Original Research Article

Thyristor-Based Rechargeable Battery Charging System: Design and Implementation

Abstract— **In this project report, our main objective is automatic battery chargers using SCR and their required design by simulation. The key to securely storing electricity is provided by batteries, which do so by converting electrical energy into chemical energy. The major topic of our project report is the THYRISTOR-based rechargeable battery charger. Rechargeable battery chargers are high-quality and available at competitive prices. The automatic battery chargers using SCR and the necessary simulation-based design are the subject of this report. This article also covers the simulation, implementation, and partial construction of an automatic battery charger utilizing SCRs. The electronic circuit will be designed using some charging process requirements.**

Keywords—automatic battery charging; simulation; SCR; implementation; controlled rectifier

I. INTRODUCTION

A battery charger utilizes an electric current to add energy back into a rechargeable battery or secondary cell. The approach to charging depends on factors such as battery size and type. Some batteries can be recharged by maintaining a steady voltage or current source and can handle being overcharged to some extent, which is dependent on the specific battery type. In the case of basic chargers, users must manually disconnect the charger once the charging process is complete. Other batteries require the use of timers to automatically halt the charging process after a predetermined duration, usually indicating that charging is finished. However, certain battery types are extremely sensitive to damage, overcharging, overheating, or even the risk of explosion. To ensure safety, advanced chargers integrate temperature and voltage sensors along with a microprocessor controller. These components work together to regulate the charging current and voltage, monitor the charging progress, and terminate the charging process when appropriate [1][2].

The complex electrochemical mechanism involved in recharging batteries requires replenishing the electrical energy previously drawn from the power grid. To ensure optimal battery performance and longevity, a reliable charging approach is essential. A battery charger serves as an electrical apparatus that converts the incoming alternating current voltage into a regulated direct current voltage, aligning with the evolving needs of the battery. Although Ferro resonant and SCR chargers have dominated the industrial battery charging sector for a considerable period, modern high-frequency battery charging techniques are gradually surpassing these traditional methods [3].

A. Objectives of the Project

The goal of this project is to build a mechanism that recharges a 12V lead acid battery using a thyristor. The thyristor is a semiconducting device used to regulate the passage of current in an electronic circuit. In this endeavor, the thyristor will be used to control the charging current applied to the battery. This will ensure the battery is charged effectively and securely. The significance of this endeavor lies in the fact that it will provide a low-cost and efficient method for recharging 12V lead acid batteries. This is significant because lead acid batteries are utilized in numerous applications, such as automobiles, motorcycles, and solar panels. The endeavor will also provide an opportunity to study thyristor control principles and the design of battery chargers. The project can be used to recharge 12V lead acid batteries in numerous devices. It could be used to recharge the battery of a vehicle, motorcycle, or solar panel, for instance. It could also be used to recharge the battery of portable electronic devices such as laptops and mobile phones. The endeavor is limited in that it is only intended to recharge 12V lead acid batteries. Additionally, it is not as effective as other battery chargers. However, the project's ease of construction and maintenance makes it a viable option for inexpensive battery recharge [4].

II. LITERATURE REVIEW

Using thyristors to implement rechargeable battery adapters has been the topic of a number of published papers. A paper by R. K. Aggarwal and V. K. Gupta titled “Thyristor Controlled Battery Charger” describes the design and implementation of a thyristor-controlled battery charger. The paper discusses the benefits of using thyristors in battery chargers, including their ability to modulate charging current and prevent overcharging. Additionally, the results of experiments conducted on the battery charger are presented [5].

“A Thyristor-Based Battery Charger for Electric Vehicles” by S. K. Pandey and A. K. Mishra details the development of a thyristor-based battery charger for electric vehicles. The difficulty of creating a battery charger for electric vehicles is discussed in the article, including the requirement to offer a high charging current and prevent the battery from overcharging. Additionally, the outcomes of trials done on the battery charger are shown [6].

