

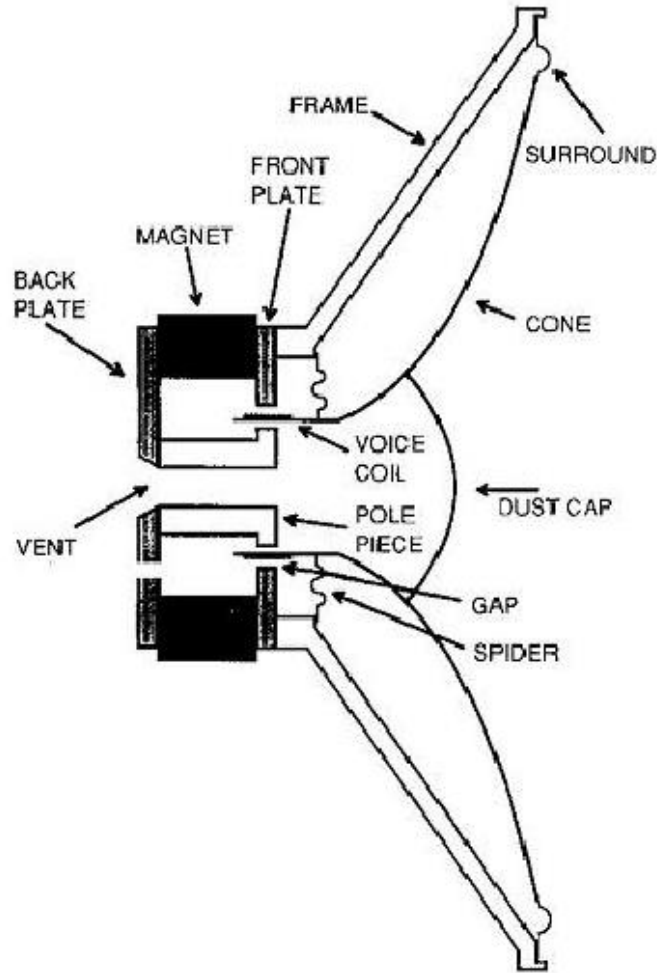
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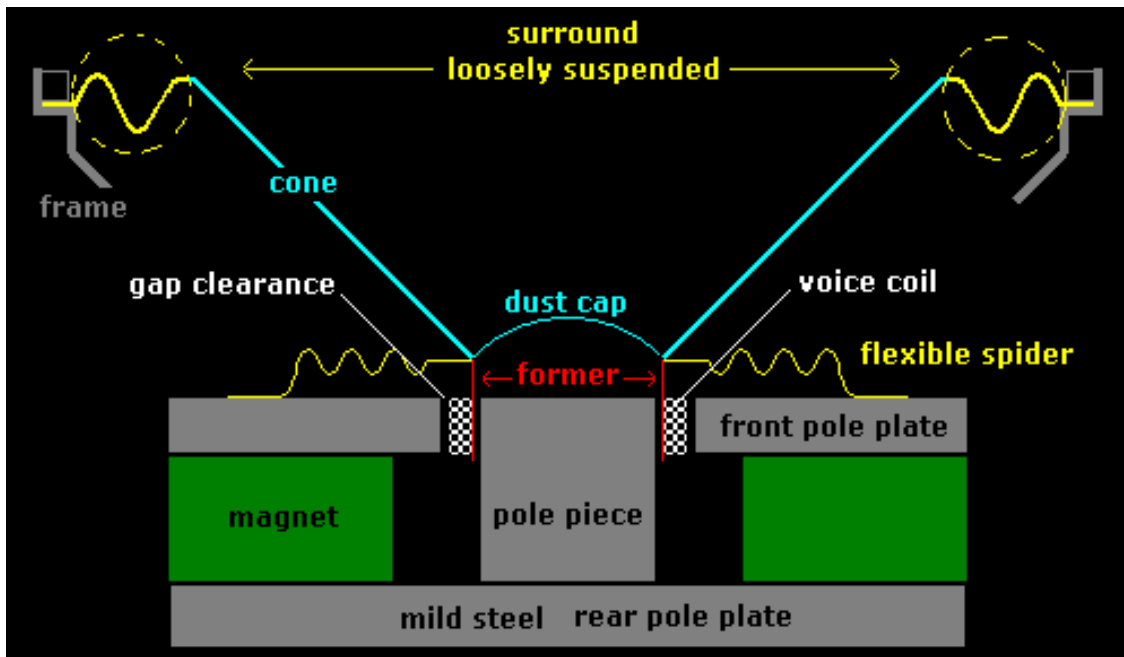
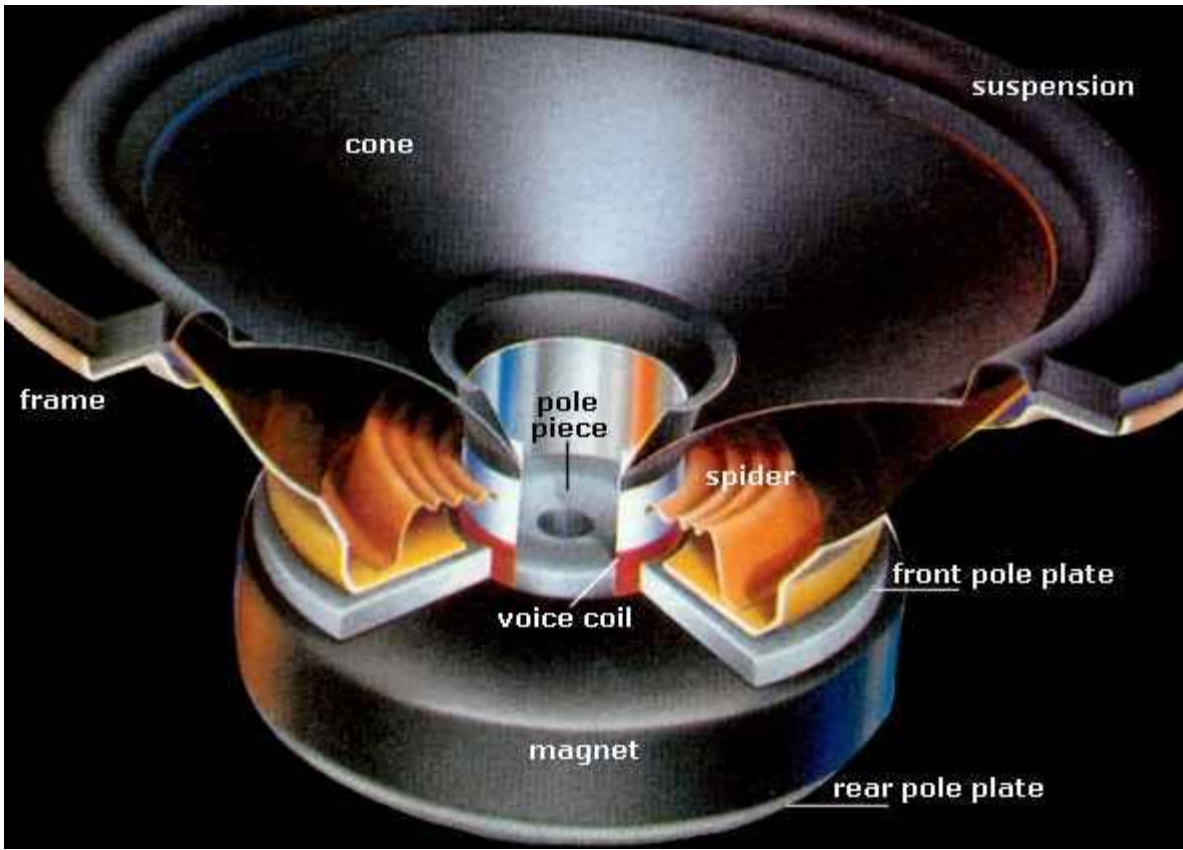
SECTION 3 – MEASURING DRIVER IMPEDANCE AND THIELE SMALL PARAMETERS

