National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering

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Semester: 4th   **Section:** D

EE215: ELECTRONIC DEVICES AND CIRCUITS

Lab 06-07:   Diodes applications: Rectifiers, limiting and/or clamping circuits

		PLO4/CLO4		PLO5/CLO5	PLO8/CLO6	PLO9/CLO7
Name	**Reg. No**	**Viva /Quiz / Lab Performance** **5 marks**	**Analysis of data in Lab Report** **5 marks**	**Modern Tool Usage** **5 marks**	**Ethics and Safety** **5 marks**	**Individual and Teamwork** **5 marks**
Hanzla Sajjad	**403214**					
Haseeb Umer	**427442**					
Irfa Farooq	**412564**					

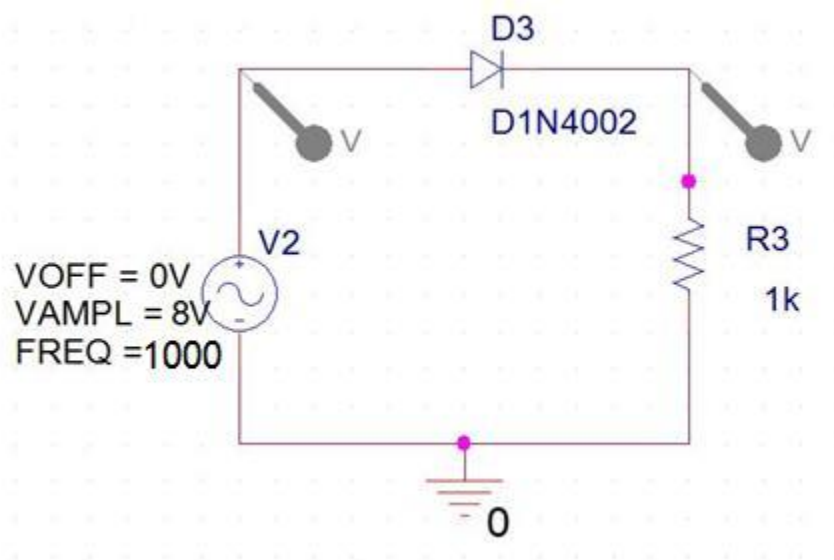## Objective: To Study the Applications of Diodes

1. The primary purpose of this lab is to develop a working knowledge of diode. Diodes can be used in a variety of circuits for various applications such as rectifiers, clippers/clampers and voltage regulators.

Components Required:

2. The following component and test equipment is required.
   - PN Diode (D1N4002 or any other diode of the same family)
   - Zener Diode
   - Oscilloscope
   - Function Generator
   - Resistors
   - Capacitors
   - Power Supply

HALF WAVE RECTIFICATION
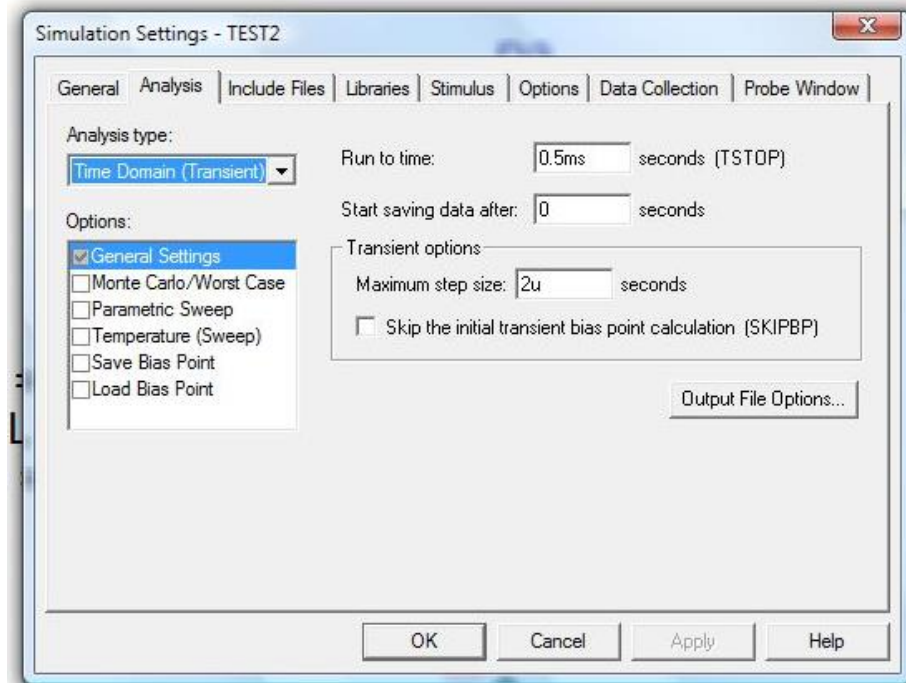
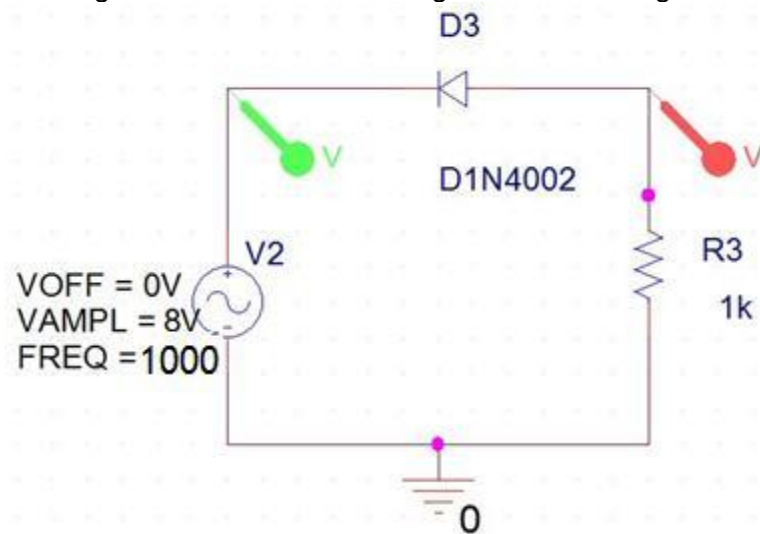## Exercise – I (Part A) [Simulation]

(Figure 2A_1)

- Draw the above circuit in OrCAD capture. Make sure you select the source VSIN, not VAC while you're drawing the circuit.
- Use the following simulation settings as shown in figure 2A_2 to simulate your circuit.

(Figure 2A_2)

- Students are encouraged to change the settings and experiment a little. This would help them gain a good understanding of the simulation. You should also try to put various step sizes and simulation times. This would help you're making your own simulations.
- Now draw the following circuit and simulate using the same settings:

(Figure 2A_3)

- **Save the graphs obtained by simulating both circuits and answer the following questions in your report:**
  - ○ **Do you observe a difference in both graphs? If yes, explain why it is happening?**
    Ans: Yes, there is a difference between the two graphs. The diode when connected in forward biased acts as a closed switch for positive voltage cycle while the diode connected in reverse biased acts as a closed switch during the negative voltage cycle and provides a negative voltage output.
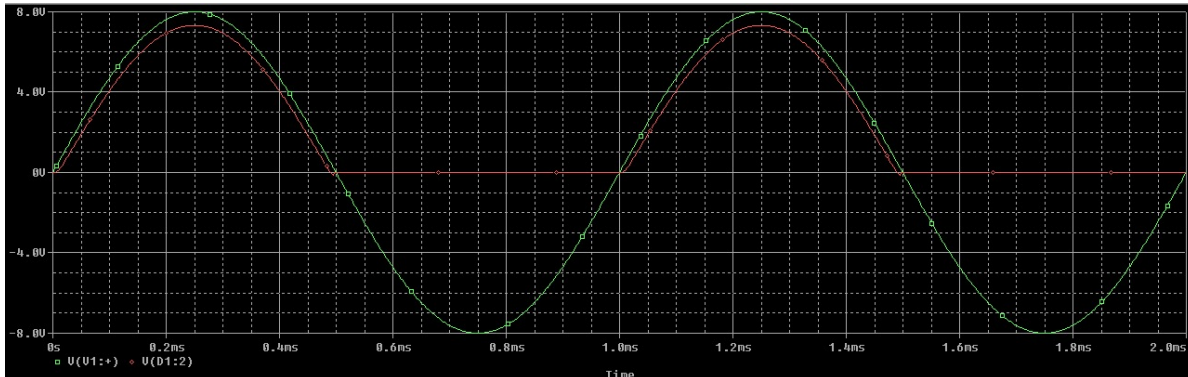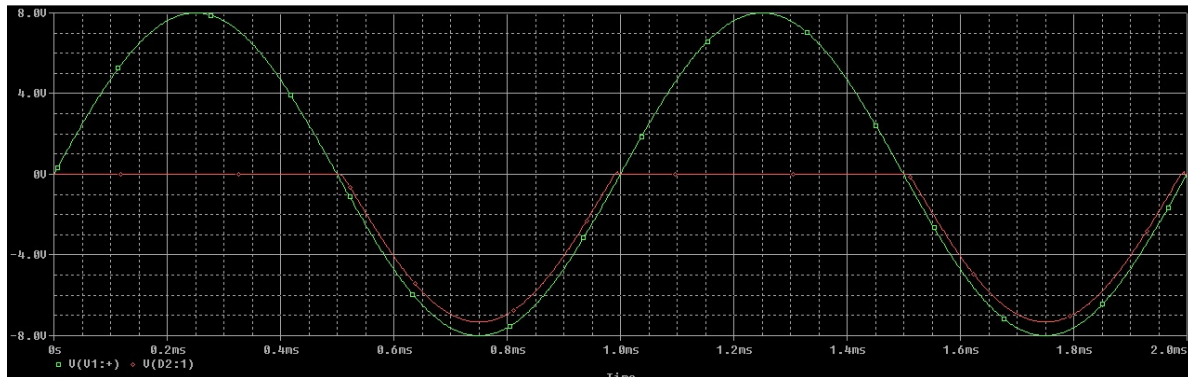

