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POWER SUPPLY DESIGN CONSIDERATIONS

Objective: In this experiment, the objective of this lab was to study the performance of power supply circuits using a full wave rectifier and a half-wave voltage doubler. Specifically, the lab aimed to compare the ripple and average voltages of the output of a full wave rectifier with those of a half-wave voltage doubler, and to observe the effects of a load on the output voltages. Additionally, the lab aimed to determine the voltage ratings required for the capacitors in the voltage doubler circuit and to investigate the advantages and disadvantages of increasing the frequency of the input AC. By completing this lab, the students gained practical experience with power supply circuits and an understanding of the trade-offs between different circuit topologies in terms of ripple voltage, average voltage, and frequency requirements.

Preliminary Calculations: For the preliminary calculations, a datasheet for the 1N4002 general-purpose rectifier diode was obtained from the given websites. The datasheet was used to populate **Table 1** with the following parameters: VRRM, the maximum repetitive peak reverse voltage; IF(AV), the maximum average forward rectified current; and VF, the maximum instantaneous forward voltage. The circuit shown below in **Circuit 1** was used to design a full-wave rectifier with an output capability of approximately 16 VDC at 130 mA, with a peak-to-peak voltage ripple of less than 0.5 V. The required value for C1 and the required working voltage of the capacitor were calculated using the equation for ripple voltage, and the value of the load resistance was calculated based on the output voltage and current specifications given. This calculation can be observed below within, **Calculation 1**.

Calculation 1: Load Resistance and Capacitance

$$R_L = \frac{V_M}{I_L} = 123.08\Omega$$

$$C = \frac{V_M}{2\pi f R_L V_r} = 2166.7\ \mu F$$

$$V_{L(REQ)} = V_M + V_r = 16.5\ V$$

The peak and average diode currents over the conduction interval were calculated, and the PIV rating required for a diode to function safely in the rectifier design was determined. These calculations can be seen below within **Calculation 2.**

Calculation 2: Average, Peak Diode Current & PIV

$$I_{D(PEAK)} = I_L(1 + \pi\sqrt{\frac{2V_M}{V_r}}) = 3.397\ A$$

$$I_{D(AVG)} = I_L(1 + \frac{\pi}{2}\sqrt{\frac{2V_M}{V_r}}) = 1.764\ A$$

$$V_S = V_M + V_\gamma = 17.1\ V$$

$$PIV = 2V_s + V_\gamma = 33.1\,V$$

We were then asked to answer 2 questions. These questions along with their answers can be observed below.

Q1. Using the information in the data sheet, how much do you expect the diode drop to be under full load? Explain your reasoning.

A. Using the data sheet we expected the diode drop under a full load to be equal to the maximum forward instant voltage(1.1V)

Q2. According to the data sheet, will a 1N4002 be sufficient in terms of current and voltage? Think carefully about this and explain your reasoning. If you have doubts, discuss your reasoning with your instructor

A. Using the data sheet we determined that in terms of current and voltage the 1N4002 to be sufficient given the diode will be within the parameter, Vrrm=100 V.

Finally, the voltage drop across one of the diodes was considered to calculate the required peak voltage of the secondary winding of the transformer for the output voltage specification of 16 VDC to be satisfied, as well as the RMS voltage of the secondary. These calculations can be observed below in **Calculations 3.**

