A LOW THERMAL GUARDED SCANNER FOR HIGH RESISTANCE MEASUREMENT SYSTEMS

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Abstract

The design and testing of a low thermal guarded scanner developed to provide completely guarded switching when used with guarded resistance bridge networks is described.

Introduction

With the automation of measurement systems used to calibrate standard resistors at NIST [1] in the 1980's and 1990's came the need for programmable connection of standard resistors to measurement systems. To reduce errors, many of the measurement systems at NIST use guard networks [2] to eliminate current leakage paths to ground. Without also guarding the switching, such errors degrade the accuracy of resistance measurements, especially at resistnces $\geq$ 100kΩ.

One approach to solving the problem was to develop a programmable, guarded coaxial panel [3] to which connections are made using an XYZ table to plug coaxial connectors into one another. The second approach described here was to redesign the circuit boards and relays of a low thermal scanner so that the measurement circuit path would be completely enclosed in a guard circuit. Driving the guard path at a potential near that of the measurement circuit ensures that negligible current is lost from the measurement circuit path.

Through a collaborative effort, Data Proof and NIST researchers have developed a low-thermal-emf, guarded scanner that has application in automated resistance bridges up to 1 GΩ without injecting any appreciable added uncertainty into the measurement system.

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Guard Circuit Design

A commercial low thermal scanner [4] was modified to incorporate a switched guard circuit. This scanner uses latching relays to make connection by shorting together adjacent gold pads on custom plated printed circuit boards. The low thermal design uses latching relays that require only a short pulse to actuate so the self heating is negligible. This scanner has typical thermal offsets of less than 20 nV.

A new relay board was designed that added guard traces completely surrounding the measurement circuit paths. Where the area between the relay pads was too narrow for traces, a notch was cut in the board. This created an air gap with the guard traces going right up to the notch. The relays have three contact arms that short out three sets of pads on the PC board. One outside contact switches the current lines, the other switches the potential lines and the center contact switches the guard shields.

Two relays are used for each resistor, one for the high side and one for the low side. This further separate and isolate the circuits as shown in Figure 1. The guard circuit is carried through shielded cables from the scanner input and output lines.

The relays used for the guarded scanner are modified by drilling and tapping a hole for a small screw to connect the center contact arm to the steel rocker plate. This places the rocker at guard potential thus shielding the measurement circuit from the relay coils. The center pair of contacts are connected together so that the rocker is at guard potential whether the relay is in the open or closed position.

Evaluation of Prototype Scanner

Several testing methods were used to evaluate the prototype scanner. These tests were designed to measure the insulation between the guard and working circuit of the scanner. All tests were performed with the current and potential leads shorted to make two terminal measurements on the standard resistors.

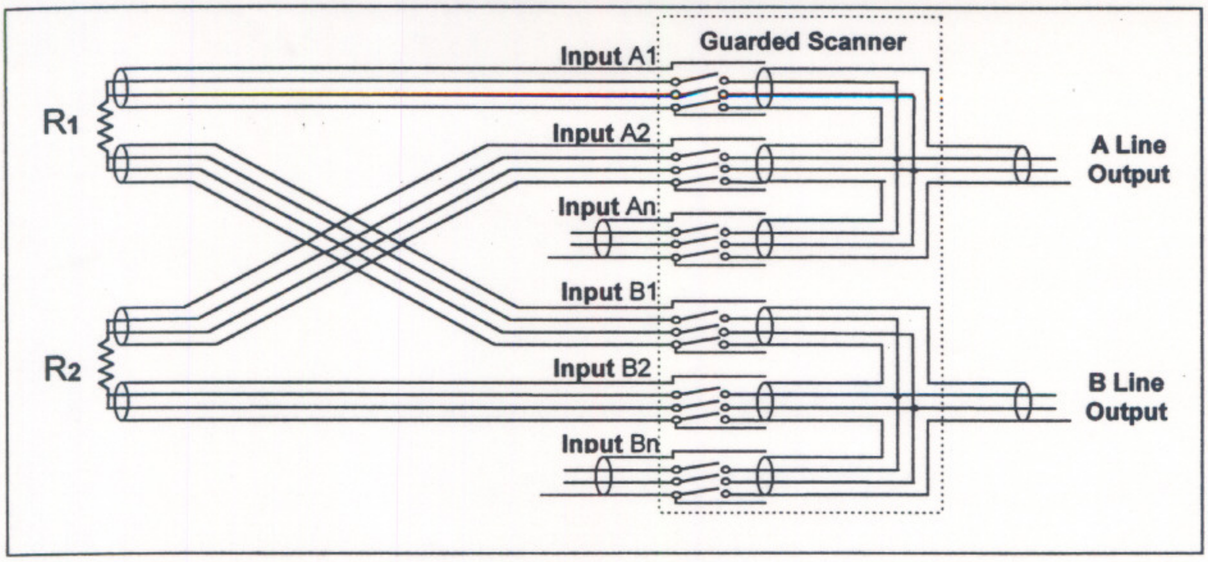

Figure 1. Low thermal scanner diagram showing switched guard shields. Only three channels are shown.

A static test of the insulation between the guard and the working circuit was performed by using a low current electrometer. The current flowing from the working circuit to the guard was measured with a known voltage applied between the guard and measurement circuits.

Measurements indicated that the insulation between the guard and measurement circuit path to be on the order of 10 TΩ. The voltage source and electrometer used in the test have an insulation of 100 TΩ, a factor of ten better than the scanner being evaluated.

To determine if the guard circuit of the prototype guarded scanner was working as expected, the guard was bypassed on a portion of the measurement circuit. This provided an unguarded region where leakage currents could flow to ground. A difference in balance proportional to the applied bridge voltage was observed; that is, as the bridge voltage increased, so did the leakage current in a linear fashion. These test were performed at 10 MΩ using a guarded Wheatstone bridge [2].

A series of test were then performed from 1 MΩ to 10 GΩ using the guarded Wheatstone bridge and the guarded scanner. A standard and check standard were calibrated on the Wheatstone bridge without the guarded scanner attached. Then the standard and check standard were immediately calibrated again with their connection to the bridge being through the guarded scanner. At 10 MΩ and 100 MΩ, the differences were less than 1 ppm. At 1 GΩ, measurements against the wirewound standard gave differences less than 2 ppm and less than 10 ppm for the metal film check standard.

At 10 GΩ, a difference of 100 ppm was observed. Addition of the prototype scanner to the Wheatstone bridge added approximately 5 meters of cable to the circuit which may have affected the measurement at 10 GΩ by adding stray capacitance to the measurement system. Further evaluation with less cabling is expected to yield better results at 10 GΩ.

Conclusions

A low thermal guarded scanner has been developed that can connect resistances up to 1 GΩ to guarded bridges and instruments without affecting the accuracy of the measurement.

Additional modifications to the scanner design are expected to improve performance at 1 GΩ and 10 GΩ and will be reported on at the conference.

References

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