# E84 Final Project Report
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## INTRODUCTION

AC-DC conversion is important, it is used constantly in our daily lives. Home electrical outlets often provide a 60 Hz, 120V AC signal but many devices we use require a DC input therefore AC-DC converters are often used to convert the wall's AC voltage to a usable DC voltage. Many devices require a DC signal to operate, such as laptop/phone chargers and electric vehicles all require DC voltages to charge. Therefore to explore this application of analog circuits our team sought to design, implement, and test an AC-DC converter, specifically a full-wave rectifier. The full-wave rectifier consists of an arrangement of diodes, capacitor, resistor, and an AC voltage source. The input to the circuit is an AC voltage source and its output is a DC signal, the output is not purely DC but with the use of a smoothing capacitor the output voltage can become relatively stable. Careful selection of a smoothing capacitor will result in a more stable DC signal at the output due to the time constant of the RC circuit formed between the capacitor and resistor.

## SYSTEM DESCRIPTION

The circuit can be seen in Figure 1, the parts required to build this circuit are 4 IN4004 diodes, 1 100 µF capacitor, 1 1 kΩ resistor, and an AC voltage source (in testing the Agilent 33120A Function/Arbitrary Waveform Generator was used as the AC voltage source). An oscilloscope was also used to analyze the signal in the circuit. The circuit depicts the voltage source fed into the diodes, and the output is probed across the 1 kΩ resistor.

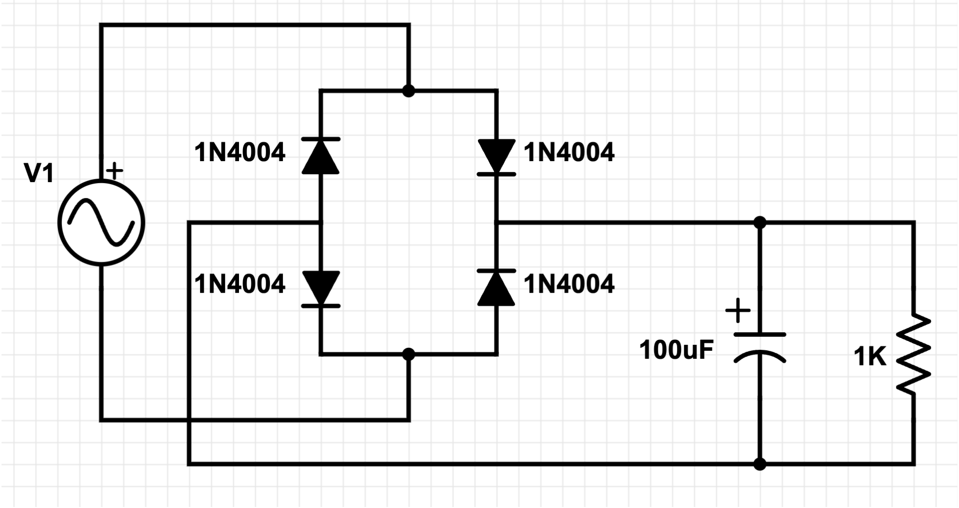


Figure 1: Circuit diagram for Full-Wave Rectifier

The IN4004 diode was chosen due to the team's familiarity with the component and availability in the lab. The 1 kΩ resistor was chosen as our load resistor due to ease of access and easy number to later calculate time constants. The smoothing capacitor had many factors leading to a 100 µF capacitor, lab availability and RC time constant. Initial prototypes included a

100 mF capacitor which produced a very stable DC output since it has a long time constant, but availability limited our selection. After checking lab availability of components and weighing the importance of a long time constant we decided on a 100 μF capacitor. This capacitor was readily available and through the use of $\tau$=RC we were able to achieve a time constant of 0.1 seconds when R = 1kΩ and C = 100 μF.

**INSTRUCTIONS**

Step 1: Gather all materials required and a breadboard, and ensure there is sufficient wire to connect the nodes in the circuit.

Step 2: Begin by constructing the diode junction on the breadboard. Pay special attention to the direction of the diodes and ensure that your circuit is replicating the same formation.

