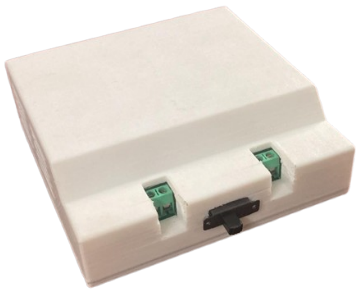
Department of Electronic & Telecommunication Engineering, University of Moratuwa, Sri Lanka.

A Battery Voltage and Current Smoother



Group Members:

220495P	Priyanjana T.P.I.M.
220004M	Aashir M.R.M.
220235V	Ilukkumbura I.M.E.I.B
220071M	Basith MNA

Submitted in partial fulfillment of the requirements for the module
EN 2091 Laboratory Practice and Projects

Date : 11 th December 2024

Abstract

This report presents the design and implementation of a battery voltage and current smoother aimed at mitigating the inherent fluctuations in battery output. The system incorporates a voltage regulation circuit using a Low Dropout (LDO) regulator to stabilize output voltage at 7.5V and a current regulation module to ensure a steady output current of approximately 50 mA. These features are achieved using components such as Zener diodes, operational amplifiers, and transistors, ensuring efficient energy utilization and extending battery life. The design process involved simulation in Proteus, PCB layout creation with Altium Designer, and enclosure design using SolidWorks. While the system performs effectively, slight deviations in output were noted, prompting future enhancements for improved precision and user adjustability. This solution offers a reliable power source for sensitive electronic devices, ensuring stable operation under varying load conditions.

Contents

1 Introduction and Functionality

Even though batteries are a portable and easy power source, they can occasionally provide varying current and voltage because of a number of variables, including ambient influences, load variations, and battery health. In electronic applications, these variations may result in noise, instability, and decreased efficiency. A smoothing circuit is used to reduce voltage fluctuations and steady the voltage in order to solve the problem.

The designed circuit regulate the input voltage to a steady 7.5 V using an LDO (Low Dropout) regulator, ensuring consistent operation of connected devices. The LDO regulator efficiently maintains a stable voltage output lower than the 9 V battery input, compensating for fluctuations in the battery's charge level. This ensures that sensitive components, such as microcontrollers or sensors, receive a reliable and precise voltage supply. Additionally, the circuit incorporates current regulation to deliver a constant current to the load, preventing overcurrent conditions and safeguarding the devices. This combination of voltage and current regulation optimizes energy utilization from the 9 V battery, enhancing its longevity while providing a dependable power source for extended operational periods.

2 System Architecture

2.1 Voltage Smoother

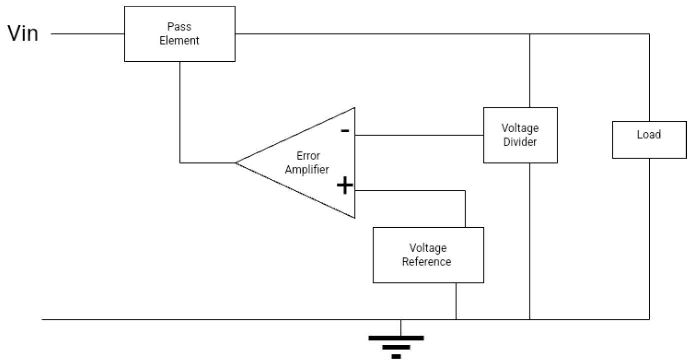


Figure 1: Constant Voltage Circuit Architecture

- Error Amplifier - The error amplifier is an operational amplifier (op-amp) that compares the output voltage to a stable reference voltage.The amplifier takes two inputs: one from the reference voltage and the other from the feedback network(Voltage Divider), which provides a fraction of the output voltage. If there is any difference (error) between these two inputs, the error amplifier generates a control signal to correct it. This ensures that the regulator responds to variations in input voltage, load changes, or other disturbances to keep the output voltage stable.
- Pass Element - The pass element is the core component of an LDO regulator responsible for regulating the current flow from the input to the output. It adjusts the current based on the control signal from the error amplifier, ensuring the desired output voltage is maintained.