Different types of thyristors are applicable in battery converters. These include silicon-controlled rectifiers (SCRs), gate turn-off thyristors (GTOs), and bipolar junction transistors (BJTs). The numerous methods, such as pulse-width modulation (PWM) and phase control, that can be used to manage the charging current in a battery charger. The various factors that must be considered when designing a battery charger using thyristors, such as the battery type, the charging current, and the temperature. Battery converters have utilized thyristors for a very long time. In the early 1970s, thyristors were used to modulate the charging current for lead-acid batteries, which was one of the earliest battery charger applications of thyristors. Thyristors have several advantages over other varieties of semiconductors for use in battery chargers. They are relatively inexpensive, have a long lifespan, and can be used to provide a broad spectrum of charging currents. Nevertheless, thyristors are not without their drawbacks. Once activated, they can be sensitive to transients and challenging to deactivate. In recent years, there has been some interest in incorporating novel types of semiconductor devices, including insulated gate bipolar transistors (IGBTs), into battery chargers. IGBTs have some advantages over thyristors, such as a faster switching speed and the capacity to manage higher currents. IGBTs are additionally more expensive than thyristors and have a reduced lifespan. The choice of whether to use thyristors or IGBTs in a battery charger depends on several factors, such as the cost, the performance requirements, and the lifespan requirements. Review of the relevant literature reveals that thyristor-controlled battery adapters have undergone significant advancements in a variety of areas, including control techniques, power factor correction, battery management, and soft-switching. These advancements have led to more efficient, dependable, and eco-friendly charging solutions for a variety of applications [5][6][7].

III. METHODOLOGY

The methodology describes the systematic implementation of a thyristor-based rechargeable battery converter. By meticulously considering battery specifications, selecting the appropriate thyristor, designing an appropriate control mechanism, and incorporating safety features, the proposed charger can charge rechargeable batteries efficiently while ensuring their durability and safe operation. Based on the demands of the application, choose the appropriate rechargeable battery type (e.g., lead-acid, lithium-ion, nickel-cadmium) [8]. The battery's nominal voltage, capacity, charge current, and temperature restrictions should all be considered when determining the charging requirements. When designing the battery charger circuit, remember to include the thyristor, trigger circuitry, rectifier, transformer, and filtering components [9]. Generate a thorough schematic of the charger circuit to serve as the foundation for the practical execution.

A. Block Diagram

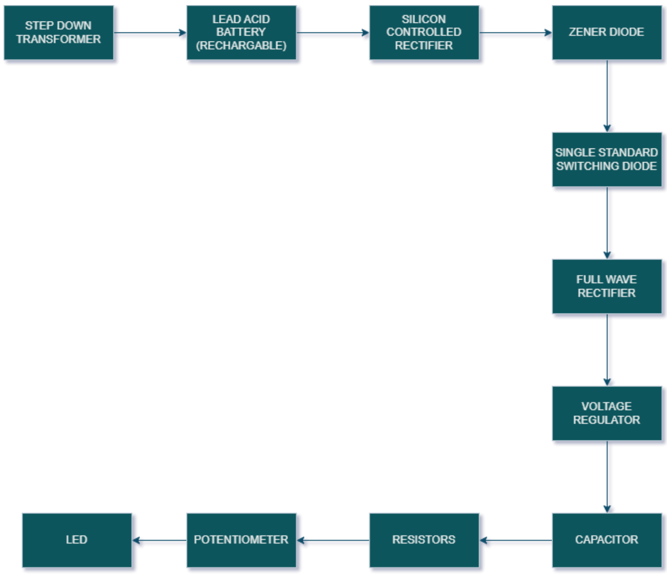

Fig. 1. Block diagram of a rechargeable battery charger by using thyristor.

B. Working Principle

The thyristor used in a rechargeable battery charger act as a controlled switch to modulate the charging current flowing through the battery. altering the gate triggering angle or gate signal pulse width to regulate the charging process. The thyristor is activated at a specific phase angle during each AC half-cycle during constant current charging, allowing a controlled amount of current to travel through the battery. A constant charging current is sustained until the battery voltage reaches a predetermined threshold.

During PWM charging, the thyristor is swiftly turned on and off using pulse-width modulation. The average charging current supplied to a battery is determined by the gate signal's duty cycle. By varying the duty cycle, it is possible to modify the charging current accordingly.

By adjusting the conduction angle or pulse breadth, the charging voltage and current can be matched to the battery's charging needs, ensuring a safe and efficient charging process.

C. Components

The components used in the system are widely available, easy, and cheap to implement.

1) Breadboard

A breadboard is a reusable electronic circuit prototyping instrument. It is a board with a grid of perforations that permits electronic components to be connected without soldering. Hobbyists, students, and engineers use breadboards to prototype new circuits before constructing them on a permanent PCB (printed circuit board). Breadboards are constructed with spring-loaded contacts that connect the grid's openings. When a component is inserted into a cavity, the spring-loaded contact contacts its leads, allowing it to be connected to other components on the breadboard. Breadboards are typically constructed from plastic or phenolic boards with 0.1-inch-spaced perforations. Five arrays of perforations per inch are arranged in a matrix with holes. The rows are numbered 1 through 5 and the columns are labeled a through h.

