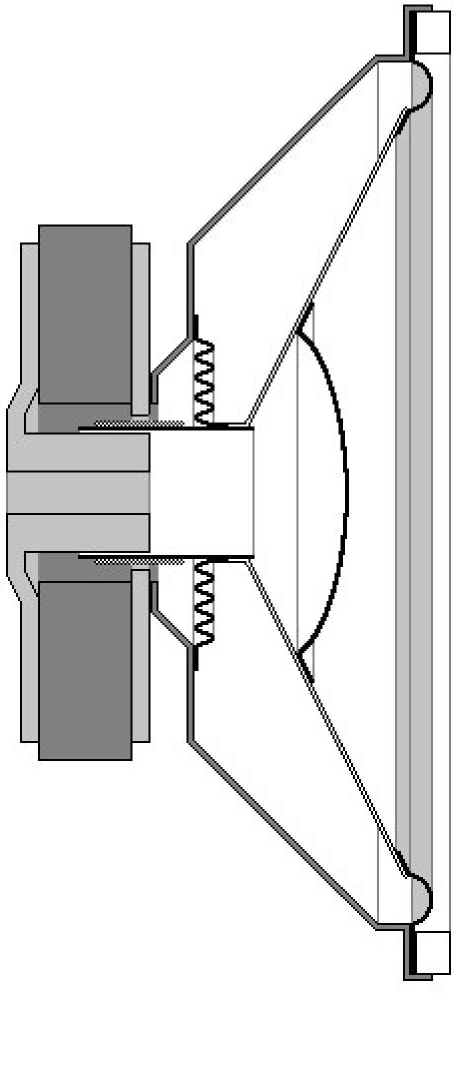
EAMS

ElectroAcoustic Measurement System



USER MANUAL

Release 1.0

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Introduction

Do-It-Yourself in the audio field is a really rewarding hobby, especially when it comes to Loudspeakers. The main task is usually sound quality, but still the costs factor has a strong influence.
Whichever material you may use for it, from the cheapest to the most valuable, the loudspeaker enclosure must be designed according to the drivers' Thiele & Small parameters to achieve the best performance.
Frequently, Thiele & Small parameters are not known at all, especially for low-cost drivers, and when declared by manufacturers, they usually vary within a +/- 10% and sometimes even larger tolerance margin between samples of the same driver.
This means that it would be good advice to always measure Thiele & Small parameters before starting the simulation process that leads to the final enclosure design.
The calculation of Thiele & Small parameters is mainly based on the analysis of the drivers' impedance curve, an accurate plot of the impedance curve is therefore needed, thus resulting in the need of a dedicated measurement instrument.
When building loudspeaker systems not just the enclosure, but also cross-over networks might be tailored to the drivers' characteristics, thus resulting in the need to design and build custom cross-over networks.
There are many computer-aided design softwares for crossover networks but, as well as it is very easy to trim capacitors to the required capacity value by connecting them in parallel or in series, it is usually very hard to find out commercial inductors with the required value of inductance; in these cases the only solution is to wind them and trim them to the required value through a measurement system.
The main issue is that the hobbyist does need a testing equipment, but can not (or does not want to) afford significant investments in it, since costs can hardly be redeemed because of the limited the number of projects developed.
EAMS is a low-cost measurement system which allows the hobbyist as well as the professional designer not just to perform accurate impedance measurements through the PC sound card and a small external unit, but also to display, print and store them to file.

Three kinds of impedance measurement are implemented:

- **Simple impedance curve measurement in the 10 Hz – 10 KHz range.**
  (For multi-purpose applications, such as trimming the tuning frequency of vented enclosures)
- **RLC-parallel bridge measurement in the 10 Hz – 10 KHz range with inductance or capacity calculation.**
  (Useful to trim self-winded inductors for cross-over networks to the required inductance value or measure capacitors)
- **Twin impedance curve measurement in the 10 Hz – 10 KHz with Thiele & Small parameters calculation.**
  Both Added-mass and Delta-Compliance methods allowed to calculate the C_{ms} and V_{as} parameters, the first is based in adding a known weight to the loudspeaker cone, the second is based on mounting the loudspeaker ina known volume enclosure.
  For loudspeakers with their own tuned rear volume the measurement process can be limited to free-air only (no added-mass test), thus allowing measurement of part of Thiele/Small parameters; this feature must be used for tweeters and dome mid-range.

The impedance measurement accuracy[1] is typically better than 0.5% of the full-scale[2], partially dependent on the quality of the sound card and its frequency response in the lower frequency range.

EAMS software has a built-in calibration procedure aimed to compensate the soundcard frequency response non-linearity thus virtually making the software suitable with most of them.
The system has been deeply tested and it is expected to be fully functional on the most of PC soundcards.

Calibration process is completely automated, in order to reduce the user's intervention to a small set of simple operations and can be easily carried out in less than five minutes.

[1]) Accuracy data referred to EAMS system after proper calibration.
[2]) The full-scale can be set by the user during the calibration process, usually a 470 Ω full-scale is suggested for most applications, values between 90 Ω and 1100 Ω are allowed.

Setup

System requirements

IBM-Compatible PC, 600 MHz or faster processor, 128 MB RAM minimum.
EAMS is designed under Windows™ 32 bit environment and tested on Windows 95, 98, ME, HP Home and XP Professional and is supposed to work under Windows 2000 Operating Systems.
Full duplex stereo soundcard featuring “LINE IN” and “LINE OUT” 3.5 mm mini-jack plugs.

Installing the software

To install the software just run the “SETUP.EXE” file you have downloaded from the web site or you can find on the EAMS installation CD.
EAMS will automatically be installed on your system.
Automatic uninstaller is also provided to allow trouble-free removal of the software.
The software will run in demo mode unless you provide the validation key code.
Demo mode allows system calibration and impedance curves measurement, but will not calculate loudspeakers parameters nor allow RLC-parallel bridge measurements.
We suggest you to test your system and soundcard in demo mode to make sure EAMS works properly on your system before purchasing the key code.
Full-featured EAMS runs on the same engine as the demo version, this will ensure the full-featured version to work properly once demo version has been successfully tested.

Connecting the external EAMS unit

The external EAMS unit plugs into the soundcards’ “LINE IN” and “LINE OUT” connectors.
Connector marked as “INPUT” in the EAMS module is to be connected to the “LINE OUT” plug on the soundcard, while connector marked as “OUTPUT” in the EAMS module is to be connected to the “LINE IN” plug on the soundcard.
Some laptop PCs, as well as some old soundcard types do not feature the “LINE OUT” connector, but just the “SPEAKERS OUT” or “MIC IN” instead of “LINE IN”, in these cases EAMS may still work, but accuracy and linearity performance will invariably decrease.

Setting up the soundcard to operate EAMS

For improved compatibility EAMS is not designed for automatically altering your soundcard’s settings, since different brand and models may differ each other.
During the calibration process you will be guided in setting the soundcard through the Windows™ mixer. Refer to the “Calibrating the system – part 1” for soundcard settings.

Running the software

Before you run the software you must make sure no other device except EAMS module is connected to the soundcard’s outlets; having loudspeaker, phones or other amplification devices connected may expose you to loud high-frequency tones which are potentially harmful for your ears and/or may result in damage to your amplification system.

