ECE 65 – Components and Circuits Lab

Lab 3 Report – Diode iv Characteristics, Zener Diode, Clipper circuit

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Abstract

The purpose of this lab is to analyze the behavior of diodes in different circuit configurations, including IV characteristics of a general-purpose diode, a Zener diode voltage regulator, and a clipper circuit.

We performed measurements of diode IV characteristics using an oscilloscope, implemented a Zener diode voltage regulator, and designed a clipper circuit using general-purpose diodes.

We concluded that diodes exhibit nonlinear IV characteristics, Zener diodes effectively regulate voltage within a certain current range, and clipper circuits successfully limit voltage swings to predefined thresholds. The results were consistent with theoretical predictions, with minor discrepancies due to circuit loading effects and component tolerances..

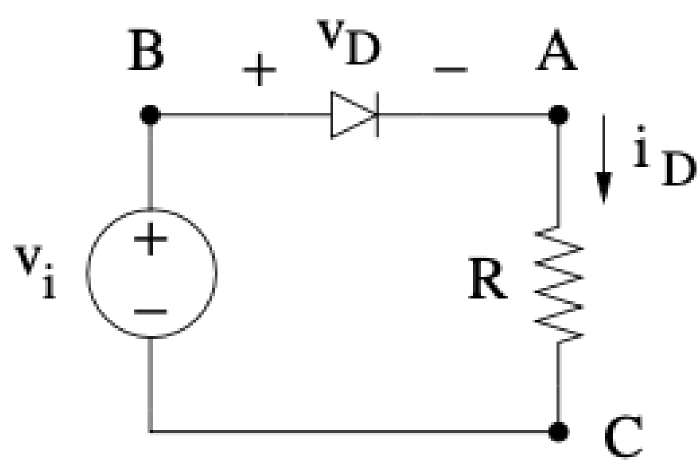
Experimental Procedures and Results

Experiment 1: General Purpose diode *iv* Characteristics

One way to measure the iv characteristics of an element is to apply a known voltage to the element and measure its current. By repeating these measurements at different voltages, we arrive at the *iv* characteristics. This experiment shows how we can measure/plot the *iv* characteristics of an element (a 1N4148 diode in this case) on the scope. It uses the (x vs. y) capability of the scope, which plots v_1 versus v_2, where v_1 and v_2 are voltages on scope channels 1 and 2, respectively.

The oscilloscope only measures voltages. To measure the diode current, we need to ”convert” it into a voltage and measure the voltage using an oscilloscope.

In the following circuit, the currents through the diode and the resistor R, in series with the diode, are the same. Thus, measuring the voltage across the resistor and scaling it by the reciprocal of the resistor value will result in the diode current. ($i_D = i_R = v_R/R$). Furthermore, in order to ”see” the plot on the scope, the plot should be refreshed continuously (i.e., we need to use a periodic input voltage).

