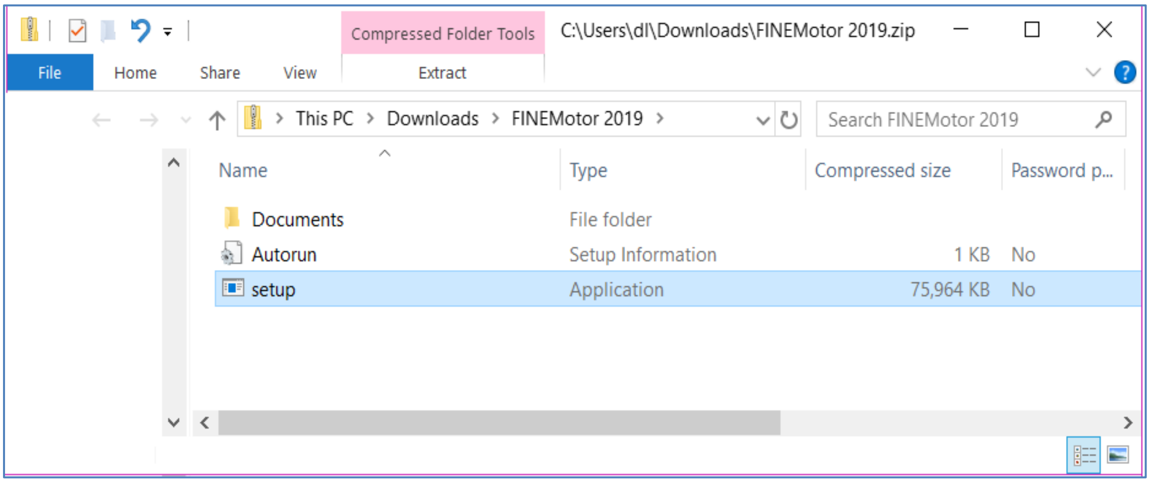

# 1. How to install the LOUDSOFT programs from a link

**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.**

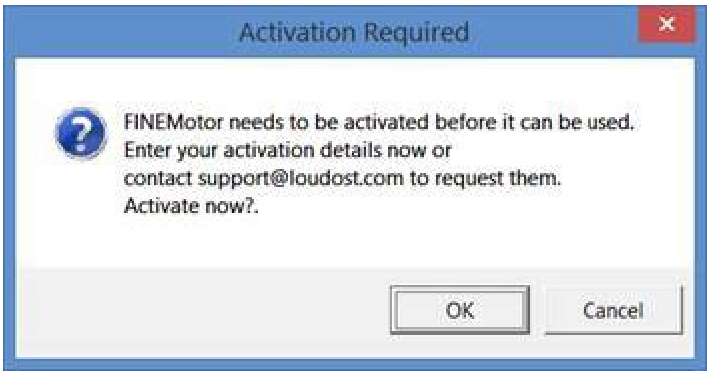
- When you click on the license link, you must download the program. Click on “Download” at the top right corner of your screen. Make sure to save it, you might need it later. We change the links from time to time for security.




- 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 must activate at once. (If you do it later, you must be Administrator of the PC AND Run as Administrator. Only then you can activate).
- 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 PPPPPPPP

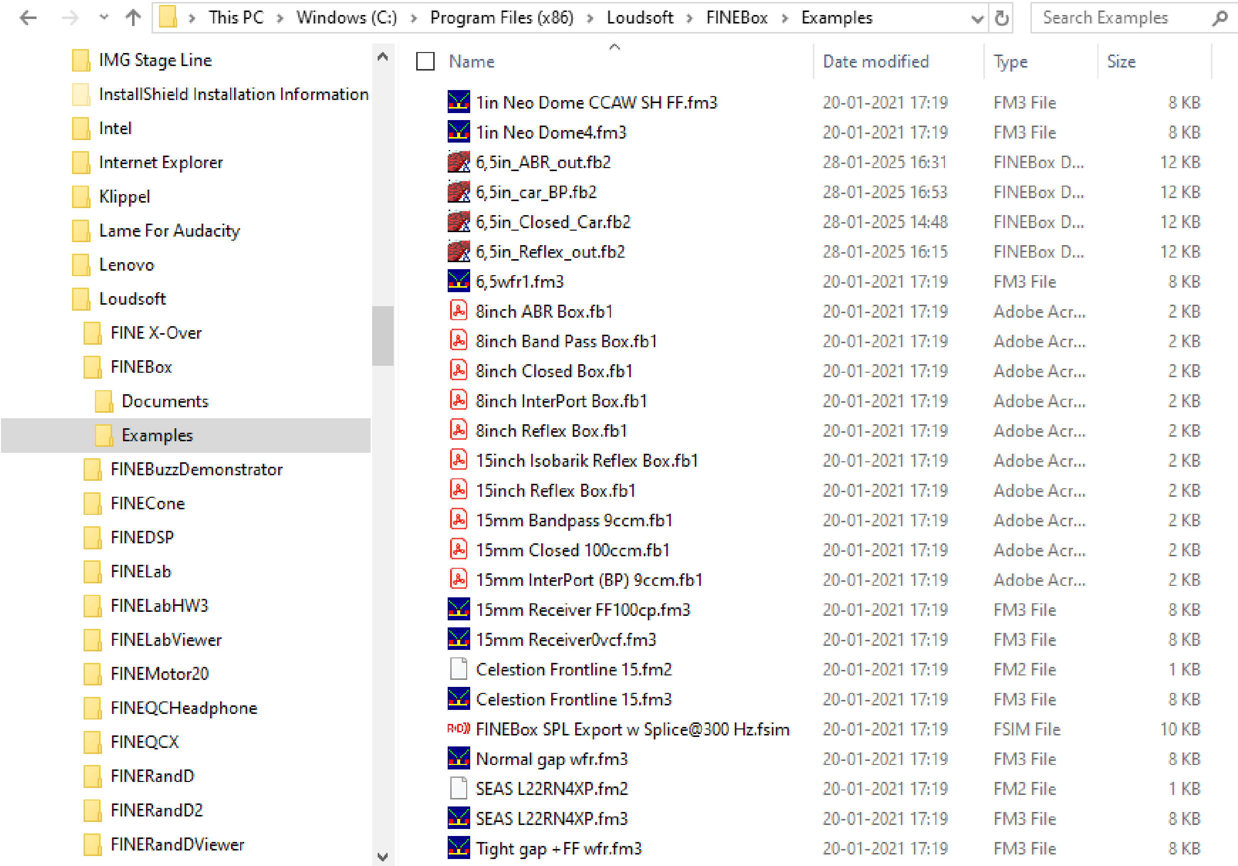

- Click OK. It is all done!

# 2. Example Files

You can find the example files here:

**C:\Program Files (x86)\Loudsoft\FINEBox**

You will find the FINEBox Fb1 examples mentioned in the manual, as well as some example files from FINEMotor (FM2, FM3) and one example of exported SPL from FINEBox (FSIM).




# 3. Direct TS parameter input

From this version you can directly input and save individual driver (TS) parameters (for example from Klippel). However, **you can also now calculate the High-Power Thermal calculations directly (without needing input from FINEMotor).**

The most accurate is still importing FM3 files from FINEMotor because all the mechanical dimensions are precisely known. FM3 files are also now imported from Radial motors made in FINEMotor.

*Note that Imported FM3 files are now using the real Xmax (based on min 82% BL)*

Press the button: TS Parameters / Drivers

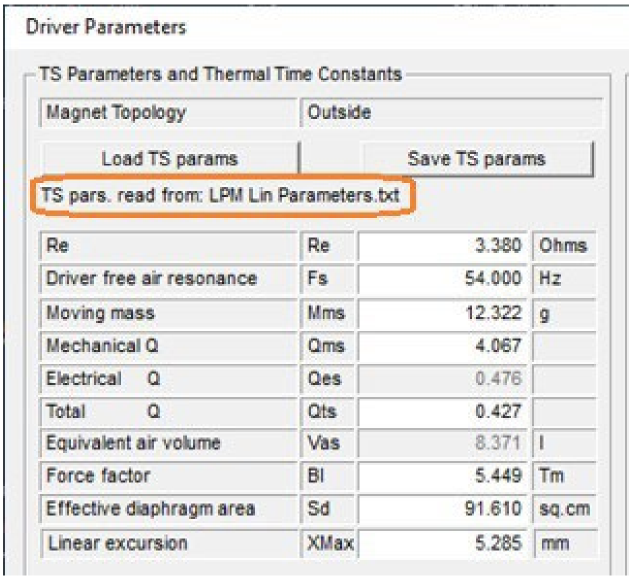



**Figure 1 – Direct input of TS parameters**

The TS parameters are shown in Fig. 1. Here you can change the TS parameters one by one and see the change in the box response as soon as you press OK.

For example, you can freely change Qts and view the change of the response in the box, see Fig. 3. Or if you want to see the effect of higher BL, you can watch Qts change and observe the response changes.

You can also save / export the TS parameters as a txt file for later use.

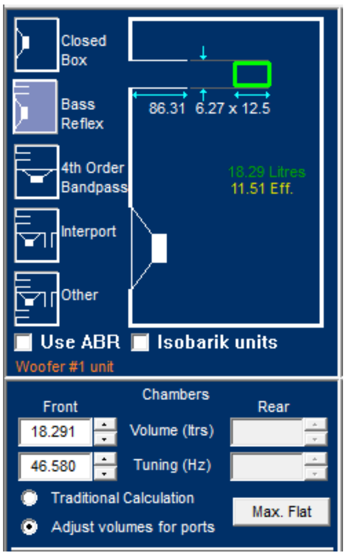



**Figure 2 - Bass reflex box, adjusted for Port volume**

The Bass reflex box volume may be adjusted for the port volume, see Figure 2. This is especially important for small boxes where the port can take up a considerable part of the available volume! The bass reflex tuning is using the adjusted volume (shown in yellow) in this mode, which saves time and is much more accurate. A message in red is shown if the volume is not big enough for the chosen port.

## 4. Max Flat Response

Pressing the Max Flat button will display the best flat bass reflex response for a given driver, by selecting box volume (Vb and tuning Fb). Fig. 3 shows Max Flat responses for the same driver, modified with different Qts. The Max Flat responses are best for Qts<=0.5

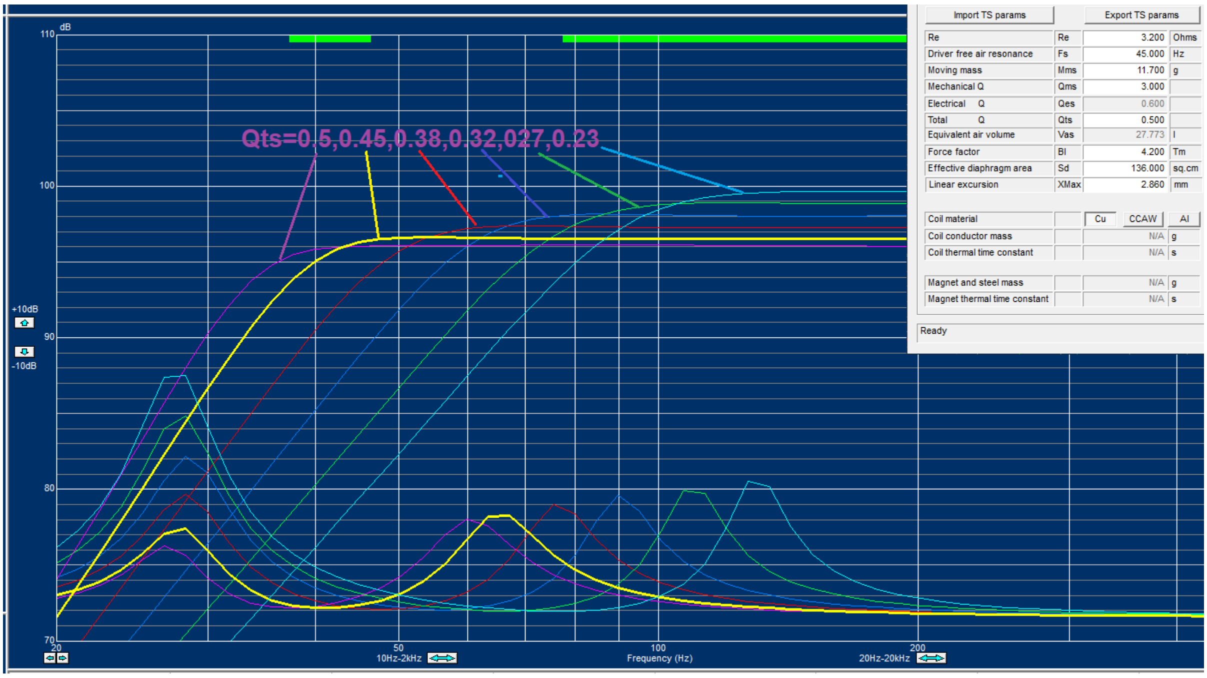
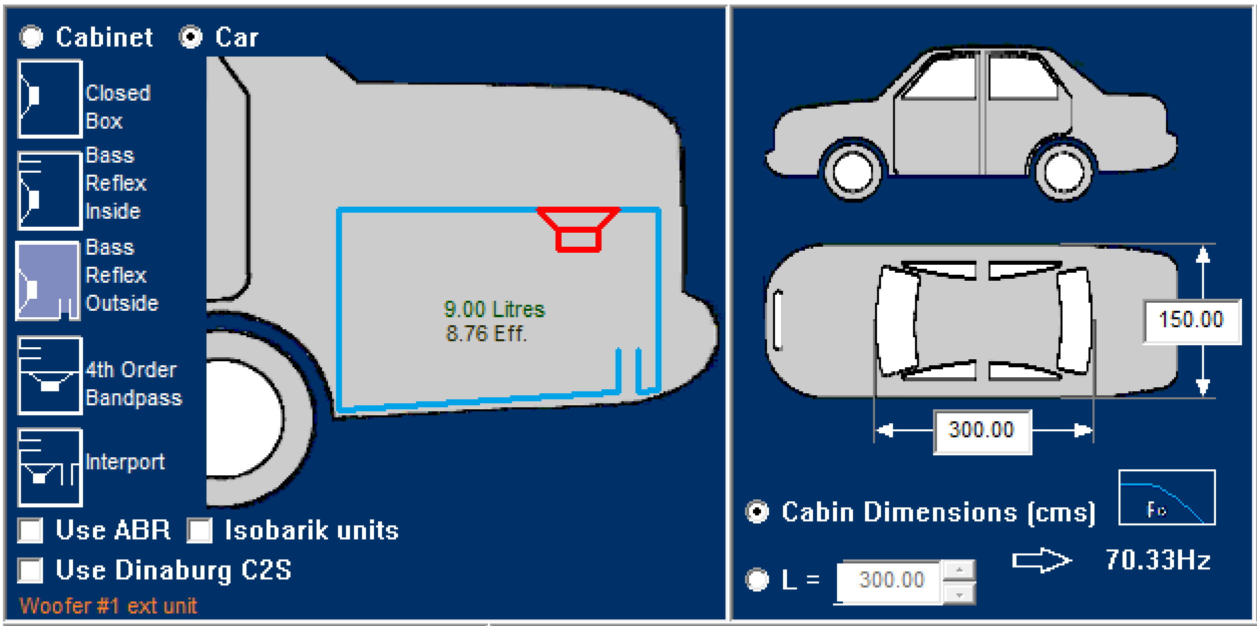



**Figure 3 - Example of Max Flat responses with different Qts**

## 5. Automotive + Cabin Gain




The Car option offers cabin gain calculations for both inside and outside bass reflex ports. The Bass Reflex Outside has the port connected to the outside of the car. Due to the sometimes-high cabin gain, the box can be quite small and still provide an extended low frequency response in the cabin.

Even a closed box can give a well-extended low frequency response in the cabin.

The cabin gain is estimated from the approximate dimensions of the cabin. Inputting the main dimensions including the longest distance will calculate the frequency, where the cabin gain starts, usually extending to the lowest frequencies.

The cabin gain is estimated, but the level and Q is dependent on the materials used in the cabin especially regarding damping.

Using fm3 files from FINEMotorPRO High power simulations will be automatically calculated. This way Power Compression is visualized, and the resulting Voice Coil and magnet temperatures are calculated. By setting the maximum outside environment temperature realistic maximum temperatures can be calculated for Voice Coil and magnet. This is extremely important especially for Neodymium magnets.

See cabin gain examples in section 16.

# 6. Inverse FINEBox

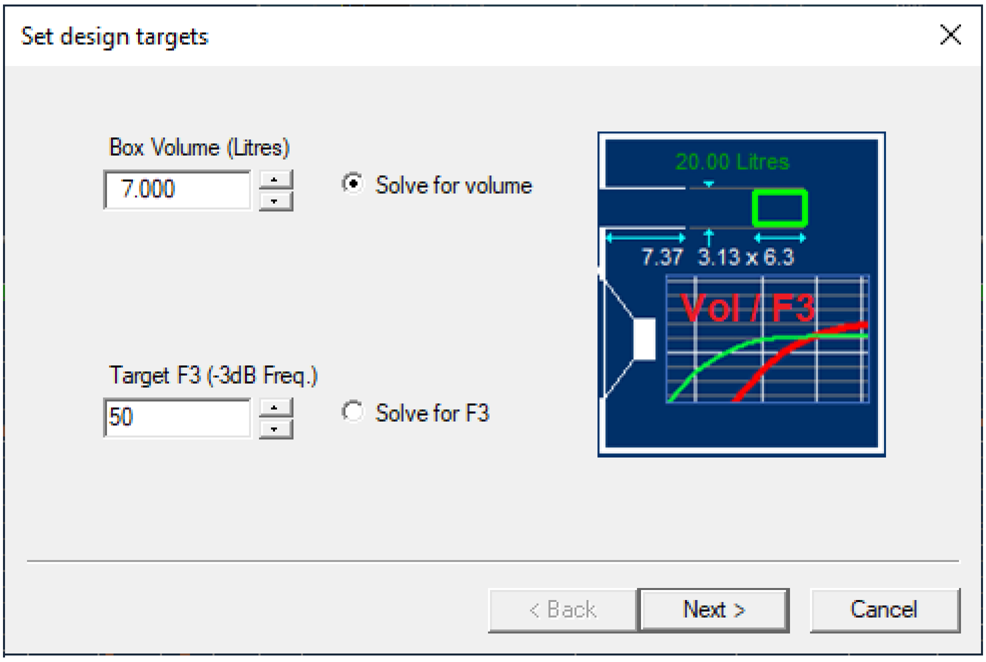



**Figure 4 - Inverse FINEBox: Solve for given Volume or F3 (-3dB)**

**Inverse FINEBox** is exactly that: Instead of simulating the bass response of a driver with certain TS parameters, you can do exactly the opposite, namely simulate a bass reflex box with tuning based on your design target.

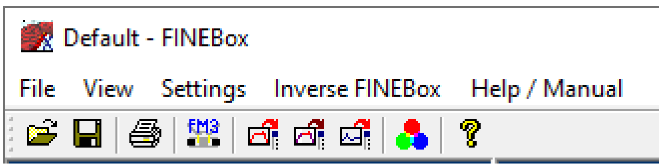



**Figure 5 - Inverse FINEBox in menu**

You will find Inverse FINEBox on the main menu, see Fig. 5.

In Fig. 4 we have selected Solve for Volume and set Box Volume (liters) to 7 liters. Pressing Next gives you Fig. 6, where you can select a typical driver, either directly, from the drop-down menu (fig. 7) or from a file (Loudsoft TXT format or FM3).

In this example we have selected the typical 100mm/4inch woofer from the drop-down menu. The TS parameters are shown on the left, and the new required TS parameters for the target 7 liters are shown in the right column. Note that a new calculated Qts is shown, as well as new tuning Fb and F3 (-3dB).

