A MEASUREMENT SETUP TO CALIBRATE PICOAMMETERS IN DC CURRENT IN THE RANGE 100 pA ÷100 nA

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Abstract

This paper describes a measurement setup for the calibration of pico-ammeters in dc current in the range 100 pA ÷ 100 nA. The system is based on a 100 MΩ Hamon network developed at INRIM to improve the traceability level of the maintained 1 GΩ standard. Besides the Hamon network, the measurement system consists of a precision dc voltage source and an electronic circuit used as voltage guard driver. A comparison with a different technique and an uncertainties considerations for the system and are also reported.

Introduction

Modern pico-ammeters are devices which conjugate high performances and simplicity of use. Hence, they are widely used both as null detectors (such as in experiments of realisation, reproduction and maintenance of electrical units in dc or in low frequency) and as detectors for photomultiplier tubes, in developing systems of semiconductor devices with ionic implantation methods, in mass spectrometers; last but not least, for insulation measurements and for characterization of the behaviour of dielectric materials. The increasing interest in this kind of instruments induced National Metrology Institutes (NMI) to extend measurement scales for low currents and to organise key comparisons to verify the measurement capabilities of the laboratories. In this paper a calibration method, working in the range 100 pA÷100 nA, based on the use of a dc voltage source and a Hamon network is presented.
Some considerations about the development of the Hamon network and a preliminary evaluation of the measurement uncertainties are also reported.

Measurement setup

The measurement system includes a dc voltage calibrator, a 10 MΩ to 1 GΩ Hamon network [1, 2] and an auxiliary digital multimeter (DMM) to monitor the temperature inside the Hamon network (Fig. 1).

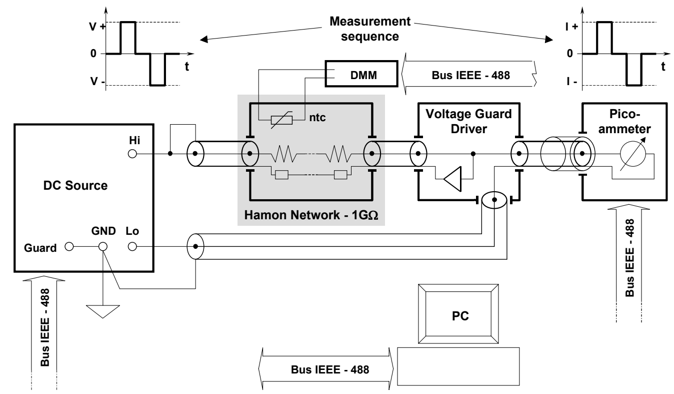

Fig. 1 - Scheme of the measurement setup.

Before the use, the Hamon network is calibrated in parallel configuration (10MΩ) by comparison with a 10 MΩ standard using a high-accuracy DMM. Then the measurement circuit of Figure 1 is assembled. An accurate dc voltage source is applied to the Hamon resistor in series configuration (1 GΩ), in order to form the current source, and to the input of the guarding system of the Hamon. The output of the Hamon resistor is connected to the pico-ammeter under calibration through a guard driver circuit and a coaxial adapter. The driver output sets the voltage of the low side of the Hamon guard circuit. The common terminal of the pico-ammeter is connected to the low output of the voltage source. With the above described setup it is possible to minimize:

- thermal effects;
- parasitic and the tribo-electric effects of the cables as the connection between the Hamon standard and the pico-ammeter is very short and rigid; (Fig. 2)
- possible interferences caused by the presence of the operator, since the whole measurement procedure is automated.

Measurement procedure

The procedure of pico-ammeter calibration was developed in order to minimize the effects of the temperature and the voltage burden.

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The temperature coefficient of the device was measured in the range (16 ÷ 27) °C , and a value of $3.8 \cdot 10^{-6}$/°C, better than declared by the manufacturer, was obtained.

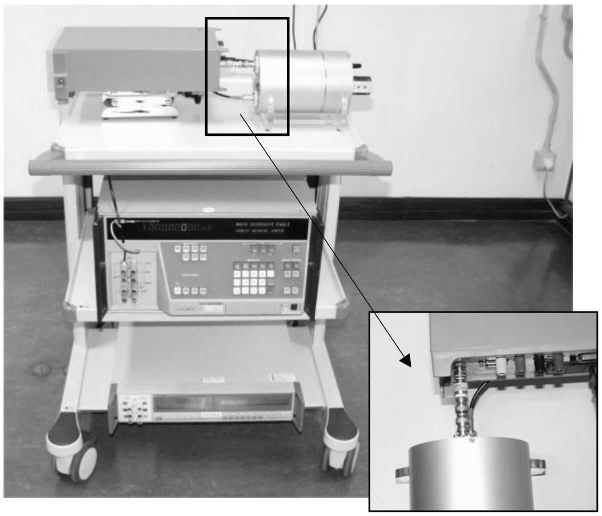

Fig. 2 – View of the measurement setup: note the connection between the Hamon network and the pico-ammeter by means of a short adapter

The adopted procedure consists on a sequence of measurements of (0, +I, 0, -I, 0) A, as shown in Fig. 1, in the range 100 pA to 100 nA. Between the measurements a waiting time of two minutes is needed for exhausting the transient phenomena and to achieve current stability. The voltage coefficient of the Hamon network resistance has been measured in the range (50÷250) V resulting negligible. Hence, the calibration of pico-ammeters in different ranges could be performed by using only one resistor. Results from the described system were compared with those obtained with a method based on the charge and discharge of a gas-dielectric capacitor [3]. A current of 100 pA was supplied by both systems and read by the same Keithley 6517 pico-ammeter. The agreement between the methods was better than $4 \cdot 10^{-5}$. Measurement of current in ranges higher than 100 pA were performed in order to evaluate noise level and the repeatability, but the comparison with a different method was not performed yet, since the capacitor-based method developed at INRIM is suitable for current values smaller than or equal to 100 pA.

Uncertainty considerations

Main sources of uncertainty of the method have been identified as:

- calibration of the Hamon standard;
- short time instability of the same standard;
- temperature and voltage effects on the resistor;
- effects due to voltage burden;
- calibration of the dc voltage source;
- accuracy specifications of the voltage source.

In Table 1 the uncertainty budget is reported.

Table 1:Relative uncertainties of the system

Current range	Uncertainty (2σ)
100 pA	$4{,}2 \cdot 10^{-4}$
1nA	$4{,}7 \cdot 10^{-5}$
10 nA	$1{,}9 \cdot 10^{-5}$
100 nA	$2{,}1 \cdot 10^{-5}$

Conclusions

At INRIM a measurement setup for calibration of pico-ammeters in dc current in the range 100 pA ÷100 nA was developed, using a commercially available dc voltage source and a home.-made Hamon network with guard driver. The encouraging results obtained with this measurement setup lead us to continue to improve and to extend the capabilities of this measurement method. In particular, future development of this work could be the measurement of the input voltage burden of the pico-ammeter, since the value declared by the manufacturer is presumably worse than the effective one. At the moment, the uncertainty budget in the 100 pA range is predominantly affected by this value., a full-range compatibility test with other methods and a more exhaustive evaluation of the method uncertainty components will be carried out.

Acknowledgements

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