

# R&S<sup>®</sup>HM8118: MEASUREMENT OF CAPACITORS AND INDUCTORS

From the expert's desk

## Your task

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 card looks at how to perform basic capacitor and inductor measurements accurately and reliably.

## Rohde & Schwarz solution

### Measurement basics

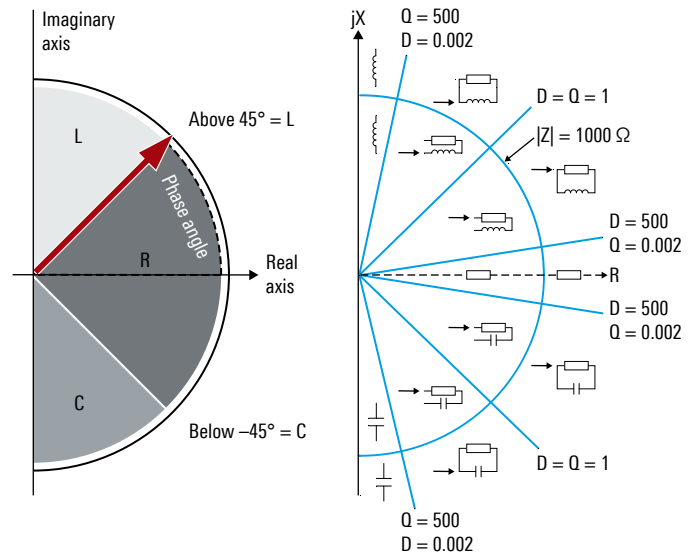
The R&S<sup>®</sup>HM8118 LCR bridge is not a typical Wien, Maxwell or Thomson bridge based instrument. Unlike other LCR bridges, it uses an AC stimulus signal to measure the impedance  $Z$  and the phase angle  $\Phi$ .

It has to be taken into account 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  $\Phi$  ( $90^\circ$  = purely inductive,  $0^\circ$  = purely ohmic,  $-90^\circ$  = 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 the parasitic elements, each measurement will be inaccurate to a certain degree, generating a systematic measurement error.

## Impedance measurement principle



## Test assembly

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 easily demonstrated with the following experiment using the standard Kelvin clamps delivered with the unit:

- First, press [RECALL] [9] to set the instrument to the factory default and perform a SHORT calibration by shorting the clamps and pressing the [SHORT] button
- Second, place the clamps at least 20 cm apart from each other and press [OPEN] to perform an OPEN calibration. Now switch to C-D mode and hold the clamps so that their tips are just not touching and look at the measurement result. It will show about 3 pF, even though no additional components have been connected and only the positions of the clamps have been changed.

Application Card | Version 01.00

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Make ideas real



The experiment shows that it is very important to choose the right test adapter for your application. The R&S®HZ181 4-terminal test fixture is a good choice for wired components and avoids distance issues.



R&S®HZ181 4-terminal test fixture

### Calibration of the test structure

To achieve optimum performance and accuracy, it is recommended to calibrate the instrument on all available frequencies (20 Hz to 200 kHz in 69 steps) 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 calibration:

- ▶ Press [RECALL] [9] to set the instrument to the factory default. To calibrate on all frequencies, press [SELECT] [3], change to (Mode) using the rotary knob and press the knob. Now change from "SGL" to "All", press the knob again and exit the menu by pressing [ESC]
- ▶ Now you can perform a SHORT calibration by first shorting the clamps and pressing [SHORT]. The SHORT calibration will run for less than 2 min
- ▶ Then open the clamps (if using Kelvin clamps, make sure these are roughly in the same position as for the intended measurements) and press [OPEN] to perform an OPEN calibration. This will take less than 2 min

### 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, switch on the test signal level indicator:

- ▶ Press [SELECT] [2]
- ▶ Change to (Vm/Im) using the rotary knob
- ▶ Change the value to "ON" and press the knob again
- ▶ Leave the menu using [ESC]

Now connect the unknown inductor to the test structure and change to Z/Φ measurement by pressing [Z – Φ]. The phase angle should be positive.

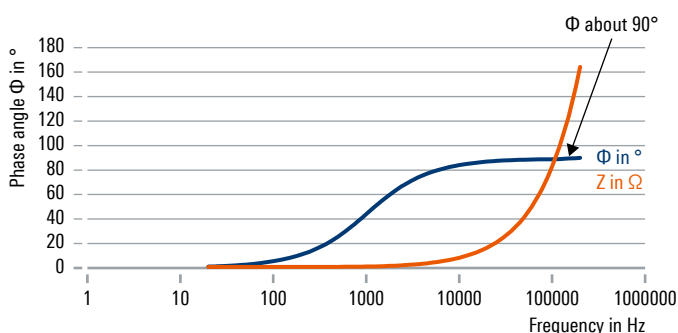
Now search for the best acquisition frequency:

- ▶ Press [FREQ]
- ▶ Use the rotary knob to change the frequency while keeping Φ as close as possible to 90°
- ▶ Press [L – R]

The inductance is now displayed together with the series resistance.

Make sure that the voltage does not drop too much (down to 35% of the nominal voltage is fine – in this case the nominal voltage is 1 V; see section "LEV" in the upper left of the display).

### Φ and Z versus frequency for a standard coil with 132 μH/enamelled copper wire



### Measurement of an unknown capacitor

**Note: Gold capacitors cannot be measured with the R&S®HM8118 as the material is too inert.**

Switch on the test signal level indicator and connect the unknown capacitor to the test structure.

Change to Z/Φ measurement by pressing [Z – Φ] (the phase angle should be negative).

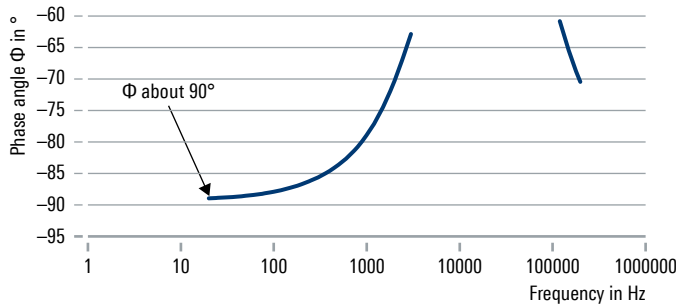
Now search for the best acquisition frequency:

- ▶ Press [FREQ]
- ▶ Use the rotary knob to change the frequency while keeping Φ as close as possible to -90°
- ▶ Press [C – D]

The capacitance is now displayed together with the series resistance.

Make sure that the voltage does not drop too much (down to 35% of the nominal voltage is fine – in this case the nominal voltage is 1 V; see section “LEV” in the upper left of the display).

### Phase angle versus frequency (270 $\mu$ F)



### Additional information

If the voltage drops below 35% of the nominal value, switch on the constant voltage mode. The calibration done before remains valid when changing to this mode.

If constant voltage mode is active (ON), the source resistance is preset to 25  $\Omega$ . The voltage applied to the component under test will be nearly constant for all components with impedance substantially higher than 25  $\Omega$ . This can improve results mostly for lower inductance values. It is important to note that accuracy is reduced by a factor of 2 when working in this mode.

It is also possible to determine the DUT's characteristics using the intended working frequency without tuning. With this approach, you can perform the calibration for just this frequency, using “SGL” mode (device menu “CORR” – “MODE: SGL”).

### References

- ▶ R&S®HM8118 user manual
- ▶ R&S FAQ “How to startup your HM8118 using a specific calibration”
- ▶ R&S FAQ “HM8118 different measurement result of the same coil”
- ▶ R&S FAQ “HM8118 to use external BIAS”

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