(Section Index)

DRIVER CONSTRUCTION



From Loudspeaker Design Cookbook, Sixth Edition, 2000 by Vance Dickason, p3



TESTING DRIVERS

(Section Index)

Prior to testing for F_s , the driver should be broken in. There are many recommendations regarding how to do this from playing a low frequency sine wave (never below the expected F_s) for anywhere from 20 minutes to days to using a 10-100 Hz sweep or just music. You should allow the driver to cool after break in for at least 5 minutes.

The idea is to loosen the suspension and the surround, which allows for a more accurate depiction of what the driver will do once in the box (there is not much additional change once the driver is initially broken in). John Dunlavy explained in a post to rec.audio (2000) that for higher frequencies, the break in period causes the voice coil and the supporting cylinder (called a “former”) to heat up. This produces a curing action that hardens the insulation of the coil and more firmly attaches the wire to the former and into the apex of the cone attached into the former. This improves the performance of the driver with respect to its impulse response, step response, and its amplitude vs. frequency performance. Vance Dickason explains that there will be little impact on the enclosure dimensions whether or not you “break in” the driver but rather this will help in identifying potential problems with the driver before designing a system around it.

Another issue is that parameters will change with changes in driver coil temperature. When a loudspeaker plays, the voice coil heats up which increases the resistance and decreases loudspeaker sensitivity. This effect is called power compression. It is sometimes considered to be a non-linear distortion mechanism but the time constants are so long (in the order of seconds to minutes) that there is really no audible distortion.

Speaker Workshop calculates the impedance values of a driver using a complex driver model (you can view this under the help index/Set equivalence dialogue). If you open the impedance chart, you can move the cursor along the plot and you can observe the impedance and equivalent resistance values by watching the status bar on the lower right of the page.

