EEE381 Tech Memo

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Subject: Lab #01

1 Abstract

The goal of this exercise was to observe the relationship between the voltage and current through a diode and extract the leakage current, I_s, and the diode non-ideality factor, n. In addition, a half-wave rectifier was simulated and built in order to evaluate its performance.

2 Theory

In order to find the leakage current I_s and the diode non-ideality factor n, the diode current and voltage relationship must be understood. The expression for current through a diode can be seen in Equation 1.

$$i_D = I_s(\exp(qV_D/nkT) - 1) \tag{1}$$

Assuming that $V_D >> 0$, this equation can be simplified slightly to the form seen in Equation 2.

$$i_D = I_s \exp(qV_D/nkT) \tag{2}$$

When the natural log of i_D is plotted against V_D, the slope of the resulting line is a function of n (Equation 3).

$$\ln(i_D) = \ln(I_s) + (\frac{q}{nkT})V_D \tag{3}$$

Assuming room tempurature, the value of n can be found by looking at the slope of the line of Equation 3.

The value of I_s can be found by looking at the current when the y-intercept, which is equal to the natural log of I_s. This value is usually very small (in the nano/pico Amp range).

A PSpice circuit was created to model this behavior and can be seen in Figure 1.

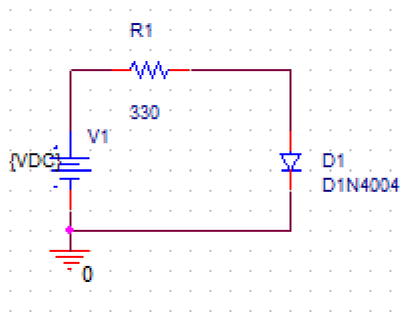


Figure 1: Basic diode circuit used for I_s and n parameter extraction

A DC Sweep simulation was run to find the $i_D - V_D$ relationship and then extract the I_s and n values. The graph of the $i_D - V_D$ curve can be seen in Figure 2.

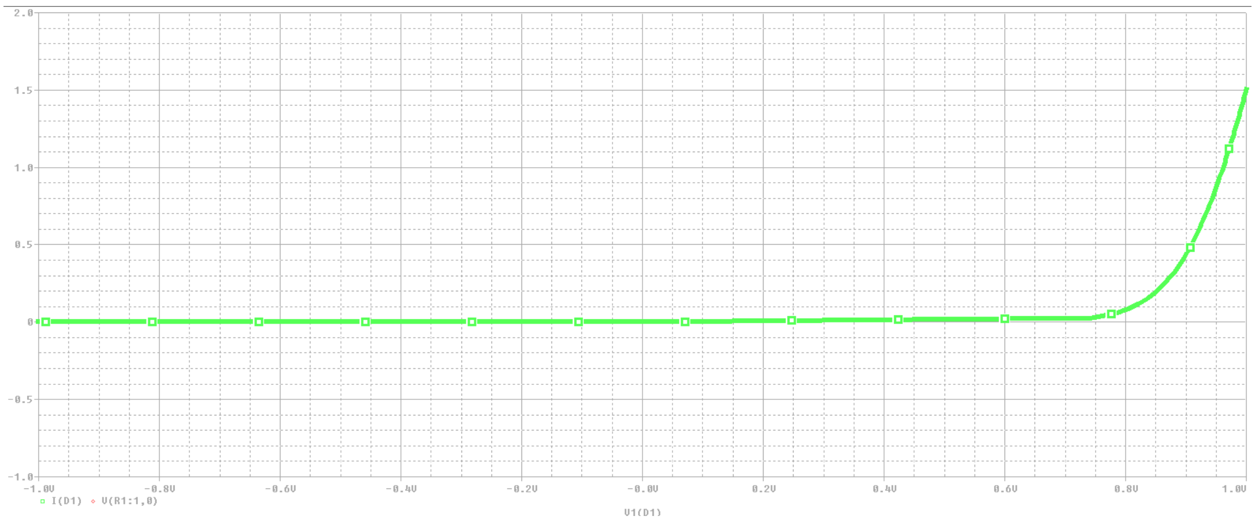


Figure 2: i_D vs. V_D graph

Using this graph, the I_s parameter can be extracted. For the 1N4004 diode, the I_s value was found to be roughly 500 pA. For the extraction of the n parameter, i_d needs to be graphed on a logarithmic scale, then the slope of the resulting line gives the n value. The value that was found during simulation based of the graph in Figure 2 was $n = 1.4815$.

