Research Paper

Efficient component procurement system for analog-digital components

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Article Info

Article History:
Received: 08 February 2025
Revised: 19 April 2025
Accepted: 25 April 2025
Published: 11 June 2025

Keywords:
Accuracy
Analog Components
Automated Testing
Report Generation
CT-07
Component

ABSTRACT

This paper presents the CT-07, an advanced system designed for efficient testing and procurement of analog and digital components. By integrating real-time supplier data, inventory levels, and pricing information, CT-07 optimizes sourcing strategies, reducing procurement costs and lead times. The system employs intelligent algorithms to ensure component compatibility, minimize shortages, and enhance project reliability. Additionally, its automated testing capabilities streamline quality assessment, identifying defective components with high accuracy. Through real-world validation, CT-07 has demonstrated its ability to improve efficiency in both procurement and testing, providing engineers and procurement specialists with a cost-effective and reliable solution. Ultimately, this innovation serves as a local solution to a local problem, addressing key challenges in component acquisition and verification.

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1. INTRODUCTION

This paper is based on original research and a project. “The project aims to address local challenges by offering a solution for testing and purchasing components efficiently. By focusing on analog, digital components mainly. The project aimed to save money, time, energy and mitigating issues”. This paper discusses a prototype called ”CT-07,” a component tester designed to detect and test seven different types of electronic components. The prototype was initiated after extensive research, beginning with the main book Testing Active and Passive Electronic Components [1] and an influential paper titled Electronic Component Testing Device [2], which significantly guided the project direction. Additional conceptual understanding was developed through books [3], [4], [5], which provided in-depth knowledge of electronic components and circuit behavior. Why is Testing Required? Electronic component testing and verification are essential for ensuring circuit reliability, minimizing errors, and improving efficiency in electronics design, production, and maintenance.

Traditional methods involving multimeters, oscilloscopes, and logic analyzers require manual setup, calibration, and interpretation, making them time-consuming and error- prone, especially for complex components such as ICs and MOSFETs. So, to solve these challenges CT-07 was designed and developed to address the local challenges and procurement system. This study introduces an efficient component tester CT-07, that automates the testing process, reduces manual effort, and delivers high-precision results for a wide range of components.

Automated Multi-Component Testing, CT-07 tests two large component categories:

Analog Component Testing: Detects, tests, and verifies the analog components such as resistors, capacitors, diodes, IC 741. It identifies the component and tests them for working condition. Digital Component Testing: Detects, tests and verifies the analog components such as IC 7400 (NAND gate), IC 7408 (AND gate) etc, with the help of an algorithm, it checks each gate of an IC and outputs whether it is fully functional, faulty, or if a specific gate is not working. The initial concept of CT-07 was envisioned to illustrate its progression from a conceptual design on paper to an AI-generated representation. The early depiction of CT-07 is shown in Figure 1. CT-07 is a prototype developed to detect, test and verify various electronic components including

Figure 1. Early Depiction of CT-07

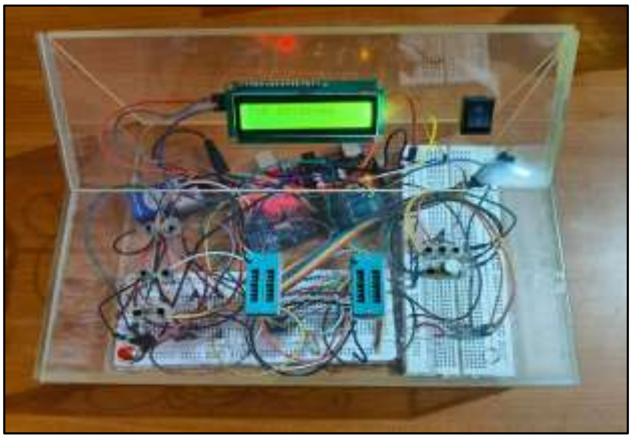

Figure 2. CT-07

Figure 3. CT-07 CADD Design

Resistors, capacitors, diodes, integrated circuits (ICs) etc. It takes care of the imperative requirement for electronics testing in terms of facilitating a fast and efficient way for ascertaining component integrity while ensuring maximum performance during circuit design, troubleshooting, and maintenance of repository and

Also offers advantages such as enhanced efficiency, reduced testing time, and improved fault detection, making it a valuable tool for engineers, students, and hobbyists. This approach aims to save time, money, and energy while mitigating common issues, thereby addressing local challenges by offering a local solution as previously mentioned. The prototype CT-07 is as shown in Figure 2 and the CADD design of CT-07 is shown in Figure 3. It exhibits profound practical applications in electronics manufacturing, design, and repair fields.

