

ELEC-313  
Lab 2: Diode Characterization

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## 1 Objective

The objective is to observe the basic operation of a diode. In addition, the Shockley equation (Eq 2) is used to find the diode's reverse saturation current ( $I_S$ ) and thermal voltage ( $V_T$ ) using values measured in the lab.

## 2 Equipment

Diode: 1N4002

Resistors:  $330\ \Omega$ ,  $470\ \Omega$ ,  $680\ \Omega$

Resistive decade box: HeathKit IN-3117

Power supply: HP E3631A

Multimeter: Fluke 8010A (x2)

## 3 Schematics

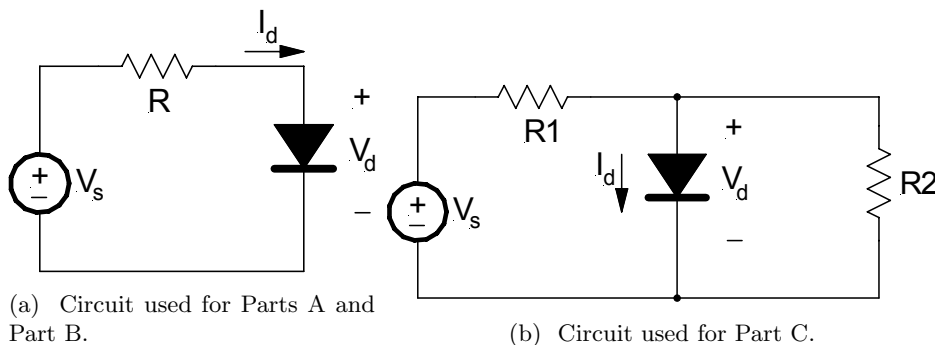


Figure 1: Circuits used in this lab.

## 4 Procedure

### 4.1 Part A

The circuit in Figure 1a was constructed with  $R = 470\ \Omega$  and the power supply as  $V_s$ . The actual resistance was measured with one a multimeter and recorded in Table 1 along with the percent difference calculated (Eq 1). Next, the multimeters were used to measure voltage across and current through the diode ( $V_d$  and  $I_d$ , respectively) while  $V_s$  was swept from  $-5\ \text{V}$  to  $10\ \text{V}$ . The step size from  $-5\ \text{V}$  to  $0\ \text{V}$  and from  $5\ \text{V}$  to  $10\ \text{V}$  was  $0.5\ \text{V}$ , and  $0.25\ \text{V}$  from  $0\ \text{V}$  to  $5\ \text{V}$ . These values were recorded in Table 2 and plotted in Figure 2.

### 4.2 Part B

The circuit in Figure 1a was constructed with the resistive decade box as  $R$  and the power supply as  $V_s$ . The multimeters were again used to measure diode

voltage ( $V_d$ ) and current ( $I_d$ ). This time  $V_s$  was held at 10 V and  $R$  varied: 200  $\Omega$ , 500  $\Omega$ , 1 k $\Omega$ , 2 k $\Omega$ , 5 k $\Omega$ , 10 k $\Omega$ , 20 k $\Omega$ , 50 k $\Omega$ , 100 k $\Omega$ . These values were recorded in Table 3 and plotted in Figure 2.

### 4.3 Part C

The circuit in Figure 1b was constructed with  $R_1 = 330 \Omega$ ,  $R_2 = 680 \Omega$ , and the power supply as  $V_s = 10 \text{ V}$ . The multimeters were again used to measure diode voltage ( $V_d$ ) and current ( $I_d$ ). Finally, the diode was removed and a multimeter was used to measure the voltage at that node ( $V_{OC}$ ). These values were recorded in Table 4.

## 5 Results

	Nominal ( $\Omega$ )	Measured ( $\Omega$ )	% Difference
$R_1$	470	465.3	1.00

Table 1: Comparison of nominal and measured resistance in Part A.

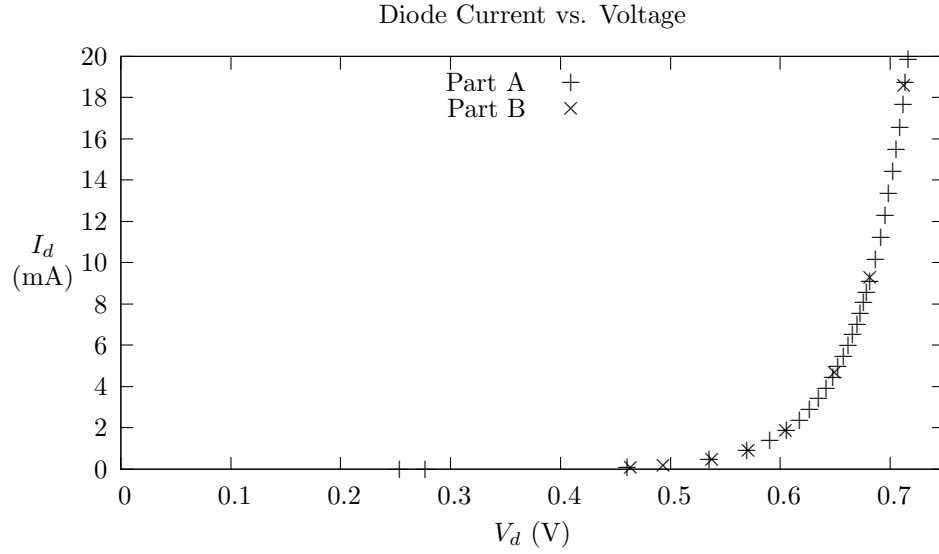


Figure 2: Diode characteristics measured in Parts A and B.

