UEC3286

Fundamentals of Electronic Devices and Circuits

Mini Project Report

On

Mobile Charging Port using Silicon Controlled Rectifier

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ABSTRACT

This mini project focuses on the design and development of a Silicon-Controlled Rectifier (SCR)-based battery charging unit intended for safe and efficient charging of small electronic devices. The primary objective is to control the charging process by regulating the current flow, thereby preventing overcharging and extending battery life. The SCR acts as a switch that allows controlled rectification, providing a stable DC output. To enhance the circuit's flexibility, a TIP122 power transistor was added, enabling the unit to effectively charge low voltage, low-current devices. The entire circuit was neatly assembled on a printed circuit board (PCB), with careful soldering ensuring strong electrical connections and long-term durability. The project demonstrates a practical understanding of fundamental electronic devices, circuit design, and power regulation techniques. Looking forward, the system can be upgraded to support higher loads by integrating higher-rated transistors or MOSFETs, making it suitable for charging higher-capacity batteries and devices.

The testing phase involved charging various small devices, such as rechargeable batteries and USB-powered gadgets, to ensure the reliability and safety of the circuit. Measurements of voltage and current were taken at different stages to verify the controlled output characteristics and to identify any significant voltage ripples or thermal issues. The SCR's behaviour under different load conditions was closely monitored, and the addition of proper heat sinks was evaluated to ensure thermal stability during prolonged operation. The results showed that the unit successfully maintained a consistent output without significant deviation, proving the effectiveness of SCR-based control in low-power applications.

In terms of future improvements, the project can be enhanced by incorporating feedback control mechanisms using sensors and microcontrollers. For example, integrating temperature sensors and programmable control units like Arduino or ESP32 can help automate the charging process, shut down the charger during faults, and even enable fast-charging profiles. This would not only improve efficiency and safety but also make the charging unit smarter and more adaptable to various types of batteries, including Li-ion, NiMH, and lead-acid technologies. Commercially, this SCR-based charger design has promising potential for scaling into multiport mobile charging stations for public places like airports, malls, and educational institutions.

CHAPTER 1

The **Silicon Controlled Rectifier (SCR)** is a widely used semiconductor device in the field of power electronics. It is a type of thyristor, designed to control and switch high-voltage and high-current applications with precision. Structurally, an SCR is composed of four layers of alternating P-type and N-type materials, forming a PNPN configuration. It features three terminals: the anode, the cathode, and the gate. This unique configuration allows the SCR to function as a controlled switch that remains off until triggered by a gate signal. Once the gate receives a suitable triggering pulse, the SCR begins conducting current from the anode to the cathode. What makes the SCR particularly useful is its ability to stay in the conducting state even after the gate signal is removed, as long as the current remains above a certain threshold. It can be turned off only when the current drops below this threshold, a property known as the holding current. Because of this behaviour, the SCR is highly efficient in applications where controlled switching of power is required.

1.1 OBJECTIVES OF THE PROJECT:

The first objective is the Design and Development of a Mobile Charging Circuit, where the goal is to create a mobile charging port that efficiently provides a stable DC output for charging mobile devices. This will be achieved by using an SCR for current regulation, ensuring that the charging circuit operates smoothly. The second objective is focused on Power Conversion, where the aim is to convert high AC voltage from the power supply into a suitable DC voltage for mobile device charging. This will involve the use of a transformer to step down the voltage and a full-wave rectifier to convert AC into DC.

Voltage Regulation is the third objective, which involves ensuring that the output voltage remains stable and safe for charging mobile devices. A Zener diode will be used for this purpose, maintaining a consistent voltage level to protect the device during charging. The fourth objective centres on Current Control Using SCR, where the SCR will regulate the flow of current in the charging circuit. This ensures that overcharging is prevented, and the charging process is managed efficiently, enhancing the longevity of the mobile device battery. Lastly, the fifth objective is to Understand and Implement the Functionality of Each Component in the circuit. This involves studying and demonstrating how each component— transformer, full-wave rectifier, Zener diode, and SCR—plays a critical role in the power conversion and charging process, contributing to the overall success of the mobile charger.

