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Bilateral Comparison of 1.018 V and 10 V Standards
between the FTMC (Lithuania) and the BIPM,
October to December 2025
(part of the ongoing BIPM key comparison BIPM.EM-K11.a and b)

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Introduction

As part of the ongoing BIPM key comparison BIPM.EM-K11.a and b, a comparison of the 1.018 V and 10 V voltage reference standards of the BIPM and the State Research Institute, Center for Physical Sciences and Technology (FTMC), Vilnius, Lithuania, was carried out from October to December 2025. Two BIPM Zener diode-based travelling standards (Fluke 732B), BIPM_8 (Z8) and BIPM_E (ZE), were transported to FTMC and back to BIPM by freight. In order to keep the Zeners powered during their transportation and during long measurement series, a dedicated auxiliary battery supply was designed and connected in parallel to the internal battery.

At FTMC, the reference standard for DC voltage is a Josephson Voltage Standard (JVS). The output electromotive force (EMF) of each travelling standard was measured by direct comparison with the primary standard.

At the BIPM, the output EMF of each travelling standard was calibrated before and after the measurements at FTMC against the PJVS developed at the BIPM around a PTB programmable SNS (Superconductor/Normal Metal/Superconductor) array.

Results of all measurements were corrected by the BIPM for the dependence of the output voltages of the Zener standards on internal temperature and ambient atmospheric pressure.

Outline of the measuring method

FTMC 1.018 V and 10 V measurements

FTMC operates a *HYPRES* primary voltage standard system in a closed-cycle refrigerator equipped with the *HYPRES* SIS 10 V Josephson junction array chip (serial number SUMCCR-25-10V).

A *Millitech* Gun oscillator CDA-12-4017N and its associated *VMetrix* power supply/modulator GS1002 together with a source locking microwave frequency counter EIP 578B by *Phase Matrix* is used as a microwave source. The 10 MHz reference frequency for the EIP 578B is provided by a cesium oscillator of the FTMC time and frequency standard laboratory.

The bias source for the array is a *VMetrix* JVS 1002 controller. The detector is an *Agilent* 3458A multimeter. The Zener reference standards were connected through a *DataProof* 106B scanner, which is used also for polarity reversals. The measurements were performed in a non-shielded room. The daily average values of the ambient conditions for measurements were reported separately.

The measurements were carried out between 25 November 2025 and 29 November 2025. All measurements were carried out with the Zeners operating on their internal batteries, being disconnected from mains at least 2 hours before measurements.

The FTMC Josephson system was run in automatic mode, computer controlled using the NISTVOLT software. A single point measurement was performed using the NISTVOLT procedure for calibrating Zener references. The algorithm accumulates measurements of voltage difference between the biased array and the Zener reference with the polarity reversals in a + – + – sequence. Ten measurements were taken for each polarity. Each of these measurements was calculated as the average from three readings of the DVM. A three-parameter least-squares fit was applied to the set of voltage difference readings to obtain the best estimates of the Zener reference voltage, the voltage offset from thermal emfs and a first order drift of the offset during the measurement. During the measurements the array was disconnected from its bias circuitry.

The internal thermistor resistance was measured with a *Fluke* 8508A Multimeter, operating in low current mode (10 µA). Average atmospheric pressure was measured using a barometer *Ahlborn* ALMEMO 2290-4.

BIPM Measurements for 1.018 V and 10 V

The output voltage of the Zener standard to be measured was connected in series opposition to the BIPM Programmable Josephson Voltage Standard - PTB 10 V SNS array (S/N: 2013-02/4a) [1], through a low thermal EMF multiplexer [2, 3]. The binding post terminals “GUARD” and “CHASSIS” of the Zener standard were connected together and connected to a single point which is the grounding reference point of the measurement setup.

The measurements started at least two hours after the mains plug at the rear of the Zeners had been disconnected in order for the Zener internal temperature to stabilize. In this comparison, the BIPM detector was a digital nanovoltmeter *Keithley 2182A* operated on its 10 mV range. A computer was used to monitor, record the measurements, acquire the data, correct for pressure and temperature dependence, and calculate results.

The BIPM array biasing frequency was adjusted in such a way that the voltage difference between the primary and the secondary voltage standards was always below 1 µV for both nominal voltages. In such a case, the nanovoltmeter gain error doesn’t affect the measurement result and the corresponding uncertainty can be neglected.

One individual measurement point was acquired according to the following:

1- The Zener and the BIPM array are set in their positive polarity, connected in series opposition and the detector data reading sequence starts;
2- The polarity of the detector is reversed and a reading sequence is carried out. The number of measurements is twice the number acquired in step 1;
3- The polarity of the detector is reversed again to match the conditions of step 1 and the reading sequence restarts;
4- The Zener and the BIPM array are set in their negative polarity, connected in series opposition and the detector data reading sequence starts;
5- The polarity of the detector is reversed and a reading sequence is carried out. The number of measurements is twice the number acquired in step 4;
6- The polarity of the detector is reversed again to match the conditions of step 4 and the reading sequence restarts.

The reversal of the array polarity (by reversing the bias current) is always accompanied by a reversal of the Zener voltage standard using the multiplexer. The reversal of the detector polarity is done to cancel out any internal thermal EMF with a constant drift rate.

