Physics 117 Lab 3: Diode properties and applications

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1. Beginning Exercises

1.1. Part A

In the opening portion of this laboratory we had to apply a Fourier transform to a 1kHz sine wave and square wave using the oscilloscope. To apply a Fourier transform we used a Waveform generator, the oscilloscope, 2 banana plugs and two splitters to wire the generator and the oscilloscope together. There circuit diagram can be seen in figure 1. Then we tuned the Waveform to send a 1kHz sine then square wave, to apply the Fourier transform we simply had to go into the math menu, set to channel 1 and then set the parameter to be a Fourier transform. The crucial part of this part was to analyze the transformed waves on the oscilloscope, what we saw was the bit by bit Sine wave combination giving us the frequency as the x axis and the y axis was the voltage. For the sine wave what we see is a single peak and noise at the bottom, for the square wave we see 1 large peak is separated by noise or nothingness until another amplitude smaller than the biggest occurs, where the other smaller peaks are octaves off of the 1kHz occurring at every point $\frac{4}{n\pi}$ away. You can see the sine and square waves in figure 2.

2. LC Resonant Circuit (3-1)

2.1. Part B

The first experiment we ran was to construct a LC resonant circuit shown in Figure 3, where specifically it causes voltage loss to a wave sent through it; but at a particular frequency related to the capacitor and inductor it has a max V_{out} which was the main component to our experiment. To construct the circuit we used a $100k\Omega$ resistor, a $.01\mu F$ Mylar Capacitor and a $10mH$

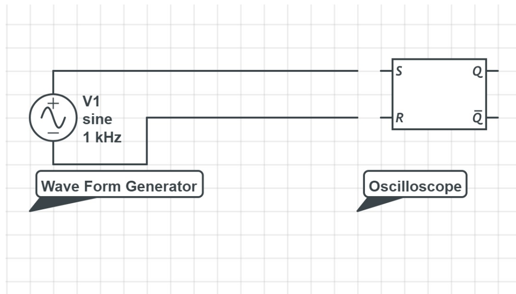

Figure 1: This simple schematic represents the connection we made between the Waveform generator and Oscilloscope

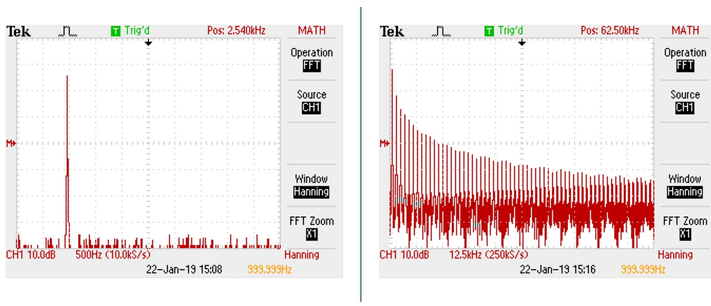

Figure 2: This figure shows the Sine and square wave, (on the left and right respectively) that have been transformed by the oscilloscopes Fourier Transform function

Inductor, as well as the Waveform generator to send varying frequency dependent voltages through the circuit, and the Oscilloscope to measure them. To mathematically find the resonant frequency we used the resonant frequency formula

$$\omega = \frac{1}{\sqrt{LC}} \qquad [1]$$

In this formula omega is equal to 2π, and L is the inductors inductance and C is the capacitance of the circuit. What this equation yields is the frequency at which the capacitor and inductor is able to acquire and dissipate charges at their max rate. For us the value we got was approximately 16kHz, though with our equipment the frequency maximized around 16.4 kHz. Which can be seen in figure 4. The next part of the lab had us do a sweep from 100Hz to 20kHz, to see the amplitude out vs frequency, this can be seen in figure 5. The graph show us what we expect a series of amplitudes that grow to the max when frequency equals 16.4 kHz and then begins to

