Detection of Internal Flaws in Conductive 3D-Printed Materials Using Voltage Mapping

Abstract

This experiment investigated whether internal flaws in conductive 3D-printed materials can be detected through spatial voltage measurements. A two-dimensional 6×6 resistor grid connected to a 9 V battery was used as a model system for this experiment. Electric potential was measured at nine evenly spaced locations across the grid. Several internal defects were simulated by removing resistors in specific patterns, including central, horizontal, vertical, and edge breaks. By comparing voltage distributions before and after each break, we analyzed how defects alter the potential field. The results demonstrate that internal flaws produce distinct and measurable changes in voltage distribution, supporting voltage mapping as an effective non-destructive probing technique for conductive materials.

Introduction

Conductive 3D-printed materials are increasingly used in applications where internal structural integrity directly affects electrical performance. Because internal defects may not be visually detectable, non-destructive methods for identifying flaws are essential. One approach is measuring defects in electric potential, as disruptions to current paths should alter voltage distributions.

In this experiment, a resistor grid was used to model a conductive material with uniform resistivity. Internal defects were simulated by removing resistors, allowing us to observe how breaks of varying size and location influence voltage distribution. Understanding these effects provides insight into how voltage mapping can be used to detect hidden flaws in real conductive systems.

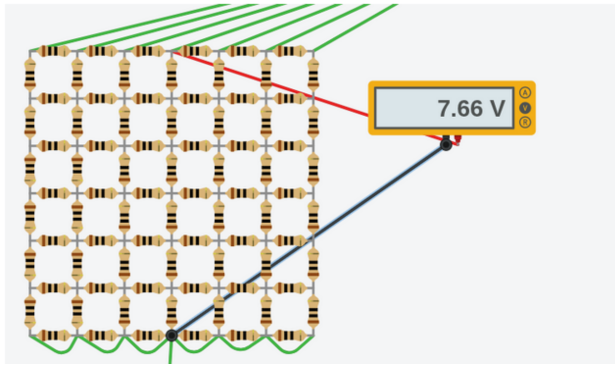

Figure 1: Baseline resistor grid with no internal breaks.

Methods and Materials

A 6×6 grid of identical resistors was constructed in TinkerCad, with each resistor connected to its neighbors to form a uniform network. The left side of the grid was connected to the positive terminal of a 9 V battery, while the right side was connected to the negative terminal (Figure 1).

Voltage measurements were taken using a virtual voltmeter at nine evenly spaced locations across the grid: top left, top middle, top right; middle left, middle middle, middle right; and bottom left, bottom middle, bottom right. These measurements established a baseline voltage distribution.

To simulate internal flaws, groups of resistors were removed in specific configurations: a central break, a large horizontal break, a large vertical break, and a vertical side break. After each modification, voltages were measured again at the same nine locations to ensure consistency across trials.

Data

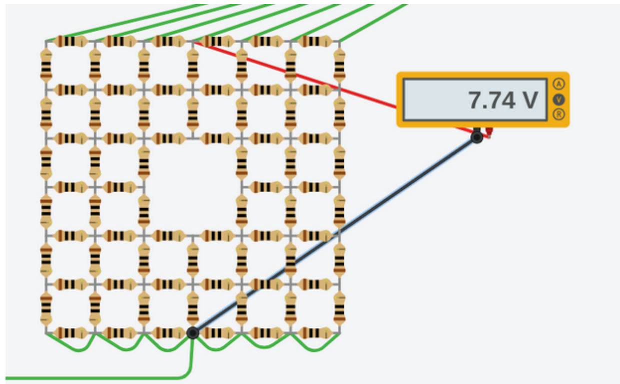

Figure 2: Voltage distribution with no breaks.

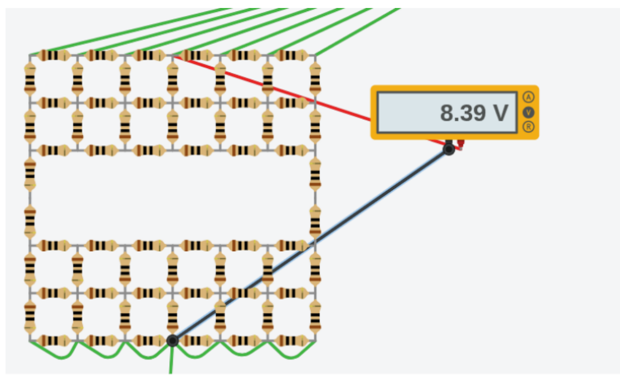

Figure 3: Voltage distribution with a central break.