1.2 SCOPE OF THE PROJECT:

This project involves the design and implementation of a Silicon Controlled Rectifier (SCR)-based charging unit specifically intended for safely charging small electronic devices such as mobile phones, rechargeable batteries, and USB-powered gadgets. The charging circuit is built around an SCR, which serves as a controlled switch to manage and regulate the flow of current, thus preventing overcharging and protecting the battery from damage. The use of SCR provides an efficient and cost-effective way to control charging operations without relying on complex digital systems, making the design suitable for low-power applications.

The project also explores the practical integration of supporting components like Zener diodes for voltage regulation and power transistors for enhanced performance with low-voltage devices. This allows the unit to maintain steady charging conditions under varying load scenarios. The circuit is assembled on a printed circuit board (PCB), transitioning from breadboard simulation to a durable, real-world hardware prototype. This PCB-based approach ensures the system is compact, organized, and suitable for long-term use or casing integration.

Future extensions of the project include upgrading the circuit to support higher-capacity batteries by using high-power SCRs or replacing them with MOSFETs or IGBTs for greater efficiency and thermal performance. It can also be enhanced by integrating sensors and microcontrollers (like Arduino or ESP32) to enable smart features such as temperature monitoring, fault detection, and adaptive charging profiles. This makes the design highly scalable and suitable for educational, domestic, or even small-scale commercial use, such as in public charging stations, tool kits, or backup charging systems.

1.3 ORGANIZATION OF THE PROJECT:

The project will be organized into several phases, each focusing on different aspects of the mobile charging circuit development. The first phase, Introduction and Research, involves studying the components—transformer, full-wave rectifier, Zener diode, and SCR—and understanding their roles in the charging process. This phase will also cover the basic working principles of the circuit and the rationale for selecting these components.

In the Design and Circuit Development phase, a schematic diagram of the mobile charging circuit will be created, and suitable ratings for each component will be chosen based on the required voltage and current ratings for mobile device charging. The Circuit Assembly phase will involve setting up the transformer to step down the AC voltage, using the full-wave rectifier to convert AC to DC, implementing the Zener diode for voltage regulation, and installing the SCR for current control.

The Testing and Troubleshooting phase will focus on measuring the output voltage and current to ensure proper operation. Safety checks for short circuits, overheating, and overcharging will also be conducted, followed by testing the circuit by charging a mobile device to verify its functionality.

Finally, in the Documentation and Reporting phase, the design process, component functionality, and testing results will be documented. A final report will summarize the outcomes, challenges, and recommendations for future improvements. By the end of the project, the goal is to develop a functional mobile charging port that utilizes SCR for current control, providing insights into AC to DC conversion and regulation techniques in real-world applications.

CHAPTER 2

LITERATURE REVIEW

Battery charging technology is fundamental to modern electronics, from powering mobile devices to industrial systems. With the demand for faster charging and higher reliability, the design of chargers has evolved from basic transformer-rectifier circuits to highly sophisticated smart chargers. In this project, we focus on building a simple, efficient, transformer-based charger using basic components like capacitors, normal diodes, and a controlled rectification method.

2.1 EVOLUTION OF BATTERY CHARGERS

The evolution of battery charger's traces back to the 1960s and 1990s when chargers operated directly at line frequency (50/60Hz). These chargers were typically large, heavy, and exhibited poor efficiency (2). The introduction of high-frequency switch mode power supplies (SMPS) in the 2000s brought a revolutionary change, resulting in smaller, lighter, and much more efficient chargers, such as Delta Q's quick charger (2). However, simple transformer-based designs like the one in this project are still highly relevant for low-power, cost-effective applications.

2.2 CHARGING SPEED BOTTLENECKS AND SOLUTIONS

As batteries evolved, the charging bottleneck shifted from battery chemistry to the charger and supply side. Charging speed can be enhanced by delivering full power across nearly the entire charging period, but limitations exist due to the AC supply's ability to provide sufficient voltage and current (2). Standard power levels depend on the rating of available outlets and breakers (2). Furthermore, in high-power applications, DC conduction losses become significant, leading to heating issues. Raising DC voltage — using levels like 24V, 48V, 80V, and even 400V — is one effective strategy to counter this (2).