Figure 1: I-V Graph for forward biased diode

Figure 2: I-V Graph for reverse biased diode

  - ○ **Measure the peak values of both the input and output signals obtained by simulating the circuit in figure 3A_1. Do you see a difference between peak values? Explain why does it occur?**
    Ans: Peak values for the forward biased circuit is **749.216V** while the peak voltage for the reverse biased circuit is **-749.216V**. The difference in the two voltages is due to the biasing effect of the two diodes as one acts as a closed switch when the voltage is positive while the other acts as a closed switch when the voltage is negative.
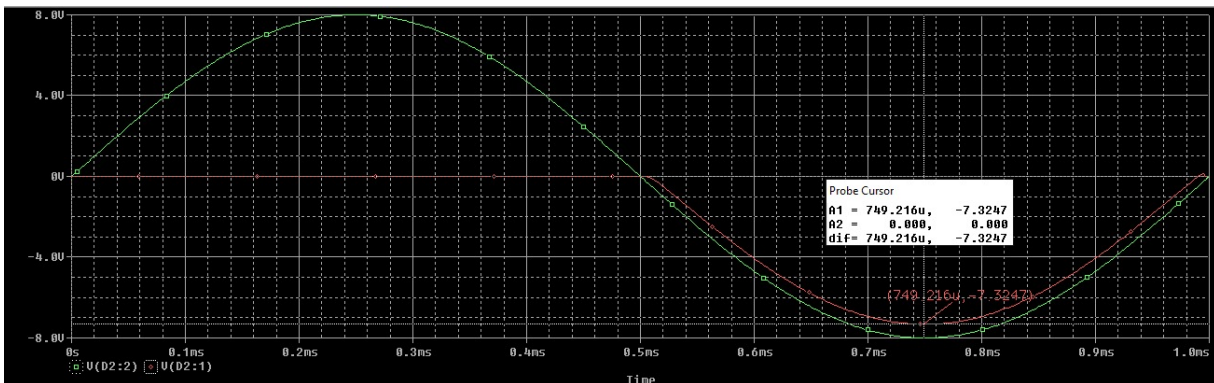
Figure 3: Peak to peak voltage for reverse biased diode

- ○ **The phenomenon that you have just witnessed is known as rectification. Could you explain why this case is referred to as half wave rectification?**
  Ans: This phenomenon is referred to as a half wave rectification because only half of the input cycle is transferred to the output while the other half is discarded of the input.

- ○ **Now change the frequency from 1K Hz to 10K Hz and observe the difference. Why do you think the graph has now changed? Explain.**
  Ans: Due to the increase in frequency from 1kHz to 10kHz, the time period for one complete cycle reduces drastically from milliseconds to microseconds.
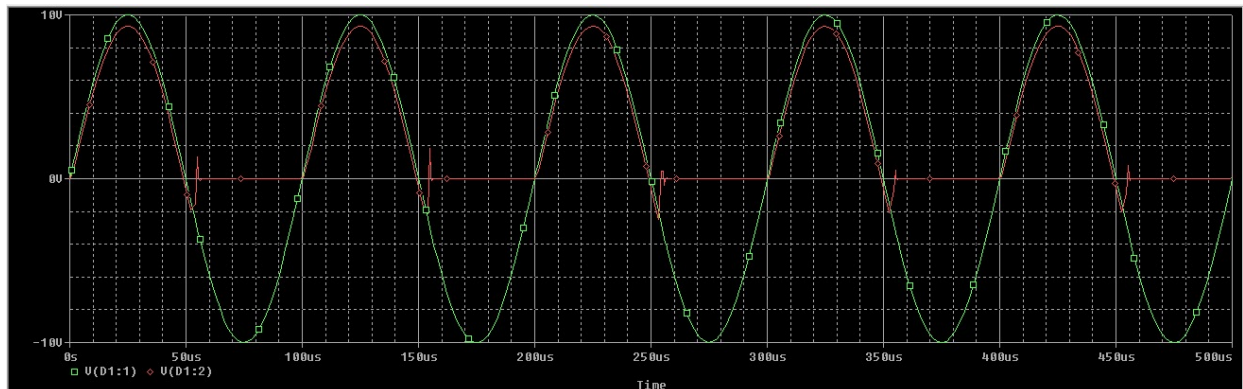

Figure 4: Decrease in time period due to increase in frequency
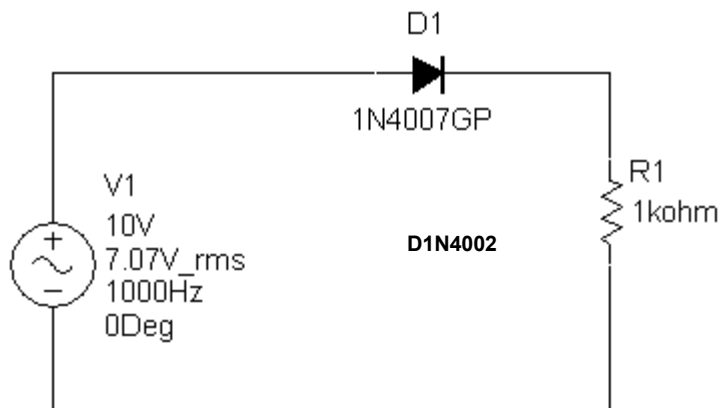
Exercise – II (Part B) [Implementation]

Figure-2B Circuits for Half-wave Rectifiers.

Procedure

Set up the circuits given in fig-2B. Apply 10-volt peak to peak sine wave as an input signal and see the output signal across the 1K Resistor, on oscilloscope for both the circuits.

Observations/Measurements:

- **Observe the Input and output waveforms on a dual trace oscilloscope. What differences are observed between input and output waveforms and why?**
  Ans: The output waveform of the diode provides a half wave output waveform when the input voltage is positive. For the negative half, the output is zero as the diode acts as an open switch.
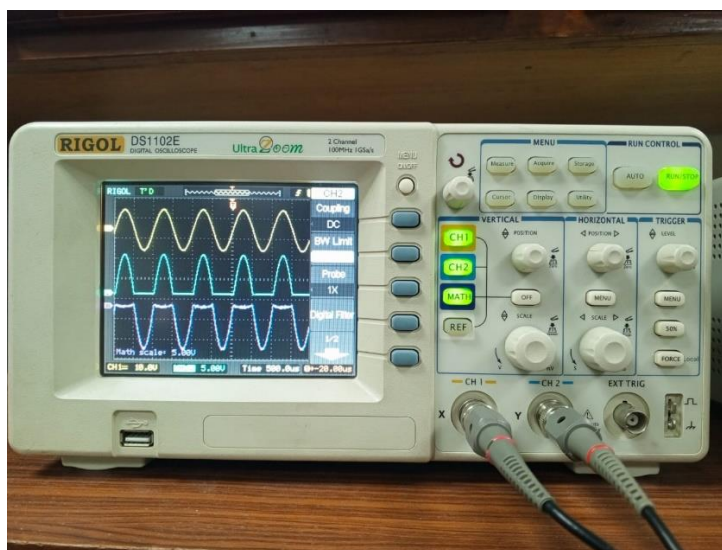

Figure 5: Vs, Vd and Difference between the two voltages

- **If we were to use two diodes in series, how would that affect the output of the circuit? Explain.**
  Ans: The overall voltage on the load will decrease by a factor of 0.7V per diode. The overall peak voltage will decrease due to this interruption.

- **Also, change the frequency of the input and observe the difference in the waveform. Why do you think it has changed?**
  Ans: Due to the increase in frequency from 1kHz to 10kHz, the time period for one complete cycle reduces drastically from milliseconds to microseconds.

Full Wave Rectifier (Part A – Simulation I)

3. In the last lab exercise you experimented with half wave rectifier circuits. Now we will experiment with wave rectification.

   Procedure
   a) First draw the circuit as shown in figure 1A_1. Make sure that you have entered the correct values for the source VSIN.
   b) We will perform a transient analysis and simulation profile should be made as shown in figure 1A_2. Just like previous experiments, students are encouraged to understand the change in graph obtained by changing various parameters of the simulation profile.
   c) Plot the graph between V_{in} and V_{out}, which to be taken across the 1k ohm resistor (**hint:** use voltage differential markers, not voltage level markers). Save the graph and attach it with your lab report.
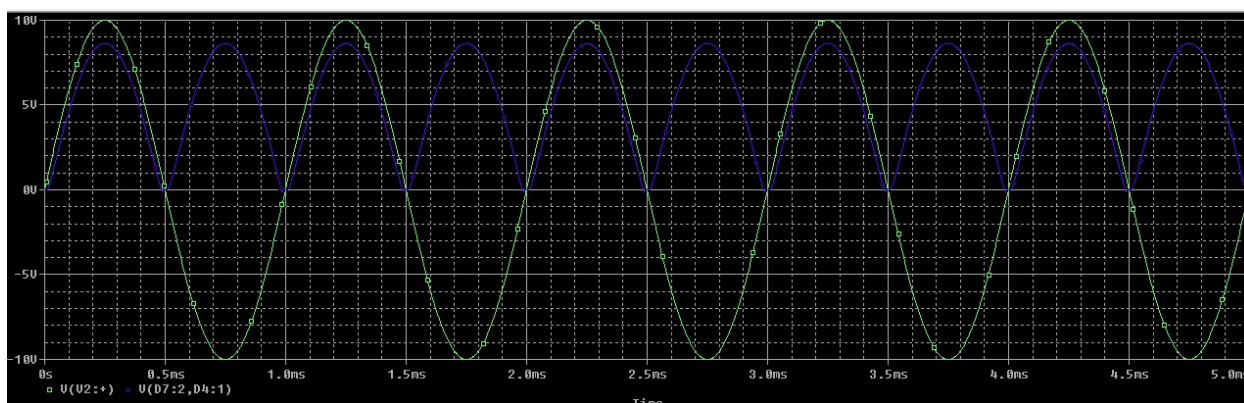

