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RELIABILITY AND FAILURE ANALYSIS LABORATORY

A New Generation of Hamon Resistor Standards

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Introduction

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- In 1954, B.V. Hamon proposed the design of a precision resistor standard
- Advances in resistor technologies, more precise calibration methods, resistor arrangements have allowed for better results
- Tolerances, temperature coefficients, and the environment can affect values
- The design of a resistance standard should account for these effects
- This presentation will discuss the efforts being undertaken at the Reliability and Failure Analysis Laboratory at the University of Alabama in Huntsville to design and construct a reliable and maintainable resistance standard

What is the Hamon Resistor?

- Proposed by B.V. Hamon in 1954
- Used to calibrate standard resistors
- Initial design consisted of eleven 10 Ω resistors
- Guard resistors are utilized to provide more accurate measurements
- Resistors may be connected in parallel or series-parallel

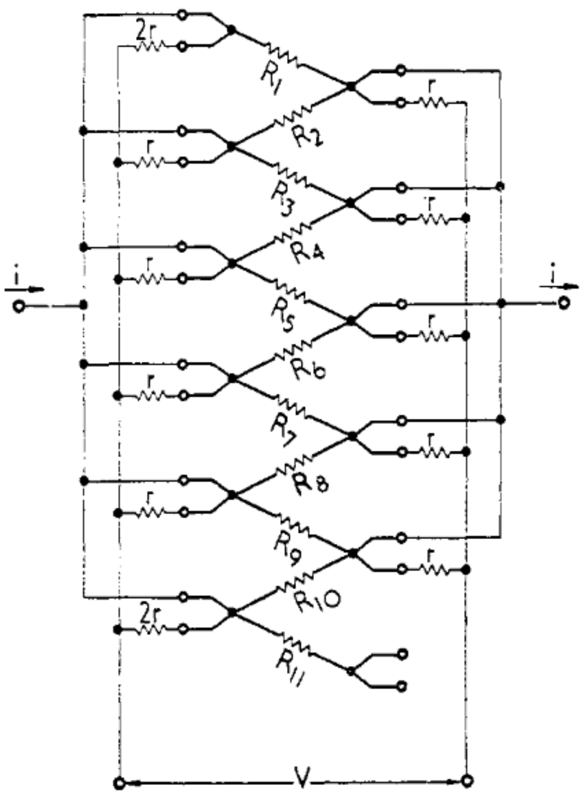

Fig. 1 | The parallel connections of *n* separate four-terminal resistors.

Automated Guarded Resistor Bridge

- Previously, calibrations of standard resistors from 10 MΩ to 1 TΩ at NIST were performed manually

- New design uses a guarded Wheatstone bridge that is automated and robust

- DC voltage calibrators in two arms of the bridge have low output impedances that reduce errors

- High resistor values guard the high side of the detector and reduce leakage currents

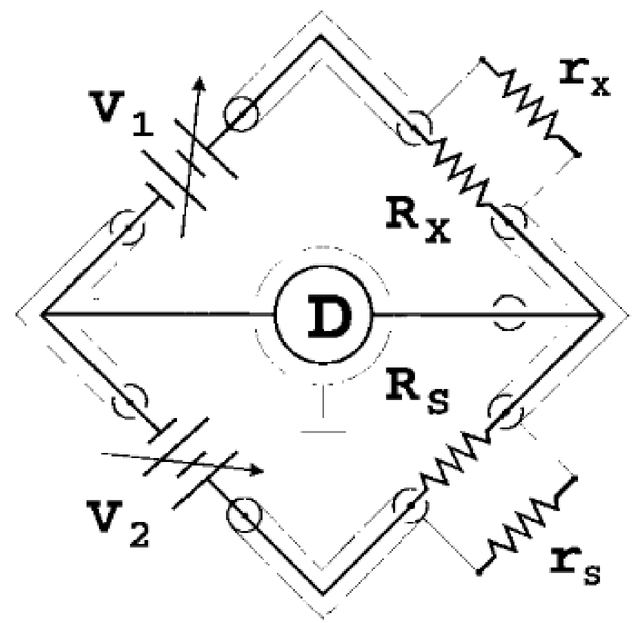

Fig. 2 | Guarded resistor bridge with programmable sources, drive resistors, and guard resistors. The detector, D, measures difference in currents flowing through Rx and Rs.

