Final Report

SIM.EM-S13

Voltage, Current and Resistance Comparison

March 2017 – September 2021

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Abstract

This is a report of the results of the third Inter-American Metrology System (SIM) comparison on the calibration of digital multimeters, performed for strengthening the interaction among National Metrology Institutes (NMIs) and for establishing the degree of equivalence between those laboratories in accordance with the CIPM Mutual Recognition Arrangement. From March 2017 to December 2019, two multimeters were used as travelling standards for measurements in thirteen countries, with ICE-Costa Rica and INTI-Argentina acting as the pilot laboratories. Results of each participant are presented as errors relative to a comparison reference value together with their measurement uncertainty.

Index Terms — Comparison, multimeter, measurement error, error mean value, measurement uncertainty.

1. Introduction

In order to strengthen the Inter-American Metrology System (SIM), interaction among its National Metrology Institutes (NMIs) is promoted. At the same time, in accordance with CIPM Mutual Recognition Arrangement (MRA) objectives, NMIs establish the degree of equivalence between their national measurement standards by performing regional comparisons, among other activities.

The objective of this comparison, registered as SIM.EM-S13, was to compare the measurement capabilities of NMIs in SIM and determine the degree of equivalence between laboratories in the areas of dc and ac voltage and current, and dc resistance.

This was an ongoing repetition of SIM.EM-S5.

2. Travelling standards and quantities

2.1. Travelling standards

The following is the detailed description of the travelling standards. Digital multimeters (DMM) were used.

Description:	Digital multimeter
Manufacturer:	Hewlett Packard
Model:	3458A
Serial Number:	2823A15147

Description:	Digital multimeter
Manufacturer:	Hewlett Packard
Model:	3458A
Serial Number:	2823A15128

2.2. Quantities measured

Table 1. Measurement points in DMM comparison

Test Nº	Quantity	Test value	Test frequency	Recommended settling time
1	DC Voltage	100 mV	DC	30 min
2		10 V		5 min
3		100 V		15 min
4	DC Current	10 mA	DC	5 min
5		1 A		30 min
6	Resistance	10 Ω	DC	10 min
7		10 MΩ		10 min
8	AC Voltage	1 V	55 Hz	5 min
9		1 V	1 kHz	5 min
10		100 V	55 Hz	5 min
11		100 V	1 kHz	5 min
12	AC Current	10 mA	55 Hz	5 min
13		10 mA	1 kHz	5 min
14		1 A	55 Hz	20 min
15		1 A	1 kHz	20 min

3. Organization

3.1. Coordinator and members of the review committee

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Due to the large number of participants in this comparison, it was decided to form 2 loops. In one of them the NMI of Central America were grouped and in another the NMI of South America. The pilot laboratory for the first loop was the Laboratorio Metrológico de Variables Eléctricas - ICE – Costa Rica, for the second loop the pilot laboratory was the Instituto Nacional de Tecnologia Industrial – INTI - Argentina. At the beginning of each loop the travelling standards were tested, one at ICE and one at INTI then dispatched from ICE or INTI to the next participant according to Table 2

3.2. Transportation

It was proposed to use courier services. When possible, hand carrying was an option. The travelling standards were shipped in properly padded containers.

Each participating laboratory covered the costs of customs clearance, and shipment to the next laboratory. Customs procedures in some countries in the Americas are one of the most difficult problems for SIM comparisons.

3.3. Participants and time Schedule

In order to complete the comparison within a reasonable period of time, six weeks were proposed for each participant; this time included clearing customs, receiving, unpacking, preparing, making measurements, analyzing data, repeat testing if necessary, and shipping to the next laboratory. Registration of this comparison in the BIPM database included a proposal for measurements during 2017 and finished in 2018. Unfortunately, customs procedures delayed many of the participants.

Saudi Standards, Metrology and Quality Organization/National Measurement and Calibration Center (SASO) was added to this supplementary comparison.

Table 2. Participants, DMMs, dates, codes.

Loop 1	Hewlett Packard 3458A S.N. 2823A15147		
Country	NMI	Measurement period	Code
Costa Rica	ICE	9 March 2017 - 23 March 2017	CR
México	CENAM	28 April 2017 - 17 May 2017	MX
Panamá	CENAMEP	12 June 2017 - 21 June 2017	PA
Colombia	INM	2 August 2017 - 11 August 2017	CO
Bolivia	IBMETRO	25 Oct 2017 - 3 Nov 2017	BO
Trinidad & Tobago	TTBS	4 Jan 2018 - 10 Jan 2018	TT
Saudi Arabia	SASO	1 April 2018 - 8 April 2018	SA
Loop 2	Hewlett Packard 3458A S.N. 2823A15128		
Country	NMI	Measurement period	Code
Argentina	INTI	7 March 2017 - 28 March 2017	AR
Brazil	INMETRO	9 June 2017 - 6 July 2017	BR
Paraguay	INTN	24 Oct 2017 - 9 Nov 2017	PY
Perú	INACAL	25 June 2018 - 3 July 2018	PE
Chile	LCPN ME	4 Jan 2019 - 18 Jan 2019	CH
Uruguay	UTE	1 March 2019 - 9 March 2019	UR
México	CENAM	7 Nov 2019 - 2 Dec 2019	MX

4. Measurement

4.1. Measurement instructions

It was recommended to inspect and report to the pilot laboratory and coordinator any abnormal condition of the travelling standard.

It was recommended to perform at least 5 independent measurements at each test point and report the mean relative error of the travelling standard in parts in $10^{6.}$ Measurements made on separate days were considered independent. Therefore, it was possible to complete the 5 sets of measurements in one week.

The relative error was defined by the following:

relative error = (measured value – reference value)/ reference value.

Then the error mean value (E_i) reported by each participant is the average of the relative error measured during the measurement period.

To avoid differences due to different configurations of the same travelling standards the following instructions were agreed upon when a multi-function calibrator (MFC) was used as a reference.

General instructions:

- Proceed to clean the air filter of the digital multimeter (DMM) when necessary.
- Energize both the HP3458A and the MFC for at least 8 hours before the test.
- Use only the front panel input terminals.
- Use the two tilt stands that allow elevating the front of the DMM for proper ventilation.
- Be sure that the internal temperature (TEMP? command) of the DMM be within ±5 °C of the adjustment temperature (CAL 59? and CAL 60?) before making measurements.
- Disconnect all inputs and perform the HP3458A ACAL ALL before starting each set of independent measurements.
- Record the internal DMM temperature of ACAL ALL (Ta) and be sure to keep it within Ta ± 1 °C during the entire calibration.
- For each measuring function, RESET the HP3458A, perform the corresponding ACAL and set the appropriate configuration listed in table 3.
- Set the HP3458A amplitude range for each test point.
- Do not perform CAL 0 command or any other CAL (calibration) command.
- Use appropriate cable for DCV measurement (low FEM and shielded).
- Use appropriate cable for DCI measurement (low FEM and shielded for 10 mA, and Fluke unshielded, 30 Amps rating for 1 A or similar).
- Use appropriate cable for Resistance measurement (Four wires, shielded).
- Use appropriate cable for ACV measurement (Coaxial, short length approx. 60 cm).
- Use appropriate cable for ACI measurement (Coaxial, short length approx. 60 cm for 10 mA, and Fluke unshielded, 30 Amps rating for 1 A or similar).
- Make sure the readings have stabilized, waiting the recommended settling time before recording data.
- Record the internal temperature of the DMM (TEMP?) at the beginning and at the end of the measurements for each calibration point.

Table 3. Setup and DMM configuration

DC Voltage	Connect the DMM to the MFC as shown in the MFC manual. HP3458A: RESET, DCV function, appropriated range, shield cable to Guard input terminal of the DMM and the other end to the Low/ Guard/ Gnd of the MFC as appropriate. GUARD to LOW switch: OPEN. NPLC: 200 NDIG: 8
DC Current	Connect the DMM to the MFC as shown in the MFC manual. HP3458A: RESET, DCI function, appropriated range, shield cable to Guard input terminal of the DMM and the other end to the Low/ Guard/ Gnd of the MFC as appropriate. GUARD to LOW switch: OPEN for 10 mA, shielded cables. GUARD to LOW switch: PRESSED for 1 A, unshielded cables. NPLC: 200 NDIG: 8
DC Resistance	Connections as shown in the MFC manual. HP3458A: RESET, OHMF (4 wires) function, appropriated range, shield cable to Guard input terminal of the DMM and the other end to the Low/ Guard/ Gnd of the MFC as appropriate. GUARD to LOW switch: OPEN. OCOMP: ON (only for 10 ohms measurement)

	DELAY: 1s NPLC: 200
AC Voltage	Connections as shown in the MFC manual. HP3458A: RESET, ACV function, appropriated range. GUARD to LOW switch: PRESSED. SET ACV: SYNC RES: 0.002 LFILTER: ON ACBAND: 45, 65 for 55 Hz; 900, 1100 for 1 kHz
AC Current	Connections as shown in the MFC manual. HP3458A: RESET, ACI function, appropriated range. GUARD to LOW switch: PRESSED. NPLC: 200 ACBAND: 45, 65 for 55 Hz; 900, 1100 for 1 kHz

4.2. Measurement methods

The following table summarize the methods used by the participants and their traceability.

Table 4 Summary of methods, reference standards and traceability of participants

Loop 1		
NMI	**Measurement method**	**Traceability**
ICE	Direct comparison against a multifunction calibrator.	METAS
CENAM	Direct comparison against a multifunction calibrator and standard resistors.	In-house
CENAMEP	Direct comparison using a multifunction calibrator, a voltage source (Zener) and 10 MΩ resistor	CENAM, INTI
INM	Direct comparison using a multifunction calibrator and standard resistors. For DCI, the travelling standard, a current source and a standard resistor were connected in series and the reference current was calculated by Ohm's law, measuring the voltage drop across the standard resistor with a reference digital multimeter.	CENAM BIPM for Resistance
IBMETRO	For Voltage and Current, substitution method, using as reference a digital multimeter For Resistance direct comparison against resistors	UKAS CALIBRATION UKAS CALIBRATION
TTBS	Direct comparison against a multifunction calibrator	Fluke USA
SASO-NMCC	Direct comparison against a multifunction calibrator	Tubitak UME

Table 4 (continuation) Summary of methods, reference standards and traceability of participants

Loop 2		
INTI	Direct comparison against a multifunction calibrator and standard resistors.	In-house
INMETRO	Direct comparison against a multifunction calibrator and standard resistors.	In-house
INTN	Substitution method, using as reference standard a digital multimeter	INMETRO
INACAL	Direct comparison against a multifunction calibrator	NPL, through an accredited laboratory
LCPN ME	Direct comparison against a multifunction calibrator and standard resistors.	In house with traceability to PTB /CENAM CENAM - DCV PTB - other quantities
UTE	Direct comparison against a standard resistor.	BIPM
CENAM	Direct comparison against a multifunction calibrator and standard resistors.	In-house

INTI, INMETRO and CENAM obtained traceability for their calibrator and resistors from quantum experiments performed in-house, so the values of the reference laboratories are not correlated.

5. Measurement report

Participants were required to report:

- Description of the measuring method.
- Connection diagrams.
- The environmental conditions of the measurement: the temperature and the humidity with limits of variation.
- Date of measurements.
- The reference standard and its traceability to the SI.
- The results of the measurements.
- The associated standard uncertainties and the expanded uncertainties.
- Uncertainty budget, the uncertainty calculation complying with the requirements of the GUM [2], including standard uncertainties, degrees of freedom, correlations, combined and expanded uncertainty. A spreadsheet format was provided for homogeneous reporting.

6. Unexpected incidents

In the loop 1, INM and CENAM reported unstable behavior of the travelling standard in the resistance function. The travelling standard was the DMM with serial number 2823A15147. The resistance measurement points were withdrawn, more details are given in Appendix 1.

In the loop 2, the travelling standard presented a linear trend in the resistance and dc current functions. The travelling standard was DMM with serial number 2823A15128. More details are given in Appendix 2.

7. Report of the comparison

Two digital multimeters (DMM) were used as travelling standards. The participating NMIs were divided into two loops. For each loop only one travelling standard was allocated. Each i^{th} participant was asked to report the measurements done in a time period, denoted as: Error mean value (E_i), for each one of the fifteen test points.

In loop 2 the comparison reference values (CRV) were obtained as the weighted mean of INTI, INMETRO and CENAM values.

In loop 1 the CRV were the values from CENAM corrected with the degree of equivalence of CENAM in loop 2. Thus, the results of the participants from loop 1 are linked to the reference value of loop 2.

The results of the SIM.EM-S13 regional supplementary comparison are presented in table format in Appendix 1. The analysis of the CRV and the degree of equivalence of the national measurement standards with respect to the CRV are presented in Appendix 2. The participant's reports are presented in Appendix 4.

8. Conclusions

Thirteen NMIs participated in the comparison, in general there is good agreement between the results of most participants.

In loop 1, 2 out of 15 measurements points of CR were not equivalent with the CRV. Corrective actions were performed after the submission of Draft A, the results are indicated in Appendix 3.

In loop 2, 5 out of 11 measurements points of PY were not equivalent with the CRV and 6 out of 15 measurements points of PE were not equivalent with the CRV.

Regarding the resistance measurement points withdrawn in loop 1, a comparison of resistance will be planned in such region. A different travelling standard could be provided by CENAM. This topic will be discussed in the next SIM meeting.

9. References

[1] CIPM MRA-D-05 Measurement comparisons in the CIPM MRA Version 1.5 March 2014

[2] JCGM 100:2008, GUM 1995 with minor corrections, Evaluation of measurement data – Guide to the expression of the uncertainty in measurement, First edition September 2008, ©JCGM 2008

[3] Cox, M. G. The evaluation of key comparison data, 2002, Metrologia, 39, pp. 589-595.

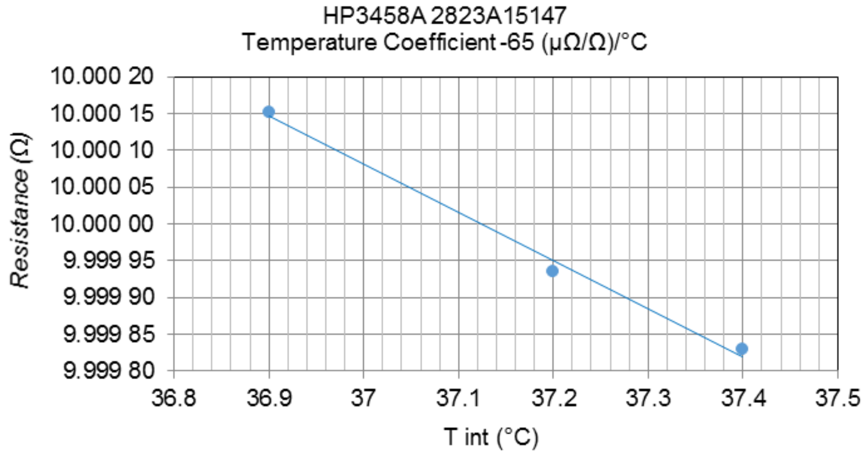
[4] N.F. Zhang, H.-K. Liu, N. Sedransk, and W.E. Strawderman, Statistical analysis of key comparisons with linear trends, Metrologia, 41, pp. 231-237, 2004.

Appendix 1.
Reported Results

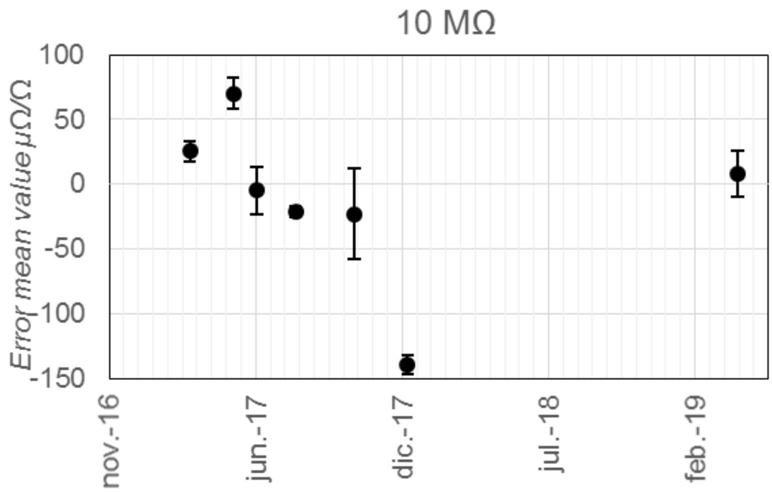
Withdrawn results

For the loop 1, where the travelling standard with serial number 2823A15147 was used, the test points corresponding to 10 Ω and 10 MΩ were withdrawn from the comparison due to an abnormal behavior of the travelling standard. INM and CENAM reported to the pilot laboratory the instability observed during their resistance measurements. At CENAM the test point of 10 Ω presented a standard deviation of 27 µΩ/Ω during the time period of measurements. The travelling standard's 1 year stability given by the manufacturer is 20 µΩ/Ω.

The graph presents the travelling standard's internal temperature during the measurements at 10 Ω.



Concerning 10 MΩ, the results along the different measurement periods were very scattered. Unlike loop 2, where there were three reference laboratories measuring along the whole time period, in loop 1 there was only one reference laboratory. So due to a possible drift of the travelling standard, it was not possible to estimate a reference value. Next graph shows the 10 MΩ measurements of NMIs in loop1.



Loop 1. Reported results

This section summarizes the results reported by the participants. They reported the expanded uncertainty with a coverage factor of k = 2.

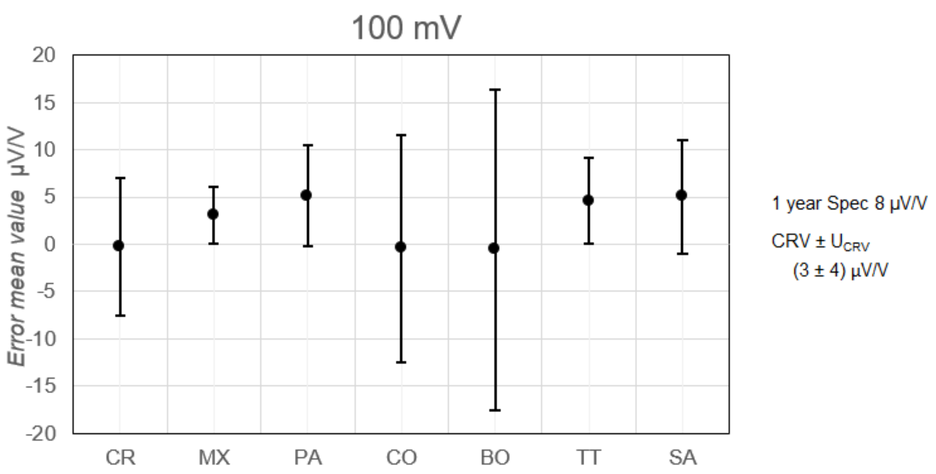
In the graphs, those results that cause the loss of resolution on the "y" axis are not shown, instead only their error and expanded uncertainty, or their expanded uncertainty are shown.

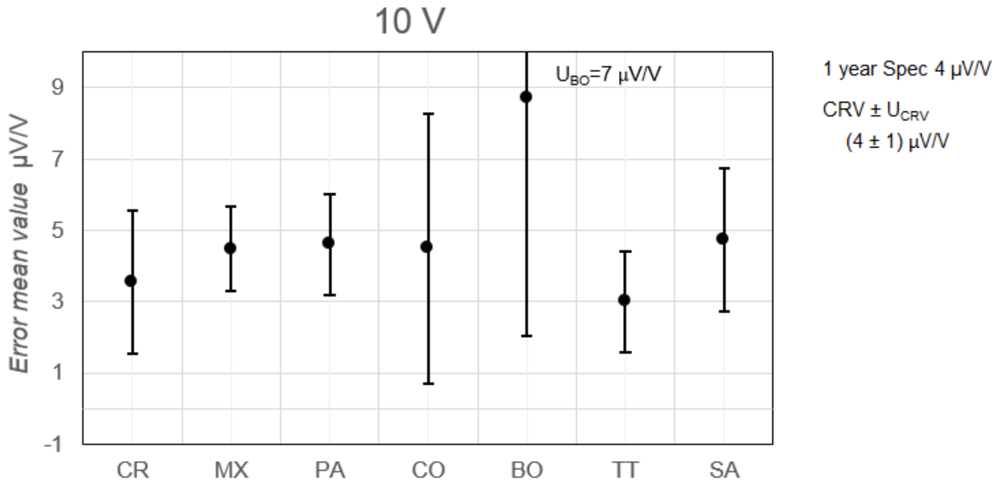
Next to the graphs there is a label indicating the travelling standard's one-year stability, given by the manufacturer, as well as the comparison reference value (CRV) with its associated expanded uncertainty. The evaluation of the CRV will be discussed further in this document.

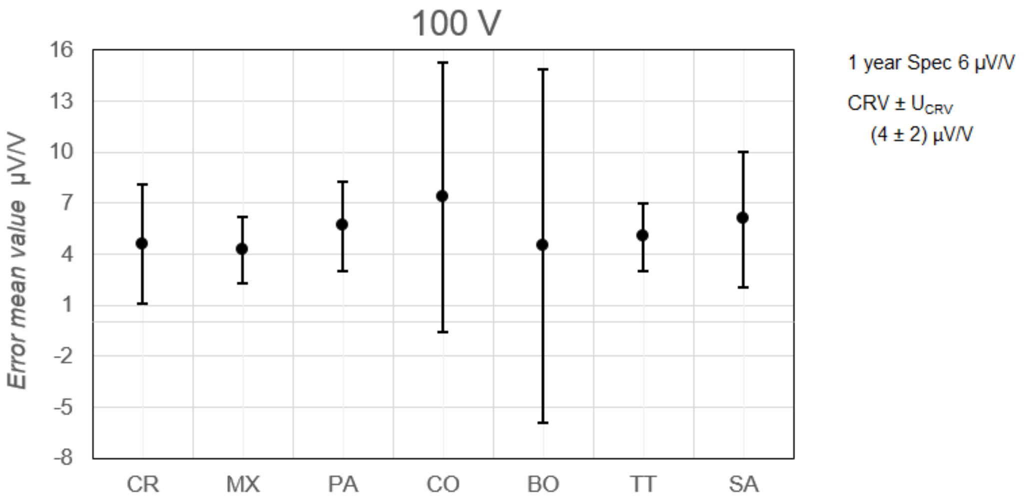
Reported Results Loop 1

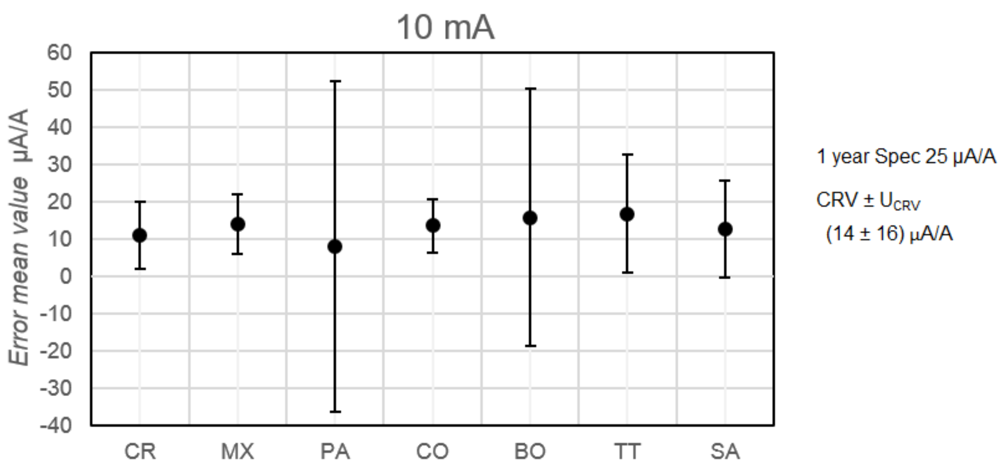
Errors and Uncertainty reported by NMIs. Loop 1																
Test point	Measured value	Units	CR	U_{CR}	MX	U_{MX}	PA	U_{PA}	CO	U_{CO}	BO	U_{BO}	TT	U_{TT}	SA	U_{SA}
1	100 mV	µV/V	0	7	3	3	5	5	0	12	-1	17	5	5	5	6
2	10 V	µV/V	4	2	4	1	5	1	4	4	9	7	3	1	5	2
3	100 V	µV/V	5	3	4	2	6	3	7	8	4	10	5	2	6	4
4	10 mA	µA/A	11	9	14	8	8	44	14	7	16	35	17	16	13	13
5	1 A	µA/A	-44	31	-42	10	-27	91	-52	93	-10	281	-29	39	29	86
8	1 V / 55 Hz	µV/V	-17	32	-16	28	-15	46	-11	52	38	173	-12	28	19	55
9	1 V / 1 kHz	µV/V	-3	15	0	28	-3	53	5	52	10	213	9	24	5	33
10	100 V / 55 Hz	µV/V	-13	36	-4	36	-11	51	-17	63	20	194	-10	21	53	64
11	100 V / 1 kHz	µV/V	-8	22	-1	36	-10	62	-13	63	-18	233	-7	15	14	63
12	10 mA / 55 Hz	µA/A	33	61	49	41	28	157	53	143	59	742	41	61	13	149
13	10 mA / 1 kHz	µA/A	86	56	111	41	83	157	112	143	79	786	132	61	83	149
14	1 A / 55 Hz	µA/A	842	66	4	73	-15	297	-10	289	681	1140	9	104	81	278
15	1 A / 1 kHz	µA/A	419	72	172	72	157	297	156	289	609	1208	205	104	138	278

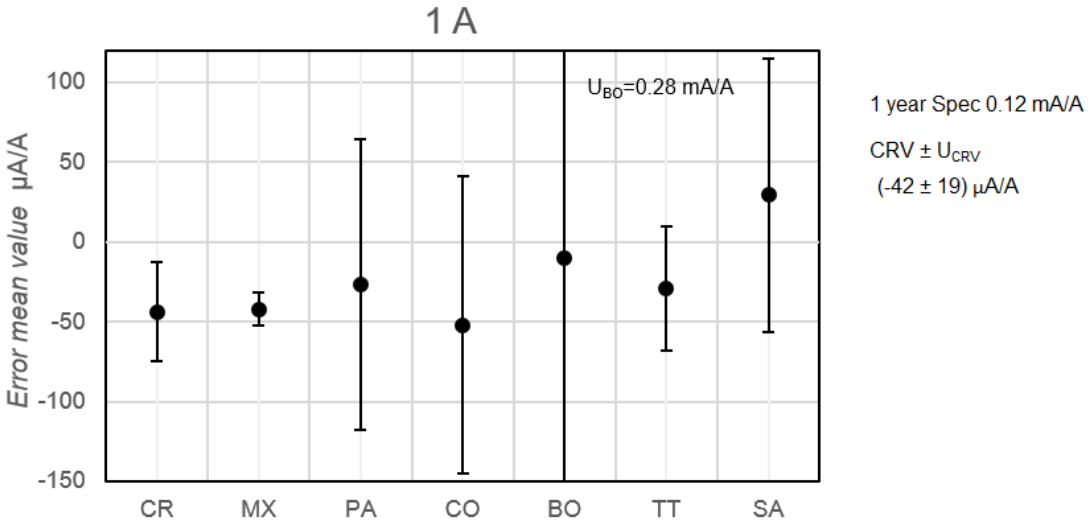
Loop 1. Graphs of reported results

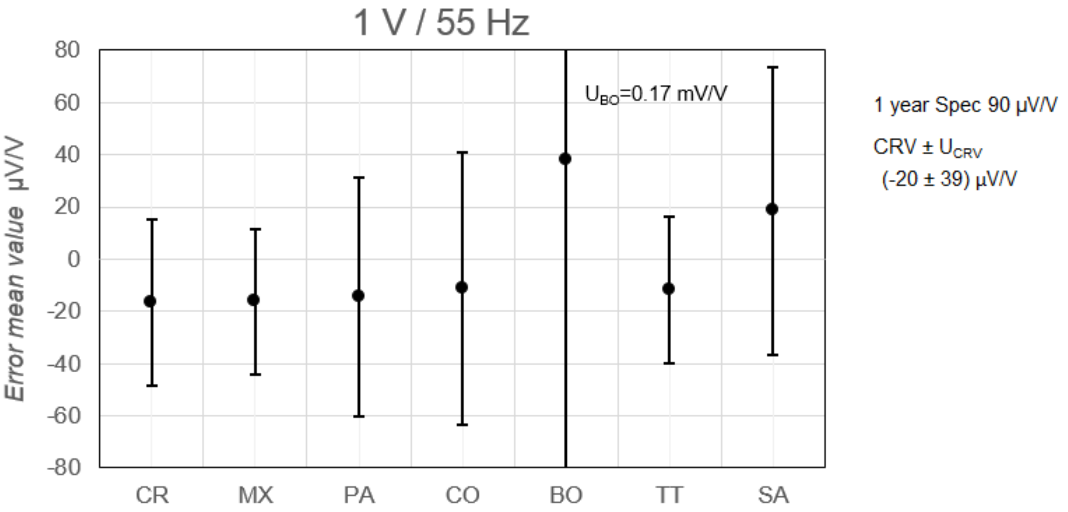


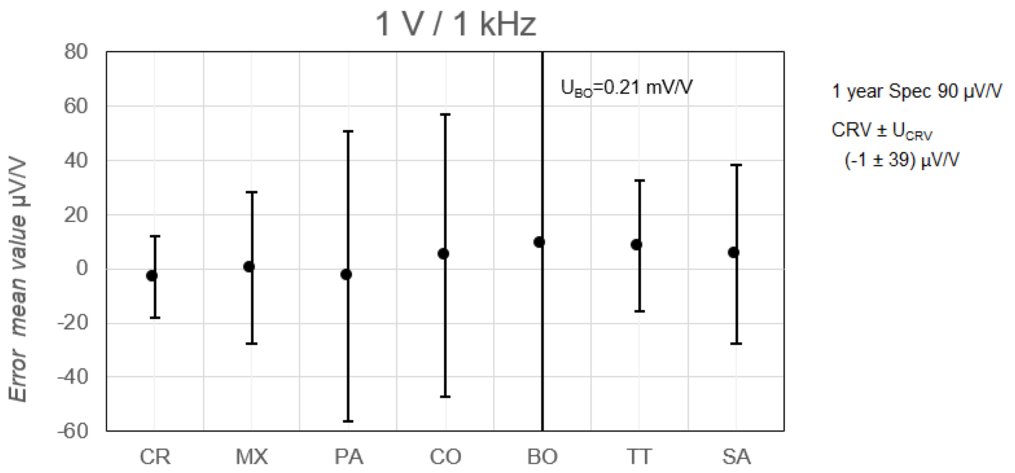

10 V
Error mean value µV/V
UBO=7 µV/V
CR
MX
PA
CO
BO
TT
SA
1 year Spec 4 µV/V
CRV ± UCRV
(4 ± 1) µV/V

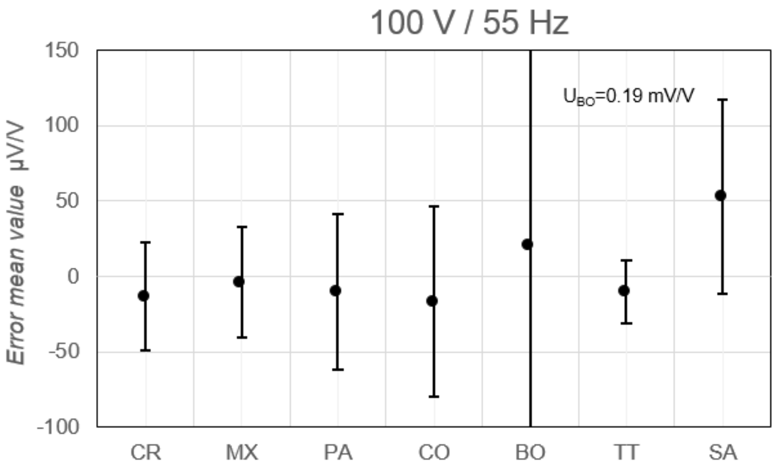

100 V
Error mean value µV/V
CR
MX
PA
CO
BO
TT
SA
1 year Spec 6 µV/V
CRV ± UCRV
(4 ± 2) µV/V


10 mA
Error mean value µA/A
CR
MX
PA
CO
BO
TT
SA
1 year Spec 25 µA/A
CRV ± UCRV
(14 ± 16) µA/A


1 A
Error mean value µA/A
100
50
0
-50
-100
-150
CR
MX
PA
CO
BO
TT
SA
U_{BO}=0.28 mA/A
1 year Spec 0.12 mA/A
CRV ± U_{CRV}
(-42 ± 19) µA/A


1 V / 55 Hz
Error mean value µV/V
80
60
40
20
0
-20
-40
-60
-80
CR
MX
PA
CO
BO
TT
SA
U_{BO}=0.17 mV/V
1 year Spec 90 µV/V
CRV ± U_{CRV}
(-20 ± 39) µV/V

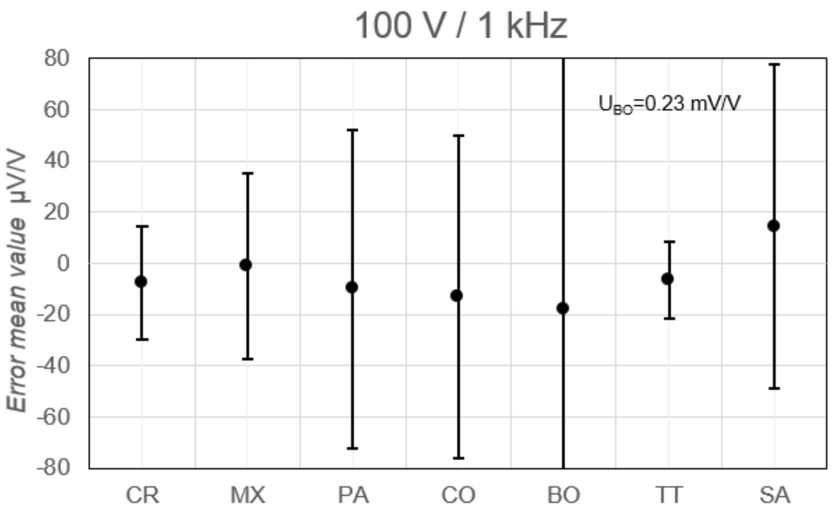

1 V / 1 kHz
Error mean value µV/V
80
60
40
20
0
-20
-40
-60
CR
MX
PA
CO
BO
TT
SA
U_{BO}=0.21 mV/V
1 year Spec 90 µV/V
CRV ± U_{CRV}
(-1 ± 39) µV/V



