Pamantasan ng Lungsod ng Maynila
Gen. Luna Cor. Muralla St., Intramuros, Manila

College of Engineering
Electronics Engineering Department

ECE 0212.1 – ELECTRONICS DEVICES AND CIRCUITS (LABORATORY)

Final Project
Adjustable 30V Regulated Dual Polarity Linear Power Supply

Schedule:	Monday 7-10am		
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Date of Performance: 30 September - 13 December 2024
Date of Submission: 13 December 2024

ECE 0212.1 – Electronic Devices and Circuits Laboratory

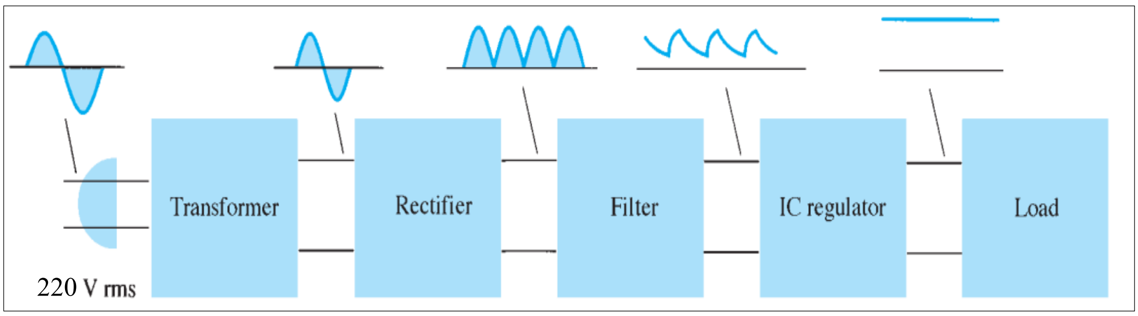
ADJUSTABLE 30V REGULATED DUAL POLARITY LINEAR POWER SUPPLY

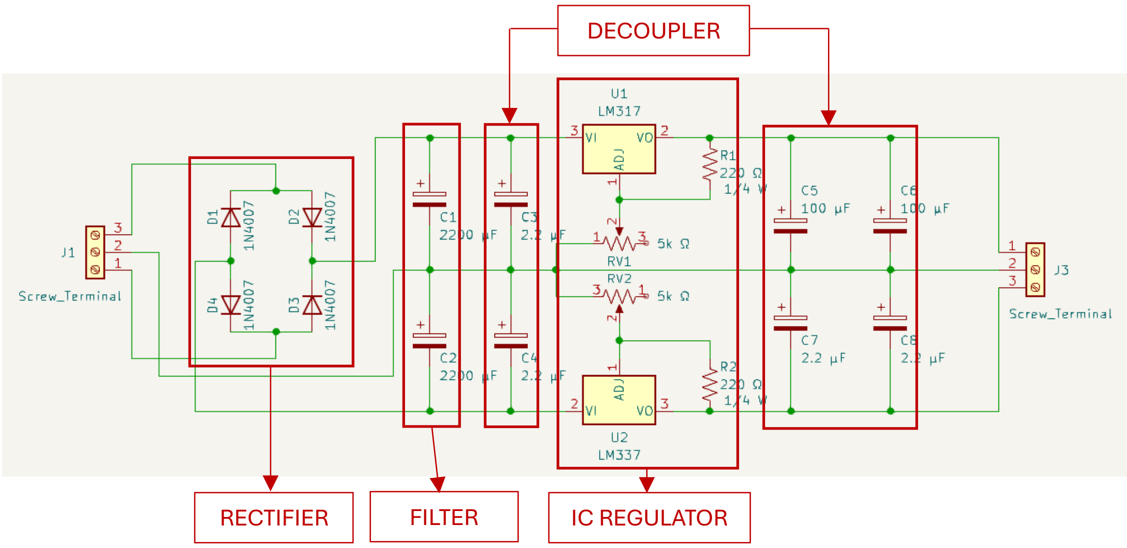
1.0 THEORETICAL DISCUSSION

This project demonstrates the application of linear power supply concepts. The input voltage is first stepped down using a transformer, then rectified and converted into direct current. The waveform is subsequently filtered to improve its quality. Linear regulators are used to maintain a constant output voltage by dissipating excess energy as heat. This type of power supply, known as a low-frequency or series power supply, operates without any switching components.

