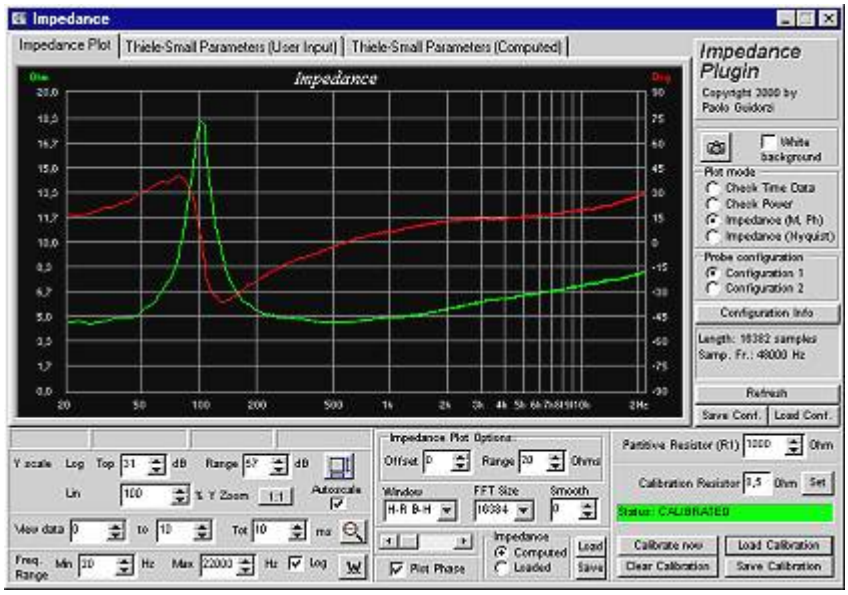
Sample Champion - Application note # 16

Impedance measurement and Thiele-Small parameters computation

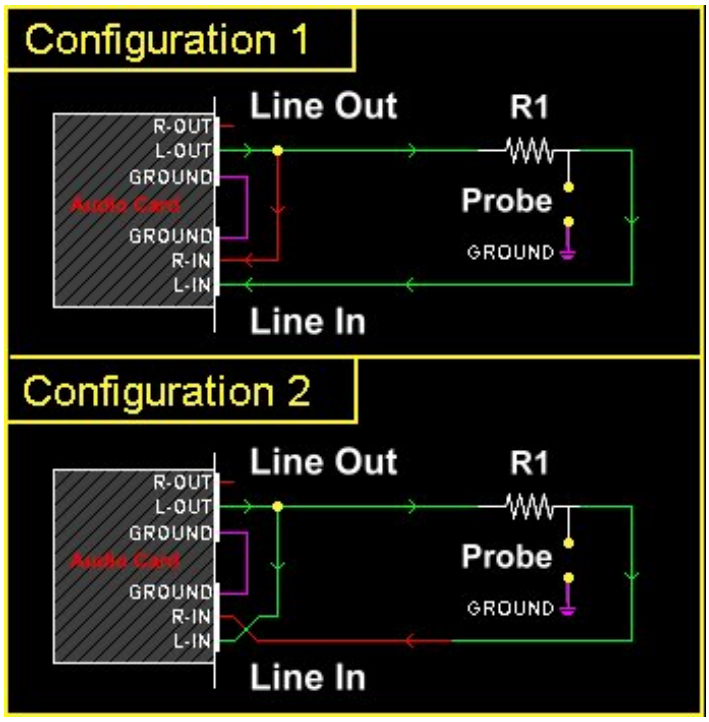
This application note describes the use of the Sample Champion **Impedance** Plugin. This module allows measuring Loudspeaker impedance by means of a single 2 channel impulse response measurement and the computation of Thiele-Small parameters.



Impedance plugin main window

This measurement requires a minimal external equipment: just two resistors! One must have a value around 1 KOhm, the other one must have a low value (around 8 Ohm). The resistance of the low value resistor must be known exactly because it is used for calibration.

The plugin accepts two different configurations for the connection of the device under test (loudspeaker).



