ET 260 Lab, Solid State Electronics Laboratory
Fall 2014

Instructor: William Lopez
Section #2

Lab 1: Semiconductor Diodes

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Angelo Galinato

ANGELO GALINATO

Experiment 4
Semiconductor Diodes

Semiconductor Diodes

An ideal diode acts like a switch that is closed when forward biased and open when reverse biased. One way to test a diode is with an analog ohmmeter. When the diode is forward biased, the ohmmeter is measuring the forward resistance R_F. When the diode is reverse biased, the ohmmeter is measuring the reverse resistance R_R. With silicon diodes, the ratio of R_R to R_F is more than 1000:1.

If you check a diode with a digital multimeter (DMM), another approach must be used. Most DMMs have a special position (marked with the diode symbol) for testing diodes. To check forward voltage, connect the red lead to the anode (unmarked), and the black lead to the cathode (marked with a colored band). A typical DMM should read 0.5 to 0.7 V for silicon diodes, 0.2 to 0.4 V for germanium diodes, and 1.4 to 2 V for LEDs. A reading near zero indicates a shorted diode, and an overrange indicates an open diode. When you reverse the leads, overrange should be displayed. A reading less than overrange indicates a very leaky diode.

Testing a diode with an ohmmeter or a DMM is an incomplete test because it checks only for major defects such as shorts, opens, or very leaky diodes. The ohmmeter cannot detect more subtle problems. For instance, a slightly leaky silicon diode may have a reverse resistance of only 10 kΩ, low enough to prevent it from working in many circuits. If you test this slightly leaky diode with a typical DMM, it will pass because the DMM will still indicate overrange when the diode is reverse biased.

The point is this: Testing a diode with an ohmmeter or DMM is conclusive only when the diode fails the test. If it passes the test, the diode may still have some defects that prevent it from working in an ac circuit. Therefore, even though a diode may pass dc testing with an ohmmeter, it must still be checked in a working circuit before you can be sure that it is all right.

Required Reading

Chapter 2 and Chap. 3 (Secs. 3-1 and 3-2) of *Electronic Principles*, 7th ed.

Equipment

1 power supply: adjustable to 10 V
1 VOM (analog multimeter)
1 DMM (digital multimeter)
Diodes: Four 1N4001
1 ½-W resistor: 1 kΩ

Procedure

1. In this part of the experiment, you will be measuring the forward and reverse resistance of a diode.
2. Do you expect the forward resistance of a diode to be low or high? Record your answer in Table 4-1.
3. Repeat Step 2 for the reverse resistance of a diode.
4. With an analog ohmmeter set to the X100 range, measure the resistance of a 1N4001 in either direction. (The polarity of the red and black leads of the ohmmeter doesn't matter because the red lead may be positive or negative with analog ohmmeters.) Then reverse the leads and measure in the other direction. You

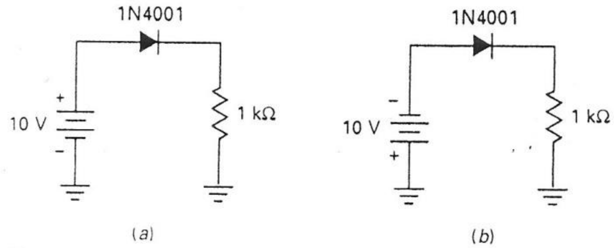


Figure 4-1

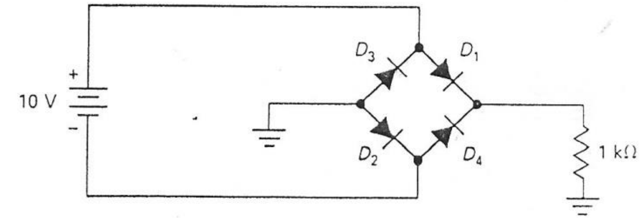


Figure 4-3

should get a low reading one way and a high reading the other way. (The exact values don't matter because the resistance of the diode will depend on the ohmmeter range.)

