

# Lab Experiment #1

## Static and dynamic characteristics of PN junction diode

# Group Members

	Student Name		Student ID #	Pre-Lab Mark (out of 30)	Lab Demo and performance (out of 70)	Total Lab Mark
	Surname	First Name				
Student 1						
Student 2						
Student 3						

**TA Signature:**

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# Experiment 1

## Static and Dynamic Characteristic of the PN Junction Diode

### ***Objective of the Experiment***

Through this experiment, we want to verify the validity of the equation of the PN junction diode:

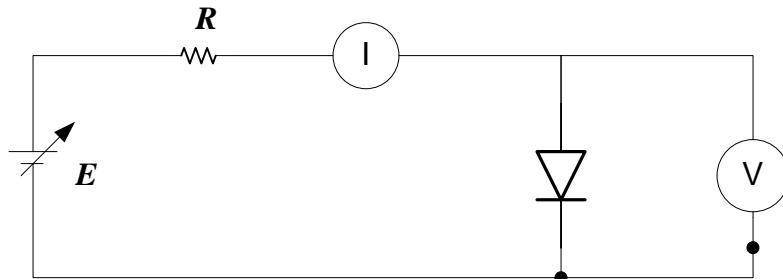
$$I = I_0 \left( e^{\frac{V}{nV_T}} - 1 \right)$$

This will be done by measuring the intensity through the diode and the voltage across it and plotting  $I$  vs  $V$  as well as  $\log I$  vs  $V$ . Those graphics will then allow us to find the characteristics of the diode, in large signal conditions as well as in small signal conditions. We want to verify that the diode acts as a dynamic resistance in the small signal conditions, with the value

$$r_{ac} = \frac{nV_T}{I_{DC}}$$

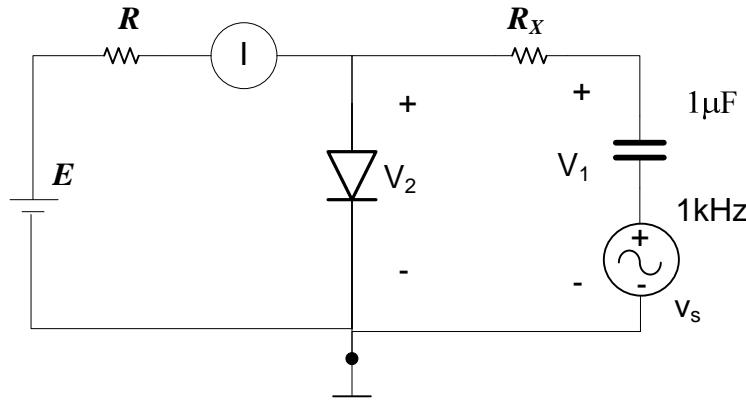
where  $I_{DC}$  is the fixed DC bias current.

Two setups will be used throughout the lab as shown in Figure 1 and Figure 2.



**Figure 1 Setup for static analysis of the diode**

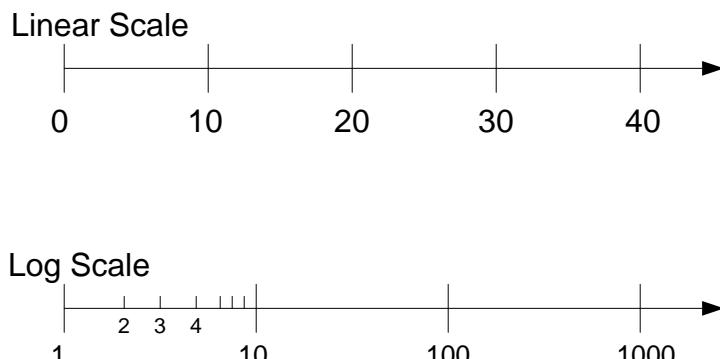
## Static and Dynamic Characteristic of the PN Junction Diode



**Figure 2 Setup for Small-Signal Analysis**

### ***Some explanations about logarithmic scales***

In a graph, the scales used along the x-axis and the y-axis are most often **linear**, which means that one unit of length on the paper will always represent the same amount of the unit measured (e.g. 1cm for 12V, 1cm for 0.5A...). However, it is sometimes more convenient to use **logarithmic** scales. In such a scale, a fixed amount of length on the paper does not represent a given quantity, but rather a constant increase (e.g. 1cm when the amount is multiplied by 10). In this lab, we will draw a graph having one linear and one logarithmic scale: it is called a log-linear graph.



