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Variable Voltage Linear Power Supply

Group Members:

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EN 2091 Laboratory Practice and Projects

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1 Introduction

This project focuses on the design and implementation of a variable-voltage linear power supply. The power supply is capable of delivering a regulated DC output voltage adjustable between 2V and 20V, with a maximum current output of 2.5A. In addition to the adjustable output, the system includes preset voltage levels for 3.3V, 5V, and 12V, which provides versatility to meet the requirements of various applications. The design ensures stable and reliable power delivery, making it suitable for use in testing, prototyping, and other practical scenarios.

2 System Architecture Overview

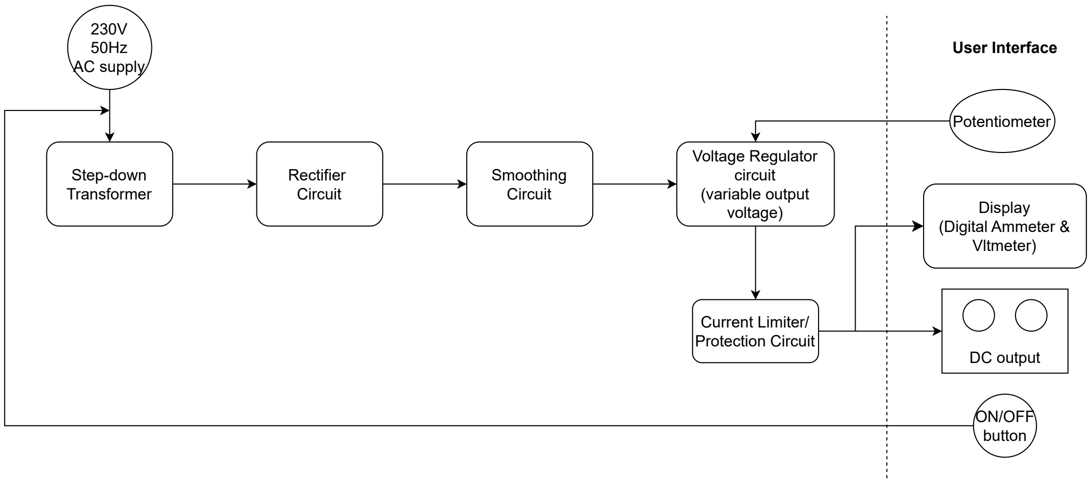


Figure 1: Block Diagram.

The abstract architecture of the linear power supply is illustrated in the functional block diagram. The system operates as follows:

- **Step-Down Transformer:**The 230V, 50Hz AC supply is stepped down to a lower AC voltage suitable for the power supply circuit.
- **Rectifier Circuit:** The stepped-down AC voltage is converted to pulsating DC voltage using a rectifier circuit (A bridge rectifier).
- **Smoothing Circuit:** A smoothing circuit, consisting of capacitors, reduces the ripple in the rectified DC voltage to provide a stable DC voltage.
- **Voltage Regulator Circuit (Variable Output Voltage):**The regulated DC voltage is obtained using a voltage regulator circuit, which allows users to vary the output voltage (from 2V to 20V) through a potentiometer.
- **Current limiter/protection circuit:** A current limiter circuit ensures that the output current does not exceed the safe operating limit of 2.5A, protecting the power supply and connected devices.
- **User Interface:**
  - **4-Pole Switch:**Allows the user to select between preset voltage modes (3.3V, 5V, 12V) and an adjustable mode for a custom output voltage.

- **Potentiometer:** Allows the user to adjust the output voltage. Used in adjustable mode to fine-tune the output voltage.
- **Display (Digital Ammeter Voltmeter):** Shows the real-time output voltage and current.
- **ON/OFF Button:** Used to turn on or off the power supply.
- **DC Output Terminals:** The final DC output is delivered through output jacks.

