EE 331 Lab Experiment 1

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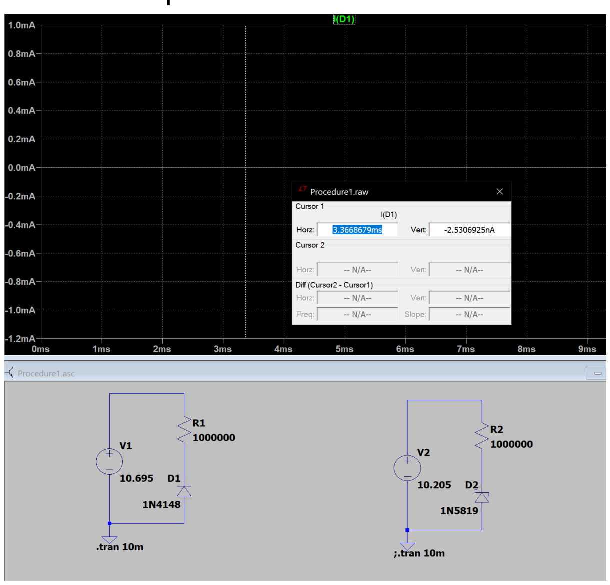
1.Introduction

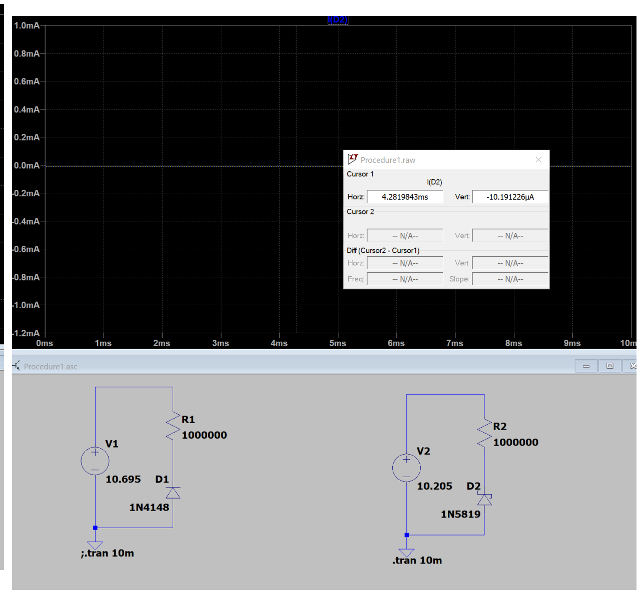
This document is a report on the fundamental characteristics of various diode circuits. The information is provided in the following format. In section 2, six procedures are explained in detail and the resulting data is presented. Procedure 1 simulates the reverse leakage current of two different diodes. Procedure 2 simulates the change of current across the diode. Procedure 3 simulates the IV characteristics of two different diodes. Procedure 4 simulates the IV characteristics of Diode 1N4732. Procedure 5 simulates the characteristics of LED. Procedure 6 simulates the characteristics of a photoconductive cell. In section 3, results are analyzed and questions regarding the procedures are addressed. Finally, in section 4 overall results are discussed and conclusions are made.

2. Data

Procedure 1

The screenshots below show circuits that test the reverse leakage current of diode 1N4148 and 1N5819 with 10V input and 1.0 Million Ohm resistors in series. Since the circuit is static, the transient simulation is run and the current of both diodes are plotted. We observe that the diode 1N4148 has a reverse leakage current of 2.5nA while the diode 1N5819 has a reverse leakage current of 10μA.

