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ELEN 115 Lab

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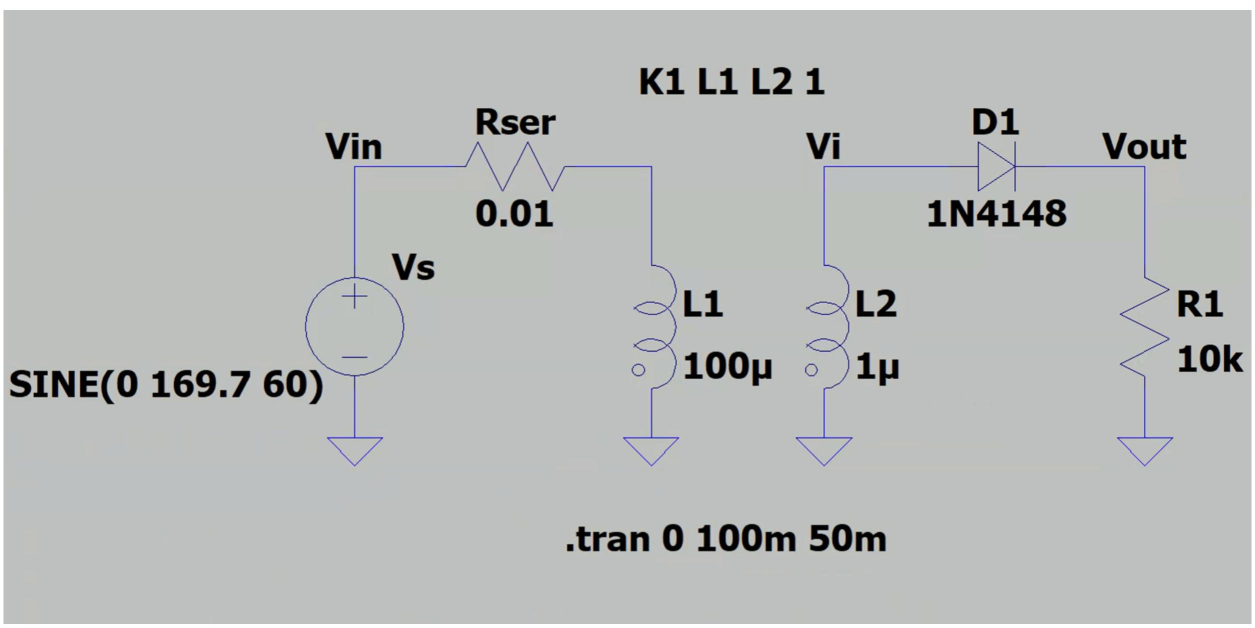
Lab 5: Diode Rectifiers and their Applications

Objective

The objective of this lab is to examine how different types of diode rectifiers behave in different conditions and applications. This lab looks specifically at half wave rectifiers and bridge rectifiers, examining their key properties relating to the output voltage and diodes. It also includes adding capacitors to see how the output voltage behavior differs with this addition.

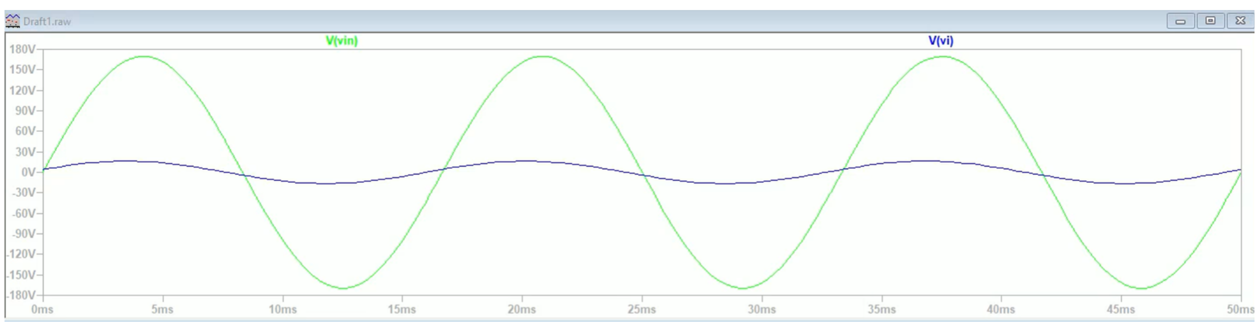
Part 1: Half Wave Rectifier



We began by creating a circuit that had a transformer and a rectifier.

(a) Give an input of 120Vrms to the transformer primary. You should then observe a 12V rms output at the primary as the turns ratio is 10:1.

We graphed the input voltage at the beginning of the circuit and at the opposite end of the transformer to verify that it was actually working with a ratio of 10:1.



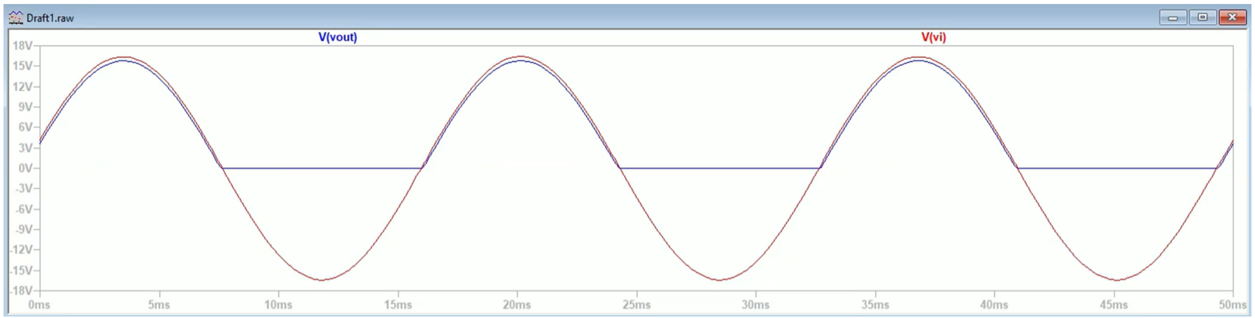
Vin Peak = 169.7 V; Vi Peak = 16.4 V; Ratio = 169.7/16.4 = 10.34

Why is a transformer used?

