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Power Supply

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Abstract

This project focuses on the design and implementation of a dual-output power supply that provides both a variable DC voltage (2V–24V) and a fixed 5V output. The circuit converts AC voltage into DC using a transformer, rectifier, filter, and voltage regulator stages. The variable section allows adjustable output for different electronic applications, while the fixed section provides a stable 5V for digital circuits. The design ensures efficient performance, low ripple, and high reliability. This power supply can be used for testing, prototyping, and powering low-voltage electronic devices in laboratories and educational projects.

Contents

1 Introduction

A power supply is one of the most essential parts of any electronic system because it delivers the electrical energy required for proper operation. Most electronic devices work with low-voltage direct current (DC), while the electricity available from the mains is high-voltage alternating current (AC). Because of this difference, a reliable power supply is necessary to convert AC power into a stable and regulated DC output that electronic circuits can safely use.

This project involves the design and construction of a dual output DC power supply that provides both a variable DC output ranging from 2 V to 24 V and a fixed 5 V output. The circuit is built using commonly available electronic components such as a step-down transformer, a bridge rectifier, filter capacitors, and voltage regulator integrated circuits. The adjustable voltage output is achieved using the LM317 voltage regulator, while the fixed 5 V output is produced using the popular 7805 voltage regulator.

The primary aim of this project is to gain practical knowledge of how a power supply operates by examining each stage of AC-to-DC conversion. These stages include voltage transformation, rectification, filtering, and voltage regulation. The final design delivers low ripple, stable output, and dependable performance. Due to its flexibility and reliability, the power supply is well suited for laboratory experiments, electronic prototyping, and powering low-voltage analog and digital circuits.

2 Equipment

- AC power supply (230 V, 50 Hz)
- Step down transformer (230 V to 24 V)
- Bridge rectifier (2W06G)
- Filter capacitor (4700 μF)
- Adjustable voltage regulator IC (LM317T)
- Fixed voltage regulator IC (7805)
- Potentiometer (5 kΩ)
- Resistors (various values)
- Capacitors (for filtering and stability)
- Voltmeters (to measure output voltage)
- Connecting wires

3 Power Supply

3.1 Definition

A power supply is an electrical device that provides the required voltage and current to operate electronic circuits or devices. It converts electrical energy from a source, such as AC mains, into stable DC voltage. The main stages of a power supply include a transformer for voltage conversion, a rectifier for AC to DC conversion, a filter to remove ripples, and a regulator to maintain constant output. Power supplies can be fixed or variable depending on the need. They are essential in almost every electronic system, from simple chargers to complex laboratories and industrial equipment.

3.2 Working Principle

The power supply works by converting AC voltage into a stable DC output. First, the transformer steps down the AC voltage to a lower level. The bridge rectifier then changes it into pulsating DC. The filter capacitor smooths the ripples, providing a steady DC voltage. Finally, the voltage regulators (LM317 and 7805) maintain constant outputs, one adjustable (2 V to 24 V) and one fixed (5 V), for different electronic applications.

3.3 Components

The main components used in the construction of the power supply are described below.

3.3.1 Transformer

A step-down transformer reduces high AC voltage from the mains to a lower AC voltage suitable for electronic circuits. It works on the principle of electromagnetic induction between primary and secondary windings.

3.3.2 Bridge Rectifier

A bridge rectifier converts AC voltage into pulsating DC voltage using four diodes arranged in a bridge form. It allows current to flow in the same direction during both halves of the AC cycle.

3.3.3 Regulator

A voltage regulator maintains a constant DC output voltage despite changes in input voltage or load conditions. It ensures stable and reliable power for electronic circuits.

3.3.4 Process

The overall process of the power supply from AC input to regulated DC output is illustrated below.