2.2 Current Smoother

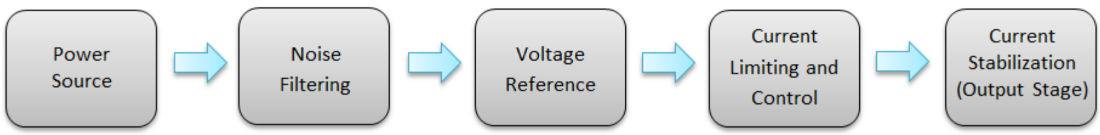


Figure 2: Constant Current Circuit Architecture

- Power Source
  Component: Battery (9V)
  Function: Provides DC input power to the circuit.
- Noise Filtering (Smoothing)
  Component: Capacitor (1µF)
  Function: Filters minor ripples and noise from the power supply.
- Voltage Reference and Regulation
  Component: Zener Diode (1N4372A)
  Function: Provides a stable reference voltage to regulate the circuit.
- Current Limiting and Control
  Components: Resistors
  Function: Controls the base voltage and current flowing into the transistor.
- Current Stabilization (Output Stage)
  Component: Transistor (2N2222A)
  Function: Ensures a regulated and stable current at the output by acting as a control switch.

This constant current source is used for LED lighting and capacitor charging applications. We selected a current value of approximately 50 mA, which is suitable for these purposes.
To prevent the transistor from entering the collector-emitter saturation region, the Zener voltage must be as low as possible. Therefore, we chose a Zener voltage of 3V.

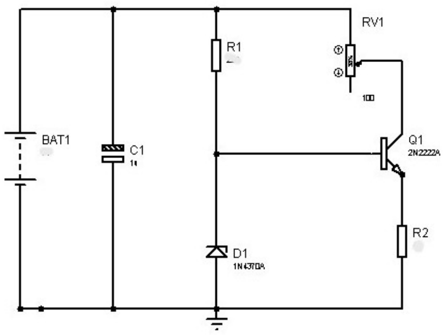


Figure 3: Constant Current Circuit Architecture

$$\boldsymbol{R_2} = \frac{\mathbf{2.3}}{\mathbf{0.05}}, \\ = 46\,\Omega. \tag{1}$$

so we choose 46Ω for $\boldsymbol{R_2}$.

Zener test current is 20mA.

$$\boldsymbol{R_1} = \frac{\mathbf{(7-3)}}{\mathbf{0.02}}, \\ = 200\,\Omega. \tag{2}$$

so we choose 220Ω for $\boldsymbol{R_1}$.

3 Specifications

3.1 Current Smoother

- Input Voltage : 9v - 7V
- Output Current : 50mA - 53 mA
- Load Resistance : 0-75Ω

