

Device Characterization Project #1 – February 7th 2007

PN DIODE CHARACTERIZATION

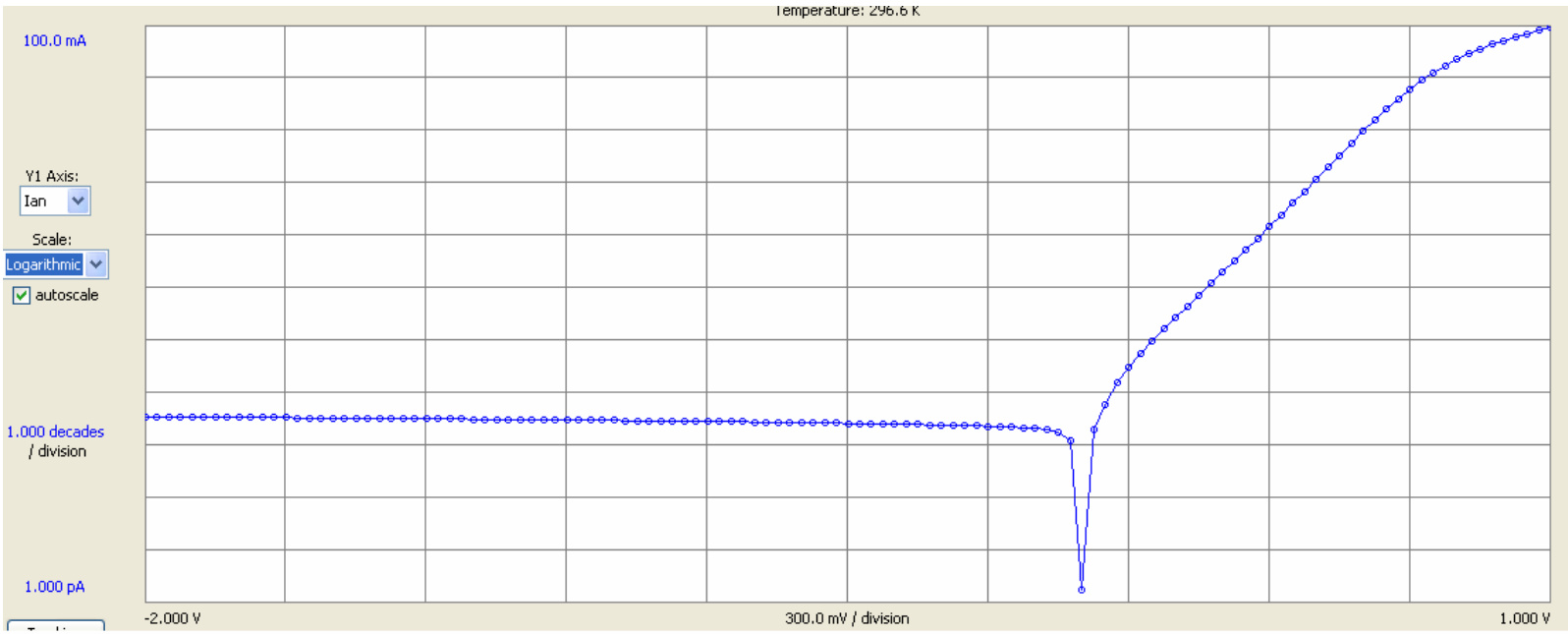
Solutions

In order to obtain Graph 1, we must sweep the diode's applied bias between -2V and 1V. The following plot was acquired by sweeping the voltage at SMU1, the anode, from -2V to 1V and grounding SMU2, the cathode. A step size of 25mV was used. The current from SMU1 was recorded.



