ECE 65 – Components and Circuits Lab

Lab 4 Report – Diode waveform shaping circuits

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Abstract

The purpose of this lab is to analyze diode waveform shaping circuits, including rectifiers, peak detectors, and clamp circuits, to understand their behavior in signal processing applications.

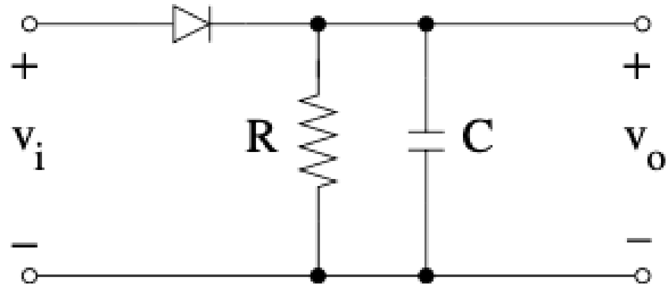
We performed simulations and experimental tests on rectifier and peak detector circuits with different capacitor values, an op-amp peak detector, and a clamp circuit. Through oscilloscope measurements, we compared the effects of component variations on circuit performance.

We concluded that capacitor selection significantly impacts peak detection and clamping behavior, with larger capacitors providing better peak retention and stability, while smaller capacitors allow faster response but result in increased distortion. Additionally, the op-amp peak detector showed improved accuracy compared to a simple diode peak detector, though our lab implementation encountered challenges in achieving expected results.

Experimental Procedures and Results

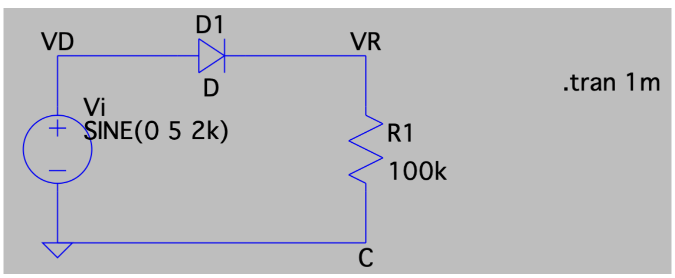
Experiment 1: Rectifier & Peak Detector Circuit

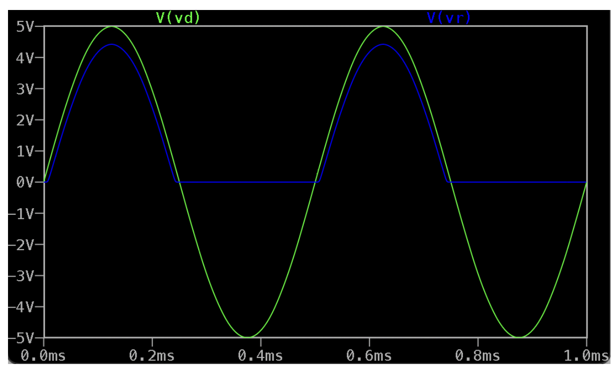
Consider the circuit below with a 1N4148 general purpose diode and R = 100 kΩ.



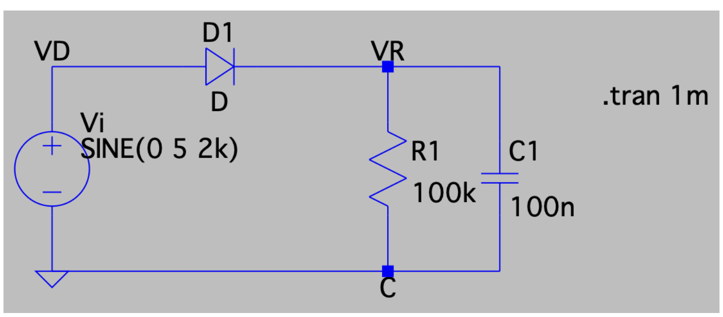
Prelab:

1. Construct the circuit without the capacitor. Apply a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz as input. Create a plot showing v_o and v_i on the same graph using Transient simulation. Make sure your step size is small enough. (You should see smooth curves.) Show two full periods on your plot.





2. Construct a peak detector circuit by adding a capacitor to the rectifier circuit (as shown in the given circuit diagram.) Select three capacitor values in the range of 1 nF to 100 nF such that the circuit would represent a good, mediocre, and not good practical peak detector. Explain how you chose the capacitor values.