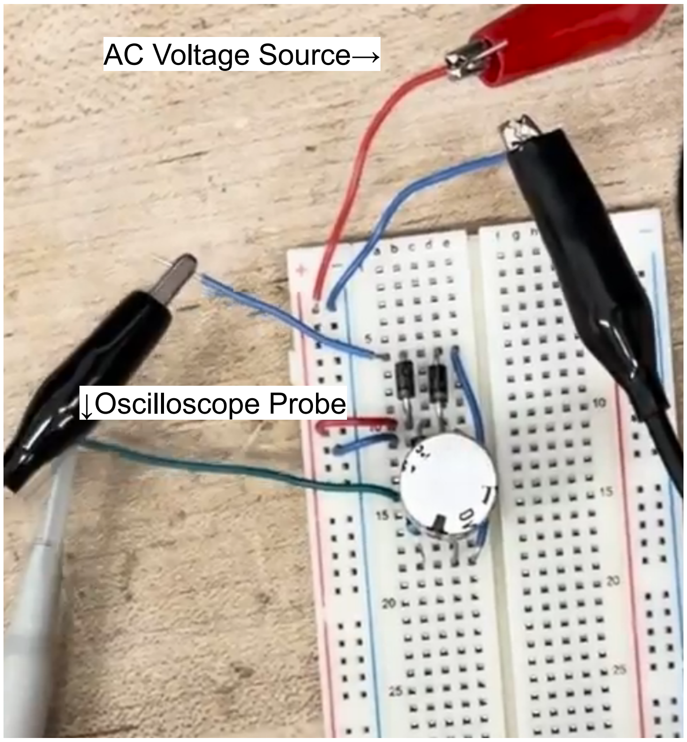


Figure 2: Full-Wave Rectifier on the breadboard

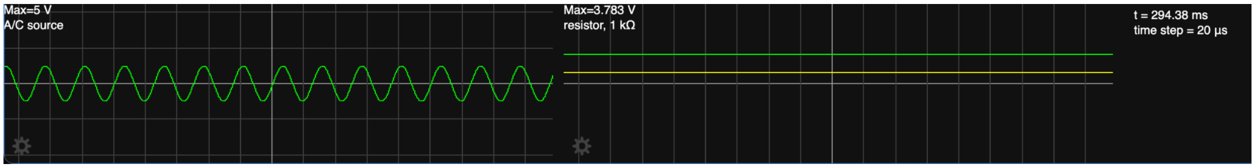
Step 3: Connect the smoothing capacitor and resistor across their respective nodes that connect the components to the diode junction. Note that the circuit's ground and the ending node for the capacitor/resistor are not the same. Confusing these nodes will affect the wave output of the circuit. The constructed full-wave rectifier circuit is shown on the breadboard in Figure 2.

Step 4: Connect the AC voltage source to the rails of the breadboard. The AC signal that was tested and simulated was a 10 Vpp, 120 Hz sinusoid.

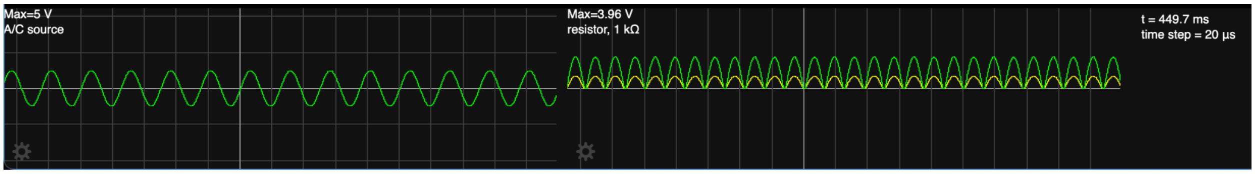
Step 5: Use an oscilloscope probe to view the signal across the resistor. You should see a DC signal at around 3 V.