General warnings

- EAMS external module must be properly connected to the soundcard and USB bus before switching ON the PC.
- EAMS external module power cable should be connected and/or disconnected with the PC powered OFF.
- EAMS test terminals must never be put in contact with conductive parts of the PC, such as the chassis.
- EAMS is designed for measuring resistors, capacitors, inductors and dynamic loudspeakers and must not be used for purposes different from those for which it was designed, in particular EAMS must not be used for measuring electrostatic or active loudspeakers, amplifiers, power sources, active filters.
- In general EAMS test terminals must never be connected to items being themselves or containing active power sources, such as AC line, DC supplies or batteries, since this may damage the PC soundcard and/or the external EAMS module.
- EAMS external module must be powered by batteries or by its power supply, the ground of which is insulated from the PC ground, Soundcard ground and AC line ground.
- EAMS is a measurement instrument giving results the quality of which is partly dependent on the skill of the user in calibrating and fine-tuning the system.

Calibration

Choosing the "Full scale" reference for EAMS measurement.

EAMS system is designed to work with user-selectable full scale limit, the full-scale value can be set in the 90 Ω - 1100Ω range, according to the resistance of the resistor which is used as full-scale reference during the calibration process; this resistor must be a precision (1% tolerance) resistor or having a known measured value, the tolerance on this resistor affects the overall system accuracy.
When selecting the full-scale value you must be aware that the widest the measurement range is, the poorest is the accuracy, which is usually better than +/- 0.5% of the full-scale reference.
The following table allows you to select the right full-scale for your application.

100 Ω	Small loudspeakers (<5")
330 Ω	Medium loudspeakers (≥5", <10")
470 Ω	Large loudspeakers (≥10")
1000 Ω	Large and/or professional loudspeakers (≥10")

The 330 Ω full-scale is usually a good choice for most applications.

About the calibration.

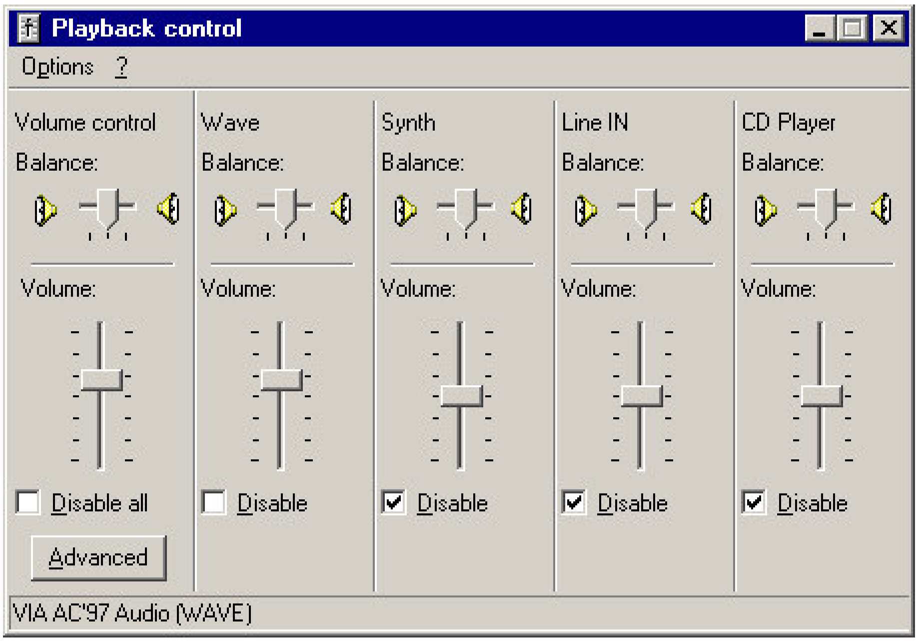
During the calibration process you will be asked to trim the soundcard levels to allow EAMS to work in the best performance conditions.
Once the system is calibrated you should not alter volume settings, since this will result in the calibration not being suitable anymore.
A freeware application called "QuickMix" from Martin Saxon is used to automatically save/restore the mixer settings.

Calibrating the system (Part 1 – Preliminary)

Before you start in calibrating and using EAMS, you have to set the soundcard for the proper playback and recording settings, this must be done by using the Windows™ soundcard mixer as follows:

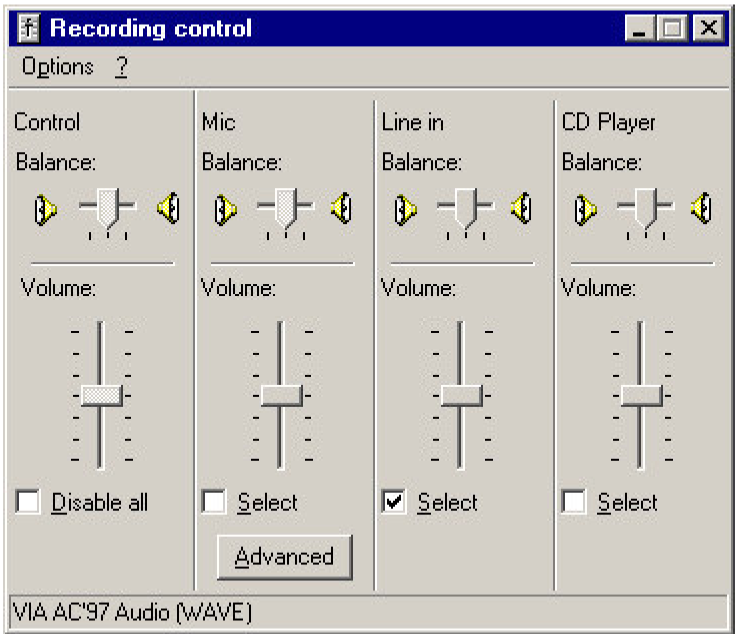
- In the "Playback control" panel all devices must be disabled except the "Wave" device and the "Volume control" device. To disable a device you have to thick the corresponding "Disable" checkbox.
- In case your soundcard has additional controls such as tone control and 3D or surrounding effects, make sure they are disabled or set in the defeat position.

The following picture shows the Windows™ mixer playback settings.
(You may get different views depending on the release and language of the operating system installed)



- In the "Recording control" panel all devices must be disabled except the "Line IN" device and the "Recording control" device. To enable a device you have to thick the corresponding "Enable" checkbox.
- If you do not disable all the unused recording devices the performance of the EAMS system may suffer from noise coming from them and deliver poor performances.

The following picture shows the Windows™ mixer recording settings.