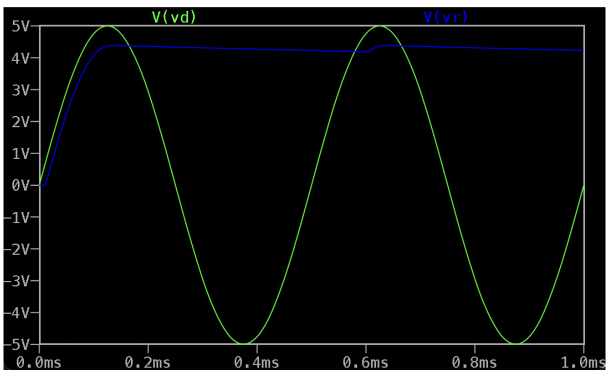
100 nF (Good Detector): The capacitor charges to the peak and discharges very slowly through the 100kΩ resistor. This keeps the output stable and accurate.

10 nF (Mediocre Detector): The capacitor still holds the peak voltage but discharges faster than the ideal case, causing some loss in peak detection.

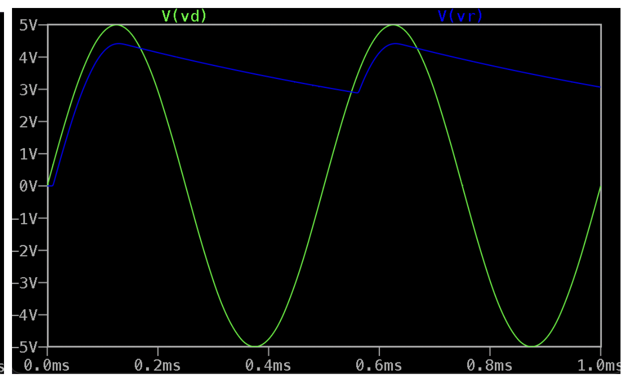
1 nF (Poor Detector): The capacitor discharges too quickly, making it ineffective as a peak detector. The output voltage will drop between peaks.

3. Create a plot showing v_o and v_i on the same graph for each one of your practical peak detector circuits.

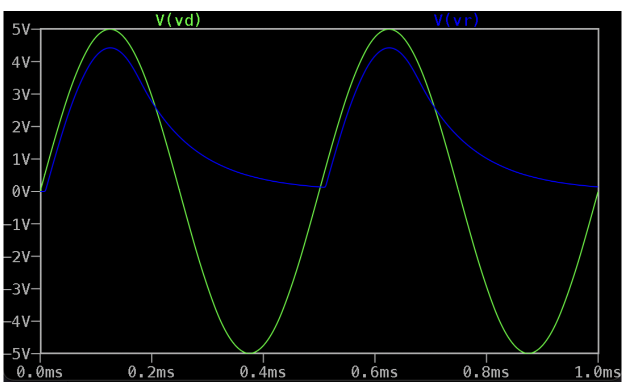
100 nF



10nF



1nF

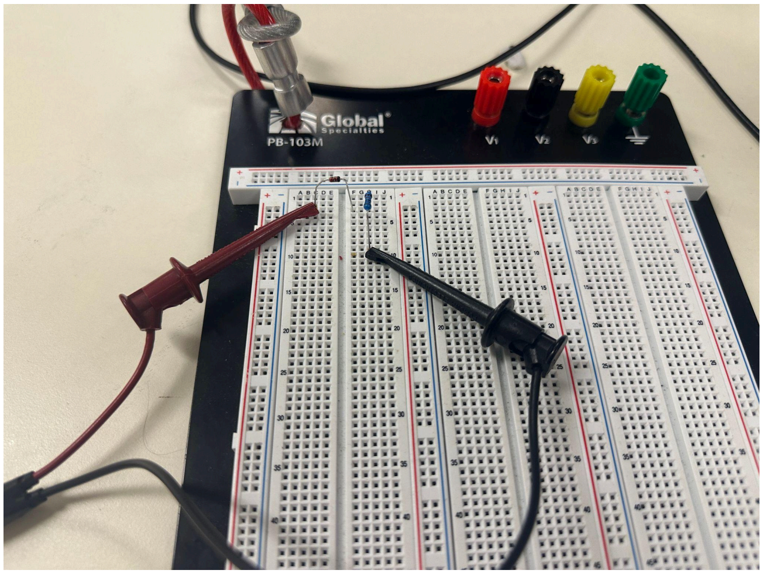


4. Do the plots match your expectations?

Yes, our plots match the expectations outlined in question 2.

