2EI4 Project 1

Name: Ricky Huang

Student Number: 400508848

Student ID: Huangr86

Date: February 9th, 2025

Professor: Dr. Yaser M. Haddara

Design

Given a 120V sinusoidal voltage source, it is required to design a system that converts this AC voltage into a DC voltage source of 3V ± 0.1V with a 10mA current. This is done by designing a transformer to dilute voltage to a lower acceptable value, a rectifier to convert the sine wave into a pulsating DC voltage, then running the voltage through a filter that reduces the amount of voltage ripples to create a constant DC voltage, and if necessary, utilizing a regulator to further reduce any residual ripple voltage by using a Zener diode.

The type of rectifier used in this design is the center-tapped full-wave rectifier. This is because between half-wave and full-wave rectifiers, the latter takes both the positive and negative of the input wave into consideration. This means the output produced will depict a more consistent and stable average DC power. With full-wave rectifiers, there are 2 types: a bridge full wave and center tapped. For this design, it utilized a center-tapped for both the fact that it required fewer diodes to create and to accommodate for the inconsistency that the AD3 shows when combined waves. Additionally, because the design uses a full-wave rectifier, the frequency is doubled compared to what a half-wave rectifier would have.

After performing calculations [2], it was determined that the minimum capacitor value required to minimize the voltage ripple to an acceptable range of ±0.1 was 25 µF. For the actual circuit, a 100 µF capacitor was used; this is because a 25 µF capacitor was not provided, thus we used a capacitor of higher value as 25 µF was the minimum. This increase in capacitor value also aided in further reducing the ripple voltage.

V_r = Ripple Voltage C = Capacitor

I_L = Current f = Frequency

$$V_r = \frac{I_L}{2fC}$$

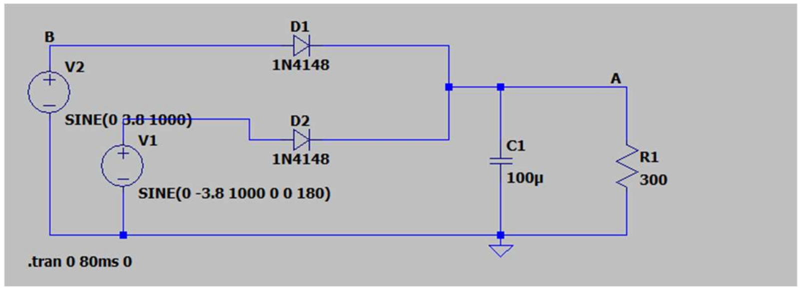
$$0.2 = \frac{10mA}{2khz(C)} = 25\mu F$$

$$C = 25\mu F$$

Figure 1: Capacitor Calculations

For this design a Zener diode regulator was not used, after simulating with and without the regulator it was discovered that our circuit provides a more stable DC voltage source with less ripples without the regulator. This is because Zener diodes will draw current regardless of what rectifier is used; however, with a center-tapped rectifier, current runs through only half the rectifier; thus, the current supplied is less. This results in the capacitor replenishing voltage slower, causing more voltage ripples in the final DC output. [1]

Figure 2: Schematic



The equations for these calculations come from the textbook.[1]

Resistor Calculations

$I_{req} = 10\text{mA}$ $\quad V_{avg} = 3\text{V}$

$$R = \frac{V}{I} = 300\Omega$$

Voltage Calculations

$V_{Diode} = 0.7\text{V}$ $\quad V_{Ripple} = 0.2\text{V}$ $\quad V_c = 3\text{V}$

$$V_o = V_c + V_{diode} + \tfrac{1}{2}(V_{ripple})$$

$$V_o = 3 + 0.7 + 0.1$$

$$= 3.8\text{V}$$

Figure 3: Component Calculations

For our design, it was not required to implement a function transformer into our circuit. Instead, we used our AD3 to simulate the calculated inputs that would be receiving if the transformer were present.

$V_o = 3.8\text{V}$

$V_{total} = 7.6\text{V}$, this is since each input voltage represents either the negative or positive side of the wave

$V_{total(rms)} = \frac{7.6V}{\sqrt{2}} \approx 5.374V$

Turn ratio $= \frac{120V}{5.374} \approx 22.33$, Thus the turn ratio for our transformer would be 22:1

Figure 4: Transformer Calculations

Listed below are the component ratings of the diode and resistor used; this is important as surpassing these values can lead to safety issues, such as potential burnouts of components, which are unlikely with these small components but with larger ones can create fire hazards. Other concerns include fumes from any potentially damaged components and electrical shock from the circuit.

