Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.10 n.45, p. 11-16. Jan/Feb, 2024

DOI: https://doi.org/10.5935/jetia.v10i45.1015

RESEARCH ARTICLE OPEN ACCESS

DESIGN AND IMPLEMENTATION OF AN INTELLIGENT ELECTRONIC PROJECT SIMULATOR BOARD

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ARTICLE INFO

Article History
Received: December 31th, 2023
Revised: January 23th, 2024
Accepted: January 25th, 2024
Published: February 29th, 2024

Keywords:
Circuit simulations,
Educational institutions,
Electronics enthusiasts,
Electronic project board,
Engineering students.

ABSTRACT

The increasing demand for a versatile electronic project board led to the creation of an innovative solution by a dedicated team. This device was meticulously designed to serve the needs of educational institutions, students, and electronics enthusiasts. The existing challenge in this field was the absence of a comprehensive project board capable of supporting complex circuit simulations. Traditional setups lacked crucial features like power supplies, waveform generation, and digital tools, limiting the effectiveness of electronic circuit exploration. The study aimed to address these limitations by developing an electronic project board with an 18W audio amplifier, a versatile function generator, and robust AC and DC power supplies with short circuit protection. Additionally, it incorporated a solderless breadboard, digital oscilloscope, and Arduino Uno board, expanding its utility to Internet of Things (IoT) applications. The board's design included key components such as the LM386 low-power audio amplifier IC, the TL082 dual JFET input operational amplifier, linear voltage regulators, resistors, diodes, capacitors, jack plugs, flexible cables, and a well-connected breadboard. The resulting project board successfully met the specifications, offering a comprehensive solution for electronic circuit simulation. Its adaptability, safety features, and IoT compatibility make it invaluable for both educational and domestic use. In conclusion, this newly developed electronic project board fills a critical gap in electronics experimentation and education. It is recommended for tertiary institutions and students' personal projects, providing a versatile tool for circuit design exploration. Future enhancements could further extend its utility in various applications.

I. INTRODUCTION

Globally, education has evolved from an instructor-centered to a student-centered approach, with the goal of encouraging independence, practicality, and self-reliance [1 - 2]. Experiments and laboratory work are essential components of engineering education and play an important role in curriculum delivery. However, the quality of education delivered in any engineering curriculum is strongly dependent on the correct execution of practical material [3]. As a result, participating in practical experiments improves students' ability to conduct experiments, collaborate within a team, and communicate effectively in order to demonstrate the practical application of theoretical concepts [4 - 6]. Consequently, in the realm of electrical electronics engineering, the significance of practical knowledge cannot be overstated. One recurring issue faced by engineering students and electronic enthusiasts is the need to visit a laboratory to access equipment like function generators, audio amplifiers, and variable power supplies

[7]. These hurdles have deterred many from engaging in multiple projects and practical experiments simultaneously. While electronic project boards are widely embraced in developed countries [8]. Nigeria and Africa at large have been slow to adopt this mobile solution. This disparity is a significant factor contributing to the lag in electronic development in the region. Upon careful consideration of these challenges, the concept of creating a mobile electronic project board was conceived. Apart from its portability, this project offers a cost-effective alternative to traditional electronic laboratories. One notable advantage of this mobile lab is its compatibility with both direct current and alternating current, making it more versatile than the predominantly alternating current-based traditional labs. Furthermore, it incorporates a frequency generator, an audio amplifier, an Arduino Uno development board, a breadboard, and a multimeter, among other valuable resources. In Nigeria's higher education institutions, the shortage of testing equipment in laboratories has dampened interest in electronic practicals among students and lab technicians [9 – 10]. This scarcity is attributed to the high cost of acquiring equipment and the fragility of imported models. Additionally, frequent power outages across the country hinder technological advancements. Moreover, the limited portability of equipment in traditional labs hinders experimentation and idea exploration. This project aims to alleviate these challenges by providing an uninterrupted power supply and essential equipment typically found only in electronic laboratories, including function generators and audio amplifiers.

II. MATERIALS AND METHODS

The design of the smart electronic project simulation board has four sections, which are the power supply, function generator, audio amplifier, and IoT (internet of things) section.

