Final Report

Contents

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1 Introduction

The Slovenian Institute of Quality and Metrology (SIQ) has built a 100 MΩ resistance transfer standard (RTS). Such RTS is needed for calibration of measurement instruments, with an analogue integrator technique or binary voltage divider to measure resistance. Our aim was to build a good low price RTS, which will be easy to use and as small as possible.

2 Construction

The RTS was constructed without active guarding because the RTS should be easy to use. It is made of a massive aluminium enclosure with twelve spaces inside (see Figure 1.).

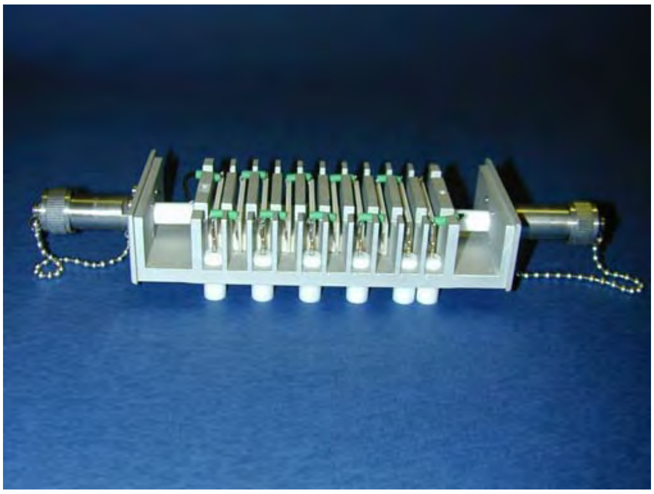


Figure 1: RTS – inside view

Each space is separated by a thick aluminium barrier (see Figure 2.).

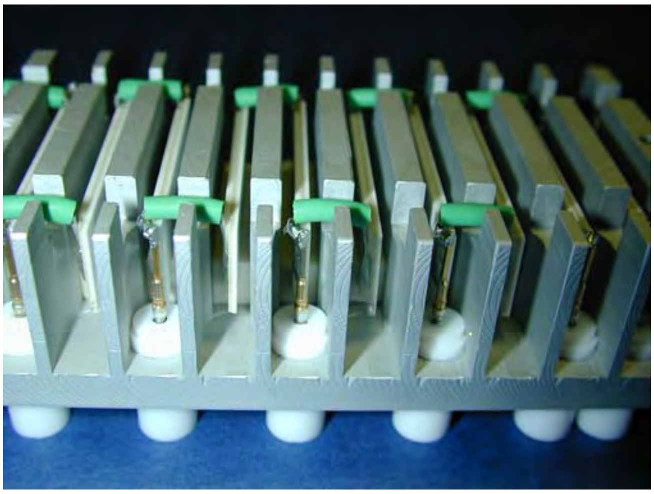


Figure 2: RTS – barriers

With these barriers very good temperature stability in the enclosure is achieved and therefore the temperature coefficient of the resistors is almost eliminated. These barriers also eliminate the capacitance between resistors. The connectors were chosen with special care as well, to prevent possible leakage currents. Finally the commercially available N-connectors with long pins and Teflon insulations were chosen.

Resistors, which were mounted into the enclosure, are made by Tetrinox® film technology and are commercially available. All resistors were pre-aged to improve their stability.

For each RTS such resistors were chosen that the calculated transfer ratio from 10 MΩ to 1 GΩ was less then 0,1 ppm.

Parallel, serial-parallel and serial cross-connections between resistors are made on special Teflon plates with golden wires and 2 mm banana plug connectors (see Figure 3.).

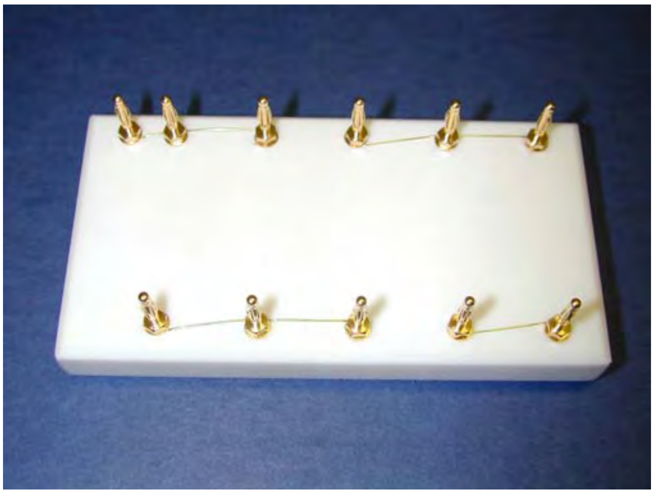


Figure 3: RTS – serial-parallel cross-connection

3 Schematic diagrams of RTS

Inside the RTS ten 100 MΩ resistors were mounted. Some connections between resistors were already made inside the enclosure (see thick connections in Figure 4.).

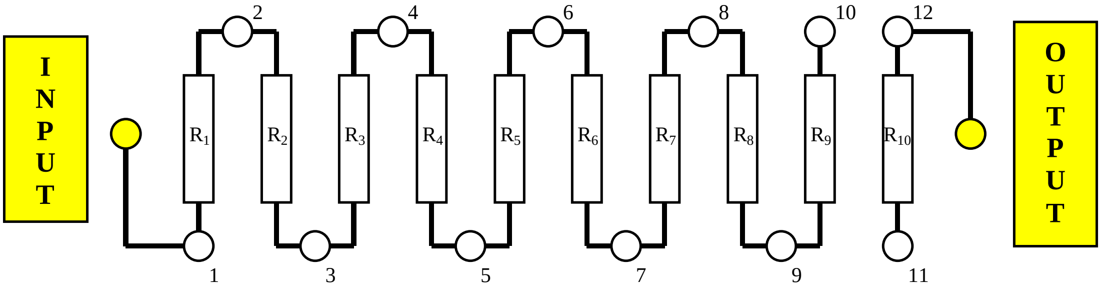


Figure 4: RTS

Figure 5. shows possible sources of leakage currents – green coloured resistors. If any of the participating laboratories have any suggestions on this topic we are open for discussion.

