BIPM Capacity Building & Knowledge Transfer Programme

2021 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Evaluation of the DC reference Voltage standard Fluke 732B behavior under controlled ambient condition.
Description	This project aims to investigate the behavior of the DC reference voltage standard Fluke 732B with simulating different ambient conditions by varying temperature from 18 °C, to 28 °C at constant based relative humidity 45 %. Then varying relative humidity from 20 % to 70 % at constant based temperature 23 °C. We used a Test cabinet TK 600 to control temperature and humidity, DMM HP 3458A to measure resistance of oven thermistor and Programmable Josephson Voltage Standard UME-PJVS to measure voltage output at 10 V.
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Motivation & Introduction

Laboratory *DEFNAT* dispose of a Josephson Voltage Standard supraVOLTcontrol system developed by Supracon able to calibrate a secondary voltage standard such as Fluke 732B with high accuracy less than 100 nV at 10 V output. The 732B is highly stable at 10V output and can be used as a direct link in the traceability chain to national standards with lower uncertainty, it can be used also in inter-laboratory comparison to check the degree of equivalence between participant laboratories and therefore have the possibility to claim DC Voltage CMCs in KCDB according to the requirement of CIPM-MRA. However, DC voltage references are affected by the variation of environmental ambient conditions notably temperature, relative humidity and pressure, therefore the uncertainty of measurement may be affected accordingly.

In fact *DEFNAT* took part in 2016 in a key comparison “BIPM.EM-K11.a and b”, the result was satisfactory ($U_{DEFNAT} - U_{BIPM} = +\,0.38\ \mu V$; $u_c = 0.10\ \mu V$, at 10 V). The Published CMC in KCDB for calibration of solid state voltage standard was claimed to 500 nV at 10 V output, whereas the effect of the temperature noise was the largest component in the uncertainty budget. The main issue that Fluke has provided a temperature coefficient (α_T) of DC voltage reference 732B at 10V Output: $\alpha_T \leq 0.04$ ppm/°C, This temperature coefficient α_T is penalizing the calibration uncertainty. Therefore quantifying the hysteresis coming from variation of ambient condition is highly recommended within voltage laboratories to improve the uncertainty of measurement for solid state voltage standard calibration. Tubitak-UME dispose of high performance measurement systems within Voltage Laboratory could help us to lead our technical research in good manner.

The aim of this project is to investigate the behavior of the DC Reference Voltage Standard Fluke 732B with simulating different ambient conditions mainly (Temperature and relative humidity) within the limit of its range of operation.

The main objective of this project is to determine:

- Temperature coefficient of the Fluke 732B's thermistor resistance,
- Temperature coefficient of the Fluke 732B at 10 V output,
- Temperature correlation function between the thermistor resistance and the voltage output at 10 V, and
- Humidity coefficient of the Fluke 732B at 10 V output.

In this project, two Zener Fluke 732B S/N 5610310 and S/N 5610410 were measured during the whole phases powered by their internal batteries. These Zener were installed inside a test Cabinet to simulate different temperature ± 5°C around based temperature 23 °C at constant humidity 45% rh, and then varying humidity to ±25% around based relative humidity 45%. The thermistor's resistance was measured by a calibrated DMM HP 3458A, and the 10 V output was measured against UME-PJVS.

The result obtained was assumed to be the average value of a series of measurement of each entity:

- Temperature coefficient of thermistor resistance is (-45 Ω/°C ± 2 Ω/°C) ,
- Temperature coefficient of Zener (S/N 5610410) is α_T = (20,8 nV/°C ± 193 nV/°C)
- Temperature coefficient of Zener (S/N 5610310) is α_T = (11,7 nV/°C ± 165 nV/°C)
- Correlation function of Zener (S/N 5610410) is α_R = (-0,68 nV/Ω ± 0,16 nV/Ω) at 10 V,
- Correlation function of Zener (S/N 5610310) is α_R = (0,48 nV/Ω ± 0,14 nV/Ω) at 10 V,
- Humidity coefficient is α_H = (-0,015 µV/%rh±0,154 µV/%rh)

Research

The measurement process was performed with a direct measurement method, first to determine the thermistor resistance of the Zener Fluke 732B via a calibrated DMM, then to determine its voltage output at 10 V via a PJVS at given simulated temperature and humidity. The corrections and measurement uncertainty was considered in the base ambient condition (23±1)°C and (45±15)% rh.

