iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72008

Boolean Algebraic Calculator

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Abstract: Boolean Algebra stands among the most widely recognized technique used especially in computer science and electrical engineering. This branch largely relates to subjects such as digital logic design, circuit optimization, and computational problems resolution. This is basically the drive behind the present assignment: To develop an Algebraic Boolean calculator capable of accepting any standard user input for analysing and simplifying Boolean expressions. Two salient features of this calculator are the Simplification Mode and the Solving Mode. In the Simplification mode, the input is a Boolean expression, and the output is the possible simplified forms of equivalent expressions. This, in turn, is helpful in optimizing digital circuits because the reduction would lessen the required number of logic gates, thus making the design more efficient. In contrast, the Solving mode will evaluate Boolean expressions with variable values as conferred by the user. It performs logical operations to crunch numbers at an extremely fast speed. This mode will, therefore, be used to assess a particular circuit/function, make a truth table, and implement real-time Boolean evaluation. Hence, two modes combined make this Boolean Algebraic Calculator an utmost evaluator to digital electronics, logical circuit designing, and computation logic students, scholars, and practitioners. It enhances the productivity of Boolean function analysis, says "as easy as ABC" to solving problems and building up to a viable design option for logical systems.
Keywords: Boolean Algebra, Simplification Mode, Solving Mode, Logic circuit design, Problem Solving.

I. INTRODUCTION

A Boolean Algebraic Calculator is a device used for the completion of logical operations and the simplification of Boolean expressions through algebraic laws. It operates with binary values of 0 and 1 and has logical operators such as AND, OR, and NOT, which come into creating and analyzing digital circuits. The calculator helps one in minimizing complex logic functions, generating truth tables, and determining the circuit behavior. The importance of this program is in its ability to assist in accuracy, reducing design time, and learning applications in digital electronics, computer science, or embedded systems skills in which Boolean logic retains importance.

The work of Ajmal and Nisanth is based on the development of a Boolean Expression Calculator that can be used in the simplification and solving of complicated Boolean expressions[1]. Their implementation used simple digital electronics components to design a system to evaluate Boolean logic with efficiency, to fast-track the circuit design and accurately. This paper would provide a foundation for our project to understand the core logic simplification process. We intend to extend the Boolean Algebraic Calculator by adding implementational improvements in algorithmic simplification, with another part of the user interface that allows the user to input expressions and obtain minimal forms more accurately and at a higher speed. Thereby the system becomes more useful as an educational tool for those engaged in digital logic applications.

In digital circuit design, in fact, Boolean algebra is the crucial tool that involves operations such as AND, OR, and NOT for simplification or analysis of the logic circuit. Logicly [2], therefore, is a software tool that can be used for designing, simulating, and validating logic circuits; hence, it's a handy tool to help model and simulate Boolean expressions. Simplifications of logic can be checked with the aid of truth tables by validating the logic circuits against these tables; in this way, one can be sure of the correctness and reliability of a logical simplification.

The provision of a visual and interactive medium through Logicly aids the grasp of the concepts of Boolean algebra. This makes the software very helpful for instructing and learning digital logic design. The software generates reliable and consistent output, and users can execute tests and validations on logic circuits. This approach aids in the simplification of Boolean expressions and the validation of circuit designs, ensuring that the simplifications and transformations utilized are correct and optimized in practice.

Boolean function simplification is significant in digital logic design to reduce the number of circuits. Petrick's Method is an exact method of minimizing Boolean functions, especially for two-level circuits, by resolving from the minimum product-of-sums form[3]. An educational tool has been developed to automate this process and thus help the user easily simplify Boolean expressions. This tool takes the burden of calculating away from the user and helps in understanding various simplification techniques. It produces optimal Boolean expressions, course minimizing the number of logic gates used, hence improving efficiency of the circuit.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