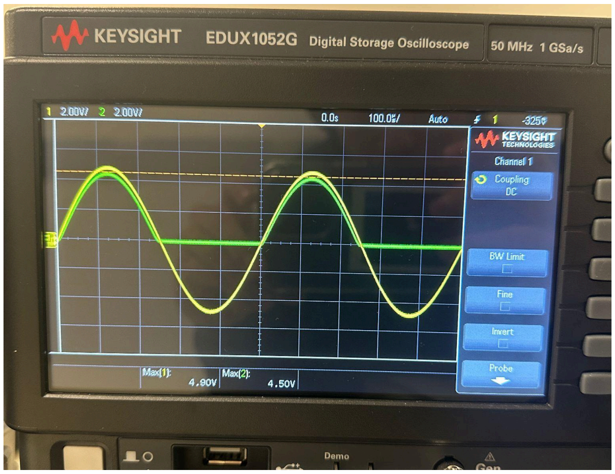
Lab exercise:

1. Assemble the circuit <u>without</u> the capacitor. Take a picture of the setup and include it in your report.

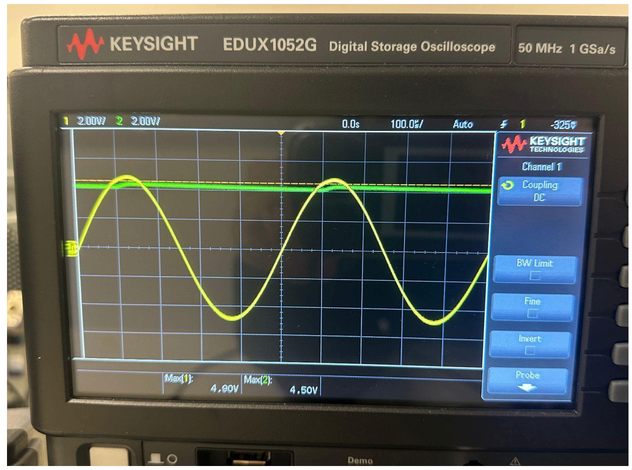


2. Set the function generator to produce a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz. Attach the function generator to v_i. Attach scope channel 1 to v_i and scope Channel 2 to v_o, and have both traces be "triggered" by channel 1. done
3. Adjust the volt per division knob such that the signal is as large as possible (i.e., fills the display). Ensure that both channels have the same volt per division setting. 2.00V/
4. Move the two traces such that the zero voltage values for both channels are in the middle of the display. Ch(1)=Ch(2) = 0.0V
5. Expand the time selection so that only 2 to 4 periods of the waveform are shown. done
6. Disconnect the function generator without changing the function generator and scope settings. Attach a 10 nF capacitor (see circuit diagram above). Attach the function generator to the circuit and print out v_o and v_i. done
7. Take a picture of the oscilloscope display and include it in your report. shown below
8. Repeat the previous two parts with the capacitor values you selected in the circuit analysis section. shown below
9. Compare the output voltage traces for three peak detector circuits. What are your conclusions? shown below

