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National Institute of Metrological Research

**EVALUATION OF THE TRANSMILLE MOD. 8081 HIGH PRECISION DIGITAL
MULTIMETER BY THE INRIM CALIBRATION LABORATORY OF MULTIFUNCTION
ELECTRICAL INSTRUMENTS**

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INRIM technical report 23/2016

July 2016

visto

Responsabile STALT

(Vito Fericola)

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TITLE AND SUMMARY

EVALUATION OF THE HIGH PRECISION TRANSMILLE MOD. 8081 DIGITAL MULTIMETER BY THE INRIM CALIBRATION LABORATORY OF MULTIFUNCTION ELECTRICAL INSTRUMENTS

This report describes the work made by the laboratory of calibration of electrical multifunction automatic instruments of the National Institute of Metrological Research (INRIM) concerning the metrological verification of a high precision TRANSMILLE mod. 8081 digital multimeter (DMM) recently produced in order to assess its accuracy and stability compared with its specifications. The instrument was tested in a six months period in the five basic electrical low frequency fundamental quantities (dc and ac voltage and current and dc resistance). Its stability and precision were compared with its accuracy manufacturer specifications and a performance index of the DMM was evaluated for each examined measurement point. The DMM showed to be in agreement with its specifications so it can be considered at the level of other top-class DMMs and in some measurements points its specifications are even better. In addition, its high current (up to 30 A range), low currents (down to 10 nA range) DC Resistance up to 2 TΩ functions are useful and not available in other DMMs. Technical dealing with TRANSMILLE was satisfactory.

TITOLO E SOMMARIO

VALUTAZIONE DEL MULTIMETRO NUMERALE DI ELEVATA PRECISIONE TRANSMILLE MOD. 8081 TRANSMILLE MOD. 8081 DA PARTE DEL LABORATORIO DI TARATURA DI STRUMENTI ELETTRICI MULTIFUNZIONE DELL'INRIM

In questo rapporto tecnico si descrive il lavoro svolto dal laboratorio di taratura di strumenti elettrici automatici multifunzione dell'Istituto Nazionale di Ricerca Metrologica (INRIM) riguardante la verifica metrologica di un multimetro commerciale di elevata accuratezza TRANSMILLE mod. 8081 di recente produzione al fine di valutarne l'accuratezza e la stabilità in confronto con le specifiche. Lo strumento è stato verificato nell'arco di sette mesi nelle cinque grandezze elettriche fondamentali in bassa frequenza (tensione e corrente continue ed alternate e resistenza in corrente continua). Le sue stabilità e precisione sono state confrontate con le specifiche di accuratezza dichiarate dal costruttore ed è stato valutato un indice di prestazione del multimetro per ogni punto di misura esaminato. Il multimetro ha dimostrato di rispettare le proprie specifiche così da poter esser considerato al livello di altri multimetri di classe elevata ed in alcuni punti di misura le sue specifiche sono perfino migliori. Inoltre le funzioni di corrente fino a 30 A, basse correnti (fino al campo 10 nA) e resistenza fino a 2 TΩ sono molto utili e non disponibili negli altri multimetri. La collaborazione tecnica con la TRANSMILLE è stata soddisfacente.

1. INTRODUCTION

Since the late eighties, high precision electrical electronic instruments, such as digital multimeters (DMMs) and multifunction calibrators (MFCs, are used by calibration and industrial laboratories in the five basic electrical low frequency quantities (direct and alternating Voltages and Currents and in direct current Resistance), both as Reference or Working Standards. Consequently, the process of traceability transfer from the Primary or National Institutes (NMI) has changed significantly [1–4]. In addition, in modern electrical calibration laboratories a high precision DMM could play a strategic

role not only as simple instrument to calibrate customer's sources or standards but also as main laboratory reference Standard or instrument to transfer the traceability from National Standards. To meet the need of calibration of DMMs and MFCs, the National Metrological Institute (INRIM) set up since the early nineties a high performance laboratory (INRIM-Lab) to calibrate these instruments. The calibration system of the INRIM-Lab consists of a group of reference standards (shown in detail in Fig. 1), such as 10 V Zener voltage reference standard, a DMM calibrated in linearity and used as voltage divider and an automated DC Voltage divider, a set of standard resistors and shunts, and a programmable ac/dc voltage transfer standard, which are periodically calibrated vs the national Standards. The system also includes three MFCs, used as working instruments, and some other auxiliary instruments used to extend the measurement fields. The calibration of DMMs and MFCs implies an adjustment and a verification in which the measurements of these instruments are compared with the INRIM-Lab reference Standards. INRIM-Lab systems typically calibrate high-stability DMMs, MFCs and DC Voltage calibrators.

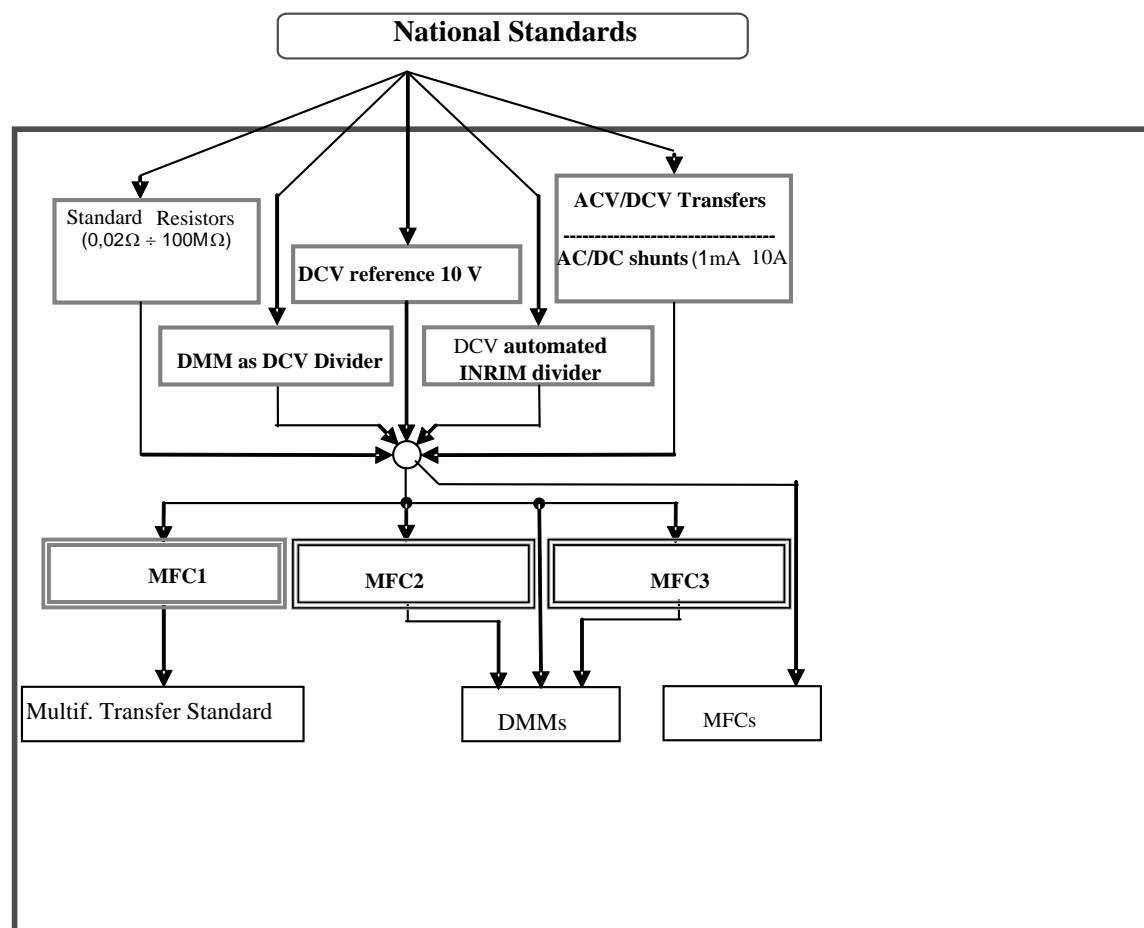


Fig. 1. Traceability chain from national Standards of the INRIM-Lab.

2. THE TRANSMILLE MOD. 8081 HIGH PRECISION DMM

TRANSMILLE was founded in 1995 as a commercial calibration service, and soon after began to develop and manufacture a range of electrical calibration products and software to answer a growing requirement for solutions to common problems. Successively TRANSMILLE worked to provide unique equipment and software for not only our own laboratory but also for calibration laboratories and manufacturers. Now TRANSMILLE produces more than 600 calibration instruments per year, for National Laboratories to small calibration and test houses. One of the top TRANSMILLE instruments is now the 8.5 digit mod. 8081 DMM, that TRANSMILLE evaluates at the same level of the best now commercially available as the J. Fluke mod. 8508 and the Agilent/HP 3458A. Manufacturer declares that the 8081's main features are:

- Precision: 4 ppm, resolution: 8.5 digit;
- Voltages AC / DC up to 1000V;
- Currents AC / DC up to a 30 A;
- Resistance measurements from 1Ω to $2 T\Omega$ with measurement voltage up to 300 V;
- Electrometer function for high value resistance measurements at low current and low noise;
- Platinum thermo-resistance (PRT) measurement function at two, three and four wires with ITS90 Callendar van Dusen linearization;
- Rear panel input terminals;
- Advanced ratio functions as adjusted value and absolute ratio;
- Simultaneous temperature and resistance display for metrological confirmation of PRT probes;
- Thermocouple measurements with display to °C, F and K;
- Dedicated pressure module interface (Option).

The DMM can display other interesting features as the visualization of the measurements standard deviation, the maximum and minimum readings, the measurement accuracy and a dynamic uncertainty that are interesting and innovative features. Nevertheless, a DMM user cannot completely trust in this uncertainty evaluation as this parameter depends by many factors and if a laboratory is accredited its uncertainty is linked to its calibration procedures and to its accredited uncertainty. In Annex 1 manufacturer specifications in the five low frequency electrical quantities are reported. TRANSMILLE sent to INRIM a first version of the 8081 DMM for evaluation. On this occasion some technical changes were suggested to be made to the instrument, for example to the input terminals that TRANSMILLE correctly implemented. A new version of the DMM was successively re-sent for evaluation to the INRIM-Lab. The DMM was periodically verified by

comparison with the Standards of the INRIM-Lab for a period of six months without performing the adjustment to evaluate its time stability with respect to its specifications.

3. GRAPHICAL RESULTS

As previously said, the TRANSMILLE mod. 8081 DMM was verified in the five fundamental low frequency electrical quantities comparing it with a MFC J. Fluke 5700 A of the INRIM-Lab in turn calibrated vs. the Reference Standards of the INRIM-Lab. To facilitate the comprehension of the measurements data, in Figures 2 to 33 are shown in graphical form the results obtained as relative deviation from the applied values. For some significant values a comparison of the results vs. the declared 180-days DMM accuracy specification was also added.

3.1 Results for DC Voltage.

In Figures from 2 to 6 the verification results for DC Voltage are graphically shown.

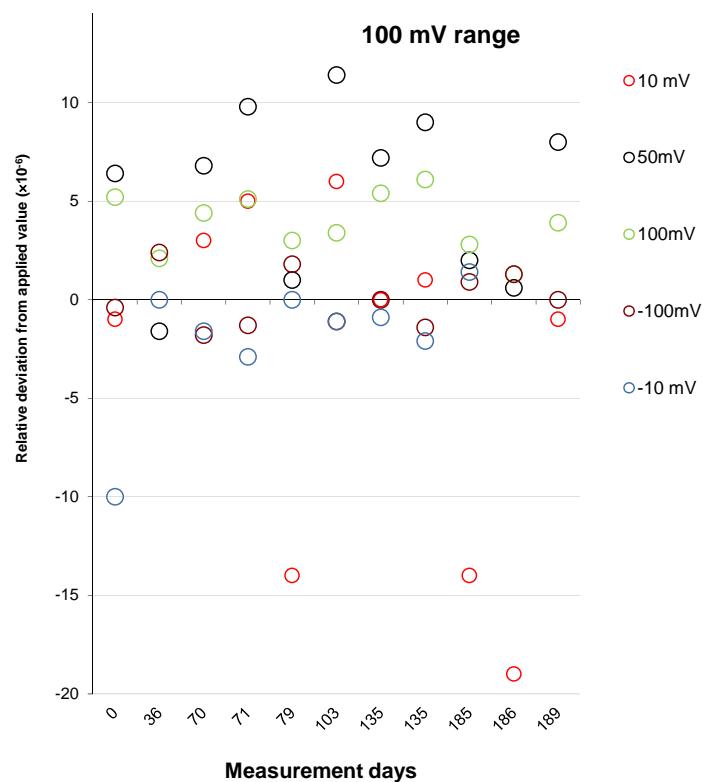


Fig. 2. Relative deviations from applied standard values in the 100 mV range.

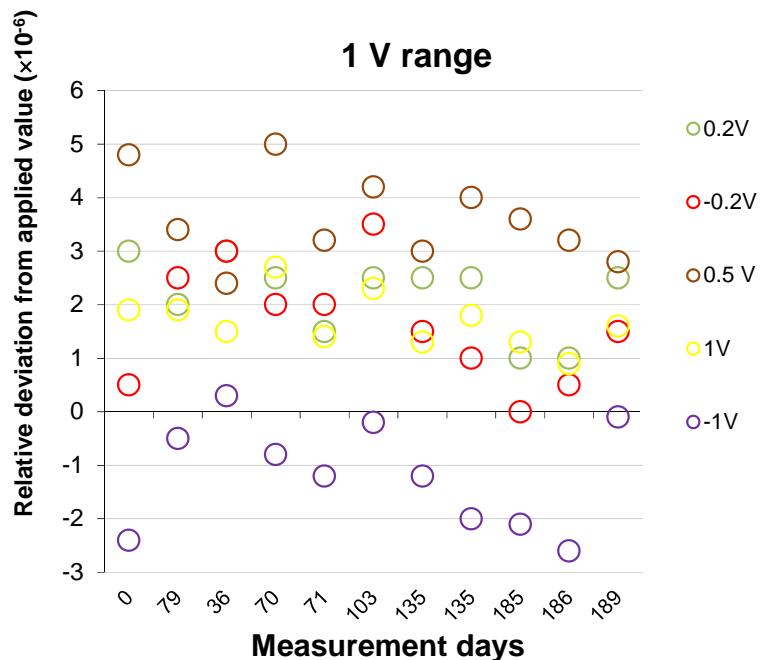


Fig. 3a). Relative deviations from applied standard values in the 1 V range.

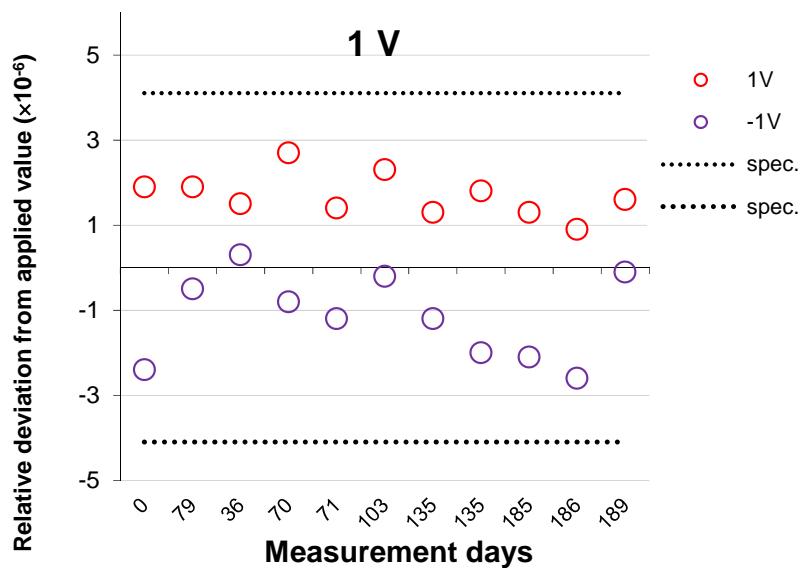


Fig. 3b). Relative deviations from applied standard values at 1 V
compared with the 180-days DMM specifications.

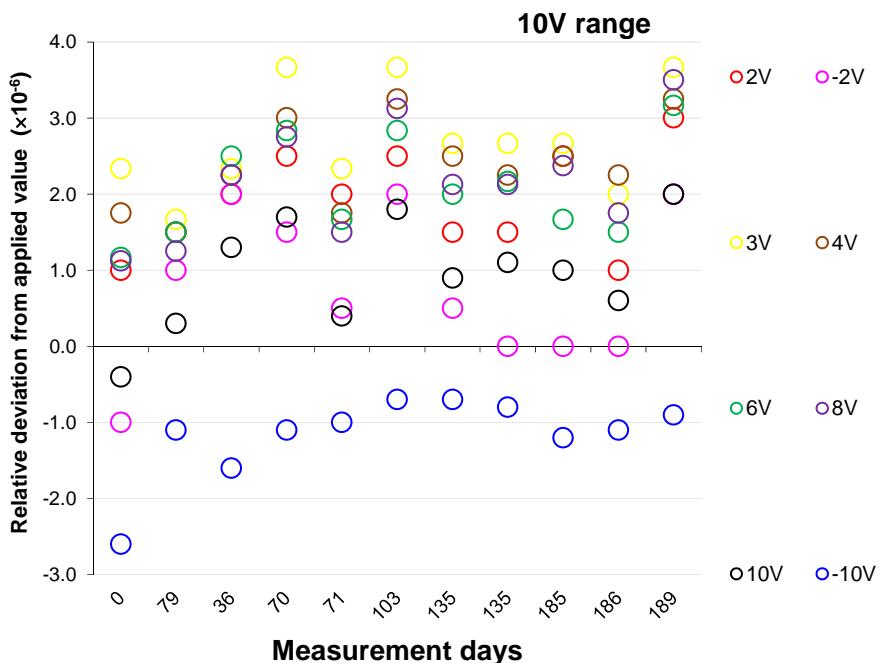


Fig. 4a). Relative deviations from applied standard values in the 10 V range.

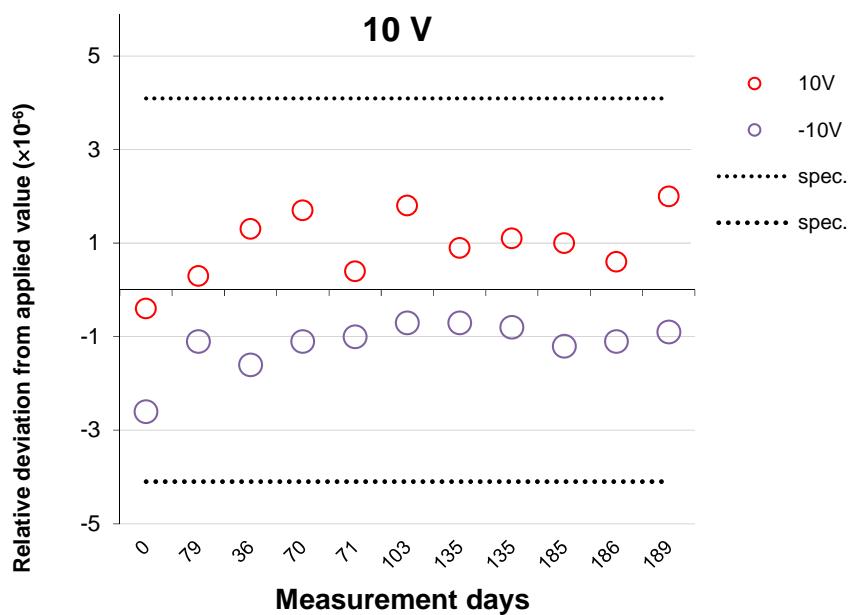


Fig. 4 b). Relative deviations from applied standard values at 10 V
Compared with the 180-days DMM specifications.