1 year Spec 0.22 mV/V

CRV ± U_{CRV}

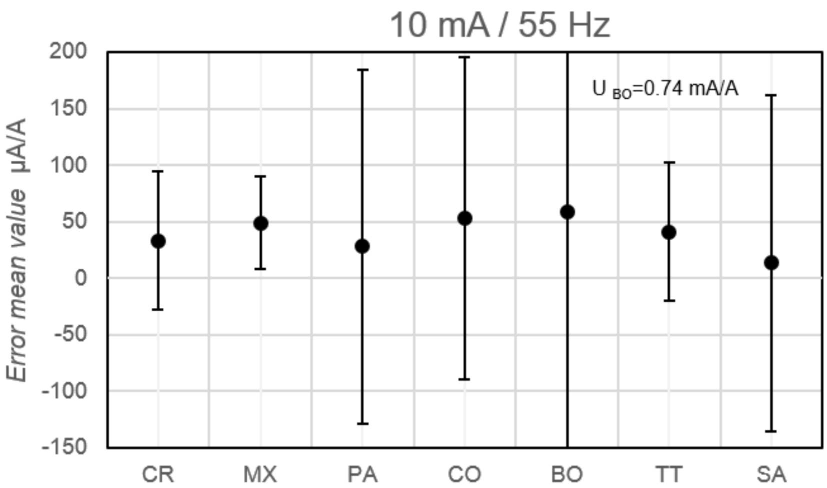
(2 ± 50) µV/V



1 year Spec 0.22 mV/V

CRV ± U_{CRV}

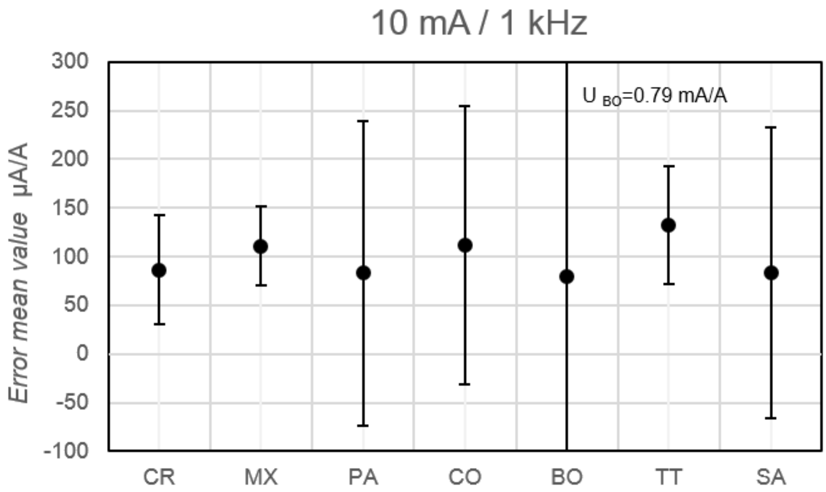
(-4 ± 50) µV/V



1 year Spec 1.6 mA/A

CRV ± U_{CRV}

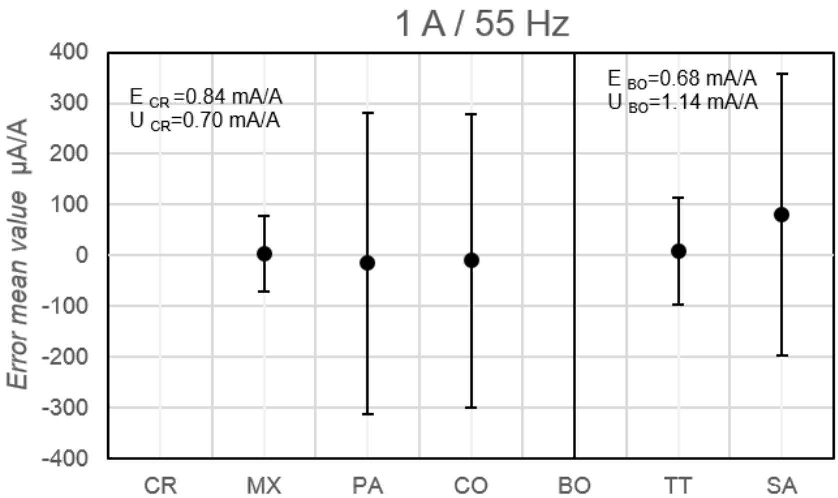
(52 ± 56) µA/A



1 year Spec 1.3 mA/A

CRV ± U_{CRV}

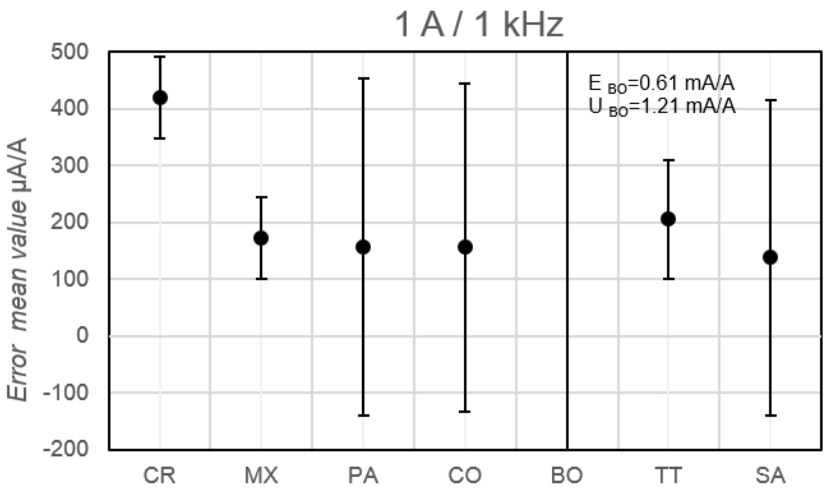
(116 ± 55) µA/A



1 year Spec 1.0 mA/A

CRV ± U_{CRV}

(21 ± 94) µA/A



1 year Spec 1.2 mA/A

CRV ± U_{CRV}

(180 ± 93) µA/A

Loop 2. Reported results

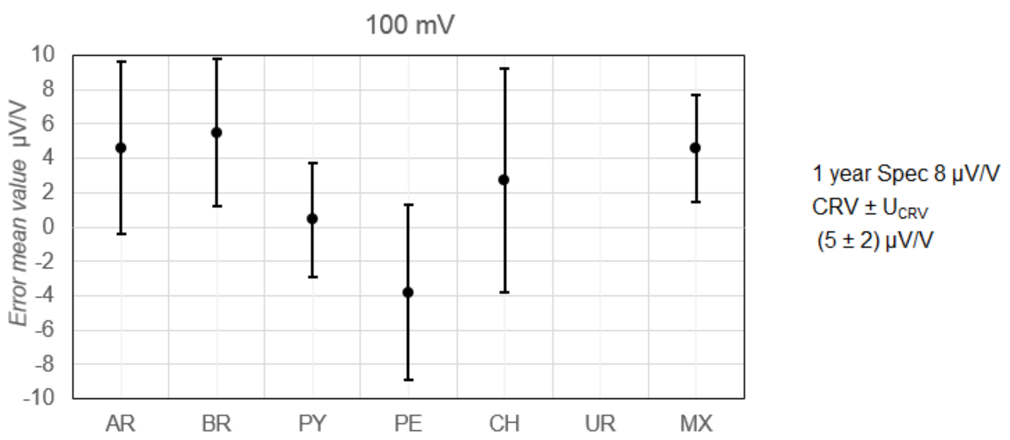
In loop 2, some laboratories did not measure the 15 test points. INTN from Paraguay measured the AC quantities only at 55 Hz and UTE from Uruguay measured only 10 Ω. Points that were not measured are indicated in gray in the tables.

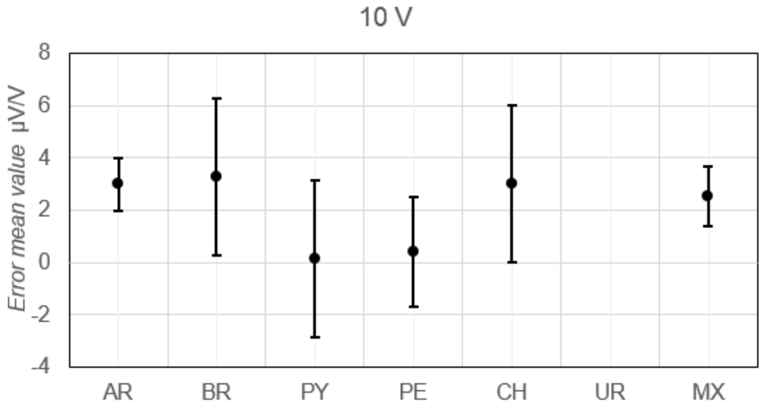
In loop 2 the travelling standard presented a linear trend in the resistance and dc current functions. In such cases the label next to the graphs indicates only the travelling standard’s one-year stability given by the manufacturer. The evaluation of the CRV will be discussed further in this document.

Reported Results Loop 2

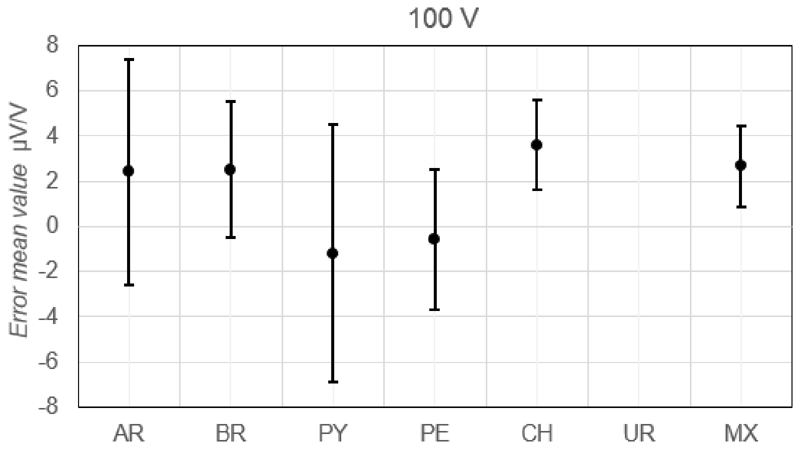
Errors and Uncertainty reported by NMI. Loop 2																
Test point	**Measured value**	**Units**	**AR**	**U_{AR}**	**BR**	**U_{BR}**	**PY**	**U_{PY}**	**PE**	**U_{PE}**	**CH**	**U_{CH}**	**UR**	**U_{UR}**	**MX**	**U_{MX}**
1	100 mV	µV/V	5	5	6	4	0	3	-4	5	3	7			5	3
2	10 V	µV/V	3	1	3	3	0	3	0	2	3	3			3	1
3	100 V	µV/V	2	5	3	3	-1	6	-1	3	4	2			3	2
4	10 mA	µA/A	4	2	5	10	10	11	3	10	5	5			2	8
5	1 A	µA/A	92	7	97	10	154	11	231	102	100	21			114	11
6	10 Ω	µΩ/Ω	-4	3	-2	3	3	5	5	6	0	2	-2	5	0	2
7	10 MΩ	µΩ/Ω	-18	15	-7	12	2	12	-22	19	10	8			5	12
8	1 V / 55 Hz	µV/V	-13	11	-18	8	30	14	46	58	-10	18			-12	28
9	1 V / 1 kHz	µV/V	5	11	1	8			28	50	17	14			4	28
10	100 V / 55 Hz	µV/V	-8	45	-27	13	64	16	23	65	-20	30			-32	36
11	100 V / 1 kHz	µV/V	-3	46	-17	13			37	47	-7	20			-13	36
12	10 mA / 55 Hz	µA/A	22	60	24	27	62	36	61	252	24	37			20	43
13	10 mA / 1 kHz	µA/A	91	60	100	27			-103	252	96	37			92	43
14	1 A / 55 Hz	µA/A	98	100	86	52	205	52	276	413	78	65			65	70
15	1 A / 1 kHz	µA/A	286	100	273	52			396	412	260	65			265	70

Loop 2. Graphs of reported results

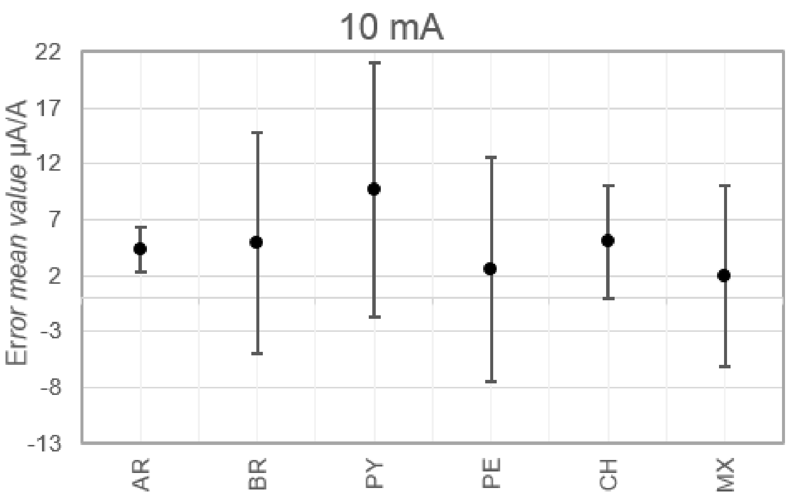




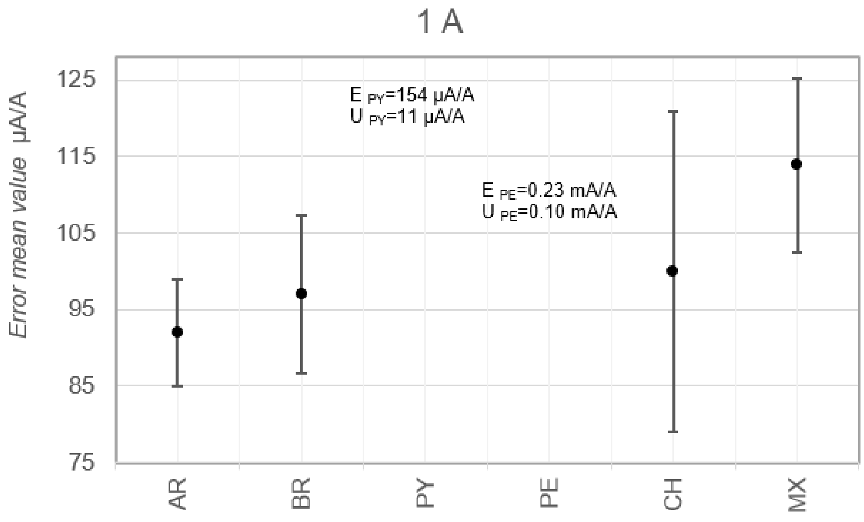
1 year Spec 4 µV/V
CRV ± U_{CRV}
(3 ± 1) µV/V



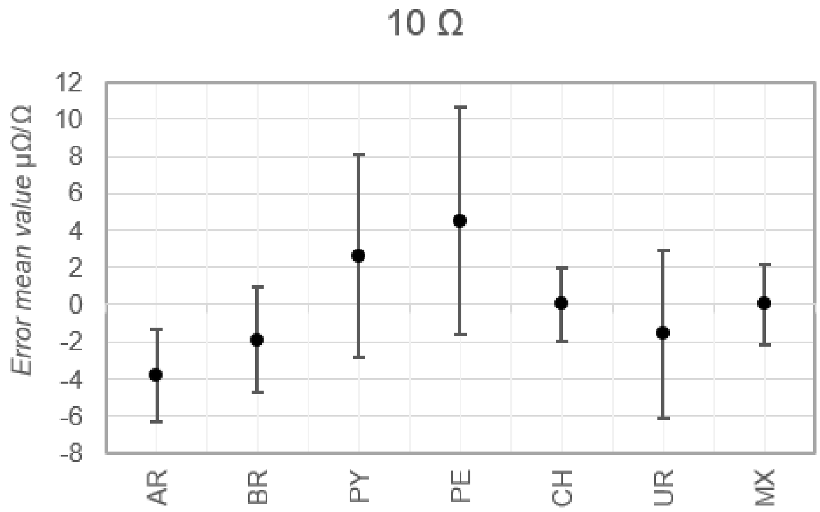
1 year Spec 6 µV/V
CRV ± U_{CRV}
(3 ± 1) µV/V



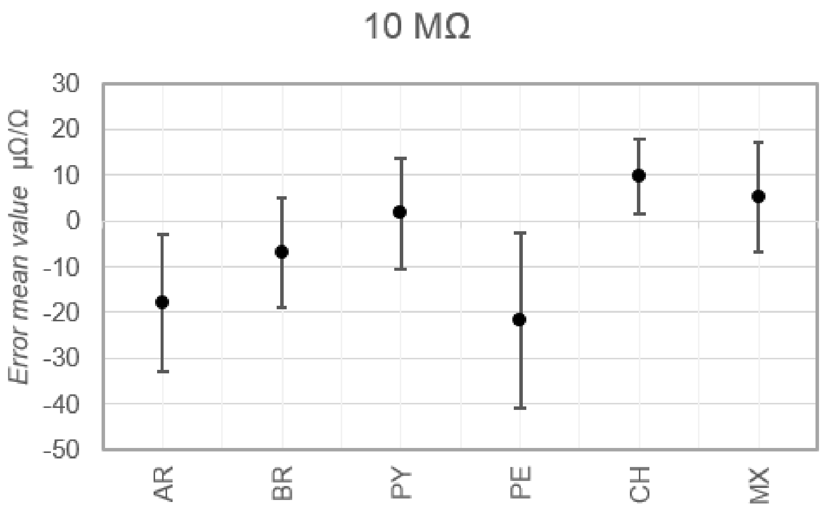
1 year Spec 25 µA/A



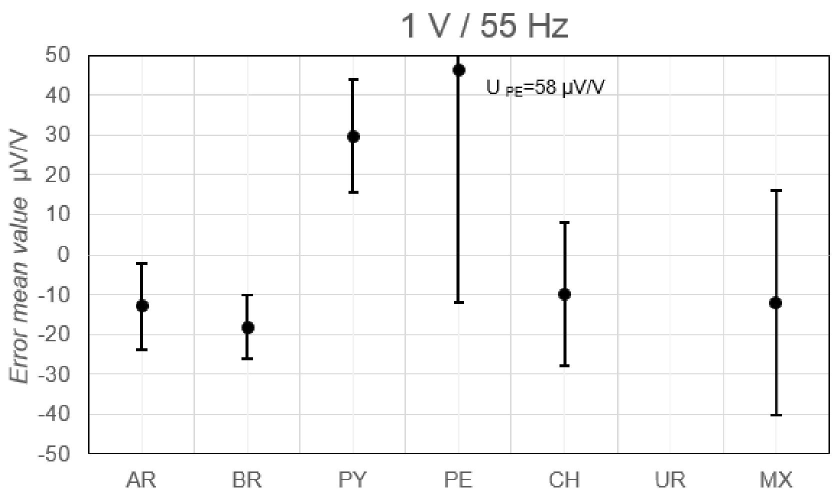
1 year Spec 0.12 mA/A



1 year Spec 20 μΩ/Ω



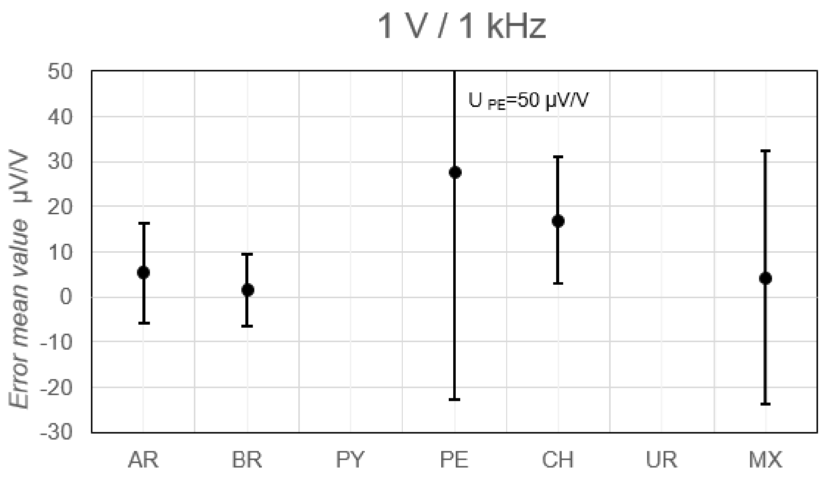
1 year Spec 60 μΩ/Ω



1 year Spec 90 µV/V

CRV ± U_{CRV}

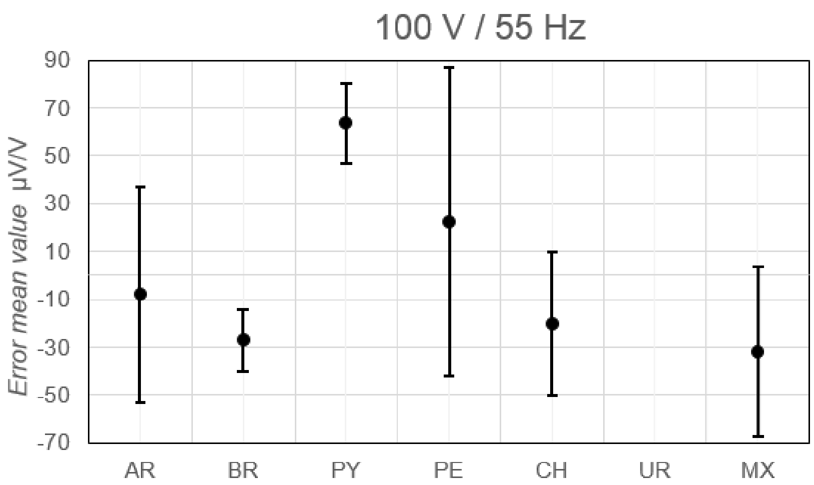
(-16 ± 6) µV/V



1 year Spec 90 µV/V

CRV ± U_{CRV}

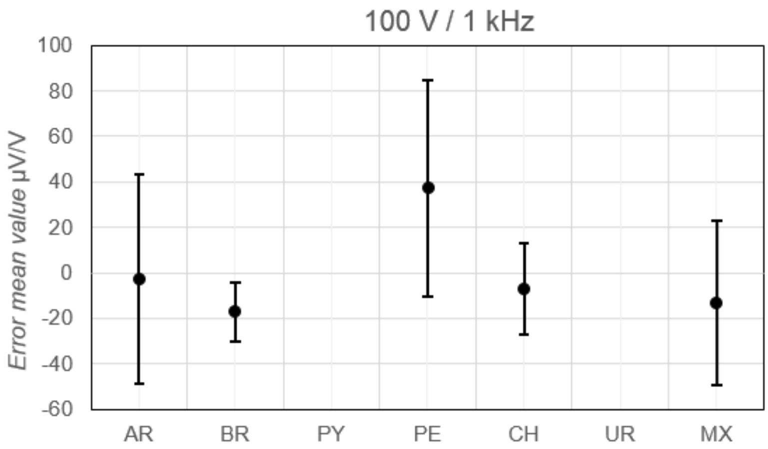
(3 ± 6) µV/V



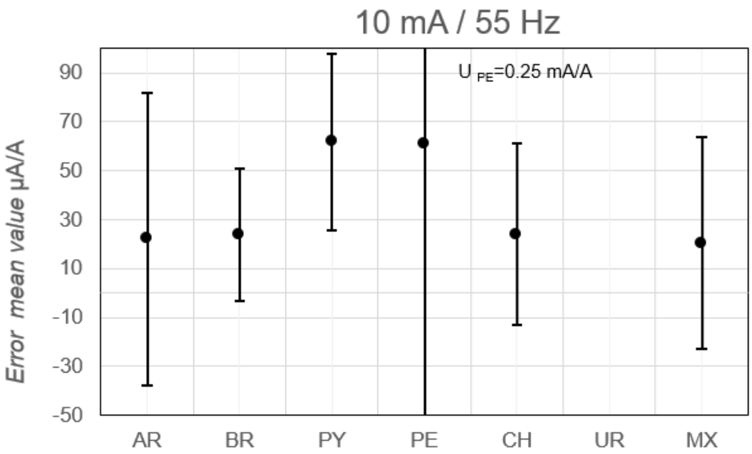
1 year Spec 0.22 mV/V

CRV ± U_{CRV}

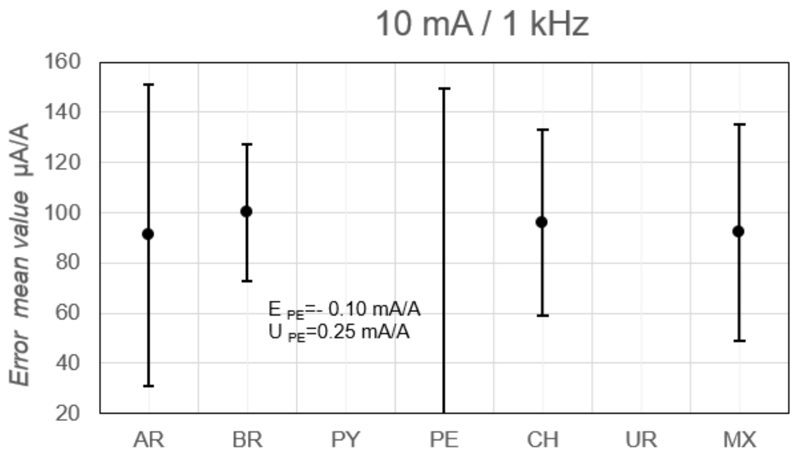
(-26 ± 12) µV/V



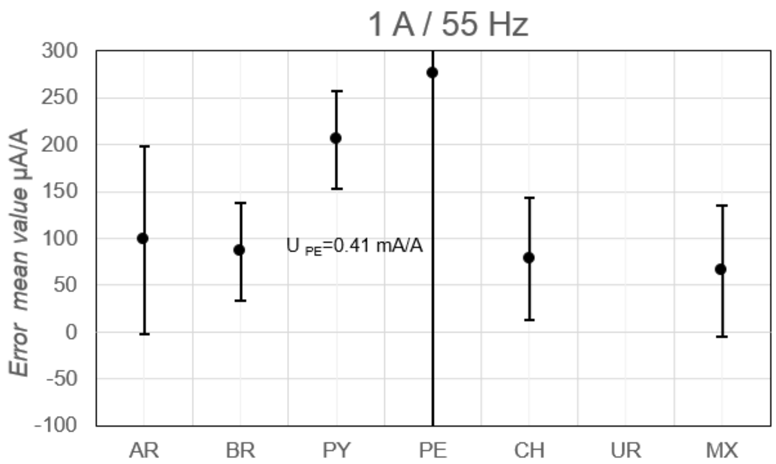
1 year Spec 0.22 mV/V
CRV ± U_{CRV}
(-16 ± 12) µV/V



1 year Spec 1.6 mA
CRV ± U_{CRV}
(23 ± 21) µA/A



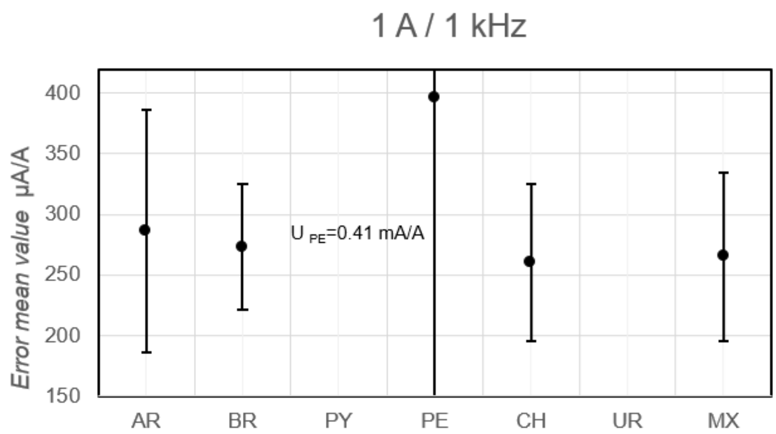
1 year Spec 1.3 mA/A
CRV ± U_{CRV}
(82 ± 39) µA/A



1 year Spec 1.0 mA/A

CRV ± U_{CRV}

273 ± 38) µA/A



1 year Spec 1.2 mA/A

CRV ± U_{CRV}

180 ± 93) µA/A

Appendix 2.
Method of computation of the Comparison Reference Value (CRV) and Degree of equivalence

Loop 1. Comparison reference value

The comparison reference values CRV for all the test points were the error mean values reported by CENAM, corrected with the degree of equivalence of CENAM's values observed in the Loop 2. The following table shows in the last column the CRV, obtained with the following equation.

$$CRV = E_{MX} - D_{MX\ loop2}$$

Test point	Measured value	Units	E_{MX}	$D_{MX\ loop2}$	*CRV*	U_{CRV}
1	100 mV	µV/V	3	0	3	4
2	10 V	µV/V	4	0	4	1
3	100 V	µV/V	4	0	4	2
4	10 mA	µA/A	14	0	14	16
5	1 A	µA/A	-42	0	-42	19
8	1 V / 55 Hz	µV/V	-16	4	-20	39
9	1 V / 1 kHz	µV/V	0	1	-1	39
10	100 V / 55 Hz	µV/V	-4	-6	2	50
11	100 V / 1 kHz	µV/V	-1	3	-4	50
12	10 mA / 55 Hz	µA/A	49	-3	52	56
13	10 mA / 1 kHz	µA/A	111	-5	116	55
14	1 A / 55 Hz	µA/A	4	-17	21	94
15	1 A / 1 kHz	µA/A	172	-8	180	93

Loop 1. Degree of equivalence

The degree of equivalence D_i between the i^{th} participant with respect to the reference value *CRV* was evaluated as follows:

$$D_i = E_i - CRV$$

The expanded uncertainty of D_i (U_{Di}) was estimated as:

$$U_{Di} = k_{Di} * \sqrt{{u_{Ei}}^2 + {u_{CRV}}^2}$$

Next table shows the degrees of equivalence, D_i with respect to the *CRV* and the corresponding expanded uncertainty U_{Di}. The results of the participants from loop 1 are linked to the reference value of loop 2.

Degrees of equivalence D_i and Uncertainty of D_i. Loop 1															
Test point	Measured value	Units	D_{CR}	$U\ D_{CR}$	D_{PA}	$U\ D_{PA}$	D_{CO}	$U\ D_{CO}$	D_{BO}	$U\ D_{BO}$	D_{TT}	$U\ D_{TT}$	D_{SA}	$U\ D_{SA}$
1	100 mV	µV/V	-3	8	2	6	-3	13	-4	17	2	6	2	7
2	10 V	µV/V	0	2	1	1	0	4	5	7	-1	1	1	2
3	100 V	µV/V	1	4	2	4	3	8	0	10	1	3	2	4
4	10 mA	µA/A	-3	18	-6	47	0	17	2	38	3	23	-1	21
5	1 A	µA/A	-2	36	15	93	-10	95	32	282	13	43	71	88
8	1 V / 55 Hz	µV/V	3	50	5	60	9	65	58	177	8	48	39	67
9	1 V / 1 kHz	µV/V	-2	42	-2	66	6	65	11	217	10	46	6	51
10	100 V / 55 Hz	µV/V	-15	62	-13	71	-19	80	18	200	-12	54	51	81
11	100 V / 1 kHz	µV/V	-4	55	-6	80	-9	80	-14	238	-3	52	18	80
12	10 mA / 55 Hz	µA/A	-19	83	-24	167	1	154	7	744	-11	83	-39	159
13	10 mA / 1 kHz	µA/A	-30	78	-33	166	-4	153	-37	788	16	82	-33	159
14	1 A / 55 Hz	µA/A	821	115	-36	312	-31	304	660	1144	-12	140	60	293
15	1 A / 1 kHz	µA/A	239	118	-8	311	-24	304	429	1212	25	140	-42	293

Loop 2. Comparison reference value.

The *CRV* for most of the test points, except for test points 4, 5, 6 and 7, were computed as the weighted mean [3] [4] of the results of the participating NMIs that independently derive the units, (i.e. INTI, INMETRO and CENAM)

$$CRV_W = \sum_{i=1}^{3} w_i * E_i$$

Where w_i was estimated as:

$$w_i = \frac{\frac{1}{{u_i}^2}}{\sum_{i=1}^{3}\left(\frac{1}{{u_i}^2}\right)}$$

The uncertainty of the *CRV* weighted was estimated as:

$$U_{CRV_w} = \mathrm{k} * \sqrt{\sum_{i=1}^{3} {w_i}^2 * {u_i}^2}$$

The CRV_W and their uncertainties $U_{CRV\ w}$ are indicated in the following table.

Test point	Measured value	CRV_w	U_{CRVw}
1	100 mV	5	2
2	10 V	3	1
3	100 V	3	1
8	1 V / 55 Hz	-16	6
9	1 V / 1 kHz	3	6
10	100 V / 55 Hz	-26	12
11	100 V / 1 kHz	-16	12
12	10 mA / 55 Hz	23	21
13	10 mA / 1 kHz	97	21
14	1 A / 55 Hz	82	39
15	1 A / 1 kHz	273	38

Loop 2. Degree of equivalence

For each one of the test points above, the degree of equivalence D_i between the i^{th} participant and the comparison reference value CRV was evaluated as follows:

$$D_i = E_i - CRV_w$$

For the participants without contribution to the *CRV* the expanded uncertainty of D_i (U_{D_i}) was estimated as:

$$U_{D_i} = k_{D_i} * \sqrt{{u_{E_i}}^2 + {u_{CRV_W}}^2}$$

For the participants with contribution to the *CRV* the expanded uncertainty of D_i (U_{D_i}) was estimated as:

$$U_{D_i} = k_{D_i} * \sqrt{{u_{E_i}}^2 - {u_{CRV_W}}^2}$$

Loop 2. Comparison reference value with linear trends

Test points 4 to 7, they are 10 mA, 1 A, 10 Ω and 10 MΩ, showed a linear trend, so the CRV was evaluated according to [4].

We assumed that the measurements of any laboratory have a linear trend in time and the slopes of the linear trends for all the laboratories are the same, while we allow for different intercepts for different laboratories.

Two of the three references laboratories were first and second making measurements, the third reference laboratory was the last one making measurements. We assume that a simple linear regression model holds for the measurements made by the reference's laboratories (i.e. INTI, INMETRO and CENAM)

$$E_{lk} = \alpha_l + \beta * t_{lk} + \varepsilon_{lk}$$

t_{lk} is the mean date during measurements of each of the reference laboratories when the measurements were made in the k^{th} period. E_{lk} is the error mean value of the corresponding measurements in that period.

We assume that the random error ε_{lk} has a zero mean and standard uncertainty of u_l.

For the others non reference laboratories the corresponding model is

$$E_i = \alpha_i + \beta * t_i + \varepsilon_i$$

where the random error, ε_i , has a zero mean and standard uncertainty of u_i.

The slope of the linear trend β was estimated using the least squares method.

The intercept α can be evaluated as.

$$\alpha_i = E_{ik} - \beta * t_{ik}$$

To calculate the *CRV* at any time t_i (CRV_{t_i}) the weighted mean of $\alpha_{lk} + \beta * t_{lk}$ over the reference laboratories (i.e. INTI, INMETRO and CENAM) was computed as follows.

$$CRV_{t_i}(w) = \sum_{l=1}^{3} w_l * (\alpha_l + \beta * t_i) = \sum_{l=1}^{3} w_l * E_i - \beta * \sum_{l=1}^{3} w_l * (t_l - t_i)$$

Where E_i and t_i are the Error mean value and the mean date measurement of the i^{th} participant.

Using the second term of the equality above the expanded uncertainty of the *CRV* $_{t(w)}$ was calculated using:

$$U_{CRV_{t_i}(W)} = k_{CRV_{t_i}(w)} * \sum_{l=1}^{3} {w_l}^2 * {u_l}^2 + \frac{\sigma^2 * \left[\sum_{l=1}^{3} w_l * (t_l - t_i)\right]^2}{\sum_{l=1}^{3} (t_l - t_i)}$$

σ is the standard deviation of the error mean values reported by the reference laboratories.