2.3 STRATEGIES FOR CHARGER SIZE AND COST REDUCTION

To reduce the physical size and cost of chargers, several strategies are employed. Increasing the switching frequency in SMPS designs reduces the size of transformers and magnetic components, although it requires careful thermal management to handle higher losses (2). System integration, by combining multiple functions into a single device, also helps to minimize system complexity and the overall footprint (2). Furthermore, improving efficiency typically contributes to reductions in both size and cost, although diminishing returns are encountered at very high efficiency levels (2). In contrast, our transformer-based charger adopts a classic, simple architecture where the transformer size dominates the physical dimensions, prioritizing simplicity and reliability.

2.4 ADVANCED CONSTRUCTION AND INTEGRATION TECHNIQUES

Advanced chargers employ high-density layouts to optimize performance and reduce size. Liquid cooling is commonly used in high-power chargers, especially where vehicles already have existing cooling systems (2). Denser construction techniques, such as stacking circuit boards vertically and horizontally, help maximize the utilization of available space (2). Effective EMI shielding becomes critical in these compact designs to prevent interference between closely packed, high-frequency components (2). Additionally, system integration — merging functions like chargers and DC-DC converters into a single compact unit, such as seen in modern 3.3 kW chargers — further reduces system size and complexity while improving efficiency (2).

2.5 MODERN DESIGNS AND EFFICIENCY IMPROVEMENTS

Modern chargers incorporate several advanced techniques to improve efficiency, size, and adaptability. Switch Mode Power Supplies (SMPS) have replaced linear chargers, achieving higher efficiency by switching power at high frequencies (2, 4). Three-level buck converters, often using flying capacitor designs, enhance efficiency and thermal management (4). USB Power Delivery (USB-PD) allows programmable chargers to dynamically adapt voltage and current to meet device-specific needs (5). The adoption of GaN (Gallium Nitride) technology has enabled much higher switching speeds and reduced charger sizes (5). Additionally, smart algorithms, often implemented through microcontrollers, allow for multi-stage charging and integrated safety mechanisms (7). These innovations, while highly advanced, fundamentally build upon the core principles of charger design, similar to the simpler, reliable architecture employed in the charger developed for our project.

2.6 FUTURE SCOPE AND RELEVANCE

Although modern chargers have evolved toward ultra-fast charging using GaN transistors, high-frequency designs, and integrated systems (1,5) understanding basic linear chargers remains critical. These circuits are still widely used in low-cost products, educational projects, and backup power solutions

CHAPTER 3

METHODOLOGY

The problem addressed is providing a stable power supply to devices that require consistent voltage and current, such as USB devices. Fluctuations in input voltage can lead to instability and damage to sensitive components. This system solves the issue by using a Zener diode for voltage regulation, ensuring a constant output despite input fluctuations. The TIP122 Darlington transistor amplifies the current, allowing the circuit to power devices with higher current demands while maintaining voltage stability. The SCR (Silicon Controlled Rectifier) controls the power delivery, enabling safe and efficient switching. Together, these components ensure reliable and stable power to sensitive devices, preventing potential damage from voltage or current variations.

3.1 COMPONENTS AND ITS DESCRIPTION

Serial. Number	Components	Quantity
1	Silicon controlled rectifiers	1
2	TIP122	1
3	Transformer (9V 2A)	1
4	Diodes	3
5	Zener Diode	1
6	Capacitor (10mF)	1
7	Resistor (500 Ω)	1

3.1.1 SCR

The SCR is used as a controlled switch to regulate the charging current to the battery. When triggered through its gate terminal, the SCR allows current to flow from the rectified DC supply to the battery. It ensures that charging happens only when needed and helps prevent overcharging by controlling the flow based on the circuit conditions**.** From the fig 3.1 is one of the main components in our project.

