THYRISTOR FIRING ANGLE CONTROL FOR BATTERY CHARGING

MINI PROJECT REPORT

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ABSTRACT

Efficient battery charging is an essential requirement in various electronic devices and systems. One effective approach to control battery charging is through the use of thyristor-based circuits, which allow for precise regulation of the charging current and voltage. This project report presents the design and implementation of a thyristor firing angle control system for battery charging applications.The report discusses the theoretical principles behind thyristor firing angle control, the design and implementation of the charging circuit, and the development of control algorithms to optimize the charging process. Experimental results demonstrate the effectiveness of the proposed system in maintaining a constant charging current and voltage, ensuring a safe and efficient battery charging operation.

The project findings contribute to the field of power electronics and battery management systems by showcasing the practical application of thyristor-based control techniques for battery charging. The insights gained from this work can be valuable for the design and development of advanced battery charging solutions for a wide range of electronic devices and energy storage systems.
Keywords: SCR, Transformer, Firing angle.

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LIST OF ABBREVIATIONS

SCR	Silicon Controlled Rectifier
TRC	Thyristor Rectifier Charger
FAC	Firing Angle Control
PAC	Phase Angle Control
TCA	Thyristor Controlled Amplifier
DCR	DC Rectifier
RCC	Rectifier Charger Controller
TPC	Thyristor Power Controller
ACR	AC Rectifier
FACR	Firing Angle Control Rectifier

Chapter 1

Introduction

1.1 Background

Batteries have become an integral part of modern life, powering a wide array of electronic devices, from portable gadgets to electric vehicles and renewable energy systems. As the demand for efficient and reliable energy storage solutions continues to grow, the need for advanced battery charging techniques has become increasingly important. Conventional battery chargers often suffer from limitations such as inefficient charging, lack of precise control over charging parameters, and potential risks of overcharging or thermal runaway, which can lead to reduced battery life and safety concerns.

Traditional battery charging methods, such as constant current (CC) or constant voltage (CV) charging, have been widely used for decades. However, these approaches have inherent drawbacks. The CC charging method, while effective in the initial stages, can cause overcharging and excessive heating in the later stages, potentially damaging the battery and posing safety risks. On the other hand, the CV charging method is typically used in combination with CC charging, but it can lead to prolonged charging times and inefficient energy transfer, especially for batteries with high capacity or those nearing the end of their charge cycle. Another method, trickle charging, involves supplying a low, continuous charging current to maintain the battery's charge level, but it is inefficient and can lead to overcharging and battery degradation over time.

Furthermore, most conventional chargers are designed for specific battery types and capacities, limiting their versatility and applicability across different applications. To address these limitations, advanced battery charging techniques have been explored, including pulse charging, resonant charging, and chargers based on power electronics circuits. Among these solutions, thyristor-based chargers have emerged as a promising approach, offering precise control over charging parameters, improved efficiency, and enhanced safety features. However, despite the potential benefits of thyristor-based chargers, their widespread adoption has been hindered by challenges such as complex circuit design, control strategies, and the need for robust protection mechanisms. Additionally, the development of user-friendly interfaces and the ability to adapt to various battery types and capacities remain areas for further improvement. In this project, we aim to design and develop a Thyristor Firing Angle Control Battery Charger that addresses these gaps and provides an efficient, controlled, and safe charging solution for a wide range of battery types and applications.

Chapter 2

Literature Survey

[1] This paper proposes a thyristor-based rechargeable battery charger design that aims to overcome the limitations of conventional chargers, such as inefficient charging, lack of overcharge protection, and potential battery damage due to overheating. The proposed circuit employs thyristors to control the charging current and voltage, enabling faster and more efficient charging while incorporating safety measures to prevent overcharging and thermal runaway. The authors present the circuit design, operating principles, and simulation results, demonstrating the potential advantages of their approach.[2] This comprehensive review paper examines various techniques for battery charging, with a focus on thyristor-based methods. It provides a detailed comparison of different charging approaches, including constant current, constant voltage, and pulsed charging. The authors highlight the potential benefits of thyristor-based chargers, such as improved efficiency, better control over charging parameters, and the ability to adapt to different battery types and conditions. They also discuss the challenges and limitations of thyristor-based chargers and suggest areas for further research and development.[3] This article delves into the concept of thyristor firing angle control for battery charging applications. It explains the working principle of thyristor-based chargers, where the firing angle of the thyristors determines the amount of current flowing into the battery. By adjusting the firing angle, the charging current and voltage can be precisely regulated, enabling efficient and controlled charging. The article

