EECE 2413
Electronics Laboratory

Lab #2: Diode Circuits

Goals

In this lab you will become familiar with several different types of pn-junction diodes. These include silicon and germanium junction diodes, light-emitting diodes (LEDs), and zener diodes. Take your time during these experiments; think about what you are being asked to do and why the experiments are important.

Once you are comfortable with the way diodes work, you will design and test your own “high-medium-low” voltage indicator using red, yellow, and green LEDs.

Prelab

Prelabs will be collected for grading at the beginning of the lab. Keep a photocopy for your own use during the lab!

1. Suppose that you make two measurements of a diode. In the first measurement, you forward bias a diode with i = 1 mA and measure a voltage of v = 0.620 volts across the device. In the second measurement you forward bias the *same* diode with 10 mA and measure 0.690 volts. At the time of these measurements you noted that the diodes are at room temperature (293 K), so $V_T = kT/q = 25$ mV.

Use the diode equation, $i = I_S\,[exp(v/nV_T) - 1]$, and the data above to find the ideality factor (n) and the saturation current (I_S) of this diode. You may want to make an approximation. Explain why it would be difficult to directly measure I_S by reverse biasing the diode. (Hint: note that for typical forward bias operation $v >> nV_T$)

2. Read over the lab experiment and see the instructor with any questions you may have.

3. Read Part 2 and sketch a circuit you think would work. You may change your design as you work through the lab, however. Assume V_{LED} = 2 volts.

HINT : Use the zener diodes available for this lab with approximate breakdown voltages of 6V and 15V.

Part 1: Basic diode behavior

Concept: Proto-board wiring

Wire together the circuit shown in Figure 1. Get in the habit of using the red and black *binding posts* on the *proto-board* for inputs and outputs (for example, voltage supply connections and voltmeter connections). These are much more stable than the wire sockets on the board itself. Notice that you can attach a wire to the binding post by unscrewing the top about half-way, slipping the stripped end of a wire through the exposed hole in the post, and screwing the top *gently* back down.

The *tie-point matrix* has short, horizontal tie-points and long vertical tie-points. In general, you will use the long vertical tie-points to distribute commonly used signals around the board. The power supply is probably the most commonly used node in an electronic circuit, so plan on using two of the long tie-point strips for V_+ and ground (the ground may already be labeled on one of the binding posts). Devices, such as diodes and resistors, are usually pushed into the short, horizontal tie-point strips. To complete a circuit layout, use short wires to connect the appropriate tie-points together.

Try to keep the wires on your board as short and neat as possible. This is important for several reasons. First, finding and debugging errors in your wiring will be much easier on a neat layout. Second, long wire leads tend to pick up electrical noise from the room. Long leads also decrease the maximum circuit speed due to parasitic inductance and capacitance.

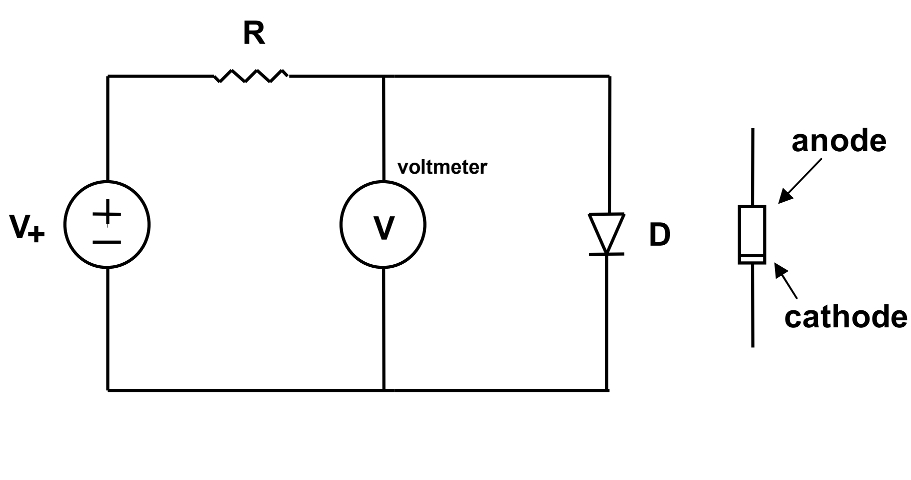

Figure 1. Basic diode test circuit
V_+ = 10 volts, R = 10 kΩ, D = 1N914 Si diode

Concept: Forward and reverse bias

Most diodes are marked with a band on one end of the device. This band indicates which of the diode's leads the cathode is. This band is meant to correspond to the line at the tip of the triangle of the diode's circuit symbol.

a. Measure and record the voltage across the forward biased diode in Figure 1. Use the lowest possible *range* on the voltmeter for the best possible accuracy.

