METRICA
METRology Institutional CAtalog

ISTITUTO NAZIONALE DI RICERCA METROLOGICA
Repository Istituzionale

Evaluation of the TRANSMILLE mod. 8081 high precision digital multimeter by the INRIM calibration laboratory of multifunction electrical instruments

Original
Evaluation of the TRANSMILLE mod. 8081 high precision digital multimeter by the INRIM calibration laboratory of multifunction electrical instruments / Galliana, F.; Lanzillotti, M.. - (2016), pp. 1-44.

Availability:
This version is available at: 11696/54767 since: 2017-03-02T11:47:28Z

Publisher:

Published
DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

20 April 2024

National Institute of Metrological Research

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

F. Galliana, M. Lanzillotti

INRIM technical report 23/2016

July 2016

visto

Responsabile STALT

(Vito Fernicola)

CONTENTS

	Pag.
TITLE AND SUMMARY	2
TITOLO E SOMMARIO	2
1. INTRODUCTION	2
2. THE TRANSMILLE MOD. 8081 HIGH PRECISION DMM	4
3. GRAPHICAL RESULTS	5
3.1 Results for DC Voltage.	5
3.2 Results for AC Voltage.	8
3.3 Results for DC Current.	12
3.4 Results for AC Current.	16
3.5 Results for DC Resistance.	19
4. DATA ANALYSIS	22
4.1 DC Voltage.	23
4.2 AC Voltage.	24
4.3 DC Current.	27
4.4 AC Current.	28
4.5 DC Resistance.	30
5. CONCLUSIONS	31
REFERENCES.	31
Annex 1. Specifications of the TRANSMILLE MOD. 8081 DMM.	32
Annex 2: Image of the TRANSMILLE mod. 8081 DMM.	38
Annex 3: Measurement results for DC Voltage.	39
Annex 4: Measurement results for AC Voltage.	40
Annex 5: Measurement results for DC Current.	41
Annex 6: Measurement results for AC Current.	42
Annex 7: Measurement results for DC Resistance	43
Annex 8: Measurement results for High Currents.	44

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.

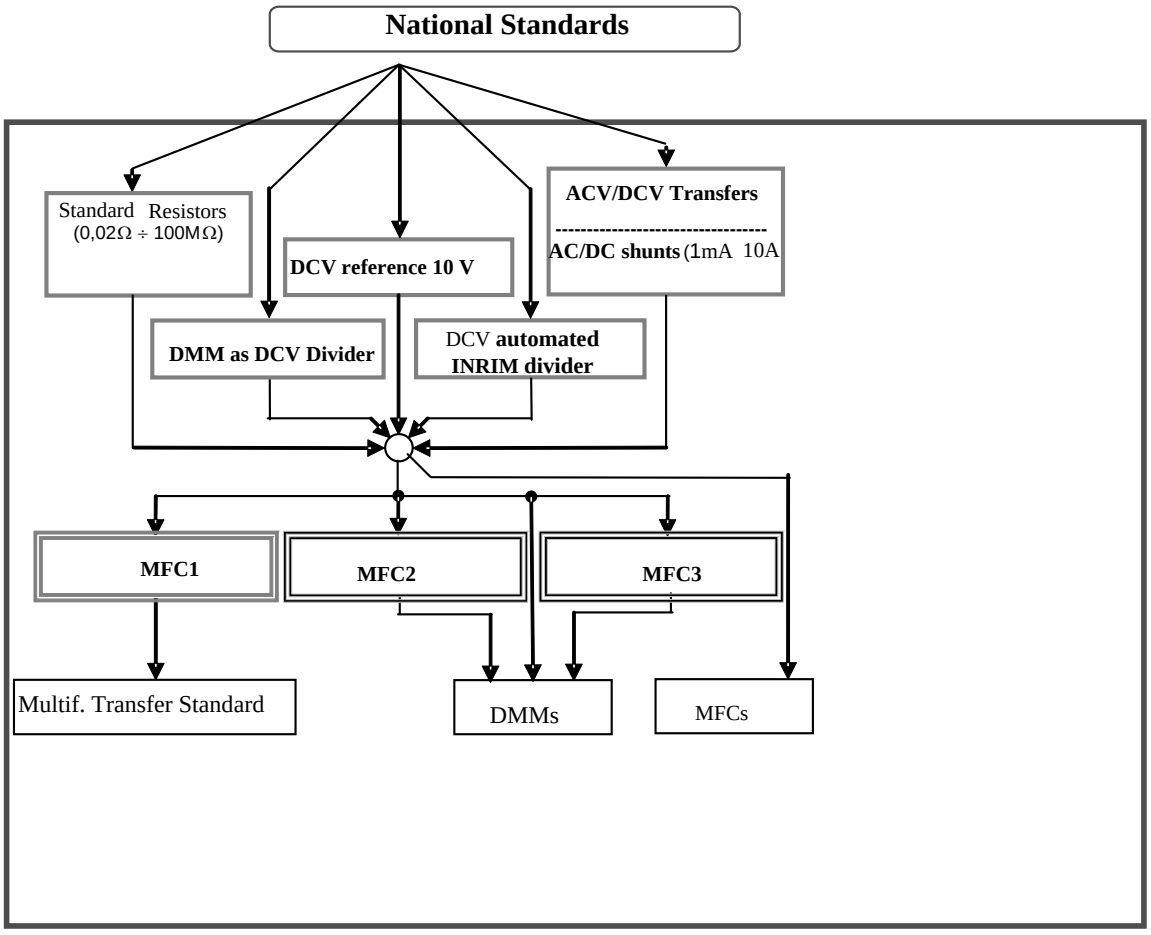

Fig. 1. Traceability chain from national Standards of the INRIM-Lab.

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 1 Ω to 2 TΩ 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.

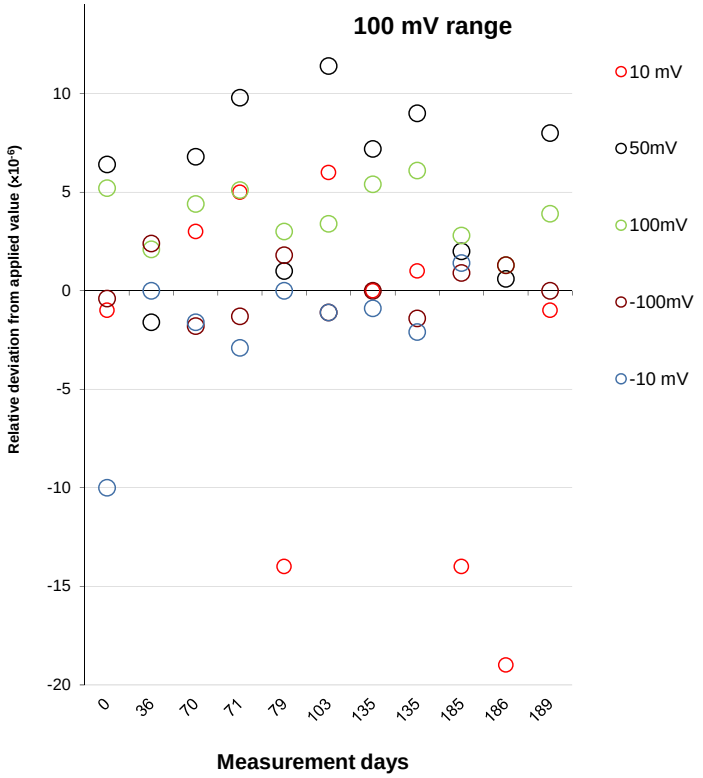

Fig. 2. Relative deviations from applied standard values in the 100 mV range.

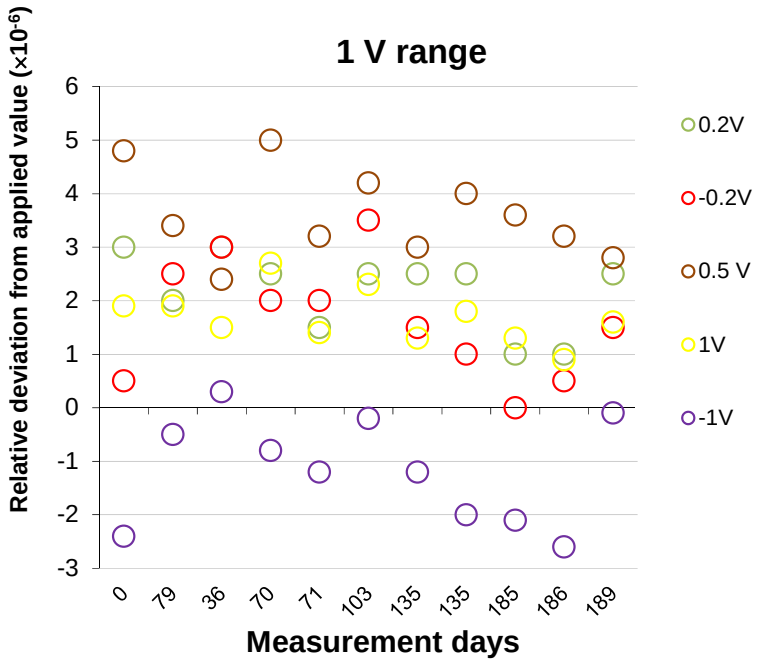

Fig. 3a). Relative deviations from applied standard values in the 1 V range.

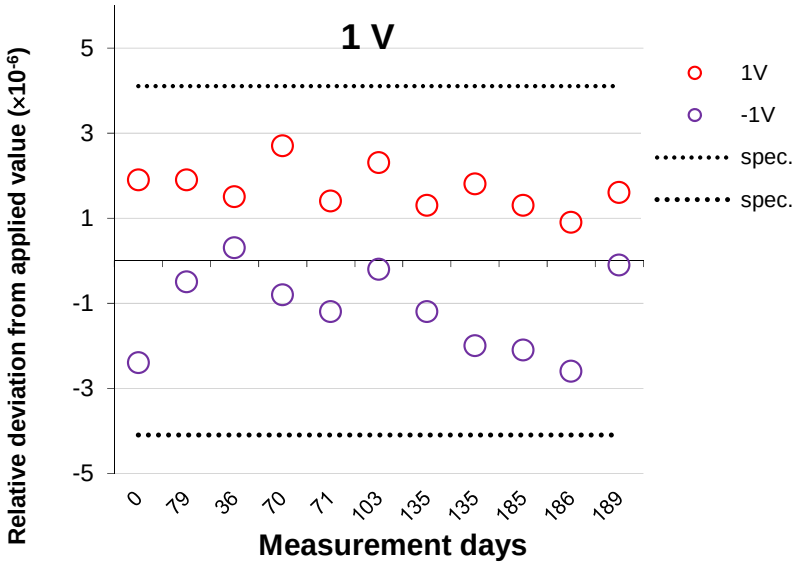

Fig. 3b). Relative deviations from applied standard values at 1 V compared with the 180-days DMM specifications.

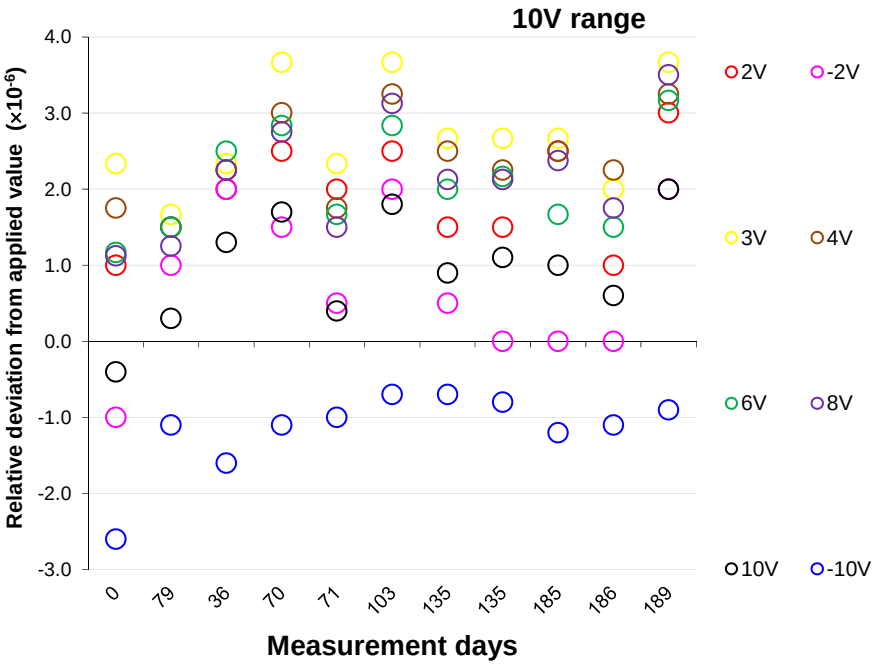

Fig. 4a). Relative deviations from applied standard values in the 10 V range.

