

Lab 1

Diode Characteristics

Purpose

The purpose of this lab is to study the characteristics of the diode. Some of the concepts that will be investigated are the I-V curve, the switching speed, and the rectification properties. The reverse bias curve of the Zener diode will also be looked at.

Material and Equipment

Oscilloscope	Power Supply
Function Generator	Multimeter
1N4004 Diode	1N4148 Diode
Zener Diode	
Assorted Resistors	

Prelab

Answer the following questions

1. Sketch the I-V characteristics of an ideal rectification diode(2 points)
2. Sketch the I-V characteristics of a real diode assuming that its ON voltage is 0.6V (2 points)
3. Sketch the I-V characteristics of a Zener diode assuming that its turn-on voltage is 0.6V and that its reverse breakdown voltage is 6V(2 points)
4. In your parts kit, you have been given three diodes. Name them all and how can you identify them(describe their physical appearance) (3 points)
5. Look up the spec. sheet of the Zener diode in your lab kit. What is the reverse breakdown voltage(3 points)

Solve the following problems. Don't just write down the answers. Show all the calculations clearly.

1. In figure 1, calculate the current flowing through the resistor (2 points)
2. In figure 2, calculate the current flowing through the diode for the following diode models (2+3+3=8 points)
 - a) Ideal diode
 - b) Diode with turn ON voltage of 0.7V and zero ON-resistance
 - c) Diode with turn ON voltage of 0.7V and 25 Ohms ON resistance
3. In figure3, calculate the current folwing through the Zener diode assuming that its Reverse breakdown voltage is 6V (8 points)

The problem below is for extra credit for 5 points.

In figure 2, assume that the diode given is a 1N4004. From the data given in the spec sheet, calculate, the current flowing through the diode. You can access the data sheet from thr following site

<http://www.ee.latrobe.edu.au/internal/workshop/store/pdf/1N4004.pdf>

Look at the graph that says forward characteristics.

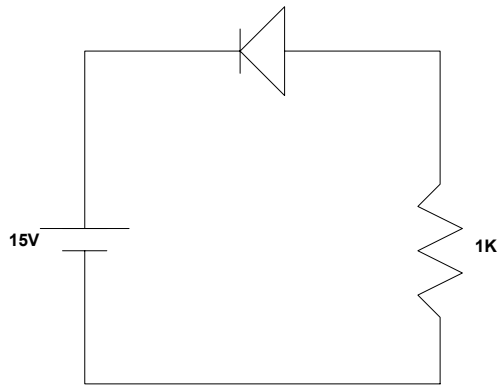


Figure 1

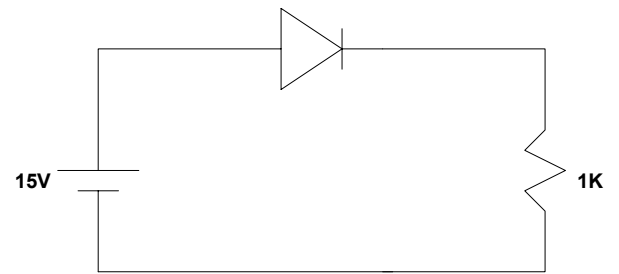


Figure 2

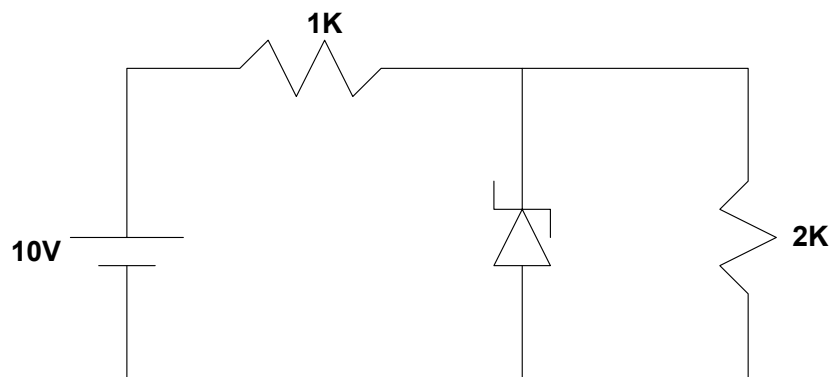


Figure 3

Background

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the anode and the lead connected to the n-type material is the cathode. In general, the cathode of a diode is marked by a solid line on the diode.