Ln4148 Diode

Power rating = 500mW

Breakdown Voltage = 100V

Maximum Forward Current = 300mA

100Ω Resistor

Power Rating = 0.25W

Maximum voltage = 5V

Tolerance = ±5%

Figure 5: Component Ratings

Measurement and Analysis

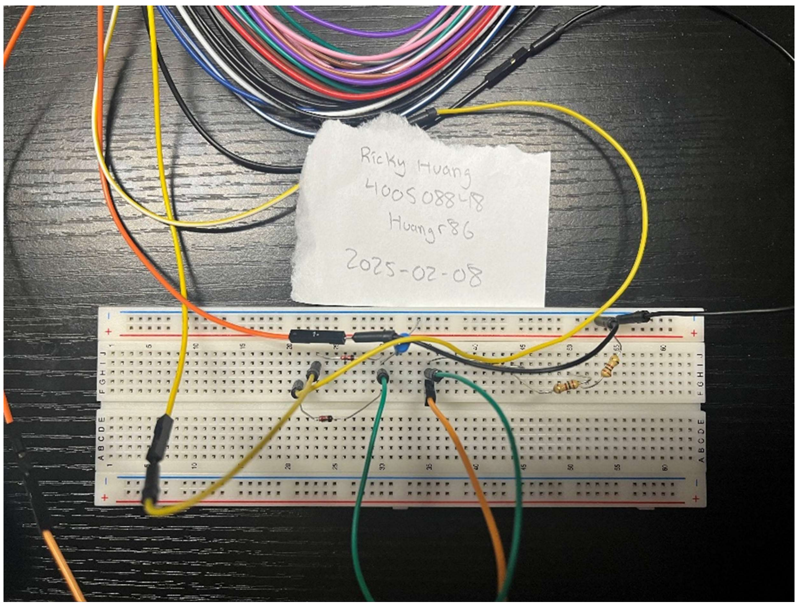


Figure 6: Circuit in Real Time

Using the wave gens to simulate the AC waves that the rectifier would receive from the transformer, the circuit was able to create a DC voltage with minimal voltage ripple, this was shown through using the oscilloscope provided by the AD3.

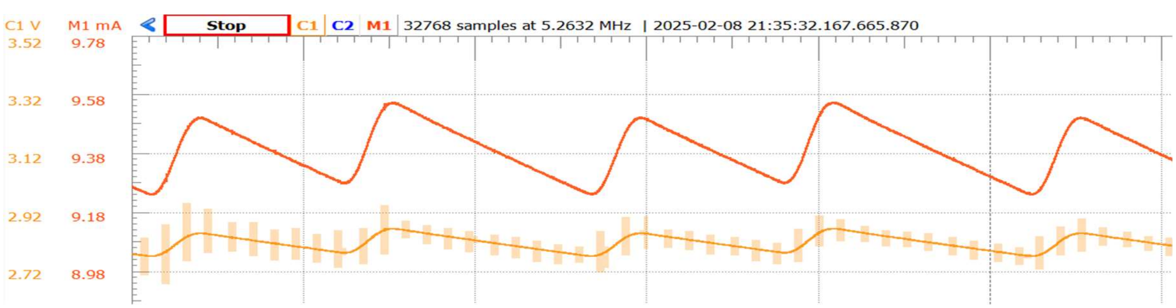


Figure 7: Circuit Results

As shown by the image given by the oscilloscope, our AC voltage has becoming a relatively stable DC voltage. Using the calculated values for all components resulted in the output voltage to be slightly lower than expected, as it rippled between 2.9V and 2.8V. Whilst the current is fluctuating at a slightly lower expected, at a range between 9.6mA and 9.2mA

Simulations

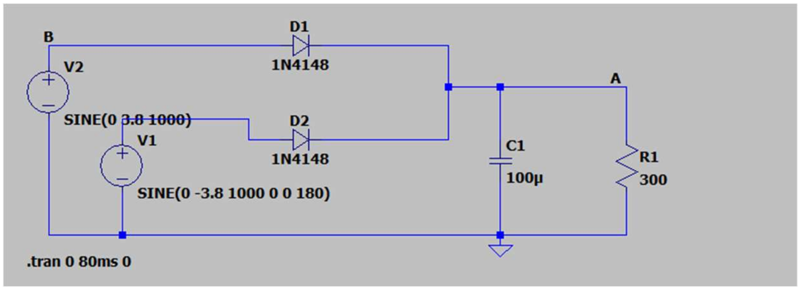


Figure 8: Schematic

Netlist:

* C:\Users\Rhrua\OneDrive\Desktop\2EI Project 1\Project.asc

V1 N001 0 SINE(0 -3.8 1000 0 0 180)

V2 B 0 SINE(0 3.8 1000)

D1 B A 1N4148

D2 N001 A 1N4148

C1 A 0 100µ

R1 A 0 300

.model D D

.lib C:\Users\Rhrua\AppData\Local\LTspice\lib\cmp\standard.dio

.tran 0 80ms 0

.backanno

.end

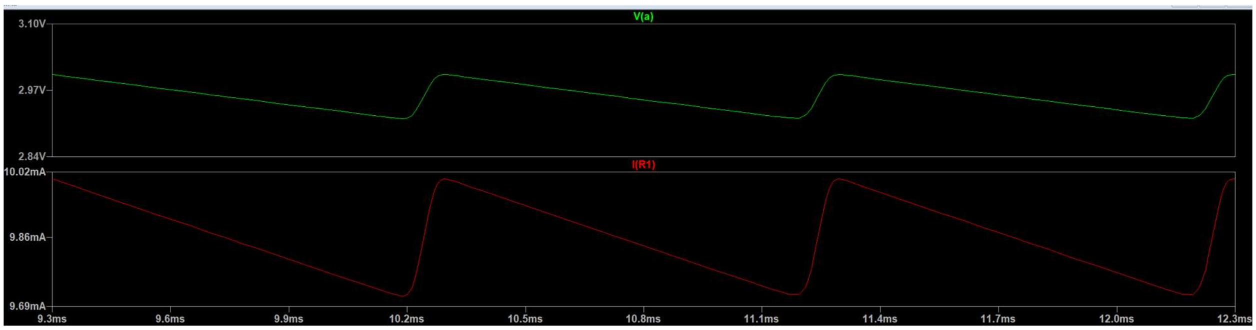


Figure 9: Simulation Outputs

In our simulation using the components calculated during the design phase of the report and under the conditions of an 80 ms stop time, which isn't shown in the picture as the wave is being zoomed in on to see the voltage ripples clearer. A 3V DC voltage with a voltage ripple of within the acceptable range of ±0.1 and on the bottom depicts the current that is running through the circuit. Its fluctuation is a result of the changing voltages, which are the voltage ripples.

<u>Discussion</u>

Comparing the results that were obtained by calculation, simulation, and real-life implementation, it can be observed that in terms of simulations, the output depicted a result that was expected through the calculation, with a DC voltage that rippled with ±0.1V around 3V. This is because during a simulation, the components and environment the circuit was built in were ideal and had no outside factors affecting it. However, during the real implementation of the circuit, the results that were outputted slightly deviate from the expected values, with a voltage value between 2.9 and 2.8. This is because, unlike the simulation, the circuit was not created in an ideal environment using ideal components. Many factors could have caused this difference; these include the tolerance of the 100Ω resistors used, as this could cause variations in our final outputted voltage. Another important factor to consider would be the internal resistance of any components used in this circuit, as although by themselves they are minor, with enough parts their collective resistance will add up and cause slight changes to the final outputted voltage. To troubleshoot for this loss of voltage, the input voltage simply needed to be increased to account for the slight deviation. Thus, when the input voltage is set to 4V, the circuit outputs are much closer to the expected values from the calculations.

Figure 10: Simulation Outputs with ±4V input

Datasheets and References

[1] A. S. Sedra, K. C. Smith, T. C. Carusone, and V. Gaudet, Microelectronic Circuits, 8th ed. New York, NY: Oxford University Press, 2020. Accessed: Feb. 9, 2025. [Online].

[2] Electronics Tutorials, "Full Wave Rectifier," *Electronics Tutorials*. [Online]. Available: https://www.electronics-tutorials.ws/diode/diode_6.html. [Accessed: Feb. 9, 2025].

Vishay, "1N4148 – Small Signal Fast Switching Diodes," Vishay Intertechnology, Inc. [Online]. Available: https://www.vishay.com/docs/81857/1n4148.pdf. [Accessed: Feb. 09, 2025].

"1/4 Watt 100 Ohm Resistor R1/4-100," Abra Electronics. [Online]. Available: https://abra-electronics.com/passive-components/resistors/1-4-watt-carbon-film-5/r1-4-100-1-4-watt-100-ohm-resistor-r1-4-100.html. [Accessed: Feb. 09, 2025].