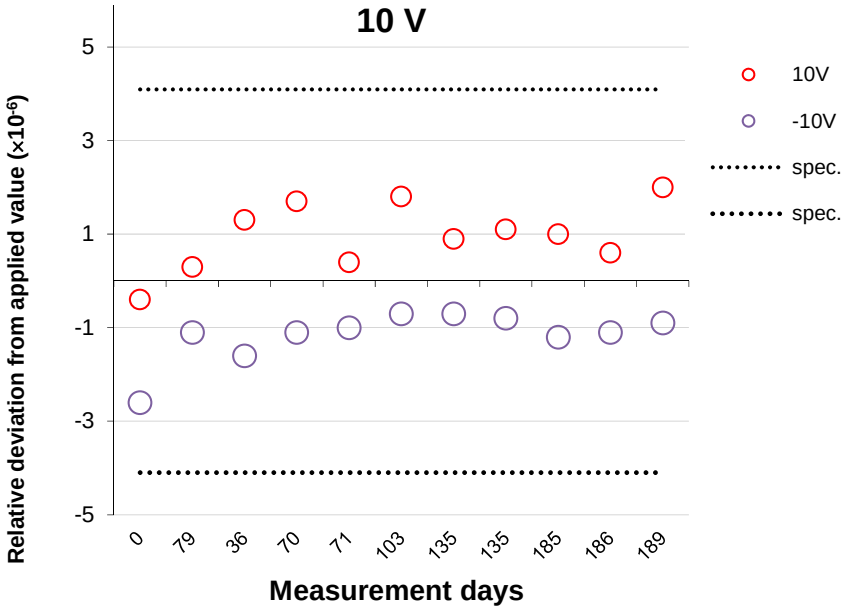

Fig. 4 b). Relative deviations from applied standard values at 10 V
Compared with the 180-days DMM specifications.

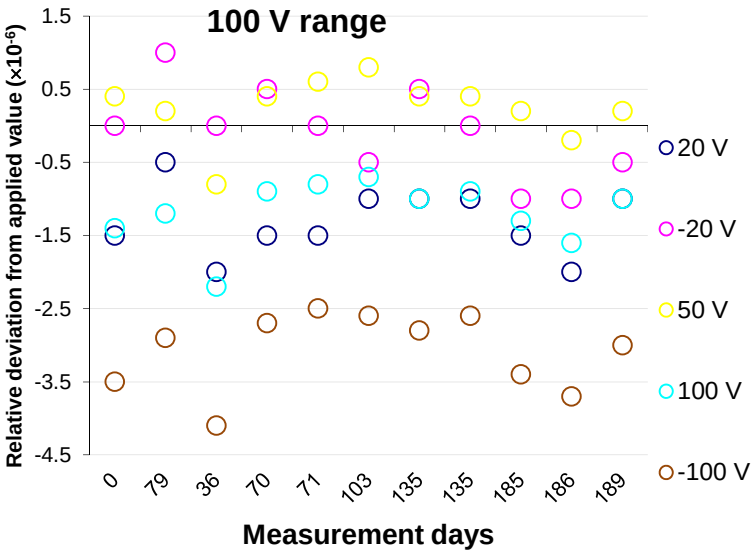

Fig. 5. Relative deviations from applied standard values in the 100 V range.

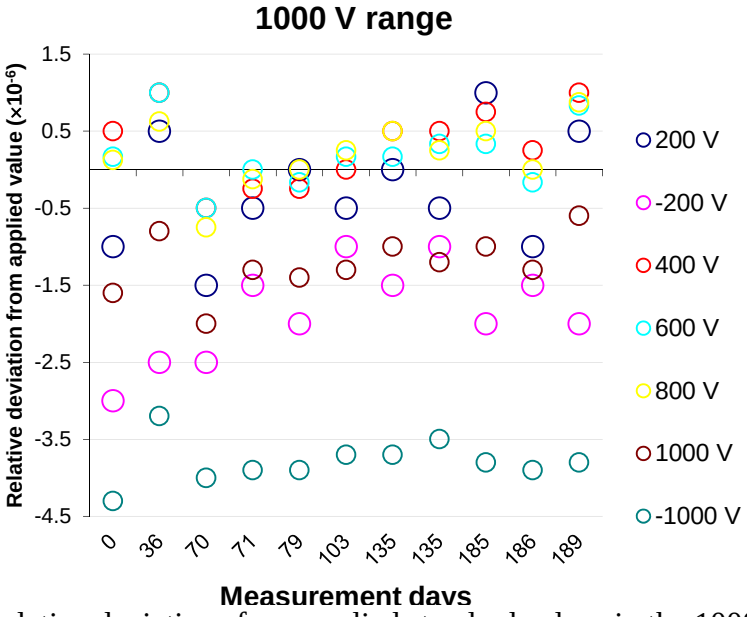

Fig. 6. Relative deviations from applied standard values in the 1000 V range.

3.2 Results for AC Voltage

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

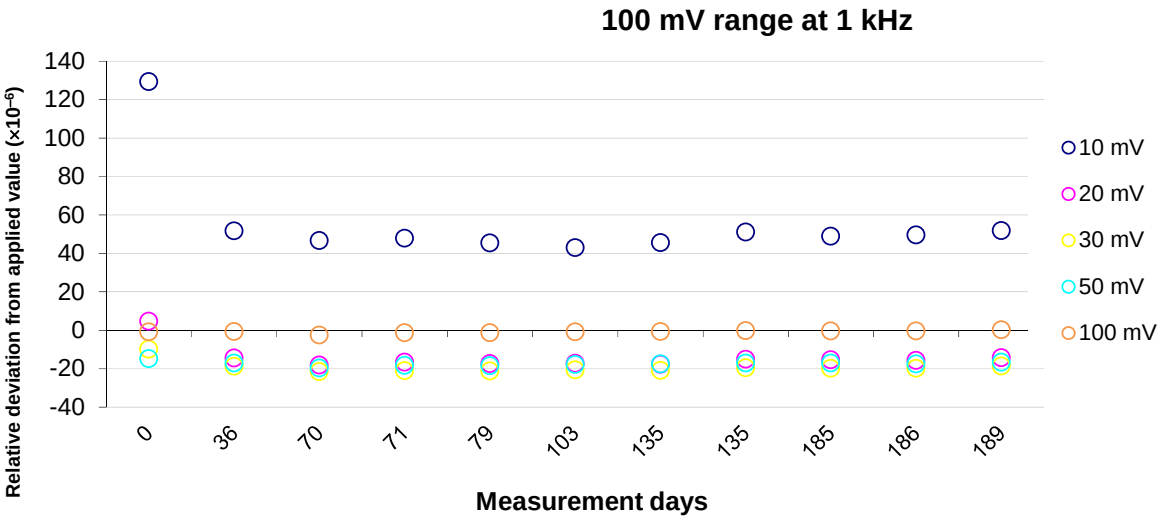

Fig. 7. Relative deviations from applied standard values in the 100 mV range at 1 kHz.

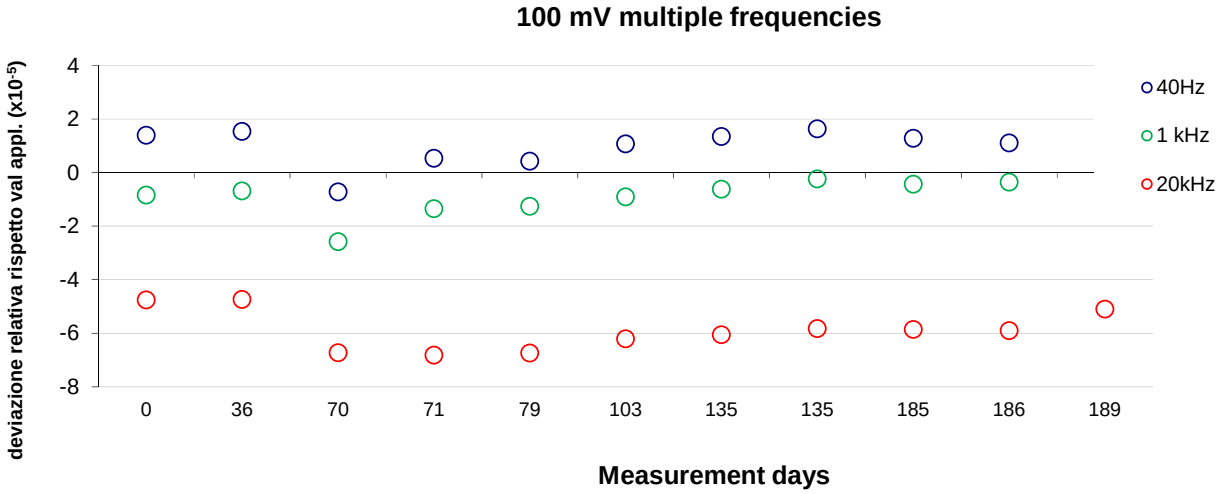

Fig. 8. Relative deviations from applied standard values at 100 mV at multiple frequencies.

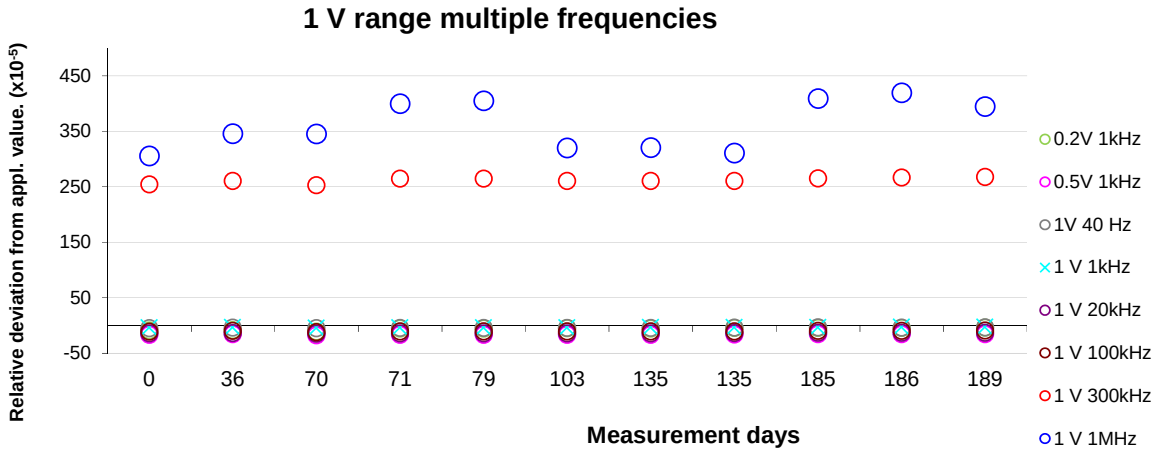

Fig. 9. Relative deviations from applied standard values in the 1 V range at multiple frequencies.

