Lab Report

Natural Science Laboratory

Signal and System Lab

Experiment 2: RLC-Circuits - Transient Response

Fall Semester 2020

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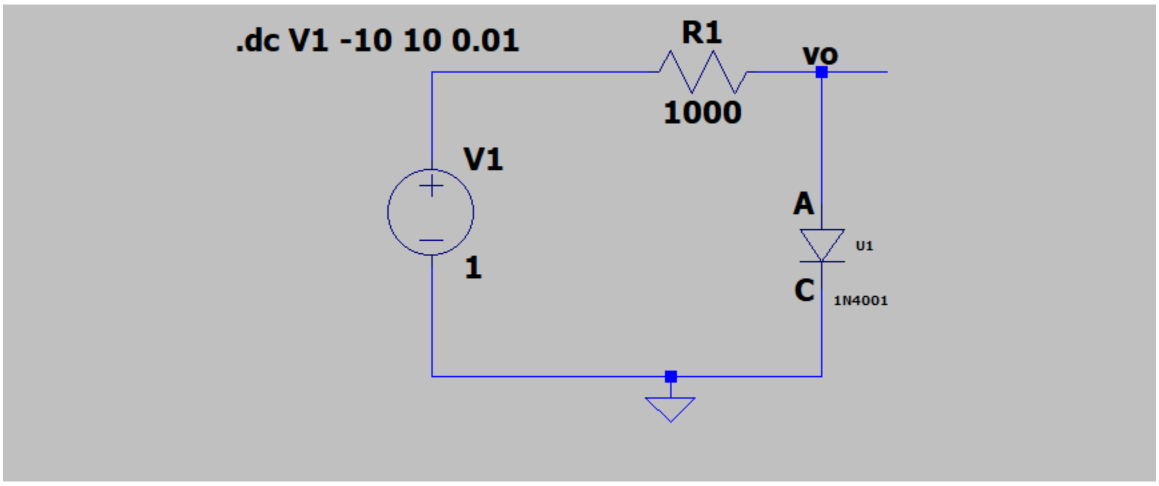
Date of Experiment: 21st October 2020

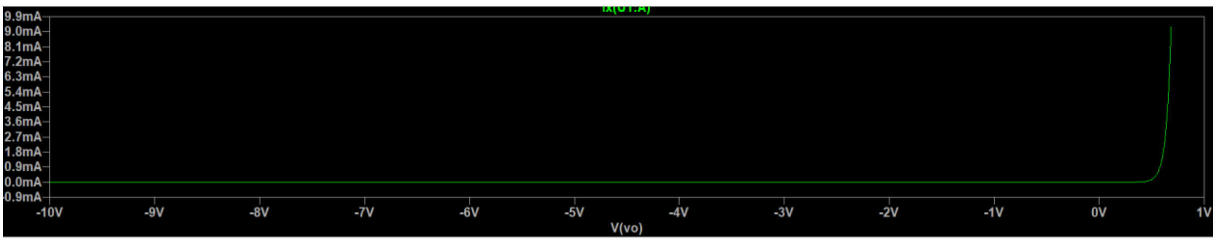
Date of Submission:

5.2 Prelab Diodes

Problem 1:

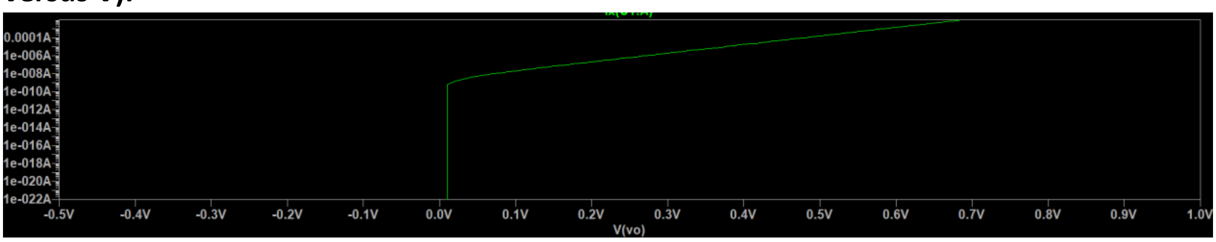
Plot the forward diode current I versus the diode voltage V using a linear scale.





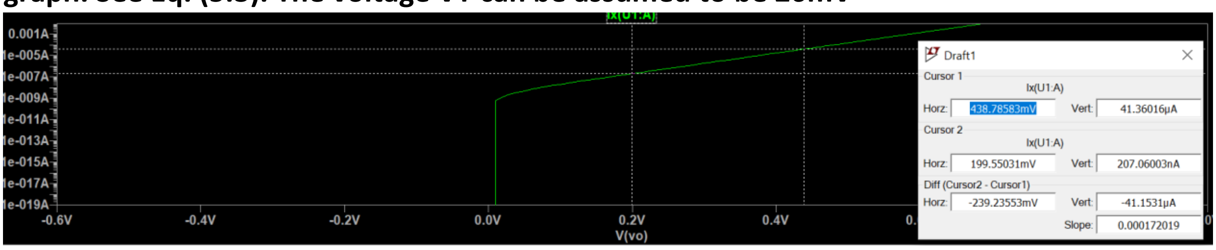
Problem 2:

Plot the forward diode current I versus the diode voltage V using a semi log plot (log (I) versus V).



Problem 3

Extract the values of ideality or diode factor, n, and the saturation current Is from the graph. See Eq. (5.3). The voltage VT can be assumed to be 26mV



Using equation 5.3

$$I = I_s\left(e^{\frac{V}{nV_T}} - 1\right)$$

$$\ln(I) = \ln(I_s) + \frac{V}{nV_T}$$

$$\ln(41.3 \times 10^{-6}) = \ln(I_s) + \frac{438.78 \times 10^{-3}}{n \times 26 \times 10^{-3}} \quad ------\rightarrow 1$$

$$\ln(207.06 \times 10^{-9}) = \ln(I_s) + \frac{199.6 \times 10^{-3}}{n \times 26 \times 10^{-3}} \quad ------\rightarrow 2$$

$$n = 1.737$$

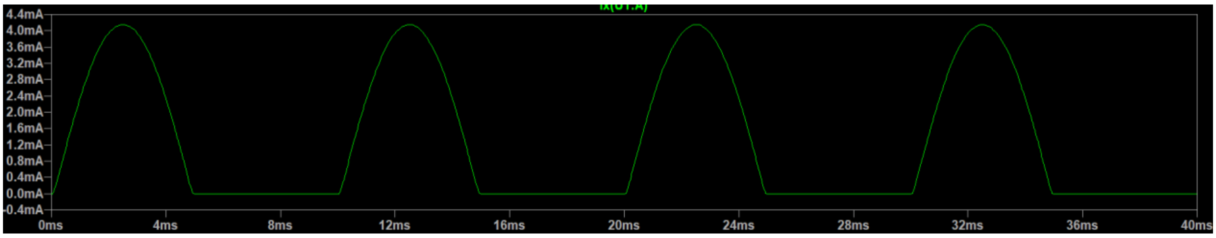
$$I_s = 2.5 \times 10^{-12}$$

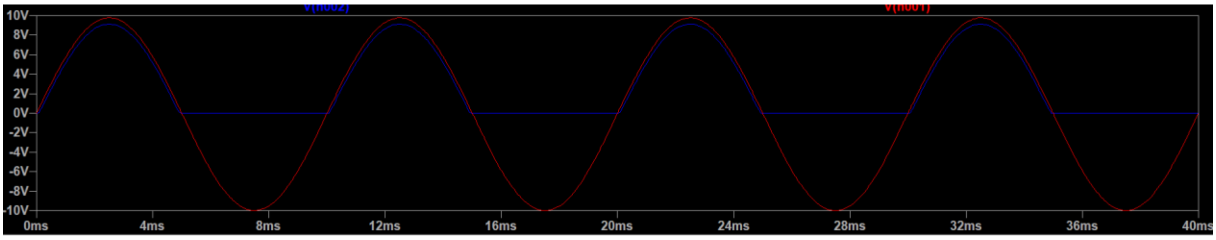
5.2.2

Problem 1

Simulate the circuit without C1. Plot U L, Vin and I D.

