ELEC ENG – 2EI4

Design Project #1

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Summary

The purpose of Design Project #1 is to design a DC power supply that can deliver 10 mA at 3 V $\pm$ 0.1 V from a source that is 120 V (RMS) at 1 kHz. The design of the DC power supply circuit consists of a transformer, rectifier, RC filter, and may include a regulator.

Design

The design process for Design Project #1 began with extensive research procedure that led to the final design which consisted of a center-tapped transformer, a full-bridge rectifier, a capacitor filter, and a load resistor. The regulator was not included in the final design as shown in Figure 1.

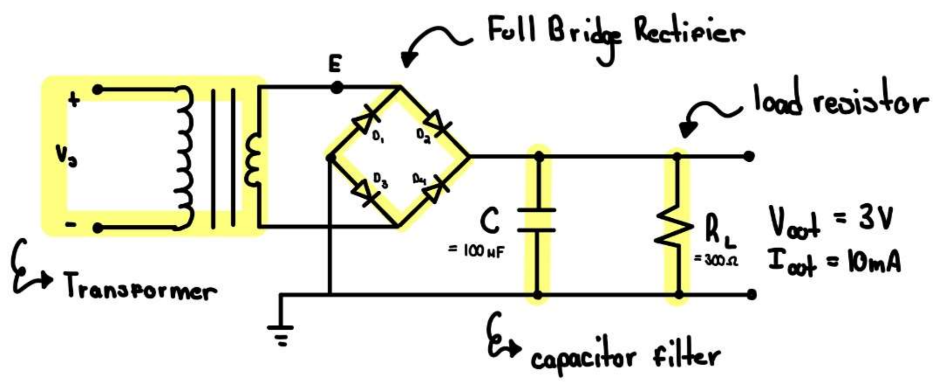

Figure 1: Completed DC Power Supply Circuit

Transformer

The DC power supply initially features a center-tapped transformer. A center-tapped transformer is a transformer in which one or more of the transformer's coils are connected via a tap to the center of the coils. This tap allows for the accessibility of connection making. These transformers are ideal for rectifier circuits as the one developed in this design project. The input voltage for this design was 4.4 V, determined through the calculations shown in Figure 2. Upon determining the input voltage to the transformer, the turns ratio subsequently determined which would be required if the input was being generated from a 120 V AC source [1]. The calculation for the turns ratio is also demonstrated in Figure 2.

Input Voltage:

$$V_{max} = V_{DC} + V_{D1} + V_{D2}$$

$$V_{max} = 3V + 0.7V + 0.7V = 4.4V$$

Turn Ratio:

$$\text{Turn Ratio} = \frac{N_P}{N_S}$$

$$= \frac{120\sqrt{2}\,V}{4.4\,V} = 38.6$$

Figure 2: Input Voltage and Turns Ratio Calculation

Rectifier

The next component of the DC power supply was a full-bridge rectifier. A full-bridge rectifier consists of four diodes that are placed in a closed loop "bridge" configuration. This configuration of the diodes allows the production of the desired output. A full-bridge rectifier was chosen as the desired rectification method for the DC power supply as it features a rectification efficiency of 81.2% that is nearly double the efficiency of a half-wave rectifier. The full-wave rectifier also features a ripple factor of 0.482 that is about three times smaller than a half-wave rectifier. The full-bride rectifier is also ideal for the DC power supply in this design project as it allows for the exclusion of a transformer that is not used in the physical-form of the circuit [2]. In this full-bridge rectifier design, Abra's 1N4148 Silicone Diode was utilized. From the datasheet, it was extrapolated that the the diode features a minimum forward voltage of 0.7 V and a maximum of 1.0 V. Whilst the breakdown voltage is 100 V [3].

Regulator and Load Resistor

The final two components of the DC power supply are the capacitor filter and the load resistor. The capacitor filter consists of Abra's CM107 ceramic 100 μF capacitor placed in parallel with the rest of the circuit. The load resistor consists of three of Abra's 100 Ω resistors to form a 300 Ω resistor that is also placed in parallel with the rest of the circuit. The resistors are rated for a ¼ Watt of power whilst, the capacitor is non-polarized and features a 20% tolerance level [4,5]. The calculations used to determine the capacitance value and the load resistance are shown in Figure 3.