provides circuit diagrams, mathematical equations, and examples to illustrate the relationship between firing angle and charging parameters. [4] This paper presents a thyristor-based battery charger design that incorporates a microcontroller for precise control and monitoring. The authors discuss the implementation details, including the circuit design, which integrates thyristors, microcontroller, and various sensing and protection components. The software algorithms for controlling the firing angle, monitoring battery parameters, and implementing safety features are also described. The paper includes experimental results and performance analysis, demonstrating the effectiveness of the proposed design in delivering efficient and safe battery charging.[5] This abstract outlines a research project focused on developing a thyristor-based battery charger with improved efficiency and enhanced safety features. The proposed design aims to address the limitations of conventional chargers, such as energy losses, overcharging, and potential battery degradation. The authors highlight the potential advantages of their thyristor-based approach, including precise control over charging parameters, overcharge protection, and thermal management.[6] This journal article explores the use of thyristors in battery charger circuits for electric vehicles. It discusses the unique challenges associated with charging high-capacity batteries used in electric vehicles, such as high charging currents, long charging times, and the need for precise control and monitoring. The authors present a thyristor-based solution that can handle the required charging currents and voltages while providing efficient and controlled charging. The paper includes circuit design considerations, control strategies, and simulation results to validate the proposed approach.[7] This article from EEWeb provides a comprehensive overview of thyristor firing angle control for industrial battery chargers. It explains the basic principles of thyristor operation and how the firing angle can be adjusted to regulate the charging current and voltage. The article discusses the advantages of this approach, such as improved efficiency, better control over charging parameters, and the ability to adapt to different battery types and conditions. It also highlights potential applications in various industries, including material handling, telecommunications, and renewable energy systems. [8] This research paper presents a thyristor-based battery charger design specifically tailored for lead-acid batteries. The authors discuss the unique charging requirements of lead-acid batteries and propose a circuit implementation that incorporates thyristors for controlled charging. The paper covers the circuit design, control algorithms for firing angle adjustment, and experimental results demonstrating the effectiveness of the proposed solution in delivering efficient and safe charging for lead-acid batteries.[9] This technical reference document outlines the design and operation of a battery charger circuit using SCRs (silicon-controlled rectifiers, a type of thyristor). It provides detailed circuit diagrams, component specifications, and implementation details. The document explains the working principles of the circuit, including how SCRs are used to control the charging current and voltage. It also discusses practical considerations, such as heat dissipation, protection circuits, and potential applications of this type of charger.[10] This document also discusses a battery charger circuit using SCRs, but with a different circuit configuration and design approach. It covers the theoretical principles behind the operation of SCR-based chargers, including the relationship between firing angle and charging parameters. The document provides circuit design considerations, component selection guidelines, and potential applications of this type of charger. It also includes simulation results and performance analysis to validate the proposed design..

Chapter 3

Proposed Methodology

3.1 Problem Statement

To Design and Develop a Thyristor Firing Angle Control Battery Charger that employs thyristors and a microcontroller-based control system to regulate charging current and voltage, providing efficient, controlled, and safe charging for various battery types with protection circuits and user-friendly interfaces.

Objective:

1. 1.The primary goal is to efficiently charge batteries using an AC power supply while maintaining precise control over the charging process.
2. 2.Achieving this involves controlling the firing angle of a thyristor (specifically a triac).

3.2 Problem Motivation

The motivation behind this project stems from the growing demand for efficient and reliable battery charging solutions across various industries and applications. As the use of battery-powered devices and systems continues to expand, the need for advanced charging techniques that can maximize battery life, ensure safety, and provide precise control over the charging process becomes increasingly crucial. Conventional battery chargers often struggle with inefficiencies, lack of control, and potential risks such as overcharging and thermal runaway. These limitations not only compromise battery performance and longevity but also raise safety concerns, particularly in applications where batteries are subjected to frequent charging cycles or operate in demanding environments. The advent of thyristor-based chargers has opened up new possibilities for addressing these challenges, offering improved efficiency, precise control over charging parameters, and enhanced safety features. However, the widespread adoption of thyristor-based chargers has been hindered by complexities in circuit design, control strategies, and the need for robust protection mechanisms, as well as the lack of user-friendly interfaces and adaptability to various battery types and capacities.

3.3 Process description

The primary objective of this project is to design and develop a Thyristor Firing Angle Control Battery Charger that addresses the limitations of conventional chargers and provides an efficient, controlled, and safe charging solution for a wide range of battery types and applications. The proposed charger will employ thyristors as the primary control elements, allowing for precise regulation of the charging current and voltage by adjusting the firing angle. This approach enables optimal charging conditions, preventing overcharging and thermal runaway while maximizing charging efficiency. Additionally, a microcontroller-based control system will be implemented to continuously monitor battery parameters such as voltage, current, and temperature. Based on these measurements, the control system will dynamically adjust the firing angle of the thyristors, ensuring that the charging process is tailored to the specific requirements of the battery being charged. Robust protection circuits and safety measures will be incorporated to safeguard the battery and the charger circuit from potential damage due to faults, short circuits, or extreme operating conditions. These measures will include overcurrent protection, overvoltage protection, and thermal management systems.