V in red,u_l in blue,I_D in green





Problem 2

Measure the peak voltage at R L and the peak current I D. (Use the cursors from the LTSpice display)

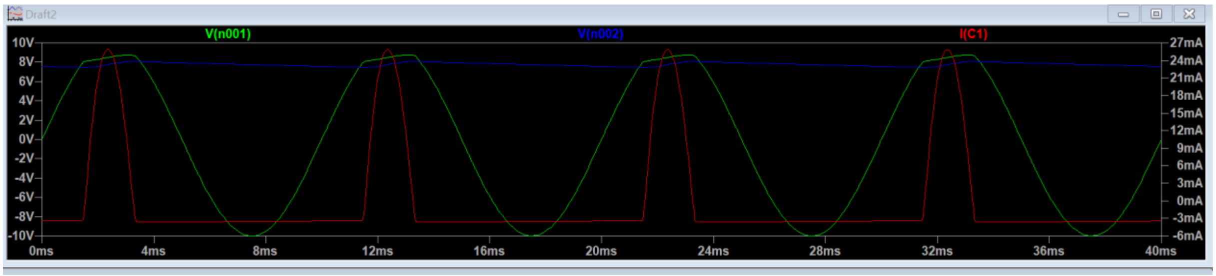
Peak voltage=9.1273345V

Max current=4.1470745mA

Problem 3

Simulate the circuit with the capacitor C1 connected. Plot U L, Vin and I D.

Green: V_in, Blue: U_L, Red: I_D



Problem 4

Measure the peak voltage and the peak current

Peak current 25.838595mA

Peak voltage 8.7219701V

Problem 5

Measure the ripple of the voltage at the load resistor. Use the formula from the handout to calculate the ripple value. Compare!

$$V_r = \frac{V_p}{fCR_L}\left(1 - \sqrt[4]{\frac{R_i}{R_l}}\right)$$

$$V_r = 0.51599$$

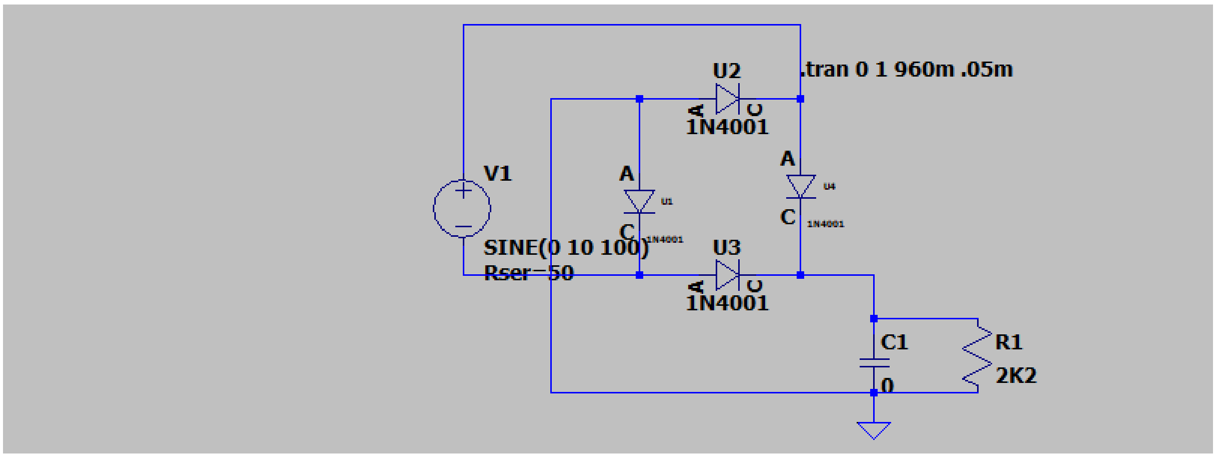
Graph Val=0.597565

The two obtained values are very close to each other. Therefore, the formula proves to be precise.

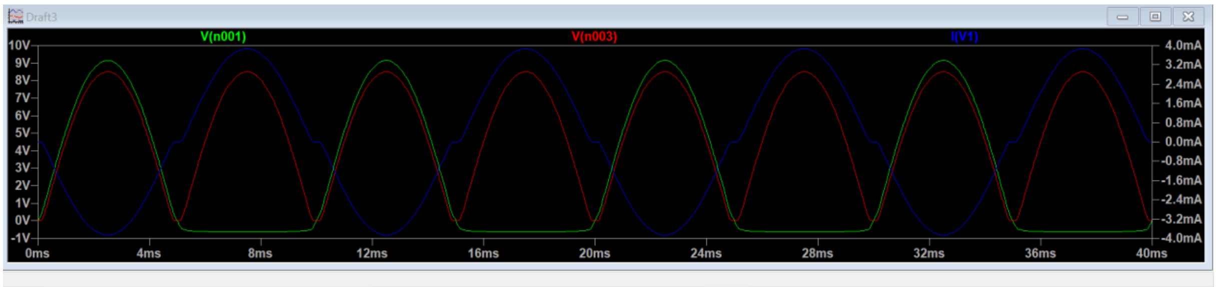
5.2.3

Problem 1

Simulate the circuit without C1. Plot U L, Vin and I D



Green: V_in, Blue: I_D, Red: U_L



Problem 2

Measure the peak voltage at R L and the peak current I D. (Use the cursors from the LTSpice display)

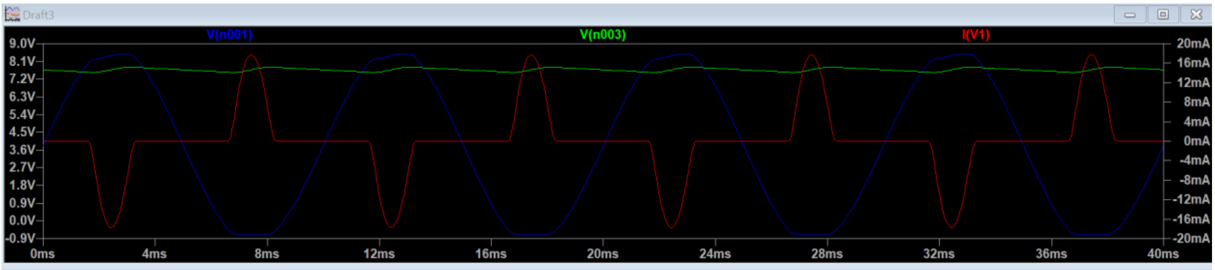
Current 3.8617445mA

Voltage = 8.5029327V

Problem 3

Simulate the circuit with the capacitor C1 connected. Plot U L, Vin and I D.

Green: U_L, Blue: V_in, Red: I_D



Problem 4

Measure the peak voltage and the peak current.

8.4773796V

17.711912mA

Problem 5

Measure the ripple of the voltage at the load resistor. Use the zoom to improve the accuracy. Use the formula from the handout to calculate the ripple value and compare!

$$\boldsymbol{V_r = \frac{V_p}{2fCR_L}\left(1 - \sqrt[4]{\frac{R_i}{R_l}}\right)}$$

$$\boldsymbol{V_r = 0.251V}$$

Graph value is 0.256V

The two obtained values are very close to each other. Therefore, the formula proves to be precise. The full wave rectifies ripple voltages.

5.2.4

Problem 1

What are the maximum peak voltages at the load for each rectifier? Why are these values different from the input sine amplitude? Why is there a difference between half- and full-wave rectifier?

The maximum values are 9.127V and 8.172V

for half-wave rectifier and the full-wave rectifier respectively. They are different due to voltage drop across the diodes. There is a difference because only one diode is conducting in half wave rectifier while in full wave rectifier, there are two diodes conducting at a time.

Problem 2

Explain the differences of the current I D for all cases. What is the consequence for the used diode in a rectifier circuit?

Rectifier: (Without capacitor) 4.1470745mA & 3.86mA

If we don't have any capacitor in the circuit, then it is possible to understand the behavior of the half-wave rectifier. When the AC source is at its positive part of cycle, the diode is in forward biased state, and when the source is at its negative cycle, the diode is in the reverse biased state. The output follows the formula: V(R_L)= i*R.

Rectifier: (With capacitor) 25.838595mA & 17.711912mA

By adding the capacitor, we were able to achieve somehow (non-perfect) DC current. At positive cycle, the capacitor charges and after it reaches the maximum value. When the Ac goes into negative cycle, the capacitor starts discharging providing energy to the load resistor. Current flows when the voltage behind the diode is higher than that of capacitor. Since the capacitor has to charge, the current through diode is higher. The current peak is higher in both the cases of full and half wave rectifier. To compensate this, we have to use a diode which can conduct higher current than AC pk-pk and the load. Capacitor keep the current more or less steady and helps us to get smoother DC output and reducing violent ripple changes.