Capacitance:

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

$$C = \frac{10\,mA}{1000\,Hz \times 0.1\,V} = 100\,\mu F$$

Resistance:

$$R_L = \frac{3V}{10\,mA}$$

$$= 300\,\Omega$$

Figure 3: Capacitance and Load Resistance Calculations

Safety Considerations

Prior to building and analyzing the physical circuit, some precautionary measures were taken to maximize safety. The circuit was initially simulated using a virtual circuit such as LTSpice to ensure that no issues would arise in the physical circuit analysis. Also, a lower value of 0.1 V rather than 0.2 V was utilized as the ripple voltage in calculations to ensure that the voltage range would remain within the bounds of the error margins.

Measurement and Analysis

The measurement procedure for this Design Project #1 consisted of connecting the W1 and W2 into the circuit. The W1 wire was connected between the top series of diodes; however, the W2 wire was connected between the bottom series of diodes. To connect the oscilloscope to the circuit, the 1+ wire was connected to the node between the full-wave bridge rectifier, capacitor, and the load resistor whilst the 1- wire was connected to the ground node. The completed physical circuit is demonstrated in Figure 4.

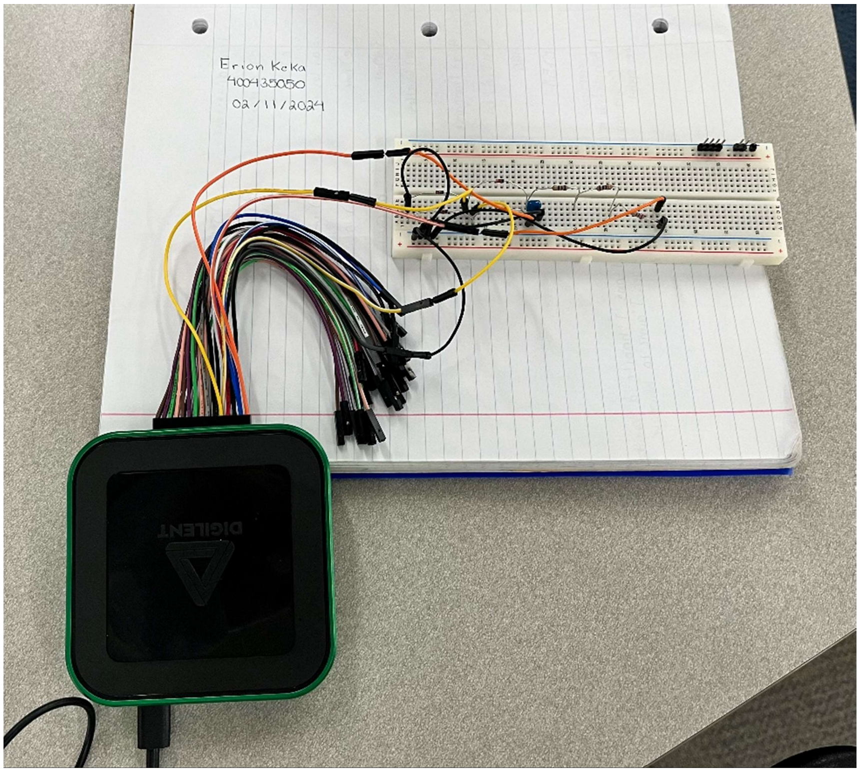

Figure 4: Physical Circuit connected to the Analog Discovery 3

From the output of oscilloscope, it is shown that the voltage gets transformed from an input voltage of a 4.4 V sinusoidal wave with a frequency of 1kHz to a lower output that lies within 2.944 V and 2.894 V as shown in Figures 5 and 6. The output current lies between 9.7 mA and 10.1 mA as shown in Figure 7.

