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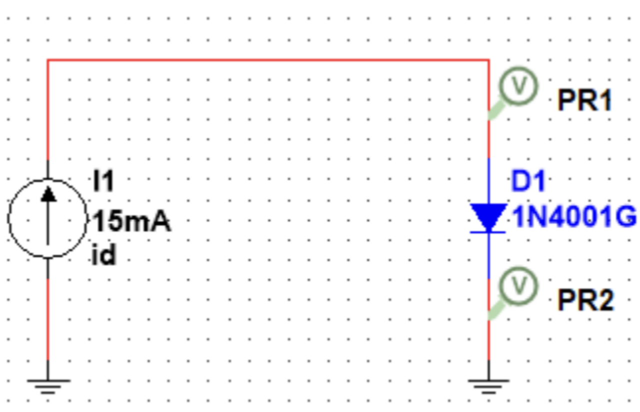
Objective

The objective of this project is to study the electrical characteristics and practical applications of diodes through simulation and experimental measurement. This includes analyzing diode I–V behavior, implementing half-wave and full-wave rectifier circuits, designing a filtered DC power supply, and evaluating Zener diode operation for voltage regulation. The goal is to understand diode behavior in forward and reverse bias and how these characteristics are applied in power electronics circuits.

Diode Characteristics

A diode allows current to flow primarily in one direction, exhibiting a nonlinear current-voltage relationship. In simulation, a DC sweep was applied from 0 V to approximately 15 V to observe the forward bias region. The expected I–V curve shows minimal current flow until the voltage reaches a threshold known as the “knee voltage,” typically around 0.6 V to 0.7 V for silicon diodes. This point marks the transition from the nonconducting to the conducting state.

The simulation data were exported and plotted using MATLAB to verify the theoretical shape of the exponential I–V relationship.



Multisim Circuit I-V Characteristics of Diode

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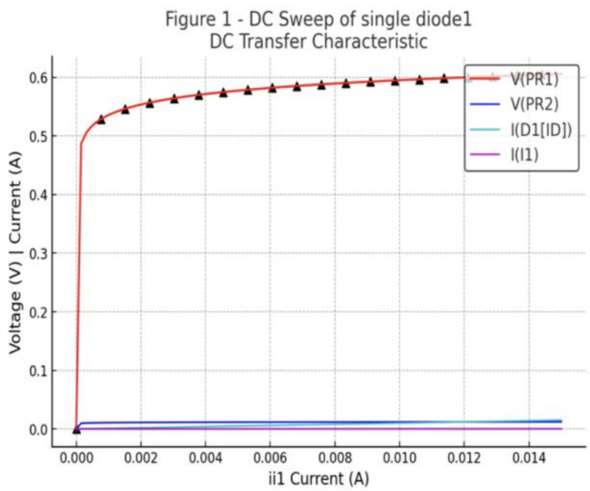
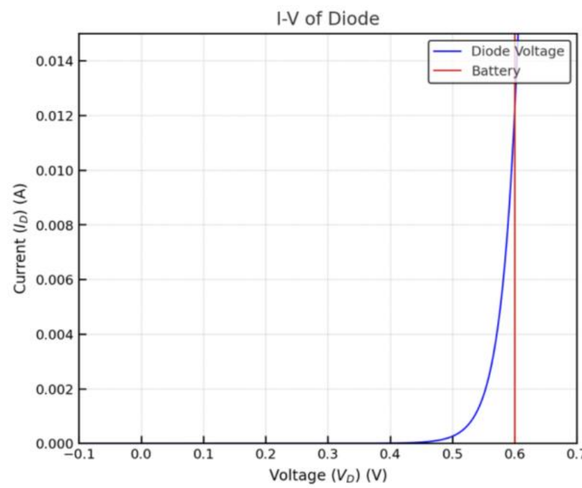
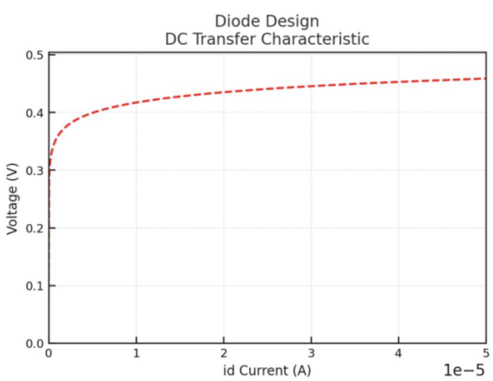


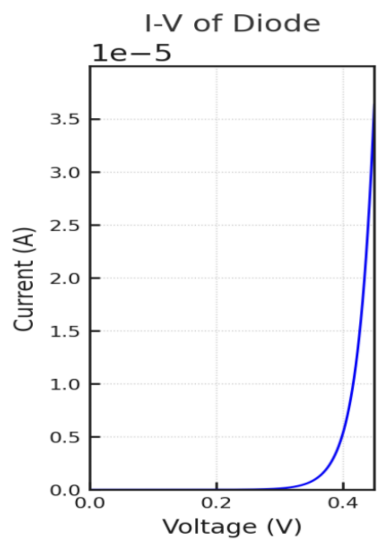
DC Sweep of Single Diode



IV Characteristics of a Diode



DC sweep from 0 to 50uA



Characteristics of the IV Diode

The measured forward voltage stabilized around 0.68 V at higher supply levels, consistent with the expected knee voltage range. The calculated current at V_s at 15V was 9.55mA.