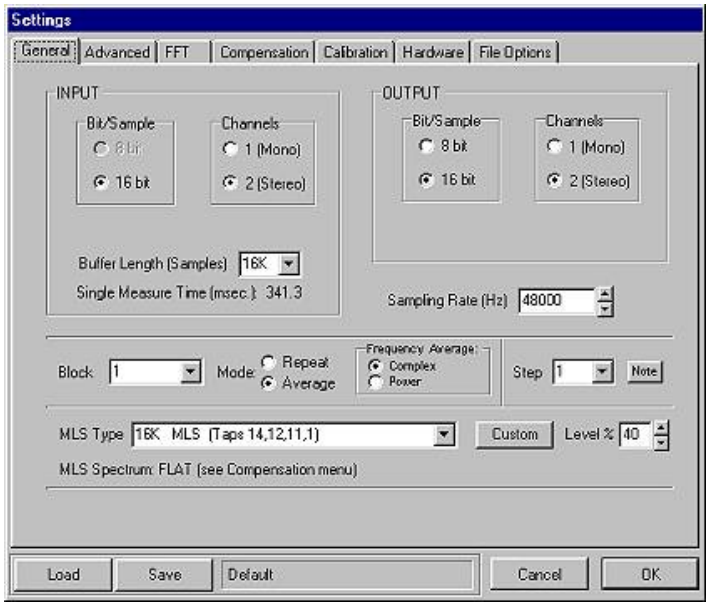
Allowed configurations

Basically, one channel output is connected directly to one channel input and the other one measures the impedance by means of a simple partitive network. The following examples refer to the first configuration.

The calibration resistor or the loudspeaker must be connected to the **Probe** terminals, as shown in the figure above.

The main program must be set for performing a 2 channel measurement; just a single cycle measure is usually sufficient.

For example the following settings could be used:



Impedance settings

The Impedance measuring procedure is now explained in detail. After the first time, you'll be able to perform an impedance mesurement in a few seconds...

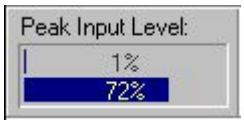
Step by step procedure for the Impedance measurement:

- Select, in the main program, an appropriate setting for Impulse Response measurement. The MLS length can be also lower than 16K. The input mode must be Stereo, the output mode can be mono or stereo.

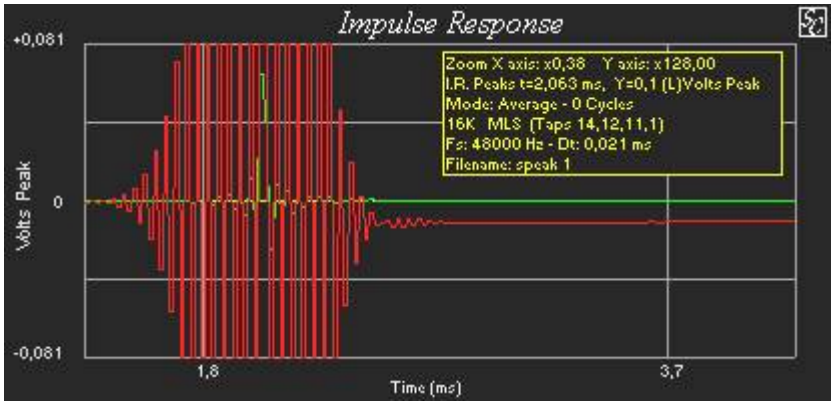
- Open the Impulse Response window in the main program

- Connect the **calibration resistor** to the probe terminals, following the scheme in the figure above

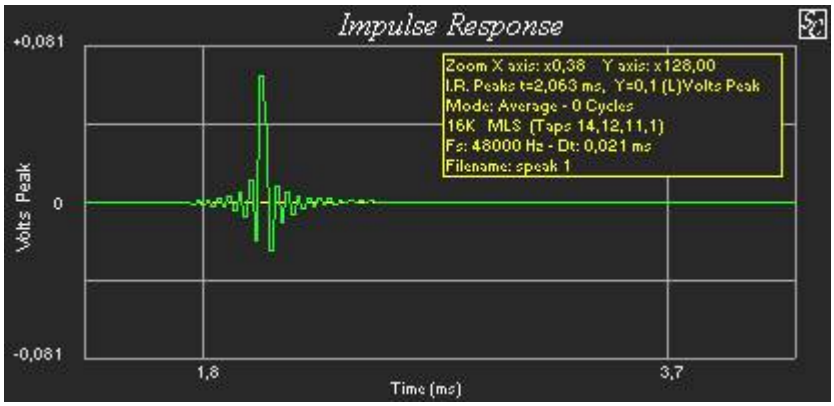
- Make a test measurement (Syncro Start/Stop MLS and Sampling) and set appropriate input and output levels with the internal (or external) mixer, in order to obtain a clean and undistorted 2 channels impulse response. Using configuration 1, during the measure, the peak level meter should show something similar to:



If the upper meter (the left channel) has values higher than 1-2%, check the contacts between the calibration resistor and the probe points. Also 0% indicates good measure (even better) because here very low levels are involved. Check in the Impulse Response window the 2 measured responses zooming the amplitude axis. The result should resemble the following:



The 2 channel measurement (amplitude zoom 128x)

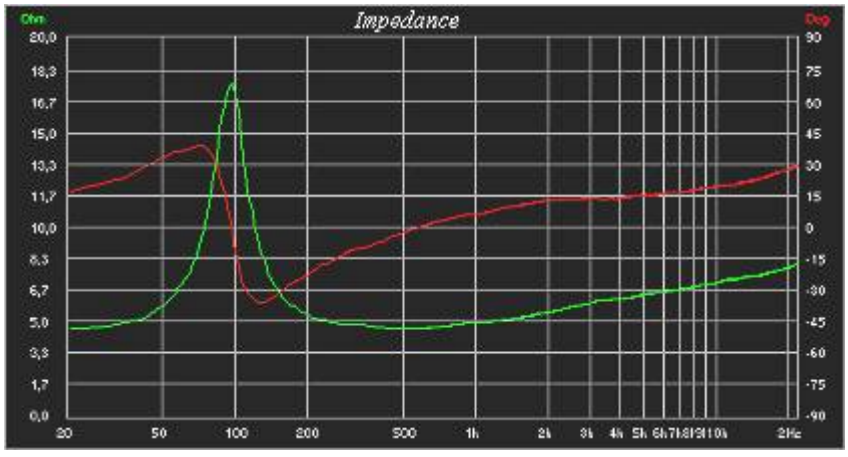


The same figure, where the right channel plot (red) has been disabled. Note that the left channel (green) has a peak value much lower than the right one

- Now open the Impedance plugin and press F5 to transfer the measured data from the main program to the plugin. The 2 impulses and their frequency spectrum can be plotted also in the plugin (with the selector at the right of the display) for checking the measurement correctness.

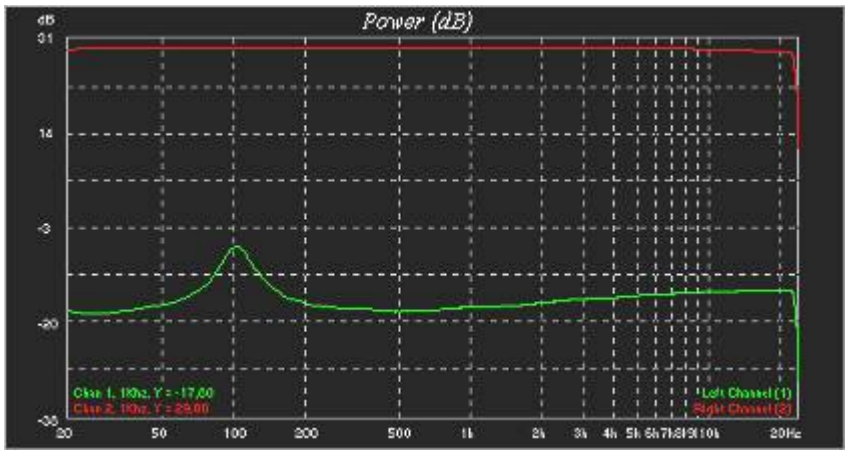
- Start a new stereo impulse response measurement in the main program (keeping open the impedance plugin) and press F5 to get the data. Now set the view mode to **Impedance (M, Ph)** and, if all has gone in the right way, a raw flat green line (the impedance magnitude) will be plotted. Also a raw red curve (the impedance phase) will be plotted; if the phase is almost flat, you have an high quality soundcard. Anyway all soundcard defects can be compensated by pressing the **Calibrate Now** button in the plugin. This action will normalize the impedance magnitude to the calibration resistor value (for example 8.5 ohm) and will zero all phase deviations.