Pressing finish displays the calculated response #2 Blue [100mm in 7 L], which is the best Max flat response for a 100mm driver in 7 liters, based on the default 100mm driver. If you are satisfied with this response, you view all the TS parameters in [TS parameters / Drivers] in the main View lower left and change any data if preferred.

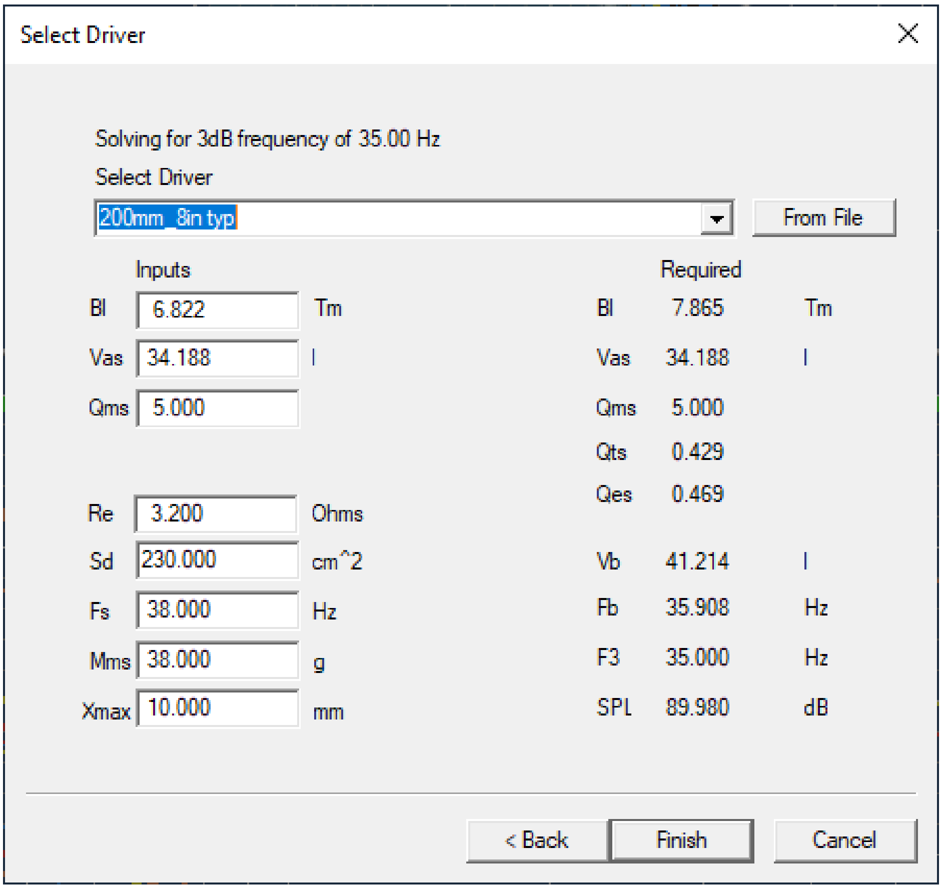



**Figure 6 - Select driver TS parameters from drop-down or input**

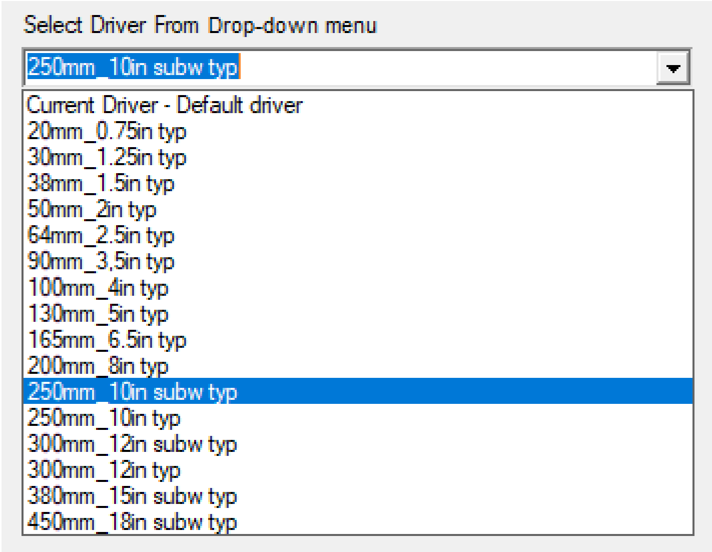



**Figure 7 - Drop-down menu of typical drivers 20-450mm**

However, if you want a certain bass extension, then press solve for F3 in Fig.4, and input 50Hz. Response #2 Red [100mm F3=50Hz] shows the new response, which is Max Flat, having the -3dB point at 50 Hz.

Next you can design a driver with these new TS parameters (see [TS parameters / Drivers] in FINEMotor or ask a vendor to provide a sample.

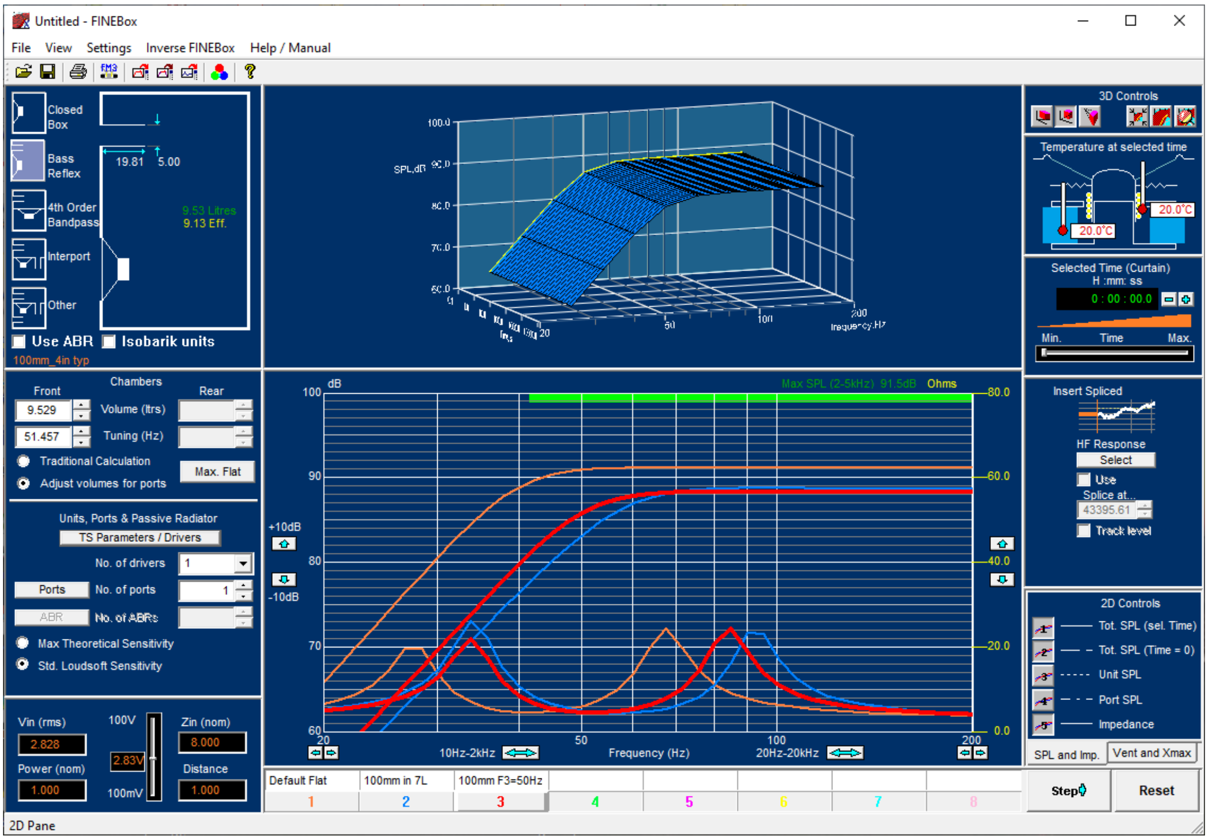



**Figure 8 - Calculated responses from Inverse FINEBox**

The typical drivers are a good starting point, but if you, for example select a too large box, there will be a warning in red, see Fig. 9, where the required Qts is 0.556, giving a less flat response when Qts is higher than the limit of 0.5.

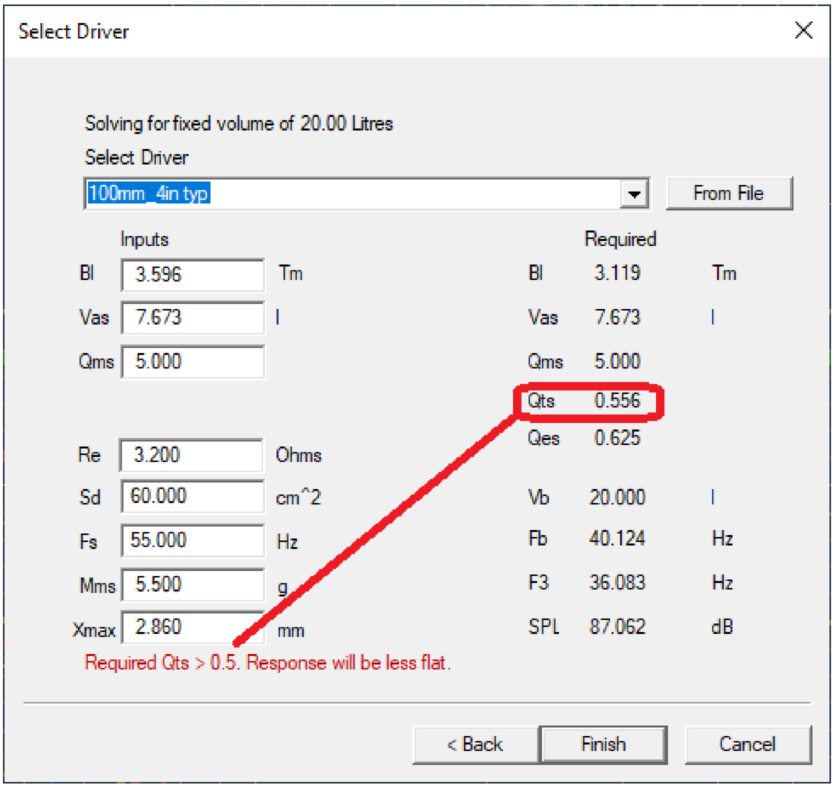



**Figure 9 - (Too) large volume with warning!**

# 7. High Power Simulations (without FINEMotor input)

From this version of FINEBox you can perform High Power calculations directly, **without needing any input from other software like FINEMotor**.

You only need to input the outer dimensions from the driver and select the VC type info from a drop-down table.

You need the dimensions shown in Fig. 10. All can be found by measuring the driver from outside, so there is no need to open or cut the driver in any way.

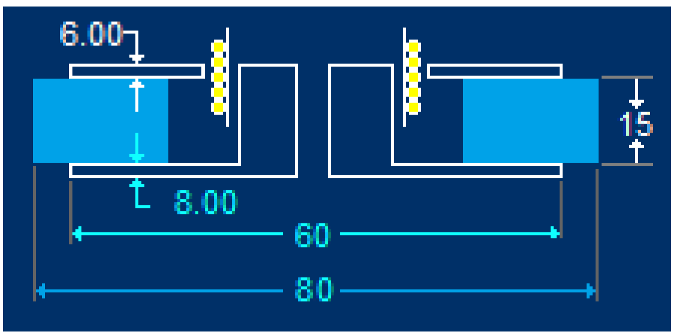



**Figure 10 - Outer dimensions needed for High Power calculations**

First press 

and input your TS parameters, which you have measured or found in a data sheet.

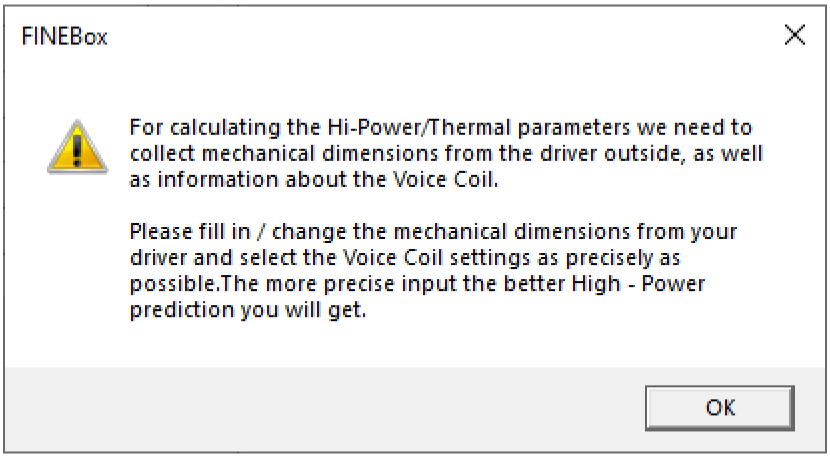
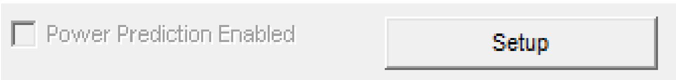



**Figure 11 – Note: Mechanical dimensions are needed for Power Prediction**




Next press Setup (Power Prediction will only be enabled after you have finished inputs)

All the inputs are shown with default values Fig. 11. Be sure to update all dimensions for your driver. This information builds a full mechanical model of the magnet system and Voice Coil, which is used by the advanced calculation engine in FINEBox to find all the Thermal parameters, giving the best estimation of Power Compression and Magnet and Voice Coil temperatures.

After filling in the mechanical data (center column) you must define the Voice Coil in the right column. Please measure or estimate the distance from the VC winding to the top of the VC former and define VC wire material, VC former material and magnet material.

Finally, you must select which predefined VC diameter and info applies for your driver in the drop-down table Fig.11.

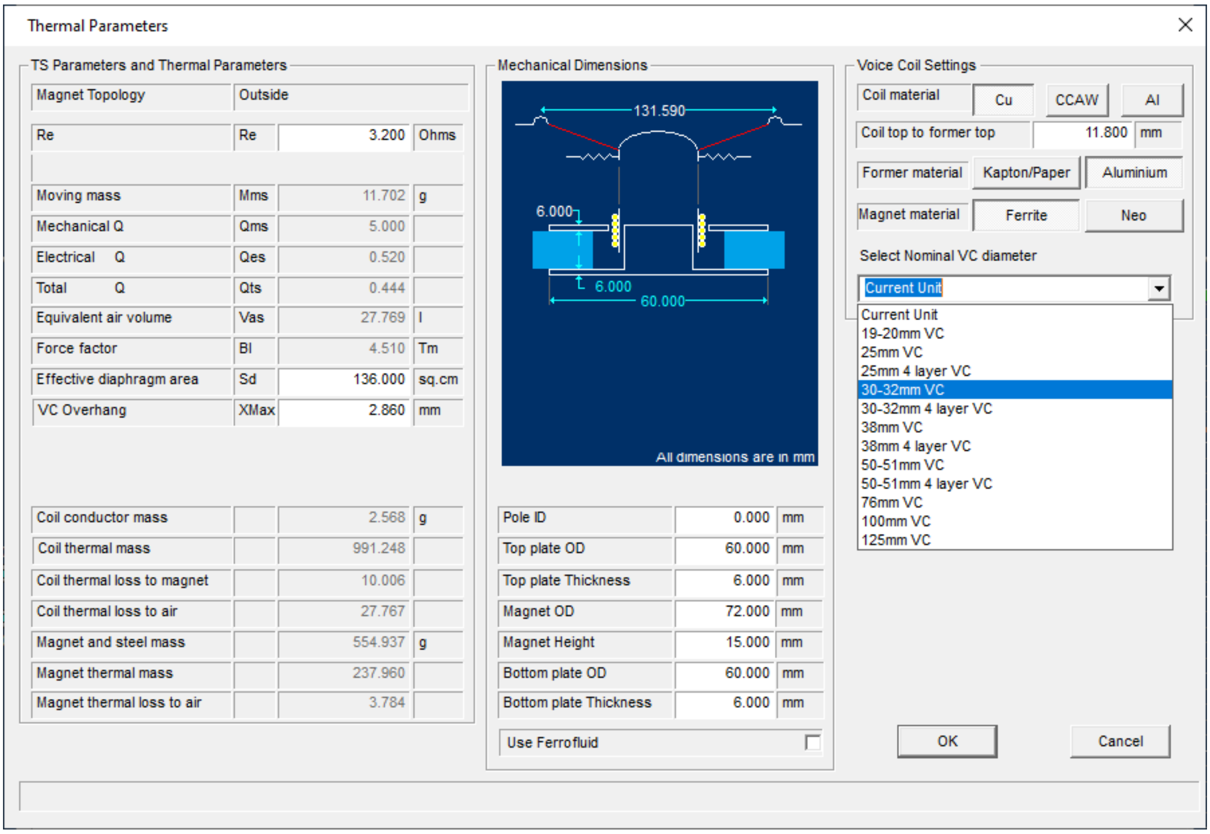



**Figure 12 – Driver Parameters with High Power dimensions Input**

After OK you will see the Power Prediction is enabled.

Now you should increase the power input in the lower left corner and see the higher SPL. Then go to Selected Time (Curtain) and pull the slider all the way to the right Fig. 14. That will produce two curves Fig.13, where the lower is the response with power compression. The VC and magnet temperatures are shown on Fig. 14.

