Development of Automated Measurement Setup for Standard Resistors

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ABSTRACT: An automated system for measurements of standard resistors has been developed. The system is based on high-accuracy direct current comparator bridge, range extender and current source. The setup is used for comparison, characterization and calibration of standard resistors in the range from 1 mΩ to 10 kΩ with relative uncertainties below (1…5) parts in 10^6.

1 INTRODUCTION

Resistance ratio bridges are the primary instruments used by National Measurement Institutes in resistance and temperature applications. In resistance measurements the bridges are used for scaling of the ohm from the quantized Hall resistance (QHR) standard [1] or resistance standards traceable to the QHR. The reliability of uncertainties obtained during scaling process of resistance is normally confirmed by performance assessment of the bridge.

For resistance measurements in the range from 1 mΩ to 10 kΩ, an automated system based on the commercially available direct current comparator bridge was developed. The performance of the setup was thoroughly characterized to confirm, that the maintenance of resistance standards with relative uncertainty 1 part in 10^6 is achievable in the electrical laboratory of Metrosert Ltd (Central Office of Metrology in Estonia).

2 DESCRIPTION OF SYSTEM

The measurement system (Fig. 1) consists of direct current comparator bridge from Measurement International (MI) type 6010B, 100 A range extender MI 6011B, DC power supply MI 6100A and four terminal matrix scanner MI 4210A. The standard resistors are immersed into the oil thermostat from Hart Scientific (HS) type 7108.

The main component of the automated system is the direct current comparator (DCC) bridge [2]. Along with the DC power supply and 100 A range extender, the measurements of resistors in the range from 0.1 mΩ to 10 kΩ with measurement currents from 10 μA to 100 A can be carried out. The same DCC bridge was previously used in Estonian National Temperature Laboratory, but without 100 A range extender and DC current source [3].

The stability of temperature in the oil bath is within (23.00 ± 0.01) °C. Sixteen fast response platinum resistance thermometers (PRT) HS type 1522-16 are inserted into resistors to monitor the temperature. Temperature values of the thermometers are recorded by using the thermometer readout type HS 1529 and two selector switches from Isotech.

Two subsystems, one for resistance and another for temperature measurements operate under control of a personal computer. The supporting software was developed at Metrosert Ltd. The devices for resistance measurements and oil thermostat are connected through the GPIB (General Purpose Interface Bus). In temperature measurements the RS-232 serial interface is used for the purpose of flexibility in other applications, where the GPIB is not present.

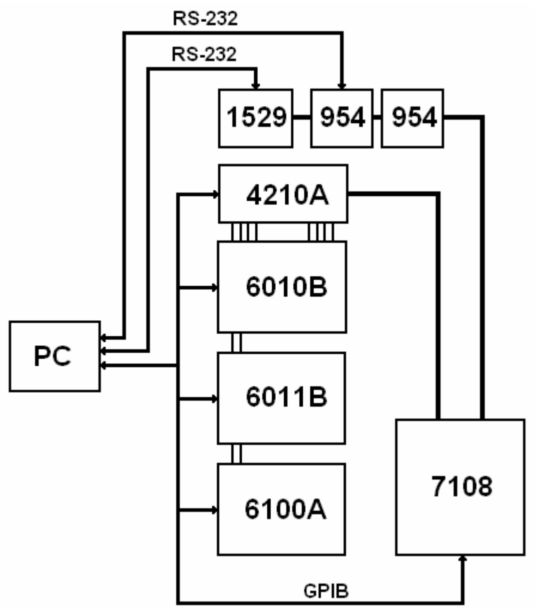

Figure 1. The automated measurement system for standard resistors.

3 MEASUREMENTS

The automated measurements are performed regularly to investigate the stability of individual standard resistors. As an example, the measurement results for 10 Ω standard resistor are shown in Figure 2. The same setup allows to determine the temperature coefficients of the resistors which are necessary to take into account the temperature effects on resistance values at the accuracy level of 1 part in 10^7.