Here a transformer is used because we want to step down the voltage. Usually we are getting voltage from a larger power supply and we want to only send a little bit of that to a circuit or a device. If we sent the large voltage it would destroy the device, so we use a transformer to manage that.

(b) Perform a transient analysis for a few cycles of the sinusoidal input.

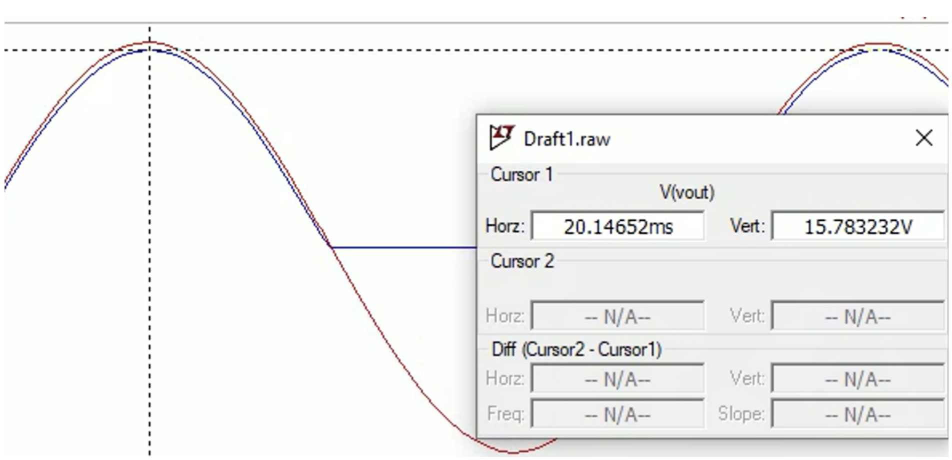
We graphed the output of the rectifier to its input to see make sure that the voltage was being cut off at 0V.



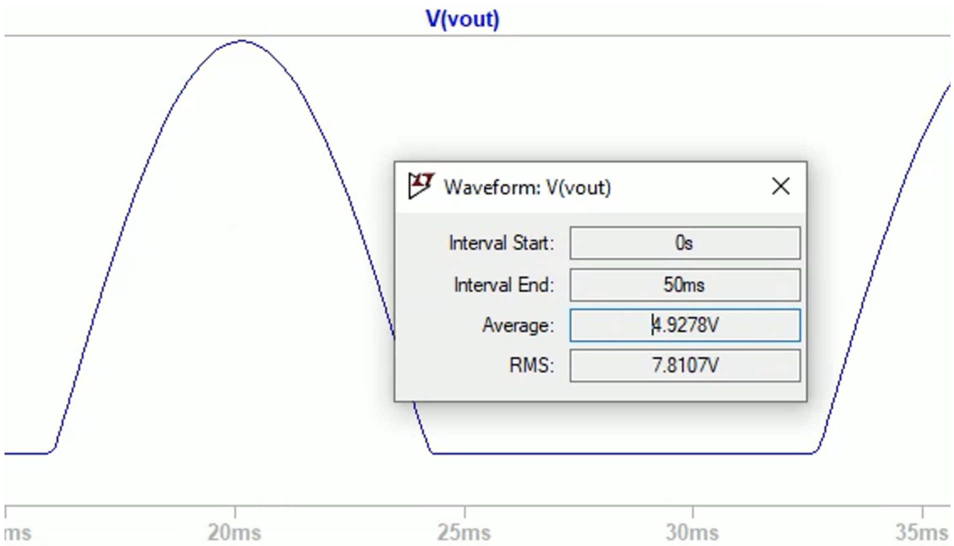
We can see the half-wave functionality as the wave is flat at 0V.

(c) Plot the input and output on one plot to observe the rectifier action. Obtain a screen shot. Find the following for the circuit.

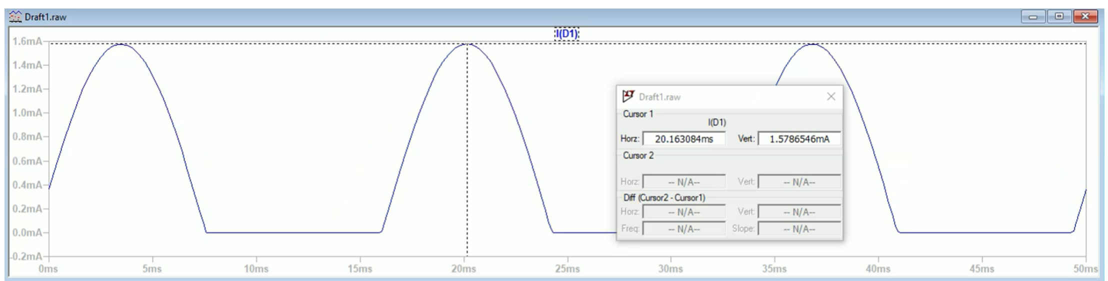
(i) The peak output voltage.



