Lab 4. Zener Diode as a Voltage Regulator

In this lab, you will learn about Zener diodes. You will explore the difference between Zener diodes and regular diodes and learn about some of their applications and uses, such as the Zener regulator.

First, you will look at the specific functions of a Zener diode in simulation and using the protoboard. Then, you will build a circuit that demonstrates the real-world application of Zener diodes as voltage regulators.

Using simulation and the NI ELVIS II/II+, you will learn about the fundamental behavior of Zener diodes by simulating a circuit in Multisim. Then, you will confirm that behavior by building a circuit and measuring the current through Zener diode.

Learning Objectives

After completing this lab, you will be able to:

1. Understand the operation of a Zener diode
2. Learn how a Zener diode works within a voltage regulator
3. Generate simulation results showing Zener diode behavior

Required Tools and Technology

Platform: NI ELVIS II/II+ Instruments used in this lab: • Instrument 1: Function Generator • Instrument 2: Oscilloscope • Instrument 3: Variable Power Supply **Note:** The NI ELVIS III Cables and Accessories Kit (purchased separately) is required for using the instruments.	View User Manual: https://bit.ly/36DFFrv https://bit.ly/36CnQZH (Credit to Clemson University) View Tutorials: https://bit.ly/35Ae9Kc (Credit to Colorado State University) Install Soft Front Panel support: https://bit.ly/2NbhTv6
Hardware: NI ELVIS II/II+ Default Prototyping Board	View Breadboard Tutorial: http://www.ni.com/tutorial/54749/en
Hardware: Electronics Kit	Components used in this lab: • Various value of resistors • Zener diode
Software: NI Multisim Live	Access online http://multisim.com View Help http://multisim.com/help/

1. Background Information

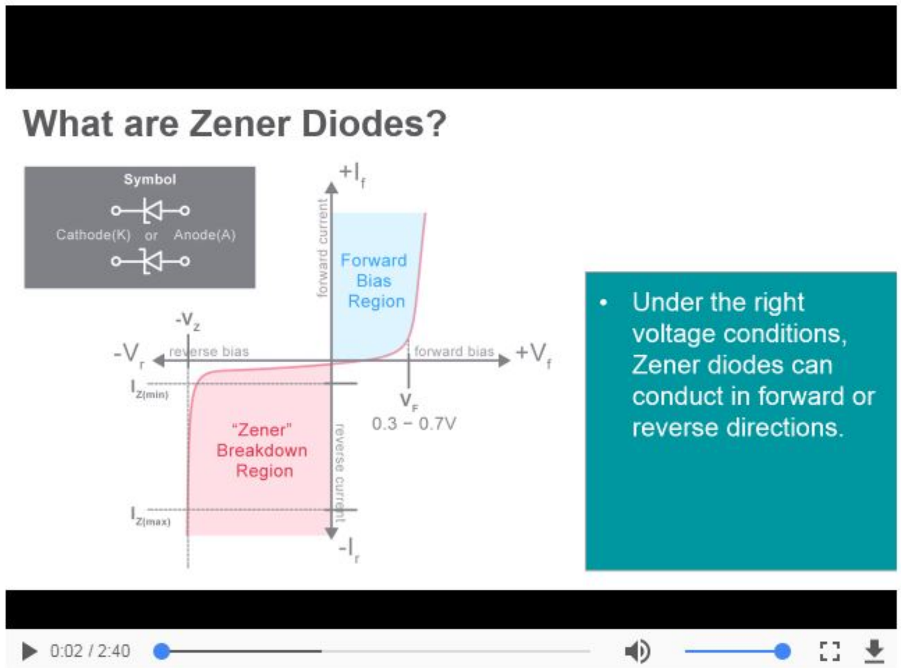


Figure 1. Video Screenshot. View the video here: youtu.be/bJ8egCJB-yw

Video Summary

- A Zener diode can conduct in forward or reverse depending on the voltage conditions present.
- Zener diodes are designed to have controlled breakdowns which keeps voltage stable and prevents damage to the diode.
- Zener diodes are used in many circuits such as: signal clipping circuits, voltage shifter circuits, and voltage regulators.

