A temperature variable high accuracy 10 kΩ resistor

P.P. Capra[1], C. Cassiago[2], F. Galliana[3], M. Astrua[4]

[1,2,3,4] *National Institute of Metrological Research, (INRM) str. delle Cacce, 91 – 10135 (TURIN Italy)*
[1] *Phone + 39 011 3919424, fax + 39 011 3919448, p.capra@inrim.it*
[2] *Phone + 39 011 3919430, fax + 39 011 3919448, c.cassiago@inrim.it*
[3] *Phone+ 39 011 3919336, fax + 39 011 3919448, f.galliana@inrim.it*
[4] *Phone+ 39 011 3919424, fax + 39 011 3919448, m.astrua@inrim.it*

Abstract-A temperature variable high accuracy (TVHA) 10 kΩ resistor has been developed at National Institute of Metrological Research, (INRIM), in order to transfer the traceability to high accuracy multifunction instruments used in the accredited calibration laboratories. The TVHA consists of ten 100 kΩ nominal value resistors inserted in a copper block and connected in parallel configuration. The thermal stability of the copper block is obtained with a temperature controller. In this paper we reported details of the development of the TVHA and on its thermal behaviour. From preliminary results its relative short time stability (2h) resulted on the order of few parts of 10^{-8}.

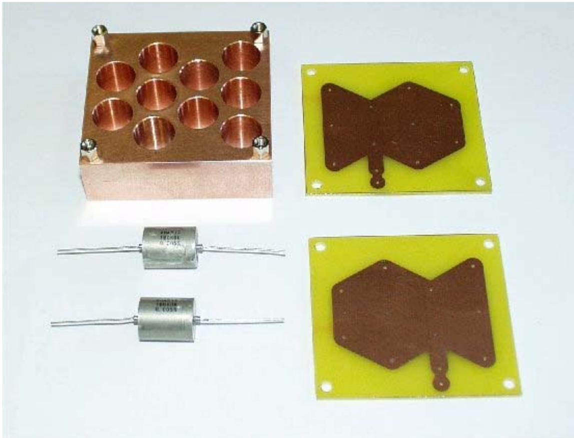
I. Introduction

Some electrical instruments like digital multimeters (DMMs) and multifunction calibrators (MFCs), widely used as standards for precision measurements are calibrated by means of a particular process, called “artifact calibration”, which requires only a small number of reference standards: 1 Ω and 10 kΩ resistance standards and a 10 V dc voltage standard [1]. Moreover, the possibility to transport from the primary laboratory (NMI) to the secondary laboratories a voltage reference and standard resistors instead of delicate instruments like calibrators increases the accuracy of the traceability transfer and makes the calibration easier and technically convenient.
We chose to develop a prototype of temperature controlled resistor for using it as standard in all those precision measurements performed at a temperature different from 23 °C (the reference temperature for electrical measurements), or in non controlled environments.

II. Building stage

A previous experience of realization of high precision resistors based on the principle to connect several resistance elements in parallel configuration is described in [2]. Also the TVHA is composed by ten Vishay resistors of 100 kΩ nominal value connected in parallel, with nominal temperature coefficient +0.6 $x10^{-6}$/ °C (from 0 °C to 25 °C); -0.6$x10^{-6}$/ °C (from 25 °C to 60 °C), power coefficient 0.75 W at 25 °C.
These resistors are foil type, oil filled, hermetically sealed VISHAY resistors (model no. VHA512) (Fig. 1b). They are fitted in a copper block (fig. 1a and 3a) which increases the heat capacity in order to reduce the sensitivity of the value of TVHA to temperature fluctuations or temporary over-currents. The block is connected to a temperature collector and a Peltier module (TEC), placed out of the resistor case (Fig. 2). The temperature is controlled by means of proportional-integrative controller (PI), a hybrid module of Wavelength Electronics HTC series, which needs a slight number of external electronic component and uses a 10kΩ NTC as sensor and sets the temperature of the block in the range of (18÷28) °C with a stability evaluated better than 3 mK/h at 23 °C. Furthermore, it is possible to use the PI controller for changing the temperature of the block in order to trim the resistance value. The 100 kΩ resistors are electrically connected in parallel with two printer boards (fig. 1c and 3b), while the connections between the TVHA and the binding post placed on the front panel have low thermal forces.

a)



c)

b)

Fig.1 – a) the copper block used as thermal equalizer b) Vishay resistors VHA512 type, c) printed boards for parallel connection.