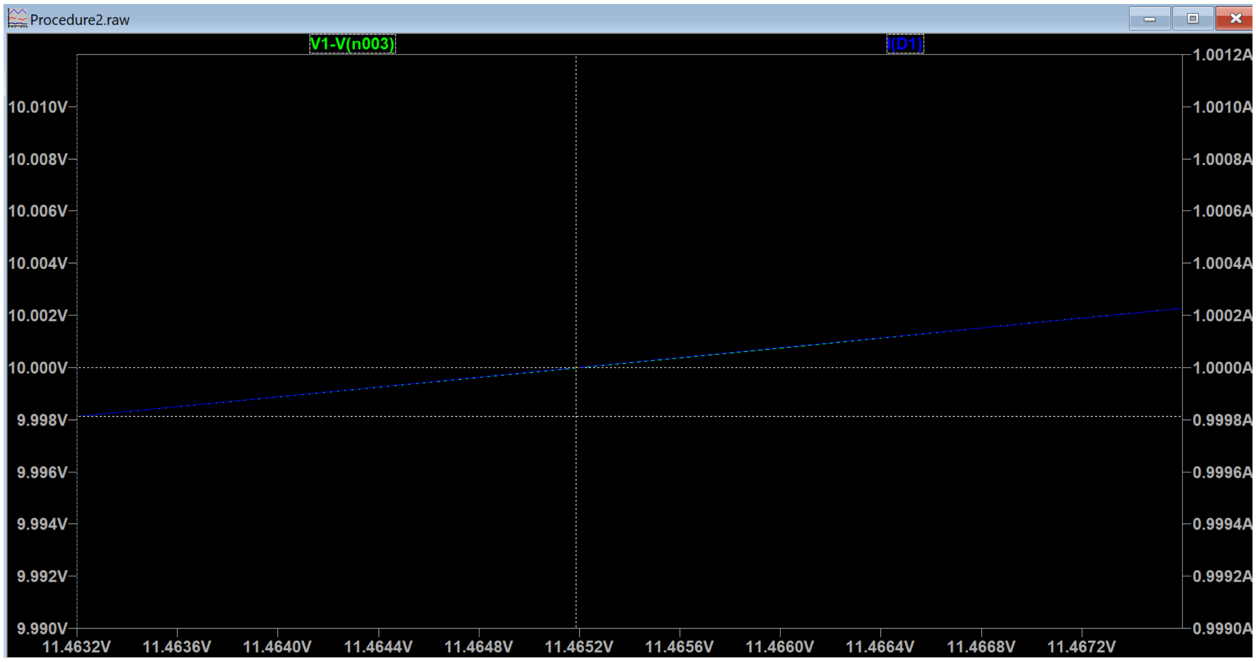




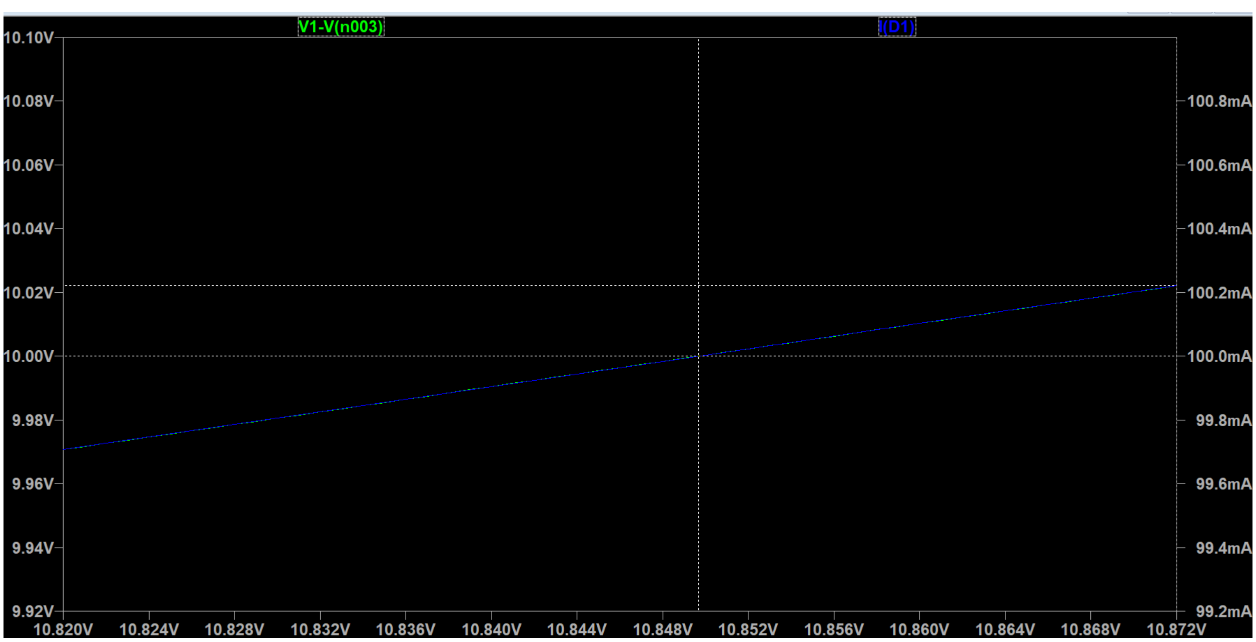
Procedure 2

In procedure 2, diodes are now forward biased and both diodes circuits will perform DC sweep with three resistors 10 Ohm, 100 Ohm, and 1K Ohm to find that I-V pair of the diode while the voltage drop of the resistor is 10V. Note that the x axis in the plot is the voltage of the power source therefore needs to be subtracted by 10V to be the actual diode voltage.

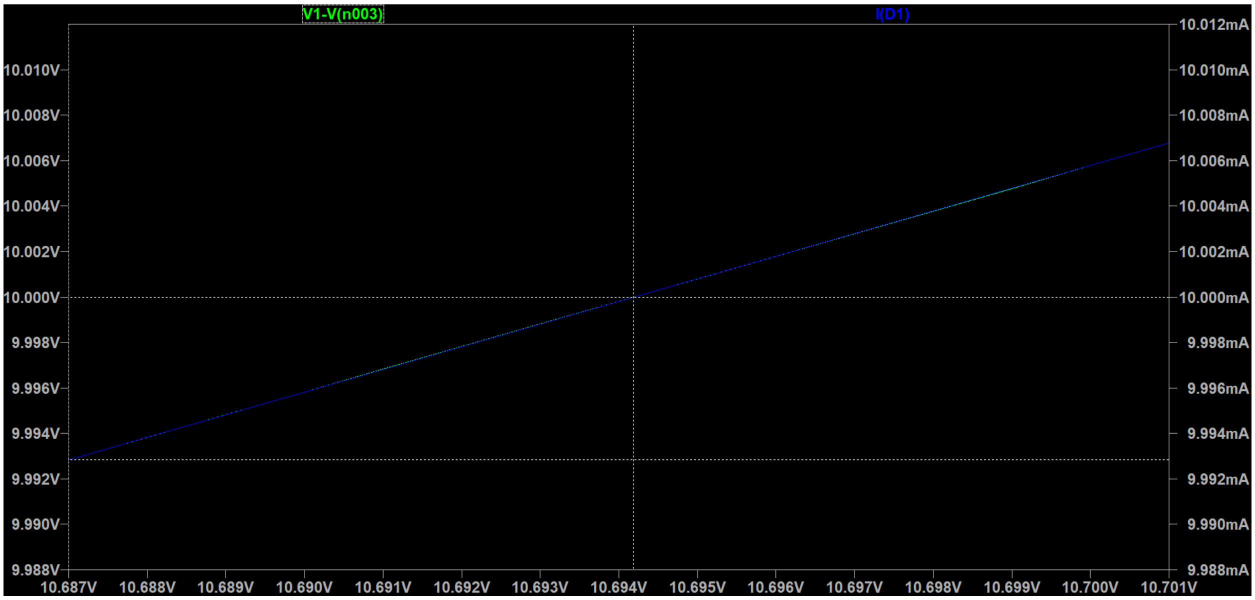
The following three plots belong to diode 1N4148:



R = 10 Ohm, $(I_D, V_D) = 1.000A,\ 1.465V$

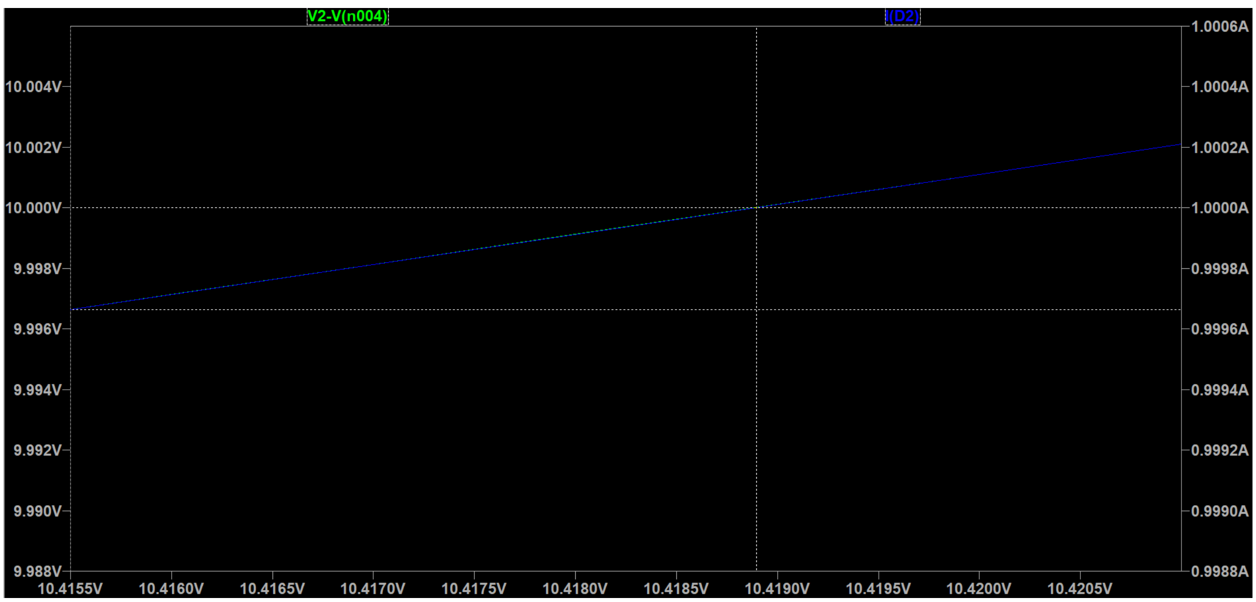


R = 100 Ohm, $(I_D, V_D) = 0.1000A,\ 0.850V$

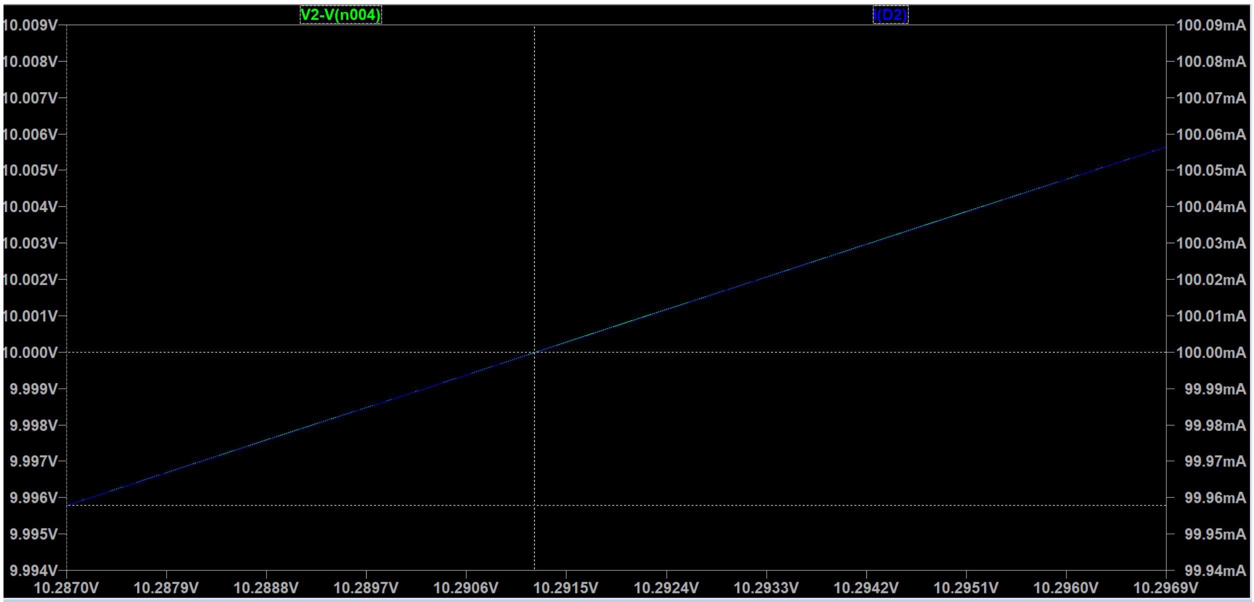


R = 1000 Ohm, $(I_D, V_D) = 0.0100A, 0.694V$

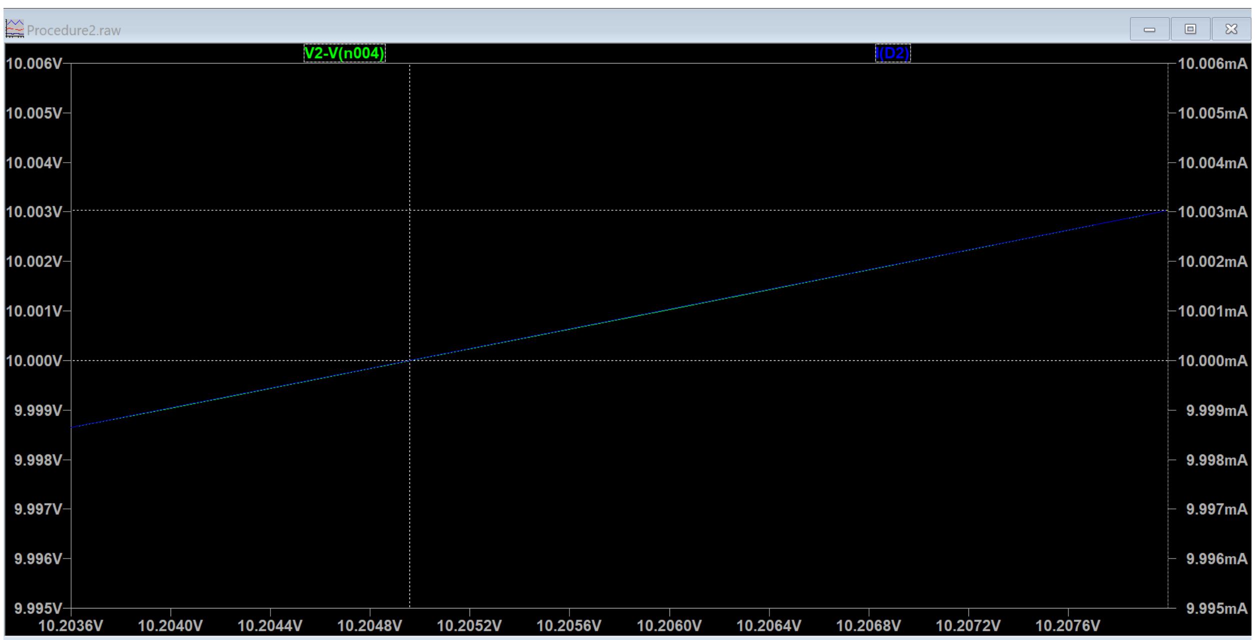