(ii) The average output voltage. Vpeak/pi = 15.78 / pi = 5.022 V



(iii) The peak diode current for the diode(s). iD = Vs / R = 16.4 / 10k = 1.64 mA



(iv) The peak reverse voltage across the diode(s).

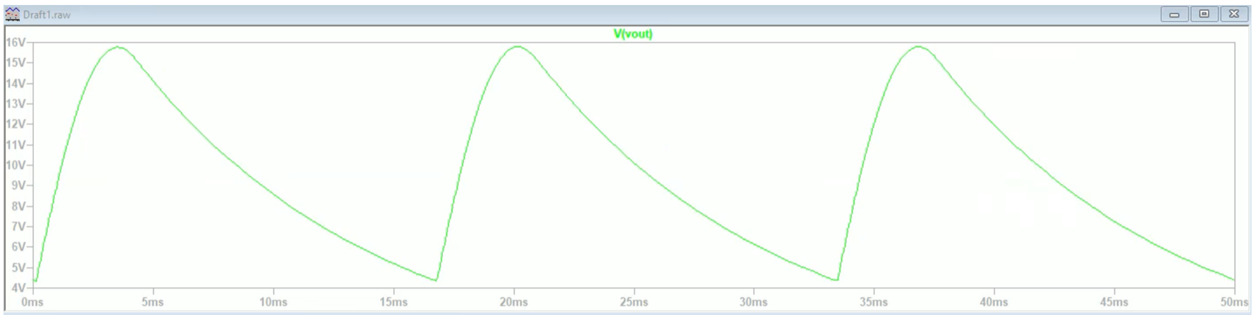
V reverse = Vs = 16.4 V

What would change if the resistor was increased by a factor of 10?

If we increased the resistor by a factor of 10 then the peak diode current would decrease by a factor of 10.

(d) Connect a capacitor of 1uF in parallel with the resistor and observe the output. Obtain a screen shot. Measure the peak-to-peak ripple.

We added a capacitor at the end of our circuit so that we could create a ripple and the voltage wouldn't completely drop after it reached its peak.

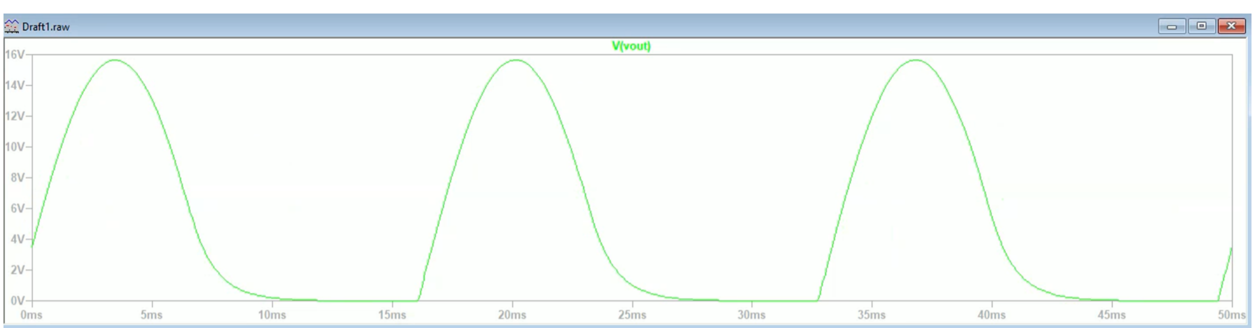


What would change if the capacitor was increased by a factor of 10?

When the capacitor is increased by a factor of 10 we see how the voltage only drops to 13.57V instead of 4.35V as it does in the original circuit.

What would change if the resistor was decreased by a factor of 10?

When we decrease the resistor by a factor of 10 we see how the circuit looks very similar to how it looked without a capacitor being attached at all.



Observe the effect on the output waveform for each case.

What is the reason for the changes you observe in these waveforms? How does this change the performance of a rectifier?

We know that the equation for the rectifier output is $\frac{V_{peak}}{f \cdot \tau}$. We know that $\tau = RC$and since R and C are the only values we can change we look at those. Since they are both in the denominator an increase in either of them, like we saw when we increased our capacitor by a factor of 10 would our answer would decrease so we would get a smaller range of values. Then when we decreased our resistor by a factor of 10 our answer increased so we got a larger range of values. By increasing our values we get a rectifier that performs better because our output voltage graph is more precise.

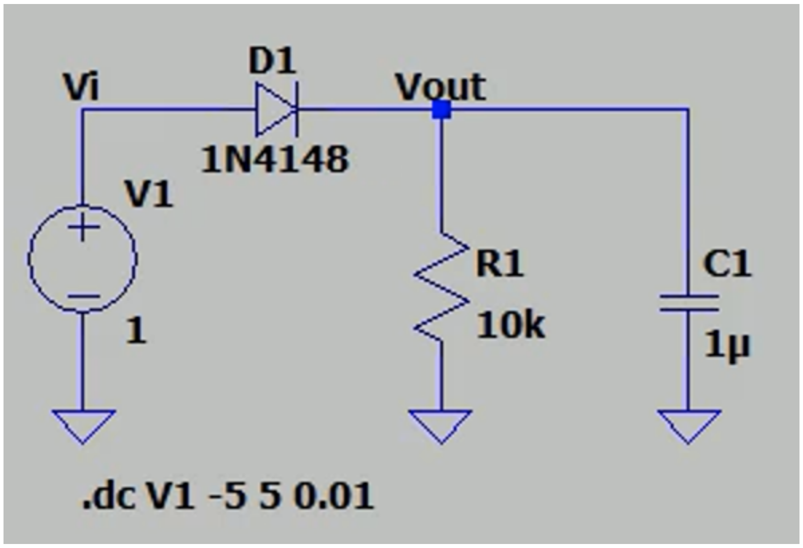
What limitations would this rectifier have?