3 System Model with Design Parameters

3.1 Design Parameters

- **Input Voltage:**
  - Source: 230V AC, 50Hz.
  - Step-down transformer output: 24V AC.
- **Output Voltage Range:**
  - Adjustable voltage: 2V to 20V DC.
  - Preset voltage levels: 3.3V, 5V, 12V.
- **Maximum Current Output:**
  - Current limit: 2.5A max.
- **Power Handling:**
  - Capable of handling a load of 50W
- **Efficiency:**
  - Linear power supplies tend to have lower efficiency due to heat dissipation.
  - Efficiency varies with the output voltage

3.2 System Components

- **Step-Down Transformer:** Converts high-voltage AC to low-voltage AC.
  - **24V 5A Transformer.**
  - Input Voltage: 230V AC, 50Hz
  - Output Voltage: 24V AC
  - Current Rating: 5A (max)
- **Rectifier:** Converts AC to pulsating DC.
  - **BR5010 Bridge Rectifier**
  - Input: 24V AC from transformer
  - Output: 34V peak rectified DC voltage
  - Max Reverse Voltage (PIV): 1000V
  - Max Forward Current: 50A
  - Forward Voltage Drop: 1V per diode (2V total for a bridge rectifier)
- **Smoothing Circuit:** Reduces ripples of rectified voltage using capacitors.
  - Although the calculated smoothing capacitance was 42 mF, a capacitance of only 4.4 mF was used. This choice was justified by the **high ripple rejection ratio of 70 dB** provided by the **LD1085CT** voltage regulator IC, effectively reducing ripple at the output. Additionally, using a **lower capacitance minimizes the RC time constant**, enabling the voltage to stabilize more quickly during operation.
  - **Two 2.2 mF** capacitors are used.
- **Voltage Regulation:**

  - 34 V peak voltage at the transformer output is first regulated to 24 V using a Zener diode(1W) assisted by the Darlington transistor.
  - Darlington transistor allows the Zener diode to operate with rated conditions(current) while passing a higher I_c controlled by lower I_b.
  - Variable Voltage regulation at the output is achieved using LD 1085 Adjustable Voltage Regulator.

- **Voltage Variation:**
  - **LD1085CT** Adjustable regulator.
  - 10k potentiometer for voltage variation.
  - 20k potentiometers for preset voltages.

- **Current Limiting Circuit:** Protection against overcurrent conditions.
  - The 0.47-ohm resistors (2 parallel resistors) sense the load current.
  - When the voltage across these resistors reaches 0.7V, it activates the 2N3904 (B2) transistor, which diverts the base current of the Darlington transistor.
  - This limits the output current to approximately 2.5A, protecting the circuit from overcurrent conditions.

  This approach is simple, and effective, and ensures reliable current limiting using minimal components.

- **Short-Circuit Protection:** To ensure the safety and reliability of the power supply, a **3A fuse** has been incorporated at the power input. This fuse protects the circuit from potential damage caused by short-circuit currents, ensuring the system operates within safe limits.

- **User Interface:**
  - Potentiometer for voltage adjustment.
  - 4-pole switch for selecting preset voltages.
  - Display units (e.g., digital voltmeter and ammeter).

- **Cooling Mechanism:** To manage heat dissipation effectively, heat sinks are mounted on the voltage regulators and power transistors. Additionally, the enclosure is designed with vents on both sides and the back to facilitate proper airflow and improve heat dissipation, ensuring the system operates within safe temperature limits.