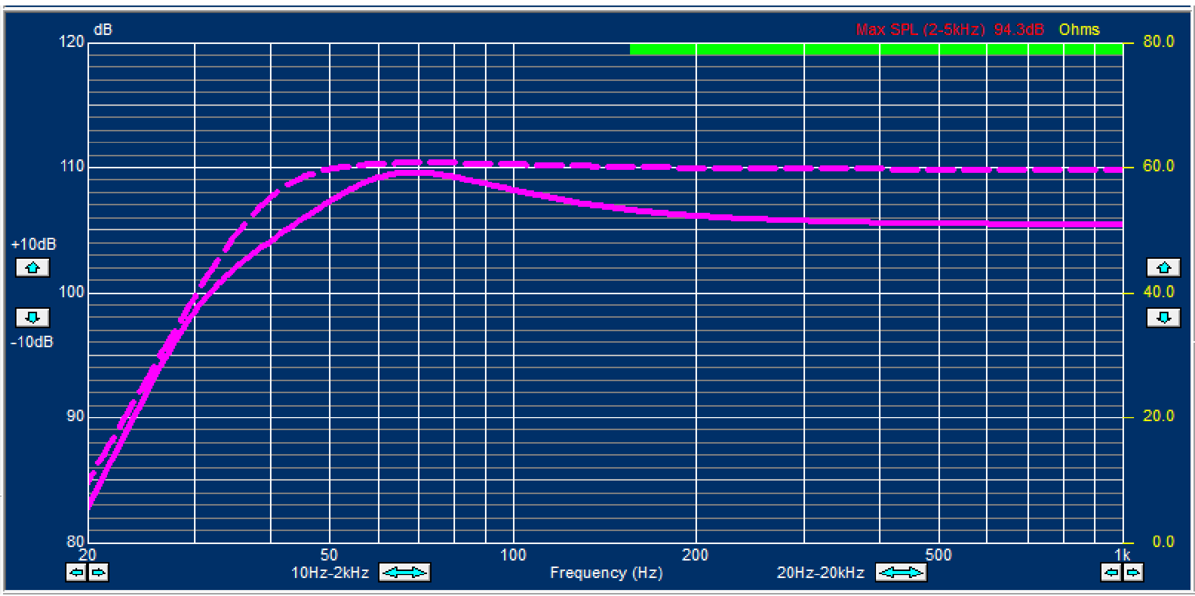



**Figure 13 - Power Compression after High Power calculation**

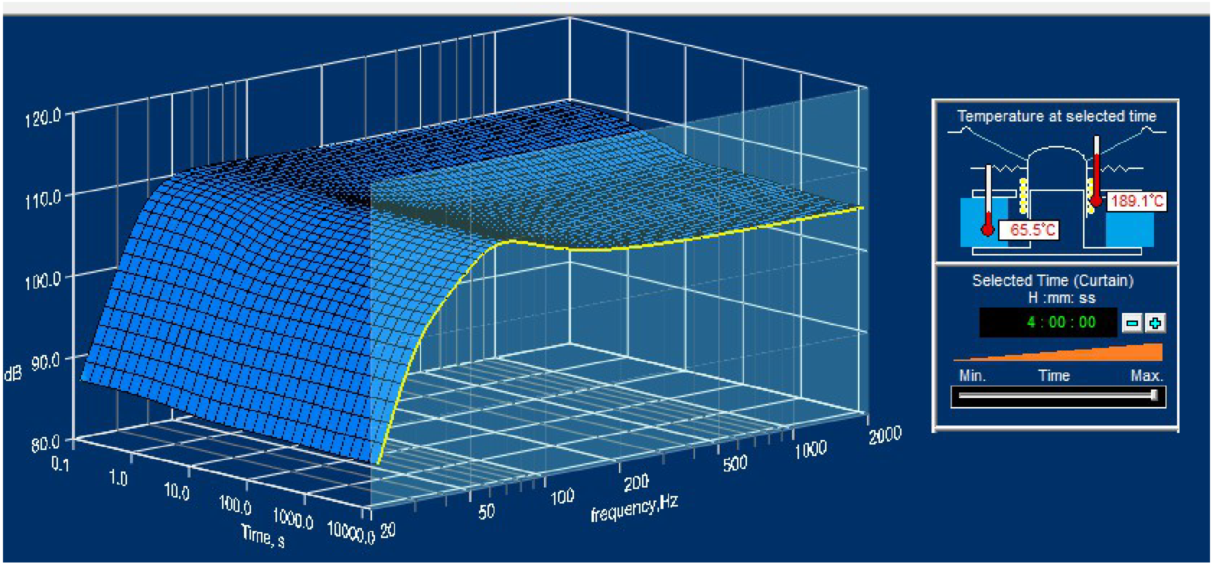



Figure 14 - Magnet and VC temperatures from High Power calculations

# 8. Export of responses WITH Voltage and power levels

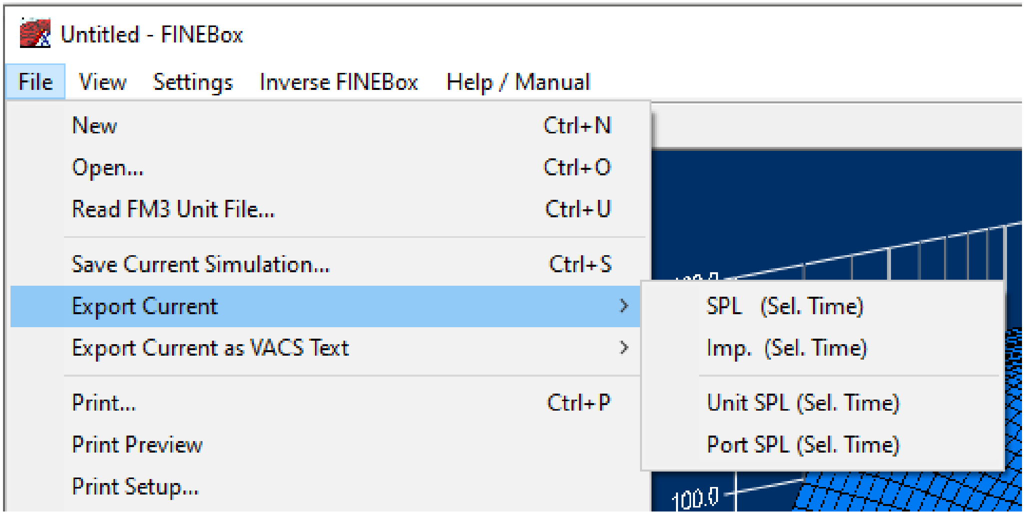



Figure 15 - Export of responses with V and W, at selected Time

Exporting a response at high Power after for example 4 hours (Time) will now include the input Voltage and Power (W) which was used in the High-Power simulation.

When you import that response into, for example FINE DSP or FINE X-over these Voltage and Power levels **are kept**. If FINE DSP is set at a different input, then the imported response will automatically be **scaled** to the **current** FINE DSP settings. See Fig. 15.

This means that the responses will always be at the correct power level, and the curves will move up and down displayed at the correct SPL.

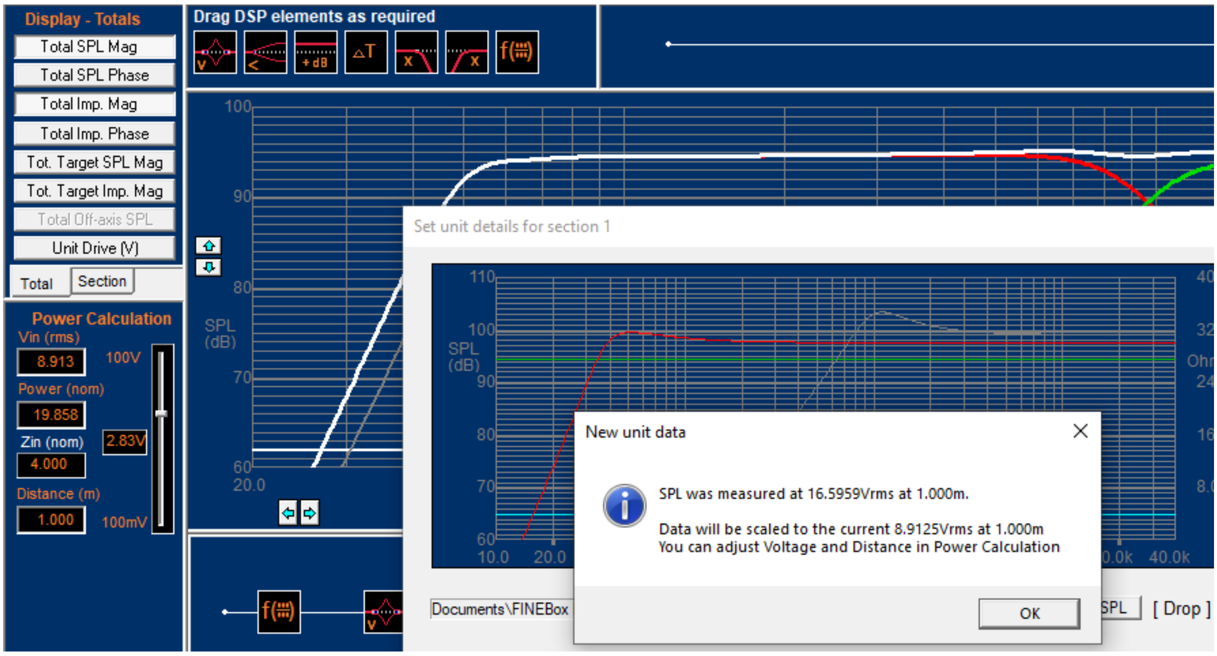



**Figure 16 - Import of exported response into FINE DSP, auto-scaled to correct V and W levels**

# 9. Bass Reflex response with MAX Boosting

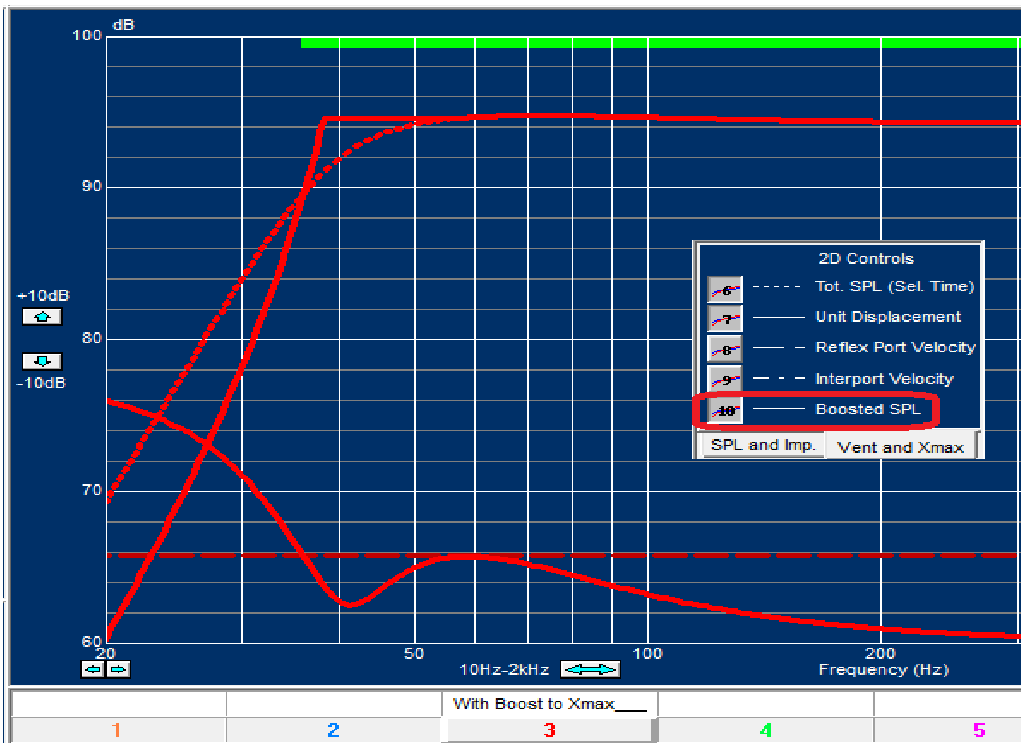
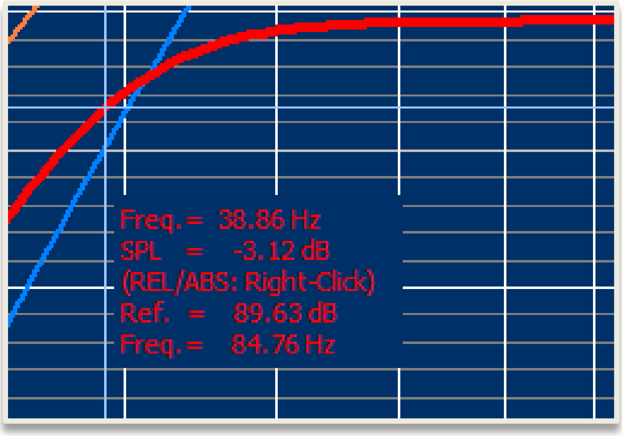



**Figure 17 - Bass Reflex with MAX Boost is now displayed as extension lines**

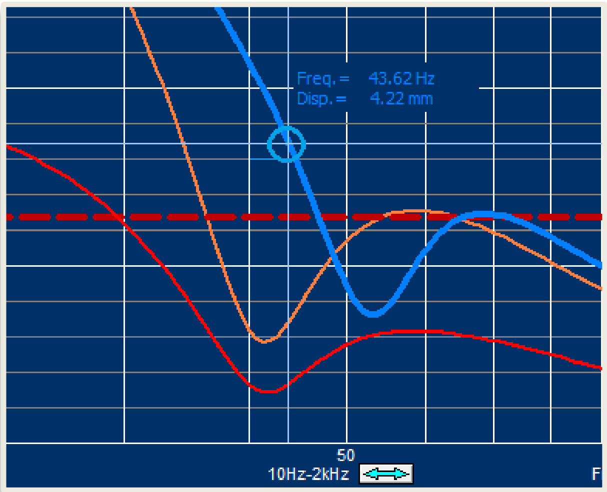
In a bass reflex system, the woofer has minimum movement at the tuning frequency Fb. This is shown as a dip in the Woofer /Unit Displacement, here ~41Hz, Fig.17. Therefore, you can safely boost the woofer up to Xmax around this frequency to extend the low frequencies. This is now indicated as two extension lines below the normal cut-off frequency. This feature is selected with button #10:___Boosted SPL.

# 10. Cursor




The cursor appears as soon as you press the left mouse button when in the graph / response area. First the frequency is reported, and the SPL level (dB).

When you right-click the SPL level is set as **0 dB** (Reference level). By holding the left mouse button down, you can see the relative SPL level (from the set 0 dB). This is shown in the picture above.




When you are in the Vent and Xmax mode (set lower right), the cursor will show the driver displacement (VC travel) in mm.

*Note that the upper Total SPL button must be OFF for this to show!*

# 11. 8-inch Woofer in different Enclosures

We are going to build several enclosures using the same 8-inch woofer to demonstrate the difference in performance. (Saved as example files). The driver is SEAS L22RN4X/P, which has the following data:

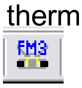
<u>SEAS L22RN4X/P main data:</u>

| | | |
|---|---|---|
| Nominal impedance | 8 | ohms |
| Long Term maximum Power | 125 | W |
| Linear voice coil Travel (p-p) | 14 | mm |
| Voice Coil Resistance (DCR) | 6.1 | ohms |
| Force Factor | 10.7 | Tm |
| Free air Resonance (Fs) | 23 | Hz |
| Moving Mass incl. air load | 44.9 | g |
| Effective Cone Area | 220 | sq. cm |
| Vas | 72 | |
| Qms | 3.62 | |
| Qes | 0.35 | |
| Qts | 0.32 | |

# 12. Closed box

Let us start with a closed box. Select the Closed Box Alignment and press Reset to erase the other simulations. Since the Qts is quite low we can expect that a volume much smaller than Vas will work. Let us therefore try with a 25L closed box, which is also the default volume.

We have previously modeled the L22RN4X/P woofer in FINEMotor, which means that we can import the non-linear T/S parameters and thermal data directly into FINEBox by pressing the “Read Unit” button.




The distance from the voice coil winding to the top of the former is approximately 20mm, but we are setting this value to 0 to estimate the effect of the open voice coil and phase plug, which provides better cooling. Set the Former conductivity to 226 Wm/K for aluminum.

All Driver Parameters can then be viewed by pressing the TS Parameter/Driver button

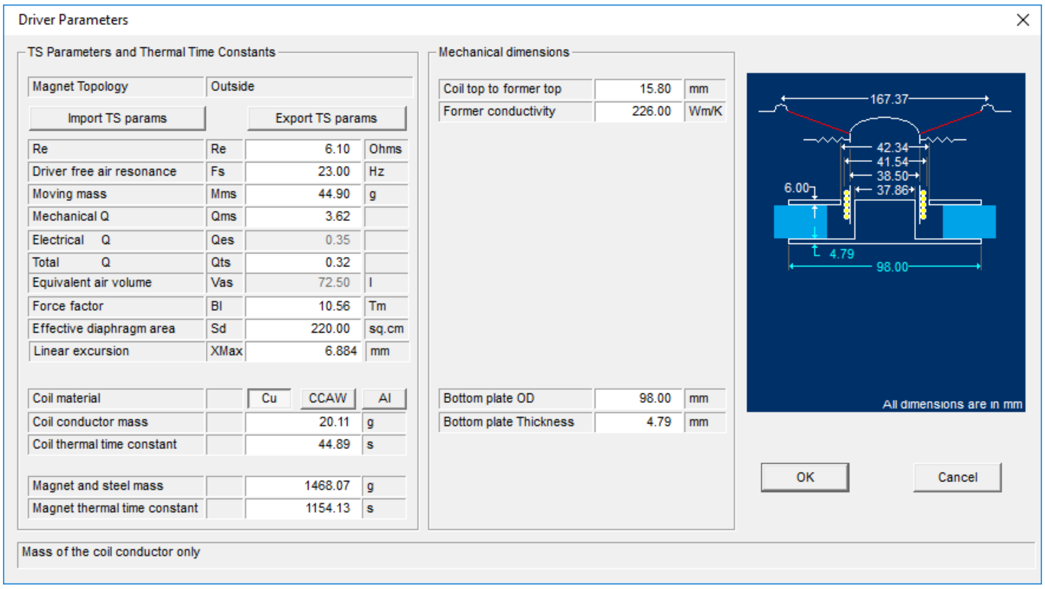



**Figure 18 - Data imported from FINEMotor**

All we must do in FINEBox is now to set the input power. The L22RN4X/P woofer is rated at 125W (Long Term Max by IEC 268-5), which is simulated music signal with 1minute On and 2 min. Off. This is effectively a duty cycle of 33% and we may therefore set the input power to 1/3 of 125 W, which is 41.7W to see the long-term effect.

The closed box response is well damped with a box resonance of approximately 45Hz, indicated by the peak on the impedance curve shown.

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Be sure to select max time by pulling the time slider to the right Fig.13. (See Time Press Step and type 125W as power (nom). The dash-dot curve is the ideal response, and the solid curve is compression. #2 ideal response is ~5dB higher in SPL, but with the compression increased from 1.5 to 4dB at higher frequencies (until impedance rise), we only get 2.5dB more SPL. However, the compression around resonance is much reduced, less than 1 dB.

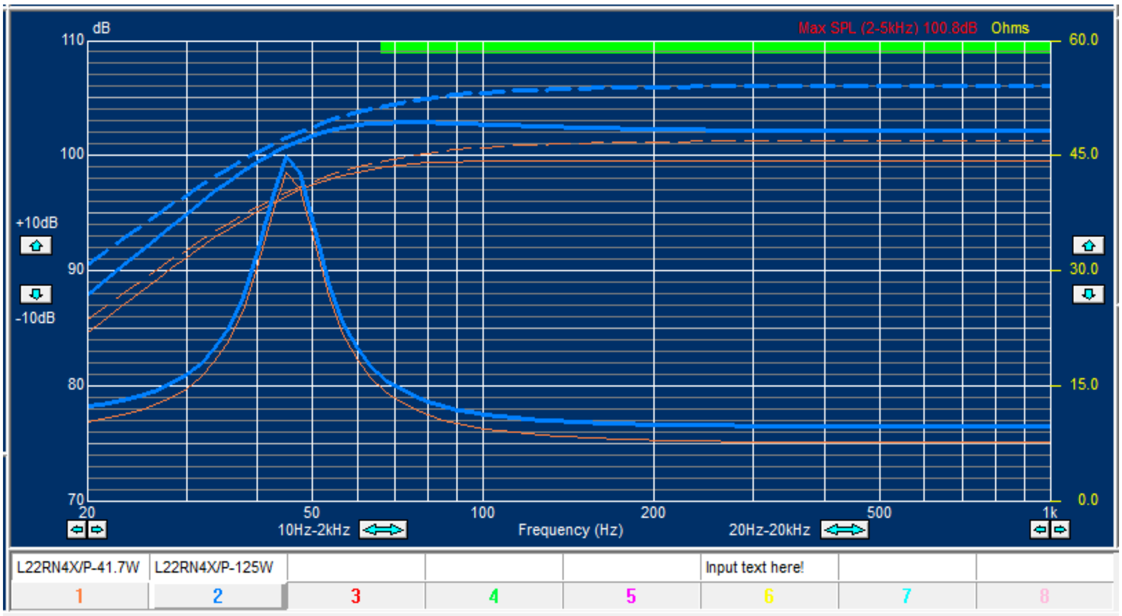



**Figure 19 - 25L Closed box compression at 41.7 and 125W (Added label text)**

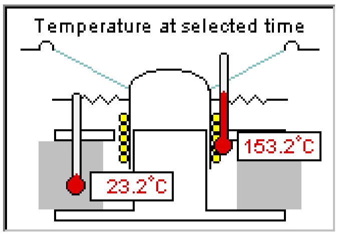



**Figure 20 - VC and motor temperatures**

Set the time Curtain Fig.13 to 2min25s (=145s), and Fig. 19 shows the high temperature of the voice coil (153.2C) and magnet system (23.2C) with 125W input. At this time the magnet system has not yet heated up. Selecting max time = 4:00:00 shows the motor + voice coil fully heated which gives a magnet system temperature of 45.2C, while the voice coil is 167.7C Fig. 20.