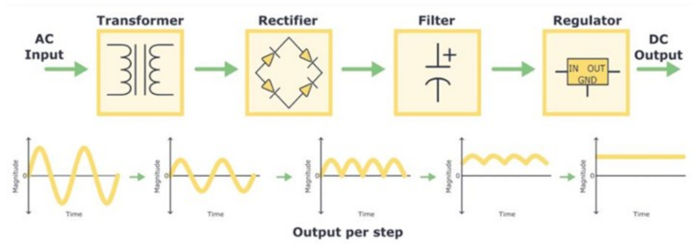

Figure 3.1: Block diagram of the power supply

- **AC Input:** The power supply receives alternating current from the mains supply.
- **Transformer:** The transformer steps down the high mains AC voltage to a lower AC voltage suitable for electronic circuits.
- **Rectifier:** The bridge rectifier converts the AC voltage into pulsating DC by allowing current to flow in only one direction.
- **Filter:** The filter capacitor smooths the pulsating DC by reducing ripples and providing a steady DC voltage.
- **Regulator:** The voltage regulator maintains a constant DC output voltage despite changes in input voltage or load conditions.
- **DC Output:** A stable and regulated DC voltage is obtained to safely power electronic devices and circuits.

4 Layout

The circuit layout illustrates the interconnection of all components used in the power supply.

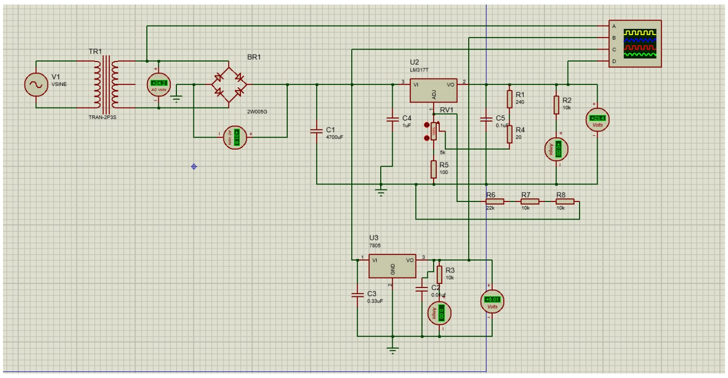

Figure 4.1: Circuit layout of the power supply

4.1 For Variable 2-24V Voltage:

4.1.1 Methodology

- The AC voltage is first stepped down using a transformer.
- The bridge rectifier converts the AC voltage into DC.
- A filter capacitor smooths the DC output by removing ripples.
- The LM317 voltage regulator controls and adjusts the output voltage.
- A potentiometer is used to vary the voltage between 2 V and 24 V as required.

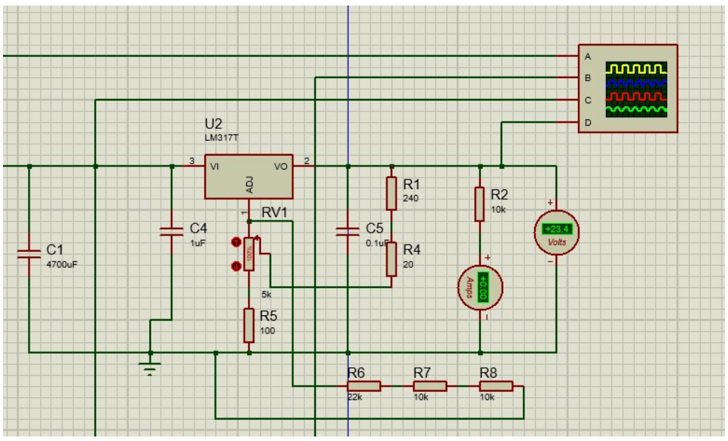

Figure 4.2: Circuit diagram for variable 2 V to 24 V DC output

4.1.2 Calculations

Secondary Peak Voltage (Before Rectifier)

- The transformer provides an RMS voltage of 24 V at the secondary winding.
- The relationship between RMS voltage and peak voltage is given by:

$$V_{PEAK(sec)} = V_{RMS} \times \sqrt{2}$$

- Substituting the given values:

$$V_{PEAK(sec)} = 24 \times 1.414 = 33.94V$$

- Therefore, the peak secondary voltage before rectification is **33.94 V**.

Peak After Bridge (No Load, After Diodes)

- When the AC signal passes through the bridge rectifier, two diodes conduct in each half cycle.
- Each conducting diode causes a voltage drop of approximately 0.85 V, so the total voltage drop across two diodes is about 1.7 V.
- The peak rectified voltage can be calculated as:

$$V_{PEAK(rect)} \approx V_{PEAK(sec)} - 1.7$$

- Substituting the given values:

$$V_{PEAK(rect)} = 33.94 - 1.7 = 32.24V$$

- Therefore, the peak voltage after the bridge rectifier under no load condition is **32.24 V**.

