COMPANY RESTRICTED

Application Note

R&S®LCX LCR METER: MEASUREMENT OF CAPACITORS AND INDUCTORS

Products:

► R&S®LCX100

► R&S®LCX200

Peter Jahns | 1GP142 | Version 0e | 02.2024

http://www.rohde-schwarz.com/appnote/1GP142

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1 Overview

Resistors, capacitors and inductors are the most basic components in electric circuits. It must be ensured that they work properly and accurately. Therefore, they need to be tested thoroughly during circuit design. This is usually done using LCR meters, which have become indispensable in the lab and in production.

This application note looks at how to perform basic capacitor and inductor measurements accurately and reliably.

2 Functional description

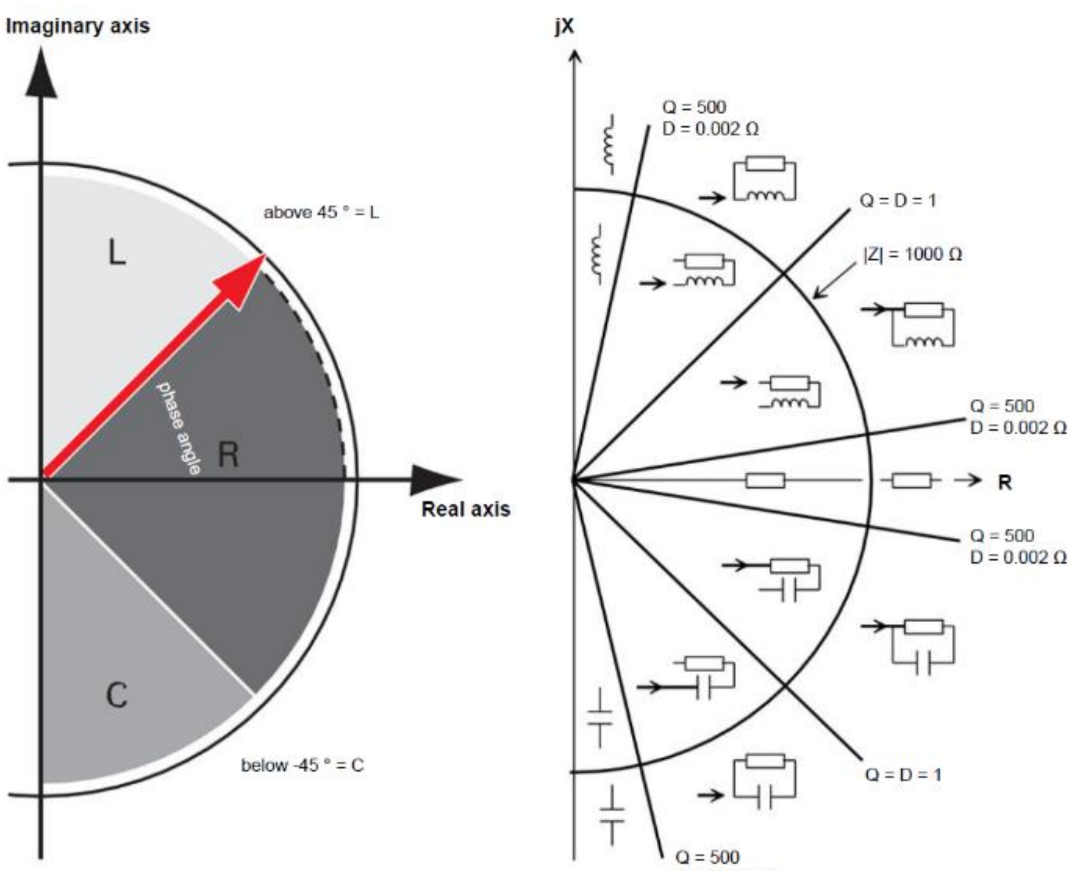
2.1 Measurement principle

The R&S®LCX100/200 bridge is not a typical Wien, Maxwell or Thomson bridge-based instrument. It uses the AC stimulus signal to measure the impedance Z and the phase angle Φ in addition.

It has to be considered when performing measurements that the properties of electrical components (e.g. capacitors) vary as a function of certain parameters, specifically frequency. Other factors affecting component behavior include aging, temperature, additional bias and electrical stress.

The equivalent circuit of each DUT contains inductive, ohmic and capacitive elements. For example, a capacitor will have parasitic inductive and ohmic elements, and an inductor will have parasitic ohmic and capacitive elements. This means that an ideal phase angle Φ (90° = purely inductive, 0° = purely ohmic, –90° = purely capacitive) will never be reached. The parasitic elements lead to self-resonance at a certain frequency for either type of component.