Figure 6: Vs and Vd for full wave rectification

   d) Observe the graph between V_{in} and V_{out}.

e) Now use both the voltage differential marker and voltage level marker across the resistor and observe the difference. Plot both curves and include them in your lab report.
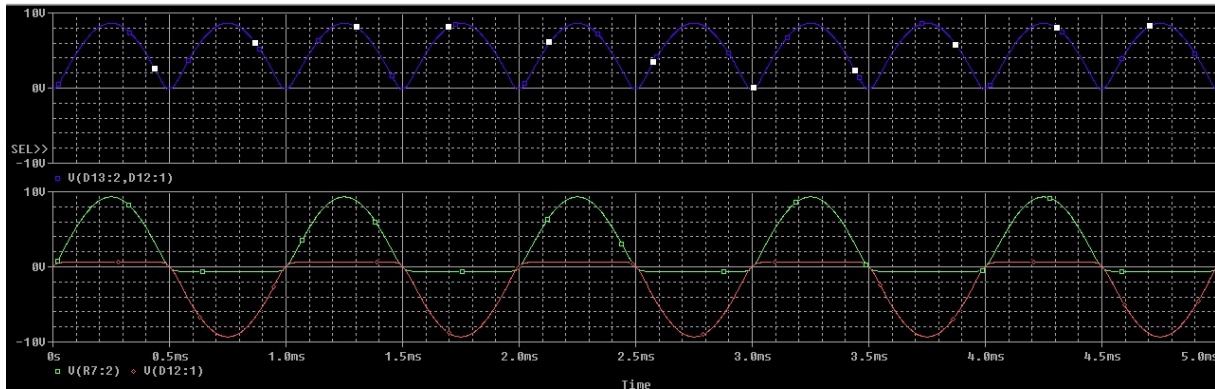

Figure 7: Voltage across diode and voltage difference
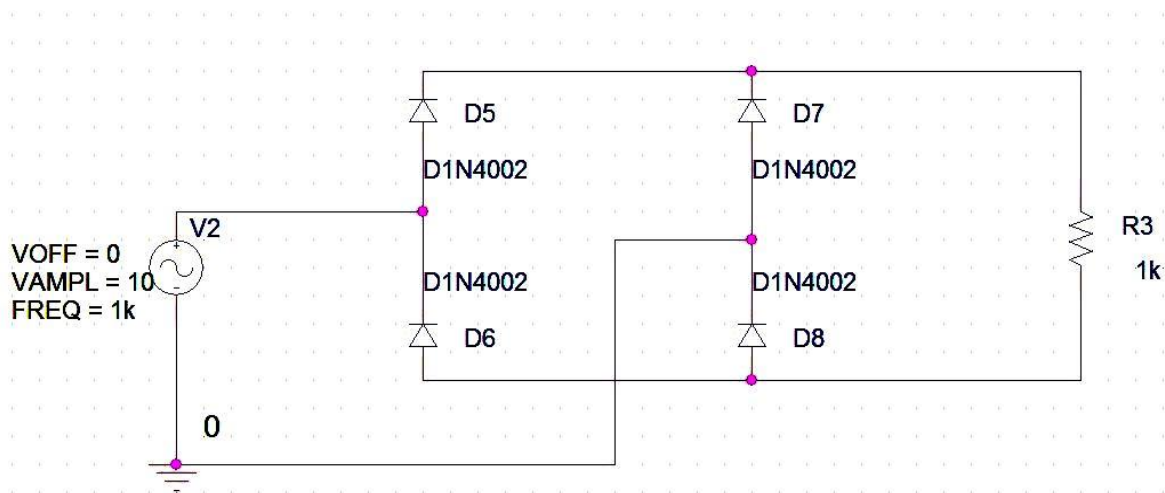
Circuit Diagrams for Exercise 1A:

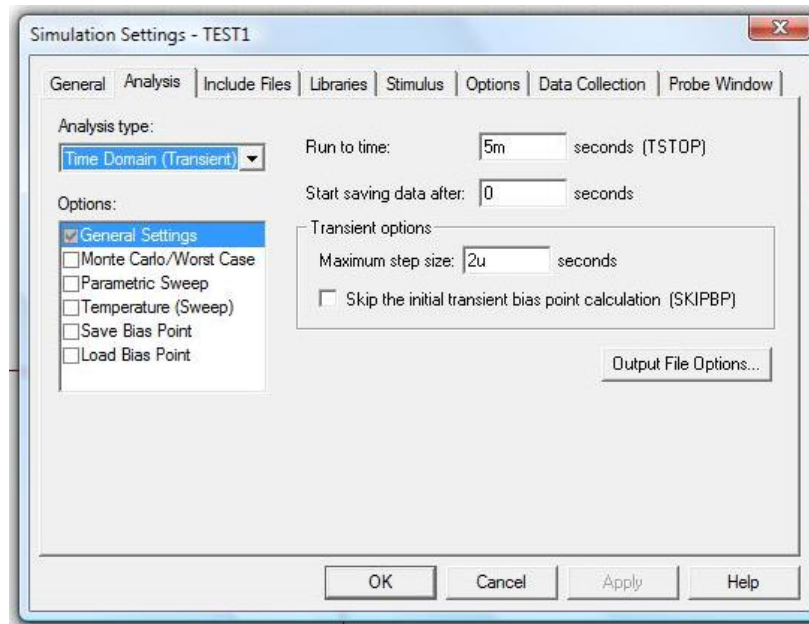**Figure 1A_1 – Circuit Diagram for Full Wave Rectifier**

Figure 1A_2 – Simulation Settings for Full Wave Rectifier

Full Wave Rectifier (Part B – Simulation)

Repeat the experiment using a Transformer as shown in figure 1B_1, and the simulation profile given in figure 1A_2 (*Note the Frequency of the source is 60 Hz)*
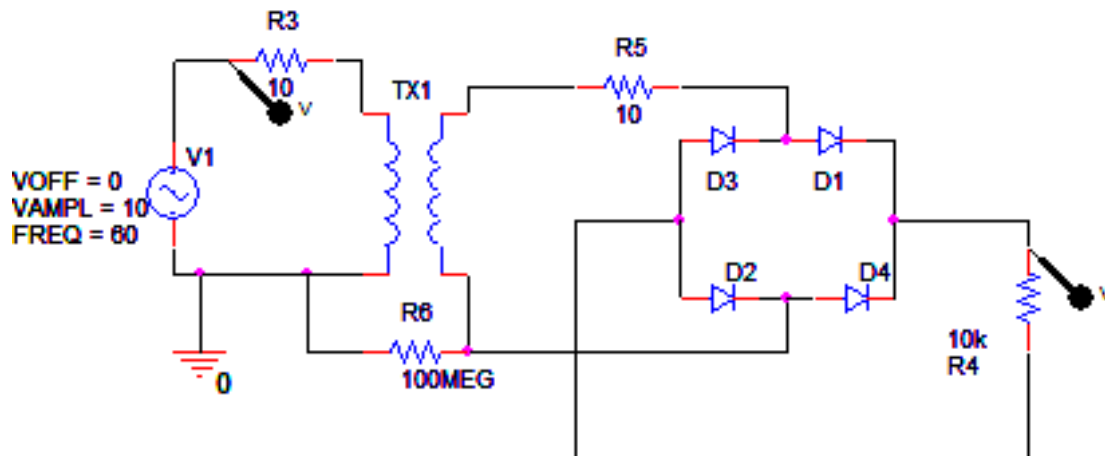

Figure 1B_1 Full Wave Rectifier with Transformer

Observations/Measurements:

4. **For the above two exercises answer the following questions in your report:**
   a) **Calculate the peak inverse voltage (PIV) of the rectifier. Include the calculations in your report.**
   Ans: From above figure, we can clearly see that:
   $V_o = V_s - 2V_d$
   Now, Considering D4 as an open circuit, the PIV for diode will be;
   PIV $= V_o - (-V_d)$
   $\qquad = V_o - 2V_d + V_d$
   $\qquad = V_o - V_d$

   b) **Do you observe the difference between peak voltages of the rectified wave and input signal? Measure the voltage and explain why the difference occurs?**
   Ans: Yes, there is a significant decrease in the input and output signals of the two voltages. The output peak voltage is somewhere around **8.366V** which is equivalent to $V_0 = 8.6V$ calculated from the formula for a bridge rectifier.

   c) **What difference do you observe between the graph obtained from "voltage differential marker" and "voltage level marker"? Explain why both the graphs are different from each other.**
   Ans: The graphs obtained from these markers differ because they are measuring different aspects of the voltage signal. The voltage differential marker focuses on the difference in voltage between two points, which may vary dynamically as the circuit operates. In contrast, the voltage level marker provides static information about the absolute voltage levels at specific points in the circuit. Therefore, while both markers provide valuable insights into the behavior of the bridge rectifier circuit, they present distinct perspectives on the voltage characteristics, leading to differences in their respective graphs.

   d) **Another technique used for full wave rectification is the use of the center tapped transformer. Explain which technique is better and why?**
   Ans: In terms of efficiency and simplicity, bridge rectifiers are generally considered better for full wave rectification. They are more commonly used in modern electronic devices due to their higher efficiency and lower cost. However, center-tapped transformers still find applications in certain scenarios where the lower PIV requirement outweighs the complexity and cost of the transformer design. Ultimately, the choice between the two techniques depends on factors such as cost, space constraints, and specific application requirements.