By pressing the Vent & Xmax tab we get the actual unit displacement (excursion) in millimeters (mm). The max displacement is reaching 8mm below resonance, which is acceptable.

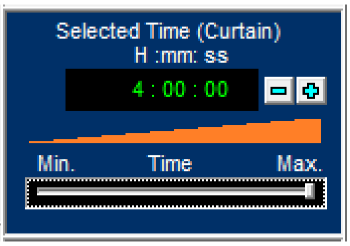



**Figure 21 - Set Digital Time for Power calculation**

# 13. Bass Reflex Enclosure

Press Step and the Bass Reflex alignment button. The new simulation is red and shown by the active button #3 in Fig.14. (You may right-click the #1 button to turn if off for now). This response is unacceptable with a high peak at 60Hz. The solution is a lower tuning frequency Fb. #4 curve (green) is therefore tuned to 27Hz and gives a nice QB3 type response with a rounded corner. The dashed responses are the driver (unit) SPL alone. (The Port responses are not shown for clarity)

To design a B4 (maximally flat/ Butterworth) response we need a larger volume. The last curve #5 (violet) is a 36 L box and is tuned to 30Hz. Note the corner is now filled out.

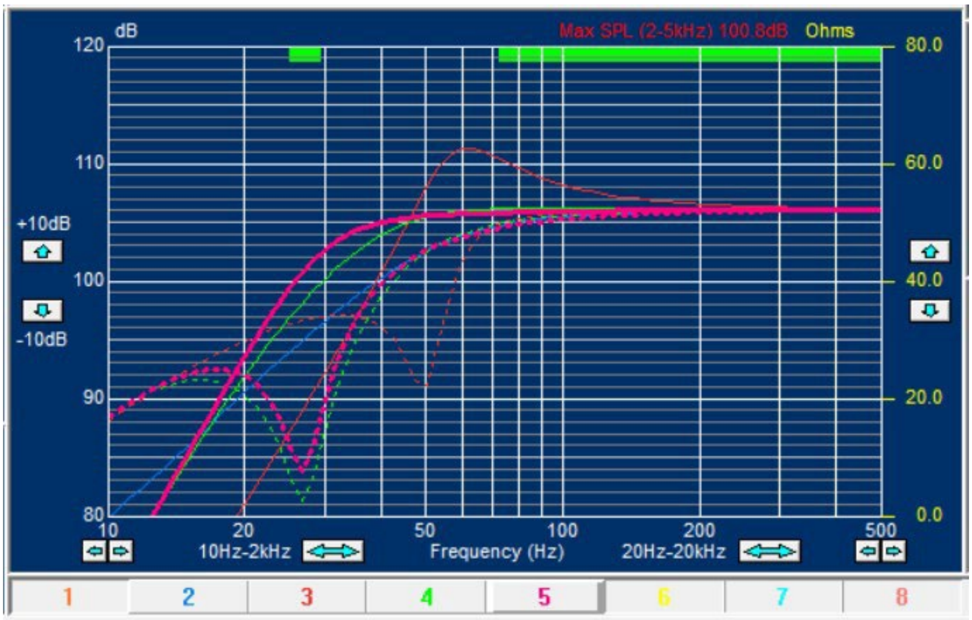



**Figure 22 - Four different Bass Reflex Simulations**

In comparison let us examine the high-power responses after 4 hours input, in detail. Set the “Digital Clock” (Time Curtain, see Fig. 20) to 4:00:00 and see the compressed responses in fig. 18 (2D Controls [1] & [2] must be depressed). Since we want to compare the last #5 response (bass reflex) against the first (closed box #2) we can turn off buttons #3 and #4 by right-clicking them (right-click to turn on again).

We now see two new curves below the previous. These are the system responses after 4 hours transferred from the 3D view and we see both responses are about 4dB lower above 200 Hz, but the reflex curve now has a large bump at 50Hz compared to the closed box, which has a flatter response. Unit and port responses are shown as dashed for the bass reflex simulation.

So, both responses are compressed at higher frequencies, but the reflex curve has changed to a non-flat response with a pronounced bumpy bass, which was not the intention.
At this point you can use FINEBox to experiment and test alternative tunings, alignments, boxes, drivers etc. Even changes to drivers can be suggested with FINEMotor and simulated in FINEBox.


**Figure 23 - High Power Bass Reflex versus Closed Box**

Press the “Vent and Xmax” tab and we get curves for unit displacement, seen in Fig.23. (the previous high-power curves are also visible). The closed box has a max displacement of 12mm below 50Hz, which is a little more than allowed (10.5). The reflex in comparison shows reduced unit displacement around 27 Hz due to the reflex port “taking over”, but increased displacement below 20 Hz. However, the energy content of normal music is much reduced below 20Hz. The bass reflex design may therefore be preferable.

Press the button: “Reflex port Velocity” in 2D controls (#8). This curve is the speed of the air in the port (vent) and is much too high at low frequencies. The rule is to keep the vent speed below 15m/s (Dashed red) to avoid “whistling”. Press the “port” button to edit the port dimensions. Let us increase the port diameter to 10cm. Curve #6 shows the resulting vent speed, which is now acceptable. We may select the flanged option to further reduce noise.

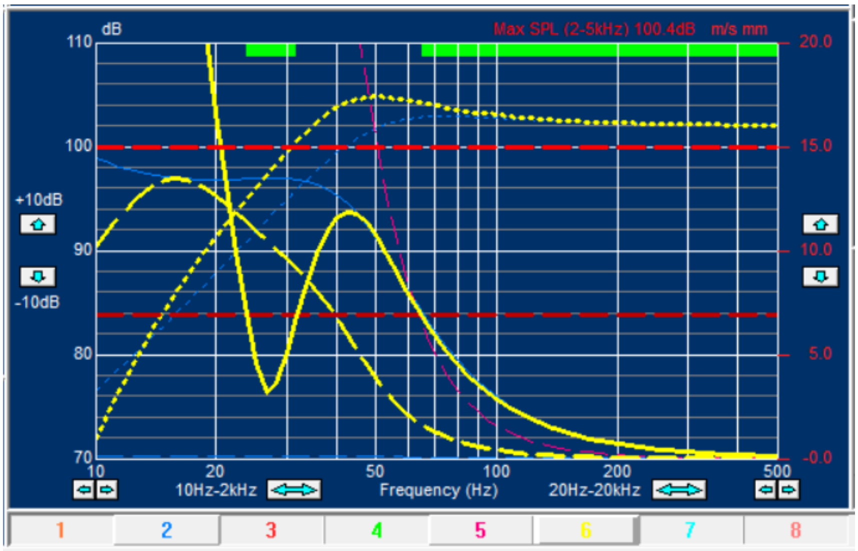



**Figure 24 - Vent Speed and Xmax of closed and Reflex Box**

The port length is 81.7cm, which may be too large. Choosing a smaller diameter will increase the vent speed at low frequencies and it may be possible to find a good compromise between port diameters and vent speed, because the energy content of normal music is reduced below 20-50Hz.

# 14. Oval / Rectangular Reflex Ports

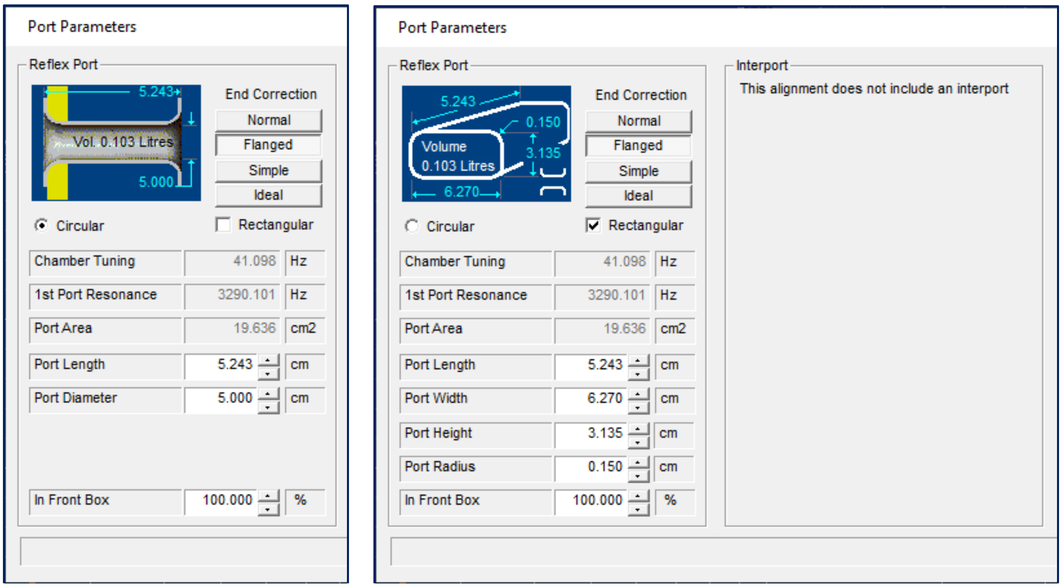



**Figure 25 - Circular and Rectangular Ports with same tuning (Port area is shown)**

You may have found port tuning giving a good response, with increased port area for controlling the air speed, however, there is not enough space for a large round port on the front baffle: In this case a rectangular port is really needed.

But how can we tune the Rectangular port? In the port dialogue a suitable port is automatically proposed while keeping the same tuning, Fig. 25. Then you can, for example, set the Port Height as 4cm, and the new Port Width is automatically calculated. You can even play with the dimensions using the mouse wheel, keeping the same tuning. In addition, you can still add a flange for reducing port noise. See also Appendix A.

## 14.1. 1st Port Resonance

The Pipe resonance in the port is shown as the 1st Port Resonance. This may disturb the sound, and is like an organ pipe resonance, which should not be confused with the Bass Reflex resonance Fb. It only depends on the length of the port, so a long port gives a low 1st Port Resonance.

# 15. ABR – Passive Radiator Enclosures

An alternative to the bass reflex enclosure is the ABR or passive radiator enclosure. The advantage is absence of port noise and suppression of un-damped resonances from inside the cabinet.

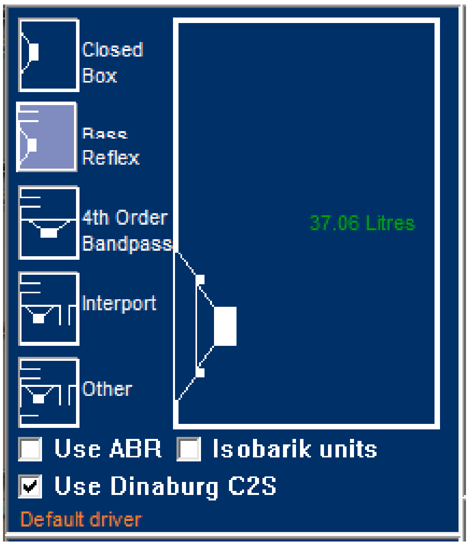



**Figure 26 - Selection of Box type including ABR's**

## 15.1. Dinaburg C2S

The special Dinaburg C2S (Concentric Coplanar Stabilizer) was selected in Fig. 26.

This is an advanced ABR, consisting of a suspended ring surrounding the active speaker. It is made of a conical ring attached to two surrounds. It is inherently more stable and offers other significant advantages, see:

http://dinaburgtech.com/Documents/Dinaburg_Technology_THEORY_of_C2S.pdf

It can be simulated as a passive body with suspensions, as shown below fig. 27:

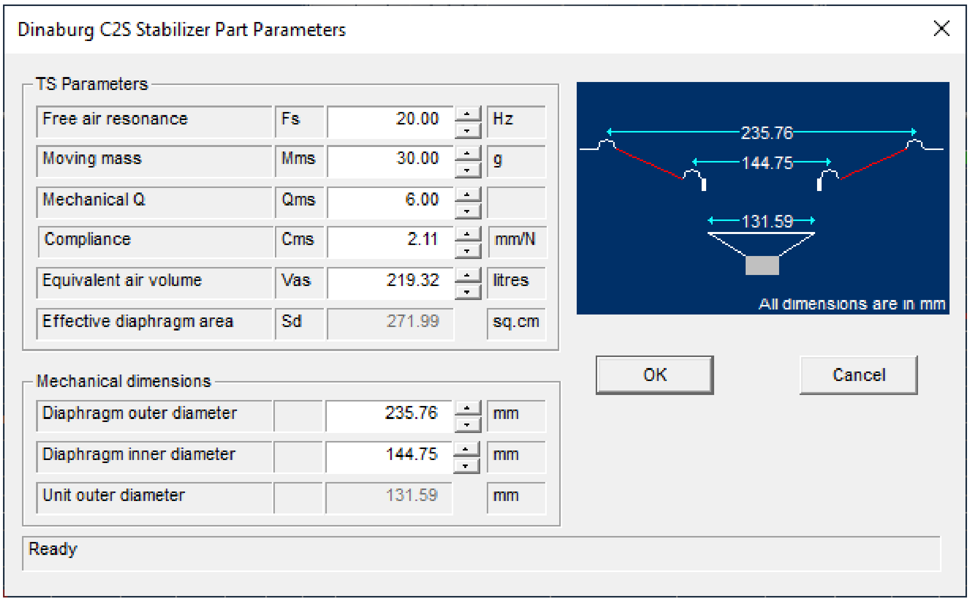



**Figure 27 - Dinaburg C2S mechanical parameter input**

## 15.2. Standard ABR

The standard ABR can be made using a shallow cone with surround + added mass for tuning.

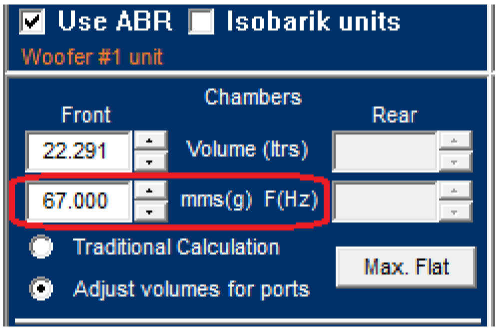



**Figure 28 - ABR tuning by Mass adjustment**

Both ABRs are tuned by adjusting the ABR mass (Mms) instead of a port. Fig.28 shows this is **easily done by adjusting the mass using the mouse wheel**.

Fig.29 shows the 36Liter bass reflex box tuned to 27 Hz from the previous example, as the blue curve. The red curve is the comparable ABR having a moving mass of 70g to provide close to the same tuning and pass band response. The ABR data are shown in Fig. 31. The Fs of the ABR is 15Hz, which causes a notch in the response at that frequency, therefore changing the slope of the low frequency response. The ABR Fs should therefore be placed well under the pass band if possible.


**Figure 29 - ABR response___ compared to bass reflex___**

## 15.3. Quasi-Flat ABR response

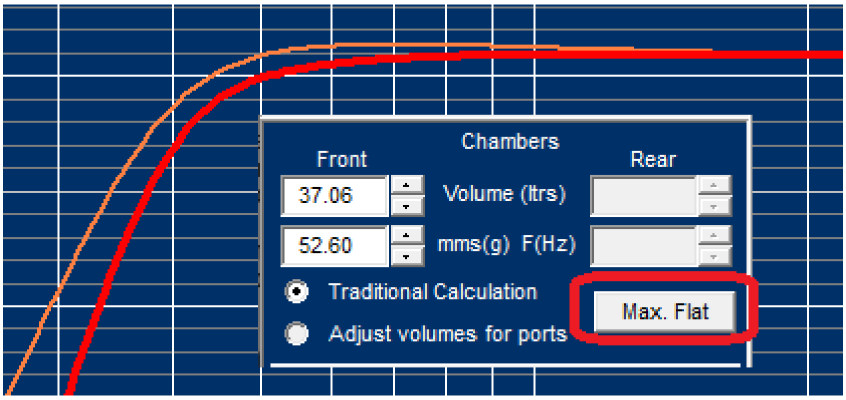



**Figure 30 – Press Max. Flat for quasi flat response**

In Fig. 30 the Max. Flat button was pressed giving the red curve. You can fine-tune it by adjusting the mass at left. The low frequency extension is affected by the Fs of the ABR as mentioned on the last page, but the "knee" is also depending on the Qms of the ABR, which really depends on the damping of the surround.

The standard passive ABR unit can be designed by pressing the [ ABR ] button to get the dialogue shown in Fig.31. You can input either Fs or Vas.

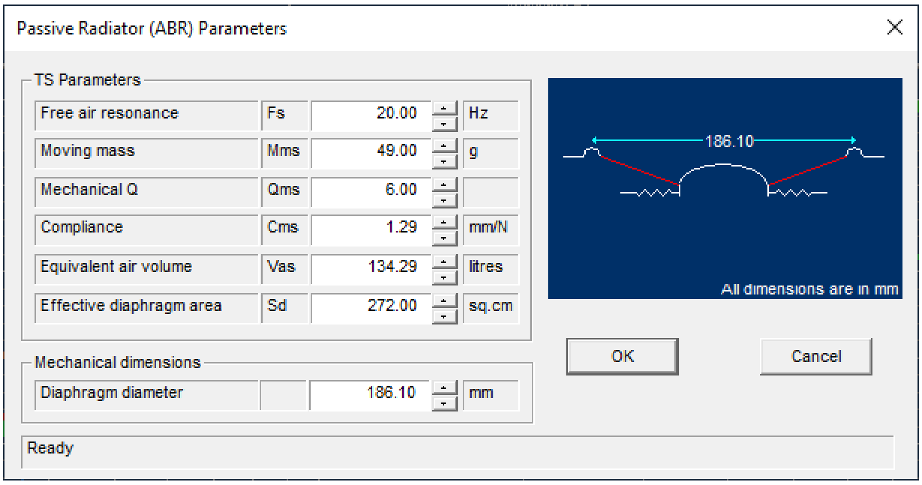



**Figure 31 - Passive ABR unit designer**

The ABR unit will have its own resonance Fs just like the cone Fo (Use FINEMotor or FINESuspension to calculate the compliance and Fs of the ABR). Fig. 31 shows the dialogue which is used to specify the ABR. The moving mass is the combination of the passive cone +½ surround, plus an added mass. Increasing the added mass will work like a lower tuning frequency in the box.

Choosing an ABR with the same area as the woofer cone area Sd, puts high demands on the excursion capability of the ABR. This is calculated in FINEBox under the [Vent and Xmax] tab. The excursion can be reduced by choosing a larger ABR diaphragm area (but the added mass must be increased). FINEBox is suggesting the double ABR area as default.

All this is calculated automatically, and the user can just experiment with different inputs.

## 15.4. Calculation of Surround / Suspensions

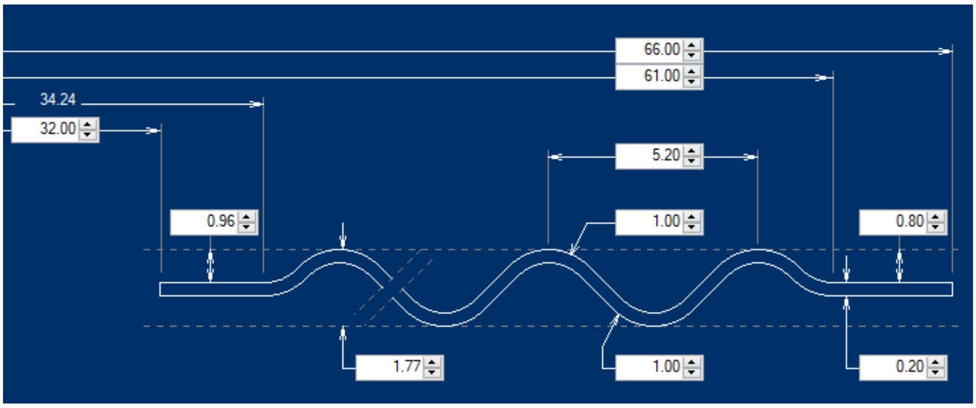
The stiffness and linearity of the ABR surround(s) may be calculated and optimized separately using the program FINESuspension available from LOUDSOFT.