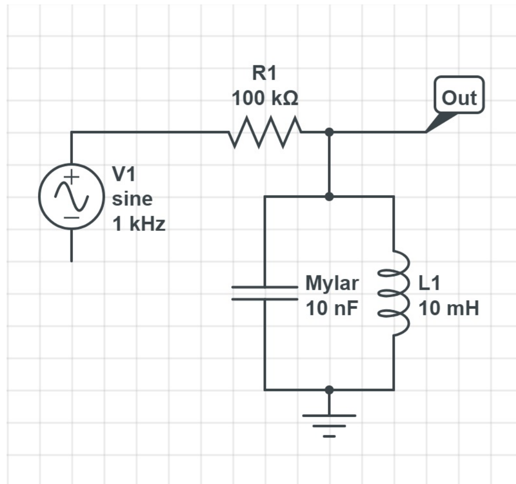

Figure 3: This Shows the circuit diagram for the LC resonant circuit

decay again in amplitude because the 16.4kHz is the resonant frequency for the circuit. As we increase the sweep rate we begin to get wiggles, these wiggles are ringing in the capacitor, so the graph after hitting resonant frequency begins to decay oddly, this is due to the Capacitor not discharging properly because once the resonant frequency is hit the capacitor becomes slow to discharge. You can see this behavior occur at around 10 microseconds of sweep time.

The next part labeled Finding Fourier Components of a Square Wave we analyzed the input waveform by then sending in square waves below the resonant frequency. The yields can bee seen in the table below,where we verify the amplitudes and frequencies of 6 terms, where the waves are separated by multiples of 3 and the voltages a factor of 2, graphs of 3 of these fundamentals can be seen in figure 6.

Frequency	max-Voltage
16.4 kHz	1.32 V
5.46 kHz	.56 V
3.28 kHz	.76 V
2.34 kHz	.436 V
1.82	.348 V
608 Hz	83.2 V

The last part of this experiment was to drive a 100 Hz square wave which can be seen as the second picture in figure 4, where the period is 59.2 microseconds and measure the resonant frequency which in this case was still the 16.4 kHz. Then we had to measure the quality factor, in this case we used equation 2

$$Q = \frac{f_r}{BandWidth} \qquad [2]$$

where f_r is the resonant frequency and the Bandwidth is the distance between the max point of power reduced by $\frac{1}{\sqrt{2}}$, where the points on the resonant frequency wave are on opposite sides of a single wave. In this case the band width we received was 620 Hz, plugging this into equation 2 we received a quality factor value of 26 which is in range of values that works.

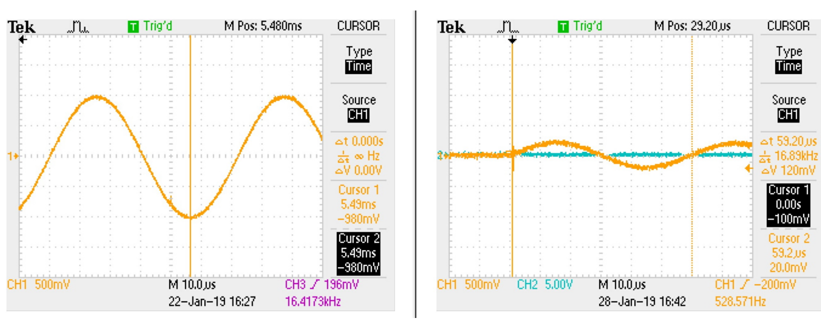

Figure 4: The first picture Shows the graph for the 16.4 kHz frequency going through the LC circuit, the other is the 100Hz square wave

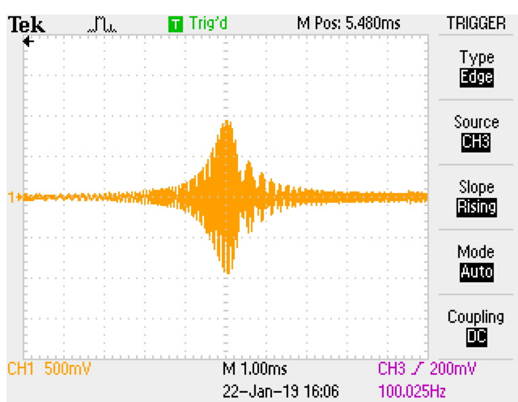

Figure 5: This figure shows the LC circuit going through a sweep showing amplitudes vs frequency

