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Development of a Power Electronics Experimental Trainer Board for Enhancing Students' Practical Knowledge.

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ABSTRACT

This paper presents the design, development, and implementation of a portable Power Electronics Experimental Trainer Board to enhance the practical understanding of Electrical Engineering Students. Theoretical knowledge or instruction often leaves students unable to understand and apply concepts to real-world electronic circuits. The developed trainer board addresses this issue by providing a hands-on platform for students to conduct experiments on fundamental power electronic circuits. The board's modular design allows easy circuit reconfiguration and safe operation with a low-voltage DC power supply. It includes built-in measurement points for voltage and current, and a user-friendly interface to facilitate learning. Performance evaluation through a pilot study with undergraduate students shows a significant improvement in their practical skills and a deeper comprehension of theoretical principles. The trainer board is a valuable educational tool that bridges the gap between classroom theory and practical application, thereby fostering a more comprehensive learning experience in power electronics.

Keywords: Power electronics, Trainer board, Practical knowledge, Experimental learning, Educational tool

1. INTRODUCTION

When it comes to handling electrical energy, power electronics are crucial. Power electronics currently possess more than 75% of the electrical energy in the globe, and this percentage is expected to rise over the next decades (Ziheng et al., 2024). Power electronics has become a crucial field of study in the quickly developing field of electrical engineering, supporting the creation of contemporary energy systems and technologies. Effective power conversion and control strategies are critical to the integration of electric vehicles, renewable energy sources, and modern industrial automation. (Ana et al., 2021). As these technologies continue to develop, there is a growing need for professionals who are proficient in power electronics and possess both theoretical knowledge and practical experience (Ojo et al., 2023).

There is still a large gap in engineering students' practical skills, especially in power electronics, despite the theoretical knowledge taught through conventional educational techniques. This disparity may make it more difficult for them to apply abstract ideas to practical situations, which may ultimately reduce their employability and productivity (Nair et al., 2020).

A Power Electronics Experimental Trainer Board is created to overcome this difficulty. By giving students real experience with various power electronic components and circuits, this cutting-edge teaching tool (power electronics trainer board) seeks to improve their practical understanding. Students will be able to investigate basic ideas like rectification, inversion, and pulse-width modulation (PWM) in a controlled setting by using this Power Electronics Experimental Trainer Board. Additionally, the trainer board will help close the gap between theory and practice by enabling experimentation with real-time data collection and control systems (Chisunum & Nwadiokwu, 2024).

This paper presents the creation of an experimental trainer board for power electronics with an instructional focus of enhancing students' practical knowledge. In addition to improving students' practical knowledge, the trainer board keeps up with the latest developments in technology and industry standards. This effort aims to develop a new generation of competent engineers prepared to contribute to the changing field of power electronics by bridging the gap between theoretical concepts and real-world implementations.

The power electronics experimental trainer boards have the following advantages;

(i) It allows students to engage directly with the concepts they are studying.

(ii) It helps students to understand how engineering principles are applied in practice.

(iii) It helps students develop essential skills such as circuit design, troubleshooting, and problem-solving. These skills are crucial for their future careers in engineering.

(iv) The trainer boards are designed for educational purposes, thereby providing a safe environment for students to experiment with electrical and electronic components without the risks associated with full-scale projects.

(v) It provides a platform for experimentation, and it encourages creativity and innovation among students, motivating them to explore new ideas and solutions.

(vi) It helps students to quickly test their designs and receive immediate feedback on their performance. This iterative process allows for rapid learning and improvement.

2. Literature Review

It is impossible to overstate the value of employing experimental trainer boards for practical knowledge in engineering education, especially in power electronics. There is an urgent need for educational learning resources that can close the gap between theoretical ideas and real-world applications as the field of power electronics develops further due to technological breakthroughs and growing energy source integration. Compared to conventional theoretical approaches, experimental trainer boards have an impact on concept mastering and knowledge retention.

