REPORT

COOMET.EM-S20 supplementary comparison on 1,018 V and 10 V voltage standards

COOMET Project 686/MD/16

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Abstract:

This report presents the results of the bilateral comparison on1,018 V and 10 V voltage standards performed by the national metrology institutes of Moldova (INM) and Germany (PTB).

Content

1. Introduction

In the Mutual Recognition Arrangement (MRA) it is stated that the metrological equivalence of national measurement standards will be determined by a set of comparisons chosen and organized by the Consultative Committees or the Regional Metrology Organizations (RMO's). The results of this COOMET supplementary comparison will be used to support the CMC claims of INM in the field of voltage.

From July 2016 to December 2016, the national institutes of Moldova (INM) and Germany (PTB) performed a supplementary comparison on 1,018 V and 10 V voltage standards. This comparison allows for a clear and unequivocal comparison of the measurement results and will show the equivalence of measurement results obtained with the measurement systems for voltage in the participating national metrology institutes.

2. Participants and schedule

2.1. List of participants

Two laboratories participated in this comparison. They are listed in table 1.

Table 1: List of participants

	Laboratory	Address, telephone, fax, web-page.	Contact person
1	National Metrology Institute of Moldova (INM)	Republic Moldova, MD-2064, Chisinau, Eugen Coca Str., 28 Phone: +373 22 903 100 Fax: +373 22 903 111 Web-page: www.metrologie.md	S. Straistari Phone: +373 22 903 136 E-mail: marimi_electrice@metrologie.md
2	Physikalisch-Technische Bundesanstalt (PTB)	Germany, 38116 Braunschweig Bundesallee 100 Phone: +49 531 5922110 Fax: +49 531 5922105	Dr. Bernhard Schumacher Phone : +49 531 5922110 E-mail: bernhard.Schuhmacher@ptb.de

2.2. Comparison schedule

The comparison took place from July 2016 to December 2016, details are given in table 2.

Table 2: Time schedule for the comparison

Country	Measurement	Transport to the next NMI	Date of reporting
Moldova	2^{nd} half of July 2016	1^{st} week of August 2016	Mid of October
Germany	2^{nd} and 3^{rd} week of August 2016	End of August 2016	Mid of October
Moldova	1st half of September 2016		Mid of October

2.3. Organization of the comparison

Following the COOMET R / GM / 11: 2017 the pilot laboratory was supported by the other participant in organizing the comparison. The travelling standards were provided by INM and transported by courier in special containers.

3. Travelling standards and measurement instructions

3.1. Description of the travelling standards

For this comparison a solid-state voltage standard, Fluke 7000T (SN 112460234), with four separate plug-ins (SN 112460080 (V1), 112460077 (V2), 112460079 (V3),112460082 (V4)) and output voltages of 1,018 V and 10 V have been chosen.

Figure 1: The travelling standard.

3.2. Measurement instructions

The measurands are the DC voltages of the four plug-ins at 1,018 V and 10 V. The measurement methods which has been adopted and the measurement results together with a detailed calculation of the uncertainty of measurement are given in Annexes A and B for both participants. After installation of the voltage standard, a minimum settling time of one day is required. The measurements should be performed under the following conditions:

room temperature (23 ± 2) °C, rel. humidity (45 ± 15) % .

The measurements have been made at different dates during the measurement period in the laboratory. Details are given in the measurement reports of the participants.

4. Methods of measurement

Measurements at INM: The National Standard 7000T of INM was calibrated by the NMI of Romania in June 2016 and therewith is traceable to the national standard of Romania. Romania has approved CMC's in this field. The measurements at INM were made using INM's measurement set-up for voltage standards. From the results of the calibration in Romania, mean values have been calculated for the group of the four standards at 1,018 V and 10 V. These values formed the basis for group measurements, where the voltage differences between the single standards have been measured by applying the differential method.

Measurements at PTB: The voltage standards were compared with the Josephson voltage standard of PTB. For all measurements, the cases of the standards were connected to measurement ground. All measurements are traceable to the PTB's realisation of the unit of voltage using the Josephson voltage standard.

Details are given in the Measurement Reports of INM and PTB in Annexes A and B.

5. Behaviour of the travelling standards

INM measured the travelling standards before and after the circulation (see tables 3 and 4).

Table 3: Results of the first and second measurement at INM at 1,018 V

	25.07.2016	**18.09.2016**	**Difference**	**Rel. Difference**
V1	1,0179959 V	1,0179963 V	4,0E-07 V	3,9E-07
V2	1,0180030 V	1,0180031 V	1,0E-07 V	9,8E-08
V3	1,0180003 V	1,0180002 V	-1,0E-07 V	-9,8E-08
V4	1,0180007 V	1,0180008 V	1,0E-07 V	9,8E-08
	INM (1)	INM (2)		

Table 4: Results of the first and second measurement at INM at 10 V

	25.07.2016	18.09.2016	Difference	Rel. Difference
V1	9,999920 V	9,999920 V	0,0E+00 V	0,0E+00
V2	9,999922 V	9,999924 V	2,0E-06 V	2,0E-07
V3	9,999894 V	9,999892 V	-2,0E-06 V	-2,0E-07
V4	9,999922 V	9,999921 V	-1,0E-06 V	-1,0E-07
	INM (1)	INM (2)		

Tables 3 and 4 show that the standards were very stable during the time of the comparison. The relative changes between the first and second measurement at INM are in the order of a few parts in 10^{-7} and therewith are much smaller than the uncertainty of measurement claimed by INM. Therefore a drift of the standards must not be taken into consideration.

6. Measurement results

6.1. Results of the participating institutes

The pilot laboratory performed measurements over the period from 20 July to 29 July 2016 and from 13 to 22 September 2016. The results for the mean dates are given in table 5a and 5b.

