EEE109 Lab 1 – Diodes

Lab Report 1

Student Name: *Yukun.Zheng22*

Student ID: *2251625*

Submission date: *21/11/2023*

Abstract:

With the objective and the aim of verifying basic behaviors of diode through experiments, this lab is mainly divided into 3 sections. The first section covers the electrical characteristics and the rest two provide real applications in power transmission. Students make use of NI ELVIS III along with Measurement Live to examine and plot their waveforms. Our group detects an error in part 2 of section 2, and we made a speculation about the possible reasons. Our results generally confirm the existence of turn-on voltage, unidirectional conductivity of the diode, and its utilization as rectifier.

1. Introduction

1.1 Background

Diode is an electronic element that plays an indispensable role in our lives. Take the process of power transformation as an example, diode engaged in the circuits of rectifier, filter and voltage regulator to make sure the success of transfer from AC high voltage in load line to DC low voltage in power supply of users.

1.2 Experiment

Firstly, it is necessary to illustrate the objectives of the experiment. We students are expected to observe the characteristics of diode by our eyes and hands instead of leaving it as untouchable knowledge in our minds. Students also need to build their circuits through instrument, and take screenshot of the waves showed on software. The third target is catching images of full-waves rectifier, and students are ought to examine their cognition of what they have learned in Chapter 2.

Secondly, the scope of this experiment is needed to be clearly demonstrated. Students must be equipped with all points in Chapter 2--Diode Circuit, which is also the range of experiment. Otherwise, students may be trapped in befuddlement.

Last but not least, it is strongly suggested that students should harbinger the potential outcomes of the experiment before clicking the “Run” button. If their prophecy is not

coincided with the data presented on the software, they will have a second opportunity to grasp the knowledge again, which corrects their understanding.

1.3 Organization

This lab report will split into 5 sections. In the beginning, the introduction of the experiment is elaborated. Then, it will outline the aim of this lab. Subsequently, the next part is procedure of the experiment. Afterwards, the concentration of this lab report will be placed on the results and discussion of this lab. Ultimately, the conclusion of this lab will be given.

2. Aim

1. Diodes
2. Diodes in Half-Wave Rectifier
3. Diodes in a Rectifier

3. Experiment procedure

- ✧ In this section, I would like to detail our experimental procedures in 3 stages, which are section 1, section2, and section3. Simultaneously, this is the story of our experiment.
- ✧ I would explain our process in section 1. In part 1.1, we positioned every element in carefully only to find that our waveform jumps violently. After the adjustment of the depth of diode, and the curve got correct.
- ✧ Then, we moved to the next part 1.2. We started running the simulation software after regulating the parameters. What startled us was that no matter how we turned the knob, the diode voltage on the screen displayed “OVER”. Initially, we checked the potentiometer, but the data on the screen would vary if we turn the knob. Boyuan (my teammate) restarted Measurement Live, but nothing has changed. In desperation, we sought teacher for assistance. After his testing, he found that we neglected to modify the voltage limitation for 50mV to automatically,

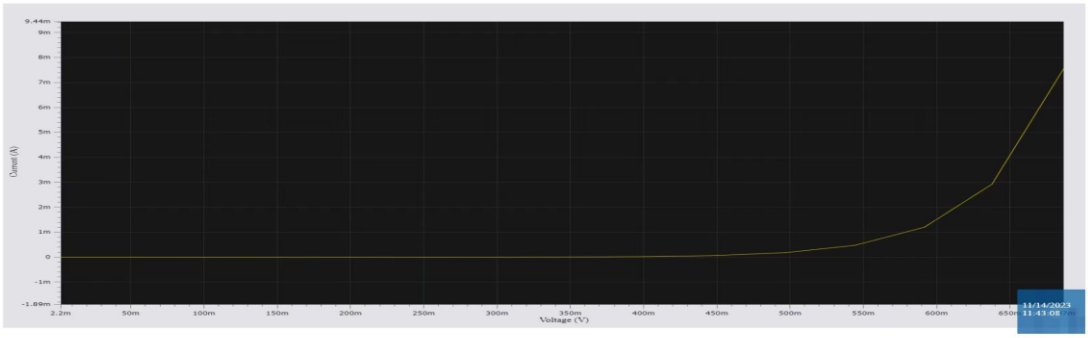
and both of us had an epiphany. Later, we used a probe to read the total current and the diode voltage. In part 1.3, the diode was in reversed-biased, so the current was always zero.