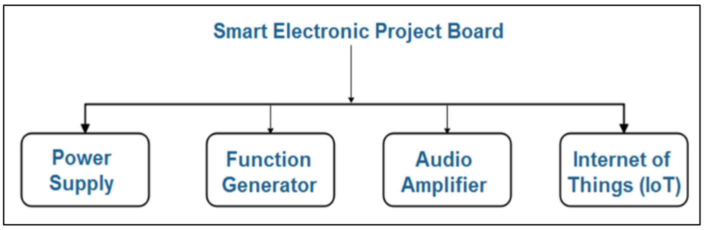

Figure 1: Block diagram of an electronic project board.
Source: Authors, (2023).

In order to have a full and detailed design analysis, each section is being analysed as a unit:

II.1 THE POWER SUPPLY SECTION

The power supply section of this innovative electronic project board plays a pivotal role in its functionality. It offers both direct current (DC) and alternating current (AC) capabilities, providing users with versatile energy sources for their experiments [11 - 12]. This feature distinguishes it from traditional labs that predominantly rely on AC power. Additionally, the inclusion of short circuit protection enhances safety, ensuring the reliability of the equipment and encouraging experimentation with confidence.

II.1.1 The AC Power

The AC power supply in this electronic project board is a vital component, sourced directly from the transformer's secondary winding, offering various taps for flexibility. This feature allows users to access a range of AC voltages, catering to different experiment requirements. It enhances the versatility and adaptability of the board for various applications.

II.1.2 The DC Power section

The DC power supply in this electronic project board is a versatile resource, offering adjustable output voltages from 2 to 28 volts. This wide voltage range accommodates diverse electronic circuit requirements, providing users with precise control over their experiments. It empowers experimentation with a broad spectrum of devices and configurations.

II.1.2.1 The voltage doubler circuit

The voltage doubler circuit is an ingenious electronic configuration that effectively doubles the input voltage. It's commonly used in power supply circuits to provide higher voltage levels. By utilising capacitors and diodes, it efficiently converts AC or pulsating DC into a higher DC voltage.

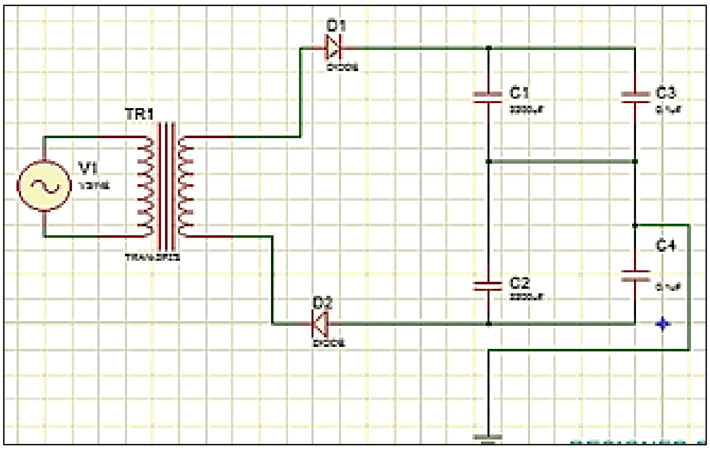

Figure 2: Voltage doubler circuit.
Source: Authors, (2023).

II.1.2.2 Linear Regulators

Linear regulators are crucial components in electronics, used to stabilise and regulate voltage levels. They efficiently reduce high and varying input voltages to a consistent, low, and precise output. This ensures a steady power supply for sensitive electronic components. Linear regulators are commonly found in various applications, from power supplies to microelectronics.

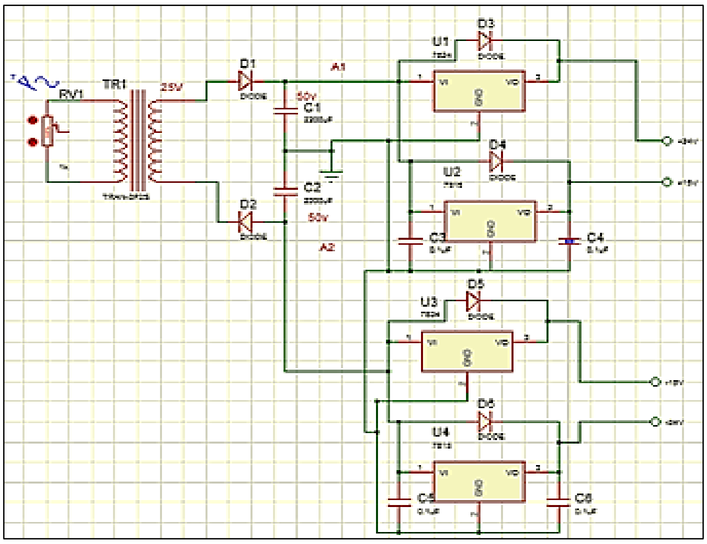

Figure 3: Fixed positive linear voltage regulators.
Source: Authors, (2023).