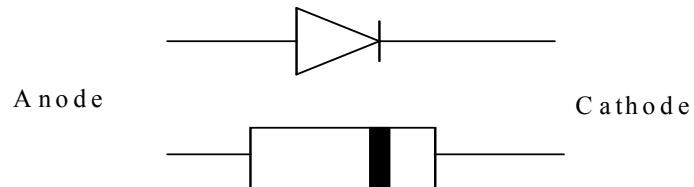


Figure 1-1: The symbol for a diode compared to an actual diode package.

The primary function of the diode is rectification. When it is forward biased (the higher potential is connected to the anode lead), it will pass current. When it is reversed biased (the higher potential is connected to the cathode lead), current flow is blocked. The characteristic curve for a real diode is seen in Figure 1-2.

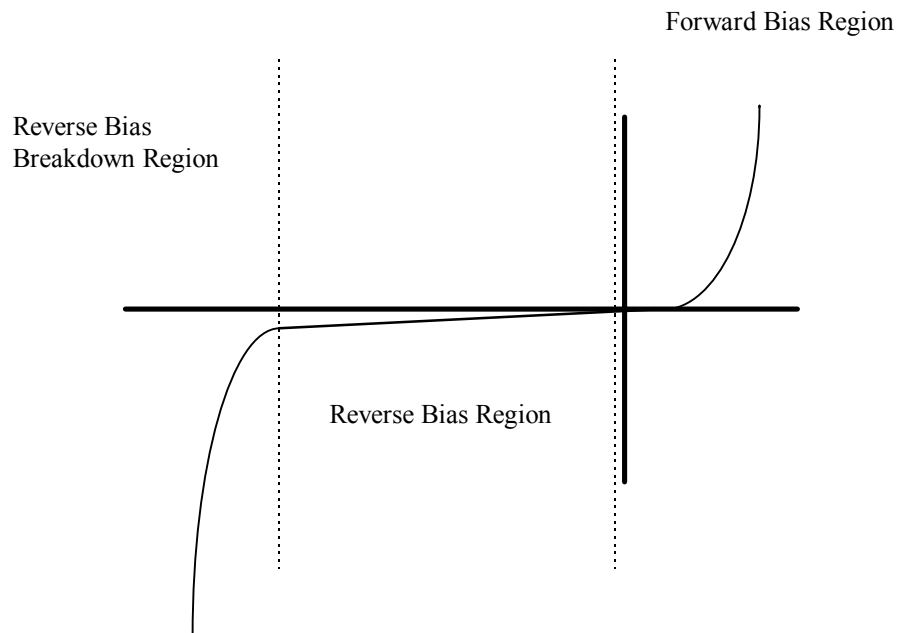


Figure 1-2: I-V Curve for a real diode.

When analyzing circuits, the real diode is usually replaced with a simpler model. In the simplest form, the diode is modeled by a switch (Figure 1-3). The switch is closed when the diode is forward biased and open when the diode is reversed biased.

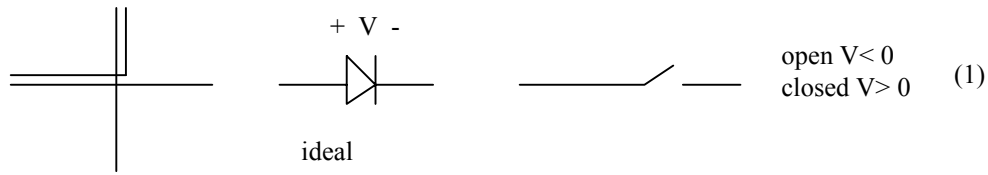


Figure 1-3: Simple model of an ideal diode.

A more sophisticated model includes a battery to model the forward voltage and a resistor to model the finite i-v slope (Figure 1-4).