1.1. What Are Zener Diodes?

A conventional diode will allow current to flow if it is reverse-biased above its reverse breakdown voltage. When this happens, a conventional diode is subject to high current. Unless protected by other circuitry, it can overheat and be permanently damaged when operating this way.

A Zener diode is specifically designed to have a lower breakdown voltage than a conventional diode. This allows the Zener diode to have a controlled breakdown, which in turn keeps the voltage across the Zener diode close to the breakdown voltage.

1.2. Why Are Zener Diodes Important?

A Zener diode is an important component in Intrinsically Safe (IS) circuits. One of the most common methods of protection is to limit electrical current with multiple resistors in series and limit electrical voltage with multiple Zener devices to ground.

Equipment and instrumentation designed for use in hazardous areas usually operates with low voltage and current. In addition to protection from over voltage, Zener diodes are used to regulate the operational voltages of these devices.

1.3. How Can We Use Zener Diodes?

There are different ways in which Zener diodes are frequently used:

1. When two Zener diodes are connected at the cathodes, they will clip both halves of an input signal. These types of circuits can reshape signals and prevent voltage spikes.

2. A Zener diode can be incorporated into a circuit with a resistor to work as a voltage shifter. The input voltage will be lowered by the circuit to an amount equal to the Zener's breakdown voltage.

3. A Zener diode can also be used to regulate the voltage applied to a load. A common configuration is the simple Zener regulator. A "shunt regulator" operates by using the Zener diode's action of maintaining a constant voltage drop when the current is sufficient to cause Zener breakdown. It is often used in low current applications as either a voltage reference or a voltage source.

2. Exercises

2.1. Simulation

In this activity, you will use Multisim Live to simulate the behavior of a Zener diode used as a voltage regulator. As you'll see, a Zener regulator can be used to maintain a voltage across a load for fluctuating source voltage or fluctuating load resistance.
Multisim Live includes a tool called DC Sweep Analysis which sweeps through voltage values and measures output parameters.

1. Launch Multisim and build a circuit shown below (reference design can be found from Multisim Live: https://www.multisim.com/content/KXP9LbiDStxth6CbdMEskU/zener-diodes-lab/open

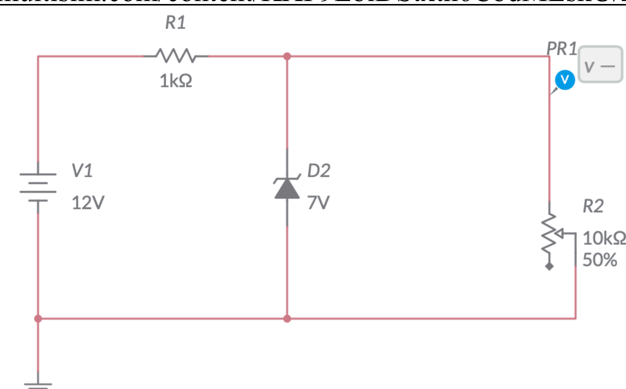
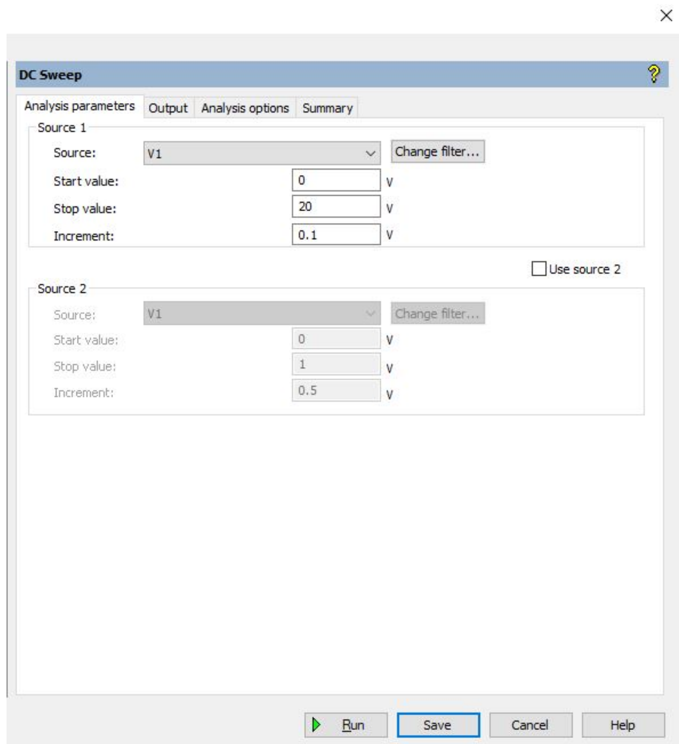