Full Wave Rectifier (Part B – Implementation)

5. After circuit simulation, the next step involves practical implementation of the circuit.

Procedure:

- Patch the circuit as shown in figure 1A_1.
- Observe the waveforms of V_{in} and V_{out} on the oscilloscope. Save your results and include them in your lab report.
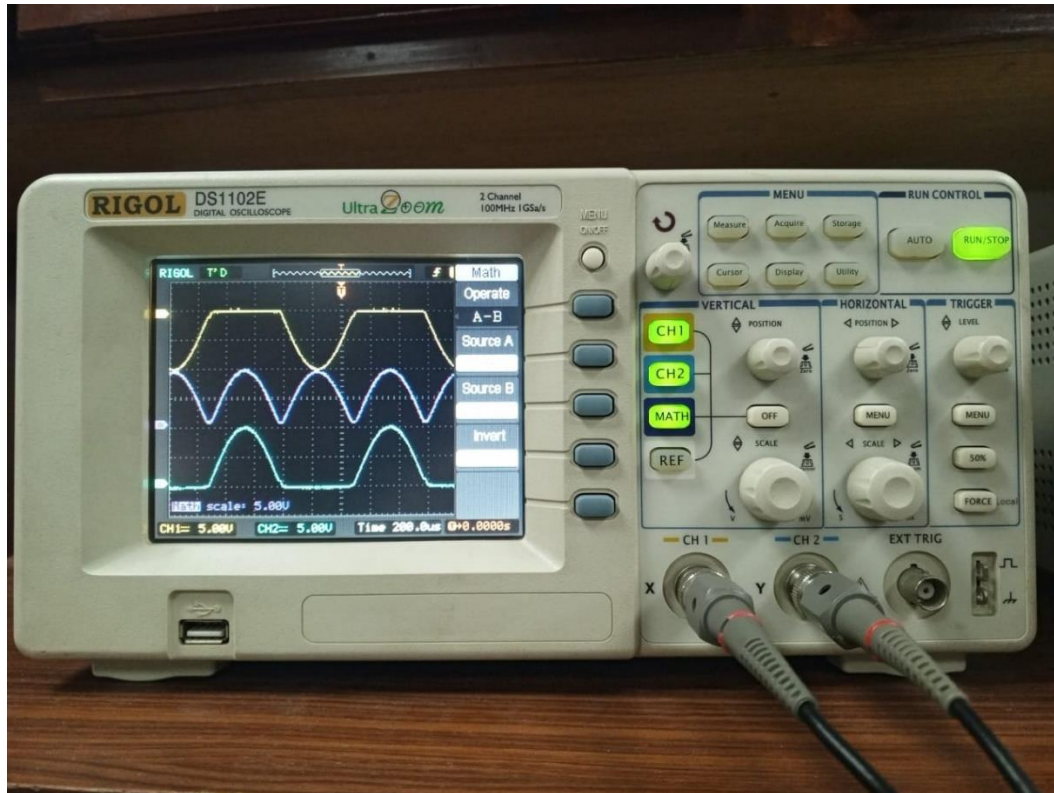

Figure 8: Full wave rectifier

- Measure the peak inverse voltage (PIV) of this practically implemented rectifier and compare the results obtained. Explain the differences, if any, in your lab report.

- As you have observed in your graph, we do not still have a pure DC voltage. The rectified voltage is still pulsating. Can you think of any technique that can help you remove these pulses? (**Hint:** Take a look at your previous labs, you've done the procedure).

- Try giving a square wave instead of a sine wave. What differences do you observe.
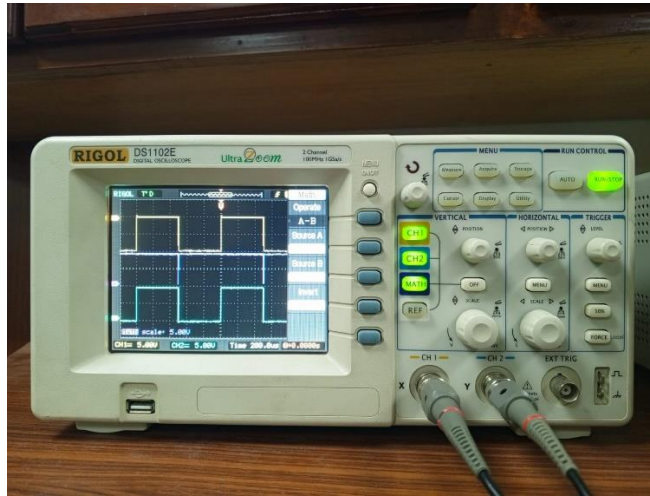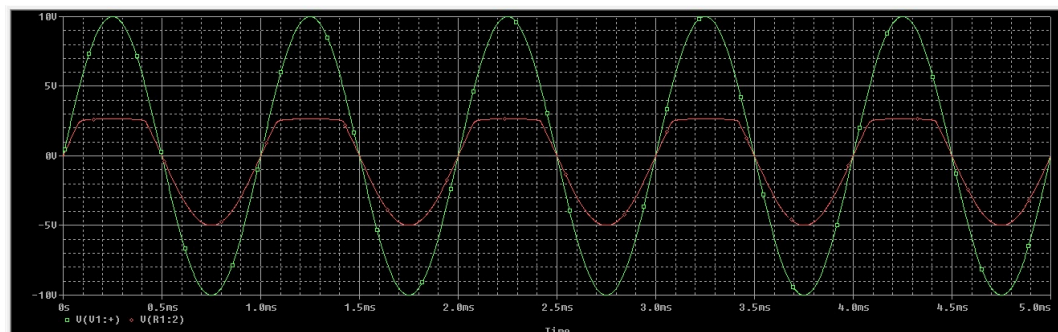 **Ans:** A relatively smooth DC output voltage is observed at the load.

Figure 9: The output is almost DC

Limiter Circuit (Part A – Simulation I)

This exercise is on another application of diode, which is known as limiter. It serves the purpose of clipping off peaks and is also known as clipper. The first part of this exercise is also simulation on OrCAD Capture Lite. Observe the following procedure for this part:

a. Draw the circuit as shown in figure 2A_1.

b. You have to simulate the circuit by creating your own simulation profile (**Hint:** use transient analysis). Make sure the graph obtained is properly drawn. Take a curves and graphs of the simulation profile settings that you have done and attach it with your report.

c. Simulate the circuit and observe the waveforms between V_{in} and V_{out}. V_{out} is taken across the diode and voltage source. Please avoid the use of voltage differential markers.

d. Simulate the circuit at different values of V2 (DC Source given in figure 2A_1). Observe the difference in waveforms.

e. For the circuit given in Figure 2A_1, draw the transfer characteristic curve with V_{out} on y-axis and V_{in} on x-axis. This can be done by using DC Sweep simulation profile. It is left for the students to make the simulation profile settings themselves and observe the results.
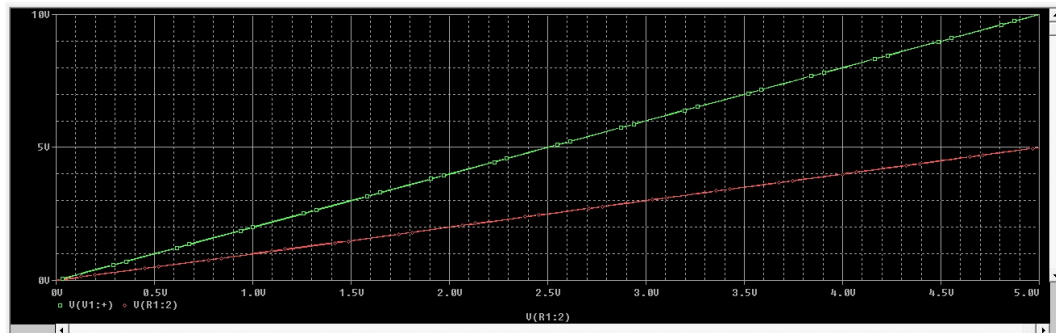

Figure 10: Vin Vs Vout

f. Attach the curves and graphs of the simulation profile settings that you use. Make sure proper settings have been done so that the curves are clearly visible and can be explained by you in the report/viva.
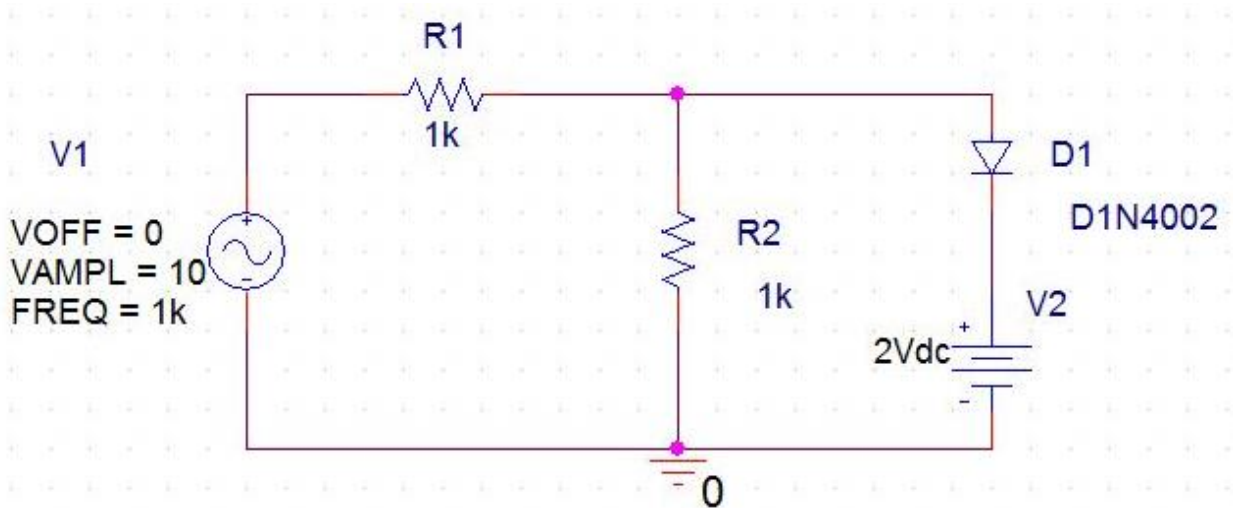

Figure 2A_1 – Limiter Circuit

Observations/Measurements:

6. Answer the following questions:

   a) **What happens when you change the value of the DC source in the circuit? Explain.**
   Ans: The output values at which the circuit clips changes as we change the input values of the DC source. With an increase in the DC source, the clipped value becomes smooth with every increase in the DC value source.

   b) **If the value of DC source exceeds the peak value of VSIN what do you think should happen? Demonstrate by the help of a graph drawn in OrCAD.**
   Ans: The output voltage becomes constant after a certain rise in the VDC source attached with the diode.

