

SWEEP TOOL FOR LCR METER R&S®LCX

Products:

- ▶ R&S®LCX100
- ▶ R&S®LCX200
- ▶ R&S®LCX-K106
- ▶ R&S®LCX-K201
- ▶ R&S®LCX-K210
- ▶ R&S®NG-B105

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<https://www.rohde-schwarz.com/appnote/1GP132>

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1 Overview

The LCR meters R&S®LCX100 and R&S®LCX200 precisely measure the complex impedance and the resulting components values over a wide frequency range. Dynamic impedance measurements allow to perform these measurements while sweeping the test signal frequency or other parameters like test signal level and DC bias. This application note provides a PC-based software tool for comfortably setting the sweeps and displaying the results in numerous charts.

2 Background

2.1 Electric impedance and admittance

If a voltage is applied across a resistor, a current flows through the resistor. The value of the current depends on the applied voltage and on the resistance of the resistor. Ohm's law defines the resistance as the ratio between applied voltage and resulting current. With an ideal resistor this law also is valid for the RMS values of an applied AC voltage and the AC current resulting from it.

If a current flows through a capacitor, the capacitor is charged with time, and a voltage across the capacitor builds up. If a voltage is applied across a coil, the magnetic field in the coil and the associated current through the coil builds up with time. If an AC signal is applied to a capacitor, the voltage lags behind the current, and if an AC signal is applied to a coil, the current lags behind the voltage. This can be expressed as a phase shift of the signal. The impedance of a component can be expressed as a complex number, with the absolute value and the phase angle as polar coordinates.

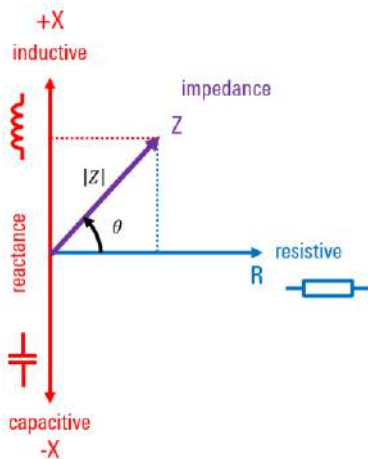


Figure 2-1 Complex impedance

The admittance of a component is the reciprocal value of its impedance. In polar coordinates the absolute value of the admittance is the reciprocal of the absolute value of the impedance, and the phase angle of the admittance is the phase angle of the impedance with opposite sign.

2.2 Frequency-dependence of impedance and admittance

The impedance of an ideal resistor is independent of the test frequency. The impedance of a capacitor decreases with increasing frequency, and the impedance of an inductor increases with increasing frequency. Since the admittance of a component is the reciprocal of its impedance, the frequency dependence is the opposite of the frequency dependence of the impedance.

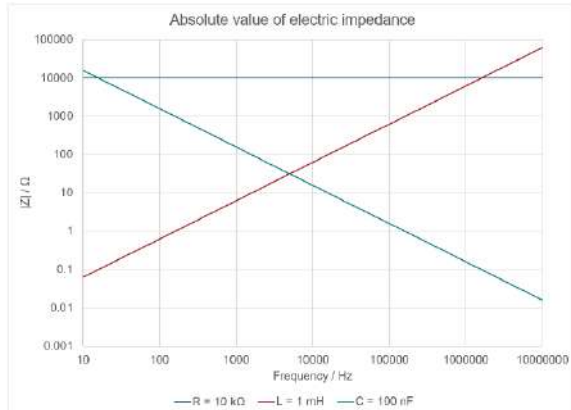


Figure 2-2 Absolute value of the impedance of electric components versus frequency

The phase angle of the impedance of a real inductor is always 90° , and the phase angle of the impedance of an ideal capacitor is always -90° .

In reality, a resistor is not ideal over the entire frequency range. Leads have a certain inductance, and there may also be some capacitance involved. Real capacitors and inductors also have parasitic elements. This can be described by appropriate equivalent circuits.