Calibrating the system (Part 2 – Soundcard levels setting)

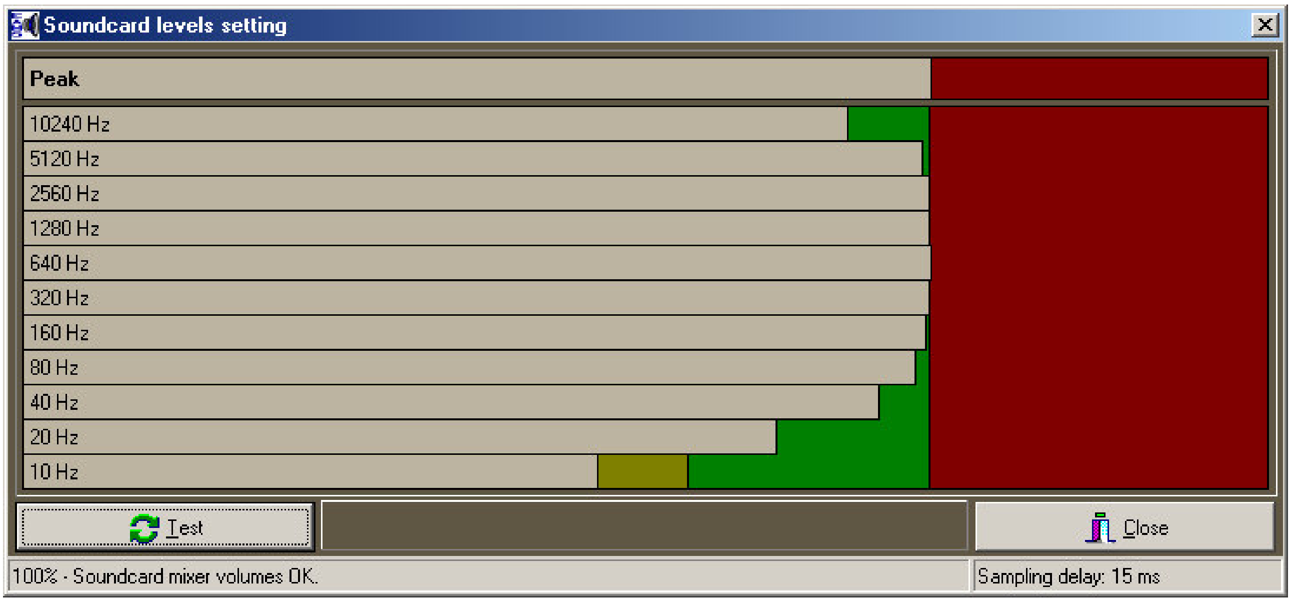
This part of the calibration process is aimed to trim the soundcard levels, this actually consists in finding out the best settings for the soundcard output and input levels to allow EAMS external unit as well as EAMS software to work in the correct signals amplitude range for improved accuracy.
Soundcard levels can be easily regulated in the Windows™ mixer panel according to the indications provided by the EAMS software.
In this calibration phase you may need to intensively act on Windows™ mixer so you may have it open during the whole process; you may then switch from EAMS to the mixer and back using the taskbar.

1) In the Windows™ mixer set all soundcard levels to the middle position, both in the playback (Volume control, Wave) and in the recording (Recording control, Line IN) control panel.
2) In the “Calibration” menu select “Soundcard levels setting”.
3) The system will display the “Soundcard levels setting” window.
   The window delivers two buttons “Test” and “Close”.
   By pressing the “Test” button, the system will test the compliance of the soundcard levels by playing a short tone burst.
4) If you don’t have a precision AC voltmeter skip to point 7.
5) Connect the voltmeter terminals to EAMS test terminals, set the voltmeter for mV AC or VAC.
6) Press the “Test” button and increase or decrease the Playback volume until you get about 500 mV on the voltmeter during the tone burst.
   A voltage reading between 400 mV and 600 mV is allowed, while you may never exceed 1000 mV.
   Once you have set the Playback volume using the voltmeter, you should not alter it later.
7) Connect the full scale resistor to test terminals as requested. (refer to “Choosing the full scale” section.)

   Press the “Test” button to play a tone burst to test the soundcard levels.
   The system will test the soundcard frequency response in 11 bands to allow proper levels calibration also when the frequency response in not linear.

8) After testing, you will get one of the situations shown in the next page:

Increase volumes (result bar is in the yellow zone).
The playback/recording levels are too low, you have to set higher levels for the playback/recording devices in the Windows™ mixer.
Although the sliders for volume setting have a smooth movement, they actually act in steps, so you may get no changes when moving the slider a little.



Always make sure playback and recording levels are homogeneously increased or decreased, it is good advice to act alternatively on recording and playback levels when needed.

Decrease volumes (Peak result bar is in the red zone).
The playback/recording levels are too high, you have to set lower levels for the playback/recording devices in the Windows™ mixer.

Volumes OK (Peak result bar is in the green zone).
The playback/recording levels are fine, this allows EAMS system to work in the best accuracy range.

In case after many tests you will not be able to get a result in the green range you are allowed to accept the nearest but lower result, this means that also results in the yellow range can be accepted, while results in the red range are never allowed.

9) After volumes have been properly set, you can close the “Volume setting” window by the “Close” button. If mixer settings are fine, the system will prompt for saving the mixer settings.

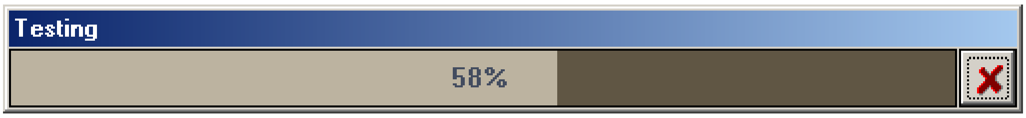
Calibrating the system (Part 3 – Full-scale and Short-circuit reference)

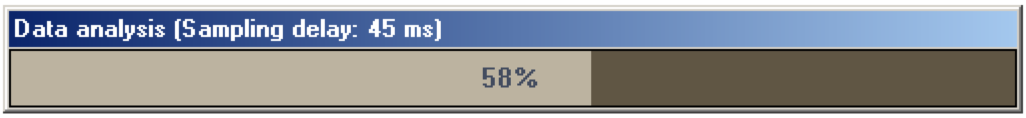
This part of the calibration process is aimed to test the full-scale and short-circuit reference values.

1) In the “Calibration” menu select “System calibration”.
2) The system will ask for the known value of the full-scale reference resistor used for calibration. Values in the 42Ω to 1100Ω can be entered, the value used for the latest calibration is displayed as default. To confirm the value you entered press the “OK” button.

3) Connect the full scale resistor to test terminals as requested, **the full-scale resistor must be the same used for soundcard levels setting**.

4) The system will run a measurement on the full-scale resistor. Measurement phase is made of two phases: Testing and calculation. The testing phase lasts about 30 seconds, while calculation phase duration is dependent on the processing speed of your PC, usually about 10 seconds. Testing phase can be aborted by pressing the Abort button, this will also abort the whole Full-scale calibration process.