The $CRV_{t_i}(w)$ and its uncertainty $U_{CRV_{t_i}(W)}$ for the different measurement periods is indicated in the following tables.

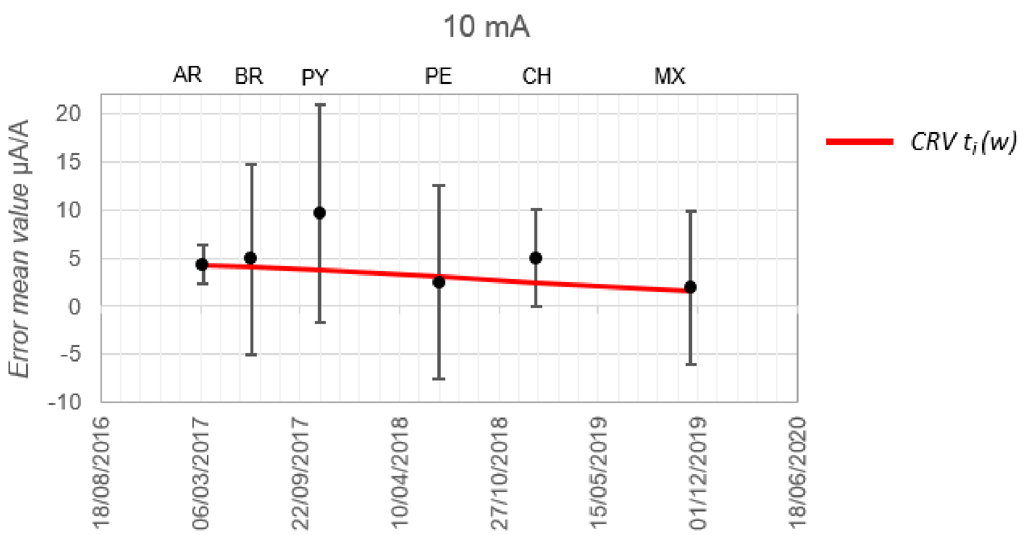
10 mA		
Mean date	$CRV_{t_i}(w)$ µA/A	$U_{CRV_{t_i}(w)}$ µA/A
11/03/2017	4	2
17/06/2017	4	2
02/11/2017	4	2
28/06/2018	3	3
10/01/2019	2	3
17/11/2019	2	3

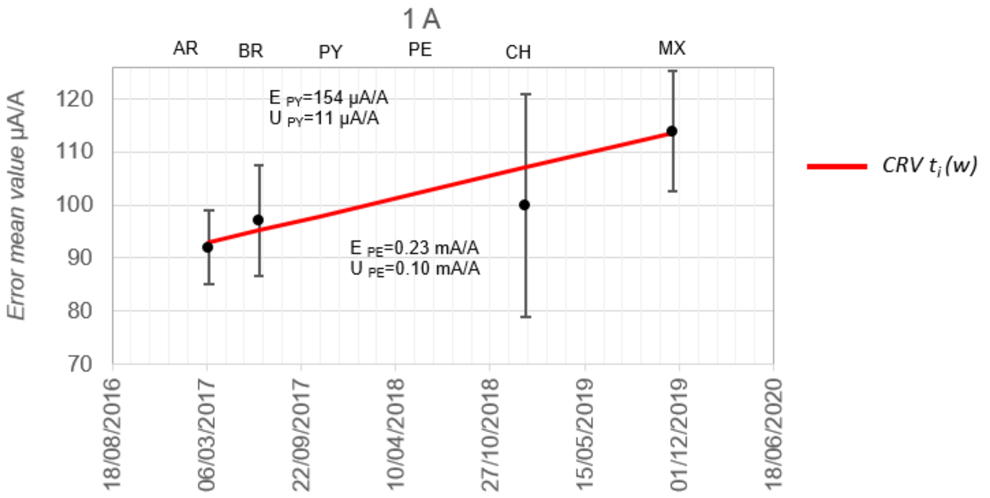
1 A		
Mean date	$CRV_{t_i}(w)$ µA/A	$U_{CRV_{t_i}(w)}$ µA/A
10/03/2017	93	7
24/06/2017	95	6
02/11/2017	98	5
28/06/2018	103	9
10/01/2019	107	12
17/11/2019	114	14

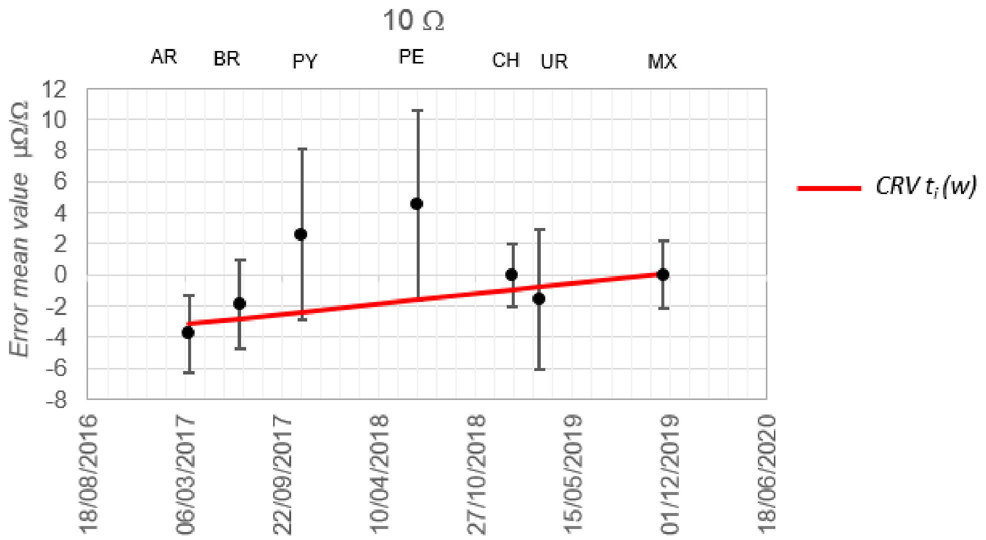
10 Ω		
Mean date	$CRV_{t_i}(w)$ µΩ/Ω	$U_{CRV_{t_i}(w)}$ µΩ/Ω
14/03/2017	-3	2
28/06/2017	-3	2
02/11/2017	-2	2
28/06/2018	-2	1
11/01/2019	-1	2
07/03/2019	-1	2
18/11/2019	0	2

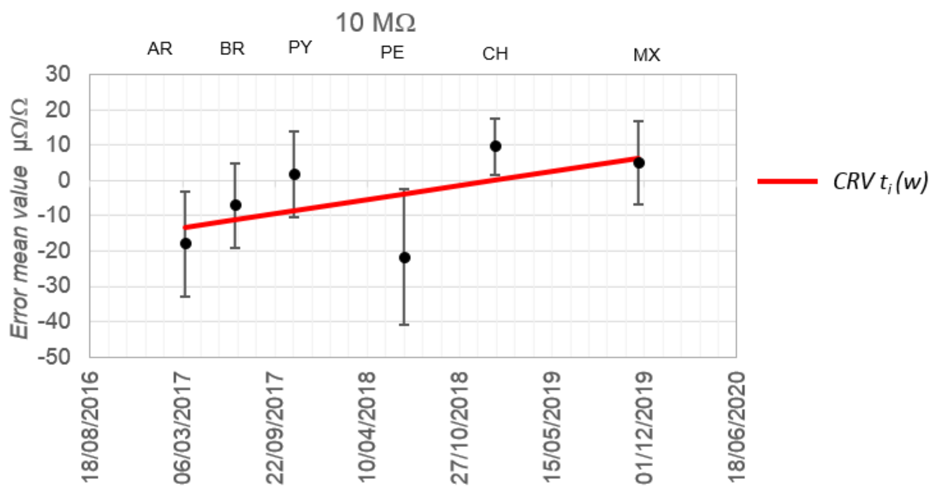
10 MΩ		
Mean date	$CRV_{t_i}(w)$ µΩ/Ω	$U_{CRV_{t_i}(w)}$ µΩ/Ω
11/03/2017	-13	12
28/06/2017	-11	11
02/11/2017	-9	9
28/06/2018	-4	7
11/01/2019	0	10
17/11/2019	6	12

Loop 2. Graphs of $CRV_{t_i}(w)$ with linear trends




1 A
AR
BR
PY
PE
CH
MX
Error mean value µA/A
E PY=154 µA/A
U PY=11 µA/A
E PE=0.23 mA/A
U PE=0.10 mA/A
120
110
100
90
80
70
18/08/2016
06/03/2017
22/09/2017
10/04/2018
27/10/2018
15/05/2019
01/12/2019
18/06/2020
CRV $t_i(w)$


10 Ω
AR
BR
PY
PE
CH
UR
MX
Error mean value µΩ/Ω
12
10
8
6
4
2
0
-2
-4
-6
-8
18/08/2016
06/03/2017
22/09/2017
10/04/2018
27/10/2018
15/05/2019
01/12/2019
18/06/2020
CRV $t_i(w)$


10 MΩ
AR
BR
PY
PE
CH
MX
Error mean value µΩ/Ω
30
20
10
0
-10
-20
-30
-40
-50
18/08/2016
06/03/2017
22/09/2017
10/04/2018
27/10/2018
15/05/2019
01/12/2019
18/06/2020
CRV $t_i(w)$

Loop 2. Degree of equivalence, with linear trends

The degree of equivalence *D_i* between the *ith* participant and the comparison reference value $CRV_{t_i}(w)$ was evaluated as follows:

$$D_i = E_i - CRV_{t_i}(w)$$

And the expanded uncertainty

$$U_{D_i} = k_{D_i} * \sqrt{[1 - 2 * w_l] * u_l^2 + \frac{1}{\sum_{l=1}^{3}\left(\frac{1}{u_l^2}\right)} + \frac{(t_i - t^*)^2 * \sigma}{\sum_{l=1}^{3}(t_l - t_i)^2}}$$

Where $t^* = \sum_{l=1}^{3} w_l * t_l$

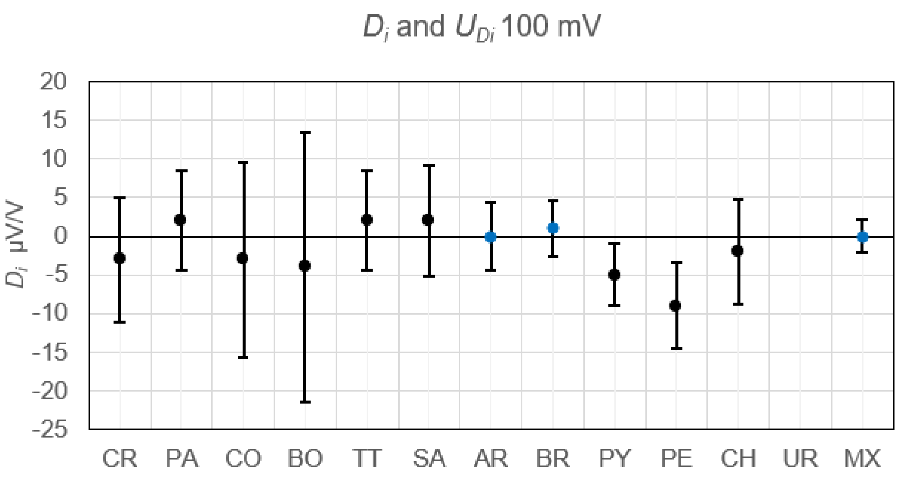
Loop 2. Summary of degree of equivalence

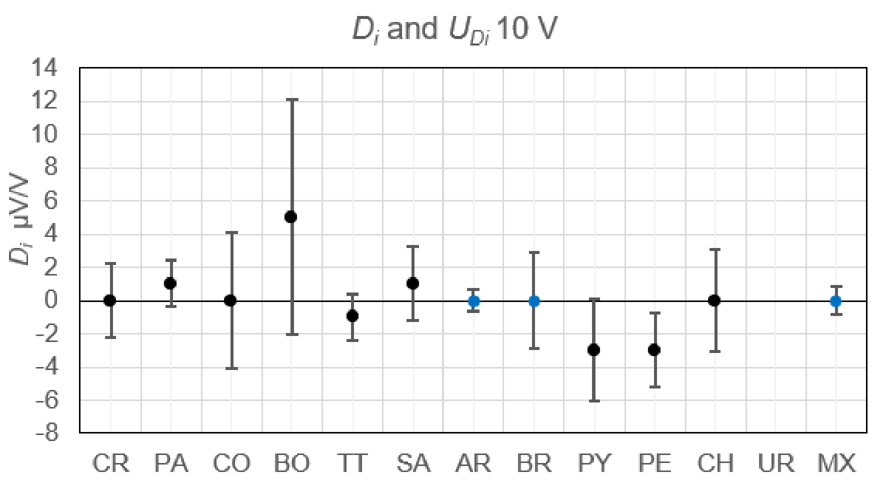
Degrees of equivalence, D_i, with respect to the $CRV_{t_i}(w)$, for the fifteen test points. Loop 2

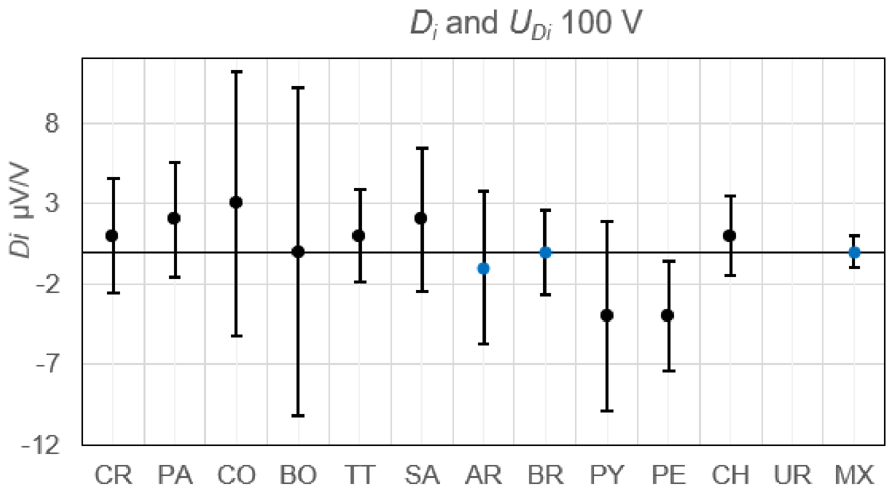
Degrees of equivalence D_i and Uncertainty of D_i. Loop 2																
Test point	Measured value	Units	D_{AR}	$U\ D_{AR}$	D_{BR}	$U\ D_{BR}$	D_{PY}	$U\ D_{PY}$	D_{PE}	$U\ D_{PE}$	D_{CH}	$U\ D_{CH}$	D_{UR}	$U\ D_{UR}$	D_{MX}	$U\ D_{MX}$
1	100 mV	µV/V	0	4	1	4	-5	4	-9	6	-2	7			0	2
2	10 V	µV/V	0	1	0	3	-3	3	-3	2	0	3			0	1
3	100 V	µV/V	-1	5	0	3	-4	6	-4	3	1	2			0	1
4	10 mA	µA/A	0	1	1	10	6	12	-1	10	3	6			0	13
5	1 A	µA/A	-1	7	2	10	56	12	128	102	-7	24			0	16
6	10 Ω	µΩ/Ω	-1	3	1	3	5	6	6	6	1	3	-1	5	0	2
7	10 MΩ	µΩ/Ω	-5	16	4	13	10	15	-18	21	10	12			-1	13
8	1 V / 55 Hz	µV/V	3	9	-2	5	46	15	62	58	6	19			4	27
9	1 V / 1 kHz	µV/V	2	9	-2	5			25	51	14	15			1	27
10	100 V / 55 Hz	µV/V	18	43	-1	5	90	20	49	66	6	32			-6	34
11	100 V / 1 kHz	µV/V	13	44	-1	5			53	49	9	23			3	34
12	10 mA / 55 Hz	µA/A	-1	56	1	16	39	42	38	253	1	43			-3	38
13	10 mA / 1 kHz	µA/A	-6	56	3	16			-200	253	-1	43			-5	38
14	1 A / 55 Hz	µA/A	16	92	4	35	123	65	194	414	-4	76			-17	59
15	1 A / 1 kHz	µA/A	13	92	0	35			123	414	-13	76			-8	58

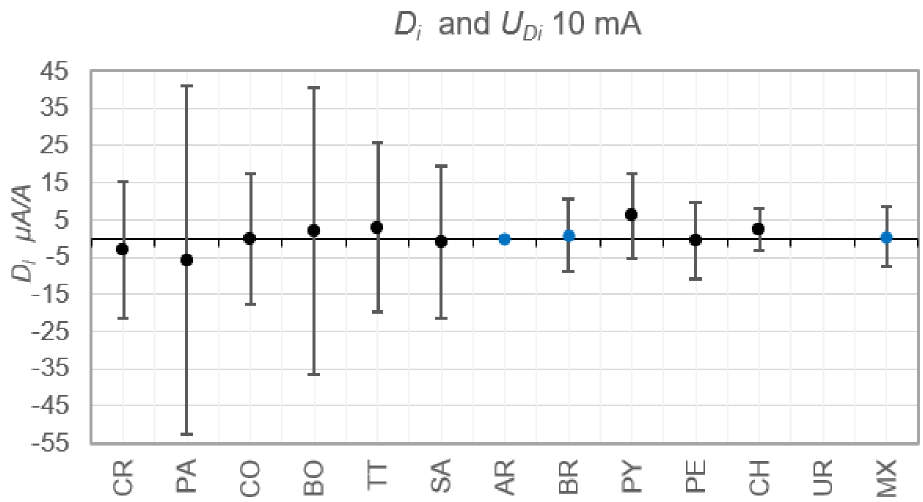
Graphs of the Degree of equivalence

In the graphics, those results that cause the loss of resolution on the "y" axis are not shown, instead only their Degree of equivalence and associated uncertainty, or their uncertainty are shown.

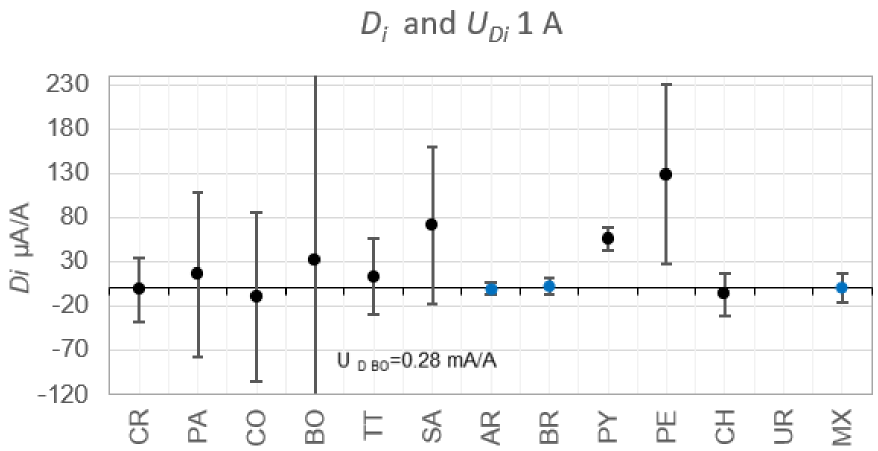




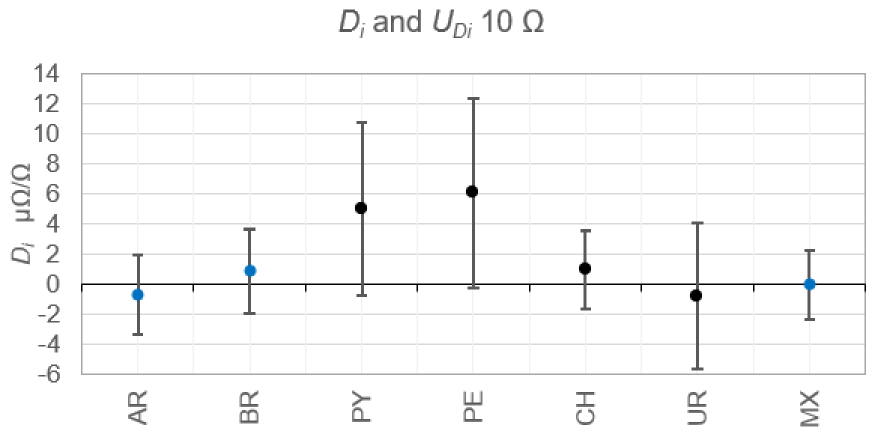




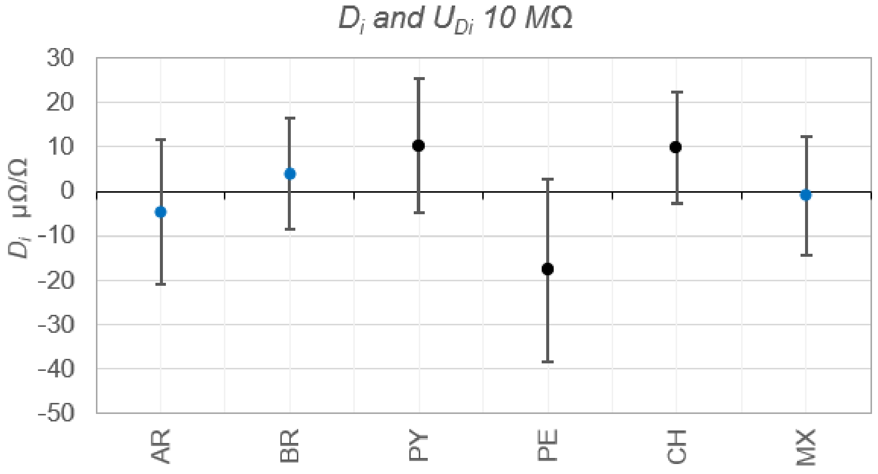
D_i and U_{Di} 10 mA
D_i µA/A
45
35
25
15
5
-5
-15
-25
-35
-45
-55
CR
PA
CO
BO
TT
SA
AR
BR
PY
PE
CH
UR
MX

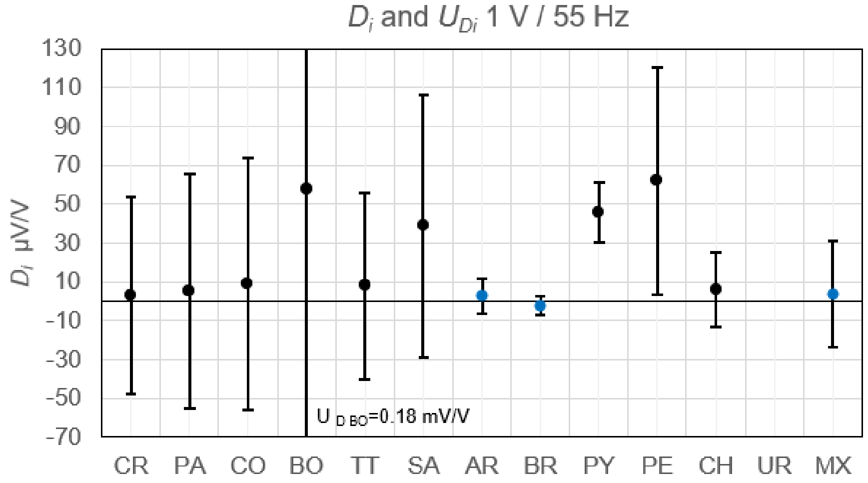


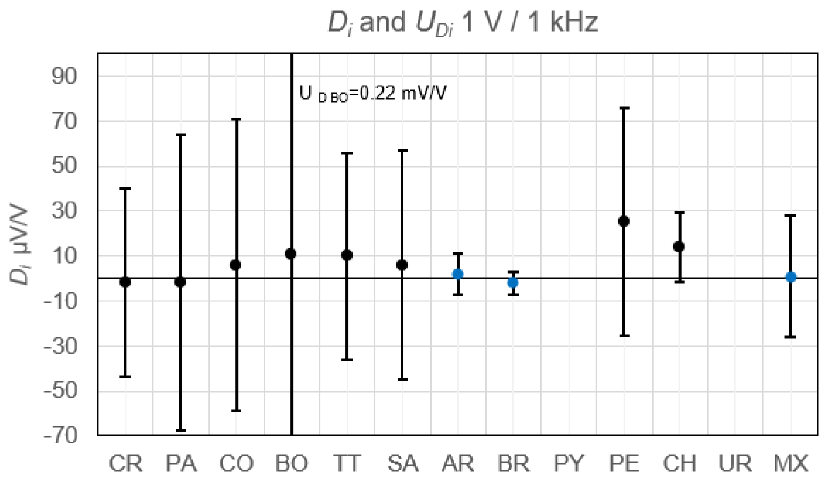
D_i and U_{Di} 1 A
Di µA/A
230
180
130
80
30
-20
-70
-120
U D BO=0.28 mA/A
CR
PA
CO
BO
TT
SA
AR
BR
PY
PE
CH
UR
MX

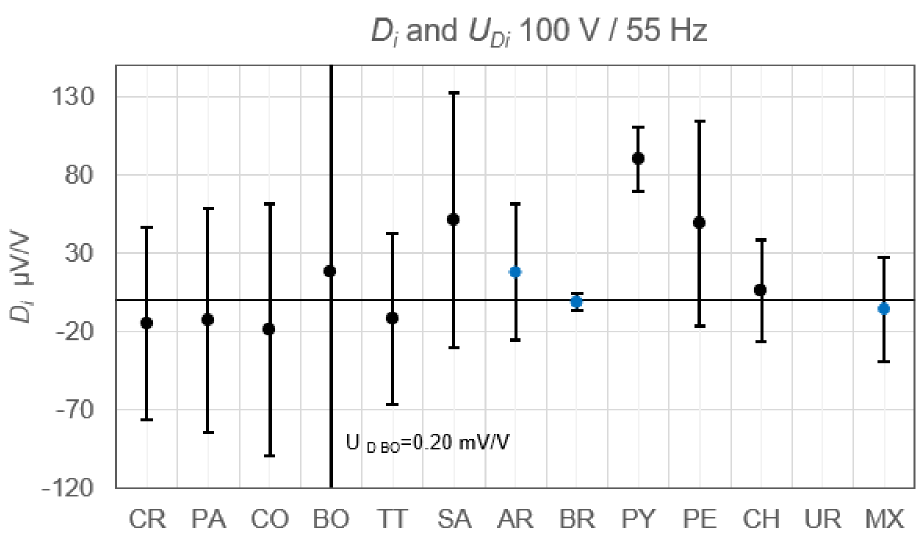


D_i and U_{Di} 10 Ω
D_i µΩ/Ω
14
12
10
8
6
4
2
0
-2
-4
-6
AR
BR
PY
PE
CH
UR
MX

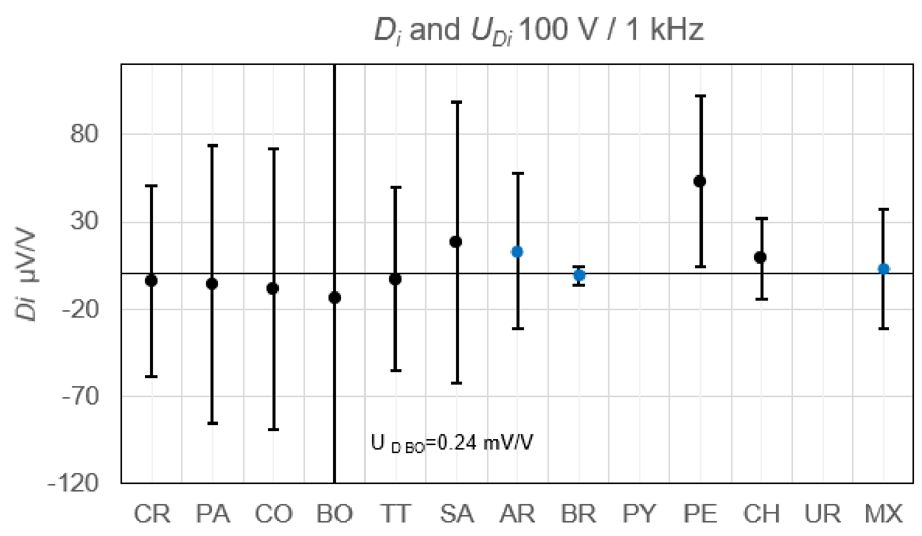

D_i and U_{Di} 10 MΩ
30
20
10
0
-10
-20
-30
-40
-50
D_i μΩ/Ω
AR
BR
PY
PE
CH
MX


D_i and U_{Di} 1 V / 55 Hz
130
110
90
70
50
30
10
-10
-30
-50
-70
D_i μV/V
U D BO=0.18 mV/V
CR
PA
CO
BO
TT
SA
AR
BR
PY
PE
CH
UR
MX

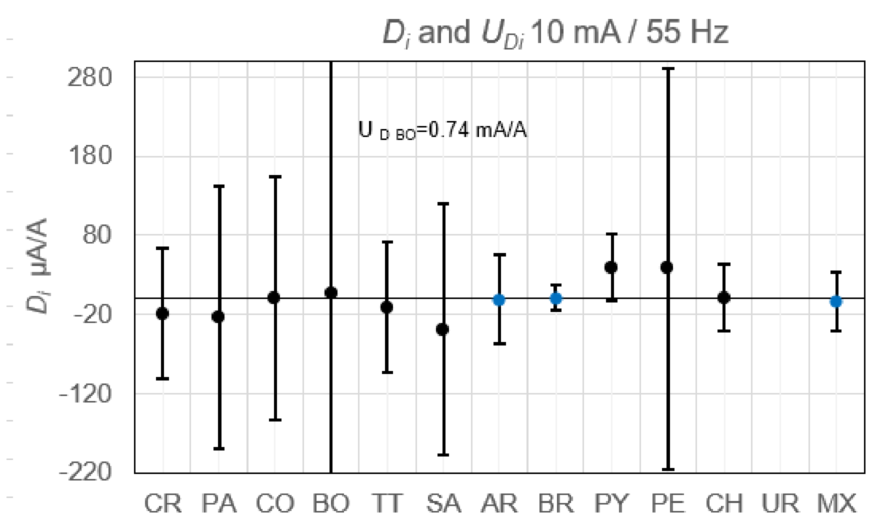

D_i and U_{Di} 1 V / 1 kHz
90
70
50
30
10
-10
-30
-50
-70
D_i μV/V
U D BO=0.22 mV/V
CR
PA
CO
BO
TT
SA
AR
BR
PY
PE
CH
UR
MX



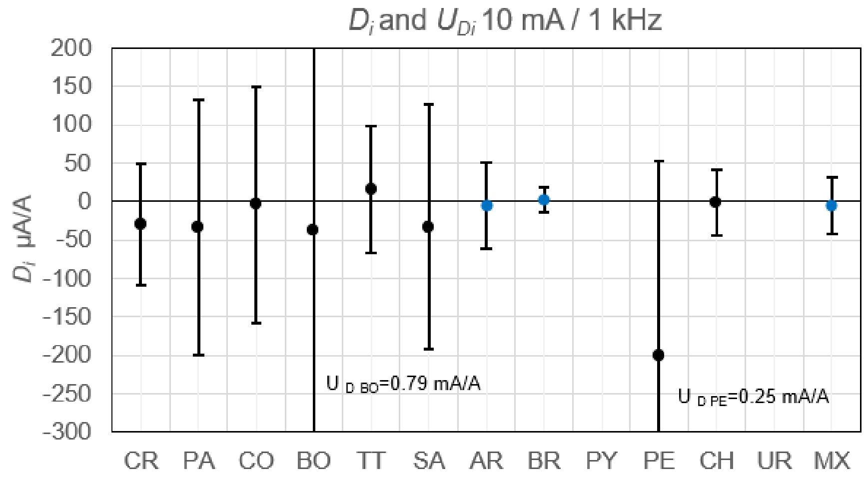
D_i and U_{Di} 100 V / 55 Hz
D_i µV/V
130
80
30
-20
-70
-120
U D BO=0.20 mV/V
CR PA CO BO TT SA AR BR PY PE CH UR MX



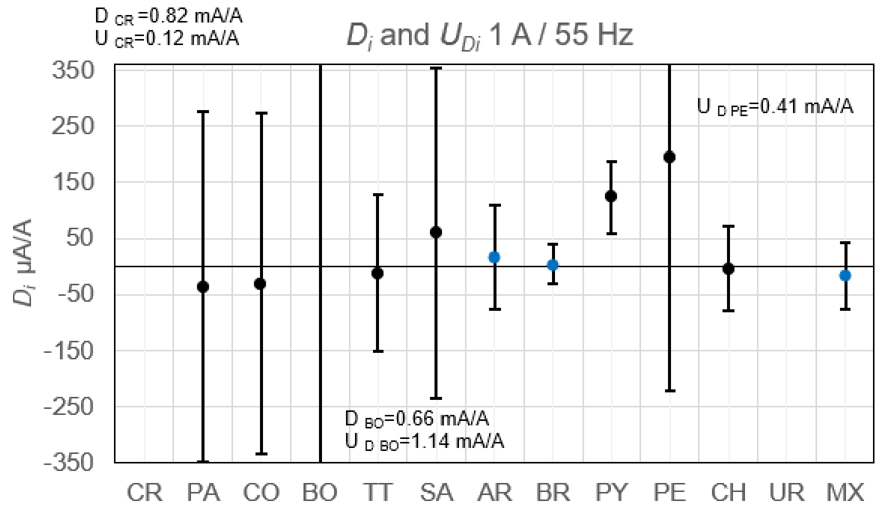
D_i and U_{Di} 100 V / 1 kHz
Di µV/V
80
30
-20
-70
-120
U D BO=0.24 mV/V
CR PA CO BO TT SA AR BR PY PE CH UR MX



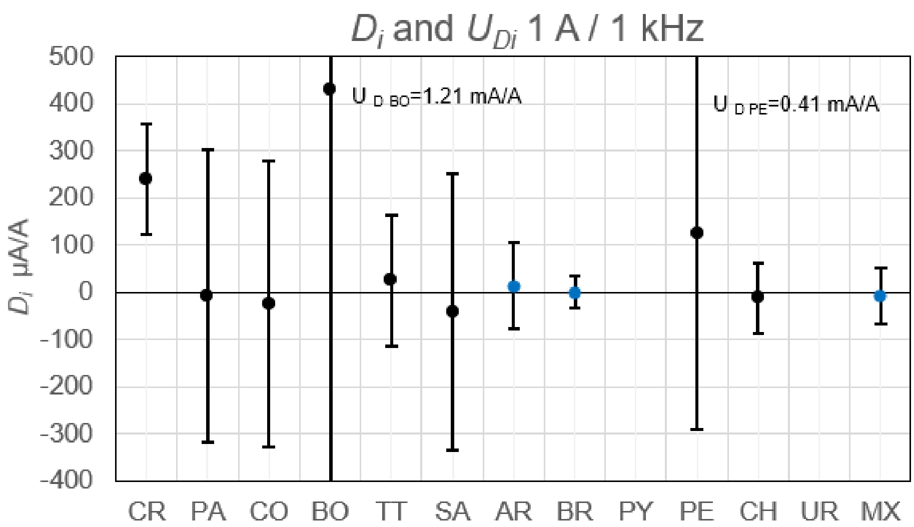
D_i and U_{Di} 10 mA / 55 Hz
D_i µA/A
280
180
80
-20
-120
-220
U D BO=0.74 mA/A
CR PA CO BO TT SA AR BR PY PE CH UR MX



Di and UDi 10 mA / 1 kHz
Di µA/A
200
150
100
50
0
-50
-100
-150
-200
-250
-300
U D BO=0.79 mA/A
U D PE=0.25 mA/A
CR PA CO BO TT SA AR BR PY PE CH UR MX



D CR =0.82 mA/A
U CR=0.12 mA/A
Di and UDi 1 A / 55 Hz
Di µA/A
350
250
150
50
-50
-150
-250
-350
U D PE=0.41 mA/A
D BO=0.66 mA/A
U D BO=1.14 mA/A
CR PA CO BO TT SA AR BR PY PE CH UR MX



Di and UDi 1 A / 1 kHz
Di µA/A
500
400
300
200
100
0
-100
-200
-300
-400
U D BO=1.21 mA/A
U D PE=0.41 mA/A
CR PA CO BO TT SA AR BR PY PE CH UR MX

Appendix 3.
Corrective actions reported by ICE CR

Corrective actions reported by ICE CR

For test points 14 and 15, after emission of the Draft A, ICE CR detected a misconfiguration of the travelling standard due to a modification made in its measurement software. At the end of the comparison when the travelling standard returned to ICE, the participant corrected the configuration and repeated measurements. The new measurements were sent to the review committee to be included as an evidence of the corrective actions.