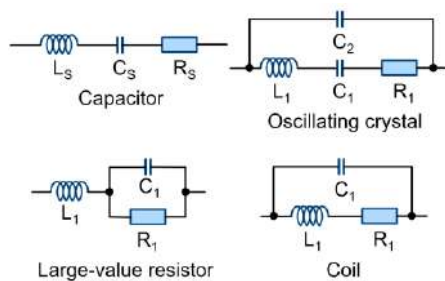


Figure 2-3 Equivalent circuits of passive components

In order to determine the components of the appropriate equivalent circuit, the complex impedance or admittance of the real component is measured at many frequency points over a large frequency range. Such a measurement is sometimes called “impedance spectroscopy”.

2.3 Sweep

A set of measurements with one of the measurement parameters systematically changed is called a “sweep”. A sweep may be stepped as a number of single measurements, or continuous with the swept parameter changing continuously. The sweeps described in this application note are stepped sweeps. Besides frequency, also the test signal level, bias voltage or bias current can be swept.

2.4 Corrections

Not only leads of components under test have properties which cause parasitic elements. This is also the case for the test fixture and the connection leads between the fixture and the component under test. The effect of these parasitic components can be eliminated by correction (or compensation) measurements. A so-called “open-correction” determines the parasitic components parallel to the component under test. It is performed in the absence of the component under test with the contacts of the fixture open. It is essential that the state of the test fixture is otherwise identical with the state during the measurement. For the so-called “short correction”, the component under test is replaced with an appropriate short-circuit bridge. The LCX-Z1 fixture for wired components comes with a low-impedance short-circuit plate for this purpose. With the LCX-Z3 fixture for SMD chip components, the contact pins touch each other automatically when there is no component inserted.

A third correction method which is not used with this application note is the so-called “load correction”. It requires a resistor with precisely known value. This value should be as close as possible to the measured impedance.

Corrections are frequency-dependent. Open and short corrections can be performed as spot correction just at the currently set measurement frequency, or as full correction over the full available frequency range. Load correction is only available as spot correction.

You should always perform open correction and short correction with the fixture you intend to use for the measurements. Correction measurements must be started locally on the LCX, and corrections must be enabled locally in the Measurement menu. A quick access is provided with the “Comp.” key on the front panel.

2.5 LCR meters R&S®LCX100 and R&S®LCX200

The R&S®LCX LCR meters are versatile, extremely accurate and perform measurements quickly. They are ideal for challenging applications in research, development and production. Two instrument models and various options cover applications with a test signal frequency of up to 10 MHz. Internal and external bias functions, comprehensive analysis options and versatile test fixtures expand the wide range of possible applications.

3 Prerequisites

3.1 Configuration of the LCX

The LCX must have option LCX-K106 (“advanced analysis functions”) installed to enable dynamic impedance measurement locally and sweeps with the LCX sweep tool.

Other options are not strictly required. However, the frequency range available for frequency sweeps depends on the LCX variant, and with LCX200 on the presence of one of the options LCX-K201 or LCX-K210.

Current bias, and consequently also sweep of bias current is only available with option LCX-K108 (“extended bias functions”).

3.2 Requirements to controlling PC and software installation

The application program runs on PCs with Windows 10.

For the instrument remote control, the controlling PC must have a compatible VISA library installed. A free VISA library is available from the R&S® web site [1].

The application program requires .NET runtime 4.0 or higher. Make sure that .NET runtime 4.0 or higher is installed on the controlling PC. A compatible version 4.5 is available for download from [2].

Copy installer “1GP132_xyz.msi” to the local hard drive of the PC and start it. Follow the instructions on the screen.

4 Test setup

Observe the following hints regarding the test setup to ensure proper operation of the application program.

4.1 Remote control

The following sections explain how the remote-control connection from the controlling PC to the instrument should be established.

4.1.1 Interfaces

R&S® instruments can usually be remote controlled via GPIB, LAN and USB.

GPIB remote control requires the option NG-B105.

The USB interface in the LCX supports two different USB classes. “CDC” emulates a serial interface via USB-to-serial converter and has the advantage of compatibility with older remote-control systems. It is recommended to use the TMC class for this application. To this end, set “USB Class” in submenu “Device → Interfaces” to “TMC”.