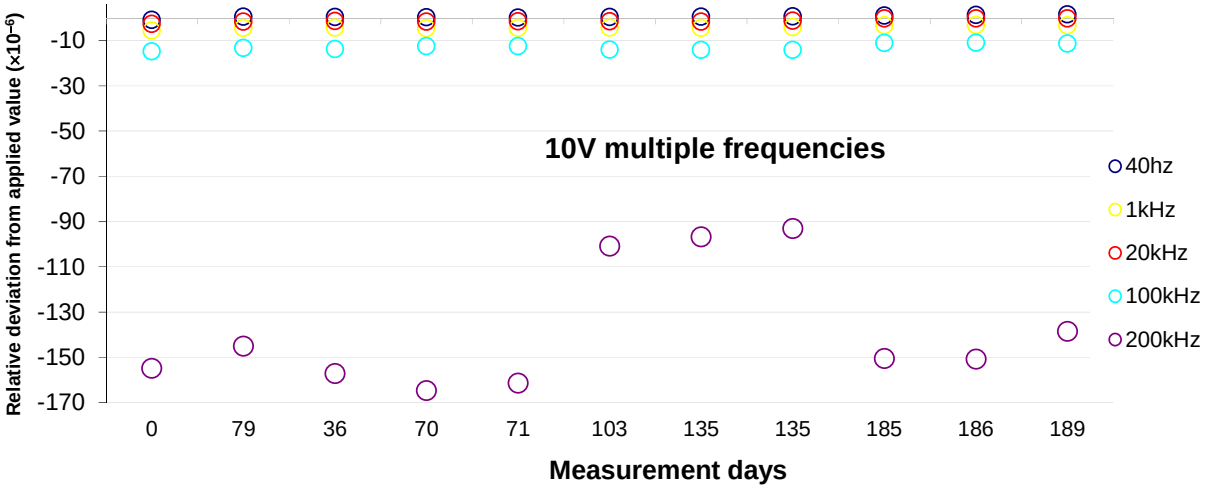

Fig. 10a). Relative deviations from applied standard values at 10 V at multiple frequencies.

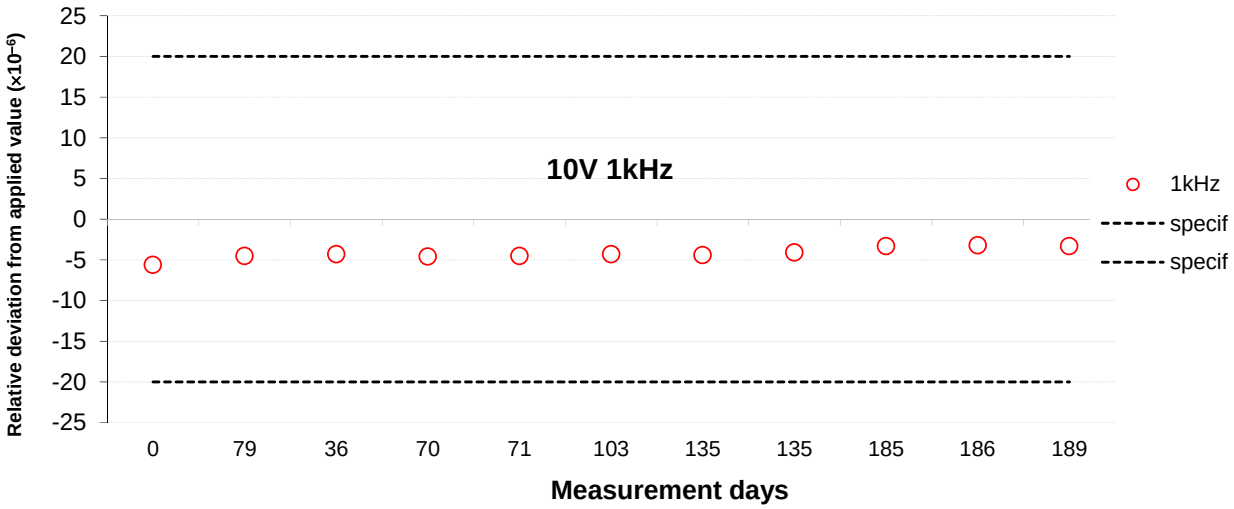

Fig. 10b). Relative deviations from applied standard values at 10 V 1 kHz compared with the 180-days DMM specifications.

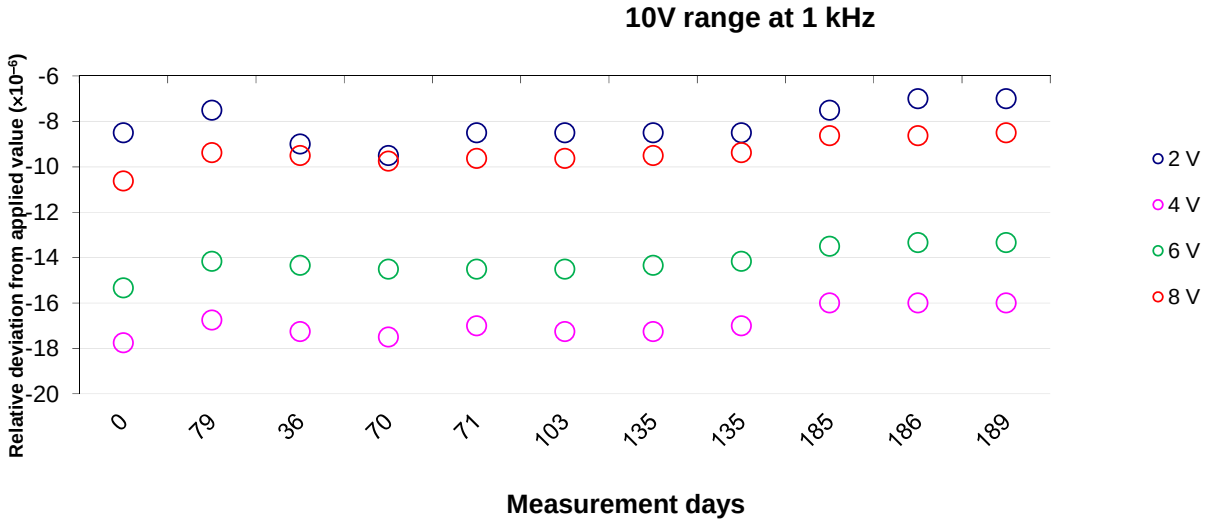

Fig. 11. Relative deviations from applied standard values in the 10 V range at 1 kHz.

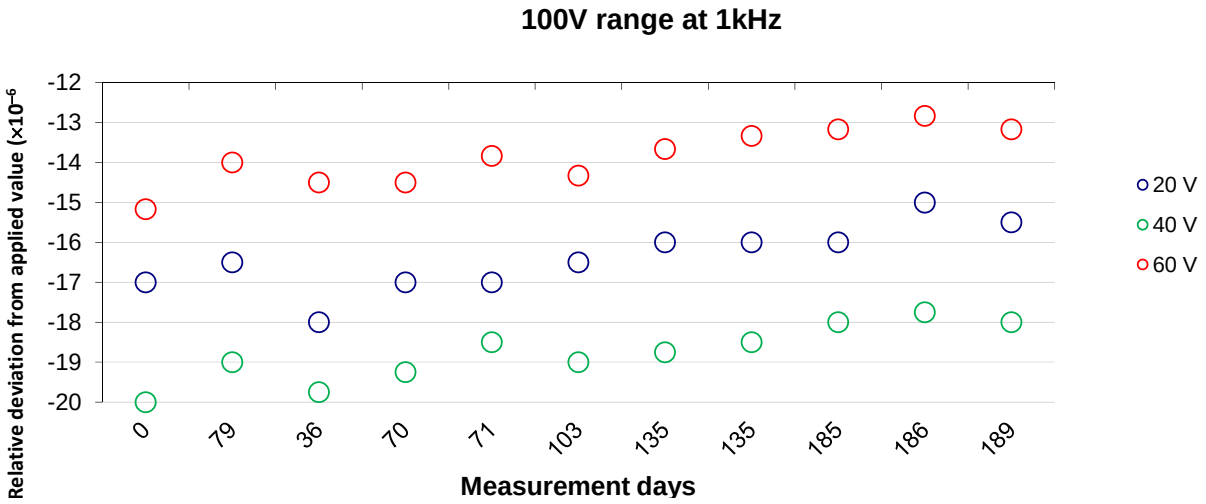

Fig. 12. Relative deviations from applied standard values in the 100 V range at 1 kHz.

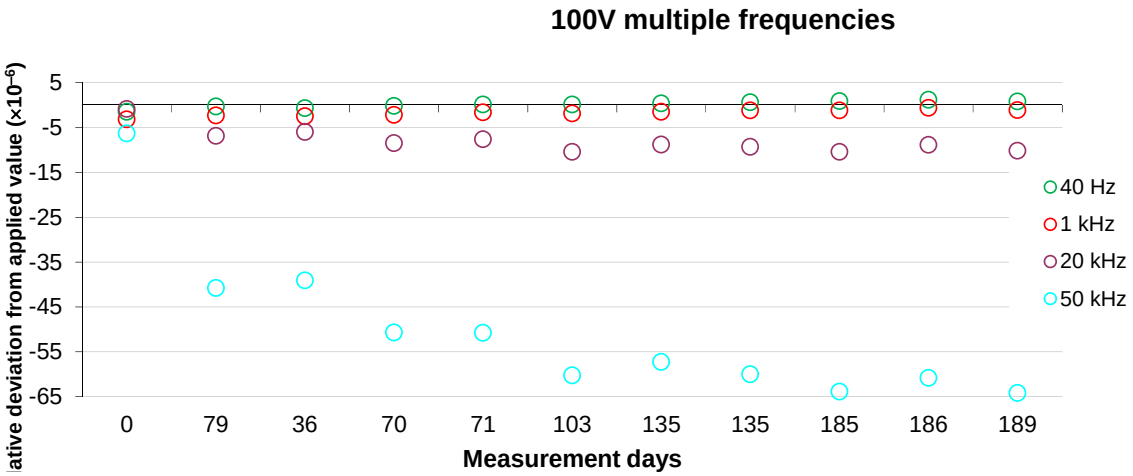

Fig. 13. Relative deviations from applied standard values at 100 V at multiple frequencies.

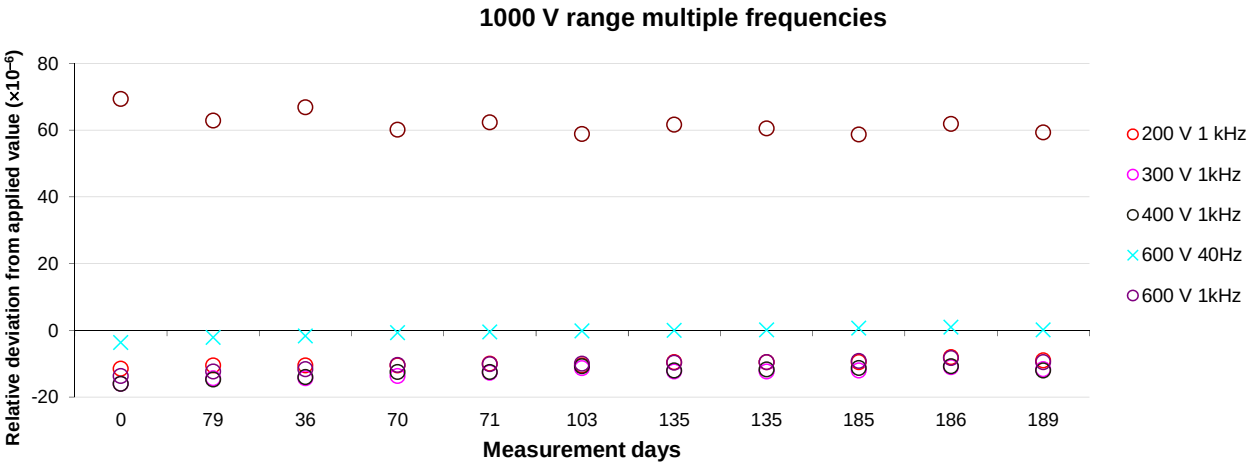

Fig. 14. Relative deviations from applied standard values in the 1000 V range at multiple frequencies.