It is also important to note that, due to parasitic elements, each measurement will be inaccurate to a certain degree, generating a systematic measurement error.



Impedance measurement principle

2.2 Test assembly and it's influence on the measurement results

Always keep in mind that the test assembly can significantly influence the measurement. For example, with capacitors in the picofarad range, the position of the clamps has considerable influence on the measurement result. This can be demonstrated with the following experiment using the Kelvin Clip Lead LCX-Z2.

R&S®LCX--Z2 Kelvin Clip Lead

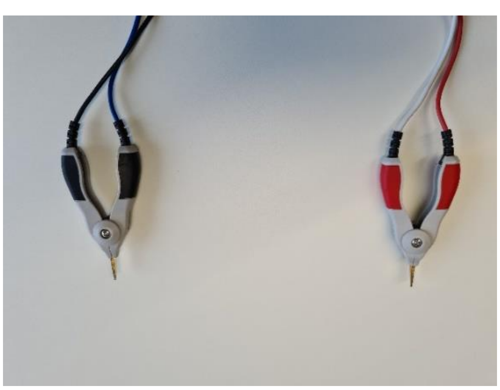
First, perform a Preset (Press [Setting*] - scroll down and select [Save/Recall Device Settings] [Default Settings]), then shorten the clamps and perform a SHORT calibration: [Comp.] [Short Correction] [Short Correction (Spot)]

*[Setting] means the key with the three lines to the left-hand side of the instrument

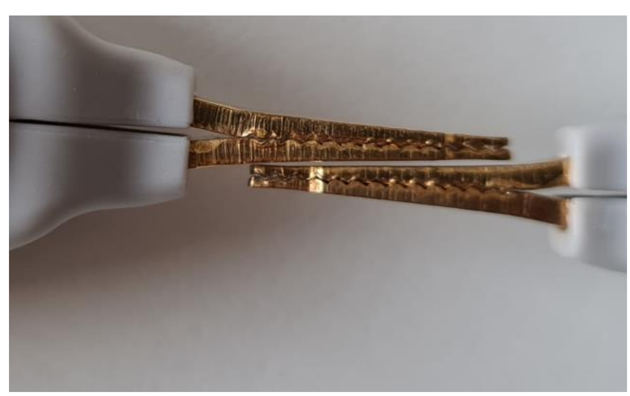
Second, place the clamps at least 20 cm apart from each other, press [Comp.] [Open Correction] [Open Correction (Spot)] and run the OPEN Compensation.

Press [Home] to get back to the main screen. The units should already display capacitance measurement values ([C] is lit). As long as the clamps are in the compensation position, the display will show a range warning. If you bring them together for just some cm, the LCX begins to display measurement values in a very low range (0.00xx pF for example).

Now hold the clamps so that their tips are just not touching and look at the measurement result.



Clamp position for the experiment: Open Compensation



During test measurement: The tips are close but do not touch each other

The measurement value will increase, in my case it showed up to 2 pF - even though no additional components have been connected and only the positions of the clamps have been changed.

The experiment shows that it can be very important to choose the right test adapter for your application. The R&S®LCX-Z1 terminal test fixture is a good choice for wired components and avoids distance issues.

R&S®LCX Z1 Terminal Test Fixture

2.3 Compensation of the test structure

To achieve optimum performance and accuracy, it is recommended to calibrate the instrument over the full frequency range when measuring unknown devices. After choosing the right test assembly and allowing the instrument to warm up for at least 30 min, follow these steps to carry out the compensation:

Press [Settings] - scroll down and select [Save/Recall Device Settings] [Default Settings] to set the instrument to a dedicated starting point

