THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON. DC

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2115: ENGINEERING ELECTRONICS LABORATORY

Experiment #1:
Solid State Diodes – Testing & Characterization

COMPONENTS

Type	*Value*	*Symbol Name*	*Multisim Part*	*Description*
Resistor	1Ω	R_1	Basic/Resistor	---
Resistor	1MΩ	R_2	Basic/Resistor	---
Capacitor	470µF	C_1	Basic/Capacitor	---
Diode	1N4148	D_1	Switching Diode/1N4148	Germanium Diode
Diode	1N4002	D_2	Diodes/1N4002G	Series Silicon Diode
Diode	SLX-LX3044HD	D_3	---	GaAsP Red LED
Diode	1N751A	D_4	Diodes/1N751A	Zener Diode

Table 1 – Component List

OBJECTIVES

- To use an ohm meter to determine the forward and reverse resistance of different types of diode· To use the Diode Test function of the DMM
- To obtain one diode i-v characteristic curve by using the information obtained from a test circuit
- To obtain the i-v reverse bias characteristic curve for a Zener diode
- To determine the value of the small signal resistance of one diode for different operating points and using three different techniques: graphically, analytically and by the application of a small signal
- To interpret the results of static and dynamic diode tests

INTRODUCTION

Understanding how to use the Analog Discovery 2 is going to be vital to succeeding in Engineering Electronics this year. The AD2 is where almost any lab starts and what makes the experiments possible. The AD2, digital multimeter (DMM), and a breadboard will be used in almost every lab this semester, and possibly in future circuit- or electronics-based labs you take. Becoming familiar and comfortable with it will allow us to spend less time in future labs getting our experiments set up and more time building and analyzing the circuits we are interested in observing.

Introduction to the DC Power Supply

A power supply is an electronic device that supplies electric power to a circuit. In any circuit, there needs to be some power source, and the AD2 will be the source in many labs throughout the semester. You may have also been provided with 3-24V 2A adjustable DC voltage supplier. Since the AD2 can only output $\pm 5V$you will have to use the adjustable DC voltage supplier for problems that require higher voltages.

Figure 1 – Analog Discovery 2

The Basics:

- The AD2 provides up to +5V and -5V power supplies
- All the pins on the AD2 and its adapter are labeled, and each pin has a specific output. These outputs can be found in the AD2's manual. That manual can be found HERE.
- The AD2 can be managed using Digilent's "Waveform" software. It has multiple tabs that can be accessed and controlled, including a waveform generator, voltmeter, and power supply (which is the device used in this lab).

Introduction to the Digital Multimeter (DMM)

A digital multimeter is a multipurpose electronic measurement device that is generally capable of measuring voltage, current, and resistance. The DMM will be used to make all DC measurements.

Figure 2 – Basic Handheld Multimeter

The Basics:

- The DMM can measure voltage (V), current (A), and resistance (Ω).
- It has three connections at the bottom right. The first is for DC current between 200mA and 5A. The second is for voltage, resistance, and DC current under 200m. The third is for ground, also known as common.

Introduction to MultiSim

You have probably used MultiSim before in classes such as Circuit theory, however, if you are unfamiliar, it is a circuit simulation software that will allow you to digitally make your circuits before you make them in the physical world. It is an invaluable tool used in almost all your labs for checking you circuit before you spend the time to make it on your breadboard

The Basics:

- You will need some way to access Multisim. To do so online, you can go to ECE Virtual Lab. The Shortcut is to go to gwu.apporto.com. From here, you should see something that says ECE Lab, click the launch and you should be in a virtual computer that has access to Multisim! You can also use MultiSim live, however this has fewerfeatures, so it is recommended to use the regular Multisim software.
- If you need a refresher on how to use Multisim, the first few labs available in the circuit theory ECE Course give a good review. You can also find how to download MultiSim onto your own computer here, however, it is a bit of a pain since you can always just use a virtual computer.
- If you are having any troubles with getting MultiSim, let your TA know and they should be able to help you

Introduction to the KLY-2402000 DC Power Supply

In previous labs, we have been able to use the AD2 to supply the voltages needed for our circuits. In this lab, we will see circuits that use more than the 5V the AD2 can supply, so we need to use an auxiliary Power Supply. In the tool kits, you have been supplied with 2 KLY-2402000 DC Power Supplies. This device is straightforward to use and can supply voltages greater than 5V. You will use these devices not only for this lab, but for future labs and the final project as well.