- Now replace the calibration resistor with the loudspeaker and perform a new measurement. The following is an example:



The impedance magnitude is plotted in green and the phase in red

If the measure is not satisfactory, check the spectra to locate the problem. The following is an example of good spectra:



Frequency spectrum check (red = right channel, green = left channel)

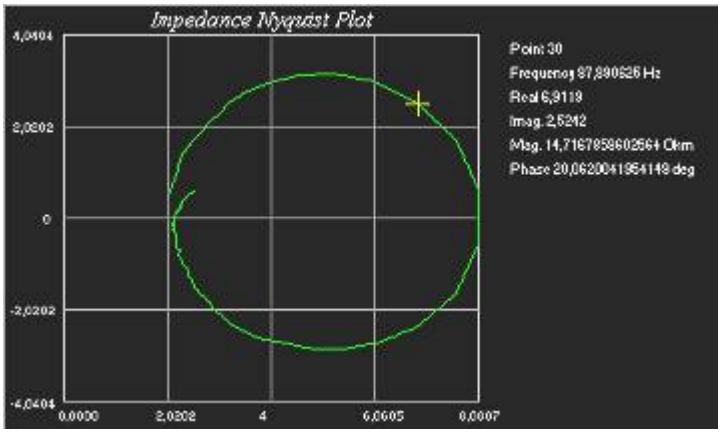
- The measured Impedance can be computed at different frequency resolutions (FFT from 4K to 64K points), data windowing and smooth factors. In most cases 16K points FFT can be sufficient; it can be also lower if the sampling frequency is low. If the plotted resonance, usually placed around 50-100 Hz, is not smooth, the FFT size in the plugin must be increased or the sampling frequency in the main program must be decreased. Normally the smooth factor setting can be left at zero.

- The computed Impedance can be saved. Note that the data are saved at the current frequency resolution. Also the calibration can be saved but it is recommended to repeat the procedure every time before loudspeaker measurement because changes in the audio device level settings and other factors can invalidate the previous calibration.

- The plugin can work on loaded Impedances or on Impedances computed using impulse response data measured in the main program. When an Impedance is loaded, the selector below becomes yellow:

Note that the frequency resolution of loaded impedances cannot be changed. When an Impedance file is loaded, the calibration is cleared.

The Impedance can be shown also as a Nyquist Plot:



Impedance Nyquist Plot

IMPORTANT NOTE: remember that any loudspeaker acts like a sensible microphone! Perform the Impedance measure in a very quiet environment and place it away from any source of vibrations (for example the table where the computer is placed). Otherwise you will get a poor measure, affected by spurious oscillations and peaks. If the background noise cannot be eliminated, an average of 4-8 measures can help. In extreme cases the smooth factor can mask small peaks, when they cannot be eliminated in other ways.

Thiele Small parameters computation:

The plugin can compute the following parameters:

- **Fs** = Resonance frequency
- **Zmax** = Impedance at resonance
- **Le** = Inductance at 1KHz
- **Qms** = Mechanical Q
- **Qes** = Electrical Q
- **Qts** = Total Q
- **Mmd** = Cone mass
- **Mms** = Dynamic mass
- **Cms** = Compliance
- **Rms** = Mechanical resistance
- **BL** = Force Factor
- η_0 = Acoustic reference efficiency
- **Vas** = Equivalent volume
- Reference Sensitivity
- Sensitivity

The computation can be performed on loaded or measured impedances. In order to compute the Thiele Small parameters, some input data must be set:

- The **DC driver resistance Re** (usually measured with an ohmmeter). It is possible also to get this value automatically, using a low frequency impedance value, but a separate measure is recommended.

- The **driver cone surface Sd**. The plugin allows also to enter the cone **diameter d** and compute automatically the surface area.

Two methods are implemented for the computation of the parameters:

- The **Delta Mass** method

- The **Delta Compliance** method

A first Impedance measurement must be performed with the driver standing at free air.

For the **Delta Mass** method, a small mass is attached on the cone and a second Impedance measurement is performed. The weight of the **added mass Ma** must be set in the plugin.

For the **Delta Compliance** method, the driver is mounted in a test box and a second Impedance measurement is performed. The **test box volume Vt** must be set in the plugin.

If the **Delta Mass** method is used, a dummy value for the test box volume can be set. If the **Delta Compliance** method is used, a dummy value for the added mass can be set.

Now an example of T-S parameters computation is shown, using Impedances saved on files. The same procedure can be followed for measured impedances.

Download the Impedance files used in the example (see application note on the website).