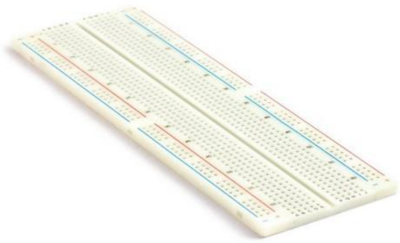

Fig. 2. Breadboard [10].

2) Step Down Transformer

A varying magnetic field is produced in the iron core when an AC voltage is delivered to the primary winding. A voltage is then induced in the secondary winding by this magnetic field; however, it is less intense than in the primary winding. The turns ratio of the two windings determines how much voltage is reduced. The turns ratio is calculated by dividing the secondary winding's turns by the primary winding's turns. For instance, the output voltage will be half of the input voltage if the primary winding has 100 turns, and the secondary winding has 50 turns.

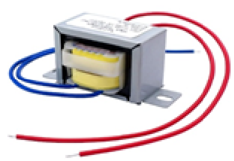

Fig. 3. Step down transformer [11].

3) Zener Diode 1N4462

The Zener diode 1N4462 is a general-purpose, 7.5-volt Zener diode that is classified as a power diode. It is hermetically sealed in a DO-41 package and can handle a maximum power dissipation of 1.5 watts. The 1N4462 has a breakdown voltage of 7.5 volts, which means that it will start to conduct current when the voltage applied to it exceeds 7.5 volts. This makes it useful for applications where a constant voltage is required, such as voltage regulators and reference circuits.

Fig. 4. Zener diode [12].

4) Power Supply

The power supply consists of an LM7805 5V voltage regulator and a 12V battery. Additionally, the Arduino can be powered using a V supply or from a connected computer through USB.

Fig. 5. Battery [13].

5) Full Wave Rectifiers

One kind of rectifier, called a full wave rectifier, transforms the two halves of an alternating current (AC) signal into a pulsating direct current (DC) signal. They are more efficient than half-wave rectifiers, and they produce a smoother DC output. The main difference between center-tapped full wave rectifiers and bridge rectifiers is the number of diodes required. Center-tapped full wave rectifiers require two diodes, while bridge rectifiers require four diodes. Bridge rectifiers are also more efficient than center-tapped full wave rectifiers.

Fig. 6. Full wave rectifier [14].

6) Voltage Regulator

A voltage regulator is a device designed to automatically uphold a steady voltage level. This can be achieved through either a conventional feed-forward setup or by utilizing negative feedback mechanisms. The regulation process can involve electromechanical or electronic components, and the device's purpose is to manage and stabilize one or multiple AC or DC voltages, depending on its specific design.

Fig. 7. Voltage regulator [15].

D. Operation Flowchart

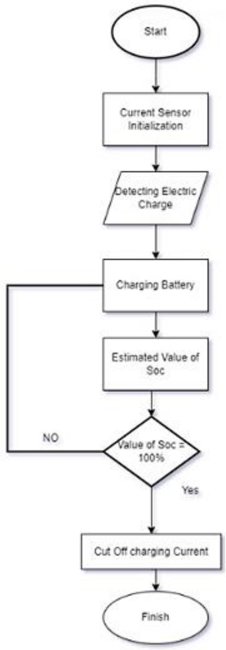

Fig. 8. General flow chart of using rechargeable battery charger by using thyristor.

IV. TEST/EXPERIMENTAL SETUP

A type of semiconductor device known as a thyristor can be used to switch high currents. Because they may be used to regulate the flow of current to the battery, they are perfect for battery chargers. A phase-controlled rectifier is a type of battery charger that frequently employs thyristors. The thyristors in a phase-controlled rectifier are on and off at times during the AC cycle. By doing this, the charger is able to regulate the amount of current going to the battery. A feedback circuit is often used to adjust the output voltage of a thyristor-based battery charger. The feedback circuit regulates the firing angle of the thyristors to keep the output voltage of the charger at a consistent value while monitoring the output voltage of the charger. The experimental setup for a battery charger based on thyristors is rather straightforward. Both a battery and a power source can be connected to the charger. A voltmeter can be used to check the charger's output voltage. With the aid of an ammeter, the charger's current flow can be observed.