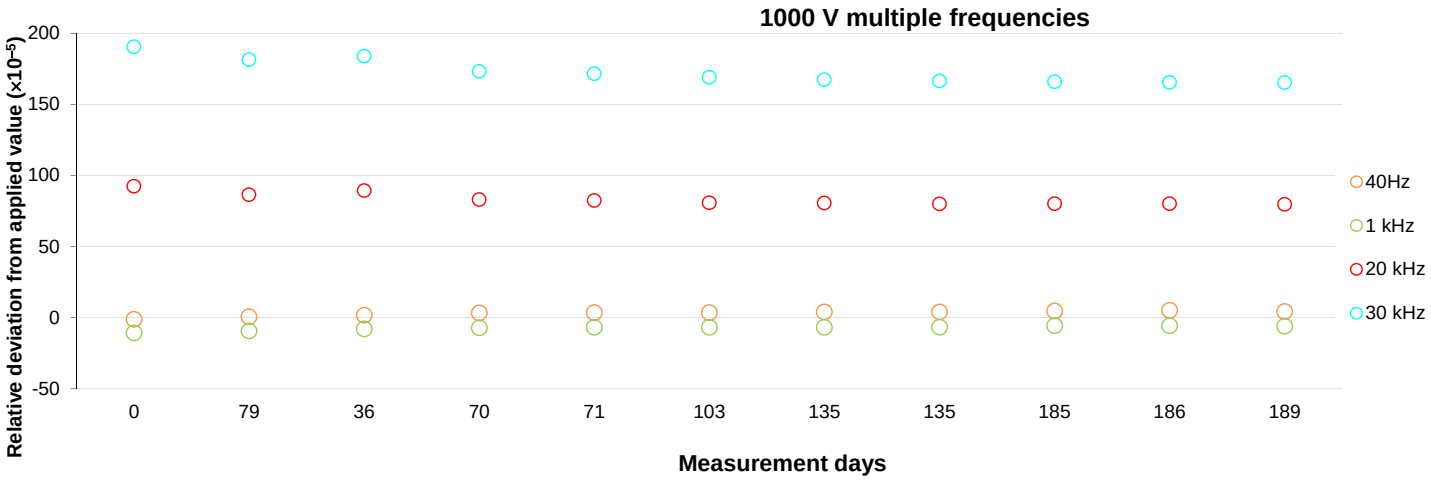

Fig. 15. Relative deviations from applied standard values at 1000 V at multiple frequencies.

3.3 Results for DC Current.

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

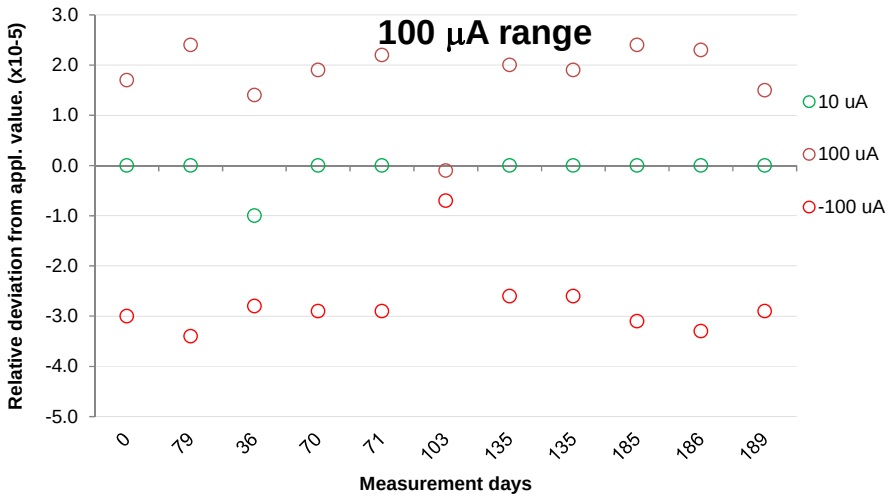

Fig. 16. Relative deviations from applied standard values in the 100 µA range.

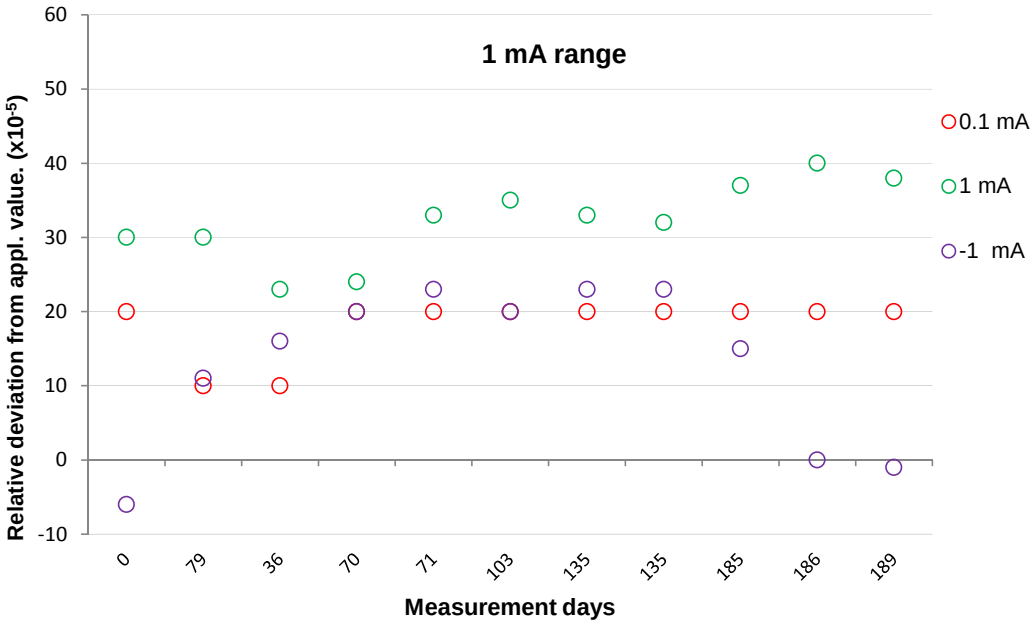

Fig. 17. deviations from applied standard values in the 1 mA range.

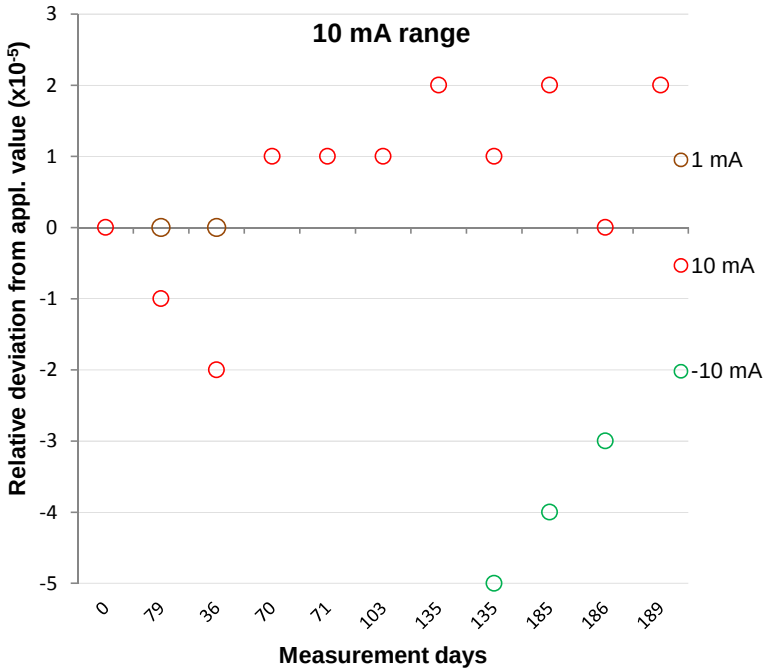

Fig. 18a). deviations from applied standard values in the 10 mA range.

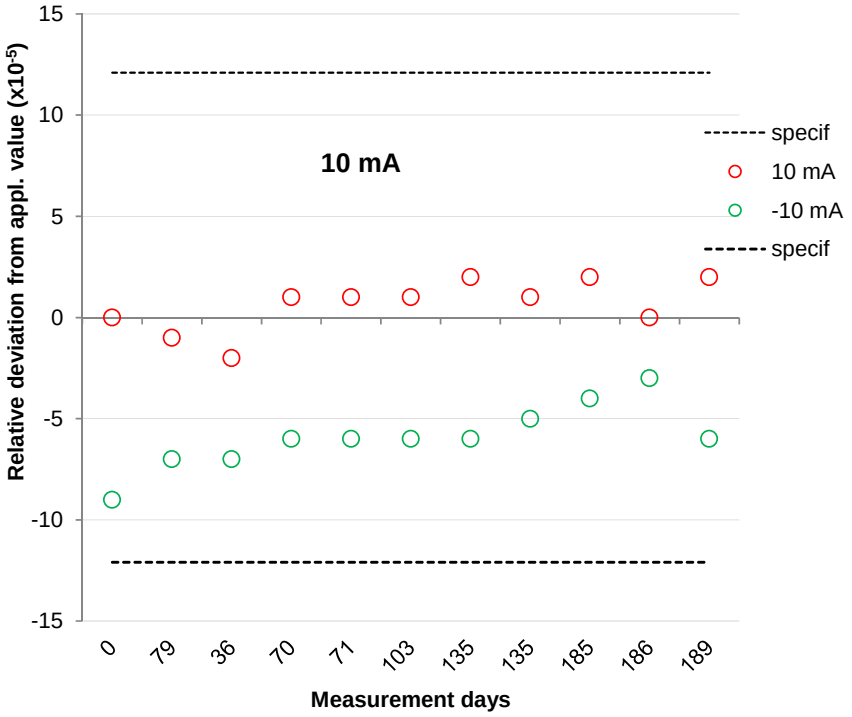

Fig. 18b). Relative deviations from applied standard values at 10 mA compared with the 180-days DMM specifications.

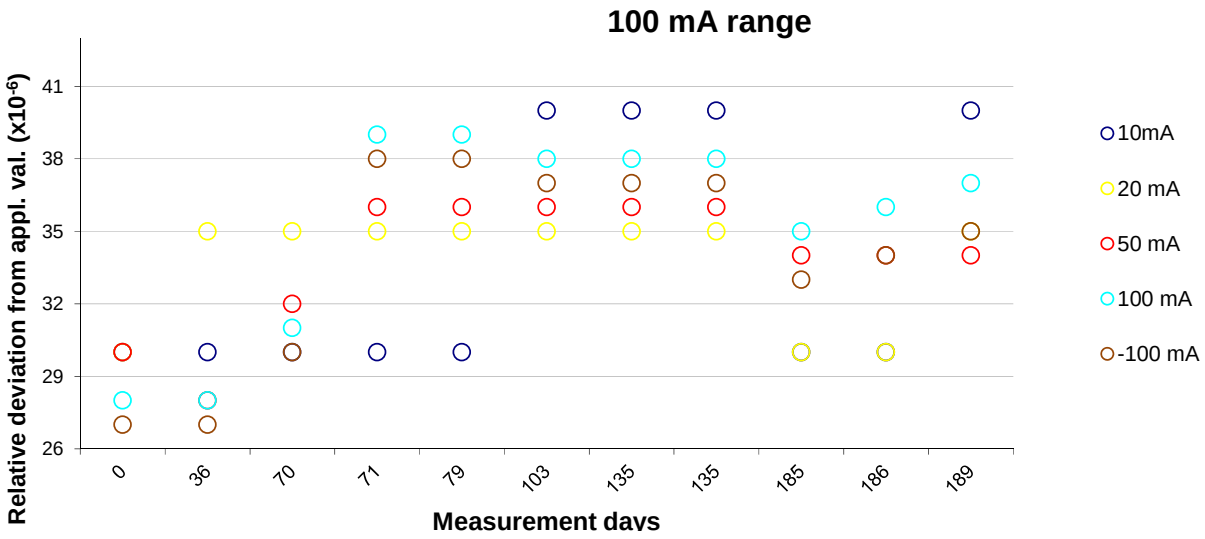

Fig. 19. Relative deviations from applied standard values in the 100 mA range.