The following files are used:

- Speak1_free_7.5 liters.txt (free standing driver 1)

- Speak1_box_7.5 liters.txt (driver 1 mounted in a 7.5 liters box)

- Speak2_free_20 grams.txt (free standing driver 2)

- Speak2_mass_20 grams.txt (driver 2 with an added 20 grams mass)

- ImpedConfig.INI (plugin configuration and Re, Sd, Ma, Vt)

Step by step procedure for the Thiele Small parameters computation:

Delta Mass method:

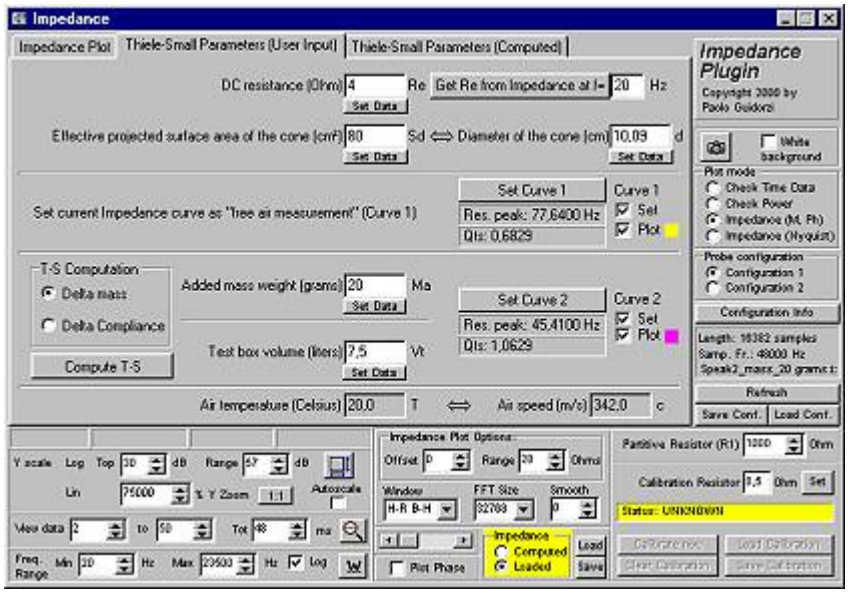
- Set **Re**, **Sd**, **Ma** and **Vt** in the plugin (or load the configuration file **ImpedConfig.INI**)

- Load the ***free standing*** measurement **Speak2_free_20 grams.txt** and press the **Set Curve 1** button in the plugin

- Load the ***added mass*** measurement **Speak2_mass_20 grams.txt** and press the **Set Curve 2** button in the plugin

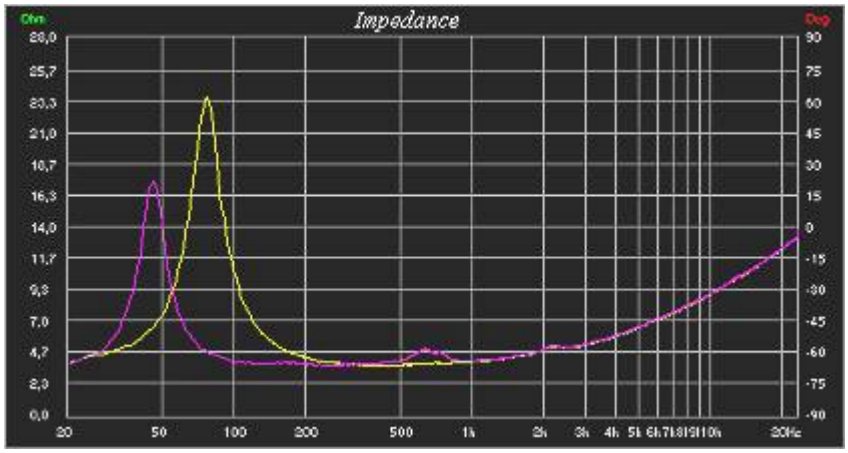
The method (Delta Mass or Delta Compliance) is automatically selected on the basis of the selected curves resonance peaks.