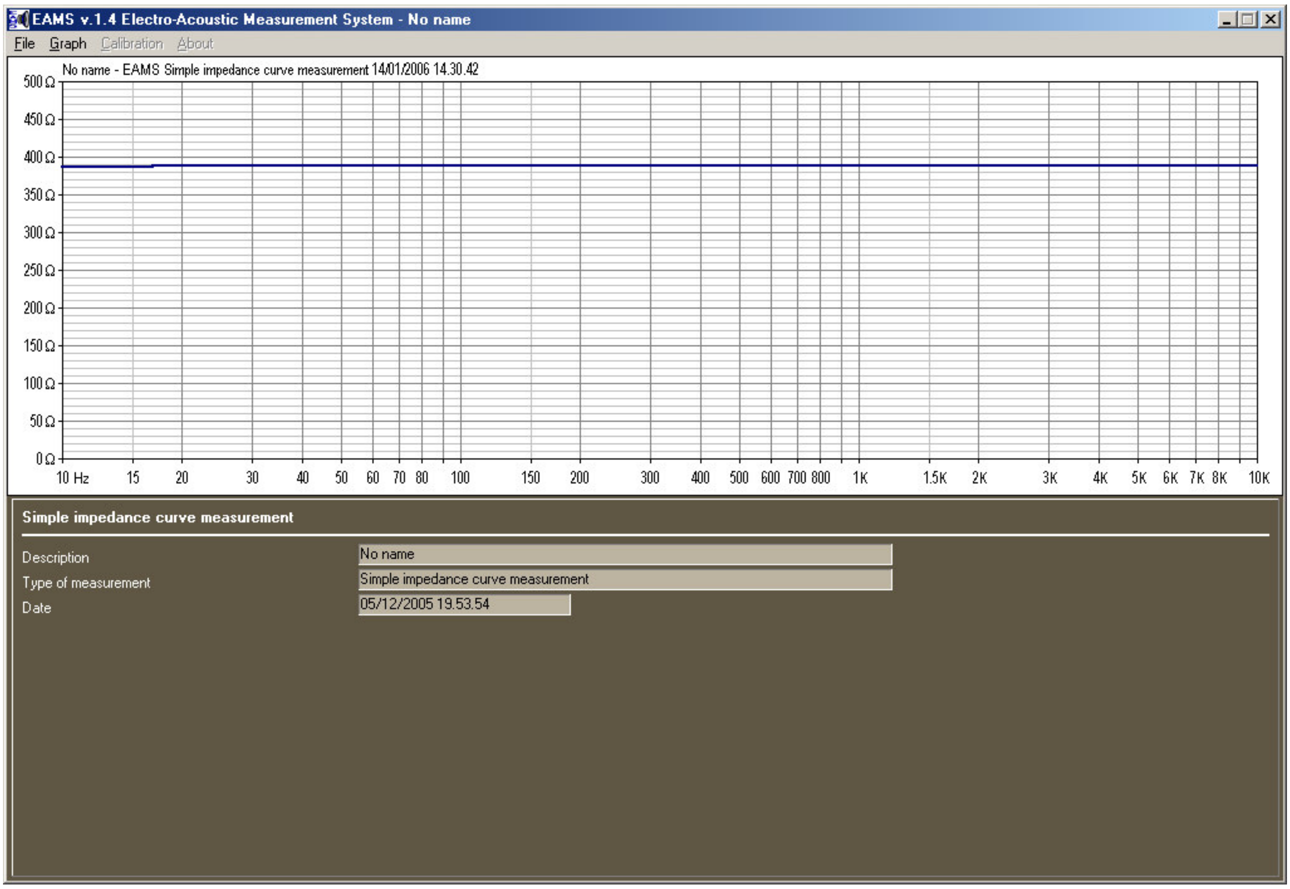


Connect the short-circuit resistor to test terminals or just short the terminals as requested. Use the same cables you will use in the testing phase in order to obliterate the parasite resistance of cables and have improved accuracy in the lower measurement range.

6) The system will run a measurement on the short-circuit resistor and then store the calibration data.

Calibrating the system (OPTIONAL Part 4 – After-calibration test)

This part of the calibration process is aimed to verify the linearity and reliability of the system after calibration. To do so, just run a “Simple impedance curve measurement” test on a resistor, if the system is properly calibrated, you will get a straight line like this:



Using EAMS

File	New	Start a new measurement process
	Open	Load a measurement result from file
	Save	Save current measurement to file
	Print	Print current measurement result
	Close	Close current measurement file
	Exit	Exit EAMS
Calibration	Soundcard levels setting	Starts the wizard for setting the soundcard levels
	System calibration	Starts the fully-automated calibration process
	Soundcard frequency response	Displays frequency response graph
	External unit setup	Shows the external unit setup screen
Graph	Thin draw	Draws the graph with a thin draw
	Thick draw	Draws the graph with a thick draw
	Smoothen	Smoothens the graph through interpolation
	Trace	Traces the graph impedance and frequency values
	Search min/max	Shows the min/max search screen
	Export	Exports the graph area to a bitmap file
	Export CSV	Exports the parameters and graph points to a CSV file
	Auto-scale	Automatic zoom factor to fit the graph in the screen
	1 KOhm full-scale	Zoom factor for 1 KOhm full-scale (20 Ohm/div.)
	500 Ohm full-scale	Zoom factor for 500 Ohm full-scale (10 Ohm/div.)
	250 Ohm full-scale	Zoom factor for 250 Ohm full-scale (5 Ohm/div.)
	100 Ohm full-scale	Zoom factor for 100 Ohm full-scale (2 Ohm/div.)
	50 Ohm full-scale	Zoom factor for 50 Ohm full-scale (1 Ohm/div.)
About	Licensing	Shows the EAMS license information

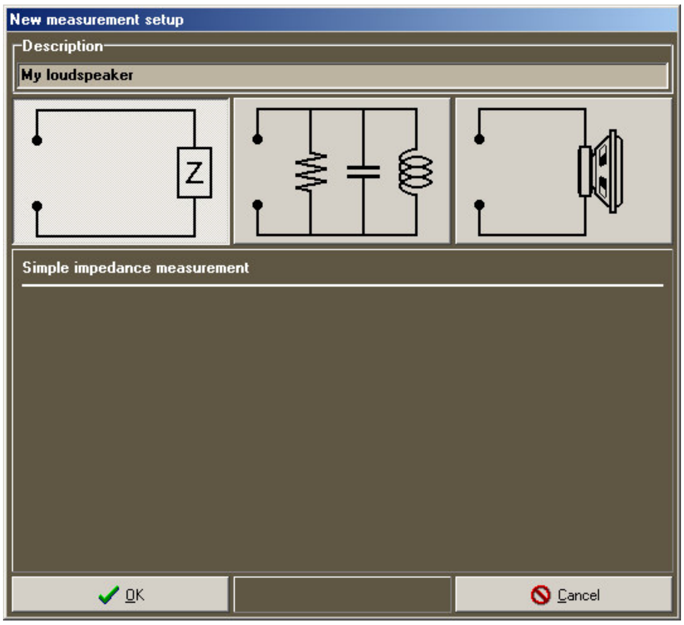
Starting a new measurement process

By selecting the “New” item in the “File“ menu, EAMS is prepared for a new measurement.
Before starting the measurement process you may enter a string in the “Measurement description” input field, such as the brand and model of the loudspeaker you are measuring.
Maximum allowed length for the description is 40 characters.
Then you have to select the type of the measurement you want to carry out in the “Measurement type” selector.
Three types of measurement are allowed plus one loudspeaker impedance simulation feature:

- Simple impedance curve — for multi-purpose applications
- Parallel RLC bridge measurement — to test inductors and capacitors with the RLC bridge
- Loudspeaker parameters — to test Thiele/Small parameters for loudspeakers