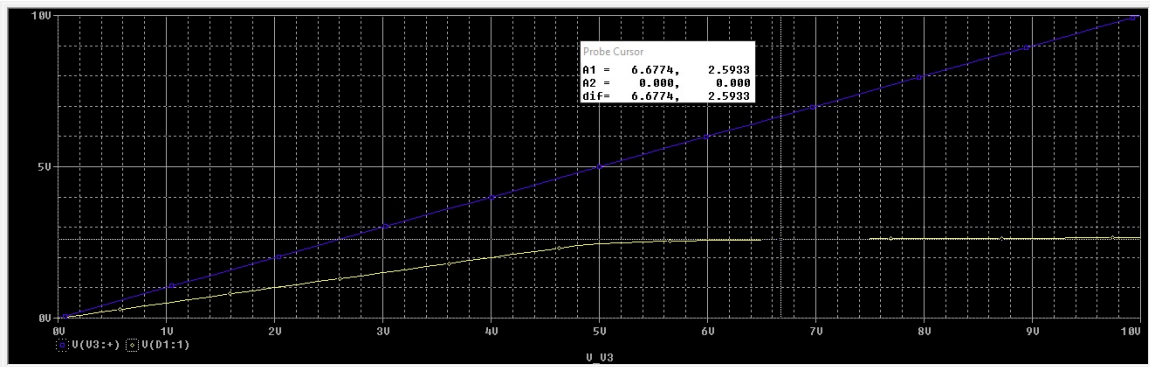*Figure 11: Vout Vs Vin when the VDC exceeds Vin*

   c) **Attach graphs at Vdc = 2V, 5V, 8V and 10V in your lab report. Explain the difference observed.**
   Ans: As the input voltage increases from 5V, the output voltage becomes almost constant as the circuit stops clipping.
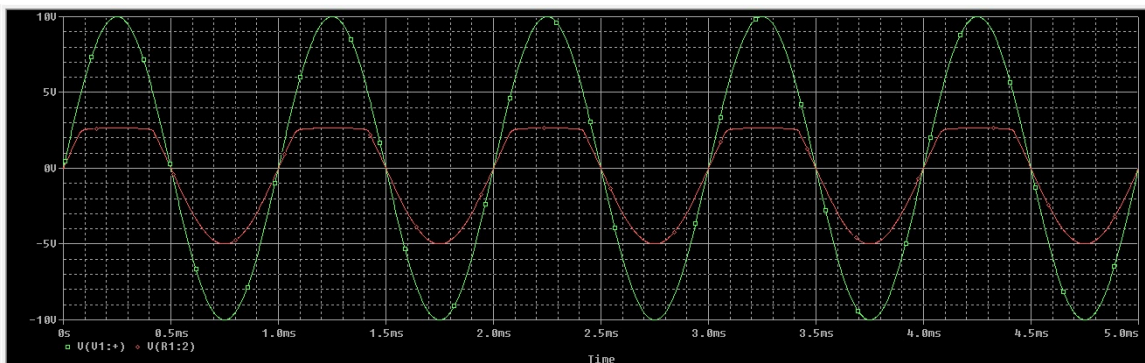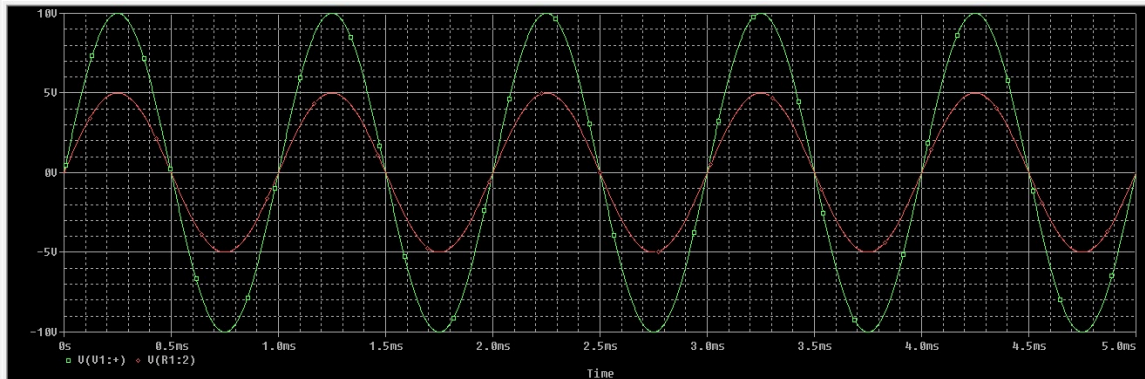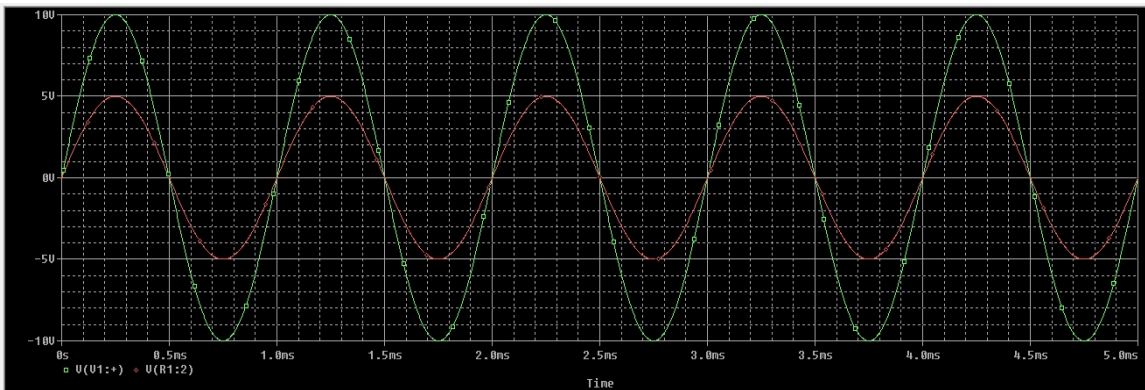

Figure 12: VDC = 2V
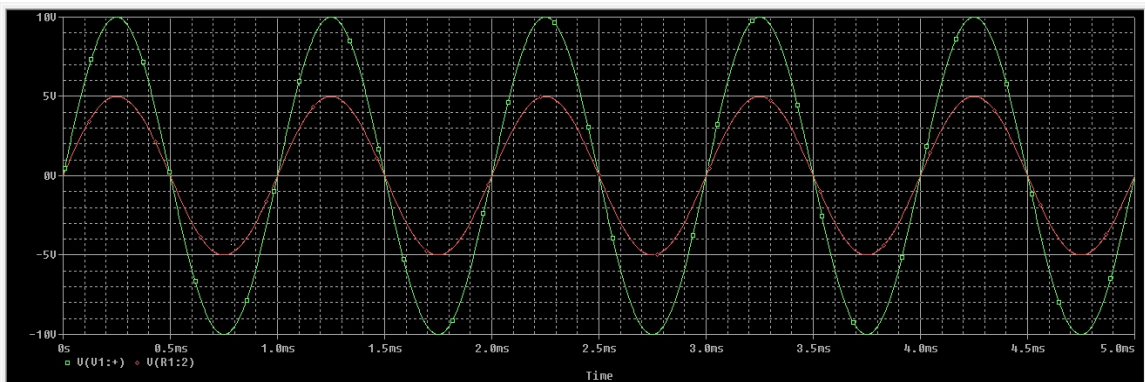
Figure 13: VDC = 5V

Figure 14: VDC = 8V

Figure 15: VDC = 10V

d) **Explain the transfer characteristic curve of the limiter circuit in two to three lines in your lab report.**
   Ans: When we change the value from 2V to 5V, the clipping interval increases. Further increase in VDC leads to clipping almost disappearing.