Problem 3

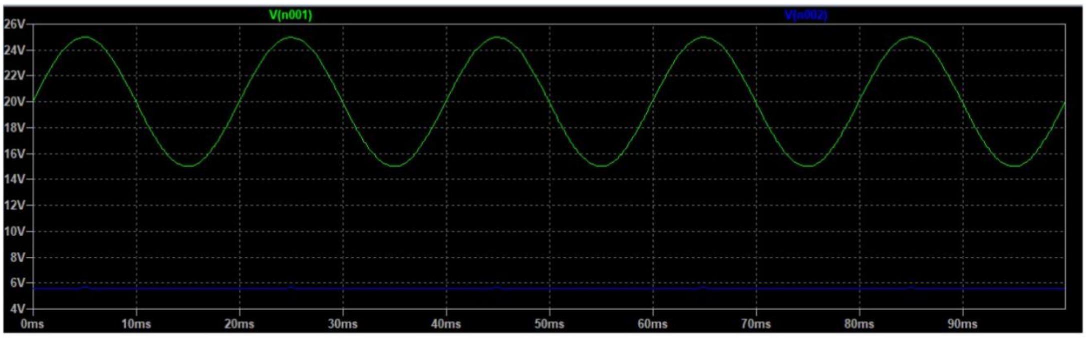
What is the influence of the ratio C ∗ RL to the quality of the output DC?

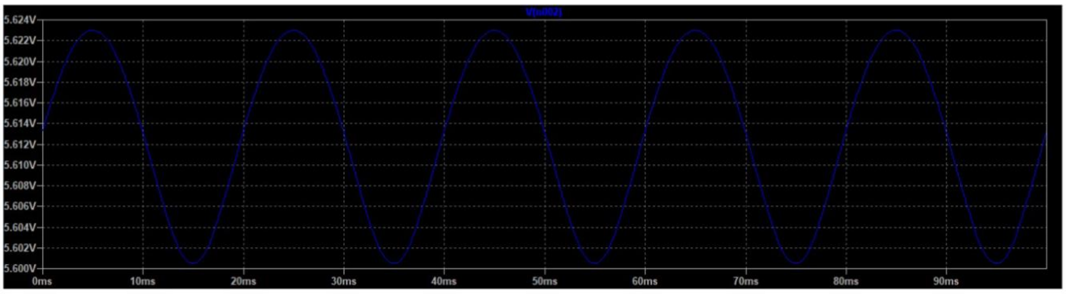
This formula represents the ripple voltages and our aim is to reduce these ones as much as possible in order to obtain smoother outputs that we can consider as DC. As seen from the formula, the greater the values of C*RL, the smaller the Vr, producing a smoother DC at the output. That is because this ratio is time constant of the capacitor discharge and greater it is, the slower the capacitor discharges through the load, avoiding violent falling slopes. Ripple depends on discharge time of Capacitor

5.2.5

Problem 1

Perform a transient analysis (5 cycles of the sinusoidal input). Plot the input voltage (DC + AC voltage) and the output voltage across the load resistor RL.





Problem 2

Explain the operation of the circuit

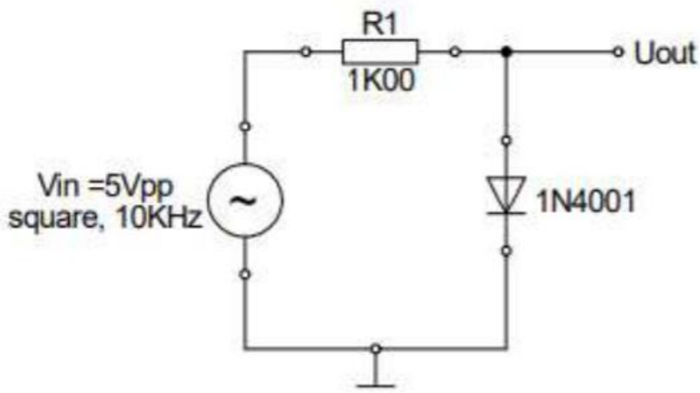
The circuit is a voltage regulator. When the voltage that comes from the source minus the voltage drop in resistor R1 is higher than the breakdown voltage, the Zener Diode will regulate the voltage at the output. For example, if the source is increased, then more current will be supplied to the output; however, the Zener diode will draw that extra current with just an irrelevant increase in its voltage; leaving the resistor obtaining almost the same current and maintaining its voltage constant. The opposite behavior occurs in the diode when the voltage source is decreased. In this case, the Zener diode draw less current and let more current pass to the resistor to keep the voltage at the output constant. Because of differential resistance being significantly smaller than the limiting resistance R1, which also ensures that the diode does not burn out.

5.3.1 Execution

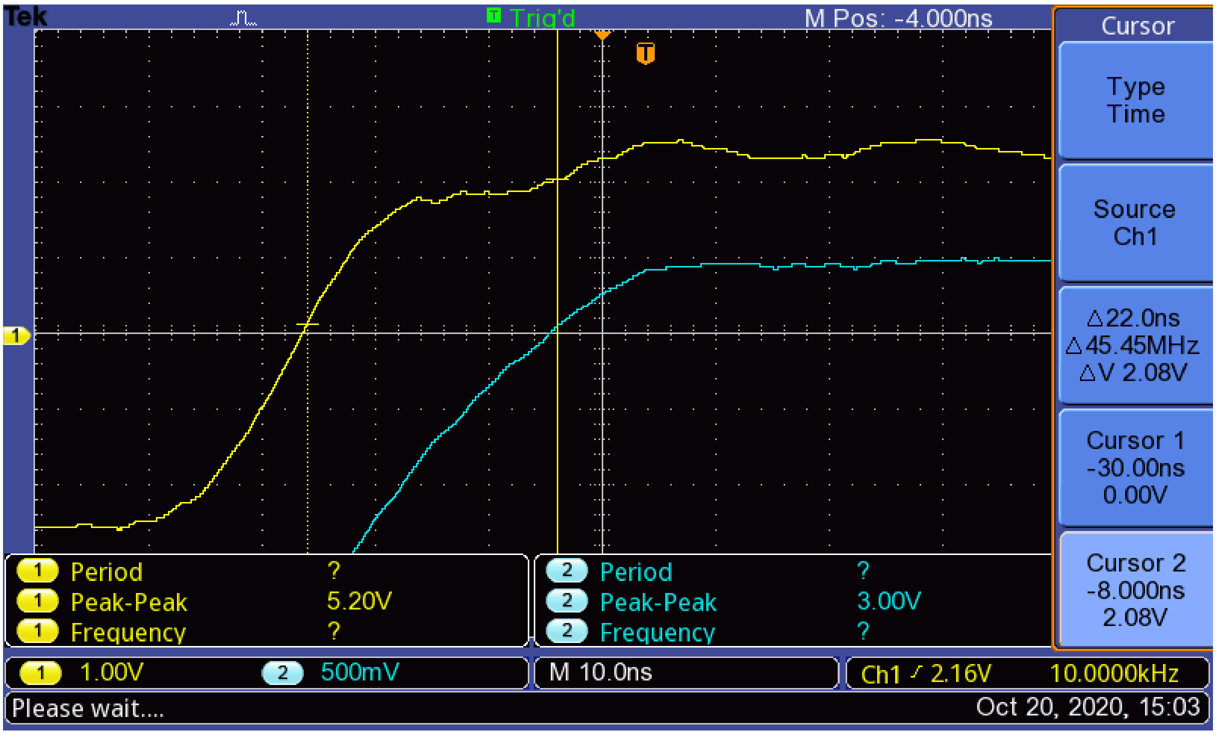
Devices Used:

Devices Used:

- Oscilloscope
- BNC cable
- Signal Generator
- Diodes (1N4001, 1N4148), Zener Diode (BZX85C5V6)
- Resistor (2K2 Ω, 1K Ω)
- Capacitor (47$\mu\mu\mu\mu$)

