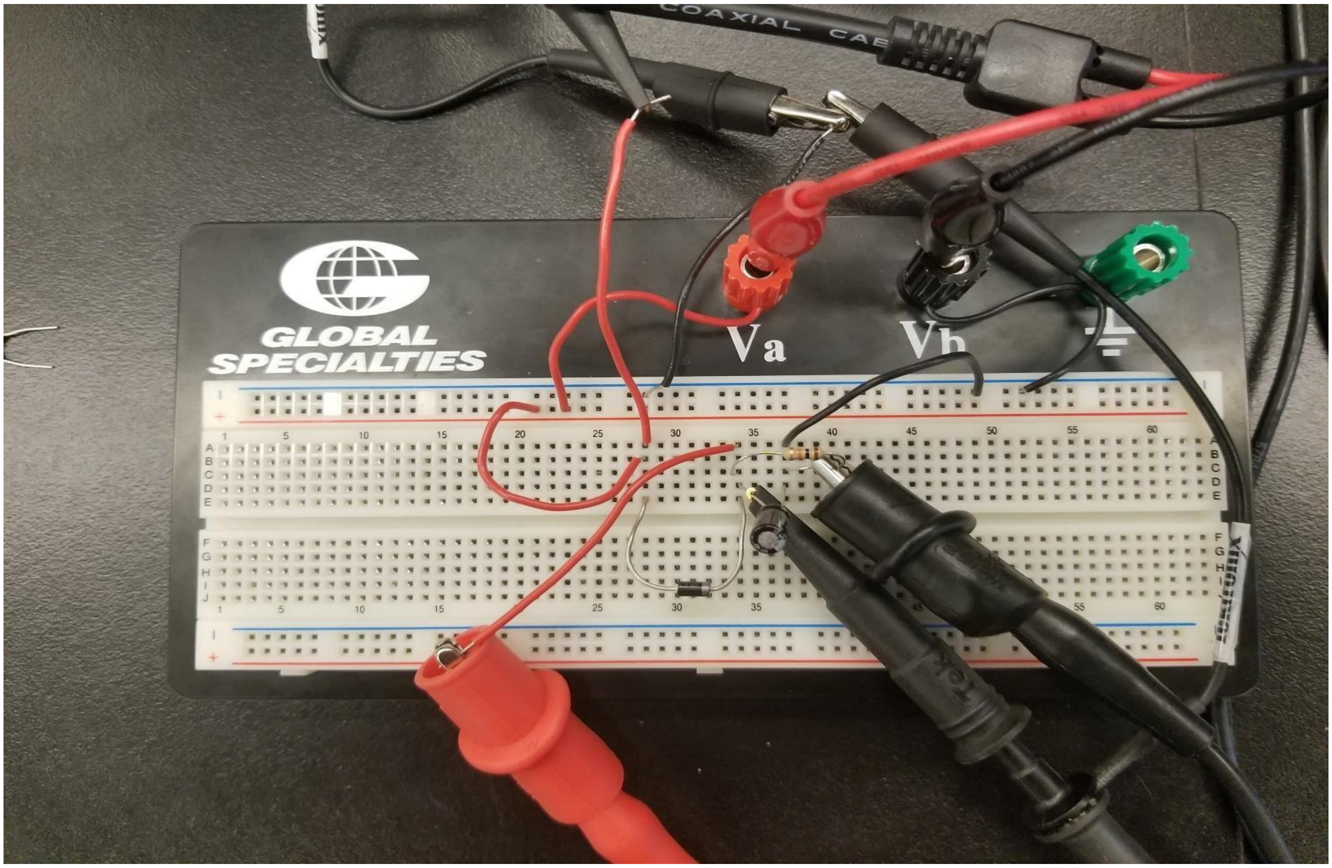
# Lab 1 Report

Dr.Gregori ENGG *3450 – Electrical Devices

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Special Thanks to the Teacher assistants in this course that helped us complete this experiment successfully during the lab. We would like to thank them for their patience and the time they invest into sharing their knowledge in Electronic Devices with the students at the University Of Guelph.