e) **Attach the transfer characteristic curve taken at Vdc = 2V, 5V, 8V and 10V. What difference do you observe? Why do the differences occur?**
Ans: We observe a variance in clipping levels for different values of Vdc used due to the change in values of VDC in series with the diode. We have a different voltage drop across the whole branch and hence a different characteristic curve.
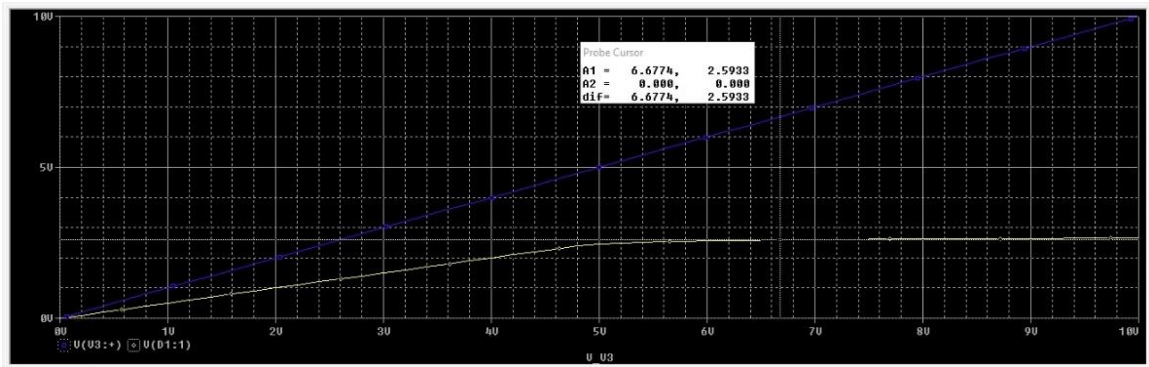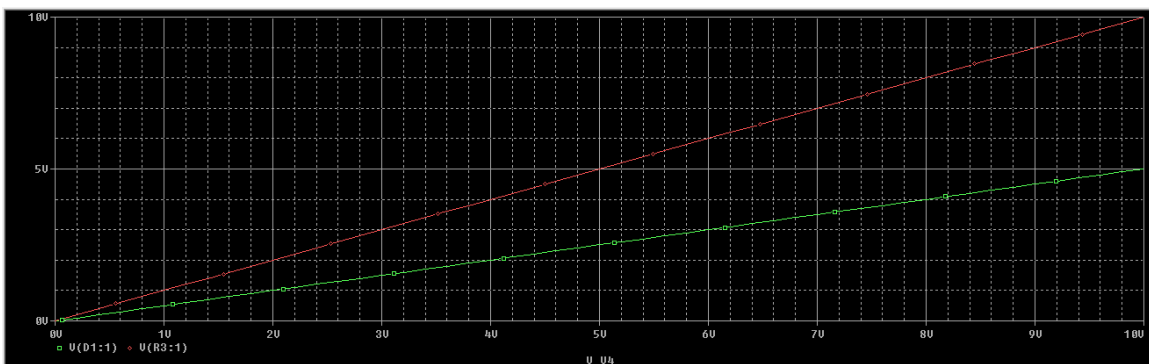

Figure 16: Transfer Characteristic curve at 2V

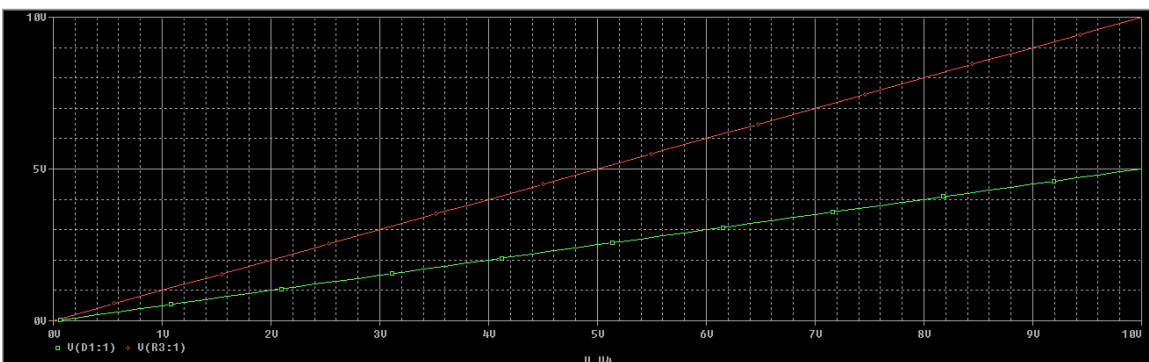*Figure 17: Transfer Characteristic curve at 5V*

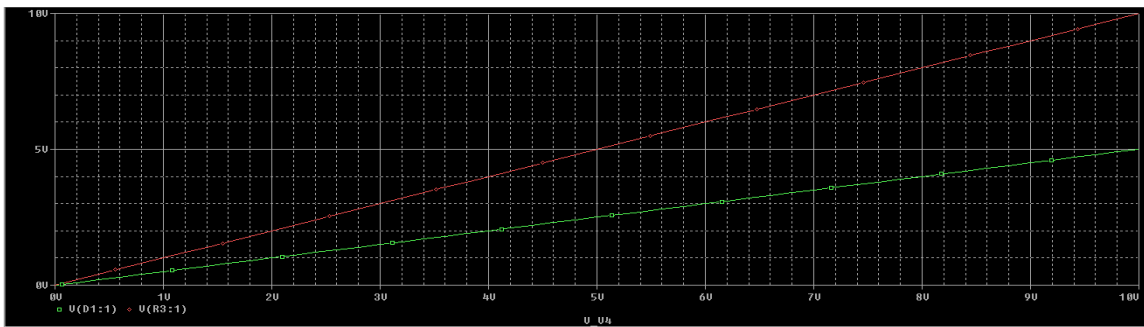*Figure 18: Transfer Characteristic curve at 8V*

Figure 19: Transfer Characteristic curve at 10V

f) **Theoretically calculate the point where V_{out} becomes constant in the transfer characteristics curve? Compare it with the results obtained via simulations. Explain the difference if any.**
   Ans: V_{const} = V_{Diode} + VDC = 0.7 + 2 = 2.7 which is relatively different from the output voltage obtained from the curve i.e., 2.59. This difference is due to the fact that we consider the ideal diode characteristics and calculate the ideal value which is affected by the hardware implementation.

Limiter Circuit (Part B – Simulation II)

7. **In this part of the exercise, you must simulate the circuit provided in figure 2A_1 but it should clip positive peak at +1.5V and negative peak at -0.2v. The procedure for doing the exercise is the same as described in part A of exercise**

8. **You must include the curves and graphs of your simulation settings and curves as asked in the procedure. From the Observations/Measurement section, please answer the following.**

   a) **Explain the transfer characteristic curve of the limiter circuit in two to three lines in your lab report.**
   Ans: We set V_{dc} for positive limit as 0.8 V because: 0.8 + V_d = 1.5V which is required and also for negative limit we set V_{dc} as -0.5V because -0.5 + Vd = 0.2V in negative cycle which is required.
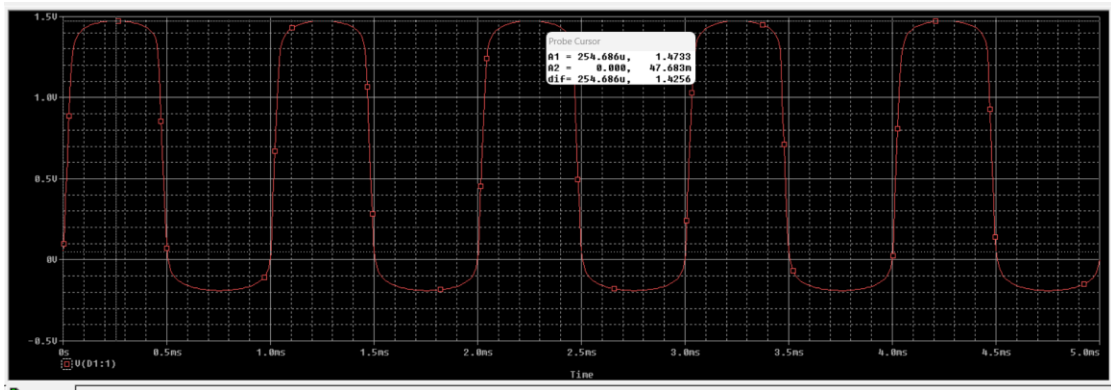

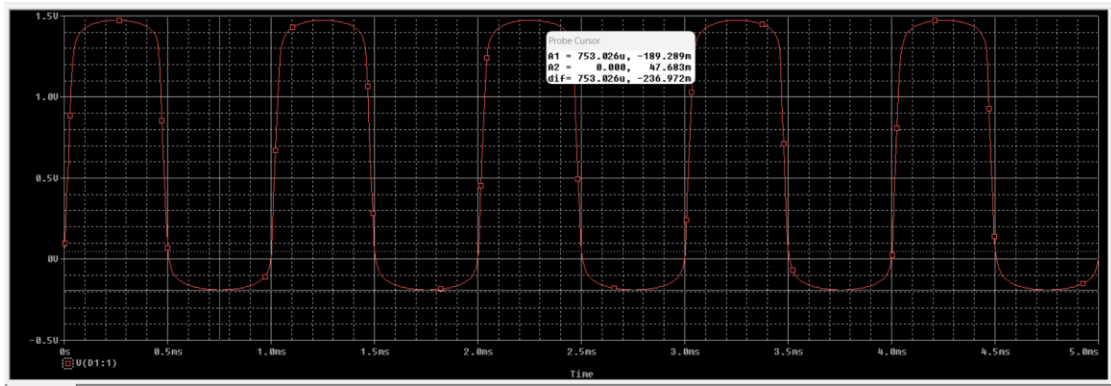*Figure 20: Output Voltage for positive cycles*

Figure 21: Output Voltage for negative cycle

9. **Explain what differences you observe with respect to the limiter in part A. Why do these differences occur?**

   Ans: We set V_{dc} for positive limit as 0.8 V because: 0.8 + V_d = 1.5V which is required and also for negative limit we set V_{dc} as -0.5V because -0.5 + Vd = 0.2V in negative cycle which is required.

