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Double quasi - balanced meter for measurement of inductor quality factor

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Abstract- A principle of operation and an implementation of a non – bridge quasi - balanced circuit designed to measure quality factor of real inductors has been presented in this paper. The circuit is based on well-known bridge circuit. A structural diagram describing the processing of signals has been presented. An implementation as a virtual instrument has been presented as well. Keywords: quasi-balanced circuits, quality factor, virtual instruments

I. Introduction

Quality factor Q_C of a real coil, modelled with serial RL elements, can be defined as follows:

$$Q_C = \frac{Q}{P} = \frac{\operatorname{Im} Z_X}{\operatorname{Re} Z_X}, \qquad (1)$$

where Q is reactive power of the inductor under test and P is active power dissipated in the inductor, Z_X is the inductor impedance.

Quality factor can be measured by bridge methods, transformer bridges, devices with digital signal processing or by quasi-balanced circuits [1...4]. These circuits have special state of quasi - equilibriums', which is usually a predetermined phase angle between the selected signals. The advantage of quasi - balanced circuits is to use only one control element, so there are no problems with the convergence of circuit. In general quasi-balanced circuits only allow the measurement of one impedance component, but it is possible to build circuits to measure two components of impedance, for example in parallel quasi-balanced circuits [5], [6].

II. Principle of operation

The quasi – balanced circuits are built as bridge and non-bridge circuits. These circuits enable typically to measure only one component of the impedance but some quasi – balanced circuits allow the measurement of the mutual relationship between the components of the impedance, e.g. quality factor. In such systems, is made double quasi - balancing in two successive steps.
The circuit of the quasi-balanced bridge, designed to measure the quality factor of real inductors is presented on Fig. 1. The symbols in Fig. 1 represent respectively: R_3 is standard variable resistor; V_S is power supply voltage, R is a potentiometer resistance; n is a potentiometer setting ($0<n<1$) and I_1, I_2 are currents of the arms of the bridge. Object under test is modeled as a series connection of resistance R_X and inductance L_X.
The quasi - balancing process requires two steps. In the first state of quasi - equilibrium the phase angle between the V_{AD} and V_{DC} equals to $\pi/2$. The slider of the potentiometer R is located in the position for which n = ½ and the regulatory element is a resistor R_3. In the second quasi-balance state the phase angle between the V_{DC} and V_{CB} voltages also equals to $\pi/2$. The control element is the potentiometer R. In second quasi-balance state the n parameter is read and then the relationship for the determination of the measured quality factor Q_C is:

$$Q_C = \frac{\sqrt{1-2n}}{n}. \qquad (2)$$

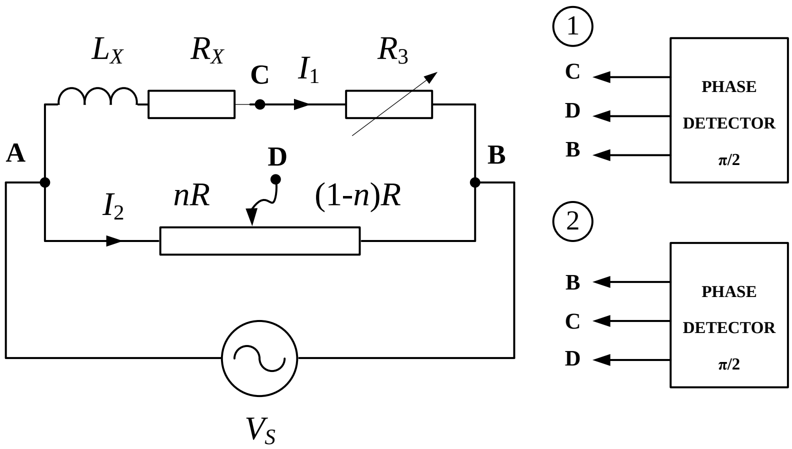

Figure 1. Diagram of the quasi-balanced bridge for loss factor measurement

Basing of the analysis of the bridge in Fig.1 it is possible to build non - bridge structure, performing the same operations on the current and voltage signals of the tested impedance. The procedure of deriving a non – bridge circuit has been presented in [6]. The non-bridge circuit has the structure shown in Fig. 2. This circuit process the measurement signals according to the principle of operation of the bridge from Fig.1. The selected signals are phase shifts between w_{11} and w_{12} signals and w_{21} and w_{22} signals. It can easily be implemented as a virtual instrument.