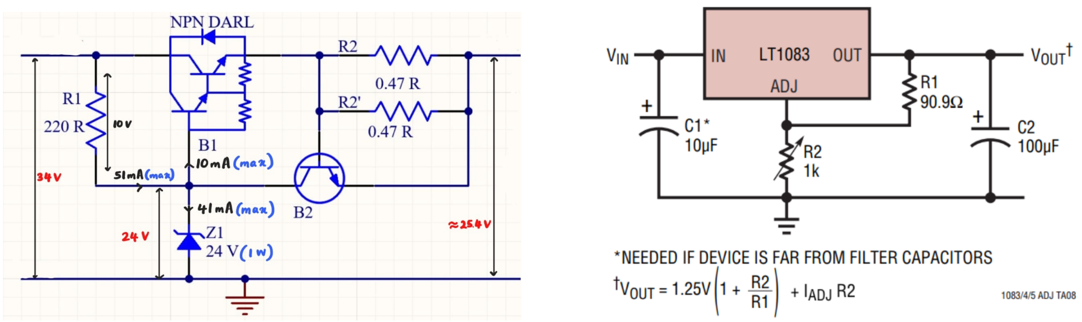


Figure 2: Voltage regulation, variation and Current limiter circuit

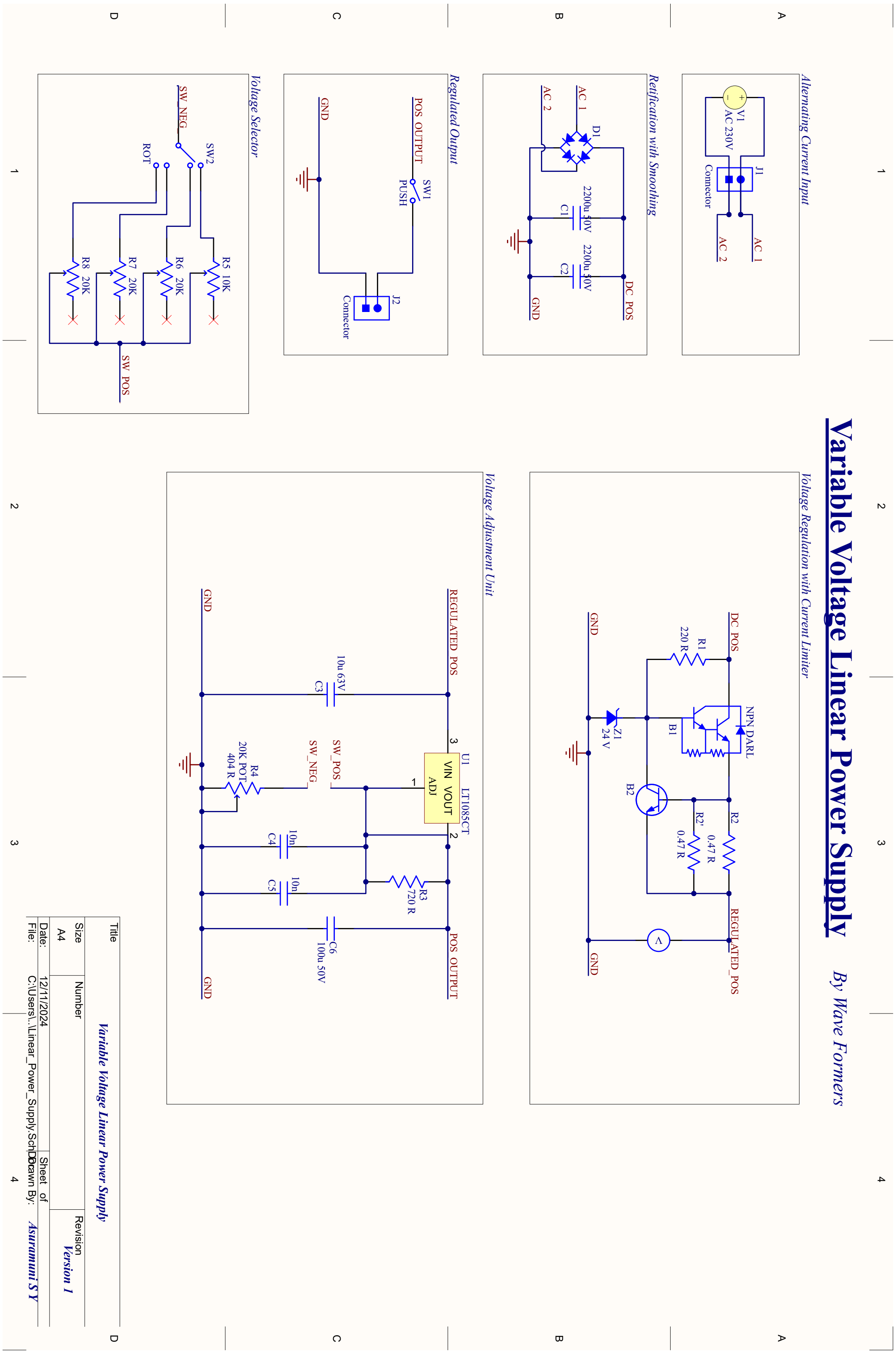


Figure 3: Schematic Diagram.

4 PCB Design

The Printed Circuit Board (PCB) for the variable voltage linear power supply was designed using *Altium Designer* and manufactured by *JLCPCB*. Key specifications are as follows:

- Layers: 2-layer PCB
- Copper Thickness: 1 oz copper
- Dimensions: 86.4 mm x 64.0 mm
- Current Capacity: Up to 2.5 A
- Voltage Handling: Up to 34 V

The top layer handles signal routing and other connections, with optimized placement of components and traces. The bottom layer of the PCB is dedicated entirely to the ground plane to ensure stability and reduce noise. Polygon pours and wide current-carrying traces (minimum trace width of 1mm) were incorporated to minimize resistance in current paths and effectively manage the relatively high voltages and currents.

