sine·phase

instrumentation technology

SinePhase Impedance Analyzer

Model 262k

Model 2097k

Model 16777k

User Manual 3.2

Revision 180120

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General Description

SinePhase Impedance Analyzers are universal high class impedance analyzers for measurements from 1 kHz up to 16777 kHz (Model 16777k). The analyzers are both powered, and controlled, through a single USB connection only. As a result, they can be operated directly from any standard[1] Laptop or PC without the need for additional battery power pack or main supply.

The USB power&control concept does not only turn the instrument into the smallest and most mobile of its art, but also features fully integrated PC control and data acquisition as the standard way of operation. The versatile operating software is included with the instrument, bringing a virtual impedance analyzer front panel onto the user's computer screen. Operating the analyzer through this virtual instrumentation panel is so effective that integration of a (but much less flexible) real user panel has been spared from the hardware design of this analyzer.

The unique mobile design allows for precision measurements in laboratory environment just the same way as needed when used for remote field applications. Versatility of the instrument brings a perfect cost-effective solution to all measurements of ultrasonic, piezoelectric, or quartz-based frequency dependent impedance analysis, as well as to any L-C-R or any other 2-pole network analyzer application generally.

[1] For basic System requirements, see chapter 1.4

1.2 List of Contents

The following items are included as a standard set of delivery:

- The Impedance Analyzer Hardware Instrument, with a USB cable (approx. 1 m) permanently connected to the rear side, and a BNC terminal provided at the front side for connecting the load (= the proband) through any probe with BNC connector.
- A CD-ROM providing easy self-explaining installation of the user software onto the user's computer. The CD-ROM also contains a PDF-version of this manual.
- A BNC-to-Wire adapter as a versatile probe for connecting any leaded loads with the BNC terminal of the instrument

Impedance Analyzer instrument [2]

BNC-to-Wire probe [2]

1.3 Optional Accessories

A BNC-to-SMD adapter for connecting unwired components such as SMD components, piezo plates, or quartz crystals. Other probe adapters are available on request.

BNC-to-SMD probe [2]

For special applications (e.g. for time-critical quality control applications of defined components, or for inductance-sensitive measurements) any specific customer defined probe socket can be designed and manufactured for the user.

For calibration purposes, high precision calibration loads can be supplied of any value also.

[2] Design may vary.

1.4 System Requirements

The Impedance Analyzer's User Software does not occupy an unusual amount of computer resources. As a result, it can be installed on almost any computer of today's regular use. However, for some old models, some restrictions may apply. The following is a list of basic requirements to allow problem-free installation and operation:

Processor (CPU):	Pentium-II-equivalent, or better
Recommended CPU clock rate:	1 GHz or higher
Minimum RAM Memory:	256 MByte
Minimum free hard drive space:	300 MByte
Minimum screen resolution	1024 x 600 pixels
Software Installation medium:	CD-ROM or DVD drive
Computer system:	Microsoft Windows 2000, ME, XP, Server 2003, 2007, Vista, or 7 [3]

[3] All Registered Trademarks of Microsoft Corporation

2. INSTALLATION

2.1 Installing the Analyzer Software

Attention!

Do not connect the analyzer instrument with your computer before Software Installation has been completed!

The Impedance Analyzer User Software is provided with the CD-ROM installation disk enclosed with the instrument. Before installing, please check whether the computer you selected meets the recommended minimum system requirements.[4]

Insert the Installation Disc into your CD- or DVD-drive of the PC you want to use with the analyzer. A setup wizard will start automatically and will guide you through the installation. In some cases (e.g. with Windows 7), installation has to be started manually by opening the disc directory and selecting the setup exe-file. Note that under Windows 7, this must be done with administration rights)

During installation, a warning message may pop up due to installation of a driver without passing Windows Logo test. In this case, click *Continue* to proceed with installation.

Finally, click *Finish* software installation when asked to do so.

[4] Refer to chapter 1.4

2.2 Installing the Analyzer Hardware

<u>Attention</u>!

Make sure that installation of the Analyzer Software (chapter 2.1) has been completed before connecting the analyzer instrument with your computer!

After installation of the Analyzer Software (chapter 2.1), connect the impedance analyzer instrument to a free USB port of your PC. The PC will detect new hardware and will prompt with a hardware installation wizard.

If asked, DO NOT select an option for searching the internet for drivers.

If asked, select to install automatically.

The drivers for the analyzer instrument will be installed.

During installation, a warning message may pop up due to installation of a driver without passing Windows Logo test. In this case, click *Continue* to proceed with installation.

Finally, click *Finish* hardware installation when asked to do so:

It is recommended that you restart your computer before using the impedance analyzer for the first time after installation.

3. BASICS OF OPERATION

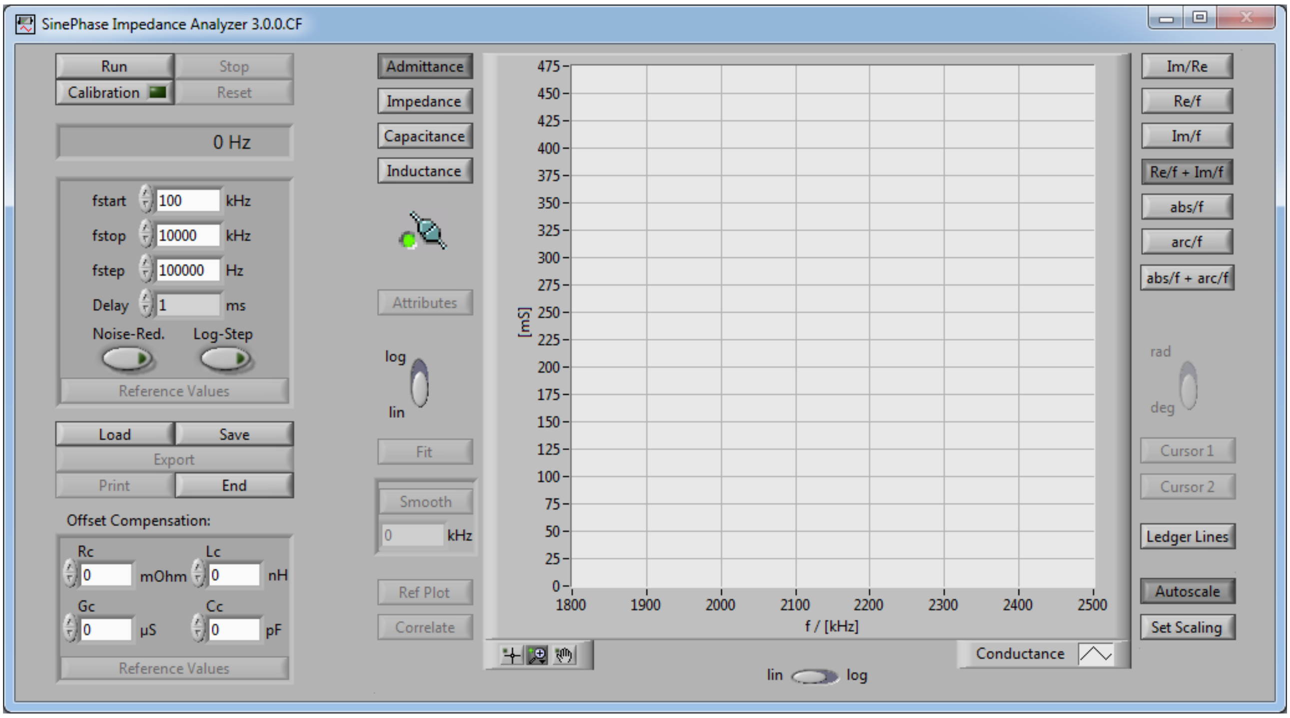
3.1 Starting the User Software

Within the Windows Start Menu, the User Software can be started from the folder that has been selected during the installation process (Default: SinePhase > SinePhase Impedance Analyzer). After a few seconds of initialization, a window will pop up, providing the user with the virtual instrumentation panel of the analyzer. Note that it is irrelevant whether the analyzer instrument is connected to the computer's USB port when starting the user software, or not.

3.2 Online and Offline Mode

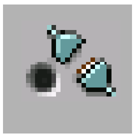
Online Mode:

At the user panel, a green indicator LED will go on if the analyzer instrument is connected to the USB port of the computer. This indicates that the analyzer hardware is online and ready for measurement.



