Current dependence coefficient determination for different DC standard resistors measurements based on V-I method

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Abstract: Current dependence and stability of the measured resistance value are very important for the accurate measurement of DC standard resistor. In this paper, the volt-ampere (V-I) measurement method has been applied to study the current dependence of four different types of standard resistors. Diverse values are obtained through the investigation of their stability at different currents. Therefore, the current dependence coefficient (CDC) can be determined for each one of the studied resistors. Research shows CDC depends on the applied current value, the measurement time and the resistor type, as clearly demonstrated in this research.

Key words: current dependence coefficient; standard resistors; volt-ampere method; resistor stability

CLD number: TM934.12 **Document code**: A

Article ID: 1674-8042(2016)04-0332-04 **doi**: 10.3969/j.issn.1674-8042.2016.04.004

0 Introduction

Practically speaking, resistors working under different operating currents are used in various electrical circuits. The resistance value changes with the changing of the applied operating current[1] which is called current dependence, and it is generally proportional to the resistor temperature coefficient[2]. The current dependence is considered useful during the accurate measurement of resistance for many applications which necessitate operations the standard resistor at different currents. Some of these applications are resistance scaling[2-3], and calibration of reference current shunt is used in DC current, ac current and power measurements[4]. So many researchers are interested in the current dependence measurements as described in Refs. [5-6]. They used cryogenic current devices, which had many limitations and precautions, to measure the current dependence of 1 Ω resistor only.

In this paper, current dependence coefficients for various standard resistors which are 1 mΩ, 10 mΩ, 100 mΩ and 1 Ω have been measured by using the V-I measurement method which is reliable and can be easily realized. Therefore, an automated measurement set-up controlled by a specially designed LabVIEW program and mainly constructed by highly accurate programmable DVM and DMM, is used to measure the voltage drop and the current, respectively. So the resistance value could be computed according to the Ohm's law. For accurate measurement of resistance, it is necessary that resistors should reach its steady-state value, and have sufficient time for each measurement. So stability of the investigated standard resistor is studied at different selected operating currents, but under the same environmental condition. Based on the obtained stability curves, the CDC of each resistor will be described in details through this work.

1 Measurement set-up

The measurement set-up of the current dependence and the stability of the standard resistor is automatically done by using a LabVIEW program, which is also developed for this purpose. Fig. 1 shows the measurement system of the standard resistor.

Received date: 2016-09-25

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Fig. 1 Measurement system of the standard resistors

The circuit set-up of the measurement system is illustrated in Fig. 2.

The passing current and the voltage drop of the standard resistor R_s are simultaneously measured by using a DMM Fluke model 8508A and a DVM Keithley model 182, respectively. Value of R_s can be calculated according to Ohm's law.