One limitation with the rectifier is that we cannot always change our load value, so if it were a very poor value we could only choose a capacitor that works so well. Then we can also never fully get rid of the ripple in our graph.

(e) Remove the transformer and connect a DC source at the input to the rectifier.

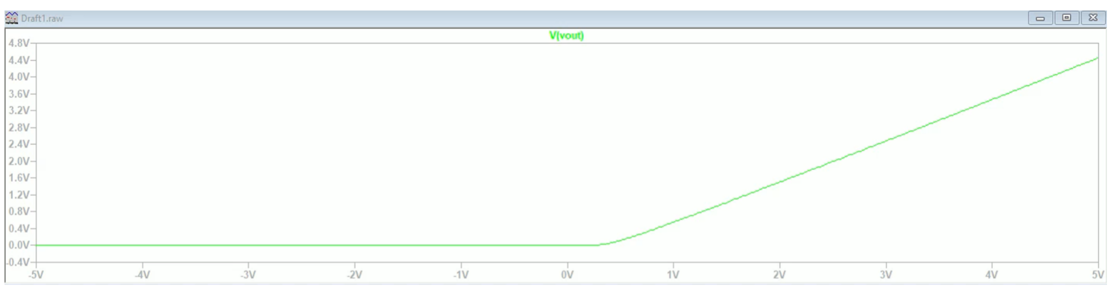
We disconnected the transformer so we could perform a DC analysis of the rectifier.

(i) Run a DC sweep from –5V to 5V.



(ii) Plot the output versus input curve to obtain the transfer characteristics.

We graphed the output voltage to see where the diode would begin to turn on and affect our circuit.

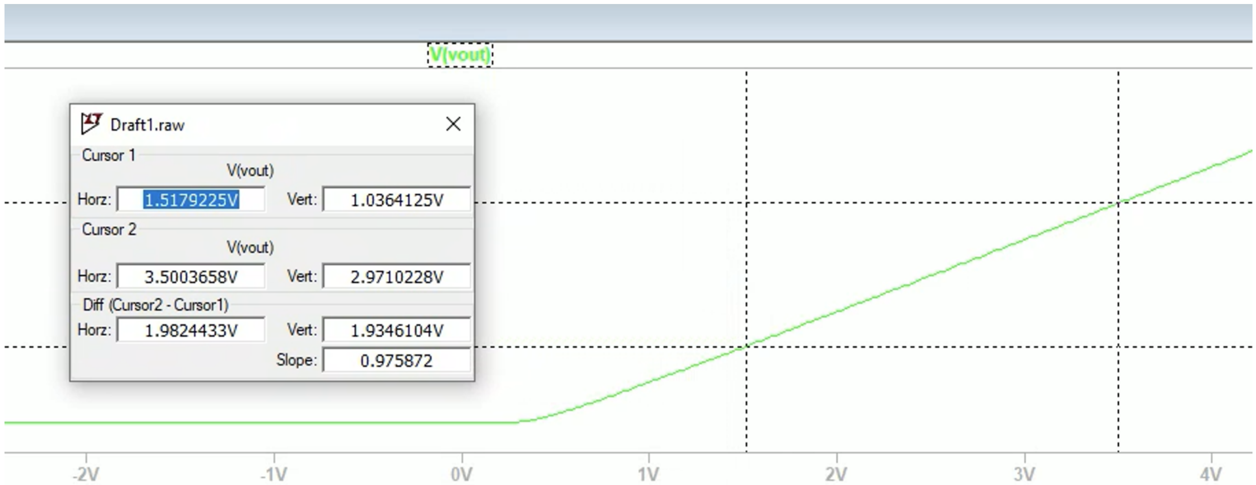


If the diode turn-on voltage changed, what would change on this curve?

If we increased the turn on voltage then, it would require a greater voltage before it started letting current through. It would also then require less voltage with a decreased turn on voltage. Basically the graph would move over to the left or to the right.