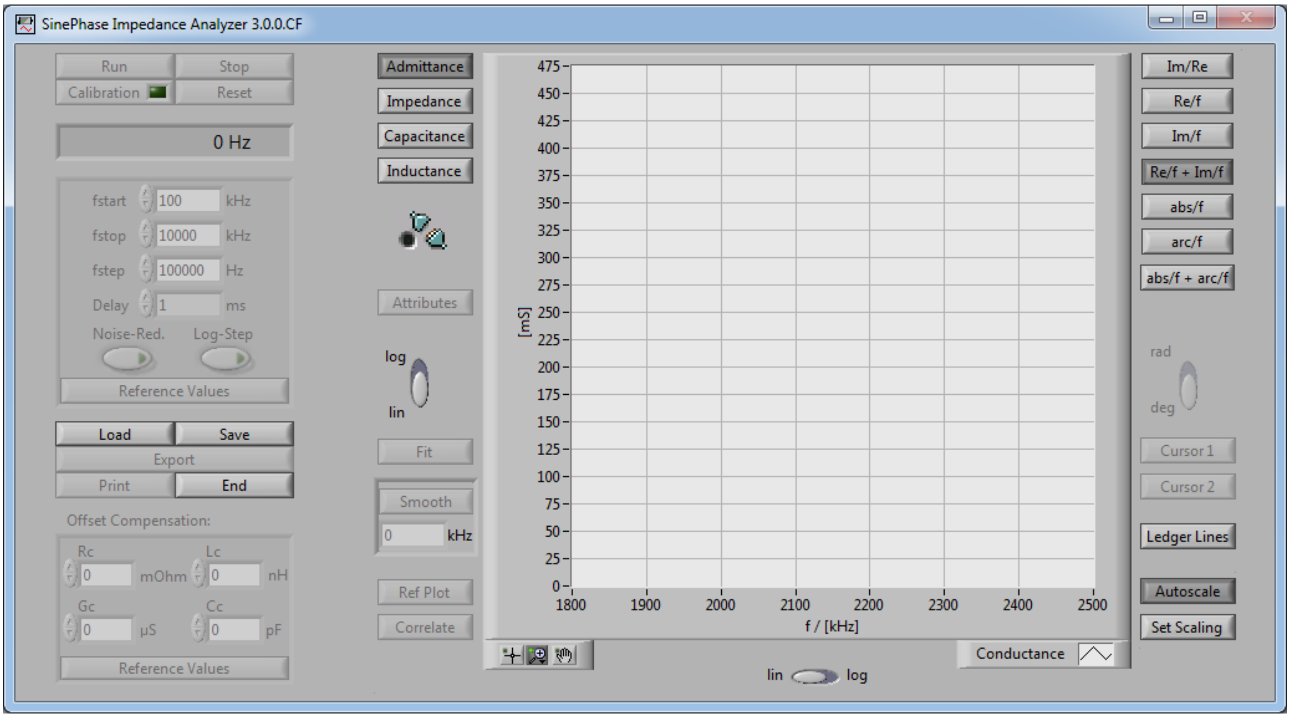
Typical online panel after starting the user software.

Offline Mode:



The green indicator LED will go out if the analyzer instrument is disconnected from the USB port of the computer. This indicates that the analyzer hardware is offline.

In Offline Mode, no new measurements can be made. However, it is still possible to load, view, export, re-scale, or print older measurements. Unavailable functions of the virtual panel will appear gray-shaded.



Typical offline panel after starting the user software.

It is possible to install the user software on several computers. This allows offline use of the software for analysis of data measured earlier while the analyzer hardware is used online on another computer for collecting new data.

3.3 Connecting the Load

WARNING!

Loads must be discharged completely and free from any hazardous potential before being connected to the instrument!

Note that some components like capacitors or piezoelectric plates can carry dangerous electric charges. In addition, excessive electric discharge through the probe port of the analyzer can destroy the instrument. Although the instrument is designed to withstand instantaneously discharging energies up to 5 milli Joule, every caution must be taken to avoid any charge being connected to the probe port of the analyzer. Especially with piezoelectric plates, special care is advised, as electric charges of several thousands of Volts can build up on the piezo's electrode as a matter of exposure of the piezo to pressure or temperature variations.

3.4 Status LED

The Status LED is the only "real" display unit of the impedance analyzer. Located either next to the BNC input or (for older models) at the top of the analyzer instrument, it indicates the status of the hardware as follows:

"green"	instrument online, no measurement active
"red"	instrument online, measurement active
none	instrument offline, or broken

Status LED positioned on the right side of the BNC input. Device is in offline mode.[5]

[5] Design may vary.

3.5 Exiting from User Software

For exiting the user software the "End" button must be clicked. This will automatically close the virtual panel. The window cannot be closed by a different method.

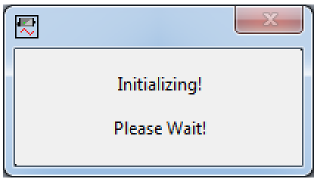
4. MEASUREMENT AND SETTINGS

4.1 Starting/Stopping and Interrupting a Measurement

Make sure that the instrument is connected to the Computer's USB port before starting a measurement. (Online mode[6])

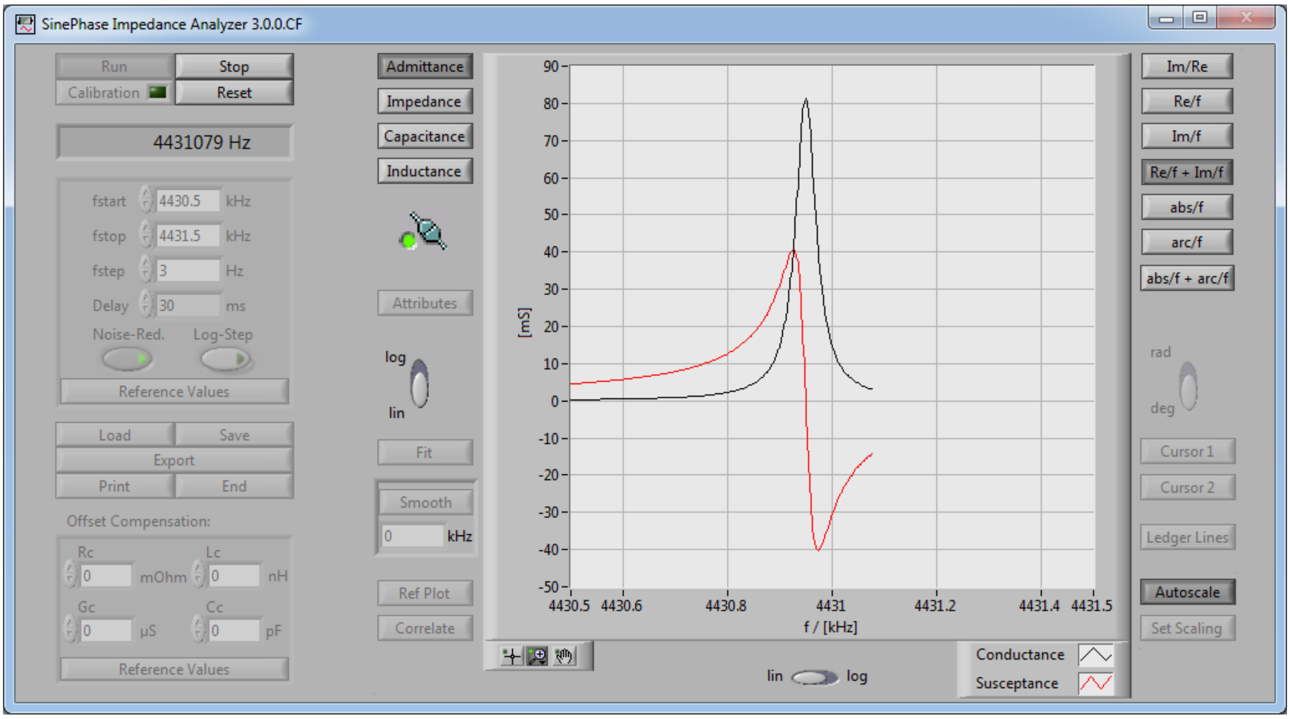
For setting the desired frequency range and other optional measurement parameters refer to the respective chapters of this manual.[7]

For starting a measurement, the "Run" button must be clicked. (In offline mode, the "Run" button appears shaded and cannot be clicked at.)



