# ECSE 331: Electronics
# Laboratory Report

## Laboratory Experiment#4

Silicon Diodes and Their Applications

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Lab Section 6, Wed. 1:35-3:35PM

Submitted:

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# Laboratory Experiement#4

## Silicon Diodes and Their Applications

*Abstract*— The purpose of laboratory experiment number four, was to explore the functions of Silicon Diodes. Three types of diodes were used to build various circuits. And their behaviors were tested in the forward and reverse biased region as well as in the breakdown region. Experimental results showed that the diodes have a voltage drop of around 0.7V at the forward biased region. Results also confirmed that a diode used in series with a voltage source, creates a rectifier. In the introduction the results will be discussed further.

### I. Introduction

The goal of this laboratory was to test, and explore the behavior of the different diodes and diode circuits with the NI Elvis-II test instrument. More specifically, the behavior of the diodes and was tested at the forward, reverse and breakdown region. The laboratory consisted in the first part finding the forward biased region voltage drop, and its behavior. In the second part, the effect of the temperature on the diode operations was found, then the I-V characteristic of the Zener diode was analyzed. Finally, Different circuits such as a rectifier, voltage regulator and limiter circuit were built and their behavior analyzed. In the main body of this lab report the results for each of the circuits analyzed will be presented in a clear and concise manner.

### II. Main Body

We conducted several experiments with the different silicon diodes, mainly the NI4148 signal diode and the IN5333A 3.3V Zener diode, to test, explore the behavior of the different diode circuits and their limitations.

**A.** I-V characteristic of Signal Diode Using Curve a Tracer
**B.** Diode Temperature Effects
**C.** Zener Diodes
**D.** Rectifier circuit
E. Voltage Regulator Using Zener Diode
F. Limiter Circuit Using Diodes

#### *A. I-V Characteristics Using Curve Tracer*

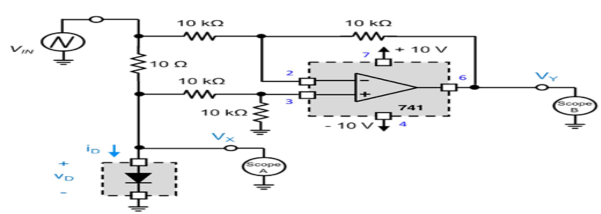



**Fig1. Ciruit digram for I-V characteristic used in part A**

I. The voltages Vx and Yy in figure 1 were calculated for various input voltages ranging from $1V_{p-p}$ to $7V_{p-p}$ and the results are presented in the following table. Vin is a sawtooth wave.

| $V_{in\ peak\text{-}peak}$ | Vx | Vy |
|---|---|---|
| 1v | 1 | 1 |
| 2v | 1.70 | 1.3 |
| 3v | 2.30 | 1.4 |
| 4v | 2.79 | 1.56 |
| 5v | 3.4 | 1.69 |
| 6v | 3.9 | 1.69 |
| 7v | 4.4 | 1.69 |

Table 1: Vx and Vy as a function of Vin

II. The two-wire analyzer of the NI-Elvis instrument was used to draw the I-V characteristic for the 1N4148 Diode, since we couldn't trace the I-V curve accurately using the Elvis instrument, and the results were very promising, they showed that starting at 0.5v the diodes lets currents pass and at 0.7V it grows very fast. Thus, as expected the in the forward based the diode has a voltage of around **0.65V, the cut-off voltage. Slope of the I-V curve** is 9mA/0.2v= **0.045.**

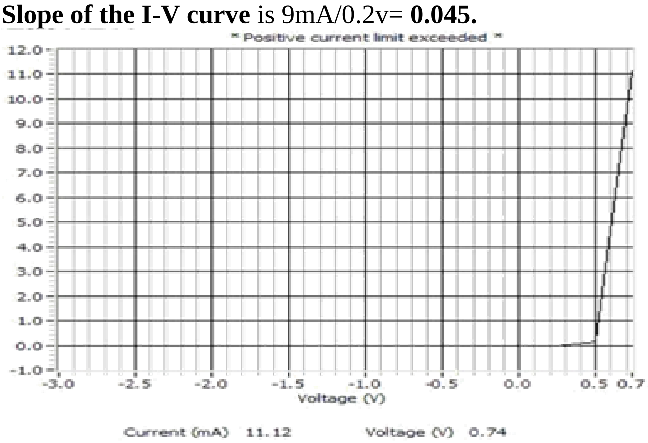



**Fig2.I-V characteristic curve for 1N4148 diode**

#### *B. Diode Temperature Effects*

The 1N4148 diode's I-V curve will be measured with two-wire analyzer at different temperatures, theoretically for higher temperature the voltage drop for the forward biased region should shift to the left by 2mV/ C.