Ripple Voltage

- The ripple voltage occurs due to the charging and discharging of the filter capacitor.
- For a full wave rectifier, the ripple frequency is twice the supply frequency, that is 100 Hz.
- The formula for ripple voltage is given by:

$$V_{ripple} = \frac{I_{load}}{2fC}$$

- Where $2f = 100\ Hz$.
- Substituting the values for $I_{load} = 1\ A$ and $C = 4700\ \mu F$:

$$V_{ripple} = \frac{1}{100 \times 4700\ \mu F} = \frac{1}{0.47} = 2.13\ V_{(pp)}$$

- The capacitor value can also be calculated using:

$$C = \frac{I_{load}}{(2f)\,V_{ripple}}$$

- For a 10% voltage allowance (approximately 2.4 V ripple):

$$C = \frac{1}{100 \times 2.4} = 0.004167\ F \approx 4167\ \mu F$$

- Therefore, a 4700 μF capacitor is sufficient for effective filtering and maintaining a low ripple voltage.

Transformer Properties

- The input voltage to the transformer is 220 V (RMS) or 311 V (Peak).
- After stepping down, the secondary voltage is 23 V (RMS) or 32.2 V (Peak).
- The relationship between the voltages and turns in a transformer is given by:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

- Substituting the given values:

$$\frac{23}{220} = 0.1045$$

- Therefore, the turns ratio is:

$$Turnsratio = \frac{N_P}{N_S} = \frac{220}{23} = 9.56$$

- Hence, the turns ratio (Primary : Secondary) is **9.56 : 1**, indicating a step down transformer.

Variable Voltage Regulator (LM317) Calculations

- The LM317 is an adjustable voltage regulator used to obtain a variable DC output. The output voltage depends on two resistors, R_1 and R_2, according to the equation:

$$V_{OUT} = 1.25\left(1 + \frac{R_2}{R_1}\right)$$

Where:

$$R_1 = 240\ \Omega \quad (fixedresistor)$$

$$R_2 = variableresistor(potentiometer)$$

- **For Minimum Output (2 V)**

  Substituting the values:

$$2 = 1.25\left(1 + \frac{R_2}{240}\right)$$

$$\frac{R_2}{240} = 0.6$$

$$R_2 = 144\ \Omega$$

  Therefore, for an output of 2 V, the value of R_2 is 144 Ω.

- **For Maximum Output (24 V)**

  Substituting the values:

$$24 = 1.25\left(1 + \frac{R_2}{240}\right)$$

$$\frac{R_2}{240} = 18.2$$

$$R_2 = 4368\ \Omega$$

  Therefore, for an output of 24 V, the value of R_2 is approximately 4.37 kΩ to 5 kΩ.

Resistor Calculation for 1 A Current (24 V Output)

- The LM317 regulator provides a variable output, set here to 24 V DC.
- The load resistor is calculated using Ohm's law:

$$R_L = \frac{V_{OUT}}{I_{OUT}}$$

- Substituting the values:

$$R_L = \frac{24}{1} = 24\ \Omega$$

- Power dissipation is calculated as:

$$P = V \times I = 24 \times 1 = 24\ W$$

- Therefore, a 24 Ω, 50 W resistor should be used to safely handle the power and prevent overheating.

4.2 For Fixed 5V Voltage

4.2.1 Methadology

- The rectified and filtered DC voltage from the bridge rectifier is fed into the 7805 voltage regulator IC.
- The 7805 regulator maintains a constant 5 V DC output, regardless of changes in input voltage or load.
- Filter capacitors are connected at the input and output of the IC to reduce voltage ripple and noise.
- The regulated 5 V output is used to power low voltage digital and electronic circuits safely.