- ✧ There were 2 sub-tasks in part 2, and we completed them separately. In section 2.1, we fetched a Red LED and a 1KΩresistor for the construction of the circuit. Although we reversed the polarity of diode unintentionally at first, we corrected our errors by our own. In section 2.2, we replaced the Red LED with Diode 1N4001, and achieved the correct waveform.
- ✧ Finally, we came to section 3 and clicked the link of full-wave rectifier. We switched the mode from Schematic to Split, and run the simulation. After catching the correct image, we stopped the simulation and took a screenshot.

4. Results and Discussion

- Section 1: Diodes
  - a) 1.1 Observing Diode Behavior

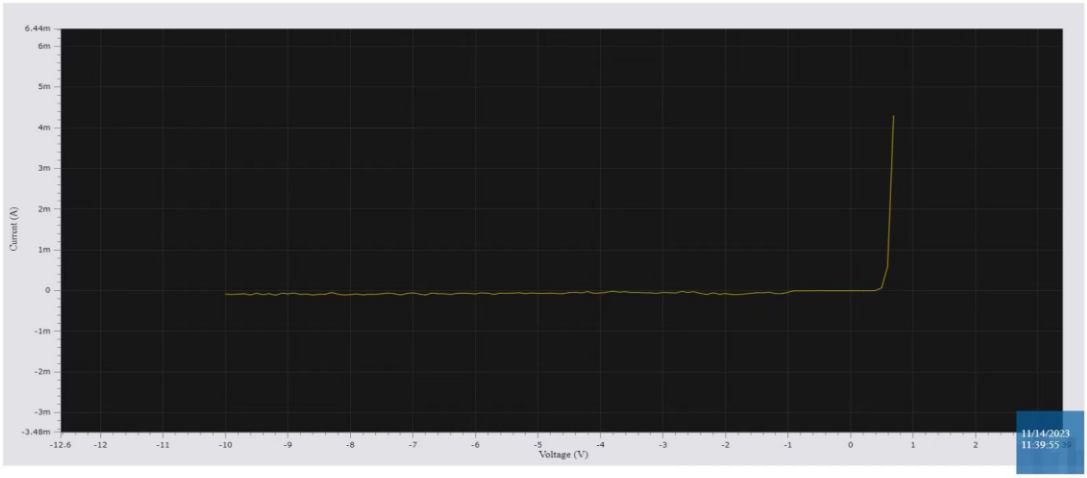
    We set the parameters as Table 1-1 shows, and obtained the graph as below.



Settings	
Mode	diode
Series Resistance	100Ω
Start Voltage	0 V
Stop Voltage	700 mV
Step	50 mV
Negative	-30 mA
Positive	30 mA

From the graph, it is clear that the current maintains 0 until the voltage reaches the value of around 400 mV, which reveals that the turn on voltage ($V\gamma$) of such diode is about 400 mV.

Repeating the previous step and replacing some parameters, we got the second graph as below.



Settings	
Mode	diode
Series Resistance	100Ω
Start Voltage	-10 V
Stop Voltage	700 mV
Step	100 mV
Negative	-30 mA
Positive	30 mA

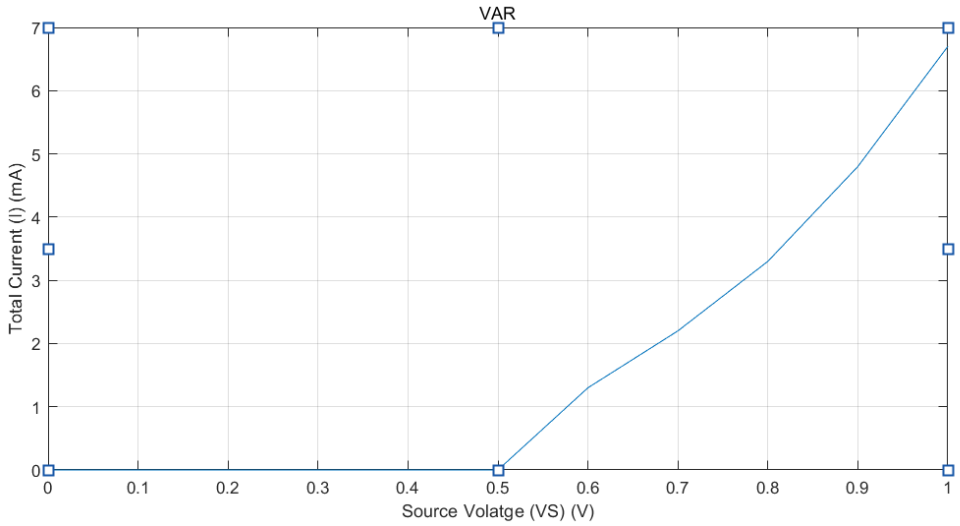
Hence, this experiment highly satisfies our cognition of the electrical characteristic of diode.

b) 1.2 Diode Measurements

We successfully applied DMM to measure the total current and the diode voltage, and acquired data as below.