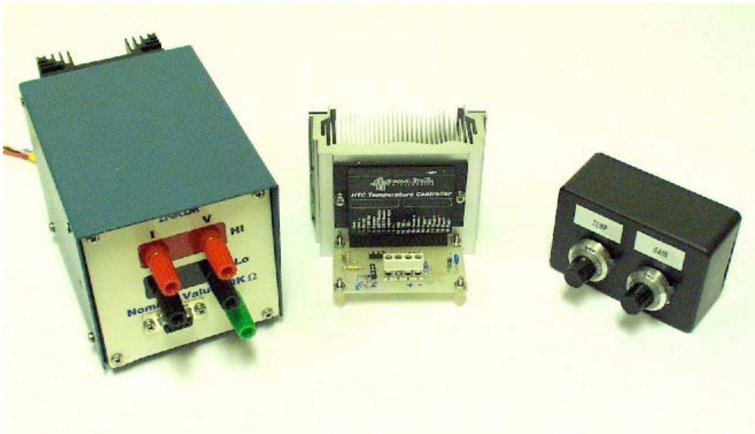


Fig.2 – The TVHA whit the temperature controller and the potentiometers to set temperature and gain.

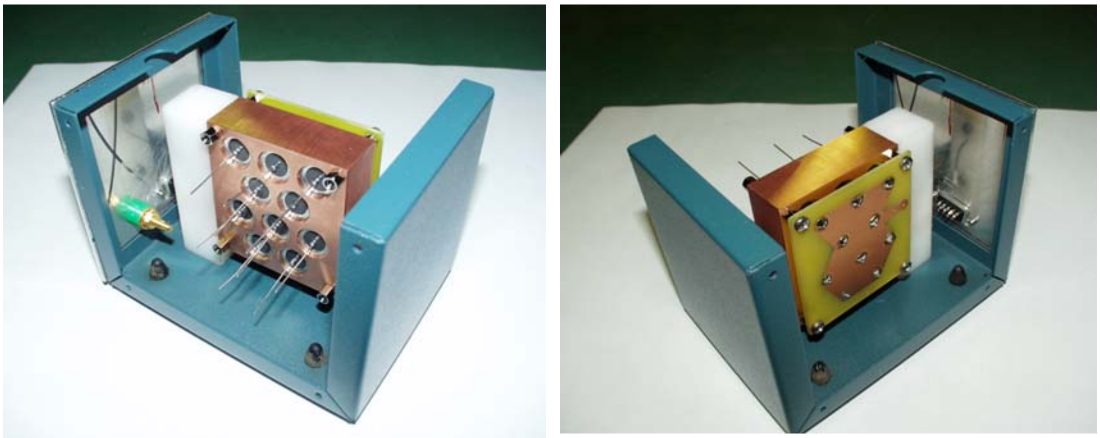


Fig. 3a) and Fig. 3b): views of the inner of the TVHA during the building stage.

III. Characterization stage

The main metrological characteristics of a standard are the time stability and the low sensitivity to the environment parameters, in particular standard resistors is mainly affected by temperature [4].

In order to evaluate the metrological performance of the TVHA, we performed a series of comparisons of this resistor against a 10 kΩ ESI SR104 widely used for its excellent metrological characteristics, such temperature coefficient-3.4x10^{-8}/°C, β =-2.9x10^{-8}/°C^{2} power coefficient (<1x10^{-6}/W), and drift on the order of 0.05x10^{-8}/year)[3]. All the comparisons are performed using a DCC bridge and a 1 kΩ standard resistor, kept in a oil bath as auxiliary transfer standard, in order to reduce the systematic errors. The aims of these comparisons were the evaluation of long and short-term stability and the thermal behaviour of the TVHA.