II.1.2 The function generator

The function generator is a fundamental tool in electronics, serving as a versatile waveform source. It produces a range of waveforms such as sine, square, and sawtooth, making it essential for various electronic experiments and testing [13]. Its adjustable frequency feature allows users to generate signals at desired frequencies, aiding in circuit analysis and development. The function generator's capacity to simulate different waveforms is invaluable for troubleshooting and exploring electronic circuit behaviour.

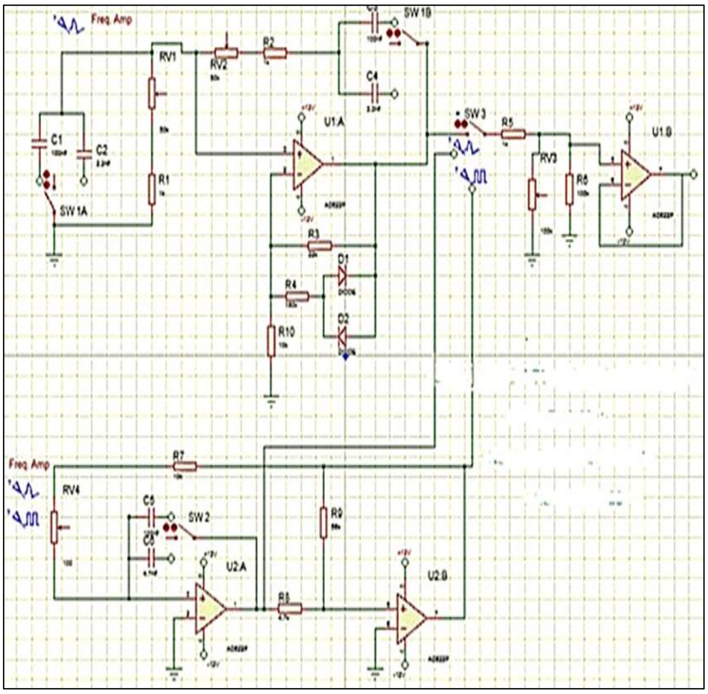

Figure 4: Schematic diagram of the frequency generator.
Source: Authors, (2023).

II.1.3 The Audio Amplifier

The audio amplifier is a critical component in electronics, designed to boost weak audio signals to a level suitable for driving speakers or headphones. Its primary function is to amplify sound, making it louder and more audible [14]. This is essential in various applications, from home audio systems to public address systems. Audio amplifiers come in various types and power ratings to match specific audio needs, ensuring clear and robust sound reproduction.

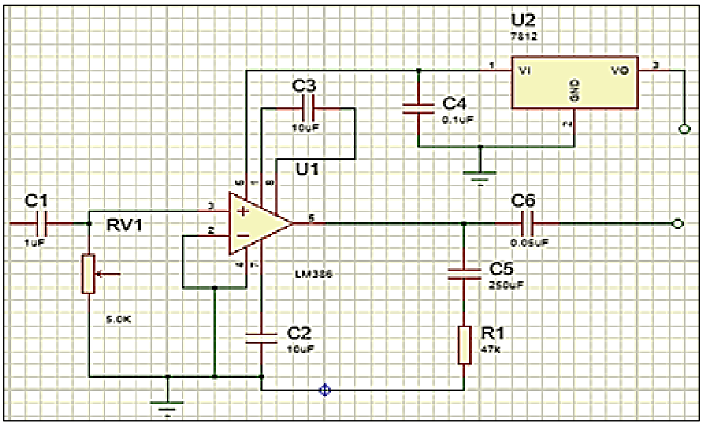

Figure 5: The audio amplifier.
Source: Authors, (2023).

II.1.4 Arduino Uno

The Arduino Uno is a versatile microcontroller board that serves as the brain of countless electronic projects. Its primary function is to control and automate a wide range of devices and systems [15]. Programmed with a user-friendly coding environment, it can read sensors, interact with other hardware, and execute predefined tasks. The Arduino Uno empowers hobbyists, students, and professionals to create custom electronic solutions, from simple LED blinkers to complex Internet of Things (IoT) applications, fostering innovation in the world of electronics [16].