I. 1N4148 Diode's behavior at room temperature:

Using the two-wire analyzer, we observe that the current shoots up around 0.7V. That is in complete agreement with the theory, which states that the diode starts letting large current flow at around 0.7V. Figure 3 shows the I-V characteristics of the 1N4148 diode at room temperature (~23 degrees).

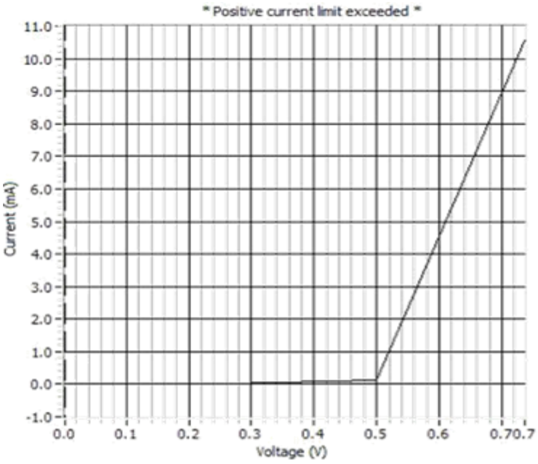



**Fig3. I-V Characteristic curve for the diode at 23 degrees**

II. 1N4148 Diode's behavior at 47 degrees:

Theoretically the I-V curve for the diode is supposed to shift to the left by 2mV/ degree C. As the curve in figure 4 show, the point at which forward current can flow has indeed shifted left and current can start flowing through diode at lower voltage than before. Thus, the increasing temperature, decreases the point where current starts flowing. (barrier voltage is lowered)

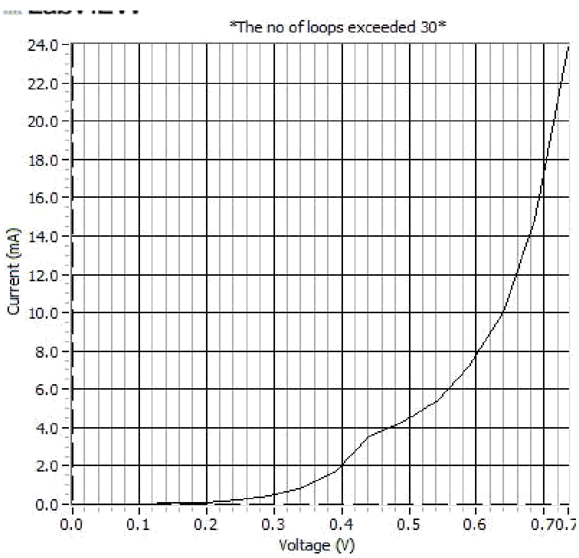



**Fig4. I-V characteristic of the diode at 47 degrees C**

III. 1N4148 Diode's behavior at 1 degrees:

From the theory, we know that if we lower the diode temperature there are going to be less thermally generated holes and free electrons to conduct electricity. This will result in a higher voltage barrier. So theoretically, as we decrease the temperature, the I-V curve should shift to the right. And that's what it does. The curve in figure 5 shows our results.