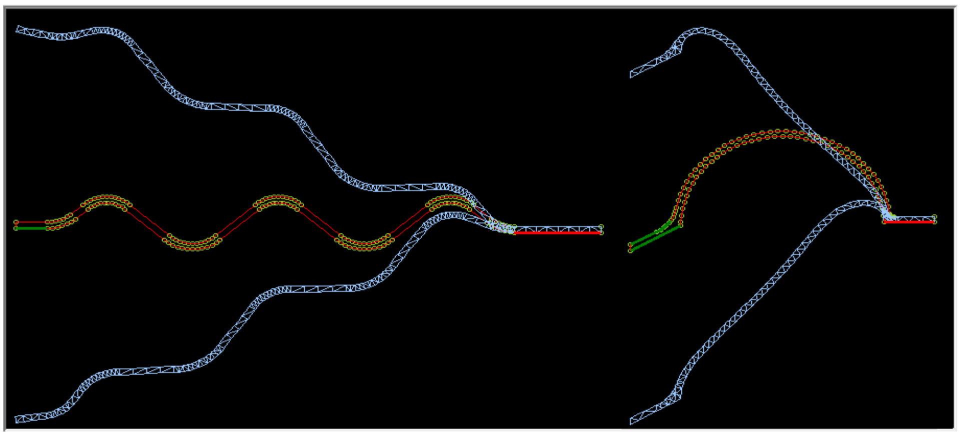
This program will display the compliances of the (combined) surround(s) which can then be directly entered into FINEBox ABR parameters.

https://loudsoft.com/finesuspension/

**FINESuspension™**

- Non-Linear FEA calc of Kms(x), Cms(x) and F(x) for Surrounds and spiders
- Spider and Surround can now be calculated as Combined
- Design Spiders and Surrounds from Geometric Templates by only dims
- Optimize Spider waves and dimensions for a linear range per IEC 62458
- Optimize Surround profiles and dimensions for a linear range per IEC 62458,
- Optimize Spiders and Surrounds for perfect symmetry at required Xmax
- Design special Spiders and Surrounds from simple CAD files (DXF format)
- Analyze Spiders and Surrounds at various Forces and materials
- Material Database with typical spider and surround materials and pars
- FINESuspension simulations are verified with generic FEA software



# 16. Car Cabin Examples

The relatively small car cabin behaves like a compression chamber, thereby amplifying the low frequencies considerably for frequencies where the wavelength is larger than the longest dimension of the car cabin.

This implies that smaller woofers and boxes may be used in typical car cabins.

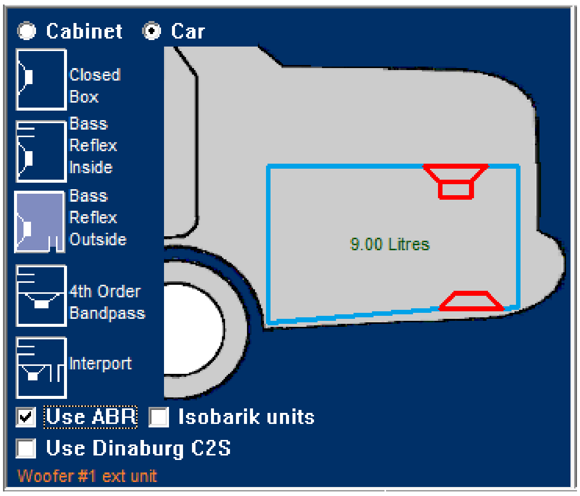



**Figure 32 - Car Configurations including Bass Reflex + ABR outside**

Several car configurations are available including Bass Reflex inside/outside or ABR / C2S see Fig. 32. The outside bass reflex is very interesting, see later Fig. 35.

## 16.1. Example 1. Closed Box with Cabin Gain

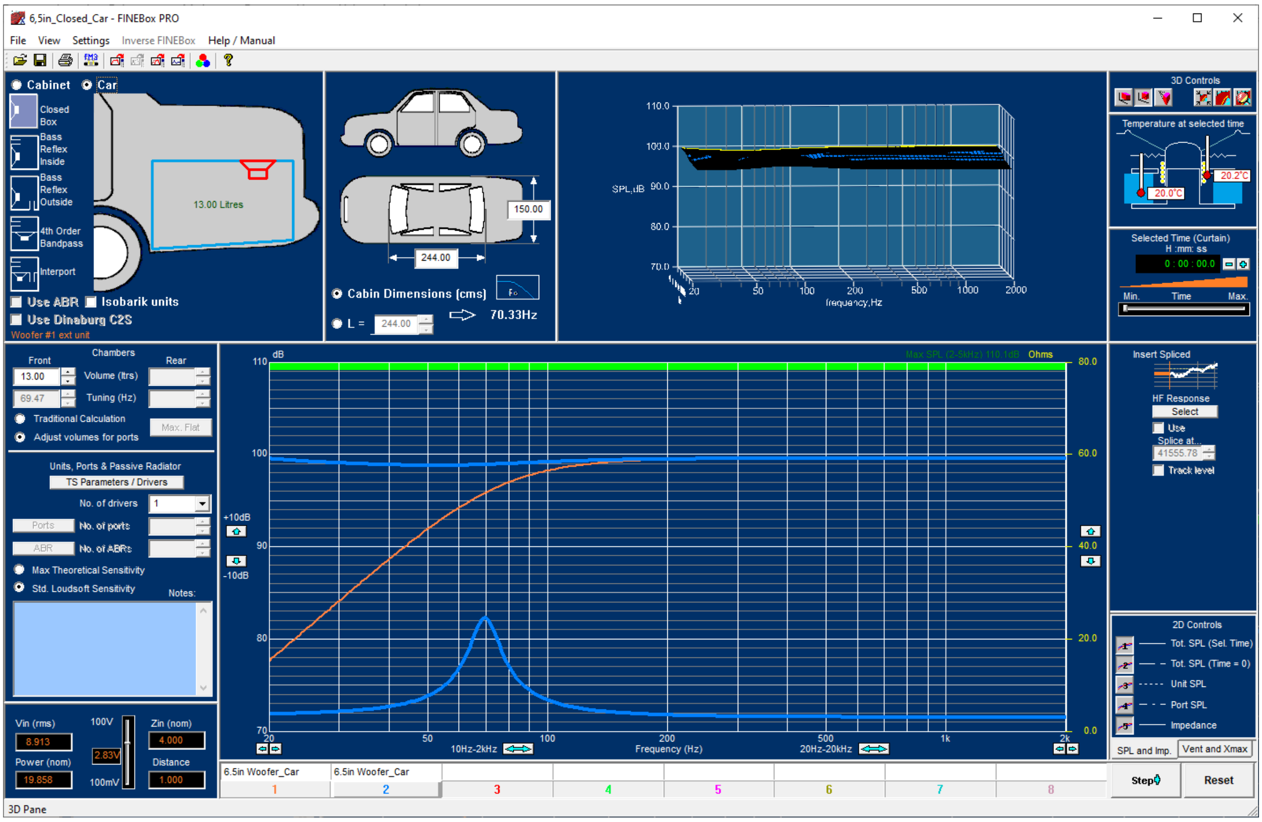



**Figure 33 - (1) 6.5inch Woofer in Closed Box / (2) Response in Car Cabin**

Fig. 33 gives the response of a 6.5” woofer imported from FINEMotor (fm3) in a 13Liter closed box (brown). The lower curve is the VC travel here being equal to Xmax at 20Hz with an input of 20W.

Curve (2) (Blue) is the response of the same woofer with the car cabin gain added. The total response is close to 100dB and now quite linear illustrating how a small woofer can exhibit a flat response when the cabin gain is included.

The cabin gain was calculated using the cabin dimensions from the center car sketch window. The longest dimension determines the frequency where the cabin gain starts. The longest dimension is here 244cm, causing cabin gain below 70.33 Hz.

Fig. 34 displays the Power Compression for the same woofer with cabin gain. The Power Compression is almost constant 1-2dB, causing a VC temperature of 82.5C, which is acceptable. The Power Compression is also visualized from the 3D curve display (upper right), where time is the 3rd axis.

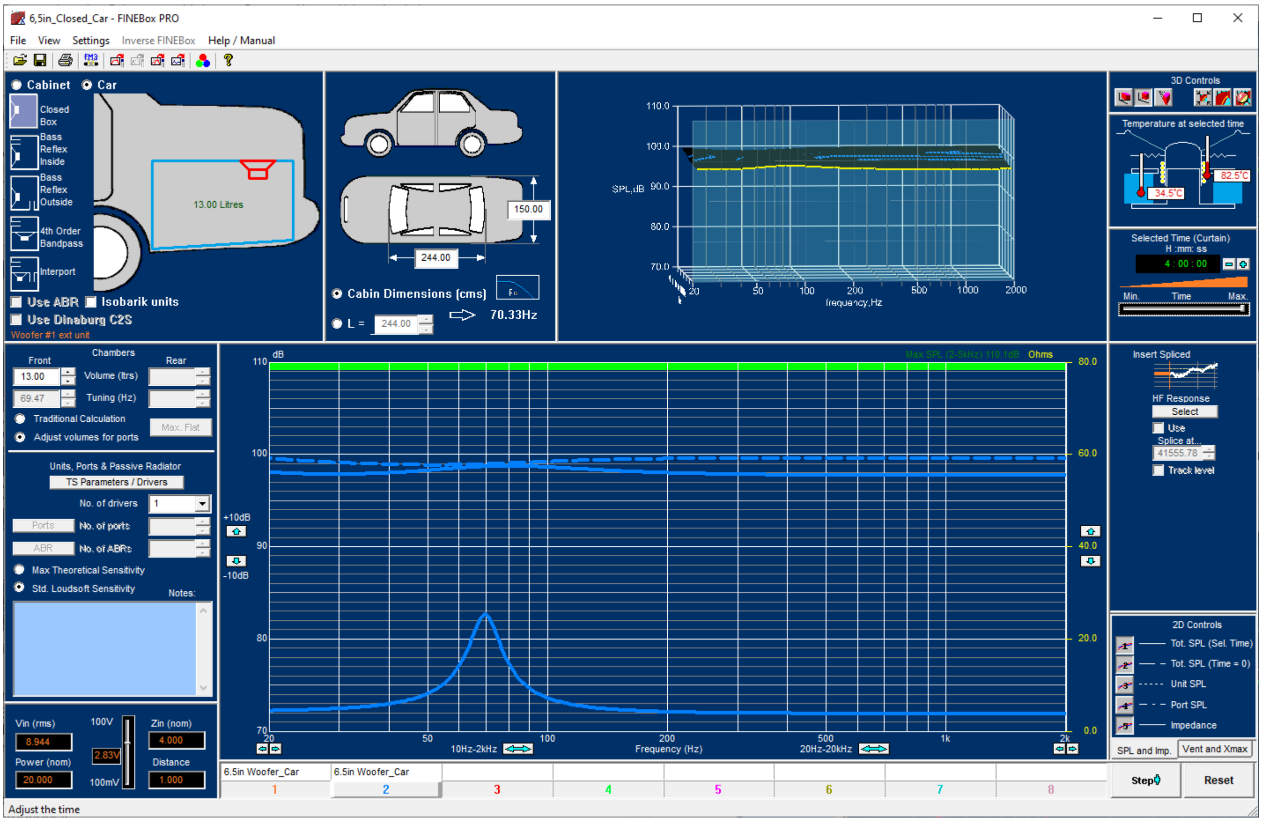



Figure 34 - 6.5" Woofer Power Compression @ 20W including Cabin Gain

## 16.2. Example 2: Outside Bass Reflex

Using a bass reflex box inside the car may not be necessary, but the outside bass reflex is a very interesting solution. Fig. 35 shows an example of this using a small bass reflex box of only 9 liters tuned to 300Hz, and where the port is connected to the outside of the car! The response of the bass reflex box is limited below 300Hz (rising curve, full red), but the cabin gain helps considerably down to 20Hz, giving an almost flat response (Red, dashed).

It is possible to use an even smaller box below 5 liters, only causing a little more variation at the 300Hz tuning frequency.

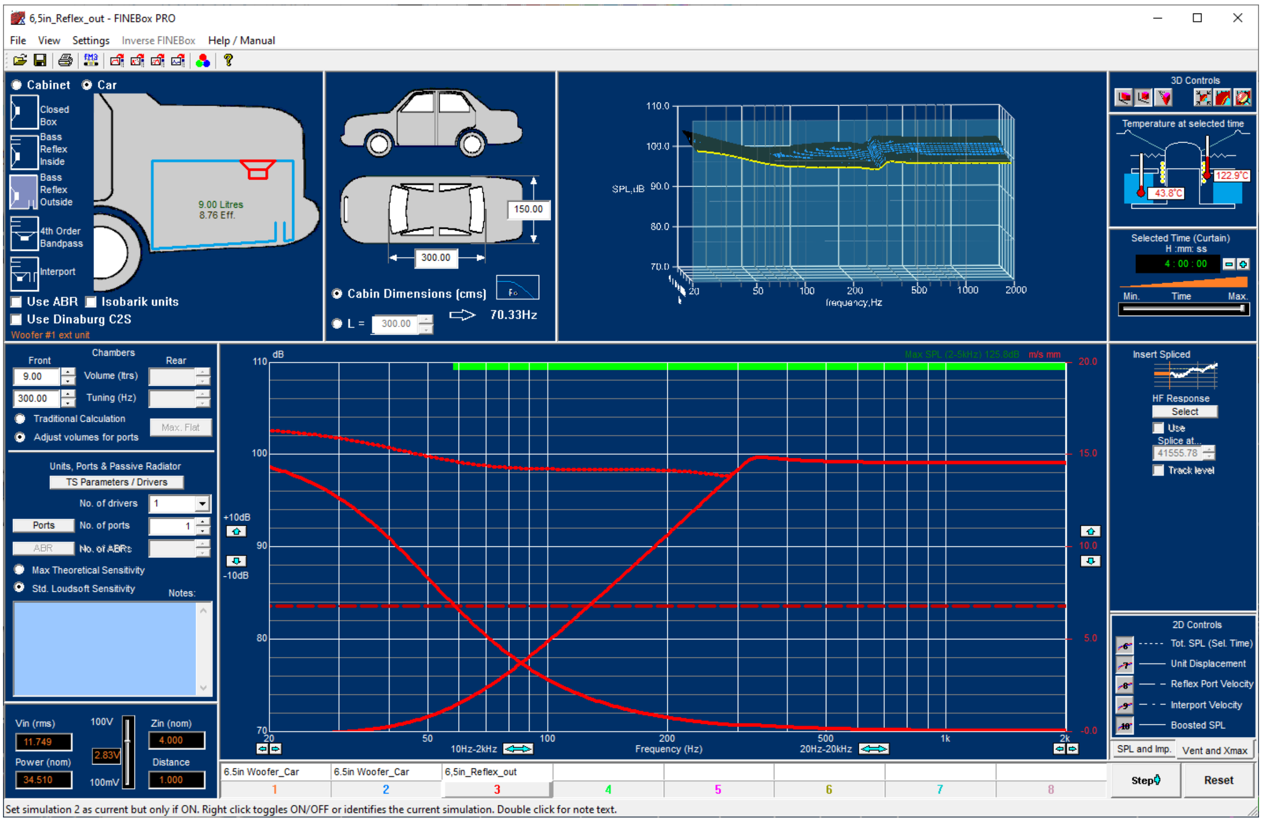



**Figure 35 - Small Bass Reflex Box with outside Port (upper curve)**

It is possible to replace the bass reflex port with a simple passive ABR, producing the same response, see Fig. 36. The rising curve (center) is the woofer without cabin gain.

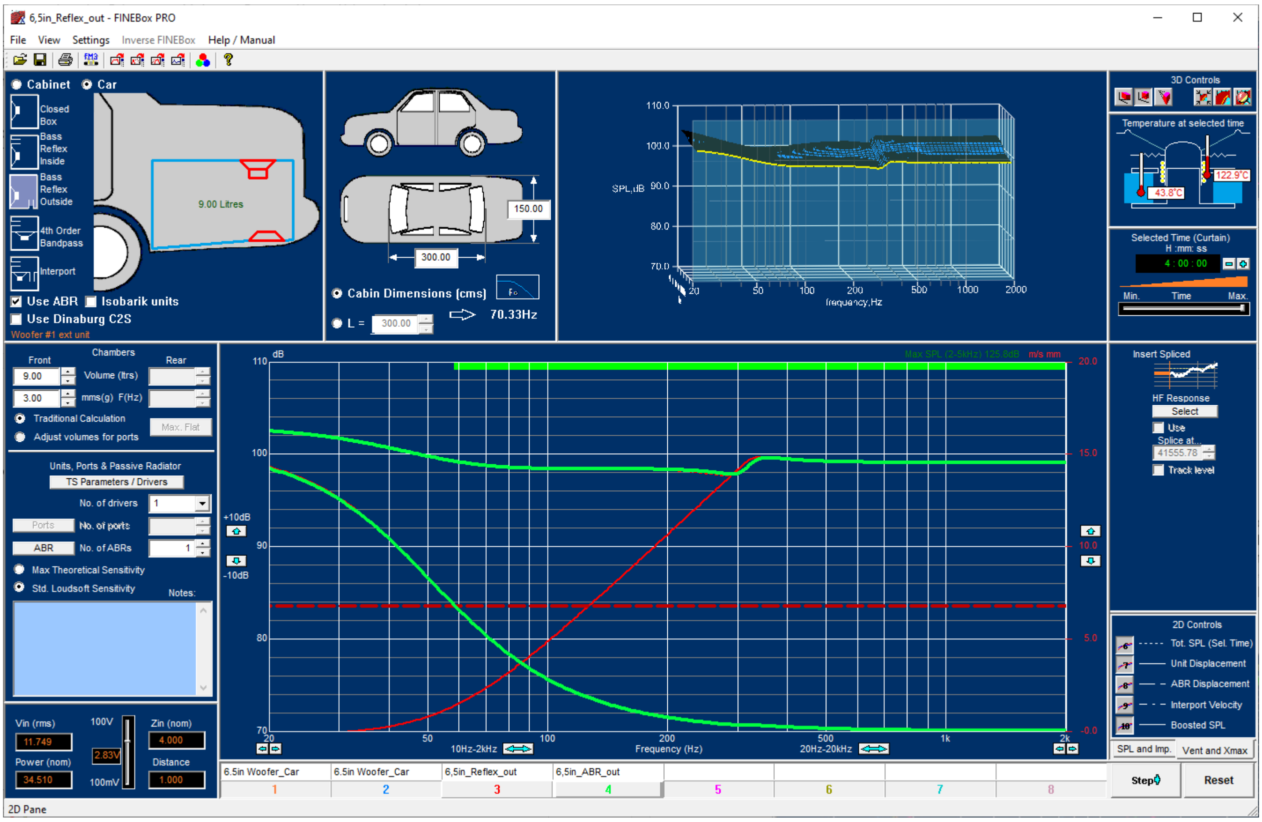



**Figure 36 - Small Box with ABR out in car**

The passive ABR unit can be designed with the ABR designer, Fig. 37.

