The City College of New York

EE32200 Electrical Engineering Laboratory II

Lab Report Experiment #3

Regulated DC Power Supply

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Introduction

In this experiment, the goal was to construct a DC power supply that consistently delivers a stable output voltage even when the input voltage or load varies. In an unregulated circuit, fluctuations in the AC source or load current can cause noticeable voltage changes at the output. To counter this, a voltage regulator is implemented, continuously comparing the output voltage to a reference and correcting any discrepancies. This process ensures that the DC output remains constant and dependable regardless of external variations.

Objective

The purpose of this lab is to design a regulated DC power supply that fulfills specific performance criteria. The output voltage should span between 0 V and 12 V DC, capable of delivering up to 200 mA. Additionally, the output ripple should not exceed 25 mV peak-to-peak, and the load regulation must remain within 1%. Load regulation can be expressed as:

- Load Regulation = $\frac{V_{out}(at\,I_{min})-V_{out}(at\,I_{max})}{V_{out}(at\,I_{min})}$

This equation quantifies how the output voltage changes when the load current increases from minimum to maximum levels.

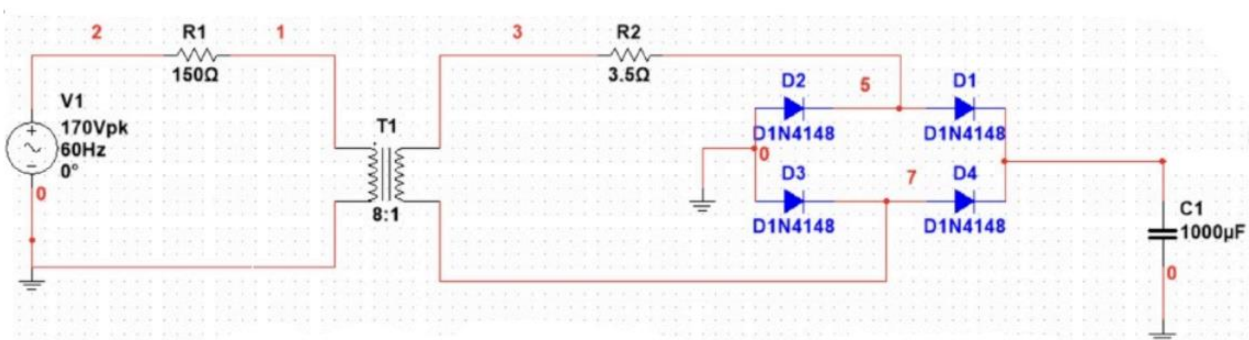

Figure A: Unregulated Power Supply

Figure A illustrates the Multisim schematic of a basic unregulated DC supply. A transformer steps down the AC input, and a bridge rectifier converts it to DC. A capacitor filters out ripples, producing a smoother waveform, while a resistive load helps analyze voltage variations under different conditions. The simulation showed that small fluctuations occur when input or load changes, typical of an unregulated system.