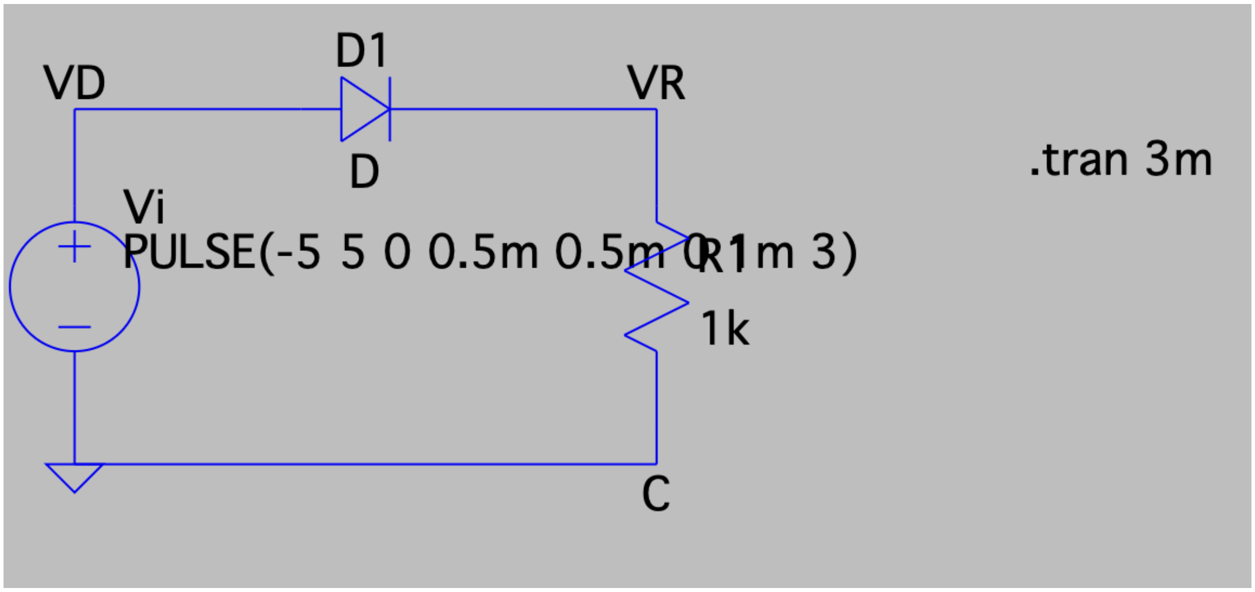


<u>Include your explanations, circuit analysis, plots, etc. here.</u>

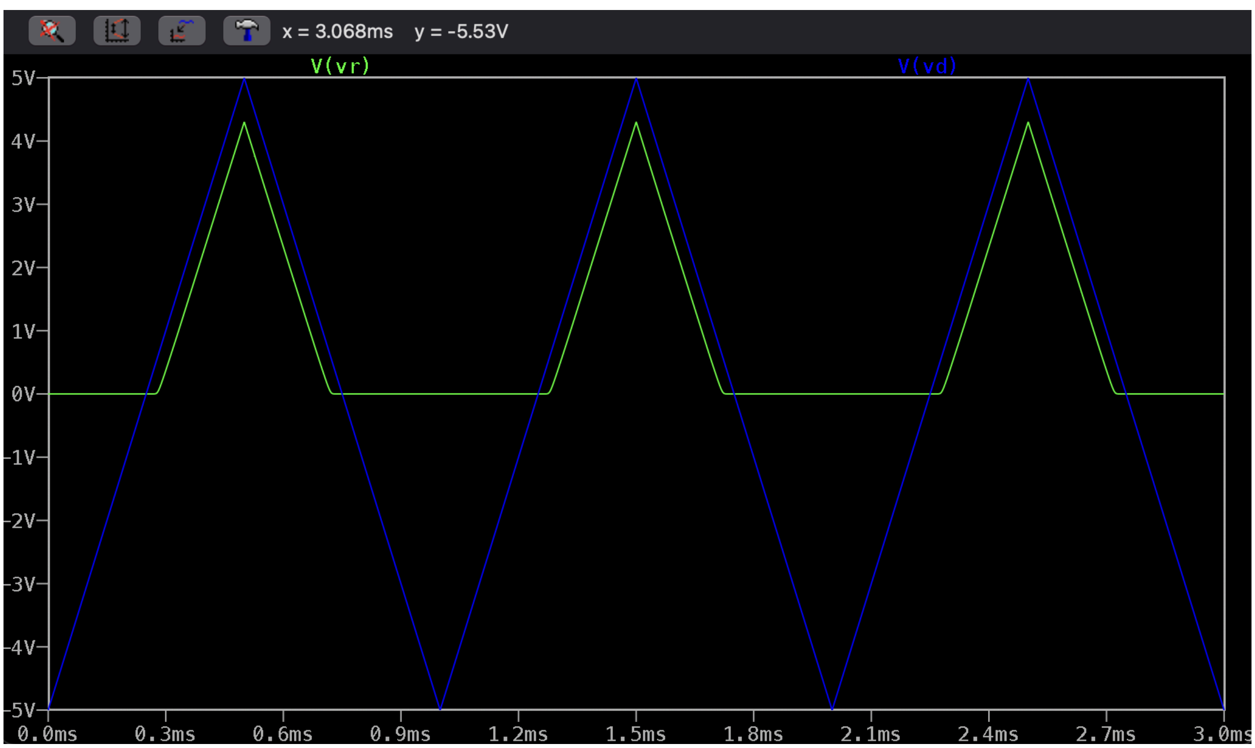
Prelab:

Simulation

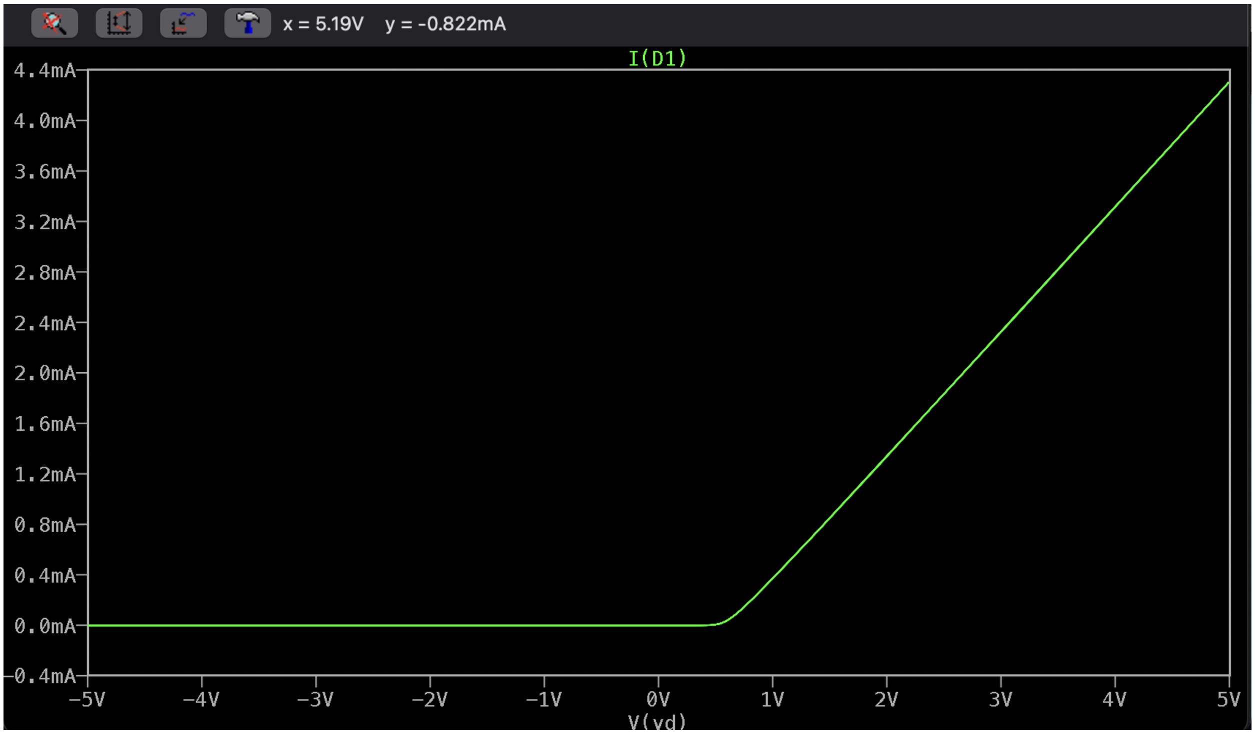
Simulate circuit of Fig. 1 with v_i being a 1-kHz triangular wave with a peak to peak value of 10 V and a DC offset of zero (*i.e.*, input signal ranges from −5 to +5 V). Run the simulation for three periods. Use R=1 kΩ.



