Fall 2019

California State University of Northridge

Department of Electrical & Computer Engineering

Experiment 2
Diode Characteristics

ECE 340L

September 18, 2019

Professor Soraya Roosta

Written by: Ridge Tejuco

Partners: Jonathan Meza, Robert Javier

Introduction:

The purpose of this experiment is to analyze and verify the characteristics of a diode, and most significantly the lab will verify the equation for the current of a diode . The lab covers Ideal diodes and linear diodes. the region of voltage that is required for the diode to be active or “forward biased”. This region is different for different diodes, but their characteristics and models should be the same. The lab also covers the characteristics of Zener diodes.

Equipment:

Type	Model
Oscilloscope	Agilent Technologies DSO1002A
Digital Multimeter	Tektronix CDM250
Function Generator	Agilent 3322OA
Power supply	Hewlett Packard E363OA
Curve Tracer	Tektronix 370A

Parts used:

QTY	Component	Value	Type
1	Resistor	1kΩ	Carbon +/- 5%
1	Resistor	1Ω	Carbon +/- 5%
1	Diode	1N4002	Tape and Reel

Software:

Pspice
Google Docs
Microsoft Excel

Background:

The equation for the current of a diode is as follows

$$i_D = I_s\,[e^{v_D/nV_T} - 1] \qquad \text{Equation 1}$$

V_T is the thermal voltage of the diode where $V_T =$ kT/q. The "k" is boltman's constant. T is the temperature in degrees Kelvin, and q is the charge of an electron. For the purposes of studying diodes, the temperature is estimated to be 300 K, so $V_T = 25.68$ mV.

I_s is the reverse saturation current of the diode, which is the extremely small amount of current that leaks through the diode when it is inactive. Looking at Figure 1, this effect can be seen when V_D is less than 0.

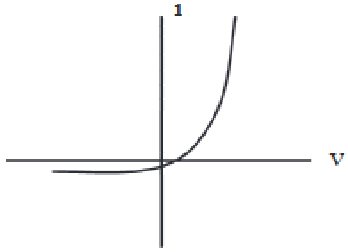
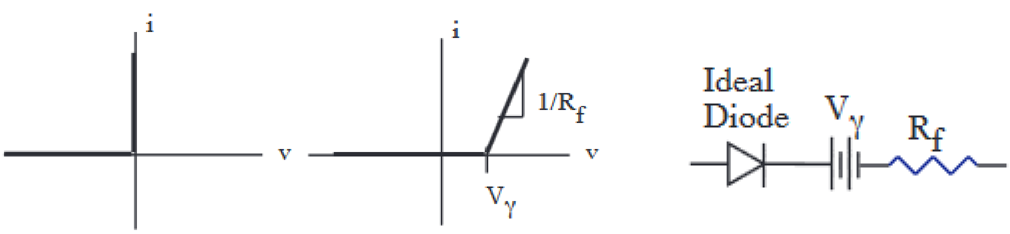


Figure 1



V_D is the voltage across the diode. Looking at Figure 1, the diode's current increases exponentially as V_D increases. This model can be approximated with the Ideal model of a diode and a cutoff resistance to get a linear model. In this model, a diode is only active when the voltage is greater than V_γ. For the 1N4002, this value is approximately at 0.65v. V_D will approximate stay at this value, and the voltage across the resistor will assume the rest of the voltage.

Procedure & Results:

The following circuit in Figure 2 was constructed with a resistance of 100Ω.

