EXPLORATIONS

Chapter 14

Features Used

TI-GRAPH LINK ™, **NewData, NewProb, DATA EDITOR, [I], [STO▸]**

Setup

[◆] 1
NewFold diode

Manipulating Lab Data: The Diode

This chapter introduces the Shockley diode equation, which gives the voltage-current characteristics of a diode. The equation is plotted and compared to actual diode data taken in a laboratory. The method of importing data to the TI-89 is shown, followed by instructions on how to manipulate the data to prepare it for plotting.

Topic 65: The Diode Equation

The diode has a voltage-current characteristic that is modeled by the Shockley diode equation

$$i = i_0\left(e^{\frac{qV}{nkT}} - 1\right)$$

where

i is the current through the diode,

i_0 is the reverse saturation current,

q is the charge of an electron (1.6022e⁻19),

V is the voltage across the diode,

n is a dimensionless factor that is theoretically 1, but ranges from 1 to 2 in real diodes,

k is Boltzmann's constant (1.3806e⁻23), and

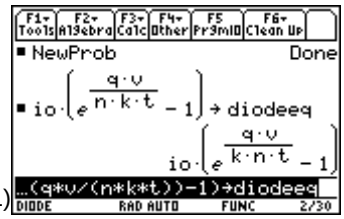
T is the temperature in Kelvin (K).

1. Clear the TI-89 by pressing [2nd] [F6] **2:NewProb** [ENTER].

2. Enter the equation as shown in screen 1.

i0 [×] [(] [◆] [e^x] q [×] v [÷] [(] n [×] k [×] t [)] [)] [−] 1 [)] [STO▸] diodeeq

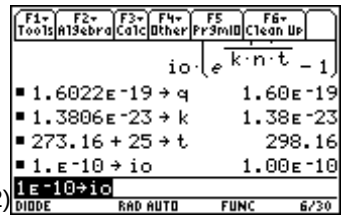
(1)



***Note**: Enter the [×] between **i0** and the [(]; otherwise, **i0** will be interpreted as a function.*

3. The values for the parameters can be entered now.

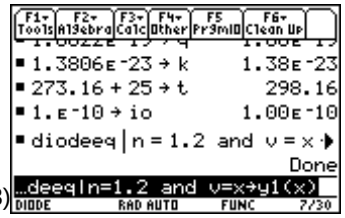
Enter **q** and **k**. Choose a typical value of **i0**=1.E-10 A and a temperature, **t**, of 273.16+25 K. The parameter **n** is not specified yet.

(2)


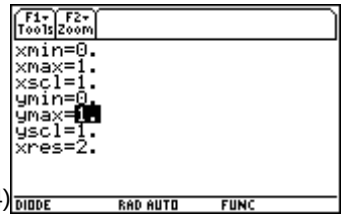
4. The usual way to plot the diode equation is to press ◆ [Y=] and enter the equation.

However, you can skip that step and enter the equation from the Home screen as shown in screen 3.

diodeeq [|] **n** [=] **1.2** [CATALOG] **and v** [=] **x** [STO▸] **y1** [(] **x** [)]

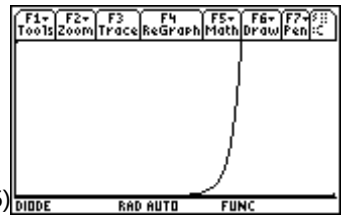
(3)


5. Press ◆ [WINDOW] and set the window variable values as shown in screen 4.

(4)


6. Press ◆ [GRAPH] to see the plot (screen 5). It takes a couple of seconds for the graph to appear since the values on the left half of the screen are nearly 0 but must be plotted.

It looks like the proper curve for a diode. The effects of **n** can be seen by plotting a second equation with a different value of **n**.

(5)


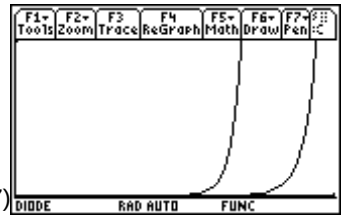
7. In the Y= Editor, enter the equation for **y2** with **n**=1.6 as shown in screen 6.

diodeeq [|] **n** [=] **1.6** [CATALOG] **and v** [=] **x**

(6)


8. Graph both equations.

Increasing **n** causes the curve to move to the right with a larger voltage drop across the diode in the "on" state (screen 7).