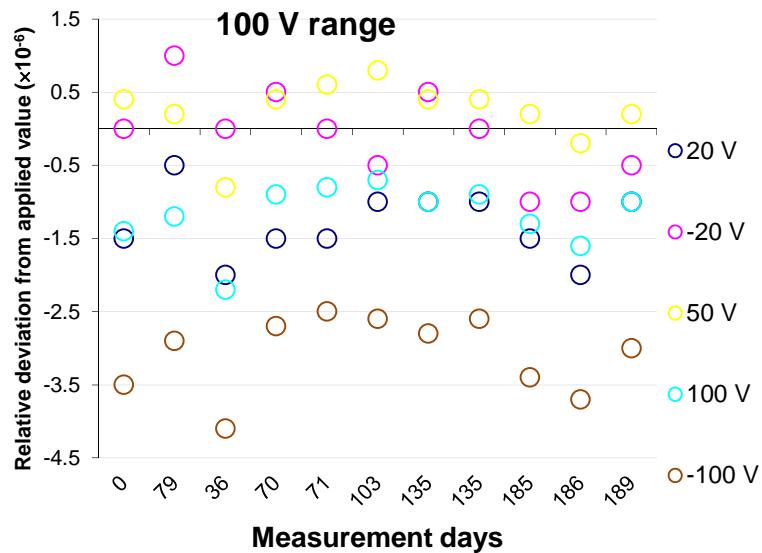


Fig. 5. Relative deviations from applied standard values in the 100 V range.

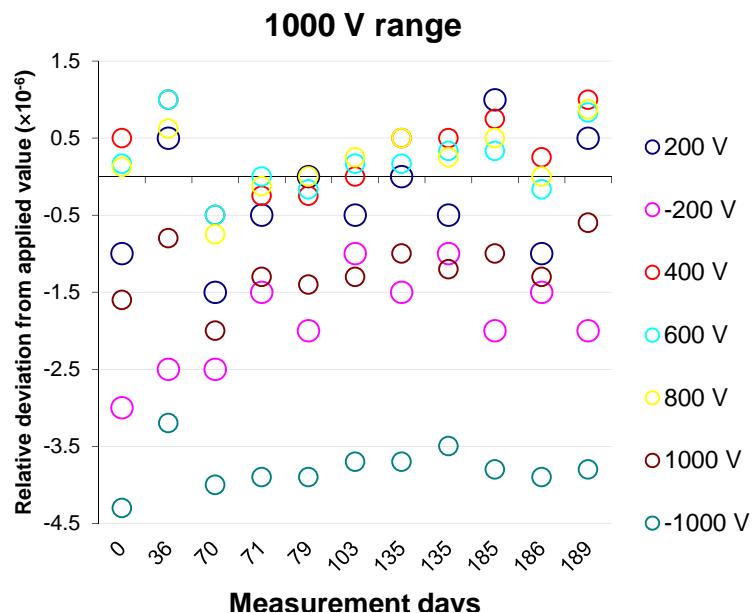


Fig. 6. Relative deviations from applied standard values in the 1000 V range.

3.2 Results for AC Voltage

In Figures from 7 to 15 the verification results for AC Voltage are graphically summarized.

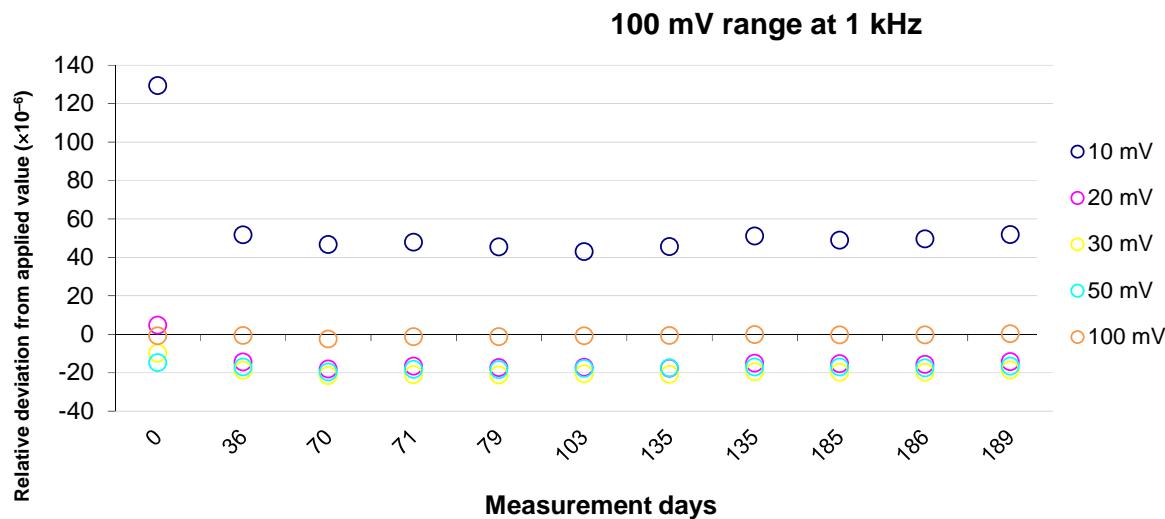


Fig. 7. Relative deviations from applied standard values in the 100 mV range at 1 kHz.

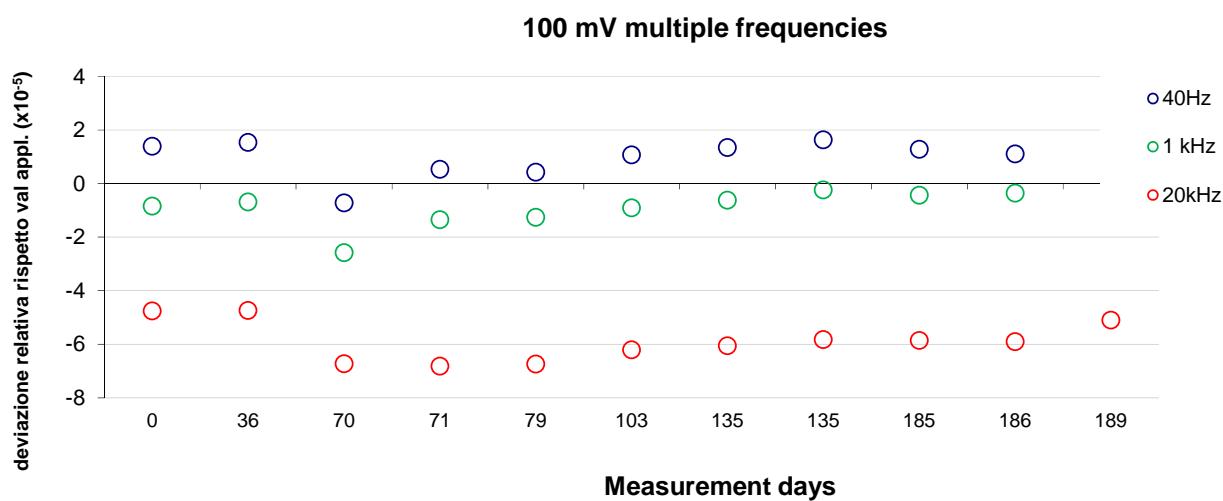


Fig. 8. Relative deviations from applied standard values at 100 mV at multiple frequencies.

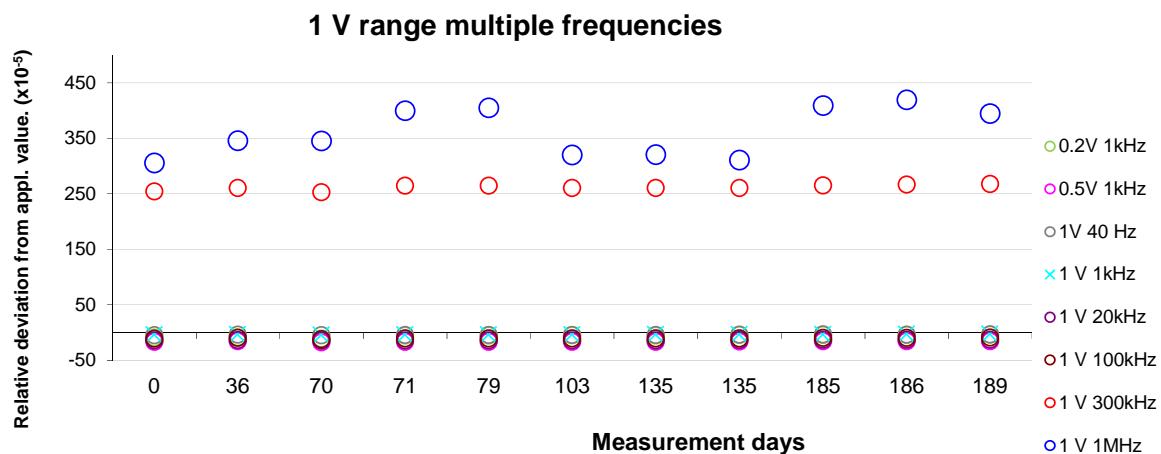


Fig. 9. Relative deviations from applied standard values in the 1 V range at multiple frequencies.

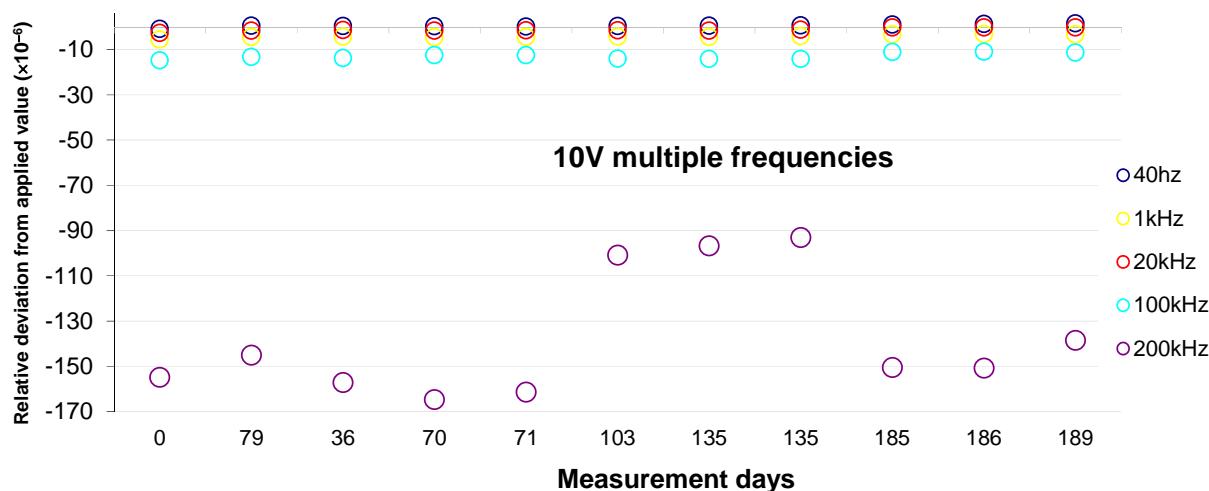


Fig. 10a). Relative deviations from applied standard values at 10 V at multiple frequencies.

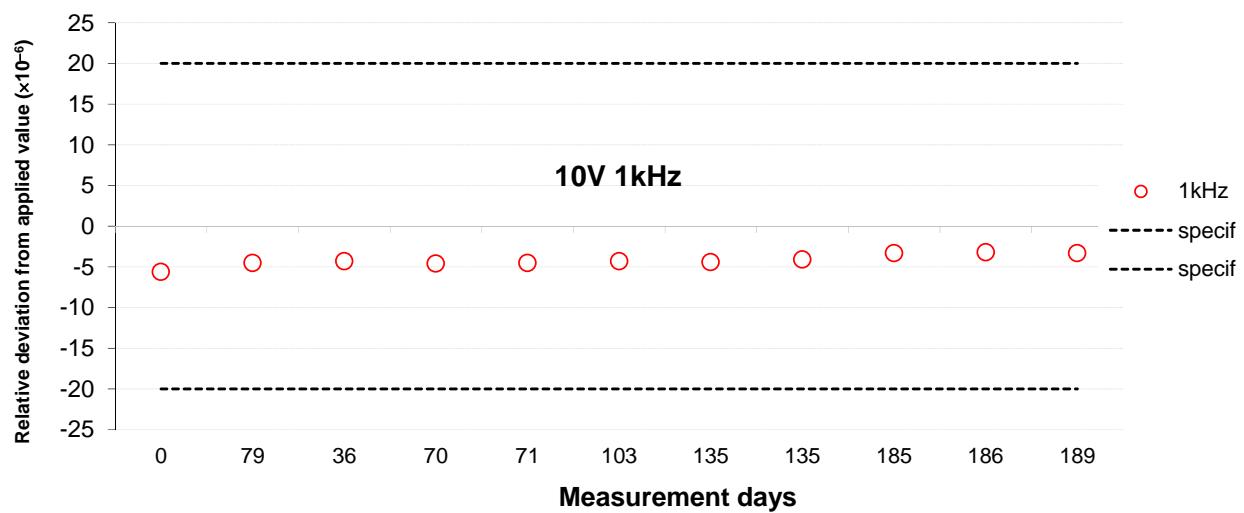


Fig. 10b). Relative deviations from applied standard values at 10 V 1 kHz
compared with the 180-days DMM specifications.

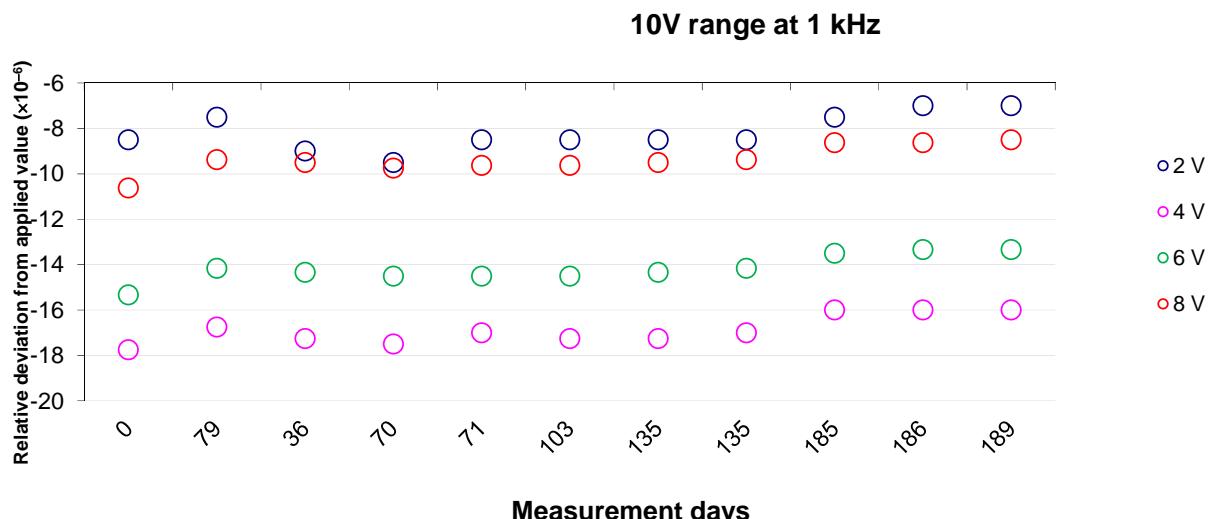


Fig. 11. Relative deviations from applied standard values in the 10 V range at 1 kHz.

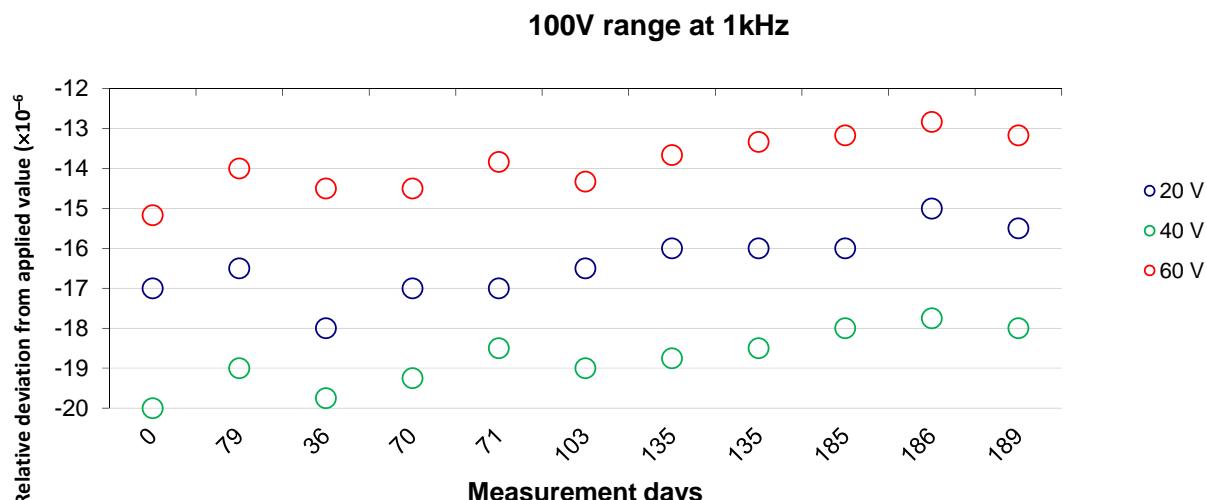


Fig. 12. Relative deviations from applied standard values
in the 100 V range at 1 kHz.