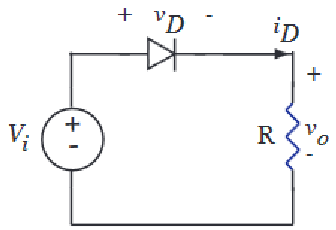
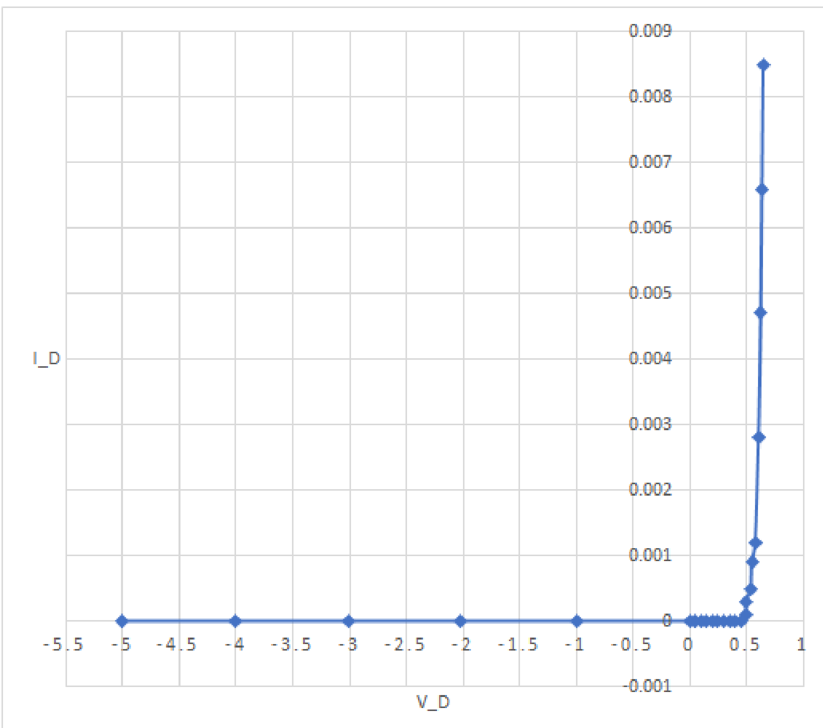


Figure 2

V_i was set to 0 v. Then from -5v to 0.695 v. V_o was recorded for every value of V_i. I_D was then calculated from these values using Ohm's Law across R. The following Plot 1 and Chart 1 are the results.

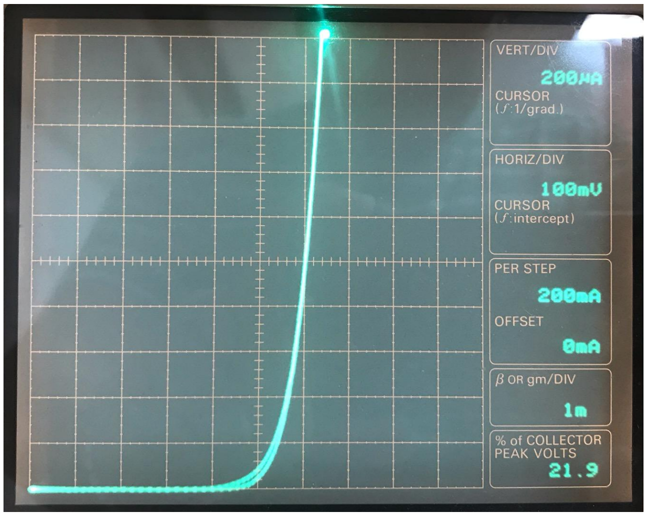


V_D (v)	I_D (A)
-5	0
-4.01	0
-3.01	0
-2.02	0
-1	0
0	0
0.05	0
0.1	0
0.15	0
0.2	0
0.25	0
0.3	0
0.35	0
0.4	0
0.45	0
0.5	0.0001
0.5	0.0003
0.54	0.0005
0.55	0.0009
0.58	0.0012
0.61	0.0028
0.63	0.0047
0.64	0.0066
0.65	0.0085

