University of Utah
Electrical & Computer Engineering Department
EE 2100
Experiment No. 4

Types of Diodes

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rev,2/4/03

Minimum required points = 61 Grade base, 100% = 87 points
Recommend parts = 80 points (about 90%)

Objectives

1.) See the characteristics of some diodes.
2.) Build some diode circuits.

Check out from stockroom:

- Wire kit
-

Parts	Exp
1kΩ and other resistors to be determined in lab	1
Small signal or switching diode (ex. 1N914, 1N4148)	1
1A rectifier diode (ex. 1N4001, 1N4004)	1
Schottky-barrier diode (probably a 2N5819)	2
4.7 V, 500 mW zener diode, 1N5230 or similar (any zener rated from 3 to 6 V will do, but make a note of what you actually get, especially note voltage and power rating)	3
Three common LEDs, red, green, & yellow	4
Super-bright LEDs (red, orange, yel, or grn), or IR LED (May only be available for check-out)	5
Bi-color red/green LED	5
Blue LED, white LED (these are quite expensive (~$3) so don't buy them just for this lab	5
Bridge rectifier (May only be available for check-out) NOT AVAILABLE THIS TIME	6

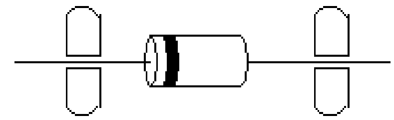
Experiment 1, Silicon Diodes (33 points, recommended)

Curve tracer

(8pts) On a table in the lab there are two Tektronix 571 curve tracers. They can be used to view and print the characteristic curves of your diodes. (Note: If both curve tracers are currently in use, you may want to start with the manual curves below.) First we'll look at the curves for the small signal and rectifier diodes. To use the curve tracers:

1. Turn on the curve tracer and the printer.
2. Work down through the menu;
   a) Function: Acquisition
   b) Type: DIODE (The rest of the menu will change with this selection)
   c) V_{amax}: 1 V

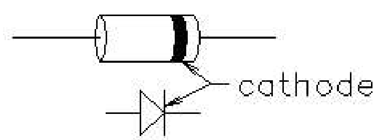
d) I_{amax}: 10 mA
e) R_{load}: .25 Ω
f) Pmax: 0.1 Watt

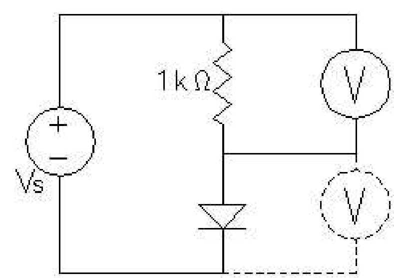


3. Place your rectifier diode in the diode holder with the band to the left.
4. Hit **Start**.
5. When you have a curve, hit **Store**.
6. Replace the rectifier diode with the small signal diode and hit **Start** again.
7. When you have the second curve and the printer is free, switch the Data Transfer Switch (small box on the table) to your curve tracer (A is left, B is right). Hit **Copy** to print. (You and your lab partner will each need a copy of the printout, but if people are waiting please make a photocopy for one of you instead of printing a second copy)
8. Before you forget, label the two curves. If you followed my instructions exactly, the dark curve is the rectifier diode and the lighter curve is the signal diode.
9. Get out of the way, people are waiting, you will do the schottky diode and LEDs later.

Manual curves

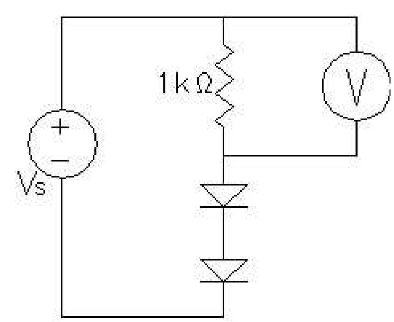
(17 pts) I want you to manually repeat what the curve tracer just did and plot your results. (Plot right on the curve tracer's print-out if you did that part.) You can measure each diode separately, or, if you're clever, you can save work by measuring both diodes at the same time. Each method is outlined below, choose one and follow those procedures.





Separately: Build the circuit shown at right using one of the two diodes. V_S is the bench power supply. V, the voltmeter, is in the upper (not dotted line) position and is used here to measure the diode current (1V reading = 1mA current). Turn up power supply until about 0.5 mA flows. Then Move the voltmeter to the dotted position, measure the diode voltage and plot it on the curve tracer output. Repeat this for 1, 2, 4, & 8 mA currents.

Repeat the whole procedure for the other diode. Skip the next paragraph.