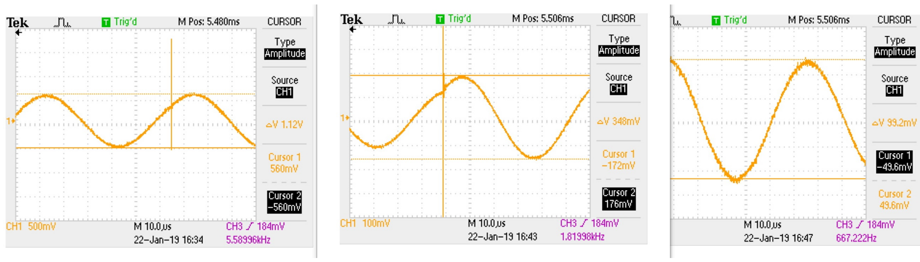

Figure 6: This figure shows the LC circuit going through various resonant frequencies below 16.4kHz

3. Half-Wave Rectifier (3-2)

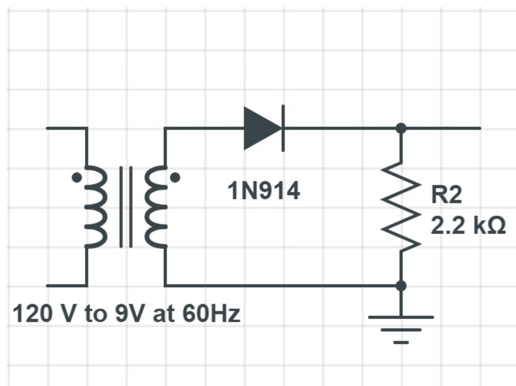

Figure 7: This figure shows the circuit diagram for the half wave rectifier

3.1. Part C

The next part of the lab was to construct a half-wave rectifier shown in figure 7. To build this we need a transformer that sends Ac to 9 Volts, then a 1N914 diode, and a 2.2 $k\Omega$ resistor. We are asked to measure this with the oscilloscope which is shown in figure 8 and if it is what we expect, the answer is yes. The reason we expect this is that the diode filters the amplitude to only allow positive polarities to flow through its anode and out its cathode, we are asked what the polarity of the diode is, in this case the in the diagram the arrow and bar representing the diode, the tip of the arrow and bar represent the positive cathode and the back of the arrow is the negative cathode. We are asked why the peak voltage is above the 9 Volts advertised on the transformer, the reason why is that the transformers typically allow more voltages to pass through, so it over preforms and gives us a larger voltage.

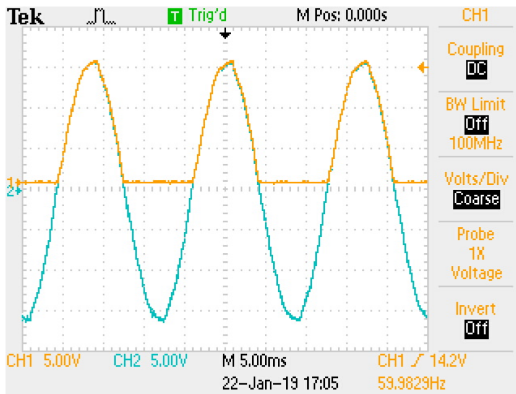

Figure 8: This figure shows how the half wave rectifier forces the wave to a single polarity

4. Full-wave Bridge Rectifier (3-3)

4.1. Part D

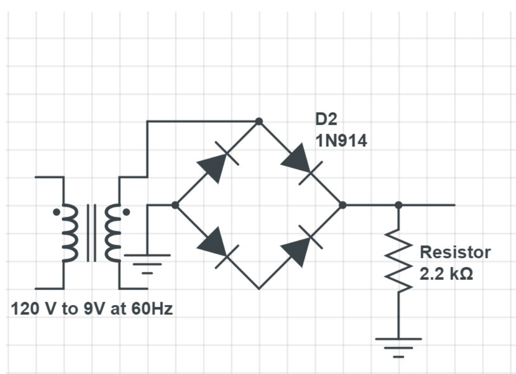

Figure 9: This shows the circuit diagram for a full wave rectifier

The next part of the experiment had us create a full wave rectifier shown in figure 9 and the output on the oscilloscope in figure 10. The full wave rectifier is like the half wave but includes two more 1N914 diodes that capture the negative component of the waves that pass through it. We are asked if the waves we received made sense in this case the diodes on the top half are filters for the positive polarities and the junction at the bottom of the