Each data acquisition step consists of 50 preliminary measurements followed by 100 measurements. Each of these should not differ from the mean of the preliminary measurements by more than four times their standard deviation. If so, the software warns the operator with a beep. If many beeps occur, it means that the Zener output value has changed. The decision on restarting the “Data Acquisition” step in progress is based on considering the graphical representation of the measurements on the computer screen. The procedure to acquire one individual measurement point is repeated five times in a row and the mean value corresponds to one result on the graph (cf. Figs. 1, 2, 3, and 4).

Results at 10 V

Figure 1 shows the measured values obtained for the two standards by the two laboratories at 10 V. Figure 2 presents the voltage evolution of the arithmetic mean of the two standards which is used to compute the final result at 10 V. A linear least squares fit is applied to the BIPM results for both standards, and to the mean value of both standards. The comparison result is the voltage difference between the mean value of the FTMC measurements and the BIPM fitted value at the mean date of the FTMC measurements (27/11/2025) together with their related uncertainties.

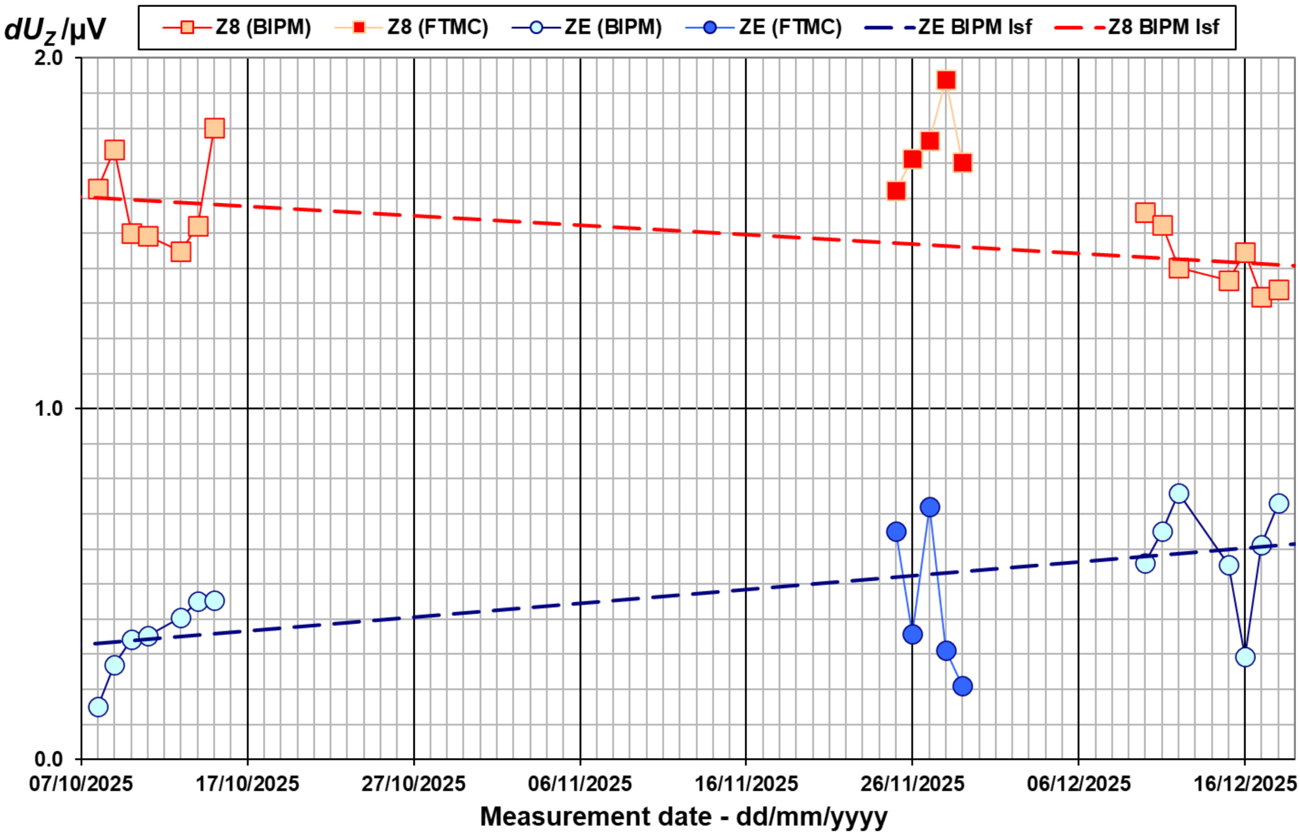

Figure 1: Voltage of Z8 (squares) and ZE (disks) at 10 V measured at both institutes (light markers for BIPM and dark markers for FTMC), referred to an arbitrary offset, as a function of the measurement date with a linear least-squares fit (lsf) to the BIPM measurements**.** Temperature and pressure corrections were applied to all the measurements.