The following 3 plots belong to diode 1N5819:



R = 10 Ohm, $(I_D, V_D) = 1.000A, 0.419V$



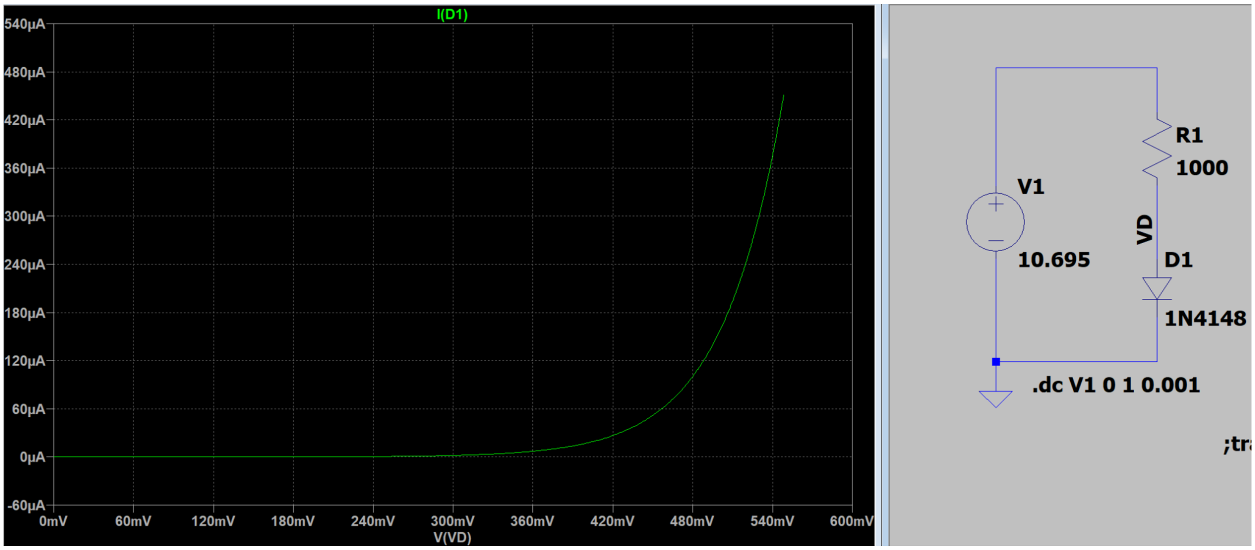
R = 100 Ohm, $(I_D, V_D) = 0.1000A, 0.291V$

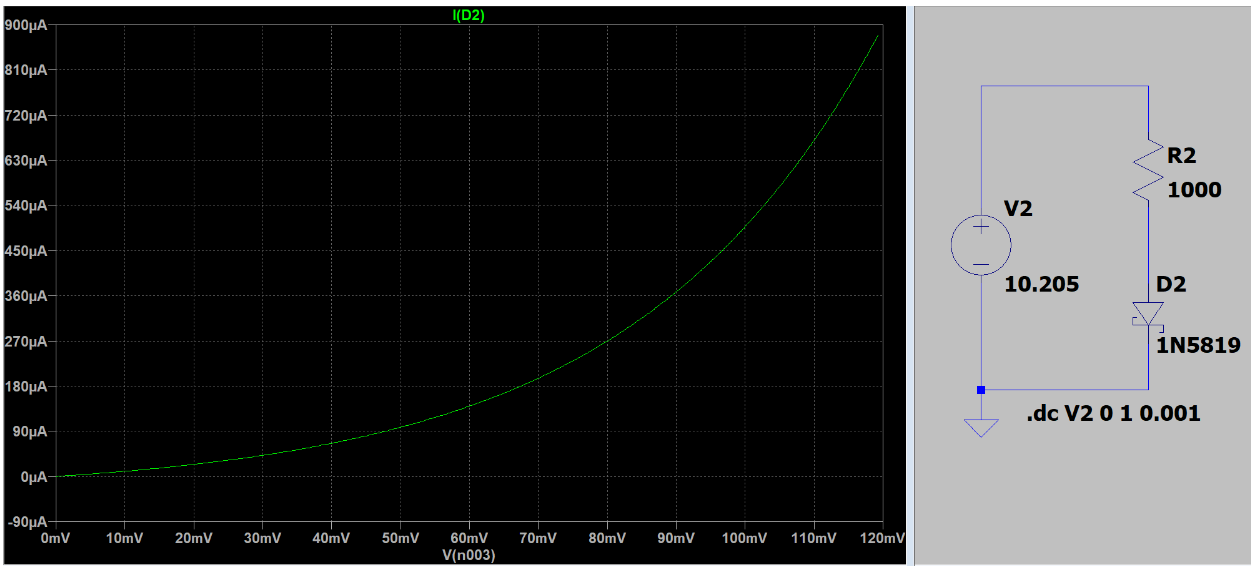


R = 1000 Ohm, $(I_D, V_D) = 0.0100A, 0.205V$

Procedure 3:

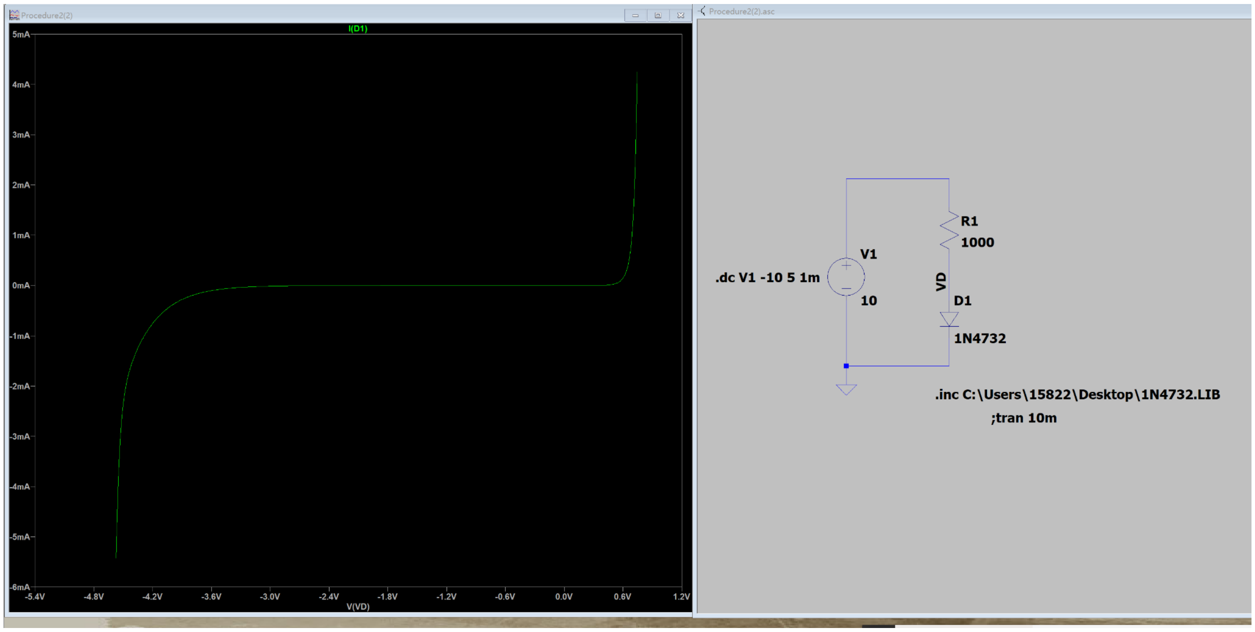
In procedure 3, we apply DC sweep from 0 volt to 1.0 volt to diode 1N4148 and 1N5819 with a 1k Ohm resistor in series. Then, we plot the I-V curse for diodes. The x-axis is the voltage across the diode and the y-axis is the current in forward bias.





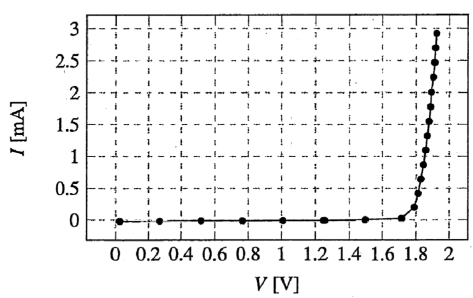
Procedure 4:

In procedure 4, the diode is replaced with the diode 1N4732 and other components are unchanged. Then we run a DC sweep and apply V-Bias from -10 Volts to 5 Volts and plot the I-V curve of the diode.

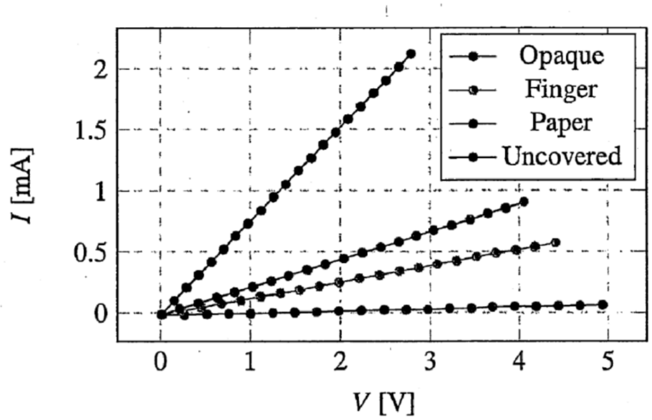


Procedure 5 and 6:

Procedure 5 and 6 discusses the characteristics of a T-1 3/4 red LED and a VacTec VT-301 photoconductive cell. The lab manual provides the IV plot of two equipment.



