EE97 Spring 2025
Thursday 1:30-4:15 PM
Lab #6: Rectifier and Voltage Regulator
Olivia Chen
Partner: Mingshan Lai
Station #6
Submission Date: 02/27/25

EXPERIMENT 1:

We observed the behavior of voltage passing through a transform and the relation of its winding ratio to its measured secondary output voltage.

PART 1 & 2: Our transformer module will be of the shape shown in Figure 3. Use the connector in Figure 4 to connect the secondary winding (transformer output plug) to the breadboard. Voltage is available from 2 of the connector's 3 pins, whose connections are interchangeable. Before plugging the module into an AC outlet, use the DMM to measure the resistance between the AC plug pins and the output to check that the resistance is infinite.

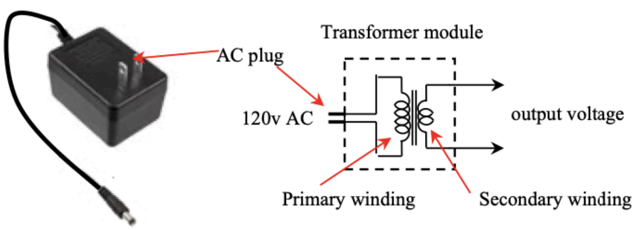

Figure 3

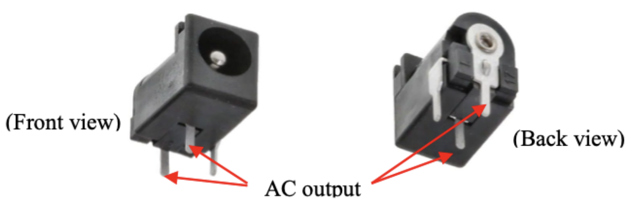

Figure 4

When resistance was attempted to be measured from the AC outputs of the transformer module, the multimeter displayed OL (overloaded = infinite resistance).

PART 3: After plugging in the transformer module, measure the module's output AC voltage, remembering to set the DMM to AC voltage mode. The DMM will then display the RMS of the measured AC voltage—does this value agree with the output voltage on the transform label? Assuming the primary AC voltage is 120V, what is the winding ratio (Nsec/Npri) of the transformer based on the measured secondary output voltage?

Equation 1.3.1: Relation between winding ratio and number of turns:

$$\frac{V_{sec}}{V_{pri}} = \frac{N_{sec}}{N_{pri}}$$

Measured AC RMS: 7.5 mV
Transform Label Output: 9.5 V

Do the transform label and measured voltage agree?:
The transform label and the measured voltage agree since the measured voltage is supposed to be stepped down from the label, and 7.5mV is much lower than the transform output 9.5V.

Winding Ratio of transformer based on measured secondary output voltage:
(Nsec/ Npri) = (Vsec/ Vpri) = 7.5 mV * 120
0.0075V * 120 = 0.9

PART 4: Observe the secondary voltage waveform using the scope, noting that there is no specific connection order between the scope input pins and the AC pins since the voltage is AC. What is the frequency of the AC voltage and the peak value (NOT Vpp) of the output voltage? Is the RMS value found in PART 2 related to the peak value by a factor of 0.707?

Measured Frequency of AC voltage: period = 16.70 ms -> 1/p = f = 59.88 Hz
Peak Value of Output Voltage: 13.4 V

Is the RMS value found in PART 2 related to the peak value by a factor of 0.707?:
7.5*(1/0.707) = 10.6
The expected peak value 10.6 V and our measured value was 13.4V. While they are significantly different, we can conclude this was due to unstable connections between the transform module and the breadboard, which we managed to secure in later parts of the lab with assistance from the professor.