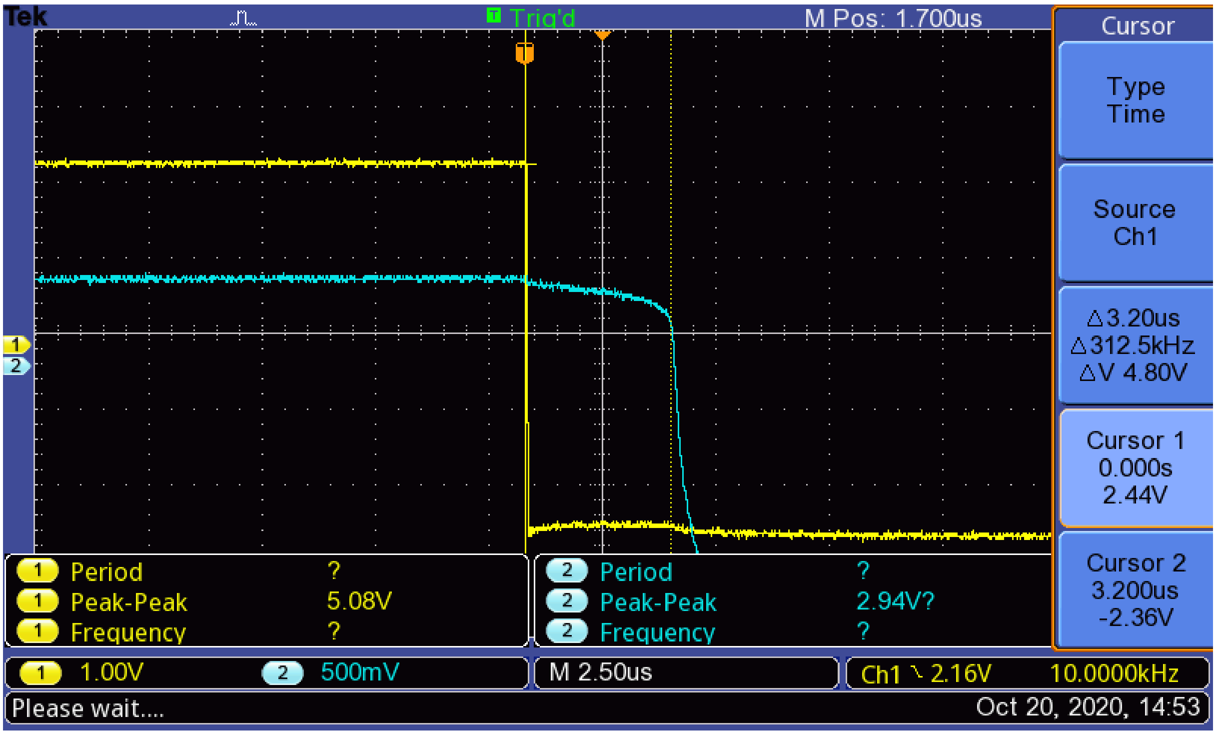


1.



Using cursors, we measure t_d = 22ns

2.



Similar way as above, we measure t_s= 3.20 µs

3.

Replacing 1N4001 rectifier diode by a 1N4148 signal diode and repeating t_s

t_s= 11.40 ns

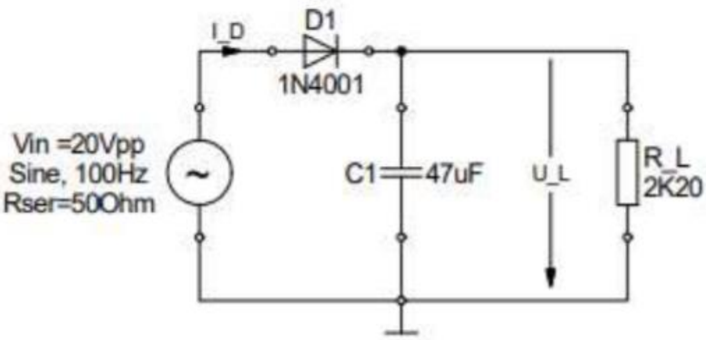
Compare the two storage times. What is the reason why the diodes needs that long time to switch off?

Ans: The diodes need such a long time to turn of because of the stored carriers inside them. Then, this charge takes some time to be compensated for by the reverse voltage, which then would form the depletion zone and block the reverse current from flowing.

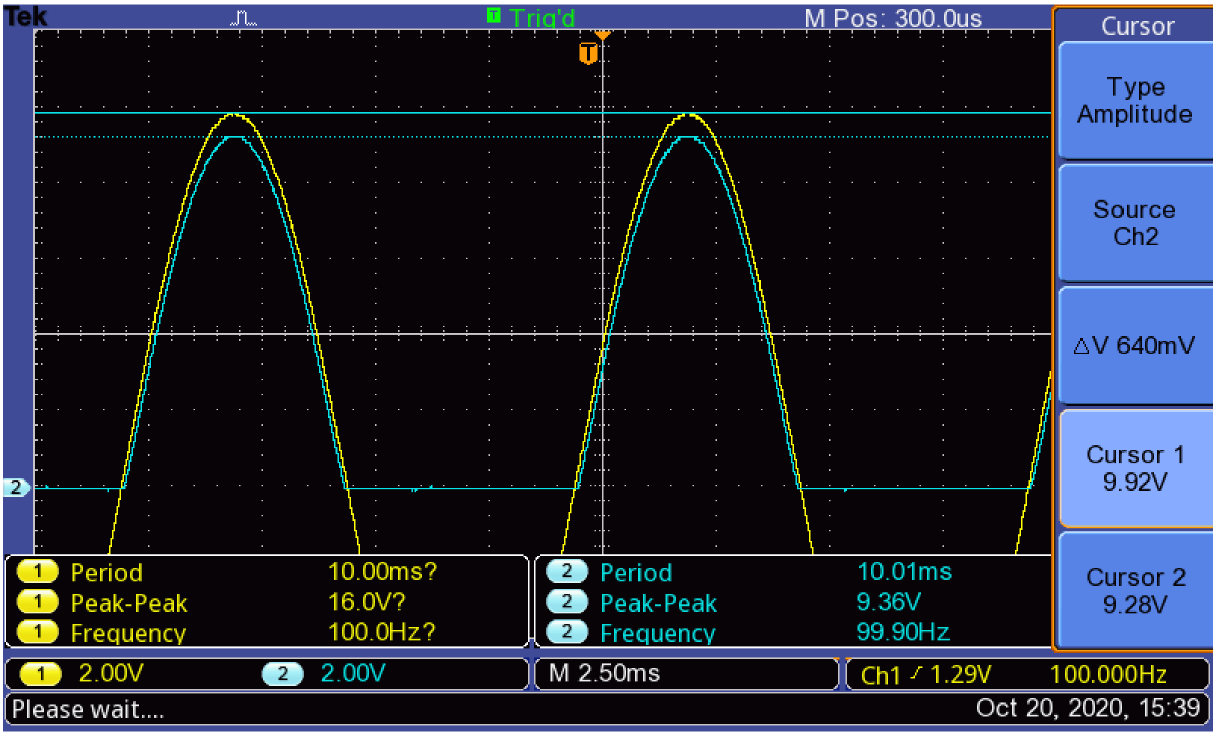
What are the consequences for using these diodes in different applications? Think of the AM demodulation experiment when using several 100KHZ!

Ans: When we use 1N4001 diode, it has a switch off time of 4.36us, which is just under the half of the wave length of a100kHz signal. It means that augmenting the frequency just three-folds, the diode will not get enough time to completely recover and will behave like a capacitor. Making it unable to properly rectify high frequency signals. When the 1N4148 diode will not have any problems with signals that reach up to MHz range due to its very short recovery time.

4.

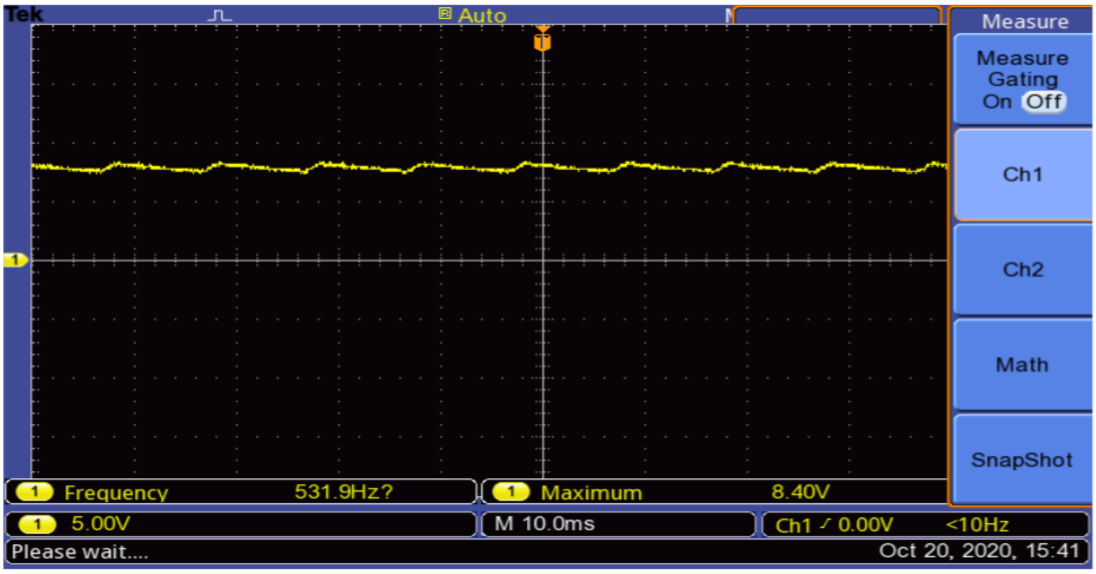


Take a hard copy of the output voltage across R L if C1 is removed from the circuit. Measure the peak voltage.



