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Objective

The objective of this project is to design, simulate, and experimentally verify a regulated DC power supply capable of maintaining a stable output voltage under varying load conditions. 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%.

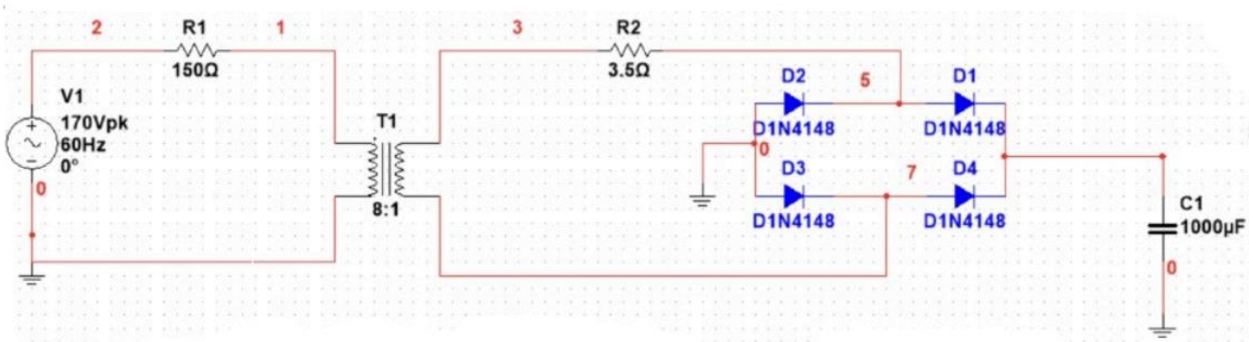

Figure A: Unregulated Power Supply

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.

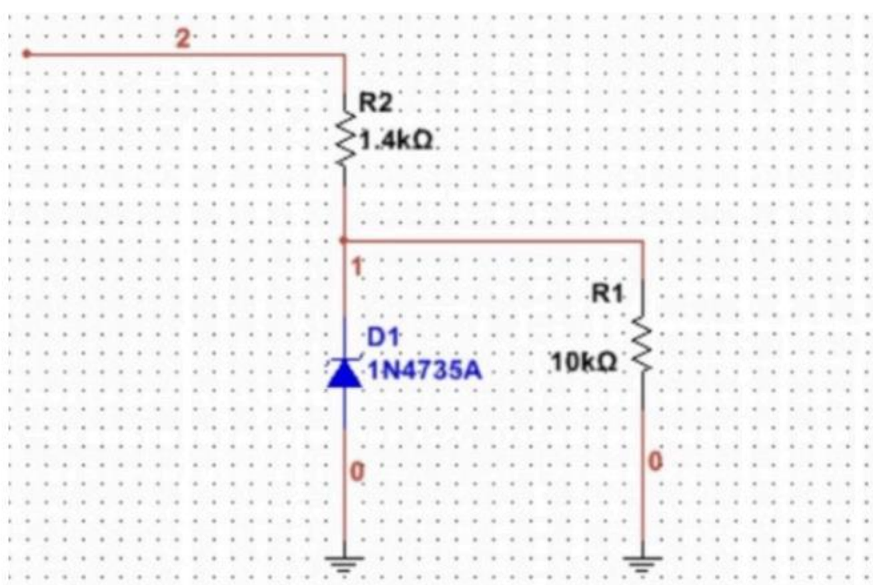

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Figure B: Zener Voltage Reference

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:

- $R = (20V - 6V) / 10mA = 1.4\ k\Omega$

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

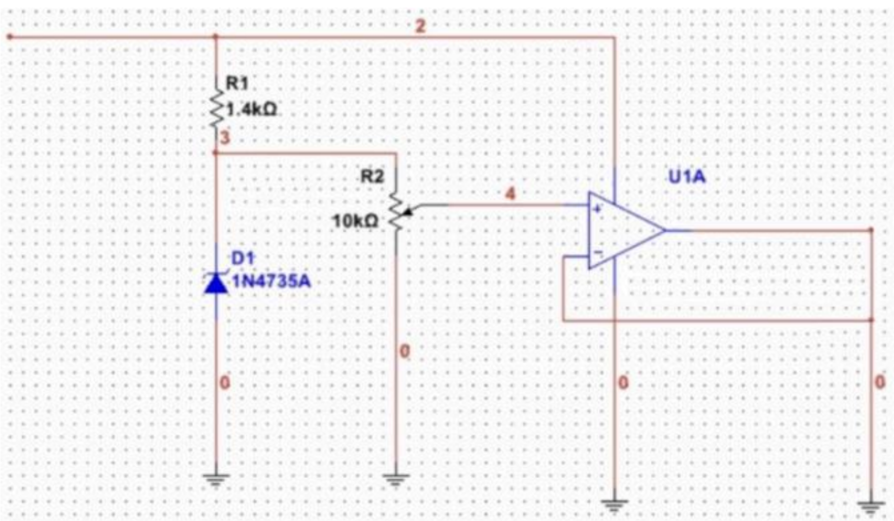

Figure C: Op-Amp Voltage Regulator

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.

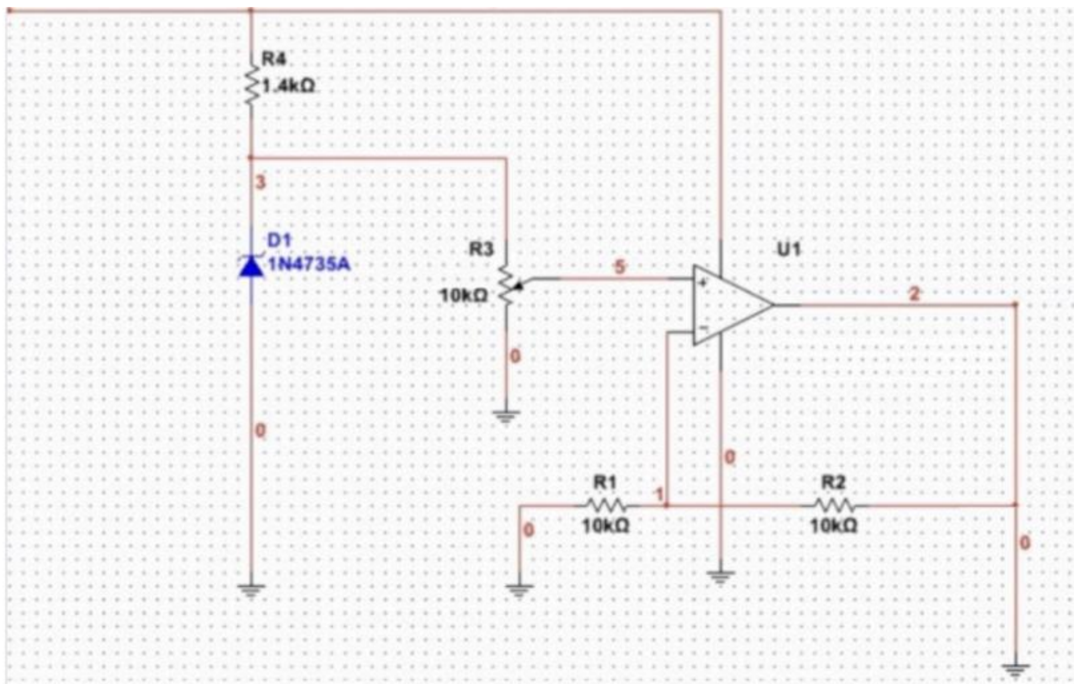

Figure D: Setting R1 and R2 for Desired Output
To achieve a 12 V output, proper resistor selection was necessary for the op-amp feedback network.

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.

