Device Characterization Project #1

PN DIODE CHARACTERIZATION

Question 1

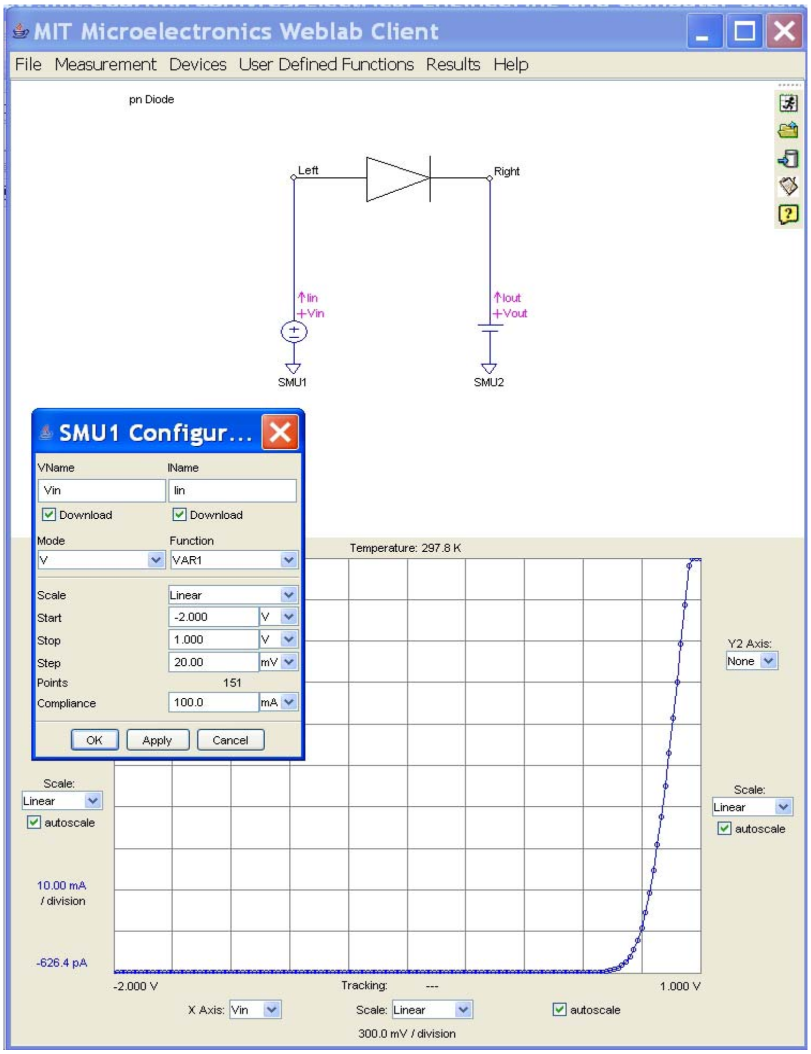

Figure 1: Screen shot of source setup for the PN Diode characterization experiment. Refer to the Weblab manual for details on how to set up source and measuring units.