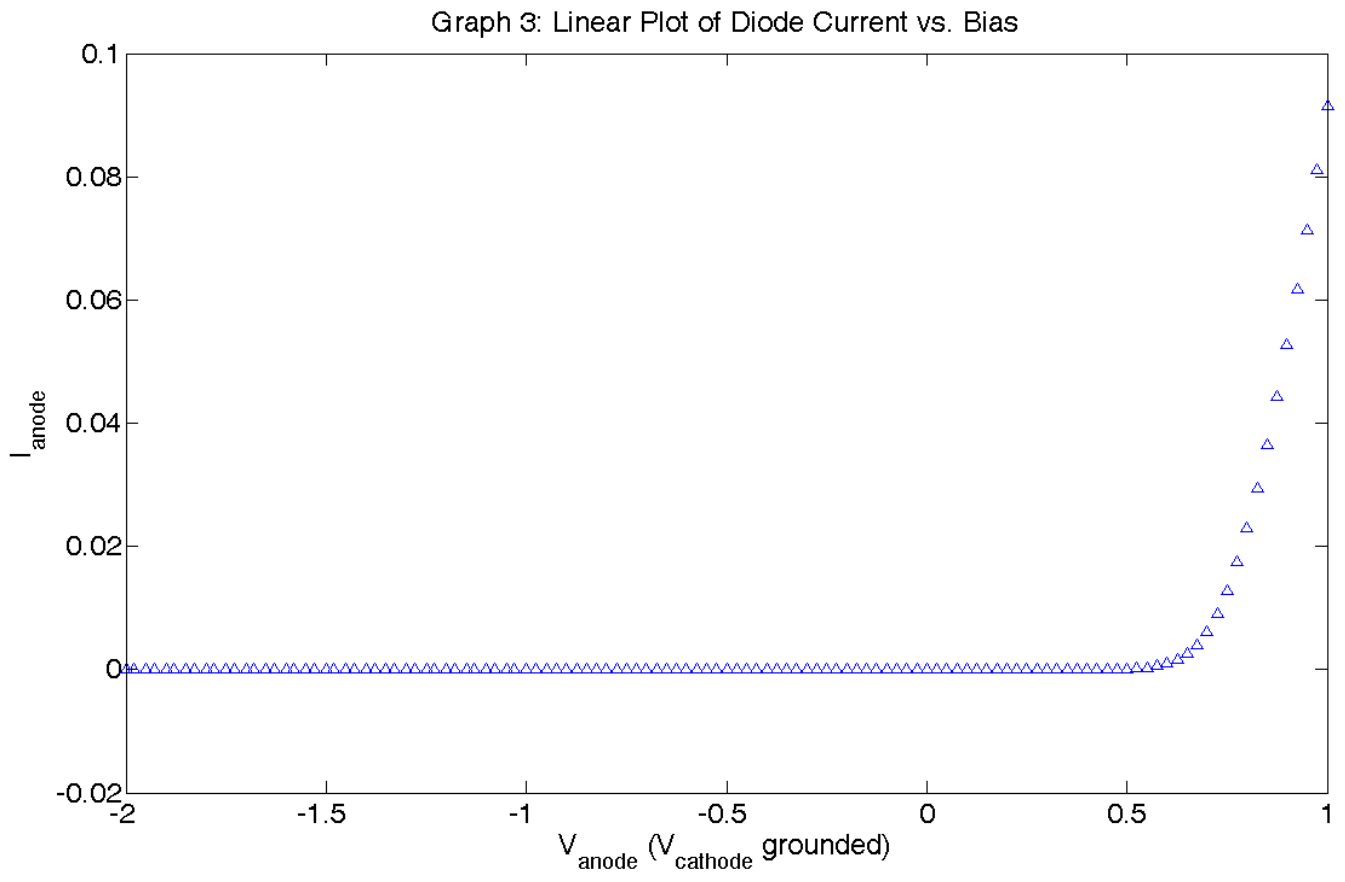
Graph 1: Linear plot of the diode current versus applied bias

By changing the y-axis to logarithmic scale, we get Graph 2. As in Graph 1, we see that the temperature of the diode is 296.6K. This is important to record, as we will need to enter it in our diode model equations.