Equipment used in the measurement process:

- DC Reference Voltage Standard Fluke 732B,
- Programmable Josephson Voltage Standard UME-PJVS
- Calibrated DMM HP 3458A
- Test Cabinet Nuve TK 600
- Calibrated Relative Humidity and temperature meter made in UME.

We used also a 40 cm low thermal effect cable soldered to a 9 pins D-Sub male connector (pin 4 and 8) to monitor the resistance of the Fluke 732B oven thermistor resistance. The cable was connected to a heavy copper adapter to perform measurement in 4 wires configuration.

Measurement process:

Phase 1:

Measurement was executed automatically via LabView program developed by UME, so both DMM 3458A and test cabinet were controlled automatically by GPIB cables.

The Zener Fluke732B was unplugged from AC power 1 hour before starting measurement.

DMM 3458A was auto calibrated and set to OHMF, Range 100 kΩ, NPLC 20.

The test cabinet was programmed to maintain a constant level of relative humidity 45% and a cycle of temperature variation (18 °C, 23 °C, 28 °C, 23 °c and 18 °C).

The measurement of the oven thermistor resistance was performed continuously during 20 hours for a cycle of 4 hours for each temperature with a pace of 1 acquisition per minute see Fig1.

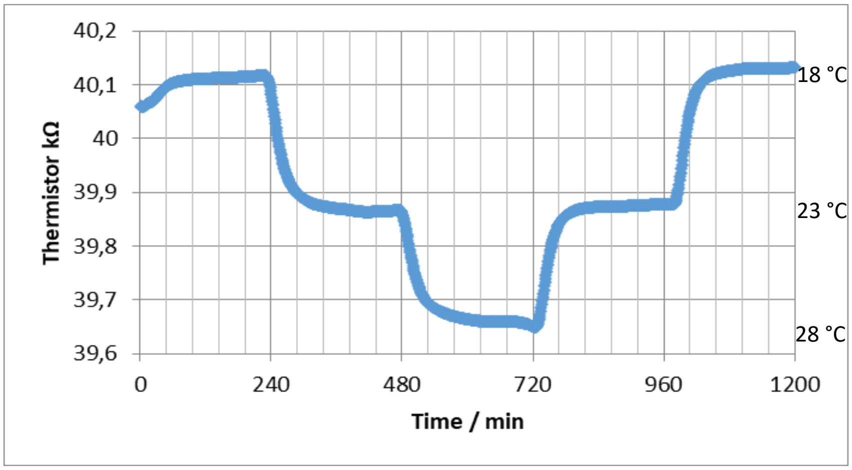

Fig 1: Behavior of thermistor resistance in variable temperature of 5 °C up and down from 23°C

The behavior of the thermistor resistance was evaluated in either way, in ascendant temperature and descendant temperature, we assumed to retain the value of the largest variation with taking into account the difference of variation between ascendant and descendant temperature as a component of uncertainty due to reversibility Fig 2.