The charger will be designed to handle a wide range of battery voltages and currents, catering to different battery types (lead-acid, lithium-ion, nickel-cadmium, etc.) and capacities. This versatility will be achieved through a robust and efficient power electronics circuit capable of adapting to various charging requirements. Furthermore, algorithms and control strategies will be developed to optimize the charging process, maximizing charging efficiency, minimizing charging time, and extending battery life. User-friendly interfaces and displays will be implemented to monitor the charging status, battery parameters, and provide diagnostic information for troubleshooting.

3.4 Requirement Analysis

Hardware Requirements:

The hardware requirements for the thyristor firing angle control battery charger are critical to ensure the proper functioning and performance of the system. These requirements include: Microcontroller Unit (MCU): A suitable microcontroller, such as an Arduino or Atmega328, is required to serve as the central control unit. This MCU should have sufficient processing power, memory, and input/output capabilities to handle the firing angle control algorithms, data acquisition, and user interface functions.

Thyristors (SCRs): High-quality thyristors or silicon-controlled rectifiers are essential components for regulating the charging current and voltage. The selection of thyristors should be based on their current and voltage ratings, as well as their switching characteristics and thermal management capabilities.

Power Supply: A robust power supply circuit is required to provide the necessary voltages and currents for the control and thyristor circuits. This may involve transformers, rectifiers, and voltage regulators, depending on the input power source and the specific voltage requirements of the system.

Sensing and Monitoring Components: Various sensors and monitoring components, such as voltage dividers, current shunt resistors, and temperature sensors, are required to accurately measure and monitor the battery parameters during the charging process. User Interface: A liquid crystal display (LCD) or other suitable display module is necessary for providing visual feedback to the user, displaying charging parameters, and conveying diagnostic information.

Protection Circuits: Implementing protection circuits, such as overcurrent protection, overvoltage protection, and thermal management systems, is crucial for ensuring the safe operation of the charger and preventing potential damage to the battery or the circuit components.

Software Requirements:

The software requirements for the thyristor firing angle control battery charger are equally important for the effective control and operation of the system. These requirements include: Programming Language and Development Environment: A suitable programming language and development environment, compatible with the chosen microcontroller, must be selected. Common choices include C/C++ for Arduino or AVR microcontrollers, or other embedded programming languages.

Firing Angle Control Algorithms: The core software component is the firing angle control algorithm, which calculates and generates the precise firing pulses for the thyristors based on the desired charging parameters and the input AC waveform.

Battery Parameter Monitoring: Software routines for monitoring battery parameters, such as voltage, current, and temperature, are required. These routines should handle data acquisition from the respective sensors and perform necessary calculations or conversions.

User Interface and Display Handling: Software modules for managing the user interface, displaying charging parameters, and conveying diagnostic information or error messages must be developed.

Fault Detection and Error Handling: Robust fault detection and error handling routines are essential for identifying and responding to potential faults, abnormal conditions, or safety-critical situations, ensuring the reliable and safe operation of the charger.

Battery Charging Profiles: Depending on the specific requirements and the types of batteries supported, the software may need to incorporate different charging profiles or algorithms tailored to various battery chemistries or capacities.

3.5 Impact Analysis

Positive Impact:

Improved Battery Life and Performance: By providing precise control over charging parameters and preventing overcharging and thermal runaway, the thyristor firing angle control battery charger can significantly extend the lifespan of batteries and maintain their optimal performance over multiple charging cycles.

Energy Efficiency: The thyristor-based firing angle control technique, combined with optimized charging algorithms, contributes to improved charging efficiency, reducing energy losses and potentially lowering operational costs in applications where battery charging is a significant component of energy consumption.

Versatility and Adaptability: The ability to charge a wide range of battery types and capacities makes the proposed charger a valuable solution for various industries, including consumer electronics, automotive, renewable energy systems, and more, reducing the need for multiple specialized chargers.

Cost Savings: By extending battery life and improving charging efficiency, the proposed charger can potentially lead to cost savings in the long run, as batteries will need to be replaced less frequently, and energy consumption during charging will be reduced.

Environmental Benefits: Improved battery life and reduced energy consumption during charging can contribute to a lower environmental impact, aligning with sustainability goals and efforts to reduce carbon footprints.

Negative Impact:

Complexity and Design Challenges: The design and implementation of the thyristor firing angle control battery charger involve complex circuit design, intricate control strategies, and robust protection mechanisms, which can pose significant challenges and require extensive expertise and resources.

Compatibility Issues: Ensuring compatibility with a wide range of battery types and capacities may require additional complexity in the hardware and software components, potentially increasing the overall cost and development time.

Electromagnetic Interference (EMI) Concerns: The high-frequency switching nature of thyristor-based circuits may generate electromagnetic interference, which could affect nearby electronic devices or systems if not properly shielded or managed. Safety Risks: Despite the implementation of protection circuits and safety measures, there is always a potential risk associated with working with high voltages and currents, particularly during the development and testing phases.