It specifically attempts to help students retain electrical engineering concepts over time and assesses how various approaches aid in the growth of practical engineering abilities, emphasizing the improvement of students' practical knowledge (Dofe & Kurwadkar, 2021). In addition to improving students' comprehension, using an experimental trainer board for practical exercises helps them develop their critical thinking and problem-solving skills (Johnson & Lee, 2022).

The integration of the experiential experimental trainer board in practical learning has effectively bridged the gap between theory and practice (Mai, 2025). According to Mai's 2025 research, adding more power electronics experimental trainer boards to practical assignments can greatly enhance students' comprehension of real-world applications. According to some recent research, creating experimental trainer boards is a good way to improve hands-on power electronics education. These boards typically include various components such as converters, inverters, and controllers that allow students to conduct experiments and observe real-time results (Almeida et al., 2022).

3. Methodology

For a better understanding, the methodology used for the power electronics experimental trainer board is presented in the form of a block diagram shown in Figure 1. The model consists of three (3) fundamental units: a power supply unit, the electronic components compartment unit, and the display output unit.

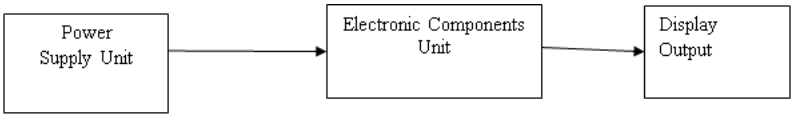

Figure 1: Power Electronics Experimental Trainer Board

3.1 Power Supply Unit

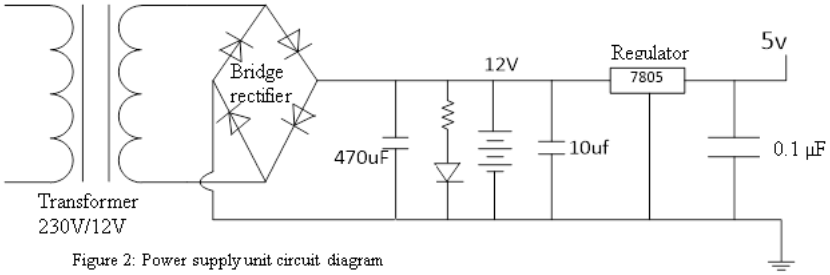

Figure 2: Power supply unit circuit diagram

The power supply unit supplies the necessary voltage and current to run the entire system. It accomplishes this by converting alternating current (AC) to

direct current (DC). Figure 2 shows the circuit diagram of a power supply unit in which a transformer converts the AC supply (230V) to a lower voltage (12V). The bridge rectifier transforms a 12V AC voltage into a pulsing DC voltage. The main function of the 470µF capacitor is to eliminate ripples from the pulsing DC. The regulator (7805) is a series power regulator that converts 12V DC to 5V, which is needed to run the entire control unit. When the mains AC supply fails, the 12V battery source is used to provide backup power to the system. The other capacitors (0.1F) ensure that the DC power output to the control unit is stable.

3.2 Electronic Components Unit

This section or compartment consists of various electronic components used for different experiments. These electronic components are widely used in power electronics and various applications in electrical engineering, and they include;

(i) Capacitors of different ranges.

(ii) Resistors of different ranges.

(iii) Diodes

(iv) LED (Light-emitting diode)

(v) Potentiometer

(vi) Buck and boost converter

(vii) SCR (Silicon controlled rectifier)

(viii) MOSFET (Metal oxide semiconductor field effect transistor)

(ix) IGBT (Insulated gate bipolar transistor)

The main purpose of different ranges of electronic components is to allow a wide range of different types of practical experiments to be performed on the power electronics experimental trainer board.

3.3 Display Output Unit

This unit consists of the ammeter and voltmeter, or an external oscilloscope, where the output from any constructed experiment is displayed. The ammeter is used to measure the value of current in amperes, the voltmeter is used to measure the value of voltages in volts, while the externally connected oscilloscope displays the expected waveform.

