ECE 2201: Microelectronic Circuits

Lab 1: Diode Characteristics

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Part 1: Diode V-I Characteristics:

Experimental Introduction:

In Part 1 of the first lab we looked at the voltage-current characteristics in the forward and reverse bias of a 1N4148 signal diode. We did this through measuring the output voltage across the diode at several input voltages and then used that information to find the current.

Theoretical Basis:

In order to allow current flow in a single direction, a diode is used. In the case that there is a large enough voltage being applied across a diode, current is then able to flow. This is called forward bias. In forward bias, the current has an exponential relationship with voltage as seen in the following equation:

ID = IS(e^(Vd/nVT)-1)

Equation 1

In the above equation, Vt is the voltage equal to 25mA at room temperature. "n" is the constant between 1 and 2 depending on the diode material/operating conditions.

When a negative voltage is applied, the diode is in revere bias. When in the reverse bias region, the current should be close to zero but it will be slightly negative until the diode's structure breaks down a larger negative current is allowed.

Circuit Description:

The following diagrams show the circuits used for the forward and reverse bias experiment:

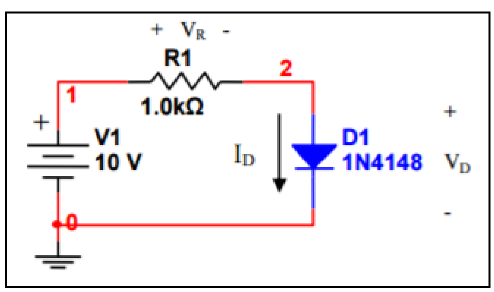

Figure 1: Circuit Diagram for Forward Bias Experiment

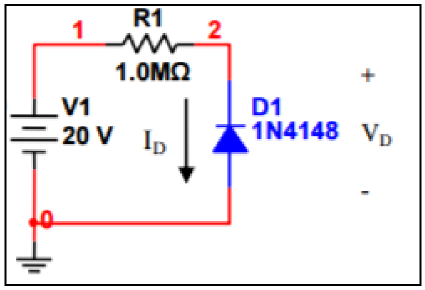

Figure 2: Circuit Diagram for Reverse Bias Experiment

Experimental Results:

Forward Bias V-I Characteristic Results:

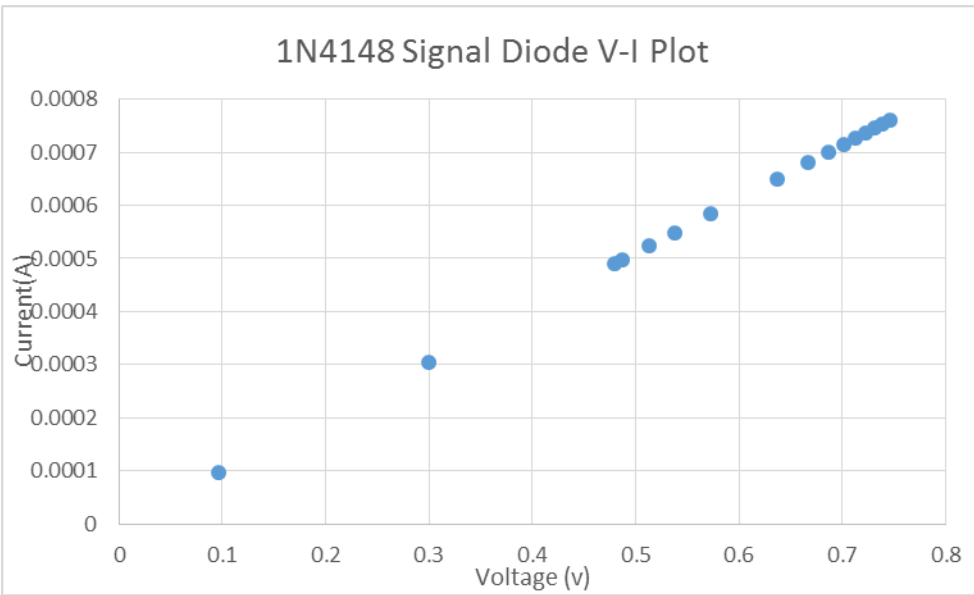

Figure 3: Forward Bias Plot

Reverse Bias V-I Characteristic Results:

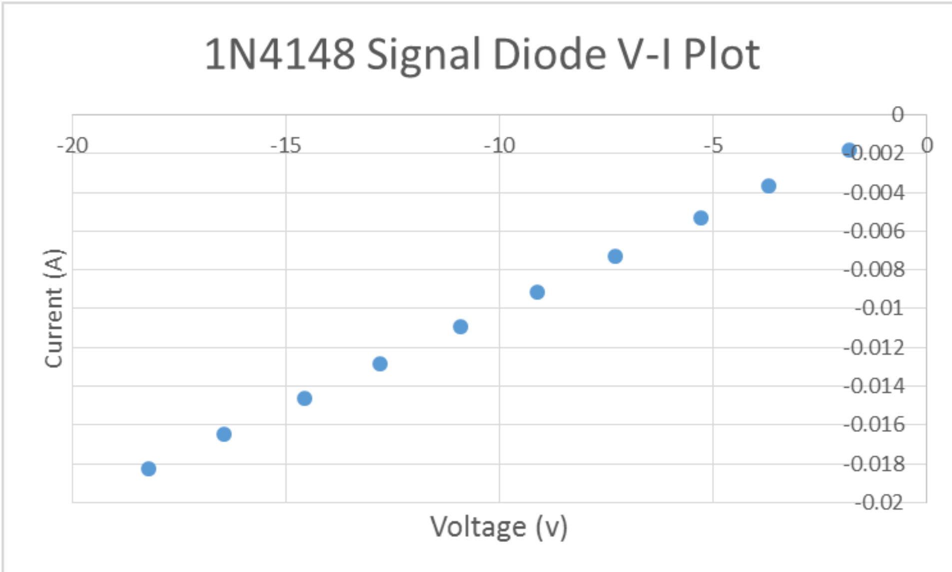

Figure 4: Reverse Bias Plot

Comparison to Theory and Simulation:

The results from our experiment align with what we had expected. As the voltage approaches 0.7V, the current increases exponentially. We also see that in the reverse bias region the current flow is very limited due to the diode semiconductor structure.

W2:

Following is the derivation of parameters Is and n. The constant n can be calculated by simply using 2 points on our curve and dividing Shockley equations. We then will use those same points in order to calculate Is. Our results appeared to be slightly off and our n value calculated was 7.28.

ID = IS(e^(Vd/nVT)-1) Starting at the Shockley Diode Equation
ID = IS(e^(Vd/nVT)) The -1 is negligible under high enough voltage
IS = ID/e^(Vd/nVT) Divide both sides by the exponential expression
IS = 0.0003/e^(0.3/(7.28*0.025))
IS = 0.000577
Using the other point:
IS = 0.00085

W3:

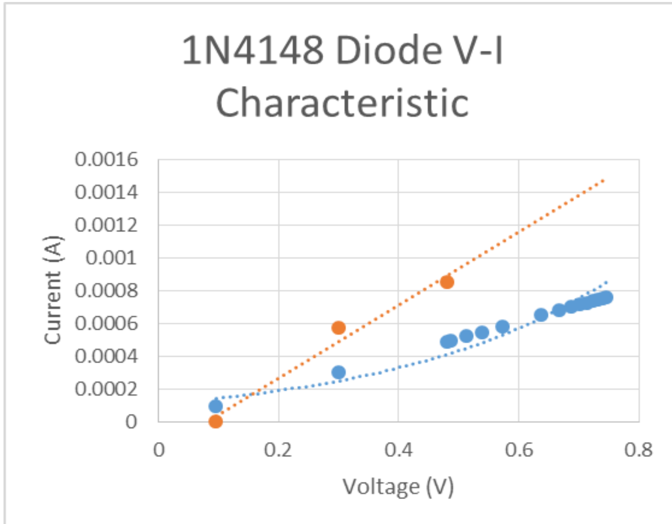

Figure 5: Shockley's diode equation vs collected Data

W4:

1.) One would expect to see a voltage of 0V due to the actual voltage at 5mA is less than 0.7V.
2.) ?
3.) These models are less accurate than the Shockley Diode Equation. At larger voltages (over 0.7) they are close enough to the real diode for most applications.
4.) Neither model is very good around the saturation voltage of 0.7V. The constant drop model can not be used to calculate voltage from current because current is either 0 or infinite. The piecewise linear model is bad at very high voltages because the diode should act like an open circuit at high voltages and not follow a linear trend.