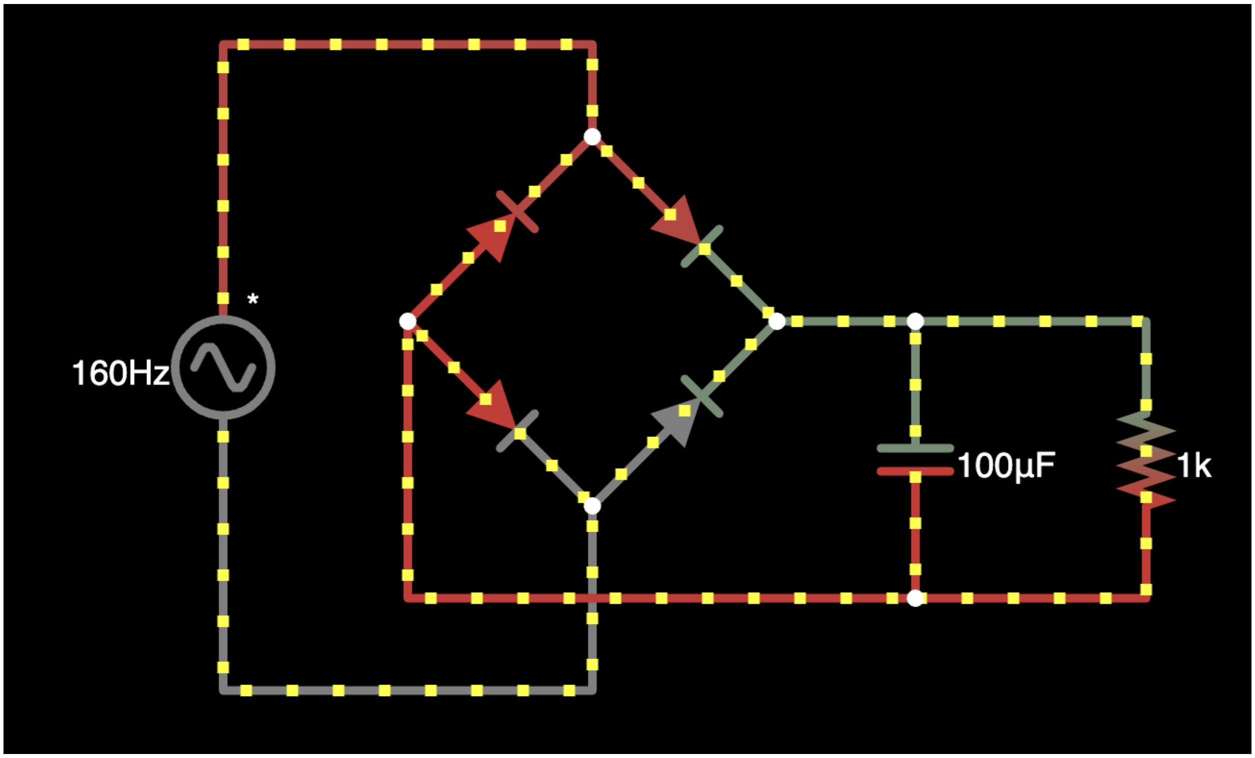
Step 6: Verify that the diode junction is working properly by removing the smoothing capacitor (the 100 µF capacitor) and viewing the voltage. It should be a sinusoid with no negative component. Every negative voltage should be flipped and now a positive voltage. This behavior is illustrated in the FALSTAD simulation graphs below, where we can see how the smoothing capacitor affects the output voltage behavior.

With 100 µF Capacitor:



Without  100 µF Capacitor:

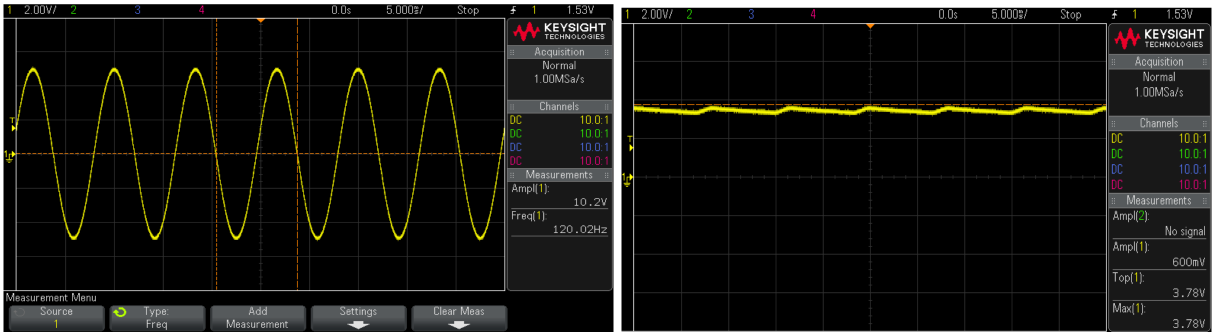




## RESULTS

### 10 Vpp at 120 Hz

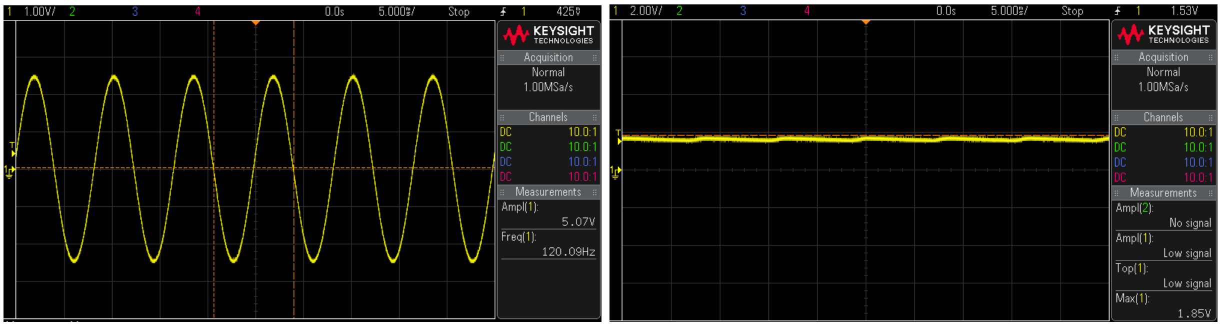
AC Signal Input | DC Signal Output



This experiment proves the function generator is producing the signal that we would expect and demonstrates an output which is consistent with both simulated and literature based predictions. The small ripples are the result of the load resistance and smoothing capacitor not having an infinite time constant, so there is a small fall off between the signal peaks as the first order step response is undergone in the system. The Voltage being less than 5 makes sense given that voltage goes down across the diodes and the value is approximately 3.6V, which is what would be expected for a 2 diodes of forward bias voltage ~0.7V.

### 5 Vpp at 120 Hz

AC Signal Input | DC Signal Output



Similar to the above analysis we see many of the same behaviors as before, but the only difference is the amplitude which makes sense given that our system should operate the same no matter the input amplitude as long as it maintains a voltage across the capacitor less than the 50V it is rated for. Other than that the peak voltage is still reduced by the ~1.4V that we would expect to lose across the diodes.

## CONCLUSION

AC to DC conversion is crucial in our everyday life, many of our daily electronics use DC to charge or operate, therefore converting the home's outlet AC signal is extremely important to using our favorite devices. The full-wave rectifier is a circuit that solves this problem but it is not a perfect circuit. Throughout the project, the overarching architecture remained the same but component values were edited to improve the functionality of the circuit. The major component that was iterated was the smoothing capacitor value, during initial simulations the capacitor had a value of 100 mF, which was not readily available. Therefore the team switched to a value of 4.7 μF but the rippling was too much due to such a small time constant of the RC circuit, the smoothing capacitor value was then changed to 100 μF. The team learned that there has to be a compromise between the ideal simulations and the real world situation, specifically component selection based on availability. The team also learned a lesson in probing for a signal, during initial experimentation we thought we were analyzing the correct signal but when trying to verify the results without a smoothing capacitor we realized we were seeing a half-wave rectifier not a full-wave therefore we had to troubleshoot the issue. We were expecting to see a sine wave with all components being positive but saw the negative components cut off. We learned that we were probing the signal incorrectly, we were confusing the negative end of the load resistor and the ground of the AC signal.