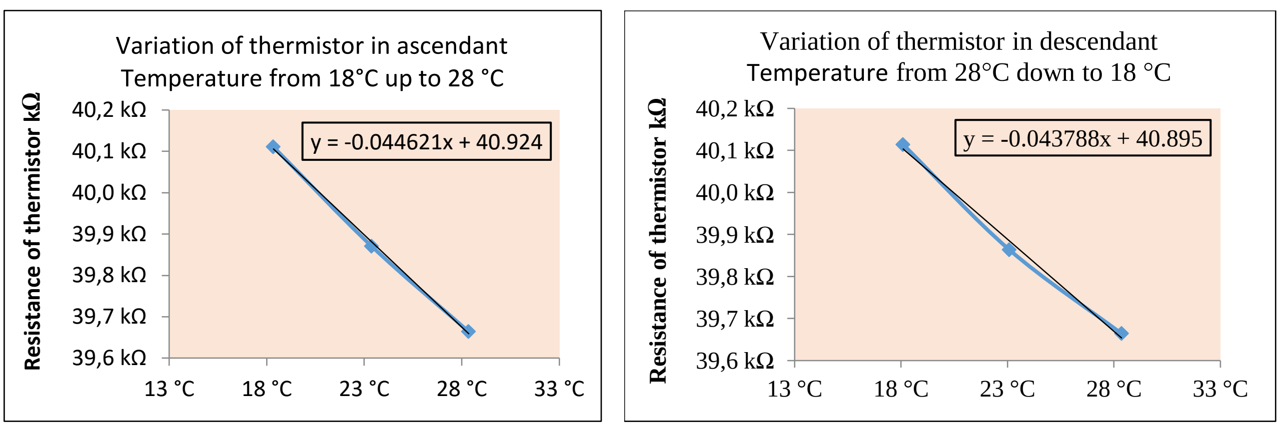

Fig 2.Thermistor resistance of DC voltage standard versus different temperatures for 10 V output voltages. The thermistor resistance changes with temperature linearly in the first-order approximation.

Phase 2:

Measurement of two Zener 732B against Programmable Josephson Voltage Standard UME-PJVS with variation of temperature (18 °C, 23 °C and 28 °C) up and down at constant level of relative humidity 45%. The Zeners were unplugged from AC power and put inside the test Cabinet one hours prior performing measurement, in each level of temperature Zener were given one hour for environment condition stabilization.

A series of measurement was performed and repeated successively to determine the temperature coefficient of voltage output at 10 V at constant humidity 45% Fig 3.

Fluke 732B (S/N:5610410)			
Date	Temperature Coeffcient α_T		
24.09.2021	52,0 nV/°C	±	119 nV/°C
23.09.2021	-16,7 nV/°C	±	449 nV/°C
21.09.2021	65,9 nV/°C	±	191 nV/°C
16.09.2021	-17,8 nV/°C	±	13 nV/°C

Fluke 732B (S/N:5610310)			
Date	Temperature Coeffcient α_T		
24.09.2021	-0,9 nV/°C	±	3 nV/°C
23.09.2021	33,6 nV/°C	±	284 nV/°C
21.09.2021	13,9 nV/°C	±	291 nV/°C
17.09.2021	0,1 nV/°C	±	81 nV/°C

Fig 3. Temperatures coefficients $\boldsymbol{\alpha_T}$

A mean difference between the measurements at another temperature and the predicted output voltage was then calculated in Fig. 4. The temperature 23 °C was used as the base temperature to monitor the drift of output voltages.

Fluke 732B (S/N:5610410)			
Date	Temperature Coeffcient α_R		
24.09.2021	-1,18 nV/Ω	±	0,08 nV/Ω
23.09.2021	0,29 nV/Ω	±	0,37 nV/Ω
22.09.2021	-1,43 nV/Ω	±	0,18 nV/Ω
16.09.2021	-0,39 nV/Ω	±	0,02 nV/Ω

Fluke 732B (S/N:5610310)			
Date	Temperature Coeffcient α_R		
24.09.2021	-0,04 nV/Ω	±	0,00 nV/Ω
23.09.2021	1,32 nV/Ω	±	0,24 nV/Ω
22.09.2021	0,59 nV/Ω	±	0,24 nV/Ω
17.09.2021	0,05 nV/Ω	±	0,06 nV/Ω

Fig 4. 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.