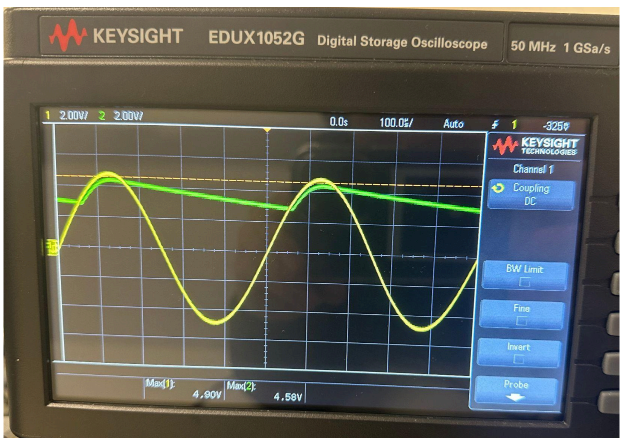
no capacitor



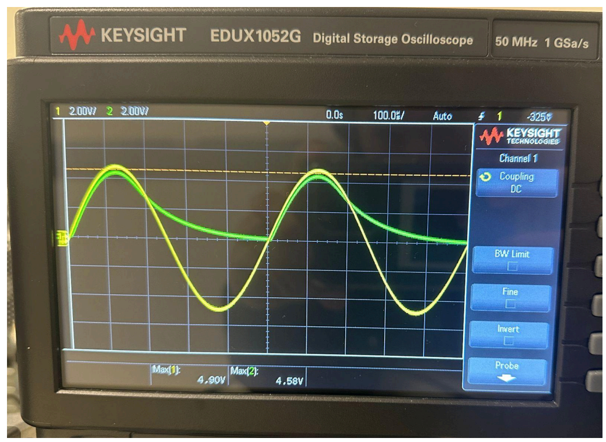
100 nF



10nF



1nF

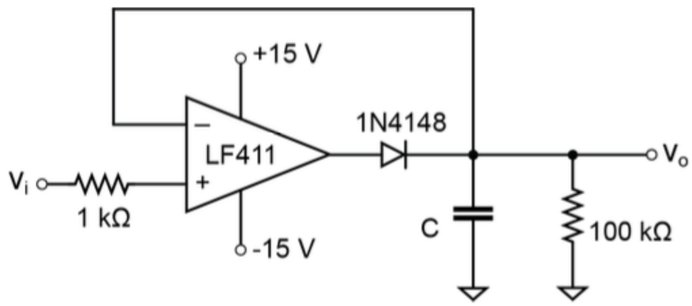


Comparison:

The output voltage traces for the three peak detector circuits showed results consistent with our simulations. With 100 nF, the circuit effectively held the peak voltage with minimal discharge, providing a stable and accurate peak detection. The 10 nF capacitor allowed some voltage decay between peaks, leading to a moderate but less ideal peak detection performance. The 1 nF capacitor, however, discharged too quickly, making it ineffective as a peak detector, as the output voltage dropped significantly between peaks. These results confirm that larger capacitors improve peak holding by slowing down discharge, while smaller capacitors lead to faster decay and less accurate peak detection.

Experiment 2: Op-amp Peak Detector

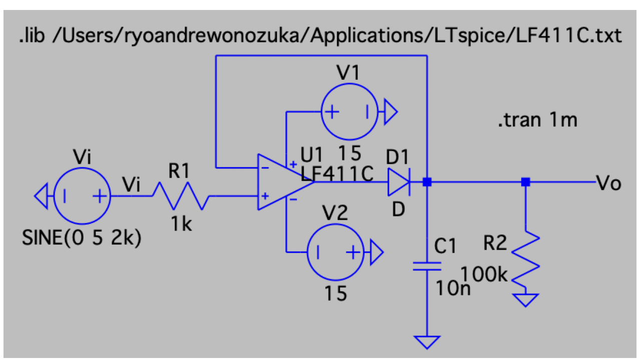
Consider the circuit below with a 1N4148 general purpose diode, and C = 10 nF.

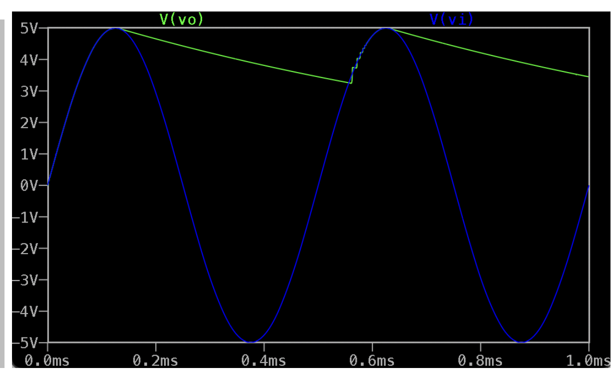


Prelab:

Simulation

1. Construct the circuit in Experiment 2. Input a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz. Create a plot showing v_o and v_i on the same graph using Transient simulation. Make sure your step size is small enough. (You should see smooth curves.) Show two full periods on your plot.