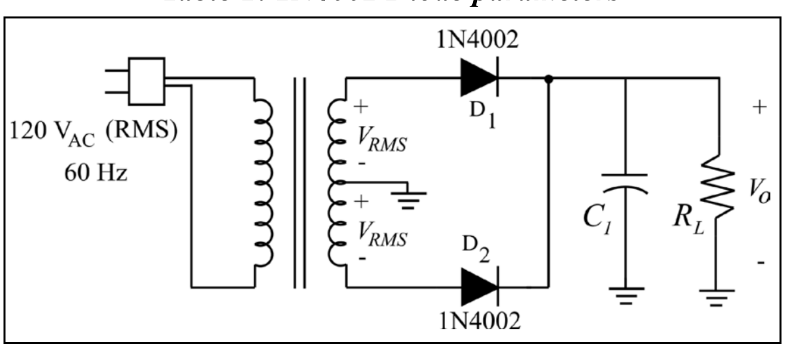
Calculation 3: Voltage source and Vrms

$$V_S = V_M + V_F = 17.1\,V$$

$$V_{rms} = \frac{V_s}{\sqrt{2}} = 12.092\,V$$

Parameters	Value
V_RRM, Maximum Repetive Peak Reverse Voltage	100 V
I_F(AV), Maximum Average Forward Rectified Current	1 A
V_F, Maximum Instantanious Forward Voltage	1.1 V

Table 1: 1N4002 Diode parameters



Circuit 1: Conventional Full-Wave Rectifier

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Procedure:

Procedure for Part A - Power Supply Circuit using a Full Wave Rectifier:

1. Obtain a transformer from the parts cabinet and measure the output of one of the secondary terminals relative to the center tap connection using a DMM. Note the value.
2. Construct the circuit of **Circuit 1** and have your lab partner(s) check over the circuit to make sure the connections are correct. Ensure that the capacitor, load resistance, and power rating meet the calculated values.
3. Energize the circuit and using an oscilloscope, observe the output voltage. Sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage.
4. Compare the measured ripple and average values with your design values. Explain any discrepancies.
5. Write down all the details of your circuit since you will be using a similar circuit in the next experiment.

Procedure for Part B - Half-Wave Voltage Doubler:

1. Determine the voltage ratings required for the capacitors and select suitable capacitors from the lab stock. Construct the circuit of **Circuit 2** without the load resistance RL and carefully check your connections.
2. Connect the oscilloscope to the output and energize the circuit. Sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage.
3. Carefully remove the transformer cord from the wall socket and connect the load resistance RL. Energize the circuit again, sketch the output waveform, and measure both the peak-to-peak ripple voltage and the dc average voltage.
4. Observe the effect of the load on the output voltage and explain any changes.
5. Discuss the advantages of increasing the frequency of the input AC.

Results and Discussions:

1. In part A of the lab experiment, a power supply circuit using a full-wave rectifier was constructed using the diagram from **Circuit 1**. A transformer was obtained from the parts cabinet and its output was measured using a DMM. We measured 3 different 16V transformers, and none of them reached the required output. We finally settled on a 24V transformer and this gave us an output that met our requirements. The circuit was then constructed and energized. Then the output voltage was observed using an oscilloscope. The output waveform was sketched, and the peak-to-peak ripple voltage and the DC average voltage were measured. We were then asked to answer the 4th question shown below. The oscilloscope output can be observed within **Figure 1** below.

Q4. How do the measured ripple and average values compare with your design values? Explain any discrepancies.

A. The measured ripple voltage was shown to be 0.52 V and the average value was 17.398 V. These values are very close to our design values, but are off by approximately $\pm\, 0.2\, V$ for each.