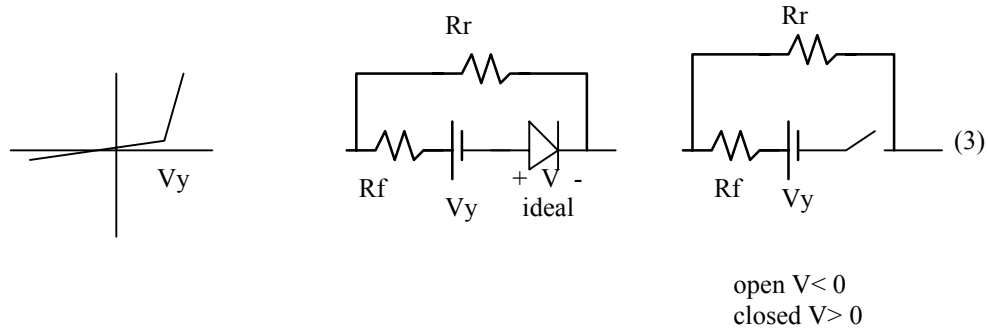


Figure 1-4: Simple model of a real diode with a finite turn-on voltage.

This model is easy to implement when analyzing circuits and it includes the important features of a real diode. This characteristic curve will be investigated as part of this lab. Two characteristics of the diode which will to be examined are reverse recovery time and reverse bias breakdown. The first, reverse recovery time, is a result of the fact that while the diode is forward biased, the depletion region is full of excess carriers. Immediately after the diode is switched to reverse bias, the depletion region is still full of carriers. Therefore, a large negative current will flow until all of the excess carriers are washed out. As the carriers are removed, the reverse current decays exponentially to approximately zero. The reverse recovery time is the time it takes for this to occur.

The other characteristic is reverse bias breakdown. In a normal diode, breakdown can result in damage to the diode. However, the Zener diode is designed to breakdown. In fact, the breakdown voltage is set to a desired point through the construction of the device. This effect can be exploited to perform voltage regulation in power supplies.

Procedure

1) Finding Diode Specifications

Look up the characteristics of the diodes in your kit (also look up the 1N34) using the web. You will need to go to a manufacturer's website (ex: Motorola) to get the datasheets. The specifications for the different kinds of diodes vary. Copy all of the specifications for each diode as well as all of the specification definitions.

2) Diode I-V Characteristics

The I-V characteristics for a diode can be displayed on an oscilloscope in X-Y mode. A time varying voltage source must be used in order to trace both the forward and reverse bias characteristics of the diode. By connecting up the circuit in Figure 1-5, the diode current (V_r/R) can be found by measuring the voltage across R and the diode voltage can be found by measuring it directly. Thus one of the oscilloscope probes must be placed across the resistor and the other across the diode. Remember that channel 1 is the X-axis and channel 2 is the Y-axis. So connect the appropriate channel across the appropriate device. Considering that the two oscilloscope probes have a common ground, how would you connect up the scope? Also remember that the probe grounds are physically connected to the ground of the source through the AC supply ground. How can this problem be solved? Think about it before asking the TA. You will get extra credit for coming up with a solution on your own.

- Connect the circuit in Figure 1-5. Use $R = 100$ ohms and a 1N4004 diode.
- Use an amplitude of 5V and a frequency of 100Hz for the input. Align the voltage waveforms across both the resistor and the diode to the center of the oscilloscope screen. If you do not know how to do this, ask the TA. Once the alignment has been performed, turn on the X-Y mode. Invert the appropriate channel. The oscilloscope will show you the I-V characteristics of the diode.
- Capture the I-V characteristics of the diode to the word document. Be sure to scale the vertical axis for current (not voltage). Now fill up the table given below. The table

#	Diode Voltage	Diode Current	Characteristic	Slope, $\Delta V/\Delta I$
1			OFF	
2			OFF	
3			JUST TURNING ON	
4	0.6 V			
5	0.65 V			
6		20mA		
7			FULLY ON	

3) Zener Diode Characteristics

The Zener diode has the unique property of maintaining a desired reverse bias voltage. This makes it useful for regulating voltage. One can purchase Zener diodes designed to regulate at practically any reasonable voltage. In this exercise, you are to sketch the I-V characteristic of the Zener diode.