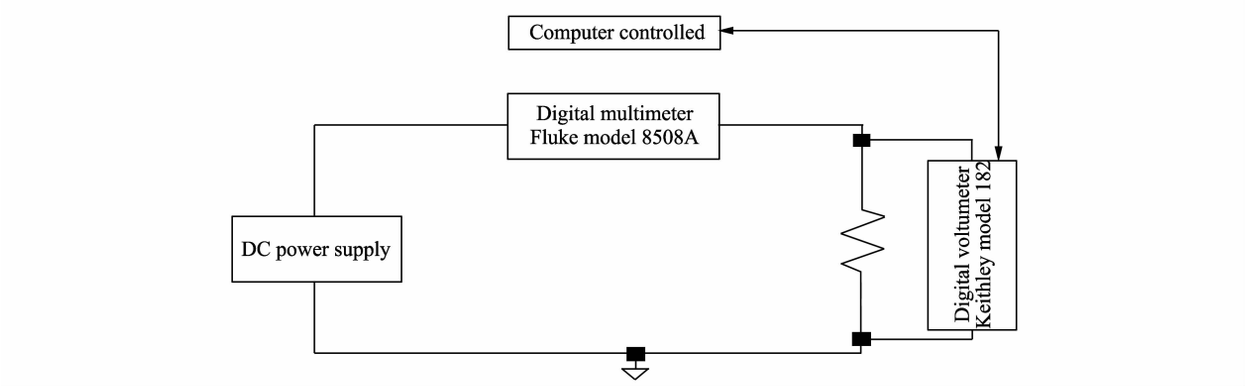
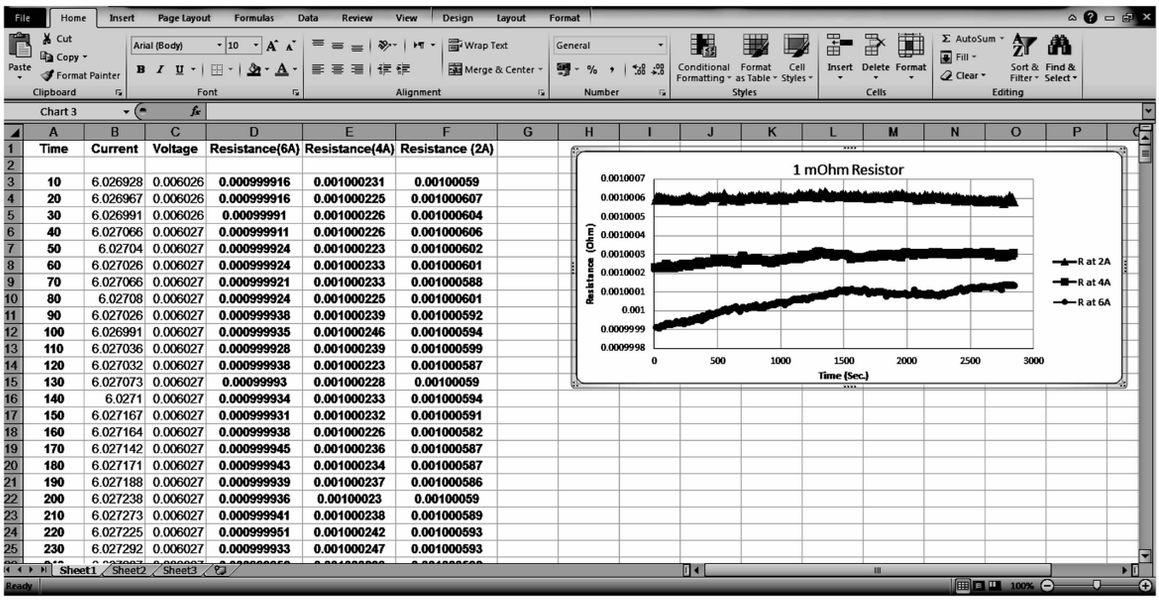


Fig. 2 Circuit set-up of measurement system

The stability of the 1 mΩ standard resistor R_s has been studied during 1 hour at constant interval. Values of the passing current and the voltage drop of the standard resistance are automatically measured each 10 s. Then the value of R_s can be computed. These values are automatically saved in an excel sheet as shown in Fig. 3. The previous steps are repeated for each applied current with waiting time at least 30 min to minimize the effect of the power dissipation of the standard resistor[3].



Time	Current	Voltage	Resistance(6A)	Resistance(4A)	Resistance (2A)
10	6.026928	0.006026	0.000999916	0.001000231	0.00100059
20	6.026967	0.006026	0.000999916	0.001000225	0.001000607
30	6.026991	0.006026	0.00099991	0.001000226	0.001000604
40	6.027066	0.006027	0.000999911	0.001000226	0.001000606
50	6.02704	0.006027	0.000999924	0.001000223	0.001000602
60	6.027026	0.006027	0.000999924	0.001000233	0.001000601
70	6.027066	0.006027	0.000999921	0.001000233	0.001000588
80	6.02708	0.006027	0.000999924	0.001000225	0.001000601
90	6.027026	0.006027	0.000999938	0.001000239	0.001000592
100	6.026991	0.006027	0.000999935	0.001000246	0.001000594
110	6.027036	0.006027	0.000999928	0.001000239	0.001000599
120	6.027032	0.006027	0.000999938	0.001000223	0.001000587
130	6.027073	0.006027	0.00099993	0.001000228	0.00100059
140	6.0271	0.006027	0.000999934	0.001000233	0.001000594
150	6.027167	0.006027	0.000999931	0.001000232	0.001000591
160	6.027164	0.006027	0.000999938	0.001000226	0.001000582
170	6.027142	0.006027	0.000999945	0.001000236	0.001000587
180	6.027171	0.006027	0.000999943	0.001000234	0.001000587
190	6.027188	0.006027	0.000999939	0.001000237	0.001000586
200	6.027238	0.006027	0.000999936	0.00100023	0.00100059
210	6.027273	0.006027	0.000999941	0.001000238	0.001000589
220	6.027225	0.006027	0.000999951	0.001000242	0.001000593
230	6.027292	0.006027	0.000999933	0.001000247	0.001000593

Fig. 3 Excel sheet of measurement results for 1 mΩ standard resistor

2 Measurement results

Stability and current dependence for various types and different values of standard resistors are measured and studied. The used standard resistors are 1 mΩ standard resistor OHM-LABS model 1003, 10 mΩ standard resistor OHM-LABS model 1002,

100 mΩ standard resistor Tinsley model 5686 and 1 Ω standard resistor Fluke model 742A.