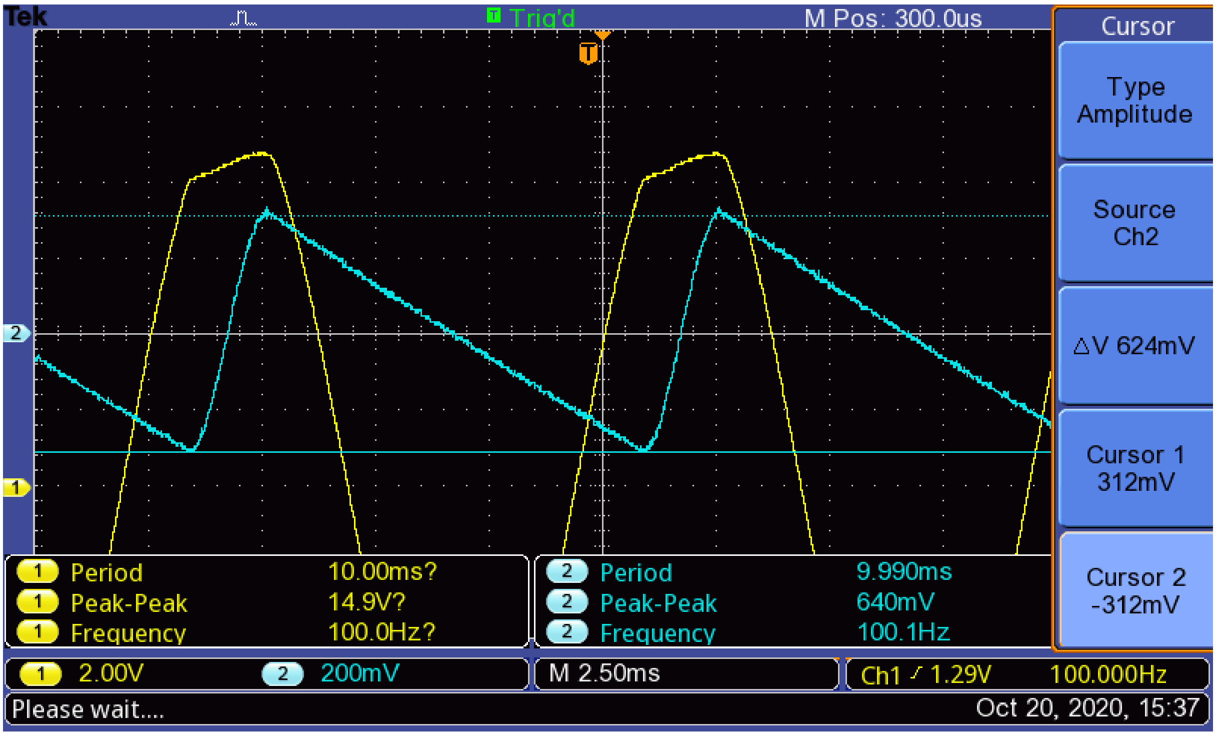
Peak voltage 9.36V

Take a hard copy of the output voltage across R L with C1 connected. Measure the peak voltage of the output



Peak voltage=8.40V

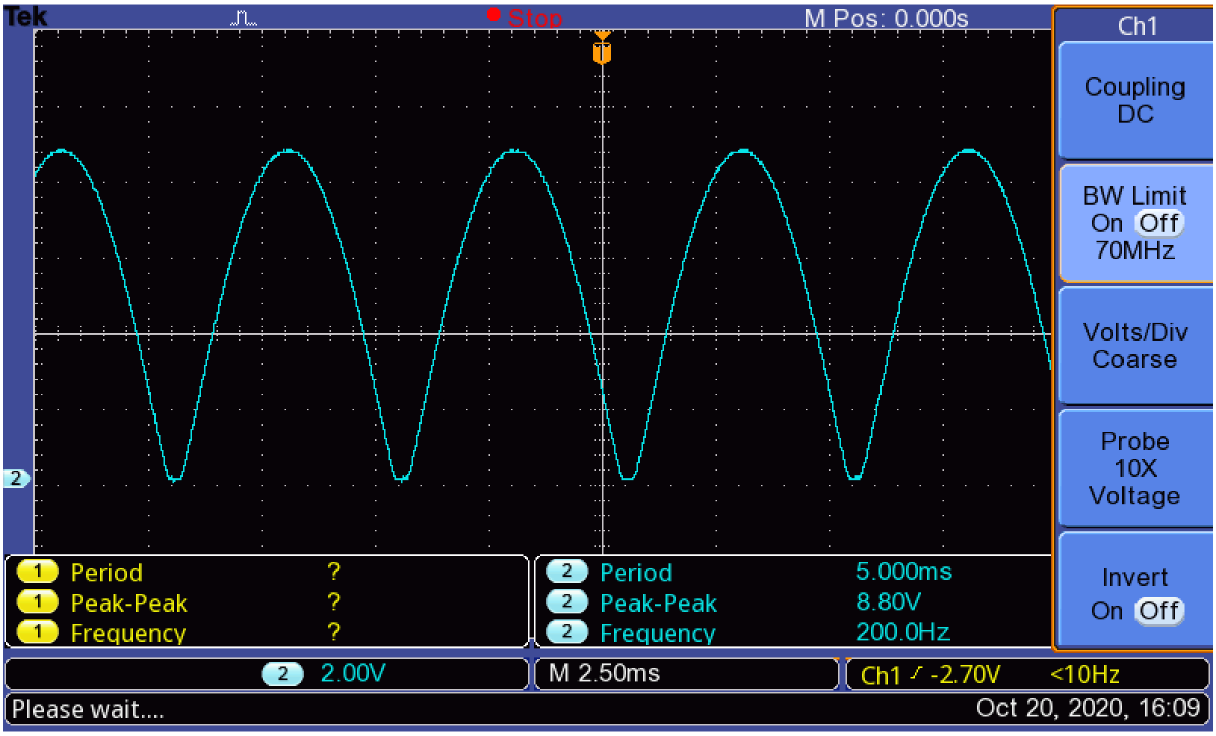
Expand the ripple voltage. Take a hard copy and measure the peak to peak voltage of the ripple.



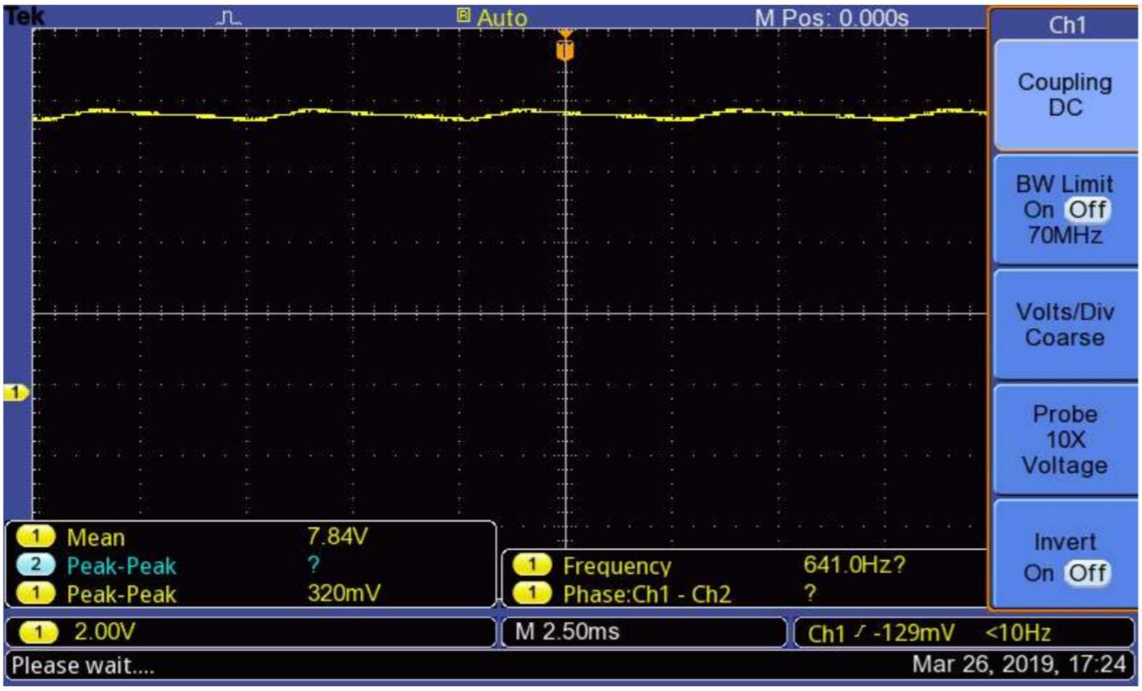
Peak to peak =640mV

2.