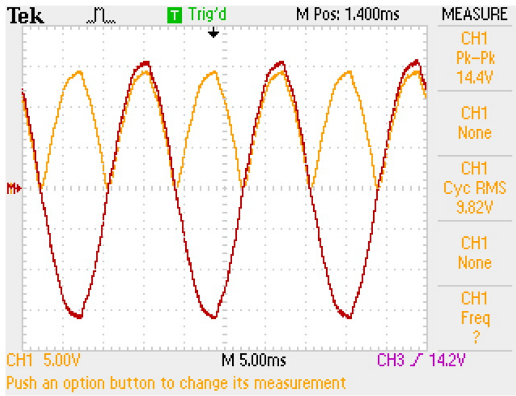

Figure 10: This shows the full wave rectifier where the red bar shows the addition of the two channels contains the positive polarity wave and the other the negative polarity of the wave

4 diodes in the figure are the ones that filter the negative polarities out for the top one and into the circuit for the bottom one. So the ones that filter negative polarities gives negative amplitudes of the waves sent through and same for diodes that filter the positive, that is why the addition of both parts using the oscilloscope yields a full wave with amplitudes going to positive to negative. Basically this can be seen as 2 half wave rectifiers for the positive and negative polarities of waves sent through the circuit. We are asked why this circuits amplitude is less than the last circuit, the reason why is that the diodes require .6 Volts to cross for 1 and in the last circuit we had two and we have doubled that causing the voltage to shift slightly down, the voltage should be raised by 1.2 voltage to match the last circuit and another 1.2 to have the initial voltage be 15.6 Volts which the circuit receives. We are asked what would happen if we reversed 1 of the diodes, since we could not test, theoretically the diodes would cause either the negative or positive polarities to build on a side of the rectifier depending on which diode you flip and then it would burn the diodes out breaking the rectifiers functionality. We are then asked if diodes break open or closed, the answer is closed since a burnt diode becomes a wire. We are then asked why do the diodes die in pairs. In this case the reason they die in pairs is that the current flows through 2 diodes at a time, the ones parallel to another filter the same polarity, so when one dies the other has to compensate and dies as a result, so the diodes break in pairs. The last aspect of the diode we needed to look at was at regions close to 0 volts there are flat regions we need to explain them and find their

duration. These areas would typically last 320 microseconds, the reason they exist is that when the wave is below .6 Volts it cannot travel through the diode as it can't beat its polarity but is trying causing the output to be flat till the wave achieves higher voltages.

4.2. Part E: Light Emitting Diodes (LED)

The next part of the experiment had us replace the Diodes with LED, this is shown in figure 11 as well as what is supposed to happen, the circuit still follows the design of figure 9. We are asked to set our signal generator to .5Hz through the circuit as well as removing the waveform generators ground from the world ground. This lead to us seeing two diodes, specifically the ones parallel to one another, to light up in pairs when the current was moving through them in the circuit, the two diodes lighting in pair can be seen in figure 11 where both pairs of the diodes are featured.

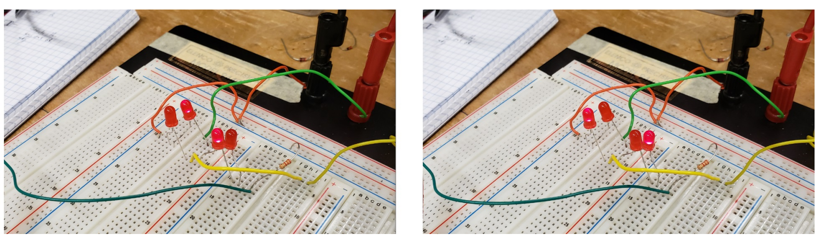

Figure 11: LED replacing diodes in full wave rectifier, lighting up when power is running through the respectively

5. Ripple (3-4)

5.1. Part F

The next section had us analyze the ripple of the full wave rectifier with the addition of a capacitor that goes to ground, which can be seen in figure 12. The capacitor we connect is a $15\mu F$ filter capacitor across the output. We are asked if the output makes sense, which it does, it shows the combined rectified wave charging the capacitor to a high voltage from which it dissipates from which can be seen in figure 13. We found that the ripple lasted 6.3 milliseconds and had a voltage of 11.4 Volts. We are asked to place a $500\mu F$ capacitor instead of the 15 when we do this the ripple becomes a practically a flat line which can be seen in figure 14.

