Laboratory Goals

- Analyze, simulate and test different diode-based circuits.
- Study different applications of Rectifier and Zener diodes
- Use the curve tracer to study the IV curve of Zener Diodes

Pre-lab / lab reading

- ELVIS instruction manual
- Course Textbook
- Oscilloscope User's Guides
- Read the pre-lab introduction below

Equipment needed

- Lab notebook, pencil
- NI ELVIS II
- Oscilloscope (Agilent or Tektronics)
- 2 oscilloscope probes (already attached to the oscilloscope)
- BNC/EZ Hook test leads
- Workstation PC, with PSICE application
- Rectifier and Zener Diodes
- Resistors and Capacitors
- Jumper Wires

Lab safety concerns

- Make sure before you apply an input signal to a circuit, that all connections are correct, and no shorted wires exist.
- Do not short the function generator signal and ground connections together .
- Do not touch the circuit wiring while power is applied to it .
- Ensure you connect devices using their correct polarity.

1. Pre-Lab Introduction

Diode Faults

Short Circuit: Diodes can be easily damaged by high voltages, especially diodes working in high-voltage or high-power conversion applications. A shorted diode will have 0Ω or a very low resistance when measured in both forward and reverse directions. If this fault happens in a power supply, a large current can flow, and obvious damage will be visible such as "cooked" diodes and / or blown fuses in the circuit.

Open Circuit: Occasionally, diodes (especially small signal diodes) may become open circuit and read very high resistance or infinity in both forward and reverse directions.

Leakage: A signal diode may become "leaky". When this happens, its forward resistance may be normal, but its reverse resistance may be lower than the expected infinity. This fault can only be detected with the diode removed from the circuit it is working in, because of the parallel resistances of other components connected across the diode.

Zener Diode Faults

Zener diodes exhibit similar faults to other diodes, but in addition they may also become "noisy". When this happens the normally very stable voltage across them suffers from very rapid fluctuations like the spiky waveform you would see on an oscilloscope when looking at an audio signal that was just a constant hiss, (also called "background noise"). As Zener diodes are often used to stabilize power supply lines, this "noise" can give rise to strange faults, depending on what voltage is being supplied by the power supply in question.

As a rule of thumb - If a circuit is behaving strangely, and noise on the power supply is suspected, check any Zener diode stabilizing that line by substituting it with a known good diode. All Zener diodes have a defined voltage, and if the voltage measured across them under working conditions, is not what is printed in the diode’s datasheet (or on the diode if you can see the markings), then the diode is faulty, (probably open circuit) and must be changed.

2. Pre-Lab

- For each of the circuits given below, calculate the expected output. If necessary, plot the output signals as a function of time.
- Investigate how to test a diode to determine if it is operating properly.
- Find out how can the reverse breakdown voltage of a Zener Diode be determined if its parameters are unknown.
- Enumerate conventional operational voltages for commercially used Zener diodes.

3. Zener Diode I-V Characteristics

Curve Tracer

- Use the current-voltage analyzer to generate the IV curves of various Zener diodes.
- Can you locate the different regions of operation? Determine the Zener voltage.
- The Teaching Assistant will verify the resulting curve and sign your lab notebook.

4. Voltage Regulation with Zener Diodes

- Build the circuit shown below using a Zener diode provided by your teaching assistant.

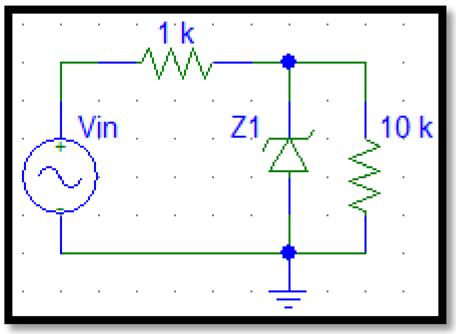

Figure 1: Zener-Diode based Circuit

- Read the diode data sheet to identify which pins correspond to the anode (positive) and cathode (negative) terminals. Also find the reverse break down voltage.
- Apply a $10V_{pk2pk}$ 1kHz sinusoid with a +2.5V DC offset using the function generator
- Measure V_o across the 10 kΩ resistor using the oscilloscope.
- Record the values of peak to peak voltage (V_{pk2pk}) and peak voltages (V_{pk}).
- Compare the input voltage V_{in} and output voltage V_o on the oscilloscope.
- Repeat this experiment for different Zener Diodes (if available).

Further Exploration

- **Variable Input Voltage:** Build the next circuit to explore the Zener's behavior with a variable input voltage. To analyze this circuit, change V_{IN} until the voltage in the load stabilizes. Write down this minimum voltage value for stability.
- For different values of V_{IN}, measure the output voltage V_O (across the second resistor) and plot it as a function of V_{IN}. This will be the circuit's voltage regulation curve.

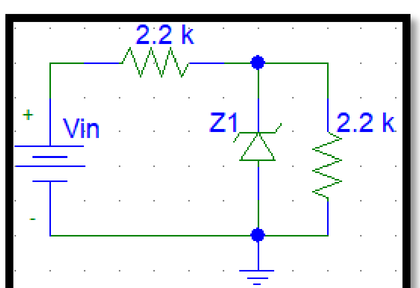

Figure 2: Zener Diode Circuit with Variable Input Voltage

4. Limiting Circuits

Consider the circuits shown below. Construct and test each circuit with the parameters indicated. For each circuit, provide a plot of Vin vs time and Vo vs time.