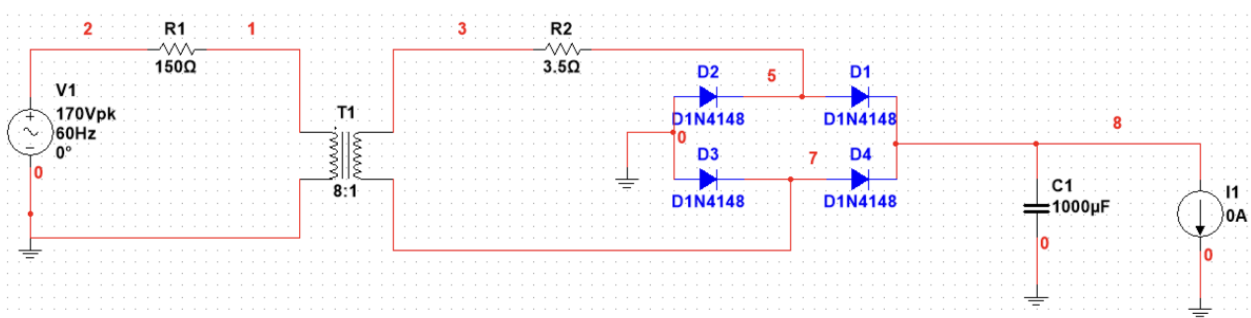

Figure E: Power Supply with no Load

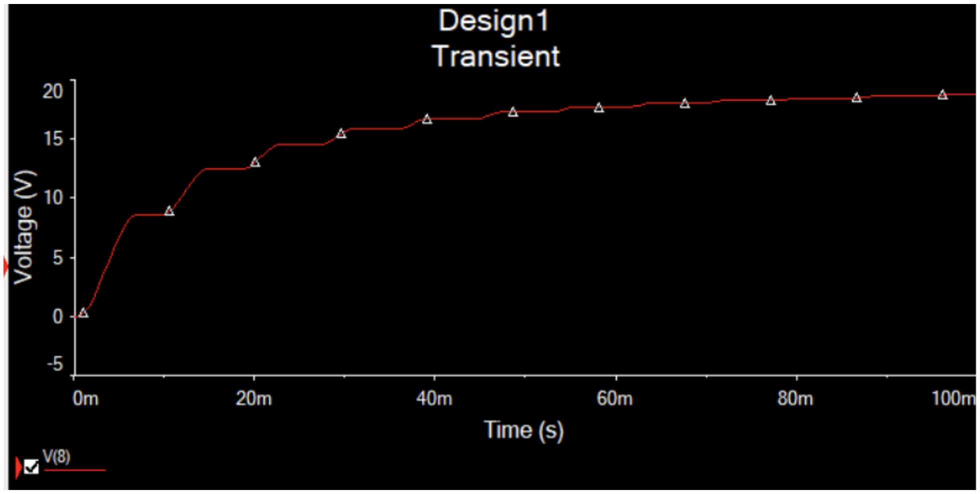

Figure F: Transient Analysis for 0 Amps

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.