In this project, a dual-polarity linear power supply is designed to provide both positive and negative DC voltages relative to a common ground, which is essential for powering circuits such as operational amplifiers and other analog devices. The circuit is based on the LM317 (positive voltage regulator) and LM337 (negative voltage regulator). It utilizes a 220V AC mains input, a 24-0-24 2A center-tapped transformer, and several additional components to ensure the power supply is safe and functional.

To expound, below is a comprehensive explanation of the operating principles and the functionality of each component within the block diagram of a power supply, as illustrated in the figure below, and utilized in the fabrication of this power supply project.





A) TRANSFORMER

- Purpose: The transformer steps down the 220 V AC mains voltage (60 Hz was assumed as per the Philippines standard frequency) to a lower voltage level suitable for the circuit.
- Operation: The transformer's primary winding receives the 240V AC input (Philippines standard frequency is 60 Hz). The secondary winding produces three terminals: +24V, 0V (center-tap, ground), and -24V AC. The center tap provides a reference point for generating positive and negative voltages.
- Wiring Correlation: The primary winding is connected to the AC mains (power outlet), and the secondary winding provides the stepped-down AC voltages (into the PCB).

B) RECTIFIER

- Purpose: The rectifier converts the AC voltage into pulsating DC voltage.
- Operation:
  - During the positive half-cycle of the AC input, diodes D1 and D3 conduct, allowing current flow to the positive side of the load.
  - During the negative half-cycle, diodes D2 and D4 conduct, providing current to the negative side of the load.
  - This creates two separate pulsating DC outputs: one positive and one negative, both relative to the center tap.
- Schematic Correlation: The diodes are rated 1N4007, suitable for high-voltage rectification.

C) FILTER

- Purpose: Smooth out the pulsating DC from the rectifier to create a steady DC voltage.
- Operation: Large electrolytic capacitors (C1 and C2, each 2200 μF) are used to filter the DC voltage. The capacitors charge during voltage peaks and discharge during dips, significantly reducing ripple voltage. The result is a relatively constant DC voltage with minor ripples.
- Schematic Correlation: Large electrolytic capacitors (C1 and C2, each 2200 μF) act as major filter capacitors. Additional smaller capacitors (C3, C4, C7, C8) are used to filter high-frequency noise which are commonly called decoupling capacitors of the regulated voltage output of the ICs.

D) IC (VOLTAGE) REGULATORS (LM317 AND LM337)

- Purpose: Provide stable, adjustable output voltages and regulate against variations in input voltage or load conditions.
- Operation:
  - LM317: Regulates the positive voltage output. RV1 adjusts the output voltage between +5V and +30V.
  - LM337: Regulates the negative voltage output. RV2 adjusts the output voltage between -5V and -30V.
  - The regulators dissipate excess voltage as heat, ensuring the output remains stable and ripple-free.
- Schematic Correlation: Each IC has input and output capacitors (e.g., C5, C6 for LM317 and C7, C8 for LM337) to improve stability and transient response.

E) LOAD

- Purpose: The load represents the circuit or device powered by the supply.
- Operation: The dual output (e.g., +30V and -30 V) powers operational amplifiers, analog circuits, other devices needing dual polarity, or any simple devices that have small voltage requirement.
- Schematic Correlation: The outputs are accessible via screw terminals (J3), allowing connection to external loads.

Key Design Considerations:

- Heat Dissipation: Linear regulators dissipate excess energy as heat, so proper heatsinking for LM317 and LM337 is attached.
- Capacitor Voltage Ratings: Capacitors must have voltage ratings higher than the peak AC voltage ($\approx 34\ V$), thus 50V capacitors were utilized.

- Output Filtering (DECOUPLER): Smaller capacitors (C3, C4: 2.2 μF; C5, C6: 100 μF) were added to eliminate residual high-frequency noise and improve stability. These capacitors act as decoupling filters, ensuring that the output voltage remains clean and free from noise.