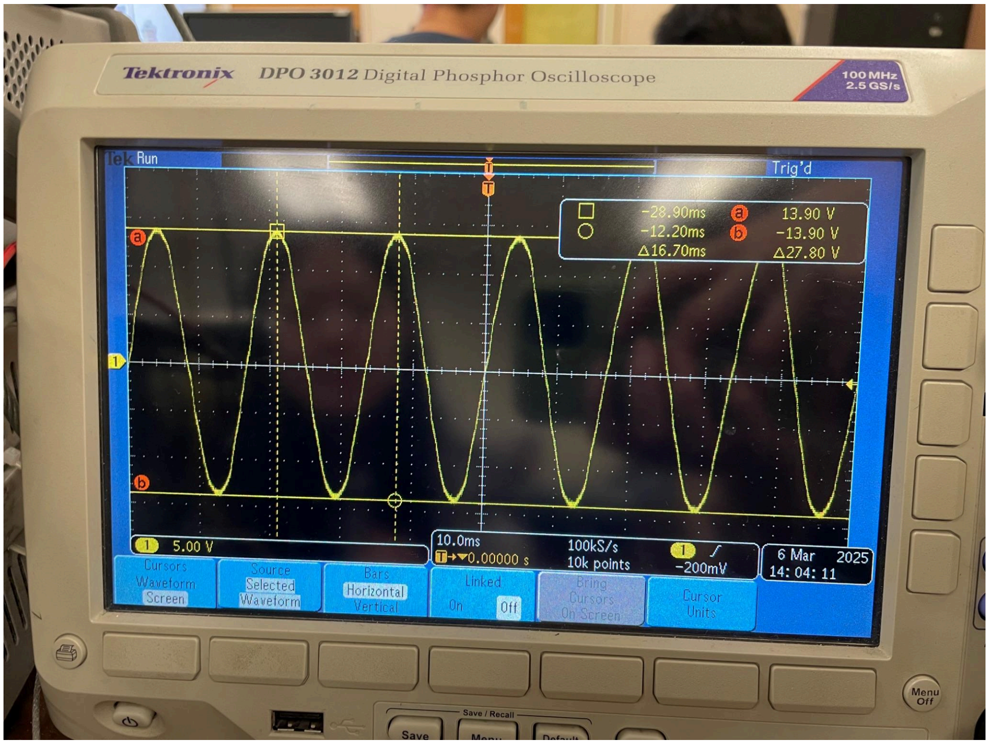

Figure 1.4.1: Secondary Voltage Waveform

EXPERIMENT 2:

We built a half-wave rectifier circuit and observed the behavior of Vs and Vo with a capacitor and additional resistors that lower the load resistor.

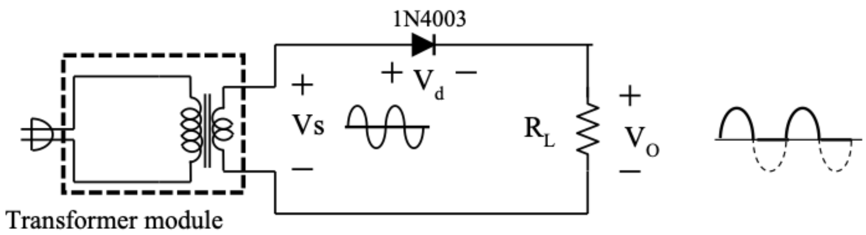

Figure 4

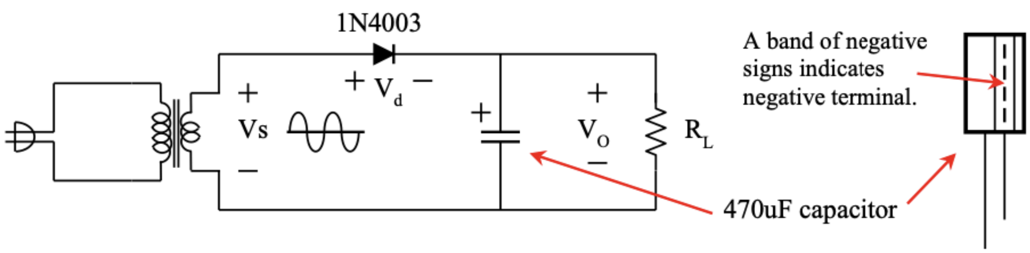

Figure 5

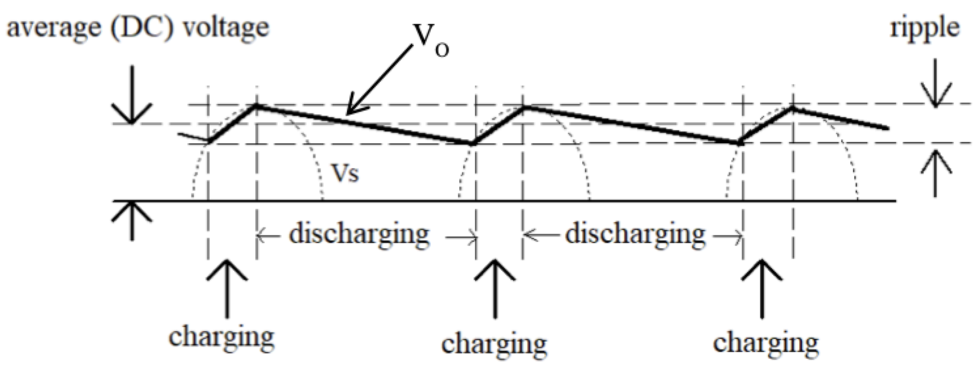

Figure 6

PART 1: Build the circuit in Figure 4 where Vs is the secondary voltage from the transformer modudule. Connect the wires from the transformer module to the circuit either way, noting the side of the 1N4003 diode with a white band is the cathode. Use a 1kohm load resistor.

PART 2: Use the scope to observe Vs and Vo as in Figure 4. The waveform should appear similar to the red waveform in Figure 7. Note that Vdc is slightly lower than Vs during the positive half-cycle due to the forward drop (Vd) of the diode.

