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Lab 6: Power Supplies

Introduction

The purpose of this lab is to construct different types of power supplies. The power supplies constructed were a half wave rectifier, zener diode regulator, and full wave rectifier shown in Figure 1, 2, and 3 respectively. In this lab, the Variac was used to measure circuit components to compare to theoretical values and to graph the voltages across the resistor and across the secondary of the transformer.

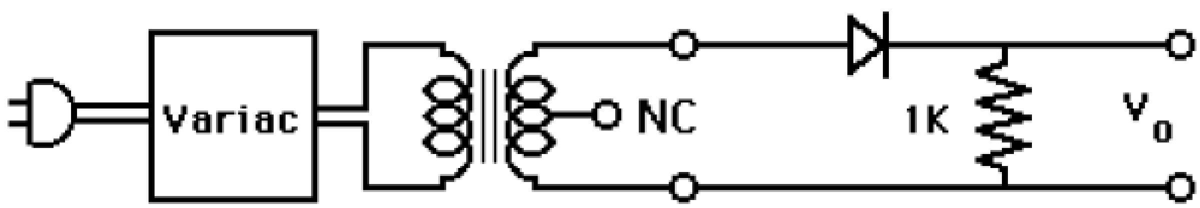

Figure 1. Half wave rectifier schematic (Monty, lab handout, 2019).

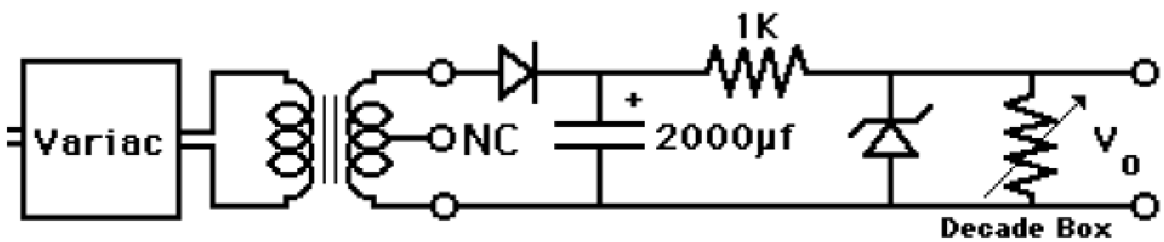

Figure 2. Zener diode regulator schematic (Monty, lab handout, 2019).

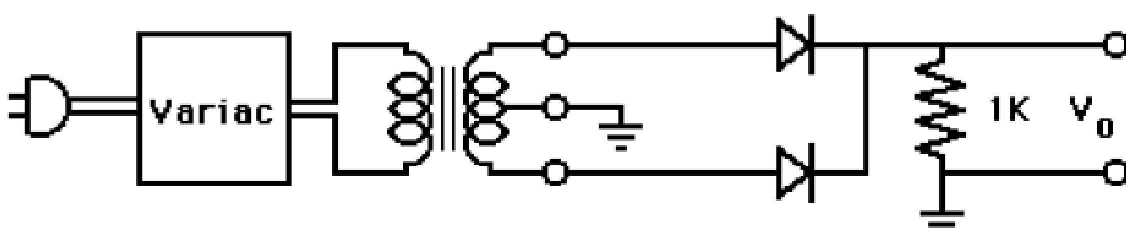

Figure 3. Full wave rectifier schematic (Monty, lab handout, 2019).

Methodology

Many of the electronic devices we use in our day-to-day lives run on low-voltage DC current; however, for reasons of efficiency and convenience, electricity is transmitted as high-voltage AC current in power lines and, at a lower voltage, in household mains. AC-to-DC power supplies, such as the wall adapters used to charge laptops and phones, function by stepping down the input voltage, rectifying the AC signal, and then filtering the output to supply a smooth and steady DC current.

