Design Project #1 - AC to DC Converter

ELECENG 2EI4- Electronic Devices and Circuits

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Summary:

The objective is to design and construct a DC power supply capable of providing a consistent output of 10 mA at 3V ± 0.1V. This power supply is intended to operate from a source with a 120V (rms) input at 1 kHz. . In the case of the design created for this report, a bridge rectifier circuit was used that included four diodes, a 100uF capacitor, and a resistance of 300 ohms.

Design:

i) Transformer:

Within this design, a transformer was not used. The input voltage required for this design was calculated to be 4.4 V. The ratio of the transformer that would be needed in the input generated from a 120V AC source would be **38.56:1**

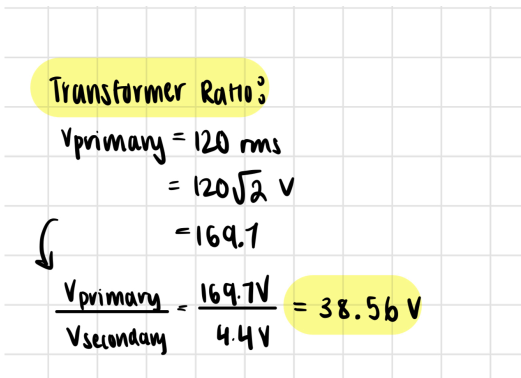

Figure 1: Transformer Ratio Calculations

ii) Rectifier:

Within this created design a full bridge rectifier was used in order to convert the 120V AC course into a DC power supply. This full bridge rectifier consisted of four 1N4148 diodes as shown in *Figure 5,* of the schematic designed for this circuit. A full-wave rectifier converts AC to DC using both halves of the input sine wave. It typically employs a center-tapped transformer, with diodes conducting during positive and negative half-cycles. This bridge rectifier was the most suitable rectifier bridge design because of its higher efficiency, constant DC output since it uses both halves of the input AC waveform , smaller and smoother ripple voltage, ability to handle higher power levels, and reduced transformer requirements.

The full bridge rectifier was chosen over a half-wave rectifier due to its ability to handle higher inputs and power levels, offering a significant advantage. Full-wave rectification enables the use of smaller transformers, enhancing overall efficiency and performance compared to half-wave rectification for the same power output. In a full-wave bridge rectifier, the diodes need to handle reverse voltage during part of the input. By using this type of rectifier and the right diodes, we can make sure the output works well in a simple and effective way.

Relevant diode parameters include the forward voltage drop and the reverse breakdown voltage. Forward voltage drop is the voltage that must be applied across a diode in the forward-biased direction for it to conduct current. The reverse breakdown voltage is the maximum reverse-biased voltage that a diode can withstand without experiencing a breakdown.

iii) Filter

The capacitance used for this design was 100 uF (for the filter) as shown in the calculations in *Figure 3*. The equation used required the output current, frequency and voltage ripple. The current is the 10 mA (0.01 A) that is going across the 300 ohm resistor. The maximum allowable voltage ripple is 0.1V but even though a tolerance of ±0.1V was provided, basing the calculations off the 0.1V ripple was done to maintain a more precise output. The frequency was given as 1 kHz.

iv) Regulator

I opted not to include a regulator in this design.

