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TRACE: A Breadboard-based Electronic Component Tester

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ABSTRACT

Electronic components are essential in circuit design, but beginners often struggle to identify and test them before use. This study presents TRACE, a system designed to identify electronic components, measure their electrical properties, and evaluate their condition in real time. The system was developed using a developmental research approach and can test components such as resistors, capacitors, LEDs, transistors, and basic logic gates. It processes data through a microcontroller and displays results to the user. Results show that TRACE can identify components and measure their values with acceptable accuracy. The system also helps detect faulty or degraded components, making it useful for basic diagnostics. Overall, TRACE provides a simple and efficient tool that helps students and beginners verify components, reduce errors, and improve learning in electronics laboratories.

Keywords: Breadboard Learning, Component Identification, Real-Time Testing, Fault Detection, Electronics Education

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INTRODUCTION

The breadboard is a fundamental tool in electronics education and circuit prototyping, providing a reusable and solderless platform for building circuits. It allows students and engineers to experiment with designs, understand component behavior, and develop practical skills.

Despite these advantages, beginners often have difficulty identifying electronic components, understanding their values, and determining whether they are working properly. These challenges can lead to incorrect circuit assembly, longer troubleshooting time, and reduced learning efficiency.

Traditional methods of testing components, such as using multimeters, require prior knowledge and manual interpretation of readings. This process can be time-consuming and may be difficult for beginners. As a result, there is a need for a more efficient and user-friendly system that can assist users in identifying and evaluating electronic components in real time.

To address this need, this study introduces TRACE: A Breadboard-Based Electronic Component Tester. The system is designed to automatically identify components, measure their values, and determine their condition as good, degraded, or damaged. By providing real-time testing and feedback, TRACE simplifies component verification and supports learning in electronics laboratories.

This study aims to reduce errors in circuit construction, improve troubleshooting efficiency, and enhance students' understanding of electronic systems. TRACE serves as a practical tool that connects theoretical knowledge with hands-on learning.

Research Gap(s)

Existing electronic component testing methods primarily rely on manual tools such as multimeters, which require user expertise and interpretation. While some automated component testers have been developed, many of these systems focus only on identifying component type and value without evaluating the operational condition of the component.

Additionally, current systems often lack real-time feedback and are not specifically designed for breadboard-based learning environments. They do not fully address the challenges faced by students in identifying faulty or degraded components before circuit assembly.

Moreover, limited studies have integrated both hardware and software approaches to provide a comprehensive, user-friendly, and portable testing system that supports educational applications. This study aims to fill these gaps by developing a system that not only identifies components but also evaluates their condition and enhances learning efficiency through real-time analysis.

Theoretical Framework

This study is grounded on several fundamental theories in electronics that support the design and functionality of the TRACE system.

Ohm's Law explains the relationship between voltage, current, and resistance, serving as the basis for measuring and verifying resistor values within the system. By applying this principle, the device can determine whether a resistor meets its expected specifications.

Semiconductor Theory provides the foundation for understanding the behavior of components such as diodes, LEDs, and transistors. It explains how these components operate under different electrical conditions, enabling the system to identify and evaluate their functionality.

Digital Logic Design supports the identification and testing of logic gate integrated circuits. By analyzing input and output relationships based on truth tables, the system can determine the type of logic gate and verify its correct operation.

These theories collectively guide the development of the TRACE system, allowing it to perform accurate component identification, measurement, and condition evaluation in real time.

Objectives

The primary objective of this study is to design and develop TRACE: A Breadboard-Based Electronic Component Identification and Testing System. Specifically, it aims to:

1. Develop a breadboard-based device capable of accurately identifying the type and value of basic electronic components.
2. Determine the operational condition of electronic components as good, degraded, or damaged.
3. Evaluate the system in terms of:
   - 3.1 Accuracy in detecting component type and value
   - 3.2 Consistency of results in repeated testing
4. Assess the system based on its:
   - 4.1 Ease of Use
   - 4.2 Reliability
   - 4.3 Compatibility
   - 4.4 Portability

Through these objectives, the study aims to create an effective and reliable tool that enhances electronics education and simplifies component testing for students and instructors.