Plot 1

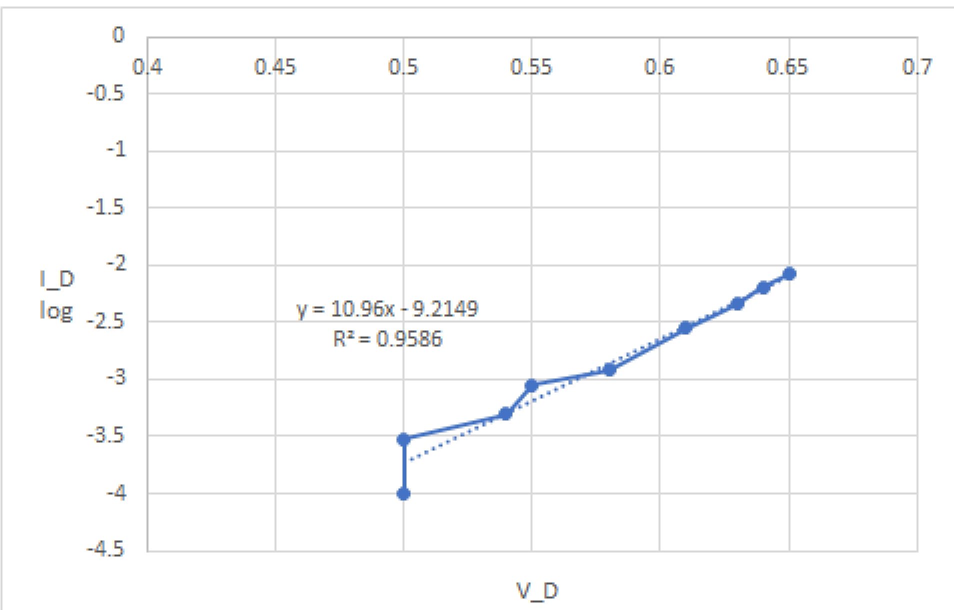
Chart 1

The curve tracer was used to find accurate current values for the 1N4002 diode which are then displayed in Plot 2. The curve trace results are fairly similar to Plot 1.



Plot 2

A plot of I_D on a logarithmic scale vs. V_D was produced in Plot 3.
Using this interpolation, the Y- intercept was found to be - 9.2149



Plot 3

Using the following Equation 2, the value of I_S was found. Log(I_S) is equivalent to Y-intercept.

$$\log(i_D) = \log(I_s) + \frac{\log(e)}{nV_T} v_D \qquad \text{Equation 2}$$

$\log(I_S) = -9.2149$

$\boldsymbol{I_S = 10^{-9.2149} = 6.0968 * 10^{-10}}$ **A.**

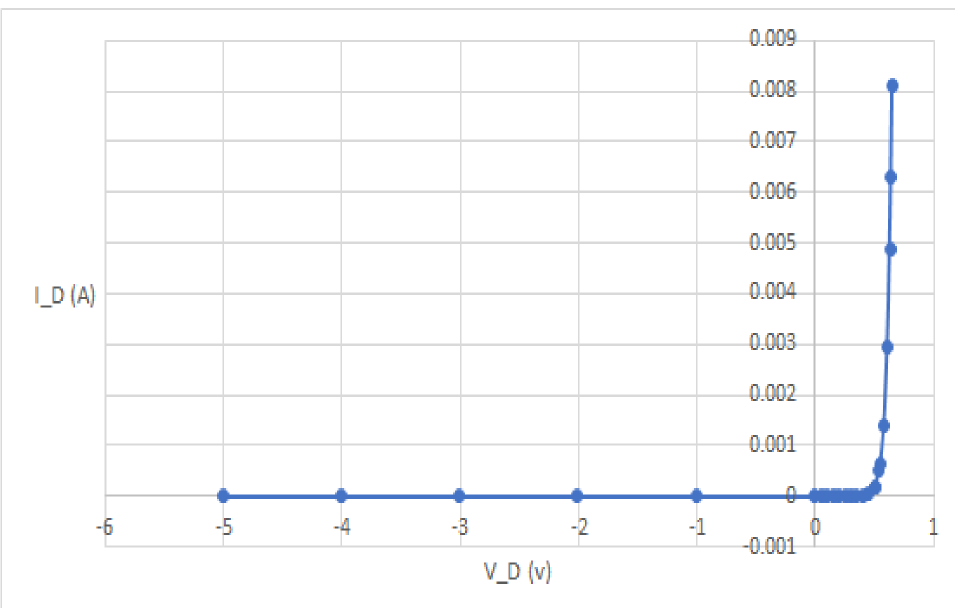
The slope of Plot 3 was 10.96. Again using Equation 2, the value of n = 1.548 was found assuming that V_T = 25.6 mV.

$$\frac{log\ (e)}{n\,V_T} = 10.96$$

$$n = \frac{log\ (e)}{10.96 * V_T} = \mathbf{1.548}$$

The values found for I_S and n were input to Equation 1 and then graphed in Plot 4 and Chart 2.