The temperature coefficients $\boldsymbol{\alpha_T}$ retained:

Fluke 732B (S/N:5610410)	20,8 nV/°C	±	193 nV/°C
Fluke 732B (S/N:5610310)	11,7 nV/°C	±	165 nV/°C

Temperature correlation coefficients $\boldsymbol{\alpha_R}$ retained:

Fluke 732B (S/N:5610410)	-0,68 nV/Ω	±	0,16 nV/Ω
Fluke 732B (S/N:5610310)	0,48 nV/Ω	±	0,14 nV/Ω

Phase 3:

Measurement of two Zener 732B against Programmable Josephson Voltage Standard UME-PJVS with variation of relative humidity (20%, 45% and 70%) up and down at constant level of temperature 23°C . The Zeners were unplugged from AC power and put inside the test Cabinet one hours prior performing measurement, in each level of humidity Zener were given one hour for environment condition stabilization.

Only one cycle of measurement was performed to investigate the behavior of Fluke 732B against humidity variation. That was not enough to give us clear idea of the humidity impact on voltage output at 10 V. Fig 5.

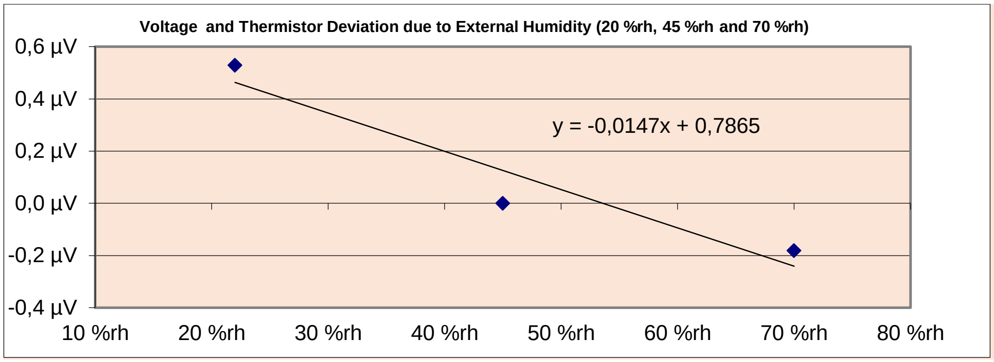

Fig 5. Impact of relative humidity variation on 10 V

The humidity coefficient obtained won't be taken into consideration due to the short period allocated to investigate this parameter. Therefore it is concluded to consider negligible the effect of humidity on Fluke 732B, however, it is recommended in the future to allocate longer period and longer phases for each level of humidity to determine accurately its coefficient.

Conclusions and Future Work

The impact of temperature and humidity variations on DC Reference Voltage Standard 732B was investigated in Tubitak-UME Voltage Laboratory with high performance equipment, the results obtained from this study were compatible compared to those provided by manufacture.

Temperature coefficients of the DC Reference Voltage Standard measured in different days are different while their results are overlapping within the uncertainty of the coefficient. The uncertainty of the coefficient (correlation between voltage and temperature) are smaller than the manufacturer's declaration, 0.40 µV/°C. Some of the coefficients and their corresponding uncertainties are much smaller. These results promise better temperature coefficient than the manufacturer's declaration. We tried to measure voltage output of Fluke 732B against PJVS simultaneously while measuring its thermistor resistance using HP 3458A. This might affected considerably the stability of measurement, it was concluded to measure the thermistor resistance before and after the calibration of the Zener against PJVS. The time of the research was too short to repeat the measurement for this case.

Also the other important thing concluded that Zeners should be unplugged from AC power during the measurement of thermistor resistance. Concerning humidity impact on the Zener Fluke 732B will be considered as negligible and will need to be performed in extended period.

This study will help us to improve the uncertainty of measurement of Zener calibration and assuring DCV traceability chain with better accuracy.

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