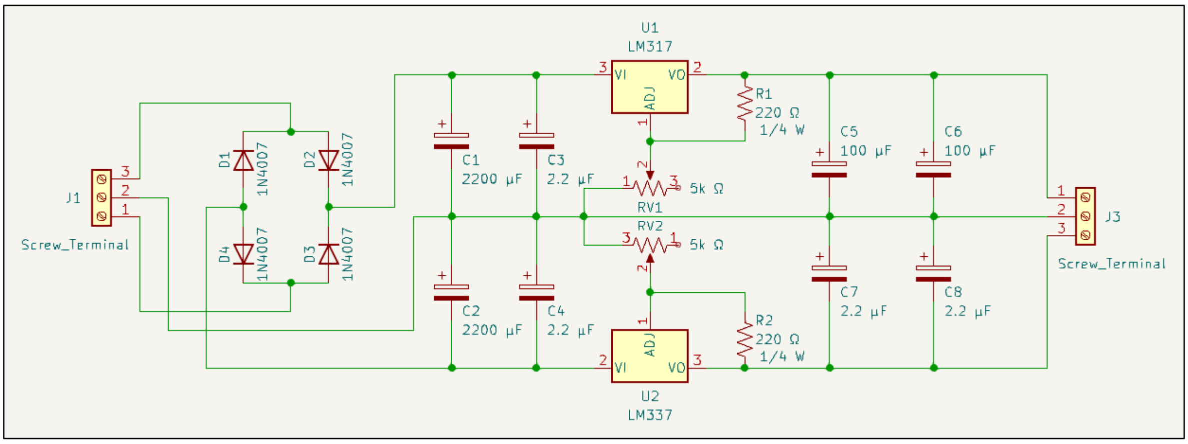
2.0 SCHEMATIC DIAGRAM

The components needed to fabricate the project are outlined in the table below, including the schematic diagram used. To clarify, the project instructions were sourced online from *Circuits Today*. However, minor modifications were necessary due to errors in the original schematic diagram. These discrepancies led to multiple failed attempts before successfully completing the project.

In detail, in the original schematic diagram, capacitor C5 was assigned a value of 2.2 μF, while C8 had a value of 100 μF. This configuration repeatedly caused the LM337 to sustain permanent damage during the development process. Troubleshooting the issue introduced additional complications, such as capacitors exploding and resistors overheating and burning out. The problem was resolved by interchanging the values of C5 and C8, which ultimately resulted in a functional prototype.

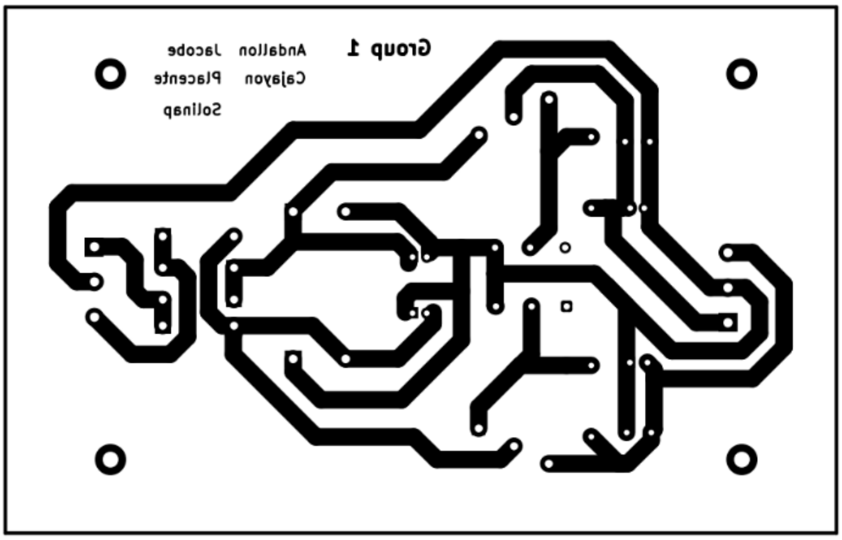
Finally, additional modifications were implemented to enhance the convenience and safety of fabricating the power supply project. These included adding a 1.5 A fuse between the transformer and the PCB, incorporating a switch directly connected between the outlet and the transformer, attaching heatsinks to the voltage regulators, utilizing screw terminals for the input and output terminals, and installing voltmeters for the two outputs.