b. Reverse the diode leads so that the device is now reverse biased. Measure and record the voltage across the diode.

c. Remove the resistor, then measure and record its resistance with an ohmmeter. If the resistor has gold band, its value is supposed to be within ±5% of the listed value. Silver bands indicate ±10%. **Is this resistor within specifications?**

d. Use the voltmeter to measure V_+. **Is the read-out on the voltage supply accurate?**

e. Determine the forward and reverse current through the diode using only measurement data from parts (a)-(d).

f. **Why is this measurement of reverse current (I_S) inaccurate in part (e)?**

Concept: Finding I_S and n

g. Forward bias the diode again, as in Figure 1. Using the technique you practiced in the *prelab*, design an experiment to determine I_S and n. Briefly describe this experiment in your lab notes and carefully record the data. (Check-point: have the instructor look at your results before you leave!). **For your lab report, calculate I_S and n.**

Concept: Temperature dependence of diodes

h. Reconstruct Fig. 1 again using the 1N914. Measure and record the diode voltage and *label* this measurement as "room temperature ~ 20 C." Get the aerosol refrigerant from the instructor and *briefly* (~1 sec.) apply it to the diode while watching the voltmeter. Record the highest voltage that the diode attains. For a constant current, the forward voltage of a silicon diode decreases 2 mV for every 1 ^{o}C rise in temperature. Engineers call this a *temperature coefficient* and write it as -2 mV/C. **How cold did your diode become after you sprayed it?** Grip the diode firmly between your fingers so that your body's heat warms the diode. **Record the result and calculate the temperature caused by your fingers.**

In general, the i-v characteristics of semiconductor devices depend on temperature. This can be useful, for example, if you wanted to construct an electronic thermometer. *But* variations in temperature can also cause electronic circuits to stop functioning properly. In the future you will learn how to design circuits which are insensitive to temperature variations.

Concept: Not all diodes are 0.7 volts!

i. Remove the 1N914 diode from the circuit in Figure 1 and replace it with a forward-biased 1N34A or 1N60A. (This diode may be unmarked...ask the TA if you need help!). Measure and record the diode voltage, remembering to *label* data. The 1N914 is a *silicon* diode and has a forward voltage of about 0.7 volts. The *energy band gap* is the energy required to free an electron and allow it to conduct current. The band gap of silicon is 1.12 eV. The 1N34A is made from *germanium* which has a lower energy band gap (0.66 eV) and a lower "on" voltage (at the same current).

j. Repeat part i. with a red then a green light-emitting diode (LED). The cathodes of LEDs are often poorly marked, but LEDs should glow when forward biased. Record the forward voltages of these two diodes. **What can you conclude about the energy band gaps of the materials used in these diodes?**

Shop Note: Notice that the digital meter has at least one ohmmeter setting marked with a diode symbol. Remembering that a diode is nearly an open circuit when reverse-biased, figure out how to use this meter to check the polarity of a diode. (If you use your fingers to hold the meter leads to the diode, you will incorrectly measure the resistance of your body *and* the diode. Try this on the 20 MΩ range if you are using Fluke 8010A Digital Multimeter and then try to avoid doing it again!) This function is also useful for determining if a diode has been destroyed so that it is permanently open or short circuited.

Concept: Reverse breakdown, zener diodes, and voltage regulation

k. Remove the LED and replace it with a reverse-biased 1N4735A *zener diode*. Starting at V_+=0 volts, measure and record the diode voltage as V_+ is increased to 15 volts. Increments of 1 volt should be fine. Notice how the zener diode allows the voltage to pass through the circuit unaltered below about 6 volts but clips the voltage above 6 volts. **In your report, describe how you could use these to protect sensitive electronics from being damaged by too much voltage. Plot V_d vs. V_+ in your final report. What is the breakdown voltage of the 1N4735A?**

l. Insert a 1N4744A zener diode into your circuit. **What is the breakdown voltage of this diode?**

m. What is the purpose of the 10kΩ resistor? *Answer:* It limits the current through the zener diode to a "safe" level. To see what happens without the resistor, try the following:

1. Put the 1N4735A zener diode back in the circuit
2. Check the output voltage to make sure the diode is in reverse breakdown. Touch the zener and notice that it is not hot.
3. Double check that $V_+ = 10$ v and turn the supply off.
4. Turn the current limit knob on the supply 0.5 A.
5. Replace the resistor with a short circuit (a wire!).
6. Turn the supply on for about 3 seconds. *Quickly* note the diode voltage.
7. AFTER the supply is off again, ***carefully*** touch the diode.