Initial Cost: The initial cost of developing and manufacturing the thyristor firing angle control battery charger may be higher compared to conventional chargers, which could impact its adoption and market penetration, especially in price-sensitive applications or markets.

Maintenance and Repair Challenges: The complexity of the system may pose challenges in terms of maintenance and repair, potentially requiring specialized technical expertise and resources, which could increase the overall operational costs. It is important to carefully evaluate and address these potential negative impacts during the design, development, and implementation phases to ensure the successful and sustainable adoption of the thyristor firing angle control battery charger.

3.6 Professional Ethics Practices to be followed

As this project involves electrical components and potentially high voltages, adhering to professional ethics and safety guidelines is of utmost importance. Ensuring the safety of users and operators should be the top priority, which necessitates strict adherence to electrical safety standards and regulations. Furthermore, responsible use of resources and minimizing environmental impact should be considered throughout the development process. Maintaining transparency and integrity in reporting findings and results is crucial for the credibility of the project. Respecting intellectual property rights and properly citing references is also an ethical obligation that must be upheld.

Chapter 4

Project Implementation

4.1 Circuit Designing

The circuit design phase is a critical step in the development of the thyristor firing angle control battery charger. It involves the selection of appropriate components, such as the microcontroller, thyristors, opto-isolators, and other essential elements. The design of the power supply, control, and thyristor circuits must be carefully executed, taking into account the required voltage and current levels, as well as the desired charging characteristics. Additionally, the implementation of protection circuits, such as overcurrent, overvoltage, and thermal protection mechanisms, is essential for ensuring the safe operation of the charger. The integration of sensing and monitoring components is also necessary for accurately tracking battery parameters and enabling precise control of the charging process. Lastly, layout considerations and PCB design guidelines must be followed to ensure proper functionality and minimize interference.

