BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Application of measurement standards in different conditions
Description	Determination of Temperature Coefficients in Zener Diode Based DC Voltage Standards
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Motivation & Introduction

The groups of Weston Standard Cells are maintained in NMCI to establish representations of the volt. Since Weston Standard Cells are highly stable over the time, they have disadvantages like intolerance to any current drain, sensitivity to vibration and external temperature deviations. The zener diode based DC voltage standards which reasonably overcome these disadvantages are used as a DC voltage standard in the voltage groups instead of Weston Standard Cells. In NMCI, it is planned to replace the Weston Standard Cells with Fluke 732B DC Standards which are based on Zener diode.

Nevertheless, the output of Zener diode based DC voltage standard drifts with time and is also affected by environmental conditions like ambient temperature, relative humidity and pressure. Therefore it is necessary to construct a mathematical model to predict its output voltage at any given time and under given environmental conditions. The temperature coefficient of the Voltage Standard is one of the main parameter in the mathematical model.

The main objective of this project is to determine temperature coefficient of a Zener based DC voltage standard. Also it is planned to get knowledge about calibration and uncertainty budget of DC Voltage Standard, establishing traceability chains for DC voltage, AC voltage, DC impedance, AC impedance, and resistance for NMCI and the requirement of a management system to comply with ISO/IEC 17025 “General requirements for the competence of testing and calibration laboratories” for a national metrology institute.

In the project, DC voltage standard calibrations were performed at 10 V and 1.018 V levels. In order to evaluate measurement results and its calibration uncertainty and to determine its drift with time the excel sheets were established. Considering the main objective, the temperature coefficient of a Fluke 732B DC Standard were determined. For the Fluke 732B DC standard tested, the temperature coefficients for 1.018 V and 10 V output voltages were determined by (-0.009 ± 0.041) nV/Ω and (+1.5 ± 0.38) nV/Ω respectively.

Research

The temperature coefficients for 10 V and 1.018 V output voltages of a Fluke 732B DC standard were determined within the project. The resistance of the thermistor of Fluke 732Bs is used as an indicator for the temperature of the internal Zener diode in the Fluke 732B. So, the temperature coefficients were expressed in terms of thermistor resistance of the standard.

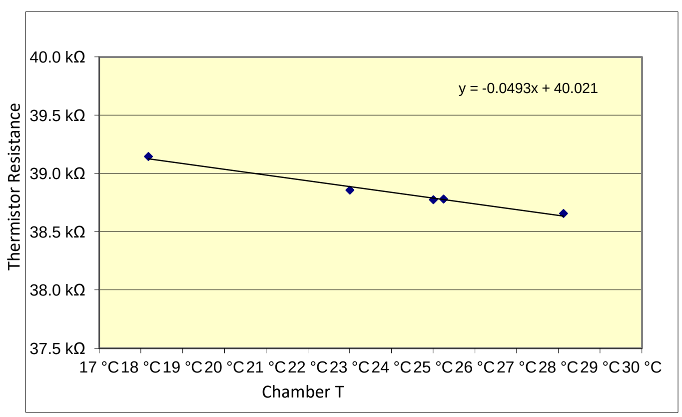
The output voltages of tested Fluke 732B were measured by the comparison with a reference Fluke 732B. The standards were powered by AC line power (220 V, 50 Hz) during the measurements. Drift with time of reference 732 is known and corrected. A Keithley 2182A Nanovoltmeter was used to measure voltage differences between the test and reference 732Bs.

The temperature of the internal Zener diode in the Fluke 732B was monitored with its internal thermistor which is around 39 kΩ. The DMM used to measure the internal thermistor resistor was a HP 3458A DMM. A 9 pin D-Sub male connector was used for the measurement of internal thermistor resistance. The DMM was used in 1 MΩ range in order to keep measuring current less than 10 µA to avoid heating up the thermistor.

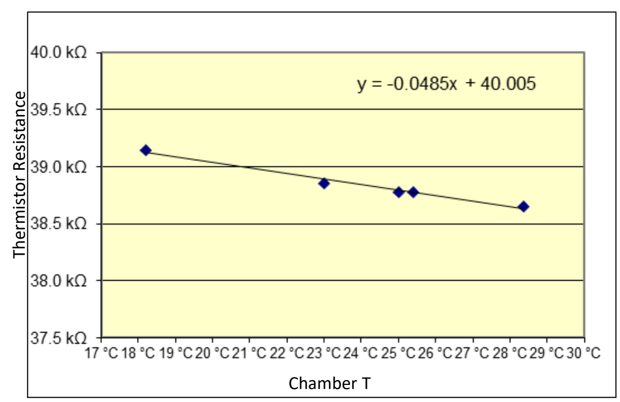
The ambient temperature in the temperature chamber was measured using a Relative Humidity and Temperature Meter throughout the measurements.