The results after corrections are the following.

Errors and Uncertainty reported by NMIs. Loop 1				
Test point	Measured value	Units	CR	U_{CR}
14	1 A / 55 Hz	µA/A	-12	66
15	1 A / 1 kHz	µA/A	173	72

Degrees of equivalence *D*i and Uncertainty of *Di*. Loop 1					after corrective actions	
Test point	Measured value	Units	D_{CR}	$U\ D_{CR}$	D_{CR}	$U\ D_{CR}$
14	1 A / 55 Hz	µA/A	821	115	-33	115
15	1 A / 1 kHz	µA/A	239	118	-42	118

Appendix 4.
Participants results

Participants Results

The uncertainty budgets of the reference laboratories consider the following uncertainty contribution:

- standard deviation of the travelling standard
- resolution of the travelling standard
- uncertainty calibration of the reference value
- long term stability of the reference value
- uncertainty of the temperature coefficient for the reference resistors

In general, those are the same contributions considered by the participating laboratories.

The following are examples of one of the reference laboratories uncertainty contributions:

CENAM. Uncertainty contribution for DC Voltage.

Calibration point (V)	Reference value (V)	Combinded uncertinty (V)	Veff	Coverage factor	Expanded uncertainty (V)	Expanded uncertainty (µV/V)
0.1	0.1	1.5E-07	117	2.0	3.1E-07	3.1
10	9.999975	5.6E-06	99	2.0	1.1E-05	1.1
100	100.00027	8.8E-05	90	2.0	1.8E-04	1.8

standard deviation of the readings with the travelling standard (V)	type A standard uncertainty (V)	sensitivity coefficient	type A uncertainty contribution (V)	Degrees of freedom
8.7E-08	3.3E-08	1	3.3E-08	6
5.6E-06	2.1E-06	1	2.1E-06	6
9.7E-05	3.7E-05	1	3.7E-05	6

resolution of the travelling standard (V)	standard uncertainty for resolution (V)	sensitivity coefficient	resolution uncertainty contribution (V)	Degrees of freedom
0.00000001	2.9E-09	1	2.9E-09	∞
0.0000001	2.9E-08	1	2.9E-08	∞
0.000001	2.9E-07	1	2.9E-07	∞

Calibration of the reference source (µV/V)	standard uncertainy of the reference source calibration	sensitivity coefficient	calibration of the reference source uncertainty contribution	Degrees of freedom
2.4	1.2E-07	-1	-1.2E-07	60
0.6	3.0E-06	-1	-3.0E-06	60
1.3	6.5E-05	-1	-6.5E-05	60

Long term stability of the reference source (µV/V)	standard uncertainty of the reference source long term stability	sensitivity coefficient	long term stability of the reference source uncertainty contribution	Degrees of freedom
1.8	9.0E-08	-1	-9.0E-08	60
0.85	4.3E-06	-1	-4.3E-06	60
0.95	4.8E-05	-1	-4.8E-05	60

CENAM. Uncertainty contribution for Resistance

Calibration point	Reference value (ohms)	Combinded uncertinty (ohms)	Veff	Coverage factor	Expanded uncertainty (ohms)	Expanded uncertainty (µohm/ohm)
10 Ω	10.00007	1.1E-05	91	2.0	2.2E-05	2.2
10 MΩ	9 999 861	5.8E+01	64	2.0	1.2E+02	11.8

standard deviation of the readings with the travelling standard (Ohms)	type A standard uncertainty (ohms)	sensitivity coefficient	type A uncertainty contribution (ohms)	Degrees of freedom
9.4E-06	3.1E-06	1	3.1E-06	8
2.8E+01	9.9E+00	1	9.9E+00	7

resolution of the travelling standard (Ohm)	standard uncertainty for resolution	sensitivity coefficient	resolution uncertainty contribution (ohms)	Degrees of freedom
0.00001	2.9E-06	1	2.9E-06	∞
1	2.9E-01	1	2.9E-01	∞

Calibration of the reference resistor (µOhm/Ohm)	standard uncertainy of the reference resistor calibration (ohms)	sensitivity coefficient	calibration of the reference resistior uncertainty contribution (ohms)	Degrees of freedom
0.5	2.5E-06	-1	-2.5E-06	60
1.1	5.5E+00	-1	-5.5E+00	60

Long term stability of the reference resistor (µOhm/Ohm)	standard uncertainty of the reference resistor long term stability (ohms)	sensitivity coefficient	long term stability of the reference resistor uncertainty contribution (ohms)	Degrees of freedom
2.2	9.6E-06	-1	-9.6E-06	60
13	5.7E+01	-1	-5.7E+01	60

reference resistor temperature coefficient (µOhm/Ohm)/°C	standard uncertainty of the reference resistor temperature coefficient	sensitivity coefficient	reference resistor temperature coefficient uncertainty contribution (ohms)	Degrees of freedom
5	1.4E-06	-1	-1.4E-06	60
5	1.4E+00	-1	-1.4E+00	60

The following are the reports of the participants.

Annex 6

Results Report

(Send via e-mail to the comparison coordinator, with copy to the SIM EM chair, as a pdf attachment)

To
Lucas Di Lillo, INTI, ldili@inti.gob.ar

Isabel Castro, ICE, bcastro@ice.go.cr

From: (sending laboratory): Laboratorio Metrológico de Variables Eléctricas

Re: **SIM comparisons SIM.EM-S31 – Comparison Report**
Date: 04/04/2017

Laboratory
Name: Laboratorio Metrológico de Variables Eléctricas
Address: ICE San Pedro, de la Fuente de la Hispanidad 100 m al sur. Apdo. 485-2050 San Pedro. Tel. (506) 2002 4007
Correo electrónico: lmve@ice.go.cr

Contact Personnel name: Róger Meléndez Poltronieri
Phone Number: (506) 2001 2376
E-mail: rmelendezpo@ice.go.cr

Standard Equipment
Standard: Multifunction Calibrator
Brand: Fluke 5720 A
Reference Number: Traceability to METAS, Certificate No. 212-05616
Serial Number: S.N. 6800201

Comparison Results:

Calibration Method:
Direct Comparison against Multifunction Calibrator output.

Environmental Conditions:

Temperature: 24.7 °C ± 0.3 °C

Relative Humidity: 39.8 % ± 2.1 %

* You must document the mean of the data for the environmental conditions and the respective uncertainty.

Measurments Results

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
1	100 mV	09/03/2017	-4.3	2.01	7.3	24.6	37.6
		13/03/2017	-2.1	2.01	7.3	24.7	40.1
		16/03/2017	0.8	2.01	7.3	24.7	39.4
		20/03/2017	2.9	2.01	7.3	24.5	37.4
		23/03/2017	1.3	2.01	7.3	24.9	36.9
	Error mean value (µV/V)		**-0.3**				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
2	10 V	09/03/2017	3.0	2.00	2.0	24.6	37.6
		13/03/2017	3.7	2.00	2.0	24.7	40.1
		16/03/2017	3.8	2.00	2.0	24.7	39.4
		20/03/2017	3.4	2.00	2.0	24.5	37.4
		23/03/2017	3.9	2.00	2.0	24.9	36.9
	Error mean value (µV/V)		**3.6**				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
3	100 V	09/03/2017	5.9	2.01	3.5	24.6	37.6
		13/03/2017	6.4	2.01	3.5	24.7	40.1
		16/03/2017	4.2	2.01	3.5	24.7	39.4
		20/03/2017	2.0	2.01	3.5	24.5	37.4
		23/03/2017	4.5	2.01	3.5	24.9	36.9
	Error mean value (µV/V)		**4.6**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
4	10 mA	09/03/2017	13.6	2.00	9.0	24.6	37.6
		13/03/2017	8.9	2.00	9.0	24.7	40.1
		16/03/2017	15.4	2.00	9.0	24.7	39.4
		20/03/2017	6.4	2.00	9.0	24.5	37.4
		23/03/2017	10.4	2.00	9.0	24.9	36.9
	Error mean value (µA/A)		**10.9**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
5	1 A	09/03/2017	-31	2.00	31	24.6	37.6
		13/03/2017	-64	2.00	31	24.7	40.1
		16/03/2017	-35	2.00	31	24.7	39.4
		20/03/2017	-47	2.00	31	24.5	37.4
		23/03/2017	-43	2.00	31	24.9	36.9
	Error mean value (µA/A)		**-44**				

Test Point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty * (µΩ/Ω)	Tamb (°C)	Hamb (%)
6	10 Ω	09/03/2017	-4.1	2.00	6.0	24.6	37.6
		13/03/2017	-6.7	2.00	6.0	24.7	40.1
		16/03/2017	-5.1	2.00	6.0	24.7	39.4
		20/03/2017	-6.0	2.01	6.2	24.5	37.4
		23/03/2017	0.0	2.01	6.0	24.9	36.9
	Error mean value (µΩ/Ω)		**-4.4**				

Test Point	Nominal Value	Date	DMM Error (μΩ/Ω)	Coverage Factor	Expanded Uncertainty * (μΩ/Ω)	Tamb (°C)	Hamb (%)
7	10 MΩ	09/03/2017	25.6	2.00	8.0	24.6	37.6
		13/03/2017	16.9	2.00	8.0	24.7	40.1
		16/03/2017	19.5	2.00	8.0	24.7	39.4
		20/03/2017	39.3	2.00	8.0	24.5	37.4
		23/03/2017	25.6	2.00	8.0	24.9	36.9
	Error mean value (μΩ/Ω)		**25.4**				

Test Point	Nominal Value	Date	DMM Error (μV/V)	Coverage Factor	Expanded Uncertainty * (μV/V)	Tamb (°C)	Hamb (%)
8	1 V @ 55 Hz	09/03/2017	-18	2.00	32	24.6	37.6
		13/03/2017	-10	2.00	32	24.7	40.1
		16/03/2017	-8	2.00	32	24.7	39.4
		20/03/2017	-37	2.00	32	24.5	37.4
		23/03/2017	-10	2.00	32	24.9	36.9
	Error mean value (μV/V)		**-17**				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
9	1 V @ 1 kHz	09/03/2017	-2	2.01	15	24.6	37.6
		13/03/2017	-1	2.01	15	24.7	40.1
		16/03/2017	6	2.01	15	24.7	39.4
		20/03/2017	-23	2.01	15	24.5	37.4
		23/03/2017	5	2.01	15	24.9	36.9
	Error mean value (µV/V)		**-3**				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
10	100 V @ 55 Hz	09/03/2017	-26	2.00	36	24.6	37.6
		13/03/2017	-12	2.00	36	24.7	40.1
		16/03/2017	-1	2.00	36	24.7	39.4
		20/03/2017	-34	2.00	36	24.5	37.4
		23/03/2017	6	2.00	36	24.9	36.9
	Error mean value (µV/V)		**-13**				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	Tamb (°C)	Hamb (%)
11	100 V @ 1 kHz	09/03/2017	-21	2.00	22	24.6	37.6
		13/03/2017	-9	2.00	22	24.7	40.1
		16/03/2017	5	2.00	22	24.7	39.4
		20/03/2017	-27	2.00	22	24.5	37.4
		23/03/2017	12	2.00	22	24.9	36.9
	Error mean value (µV/V)		**-8**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
12	10 mA @ 55 Hz	09/03/2017	33	2.00	61	24.6	37.6
		13/03/2017	32	2.00	61	24.7	40.1
		16/03/2017	49	2.00	61	24.7	39.4
		20/03/2017	-4	2.00	61	24.5	37.4
		23/03/2017	56	2.00	61	24.9	36.9
	Error mean value (µA/A)		**33**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
13	10 mA @ 1 kHz	09/03/2017	85	2.00	56	24.6	37.6
		13/03/2017	84	2.00	56	24.7	40.1
		16/03/2017	102	2.00	56	24.7	39.4
		20/03/2017	52	2.00	56	24.5	37.4
		23/03/2017	109	2.00	56	24.9	36.9
	Error mean value (µA/A)		**86**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
14	1 A @ 55 Hz	09/03/2017	780	2.01	66	24.6	37.6
		13/03/2017	785	2.01	66	24.7	40.1
		16/03/2017	936	2.01	66	24.7	39.4
		20/03/2017	858	2.01	66	24.5	37.4
		23/03/2017	850	2.01	66	24.9	36.9
	Error mean value (µA/A)		**842**				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	Tamb (°C)	Hamb (%)
15	1 A @ 1 kHz	09/03/2017	413	2.00	72	24.6	37.6
		13/03/2017	400	2.00	72	24.7	40.1
		16/03/2017	434	2.00	72	24.7	39.4
		20/03/2017	402	2.00	72	24.5	37.4
		23/03/2017	449	2.00	72	24.9	36.9
	Error mean value (µA/A)		**419**				

*The uncertainty calculation sheet must be documented.

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the GUM.

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	0.10	V	N6828	*0.00*	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	-0.000 000 090	V	N9545	0.000 000 200	V	2.00	0.00000010	200	1	1/A	1.000E-14	5.000E-31	7.561%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	V	R	0.000 000 340	V	1.73	0.00000020	200	1	1/A	3.862E-14	7.459E-30	29.203%
2	**δVconnection**	Debido a la experien	*0.00*	V	R	0.000 000 500	V	1.73	0.00000029	200	1	1/A	8.353E-14	3.489E-29	63.155%
1.3	**δVTemp_coeff**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	0.100 0002	V	R	0.000 000 005	V	1.73	0.00000000	9	1	1/A	8.352E-18	7.750E-36	0.006%
4.1	**δVIND**	Valor de resolución	*0.00*	V	N6828	0.000 000 010	V	1.00	0.00000001	200	-1	1/A	1.000E-16	5.000E-35	0.076%

U	**ΔVIND**	0.000 000	V	**0.000 000 73**

Incertidumbre Combinada: 0.000 000 364 — **Total**: **100.000%**

Acreditado 0.000 000 700

ν eff: 408.29

Valor de k calculado: 2.01

Incetidumbre Expandida: 0.000 000 730

$$\nu_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\nu_i}}$$

PUNTO No. 1

ΔVIND = 0.000 000 08 **V** ± 0.000 000 73 **V**

Acreditado = 0.000 000 700

0.1 V @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	10.00	V	N6828	*0.00*	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	0.000 000 000	V	N9545	0.000 010 000	V	2.00	0.00000500	200	1	1/A	2.500E-11	3.125E-24	34.149%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	V	R	0.000 012 000	V	1.73	0.00000694	200	1	1/A	4.811E-11	1.157E-23	65.721%
2	**δVconnection**	Debido a la experien	*0.00*	V	R	0.000 000 500	V	1.73	0.00000029	200	1	1/A	8.353E-14	3.489E-29	0.114%
1.3	**δVTemp_coeff**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	10.000 0377	V	R	0.000 000 073	V	1.73	0.00000004	9	1	1/A	1.804E-15	3.615E-31	0.002%
4.1	**δVIND**	Valor de resolución	*0.00*	V	N6828	0.000 000 100	V	1.00	0.00000010	200	-1	1/A	1.000E-14	5.000E-31	0.014%

U	**ΔVIND**	0.000 038	V	**0.000 017 17**

Incertidumbre Combinada: 0.000 008 556 — **Total**: **100.000%**

Acreditado 0.000 020 000

ν eff: 364.60

Valor de k calculado: 2.01

Incetidumbre Expandida: 0.000 017 171

$$\nu_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\nu_i}}$$

PUNTO No. 2

ΔVIND = 0.000 037 69 **V** ± 0.000 017 17 **V**

Acreditado = 0.000 020 000

10 V @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	100.00	V	N6828	*0.00*	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	0.000 130 000	V	N9545	0.000 300 000	V	2.00	0.00015000	200	1	1/A	2.250E-08	2.531E-18	74.951%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	V	R	0.000 150 000	V	1.73	0.00008671	200	1	1/A	7.518E-09	2.826E-19	25.043%
2	**δVconnection**	Debido a la experien	*0.00*	V	R	0.000 000 500	V	1.73	0.00000029	200	1	1/A	8.353E-14	3.489E-29	0.000%
1.3	**δVTemp_coeff**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del F	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	100.000 2906	V	R	0.000 001 444	V	1.73	0.00000083	9	1	1/A	6.966E-13	5.391E-26	0.002%
4.1	**δVIND**	Valor de resolución	*0.00*	V	N6828	0.000 001 000	V	1.00	0.00000100	200	-1	1/A	1.000E-12	5.000E-27	0.003%
	U	**ΔVIND**	0.000 421	V		**0.000 347 88**					Incertidumbre Combinada		0.000 173 262	**Total**	**100.000%**
	Acreditado					0.000 300 000					*v eff*		320.27		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 347 882		

PUNTO No. 3

ΔVIND =	0.000 420 56	**V**	±	0.000 347 88	**V**

Acreditado = 0.000 300 000

$$\nu_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\nu_i}}$$

100 V @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	0.01	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	0.000 000 050	A	N9545	0.000 000 050	A	2.00	0.00000003	200	1	1/A	6.250E-16	1.953E-33	32.707%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	A	R	0.000 000 062	A	1.73	0.00000004	200	1	1/A	1.284E-15	8.248E-33	67.213%
2	**δVconnection**	Debido a la experien	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del F	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del F	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	0.010 0001	A	R	0.000 000 001	A	1.73	0.00000000	9	1	1/A	5.361E-19	3.193E-38	0.028%
4.1	**δVIND**	Valor de resolución	*0.00*	A	N6828	0.000 000 001	A	1.00	0.00000000	200	-1	1/A	1.000E-18	5.000E-39	0.052%
	U	**ΔVIND**	0.000 000	A		**0.000 000 09**					Incertidumbre Combinada		0.000 000 044	**Total**	**100.000%**
	Acreditado					0.000 000 090					*v eff*		357.95		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 000 088		

PUNTO No. 4

ΔVIND =	0.000 000 15	**A**	±	0.000 000 09	**A**

Acreditado = 0.000 000 090

$$\nu_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\nu_i}}$$

0.01 A @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	1.00	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	-0.000 021 900	A	N9545	0.000 010 000	A	2.00	0.00000500	200	1	1/A	2.500E-11	3.125E-24	10.845%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	A	R	0.000 024 800	A	1.73	0.00001434	200	1	1/A	2.055E-10	2.112E-22	89.147%
2	**δVconnection**	Debido a la experien	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	0.999 9871	A	R	0.000 000 143	A	1.73	0.00000008	9	1	1/A	6.817E-15	5.164E-30	0.003%
4.1	**δVIND**	Valor de resolución	*0.00*	A	N6828	0.000 000 100	A	1.00	0.00000010	200	-1	1/A	1.000E-14	5.000E-31	0.004%

U	**ΔVIND**	-0.000 035	A	**0.000 030 52**
Acreditado				0.000 031 000

Incertidumbre Combinada	0.000 015 183	**Total**	**100.000%**
v eff	247.99		
Valor de k calculado	2.01		
Incetidumbre Expandida	0.000 030 520		

$$\upsilon_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\upsilon_i}}$$

PUNTO No. 5

ΔVIND = -0.000 034 78 **A** ± 0.000 030 52 **A**

Acreditado = 0.000 031 000

1 A @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	10.00	Ω	N6828	*0.00*	Ω	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	0.000 056 000	Ω	N9545	0.000 010 000	Ω	2.00	0.00000500	200	1	1/A	2.500E-11	3.125E-24	2.878%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	Ω	R	0.000 047 000	Ω	1.73	0.00002717	200	1	1/A	7.381E-10	2.724E-21	84.968%
2	**δVconnection**	Debido a la experien	*0.00*	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del Fa	*0.00*	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del Fa	*0.00*	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	9.999 8930	Ω	R	0.000 004 086	Ω	1.73	0.00000236	9	1	1/A	5.577E-12	3.456E-24	0.642%
4.1	**δVIND**	Valor de resolución	*0.00*	Ω	N6828	0.000 010 000	Ω	1.00	0.00001000	200	-1	1/A	1.000E-10	5.000E-23	11.512%

U	**ΔVIND**	-0.000 051	Ω	**0.000 059 22**
Acreditado				0.000 060 000

Incertidumbre Combinada	0.000 029 473	**Total**	**100.000%**
v eff	271.39		
Valor de k calculado	2.01		
Incetidumbre Expandida	0.000 059 219		

$$\upsilon_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\upsilon_i}}$$

PUNTO No. 6

ΔVIND = -0.000 051 00 **Ω** ± 0.000 059 22 **Ω**

Acreditado = 0.000 060 000

10 Ω @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	W - S	% contribución
1	VCAL	Valor aplicado (Set	10000000.00	Ω	N6828	0.00	Ω	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	1327.000 000 000	Ω	N9545	20.000 000 000	Ω	2.00	10.00000000	200	1	1/A	1.000E+02	5.000E+01	10.219%
1.2	δVCAL	Deriva o Especifica	0.00	Ω	R	51.000 000 000	Ω	1.73	29.47976879	200	1	1/A	8.691E+02	3.776E+03	88.809%
2	δVconnection	Debido a la experien	0.00	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del F	0.00	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω_out_imp	Según manual del F	0.00	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	Ω	R	0.000 000 000	Ω	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	9998867.923 6000	Ω	R	5.047 347 369	Ω	1.73	2.91754183	9	1	1/A	8.512E+00	8.051E+00	0.870%
4.1	δVIND	Valor de resolución	0.00	Ω	N6828	1.000 000 000	Ω	1.00	1.00000000	200	-1	1/A	1.000E+00	5.000E-03	0.102%
	U	ΔVIND	194.923 600	Ω		62.879 874 81					Incertidumbre Combinada		31.282 084 618	Total	100.000%
	Acreditado					80.000 000 000					v eff		249.74		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		62.879 874 813		

$$v_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{v_i}}$$

PUNTO No. 7

ΔVIND = 194.923 600 00 Ω ± 62.879 874 81 Ω

Acreditado = 80.000 000 000

10000000 Ω @ 0 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	W - S	% contribución
1	VCAL	Valor aplicado (Set	1.00	V	N6828	0.00	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	-0.000 002 000	V	N9545	0.000 022 000	V	2.00	0.00001100	200	1	1/A	1.210E-10	7.321E-23	95.565%
1.2	δVCAL	Deriva o Especifica	0.00	V	R	0.000 004 000	V	1.73	0.00000231	200	1	1/A	5.346E-12	1.429E-25	4.222%
2	δVconnection	Debido a la experien	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del F	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω_out_imp	Según manual del F	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	0.999 9943	V	R	0.000 000 881	V	1.73	0.00000051	9	1	1/A	2.592E-13	7.467E-27	0.205%
4.1	δVIND	Valor de resolución	0.00	V	N6828	0.000 000 100	V	1.00	0.00000010	200	-1	1/A	1.000E-14	5.000E-31	0.008%
	U	ΔVIND	-0.000 008	V		0.000 022 63					Incertidumbre Combinada		0.000 011 252	Total	100.000%
	Acreditado					0.000 032 000					v eff		218.54		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 022 634		

$$v_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{v_i}}$$

PUNTO No. 8

ΔVIND = -0.000 007 69 V ± 0.000 022 63 V

Acreditado = 0.000 032 000

1 V @ 55 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	W - S	% contribución
1	VCAL	Valor aplicado (Set	1.00	V	N6828	0.00	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	-0.000 004 000	V	N9545	0.000 014 000	V	2.00	0.00000700	200	1	1/A	4.900E-11	1.201E-23	88.607%
1.2	δVCAL	Deriva o Especifica	0.00	V	R	0.000 004 000	V	1.73	0.00000231	200	1	1/A	5.346E-12	1.429E-25	9.667%
2	δVconnection	Debido a la experier	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del Fa	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω_out_imp	Según manual del Fa	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	1.000 0100	V	R	0.000 001 681	V	1.73	0.00000097	9	1	1/A	9.442E-13	9.906E-26	1.707%
4.1	δVIND	Valor de resolución	0.00	V	N6828	0.000 000 100	V	1.00	0.00000010	200	-1	1/A	1.000E-14	5.000E-31	0.018%
	U	ΔVIND	0.000 006	V		0.000 014 95					Incertidumbre Combinada		0.000 007 436	Total	100.000%
	Acreditado					0.000 014 000					v eff		249.70		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 014 948		

PUNTO No. 9

ΔVIND = 0.000 005 97 **V** ± 0.000 014 95 **V**

Acreditado = 0.000 014 000

$$v_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{v_i}}$$

1 V @ 1 000 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	W - S	% contribución
1	VCAL	Valor aplicado (Set	100.00	V	N6828	0.00	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	0.000 600 000	V	N9545	0.003 000 000	V	2.00	0.00150000	200	1	1/A	2.250E-06	2.531E-14	96.374%
1.2	δVCAL	Deriva o Especifica	0.00	V	R	0.000 500 000	V	1.73	0.00028902	200	1	1/A	8.353E-08	3.489E-17	3.578%
2	δVconnection	Debido a la experier	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del Fa	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω_out_imp	Según manual del Fa	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	99.999 3462	V	R	0.000 055 049	V	1.73	0.00003182	9	1	1/A	1.013E-09	1.139E-19	0.043%
4.1	δVIND	Valor de resolución	0.00	V	N6828	0.000 010 000	V	1.00	0.00001000	200	-1	1/A	1.000E-10	5.000E-23	0.004%
	U	ΔVIND	-0.000 054	V		0.003 073 78					Incertidumbre Combinada		0.001 527 954	Total	100.000%
	Acreditado					0.003 600 000					v eff		215.03		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.003 073 780		

PUNTO No. 10

ΔVIND = -0.000 053 82 **V** ± 0.003 073 78 **V**

Acreditado = 0.003 600 000

$$v_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{v_i}}$$

100 V @ 55 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	VCAL	Valor aplicado (Set	100.00	V	N6828	*0.00*	V	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	0.000 800 000	V	N9545	0.002 100 000	V	2.00	0.00105000	200	1	1/A	1.103E-06	6.078E-15	92.818%
1.2	δVCAL	Deriva o Especifica	*0.00*	V	R	0.000 500 000	V	1.73	0.00028902	200	1	1/A	8.353E-08	3.489E-17	7.032%
2	δVconnection	Debido a la experien	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del Fa	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω _out_imp	Según manual del Fa	*0.00*	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	V	R	0.000 000 000	V	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	99.999 7337	V	R	0.000 070 958	V	1.73	0.00004102	9	1	1/A	1.682E-09	3.145E-19	0.142%
4.1	δVIND	Valor de resolución	*0.00*	V	N6828	0.000 010 000	V	1.00	0.00001000	200	-1	1/A	1.000E-10	5.000E-23	0.008%
	U	ΔVIND	0.000 534	V		0.002 191 65					Incertidumbre Combinada		0.001 089 869	Total	100.000%
	Acreditado					0.002 200 000					*v eff*		230.81		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.002 191 649		

PUNTO No. 11

ΔVIND = 0.000 533 71 V ± 0.002 191 65 V

Acreditado = 0.002 200 000

$$\upsilon_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\upsilon_i}}$$

100 V @ 1 000 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	VCAL	Valor aplicado (Set	0.01	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	ΔVCAL	Certificado de Calib	-0.000 000 040	A	N9545	0.000 000 550	A	2.00	0.00000028	200	1	1/A	7.563E-14	2.860E-29	96.417%
1.2	δVCAL	Deriva o Especifica	*0.00*	A	R	0.000 000 090	A	1.73	0.00000005	200	1	1/A	2.706E-15	3.662E-32	3.450%
2	δVconnection	Debido a la experien	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	δVTemp_coeff	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	δV50 Ω _out_imp	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	δOpt	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	VIND	Valor indicado (indi	0.010 0005	A	R	0.000 000 004	A	1.73	0.00000000	9	1	1/A	4.279E-18	2.034E-36	0.005%
4.1	δVIND	Valor de resolución	*0.00*	A	N6828	0.000 000 010	A	1.00	0.00000001	200	-1	1/A	1.000E-16	5.000E-35	0.127%
	U	ΔVIND	0.000 000	A		0.000 000 56					Incertidumbre Combinada		0.000 000 280	Total	100.000%
	Acreditado					0.000 000 610					*v eff*		214.87		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 000 563		

PUNTO No. 12

ΔVIND = 0.000 000 49 A ± 0.000 000 56 A

Acreditado = 0.000 000 610

$$\upsilon_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\upsilon_i}}$$

0.01 A @ 55 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	0.01	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	-0.000 000 120	A	N9545	0.000 000 550	A	2.00	0.00000028	200	1	1/A	7.563E-14	2.860E-29	98.304%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	A	R	0.000 000 060	A	1.73	0.00000003	200	1	1/A	1.203E-15	7.234E-33	1.564%
2	**δVconnection**	Debido a la experier	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	0.010 0011	A	R	0.000 000 002	A	1.73	0.00000000	9	1	1/A	1.561E-18	2.707E-37	0.002%
4.1	**δVIND**	Valor de resolución	*0.00*	A	N6828	0.000 000 010	A	1.00	0.00000001	200	-1	1/A	1.000E-16	5.000E-35	0.130%
	U	**ΔVIND**	0.000 001	A		**0.000 000 56**					Incertidumbre Combinada		0.000 000 277	**Total**	**100.000%**
	Acreditado					0.000 000 560					*v eff*		206.91		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 000 558		

$$v_{eff} = \frac{u^4_{c(y)}}{\sum_{i=1}^{n} \frac{c_i^4 u^4_{(x_i)}}{v_i}}$$

PUNTO No. 13

ΔVIND = 0.000 001 02 **A** ± 0.000 000 56 **A**

Acreditado = 0.000 000 560

0.01 A @ 1 000 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	1.00	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	-0.000 036 000	A	N9545	0.000 065 000	A	2.00	0.00003250	200	1	1/A	1.056E-09	5.578E-21	97.392%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	A	R	0.000 009 000	A	1.73	0.00000520	200	1	1/A	2.706E-11	3.662E-24	2.495%
2	**δVconnection**	Debido a la experier	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	1.000 9719	A	R	0.000 000 822	A	1.73	0.00000048	9	1	1/A	2.259E-13	5.669E-27	0.021%
4.1	**δVIND**	Valor de resolución	*0.00*	A	N6828	0.000 001 000	A	1.00	0.00000100	200	-1	1/A	1.000E-12	5.000E-27	0.092%
	U	**ΔVIND**	0.000 936	A		**0.000 066 26**					Incertidumbre Combinada		0.000 032 932	**Total**	**100.000%**
	Acreditado					0.000 066 000					*v eff*		210.72		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 066 259		

$$v_{eff} = \frac{u^4_{c(y)}}{\sum_{i=1}^{n} \frac{c_i^4 u^4_{(x_i)}}{v_i}}$$

PUNTO No. 14

ΔVIND = 0.000 935 90 **A** ± 0.000 066 26 **A**

Acreditado = 0.000 066 000

1 A @ 55 Hz

No.	Componente	Fuente de informacion	Valor estimado		Distribución	Valor incertidumbre		Factor cobertura [k]	Valor incertidumbre (68.28 %)	Grados libertad	Coeficiente de sensibilidad		Contribución i a la incertidumbre, al cuadrado	*W - S*	% contribución
1	**VCAL**	Valor aplicado (Set	1.00	A	N6828	*0.00*	A	1.00	0.00000000	200	1	1/A	0.000E+00		0.000%
1.1	**ΔVCAL**	Certificado de Calib	-0.000 045 000	A	N9545	0.000 065 000	A	2.00	0.00003250	200	1	1/A	1.056E-09	5.578E-21	87.682%
1.2	**δVCAL**	Deriva o Especifica	*0.00*	A	R	0.000 021 000	A	1.73	0.00001214	200	1	1/A	1.473E-10	1.086E-22	12.232%
2	**δVconnection**	Debido a la experien	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.3	**δVTemp_coeff**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
1.4	**δV50 Ω_out_imp**	Según manual del Fa	*0.00*	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
3	**δOpt**	Opcional	0.00	A	R	0.000 000 000	A	1.73	0.00000000	200	1	1/A	0.000E+00	0.000E+00	0.000%
4	**VIND**	Valor indicado (indi	1.000 4787	A	R	0.000 000 317	A	1.73	0.00000018	9	1	1/A	3.364E-14	1.257E-28	0.003%
4.1	**δVIND**	Valor de resolución	*0.00*	A	N6828	0.000 001 000	A	1.00	0.00000100	200	-1	1/A	1.000E-12	5.000E-27	0.083%
	U	**ΔVIND**	0.000 434	A		**0.000 069 76**					Incertidumbre Combinada		0.000 034 708	**Total**	**100.000%**
	Acreditado					0.000 072 000					*ν eff*		255.17		
											Valor de k calculado		2.01		
											Incetidumbre Expandida		0.000 069 758		

$$\upsilon_{eff} = \frac{u_{c(y)}^4}{\sum_{i=1}^{n} \frac{c_i^4 u_{(x_i)}^4}{\upsilon_i}}$$