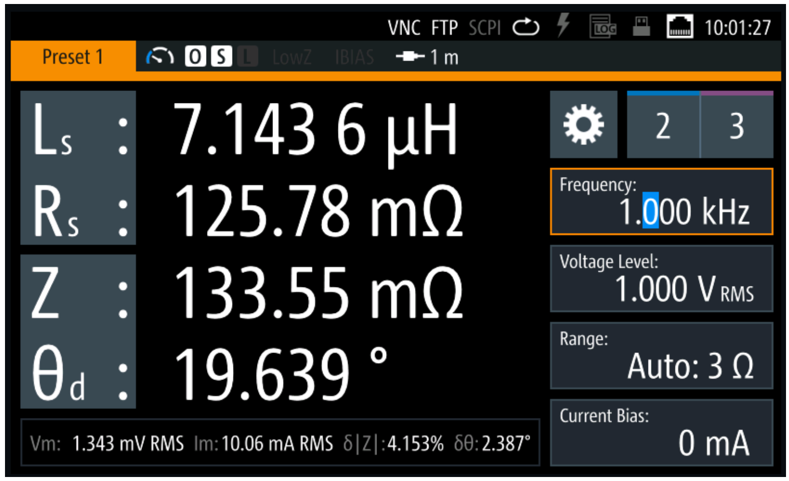
Now you can perform a SHORT calibration by first shorting the clamps, then pressing [Comp.] [Short Correction] [Start] at Short Correction (Full). Depending on your instrument it can now take more than two minutes before the unit confirms the correction being complete.

Then open the clamps (if using Kelvin clamps, make sure these are roughly in the same position as for the intended measurements), press [Comp.] [Short Correction] [Start] at Short Correction (Full).

2.4 Measurement of an unknown inductor

Note: Inductors containing ferromagnetic core material are usually specified for a certain frequency band. If an inductor is tested with a measurement frequency outside this band, results may differ from the inductor specification. This should be checked before.

First of all, connect the unknown inductor to the test fixture
Press [Home] and [L] to get into the adequate measurement window.
Except for the measurement values, the LCX screen should look like this now:



Now search for the best acquisition frequency by keeping an eye on these parameters:
- Phase angle is as close as possible to 90°
- Measurement voltage does not fall down to less than 50% in comparison to the set level
- Z is adequate to the source impedance range

"Low Z" complies to a source impedance of 10 Ω with a specified measurement range between 10 mΩ and 100 Ω while "High Z" complies to a source impedance of 100 Ω (specified measurement range from 100 mΩ up to 100 MΩ). Because of accuracy it makes sense to change to "Low Z" when measuring in an Impedance range lower than 100 Ω.

Click on the Frequency Tab and then choose an adequate decimal place which to tune on. The appropriate digit will be marked in blue color like in the screenshot above.

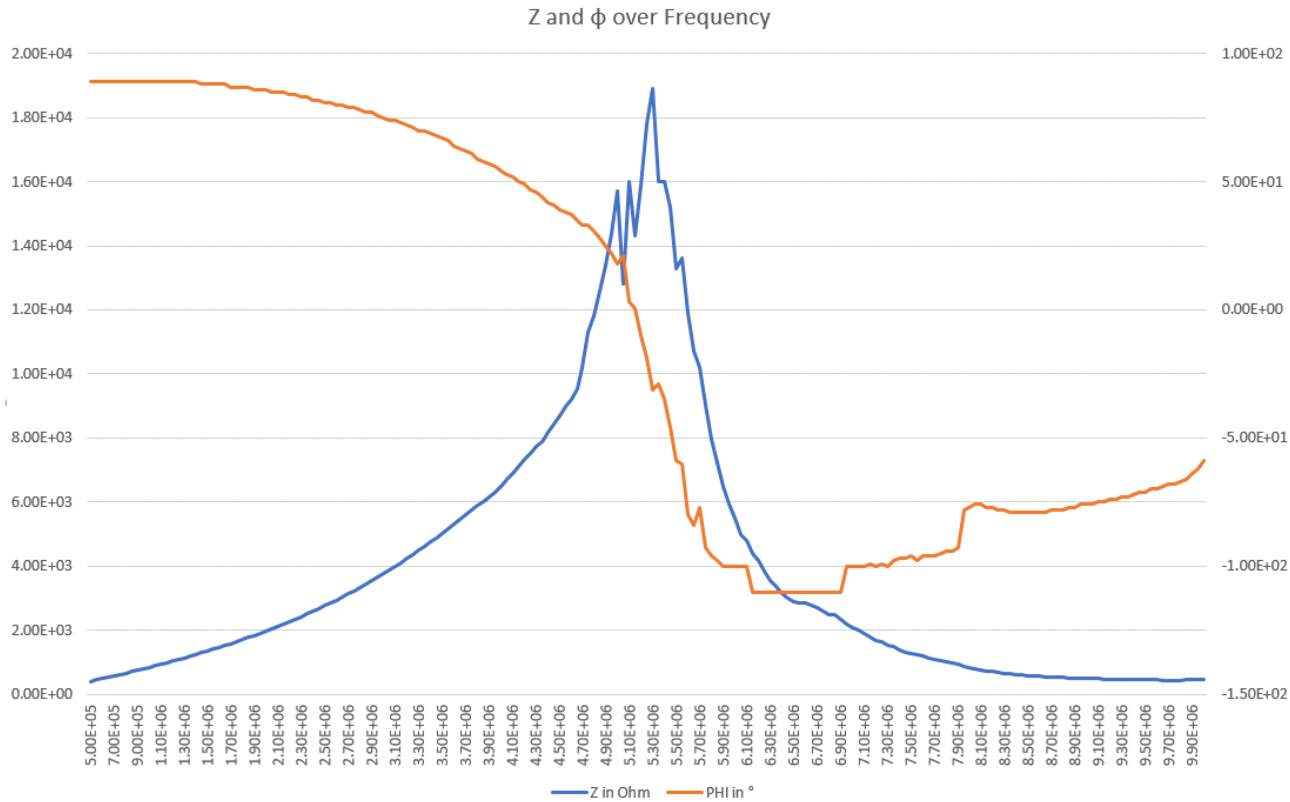
Select your choice by clicking on the check mark Use the rotary knob to change the frequency for best phase angle ϕ in combination with adequate Vm and Z. At the end you can read the best matching inductance value from the display.