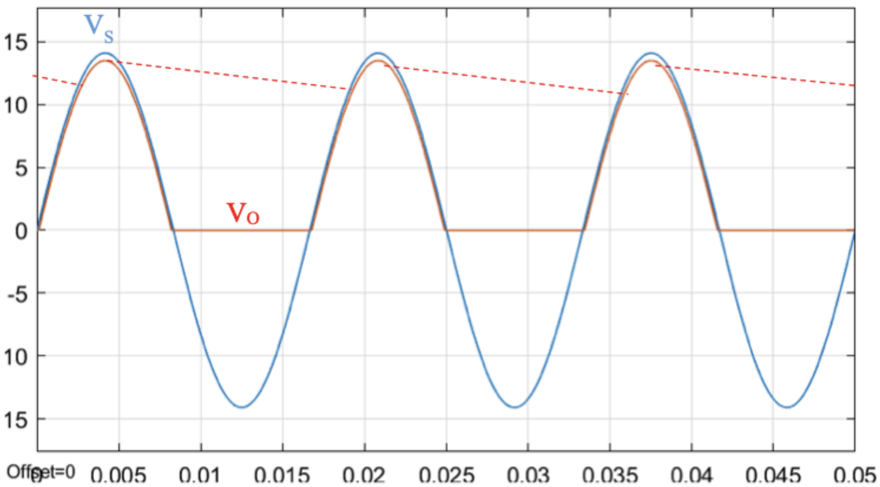

Figure 7

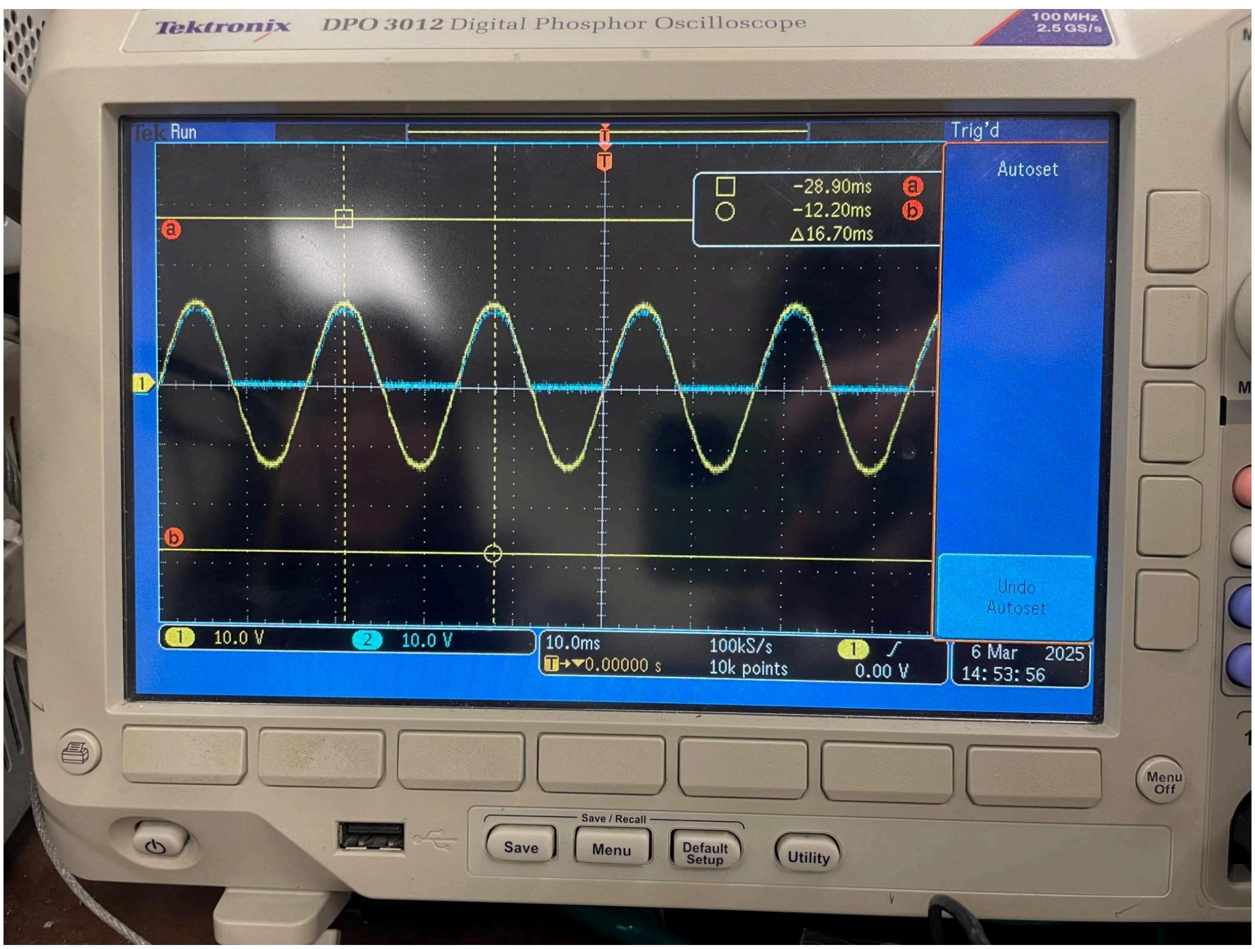

Figure 2.2.1: Oscilloscope Reading for Vs and Vo

PART 3 & 4: Add a 470microF filtering capacitor to the circuit as shown in Figure 5, being sure to identify the polarity of the capacitor according to Figure 5. Use the scope to observe Vs and Vo with the capacitor connected.