Balancing the Resistor Bridge

• An electrometer with a resolution of +/- 3 fA in the current mode is used as the detector to measure differences in currents

• Initially, voltage sources are chosen to have the same nominal ratio as *Rx* and *Rs*

• A linear relationship exists between applied test voltage and the current measured by the detector

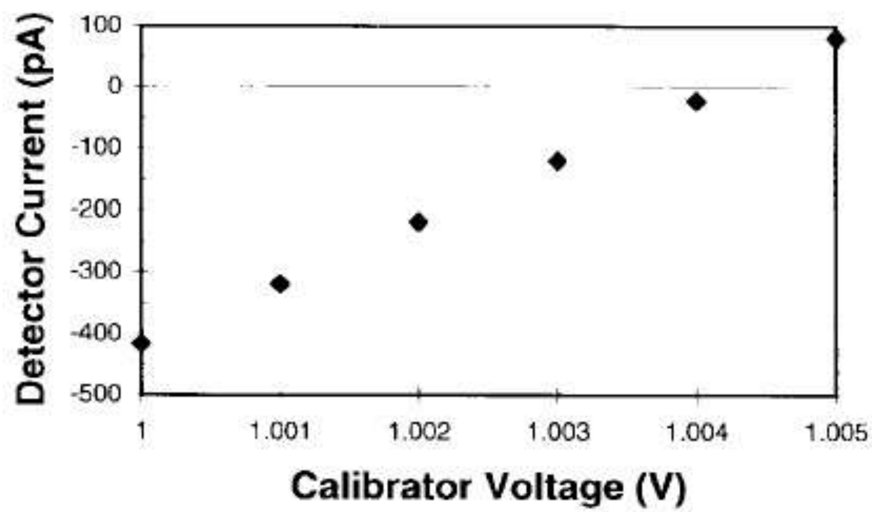

Fig. 3 | Detector current vs. calibrator voltage in the guarded bridge.

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Hamon-Guarded 10x100 MΩ Network

- Guarded resistor bridge developed at the National Institute of Metrological Research

- Consists of ten thick-film resistors, each with a nominal value of 100 MΩ

- Each guard resistor has a value of 10 MΩ

- Resistor network is encased in an aluminum cylinder and series to parallel connections are made through use of a mobile link

a)

b)

Fig. 4 | a) View of the 1 GΩ output of the Hamon network. b) View of the 10 MΩ output of the Hamon network.

Guarding System for the Hamon Network

- Consists of ten resistors with a nominal value of 10 MΩ
- Mounted on the cylindrical body of the main resistors by means of two metal rings
- The leakage resistance of each main resistor is divided into three parts by means of the two rings
- Guard resistor maintains the same potential as across the main resistor so part of the leakage resistance between points *b* and *c* is in parallel with the guard resistor

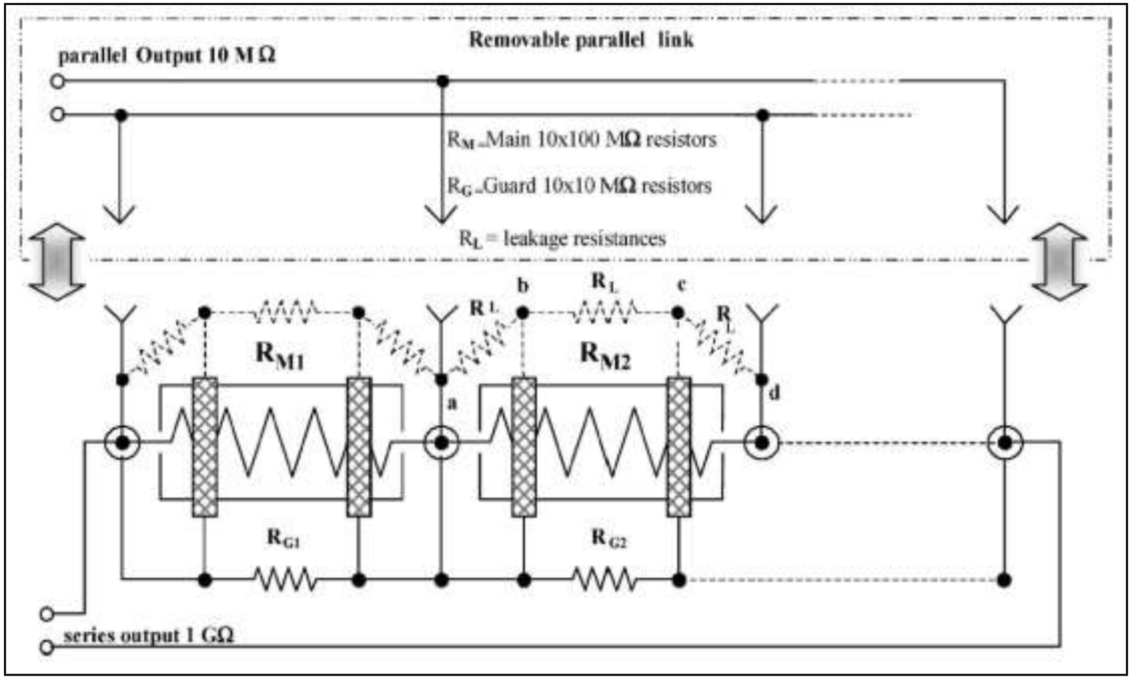


Fig. 5 | Schematic of the 100 MΩ step network, denoting main, guard, and leakage resistances.