(7)


Topic 66: Lab Data

The Shockley equation attempts to model a diode, but how close is it? The only way to tell is to take some real data from a diode and compare it to the equation. Figure 1 shows the diagram of a circuit that was built to measure such diode characteristics. (The value for the resistor is the measured value of a resistor marked as 1kΩ.)

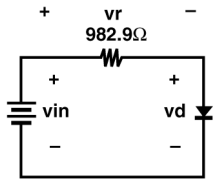


Figure 1. Diode measurement circuit

Several values for **vin** and **vr** were measured in the lab and entered into two files (called **vin.txt** and **vr.txt**, respectively) on a computer. These values can be downloaded to the TI-89 using the TI-GRAPH LINK™ cable and software. Alternatively, the data from **vin** and **vr** can be entered directly into the TI-89 by hand.

A single data value is entered on each line of the text file. The data presented here is inserted into a table to save space, **vin.txt** in Table 1 and **vr.txt** in Table 2. (Read across each row and then continue at the left of the next row.)

0.2002	0.2507	0.3003	0.3501
0.4008	0.4501	0.5014	0.5506
0.6001	0.6504	0.7006	0.7503
0.8008	0.8501	0.9	0.951
1.0005	1.1022	1.2029	1.3017
1.4013	1.5032	2.002	2.502
2.999	4.007	5.003	7.502
10.003			

Table 1. vin.txt data

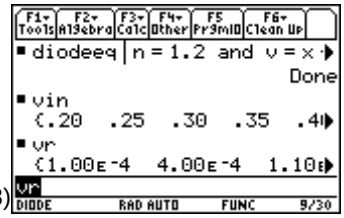
0.0001	0.0004	0.0011	0.0031
0.008	0.0182	0.0368	0.062
0.0928	0.1282	0.1666	0.2063
0.2484	0.2902	0.3336	0.3778
0.4231	0.5158	0.6087	0.7007
0.7951	0.8912	1.369	1.855
2.341	3.331	4.315	6.79
9.274			

Table 2. vr.txt data

Method 1: Using the TI-GRAPH LINK™

Download the values from the computer into the TI-89 using TI-GRAPH LINK.

1. Start TI-GRAPH LINK on the PC and select **Tools:Import:ASCII Data**. A file selection box appears.
2. Select **vin.txt** on the computer and click **OK**. Naming the converted file as the default, **vin.9xl**, is fine, so click **OK**.
3. Repeat these steps for **vr.txt**.
4. Use the cable to connect the computer and the TI-89.
5. On the TI-89 screen, display the Home screen.
6. Now transfer these files to the TI-89 by selecting **Link:Send** on the computer.
7. Double-click on **vin.9xl** and **vr.9xl**, and then click **OK**. A window opens showing the progress of the file transfer. It shouldn't take long.
8. Click **OK** once the "** Complete **" message appears. The data is now stored in list form in the TI-89.
9. Check the values by entering **vin** and **vr** on the Home screen. The results should match screen 8.



(8)

***Note**: The default mode used in this book is "FIX 2"; therefore, only 2 digits are displayed even though 4 were entered.*

Method 2: Entering the Data Directly

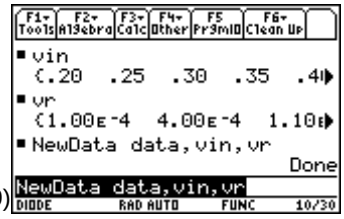
On the Home screen, enter the data directly as a list separated by commas.

2nd [{] **.2002**,**.4008**,…,**7.502** [}] STO▸ **vin**

2nd [{] **.0001**,**.008**,…,**6.79** [}] STO▸ **vr**

1. Combine the two sets of data, **vin** and **vr**, into one data file by using **NewData** as shown in screen 9.

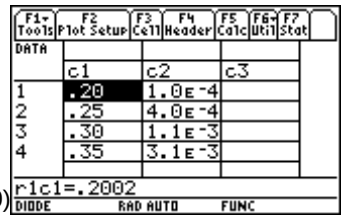
   CATALOG **NewData data** , **vin** , **vr**



(9)

2. The contents of **data** do not appear on the Home screen, but they can be viewed by pressing APPS **6:Data/Matrix Editor 2:Open,** specifying **Type** as **Data**, and selecting the variable **data**. (screen 10).