Figure 5: Input Variables of the Analog Discovery 3

Figure 6: Output Voltage of the Analog Discovery 3

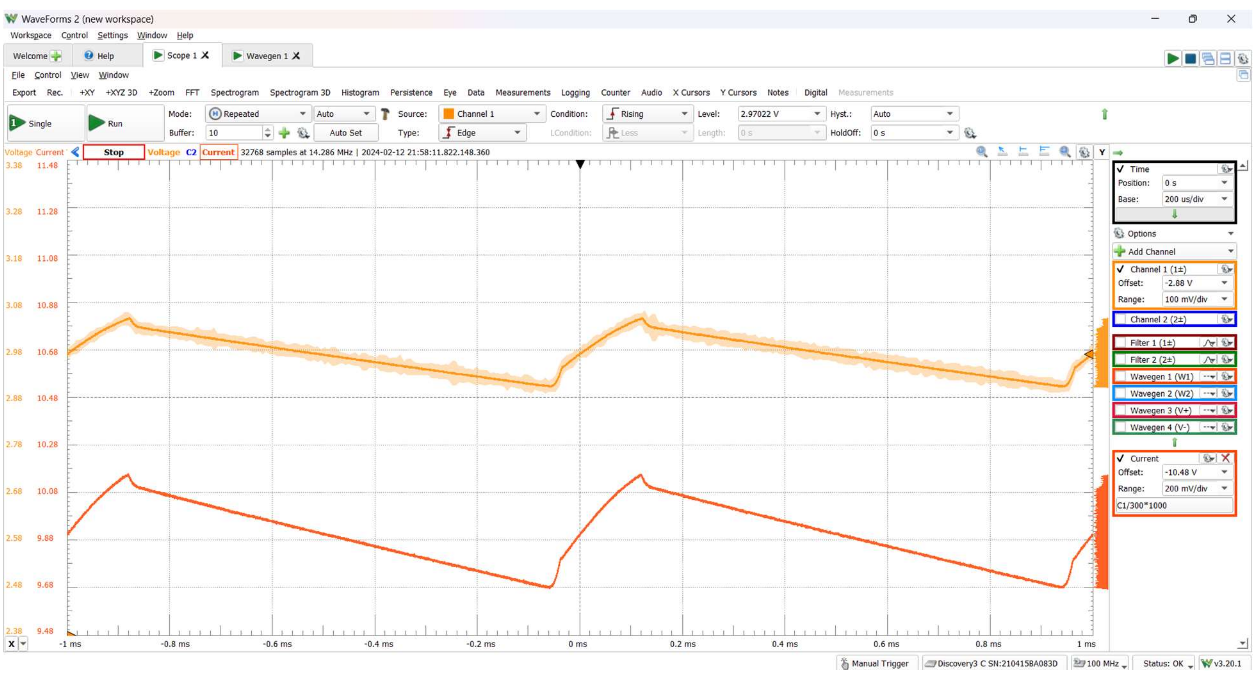

Figure 7: Output Current and Voltage of the Analog Discovery 3

Simulation

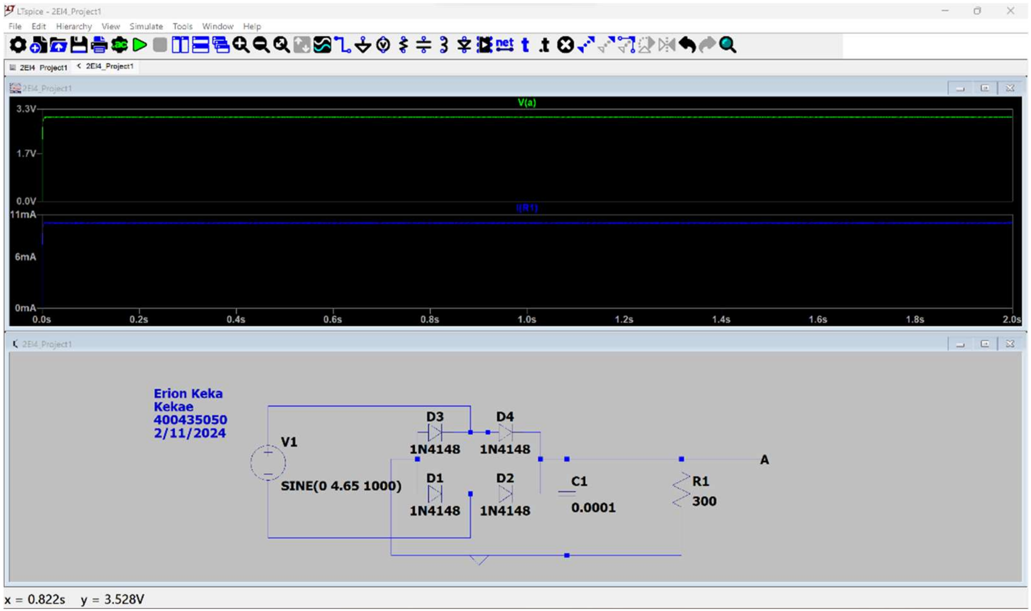

Figure 8: Circuit Schematic and Simulation Output (Current & Voltage)

SPICE Netlist: C:\Users\erion\OneDrive\Documents\LTspice\2EI4_Project1.net

```
* C:\Users\erion\OneDrive\Documents\LTspice\2EI4_Project1.asc
R1 A 0 300
C1 A 0 0.0001
D1 0 N002 1N4148
D2 N002 A 1N4148
D3 0 N001 1N4148
D4 N001 A 1N4148
V1 N001 N002 SINE(0 4.65 1000)
.model D D
.lib C:\Users\erion\AppData\Local\LTspice\lib\cmp\standard.dio
.tran 0 2 0 1
* Erion Keka
* 400435050
* 2/11/2024
* Kekae
.backanno
.end
```