1. Plot v_D and v_R as functions of time.



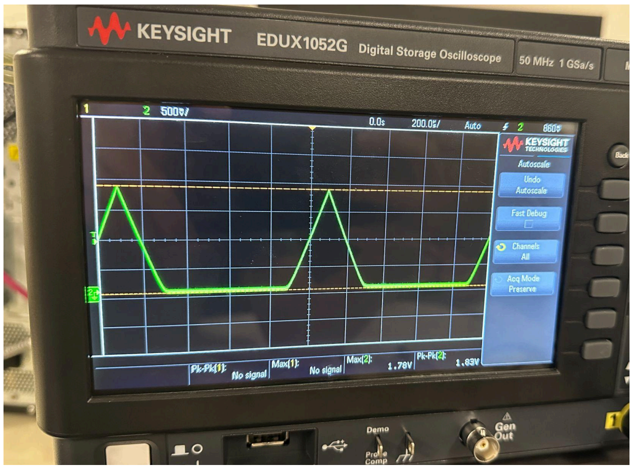
2. Plot $i_D = \frac{v_R}{R}$ as a function of v_D. On your plot, identify forward-bias and reverse-bias regions. (To accomplish this, you need to change the x-axis to v_D and then plot $\frac{v_R}{R}$. Do not change the simulation profile settings for this.)



Lab exercise:

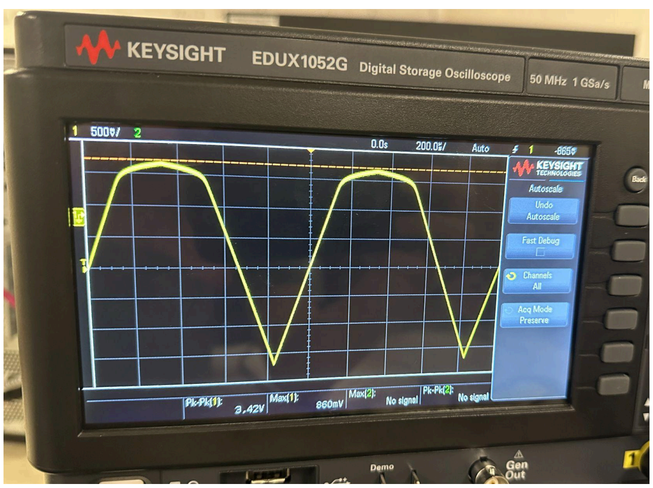
It turns out that the circuit of Fig 1 will not work in the lab, and we need a more complicated circuit. To understand the reason, build the circuit of Fig. 1. v_i is supplied by the function generator and is a 1-kHz triangular wave with a peak to peak value of 10 V and a DC offset of zero (similar to simulation). The scope should be in its default mode of showing channel traces as functions of time.

1. Use scope probe for channel 2 to view v_R (i.e., attach the scope ground to point C and the probe to point A). Compare with your simulation.



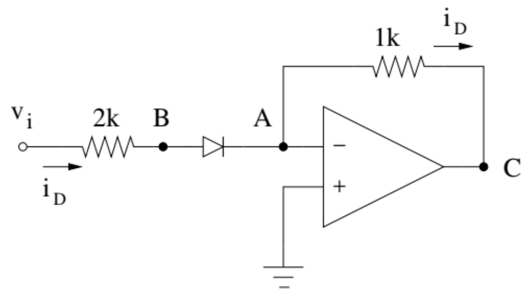
Consistent with our simulation graphs.

2. Try to simultaneously read v_D on channel 1 of the scope. What happens to the channel 2 trace? Explain why this setup does not work while the circuit simulator gives the correct answer.

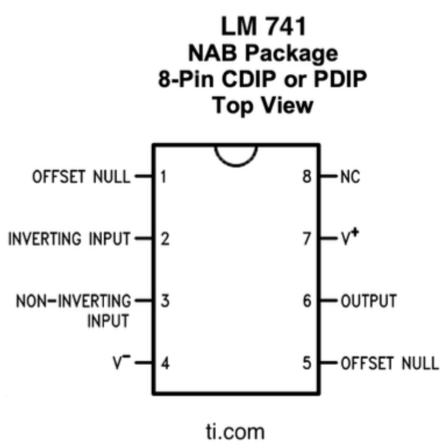


The channel 2 trace disappears. This is because we are effectively shorting the circuit when we measure the voltage across V_D.

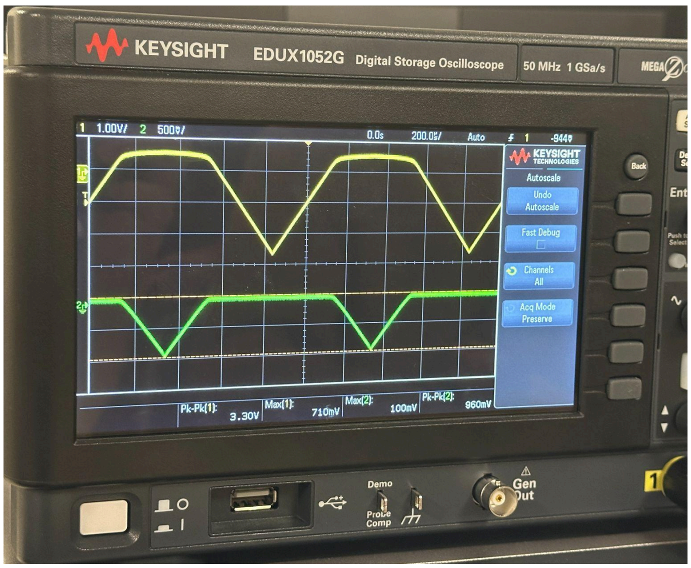
3. Build the below circuit with a 741 Op-amp chip.