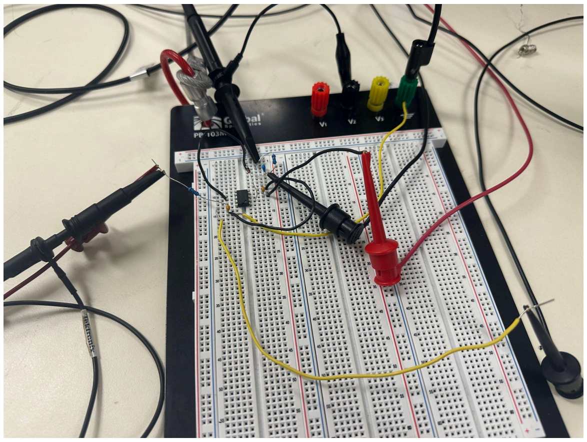


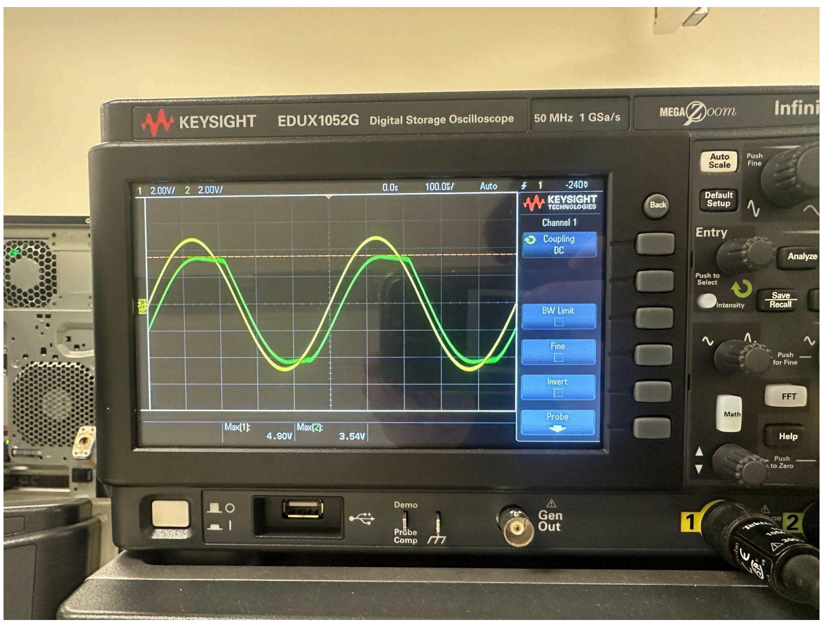
2. Explain how the circuit works and the difference between this peak detector and the one in experiment 1. Make sure to simulate the circuit in experiment 1 with C = 10 nF to compare the results.

The op-amp peak detector accurately tracks the highest voltage of v_i , with the diode preventing backflow and the 100kΩ resistor ensuring gradual discharge. Compared to Experiment 1, it offers better accuracy by compensating for diode voltage drop, a faster response due to high op-amp gain, and lower voltage losses, making it a more effective peak detector.

Lab exercise:

1. Assemble the circuit. Set the function generator to produce a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz. Attach the function generator to v_i. Attach the scope channel 1 to v_i and the scope Channel 2 to v_o.
2. Take a picture of the oscilloscope display and include it in your report.

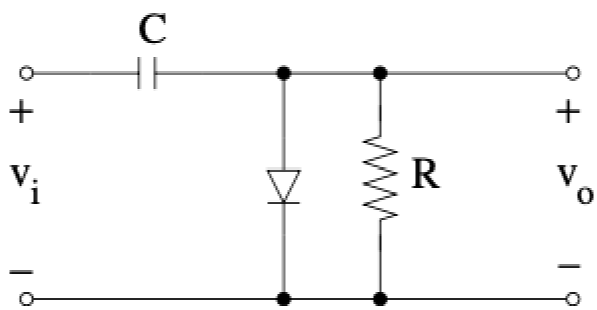




was unable to get it to properly detect the peaks despite constructing:
vi into 1k R into noninverting input port 3, +/- 15 V into ports 7 and 4, output into 1N4148 diode into inverting terminal, 100k R and 10 nF.