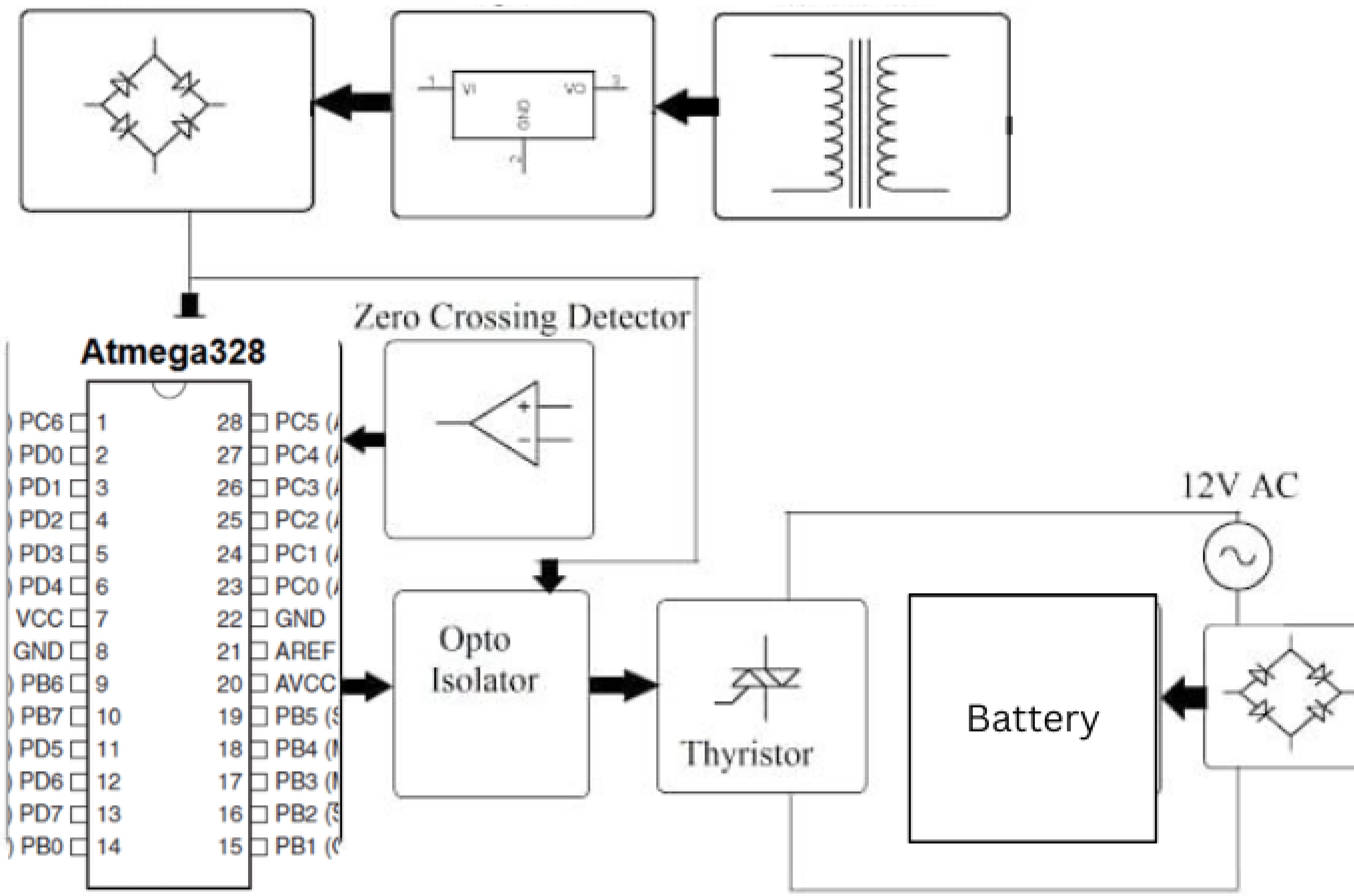

Figure 4.1: Circuit Diagram

4.2 Simulation and Bread Board Testing

Before proceeding to the final implementation, it is imperative to validate the circuit design through simulations and breadboard testing. Circuit simulations using software tools like SPICE or Proteus can provide valuable insights into the expected behavior and performance of the designed circuit. Careful analysis of the simulation results can aid in identifying potential design improvements or areas of concern. Subsequently, a breadboard prototype should be constructed and tested to verify the circuit's functionality and performance in a practical setting. This testing phase allows for troubleshooting and making necessary adjustments to the design, ensuring that the final implementation meets the desired specifications.