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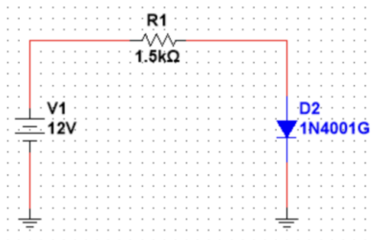
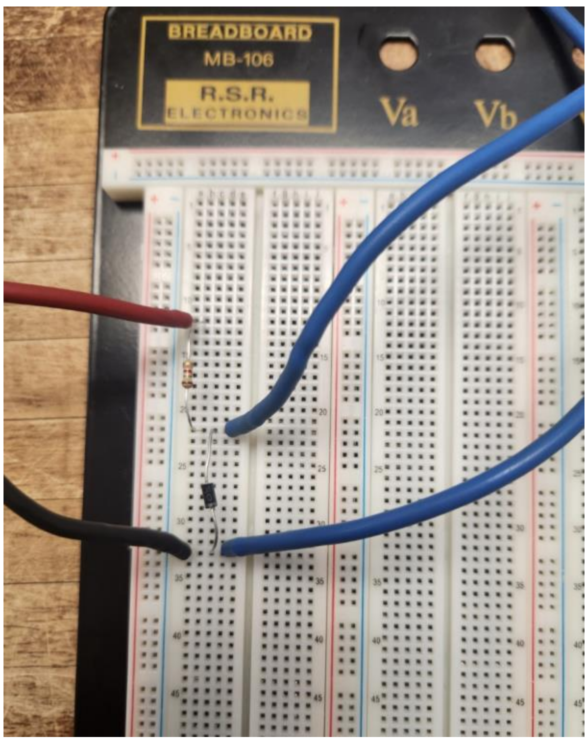
The measured value closely matched simulation results, showing less than 3 % error. This confirmed the diode's exponential behavior and its function as a one way current path.



Multisim to measure I-V characteristics of diode



Circuit built on protoboard consisting of diode and resistor

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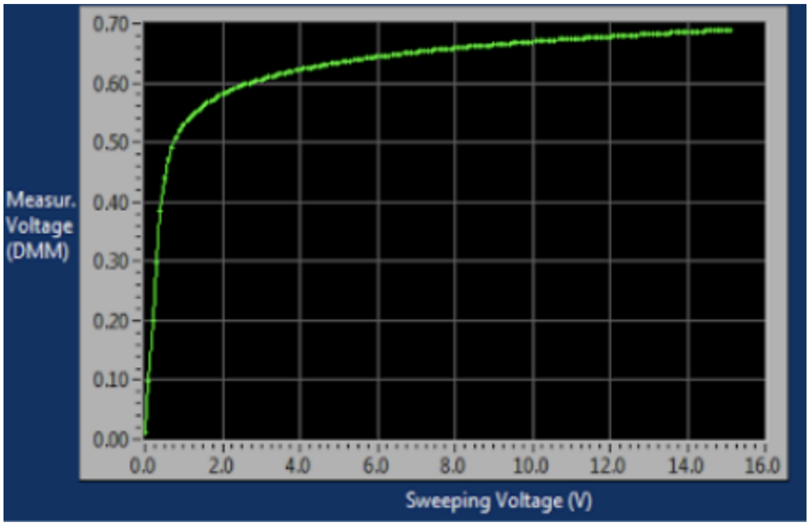

LabView of voltage sweep

This LabView is the result of a voltage sweep across the circuit constructed on the protoboard above.

Half-Wave Rectifier

A half-wave rectifier converts AC input into pulsating DC by allowing only the positive half of the waveform to pass. The diode conducts when the input is positive and blocks when it is negative, resulting in a unidirectional output.

Procedure and Observations

1. The circuit was assembled with a single diode and a 1.5 kΩ load resistor.
2. The input was a 60 Hz sine wave from the function generator with a 5 V peak amplitude.
3. The oscilloscope measured both input (Channel 1) and output (Channel 2).

To clearly view the waveforms:

- Coupling was set to DC.
- Vertical scale: 2 V/div.
- Time base: 5 ms/div.
- Trigger level set at 0 V with positive slope.

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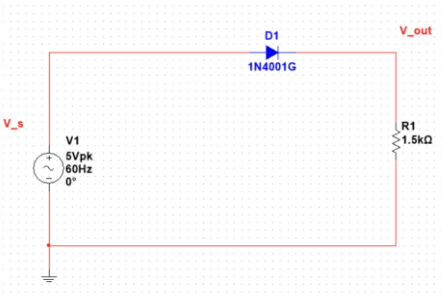
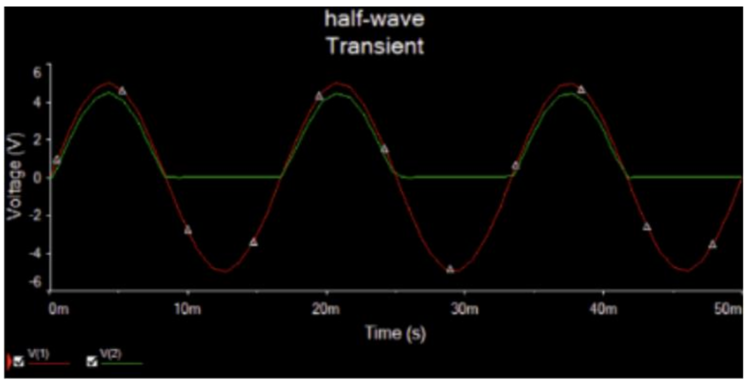
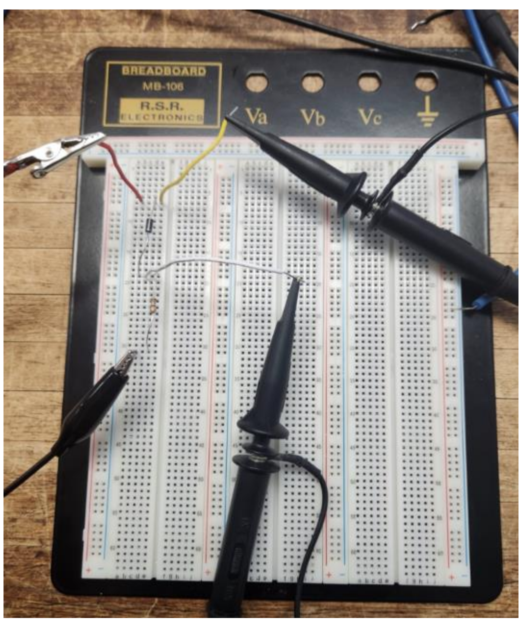