# Experiment 1- Diode Characteristics Analysis (R = 1008 Ohms):

| | |
|---|---|
| Rf = ΔV/ΔI | Rr = ΔV/ΔI |
| = (0.6797 - 0.192)/(9.348998 - 0.123246) | = (10.04 - 0.577)/(0.067134 - 0.17034) |
| = 0.0529 V/A | = 188.9 V/A |

In the forward-biased region, voltage over the 1N4004 diode exponentially increased as current began to flow through the circuit. Between 0.12325 and 0.5488 V, current increased by 140% thereby determining the turn-on voltage to exist in that region. Current remained close to zero in the reverse-biased region, even as the negative voltage magnitude increased to 10.04 V. This validates the exceedingly large value representing the rate of voltage change with respect to current, in the reverse-biased region (see calculation above). It makes sense that Rr is significantly greater than Rf, since voltage across the reverse-biased region is resistant to change despite the increasing magnitude of current, whereas voltage in the forward-biased region was observed to be sensitive to a small change in current.

| | | |
|---|---|---|
| Rf = ΔV/ΔI | Rr = ΔV/ΔI | Rz = ΔV/ΔI |
| = (0.8027 - 0.5432)/(9.30591 - 0.2113 | = (3.933 - 0.601)/(0.0014 + 0.17234) | = (5.078 - 3.933)/(2.92084 - 0.17234) |
| = 0.0285 V/A | = 19.17 V/A | = 0.4166 V/A |

In the forward-biased region, voltage over the 1N4733 zener diode showed for the same response as the 1N4004 diode, exponentially increasing as current began to flow through the circuit. Compared to the 1N4004 diode, the zener diode required a slightly higher voltage to initiate current flow. Between 0.5432 and 0.7011 V, current increased by 170% however, even before that current increased from 0.0014 to 0.2113 mA over the region containing zero volts. From the graph, it can be determined that the Turn-on voltage exists in the lower end of the range, between 0.5 and 0.7 V. For the zener diode, the reverse-biased region was found between voltage values from zero to approximately -4 V. As seen by the 1N4004 diode, again Rf is significantly greater than Rr for the same reason. For the zener diode however, rate of change calculations determined current to be slightly more responsive to a change in voltage for both the forward and reverse-biased regions. The Rr value calculated for the zener diode was significantly lesser than the 1N4004 diode due to their difference in behaviour in the negative voltage region. Where current over the 1N4004 diode neared zero in the reverse-biased region, current over the zener diode continued to build up as voltage magnitude increased into the breakdown region. Conversely from the 1N4004 diode, the zener diode permitted the build up of a negative current for some voltage existing in the region between -2.054 and -3.933 V. Negative voltages with a magnitude greater than 5 volts comprised the breakdown region for the specific diode used in this experiment, thereby determining the constant zener voltage to be approximately -5 V. The rate of change in voltage with respect to current was determined to be slightly greater than the response observed in the forward-biased region, meaning that while current continued to build up in the breakdown region, it showed for a slower response to voltage change.

greater than 5 volts comprised the breakdown region for the specific diode used in this experiment, thereby determining the constant zener voltage to be approximately -5 V. The rate of change in voltage with respect to current was determined to be slightly greater than the response observed in the forward-biased region, meaning that while current continued to build up in the breakdown region, it showed for a slower response to voltage change. For the photovoltaic cell, it supplies power when current and voltage is positive only. In this experiment, a V(d) of 0.029 was needed to supply the circuit with a current value of 1.06mA. The maximum power that can be delivered is 25.3 mW according to the results of the current and the volts at peak (4.981volts and 5.074mA).