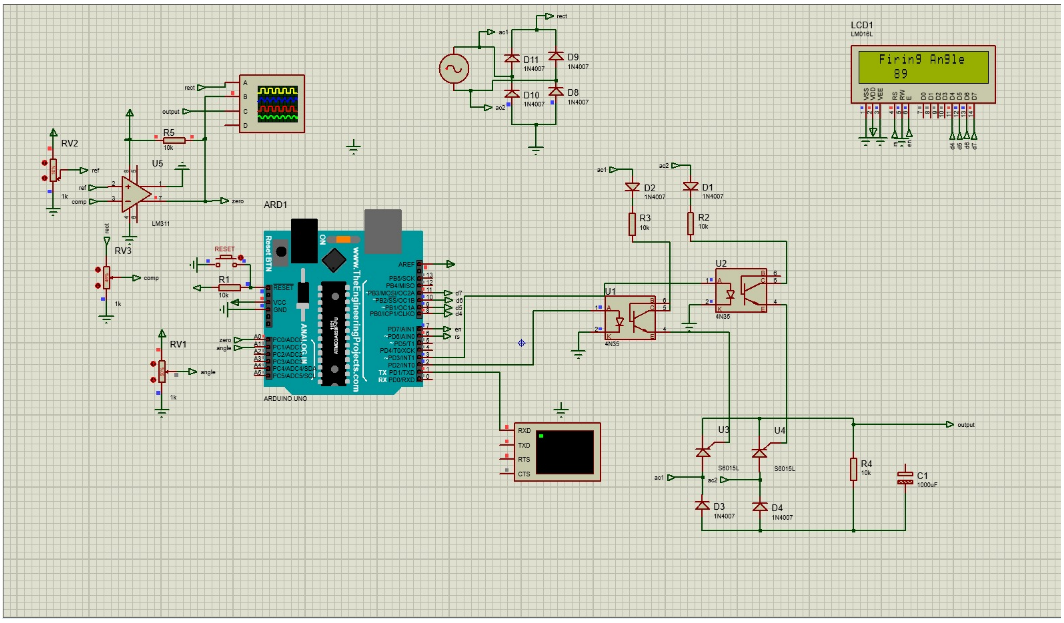

Figure 4.2: Simulation 1

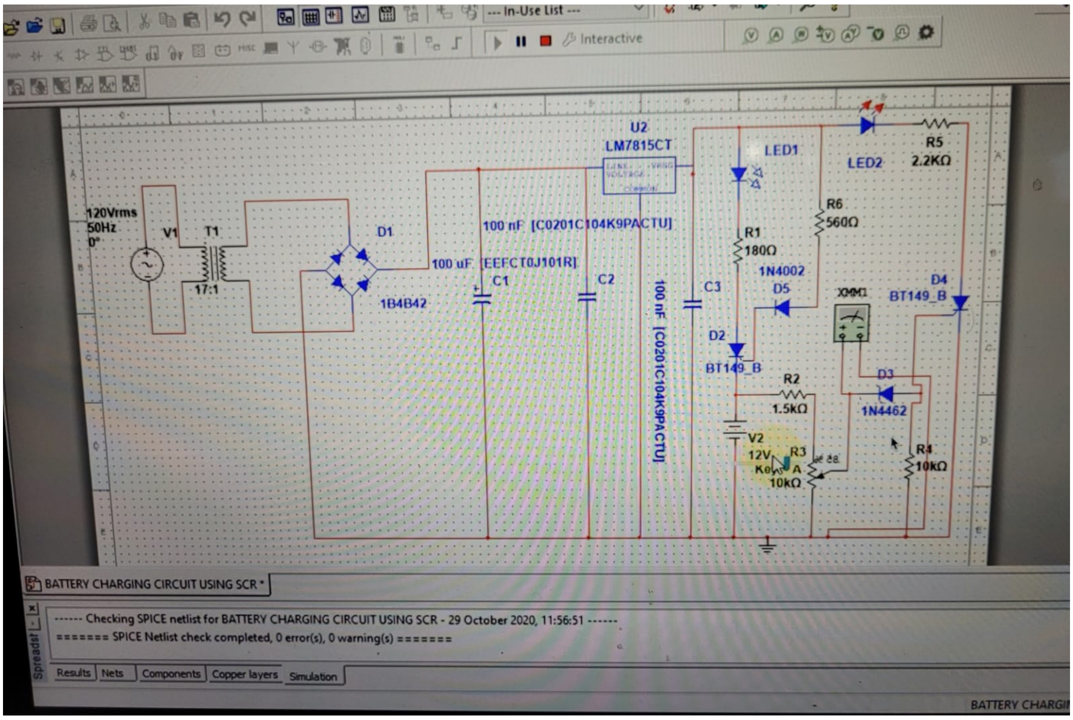

Figure 4.3: Simulation 2

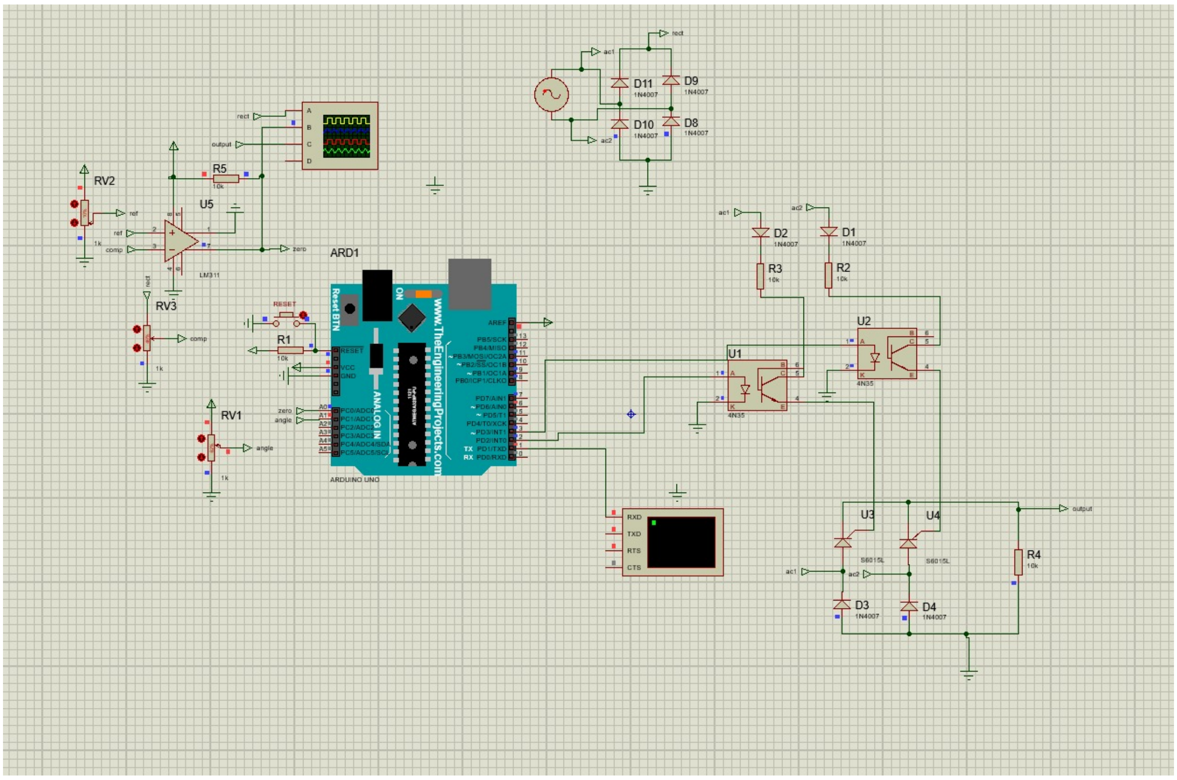

Figure 4.4: Simulation 3

4.3 PCB designing

Once the circuit design has been validated through simulations and breadboard testing, the next step is to create a printed circuit board (PCB) for the final implementation. This process involves the use of PCB design software and tools to lay out the components, route the traces, and incorporate necessary grounding and shielding mechanisms. Layout considerations, such as component placement and trace routing, play a crucial role in ensuring proper functionality and minimizing interference. The PCB fabrication process and techniques employed must also be carefully considered to maintain the desired quality and reliability of the final product. Quality control and testing of the fabricated PCB are essential steps to ensure that the board meets the design specifications and is ready for integration into the thyristor firing angle control battery charger.