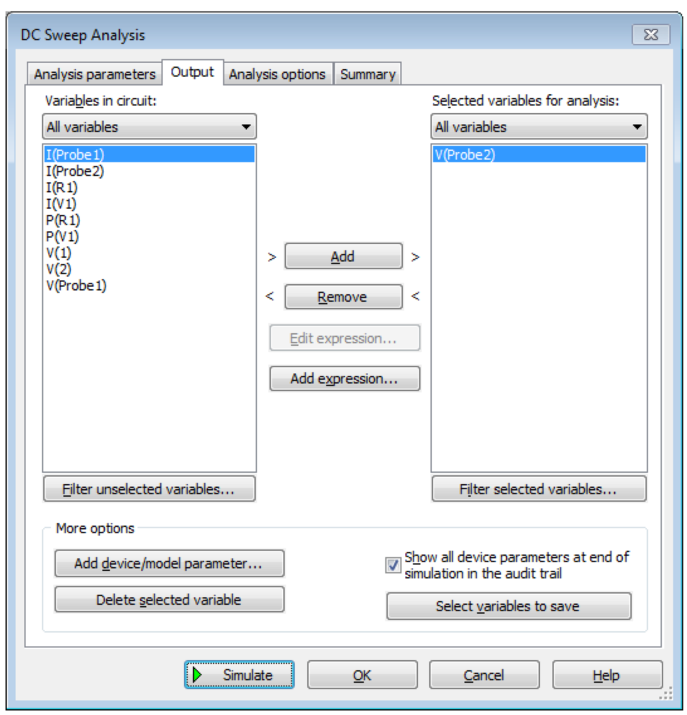
Figure 2. Zener diode circuit

2. Select Simulate>>Analyses>>DC sweep from the shortcut menu to open this tool.
3. DC Sweep Analysis >> Analysis parameters.
4. Source 1 determines which variable will be graphed along the X axis. We want to show Source voltage, so set Source to V1.

5. Set Start value to 0V.
6. Set Stop value to 20V
7. Set Increment to 0.1V



8. Select the Output tab.
9. We want the voltage across the load to be graphed along the Y axis, so select V(Probe2) from the variables list and click Add.



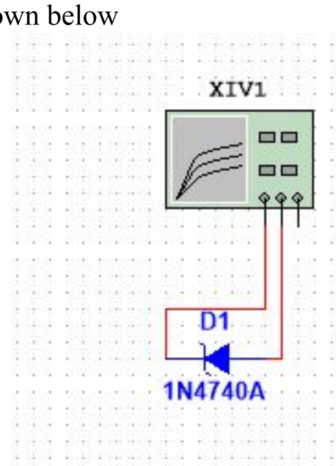
10. Click the Simulate button to run the simulated sweep.
    - At what approximate load voltage value, along the y-axis, does the graph level out? You can use the cursors to measure the values more closely.
    - What physical property of the circuit does this value correspond to?
    - There are two regions to this graph.
        - In the region where both voltages are increasing, the Zener diode is **not conducting** current and therefore the voltage drop is across the load.
        - In the region where the load voltage has become stable, the Zener diode **begins conducting** current. The current is divided between the loads in such a way that the same voltage drop is maintained across the load.
11. When complete, close the graph.
12. Observe the voltage across the load as the resistance of the load changes.
13. Click the Run button to begin the simulation.
14. Modify the resistance of the Potentiometer by pressing <A> or <Shift+A>.
15. Observe that the voltage across the Potentiometer stays relatively constant.
    - **Note:** If the resistance goes too low, the load voltage will decrease (the 1 kΩ resistor and the Potentiometer form a voltage divider).