After pressing the "Run" button, a message window will appear informing about an internal initializing algorithm. This process takes approx. 3 seconds.

With the initializing procedure completed, the progress of the current measurement starts to be monitored in the graphics display window according to the display mode[8] chosen.



Example for a measurement in progress.

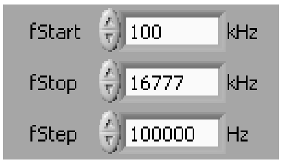
[6] Refer to chapter 3.2
[7] Refer to chapter 4.2, 4.3, and 4.4
[8] For setting the display mode refer to chapter 4.5

The actual frequency of a measurement in progress is displayed just below the Run/Stop/Reset button group.

During measurement, parameters cannot be changed. However, measurements can be interrupted by clicking at the “Stop” button, allowing alteration of parameters. Clicking at the “Run” button will continue the measurement.

A click on the “Reset” button will terminate the measurement irrespectively its progress. In this case, the data in the graphics display will be cleared, and the instrument is ready for starting a new measurement. Loaded Reference Measurements[9] will not be cleared.

4.2 Frequency Range and Step Width of a Measurement



Three fields are provided for setting *Start Frequency* (f_{Start}), *Stop Frequency* (f_{Stop}), and *Frequency Step Width* (f_{Step}) of a measurement. These three values define the frequency range and the width between two adjacent measurement values recorded versus frequency.

f_{Start} and f_{Stop} are to be set in kilo Hertz. For the 16777k-Model, values may be chosen between 1.000 kHz and 16777.000 kHz; for the 2097k-Model, values may be chosen between 1.000 kHz and 2097.000 kHz; for the 262k-Model, values may be chosen between 1.000 kHz and 262.000 kHz. The setting of these two parameters allow for a resolution of 0.001 kHz (= 1 Hz). Alternatively, values may also be increased or decreased by clicking at the respective up/down arrow buttons at the left of the entry fields.

f_{Step} is to be set in Hertz, whereby values may range between 1 Hz and 250000 Hz. This setting allows for a resolution of 1 Hz. Alternatively, the value may also be increased or decreased by clicking at the respective up/down arrow button at the left of the entry field.

For a loaded *Reference Measurement*[9] the “Reference Values” button below the frequency input fields is activated. Clicking on it will take over the frequency fields from the loaded Reference Measurement.

[9] Refer to chapter 4.8

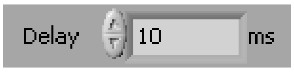
4.3 Logarithmic Steps

Typically, a frequency is calculated from the previous applied frequency by increasing its value by the step width f_{Step} set by the user. This leads to a linear distribution of the frequency steps over the whole measurement range.

With the “Log-Step” button these frequency steps can also be increased logarithmically. In this case the f_{Step} value entered defines the frequency increase of the first frequency step. Subsequent frequency steps are automatically calculated to form a geometric series of frequency points measured. This feature is especially advantageous for measurements over large frequency range covering several magnitudes of order.[10]

[10] New Frequency: $f_n = f_{Start}*(1 + f_{Step}/f_{Start})$^(n+1); $n \geq 0$

4.4 Delay Time



The *Delay Time* defines the waiting period of the system between the moment when a new frequency signal is applied to the Load connected to the BNC terminal, and the moment of acquisition of measurement data related to that frequency.

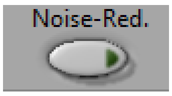
Selection of an appropriate Delay Time ΔT ensures that measurement values are not falsified by transient oscillations of the Load but represent steady state condition. As a rule of thump, *Delay Time* shall be chosen such that it is considerably larger than the quotient between the expected Q-value of the load, and measurement frequency f:[11]

$$\Delta T >> Q/f$$

By clicking into the entry field, discrete values ranging from 1 ms to 300 ms can be selected, or incremented/decremented by clicking at the related up/down buttons.

4.5 Noise Reduction

Noise Reduction is a tool that reduces noise due to reduced accuracy of the measurement at high (>1 kOhm) or low (<1 Ohm) impedance values of the load.



Noise Reduction can be activated, and deactivated, by clicking at the respective button. If activated, the green indicator of the button will turn bright green.

However, Noise Reduction increases measurement time by approx. 30 ms per frequency point. Especially for measurements performed over a spectrum of several thousands of frequency points, this function should not be engaged if not needed.

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[11] Naturally, longer delay times will slow down measurement, as it applies to every frequency point twice (once before the real measurement value is recorded, and a second time before the complex measurement value is recorded).

- For example, a measurement recorded from 1000 kHz to 3000 kHz at 500 Hz steps, with the Delay set to the smallest value of 1 ms will result into a total delay of (3000-1000):0,5 x 2 x 1 ms = 8 seconds.
- In contrast, with the Delay set to the highest value of 300 ms, total delay results to (3000-1000):0,5 x 2 x 300 ms = 2400 seconds = 40 minutes.

For most electronic components other than piezos and quartz plates, Q value can be considered too low as for being of any significance. As a result, a Delay of 10 ms will be sufficient over the whole frequency range. However, if the Q-value cannot be considered insignificant upfront, appropriate Delay can be found experimentally by several measurements over a few frequency points of the lowest frequency range of interest, while reducing Delay from measurement to measurement. By comparison of the significance of change of measurement values, the smallest Delay still ensuring acceptable accuracy of data can easily be identified.

4.6 Display Modes

Admittance
Impedance
Capacitance
Inductance

The virtual instrumentation panel offers several modes for displaying measurement values. These Modes can be selected by clicking “Admittance”, “Impedance”, “Capacitance” or “Inductance”, at the main selector button array at the upper left corner of the graphics display.

For Admittance and Impedance, specific display modes can be selected from a second button array positioned at the upper right corner of the graphics display:

Display Modes for main selector at Admittance

Button	*vertical axis*	*horizontal axis*
Im/Re	Susceptance	Conductance
Re/f	Conductance	Frequency
Im/f	Susceptance	Frequency
Re/f + Im/f	Conductance and Susceptance	Frequency
abs/f	Magnitude of Admittance [12]	Frequency
arc/f	Phase of Admittance [13]	Frequency
abs/f + arc/f	Magnitude and Phase of Admittance	Frequency

Display Modes for main selector at Impedance

Button	*vertical axis*	*horizontal axis*
Im/Re	Reactance	Resistance
Re/f	Resistance	Frequency
Im/f	Reactance	Frequency
Re/f + Im/f	Resistance and Reactance	Frequency
abs/f	Magnitude of Impedance [14]	Frequency
arc/f	Phase of Impedance [15]	Frequency
abs/f + arc/f	Magnitude and Phase of Impedance	Frequency

[12] Magnitude of Admittance = $\sqrt{\text{Conductance}^2 + \text{Susceptance}^2}$

[13] Phase of Admittance = arctan(Susceptance/Conductance)