Multisim of Half-Wave rectifier



Half-wave rectifier simulation



Half-Wave rectifier constructed on protoboard

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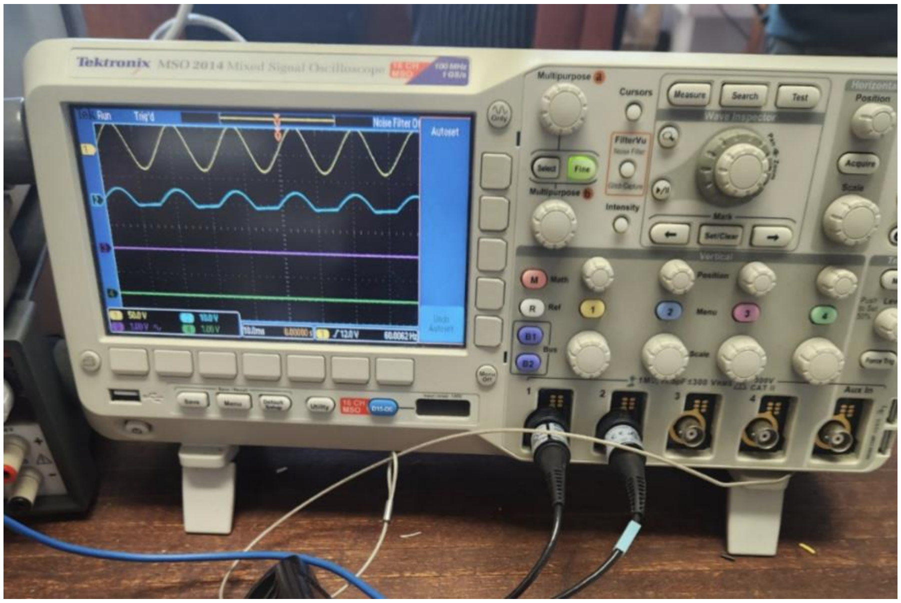
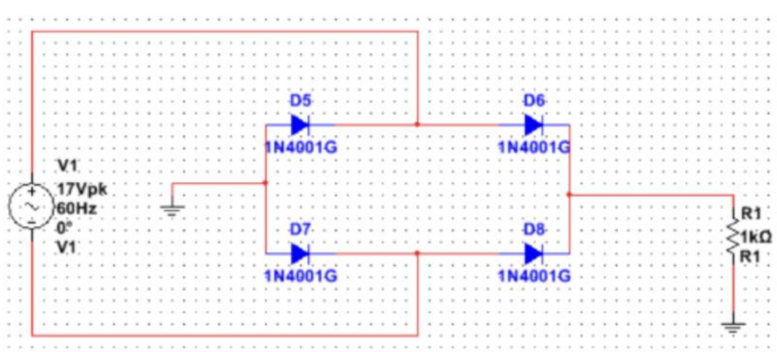


Oscilloscope of Half-Wave rectifier showing both input and output

The oscilloscope showed that the diode conducted only during the positive half-cycles. The output waveform followed the positive input peaks and dropped to zero during the negative half. This confirmed proper half-wave rectification. The output amplitude was slightly reduced due to the diode's forward voltage drop (~0.7 V).

Full-Wave Rectifier

A full-wave rectifier utilizes four diodes in a bridge configuration to convert both halves of an AC waveform into positive pulses. The advantage is improved efficiency, as both halves contribute to the DC output.



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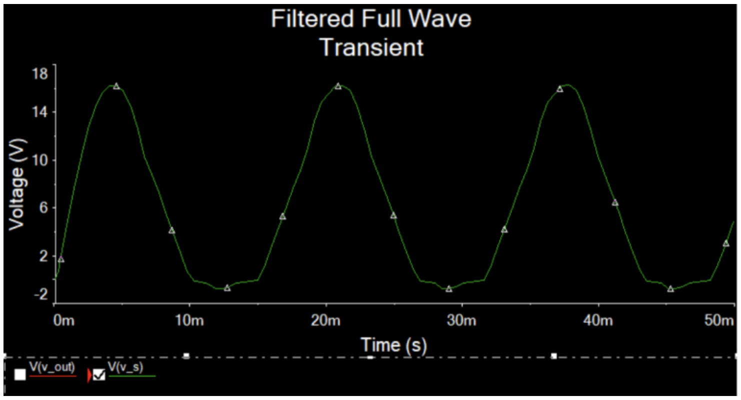
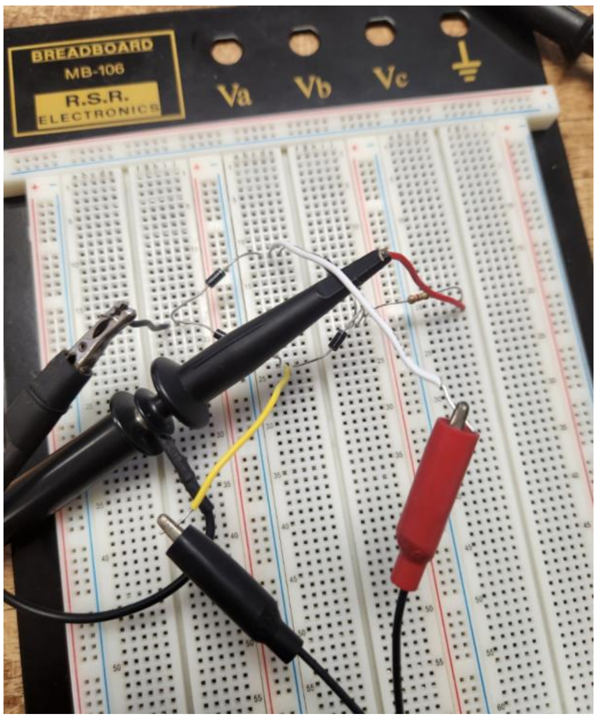
Constructed on Multisim is the Full-Wave rectifier