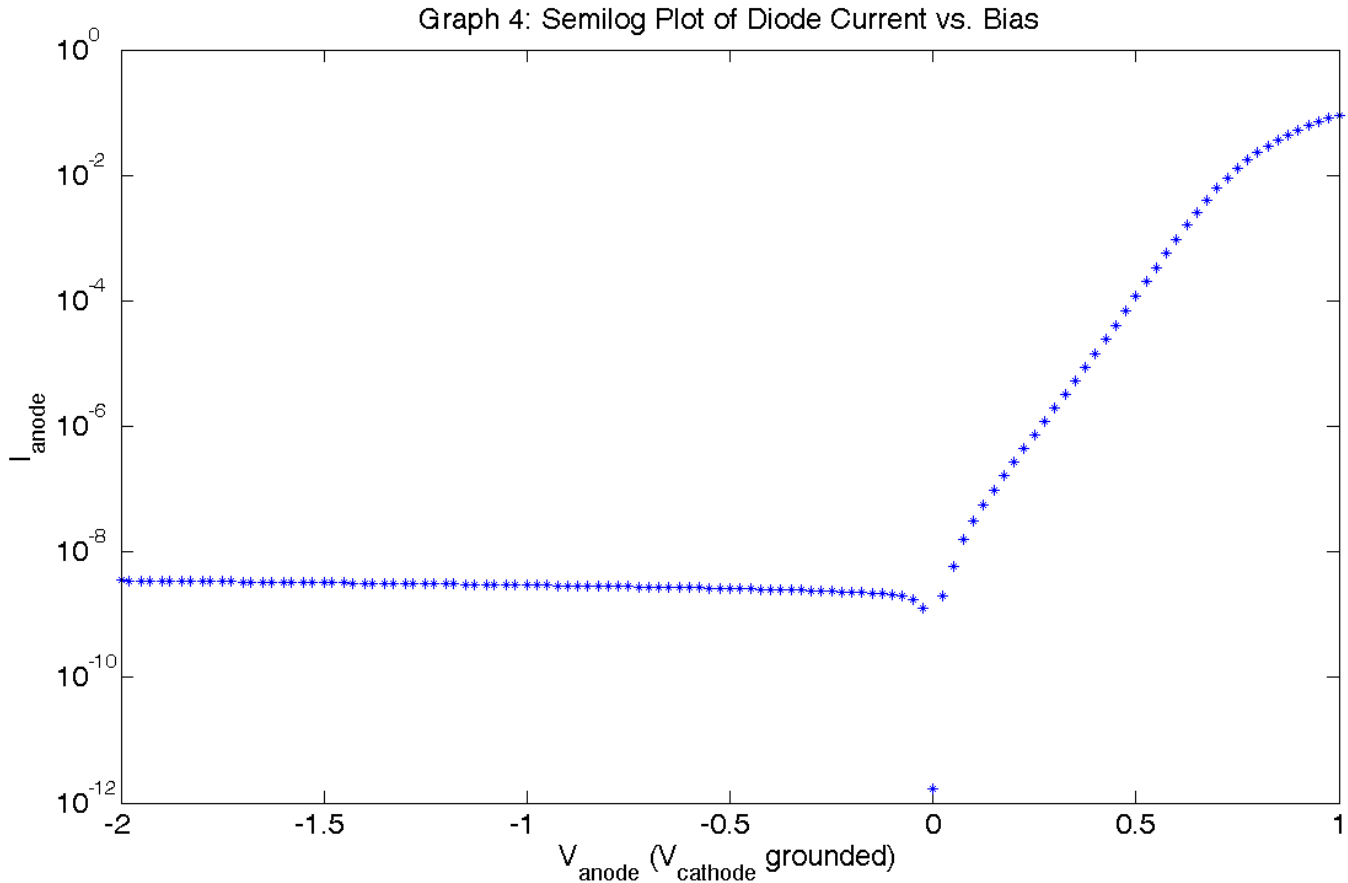


Graph 2: Semilog plot of the diode current versus applied bias

Exporting the data from weblab and importing to MATLAB gives us Graphs 3 & 4.



Graph 3: Linear plot of the diode current versus applied bias from MATLAB



Graph 4: Semilog plot of the diode current versus applied bias from MATLAB

Graph 4 makes it easy to obtain I_s . We see from the first order diode equation that the diode current at reverse bias will be $-I_s$.