2.5 Parasitic components during the measurement

Only ideal devices - not existing in the real world - would have no parasitic components. In the real world we have to deal with unwanted effects like the ohmic resistance of the component's leads or the capacitance between the turns of a coil.
At the end these components affect the measurement. For example, an additional parasitic capacitance is responsible for never reaching a phase angle of 90° on a coil.
To understand these interrelations, a sample measurement of different parameters (Z / ϕ / Vm / L / C / accuracy values) has been taken over frequency. Please find the corresponding Python Script and the measurement data in the attachment of this Application Note.

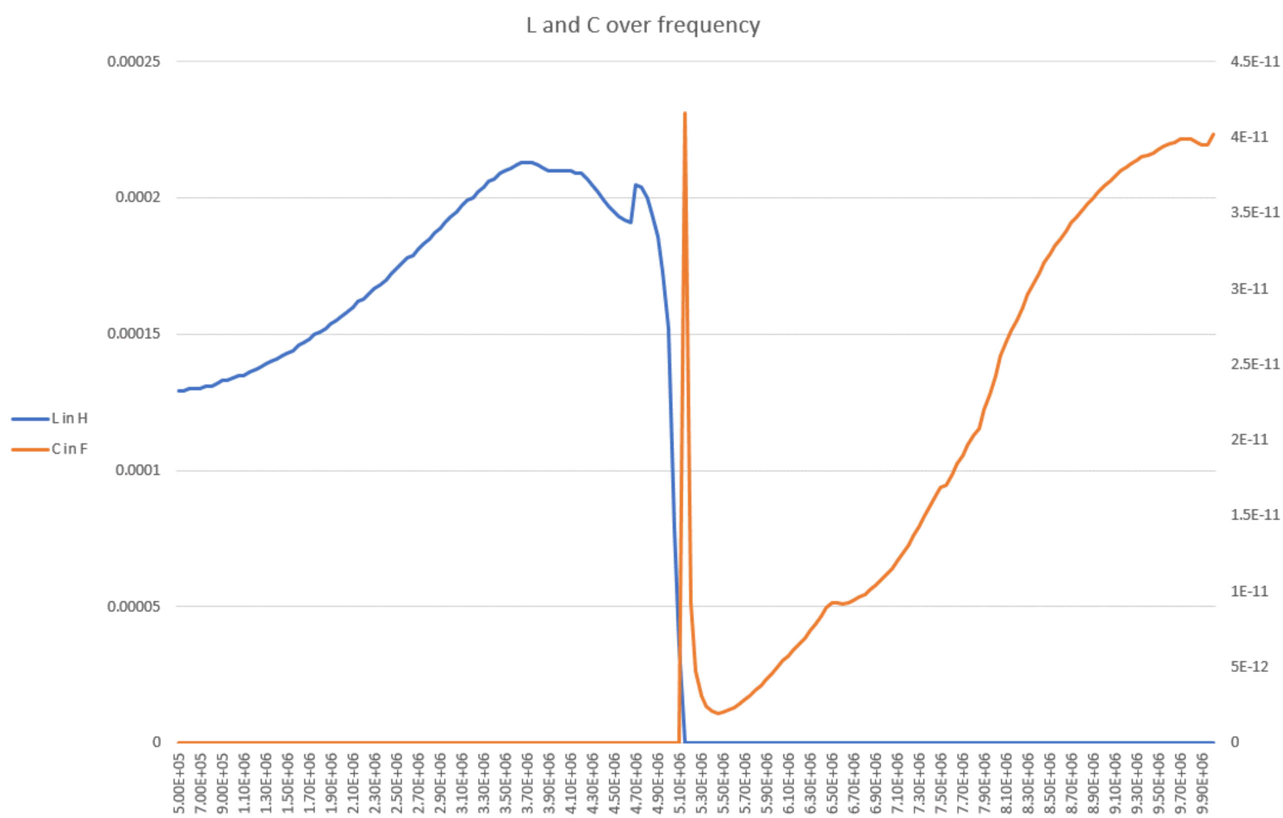
The first look shows a more or less stable phase angle in a range of about 90 ° at the beginning of the measurement. So this must be the best frequency range to check for the best matching inductance value.