All components used on the PCB are through-hole, ensuring durability, ease of soldering, and reliable performance under high current conditions. The layout prioritizes efficient routing, proper grounding, and thermal management to meet the power supply requirements.

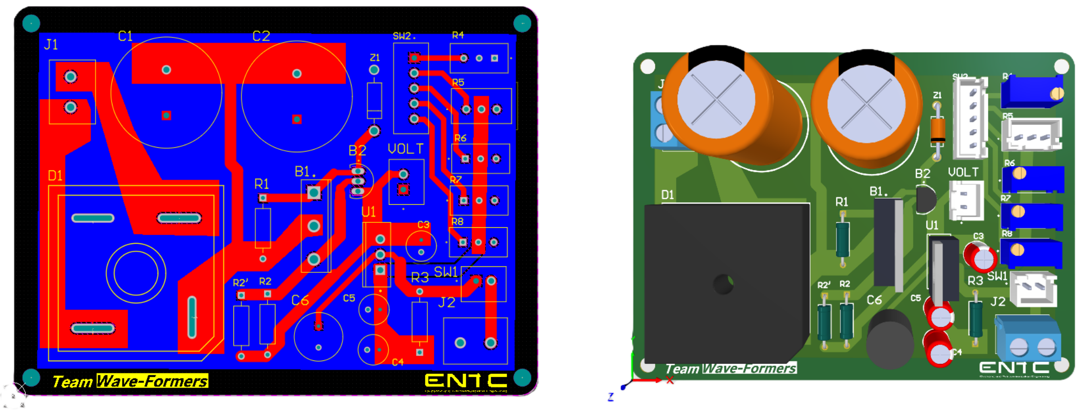


Figure 4: PCB design

5 Enclosure Design

The enclosure was designed using *SOLIDWORKS* (sheet metal design). Provides sufficient space for the PCB and cooling mechanisms. An air intake vent was positioned at the back, while two exhaust vents were placed on the sides for efficient airflow. The Power Input and fuse were located at the back, whereas the Power Output, Power Switch, and Digital Display were positioned on the front panel for easy access. The enclosure was built from **0.8mm Zn coated steel** to ensure a lightweight design while maintaining structural integrity. It is also covered with a Carbon Fiber sticker for insulation to ensure the user's safety. A **two-part design** was implemented to facilitate easy access to the interior.

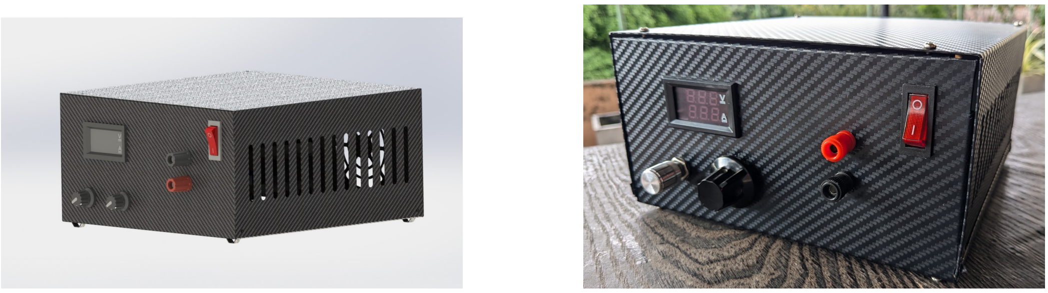


Figure 5: Front View

Figure 6: Back View

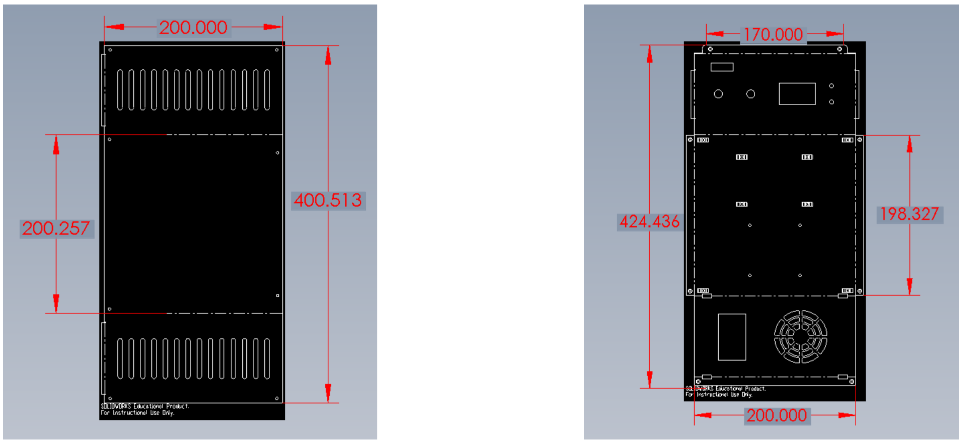


Figure 7: Sheet

6 Software Simulation and Hardware Testing

To validate the design and ensure the functionality of the linear power supply, both **software simulation** and **hardware testing** were conducted.