I-V characteristics of the LED



I-V characteristics of photoconductive cell (Order of labels is opposite)

3. Questions

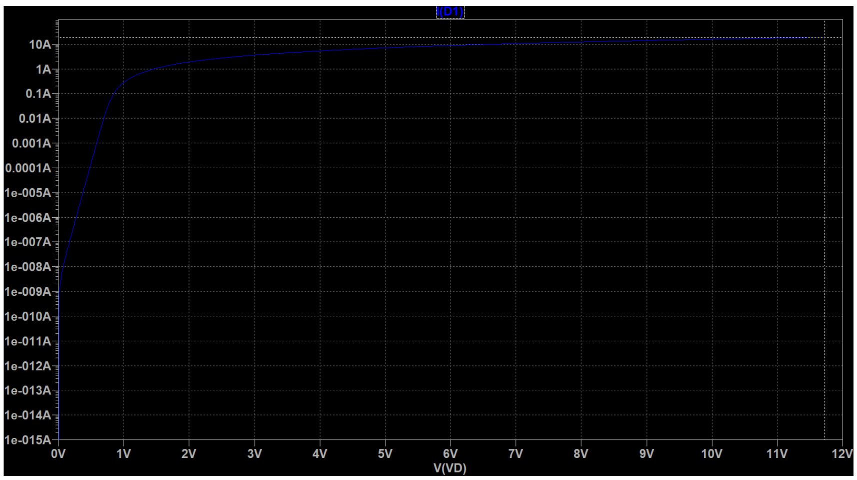
Q1:

Between 1N4148 and 1N5819, 1N4148 has a smaller reverse leakage current and 1N5819 would be the most suitable for charging up a capacitor and allowing the capacitor to keep its charge for the longest period of time because it has a larger reverse leakage current. The reverse leakage current for 1N4148 is about 2.5nA, and for 1N5819 is 10µA. 2.5nA is less than 10µA in magnitude.

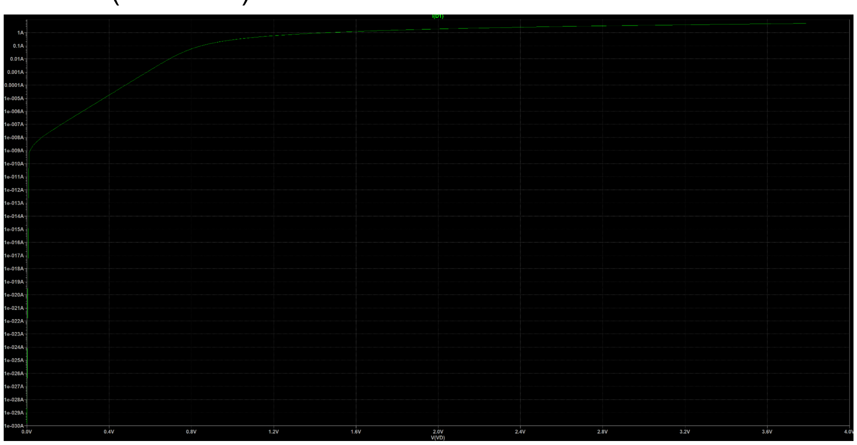
Question 2

(a) Plot the voltage across each diode versus the common logarithm of the current.

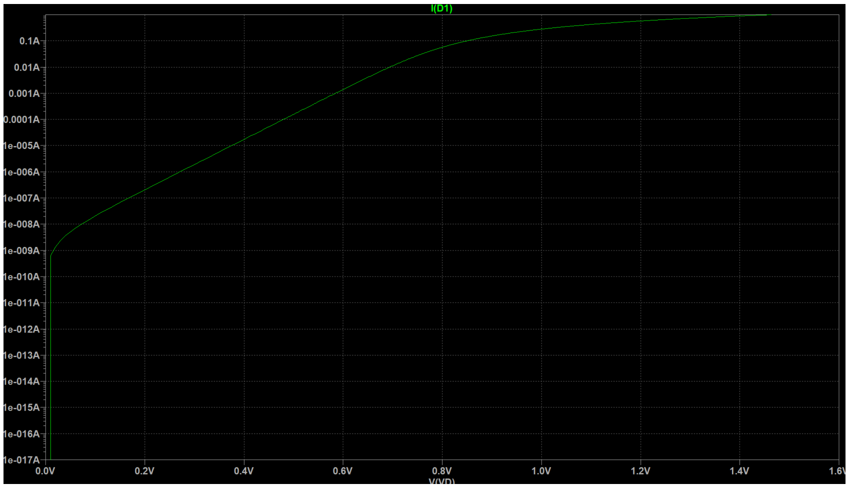
1N4148 (10 Ohm):



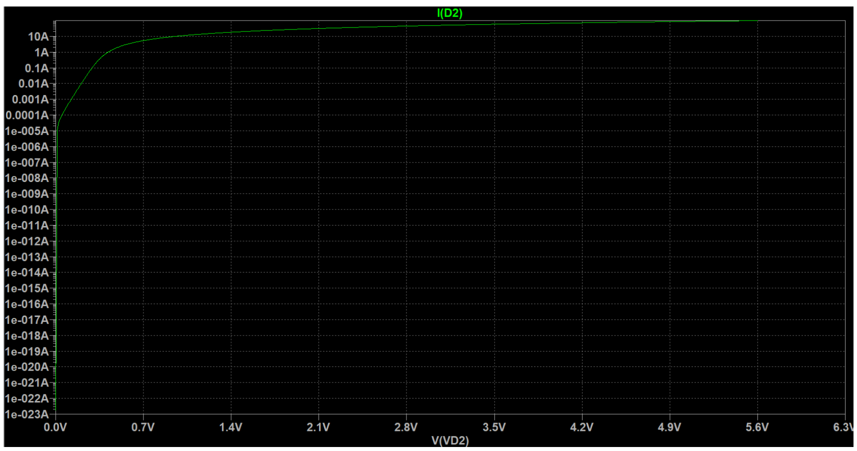
1N4148 (100 Ohm):