To confirm the performance of our DCC bridge we applied methods of complements checks and comparison with calibrated standard resistors [4, 5]. The results of complements checks for 1:1 ratios with nominal values from 1 Ω to 10 kΩ are shown in Table I. Two measurements are conducted by exchanging resistors R_X and R_S. The given measurement results indicate that 1:1 resistance ratios of our bridge are within ±1 part in 10^7, which complies with accuracy specification of the bridge.

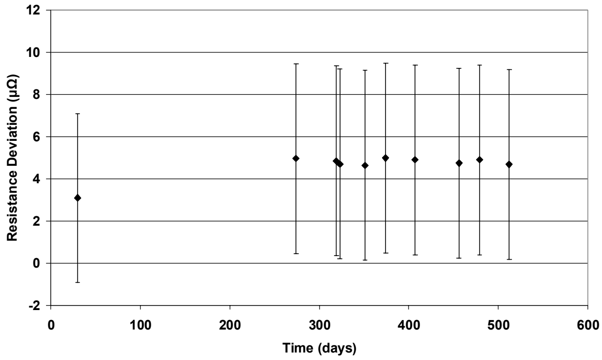

Figure 2. Stability of the 10 Ω standard resistor.

Table I

Complements checks results for DCC bridge

Nominal value, Ω	Current, mA	Relative difference in ratio, $\cdot 10^{-6}$	Standard deviation, $\cdot 10^{-6}$
1	100	-0.012	0.0007
10	30	-0.002	0.0003
100	5	-0.015	0.0011
1 k	3	-0.024	0.0020
10 k	0.3	-0.067	0.0125

Table II

Results of comparisons with calibrated resistors

Ratio, $R_X : R_S$	Cal. Date, R_S	Relative difference in ratio, $\cdot 10^{-6}$	Relative expanded uncertainty, $\cdot 10^{-6}$
1 Ω : 1 mΩ	2005	-0.62	20.0
1 Ω : 10 mΩ	2004	0.57	2.00
1 Ω : 100 mΩ	2004	0.23	0.91
1 kΩ -> 1 Ω	2005	0.25	0.61
1 kΩ -> 10 Ω	2004	-0.17	0.61
1 kΩ : 100 Ω	2004	-0.11	0.45
10 kΩ : 1 kΩ	2005	0.25	0.58

To check 10:1 resistance ratios, the calibrated reference resistors are compared to the values obtained with the resistance bridge. The results are presented in Table II. The symbol "->" denotes, that the measurements were performed in decade steps. Three resistors have been calibrated abroad in 2005: 10 kΩ, 1 kΩ and 1 Ω with relative uncertainty 4 parts in 10^7. One resistor with nominal value of 1 mΩ was calibrated at the relative uncertainty of 20 parts in 10^6. For other resistors, the differences in ratio and the related uncertainties were found from calibration history and measurement results.

The accuracy specification of the bridge for the decade ratios in the range from 1 Ω to 10 kΩ is 1 part in 10^7, which is smaller than the calibration uncertainties of the resistors. For that reason, it is difficult to estimate the conformance of the measurement results with bridge specifications. However, the differences in ratio are less than 3 parts in 10^7 being smaller as compared to the calibration uncertainties. The differences larger than specifications of the bridge can be due to the calibration uncertainty and stability of the resistors and/or inaccuracy of the bridge.

For the higher degree of conformance with the bridge specification, either smaller uncertainty of the reference resistors or Hamon-type device should be used.

3 CONCLUSIONS

The automated setup for measurements of standard resistors was developed. The new system is used in high-accuracy resistance measurements and calibration of customers' standard resistors demanding low uncertainties.

The characterization of the bridge was carried out to verify, that the uncertainties of resistance scaling using our system are less than (1…5) parts in 10^6 in the range from 1 mΩ to 10 kΩ.

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