VOLTAGE RATIO MEASUREMENTS OF A ZENER REFERENCE USING A DIGITAL VOLTMETER

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Abstract

A high precision digital voltmeter can be used to measure the ratio of 1 V to 10 V very accurately. Preliminary tests of calibrating 10-V Zener references from a 1-V Josephson array standard indicate that an accuracy with an uncertainty of several parts in 10^8 is possible.

Introduction

There is currently a transition from 1.018 V Weston cells to 10-V Zener reference standards taking place in the metrology community. To avoid the situation of maintaining or transferring two representations of the volt, one at 1.018 V and another at 10 V, there is an increasing need to measure 1:10 V ratios accurately. Josephson array voltage standards are becoming more commonplace, but the availability of 10-V Josephson arrays may be irregular for some time. Therefore a method of stepping up to the 10-V level would be especially advantageous to 1-V array users. Procedures relying on resistive dividers can be fairly accurate, but have a large number of uncertainty components [1-2]. High precision digital voltmeters (DVMs) have recently been introduced, which have extremely good linearity specifications. This linearity may also be stable for long periods of time. Thus, DVMs may provide both a cost and time effective solution for 1:10 V ratio requirements. Toward this end, we investigated the accuracy of using a 1-V array with an 8 1/2 digit voltmeter in making the transition from the 1-V level to the 10-V level of a Zener reference standard.

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Investigation Procedure

Resolution, linearity, and impedance loading are important parameters in making accurate ratio measurements on DVMs. Long term stability of any nonlinearities is essential if the DVM ratio measurements are intended for a general calibration workload. Since these parameters vary with model types, we state here that the preliminary measurements of this study used Fluke 732A DC Zener Reference Standards and a Hewlett-Packard 3458 Digital Voltmeter*. The operation of the Josephson array has been described elsewhere [3], but it is useful to note that a precision DVM is a component of most array standard systems. A 10-V array standard system obtained the 1-V and 10-V Zener reference values with an uncertainty of about 0.005 ppm, against which the DVM ratios were compared.

For this procedure, it was convenient to use the same DVM as in the array system. The DVM was fixed to the 10-V dc range for both input voltage levels. For each individual measurement polarity, six DVM readings were averaged with integration times of 100 line cycles. A single data point consisted of measuring the Zener reference over all four relative polarities of the voltmeter and reference leads to obtain an average voltage. DVM values for the 1-V value were obtained immediately after a 10-V measurement. This procedure was repeated six times each for adequate statistics, both while the reference was under line power and on battery. There was no resulting difference between either case. Measuring the thermal emfs of the connecting wires was unnecessary in this case, since the connection scheme was identical for both the ratio and the direct array measurements [4].

Results and Discussion

The key test of the technique described here is the comparison of the voltage of the 10-V Zener reference standard calculated from the ratio measurements taken with the digital voltmeter with the actual voltage determined by the Josephson array. The calculated voltage of the 10-V Zener reference is given by

$$V_{10} = \left\{ \frac{V_1\,(\text{Array})}{V_1\,(\text{DVM})} \right\} V_{10}\,(\text{DVM})\,, \qquad (1)$$

where V is the voltage. The subscripts refer to the nominal voltages of the Zener references, and the terms in parentheses refer to the instruments used to measure the voltage of the Zener reference. The term in the brackets is essentially the gain correction for the digital voltmeter.

Performing the calculation given by Eq. (1) for measurements described above yielded a deviation from 10 V nominal value for V_{10}(DVM) of -2.068 ± 0.036 ppm. When compared with the voltage measured with the 10-V Josephson array, -2.081 ± 0.006 ppm, the relative error between these two values is only 0.013 ± 0.037 ppm. For these short-term special tests, this random uncertainty is similar to the NIST 10-V calibration service [4]. Similar results, but with less precision due to fewer repeated measurements, have been obtained for several other Fluke Zener reference standards.

From the small relative error reported above, these preliminary results indicate it is indeed possible to achieve an accurate calibration of a 10-V Zener reference standard by voltage ratio techniques using a high-precision digital voltmeter, especially from 1-V Josephson array measurements. This demonstrates that linearity corrections and impedance loading of the digital voltmeter may be minimal. Additional measurements with other voltmeters and Zener references are needed in order to verify the applicability of this technique. Also, since measuring the gain of the DVM directly with the array is possible, this will be investigated as a way to indicate possible systematic errors from severe nonlinearities. Whether nonlinearities on the 1-V range are precisely the same on the 10-V range will be examined closely. It is expected that these additional measurements will yield positive results, which will allow a relatively easy and inexpensive technique for calibrating 10-V Zener reference standards to within a few parts in 10^8, especially with a 1-V Josephson array standard.

References

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