5. Record your readings in Table 4-1 under "Measured 1." If the reverse resistance is too high to read, record "open."
6. Repeat Steps 4 and 5 for two more diodes.
7. Next, use a DMM to test a diode as follows: Select the special diode position (marked with a diode symbol). Connect the red lead to the anode and the black lead to the cathode of a 1N4001. With DMMs, the red and black leads are polarized because the red lead is always positive on the special diode position. The DMM will forward-bias the diode and display the voltage across it. Record the voltage in Table 4-2 under "Measured 1."
8. The reading you got in the preceding step depends on the DMM used. Since a 1N4001 is a silicon diode, the reading should be from 0.5 to 0.7 V, depending on how much current the DMM produces in the diode.
9. Now, reverse the leads and you should get an overrange display (typically shown as OL). Record the reading in Table 4-2 (use OL if it is an overrange).
10. Repeat Steps 7 to 9 for two more diodes.
11. In Fig. 4-1*a*, calculate the voltage across the diode and across the load resistor. Record your calculated values in Table 4-3.
12. Build the circuit of Fig. 4-1*a*. Measure and record the diode and load voltages in Table 4-3.
13. Repeat Steps 11 and 12 for two more diodes.
14. In Fig. 4-1*b*, calculate the voltage across the diode and across the load resistor. Record your calculated values in Table 4-4.
15. Build the circuit of Fig. 4-1*b*. Measure and record the diode and load voltages in Table 4-4.
16. Repeat Step 15 for two more diodes.
17. Figure 4-2 shows a diode circuit. Is diode D_1 on or off? Record your answer in Table 4-5 under "D_1 normal."
18. Repeat Step 17 for the remaining diodes shown in Fig. 4-2.
19. Assume that the polarity of the battery is reversed in Fig. 4-2. Determine whether each diode is on or off. Record your answers in Table 4-5 for the reverse condition.
20. In Fig. 4-3, determine whether each diode is on or off. Record your answers in Table 4-6.
21. Assume that the polarity of the battery is reversed in Fig. 4-3. Record the on-off condition of each diode in Table 4-6.
22. Calculate the voltage across each diode in Fig. 4-3. Also calculate the load voltage. Record all values in Table 4-7.
23. Build the circuit of Fig. 4-3. Measure and record all voltages listed in Table 4-7.

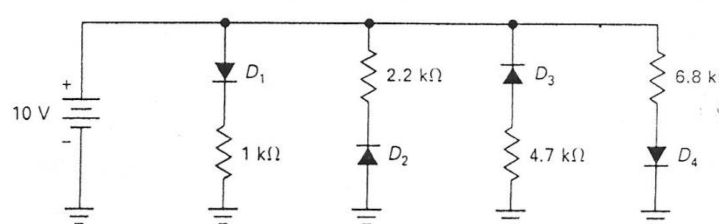


Figure 4-2

NAME ______________________________ DATE ______________

Data for Experiment 4

TABLE 4-1. OHMMETER TESTING

	Expected	Measured 1	Measured 2	Measured 3
R_F	9 MΩ	4.26 MΩ	N/A	N/A
R_R	1.23GΩ	OL	N/A	N/A

TABLE 4-2. DMM TESTING

	Measured 1		Measured 2		Measured 3	
	MultiSim	Actual	MultiSim	Actual	MultiSim	Actual
Forward	59.62 MΩ	609	N/A	N/A	N/A	N/A
Reverse	999.93 MΩ	OL	N/A	N/A	N/A	N/A

TABLE 4-3. DATA FOR FORWARD BIAS

	Calculated		Measured			
			MultiSim		Actual	
	V_D	V_L	V_D	V_L	V_D	V_L
Diode 1	0.7V	9.3V	596.15 mV	9.40V	0.65V	9.28V
Diode 2	N/A	N/A	N/A	N/A	N/A	N/A
Diode 3	N/A	N/A	N/A	N/A	N/A	N/A

TABLE 4-4. DATA FOR REVERSE BIAS

	Calculated		Measured			
			MultiSim		Actual	
	V_D	V_L	V_D	V_L	V_D	V_L
Diode 1	10V	0V	9.999 V	679.81 µV	9.95V	0V
Diode 2	N/A	N/A	N/A	N/A	N/A	N/A
Diode 3	N/A	N/A	N/A	N/A	N/A	N/A

TABLE 4-5. DIODE CONDUCTION

	D_1	D_2	D_3	D_4
Normal	ON	OFF	OFF	ON
Reversed	OFF	ON	ON	OFF

TABLE 4-6. DIODE CONDUCTION

	D_1	D_2	D_3	D_4
Normal	ON	OFF	OFF	OFF
Reversed	OFF	OFF	OFF	ON

TABLE 4-7. DIODE AND LOAD VOLTAGES

	Calculated	Measured	
		MultiSim	Actual
V_{D1}	0.7 V	592 mV	N/A
V_{D2}	0.7 V	592 mV	N/A
V_{D3}	9.3V	9.41 V	N/A
V_{D4}	9.3V	9.41 V	N/A
V_L	9.3V	8.82V	N/A