4.1.2 VISA ident strings

The LCX VISA ident string for USB has the format “USB0::0x0AAD::0x0197::3638.8856k02-123456::INSTR”. The black digits and characters are invariant for all LCX, and specify interface type, manufacturer and instrument type. The blue digit specifies the instrument variant. It is “2” for LCX100 and “3” for LCX200. The green digits represent the serial number of the individual instrument. The type number and serial number are shown in menu item “Device → Device Information” on the instrument.

The ident string for the IP LAN connection to the LCX has the format “TCPIP0::aaa.bbb.ccc.ddd::inst0::INSTR”. The black part is common for most instruments and for all LCX. The green part represents the IPv4 address which can be read with LCX in menu item “LAN” of sub-menu “Device → Interfaces → Network”. “aaa” can have two or three digits. All other numbers in the string can have between one and three digits.

The “IP” button enters the template shown above in the resource combobox which then has to be completed with the actual IP address.

It is also possible to use the “Find” button (see below) for discovering the instruments on USB and GPIB interfaces and obtaining their VISA ident strings. The LAN interface is not searched with the “Find” button.

4.2 Connecting the component under test

Use one of the test fixtures listed in the ordering information below to connect the component under test. LCX-Z1 should be preferred for components with sufficiently long leads. If the length of the leads is less than about 8 mm, LCX-Z2 can be used. For chip-type SMD components, LCX-Z3 should be preferred.

5 User interface of the application software

5.1 Remote control tab

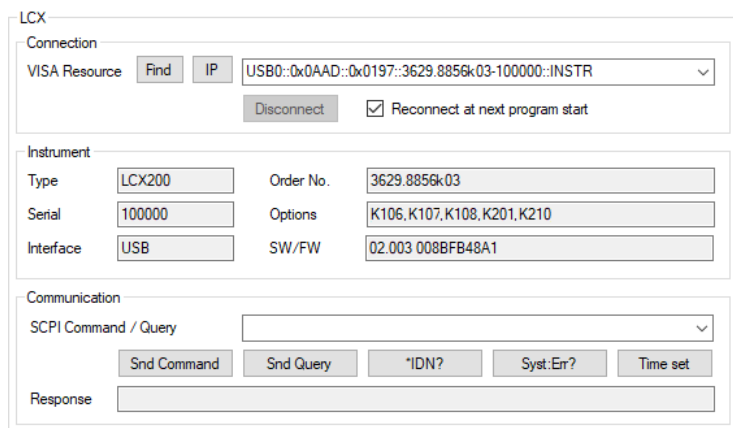


Figure 5-1 LCX field of the remote-control tab

The remote-control tab allows configuration and test of the remote-control connection to the connected LCX. Enter the VISA resource string of the power supply as described in section 4.1.2 into the Visa Resource text box.

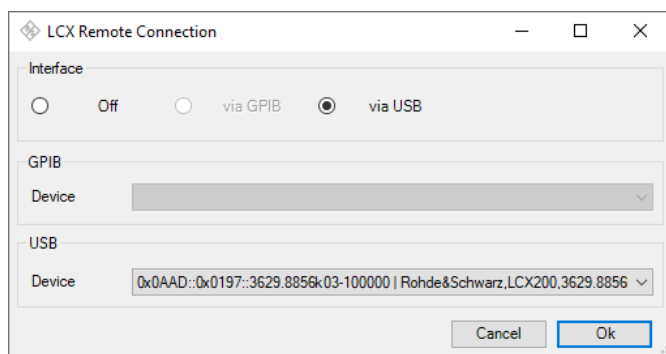


Figure 5-2 Remote connection window

Clicking the “Find” button starts a search on the USB and GPIB interfaces and displays found LCX instruments in a new remote connection window (Figure 5-2 Remote connection window. If multiple devices are detected, one on each interface can be selected in the comboboxes showing the resource strings, and the interface to be used can be selected with the radio buttons on top.

Clicking the “IP” button enters the resource string template for IP connections into the resource combobox.



Figure 5-3 Resource string template for IP connections

Enter the actual IP address of the LCX in the places marked with “aaa.bbb.ccc.ddd”. The IP address can be read from the “Interfaces → Network” sub-menu of the device menu.