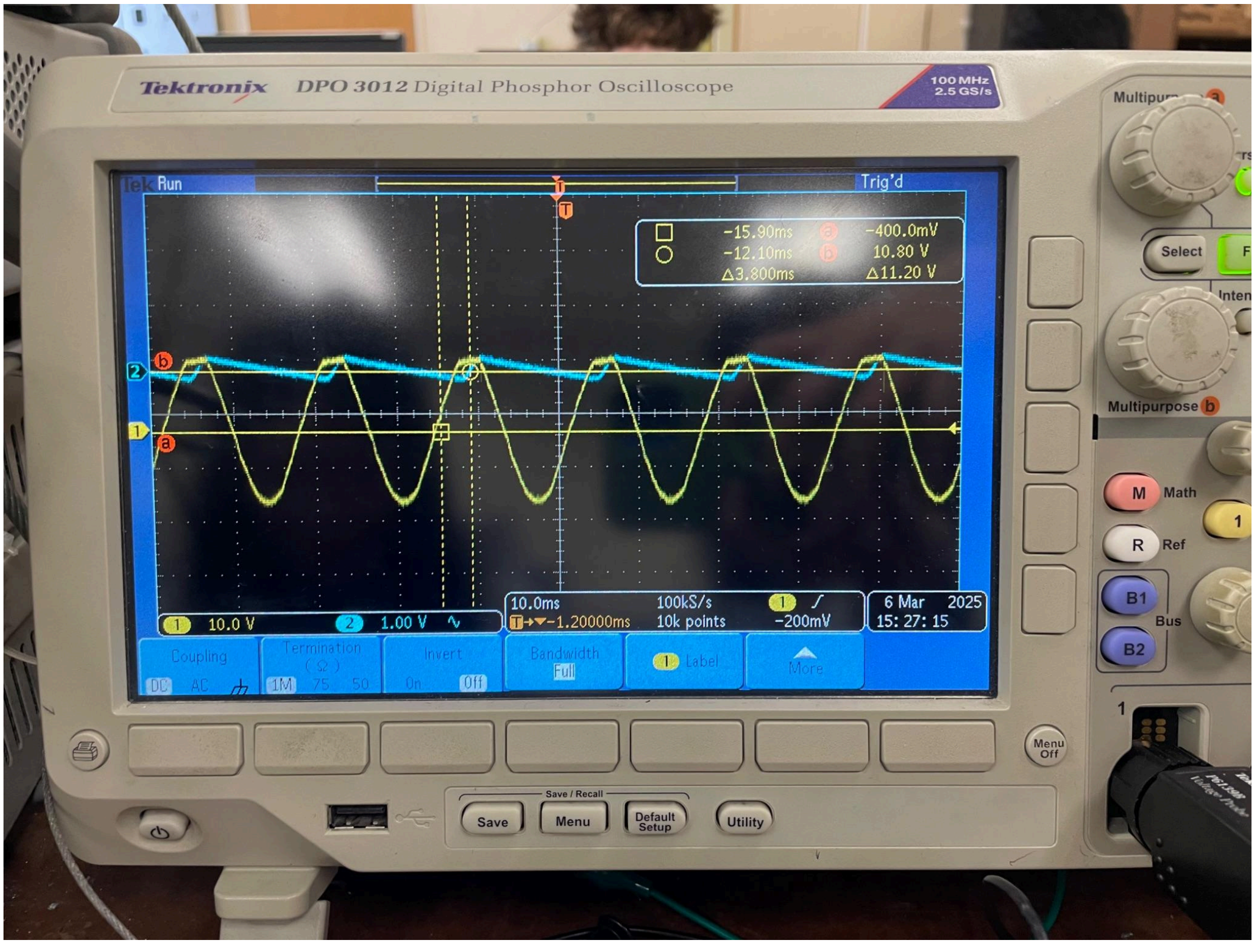

Figure 2.4.1: Oscilloscope Reading for Vs and Vo with Capacitor Connected

What is the average DC voltage?: 11.2V What is the peak -to-peak of the ripple voltage on Vo? Zoom in by selecting the AC coupling option on the scope so that only the time-varying part of the signal (ripple) is shown: 460mV

PART 5: Add another 1kohm resistor in parallel with the 1kohm resistor already in the circuit and repeat the previous step. This additional 1kohm resistor essentially makes the load resistor 500ohms.