2.1 Resistor stability

The stability of the used standard resistors has been studied at different currents. For the 1 mΩ standard resistor, its stability is measured at 2 A, 4 A and 6 A. 10 mΩ standard resistor is measured at 1 A, 3 A and 5 A. 100 mΩ standard resistor is measured at 1.5 A, 2 A and 2.5 A. For the 1 Ω standard resistor, its value is measured at 100 mA, 250 mA and 400 mA.

Fig. 4 shows the stability charts for each standard resistor.

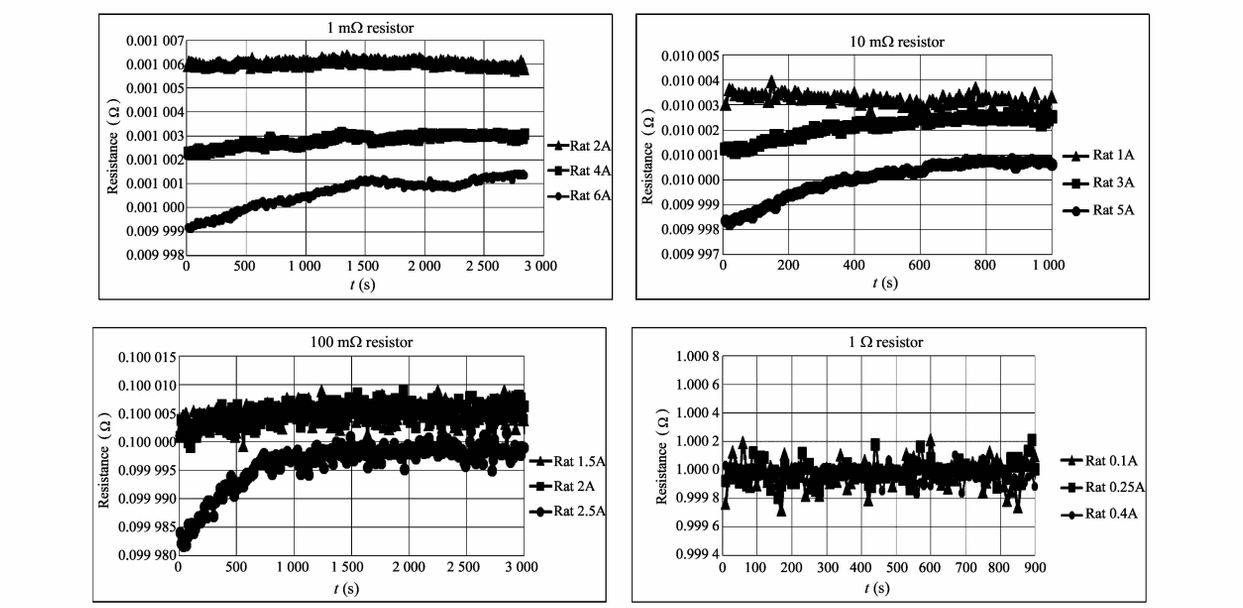


Fig. 4 Stability study of used standard resistors

2.2 Current dependence coefficient results

Current dependence of each resistor is studied at different currents depending on their stability study. Fig. 5 shows the current dependence of the used standard resistors.