Comparison of Resistor Technologies

<u>Thin Film Resistors</u>

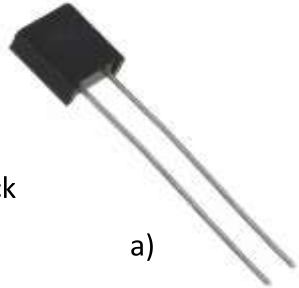
- Manufactured through a sputtering process, provides a uniform metallic film
- Resistive element is approximately 1000 Angstroms thick
- Able to achieve much lower tolerances and temperature coefficients
- Improved characteristics and performance leads to higher cost

<u>Thick Film Resistors</u>

- Most widely available and are the lowest cost of any resistor technology
- Good solution if the application in question does not require low TCR or tight tolerance
- Resistive element is thousands of times thicker than thin film elements

<u>Foil Resistors</u>

- Best precision and stability
- Resistive element is an alloy that is several micrometers thick
- Limited by resistance value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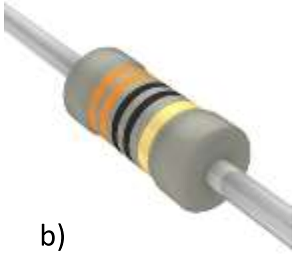
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c)

Fig. 6 | a) A through-hole foil resistor. b) An axial thin film resistor. c) A surface mount thick film resistor.

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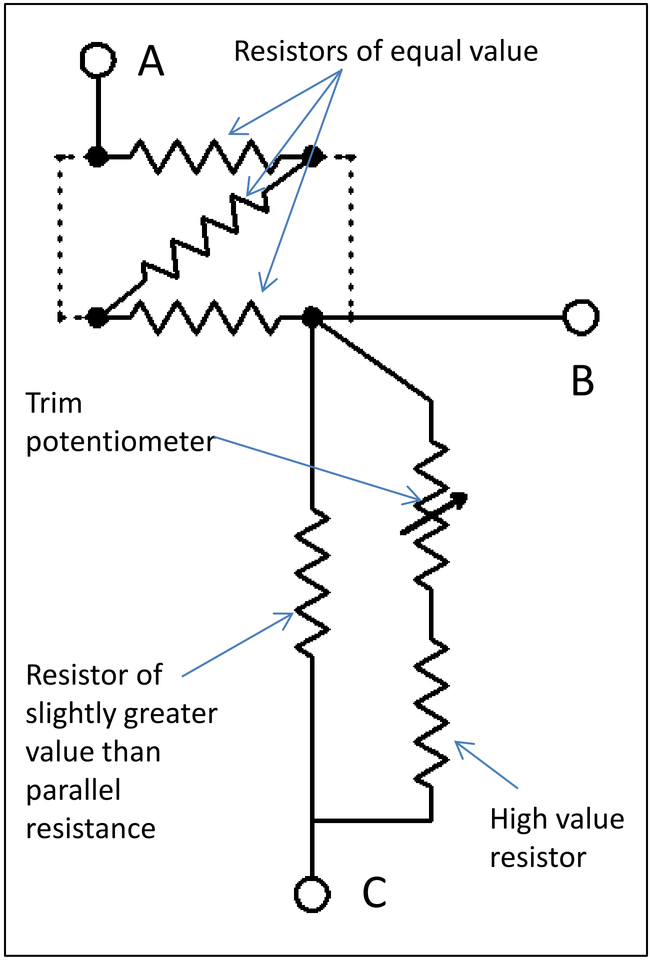
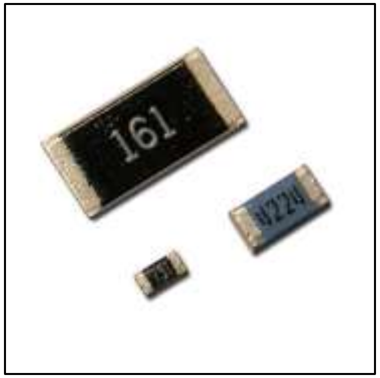
What factors can affect resistance output?

- Temperature coefficients of resistance, or TCRs
  - TCR of thin film resistors is around 25ppm/K, TCR for thick film resistors is around 200 to 250 ppm/K
- Tolerances of resistors
- Oxidation of solder joints
- Connection points contribute impedances
- RF interference
- Thermal shock or vibration

Our Design Approach





Conclusion

- Resistance standards are simple in concept, but difficult in design
- Prototype of a new resistor standard has been constructed, testing to begin soon
- The resistor standard should yield precise and stable values since circuit components possess optimal specifications
- Increase in resistance values creates concern for stability due to increases in TCR and tolerance
- The potentiometer in the circuit will need to be stabilized to prevent drift in values

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Questions/Comments?

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