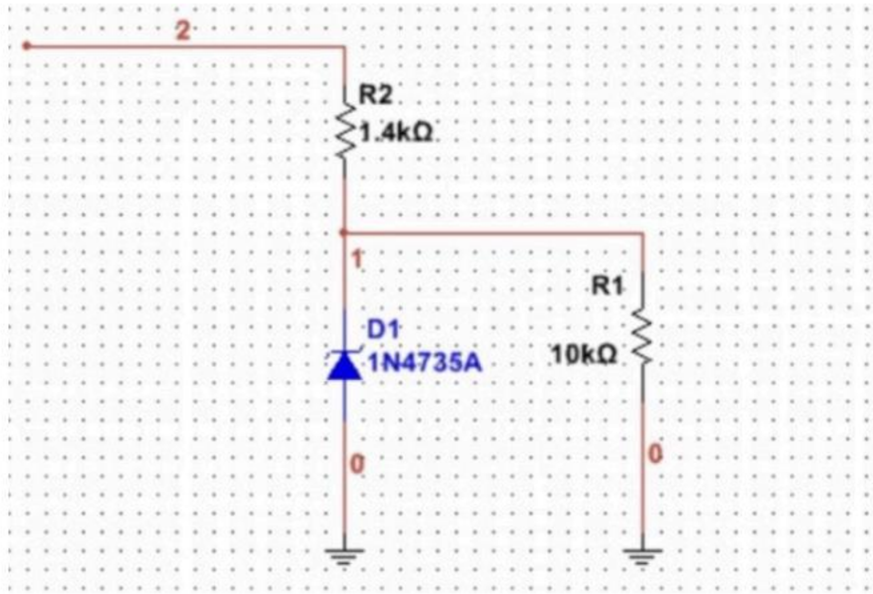

Figure B: Zener Voltage Reference

Figure B presents a Zener diode-based voltage reference circuit. This section utilizes the previously unregulated DC signal to generate a stable reference. A series resistor limits current to keep the Zener diode in its breakdown region, ensuring consistent operation. A potentiometer allows fine tuning of the output. For this design, a 20 V input and a 6 V regulated output were used, with 10 mA flowing through the Zener diode. Applying Ohm's Law:

- R = (20V − 6V) / 10mA = 1.4 kΩ

This resistance allows sufficient current to sustain the Zener diode while protecting other components from excessive current.

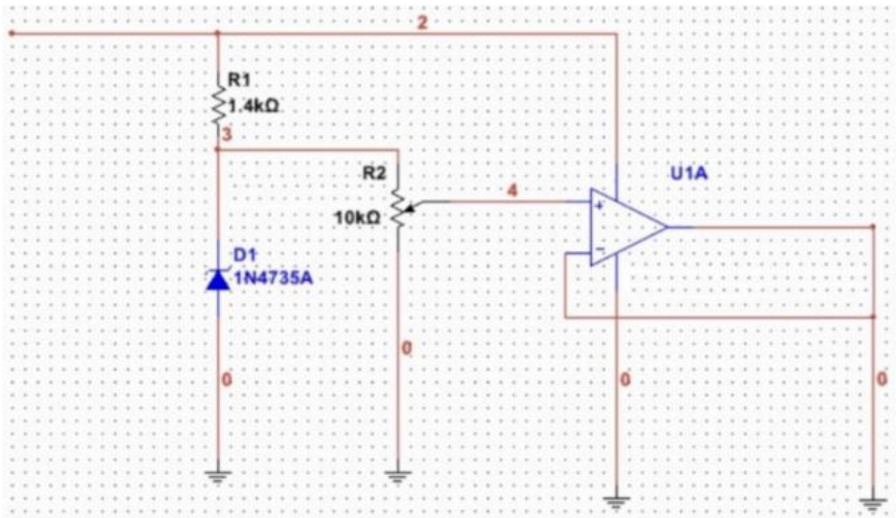

Figure C: Op-Amp Voltage Regulator

Figure C demonstrates an op-amp-based regulator. The operational amplifier continuously monitors and adjusts the output voltage relative to the reference. During simulation, a slight output offset was observed, which was corrected by inserting a voltage divider into the feedback loop. This adjustment stabilized the output to the desired level, increasing voltage regulation.