Transformers consist of two solenoids wrapped around a ferromagnetic core. When AC current is passed through the primary coil, it creates a changing magnetic field that is direct through the core to the secondary coil. The changing magnetic flux through the secondary creates an electromotive force that can drive a current when connected to a load. The strengths of the magnetic field and electromotive force depend on the number of coils in the primary and secondary, respectively; as a result, the voltages can be related by the turn ratio of the transformer:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

As discussed in the previous lab, rectifiers use diodes to convert AC current, which has an average voltage of zero, to a waveform with a non-zero average. However, this signal is still to variable to count as DC current; to smooth out the waveform, a capacitor can be added in parallel with the load. This addition helps shunt the AC component to ground, leaving a steady DC voltage across the load. More intuitively, the capacitor acts as a charge reservoir, so when the voltage of the rectified AC signal begins to fall, the stored charge can maintain a steady voltage until the signal approaches its peak again.

In practice, the output may still have a small oscillatory component to it. For some applications this is fine, but more sensitive electronics require a higher degree of smoothness to function properly. This smoothness is described by the ripple factor, which is the ratio of the RMS voltage of the AC component to the signal's DC voltage:

$$r = \frac{V_{rms}}{V_{DC}} = \frac{1}{2\sqrt{3}fRC}$$

Even with a low ripple factor, the DC output of a rectifier circuit is dependent on the load resistance attached to it. To further stabilize the output, a Zener diode can be added in parallel with the load to form a Zener regulator, as shown in Figure 2. Because of the nature of the diode breakdown region, it maintains a very stable voltage even under a changing load resistance. In particular, voltage regulation is said to occur when the voltage drop across the load is at least 95% of the open-circuit voltage drop.

For this lab, we used a transformer with a 10:1 turn ratio to step down the 120v mains voltage to about 12v RMS for our AC power supply. As shown in Figures 1 and 2, the current was then passed through a silicon diode, acting as a half-wave rectifier. For each circuit, we used an oscilloscope to visualize the waveforms and see how the capacitor, Zener diode, and resistors affected the character of the output. In addition, we compared our theoretical calculations for values such as ripple voltage and DC voltage with our experimental results. We also constructed a full-wave rectifier using the center tap of our transformer and compared it with the half-wave rectifier from the previous parts.

Results and Discussion

The output of the halfway rectifier across the secondary and load resistor is shown in Figure 4. As expected, the wave across the resistor is equal to or greater than zero since only positive voltage passes through the diode. The measured max, peak to peak, and RMS voltage for the half wave rectifier are shown in Table 1. Measured DC voltage, calculated DC voltage, and calculated DC current for the half wave rectifier are displayed in Table 2. There was only a difference of 0.03 V between the measured and calculated DC voltage. Table 3 contains the measured and calculated DC voltage, the max voltage, and peak to peak voltage of the half wave rectifier with the addition of a capacitor. With the addition of the capacitor, the difference between the measured and calculated DC voltage was 0.03 V. The measured and calculated RMS voltage and ripple factor associated with it is shown in Table 4. DC theoretical and measured voltage differed by 0.072 V. A difference of 0.007 was observed between the measured and calculated ripple factor. The ripple voltage observed on the scope is shown in Figure 3. The ripples appeared to look like a sawtooth shape, which was expected. The measured and calculated results for the zener diode regulator is shown in Table 5. Figure 6 displays the waveforms across the secondary and resistor. The full wave rectifier wave stayed positive and with a gap below the input waveform. The input waveform oscillated between positive and negative. The measured and calculated DC voltage for the full wave rectifier is shown in Table 6. The percent difference between the two was 5.27%, which is fairly small.

Table 1. Voltage measurements across the resistor and secondary of the transformer for the half wave rectifier.