$$i_D = 6.0968 * 10^{-10}[e^{\frac{V_D}{1.548 * V_T}} - 1]$$



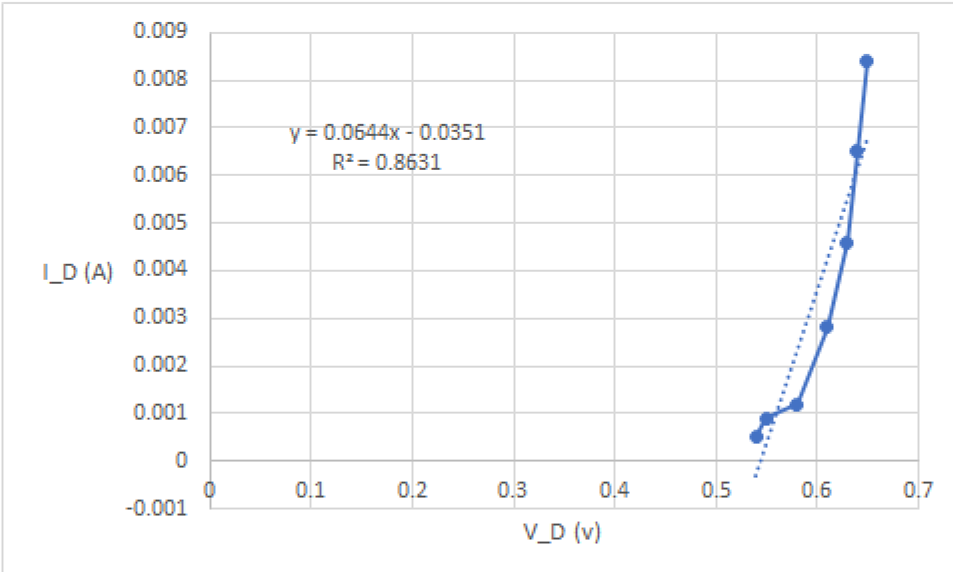
V_D (v)	I_D (A)
-5	-6.097E-10
-4.01	-6.097E-10
-3.01	-6.097E-10
-2.02	-6.097E-10
-1	-6.097E-10
0	0
0.05	1.5434E-09
0.1	6.9937E-09
0.15	2.6241E-08
0.2	9.4213E-08
0.25	3.3425E-07
0.3	1.1819E-06
0.35	4.1755E-06
0.4	1.4747E-05
0.45	5.208E-05
0.5	0.00018392
0.5	0.00018392
0.54	0.00050466
0.55	0.00064951
0.58	0.00138471
0.61	0.00295209
0.63	0.00489002
0.64	0.00629364
0.65	0.00810014

Plot 4

Chart 2

Upon closer review of the results, the values of I_D for the 1N4001 are very close to the calculated values. Comparing Plot 4, Plot 2, and Plot 1, the graphs are identical in shape and magnitude. Comparing Charts 1 and 2, the results are accurate to the mA range.

A linear piecewise model was graphed in Plot 5. The linear function was used to determine the cut-in voltage and the forward resistance.



Plot 5

The cut-in voltage was determined by setting Y to 0.