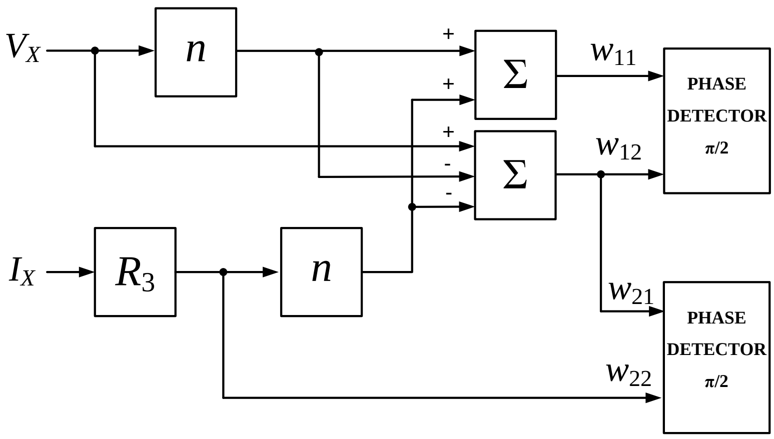

Figure.2. Block diagram of a quasi – balanced circuit with dual quasi - balancing

III. Realization

Fig. 5 shows a view of the prototype of the quality factor meter built according to the previously described concept.
A coil under test was powered from the Rigol DG1022 DDS generator. The current of the object was converted to a voltage across the 1 kΩ standard resistor with accuracy class 0.01. The voltage of the object and the voltage proportional to its current were connected to the 16-bit DAQ NI USB-6251 [9].

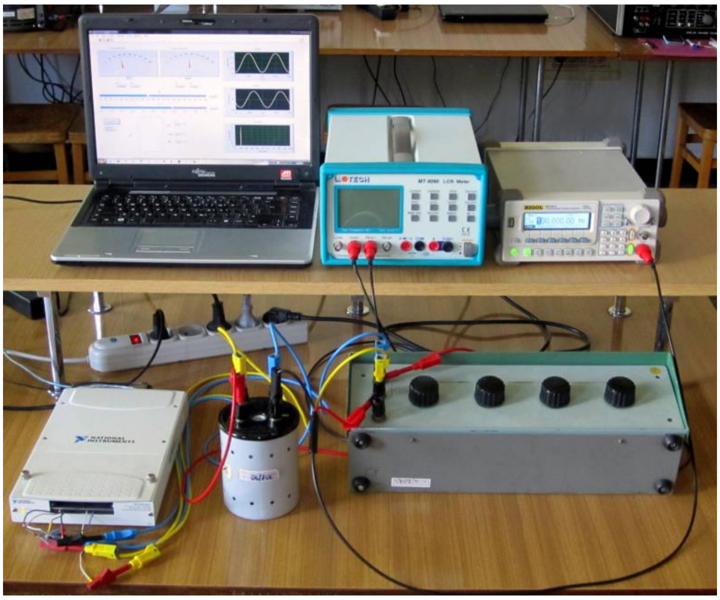

Figure 3. View of the prototype of the quality factor meter realized as the quasi – balanced circuit with dual quasi – balancing

The LabVIEW 2011 software packet was used to build the virtual instrument [9]. The diagram of the virtual instrument is shown in Fig. 4 and its front panel in Fig. 5. An algorithm for phase shift measurement described in [8] was used in the circuit.

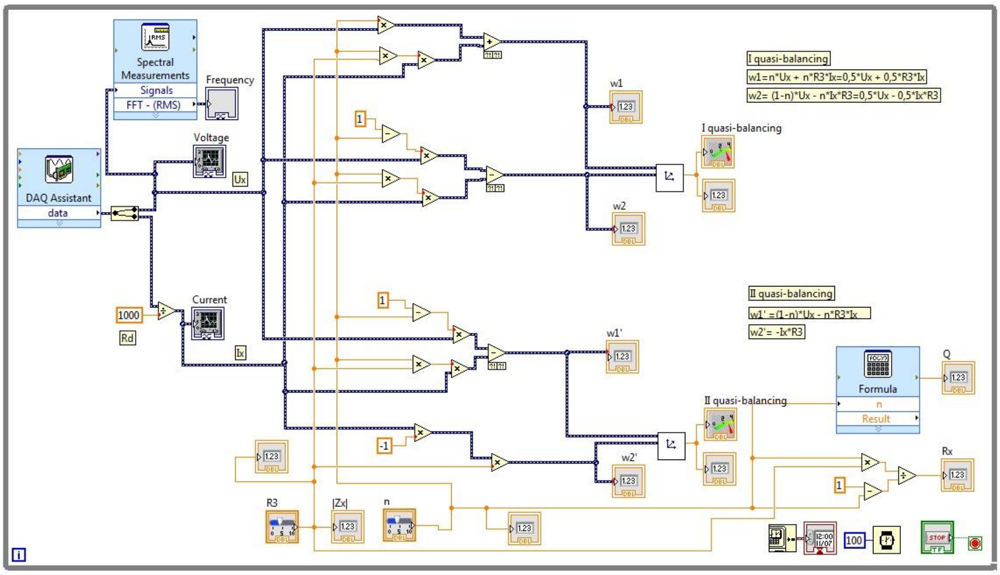

Figure 4. Block diagram of a quasi – balanced circuit with dual quasi – balancing