Figure 9: Netlist Screenshot

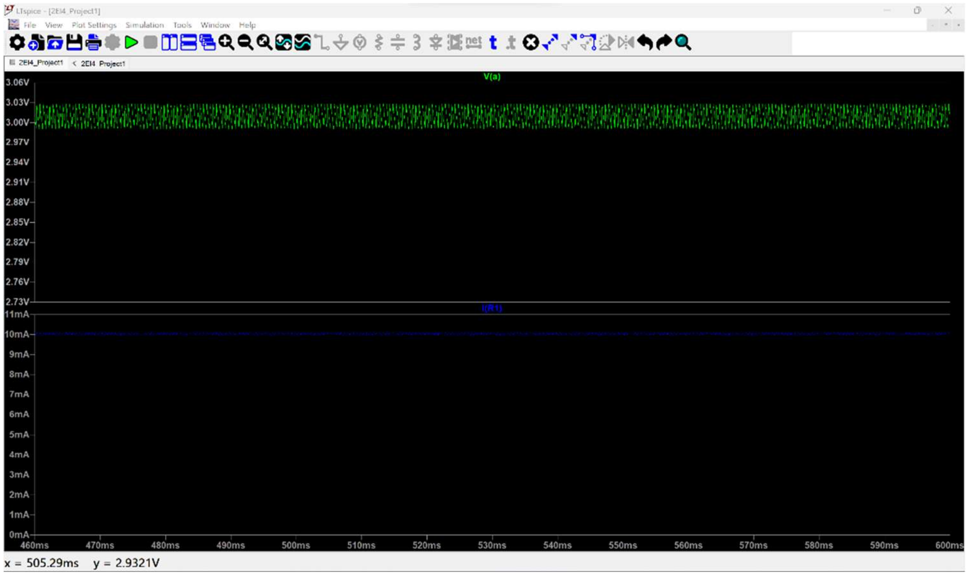

Figure 10: Enlarged Simulation Output of Current and Voltage

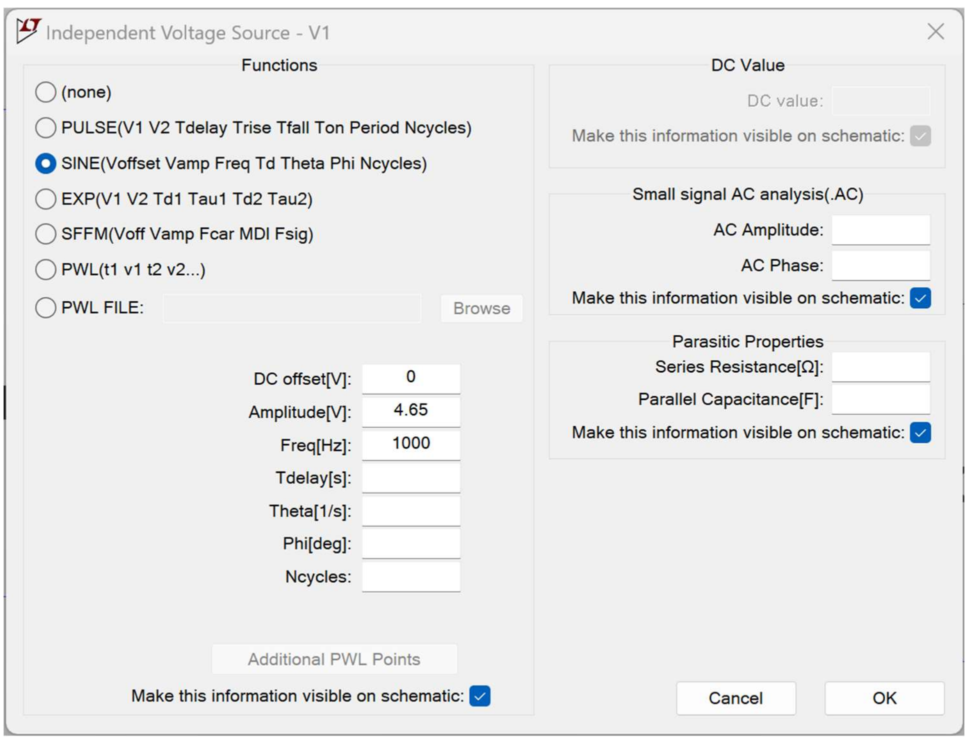

Figure 11: Simulation Conditions of Sinusoidal Input (Transient Analysis)

Discussion

The desired output of the circuit of delivering 10 mA at 3 V ± 0.1 V. The simulation performed in LTSpice did not match the analytical calculation exactly. A discrepancy arose with the input voltage. To output the desired output in LTSpice, the input voltage had to be increased to 4.65 V from the 4.4 V that was calculated analytically. This results in a 5.5% difference between the analytical calculation and the LTSpice simulation. This discrepancy has arisen. This led to a when calculating the nor the circuit measurement matched the analytical calculations. The circuit built and analyzed using the Analog Discovery 3 aligned with the output of LTSpice as they both resulted in an input voltage of 4.65V being required for an output of the desired output. As a result, it has also resulted in a 5.5% difference between the analytical calculation and the LTSpice simulation. This concludes that there are discrepancies present in both the LTSpice simulation and with the circuit analysis using the Analog Discovery 3. These discrepancies can arise from improper simulation settings, component tolerances, and measurement errors. Improper simulation settings can have an impact on the results as they can influence the simulation results. The component tolerances can also impact the results as components have