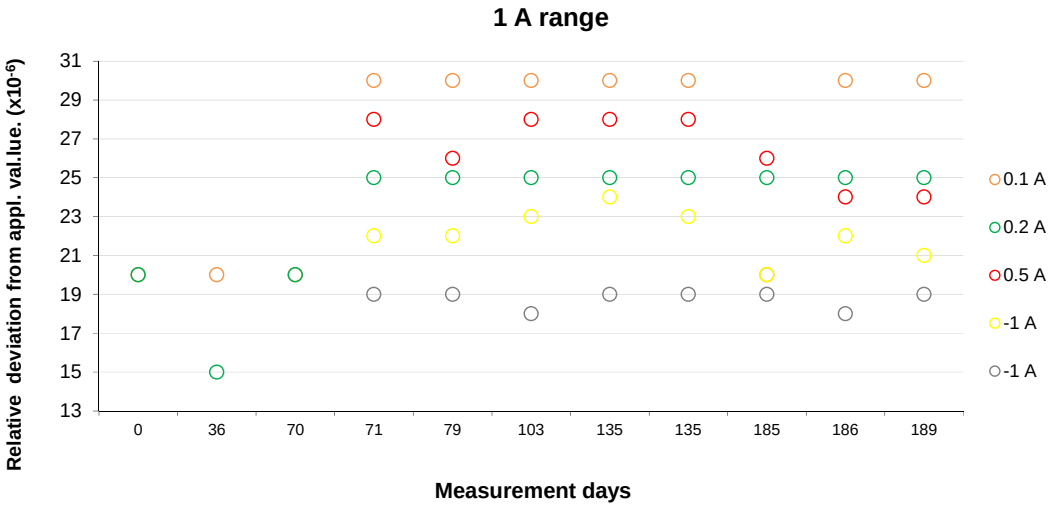

Fig. 20. Relative deviations from applied standard values in the 1 A range.

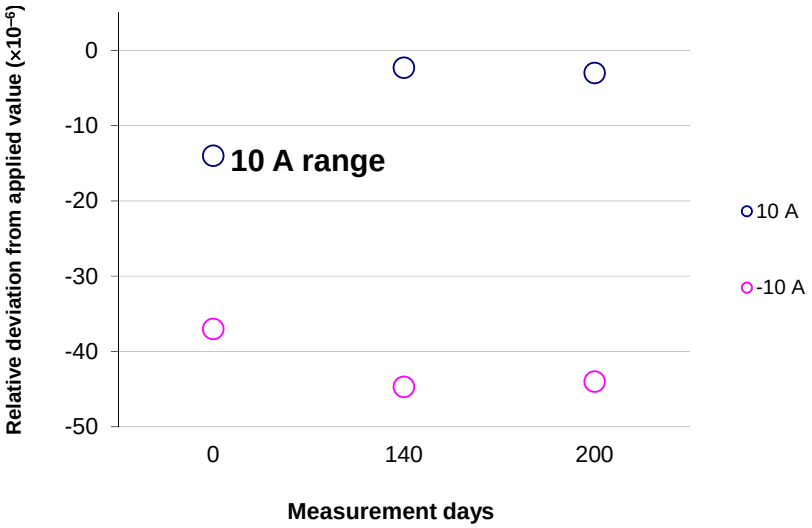

Fig. 21. Relative deviations from applied standard values in the 10 A range.

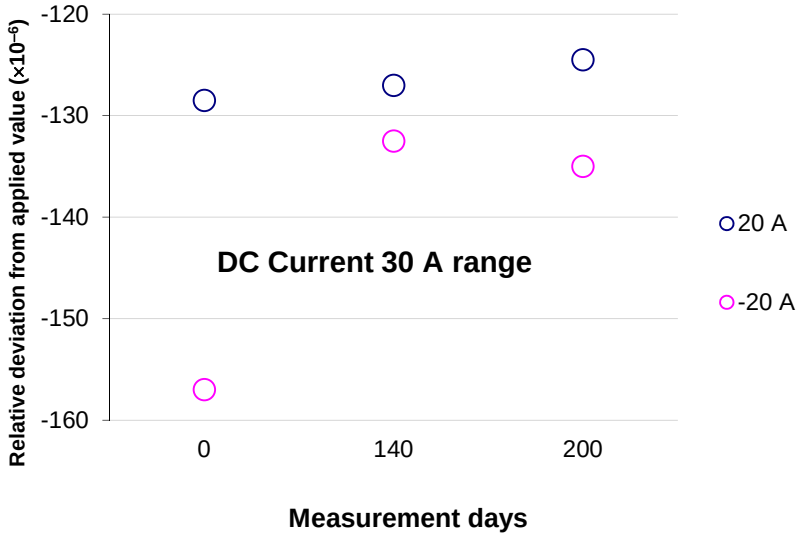

Fig. 22. Relative deviations from applied standard values in the 30 A range.

3.4 Results for AC Current.

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

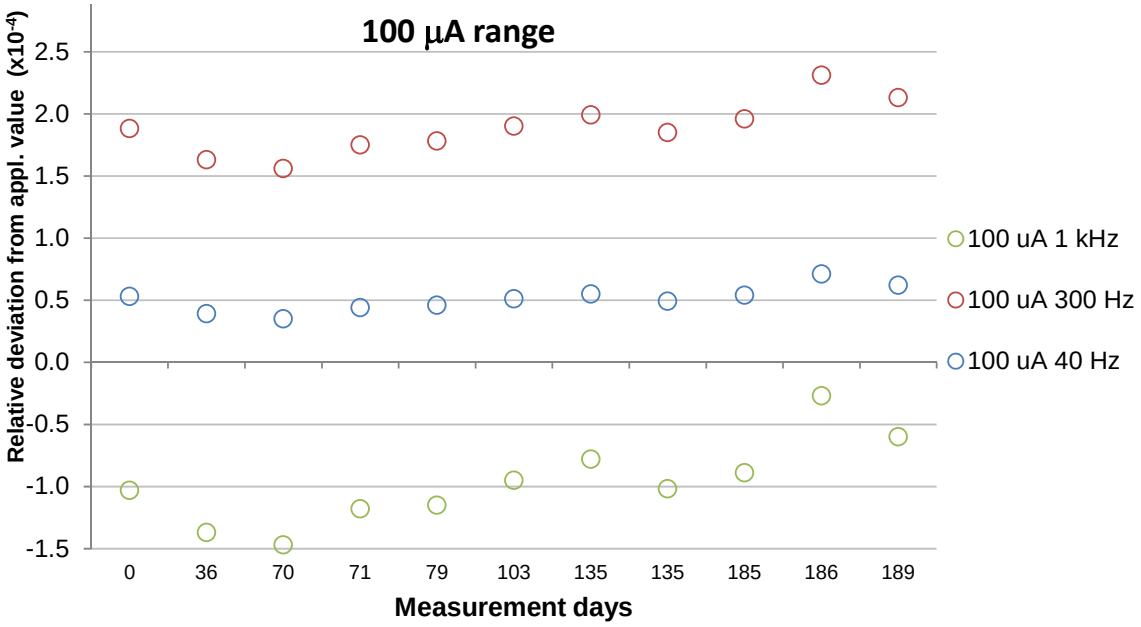

Fig. 23. Relative deviations from applied standard Values in the 100 μA range at multiple frequencies.

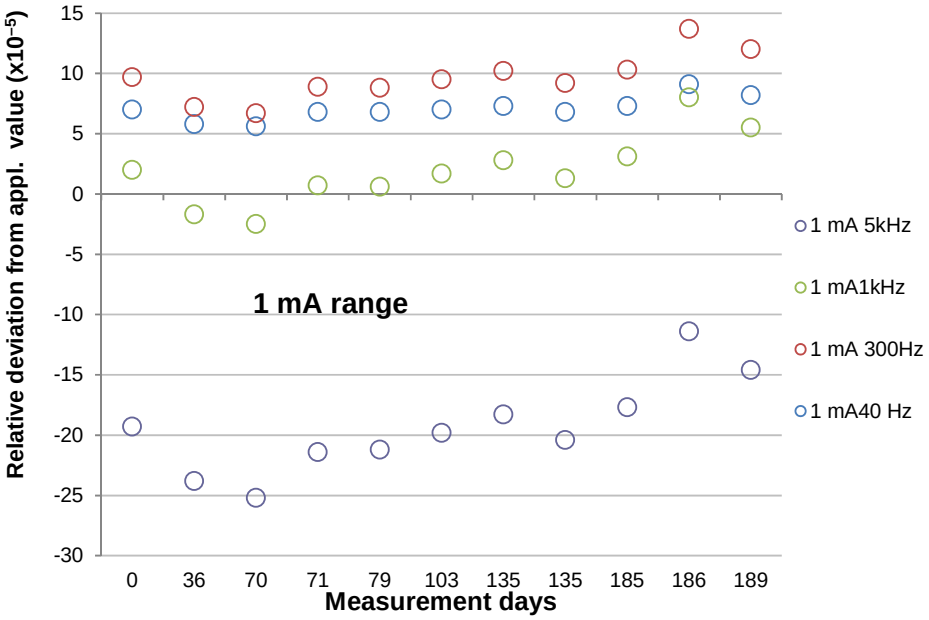

Fig. 24. Relative deviations from applied standard values in the 1 mA range at multiple frequencies.

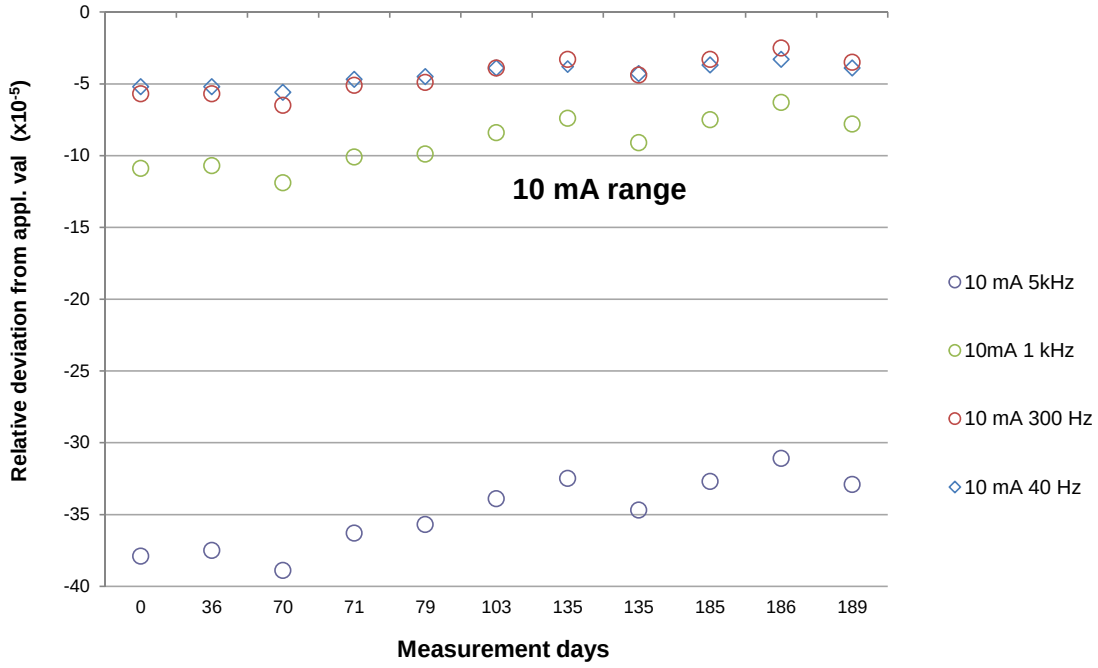

Fig. 25. Relative deviations from applied standard values in the 10 mA range at multiple frequencies.