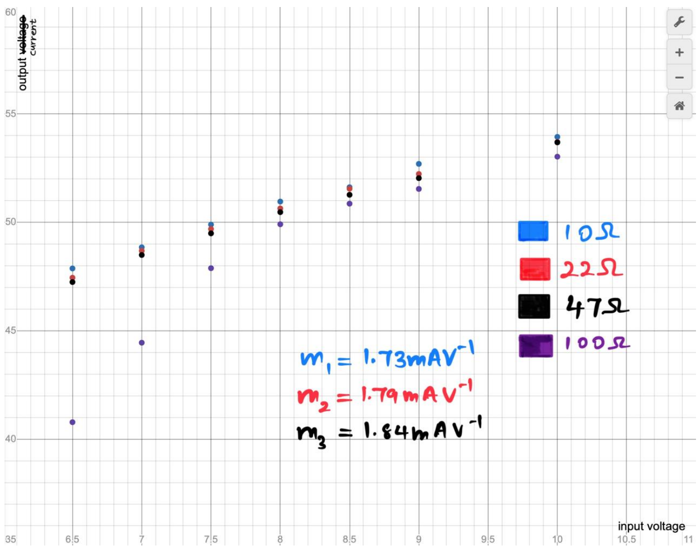


Figure 4: Output current for different loads

3.2 Voltage Smoother

- Input Voltage : 9v - 7V
- Output Voltage : 7V
- Min Load Resistance : 470Ω

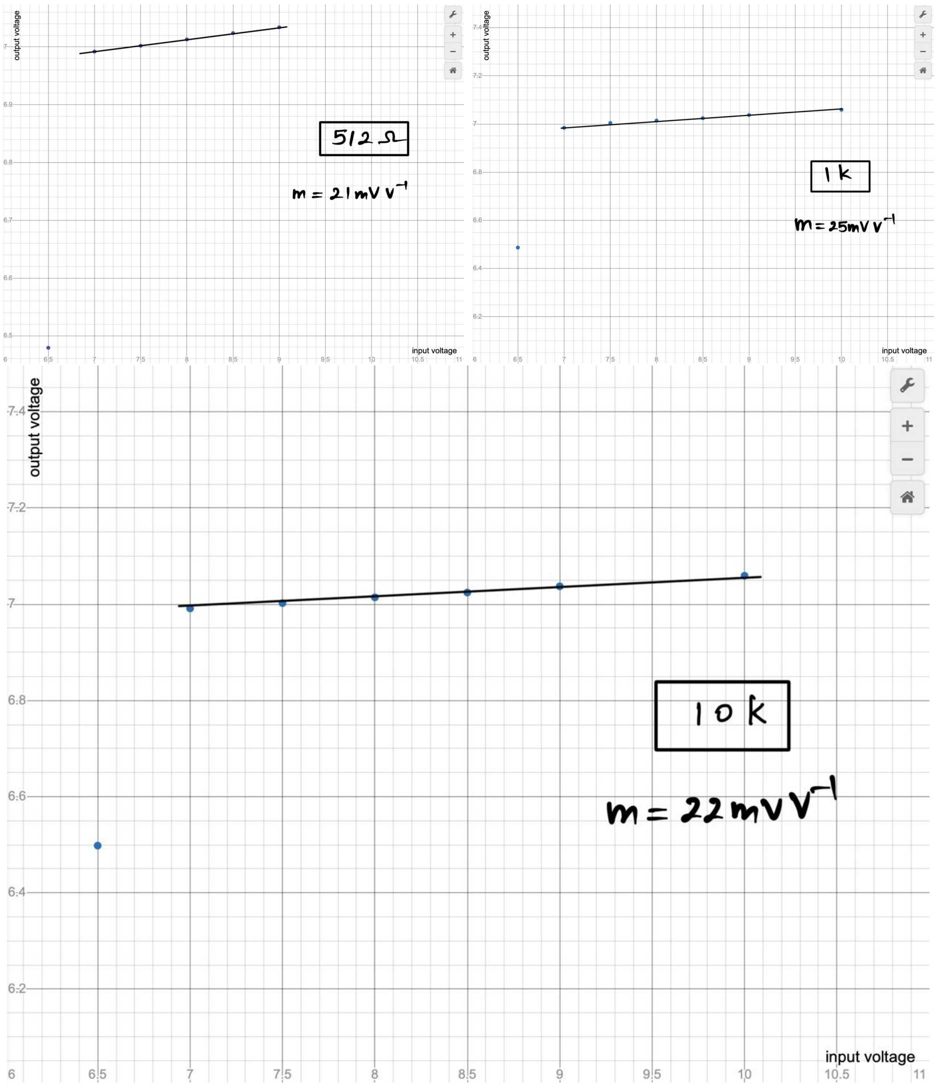


Figure 5: Output voltage for different loads

4 Circuit Diagram

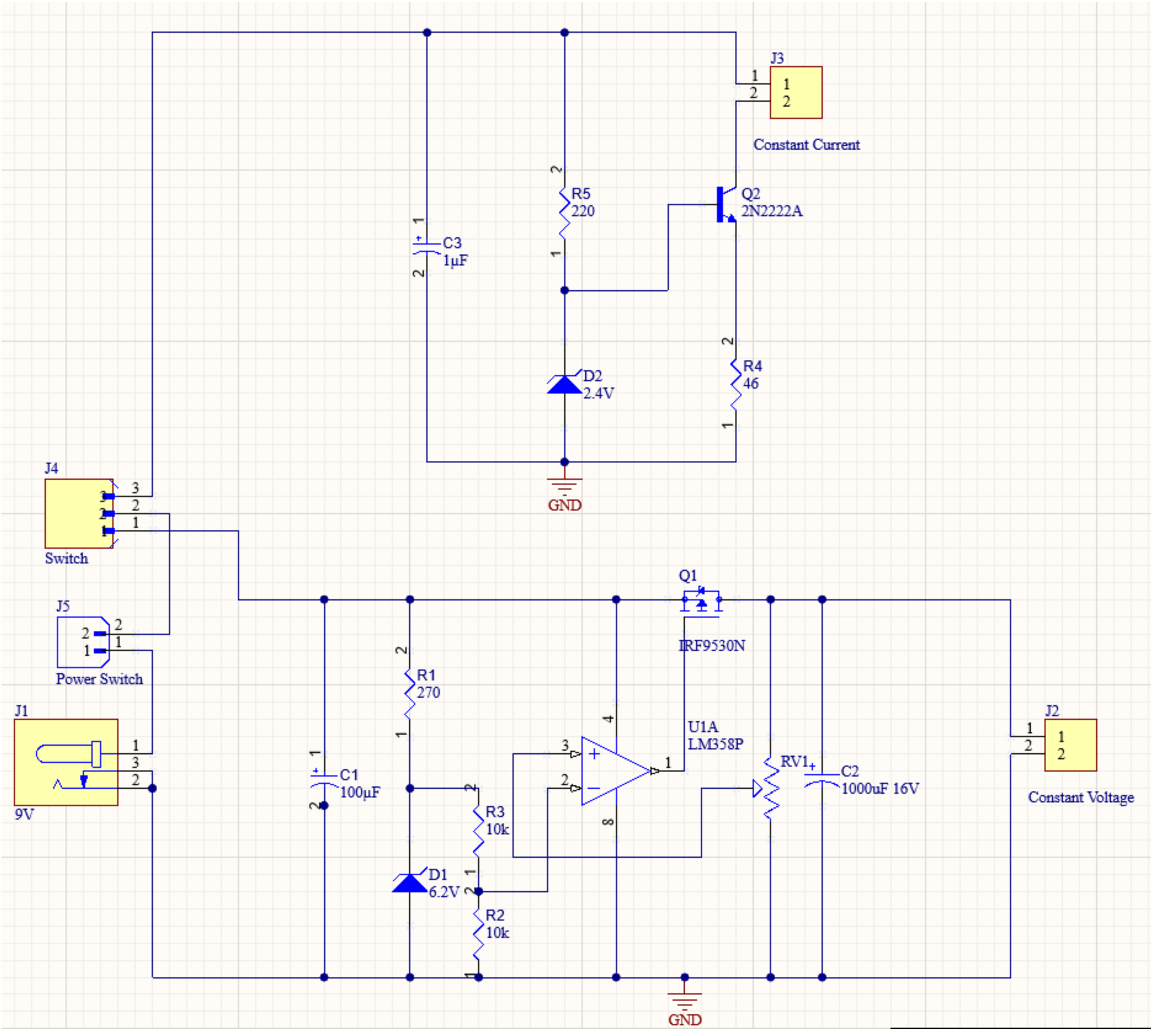


Figure 6: Circuit Diagram

5 Component Selection

5.1 Current Smoother

- 1μF Electrolytic Capacitor :
  Stabilizing Voltage Across the Zener Diode: The capacitor helps maintain a stable voltage across the Zener diode by smoothing out any fluctuations or ripples.
  Noise Filtering: It filters out high-frequency noise, ensuring a clean and stable DC voltage.
  Sufficient Value: A small value like 1 µF is adequate for filtering minor ripples or noise in a low-current, low-voltage circuit like this one.