The chip should be powered with ±15 V supplies. This type of chip has two important properties which are relevant to this experiment. One, the current flowing into chip input terminals (marked by − and + signs) is very small and can be ignored. Second, if we operate this chip in the negative feedback mode (as is done in the above circuit), the voltages at the ”inverting” terminal (marked by−) and the ”non-inverting” terminal (marked by +) are almost equal. The following picture shows the pinout of LM741 IC.

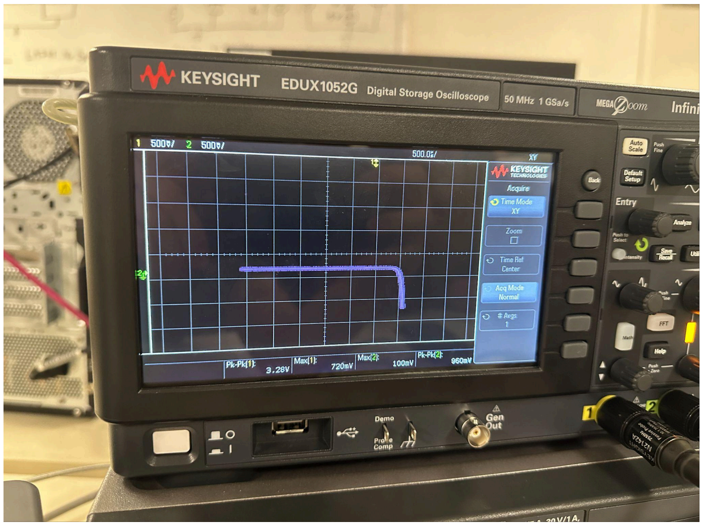


Set the function generator to produce a 1 kHz triangular wave with a peak to peak value of 10 V and a DC offset of zero. Attach the scope ground to the non-inverting terminal of the Op-amp, which is grounded (inverting and non-inverting terminals have the same voltage and, thus, point A is effectively grounded). Attach Channel 1 probe to point B (so Channel 1 reads vD) and Channel 2 probe to point C (which will read 103iD). Print out the traces and compare the results to your simulations. Explain why this circuit works.

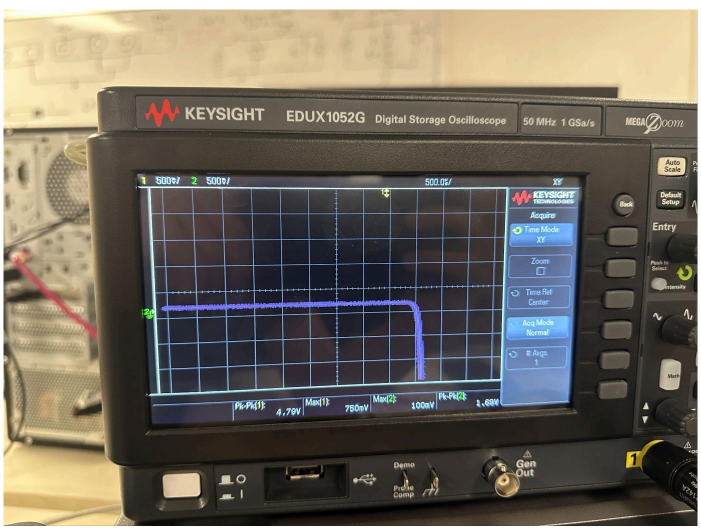


Incorporating the opamp into our circuit allows us to isolate the circuit from the oscilloscope probes by buffering the diode and resistor signals. The oscilloscope is able to measure the opamp's output, which is unaffected by the probe's impedance.

4. Using the same function generator setting, set the scope to show (x vs y). Set both channels to 1 V/division. The scope should show one point. Move the point such that it is at the lowest, right-most voltage division marks on the scope. Slowly increase the amplitude of the input. The scope shows the $i - v$ characteristics of the diode. Increase the amplitude of the input wave until the diode iv curves "fills" the scope display. Print out the scope output and mark and label the axes.



input amplitude: 5V x-axis: V_D (V) y-axis: i_D (A)



input amplitude: 8V x-axis: V_D (V) y-axis: i_D (A)

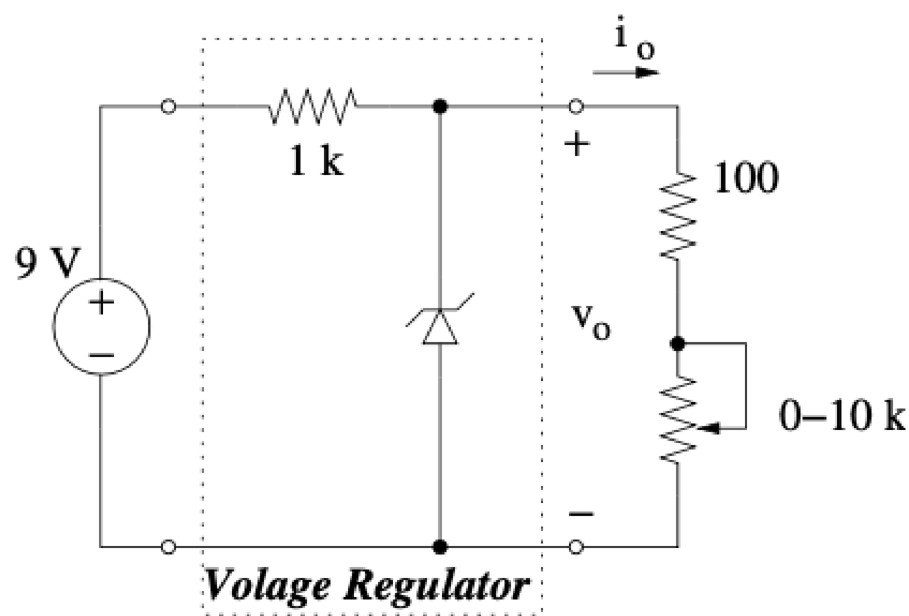
5. What is the function of the 2 k resistor?