**Figure 3 Comparing the Logarithmic versus the Linear Scales**

Note that it is impossible to have the value 0 on a logarithmic scale. In the lower part of Figure 3, going to the left of the scale will lead to  $10^{-1}$ ,  $10^{-2}$ ,  $10^{-3}$ ... but 0 will never be reached. Also note that the distance between 1 and 3 (and also 10 and 30, 100 and 300...) is about half the distance between 1 and 10 (a decade), and that the distance between 1 and 5 (and between 10 and 50, 100 and 500...) is approximately 0.7 times the length of a decade. This will be useful to draw a logarithmic scale on linear graph paper.

## **Static and Dynamic Characteristic of the PN Junction Diode**

## ***Lab preparation***

1. Explain, in the space provided below or in a separate sheet, why plotting I vs V using a logarithmic scale for I and a linear scale for V should yield a straight line.
  2. What is the slope of this line?

**Hint:** Derive an expression for  $\log(I/I_0)$  from the theoretical equation given above and show that according to this expression, when  $I$  is multiplied by 10, the increase in  $V$  is constant. The slope of the line, in Volts per decade, is this constant.

3. The simplest large-signal model for the diode is composed of an ideal diode, a forward resistance  $R_f$  and a cut-in voltage  $V_{on}$  (“battery plus resistance” model). Redraw figure 1 using this model.

**Static and Dynamic Characteristic of the PN Junction Diode**

4. The small signal conditions for the diode are small variations of I (the current through the diode) and V (the voltage across the diode) around a constant, fixed value, given by the DC. Under those conditions, it has been shown theoretically that  $v_{ac} = r_{ac} \cdot i_{ac}$ , where  $v_{ac}$  is the AC (the small-variations) voltage across the diode and  $i_{ac}$  the AC (the small-variations) current going through it. Note that the value of  $r_{ac}$  depends on the value chosen for the DC current  $I_{DC}$ . Express the value of  $r_{ac}$  with respect to what will be measured in the experiment that is in terms of  $v_1$ ,  $v_2$  and  $R_x$  shown in Figure 2.

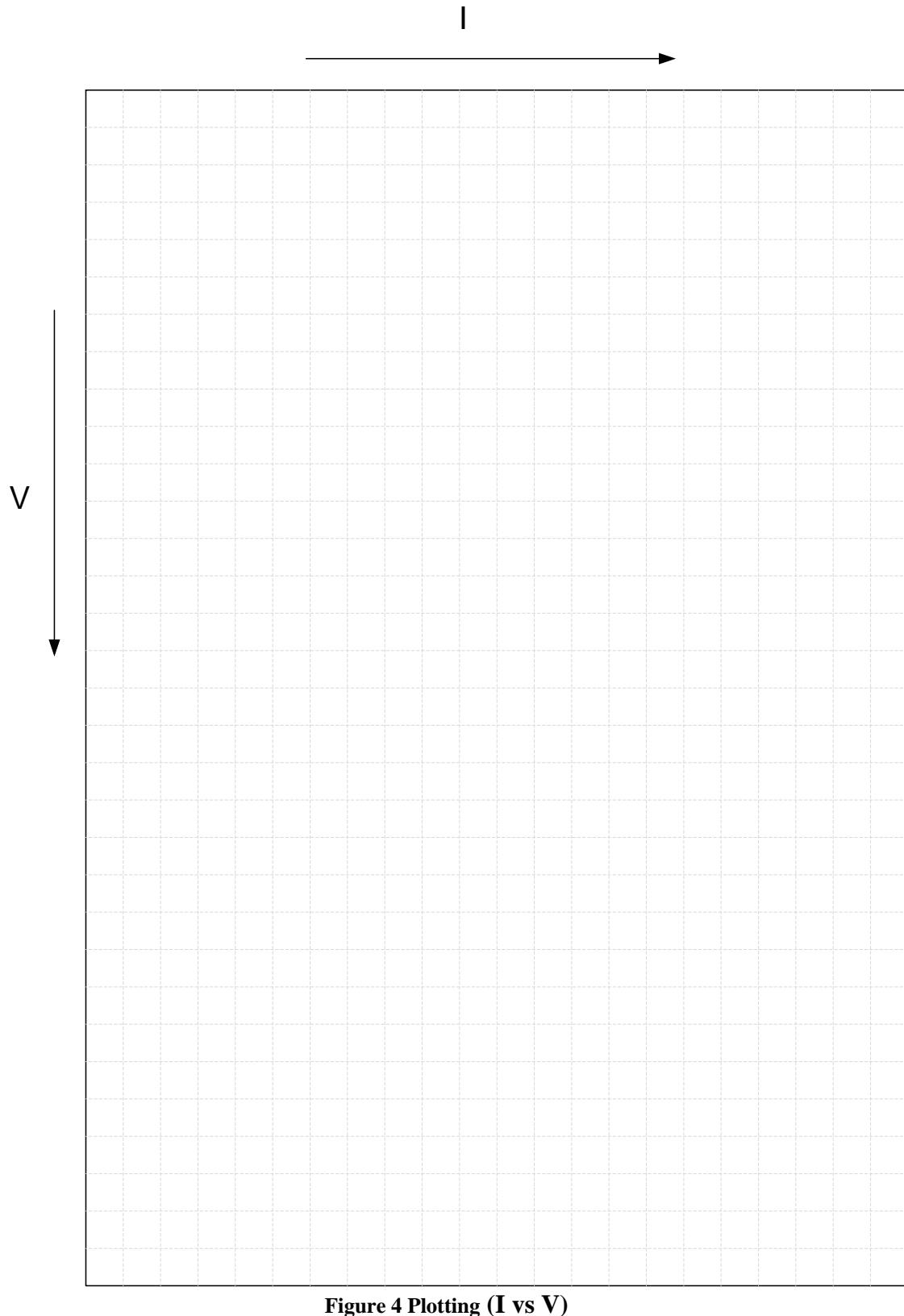
**Static and Dynamic Characteristic of the PN Junction Diode****Lab Components**