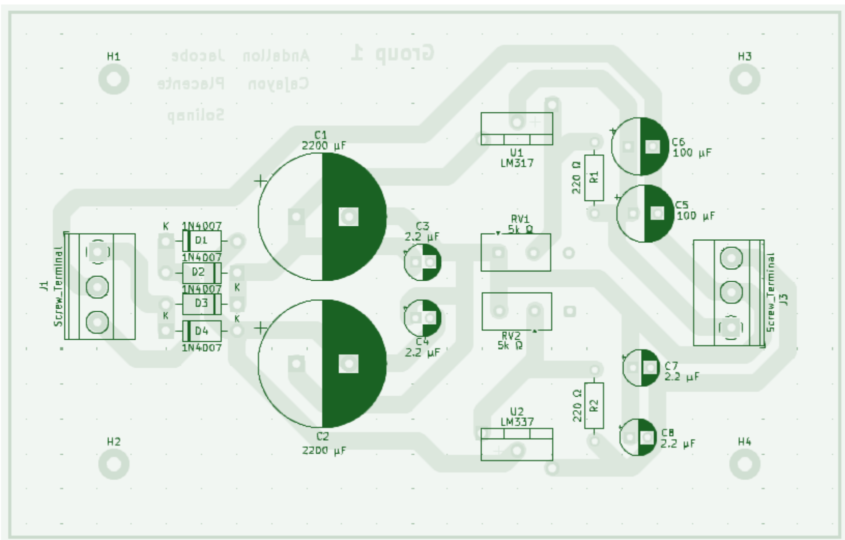
Component	Specification	Name
C1, C2	2200 uF	50V Electrolytic Capacitor
C3, C4, C7, C8	2.2 uF	50V Electrolytic Capacitor
C5, C6	100 uF	50V Electrolytic Capacitor
R1, R4	5K Ohms	Potentiometer
R2, R3	220 Ohms	1/4 W Resistor
D1, D2, D3, D4	IN 4007	Diodes
U1	LM317	Voltage Regulator IC
U2	LM337	Voltage Regulator IC
J1, J2	3-pin Terminal Block	Screw Terminal
Additional:	(2x) 1.5A fuse, (2x) panel mount fuse holder, (2x) voltmeter, (2x) heatsink, 24-0-24 2A center-tapped transformer	