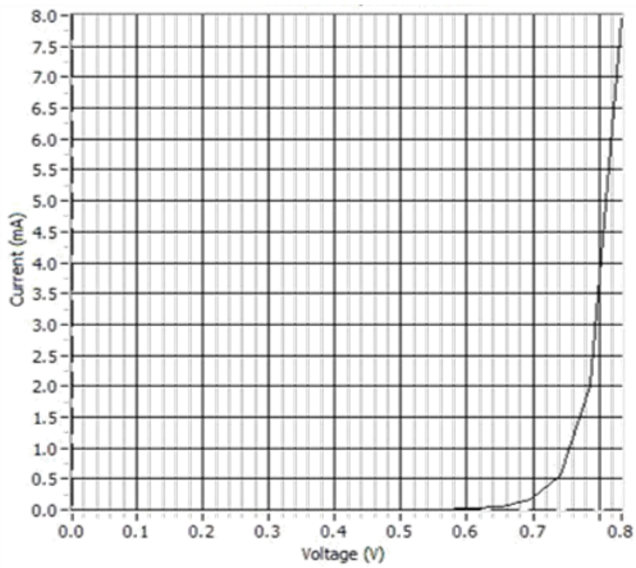



**Fig5. I-V characteristics of the diode at 1 degree C**

IV As was explained earlier, from diode theory, we know that its behavior changes with temperature, as temperature increases the I-V curve shifts to the left, so the barrier voltage is lowered and when the temperature is decreased, the curve shift to the right, which means the barrier voltage is increased. This follows from the fact that as the temperature increases, we have more thermally generated holes and free electrons, this will decrease the voltage barrier at the PN junction. Which causes the diode to conduct current at lower voltages.

### *C. Zener Diodes*

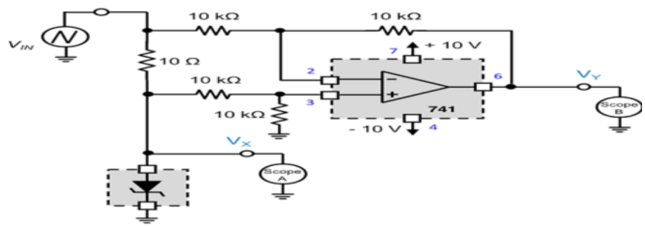



**Fig6. Circuit diagram used in part C**

I.For the Zener diode in the configuration of figure 6, we applied a sawtooth input signal and varied the amplitude. The corresponding voltages for Vx and Vy are recorded in the following table

| $V_{in\ peak\text{-}peak}$ | Vx | Vy |
|---|---|---|
| 1v | 1 | 1 |
| 2v | 1.75 | 1.3 |
| 3v | 1.85 | 1.46 |
| 4v | 1.87 | 1.56 |
| 5v | 1.89 | 1.60 |
| 6v | 1.9 | 1.62 |
| 7v | 1.9 | 1.64 |

**Table 2: Vx and Vy as a function of a sawtooth signal Vin**

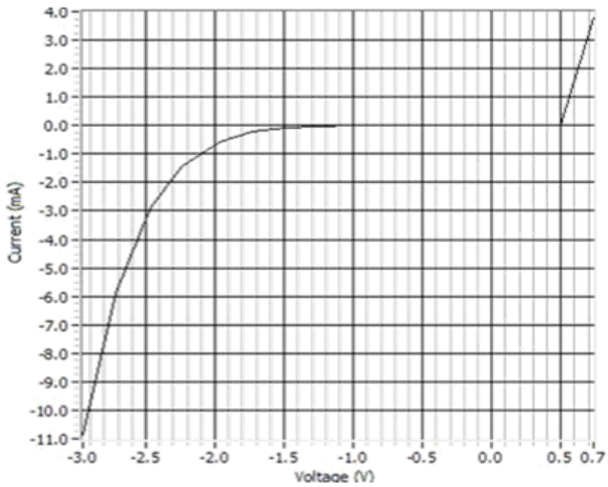


**Fig7. Zener Diode I-V characteristic Using two-wire analyzer**

II. As the I-V curve in figure 7 show, the Zener diode starts conducting large current when Vz is below a certain voltage, in this case that seems to be around -2.5V. Thus the Zener diode breakdown happens around a voltage of -2.5V.

The AC resistance inside the breakdown region is 1/slope of the breakdown region. Slope= (-3mA- -11mA)/(-2.5v- -3V) Slope= 0.016, $r_{z=}$62.5 Ohms.

### *D. Rectifier Circuit*

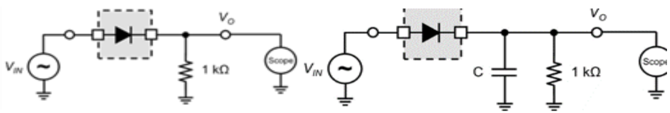


**Fig8a. Half rectifier circuit** **fig8b.Half rect with capacitor**

**I**. When the half-wave rectifier of figure 8s is built and an input of 60Hz, 5V sin is applied, the output will be rectified, it will only have positive values at the output. As it can be seen in figure 10, the voltage of the output goes from 0v to 2.836 Volts. (in figure 10, ch1 is input and ch0 is output)