The second circuit that was simulated was the half-wave rectifier circuit that is shown in Figure 3.

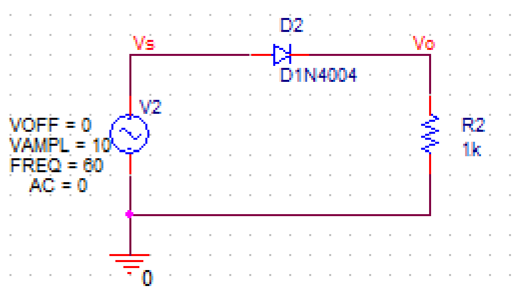
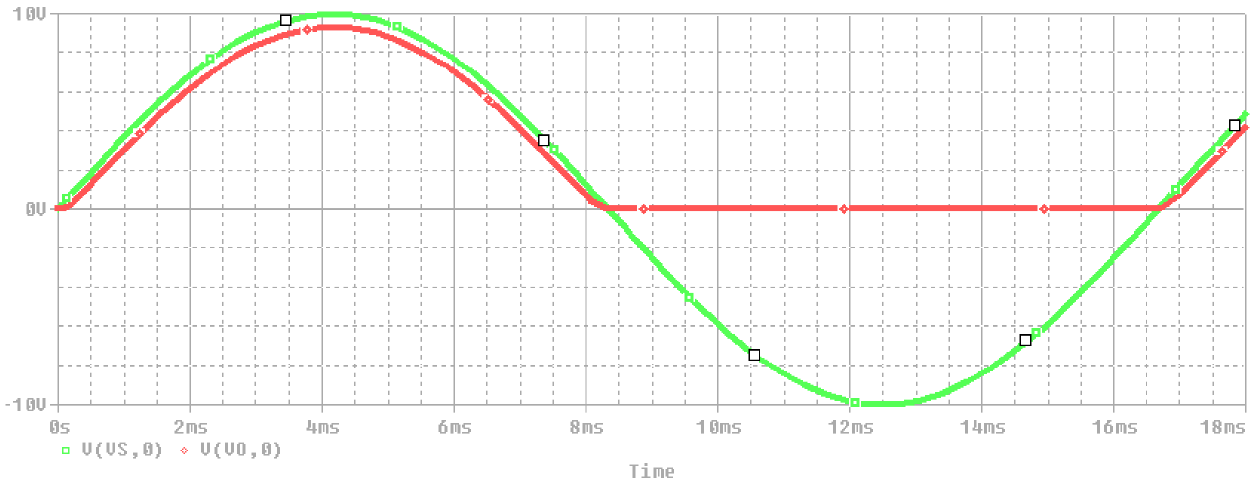


Figure 3: Half-wave rectifier circuit with 1kΩ load

The purpose of this circuit is to change the sinusoidal (AC) source to something closer to a DC source. The diode blocks current flowing backwards, causing the voltage across the resistor to never go negative and have a positive average value. In this case, the AC source has a peak voltage of 10 V and a frequency of 60 Hz. If the diode in Figure 3 were ideal, then the voltage across the resistor would follow the positive voltages from the source exactly and be zero when the source voltage went negative. Because it is a non-ideal diode, the voltage across the resistor does not follow the source voltage exactly. It can be modeled ,using the constant voltage drop model, as a voltage source and a resistor in series. The value of the voltage source is always assumed to be

0.7 V and the value of the resistor can be derived by looking at the voltage across the resistor vs. the voltage from the source. This graph can be seen in Figure 4.