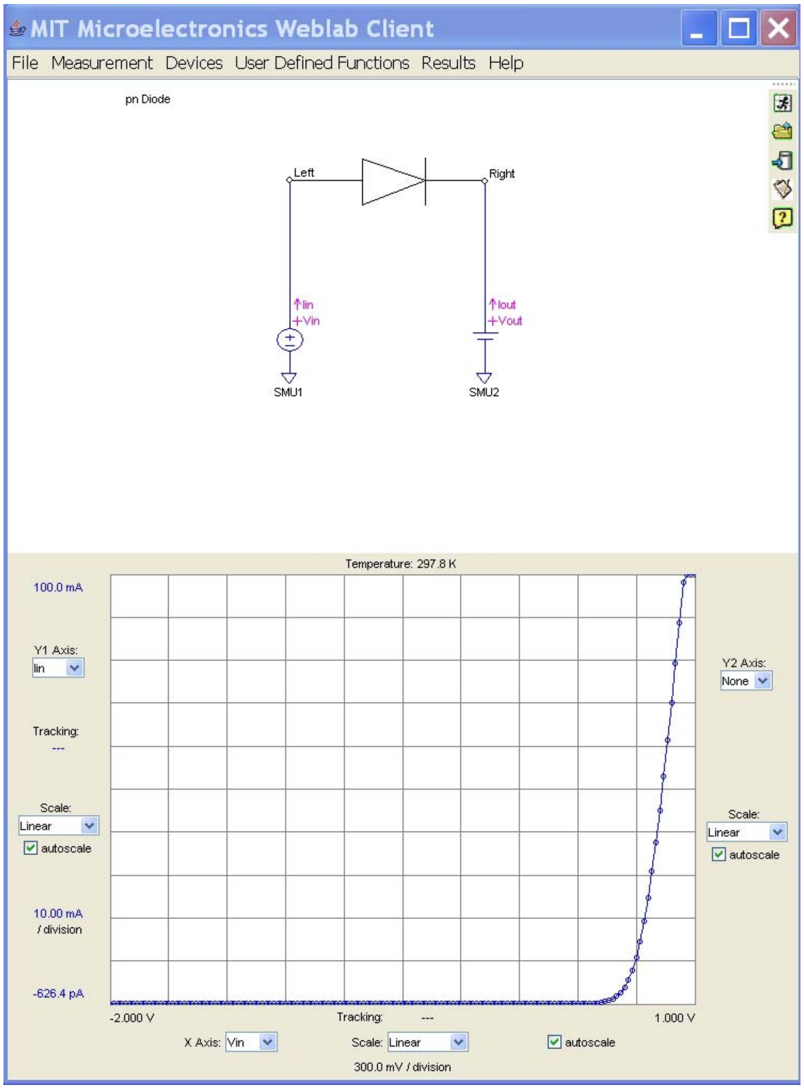

Figure 2: Screen shot of linear plot of PN Diode I-V characteristics

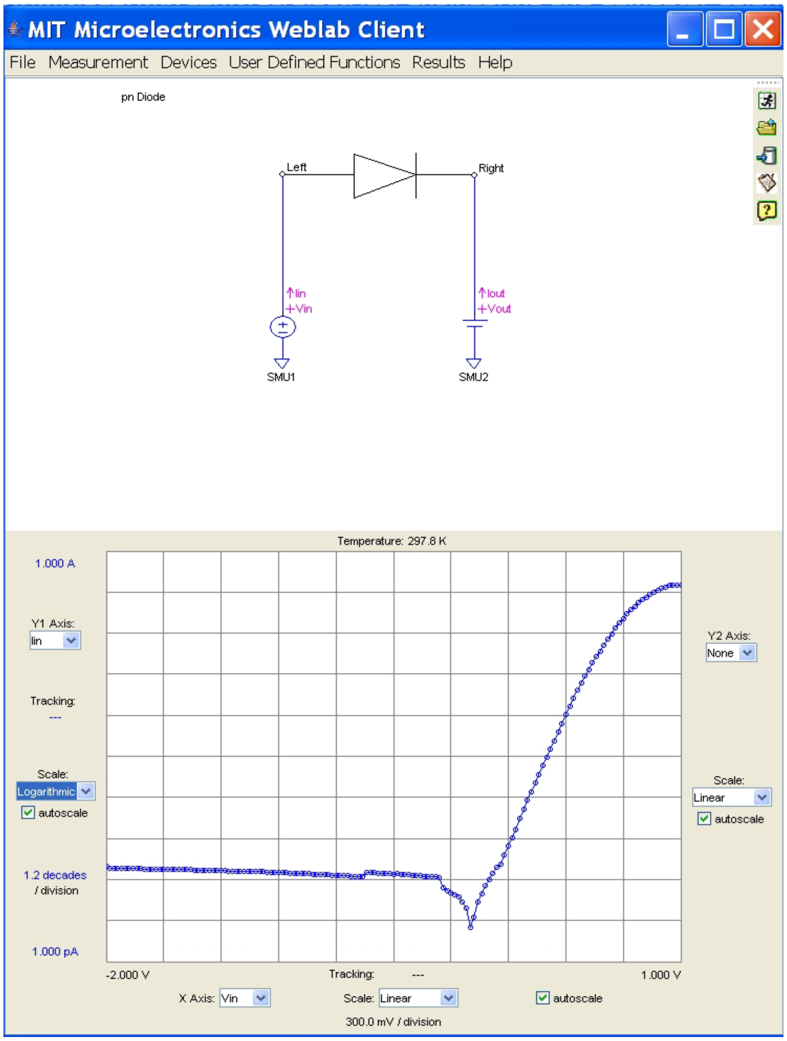