2.2. Experiments

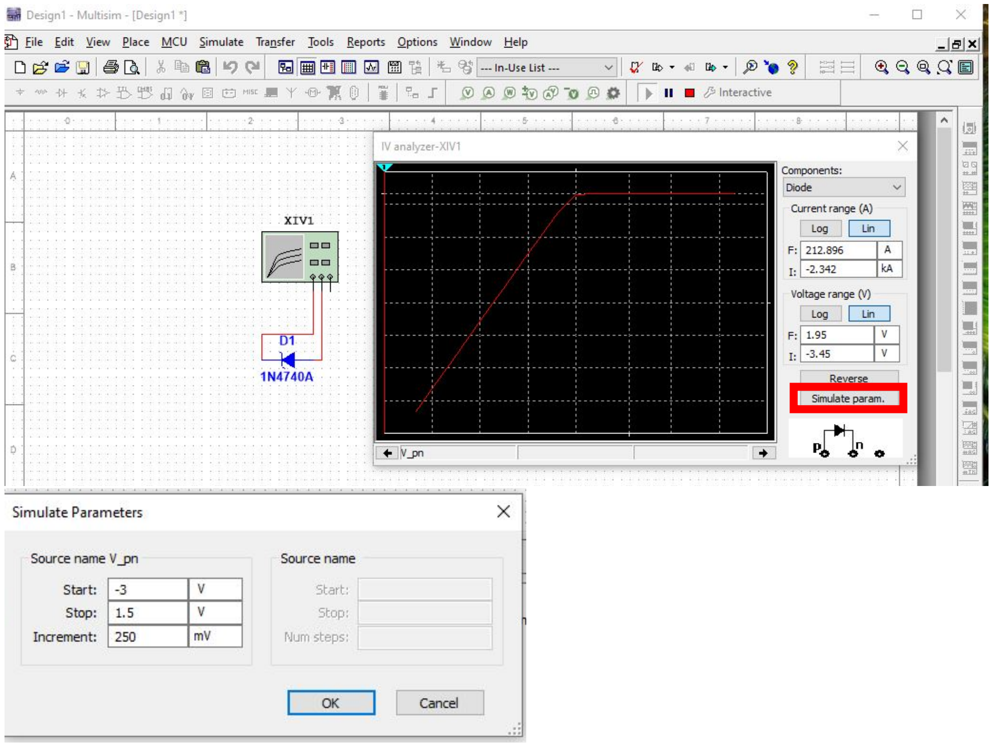
2.2.1. Zener Diode Behavior

1. Place the IV analyzer in multisim, can be found under:
    - Simulate → Instruments → IV Analyzer

2. Attach any Zener diode as shown below



3. Set the instrument as illustrated below, by double clicking on the analyzer and then selecting sim parameters.

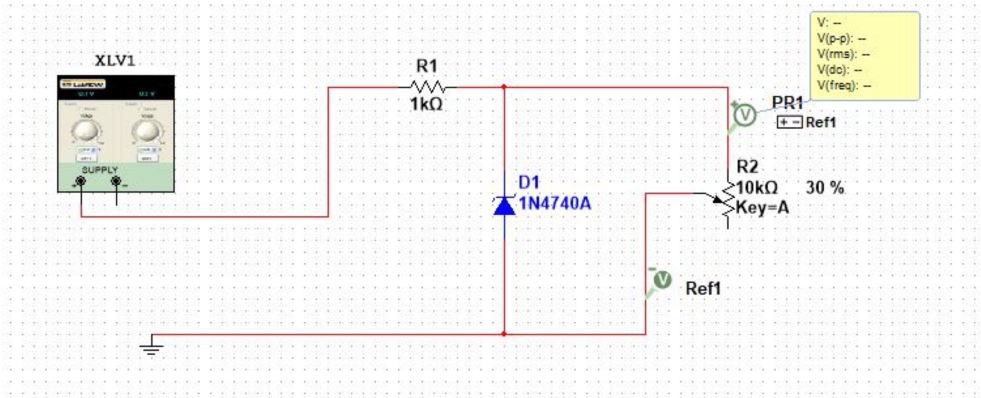


- Set Start to -3.00 V.
- Set Increment to 0.25 V.
- Set Stop to 1.5 V.
- Click the Run button to run the analysis (top of screen in interactive mode).

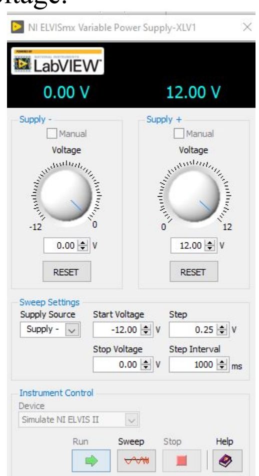
4. Analyze the results.
   - **Note:** At a certain negative voltage, negative current is allowed to flow. This is the **breakdown voltage** of the Zener diode. With positive voltage applied, the Zener diode behaves similarly to the diodes you've seen before.

2.2.2. Zener Diode in a Voltage Regulator

1. Use Multisim to set up the following circuit
   - Here we are using the NI Variable Power supply which can be found as follows
   - Simulate → Instruments → NI ELVISmx instruments → NI ELVISmx Variable Power supply
   - Or you can use any other DC power source



2. Setup the DMM to observe the voltage across the potentiometer.
3. Begin applying voltage to the load.
    - In the Variable Power Supply window, click the Run button.
    - Increase the Supply+ voltage.



4. Observe the voltage across the potentiometer as the supply voltage changes.
    - Increase the Supply+ voltage until the voltage measured on the DMM stops increasing.
    - At what voltage does it level off?

5. Confirm that this voltage corresponds to the breakdown voltage of the Zener diode, if you can.
6. Observe the Voltage across Potentiometer
    - Set the Supply+ voltage to 12V.
    - Modify the resistance of the potentiometer.