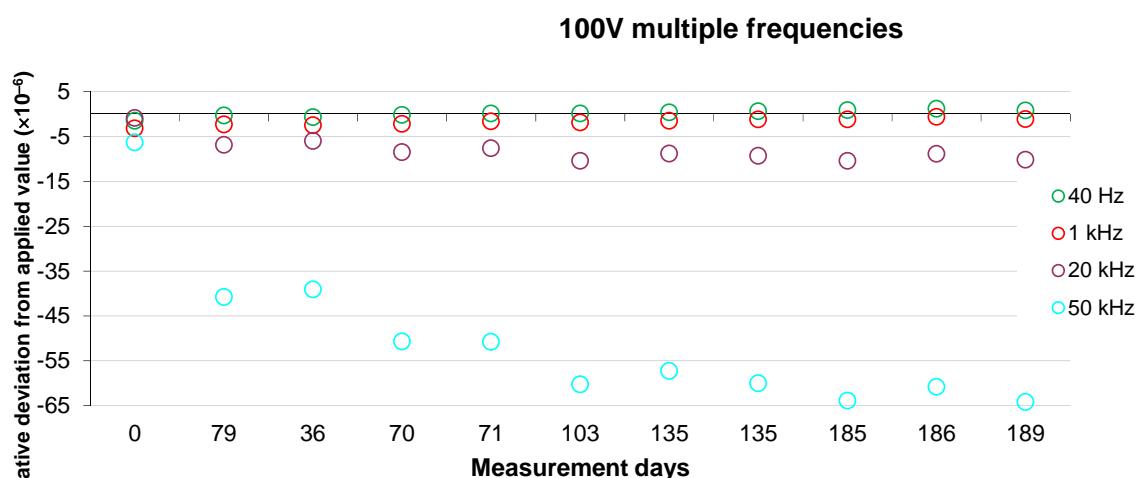


Fig. 13. Relative deviations from applied standard
values at 100 V at multiple frequencies.

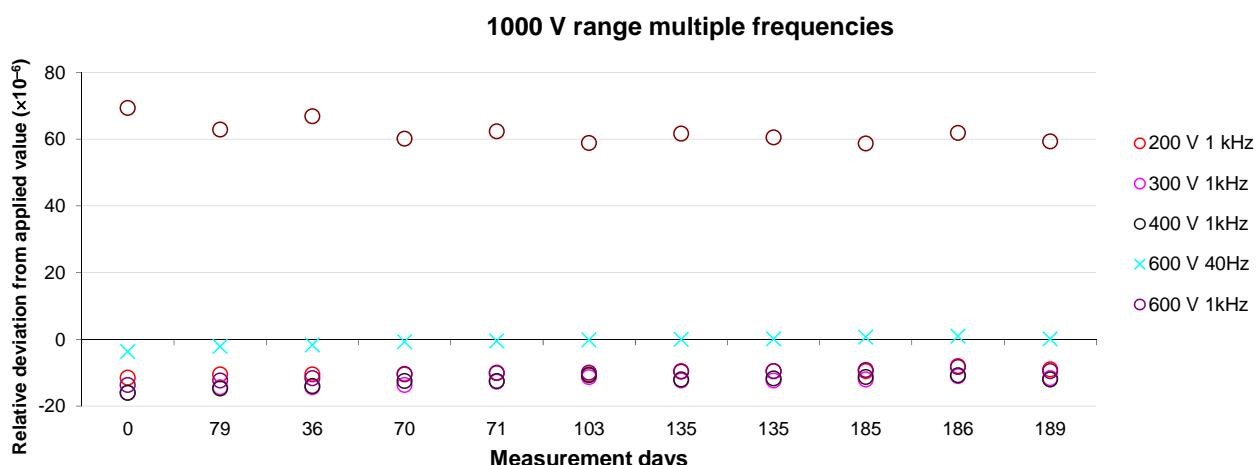


Fig. 14. Relative deviations from applied standard values
in the 1000 V range at multiple frequencies.

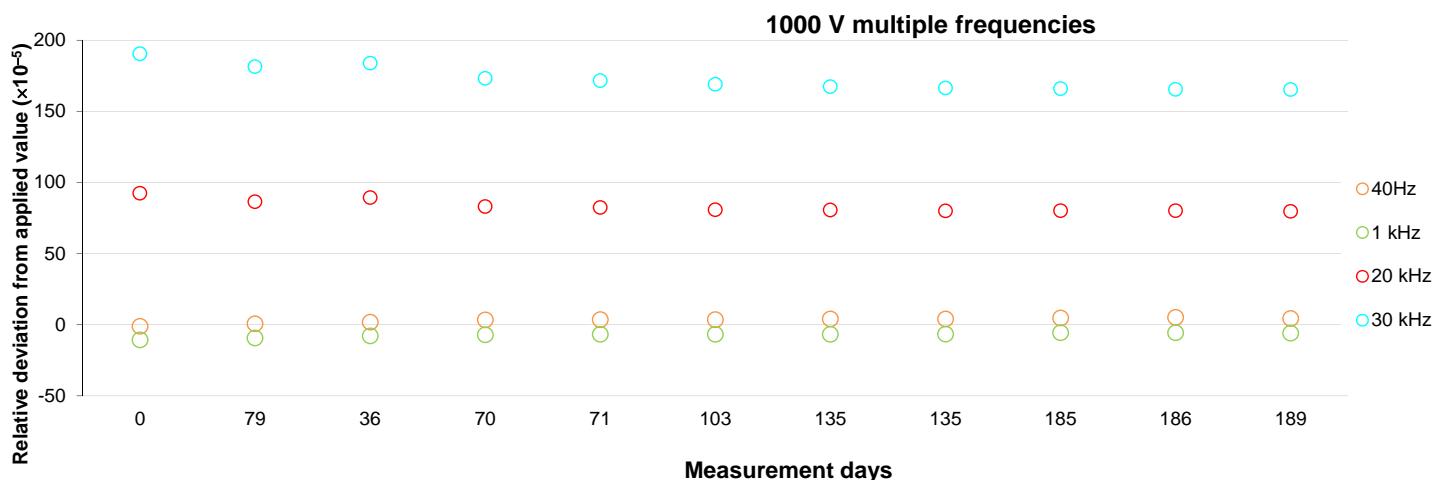


Fig. 15. Relative deviations from applied standard values at 1000 V at multiple frequencies.

3.3 Results for DC Current.

In Figures from 16 to 22 the verification results for DC Current are graphically summarized.

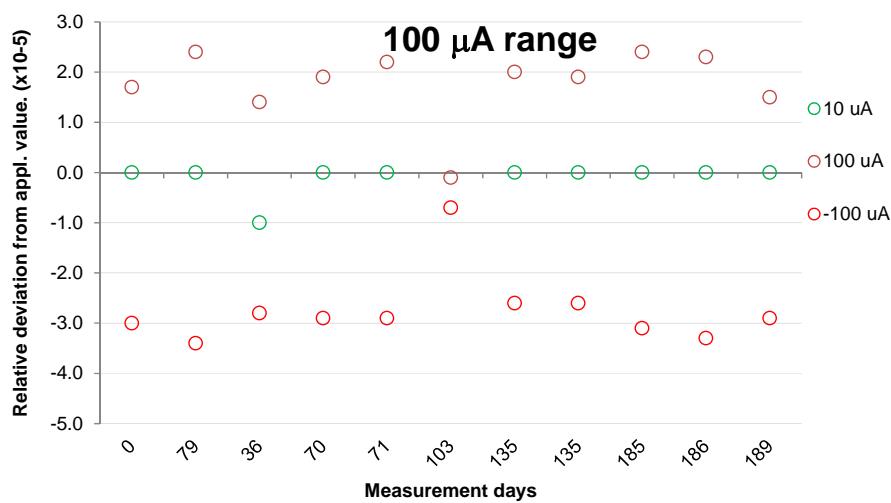


Fig. 16. Relative deviations from applied standard values in the 100 μ A range.

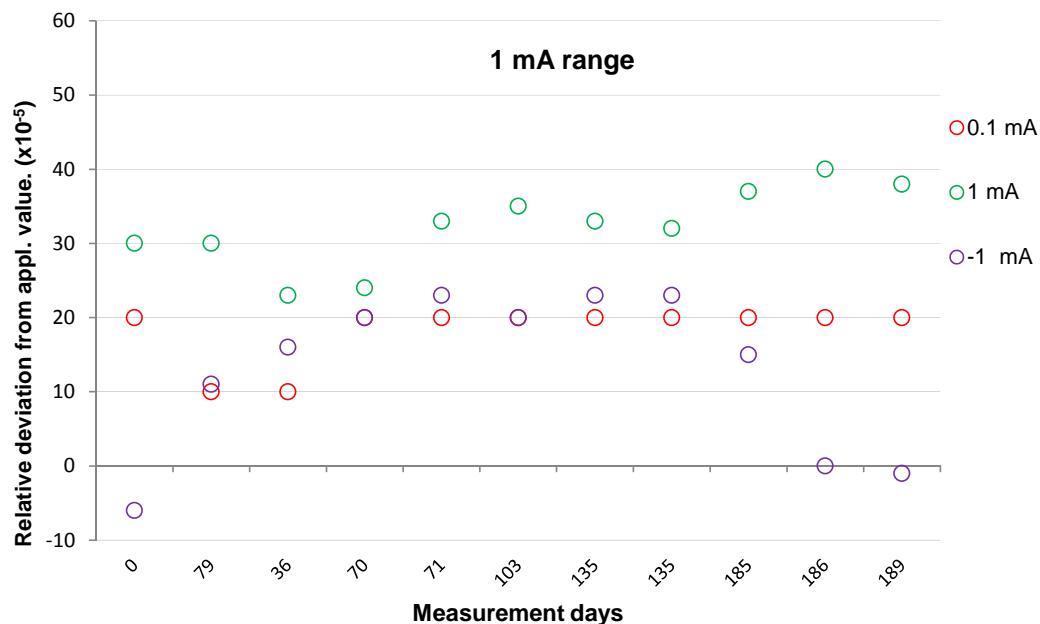


Fig. 17. deviations from applied standard values in the 1 mA range.

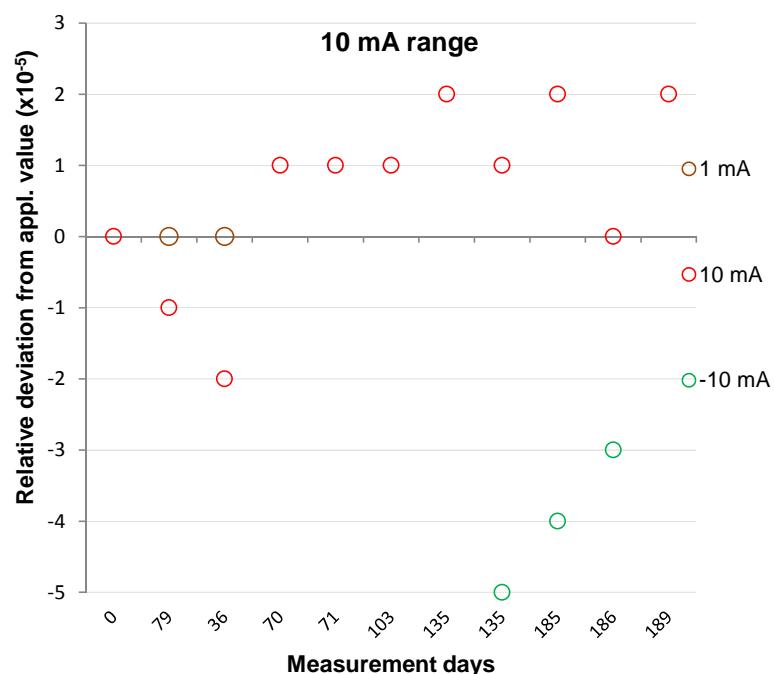


Fig. 18a). deviations from applied standard values in the 10 mA range.

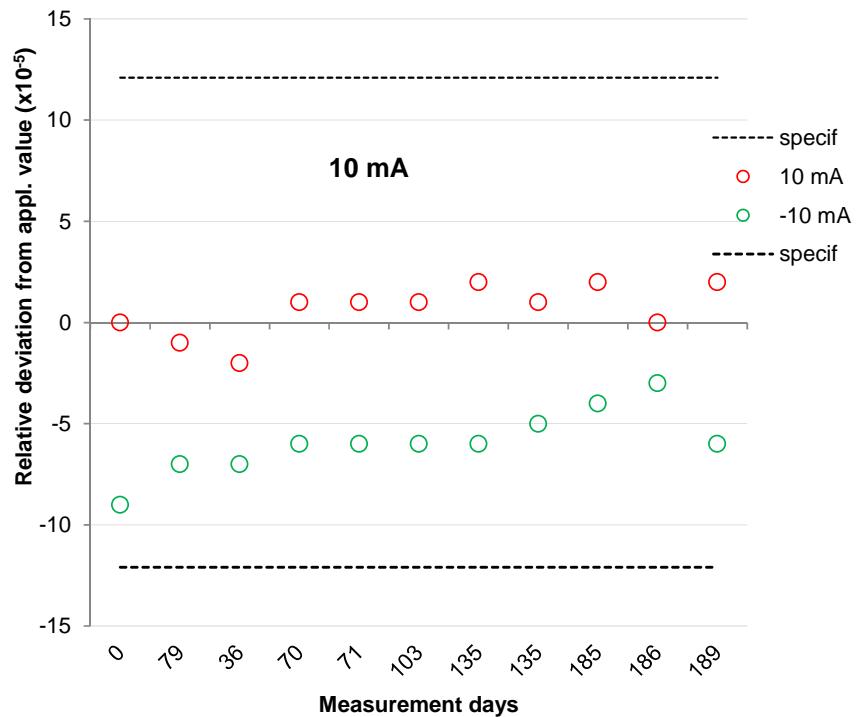


Fig. 18b). Relative deviations from applied standard values at 10 mA compared with the 180-days DMM specifications.

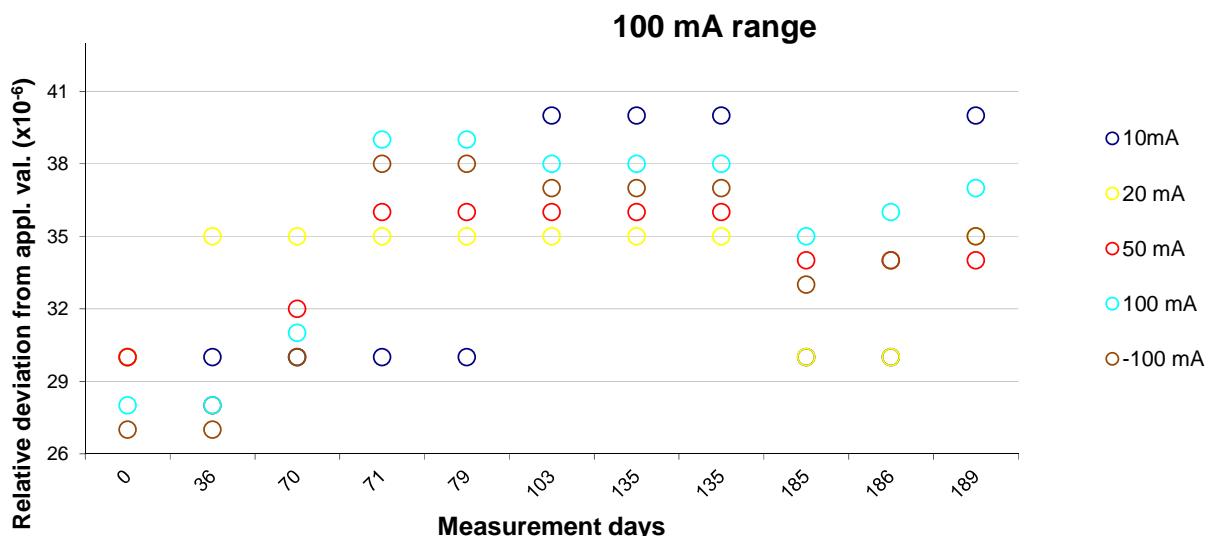


Fig. 19. Relative deviations from applied standard values in the 100 mA range.

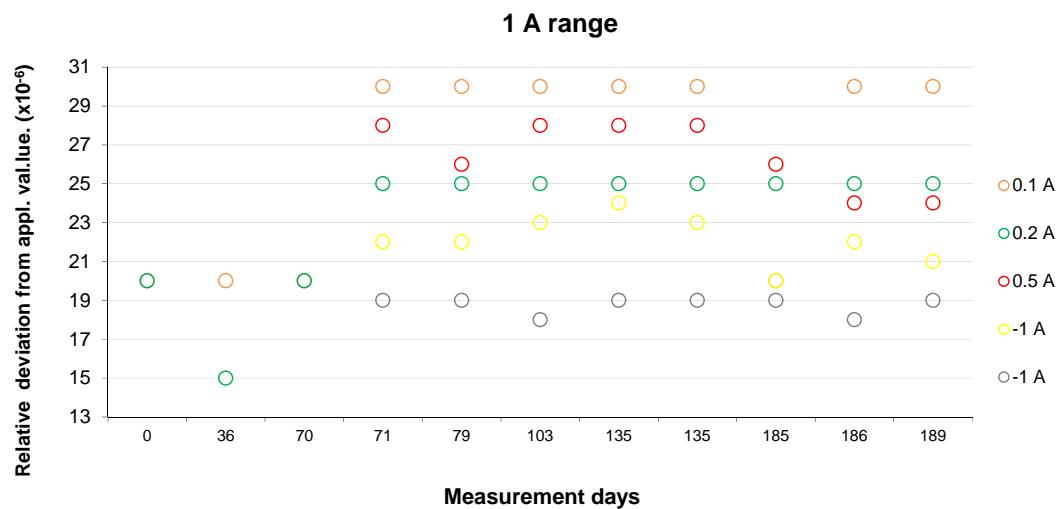


Fig. 20. Relative deviations from applied standard values in the 1 A range.



Fig. 21. Relative deviations from applied standard values in the 10 A range.

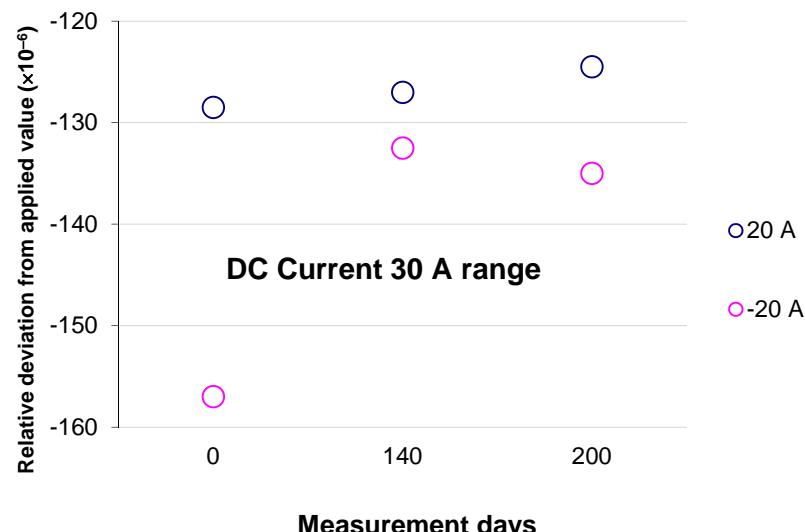


Fig. 22. Relative deviations from applied standard values in the 30 A range.

3.4 Results for AC Current.

In Figures from 23 to 30 the verification results for AC Current are graphically summarized.