A. Features of CT-07

Table 1. Integrated Functional Features of the Proposed Testing System

Automated Testing & Error Reduction	**Dual Power Modes**
User-Friendly Interface	High-Precision Measurements
Portable & Robust Design	Real-Time Data
Calibration and Self-Test Functions	Data Logging and Storage
Multi-Component Compatibility	Energy Efficiency
Multi-Channel Testing	Cost-Effective Maintenance

Table 1 presents the core features embedded in the proposed analog-digital component testing system. These functionalities collectively enhance testing accuracy, usability, and energy efficiency. Designed with a focus on automation, portability, and real-time data handling, the system is suitable for diverse testing environments. Such integration ensures reduced manual errors, streamlined operation, and cost-effective maintenance.

B. Advantages of CT-07

TME: Reduces time, money, and energy and helps in rapid testing and efficient procurement of components.

Efficiency: It's more efficient (when compared to models like DIT 2040, DM 3/34 models, etc., which are manual and inefficient for high-volume testing). Testing of 100 components was completed in 80 seconds

Cost-Effective: Minimizes operational costs by automating repetitive tasks and reducing labor dependency. The CT-07 prototype was built at a cost of approximately Rs4000, including GST.

High Precision: Ensures consistent, accurate results with advanced ADCs and temperature-compensated circuits.

C. Applications of CT-07

Circuit Design: Assists engineers in verifying components during prototype development.

Quality Assurance: Helps manufacturers identify defective parts before assembly.
Fault Diagnosis: Enables repair technicians to diagnose faults effectively.
Educational Use: Serves as a learning tool for students to understand component behavior.
Research and Development: Facilitates component analysis and performance evaluation in labs.

By automating component testing with precision and efficiency, the CT-07 offers a fast, reliable, and versatile solution for modern electronics development and repair. By streamlining the testing and verification process, it enhances productivity, reduces costs, and improves accuracy in electronics design and maintenance. This encapsulates the overall concept, purpose and overview of CT-07.

2. RELATED WORK

The literature review was a cornerstone in the development of CT-07, guiding critical design decisions through insights from existing research, technological advancements, and industry needs. These insights not only guided the technical development but also ensured the device addresses practical industry needs. Conducted over 3–4 months, this comprehensive review laid the foundation for identifying gaps, setting objectives, and aligning with current technological trends. By examining research papers, industry reports, and existing testing devices, the study aimed to understand the evolution of component testing in electronics.

This meticulous process helped uncover persistent challenges and highlight opportunities for innovation. The development of CT-07 was significantly influenced by seven primary literature sources [6], [7], [8], [9], [10], [11], [12] see Table 2, which provided essential insights into automation, testing methodologies, and reliability. Alongside these key references, a broad array of books, articles, journals, research papers, and review papers also played a crucial role in refining the device's conceptual framework.

Table 2. Literature Review Table

Sl.	Title	Authors	Year	Key Contributions	Limitations
1.	A GUI Based Digital IC Tester	Abbas Murtaza, Khagen-dra Joshi, Sana Ali Naqvi, Vivek Ashok Bohara	2024	Introduces a graphical user interface (GUI)-Based digital IC testing system that simplifies operation and enhances output visualization.	Lacks compatibility with analog ICs and complex programmable components.
2.	A Literature Review on Compo-nent Testing	Karambir Karambir, Damini Verma	2023	Demonstrates the benefits of NFA and DFA-based testing models in enhancing component-level test reliability and coverage.	Relies heavily on third-party tools, raising potential compatibility and security concerns.
3.	Design and Implementation of Microcontroller Based Digital Logic Gate IC Tester	Chirayu Darji	2021	Presents a cost-effective solution for testing Digital logic gate ICs using microcontroller integration.	Limited to basic logic ICs; not suitable for Testing complex digital or programmable de-vices.
4.	Low Cost High Performance Microcontroller-Based Semiconductor Device Tester	Kanade Jyoti Suresh, Kulkarni Vishwashri Amrut	2013	Delivers a multi-functional microcontroller-Based tester for semiconductors like diodes, BJTs, and JFETs.	Precision limitations in measurement accu- racy due to low-cost component usage.
5.	A Literature Survey on Com-ponent Testing in Component- Based	Ravinder Kumar	2012	Highlights the necessity of dedicated tools And practices for ensuring software compo- nent integrity.	Overlooks advancements in testing strategies introduced after 2005.

	Software Engineering				
6.	An Engineer's Guide to Automated Testing High-Speed Interfaces	Jose´ Moreira, Hubert Werkmann	2010	Explains the design and advantages of automated test equipment in high-speed digital interface testing, improving repeatability and efficiency.	Requires significant upfront investment and specialized technical know-how.
7.	Microprocessor Based Instrument for Resistance and Diode Testing	J. S. Sohal, B. K. Sawh- ney	1980	Describes a programmable resistance and Diode tester built using Intel 8085, featuring ADC support and signal interpretation.	Complex circuit design may pose challenges For users lacking in-depth electronics expertise.