6.1 Software Simulation

The circuit was simulated using **LTspice** to analyze the performance of key features such as **voltage regulation**, **ripple reduction**, and **current limiting**.

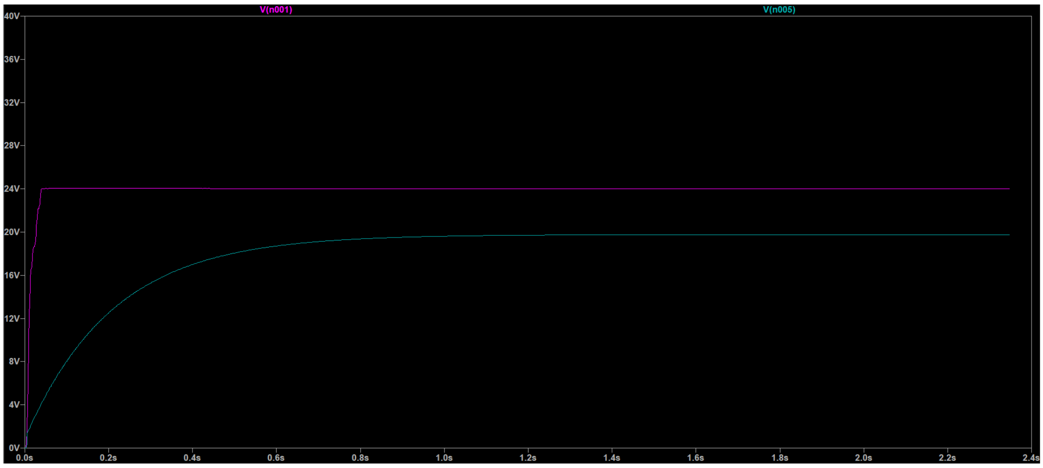


Figure 8: Regulated Voltage (Pink) and Variable Output(Blue)