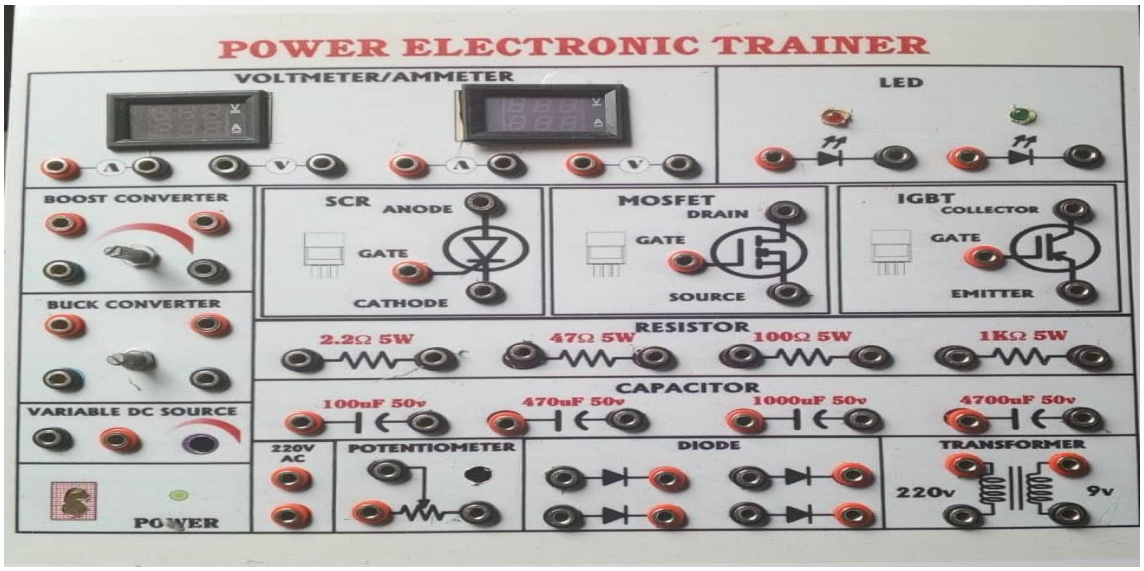

Figure 3: External surface area of power electronics experimental trainer board.