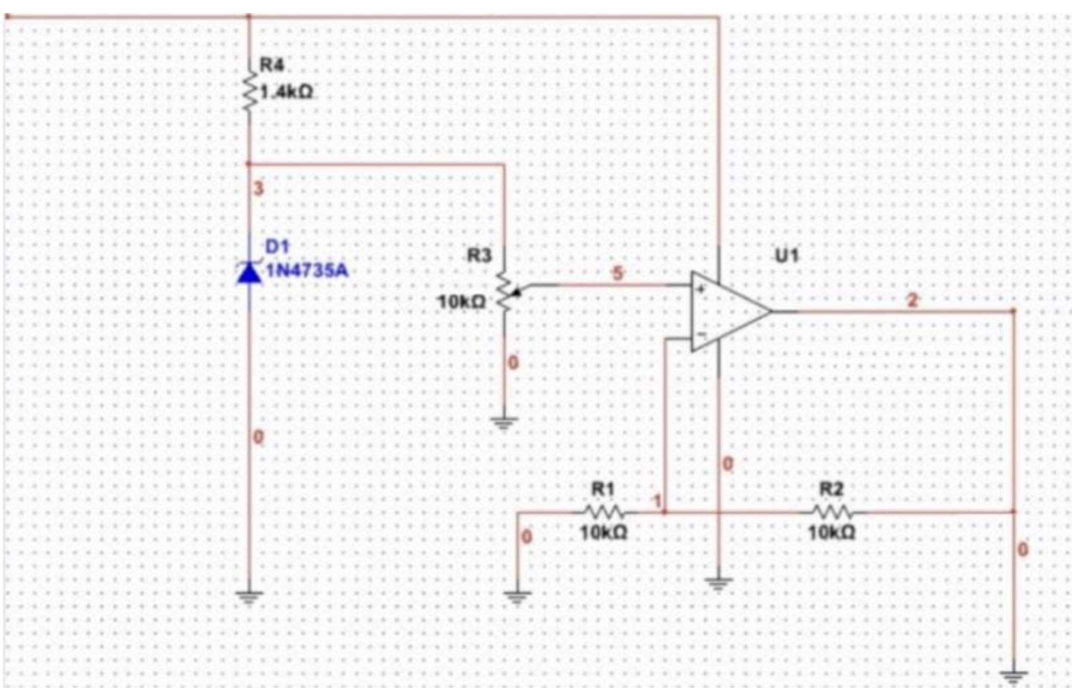

Figure D: Setting R1 and R2 for Desired Output

To achieve a 12 V output, proper resistor selection was necessary for the op-amp feedback network. The voltage gain of a non-inverting amplifier is given by:

- Gain $= \frac{V_{out}}{V_{in}}$, $\frac{V_{out}}{R_1} = \frac{V_{ref}}{R_1} + \frac{V_{ref}}{R_2}$, Gain$= 1 + \frac{R_1}{R_2}$

To achieve a gain of 2, R1 was set equal to R2 resulting in the new equation $\frac{R_1}{R_2} = 1$. Both resistors were selected as 10 kΩ to minimize current draw while maintaining correct gain.