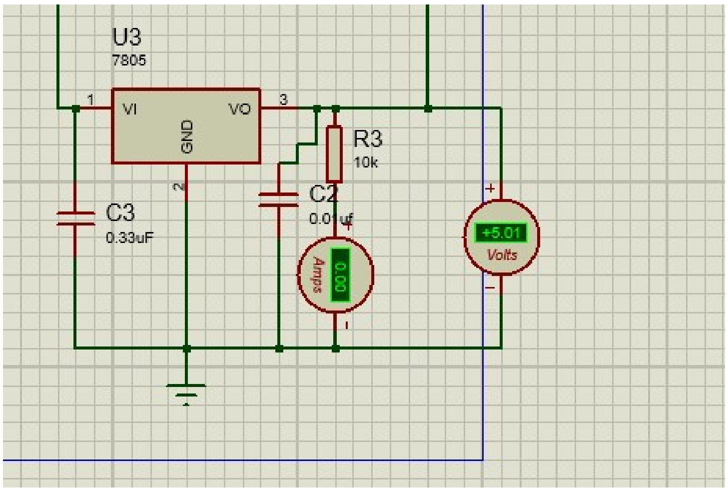

Figure 4.3: Circuit diagram for fixed 5 V DC output

4.2.2 Calculation

Resistor Calculation for 1 A Current (Fixed 5 V Output)

- The 7805 regulator provides a fixed 5 V DC output.
- The load resistor is calculated using Ohm's law:

$$R_L = \frac{V_{OUT}}{I_{OUT}}$$

- Substituting the values:

$$R_L = \frac{5}{1} = 5\ \Omega$$

- Power dissipation is calculated as:

$$P = V \times I = 5 \times 1 = 5\ W$$

- Therefore, a 5 Ω, 10 W resistor should be used for safe operation.

5 Veroboard Implementation

Below is the veroboard implementation of power supply

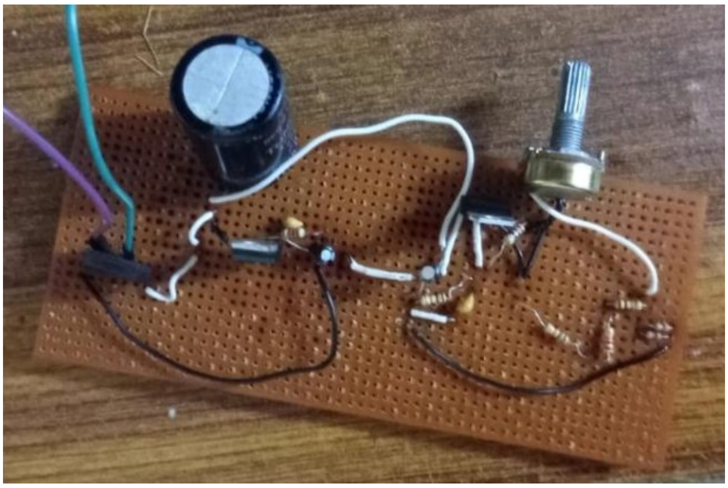

Figure 5.1: Veroboard implementation of the power supply circuit

- The designed power supply circuit was implemented practically on a veroboard using discrete electronic components.
- All components were mounted and soldered according to the circuit layout to ensure proper electrical connections.
- Care was taken to minimize loose connections and short circuits during assembly.
- The completed veroboard circuit was tested using a DC power source and measuring instruments.
- The implementation confirms the practical feasibility of the designed power supply.

6 Outputs

6.1 Multimeter reading

For Fixed 5 V

Figure 6.1: Measured output voltage for fixed 5 V

For Variable Output (Minimum)

Figure 6.2: Measured minimum output voltage of the variable power supply

For Variable Output (Maximum)

Figure 6.3: Measured maximum output voltage of the variable power supply

6.2 Waveform Analysis

Input Waveform

The input waveform applied to the power supply circuit.

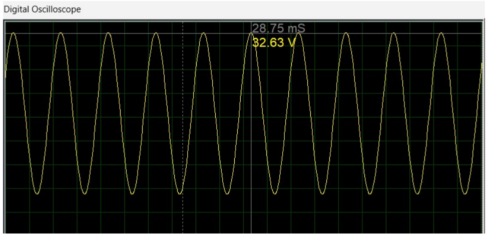

Figure 6.4: Input waveform

Maximum Output Voltage

The output voltage observed at the maximum operating condition.

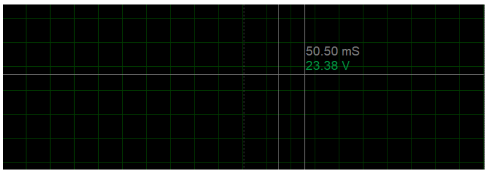

Figure 6.5: Maximum output voltage

Minimum Output Voltage

The output voltage observed at the minimum operating condition.