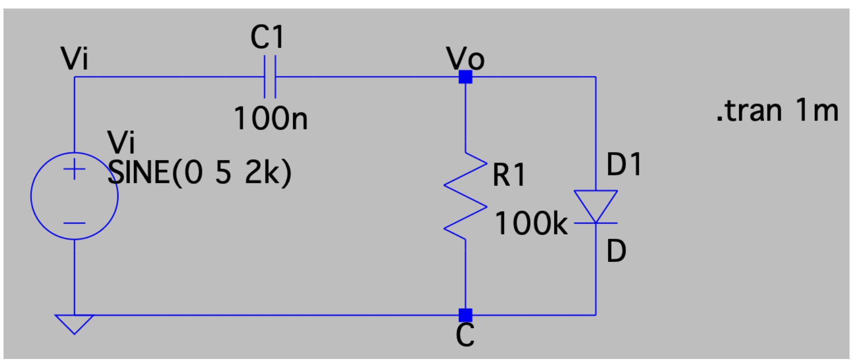
Experiment 3: Clamp Circuit

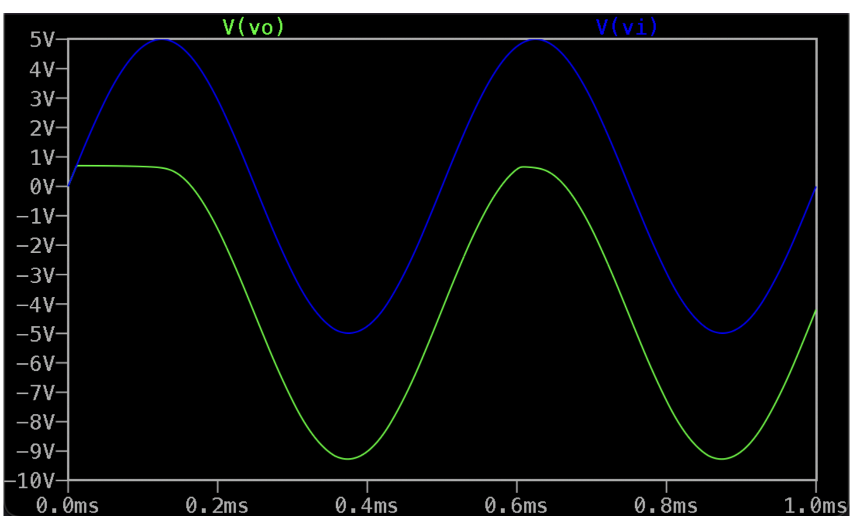
Consider the circuit below with a 1N4148 general purpose diode, R = 100 kΩ, and C = 100 nF.



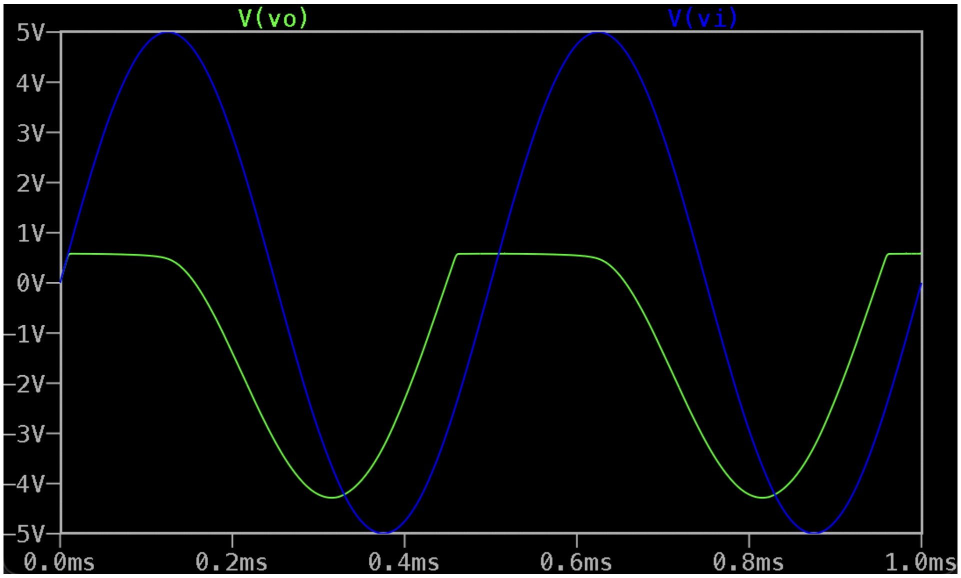
Prelab:

1. Build the circuit. Input a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz. Create a plot showing vo and vi on the same graph using Transient simulation. Make sure your step size is small enough. (You should see smooth curves.) Show two full periods on your plot.