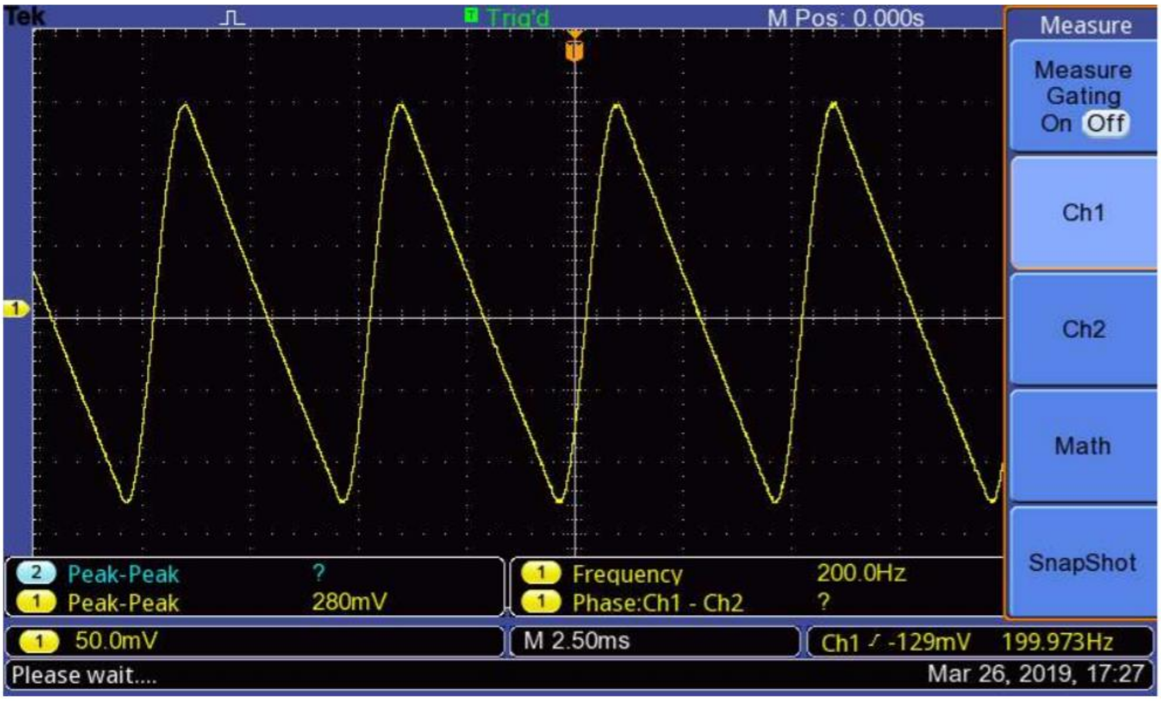
Take a hard copy of the output voltage across R L if C1 is removed from the circuit. Measure the peak voltage



Take a hard copy of the output voltage across R L with C1 connected. Measure the peak voltage of the output

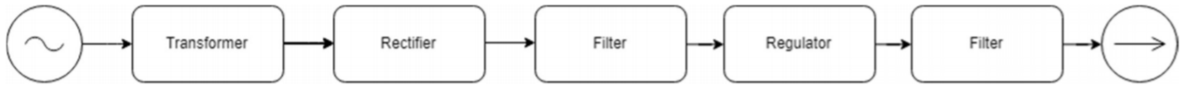


Expand the ripple voltage. Take a hard copy and measure the peak to peak voltage of the ripple



Peak-peak value=280mV

Draw a schematic diagram showing the building blocks of a DC power supply and explain the needs of each building block.



Solution:

Transformer: The transformer allows the source voltage to be stepped up or stepped down. The AC power source is electrically isolated from the rectifier circuit. It reduces the changes of getting a shock.

Rectifier: The rectifier changes the AC input into a DC voltage with some ripple effect still left over. To reduce AC components from the rectifier output voltage a filter circuit is required Filter. The filter is used to suppress the ripple effect of the output from appearing in the output while at the same time allowing as much of the DC component to pass through. The filters are usually constructed from reactive circuit elements such as capacitors and/or inductors and resistors.

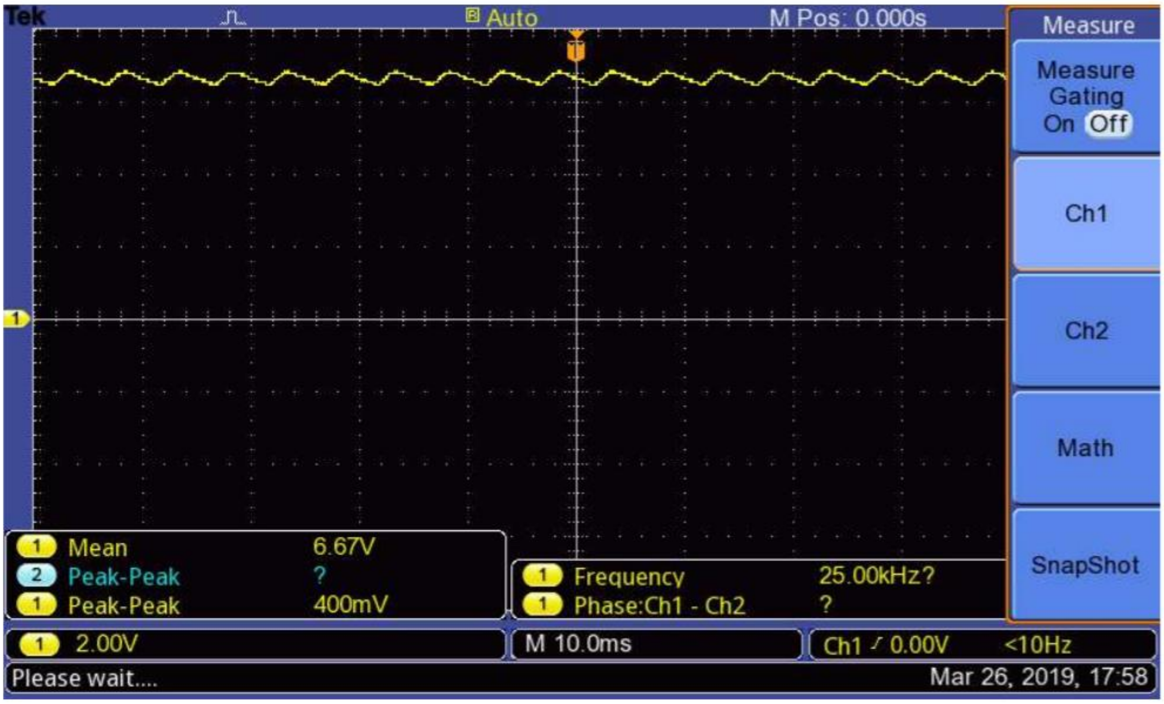
Regulator: This is used to maintain a constant DC output voltage which allows the load to keep operating properly regardless of the change of input voltage.

Compare the measured values of the peak-to-peak ripple voltage with the values from simulation and calculated using the equations given in the handout

Calculated Value	Simulated Value	Measured Vr
0.49802V	**0.560V**	**0.280*2**

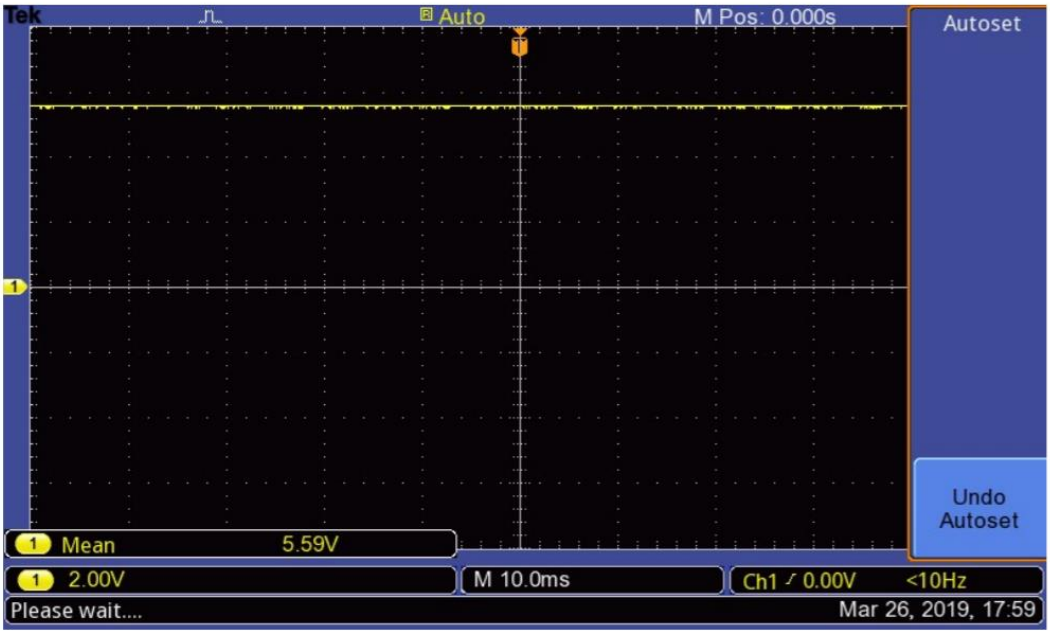
We can see all the values are well within the range of each other. The reason our values fluctuates is because of the tolerances in the components used.