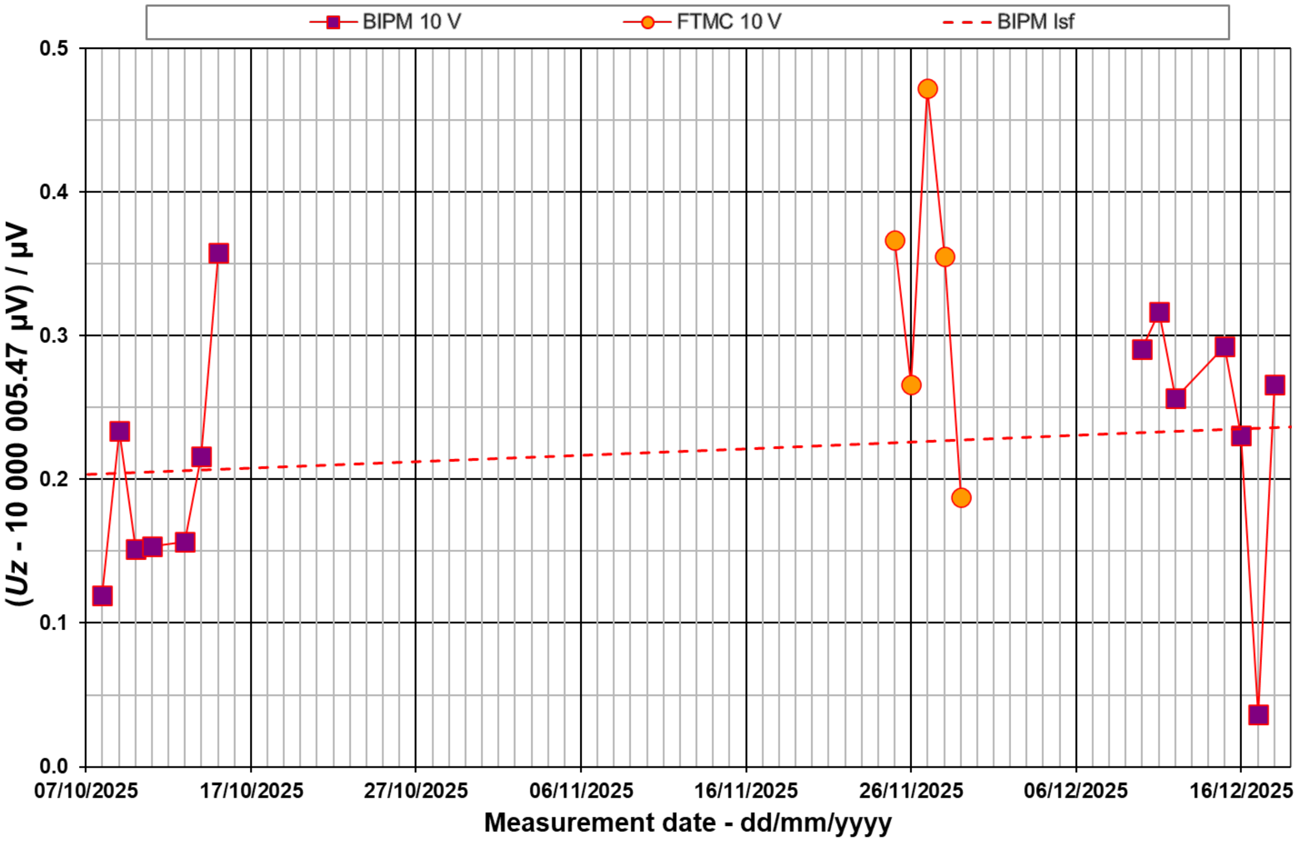

Figure 2: Voltage evolution of the arithmetic mean of the two standards at 10 V. FTMC measurements are represented by disks and BIPM measurements by squares. A least-squares fit is applied to the BIPM measurements.

Uncertainty Budgets at 10 V

BIPM uncertainty budget at 10 V

Table 1 summarizes the uncertainties related to the calibration of a Zener against the PJVS at the BIPM at the level of 10 V.

Experience has shown that flicker or 1/*f* noise ultimately limits the stability characteristics of Zener standards and it is not appropriate to use the standard deviation divided by the square root of the number of observations to characterize the dispersion of measured values. For the present standards, the relative value of the voltage noise floor due to flicker noise is about 1 part in 10^8 [4]. The Type A standard uncertainty in Table 1 therefore has a lower limit of 100 nV. However, if the standard deviation of the measurements at the mean date of the participant is larger than the flicker noise floor, it is this standard deviation which is considered to be the Type A standard uncertainty.

PJVS & detector uncertainty components	**Uncertainty (nV)**	**Degrees of freedom**
Noise of the measurement loop that includes the residual thermal EMF including the residual EMF of the reversing switch (Type A)	2	399
Detector gain (Type B)	negligible	∞
Leakage resistance (Type B)	4	∞
Frequency (Type B)	0.1	∞
Zener noise (Type A)	Not lower than the 1/*f* noise estimated as 100 nV, included in the comparison uncertainty budget (Table 3)	
Zener temperature correction	Included in the comparison uncertainty budget (Table 3)	10
Zener pressure correction		14

Table 1: Estimated standard uncertainties arising from the PJVS and the measurement setup for Zener calibrations with the BIPM equipment at the level of 10 V.

FTMC uncertainty budget at 10 V

Tables 2a and 2b list the uncertainties related to the calibration of the Zeners at FTMC for Z8 and ZE, respectively.

