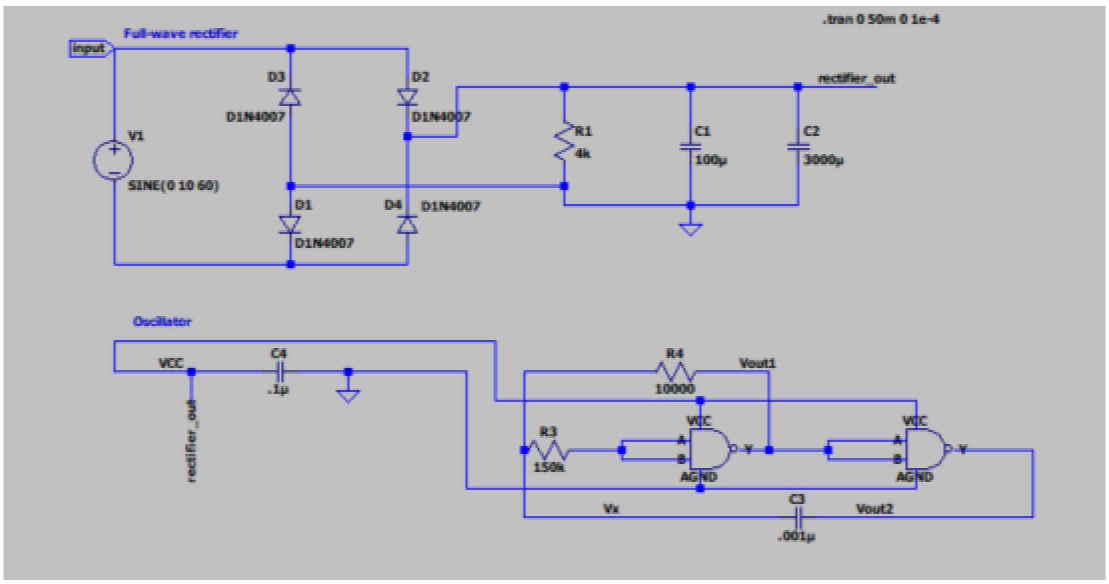
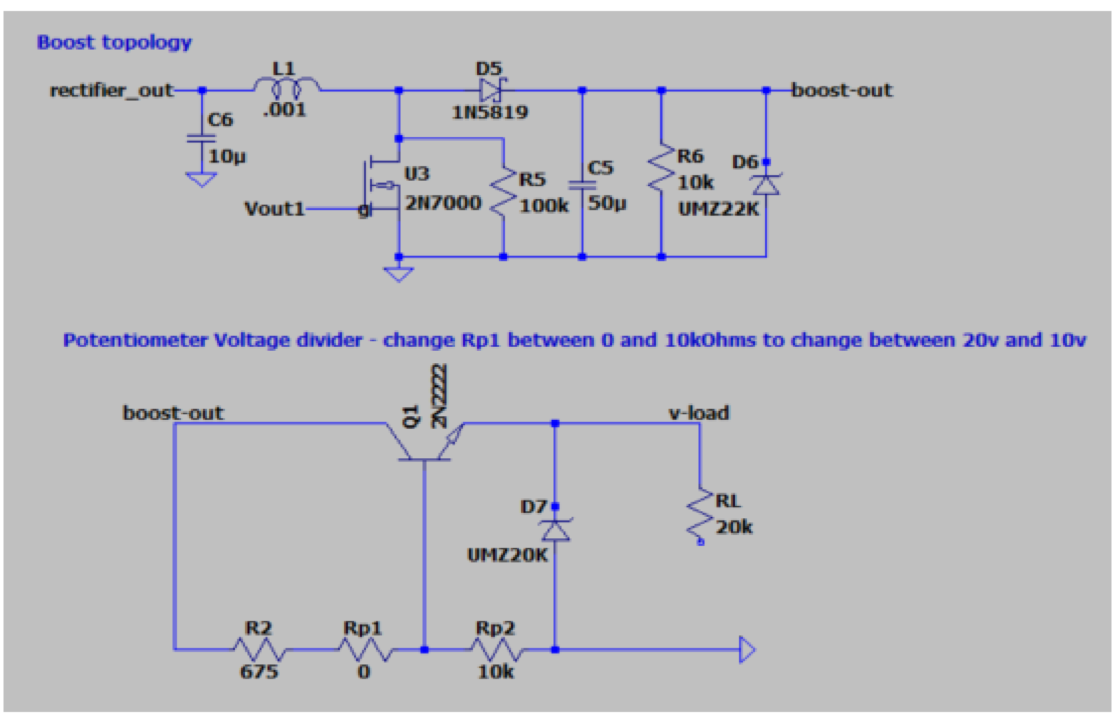
AC to DC converter