The Table 2 gives us lot of insights about the testing and other features. Using the information and deep understanding, which helped in crucial building of CT-07.

3. METHODOLOGY

The development of the Efficient Component Tester or Procurement System for Analog-Digital Components or the CT-07, followed a systematic approach aimed at achieving high accuracy, automation, and versatility in component testing. The project began on 12th February 2024 with the fundamental goal of providing a local solution to local problems at institute level, as highlighted in the introduction. The fully functioning CT-07 was completed on 7th January 2025.

Idea and Conceptualization

The project originated from the need to create a versatile, cost-effective, and efficient component tester at our institute. Initial brainstorming sessions focused on addressing the limitations of traditional testers (such as DIT 2040, CT-3100, Model 815), including human error, limited component compatibility, and time inefficiency. The goal was to build a device capable of automatically identifying and testing analog, digital, and power electronic components with high accuracy.

Planning In the planning phase, detailed discussions were held to outline objectives, deliverables, and timelines. Tasks were divided among team members, and milestones were set to ensure steady progress. Critical design aspects such as hardware selection, software integration, and automated testing features were discussed and documented.

Research

An extensive literature review was conducted to understand existing component testing methodologies and technologies, discussed more in detail in section - Literature Review. Research focused on automation, digital logic testing, parameter analysis. Insights from journals, conference papers, books, and previous works helped refine the project's direction, guiding both hardware and software development.

Theoretical Design

Theoretical design involved paper-based circuit schematics, block diagrams, and mathematical modeling. Formulas for component measurements, few including Ohm's law for resistance, charge-discharge equations for capacitance, and digital logic validation for ICs, were derived. The prototype design and hardware validation were supported using several software tools. Visual design and modeling outputs were generated using Fusion 360, Tinkercad, Arduino IDE, PLX-DAQ, and Microsoft Excel with representative images or graphs included in this paper. Additional platforms such as TINA-TI, Cadence Virtuoso, Proteus Design Suite, and AutoCAD 2012 were also employed for designing, simulation, layout and others. However, due to legacy or proprietary constraints, the output of these environments has not been disclosed in this document [13], [14], [15], [16], [17], [18], [19], [20].

Practical Implementation

The practical phase focused on translating theoretical designs into physical circuits. Hardware development began with component procurement, followed by iterative testing on breadboards to validate functionality. After successive trials and troubleshooting:- Analog Components: Resistors, capacitors, Diodes, Transistors were tested with a deviation of less than ±0.2%. - Digital Components: Logic ICs, IC 741 (Operational Amplifier) were tested for pass/fail status and functionality.

The hardware prototype was assembled using glass and a laser-cutting machine, avoiding PCB manufacturing.

This approach provided flexibility for modifications and was cost-effective for prototyping. Software development was carried out in parallel using the Arduino IDE and implemented altogether at this stage.

Integration and Final Testing

Hardware and software modules were integrated to enable seamless communication between the microcontrollers and peripheral components. Extensive testing ensured consistency in measurements and device reliability. Comparative tests with standard instruments verified the device's precision.

Final testing was performed in laboratories and repair workshops, where CT-07 demonstrated a 70% reduction in testing time compared to conventional methods. User feedback from students, faculty, and technicians led to minor improvements in result readability and operational simplicity.

Research Paper Writing and Publishing

After successful completion and validation, the project's findings and technical innovations were documented. A research paper was made for publication "Efficient Component Procurement System for Analog-Digital Components".

This process involved presenting methodology, experimental results, and analysis, highlighting CT-07's contribution to the field of electronics testing. The research details and project methodology were depicted in the paper.

Working and Operation of CT-07

The CT-07 operates through a structured and automated process designed for efficient testing of analog and digital components. The process begins with powering on the system, where the Arduino UNO microcontroller initializes and activates the peripheral modules.

Once a component is placed, the system detects its presence. Upon successful detection, a switch-case logic structure is employed to identify the component type resistors, capacitors, diodes, transistors, MOSFETs, or ICs, and execute the corresponding test routine. During testing, critical electrical parameters such as resistance, capacitance, forward voltage drop, gain (hFE), and logic states are measured and compared against predefined thresholds.

The CT-07 then, detects and tells the values wherever required. For example:- Resistor:- Input: Resistor with color code Red-Red-Black-Gold.

Output:

Resistor Detected!

Resistance = 998.42 Ohm

If no component is detected, the system bypasses the testing phase and directly displays a "Not Detected" message. The flowchart in Figure 4 illustrates the systematic component testing process, providing a high- level abstraction of the CT-07's functionality. The CT-07 has been designed to operate in different modes, catering to various testing and procurement needs, as follows:

Normal Testing Mode

Single Run: Conducts a one-time test on a component. Generates logs and graphs of defect vs. non-defect components.