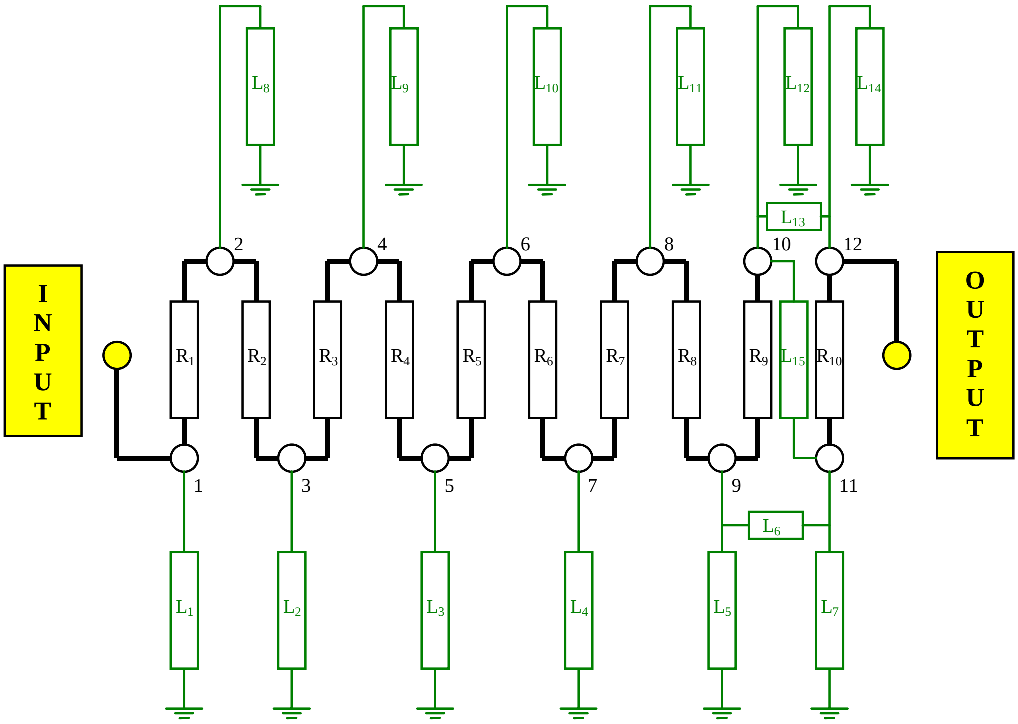


Figure 5: RTS – leakage currents

Figure 6., figure 7. and figure 8. show how the interconnections are made for each possible value – see thick red lines.