Barr, Tristan 1838047

Lowe, Connor 1573616





Purpose of the project, features, ratings

This lab is designed to build on and show our knowledge of diodes, MOSFETS, and CMOS and their applications in regards to rectifying AC voltage, regulating voltage, and boosting voltage, as well as creating oscillators. This lab asked us to combine the concepts learned throughout the quarter to create an AC to DC boost converter that can produce an output voltage from 10V to 20V with a ripple of less than 100mV and a current of no more than 1mA.

We started out by implementing a full-wave rectifier to achieve a DC signal of about 10v from the 10v input sine wave. To reduce ripple on our rectified output we implemented a two stage capacitive filter to achieve a ripple of 0.57v. From here we were able to provide a DC source for other elements in our circuit such as our oscillator and our boost topology. Our oscillator takes in the created DC signal and generates a square wave with frequency around 20kH. The boost topology takes in the DC signal we made and is switched by the signal from our oscillator, allowing us to boost the DC signal to 20v. Once we have boosted our signal we implemented a voltage divider with a potentiometer that the user can use to change the output voltage between 10v and 20v. All of this allows us to successfully convert a 10v sine wave to a DC signal that the user can switch between 10v and 20v, with a ripple of about 20mV, independent of the load. Our converter additionally delivers up to 1mA of current to a given load.

We will now discuss the ratings for the components in our circuit.

For our rectifier circuit, we chose diodes that would have a sufficiently small turn-on voltage of 0.7v so the overall voltage drop from our rectifier would not cause too much trouble. Additionally, we chose 100 and 3000 micro farads, because a greater capacitance value would result in less frequent oscillations and greater smoothing. Finally, the resistor we chose had a large resistance of 4k to help in smoothing the output voltage as well.

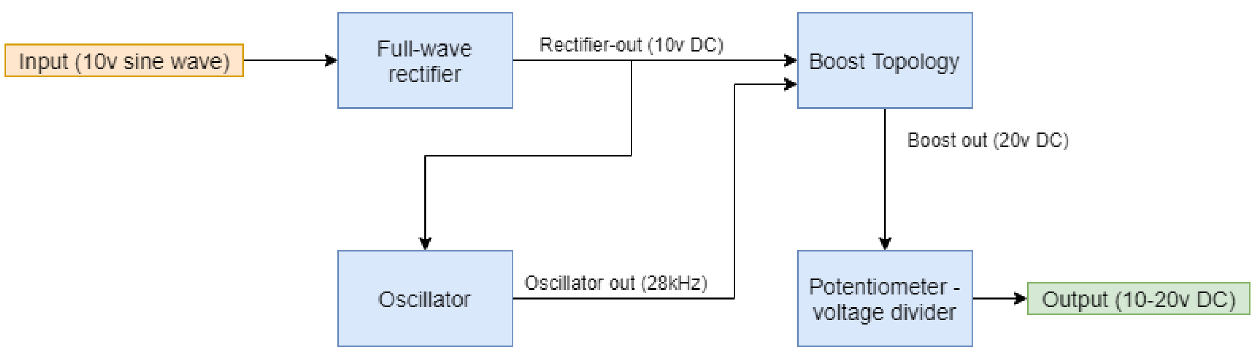
For our oscillator circuit, we chose an R4 value of around 10k ohms. Since R4 has direct control over the frequency of the output waveforms, we determined a value of 10k ohms gave us the frequency output waveforms we desired. Additionally, we chose an R3 value of 130k ohms. This resistor has direct control over the duty cycle of the output waveforms. We wanted a duty cycle of about 80%, since this would allow us to boost over 200% of the input for the boost topology circuit, so we determined that 130k ohms allowed us to achieve an 80% duty cycle.

For the boost topology circuit, we incorporated a zener diode with a breakdown voltage of 22V, this would allow for the current to be capped at 22V and serve as a voltage regulator for our circuit. For the inductor, we chose an inductance value of 1 mH, which, determined by trial and error, gave us the waveshape we desired. Additionally, we experimented with different capacitor values for C5 and C6. A value of 50 microfarads for the catch diode C5 gave us the smoothest graph without reducing the input to output time. Likewise, we determined a value of 10 microfarads to produce the smoothest waveforms for the C6 capacitor. We incorporated R5 in order to reduce the noise on the output waveform, this is something we learned in lab 5. We simply choose a sufficiently high resistance, and we settled on 100k ohms. For the resistor R6, this provides a lane for the voltage to dissipate when the zener diode has reached breakdown. We found through trial and error that a value of 10k was sufficient for this resistor.