Figure 3: Screen shot of semi-logarithmic plot of PN Diode I-V characteristics

Question 2

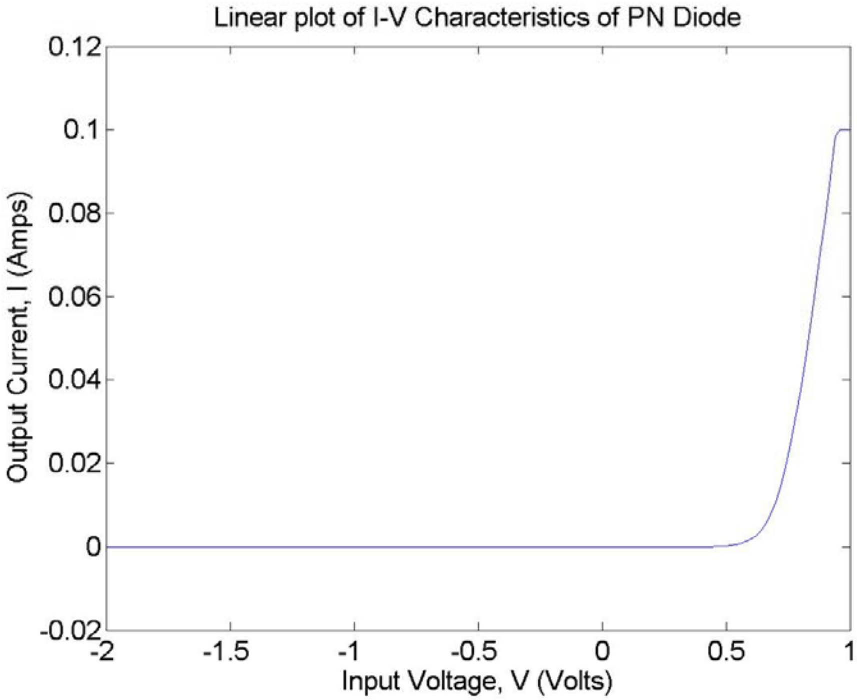

Figure 4:

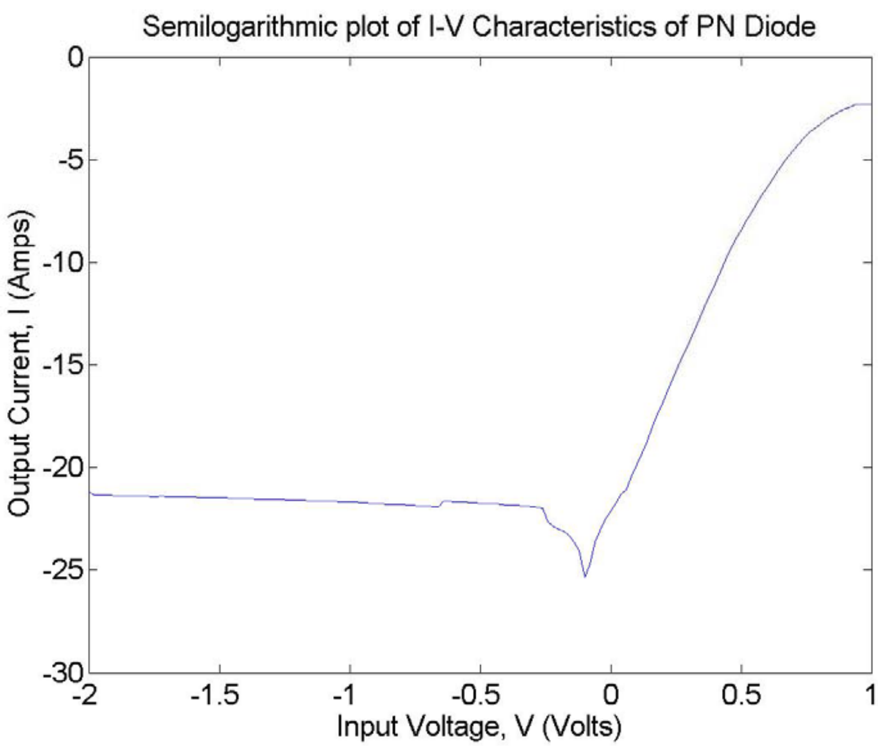

Figure 5:

Question 3

Ideal I-V characteristics of pn diode is given by:

$$\mathrm{I} = \mathrm{I_S}\left(\exp\frac{qV}{kT} - 1\right)$$

When the voltage across the diode is sufficiently above the threshold, the exponential term in the expression above is significantly greater than. Hence the unity term could be dropped from the equation. Taking the logarithm of the resultant equation, the following equation is obtained.

$$\log(\mathrm{I}) = \log(\mathrm{I_S}) + \frac{qV}{kT}$$

The saturation current, $\mathrm{I_S}$ and temperature, T, can be obtained from the slope and the y-intercept of the linear equation above. This is obtained from the semi-logarithmic plot of the pn diode I-V characteristic obtained in question 2. Specifically,

$$\text{intercept} = \log(I_S) \Rightarrow I_S = \exp(\text{intercept})$$

$$slope = \frac{q}{kT} \Rightarrow T = \frac{q}{k*(slope)}$$

The intercept and slope were obtained by employing Matlab to fit a linear polynomial to the straight line portion of the semi-logarithmic I-V characteristics. Hence,

$$I_S = \exp(\text{-}22.745) = 1.32*10^{-10}\,A$$

$$T = \frac{1.602*10^{-19}}{1.383*10^{-23}*(29.456)} = 393.4K$$

The value of temperature computed above is significantly different from the measured temperature of 297.8K. This is due to the inaccuracies introduced by the simplicity of the ideal diode model.

Question 4

The value of R_S can be computed from the slope of the linear I-V characteristics for larger values of V and I. This is the region of the I-V characteristics at which the graph appears linear.