METHODOLOGY

Research Design

This study used a developmental research method focused on designing, building, and evaluating a functional prototype. The process included planning, design, development, testing, and improvement. A modified iterative approach was applied to refine the system through repeated testing.

Participants and Sampling Technique

The study involved 30 participants from Bulacan State University, including students and faculty with knowledge of electronics. Purposive sampling was used to select respondents who could provide relevant feedback on the system.

Instrument

A structured questionnaire using a five-point Likert scale was used to evaluate the system's performance in terms of accuracy, reliability, usability, compatibility, and portability. The instrument was based on ISO/IEC 25010:2011 standards.

Data Gathering Procedure

The researchers conducted system testing and observations during the development phase to monitor TRACE's functionality and performance. After completing the prototype, respondents were asked to use the system in actual testing scenarios. Following this, the survey questionnaire was distributed to collect user feedback. The responses were then compiled and organized for analysis to determine the system's effectiveness and usability.

Data Analysis Procedure

Data was analyzed using descriptive statistics, particularly mean values. Accuracy was measured by comparing results with reference values and computing percent errors. Lower error indicates higher accuracy.

Ethical Consideration

The researchers ensured that ethical standards were followed throughout the study. Participation was voluntary, and respondents were informed about the purpose of the research. All collected data were handled confidentially and used solely for academic purposes. The researchers also ensured that no harm was caused to participants during the testing and evaluation of the system.

RESULTS

This section presents the results obtained from the testing and evaluation of the TRACE: A Breadboard-Based Electronic Component Identification and Testing System. The findings include the accuracy test, fault detection capability, repeatability of results, and system evaluation based on user responses. The data gathered were analyzed and interpreted to determine the overall performance of the system.

Table 1
Results of Accuracy Test of TRACE System

Component Type	Mean Percent Error
Resistor	5.01%
Capacitor	4.36%
Transistor	8.39%
Logic Gates	0%
LED	1.52%
Overall Accuracy	**96.14%**

As shown in Table 1, the TRACE system achieved an overall accuracy of 96.14%, with low percent errors across all tested components and a 0% error rate for logic gates, indicating precise identification and measurement performance. These findings are consistent with prior studies on automated component testers, which report improved accuracy and reduced human error compared to manual testing methods (Mohan & Kumar, 2021; Kumar & Singh, 2020). The results support the effectiveness of automation in achieving reliable component identification and measurement within acceptable tolerance ranges.

Table 2
Results of Fault Detection Test of TRACE System

Interpretation	Count	Percentage
Good	5	38.46%
Degraded	3	23.08%
Damaged	5	38.46%
Total	**13**	**100%**

As presented in Table 2, the TRACE system classified components as good (38.46%), degraded (23.08%), and damaged (38.46%), demonstrating its capability to distinguish multiple levels of component condition. This approach aligns with existing fault detection frameworks that emphasize the importance of identifying varying degrees of system faults rather than relying solely on binary classification (Di Leo et al., 2023; Sharma et al., 2023). Furthermore, the inclusion of a degraded category supports improved diagnostic evaluation, as recognizing partial faults has been identified as essential for enhancing system reliability and data quality (Abdallah et al., 2020).

Table 3
Results of Repeatability Test of TRACE System

Component	Total Trials	Correct Identification	Consistency Rate
Resistor	10	10	100%
Capacitor	10	10	100%
Transistor	10	10	100%
Logic Gates	10	10	100%
LED	10	10	100%
Total	**50**	**50**	**100%**

As shown in Table 3, the TRACE system achieved a 100% consistency rate, correctly identifying all components across repeated trials, indicating strong repeatability and reliability. This result is consistent with findings from automated and sensor-based diagnostic systems, which demonstrate stable outputs under repeated testing conditions when properly designed and validated (Islam et al., 2023). The observed consistency also supports principles of developmental research, where iterative design and testing contribute to improved system stability and performance (Richey & Klein, 1993).