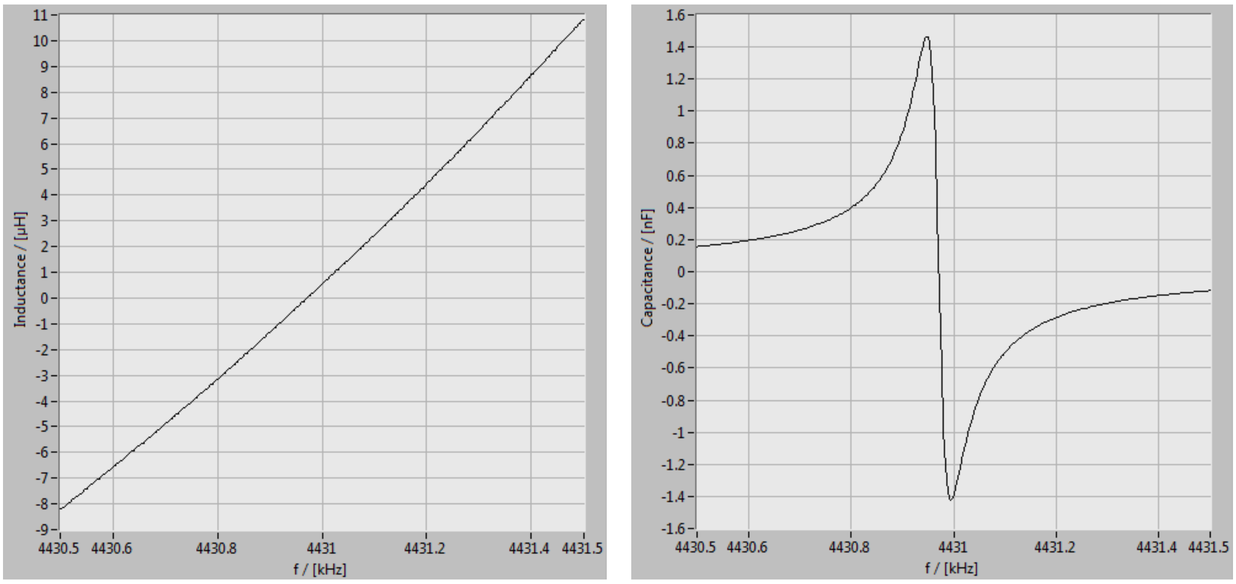
[14] Magnitude of Impedance = $\sqrt{\text{Resistance}^2 + \text{Reactance}^2}$

[15] Phase of Impedance = arctan(Reactance/Resistance)

Main selector at either Capacitance **or** Inductance

With the main selector “Capacitance” or “Inductance”, the proband is assumed to be a capacitor, or an inductor. Its susceptance, and reactance, is converted into a capacitance, and an inductance, respectively.

LC-circuitries, piezos, or quartz crystals may change from capacitive characteristics into inductive characteristics over the course of a frequency scan. This fact leads to the change from positive to negative values (or vice versa) of the capacitance or inductance at the resonance frequency, as depicted in both example plots.

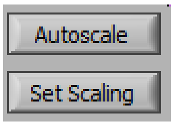


Inductance and Capacitance for a quartz crystal with series resonance frequency at 4430977 Hz. Before resonance frequency, the crystal's frequency response is dominated by its dynamic capacitive characteristics, while the crystal's dynamic inductive characteristic dominates the frequency response after the series resonance frequency of the crystal. These behavior leads to calculated negative inductance values for frequencies smaller than the resonance frequency, as well as negative capacitance values for frequencies higher than the resonance frequency.

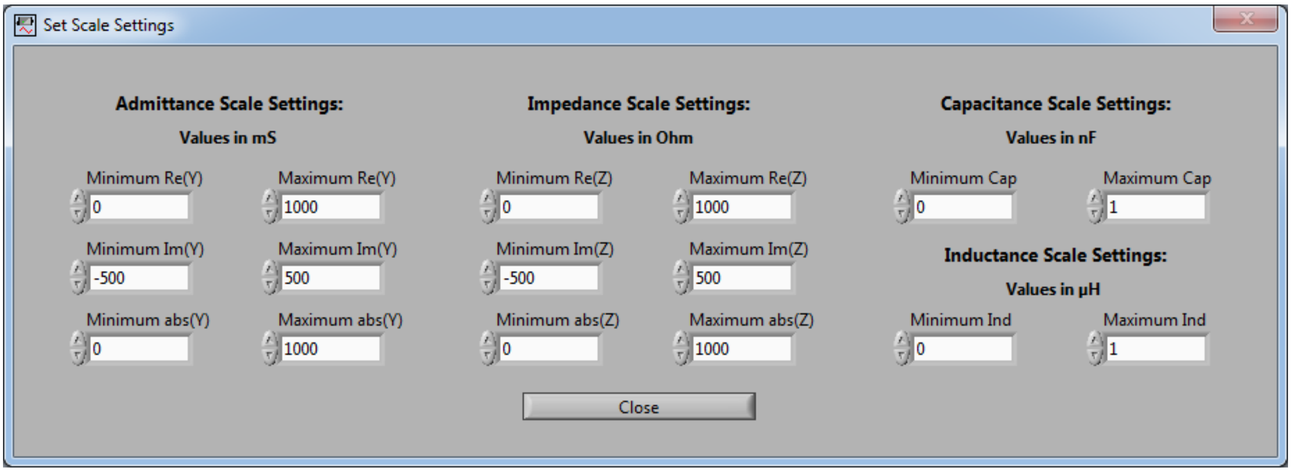
The specific display mode button array to the right of the graphic display is disabled if the main selector is set to the “Capacitance” or “Inductance” mode.

4.7 Scaling Options

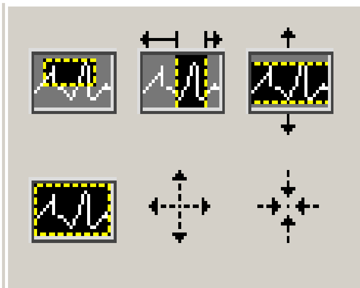
Aside from a variety of Manual Scaling options the system also offers an Automatic Scaling option programmed to choose scale in such way that the measured data are completely displayed, yet at highest resolution possible.

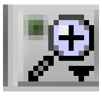


The *Auto Scaling* mode can be enabled/disabled by clicking at the "Autoscale" button located at the lower right corner of the graphic display. In *Manual Scaling* mode ("Autoscale" deactivated) full scale parameters can be set through a separate window popping up when clicking at the "Set Scaling" button:

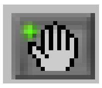


With both, *Auto scale,* and *Manual Scale* mode, the user may select from several tools for manually enlarging, or reducing specific sections of the measurement plot. These tools are provided through another pop up window launched

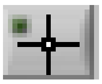




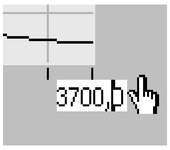
by clicking at the magnifier symbol in the lower left corner of the graphics display.



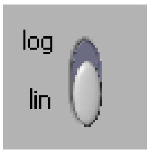
With the Hands-button, the whole plot can be moved relative to the graphics display's axes by click-and-hold the left button of the mouse.



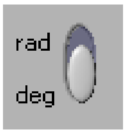
Clicking the cross symbol exits the magnifier and hands modes described above. This tool has to be selected to move activated cursors.



However, the graphic display's scale can also be modified by simply overwriting the lowest and highest values of both, the horizontal or the vertical axis.

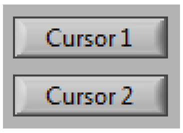


Logarithmic and linear scale can be chosen for both, horizontal and vertical axis by clicking at the slide switch symbol located on the left side, and below, the graphics display.[16]



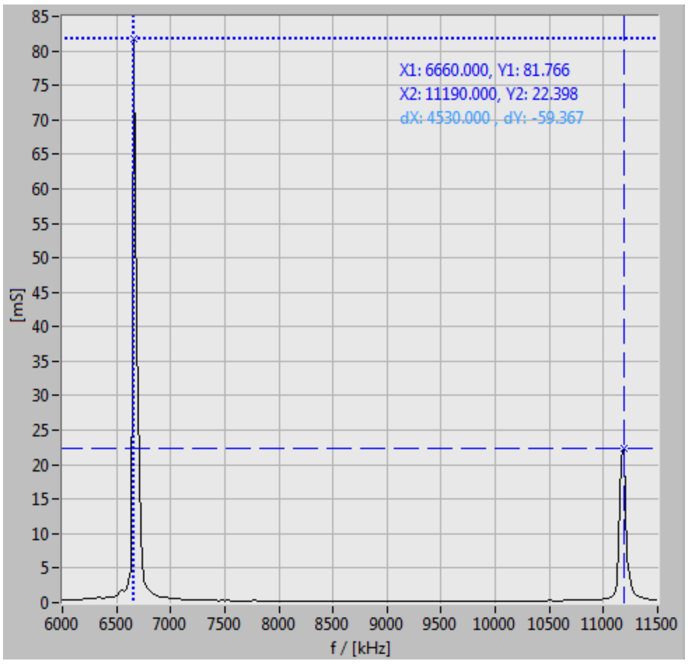
Finally, for all display modes involving Phase a slide switch symbol is provided for selection of degree or radiant scale of the vertical axis.

4.8 Cursor



For accurate determination of measured values at specific frequencies, a double cursor tool is provided through buttons "Cursor 1" and "Cursor 2".