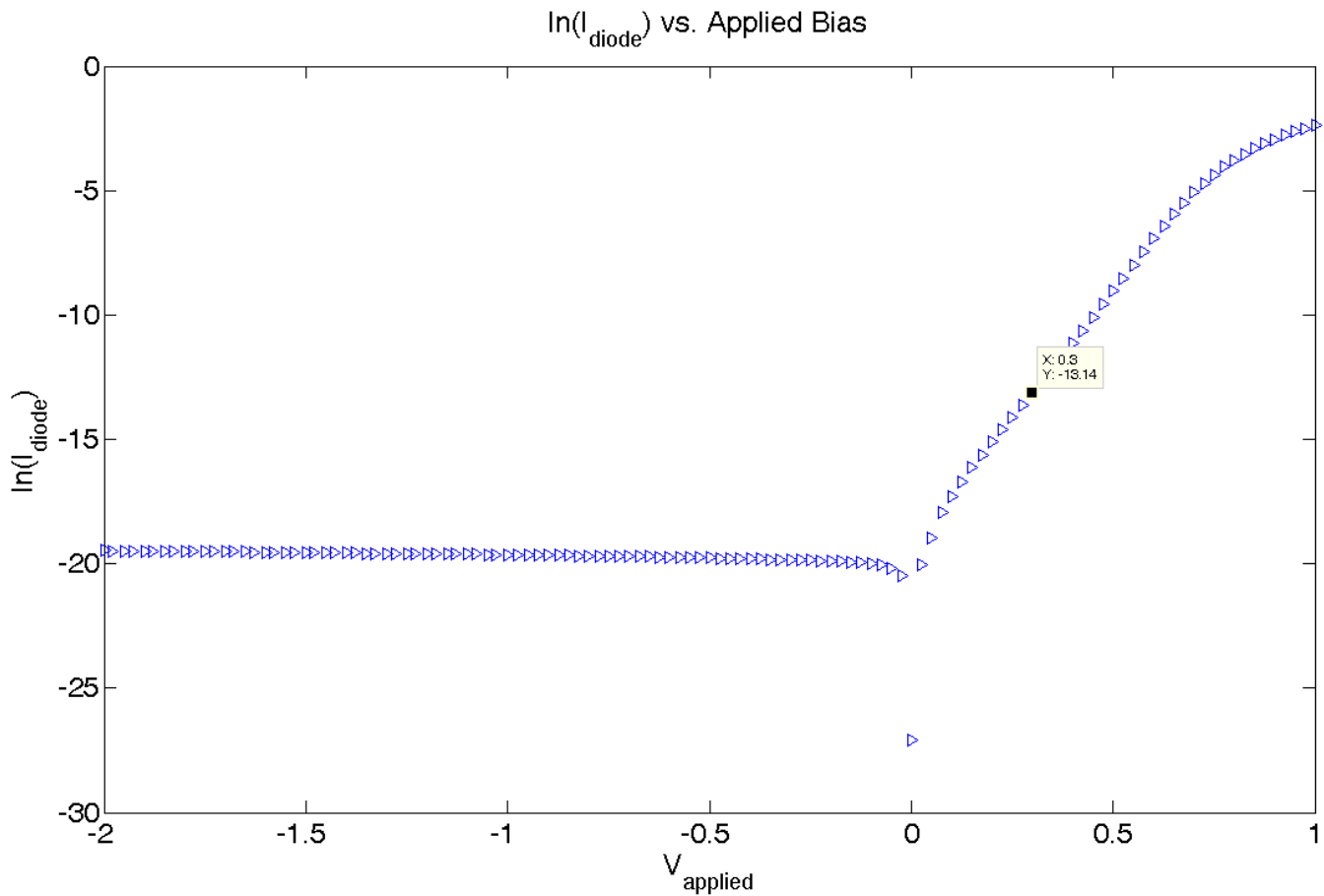
$$I = I_s \left[\exp\left(\frac{qV}{kT}\right) - 1 \right] \rightarrow \approx -I_s \quad \text{Equation 1}$$

From Graph 4, we see $I_s = 3.5 \text{ nA}$. Note that Graph 4 plots the absolute value of the current.

Real diodes exhibit significant non-idealities, so as a first order model we will be using the following equation. Note the parameter m .

$$I = I_s \left[\exp\left(\frac{qV}{mkT}\right) - 1 \right] \quad \text{Equation 2}$$

Our next task is to find m . We know that $I_s = 3.5 \text{ nA}$, and that the diode at low forward bias (before series resistance dominates) will closely match Equation 2.