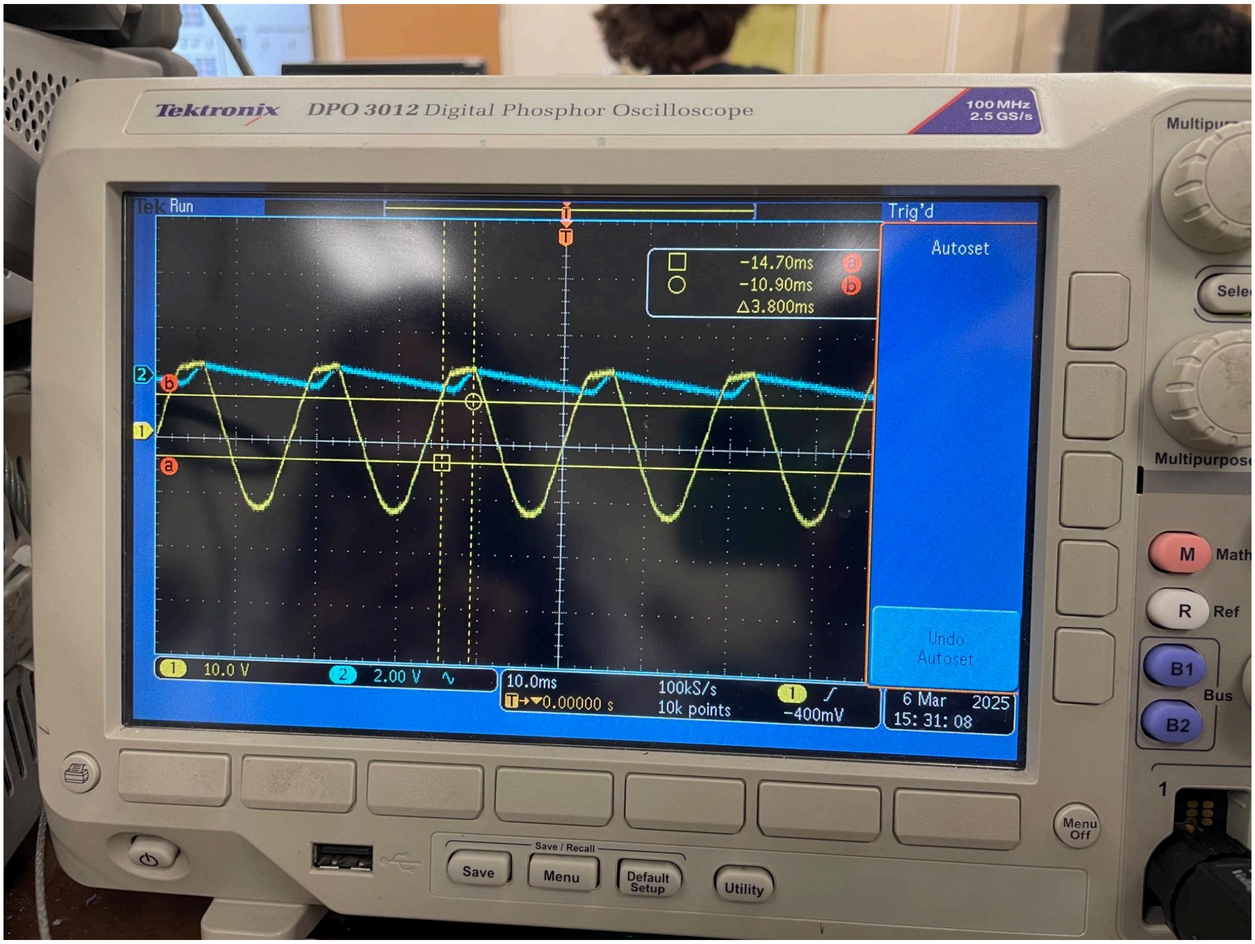

Figure 2.5.1: Oscilloscope Reading for Vs and Vo

What is the average DC voltage (middle of ripple)?: 11.8V

What is the ripple voltage on Vo?: 720mV

Explain why the ripple voltage and average DC voltage are different from those measured previously: Since the load resistance is now 500 ohms, the current draw is increased by the lowered resistance. With a higher current draw, the capacitor discharges faster before the next AC cycle replenishes it, creating more of a gap for the capacitor to bridge. The increased voltage drop across the capacitor creates a higher ripple voltage.

PART 6: Remove both 1kohm resistors so that no load resistor is used and repeat PART 4.

Figure 2.6.1: Oscilloscope Reading for Vs and Vo

What is the average DC voltage (middle of ripple)?: Unmeasurable

What is the peak -to-peak of the ripple voltage on Vo?: Unmeasureable

Explain why the ripple voltage and average DC voltage are different from those measured previously in PART 5: Without a load resistor, the circuit cannot maintain a steady output voltage because there is nothing to deplete the charge from the capacitor. With the capacitor remaining fully charged, it acts like an open circuit, meaning there is little to no current flowing through the circuit. Thus, there is nothing for the oscilloscope to detect and we cannot measure the DC voltage or the ripple voltage.

EXPERIMENT 3:

We built a full-wave rectifier circuit with a four-diode configuration (bridge rectifier), observing how Vo appears as a continuous series of positive half cycles as shown in Figures 8 or 9.

