DESIGN AND FABRICATION OF HIGH VALUE STANDARD RESISTORS AT INTI

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Abstract

We have designed and fabricated a set of twelve high value standard resistors of 10 MΩ, 100 MΩ and 1 GΩ nominal values. A subset of three of them were measured at NIST during January, 2008, showing to have good stability and design, a short settling time and an important voltage coefficient.

Introduction

INTI is involved in a project with other NMIs and leaded by NIST to construct a cryogenic current comparator (CCC) for high value resistance range [1]. This CCC will improve measurement uncertainty over a range of resistance values from 10 kΩ to 1 GΩ. Connected to this project we have constructed a set of high value standard resistors to increase the number of our standards in this range to compare them against the QHR. The design of these resistors follows closely the references [2] and [3], with slight modifications. To construct the resistors we have used commercial film-type resistance elements with low thermal coefficient of resistance (TCR) for 10 MΩ and 100 MΩ and a commercial resistance element with low TCR for 1GΩ. These resistive elements were chosen because of its high stability and high resistance values with reasonable sizes. An aluminum oxide ceramic sandwich with good thermal conductivity used for 10 MΩ resistors minimizes the resistance drift because of the self-heating temperature rise of the resistor. The resistive elements were previously heat treated and then hermetically sealed in containers. Each container was finally introduced in aluminum boxes to increase the electrostatic shielding.

Design and fabrication

To design and fabricate the resistors we took into account the following:

- The containers must be hermetically sealed to avoid the drift of the resistances due to changes in the atmospheric pressure.
- The containers must be dry and clean because moisture and air contamination would affect the internal resistors.
- All connections must be insulated with low water absorption, low dielectric coefficient and high resistivity materials.
- Thermal isolation of the internal resistance elements.
- Guards must be separate from shielding, to minimize parasitic capacities.
- Connectors with wide surface contact and low thermal emf against cooper.
- The container must be shielded to reduce EM interferences and to minimize piezoelectrical and triboelectrical effects

The resistance elements were previously heat treated at 50 ºC during 250 h, at low humidity (approximately 10 % RH) in a very clean environment. Changes in temperature were slow.
The containers for each resistor are rectangular brass boxes with square section. Their sizes depended on the internal resistive elements sizes. Typically, for 10 MΩ and 100 MΩ the container's size is 38 mm x 38 mm x 100 mm and for 1 GΩ the size is 38 mm x 38 mm x 200 mm. The containers have good thermal and electrical conductions and low dilation with temperature and pressure.
Each terminal of the resistive elements was soldered to the inner terminal of type N connectors. The outer terminal of each connector was soldered to the container. These connectors specified leakage helium of $2*10^{-8}$ cc/sec so we obtain a good sealed with low capacitance. Each connector was isolated from the aluminum box with an isolation disk-shape surfaces made with polytetrafluoroethylene (PTFE), see figures 1 and 2.
As in Ref. [2], two thin cooper tubes were soldered in two opposite sides of each container. These tubes were used to circulate dry nitrogen gas through the container, where the resistive element was placed, removing gases and contamination caused by the soldering process.
After purged with nitrogen gas, each container was hermetically closed by crimping the cooper thin tubes and soldering their ends. They were sealed with 1050 hPa overpressure of Nitrogen at 23 ºC. This overpressure allows to have positive differential pressure in a wide range of temperatures, to avoid the entrance of contamination.

Figure 1. 10 MΩ and 100 MΩ INTI's resistors.

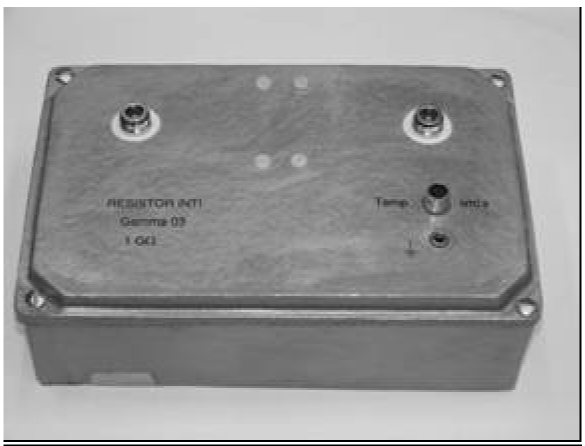

Figure 2. 1 GΩ INTI's resistors

Each container was mounted in an aluminum box. This box contains a binding-post ground connector and an internal 10 kΩ negative temperature coefficient thermistor to measure the internal temperature of the resistor.

Measurements and Results

We show some previous measurements made at INTI with a bridge method, before the resistors were sent to NIST

At present, resistors are being measured at NIST. They are measured against 1MΩ standard resistors with a CCC at different voltages and different measurement times. We show some preliminary results. Definitive results will be presented at conference.

TableI. First measurements at INTI with a bridge method

	R [Ω]	Sd (ppm)	At Va_{pp}
10 MΩ	10000276.7	2	10 V
100 MΩ	100008873.6	9	10 V
1 GΩ	999772991.8	20	100 V

TableII. 10 MΩ, 100 MΩ and 1 GΩ first results, measured at 1 V and 10 V. They were measured against 1MΩ NIST' standard resistors with a CCC. Resistors values are given in Ω.

	V_{app} 1V	Sd_{1V} [ppm]	V_{app} 10V	Sd_{10V} [ppm]
10MΩ	10000312.55	0.28	10000308.10	0.03
100MΩ	100008874.41	-	100008688.72	0.06
1GΩ	-	-	999804669.95	0.86

The resistors were measured at constant temperature, (approximately 22 ºC). In these previous measurements they show good repeatability and short settling time but a strong dependency of voltage of measurement (the differences are in the order of 0,5 ppm in 10 MΩ and 19 ppm at 100 MΩ).

Conclusions

We have built a set of high value standard resistors to increase our set of standards. Some of these resistors will be delivered to another calibration laboratories in our country to maintain a set of high value standard resistors and systems of measurement. The resistors showed good long term stability and very short settling time. As a drawback they exhibit an important voltage coefficient. Future measurements will allow us to verify the featuring of these resistors.

References

[1] R. Elmquist, G. R. Jones, Jr. B. Pritchard, M. Bierzychudek and F. Hernandez, "High resistance scaling from 10 kΩ and QHR standards using a cryogenic current comparator", submitted to this conference.

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