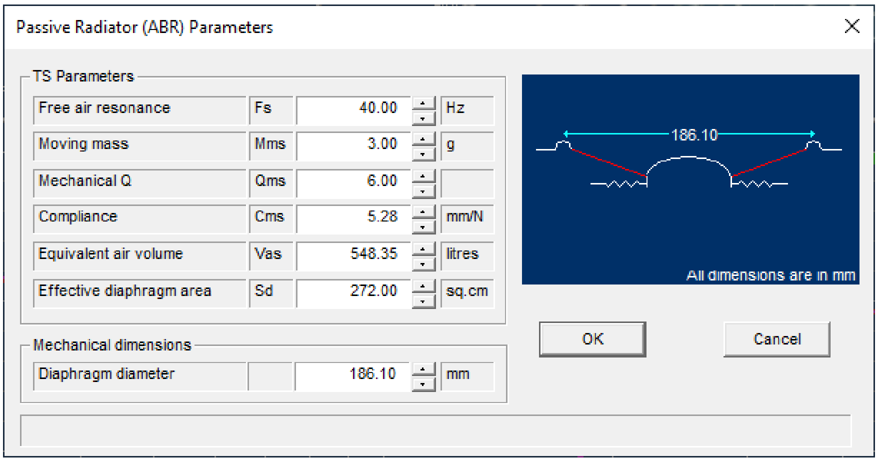



**Figure 37 - ABR Designer**

## 16.3. Example 3: Bandpass box with cabin gain

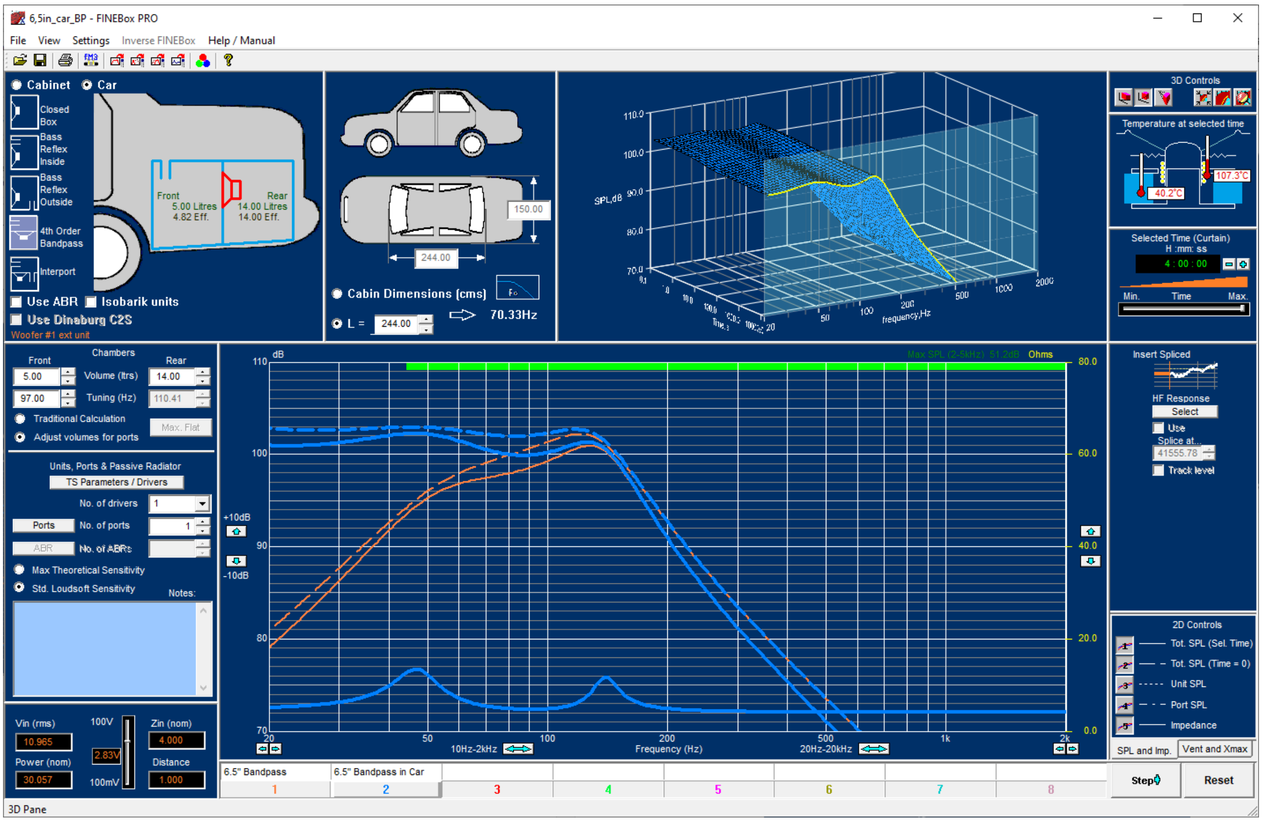



**Figure 38 - Bandpass box with cabin gain**

Fig. 38 gives the response plus High power compression for a 6.5in woofer in a Bandpass cabinet as shown upper left. The brown curve is the normal response, and the blue curve includes the cabin gain.

# 17. Band Pass Enclosure

First we will press Reset and OK to keep only the last bass reflex simulation on the screen for comparison. Then press the Band Pass alignment button. The new simulation is blue and shown by the active button #2 in Fig.39. However, this response is tilted and not good due to mistuning. Chance the tuning to 45Hz (press the step button each time to keep the old responses) and see a nice symmetrical response but with limited bandwidth. In addition, the box is quite large, 36+25 = 61L.

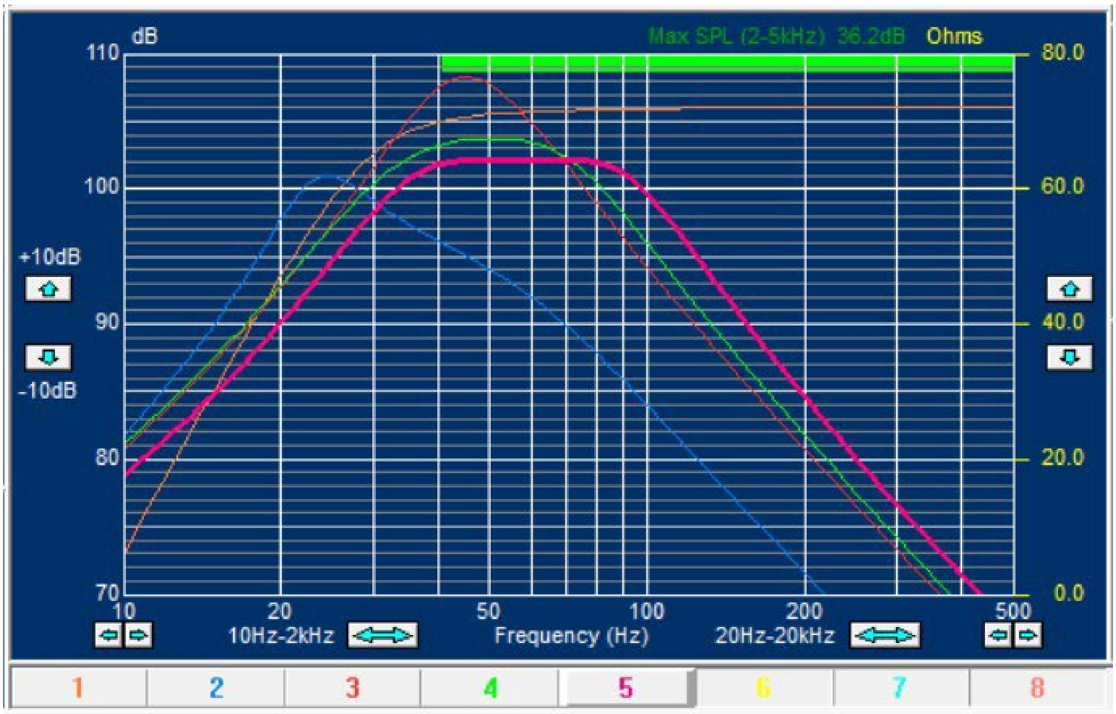



**Figure 39 - Band Pass simulations**

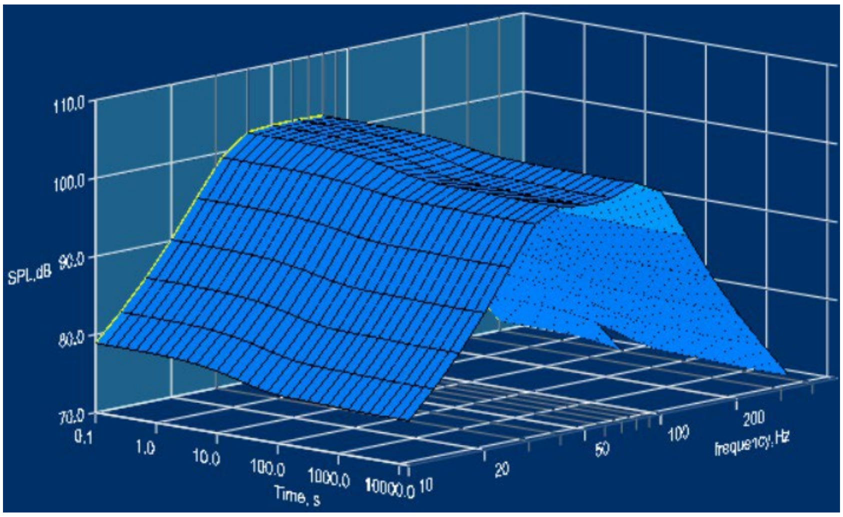



**Figure 40 - Band Pass Response has less compression**

The front volume can safely be made smaller, let us try 16 l and 47Hz tuning, which becomes simulation #4. Interestingly the low end is unchanged, and the top is much reduced in level making the response more band pass. There are several ways to design Band Pass systems, and we will only show another here. Changing the front volume to 10 l and the rear volume to 15 l plus 53Hz tuning we get a new flatter Band Pass response (#5) slightly lower in level and with more high frequency extension.

Fig. 40 shows the #5 response that maintains the Band Pass shape with high input power and has less compression.

# 18. 15-inch PRO-Sound Woofer

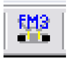
We will show how a typical 15inch PA woofer and Bass Reflex enclosure was simulated in FINEBox with regards to driver non-linearities and compression at various power levels.

The driver is Celestion Frontline 15, which has a die-cast aluminum frame, 4in/100mm voice coil and a large ferrite motor.

<u>Frontline 15 main data:</u>

| | | |
|---|---|---|
| Nominal impedance | 8 | ohms |
| Rated Power (Pink Noise) | 600 | W (rms) |
| Voice coil Travel Xmax (+/-) | 3.7 | mm |
| Voice Coil Resistance (DCR) | 6.0 | ohms |
| Force Factor | 25.6 | Tm |
| Free air Resonance (Fs) | 37 | Hz |
| Moving Mass incl. air load | 109.5 | g |
| Effective Cone Area | 855.3 | sq. cm |
| Vas | 173.6 | liters |
| Qms | 5.6 | |
| Qts | 0.22 | |

Since we have previously modelled the Frontline 15 woofer in FINEMotor, we can import the non-linear T/S parameters and thermal data directly into FINEBox by pressing the "Read Unit" button.




Use 40mm and 700 Wm/K for initial input. (This is the 15inch Reflex Box.fb1 example file).

Press the driver button to view these data, see Fig.41, which include mechanical dimensions plus voice coil and magnet system masses besides the thermal Time Constants. (For example, the voice coil Time Constant indicates the linear start of the exponential voice coil heating, i.e., like the charging of a capacitor).

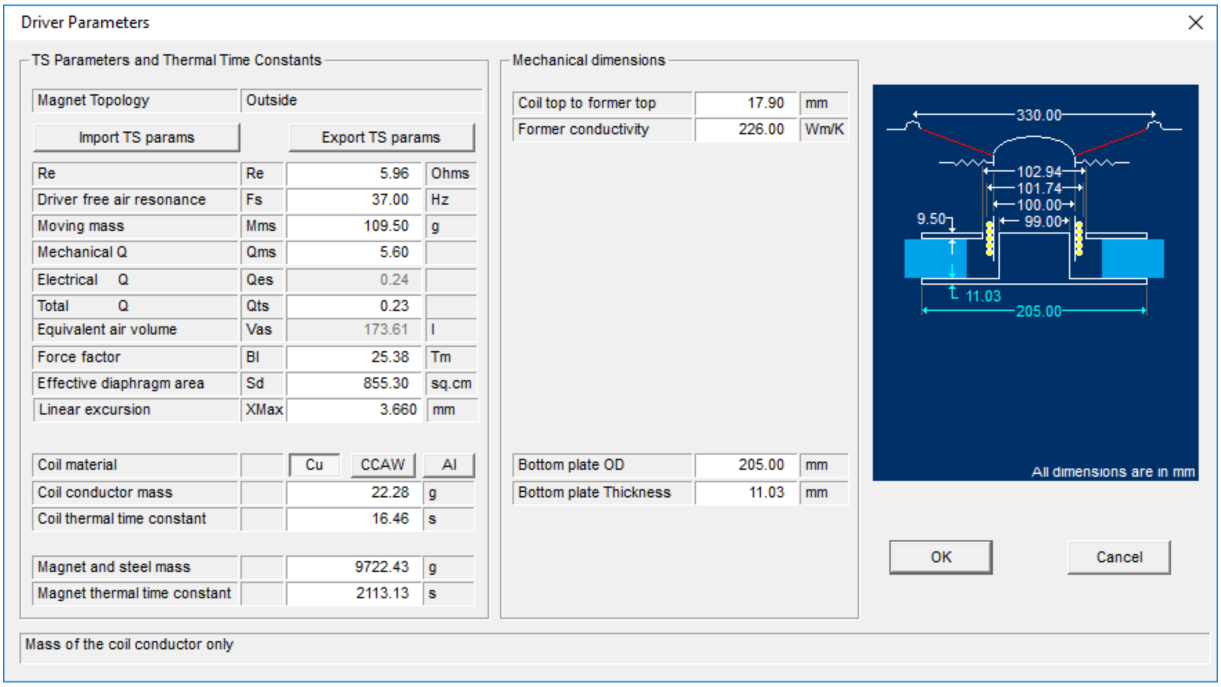



**Figure 41 - 15-inch woofer data imported from FINEMotor**

Note the (VC-) former conductivity was increased from 0.45 for Kapton to 700 Wm/K to estimate the cooling of the ø60mm pole vent. Distance from coil to former top is 40mm, and the bottom plate is tapering to 7mm, so the thickness is set to 7mm. Set power to 600W. The voice coil thermal Time Constant is 15.45 seconds compared to 1926.63 s for the Magnet (system) as shown in fig.41. So, the voice coil will heat up much faster than the motor, also because the magnet and steel mass is much higher than the voice coil mass.

Open the 15inch Reflex Box.fb1 example and select one of the 3D view buttons  and view the high-power response using the non-linear T/S parameters (Bring the response in view using the –10dB arrow). Fig.42 shows the perspective 3D view. Note the third axis, which is Time. The response on the "left rear wall" is the initial low frequency system response, which can also be viewed below on the 2D normal frequency response curve.

The blue "carpet" shows what happens with the response when the 600W high input power is applied for a long time.

# 19. Power / Time calculations with Time Curtain

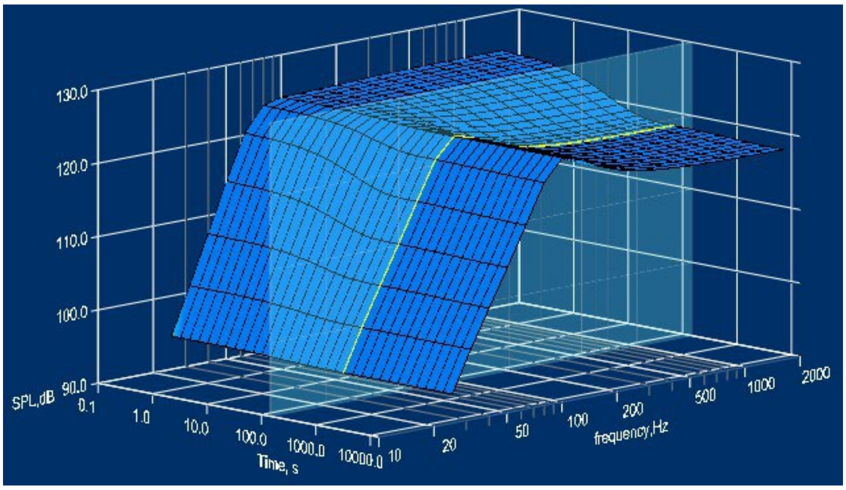



**Figure 42 - 3D Frequency / Time response with "Curtain"**

*Note1: You can rotate the 3D curve left/right and up/down by dragging! And the divider between 2D and 3D windows can move up/down.*

*Note2: The time axis is logarithmic enabling the user to see both the short voice coil time constant and the much longer magnet system time constant.*

Between 10-100 seconds the curve changes in SPL level and response shape first due to heating of the voice coil, which is increasing the DCR value, and later heating of the magnet system.

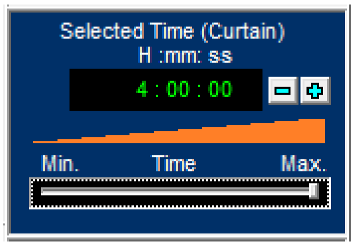



**Figure 43 - Time Curtain setting**

Fig.44 shows the "Digital Clock" used to set the time of the "Glass Layer" Curtain, to select a detailed response. Use the slider to adjust.

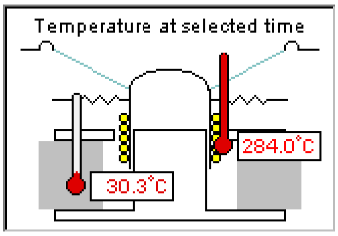
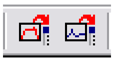



**Figure 44 - VC and motor temperatures**

Set the time Curtain at 10min10s (=610s) and the Temperature view in selected Time. Fig. 44 shows the high temperature of the voice coil (284.0C) and magnet system (30.3C). At this time the magnet system has not yet heated up. Selecting max time = 4:00:00 shows the motor + voice coil fully heated which gives a magnet system temperature of 57.2C, while the voice coil is 305.5C (from 15inch Reflex Box.fb1 example).

# 20. 15-inch Bass reflex Enclosure

Due to the very low Qts we can expect to use this woofer with a bass reflex enclosure having a volume much lower than Vas. Accepting the default volume of 25L and selecting a tuning frequency Fb of 63Hz (use the mouse wheel for easy tuning) gives a rounded QB3 type response with –3dB at 90Hz. View these details on the lower 2D frequency response, shown in fig.38. However, we would like some more bass extension. Press Step and change the volume to 44L and the new curve #2 (blue) shows a –3dB point of 65Hz and this response is quite close to a B4 (4'th order Butterworth/maximally flat).

Note: Use  to export the response + impedance to FINE X-over and here calculate the actual power with crossover. For example, the real power in this woofer would go down from 600W to 209W with one series 2.2mH inductor.

