Lab 3 - Diode Based Limiting and Clamping Circuits

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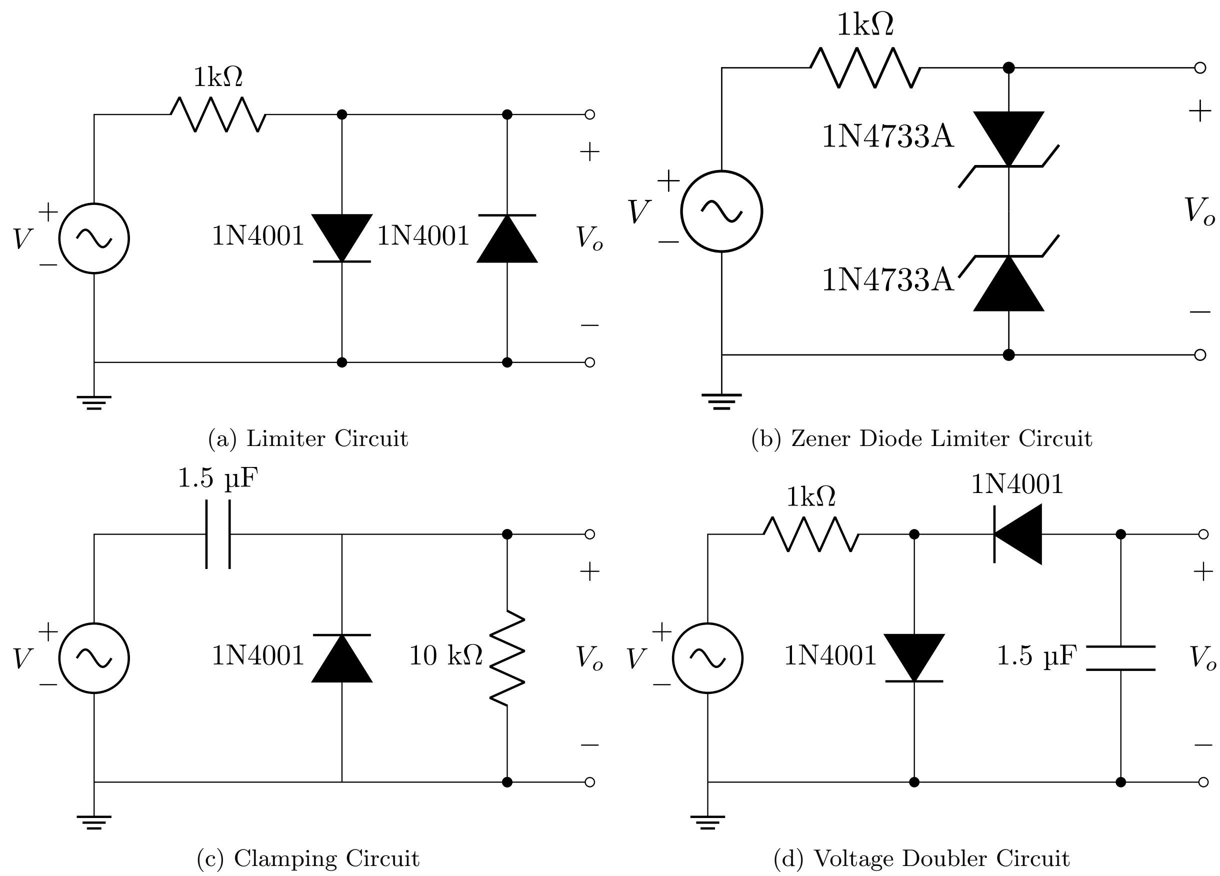
1 Introduction

In this report we analyze the circuits shown in Fig. 1 through computer simulation, then compare the results with measurements we record in the lab with the oscilloscope. All of these circuits are commonly used diode circuits and will produce unique outputs.



(a) Limiter Circuit

(b) Zener Diode Limiter Circuit

(c) Clamping Circuit

(d) Voltage Doubler Circuit

Figure 1: Circuits That are Used in This Lab

2 Limiter Circuits

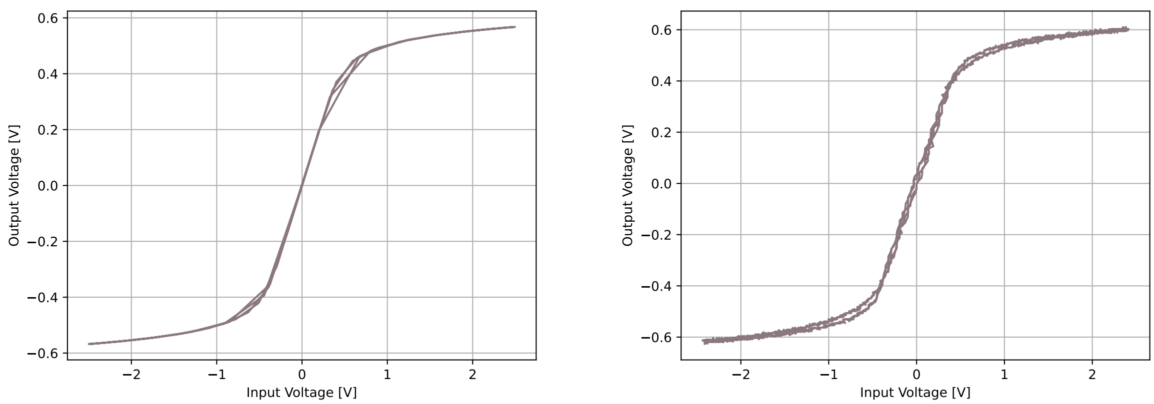
Limiter circuits are used to limit the output of an input wave. They often appear linear until some certain voltage threshold where they cut off and almost stop increasing entirely.