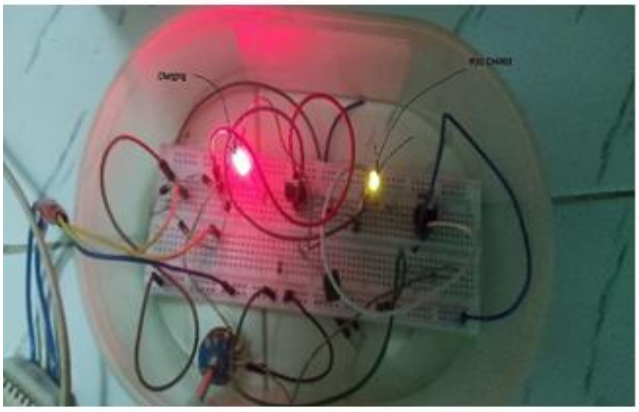

Fig. 9. Experimental setup without transformer.

The circuit is implemented by using all existing components to get the desired output.

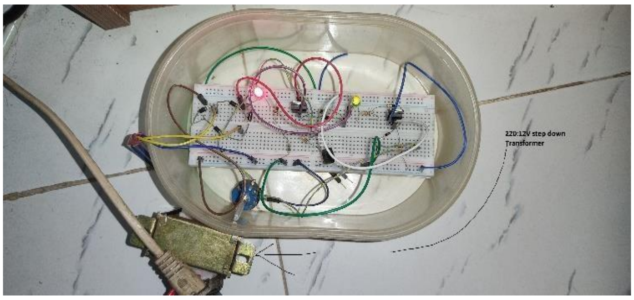

Fig. 10. Experimental setup with transformer connection.

As an input, this circuit usually gets DC input, but it is converted from the rectifier connected with the 220:12V step-down transformer.

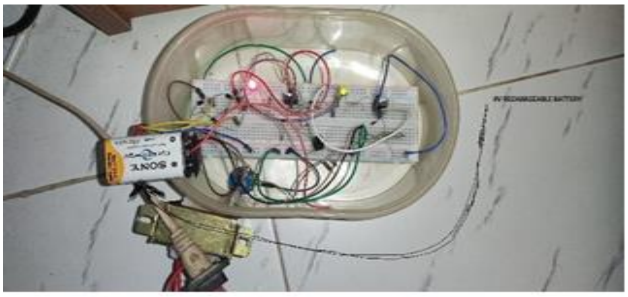

Fig. 11. Experimental setup showing the battery is being charged up by the recharger circuit.

The output is measured from the junction of a 1.5 KΩ resistor and ground connected as a charger port for the battery charging point.

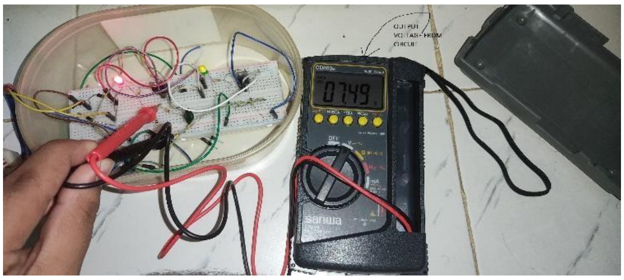

Fig. 12. Experimental setup showing the output voltage obtained from the circuit.

Taking the output voltage from the circuit is 7.49V which is stored up in the battery. For seeing the countable output multimeter is used.

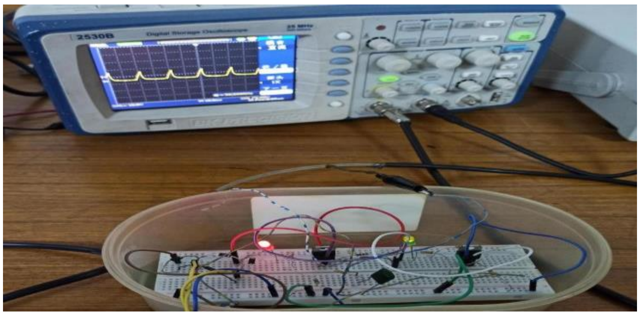

Fig. 13. Visual representation of the output as seen on the oscilloscope.