| 1N4004 Diode | | | 1N4733 Diode | | | Photocell Face Up | | | Photocell Face Down | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V(D) | V(S) | I(mA) | V(D) | V(S) | I(mA) | V(D) | V(S) | I(mA) | V(D) | V(S) | I(mA) |
| 10.01 | 0.6797 | 9.3490 | 10.09 | 0.8027 | 9.3059 | 10.11 | 4.981 | 5.074 | 10.11 | 4.995 | 5.088 |
| 8.09 | 0.6694 | 7.4355 | 8.041 | 0.7959 | 7.2596 | 8.112 | 4.702 | 3.352 | 8.066 | 4.733 | 3.337 |
| 6.094 | 0.6546 | 5.4503 | 6.088 | 0.7872 | 5.3114 | 6.081 | 4.227 | 1.794 | 6.076 | 4.273 | 1.834 |
| 4.09 | 0.633 | 3.4639 | 4.103 | 0.7743 | 3.3354 | 4.002 | 3.35 | 0.556 | 4.091 | 3.442 | 0.735 |
| 2.05 | 0.5904 | 1.4625 | 2.037 | 0.7472 | 1.2924 | 2.084 | 1.892 | 0.048 | 2.101 | 2.036 | 0.207 |
| 1.475 | 0.5811 | 0.8957 | 1.532 | 0.7212 | 0.7843 | 1.532 | 1.47 | -0.073 | 1.544 | 1.606 | 0.073 |
| 1.11 | 0.4623 | 0.5488 | 1.012 | 0.7011 | 0.5685 | 1.004 | 1.035 | -0.140 | 1.064 | 1.145 | 0.029 |
| 0.575 | 0.192 | 0.1232 | 0.721 | 0.5432 | 0.2113 | 0.5873 | 0.5517 | -0.129 | 0.5104 | 0.717 | -0.041 |
| -0.51 | -0.577 | 0.0671 | -0.701 | -0.601 | 0.0014 | -0.587 | -0.502 | -0.199 | -0.511 | -0.386 | -0.009 |
| -1.11 | -1.122 | 0.0632 | -1.512 | -1.053 | 0.0075 | -1.051 | -1.028 | -0.207 | -1.033 | -0.842 | -0.005 |
| -1.491 | -1.495 | 0.0588 | -2.039 | -1.534 | 0.0103 | -1.503 | -1.533 | -0.164 | -1.555 | -1.338 | -0.022 |
| -2.001 | -2.052 | 0.0511 | -4.105 | -2.054 | 0.0150 | -2.055 | -2.029 | -0.163 | -2.048 | -1.891 | -0.019 |
| -4.054 | -4.092 | 0.0381 | -6.09 | -3.933 | -0.172 | -4.107 | -4.076 | -0.275 | -4.078 | -3.830 | -0.002 |
| -6.075 | -6.096 | 0.0210 | -7.976 | -4.789 | -1.304 | -6.025 | -6.037 | -0.164 | -6.048 | -5.860 | -0.011 |
| -8.081 | -8.092 | 0.0110 | -7.993 | -4.997 | -2.985 | -8.088 | -7.934 | -0.249 | -8.026 | -7.837 | -0.091 |

*Table 1: 1N4004 diode data* *Table 2: 1N4733 diode data* *Table 3: Photocell Face Up* *Table 4: Photocell Face down*