The function of the 2k resistor is to ensure proper current flow through the diode and stable operation of the feedback loop. The op-amp is added to prevent the loading effects that caused issues with the initial simple design.

Experiment 2: Zener Diode Power Supply

Set up the circuit below with a 1N5232B Zener diode (V_Z = 5.6 V). In this circuit, the 9-V supply represents the "unregulated voltage." The elements in the box (1 kΩ resistor and the Zener diode) form the regulator circuit. The combination of the variable resistor (potentiometer) and 100 Ω resistor represents the "load" in this circuit (call their combination R_L). With varying the resistance of the potentiometer, we can draw a different amount of current from the regulator circuit.

Include your explanations, circuit analysis, plots, etc. here.



Prelab:

Circuit analysis

Using a "Constant voltage" model for the Zener region, calculate the output voltage of the regulator (v_o) as a function of its output current (i_o). Estimate the maximum load current for the circuit to act as a voltage regulator.

In the Zener region, the output voltage is clamped by the Zener diode at $v_o = v_z = 5.6V$.

Total Series Current $I_R = \frac{v_{in}-V_o}{R} = \frac{9-5.6}{1k} = 3.4\ mA$

Load Current $I_o = \frac{V_o}{R_L}$ $R_L = R_P + 100$ $I_o = \frac{5.6}{R_p+100}$

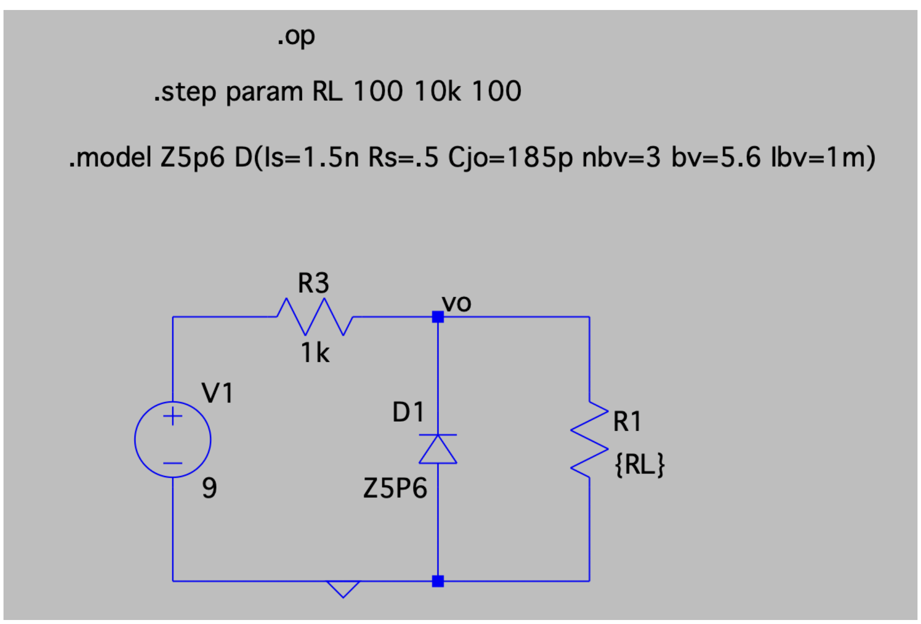
Zener Current $I_Z = I_R - I_o$ $I_Z = 3.4mA - \frac{5.6}{R_p+100}$

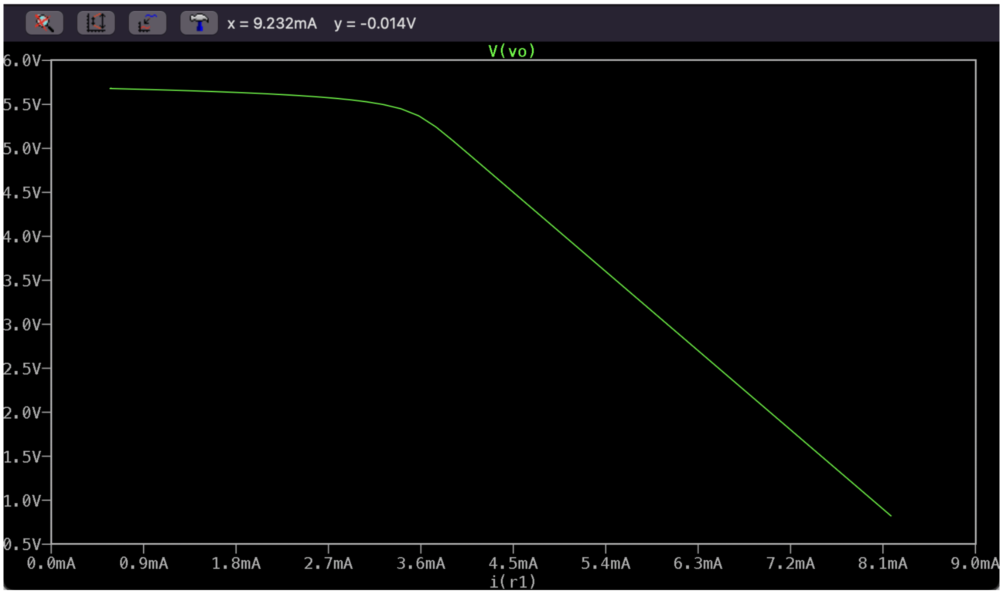
Maximum Load Current $I_{Z,min} = 1mA$

$I_o = I_R - I_{Z,min} = 3.4mA - 1mA = 2.4mA$

Simulation

Simulate the circuit with R_L (combination of the potentiometer and 100 Ω resistor) as a parameter with a range of 100 Ω to 10 kΩ (do NOT include the 100 Ω resistor in your simulation!). Plot v_o versus i_o and compare with your analytical results. (Change the x-axis to display i_o instead of resistance.)