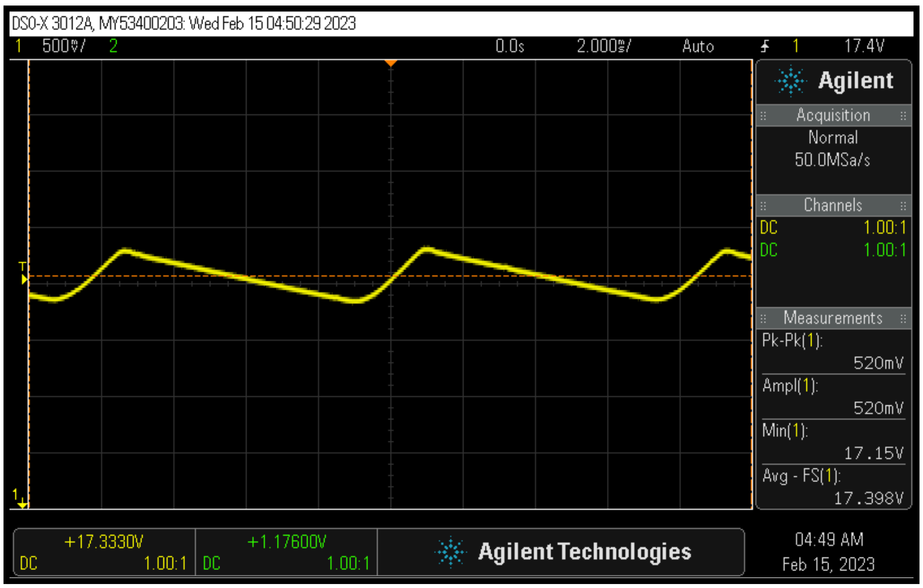


Figure 1: Conventional Full-Wave Rectifier Oscilloscope

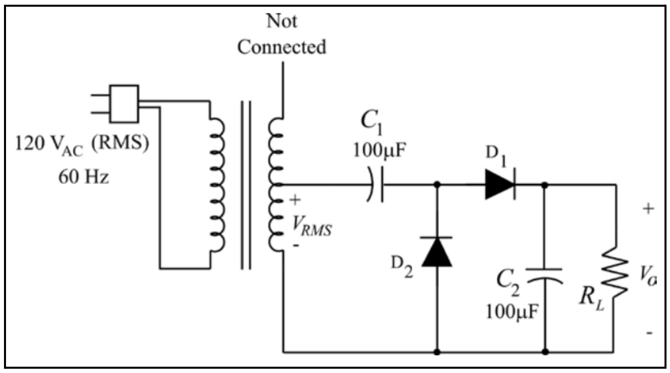
2. In part B, the focus is on the half-wave voltage doubler circuit shown below in **Circuit 2**. The goal is to determine the voltage ratings required for the capacitors and select suitable capacitors from the lab stock, this was determined to be approximately 4 watt capacitors. First, the circuit is constructed without the load resistance RL. The oscilloscope is then connected to the output, and the circuit is energized to observe the output waveform. We were asked to measure both the peak-to-peak ripple voltage, and the dc average voltage. This oscilloscope output can be observed below within **Figure 2.** There was no ripple voltage observed within this output and the DC average was shown to be 38.18 V. Next, the load resistance RL is connected, and the circuit is energized again to observe the output waveform. We were again asked to measure both the peak-to-peak ripple voltage, and the dc average voltage. This output can be observed below within **Figure 3,** the ripple voltage was observed to be 11.5 V, and the DC average was shown to be 13.759 V. Finally, the effects of the load on the output voltage are studied, and the potential advantages of increasing the frequency of the input AC are discussed within the questions below.

Q5. What effect does the load have on the output voltage?

A. The effect that the load had on the output voltage seemed to cause a large ripple voltage, likely due to the charging and uncharging of the capacitors.

Q6. What would the advantage be if you could increase the frequency of the input AC?

A. The advantage of increasing the frequency of the AC input frequency can be observed below in **Figure 4 & 5.** It was observed from these outputs that if the frequency was increased to ripple voltage would decrease by about half.



