Determination of AC-DC Transfer Difference of SUT Calculable Thermal Voltage Converters in 1 MHz - 30 MHz Frequency Range

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***Abstract* — The paper presents results of determination of the AC-DC voltage transfer differences in 1 MHz - 30 MHz frequency range of the two reference thermal voltage converters developed at Silesian University of Technology (SUT). Two experimental methods confirmed high accuracy of results obtained from the mathematical model.**

***Index Terms*—measurement standards, thermal converter, AC-DC transfer, AC-DC transfer difference, AC voltage standard, mathematical modeling.**

I. Introduction

In [1] we described two reference thermal voltage converters (TVC), developed at the Silesian University of Technology (SUT). The nominal input voltages of these TVCs are $U_N = 3$ V and $U_N = 5$ V. The mathematical model of these standards, based on [2], allowed to calculate AC–DC transfer difference of these converters in frequency range from 10 kHz to 1 MHz. Both commercial calibration performed at PTB and interlaboratory comparison confirmed good accuracy of the calculated AC–DC transfer differences of these standards [1,3].

The paper presents results of determination of the frequency-dependent component of the AC–DC voltage transfer differences of the two SUT reference thermal voltage converters in 1 MHz – 30 MHz frequency range.

II. AC–DC Transfer Difference of AC Standards

The frequency-dependent component of the AC–DC transfer difference and its uncertainty of both SUT reference TVCs was calculated using a mathematical model presented in [1]. Some parameters of that model had to be to be modified to be useful at higher frequencies. For example, the impedance of TVC dumet leads was calculated for each frequency using a finite element method (FEM). The calculated frequency-dependent component of AC–DC transfer differences of both calculable SUT AC voltage standards is presented in Fig. 1. The uncertainty of the calculated AC–DC transfer differences was estimated using mathematical model presented in [1] and Monte Carlo method. The uncertainty budget includes influence of all materials constants and geometrical dimensions of the TVCs. The frequency-independent component, determined experimentally, is ±0.1 µV/V with combined standard uncertainty 0.4 µV/V [4].

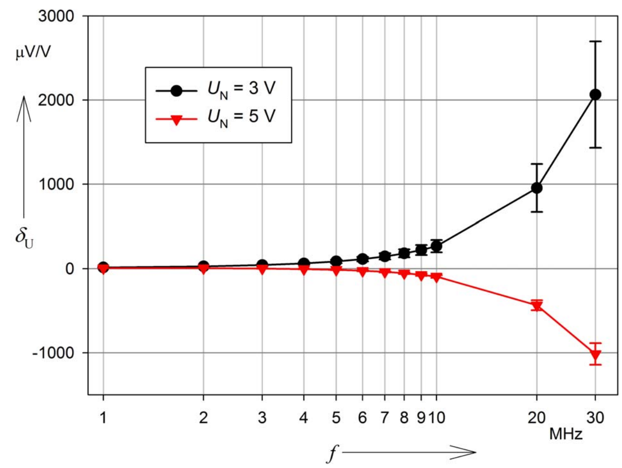

Fig. 1. Calculated AC–DC transfer differences of the two SUT reference TVCs.

III. Verification of the Correctness of the Model

Correctness of the calculation of the frequency-independent component of the AC–DC transfer difference of SUT reference TVCs was verified using two methods:

1) by comparing calculated and measured differences between AC–DC transfer differences of the two calculable TVCs of different nominal input voltages and dimensions;
2) by measuring the AC-DC transfer difference of the SUT 5 V reference standard using a "traveling" TVC, which was commercially calibrated at PTB and during interlaboratory comparison with RiSE (Sweden) and Trescal (Denmark) [5].

A. Internal comparison at SUT

The two AC voltage standards were compared using SUT AC–DC comparator. The measured and calculated AC–DC transfer difference between the two SUT reference TVCs is presented in Fig. 2. Due to the limited output power of the AC voltage source, the measurements were performed at lower input voltage ($U_{IN} = 2.5$ V) what resulted in lower output voltage of the standards and increased A-type uncertainty.

