Griffin Kowash
Sabrinna Rios Romero
PHYX 315
03/15/19

Lab 5: Diode Introduction

Introduction

The purpose of this lab is to become familiar with analyzing how diodes influence the characteristics of a circuit. To do this, voltage measurements across the resistor and diode were taken using the channels Ai0 and Ai1 along side with LabView. The two diodes analyzed were the 1N4004 Silicon diode and a Zener diode with a 5.1 V minimum to turn on. The lab was broken up into three sections: I versus V curve of a diode, rectified voltage across a resistor, and zener diodes.

Methodology

The first part of the lab involved experimentally determining the relationship between current and voltage for a silicon diode. An ideal diode acts as a perfect closed circuit under forward bias; in reality, diodes exhibit a voltage drop (about 0.7V for silicon), and they pass a small current at voltages below this threshold. The current has an exponential relationship with the voltage, given by the following equation:

$$I = I_0(e^{\frac{qV}{nkT}} - 1)$$

where I_0 is the leakage current under reverse bias, q is the fundamental unit of charge, V is the voltage across the diode, n is a constant between 1 and 2 called the ideality factor, k is Boltzmann's constant, and T is the diode's temperature in Kelvin. This exponential voltage-current relationship means that once a diode begins conducting a significant current, its voltage changes very little, even if the increase in current is large.

Under reverse bias, diodes pass very little current, acting in the ideal case as an open circuit. As a result, they output only the positive half of an AC waveform. This process is called rectification, and it is the key element in AC to DC conversion. To be precise, the removal of the negative half is known as half-wave rectification, because only half of the waveform appears in the output. Configurations of multiple diodes, such as bridge rectifiers, can perform full-wave rectification, which outputs the absolute value of the input signal. This process is more efficient, as it utilizes the entire input waveform in the output. Part two of our lab involved making measurements on a half-wave rectifier to calculate the DC component of the output.

When the reverse bias exceeds a threshold known as the breakdown voltage, the diode begins conducting current in the negative direction, generally resulting in failure of the component. However, Zener diodes are designed to take advantage of this property. As long as the power is kept below its rated value, they can conduct in this regime without damage. This property is useful for voltage regulation for two reasons: they maintain a constant voltage in their "on" state with very little deviation, and the breakdown voltage, also called the Zener voltage, is much larger than standard diode voltages. We explored this property in part three of our lab, where we plotted current versus voltage and experimentally found our diode's Zener voltage.

Table 1. Resistor description of theoretical and measured value.

Circuit element	value	measured value	units
resistor	10	9.98	kΩ

Results and Discussion

The diode characteristics curve for the first section of the lab is shown in Figure 1. In this lab, the y-axis represent the current and the x-axis represents the voltage. From 0 V to 0.4 V the current was 0 Amps. Right after the 0.4 V the current rises exponentially. The axis chosen to be mapped as log is the y-axis. This is because the exponential is due to the y equation for the relationship. Therefore, logging the y-axis creates a linear relationship with the linear x-axis. The logged y-axis relationship is shown in Figure 2. The relationship does not seem perfectly linear, but it approaches a more linear relationship once there are more data points at about 0.5 V.

For the second part of the lab, the half-wave rectifier relationship of voltage across time for the resistor is shown in Figure 3. The diode is forward biased when the input is positive, but when the input is negative the diode is reverse biased (Electronics Tutorials n.d.) Current only flows through the diode and circuit when forward biased. Therefore, through the resistor the voltage is equal to the input voltage minus the voltage needed for the diode. However, when the input voltage is negative, the voltage across the resistor is a constant 0 V since current does not flow through the diode. Looking at the block diagram, the DV voltage is calculated by taking the mean and dividing that averaged voltage by pi. This is where the number 0.318 comes into the equation to solve for DC voltage that is shown in the book (Boylestad and Nashelsky 2006).

In the final part of the lab, we tested three Zener diodes, with Zener voltages ranging from about 3V to 9V. As shown in our plots, each diode begins conducting under reverse bias near its Zener voltage. However, our data did not meet our expectations perfectly. The measured Zener voltage for each of our diodes was slightly less than the rated value of the component. In addition, the current versus voltage curve had a very sudden change in slope at a forward bias of 0.7V, while it followed a more gradual exponential curve under reverse bias near the Zener voltage. This is the opposite of our predictions; we expected the sharp slope to occur at the diode's breakdown point, and the gentler slope to occur near 0.7V like a typical diode. At this point we are unsure whether this discrepancy is caused by measurement errors or a theoretical misunderstanding.

Conclusion

Diodes are semiconductor devices with numerous applications, such as AC voltage rectification and DC voltage regulation. In this lab we explored the current versus voltage curves of both standard silicon diodes and Zener diodes, and we constructed a half-wave rectifier and found the equivalent DC output. We were able to confirm that the current through a forward-biased diode follows an exponential relationship with the voltage. Our results for the Zener diodes were less clear; they began conducting under reverse bias near the expected voltage, but the curve had a different shape than we expected. Still, we demonstrated some basic characteristics of diodes, and we are now more prepared to use them in future projects.

References

Boylestad, Robert L., and Louis Nashelsky. *Introduction to Electricity, Electronics, and Electromagnetics*. Pearson Education Taiwan, 2006.

"Power Diodes Used as Half-Wave Rectifiers." *Basic Electronics Tutorials*, Electronics Tutorials, 4 Feb. 2019, www.electronics-tutorials.ws/diode/diode_5.html.