- 2N2222A Transistor : Can handle up to 800 mA , Vce(sat) is low.
  For low current applications, 2N2222A (NPN) or BC547 (NPN) are suitable options, with the 2N2222A being an easy and reliable choice. For higher current applications, TIP31 (NPN) or TIP32 (PNP) are better alternatives.

- 1N4372 Zener Diode : Zener Voltage 3V.
  To prevent the transistor from entering the saturation region, the Zener voltage should be kept as low as possible.
- Resistors : 220Ω , 46Ω
  choose these value according to calculation.

5.2 Voltage Smoother

- LM358N : It is a low-cost, dual op-amp that operates across a wide supply voltage range, from 3V to 32V for a single supply. The LM358N consumes minimal power, making it ideal for battery-powered or low-power applications. Additionally, its input common-mode range includes ground, ensuring proper operation even when the input voltage is near zero.
- IRF9530N : The IRF9530N is a P-channel MOSFET that serves as pass element in an LDO regulator. The low on-resistance of approximately 0.3 ohms minimizes power loss and heat dissipation, enhancing overall efficiency. As a P-channel MOSFET, it simplifies circuit design because it can be directly driven by the LM358N without requiring a separate high-side driver.
- 6.1V Zener diode : When connected in reverse bias at its breakdown voltage, a Zener diode maintains a stable voltage across it, which can be used as a reference for the error amplifier.
- Capacitors : Ensures stability of the LDO by working with the error amplifier and pass element.

6 PCB Design

The PCB design for this project was created using Altium Designer, a professional software tool known for its comprehensive capabilities in schematic capture, PCB layout, and simulation. The manufactured PCB was produced by JLCPCB, a well-established PCB manufacturing company based in China, known for providing cost-effective and high-quality PCB fabrication services.

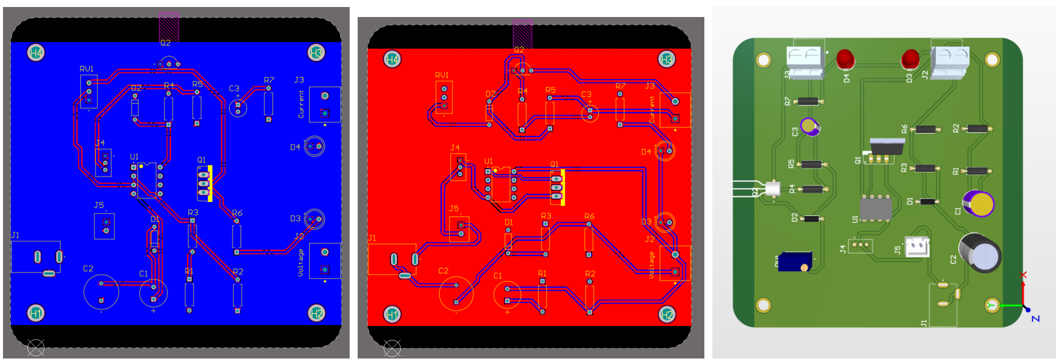


Figure 7: PCB

7 Enclosure Design

The enclosure design for this project was carried out using SolidWorks, a powerful 3D CAD software widely used for mechanical design and product development.