Measure the voltage at C1, the output DC voltage and the ripple across the load resistor RL. Take hard copies

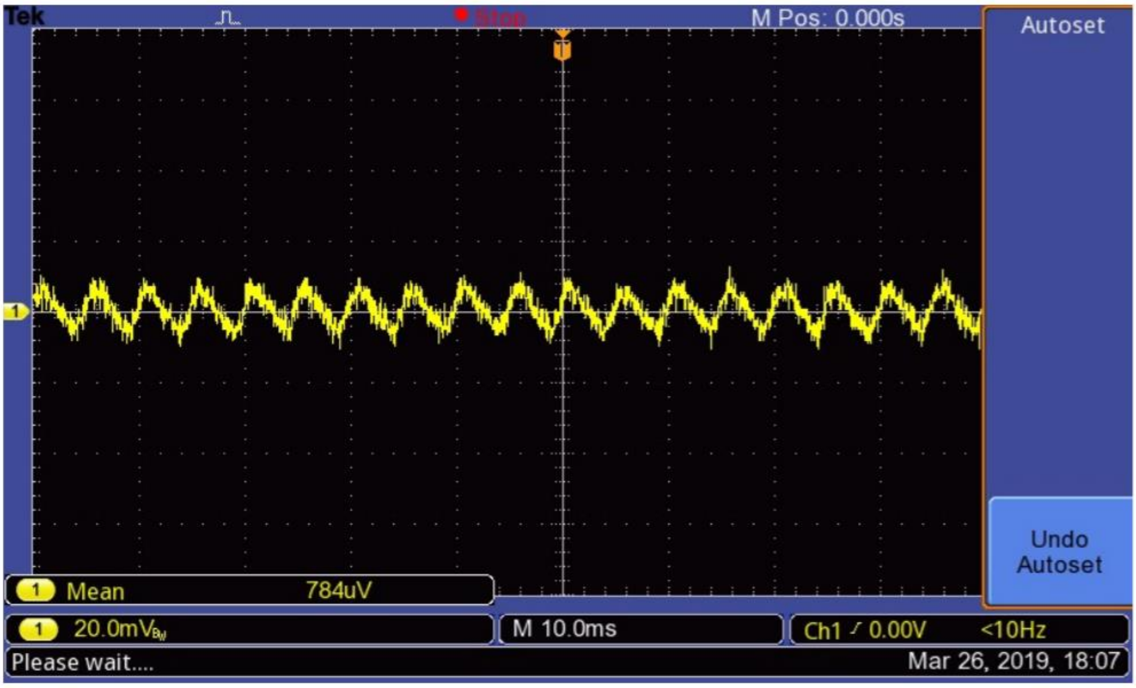


C1: 6.67V

the output DC voltage: 5.59V



The ripple across the load resistor RL: 784uV



The Vpp that was expected was around 8mV. However, what we obtained was just noise due to resolution of the oscilloscope.

Calculate the approximate current through the Z-diode!

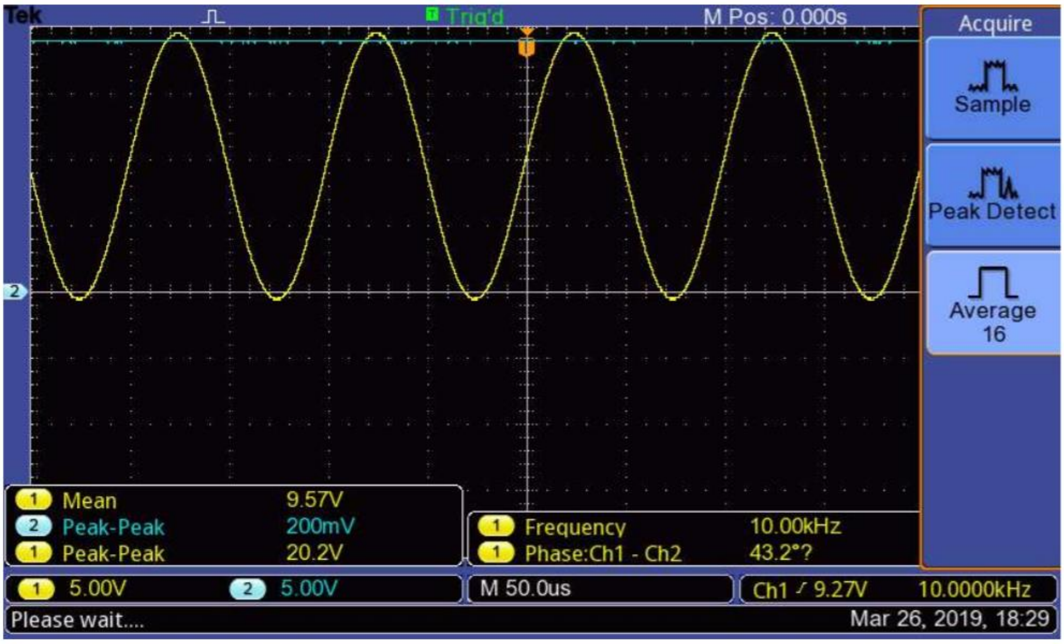
The hardcopy does not provide information about the DC value at the capacitor. Therefore, simulation was done to get Vc= 11.72014V. From hard copies we got R_L to be 5.59V.

Ir1= 6.78-5.59/100= 0.0119

Irl=5.59/39000=1.43e^-4

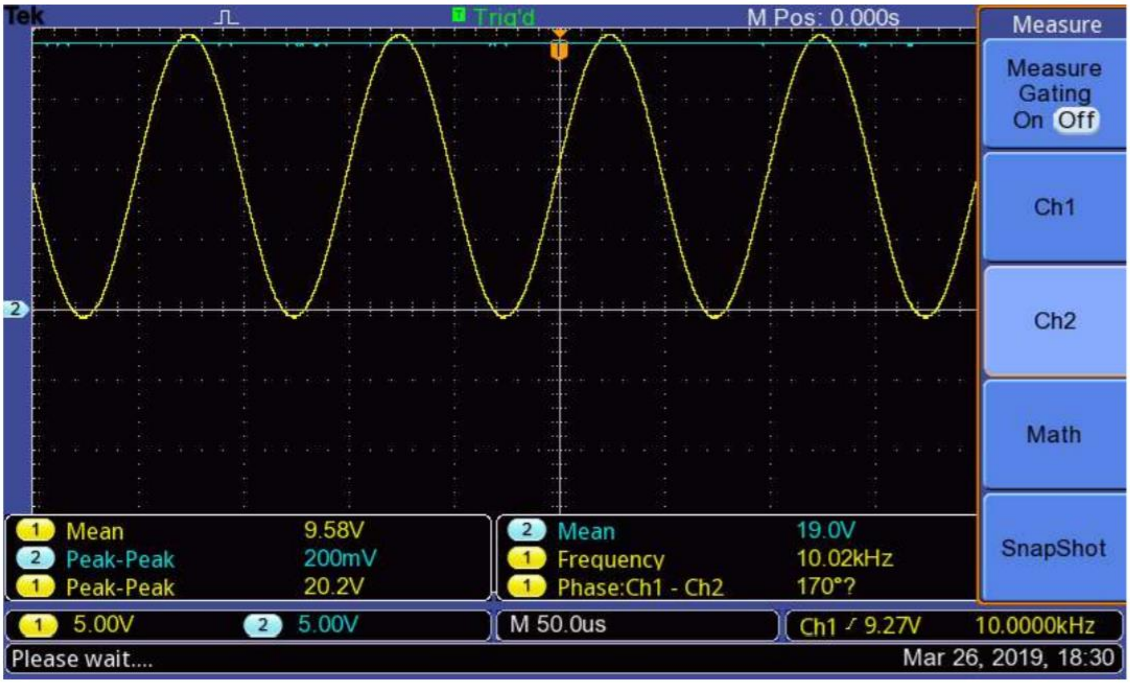
Iz=Ir1-Irl= 0.0119-1.433e^-4= 0.01176 or 11.76mA