$0 = 0.0644x - .0351$

$0.0351 = .0644x$

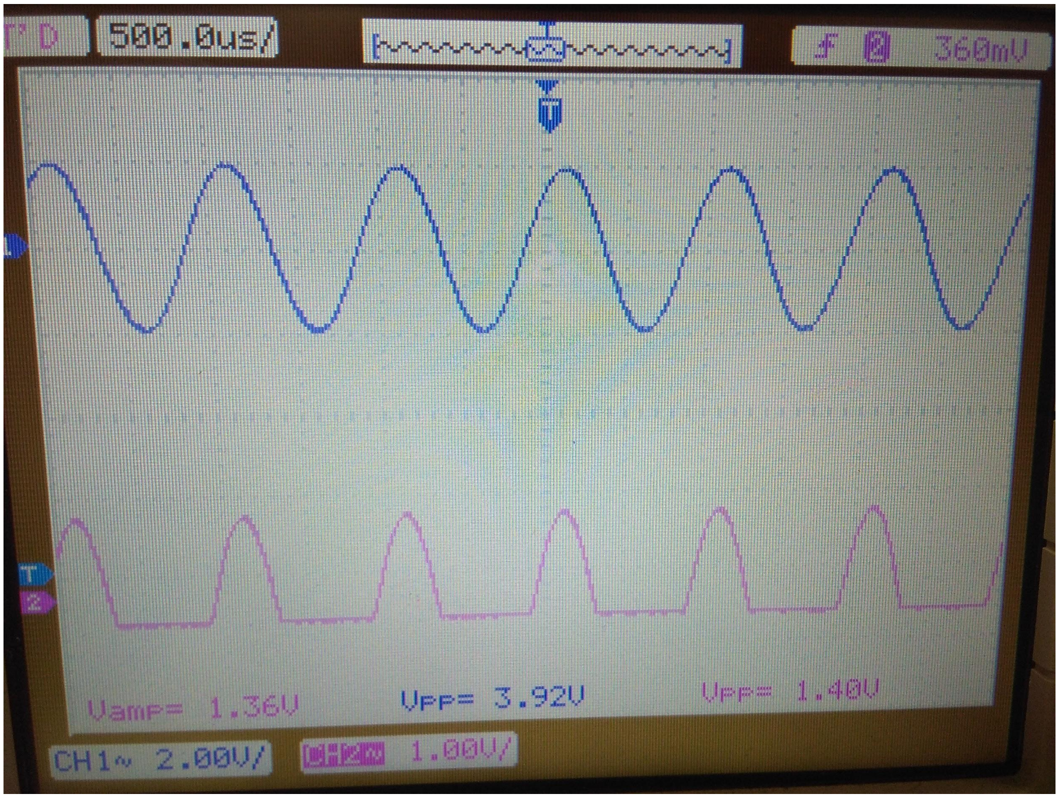
$V_\gamma = x = 0.0351 / 0.0644 = \mathbf{0.5451\ v}$

The forward resistance was found using the slope

$1/R_f = 0.0644$

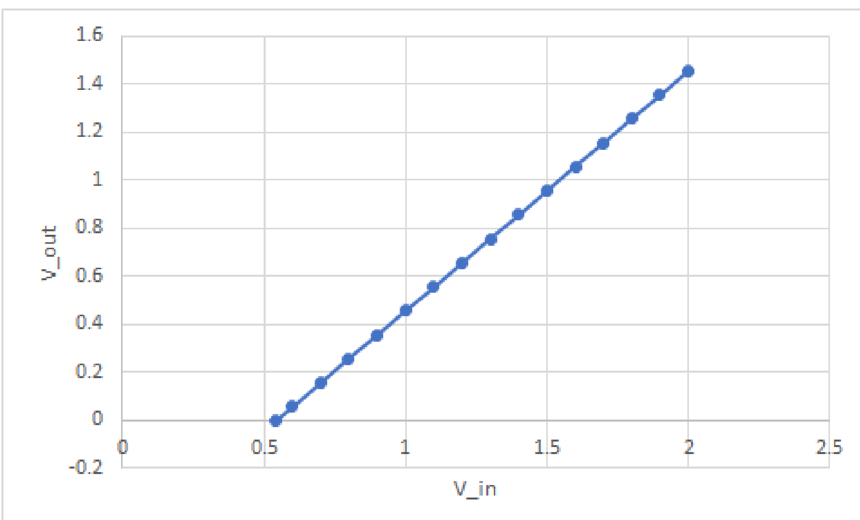
$R_f = 1/0.0644 = \mathbf{15.53\ \Omega}$

Next the DC source of Figure 2 was replaced with a 2 volt-peak which is 4 volt peak to peak. R was replaced with 1kΩ resistor. The Oscilloscope was used to measure the input of the function generator and the output across the resistor in Plot 6.



Plot 6.

The expected values of the resistor voltage was graphed in Plot 7 using a piecewise linear model. A piecewise linear model of V_O across the resistor was plotted using the value of $V_\gamma = 0.5451$ v.