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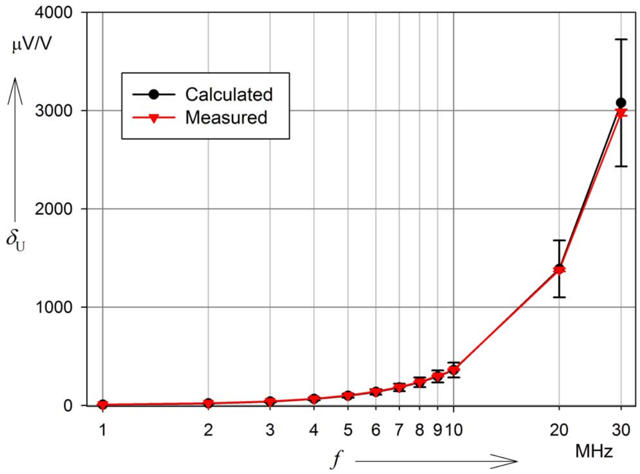

Fig. 2. Measured and calculated differences between AC–DC transfer differences of 3 V and 5 V SUT reference TVC

Nevertheless, the difference between measured and calculated values was lower than combined standard uncertainty of these measurements. The time-consuming searching for a replacement of the hitherto used AC voltage source is described in [6].

The highest difference was obtained at 30 MHz, but it was still below 100 μV/V. The comparison presented in Fig.2. partially confirmed the correctness of the mathematical model of both SUT calculable AC voltage standards in 1 MHz – 30 MHz frequency range.

B. Comparison with other NMIs

The second method of verifying the correctness of the model was calibration of a traveling TVC at SUT and two foreign laboratories: RiSE and Trescal [5]. The traveling standard was a planar multijunction thermal converter of input voltage U_N = 3 V, manufactured by NIST [7]. This TVC is more robust than the SUT calculable standard, which is relatively fragile and could get damaged during transport. After the calibrations performed RiSE and Trescal, the traveling standard was again compared with the SUT 5 V reference TVC using the SUT AC–DC comparator. The result of the measurement with bars representing combined standard uncertainties is shown in Fig.3.

Again, a good consistency could be observed between the two curves presented in Fig. 3. The maximum discrepancy is below 80 μV/V at 20 MHz and is lower than the combined uncertainty of both measurements.

IV. Summary

The AC–DC transfer difference of the SUT calculable AC voltage standard was calculated from the mathematical model at selected frequencies from 1 MHz to 30 MHz. Direct comparison of the 3 V reference TVC with the 5 V reference TVC partially confirmed correctness of the results obtained from the mathematical model. The difference between the calculated and measured AC–DC transfer differences is lower than the combined standard uncertainty of the measurement. To obtain another confirmation of the correctness of the mathematical model, a traveling 3 V TVC was calibrated at a foreign NMIs and next the 5 V SUT reference TVC was calibrated using the traveling TVC in 1 MHz – 30 MHz frequency range. Also these measurements show good agreement between calculated and measured values.

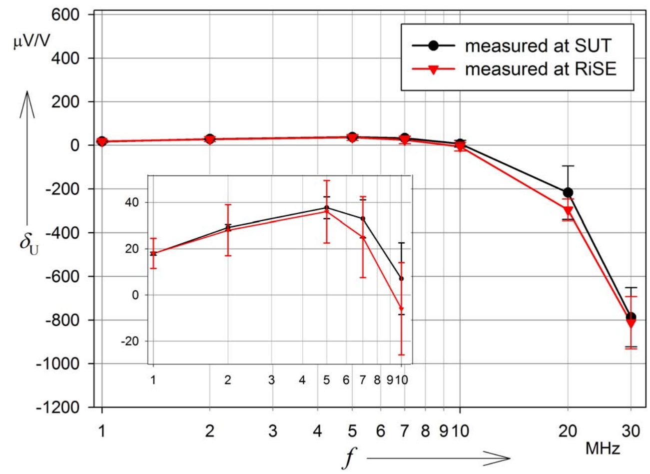

Fig. 3. AC–DC transfer difference of the 3 V traveling standard measured using the new standard developed at SUT and measured at RiSE [5]. The inset magnifies results obtained in 1 - 10 MHz range.

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