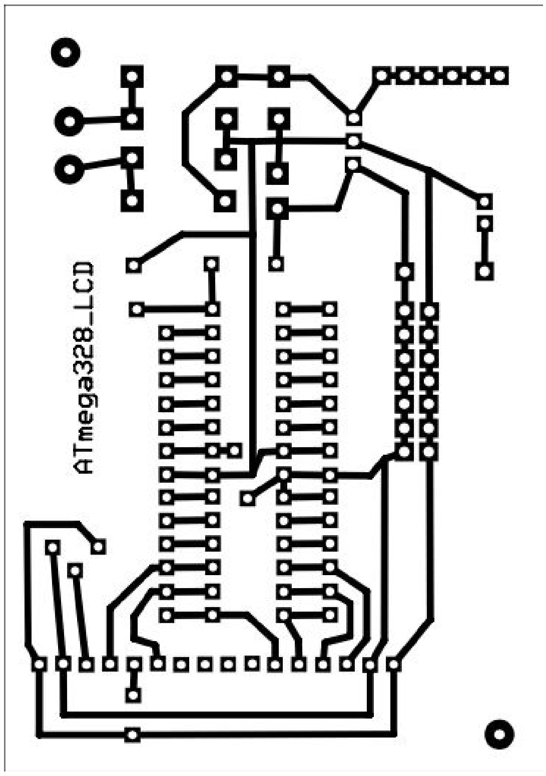

Figure 4.5: pcb desigining

4.4 Programming

While the hardware components were being developed, the programming aspect of the project was also addressed. The microcontroller or digital control circuitry responsible for monitoring the battery voltage and adjusting the firing angle of the thyristor was programmed using the appropriate language and development environment. The programming involved implementing algorithms for voltage sensing, feedback control, and precise timing for the thyristor firing angle modulation. Extensive testing and debugging of the software were carried out to ensure reliable and accurate operation of the system. Upon receiving the manufactured PCB, the components were carefully soldered and assembled, following industry-standard practices for electronic assembly. The programmed microcontroller or control circuitry was integrated with the hardware, and thorough testing was conducted to verify the overall functionality and performance of the thyristor-based firing angle control battery charger system.