Loop Mode: Continuously tests components in sequence. Generates logs and graphs of defect vs. non-defect components.

Component Procurement Mode: Generates logs and statistical reports of defect and non-defect components. Also generates a report if required.

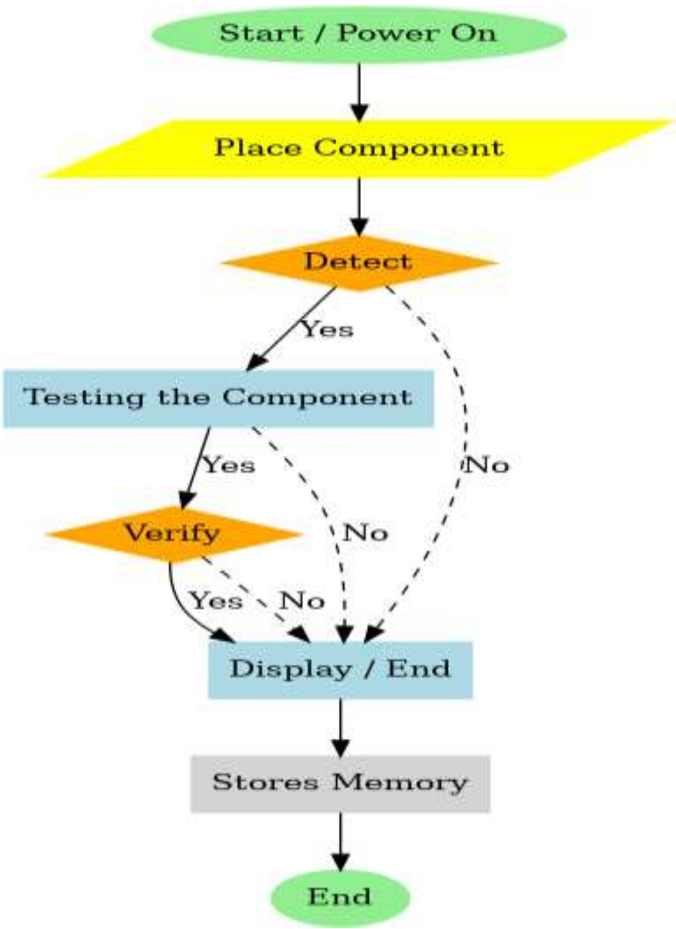

Figure 4. Component Testing Process Flowchart

4. RESULTS AND DISCUSSION

The process of developing CT-07 was a multi-step processinvolving circuit design, code development, testing, and assembling the outer casing to achieve a fully functional prototype. As discussed in the Methodology section, the development of the CT-07 project followed a structured approach comprising multiple phases, ensuring systematic progression from conceptualization to realization. The process began with an initial idea aimed at addressing the challenges of component testing in electronic circuits. This idea evolved through detailed planning, simulations, hardware-software integration, and finally, a working prototype CT-07. Each phase was meticulously executed to enhance the accuracy and efficiency of component testing. This section discusses the design and implementation from an engineering perspective, avoiding repetition of the methodology already explained.

Software Tools

Arduino IDE: For programming and hardware control.

TINA, Tinkercad, Virtuoso, Proteus: For circuit simulation testing and validation.

AutoCAD 2012, Tinkercad, Fusion 360: For 3D modeling and prototype design.

Cadence Virtuoso: For precision circuit analysis.

Hardware Tools, Components:

Electronic Components and parts: Resistors, capacitors, diodes, BJTs, MOSFETs, IC's, Battery etc.

Microcontroller: Arduino UNO for control and processing.

Prototyping Equipment: Breadboards, jumper wires, ZIF sockets, DM (Digital Multimeter) for testing and verification.

Structural Assembly: Glass structure using laser-cutting.

Conceptualization and Theoretical Framework

The initial phase involved brainstorming and understanding the need for an efficient component tester. Preliminary sketches and block diagrams were created to visualize the system. Circuit analysis and theoretical research were conducted to determine the feasibility of testing analog, digital, and MOSFET components. Research papers, datasheets, and industry standards were reviewed to align with best practices.

$$Resistor = \frac{V \times 1000}{5 - V}$$

Paper and Simulation Work

Before moving to hardware implementation, significant work was carried out on paper and through simulations to validate the design. Key references and books were used for measurement and analysis. Simulations were conducted using software tools to ensure the accuracy of theoretical assumptions. These simulations refined circuit parameters and identified potential issues in advance. The equations and component identification techniques are discussed next, refer Figure 5 for schematics for particular circuit part or schematic. Because same label is used for equations for better and easy understanding.