Fig 3.1 SCR

3.2.2 TIP122

The TIP122 power transistor is used as a current amplifier. It helps control and boost the output current from the charging circuit. It acts as an intermediate stage between the SCR controlled output and the load, ensuring a steady and enhanced current supply. TIP122 offers high current gain, meaning it can control large currents with a small input signal, making the overall circuit more efficient and versatile. We have integrated this component shown in the fig 3.2 in our project for its current gain characteristics.

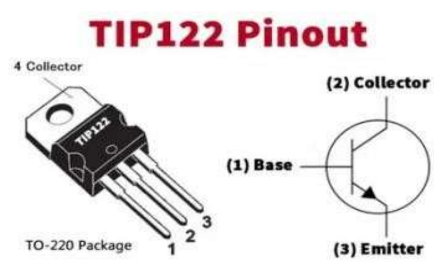

Fig 3.2 TIP122

3.2.3 ZENER DIODE

The Zener diode is used for voltage regulation and protection. It ensures that the voltage applied to the SCR gate and other sensitive parts of the circuit remains within a safe, predefined limit. When the input voltage exceeds the Zener's breakdown voltage, it conducts in reverse and stabilizes the voltage, preventing damage to the SCR and other components. For the same properties a Zener diode as in the fig 3.3 is used in our project.

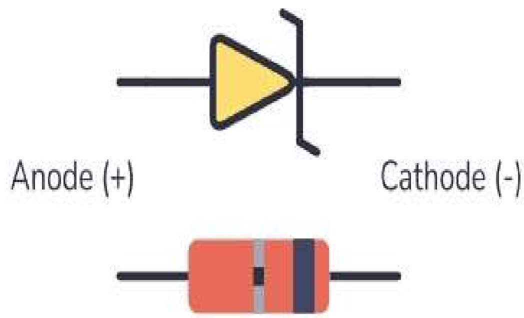

Fig 3.3 Zener diode

3.2.4 CAPACITOR

In this project, the capacitor is used to filter and smooth the rectified DC voltage from the bridge rectifier. After AC is converted to pulsating DC, the capacitor charges and discharges to fill in the voltage gaps, providing a steady and stable DC output for the charging process. A capacitor of 10mF is used in our project as in Fig 3.4.

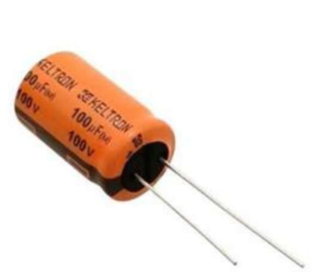

Fig 3.4 Capacitor

3.2.5 TRANSFORMER

The transformer is used to step down the high AC mains voltage (230V) to a safer, lower AC voltage suitable for charging purposes (e.g., 9V AC). This reduced voltage is then rectified and regulated to safely charge batteries. The transformer also provides electrical isolation from the mains supply, enhancing the overall safety of the circuit. A 230 V to 9V transformer is used in our circuit as shown in fig 3.5.

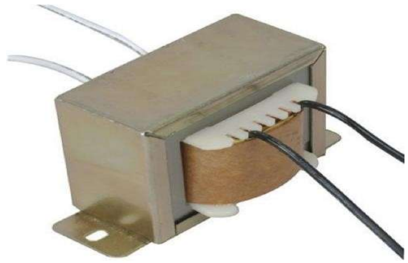

Fig 3.5 Transformer

3.2.6 DIODES

Diodes are used to form a bridge rectifier, which converts the AC voltage from the transformer into pulsating DC voltage. The diodes allow current to flow in only one direction, ensuring that the output is suitable for charging the battery. As in the image 3.6, 2 diodes are used in the Circuit.