Table 5a: Results of the first measurements at INM

Mean date of measurement	Voltage	Measurement result in V	Rel. uncertainty in µV/V
25.07.2016	SN 112460080 (V1)	1,0179959	1,83
25.07.2016	SN 112460077 (V2)	1,0180030	1,85
25.07.2016	SN112460079 (V3)	1,0180003	1,89
25.07.2016	SN 112460082 (V4)	1,0180007	1,81
25.07.2016	SN 112460080 (V1)	9,999920	1,04
25.07.2016	SN 112460077 (V2)	9,999922	1,04
25.07.2016	SN112460079 (V3)	9,999894	1,08
25.07.2016	SN 112460082 (V4)	9,999922	1,02

Table 5b: Results of the second measurements at INM

Mean date of measurement	Voltage	Measurement result in V	Rel. uncertainty in µV/V
18.09.2016	SN 112460080 (V1)	1,0179963	1,72
18.09.2016	SN 112460077 (V2)	1,0180031	1,72
18.09.2016	SN112460079 (V3)	1,0180002	1,74
18.09.2016	SN 112460082 (V4)	1,0180008	1,71
18.09.2016	SN 112460080 (V1)	9,999920	1,07
18.09.2016	SN 112460077 (V2)	9,999924	1,07
18.09.2016	SN112460079 (V3)	9,999892	1,13
18.09.2016	SN 112460082 (V4)	9,999921	1,07

PTB performed the measurements in the period from 15 August to 29 August. The results reported by PTB are given in table 6.

Table 6: Results of the measurements at PTB

Mean date of measurement	Voltage	Measurement result in V	Rel. uncertainty in µV/V
22.08.2016	SN 112460080 (V1)	1,017 997 61	0,18
22.08.2016	SN 112460077 (V2)	1,018 004 19	0,18
22.08.2016	SN112460079 (V3)	1,018 001 91	0,61
22.08.2016	SN 112460082 (V4)	1,018 002 15	0.18
22.08.2016	SN 112460080 (V1)	9,999 9188	0,065
22.08.2016	SN 112460077 (V2)	9,999 9209	0,065
22.08.2016	SN112460079 (V3)	9,999 8956	0,56
22.08.2016	SN 112460082 (V4)	9,999 9197	0,065