Quantity	**Distr.**	**Estimate**	**Standard uncertainty**	**Type**	**Sensitivity coefficient**	**Uncertainty contribution**	**Degrees of freedom**
Frequency u_{vf}	Rect.	75984600000 Hz	8.7 Hz	B	132 pV/Hz	1.15 nV	∞
Leakage u_{l}	Rect.	0 V	0.12 nV	B	1	0.12 nV	∞
Zero offset u_{z}	Norm.	0 V	8.5 nV	A	1	8.5 nV	270
Measurement result u_{x}	Norm.	0 V	20.8 nV	A	1	20.8 nV	26
Repeatability of results u_{r}	Norm.	9.999916617 V	88.9 nV	A	1	88.9 nV	4
[7]		**Combined uncertainty**				**91.7 nV**	
		Expanded uncertainty ($k_{0.95} = 2.78$)				**255 nV**	

Table 2a: Estimated standard uncertainties for a Zener calibration with the FTMC equipment at the level of 10 V for Zener Z8.

Quantity	**Distr.**	**Estimate**	**Standard uncertainty**	**Type**	**Sensitivity coefficient**	**Uncertainty contribution**	**Degrees of freedom**
Frequency u_{vf}	Rect.	75984600000 Hz	8.7 Hz	B	132 pV/Hz	1.15 nV	∞
Leakage u_{l}	Rect.	0 V	0.12 nV	B	1	0.12 nV	∞
Zero offset u_{z}	Norm.	0 V	8.5 nV	A	1	8.5 nV	270
Measurement result u_{x}	Norm.	0 V	23.5 nV	A	1	23.5 nV	30
Repeatability of results u_{r}	Norm.	10.00009437 V	87.5 nV	A	1	87.5 nV	4
[7]		**Combined uncertainty**				**91.0 nV**	
		Expanded uncertainty ($k_{0.95} = 2.78$)				**253 nV**	

Table 2b: Estimated standard uncertainties for a Zener calibration with the FTMC equipment at the level of 10 V for Zener ZE.

Uncertainty contributions for the comparison FTMC/BIPM at 10 V

Table 3 lists the results and the uncertainty contributions for the comparison FTMC/BIPM at 10 V.

		Results/μV		Uncertainty/μV	
		Z8	**ZE**	**Z8**	**ZE**
1	FTMC (U_{FTMC} – 10 V)	-83.05	94.65		
2	Type A uncertainty			0.092	0.091
3	correlated (Type B) uncertainty			0.001	
4	BIPM (U_{BIPM} – 10 V)	-83.33	94.73		
5	Type A uncertainty			0.100	0.100
6	correlated (Type B) uncertainty			0.004	
7	pressure and temperature correction uncertainty			0.015	0.016
8	($U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}}$)	0.28	-0.08		
9	Total uncorrelated uncertainty			0.137	0.136
10	Total correlated uncertainty			0.004	
11	$< U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}} >$	**0.10**			
12	*a priori* uncertainty			0.097	
13	*a posteriori* uncertainty			0.180	
14	**comparison total standard uncertainty**			**0.18**	

Table 3: Results and uncertainties of the FTMC (Lithuania)/BIPM bilateral comparison of 10 V standards using two Zener travelling standards. Standard uncertainties are used throughout.

In Table 3, the following elements are listed:

(1) the value attributed by FTMC to each Zener, U_{FTMC}, computed as the arithmetic mean of all data from FTMC and corrected for temperature and pressure differences between both laboratories by the BIPM.
(2) FTMC combined Type A uncertainty (cf. Tables 2a and 2b).
(3) the uncertainty component arising from the realization and maintenance of the volt at FTMC: it is the quadratic combination of the Type B components of the participant uncertainty budget listed in Tables 2a and 2b. This uncertainty is completely correlated between the different Zeners used for the comparison.

(4-6) the corresponding quantities for the BIPM referenced to the mean date of the FTMC measurements. In this case, the Type A uncertainty is limited by the flicker noise level of 100 nV.

(7) the uncertainty due to the combined effects of the pressure and temperature coefficients [5, 6] and to the differences of the mean pressures and temperatures in the participating laboratories is calculated as follows:

The uncertainty of the temperature correction $u_{T,i}$ of Zener *i* is determined for the difference ΔR_i between the mean values of the thermistor resistances measured at both institutes which is then multiplied by the uncertainty $u(c_{T,i})$ of the relative temperature coefficients of each Zener standard:

$$u_{T,i} = U \times u(c_{T,i}) \times \Delta R_i$$

where U = 10 V, $u(c_{T,Z8})$ = 0.294 × 10^{-7} / kΩ, $u(c_{T,ZE})$ = 0.311 × 10^{-7} / kΩ,

ΔR_{Z8} = 0.041 kΩ and ΔR_{ZE} = 0.044 kΩ.

The same procedure is applied for the uncertainty $u_{P,i}$ of the pressure correction for the difference ΔP_i between the mean values of the pressure measured at both institutes:

$$u_{P,i} = U \times u(c_{P,i}) \times \Delta P_i$$

where U = 10 V, $u(c_{P,Z8})$ = 0.050 × 10^{-9} / hPa, $u(c_{P,ZE})$ = 0.042 × 10^{-9} / hPa,

ΔP_{Z8} = 18.3 hPa and ΔP_{ZE} = 18.4 hPa.