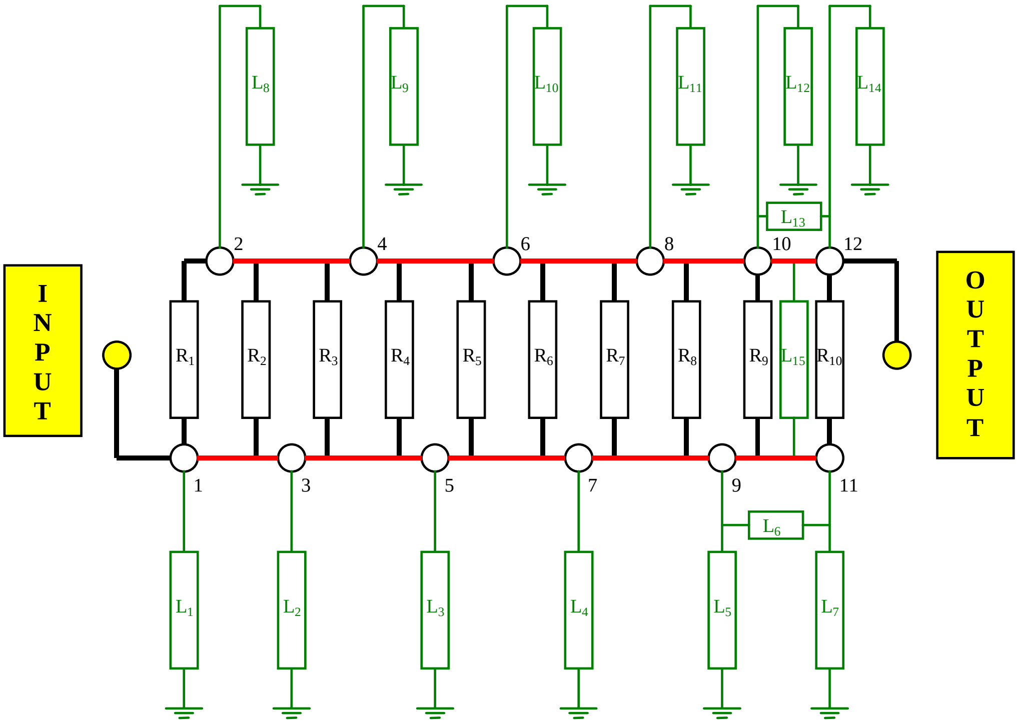


Figure 6: RTS – 10 MΩ connections

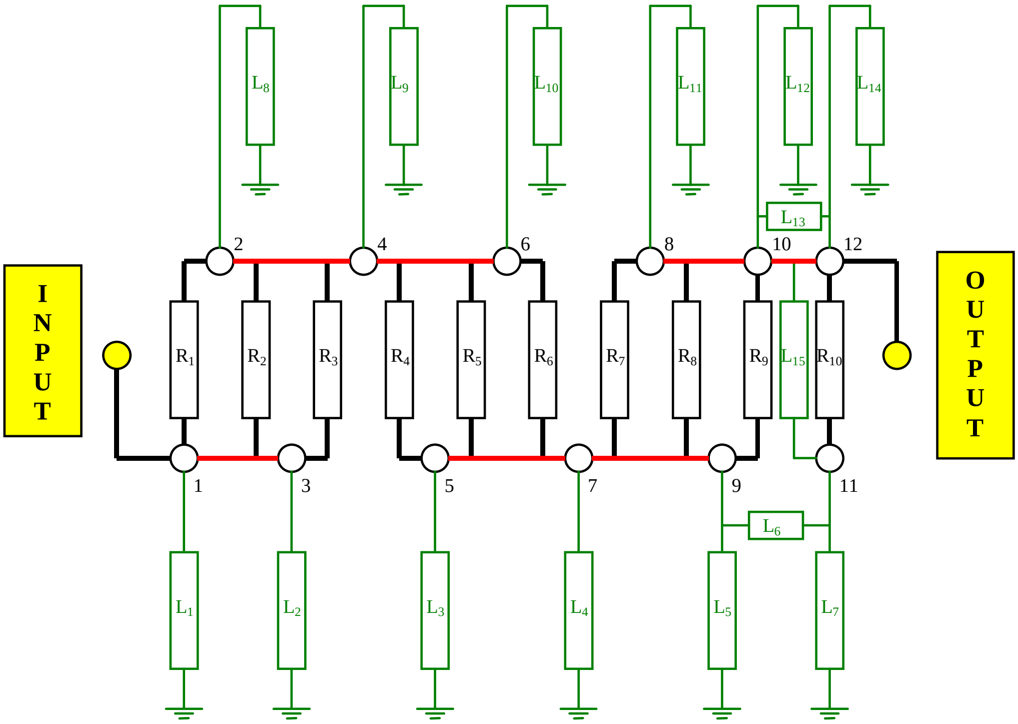


Figure 7: RTS – 100 MΩ connections

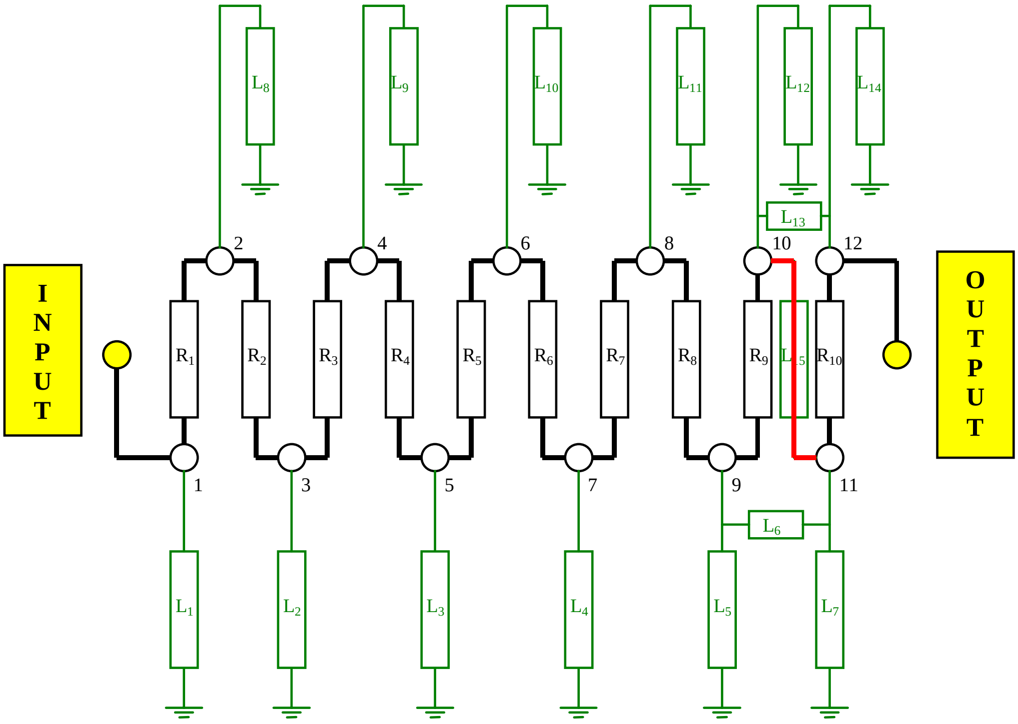


Figure 8: RTS – 1 GΩ connections

4 Results

All measurements have been performed on a commercial high resistance binary divider bridge employing the Cutkosky design. Individual internal 100 MΩ resistors were measured separately and theoretical ratios calculated. These were within 1 x 10^{-7} from nominal value (e.g. equivalent parallel, serial-parallel and serial circuit resistances were 10.000 556 MΩ, 100.005 55 MΩ and 1000.055 6 MΩ respectively). These values did not change by more than 2 µΩ/Ω in the course of 4 months during which evaluations were performed. The changes were always in the same direction and by the same amount for all three values so that calculated ratios remained unchanged. The calculated values were compared to the results from the binary divider bridge to determine the ratio error, relying on the bridge ratio accuracy.

The measurements consisted of quantifying the transfer ratio error at 10 V to 100 V and ambient conditions (23 °C ± 1 °C), measuring voltage dependence of the transfer device in parallel mode in the range 10 V to 100 V and, measuring temperature coefficient of the transfer device used as a resistor set to parallel, parallel - serial and serial mode in the range from 18 °C to 28 °C.

4.1 Ratio measurements

The most important task in our evaluation was to determine ratio error from 10 V to 100 V. As compared to binary divider bridge ratio maximum measured deviations from theoretical ratio were as given in Table 1.

It should be noted that reported uncertainties represent bridge manufacturer’s specifications only. At this time our own uncertainty estimates are 3 µΩ/Ω at 100 MΩ and 15 µΩ/Ω at 1 GΩ.

Since an increase in ratio was measured we can conclude that there should still be some leakage from internal resistor junctions to a casing that would be expected to be higher in serial connection than in other two. At this point, however, we cannot yet preclude leakages in the measurement system and possible bridge ratio errors.

4.2 Voltage coefficient

Voltage coefficient was measured only in the parallel connection of the ratio device. A 1 MΩ reference resistor was connected to the lower arm of the ratio bridge, the unknown 10 MΩ resistor in the upper arm and bridge voltage changed from 10 V to 110 V. It was assumed that the reference resistor changed negligibly from approximately 0.9 V to 10 V (a Fluke 742-1M resistor was used). It was further assumed that no more than 100 V shall be applied to the device in parallel mode, no more than 300 V in serial - parallel mode and that 1000 V can be applied in serial mode, i.e. when the device represents a 1 GΩ resistor. These values conform with most high resistance measurements systems and were considered adequate. In this range measured voltage coefficient was < - 0,02 µΩ/Ω/V ± 0,02 µΩ/Ω/V. This value is very low, but it implies that the internal resistors are used less than 1/10 of the rated voltage, see Figure 9.

4.3 Temperature coefficient

The temperature coefficient was measured for the three basic resistance configurations of the transfer device, i.e. the 10 MΩ, the 100 MΩ and the 1 GΩ at 10 V applied voltage (see Figure 10, Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15). The device was placed in a temperature controlled chamber and the temperature varied from 18 °C to 28 °C. Due to the low applied voltage the effect of self-heating was negligible and we estimated the uncertainty of the locally measured temperature to be less than 0.2 °C.

In all three case the measured temperature coefficient was practically identical, i.e. from 5.1 µΩ/Ω/°C to 5.2 µΩ/Ω/°C with estimated uncertainty of 0.2 µΩ/Ω/°C.

Furthermore, the ratio error was determined at all three temperatures. The 100/1 ratio error at 18 °C was measured to be 5.1 µΩ/Ω, 2.1 µΩ/Ω at 23 °C and 3.9 µΩ/Ω at 28 °C, which is within measurement uncertainty of the bridge and roughly corresponds to spread of results obtained by measurements at 23 °C.