Graph A: Semilog plot of the diode current versus applied bias from MATLAB with extracted data point

We can rewrite Equation 2 to find m .

$$m = \frac{V_{\text{applied}}}{\ln\left(\frac{I}{I_s}\right) \times kT} \quad \text{Equation 3}$$

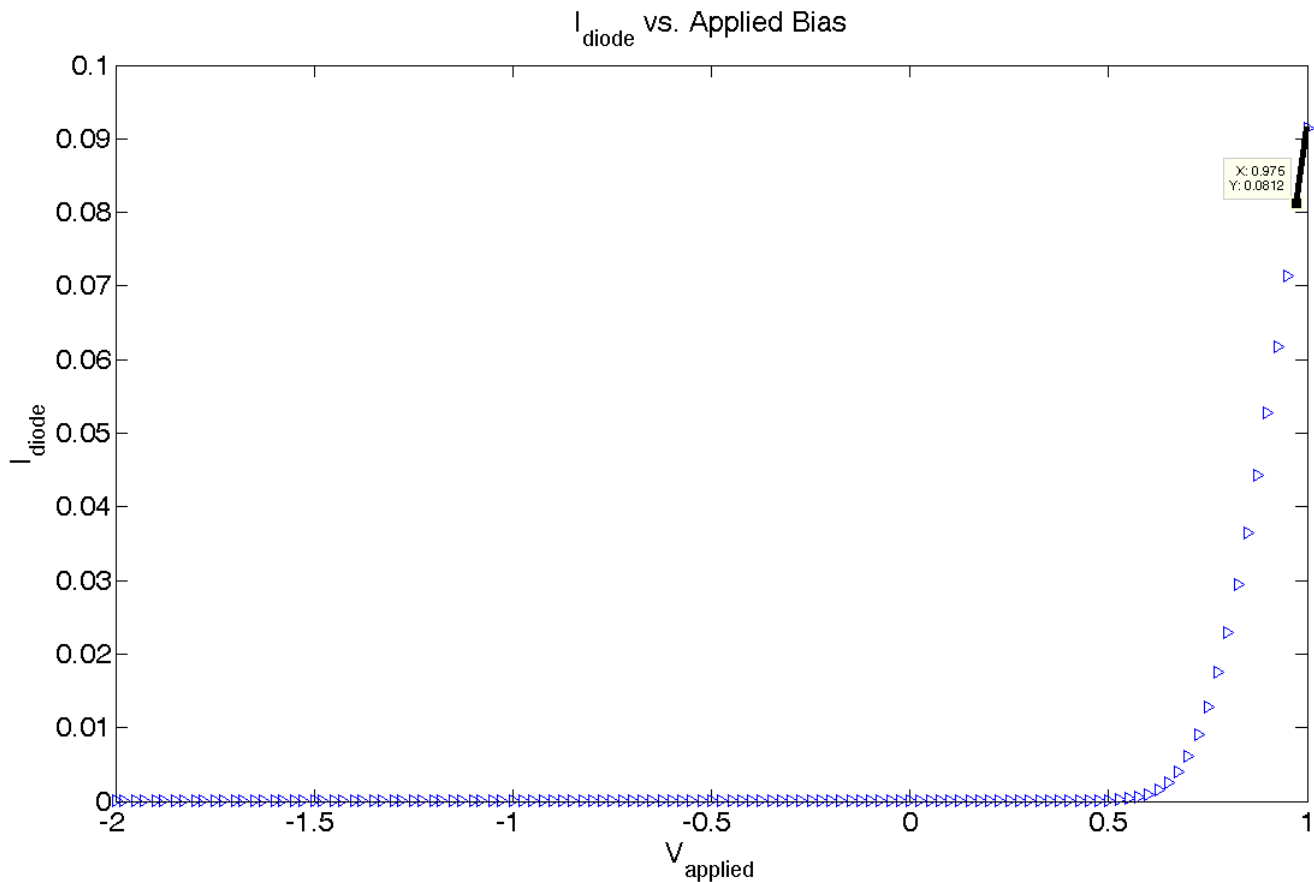
The above plot shows a data point of $V_{\text{applied}}=0.3\text{V}$, $\ln(I)=-13.14$. We also know boltzmann's constant, $k=8.617 \times 10^{-5} \text{ eV/K}$, $T=296.9\text{K}$, and $I_s=3.5\text{nA}$. Plugging these values into Equation 3, we obtain $m=1.8512$.

This first order model neglects the diode's series resistance, which we will find next to obtain a second order model. At high forward bias voltages, we can find the series resistance for the second order model equation.

$$I = I_s \left[\exp\left(\frac{q(V - IR_s)}{mkT}\right) - 1 \right]$$

Equation 4

Since the series resistance becomes dominant at high forward bias voltages, we will look at data points in that region.