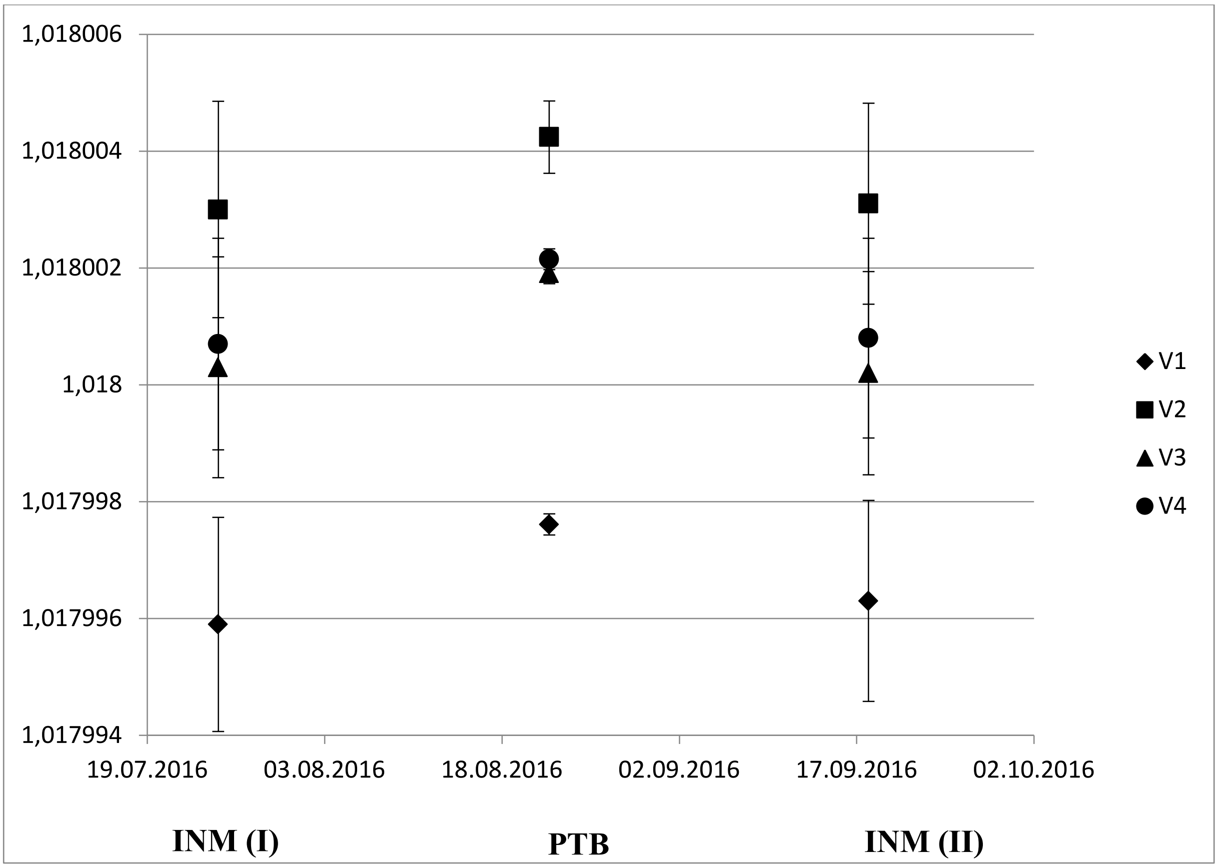

Figure 2: Results at 1,018 V

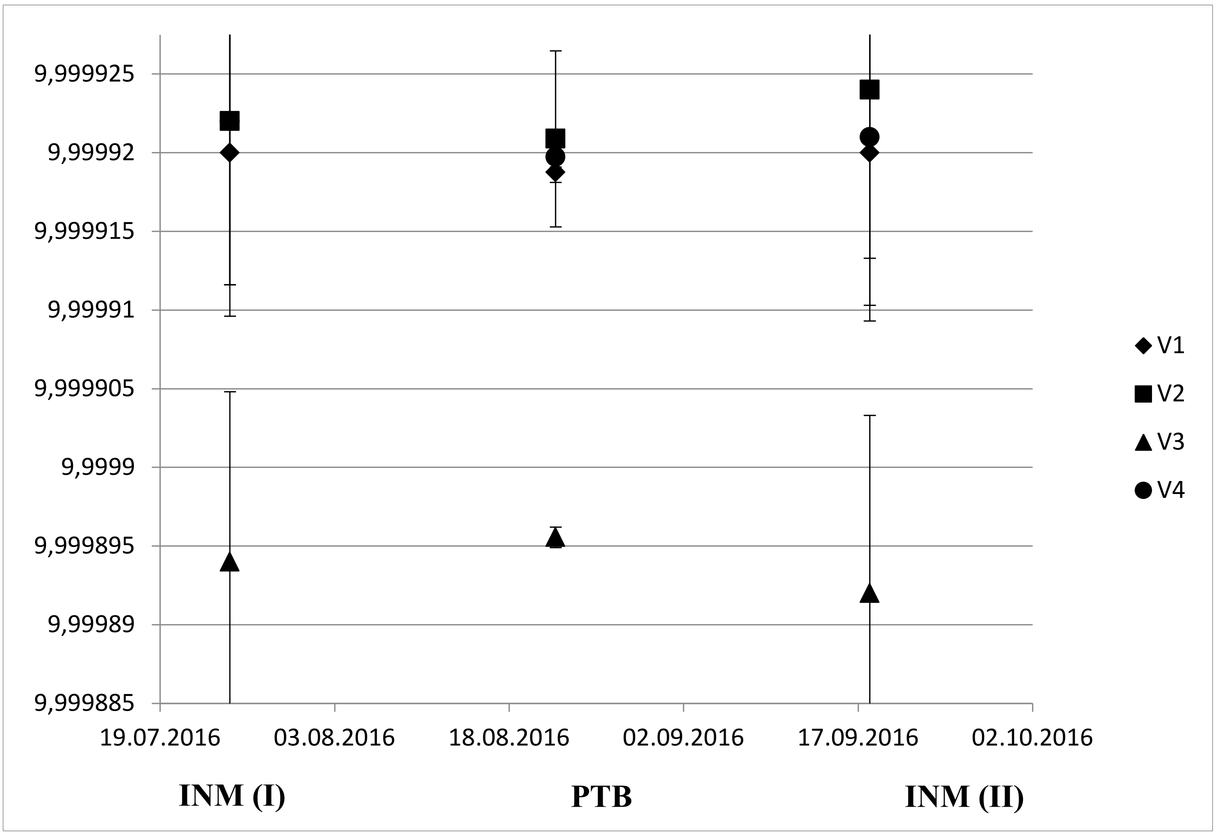

Figure 3: Results at 10 V

6.2. Calculation of the En value

The E_n-value is defined as

$$E_n = \frac{\left| V_{CalPTB} - V_{CalINM} \right|}{\sqrt{U_{PTB}^2 + U_{INM}^2}} \qquad (1)$$

The E_n-values for the first and second measurements performed at INM and PTB are given in tables 7a, b and 8a, b.

Table 7a: E_n-values for the first round at 1,018 V

V	INM value in V	INM uncertainty in V	PTB value in V	PTB uncertainty in V	E_n-value
V1	1,0179959	1,83E-06	1,01799761	1,80E-07	0,93
V2	1,0180030	1,85E-06	1,01800424	6,20E-07	0,64
V3	1,0180003	1,89E-06	1,01800191	1,80E-07	0,85
V4	1,0180007	1,81E-06	1,01800215	1,80E-07	0,80

Table 7b: E_n-values for the second round at 1,018 V

V	INM value in V	INM uncertainty in V	PTB value in V	PTB uncertainty in V	E_n-value
V1	1,0179963	1,72E-06	1,01799761	1,80E-07	0,76
V2	1,0180031	1,72E-06	1,01800424	6,20E-07	0,62
V3	1,0180002	1,74E-06	1,01800191	1,80E-07	0,98
V4	1,0180008	1,71E-06	1,01800215	1,80E-07	0,79

Table 8a: E_n-values for the first round at 10 V

V	INM value in V	INM uncertainty in V	PTB value in V	PTB uncertainty in V	E_n-value
V1	9,999920	1,04E-05	9,99991876	6,50E-07	0,12
V2	9,999922	1,04E-05	9,99992088	5,60E-06	0,09
V3	9,999894	1,08E-05	9,99989556	6,50E-07	0,14
V4	9,999922	1,04E-05	9,99991973	6,50E-07	0,22

Table 8b: E_n-values for the second round at 10 V

V	INM value in V	INM uncertainty in V	PTB value in V	PTB uncertainty in V	E_n-value
V1	9,999920	1,07E-05	9,99991876	6,50E-07	0,12
V2	9,999924	1,07E-05	9,99992088	5,60E-06	0,26
V3	9,999892	1,13E-05	9,99989556	6,50E-07	0,31
V4	9,999921	1,07E-05	9,99991973	6,50E-07	0,12

7. Conclusion

A bilateral voltage comparison has been performed by INM and PTB to justify the measurement capabilities of INM. The differences of the results at INM and PTB are very small and lie well within the combined standard uncertainties of the measurements and therewith support the measurement capabilities of INM for voltage.

