A DUAL-BALANCE HIGH-RESISTANCE BRIDGE IN THE RANGE 1 TΩ TO 100 TΩ

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Abstract

The NIST dual-balance guarded active-arm bridge, using a third dc source and a second detector to balance the guard network, is described. Improvements to the NIST guarded active-arm bridge and the design and construction of improved high resistance standards have facilitated the extension of NIST calibration services to the 10 TΩ and 100 TΩ decades of resistance.

Introduction

In recent years, much work has been done at NIST to support the re-establishment of NIST calibration services at 10 TΩ and 100 TΩ. Installation of environmental chambers [1], implementation of the active-arm bridge [2,3], and the development of new standards [4,5] have been important contributions to the process to improve and extend NIST calibration services in the high-resistance range from 10 MΩ to 100 TΩ.

At resistance levels of 1 GΩ and above, resistance standards are of the film-type. These resistors often have larger voltage coefficients (>10 x 10^{-6}/V) and large corrections from nominal (>5000 x 10^{-6}) compared to those of wire-wound standard resistors available at the 100 MΩ level and below [6]. One or a combination of both of these effects can cause a mismatch of the main and guard resistors [5], which allows leakage currents to flow between the main and guard circuits, thus making it difficult to accurately balance the guarded active-arm bridge.

There were two solutions considered to solve the problem of mismatched guard resistors. The first was to match the guard resistor to the unknown. However, this would require some preliminary measurements of the unknown to select well matched guard resistors and would be impractical for an automated calibration system. The second solution, described here, is to use a third programmable voltage source to drive the unknown side of the guard network. A second detector is needed to monitor the voltage to adjust the guard voltage until the guard circuit midpoint is at the same potential as the main circuit. Once the guard circuit is balanced, then the main circuit can be balanced.

Guarded Active-Arm Bridge

The basic configuration of the NIST guarded active-arm bridge is shown in figure 1. Programmable sources (V_1 and V_2) drive the main resistors (R_X and R_S) and the guard resistors (r_x and r_s). The detector D measures the difference in current flowing through R_X and R_S. The guarded active-arm bridge has been evaluated over the range 10 MΩ to 1 TΩ [3]. When measurements were made at 10 TΩ, an accurate balance of the bridge could not be obtained for all unknown resistors R_X. Further investigation revealed that the mismatch between the main and guard circuits was generating leakage currents due to one of the 10 TΩ unknown resistors R_X having a large correction from nominal on the order of 40,000 x 10^{-6}. This mismatch of the main-to-guard resistor ratios causes errors in the measurement of the current by detector D.

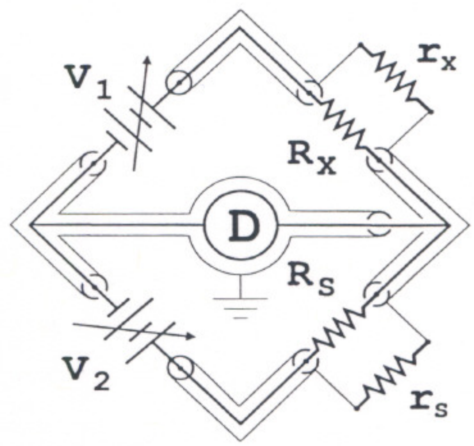

Fig. 1. Basic configuration of the guarded active-arm bridge.

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Dual-Balance Guarded Active-Arm Bridge

Figure 2 shows the guarded active-arm bridge, with dual-balances, configured for measuring resistance standards in the range 1 TΩ to 100 TΩ that may have large corrections from nominal. The third source V_G drives the unknown guard resistor r_x and the guard detector D_G monitors the guard potential at the midpoint to match the guard potential to that of the main circuit. After V_G is set, the source V_1 can be adjusted to balance the main circuit. The standard resistor R_s and guard r_s can be matched to minimize leakages in the standard arm of the bridge. The standard may be a guarded transfer standard [5] which should have a guard resistors matched to the main resistors of the transfer standard.

Another bridge configuration being considered is to place the guard detector D_G between the main and guard circuits. However, if left in place during the main balance, the guard detector could create a leakage path between the main and guard circuits. Placing the detector between the circuit virtual ground (junction of V_1 and V_2) and the guard circuit midpoint (junction of r_x and r_s) simplifies the automation of the dual-balance guarded active-arm bridge.

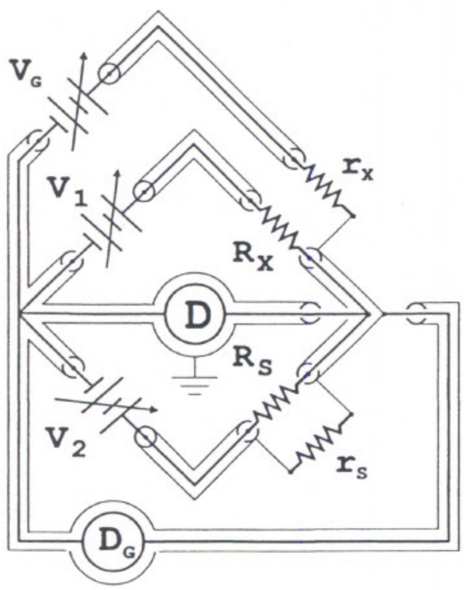

Fig. 2. The dual-balance guarded active-arm bridge with third source (V_G) and second detector (D_G) added to drive the guard circuit to a null.

Conclusion

An analysis of the dual-balance guarding technique will be reported at the conference. Measurements at 10 TΩ and 100 TΩ are under way. The technique will also be evaluated at nominal values of 1 TΩ and below but is not expected to significantly improve the measurement of standard resistors with corrections close to nominal value.

References

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