Two at a time: Build the circuit shown at right using both diodes. Turn up power supply until about 0.5 mA flows (the voltmeter will show you the current or see if you can get that reading from the power supply). Use the voltmeter to measure each diode voltage (one at a time) and plot them both on the curve tracer output. Repeat this for 1, 2, 4, & 8 mA currents.

Curves

(2pts) These measurements that you've just taken manually should closely follow those taken by the curve tracer, if not, measure your 1 kΩ resistor. That should account for most of the differences. Tape, paste, or staple these curves in your lab notebook.

Note that these curves are different from one another. In general, the larger the diode, the quicker its current curve rises. Comment in your notebook.

Multimeter diode test

(4pts) Most multimeters won't forward bias a diode in the regular ohmmeter setting. The ohmmeter just doesn't put out enough voltage to overcome the diode's forward voltage drop. Therefore, they won't show significant conductivity in either diode direction. Try it yourself and see. Set the bench multimeter to the ohmmeter setting. Measure the resistance of a diode in both directions. A little problematic isn't it? You may find that your own body's conductivity is better than the diode's. Just hold the metal tips of the two meter probes in your two hands to see what I mean.

Most multimeters provide a special ohmmeter setting to measure diodes, usually marked with a small diode symbol. In this setting they use a high enough voltage to turn the diode on. Look for a diode symbol on your meter and set the meter to that position (It's a blue shift setting on the HP meter). Now the meter will test diodes, try it on your diode. Most meters will show volts or mV (rather than Ω) when connected to the diode the right way. This indicates the forward drop across the diode at some low current and can be useful when comparing diodes. Comment in your notebook about the special meter setting. Test both diodes in both directions, record the readings (a table might be nice).

(2 pts) Remember to always end an experiment with a conclusion.

Experiment 2, Schottky-Barrier Diode (6 points, recommended)

Go back to the curve tracer and set the menu as before. Obtain and print the curve for the Schottky-barrier diode. (If no one is waiting to use the curve tracer, now may be a good time to jump ahead and take the curves for the LEDs too.)

Conclude with a comment on the difference between the Schottky curve and those of the silicon pn-junction diodes you took earlier. (Your book describes Schottky-barrier diodes on p.197.) Can you see any advantage to a lower forward voltage drop? Actually, the biggest advantage of the Schotty diode would be hard for us to measure in this lab. Schottky diodes switch on and off much faster than pn diodes.

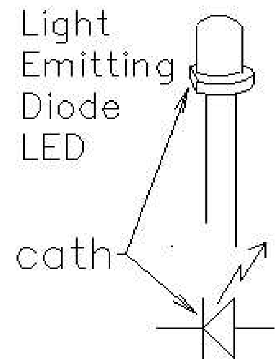
Experiment 3, Zener Diode (10 points, recommended)

Figure out a reverse current rating for this diode, given its zener voltage and its power rating.

Go back to the curve tracer with your zener diode and confirm that it functions just like a regular silicon diode in the forward direction. You don't need to print this forward curve, but do comment in your notebook.

Turn the diode around in the holder and change the settings of the curve tracer to display the reverse bias characteristics of this diode, showing the knee and beyond to at least 50% of the current rating. There are some bad zeners mixed in with those being sold by the lab. If your diode doesn't show a good, sharp knee like that shown on p.172 of your textbook, you have one of these bad diodes. Either get another one or be aware that the curve you're getting isn't very representative of zeners in general. Print the curve from the curve tracer. Mark the curve as a bad zener if it is. As always, write a line of conclusion.

Experiment 4, Basic Light Emitting Diodes (LEDs) (25 points, recommended)
In this section you'll see some of the characteristics of common red, green, and yellow LEDs. First, If it's available, go back to the curve tracer.



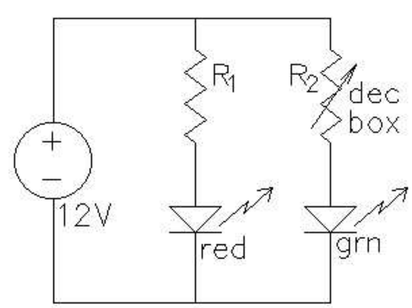
Set the menu as before with these differences:

a) V_{amax}: 5 V
b) I_{amax}: 50 mA
c) Pmax: 0.5 Watt

1. Place your red LED in the diode holder--flat spot to the left.
2. Hit **Start**, When you have a curve, hit **Store**.
3. Replace with the green LED and hit **Start** again.
4. Hit **Copy** to print.
5. Before you forget, label the two curves. The dark curve should be the red LED.
6. Hit **Store** to store the green LED curve. This will erase the red one.
7. Replace with the yellow LED and hit **Start** again. Hit **Copy** to print.