Output of Full-Wave rectifier

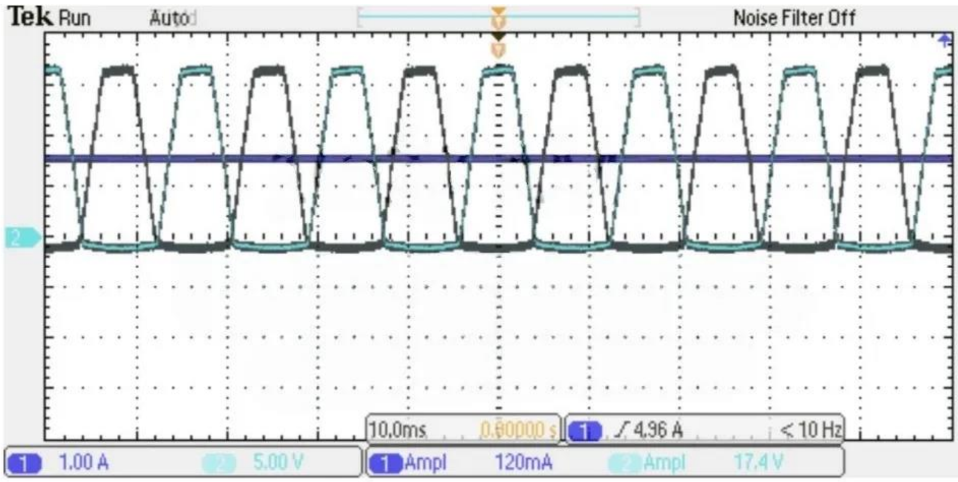
During full-wave rectification, the output voltage experiences a total drop of approximately 1.4 V since the current flows through two diodes in each conduction path.



Full-Wave rectifier on protoboard

Oscilloscope readings displayed output voltage pulses occurring twice per input cycle, confirming full-wave behavior.

Each conduction path included two diodes, leading to a total drop of about 1.4 V. Despite this, the circuit effectively produced a rectified signal that remained positive throughout the period.



Oscilloscope of Full-Wave rectifier

The simulation and physical measurements matched closely, verifying successful implementation of the full-wave bridge rectifier.

DC Power Supply

To maintain ≤ 5 % ripple for a 100 mA load, a capacitor of approximately 1 mF was selected with a 150 Ω load resistor.

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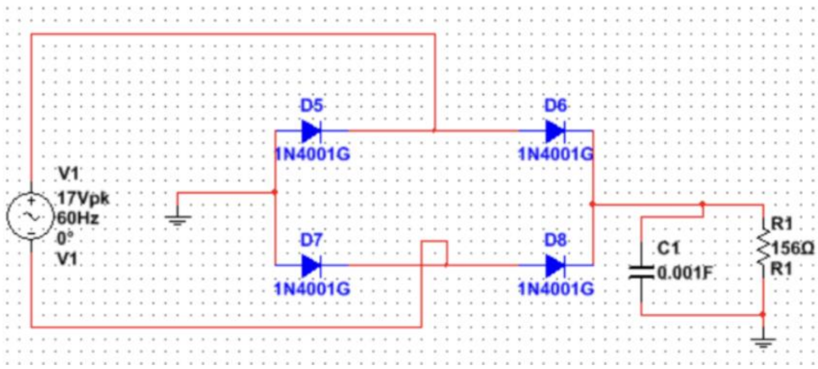
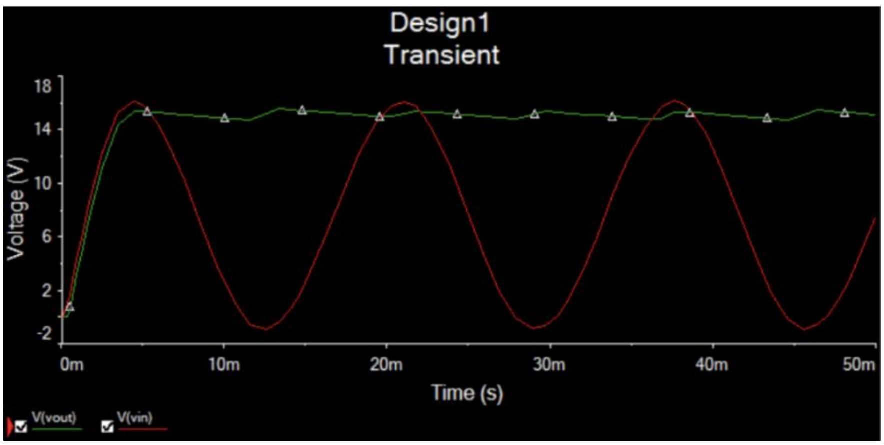


Multisim of DC power supply circuit



Input and Output of the DC power supply circuit

The output waveform is noticeably smoother than the input. The capacitor serves as a filter, reducing ripple and providing a more consistent DC voltage.