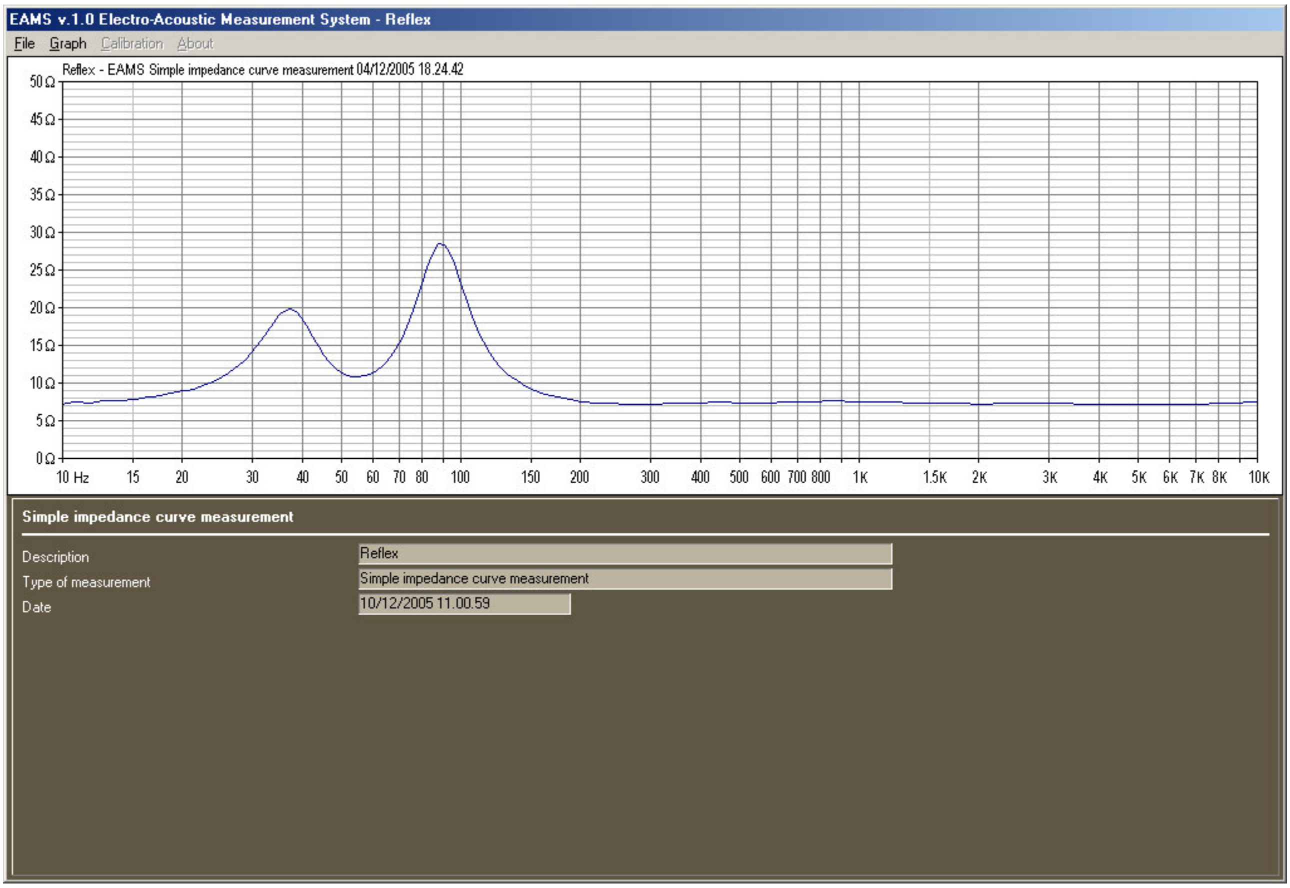
Simple impedance curve measurement

Use this feature to plot the impedance curve in the 10Hz – 2KHz range.



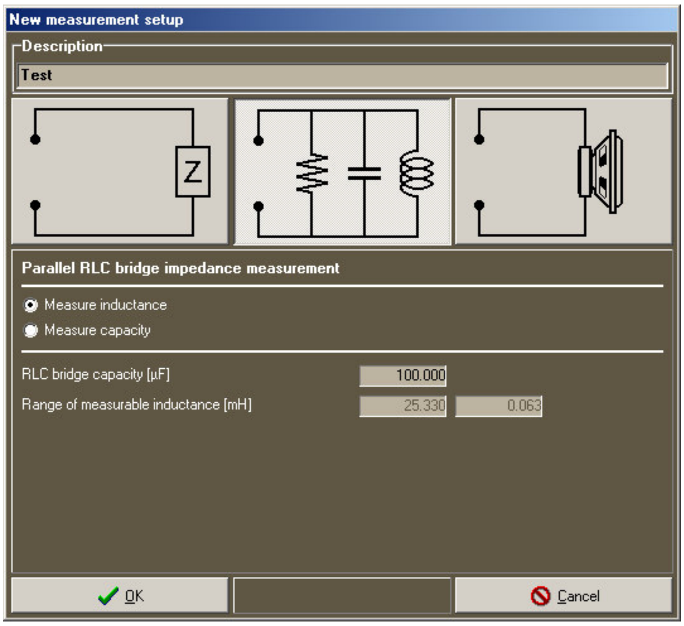
Although this is a general-purpose feature, it is very useful when trimming the length of vents in reflex enclosures, since the tuning frequency of a ported system can be deduced by finding the two impedance peaks in the impedance and calculating the square root of their product.

The following screenshot shows the results of an impedance measurement of a reflex ported enclosure in which the tuning frequency is about 57 Hz.