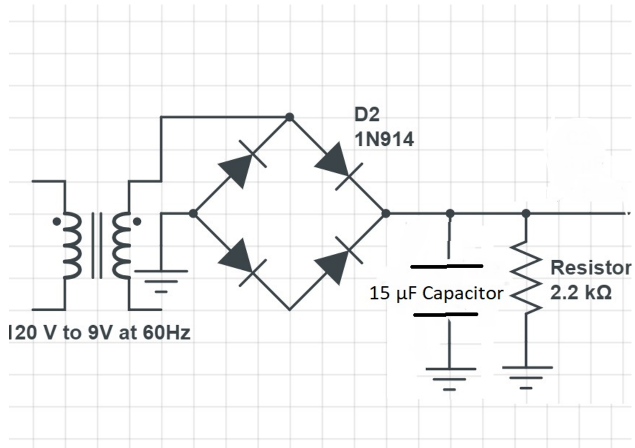

Figure 12: This shows the circuit diagram for the ripple, adding a capacitor to full wave rectifier.

6. Signal Diodes (3-5)

6.1. Part G

The next section has us create a rectified differentiator, which basically means adding a IN914 diode a 2.2 $k\Omega$ resistor before the output of a high pass circuit constructed with a 560 pF capacitor and 1 $k\Omega$ resistor which can be seen in figure 15. We are asked to drive a 10 kHz square wave through the circuit at the maximum amplitude. We are asked to show both channel output of Signal generator and output wave it is shown in figure 16, we are also asked if it makes sense, which it does as it basically differentiates the square wave inputted but only the positive polarity components of the inputted wave. We are then asked to remove the 2.2 $k\Omega$ resistor from the output and see what occurs, as shown in figure 17. What is occurring in the figure is that the capacitor is discharging, the reason why is that load becomes the oscilloscopes resistance, which in this case is 1 $M\Omega$ changing the RC time, which the resistance was 2.2 kOhms multiplied by 15 μF capacitor which lead to an RC time of 30 sec, the 1 MegaOhm resistor is causes it to have and RC time of .06 seconds which causes this discharge tail when differentiating since the capacitor has way less time to properly function. The last thing we are asked to do is change the direction of the diode in the circuit, which we did inevitably causing the peaks to occur in the negative regions rather than positive.

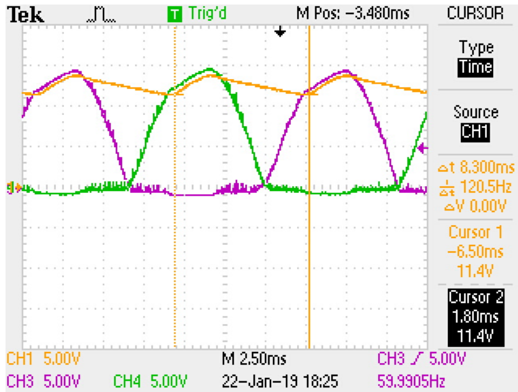

Figure 13: This shows the ripple output on the yellow bar, after leaving the full wave rectifier, the drag down is the capacitor dissipating

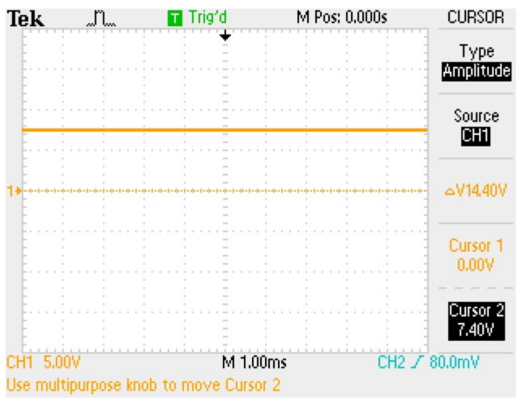

Figure 14: This shows the ripple when a very large capacitor is placed, basically creating a DC voltage