Activated cursors will display the selected frequency values together with their corresponding measured values as absolute (X1/Y1 and X2/Y2), as well as differential (dX/dY) pair of figures.



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[16] For horizontal axis log/lin cannot be changed during measurement.

4.9 Ledger Lines

Automatically disposed horizontal and vertical ledger lines help for orientation within the plotting area. In many cases however, it is advantageous to add additional ledger lines at specific horizontal or vertical values in the plotting area.

For this case the "Ledger Lines" button offers the possibility to add up to ten additional horizontal and vertical ledger lines, respectively.

4.10 Reference Plots and Reference Values

Any earlier measurement can be loaded as a *Reference Measurement* through the Load menu.[17] This opens the possibility for comparing the loaded *Reference Measurement* with the current measurement.

The respective Reference Plots of a loaded Reference Measurement are displayed as dotted lines in addition to the current measurement. These dotted lines can be hidden or shown by clicking at the "Ref Plot" button located at the left side of the graphic display.

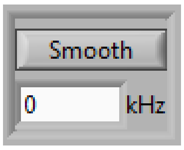
By default, a Reference Measurement is displayed within the frequency range specified by the f_{start} and f_{stop} values chosen for the current measurement.[18] However, it is possible to take over the frequency range defined for the whole Reference Measurement by clicking the "Reference Values" button below the "Noise-Red." and "Log-Step" button. Clicking the mentioned button will display the loaded Reference Values exactly over the recorded frequency range. In this case the current measurement will be reduced or zoomed to fit the new defined frequency axis. (Note that the adopted Reference Values will also be valid for a new measurement, if started while the "Reference Values" button is active.) Another click onto "Reference Values" button will return the frequency parameters to the values last defined before the "Reference Values" button has been activated.

Similarly, Offset Compensation Values[19] as used for the Reference Measurement can be taken over for the current measurement if the "Reference Values" button of the Offset Compensation window is pressed. Another click on that button will return that values to the last defined before the "Reference Values" button has been activated.

[17] Refer to chapter 4.12
[18] Refer to chapter 4.2
[19] Refer to chapter 4.11

Although the Reference Plot can be shown/hidden by using the "Ref Plot" button, the Reference Plot will not be deleted but only be hidden. Even if a new measurement is started, or a current measurement is aborted by pressing the "Reset" button, the data of the Reference Measurement will not be lost. However, the Reference Measurement will be overwritten as soon as another measurement is loaded as a Reference Measurement through the Load menu.

4.11 Smoothing Option



With the smoothing function noisy progressions can be smoothed. This function is activated by clicking on the "Smooth" button. The strength of the smoothing is dependent on the smoothing bandwidth which has to be entered in the field under the "Smooth" button. This bandwidth must be a multiple of the twice the frequency step value f_{step}.[20] Any entered value not equaling the mentioned multiple will be automatically corrected into the next smaller multiple of the doubled frequency step width.

The smoothing algorithm itself is a FIR smoothing filter with a moving window. The data points in the moving window consist of the actual measurement point and the measurement points within the half smoothing bandwidth on the left and right side of the actual measurement point frequency.

4.12 Correlation Function (optional)

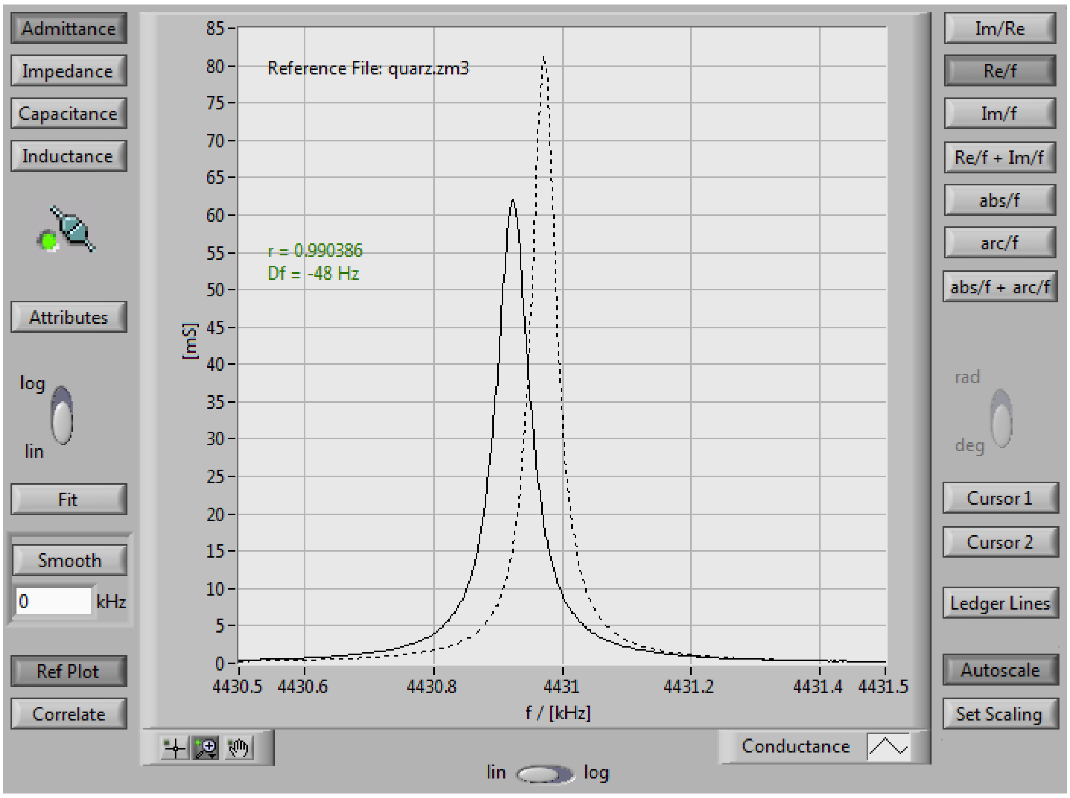
The Correlation Function is an optional tool that can be supplied as an add-in to the standard measurement software.[21] With this function, the correlation between a current measurement and a Reference Plot is calculated based on the mathematically defined cross correlation of the two functions. In order to use this tool, a Reference Plot must be loaded and actively displayed.[22] The tool can only be used for the display modes "Re/f", "Im/f", and "abs/f".[23] Note that both, frequency range, and step width, of data recorded must be identical for the current measurement and the reference measurement.[24]

[20] Possible smoothing bandwidths: $f_{Smooth} = n*2*f_{Step}$; $n \geq 1$
[21] For ordering, please contact support@sinephase.com
[22] Refer to chapter 4.8
[23] Refer to chapter 4.5
[24] Refer to chapter 4.2

The calculation of correlation is started by clicking at the "Correlate" button. Usually, this calculation only takes a fraction of a second. As a result the following two values are plotted into the graphic area:

r …. Coefficient of correlation Df …. Frequency shift of measured data

The value *Df* describes the *Frequency Shift* of the measured data from a best case correlation situation with the Reference Plot, whereby the *Coefficient of Correlation r* describes the degree of correlation assuming measured data being compensated for such frequency shift. Note that accuracy of the value *Df* is limited by the respective step width of the measurement.