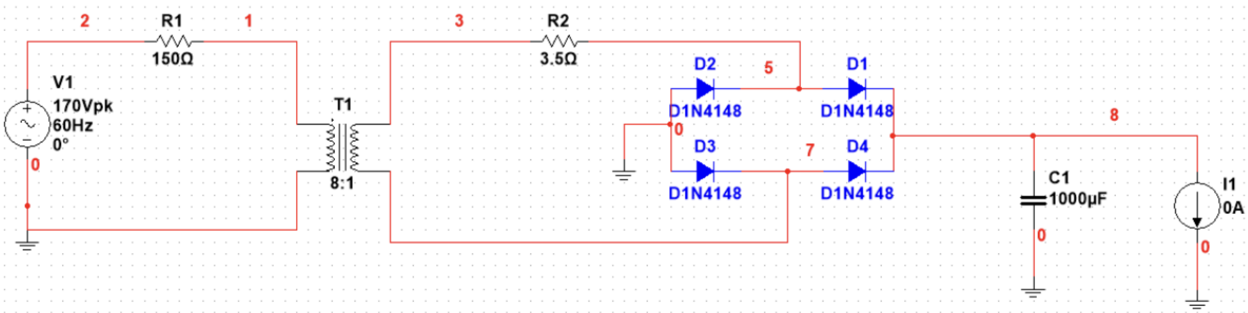

Figure E: Power Supply with no Load

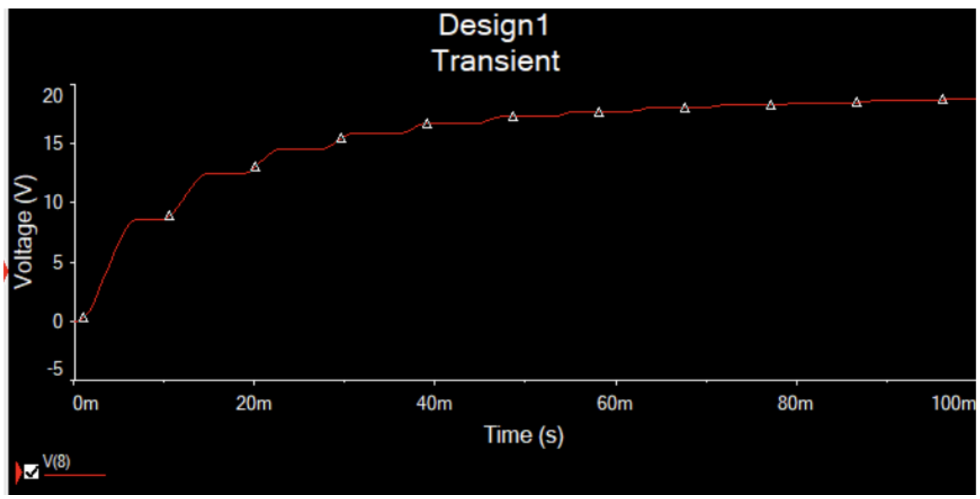

Figure F: Transient Analysis for 0 Amps

Under no-load conditions (0 A), the Multisim simulation indicated an output voltage of 19.5 V. During the transient test, the output voltage rises and stabilizes at its peak value since no current is drawn from the source. This analysis verifies that the circuit delivers a stable DC output in the absence of a load and serves as a baseline for comparison when a load is later applied.