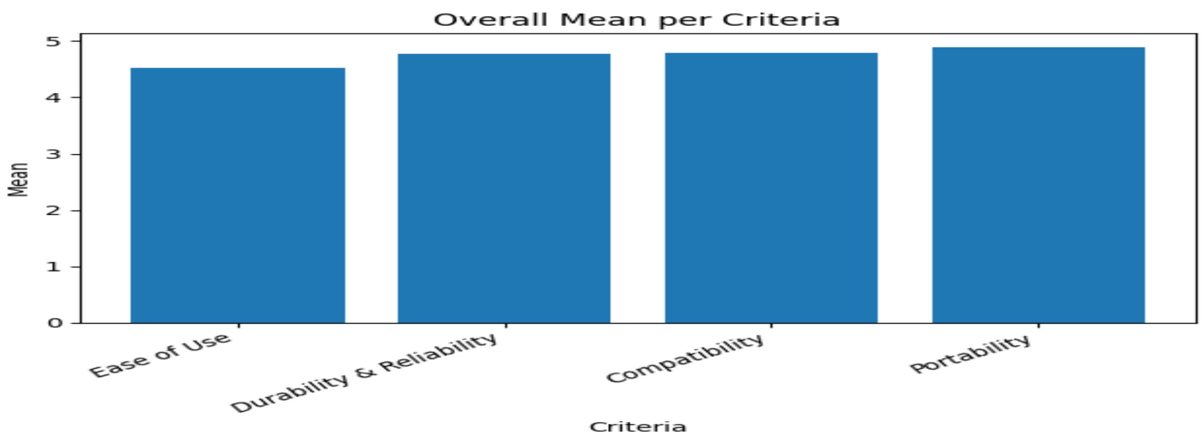
Table 4
Results System Evaluation and Performance of TRACE System

Criteria	Mean	Interpretation
Ease of Use	4.53	Strongly Agree
Reliability	4.78	Strongly Agree
Compatibility	4.79	Strongly Agree
Portability	4.89	Strongly Agree
Overall Weighted Mean	**4.75**	**Strongly Agree**

As reflected in Table 4, the TRACE system obtained an overall weighted mean of 4.75, interpreted as “Strongly Agree,” indicating high user acceptance across all evaluated criteria. This finding is supported by literature emphasizing that user-friendly and practical electronic tools enhance learning effectiveness and usability in educational environments (Floyd, 2018; Horowitz & Hill, 2015). Additionally, systems developed through iterative design processes are commonly associated with positive user evaluations due to continuous refinement and alignment with user needs (Richey & Klein, 1993).

Figure 1

Results of System Evaluation and Performance



As shown in Figure 1, the system got high ratings in all areas, with portability as the highest, followed by compatibility, reliability, and ease of use. This supports the results in Table 4 and shows that users find the system useful and easy to use. This is similar to studies showing that simple and user-friendly tools help improve learning (Floyd, 2018; Horowitz & Hill, 2015) and that continuous improvement makes systems better (Richey & Klein, 1993).

DISCUSSIONS

The results of the study demonstrate that the TRACE system is effective in identifying and evaluating electronic components based on their electrical characteristics. The system achieved a high overall accuracy of 96.14%, indicating that most measured values were within acceptable tolerance ranges. Components such as resistors, capacitors, LEDs, transistors, and logic gates were successfully identified, with logic gates achieving a 0% error rate, highlighting the system's reliability in digital component detection. Furthermore, the fault detection capability of the system allowed it to classify components as good, degraded, or damaged based on user-defined values, which enhances its practical use in laboratory environments. The repeatability test also confirmed that the system provides consistent results, achieving a 100% consistency rate across all tested components.

Compared to traditional tools such as multimeters, TRACE provides faster and more user-friendly testing by reducing the need for manual interpretation. Unlike some existing component testers that only identify type and value, TRACE also evaluates the condition of components. This makes it more useful in educational settings, especially for beginners.

CONCLUSIONS

The study concludes that TRACE is an effective breadboard-based electronic component tester capable of identifying components, measuring their values, and evaluating their condition. The system demonstrated high accuracy, consistency, and reliability during testing. It helps improve efficiency, reduce troubleshooting time, and support learning in electronics laboratories. Therefore, TRACE is a practical and user-friendly tool for real-time component testing.

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Declaration of Generative AI

During the creation of this manuscript, the authors used ChatGPT (OpenAI, GPT-5.3) to help with the language editing and refining the document. The tool was used simply to enhance clarity, grammar, and readability. The authors examined and edited the output as needed and accept full responsibility for the content of the work.

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