II. BOOLEAN ALGEBRAIC CALCULATOR

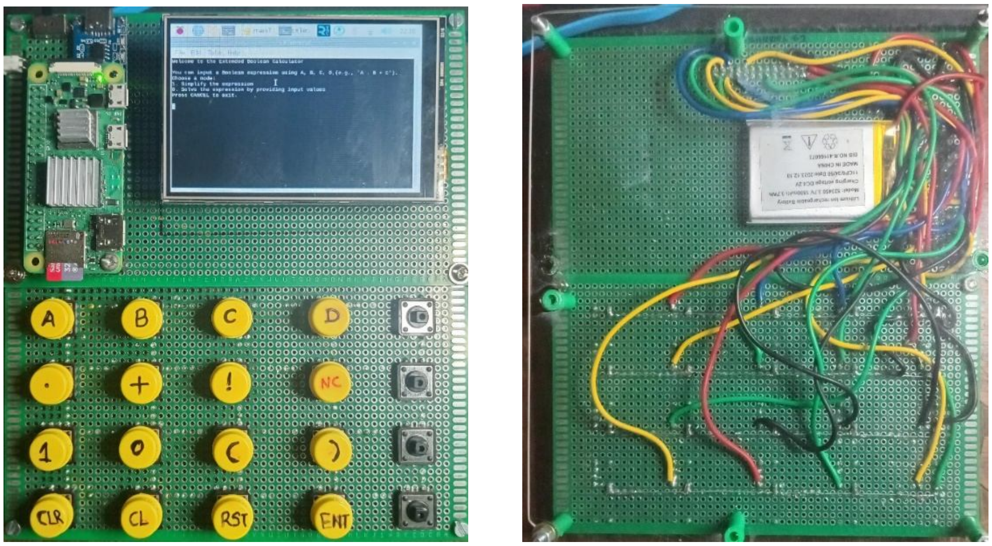

Fig. 1 Boolean Algebraic Calculator

The input section encompasses a 4x4 keypad serving as a primary input means for Boolean expressions. It is designed to allow users to enter operations like AND, OR, NOT, XOR, and other basic Boolean functions[2]. Each key is detected and sent as a signal for processing, giving users the ability to enter and modify Boolean equations. The keypad guarantees smooth user interaction, allowing for quick entries and adjustments.

The central component for control and display is powered by a Raspberry Pi Zero W. At a higher level, the module accepts Boolean expressions, carries out the related logic operations on them, and finally simplifies them using the algorithms encoded within. Essentially, the Raspberry Pi has a script that takes as input Boolean expressions, applies various simplification techniques, and computes a final answer.

Once all those computations are completed, the output is pushed to an LCD display, thereby providing near real-time feedback. Such feedback guarantees that users see their input expressions, intermediate steps, and final results clearly displayed on screen. Additionally, this small footprint of Raspberry Pi Zero W contributes to keeping the system compact and a little cheap computationally while readily carrying out complicated Boolean simplifications. Future upgrades could have cloud-based computation, remote access, or extended data-storage allegiance, bringing enhanced functionality and accessibility.

The system is equipped with an exclusive power supply unit to ensure stability and portability across the entire setup[4][5]. It consists of a USB charger, a TP4056 module, and 18650 lithium-ion battery. The TP4056 module charges the 18650 lithium battery so that the system can run for an extended time without being plugged in. The boost converter maintains a steady voltage at the output to power the Raspberry Pi Zero W, allowing for stable performance. Since both the keypad and the LCD display are powered directly from the Raspberry Pi Zero W, no extra power sources are required, thereby adding to the system's portability and ease of use. Such a power management system stands for efficient operation and, hence, makes the calculator truly useful in the classroom as well as for on-the-go learning.

The Boolean Algebra Calculator is a system that operates under closed loop; hence, there is continuous interaction between the user and the calculator. Users type in Boolean expressions through the keypad, and these inputs are tested by the Raspberry Pi in simplification and logical operations[1][2]. The resulting answers are displayed clearly and simultaneously on the LCD display for the users, so they can change their expressions or enter new ones, fostering a completely interactive process. This design enables quick application of the calculator by students and professionals for education or practical purposes[2][5]. The portability and self-contained nature of the system make it ideal for learning Boolean algebra, testing logic circuits, and simplifying Boolean expressions in engineering and computer science.

The Boolean Algebra Calculator is a well-organized system that combines key functional elements to offer a productive and intuitive user experience.

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III. EXPERIMENTATION

A Raspberry Pi Zero 2 W-based Boolean calculator computes results based on binary inputs using digital logic operations like AND, OR, NOT, and XOR. Either a 3.5-inch touch screen LCD display with a graphical user interface or tactile push buttons are used to provide these inputs. A simple Python application on the Raspberry Pi reads user input, makes logical calculations, and outputs the results on the screen. A 3.7V 1800mAh Li-Po rechargeable battery powers the system and is connected via a TP4056 charging module for secure charging and safeguarding. The Raspberry Pi Zero 2 W typically uses 250–300mA of current, while the LCD display draws 150–200mA, for a total of 400–500mA.