For the final part of our circuit, we implemented a transistor voltage divider biased circuit to isolate the load from the output voltage. We strategically placed a 650 ohm resistor in series with our potentiometer voltage divider to ensure the max voltage of an open circuit load would not exceed 20v. We also choose to implement a 10 kohm potentiometer to allow the user maximum control over switching the voltage in the range of 10v-20v. This is done by changing the value of Rp1 from 0-10 kohms. For the transistor we chose a 2N2222 BJT to isolate our load and ensured it could handle our maximum load of 1mA, which it can handle 800mA. Finally, we included another zener diode with a breakdown voltage of 20v to ensure our output voltage would be capped at 20v.

Block diagram

The following picture shows the block diagram for our AC-DC converter. We have the 10v sine wave being inputted into a full-wave rectifier to achieve a constant DC voltage of about 10v. After we have a constant DC signal, that is used to power an oscillator for our circuit. The constant DC signal and oscillator are both then fed to a boost converter to achieve a 20v DC output. Once we have the 20v DC signal we can use our potentiometer in a voltage divider to vary the output between 20v and 10v, independent of the load.



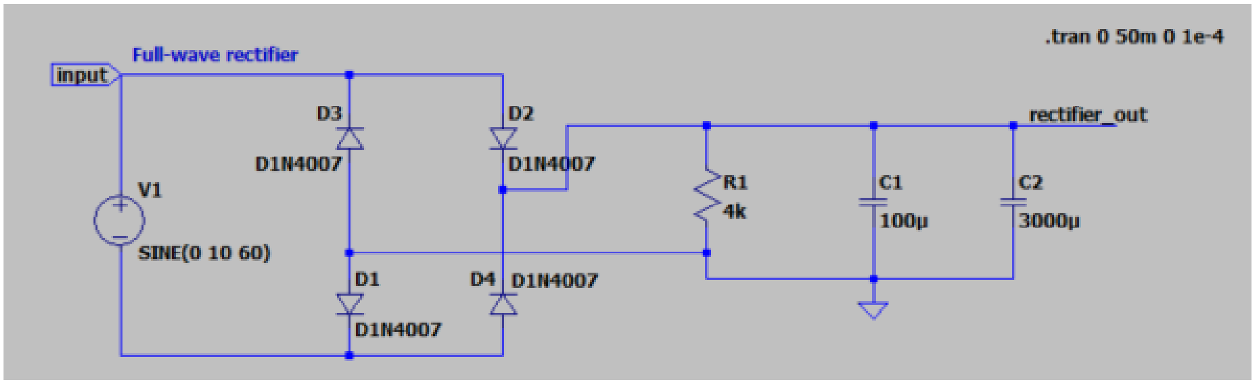
Complete schematic

Our schematic is divided into four different sections, which we will present separately below:

Full-wave rectification

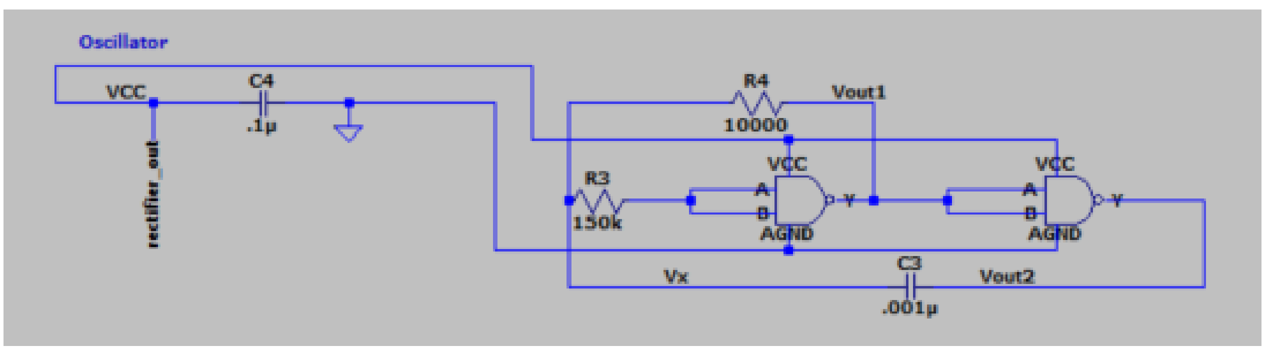
We built the circuit below to rectify the AC input of 10V to a constant DC signal. To do this we employed a normal 4 diode configuration and achieved an output that peaked at

8.17V, which we expected due to the voltage consumed by two diodes. To help reduce the ripple voltage that came out of our rectifier we utilized a two stage capacitive filter and was able to reduce our ripple to 0.57v.



