COMPARISON OF THE METHODS USED TO LOW LEVEL DC VOLTAGE MEASUREMENT

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Abstract: This paper deals with comparison of three methods used to measure low level DC voltage. It is about Reference Step Method, potentiometric method and direct method. Measurement was held in cooperation with the Czech metrology institute. Comparison of the methods consist of a graphic comparison and a key comparison. Results showed good agreement of all methods except for potentiometric method at one range of a device under test.

Keywords: DC voltage, Reference Step Method, potentiometric method, uncertainty

1. INTRODUCTION

Reference step method, potentiometric method and direct method are three methods which can be used to measure low level DC voltage. Reference step method evaluates gains of ranges of a calibrator and uses only commonly available instruments. Potentiometric method is based on a potentiometer Measurement International 8000A which divides the voltage of a Zener reference. Direct method used a voltmeter which is calibrated by Josephson Voltage Standard.

All methods were used to calibrate a device under test Fluke 5720A. Measurement by each method was repeated several times. Measured data were corrected and the uncertainties were evaluated. The graphs for comparison were created and the key comparison were evaluated.

2. METHODS USED TO LOW LEVEL DC VOLTAGE MEASUREMENT

Direct method is based on the use of a voltmeter and a calibrator as a device under test (DUT). Voltmeter measures the absolute value of the DUT. During comparison the voltmeter was Keithley 2182A and the tested calibrator was Fluke 5720A. Before measurement the voltmeter was calibrated by Josephson Voltage Standard. The Josephson Voltage Standard is described in detail in [1].

After calibration the gain of voltmeter Keithley 2182A was evaluated. Then the errors of Keithley 2182A were calculated and the data measured by Keithley 2182A were corrected. The standard expanded uncertainty was evaluated according GUM for all measured values. Ten measured data were used for type A evaluation of uncertainty.

Reference Step Method (RSM) was developed by L. A. Christian at New Zealand [2]. The method evaluates gains of ranges of device under test. The main advantage of RSM is that it uses commonly available instruments. Basic prerequisite is very good linearity of the voltmeter.

Principle of the method consists in measurement the ratio of gains of different ranges of device under test. RSM uses two calibrators and a voltmeter. The first calibrator is a source of reference voltage and the second calibrator represents DUT. The voltmeter is used for measurement the difference between two calibrators. The connection arrangement is shown in **Figure 1**. The device under test was calibrator Fluke 5720A, the reference calibrator was a Datron 4808 and voltmeter was a HP 3458A.

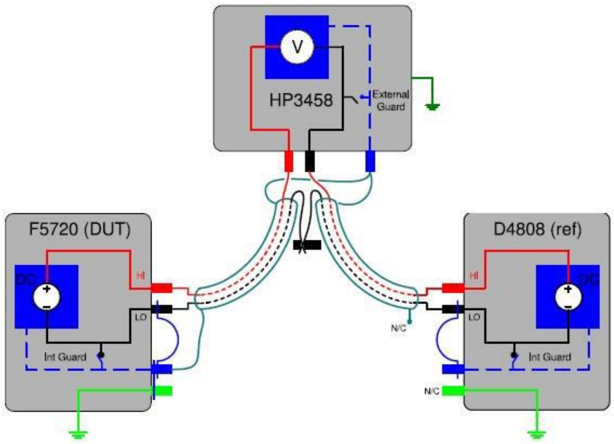

Figure 1: Connection arrangement for Reference Step Method [2]

At the end of whole measurement other method was used to calibrate one range of DUT. During comparison it was the precision Zener reference which measures absolute values of one range of the DUT. Then the absolute values of voltage for all ranges of DUT were calculated. The uncertainties were evaluated by Monte Carlo method which was used because of complicated evaluation uncertainties according GUM. Matlab was used for evaluation uncertainties by Monte Carlo method. RSM is fully automated, but it is time consuming. The RSM is described in detail in [2].

The last method is potentiometric method. This method is based on using the potentiometer Measurement International 8000A [3]. The potentiometer divides the voltage of a Zener reference, which is calibrated by Josephson Voltage Standard. The voltmeter measures difference between divided value of the Zener reference and the DUT. The circuit arrangement is displayed in **Figure 2**. The Zener reference used during comparison was Fluke 732A, the voltmeter was Keithley 2182A and the DUT was Fluke 5720A.

The measurement is fully automated. The uncertainties were evaluated according GUM by potentiometer software because of the large amount of variables. Ten measured data were used for type A evaluation of uncertainty. The potentiometric method is described in detail in [3].