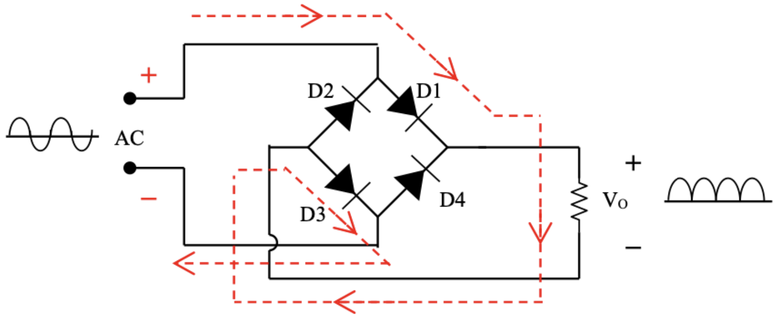

Figure 8

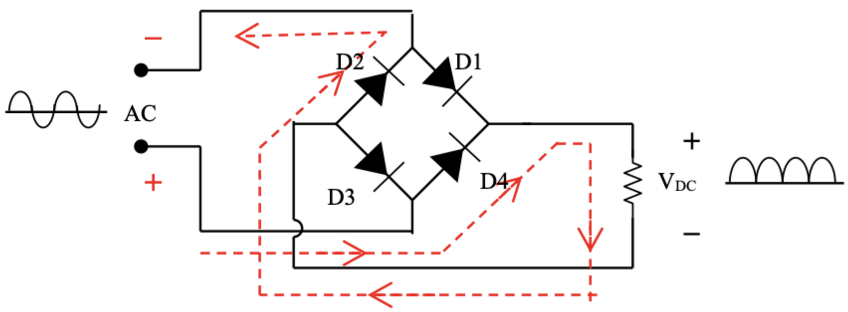

Figure 9

PART 1 & 2: Build the full-wave rectifier circuit in Figure 11, using Rl=1kohm, but not yet installing the 470microF capacitor. Plug the AC adaptor in only after you complete building the circuit. Use one of the scope probes to observe Vo without the capacitor. The waveform of Vo should be similar to that in Figure 8.