Measurement Results

Evaluate	Measurement	Value
☑	Max(V(VS,0))-Max(V(VO,0))	687.91438m
☑	((XatNthY(V(VS,0),0.7,2))-(XatNthY(...	955.38667m

Figure 4: Half-wave rectifier input vs. output

Another value that is important to look at when using rectifiers is the conductance ratio, or the amount of time that diode is conducting, relative to the period of the signal that is being rectified. Ideally, this value would be exactly half the period as the diode would conduct exactly when the source voltage goes positive. However, there is a short period of time where the diode is not conducting, despite the input voltage being positive. This is due to the fact that the voltage across the diod has to be roughly 0.7 Vbefore the diode starts conducting. In Figure 4 the conduction ratio was found to be 0.47769.

The final circuit that was simulated was another half-wave rectifier, but with a 10 µF capacitor in parallel with the load resistor. This causes an RC discharge circuit to form when the source voltage falls below zero and the diode stops conducting. This means that as long as the RC time constant is big enough so that the capacitor does not discharge fully, the output signal looks much more like a DC signal. This can be seen in Figure 5.

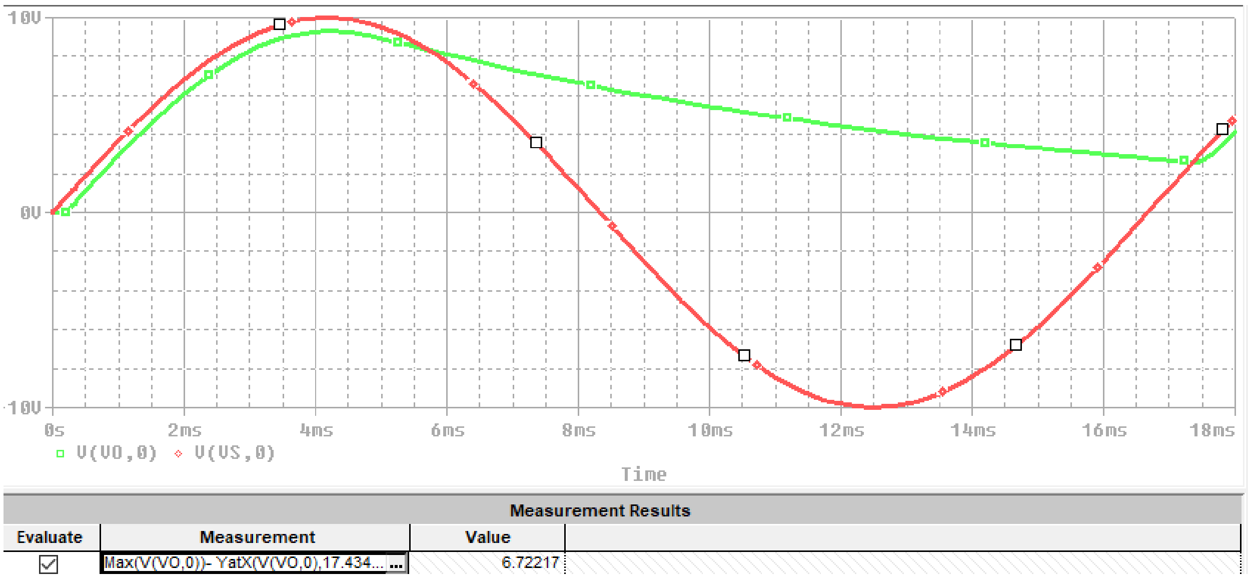


Figure 5: Half-wave rectifier input vs. output with parallel capacitor

The differnce between the peak output voltage and the voltage that the RC circuit drops to is called the ripple voltage (V_r). The smaller this value is, the closer the output signal is to an actual DC value. In this case, the ripple voltage that was found in simulation was 6.72217 V.

3 Results and Discussion

The first circuit that was tested experimental was the circuit in Figure 1. It was tested by using a DC power supply and applying various voltages from 1 Vto 10 Vand measuring the voltage drop across the resistor and the current draw that the power supply experienced. This data can be seen in Table 1 and in Figure 6.