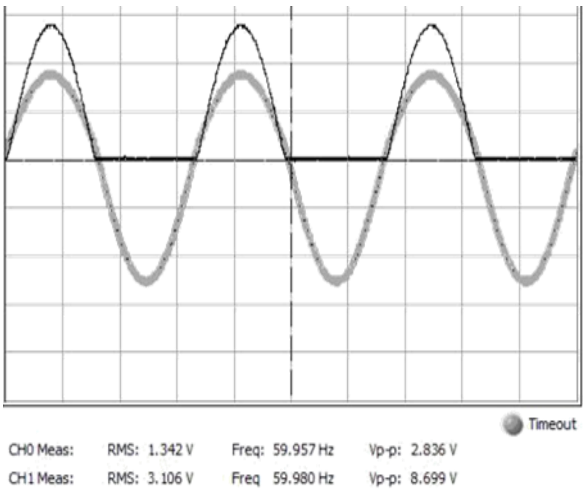


**Fig10. Vin and Vo for the rectifier circuit in fig8**

**II.** For the circuit in figure 8b, with the same voltage as in part I, the graph for Vin and Vo is pretty much the same as in part I, Vo is only the positive current, and its peak is a bit lower than in part I, as it can be seen in figure 12.

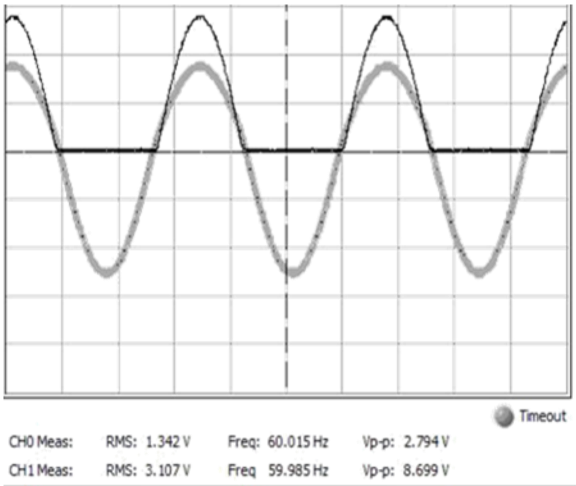
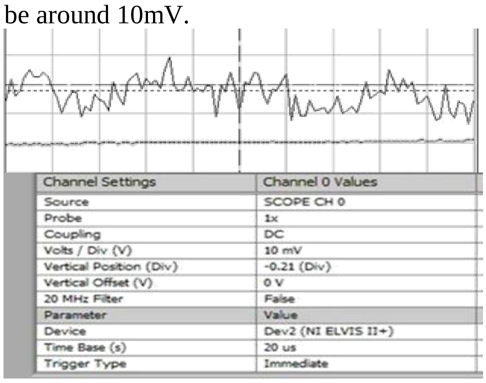


**Fig11.Vin and Vo for the half rectifier with capacitor**

**III.** As we can see on the graph in figure 12, there are some ripples present in the output signal. From the graph, the frequency of the ripples was calculated to be around 4/20uS=200KHz. The amplitude of the ripple was measured to be around 10mV.



| Channel Settings | Channel 0 Values |
|---|---|
| Source | SCOPE CH 0 |
| Probe | 1x |
| Coupling | DC |
| Volts / Div (V) | 10 mV |
| Vertical Position (Div) | -0.21 (Div) |
| Vertical Offset (V) | 0 V |
| 20 MHz Filter | False |
| Parameter | Value |
| Device | Dev2 (NI ELVIS II+) |
| Time Base (s) | 20 us |
| Trigger Type | Immediate |

**Fig12. Graph of Vo ripples**

IV. If we increase the capacitance to 100nF and repeat the same experiment, the peak amplitude of the output function decreases to around 1.293V. It goes from 0 to 1.293V, as can be seen in the graph in figure 13 below.

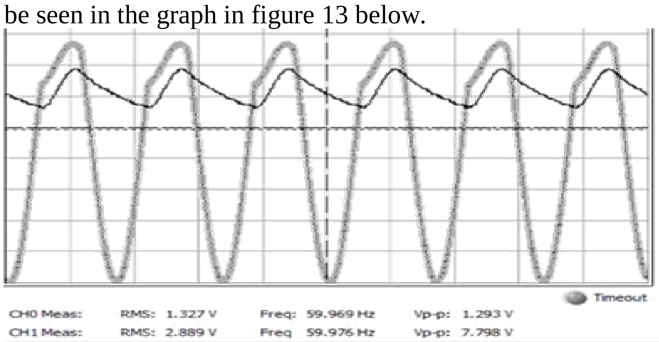


**Fig13. Graph of Vo and Vi for rectifier with 100uF capacitor**

V. For the half-rectifier with 100nF capacitor, ripple amplitude is around 5mV, so less than when a 1uF capacitor was used, and also the frequency of the ripples is 2/(200uS)=10KHz, which is less than for a 1uF capacitor.