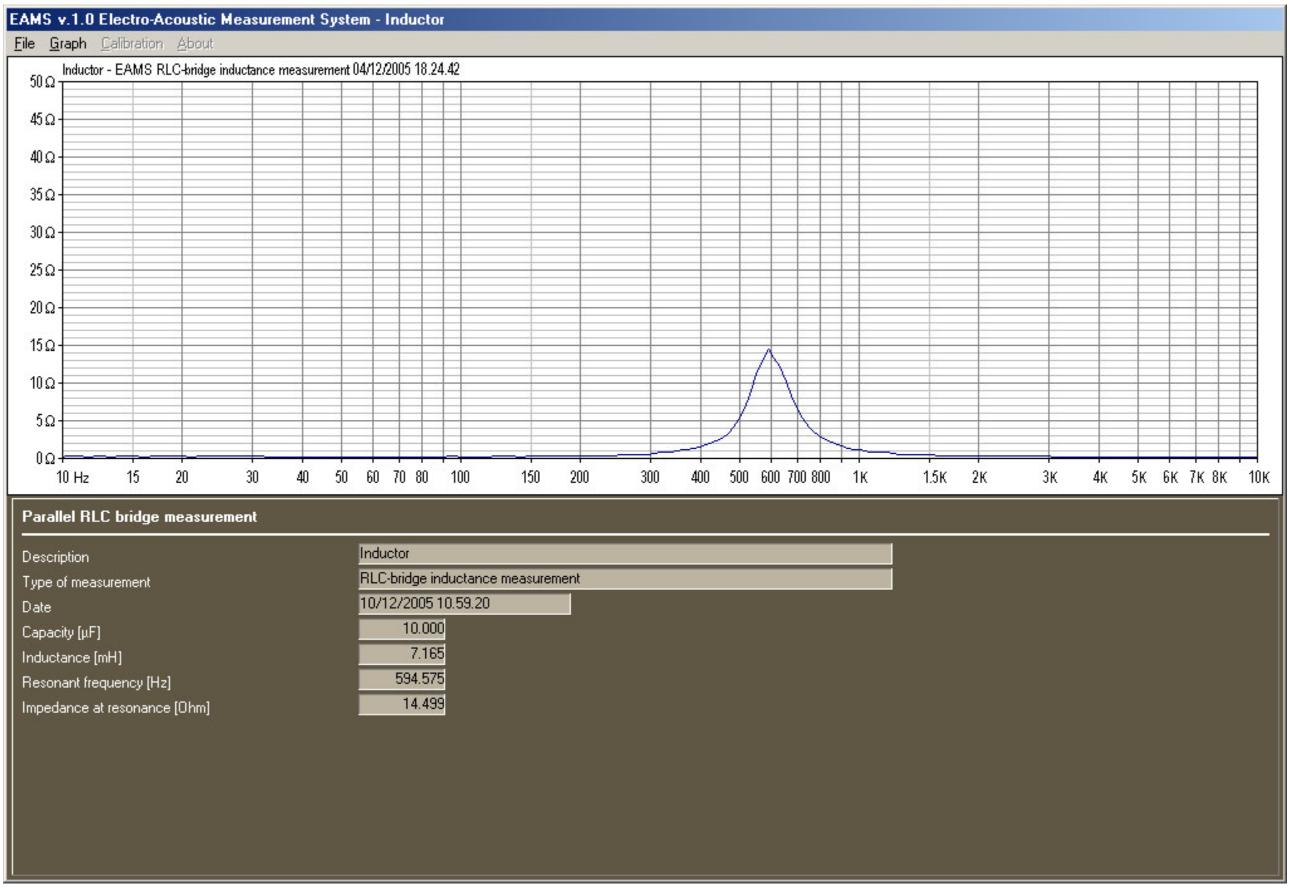


Parallel RLC bridge measurement

This measurement system is based in finding the resonant frequency of a Parallel RLC bridge.
Use this feature to measure an inductor by using a known capacitor in the RLC bridge or to measure a capacitor by using a known inductor; the resistor in the RLC bridge should be equal to the full-scale resistor used in calibration.

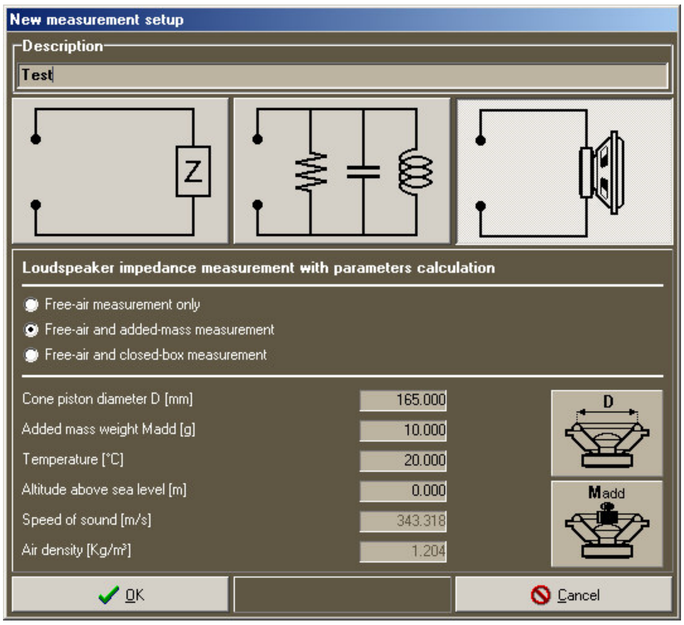


The resonant frequency of the RLC bridge must be within the 20Hz – 2KHz range of the system and by varying the fixed capacitor or inductor value it is possible to measure virtually any capacitor or inductor.
By entering the value of the known fixed capacitor or inductor, the system is able to determine the range for the item to be measured, inductor or capacitor, respectively.
This feature is to be used when trimming the inductors or capacitors to be used in cross-over filters. The initial dialog box allows selection of the type of load to be measured, inductor or capacitor.
The following screenshot shows the results of an impedance measurement through the Parallel RLC bridge.
This measurement was aimed to measure an inductor through a known 10 µF capacitor.



Loudspeaker parameters measurement (Added mass method)

Use this feature to measure loudspeaker Thiele & Small parameters.
This kind of measurement is really effective and accurate for dynamic loudspeaker-type loads only, this means that a impedance peak due to the mechanical resonance is expected; measuring different loads may result in wrong calculated electrical parameters.
The measurement consists in testing the impedance curve twice, the first one having the speaker in free air and the second one having a known added mass weighing on the loudspeaker cone, for this reason you must put the loudspeaker having the cone facing upwards and the magnetic bracing on a concrete non-resonant support.
The loudspeaker's Thiele/Small parameters are calculated on the comparison of the two curves.
Please notice that the loudspeaker act as a microphone during the testing phase so the test must take place in a quiet environment, in order not to disturb the measurement.



Measurement can be limited to free-air impedance measurement only, but this will result in a reduced set of calculated parameters.

The initial dialog box allows editing of the test parameters:

- The weight of the non-resonant added mass[1] you will use for testing in grams.
- The piston diameter[2] of the loudspeaker cone in millimeters.
- The ambient temperature in Celsius degrees of the testing site
- The altitude above sea level of the testing site

In case the ambient temperature and/or the altitude of the testing site is not known, default values can be entered (20 degrees Celsius, 0 m a.s.l. = sea level).

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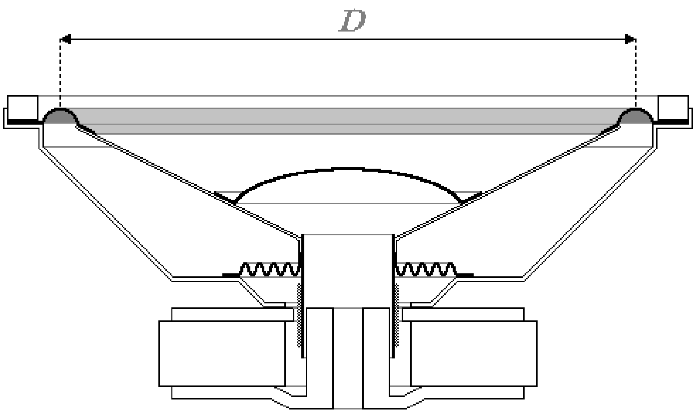
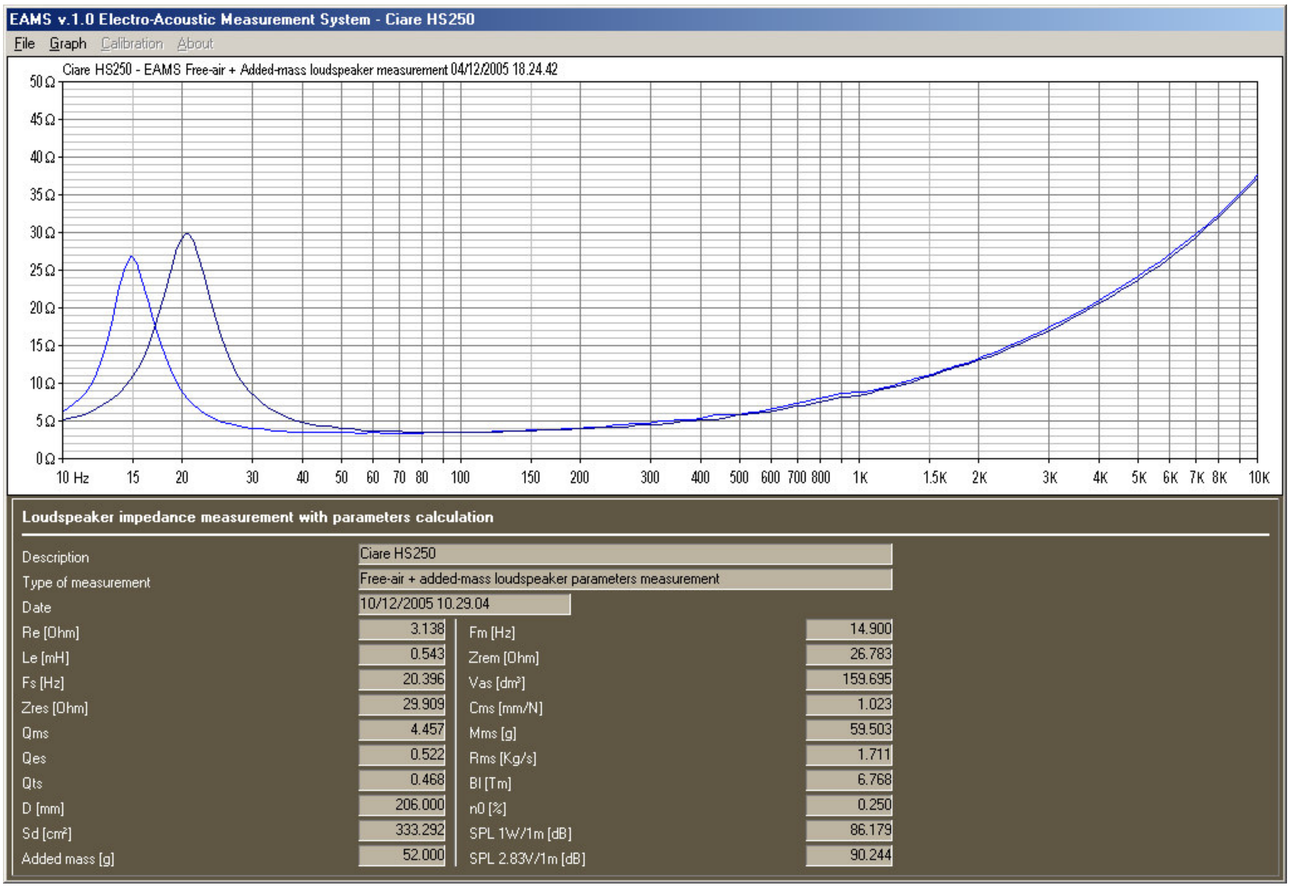
1) The added mass weight must be selected according to the "Choosing the added mass" chapter.
2) The nominal cone diameter must be measured including half of the cone suspension as shown in the following picture:

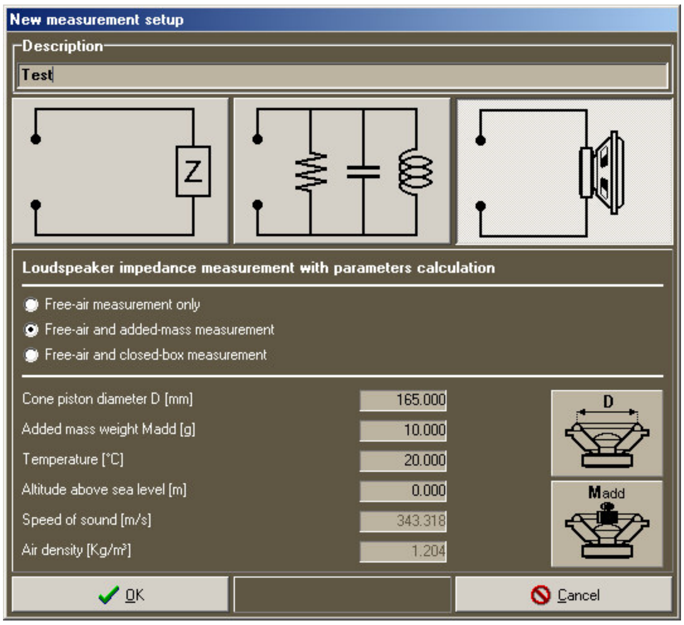


The screenshot in the following picture shows the results of a loudspeaker parameters measurement (12" Ciare Woofer) through two impedance measurements.
Any error in the added mass will invariably result in an error in the calculation of some parameters.



Loudspeaker parameters measurement (Delta compliance method)

Use this feature to measure loudspeaker Thiele & Small parameters.
This kind of measurement is really effective and accurate for dynamic loudspeaker-type loads only, this means that a impedance peak due to the mechanical resonance is expected; measuring different loads may result in wrong calculated electrical parameters.
The measurement consists in testing the impedance curve twice, the first one having the speaker in free air and the second one having the loudspeaker mounted in a known volume closed box, for this reason you must build an appropriate leakage-free enclosure and take into account the volume occupied by the loudspeaker magnet and bracing.
The loudspeaker's Thiele/Small parameters are calculated on the comparison of the two curves.
Please notice that the loudspeaker act as a microphone during the testing phase so the test must take place in a quiet environment, in order not to disturb the measurement.



Measurement can be limited to free-air impedance measurement only, but this will result in a reduced set of calculated parameters.

The initial dialog box allows editing of the test parameters:

- The volume of the closed box used for testing[1].
- The piston diameter[2] of the loudspeaker cone in millimeters.
- The ambient temperature in Celsius degrees of the testing site
- The altitude above sea level of the testing site

In case the ambient temperature and/or the altitude of the testing site is not known, default values can be entered (20 degrees Celsius, 0 m a.s.l. = sea level).

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[1]) The volume is intended as net volume, with no stuffing, take into account the volume occupied by the loudspeaker magnet and bracing. the suggested box is a cube sizing twice the loudspeaker diameter, for instance a 8" woofer (200 mm) should be mounted in a box 16" x 16" x 16" (400 mm x 400 mm x 400 mm).
[2]) The nominal cone diameter must be measured including half of the cone suspension.

Choosing the added mass

When measuring a loudspeaker the added mass test is very important to calculate the suspension elastic properties (*mechanical compliance* C_{ms}) leading to the calculation of the *equivalent acoustic volume* V_{as} parameter, which is on of the three Thiele/Small parameters really needed to perform loudspeaker response simulation (remaining two are *total damping factor* Q_{ts} and *resonant frequency* F_s).
The added mass method is based on calculating the mechanical compliance from the loudspeaker resonant frequency shift when loaded with an added mass.
The frequency shift should never be larger than 30% of the resonant frequency because the excessive load on the speaker cone may lead to incorrect results, while frequency shifts smaller then 10% may also result in poor results because of calculation approximations.
Since it is hard to foresee what the frequency shift will be, there is no general rule for choosing the appropriate added mass.
The following table includes a suggestion for choosing the added mass weights, this does not imply that you won’t have to use different ones when needed.
EAMS software does not mind if whether the frequency shift is larger than 30% or smaller than 10%, but you must be aware that these are not favorable test conditions.

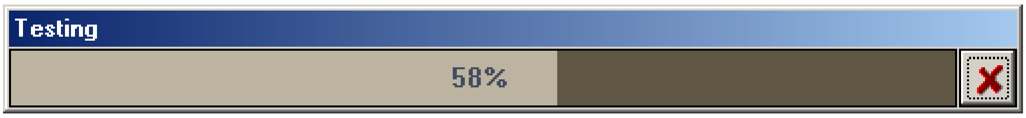
Nominal cone diameter		**Suggested added mass weight**
<5”	<125 mm	10 g
≥5” - <8”	125mm – 200mm	15 g
≥8” - <10”	200mm – 250mm	25 g
≥10” - <12”	250mm – 300mm	50 g
≥12” - <15”	300mm – 380 mm	100 g
≥15”	≥380mm	200 g

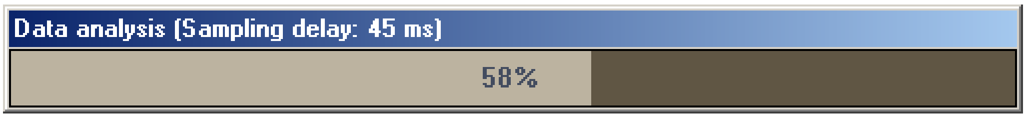
The system informs the user in case the added mass is too light or too heavy thus degrading the accuracy of the measurement.
In both these cases, it would be good advice to repeat the measurement using a different added mass.