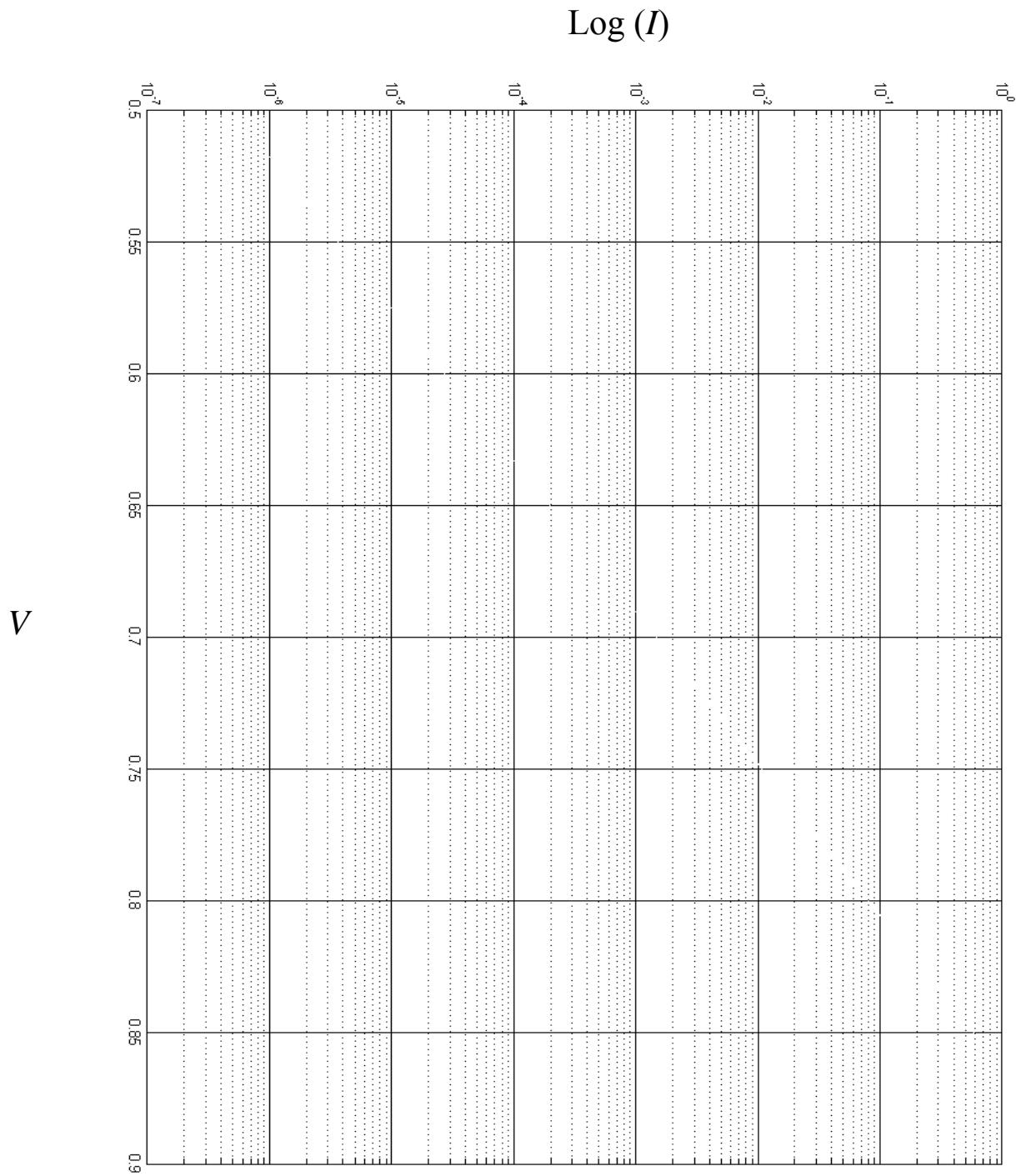
- 1 D = Diode 1N4004
- 1 E = DC power supply
- 1  $v_s$  = Signal generator
- 1 I = DC ammeter
- 1 D = DC voltmeter
- 1  $v_1, v_2$  = AC true RMS voltmeter
- 1 C =  $1\mu F$  capacitor
- 1 R =  $1k\Omega$  standard resistor
- 1 R =  $33\Omega$  500mW resistor
- 2  $R_x = 100\Omega$  standard resistors, in parallel to form a  $50\Omega$  resistor.