These power supplies come with special adapters, that allow us to probe wires into them so that we can attach the Power Supplies to our breadboard. To do this, simply take the adapter (shown in Figure 5), and unscrew the screws seen within. You do not have to unscrew them all the way, just enough to where you can fit a wire into the ports. The polarity on the adapter is labeled, and it is very important that you know which side positive and which side is negative, so that you do not damage any of the components within your circuit. It is recommended that you attach a red wire to the positive terminal, and a black wire to the negative, so that they are easy to distinguish. In Figure 5, you can see the wires already attached to this adapter.

After you have setup and attached the adapter, you can now connect this supply to the breadboard. The KLY-2402000 can supply 3-24V and up to 2A of current, so it is extremely important that you handle these devices with care, and always triple check your connections, and this supply can easily burn out capacitors and Integrated Circuit Chips, or IC's. To use this supply, you just simply plug it in, and there is a knob on the top that allows you to adjust the voltage. Turning it clockwise will increase the voltage, counterclockwise will decrease it and turn it off. Make sure to always have the supply plugged into your circuit before turning it on.

Figure 3 – Adapter Piece with Red Wire Attached to the positive terminal and Black Wire attached to Negative Terminal

Figure 4–KLY-2402000 Power Supply

PRELAB

Part I – Generate Equipment List

1. Read through the lab manual and generate an equipment list.

Part II – Print Specification Sheets

1. **Download** and **print** the spec sheets for the four diodes: 1N4148 1N4002, MV5753, 1N751A
2. **Use** the spec sheets to populate the following table.

Diode	V_F	I_F	V_R
1N4148			
1N4002			
SLX-LX3044HD			
1N751A			

Table P.1 – Diode Characterization Table

Part III – Plotting i-v Curves for Diodes

1. **Read** "*Tutorial #1 – DC Sweep Analysis in Multisim*" on the lab website.
2. **Use** the tutorial to plot the i-v characteristic curve for diodes: 1N4002 and 1N751A. Sweep the voltage to show the i-v characteristic for the range from -1A to +1A. **Label** the end values for each curve. Notice the diodes have different part names in Multisim as shown in Table 1 above.
3. **Plot** only the **forward characteristic** i-v curve for the two diodes: 1N4002 and 1N751A. Sweep the voltage such that it shows the i-v characteristic for the range from 0mA to 20mA. a. Do your graphs line up with the values collected from the spec sheets in **Table P.1**?
4. **Memorize** the following in the event of a pre-lab quiz:
   a. The symbols for a diode, LED, and zener diode (which terminal is anode/cathode). Be able to identify the 4 diodes in your kit on sight
   b. The forward region i-v relationship equation (given later in this lab manual)
   c. Know the shape of a typical diode i-v Curve
   d. Read the rest of the lab manual to have a general understanding of how we will use the data you have generated in this prelab.

LAB

Part I – Data & Static Diode Tests

1. **Prepare** a table with the four diodes in the left column and the parameters you will record as titles in adjacent columns
2. **Set** the DMM to measure resistance (Ohms).
3. **Connect** the positive lead from the DMM to the anode of the diode and the negative lead from the DMM to the cathode of the diode.
4. **Measure** and **record** the forward direction resistance (R_f) of D_1, D_2, D_3, and D_4.
5. **Reverse** the direction of the leads to **measure** and **record** the reverse direction resistance (R_r) of D_1, D_2, D_3, and D_4. Place this data in your table.
6. **Calculate** the back to front ratio (R_r/R_f) for D_1, D_2, D_3, and D_4. **Record** this data in your table.
7. **Set** the DMM to perform a **diode test** (look for the diode symbol).
8. **Measure** and **record** the **forward bias voltage** readings for D_1, D_2, D_3, and D_4. This information will complete your table.