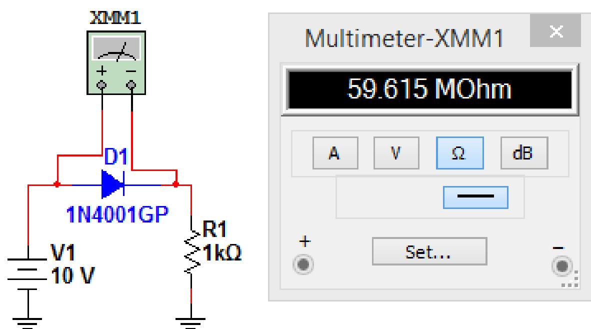
Questions for Experiment 4

1. A forward-biased diode ideally appears as: ( )
   (a) a closed switch; (b) an open switch; (c) a high resistance; (d) an insulator.
2. A reverse biased diode ideally appears as: ( )
   (a) a closed switch; (b) an open switch; (c) a low resistance; (d) a conductor.
3. When reverse-biased, a diode: ( )
   (a) appears shorted; (b) has a low resistance; (c) has 0 V across it; (d) appears open.
4. When a diode is tested with a DMM, the indication with reverse bias is normally: ( )
   (a) 0.5 V; (b) 0.7 V; (c) an overrange; (d) low.
5. The diode of Fig. 4-1*b* is: ( )
   (a) conducting heavily; (b) reverse-biased; (c) forward-biased; (d) on.
6. In Fig. 4-2, diode D_3 is: ( )
   (a) conducting heavily; (b) reverse-biased; (c) forward-biased; (d) on.
7. In Fig. 4-3, diode D_2 is: ( )
   (a) not conducting; (b) reverse-biased; (c) forward-biased; (d) off.
8. If a diode in Fig. 4-3 has a voltage of 0.7 V across it when conducting, the load voltage will be: ( )
   (a) 0; (b) 8.6 V; (c) 9.3 V; (d) 10 V.
9. If a diode D_1 opens in Fig. 4-3, the load voltage will be: ( )
   (a) 0; (b) 8.6 V; (c) 9.3 V; (d) 10 V.
10. If a diode in Fig. 4-3 has a voltage of 0.7 V across it when conducting, the voltage across D_4 will be: ( )
    (a) 0; (b) 8.6 V; (c) 9.3 V; (d) 10 V.

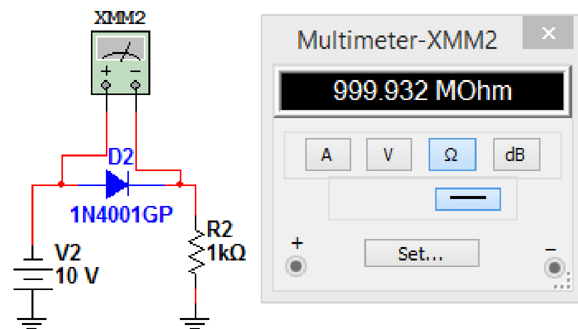
DMM TESTING

The circuit on the left is the measurement of the forward resistance of the diode and on the right is the measurement of its reverse resistance. I assumed that the reverse resistance should be 1000 times more than the forward resistance but it is not. Nonetheless, there is a big difference between the forward and reverse resistance of the diode. There is a clear indication that the reverse resistance is way more than the forward resistance.