THIELE SMALL MEASUREMENTS

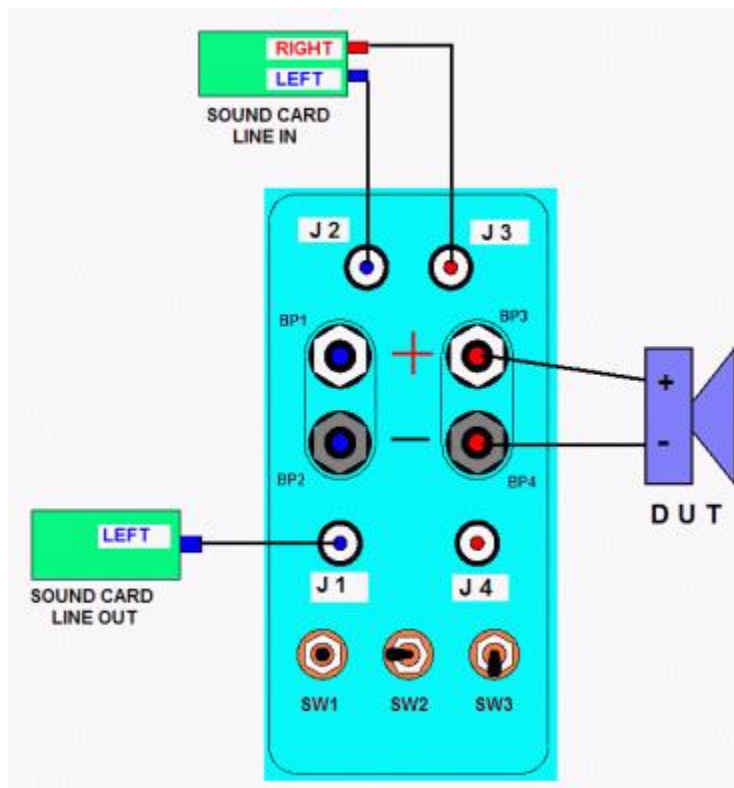
(Section Index)

1. Break in the driver with your preference of break in procedure.
2. All of the Thiele Small Parameters except VAS can be easily tested and should be tested with the driver placed vertically as this will be the final position.
3. The driver must be fixed well to avoid vibration during testing. The use of a jig is encouraged though you could clamp the driver to fixed surfaces.
4. Keep acoustic reflecting surfaces as far away from the driver as possible during this testing.

Without the Wallin Jig (Cable testing):

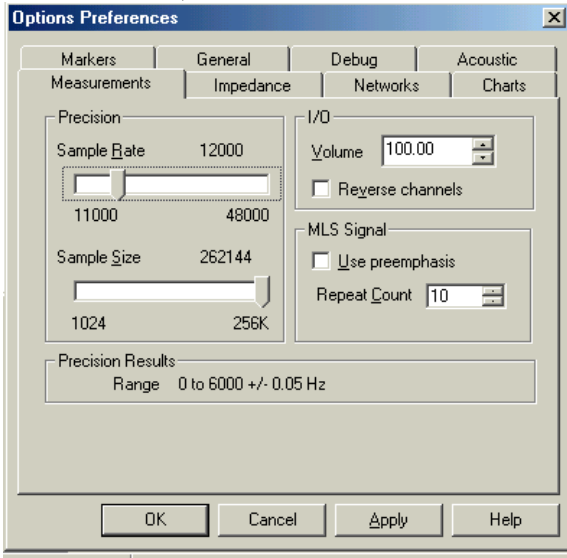
1. Use the Impedance Cable with a reference resistor equal to that used in the calibration phase (about 10 – 20 ohms though 16 ohms was used in the example above).
2. Connect the Driver to the DUT cable and pay attention to polarity.
3. Skip to step 4 below.

With the Wallin Jig, hook up as below for the Impedance Measurement and then skip to step 4.

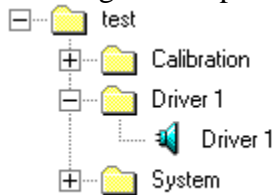


4. Recall the Saved Volume setting file.
5. Open SW/Options/Preference/Measurement

6. Assure that the sample rate is the one you chose earlier with RMAA. If you chose not to use RMAA, a lower sample rate (11,000 instead of 48,000) and a higher sample size (256K instead of something lower) will provide the greatest resolution but more potential noise so you will need to increase the repeat count.
7. Set the sample size to 256k.
8. Increase the repeat count to 10 or more (the more measurements, the more reliable the results).