Limiter Circuit (Part C – Implementation)

11. **The following procedure should be adopted while practical implementation of the circuit given in figure 2A_1:**
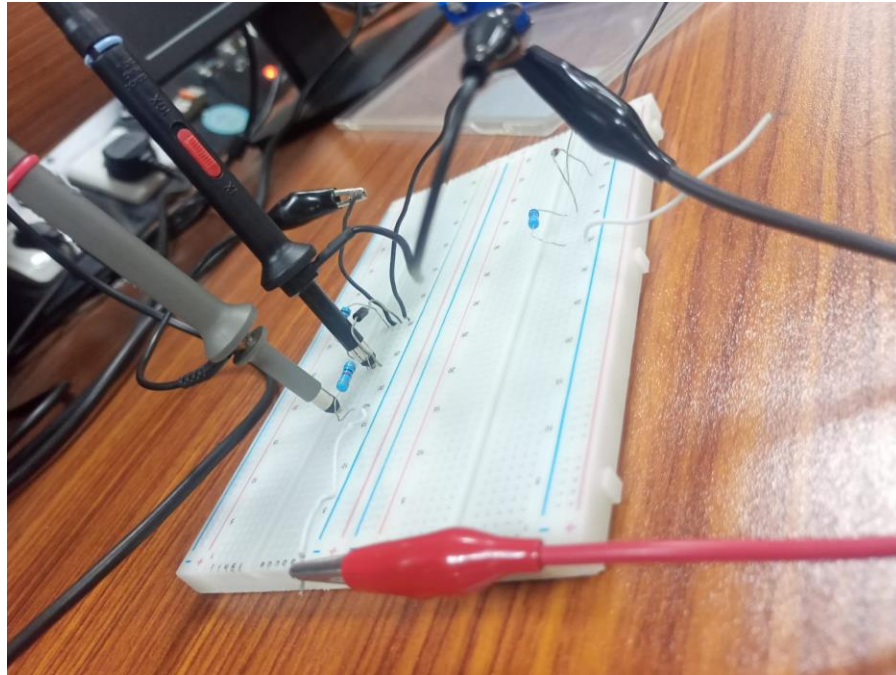   a. **Patch the circuit as shown in the figure.**

Figure 22: Hardware Implementation

    b. **Try to observe the input and output curves on a dual channel oscilloscope. Save your results and add them to your report.**
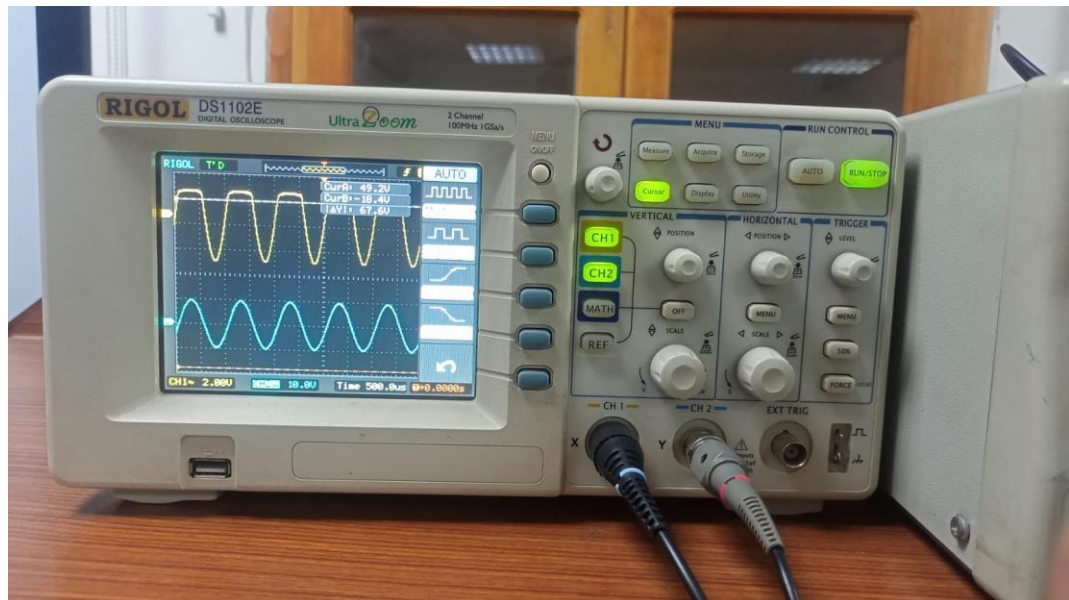

Figure 23: Input and Output curves on Oscilloscope

Limiter Circuits (Part A – Simulation)

In the previous lab exercise you worked with some limiter circuits. In this lab, we will take the basic limiter circuit and modify it, to come up with modified V_o vs. V_{in} curve. The second limiter circuit will be using Zener diodes.
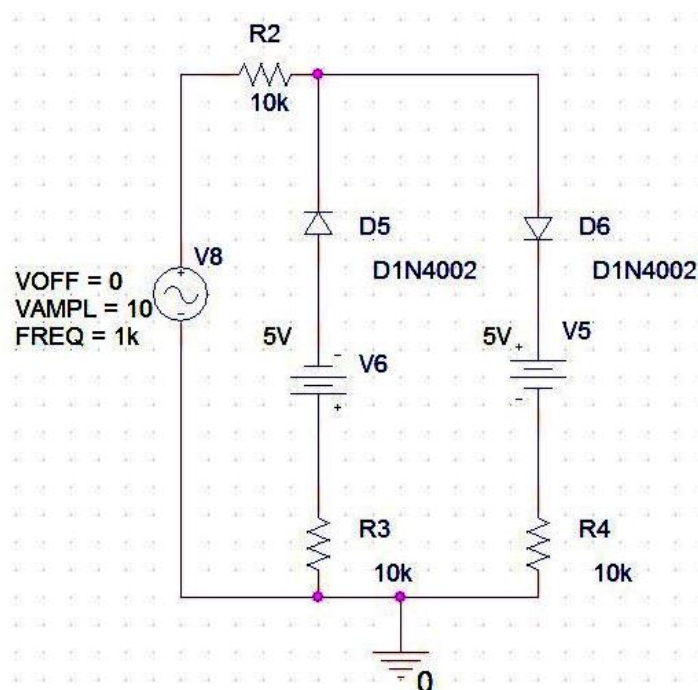

Figure 1A – Circuit Diagram for Limiter Circuit - I

Procedure

    a) Using ORCAD PSpice software, draw the circuit diagram as shown in figure 1A.

    b) Generate an appropriate the simulation profile and obtain the graphs showing time domain variation of V_o and V_{in} on the same chart. Kindly make sure that the recorded graphs are clear and readable.

    c) In addition to the above graphs, get a plot of V_o vs. V_{in}; make use of axis variables and traces, *do not use Sweep analysis,* since we're only interested in observing the behavior of V_o as input sine wave varies in time from -10V to 10V.

    d) Once the graphs are obtained after simulating the above circuit with the appropriate simulation profile, answer the questions given at the end of this part.

Observations/Measurements and Explanation:

10. Accomplish the following and explain your results:

    e) Generate the **V$_o$ vs V$_{in}$** curve by selecting a suitable DC sweep analysis simulation profile setting. Include this plot your report. Is this plot different from the one obtained in paragraph 4 (c) above? Explain any differences that you observe.
    Ans: Graphs are almost the same. There is no such difference.
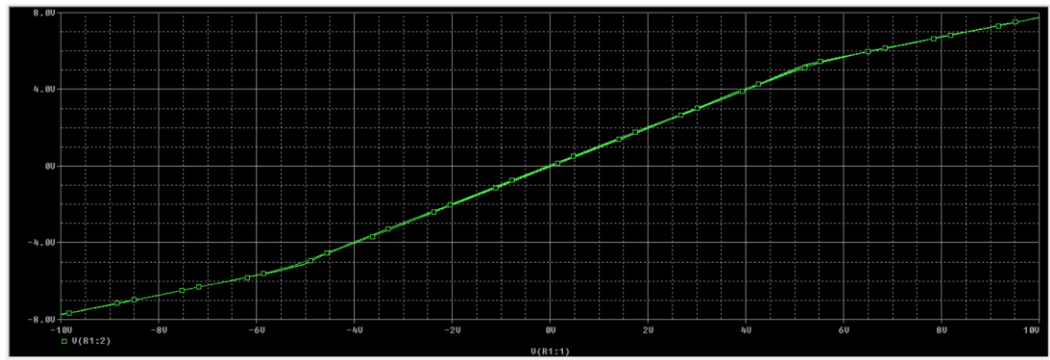

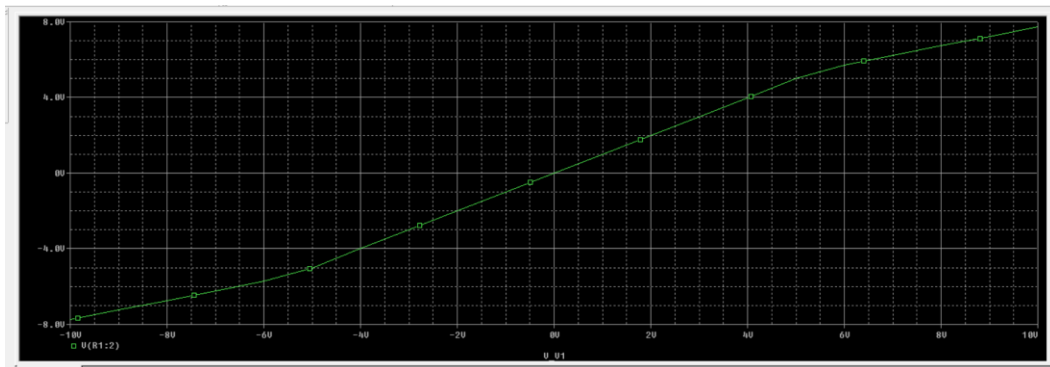*Figure 24: Output Voltage for Part A limiter Circuit*

Figure 25: Output Voltage for Part B Limiter Circuit

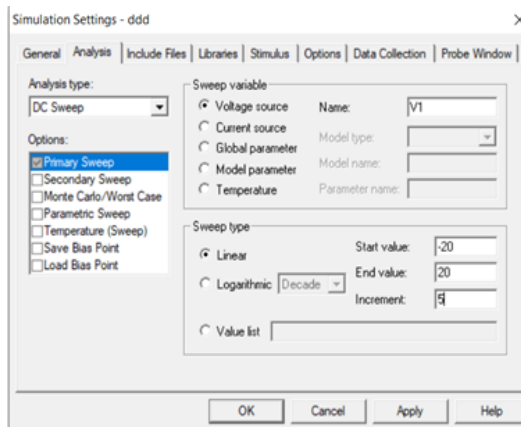   f) Attach the screenshot of your simulation profiles and explain the reasons for the chosen settings.