The window must look like the following:



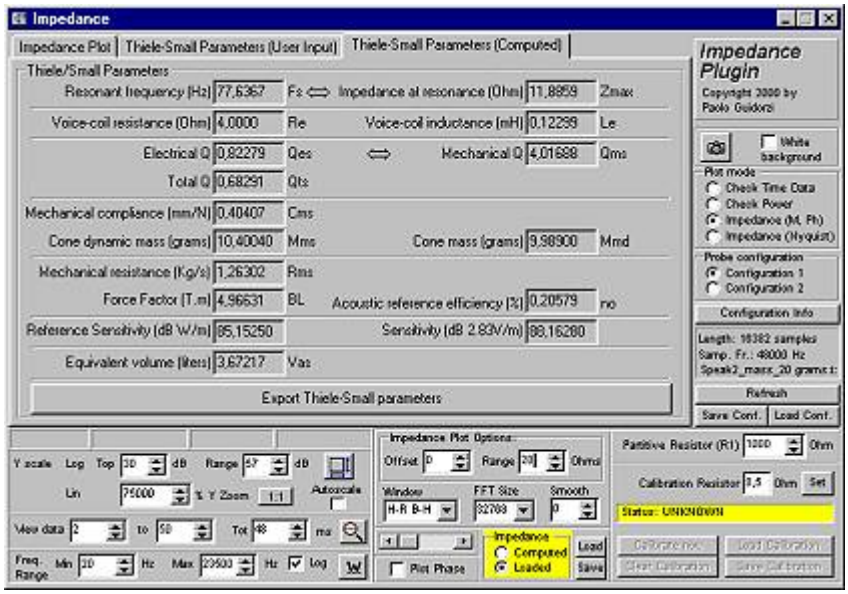
Delta Mass configuration

The 2 Impedance curves can be plotted:



Curve 1 (yellow) and Curve 2 (purple)

- Press the **Compute T-S** button and that's all! All the computed Thiele Small parameters will be shown:



Thiele Small parameters computed by means of Delta Mass method

The computation by means of the Delta Compliance method is quite similar:

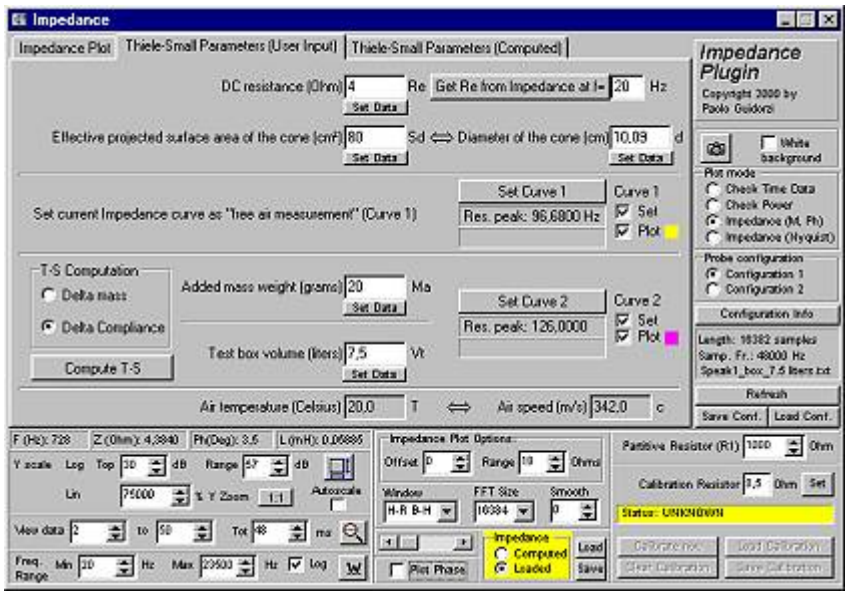
Delta Compliance method:

- Set **Re**, **Sd**, **Ma** and **Vt** in the plugin (or load the configuration file **ImpedConfig.INI**)

- Load the ***free standing*** measurement **Speak1_free_7.5 liters.txt** and press the **Set Curve 1** button in the plugin

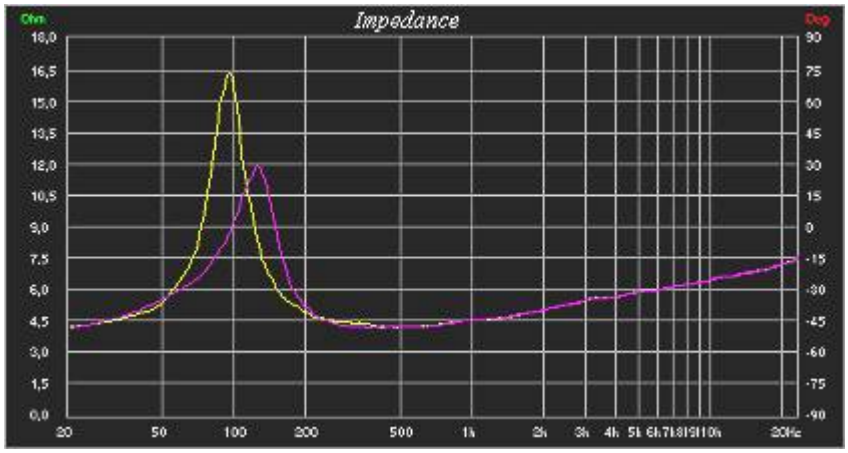
- Load the ***mounted in a box*** measurement **Speak1_box_7.5 liters.txt** and press the **Set Curve 2** button in the plugin