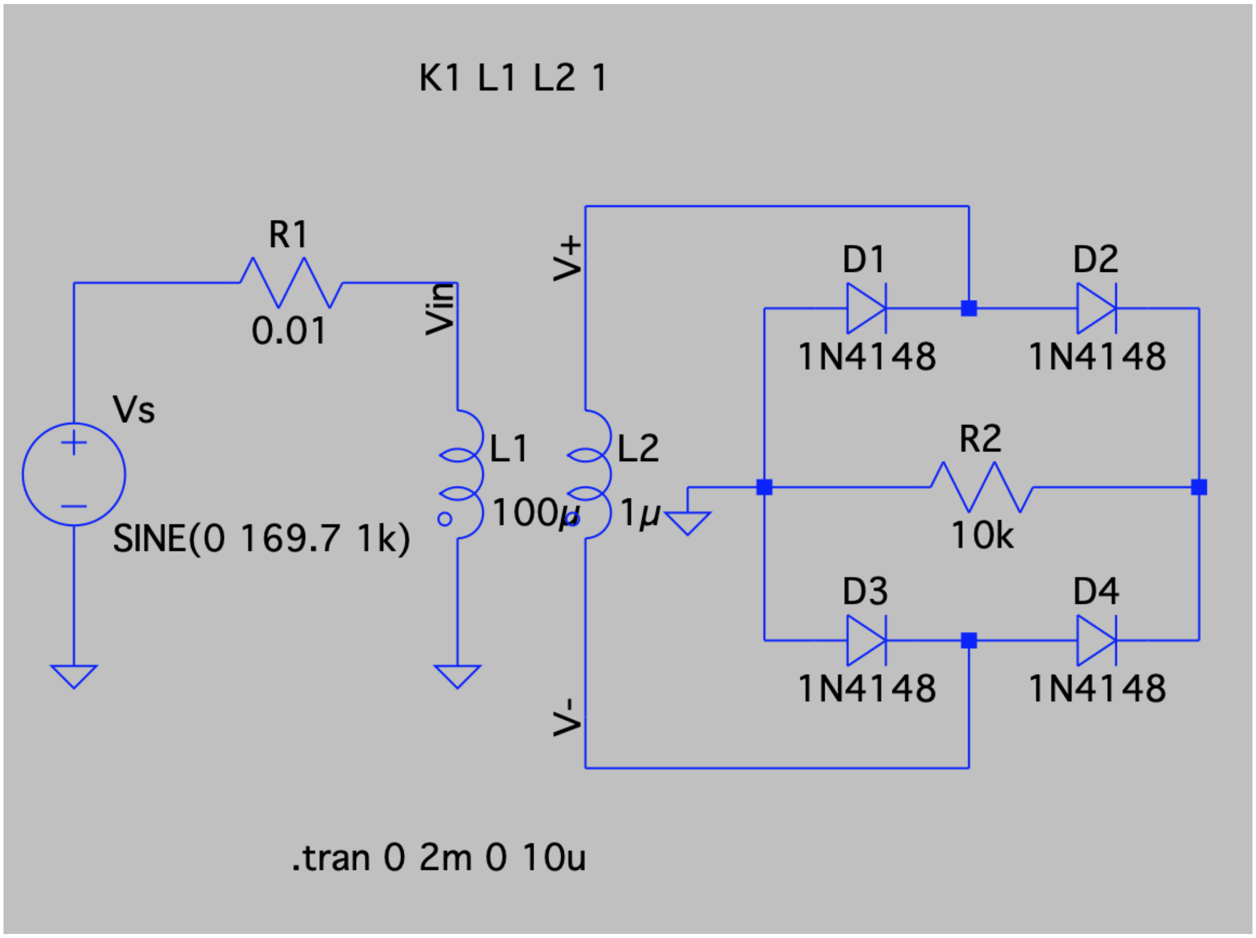
What does the slope of the curve indicate?

Since the slope is very close to 1 it shows that the diode has very little resistance.



Part 2: Bridge Rectifier

(a) The first step of part 2 is to construct the bridge circuit. To do this, first add a low resistance resistor (0.01Ω) and an inductor in series to a voltage source. Using a spice directive, couple another inductor to the one attached to the voltage source, and add the diode bridge across this inductor. Lastly, connect one end of the resistor inside the bridge to ground, with the output voltage being located on the opposite side of that resistor. The following image shows the completed circuit.



(b) First, set the voltage source to have an RMS of 120V. Then, run a transient analysis capturing a few periods to analyze the circuit behavior.

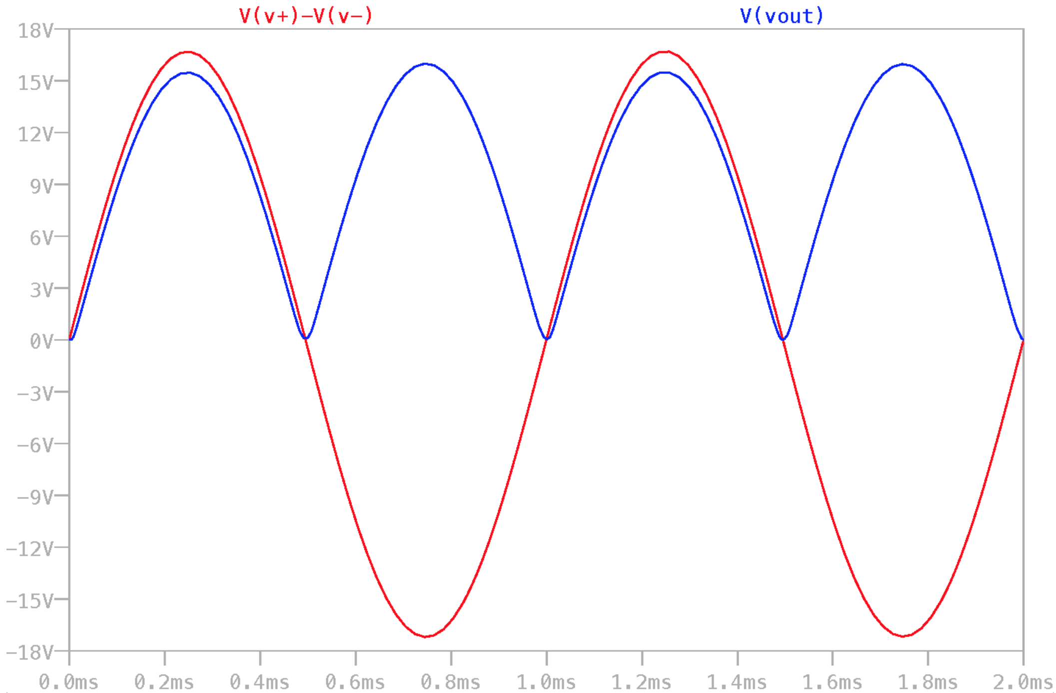


Figure of plot of Vout and V+ - V-

(c) To find several of the specified values of the circuit, conduct a transient analysis on the circuit. After plotting the output voltage, find the peak and average output voltage using LTspice's cursor and averaging feature. To find the peak diode current and peak reverse voltage, examine each diode in the transient response until one gives the largest value.