Appendix A.

Measurement Report of INM

RMO Supplementary Comparison COOMET.EM-S20

Comparison of Voltage Standards

Results

Stella Straistari

National Institute of Metrology, Chisinau, Moldova

The voltage standards were measured at INM from 20 July to 29 July and from 13 September to 22 September 2016.

1. Measurand

The measurand is DC voltage at 1,018 V and 10 V for the standards 7000T/1 to 7000T/4.

2. Measurement standard measurement procedure and traceability scheme

The National Standard 7000T of INM was calibrated by INM Romania in June 2016 and therewith is traceable to the national standard of INM, Romania. INM, Romania has approved CMC's in this field.

The measurements were made using INM's measurement set-up for voltage standards.

The travelling standard was a four channel electronic voltage standard from FLUKE, Modell 7000T, SN 112460234 (4 channels: SN 112460080(V1); 112460077(V2); 112460079(V3);112460082(V4)).

3. Measurement set-up for the calibration of voltage standards

From the calibration results for the four standards mean values have been calculated for 1,018 V and 10 V. These values formed the basis for group measurements, where the voltage differences between the single standards have been measured by applying the differential method.

All measurements were carried out under controlled environmental conditions at a room temperature of 23 °C ± 2 K and a relative humidity of (45 ± 15)%.

The measurement uncertainty includes contributions for the calibration uncertainty of the standards, the stability of the standards and the uncertainty of the differential measurement. All quantities are considered to be uncorrelated.

4. Results

4.1 First round of measurements for voltage standards at 1,018 V

Date	V_1 in V	V_2 in V	V_3 in V	V_4 in V
20.07.2016	1,0179958	1,0180029	1,0180000	1,0180004
20.07.2016	1,0179950	1,0180027	1,0180005	1,0180003
21.07.2016	1,0179959	1,0180025	1,0180009	1,0180000
21.07.2016	1,0179956	1,0180021	1,0180009	1,0180007
22.07.2016	1,0179954	1,0180033	1,0179999	1,0180010
22.07.2016	1,0179962	1,0180029	1,0180001	1,0180008
25.07.2016	1,0179960	1,0180032	1,0179997	1,0180007
25.07.2016	1,0179957	1,0180027	1,0180000	1,0180006
26.07.2016	1,0179966	1,0180033	1,0180008	1,0180013
26.07.2016	1,0179962	1,0180034	1,0180008	1,0180013
27.07.2016	1,0179958	1,0180036	1,0179996	1,0180006
27.07.2016	1,0179964	1,0180034	1,0180010	1,0180006
28.07.2016	1,0179963	1,0180024	1,0180001	1,0180011
28.07.2016	1,0179964	1,0180029	1,0180008	1,0180001
29.07.2016	1,0179956	1,0180027	1,0180003	1,0180012
29.07.2016	1,0179961	1,0180036	1,0179998	1,0180005
Mean	1,0179959	1,0180030	1,0180003	1,0180007
Std. Dev.	4,1E-07	4,3E-07	4,7E-07	3,9E-07
Rel. Std. Dev.	4,0E-07	4,2E-07	4,6E-07	3,8E-07
U	1,83E-06	1,85E-06	1,89E-06	1,81E-06

4.2 First round of measurements for voltage standards at 10 V

Date	V_1 in V	V_2 in V	V_3 in V	V_4 in V
20.07.2016	9,999919	9,999921	9,999895	9,999921
20.07.2016	9,999919	9,999921	9,999895	9,999922
21.07.2016	9,999919	9,999921	9,999897	9,999922
21.07.2016	9,999919	9,999921	9,999897	9,999921
22.07.2016	9,999918	9,999921	9,999897	9,999921

22.07.2016	9,999921	9,999924	9,999890	9,999922
25.07.2016	9,999923	9,999925	9,999895	9,999923
25.07.2016	9,999920	9,999922	9,999892	9,999922
26.07.2016	9,999920	9,999921	9,999895	9,999921
26.07.2016	9,999919	9,999921	9,999896	9,999921
27.07.2016	9,999920	9,999922	9,999894	9,999921
27.07.2016	9,999920	9,999921	9,999893	9,999921
28.07.2016	9,999920	9,999922	9,999893	9,999922
28.07.2016	9,999920	9,999922	9,999893	9,999922
29.07.2016	9,999920	9,999923	9,999894	9,999922
29.07.2016	9,999921	9,999923	9,999894	9,999922
Mean	9,999920	9,999922	9,999894	9,999922
Std. Dev.	1,1E-06	1,1E-06	1,8E-06	0,5E-06
Rel. Std. Dev.	1,1E-07	1,1E-07	1,8E-07	0,5E-07
U	10,4E-06	10,4E-06	10,8E-06	10,2E-06