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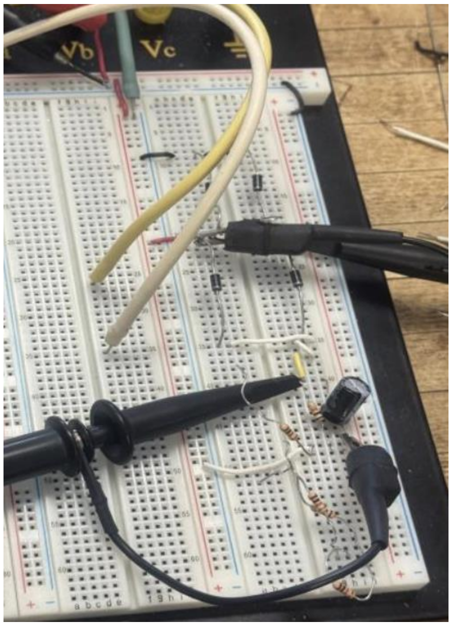
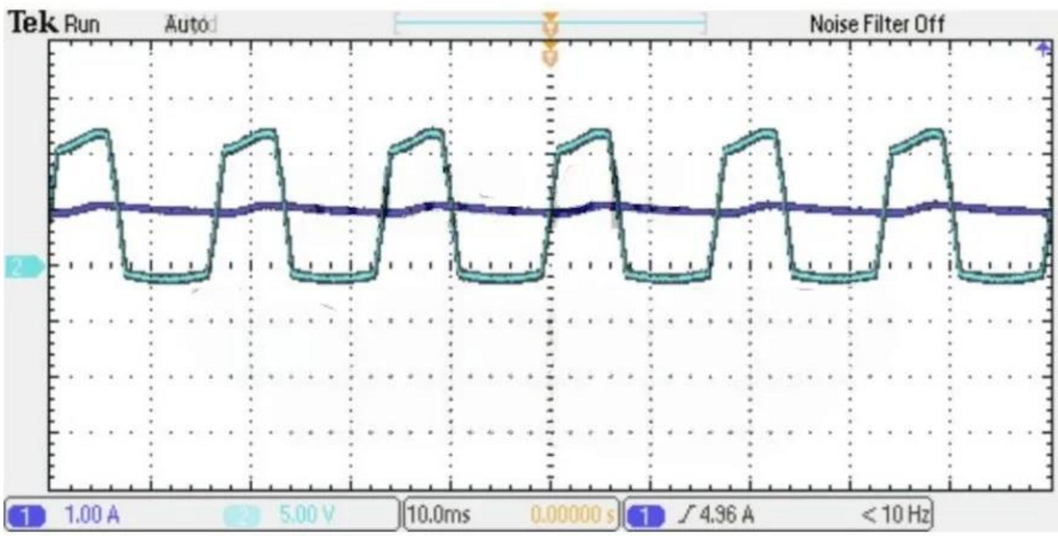


DC power supply constructed onto protoboard



Oscilloscope data for DC power supply circuit

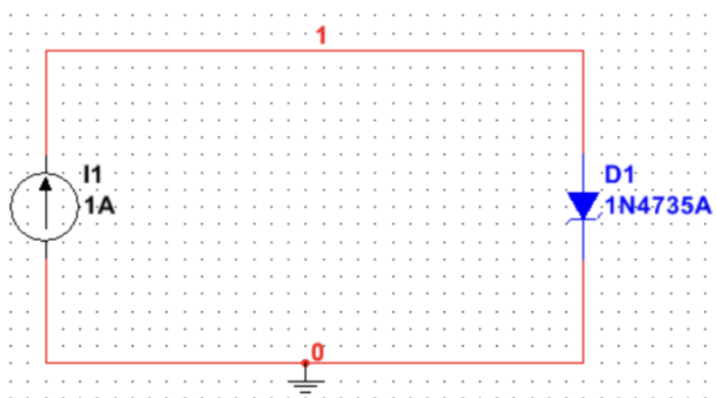
The full-wave rectifier circuit was combined with the capacitor filter. The oscilloscope displayed a significant reduction in ripple after adding the capacitor. Expected output was around 15.6 V, but the measured output was approximately 16.6 V. This discrepancy occurred because the transformer output was slightly higher (19 V p-p instead of 17 V p-p). The explanation aligns with realistic transformer tolerances.

Overall, the circuit provided a smoother DC output, confirming the filter's effectiveness in reducing voltage fluctuations.

Zener Diode Characteristics

Zener diodes are designed to conduct in reverse once the voltage exceeds a specified breakdown level. In this setup, a current sweep from –10 mA to +10 mA was performed in simulation to record both forward and reverse I–V regions.

The expected forward knee voltage is about 0.7 V, and the reverse breakdown voltage for the Zener diode is roughly 6.2 V.