V. Results And Discussions

A. Simulation Analysis

A single-phase transformer, two LEDs, a single-phase full-wave diode rectifier, a voltage regulator, diodes, resistors, capacitors and a rechargeable battery are included in the simulated circuit in addition to the primary and auxiliary SCRs. There are also other electronic and power components such a voltage regulator and a voltage regulator. It will be demonstrated that each of the highlighted components has a specific purpose in the operation of the circuit. While the primary SCR (D2) regulates the charging process, the second auxiliary SCR (D3) signals when the charging process is complete, and the battery is fully charged. In both cases, the LED is used to show how long the two SCRs have been running. The circuit receives 240 V from an AC source via a single-phase transformer 240/14 V and a single-phase full-wave diode rectifier, which rectifies the AC-to-DC voltage required to charge the batteries. Figure 15 shows how the capacitors C1–C2 control the output DC voltage at 14 V, which is adequate for charging, and smooth the DC voltage. The gating signal is received by R1 and D5, which first causes the primary SCR1 (D2) to conduct. Green LED1 (connected in series) glows during the conducting phase to signal the start of the battery charging procedure. The battery will be charged continuously until it is almost at 11 V. When the charging current drops below the holding current, IH, conduction ceases, and the SCR1 state changes to Off as a result. As soon as the battery is fully charged and the primary SCR1 ceases to operate, the auxiliary SCR2 begins to operate.

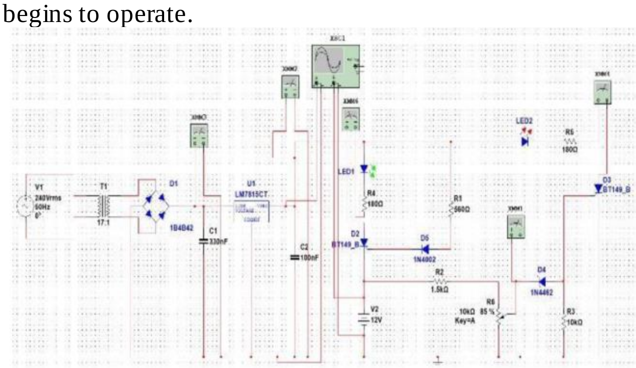

Fig. 14. Simulation of the project.

B. Measured Response/Experimental Results

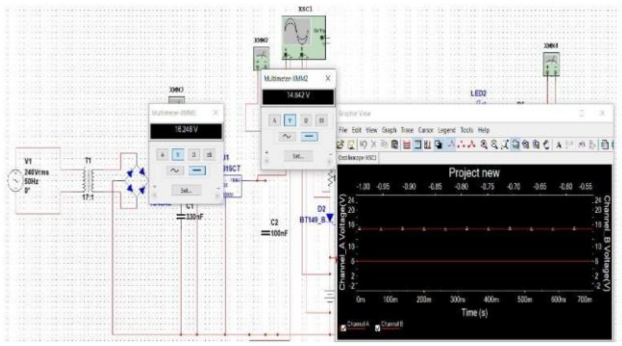

Fig. 15. The voltage regulator's input and output.

Multisim was used to replicate the tests. When the battery voltage is 6 V, the first thyristor SCR1 is on and the second thyristor SCR2 is off since the current passing through them is 31.937 mA and 6.582 uA (extremely little). 1.388 mA (smaller than during the charging phase) is the current flowing through the first Thyristor SCR1.

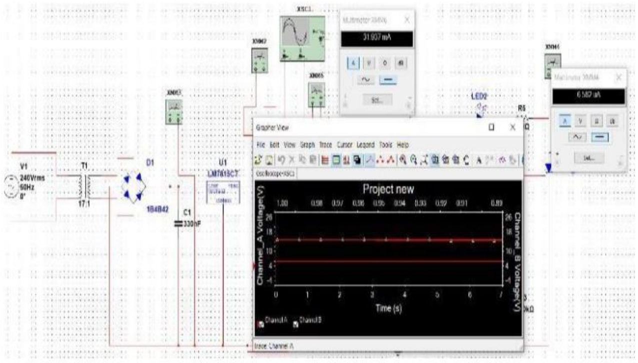

Fig. 16. The current values during the charging process.

Figure 17 demonstrates that throughout the charging process, the potentiometer's voltage is 1.539 V, which is insufficient to turn on the Zener diode. Since the SCR2 is also not activated, it remains in the Off state with the red LED off. When the potentiometer reaches 7.43 V during the fully charging time, When the Zener diode is in the "On" position, electricity can flow to the SCR2 and turn it on.