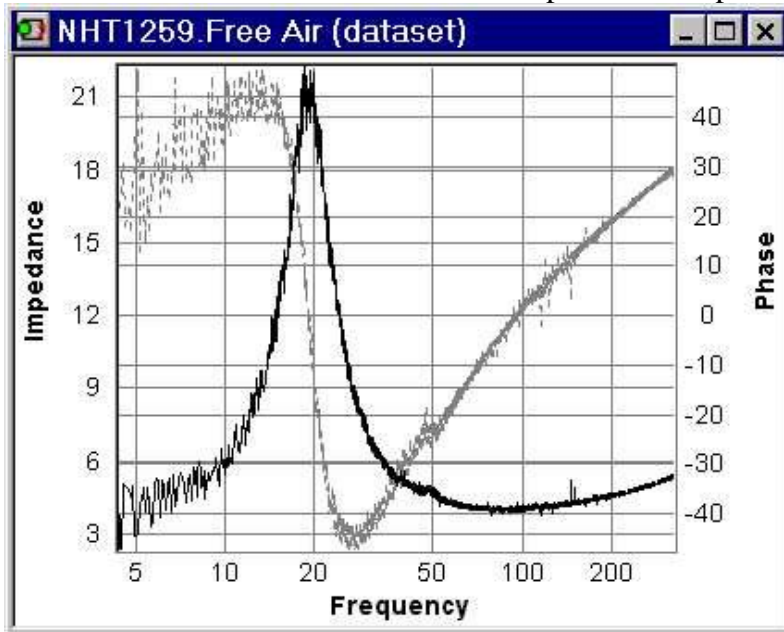


9. Click OK.
10. Click Resource/New/Folder to create a folder.
11. Name it with an identification name for this driver and click OK.
12. Drag and drop the new icon into this folder.





13. Double click on the Driver icon with the name of your driver (in the above example).
14. Click Measure/Impedance/Free Air (or you just click on Z_f).
15. A sound will come from the driver.
16. A new file will appear in the tree menu that is the free air impedance of the speaker (you will recognize it because it will be preceded by a “z” and it will contain the same name for the driver you enter with *.free air*).

17. Double click on this icon and a chart with phase and impedance will appear.



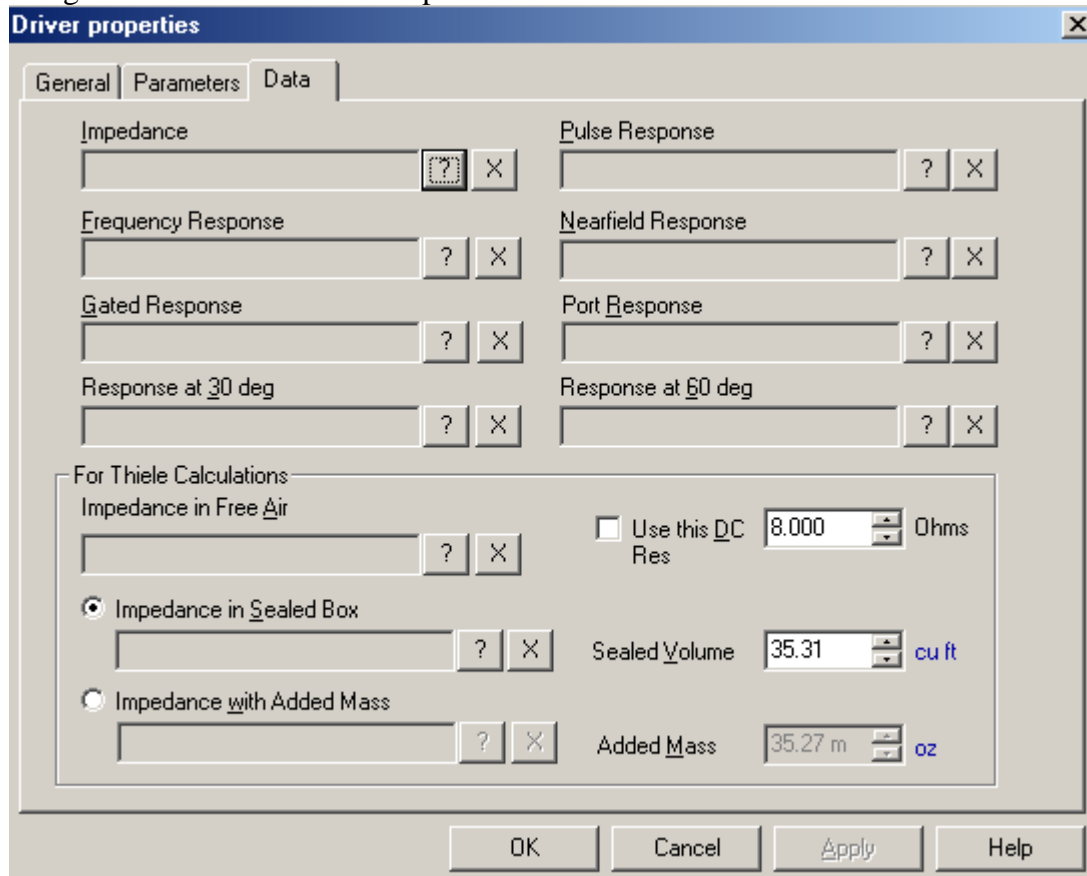
18. Double click on the chart and set it up as follows:

- a. X Axis (name it Frequency (Hz))
 - i. Scale
 1. Logarithmic should be checked
 2. No check in Auto Minmax
 3. Minimum 10
 - a. Do not set this value to anything below 10 as Sound Cards lose accuracy the closer you get to DC (0 Hz) current.
 4. Maximum 20k
 - a. If you get an error message that says “Invalid Frequency Range”, it suggests that your frequency range does not include a full impedance peak. With the recommended settings, this should not be a problem.
 - ii. Grid Lines
 1. Check Auto Minmax
 2. Check Major and set for 10.000
 3. Do not check Minor
 - iii. Style
 1. Check all boxes.
- b. Axis Y (name it Impedance (Ohms))
 - i. Scale
 1. Don't check logarithmic
 2. Check Auto Minmax
 3. Minimum 0
 4. Maximum 50 (may have to set this higher if the driver has a very high impedance)

- ii. Grid Lines
 - 1. Check Auto Minmax
 - 2. Check Major and set to 10.000
 - 3. Don't check Minor but set to 2.500
 - iii. Style
 - 1. Check all boxes
19. Right click on the chart area and make this the chart default.
20. Note that you can zoom in or out of the chart using .
21. **Do not apply smoothing to impedance graphs, as it will lead to incorrect calculations of T/S parameters.**
22. To convert the impedance graph into a .zma file
- a. Click on the Open Graph
 - b. Resource/Export
 - c. Give a name to file
 - d. Save it
 - e. Open it with WordPad or Notepad
 - f. The first column is the frequency, the second is the impedance and the third is the phase.
23. Double click on  and a new window appears.

Driver: Untitled			
Description:			
Resonance (Fs)	50.000 Hz	Piston Area (SD**2)	3100.006 Sq in
Compliance (Vas)	35.315 Cu ft	Max excursion (Xmax)	0.394 In
Total Q (Qts)	0.400	Sensitivity (W/M)	1.000 W/M
Mechanical Q (Qms)	0.500	Max power input (Pe)	10.000 W
Electrical Q (Qes)	0.500	Motor strength (BL)	0.100
Inductance (Le)	1.000 mH	Volume of Sealed Box	35.315 Cu ft
Inductance (L1)	100.000 mH	Added mass	0.035 oz
Series Res (R1)	10.000 Ohms	User supplied Re	No
DC Resistance (Re)	1.000 Ohms	Use added math method	No

24. Right click inside this box/Properties/Data



25. Enter the DCR of the driver as measured by you with your DMM by touching the positive and negative terminals with your probes simultaneously.
 - a. Make certain that “use this DC Res” is selected.
 - b. Make certain that you have the correct impedance data files in the impedance section for free air and closed box slots.
26. Under Impedance in Free Air you will see the name of the file created during this measurement (SpeakerA.Free Air).
27. Select the tab parameters and enter those available to you from the manufacturer, if any. SW uses only Sd so if this is not available, measure from where the surround attaches to the frame on one side to where the cone attaches to the surround on the other. Sd can be calculated by $\frac{1}{2}$ of this distance squared and multiplied by PI (3.14159).

Note: That the parameters max excursion, Sd, and VAS have scrolling units and can be switched by left clicking on the units.

28. Click OK.
29. Now to get the Thiele/Small Parameters, Go to Driver/Estimate Parameters
30. Set the frequency range around the parameters that appear to be clean and without noise or rapid phase shifts; if the entire spectrum looks good click the top left option. The more of the curve you show that is clean, the more accurate the calculations will be.

31. Click OK.

Driver: Untitled			
Paste	Description:		
Resonance (Fs)	50.000 Hz	Piston Area (SD**2)	3100.006 Sq in
Compliance (Vas)	35.315 Cu ft	Max excursion (Xmax)	0.394 In
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Series Res (R1)	10.000 Ohms	User supplied Re	No
DC Resistance (Re)	1.000 Ohms	Use added math method	No

32. Note that the VAS will not display accurately, yet.
33. A new file will appear in the folder called (z SpeakerA.estimate). This is because this is based upon estimated parameters.
34. You can compare the free air impedance measurement graph to the measurement with added mass graph and the estimate graph. The basic curves should be quite similar with only the curve shifted. If the graphs are very similar, the estimated parameters are likely to be correct.
35. Compare the results to z SpeakerA.free air to see how close your measurements are to those of the manufacturer. Your data is more likely accurate as you measured this driver!
36. Select the 2nd driver in the pair and create a Driver B folder as we did above for Driver A. Repeat steps in this section.
37. All Thiele Small Measurements are now taken except VAS.

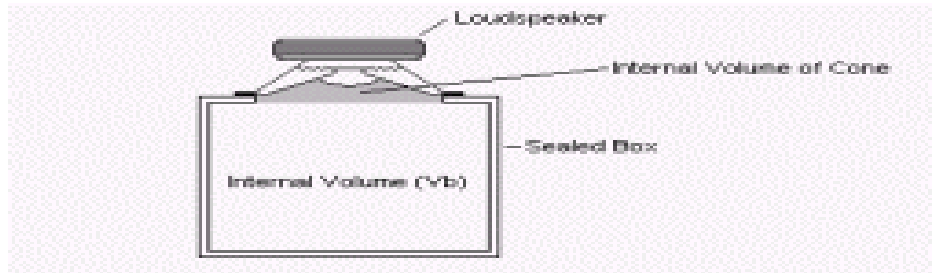
MEASURING VAS

(Section Index)