- Connect of the circuit in Figure 1-5. Use $R = 100$ ohms and a Zener diode.
- Use an amplitude of 10V and a frequency of 100Hz for the input. Align the voltage waveforms across both the resistor and the zener to the center of the oscilloscope screen. Once the alignment has been performed, turn on the X-Y mode. Invert the appropriate channel. The oscilloscope will show you the I-V characteristics of the zener.

c) Capture the I-V characteristics of the zener to the word document. Fill up the table of zener characteristics given below

#	voltage	current	Slope, $\Delta V/\Delta I$	characteristic
1		20mA		
2				Full reverse conduction
3				Full reverse conduction
4	6.2/6.0 V			
5				off
6				off
7				Just turning ON
8	0.65/0.7 V			
9		20mA		
10				Fully On

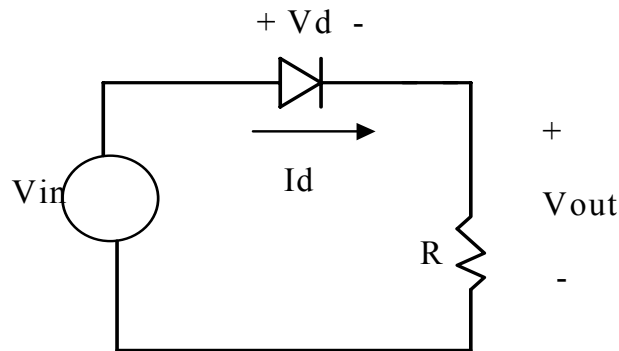


Figure 1-5: Circuit for the experiments a-d.

4) Reverse Recovery Time

When the diode is switched from forward to reverse bias, the current does not immediately stop due to the excess carriers in the depletion region at the time of switching. The reverse recovery time is measured as the time delay between switching and when the current reaches ten percent of its maximum reverse value (Figure 1-6).

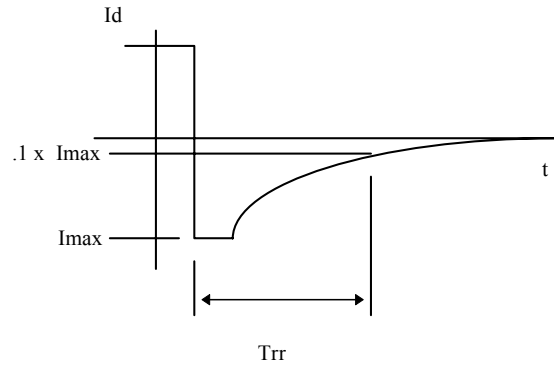


Figure 1-6: Graph of reverse recovery time of diode.

- a) Use the circuit in figure 1-5. Use a 1N4004 diode. (This may already be in place.) For the input signal, use a square wave signal. The frequency may have to be adjusted in order to see the recovery artifact.
- b) By measuring the voltage across the resistor, one can measure the diode current. (Remember to scale it correctly) . Capture the profile of the diode current and paste it onto your word document. The graph must show the position of the cursors.
- c) Measure the reverse recovery time from your graph.

Questions and Requirements for Lab Report

- 1) Compare the important features of a silicon diode versus a germanium diode. Use diode specifications for the 1N4004 and the 1N34 in your discussion.
- 2) Does the slope $\Delta V/\Delta I$ increase or decrease as the current through the diode increases? Is this expected from theory?
- 3) Discuss reverse recovery time. Is this predicted by the model for an ideal diode?
- 4) From your measurements, you calculated the resistance of the reverse bias tail on the Zener diode. What should this resistance ideally be? What does this finite resistance mean in terms of the Zener diode's ability to regulate voltage?
- 5) How did you solve the common ground problem of the oscilloscope for obtaining the V-I characteristics in the X-Y mode.
- 6) The diode I-V characteristics can be best described as
 - a) Linear
 - b) Exponential
 - c) Sinusoidal
 - d) Quadratic