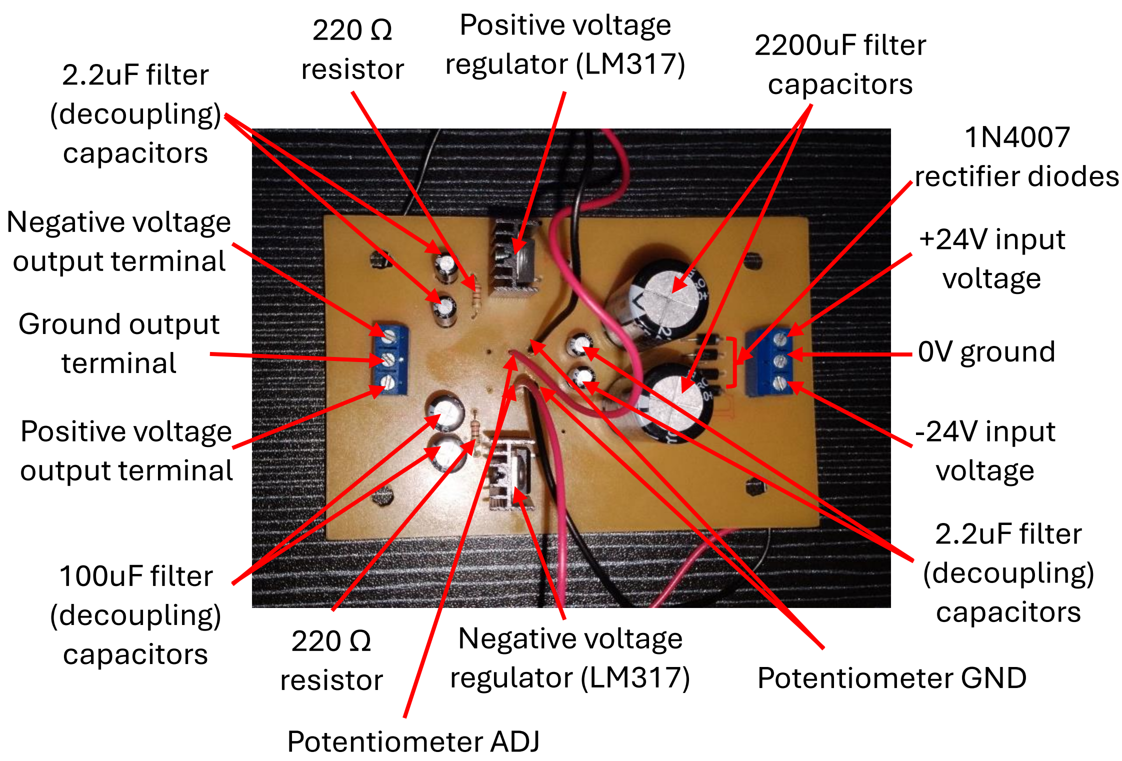
3.0 PCB DESIGN

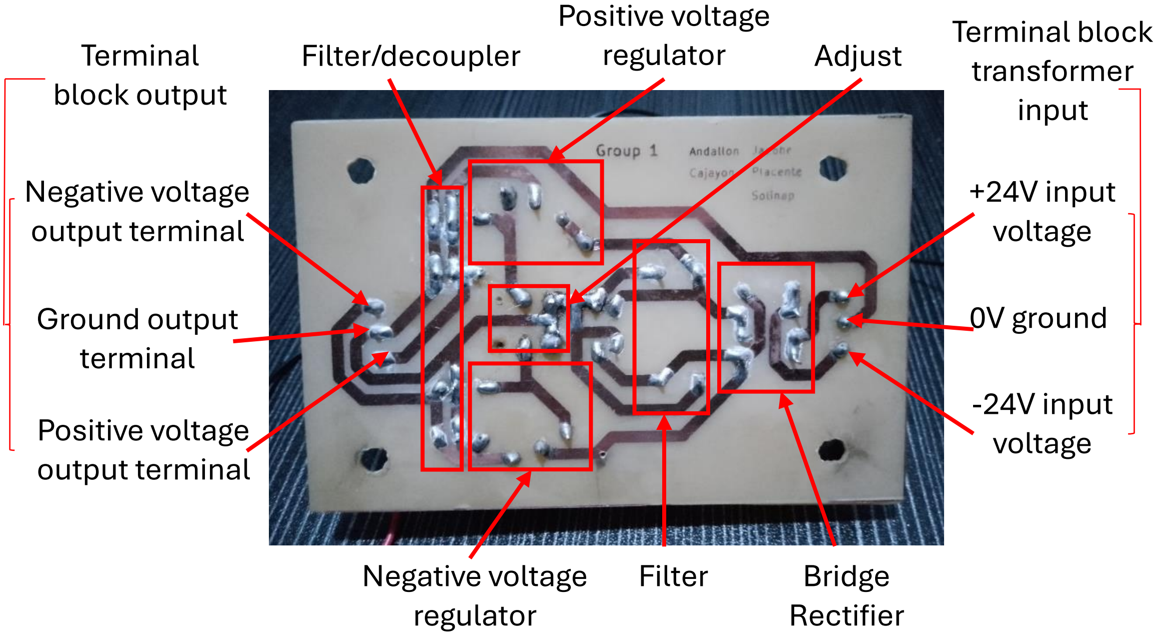
The circuit design for the Printed Circuit Board (PCB) is shown in the first illustration below, while the succeeding illustration shows the placement of the components on the PCB layout.