1. **Use the oscilloscope to measure the voltage at ’A’ and ’C’. Take a hardcopy with both signals together on the screen**



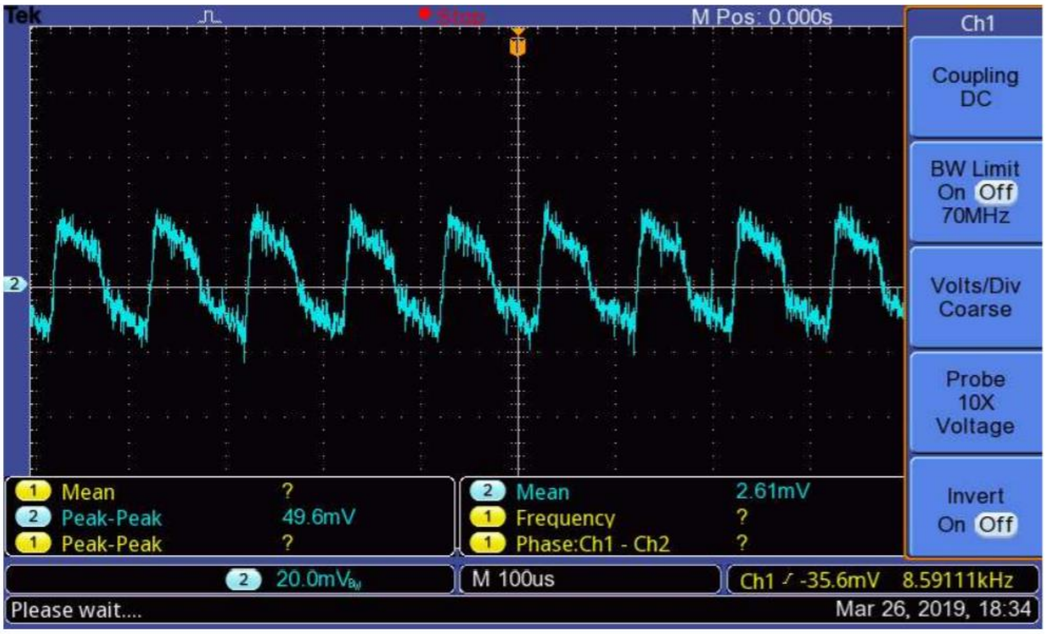
Voltage at 'A' (Blue) and 'C' (Yellow)

2. **Use the oscilloscope to measure the voltage at 'B' and 'Uout'. Take a hardcopy with both signals together on the screen.**



Voltage at 'B' (Blue) and 'Vout' (Yellow)

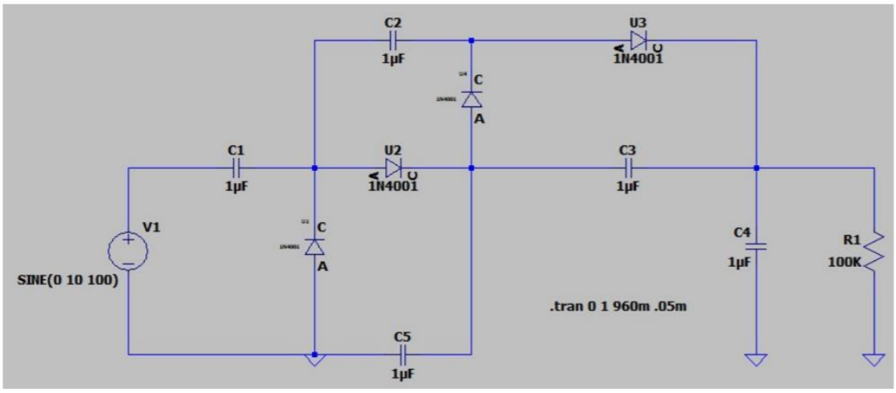
3. **Use the oscilloscope to measure the ripple voltage at 'Uout'. Take a hardcopy.**

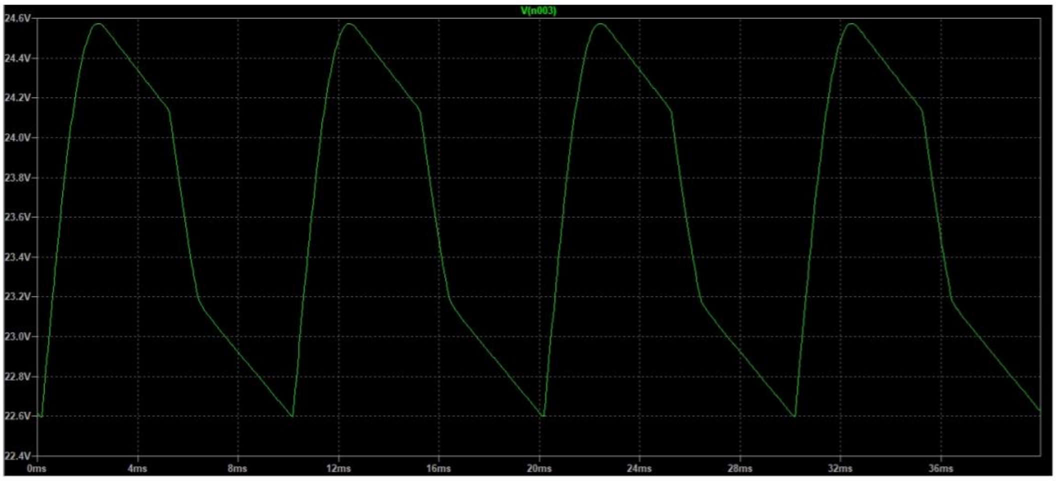


4. **Measure and record the voltages at 'C' and 'Uout' using a multimeter.**
   Vc= 17.74; Vout= 35.48

   1. **From which circuits in the Diode Application part of the handout this circuit is composed?**
      The circuit 1 composed of two stages of one clamper and a half wave rectifier. First comes the clamper and then comes the rectifier.
   2. **Explain the function.**
      Since the two stages are identical, it is only necessary to describe the working of the first stage. First, when the source is providing negative voltage the current will flow through D1 and charge C1 up to Vcc=Vpp. This adds a DC offset to the generated sine wave which can be seen at node A. Then, the sine with maxima 2Vpp goes into the rectifier and charges C3 and generated a DC Voltage of value 2Vpp. Following the same pattern, a DC voltage of 4Vpp will be observed at Uout. At this node, the extra capacitor and resistor are there to further smooth out the DC output.
   3. **What is the multiplication factor between input amplitude and output voltage? Comparer the measured to the ideal one. Why there is a difference?**
      The ideal multiplication factor is 4. Although the measured value was 35.48/10 =3.548V. There is a difference because of the voltage drop across the capacitors, which of we account for them would give us (40-2.8)/10=3.72V which is still not as low as measured one. This is because we still have not accounted for the small voltage drops over the capacitors and resistances in the wires and sources.
   4. **For which maximum voltage each element has to be selected?**
      The diodes must be selected in such a manner that their breakdown voltages are not exceeded. Because in the circuit, these are only intended to conduct current only in one direction. For the 1N4148 diode used, the breakdown voltage is 75V. This means higher voltages should be avoided. For capacitor of 1uF, the voltage marking is 50V i.e it should be less than 50V. Therefore, it should be less than 50V.
   5. **What happens to Uout if the frequency of the input voltage is reduced to 100Hz (Voltage & ripple!)? Explain in words!!! Show a prove of your statement using PSpice!**

The output voltage should be reduced, due to characteristics of the capacitor blocking low frequency signals. While the ripple voltage will increase, credit to the capacitor for having a longer time to discharge.





As expected, the ripple voltage has augmented and the DC output voltage has decreased.
Conclusion:

This experiment helped us to analyze the structure and functionality of diodes and we compared simulations in LTspice to that of laboratory experiments. We observed that the values were quite similar to the each other. The utility function of circuits for half and full wave rectifiers were explained in detail in the prelab and the laboratory report was further explanation and comparison for them. We also analyzed the delay and storage times of two diodes (being 1N4001 as slow diode and 1N4148 being high speed diode). We also explained in detail the process of voltage doubler, making it extensive to a quadrupler. We also tested different parameters such as variations in frequencies to see the impact of this fact in the output voltage. Taking in account the similarity in results, we can conclude experiment has been successful. Even though we experienced some difficulties in lab. One difficulty faced was to decide whether to include 50Ohm resistance with signal generator or not. There were some variations due to noise from components and the resolution of equipment that cause the error. The error sources were wires, noise from oscilloscope itself, resistances of components etc. References:

Lab Manual, Signal Diode Data Sheet