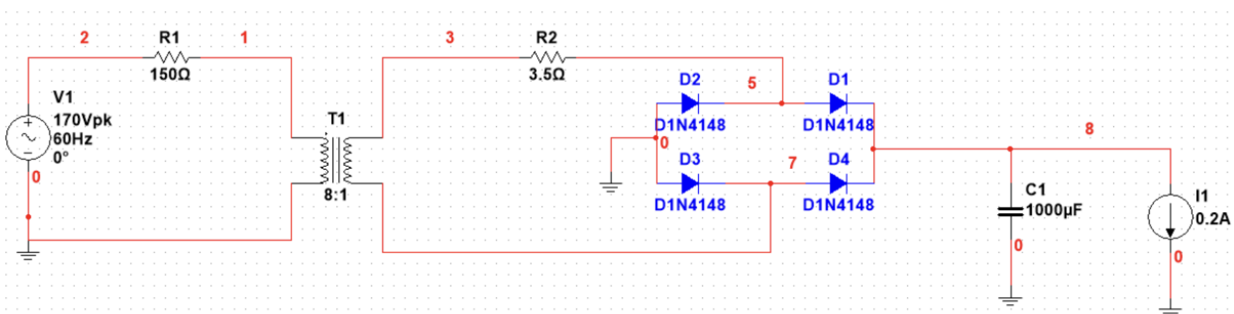

Figure G: Power Supply with 0.2 Amps

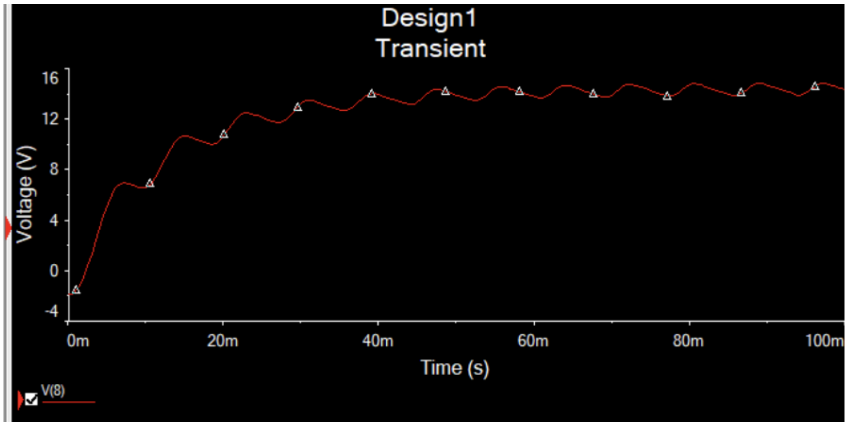

Figure H: Transient Analysis for 0.2 Amps

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

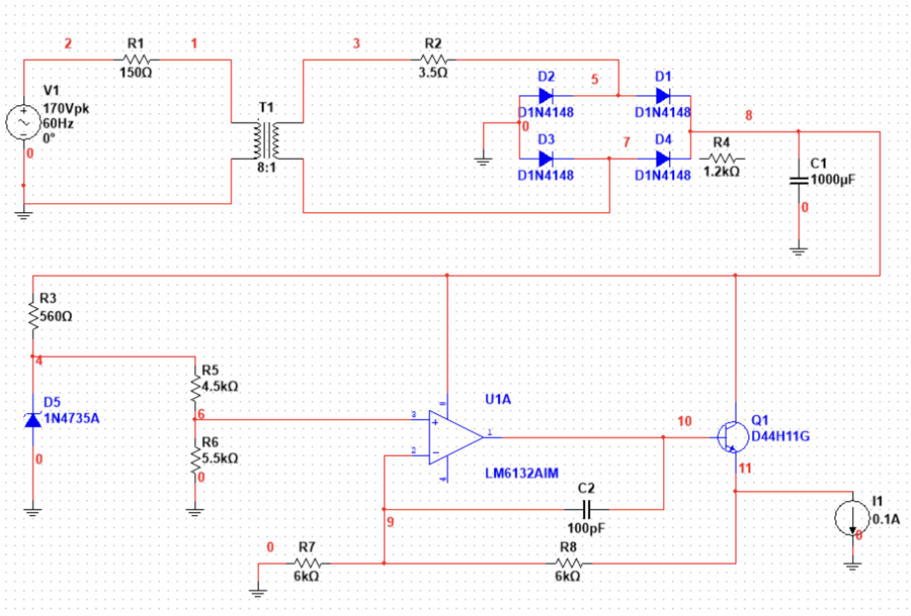

Figure I: Regulated Power Supply Schematic at Heavy Load (0.1 A)

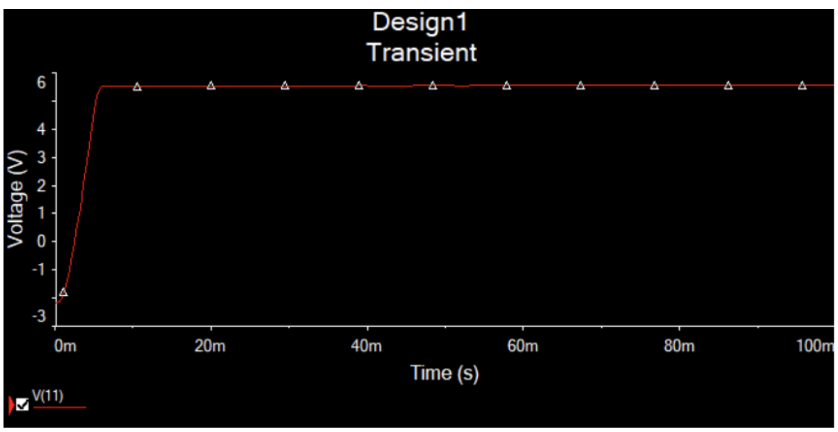

Figure J: Transient Analysis for Regulated Power Supply at Heavy Load (0.1 A)