Zener Diode circuit constructed on Multisim

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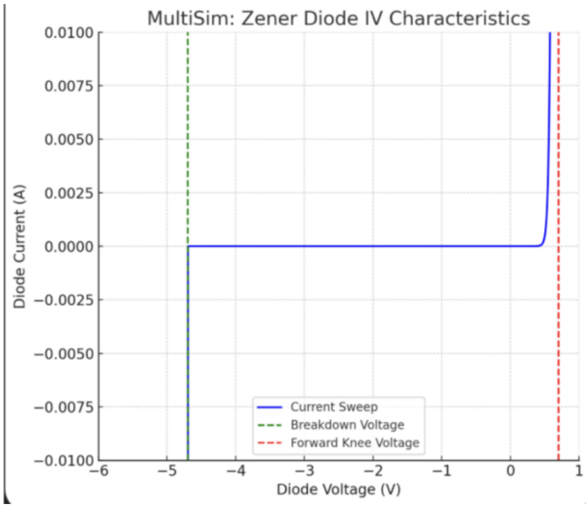
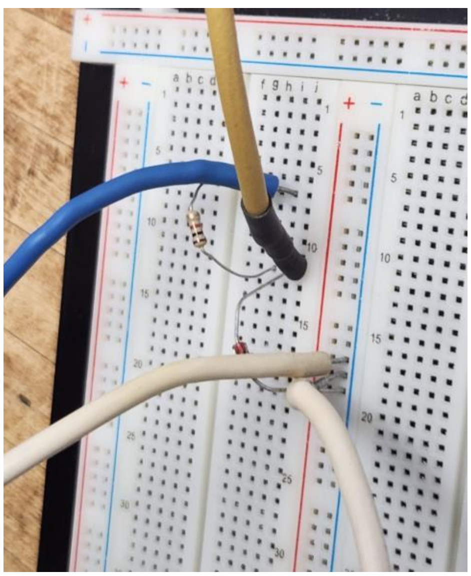


I-V characteristics of a Zener Diode



Zener Diode circuit constructed on the protoboard

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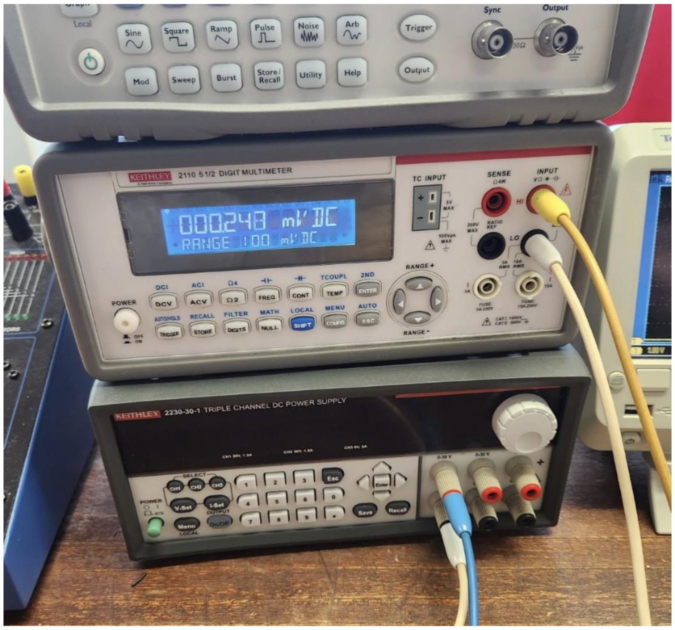
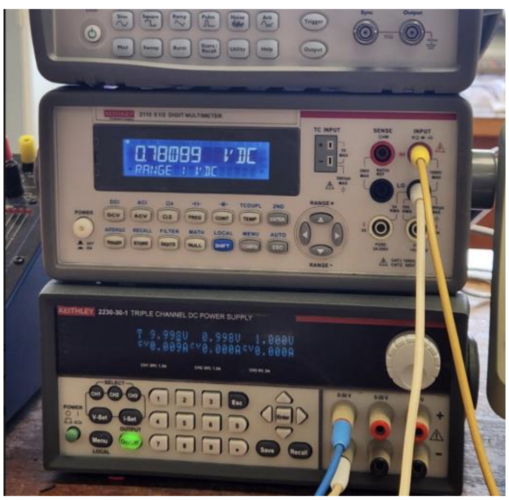


Voltage set to 0V



Voltage set to 10V

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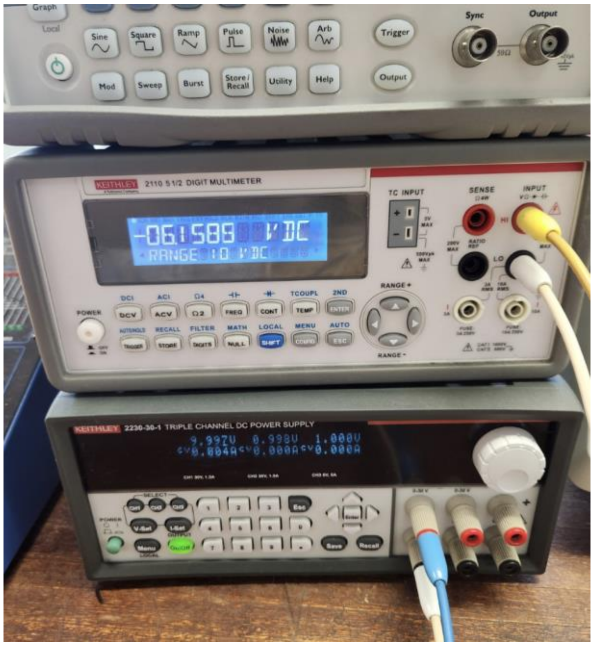

Voltage set to –10V (leads are reversed on protoboard)

The Multisim simulation showed the Zener diode breaking down near –5 V and conducting forward around 0.7 V. The physical measurements at –10 V, 0 V, and +10 V confirmed this behavior, with the diode maintaining a stable reverse voltage and a typical forward drop. Minor differences between simulation and project likely came from components and measurement limits, but overall, both sets of data matched closely and verified the expected Zener characteristics.