tolerances meaning that components can vary within the tolerance ranges. These tolerances are typically small; however, they can add-up in bulk. In addition, the measurement errors also can impact the results through inaccuracies such as interference or weak signals that may be present in the physical circuit analysis. To overcome these discrepancies in the future, the components should each be individually tested prior to being put in the circuit to ensure that there are no issues with each. Also, an inductor and a regulator could be utilized in the circuit to provide a more efficient and efficient filter. This could result in an improved DC power supply and provide more accurate outputs.

Works Cited

[1] “12-0-12 center tapped transformer,” Components101, https://components101.com/transformers/12-0-12-center-tapped-transformer (accessed Feb. 11, 2024).

[2] Admin, “Full wave rectifier - definition, circuit construction, working, advantages,” BYJUS, https://byjus.com/physics/full-wave-rectifier/#:~:text=The%20value%20of%20ripple%20factor,rectifier%20it%20is%20about%201.21. (accessed Feb. 11, 2024).

[3] 1N4148 small signal fast switching diodes, https://www.vishay.com/docs/81857/1n4148.pdf (accessed Feb. 12, 2024).

[4] CM107 capacitor ceramic 100uf 20% 6,3 volts X5R 5mm, https://abra-electronics.com/passive-components/capacitors/ceramic-monolithic-capacitors-radial/cm107-capacitor-ceramic-100uf-20-6-3-volts-x5r-5mm.html (accessed Feb. 12, 2024).

[5] R1/4-100: 1/4 watt- 100 ohm resistor, 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. 12, 2024).