Lab exercise:

Assemble the circuit. Start with the potentiometer set at maximum resistance (*i.e.*, about 10 kΩ). Measure the load current and the load voltage. Then, vary the potentiometer resistance and measure the load voltage for a range of load currents. Plot v_o, versus i_o. Compare with your circuit analysis and simulation and explain the results (especially the observed slight drop in v_o when i_o is increased).

Load Resistance	Load Voltage	Load Current
10 kΩ	5.459 V	3.563 mA
7.5 kΩ	5.453 V	3.569 mA
5 kΩ	5.439 V	3.583 mA
2.5 kΩ	5.285 V	3.739 mA
100 Ω	0.831 V	8.224 mA

We can see that at high load resistance, V_o is close to the Zener voltage of 5.6V. This means that the current drawn by the load is small. As R_L decreases, the load current i_o increases. V_o begins to drop slightly because of the Zener diode's dynamic resistance which causes a voltage drop proportional to the Zener current (i_Z). At very low load resistances towards the end, the load current increases significantly, exceeding the circuit's ability to maintain regulation - resulting in the sharp drop of V_o. This is consistent with our pre-lab simulation graph, shown above.

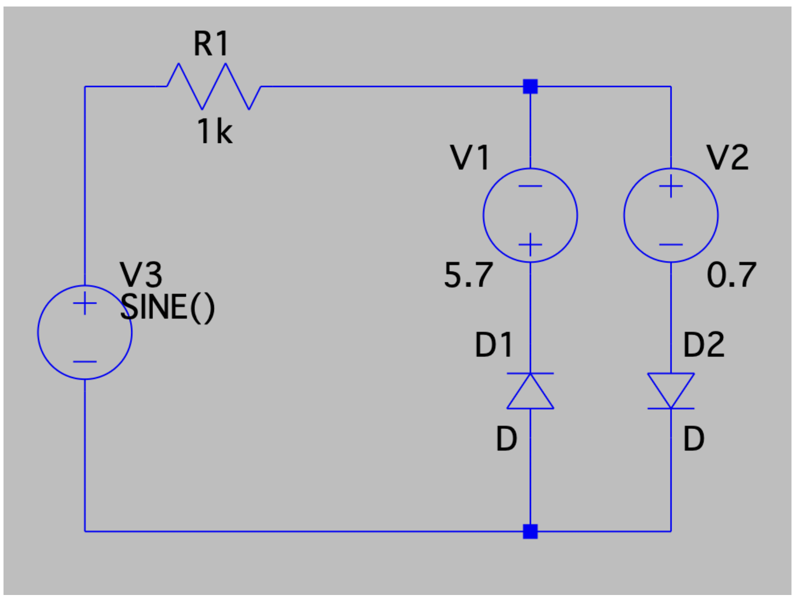
We didn't do more points to plot the lab results, but we got it approved by TA David.

Experiment 3: Zener Diode Power Supply

Prelab:

Circuit Design

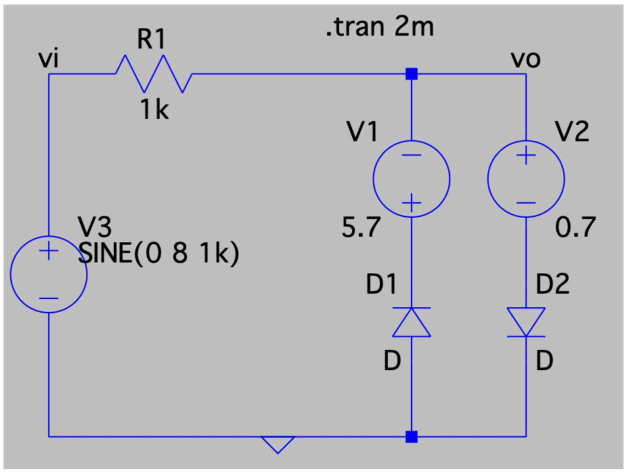
Design a clipper circuit using 1N4148 general purpose diodes and a R = 1 kΩ to clip the input signal voltages that are above 5.7 V or less than−0.7 V. Make sure to use a DC source in your design, and do NOT use Zener diodes.