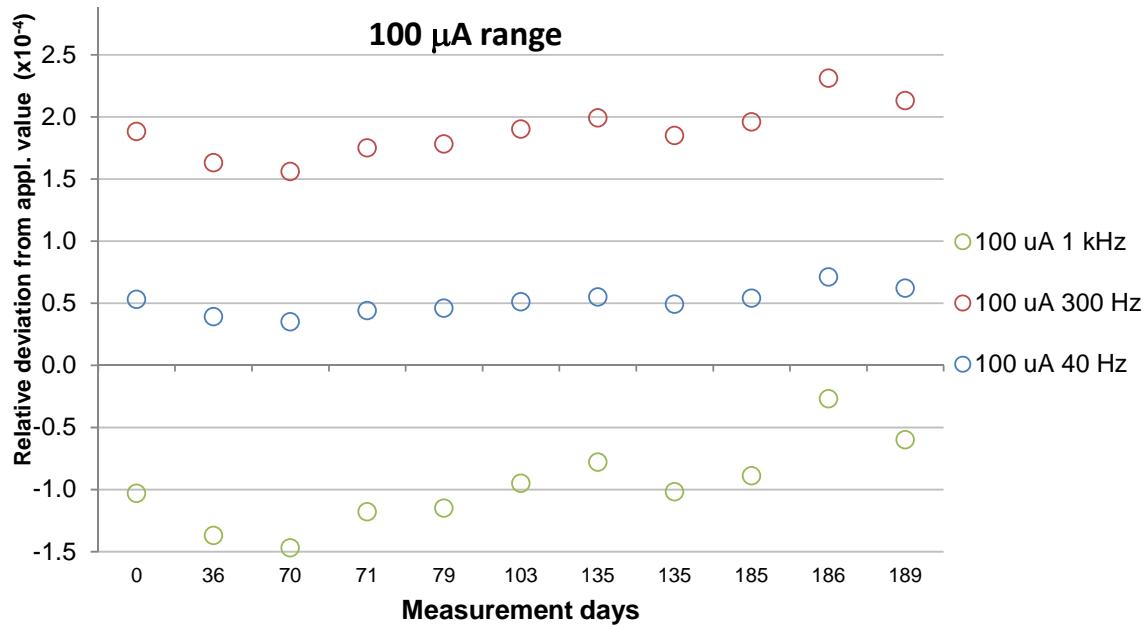


Fig. 23. Relative deviations from applied standard
Values in the 100 μ A range at multiple frequencies.

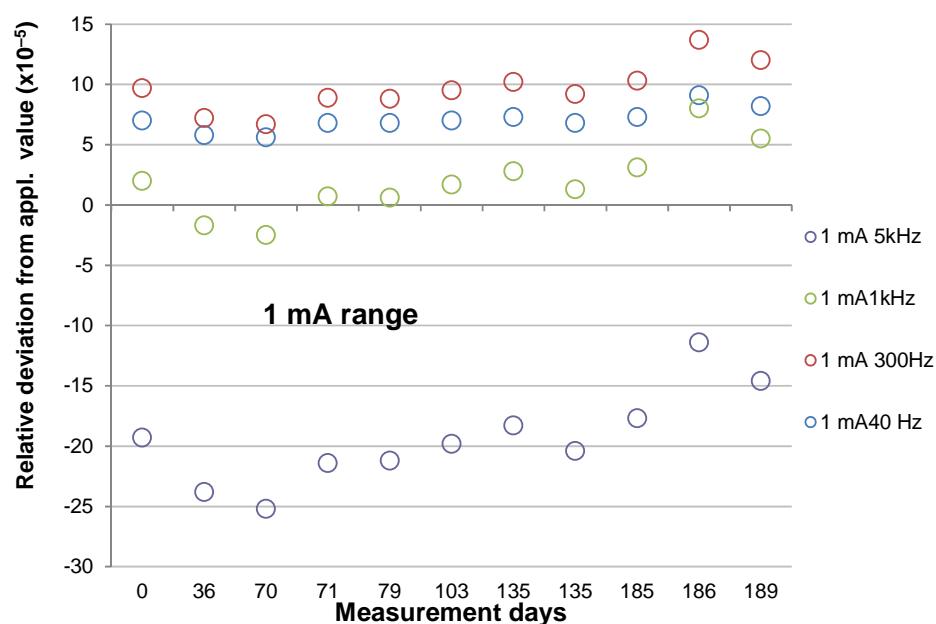


Fig. 24. Relative deviations from applied standard
values in the 1 mA range at multiple frequencies.

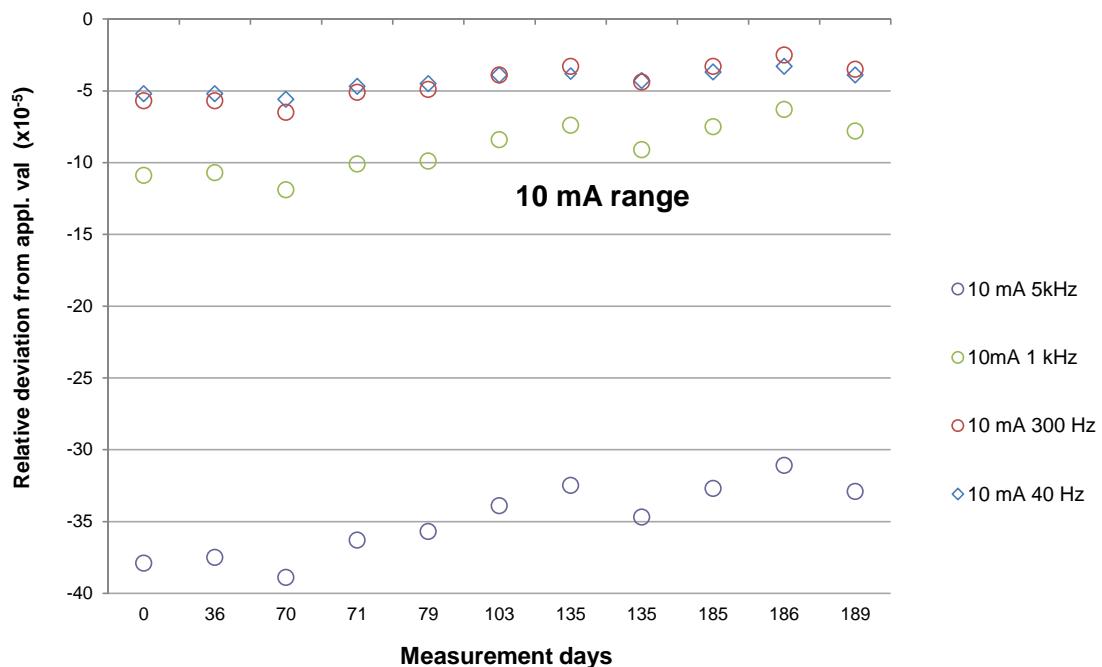


Fig. 25. Relative deviations from applied standard values in the 10 mA range at multiple frequencies.

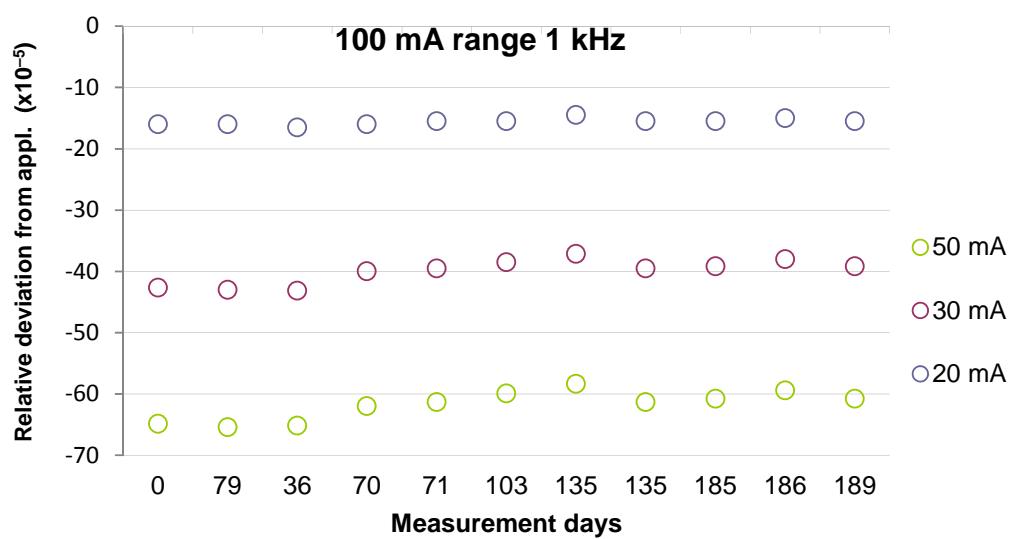


Fig. 26. Relative deviations from applied standard values in the 100 mA range at 1 kHz.

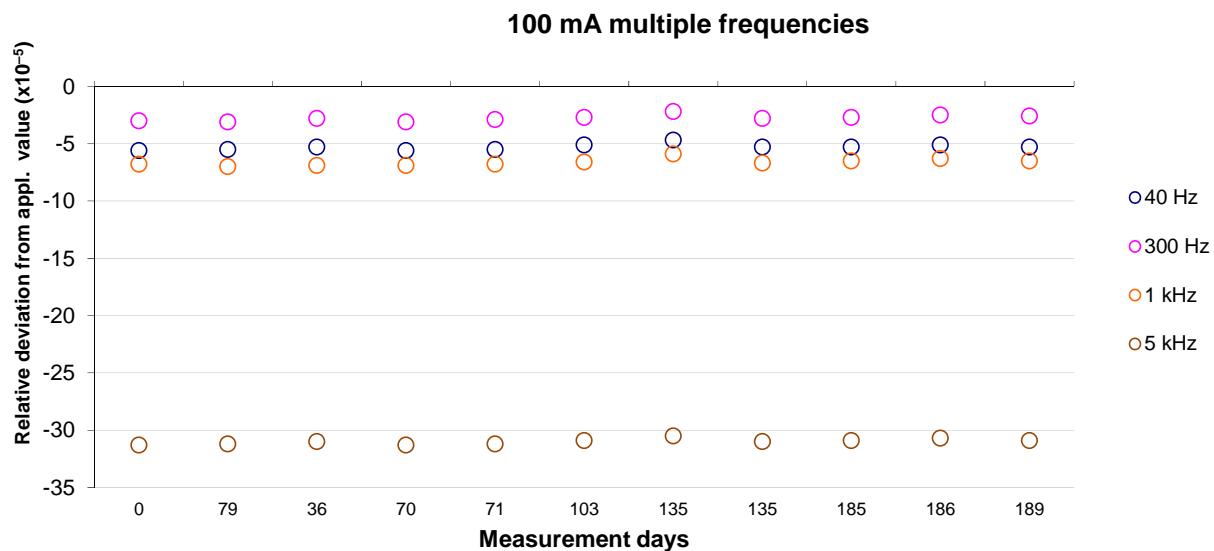


Fig. 27a). Relative deviations from applied standard values at 100 mA at multiple frequencies.

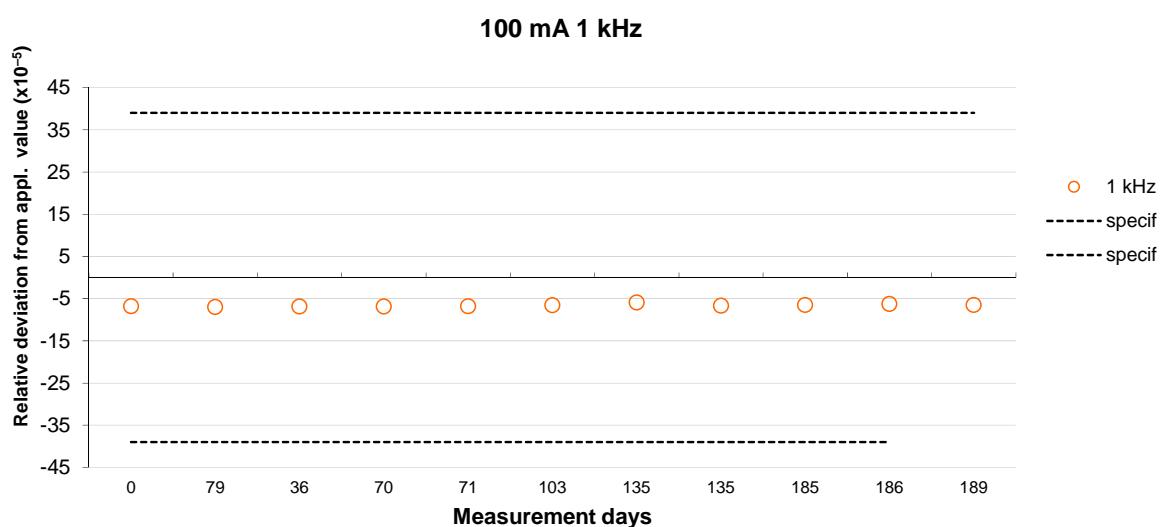


Fig. 27b). Relative deviations from applied standard values at 100 mA, 1 kHz compared with the 180-days DMM specifications.

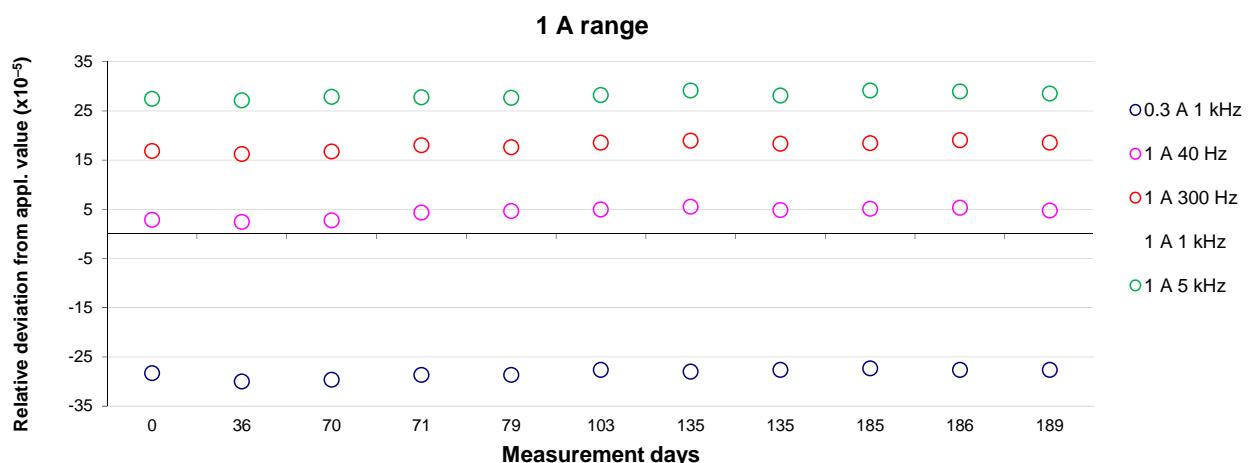


Fig. 28. Relative deviations from applied standard values in the 1 A range at multiple frequencies.

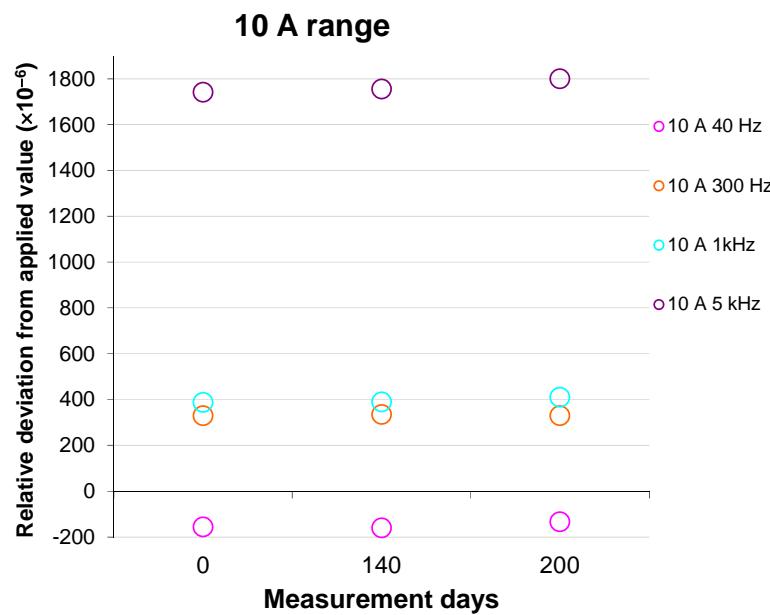


Fig. 29. Relative deviations from applied standard values in the 10 A range at multiple frequencies.

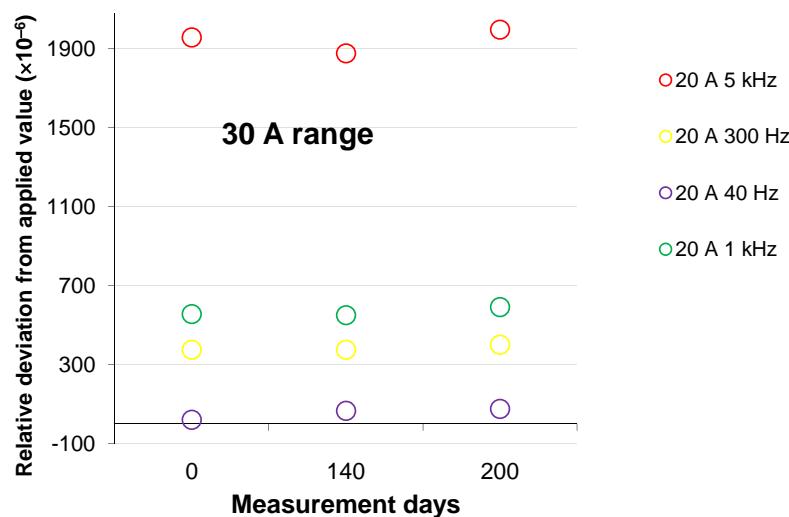


Fig. 30. Relative deviations from applied standard values in the 30 A range at multiple frequencies.

3.5 Results for DC Resistance.

Figures from 31 to 33 the verification results for DC Resistance are graphically summarized.

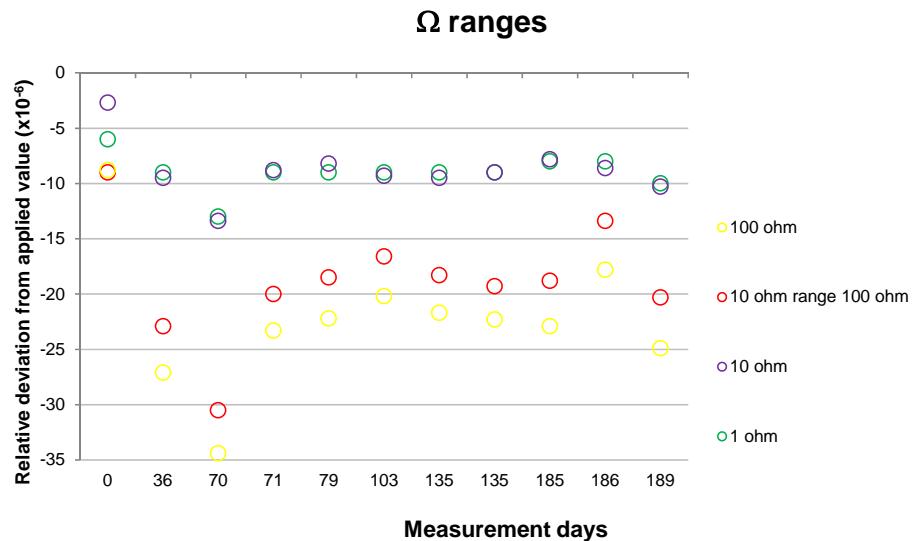


Fig. 31a). Relative deviations from applied standard values in the 1 Ω , 10 Ω and 100 Ω ranges.