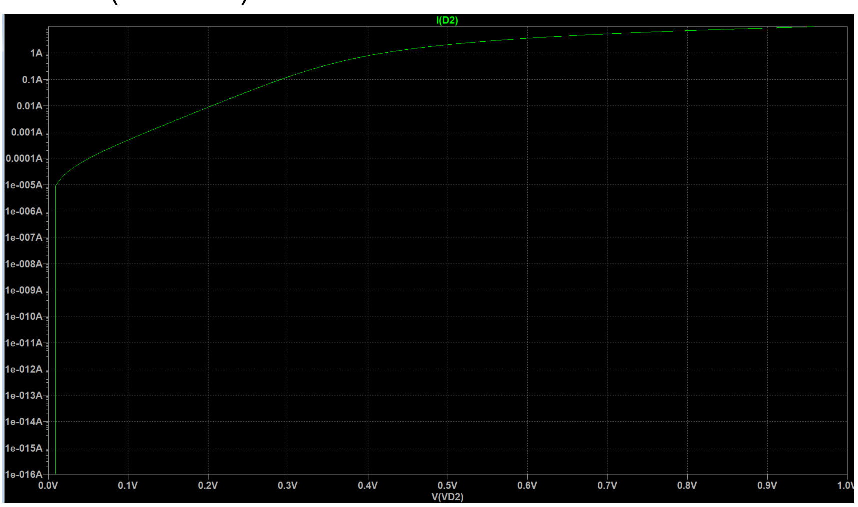
1N4148 (1000 Ohm):



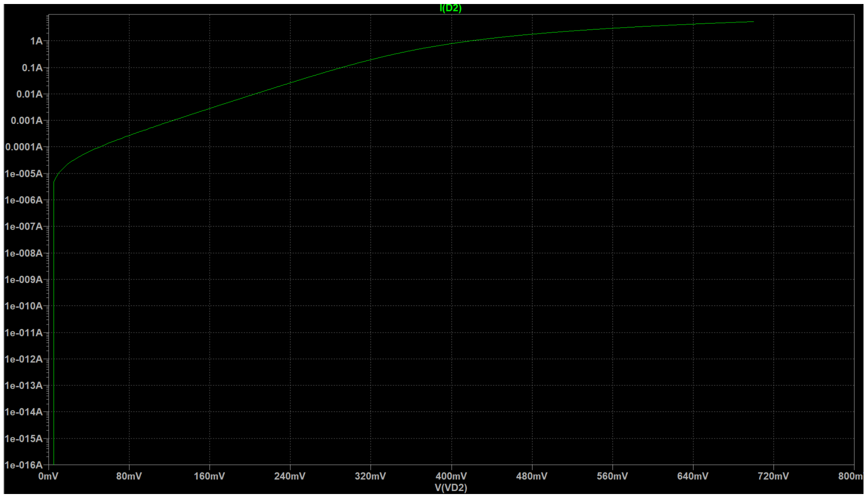
1N5819 (10 Ohm):



1N5819 (100 Ohm):



1N5819 (1000 Ohm):



(b) For each decade of increase in diode current, diode turn on voltage increases from 0.694V to 0.850V to 1.465V which increases 0.156V and 0.615V For 1N5819, diode turn on voltage increases from 0.205V to 0.291V to 0.419V which increases 0.086V and 0.128V.

(c) Based on the formula:

$$I_D = I_S \exp\left(\frac{V_D}{nV_T} - 1\right)$$

$$\frac{I_D}{I_S} = e^{\left(\frac{V_D}{nV_T} - 1\right)}$$

$$\frac{V_D}{nV_T} = \ln\left(\frac{I_D}{I_S} - 1\right)$$

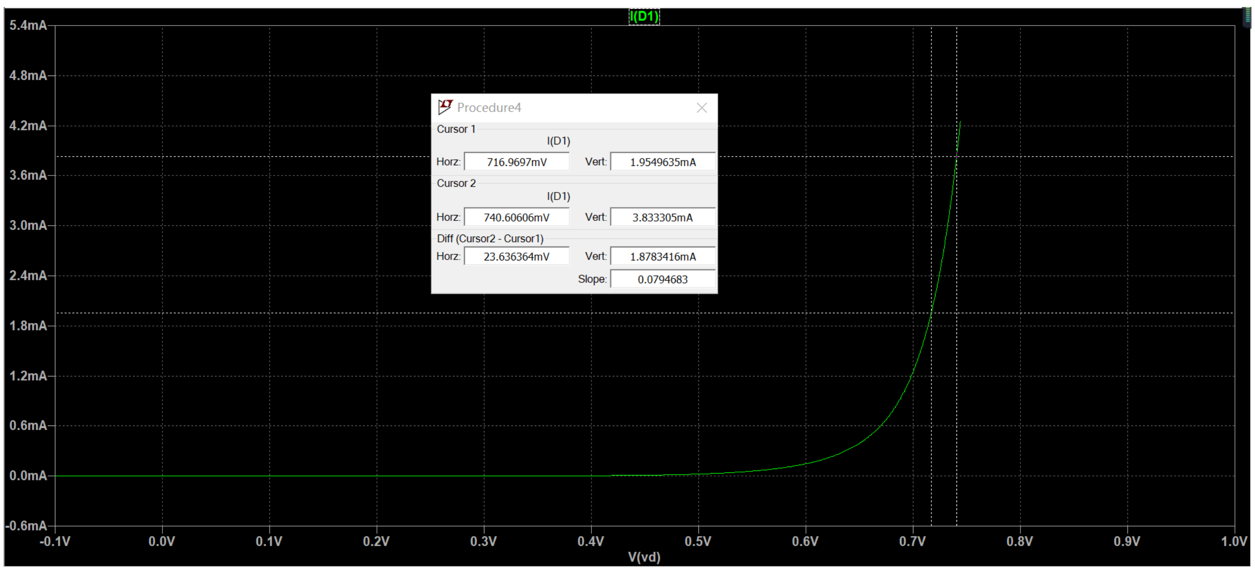
$$n = \frac{V_D}{V_T \ln\left(\frac{I_D}{I_S} - 1\right)}$$

Vt = 0.0258V, I_4148= 2.5 nA, I_5819 = 10 uA
for 1N4148:
R = 10 ohm, Vd = 1.465V, Id = 1A, n = 2.87
R = 100 ohm, Vd = 0.850V, Id = 0.1A, n = 1.88
R = 1000 ohm, Vd = 0.694, Id = 0.01A, n = 1.77
In this case, we cannot find a resistor corresponding to n = 1. For n = 2, we can roughly approximate the current range to 0.1 A to 1A. However, the upper limit is not very accurate since there is no resistance corresponding to a n slightly higher than 2.
For 1N5819,
R = 10 ohm, Vd = 0.419V, Id = 1A, n = 1.41
R = 100 ohm, Vd = 0.291V, Id = 0.1A, n = 1.22
R = 1000 ohm, Vd = 0.205V, Id = 0.01A, n = 1.15
In this case, we cannot find a resistor corresponding to n = 2. For n = 1, we can only approximate the current range to be below 0.01 A, since there is no resistor that corresponds to a n < 1.
Overall, we also observe that as R increases, the corresponding Vd and Id decreases, n also decreases.