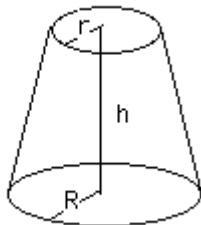
There are two methods that can be used to measure VAS. One is the Closed box method and the other is the Added Mass Method. The Added Mass Method is much easier as you do not have to construct a box to do this but rather you add mass to the driver. Calculating VAS is going to be accurate with the added mass method as long as the F_s is not below 25 Hz or so as most Soundcards start to lose accuracy around 20 Hz. For drivers with F_s less than 25 Hz, a closed box method of determination will be more accurate. Added Mass is more sensitive to temperature and humidity than Sealed Box testing.

The accuracy of VAS will be impacted by the accuracy of S_d with the added mass method so assure accuracy here.

1. Closed Box Method



- Attach the driver facing into a sealed box assuring no air leakage.
- You must know the exact internal dimensions of the box to calculate an exact volume.
- You must add the volume of the driver to the total volume when doing calculations. The following diagram may be of assistance in calculating this amount:



The Formula

$$V = \frac{\pi h}{3} (R^2 + Rr + r^2)$$

- This should raise the F_s by about 25% to be accurate and is best used for drivers with very low F_s 's.

- e. If F_s does not increase by at least 25%, the test volume may be too large. You can decrease this by inserting a block of wood or a brick. Remember to subtract the volume of the wood from the total box volume when doing your calculations.
- f. Suggested test box volumes:

Diameter (inches)	4-5	6-7	8	10	12	15
Diameter (cm)	10-13	15-18	20	25	30	38
Test box volume (inches ³)	220	860	1700	2500	3450	4300
Test box volume (cm ³)	3605	14100	28000	41000	56500	70500

2. Added Mass (Weight) Method

- a. This is the only time to measure the driver horizontally (note that added mass may cause the suspension to sag and alter compliance and BI if the drive unit is facing upwards though this is generally a minor change).
- b. You will want to lower the F_s by approximately 25% to be most accurate.
- c. You must be able to be as exact as possible in knowing the amount of added weight to assure accurate calculations.
- d. Adding approximately 75% of M_{ms} will likely be in the ballpark (if you know the M_{ms}).
- e. Another way to estimate is by following this approximation:

Inches	5.25	6.5	8	10	12	15	18
Grams	20	40	60	80	100	120	140

- f. Use either 4 coins placed symmetrically, blue tac, fun tac, poster tac or a centered weight. If using coins, it is best to secure them with tac of some sort as their motion during testing may impact the measurements. If adding tac, adhering it to the back of the driver will avoid the residual mark from being visible

3. To measure:

- a. Double click on the driver icon and the driver parameter window should open.
- b. Right click on this box and click Properties/Parameters and make certain to add S_d .
- c. Right click on this box and click Properties/Data/Check Added Mass (or Check Closed Box) Impedance
- d. Enter either the added mass (weight) or box volume.
- e. Make certain that the DCR is entered.
- f. Click OK, which closes the box.
- g. Menu/Measure Impedance (either closed box or with added mass).
- h. After the test, a new file will be added into the folder: "z Speaker A.added mass".
- i. Verify that the F_s has changed by about 25% (up to 33% is fine). If not, either add mass or use a bigger box. If there is too much of an F_s change, either decrease the amount of added mass or added bricks into the box to decrease the effective volume.
- j. Use the range of the graph only that has little noise.

Note: The Fs can be seen where the impedance peaks at a phase of zero. If you move the cursor along the peak you can read the Fs below more accurately.

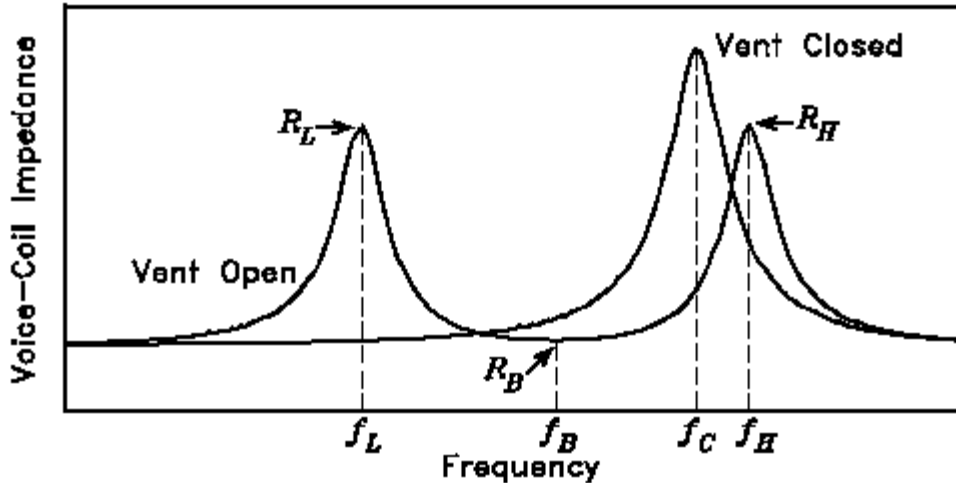
- k. Go to Menu/Driver/Estimate Parameters
- l. Click OK and SW will estimate VAS. In addition to the other T/S parameters.
- m. Click OK and repeat for Driver B.