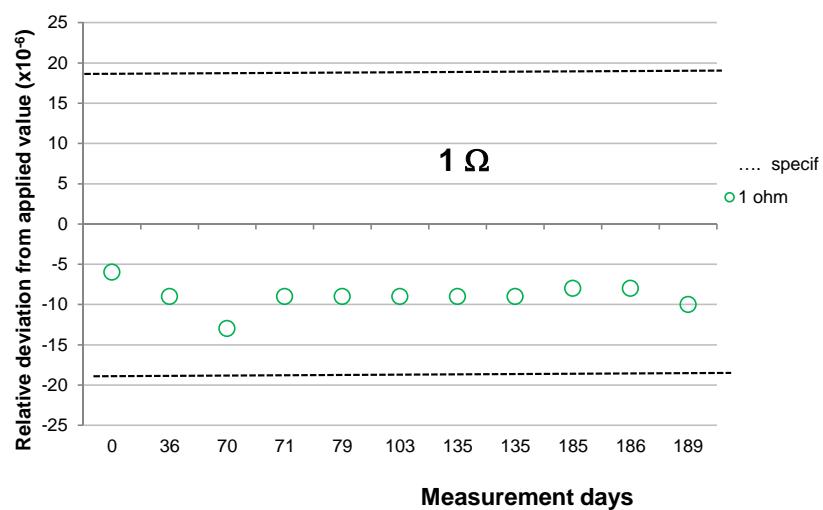


Fig. 31b). Relative deviations from applied standard values at 1 Ω compared with the 180-days DMM specifications.

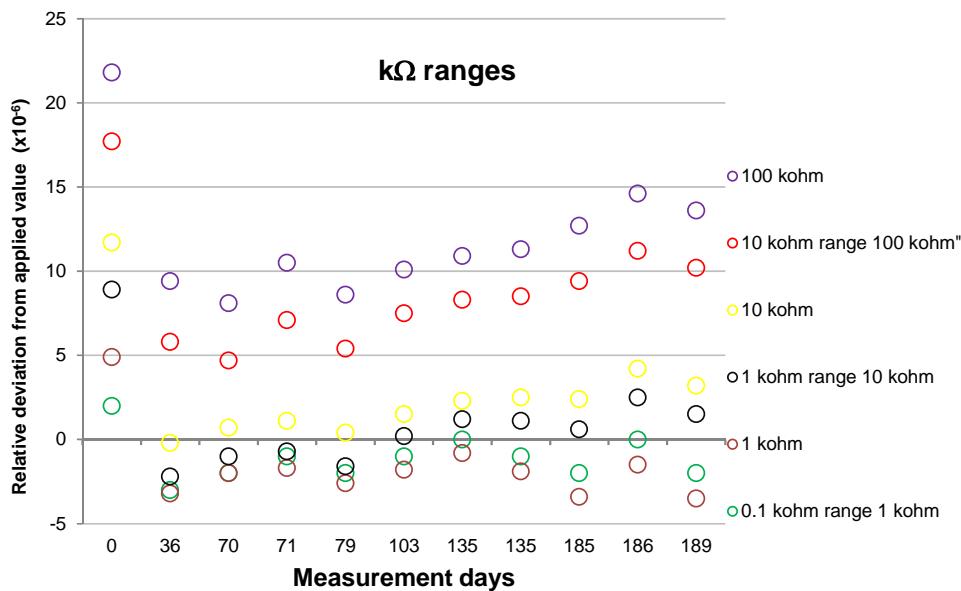


Fig. 32a). Relative deviations from applied standard values in the 1 kΩ, 10 kΩ and 100 kΩ ranges.

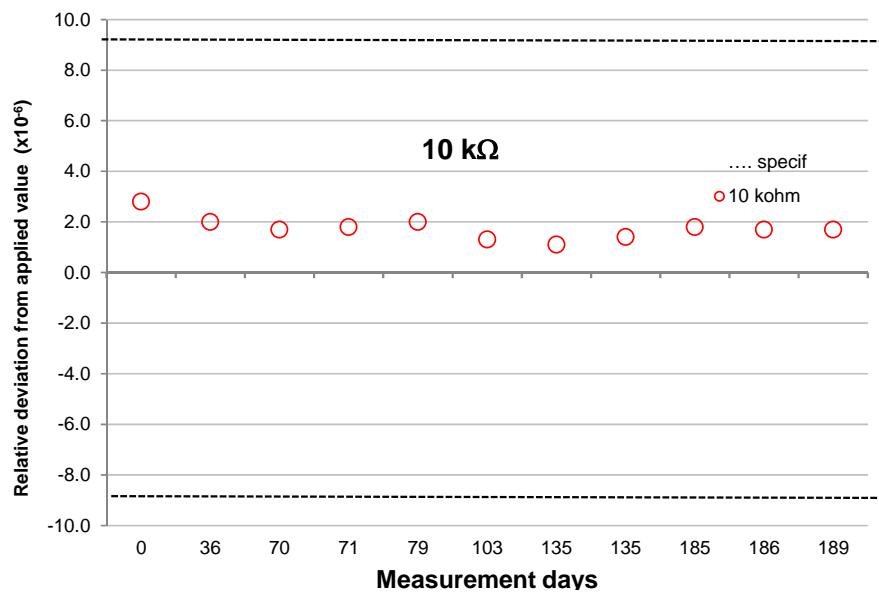


Fig. 32b). Relative deviations from applied standard values at 10 kΩ compared with the 180-days DMM specifications.

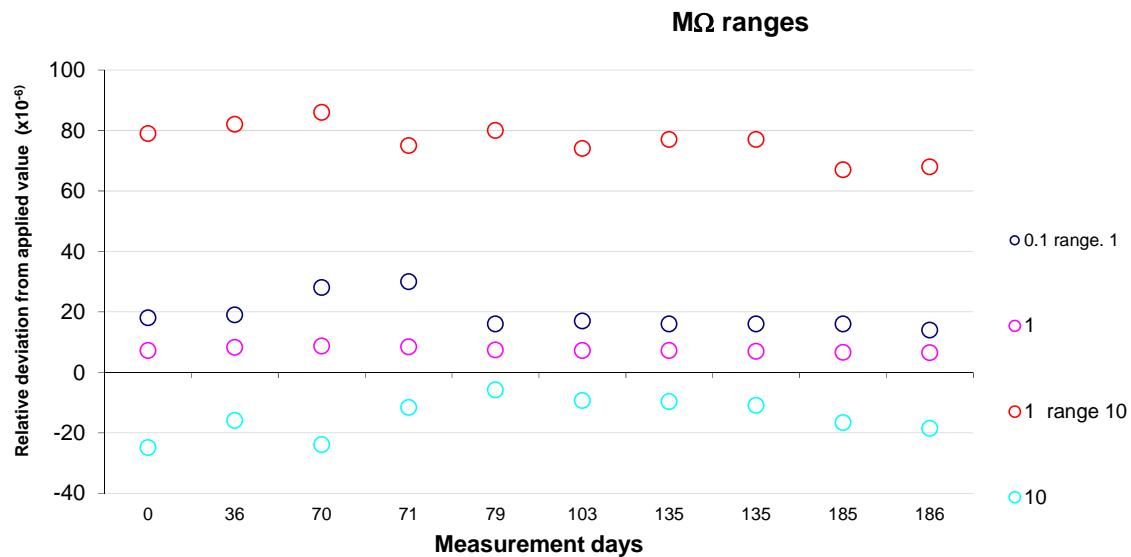


Fig. 33. Relative deviations from applied standard values in the 1 MΩ and 10 MΩ ranges.

4. DATA ANALYSIS

In Tables 1 to 5 the values obtained, expressed as relative deviations with respect to the applied standard values, are compared with the manufacturer specifications at 180 days. From column 1 to 8 are shown respectively: the range, the measurement value, the frequency (for alternating quantities), the 180 days manufacturer specification, the deviation between the first and the last verification $\Delta_{(fin-first)}$, the max deviation from the applied standard value in absolute value Δ_{max_abs} , the relative uncertainty of the applied reference values and a DMM performance index evaluated as follows:

$$pi = \frac{\Delta_{max_abs}}{\sqrt{U_{8081}^2 + U_{INRIM}^2}} \quad (1)$$

where U_{8081} is the 180-days accuracy specifications of the DMM while U_{INRIM} is the expanded calibration uncertainty of the INRIM-Lab measurements. The performance can be considered satisfactory if $|pi| \leq 1$.

4.1 DC Voltage.

Table 1. 8081 DMM performance in DC Voltage.

| <i>range</i> | <i>Value</i> (mV) | <i>freq.</i> | <i>180 days spec.</i> ($\times 10^{-6}$) | $\Delta_{fin-first}$ ($\times 10^{-6}$) | $\Delta_{max-abs}$ ($\times 10^{-6}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|---------------|----------------------|--------------|---|--|--|-------------------------------------|------------------|
| 100 mV | 1 | | 174 | -150 | 280 | 35 | 0.7 ¹ |
| | 10 | | 21 | 0.0 | 26 | 3.9 | 0.6 ¹ |
| | -10 | | 21 | -1.6 | 40 | 3.9 | 0.9 ¹ |
| | 50 | | 7.7 | 1.6 | 11.4 | 1.0 | 0.9 ¹ |
| | 100 | | 6.0 | -1.3 | 6.1 | 0.5 | 0.8 |
| | -100 | | 6.0 | 0.4 | 2.4 | 0.5 | 0.3 |
| | V | | | | | ($\times 10^{-6}$) | |
| 1 V | 0.2 | | 6.5 | -0.5 | 3.0 | 4.0 | 0.4 |
| | -0.2 | | 6.5 | 1.0 | 3.5 | 4.0 | 0.5 |
| | 0.5 | | 4.7 | -2.0 | 5 | 3.5 | 0.9 |
| | 1 | | 4.1 | -0.3 | 2.7 | 3.0 | 0.5 |
| | -1 | | 4.1 | 2.3 | 2.6 | 3.0 | 0.5 |
| 10 V | 2 | | 6.9 | 2.0 | 3.0 | 2.0 | 0.4 |
| | -2 | | 6.9 | 3.0 | 2.0 | 2.0 | 0.3 |
| | 3 | | 5.5 | 1.3 | 3.7 | 1.8 | 0.6 |
| | 4 | | 5.0 | 1.5 | 3.3 | 1.8 | 0.6 |
| | 6 | | 4.5 | 2.0 | 3.2 | 1.7 | 0.7 |
| | 8 | | 4.3 | 2.4 | 3.5 | 1.7 | 0.8 |
| | 10 | | 4.1 | 2.4 | 2.0 | 1.7 | 0.5 |
| | -10 | | 4.1 | 1.7 | 2.6 | 1.7 | 0.6 |

¹ For these values the *pi* cannot be considered completely significant as the DMM declared 180-days specification is smaller than the INRIM capability, that comprehends the uncertainties of National standards, those of the traceability transfer to the MFC J. Fluke 5700 A of the INRIM-Lab and its one year use uncertainty [5].

| <i>range</i> | <i>Value</i> (V) | <i>freq.</i> | <i>180 days spec.</i> ($\times 10^{-6}$) | $\Delta_{fin-first}$ ($\times 10^{-6}$) | $\Delta_{max-abs}$ ($\times 10^{-6}$) | U_{INRIM} ($\times 10^{-6}$) | <i>pi</i> |
|---------------|---------------------|--------------|---|--|--|-------------------------------------|-----------|
| 100 V | 20 | | 9.2 | 0.5 | 2.0 | 2.8 | 0.2 |
| | -20 | | 9.2 | -0.5 | 1.0 | 2.8 | 0.1 |
| | 50 | | 7.4 | -0.2 | 0.8 | 2.8 | 0.1 |
| | 100 | | 6.6 | 0.4 | 2.2 | 2.8 | 0.3 |
| | -100 | | 6.6 | 0.5 | 4.1 | 2.8 | 0.6 |
| 1000 V | 200 | | 11.2 | 1.5 | 1.5 | 3.5 | 0.1 |
| | -200 | | 11.2 | 1.0 | 3.0 | 3.5 | 0.3 |
| | 400 | | 8.2 | 0.5 | 1.0 | 3.5 | 0.1 |
| | 600 | | 7.2 | 0.7 | 1.0 | 3.5 | 0.1 |
| | 800 | | 6.7 | 0.8 | 0.9 | 3.5 | 0.1 |
| | 1000 | | 6.4 | 1.0 | 2.0 | 3.5 | 0.3 |
| | -1000 | | 6.4 | 0.5 | 4.3 | 3.5 | 0.6 |

4.2 AC Voltage.

Table 2: 8081 DMM performance in AC Voltage.

| <i>range</i> | <i>Value</i> (mV) | <i>freq.</i> (kHz) | <i>180 days</i> <i>spec.</i> ($\times 10^{-5}$) | $\Delta_{fin-first}$ ($\times 10^{-5}$) | $\Delta_{max-abs}$ ($\times 10^{-5}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|---------------|----------------------|-----------------------|---|--|--|-------------------------------------|-----------|
| 100 mV | 10 | 1 | 95 | -77.6 | 129.4 | 20 | 0.6 |
| | 20 | 1 | 55 | -19.0 | 18.2 | 10 | 0.2 |
| | 30 | 1 | 42 | -8.6 | 21.5 | 10 | 0.2 |
| | 50 | 1 | 31 | -1.9 | 19.6 | 10 | 0.2 |
| | 100 | 0.04 | 28 | 0.7 | 2.1 | 7 | 0.0 |
| | 100 | 1 | 23 | 1.1 | 2.6 | 7 | 0.0 |
| | 100 | 20 | 33 | -0.3 | 6.8 | 7 | 0.1 |

| <i>range</i> | <i>Value</i> (V) | <i>freq.</i> (kHz) | <i>180 days</i> <i>spec.</i> ($\times 10^{-5}$) | $\Delta_{fin-first}$ ($\times 10^{-5}$) | $\Delta_{max-abs}$ ($\times 10^{-5}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|--------------|---------------------|-----------------------|---|--|--|-------------------------------------|-----------|
| 1 V | 0.2 | 1 | 44 | 5.5 | 11.5 | 6 | 0.2 |
| | 0.5 | 1 | 26 | 1.4 | 18.2 | 5 | 0.3 |
| | 1 | 0.04 | 23 | 1.4 | 5.3 | 4 | 0.1 |
| | 1 | 1 | 20 | 1.2 | 4.7 | 4 | 0.1 |
| | 1 | 20 | 33 | 1.3 | 15.2 | 5 | 0.3 |
| | 1 | 100 | 104 | 1.9 | 12.3 | 8 | 0.1 |
| | 1 | 300 | 3400 | 13.5 | 267.5 | 38 | 0.1 |
| | 1 | 1000 | 3400 | 89.2 | 419.3 | 100 | 0.1 |
| 10 V | 2 | 1 | 44 | 1.5 | 9.5 | 4 | 0.2 |
| | 4 | 1 | 29 | 1.8 | 17.8 | 4 | 0.4 |
| | 6 | 1 | 24 | 2.0 | 15.3 | 4 | 0.3 |
| | 8 | 1 | 22 | 2.1 | 10.6 | 4 | 0.2 |
| | 10 | 0.04 | 23 | 2.5 | 1.6 | 4 | 0.1 |
| | 10 | 1 | 20 | 2.3 | 5.6 | 4 | 0.1 |
| | 10 | 20 | 33 | 2.4 | 2.6 | 6 | 0.1 |
| | 10 | 100 | 104 | 3.4 | 14.8 | 9 | 0.1 |
| | 10 | 200 | 3400 | 16.4 | 164.7 | 40 | 0.0 |
| 100 V | 20 | 1 | 51 | 1.5 | 18.0 | 4 | 0.3 |
| | 40 | 1 | 34 | 2.0 | 20.0 | 4 | 0.4 |
| | 60 | 1 | 28 | 2.0 | 15.2 | 4 | 0.3 |
| | 100 | 0.04 | 27 | 2.3 | 1.5 | 5 | 0.0 |
| | 100 | 1 | 23 | 2.1 | 3.2 | 5 | 0.1 |
| | 100 | 20 | 37 | -9.3 | 10.4 | 5 | 0.2 |
| | 100 | 50 | 122 | -57.9 | 64.2 | 10 | 0.4 |

| <i>range</i> | <i>Value</i> (V) | <i>freq.</i> (kHz) | <i>180 days</i> <i>spec.</i> ($\times 10^{-5}$) | $\Delta_{fin-first}$ ($\times 10^{-5}$) | $\Delta_{max-abs}$ ($\times 10^{-5}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|---------------|---------------------|-----------------------|---|--|--|-------------------------------------|-----------|
| 1000 V | 200 | 1 | 51 | 2.5 | 11.5 | 5 | 0.2 |
| | 300 | 1 | 39 | 4.3 | 16.0 | 5 | 0.3 |
| | 400 | 1 | 34 | 4.0 | 16.0 | 5 | 0.3 |
| | 600 | 0.04 | 33 | 3.8 | 3.7 | 6 | 0.1 |
| | 600 | 1 | 28 | 4.2 | 13.7 | 6 | 0.2 |
| | 600 | 20 | 44 | -10.0 | 69.3 | 12 | 0.5 |
| | 600 | 100 | 80 | 0.0 | 0.0 | 55 | 0.0 |
| | 1000 | 0.04 | 27 | 5.5 | 5.1 | 6 | 0.1 |
| | 1000 | 1 | 23 | 4.7 | 10.7 | 6 | 0.2 |
| | 1000 | 20 | 37 | -12.8 | 92.4 | 13 | 0.7 |
| | 1000 | 30 | 77 | -25.2 | 190.4 | 26 | 0.7 |

4.3 DC Current.

Table 3: 8081 DMM performance in DC Current.

| <i>range</i> | <i>Value</i> (μA) | <i>freq.</i> (kHz) | <i>180 days spec.</i> ($\times 10^{-5}$) | $\Delta_{fin-first}$ ($\times 10^{-5}$) | $\Delta_{max-abs}$ ($\times 10^{-5}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|-------------------------------------|-----------------------------------|-----------------------|---|--|--|-------------------------------------|------------------|
| 100 μA | 10 | | 46 | 0.0 | 18.0 | 9.8 | 0.4 |
| | 100 | | 10 | -0.2 | 2.4 | 2.3 | 0.2 |
| | -100 | | 10 | 0.1 | 3.4 | 2.3 | 0.3 |
| | mA | | ($\times 10^{-6}$) | ($\times 10^{-6}$) | ($\times 10^{-6}$) | ($\times 10^{-6}$) | |
| 1 mA | 0.1 | | 46 | 0.0 | 20.0 | 23 | 0.4 |
| | 1 | | 10 | 8.0 | 40.0 | 15 | 0.4 ² |
| | -1 | | 10 | 5.0 | 23.0 | 15 | 0.3 ² |
| 10 mA | 1 | | 48 | 0.0 | 10.0 | 15 | 0.2 |
| | 10 | | 12.1 | 2.0 | 2.0 | 13 | 0.1 |
| | -10 | | 12.1 | 3.0 | 9.0 | 13 | 0.5 |
| | 100 | | | | | | |
| 100 mA | 10 | | 84 | 10.0 | 40.0 | 15 | 0.5 |
| | 20 | | 54 | 5.0 | 35.0 | 15 | 0.6 |
| | 50 | | 36 | 4.0 | 36.0 | 15 | 0.9 |
| | 100 | | 30 | 9.0 | 39.0 | 15 | 0.3 ³ |
| | -100 | | 30 | 8.0 | 38.0 | 15 | 0.3 ³ |
| 1 A | 0.1 | | 265 | 10.0 | 30.0 | 20 | 0.1 |
| | 0.2 | | 200 | 5.0 | 25.0 | 20 | 0.1 |
| | 0.5 | | 161 | 24.0 | 28.0 | 20 | 0.2 |
| | 1.0 | | 148 | 21.0 | 24.0 | 20 | 0.2 |
| | -1.0 | | 148 | 19.0 | 19.0 | 20 | 0.1 |
| 10 A | 10 | | 355 | -11.0 | 14.0 | 100 | 0.0 |
| | -10 | | 355 | 7.0 | 44.7 | 100 | 0.1 |

² These performance values were evaluated taking into account $\Delta_{fin-first}$ instead of $\Delta_{max-abs}$ as the declared accuracy in these points is presumably too small.

