TRANSFER OF THE UNITS SIZE BY THE RANGE OF VALUES WITH USING THE STATE PRIMARY STANDARD OF THE UNITS OF ELECTRICAL CAPACITANCE AND DISSIPATION FACTOR

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Abstract: The procedure of support of traceability of measurements when transferring the units size by the range of values with using the State primary standard of the units of electrical capacitance and dissipation factor with the estimation of uncertainty is considered in the article.

Keywords: standard, the capacitance measure, total standard uncertainty, expanded uncertainty.

Introduction

The State primary standard of the units of electrical capacitance and dissipation factor (DETU 08-06-01) was created and successfully is used in State Enterprise "All-Ukrainian State Scientific and Production Centre for Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetrteststandard") since 2001 [1].

Similar standards were created in SE "Ukrmetrteststandard" for such national metrology institutes as BelGIM (Belarus), GUM (Poland) and NIST (USA).

The aim of the article – the main points of the calibration procedure of capacity measures with using the State primary standard of the units of electrical capacitance and dissipation factor (DETU 08-06-01) with the estimation of uncertainty based on a modern approach to the processing of measurement results must be provided.

1. Basic Points

The DETU 08-06-01 standard includes the measures of Andeen-Hagerling (USA) AH11A model with the nominal values of capacitance measures of 10 pF and 100 pF. For them, in addition to the results of international comparisons, there are calibration certificates of national metrology institutes (NMIs) NIST (USA), PTB (Germany), and NPL (Great Britain). The values of these measures have the expanded uncertainty $U_{AH} = 7.4 \cdot 10^{-6}$ pF with a probability $P = 0.95$ at the coverage factor $k = 2$.

The transmission of the unit size of capacitance over the value range is carried out with the use of the universal automated precision comparator included in the DETU 08-06-01 standard [2]. The comparator has two transmission ratio values: 1:1 or 1:10. Using these two transmission ratio values only, it is possible to realize the transmission of the unit size of capacitance by consecutive calibrations of capacitance measures in the wide range of values toward both high and low impedance.

An example of transmission of the unit size of capacitance over the value range in the calibration of capacitance measures with the nominal value of 10 nF based on the standard capacitance measure of 100 pF and with the use of intermediate capacitance measure of 1 nF is represented in Fig. 1.

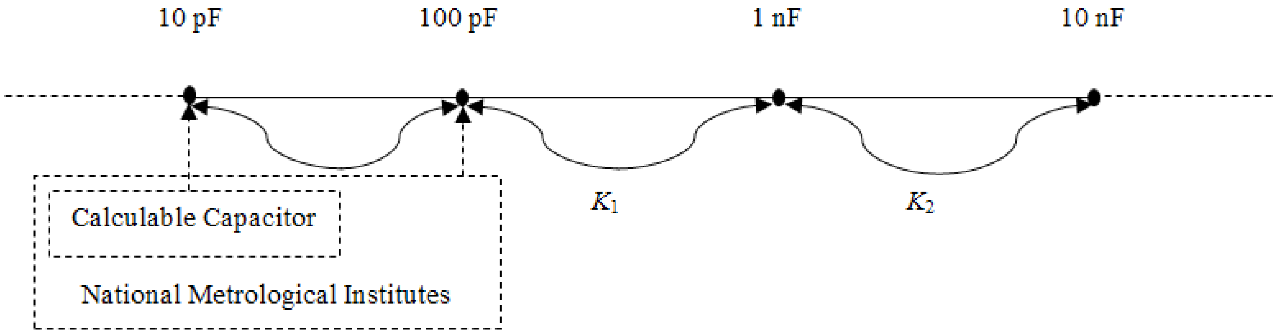

Fig. 1. The transmission of the unit size of capacitance over the value range

2. The estimation of uncertainty in the calibration of capacitance measures

The estimation of uncertainty in the calibration of capacitance measures is carried out according to the model (equation) of measurement by the expression:

$$C_X = \frac{C_S + \Delta C_{TS} + \Delta C_{fS} + \Delta C_{\gamma S}}{K_1 K_2}, \quad (1)$$

where C_S is the value of capacitance of a standard measure with the nominal value of 100 pF, indicated in a calibration certificate;

ΔC_{TS} is correction for temperature dependence of standard measures;

ΔC_{fS} is correction for frequency dependence of standard measures;

$\Delta C_{\gamma S}$ is correction for a drift of standard measures from the moment of the last calibration;