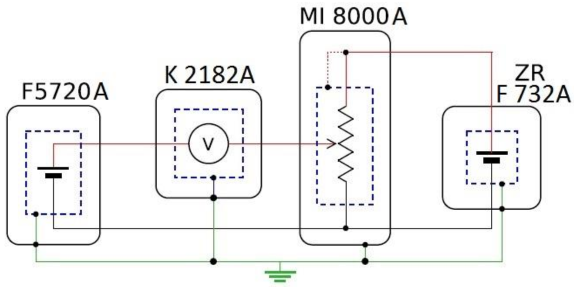

Figure 2: Circuit arrangement for the potentiometric method [2]

3. COMPARISON

Comparison was made for two ranges of the calibrator Fluke 5720A. Calibration points were selected from 1mV to 10mV for both polarities at range 220mV. Calibration points were from 3V to 10V for both polarities at range 11V. The device under test was measured three times by direct method, four times by RSM and twice or three times by potentiometric method. The reason for the difference in the number of measurement by each method was organization of work at CMI. All measurements lasted about 6 days (140 hours). During this 6 days were alternated methods due to the avability of devices at CMI. It was not necessary to deal with drift of the calibrator Fluke 5720A because of its very good stability. [5]

The first part of comparison was a graphic comparison. Graphs show differences between absolute values of measured voltage and nominal values of voltage including expanded uncertainty. The x-axis labels give time in hours when the measurement was made. Uncertainties were evaluated for a level of confidence of 95.45 % for every calibration point. The second part of comparison was the key comparison which is described in detail in [6].

4. ACHIEVED RESULTS

All methods are in good agreement at range 11 V of the calibrator Fluke 5720A for each calibration point and both polarities. It is displayed in Figure 3. Data measured by direct method are very different, which is shown in Figure 4. These different values are in good agreement with other methods because of the larger uncertainty of direct method. The larger uncertainty is consisting especially of the uncertainty calculated from specification of the voltmeter Keithley 2182A. The uncertainty of Keithley 2182A depends on the measured value. Voltmeter Keithley 2182A is better for measurement of voltage lower than 1 V because of the stable gain. It will be better to use for instance Fluke 8508A instead of Keithley 2182A for voltages higher than 1 V.

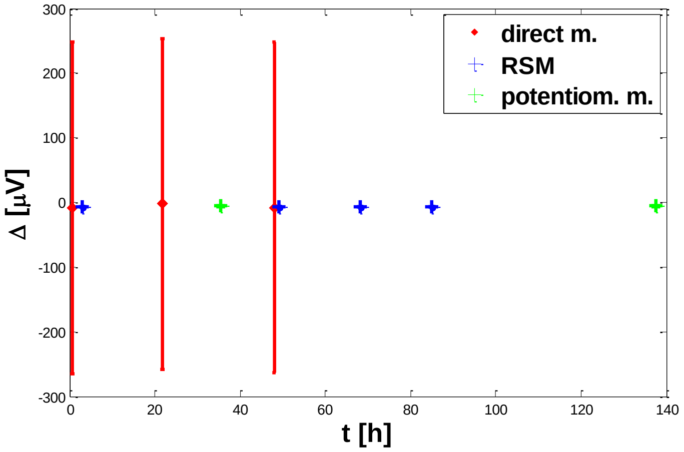

Figure 3: Difference Δ between absolute value of measured voltage and nominal voltage 4 V, uncertainties are at level of confidence of 95.45 %

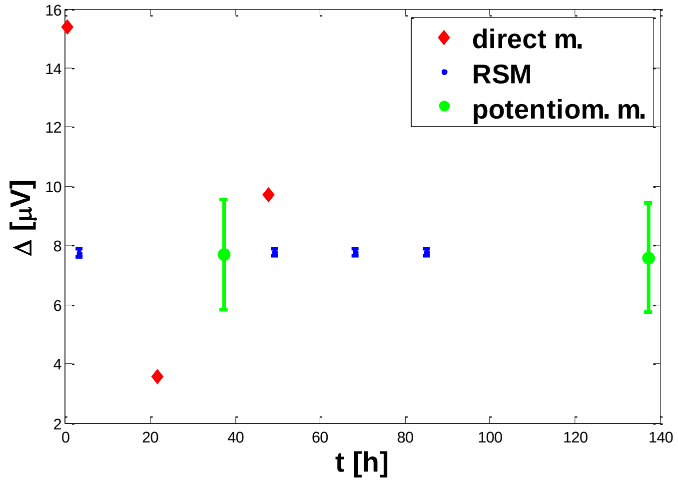

Figure 4: Difference Δ between absolute value of measured voltage and nominal voltage -9 V, uncertainties are at level of confidence of 95.45 %, the differences of direct method are displayed without uncertainties

RSM and direct method are in good agreement at range 220 mV of the calibrator Fluke 5720A. Data measured by potentiometric method are different from other methods for nominal voltage lower than 10 mV. Potentiometric method is in good agreement only with direct method (Figure 5) except for three measured points (1 mV, 2 mV, 3 mV). Figure 6 shows that potentiometric method is not in good agreement with other methods for nominal value 2 mV. The difference between data measured by potentiometric method and RSM is approximately 35 ppm for nominal value 10 mV and approximately 400 ppm for nominal value 1 mV. It can be deduced that potentiometric method is more different from other methods with decreasing voltage. Therefore, it was measured voltage for nominal value 50 μV. Difference between direct method and potentiometric method was approximately 800 ppm. Consequently, difference between potentiometric method and other methods increase with decreasing voltage.