v) Circuit Schematic

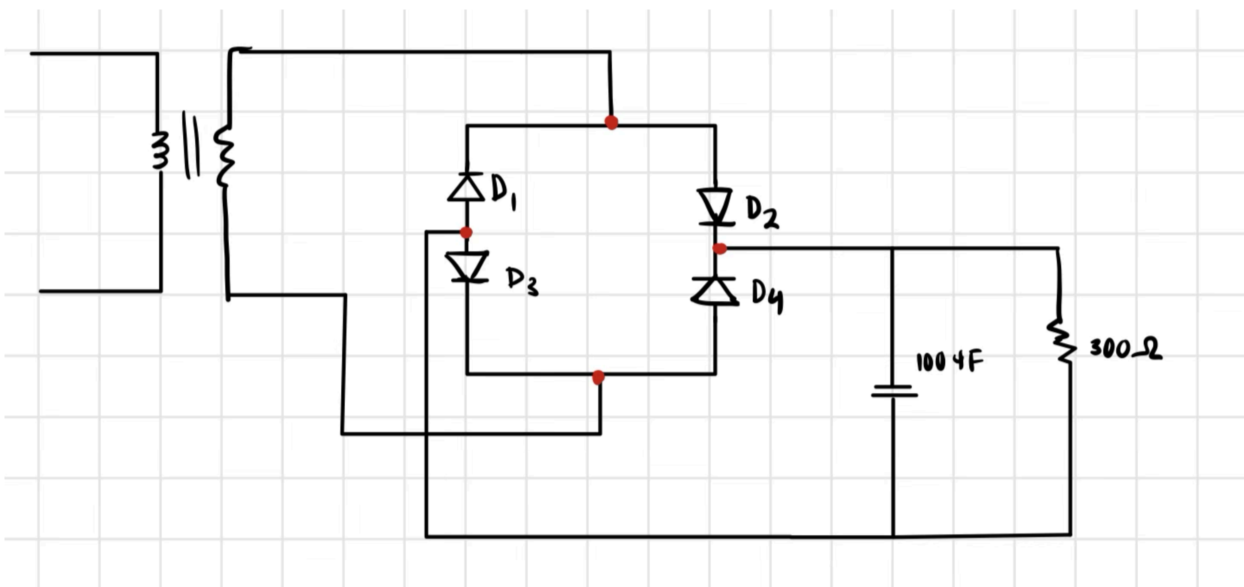

Figure 2: Design Circuit Schematic

vi) Calculations:

Capacitance:

$$V_{rpp} = \frac{I_{out}}{fC}$$

$$C = \frac{I_{out}}{f V_{rpp}}$$

$$= \frac{10mA}{1kHz \cdot 0.1V}$$

$$= \frac{0.01}{1000 \cdot 0.1}$$

$$C = 100\mu F$$

Resistance:

$$V = IR$$

$$R = \frac{3}{10mA}$$

$$= 300\Omega$$

Secondary Voltage:

$$E_S - V_{D2} - V_R - V_{D3} = 0$$

$$\left.\begin{aligned} E_S &= V_{D2} + V_R + V_{D3} \\ &= 3 + 2(0.7) \end{aligned}\right\} V_D \text{ is assumed to be } 0.7V$$

$$= 4.4V$$

Figure 3: Calculations for capacitance, resistance and secondary voltage

vii) Expected Performance

With the calculations and the design made, the 300 ohm resistance should have a steady DC output of 3V with a current of 10 mA. When the voltage drops to 3V from the transformer's 4.4V (secondary voltage) input, positive voltages are generated as both diodes conduct during the AC waveform's half-cycles. The filter then flattens the waveform, giving a maximum ripple voltage of 0.1V.

viii) Trade Offs, Design Margins, Component ratings, Safety

A 300-ohm resistor wasn't on hand for this design, so three 100-ohm resistors were connected in series to achieve the desired 300-ohm resistance. The kit provided a 100uF capacitor with the code 107. Prior to assembling the actual circuit, the power rating of each component was verified during the simulation to ensure safety and prevent any burning or overloading.

MEASUREMENTS AND ANALYSIS:

i) Circuit

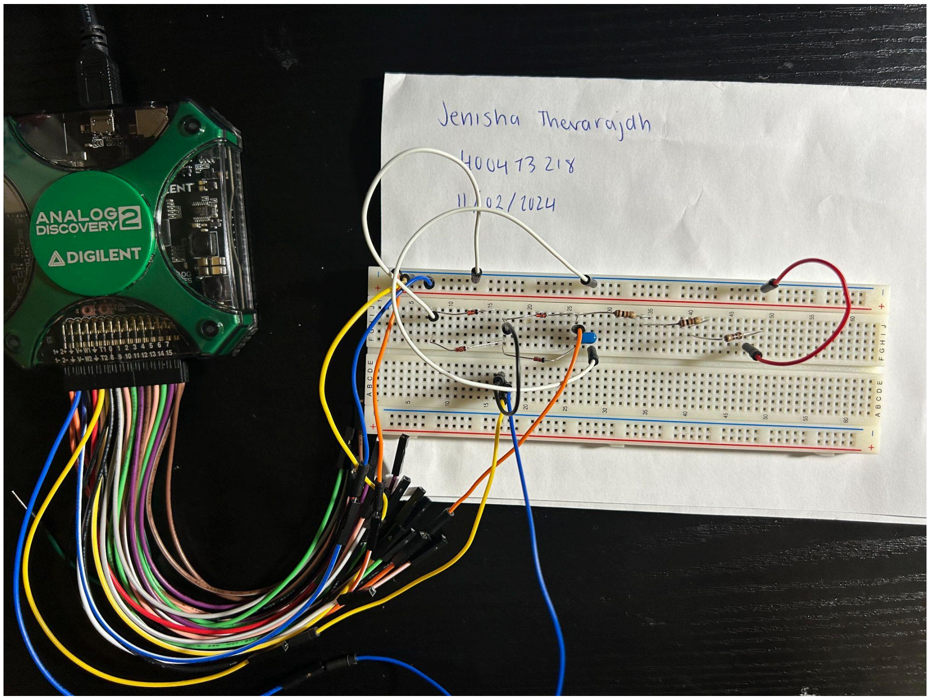

Figure 4: Circuit connected to AD2

ii) Measurement Procedure:

To conduct measurements on Waveforms, the Channel 1 (shown as the orange wire) oscilloscope was used to record the voltage and current (using ohm's law for current) across the 300-ohm resistor. Also, Channel 2 and the 1+ lead of the Wavegen (shown as the blue and yellow wires) were utilized to measure the input voltage, connected to the same node as the waveform input. Upon analyzing the oscilloscope output, it was noted that the input sinusoidal wave, with an amplitude of 4.65V, yielded an output voltage of 2.6V. As I continued to increase the amplitude to the maximum amount of 5V which led to an average of 2.7067V as shown in the measurement of C1 peak in *Figure 5*.

iii) Measurement Results:

Input Voltage: 5V; Max Output Voltage: 2.75V; Average Output Voltage: 2.706; Current: 10mA

iv) Oscilloscope

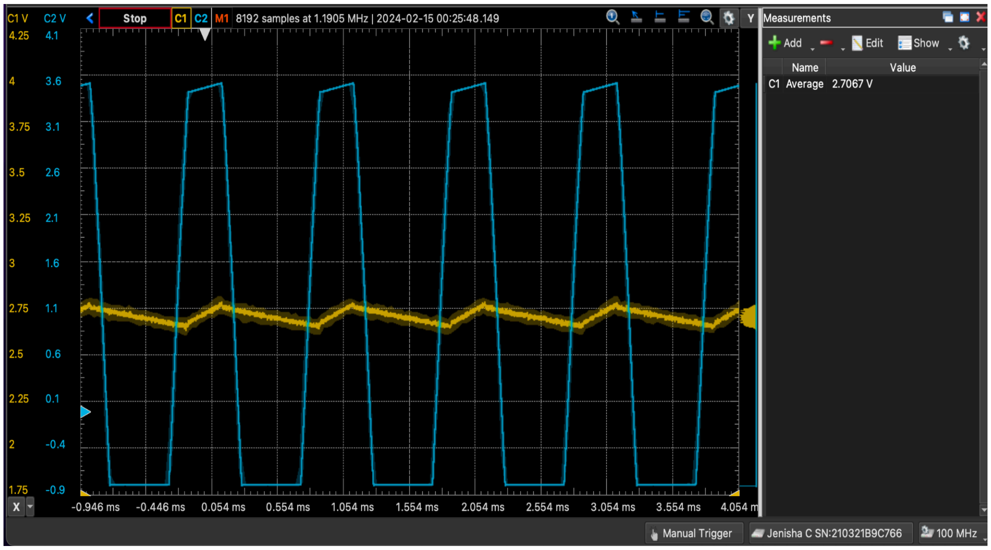

Figure 5: Oscilloscope clearly marked 2.7067 V is measurements to show the performance obtained

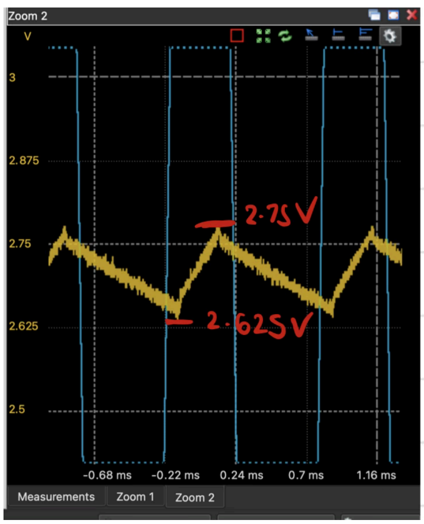

Figure 6: Close up with markings

SIMULATION:

i) Circuit Schematic

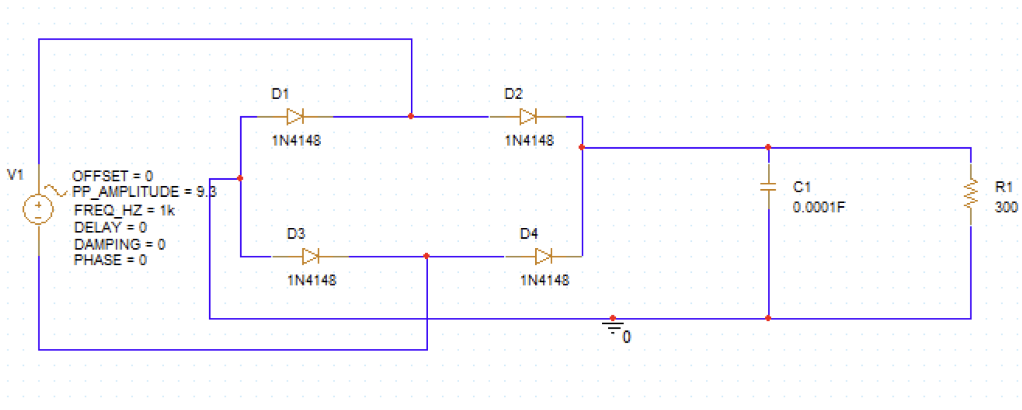

Figure 7: Circuit Schematic on PSpice

ii) NetList

```
* source ATTEMPT2
X_D1          0 N00207 awb1n4148 PARAMS:
X_D2          N00207 N00211 awb1n4148 PARAMS:
X_D3          0 N00218 awb1n4148 PARAMS:
X_D4          N00218 N00211 awb1n4148 PARAMS:
V_V1          N00207 N00218 DC 0Vdc AC 0Vac
+SIN 0 {.5*9.3} 1k 0 0 0
R_R1          0 N00211  300 TC=0,0
C_C1          0 N00211  0.0001F  TC=0,0
```