³ These performance values were evaluated taking into account $\Delta_{fin-first}$ instead of $\Delta_{max-abs}$ as presumably a systematic error in the DMM adjustment process happened.

| <i>range</i> | <i>Value</i> (A) | <i>freq.</i> (kHz) | <i>180 days spec.</i> ($\times 10^{-6}$) | $\Delta_{fin-first}$ ($\times 10^{-6}$) | $\Delta_{max-abs}$ ($\times 10^{-6}$) | U_{INRIM} ($\times 10^{-6}$) | <i>pi</i> |
|--------------|---------------------|-----------------------|---|--|--|-------------------------------------|-----------|
| 30 A | 20 | | 658 | -4.0 | 128.5 | 100 | 0.2 |
| | -20 | | 658 | -22.0 | 157.0 | 100 | 0.2 |

4.4 AC Current.

Table 4: 8081 DMM performance in AC Current.

| <i>range</i> | <i>Value</i> (μ A) | <i>freq.</i> (kHz) | <i>180 days</i> <i>spec.</i> ($\times 10^{-4}$) | $\Delta_{fin-first}$ ($\times 10^{-4}$) | $\Delta_{max-abs}$ ($\times 10^{-4}$) | U_{INRIM} ($\times 10^{-4}$) | <i>pi</i> |
|------------------------------|----------------------------|-----------------------|---|--|--|-------------------------------------|-----------|
| 100 μA | 100 | 0.04 | 3.9 | 0.2 | 0.7 | 1.5 | 0.2 |
| | 100 | 0.3 | 3.9 | 0.3 | 1.6 | 1.5 | 0.4 |
| | 100 | 1 | 3.9 | 0.3 | 3.0 | 1.5 | 0.7 |
| | mA | | ($\times 10^{-5}$) | ($\times 10^{-5}$) | ($\times 10^{-5}$) | ($\times 10^{-5}$) | |
| 1 mA | 1 | 0.04 | 39 | -4.8 | 9.1 | 12 | 0.2 |
| | 1 | 0.3 | 39 | -0.4 | 4.6 | 12 | 0.1 |
| | 1 | 1 | 39 | 9.9 | 9.2 | 12 | 0.2 |
| | 1 | 5 | 93 | 23.0 | 22.7 | 20 | 0.2 |
| 10 mA | 10 | 0.04 | 28 | 5.9 | 5.6 | 8 | 0.2 |
| | 10 | 0.3 | 28 | 1.0 | 0.9 | 8 | 0.0 |
| | 10 | 1 | 28 | 5.5 | 5.4 | 8 | 0.2 |
| | 10 | 5 | 30 | 27.6 | 27.0 | 15 | 0.8 |
| 100 mA | 20 | 1 | 87 | 16.5 | 16.5 | 8 | 0.2 |
| | 30 | 1 | 67 | 28.6 | 27.0 | 8 | 0.4 |
| | 50 | 1 | 51 | 22.8 | 22.4 | 8 | 0.4 |
| | 100 | 0.04 | 39 | 5.8 | 5.6 | 8 | 0.1 |
| | 100 | 0.3 | 39 | 3.4 | 3.1 | 8 | 0.1 |
| | 100 | 1 | 39 | 7.3 | 7.0 | 8 | 0.2 |
| | 100 | 5 | 93 | 31.5 | 31.3 | 15 | 0.3 |

| <i>range</i> | <i>Value</i> (A) | <i>freq.</i> (kHz) | <i>180 days</i> <i>spec.</i> ($\times 10^{-5}$) | $\Delta_{fin-first}$ ($\times 10^{-5}$) | $\Delta_{max-abs}$ ($\times 10^{-5}$) | U_{INRIM} ($\times 10^{-5}$) | <i>pi</i> |
|--------------|---------------------|-----------------------|---|--|--|-------------------------------------|------------------|
| 1 A | (A) 0.3 | 1 | 86 | 30.9 | 30.0 | 10 | 0.3 |
| | 1 | 0.04 | 51 | -1.3 | 5.5 | 10 | 0.1 |
| | 1 | 0.3 | 51 | -15.3 | 19.0 | 10 | 0.4 |
| | 1 | 1 | 51 | 5.1 | 5.2 | 10 | 0.1 |
| | 1 | 5 | 113 | -26.4 | 29.1 | 20 | 0.3 |
| 10 A | (A) 10 | 0.04 | ($\times 10^{-6}$) 1120 | ($\times 10^{-6}$) -22 | ($\times 10^{-6}$) 160 | ($\times 10^{-6}$) 300 | 0.1 |
| | 10 | 0.3 | 930 | 0 | 335 | 300 | 0.3 |
| | 10 | 1 | 930 | -23 | 410 | 300 | 0.4 |
| | 10 | 5 | 930 | -58 | 1800 | 500 | 1.7 ⁴ |
| | (A) 20 | 0.04 | ($\times 10^{-6}$) 1320 | ($\times 10^{-6}$) -55 | ($\times 10^{-6}$) 75 | ($\times 10^{-6}$) 300 | 0.1 |
| 30 A | 20 | 0.3 | 780 | -25 | 400 | 300 | 0.5 |
| | 20 | 1 | 780 | -35 | 590 | 300 | 0.7 |
| | 20 | 5 | 780 | -40 | 1995 | 500 | 2.2 ⁴ |
| | | | | | | | |

⁴ These measurement points were evaluated although outside the 8081 DMM specifications and considering the same specification value at 1 kHz.

4.5 DC Resistance.

Table 5: 8081 DMM performance in DC Resistance.

| <i>Range</i> (Ω) | <i>Value</i> (Ω) | <i>freq.</i> | <i>180 days spec.</i> ($\times 10^{-6}$) | $\Delta_{fin-first}$ ($\times 10^{-6}$) | $\Delta_{max-abs}$ ($\times 10^{-6}$) | U_{INRIM} ($\times 10^{-6}$) | <i>pi</i> |
|------------------------------|------------------------------|--------------|---|--|--|-------------------------------------|-----------|
| 1 | 1 | | 19 | -4.0 | 13.0 | 10 | 0.6 |
| 10 | 10 | | 12 | -3.6 | 3.3 | 5 | 0.3 |
| 100 | 10 | | 18 | -3.7 | 17.1 | 5 | 0.9 |
| | 100 | | 9 | -4.8 | 4.6 | 5 | 0.4 |
| (k Ω) | (k Ω) | | | | | | |
| 1 | 0.1 | | 15 | -4.0 | 3.0 | 5 | 0.2 |
| | 1 | | 7.8 | -4.4 | 2.9 | 5 | 0.3 |
| 10 | 1 | | 16.5 | 1.0 | 5.0 | 5 | 0.3 |
| | 10 | | 9.3 | -1.1 | 2.8 | 5 | 0.3 |
| 100 | 10 | | 17 | 1.0 | 7.0 | 5 | 0.4 |
| | 100 | | 9.8 | -0.7 | 4.1 | 5 | 0.4 |
| (M Ω) | (M Ω) | | | | | | |
| 1 | 0.1 | | 30 | -14.6 | 30 | 5 | 1.0 |
| | 1 | | 12 | -2.8 | 8.7 | 8 | 0.6 |
| 10 | 1 | | 94 | -73.6 | 86 | 8 | 0.9 |
| | 10 | | 22 | 31.3 | 24.9 | 16 | 0.9 |

CONCLUSIONS

In this report the TRANSMILLE mod. 8081 high precision DMM was evaluated by the INRIM-Lab for multifunction programmable instruments calibration in a six-months period. The DMM showed a satisfactory stability and a good agreement with the declared accuracy specifications that are at the level and somewhere even better than other top-class 8.5 digits DMMs. 8081 high Currents (up to 30 A range), low Currents (down to 10 nA range) DC Resistance up to 2 TΩ functions are very useful and not available in other DMMs. Only the 10mA and 100 mA DC current ranges have to be further verified either as declared accuracy and in the adjustment process. In the 10 A and 30 A ranges in AC Current, the DMM was evaluated also at 5 kHz showing a satisfactory stability. Hence, an evaluation of the specification values for these points could be made by TRANSMILLE and successively added to the current 8081 DMM specifications.

REFERENCES

- [1] G. C. Bosco, G. La Paglia, U. Pogliano, G. Zago, "A system for traceability maintenance and verification based on high stability multimeters," Proc XIII IMEKO World Congress, Torino, 1994, pp. 517–522.
- [2] U. Pogliano, G. C. Bosco, R. Cerri, G. La Paglia, "An alternative approach to ensure traceability utilizing high stability multimeters," Proc. Métrologie 97, Nimes, France, 1995, pp 346–351.
- [3] G. C. Bosco, R. Cerri, C. Cassiago, G. La Paglia, and U. Pogliano, "Investigation on the use of multifunction programmable instruments," in Proc. X IMEKO TC4 Symp., 1998, pp. 489–492.
- [4] C. Cassiago, G. La Paglia, U. Pogliano, "Stability Evaluation of High-Precision Multifunction Instruments for Traceability Transfer". IEEE Trans. Meas., Vol. 49 no. 6, pp. 1206–1210, December 2000.
- [5] W. Bich, F. Pennecchi, On the in-use uncertainty of an instrument, in: P. Ciarlini, M. G. Cox, E. Filipe, F. Pavese, D. Richter (Eds), Advanced Mathematical & Computational Tools in Metrology, World Scientific, Singapore, 2004, pp. 59–169.

Annex 1: Specifications of the TRANSMILLE mod. 8081 DMM.

DC Voltage

Instrument Uncertainty Relative to Calibration Standards

| Range | Full Scale | Resolution | Input Impedance | 90 Day | | 180 Day | | 1 Year | | 2 Year | |
|-------|--------------|------------|-----------------|-----------------------------|-------|---------|-------|--------|-------|--------|-------|
| | | | | ± (ppm Reading + ppm Range) | | | | | | | |
| 100mV | 120,000,000 | 1nV | > 10 GOhms | 3.8 | + 1.7 | 4.3 | + 1.7 | 4.8 | + 1.7 | 7.0 | + 1.7 |
| 1V | 1.200,000,00 | 10nV | > 10 GOhms | 3.0 | + 0.6 | 3.5 | + 0.6 | 3.9 | + 0.6 | 5.5 | + 0.6 |
| 10V | 12.000,000,0 | 100nV | > 10 GOhms | 3.0 | + 0.6 | 3.5 | + 0.6 | 3.9 | + 0.6 | 5.5 | + 0.6 |
| 100V | 120.000,000 | 1uV | 10 MOhms, 1% | 4.6 | + 0.8 | 5.2 | + 0.8 | 5.8 | + 0.8 | 8.0 | + 0.8 |
| 1000V | 1.050,000,00 | 10uV | 10 MOhms, 1% | 4.6 | + 1.2 | 5.2 | + 1.2 | 5.8 | + 1.2 | 8.0 | + 1.2 |

Absolute Uncertainty (95% Confidence)

| Range | 1 Year | | |
|-------|-----------------------------|-------|------------|
| | Tcal ± 1°C | | Tcal ± 3°C |
| | ± (ppm Reading + ppm Range) | | |
| 100mV | 7.5 | + 1.7 | 9.0 + 1.7 |
| 1V | 4.9 | + 0.6 | 6.4 + 0.6 |
| 10V | 5.4 | + 0.6 | 6.8 + 0.6 |
| 100V | 7.3 | + 0.8 | 9.5 + 0.8 |
| 1000V | 7.3 | + 1.2 | 9.5 + 1.2 |

Input Protection : 1100Volts

Ratio Uncertainty

Same Range : Apply 90 Day Accuracy

Different Ranges : ± (Front Terminal Range Accuracy + Rear Terminal Range Accuracy)

DC Current

Instrument Uncertainty Relative to Calibration Standards

| Range | Full Scale | Resolution | Input Impedance | 90 Day | | 180 Day | | 1 Year | | 2 Year | | |
|-------|-------------|------------|-----------------|-----------------------------|---|---------|------|--------|-----|--------|---|-----|
| | | | | ± (ppm Reading + ppm Range) | | | | | | | | |
| 10nA | 12.000,00 | 0.01pA | Virtual Ground | 4000 | + | 80 | 4500 | + | 80 | 5000 | + | 80 |
| 100nA | 120.000,0 | 0.1pA | Virtual Ground | 1440 | + | 34 | 1620 | + | 34 | 1800 | + | 34 |
| 1uA | 1.200.000 | 1pA | Virtual Ground | 160 | + | 17 | 180 | + | 17 | 200 | + | 17 |
| 10uA | 12.000,00 | 10pA | Virtual Ground | 24 | + | 10 | 27 | + | 10 | 30 | + | 10 |
| 100uA | 120.000,00 | 10pA | 10 kOhms | 5.5 | + | 4 | 6 | + | 4 | 7 | + | 4 |
| 1mA | 1.200.000,0 | 100pA | 1 kOhms | 5.5 | + | 4 | 6 | + | 4 | 7 | + | 4 |
| 10mA | 12.000.000 | 1nA | 100 Ohms | 7.2 | + | 4 | 8.1 | + | 4 | 9 | + | 4 |
| 100mA | 120.000,00 | 10nA | 10 Ohms | 24 | + | 6 | 27 | + | 6 | 30 | + | 6 |
| 1A | 1.200.000,0 | 100nA | 0.5 Ohms | 120 | + | 13 | 135 | + | 13 | 150 | + | 13 |
| 10A | 12.000.000 | 1uA | 10 mOhms | 290 | + | 35 | 320 | + | 35 | 360 | + | 35 |
| 30A | 30.500,00 | 10uA | 10 mOhms | 390 | + | 145 | 440 | + | 145 | 490 | + | 145 |

Absolute Uncertainty (95% Confidence)

| Range | 1 Year | | | | | |
|-------|-----------------------------|---|------------|-------|---|-----|
| | Tcal ± 1°C | | Tcal ± 3°C | | | |
| | ± (ppm Reading + ppm Range) | | | | | |
| 10nA | 14227 | + | 80 | 15148 | + | 80 |
| 100nA | 2454 | + | 34 | 3087 | + | 34 |
| 1uA | 268 | + | 17 | 339 | + | 17 |
| 10uA | 40 | + | 10 | 50 | + | 10 |
| | | | | | | |
| 100uA | 11 | + | 4 | 14 | + | 4 |
| 1mA | 11 | + | 4 | 14 | + | 4 |
| 10mA | 13 | + | 4 | 16 | + | 4 |
| 100mA | 36 | + | 6 | 47 | + | 6 |
| 1A | 174 | + | 13 | 234 | + | 13 |
| 10A | 418 | + | 35 | 561 | + | 35 |
| 30A | 569 | + | 145 | 764 | + | 145 |

AC Voltage

Instrument Uncertainty Relative to Calibration Standards

| Range | Full Scale | Resolution | Input Impedance | Frequency | 90 Day | | 180 Day | | 1 Year | | 2 Year | | |
|---------|------------|------------|-----------------|-----------------|-------------------------|---|-------------------------|-------|-------------------------|-------|-------------------------|---|-------|
| | | | | | ± (% Reading + % Range) | | ± (% Reading + % Range) | | ± (% Reading + % Range) | | ± (% Reading + % Range) | | |
| 100mV | 105.000,0 | 0.1uV | >1 GOhm / 90pF | 10Hz to 40Hz | 0.040 | + | 0.015 | 0.045 | + | 0.015 | 0.05 | + | 0.015 |
| | | | | 40Hz to 200Hz | 0.017 | + | 0.009 | 0.019 | + | 0.009 | 0.021 | + | 0.009 |
| | | | | 200Hz to 1kHz | 0.014 | + | 0.008 | 0.015 | + | 0.008 | 0.017 | + | 0.008 |
| | | | | 1kHz to 2kHz | 0.014 | + | 0.008 | 0.015 | + | 0.008 | 0.017 | + | 0.008 |
| | | | | 2kHz to 20kHz | 0.020 | + | 0.01 | 0.023 | + | 0.01 | 0.025 | + | 0.010 |
| | | | | 20kHz to 100kHz | 0.048 | + | 0.05 | 0.054 | + | 0.05 | 0.06 | + | 0.050 |
| 1V | 1.050.000 | 1uV | >1 GOhm / 90pF | 10Hz to 40Hz | 0.030 | + | 0.015 | 0.036 | + | 0.015 | 0.04 | + | 0.015 |
| | | | | 40Hz to 200Hz | 0.015 | + | 0.006 | 0.017 | + | 0.006 | 0.019 | + | 0.006 |
| | | | | 200Hz to 1kHz | 0.012 | + | 0.006 | 0.014 | + | 0.006 | 0.015 | + | 0.006 |
| | | | | 1kHz to 2kHz | 0.012 | + | 0.006 | 0.014 | + | 0.006 | 0.016 | + | 0.006 |
| | | | | 2kHz to 20kHz | 0.020 | + | 0.01 | 0.023 | + | 0.01 | 0.025 | + | 0.010 |
| | | | | 20kHz to 100kHz | 0.048 | + | 0.05 | 0.054 | + | 0.05 | 0.06 | + | 0.050 |
| 10V * | 10.500.00 | 10uV | >1 GOhm / 90pF | 10Hz to 40Hz | 0.800 | + | 2.5 | 0.900 | + | 2.5 | 1 | + | 2.5 |
| | | | | 40Hz to 200Hz | 0.015 | + | 0.006 | 0.017 | + | 0.006 | 0.019 | + | 0.006 |
| | | | | 200Hz to 1kHz | 0.012 | + | 0.006 | 0.014 | + | 0.006 | 0.015 | + | 0.006 |
| | | | | 1kHz to 2kHz | 0.012 | + | 0.006 | 0.014 | + | 0.006 | 0.016 | + | 0.006 |
| | | | | 2kHz to 20kHz | 0.020 | + | 0.01 | 0.023 | + | 0.01 | 0.025 | + | 0.010 |
| | | | | 20kHz to 1MHz* | 0.048 | + | 0.05 | 0.054 | + | 0.05 | 0.06 | + | 0.050 |
| 100V | 105.000,0 | 100uV | 1 MOhm / 130pF | 10Hz to 40Hz | 0.040 | + | 0.015 | 0.045 | + | 0.015 | 0.05 | + | 0.015 |
| | | | | 40Hz to 200Hz | 0.016 | + | 0.009 | 0.018 | + | 0.009 | 0.02 | + | 0.009 |
| | | | | 200Hz to 1kHz | 0.014 | + | 0.007 | 0.016 | + | 0.007 | 0.018 | + | 0.007 |
| | | | | 1kHz to 2kHz | 0.014 | + | 0.007 | 0.016 | + | 0.007 | 0.018 | + | 0.007 |
| | | | | 2kHz to 20kHz | 0.024 | + | 0.01 | 0.027 | + | 0.01 | 0.03 | + | 0.010 |
| | | | | 20kHz to 50kHz | 0.064 | + | 0.05 | 0.072 | + | 0.05 | 0.08 | + | 0.050 |
| 1000V * | 1050.000 | 1mV | 1 MOhm / 130pF | 10Hz to 40Hz | 0.040 | + | 0.015 | 0.045 | + | 0.015 | 0.05 | + | 0.015 |
| | | | | 40Hz to 200Hz | 0.016 | + | 0.009 | 0.018 | + | 0.009 | 0.02 | + | 0.009 |
| | | | | 200Hz to 1kHz | 0.014 | + | 0.007 | 0.016 | + | 0.007 | 0.018 | + | 0.007 |
| | | | | 1kHz to 2kHz | 0.014 | + | 0.007 | 0.016 | + | 0.007 | 0.018 | + | 0.007 |
| | | | | 2kHz to 20kHz | 0.024 | + | 0.01 | 0.027 | + | 0.01 | 0.03 | + | 0.010 |
| | | | | 20kHz to 50kHz | 0.064 | + | 0.05 | 0.072 | + | 0.05 | 0.08 | + | 0.050 |

