CHARACTERIZATION OF A LOW THERMAL SCANNER FOR AUTOMATIC VOLTAGE MEASUREMENT WITH THE NIST JOSEPHSON VOLTAGE STANDARD*

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Abstract - *In order to increase the capacity of the NIST 10V Josephson Voltage Standard (JVS) system used for the automatic calibration of Zener reference standards from the present 32 channels, a 64 channel low thermal scanner was procured. In the NIST JVS system, the scanner output lines are cross-connected to cancel the thermal emf of the scanner channels. The new scanner has been fully characterized in this mode to simulate the same measurement condition used in the "NISTVolt" software that performs the automatic calibration of Zener standards. The results of this characterization show that thermal emfs of the scanner channels are well within the required 50 nV. The 64 channel scanner was installed in the NIST 10 V Josephson Voltage Standard system and used to calibrate Zener standards. The control chart of a typical Zener calibration using the 64 channel scanner and the previous 32 channel scanner show that the data taken over several months follows the same trend line. The 64 channel scanner is taken to be verified and working satisfactorily.*

Keywords: Calibration, Josephson Voltage Standard, low thermal scanner, Zener reference standard.

1. INTRODUCTION

Low thermal scanners and switches are used for scanning a number of instruments without physically changing their connections or for changing the polarity of a device under test (DUT). Initially, these switches were manually operated. The widespread use of computers to automate measurements has led to the development of low thermal switches and scanners that are remotely controlled through the IEEE-488 interface.

Recently, NIST has procured a 64 channel 640B Data Proof† low thermal scanner to increase the capacity of the JVS system that performs the automatic calibration of Zener reference standards. The 640B has two 32 channel 320B scanners that are housed in a common enclosure and whose outputs are physically connected in parallel. The 640B has a single IEEE-488 interface that can address the two 320B scanners individually.

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† Commercial equipment and materials are identified in order to adequately specify certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

The characterization of the 640B scanner will be described and the results reported.

2. 640B SCANNER CONFIGURATION

The 640B scanner can be configured for four measurement modes. We will be discussing only the configuration (Fig. 1) that is used for the Josephson Voltage Standard system, where the scanner output lines are cross-connected. For the thermal emf measurement of a scanner channel, the scanner channel input is shorted through a short copper wire.

When one of the 32 channel scanners in the 640B scanner is switched to output line A, the output voltage's polarity is positive. When the same 32 channel scanner is switched to output line B, the output voltage's polarity is negative. The resultant output voltage (output line A voltage minus output line B voltage) is the average of the two output voltages. The scanner channel thermal emfs are cancelled or compensated for when the same scanner channel is activated for output lines A and B. The measured voltage is the residual thermal and noise from the selected scanner channel and the measurement system. This scanner configuration mode is designed for the "NISTVolt" software[‡], which is used for the JVS automatic Zener calibration system. This configuration does not require a separate determination of the zero offset of the system digital voltmeter (DVM). The "NISTVolt" software switches the scanner using a + – + – sequence to minimize the thermal emfs and DVM offsets.

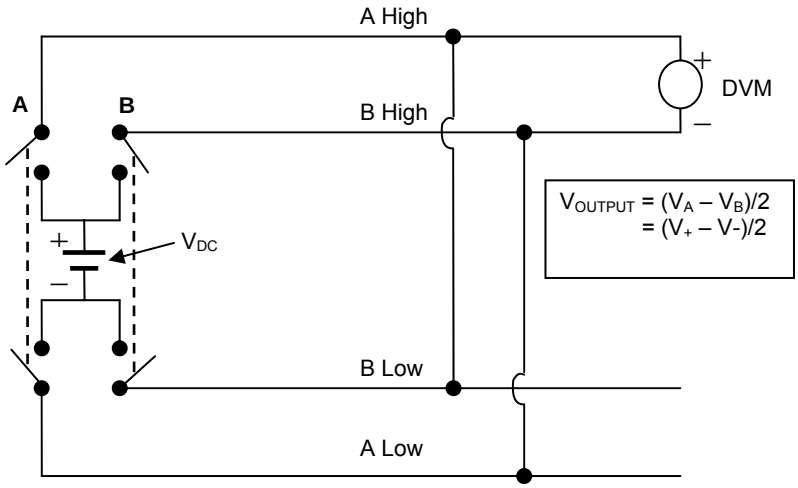

Fig. 1 Operation of scanner with cross-connected scanner output lines.

3. THERMAL EMF MEASUREMENTS

An Agilent 34420A DVM and a computer, running a QBasic software program, were used to automate the thermal emf measurements. The measurement setup is shown in Fig. 2.

