Lab 5: Diodes

U.C. Davis Physics 116A

INTRODUCTION

The purpose of this lab is to measure the properties of a diode and a zener diode. You will make I-V curves for each and will see how a diode can be used as a voltage rectifier.

1. DIODE I-V CURVE

In this section, you will get all the data points necessary to draw the full I-V curve for a diode. The basic circuit for doing this is shown in figure 1. Construct this circuit with several different values for R, such as 1MΩ, 100kΩ, 10kΩ, 6.8kΩ, 2.2kΩ, 1kΩ, and 680Ω, (not less than 680Ω) to produce a wide range of currents. For each different value of R, measure the voltage across the diode and the current through the diode. (To measure the current through the diode, measure the voltage across the resistor and use Ohm's law. Note that the voltage across the diode can be measured directly or it can be measured indirectly by subtracting the voltage across the resistor from 10V. Which do you think is better?)

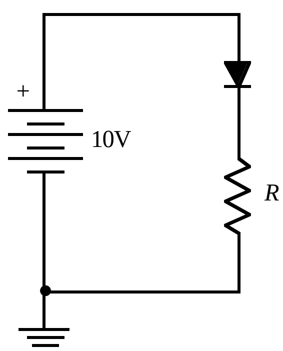

Figure 1: Circuit for measuring forward biased diode I-V curve data points.

To get a very low current data point, you'll use the following "trick": Our multimeters have an effective resistance of 22MΩ in voltage mode. Thus, you can use the multimeter itself as the resistor R in figure 1. Use this technique to get a very low current data point. (Should you measure the voltage across the diode directly or indirectly here?)

A diode will conduct a small amount of current when reverse biased also. To measure this, reverse the direction of the diode in the circuit of figure 1. Get at least two data points for this reverse biased circuit, one for $R = 1\text{M}\Omega$ and one using the 22MΩ of the voltmeter. The larger of these currents is probably a good order-of-magnitude guess for I_0. Call this the "measured" I_0.

For your lab report, tabulate your data points with their error estimates, answer the two questions in the paragraphs above, and make two separate plots of the data. (The next two paragraphs describe these two graphs.)

The first plot should be a direct linear-linear graph of I *vs.* V. Many of the currents will be indistinguishable from zero in this graph. Briefly discuss the shape of this graph, indicating how it "rectifies". Also indicate how a straight line (which does *not* pass through the origin) can fit many of the data points. This straight line models a diode as a resistor and a battery.

For the second graph, plot $\ln I$ *vs.* V for the positive currents. The I-V equation for a diode is

$$I \;=\; I_0\,(e^{V/nV_T} - 1) \;\approx\; I_0\,e^{V/nV_T}$$

where the approximation is valid if $e^{V/nV_T} >> 1$. Now take the natural log of both sides (properly, we must divide both sides by 1 Amp to get dimensionless quantities first):

$$\ln I \;=\; \ln(I_0\,e^{V/nV_T}) \;=\; \ln I_0 + V/nV_T.$$

This is an equation for a straight line with slope $1/nV_T$ and y-intercept $\ln I_0$. Draw a best fit straight line through your data points (you can do this by eye or using a computer) and determine I_0 and nV_T from the slope and y-intercept of this graph. Compare this value of I_0 to the "measured" value above and to "typical" values. Compare nV_T to the theoretical value.

2. ZENER DIODE

In this section, you will measure the I-V curve for a Zener diode. The symbol for a Zener diode is shown in figure 2. Make essentially the same measurements for the Zener diode as you did for the regular diode in section 1. For this diode, however, take as many data points in the reverse direction as you take for the forward direction. For your report, tabulate the data and make only the linear-linear graph. On the graph, identify the Zener breakdown region and indicate your Zener's rated voltage. Compare your graph with a friend who used a Zener diode with a different rated voltage and describe how the curves differ.

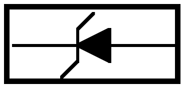

Figure 2: Symbol for a Zener Diode.

3. THE DIODE AS A RECTIFIER

In this section, you will see how a diode can "rectify" a signal, passing only positive voltages. Use the regular (non-Zener) diode in this section. Replace the DC power supply of figure 1 with an AC supply as shown in figure 3. (Use the function generator with a sine wave output for the AC supply.) First, use $R = 1\text{k}\Omega$ then repeat with $R = 1\text{M}\Omega$. Being careful to adjust the zeros of both traces, draw the input and output voltage waveforms for this circuit. The diode will appear to conduct only in one direction (positive voltage referenced to ground), but even for that polarity, it will "drop" the voltage by a few tenths of a volt. Measure that voltage drop for both *R*'s. Could you have predicted these voltage drops from the I-V curve for the diode? Try a different wave shape, like a triangle wave or square wave and see if the voltage drop remains approximately constant.

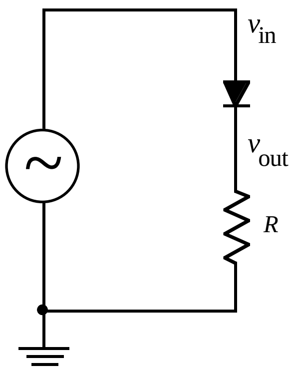

Figure 3: Circuit to demonstrate the diode as a rectifier.

For your report, include a brief description of what "rectify" means, the two oscilloscope sketches (each of two traces, v_{in} and v_{out}), the voltage drop for each, and a description of how those voltage drops can be determined from the diode's I-V curve.