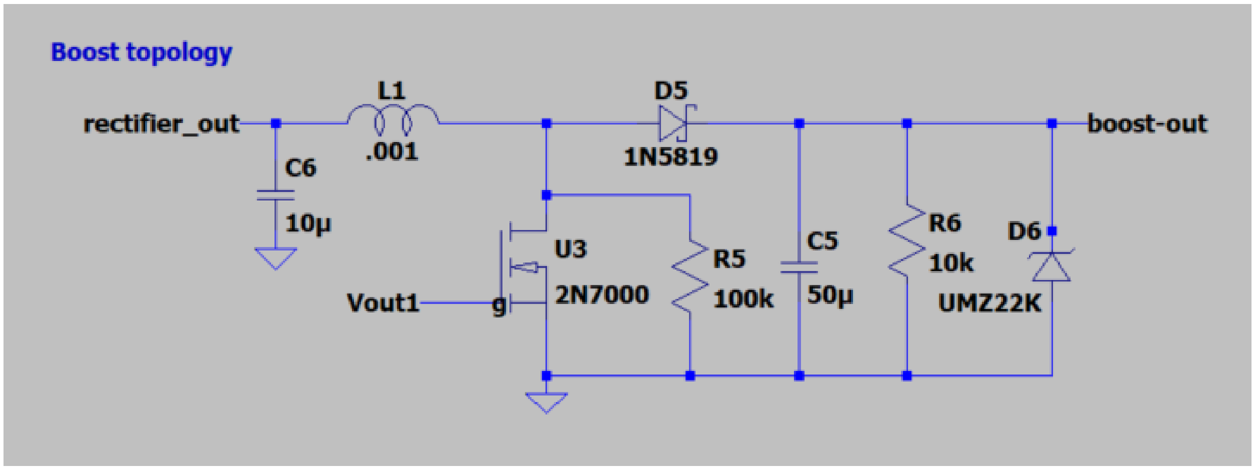
Oscillator

The circuit below shows an oscillator for our circuit that creates a 28.2kHz signal with an 80 percent duty cycle. The decision for such a high duty cycle came because we wanted to be able to boost our input to our boost topology super high, and an 80 percent duty cycle would let us boost to 5 times the input voltage. To achieve these specifications we strategically chose R3 and R4 to be 150kOhms and 10kOhms. The rest of our oscillator relies on two NAND gates cascaded to produce an oscillating DC signal.



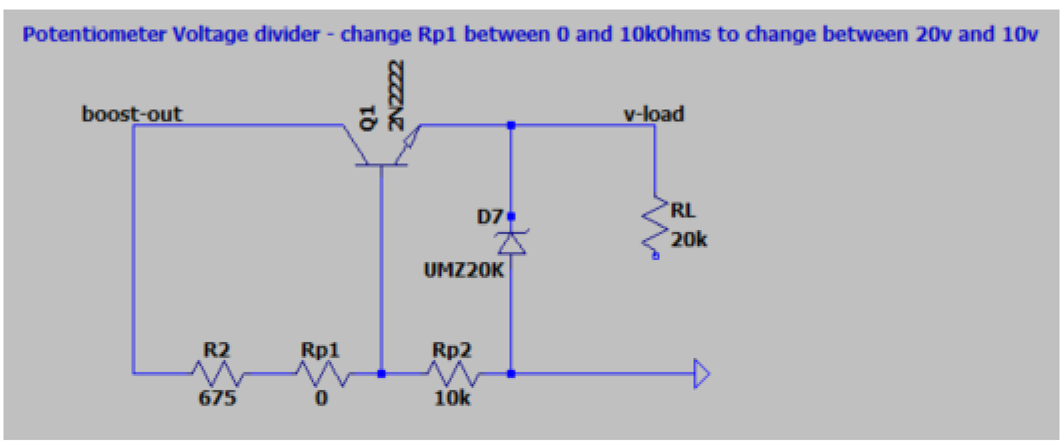
Boost topology

We implemented the following boost topology in order to take our rectifier output of about 10v to a 22v signal. This was done by using a N-channel MOSFET that is switched by our previously made oscillator signal. The transistor works to switch on the inductor to feed the catch diode, which will then feed out output. To further smooth out voltage on our output we added a zener diode to act as a voltage regulator.