Absolute Uncertainty (95% Confidence)

| Range | Frequency | 1 Year | | | | | |
|-------|-----------------|-------------------------|------------|-------|------|---|-------|
| | | Tcal ± 1°C | Tcal ± 3°C | | | | |
| | | ± (% Reading + % Range) | | | | | |
| 100mV | 10Hz to 40Hz | 0.04 | + | 0.015 | 0.08 | + | 0.015 |
| | 40Hz to 200Hz | 0.03 | + | 0.009 | 0.03 | + | 0.009 |
| | 200Hz to 1kHz | 0.03 | + | 0.008 | 0.03 | + | 0.008 |
| | 1kHz to 2kHz | 0.04 | + | 0.008 | 0.03 | + | 0.008 |
| | 2kHz to 20kHz | 0.04 | + | 0.01 | 0.04 | + | 0.01 |
| | 20kHz to 100kHz | 0.08 | + | 0.050 | 0.09 | + | 0.05 |
| 1V | 10Hz to 40Hz | 0.05 | + | 0.015 | 0.06 | + | 0.015 |
| | 40Hz to 200Hz | 0.03 | + | 0.006 | 0.03 | + | 0.006 |
| | 200Hz to 1kHz | 0.02 | + | 0.006 | 0.02 | + | 0.006 |
| | 1kHz to 2kHz | 0.02 | + | 0.006 | 0.02 | + | 0.006 |
| | 2kHz to 20kHz | 0.04 | + | 0.01 | 0.04 | + | 0.01 |
| | 20kHz to 100kHz | 0.08 | + | 0.050 | 0.09 | + | 0.05 |
| 10V * | 10Hz to 40Hz | 1.16 | + | 2.5 | 1.56 | + | 2.5 |
| | 40Hz to 200Hz | 0.03 | + | 0.009 | 0.03 | + | 0.009 |
| | 200Hz to 1kHz | 0.02 | + | 0.007 | 0.03 | + | 0.007 |
| | 1kHz to 2kHz | 0.04 | + | 0.007 | 0.03 | + | 0.007 |
| | 2kHz to 20kHz | 0.05 | + | 0.010 | 0.05 | + | 0.01 |
| | 20kHz to 50kHz | 0.10 | + | 0.05 | 0.12 | + | 0.05 |
| 100V | 10Hz to 40Hz | 0.07 | + | 0.015 | 0.08 | + | 0.015 |
| | 40Hz to 200Hz | 0.03 | + | 0.009 | 0.03 | + | 0.009 |
| | 200Hz to 1kHz | 0.02 | + | 0.007 | 0.03 | + | 0.007 |
| | 1kHz to 2kHz | 0.04 | + | 0.007 | 0.03 | + | 0.007 |
| | 2kHz to 20kHz | 0.05 | + | 0.010 | 0.05 | + | 0.01 |
| | 20kHz to 50kHz | 0.10 | + | 0.05 | 0.12 | + | 0.05 |

*1V Range to 1MHz : 10V Range to 200kHz

*100V Range to 50kHz : 1000V Range to 10kHz

All specifications apply from 10% of full scale + 3mV

AC Current

Instrument Uncertainty Relative to Calibration Standards

| Range | Full Scale | Resolution | Input Impedance | Frequency | 90 Day | | 180 Day | | 1 Year | | 2 Year | | |
|-------|------------|------------|-----------------|---------------|-------------------------|---|---------|-------|--------|-------|--------|---|-------|
| | | | | | ± (% Reading + % Range) | | | | | | | | |
| 100uA | 100.500,0 | 0.1nA | 10 kOhms | 10Hz to 40Hz | 0.040 | + | 0.015 | 0.045 | + | 0.015 | 0.05 | + | 0.015 |
| 1mA | 1.050.000 | 1nA | 1 kOhm | 40Hz to 1kHz | 0.024 | + | 0.012 | 0.027 | + | 0.012 | 0.03 | + | 0.012 |
| 10mA | 10.500,00 | 10nA | 100 Ohms | 1KHz to 10kHz | 0.056 | + | 0.030 | 0.063 | + | 0.030 | 0.07 | + | 0.030 |
| 100mA | 105.000,0 | 100nA | 10 Ohms | | | | | | | | 0.098 | + | 0.030 |
| 1A | 1.050.000 | 1uA | 0.5 Ohms | 10Hz to 40Hz | 0.048 | + | 0.020 | 0.054 | + | 0.020 | 0.06 | + | 0.020 |
| | | | | 40Hz to 1kHz | 0.032 | + | 0.015 | 0.036 | + | 0.015 | 0.04 | + | 0.015 |
| | | | | 1KHz to 10kHz | 0.056 | + | 0.050 | 0.063 | + | 0.050 | 0.07 | + | 0.050 |
| 10A | 10.500,00 | 10uA | 10 mOhms | 10Hz to 40Hz | 0.064 | + | 0.040 | 0.072 | + | 0.040 | 0.08 | + | 0.040 |
| 30A | 30.500,0 | 100uA | 10 mOhms | 40Hz to 1kHz | 0.056 | + | 0.030 | 0.063 | + | 0.030 | 0.07 | + | 0.030 |
| | | | | | | | | | | | 0.098 | + | 0.030 |

Absolute Uncertainty (95% Confidence)

| Range | Frequency | 1 Year | | |
|-------|---------------|-------------------------|---|------------|
| | | Tcal ± 1°C | | Tcal ± 3°C |
| | | ± (% Reading + % Range) | | |
| 100uA | 10Hz to 40Hz | 0.07 | + | 0.015 |
| 1mA | 40Hz to 1kHz | 0.04 | + | 0.012 |
| 10mA | 1kHz to 10kHz | 0.09 | + | 0.03 |
| 100mA | | | | |
| 1A | 10Hz to 40Hz | 0.09 | + | 0.02 |
| | 40Hz to 1kHz | 0.06 | + | 0.015 |
| | 1kHz to 10kHz | 0.10 | + | 0.05 |
| 10A | 10Hz to 40Hz | 0.14 | + | 0.04 |
| 30A | 40Hz to 1kHz | 0.10 | + | 0.03 |
| | | 0.12 | + | 0.03 |

All specifications apply from 10% of full scale + 3mV

Resistance

Instrument Uncertainty Relative to Calibration Standards

| Range | Full Scale | Resolution | Measurement Current | 90 Day | | 180 Day | | 1 Year | | 2 Year | | |
|---------------------|--------------|------------|---------------------|-----------------------------|---|---------|------|--------|-----|--------|---|-----|
| | | | | ± (ppm Reading + ppm Range) | | | | | | | | |
| 1 Ohm | 1.200.000,00 | 0.01 uOhm | 100mA | 12.0 | + | 6.0 | 13.0 | + | 6.0 | 15.0 | + | 6.0 |
| 10 Ohm | 12.000.000,0 | 0.1 uOhm | 10mA | 8.0 | + | 3.0 | 9.0 | + | 3.0 | 10.0 | + | 3.0 |
| 100 Ohm | 120.000.000 | 1 uOhm | 10mA | 7.0 | + | 1.0 | 8.0 | + | 1.0 | 9.0 | + | 1.0 |
| 100 Ohm Low Current | 120.000.000 | 1 uOhm | 1mA | 8.0 | + | 7.0 | 9.0 | + | 7.0 | 10.0 | + | 7.0 |
| 1 kOhm | 1.200.000,00 | 10 uOhms | 10mA | 6.5 | + | 0.8 | 7.0 | + | 0.8 | 8.0 | + | 0.8 |
| 1 kOhm Low Current | 1.200.000,00 | 10 uOhms | 1mA | 7.5 | + | 3.0 | 8.0 | + | 3.0 | 9.0 | + | 3.0 |
| 10 kOhm | 12.000.000,0 | 100 uOhms | 1mA | 7.5 | + | 0.8 | 8.5 | + | 0.8 | 9.5 | + | 0.8 |
| 10 kOhm Low Current | 12.000.000,0 | 100 uOhms | 100uA | 8.5 | + | 8.0 | 9.5 | + | 8.0 | 10.5 | + | 8.0 |
| 100 kOhm | 120.000.000 | 1 mOhms | 100uA | 8.0 | + | 0.8 | 9.0 | + | 0.8 | 10.0 | + | 0.8 |
| 1 MOhm* | 1.200.000,00 | 10 mOhms | 10uA | 9.0 | + | 2.0 | 10.0 | + | 2.0 | 11.0 | + | 2.0 |
| 10 MOhm* | 12.000.000,0 | 100 mOhms | 1uA | 12.0 | + | 8.0 | 13.5 | + | 8.0 | 15.0 | + | 8.0 |

Absolute Uncertainty (95% Confidence)

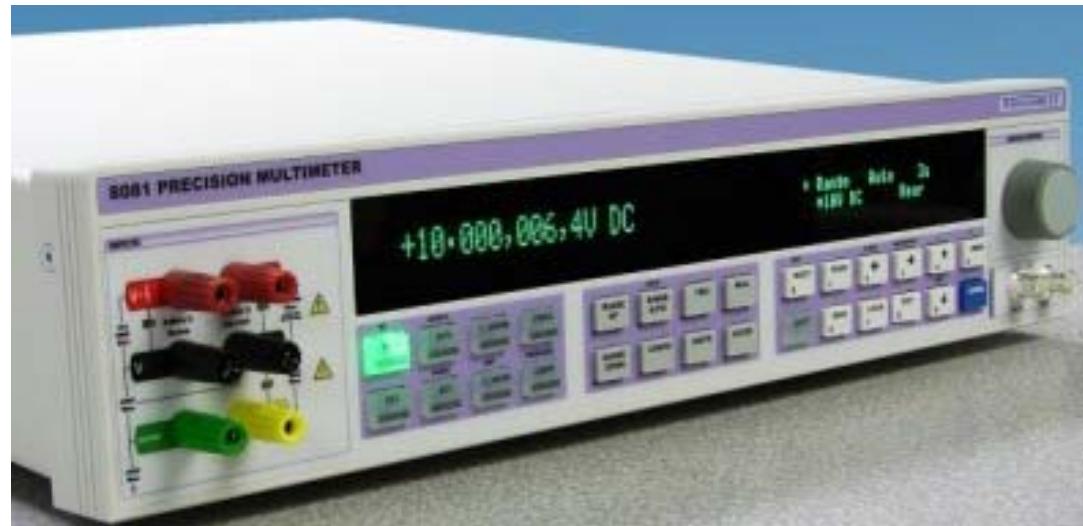
| Range | 1 Year | | |
|---------------------|-----------------------------|---|------------|
| | Tcal ± 1°C | | Tcal ± 3°C |
| | ± (ppm Reading + ppm Range) | | |
| 1 Ohm | 17.6 | + | 6 |
| 10 Ohm | 11.9 | + | 3 |
| 100 Ohm | 10.6 | + | 1.0 |
| 100 Ohm Low Current | 11.7 | + | 7 |
| 1 kOhm | 9.4 | + | 0.8 |
| 1 kOhm Low Current | 10.5 | + | 3 |
| 10 kOhm | 11.1 | + | 0.8 |
| 10 kOhm Low Current | 12.2 | + | 8 |
| 100 kOhm | 11.8 | + | 8 |
| 1 MOhm * | 14.1 | + | 2 |
| 10 MOhm* | 18.0 | + | 8 |

Electrometer Resistance

Instrument Uncertainty Relative to Calibration Standards

| Voltage Setting* | Current Range | Resistance Range | Resolution | 90 Day | 180 Day | 1 Year | 2 Year |
|------------------|---------------|----------------------|------------|---------------|---------|--------|--------|
| | | | | ± ppm Reading | | | |
| 10V | 10uA | 800kOhm - 9MOhm | 10 Ohm | 112 | 125 | 140 | 195 |
| | 1uA | 8M Ohm - 90 Mohm | | | | | |
| | 100nA | 80 Mohm - 900 Mohm | | | | | |
| | 10nA | 800 Mohm - 1TOhm | | | | | |
| 50V | 10uA | 5M Ohm - 45 MOhm | 100 Ohm | 360 | 405 | 450 | 630 |
| | 1uA | 40M Ohm - 450 Mohm | | | | | |
| | 100nA | 400 Mohm - 4.5GOhm | | | | | |
| | 10nA | 4 Gohm - 1TOhm | | | | | |
| 100V | 10uA | 8M Ohm - 90 Mohm | 1kOhm | 1440 | 1620 | 1800 | 2520 |
| | 1uA | 80 Mohm - 900 Mohm | | | | | |
| | 100nA | 800Mohm - 9GOhm | | | | | |
| | 10nA | 8GOhm - 2TOhm | | | | | |
| 150V | 10uA | 12M Ohm - 135 MOhm | 10 Ohm | 108 | 121.5 | 135 | 189 |
| | 1uA | 120M Ohm - 1350 Mohm | | | | | |
| | 100nA | 1200 Mohm - 13.5GOhm | | | | | |
| | 10nA | 12 Gohm - 2TOhm | | | | | |
| 200V | 10uA | 20M Ohm - 180 MOhm | 100 Ohm | 344 | 387 | 430 | 602 |
| | 1uA | 160M Ohm - 1600 Mohm | | | | | |
| | 100nA | 1600 Mohm - 18GOhm | | | | | |
| | 10nA | 16 Gohm - 2TOhm | | | | | |
| 250V | 10uA | 25M Ohm - 225 MOhm | 10 Ohm | 105.5 | 118.8 | 132 | 184.8 |
| | 1uA | 200M Ohm - 2250 Mohm | | | | | |
| | 100nA | 2000 Mohm - 22.5GOhm | | | | | |
| | 10nA | 20 Gohm - 2TOhm | | | | | |
| 300V | 10uA | 30M Ohm - 270 MOhm | 100 Ohm | 332 | 373.5 | 415 | 581 |
| | 1uA | 240M Ohm - 2700 Mohm | | | | | |
| | 100nA | 2400 Mohm - 27GOhm | | | | | |
| | 10nA | 24 Gohm - 2TOhm | | | | | |

Annex 2: Image of the TRANSMILLE mod. 8081 DMM.