Any resource which has been connected successfully in the past, is stored with the settings of the user interface and appears in the resource combobox after the next start of the program. If “Reconnect at next program start” is checked, the instrument which has been connected last before closing the application will be reconnected when it is started next time. If required, the “Disconnect” button can be used to end an existing remote-control connection.

The “Instrument” groupbox shows information about the instrument which has been successfully connected last.

The function of the remote connection can be checked with the buttons in the “Communication” groupbox. It is recommended to check the remote-control connection before starting a battery cycling operation.

“Snd Command” sends a SCPI command entered in the “SCPI Command / Query” combobox to the instrument.

“Snd Query” sends a SCPI command entered in the “SCPI Command / Query” combobox to the instrument, reads the response from the interface and displays it in the “Response” textbox.

The “SCPI Command / Query” combobox remembers the last 20 commands which have been sent successfully. To send one of these commands again, open the combobox using the small arrow on the right side, and select the desired command before clicking the “Snd Command” or “Snd Query” button, respectively.

“*IDN?” displays the identification string returned from the instrument in the response textbox.

Note: It is recommended to execute the “*IDN?” function before proceeding with the battery cycling setup. This ensures that the instrument can be reached by remote control. Based on the identity reported by the instrument, appropriate controls are enabled in the sweep tab, if supported by the type of the connected power supply.

“Syst:Err?” reads one entry from the error queue and displays it in the response textbox. The error queue can be regarded as a first-in-first-out buffer to which SCPI errors caused by remote commands are written by the instrument and picked up by the “SYST:ERR?” command.

“Time set” sets the real-time clock of the instrument to that of the controlling PC.

The “Working Folder” textbox displays the path of the working folder on the controlling PC used by the application program. This folder contains a file “trace.log” where error messages from the application program are written, and a file “settings.sup” memorizing the settings of the user interface at the time the application program was terminated last time. The “Open” button opens a file explorer in the application folder.

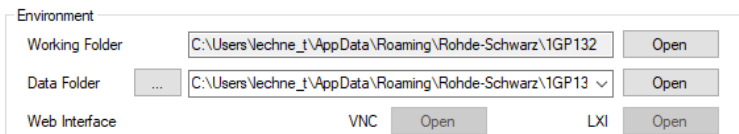


Figure 5-4 Environment field of the Remote Control tab

The “Data Folder” Combobox displays the path of the data folder on the controlling PC used by the application program. This folder is the target for sweep data from the LCX. Initially the data folder is the same as the working folder, but a different location can be selected by clicking the “...” button.

Note: The selected file location has to support the data rate and access speed required for the fast logging operation. “Jumps” in the IV diagram may be due to missing portions of fast log traces, caused by inappropriate storage media.

The “Open” button opens a file explorer in the data folder.

The web interface buttons are only enabled with an IP connection to the LCX. “LXI” opens a browser window with the LXI web page of the LCX. “VNC” opens a browser window with the remote GUI of the LCX. Prerequisite is that VNC is enabled in the “Interfaces → Network” item of the device menu on the LCX.

The combobox on bottom of the window shows the last 64 messages on the remote-control interface in use. While the combobox is closed, it shows the last message. To see the last 64 messages, click on the arrow on the right side.

6 Settings Tab

6.1 Save and load signal, measurement and sweep settings

When the LCX sweep tool is closed, all settings are automatically written to a file from where they are restored upon the next start of the program.

To be able to save a collection of different settings for different measurement purpose, all instrument and sweep settings can be saved to and loaded from dedicated files. Selection of charts to be displayed, charts layout and data save settings are also stored in this file.



Figure 6-1 Field for saving and loading settings

With this functionality it is for example possible to keep separate settings for the test of certain component types like resistors, ceramic capacitors, electrolyte capacitors and inductors. After a file has been loaded, all settings can be individually adapted.

6.2 Test signal settings

This field provides controls for the test signal parameters available on the LCX.