PUNTO No. 15

ΔVIND = 0.000 433 70 **A** ± 0.000 069 76 **A**

Acreditado = 0.000 072 000

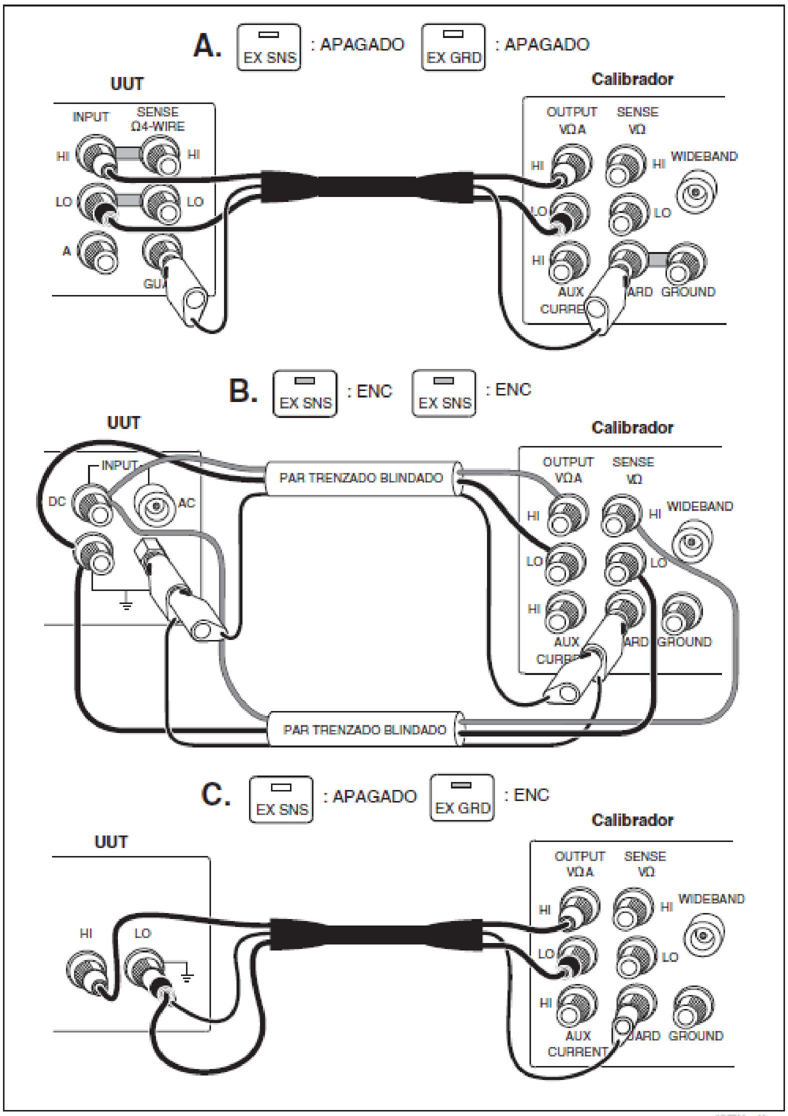
1 A @ 1 000 Hz

Connection diagrams

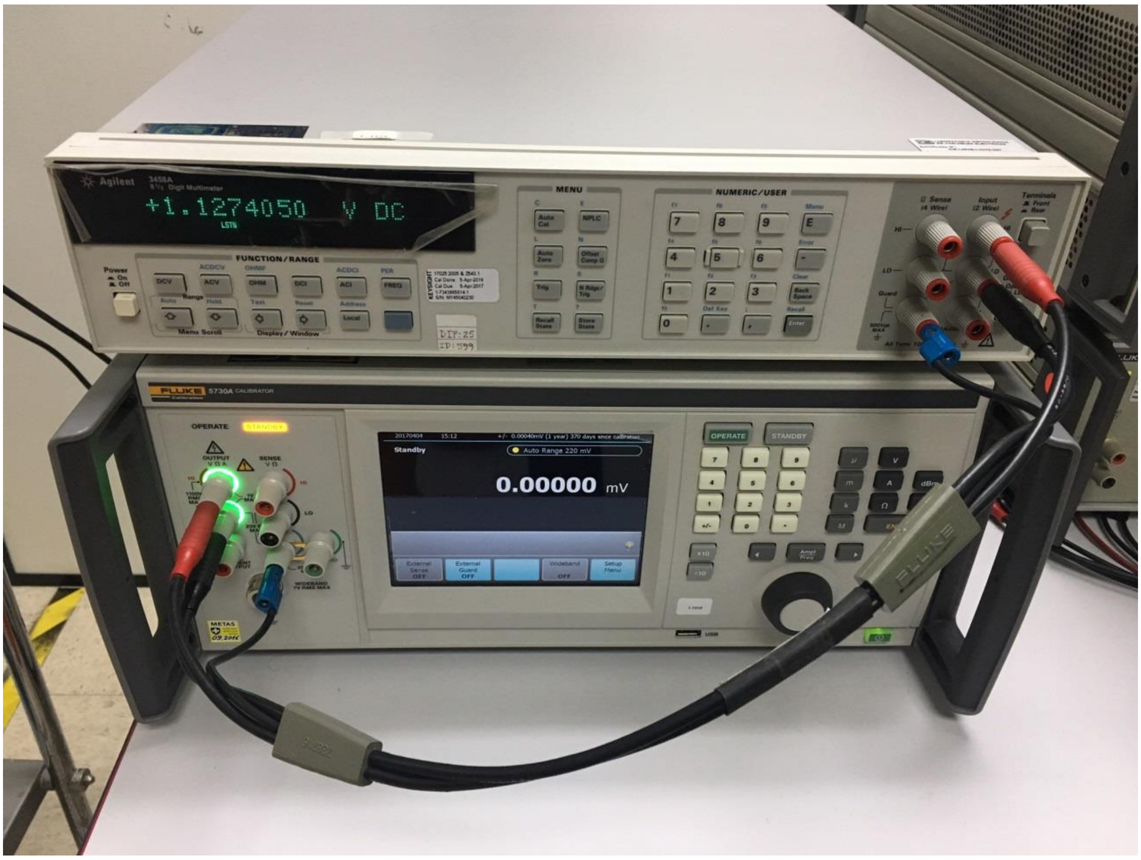
See Fluke 5720 A User Manual

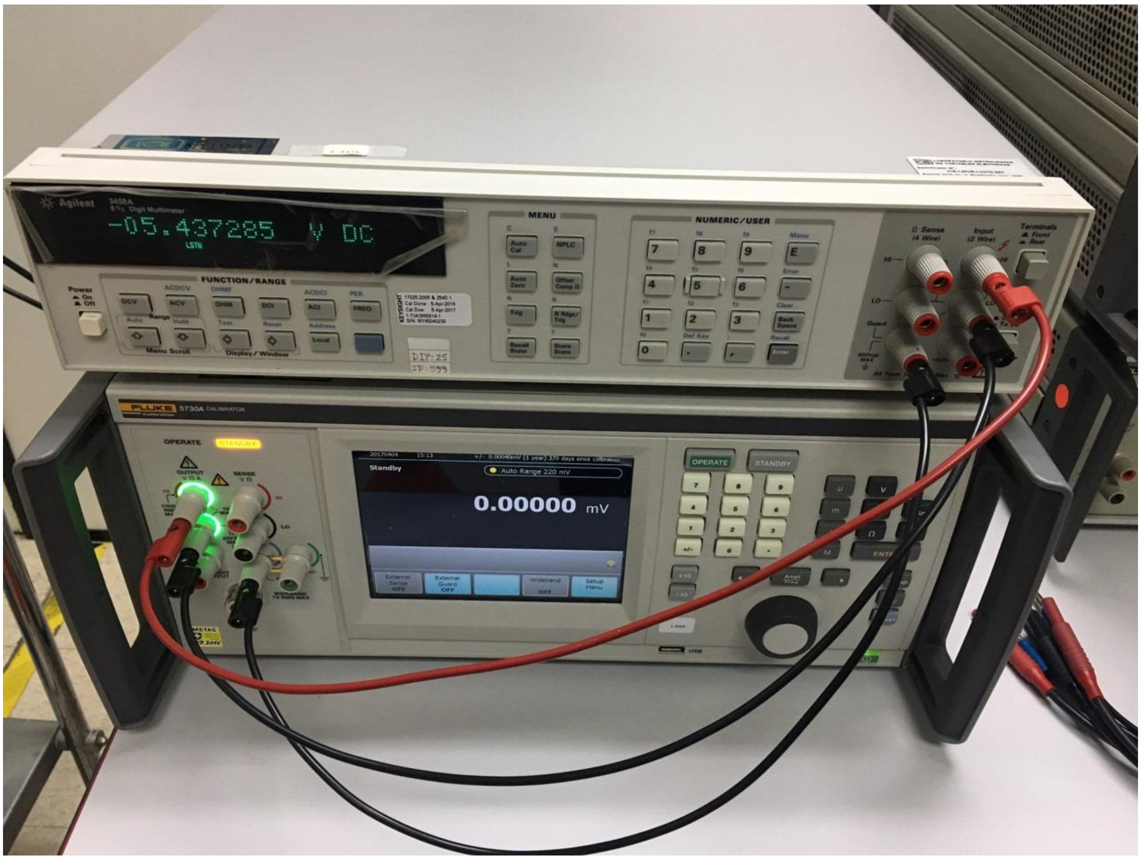
i. DC Voltage and AC Voltage: Following section **A. wiring.**

Conexión a una UAP (Unidad a Prueba)

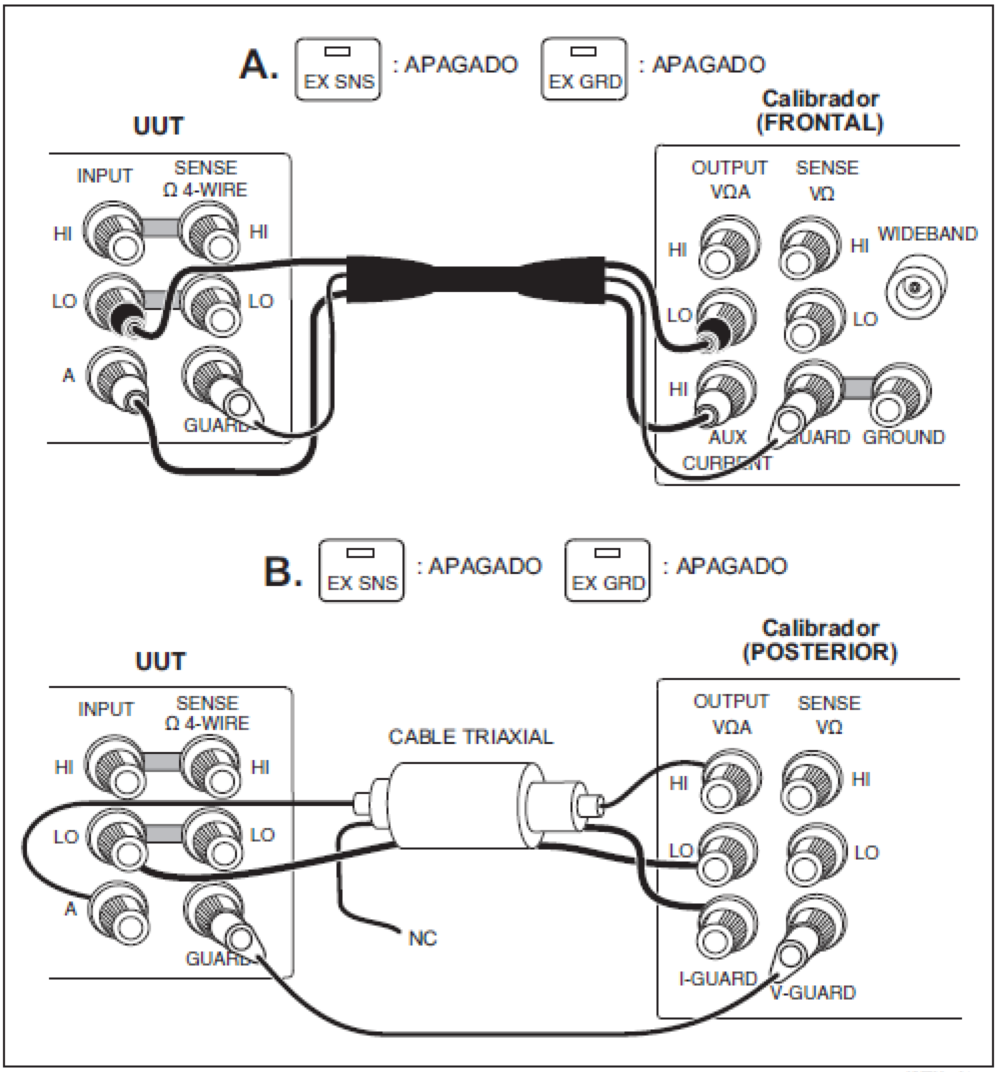


Tensión de cc, Tensión de ca ≤ 10 kHz

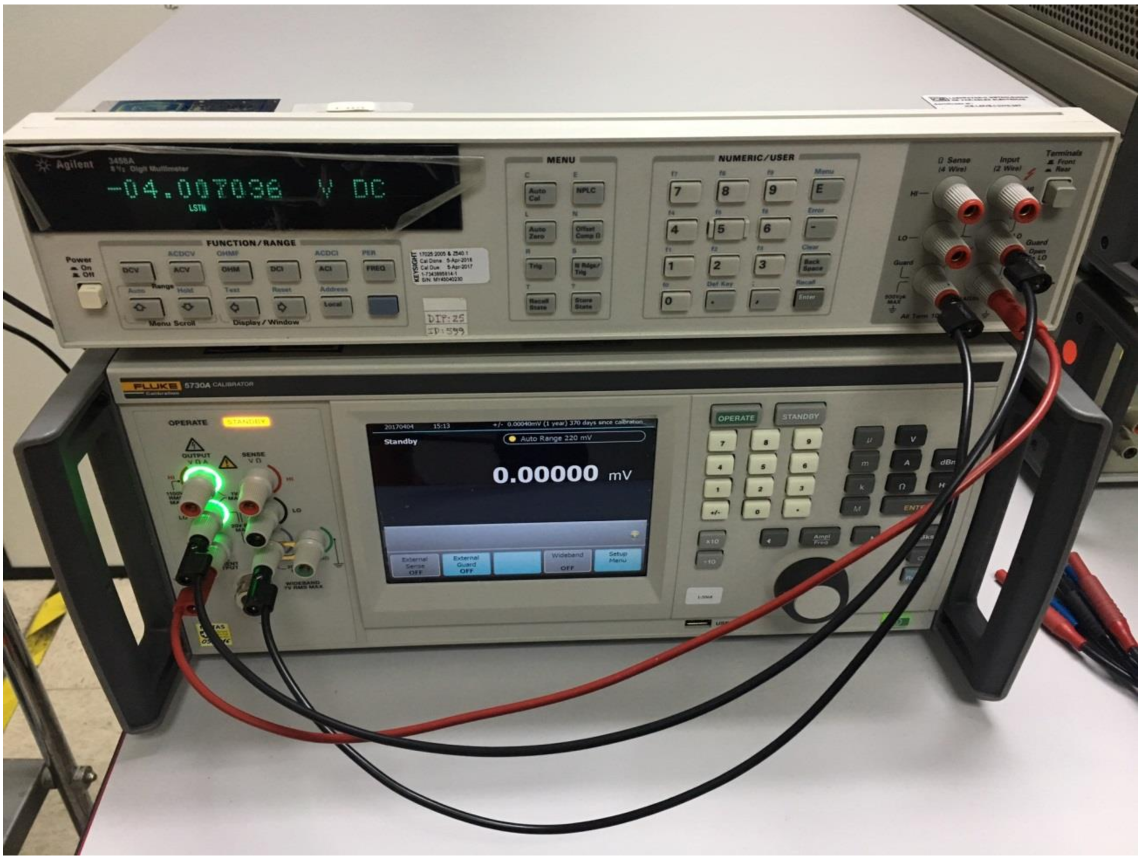




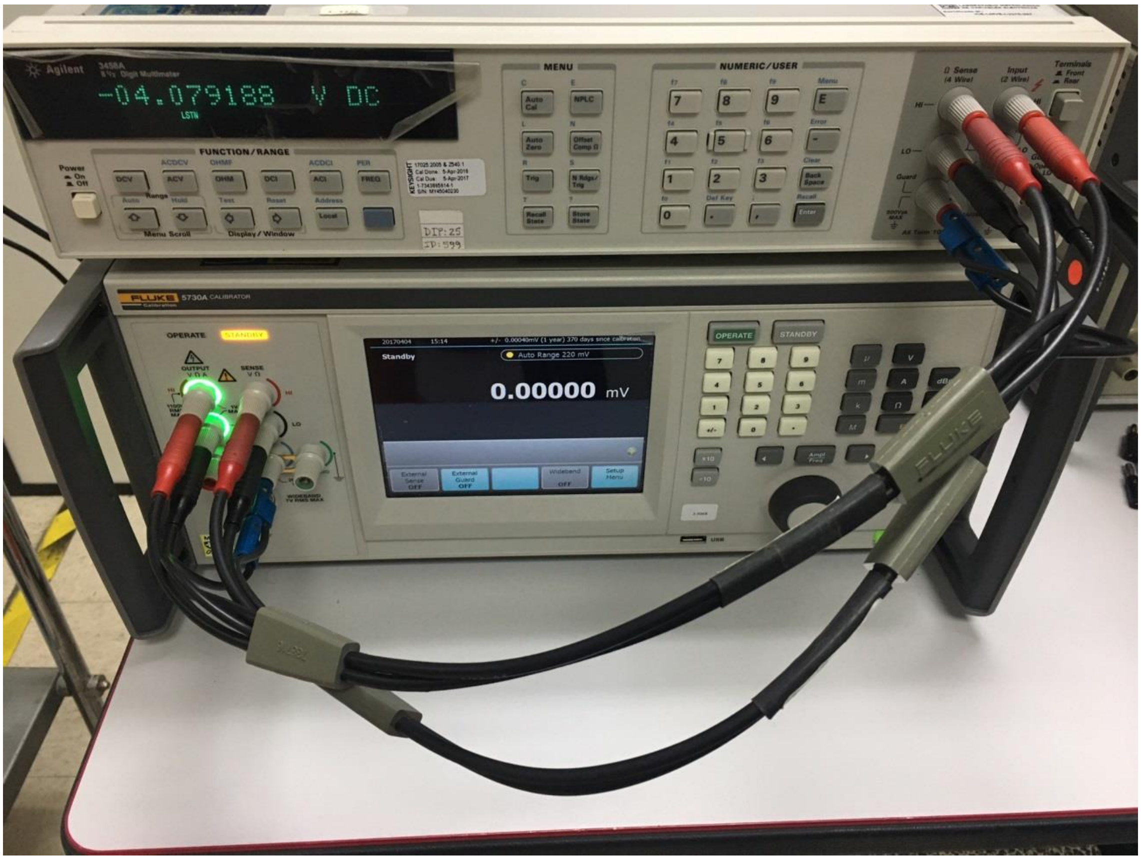
ii. DC Current and AC Current: Following section **A. wiring.**



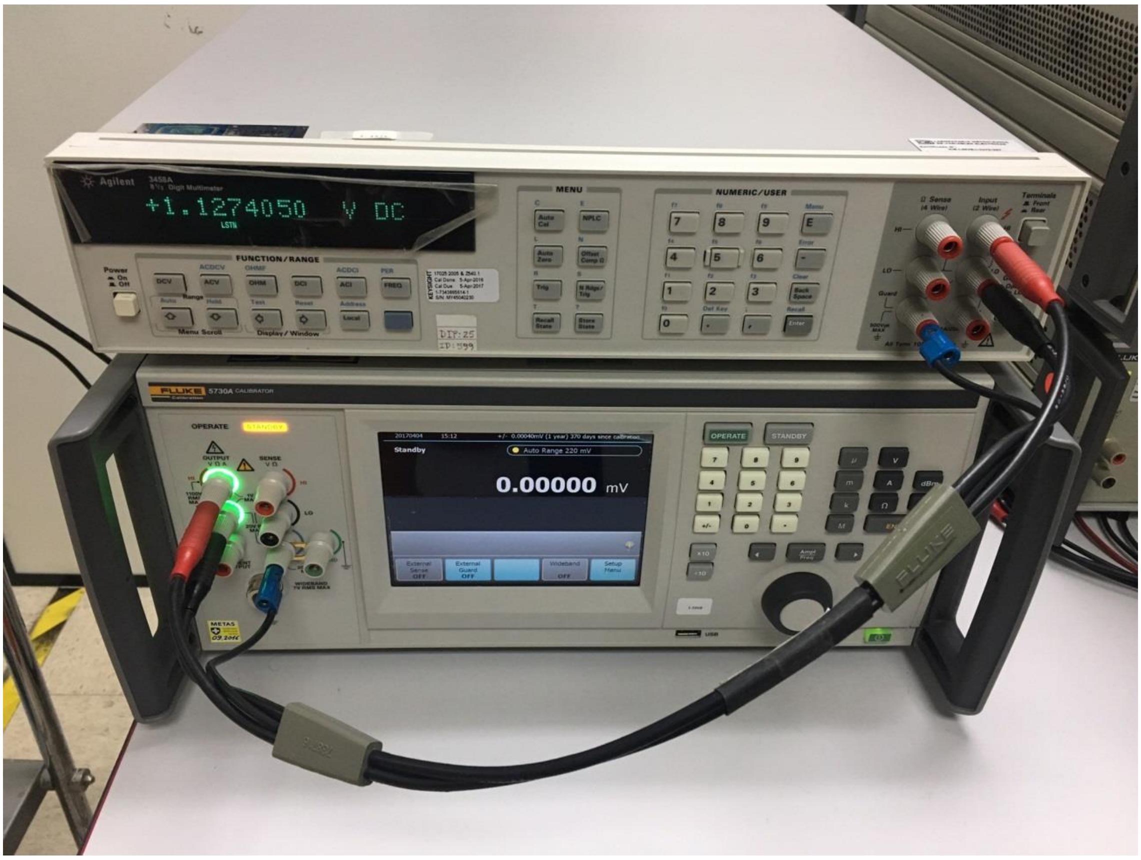
Corriente alterna ≤ 2A



iii. 4 Wire Resistance as follows



iv. 2 Wire Resistance as follows



Date: 04/04/2017

Signature:

Digital Multi-Meters (DMM) Comparison

SIM.EM-S13 COMPARISON

March 2017 – January 2018

Results Report

To:

Lic. Lucas Di Lillo
Instituto Nacional de Tecnología Industrial
Coordinador Unidad Técnica Electricidad, INTI - Física y Metrología
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Tel: + 506 2001-2374

From: **CENAM**

Re: **SIM.EM-S.13 – Comparison Report**
Date: (11/12/2017)

Laboratory

Name: **CENTRO NACIONAL DE METROLOGÍA**
Address: km 4.5 carretera a los Cués, Municipio El Marques, C.P. 76246, Querétaro, **MÉXICO**.

Personnel name:	**Dionisio Hernández Villaseñor**	Technnical contact
	Eduardo Gutierrez González	Metrologist
	Carlos David Avilés Castro	Cientific Coordinator
Phone Number:	+**(55) 442-211 05 00**	

E-mail: dhernand@cenam.mx
egutierr@cenam.mx
caviles @cenam.mx

Standard Equipment

Standards:

Traveling Standard of the Comparison	CENAM´s Standards
Digital multimeter Brand: Hewlett Packard Reference Number: 3458A Serial Number: 2823A15147	**Multifunction Calibrator** Brand: Fluke Reference Number: 5720A Serial Number: 9680207
	Standard Resistor : Brand: L&N 4025-B /**10 Ω** Serial Number: 1893729 Brand: Fluke 742A /**10 MΩ** Serial Number: 2468005

Environmental Conditions of the Measurement:

Temperature: **23.0 °C ± 0.5°C** Relative Humidity: **45 % ± 10 %**

Date of measurements: April 28th to May 17th of 2017

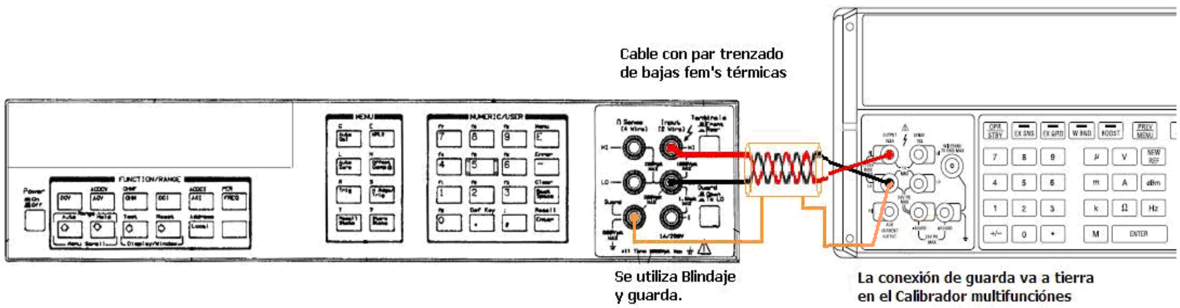
Description of the measuring method

Measurand		Method of mesurement	CENAM´s Procedures
DC Voltage	DCV	Direct	410-AC-P.037
DC Current	DCI	Direct	410-AC-P.040
Resistance	RES	Direct	410-AC-P.038
AC Voltage	ACV	Direct	410-AC-P.039
AC Current	ACI	Direct	410-AC-P.041

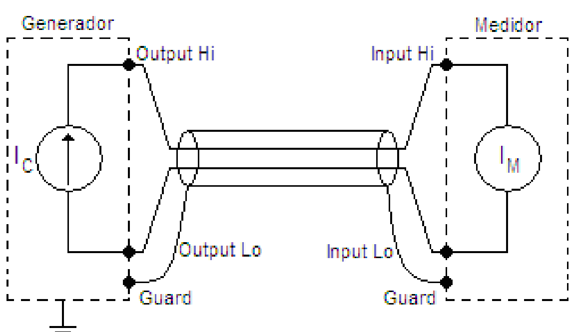
Connection diagrams

DC Voltage

Using the reversal polarity technique

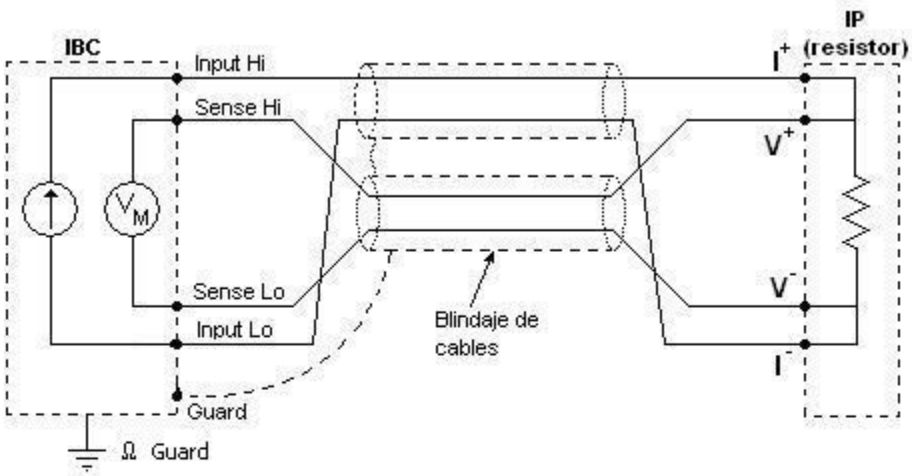


DC Current

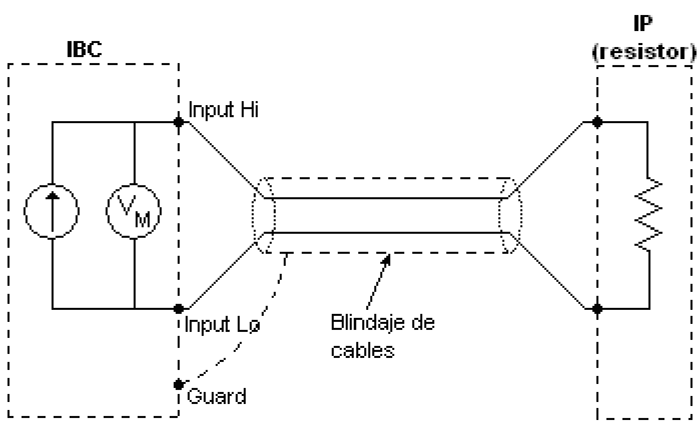


I_M is the measurement, including the internal offset

Resistance 10 Ω

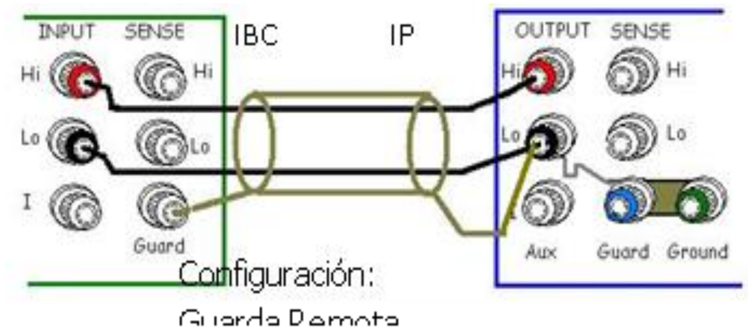


Resistance 10 MΩ



AC Voltage and AC Current

(Coaxial cable was used for AC voltage)



The reference standard and its traceability to the SI

Parameter (Measurand)	Reference standard used	Traceability to the SI
DC Voltage	**Multifunction Calibrator** Fluke 5720A SN: 9680207	**DC Voltage National Standard**
DC Current	**Multifunction Calibrator** Fluke 5720A SN: 9680207	**DC Current National Standard**
Resistance	**Standard Resistor** Leeds & Northrup Co 4025-B /10 Ω SN: 1893729	**Resistance National Standard**
	Standard Resistor Fluke 742A-10 MΩ SN: 2468005	
AC Voltage	**Multifunction Calibrator** Fluke 5720A SN: 9680207	**AC Voltage National Standard**
AC Current	**Multifunction Calibrator** Fluke 5720A SN: 9680207	**AC Current National Standard**

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Comparison Results:

Measurements Results

DC Voltage

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
1	**100 mV**	12/05/2017	3.3	2.0	3.0	23.0	45
		15/05/2017	2.4	2.0	3.0	23.0	45
		15/05/2017	2.7	2.0	3.0	23.0	45
		16/05/2017	3.9	2.0	3.0	23.0	45
	Error mean value (µV/V)		**3.1**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
2	**10 V**	28/04/2017	4.7	2.0	1.2	23.0	45
		28/04/2017	4.5	2.0	1.2	23.0	45
		12/05/2017	4.3	2.0	1.2	23.0	45
		15/05/2017	4.4	2.0	1.2	23.0	45
		15/05/2017	4.4	2.0	1.2	23.0	45
	Error mean value (µV/V)		**4.5**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
3	**100 V**	28/04/2017	4.9	2.0	1.9	23.0	45
		28/04/2017	5.1	2.0	1.9	23.0	45
		12/05/2017	4.2	2.0	1.9	23.0	45
		15/05/2017	3.3	2.0	1.9	23.0	45
		15/05/2017	3.5	2.0	1.9	23.0	45
	Error mean value (µV/V)		**4.2**				

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DC Current

Test point	Nominal Valu	Date	DMM Error (µ	Coverage Factor	Expanded Uncertainty* (µA/A)	Tamb (°C)	Hamb (%)
4	**10 mA**	15/05/2017	16.1	2.0	8.0	23.0	45
		15/05/2017	16.2	2.0	8.0	23.0	45
		16/05/2017	12.9	2.0	8.0	23.0	45
		17/05/2017	11.3	2.0	8.0	23.0	45
	Error mean value (µA/A)		**14.1**				

Test point	Nominal Valu	Date	DMM Error (µ	Coverage Factor	Expanded Uncertainty* (µA/A)	Tamb (°C)	Hamb (%)
5	**1 A**	27/04/2017	-42.1	2.0	10	23.0	45
		28/04/2017	-40.6	2.0	10	23.0	45
		28/04/2017	-39.9	2.0	10	23.0	45
		16/05/2017	-45.7	2.0	10	23.0	45
	Error mean value (µA/A)		**-42**				

Resistance

Test point	Nominal Valu	Date	DMM Error (µΩ/Ω)	Coverage Fac	Expanded Uncertainty* (µΩ/Ω)	Tamb (°C)	Hamb (%)
6	**10 Ω**	28/04/2017	-41	2.1	27	23.0	45
		15/05/2017	-28	2.1	27	23.0	45
		16/05/2017	-24	2.1	27	23.0	45
		16/05/2017	8	2.1	27	23.0	45
		17/05/2017	-13	2.1	27	23.0	45
	Error mean value (µΩ/Ω)		-20				

Test point	Nominal Valu	Date	DMM Error (µΩ/Ω)	Coverage Fac	Expanded Uncertainty* (µΩ/Ω)	Tamb (°C)	Hamb (%)
7	**10 MΩ**	12/05/2017	67	2.0	12	23.0	45
		13/05/2017	69	2.0	12	23.0	45
		14/05/2017	69	2.0	12	23.0	45
		15/05/2017	65	2.0	12	23.0	45
		16/05/2017	73	2.0	12	23.0	45
		17/05/2017	78	2.0	12	23.0	45
	Error mean value (µΩ/Ω)		70				

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AC Voltage

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
8	**1 V / 55 Hz**	11/05/2017	-19	2.0	28	23.0	45
		12/05/2017	-19	2.0	28	23.0	45
		15/05/2017	-12	2.0	28	23.0	45
		16/05/2017	-13	2.0	28	23.0	45
		17/05/2017	-17	2.0	28	23.0	45
	Error mean value (µV/V)		**-16**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
9	**1 V / 1 kHz**	11/05/2017	-2	2.0	28	23.0	45
		12/05/2017	0	2.0	28	23.0	45
		15/05/2017	4	2.0	28	23.0	45
		16/05/2017	5	2.0	28	23.0	45
		17/05/2017	-5	2.0	28	23.0	45
	Error mean value (µV/V)		**0**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
10	**100 V / 55 Hz**	11/05/2017	-15	2.0	36	23.0	45
		12/05/2017	4	2.0	36	23.0	45
		15/05/2017	4	2.0	36	23.0	45
		16/05/2017	7	2.0	36	23.0	45
		17/05/2017	-19	2.0	36	23.0	45
	Error mean value (µV/V)		**-4**				

Test point	Nominal Value	Date	DMM Error (µ	Coverage Fac	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
11	**100 V / 1 kHz**	11/05/2017	-11	2.0	36	23.0	45
		12/05/2017	7	2.0	36	23.0	45
		15/05/2017	8	2.0	36	23.0	45
		16/05/2017	8	2.0	36	23.0	45
		17/05/2017	-18	2.0	36	23.0	45
	Error mean value (µV/V)		**-1**				

AC Current

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
12	**10 mA / 55 Hz**	11/05/2017	44	2.0	41	23.0	45
		11/05/2017	39	2.0	41	23.0	45
		12/05/2017	22	2.0	41	23.0	45
		15/05/2017	60	2.0	41	23.0	45
		16/05/2017	87	2.0	41	23.0	45
		17/05/2017	41	2.0	41	23.0	45
	Error mean value (μV/V)		**49**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
13	**10 mA / 1 kHz**	11/05/2017	109	2.0	41	23.0	45
		11/05/2017	104	2.0	41	23.0	45
		12/05/2017	87	2.0	41	23.0	45
		15/05/2017	117	2.0	41	23.0	45
		16/05/2017	148	2.0	41	23.0	45
		17/05/2017	100	2.0	41	23.0	45
	Error mean value (μV/V)		**111**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
14	**1 A / 55 Hz**	11/05/2017	-16	2.0	73	23.0	45
		11/05/2017	-21	2.0	73	23.0	45
		12/05/2017	-29	2.0	73	23.0	45
		15/05/2017	41	2.0	73	23.0	45
		16/05/2017	33	2.0	73	23.0	45
		17/05/2017	15	2.0	73	23.0	45
	Error mean value (μV/V)		**4**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Fact	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
15	**1 A / 1 kHz**	11/05/2017	150	2.0	72	23.0	45
		11/05/2017	147	2.0	72	23.0	45
		12/05/2017	151	2.0	72	23.0	45
		15/05/2017	209	2.0	72	23.0	45
		16/05/2017	197	2.0	72	23.0	45
		17/05/2017	180	2.0	72	23.0	45
	Error mean value (μV/V)		**172**				

Uncertainty Budget and the uncertainty calculation based on GUM guildlines.

A Summary spreadsheet, and Uncertainty budget spreadsheet are given in the attached file with this report.