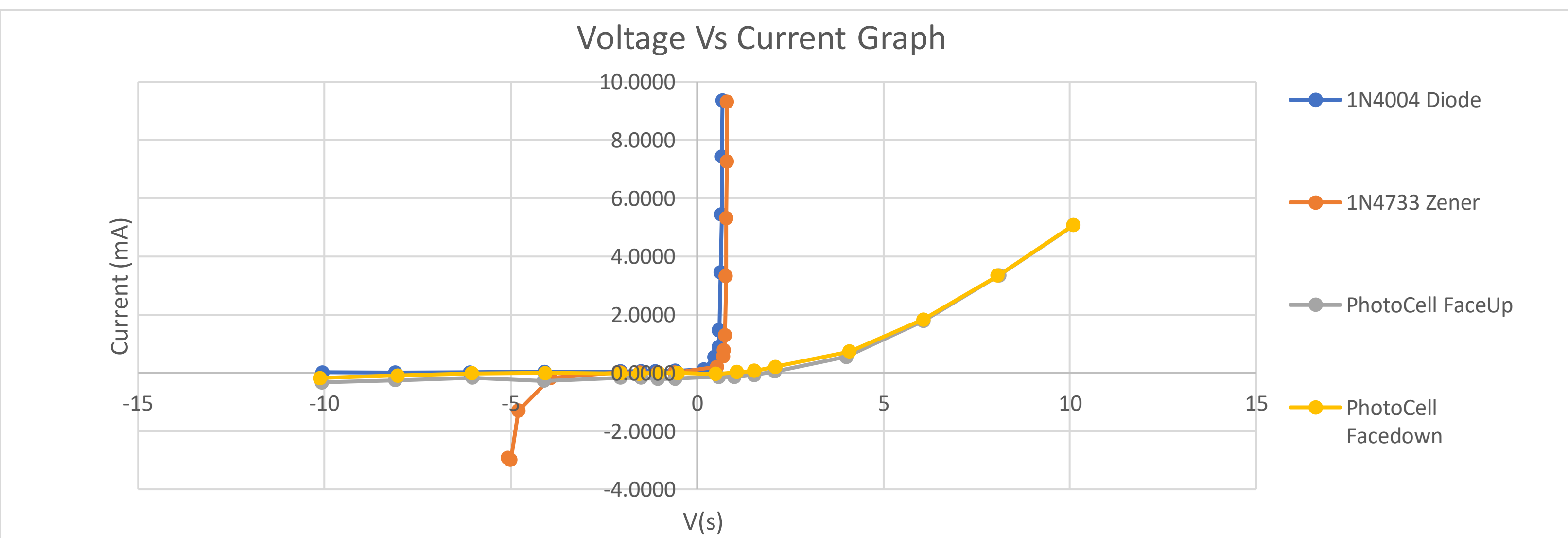


*Figure 1- Diode I-V characteristics*

## Experiment 2- Light-Emitting Diodes (R = 1008 Ohms):

| Green LED Status | Red LED Status | Possible | Range of Values of Vo | Range of Values Of I | Light Intensity Variation Description |
|---|---|---|---|---|---|
| On | Off | Yes | 1.8 V - 2.03 V | 7.159 mA -8.143 mA | As +V is supplied to the circuit the green led changes from a faint glow to a stronger/brighter glow as Volts increase. |
| Off | On | Yes | -1.629 V -1.832 V | -0.368 mA -8.10 mA | As -V is supplied to the circuit the red led changes from a faint glow to a stronger glow as volts increase. |
| Off | Off | Yes | -1.629 1.8 | -0.368 mA 0.198 mA | N/A |
| On | On | No | N/A | N/A | N/A |

*Table 5: LED results table*

The green LED light was on for all negative voltage values greater than or equal to 2 V in magnitude. Current at the cut-in voltage was calculated to be approximately -0.26 mA and reached nearly -12 mA by -10 V. Light intensity was initially very low but gradually increased with voltage magnitude. At -2 V the LED light was barely noticeable, increasing magnitude by 2 V (output -4 V) gave a dim light, increasing again (output -6 V) gave a bright light and increasing to an output voltage of -8 V the light shone full-force. No difference in light intensity was observed between -8 and -10 V, thus determining the LEDs full capacity to have been reached by -8 V.

The red LED light was on for all positive voltage values greater than or equal to 2 V. Current at the cut-in voltage was calculated to be approximately 0.45 mA and reached 8.2 mA by 10 V. Light intensity for the red LED varied the same as was observed with the green LED light. The same light readings were made for the positive equivalent voltages however, calculated values for current show that the current build-up provided was slightly larger for the red LED compared to the green LED (0.45 mA vs 0.26 mA in magnitude). This difference suggests that cut-in voltage could have been more accurately determined if observations were recorded between voltage magnitudes of 1.5 to 2 V.

Both LEDs appeared to be off for voltages less than 2 V in magnitude. Calculations for the equivalent current values were approximately less than 0.26 mA in magnitude. The voltage range observed was large relative to the diodes used in the previous experiment, where cut-in voltage was observed to be approximately 0.5 V. This was to be expected since LEDs typically show for a larger cut-in voltage in comparison to most semiconductor diodes.

Both LEDs were never on simultaneously for the same voltage output. This observation agrees with the theoretical behaviour of LEDs, which only generate light when there is sufficient forward current. In this experiment, the green and red LEDs were positioned in parallel, which meant that the current over them was equal and opposite in polarity. Having opposing polarity, when one LED experienced a forward current, the other would experience the same current in the reverse direction. Even if the voltage magnitude exceeded the cut-in value, the reverse-polarity would not permit light generation.