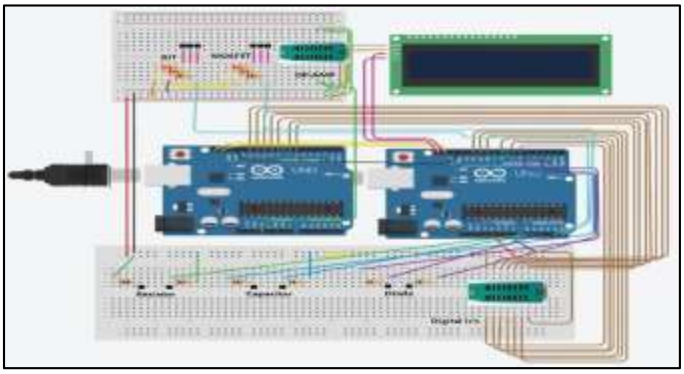

Figure 5. Schematic Diagram of the Detection Circuit

Electronic Component Identification Techniques

Here are few terms used in the electronic component identification techniques:

Resistor Detection: A voltage divider circuit is used to measure an unknown resistor:

$$Resistor = \frac{V \times 1000}{5 - V} \quad (1)$$

Where V is the measured resistance voltage, the value V can be obtained by dividing the voltage of Ao port of arduino uno by 1023,

$$V = \frac{A_O}{1023} \quad (2)$$

Capacitor Detection: The capacitance is given by:

$$Capacitor = \frac{1}{WR_1}\left(\left(\frac{DV_{in}}{V_{out}}\right)^2 - 1\right)^{\frac{1}{2}} \quad (3)$$

Given Values:
W = 1000 rad/s
R1 = 10ohm
D = 0.8
Vin = 5V

Substituting these values into the formula will give the capacitance C. For capacitors of 10nF and 100nF, appropriate Vout values are 2.84V and 0.85V respectively.

Diode Detection: The voltage across the diode is given by:

$$Diodes = 5 - \left(20000. \frac{5}{10000 + R_{diode} + 10000}\right) \quad (4)$$

This equation calculates the voltage across a diode in a circuit with a 5 V supply and a resistor network of resistance Rdiode. In this configuration, the expression represents the voltage divider output. The product of this term and 20000 is subtracted from 5 V to obtain the diode voltage
Vdiode. Depending on the measured

Voltage across the diode:
If Vdiode ≈ 0.7 V, the diode is likely a pn junction diode.
If Vdiode ≈ 1.8 V or 2.2 V, the diode is likely a light emitting diode (LED).
If Vdiode ≈ 2.5 V or 2.7 V, the diode is likely a zener diode.
Digital IC's Detection: Digital IC contains logic gates, which are fundamental building blocks of digital circuits. Here's the logic implemented, to detect logic gates:
AND Gate (IC 7408): Outputs HIGH only when both inputs are HIGH.
OR Gate (IC 7432): Outputs HIGH if at least one input is HIGH.
NOT Gate (IC 7404): Inverts the input signal.
NAND Gate (IC 7400): Outputs LOW only when both inputs are HIGH.
NOR Gate (IC 7402): Outputs HIGH only when both inputs are LOW.
XOR Gate (IC 7486): Outputs HIGH when inputs are different.
XNOR Gate (IC 74266): Outputs HIGH when inputs are the same.
BUFFER (IC 7417): Used to strengthen signals without inverting them.

These ICs are widely used in digital electronics for computations, signal processing, and circuit design.

Operational Amplifier Detection: An op-amp is tested in a voltage follower configuration:

$$Gain\ is\ A = \frac{V_{out}}{V_{in}} \quad (5)$$

$$A_v = \frac{V_{out}}{V_{in}}$$

The voltage gain is given by:
Ideally, Av = 1 for a unity gain buffer.

Transistor Detection: Transistors, including Bipolar Junction Transistors (BJTs) and Metal-Oxide-

Semiconductor Field- Effect Transistors (MOSFETs), are identified based on their electrical behavior.

MOSFET Detection:

$$ID = K(VGS - Vth)2 \tag{6}$$

$$VDS = VDD - IDRD - IDRS \tag{7}$$

Where ID is the drain current, K is a constant, VGS is the gate-to-source voltage, and Vth is the threshold voltage. However, using Arduino Uno, the values VD and VS can be obtained directly from analog pins, thus:

$$MOSFET = VDS = VD - VS \tag{8}$$

The transistor under test (TUT) is being examined, and a table is created for the detection of NMOS or PMOS transistors in MOSFET operation across different regions. So, from the analog value obtained from Uno, the code algorithm is programmed

Table 3. MOSFET Testing and Identification Table

Region	NMOS	PMOS	State
Cut-off	VGS < Vth, ID = 0A	VSG < Vth, ID = 0A	Transistor OFF
Triode	VGS > Vth, VDS < (VGS −Vth)	VSG > Vth, VSD < (VSG −Vth)	Linear Region (Amplifying)
Saturation	VGS > Vth, VDS > (VGS −Vth)	VSG > Vth, VSD > (VSG −Vth)	Fully ON (Switching)

In such a way that if all of these conditions are satisfied, the transistor (nmos or pmos) is detected and tested, refer Table 3.

