Portable DC Voltage and Resistance Reference with Switching Unit for Calibration of Electrical Precision Multifunction Instruments

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***Abstract* — A portable temperature controlled DC Voltage and DC Resistance Reference with Switching Unit (RSU) has been developed at National Institute of Metrological Research (INRIM) to calibrate multifunction electrical instruments involving 10 V, a 1 Ω and a 10 kΩ Standards. The resistors are made with two resistors nets while the 10 V is a low noise-drift INRIM-projected circuit. Preliminary measurement over one-month period shows standards uncertainties span from 3.0×10^{-7} to 6.4×10^{-7}, suitable for artifact calibration. With a real clock calendar, the RSU can show both the RSU Standards calibration values and updated ones between two calibrations according to an internal algorithm.**

***Index Terms* — DC Voltage, DC Resistance, calibrator, multimeter, artifact calibration, measurement uncertainties.**

I. Introduction

High-precision digital multi-meters (DMMs) and multifunction calibrators (MFCs), operating in the five low-frequency electrical quantities, are widely used in calibration laboratories. These instruments can be calibrated by means of “artifact calibration”, requiring only 10 V, 1 Ω and 10 kΩ standards. This process updates the internal instruments references [1, 2]. At the National Institute of Metrological Research (INRIM), a DC Voltage and DC Resistance temperature controlled Reference with Switching Unit (RSU) has been built. The RSU could be also involved as local standard due to its suitable accuracy and to avoid thermal enclosures necessary for primary resistance standards [3] or specially made [4] and for its suitable in-use uncertainties [5]. In addition, the RSU standards could act as traveling standards for inter-laboratory comparisons (ILCs) [6, 7].

II. The RSU Standards

The DC Resistance standards of the RSU have been developed by means of two parallel-resistor nets involving ten 10 Ω and ten 100 kΩ resistance elements respectively. Details of standards of similar type realizations are reported in [8]. The 10 V is based on a temperature stabilized Zener diode Linear LTZ1000 circuit. This has been developed at INRIM and operates at 23 °C utilizing technical details built by a 3D printer for temperature shield of the integrated at 48°C. Usually, the output voltage stability and the short-term noise of a DC Voltage reference are affected by undesired thermal effects due to the contacts between the Zener pins and the board tracks. Our printed board has been developed to minimize these effects. Copper tracks were made in gold and the components are welded using alloys with low electro-motive forces (emfs). Moreover, the LTZ1000 is placed in a shield to minimize airflow effects.

III. The RSU Structure

Fig. 1 shows the block schematic of the RSU. Inside a copper box the three standards are housed and thermally controlled by a PID system. The output of the desired standard is connected to a low thermal force DC switch made of latching relays inserted in the copper box and maintained at the same temperature of the standards. The temperature of the standards is controlled by a microprocessor. The system can operate in stand-alone mode or with a PC connection via USB 2.0. With the real clock calendar, it is possible to compensate the time drift of the standards. The display can show either the actual or compensated value of the standard .

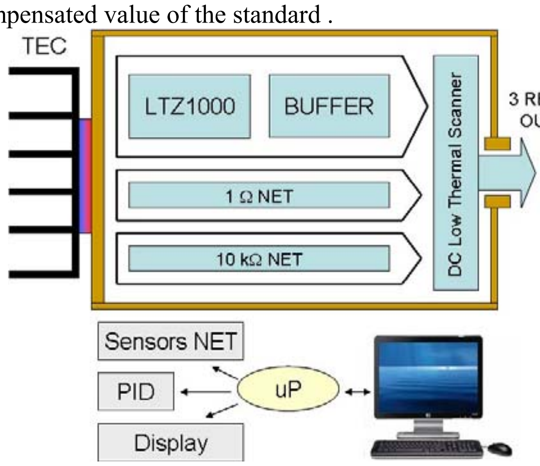

Fig. 1. Block-scheme of the RSU.

The two resistors are also kept inside an aluminum cylinder (acting as thermal equalizer). The 1 Ω net is inside an aluminum cylinder, which acts as thermal equalizer, filled of silicone oil-bath along with its connectors. The resistors of the 10 kΩ net are put around the cylinder and not in oil. The DC Voltage Standard board is inside the copper box, which in turn is inserted into the main external case connected to the ground potential.

The RSU temperature can be measured either with a 100 Ω platinum thermometer or with an electronic thermometer connected to the microcontroller. The RSU temperature stability is ±0.01 °C, with the RSU in a laboratory at 23 ±0.5 °C. A photo of the RSU calibrating a high precision DMM is shown in Fig. 2.

Fig. 2. View of the RSU calibrating high precision DMMs. The selected standard is available at a LEMO four-pole connector whose shield is connected to the guard and to the temperature control minimizing the temperature difference between it and the connectors of a connected instrument lowering the emfs.

IV. TEMPERATURE COEFFICIENTS

The temperature coefficients (TCRs) of the Standards without the temperature control were evaluated by placing the open RSU in an air-bath from 21 °C to 25 °C. The TCR of the 10 kΩ and the 10 V were respectively $1.0\times10^{-7}\,K^{-1}$ and $3.0\times10^{-8}\,K^{-1}$ while 1 Ω Standard's TCR was $2.0\times10^{-6}\,K^{-1}$.

V. RSU STANDARD STABILITY: FIRST RESULTS

The RSU standards have been calibrated vs. INRIM reference standards. Preliminary results of short and mid-term stabilities are listed in Table 1.

TABLE I. SHORT AND MID-TERM STABILITIES OF THE RSU STANDARDS.

Standard	3 h	24 h	1 month
	$(\times10^{-7})$	$(\times10^{-7})$	$(\times10^{-7})$
10 V	0.1	0.6	1.0
1 Ω	0.1	0.6	5.0
10 kΩ	negl.	negl.	0.1

VI. PRELIMINARY IN-USE UNCERTAINTY OF THE RSU STANDARDS

The "in-use uncertainty" of a standard or instrument includes components such as calibration, drift, environmental conditions and other influencial parameters [5]. Table 2 lists the use uncertainties of the RSU Standards after one month of the INRIM calibrations. This evaluation has been made because the calibration of electrical instruments has to be carried out within one month of the calibration of their refence standards.

TABLE II. RSU STANDARDS ONE MONTH USE UNCERTAINTIES

Component	10 V	1 Ω	10 kΩ
	1 σ (μV/V)	1 σ (μΩ/Ω)	1 σ (μΩ/Ω)
calibration	0.25	0.08	0.06
Drift	0.06	0.29	0.01
Emfs	0.03	0.12	negl.
Temp. effect	negl.	0.01	negl
Power effect	-------	0.002[1]	0.14[1]
RSS	0.26	0.32	0.15

VII. CONCLUSION

Preliminary in-use uncertainties of the RSU Standards seem to fit those required for artifact calibration. Nevertheless, these results have to be confirmed in next months. Additionally, to correctly evaluate the uncertainties for artifact calibration, a transport effect and a TCR evaluation of the RSU standards with the RSU in its final stage and with its temperature control set at 23 °C has to be carried out.

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[1] This component has been evaluated considering the maximum applied power difference between the calibration at INRIM and in the employment in a calibration laboratory of the standard.