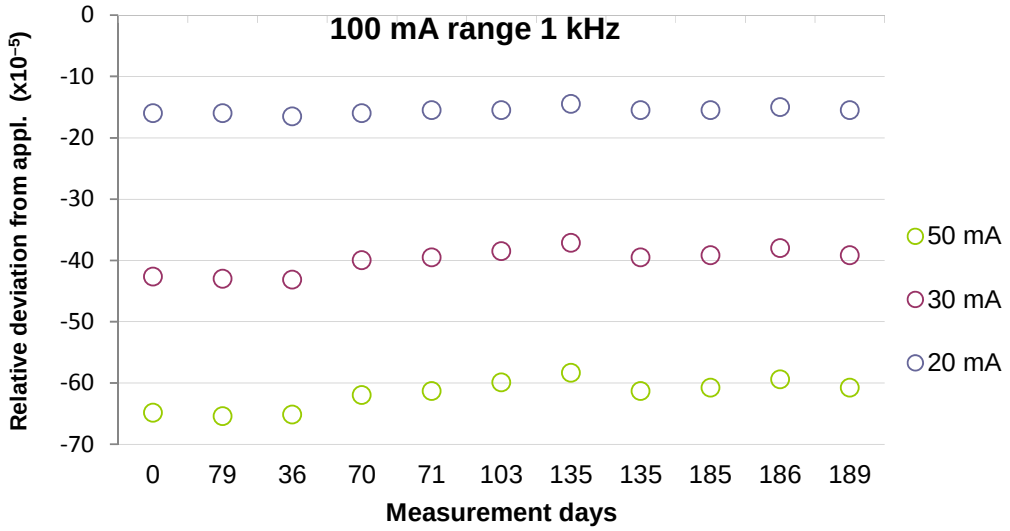

Fig. 26. Relative deviations from applied standard values in the 100 mA range at 1 kHz.

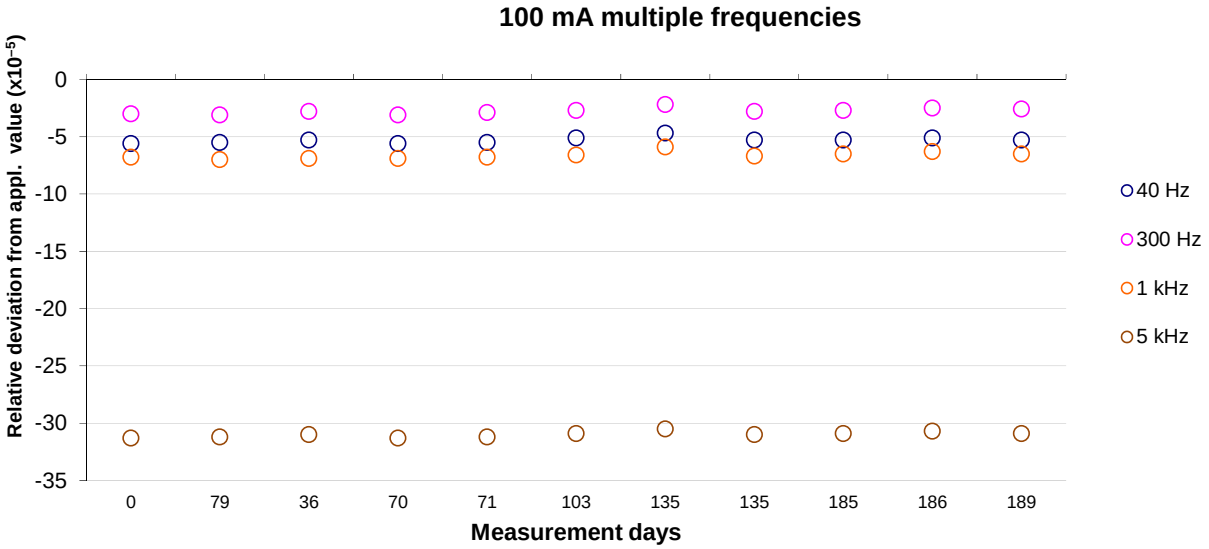

Fig. 27a). Relative deviations from applied standard values at 100 mA at multiple frequencies.

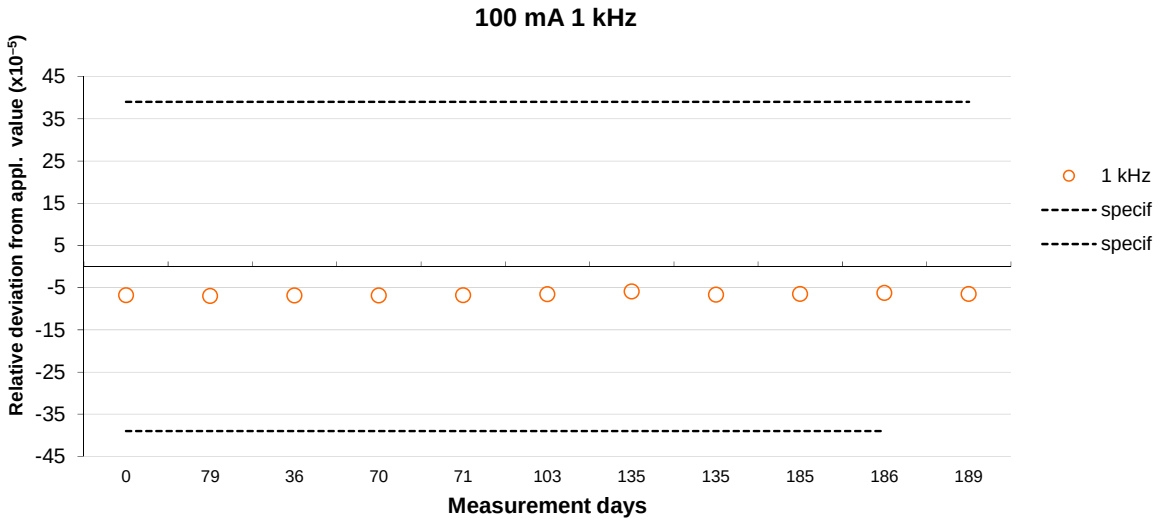

Fig. 27b). Relative deviations from applied standard values at 100 mA, 1 kHz compared with the 180-days DMM specifications.

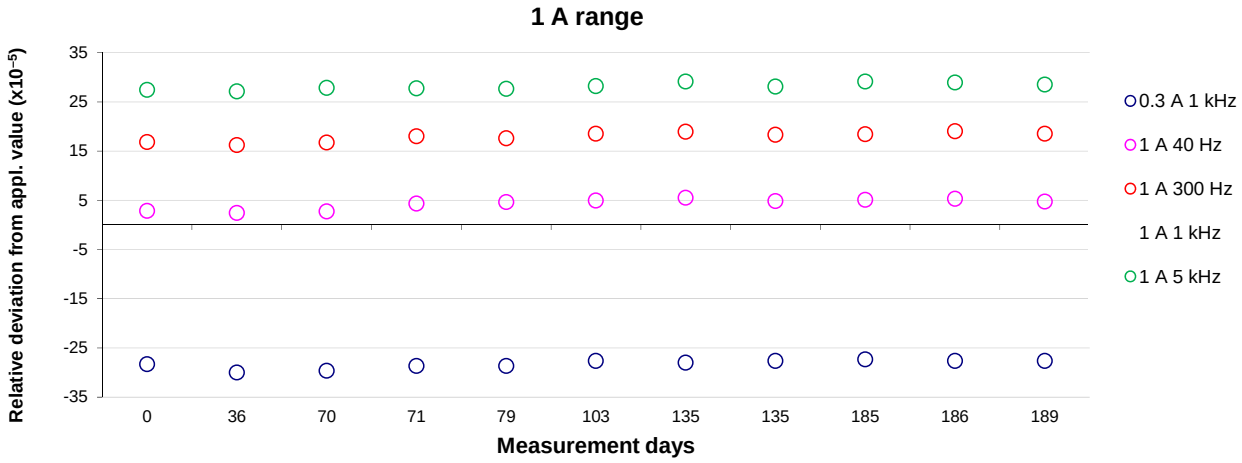

Fig. 28. Relative deviations from applied standard values in the 1 A range at multiple frequencies.

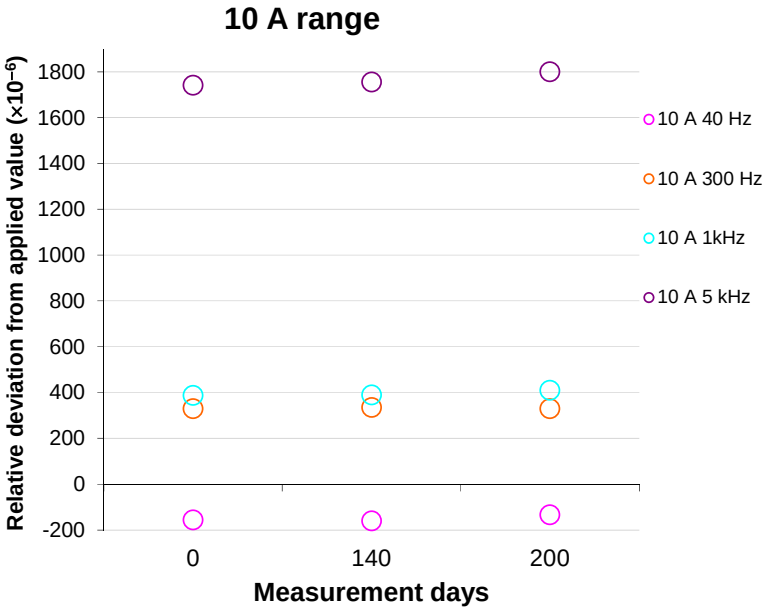

Fig. 29. Relative deviations from applied standard values in the 10 A range at multiple frequencies.

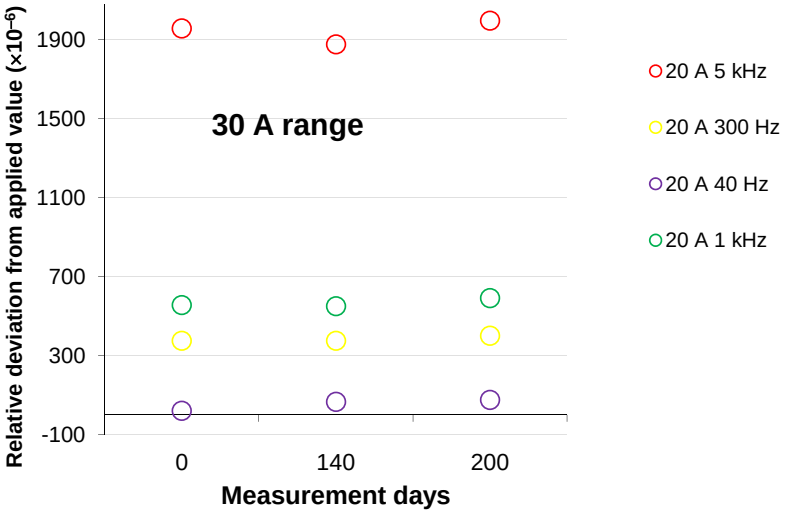

Fig. 30. Relative deviations from applied standard values in the 30 A range at multiple frequencies.