Measurement process phases

The system will ask you to connect the item to be measured to the EAMS external unit test terminals.

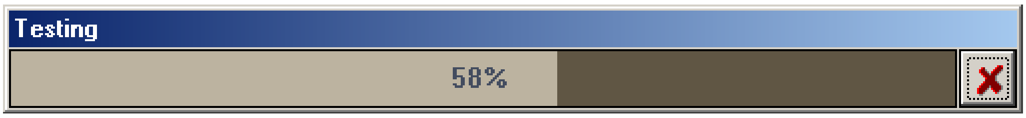
When done, the system will run the testing process made of two phases, one for test and one for calculations.

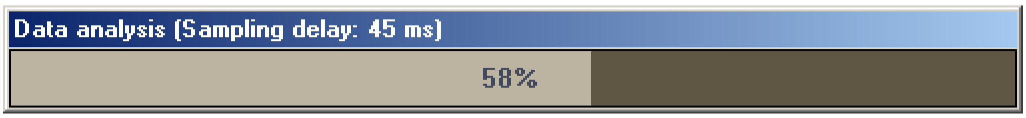




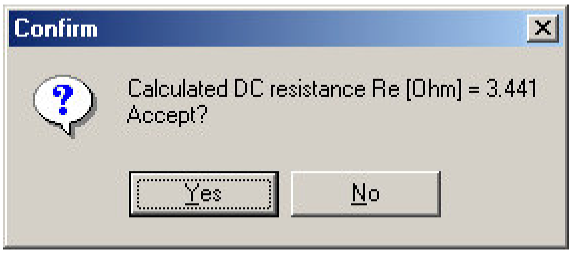
Simple impedance curve measurements and RLC bridge-based measurements will be completed at this step, while, when measuring loudspeakers, further steps will be needed:
The system will ask you to put the test mass on the loudspeaker cone before starting a new measurement phase.

When done, the system will again run the testing process made of two phases, one for test and one for calculations.





Sometimes, when the soundcard is very weak in the low end, the error in the calculation of DC resistance may be quite significant, therefore the system allows for manual introduction of this value; in this case the DC resistance must be measured using a precision multi-meter, please notice that usually in the lower end (below 10 Ohm) multi-meters are not very reliable (try to short the probes, you probably won’t get 0 Ohm!).

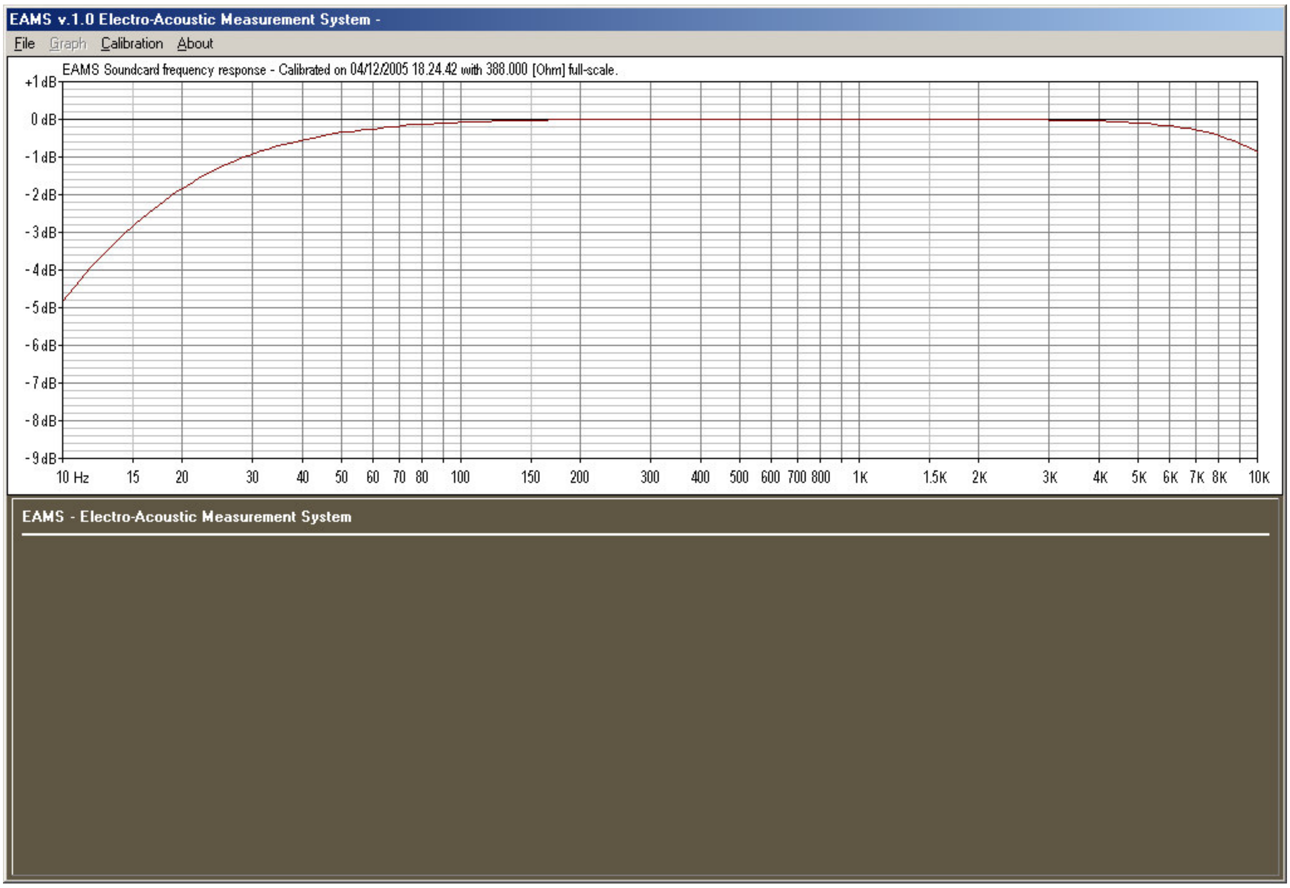


By answering “NO” to the question, the following screen is displayed, allowing manual entry of DC resistance.

In the and, after this optional phase, the system shows the results on screen.

Viewing calibration reference curves

When no measurement is open, by selecting the “Soundcard frequency response” option in the “Calibration” menu the reference calibration frequency response curve is displayed.



This graph is useful to view the actual frequency response in the overall playback/recording process of the soundcard.

EAMS automatically compensates the response non-linearity, but in case the curves are not so smooth and have large amplitude local peaks, it might not just be due to poor frequency response linearity, but also to errors in the calibration phase.

The main pitfall is usually having poor contacts on the resistors terminals during the calibration phase resulting in a flickering contact, alligator clips have been found to be not reliable as they deliver poor contact quality.

The graph shown in the picture, obtained with a VIA AC’97 soundcard integrated in a ECS mainboard, shows the amplitude of signals sloping down for frequencies under 100 Hz and over 3 KHz., the minimum point is about –5dB, the performance of EAMS in this case has been very good during tests (always below 1% error).