A temperature chamber has been set up to change the temperature at (23 ± 5) °C. Humidity inside the chamber was maintained at a constant level, 45%rh.The Fluke 732B was placed in an enclosure in which the temperature is varied in a step-wise fashion and held on a constant-temperature approximately 5 hours for thermal equilibrium to be established. Then the output voltages were compared to the corresponding output of the reference Fluke 732B.

Figure 1 shows the thermistor resistance changes of tested Fluke 732B and corresponding to the chamber temperatures for 1.018 V and 10 V.



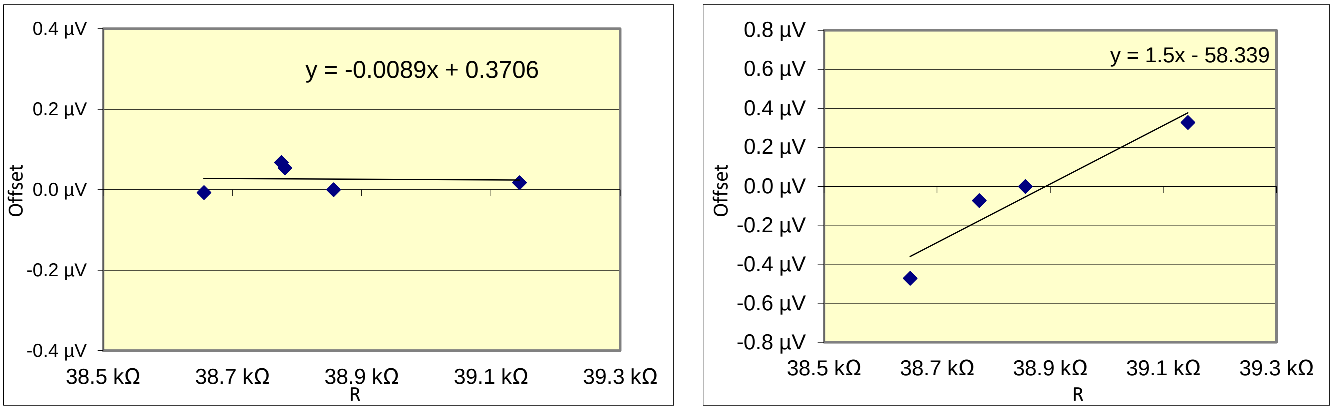
(a) 1.018 V



(b) 10 V

Fig. 1. Thermistor resistance of DC voltage standard versus different temperatures for 1.018 V and 10 V output voltages. The thermistor resistance changes with temperature linearly in the first-order approximation.

A mean difference between the measurements at another temperature and the predicted output voltage was then calculated in Fig. 2. The temperature 23 °C was used as the base temperature to monitor the drift of output voltages. In the Table 1, determined the temperature coefficients for 10 V and 1.018 V output voltages of the test 732B are given.



(a) 1.018 V

(b) 10 V

Fig. 2. Linear least sum of squares fit of thermistor resistor (R) versus offset of DC voltage standard from the reference point corresponding to the environmental temperature of 23 °C.

Table 1. Temperature coefficients

Output	Temperature Coefficient	Uncertainty
1.018 V	-0.009 nV/Ω	0.041 nV/Ω
10 V	1.5 nV/Ω	0.38 nV/Ω

We have characterized temperature coefficients for 1.018 V and 10 V output voltages of a Fluke 732B DC standard. The ambient temperature effect on the standard can be corrected using the determined temperature coefficients, but the uncertainties of the temperature coefficient measurements should be counted as contributions to the uncertainty budget.

Conclusions and Future Work

The DC voltage standard we studied has small but statistically significant temperature coefficient but the variations of output voltages are nevertheless within the manufacturer's specifications. Temperature effects can cause errors and unstable output voltages in different temperatures. Improved accuracy of comparison measurement can be achieved by measuring temperature coefficients and applying corrections based on the resistance of the internal thermistor. For future research researchers can work on characterization of Zener standards for pressure and humidity for improving the uncertainty of a measurement.

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