Example for using the Correlation Tool: Measured data are 48 Hz offset from the optimum correlation with the Reference Plot (loaded as a dotted line), whereby such frequency-compensated correlation results to r = 0.990386

4.13 Fit Function (optional)

The Fit Function is an optional tool that can be supplied as an add-in to the standard measurement software.[25] It calculates any series and parallel resonance frequency as well as the frequencies of maximum and minimum impedance of the proband by means of an

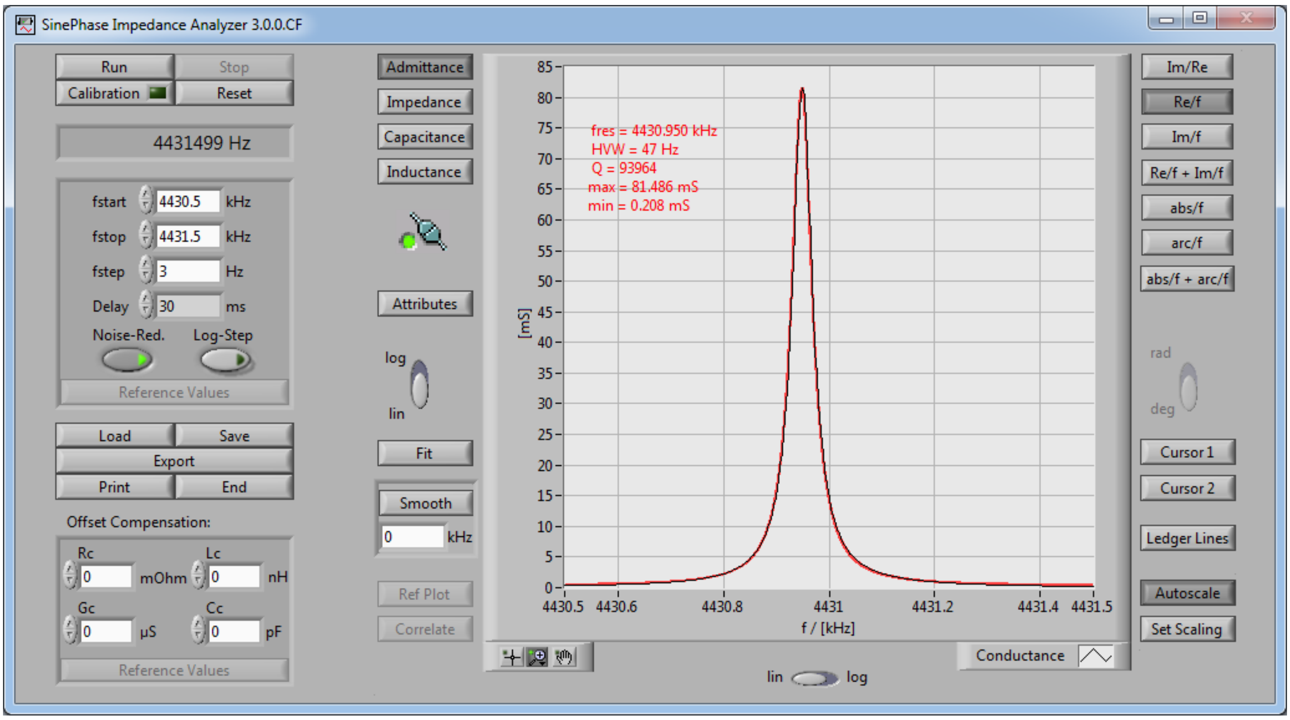
[25] For ordering, please contact support@sinephase.com

idealized resonance function based on the Least Square Method from the measured conductance or resistance.[26]

Fitting series and parallel resonance frequencies:

After having zoomed into the frequency interval of interest[27] the fitting process is started by clicking at the “Fit” button. Depending on the amount of measurement data available, the fitting process may take from fractions of a second up to one minute. After the fitting algorithm has been completed, the calculated best fit is displayed as a red plot superimposing the measurement plot. Characteristic values of that idealized resonance function are also plotted into the graphic area:

fres	….	Resonance Frequency of the fit function
HVW	….	Half Value Width of the fit function
Q	….	Q-value of the fit function (= fres/HVW)
max	….	Height of peak of the fit function
min	….	Base line of the fit function



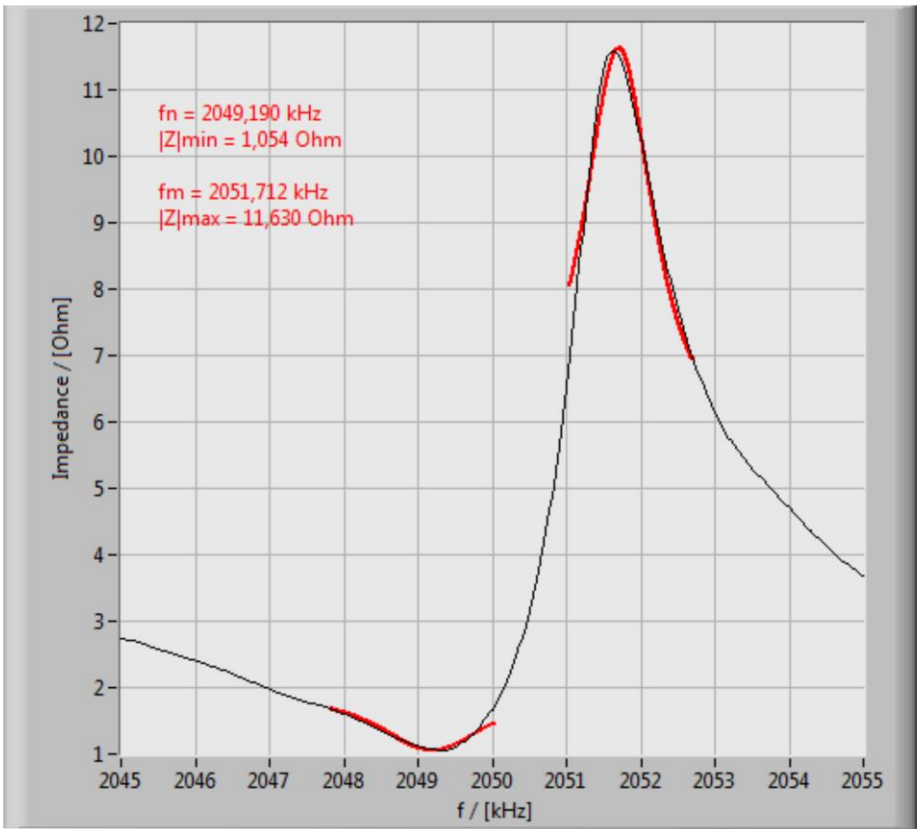
Example for using the Fitting Tool for detection of a series resonance frequency.

[26] Please refer to the application note: appnote_resonance_140916
[27] Refer to chapter 4.6

Fitting frequencies of maximum and minimum impedance (admittance):

In the absolute impedance (or admittance) display mode the frequencies of maximum and minimum impedance (or admittance) can be found by pressing the “Fit” button. The fitting tool will display the calculated best fit for the maximum and/or minimum point as a red plot. The characteristic values and their frequencies are also plotted into the graphic area:

fn	….	Frequency of min. impedance (max. admittance)
|Z|min (|Y|max)	….	Min. (max.) value of the impedance (admittance) fit function
fm	….	Frequency of max. impedance (min. admittance)
|Z|max (|Y|min)	….	Max. (min.) value of the impedance (admittance) fit function



Example for using the Fitting Tool for detecting the frequencies of max. and min. impedance.

4.14 Offset Compensation

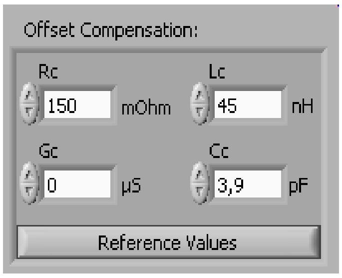
The Instrument is calibrated for accurate measurement of impedance or admittance from the instrument's BNC terminal onwards. This means that any probe, or any piece of wire, or any hardware set up, that connects the Load to the BNC terminal will be added to the impedance (or admittance) measured. In some cases this measurement of “total” Load characteristics is desired, e.g., when measuring an ultrasonic transducer together with the original wiring that shall connect the transducer to the ultrasonic power generator: Here, the total impedance of transducer including cable is the property of interest, as it is the total impedance that forms the load to be matched with the output specifications of the respective power generator.

In other cases however, impedance added by wiring, or the influence of a probe used for connecting the proband, is not of interest. The mentioned offset can be extinguished by two different methods offered by the software:

- A *Calibration* function is implemented for automatic annihilation of any electrical influence by probes or other means of connection, over the whole frequency range.
- A manual *Offset Compensation* function is also implemented for extinguishing offset effects by subtraction of four compensation properties. This function is suitable if only a narrow range of frequency is of interest, since such a set of compensation values is exactly defined and valid for one specific frequency only.

While automated calibration is described in chapter 5.1, the latter method of manual offset compensation is hereby described further.

For the input of respective compensation properties, the instrumentation panel provides four input fields:



R_c … to compensate for any series resistance,
L_c … to compensate for any series inductance,
G_c … to compensate for any parallel (=”leaking”) conductance[28],
C_c … to compensate for any parallel capacitance,
of the Load's wiring with (or connection to) the analyzer's BNC port.

