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## SOFTWARE FOR AUTOMATION OF MEASUREMENTS WITH KEYSIGHT E4980A LCR METER

The paper presents software dedicated for automatic impedance measurements performed using Keysight E4980A precision LCR meter. The software has been written in Microsoft Office Excel Visual Basic for Applications (VBA) and is very useful for automated determination of impedance frequency characteristics and for plotting them in Microsoft Excel. Another useful function implemented in the developed software is the possibility of calculation of absolute measurement error. The application software controls the LCR meter through USB interface.

## OPROGRAMOWANIE AUTOMATYZUJĄCE POMIARY WYKONYWANE MIERNIKIEM RLC KEYSIGHT E4980A

W artykule przedstawiono oprogramowanie automatyzujące pomiary składowych impedancji, wykonywane miernikiem RLC Keysight E4980A. Oprogramowanie, napisane w środowisku Microsoft Office Excel Visual Basic for Applications (VBA), jest szczególnie przydatne w przypadku wyznaczania charakterystyk częstotliwościowych składowych impedancji oraz ich wykreślenia w programie Microsoft Excel. Bardzo przydatną cechą programu jest możliwość obliczania błędów granicznych zmierzonych parametrów RLC. Oprogramowanie steruje miernikiem przy wykorzystaniu interfejsu USB.

### 1. INTRODUCTION

Commercial LCR meters are widely used both in industry and lower precision applications [1], and also for high-precision measurements, like impedance standard components or residual parameters of passive elements used in primary metrology [2]. The meters are usually equipped with Universal Serial Bus (USB), General-Purpose Interface Bus (GPIB) or Local Area Network (LAN) interfaces, therefore control and automation of measurement is possible. The Keysight E4980A LCR meter is one of the most precise commercial LCR meter available on the market. It enables impedance measurements in frequency range from 20 Hz to 2 MHz with relative inaccuracy on the level of  $10^{-4}$ . Department of Measurements, Automation and Control (KMEiA) of Silesian University of Technology (SUT) is equipped with the Keysight E4980A LCR meter. Due to the need of automation measurements performed in our department an application software was written in Microsoft Office Excel Visual Basic for Applications (VBA). The application controls the Keysight E4980A LCR meter and calculates absolute error of measurements. A script sends SCPI (*Standard Commands for Programmable Instruments*) commands and receives data using USB interface. An option to compensate for any error caused by disturbances such as stray admittances and residual impedances, and caused by cables' impedance is considered in the software application. Therefore, "SHORT" and "OPEN" correction is implemented in the software [3], [4].

Manufacturer of the Keysight E4980A LCR meter shares a simple VBA script, but it has a very limited functionality and does not perform calculation of the measurement error, which can be quite troublesome, especially for an inexperienced user. A more advanced controlling commercial software, called PathWave BenchVue is extra paid.

In the nearest future the script written in VBA will be used in measurements of residual inductance of Vishay resistors used in design and evaluation of precision wideband current shunts. During the development of the software, we focused mainly on measurements of an inductance connected in series with a resistance ( $Ls-Rs$ ) and a capacitance connected in parallel with a resistance ( $Cp-Rp$ ).

## 2. DESCRIPTION OF MEASUREMENT SOFTWARE

Measurement system includes a personal computer (PC) connected with Keysight E4980A using the USB interface. For the proper operation of the program, VISA (*Virtual Instrument Software Architecture*) drivers were installed on computer. Screenshot of the user interface, created in Microsoft Excel is presented in Fig. 1.

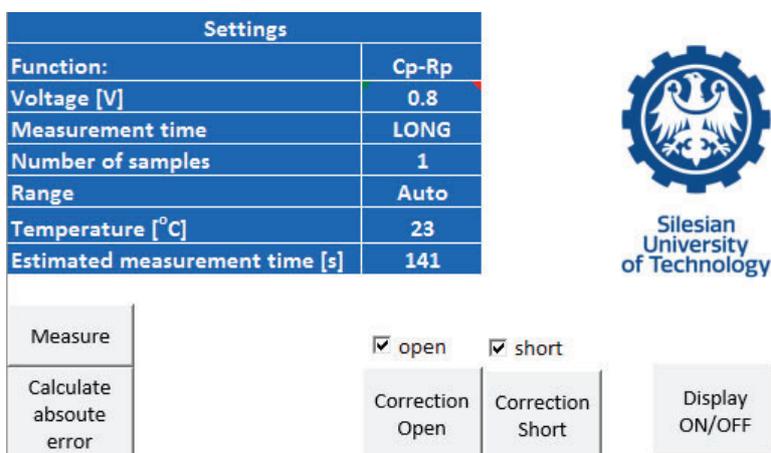


Fig. 1. User interface.

The blue table visible in Fig. 1 includes settings of measurement. These settings must be configured by the user before a measurement. The most important parameters which has to be set are:

*Function* – pair of impedance parameters to be measured, selected from drop down list.

*Voltage* – root-mean-square (RMS) voltage of testing sinusoidal signal. Available range is from 0 to 2 V.

*Measurement time* – time (in seconds) needed for setting the frequency and performing measurement. There are three variants: SHORT, MEDIUM and LONG.

*Number of samples* - number of samples needed to calculate average value of measured parameters. Available range: 1-256 samples.

*Range* – selection of measurement range. The following values can be selected from the drop down list: Auto|100 mΩ|1 Ω|10 Ω|100 Ω|300 Ω|1 kΩ|3 kΩ|10 kΩ|30 kΩ| 100 kΩ. The default mode is Auto.

*Temperature* – ambient temperature declared by user. The value of ambient temperature is necessary for calculation of the measurement error.