Step	Ratio Error (µΩ/Ω)	Uncertainty (µΩ/Ω)
from 10 MΩ to 100 MΩ	1,5	1,5
from 100 MΩ to 1 GΩ	3,5	6,0
from 10 MΩ to 1 GΩ	5,0	6,0

Table 1

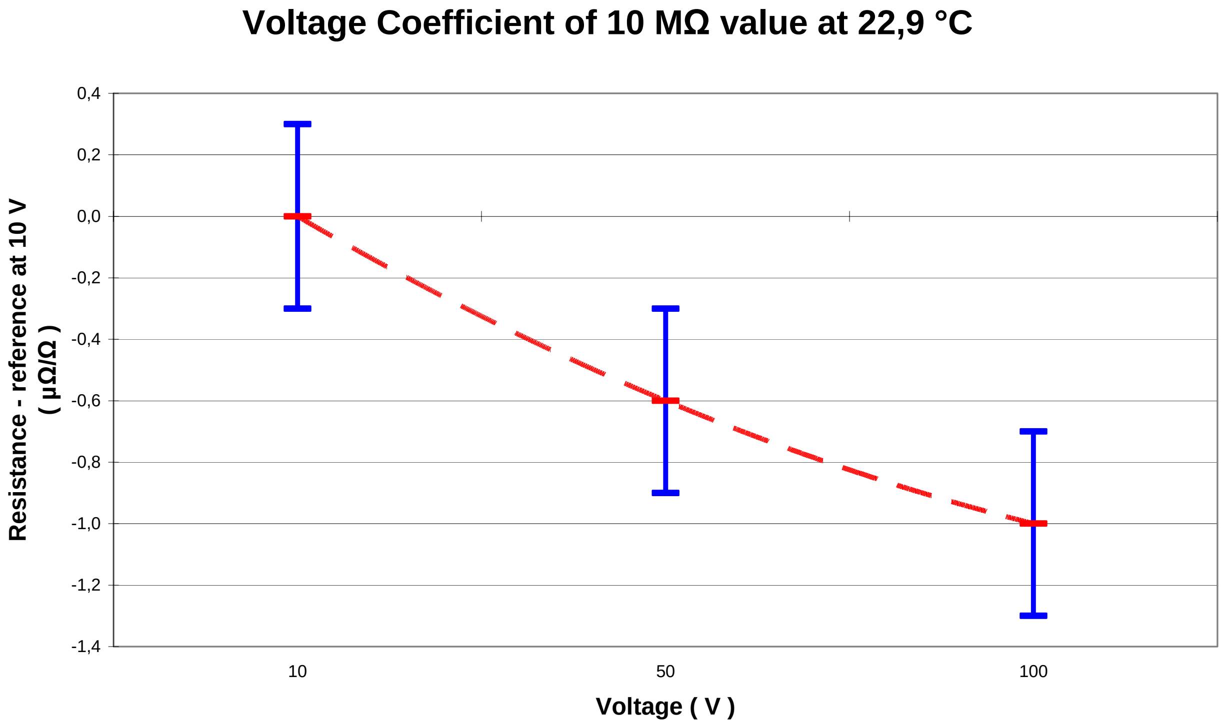


Figure 9

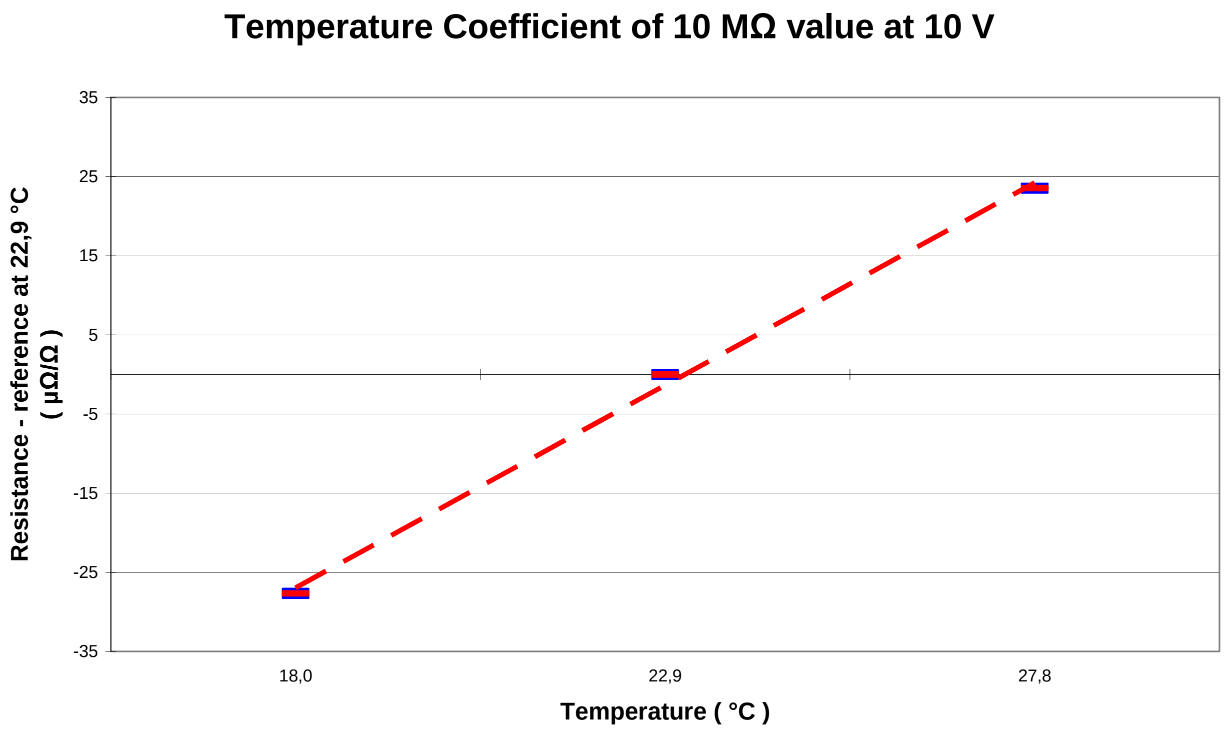


Figure 10

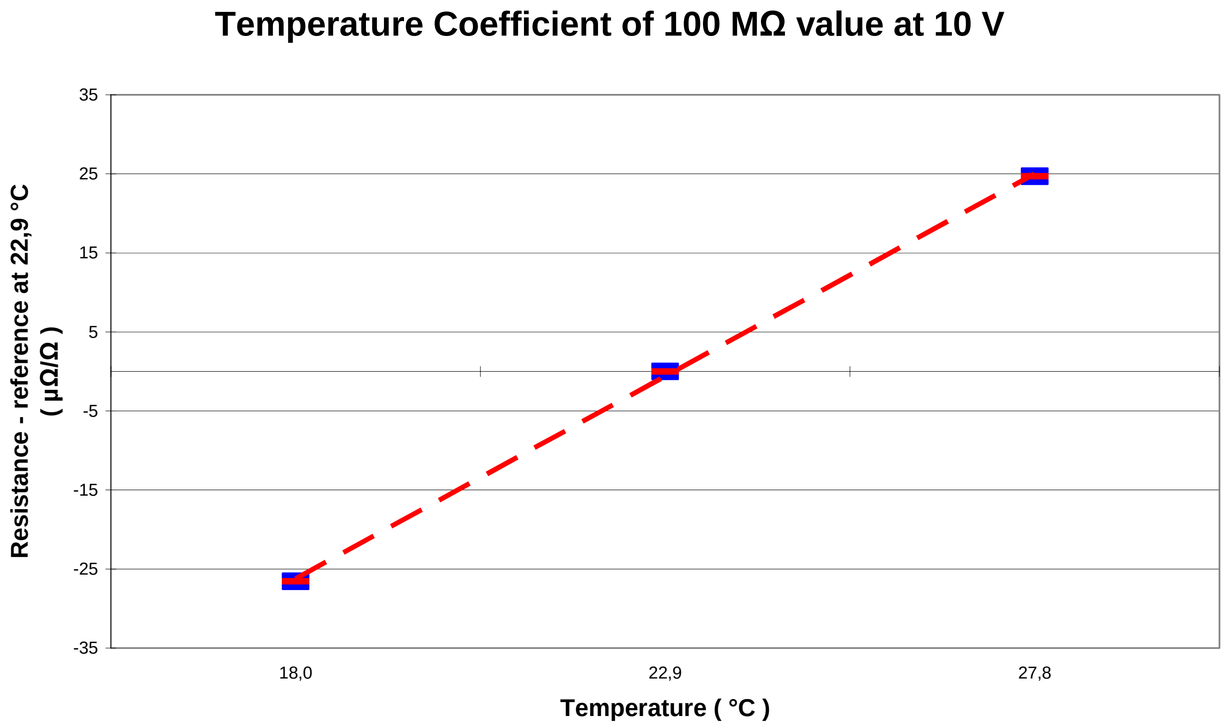


Figure 11

Temperature Coefficient of 1 GΩ value at 10 V