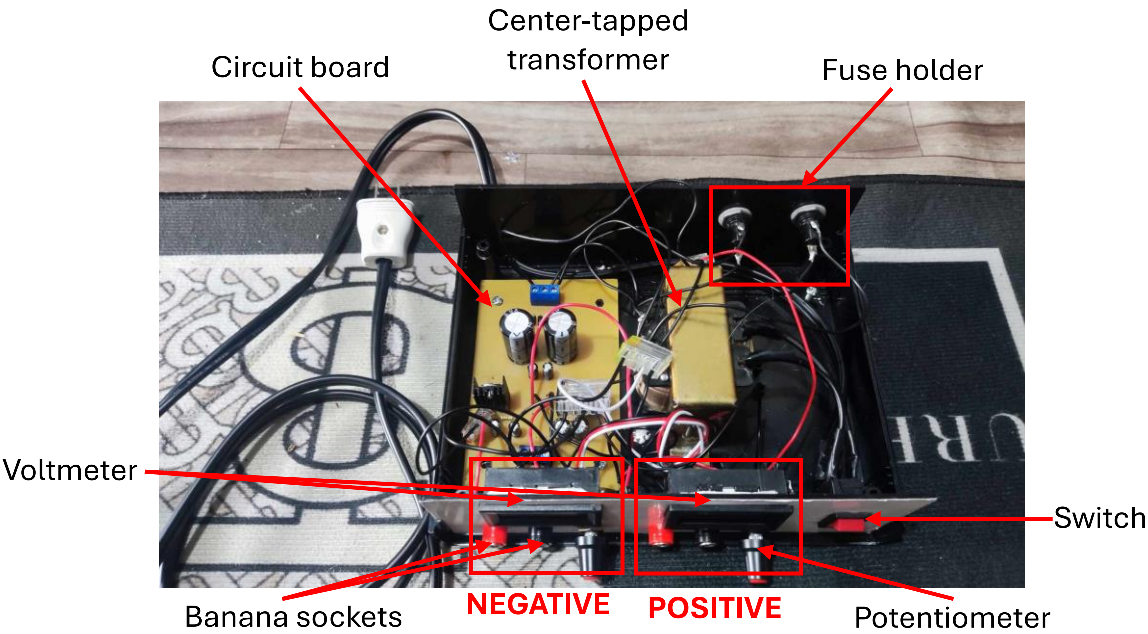


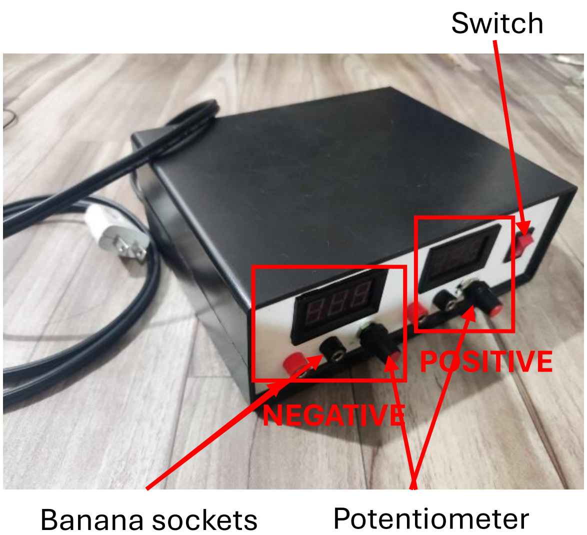
4.0 CIRCUIT PROTOTYPE





This inside part, front panel, and rear panel of the chassis are shown and labeled below:





5.0 TESTING AND ANALYSIS

The power supply was tested by measuring the resulting voltage and current under varying load conditions. These load conditions were achieved by using resistors of different values connected to the power supply. The experiment was conducted for both positive and negative supply voltages at three distinct voltage levels for each polarity.

Experimental Setup:

The experimental setup consisted of a resistor in series with the power supply. Two digital multimeters were employed: one connected in parallel with the resistor to measure the load voltage (V_L), and the other connected in series with the circuit to measure the load current (I_L). The setup was straightforward yet highly efficient for the intended measurements because:

1. Precision in Measurement

Using a multimeter in parallel for voltage and another in series for current ensured direct and accurate readings. The high input impedance of the voltage meter minimized interference, while the series configuration for current captured true flow without requiring additional calculations.

2. Minimized Complexity

The simple series circuit reduced potential points of error, interference, and noise. Its straightforward design ensured reliable measurements and made troubleshooting easy, with all observations directly reflecting the power supply's behavior.

3. Controlled Testing

Varying the resistance allowed precise control over load conditions, enabling systematic analysis of the power supply across a wide range of currents. The use of discrete resistor values ensured reproducibility and facilitated predictable, reliable testing.

4. Applicability to Both Polarity Tests

The same setup was used effectively for both positive and negative supply voltages, ensuring consistency across tests.

Result Analysis:

The results of the experiment are summarized in two tables for positive and negative supply voltages below. Key observations are as follows:

1. Voltage Stability:

The measured voltage across the load (V_L) was consistently close to the supplied voltage (V_{supply}), indicating minimal voltage drop across the internal resistance of the power supply. For example, at V_{supply}=10.05 V and R=1 kΩ, VL=10.02, which is a negligible difference. This reflects the power supply's ability to maintain stable output under load.

2. Current-Load Relationship:

The current through the resistor decreased with increasing resistance, following Ohm's law. For instance, at V_{supply}=5.008:

- R=1 kΩ: I_L=5.06 mA
- R=10 kΩ: I_L=0.49 mA

These results confirm that the power supply behaves as an ideal voltage source under the tested conditions.

3. Positive vs. Negative Voltage Performance:

For both polarities, the behavior was symmetric and consistent, indicating reliable performance regardless of the polarity. For example, at V_{supply}=−9.94 V, the results (V_L=−9.87 V, I_L=−10.01 mA) closely mirrored the performance observed at V_{supply}= +10.05 V.

4. Load-Voltage Deviation:

Slight deviations were observed for very high resistances, particularly in negative supply measurements, where the internal resistance of the power supply became more noticeable. For example, at R=10 kΩ and V_{supply}=−1.945 V, V_L=−2.022 V. These minor deviations observed at higher resistances are consistent with real-world limitations of practical power supplies.