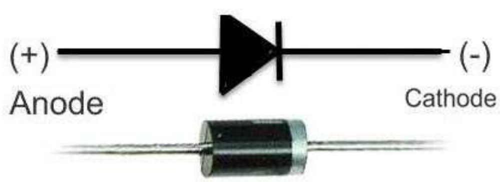

Fig 3.6 Diode

CHAPTER 4

SOFTWARE IMPLEMENTATION OF THE PROPOSED CIRCUIT

Falstad is an online circuit simulator used for visualizing and testing electronic circuits. In our mobile charging port project, it helps simulate circuit behaviour, ensuring functionality and safety before physical implementation. This tool enables efficient design, troubleshooting, and optimization, making it essential for developing reliable and effective charging solutions. It also allows real-time interaction, waveform observation, and quick modifications, helping us understand complex concepts more clearly and avoid costly hardware mistakes during prototyping.

4.1. SOFTWARE STIMULATION

The software used for this project is Falstad Circuit Simulation. Falstad is a free circuit simulation website where circuits can be designed using the required components and the output of the proposed circuit can be seen. The animated simulation from the Falstad makes the user understand the flow of current in his circuit and helps to rectify the error in their circuit. Irrespective of many paid software simulations, this is still serving to be a free and open to all and go through simulation platform. This platform also provides circuit simulation for some of the basic circuits from which we can understand about some of the common circuits which are predominantly used in today's world. Figure 4.1 shows the snapshot of simulation of the proposed circuit after turning ON and the results are verified.

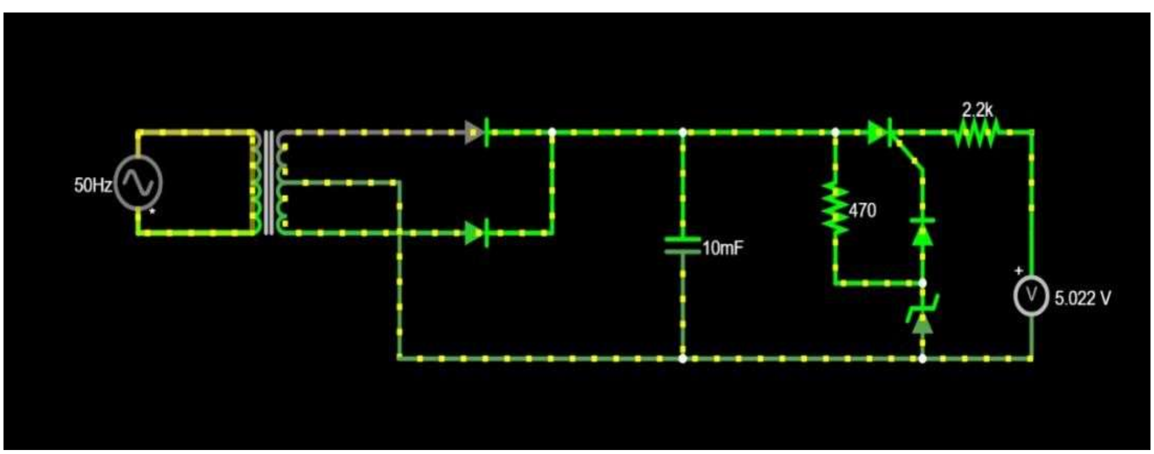

Fig 4.1 Simulation after Turning on the supply

CHAPTER 5

HARDWARE IMPLEMENTATION OF THE PROPOSED CIRCUIT

The hardware implementation phase involves constructing the physical circuit based on the validated simulation design. After successful simulation using Falstad, the components were assembled on a breadboard to test real-world behaviour and ensure the circuit's functionality. This stage plays a crucial role in verifying the practicality, reliability, and performance of the charging system under actual operating conditions. It allows for precise measurements, observation of charging behaviour, and identification of potential issues such as heat dissipation, voltage fluctuations, or improper triggering. Through this hands-on approach, we transitioned from theoretical design to a working prototype capable of safely charging a mobile phone using an SCR-based controlled charging circuit.