Source Voltage (VS)	Total Current I (mA)	Diode Voltage (V)
0.0	0 mA	0 V
0.1	0 mA	0.100 V
0.2	0 mA	0.200 V
0.3	0 mA	0.300 V
0.4	0 mA	0.409 V
0.5	0 mA	0.512 V
0.6	1.3 mA	0.588 V
0.7	2.2 mA	0.653 V
0.8	3.3 mA	0.667 V
0.9	4.8 mA	0.674 V
1.0	6.7 mA	0.686 V

Based on the results labeled on the table, it is clear that the Total current I remains 0 mA until the source voltage approached 0.6 V. Observing that horizontal line (VS=0.6 V), the diode voltage we measured is 0.588 V, which indicates that the turn-on voltage $V\gamma$ of Diode 1N4001 is between 0.512 V and 0.588 V. We collected the scatter points on MATLAB and plotted the graph as below.



In the preceding part, we took a photo of the diode voltage along with total current as well. Comparing the two graphs, it is generally appropriate to regard as these two as the same. The Source Voltage decides the magnitude of Diode Voltage, and thus the tendencies are similar. Moreover, the reason why the curve is so steep is because the choose of points is relevantly far away. If we take the distance between adjacent voltages from 0.1 to 0.05, and we measured and plotted the corresponding current, the curve will be smoother, which will be more similar to that of the previous one.

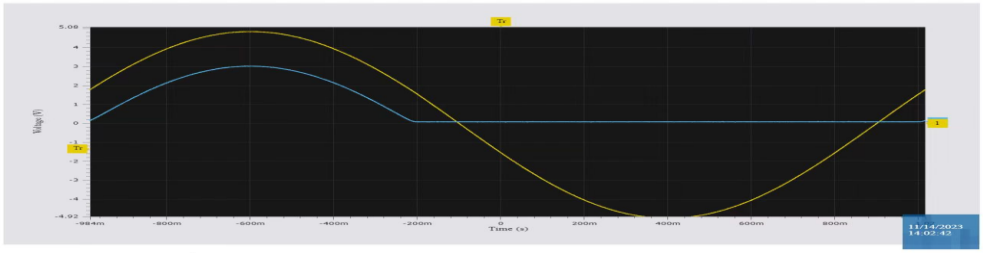
c) 1.3 Reverse the Polarity of the Diode

if the diode is reverse-biased and the polarity of the source voltage cannot change, both the total current and the diode voltage are always zero.

● Section 2: Diodes in a Half-Wave Rectifier

a) Diodes in Half-Wave Rectifier

In the circuit, we positioned CH1 and CH2 in anode and cathode of the diode, and run the Function Generator.



General Settings	
Trigger Type	Analog edge
Trigger Source	Channel 1
Trigger Slope	Rising
Trigger Level	-1.342 V
Time Per Division	200 ms
Sampling Mode	Decimate
Repetitive Sampling Mode	Off

Advanced Trigger Settings	
Acquisition Delay	Disabled
Trigger Position	16.94 ms

Channels						
Name	State	Coupling	Probe Attenuation	Vertical Offset	Vertical Position	Volt Per Division
Channel 1	Enabled	DC	1x	0 V	84.6 mV	1 V
Channel 2	Enabled	DC	1x	0 V	0 V	1 V
Channel 3	Disabled					
Channel 4	Disabled					

Reference Channels						
Name	State	Reference Mode	Source File Name	Source File Channel	Vertical Position	Volt Per Division
Reference 1	Disabled					
Reference 2	Disabled					
Reference 3	Disabled					
Reference 4	Disabled					

Reference Channels							
Name	State	Reference Mode	Source Circuit	Source Probe	Trigger Source Checked	Vertical Position	Volt Per Division

Additional Channels - FFT	
Name	FFT
State	Disabled

Additional Channels - Math	
Name	Math
State	Disabled

Channel Measurements Data				
Channel Name	VPP	RMS	Frequency	Period
Ch 1	9.894 V	3.49 V	- - - Hz	- - - s
Ch 2	3.002 V	1.302 V	- - - Hz	- - - s

We obtained the curve on the condition that the source voltage is a sinusoidal wave. From the image, we are able to summary 3 significant points.