POSITIVE VOLTAGE POWER SUPPLY						
	V_{supply} = 1.366 V		V_{supply} = 5.008 V		V_{supply} = 10.05 V	
Resistance (Ω)	V_L (V)	I_L (mA)	V_L (V)	I_L (mA)	V_L (V)	I_L (mA)
1 kΩ	1.364	1.36	5.008	5.06	10.02	10.14
2.2 kΩ	1.364	0.61	5.008	2.29	10.04	4.61
5.6 kΩ	1.367	0.23	5.001	0.88	10.04	1.79
7.5 kΩ	1.367	0.16	5.006	0.65	10.04	1.33
10 kΩ	1.368	0.12	5.005	0.49	10.04	1.00

NEGATIVE VOLTAGE POWER SUPPLY						
	V_{supply} = -1.945 V		V_{supply} = -4.712 V		V_{supply} = -9.94 V	
Resistance (Ω)	V_L (V)	I_L (mA)	V_L (V)	I_L (mA)	V_L (V)	I_L (mA)

1 kΩ	-1.881	-1.91	-4.567	-4.59	-9.87	-10.01
2.2 kΩ	-1.897	-0.88	-4.512	-2.08	-9.94	-4.59
5.6 kΩ	-1.914	-0.35	-4.505	-0.81	-9.96	-1.80
7.5 kΩ	-1.952	-0.27	-4.513	-0.61	-9.97	-1.35
10 kΩ	-2.022	-0.21	-4.550	-0.47	-10.02	-1.02

6.0 CONCLUSION

The experiment confirmed the power supply's ability to deliver stable and reliable output under varying load conditions. Both positive and negative voltage tests demonstrated consistent performance, with the supply maintaining voltages close to the set values across different resistance loads. The observed current-load relationship followed Ohm's law, affirming the supply's behavior as a near-ideal voltage source.

Minor deviations at higher resistances, especially in the negative polarity tests, were within acceptable limits and consistent with the characteristics of real-world power supplies. Importantly, the supply exhibited symmetry in performance for both polarities, showcasing its versatility and dependability.

In brief, the power supply proved to be robust, precise, and suitable for applications requiring stable operation across a range of load conditions and polarities.

7.0 DEVELOPMENTAL PROCESS

The summary of the developmental process undertaken in completing the project is tabulated below:

SUMMARY OF THE DEVELOPMENTAL PROCESS		
PCB MAKING		
1ST TRIAL		
DATE	PROCESS	STATUS
October 6, 2024	Schematic Diagram	SUCCESS
October 12, 2024	PCB Etching	FAILED (Defective)
November 3, 2024	PCB Etching	FAILED (Not Mirrored)
November 4, 2024	PCB Drilling	SUCCESS
November 5, 2024	PCB Soldering	FAILED
November 6, 2024	PCB Soldering	FAILED
2ND TRIAL		
November 5, 2024	Schematic Diagram	SUCCESS
November 9, 2024	PCB Etching	SUCCESS (Prototype)
November 9, 2024	PCB Etching	SUCCESS (Final)
November 9, 2024	PCB Drilling	SUCCESS
November 9, 2024	PCB Soldering	SUCCESS
BREADBOARDING		

DATE	TRIAL	STATUS
October 6, 2024	1st	FAILED
November 3, 2024	2nd	FAILED
November 6, 2024	3rd	SUCCESS
November 9, 2024	4th	SUCCESS
CASE MAKING/WIRING		
DATE	**TRIAL**	**STATUS**
November 10, 2024	1st	PROGRESS
December 10, 2024	2nd	FINALIZED

Consequently, this discussion focuses on the major aspects of the developmental project, omitting minor events. It is important to note that neither the summary nor this discussion covers every developmental process undertaken. Instead, they emphasize the key and frequently repeated actions that played a significant role in the project's accomplishment.

Detailed Process for Completing the Dual Adjustable Power Supply Project:

October 6, 2024: Initial Breadboarding and Schematic Design

Our first attempt at breadboarding faced a major issue: the potentiometers kept burning out. Despite this setback, we proceeded to design the circuit layout and create the schematic using KiCad software. This step was crucial in visualizing the circuit and planning the PCB layout.

October 12, 2024: Second Breadboarding Attempt

In our second breadboarding attempt, we encountered defective tracks. The circuit lines had several cuts, making it impossible to achieve proper continuity. These issues highlighted the importance of thoroughly inspecting the breadboard before use.