The limiter circuit shown in Fig. 1a is a circuit that uses the voltage drop over a single 1N4001 diode to limit the output voltage of the circuit. Because the voltage increase is extremely low for any extreme increase in current, the voltage over the diode peaks at around 0.6 V. The function works by acting linear, essentially just a voltage passing through a resistor, when neither of the diodes are turned on. Though, when one of the diodes becomes forward biased, it acts as a short circuit and only the voltage drop across the diode is seen at the output.

By placing two diodes in parallel and facing opposite directions, the circuit doesn't limit only when the voltage is positive (or negative). Rather, the circuit is able to allow current to pass through the diodes in either case, and the voltage is seen on the output whether the input voltage is positive or negative.

To increase the limiting voltage to 1.4 V, all that we needed to do was place another diode in series with each of the two diodes. This made the voltage drop across the network equal to 2 times the original voltage drop, and it was very close 1.4 V.

In Fig. 2 you can see the voltage of the output graphed with respect to the input in both the simulation and the experiment. Clearly, the behavior was modeled well and the circuit behaves as expected.

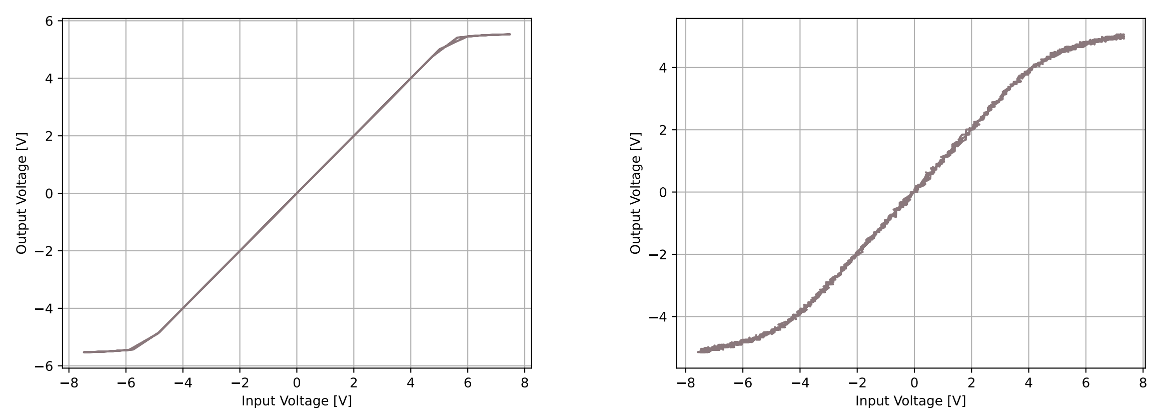


(a) Simulated

(b) Measured

Figure 2: Limiter Circuit Simulation and Measurements

Similar to the normal diode limiter circuit, Zener diodes (see Fig. 1b) can be utilized to specify the target voltage that the input will be limited to. The Zener diodes that we chose (1N4733A) become forward biased at around 5 V, and as such the output voltage is limited to that value. See Fig. 3 to compare the simulated vs measured results of the Zener diode limiter.



(a) Simulated

(b) Measured

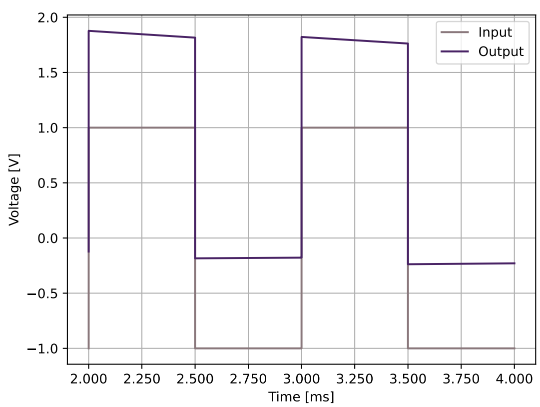
Figure 3: Zener Diode Limiter Circuit Simulation and Measurements