    - Confirm that the voltage across the potentiometer does not change as the resistance changes.
    - **This assumes that the resistance stays above approximately 1kΩ. At lower values, the voltage will go below the breakdown voltage of the Zener diode, and the voltage regulator will not function.**

3. Analysis

- Why does the voltage regulator stop working when the load resistance is too low?
- What is the path of the current?
- When the breakdown voltage of the Zener diode was reached, why was the supply voltage higher than the breakdown voltage?

APPENDIX

The following is the template of the ECE 3313 report. Note that the report must be typed using Microsoft Words/Excel. Please download the template from the Canvas website.

ECE 3313 Lab X Report Your Name

<u>**Title:**</u> Lab 1: Observation, Modeling, and Communication

NAME: **Partner:**

General Objective: One or two sentences that describe the objective of this specific lab.

1.0 Prelab Activities: If there is any

2.0 Background Activities: Read background information and summarize important theory, equation, etc.

3.0 Procedure: Describe step-by-step procedure, including circuit schematic, calculation, and etc.

4.0 Results: A lab often includes questions. Please include your answer under the result sections.

- **4.1 Simulation Results:** Make sure to fully discuss about the results, figure, etc.
- **4.2 Experimental Results:** Make sure to fully discuss about the results, figure, etc.

5.0 Conclusions

Remark: Your lab report should include ALL relevant calculations, pictures and work needed for completion of the experiment. Circuit output validation using Multisim is also required. Detailed explanations for decisions made throughout the lab need to be included in the Discussion section of your report as outlined in the Report Guidelines.

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