[28] Leaking conductance can also be modeled as the reciprocal value of resistance placed parallel to the Load.

While probe compensation values may be set by fixed increments/decrements by clicking at respective up/down arrow buttons, any decimal values can be directly entered into the fields also.

If a *Reference Measurement*[29] has been loaded, a click at the "Reference Values" button above the frequency input fields will disable the *Probe Compensation* fields and the respective parameters will be taken over from the *Reference Measurement* loaded.

4.15 Attributes Window

The software offers the possibility to append specific attributes to a measurement. These attributes will be saved together with the measurement data in the respective *.zm3 file and can be seen or edited anytime or after reloading.

Clicking on the "Attributes" button will open a pop-up window presenting the *Measurement File Attributes* of the current (or loaded) measurement, and the reference file (if loaded). For both, the measurement file, and the reference file, four fields are shown where only fields with white background are editable:

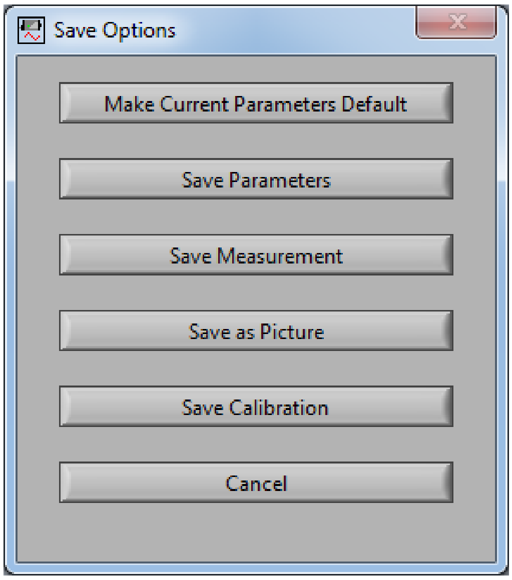
- Measurement Time: Timestamp of measurement completed
- DUT Component-ID: To define ID of specific component under test
- DUT System-ID: To define ID of specific setup under test
- Comments: To comment on environmental conditions (location, temperature, etc.)

[29] Refer to chapter 4.8

4.16 Save and Load Measurements and Parameters

After a measurement is completed, the measurement itself or its parameters may be saved.

Clicking at the "Save" button opens a window from which several options may be selected:



First, all "*Measurement Parameters*" (f_{start}, f_{stop}, f_{step}, Delay, Noise Reduction, Logarithmic Steps[30], as well as Offset Compensation values[31]), together with "*Display Parameters*" (display mode selector, scale settings, smoothing parameters, and ledger lines) may be stored as *Default* parameters for all future measurements. These values may also be saved into a specific parameter file (*.par) by clicking at the "Save Parameters" button.

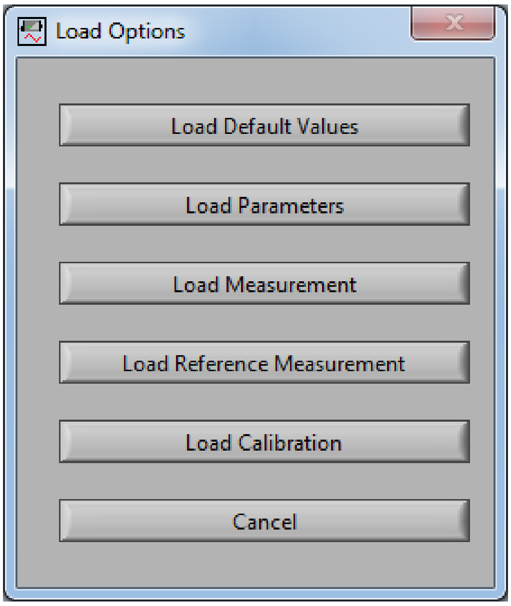
With the "Save Measurement" button, the whole measurement can be stored into a measurement file (*.zm3), including the *Measurement Parameters* as defined above but excluding any *Display Parameters*.

With the "Save as Picture" button the measurement can saved as an image (jpg, bmp, or png) of either the graphics display area only, or of the virtual instrumentation panel as a whole.

Finally, the "Save Calibration" button is used to save the performed full frequency range probe calibration[32] for the applied probe connector in the calibration file format (*.cal).

[30] refer to chapter 4.2, 4.3, and 4.4
[31] refer to chapter 4.11
[32] refer to chapter 5.1

Measurement parameters saved into a parameter file, as well as whole measurements (except if saved as images only), and saved calibration files may be re-loaded for further analysis, printing, or exporting data. This is provided by a separate *Load Options* window which pops up when clicking at the "Load" button.



With the "Load Reference Measurement" option, a measurement can be loaded as a dotted-line reference plot into the graphic area, for comparison between current measurements, and such earlier measurement.[33] Furthermore, saved calibration files for specific probe connectors can be loaded with the "Load Calibration" button.

[33] refer to chapter 4.8

4.17 Exporting Measurement Data

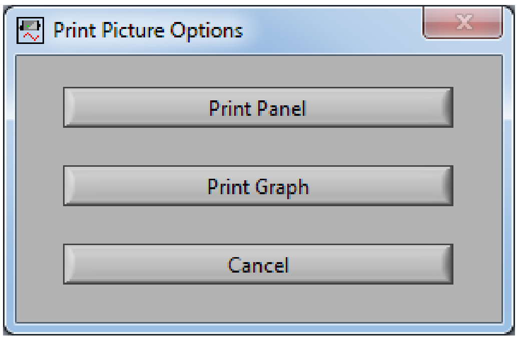
The export function is a tool for extracting measurement data into either a Microsoft Excel spread sheet file (*.xls), a text file (*.txt), or into MATLAB file (*.mat) for further data analysis using external Software, or simply for reporting purposes.

In order to eliminate any problems with decimal point standards (e.g. comma versus dot) the magnitude of units of exported data are chosen such that no decimal point is required. The below table summarizes the units of the exported data:

exported values	*exported units*
Frequency	Hertz (Hz)
Conductance	micro Siemens (µS)
Susceptance	micro Siemens (µS)
Resistance	milli Ohm (mΩ)
Reactance	milli Ohm (mΩ)

4.18 Printing Function

For printing a measurement, simply click at the "Print" button. This will open a separate window providing a choice whether the whole panel, or just the graphics display together with the attributes, shall be printed.



Alternatively the panel or the graphics area only can be saved as a picture[34] for importing into other documents.

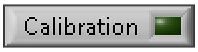
[34] Refer to chapter 4.12

5. CALIBRATION

5.1 Probe Calibration

The Instrument is factory-calibrated for accurate measurement of impedance and admittance from the instrument's BNC terminal onwards.[35] This means that any probe, or any piece of wire, or any hardware set up, that is used for connection of the load to the BNC terminal will be add to the impedance (or admittance) measured. In some cases this measurement of "total" load characteristics is desired, e.g., when measuring an ultrasonic transducer together with the original wiring that shall connect the transducer to the ultrasonic power generator.

In many cases however, effects of the probe wire on the impedance measured must be compensated for, in order to measure the pure characteristics of the proband only. For such cases, the user software provides a semi-automated probe calibration routine as follows:



With the probe chosen for the measurement connected to the BNC port of the instrument, a three-step calibration process is started by clicking at the "Calibration" button located below the "Run" button. A pop up message will ask the user to set up the instrument for

SHORT Calibration: Shorten the free leads of the probe wire connected to the BNC terminal and click OK. A pop up window will inform about the progress of this first step of the probe calibration routine (typically completed within 1 minute), followed by a pop up message asking for to set up the instrument for

OPEN Calibration: Open the free leads of the probe wire connected to the BNC terminal and click OK. A pop up window will inform about the progress of this second step of the probe calibration routine (typically completed within 1 minute), followed by a pop up message asking for to set up the instrument for

[35] For specific information on accuracy, please refer to the Technical Specifications, capter 7. It is recommended that the instrument is returned to SinePhase at least every three years for renewal of the internal basis calibration of the BNC terminal.

LOAD Calibration: Connect a Calibration Load to the free leads of the probe wire connected to the BNC terminal, type in the impedance value of the Calibration Load, and click OK. A pop up window will inform about the progress of this final step of the probe calibration routine (typically completed within 1 minute).