7. Diode Clamp (3-6)

7.1. Part H

The next section we had to do had us create a Diode Clamp shown in figure 18 consisting of a 1 kOhm resistor, IN914 diode and a DC voltage supplier, putting 5 volts on the cathode of the diode. We are asked to drive a 1kHz sine wave from the function generator through the circuit at maximum amplitude. What we see is the top part of the voltage being removed because the DC voltage applied to the Cathode of the diode causes it to have a high impedance. This can be seen in figure 19. The diode also has a non-zero impedance which causes the top part of the wave to not be completely flat

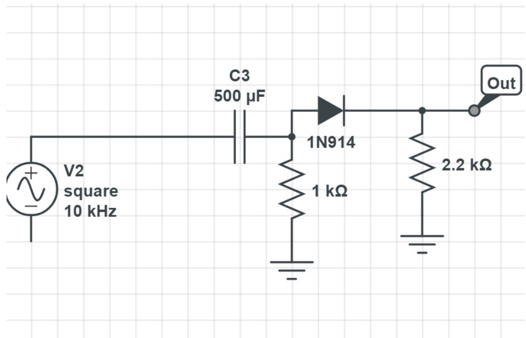

Figure 15: This shows the circuit diagram for the rectified high pass filter

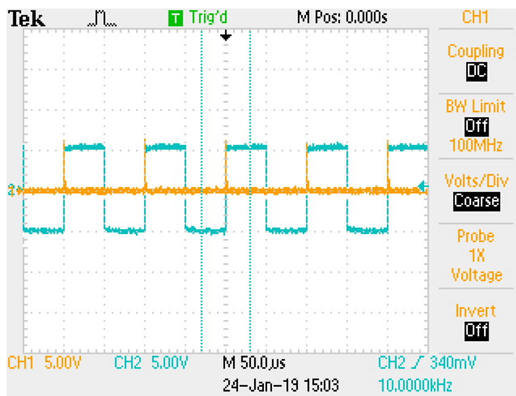

Figure 16: This shows the rectified differentiator output

which can be seen in figure 20.

8. Diode Limiter (3-7)

8.1. Part I

The last textbook experiment we conducted was constructing the Diode limiter which is the Diode clamp but with an extra diode to the output but flipped and no DC current at all, shown in figure 21. We are then asked to drive it with sines, triangles and square waves of various amplitudes and describe what it does and a possible use. We show the driven waves in figure 22, these figures make sense for what is occurring is the diodes own voltage is used as the source of impedance across the diode, for both the negative and positive polarities themselves, basically then creating a dual voltage clamp capturing the positive and negative polarities in the clamp so a wave with

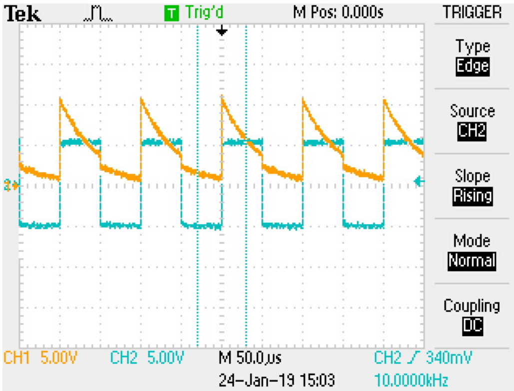

Figure 17: This shows the differentitor without the 2.2 $k\Omega$ resistor

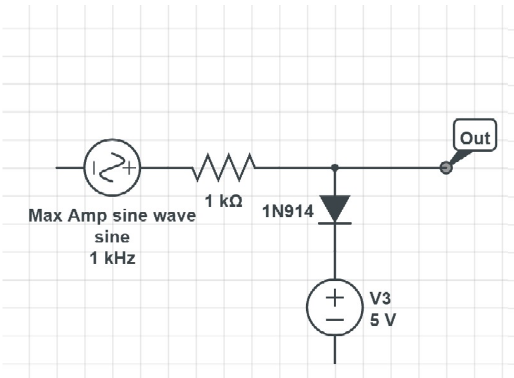

Figure 18: This shows the circuit diagram the Diode Clamp

the top and bottom amplitudes are cut are passed through. We are lastly asked for a possible use, in another laboratory for Solid State physics, we had a circuit to measure the voltages across a particular compound, in the circuit the Diode limiter was used as a way to make sure that stray current was caught and then unable to effect the results.