FORWARD

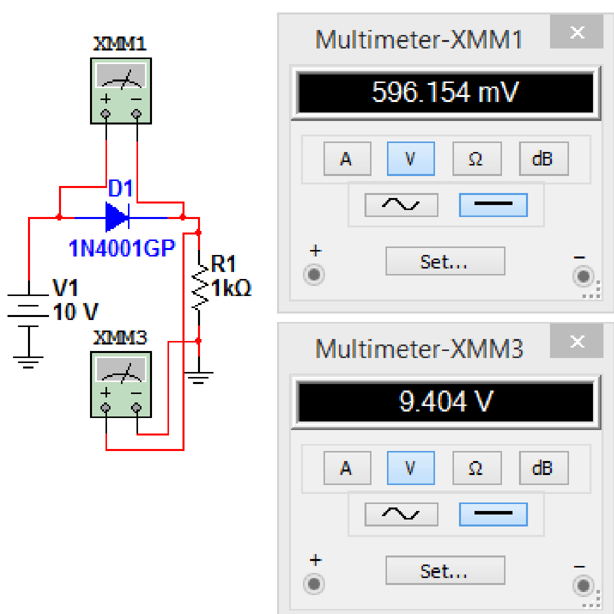


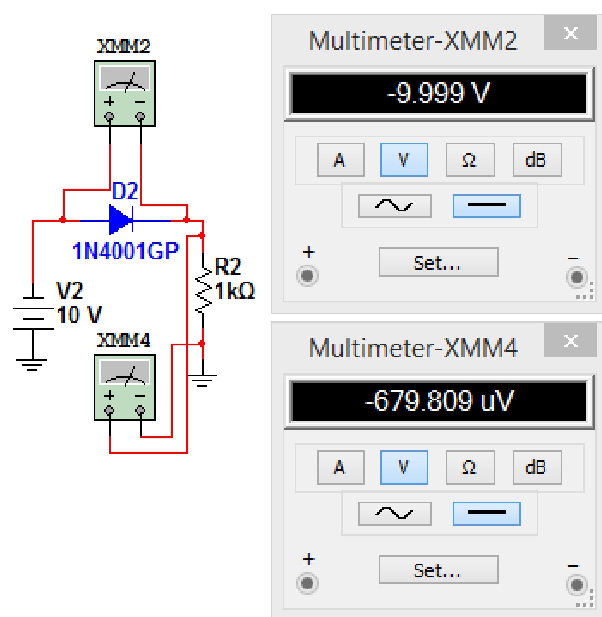
REVERSE



DATA FOR FORWARD BIAS (LEFT) AND REVERSE BIAS (RIGHT)

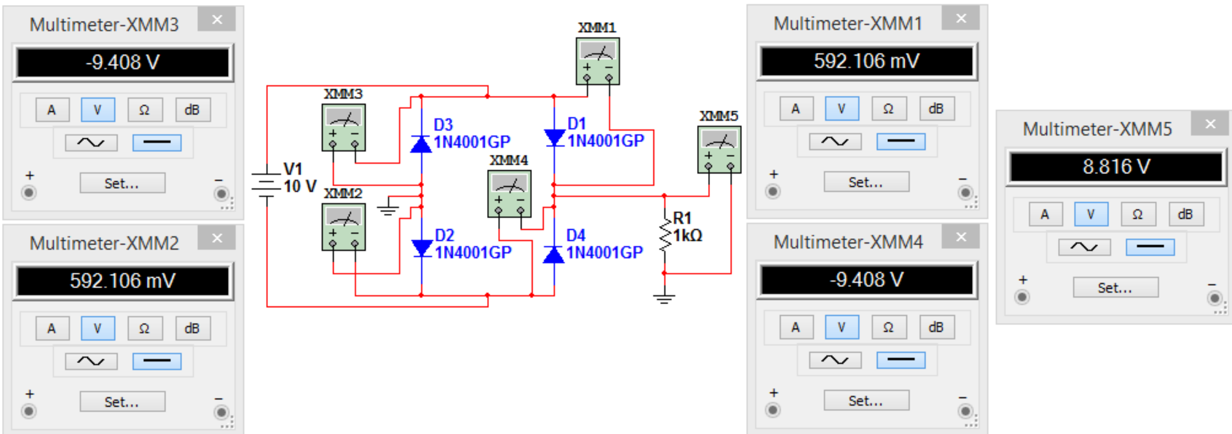
Here are the voltage measurements I acquired from Multisim. The voltage on the diode that is forward bias shows a very low voltage and most of it is going through the load. On the other hand, the voltage on the diode that is reverse bias shows a measurement that is almost equal to the voltage source and very little voltage is going through the load.





DIODE AND LOAD VOLTAGES

The circuit below is a replica of the schematic in Figure 4-3 of the lab. I matched the number label of the diodes with the number label of the multimeter. The voltages of the diodes show which ones are forward and reverse biased. The two diodes with 592mV are forward biased and the other two with 9.40V are reverse biased.



CONCLUSION

In this lab, I learned more about semiconductor diodes. The reverse resistance of a silicon diode is about 1000 times more than the forward resistance. On my Multisim experiment, the measurement that I acquired is not close to the theoretical values, but it still shows how the reverse resistance is a lot more compared to the forward resistance. A diode that is forward biased serves like a closed switch. When connected in series with a load of 1kΩ resistor, very low voltage is going through the diode and most of it is through the load. The voltage drop of a silicon diode that is forward biased should read 0.5 – 0.7V, 0.2 – 0.4V for germanium, and 1.4 – 2V for LEDs. For this lab, we just used the silicon diode. The diode that is reverse biased is the opposite; it acts as an open switch. The voltage measurement through the diode is about equal as the voltage source and this time only a few is going through the load. Since we didn't have enough diodes and knowledge with AC circuits, we had to skip few parts of the lab. Overall, this lab helped me know more about semiconductor diodes.