References

[1] SIM.EM-S13 COMPARISON PROTOCOL Voltage, current and resistance March 2017 – January 2018

[2] JCGM 100, Guide to the expression of uncertainty in measurement, GUM, 2008.

[3] Quality System of CENAM (Sistema de Gestión de Calidad).

CENAM

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of

MÉXICO

Dirección General de Metrología Eléctrica
Dirección de Mediciones Electromagnéticas
Laboratorio de Patrones Eléctricos Multifunciones

Date: January 9th, 2018 **Dionisio Hernández Villaseñor**

CENAMEP AIP

Centro Nacional de Metrología de Panamá AIP

To:

Isabel Castro Blanco
Laboratorio Metrológico de Variables Eléctricas
Instituto Costarricense de Electricidad

From: CENAMEP AIP

Re: **SIM comparison SIM.EM-S13 – Comparison Report**

Date:....................................(26/10/2017)

Laboratory

Name:	CENAMEP AIP
Address:	Panamá, Clayton, Ciudad del Saber, Edificio 206
Contact Personnel name:	Carlos Espinosa
Phone Number:	+507-517-3108
E-mail:	cespinosa@cenamep.org.pa

Standard Equipment

Standard:	Multifunction Calibrator
Brand:	FLUKE
Reference Number:	5720A
Serial Number:	8850201

Standard: Zener
Brand: FLUKE
Reference Number: 732B
Serial Number: 8008002

Standard: 10 MΩ Resistor
Brand: Measurement International
Reference Number: 9331
Serial Number: 1102346

Comparison Results

Calibration Method:
Direct comparison using a multifunction calibrator, a voltage source (Zener) and 10 MΩ resistor as references.

Environmental Conditions:

Temperature: 22.7 ± 0.6 °C
Relative Humidity: 50 ± 8 %

Measurement Results

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
1	100 mV	12-jun-2017	4.8	2	5.3	22.7	49
		14-jun-2017	4.4	2	5.3	22.8	51
		16-jun-2017	6.2	2	5.3	22.7	50
	Error mean value (uV/V)		5.1				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
2	10 V	12-jun-2017	4.3	2	1.4	22.7	49
		14-jun-2017	4.5	2	1.4	22.8	51
		16-jun-2017	5.0	2	1.4	22.7	50
	Error mean value (uV/V)		4.6				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
3	100 V	12-jun-2017	6.9	2	2.6	22.7	49
		14-jun-2017	4.4	2	2.6	22.8	51
		16-jun-2017	5.7	2	2.6	22.7	50
	Error mean value (uV/V)		5.6				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
4	10 mA	12-jun-2017	11	2	44	22.7	49
		14-jun-2017	10	2	44	22.8	51
		16-jun-2017	8	2	44	22.7	50
		20-jun-2017	0	2	44	22.6	50
		21-jun-2017	11	2	44	22.7	50
	Error mean value (uA/A)		8				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
5	1 A	12-jun-2017	-36	2	91	22.7	49
		14-jun-2017	-7	2	91	22.8	51
		16-jun-2017	-41	2	91	22.7	50
		20-jun-2017	-51	2	91	22.6	50
		21-jun-2017	2	2	91	22.7	50
	Error mean value (uA/A)		-27				

Test point	nominal value	date	DMM Error (uΩ/Ω)	k	U (uΩ/Ω)	T (°C)	Hr (%)
6	10 Ω	13-jun-2017	-14	2	6	22.7	50
		15-jun-2017	-18	2	6	22.9	52
		19-jun-2017	-15	2	6	22.5	52
	Error mean value (uΩ/Ω)		-16				

Test point	nominal value	date	DMM Error (uΩ/Ω)	k	U (uΩ/Ω)	T (°C)	Hr (%)
7	10 MΩ	13-jun-2017	-10	2	18	22.7	50
		15-jun-2017	-5	2	18	22.9	52
		19-jun-2017	1	2	18	22.5	52
	Error mean value (uΩ/Ω)		-5				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
8	1 V / 55 Hz	13-jun-2017	-20	2	46	22.7	50
		15-jun-2017	-14	2	46	22.9	52
		19-jun-2017	-10	2	46	22.5	52
	Error mean value (uV/V)		-15				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
9	1 V / 1 kHz	13-jun-2017	-5	2	53	22.7	50
		15-jun-2017	-2	2	53	22.9	52
		19-jun-2017	-1	2	53	22.5	52
	Error mean value (uV/V)		-3				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
10	100 V / 55 Hz	13-jun-2017	-15	2	51	22.7	50
		15-jun-2017	-17	2	51	22.9	52
		19-jun-2017	0	2	51	22.5	52
	Error mean value (uV/V)		-11				

Test point	nominal value	date	DMM Error (uV/V)	k	U (uV/V)	T (°C)	Hr (%)
11	100 V / 1 kHz	13-jun-2017	-17	2	62	22.7	50
		15-jun-2017	-16	2	62	22.9	52
		19-jun-2017	3	2	62	22.5	52
	Error mean value (uV/V)		-10				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
12	10 mA / 55 Hz	13-jun-2017	25	2	157	22.7	50
		15-jun-2017	37	2	157	22.9	52
		19-jun-2017	21	2	157	22.5	52
	Error mean value (uA/A)		28				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
13	10 mA / 1 kHz	13-jun-2017	77	2	157	22.7	50
		15-jun-2017	96	2	157	22.9	52
		19-jun-2017	76	2	157	22.5	52
	Error mean value (uA/A)		83				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
14	1 A / 55 Hz	13-jun-2017	-26	2	297	22.7	50
		15-jun-2017	1	2	297	22.9	52
		19-jun-2017	-21	2	297	22.5	52
	Error mean value (uA/A)		-15				

Test point	nominal value	date	DMM Error (uA/A)	k	U (uA/A)	T (°C)	Hr (%)
15	1 A / 1 kHz	13-jun-2017	148	2	297	22.7	50
		15-jun-2017	166	2	297	22.9	52
		19-jun-2017	158	2	297	22.5	52
	Error mean value (uA/A)		157				

Date: 2017-oct-26 Signature: Carlos Espinosa

To

Coordinator and Pilot Laboratory SIM comparison SIM.EM-S13

From:

Instituto Nacional de Metrología – INM - Colombia

Re: **SIM comparison SIM.EM-S13 – Comparison Report**

Date:………13/10/2017…………..

Laboratory

Name: Instituto Nacional de Metrología – INM –Colombia
Address: Av. Carrera 50 # 26 – 55 Int.2
Contact Personnel name: Mauricio Sáchica Avellaneda -Alexander Martínez López
Phone Number: (57-1) 2542222 ext. 1617
E-mail: msachica@inm.gov.co ; amartinez@inm.gov.co

Standard Equipment

Standard: Multifunction Calibrator
Brand: Fluke
Reference Number: 5730A
Serial Number: 3092501

Standard: Standard Resistor 100 Ω
Brand: Fluke
Reference Number: 742A-100
Serial Number: 3084002

Standard: Standard Resistor 10 Ω
Brand: Fluke
Reference Number: 742A-10
Serial Number: 3084001

Standard: Standard Resistor 10 MΩ
Brand: Fluke
Reference Number: 742A-10M
Serial Number: 3084004

Standard: Digital Multimeter
Brand: Fluke
Reference Number: 8508A
Serial Number: 950155045

Comparison Results:

Calibration Method:

To Measurement points 1, 2, 3, 5, 8, 9, 10, 11, 12, 13, 14, 15:

Direct measurement: Digital Multimeter HP 3458A is connected directly to Multifunction Calibrator. Multimeter readings are compared to characterized values of the Calibrator

To Measurement points 6, 7:

Direct measurement: Standard Resistors are connected directly to Digital Multimeter HP 3458A. Multimeter readings are compared to characterized values of the Standard Resistors

To Measurement point 4 (10 mA):

Indirect measurement by Ohm's law: The Digital Multimeter HP 3458A, a Current Source and a Standard Resistor are connected in series and the current flowing through them is calculated by Ohm's law using the characterized value of the Standard Resistor and measuring the voltage drop across it. Multimeter readings are compared to the calculated value of current.

Environmental Conditions:

Temperature: 23 °C ± 1 °C

Relative Humidity: 45 % ± 10 %

Measurements Results

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
1	100 mV	2017-08-02	1.7	2.0	12	23.40	39.77
		2017-08-03	-2.7	2.0	12	23.10	41.21
		2017-08-04	0.3	2.0	12	23.31	43.57
		2017-08-08	2.1	2.0	12	22.75	43.07
		2017-08-09	-1.1	2.0	12	23.10	42.64
		2017-08-10	-1.8	2.0	12	22.75	41.83
		2017-08-11	-1.7	2.0	12	23.05	41.28
	Error mean value (µV/V)		**-0.4**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
2	10 V	2017-08-02	4.5	2.0	3.8	23.35	40.00
		2017-08-03	4.6	2.0	3.8	22.97	41.38
		2017-08-04	4.6	2.0	3.8	23.37	43.75
		2017-08-08	4.2	2.0	3.8	22.77	42.61
		2017-08-09	4.5	2.0	3.8	23.06	43.95
		2017-08-10	4.6	2.0	3.8	22.82	41.84
		2017-08-11	4.4	2.0	3.8	23.11	41.39
	Error mean value (µV/V)		**4.5**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
3	100 V	2017-08-02	7.7	2.0	7.9	23.35	40.10
		2017-08-03	9.6	2.0	7.9	22.92	41.48
		2017-08-04	7.3	2.0	7.9	23.35	43.98
		2017-08-08	3.6	2.0	7.9	22.75	42.48
		2017-08-09	5.0	2.0	7.9	23.82	42.93
		2017-08-10	9.0	2.0	7.9	22.84	41.64
		2017-08-11	9.1	2.0	7.9	23.11	41.47
	Error mean value (µV/V)		**7.3**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
4	10 mA	2017-08-03	13.5	2.1	7.2	23.15	40.80
		2017-08-04	11.3	2.1	7.2	23.24	42.47
		2017-08-08	13.3	2.1	7.2	23.09	41.04
		2017-08-09	17.6	2.1	7.2	23.43	40.19
		2017-08-10	12.5	2.1	7.2	23.05	40.68
		2017-08-15	13.9	2.1	7.2	23.16	39.04
	Error mean value (µA/A)		**13.7**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
5	1 A	2017-08-02	-38	2.0	93	23.42	40.14
		2017-08-03	-50	2.0	93	23.04	41.17
		2017-08-04	-64	2.0	93	23.07	45.47
		2017-08-08	-58	2.0	93	22.95	41.42
		2017-08-09	-46	2.0	93	23.06	41.80
		2017-08-10	-57	2.0	93	22.97	40.84
	Error mean value (µA/A)		**-52**				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
6	10 Ω	2017-08-02	-17.5	2.0	2.3	23.04	41.36
		2017-08-03	-22.8	2.0	2.3	23.23	40.46
		2017-08-04	-21.7	2.0	2.0	23.29	42.83
		2017-08-08	-11.4	2.0	2.2	23.06	41.40
		2017-08-09	-7.5	2.0	2.4	23.02	42.72
		2017-08-10	-12.1	2.0	2.3	23.24	39.90
		2017-08-11	-15.9	2.0	2.1	23.01	42.43
	Error mean value (µΩ/Ω)		**-15.6**				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
7	10 MΩ	2017-08-02	-31.8	2.0	4.3	22.97	42.00
		2017-08-03	-24.0	2.0	4.1	23.22	40.63
		2017-08-04	-20.3	2.0	4.1	23.24	42.66
		2017-08-08	-26.0	2.0	4.4	23.10	41.18
		2017-08-09	-10.7	2.0	4.1	23.03	42.64
		2017-08-10	-20.6	2.0	4.5	22.90	41.55
		2017-08-11	-12.9	2.0	4.1	23.21	41.56
	Error mean value (µΩ/Ω)		**-20.9**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
8	1 V (55 Hz)	2017-08-02	-18	2.0	52	23.07	42.04
		2017-08-04	-11	2.0	52	23.35	44.25
		2017-08-08	-6	2.0	52	22.75	42.32
		2017-08-09	-10	2.0	52	22.95	42.45
		2017-08-10	-10	2.0	52	22.98	41.37
		2017-08-11	-12	2.0	52	23.19	41.41
	Error mean value (µV/V)		**-11**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
9	1 V (1 kHz)	2017-08-02	1	2.0	52	23.05	42.27
		2017-08-04	6	2.0	52	23.36	44.35
		2017-08-08	11	2.0	52	22.75	42.34
		2017-08-09	4	2.0	52	22.94	42.23
		2017-08-10	2	2.0	52	22.94	41.43
		2017-08-11	5	2.0	52	23.23	41.39
	Error mean value (µV/V)		**5**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
10	100 V (55 Hz)	2017-08-02	-15	2.0	63	23.01	42.34
		2017-08-04	-11	2.0	63	23.28	44.54
		2017-08-08	-24	2.0	63	22.77	42.21
		2017-08-09	-9	2.0	63	22.98	42.13
		2017-08-10	-23	2.0	63	22.95	41.34
		2017-08-11	-20	2.0	63	23.19	41.34
	Error mean value (µV/V)		**-17**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
11	100 V (1 kHz)	2017-08-02	-12	2.0	63	23.03	42.47
		2017-08-04	-5	2.0	63	23.20	44.81
		2017-08-08	-23	2.0	63	22.79	42.09
		2017-08-09	-5	2.0	63	22.99	42.02
		2017-08-10	-19	2.0	63	22.96	41.30
		2017-08-11	-17	2.0	63	23.19	41.68
	Error mean value (µV/V)		**-13**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
12	10 mA (55 Hz)	2017-08-02	50	2.0	143	23.13	42.26
		2017-08-04	76	2.0	143	23.25	43.99
		2017-08-08	22	2.0	143	22.96	41.60
		2017-08-09	74	2.0	143	23.08	41.08
		2017-08-10	47	2.0	143	23.13	40.65
		2017-08-11	48	2.0	143	23.83	39.29
	Error mean value (µA/A)		**53**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
13	10 mA (1 kHz)	2017-08-02	115	2.0	143	23.08	42.54
		2017-08-04	131	2.0	143	23.26	43.69
		2017-08-08	81	2.0	143	22.96	41.61
		2017-08-09	133	2.0	143	23.07	41.10
		2017-08-10	106	2.0	143	23.12	40.63
		2017-08-11	105	2.0	143	23.78	39.39
	Error mean value (µA/A)		**112**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
14	1 A (55 Hz)	2017-08-02	-6	2.0	289	23.06	42.62
		2017-08-04	-17	2.0	289	23.23	43.63
		2017-08-08	-42	2.0	289	23.00	41.55
		2017-08-09	16	2.0	289	22.95	41.12
		2017-08-10	-20	2.0	289	23.06	40.60
		2017-08-11	8	2.0	289	23.50	39.74
	Error mean value (µA/A)		**-10**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
15	1 A (1 kHz)	2017-08-02	164	2.0	289	23.05	42.77
		2017-08-04	146	2.0	289	23.31	43.42
		2017-08-08	123	2.0	289	23.00	41.40
		2017-08-09	182	2.0	289	23.03	41.11
		2017-08-10	142	2.0	289	23.05	40.91
		2017-08-11	179	2.0	289	23.27	40.13
	Error mean value (µA/A)		**156**				

Additional information:

Resistance measurements (10 Ω, 10 MΩ) were unstable as reported to the Coordinator and Pilot Laboratory SIM comparison SIM.EM-S13 on 17/08/2017. Instability is attributed to the Digital Multimeter, however in this report the resistance results are included

Date: 13/10/2017

Signature:

RESULTS REPORT

To :	Ing. Isabel Castro Blanco
From :	Juan José Mendoza Aguirre - IBMETRO
Re :	SIM.EM.-S13 COMPARISON PROTOCOL
Date :	23/03/2018

Laboratory :

Name :	Instituto Boliviano de Metrologia - IBMETRO
Address :	Av. CamachoNro. 1488
Contact Personel Name :	Juan José Mendoza Aguirre - IBMETRO
Phone Number :	(+591) 77775448
E-mail :	jjmendoza@ibmetro.gob.bo

Standard Equipment :

	Standard 1	**Standard 2**	**Standard 3**
Standard :	Reference Multimeter	Calibrator Multifunction	Presicion Resistance
Brand :	Fluke	Transmille	Transmille
Reference Number :	8508A	3010A	3000RS
Serial Number :	368071631	J1193J13	111235I14

Comparison Results :

Method Calibration: For the calibration of voltaje and current, the employed method was transfer. The primary estandard was the Fluke multimeter, the secondary standard was the Transmille multicalibrator who done the transfer to calibrate the Agilent-hp multimeter.
For the calibration of resistance, the direct comparison method is used.

Environmental Conditions:

Temperature :	23,7 °C	±	0,7 °C
Relative Humidity :	32,9 %	±	3,0 %

Measurements Results :

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
1	100 mV	25/10/2017	-1,9	2	17,0	23,8	37,2
		27/10/2017	0,3	2	17,0	22,9	39,7
		30/10/2017	-1,6	2	17,0	22,5	33,8
		31/10/2017	-0,8	2	17,0	22,6	30,9
		03/11/2017	1,2	2	17,0	23,1	35,9
	Error mean value (µV/V)		-0,5				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
2	10 V	26/10/2017	8,8	2	6,7	22,9	34,8
		27/10/2017	9,1	2	6,7	23,0	39,4
		30/10/2017	8,4	2	6,7	22,5	33,6
		31/10/2017	8,9	2	6,7	22,7	33,4
		03/11/2017	8,4	2	6,7	23,0	35,5
	Error mean value (µV/V)		8,7				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
3	100 V	25/10/2017	2,92	2	10,4	23,8	36
		27/10/2017	4,65	2	10,4	23,1	36,0
		30/10/2017	2,75	2	10,5	22,6	32,7
		31/10/2017	8,34	2	10,4	22,7	32,7
		03/11/2017	3,70	2	10,4	23,1	34,8
	Error mean value (µV/V)		4,47				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
4	10 mA	23/10/2017	13,8	2	34,6	22,9	35,6
		24/10/2017	16,7	2	34,6	23,3	33,5
		26/10/2017	16,0	2	34,6	23,0	33,7
		31/10/2017	16,1	2	34,6	22,8	32,9
		03/11/2017	16,6	2	34,6	23,2	33,7
	Error mean value (µA/A)		15,8				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
5	1 A	23/10/2017	-6,6	2	280,8	23,4	31,7
		24/10/2017	-12,2	2	280,8	23,3	30,9
		26/10/2017	-15,3	2	280,8	23,0	34,8
		30/10/2017	-8,5	2	280,8	22,7	33,0
		31/10/2017	-6,2	2	280,8	22,8	31,8
	Error mean value (µA/A)		-9,8				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T amb (ºC)	H amb (%)
6	10 Ω	23/10/2017	9,6	2	17,6	23,9	32,6
		24/10/2017	13,6	2	17,6	24	31,8
		26/10/2017	3,2	2	17,7	23,5	33,8
		31/10/2017	12,0	2	17,8	23,7	30,6
		03/11/2017	5,6	2	17,6	23,4	30,8
	Error mean value (µΩ/Ω)		8,8				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T amb (ºC)	H amb (%)
7	10 MΩ	23/10/2017	-21,8	2	34,7	23,9	31,9
		24/10/2017	-23,2	2	34,7	24	32,6
		25/10/2017	-22,0	2	34,6	24,1	31,8
		30/10/2017	-26,0	2	34,7	23,6	31,1
		31/10/2017	-21,2	2	34,7	23,9	30,0
	Error mean value (µΩ/Ω)		-22,9				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
8	1 V 55 Hz	25/10/2017	35,4	2	173,1	24	30,9
		26/10/2017	40,2	2	173,1	23,9	30,6
		27/10/2017	42,8	2	173,1	23,9	34,9
		30/10/2017	39,8	2	173,1	23,8	32,8
		31/10/2017	30,6	2	173,1	24,0	30
	Error mean value (µV/V)		37,8				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
9	1 V 1 kHz	25/10/2017	8,4	2	212,9	24,3	31,2
		27/10/2017	18,0	2	213,2	23,9	34,5
		30/10/2017	5,0	2	213,0	24,1	31,7
		31/10/2017	12,2	2	213,4	24,1	32,3
		03/11/2017	4,0	2	214,4	23,4	31,7
	Error mean value (µV/V)		7,4				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
10	100 V 55 Hz	23/10/2017	-8,6	2	194,2	24,3	31,8
		25/10/2017	15,4	2	194,3	24,4	30,9
		26/10/2017	29,2	2	194,3	24,1	30,6
		27/10/2017	34,6	2	194,4	24,0	34,9
		03/11/2017	29,2	2	194,4	23,5	33,6
	Error mean value (µV/V)		20,0				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T amb (ºC)	H amb (%)
11	100 V 1 kHz	23/10/2017	-31,0	2	248,2	23,3	31,8
		25/10/2017	-16,6	2	228,6	24,4	31,1
		30/10/2017	-27,2	2	228,6	24,5	30,9
		31/10/2017	-28,0	2	230,2	24,3	30
		03/11/2017	13,0	2	230,6	23,6	33,8
	Error mean value (µV/V)		-18,0				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
12	10 mA 55 Hz	23/10/2017	50,4	2	742,1	24,4	33,1
		24/10/2017	45,8	2	742,1	24,7	32,3
		26/10/2017	72,4	2	742,1	24,2	31,6
		31/10/2017	65,4	2	742,0	24,4	30,0
		03/11/2017	60,2	2	742,0	24,4	22,0
	Error mean value (µA/A)		58,8				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
13	10 mA 1kHz	23/10/2017	66,8	2	785,7	24,3	31,6
		26/10/2017	88,6	2	785,7	24,2	30,6
		30/10/2017	87,2	2	786,0	24,6	30
		31/10/2017	64,6	2	785,8	24,5	30
		03/11/2017	88,0	2	785,8	23,5	32,7
	Error mean value (µA/A)		79,1				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
14	1 A 55 Hz	23/10/2017	353,0	2	1139,0	24,1	32,9
		25/10/2017	769,9	2	1139,0	24,2	31,8
		30/10/2017	633,5	2	1145,1	24,5	24,9
		31/10/2017	970,9	2	1139,5	24,6	30
		03/11/2017	680,1	2	1139,6	23,5	32,6
	Error mean value (µA/A)		681,5				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T amb (ºC)	H amb (%)
15	1 A 1kHz	23/10/2017	611,9	2	1207,2	24,4	33,8
		24/10/2017	452,3	2	1209,1	25,2	33,8
		25/10/2017	665,7	2	1207,3	24,2	31,8
		30/10/2017	644,9	2	1207,5	24,6	32,0
		31/10/2017	668,1	2	1208,3	24,6	32,8
	Error mean value (µA/A)		608,6				

Date: 2018/04/12 Signature : Juan José Mendoza Aguirre - IBMETRO

To: Ing. Castro Blanco Blanca Isabel
Laboratorio Metrológico de Variables Eléctricas (ICE)

From: Siew Durga
Trinidad and Tobago Bureau of Standards (TTBS)

Re: **SIM comparison SIM.EM-S13 - Comparison Report**
Date: 15/03/2018

Laboratory

Name: Trinidad and Tobago Bureau of Standards (TTBS)
Address: 1-2 Century Drive, Trincity Industrial Estate, Macoya, Tunapuna, Trinidad
Contact Personnel Name: Siew Durga
Phone Number: (868) 662-8827
E-mail: Siew.Durga@ttbs.org.tt

Standard Equipment

Standard: Multifunction Calibrator 5720A
Brand: Fluke
Reference Number: MET497
Serial Number: 7015201

Comparison Results:

Calibration Method:

As outlined in section 4.3 of SIM.EM-S13 Comparison Protocol

Environmental Conditions:

Temperature: 23.6 °C ± 0.3 °C

Relative Humidity 52.3 % ± 1.65 %

Date: 2018-03-15 Signature: [signature]

Meaasurement Results: HP 3458A DMM (Serial No. 2823A15147)

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
1	100 mV	04/01/2018	4.74	2	4.5	22.0	56.6
		05/01/2018	2.72	2	4.5	24.1	51.2
		08/01/2018	6.68	2	4.5	23.7	51.3
		09/01/2018	4.48	2	4.5	23.3	52.4
		10/01/2018	4.44	2	4.5	23.3	52.3
	Error mean value (µV/V)		**4.61**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
2	10 V	04/01/2018	3.58	2	1.4	22.1	56.7
		05/01/2018	1.22	2	1.4	23.9	51.4
		08/01/2018	3.07	2	1.4	23.7	51.1
		09/01/2018	3.56	2	1.4	23.4	52.9
		10/01/2018	3.56	2	1.4	23.4	53.2
	Error mean value (µV/V)		**3.00**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
3	100 V	04/01/2018	5.92	2	2.0	22.1	56.6
		05/01/2018	3.59	2	2.0	23.9	51.0
		08/01/2018	5.95	2	2.0	23.7	51.2
		09/01/2018	4.72	2	2.0	21.7	58.9
		10/01/2018	4.84	2	2.0	23.5	53.7
	Error mean value (µV/V)		**5.00**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
4	10 mA	04/01/2018	17.2	2	16	23.9	62.9
		05/01/2018	16.4	2	16	23.5	50.4
		08/01/2018	10.0	2	16	24.0	51.5
		09/01/2018	20.6	2	16	23.6	53.9
		10/01/2018	20.3	2	16	23.7	53.9
	Error mean value (µA/A)		**16.9**				

Date: 2018-03-15 Signature: Durga

Meaasurement Results: HP 3458A DMM (Serial No. 2823A15147)

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb} (%)
5	1 A	04/01/2018	-43.8	2	39	24.1	55.3
		05/01/2018	-45.5	2	39	23.7	51.5
		08/01/2018	-18.9	2	39	23.8	51.2
		09/01/2018	-18.6	2	39	24.0	53.8
		10/01/2018	-18.6	2	39	24.1	53.6
	Error mean value (µA/A)		**-29.1**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
6	10 Ω	04/01/2018	-12.75	2	1.9	23.5	51.9
		05/01/2018	-3.75	2	1.9	24.1	53.9
		08/01/2018	10.75	2	1.9	23.6	51.2
		09/01/2018	5.25	2	2.0	24.3	52.2
		10/01/2018	-3.40	2	1.9	24.3	52.0
	Error mean value (µΩ/Ω)		**-0.78**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
7	10 MΩ	04/01/2018	-158.38	2	10.2	23.5	51.6
		05/01/2018	-150.38	2	6.9	23.6	57.2
		08/01/2018	-126.45	2	6.8	23.9	51.0
		09/01/2018	-132.53	2	7.0	24.2	51.9
		10/01/2018	-128.44	2	6.8	24.2	51.8
	Error mean value (µΩ/Ω)		**-139.23**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
8	1 V @ 55 Hz	04/01/2018	-14.1	2	28	23.5	56.3
		05/01/2018	-11.2	2	28	23.7	53.2
		08/01/2018	-14.4	2	28	24.0	50.4
		09/01/2018	-8.6	2	28	24.2	51.4
		10/01/2018	-10.2	2	28	24.2	51.4
	Error mean value (µV/V)		**-11.70**				

Date: 2018-03-15 Signature: Dwoge

Meaasurement Results: HP 3458A DMM (Serial No. 2823A15147)

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
9	1 V @ 1 kHz	04/01/2018	5.8	2	24	23.5	54.1
		05/01/2018	6.6	2	24	23.9	51.0
		08/01/2018	4.6	2	24	24.0	50.5
		09/01/2018	18.8	2	24	23.7	51.4
		10/01/2018	6.8	2	24	24.2	51.0
	Error mean value (µV/V)		**8.52**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
10	100 V @ 55 Hz	04/01/2018	18.2	2	21	23.5	51.6
		05/01/2018	-25.2	2	21	23.9	50.9
		08/01/2018	-27.8	2	21	24.0	50.5
		09/01/2018	-7.0	2	21	21.7	58.9
		10/01/2018	-9.0	2	21	23.6	49.9
	Error mean value (µV/V)		**-10.16**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
11	100 V @ 1 kHz	04/01/2018	17.8	2	15	23.5	51.3
		05/01/2018	-24.6	2	15	23.9	50.8
		08/01/2018	-24.2	2	15	24.0	50.7
		09/01/2018	-1.2	2	15	21.7	58.9
		10/01/2018	-1.6	2	15	23.4	55.4
	Error mean value (µV/V)		**-6.76**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
12	10 mA @ 55 Hz	04/01/2018	59.50	2	61	23.4	51.2
		05/01/2018	11.25	2	61	24.0	50.4
		08/01/2018	15.75	2	61	24.0	50.4
		09/01/2018	84.25	2	61	23.7	51.0
		10/01/2018	34.60	2	61	23.6	51.8
	Error mean value (µA/A)		**41.07**				

Date: 2018-03-15

Signature:

Meaasurement Results: HP 3458A DMM (Serial No. 2823A15147)

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
13	10 mA @ 1 kHz	04/01/2018	155.75	2	61	23.4	51.1
		05/01/2018	105.00	2	61	24.0	50.5
		08/01/2018	108.50	2	61	24.0	50.4
		09/01/2018	172.00	2	61	23.7	51.1
		10/01/2018	121.20	2	61	23.1	51.8
	Error mean value (µA/A)		**132.49**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
14	1 A @ 55 Hz	04/01/2018	15.25	2	104	23.4	51.2
		05/01/2018	-6.00	2	104	24.0	50.3
		08/01/2018	-13.25	2	104	23.9	50.1
		09/01/2018	39.75	2	104	21.7	58.9
		10/01/2018	8.00	2	104	22.8	53.7
	Error mean value (µA/A)		**8.75**				

Test point	Nominal Value	Date (dd/mm/yyyy)	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb} (%)
15	1 A @ 1 kHz	04/01/2018	207.50	2	104	23.5	64.0
		05/01/2018	193.50	2	104	24.0	50.2
		08/01/2018	190.00	2	104	23.8	50.0
		09/01/2018	244.50	2	104	21.7	58.9
		10/01/2018	190.20	2	104	22.5	56.7
	Error mean value (µA/A)		**205.14**				

Date: 2018-03-15 **Signature:**

الهيئة السعودية للمواصفات والمقاييس والجودة
Saudi Standards, Metrology and Quality Org.

المركز الوطني للقياس والمعايرة
National Measurement & Calibration Center

Report of

SIM.EM-S13 Comparison on Digital Multimeter

Performed By:

Abdullah M. Alrobaish

Ahmed R. AlAyali

Mohammed S. AlTkroni

Ahmed N. AlJomaie

05/05/2019

To

Castro Blanco Blanca Isabel

From: Saudi Standards, Metrology and Quality Organization-National Measurements and Calibration Center.SASO-NMCC

Re: **SIM comparisons SIM.EM-S13 – Comparison Report**

Date:05/05/2019

Laboratory

Name:	Saudi Standards, Metrology and Quality Organization
Address:	Saudi Arabia, Riyadh 11636
Contact Personnel name:	Ahmed N. Aljomaie
Phone Number :	+966554473399
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Standard Equipment

Standard:	Digital multimeter
Brand:	Hewlett Packard
Reference Number:	3458A
Serial Number:	2823A15147

Comparison Results:

Calibration Method:

The Measurements of the Digital multimeter are performed by directly connecting the Multifunction Calibrator Fluke 5730A output to DMM input and apply the desired value from Fluke 5730A.

Figure 1:Example of "AC Current the Connection "

Environmental Conditions:

Temperature:	(23 ± 2)°C
Relative Humidity:	(50 ± 20) %

- **Measurements Results**

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (^oC)	H_{amb}(%)
1	100 mV	1/04/2019	4.29	2.06	6.0	22.2	41
		2/04/2019	2.89	2.06	6.0	22.6	39
		3/04/2019	0.10	2.06	6.0	22.3	37
		4/04/2019	12.55	2.06	6.0	22.5	39
		7/04/2019	5.48	2.06	6.0	22.8	40
Error Mean Value (µV/V)			5.06				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (^oC)	H_{amb}(%)
2	10 V	1/04/2019	4.93	2.06	2.0	22.2	41
		2/04/2019	5.11	2.06	2.0	22.6	39
		3/04/2019	4.84	2.06	2.0	22.3	37
		4/04/2019	4.61	2.06	2.0	22.5	39
		7/04/2019	4.22	2.06	2.0	22.8	40
Error Mean Value (µV/V)			4.74				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (^oC)	H_{amb}(%)
3	100 V	1/04/2019	5.91	2.06	4.0	22.2	41
		2/04/2019	6.49	2.06	4.0	22.6	39
		3/04/2019	5.56	2.06	4.0	22.3	37
		4/04/2019	3.01	2.06	4.0	22.5	39
		7/04/2019	9.20	2.06	4.0	22.8	40
Error Mean Value (µV/V)			6.03				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
4	10 mA	1/04/2019	18.38	2.06	13	22.3	40
		2/04/2019	15.63	2.06	13	22.5	40
		3/04/2019	8.55	2.06	13	22.4	39
		4/04/2019	11.15	2.06	13	22.4	41
		7/04/2019	9.74	2.06	13	22.5	41
Error Mean Value (µA/A)			12.69				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
5	1 A	1/04/2019	12.66	2.09	86	22.3	40
		2/04/2019	11.17	2.09	86	22.5	40
		3/04/2019	42.12	2.09	86	22.4	39
		4/04/2019	43.67	2.09	86	22.4	41
		7/04/2019	36.51	2.09	86	22.5	41
Error Mean Value (µA/A)			29.23				

Test Point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T_{amb} (°C)	H_{amb}(%)
6	10 Ω	1/04/2019	4.60	2.06	6.0	22.5	38
		2/04/2019	0.90	2.06	6.0	22.4	38
		3/04/2019	4.30	2.06	6.0	22.3	37
		4/04/2019	1.40	2.06	6.0	22.2	39
		7/04/2019	11.50	2.06	6.0	22.3	39
Error Mean Value (µΩ/Ω)			4.54				

Test Point	Nominal Value	Date	DMM Error (μΩ/Ω)	Coverage Factor	Expanded Uncertainty (μΩ/Ω)	T_{amb} (°C)	H_{amb}(%)
7	10 MΩ	1/04/2019	5.47	2.06	18	22.5	38
		2/04/2019	6.85	2.06	18	22.4	38
		3/04/2019	3.51	2.06	18	22.3	37
		4/04/2019	1.09	2.06	18	22.2	39
		7/04/2019	22.25	2.06	18	22.3	39
Error Mean Value (μΩ/Ω)			7.83				

Test Point	Nominal Value	Date	DMM Error (μV/V)	Coverage Factor	Expanded Uncertainty (μV/V)	T_{amb} (°C)	H_{amb}(%)
8	1 V @55Hz	1/04/2019	17.80	2.09	55	23	41
		2/04/2019	13.80	2.09	55	22.7	42
		3/04/2019	18.80	2.09	55	22.7	40
		4/04/2019	19.30	2.09	55	22.6	39
		7/04/2019	23.20	2.09	55	22.7	39
Error Mean Value (μV/V)			18.58				

Test Point	Nominal Value	Date	DMM Error (μV/V)	Coverage Factor	Expanded Uncertainty (μV/V)	T_{amb} (°C)	H_{amb}(%)
9	1 V @1kHz	1/04/2019	6.00	2.06	33	23	41
		2/04/2019	10.60	2.06	33	22.7	42
		3/04/2019	2.70	2.06	33	22.7	40
		4/04/2019	6.10	2.06	33	22.6	39
		7/04/2019	1.50	2.06	33	22.7	39
Error Mean Value (μV/V)			5.38				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb}(%)
10	100 V @55Hz	1/04/2019	45.40	2.06	64	23	41
		2/04/2019	46.00	2.06	64	22.7	42
		3/04/2019	51.30	2.06	64	22.7	40
		4/04/2019	62.60	2.06	64	22.6	39
		7/04/2019	58.00	2.06	64	22.7	39
Error Mean Value (µV/V)			52.66				

Test Point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T_{amb} (°C)	H_{amb}(%)
11	100 V @1kHz	1/04/2019	9.90	2.09	63	23	41
		2/04/2019	0.90	2.09	63	22.7	42
		3/04/2019	14.90	2.09	63	22.7	40
		4/04/2019	24.50	2.09	63	22.6	39
		7/04/2019	21.50	2.09	63	22.7	39
Error Mean Value (µV/V)			14.34				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
12	10 mA @55Hz	1/04/2019	8.70	2.09	149	22.5	41
		2/04/2019	51.10	2.09	149	22.6	43
		3/04/2019	0.24	2.09	149	22.6	40
		4/04/2019	3.40	2.09	149	22.5	41
		7/04/2019	2.70	2.09	149	22.3	39
Error Mean Value (µA/A)			13.23				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
13	10 mA @1kHz	1/04/2019	100.30	2.09	149	22.5	41
		2/04/2019	52.00	2.09	149	22.6	43
		3/04/2019	92.60	2.09	149	22.6	40
		4/04/2019	85.70	2.09	149	22.5	41
		7/04/2019	85.90	2.09	149	22.3	39
Error Mean Value (µA/A)			83.30				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
14	1 A @55Hz	1/04/2019	49.50	2.09	278	22.5	41
		2/04/2019	109.30	2.09	278	22.6	43
		3/04/2019	98.70	2.09	278	22.6	40
		4/04/2019	33.30	2.09	278	22.5	41
		7/04/2019	112.80	2.09	278	22.3	39
Error Mean Value (µA/A)			80.72				

Test Point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T_{amb} (°C)	H_{amb}(%)
15	1 A @1kHz	1/04/2019	173.00	2.09	278	22.5	41
		2/04/2019	120.10	2.09	278	22.6	43
		3/04/2019	116.70	2.09	278	22.6	40
		4/04/2019	162.60	2.09	278	22.5	41
		7/04/2019	119.50	2.09	278	22.3	39
Error Mean Value (µA/A)			138.38				

Date:05/05/2019 Signature:

Informe de intercomparacíon SIM.EM-S13

Re: SIM comparisons SIM.EM-S13 – Comparison Report

Date: (03/04/2017)

Laboratorio:

INTI - Instituto Nacional de Tecnología Industrial

Laboratorio de multímetros y calibradores.