[‡] NISTVolt (Windows) was created in a joint project between the National Institute of Standards and Technology, USA, and the U.S. Army Primary Standards Laboratory at Redstone Arsenal, AL, and Sandia National Laboratories, Albuquerque, NM. It is available without charge to users of Josephson Voltage Standards.

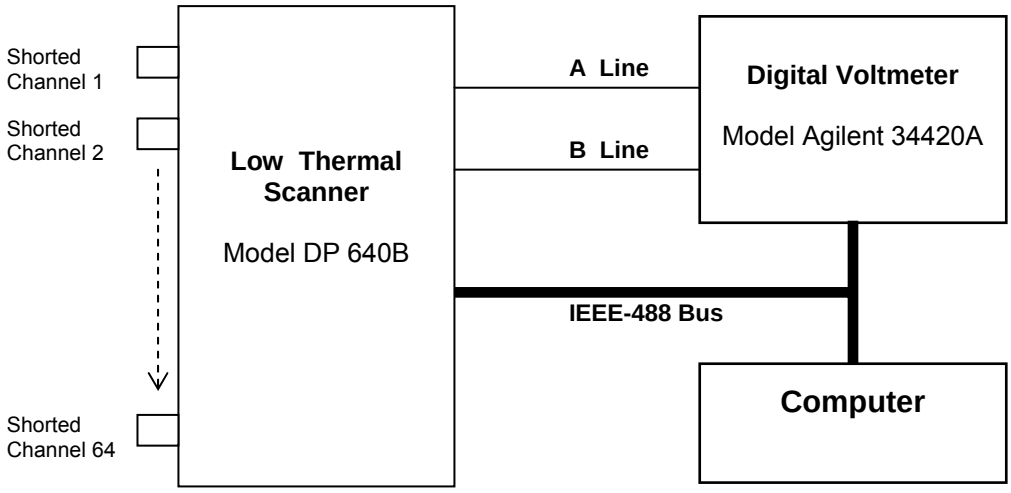

Fig. 2 Thermal emf measurement setup for the 640B Low Thermal Scanner

The DVM was configured for the 1 mV range and 10 power line cycles (PLC). The DVM's channel 1 output lines were connected to the scanner's output lines. A single scanner channel measurement point was the average of ten DVM readings. Ten single measurement points were then used to calculate an average emf and standard deviation. Ten average emfs and standard deviations were used for the calculation of a scanner channel thermal emf and standard deviation. This protocol was repeated using the sequence + – + –, producing 40 measurements. The reported scanner channel thermal emf was the average of the 40 measurements. The plot in Fig. 3, indicates that all of the scanner channels, except for channel number 60, have thermal emfs that are within 30 nV. This is sufficient for Zener calibrations, since the calibration uncertainty is dominated by the noise of the Zener standard and its non-linear drift.

4. ZENER CALIBRATION PERFORMANCE USING THE JVS AND THE 640B SCANNER

After characterization of the 640B scanner, its performance was also verified using the NIST 10 V Josephson Voltage Standard system [1]. All of the scanner channel inputs were shorted with short copper wires. The "NISTVolt" software was used to measure the thermal emfs. To avoid the RF induced offset in the measurements, the microwave was completely blocked by an attenuator. This forced the Josephson array to a zero step. The data from these measurements were consistent with the data previously obtained with the setup shown in Fig. 1.

Preparation of the 640B scanner for Zener calibrations involved the construction of 64 pairs of low thermal cables. The cables were verified by connecting one end of each cable to a scanner input channel input and shorting the other end. The residual thermal emf contribution from the measurement system (bias controller, DVM, cryoprobe, and scanner) and noise was less than 50 nV, proving the model 640B's suitability for use in the NIST 10V JVS system. The model 640B scanner was installed in the JVS system and Zener calibrations were performed over several months. Fig. 4 shows the control chart of a typical Zener reference calibration using the 640B scanner and a 320B scanner. The Zener calibration uncertainty was calculated by the "NISTVolt" software as per ISO guidelines [2, 3]. We can conclude from the control chart that the data trend for a Zener reference calibration is consistent. This validates the satisfactory performance of the 640B scanner.