Figure 6.6: Minimum output voltage

Constant Regulated Output

The regulated output showing a constant DC voltage.

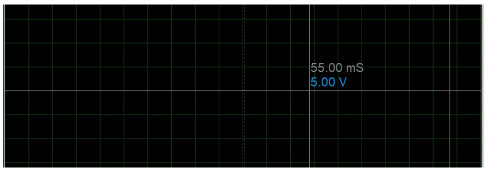

Figure 6.7: Constant regulated output

7 PCB Implementation

This section describes the PCB layout and implementation of the designed power supply circuit.

7.1 Schematic

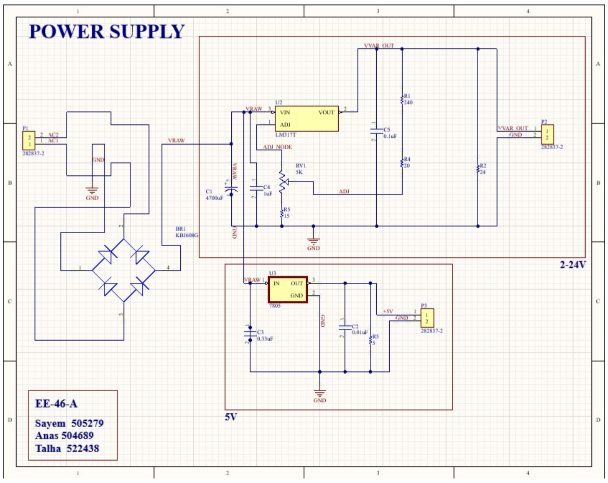

Figure 7.1: Power supply circuit schematic

7.2 Routing

Before Polygon Pour

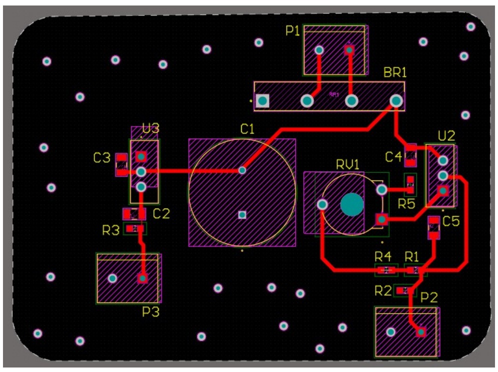

Figure 7.2: PCB routing of the power supply circuit

After Polygon Pour

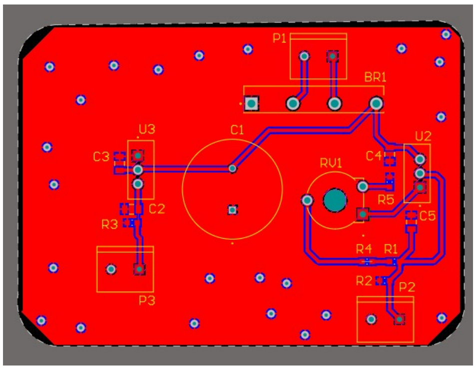

Figure 7.3: PCB layout with polygon pour for the power supply circuit

7.3 3D Model

3D visualization of the finalized PCB design.

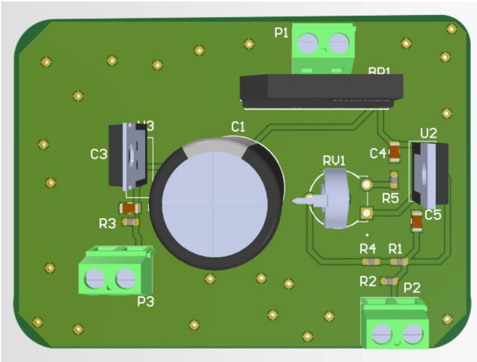

Figure 7.4: 3D view of the power supply PCB

8 Conclusion

In this project, a regulated DC power supply was successfully designed, implemented, and tested to meet the required performance specifications. The system effectively converts AC input into a stable DC output through rectification, filtering, and regulation stages. Careful component selection and proper PCB layout ensured reliable operation, reduced noise, and improved thermal performance. The routing and polygon pour further enhanced current handling and grounding. The final PCB and 3D model verified mechanical feasibility and component placement. Overall, the designed power supply demonstrates stable output, robustness, and suitability for use in low-voltage electronic applications.