Potentiometer voltage divider

The last part of our circuit was implementing a voltage divider in the form of a potentiometer so that the user can change the output voltage between 10v and 20v. To keep the load independent of the output voltage we have utilized a n-channel transistor that works to isolate the load from our circuit. The added series resistor to our potentiometer works to keep the high voltage range under 20v. After this we have also implemented another zener diode to further smooth any voltage ripple that might occur. This allowed us to properly allow users to tune the output voltage between 10-20v, while delivering under 1mA of current, regardless of the load.

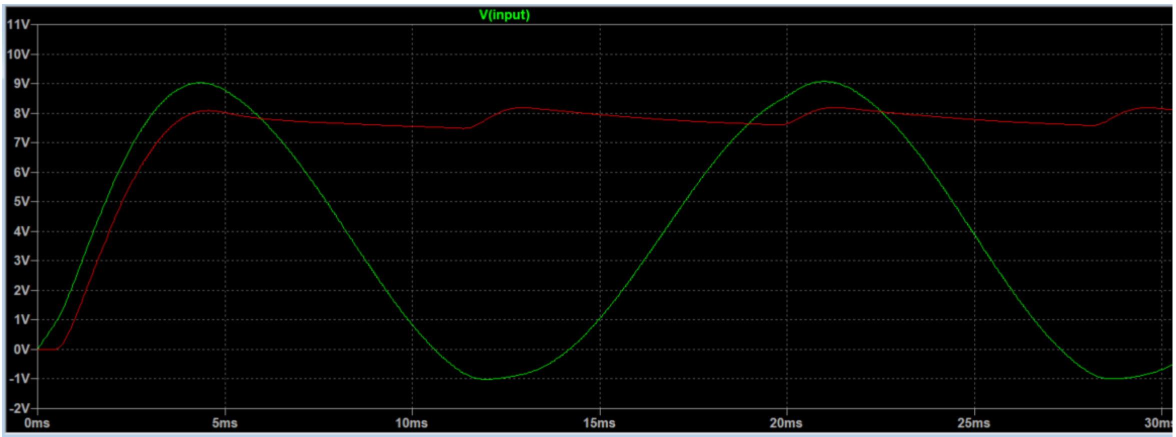


Circuit Simulation Results

We simulated each component of the overall circuit, and have provided simulation results for each individually. These results are shown below, with the overall circuit simulation results being included in the potentiometer voltage divider section:

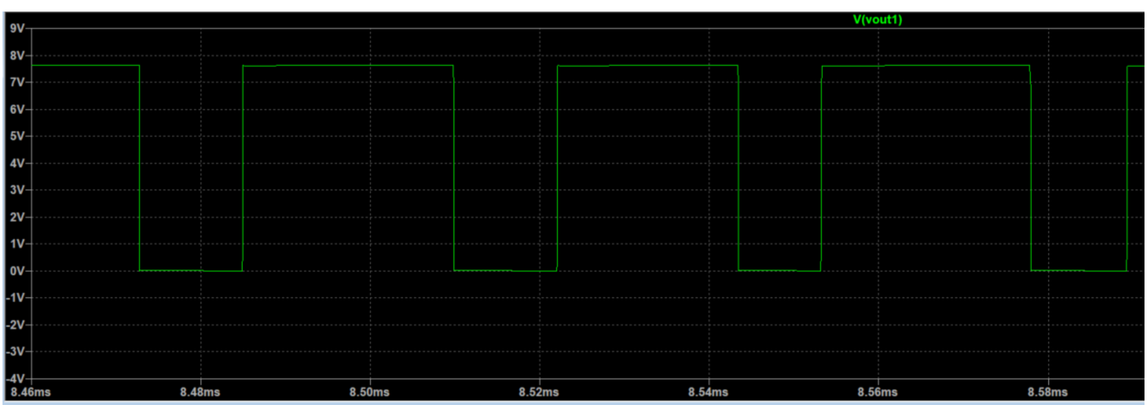
Full-wave rectification

Below are the simulated results from our full-wave rectifier. We can see the input voltage sine wave being transformed into more of a DC signal. Our rectified output peaks at 8.17v with a ripple of 0.57v. Thus, our rectifier is operating as expected with a low ripple voltage.