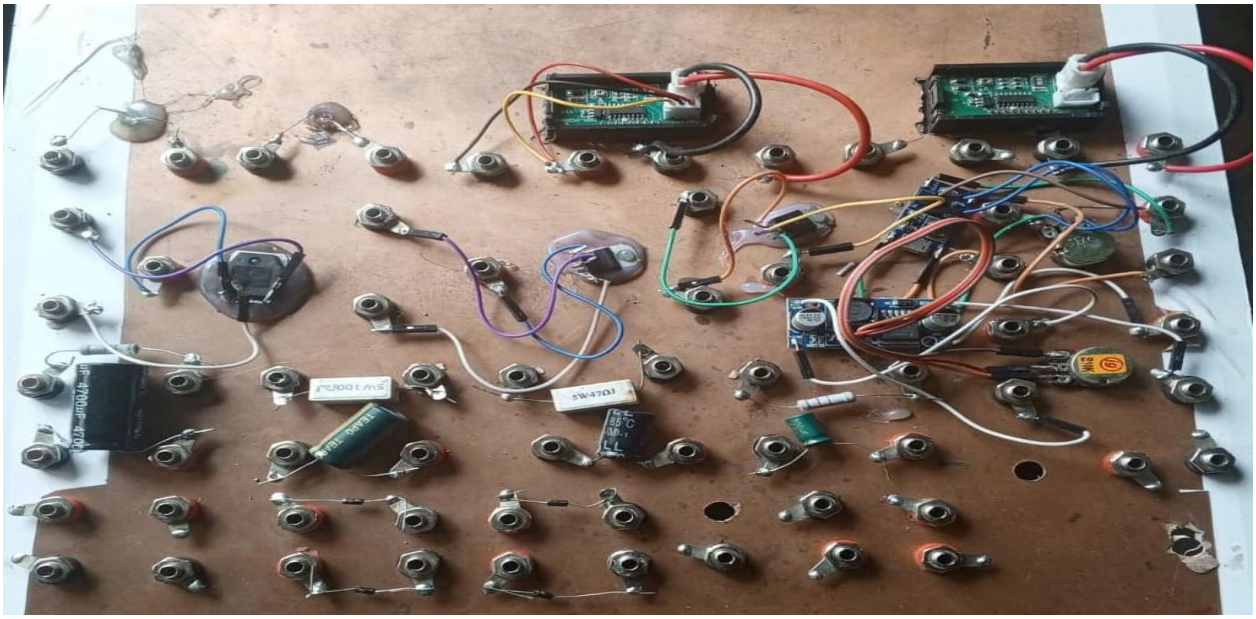

Figure 4: Internal surface area of power electronics experimental trainer board.

3.4 Mode of Operation

The power electronics trainer board operates in a very simple and straightforward manner. The ammeter, voltmeter, or external oscilloscope will display the anticipated results or reading if you simply connect the necessary circuit on the trainer board and power it through the power supply module. To observe the desired modifications at the output display, adjust the parameters of your components. With its thorough setup, the trainer board enables users to play and comprehend the functions of each component. The Power Electronics Trainer Board is a versatile and educational instrument for learning power electronics.

4. Results and Discussions

The Power Electronics Trainer Board's boost and buck converters performed well; the voltage was successfully raised from 12V to 18V by the boost converter and lowered from 12V to 5V by the buck converter. The efficiency of both converters was demonstrated by the steady output voltages they produced, which is essential for understanding how power supplies function in practical applications. Some of the tests conducted with the board aligned well with theoretical assumptions, demonstrating its efficacy as an innovative educational tool for enhancing students' practical knowledge.

The board's durability and stability show how useful it is for teaching voltage regulation. The trainer board also demonstrated the functionality of semiconductor devices such as the IGBT, MOSFET, and SCR. When a 2V gate voltage was provided during testing, the SCR showed exact control over the current flow. Furthermore, the MOSFET and IGBT demonstrated their critical functions in power management and switching inside circuits by performing magnificently and responding appropriately to a 5V gate voltage. This practical exercise strengthens students' theoretical comprehension of these elements.

Other practicals performed on the power electronics experimental trainer board generally cover the fundamental characteristics of power devices and the operation of the main types of power converter circuits. The practical includes;

(i) V-I Characteristics: Plotting the relationship between anode voltage V_{AK} and anode current I_A for various gate currents I_G.

(ii) Gate Triggering: Determining the minimum gate current I_G and gate voltage V_{GK} required to turn on the SCR.

(iii) Latching and Holding Current: Measuring I_L (latching current), I_H (holding current).

(iv) Output and transfer characteristics of Power MOSFETs and IGBTs.

(v) Study of Single-phase Half-controlled and Fully-controlled bridge converters with R and RL loads.

(vi) Observing the output voltage waveform and its average/rms values as a function of the firing angle control.

(vii) Studying the operation and output voltage control using pulse width modulation (PWM).

(viii) Studying the operation and output voltage control.

(ix) Studying the single-phase AC voltage controller using SCRs with R and RL loads, focusing on phase control.

The external oscilloscope is used to view various waveforms, assess device characteristics, validate theoretical formulas, and comprehend how varied loads (R, L, RL, RLE) and control factors (such as firing angle or duty cycle) affect circuit performance.

5. Conclusion

An important step in improving students' practical understanding of power electronics is the creation of a Power Electronics Experimental Trainer Board. These instructional resources can help students get ready for the complexity of today's engineering problems by bridging the gap between theory and practice. To optimize these technologies' efficacy in engineering education, future research should concentrate on improving them and investigating cutting-edge pedagogical approaches.

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