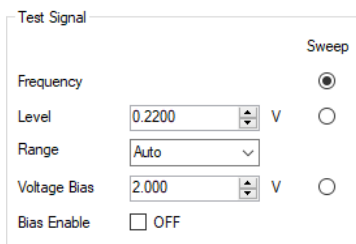


Figure 6-2 Test signal settings

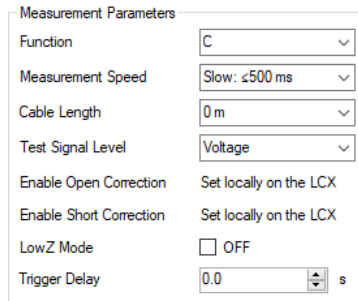
One of the parameters is selected as sweep parameter. The sweep parameter cannot be set in this field, as it is controlled by the sweep functionality.

For details on the test signal settings, see the LCX user manual [3].

6.3 Measurement parameter settings

Set here the measurement parameters appropriate for the component under test and the setup in use.

For details on the measurement parameter settings, see the LCX user manual [3].



Measurement Parameters	
Function	C
Measurement Speed	Slow: ≤500 ms
Cable Length	0 m
Test Signal Level	Voltage
Enable Open Correction	Set locally on the LCX
Enable Short Correction	Set locally on the LCX
LowZ Mode	☐ OFF
Trigger Delay	0.0 s

Figure 6-3 Measurement parameters

The corrections must be enabled locally on the LCX. Press the “Comp.” key to be guided to the appropriate menu item. You must perform full open and short correction measurements with the same test fixture you are using for the sweep.

Pressing the “Set” button transfers the settings to the LCX.

6.4 Dependencies between measurement and signal settings

There are a few signal and measurement settings whose availability and available range depend on other settings. Here is a short list:

- Available bias functions depend on the measurement function. Bias voltage is only available with capacitor measurements, bias current is only available with inductor measurement and the additional presence of option LCX-K108.
- Maximum test signal voltage and current depend on the test signal frequency and on the source impedance.
- Maximum DC bias voltage depends on the source impedance.
- Available measurement ranges depend on the source impedance.

The application program tries to take these dependencies into account. If the transfer of the settings to the LCX results in an error message, or if the sweep produces an error message at certain frequencies, please consult the LCX manual [3] and data sheet to confirm the compatibility of all settings.

7 Sweep Tab

7.1 Sweep configuration

The sweep configuration selects the sweep parameter, sets the sweep range and the number of sweep steps. Linearly or logarithmically equidistant modes can be selected for the spacing of the sweep points.

Sweep	Start	V	Stop	V	Steps	Spacing
☒ Frequency	0.0100	kHz	1000	kHz	100	☐ Linear ☒ Logarithmic
☐ Voltage Level	10.00	V	10.00	V	10	☒ Linear ☐ Logarithmic
☐ Current Level	1.00	mA	100.0	mA	100	☒ Linear ☐ Logarithmic
☐ Current Bias	0.000	mA	20.000	mA	100	☒ Linear ☐ Logarithmic
☐ Voltage Bias	0.000	V	10.000	V	100	☒ Linear ☐ Logarithmic

Figure 7-1 Sweep settings

7.2 Charts

Select here the charts for the measurement results of interest. Most of the charts plot impedance, admittance component value, quality or loss factor versus frequency. The Nyquist charts show a curve of the measured complex results in the complex plane (see 8.3).

Charts can be opened separately such that they can be individually resized and repositioned. Alternatively they can be put into tabs or tiles of a container window.

If the “Auto Save” checkbox is checked, the measurement results are stored with each sweep run to an ASCII file with auto-generated file name. In addition it is possible to store the results of the last completed sweep run by clicking the “Save ...” button. The selection of result columns in the ASCII file depends on the selection of the charts, unless the “All” checkbox is checked. In this case all available results are saved to the ASCII file, even if they are not applicable for the measured component with the applies measurement parameters. For example, (in this case negative) capacitance values are stored, even when the measured impedance is inductive.

Charts									
☐ Re Z	☐ Im Z	☐ Abs (Z)	☐ θ (Z)	☐ Nyquist (Z)	☐ Ls	☒ Cs	☐ Rs	☐ Q	☐ D
☐ Re Y	☐ Im Y	☒ Abs (Y)	☒ θ (Y)	☒ Nyquist (Y)	☐ Q	☒ D	☐ X	☐ Ls	☐ Rs
Layout					Save Data				
☐ Tabs ☐ Tiles ☒ Separate					☒ Auto Save ☐ Selected ☒ All Save ...				