***Basic Experiment.***

1. Measure the forward static characteristic of a silicon pn junction diode (current  $I_{DC}$  through the diode vs voltage  $V_{DC}$  across the diode) using the circuit of Figure 1.
  - E is a variable DC source regulated in voltage, limited in current.
  - I is a DC ammeter, V is a DC voltmeter.
  - Multimeters available in the lab may be used for I and V.
  - D is a 1N4004 diode, where the thin band represents the cathode.
  - R is a resistance used to limit the current in the circuit.
  - Use a  $1k\Omega$  resistance for currents going from 0.1 to 10mA, and a  $33\Omega$  500mW resistance (this is **not** a common  $33\Omega$  resistance) for currents from 10 to 100mA. **Be extremely aware** of the power dissipated by the resistance. An excessive voltage applied to a resistance will lead to heating, which will burn the resistance and may melt the breadboard.
2. Set the voltage E so that I reaches the following values, in mA: 0.1, 0.3, 0.5, 1, 3, 5, 10, 30, 50, 100, plus other values between 10mA and 100mA, as needed to obtain a good linear graph. For each value of I, measure the value of the voltage across the diode, V, and plot it simultaneously on a linear graph (I vs V) and on a log-linear graph (log I vs V). Use the graph papers provided next.

I	0.1	0.3	0.5	1	3	5	7	9	10
V									
I	20	30	40	50	60	70	80	90	100
V									

**Static and Dynamic Characteristic of the PN Junction Diode****Figure 4 Plotting (I vs V)**

**Static and Dynamic Characteristic of the PN Junction Diode****Figure 5 Plotting (log(I) vs V)**

**Static and Dynamic Characteristic of the PN Junction Diode**

3. From the log-linear graph obtained above, evaluate the parameter “n”: Use two points of the graph and carry out an **algebraic calculation** to find the slope of the graph. Then use the results found in the first part of the preparation to find n.

$$n =$$

4. Using the circuit of Figure 2, measure  $v_1$ ,  $v_2$  and the voltage across R for three values of forward DC current: 0.1mA, 1mA and 10mA. Those measures are AC measures, that have to be done with a RMS voltmeter. For  $R_X$ , take a value close to the expected  $r_{AC}$ , e.g.  $50\Omega$ . Operate with an AC voltage as small as possible, in order to stay in the small signal conditions, and to be sure not to modify the DC loop. Using the lab preparation, determine the value of  $r_{AC}$  yielded by those measurements. Compare it with the theoretical value of  $r_{AC}$ .

$$r_{AC} \text{ (From Measurements)} =$$

5. At some time during the lab contact one of the TAs and observe on the Tektronix curve tracer the characteristic of a Zener diode. Note the value of the breakdown voltage and the reverse current of the diode at two values of reverse voltage, that is 2 and 30 volts.