$$R_S = \frac{1}{slope} = \frac{1}{0.41} = 2.44\Omega$$

Question 5

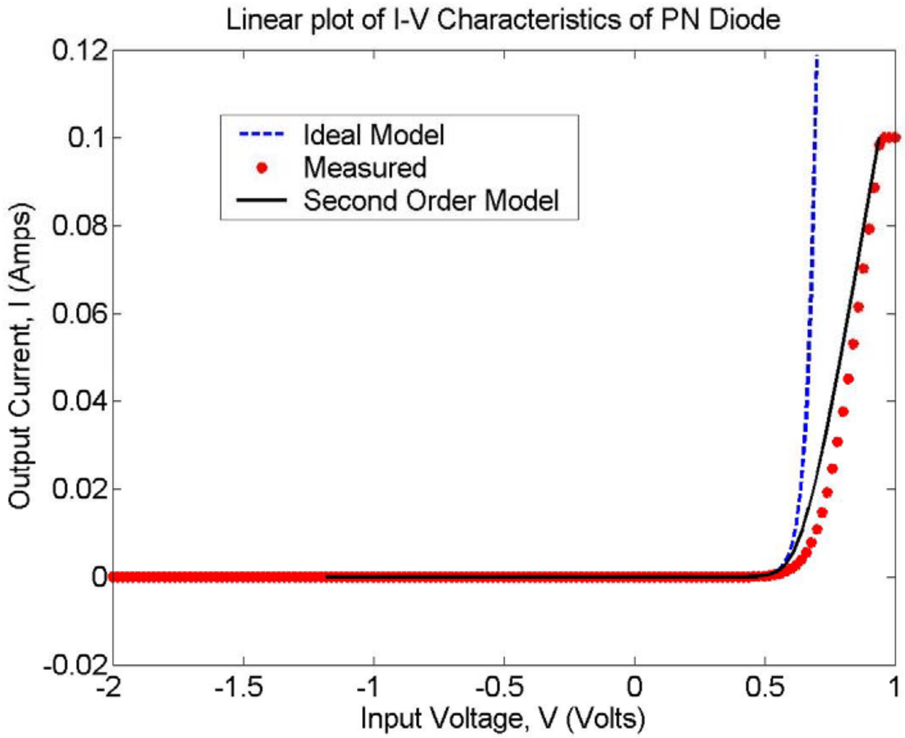

Figure 6:

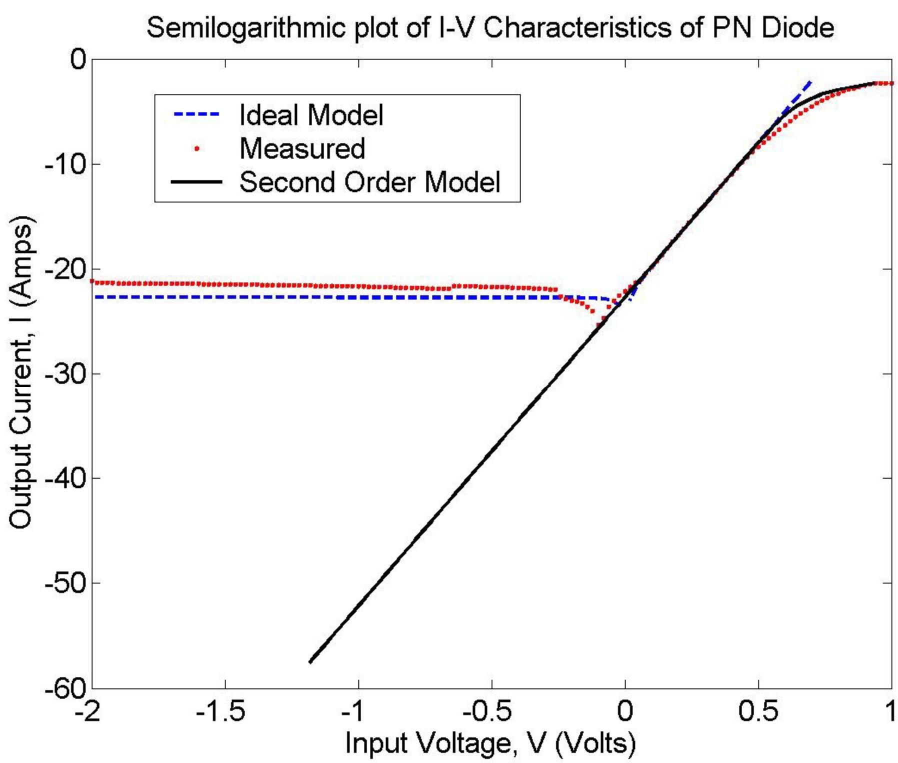

Figure 7:

The matlab script below was used to compute a vector of diode voltages for a given range of diode currents using the second order model equation. These values were then used to plot the linear and semi-logarithmic I-V characteristics.

```
% Matlab script used to compute the data points for the second order model

Rs = 2.44;
k = 1.38e-23;
q = 1.602e-19;
Is = 1.32e-10;
I = logspace(-25, -1, 150);
T = 393.4;

V = I*Rs + (k*T/q)*(log(I) - log(Is));
```

The plots above clearly show that the second order model provides a better estimate of the pn diode IV characteristics than the ideal diode for values of V greater than the threshold or turn on voltage. The ideal model is more accurate in the reverse biased regime when the diode is turned off.