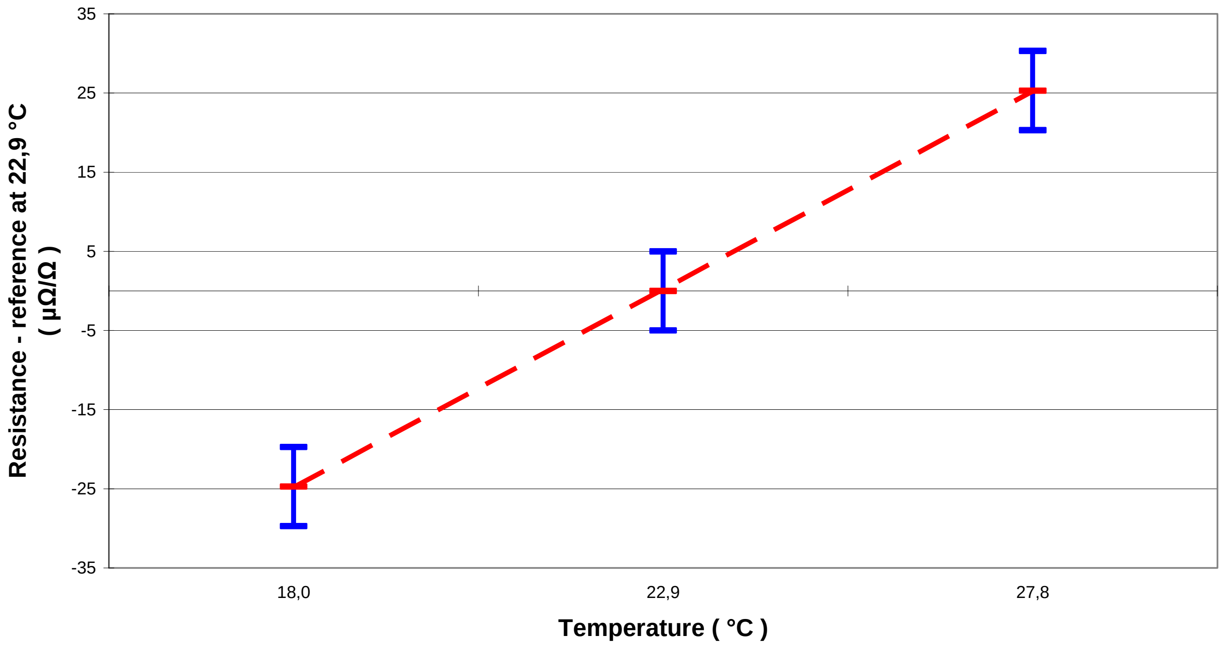


Figure 12

Ratio Error at 10 V and 18,0 °C

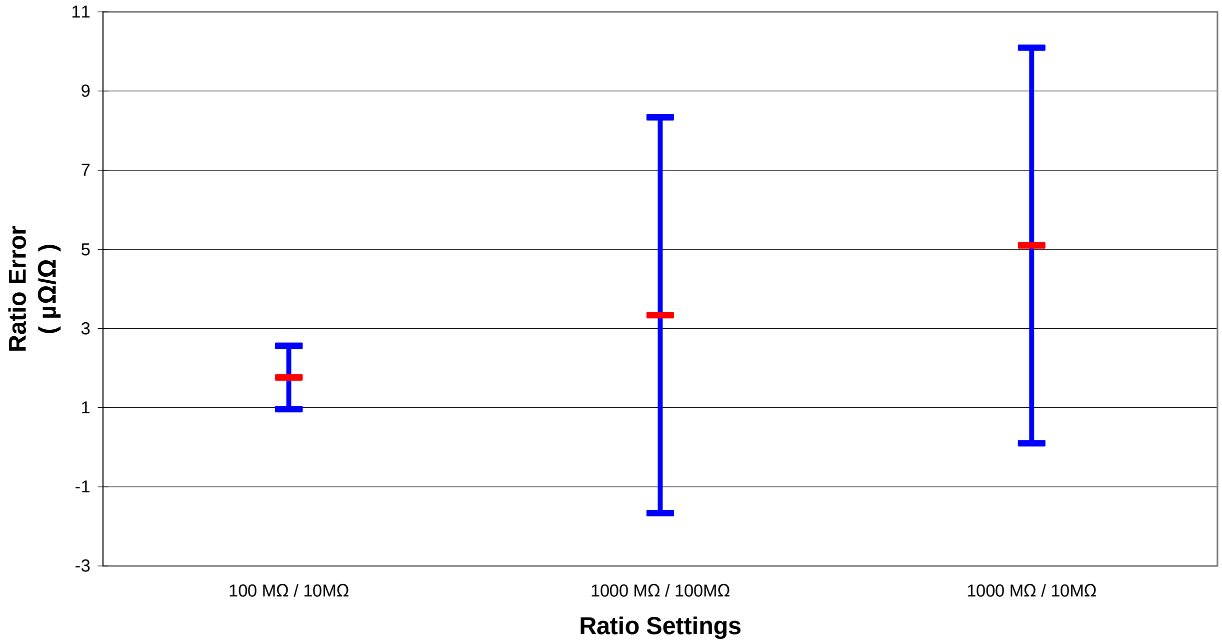


Figure 13

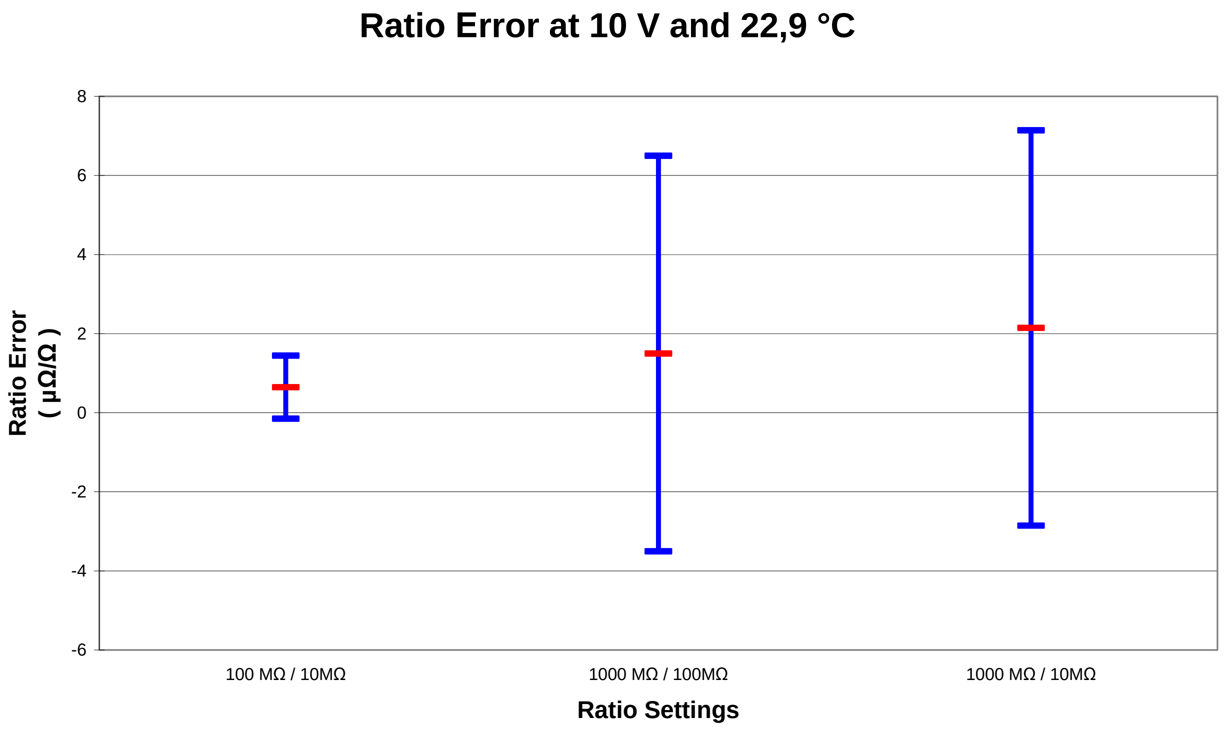


Figure 14

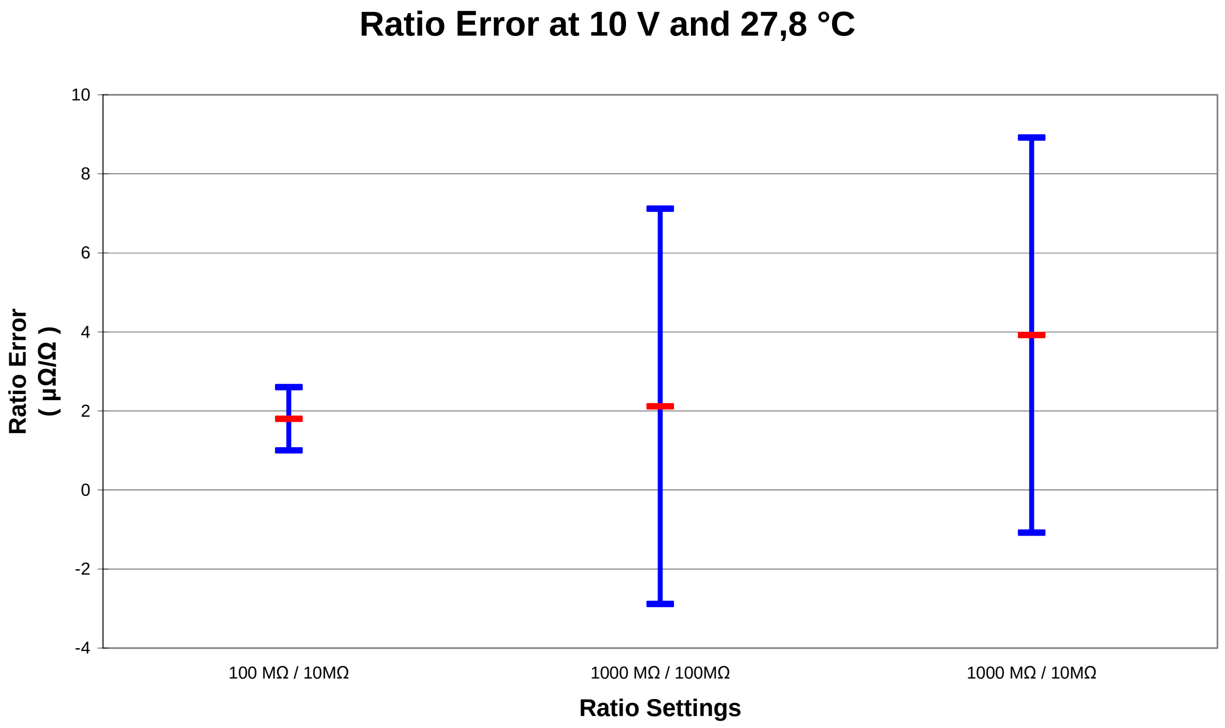


Figure 15

4.4 NMi-VSL resistance transfer standard

Netherlands National Metrological Institute NMi-VSL already purchased a 100 MΩ resistance transfer standard produced by SIQ a few years ago. In January - February this year, they have compared their measurement system (based on programmable voltage sources, pioneered by Lesley Henderson) with our 100 MΩ resistance transfer standard. The results are shown in the graph below (Figure 16). The deviation from nominal value of the 100 ratio is less than 1 ppm.