4.3 Second round of measurements for voltage standards at 1,018 V

Date	V_1 in V	V_2 in V	V_3 in V	V_4 in V
13.09.2016	1,0179962	1,0180031	1,0180002	1,0180009
13.09.2016	1,0179961	1,0180028	1,0180002	1,0180008
14.09.2016	1,0179962	1,0180031	1,0180000	1,0180006
14.09.2016	1,0179963	1,0180031	1,0180003	1,0180008
15.09.2016	1,0179962	1,0180030	1,0180006	1,0180007
15.09.2016	1,0179963	1,0180031	1,0180002	1,0180009
16.09.2016	1,0179964	1,0180032	1,0179998	1,0180008
16.09.2016	1,0179965	1,0180031	1,0179999	1,0180007
19.09.2016	1,0179961	1,0180031	1,0180000	1,0180007
19.09.2016	1,0179962	1,0180030	1,0180002	1,0180008
20.09.2016	1,0179963	1,0180032	1,0180003	1,0180010
20.09.2016	1,0179964	1,0180033	1,0180001	1,0180009
21.09.2016	1,0179964	1,0180032	1,0180003	1,0180009
21.09.2016	1,0179963	1,0180031	1,0180002	1,0180009
22.09.2016	1,0179963	1,0180032	1,0180002	1,0180008
22.09.2016	1,0179964	1,0180032	1,0180002	1,0180008
Mean	1,0179963	1,0180031	1,0180002	1,0180008

Std. Dev.	1,1E-07	1,1E-07	1,8E-07	1,0E-07
Rel. Std. Dev.	1,1E-07	1,1E-07	1,8E-07	1,0E-07
U	1,72E-06	1,72E-06	1,74E-06	1,71E-06

4.4 Second round of measurements for voltage standards at 10 V

Date	V_1 in V	V_2 in V	V_3 in V	V_4 in V
13.09.2016	9,999921	9,999924	9,999890	9,999922
13.09.2016	9,999920	9,999922	9,999893	9,999920
14.09.2016	9,999920	9,999924	9,999892	9,999921
14.09.2016	9,999921	9,999924	9,999892	9,999921
15.09.2016	9,999920	9,999924	9,999895	9,999920
15.09.2016	9,999921	9,999924	9,999891	9,999921
16.09.2016	9,999922	9,999925	9,999888	9,999922
16.09.2016	9,999921	9,999924	9,999889	9,999922
19.09.2016	9,999920	9,999924	9,999891	9,999921
19.09.2016	9,999920	9,999924	9,999892	9,999920
20.09.2016	9,999920	9,999923	9,999892	9,999921
20.09.2016	9,999921	9,999924	9,999890	9,999921
21.09.2016	9,999920	9,999923	9,999894	9,999921
21.09.2016	9,999920	9,999924	9,999894	9,999921
22.09.2016	9,999920	9,999924	9,999892	9,999921
22.09.2016	9,999919	9,999923	9,999894	9,999920
Mean	9,999920	9,999924	9,999892	9,999921
Std. Dev.	0,7E-06	0,5E-06	1,9E-06	0,7E-06
Rel. Std. Dev.	0,7E-07	0,5E-07	1,9E-07	0,7E-07
U	10,7E-06	10,7E-06	11,3E-06	10,7E-06

5. Detailed uncertainty budget

Mathematical Model:

The model function has been derived for the individual voltage V_1. For the other three voltages one gets similar equations.

$$V_1 = V_0\left(1 + \frac{\delta V_{cal}}{V_0} + \frac{\delta V_{Stab}}{V_0}\right)\left(1 - \frac{a_2 + 2a_3 + 3a_4 - 6}{4} - \frac{\delta V_{ij}}{V_0}\right),$$

with $V_0 = \frac{1}{4} \cdot (V_{10} + V_{20} + V_{30} + V_{40})$, $a_2 = 1 + \frac{\Delta V_{23}}{V_0} + \frac{\delta V_{23}}{V_0} \approx 1 + \frac{\Delta V_{23}}{V_0} + \frac{\delta V_{ij}}{V_0}$,

$a_3 = 1 + \frac{\Delta V_{34}}{V_0} + \frac{\delta V_{34}}{V_0} \approx 1 + \frac{\Delta V_{34}}{V_0} + \frac{\delta V_{ij}}{V_0}$ and

$a_4 = 1 + \frac{\Delta V_{41}}{V_0} + \frac{\delta V_{41}}{V_0} \approx 1 + \frac{\Delta V_{41}}{V_0} + \frac{\delta V_{ij}}{V_0}$.

Quantity	Unit	Definition
V_{10}, V_{20}, V_{30}, V_{40}	V	Individual voltages of the standard at the time of calibration
V_0	V	Group voltage derived from the individual voltages at the time of calibration
ΔV_{23}, ΔV_{34}, ΔV_{41}	V	Differential voltages of each two individual voltages
δV_{Cal}	V	Uncertainty of calibration; it is assumed that the uncertainty is the same for the individual voltages, because they are measured by the same laboratory with the same equipment at the same time. The uncertainties for the individual voltages are strongly correlated.
δV_{Stab}	V	Uncertainty due to the instability of the standard; It can be estimated from the results of former calibrations of the standard
δV_{ij}	V	Measurement uncertainty for the differential voltage; it is assumed that it is the same for all differential voltages, because they have the same order of magnitude and are measured with the same Nanovoltmeter at the same time. The uncertainties for the differential voltages are strongly correlated.
Type A uncertainty	V	Represents the scattering of the measurement results

Uncertainty budget for 1,018 V:

Quantity	Value	Std. Unc.	DoF	Sens. Coef.	Unc. Contr.
V_0	1,0180000 V	0			
$1 - \frac{a_2 + 2a_3 + 3a_4 - 6}{4}$	0,9999960	0			
δV_{Cal}	0	0,55 µV	∞	1	0,55 µV
δV_{Stab}	0	0,083 µV	∞	1	0,23 µV
δV_{ij}	0	0,6 µV	∞	1	0,6 µV
Type A	0	0,41 µV	15	1	0,41 µV
V_1	1,0179959	0,91 µV	240		

Uncertainty budget for 10 V:

Quantity	Value	Std. Unc.	DoF	Sens. Coef.	Unc. Contr.
V_0	9,9999143 V	0			
$1 - \frac{a_2 + 2a_3 + 3a_4 - 6}{4}$	1,0000006	0			
δV_{Cal}		5 µV	∞	1	5 µV
δV_{Stab}		1 µV	∞	1	1 µV
δV_{ij}		0,6 µV	∞	1	0,6 µV
Type A		1,1 µV	15	1	1,1 µV
V_1	9,9999199	5,18 µV	240		

Results (First round, 1,018 V):

Quantity	Value, V	Exp. Unc., µV	Cov. Factor	Coverage
V_1	1,0179959 V	1,83	2	95 %
V_2	1,0180030 V	1,85	2	95 %
V_3	1,0180003 V	1,89	2	95 %
V_4	1,0180007 V	1,81	2	95 %

Results (First round, 10 V):

Quantity	Value, V	Exp. Unc., µV	Cov. Factor	Coverage
V_1	9,999920 V	10,4	2	95 %
V_2	9,999922 V	10,4	2	95 %
V_3	9,999894 V	10,8	2	95 %
V_4	9,999922 V	10,2	2	95 %

Results (Second round, 1,018 V):

Quantity	Value, V	Exp. Unc., µV	Cov. Factor	Coverage
V_1	1,0179963	1,72	2	95 %
V_2	1,0180031	1,72	2	95 %
V_3	1,0180002	1,74	2	95 %
V_4	1,0180008	1,71	2	95 %

Results (Second round, 10 V):

Quantity	Value, V	Exp. Unc., µV	Cov. Factor	Coverage
V_1	9,999920	10,7	2	95 %
V_2	9,999924	10,7	2	95 %
V_3	9,999892	11,3	2	95 %
V_4	9,999921	10,7	2	95 %

Appendix B.
Measurement Report of PTB

Draft Report 2017-03-27

RMO Comparison COOMET.EM-S20

Comparison of Voltage Standards at 10 V and 1.018 V

Results

Bernd Schumacher

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Measurement report

The standards were received at PTB on August 11th. The standards were placed in the laboratory on August 12th and measurements started on August 15th. The measurements were finished on August 29th. On September 7th they were sent back to the pilot laboratory.

1. Measurand

The measurand is the quantity DC-voltage at 10 V and at 1.018 V

2. Measurement procedure and Traceability scheme

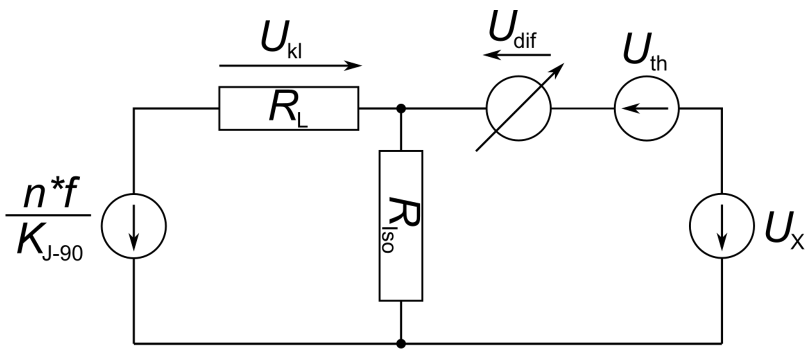
The voltage standards were compared with the Josephson voltage standard of PTB.

For all measurements, the cases of the standards were connected to measurement ground.

All measurements are traceable to the PTB's realisation of the unit of voltage using the Josephson voltage standard.

3. Measurement set-up

3.1 Set-up of the Josephson voltage standard



The value for U_X is determined by

$$U_x = n \cdot f/K_{J-90} - U_{lk} + U_{dif} + U_{th}$$

where

- n denotes the number of active Josephson elements,
- *f* denotes the microwave frequency,
- K_{J-90} is the Josephson constant,
- U_{lk} denotes a leakage voltage due to isolation and wiring,
- U_{dif} is the measured differential voltage between the Josephson standard and the voltage reference,
- U_{th} denotes uncompensated thermoelectric voltages.

The Type-A uncertainty of the repeated measurements is included as U_{repeat}.

All quantities are considered to be uncorrelated.

4. Results and environmental conditions

nom. value	Standard serial no.	mean date	mean result	expanded uncertainty
1,018 V	112 460 077	22.08.2016	1,018 004 19 V	0,18 µV
	112 460 079	22.08.2016	1,018 001 91 V	0,63 µV
	112 460 080	22.08.2016	1,017 997 61 V	0,18 µV
	112 460 082	22.08.2016	1,018 002 15 V	0,18 µV
10 V	112 460 077	22.08.2016	9,999 9209 V	0,65 µV
	112 460 079	22.08.2016	9,999 8956 V	5,6 µV
	112 460 080	22.08.2016	9,999 9188 V	0,65 µV
	112 460 082	22.08.2016	9,999 9197 V	0,65 µV
	112 460 234	22.08.2016	9,999 9143 V	1,6 µV

The mean temperature throughout the measurements was (22,9 ± 0,5) °C and the relative humidity was (40 ± 5) %.