Bipolar Junction Transistor (BJT) Detection

$$hFE = \frac{IC}{IB} \tag{9}$$

$$VCE = VCC - ICRC - IERE \tag{10}$$

However, using Arduino Uno, the values can be directly measured, VC and VE, thus:

$$BJT = VCE = VC - VE \tag{11}$$

The transistor under test (TUT) is being examined, and a table is created for the detection of NPN or PNP transistors in BJT operation across different regions. So, from the output value obtained from Uno, the code algorithm is programmed in such a way that if all of these conditions are satisfied, the transistor (npn or pnp) is detected and tested, refer Table 4.

Table 4. BJT Testing and Identification Table

Region	NPN	PNP	State
Cut-off	VBE = 0V , VCE ≈ 5V ,	VBE = 0V , VCE ≈ 5V ,	Transistor OFF

	IC = 0A	IC = 0A	
Active	VBE = 0.6 – 0.7V , VCE = 0.2 – 5V , IC = hFEIB	VBE = 0.6 –0.7V , VCE = 0.2–5V, IC = hFEIB	Linear Region (Amplifying)
Saturation	VBE = 0.6 – 0.7V , VCE ≈ 0.1 – 0.3V , IC = IC (Max)	VBE = 0.6–0.7V , VCE ≈ 0.1–0.3V , IC = IC (Max)	Fully ON (Switching)

These components (except IC's) can be placed in either orientation, as the CT-07 is designed to check for both forward and reverse connections, ensuring accurate identification regardless of polarity. This comprehensive approach ensures that electronic components are correctly identified in CT-07, enhancing reliability and ease of use.

Hardware Implementation

The hardware implementation was executed in stages to facilitate troubleshooting and optimization.

Component-wise Testing

Initially, each component was tested individually to ensure correct functionality. Breadboards were employed to set up basic testing circuits for resistors, capacitors, transistors, and diode.

Integration and Optimization

After successful individual tests, all circuits were integrated onto a single breadboard. Optimizations were carried out to reduce wirings, noise, improve accuracy, and ensure seamless interaction among components. Image documenting the optimization of circuit in the breadboard is shown in Figure 6.

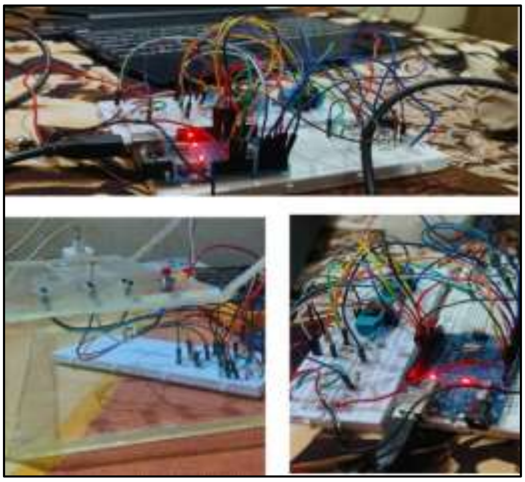

Figure 6. Hardware Implementation on a Single Breadboard during the Optimization Phase

Software Development

The software component involved extensive coding in Arduino IDE, with the software consisted of over 1100 lines of optimized Arduino C++ code, handling detection, measurement, and display functionalities, to reduce execution time and improve system response. To maintain brevity, only the logical flow and key.

Functions are Discussed

Component Detection: Automated identification of component type based on input readings.
Measurement Algorithms: Accurate measurement of resistance, capacitance, transistor gain, and other parameters through analog GPIOs.

Conversion Algorithms: Conversion of raw analog readings into meaningful electrical parameters.
Decision and Control Algorithms: Logical decision-making to validate component behavior and control hardware interactions.
Display Output: Processed results displayed on an LCD screen for real-time feedback.

Body Design and Fabrication

The initial body design was modeled using CAD software's to visualize the final prototype, as shown in Figure 7.

Figure 7. Early CAD Design of CT-07 Body

However, due to budget constraints, the design was adapted for glass fabrication using a laser cutting machine, as shown in Figure 8 the glass body provided sufficient rigidity while maintaining cost efficiency.

Figure 8. CT-07 Final Body Design

Assembly

Assembly involved integrating all hardware components into the fabricated body. Proper cable management and insulation were prioritized to prevent short circuits. After assembly, rigorous inspections were carried out to ensure reliability. The assembled prototype can be seen in Figure 1.