Plot 7

In the last part, PSPICE was used to simulate the Following Figure 3.

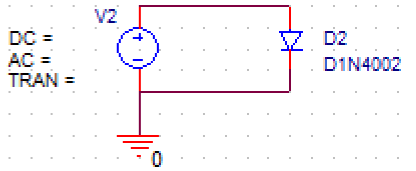
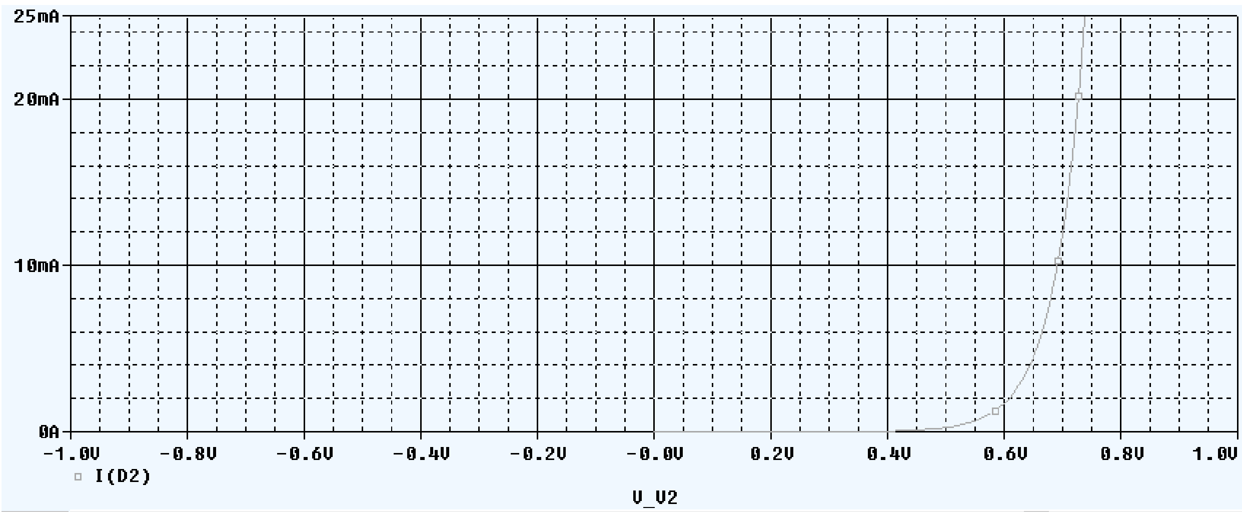