A. Long and short-term stability

For the long-term stability we performed a series of evaluation of the resistance value of TVHA with a rate of about six months for a period of two years and we found a relative difference of about 5x10^{-7}, presumably as a consequence of the stabilization process and in agreement of the Vishay specifications. The results of the short-term stability evaluation are showed in Fig. 4, where the relative variations of the values of both 10 kΩ standards are few parts of 10^{-8}.

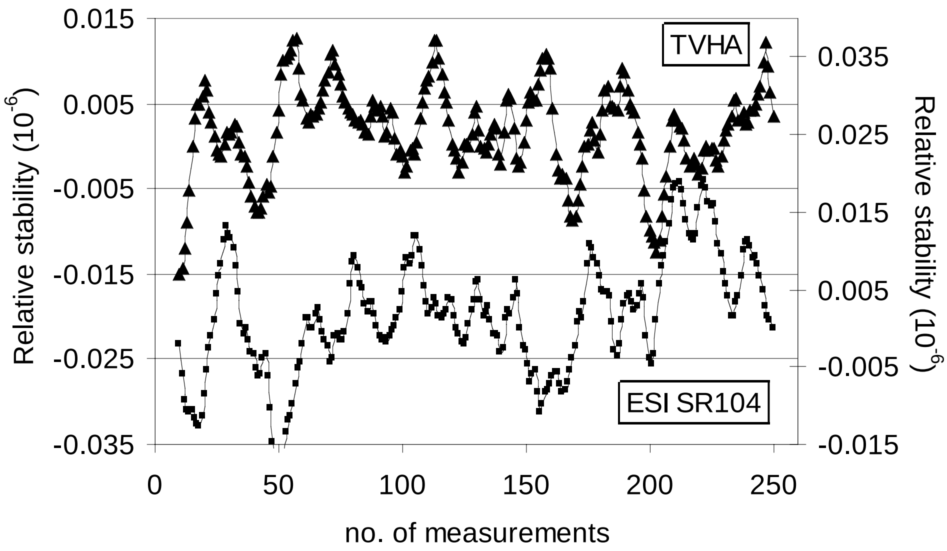


Fig. 4 – Comparison of TVHA and ESI SR104 both in free air against a 1 kΩ transfer standard resistor kept in a oil bath. The measurements have been made with a current of 0.3 mA.

B. Thermal behaviour

In order to evaluate the temperature coefficient (TC) of the TVHA, the resistor has been placed in an air bath with a variable temperature in a range from 18 to 28 °C and stability of 0.01 °C. The resistance value of the TVHA, with the temperature controller setting point at 23 °C ± 0.1 °C, was compared against a 1 kΩ standard keep in a oil bath, at the fixed temperature of 23 ± 0.002 °C. The ratio measurements between the mentioned resistors were evaluated, with a DCC bridge, in the range 20-25 °C, and the results are showed in Fig. 5. The TVHA has a very stable behaviour in the range 21-23 °C, due to the effect of the temperature controller, and however it has a value change less than 0.2 μΩ/Ω when the temperature changes up to 5 degree.

A second evaluation of the thermal behaviour of the TVHA concerned the resistance value changes caused by the set point changes of temperature controller. The temperature of the TVHA reaches a satisfactory stability in less than 10 minutes after the set point change, as showed in Fig. 6, and a variation of about 7x10^{-6} can be obtained by a temperature variation of about 10 °C.