# Experiment 3- Half-Wave Rectifier (R = 9770 Ohms):

## 1 µF capacitor Input Signal

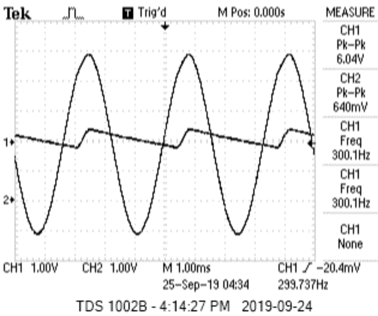


*Figure 2: 1 µF capacitor at 200 Hz.*

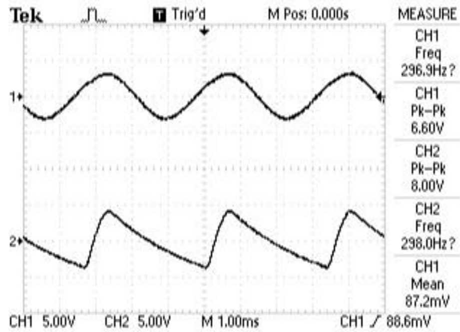


*Figure 3: 1 µF capacitor at 300 Hz*

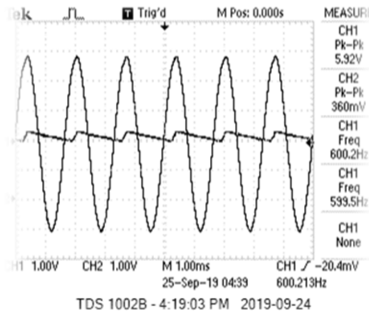


*Figure 4: 1 µF capacitor at 600 Hz*

## 22 µF capacitor Input Signal

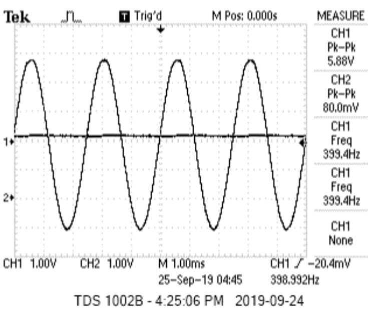


*Figure 5: 22 µF capacitor at 400 Hz*

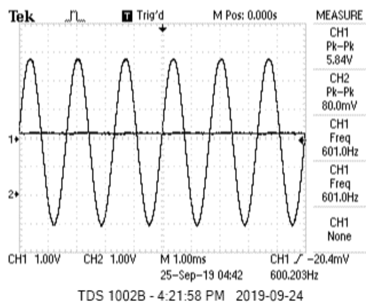


*Figure 6: 22 µF capacitor at 600 Hz*

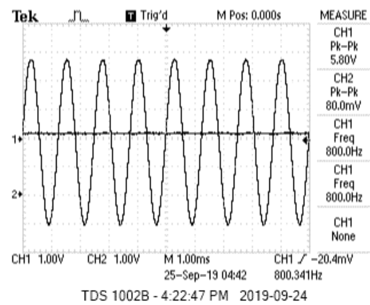


*Figure 7:* 22 µF capacitor at 800 Hz

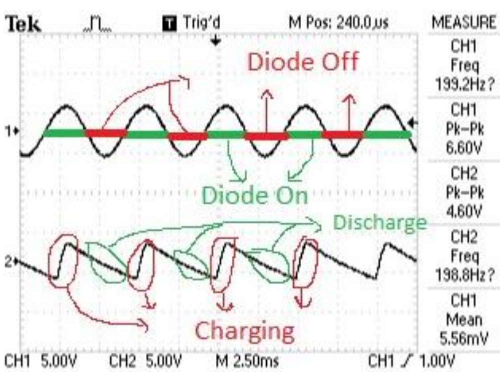


*Figure 8: Showing where the diode is on and off and where the capacitor is charging and discharging.*

| Capacitor | Frequency | Channel 1 | Channel 2 |
|---|---|---|---|
| 1 µF Capacitor | 300 Hz | 6.04 V | 0.640 V |
| | 600 Hz | 5.32 V | 0.600 V |
| 22 µF Capacitor | 300 Hz | 5.88 V | 0.081 mV |
| | 500 Hz | 5.84 V | 0.060 mV |
| | 700 Hz | 5.00 V | 0.80 mV |

