A SIMPLE AND HIGH PRECISION RLC BRIDGE BASED ON GENERAL-PURPOSE INSTRUMENTS

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Abstract

In this paper an alternative method for ac impedance measurements is proposed. It uses only general-purpose instruments, instead of using complex and expensive bridges. The accuracy can reach few parts in 10^6, which is enough for many applications.

Introduction

Many different types of resistance, inductance and capacitance (RLC) bridges have been proposed. The most accurate ones are based on inductive voltage dividers, reaching uncertainties of few parts in 10^9 [1]. However, they have high cost and complexity, and not all laboratories need such high precision. The main idea of this paper is to propose a bridge that only uses general purposes laboratory equipment, easy to implement. The bridge has two adjustable synchronized voltage sources, a null detector and an ac voltmeter to measures the voltage drops on the two impedances to be compared. Similar measuring systems were proposed [2], but some dedicated instrumentation is necessary for them, and only two terminal impedances can be measured. This limits their application fields. The improvement presented in this paper allows to compare two and four terminal impedances, even of different quantities.

Description of the system

Fig. 1 shows a diagram of the proposal. U_1 and U_2 are two adjustable voltage sources, synchronized at the same frequency (generally, 1 kHz). In our system we use a FLUKE calibrator, model 5500A, which has two independent outputs. Z_N is the standard and Z_X the impedance under test. They can be of the same quantity or not. For example, a capacitor can be calibrated against a resistor. The null current detector is formed with a low cost transconductance amplifier and a general purposes digital oscilloscope with FFT and averaging capabilities (for our system, Tektronix TDS3012). The trigger of this last instrument comes from the voltage U_1, through an opto-isolated coupler. In this way, with large averaging numbers (between 128 and 512), a low noise and stable signal can be got, and the amplitude at the working frequency can be easily measured using the FFT transformation. Note that it is not necessary a wideband amplifier.

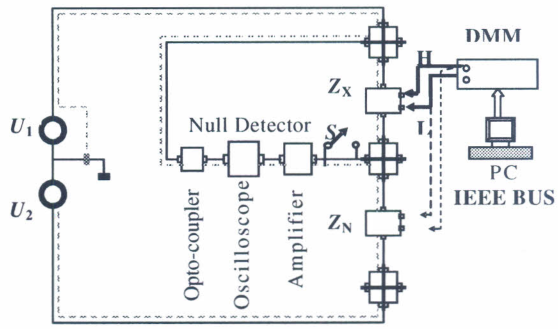

Fig. 1. Schematic diagram of the proposed system.

On the contrary, a bandwidth just to cover the working frequency is better, because this reduces harmonics. In some cases, a band-pass filter after the amplifier can be necessary to reduce harmonics, or power frequency noise.

Once the sources are adjusted in amplitude and phase to get null detector current, an AGILENT 3458A digital multimeter (DMM) alternatively measures the voltage drops on the voltage terminals of the two impedances. During this step, the switch *S* is closed, grounding the connection point between the impedances. This is necessary to avoid the influence of the input voltmeter impedance on the circuit. As the voltage at that point was zero before closing *S*, no voltage change is produced when the switch is closed. The input impedance of the DMM produces negligible errors under this condition, with under test impedances from hundreds of ohms up to 16 MΩ (corresponding to 10 pF at 1 kHz).

An external algorithm [3] controls the DMM to get lower errors than those showed in its specifications. Voltage ratio uncertainties of 5×10^{-6}, at 1 kHz, can be achieved, instead of more than 100×10^{-6} using the conventional DMM ac mode.

The ratio between the magnitudes of both impedances is equal to the voltage ratio, as measured by the DMM.

$$\frac{|Z_X|}{|Z_N|} = \frac{U_1}{U_2} \quad (1)$$

Regarding the phase angle, it is stated by the sources angle setting. In this case, the uncertainty is higher because it depends on the sources phase accuracy, but generally it is not necessary to measure the angle of impedances with very high accuracy.

Uncertainty calculation

As an example, the uncertainty of a capacitor calibration will be presented. A capacitor of 1000 pF was compared against an ac resistor of 10 kΩ that was calibrated (using this same bridge) with a calculable resistor of 1 kΩ [4]. The sources were adjusted until null current was measured by the detector, nearly to 8 V and 0.5 V (ratio 16/1), 1 kHz, 90°. The main uncertainty sources are the following.

A. *DMM voltage ratio.*

The DMM is controlled by an external algorithm [3] that greatly reduces its errors. The type B uncertainty of the 8 V/0.5 V ratio was evaluated in 1.1×10^{-6} of its nominal value.

B. *Reference standard.*

The ac/dc impedance ratio of the resistor used as standard was evaluated against a calculable resistor. Its magnitude difference at 1 kHz is negligible in this test. Its dc uncertainty was evaluated in 2.0 μΩ/Ω.

C. *Frequency*

As one of the branches is a resistor and the other a capacitor, the frequency of the sources influences the results. This frequency was permanently measured by the DMM, as it has this capability. Its influence in the uncertainty of the capacitance measurement was evaluated in 0.5 μF/F.

D. *Type A uncertainty*

There were done 9 ratio measurements, taking the average of 3 single voltage measurements in each point. The standard deviation of the average value was 1.7 μF/F.

E. Combined uncertainty

The value of the combined uncertainty (k=1), therefore, is 2.9 μF/F.

Conclusions

A simple method for impedances measurements, which only uses conventional laboratory equipment, was presented. It only requires of a voltage source (calibrator), an oscilloscope and a DMM, as main equipment. This system can compare not only elements of the same quantity (resistance, capacitance or inductance), but also different quantities. The comparison of a capacitor against a resistor, with uncertainties of 3×10^{-6} (k=1), was shown. This is an interesting capability for the trazability point of view. A simple calculable resistor can be the base for capacitance and inductance measurements using general-purpose instruments.

References

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