Note: VAS is directly proportional to air density so this may vary when tested on different days by up to about 5%.

VERIFICATION OF THE THIELE SMALL RESULTS

[\(Section Index\)](#)

You can check your results against calculated results using one of the following programs/spreadsheets. Definitions of f_h , R_h , f_l , R_l , etc can be identified from the following chart:



Note : In a reflex system (ported) if the $F_b = F_s$, the two impedance peaks will be equal in amplitude. If the second peak is larger, it means that $F_s > F_b$ while if the first peak is larger it means that $F_b > F_s$.

1. Dick Van Nierop's Spreadsheet:



"Nierop Thiele Small
Estimates.xls"

2. Claudio Negro's Spreadsheet:



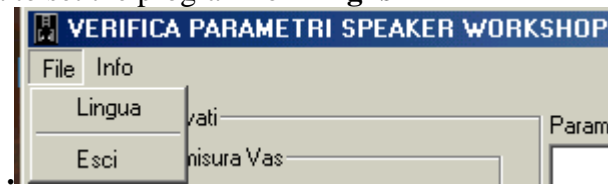
"Claudio's Data
Check.xls"



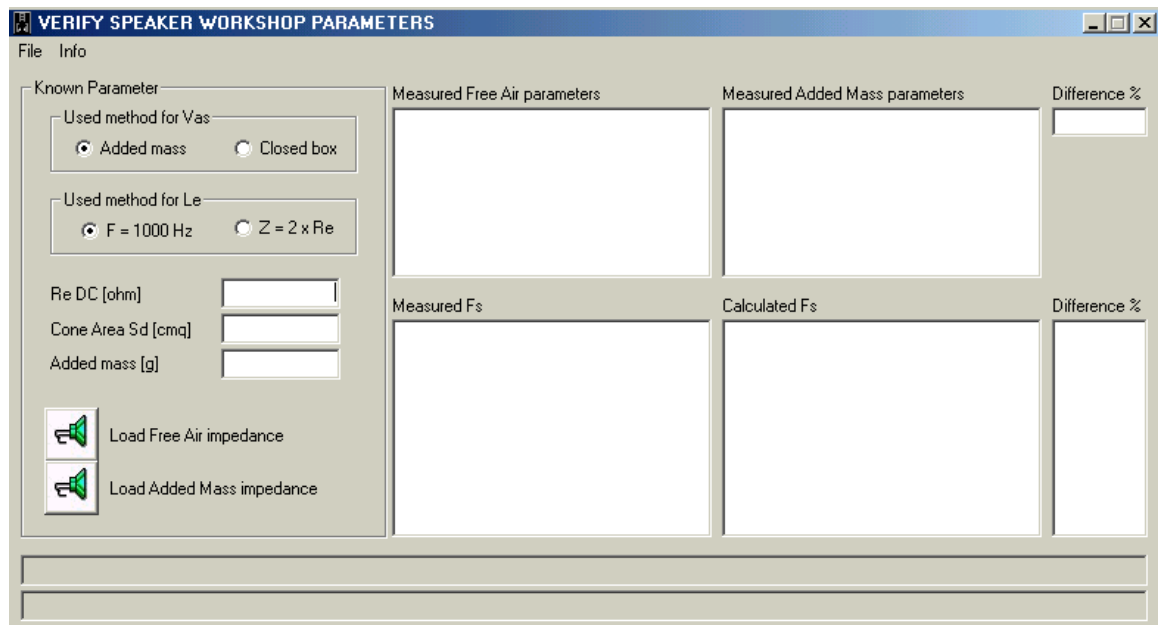
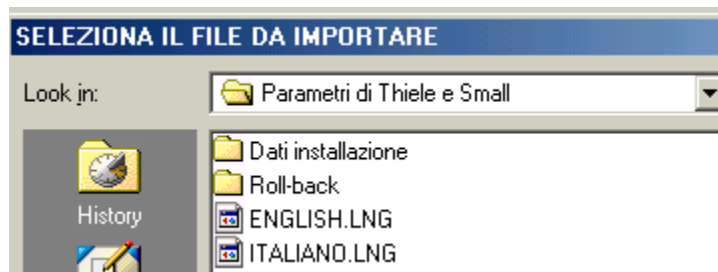
"verify TS.zip"

3. Or by using a program written by Bruno Dalle Carbonare, which uses a different algorithm than Speaker Workshop (so the values may be off slightly) but can import FRD files (the format that is saved by Speaker Workshop) and then it automatically calculates parameters and compares them to measured parameters to assure that the results make sense. This program was originally written in Italian but it has an English option that you can select by going to File/English. The interface looks like this with warnings that come up in red in the bottom rows about potential problems:

- a. File/Lingua to set the program for **English**



- b. Select English.LNG



- c. Select Added Mass or Closed Box, Method of measurement for Le, and input the Re, Cone Area in cm^2 , and added mass in grams.
- d. You import the FRD files for both measured parameters; with added mass or closed box parameters and the original measurements using the speaker icons on the bottom left.
- e. The program will demonstrate differences with low percentage differences being good (target under 5%). You need approximately a 25% or slightly larger change between original measurements and added mass/closed box measurements. These programs help to verify the measurements made are accurate.