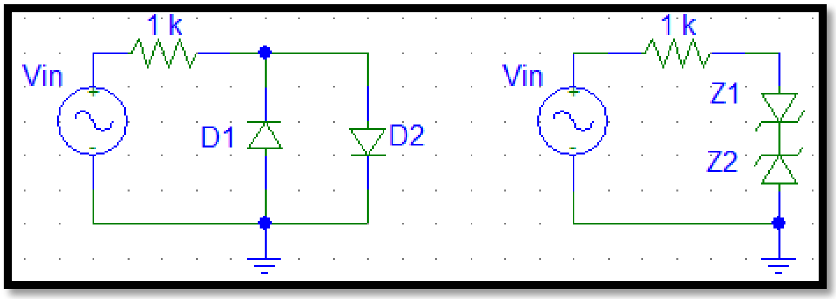

Figure 3: Limiting Circuits with Rectifier Diodes (left) and Zener Diodes (right).

Rectifier Diode Limiting Circuit :

- Use a 1kΩ resistor and rectifier diodes provided by your TA.
- Test using a 5-Vpk-pk 100Hz input sinusoid with no DC components.
- Use the Tektronics Oscilloscope's X-Y mode to plot Vo vs Vi.

Zener Diode Limiting Circuit :

- Use a 1kΩ resistor and Zener Diodes provided by your TA.
- Test using a 15-Vpk-pk 100Hz input sinusoid with no DC component.
- Use the Tektronics Oscilloscope's X-Y mode to plot Vo vs Vi.

Measurements

- ❑ Using the testing technique from the prelab, verify that all diodes are properly functioning.
- ❑ For each circuit, apply the input specified waveform using the function generator FGEN, and capture the output voltage waveforms on the oscilloscope.
- ❑ Record for every case the highest and lowest output voltage value in the oscilloscope.
- ❑ Capture images of the Tektronics oscilloscope's Vo vs V_{IN} plots.
- ❑ How could you change the limiting voltages for the first circuit to approximately ±1.4V?
- ❑ Will the output voltage change if a 10kΩ Resistor is added in parallel, like in Figure 4?
- ❑ How will the output change if DC sources are added like shown in Figure 5?

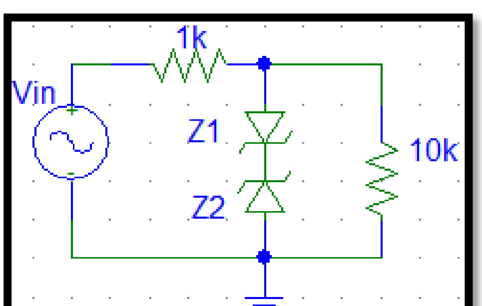

Figure 4: Zener Limiting Circuits with Resistive Load

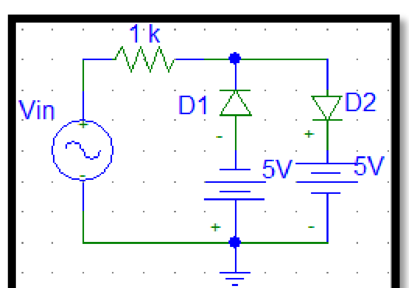

Figure 5: Polarized Limiting Circuit

5. Clamping Circuits

- Build the circuit shown below in Figure 6 using a rectifier diode provided by your teaching assistant and available capacitors and resistors.

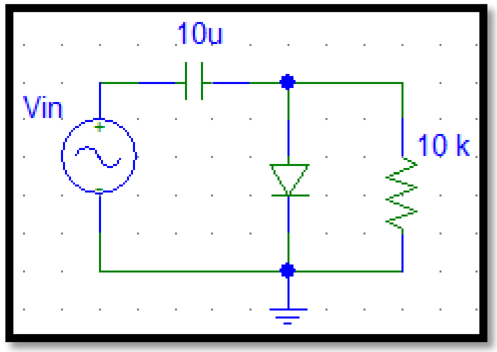

Figure 6: Clamping Circuit

- Test the circuit using a 10-Vpk-pk 1-kHz sinusoid from the function generator.
- Provide plot of V_{IN} and V_O versus time using the oscilloscope and report the peak voltage.

Further Exploration

- What would happen if the diode was reversed?
- What happens if the waveform is changed to be a square wave instead of a sinusoid?

6. Voltage Multipliers

Build the next voltage duplicator circuit, test and explain its functioning. Using a DC voltmeter measure the voltages in each capacitor and output. Explain their values. Use the largest capacitors available and use a 9V, 1kHz sinusoid input signal from the function generator.

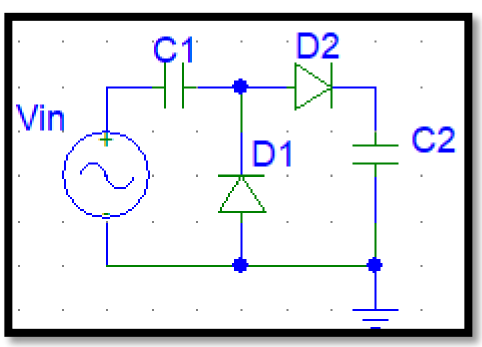

Figure 7: Voltage Duplicator

Further Exploration

Design voltage triplicator and quadruplicator circuits using diodes and capacitors.

5. Simulations

In the previous labs, you learned about SPICE based simulation software like MULTISIM or PSPICE. Provide simulations with either tool for the circuits studied today. How do the simulations compare to measurements taken?

7. Analysis

Write a summary report for the lab. Be sure to also include the following topics:

1. Draw a junction diode cross section diagram.
2. Draw a Zener diode cross section diagram.
3. Identify and explain the operating regions of the IV curve generated for the Zener diodes.
4. Compare the results of the hand computation, physical experiment and curve tracer output graphs. Do the values generally agree? Explain possible reasons for any differences.
5. Explain any difficulties you had with these labs. (Please include any suggestions to improve them).