Variac measurement component	across secondary of the transformer	across resistor
V_{max} [V]	27.8	13
V_{pp} [V]	9.87	13.4
V_{RMS} [V]	14	6.43

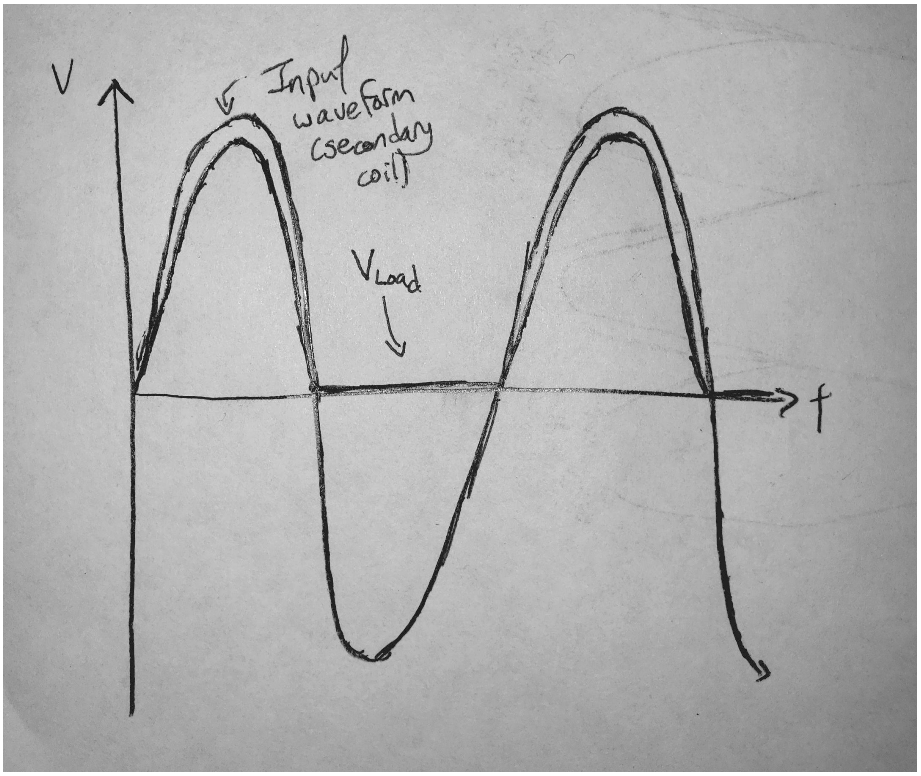

Figure 4. Output of half-wave rectifier without filter capacitor.

Table 2. Voltage, current, and resistance DC values for the half wave rectifier.

measured V_{DC} [V]	measured R [kΩ]	calculated V_{DC} [V]	calculated I_{DC} [A]
4.11	0.994	4.14	0.00413

Table 3. Measured and calculated voltages for the half wave rectifier when a 220 μF capacitor is placed.

V_{max} of the resistor [V]	theoretical V_{DC} [V]	measured V_{DC} [V]	measured $V_{R(p\text{-}p)}$ [V]
12.4	11.93	11.9	1.2

Table 4. Measured and calculated VRMS and ripple factors for the half wave rectifier when a 220 μF capacitor is placed.

measured $V_{RMS,\ ripple}$ [V]	calculated V_{RMS} [V]	measured ripple factor	calculated ripple factor
0.274	0.346	0.022	0.029