9. Testing Scope Probe

9.1. Part J

This section is devoted to testing the Scope probe by simply reading a voltage measurement. The circuit we constructed shown in figure 23, had a 15V DC power supply power which ran across 2 10 kΩ resistors to a ground we then used the probe to measure between the resistors. The resultant

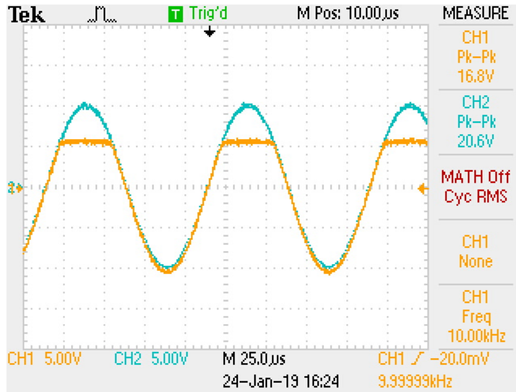

Figure 19: This figure shows the diode clamp chopping the head off and shifting the sine wave

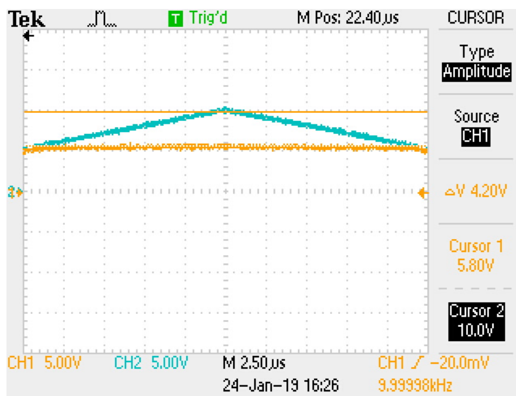

Figure 20: This shows slight non flatness of the inputted wave to the diode clamp showing the diode has resistance

voltage we received on the 1x attenuation on the scope probe was 7.5 Volts consistent with what we would expect with this simple circuit half the voltage across 1 resistor. We then used the 10x switch on the scope probe which read .75 Volts till we attuned the Oscilloscope to have 10x readings making it 7.5 Volts again consistent with what would predict. You can see the figure for our Scope Probe output on figure 26.

10. Zener Diodes

10.1. Part K

The last part of our experiment was to check weather or not a diode was a Zener diode. The difference between a regular diode and Zener diode is that

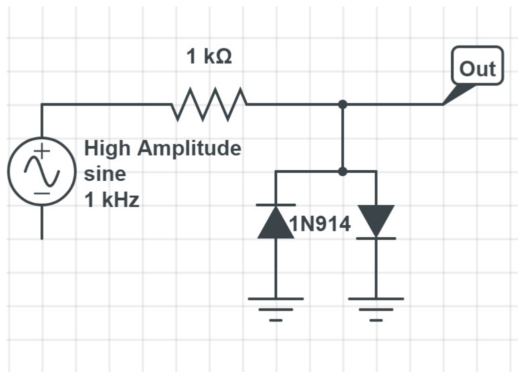

Figure 21: This shows the circuit diagram for the Diode limiter

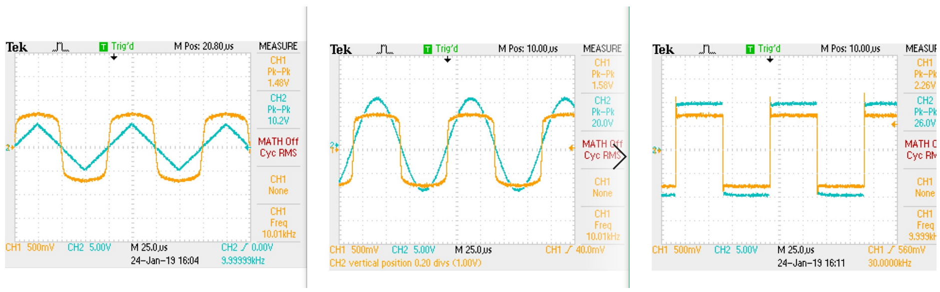

Figure 22: This shows the triangle, sine, and square waves through the Diode limiter respectively