VERIFY SPEAKER WORKSHOP PARAMETERS

File Info

Known Parameter


Used method for Vas: Added mass Closed box


Used method for Le: F = 1000 Hz Z = 2 x Re

Re DC [ohm]:

Cone Area Sd [cmq]:

Added mass [g]:

 Load Free Air impedance

 Load Added Mass impedance

Measured Free Air parameters		Measured Added Mass parameters		Difference %
Fs	= 44,908 [Hz]	Fs AM	= 31,202 [Hz]	-30,53
Re	= 6,060 [Ohm]	Weight	= 15,970 [g]	
Zmax	= 101,018 [Ohm]	Zmax AM	= 77,732 [Ohm]	
Area	= 176,700 [Cmq]	F1	= 33,512 [Hz]	
RO	= 16,670 [Ohm]	F2	= 59,741 [Hz]	
ZF1, ZF2	= 24,742 [Ohm]	Fs	= 44,744 [Hz]	
Le	= 1,213 [mH]	Mms	= 14,904 [g]	

Measured Fs		Calculated Fs		Difference %
Fs	= 44,908 [Hz]	Fs	= 44,744 [Hz]	-0,37
Qms	= 6,990	Qms	= 6,965	-0,37
Qes	= 0,446	Qes	= 0,444	-0,37
Qts	= 0,419	Qts	= 0,418	-0,37
Mms	= 14,904 [g]	Mms	= 15,117 [g]	1,43
Cms	= 0,843 [m/N]	Cms	= 0,837 [m/N]	-0,69
Vas	= 36,742 [Liters]	Vas	= 36,490 [Liters]	-0,69
Bx1	= 7,568 [Wb/m]	Bx1	= 7,622 [Wb/m]	0,71
dB	= 90,750	dB	= 90,688	-0,07

C:\d-Bruno\test 7\focalAL.ZMA Fs = 1/1

C:\d-Bruno\test 7\focalMA.ZMA Fs AM = 1/1

Note that more parameters can be calculated using the above information, if necessary, by the [Driver Parameter Calculator version 0.6.1](#), Copyright 1996 by Claus Futtrup. DPC is an interactive editor for loudspeaker driver parameters. You enter known parameters and DPC calculates other parameters for you. It is DOS based but should run on most operating systems.

OPTIONAL: CALCULATING AVERAGE PARAMETERS OF THE DRIVERS FOR ENCLOSURE DESIGN:

(Section Index)

Note: You can design a box using the average parameters of two drivers as long as either the driver parameters are within 15% of one another or the enclosure that each driver's parameters would individually call for is roughly within 15% of one another.

1. Go to [Claudio Negro's Data Check](#) Spreadsheet and fill in the parameters and verify consistency. Other parameters will be calculated for you as well.

2. Go to the Calculated Parameter Section of the spreadsheet
3. Look at the values of zF_1 and zF_2
4. Find the corresponding frequencies for the impedance points at F_1 and F_2 by one of two ways:
 - a. Go to the graph for z SpeakerA.free air and using the mouse locate the corresponding frequencies (one higher and one lower than F_s)
 - b. OR with the chart open
 - i. Resource/Export
 - ii. Name the file and save it noting where it is being saved.
 - iii. Open the file with WordPad or Notepad and the file should appear as 3 columns: Frequency, Impedance, and Phase.
 - iv. Find the zF_1 and zF_2 impedance values above and below F_s at the first place they occur and document the corresponding F_1 and F_2 . You may have to find a value above and below the impedance values and interpolate; i.e. if the value you are looking for is 40% of the way between the impedances, calculate a corresponding frequency.
 - v. Enter F_1 and F_2 into the Excel Spreadsheet.
 - vi. Repeat this procedure for Speaker B.
5. Return to the Spreadsheet and go to the area that allows for the calculation of average parameters between the drivers. Use this in designing an enclosure.

OPTIONAL: IMPACT OF DUAL VOICE COIL ON THIELE SMALL PARAMETERS:

[\(Section Index\)](#)

DUAL-VOICE-COIL (DVC) DRIVER: a loudspeaker driver in which two separate voice coils are wound on the same former. Each coil can be connected to a separate channel on a stereo amplifier, or they can be wired in series or parallel and powered by one amplifier. Thiele Small Parameters will change based upon how you hook up a dual voice coil driver. This spreadsheet will show you how.



"DVC
parameters.xls"