Voltage Regulation

In voltage regulation circuits, a reverse biased Zener diode maintains nearly constant output voltage despite changes in load current or supply voltage. In simulation, the load current was varied from 0 to 5 mA to observe the voltage across the diode and determine the regulation limits.

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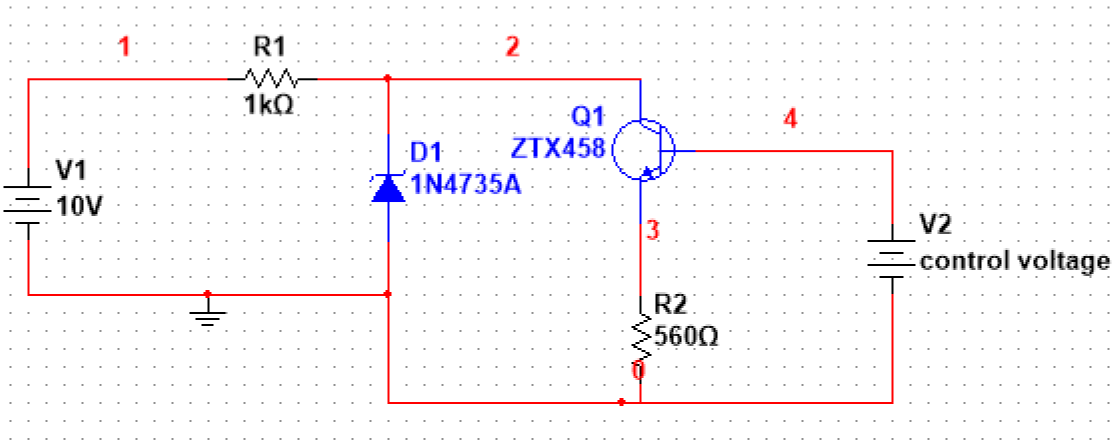

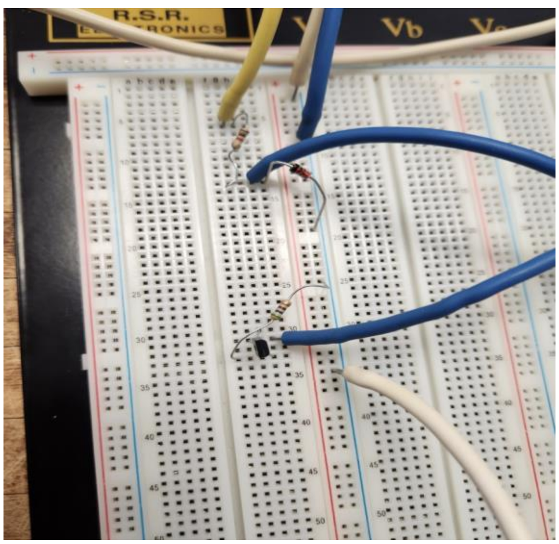

Reverse Biased Zener Diode for Voltage Regulation

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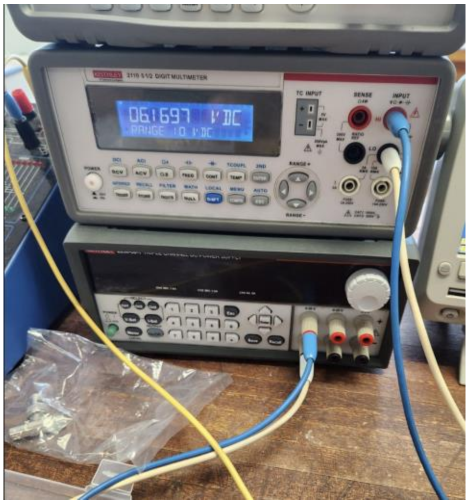
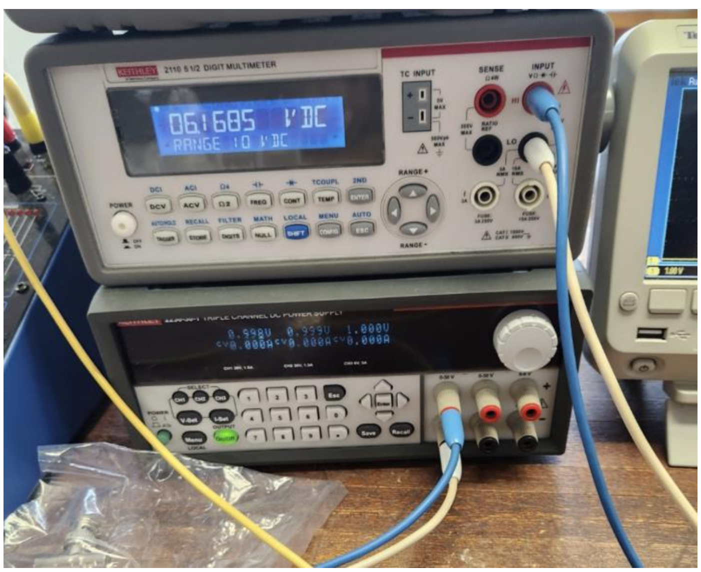