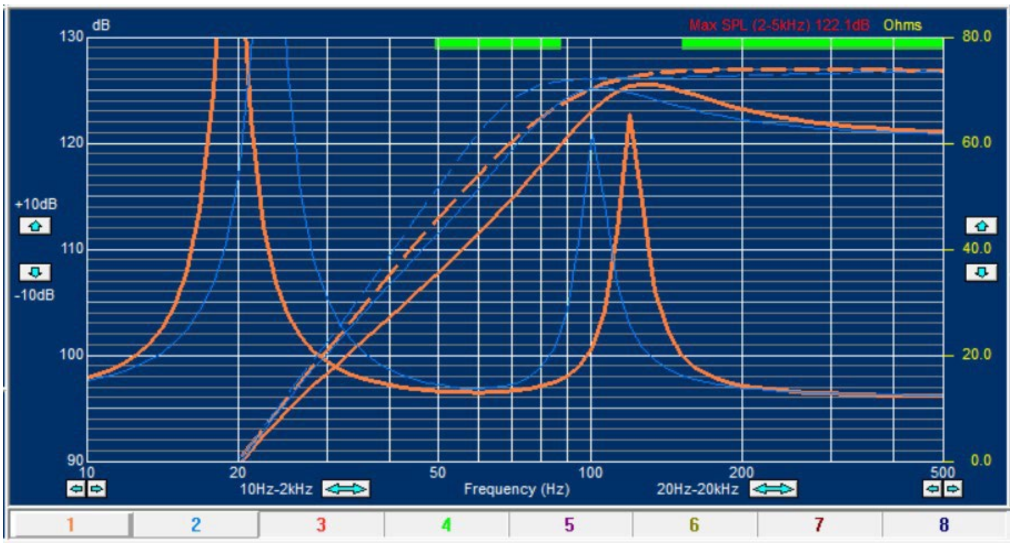



**Figure 45 - 15-inch Bass Reflex Box at 600W, 25L____/44L____**

When the [1] [2] buttons next to the 2D frequency response are selected, we also see a copy of the "curtain" frequency response i.e., the response WITH compression (solid line). At the max time (4 hrs.) and 600W power, the response is no longer flat but has a peak at 100Hz. The difference between the dashed and solid curves is the compression. The compression of the blue curve (#2) is only 1dB at 100Hz, increasing to around 6dB below and over this frequency (less due to VC inductance).

Fig.39 shows the port for the 63Hz tuning: The flange reduces port noise.

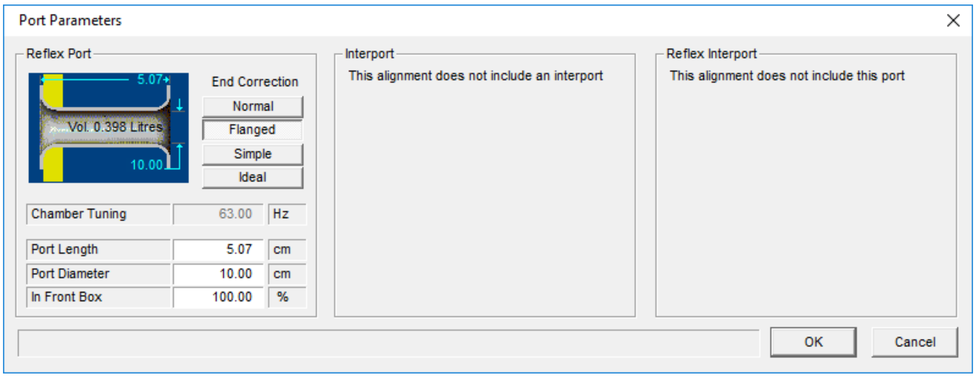



**Figure 46 - Flanged Bass Reflex Port**

# 21. 15-inch Bass reflex using Isobaric (dual) Woofers

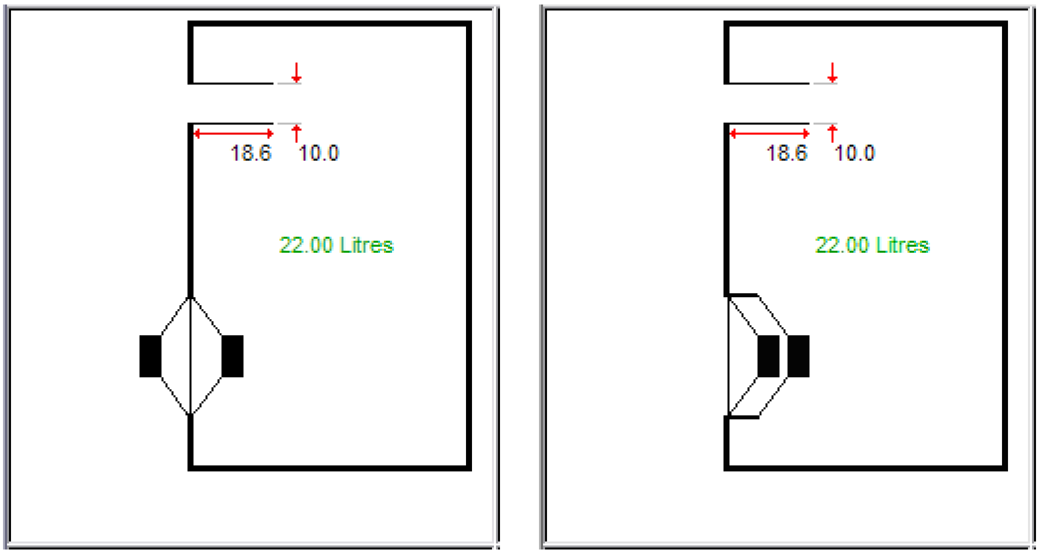



**Figure 47 - Alternative Isobaric (dual) woofers**

The isobaric concept is simply two woofers put together face to face. Two examples are shown above, and effectively the two woofers will perform as one “super-” woofer with double mass and half Vas and impedance when the two Voice Coils are connected in parallel.

The previous bass reflex box of 44 liters is shown in Fig.48 as the orange response and the red response is an isobaric consisting of two of the same 15” woofers. Note the box size is now only 22 liters due to the isobaric principle. (The red curve was moved 1 dB up for clarity).

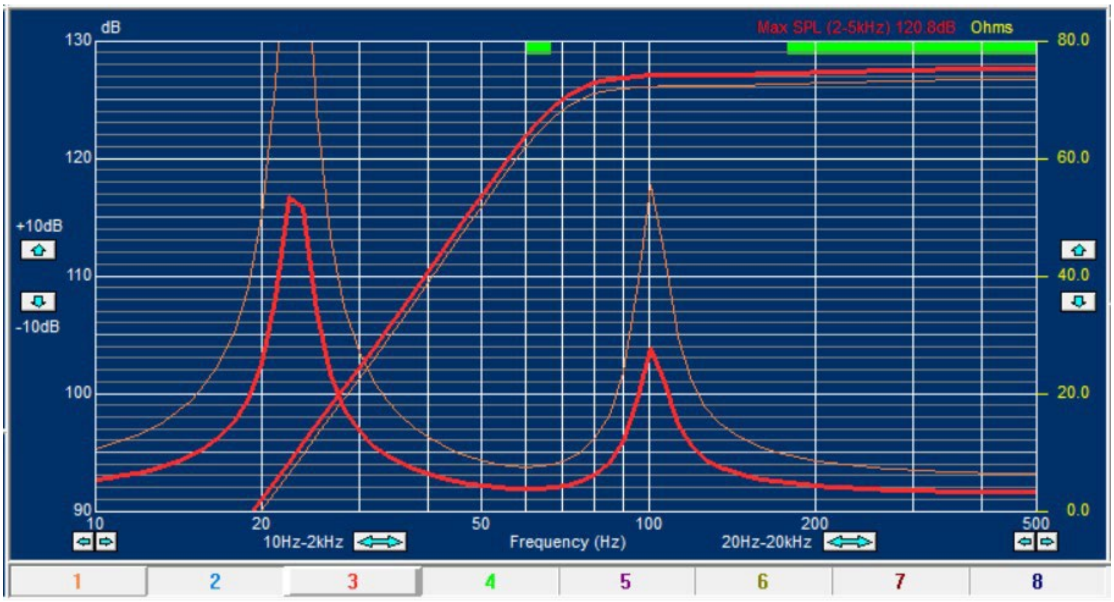



**Figure 48 - 15-inch isobaric woofer in 22L Bass Reflex Box__ (+1 dB up for clarity) / Single woofer in 44L Bass reflex Box___**

# 22. Micro Loudspeaker / Receiver Box Design

Micro loudspeakers and receivers can be designed in FINEMotor and imported into FINEBox, where the acoustic loading / box volume and tuning can be simulated.
(See the Appendix for special micro settings)

(You may go to Settings and select: Display values with extra precision xx.xxx)

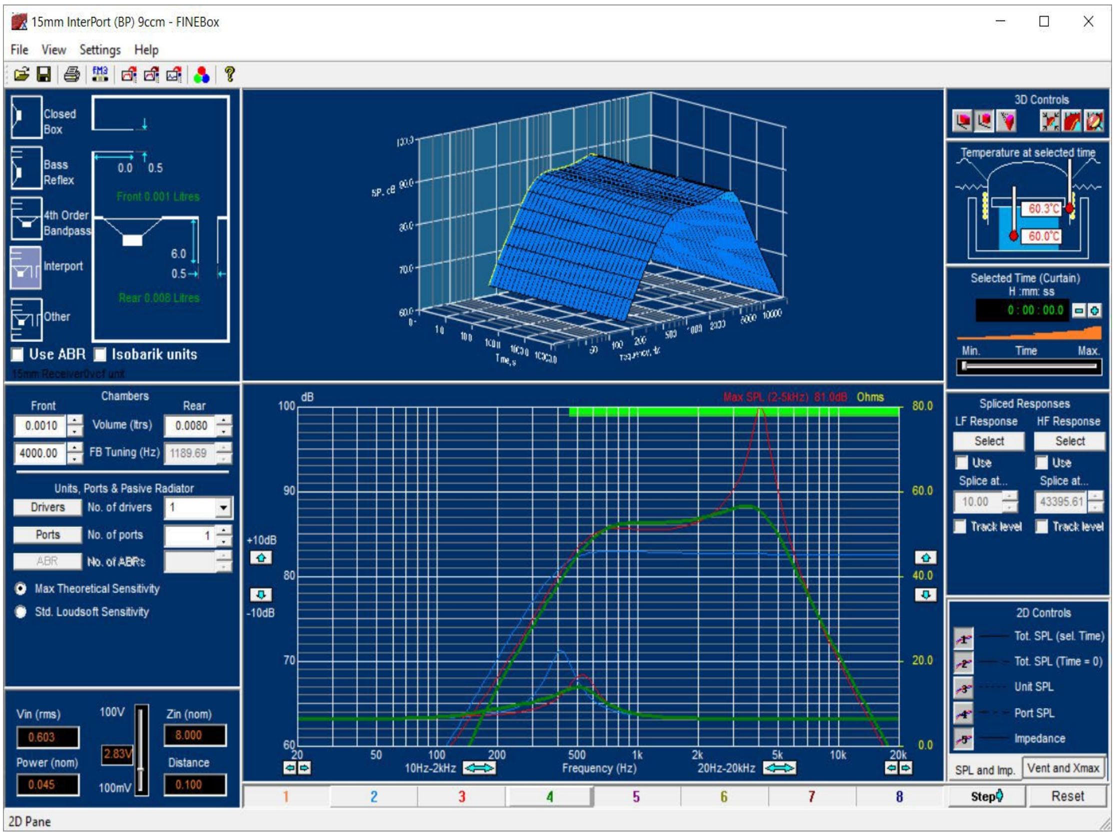


**Figure 49- 15mm micro speaker in closed___/Band pass___/ damped InterPort___**

### Sensitivity

Note that you can display the sensitivity in two different modes:

- Max. Theoretical Sensitivity (This is very useful for micro speakers)
- Std. Loudsoft Sensitivity (This is the lower conservative Loudsoft SPL)
-

*Note: The Max. Theoretical Sensitivity is using the original formula based on Re*
*The Std. Loudsoft Sensitivity is most valid for normal / Hi-Fi drivers*

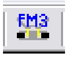
We will start a 15mm box design by importing a FINEMotor file (with T/S parameters and thermal data) directly into FINEBox by pressing the FM3 button. 

Fig. 50 defines the additional information. The first is the distance from winding to diaphragm, which here is 0 since the VC is glued directly to the diaphragm. The second number is thermal conductivity, which here is the lower number 0.45 Wm/K for isolating materials. The linear excursion Xmax=0.276mm is also imported.

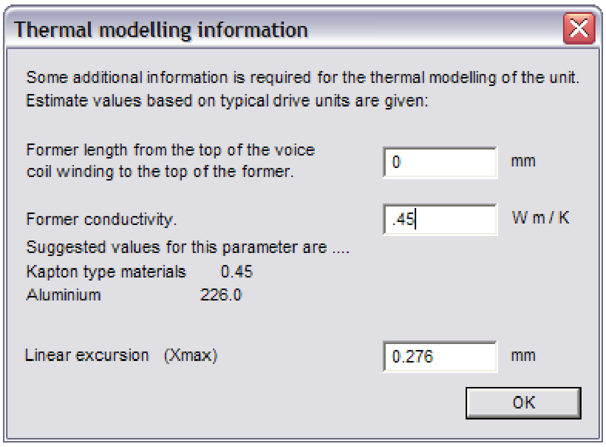



**Figure 50 - Thermal Info Input**

Fig. 51 shows the complete driver data imported from FINEMotor. The thermal time constants of the VC and motor are automatically calculated.

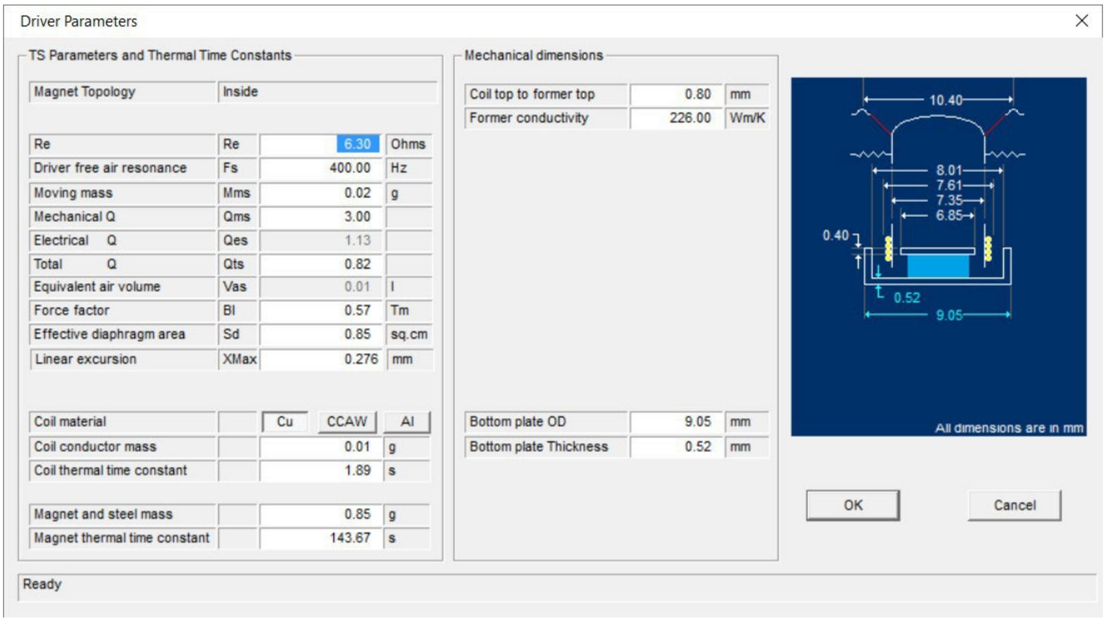



**Figure 51 - Complete 15mm micro speaker data imported from FINEMotor**

The FINEMotor FM3 import takes advantage of the high-power thermal calculations of VC temperature, motor temperature, power compression etc.

Now the 15mm micro speaker/receiver unit is placed in a closed box volume of 0.1 L (100ccm) by selecting the upper left button “Closed Box” and adjusting the (Front-) volume to 0.100 L by rolling the mouse wheel. This is shown as the blue curve in Fig.55 (Button #2).

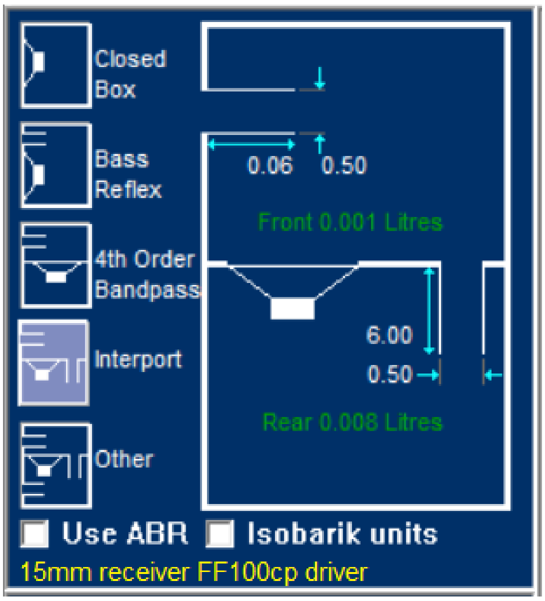



**Figure 52 - FINEBox Acoustic Loadings**

The blue curve (#2) has an impedance peak close to 400 Hz, which is the resonance Fs. The input voltage was adjusted to give an Xmax excursion of 0.28mm, (= Xmlin: max excursion with VC still in the gap). This gives a max SPL of 81dB at 0.1m defined by the frequency range indicated by the green line.

In contrast the red curve #3 is a bandpass design with a small hole (port) in front of the speaker. This port is tuned to 5000 Hz after which the response drops at higher frequencies. Again, the input voltage was adjusted to give a max excursion of 0.28mm, giving a max SPL of ~83.7 dB at 0.1m. However, there is a very large peak at 5000 Hz.

Choosing the InterPort option in Fig.45 and adjusting the InterPort Q to 0.9 as shown in Fig.53 brings down the peak and gives a quite flat bandpass response. The high damping (lower Q) is made by covering the (inter-) port with a cloth or felt, which will pass air but add damping. The front port can be damped in the same way. Max SPL (2-5 kHz) is dB.

The VC and magnet temperature are in the upper right picture. The VC is at 28.9C which is no problem. See the next two sections regarding high power simulations.

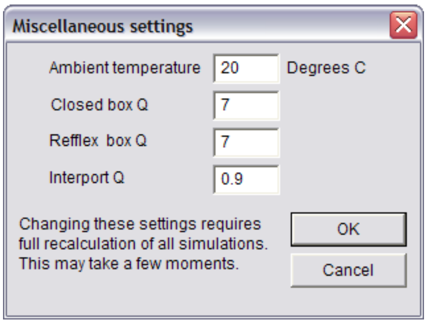



**Figure 53 - Setting of Port Q and damping**

The ports can be changed by modifying the port diameters as done in Fig.54 and the length will automatically be calculated according to the chosen tuning frequency. A flange (trumpet-like design) can reduce port noise/whistling.

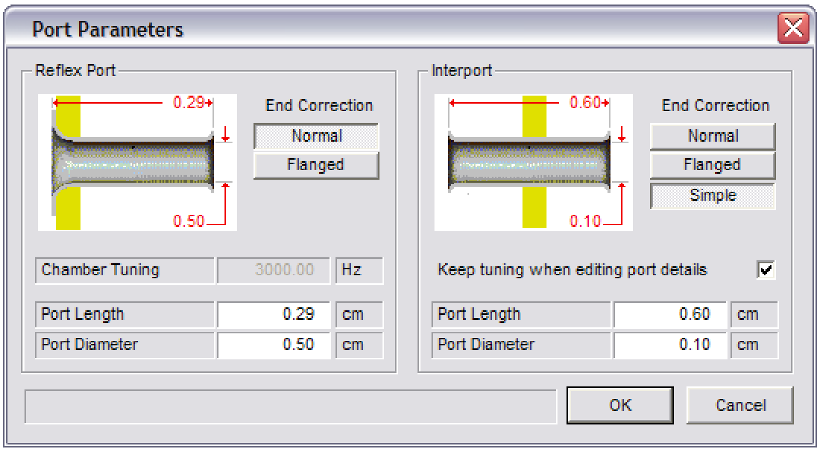



**Figure 54 - Change of Port diameters and calculated lengths**


**Figure 55 - Excursion of 15mm closed/Band pass/InterPort**

Fig. 55 shows the VC excursion of the 3 designs, where the input was set to produce 0.28mm (Xmlin) at the resonance frequency (Fs) in the box. Because the excursion is increased at low frequencies, the design with the higher box resonance (green #4) can produce a higher SPL in the pass band. To prevent problems, it is advisable to insert a high pass filter to limit the low frequencies below Fs.