Av. Gral. Paz 5445 - CP 1650 - Edificio 3 y 44 San Martín - Buenos Aires - Rep. Argentina

(54 11) 4724-6200 Interno 6675 E-mail: atoran@inti.gob.ar

Equipos utilizados:

Calibrador multifunción	Modelo 5700A s/n 6375303
Patrón de tensión de referencia	Fluke 732B s/n C215015
Resistor patrón 10 MΩ	INTI Gamma2-10M

Método de calibración:

El multímetro fue calibrado por comparación directa, utilizando el procedimiento PEE51, con un calibrador Fluke modelo 5700A, patrón de tensión de referencia y patrón de resistencia.

Para los distintos puntos de medición propuestos se configuro en multímetro según las indicaciones del protocolo y se respetaron los tiempos de calentamiento propuestos en el mencionado protocolo.

Condiciones ambientales:

Temperatura ambiente de medición: (23 ± 1) ºC
Humedad relativa ambiente: (50 ± 10) %

Resultados de las mediciones:

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
1	100 mV	07/03/2017	4,9	2	5,0	23	50	37,3
		13/03/2017	5,5	2	5,0	23	50	37,1
		20/03/2017	4,1	2	5,0	23	50	36,8
		28/03/2017	4,0	2	5,0	23	50	37,2
				2	5,0	23	50	
	ERROR MEAN VALUE (µV/V)		4,6					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
2	10 V	07/03/2017	2,6	2	1,0	23	50	36,8
		13/03/2017	2,2	2	1,0	23	50	37,3
		21/03/2017	4,4	2	1,0	23	50	37,3
		22/03/2017	3,3	2	1,0	23	50	37,0
		28/03/2017	2,6	2	1,0	23	50	37,1
	ERROR MEAN VALUE (µV/V)		3,0					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
3	100 V	08/03/2017	2,9	2	5,0	23	50	35,6
		22/03/2017	1,7	2	5,0	23	50	
		08/03/2017	1,5	2	5,0	23	50	
		23/03/2017	2,1	2	5,0	23	50	
		28/03/2017	4,0	2	5,0	23	50	
	ERROR MEAN VALUE (µV/V)		2,4					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
4	10 mA	08/03/2017	5,0	2	2,0	23	50	37,4
		09/03/2017	2,5	2	2,0	23	50	37,2
		15/03/2017	4,8	2	2,0	23	50	36,9
		15/03/2017	4,9	2	2,0	23	50	37,5
				2	2,0	23	50	
	ERROR MEAN VALUE (µA/A)		4,3					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
5	1 A	08/03/2017	94	2	7,0	23	50	37,4
		09/03/2017	75	2	7,0	23	50	36,9
		15/03/2017	107	2	7,0	23	50	37,6
				2	7,0	23	50	
				2	7,0	23	50	
	ERROR MEAN VALUE (µA/A)		92					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µΩ/Ω)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µΩ/Ω)	Tamb (°C)	HR (%)	TEMP? (°C)
6	10 Ω	09/03/2017	-3,8	2	2,5	23	50	37,1
		10/03/2017	-4,6	2	2,5	23	50	37,3
		14/03/2017	-4,1	2	2,5	23	50	37,8
		15/03/2017	-5,3	2	2,5	23	50	37,6
		22/03/2017	-1,4	2	2,5	23	50	37,2
	ERROR MEAN VALUE (µΩ/Ω)		-3,8					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µΩ/Ω)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µΩ/Ω)	Tamb (°C)	HR (%)	TEMP? (°C)
7	10 MΩ	09/03/2017	-28	2	15	23	50	36,9
		10/03/2017	-21	2	15	23	50	37,3
		10/03/2017	-16	2	15	23	50	37,3
		14/03/2017	-10	2	15	23	50	37,6
		16/03/2017	-19	2	15	23	50	37,4
	ERROR MEAN VALUE (µΩ/Ω)		-18					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
8	1 V, 55 Hz	08/03/2017	-17	2	11	23	50	37,2
		09/03/2017	-17	2	11	23	50	37,5
		14/03/2017	-13	2	11	23	50	37,1
		21/03/2017	-8	2	11	23	50	37,6
		21/03/2017	-9	2	11	23	50	37,6
	ERROR MEAN VALUE (µV/V)		-13					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
9	1 V, 1 kHz	08/03/2017	1,3	2	11	23	50	37,2
		09/03/2017	2,8	2	11	23	50	37,3
		14/03/2017	5,2	2	11	23	50	37,2
		21/03/2017	10,2	2	11	23	50	37,6
		21/03/2017	7,1	2	11	23	50	37,6
	ERROR MEAN VALUE (µV/V)		5,3					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
10	100 V, 55 Hz	14/03/2017	-8	2	45	23	50	37,3
		21/03/2017	-8	2	45	23	50	37,0
		23/03/2017	-7	2	45	23	50	38,1
		23/03/2017	-10	2	45	23	50	38,1
				2	45	23	50	
	ERROR MEAN VALUE (µV/V)		-8					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µV/V)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µV/V)	Tamb (°C)	HR (%)	TEMP? (°C)
11	100 V, 1 kHz	14/03/2017	-3	2	46	23	50	37,0
		21/03/2017	-2	2	46	23	50	36,8
		23/03/2017	-4	2	46	23	50	38,1
		23/03/2017	-4	2	46	23	50	37,8
				2	46	23	50	
	ERROR MEAN VALUE (µV/V)		-3					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
12	10 mA, 55 Hz	09/03/2017	25	2	125	23	50	36,9
		10/03/2017	27	2	125	23	50	37,3
		14/03/2017	29	2	125	23	50	36,4
		16/03/2017	15	2	125	23	50	37,6
		17/03/2017	16	2	125	23	50	37,8
	ERROR MEAN VALUE (µA/A)		22					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
13	10 mA, 1 kHz	09/03/2017	92	2	125	23	50	36,9
		10/03/2017	97	2	125	23	50	37,3
		14/03/2017	102	2	125	23	50	37,0
		16/03/2017	82	2	125	23	50	37,6
		17/03/2017	83	2	125	23	50	37,5
	ERROR MEAN VALUE (µA/A)		91					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
14	1 A, 55 Hz	09/03/2017	84	2	450	23	50	36,9
		10/03/2017	125	2	450	23	50	37,2
		14/03/2017	97	2	450	23	50	37,5
		16/03/2017	92	2	450	23	50	37,6
		17/03/2017	93	2	450	23	50	37,6
	ERROR MEAN VALUE (µA/A)		98					

TEST POINT	NOMINAL VALUE	DATE	DMM ERROR (µA/A)	COVERAGE FACTOR	EXPANDED UNCERTAINTY (µA/A)	Tamb (°C)	HR (%)	TEMP? (°C)
15	1 A, 1 kHz	09/03/2017	266	2	450	23	50	36,9
		10/03/2017	307	2	450	23	50	36,9
		14/03/2017	282	2	450	23	50	37,8
		16/03/2017	285	2	450	23	50	37,6
		17/03/2017	293	2	450	23	50	37,8
	ERROR MEAN VALUE (µA/A)		286					

To:

Isabel Castro Blanco
Laboratorio Metrológico de Variables Eléctricas
Instituto Costarricense de Electricidad
Costa Rica

and

Lucas Di Lillo
Instituto Nacional de Tecnología Industrial
Argentina

From:

Rodrigo Ventura
Laboratory of Calibration in Electrical Metrology
National Institute of Metrology, Quality and Technology
Brazil

Re: **SIM comparisons SIM.EM-SX – Comparison Report**
Date: 05/08/2017

Laboratory

Name: Instituto Nacional de Metrologia, Qualidade e Tecnologia – Inmetro
Address: Av. Nossa Senhora das Graças, nº 50, Prédio 2 – Xerém – Duque de Caxias – RJ – Brasil – 25250-020
Contact Personnel name: Rodrigo Ventura
Phone Number: +55 21 2679-9244
E-mail: rvventura@inmetro.gov.br

Standard Equipment

Standard: Multifunction Calibrators
Brand: Fluke
Reference Number: 5720A
Serial Numbers: 6695201, 6650204 and 7930202

Standard: 10 Ω Standard Resistor's
Brand: Tinsley
Reference Number: 5685A
Serial Numbers: 279865 and 270296

Standard: 10 MΩ Standard Resistor
Brand: Guildline
Reference Number: 9334A-10M
Serial Number: 70272

Comparison Results:

Calibration Method:
Direct reading with characterized multifunction calibrators and standard resistor's.

Environmental Conditions:
Temperature: 22,6 °C ± 0,5 °C
Relative Humidity: 58 % ± 5 %

Measurments Results

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
1	100 mV	09/06/2017	4,4	2,00	3,8	22,7	62
		14/06/2017	4,8	2,00	3,8	23,0	55
		03/07/2017	5,9	2,00	4,6	22,1	56
		04/07/2017	6,7	2,00	4,6	22,4	52
		05/07/2017	5,8	2,00	4,6	22,2	54
	Error mean value (µV/V)		**5,5**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
2	10 V	09/06/2017	3,4	2,00	3,0	22,7	62
		14/06/2017	2,9	2,00	3,0	23,0	55
		16/06/2017	2,7	2,00	3,0	22,8	56
		20/06/2017	3,8	2,00	3,0	22,5	58
		21/06/2017	3,8	2,00	3,0	22,5	59
	Error mean value (µV/V)		**3,3**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
3	100 V	09/06/2017	3,0	2,00	3,0	22,7	62
		14/06/2017	2,2	2,00	3,0	23,0	55
		16/06/2017	1,5	2,00	3,0	22,8	56
		20/06/2017	3,0	2,00	3,0	22,5	58
		21/06/2017	2,7	2,00	3,0	22,5	59
	Error mean value (µV/V)		**2,5**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
4	10 mA	09/06/2017	2,1	2,00	9,9	22,7	62
		14/06/2017	1,6	2,00	9,9	23,0	55
		19/06/2017	4,9	2,00	9,9	22,6	57
		20/06/2017	8,8	2,00	9,9	22,5	58
		23/06/2017	7,3	2,00	9,9	22,3	59
	Error mean value (µA/A)		**4,9**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
5	1 A	09/06/2017	100	2,00	10	22,7	62
		19/06/2017	82	2,00	10	23,0	55
		23/06/2017	104	2,00	10	22,3	59
		05/07/2017	84	2,00	11	22,5	58
		06/07/2017	116	2,00	11	22,1	56
	Error mean value (µA/A)		**97**				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	Tamb (°C)	Hamb (%)
6	10 Ω	26/06/2017	-2,4	2,00	2,7	22,8	58
		27/06/2017	-1,7	2,00	2,7	22,8	58
		28/06/2017	-2,4	2,00	3,3	22,8	58
		29/06/2017	-1,2	2,00	2,7	23,1	58
		30/06/2017	-1,7	2,00	2,7	22,8	58
	Error mean value (µA/A)		**-1,9**				

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	Tamb (°C)	Hamb (%)
7	10 MΩ	26/06/2017	-4	2,00	12	22,8	58
		27/06/2017	-7	2,00	12	22,8	58
		28/06/2017	-7	2,00	12	22,9	58
		29/06/2017	-7	2,00	12	23,1	58
		30/06/2017	-8	2,00	12	22,8	58
	Error mean value (µA/A)		**-7**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
8	1 V (55 Hz)	14/6/2017	-20,3	2,00	8,0	23,0	55
		19/6/2017	-23,4	2,00	8,0	22,6	57
		20/6/2017	-14,6	2,00	8,0	22,5	58
		04/7/2017	-16,8	2,00	8,0	22,2	54
		05/7/2017	-15,7	2,00	8,0	22,2	58
	Error mean value (µV/V)		**-18,2**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
9	1 V (1 kHz)	14/6/2017	3,1	2,00	8,0	23,0	55
		19/6/2017	-4,4	2,00	8,0	22,6	57
		20/6/2017	1,2	2,00	8,0	22,5	58
		04/7/2017	2,7	2,00	8,0	22,2	54
		05/7/2017	4,5	2,00	8,0	22,2	58
	Error mean value (µV/V)		**1,4**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
10	100 V (55 Hz)	14/6/2017	-32	2,00	13	23,0	55
		19/6/2017	-29	2,00	13	22,6	57
		20/6/2017	-21	2,00	13	22,5	58
		04/7/2017	-23	2,00	13	22,2	54
		05/7/2017	-29	2,00	13	22,2	58
	Error mean value (µV/V)		**-27**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
11	100 V (1 kHz)	14/6/2017	-25	2,00	13	23,0	55
		19/6/2017	-20	2,00	13	22,6	57
		20/6/2017	-11	2,00	13	22,5	58
		04/7/2017	-12	2,00	13	22,2	54
		05/7/2017	-17	2,00	13	22,2	58
	Error mean value (µV/V)		**-17**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
12	10 mA (55 Hz)	09/6/2017	21	2,00	27	22,7	62
		14/6/2017	14	2,00	27	23,0	55
		19/6/2017	32	2,00	27	22,6	57
		20/6/2017	4	2,00	27	22,5	58
		23/6/2017	48	2,00	27	22,3	59
	Error mean value (µA/A)		**24**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
13	10 mA (1 kHz)	09/6/2017	98	2,00	27	22,7	62
		14/6/2017	96	2,00	27	23,0	55
		19/6/2017	106	2,00	27	22,6	57
		20/6/2017	86	2,00	27	22,5	58
		23/6/2017	113	2,00	27	22,3	59
	Error mean value (µA/A)		**100**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
14	1 A (55 Hz)	09/6/2017	85	2,00	52	22,7	62
		14/6/2017	92	2,00	52	23,0	55
		19/6/2017	82	2,00	52	22,6	57
		20/6/2017	96	2,00	52	22,5	58
		23/6/2017	74	2,00	52	22,3	59
	Error mean value (µA/A)		**86**				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
15	1 A (1 kHz)	09/6/2017	270	2,00	52	22,7	62
		14/6/2017	277	2,00	52	23,0	55
		19/6/2017	275	2,00	52	22,6	57
		20/6/2017	284	2,00	52	22,5	58
		23/6/2017	261	2,00	52	22,3	59
	Error mean value (µA/A)		**273**				

Date: 05/08/2017

Signature: Rodrigo Ventura
Head of the Laboratory of Calibration in Electrical Metrology

Annex 6
Results Report

To
Comparison Coordinators
Lucas Di Lillo, INTI
Isabel Castro, ICE

From: INTN - Paraguay
Re: **SIM comparisons SIM.EM-S13 – Comparison Report**
Date: 24/01/2018

Laboratory

Name: Instituto Nacional de Tecnología, Normalización y Metrología
Address: Avda. Artigas 3973 y Gral. Roa, Asunción - Paraguay
Contact Personnel name: Jorge Luis Parra Román
Phone Number: +59 521 290 160
E-mail: jparra@intn.gov.py

Standard Equipment

Standard: Digital Multimeter
Brand: Hewlett Packard
Reference Number: DMM Hewlett Packard HP3458A
Serial Number: 2823A15128

Comparison Results:

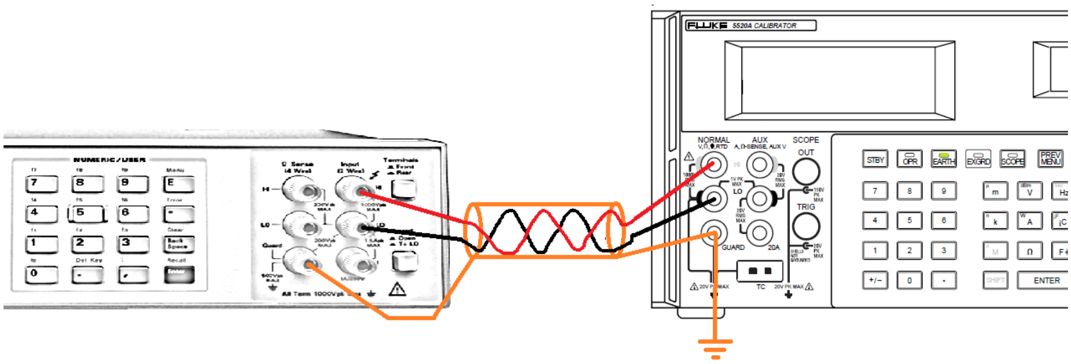
Calibration Method:

In the measurement process, the substitution method was used, that is, measuring the signal generated by the calibrator first with the traveler standard, and immediately afterwards, it is measured with the reference multimeter of the laboratory.

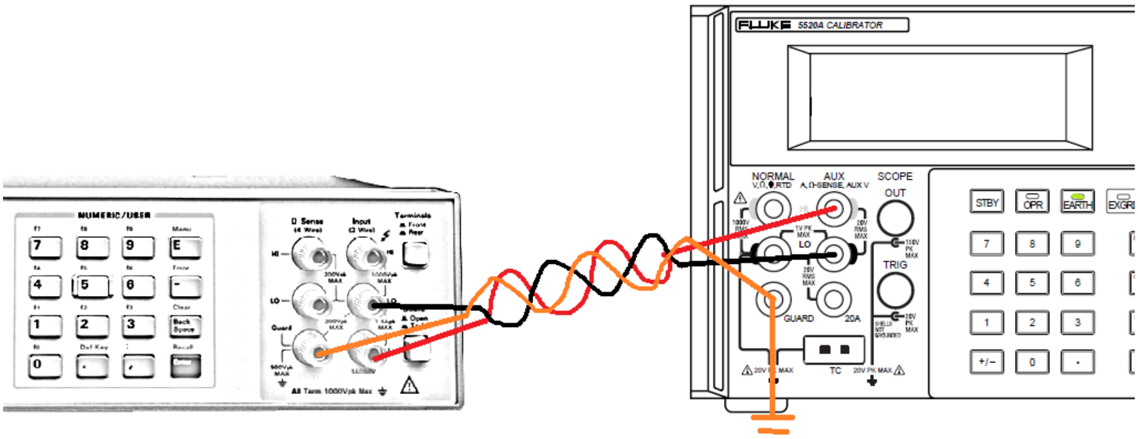
Environmental Conditions:
Temperature: 23 °C ± 3 °C
Relative Humidity: 50 % ± 25 %

Conections Diagrams:

DC Voltage

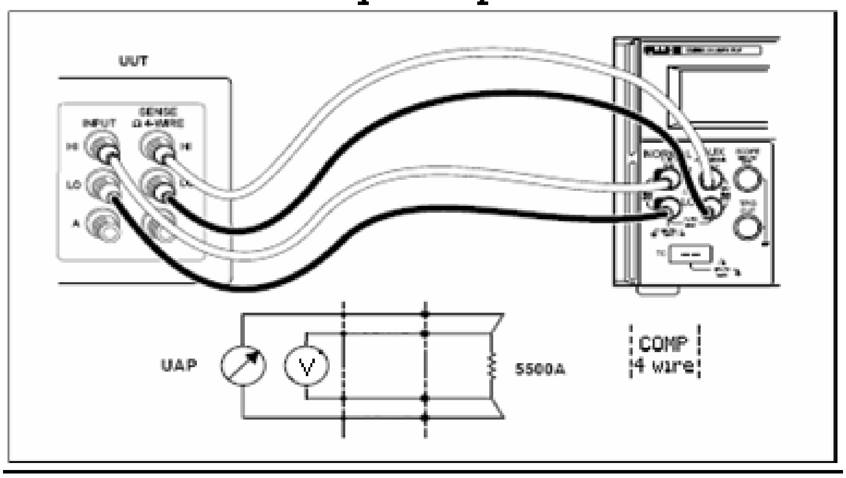


DC Current

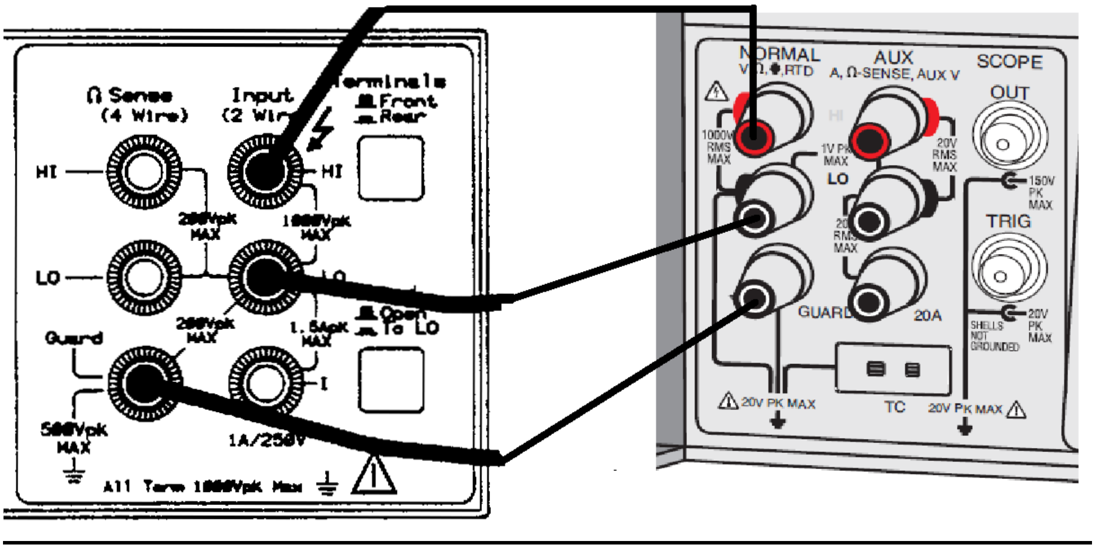


Resistance

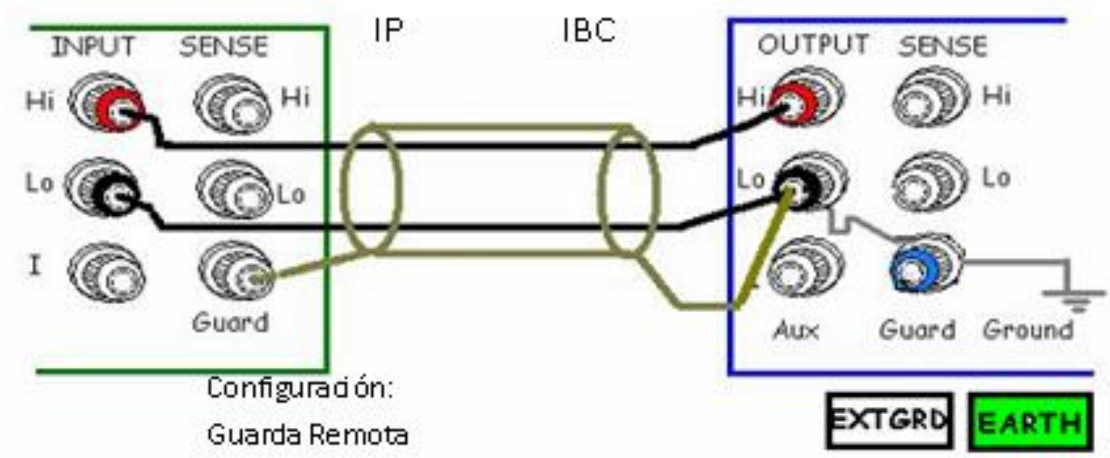
(4 wires)



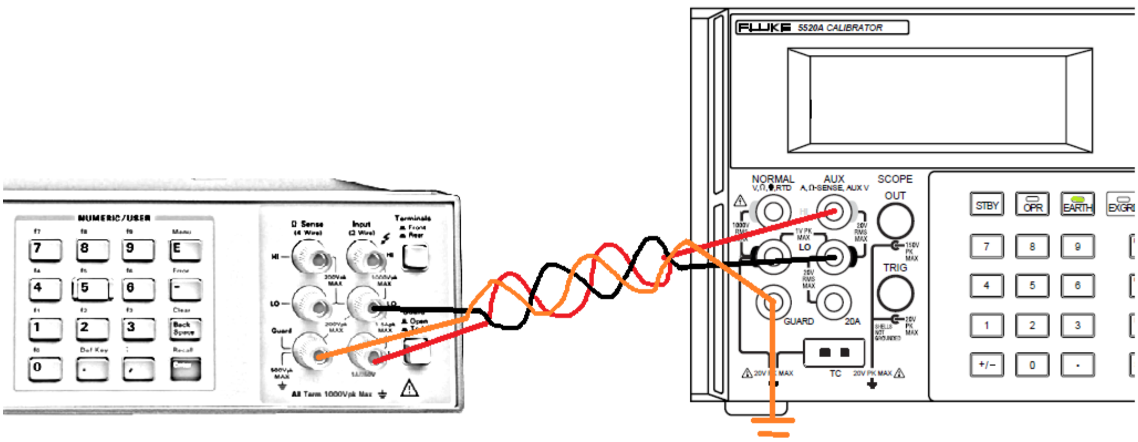
(2 wires)



AC Voltage



AC Current



Reference Standard

The Standard of the laboratory of INTN (FLUKE 8508A), it is traceable to the SI trough INMETRO, with Certificate of Calibration number DIMCI 2273/2015.

Measurments Results

DC Voltage

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
1	100 mV	2017-10-24	-12,67	2,03	3,45	24,8	53,0
		2017-10-30	12,17	2,00	2,82	24,6	51,7
		2017-11-01	-1,83	2,00	2,84	22,2	58,2
		2017-11-06	-3,15	2,21	4,62	22,6	60,2
		2017-11-08	7,56	2,01	3,01	21,0	55,4
Error mean value (µV/V)			0,42				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
2	10 V	2017-10-24	0,47	2,00	3,00	23,9	54,5
		2017-10-30	-0,02	2,00	3,00	25,0	51,9
		2017-11-01	0,12	2,00	3,00	21,7	61,3
		2017-11-06	-0,74	2,00	3,00	23,9	54,0
		2017-11-08	0,90	2,00	3,01	21,5	58,4
Error mean value (µV/V)			0,15				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
3	100 V	2017-10-24	-1,44	2,00	3,11	22,3	54,5
		2017-10-30	-0,58	2,00	3,10	24,1	51,3
		2017-11-01	-6,65	2,87	16,09	22,5	62,4
		2017-11-06	1,59	2,00	3,10	24,1	55,7
		2017-11-08	1,07	2,00	3,11	21,0	57,2
Error mean value (µV/V)			-1,20				

DC Current

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
4	10 mA	2017-10-25	11,50	2,02	12,44	23,0	59,3
		2017-10-30	9,20	2,00	11,01	22,4	58,4
		2017-11-02	10,94	2,00	11,01	22,0	64,2
		2017-11-07	6,82	2,00	11,19	24,5	55,9
		2017-11-09	9,90	2,00	11,17	21,4	59,6
Error mean value (µV/V)			9,67				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
5	1 A	2017-10-25	98,83	2,00	11,06	22,8	60,0
		2017-10-30	213,52	2,00	11,01	23,8	57,4
		2017-11-02	169,06	2,00	11,01	20,8	65,1
		2017-11-07	147,53	2,02	12,32	24,1	57,8
		2017-11-09	139,21	2,00	11,09	22,9	53,8
Error mean value (µV/V)			153,63				

Resistance

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	Tamb (°C)	Hamb (%)
6	10 Ω	2017-10-26	-4,35	2,01	5,43	23,4	51,9
		2017-11-01	-1,59	2,01	5,37	22,7	41,7
		2017-11-03	4,78	2,00	5,12	24,2	46,7
		2017-11-06	9,39	2,02	5,70	22,2	50,9
		2017-11-08	4,81	2,02	5,68	24,3	61,9
Error mean value (µV/V)			2,61				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	Tamb (°C)	Hamb (%)
7	10 MΩ	2017-10-26	-2,32	12,25	12,25	23,4	52,2
		2017-11-01	3,47	12,09	12,09	23,2	46,1
		2017-11-03	4,13	12,06	12,06	24,8	49,3
		2017-11-06	3,39	12,02	12,02	23,5	53,9
		2017-11-08	-0,19	12,15	12,15	23,2	59,6
Error mean value (µV/V)			1,70				

AC Voltage

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
8	1 V	2017-10-26	59,00	2,04	10,38	23,5	51,9
		2017-10-30	21,20	2,21	14,00	23,5	57,1
		2017-11-02	6,00	2,02	9,50	21,5	71,5
	55 Hz	2017-11-08	28,40	2,15	14,43	23,8	64,4
		2017-11-09	33,80	2,28	22,48	22,2	58,0
Error mean value (µV/V)			29,68				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	Tamb (°C)	Hamb (%)
10	100 V	2017-10-26	92,81	2,04	16,36	23,2	53,9
		2017-10-30	71,41	2,00	13,47	24,0	51,2
		2017-11-02	34,20	2,00	13,27	21,6	59,6
	55 Hz	2017-11-08	62,40	2,07	18,40	24,1	63,2
		2017-11-09	57,40	2,11	20,96	21,0	54,9
Error mean value (µV/V)			63,64				

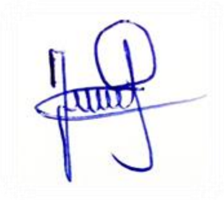
AC Current

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
12	10 mA	2017-10-27	71,60	2,01	32,48	21,9	51,7
		2017-11-02	69,86	2,28	54,66	24,3	46,8
		2017-11-07	22,80	2,00	30,23	21,6	67,7
	55 Hz	2017-11-08	80,40	2,00	31,19	23,5	49,4
		2017-11-09	64,60	2,00	31,76	22,2	55,8
Error mean value (µV/V)			61,85				

TEST POINT	NOMINAL VALUE	DATE	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	Tamb (°C)	Hamb (%)
14	1 A	2017-10-27	254,60	2,00	52,24	22,2	52,7
		2017-11-02	224,60	2,00	50,83	24,5	44,2
		2017-11-07	159,40	2,00	50,79	21,7	63,9
	55 Hz	2017-11-08	222,80	2,00	50,67	23,5	50,9
		2017-11-09	164,80	2,01	55,03	21,3	53,7
Error mean value (µV/V)			205,24				

Date: 24 / 01 / 2018

Signature:



To: Lucas Di Lillo

From: INSTITUTO NACIONAL DE CALIDAD (INACAL)

Re: **SIM comparisons SIM.EM-SX – Comparison Report**

Date: 2018-09-20

Laboratory

Name: Laboratorio de Electricidad
Address: Calle de la Prosa N° 150, Lima - Perú
Contact Personnel name: Lady Pereira / Billy Quispe
Phone Number: 511-6408820 Anexo 1514
E-mail: lpereira@inacal.gob.pe / bquispe@inacal.gob.pe

Standard Equipment

Standard: Multímetro de 8 ½ dígitos
Brand: Fluke
Reference Number: LE 03 046
Serial Number: 358871363

Comparison Results:

Calibration Method:

Por comparación utilizando como fuente un calibrador multiproducto Fluke 5520A

Environmental Conditions:

Temperature: 23 °C ± 2 °C

Relative Humidity: 50 % ± 10 %

Results:

TENSIÓN CONTINUA

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty*	T_{amb} (°C)	H_{amb} (%)
1	100 mV	2018-06-25	-7,7	2	5,1	23,4	59,9
		2018-06-26	-5,0	2	5,1	23,7	59,7
		2018-06-28	-3,2	2	5,1	22,9	61,0
		2018-07-02	-2,5	2	5,1	23,3	58,1
		2018-07-03	-0,6	2	5,1	23,3	56,4
	Error mean value (µV/V)		-3,8				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty*	T_{amb} (°C)	H_{amb} (%)
2	10 V	2018-06-25	0,1	2	2,1	23,4	59,9
		2018-06-26	0,1	2	2,1	23,7	59,7
		2018-06-28	0,8	2	2,1	22,9	61,0
		2018-07-02	0,6	2	2,1	23,3	58,1
		2018-07-03	0,2	2	2,1	23,3	56,4
	Error mean value		0,4				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty*	T_{amb} (°C)	H_{amb} (%)
3	100 V	2018-06-25	-1,2	2	3,1	23,4	59,9
		2018-06-26	-0,3	2	3,1	23,7	59,7
		2018-06-28	-1,1	2	3,1	22,9	61,0
		2018-07-02	-0,2	2	3,1	23,3	58,1
		2018-07-03	-0,2	2	3,1	23,3	56,4
	Error mean value		-0,6				

CORRIENTE CONTINUA

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty*	T_{amb} (°C)	H_{amb} (%)
8	10 mA	2018-06-25	2,3	2	10,0	23,4	59,9
		2018-06-26	2,6	2	10,0	23,7	59,7
		2018-06-28	2,5	2	10,0	22,9	61,0
		2018-07-02	2,9	2	10,0	23,3	58,1
		2018-07-03	2,1	2	10,0	23,3	56,4
	Error mean value (µA/A)		2,5				

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty*	T_{amb} (°C)	H_{amb} (%)
9	1 A	2018-06-25	222,8	2	101,5	23,4	59,9
		2018-06-26	234,8	2	101,5	23,7	59,7
		2018-06-28	217,7	2	101,5	22,9	61,0
		2018-07-02	239,5	2	101,5	23,3	58,1
		2018-07-03	240,1	2	101,5	23,3	56,4
	Error mean value		231,0				

TENSIÓN ALTERNA

Test point	Nominal Value	Frecuencia	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	T_{amb} (°C)	H_{amb} (%)
4	1 V	55 Hz	2018-06-25	34,7	2	58,0	23,4	59,9
			2018-06-26	51,2	2	58,0	23,7	59,7
			2018-06-28	50,5	2	58,0	22,9	61,0
			2018-07-02	51,5	2	58,1	23,3	58,1
			2018-07-03	43,2	2	58,0	23,3	56,4
	Error mean value (µV/V)			46,2				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	T_{amb} (°C)	H_{amb} (%)
5	1 V	1 kHz	2018-06-25	56,0	2	50,4	23,3	56,4
			2018-06-26	11,2	2	50,2	23,4	59,9
			2018-06-28	38,2	2	50,3	23,7	59,7
			2018-07-02	22,2	2	50,3	22,9	61,0
			2018-07-03	9,7	2	50,3	23,3	58,1
	Error mean value (µV/V)			27,5				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	T_{amb} (°C)	H_{amb} (%)
6	100 V	55 Hz	2018-06-25	32,0	2	64,7	23,4	59,9
			2018-06-26	12,5	2	64,7	23,7	59,7
			2018-06-28	25,7	2	64,7	22,9	61,0
			2018-07-02	14,0	2	64,7	23,3	58,1
			2018-07-03	29,0	2	64,7	23,3	56,4
	Error mean value (µV/V)			22,6				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty * (µV/V)	T_{amb} (°C)	H_{amb} (%)
7	100 V	1 kHz	2018-06-25	74,2	2	54,3	23,4	59,9
			2018-06-26	9,5	2	54,2	23,7	59,7
			2018-06-28	75,2	2	54,3	22,9	61,0
			2018-07-02	20,5	2	54,6	23,3	58,1
			2018-07-03	6,7	2	54,3	23,3	56,4
	Error mean value (µV/V)			37,2				

CORRIENTE ALTERNA

Test point	Nominal Value	Frecuencia	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	T_{amb} (°C)	H_{amb} (%)
10	10 mA	55 Hz	2018-06-25	53,0	2	252,3	23,4	59,9
			2018-06-26	61,2	2	252,3	23,7	59,7
			2018-06-28	50,2	2	252,4	22,9	61,0
			2018-07-02	65,7	2	252,3	23,3	58,1
			2018-07-03	73,5	2	252,3	23,3	56,4
	Error mean value (µA/A)			60,7				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	T_{amb} (°C)	H_{amb} (%)
11	10 mA	1 kHz	2018-06-25	-100,8	2	252,2	23,4	59,9
			2018-06-26	-96,5	2	252,2	23,7	59,7
			2018-06-28	-94,0	2	252,2	22,9	61,0
			2018-07-02	-96,5	2	252,2	23,3	58,1
			2018-07-03	-125,0	2	252,2	23,3	56,4
	Error mean value (µA/A)			-102,6				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	T_{amb} (°C)	H_{amb} (%)
12	1 A	55 Hz	2018-06-25	271,2	2	412,6	23,4	59,9
			2018-06-26	253,7	2	412,7	23,7	59,7
			2018-06-28	261,4	2	412,6	22,9	61,0
			2018-07-02	279,2	2	412,6	23,3	58,1
			2018-07-03	316,2	2	412,6	23,3	56,4
	Error mean value (µA/A)			276,3				

Test point	Nominal Value	Frecuencia	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty * (µA/A)	T_{amb} (°C)	H_{amb} (%)
13	1 A	1 kHz	2018-06-25	388,9	2	412,0	23,4	59,9
			2018-06-26	378,4	2	412,0	23,7	59,7
			2018-06-28	378,6	2	412,0	22,9	61,0
			2018-07-02	396,6	2	412,0	23,3	58,1
			2018-07-03	437,6	2	412,0	23,3	56,4
	Error mean value (µA/A)			396,0				

RESISTENCIA

Test point	Nominal Value	Date	DMM Error (μΩ/Ω)	Coverage Factor	Expanded Uncertainty* (μΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
14	10 W	2018-06-25	4,2	2	6,1	23,4	59,9
		2018-06-26	7,6	2	6,1	23,7	59,7
		2018-06-28	5,4	2	6,1	22,9	61,0
		2018-07-02	1,9	2	6,1	23,3	58,1
		2018-07-03	3,1	2	6,1	23,3	56,4
	Error mean value (μV/V)		4,5				

Test point	Nominal Value	Date	DMM Error (μΩ/Ω)	Coverage Factor	Expanded Uncertainty* (μΩ/Ω)	T_{amb} (°C)	H_{amb} (%)
15	10 MW	2018-06-25	-22,3	2	19,2	23,4	59,9
		2018-06-26	-22,3	2	19,2	23,7	59,7
		2018-06-28	-22,5	2	19,2	22,9	61,0
		2018-07-02	-22,2	2	19,2	23,3	58,1
		2018-07-03	-19,0	2	19,2	23,3	56,4
	Error mean value		-21,7				

*The uncertainty calculation sheet must be documented.