Figure 7-2 Selection and layout of charts and settings for data collection

7.3 Sweep control

You can start a sweep here or abort a running sweep. The sweep progress is shown in the progress bar.

7.4 Structure of saved sweep data

Sweep data is saved into a comma-separated ASCII file which can be loaded into a spreadsheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10	Column11	Column12	Column13	Column14
2	LCX Sweep Results													
3	f	Z	∠(Z)	Re(Z)	Im(Z)	Y	∠(Y)	Re(Y)	Im(Y)	Ls	Lp	Q	D	Rs(L)
4	Hz	Ω	°	Ω	Ω	S	°	S	S	H	H			Ω
5	1.000000E+001	7.541757E+002	-1.723145E+001	7.203252E+002	-2.234113E+002	1.325951E-003	1.723145E+001	1.266437E-003	3.927896E-004	-3.555700E+000	-4.051913E+001	3.101533E-001	3.224212E+000	7.203252
6	1.123324E+001	7.482913E+002	-1.957361E+001	7.050489E+002	-2.506908E+002	1.336378E-003	1.957361E+001	1.259151E-003	4.477102E-004	-3.551840E+000	-3.164595E+001	3.555651E-001	2.812425E+000	7.050489
7	1.261857E+001	7.397247E+002	-2.224708E+001	6.846594E+002	-2.800608E+002	1.351854E-003	2.224708E+001	1.251222E-003	5.118140E-004	-3.532339E+000	-2.464324E+001	4.090513E-001	2.444681E+000	6.846594
8	1.417474E+001	7.287940E+002	-2.523893E+001	6.592215E+002	-3.107534E+002	1.372130E-003	2.523893E+001	1.241143E-003	5.850679E-004	-3.489160E+000	-1.919105E+001	4.713945E-001	2.121366E+000	6.592215
9	1.592283E+001	7.120955E+002	-2.805717E+001	6.284091E+002	-3.349358E+002	1.404306E-003	2.805717E+001	1.239270E-003	6.605186E-004	-3.347815E+000	-1.513265E+001	5.329900E-001	1.876208E+000	6.284091
10	1.788650E+001	6.930027E+002	-3.133156E+001	5.919439E+002	-3.603543E+002	1.442996E-003	3.133156E+001	1.232567E-003	7.503430E-004	-3.206450E+000	-1.185865E+001	6.087642E-001	1.642672E+000	5.919439
11	2.009233E+001	6.704202E+002	-3.466063E+001	5.514441E+002	-3.812777E+002	1.491602E-003	3.466063E+001	1.226895E-003	8.482955E-004	-3.020169E+000	-9.337759E+000	6.914167E-001	1.446306E+000	5.514441
12	2.257020E+001	6.439764E+002	-3.813393E+001	5.065322E+002	-3.976566E+002	1.552852E-003	3.813393E+001	1.221426E-003	9.588888E-004	-2.804096E+000	-7.353880E+000	7.850569E-001	1.273793E+000	5.065322
13	2.535364E+001	6.139080E+002	-4.161667E+001	4.589606E+002	-4.077232E+002	1.628909E-003	4.161667E+001	1.217780E-003	1.081829E-003	-2.559441E+000	-5.802577E+000	8.883620E-001	1.125667E+000	4.589606
14	2.848036E+001	5.811142E+002	-4.500765E+001	4.108549E+002	-4.109647E+002	1.720832E-003	4.500765E+001	1.216650E-003	1.216975E-003	-2.296567E+000	-4.591908E+000	1.000267E+000	9.997330E-001	4.108549
15	3.199267E+001	5.462157E+002	-4.837129E+001	3.628515E+002	-4.082773E+002	1.830779E-003	4.837129E+001	1.216188E-003	1.368443E-003	-2.031070E+000	-3.635321E+000	1.125191E+000	8.887380E-001	3.628515
16	3.593814E+001	5.100785E+002	-5.163792E+001	3.165695E+002	-3.999548E+002	1.960483E-003	5.163792E+001	1.216732E-003	1.537223E-003	-1.771232E+000	-2.880897E+000	1.263403E+000	7.915132E-001	3.165695
17	4.037017E+001	4.725599E+002	-5.490852E+001	2.716669E+002	-3.866652E+002	2.116134E-003	5.490852E+001	1.216531E-003	1.731495E-003	-1.524385E+000	-2.276870E+000	1.423306E+000	7.025896E-001	2.716669
18	4.534879E+001	4.363229E+002	-5.794225E+001	2.315887E+002	-3.697896E+002	2.291881E-003	5.794225E+001	1.216470E-003	1.942400E-003	-1.297804E+000	-1.806824E+000	1.596751E+000	6.262717E-001	2.315887