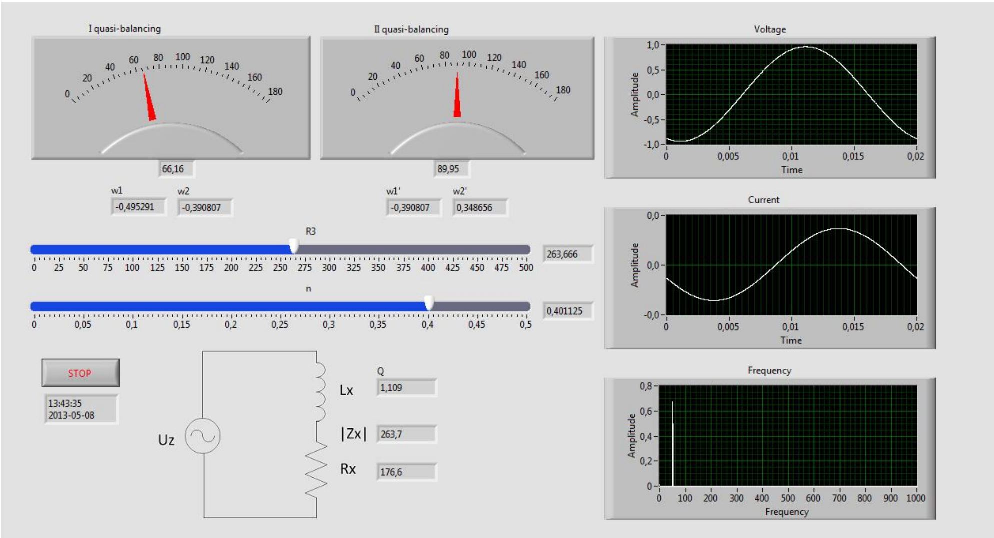

Figure 5. Front panel of a quasi – balanced meter with dual quasi – balancing

During the work was abandoned with the development of the microprocessor version of the instrument. It was decided to focus on the virtual instrument. Such an instrument is easier to test and change the parameters.

IV. Tests

The first tests were done as a simulation. The simulations confirmed the usefulness of the system to measure the quality factor of inductors.

Tests of the circuit were performed for the reference inductance in the range of from 0.05 H to 1 H at a frequency of 100 Hz. The results were compared with the results obtained from the meter Motech MIC-4090, for which the manufacturer declares a quality factor accuracy of 0.5%. The exemplary dependence of the errors versus the measured quality factor is shown in Fig. 6.

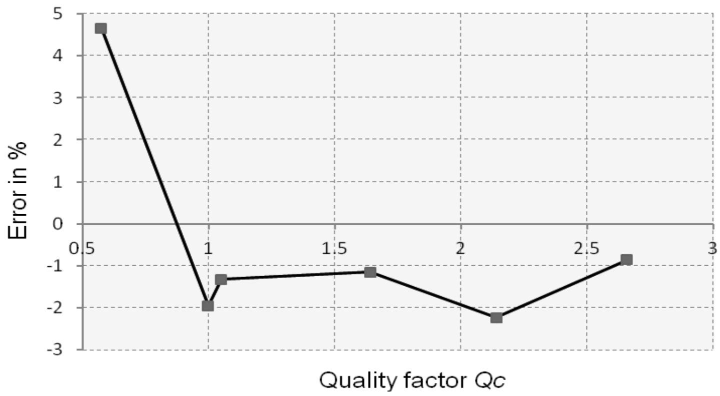

Figure 6. Error vs. the measured quality factor

V. Conclusions

The theory and implementation of a non - bridge quasi - balanced measuring circuit with dual quasi - balancing, designed for measurements of quality factor have been presented. The main advantage of the circuit is maximum convergence and a simple measuring process. It requires two independent controls.

Circuit described above has been implemented as a virtual system. LabView package was used. Simulation tests and tests carried out on real object confirmed the usefulness of the proposed solutions. Although the level of errors reaches 5%, but the study focused on the prototype, which will be even improved.

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