EVALUATION OF THE SELF-ADJUSTMENT ROUTINE OF A COMMERCIAL LCR METER

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Abstract

In a combined project of NMi and NPL we have evaluated the self-adjustment facility of a commercial LCR meter. The evaluation concerned both the hardware as the embedded software that is controlling the adjustment process. The main finding of the evaluation is that the adjustment procedure has a good potential for being the basis of a traceable calibration of the instrument, but that especially the software needs to be significantly improved upon.

Introduction

LCR meters are flexible meters for measuring the complex impedance Z over a large range in values and frequencies. Their large capabilities make the calibration of these instruments a challenge: a wide range of reference standards (capacitance, inductance, ac resistance) is required, that all have been calibrated over a relatively large frequency range – up to 2 MHz. Because of this, calibration laboratories in practice typically calibrate their LCR meters only at a limited amount of reference points, thereby realizing only a very limited traceability of the instrument.

In this paper we present the results of an evaluation study on the possibility of using the self-adjustment procedure of a commercial LCR meter for the realization of the traceability of the instrument. De evaluation concerned both the (metrological) hardware and the embedded software of the LCR meter and was performed in a cooperation project of NMi (NL) and NPL (UK).

LCR meter

There is a variety of high accuracy LCR meters available on the market. In our study, we decided to analyse the QuadTech 7600 LCR meter, since it not only has high accuracy, but also an internal adjustment procedure.

Figure 1: Photograph of the front panel of the evaluated LCR meter.

A decisive argument for selecting this particular instrument was that the manufacturer was willing to supply the evaluation team with the source code of the embedded software of the instrument as well as other technical details that are not available in the technical manual of the LCR meter [1].

Operation principle

The first task in the evaluation was to study the operation principle of the LCR meter. A schematic diagram of the meter is given in figure 2.

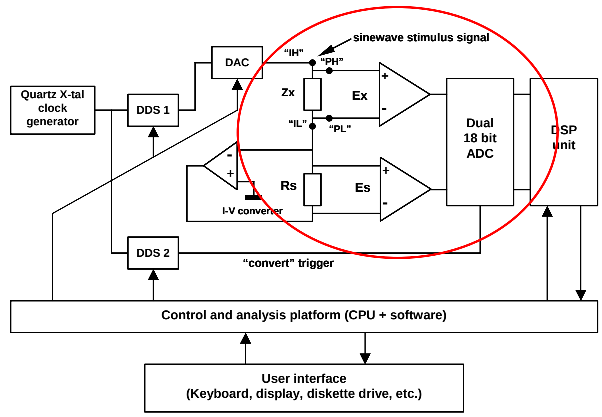

Figure 2: Schematic diagram of the LCR meter, with the core measurement part indicated by the circle.

The basis of the measurements is that an excitation current or voltage is applied to a series position of the unknown impedance Z_x and the known, internal AC resistance reference, R_s. A dual AD converter synchronously samples the voltages resulting from the excitation. An internal processor subsequently converts the raw ADC readings to a value of admittance $Y_x = 1 / Z_x$:

$$Y_x = \frac{(t_u - t_{oc})}{(1 - t_u / t_{sc})} \cdot Y_s \qquad (1)$$

Here $t_u = E_s / E_x$ as measured by the ADC, Y_s is the admittance of the internal reference, and t_{oc} and t_{sc} are corrections for the open and short impedance respectively of the measurement cables that are used.

In order to obtain sufficient signal levels at the ADC for the complete frequency range, a series of amplifiers is placed between Z_x, R_s and the ADC. To cover the complete impedance range of 0.1 μΩ to 100 MΩ, four internal references are available in the instrument.

Self-adjustment routine

The QuadTech 7600 LCR meter has a frequency range of 10 Hz to 2 MHz. As can be seen from formula 1, the measurement values of the unknown impedance not only depends on the ADC readings (with amplifiers) and the value of the internal reference, but also contains corrections for cable influences. Such corrections are especially important at the higher frequencies.

The internal calibration routine determines all relevant calibration parameters in three phases. In the first phase the gains of the amplifiers between Z_x, R_s and the ADC are calibrated, for all gain combinations, at all three source voltage settings, and at each calibration frequency. The results are all normalised to the setting with unity gain. The second phase measures the short circuit and open circuit impedance of the internal circuit together with the coaxial connection cables. Here the user is instructed to connect the appropriate open or short to the input of the meter. In the third and last phase of the adjustment procedure, the admittance values of the four internal AC reference resistors are measured against external standards, with approximately the same nominal value. Calibration values are again recorded for all source voltage settings and all calibration frequencies. The calculations in this phase make use of the parameters determined in the previous two phases.

Hardware evaluation

The metrological evaluation of the hardware of the self-adjustment procedure was done in two parts. First the general functionality and adjustment approach was studied, with the results as described above. The conclusion is that the adopted approach is powerful and contains the essential elements for realizing traceability.

Subsequently, several details of the hardware implementation were studied. The open /short correction routine was found to work correctly, provided that the *complete* calibration was performed when a new cable set is used. Applied shifts in real and /or imaginary values of the reference resistors in the third phase of the adjustment process resulted in accordingly shifted measurement values. This greatly confirmed the correct functionality of the instrument and the self-adjustment procedure.

The major problem found in this part of the evaluation is that the "AutoAcc" function of the LCR meter, that provides the user with the uncertainty of the instrument, is not metrologically correct: it divides a basic uncertainty value by the square root of the number of readings, which is not allowed since many important systematic uncertainty contributions can not be reduced by averaging.

Software evaluation

An important part of the project was devoted to the evaluation of the embedded software in the instrument. The main aim of this part of the evaluation was to increase the confidence in the correct functioning of the self-adjustment software in the instrument. Since no 100% confidence can be achieved, the focus of the software evaluation lied in those procedures that are critical to the self-adjustment [2].

In the first phase of the software evaluation an overview of the structure of the source code was made, and the digital hardware was studied. This took a considerable amount of time, since a good description of these parts of the LCR meter is essentially lacking. The general evaluation of the source code revealed that there is no information on the development process of the code, and that the code contains large unused parts and explanations that are inconsistent with the actual code.

The subsequent detailed evaluation had to be done by 'reverse engineering', which is time-consuming and not very effective. Consequently, only the critical parts and procedures were studied. Among others this concerned the correct implementation of calculations (of e.g. formula 1), the handling and checking of calibration constants, the correct implementation of the open and short cable corrections and the frequency interpolation of calibration points.

The conclusion is that the software procedures are consistent with the hardware description, and that no errors are found, but also that there is much redundant program code and misleading comments. This makes that final conclusions can only be drawn when a significantly updated and better-documented version of the software would become available.

Conclusion

Even though not primarily intended by the manufacturer, the internal adjustment procedure of the 7600 LCR meter is a good basis for realizing traceability of the instrument. The processes and calculations that were studied are correct; no errors were found in the limited time available for the evaluation project. However, in its present form the adjustment procedure needs considerable improvement, especially in the software and the calculation of the uncertainty / specifications of the instrument.

As in one of our previous evaluation projects [2, 3], the good cooperation between hardware (metrology) experts and software specialists appeared to be crucial for the successful completion of the evaluation.

References

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