3.5 Results for DC Resistance.

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

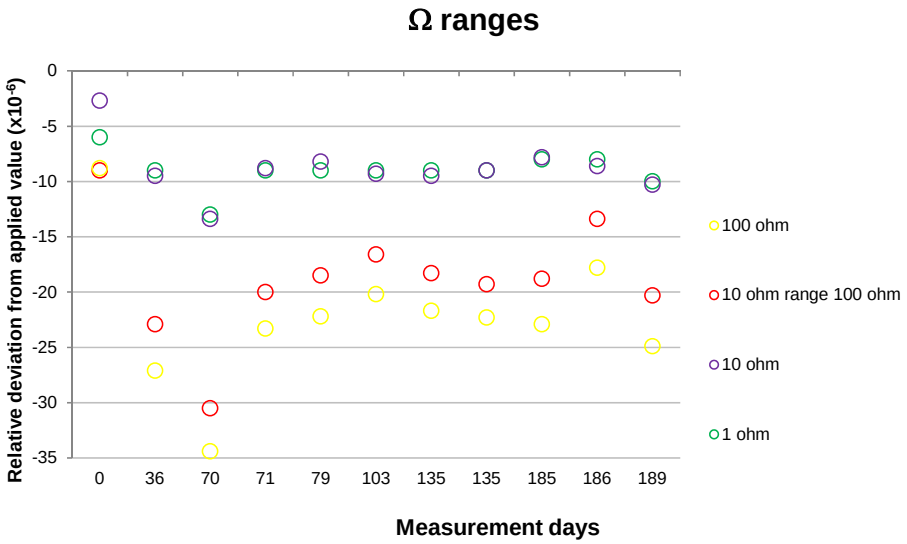

Fig. 31a). Relative deviations from applied standard values in the 1 Ω, 10 Ω and 100 Ω ranges.

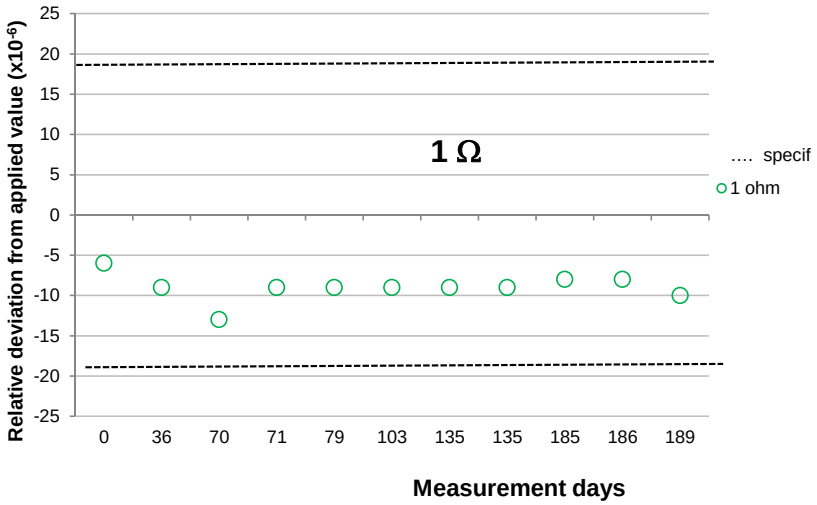

Fig. 31b). Relative deviations from applied standard values at 1 Ω compared with the 180-days DMM specifications.

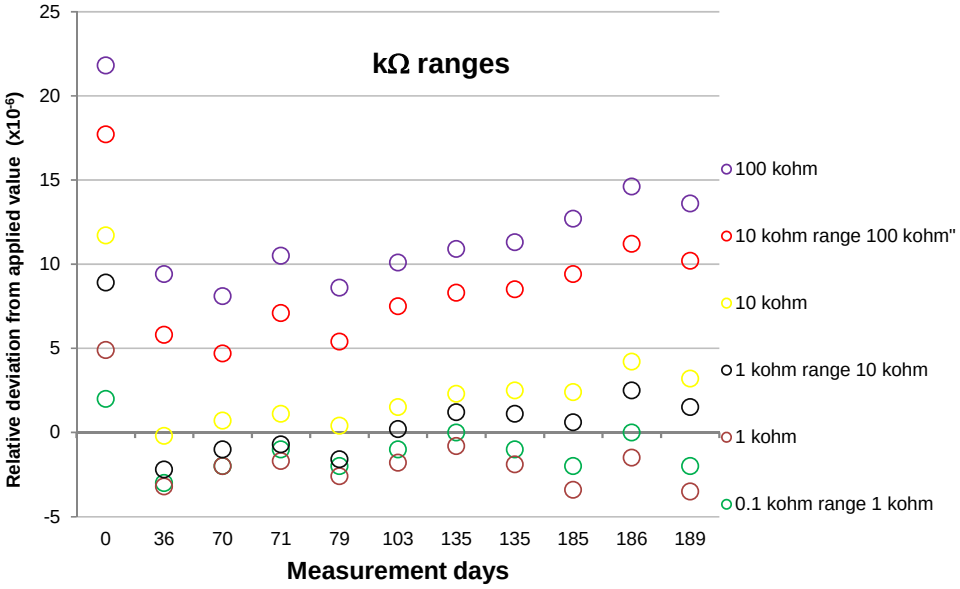

Fig. 32a). Relative deviations from applied standard values in the 1 kΩ, 10 kΩ and 100 kΩ ranges.

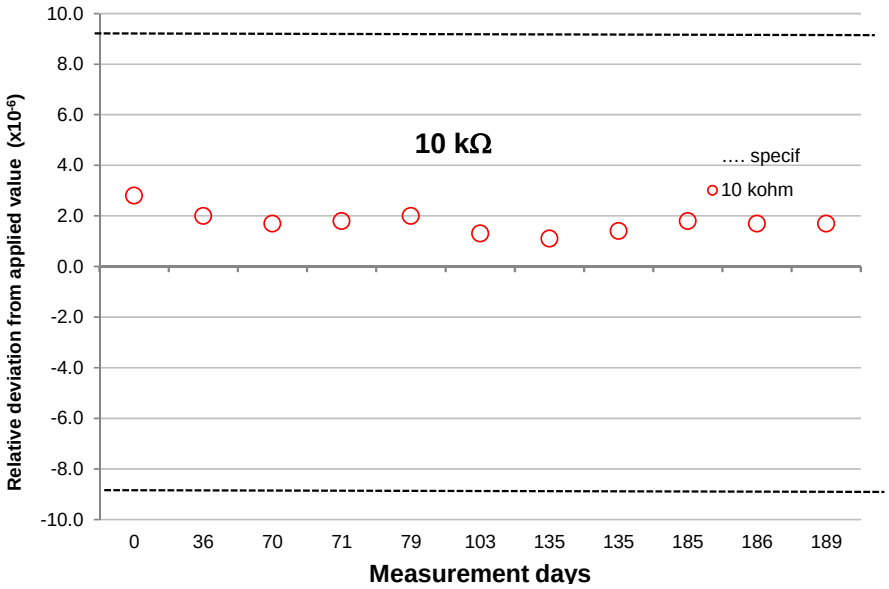

Fig. 32b). Relative deviations from applied standard values at 10 kΩ compared with the 180-days DMM specifications.

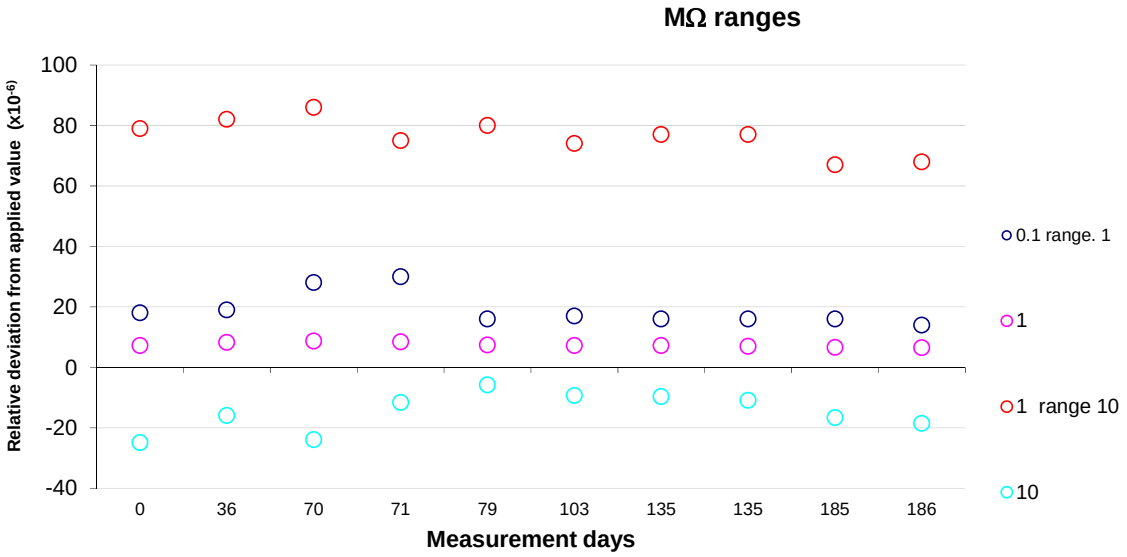

Fig. 33. Relative deviations from applied standard values in the 1 MΩ and 10 MΩ ranges.

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 $\Delta_{(fin\text{-}first)}$, 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:

$$pi = \frac{\Delta_{\max-abs}}{\sqrt{U_{8081}^2 + U_{INRIM}^2}} \qquad (1)$$

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.

range	*Value* (mV)	*freq.*	*180 days spec.* ($\times 10^{-6}$)	$\Delta_{fin-first}$ ($\times 10^{-6}$)	$\Delta_{max-abs}$ ($\times 10^{-6}$)	U_{INRIM} ($\times 10^{-5}$)	*pi*
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] .

range	*Value* (V)	*freq.*	*180 days spec.* ($\times 10^{-6}$)	$\Delta_{fin-first}$ ($\times 10^{-6}$)	$\Delta_{max-abs}$ ($\times 10^{-6}$)	U_{INRIM} ($\times 10^{-6}$)	*pi*
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.

range	*Value* (mV)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-5}$)	$\Delta_{fin-first}$ ($\times 10^{-5}$)	$\Delta_{max-abs}$ ($\times 10^{-5}$)	U_{INRIM} ($\times 10^{-5}$)	*pi*
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

range	*Value* (V)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-5}$)	$\Delta_{fin-first}$ ($\times 10^{-5}$)	$\Delta_{max-abs}$ ($\times 10^{-5}$)	U_{INRIM} ($\times 10^{-5}$)	*pi*
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

range	*Value* (V)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-5}$)	$\Delta_{fin-first}$ ($\times 10^{-5}$)	$\Delta_{max-abs}$ ($\times 10^{-5}$)	U_{INRIM} ($\times 10^{-5}$)	*pi*
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.

range	*Value* (μA)	*freq.* (kHz)	*180 days spec.* ($\times10^{-5}$)	$\Delta_{fin-first}$ ($\times10^{-5}$)	$\Delta_{max-abs}$ ($\times10^{-5}$)	U_{INRIM} ($\times10^{-5}$)	*pi*
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		($\times10^{-6}$)	($\times10^{-6}$)	($\times10^{-6}$)	($\times10^{-6}$)	
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 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.

range	*Value* (A)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-6}$)	$\Delta_{fin\text{-}first}$ ($\times 10^{-6}$)	$\Delta_{max\text{-}abs}$ ($\times 10^{-6}$)	U_{INRIM} ($\times 10^{-6}$)	*pi*
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.

range	*Value* (μA)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-4}$)	$\Delta_{fin\text{-}first}$ ($\times 10^{-4}$)	$\Delta_{max\text{-}abs}$ ($\times 10^{-4}$)	U_{INRIM} ($\times 10^{-4}$)	*pi*
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

range	*Value* (A)	*freq.* (kHz)	*180 days spec.* ($\times 10^{-5}$)	$\Delta_{fin-first}$ ($\times 10^{-5}$)	$\Delta_{max-abs}$ ($\times 10^{-5}$)	U_{INRIM} ($\times 10^{-5}$)	*pi*
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)		($\times 10^{-6}$)	($\times 10^{-6}$)	($\times 10^{-6}$)	($\times 10^{-6}$)	
	10	0.04	1120	–22	160	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]
30 A	(A)		($\times 10^{-6}$)	($\times 10^{-6}$)	($\times 10^{-6}$)	($\times 10^{-6}$)	
	20	0.04	1320	–55	75	300	0.1
	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.