K_1 is the transmission factor of the comparator in the calibration of the intermediate capacitance measure of 1 nF C_S from the set of the temperature-stabilized measures CA 5200RC based on the capacitance measure with the nominal value of 100 pF:

$$K_1 = \frac{C_{1nF}}{C_S} \quad (2)$$

K_2 is the transmission factor of the comparator in the calibration of the intermediate capacitance measure C_X with the nominal value of 10 nF based on the intermediate capacitance measure with the nominal value of 1 nF:

$$K_3 = \frac{C_X}{C_{10nF}} \quad (3)$$

The example of the uncertainty budget of measurements of the capacitance value in the calibration of the measure C_X is presented in Table 1 [3].

Calculation of the relative total standard uncertainty $w(C_X)$ and relative expanded uncertainty $W(C_X)$ in the transmission of the size of the physical quantity from the capacitance measure with the nominal value of 100 pF to the calibrated capacitance measure with the nominal value of 10 pF is carried out in a relative form by the formulas (4, 5):

Table 1. The measurement uncertainty budget in the calibration of the measure

Quantity X_i	Value x_i	Relative standard uncertainty $w(x_i)$	Distribution law	Type of evaluation	Sensitivity coefficient p_i	Contribution to uncertainty $p_i \cdot w(x_i)$
1	2	3	4	5	6	7
k_1	0.099996	1.20E-07	normal	*A*	-1	-1.20E-07
k_2	0.099999	1.40E-07	normal	*A*	-1	-1.40E-07
1	2	3	4	5	6	7
C_S	100.000020 pF	3.70E-06	normal	B	1	3.70E-06
ΔC_{TS}	0 pF	7.10E-07	normal	B	1	7.10E-07
ΔC_{fS}	0 pF	4.10E-07	normal	B	1	4.10E-07
$\Delta C_{\gamma S}$	-1.10E-06 pF	5.08E-07	normal	B	1	5.08E-07
C_X	**10000.439907 pF**					
		Relative total standard uncertainty			$w(C_X)$	3.76E-06
		Effective number of degrees of freedom			ν_{eff}	>200, *k*=2
		Relative expanded uncertainty (*P* ≈ 95 %)			$W(C_X)$	**7.52E-06**

$$w(C_X) = \sqrt{w^2(C_S) + \sum_{i=1}^{N} p_i^2 w_i^2(x_i)} \qquad (4)$$

$$W(C_X) = kw(C_X) \qquad (5)$$

The value of standard uncertainty of the factors K_1, K_2 takes into account:

– the deviation caused by the comparator quantization error;

– correction for the sensitivity of the comparator and the error of comparisons.

The values of the factors K_1, K_2 are indicated in the comparator certificate, but these factors can be specified for every point of the measurement range by the comparison of precalibrated measures. It should be noted that in the total standard measurement uncertainty of the calibration result, it is also necessary to take into account the frequency dependence of the transmission factor of the comparator, which has a substantial influence on the measurement result in the calibration of capacitance measures. However, during the measurements, the frequency drift is negligible and the measurement uncertainty is about the value of $1 \cdot 10^{-10}$.

Thus, the components of uncertainty introduced by the frequency dependence can be neglected.

The measurable value of capacitance of the measure with the nominal value of 10 nF at the measurement temperature of (22÷24) °C and relative humidity of (30÷45) % at the frequency of the examined signal of 1 kHz made up 10.0004399 nF ±7.52 μF/F.

CMC of NMIs of countries are published as pdf-files in the Annex C of the BIPM Key Comparison Database (KCDB) in the form of tables [4]. The above-mentioned values of measurement uncertainties correspond to the data published in the KCDB for Ukraine in the range of capacitance values from 10 pF to 10 nF.

Conclusions

The developed calibration procedure allows to estimate the relative total standard and relative extended measurement uncertainty when calibrating the reference capacitance measures with using the State primary standard of the units of electrical capacitance and dissipation factor (DETU 08-06-01).

The methodology of evaluation of measurement uncertainty in the wide range of capacitance values is proposed. The results of the calculations of the values of measurement uncertainties revealed that the results correspond to the data published in the international key comparison database for Ukraine in the range of capacitance values from 10 pF to 10 nF on frequencies of 1 kHz and 1.592 kHz.

The use of this calibration procedure allows to estimate the measurement uncertainty of the capacitance value of reference measures within the framework of international comparisons are made.

References

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