For performing the LOAD Calibration step, the instrument is supplied with a 50 Ohm resistor (0.1 % max. tolerance) as a standard, but any other resistor of known value may be used, too. However, for the selection of a suitable resistor for completing the LOAD calibration step, the following two criteria should be taken into consideration:

- For optimized repetitive accuracy of subsequent measurements, the impedance of the resistor used for completion of the LOAD calibration step shall be of similar magnitude as expected from the average magnitude of the impedance of the probands to be measured within the frequency area of interest, and

- Absolute accuracy of subsequent measurements is limited by the accuracy of the impedance of the resistor chosen, used for completion of the LOAD calibration step.

For achieving maximum repetitive accuracy, the instrument should be fully warmed up (connected to a USB port of a computer for at least 60 minutes).

5.2 Save and Load a Calibration Measurement

After performing the probe calibration routine the acquired calibration data can be saved by means of the *Save Options* menu in the specific *.cal file. Already saved extern calibration data can be loaded through the *Load Options* menu. However, users should keep in mind that recalibration may be required every time the setup of the measurement is changed or moved as a result of dislocation of probe or connection wiring.

Note that saving of calibration data is required for the implementation of probe calibration when using the *Application Programming Interface* as described in section 6.

5.3 Frequency Monitor Terminal

The instrument's internal oscillator is specified to meet a typical absolute accuracy of 10 ppm. As the analyzer only provides signals at the BNC terminal during measurements (for very short repetitive periods of few milliseconds), calibration of frequency can hardly be monitored directly at the BNC terminal of the instrument. However, for monitoring purposes a frequency monitor terminal is provided at the left side of the BNC terminal.

The terminal fits, e.g., the pin of a standard oscilloscope probe. For a reliably monitoring frequency count, connect the ground clamp of the scope's probe to the ground shield of the BNC terminal of the instrument.

Monitoring Nominal Frequency; the red arrow indicates the frequency monitor terminal.

Nominal monitor frequency:

1048576 Hz

The monitor frequency is directly linked with the internal oscillator reference frequency. As a result, any deviation monitored from the above nominal value relates pro rata to an absolute inaccuracy of the measurement frequency.

6. APPLICATION PROGRAMMING INTERFACE (OPTIONAL)

Generally, the purpose of an *Application Programming Interface* (API) is to allow control of an instrument by individually programmed measurement software rather than by standard measurement software provided by the supplier of that instrument.

Also for the impedance analyzer, an API Toolkit can optionally be supplied.[36] In this case, all files being part of the toolkit are provided with the installation CD under a separate directory called “API”.

The API directory contains a demonstration example for LabVIEW, and a subdirectory with *.dll, *.h and *.lib files. These files have to be used for the programmatic connection and communication with the device.

6.1 Dynamic Link Library

The dynamic link library “ZA01-A2-200.dll” contains seven functions which are necessary to connect and communicate with the device, as follows:

Init

This function searches for a new device connected to the PC and returns its device handle and its intern calibration values.

- Input Parameters: none
- Output Parameters: - Device Handle (32 bit Integer)
  - Connection Status (Boolean)
  - Device Calibration Data

[36] For ordering, please contact support@sinephase.com

GetOffset

This function measures the offset at the input of the device.

- Input Parameters: - Device Handle (32 bit Integer)
  - Length of Offset Data Array (32 bit Integer)
    The value of this parameter has to be “4”.
- Output Parameters: - Offset Data Array (Array of 16 bit integer values)
  - Surge Status (Boolean)

GetImpedance

This function returns the real and imaginary part of the complex impedance at a certain frequency for the probe connected to the device.

- Input Parameters: - Device Handle (32 bit Integer)
  - Frequency in Hz (32 bit Integer)
    allowed values, model 16777k: 1000 to 16777000
    allowed values, model 2097k: 1000 to 2097000
    allowed values, model 262k: 1000 to 262000
  - Device Calibration Data (Structure of 14 elements)
  - Offset Data Array (Array of 16 bit integer values
  - Length of Offset Data Array (32 bit Integer)
    The value of this parameter has to be “4”.
  - Delay Time in ms (16 bit Integer)
    allowed values: 1, 3, 10, 30, 100, 300
  - Noise Reduction (Boolean)
- Output Parameters: -Communication Error Output (Boolean)
  -Measured real part of complex impedance (Double)
  -Measured imaginary part of complex impedance (Double)

CloseDeviceHandle

This function closes the device handle.

- Input Parameters: - Device Handle (32 bit Integer)
- Output Parameters: none

LoadCalFile (optional)

This function is used for loading an existing calibration file (*.cal) of a performed probe calibration. The calibration file has to be generated with the standard measurement software.

- Input Parameters: - Absolute file path to *.cal file
- Output Parameters: - Probe Calibration Data

ExecCal (optional)

Within this function the probe calibration values from the loaded calibration files are applied on the measured data got from the GetImpedance function. The result is the corrected complex impedance at the specific frequency point.

- Input Parameters: - Frequency in Hz (32 bit Integer)
  allowed values, model 16777k: 1000 to 16777000
  allowed values, model 2097k: 1000 to 2097000
  allowed values, model 262k: 1000 to 262000
  - Probe Calibration Data
  - Noncalibrated real part of the complex impedance
  - Noncalibrated imaginary part of the complex impedance
- Output Parameters: - Calibrated real part of the complex impedance
  - Calibrated imaginary part of the complex impedance

ConvZtoY (optional)

This function converts the real and imaginary part of the complex impedance into a real and imaginary part of a complex admittance.

- Input Parameters: - Real part of complex impedance
  - Imaginary part of complex impedance
- Output Parameters: - Real part of complex admittance
  - Imaginary part of complex admittance

6.2 Calling Order

For a reliable connection and communication with the device the following sequence is necessary:

1. Call function “Init”.
2. Call function “GetOffset”.

An existing calibration file has to be loaded in case that a following measurement correction should be applied:

3. Call function “LoadCalibFile”.

After calling the above steps, the device will be connected to the software the DLL has been implemented into. Now, for example, a loop can be realized for measuring the complex impedance for a whole range of frequencies by repeatedly calling the function

4. “GetImpedance”.

Remember that in this function the parameter “Length of Offset Data Array” has to be set to 4.
In case of loaded probe calibration data a measurement correction can be performed within the loop by calling the

5. “ExecCalib”

function after each measured value (step. 4.).
Furthermore if a complex admittance is required, then the function

6. “ConvZtoY”

can be called within the loop after either step 4. or 5..

When the measurement is finished the device has to be disconnected from the software by calling the function

7. “CloseDeviceHandle”.

The last function should only be used when all measurements were done and the device will be disconnected from the software. It is not recommended to call this function in case that the device should remain connected to the software for e.g. performing an upcoming new measurement. In this case it is recommended to continue with the *GetOffset* function (step 2.) before starting the new measurement.

7. TECHNICAL SPECIFICATIONS

System Requirements

minimum PC/Laptop requirements	- 1 GHz clock rate - 256 MByte RAM - 300 MByte available harddrive space - 1024 x 600 pixels resolution - CD-ROM drive (for installation of user software)
operating system	Microsoft Windows 2000, 2003, ME, XP, Vista, or Windows 7 (other on request)

General Specifications

power consumption	5 VDC; 400mA
power source	USB port
control interface	USB port
built-in protection	USB interface galvanically isolated (1000 VDC /1min, 3000 VDC /1sec)
weight	0.2 kg
dimensions	32 x 81 x 126 mm (without connectors)
operating condition	-15 to +65 °C / 0 to 150 °F at < 80% humidity, non condensing (extended range on request)
electromagnetic compliance	emitted radiation: EN 55011, class B (stringest class) immunity against discharge: EN 61000-4-2, criterion A (highest immunity) immunity against EM fields: EN 61000-4-3, criterion A (highest immunity)

Probe Port

terminal type	BNC
output signal amplitude	measurement on: max. 316 mV_p max. 9,6 mA_p measurement off: no signal
output frequency range	model 262k: 1 kHz to 262 kHz model 2097k: 1 kHz to 2.097 MHz model 16777k: 1 kHz to 16.777 MHz
output impedance	measurement on: 33 Ohm measurement off: 330 kOhm
discharge energy absorption	max. 1 mJoule