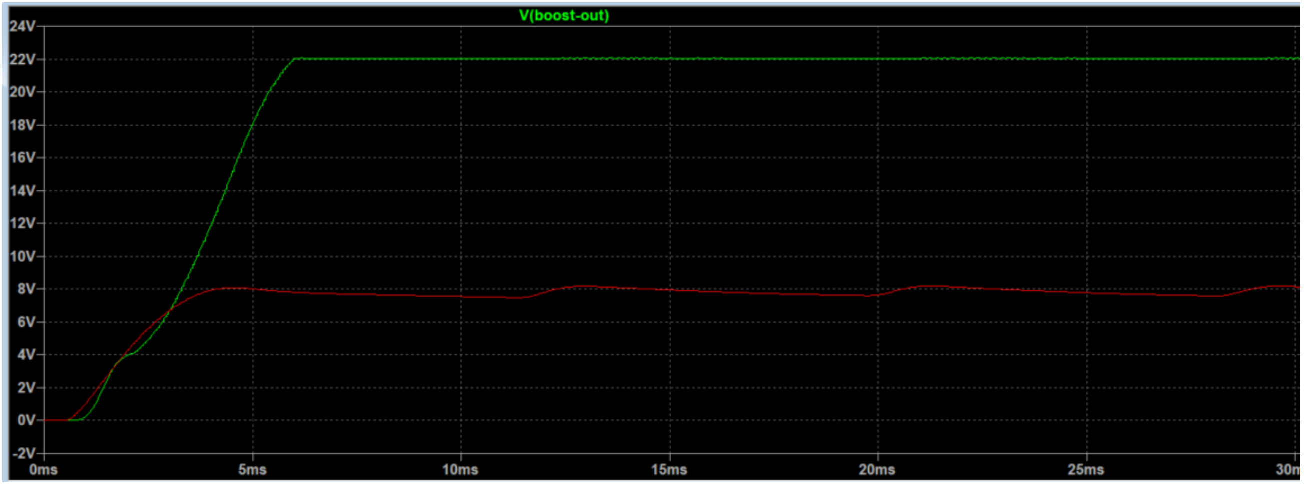
Oscillator

Shown below are our results from our oscillator. We tuned our output frequency to be about 28.2kHz with a duty cycle of 80 percent. Our oscillator is powered by our rectified output so we expect the high voltage to be the same. This ensures that our N-channel mosfet for our boost topology will be properly switched.



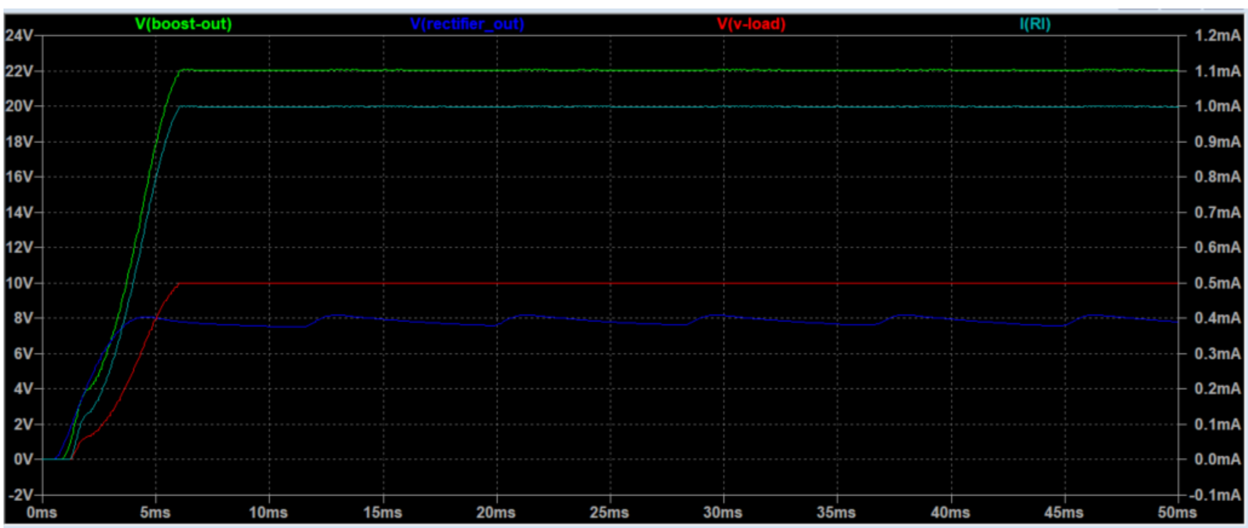
Boost topology

Below are the results from our boost topology, showing the output of our rectifier being boosted up to 22v. We also have a much smoother output on our boost topology because we implemented a zener diode to act as a voltage regulator.