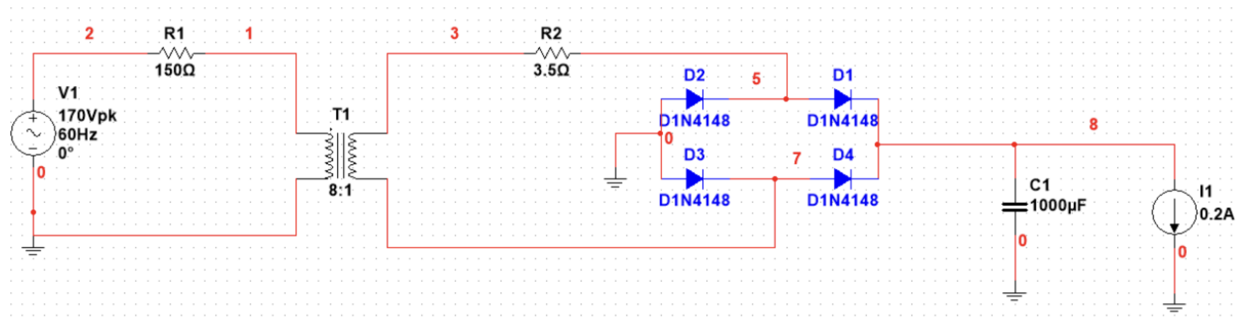

Figure G: Power Supply with 0.2 Amps

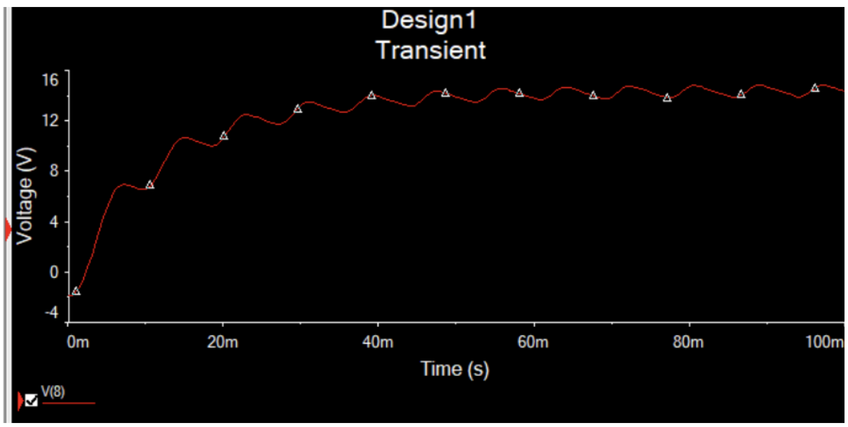

Figure H: Transient Analysis for 0.2 Amps

When a 200 mA load was applied, the voltage dropped to 15.8 V.

Load Regulation $= \frac{V_{no\ load} - V_{full\ load}}{V_{no\ load}} \cdot 100\% \ = \ \frac{19.5-15.8}{19.5} \cdot 100\% = 19\%$

The percent load regulation was approximately 19%, reflecting a significant voltage drop as the load current increased.

Percent Ripple

$$\%\,ripple\ =\ \left(\frac{V_{ripple}}{V_{DC}}\right)\cdot 100\%$$

0 Amps:

$$V_{ripple} = 0.6V,\ V_{DC}\ = 19.5V,\ \%\,ripple = 3.1\%$$

0.2 Amps:

$$V_{ripple} = 2.8V,\ V_{DC}\ = 15.8V,\ \%\,ripple = 17.7\%$$

Ripple analysis revealed that at no load, the ripple voltage was 0.6 V (VDC = 19.5 V), and at full load, it rose to 2.8 V (VDC = 15.8 V). This increase is due to reduced capacitor charging time as current demand increases. The unregulated circuit therefore exhibits poor regulation and higher ripple under heavier loads.

Regulated Power Supply with Heavy and Light Loads

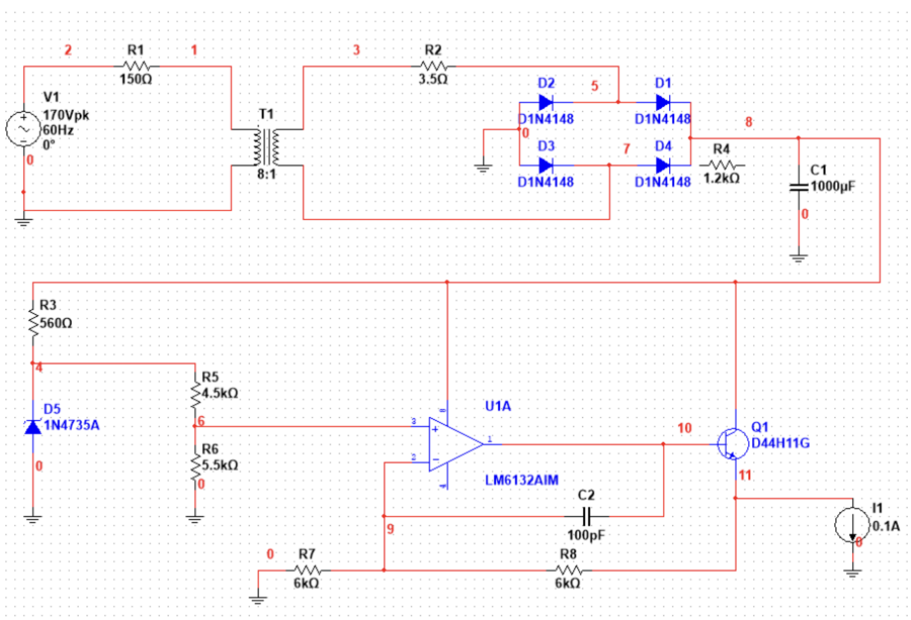

Figure I: Regulated Power Supply Schematic at Heavy Load (0.1 A)