# 23. InterPort Enclosure

Now let us test an InterPort design. A front volume of 20 l and 15l rear tuned to 65Hz works fine (#6). The sensitivity is high but with less low frequency extension Fig. 49.

Note the displacement of the band pass design #6 in Fig.56, which exceeds Xmax (dashed horizontal line close to 7mm) below 53 Hz indicated by the upper green wide line. #5 is below Xmax down to 40 Hz, which is clearly better.

The InterPort displacements are high at low frequencies, like the previous bass reflex. However, the energy content of normal music is reduced below 20-50Hz, which will limit the displacement.


**Figure 56 - Band Pass and InterPort unit displacements**

Press the Ports button to design the InterPort. Choose between normal and flanged port like the bass reflex, but in addition a simple port may be selected. Note the option to keep tuning when editing port details.

# 24. Multiple Drivers and Ports or ABR’s

Sometimes it is an advantage to use more than one driver in a box. You can select up to 4 drivers connected in different ways, see Fig.57.

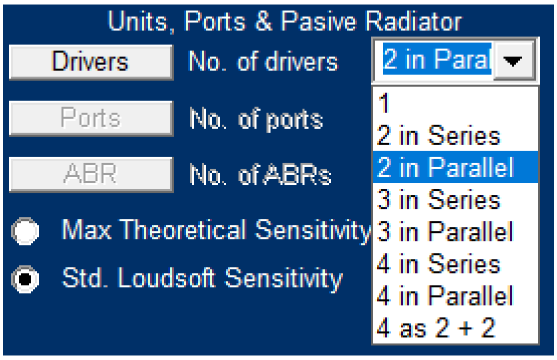
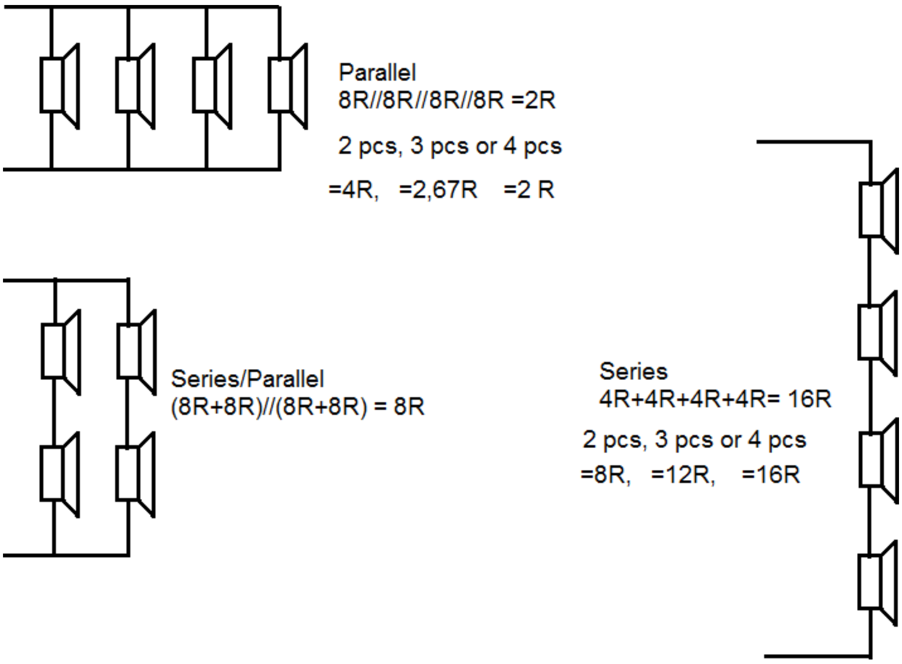



**Figure 57 - Driver (Unit) combinations**

Below are examples of 4 drivers in Parallel, Series and Series/Parallel (2 +2)



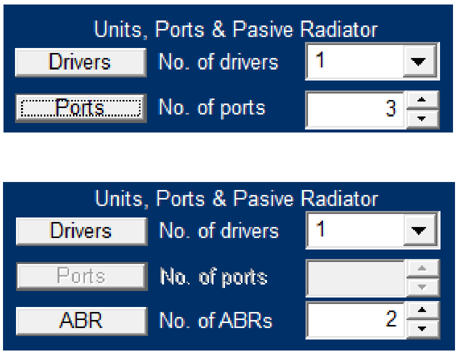



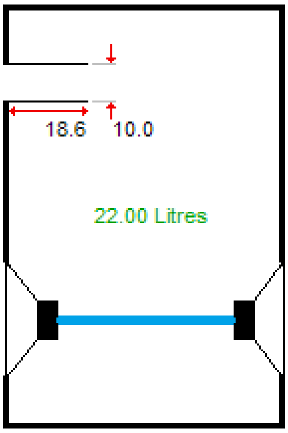

**Figure 58 - Set number of Bass Reflex Ports or ABRs**

# 25. Push-Pull Box

FINEBox can simulate the Push-Pull configuration using two woofers, one in front and the other in the back of the same box, electrically coupled in series or parallel.

In this Push-Pull configuration they are in phase (both + to +) and produce +6dB SPL with the same input voltage. This works well for low frequencies and will cancel at high frequencies when the ½ wavelength is equal to the path difference.

They can be placed opposite, and may be fixed with a steel rod, to cancel the vibrations.




# 26. Spliced Simulated + Measured Responses

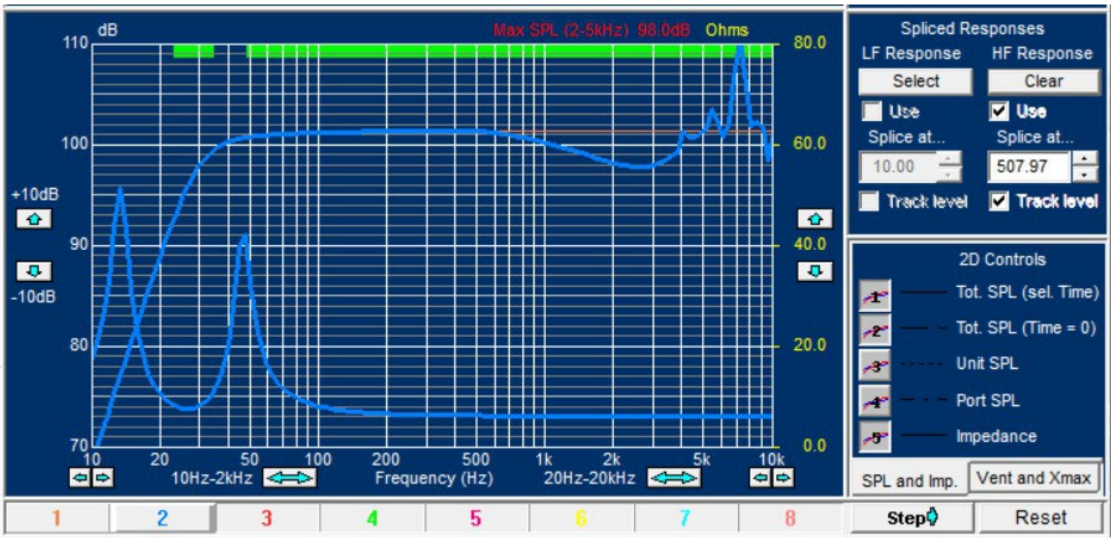



**Figure 59 - Simulation with spliced response from 500 Hz**

Further it is possible to mix a simulated response with a measured one from, for example FINE R+D, or a simulated response from other software simulations, see Fig.59. Here the simulated response is the 6_5 Woofer Large Dust Cap. FSIM was spliced to the FINEBox 8inch bass reflex simulation at 500 Hz. In addition, the level was matched (at 500 Hz) by checking the Track level box [x].

The magnitude of the combined response may even be exported, for example to FINE X-over. Export the combined response in the FSIM format, which can be read by other FINE programs, by pressing the button. 

# 27. Printing - Summery

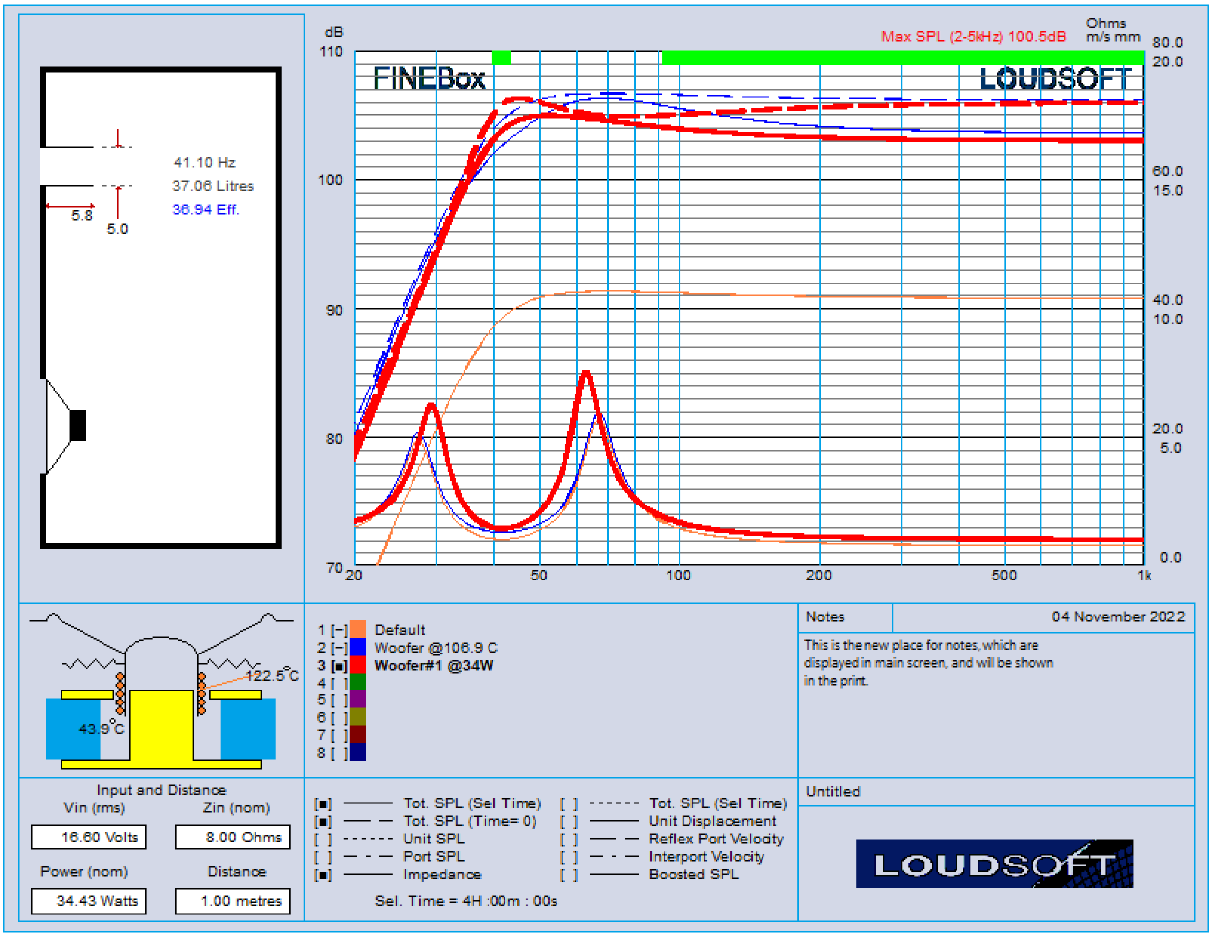



**Figure 60 - New Summery PRINT with all main information (Main notes are shown)**

The new summery print Fig. 60 is set by default Fig. 61.

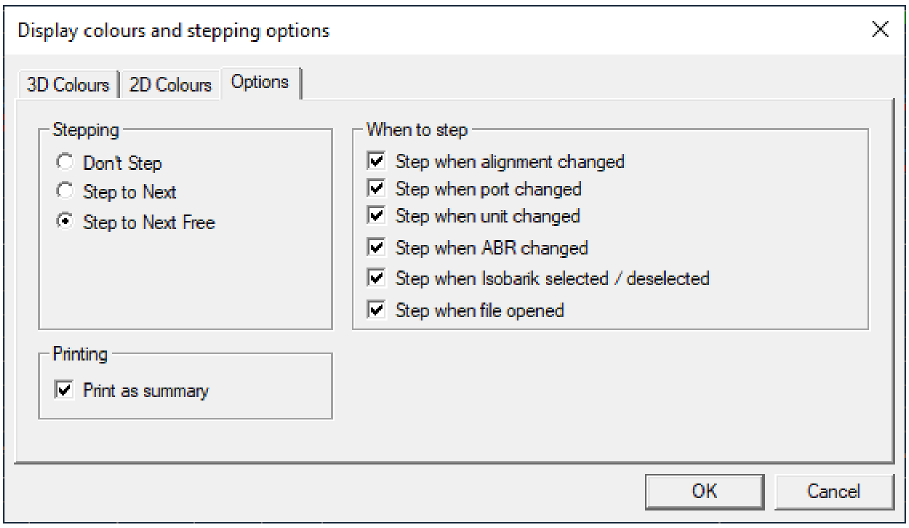
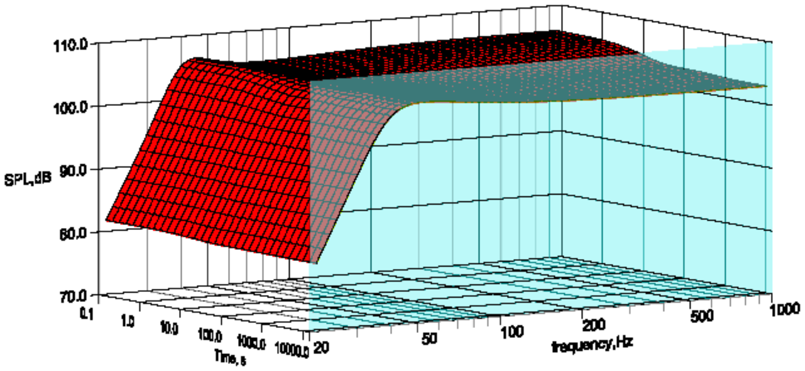



**Figure 61 - Select Summery print as default in Settings**




| Drive Unit Details - Woofer #1 unit | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outside magnet | | | | Top plate OD | | 78.00 | mm |
| Free air resonance | Fs | 45.00 | Hz | Top plate thickness | | 6.00 | mm |
| Force factor | Bl | 5.75 | Tm | Top plate ID | | 33.95 | mm |
| Moving mass | Md | 16.32 | g | Coil OD | | 33.35 | mm |
| Mechanical Q | Qms | 6.00 | | Former ID | | 32.00 | mm |
| Voice coil resistance | Re | 3.00 | Ohms | Pole OD | | 31.50 | mm |
| Effective radiating area | Sd | 136.00 | Sq cms | Magnet OD | | 90.00 | mm |
| Linear excursion | Xmax | 5.285 | mm | Magnet ID | | 36.00 | mm |
| | | | | Magnet length | | 17.00 | mm |
| Copper coil | | | | Bottom plate OD | | 78.00 | mm |
| Mass of conductor | | 5.32 | g | Bottom plate thickness | | 6.20 | mm |
| Voice coil thermal TC | | 17.24 | s | | | | |
| Mass of the motor | | 985.42 | g | | | | |
| Motor thermal TC | | 1076.30 | s | | | | |
| Coil top to former top | | 13.50 | mm | | | | |
| Former conductivity | | 0.45 | Wm/K | | | | |

**Figure 62 - Print with driver details, available when Summery print is de-selected**

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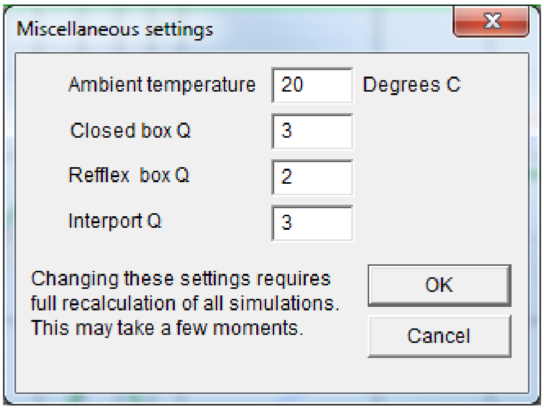
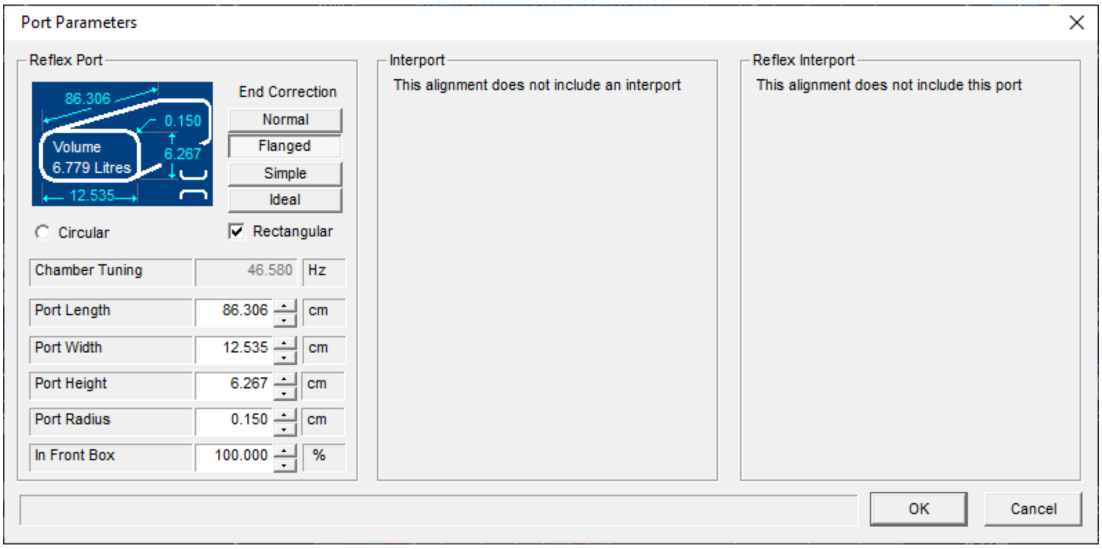
# A. Appendix: Special settings for Micro Speakers

This version will import fm3 files from FINEMotor 2012 and up.

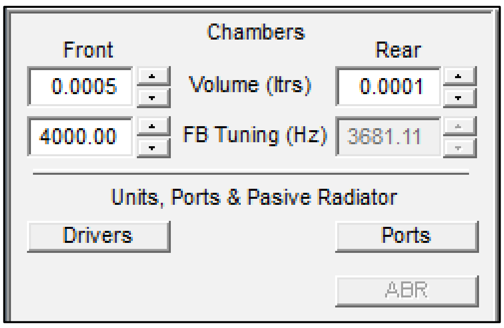



Q values can now be lower than 3, to simulate ports with cloth etc.




**Ports:**

Normal One flange with correction
Flanged Two flanges with correction
Simple No flanges with correction
Ideal No flanges without correction (use for small channels)




Volumes down to 0.0001L (=0.1ccm) – Use mouse wheel to step through range.