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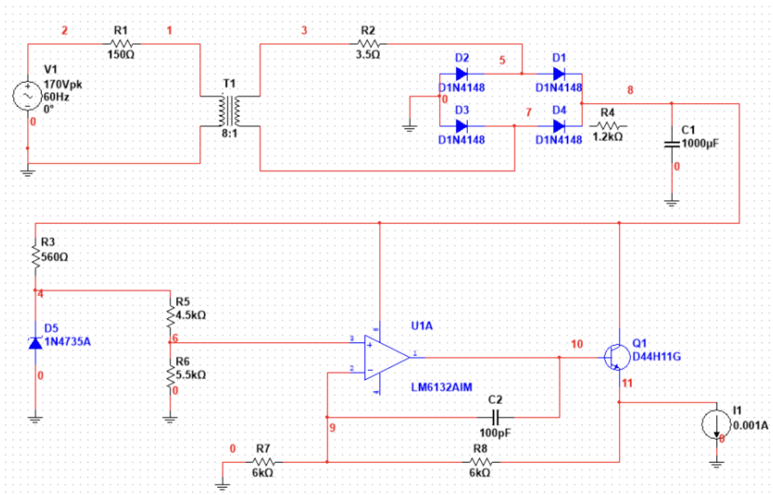

Figure K: Regulated Power Supply Circuit at Light Load (0.001 A)

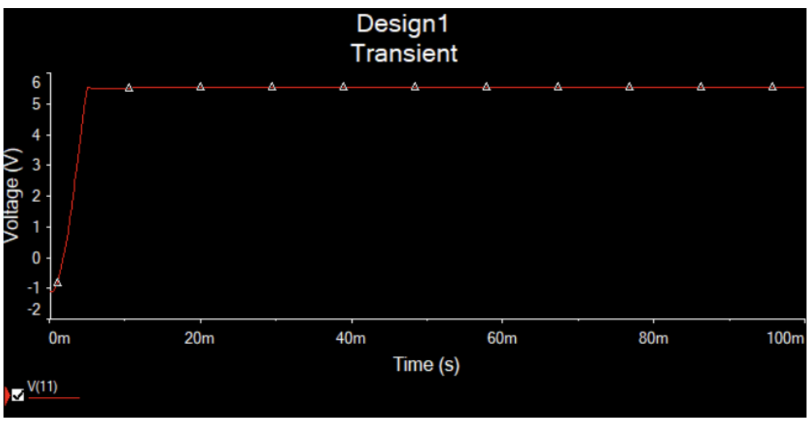

Figure L: Transient Analysis for Regulated Power Supply at Light Load (0.001 A)

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.

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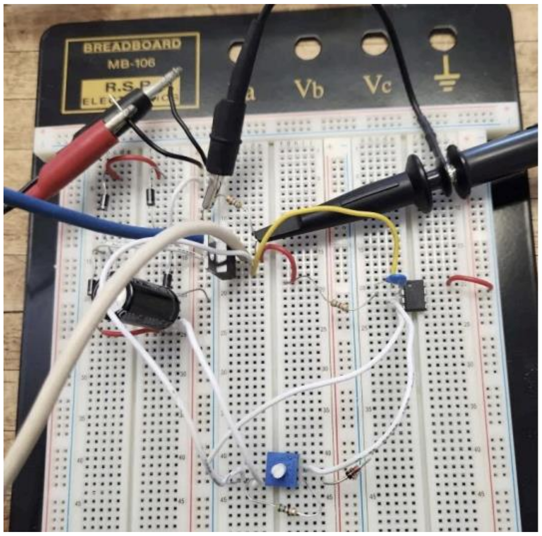