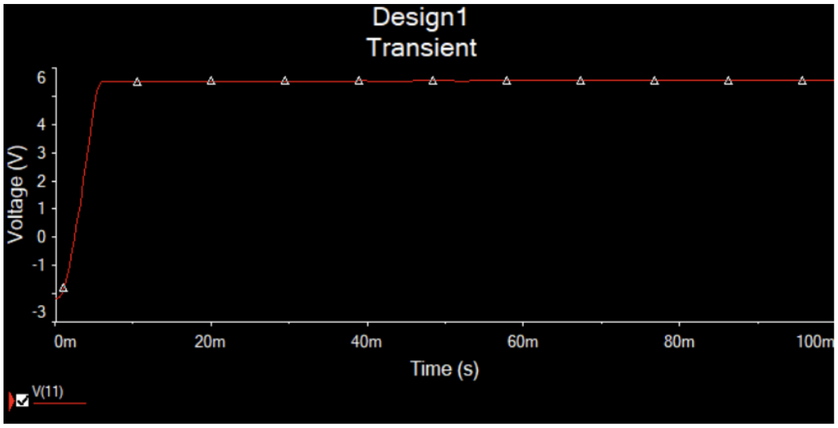

Figure J: Transient Analysis for Regulated Power Supply at Heavy Load (0.1 A)

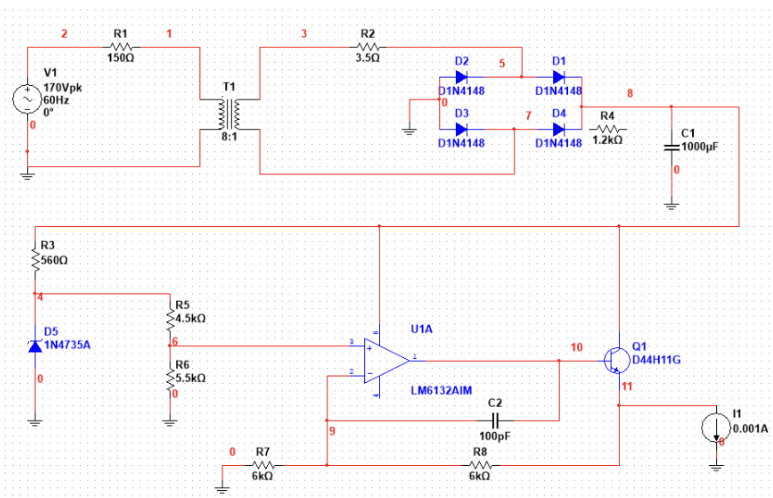

Figure K: Regulated Power Supply Circuit at Light Load (0.001 A)

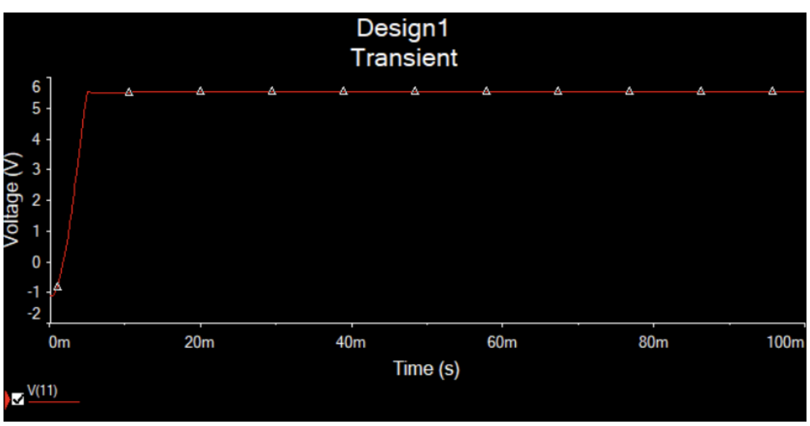

Figure L: Transient Analysis for Regulated Power Supply at Light Load (0.001 A)

Regulated Power Supply Results

A regulated power supply was simulated and analyzed under varying load conditions. At 0.1 A load, the output stabilized at 5.8 V with minimal ripple. At a lighter load of 0.001 A, the voltage settled at approximately 5.5 V. In both cases, the voltage remained steady, validating the effectiveness of the regulator circuit.