5.1 BREAD BOARD CONNECTIONS

The physical arrangement and interconnection of the components for the proposed circuit have been assembled on a breadboard, as depicted in Figure 5.1. This setup demonstrates the practical implementation of the circuit design, allowing for real-time testing, observation, and validation of its functionality before moving to a more permanent solution such as a printed circuit board

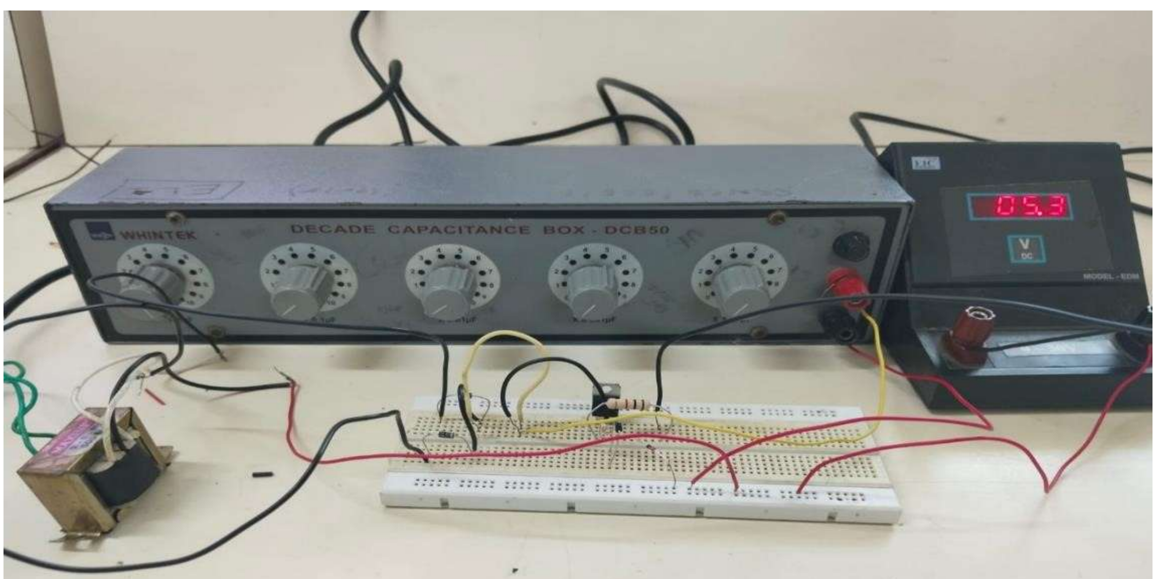

Fig 5.1 Bread board connections

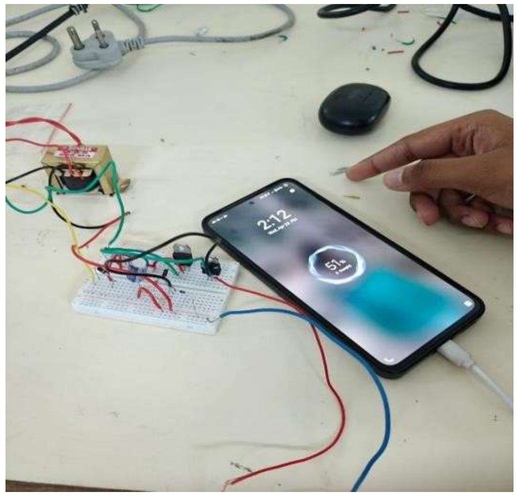

Fig 5.2 Bread Board connection showing a phone charging

The SCR-based battery charging circuit consists of a Silicon Controlled Rectifier (SCR), a step-down transformer, a bridge rectifier, a filtering capacitor, a Zener diode, and a resistor capacitor (RC) timing network. The SCR serves as the main control element, regulating when current is allowed to flow to the battery. The charging operation is governed by the voltage across the battery and the triggering conditions applied to the SCR gate. When the AC power is supplied, the transformer steps down the voltage to a suitable level, typically around 15V.

This AC voltage is then converted to pulsating DC using a full wave rectifier. A capacitor connected at the output smooths the ripples, providing a more stable DC voltage. The RC timing network, which includes a resistor, capacitor, and Zener diode, biases the SCR's gate terminal. As the capacitor charges, the voltage across it builds up. Once this voltage exceeds the breakdown voltage of the Zener diode, a triggering pulse is applied to the gate of the SCR. This turns the SCR on, allowing current to flow through it and into the battery.