Date: 2019-04-29

Signature: Lady Pereira

Annex 6

Results Report

To: Lucas Di Lillo, INTI.

From: Daniel Cárcamo, LCPN ME / CHILE

Re: SIM Comparisons SIM.EM-S13 – Comparison Report

Date: 01/04/2019

Laboratory

Name: Laboratorio Custodio Patrón Nacional de Magnitudes Eléctricas (LCPN ME) CHILE

Address: Edificio Tecnológico Mecánico 2do piso Facultad de Ingeniería Universidad de Concepción

Contact Personnel name: Daniel Cárcamo Mayorga

Phone Number: 56 41 2661088

E-mail: dacarcam@udec.cl

Traveling Standard

Description: Digital Multimeter

Manufacturer: Hewlett Packard

Model: 3458A

Serial Number: 2823A15128

Reference Standards

Qty	Description	Model	Brand	Serial Nº
1	Source of V AC / V DC, I AC / I DC	5720A	Fluke	7690202
1	Standard resistor 10 Ohm	9334A-10	Guildline	68886
1	Standard resistor 10 MOhm	9334A-10M	Guildline	68484

Comparison Results

Calibration Method :

The method to use is by direct comparison with the reference standard. For this purpose, the value indicated in the calibration certificate of the standard is used for the different magnitudes DCV, ACV, DCI, ACI and Resistance, the equation that represents the deviation (Error) of the DMM can be expressed as follows:

$$Deviation_{\ Multimeter} = Reading_{\ Multimeter} - Value_{\ Standard} \quad (1)$$

Enviromental Conditions:

Temperature: 23.0 °C ± 1 °C

Relative Humidity: 45 % ± 10 %

Measurements Results :

The measurements were performed between January 4th and January 18th, 2019.

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
1	100 mV	08/01/2019	2.7	2	6.5	23.1	46.7
		09/01/2019	3.0	2	6.5	23.0	47.4
		11/01/2019	2.1	2	6.5	23.2	46.6
		14/01/2019	2.4	2	6.5	22.4	48.5
		15/01/2019	3.1	2	6.5	22.3	48.9
		18/01/2019	2.7	2	6.5	22.3	49.3
	Error mean value (µV/V)		**2.7**	**U exp**	**6.5**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
2	10 V	08/01/2019	3.4	2	2.0	23.1	46.7
		09/01/2019	2.6	2	2.0	23.0	47.4
		11/01/2019	2.9	2	2.0	23.2	46.6
		14/01/2019	3.0	2	2.0	22.4	48.5
		15/01/2019	3.3	2	2.0	22.3	48.9
		18/01/2019	3.0	2	2.0	22.3	49.3
	Error mean value (µV/V)		**3.0**	**U exp**	**2.0**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
3	100 V	04/01/2019	4.1	2	2.0	23.1	47.5
		08/01/2019	4.2	2	2.0	23.1	46.7
		09/01/2019	2.9	2	2.0	23.0	47.4
		11/01/2019	3.5	2	2.0	23.2	46.6
		14/01/2019	2.7	2	2.0	22.4	48.5
		15/01/2019	4.0	2	2.0	22.3	48.9
	Error mean value (µV/V)		**3.6**	**U exp**	**2.0**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
4	10 mA	04/01/2019	4	2	5.0	22.5	48.6
		08/01/2019	5	2	5.0	23.2	46.7
		09/01/2019	3	2	5.0	23.2	46.7
		11/01/2019	6	2	5.0	22.7	48.6
		14/01/2019	6	2	5.0	22.3	48.7
		15/01/2019	6	2	5.0	22.3	49.5
	Error mean value (µA/A)		**5**	**U exp**	**5.0**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
5	1 A	04/01/2019	110	2	21	22.5	48.6
		08/01/2019	104	2	21	23.2	46.7
		09/01/2019	91	2	21	23.2	46.7
		11/01/2019	105	2	21	22.7	48.6
		14/01/2019	92	2	21	22.3	48.7
		15/01/2019	100	2	21	22.3	49.5
	Error mean value (µA/A)		**100**	**U exp**	**21**		

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty (µΩ/Ω)	T° (°C)	H (%)
6	10 Ω	08/01/2019	0	2.0	2.0	23.2	46.7
		09/01/2019	-1	2.0	2.0	23.2	46.7
		11/01/2019	-1	2.0	2.0	22.7	48.6
		14/01/2019	1	2.0	2.0	22.3	48.7
		15/01/2019	0	2.0	2.0	22.3	49.5
	Error mean value (µΩ/Ω)		**0**	**U exp**	**2.0**		

Test point	Nominal Value	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty(µΩ/Ω)	T° (°C)	H (%)
7	10 MΩ	08/01/2019	9.4	2.0	8.0	23.2	46.7
		09/01/2019	10.6	2.0	8.0	23.2	46.7
		11/01/2019	8.2	2.0	8.0	22.7	48.6
		14/01/2019	9.4	2.0	8.0	22.3	48.7
		15/01/2019	10.7	2.0	8.0	22.3	49.5
	Error mean value (µΩ/Ω)		**9.7**	**U exp**	**8.0**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
8	1 V 55 Hz	08/01/2019	-9	2.0	18	23.2	47.3
		10/01/2019	-14	2.0	18	23.2	44.8
		14/01/2019	-10	2.0	18	22.9	47.6
		15/01/2019	-9	2.0	18	22.4	48.6
		16/01/2019	-6	2.0	18	22.9	48.0
	Error mean value (µV/V)		**-10**	**U exp**	**18**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
9	1 V 1 kHz	08/01/2019	14	2.0	14	23.2	47.3
		10/01/2019	18	2.0	14	23.2	44.8
		14/01/2019	15	2.0	14	22.9	47.6
		15/01/2019	17	2.0	14	22.4	48.6
		16/01/2019	20	2.0	14	22.9	48.0
	Error mean value (µV/V)		**17**	**U exp**	**14**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
10	100 V 55 Hz	04/01/2019	-19	2.0	30	22.4	49.3
		08/01/2019	-12	2.0	30	23.2	47.3
		10/01/2019	-16	2.0	30	23.2	44.8
		14/01/2019	-28	2.0	30	22.9	47.6
		15/01/2019	-25	2.0	30	22.4	48.6
	Error mean value (µV/V)		**-20**	**U exp**	**30**		

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty (µV/V)	T° (°C)	H (%)
11	100 V 1 kHz	04/01/2019	-6	2.0	20	22.4	49.3
		08/01/2019	1	2.0	20	23.2	47.3
		10/01/2019	-2	2.0	20	23.2	44.8
		14/01/2019	-14	2.0	20	22.9	47.6
		15/01/2019	-12	2.0	20	22.4	48.6
	Error mean value (µV/V)		**-7**	**U exp**	**20**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
12	10 mA 55 Hz	07/01/2019	20	2.0	37	23.3	47.2
		08/01/2019	10	2.0	37	23.2	47.3
		10/01/2019	30	2.0	37	23.2	44.8
		14/01/2019	30	2.0	37	22.9	47.6
		15/01/2019	30	2.0	37	22.4	48.6
	Error mean value (µA/A)		**24**	**U exp**	**37**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
13	10 mA 1 kHz	07/01/2019	90	2.0	37	23.3	47.2
		08/01/2019	90	2.0	37	23.2	47.3
		10/01/2019	100	2.0	37	23.2	44.8
		14/01/2019	100	2.0	37	22.9	47.6
		15/01/2019	100	2.0	37	22.4	48.6
	Error mean value (µA/A)		**96**	**U exp**	**37**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
14	1 A 55 Hz	07/01/2019	70	2.0	65	23.3	47.2
		08/01/2019	70	2.0	65	23.2	47.3
		10/01/2019	70	2.0	65	23.2	44.8
		15/01/2019	100	2.0	65	22.9	47.6
		16/01/2019	80	2.0	65	22.4	48.6
	Error mean value (µA/A)		**78**	**U exp**	**65**		

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty (µA/A)	T° (°C)	H (%)
15	1 A 1 kHz	07/01/2019	250	2.0	65	23.3	47.2
		08/01/2019	250	2.0	65	23.2	47.3
		10/01/2019	260	2.0	65	23.2	44.8
		15/01/2019	280	2.0	65	22.9	47.6
		16/01/2019	260	2.0	65	22.4	48.6
	Error mean value (µA/A)		**260**	**U exp**	**65**		

Date: April 2nd, 2019

Signature:..................................

SIM.EM-S13

Final measurement report

Laboratorio de UTE
Paraguay 2385.
Montevideo. Uruguay.
http://www.ute.com.uy/empresa/lineas/tecnologia/laboratorio.htm
Tel.: (+ 598) 2 9242049
Fax: (+ 598) 2 9242004
C.P.: 11800
e-mail: labute@ute.com.uy

LABORATORIO

To: INTI (Pilot Lab)

From: UTE

Re: **SIM comparisons SIM.EM-S13 – Comparison Report**
Date: 20/03/2019

Laboratory

Name: Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE)
Address: Paraguay 2385, Montevideo Uruguay
Contact Personnel name: Daniel Izquierdo
Phone Number: (+598 29242042)
E-mail: dizquierdo@ute.com.uy

Standard Equipment

Standard: Digital multimeter
Brand: Hewlett Packard
Model: 3458A
Serial Number: 2823A15128

Comparison Results:

Calibration Method:

The calibration was done directly by measurement of a reference resistor.
The reference resistor was connected by coaxial wires with cooper terminal.
The multimeter was configured in accordance with protocol specifications.
Each daily measurement is an average of a two set of fifty measurements.

Environmental Conditions:

Temperature: 23 °C ± 1 °C

Relative Humidity: 45 % ± 15 %

LABORATORIO

Measurements Results

Test point	Nominal Value	Date	DMM Error (μΩ/Ω)	Coverage factor	Expanded Uncertainty (μΩ/Ω)	T. amb. (°C)	H. amb. (%)
6	**10 Ω**	01/03/2019	-2,2	2	4,5	23,3	48
		02/03/2019	-2,2	2	4,5	23,3	50
		06/03/2019	-0,9	2	4,5	23,4	51
		07/03/2019	-2,0	2	4,5	23,4	49
		08/03/2019	-0,9	2	4,5	23,5	52
		09/03/2019	-1,6	2	4,5	23,7	51
	Error mean value (μΩ/Ω)		**-1,6**				

Uncertainty budget

Model equation of the measurement:

$$e_x = R_{xi} + \delta R_{xi} - (R_{so} + \Delta R_{st} + \Delta R_{sd})$$

Quantity	Standard uncertainty		Probability distribution	Sensitivity coefficient		Unc.con.ui(y)		Degrees of freedom
R_{SO}	2,2E-05	Ω	Normal	1		2,2E-05	Ω	∞
ΔR_{SD}	0,0E+00	Ω	Normal	-1		0,0E+00	Ω	∞
ΔR_{ST}	8,3E-09	Ω	Rectangular	-1		-8,3E-09	Ω	∞
δR_{Xi}	2,9E-06	Ω	Rectangular	1		2,9E-06	Ω	∞
Combined Type B std. unc. and effective degrees of freedom						2,2E-05	Ω	∞
Combined Type A std. unc. and effective degrees of freedom						2,5E-06	Ω	5
Combined standard uncertainty and effective degrees of freedom						2,2E-05	Ω	∞
Expanded uncertainty (95,45 % coverage factor)						**4,5**	**μΩ/Ω**	

R_{SO}: last calibration uncertainty of the reference resistor
R_{xi}: measurements (type A uncertainty of the measurements)
ΔR_{sd}: drift of the reference resistor
ΔR_{ST}: temperature correction of the reference resistor
δR_{Xi}: ohmmeter resolution

Traceability

Reference resistor: 10 Ω, Fluke, mod. 742-10
Traceability through Thomas resistor 1 Ω, mod. 4210 (Last calibration: BIPM, 08/2016)

CENTRO NACIONAL DE METROLOGÍA

Digital Multi-Meters (DMM) Comparison

SIM.EM-S13 COMPARISON

Results Report

To:

Lic. Lucas Di Lillo
Instituto Nacional de Tecnología Industrial
Jefe del Departamento de Electricidad, INTI – Metrología Física
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Isabel Castro Blanco
Instituto Costarricense de Electricidad
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San Pedro de Montes de Oca, Edificio ICE, Piso # 4, Puerta # 36
COSTA RICA
Email: bcastro@ice.go.cr
Tel: + 506 2001-2374

From: **CENAM**

Re: **SIM.EM-S.13 – Comparison Report**
Date: (09/01/2020)

Laboratory

Name: **CENTRO NACIONAL DE METROLOGÍA**
Address: km 4.5 carretera a los Cués, Municipio El Marqués, C.P. 76246, Querétaro, **MÉXICO**.

Personnel name: **Sara Andrea Campos Hernández** Technnical contact
Eduardo Gutiérrez González Metrologist

Phone Number: **(55) 442-211 05 00**

E-mail: scampos@cenam.mx
egutierr@cenam.mx

CENAM
CENTRO NACIONAL DE METROLOGÍA

Standard Equipment

Standards:

Comparison Traveling Standard	CENAM Standard
Digital multimeter Brand: Hewlett Packard Reference Number: 3458A Serial Number: 2823A15128	**Multifunction Calibrator** Brand: Fluke Reference Number: 5720A Serial Number: 7590202
	Standard Resistor : Brand: L&N 4025-B /**10 Ω** Serial Number: 1893729 Brand: Fluke 742A /**10 MΩ** Serial Number: 2468005

Environmental Conditions of the measurement:

Temperature: **23.2 °C ± 0.4°C** Relative Humidity: **43 % ± 7 %**

Date of measurements:

Nov 07th to Dec 02nd of 2019

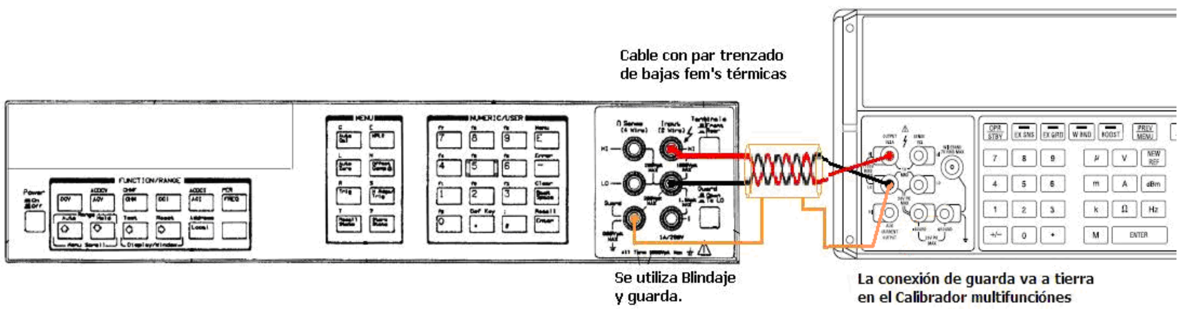
Description of the measuring method

MEASURAND		METHOD	PROCEDURE´s CENAM
DC Voltage (Tensión Eléctrica Continua)	VCC	Direct	410-AC-P.037
DC Current (Corriente Eléctrica Continua)	ICC	Direct	410-AC-P.040
Resistance (Resistencia Eléctrica)	R	Direct	410-AC-P.038
AC Voltage (Tensión Eléctrica Alterna)	VCA	Direct	410-AC-P.039
AC Current (Corriente Eléctrica Alterna)	ICA	Direct	410-AC-P.041

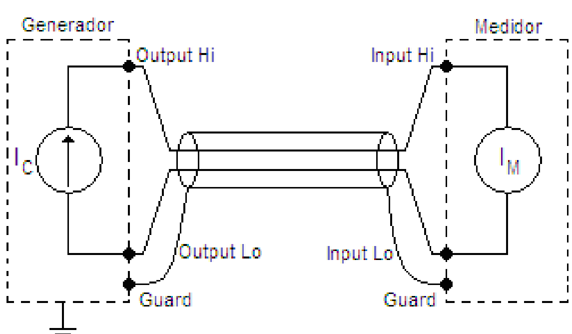
Connection diagrams

DC Voltage

Using reverse polarity technique

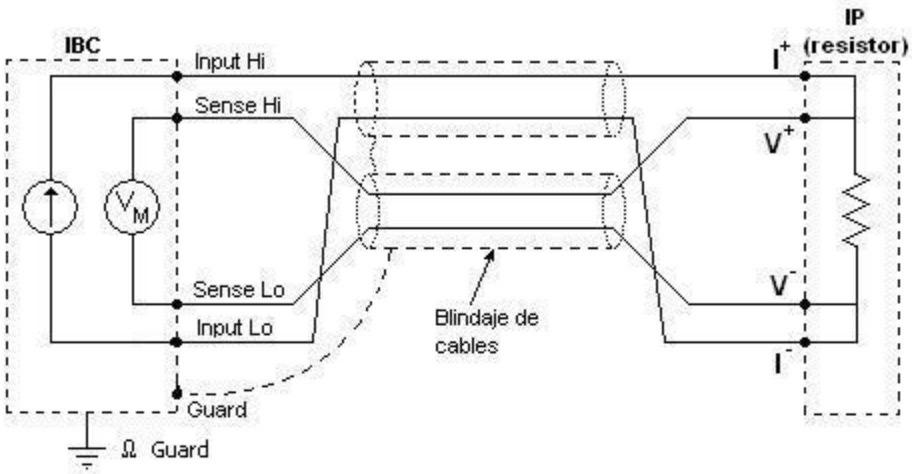


DC Current

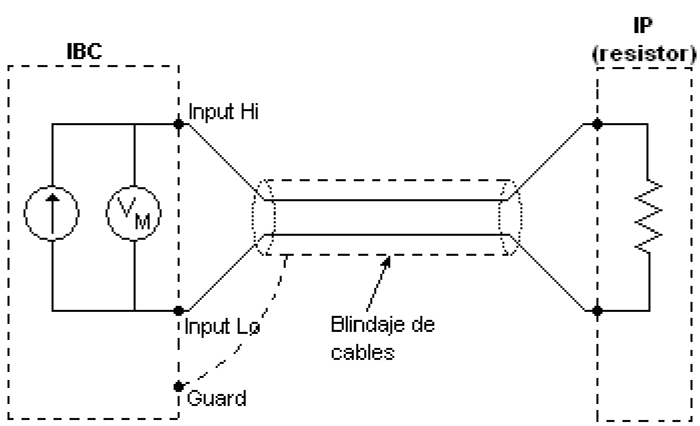


I_M stands for dmm reading, including internal offset

Resistance 10 Ω

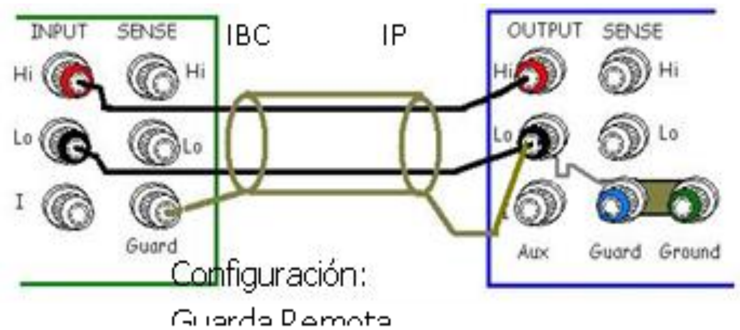


Resistance 10 MΩ



AC Voltage and AC Current

(using coaxial cable for alternating current voltage)



The reference standard and its traceability to the SI

Measurand	Reference standard used	Traceability to the SI
Tensión Eléctrica Continua *(DC Voltage)*	**Calibrador Multifunción** Fluke 5720A Serie 7590202	**Patrón Nacional de Tensión Eléctrica Continua**
Corriente Eléctrica Continua *(DC Current)*	**Calibrador Multifunción** Fluke 5720A Serie 7590202	**Patrón Nacional de Tensión Eléctrica Continua y Patrón Nacional de Resistencia Eléctrica**
Resistencia Eléctrica *(Resistance)*	**Resistor Patrón** Leeds & Northrup Co 4025-B /10 Ω Serie 1893729	**Patrón Nacional de Resistencia Eléctrica**
	Resistor Patrón Fluke 742A-10 MΩ Serie 2468005	
Tensión Eléctrica Alterna *(AC Voltage)*	**Calibrador Multifunción** Fluke 5720A Serie 7590202	**Patrón Nacional de Tensión Eléctrica Alterna**
Corriente Eléctrica Alterna *(AC Current)*	**Calibrador Multifunción** Fluke 5720A Serie 7590202	**Patrón Nacional de Corriente Eléctrica Alterna**

Comparison Results:

Measurements Results

DC Voltage

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
1	**100 mV**	08/11/2019	4.7	2.0	3.1	23.2	45.1
		11/11/2019	5.0	2.0	3.1	23.2	38.1
		12/11/2019	4.9	2.0	3.1	23.2	38.1
		12/11/2019	5.2	2.0	3.1	23.3	41.9
		25/11/2019	2.9	2.0	3.1	23.0	42.6
		26/11/2019	4.1	2.0	3.1	23.3	44.2
		27/11/2019	5.4	2.0	3.1	23.2	45.1
	Error mean value (µV/V)		**4.6**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
2	**10 V**	08/11/2019	2.4	2.0	1.1	23.2	45.1
		11/11/2019	2.8	2.0	1.1	23.2	38.1
		12/11/2019	2.5	2.0	1.1	23.2	38.1
		12/11/2019	3.7	2.0	1.1	23.3	41.9
		25/11/2019	2.2	2.0	1.1	23.0	42.6
		26/11/2019	2.3	2.0	1.1	23.3	44.2
		27/11/2019	2.0	2.0	1.1	23.2	45.1
	Error mean value (µV/V)		**2.5**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
3	**100 V**	08/11/2019	1.9	2.0	1.8	23.2	45.1
		11/11/2019	3.5	2.0	1.8	23.2	38.1
		12/11/2019	2.9	2.0	1.8	23.2	38.1
		12/11/2019	4.3	2.0	1.8	23.3	41.9
		25/11/2019	2.3	2.0	1.8	23.0	42.6
		26/11/2019	1.5	2.0	1.8	23.3	44.2
		27/11/2019	2.2	2.0	1.8	23.2	45.1
	Error mean value (µV/V)		**2.7**				

DC Current

Test point	Nominal Valu	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty* (µA/A)	Tamb (°C)	Hamb (%)
4	**10 mA**	07/11/2019	1.6	2.0	8.0	23.2	42.7
		08/11/2019	-0.3	2.0	8.0	23.2	45.1
		12/11/2019	4.7	2.0	8.0	23.2	38.1
		12/11/2019	2.3	2.0	8.0	23.2	38.1
		26/11/2019	1.7	2.0	8.0	23.3	44.2
		26/11/2019	0.9	2.0	8.0	23.3	44.2
		27/11/2019	2.7	2.0	8.0	23.2	45.1
	Error mean value (µA/A)		**1.9**				

Test point	Nominal Valu	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty* (µA/A)	Tamb (°C)	Hamb (%)
5	**1 A**	07/11/2019	115	2.0	11	23.2	42.7
		08/11/2019	126	2.0	11	23.2	45.1
		12/11/2019	117	2.0	11	23.2	38.1
		12/11/2019	111	2.0	11	23.2	38.1
		26/11/2019	113	2.0	11	23.3	44.2
		26/11/2019	111	2.0	11	23.3	44.2
		27/11/2019	104	2.0	11	23.2	45.1
	Error mean value (µA/A)		**114**				

Resistance

Test point	Nominal Valu	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty* (µΩ/Ω)	Tamb (°C)	Hamb (%)
6	**10 Ω**	15/11/2019	0	2.0	2	22.9	44.5
		19/11/2019	-1	2.0	2	22.9	44.5
		19/11/2019	0	2.0	2	22.9	44.5
		20/11/2019	0	2.0	2	22.9	44.5
		20/11/2019	1	2.0	2	22.9	44.5
		20/11/2019	1	2.0	2	22.9	42.5
		21/11/2019	1	2.0	2	22.9	42.5
		13/11/2019	-1	2.0	2	22.9	43.4
		14/11/2019	-1	2.0	2	22.9	43.4
	Error mean value (µΩ/Ω)		0				

Test point	Nominal Valu	Date	DMM Error (µΩ/Ω)	Coverage Factor	Expanded Uncertainty* (µΩ/Ω)	Tamb (°C)	Hamb (%)
7	**10 MΩ**	19/11/2019	2	2.0	12	22.9	44.5
		19/11/2019	4	2.0	12	22.9	44.5
		20/11/2019	4	2.0	12	22.9	44.5
		20/11/2019	7	2.0	12	22.9	42.5
		21/11/2019	3	2.0	12	22.9	42.5
		13/11/2019	5	2.0	12	22.9	43.4
		13/11/2019	5	2.0	12	22.9	43.4
		14/11/2019	11	2.0	12	22.9	43.4
	Error mean value (µΩ/Ω)		5				

AC Voltage

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
8	**1 V / 55 Hz**	07/11/2019	-10	2.0	28	23.2	42.7
		08/11/2019	-13	2.0	28	23.2	45.1
		08/11/2019	-17	2.0	28	23.2	45.1
		11/11/2019	-11	2.0	28	23.2	38.1
		12/11/2019	-5	2.0	28	23.2	38.1
		25/11/2019	-16	2.0	28	23.0	42.6
		27/11/2019	-11	2.0	28	23.2	45.1
		02/12/2019	-15	2.0	28	23.2	45.1
	Error mean value (µV/V)		**-12**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
9	**1 V / 1 kHz**	07/11/2019	4	2.0	28	23.2	42.7
		08/11/2019	2	2.0	28	23.2	45.1
		08/11/2019	0	2.0	28	23.2	45.1
		11/11/2019	4	2.0	28	23.2	38.1
		12/11/2019	13	2.0	28	23.2	38.1
		25/11/2019	1	2.0	28	23.0	42.6
		27/11/2019	7	2.0	28	23.2	45.1
		02/12/2019	3	2.0	28	23.2	45.1
	Error mean value (µV/V)		**4**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
10	**100 V / 55 Hz**	07/11/2019	-20	2.0	36	23.2	42.7
		08/11/2019	-35	2.0	36	23.2	45.1
		08/11/2019	-35	2.0	36	23.2	45.1
		11/11/2019	-33	2.0	36	23.2	38.1
		12/11/2019	-23	2.0	36	23.2	38.1
		25/11/2019	-54	2.0	36	23.0	42.6
		27/11/2019	-31	2.0	36	23.2	45.1
		02/12/2019	-23	2.0	36	23.2	45.1
	Error mean value (µV/V)		**-32**				

Test point	Nominal Value	Date	DMM Error (µV/V)	Coverage Factor	Expanded Uncertainty* (µV/V)	Tamb (°C)	Hamb (%)
11	**100 V / 1 kHz**	07/11/2019	-2	2.0	36	23.2	42.7
		08/11/2019	-17	2.0	36	23.2	45.1
		11/11/2019	-13	2.0	36	23.2	38.1
		12/11/2019	-5	2.0	36	23.2	38.1
		25/11/2019	-36	2.0	36	23.0	42.6
		27/11/2019	-14	2.0	36	23.2	45.1
		02/12/2019	-5	2.0	36	23.2	45.1
	Error mean value (µV/V)		**-13**				

AC Current

Test point	Nominal Value	Date	DMM Error (µA/A)	Coverage Factor	Expanded Uncertainty* (µA/A)	Tamb (°C)	Hamb (%)
12	**10 mA / 55 Hz**	07/11/2019	34	2.0	43	23.2	42.7
		08/11/2019	25	2.0	43	23.2	42.7
		08/11/2019	21	2.0	43	23.2	42.5
		12/11/2019	35	2.0	43	23.2	38.1
		12/11/2019	30	2.0	43	23.2	38.1
		26/11/2019	2	2.0	43	23.3	44.2
		26/11/2019	3	2.0	43	23.3	44.2
		27/11/2019	24	2.0	43	23.2	45.1
		02/12/2019	8	2.0	43	23.2	43.2
	Error mean value (µA/A)		**20**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
13	**10 mA / 1 kHz**	07/11/2019	107	2.0	43	23.2	42.7
		08/11/2019	99	2.0	43	23.2	42.5
		12/11/2019	102	2.0	43	23.2	38.1
		12/11/2019	100	2.0	43	23.2	38.1
		26/11/2019	76	2.0	43	23.3	44.2
		26/11/2019	77	2.0	43	23.3	44.2
		27/11/2019	95	2.0	43	23.2	45.1
		02/12/2019	81	2.0	43	23.2	43.2
	Error mean value (μA/A)		**92**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
14	**1 A / 55 Hz**	08/11/2019	93	2.0	70	23.2	42.7
		08/11/2019	89	2.0	70	23.2	42.5
		12/11/2019	68	2.0	70	23.2	38.1
		12/11/2019	73	2.0	70	23.2	38.1
		26/11/2019	51	2.0	70	23.3	44.2
		26/11/2019	47	2.0	70	23.3	44.2
		27/11/2019	60	2.0	70	23.2	45.1
		02/12/2019	42	2.0	70	23.2	43.2
	Error mean value (μA/A)		**65**				

Test point	Nominal Value	Date	DMM Error (μA/A)	Coverage Factor	Expanded Uncertainty* (μA/A)	Tamb (°C)	Hamb (%)
15	**1 A / 1 kHz**	08/11/2019	274	2.0	70	23.2	42.7
		08/11/2019	293	2.0	70	23.2	42.5
		12/11/2019	270	2.0	70	23.2	38.1
		12/11/2019	268	2.0	70	23.2	38.1
		26/11/2019	253	2.0	70	23.3	44.2
		26/11/2019	255	2.0	70	23.3	44.2
		27/11/2019	267	2.0	70	23.2	45.1
		02/12/2019	244	2.0	70	23.2	43.2
	Error mean value (μA/A)		**265**				

Uncertainty Budget and the uncertainty calculation

A Summary spreadsheet, and uncertainty budget spreadsheet are given in the attached file

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MÉXICO

Dirección General de Metrología Eléctrica
Dirección de Mediciones Electromagnéticas
Laboratorio de Patrones Eléctricos Multifunciones

Date: January 09th, 2020 **Eduardo Gutiérrez González**