3 Clamping Circuit

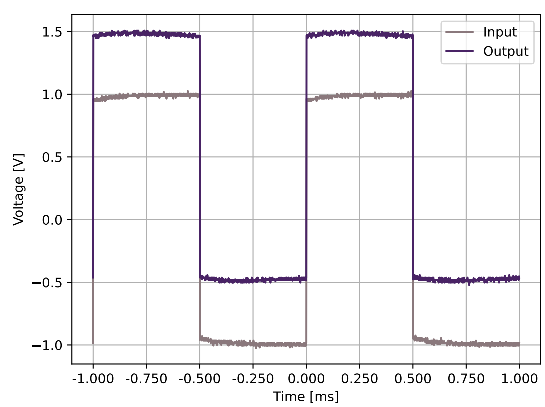
A clamper circuit is used to translate some input voltage to either a completely positive voltage or a completely negative voltage. The circuit works by charging the capacitor when the input voltage is negative and the diode is forward biased, and when the input voltage is positive the diode is reverse biased and as such doesn't allow current to flow, so the output is just the input voltage plus whatever the capacitor was charged to while the input was negative.

Assuming an ideal diode, the output voltage of the circuit would be exactly equal to the input voltage shifted until it all becomes positive. Of course, because of the non-zero voltage drop over the resistor, this isn't exactly the case, but the circuit still reaches a nearly all-positive state, within the voltage drop of the diode.

In the simulation, as shown in Fig. 4a, we can see that the output voltage is higher than in the experimental measurement. This is because we did not wait in the simulation for long enough so that the circuit could find a consistent state. The capacitor was still charged more than it would be several iterations past this point. Given enough time that the simulated circuit could reach some form of equilibrium, it is anticipated that it would appear very similar to the measured results, which were captured after the circuit had ample time to settle.



(a) Simulated



(b) Measured

Figure 4: Limiter Circuit Simulation and Measurements

By changing the direction of the diode and having it face backwards, the voltage of the output voltage of the circuit is clamped the other way and the voltage moves to be completely negative, or with real components the output voltage is clamped to less than 0.5 V. See Fig. 5.

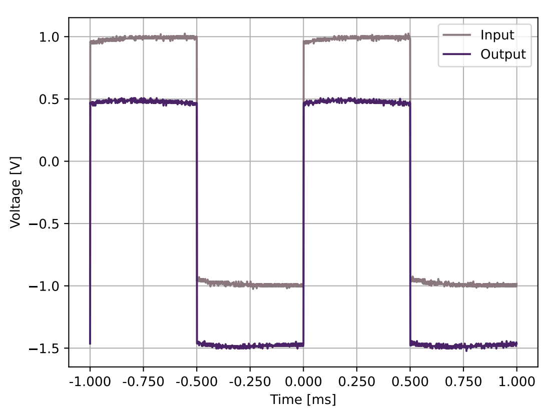
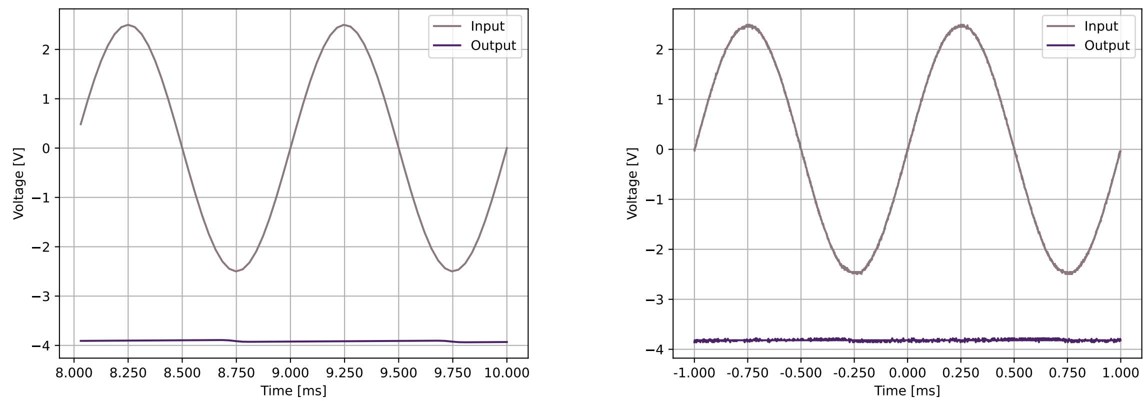


Figure 5: Negative clamping circuit measurement

4 Voltage Doubler Circuit

The voltage doubler is essentially a peak rectifier circuit with a configuration of diodes that allows a capacitor to feed into itself alongside the voltage source. The result of passing in an AC voltage is essentially a DC voltage output that is just larger than 2 times the RMS voltage of the input, with a very slight ripple. Refer to Fig. 6 to see the simulated and experimental results.



(a) Simulated

(b) Measured

Figure 6: Limiter Circuit Simulation and Measurements

5 Conclusion

After reviewing these circuits, we found that the expected behavior of all the circuits was very similar to our simulation results. Allowing the clamper circuit simulation to settle a bit longer before grabbing the results would have likely resulted in our numbers lining up just a bit better, but regardless our simulations and experimental measurements were consistent. Personally, I find developing an intuition for some of these circuits a little bit difficult, especially the clamper and doubler circuits, but practice in the lab aids in learning how all of these circuits function.