the impedance cut off for the cathode of the circuit begins at -3.6 Volts rather than an incredibly high voltage. So applying the Zener diode instead of a regular diode in our Diode Clamp experiment would give us results similar to our Diode limiter as the DC current can actually run across the diode and chops the bottom part of wave inputted while the regular top is chopped as the wave tries to travel through the diode, the circuit is shown in figure 24 and resulting waveform is in figure 25.

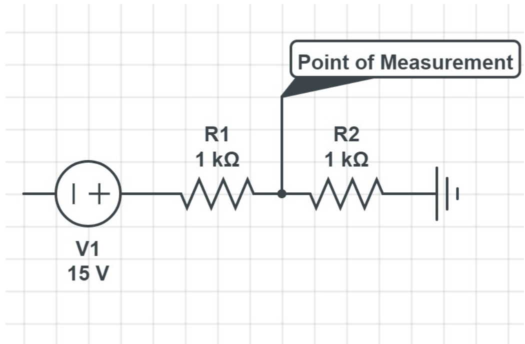

Figure 23: This shows the simple circuit we used the scope probe to measure on

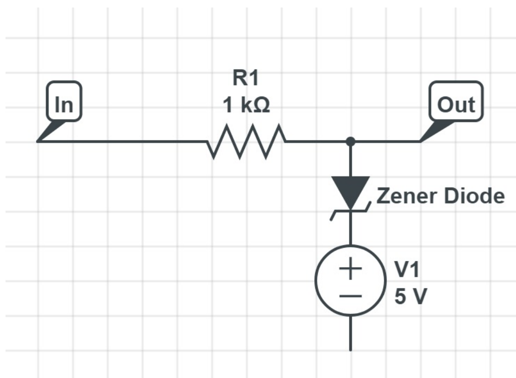

Figure 24: This shows the Zener Diode replacing the regular diode in the Diode clamp basically creating a hed waveform where both the top and bottom are cut like the Diode limiter

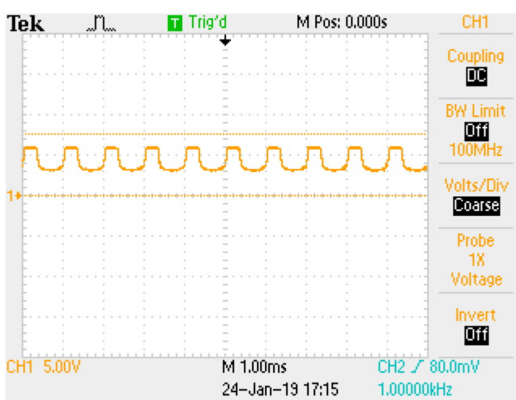

Figure 25: This shows the output of a regular diode clamp circuit with Zener diode

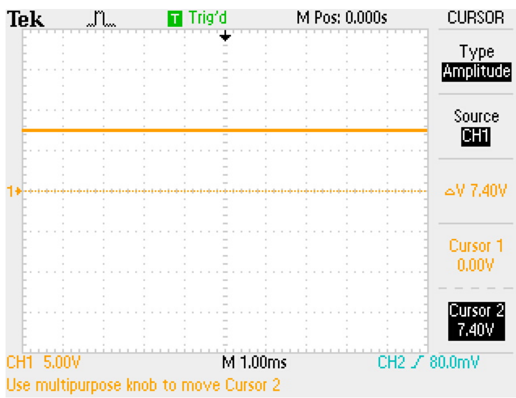

Figure 26: output of a Scope probe reading a Voltage divider, getting a reading of 7.4 Volts in range of our 7.5 volts