November 4, 2024: PCB Drilling

On November 3, we completed our first PCB etching. The next day, we drilled holes for component placement. Initially, the PCB seemed successful, but testing revealed incorrect outputs after soldering the components on November 5. Additionally, a couple of potentiometers were damaged.

November 6, 2024: Troubleshooting and Design Modifications

We considered soldering the components on the opposite side of the PCB. However, this led to multiple issues, including incorrect outputs, resistors and potentiometers burning out, damaged ICs, and a capacitor explosion These failures prompted us to double-check and modify the schematic diagram and circuit design in KiCad to ensure accuracy and reliability.

November 9, 2024: Successful Breadboarding and Testing

Using the revised schematic, we constructed the circuit on a breadboard. This attempt was successful, confirming the design's functionality. We then proceeded to: etch a PCB for testing, drill holes and solder components, and test the assembled PCB.

During testing, we experimented by interchanging the values of C5 and C8 capacitors. This caused the LM337 to fail, but reverting to the original modifications restored functionality. Once satisfied with the results, we etched a PCB for the final design, drilled holes, and soldered the components to complete the assembly.

November 10, 2024: Enclosure Preparation

We created holes in the power supply case to accommodate the components and assembled a prototype. The prototype was functional but required finishing touches.

December 10, 2024: Final Polishing

The case was polished by adding labels using stickers and concealing any visible scratches. This final step ensured a professional and aesthetically pleasing appearance for the power supply.

November 13 – December 13: Laboratory Report

This process progressed steadily over the course of a month. However, significant advancements were achieved only by December 6, with completion on December 13.

8.0 MEMBER'S PARTICIPATION

MEMBER	PARTICIPATION
Andallon, Yvon Jaimee P.	Technical: - Assisted in etching 2 out of 4 of the PCBs made.

	- Assisted in drilling holes on 3 out of 4 PCBs made.
	Non-technical: - Assisted in creating the initial schematic diagram of the circuit. - Assisted in accomplishing the following sections in the laboratory report: o 1.0 Theoretical Discussion (Introduction and background) o 6.0 Conclusion
Cajayon, Charles Aldus A.	Technical: - Assisted in the last breadboarding. - Assisted in etching 3 out of 4 of the PCBs made. - Assisted in drilling holes on all the PCBs made. - Assisted in all the soldering activities. - Assisted in the first activity of assembling the chassis and wiring. - Responsible for procuring essential materials and components for the project.
	Non-technical: - Assisted in accomplishing the following sections in the laboratory report: o 7.0 Developmental Process (Documentations and dates)
Jacobe, Jan Leander G.	Technical: - Assisted in the last breadboarding. - Assisted in etching 2 out of 4 of the PCBs made. - Assisted in drilling holes on all the PCBs made. - Assisted in all the soldering activities. - Assisted in all assembling the chassis and wiring activities. - Most responsible for procuring essential materials and components for the project.
	Non-technical: - Assisted in accomplishing the following sections in the laboratory report: o 4.0 Circuit Prototype (documentation)

	○ 5.0 Testing and Analysis (values and performing the experiment) ○ 7.0 Developmental Process (Documentations and dates)
Placente, Nina Christel C.	Technical: - Assisted in drilling holes on Nov. 4.
	Non-technical: - Assisted in creating the initial circuit layout. - Assisted in accomplishing the following sections in the laboratory report: ○ 1.0 Theoretical Discussion (Introduction and background) ○ 2.0 Schematic Diagram ○ 3.0 PCB Design ○ 7.0 Developmental Process (Created the tabulated summary)
Solinap, Charles Hendricks D.	Technical: - Performed all the breadboarding activities. - Assisted in etching all the PCBs made. - Assisted in drilling holes on Nov. 4 and accomplished one from the PCB on Nov. 9. - Performed and assisted in all the soldering activities. - Assisted in all assembling the chassis and wiring activities. - Responsible for procuring essential materials and components for the project.
	Non-technical: - Created the initial and final schematic diagram of the circuit. - Created the initial and final circuit layout. - Assisted in accomplishing the following sections in the laboratory report: ○ Composed the block diagram explanation. ○ 2.0 Schematic Diagram ○ 3.0 PCB Design ○ 4.0 Circuit Prototype ○ 5.0 Testing and Analysis

	○ 6.0 Conclusion ○ 7.0 Developmental Process (Compiled the documentations, identified the activities on certain dates, and composed the discussion)