The maximum power that the 1N4735A should dissipate is 1 watt. **How much power did the diode dissipate in this experiment?** If you left the voltage supply on longer, the diode would eventually fail from overheating. **What is the maximum current that this diode can safely handle in reverse breakdown?**

n. Place an LED between the anode of the zener diode and ground as shown in Figure 2. (Don't forget to remove the short circuit from the previous section). Vary the input voltage and record the voltage at the power supply for which the LED begins to glow.

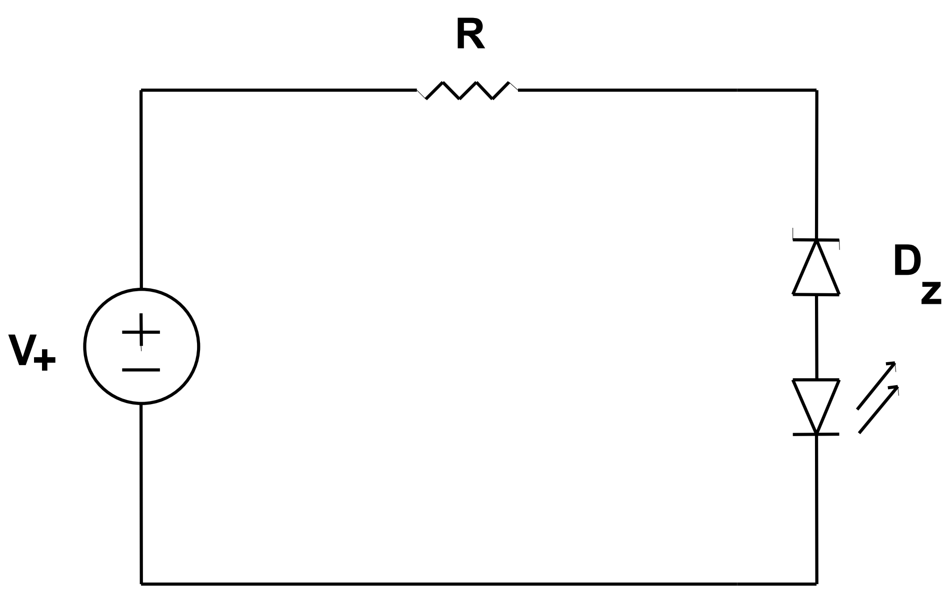

Figure 2. Zener diode voltage indicator using an LED
V_+ = 0-15 volts, R = 1 0 kΩ, D_Z = 1N4735A

b. Replace the 10 kΩ resistor with a 100 kΩ resistor. Set V_+ to 10 volts. **Why is the diode dim?** Use the voltmeter to check out the circuit's node voltages, and then deduce the LED current. **What can you conclude about the current that these LEDs require to produce light?**

You are now finished with Part 1. Remember that lab reports are due in one week.

Part 2: Design of an LED voltage indicator

Design and build a circuit that indicates voltages using a red, a yellow, and a green LED. Use the lab's voltage source as an input to your circuit, and other components (resistors, zener diodes, etc.) as needed. The LEDs should light-up as shown in the following table:

TABLE I. Design Specifications

Voltage Input	*Red LED*	*Yellow LED*	*Green LED*
0-2 V	off	off	off
2-8 V	on	off	off
8-17 V	on	on	off
17-24 V	on	on	on

Pay attention to getting enough current through each LED that it lights, but not so much current that any of the devices get hot and fail. The maximum allowed power for each device is given below:

Maximum Power Ratings: Zeners -- 1 W
Resistors -- 1/4 W
LEDs -- 60 mW

When your design is working, draw a schematic of the circuit, **indicating on the schematic the maximum power dissipated in each component.** Then, demonstrate the design to the instructor, and get the instructor's *design approval* on your schematic.

In your lab notebook, describe the operation of your design, the rationale of picking the devices, and include a schematic with the instructor's design approval. Do not tear pages from your lab book since you will hand this book in at the end of the course for grading!

JH9.96
rev.8.05
rev.7.08
rev.6.10

Equipment List -- Lab #2

Agilent E3647A dual output power supply
Fluke 8010A digital multimeter
Fluke 45 Dual Display Multimeter
Proto-Board model PB-103

4 banana plug-terminated test leads
#20 hook up wire
wire strippers
Aerosol component coolant (non-CFC)

Diodes:

1N914	(1)	Si diode
1N34A (or equiv.)	(1)	Ge diode
1N4735A	(1)	Zener diode
1N4744A	(1)	Zener diode
Red LED	(1)	
Yellow LED	(1)	
Green LED	(1)	

Resistors: 1/4 W unless otherwise specified

1.0 kΩ	±5%	(3)
4.7 kΩ	±5%	(2)
10 kΩ	±5%	(2)
100 kΩ	±5%	(1)

Other resistor values are available from the lab technicians.

Resistor Color Codes

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Example:

20 kΩ =

RED	+	BLACK	+	ORANGE
2		0	x	10^3