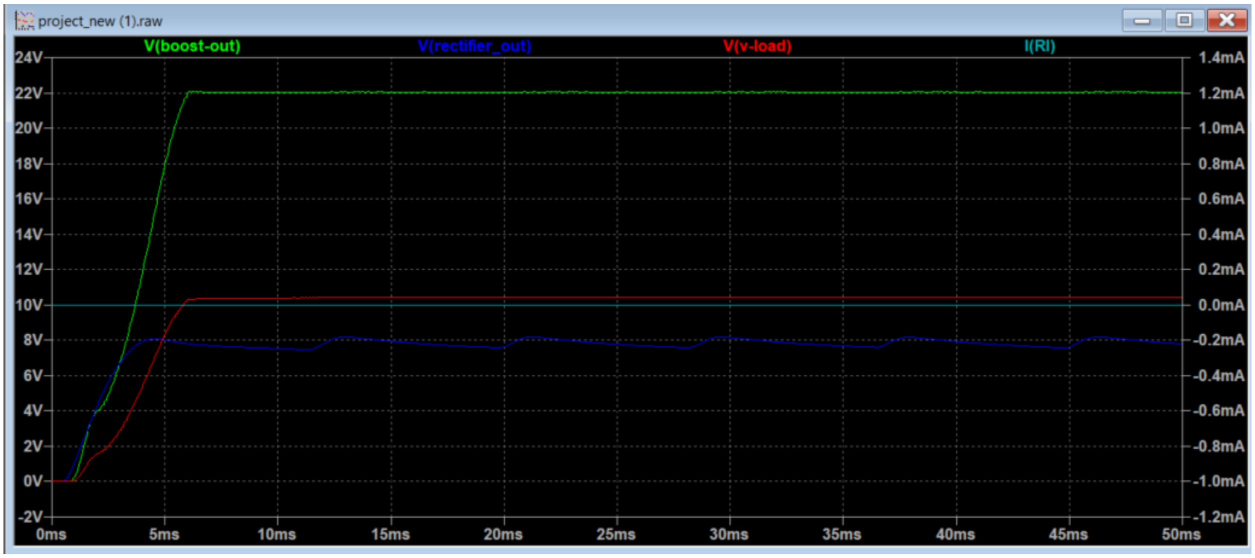
Potentiometer voltage divider

For our first simulation below we have a 10kOhm load attached to our output and we have tuned our potentiometer to produce 10v.



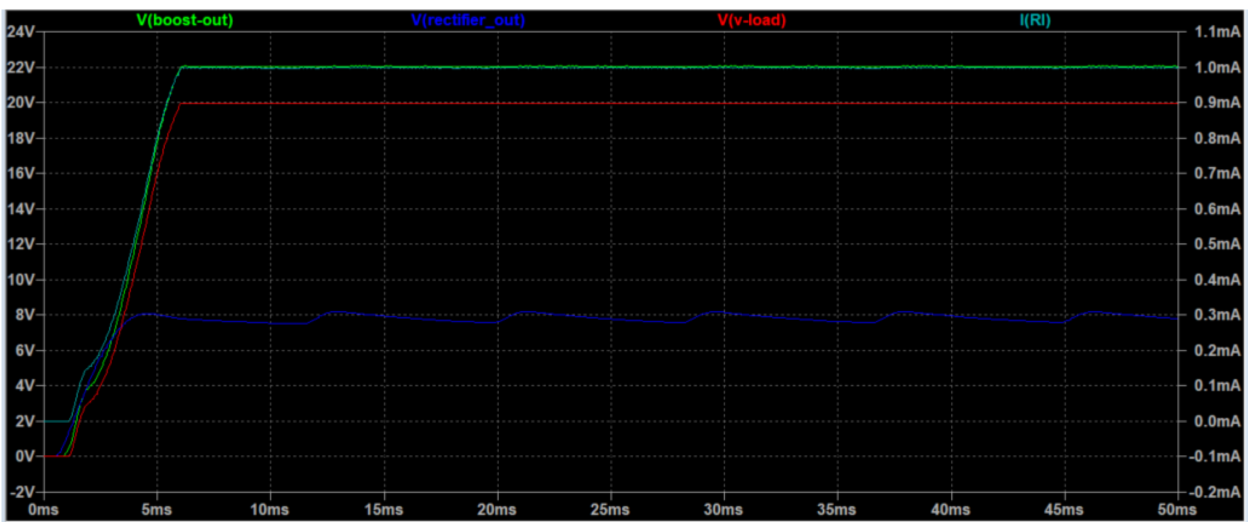
We can see that the load output voltage (shown in red) stabilizes at 10V with 20mV of ripple. Similarly, the output current (shown in teal) is capped at 1mA.