Testing and Calibration

The final stage involved comprehensive testing of the assembled prototype. Each component type was tested repeatedly to ensure consistency in readings. Calibration was performed using reference components to maintain accuracy. The test results indicated a high level of precision, validating the system's efficacy. And the final prototype, CT-07 was made as shown in the Figure 1.

Result

The CT-07 was extensively tested across various electronic components to ensure accuracy and efficiency. The device successfully analyzed analog components such as resistors, capacitors, diodes, and transistors, along with digital components like ICs and logic gates—all without manual intervention.

Following the prototype assembly, an initial large-scale test was conducted on 100 randomly selected components within 80 seconds, revealing that 85% were functional while 15% were defective or undetected. This trial is labeled as Test-1 for reference. Subsequent verification using other testing tools confirmed the same results. The results are as shown in Figure 9.

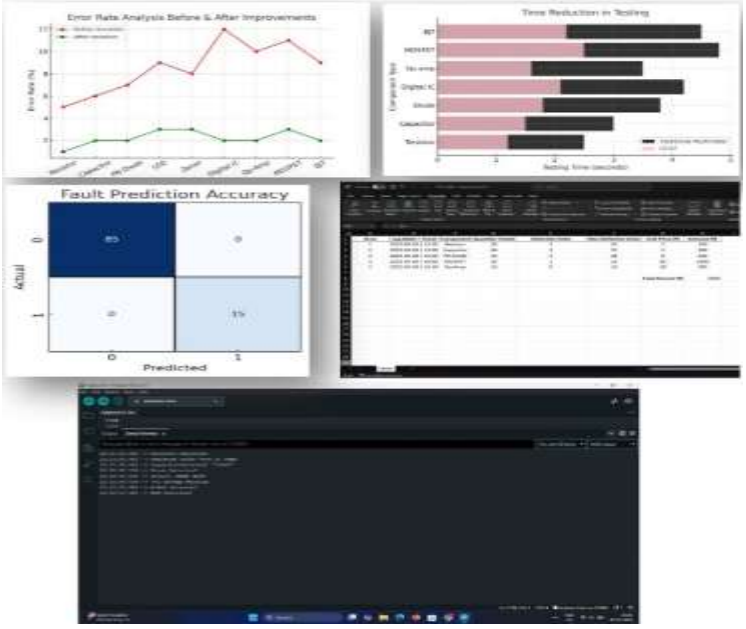

Figure 9. CT-07 Results of Test-1

As testing progressed, CT-07 was actively used in our college laboratory and later extended to nearby technical institutes. Feedback from students and professionals confirmed that the device is user-friendly, significantly reduces troubleshooting time, and enhances the learning experience. Performance analysis showed that CT-07 reduced testing time by 15%–25% compared to traditional multimeters and component testers, while maintaining an error rate of less than 0.01% in resistance and capacitance measurements.

Discussion

CT-07 was found to be helpful in component testing, reflecting consistent results across various test environments. Nonetheless, there is always more that can be done. The succeeding version could greatly improve with wiser technologies.

One of these concepts is to apply machine learning. If the system was able to learn from the test findings over time, then it could become more effective at detecting slight faults that are simple to overlook. And introducing AI to predict when a part may fail, Even before it fails, may revolutionize how maintenance is performed.

The results indicate that CT-07 is a good and functional electronic component tester. However, further development can be accomplished to enhance its functionality:

Machine Learning (ML): Utilizing ML algorithms for the analysis of test data, pattern identification, and improvement of Fault detection.

Artificial Intelligence (AI): Offering predictive diagnostics to recognize component degradation before failure.

Wireless Connectivity: Adding Bluetooth/Wi-Fi for remote operation and real-time cloud storage of test data.

Programmable Test Sequences: Allowing the user to automate advanced test scenarios and create personalized test patterns.

Self-Calibration and Auto-Diagnosis: Designing a brilliant self-calibrating mechanism to minimize human intervention and achieve high-precision testing.

Miniaturization and Capacitance Expansion: Reducing the device size while implementing support for

additional components.
Advanced Test Modes: Implementing adaptive stress testing, in-circuit analysis, and artificial intelligence fault injection to predict failures and enhance diagnostic accuracy.

Challenges Faced

As in any project in the real world, development of CT-07 did have its share of issues. A few of them were anticipated; others were unexpected. Despite its success, CT-07 experienced several issues throughout development, some of which are listed. First, theoretical calculations were not always aligned with field results, where adjustments such as the offset were made to achieve correct readings. The measurement values fluctuated randomly with time, leading to inconsistent readings that needed to be stabilized. Two-way communication between two Arduino UNOs and the display was problematic in the initial stage, and amazingly two LCD screens were found to be damaged when all three were combined. The system's reliability was also random, something that would work on a particular day would not work on another day, until multiple tweaks and troubleshooting solved the issue. Budget constraints gave another blow, as the estimated cost was Rs. 5,000 but the actual cost reached nearly Rs. 7,000 in terms of component replacement and upgrades that were not expected. Also, there were cases where in certain places, on testing, the device did not function as expected, requiring recalibration and multiple algorithm adjustments before it could achieve stable operation. Fixing these has made CT-07 a significantly better testing solution from the performance perspective, having turned more robust and dependable.