Part II – Reverse Saturation Current

1. **Construct** the circuit depicted in **Figure 2.1** on a breadboard using the following specifications:
   a. Vd = **-**10V

      (You will need to use the voltage adapter for this part, plug in the provided adapter to the end of the power supply cable, then input 2 separate wires into the square ports at the end of the adapter. Make sure you tighten the screws to ensure that the wires are held in place. Now, to turn on the power supply, turn the dial to 10V. BE CAREFUL, this is live electricity and WILL hurt. To get the -10V like you need to, plug the negative terminal into the positive and the positive into the negative.)

   b. R = R_2 (see **Table 1**)

   c. D = D_1 (see **Table 1**)

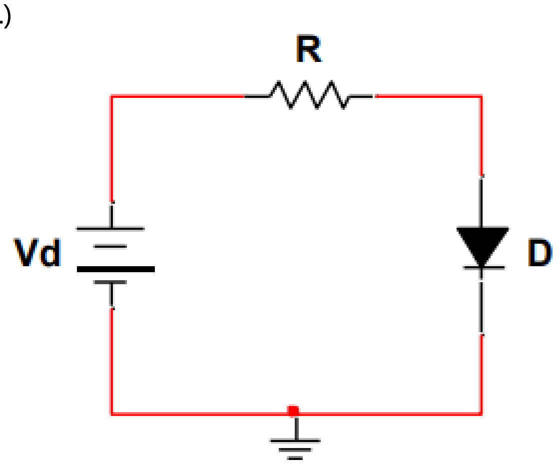


Figure 2.1 – Diode Test Circuit

2. **Measure** the **reverse saturation current I_S** of the diode using the DMM. (Remember, to measure current, you turn you DMM to current and you put it in SERIES with the circuit)
3. **Repeat** this procedure for diode D_2.
4. **What** is the value of **I_S** that Multisim uses to model this diode D_2 (look at the SPICE model settings under the part properties)?

Part III – Forward i-v Characteristic

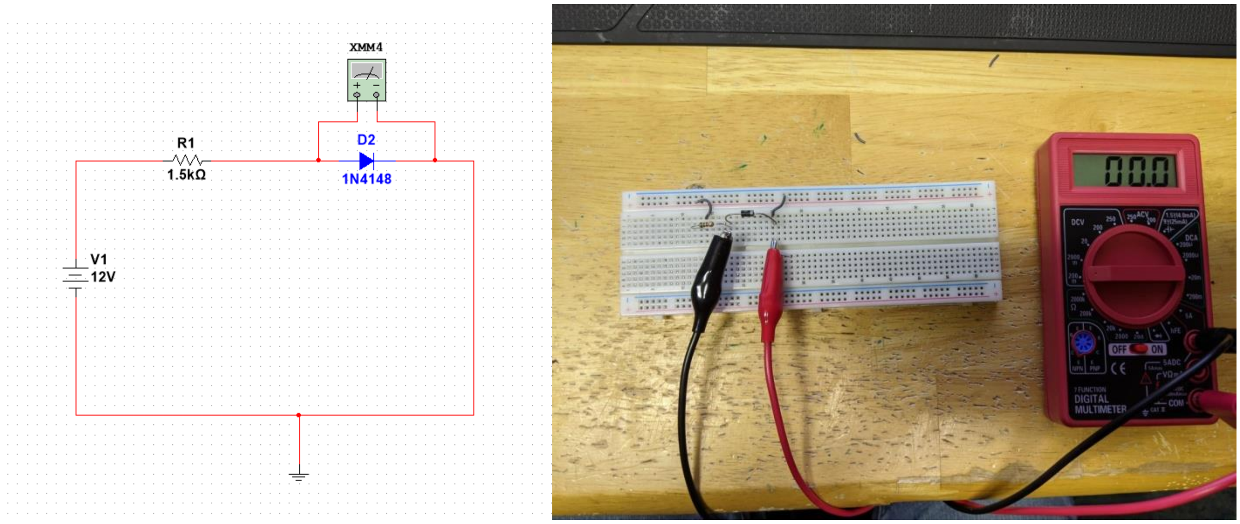


Figure 2.2 – Diode Test Circuit for Finding Forward i-v Characteristic

1. **Build** the circuit shown above. The goal is to generate the i-v curve for the diode as you did in the prelab. The DC Voltage Source above is the 3-24V Adjustable power Source.