Voltage set to 0V



Voltage set to 1V

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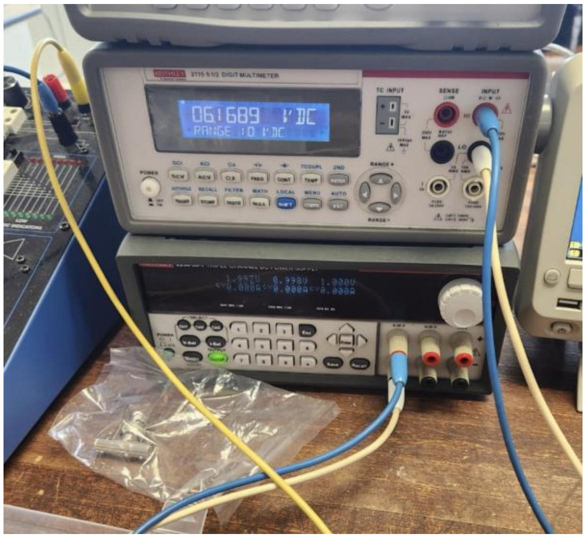
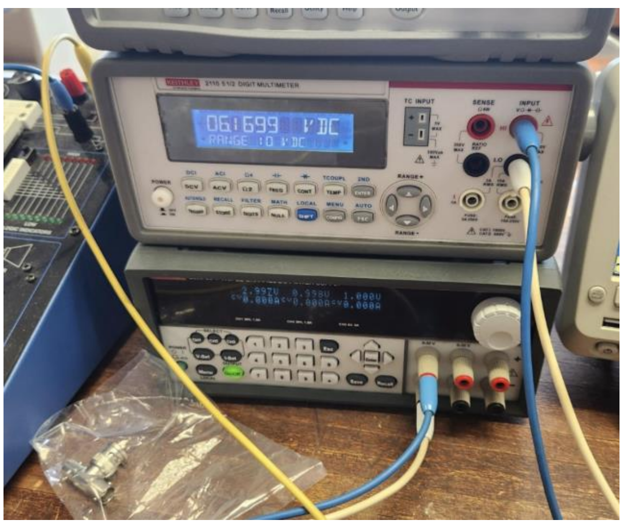


Voltage set to 2V



Voltage set to 3V

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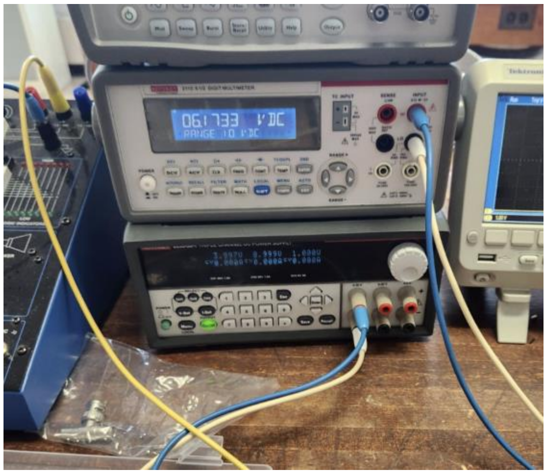
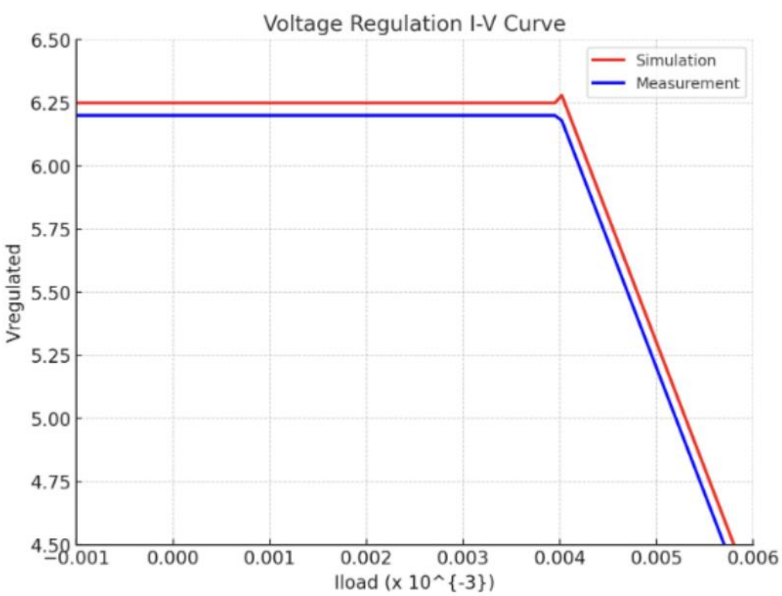


Voltage set to 4V

From the data above I constructed the following MATLAB graph



A transistor was added as a variable load controlled by a DC input signal. The Zener diode remained reverse biased and maintained a stable output near its breakdown voltage until the current dropped below about 0.5 mA. When the Zener current fell too low, the voltage could no longer remain constant; a predictable behavior based on diode physics. This confirmed that voltage regulation works effectively only when the Zener operates within its recommended current range.

Results and Observations

Experimental measurements closely matched simulation results across all diode circuits. The diode I–V characteristics exhibited the expected exponential behavior in forward bias, with a knee voltage observed in the 0.6–0.7 V range. Rectifier circuits produced the expected pulsating DC outputs, with the full-wave bridge rectifier demonstrating improved waveform utilization compared to the half-wave configuration.

The addition of a capacitor filter significantly reduced output ripple voltage, resulting in a smoother DC output consistent with theoretical predictions. Zener diode testing confirmed stable reverse breakdown near the specified Zener voltage, and the regulation circuit maintained a nearly constant output voltage within the proper operating current range. Minor discrepancies were attributed to component tolerances and measurement limitations.