When taking a second look at this exemplary inductor measurement, one can see a resonance point at a frequency of about 5,3 MHz. Since Z is very high at this point, we have to do with a parallel resonance circuit in this case.



But why is this?
Beginning at lower frequencies, this coil is inductive with a dedicated ohmic part. With rising frequency, the capacitance between every single turn of the coil begins to take effect and also the inductance more and more blocks the signal. At the resonance point there is some kind of balance between capacitive and inductive vectors. It is close to the point where the phase angle ϕ is zero degrees.
Still increasing frequency, the vector ratio begins to turn into negative phase angle, which means that the capacitive part now overbalances.

The next data graph -taken out of the same measurement like before- exactly displays the described behavior, but now looking for L and C:



Conclusion: When taking measurements on a completely unknown DUT, it makes sense to acquire measurement data over the full frequency range of the instrument. Only taking a look at the phase angle over frequency will probably give all the necessary information. In our example ϕ only is stable and close to 90 ° in the lower frequency range. So there is no doubt if it’s really an inductor at the end.

3 Literature

[1] "R&S®LCX LCR meter homepage," [Online]. Available: https://www.rohde-schwarz.com/products/test-and-measurement/lcr-meters-and-impedance-analyzers/rs-lcx-lcr-meter_63493-1172288.html. [Accessed 07 02 2024].

[2] "R&S® LCR meters and impedance analyzers," [Online]. Available: https://www.rohde-schwarz.com/products/test-and-measurement/lcr-meters-and-impedance-analyzers_255440.html. [Accessed 07 02 2024].

[3] "R&S®LCX LCR meter Datasheet," [Online]. Available: https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_common_library/dl_brochures_and_datasheets/pdf_1/LCX_dat_en_3609-8309-32_v0201.pdf. [Accessed 07 02 2024].

[4] "R&S® LCX Series User Manuals," [Online]. Available: https://www.rohde-schwarz.com/manual/lcx/. [Accessed 07 02 2024].

[5] "FAQ - How to determine the accuracy for L and C with the R&S LCX series LCR Meters," Rohde & Schwarz, [Online]. Available: https://www.rohde-schwarz.com/faq/how-to-determine-the-accuracy-for-l-and-c-with-the-r-s-lcx-series-lcr-meters-faq_78704-1309773.html. [Accessed 07 02 2024].

[6] "FAQ: Measurement ranges of the LCX series," Rohde & Schwarz, [Online]. Available: https://www.rohde-schwarz.com/faq/measurement-ranges-of-the-lcx-series-faq_78704-1309762.html. [Accessed 07 02 2024].

[7] "FAQ: Compensation type symbols in main display of the LCX LCR Meter," Rohde & Schwarz, [Online]. Available: https://www.rohde-schwarz.com/faq/compensation-type-symbols-in-main-display-of-the-lcx-lcr-meter-faq_78704-1421376.html. [Accessed 07 02 2024].

4 Ordering information

Designation	Type	Order No.
LCR-Meter, 300kHz	R&S®LCX100	3629.8856.02
LCR-Meter, 500 kHz	R&S®LCX200	3629.8856.03
Frequency upgrade to 1 MHz, for R&S®LCX200	R&S®LCX-K201	3630.1880.03
Frequency upgrade to 1 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
Transformer test cables	R&S®LCX-Z5	3639.2521.02
BNC extension, length: 1 m	R&S®LCX-Z11	3639.2538.02

5 Appendix

A Python script and measurement data example

- Python example script about how to test a DUT's frequency response
- CSV data file containing exemplary measurement data

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Application Note | R&S®LCX LCR Meter: Measurement of capacitors and inductors
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