Graph B: Linear plot of the diode current versus applied bias from MATLAB with extracted data point

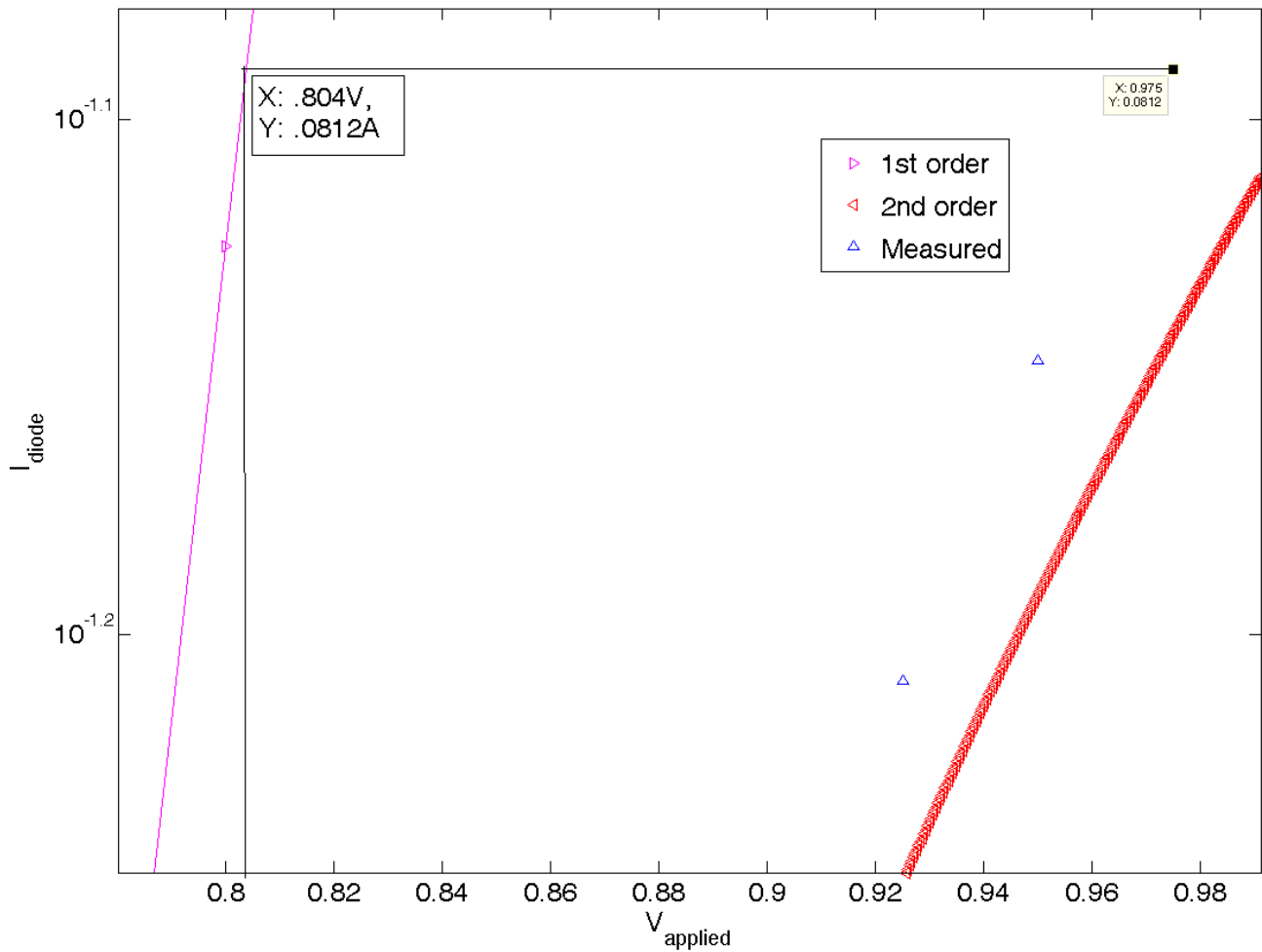
At these high bias voltages, the slope of the I-V should be equal to $1/R_s$. To find that slope, we look at voltages of .975V and 1V. These give currents of .0812A and .0914A, respectively. Solving for R_s yields **$R_s=2.45\Omega$** .