2. **Using** diode D_1, vary $\mathbf{I_D}$ by changing the V of the Voltage Source. With a Voltage of 3.6V, you should have a Current of roughly **2mA.** When the Voltage is 6.6 V, the current should be 4mA and ect. This trend should continue up until 24.6V being roughly 16mA. Do this for 2mA to 16mA in steps of 2mA. Use your DMM to confirm the Current and to **Record** the voltage drop (V_D) across the diode for each value of I_D. Repeat this procedure for diodes D_2, D_3, and D_4. Make sure you are checking the Current values for the circuit for these diodes so that you have I_D equaling the correct 2mA, 4mA, ect.

   Note: This problem originally called for you to use a current source. However, since you do not have one, a different way to achieve the same must be employed

3. In either Microsoft Excel or MATLAB, **plot** the values obtained in step 2 and those predicted by Equation **1** (you should have two overlapping curves: **expected** and **measured** for each diode). \

4. **Mark** the point on the measured i-v curve that indicates the voltage drop across the diode when the forward current is equal to **10mA** and again when the forward current is equal to **20mA**.

5. In the forward region, the i-v relationship is closely approximated by:

$$I_D = I_S[e^{V_D/(nV_T)} - 1]$$

Equation 1 – Shockley Ideal Diode Equation

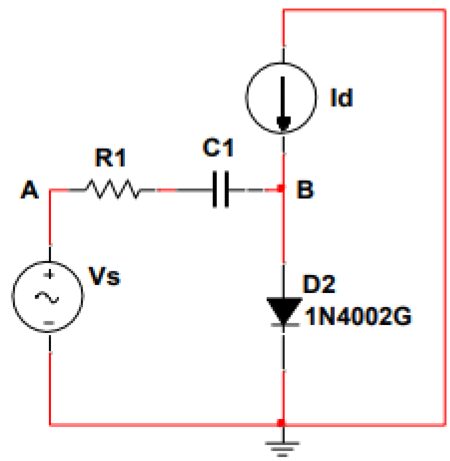
6. **Use** the two points you have marked on the i-v curve (Id = 6mA, Vd) and (Id = 12mA, Vd) to determine the values of **n** and $\mathbf{I_S}$. You have **two** equations and **two** unknowns. Do this for diodes D_1 and D_2.

7. **Compare** the values of I_S obtained in **Part II** with the values you have calculated in **Part III** for

diodes D_1 and D_2

Part IV – Small Signal Analysis (Multisim Extra Credit)

1. **Compute** r_D analytically for $I_D = 6mA$, and for $I_D = 14mA$ using $r_D = \frac{dvD}{diD} = \frac{nVT}{I_D}$. You have already estimated the value for nV_T
2. **Compute** the small signal resistance for D_2 graphically for $I_D = 6mA$, and for $I_D = 14mA$ using $r_D = \frac{dvD}{diD}$ and Plot #2.



3. **Build** the circuit shown above in Multisim. C1 can be found in the table on page 1.
4. **Set** $I_D = 14mA$, $v_s = 15mV_{RMS}$, 100 kHz sinusoidal signal, and **measure** $v_a(v_s)\ and v_B(v_D)$
5. **Compute** the small signal resistance of the diode for this operating point: $r_D = \frac{dvD}{diD}$
6. **Compare** the values of r_D obtained by the 3 different techniques.

POST-LAB ANALYSIS

In your prelab and in the lab, you have used 2 different techniques to obtain the i-v characteristic curves for the diodes: Simulation-based and Digital Multimeter-based. **Compare** and **contrast** the methods in your analysis. In addition, **compare** the data you have collected to the data specifications from the manufacturer. If the data collected is not accurate, calculate **percent error** in each case.