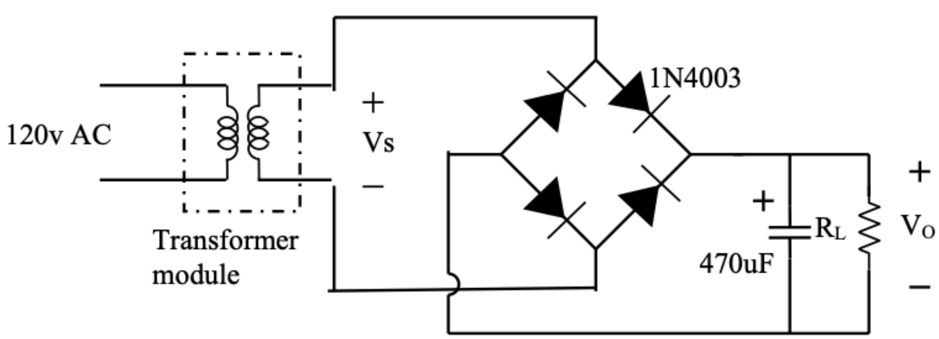

Figure 11

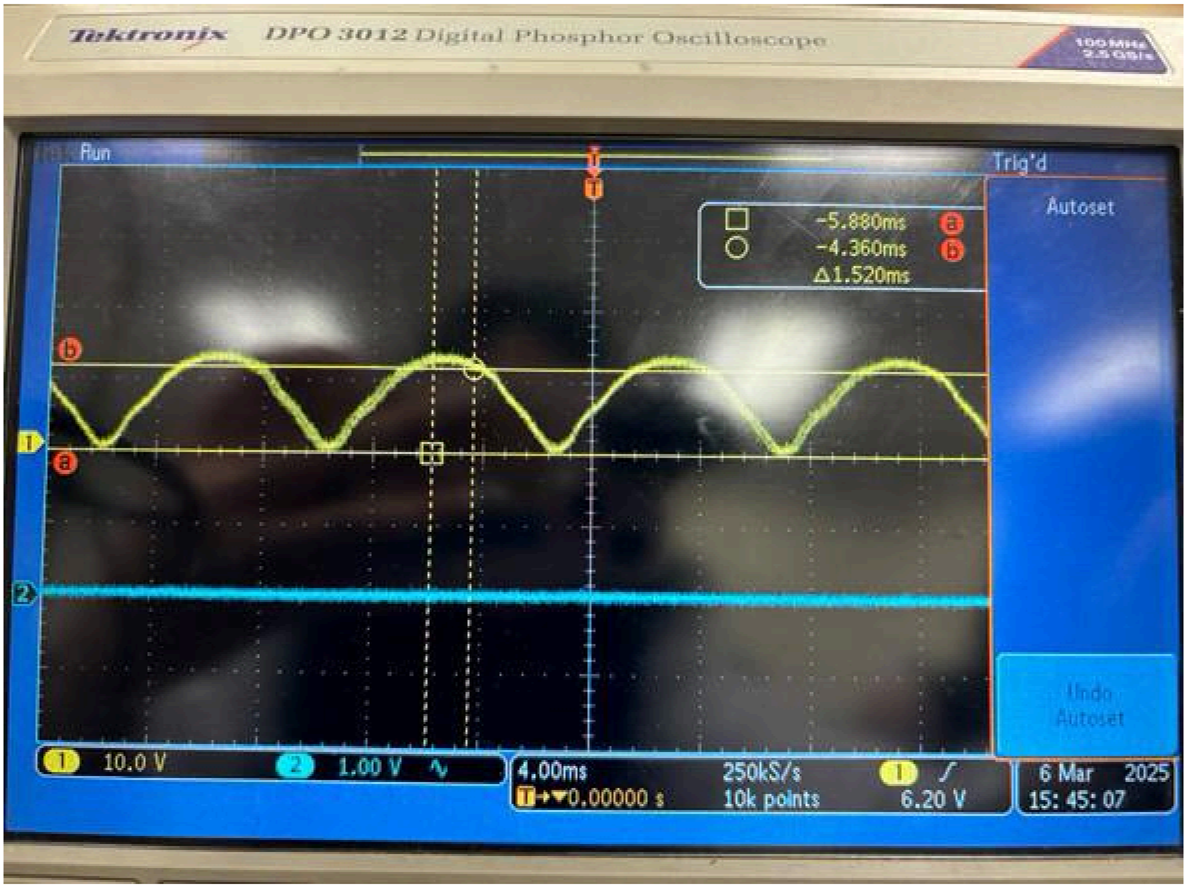

Figure 3.2.1: Oscilloscope Waveform of Vo Without Capacitor (Yellow Channel 1)

Explanation: We used the four-diode configuration in Figure 8 to create a bridge rectifier, where we have two pairs of diodes in opposite biases. This allows current to flow along the path in the same direction in both the positive and the negative half-cycle. Thus, we have the continuous positive arches making up Vo as shown above.

PART 3: Install the 470microF capacitor as in Figure 11, and use the scope to observe Vo.

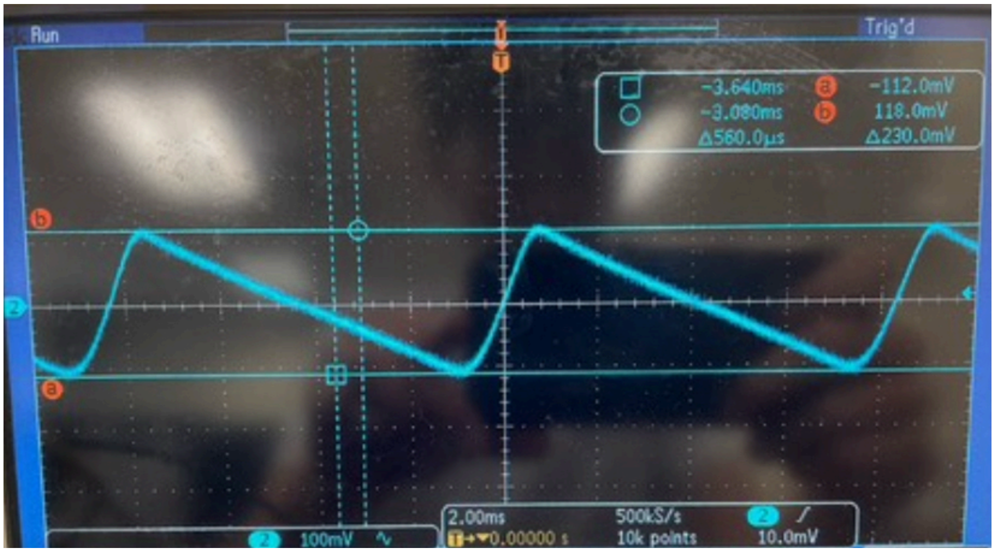

Figure 3.3.1: Oscilloscope Waveform of Vo With Capacitor

What is the average DC voltage?: 15.85 V What is the peak-to-peak of the ripple voltage on Vo?: 230 mV Explain why this ripple voltage is smaller than that from PART 5 of Experiment 2: Since we are using a full-wave rectifier circuit this time, the current flows through the load in the same direction no matter the positive or negative half-cycle of the voltage wave. Since there are more positive waves, there is less of a time gap (compared to the half-wave rectifier circuit) for the capacitor to “bridge.” In other words, the capacitor is replenished twice as often. This leads to a smoother ripple wave and thus a decrease in the ripple voltage.

PART 4: Add another 1kohm resistor in parallel with the 1kohm resistor already in the circuit and repeat the previous step. This additional 1kohm resistor makes the load resistor 500 ohms.

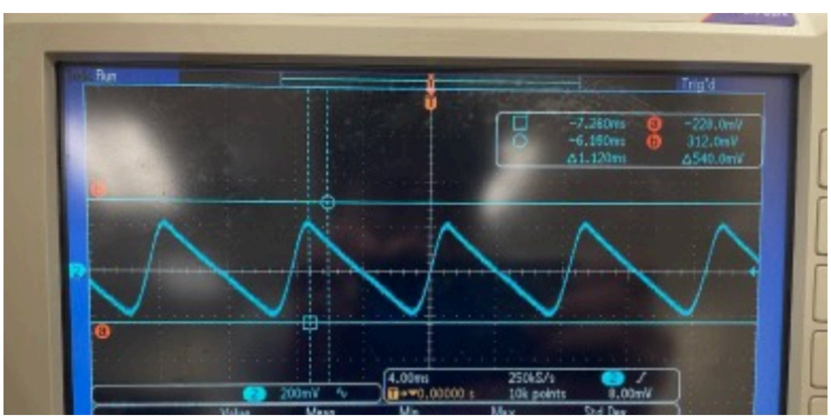

Figure 3.4.1: Oscilloscope Waveform of Vo With Capacitor and 500 ohm Load Resistance

What is the average DC voltage?: 14.93 V What is the peak-to-peak of the ripple voltage on Vo?: 440 mV Explain why the ripple voltage and average DC voltage are different from those measured in PART 3: This time, the ripple voltage is noticeably higher because of the lowered resistance, which draws more current, discharging the capacitor faster and decreasing the average voltage. Since the capacitor does not have sufficient time to fully recharge before the next cycle, there is more variation in voltage and so an increase in ripple voltage

PART 5: Remove all load resistors and repeat PART 3.