Alternatively, you could look at the difference between the first order model and the measured data. At high biases, the difference in voltage between these curves for a constant current is given by $I \cdot R_s$. That is,

$$V_{measured} - V_{1storder} = I \times R_s$$

Equation 5

Graph 6: Semilog Plot of I_{diode} vs. Applied Bias

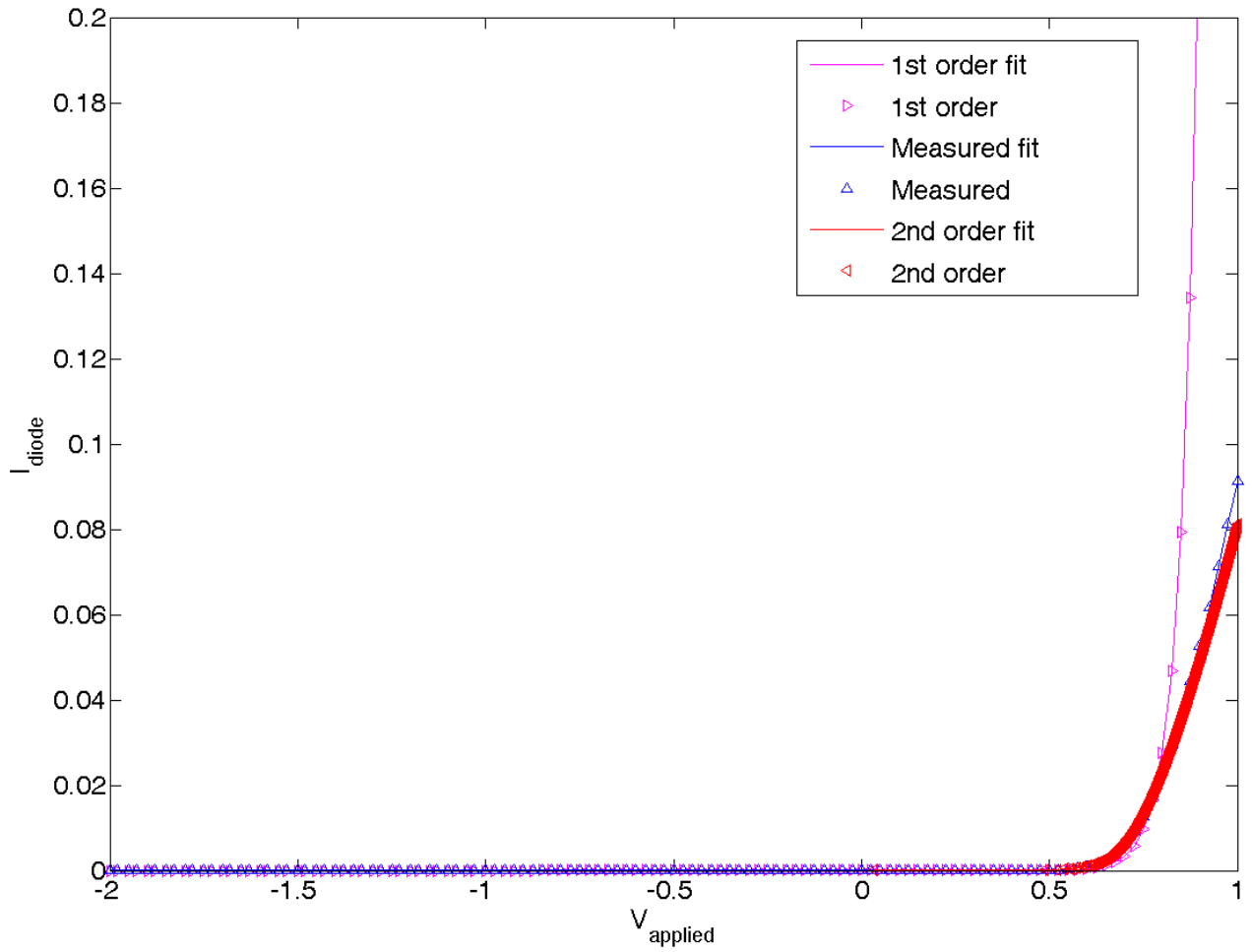


Graph C: Linear plot of measured data and diode models, illustrating alternative method to extract R_s

In this case, $\Delta V = 0.171V$, for a current of 81.2mA, giving an R_s of 2.1Ω , approximately equal to our previous calculation.