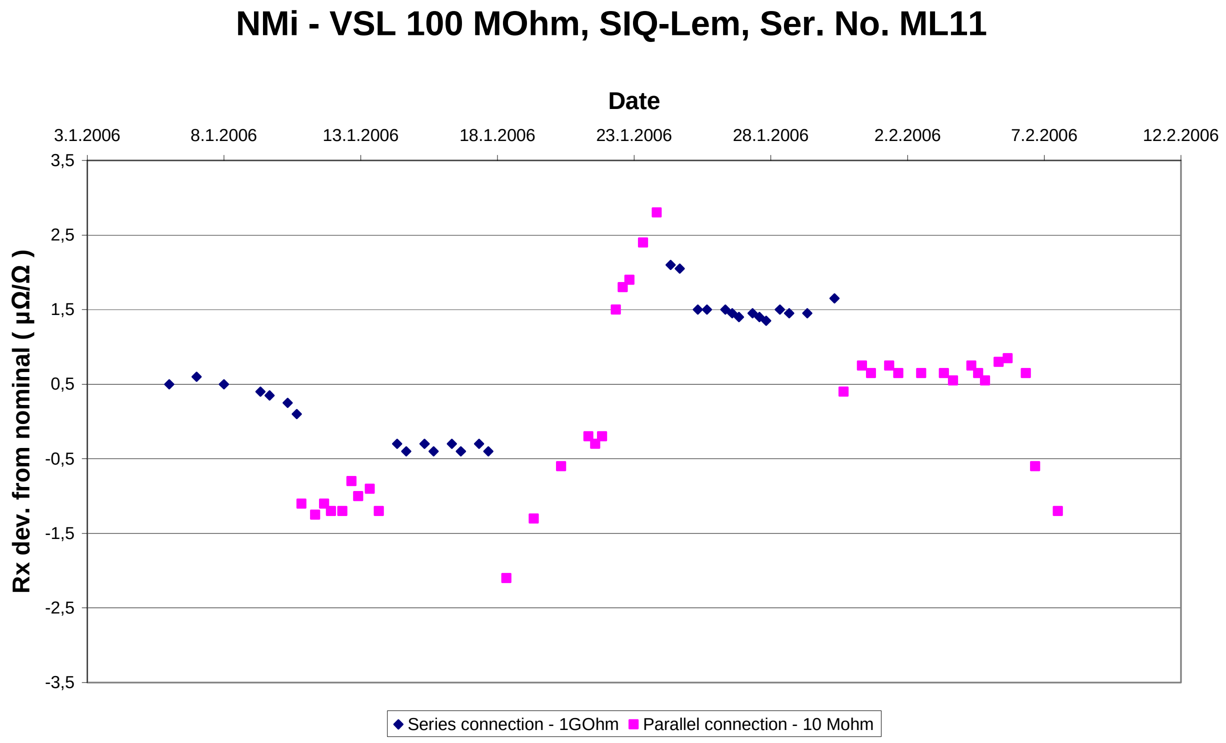


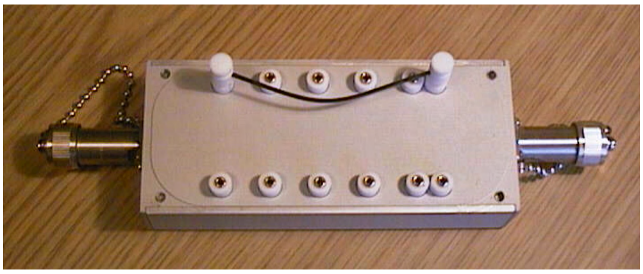
Figure 16

A. User's Guide

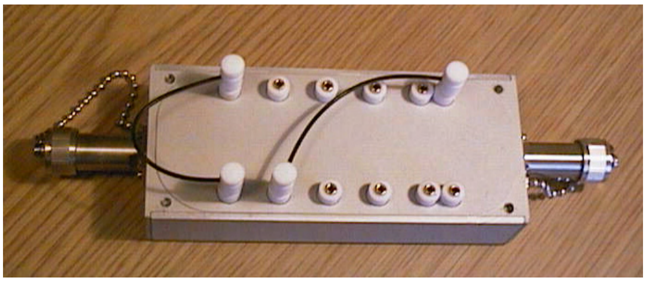
RESISTANCE TRANSFER STANDARD 100 MΩ

- ✓ difference from the nominal value less then 0,1 %
- ✓ difference in the transfer ratio less then 2 ppm
- ✓ temperature coefficient less then 5 ppm/°C at 23°C
- ✓ voltage coefficient less then 2 ppm/V
- ✓ repeatability less then 2 ppm
- ✓ dimensions of enclosure: 140 mm / 58 mm / 60 mm (W / H / D)

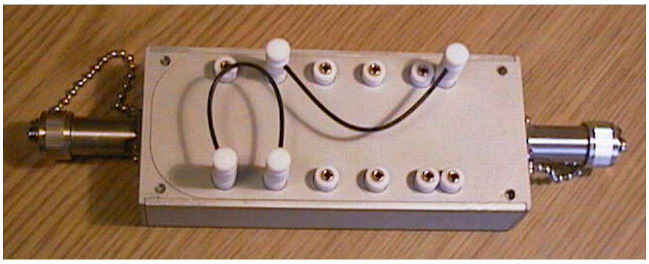
Connection for measurements of the first resistor (R1) in the Resistance Transfer Standard 100 MΩ:



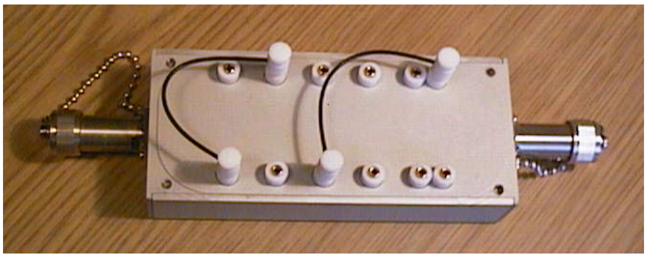
Connection for measurements of the second resistor (R2) in the Resistance Transfer Standard 100 MΩ:



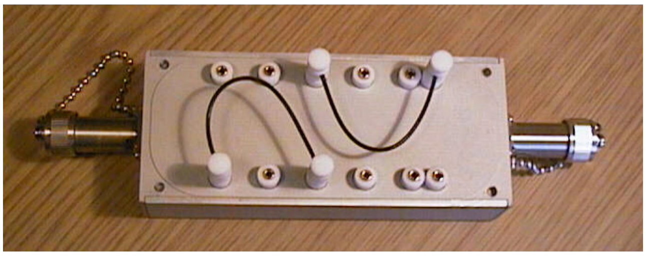
Connection for measurements of the third resistor (R3) in the Resistance Transfer Standard 100 MΩ:



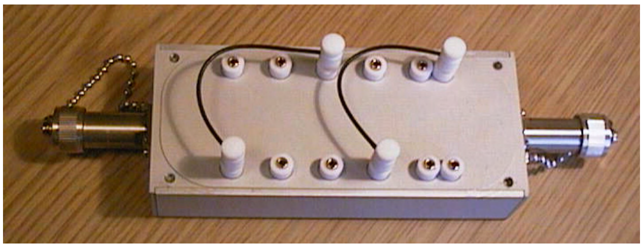
Connection for measurements of the fourth resistor (R4) in the Resistance Transfer Standard 100 MΩ:



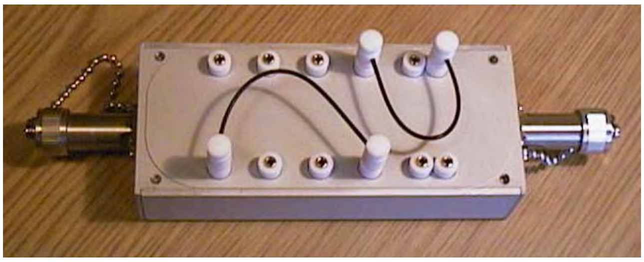
Connection for measurements of the fifth resistor (R5) in the Resistance Transfer Standard 100 MΩ:



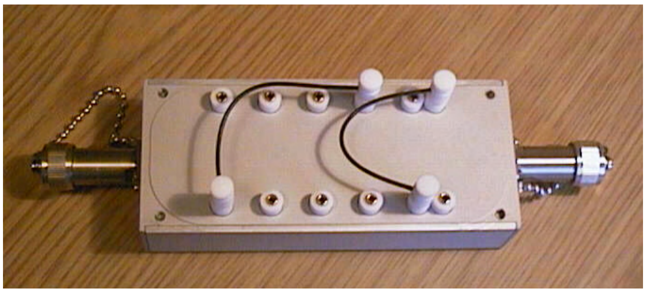
Connection for measurements of the sixth resistor (R6) in the Resistance Transfer Standard 100 MΩ:



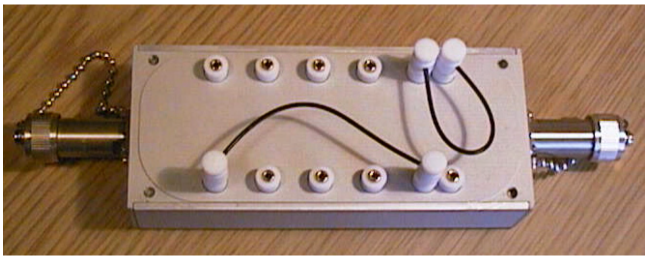
Connection for measurements of the seventh resistor (R7) in the Resistance Transfer Standard 100 MΩ:



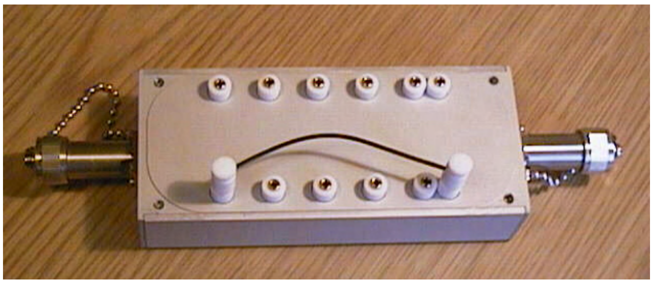
Connection for measurements of the eighth resistor (R8) in the Resistance Transfer Standard 100 MΩ:



Connection for measurements of the ninth resistor (R9) in the Resistance Transfer Standard 100 MΩ:



Connection for measurements of the tenth resistor (R10) in the Resistance Transfer Standard 100 MΩ:



10 MΩ value of the resistance transfer standard:

$Rp = 1/(1/R1 + 1/R2 + 1/R3 + 1/R4 + 1/R5 + 1/R6 + 1/R7 + 1/R8 + 1/R9 + 1/R10)$

100 MΩ value of the resistance transfer standard:

$Rsp = 1/(1/R1 + 1/R2 + 1/R3) + 1/(1/R4 + 1/R5 + 1/R6) + 1/(1/R7 + 1/R8 + 1/R9)$

1 GΩ value of the resistance transfer standard:

$Rs = R1 + R2 + R3 + R4 + R5 + R6 + R7 + R8 + R9 + R10$

B. Questionnaire

RESISTANCE TRANSFER STANDARD 100 MΩ

Institute: ………………………………………………………………………………………

Acronym: ………………………………………………………………………………………

Address: ………………………………………………………………………………………

Country: ………………………………………………………………………………………

Contact person

Name: ………………………………………………………………………………………

Telephone: ………………………………………………………………………………………

Fax: ………………………………………………………………………………………

e-mail: ………………………………………………………………………………………

Are you prepared to participate in the project?

YES:		NO:	

What period would be most convenient for you?

Time schedule:	

- remarks: ..……………………………………………………………………

Parameters to be measured:

a. see paragraph 4.1:

YES:		NO:	

- measurement uncertainty: ………………...……………………………………
- remarks: ..……………………………………………………………………
..……………………………………………………………………
..……………………………………………………………………

b. see paragraph 4.2:

YES:		NO:	

- remarks: ..……………………………………………………………………
..……………………………………………………………………
..……………………………………………………………………

c. see paragraph 4.3:

YES:		NO:	

- remarks: ....
  ....
  ....

d. see paragraph 4.4:

YES:		NO:	

- measurement uncertainty: ....
- remarks: ....
  ....
  ....

e. see paragraph 4.5:

YES:		NO:	

- measurement uncertainty: ....
- remarks: ....
  ....
  ....

f. see paragraph 4.6:

YES:		NO:	

- remarks: ....
  ....
  ....

g. see paragraph 4.7:

YES:		NO:	

- measurement uncertainty: ....
- remarks: ....
  ....
  ....