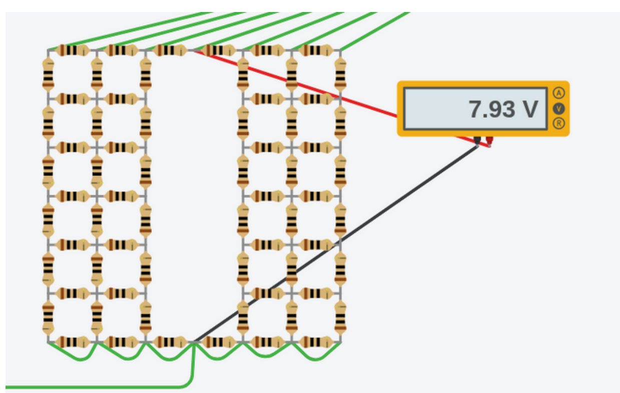

Figure 4: Voltage distribution with a large horizontal break.

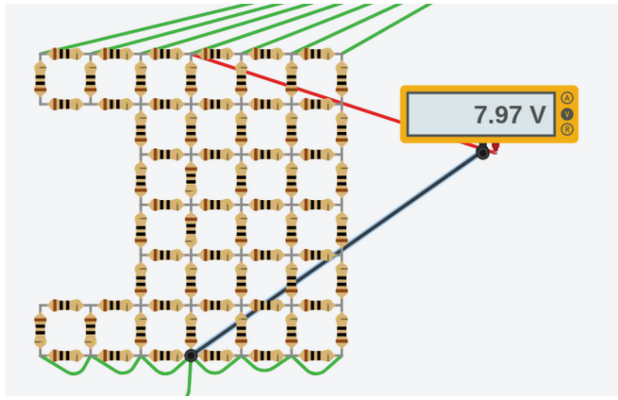

Figure 5: Voltage distribution with a large vertical break.

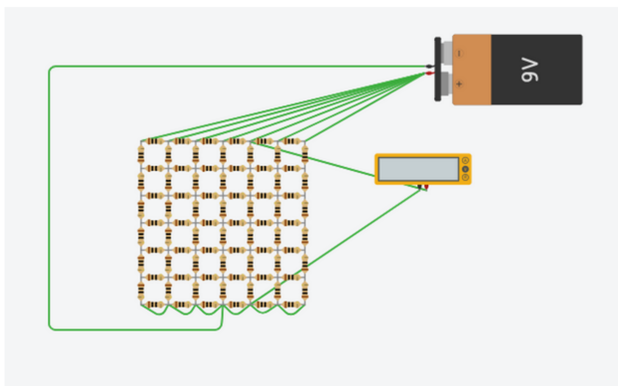

Figure 6: Voltage distribution with a vertical side break.

Results

Table 1: Measured voltages (V) at nine locations for each grid configuration.

Configuration	Top L	Top M	Top R	Mid L	Mid M	Mid R	Bot L	Bot M	Bot R
No Breaks	7.66	7.66	7.66	3.83	3.83	3.83	0	0	0
Center Break	7.74	7.74	7.74	3.87	—	3.87	0	0	0
Large Horizontal Break	8.39	8.39	8.39	4.19	—	4.19	0	0	0
Large Vertical Break	7.93	7.93	7.93	3.96	—	3.96	0	0	0
Vertical Side Break	7.97	7.97	7.97	—	3.99	3.99	0	0	0

The intact grid displayed a nearly uniform voltage gradient from the positive to the negative terminal. Introducing breaks altered this distribution, producing localized increases in voltage near the breaks. Larger and centrally located breaks produced the greatest deviations from the default configuration.

Discussion

The results indicate that internal defects significantly influence the voltage distribution within a conductive grid. Central breaks produced larger voltage changes than edge breaks, suggesting that disruptions closer to the primary current pathways have a greater effect on the overall potential field. This behavior is consistent with Kirchhoff's laws, as removing resistors forces current to redistribute through fewer available paths, increasing voltage drops in surrounding regions.

Edge breaks produced smaller changes, as current could more easily reroute around the defect without substantially altering the main pathways. These observations suggest that voltage mapping is particularly sensitive to defects located near the center of a conductive material.

Conclusion

This experiment demonstrates that spatial voltage measurements can be used to identify internal flaws in conductive materials without physically damaging them. Different defect geometries produced distinct voltage patterns, with central and larger breaks having the greatest impact on the potential field. These findings support the use of voltage mapping as a non-destructive diagnostic technique for conductive 3D-printed materials. Future work could involve constructing a physical resistor grid or scaling the system to determine how defect size and grid dimensions quantitatively affect voltage redistribution.

Sources

Tipler, Paul A., and Gene Mosca. *Physics for Scientists and Engineers*. 5th ed., W. H. Freeman and Company, 2004.

Acknowledgements

- Aryanna Cetrulo: Collected the data
- Andrew Kabatsky: Latex and editing
- Sharone Krasnapolsky: Collected the data and set up the lab
- Connor Paszkiewicz: Completed the discussion section

- Sameera Patil and Kriti Malhotra: Completed the abstract and results section