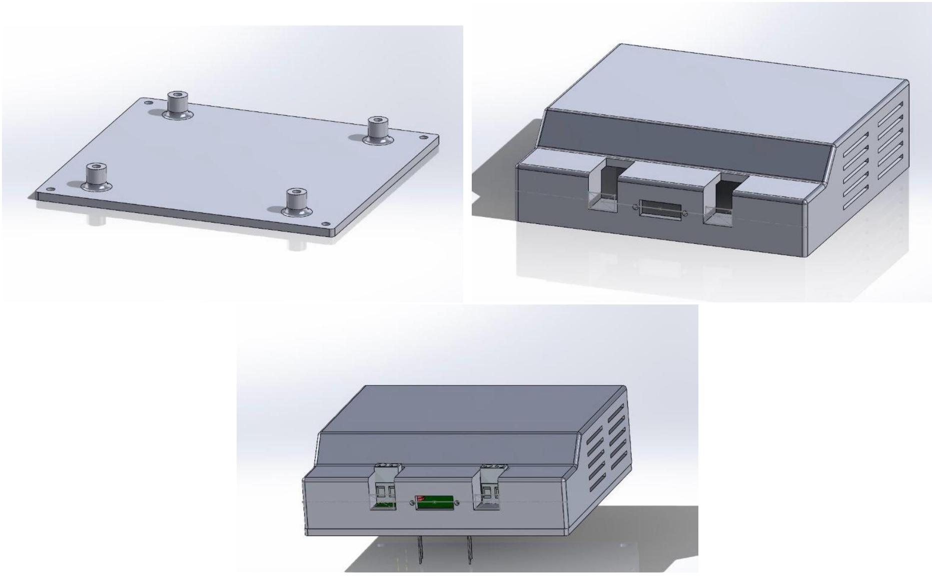


Figure 8: Enclosure

8 Software Simulation and Hardware Testing

The software simulation for this project was conducted using Proteus, a widely used platform for simulating electronic circuits and systems. Proteus allows for the testing and validation of designs in a virtual environment, enabling efficient troubleshooting and optimization before hardware implementation. This tool is particularly useful for verifying circuit functionality, performing real-time simulation.

8.1 Proteus Simulation

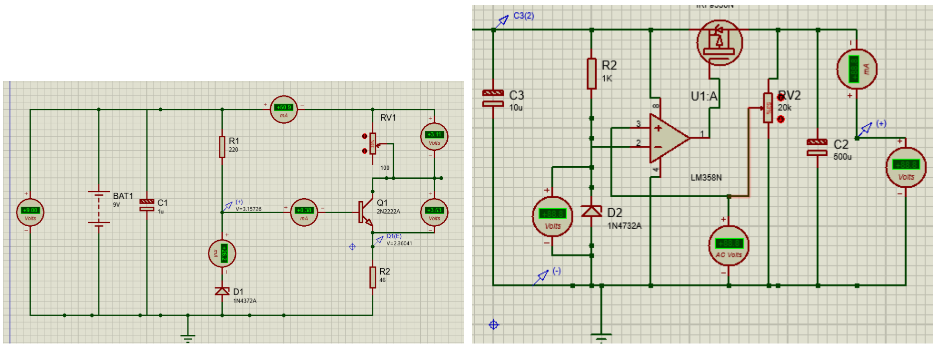


Figure 9: Current and voltage Smoother Circuits.