Table 1: I_D vs V_D data

V_s(V)	V_D(V)	I_D(A)
1	0.6032	0.001
2	0.6560	0.003
3	0.6787	0.006
4	0.6934	0.009
5	0.7040	0.012
6	0.7121	0.016
7	0.7176	0.019
8	0.7225	0.022
9	0.7275	0.025
10	0.7305	0.028

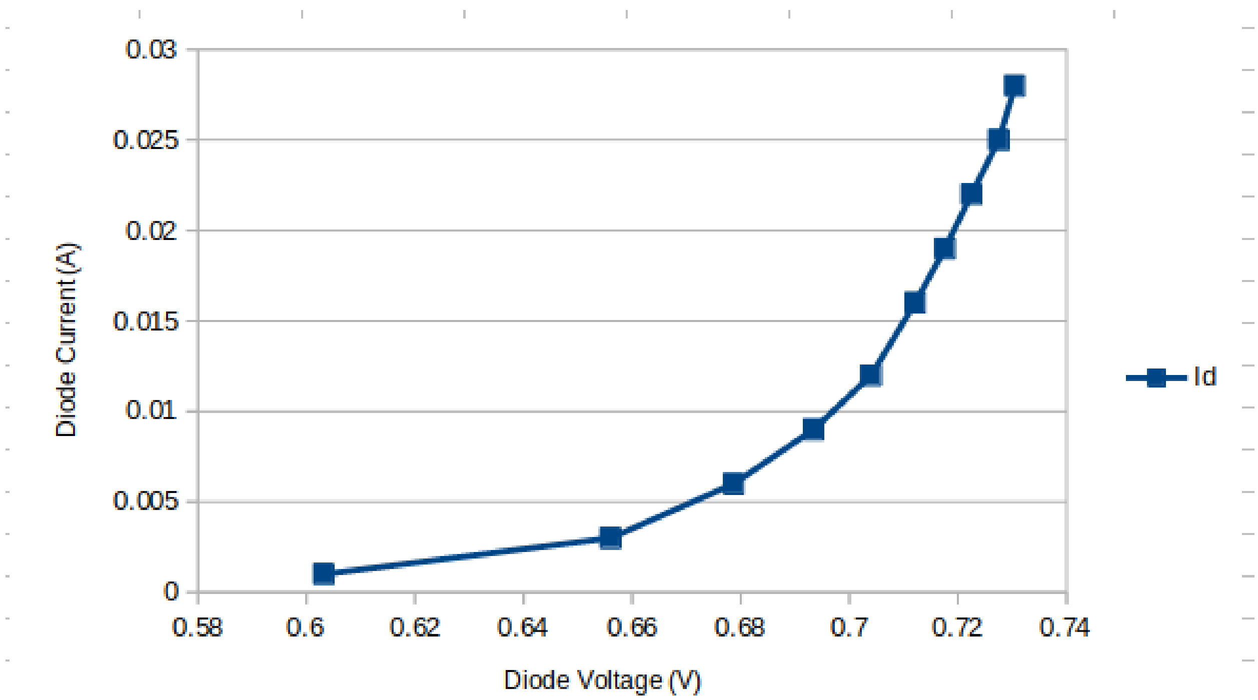


Figure 6: Graph of I_D vs V_D Experimental

The extracted n value that was obtained from this data was 26.176. The extracted value for I_s was -23.1906 A. These values were extremley far off from the values found during simulation. This could have been due to the fact that the measurements were incorrectly taken, the circuit was improperly set up, or the way the values were calculated was incorrect.

The next circuit that was built in lab was the half-wave recitifier from Figure 3. The circuit was powered using a waveform generator generating a 10V peak-peak sinusoidal signal with a frequency of 60Hz. (Note: this is the improper setup as the signal should have been a 10V amplitude as it was in simulation, not peak-peak). The circuit was monitored using an oscilloscope and the output can be seen in Figure 7.