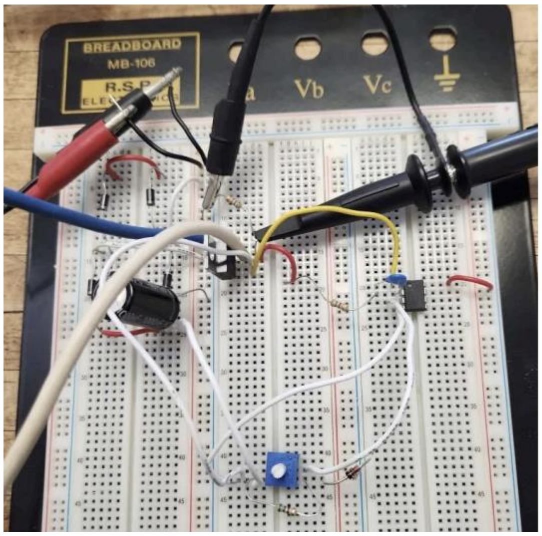

Figure M: Regulated DC Power Supply Circuit

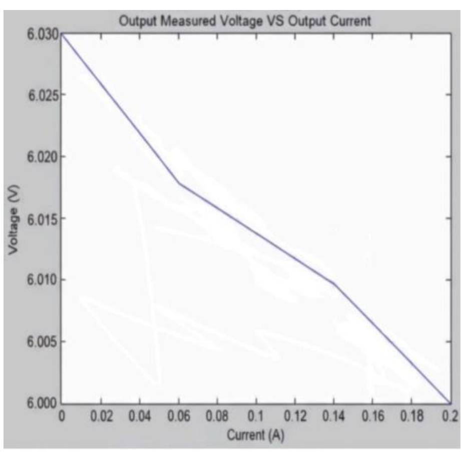

Figure N: 6V Output Voltage vs Load Current

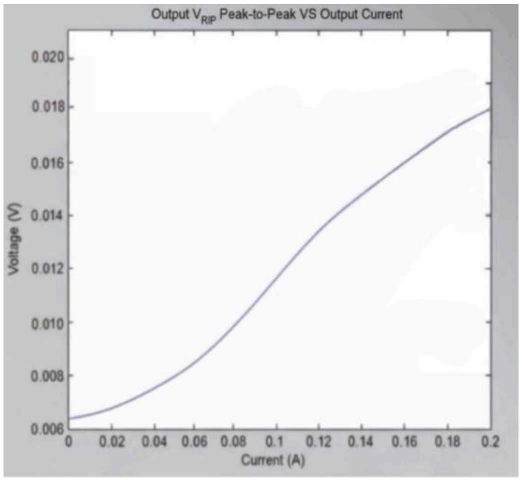

Figure O: 6V Peak-to-Peak Ripple Voltage vs Load Current

Load Current (mA)	Output Voltage (V)	Vpp Ripple (mV)
0	6.030	6.3
40	6.025	7.5
80	6.020	10.0
120	6.015	13.0
160	6.008	16.2
200	6.000	18.0

For the 6 V regulated supply, the measured values were 6.030 V at no load and 6.000 V at 200 mA. This corresponds to a load regulation of about 0.5%. The ripple increased from 6.3 mV to 18.0 mV as load increased, indicating excellent stability and expected ripple growth due to higher current flow.