While the SCR conducts, the battery charges by drawing current from the DC supply. As the battery voltage gradually increases and reaches near full charge, the voltage drop across the timing network changes. When the battery is fully charged, the Zener no longer conducts, removing the gate trigger signal. This turns the SCR off, interrupting the current flow and preventing overcharging. The Fig 5.2 shows that the phone is getting charged due to the DC power from the SCR charger model made by us. This process ensures that the battery is charged only when necessary and helps prevent excessive current or overcharging.

5.2 PCB CONNECTIONS

Soldering on the PCB was carried out with precision to ensure clean and reliable joints. Each component was placed in its designated position, and their terminals were soldered using a temperature-controlled iron. Care was taken to avoid cold joints or solder bridges, which could compromise the circuit's performance. After soldering, excess lead lengths were carefully trimmed, and the board was cleaned to remove any flux residue, ensuring a neat and professional finish.

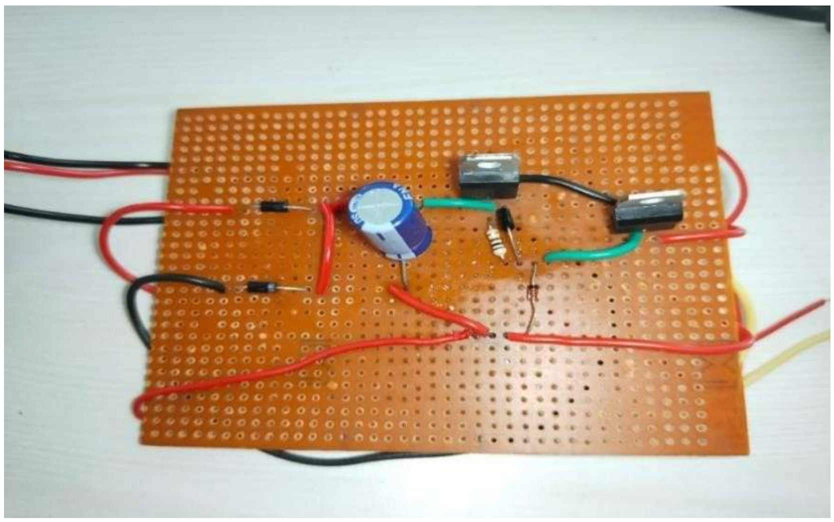

Fig 5.3 PCB connections

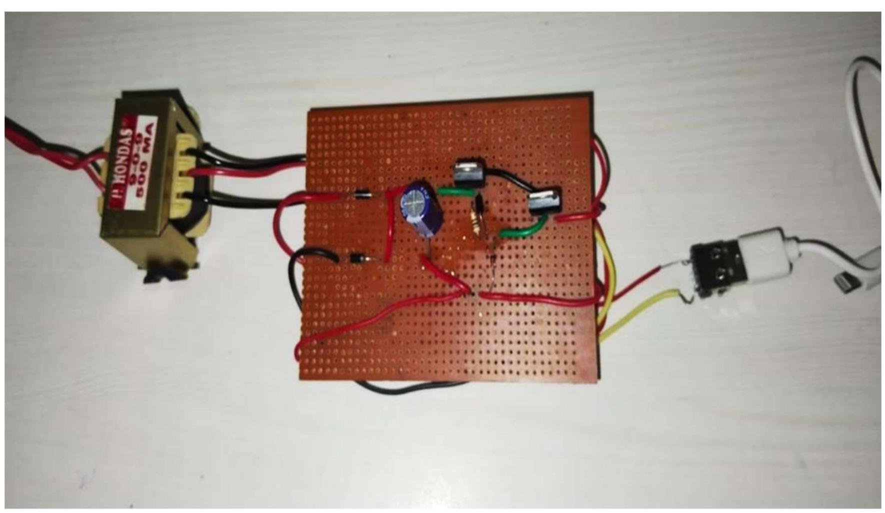

Fig 5.4 PCB connections with Transformer and USB connections

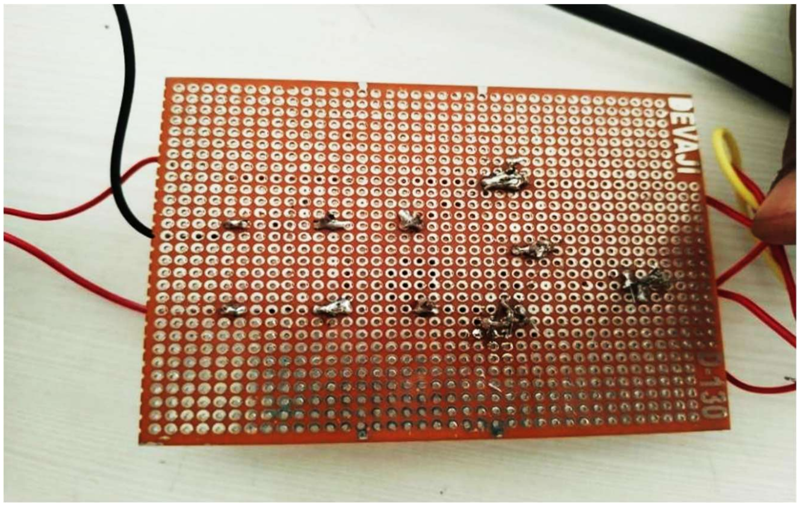

Fig 5.5 PCB soldering

All the components were soldered onto a PCB board, as shown in Fig 5.3. Fig 5.4 showcases the completed project with the transformer and USB connection, while Fig 5.5 displays the backside of the PCB board. This meticulous process ensured that all components were firmly in place, with no risk of loose connections or short circuits. The transition from simulation