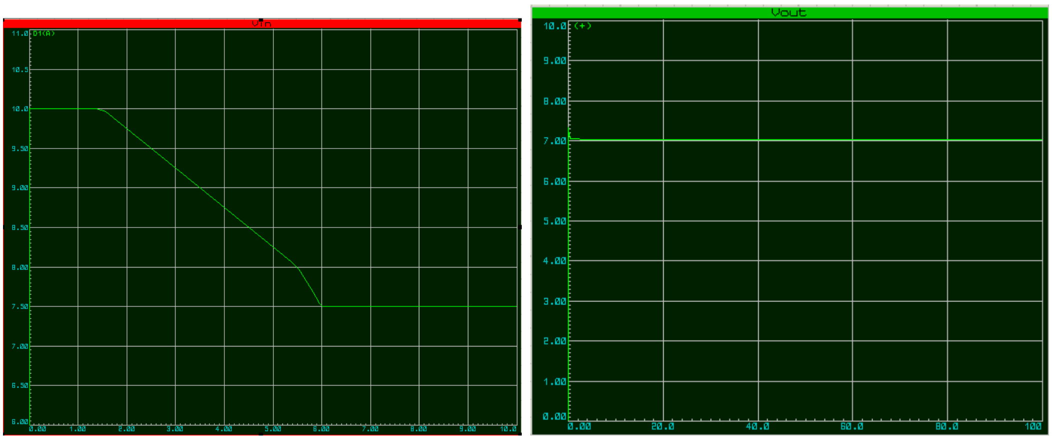


Figure 10: Vin and Vout

8.2 Hardware Testing

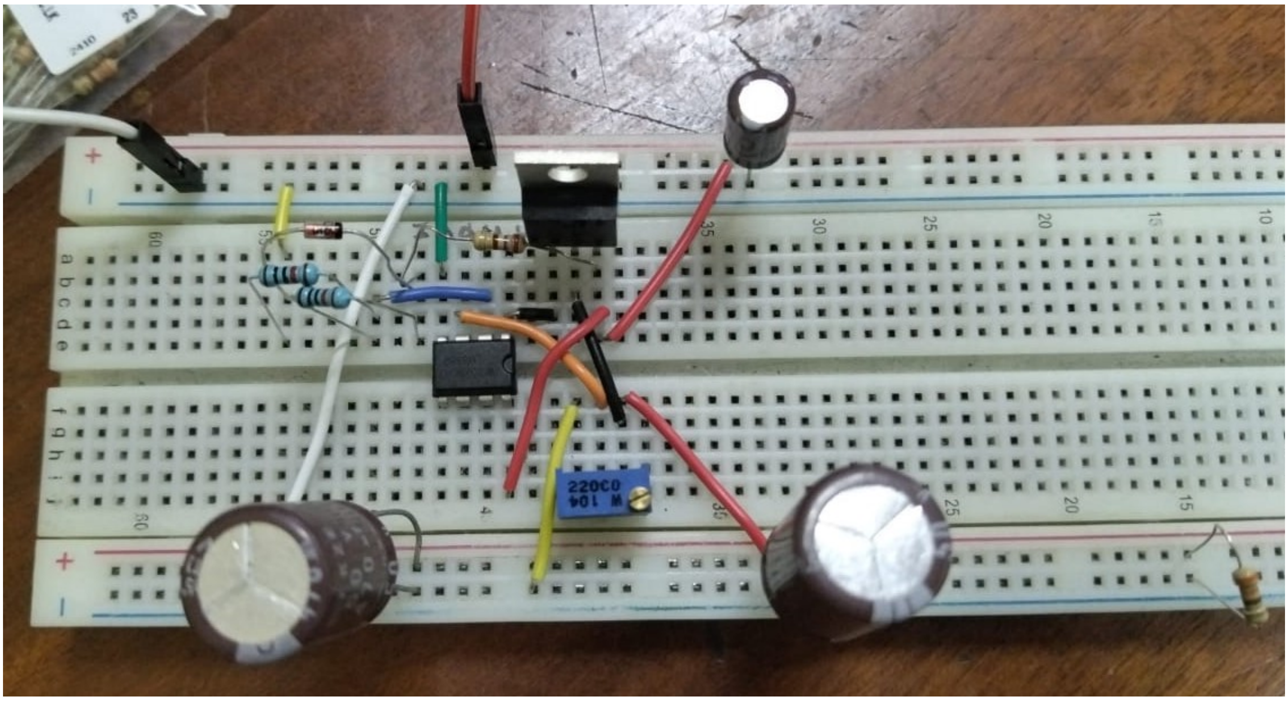


Figure 11: Bread Board Implementation.

9 Conclusion & Future Works

9.1 Conclusion

The project was performed successfully, achieving the primary objectives. However, certain limitations were observed, including slight variations in the output current and voltage, as well as constraints on load variability. Although these variations are minor, they remain significant.

9.2 Future Work

To address these limitations, precise control of the output current and voltage is planned. A knob will be incorporated to enable easy adjustments, providing greater flexibility and control for users.

10 Contribution of Group Members

Name	Task
Ilukkumbura IMEIB	Constant voltage circuit design and simulation
Priyanjana TPIM	PCB design and circuit testing
Aashir MRM	Constant current circuit design and simulation
Basith MNA	Enclosure design and circuit testing

Acknowledgment

The successful completion of this project was made possible through the invaluable feedback and guidance provided by our lecturer, Chameera Edusooriya, during the mid-evaluations. Gratitude is also extended to Lathika Wathsala, a senior from the previous batches, for his mentorship throughout the process, and to the lab assistants for their technical assistance. Finally, appreciation goes to all team members, whose collective efforts and dedication were crucial to the project's success.