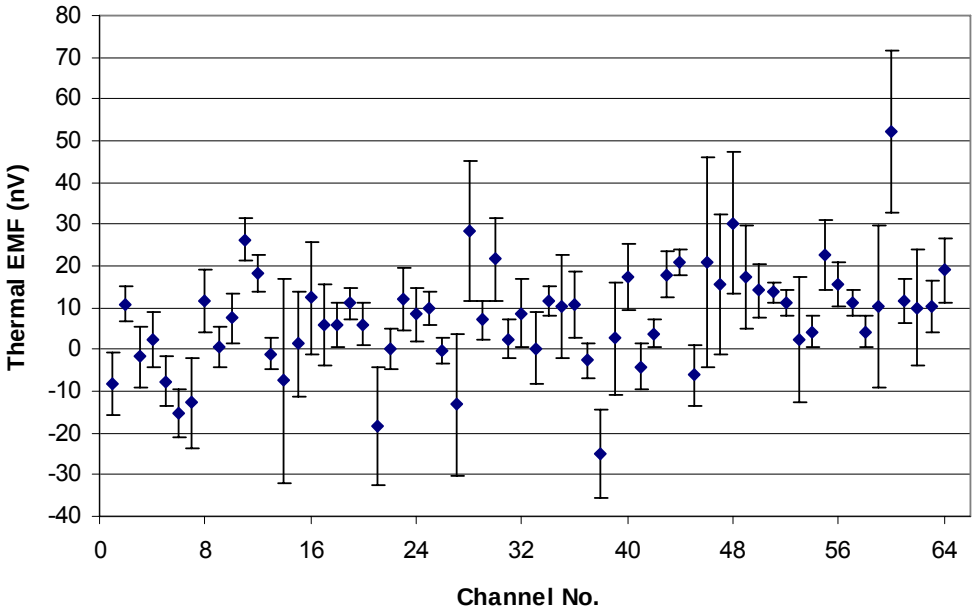

Fig. 3 Thermal emfs of the individual channels of the 640B low thermal scanner (all the error bars are at 1 standard deviation)

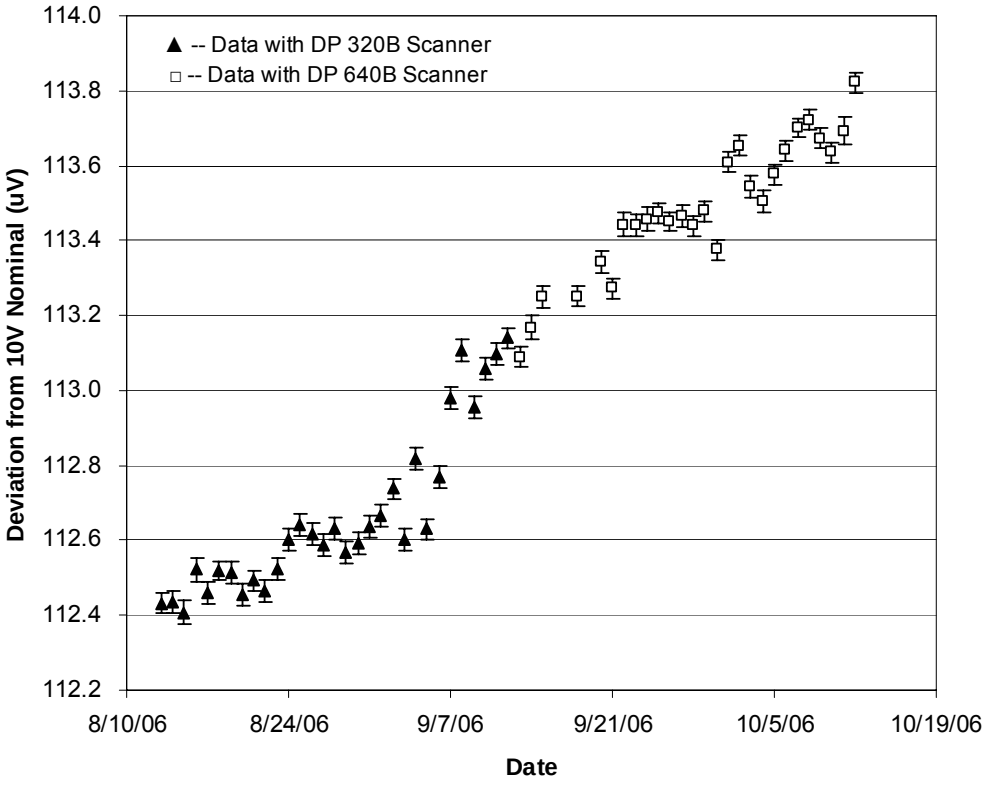

Fig. 4 Control chart of a typical Zener reference calibration

5. CONCLUSION

The results of the characterization of the 640B low thermal scanner indicated that the thermal emfs of all the channels, except for channel number 60, are within the required 50 nV. When all of the 640B scanner channel inputs were connected to low thermal cables (for Zener calibrations) and the cable ends shorted, the residual thermal emfs and noise contribution of the measurement system (low thermal cables, 640B scanner, DVM, cryoprobe circuit and JVS 1000 controller) were within 50 nV. The 640B scanner was installed in the NIST 10V JVS system and used to perform Zener calibrations. The control chart of a typical Zener reference calibration, using the 640B low thermal scanner, verifies it is operating satisfactorily.

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