The uncertainties of the temperature and the pressure measurements are negligible.

(8) the difference ($U_{\text{FTMC}} - U_{\text{BIPM}}$) for each Zener, and (9) the uncorrelated part of the uncertainty, calculated as the root sum square of lines 2, 5 and 7.

(10) the correlated part of the uncertainty, calculated as the root sum square of lines 3 and 6, for each travelling standard.

(11) the result of the comparison is the arithmetic mean of the differences of the calibration results for the different standards.

(12 and 13) the uncertainty related to the transfer, estimated by comparing the following uncertainties:

> (12) the *a priori* uncertainty, determined as the standard uncertainty of the mean, obtained by propagating the uncorrelated uncertainties for both Zeners;
>
> (13) the *a posteriori* uncertainty, which is the standard deviation of the mean of the two results.

(14) the total uncertainty of the comparison, which is the root sum square of the correlated part of the uncertainty (10) and the larger of (12) and (13).

To estimate the uncertainty related to the stability of the standards during transportation, we have calculated the “*a priori”* uncertainty of the mean of the results obtained for the two standards (also called statistical internal consistency). It consists of half the root sum square of the uncorrelated uncertainties of each result. We compared this component to the “*a posteriori”* uncertainty (also called statistical external consistency) which consists of the experimental standard deviation of the mean of the results from the two travelling standards*.

If the “*a posteriori*” uncertainty is significantly larger than the “*a priori*” uncertainty, we assume that a standard has changed in an unusual way, probably during their transportation. This is the case in the present comparison and the a posteriori uncertainty is used in the uncertainty budget. However, comparing the results obtained at BIPM of the Zeners before and after their return, it seems not obvious to conclude that the metrological quality of the standards was affected by their shipment.

The comparison result is presented as the difference between the value assigned to a 10 V standard by FTMC, at FTMC, U_{FTMC}, and that assigned by the BIPM, at the BIPM, U_{BIPM}, on the reference date of the 27th of November 2025:

$$\boldsymbol{U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}} = 0.10\ \mu\mathrm{V}; \qquad u_{\mathrm{c}} = 0.18\ \mu\mathrm{V}}$$

where u_{c} is the combined standard uncertainty associated with the measured difference, including the uncertainty of the realization of the volt at FTMC, at the BIPM, and the uncertainty related to the comparison.

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* With only two travelling standards, the uncertainty of the standard deviation of the mean is comparable to the value of the standard deviation of the mean itself.

Results at 1.018 V

Figure 3 shows the measured values obtained for the two standards by the two laboratories at 1.018 V and Figure 4 presents the voltage evolution of the arithmetic mean of the two standards which is used to compute the final result at 1.018 V.

A linear least squares fit is applied to the results of the BIPM, before and after the measurements at FTMC, to obtain the results for both standards and their uncertainties at the mean date of the FTMC measurements (27/11/2025).