*Table 6: Half-wave rectifier results*

## Interpretation of the Results:

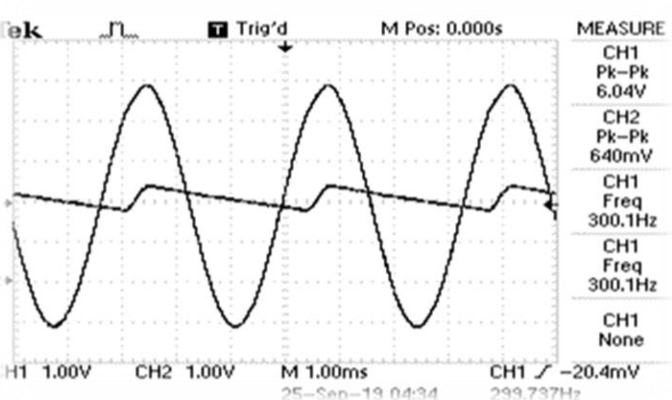


*Figure 9: 1 µF capacitor at 300 Hz*

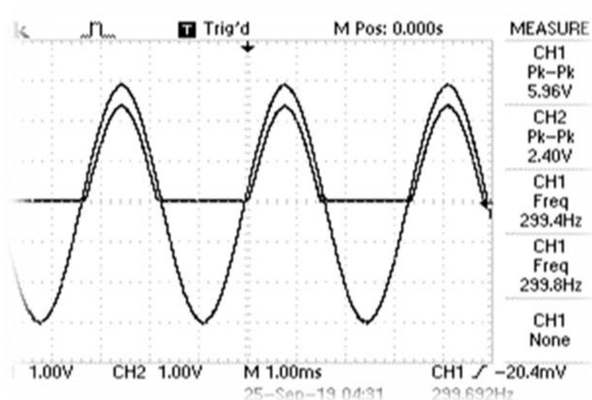


figure 10: Diode Effect on graph

For a constant capacitance of 1 $\mu$F, the output peak-to-peak voltage and average voltage decreased as the frequency of the input signal was increased. Peak-to-peak voltage was 800 mV for a frequency of 200 Hz, 640 mV for 300 Hz and 360 mV for 600 Hz, each case having an input peak-to-peak signal of approximately 6 V. For the circuit having a capacitance of 22 $\mu$F, peak-to-peak voltage remained constant at 80 mV for frequencies 400, 600 and 800 Hz, each case having an input peak-to-peak signal of approximately 5.8-5.9 V. The circuit response differed between these cases can be explained by the significant difference between capacitors, the 22 $\mu$F being a sufficiently large enough capacitance for voltage over the element to near zero (given v = q/C). If the experiment had been repeated with a third capacitor, between 1 and 22 $\mu$F, it would be expected to observe a decrease in the output peak-to-peak voltage and average voltage with increased frequency of the input signal, but to a lesser degree than observed by the 1 $\mu$F capacitor.

As capacitance increased, the output voltage signal significantly decreased. For a frequency of 600 Hz and input voltage between 5.84 and 6 V, the observed output voltage was 360mV and 80 mV for capacitors 1 and 22 $\mu$F, respectively. This trend is the result of reduced voltage over the capacitor, as capacitance increased (given v = q/C). Instead, current flows parallel to the capacitor, through the resistor, providing a dramatically greater voltage drop in the case of the 22 $\mu$F compared to the case of the 1 $\mu$F.

While both circuits using the 1N4004 diode in Experiment 1 and 3 were both characterized by a resistor in series with a diode, the sequence used in Experiment 1 had the resistor preceding the diode, while the sequence used in Experiment 3 had the diode preceding the resistor. Because the resistor and diode were connected in series, they experienced the same current in both cases and therefore the same voltage-drop over the individual elements, regardless of order. Thus, the relationship between the supply voltage and peak voltage drop over the resistor can be explored using observations from Experiment 1 without having to consider the effect of sequential difference. For $v_I > v_D$, such that $v_D$ is the voltage drop over the diode, current is in the forward-biased direction, meaning the diode is on and voltage over the resistor can be calculated by $v_O = (v_I - v_D)$. Based on this equation and the observations made in Experiment 1, the difference between peak voltage for $v_I$ and $v_O$ is equivalent to the voltage drop over the diode. As the input voltage signal increases, voltage drop over the diode remains relatively close to the cut-in voltage, which acts as the first valid input voltage signal in the forward-biased region. This means that the difference in peak voltage for $v_I$ and $v_O$ is initially close to zero and increases as $v_I$ increases at a significantly greater rate than $v_O$ for the range of voltages in the forward-biased region.