2. Now, replace the 100 nF capacitor with a 1 nF one. Print out v_o and v_i.

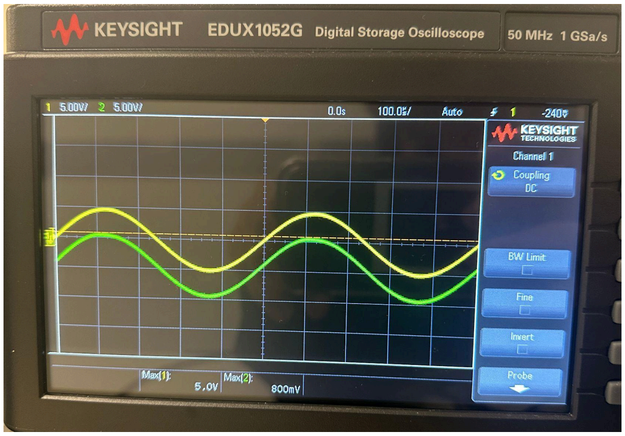


3. Compare the two cases. What are your conclusions?

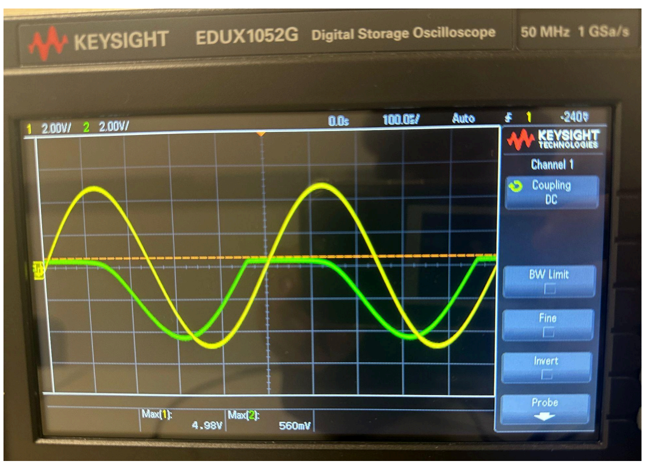
Replacing the 100 nF capacitor with a 1 nF capacitor significantly impacts the clamping behavior of the circuit. With 100 nF, the capacitor charges and discharges more gradually, resulting in a smooth and stable DC shift of the waveform, effectively maintaining its shape. In contrast, with 1 nF, the capacitor responds much faster, but this leads to an unstable and less effective clamping effect, causing distortions in the output voltage. The larger capacitor provides a better peak-holding effect, while the smaller capacitor allows faster response but at the cost of increased waveform fluctuations.

Lab exercise:

1. Assemble the circuit. Set the function generator to produce a sinusoidal wave with an amplitude of 5 V, zero DC offset, and frequency of 2 kHz. Attach the function generator to vi. Attach the scope channel 1 to vi, and the scope Channel 2 to vo. Take a picture of the oscilloscope display and include it in your report.



2. Disconnect the function generator without changing the function generator and scope settings. Replace the 100 nF capacitor with a 1 nF one. Take a picture of the oscilloscope display and include it in your report.



3. Compare the two cases. What are your conclusions?

In our clamp circuit experiment, replacing 100 nF with 1 nF affected the waveform's stability. With 100 nF, the capacitor gradually charged and discharged, creating a smooth and stable downward shift of the waveform. With 1 nF, the faster response led to more fluctuations and a less effective clamping effect. Overall, a larger capacitor provides better stability, while a smaller capacitor increases distortion.

Conclusion

In this lab, we investigated the behavior of diode waveform shaping circuits, including rectifiers, peak detectors, and clamp circuits, analyzing their performance through both simulations and experiments. By varying capacitor values, we observed their impact on peak detection accuracy and waveform stability.

For the rectifier and peak detector circuits, we confirmed that larger capacitors, such as 100 nF, effectively held the peak voltage with minimal decay, while smaller capacitors, like 1 nF, discharged too quickly, making them ineffective as peak detectors. The op-amp peak detector was expected to improve accuracy by compensating for the diode voltage drop, but our lab implementation did not function as intended, highlighting the challenges of real-world circuit behavior and troubleshooting.

In the clamp circuit, replacing 100 nF with 1 nF led to increased waveform fluctuations, reinforcing that larger capacitors provide better DC shift stability, while smaller ones allow faster response at the cost of distortion.

Overall, this lab demonstrated the importance of component selection in shaping circuit behavior. While our simulations aligned with theoretical predictions, experimental results underscored real-world challenges, emphasizing the need for careful measurement, troubleshooting, and understanding of practical circuit limitations.