Annex 3: Measurement results for DC Voltage.

| (mV) | Portata | measurement days | | | | | | | | | | |
|--------|---------|------------------|-------|------|------|-------|------|------|------|-------|-------|------|
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 1 | | 10 | -150 | 0 | -130 | -210 | -130 | -140 | -80 | -280 | -220 | -140 |
| 10 | | -1.0 | -26.0 | 3.0 | 5.0 | -14.0 | 6.0 | 0.0 | 1.0 | -14.0 | -19.0 | -1.0 |
| -10 | (mV) | 3.0 | -40 | -10 | 0 | -1.6 | -2.9 | 0.0 | -1.1 | -0.9 | -2.1 | 1.4 |
| 50 | 100 | 6.4 | -1.6 | 6.8 | 9.8 | 1.0 | 11.4 | 7.2 | 9.0 | 2.0 | 0.6 | 8.0 |
| 100 | | 5.2 | 2.1 | 4.4 | 5.1 | 3.0 | 3.4 | 5.4 | 6.1 | 2.8 | 1.3 | 3.9 |
| -100 | | -0.4 | 2.4 | -1.8 | -1.3 | 1.8 | -1.1 | 0.0 | -1.4 | 0.9 | 1.3 | 0.0 |
| <hr/> | | | | | | | | | | | | |
| (V) | | | | | | | | | | | | |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 0.2 | | 3.0 | 2.0 | 3.0 | 2.5 | 1.5 | 2.5 | 2.5 | 2.5 | 1.0 | 1.0 | 2.5 |
| -0.2 | (V) | 0.5 | 2.5 | 3.0 | 2.0 | 2.0 | 3.5 | 1.5 | 1.0 | 0.0 | 0.5 | 1.5 |
| 0.5 | 1 | 4.8 | 3.4 | 2.4 | 5.0 | 3.2 | 4.2 | 3.0 | 4.0 | 3.6 | 3.2 | 2.8 |
| 1 | | 1.9 | 1.9 | 1.5 | 2.7 | 1.4 | 2.3 | 1.3 | 1.8 | 1.3 | 0.9 | 1.6 |
| -1 | | -2.4 | -0.5 | 0.3 | -0.8 | -1.2 | -0.2 | -1.2 | -2.0 | -2.1 | -2.6 | -0.1 |
| <hr/> | | | | | | | | | | | | |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 2 | | 1.0 | 1.5 | 2.0 | 2.5 | 2.0 | 2.5 | 1.5 | 1.5 | 2.5 | 1.0 | 3.0 |
| -2 | 10 | -1.0 | 1.0 | 2.0 | 1.5 | 0.5 | 2.0 | 0.5 | 0.0 | 0.0 | 0.0 | 2.0 |
| 3 | | 2.3 | 1.7 | 2.3 | 3.7 | 2.3 | 3.7 | 2.7 | 2.7 | 2.7 | 2.0 | 3.7 |
| 4 | | 1.8 | 1.5 | 2.3 | 3.0 | 1.8 | 3.3 | 2.5 | 2.3 | 2.5 | 2.3 | 3.3 |
| 6 | | 1.2 | 1.5 | 2.5 | 2.8 | 1.7 | 2.8 | 2.0 | 2.2 | 1.7 | 1.5 | 3.2 |
| 8 | | 1.1 | 1.2 | 2.3 | 2.7 | 1.5 | 3.1 | 2.1 | 2.1 | 2.4 | 1.8 | 3.5 |
| 10 | | -0.4 | 0.3 | 1.3 | 1.7 | 0.4 | 1.8 | 0.9 | 1.1 | 1.0 | 0.6 | 2.0 |
| -10 | | -2.6 | -1.1 | -1.6 | -1.1 | -1.0 | -0.7 | -0.7 | -0.8 | -1.2 | -1.1 | -0.9 |
| <hr/> | | | | | | | | | | | | |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 20 V | | -1.5 | -0.5 | -2.0 | -1.5 | -1.5 | -1.0 | -1.0 | -1.0 | -1.5 | -2.0 | -1.0 |
| -20 V | | 0.0 | 1.0 | 0.0 | 0.5 | 0.0 | -0.5 | 0.5 | 0.0 | -1.0 | -1.0 | -0.5 |
| 50 V | | 0.4 | 0.2 | -0.8 | 0.4 | 0.6 | 0.8 | 0.4 | 0.4 | 0.2 | -0.2 | 0.2 |
| 100 V | | -1.4 | -1.2 | -2.2 | -0.9 | -0.8 | -0.7 | -1.0 | -0.9 | -1.3 | -1.6 | -1.0 |
| -100 V | | -3.5 | -2.9 | -4.1 | -2.7 | -2.5 | -2.6 | -2.8 | -2.6 | -3.4 | -3.7 | -3.0 |
| <hr/> | | | | | | | | | | | | |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 200 | | -1.0 | 0.5 | -1.5 | -0.5 | 0.0 | -0.5 | 0.0 | -0.5 | 1.0 | -1.0 | 0.5 |
| -200 | 1000 | -3.0 | -2.5 | -2.5 | -1.5 | -2.0 | -1.0 | -1.5 | -1.0 | -2.0 | -1.5 | -2.0 |
| 400 | | 0.5 | 1.0 | -0.5 | -0.2 | -0.2 | 0.0 | 0.5 | 0.5 | 0.7 | 0.2 | 1.0 |
| 600 | | 0.2 | 1.0 | -0.5 | 0.0 | -0.2 | 0.2 | 0.2 | 0.3 | 0.3 | -0.2 | 0.8 |
| 800 | | 0.1 | 0.6 | -0.7 | -0.1 | 0.0 | 0.2 | 0.5 | 0.2 | 0.5 | 0.0 | 0.9 |
| 1000 | | -1.6 | -0.8 | -2.0 | -1.3 | -1.4 | -1.3 | -1.0 | -1.2 | -1.0 | -1.3 | -0.6 |
| -1000 | | -4.3 | -3.2 | -4.0 | -3.9 | -3.9 | -3.7 | -3.7 | -3.5 | -3.8 | -3.9 | -3.8 |

Annex 4: Measurement results for AC Voltage.

| Valore | f | measurement days | | | | | | | | | | | |
|-----------------|-------------|------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|------|
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 | |
| (mV) | (kHz) | (mV) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | |
| 1.000 | 1 | 100 | 4407 | 3293 | 3425 | 3252 | 3431 | 3223 | 3400 | 3435 | 3219 | 3428 | 3504 |
| 10.000 | 1 | | 129 | 52 | 47 | 48 | 45 | 43 | 46 | 51 | 49 | 50 | 52 |
| 20.000 | 1 | | 5 | -15 | -18 | -17 | -17 | -17 | -18 | -15 | -15 | -16 | -14 |
| 30.000 | 1 | | -10 | -19 | -22 | -21 | -21 | -21 | -21 | -20 | -20 | -20 | -19 |
| 50.000 | 1 | | -15 | -17 | -20 | -18 | -19 | -18 | -18 | -17 | -17 | -17 | -17 |
| 100.000 | 0,04 | 100 | 1 | 2 | -1 | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 2 |
| 100.000 | 1 | | -1 | -1 | -3 | -1 | -1 | -1 | -1 | 0 | 0 | 0 | 0 |
| 100.000 | 20 | | -5 | -5 | -7 | -7 | -7 | -6 | -6 | -6 | -6 | -6 | -5 |
| | | | | | | | | | | | | | |
| (V) | (kHz) | (V) | | | | | | | | | | | |
| 0.20000 | 1 | 1 | -10 | -9 | -12 | -6 | -6 | -5 | -6 | -5 | -5 | -5 | -4 |
| 0.50000 | 1 | | -17 | -16 | -18 | -17 | -17 | -17 | -17 | -17 | -16 | -16 | -16 |
| 1.00000 | 0,04 | 1 | -5 | -4 | -5 | -5 | -5 | -5 | -4 | -4 | -4 | -4 | -4 |
| 1.00000 | 1 | | -4 | -3 | -5 | -4 | -4 | -4 | -4 | -4 | -3 | -3 | -3 |
| 1.00000 | 20 | | -15 | -14 | -15 | -14 | -14 | -14 | -14 | -14 | -14 | -14 | -13 |
| 1.00000 | 100 | | -11 | -10 | -12 | -11 | -11 | -11 | -11 | -11 | -10 | -10 | -9 |
| 1.00000 | 300 | | 254 | 260 | 253 | 264 | 265 | 260 | 260 | 260 | 265 | 266 | 267 |
| 1.000000 | 1000 | | 306 | 345 | 345 | 399 | 405 | 320 | 320 | 310 | 409 | 419 | 395 |
| | | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 |
| | | | | | | | | | | | | | |
| 2.0000 | 1 | 10 | -9 | -8 | -9 | -9 | -9 | -9 | -9 | -8 | -7 | -7 | -7 |
| 4.0000 | 1 | | -18 | -17 | -17 | -18 | -17 | -17 | -17 | -17 | -16 | -16 | -16 |
| 6.0000 | 1 | | -15 | -14 | -14 | -14 | -14 | -14 | -14 | -14 | -14 | -13 | -13 |
| 8.0000 | 1 | | -11 | -9 | -9 | -10 | -10 | -10 | -9 | -9 | -9 | -9 | -9 |
| 10.0000 | 0,04 | 10 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 |
| 10.0000 | 1 | | -6 | -5 | -4 | -5 | -5 | -4 | -4 | -4 | -3 | -3 | -3 |
| 10.0000 | 20 | | -3 | -2 | -1 | -2 | -1 | -1 | -2 | -1 | 0 | 0 | 0 |
| 10.0000 | 100 | | -15 | -13 | -14 | -13 | -13 | -14 | -14 | -14 | -11 | -11 | -11 |
| 10.0000 | 200 | | -155 | -145 | -157 | -165 | -161 | -101 | -97 | -93 | -151 | -151 | -138 |
| | | | | | | | | | | | | | |
| | | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 |
| 20.000 | 1 | 100 | -17 | -16 | -18 | -17 | -17 | -16 | -16 | -16 | -16 | -15 | -15 |
| 40.000 | 1 | | -20 | -19 | -20 | -19 | -18 | -19 | -19 | -19 | -18 | -18 | -18 |
| 60.000 | 1 | | -15 | -14 | -14 | -14 | -14 | -14 | -14 | -13 | -13 | -13 | -13 |
| 100.000 | 0,04 | 100 | -1 | 0 | -1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 100.000 | 1 | | -3 | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 | -1 | -1 |
| 100.000 | 20 | | -1 | -7 | -6 | -8 | -8 | -10 | -9 | -9 | -10 | -9 | -10 |
| 100.000 | 50 | | -6 | -41 | -39 | -51 | -51 | -60 | -57 | -60 | -64 | -61 | -64 |
| 200.00 | 1 | 1000 | -11 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -8 | -9 |
| 300.00 | 1 | | -16 | -14 | -14 | -14 | -13 | -11 | -12 | -12 | -12 | -11 | -12 |
| 400.00 | 1 | | -16 | -15 | -14 | -13 | -13 | -11 | -12 | -12 | -11 | -11 | -12 |
| 600.00 | 0,04 | | -4 | -2 | -2 | -1 | -1 | 0 | 0 | 1 | 1 | 0 | |
| 600.00 | 1 | | -14 | -12 | -12 | -10 | -10 | -10 | -10 | -9 | -8 | -8 | -10 |
| 600.00 | 20 | | 69 | 63 | 67 | 60 | 62 | 59 | 62 | 61 | 59 | 62 | 59 |
| 600.00 | 100 | | | | | | | | | | | | |
| 1000.00 | 0,04 | 1000 | -1 | 1 | 2 | 3 | 4 | 3 | 4 | 4 | 5 | 5 | 4 |
| 1000.00 | 1 | | -11 | -9 | -8 | -7 | -7 | -7 | -7 | -6 | -6 | -6 | -6 |
| 1000.00 | 20 | | 92 | 86 | 89 | 83 | 82 | 81 | 81 | 80 | 80 | 80 | 80 |
| 1000.00 | 30 | | 190 | 181 | 184 | 173 | 172 | 169 | 167 | 166 | 165 | 165 | 165 |

Annex 5: Measurement results for DC Current.

| applicata | | | | | | | | | | Corrente | | |
|-------------------------|------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 0 | | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | |
| measurement days | | | | | | | | | | | | |
| (mA) | (mA) | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 |
| 10.0000 | 100 | 0.0 | 0.0 | -1.0 | 0.0 | 0.0 | -18.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 100.000 | | 1.7 | 2.4 | 1.4 | 1.9 | 2.2 | -0.1 | 2.0 | 1.9 | 2.4 | 2.3 | 1.5 |
| -100.000 | | -3.0 | -3.4 | -2.8 | -2.9 | -2.9 | -0.7 | -2.6 | -2.6 | -3.1 | -3.3 | -2.9 |
| (mA) | (mA) | (10-6) |
| | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 |
| 0.100000 | 1 | 20 | 10 | 10 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 1.00000 | | 30 | 30 | 23 | 24 | 33 | 35 | 33 | 32 | 37 | 40 | 38 |
| -1.00000 | | -6 | 11 | 16 | 20 | 23 | 20 | 23 | 23 | 15 | 0 | -1 |
| | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 |
| 1.00000 | 10 | 10 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 10.0000 | | 0 | -1 | -2 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 2 |
| -10.0000 | | -9 | -7 | -7 | -6 | -6 | -6 | -6 | -5 | -4 | -3 | -6 |
| | | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | | -12 | -12 | -12 | -12 | -12 | -12 | -12 | -12 | -12 | -12 | -12 |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 10.0000 | 100 | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 30 | 30 | 40 |
| 20.0000 | | 30 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 30 | 30 | 35 |
| 50.0000 | | 30 | 28 | 32 | 36 | 36 | 36 | 36 | 36 | 34 | 34 | 34 |
| 100.000 | | 28 | 28 | 31 | 39 | 39 | 38 | 38 | 38 | 35 | 36 | 37 |
| -100.000 | | 27 | 27 | 30 | 38 | 38 | 37 | 37 | 37 | 33 | 34 | 35 |
| | | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| (A) | (A) | -30 | -30 | -30 | -30 | -30 | -30 | -30 | -30 | -30 | -30 | -30 |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 0.100000 | 1 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 30 | 20 | 30 | 30 |
| 0.200000 | | 20 | 15 | 20 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| 0.50000 | | | | | 28 | 26 | 28 | 28 | 28 | 26 | 24 | 24 |
| 1.00000 | | | | | 22 | 22 | 23 | 24 | 23 | 20 | 22 | 21 |
| -1.00000 | | | | | 19 | 19 | 18 | 19 | 19 | 18 | 18 | 19 |

Annex 6: Measurement results for AC Current.

| Valore (mA) | f (kHz) | measurement days | | | | | | | | | | | |
|----------------|------------|------------------|--------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|--------|
| | | 0 (10-4) | 36 (10-4) | 70 (10-4) | 71 (10-4) | 79 (10-4) | 103 (10-4) | 135 (10-4) | 135 (10-4) | 185 (10-4) | 186 (10-4) | 189 (10-4) | |
| 100.000 | 0,04 | 200 | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.6 |
| 100.000 | 0,3 | | 1.3 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.4 | 1.6 | 1.5 |
| 100.000 | 1 | | -2.9 | -3.0 | -3.0 | -2.9 | -2.9 | -2.8 | -2.8 | -2.9 | -2.8 | -2.6 | -2.7 |
| (mA) | (kHz) | (mA) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) |
| 1.00000 | 0,04 | 2 | 7 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 9 | 8 | |
| 1.00000 | 0,3 | | 3 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 3 | 5 | 4 |
| 1.00000 | 1 | | -8 | -9 | -9 | -8 | -8 | -8 | -7 | -8 | -7 | -6 | -6 |
| 1.00000 | 5 | | -21 | -22 | -23 | -22 | -22 | -21 | -21 | -22 | -21 | -19 | -20 |
| (kHz) | (mA) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) |
| 10.0000 | 0,040 | 20 | -5 | -5 | -6 | -5 | -5 | -4 | -4 | -4 | -4 | -3 | -4 |
| 10.0000 | 0,3 | | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 10.0000 | 1 | | -5 | -5 | -5 | -5 | -5 | -5 | -4 | -5 | -4 | -4 | -4 |
| 10.0000 | 5 | | -27 | -27 | -27 | -26 | -26 | -25 | -25 | -26 | -25 | -25 | -25 |
| (kHz) | (mA) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) | (10-5) |
| | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 | |
| 20.0000 | 1 | 100 | -16 | -16 | -16 | -16 | -15 | -15 | -15 | -15 | -15 | -15 | -15 |
| 30.000 | 1 | | -27 | -27 | -27 | -24 | -24 | -23 | -23 | -24 | -24 | -23 | -24 |
| 50.000 | 1 | | -22 | -22 | -22 | -22 | -22 | -21 | -21 | -22 | -22 | -21 | -22 |
| | | 0 | 79 | 36 | 70 | 71 | 103 | 135 | 135 | 185 | 186 | 189 | |
| 100.000 | 0,04 | 100 | -6 | -5 | -5 | -6 | -5 | -5 | -5 | -5 | -5 | -5 | -5 |
| 100.000 | 0,3 | | -3 | -3 | -3 | -3 | -3 | -2 | -2 | -3 | -3 | -2 | -3 |
| 100.000 | 1 | | -7 | -7 | -7 | -7 | -7 | -7 | -6 | -7 | -7 | -6 | -7 |
| 100.000 | 5 | | -31 | -31 | -31 | -31 | -31 | -31 | -31 | -31 | -31 | -31 | -31 |
| (A) | (kHz) | (A) | | | | | | | | | | | |
| | | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| 0.30000 | 1 | 1 | -28 | -30 | -30 | -29 | -29 | -28 | -28 | -28 | -27 | -28 | -28 |
| 1.00000 | 0,04 | 1 | 3 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 1.00000 | 0,3 | | 17 | 16 | 17 | 18 | 18 | 19 | 19 | 18 | 18 | 19 | 19 |
| 1.00000 | 1 | | -4 | -5 | -4 | -5 | -5 | -4 | -4 | -5 | -4 | -4 | -5 |
| 1.00000 | 5 | | 27 | 27 | 28 | 28 | 28 | 28 | 29 | 28 | 29 | 29 | 29 |

Annex 7: Measurement results for DC Resistance.

Measurement days

| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
|-----------|------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| (Ω) | (Ω) | (10 ⁻⁶) |
| 1.00000 | 1 | -6 | -9 | -13 | -9 | -9 | -9 | -9 | -9 | -8 | -8 | -10 |
| 10.00000 | 10 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | -1 | 0 |
| 10.00000 | 100 | -6 | -13 | -17 | -11 | -10 | -7 | -9 | -10 | -11 | -5 | -10 |
| 100.0000 | | 0 | -4 | -4 | -3 | -4 | -4 | -3 | -3 | -4 | -4 | -5 |
| | | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| | | -19 | -19 | -19 | -19 | -19 | -19 | -19 | -19 | -19 | -19 | -19 |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| (kΩ) | (kΩ) | (10 ⁻⁶) |
| 0.10000 | 1 | 2 | -3 | -2 | -1 | -2 | -1 | 0 | -1 | -2 | 0 | -2 |
| 1.000000 | | 3 | 0 | 0 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| 1.000000 | 10 | 4 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 |
| 10.00000 | | 2.8 | 2.0 | 1.7 | 1.8 | 2.0 | 1.3 | 1.1 | 1.4 | 1.8 | 1.7 | 1.7 |
| 10.00000 | 100 | 6 | 6 | 4 | 6 | 5 | 6 | 6 | 6 | 7 | 7 | 7 |
| 100.0000 | | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | | | | | | | | | | | | |
| | | 0 | 36 | 70 | 71 | 79 | 103 | 135 | 135 | 185 | 186 | 189 |
| (MΩ) | (MΩ) | (10 ⁻⁶) |
| 0.1000000 | 1 | 18 | 19 | 28 | 30 | 16 | 17 | 16 | 16 | 16 | 14 | 3 |
| 1.000000 | | 7 | 8 | 9 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 4 |
| 1.00000 | 10 | 79 | 82 | 86 | 75 | 80 | 74 | 77 | 77 | 67 | 68 | 5 |
| 10.0000 | | -25 | -16 | -24 | -12 | -6 | -9 | -10 | -11 | -17 | -19 | 6 |

Annex 8: Measurement results for High currents.

10 A range

| port 10 A | (10 ⁻⁶) | (10 ⁻⁶) | (10 ⁻⁶) |
|-----------|---------------------|---------------------|---------------------|
| | 0 | 140 | 200 |
| 10 | -14 | -2.3 | -3 |
| -10 | -37 | -44.7 | -44 |

| f (kHz) | port 10 A | (10 ⁻⁶) | (10 ⁻⁶) | (10 ⁻⁶) |
|------------|-----------|---------------------|---------------------|---------------------|
| | | 0 | 140 | 200 |
| 0,04 | | -156 | -160 | -134 |
| 0,3 | 10 | 330 | 335 | 330 |
| 1 | | 387 | 390 | 410 |
| 5 | | 1742 | 1755 | 1800 |

30 A range

| | (10 ⁻⁶) | (10 ⁻⁶) | (10 ⁻⁶) |
|-----|---------------------|---------------------|---------------------|
| | 0 | 140 | 200 |
| 20 | -128.5 | -127 | -124.5 |
| -20 | -157 | -132.5 | -135 |

| f (kHz) | | (10 ⁻⁶) | (10 ⁻⁶) | (10 ⁻⁶) |
|------------|----|---------------------|---------------------|---------------------|
| | | 0 | 140 | 200 |
| 0,04 | 20 | 20 | 65 | 75 |
| 0,3 | | 375 | 375 | 400 |
| 1 | | 555 | 550 | 590 |
| 5 | | 1955 | 1875 | 1995 |