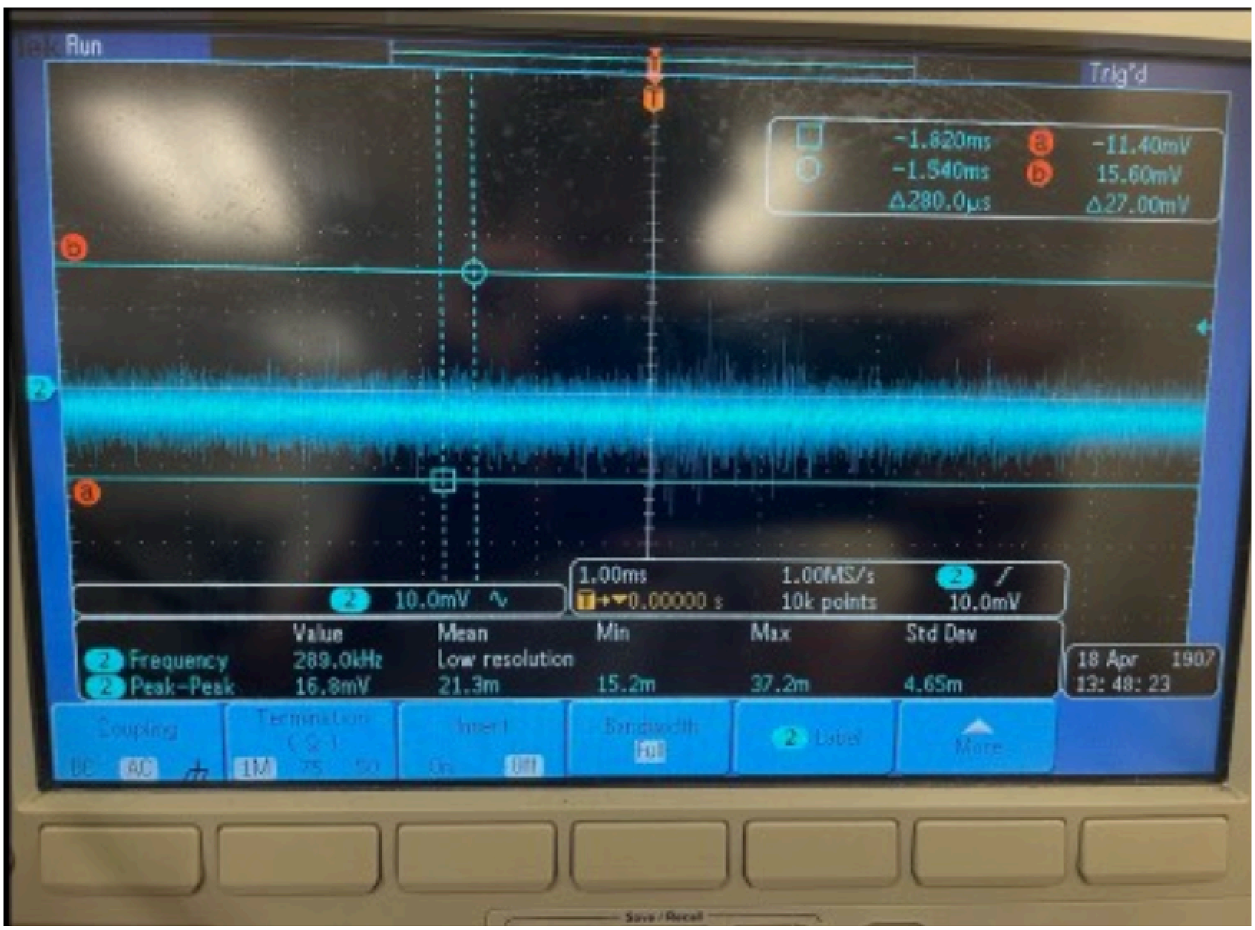

Figure 3.5.1: Oscilloscope Waveform of Vo with Capacitor and No Load Resistors

What is the average DC voltage?: 16.3 V

What is the peak-to-peak of the ripple voltage on Vo?: 20.3 mV

Explain why the ripple voltage and average DC voltage are different from those measured before: Minimal current drawn from the capacitor means that it is not discharging much, creating a higher average DC voltage. We measured the average DC voltage to be 16.3V, which is closer to the peak voltage of the rectified waveform.

PART 6: Explain why it is not possible to show both Vs and Vo on the scope at the same time:

It’s not possible for both Vs and Vo to show simultaneously on the scope because the oscilloscope channels share a common reference ground, meaning that measuring one waveform may cause interference if another waveform is measured at the same time. Seeing as Vs is referenced to the AC source while Vo is referenced to the rectifier circuit ground, measuring both at the same time can cause interference or short the circuit.