The window must look like the following:



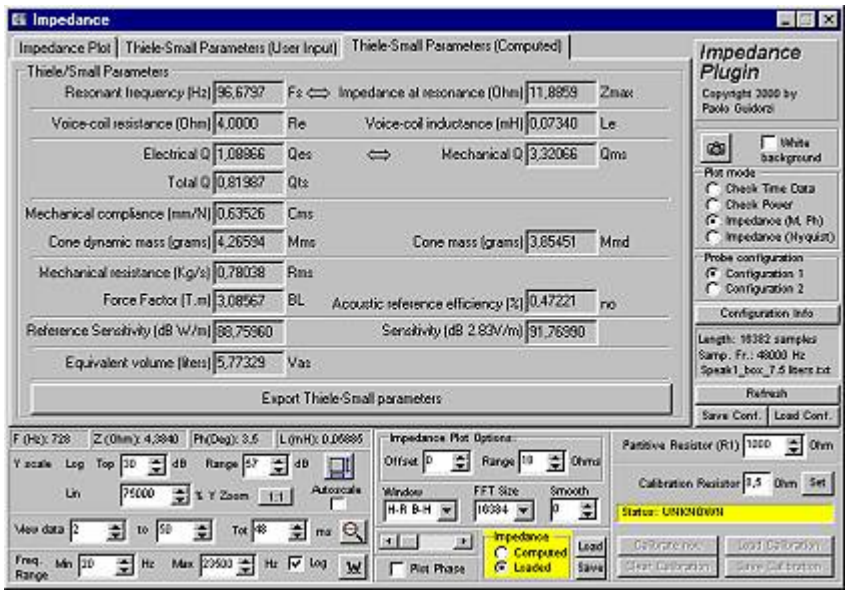
Delta Compliance configuration

The 2 Impedance curves can be plot:



Curve 1 (yellow) and Curve 2 (purple)

- Press the **Compute T-S** button and that's all! All the computed Thiele Small parameters will be shown:



Thiele Small parameters computed by means of Delta Compliance method

IMPORTANT NOTE: the 2 impedance curves used for T-S computation **must**:

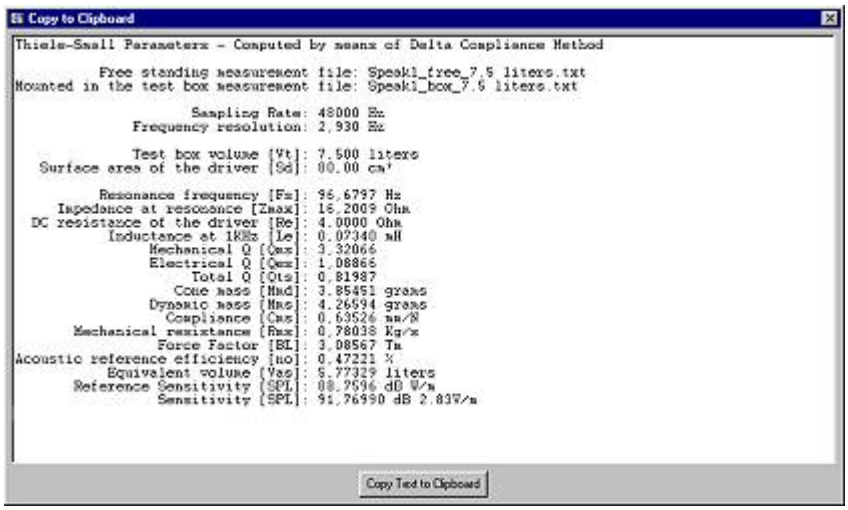
- have the same frequency resolution

- have the same sampling frequency

- have the resonance peaks at different frequencies

- be computed using the same smooth factor (because it can slightly affect the resonance peak)

The numerical values can be exported (copied to clipboard).



Parameters exporting

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