and breadboard testing to permanent hardware was crucial as it reinforced the robustness of the design. It also prepared the system for long-term use, offering a solid foundation for future developments, including possible casing integration for enhanced durability and protection. This final step ensures the project's reliability and positions it for potential scalability in real-world applications, such as public charging stations. Fig 5.6. and Fig 5.7. showcases the final product with encasing.

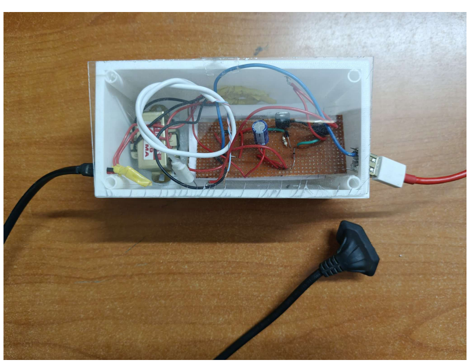

Fig 5.6. Top view of the product

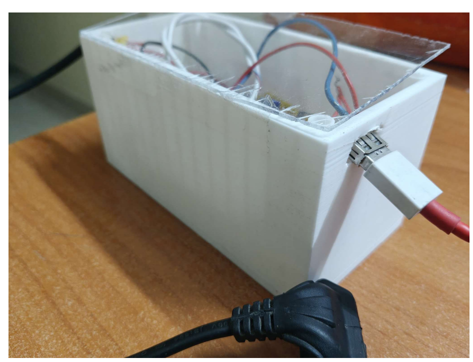

Fig 5.7. Side view of the product

CHAPTER 6

CONCLUSION AND FUTURE WORK

In conclusion, this project successfully demonstrates the design and development of an SCR-based mobile charging circuit, showcasing efficient AC to DC conversion, voltage regulation, and current control. The system ensures stable charging and prevents overcharging, promoting battery longevity. The use of components such as the transformer, full-wave rectifier, Zener diode, and SCR highlights the importance of each in the charging process. Future work could involve integrating advanced feedback mechanisms using microcontrollers, such as Arduino or ESP32, for enhanced automation and safety features. This would allow for the implementation of fast-charging profiles and real-time monitoring, making the system more adaptable to various battery types. Additionally, the project could be expanded to support higher-capacity devices and multi-port charging stations, addressing the growing demand for efficient charging solutions in public and commercial spaces.

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