*Estimated measurement time* – estimated time (in seconds) needed for execution of measurements and storing them in the Excel sheet.

Five buttons to control RLC meter are placed below the blue table:

*Measure* – sends commands with settings to the instrument and execute measurement. Collected results are written to the Excel sheet.

*Calculate absolute error* – button launches script with absolute error calculations based on [4].

*Correction SHORT* and *Correction OPEN* – allows for correction of parasitic and residual impedances of the test fixture and connecting cables. “OPEN” correction corrects for capacitance and leakage between open terminals of the fixture, while “SHORT” correction eliminates residual impedance of the circuit between the meter and device under tests (DUT). Both types of corrections are automatically performed for 51 frequency points set by manufacturer in the range 20 Hz – 2 MHz. Both corrections are necessary in case of high-precision measurements. There are checkboxes that confirms the user whether a relevant correction was successfully finished or not. The test fixture 16047E was used as an adapter for through-hole (THT) DUT. Of course, the software developed at SUT can be used with any other test fixture and any reasonable cable length.

*Display ON/OFF* – turns the display on or off. This function is helpful to check the communication with instrument.

### 3. SAMPLE RESULTS

Software developed at SUT has been tested by remote automatic measurements of frequency characteristic of 180  $\mu\text{H}$  cylindrical coil. Results obtained for two time modes are presented in Fig. 2. Measurements were executed at test voltage equal to 0.7 V, using the auto range mode. The number of samples were set to 30. Ambient temperature was 23°C. Both types of correction (“OPEN” and “SHORT”) were performed before measurement.

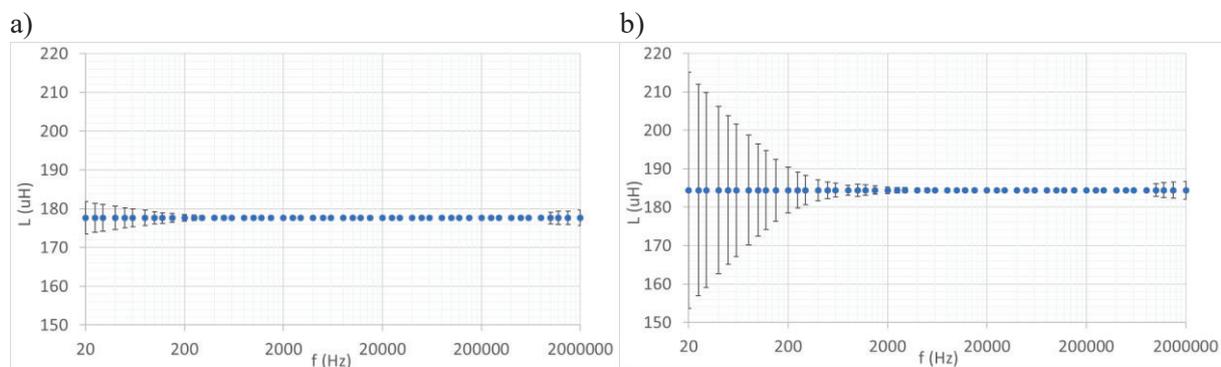


Fig. 2. Results of inductance measurements of a coil performed at two different measurement times a) LONG and b) SHORT. Bars represent the absolute error of the measurement calculated according to [3]. The same scale makes the comparison easier.

The above figures demonstrate the advantages of using LONG time mode. According to the Keysight E4980A manufacturer, the most stable and precise results can be obtained only using the LONG time mode. Moreover, Fig. 2 shows that the biggest absolute errors appear at low frequencies, up to approximately 2 kHz. Such big errors in both modes are unacceptable in precision measurements.

Another problem arises when measuring residual inductance of a precision metal-foil resistor. Manufacturer of Keysight E4980A declares in [4] that the best measurement accuracy is achievable when impedance module of DUT is approximately 100  $\Omega$ . So measuring impedance of a resistor of such value seems to be accurate. However, residual inductance of surface-mount (SMD) Vishay precision foil resistors declared by the manufacturer is 80 nH [5]. Hence, at frequency 1 kHz the impedance of the resistor is approximately equal to  $100 + j500 \cdot 10^{-6} \Omega$ , i.e. the imaginary part

representing reactance is approximately 200 000 times smaller than the real part. Measurement of the relatively small reactive component is very difficult in this case. To investigate and determine the error it is planned to use a of calculable planar inductors with adjustable in-series resistance. The inductors have form of spiral copper traces on a printed-circuit board (PCB) with solder pads for a series SMD resistor of 0805 size. The artwork of the 100 nH inductor is presented in Fig. 3.

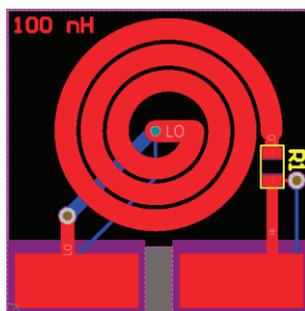


Fig. 3. Artwork of the 100 nH planar inductor with a series SMD resistor.

Separate pads for current and voltage circuits have been provided to enable four-wire measurements. Inductance of the coil was calculated according to [6], [7]. The accuracy of the coil inductance is not critical, but should be stable and of small resistance. The coils are currently under production and their parameters have to be evaluated.

#### 4. SUMMARY

The paper presents software dedicated for automatic impedance measurements performed using Keysight E4980A precision LCR meter. The software has been written in Microsoft Office Excel Visual Basic for Applications (VBA) and is very useful for automated determination of impedance frequency characteristics and for plotting them in Microsoft Excel. Another useful function implemented in the developed software is the possibility of calculation of absolute measurement error. A proposal of increasing the accuracy of the troublesome measurement of the small residual inductance of the precision foil resistors is presented.

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