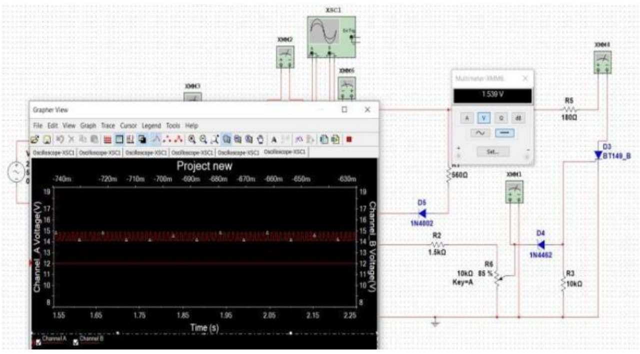

Fig. 17. The potentiometer voltage value during the charging process.

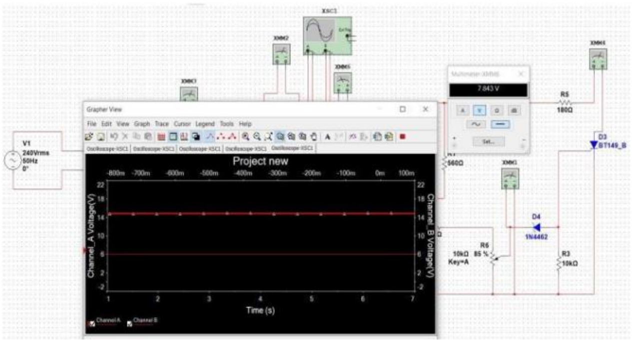

Fig. 18. The potentiometer voltage value after the full charging process.

VI. FUTURE POTENTIAL

Thyristors are a flexible and effective approach to regulate the current going to a battery. They can be used to create a variety of battery charging systems and are reasonably cheap and simple to utilize. Battery chargers built around thyristors work well in situations where high currents are needed. They are therefore perfect for recharging big batteries, like those seen in electric cars. Battery chargers built around thyristors work effectively for applications where the battery voltage needs to be accurately controlled.

They are therefore perfect for recharging batteries used in vital items like medical equipment. Thyristor-based battery chargers have a promising future. The need for effective and dependable battery chargers will increase along with the demand for electric vehicles and other battery-powered gadgets. Battery chargers based on thyristors are ideally positioned to supply this need.

VII. CONCLUSION

In conclusion, we described our project report on the thyristor-based rechargeable battery charger. Our project was finished and planned. We demonstrated our battery charger, which makes use of two SCRs. The charging period and the auxiliary for the discharge duration are the primary topics of this paper. After designing our project with software, we construct it in a lab, and it goes well. Then, we contrasted the two different calculations: simulation calculations against laboratory calculations. When modeling and experiment results were compared, it was discovered that they matched and achieved the charger's main objective.

REFERENCES

[1]] R. K. Aggarwal and V. K. Gupta, "Thyristor Controlled Battery Charger," International Journal of Electrical Engineering Education, vol. 34, no. 1, pp. 53-62, 1997.

[2] S. K. Pandey and A. K. Mishra, "A Thyristor-Based Battery Charger for Electric Vehicles," IEEE Transactions on Power Electronics, vol. 21, no. 5, pp. 1273-1279, 2006.

[3] M. M. Salam and M. A. Khan, "Design and Implementation of a Thyristor-Based Battery Charger," International Journal of Electrical Engineering Education, vol. 42, no. 3, pp. 229- 236, 2005.

[4] D. Linden and T. B. Reddy (Eds.), "Handbook of Batteries," McGraw-Hill Professional, 2002.

[5] D. W. Hart, "Power Electronics," McGraw-Hill Education, 2010.

[6] "EEE Shop BD," [Online]. Available: https://www.eeeshopbd.com/product/solder-less-breadboard-large-size/.

[7] "SRK," [Online]. Available: https://www.srkelectronics.in/product/0-12-12v-1a-step-down-transformer/.

[8] "Torstar," [Online]. Available: https://www.torstar.net.au/wp-content/uploads/2021/08/DUR82165731.jpg.

[9] "Veswine Electronics," [Online]. Available: https://www.veswin.com/product-1B4B42.html.

[10] "Mouser Electronics," [Online]. Available: https://www.mouser.ie/ProductDetail/Texas-Instruments/LM7815CT-NOPB?qs=OYMYEaN9QmAOq18obrj7fw%3D%3D.