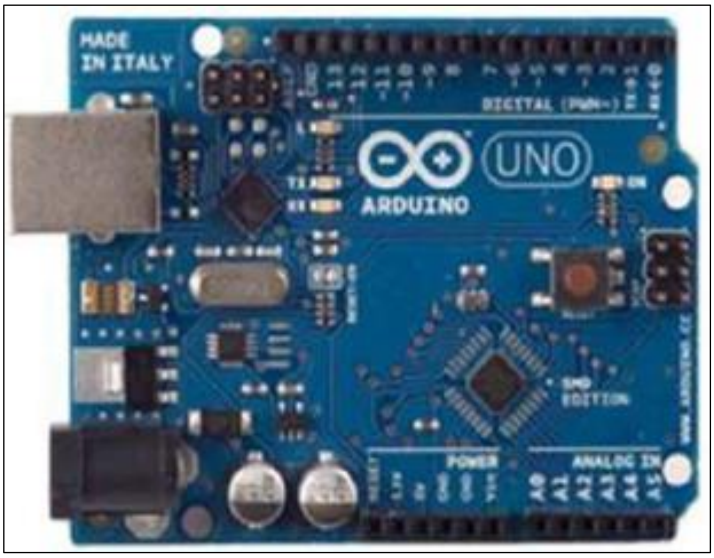

Figure 6: Arduino UNO development board.
Source: Authors, (2023).

III. RESULTS AND DISCUSSIONS

The design and implementation of an intelligent electronic project simulator board successfully met the specified objectives and demonstrated its functionality through rigorous testing and experimentation.

III.1 TESTING

Each segment of this apparatus underwent individual testing both before and after the soldering process. Multiple tests were conducted for each segment, and necessary modifications were implemented to ensure the specified outputs were achieved. The subsequent section provides the outcomes from the conclusive tests conducted on these segments.

Note: All tests were conducted using an input voltage of 220 Vrms.

III.1.1 AC/DC Power Supplies

The board's power supplies, both AC and DC, demonstrated reliability and versatility. The adjustable DC power supply with a range of 2 to 28 volts proved instrumental in accommodating diverse circuit voltage requirements. The regulated ±5V to ±25V DC supply exhibited stability under varying load conditions.

III.1.1.1 A.C Power

The AC power is sourced from an auto-transformer equipped with 11 output terminals, each yielding varying voltages. When the meter is set to 400V AC, the following results were recorded:

Table 1: The output voltages from positive voltage regulator.

Terminals	Voltage Levels (Volts)
Terminal 1	5.85
Terminal 2	9.2
Terminal 3	11.9
Terminal 4	14.5
Terminal 5	23.9
Terminal 6	47.8
Terminal 7	98
Terminal 8	146
Terminal 9	175
Terminal 10	234
Terminal 11	256

Source: Authors, (2023).

Table 1 shows the output voltages from positive voltage regulator at different terminals while Figure 7 depicts an upwards directions of voltage at different terminals of the positive voltage regulator.

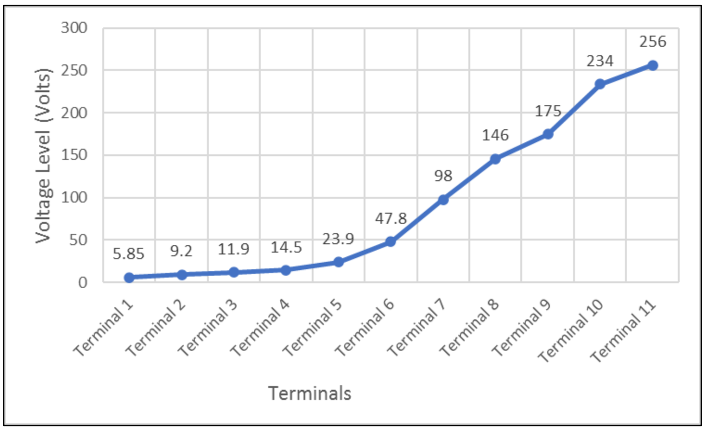

Figure 7: Graph of positive voltage regulator.
Source: Authors, (2023).

III.1.1.2 DC Power

The DC power section produces both fixed and variable supplies. Results obtained from tests carried out on the adjustable positive voltage regulator outputs are shown in Table 2.

Table 2: Adjustable positive voltage regulator outputs.