For the next simulation we have disconnected the load and kept our potentiometer tuned for 10v.



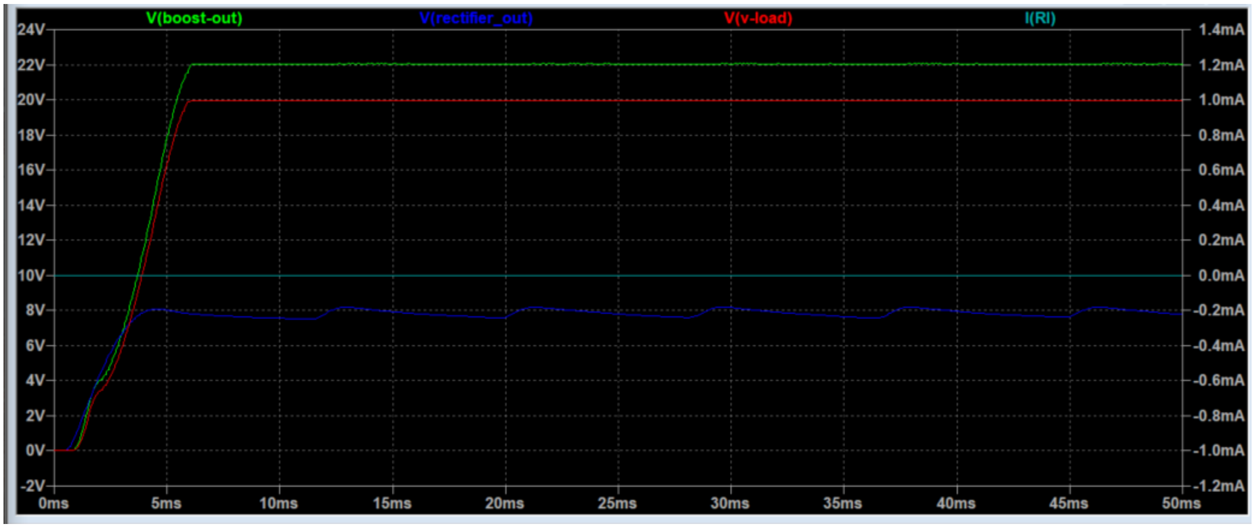
We can see that the load output voltage stabilizes around 10V, with a ripple of 20mV. Similarly, we see that the load current is zero, since it is an open circuit.

The next simulation shows our results with a 20kOhm load attached to the output after our potentiometer is tuned for 20v on the output.



We can see that our load output voltage stabilizes around 20V with a ripple of 20mV. Similarly, the load current is capped at 1mA.

The last simulation shown below shows our results with the load disconnected and our potentiometer tuned for 20v on the output.



As shown, our load output voltage stabilizes at around 20V with a ripple of 20mV. Similarly, our load current is zero since it is an open circuit.

Conclusion

This project combined all of the knowledge given to us in lecture and previous labs. Overall, we successfully created and combined a full-wave bridge rectifier, a CMOS square wave oscillator, a MOSFET-triggered boost converter, and a potentiometer voltage divider. This circuit allows us to convert a 10V sine input to a 10V-20V DC output which can deliver 0 to 1mA of current to a load. We used our knowledge of diodes and capacitive filters to create the bridge rectifier, using concepts we previously learned to attain the output ripple voltage and magnitude we desired. We then used our knowledge of CMOS and its role in logic circuits to create a square wave oscillator. We expanded our knowledge of MOSFETs and diodes to create the boost topology circuit and change its output behavior to what we desired. Finally, we created a potentiometer and voltage divider circuit to allow for the user to change the output voltage between 10V and 20V. We have created a practical circuit that could be used in a variety of different applications. This lab gave us the opportunity to create a complex circuit from the ground up, and has given us the confidence to utilize the concepts learned throughout this class in the future.