Observation and Conclusion:

While our results seemed to slightly skewed, this experiment still verifies the Shockley Diode Equation (EQ 1a). It shows that diode current increases exponentially as diode voltage asymptotically approaches a voltage around 0.73V for the 1N4148 signal diode. In the reverse bias region, there is a small negative current on the order of a few nano amps.

Part 2: Diode V-I Characteristics (Sweep Method)

Experimental Introduction:

In Part 2 of the experiment we looked at the voltage-current characteristics in the forward bias and reverse bias ranges of a 1N4004 diode and 1N5231 zener diode using the sweep method. Using a transformer to bring down the amplitude of a standard 120V AC wall outlet, we observed the voltage across each diode in comparison to a resistor in series. We then configured an oscilloscope in X-Y mode to display the V-I characteristics of a diode.

Theoretical Basis:

This experiment uses a zener diode. This diode takes advantage of the reverse bias region. At a critical negative voltage, this diode allows current to flow. It is similar to the previous diode except that it is used for its reverse bias behavior. This experiment also uses a transformer. A transformer converts the flow of electrons through a coil to a magnetic field, which is then used to induce a current in an adjacent coil. The number of coil turns in the primary coil divided by the turns in the secondary coil is equal to the voltage across the primary coil divided by the voltage across the secondary coil.

Circuit Description:

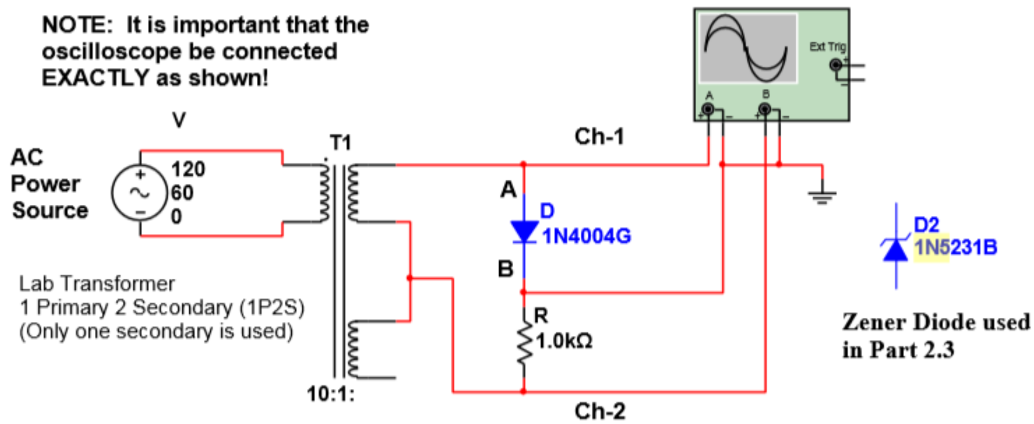

Figure 6: Circuit Diagram for the second part of the experiment

A 10:1 transformer is connected to a diode and resistor in series. The oscilloscope is measuring the voltage drop across the diode and resistor.

Experimental Results:

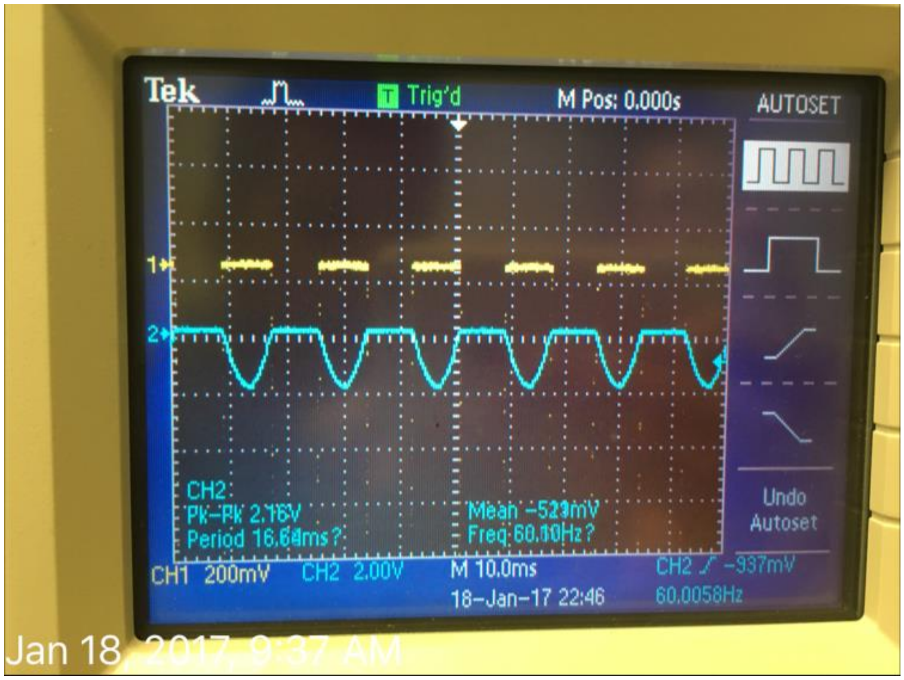

Figure 7: 1N4004 Diode using Sweep Method

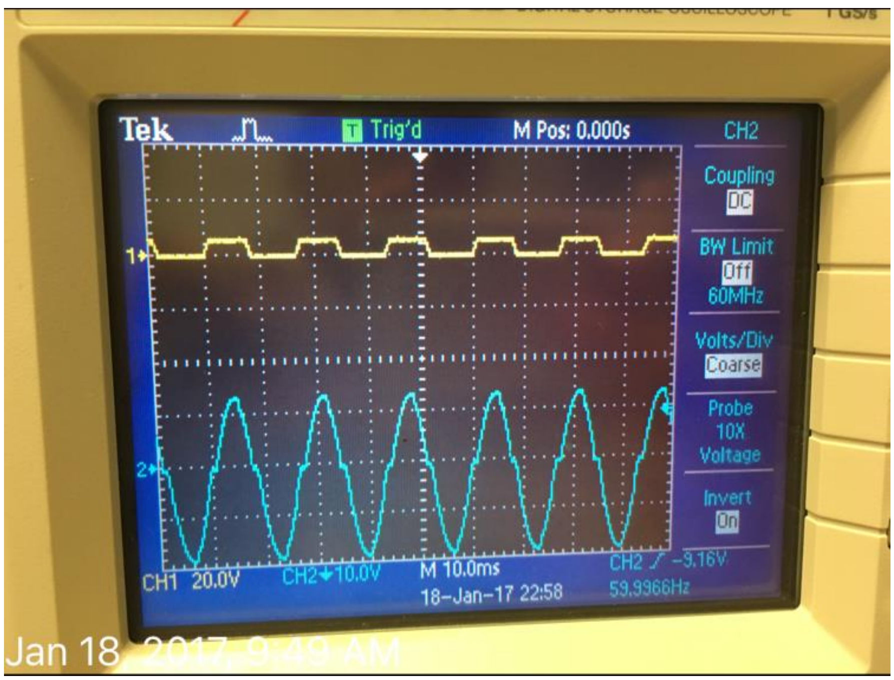

Figure 8: 1N5231 Diode Using Sweep Method

Comparison to Theory and Simulation:

Our results align very well with the theory for both diodes. Our results shows that the current begins to increase dramatically around 0.7V. It is an exponential relationship between voltage and current, which is in agreement with Shockley's diode equation. The Zener diode V-I characteristic is also what we expected. There is no current until the breakdown point in the reverse bias. In lab we were told not to include the simulation results because of some problems experienced with multisim for many students. However, the lab instructor's multisim simulation looked very similar to these results.

Observation and Conclusion:

Overall, this experiment verifies the expected V-I behavior for a diode and a zener diode using the sweep method. In this method, an AC source was applied to each diode and an X-Y oscilloscope plot showed the V-I characteristics. The 1N4004 diode current was low until voltage began approaching the saturation voltage of around 0.7V. With the zener diode current was low unless a large negative voltage was reached in the reverse bias region.