Input Power Supply	Output Voltages	
	Minimum (Volts)	Maximum (Volts)
Utility Power	1.24	28.1
Backup Power	0	23.4

Source: Authors, (2023).

III.1.2 Function Generator Performance

The function generator component delivered precise waveforms, including sine, square, and sawtooth, with adjustable frequencies. Tests revealed accurate frequency generation across a wide range, enhancing its utility for circuit analysis and experimentation. Table 3 below shows a test result from the function generator displaying the output voltage and frequency.

Table 3: Test result from the function generator.

Waveform	Output	
	Voltage (Volts)	Frequency (Hz)
Sine	± 10	1,150
Square	± 10	1,000
Triangle	± 5	1,000

Source: Authors, (2023).

III.1.3 Audio Amplifier Efficiency

The integrated 18W audio amplifier exhibited excellent performance, amplifying audio signals while maintaining low distortion levels. Audio testing confirmed its ability to produce high-quality sound output for various applications, from signal testing to audio projects.

III.1.4 Digital Tools Integration

The inclusion of a digital oscilloscope and Arduino Uno board enhanced the board's functionality. The oscilloscope provided real-time signal visualisation, aiding in waveform analysis, while the Arduino Uno facilitated IoT applications, showcasing the board's adaptability and future potential.

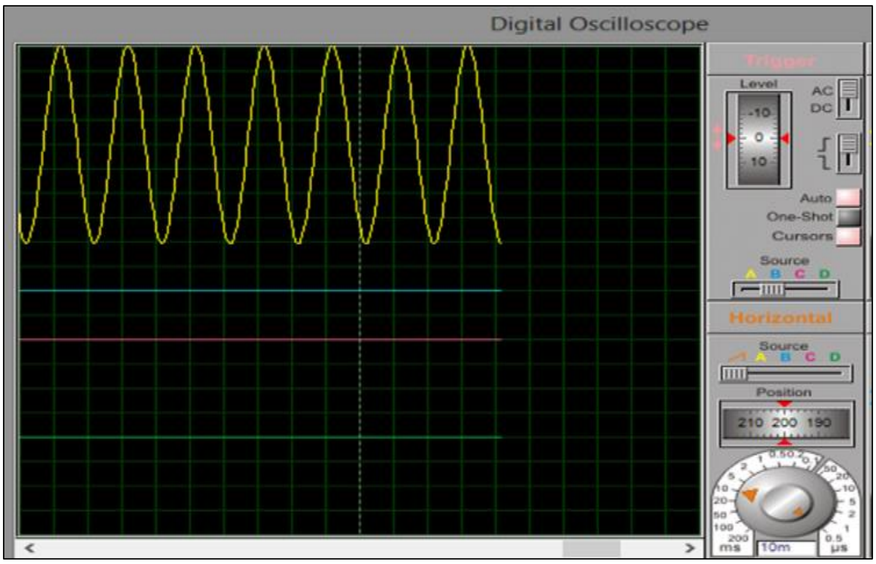

Figure 8: Measurement of the function generator signal.
Source: Authors, (2023).

III.2 CASING

The construction of a casing for electronic equipment holds significant importance, as it plays a pivotal role in either attracting or discouraging the consumer or end user. A superior casing transcends being a mere enclosure; it serves as an aesthetically appealing container, drawing in the intended consumer base. The selection of material for the casing of any electronic equipment demands meticulous consideration, as it must meet fundamental safety standards. Various options such as metal, wood, plastic, and fibers were available for consideration. Additional factors that influenced our material choice encompassed cost, size, weight, and the potential risk of electric shock. Upon weighing these aforementioned factors, we opted for wood as the primary material for crafting the casing. The precise dimensions of the casing are *71cm x 33cm x 30cm* and it is illustrated in Figure 9 below.