5. Detailed uncertainty budget

5.1 Uncertainty budget for the 10 V standard

Uncertainty Budgets:

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n	68595.0					
f	70.50000000000 GHz	$2.31\cdot10^{-9}$ GHz	rectangular	0.14	$330\cdot10^{-12}$ V	0.0 %
K_{J-90}	$483.5979\cdot10^{3}$ GHz/V					
U_{lk}	0.0 V	$577\cdot10^{-12}$ V	rectangular	-1.0	$-580\cdot10^{-12}$ V	0.0 %
U_{dif}	$10.0000\cdot10^{-6}$ V	$32.0\cdot10^{-9}$ V	normal	1.0	$32\cdot10^{-9}$ V	1.4 %
U_{th}	0.0 V	$11.5\cdot10^{-9}$ V	rectangular	1.0	$12\cdot10^{-9}$ V	0.2 %
U_{repeat}	0.0 V	$270\cdot10^{-9}$ V	normal	1.0	$270\cdot10^{-9}$ V	98.4 %
U_x	9.999944863 V	$272\cdot10^{-9}$ V				

5.2 Uncertainty budget for the 1.018 V standard

Uncertainty Budgets:

Quantity	Value	Standard Uncertainty	Degrees of Freedom	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
n	6860.0						
f	70.50000000 GHz	$2.31\cdot10^{-9}$ GHz	□	rectangular	0.014	$33\cdot10^{-12}$ V	0.0 %
K_{J-90}	$483.5979\cdot10^{3}$ GHz/V						
U_{lk}	0.0 V	$577\cdot10^{-12}$ V	□	rectangular	-1.0	$-580\cdot10^{-12}$ V	0.0 %
U_{dif}	$10.00000\cdot10^{-6}$ V	$6.00\cdot10^{-9}$ V	9	normal	1.0	$6.0\cdot10^{-9}$ V	1.5 %
U_{th}	0.0 V	$11.5\cdot10^{-9}$ V	□	rectangular	1.0	$12\cdot10^{-9}$ V	5.4 %
U_{repeat}	0.0 V	$48.0\cdot10^{-9}$ V	10	normal	1.0	$48\cdot10^{-9}$ V	93.1 %
U_x	1.0000763775 V	$49.7\cdot10^{-9}$ V	11				

Appendix: Detailed results

Measurement of 10 V (all values in V)

Date	#112460077	#112460079	#112460080	#112460082	#T_112460234
15.08.2016	9,99992122	9,99989141	9,99991871	9,99991978	9,99991320
16.08.2016	9,99992122	9,99989795	9,99991846	9,99991956	9,99991462
17.08.2016	9,99992085	9,99990028	9,99991889	9,99992054	9,99991546
18.08.2016	9,99992074	9,99989930	9,99991884	9,99991946	9,99991494
19.08.2016	9,99992060	9,99989564	9,99991860	9,99991978	9,99991427
22.08.2016	9,99992111	9,99989642	9,99991899	9,99992007	9,99991418
23.08.2016	9,99992096	9,99989564	9,99991891	9,99991995	9,99991481
24.08.2016	9,99992057	9,99989408	9,99991897	9,99991983	9,99991499
25.08.2016	9,99992043	9,99989393	9,99991896	9,99992004	9,99991341
26.08.2016	9,99992106	9,99989358	9,99991891	9,99991933	9,99991392
29.08.2016	9,99992093	9,99989288	9,99991807	9,99991867	9,99991325
Mean	9,99992088	9,99989556	9,99991876	9,99991973	9,99991428
Std. dev.	2,7E-07	2,75E-06	2,8E-07	4,8E-07	7,6E-07

Measurement of 1,018 V

Date	#112460077	#112460079	#112460080	#112460082
15.08.2016	1,018004192	1,018001504	1,017997580	1,018002028
16.08.2016	1,018004285	1,018002164	1,017997568	1,018002109
17.08.2016	1,018004147	1,018002495	1,017997588	1,018002145
18.08.2016	1,018004203	1,018002156	1,017997571	1,018002125
19.08.2016	1,018004227	1,018001675	1,017997669	1,018002179
22.08.2016	1,018004291	1,018001633	1,017997685	1,018002175
24.08.2016	1,018004225	1,018002045	1,017997617	1,018002241
25.08.2016	1,018004249	1,018001965	1,017997601	1,018002209

26.08.2016	1,018004297	1,018001815	1,017997676	1,018002164
29.08.2016	1,018004252	1,018001607	1,017997570	1,018002075
Mean	1,018004237	1,018001906	1,017997612	1,018002145
Std. dev.	4,8E-08	3,14E-07	4,7E-08	6,3E-08
Std. dev. mean		9,9E-08		

Appendix C

TECHNICAL PROTOCOL

project COOMET 686/MD/16

COOMET Supplementary Comparison of Voltage at 10 V and 1,018V

(COOMET.EM-S20)

S. Straistari
National Metrology Institute. (INM), Chisinau, Moldova

July 2016

Content

1. Introduction

This bilateral COOMET Supplementary Comparison on voltage at 10 V and 1,018 V is performed in the frame of COOMET project 686/MD/16. The comparison identifier is COOMET.EM-S20.

The comparison is performed according to the state of the art of voltage measurements and is thought to check the equivalence of the national standards of the participants. It shall also underpin the calibration and measuring capabilities of the National Institute of Metrology of Moldova.

This comparison is organized among the COOMET members INM (Moldova) and PTB (Germany) with INM acting as the pilot laboratory.

2. Description of travelling standards

For this comparison a Fluke standard Type 7004T, Ser. No. 112460234, with four independent units will be used.

- Unit 1: Output voltages 1,018 V and 10 V, Ser. No. 112460080
- Unit 2: Output voltages 1,018 V and 10 V, Ser. No. 112460077
- Unit 3: Output voltages 1,018 V and 10 V, Ser. No. 112460079
- Unit 4: Output voltages 1,018 V and 10 V, Ser. No. 112460082

Operating temperature range: 15 °C to 35 °C, but measurements should be performed at (23 ± 2) °C.

3. Organization

The National Metrology Institute of Moldova (INM) will act as the pilot laboratory, Mrs. Stella Straistari being the coordinator of the comparison. The pilot laboratory is responsible for providing the travelling standards, coordinating the schedule, collecting and analysing the comparison data, preparing the draft report, etc.