Figure 8: Netlist in PSpice

iii) Simulation Conditions:

This simulation was a transient simulation using Pspice. It was at a transient analysis stop time of 0.0001 seconds. In figure 9, it displays the voltage drop at the resistor. In the simulation, 1N4148 diodes were utilized, aligning with the specified diodes for the entire project.

iv) Simulation Output

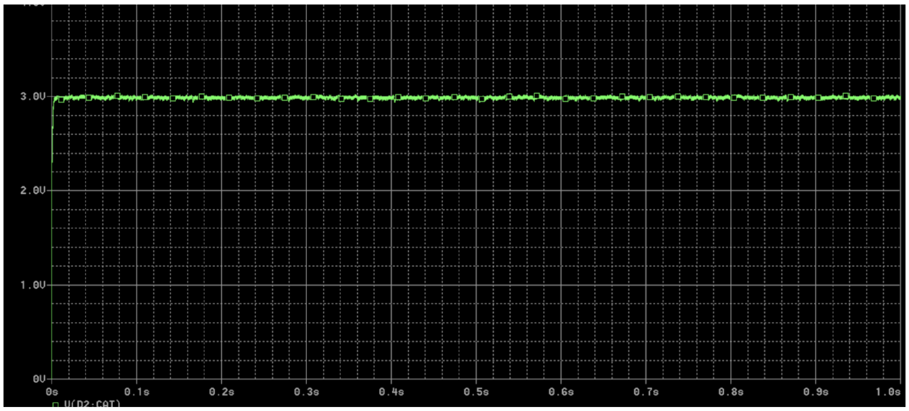

Figure 9: Simulation output set at 4.55V

Figure 9 clearly displays the expected output of 3V across the resistor. In order to get to this output however, the sine voltage source was first set to 4.55 V, which surpassed the calculations of 4.4 V done in *Figure 3.* This minor deviation in values might have arisen due to our assumption that the diodes were at 0.7V.

DISCUSSION:

i) Compare the results from design, simulation, and measurement.

The results between the design, simulation and measurement had some discrepancies, particularly within the input voltage. The analytical calculations stated that the input voltage 4.4V would have an output of 3V and 10mA with a 100uF capacitor across a 300 ohm resistor. Within the Pspice simulation, in order to obtain that desired value of 3V, the input voltage was increased to a 4.55V sine wave. The values were remarkably close, with differences not exceeding 0.05V for the output and 0.25mA for the current. This proximity was more pronounced than the calculated values on the AD2. To obtain the desired output, the input voltage (amplitude) for the AD2 was set to 5V, as the initial 4.4V did not give the desired result. Even then, with the 5V input voltage, the output only reached a maximum of 2.75 V.

ii) Discrepancies Observed

As mentioned earlier, the most significant disparity was observed in the input voltage, preventing the output voltage from reaching our intended range of 2.9-3.1V. Regarding the input voltage discrepancy in the simulation, as previously mentioned, it may have originated from assuming a 0.7V voltage drop for the diodes during analytical calculations. In reality, the diodes might have experienced a higher voltage drop. For the AD2 input voltage, there may have been a discrepancy within the AD2 causing the maximum input voltage not being able to reach the desired output voltage value.

iii) Limitations of the Design and Measurements

The first limitation is the AD2 because when generating the input voltage, our maximum input voltage is capped at 5V. Another drawback is that the output voltage can increase a lot when there's no load because there isn't sufficient load regulation. The lack of components and equipment can result in limitations for measurements because it can impact how precise the measurements are. Component availability and cost influenced our choices. Lastly, the rectifier output voltage might decrease if the load resistance surpasses a certain threshold.

iv) Problems Encountered in Measurements

A common issue in this design and its measurements pertains to the AD2 readings for both input and output voltage. Despite raising the input voltage to 5V on the AD2, I couldn't achieve the desired output voltage within the range of 2.9V to 3.1V. This problem could be linked to the AD2 itself. While examining the input voltage waveform, it became apparent that the AD2 caused clipping, resulting in a decrease in the output voltage.Thinking it was an AD2 problem, I couldn't discover a resolution for this issue.