Figure 7-3 Structure of saved sweep data

The file starts with a line containing “LCX Sweep Results”. The next two lines contain the designation and the unit for each value. The columns vary according to the settings selected for the saved data. The first column always contains the sweep parameter. There is one row for each sweep point.

8 Charts

8.1 Common properties

While the sweep is running, the traces in the charts are constantly updated. The scaling is automatically adapted to the range of values in the respective trace. Furthermore, the axis divisions are adapted to the respective axis range and the size of the chart on the screen, such that the divisions always have a convenient size.

Units are automatically formatted with appropriate SI prefixes. For example, a capacitance of $1 \cdot 10^{-5}$ F is written as 10 µF in axis labels and tooltips.

Charts can be zoomed by dragging a rectangle in the plot area with left mouse button depressed. Zooming can be reverted completely and stepwise from the context menu of each chart.

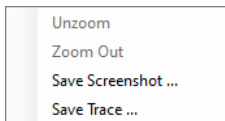


Figure 8-1 Chart context menu

The context menu also allows to save a screenshot of the chart, and to save the trace data to a text file or csv file.

8.2 Sweep Charts

Sweep charts plot a measured or calculated value versus the swept parameter. Measured values are absolute value and phase of the complex impedance or admittance, or imaginary part and real part thereof. Calculated values are resistance, capacitance, inductance, quality and loss factor.

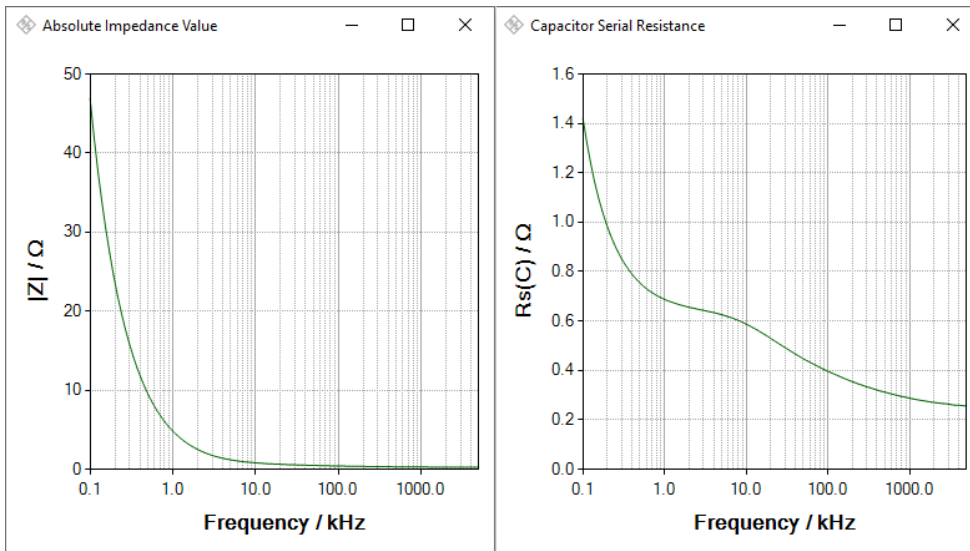


Figure 8-2 Sweep charts of impedance and ESR of a tantalum electrolytic capacitor

8.3 Nyquist Charts

Nyquist charts plot a curve of the measured complex impedance or complex admittance in the complex plane. The X axis represents the real part and the Y axis represents the imaginary part. Consequently the X axis has only positive values for all passive components.