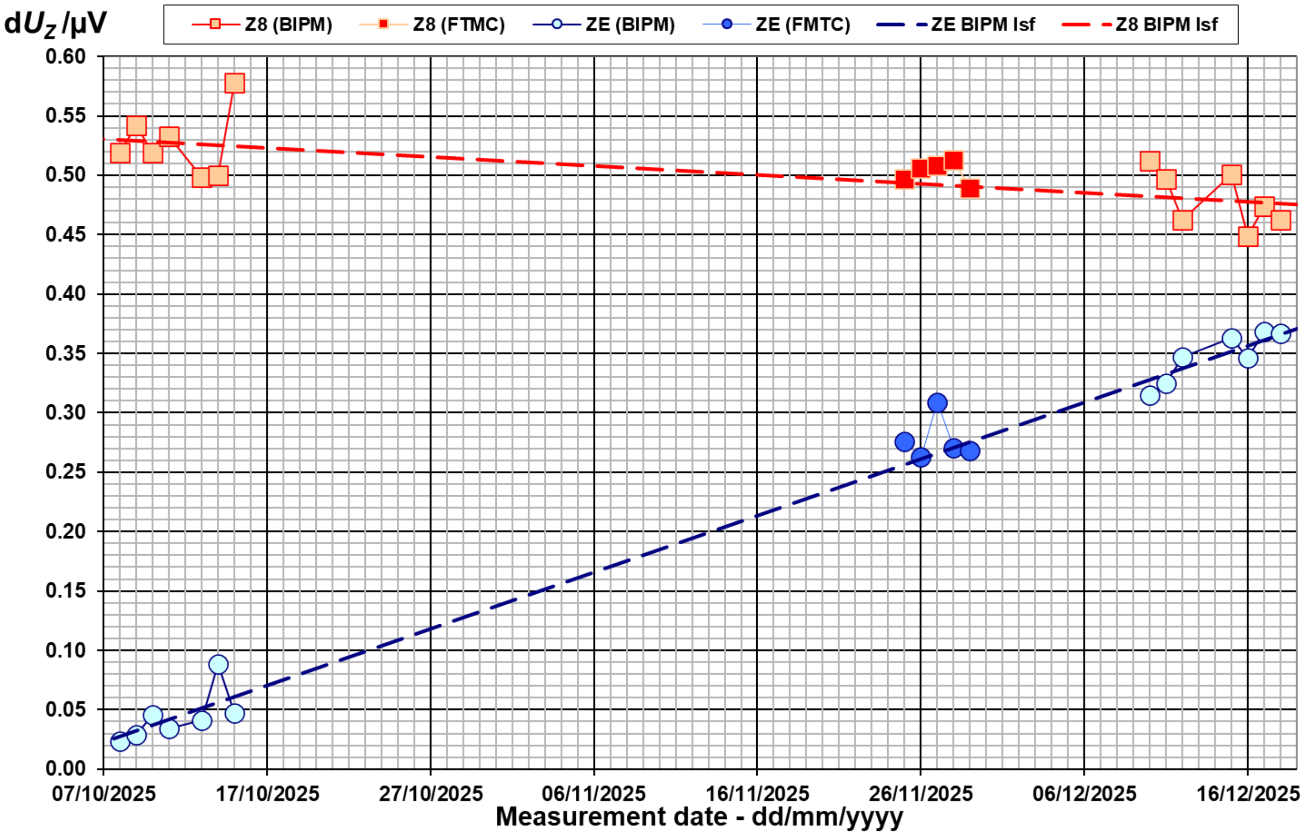

Figure 3: Voltage of Z8 (squares) and ZE (disks) at 1.018 V measured at both institutes (light markers for BIPM and dark markers for FTMC), referred to an arbitrary offset, as a function of the measurement date with a linear least-squares fit (lsf) to the BIPM measurements**.**

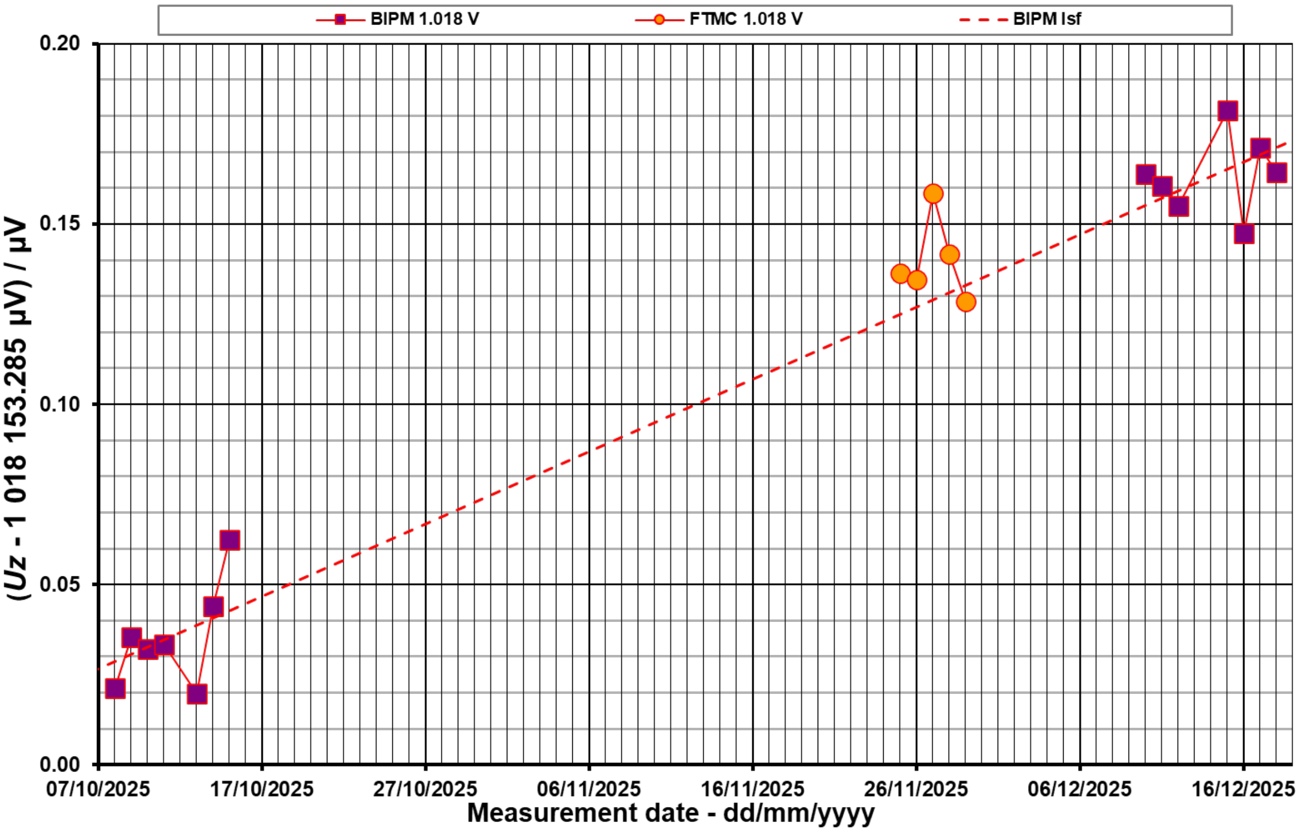

Figure 4: Voltage evolution of the arithmetic mean of the two standards at 1.018 V. FTMC measurements are represented by disks and BIPM measurements by squares. A least-squares fit is applied to the BIPM measurements.