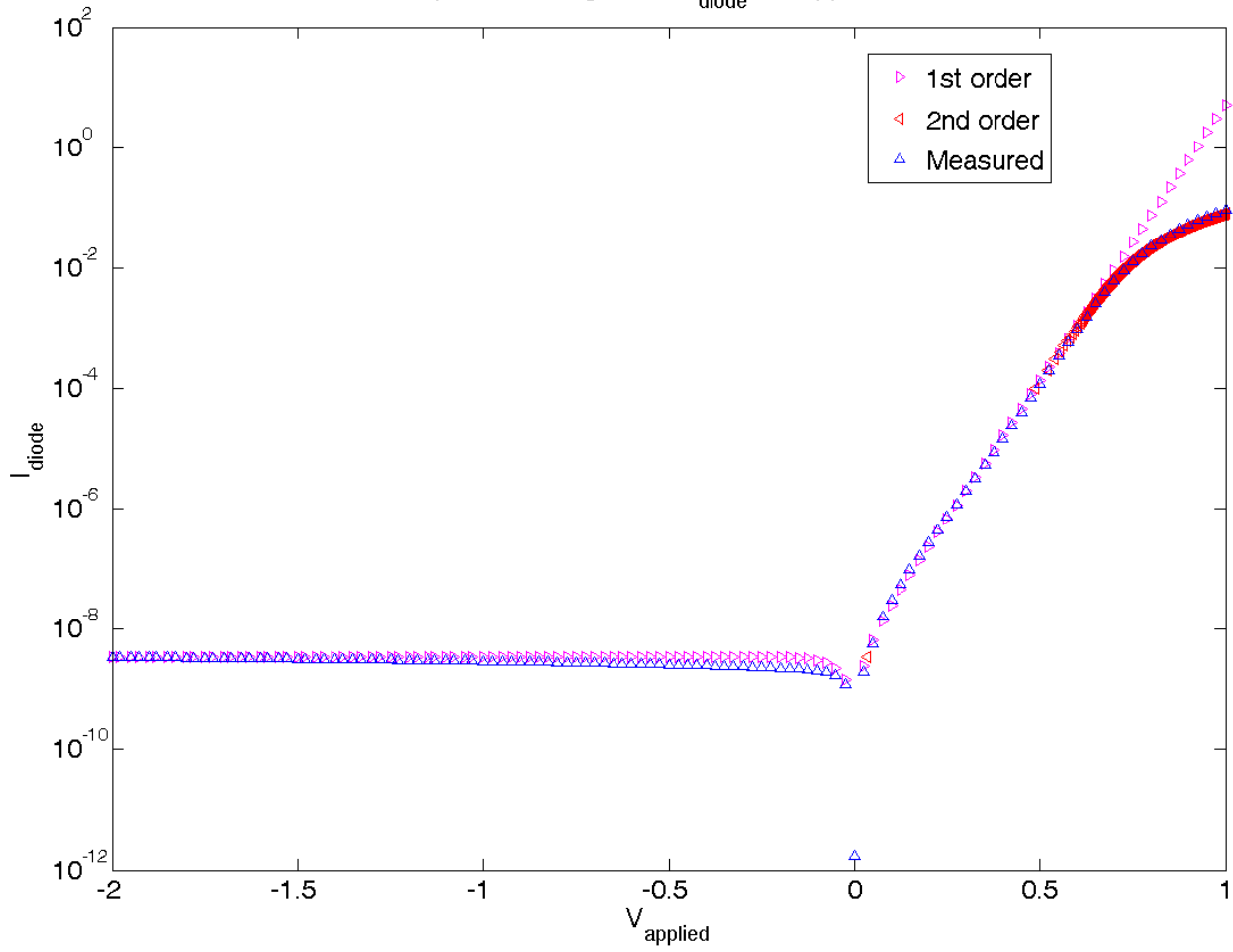
We now know all the model parameters for our first and second order models, Equation 2 & Equation 4. Plotting these models along with our measured data gives us Graph 5 & 6.

Graph 5: I_{diode} vs. Applied Bias



Graph 5: Linear plot of the diode current for measured, first order, and second order models

Graph 6: Semilog Plot of I_{diode} vs. Applied Bias



Graph 6: Semilog plot of the diode current for measured, first order, and second order models