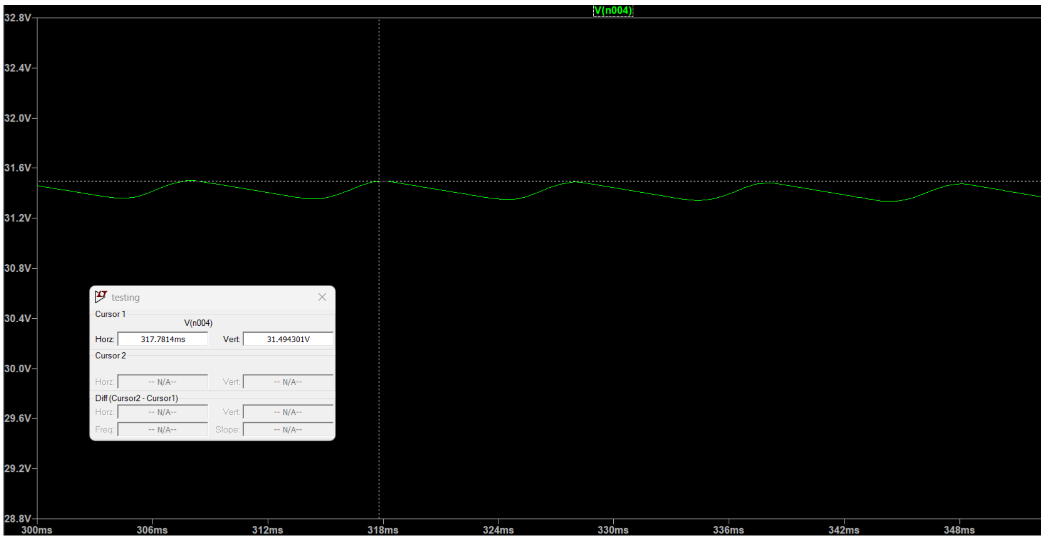


Figure 9: 150mV Pk-Pk ripple after smoothing

6.2 Hardware Testing

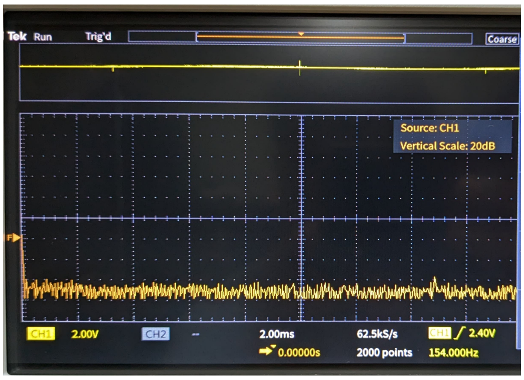
The hardware implementation of the linear power supply was tested in the lab to validate its performance against the simulated results. Key testing parameters included:

- **Voltage Regulation:**

  - The output voltage was measured using a **digital multimeter** for different load conditions.
  - Results showed an adjustable range of **2V to 20V** with minimal deviation.

- **Current Limiting:**
  - Load current was increased incrementally until the current-limiting circuit activated.
  - The output current stabilized at approximately **2.5A**, confirming proper operation of the current-limiting mechanism.

- **Ripple Voltage:**
  - Ripple voltage at the output was measured using an oscilloscope, verifying the effectiveness of the smoothing capacitors and regulators.



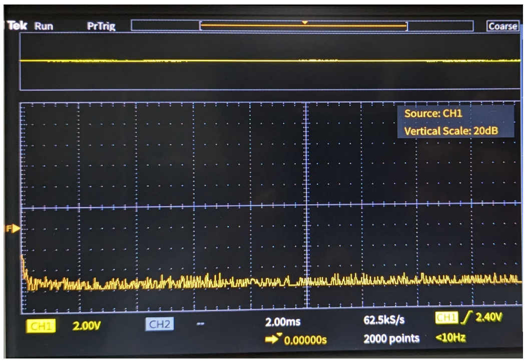


Figure 10: Probes connected to the output(L) Probes not connected (R)

The combined results from **simulation** and **hardware testing** demonstrated that the design meets the intended specifications, with stable voltage regulation, effective current limiting, and low ripple voltage.

7 Conclusion & Future Works

In this project, a variable-voltage linear power supply was designed and implemented to provide a regulated DC output voltage with a range of 2V to 20V and a maximum output current of 2.5A. The power supply incorporates key components such as the LD1085CT voltage regulator, TIP142 power transistor, and a 24V transformer to efficiently regulate the output. The system successfully demonstrates adjustable voltage output and effective current limiting, making it suitable for a variety of applications.
However, there are several areas where improvements can be made:

- **Transformer Output**: The current transformer output is slightly higher in RMS voltage than anticipated. In future designs, it may be beneficial to replace the current transformer by another with lower RMS value of 20V which can directly feed into the LT1085 after smoothing. This approach would simplify the design by eliminating the need for additional components like the Zener diode and Darlington transistor, potentially leading to a more efficient system overall.
- **Dual-Channel Power Supply**: A potential future enhancement could involve developing the power supply into a dual-channel design. This would allow for two independent adjustable voltage outputs, which would be beneficial for powering multiple devices with different voltage requirements simultaneously. This addition would make the power supply more versatile and capable of handling more complex applications.
- **Display Precision**: To enhance the user experience, a more precise display system could be implemented to provide better voltage and current readings, improving the overall usability of the power supply.
- **Cooling Mechanism**: Although heat sinks and venting were used for cooling, the implementation of an active cooling solution, such as a fan, could further improve the efficiency by reducing heat buildup, especially under higher loads or prolonged usage.

These future enhancements will contribute to improving the efficiency, stability, and reliability of the power supply, making it even more versatile for a wide range of applications.

8 Contribution of Group Members

Team Member	Responsibilities
220046R Asuramuni S. Y.	- PCB Design - Testing & Debugging - Product Assembly
220280D Jayawardena H.D.S.S.	- PCB Design - Circuit Design - Component Selection
220429U Nimantha K.L.W.O.	- Enclosure Design - Product Assembly - Documentation
220692R Weragoda W.A.A.P.	- Circuit Design & Calculations - Component Selection - Testing & Debugging

Table 1: Team Members and Their Responsibilities

9 References

- https://github.com/DulminEdirisinghe/LinearPowerSupply/tree/main
- https://www.instructables.com/10Amp-Linear-Power-Supply/
- Datasheets (added to a separate folder)