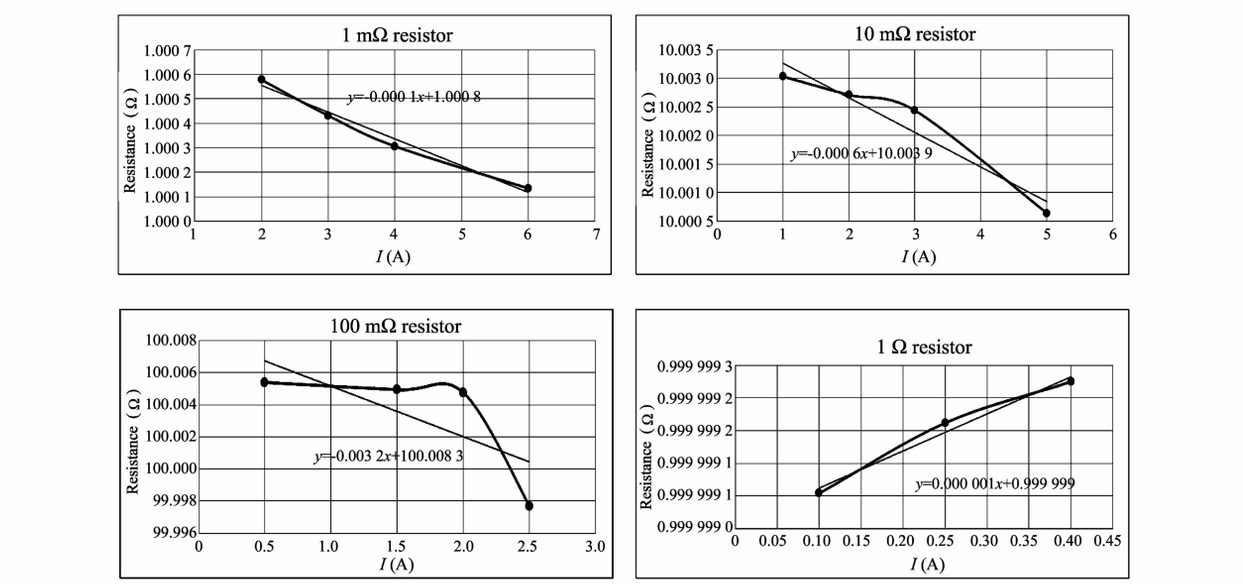


Fig. 5 Current dependence of used resistors

It shows that the CDC of the standard resistor 1 mΩ is −0.1 μΩ/A, CDC of the standard resistor 10 mΩ is −0.6 μΩ/A, and CDC of the 100 mΩ standard resistor is −3.2 μΩ/A, while the CDC of the resistance standard 1 Ω, which carries the maximum current 500 mA, is 0.001 μΩ/mA.

It is demonstrated that the standard resistors of 1 mΩ, 10 mΩ and 100 mΩ have negative CDC, and they are stable at longer time even increasing the applied current. However, the standard resistor 1 Ω has very small CDC, and it is stable in relatively very short time, which is independent of the applied current.

3 Conclusion

An easy and dependable measurement method has been used to evaluate the current dependence for different types and values of standard resistors. It has been proved that, measurement stability of resistors which have negative current dependence coefficients is obtained in relatively shorter time at the lower operating current. However, values of the resistors that have relatively small current dependence coefficients could be considered stable in relatively very short time, and independent of the applied current.

References

[1] Miller C H. Accurate determination of resistor load corrections. Electrical Engineers Proceedings of the Institution of, 1966, 113(1): 203-208.

[2] Elmquist R E, Dziuba R F. Loading effects in resistance scaling. Conference on Precision Electromagnetic Measurements Digest, 1996, 46(2): 334-335.

[3] Flavio Galliana, Giorgio Boella. The electrical DC resistance scale from 100 k to 1 t at ien. IEEE Trans. Instrum. Meas, 2000, 49(5): 959-963.

[4] Zhang J, Pan X, Lin J, et al. A new method for measuring the level dependence of ac shunts, IEEE Trans. Instrum. Meas., 2010, 59(2): 140-144.

[5] Nakanishi M, Kinoshita J. Cryogenic current comparator bridge supplying current up to 1A and current dependence measurement of 1 resistor. Jpn. J. Appl. Phys., 2003, 42(10): 6641-6644.

[6] Nakanishi M, Kinoshita J, Sakamoto Y, et al. Current dependence measurement of 1 standard resistors using a cryogenic current source with linear output. IEEE Trans. Instrum. Meas., 2001,50(2): 255-258.

基于伏-安法测量不同直流标准电阻器的电流依赖性参数

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摘　要： 电流依赖性参数和电阻值的稳定性对直流标准电阻器的准确测量是非常重要的。本文利用伏-安法来测量四种不同标准电阻器的电流依赖性参数，并获得了不同电流下它们的电阻值稳定性。研究表明，CDC 与电流值、测量时间及电阻类型有很大关系。

关键词： 电流依赖性参数；标准电阻；伏-安法；电阻稳定性

引用格式： Ali R S M, Raouf M H A. Current dependence coefficient determination for different DC standard resistors measurements based on V-I method. Journal of Measurement Science and Instrumentation, 2016, 7(4): 332-335. [doi: 10.3969/j.issn.1674-8042.2016.04.004]