$V_s$ (V)	$V_d$ (V)	$I_d$ (mA)	$V_s$ (V)	$V_d$ (V)	$I_d$ (mA)
-5.00	-5.000	0.01	2.75	0.648	4.44
-4.50	-4.500	0.01	3.00	0.653	4.95
-4.00	-4.000	0.01	3.25	0.658	5.47
-3.50	-3.500	0.01	3.50	0.662	5.99
-3.00	-3.000	0.01	3.75	0.666	6.51
-2.50	-2.500	0.01	4.00	0.670	7.03
-2.00	-2.000	0.01	4.25	0.673	7.55
-1.50	-1.500	0.01	4.50	0.676	8.08
-1.00	-1.000	0.01	4.75	0.679	8.60
-0.50	-0.500	0.01	5.00	0.682	9.13
0.00	0.277	0.010	5.50	0.687	10.18
0.25	0.254	0.010	6.00	0.692	11.23
0.50	0.461	0.105	6.50	0.696	12.30
0.75	0.536	0.469	7.00	0.699	13.36
1.00	0.570	0.922	7.50	0.703	14.42
1.25	0.591	1.40	8.00	0.706	15.49
1.50	0.606	1.89	8.50	0.709	16.56
1.75	0.618	2.39	9.00	0.712	17.66
2.00	0.627	2.90	9.50	0.714	18.75
2.25	0.635	3.41	10.00	0.717	19.84
2.50	0.642	3.92			

Table 2: Diode characteristics measured in Part A.

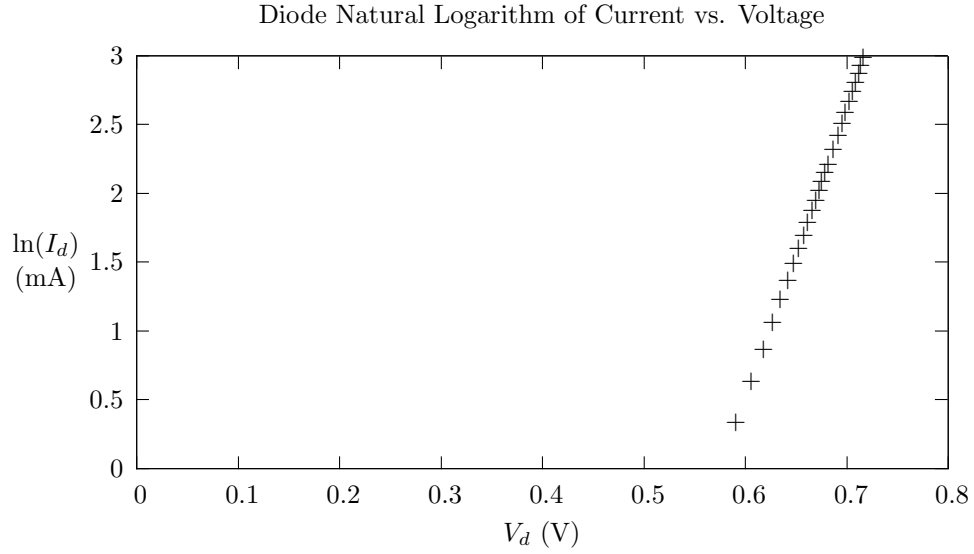


Figure 3:  $\ln(I_d)$  vs.  $V_d$ .

$R$ ( $\Omega$ )	$V_d$ (V)	$I_d$ (mA)
200	0.751	46.00
500	0.713	18.60
1k	0.682	9.30
2k	0.650	4.70
5k	0.605	1.85
10k	0.571	0.94
20k	0.538	0.47
50k	0.494	0.19
100k	0.464	0.10

Table 3: Diode characteristics measured in Part B.

$V_d$ (V)	$I_d$ (mA)	$V_{OC}$ (V)
0.712	27.2	6.70

Table 4: Diode characteristics measured in Part C.

## 6 Conclusion

As seen in Figure A, the graph of the natural log of  $I_d$  vs.  $V_d$  derived from Part A data (Table 2) generates a curve that is closely represented by a straight line, as seen in multiple examples from circuits textbooks. The slope ( $m$ ) of this line was approximated by using two data points (Table C). The inverse of the  $m$  generated a calculated thermal voltage ( $V_T$ ) and it was also recorded in Table C. Two corresponding  $I_d$  and  $V_d$  values (shown in Table C) along with  $V_T$  were plugged into the Shockley equation (Eq 2) to derive the saturation current ( $I_S$ ) seen in (Table C). The value of  $V_T$  is very close to the assumed value of 0.026 V. Also the value of  $I_S$  seems to be close to what is typically seen in circuits textbooks thus showing that diode parameters can be calculated by using the Shockley equation. As seen in Table A, the measured values of  $V_d$  and the  $I_d$  taken in Part B of the experiment were very close to the theoretical values calculated in PSpice. The largest %difference was only 2.65%. As seen in Table B, the measured values of  $V_d$  and the  $I_d$  taken in Part C of the experiment were very close to the theoretical values calculated in PSpice. The largest %difference was on 4.17%.

$m$	$V_T$ (V)	$V_d$ (V)	$I_d$ (mA)	$I_s$ ( $\mu$ A)
21.772	0.046	0.687	10.18	0.325

Table 5: Results from data analysis.

## 7 Equations

$$\%_{diff} = \frac{|nominal - measured|}{nominal} 100\% \quad (1)$$

$$I_D = I_S \left( e^{\frac{V_D}{V_T}} - 1 \right) \quad (2)$$

$$m = \frac{1}{V_T} \quad (3)$$

$$m = \frac{\ln(I_2) - \ln(I_1)}{V_2 - V_1} \quad (4)$$