Range (Ω)	*Value* (Ω)	*freq.*	*180 days spec.* ($\times 10^{-6}$)	$\Delta_{fin-first}$ ($\times 10^{-6}$)	$\Delta_{max-abs}$ ($\times 10^{-6}$)	U_{INRIM} ($\times 10^{-6}$)	*pi*
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
(kΩ)	(kΩ)						
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
(MΩ)	(MΩ)						
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 TRANSILLE 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	7000	+	80
100nA	120.000,0	0.1pA	Virtual Ground	1440	+	34	1620	+	34	1800	+	34	2520	+	34
1uA	1.200,000	1pA	Virtual Ground	160	+	17	180	+	17	200	+	17	280	+	17
10uA	12,000,00	10pA	Virtual Ground	24	+	10	27	+	10	30	+	10	42	+	10
100uA	120,000,00	10pA	10 kOhms	5.5	+	4	6	+	4	7	+	4	10	+	4
1mA	1.200,000,0	100pA	1 kOhms	5.5	+	4	6	+	4	7	+	4	10	+	4
10mA	12.000,000	1nA	100 Ohms	7.2	+	4	8.1	+	4	9	+	4	13	+	4
100mA	120,000,00	10nA	10 Ohms	24	+	6	27	+	6	30	+	6	42	+	6
1A	1.200,000,0	100nA	0.5 Ohms	120	+	13	135	+	13	150	+	13	210	+	13
10A	12.000,000	1uA	10 mOhms	290	+	35	320	+	35	360	+	35	500	+	35
30A	30.500,00	10uA	10 mOhms	390	+	145	440	+	145	490	+	145	690	+	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 Impedence	Frequency	90 Day			180 Day			1 Year			2 Year		
					± (% 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	0.070	+	0.015
				40Hz to 200Hz	0.017	+	0.009	0.019	+	0.009	0.021	+	0.009	0.029	+	0.009
				200Hz to 1KHz	0.014	+	0.008	0.015	+	0.008	0.017	+	0.008	0.024	+	0.008
				1kHz to 2kHz	0.014	+	0.008	0.015	+	0.008	0.017	+	0.008	0.024	+	0.008
				2kHz to 20kHz	0.020	+	0.01	0.023	+	0.01	0.025	+	0.010	0.035	+	0.010
				20kHz to 100kHz	0.048	+	0.05	0.054	+	0.05	0.06	+	0.050	0.080	+	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	0.060	+	0.015
10V *	10.500,00	10uV	>1 GOhm / 90pF	40Hz to 200Hz	0.015	+	0.006	0.017	+	0.006	0.019	+	0.006	0.027	+	0.006
				200Hz to 1KHz	0.012	+	0.006	0.014	+	0.006	0.015	+	0.006	0.021	+	0.006
				1KHz to 2KHz	0.012	+	0.006	0.014	+	0.006	0.015	+	0.006	0.021	+	0.006
				2kHz to 20kHz	0.020	+	0.01	0.023	+	0.01	0.025	+	0.010	0.035	+	0.010
				20kHz to 100kHz	0.048	+	0.05	0.054	+	0.05	0.06	+	0.050	0.084	+	0.050
				100kHz to 1MHz*	0.800	+	2.5	0.900	+	2.5	1	+	2.5	1.400	+	2.5
100V	105.000,0	100uV	1 MOhm / 130pF	10Hz to 40Hz	0.040	+	0.015	0.045	+	0.015	0.05	+	0.015	0.070	+	0.015
1000V *	1050.000	1mV	1 MOhm / 130pF	40Hz to 200Hz	0.015	+	0.009	0.018	+	0.009	0.02	+	0.009	0.028	+	0.009
				200Hz to 1kHz	0.014	+	0.007	0.016	+	0.007	0.018	+	0.007	0.025	+	0.007
				1kHz to 2kHz	0.014	+	0.007	0.016	+	0.007	0.018	+	0.007	0.025	+	0.007
				2kHz to 20kHz	0.024	+	0.01	0.027	+	0.01	0.03	+	0.010	0.042	+	0.010
				20kHz to 50kHz	0.064	+	0.05	0.072	+	0.05	0.08	+	0.050	0.112	+	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
10V *	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
	100kHz to 1MHz*	1.16	+	2.5	1.56	+	2.5
100V	10Hz to 40Hz	0.07	+	0.015	0.08	+	0.015
1000V *	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	0.07 + 0.015
1mA	1.050,000	1nA	1 kOhm	40Hz to 1kHz	0.024 + 0.012	0.027 + 0.012	0.03 + 0.012	0.042 + 0.012
10mA	10.500,00	10nA	100 Ohms	1KHz to 10kHz	0.056 + 0.030	0.063 + 0.030	0.07 + 0.030	0.098 + 0.030
100mA	105.000,0	100nA	10 Ohms					
1A	1.050,000	1uA	0.5 Ohms	10Hz to 40Hz	0.048 + 0.020	0.054 + 0.020	0.06 + 0.020	0.084 + 0.020
				40Hz to 1kHz	0.032 + 0.015	0.036 + 0.015	0.04 + 0.015	0.056 + 0.015
				1KHz to 10kHz	0.056 + 0.050	0.063 + 0.050	0.07 + 0.050	0.098 + 0.050
10A	10.500,00	10uA	10 mOhms	10Hz to 40Hz	0.064 + 0.040	0.072 + 0.040	0.08 + 0.040	0.112 + 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	0.09 + 0.015
1mA	40Hz to 1kHz	0.04 + 0.012	0.05 + 0.012
10mA	1kHz to 10kHz	0.09 + 0.03	0.12 + 0.03
100mA			
1A	10Hz to 40Hz	0.09 + 0.02	0.11 + 0.02
	40Hz to 1kHz	0.06 + 0.015	0.07 + 0.015
	1kHz to 10kHz	0.10 + 0.05	0.13 + 0.05
10A	10Hz to 40Hz	0.14 + 0.04	0.16 + 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	Measurment 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	21.0	+	6.0
10 Ohm	12.000,000,0	0.1 uOhm	10mA	8.0	+	3.0	9.0	+	3.0	10.0	+	3.0	14.0	+	3.0
100 Ohm	120.000,000	1 uOhm	10mA	7.0	+	1.0	8.0	+	1.0	9.0	+	1.0	13.0	+	1.0
100 Ohm Low Current	120.000,000	1 uOhm	1mA	8.0	+	7.0	9.0	+	7.0	10.0	+	7.0	14.0	+	7.0
1 kOhm	1.200,000,00	10 uOhms	10mA	6.5	+	0.8	7.0	+	0.8	8.0	+	0.8	11.0	+	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	12.0	+	3.0
10 kOhm	12.000,000,0	100 uOhms	1mA	7.5	+	0.8	8.5	+	0.8	9.5	+	0.8	13.0	+	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	14.0	+	8.0
100 kOhm	120.000,000	1 mOhms	100uA	8.0	+	0.8	9.0	+	0.8	10.0	+	0.8	14.0	+	0.8
1 MOhm*	1.200,000,00	10 mOhms	10uA	9.0	+	2.0	10.0	+	2.0	11.0	+	2.0	15.0	+	2.0
10 MOhm*	12.000,000,0	100 mOhms	1uA	12.0	+	8.0	13.5	+	8.0	15.0	+	8.0	21.0	+	8.0

Absolute Uncertainty (95% Confidence)

Range	1 Year					
	Tcal ± 1°C			Tcal ± 3°C		
	± (ppm Reading + ppm Range)					
1 Ohm	17.6	+	6	23.5	+	6
10 Ohm	11.9	+	3	15.8	+	3
100 Ohm	10.6	+	1.0	14.1	+	1
100 Ohm Low Current	11.7	+	7	15.7	+	7
1 kOhm	9.4	+	0.8	12.5	+	0.8
1 kOhm Low Current	10.5	+	3	14.1	+	3
10 kOhm	11.1	+	0.8	14.9	+	0.8
10 kOhm Low Current	12.2	+	8	16.4	+	8
100 kOhm	11.8	+	8	15.7	+	8
1 MOhm *	14.1	+	2	18.2	+	2
10 MOhm*	18.0	+	8	23.9	+	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					
	1uA	8M Ohm - 90 Mohm					
	100nA	80 Mohm - 900 Mohm					
	10nA	800 Mohm - 1TOhm					
50V	10uA	5M Ohm - 45 MOhm	10 Ohm	112	126	140	196
	1uA	40M Ohm - 450 Mohm	100 Ohm	360	405	450	630
	100nA	400 Mohm - 4.5GOhm	1kOhm	1440	1620	1800	2520
	10nA	4 Gohm - 1TOhm	100kOhm	18400	20700	23000	32200
100V	10uA	8M Ohm - 90 Mohm	10 Ohm	112	126	140	196
	1uA	80 Mohm - 900 Mohm	100 Ohm	332.8	374.4	416	582.4
	100nA	800Mohm - 9GOhm	1kOhm	1448	1629	1810	2534
	10nA	8GOhm - 2TOhm	100kOhm	18400	20700	23000	32200
150V	10uA	12M Ohm - 135 MOhm	10 Ohm	108	121.5	135	189
	1uA	120M Ohm - 1350 Mohm	100 Ohm	368	414	460	644
	100nA	1200 Mohm - 13.5GOhm	1kOhm	1520	1710	1900	2660
	10nA	12 Gohm - 2TOhm	100kOhm	14134	15900	17667	24734
200V	10uA	20M Ohm - 180 MOhm	10 Ohm	108	121.5	135	189
	1uA	160M Ohm - 1800 Mohm	100 Ohm	344	387	430	602
	100nA	1600 Mohm - 18GOhm	1kOhm	1448	1629	1810	2534
	10nA	16 Gohm - 2TOhm	100kOhm	12000	13500	15000	21000
250V	10uA	25M Ohm - 225 MOhm	10 Ohm	105.6	118.8	132	184.8
	1uA	200M Ohm - 2250 Mohm	100 Ohm	344	387	430	602
	100nA	2000 Mohm - 22.5GOhm	1kOhm	1448	1629	1810	2534
	10nA	20 Gohm - 2TOhm	100kOhm	10720	12060	13400	18760
300V	10uA	30M Ohm - 270 MOhm	10 Ohm	105.6	118.8	132	184.8
	1uA	240M Ohm - 2700 Mohm	100 Ohm	332	373.5	415	581
	100nA	2400 Mohm - 27GOhm	1kOhm	1448	1629	1810	2534
	10nA	24 Gohm - 2TOhm	100kOhm	9840	11070	12300	17220

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

Annex 3: Measurement results for DC Voltage.

		measurement days										
(mV)	Portata	**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
(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
		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
		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
		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)	(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
1.00000	**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	-9	-8	-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	-18	-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	0	1	1	0
600.00	1		-14	-12	-12	-10	-10	-10	-10	-10	-9	-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	-7	-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	166	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**)	(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**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(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	19	18	19

Annex 6: Measurement results for AC Current.

			measurement days										
Valore	f		**0**	**36**	**70**	**71**	**79**	**103**	**135**	**135**	**185**	**186**	**189**
(mA)	(kHz)	(mA)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(10-**4**)	(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	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**)
10.0000	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**)
			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	-3	-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**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(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**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(10-**6**)	(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
(MΩ)	(MΩ)	**0**	**36**	**70**	**71**	**79**	**103**	**135**	**135**	**185**	**186**	**189**
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		(10^{-6})	(10^{-6})	(10^{-6})
(kHz)	**port 10 A**	**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		(10^{-6})	(10^{-6})	(10^{-6})
(kHz)		**0**	**140**	**200**
0,04	20	20	65	75
0,3		375	375	400
1		555	550	590
5		1955	1875	1995