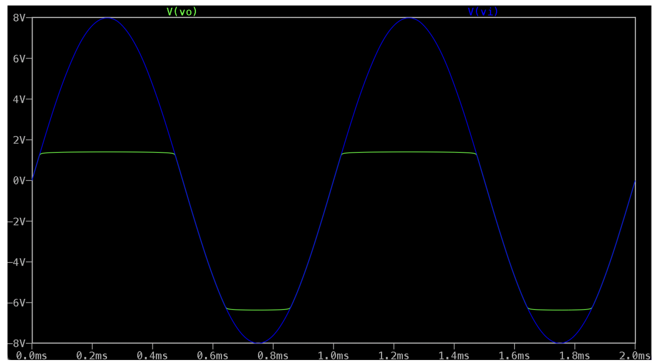


Simulation

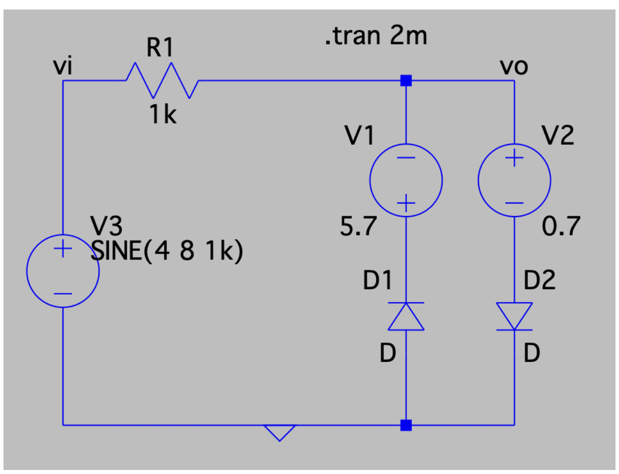
Using Transient analysis, simulate the circuit you have designed with two input waveforms:

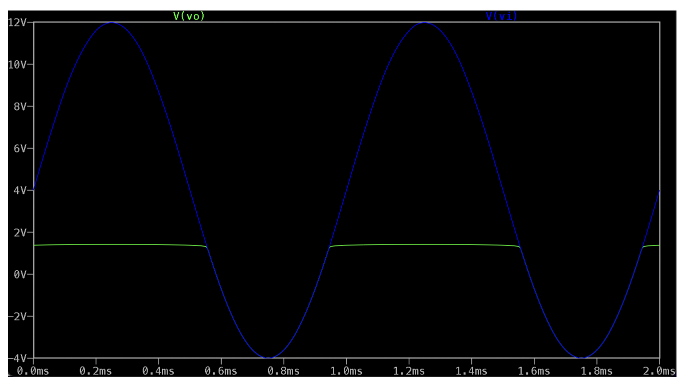
1. A sinusoidal wave with a frequency of 1 kHz, an amplitude of 8 V, and a DC offset of zero





2. A sinusoidal wave with an amplitude of 8 V and a DC offset of 4 V. In each case, plot v_o and v_i for two periods (both traces on the same graph).

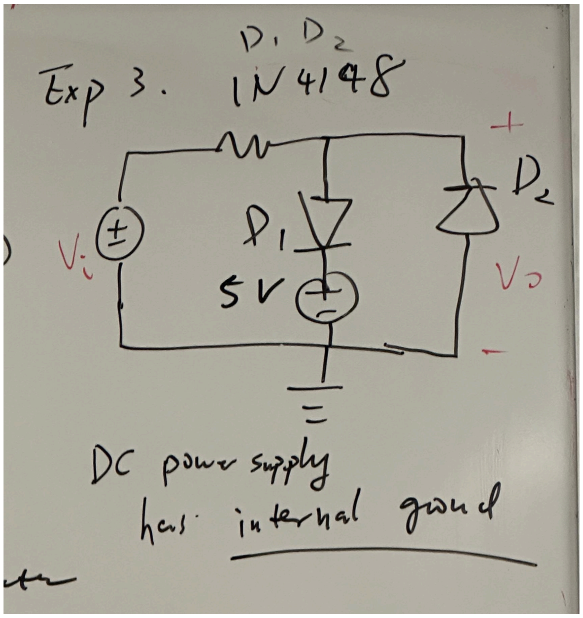


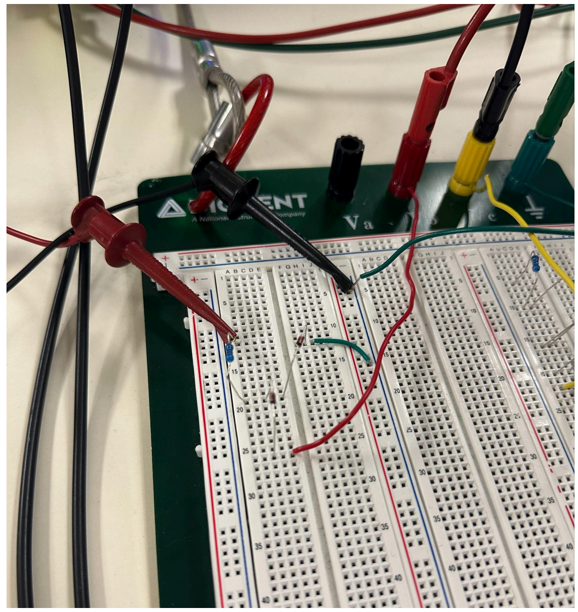


Note: Make sure your step size is small enough. You should see smooth curves.