The first one is that the voltage on channel 2 keeps zero when time is over half of the period (0.5 T~ T) and begins climbing in the next period. That is because the diode is reverse-biased after 0.5 T, and the diode is in cut-off region, so the voltage and the current passing it will be zero. When it reaches the next period, the diode is forward-biased because of the sign of input voltage diverting from negative to positive.

Before discussing about the second point, it is meaningful to define the functions of Source Voltage (equivalent to channel 1) and the cathode voltage of diode (equivalent to channel 2) as $F_{CH1}(t)$, and $G_{CH2}(t)$.

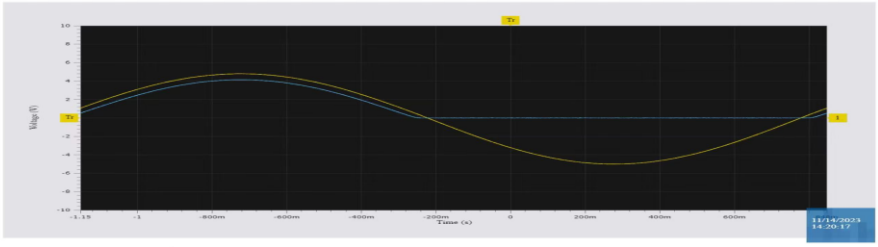
Thus, we are able to discuss about the second point in a lucid method. Based on the image we showed above, we can discover that the zeros of $F_{CH1}(t)$ and that of $G_{CH2}(t)$ are not coincided. The phenomenon mainly attributes to the existence of the turn-on voltage of a diode as I mentioned in previous parts. In other words, the distance

between two zeros in the same order (1st zero of $F_{CH1}(t)$ and 1st zero of $G_{CH2}(t)$) is the time that the diode voltage reaches its Vγ.

Ultimately, the third point is that we can find that when the difference between voltage on CH1 and CH2 is seemingly a definite value. To explore it, we first need to know what it represents. By applying Kirchhoff Voltage Law, the voltage discrepancy is the voltage of diode. Next, we take t=0.5 T as an example, and find that the voltage difference is about “4.85 V-3.00 V=1.85 V”. After that, we must keep in mind that the diode here is not an ordinary diode, but a LED. Common sense tells us that the turn-on voltage of LED is ranging from 1 V to 3 V. Obviously, the voltage here is rational.

b) Replace the LED with a Normal Diode && Configure the Oscilloscope

We substitute Red LED for a normal diode, and repeat the process.



General Settings	
Trigger Type	Analog edge
Trigger Source	Channel 1
Trigger Slope	Rising
Trigger Level	0 V
Time Per Division	200 ms
Sampling Mode	Decimate
Repetitive Sampling Mode	Off

Advanced Trigger Settings	
Acquisition Delay	Disabled
Trigger Position	-152.5 ms

Channels						
Name	State	Coupling	Probe Attenuation	Vertical Offset	Vertical Position	Volt Per Division
Channel 1	Enabled	DC	1x	0 V	0 V	2 V
Channel 2	Enabled	DC	1x	0 V	0 V	2 V
Channel 3	Disabled					
Channel 4	Disabled					

Reference Channels						
Name	State	Reference Mode	Source File Name	Source File Channel	Vertical Position	Volt Per Division
Reference 1	Disabled					
Reference 2	Disabled					
Reference 3	Disabled					
Reference 4	Disabled					

Reference Channels							
Name	State	Reference Mode	Source Circuit	Source Probe	Trigger Source Checked	Vertical Position	Volt Per Division

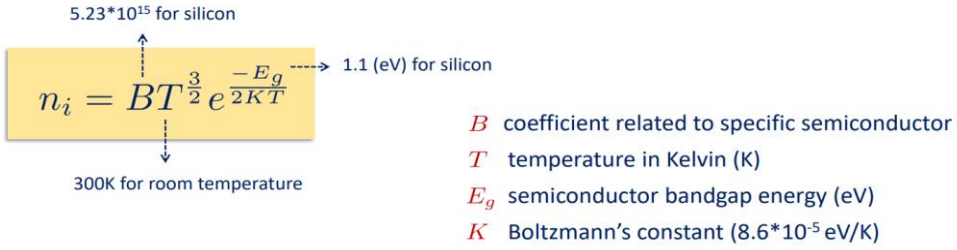
Additional Channels - FFT	
Name	FFT
State	Disabled