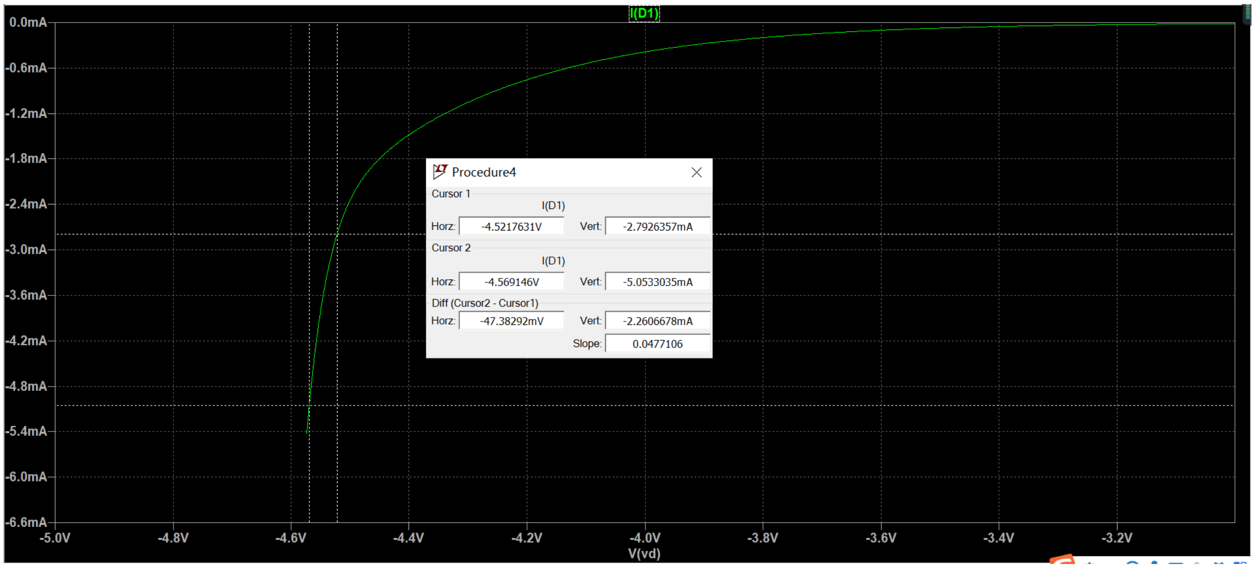
(d) The diode 1N4148 has a larger turn-on voltage and the diode 1N5819 has a larger reverse leakage current.
(e) The diode 1N5819 is the most suitable for building a bridge rectifier since it has a smaller turn on voltage.

Question 3
(a) I would expect the I-V curve to reach negative saturation current. The current will become more negative as the voltage becomes more negative. Then, the negative will reach negative saturation current
(b) The expected I-V curve will be a straight line since the circuit becomes purely resistive. The slope of the resulting I-V curve corresponds to the conductance of the replaced 1.0kOhm resistor.

Question 4:
(a)



For Rf, as shown in the figure, the slope = 0.0795 A/V, Rf = 1/slope = 12.58 Ω



For Rz, as shown in the figure, the slope = 0.0477A/V, Rf = 1/slope = 20.96 Ω

(b) From the graph, we see that Vf = 0.7V, Vz = 4.5V. Thus, based on the formula P=IV, the maximum current in the forward direction is I_f = P / V_f = 1W / 0.7V = 1.43A, I_z = P / V_z = 1W / 4.5V = 0.22A.

Question 5:

LED requires higher turn-on voltage because it is not purely made of silicon like the rectifier diode. It is more likely composed of GaAs and GaP, thus, the electrons in the n-region have a higher energy level and the holes in the p-region have a lower energy level as compared to intrinsic silicon, indicating that they require higher voltage to provide the initial energy to overcome the energy gap. Thus, LED requires higher turn-on voltage.

Question 6:

a) First, we can conclude from the graph that the resistance of the cell, which equals 1/slope, is constant under each condition as the I-V curves are all linear. Also, we observed that when the light passed through decreases, the slope gradually decreases based on the condition, indicating a continuously increasing resistance of the photoconductive cell. Thus, we can say that the photoconductive cell is linear.
b) Since R = 1/slope = 1 / (I / V) = V / I,
   R_uncovered = 2V / 1.5mA = 1333.33 ohm
   R_paper = 2.25V / 0.5mA = 4500 ohm
   R_finger = 4V / 0.5mA = 8000 ohm
   R_opaque = 5V / 0.1mA = 50000 ohm
c) For dusk-like light level, R_cell = R_finger = 8000 ohm,
   For voltage division of 2:1: R_L : R_cell = V_L : V_cell = 2 : 1
   Thus, R_L = 2 * R_cell = 16000 ohm = 16 kΩ
   The circuit is simply a voltage source, a photoconductive cell as given, and a 16kΩ resistor connected in series.

4. Conclusion

In this report, various diodes are tested under different conditions. Now the team is familiar with the I-V characteristics of diodes and zener diodes including reverse leakage current, forward bias current, reverse bias current, ideality factor, and turn on voltage. In the last two procedures, we also analyze the characteristics of semiconductor applications, LED and photoconductive cells, and make a voltage divider based on photoconductive cells.