Uncertainty Budgets at 1.018 V

BIPM uncertainty budget at 1.018 V

Table 4 summarizes the uncertainties related to the calibration of a Zener against the Programmable Josephson Voltage Standard at the BIPM at the level of 1.018 V.

PJVS & detector uncertainty components	**Uncertainty (nV)**	**Degrees of freedom**
Noise of the measurement loop that includes the residual thermal EMF including the residual EMF of the reversing switch (Type A)	2	399
Detector gain (Type B)	negligible	∞
Leakage resistance (Type B)	0.4	∞
Frequency (Type B)	0.01	∞
Zener noise (Type A)	Not lower than the 1/*f* noise estimated as 10 nV, included in the comparison uncertainty budget (Table 6)	
Zener temperature correction	Included in the comparison uncertainty budget (Table 6)	10
Zener pressure correction		14

Table 4: Estimated standard uncertainties arising from the PJVS and the measurement setup for Zener calibrations with the BIPM equipment at the level of 1.018 V.

FTMC uncertainty budget at 1.018 V

Tables 5a and 5b list the uncertainties related to the calibration of the Zeners at FTMC for Z8 and ZE, respectively.

Quantity	**Distr.**	**Estimate**	**Standard uncertainty**	**Type**	**Sensitivity coefficient**	**Uncertainty contribution**	**Degrees of freedom**
Frequency u_{vf}	Rect.	75984600000 Hz	8.7 Hz	B	13.4 pV/Hz	0.12 nV	∞
Leakage u_{l}	Rect.	0 V	0.01 nV	B	1	0.01 nV	∞
Zero offset u_{z}	Norm.	0 V	8.5 nV	A	1	8.5 nV	270
Measurement result u_{x}	Norm.	0 V	8.23 nV	A	1	8.23 nV	28
Repeatability of results u_{r}	Norm.	1.018177017 V	5.74 nV	A	1	5.74 nV	4
[7]		**Combined uncertainty**				**13.2 nV**	
		Expanded uncertainty ($k_{0.95} = 2.00$)				**26.4 nV**	

Table 5a: Estimated standard uncertainties for a Zener calibration with the FTMC equipment at the level of 1.018 V for Zener Z8.

Quantity	**Distr.**	**Estimate**	**Standard uncertainty**	**Type**	**Sensitivity coefficient**	**Uncertainty contribution**	**Degrees of freedom**
Frequency u_{vf}	Rect.	75984600000 Hz	8.7 Hz	B	13.4 pV/Hz	0.12 nV	∞
Leakage u_{l}	Rect.	0 V	0.01 nV	B	1	0.01 nV	∞
Zero offset u_{z}	Norm.	0 V	8.5 nV	A	1	8.5 nV	270
Measurement result u_{x}	Norm.	0 V	7.92 nV	A	1	7.92 nV	27
Repeatability of results u_{r}	Norm.	1.018129904 V	8.57 nV	A	1	8.57 nV	4
[7]		**Combined uncertainty**				**14.4 nV**	
		Expanded uncertainty ($k_{0.95} = 2.05$)				**29.6 nV**	

Table 5b: Estimated standard uncertainties for a Zener calibration with the FTMC equipment at the level of 1.018 V for Zener ZE.

Uncertainty contributions for the comparison FTMC/BIPM at 1.018 V

Table 6 lists the results and the uncertainty contributions for the comparison FTMC/BIPM at 1.018 V.

		Results/µV		**Uncertainty/µV**	
		Z8	**ZE**	**Z8**	**ZE**
1	FTMC (U_{FTMC} – 1.018 V)	177.053	129.797		
2	Type A uncertainty			0.013	0.014
3	correlated (Type B) uncertainty			<0.001	
4	BIPM (U_{BIPM} – 1.018 V)	177.042	129.786		
5	Type A uncertainty			0.010	0.010
6	correlated (Type B) uncertainty			<0.001	
7	pressure and temperature correction uncertainty			0.001	0.002
8	($U_{\mathrm{FTMC}} – U_{\mathrm{BIPM}}$)	0.011	0.011		
9	Total uncorrelated uncertainty			0.016	0.017
10	Total correlated uncertainty			<0.001	
11	< $U_{\mathrm{FTMC}} – U_{\mathrm{BIPM}}$ >	**0.011**			
12	*a priori* uncertainty			0.012	
13	*a posteriori* uncertainty			0.000	
14	**comparison total standard uncertainty**			**0.012**	

Table 6: Results and uncertainties of FTMC (Lithuania)/BIPM bilateral comparison of 1.018 V standards using two Zener travelling standards: reference date 27 November 2025. Standard uncertainties are used throughout.

In Table 6, the following elements are listed:

(1) the value attributed by FTMC to each Zener U_{FTMC}, computed as the arithmetic mean of all data from FTMC and corrected for temperature and pressure differences between both laboratories by the BIPM.

(2) FTMC combined Type A uncertainty (cf. Tables 5a and 5b).