Nyquist charts give a quick overview over the nature of a component (capacitive or inductive reactance or susceptance, respectively, and losses) depending on the frequency.

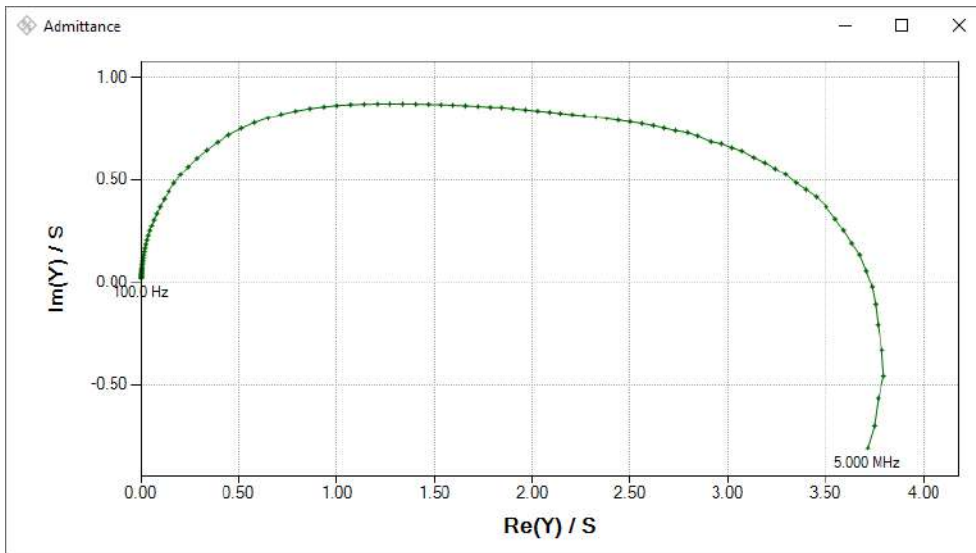


Figure 8-3 Nyquist chart of the admittance measured on a tantalum electrolytic capacitor

Since the swept parameter is not directly plotted in the Nyquist chart, it is labelled at the beginning and at the end of the trace. Furthermore, the measured values are marked on the trace, and the sweep parameter for a measured value is shown in the mouse tooltip when the mouse cursor is hovered over it.

A Nyquist chart has always identical divisions for the real and imaginary axis. The scales are also identical such that the shape of the curve is maintained when the chart is resized.

9 Literature

- [1] Rohde & Schwarz, "R&S®VISA," Rohde & Schwarz GmbH & Co. KG, 11 May 2018. [Online]. Available: https://www.rohde-schwarz.com/applications/r-s-visa-application-note_56280-148812.html. [Accessed 08 December 2021].
- [2] Microsoft, ".Net Framework," Microsoft, 2019. [Online]. Available: <https://www.microsoft.com/en-us/search?q=.NET+Framework+4.0>. [Accessed 23 October 2019].
- [3] Rohde & Schwarz, "R&S®LCX Series LCR Meter User Manual," 16 March 2022. [Online]. Available: <https://www.rohde-schwarz.com/manual/lcx>.

10 Ordering Information

Designation	Type	Order No.
LCR meter, 300 kHz	R&S®LCX100	3629.8856.02
LCR meter, 500 kHz	R&S®LCX200	3629.8856.03
IEEE-488 (GPIB) interface for R&S®NGP/LCX	R&S®NG-B105	5601.6000.02
Advanced analysis functions	R&S®LCX-K106	3630.1922.03
Extended bias functions	R&S®LCX-K108	3692.9791.03
Frequency upgrade to 1 MHz for R&S®LCX200	R&S®LCX-K201	3630.1880.03
Frequency upgrade to 10 MHz for R&S®LCX200	R&S®LCX-K210	3630.1900.03
Test fixture for axial/radial lead type devices	R&S®LCX-Z1	3639.2296.02
Kelvin clip lead	R&S®LCX-Z2	3638.6446.02
Test fixture for SMD components	R&S®LCX-Z3	3639.2509.02
Test tweezers for SMD components	R&S®LCX-Z4	3639.2515.02

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