In order to get all three curves, place the two pages you just printed on top of one another and lay them on a white surface so that you can trace the missing curve onto the top sheet. If you figure out a way to make the curve tracer store and print all three curves together, I'd like to hear about it. Label all three curves (red, green, and yellow) and place the print-out in your lab notebook. If there's a wait for the curve tracer you may share your extra print-outs with another group.

Notice that these curves are quite different from those for the silicon diodes. These diodes are made from galium and arsenide and have a considerably larger forward voltage drop. Instead of assuming the forward drop is 0.7 V like a silicon diode, you assume about 2 V for an LED. Comment in your notebook.



Relative brightness: Consider the circuit at right. Select a value of R_1 so that the current through the red LED will be about 15 mA. Use the 2 V drop assumption. Determine the power dissipated by this resistor and buy a suitable resistor or resistors.

Make the circuit, using a decade box or resistor substitution box (set at value of R_1) for R_2. Make a table in your notebook like that on the next page. Measure the voltage across the red LED and record it in the table. Determine the actual current flowing through the red LED by measuring the voltage across R_1. Record that in the rightmost column of the table.

LED	V_D (volts) (Forward voltage drop)	Relative brightness when I_D same as red LED	I_D (mA) For same brightness as red LED
red		X	
green			
yellow			

Determine the current flowing through the green LED by measuring the voltage across the decade box. If it's not the same as the red LED adjust the decade box until they are the same (±10%). (Note: Be very careful adjusting the decade box. If you switch it to too small a value, even for just a second, you' ll fry the green LED). Measure the voltage across the green LED and record it in the table. Decide if the green LED is brighter than the red LED and record in the table (much dimmer, dimmer, same, brighter, much brighter, etc.). Judgements of brightness are very subjective on your part and there's no right answer, but at least you' ll see how the current through the LED affects the brightness and that LEDs are not all equal. Carefully adjust the decade box until the brightness of the green LED is about the same as the red one. When you think they're equally bright, find the current and record that.

Repeat this step for the yellow LED.

Conclude: Compare the relative currents necessary to make each LED shine at about the same brightness. Comment on the 2 V assumption.

Experiment 5, Other LEDs (12 points, 1 recommended, up to 2 more extra)

Select one of the other LEDs (IR emitter, super bright, blue, or white) and fill in another line of the relative brightness table above. Obviously you can only find the forward voltage drop of the IR LED, so just x-out the other two entries. If other current-for-same-brightness measurements become unreasonable, you can replace numbers with comments. Handle blue and white LEDs as static sensitive parts.

If you bought the Bi-color red/green LED, it will light red if you hook up + and - one way and green if you switch the leads. AC will give you red + green = yellow light. Try it all three ways and comment in notebook.

Conclude: Compare brightnesses and voltage drops to the basic LEDs.

Experiment 6, Bridge Rectifiers (5 points)

When a diode is used to convert AC power to DC it is often called a "rectifier". Many times four rectifiers will be connected in a bridge circuit (see textbook, p.184). This is such a common arrangement that you can buy full bridge rectifiers with all four diodes in one package. Test (I suggest the multimeter) your bridge rectifier to confirm that it indeed contains four diodes wired into a bridge circuit. Draw a picture of the bridge rectifier in your notebook showing the internal diodes and make a concluding comment.

Experiment 7, Diode models (25 points)

Piecewise linear model

(7 pts) Use your curves of the two silicon diodes to create a small-signal or *piecewise-linear* model of each diode. (Draw a tangent line at about 5 mA, find V_{D0} and r_d as shown on Fig. 3.25, p.164 of your textbook.) Using eq. 3.53, p.165, and a V_T of 25 mV, find a value of n for each diode. The value of n should be about 2 for discrete (not on an integrated circuit) diodes. Comment on the actual values of n that you found.

Diode equation

(8 pts) The theoretical equation of the silicon diode curves are given by Eq. (3.3), p.133 in your textbook, repeated here:

$$i = I_S e^{\frac{v}{n V_T}}$$

i & v are the diode current and voltage.
n $\simeq$ 2 or use value found above.
$V_T \simeq$ 25 mV.
I_S is known as the *saturation current* or *scale* current, and is proportional to the cross-sectional area of the diode. Determine i and v for one diode from some point (say at 1 mA) on the curve, use these to and the equation above to find I_S. (See Example 3.3, p. 135.) Use Matlab or a speadsheet to calculate and plot the theoretical diode curve and compare it to your experimental results. Comment on how the theoretical curve matches the measured curve.

(5 pts) Repeat for other silicon diode.

Zener

(5 pts) Use your curve of the zener diode to create a model of the zener diode. Draw a tangent line at about half the current rating and find V_{Z0}, r_z, V_{ZK} and I_{ZK} as shown on Fig. 3.30, p.172 of your textbook.

No conclusion is necessary for this last experiment