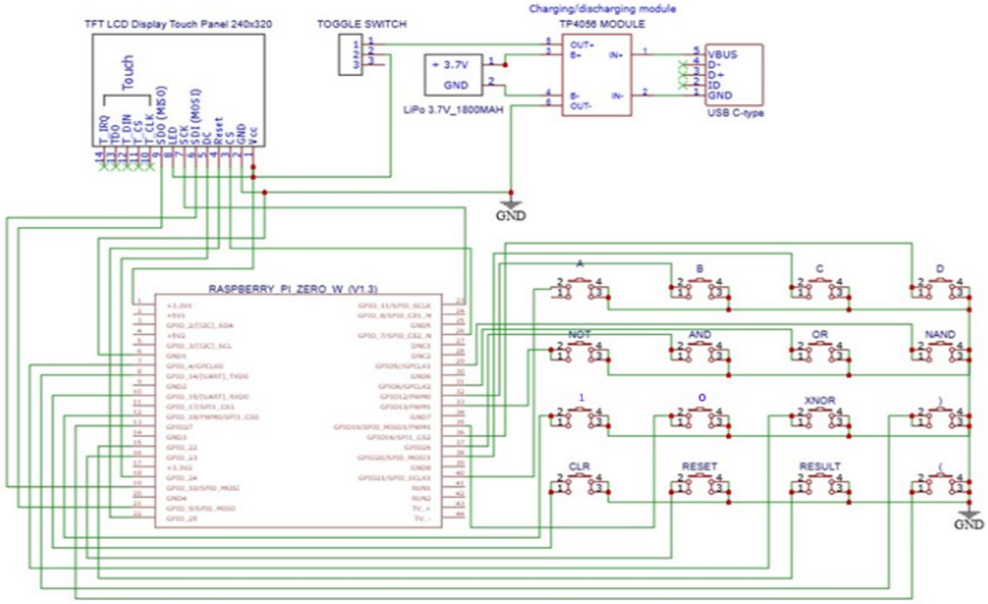

Fig. 2 Schematic diagram of Boolean Algebraic Calculator

A Boolean calculator based on the Raspberry Pi Zero 2W (v1.3) and powered by a 3.7V 1800mAh Li-Po battery connected via a TP4056 charging/discharging module is depicted in this circuit diagram. Through a toggle switch, the TP4056 provides the Raspberry Pi with controlled power and guarantees safe charging. To select operations and view results, a TFT LCD touch display (240x320) is connected to the Pi's GPIO pins and functions as both an input and output interface. Along with control buttons for CLR (Clear), RESET, and RESULT, the Pi is also wired to a set of tactile push buttons that represent binary inputs (A, B, C, and D) and Boolean functions like NOT, AND, OR, NAND, NOR, XOR, and XNOR.These switches transmit signals to particular GPIO pins, which the Pi reads and uses to carry out software-coded logic operations. After processing the logic, the Raspberry Pi displays the results on the touch screen. The entire system is constructed on a 9x15 cm universal PCB board, and passive cooling may be accomplished with heatsinks. To satisfy the Pi's and LCD's power needs, the XY-016 step-up module raises the battery voltage to 5V. With both hardware and touchscreen input, this configuration provides a small, interactive Boolean calculator.

IV. OBSERVATIONS

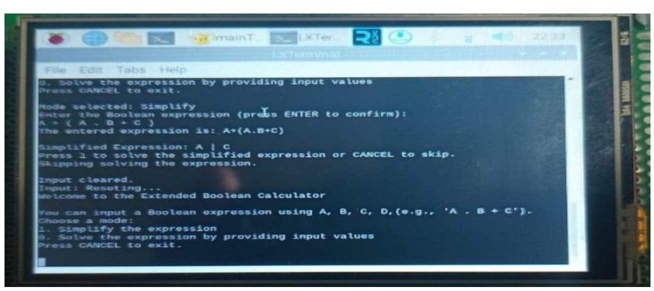

Fig. 2 Schematic diagram of Boolean Algebraic Calculator

The user has entered the Boolean expression A*(A+B*C) and chosen the "Simplify" mode in the session that is displayed. The program has successfully processed the input and reduced the expression to A | C, proving that the logic simplification algorithm is operating as intended. Additional instructions are also displayed on the terminal, such as how to solve expressions by entering binary values and switch between modes like evaluation and simplification. This demonstrates that the Raspberry Pi is correctly managing input/output operations, carrying out calculations using Boolean logic, and presenting the results in real time through the touch screen interface. Because it walks the user through each step of the calculation process in detail, the system is both accurate and easy to use.

V. CONCLUSION

The Boolean Algebraic Calculator is a small, interactive learning aid that evaluates and simplifies Boolean expressions using a Raspberry Pi Zero W, a 4x4 keypad, and an LCD display. It helps reinforce concepts in digital logic and Boolean algebra by enabling users to perform logical operations like AND, OR, and NOT. It is intended for students, educators, and electronics enthusiasts. The system is portable and can be used in labs, classrooms, or while on the go thanks to its USB-C compatible rechargeable lithium-ion battery. It is simple to enter expressions and view results thanks to the user-friendly interface provided by the physical keypad and real-time display. It provides a useful platform for experimenting with logic gates, truth tables, and expression simplification outside of the classroom.

The project is scalable and an interesting way to learn basic computing concepts because it also provides space for future improvements like digital circuit simulation or support for Karnaugh maps.

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