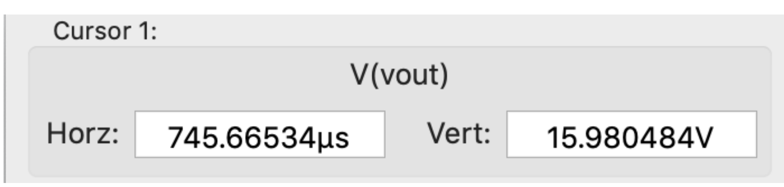


Figure of cursor at peak output voltage

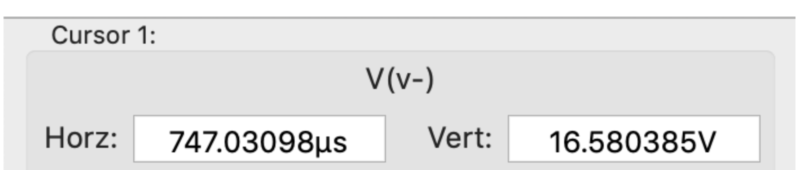


Figure of cursor at peak reverse voltage

Peak output voltage: 15.98V

Average output voltage: 9.66 V

Peak diode current for the diode(s): 1.60 mA

Peak reverse voltage across the diode(s): 16.58V

(d) Next, connect a capacitor of 1uF in parallel with the resistor and observe the output. Obtain a screenshot and measure the peak-to-peak ripple.

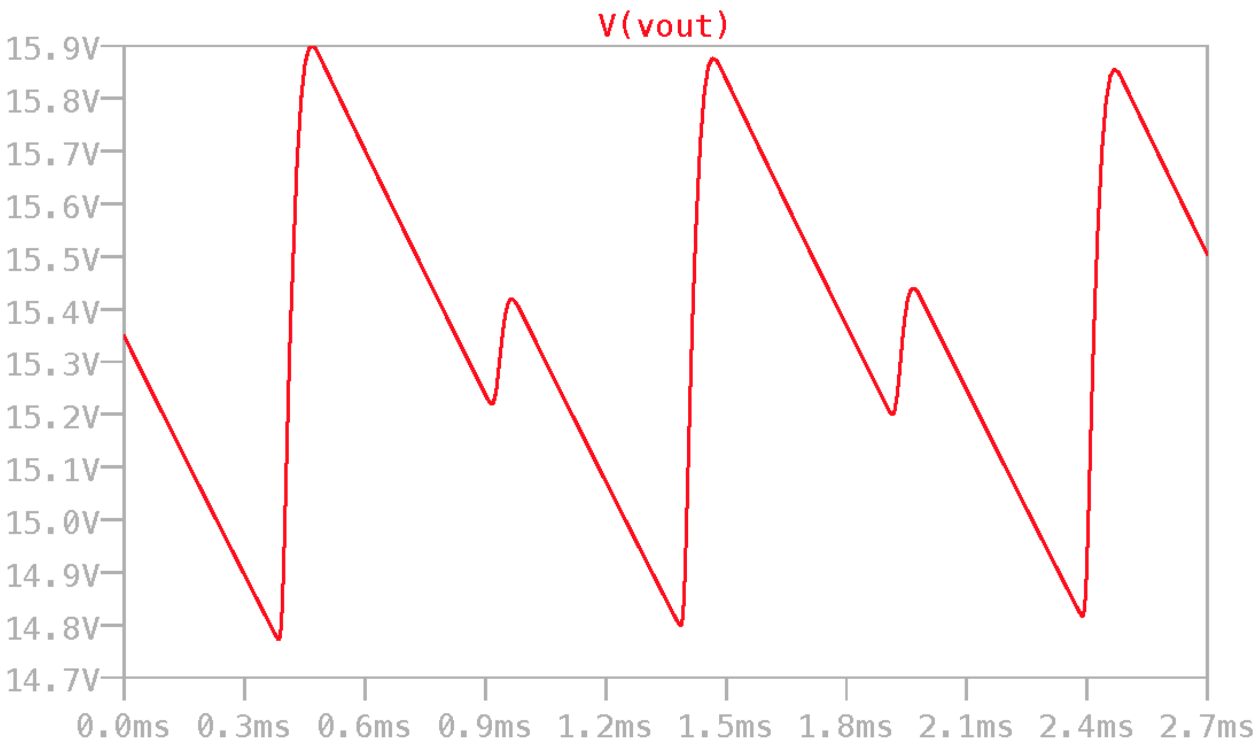


Figure of Vout with 1uF capacitor

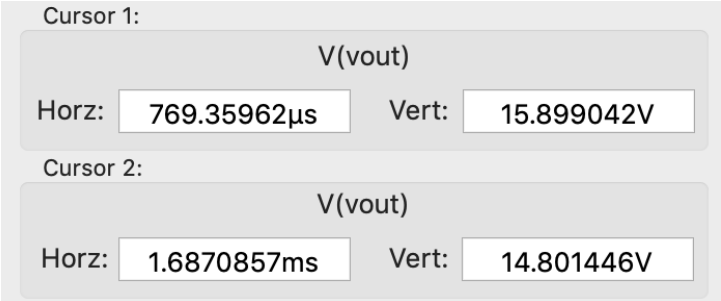


Figure of the cursor values at the peaks of the output

Peak-to-peak ripple: 1.01V

What would change if the capacitor was increased by a factor of 10?