Figure 26: Power Sweep for Circuit Simulation

g) What further settings did you change to ensure that the recorded graphs are clearly readable and are appropriately showing the simulation results?
Ans: Since the graph has not completely cut off at the required limiting voltages, a filter inserted at both ends will cut off at the required point.

h) Change the value of the above DC sources to V6 = 3V and V7 = 6V. What changes to **V$_o$ vs V$_{in}$** do you anticipate show by appropriate equations that are anticipated and draw a hand drawn graph of the **V$_o$ vs V$_{in}$** for the new settings of voltages (V6 = 3V and V7 = 6V) but change the value of R3 to 15K and R2 to 5K.
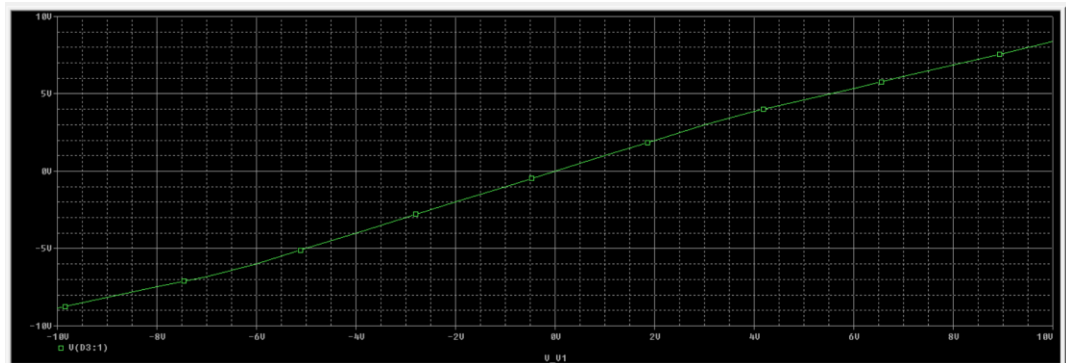

Figure 27: Transfer Characteristic curve for Part B Limiter Circuit

Part B:
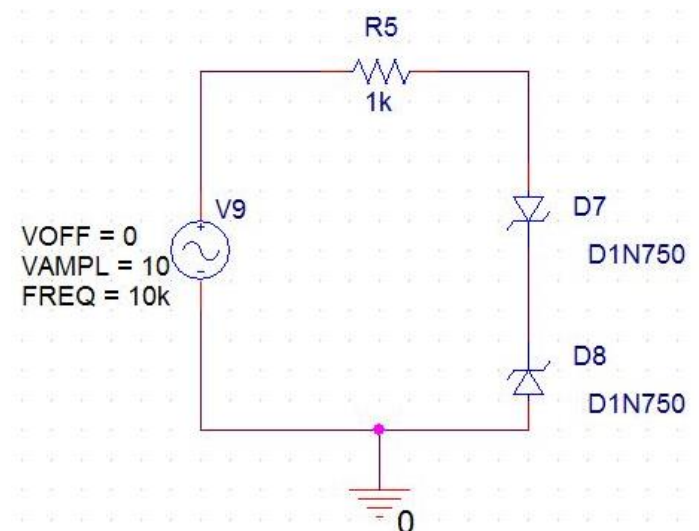
Limiter Circuit Using Zener Diode

Figure 1B – Circuit Diagram for Limiter Circuit II

(Implementation)

This part of the limiter circuits involves the implementation of a limiter circuit using D1N750 Zener diode.
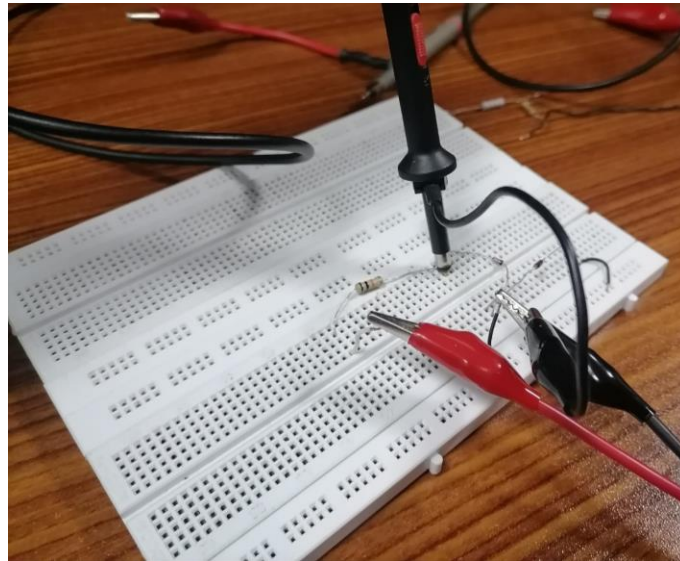
Hardware Implementation:

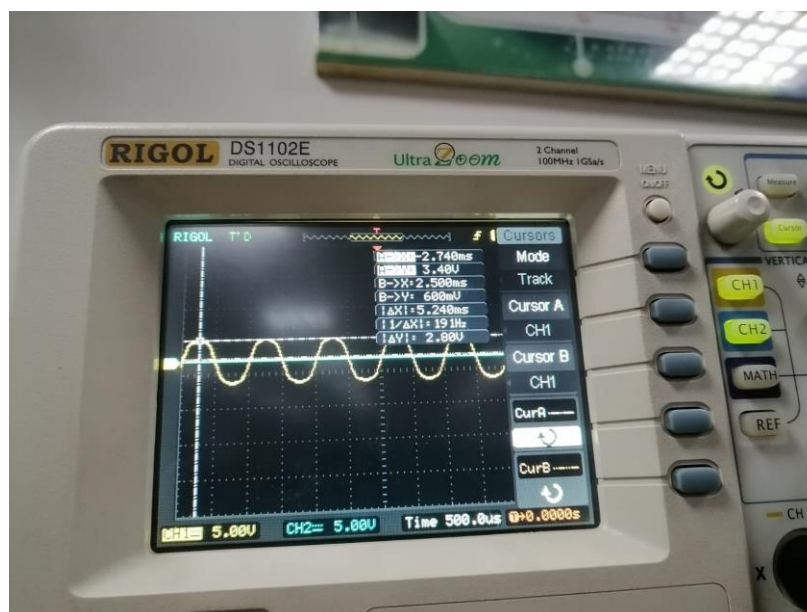*Figure 28: Hardware Implementation*

Oscilloscope Readings:

Figure 29: Oscilloscope Output Waveform

Procedure:

- Patch-up the circuit shown in figure 1B above.
- Using a function generator give an input sinusoidal signal as shown in the figure-1B. Measure the output waveform between the anode of D7 and ground.
- Save the waveforms and include these in your report.
- Manually draw (use MS Word for curve generation to attach hand drawn curves) V_o vs. V_{in} response for this circuit using manual calculations. Include this curve and all the relevant calculations in your report.
- Can you generate the V_o vs. V_{in} response on the oscilloscope? Explain the procedure to that you will use and generate the required response on the oscilloscope and record the result.
  Ans: Yes, this is done by clicking menu and changing the time base settings.

Observations/Measurements

Answer the following questions and include them in your report. Support your answers by mathematical equations where necessary.

a. Using 1N4002 diodes design a circuit that would generate a V_o vs V_{in} response similar to the one that was obtained using circuit given in figure-1B.

b. Draw the circuit and prove by using relevant equations that your designed circuit has the required response. Draw a manual plot of V_o vs V_{in} of the designed circuit.

c. Explain logically which circuit is better and more appropriate for practical use.

Answers:

Zener diodes are the preferred choice for applications requiring precise clamping voltages, while general-purpose diodes are more suitable for simpler, less precise clamping tasks or for situations where only overvoltage protection is necessary. The decision on which type of diode to use depends on the specific application. Zener diodes, such as the D1N750, are designed for stable voltage regulation and can withstand reverse breakdown voltages without being damaged, making them well-suited for precise voltage clamping applications. In contrast, general-purpose rectifier diodes like the 1N4002 are not designed for voltage regulation but can still offer overvoltage protection, as long as the clamping voltage falls within their forward voltage range.

$$\begin{cases} V_{in} & \text{if } |V_{in}| < V_f \\ V_f & \text{if } V_{in} \geq V_f \\ -V_f & \text{if } V_{in} \leq -V_f \end{cases}$$

- For $V_{in} < -0.7V$, we would have $V_o = -0.7V$.
- For $-0.7V \leq V_{in} \leq 0.7V$, we would have $V_o = V_{in}$.
- For $V_{in} > 0.7V$, we would have $V_o = 0.7V$.

Conclusion

In conclusion, this lab has provided a comprehensive introduction to the functionality and applications of diodes in electronic circuits. Through hands-on experimentation, we have developed a practical understanding of how diodes can be utilized as rectifiers, clippers/clampers, and voltage regulators. These fundamental concepts are essential for anyone looking to work with electronic circuits, as diodes play a crucial role in ensuring proper signal processing and power management. Overall, this lab has been instrumental in enhancing our knowledge and skills in utilizing diodes effectively in various circuit configurations.