Figure M: Regulated DC Power Supply Circuit

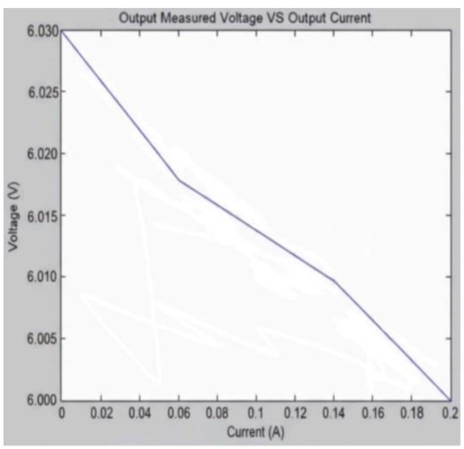

Figure N: 6V Output Voltage vs Load Current

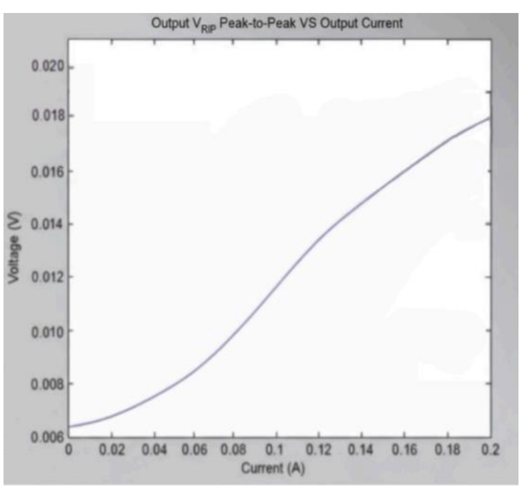

Figure O: 6V Peak to Peak Ripple Voltage vs Load Current

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.

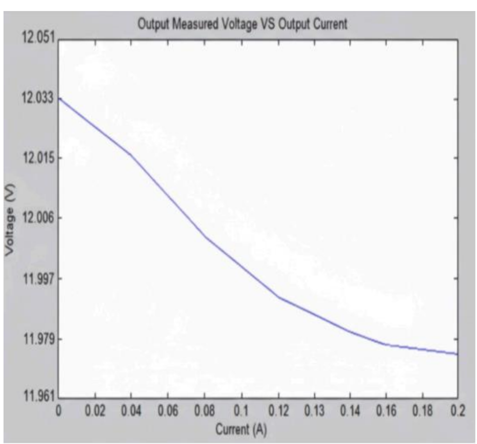

Figure P: 12 V Output Voltage vs Load Current

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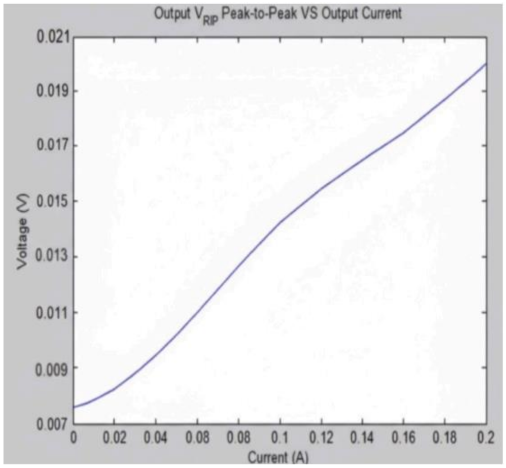

Figure Q: 12 V Peak to Peak Ripple Voltage vs Load Current

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.

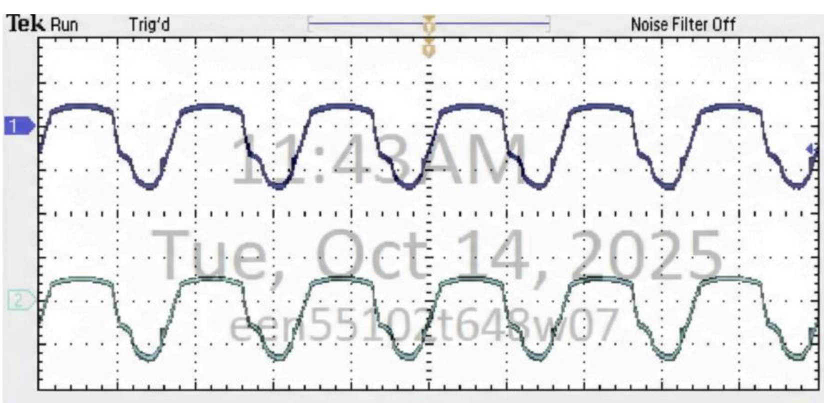

Figure R: Oscilloscope waveform

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.

Results and Observations

The unregulated power supply showed significant voltage drop and increased ripple as load current increased, indicating poor load regulation. After adding voltage regulation, the 6 V and 12 V outputs remained stable with minimal ripple across varying load conditions. Measured load regulation was approximately 0.5% at 6 V and 0.75% at 12 V, confirming effective regulator performance. Minor differences between simulation and measurements were attributed to component tolerances.