(3) the uncertainty component arising from the realization and maintenance of the volt at FTMC: it is the quadratic combination of the Type B components of the participant uncertainty budget listed in Tables 5a and 5b. This uncertainty is completely correlated between the different Zeners used for the comparison.

(4-6) the corresponding quantities for the BIPM referenced to the mean date of FTMC measurements. In this case, the Type A uncertainty is limited by the flicker noise level of 10 nV.

(7) the uncertainty due to the combined effects of the pressure and temperature coefficients [5, 6] and to the differences of the mean pressures and temperatures in the participating laboratories is calculated as follows:

The uncertainty of the temperature correction $u_{T,i}$ of Zener *i* is determined for the difference ΔR_i between the mean values of the thermistor resistances measured at both institutes which is then multiplied by the uncertainty $u(c_{T,i})$ of the relative temperature coefficients of each Zener standard:

$$u_{T,i} = U \times u(c_{T,i}) \times \Delta R_i$$

where U = 1.018 V, $u(c_{T,Z8})$ = 0.306 × 10^{-7} / kΩ, $u(c_{T,ZE})$ = 0.347 × 10^{-7} / kΩ, ΔR_{Z8} = 0.033 kΩ and ΔR_{ZE} = 0.041 kΩ.

The same procedure is applied for the uncertainty $u_{P,i}$ of the pressure correction for the difference ΔP_i between the mean values of the pressure measured at both institutes:

$$u_{P,i} = U \times u(c_{P,i}) \times \Delta P_i$$

where U = 1.018 V, $u(c_{P,Z8})$ = 0.040 × 10^{-9} / hPa, $u(c_{P,ZE})$ = 0.049 × 10^{-9} / hPa, ΔP_{Z8} = 18.5 hPa and ΔP_{ZE} = 18.5 hPa.

The uncertainties of the measurement of the temperature and the pressure are negligible.

(8) the difference (U_{BFTMC} – U_{BIPM}) for each Zener, and (9) the uncorrelated part of the uncertainty, calculated as the root sum square of lines 2, 5 and 7.

(10) the correlated part of the uncertainty, calculated as the root sum square of lines 3 and 6, for each travelling standard.

(11) the result of the comparison is the arithmetic mean of the differences of the calibration results for the different standards.

(12 and 13) the uncertainty related to the transfer, estimated by comparing the following uncertainties:

> (12) the *a priori* uncertainty, determined as the standard uncertainty of the mean, obtained by propagating the uncorrelated uncertainties for both Zeners;
>
> (13) the *a posteriori* uncertainty, which is the standard deviation of the mean of the two results.

(14) the total uncertainty of the comparison, which is the root sum square of the correlated part of the uncertainty (10) and the larger of (12) and (13).

In this case the *a priori* uncertainty is larger than the *a posteriori* uncertainty. We conclude that at 1.018 V both Zeners behaved consistently within the uncertainty of the comparison.

The result of the comparison is presented as the difference between the value assigned to a 1.018 V standard by FTMC, at FTMC, U_{FTMC}, and that assigned by the BIPM, at the BIPM, U_{BIPM}, on the reference date of the 27th of November 2025:

$$\boldsymbol{U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}} = 0.011\ \mu\mathrm{V}; \quad u_{\mathrm{c}} = 0.012\ \mu\mathrm{V}}$$

where u_{c} is the combined standard uncertainty associated with the measured difference, including the uncertainty of the realization of the volt at the BIPM and at FTMC and the uncertainty related to the comparison.

Conclusion

The final result of the comparison is presented as the difference between the values assigned to DC voltage standards by FTMC, at the level of 1.018 V and 10 V, at FTMC, U_{FTMC}, and those assigned by the BIPM, at the BIPM, U_{BIPM}, at the reference date of the 27th of November 2025.

$$\boldsymbol{U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}} = 0.011\ \mu\mathrm{V}; \quad u_{\mathrm{c}} = 0.012\ \mu\mathrm{V},\ \text{at } 1.018\ \mathrm{V}}$$

$$\boldsymbol{U_{\mathrm{FTMC}} - U_{\mathrm{BIPM}} = 0.10\ \mu\mathrm{V}; \quad u_{\mathrm{c}} = 0.18\ \mu\mathrm{V},\ \text{at } 10\ \mathrm{V}}$$

where u_{c} is the combined standard uncertainty associated with the measured difference, including the uncertainty of the realization of the volt at the BIPM and at FTMC, and the uncertainty related to the comparison.

We note that the FTMC mean value of Z8 is 280 nV higher than the BIPM mean value at 10 V. It is not the case for the second voltage standard (ZE) for the same voltage. It is possible that the selected channel of the *Dataproof* multiplexer is exhibiting a leakage error. The point that such discrepancy doesn’t exist at the 1 V level supports this assumption.

On the 27th of October 2025 FTMC requested to keep the traveling standards in their laboratory for longer than initially planned as they were facing an issue with their JVS. This explains why the FTMC measurements are not centred in between the BIPM measurements. Nevertheless, the natural drift of the standards during the comparison is in accordance with their long-term drift.

These are very good results for both nominal voltages. The comparison results show that the voltage standards maintained by FTMC and the BIPM are equivalent within their stated standard uncertainties.

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