It is planned to complete this comparison at the end of October 2016.
The chairperson of the COOMET TC 1.3 “Electricity and Magnetism” will be regularly informed about the progress of this comparison.

3.1 Participants

The address and contact information of the participating laboratories are given in Table 1.

Table 1. List of participants and contact information

	Laboratory	Address, telephone, fax, web-page.	Contact person
1	National Metrology Institute of Moldova (INM)	Republic Moldova, MD-2064, Chisinau, Eugen Coca Str., 28 Phone: +373 22 903 100 Fax: +373 22 903 111 Web-page: www.metrologie.md	S. Straistari Phone: +373 22 903 136 E-mail: marimi_electrice@metrologie.md
2	Physikalisch-Technische Bundesanstalt (PTB)	Germany, 38116 Braunschweig Bundesallee 100 Phone: +49 531 5922110 Fax: +49 531 5922105	Dr. Bernhard Schumacher Phone : +49 531 5922110 E-mail: Bernhard.Schuhmacher@ptb.de

3.2 Time schedule

The time schedule for the comparison is given in the table 2.

Table 2. Time schedule for the comparison

Country	Measurement	Transport to the next NMI	Date of reporting
Moldova	2nd half of July	1st week of August 2016	Mid of October
Germany	2nd and 3rd week of August	End of August 2016	Mid of October
Moldova	1st half of September		Mid of October

For the measurements in each laboratory a period of two to three weeks is allowed, including time necessary for transportation.

In agreeing with the proposed circulation time schedule, each participating laboratory confirms that it is capable to perform the measurements in the limited time period allocated in the time schedule. If, for some reasons, the measurement facility is not ready or custom clearance should take too much time, the laboratory is requested to contact immediately the co-ordinator in the pilot laboratory.

If a carnet is used, it must be used properly. Upon each movement of the package the person organising the transit must ensure that the carnet is presented to customs on entering and leaving the country. When the package is sent unaccompanied the carnet must be included with the other forwarding documents so that the handling agent can obtain customs clearance. The carnet must be saved in the laboratory very carefully because a loss of the carnet may cause a serious delay in the comparison schedule.

3.3 Transportation

Transportation is on each laboratory's own responsibility and cost. The voltage standard will be shipped in an appropriate container. Shipping using courier services is obligatory. The shipment should be arranged in a way that the time for transport is as short as possible, preferably day to day courier service. This means that customs procedures, where appropriate, have to be examined in advance of the transport. Particular care should be taken to avoid the shipping cases being exposed to extreme temperatures, e.g. left standing on the airport.

After arrival of the package the pilot laboratory and/or the sender must be informed by a confirmation note of receipt *(see Annex A3)* by e-mail or fax.

Immediately after having completed the measurements, the package must be transported to the next participant. It is advisable to prepare and organise this transportation beforehand. The pilot laboratory and/or the recipient must be informed by means of a confirmation note of dispatch (see Annex 4) by e-mail or Fax.

3.4 Unpacking, handling, packing

The package contains the following items:

- Voltage standard Fluke 7004T
- Power supply for the standard
- Special transport container from the manufacturer
- Instruction Manual.

After the receipt of the container, the standard have to be inspected for any damage. When the measurements have been finished ensure that the package is complete (see list above) before sending it in the original transportation container to the next participant.

3.5 Failure of the travelling standard

Should the travelling standard be damaged during transportation or during the comparison the pilot laboratory must be informed immediately.

3.6 Financial aspects, insurance

Each participating laboratory covers the costs of the measurement, transportation and eventual customs formalities as well as for any damage that may have occurred within its country. The overall costs for the organization of the comparison are covered by the organizing pilot laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during transportation.

4. Measurement instructions

The measurand of this comparison is the value of the DC voltage of items 1 to 4 at 1,018 V and 10 V. The measurement method which is adopted should be mentioned in reporting the results. Together with the measurement results, a short description of the individual measuring methods used must be included for the final report.
After installation of the voltage standard a minimum settling time of one day is required. The measurements should be carried out with these preferred conditions:

- ambient temperature (23 ± 2) °C

The ambient temperature and humidity should be recorded and reported. The measurements should be made at different dates during the period in the laboratory.

5. Uncertainty of measurement

Since this comparison is a COOMET comparison all participants must provide their results with the associated uncertainty of measurement and a complete uncertainty budget including the degrees of freedom (see Annex A1). The uncertainty must be evaluated at a level of one standard uncertainty. The uncertainty of measurement of the measuring results must be estimated according to the *ISO Guide to the Expression of Uncertainty in Measurement* (GUM). A list of the principal components of the uncertainty budget to be evaluated by each participant is included in this technical protocol (annex A1).

6. Measurement report

The individual results with date, temperature and the standard uncertainty should be reported to the pilot laboratory (**please use the attached summary of results sheet, annex A4**). Furthermore, a short description of the measuring set-up used and a detailed evaluation of the uncertainty of measurement has to be reported. Preliminary results can be sent by email. In any case, a printed and signed report of the results must be sent by mail. In case of any differences, the paper forms are considered to be the valid version.
The reports should be sent to the pilot laboratory no later than six weeks after the measurements have been completed. No information about differences of the reported results with respect to others will be communicated before the completion of the comparison, unless larger deviations between the results and the preliminary reference results obtained by the pilot laboratory have been observed. In this case the laboratory in question will be contacted.

7. Report of the comparison

Within 1 month after receiving the last measurement report, the pilot laboratory will prepare a first draft report and send it to the participant for comments. In this report an overview about the different measuring systems and a proposed comparison reference value will be included. Subsequently, the procedure outlined in the CCEM Guidelines will be followed.