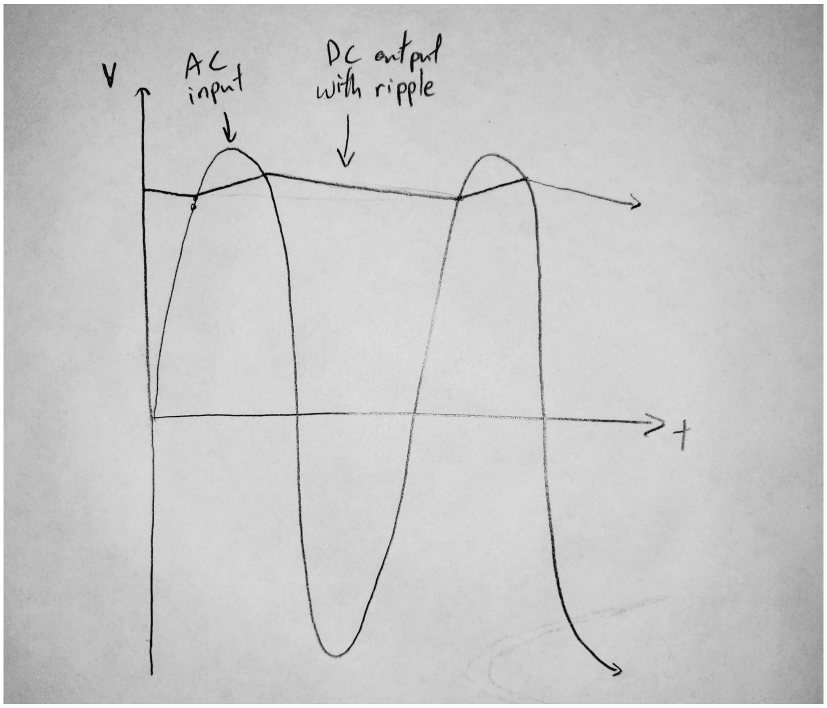

Figure 5. Output of half-wave rectifier with filter capacitor.

Table 5. Measured and calculated voltages and measured resistor value for the zener diode regulator.

Vo with R_L disconnected [V]	when voltage regulation occurs	measured R_L [kΩ]	measured V_{max} [V]	measured $V_{IN, DC}$ [V]	measured $V_{DC, Z0}$ [V]	calculated voltage regulation from measured $V_{DC, Z0}$ [V]	calculated $R_{L,min}$ [kΩ]
8.8	V_{RL} > 8.36 V	1.92	8.4	12.4	8.6	8.17	1.92

Table 6. Measured and theoretical DC voltage across the resistor for the full wave rectifier.

measured V_{DC} across R [V]	theoretical V_{DC} across R [V]	percent difference [%]
6.28	6.62	5.27

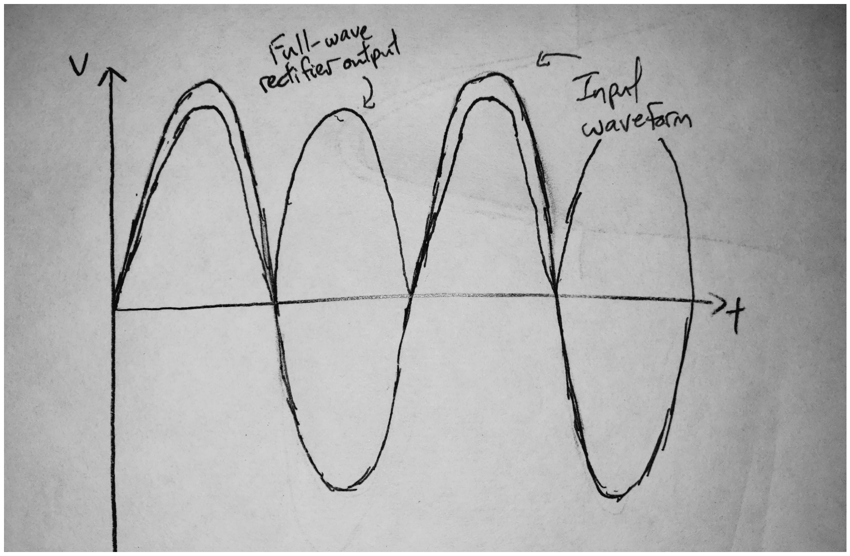

Figure 6. Output of full-wave rectifier without filter capacitor.

Conclusion

In this lab we explored techniques for converting alternating current to direct current. We began by constructing a simple half-wave rectifier and found the DC voltage of the output signal. We then added a filter capacitor in parallel with the load, and using an oscilloscope, we measured the ripple factor and compared it to our calculated theoretical value. Next, we added a Zener diode and found the minimum load resistance required for voltage regulation. Finally, we constructed a center-tapped full wave rectifier and compared the measured DC value to our theoretical calculation. In all cases our results agreed very closely with theory, particularly for the Zener regulator, where our prediction matched our experimental result to within less than 1%.