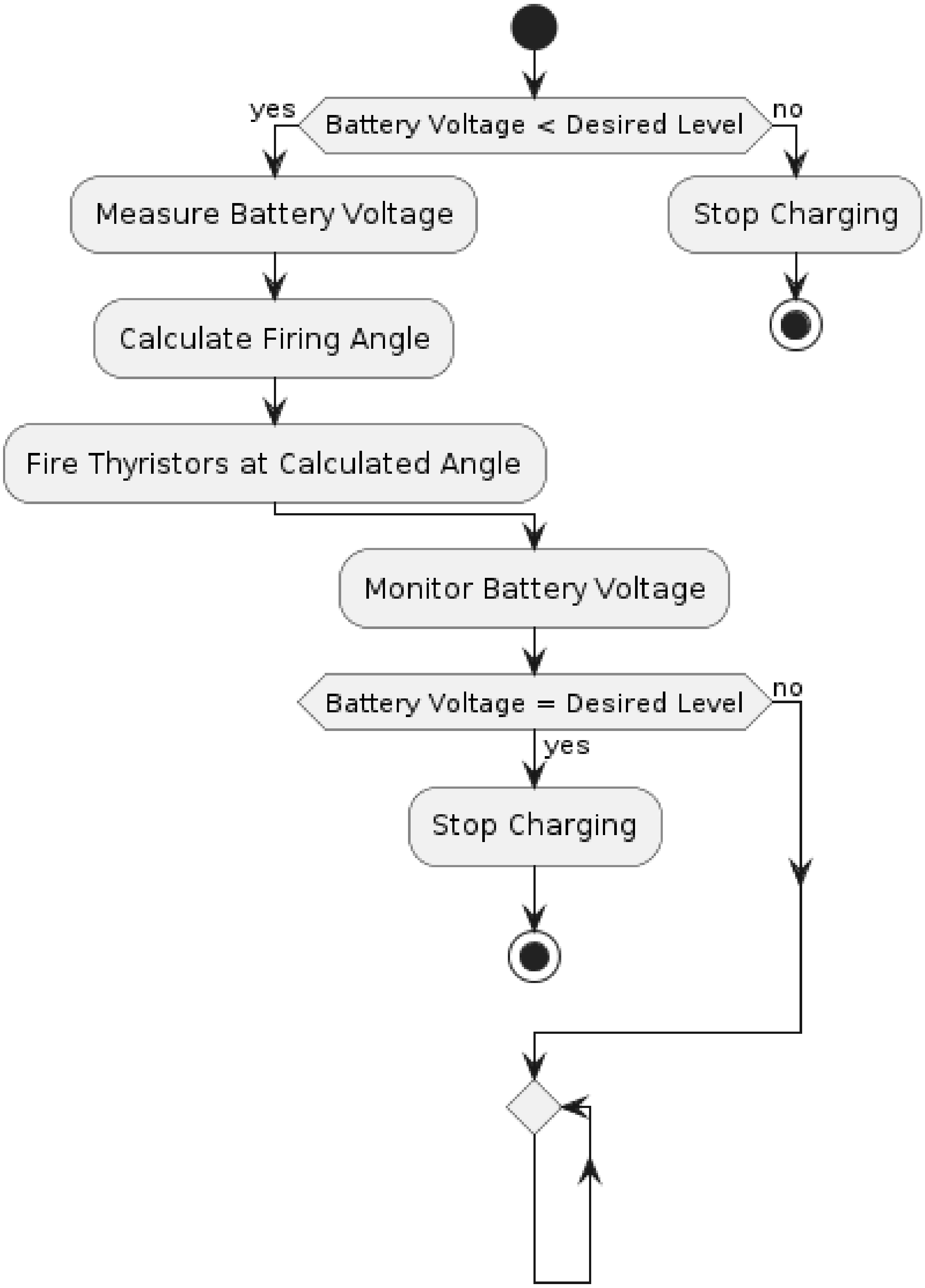

Figure 4.6: FLOWCHART

Chapter 5

Result and Discussion

5.1 Background

Upon the successful implementation of the thyristor firing angle control battery charger, it is essential to present and analyze the obtained results. This section should provide a comprehensive performance evaluation, including assessments of charging efficiency, charging time, and potential battery life extension. Comparisons with existing battery charging methods should be made to highlight the advantages and improvements offered by the developed charger. Additionally, a discussion of the challenges faced during the development process and potential improvements or future work should be included. An analysis of the impact and applications of the developed charger across various industries and sectors should be presented, emphasizing its potential contributions and significance. Finally, recommendations for further research or development in this field should be provided, paving the way for future advancements and innovations in battery charging technology.

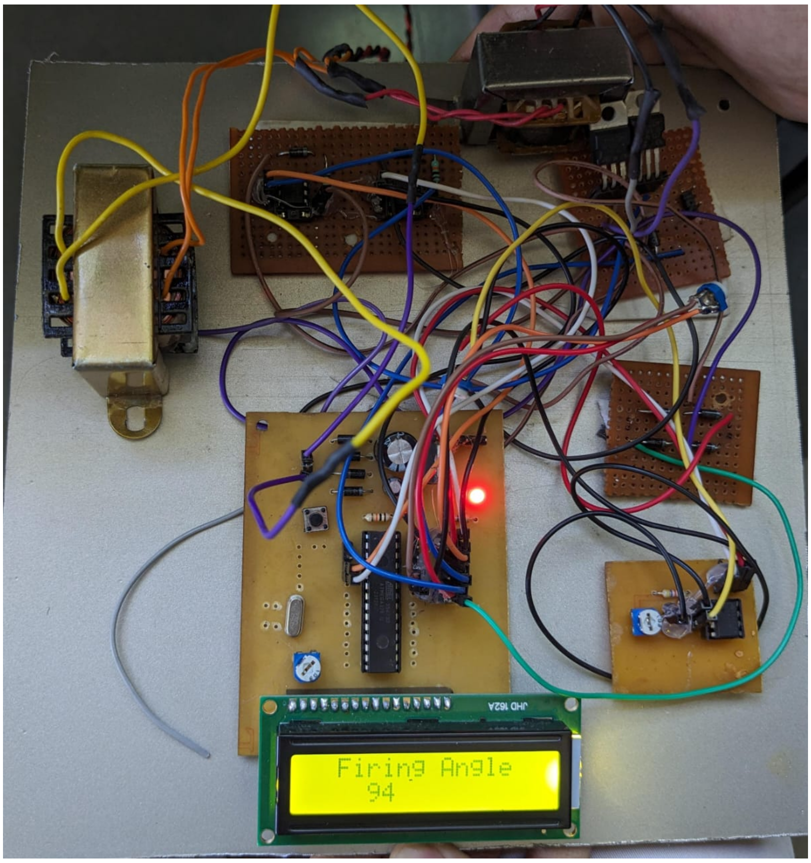

Figure 5.1: OUTPUT 1 alpha=74

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