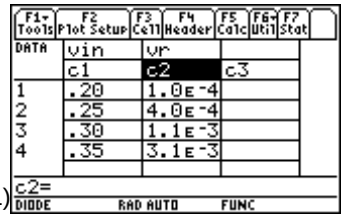
(10)



3. It's a good idea to label each column of the data so that the two sets of data are not confused.

Press ▲▲ and enter **vin**. Then press ENTER ▶ ▲▲ **vr** ENTER (screen 11).

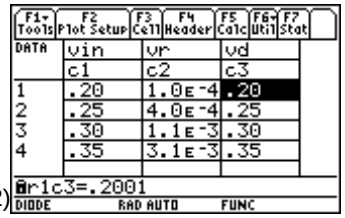
(11)



4. The diode voltage, **vd=vin–vr**, is placed in column **c3** by pressing ▶ ▲ **vd** ENTER **c1** − **c2** ENTER (screen 12).

Note that the contents of the computed cells are "locked" to their computed values. This is indicated by the 🔒 symbol preceding the cell name in the command line.

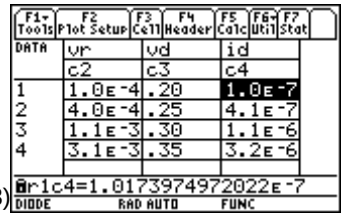
(12)



5. The current through the diode is the same as the current through the resistor, which is **vr/982.9**.

Place this in column **c4** by pressing ▶ ▲▲ **id** ENTER **c2/982.9** ENTER (screen 13).

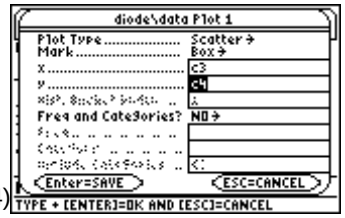
(13)



6. Plot the diode current in **c4** versus the diode voltage in **c3** by pressing F2 **Plot Setup** F1 **Define**.

7. Change **Mark** to **Box**. Then make sure the plot parameters are **c3** and **c4**, as shown in screen 14.

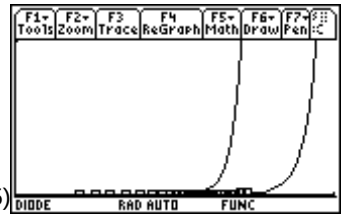
(14)



8. Press ◆ [GRAPH] to see the plot (screen 15).

The squares on the bottom are the lab data. The solid curves are the plots from Topic 65. The plot range isn't right for the data.

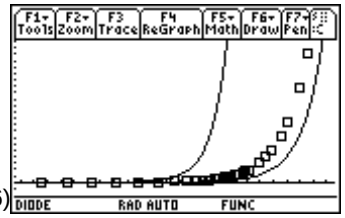
(15)



9. Press F2 **9:ZoomData** to scale the graph to the data (screen 16).

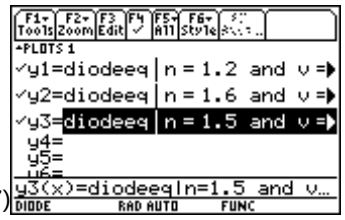
The left curve was for **n**=1.2, and the right was for **n**=1.6. The data looks like it fits a curve where **n** ≈1.5. Try it.

(16)



10. Press ◆ [Y=] and enter the diode equation as **y3** with **n** =1.5 as shown in screen 17.

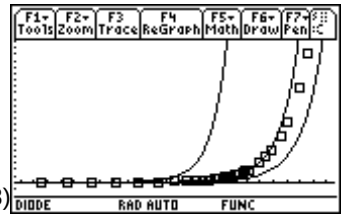
diodeeq [ ] **n** [=] **1.5** [CATALOG] **and v** [=] **x**



(17)

11. Press ◆ [GRAPH] (screen 18).

The laboratory data closely fits the **n**=1.5 curve. The actual value of **n** may be a little more than 1.5.



(18)

Tips and Generalizations

Any sort of lab data can be plotted using the techniques shown in this chapter. Plotting the data as it is taken in the lab could show quickly when anomalous data has been collected.

Chapter 15 shows how to compute what money is worth both now and in the future.