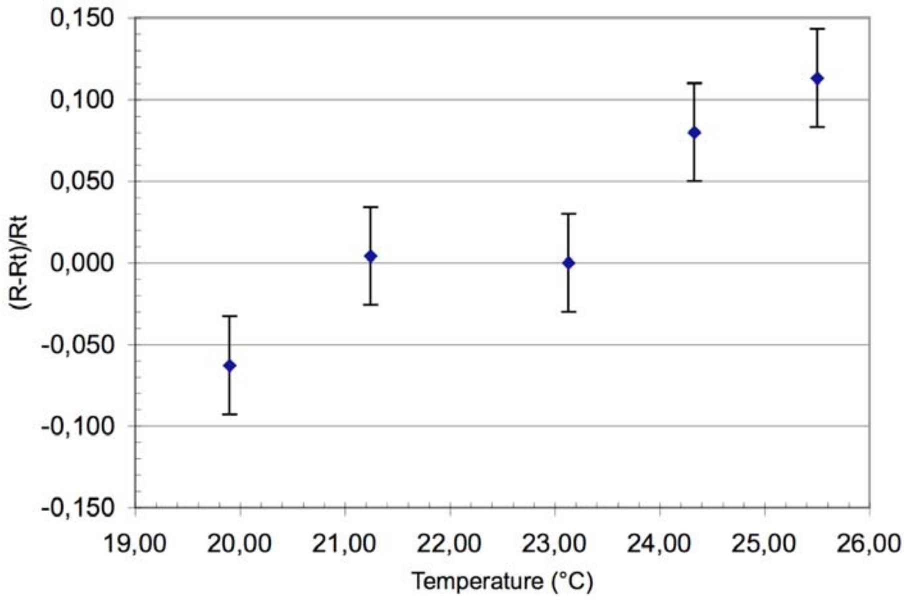


Fig. 5 – Comparison of TVHA and 1 kΩ transfer standard resistor kept in a oil bath, where Rt is the TVHA value at 23 °C and R is the value at various set temperature values.

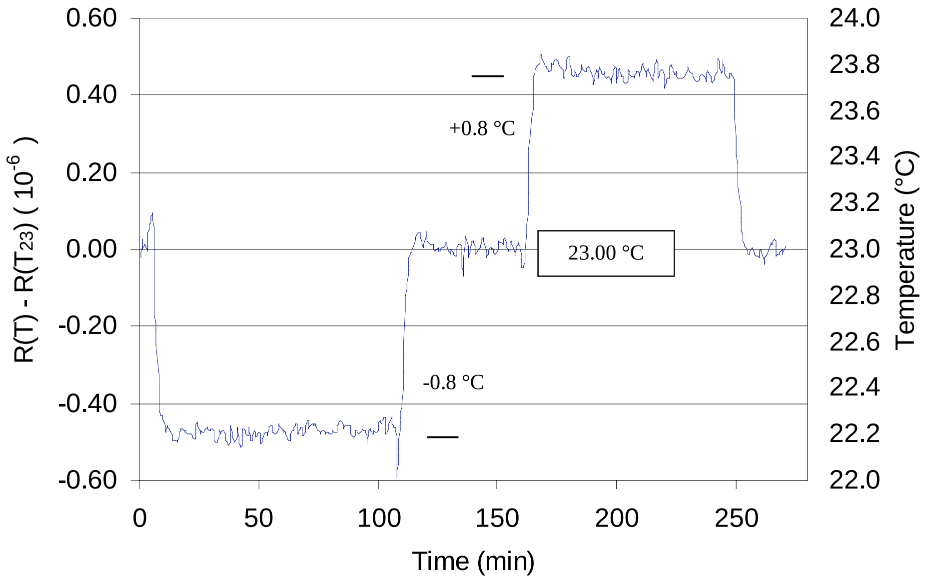


Fig. 6 – Relative resistance stability of TVHA vs. induced temperature change by its controller. ($R(T_{23})$ is the resistance value at 23 °C.

IV. Conclusions

The paper shows the development of a 10 kΩ resistor suitable for various applications. Its short time stability is equivalent than a high performance standard resistor while the temperature controller improves its use both as travelling and reference standard. We are performing other measurements for a better determination of its long time stability and power coefficients. Instead the possibility of the determination of the transports effects can be achieved by a inter-laboratory comparison.

References

[1] Calibration: Philosophy in Practice, Fluke Corporation, Second Edition.

[2] A.C.Grossenbacher, ”Development of a precision one ohm resistance standard” *Precision Electromagnetic Measurements Digest, 2002 Conference on 16-21 June 2002, pp:50–51*.

[3] G. Boella, P.P. Capra, C. Cassiago, R. Cerri, G. Marullo Reedtz, and A. Sosso “Traceability of the 10-kΩ Standard at IEN *IEEE Trans. Meas.*, *Vol. 50, no. 2, pp: 245-248*, *April 2001*.

[4] A. F. Dunn, ”Increased Accuracy for Resistance Measurements”, *IEEE Trans. Meas.*, *Vol. IM-15, no. 4, pp: 220-226, December 1966.*