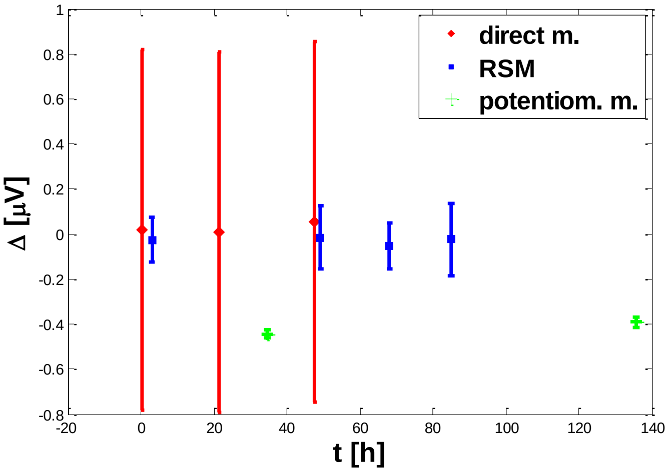

Figure 5: Difference *Δ* between absolute value of measured voltage and nominal voltage 9 mV, uncertainties are at level of confidence of 95.45 %

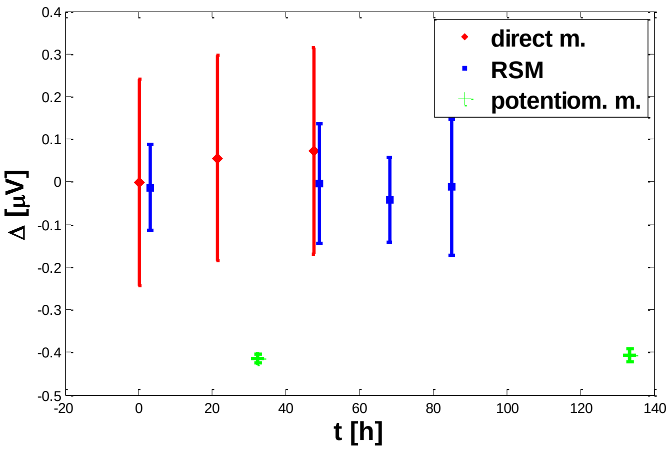

Figure 6: Difference *Δ* between absolute value of measured voltage and nominal voltage 2 mV, uncertainties are at level of confidence of 95.45 %

The uncertainties of potentiometric method are very small for measured points smaller than 10 mV. It is the second reason why potentiometric method is not in good agreement with other methods. The uncertainties of potentiometric method were evaluated by potentiometer software. When the potentiometer measures small value it uses larger dividing ratio so its uncertainty should be larger. Therefore, it was found that potentiometer software do not evaluate the uncertainty correctly.

The second part of comparison was Procedure A of the key comparison for both ranges of the calibrator Fluke 5720A. The most accurate method at range 11 V of Fluke 5720A was the Reference Step method. At range 220 mV of Fluke 5720A it was evaluated that potentiometric method is the most accurate method but this result was not correct. The reason was the very low uncertainty of the potentiometric method. Therefore, the potentiometric method was eliminated from the key comparison. Then the most accurate method was the direct method at range 220 mV of the calibrator Fluke 5720A.

5. CONCLUSION

The results of the comparison showed that all methods are in good agreement at range 11 V of the calibrator Fluke 5720A. Data measured by voltmeter Keithley 2182A are very different but it corresponds to greater uncertainty of direct method.

Direct method and RSM are in good agreement at range 220 mV of the calibrator Fluke 5720A. Potentiometric method is in good agreement only with direct method. For calibration point 1 mV, 2 mV and 3 mV potentiometric method is not in good agreement with both other methods. It was deduced that difference between potentiometric method and other methods increase with decreasing voltage. It was found that potentiometer software do not evaluate the uncertainty correctly. Therefore, it should be corrected the errors in software.

According to the key comparison the most accurate method at range 11 V of the calibrator Fluke 5720A was the Reference Step method. The direct method was the most accurate method at range 220 mV of calibrator Fluke 5720A.

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