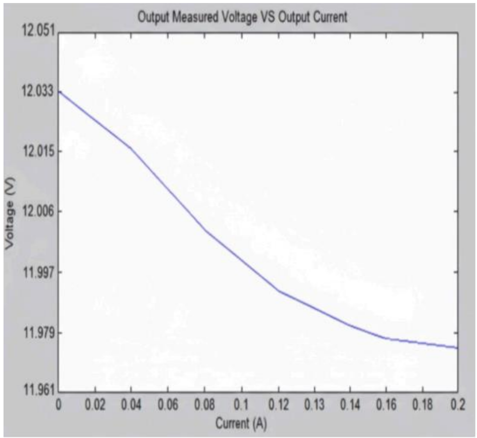

Figure P: 12 V Output Voltage vs Load Current

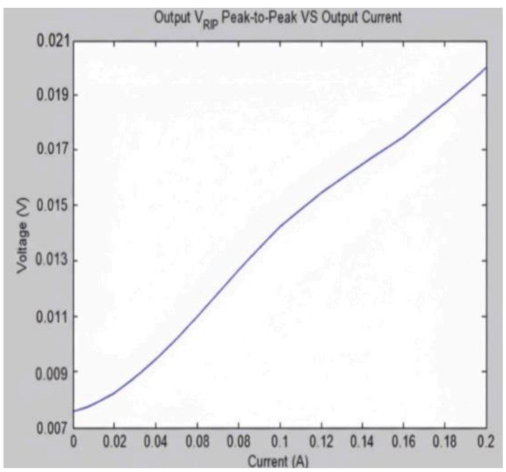

Figure Q: 12 V Peak-to-Peak Ripple Voltage vs Load Current

Load Current (mA)	Output Voltage (V)	Vpp Ripple (mV)
0	12.033	7.0
40	12.015	8.4
80	11.997	11.2
120	11.979	14.8
160	11.961	17.6
200	11.943	20.5

For the 12 V regulated supply, the output was 12.033 V at no load and 11.943 V at 200 mA, resulting in a load regulation of 0.75%. Ripple voltage increased slightly from 7.0 mV to 20.5 mV. Overall, the circuit maintained outstanding voltage regulation across different load levels.

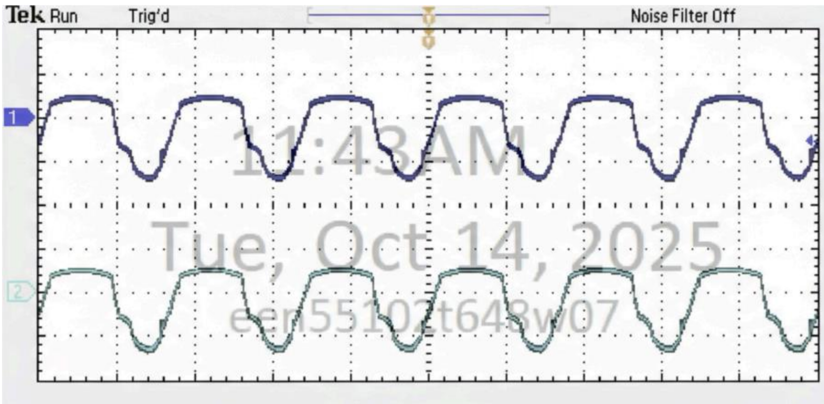

Figure R: Oscilloscope waveform

Oscilloscope Verification

Oscilloscope readings confirmed the simulation outcomes. Both the 6 V and 12 V regulated outputs showed stable DC levels with negligible ripple. At higher current draws, minor increases in ripple were observed due to capacitor discharge intervals, but overall waveform integrity remained excellent.

Conclusion

This experiment successfully demonstrated the construction and analysis of a regulated DC power supply using both Multisim simulation and breadboard implementation. The system provided consistent voltage levels of 6 V and 12 V up to 200 mA of load current. Measured load regulation values (0.50% for 6 V and 0.75% for 12 V) confirm high voltage stability, while ripple voltages remained well within the acceptable range. Overall, the designed power supply effectively delivered steady DC output with good regulation and minimal ripple.