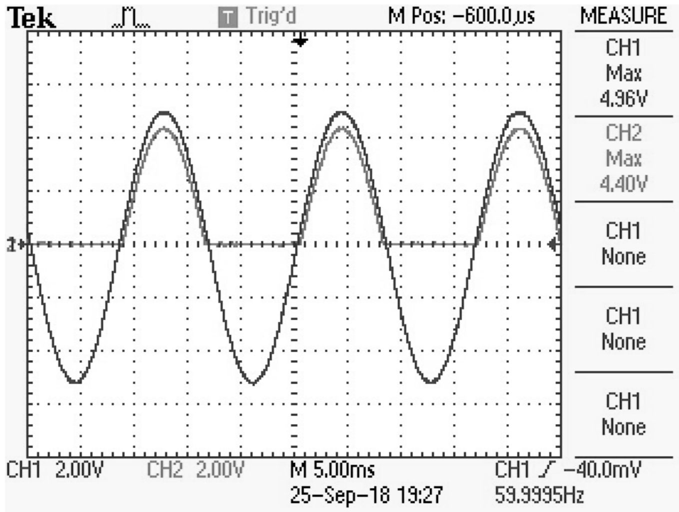


Figure 7: Oscilloscope capture of half-wave rectifier in Figure 3

Using the data captured by the oscilloscope, the experimental conduction ratio was found to be 0.4692. This value is relativley close with the value for conduction ratio during simulation, despite the fact that the voltage source was improperly configured. This, however, makes sense due to the fact that the 5Vpeak is still much greater than the threshold voltage of 0.7V. This means that the diode is still conducting for roughly the same amount of time during the period. The difference between these two values can be attributed to the slight difference in the amount of time it took for the simulated voltage across the diode to raise above 0.7V and the slightly longer amount of time that the experimental voltage across the diode to raise above 0.7V as the sinusoid with a larger peak voltage will cross 0.7V faster than a sinusoid with a lower peak voltage.

The final circuit that was tested experimentally was the half-wave rectifier circuit with the 10µF capacitor in parallel with the load resistor. As established in section 2, this should produce an output signal much closer to a DC signal due to the RC circuit that forms. This circuit was powered with the same 10V peak-peak, 60Hz signal that the previous circuit was powered with. (Note: this is still incorrect as the simulation used at 10V amplitude signal, not peak-peak). The oscilloscope capture can be seen in Figure 8.

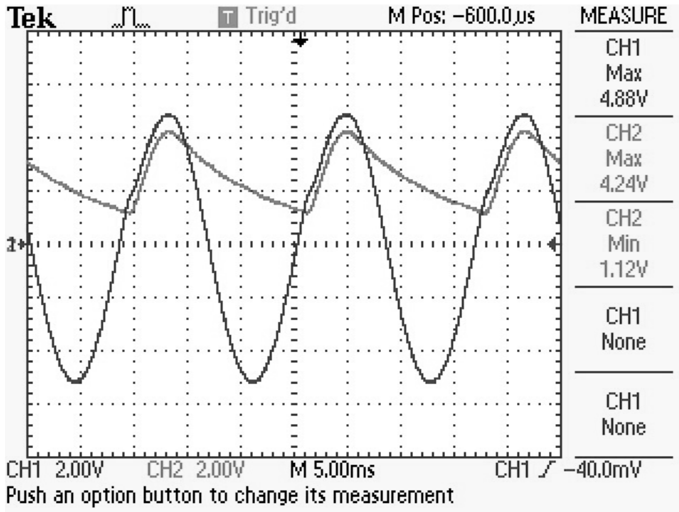


Figure 8: Half-wave rectifier with 10µF capacitor

The experimentally found ripple voltage was 3.12V. While this is not close to the ripple voltage found during simulation, it can be attributed to the fact that the voltage source was improperly configured to be a 10V peak-peak signal. This means that the voltage across the resistor and capacitor only rose to slightyly under 5V, rather than the 10V that it did in simulation, resulting in a significantly lower ripple voltage.

4 Conclusion

The goal for this exercise was to observe and extract properties of non-ideal diodes and to use diodes in a practical application. The leakage current and non-ideality factors were extracted from the diode $I_D - V_D$ curve and the diodes were used in two different half-wave rectifier circuits to convert an AC source into a more DC-like signal.

Most experimental values matched the simulated values, other than the leakage current and diode non-ideality factor. The others either matched almost exactly, or differences could be attributed to the fact that the voltage sources for the two half-wave rectifier circuits were improperly configured.