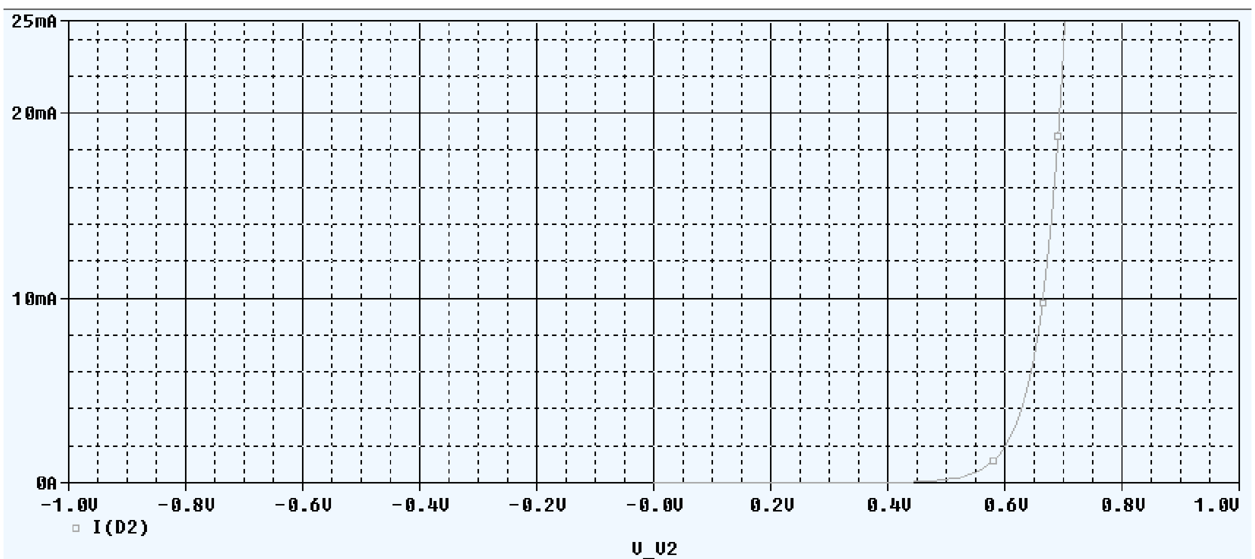
Figure 3

The following Plot 8 shows the simulation of the current going through the 1N4002.



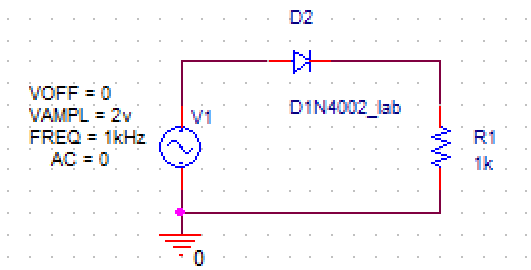
Plot 8

By modifying the diode 1N4002 to have the I_S and n values from parts 4 and 5. Plot 9 was graphed.

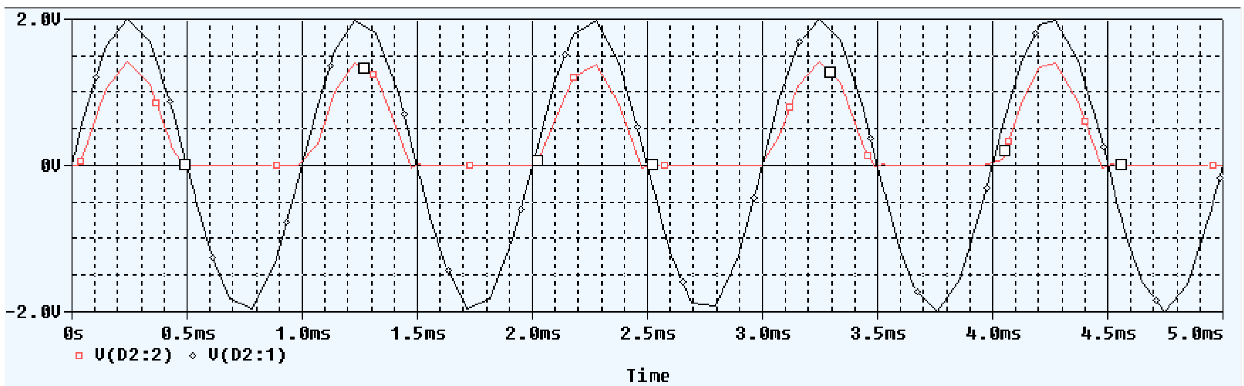


Plot 9

Lastly, the modified diode was used to simulate the circuit in step 8.



The following Plot 10 is the result of the input voltage vs the output voltage.



Plot 10

By comparing Plot 10 to Plot 6, the size and magnitude of the curves are similar. However, the V_γ of our plot seems to be around 0.7v compared to our calculated value of 0.5451 v. This most likely is due to error and lack of precision in recording data with the digital multimeter. Had data from the curve tracer been used instead, the data would have been more precise and accurate.

Conclusion

The experiment was a success in verifying the theory of a Diode both through the realistic model in Equation 1 and through the linear model in Figure 1. By comparing the Charts 1 and Charts 2, the measured values of I_D are close to the nearest mA. This shows that the linear and realistic models are exceptionally accurate.

The cut-in voltage and forward resistance were correctly interpolated using the linear piecewise model. Values of n and I_S, the reverse saturation current, were correctly identified for the 1N4002 diode.

Using PSPICE, the model was modified and correctly adjusted to fit the 1N4002 used in the lab. Upon modification of the diode, the results of PSPICE were slightly off the fit of curves found in Plot 4, Plot 2, and Plot 1. This is due to error in the precision of the tools when recording values.