Additional Channels - Math	
Name	Math
State	Disabled

Channel Measurements Data				
Channel Name	VPP	RMS	Frequency	Period
Ch 1	9.65 V	3.467 V	- - - Hz	- - - s
Ch 2	4.199 V	2.003 V	- - - Hz	- - - s

The main findings are totally the same as that of LED, only the turn-on voltage Vγ has changed. In this situation, its value is “0.52 V-0.22 V=0.30 V” (take x=0). However, the Vγ may be the parameter of diodes made by germanium instead of silicon (the material of Diode 1N4001). That is not what we expect.

Here we categorize the measuring error into 2 groups. The first group is systematic error. It is entirely possible that the diode we fetched was aged, causing the internal resistance increase. Perhaps, the resistance of the probe is inappropriate, leading to the abnormality of the result. The second group is random errors. I would like to focus on the factor called temperature, for the reason that when we touch the diode, contributing to diode’s change in temperature. We know that every diode has its turn-on voltage Vγ. Actually, Vγ makes sure the carriers in diode pass through PN junction to the load line. What we learnt in EEE109 Chapter 1 can explicitly explain my thoughts.

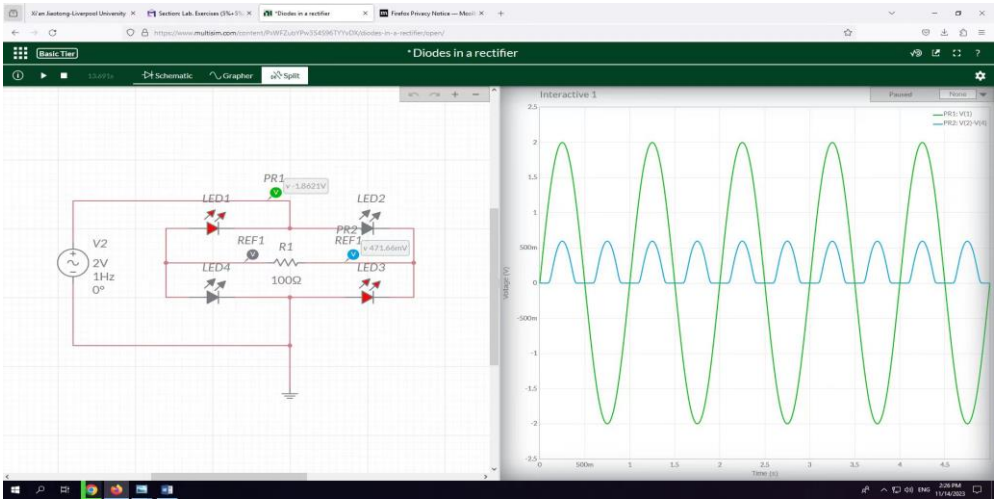


The formula shows how to calculate the intrinsic carrier concentration. As the temperature rises by the heat transfer from our hands, parameter T increase, and the width of forbidden gap decrease which illustrates the same thing of decrement in E_g, so the value of n_i increase. In other words, the degree of diffusion multiplies, and the motion of carriers become more intense. It is easier for them to get rid of PN junction and access to the load line, thus resulting in the dwindle of Vγ.

- Section 3: Diodes in a Rectifier

  a) Full-wave Rectifier

  We follow the steps and caught the graph as below.



By setting the bridge rectifier with 4 diodes, the diode can work in the whole period except the time waiting for the voltage reaching V_S - 2 Vγ.The struct of the circuit is highly coincided with Chapter 2 of EEE109.

5. Conclusion

In summary, this lab covers some basic behaviors of diodes which are electrical characteristic (turn-on voltage Vγ), unidirectional conductivity, roles as rectifiers in industry. Most of the results are reliable, except that in the second part of section 2. After my analysis, I am inclined to the random error which is the variation in heat. The error alerts us that we students are ought to be careful with elements, because any minor mistake can lead to errors in the measurement. Also, this lab helps us review what we have studied in Chapter 2, and strengthen our key capability of team-work spirit which may be crucial in our future. Finally, our team generally reaches the goal annotated on the lab script, and provide we students opportunities to work and reflect.