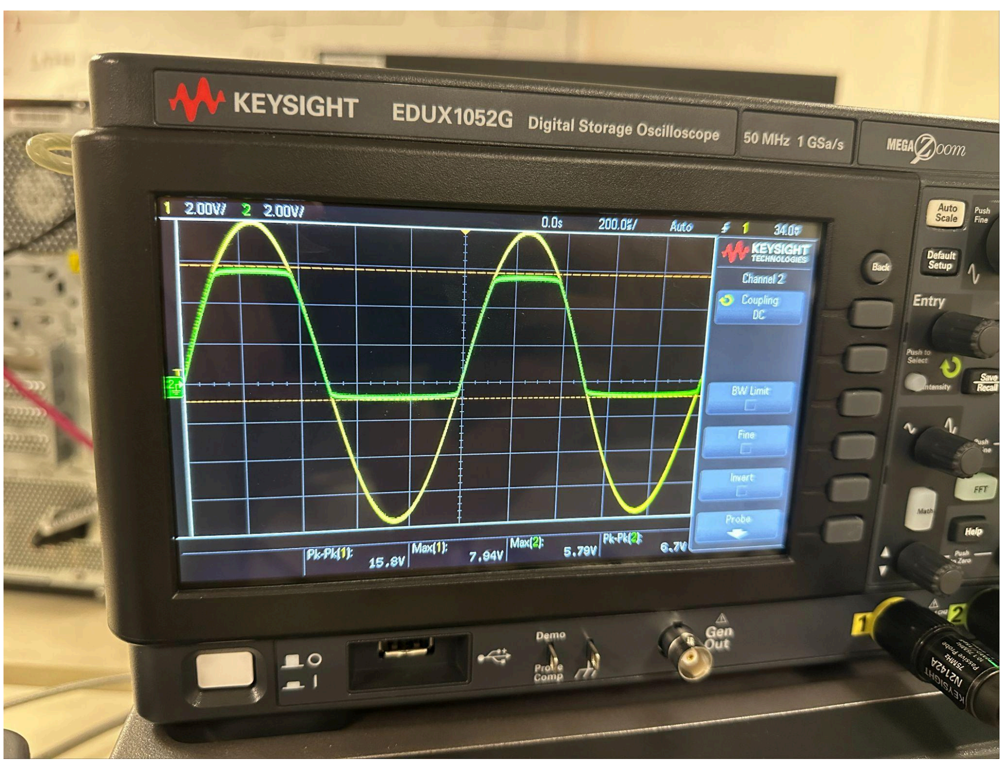
Lab exercise:

1. Assemble the circuit that you have designed. Take a picture of the setup and include it in your report.

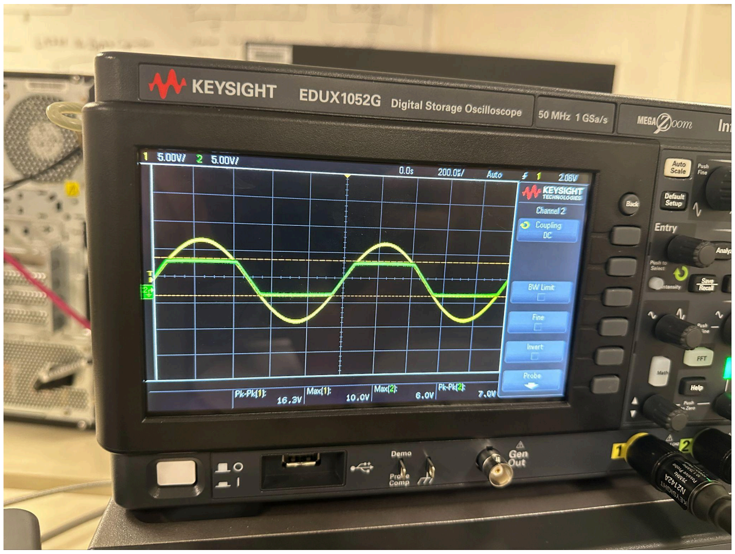




2. Apply a sinusoidal wave with a frequency of 1 kHz, an amplitude of 8 V, and a DC offset of zero to the circuit. Adjust the oscilloscope settings to display vi and vo properly. Take a picture of the oscilloscope display and include it in your report.

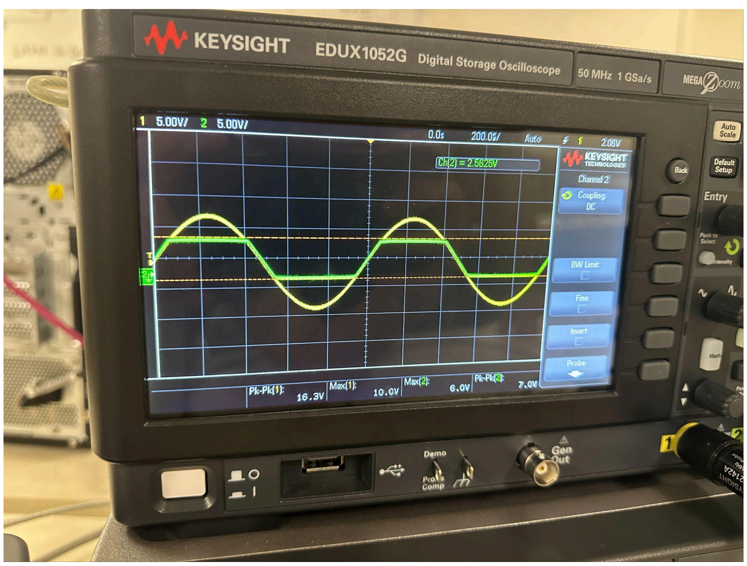


3. Increase the DC offset of the input. What do you see? Does it follow your simulation results? Explain.



We see that as we increase the offset, we can see the clipping range change. It follows our simulation results.

4. Set the DC offset to +2V. Adjust the oscilloscope settings to display v_i and v_o properly. Take a picture of the oscilloscope display and include it in your report. Explain the results.



Similar to above, we can see that it still clips on both the top and bottom, the offset just changes the range.

Conclusion

Include your conclusion here.

This lab demonstrated the practical behavior of diodes in various circuit applications. In Experiment 1, we observed the IV characteristics of a 1N4148 diode and learned that direct oscilloscope measurements could interfere with results, necessitating the use of an operational amplifier for accurate readings. In Experiment 2, we confirmed that Zener diodes maintain a stable voltage in a voltage regulator circuit, but load resistance affects regulation, leading to voltage drops at higher currents. In Experiment 3, the clipper circuit successfully limited voltage excursions beyond +5.7 V and -0.7 V, demonstrating diode-based signal shaping. The experimental results closely matched simulations, reinforcing the theoretical understanding of diode operation and circuit behavior in real-world conditions.