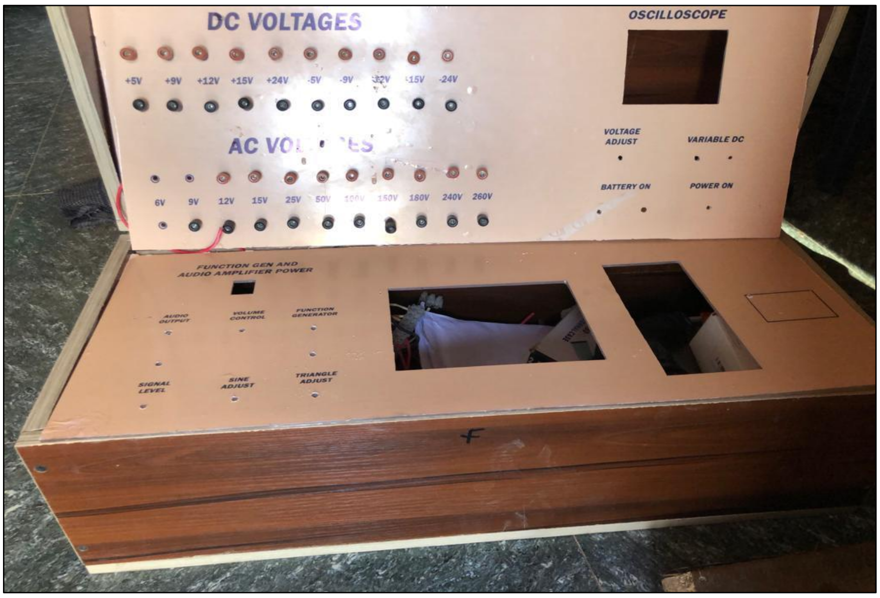

Figure 9: The smart electronic project lab casing.
Source: Authors, (2023).

The results confirm that the Intelligent Electronic Project Simulator Board is a valuable tool for electronics enthusiasts, students, and educational institutions. Its functionality and performance surpass conventional laboratory setups in several ways, some of the which are:

Versatility and Accessibility: The board's comprehensive features, including the function generator, audio amplifier, and digital tools, address the longstanding issue of limited access to essential equipment in electronics education. Its versatility accommodates a wide range of experiments and projects, fostering hands-on learning.

Portability and Cost-Effectiveness: The board's portability and cost-effectiveness make it an attractive alternative to traditional laboratory setups, particularly in resource-constrained environments. Its affordability and compact design enable users to conduct experiments conveniently, even outside the laboratory.

IoT Integration: The incorporation of the Arduino Uno board positions the system at the forefront of IoT development. This opens doors to innovative projects and applications, aligning with the evolving landscape of electronics and technology.

Educational and Practical Impact: The board's potential impact on education and practical application is substantial. It bridges the gap between theoretical knowledge and hands-on experience, encouraging active learning and experimentation.

IV. CONCLUSIONS

The Design and Implementation of an Intelligent Electronic Project Simulator Board represents a significant leap forward in the field of electronics experimentation and education. This innovative board, with its diverse features and capabilities, addresses longstanding challenges faced by students, educators, and electronics enthusiasts alike. By providing a versatile platform for circuit simulation, this project board empowers users to explore and experiment with electronic circuits without the constraints of traditional laboratory setups. Its inclusion of an 18W audio amplifier, function generator, and AC/DC power supplies with short circuit protection ensures that users have the necessary tools at their disposal to conduct a wide range of experiments efficiently and safely. Furthermore, the integration of digital tools such as a digital oscilloscope and an Arduino Uno board for IoT applications adds another layer of versatility and functionality. This enables users to delve into more advanced projects and embrace emerging technologies. The project board's emphasis on portability and cost-effectiveness makes it a practical choice for educational institutions and individuals, particularly in regions where access to sophisticated laboratory equipment is limited. In summary, the intelligent electronic project simulator board not only fills a critical gap in electronics education but also fosters innovation and hands-on learning. Its potential impact on the field of electronics is significant, and it is recommended for adoption in educational institutions and by electronics enthusiasts seeking to expand their horizons. Further refinements and enhancements could propel it to even greater heights in the realm of electronics experimentation and innovation.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Matthew B. Olajide, Najeem O. Adelakun and David S. Kuponiyi.
Methodology: Peter B. Olayioye and Oludipe Toluwanimi.
Investigation: Matthew B. Olajide, Peter B. Olayioye and Oludipe Toluwanimi.

Discussion of results: Najeem O. Adelakun and David S. Kuponiyi.
Writing – Original Draft: Matthew B. Olajide, Peter B. Olayioye and Oludipe Toluwanimi.
Writing – Review and Editing: Matthew B. Olajide and Najeem O. Adelakun.
Resources: Peter B. Olayioye and Oludipe Toluwanimi.
Supervision: Matthew B. Olajide and Najeem O. Adelakun.
Approval of the final text: Matthew B. Olajide, Najeem O. Adelakun and David S. Kuponiyi.

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