If the capacitor was increased by a factor of 10, it would decrease the ripple by a factor of roughly 10. The following plot is of the output voltage when the capacitance is increased by a factor of 10.

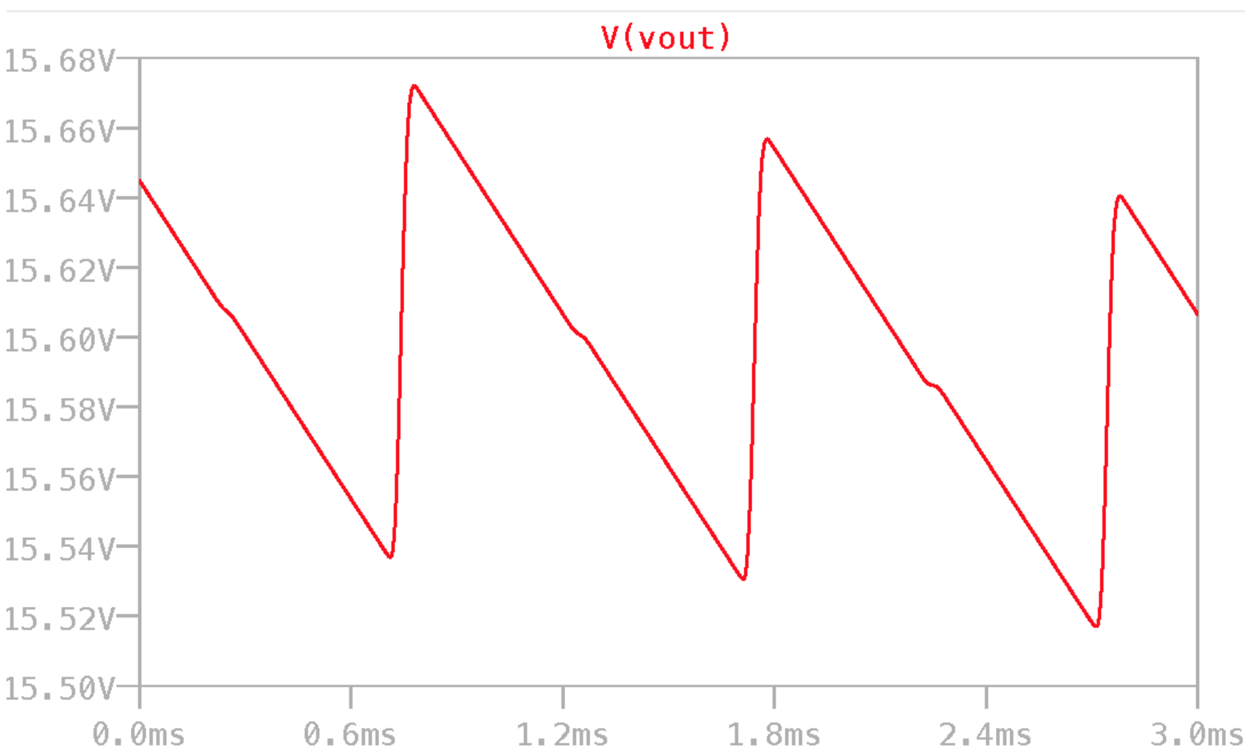


Figure of Vout with 10uF capacitor

What would change if the capacitor was decreased by a factor of 10?

If the capacitor was decreased by a factor of 10, it would increase the ripple by a factor of roughly 10. The following plot is of the output voltage when the capacitance is decreased by a factor of 10.