5. CONCLUSION

The CT-07 represents a transformative advancement in electronic component testing by integrating both analog and digital component analysis into a single, automated, and high-precision system. Designed to address the inefficiencies of traditional testing methods. The system significantly reduces testing time while maintaining an exceptionally low error rate, system's intuitive graphical interface and real-time data logging facilitate easy operation, the logging facility is shown for reference in Figure 10 when CT-07 is operating in Component Procurement Mode.

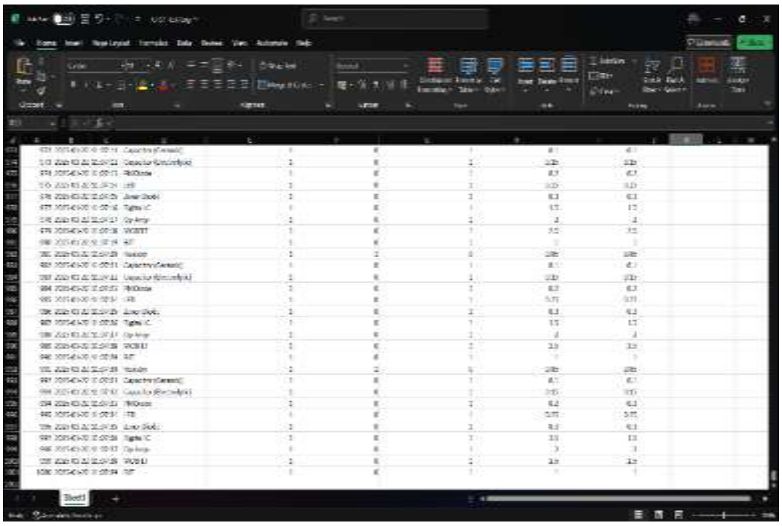

Figure 10. Log Output

The device has several testing modes, including Normal Testing mode which facilitates rapid defect evaluation, and Component Procurement Mode that optimizes procurement and testing for large scale testing. Testing CT-07 extensively showed its c apabilities when analyzing a set of 100 randomly selected components within 80 seconds. It achieved 99% accuracy in measuring resistance and capacitance. These findings stand accurate after comparative analysis with accepted laboratory equipment. The incorporation of CT-07 in educational setups improved the practical learning experience multit-fold, as students could achieve complete recording and measurement within reduced troubleshooting time which is 15% to 25% less than the time spent using traditional multimeters and component testers.

The capability of CT-07 will further be improved by future enhancements, like fault detection, wireless connectivity, auto-calibration, and additional component compatibility. As designed, the CT-07 addresses the problem of component testing in resource constrained environments, providing a local solution to a local problem. Its efficiency, accuracy and simplicity make it a powerful yet affordable advanced testing solution for academia, research, and industry.

Acknowledgments

The authors sincerely thank the Department of Electronics and Communication Engineering at The National Institute of Engineering, Mysuru, for providing the necessary resources, technical support, and laboratory facilities throughout the development of CT-07. We also acknowledge the valuable inputs from faculty mentors and technicians whose feedback helped in refining the design and improving the accuracy of the system. Special thanks to the students and staff who participated in the testing and validation process of the prototype.

Funding Information

This research was self-funded by the authors and did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Development costs were collectively managed and supported by the student authors with minor in-kind support from the host institution for component access and laboratory usage.

Author Contribution Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper. All contributions and results have been presented with transparency and objectivity, with no competing financial or personal relationships that could have influenced the work reported in this study.

Informed Consent

Not applicable. This study did not involve human participants or animal subjects. Therefore, no informed consent was required or obtained.

Ethical Approval

This project involved the development and testing of an electronic system and did not require ethical approval from an Institutional Review Board (IRB). All procedures were conducted in accordance with academic guidelines and institutional safety protocols.

Data Availability

All data generated or analyzed during this study are included in this published article. Additional supporting information such as circuit schematics, source code, test results, and raw component measurements can be made available by the corresponding author upon reasonable request.

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How to Cite: Bhargava Dantapur, Aman Gupta, Dakshit Shringi, Kundan Kumar, Dr. S. Parameshwara. (2025). Efficient component procurement system for analog-digital components. Journal of Electronics, Computer Networking and Applied Mathematics, 5(1), 16–32. https://doi.org/10.55529/jecnam.51.16.32

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