Circuit 2: A half-wave voltage doubler test circuit

Figure 2: Voltage Doubler No Load

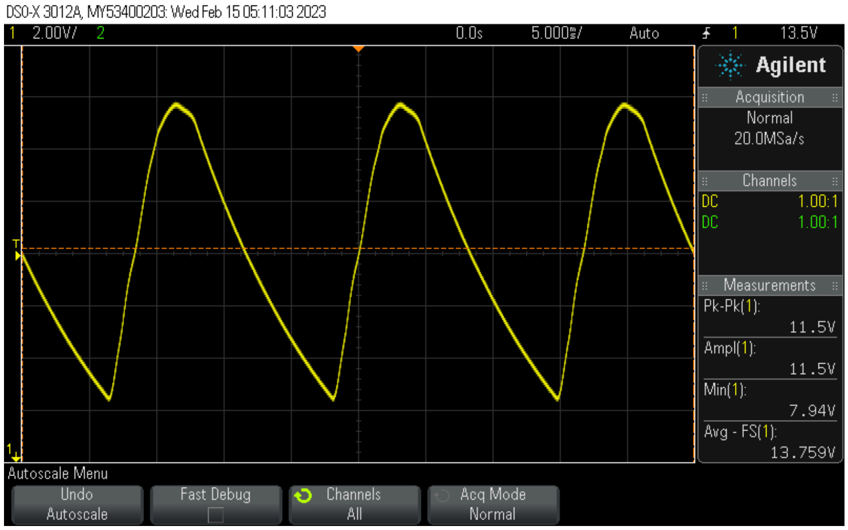


Figure 3: Voltage Doubler With Load

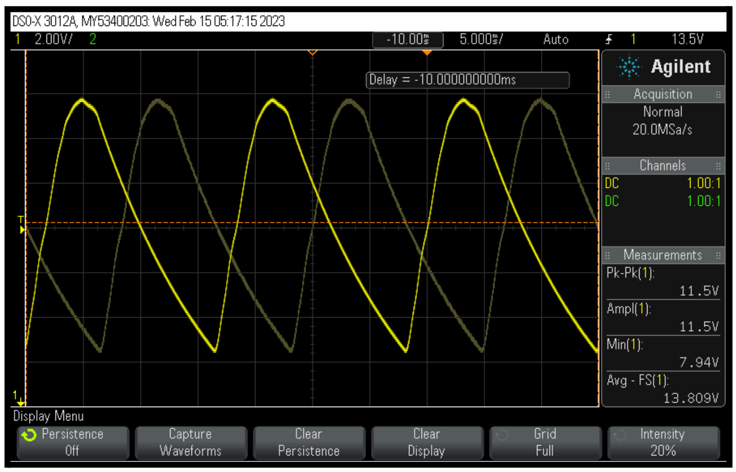


Figure 4: Voltage Doubler if frequency is doubled

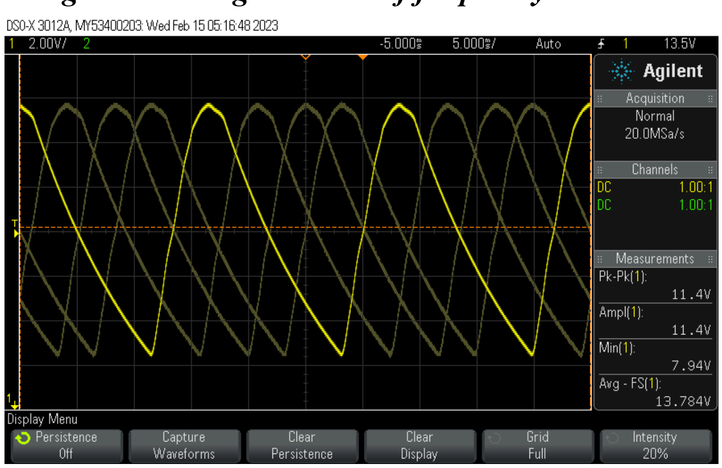


Figure 5: Voltage Doubler if frequency is tripled

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Conclusion: In conclusion, this lab provided hands-on experience with power supply circuits using full-wave rectifiers and half-wave voltage doublers. It was found that the conventional full-wave rectifier circuit provided a better job of creating small ripple voltages for lower frequencies with a load. On the other hand, the voltage doubler circuit was effective at increasing the voltage output, but it had a large ripple voltage that made it practically useless unless the frequency input was increased to approximately 3x the original 60 Hz. This underscores the importance of careful circuit design and component selection to achieve the desired circuit performance. Overall, this lab was an effective learning experience in power supply circuits, and it provided a foundation for more advanced circuit design and analysis.