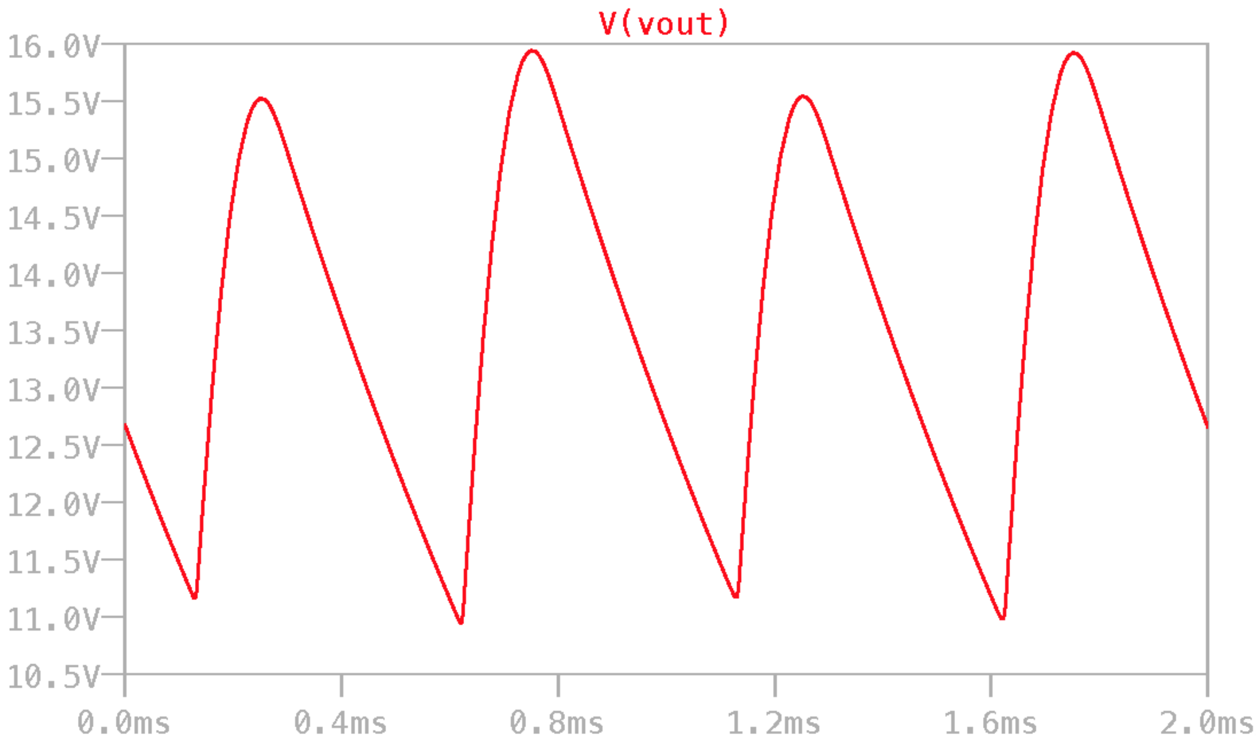


Figure of Vout with 0.1uF capacitor

What is the reason for the changes you observe in these waveforms?

The waveform changes since the capacitor cannot hold as large of a charge. When the capacitance is lower, it has less charge to keep the voltage constant. When the capacitance is higher, it can store more charge to better keep the voltage constant.

How does this change the performance of a rectifier?

When the capacitance is higher, it improves the performance of a rectifier. Higher capacitance means that the ripple is reduced, making the output closer to DC.

What limitations would this rectifier have?

Unfortunately, there will always be a ripple for this type of rectifier. Also, the rectifier would do a poorer job with lower load resistances.

(e) To find the output voltage with respect to the input voltage, connect the bridge rectifier to a voltage source. Run a DC sweep on the voltage source, and plot the output voltage with respect to the voltage source.

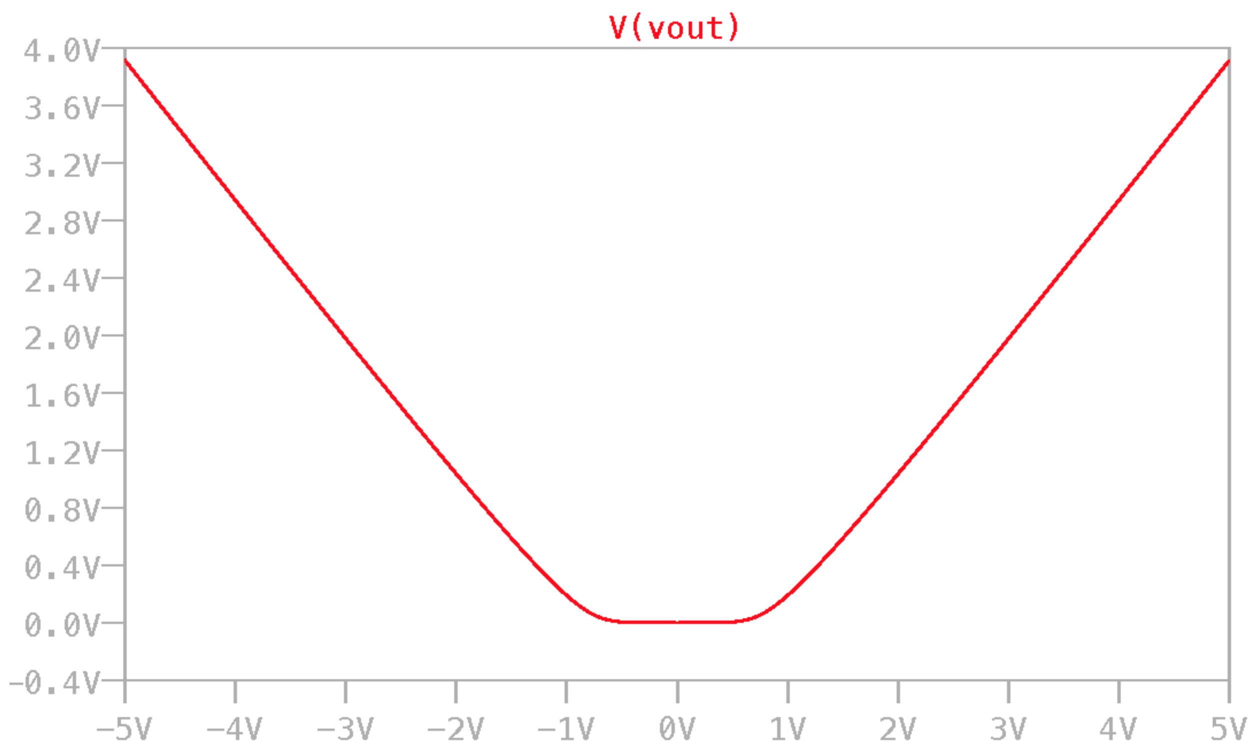


Figure of plot of Vout vs. V+ - V- (DC analysis, -5V to 5V)

If the turn-on voltage changed, what would change on the curve?

If the turn-on voltage changed, then the width of the flat portion in the middle of this graph would also change. If the turn-on voltage increased, the width would also increase.

What does the slope of the curve indicate?

The slope of this curve indicates that the diode consumes some of the voltage, since it has a small resistance.

Conclusion

In this lab we created two types of diode rectifiers, one half-wave, and one bridge to be able to see the benefits of having each in our circuit. We were able to see how by having a transformer we were able to take a closer look at a fraction of our output voltage, then use a rectifier to place limits on that output, and finally use a capacitor to try to keep it as constant as possible. This shows us how we can take an AC voltage as an input and convert it to DC voltage which is important for many of our circuits to function properly without destroying whatever device we are using.