VI. An equation that relates the frequency of the ripple to the current in the circuit, the capacitance used and the peak-peak value of the ripple is given by Vpp= I/fC

Using this formula, we get a ripple frequency of 250KHz when a 1uF is used and of 15KHz when 100uF capacitor is used. Our data relate closely to these results.

### *E. Voltage Regulation Using Zener Diode*

Testing two ways to reduce a DC level from a fixed DC supply.

I. Using the half-rectifier circuit in top circuit in figure 14: The circuit was built in a way to give 3.3V at Vo, R1 was chosen to be 340 ohm and R2 was chosen to be 660 Ohm.

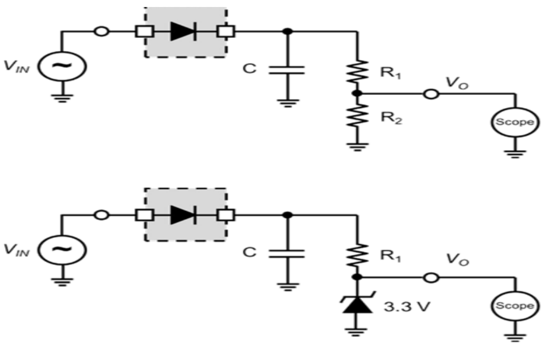



**Fig14. Circuit diagram for half rectifiers using diode and Zener diode**

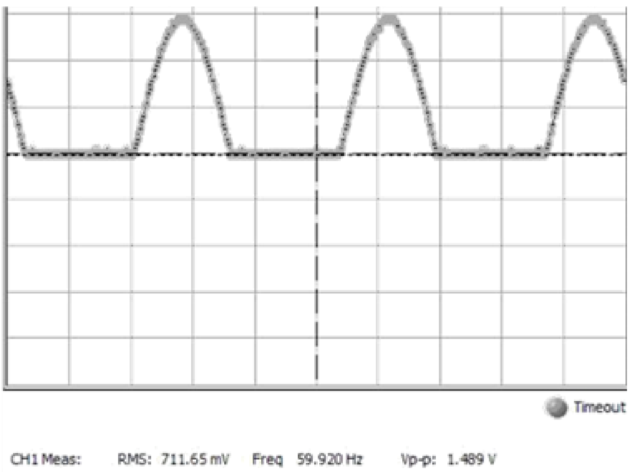
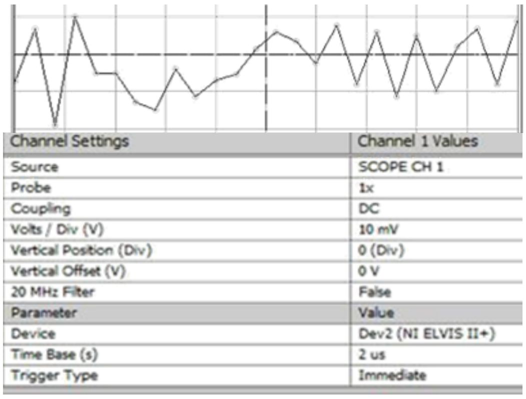



**Fig15. Vo for the half-rectifier where R1=340 Ohm and R2=0.66Ohm**

II. As the graph in figure 15 show, the rectifier signal has an amplitude going from 0 to 1.49V. The average value is 1.49V/(PI/2)= 1.49V*0.6366= 0.948V.

The amplitude of the ripples is on average 10mV and the frequency the ripples is around 1MHz. Figure 16 shows the above results.



| Channel Settings | Channel 1 Values |
|---|---|
| Source | SCOPE CH 1 |
| Probe | 1x |
| Coupling | DC |
| Volts / Div (V) | 10 mV |
| Vertical Position (Div) | 0 (Div) |
| Vertical Offset (V) | 0 V |
| 20 MHz Filter | False |
| **Parameter** | **Value** |
| Device | Dev2 (NI ELVIS II+) |
| Time Base (s) | 2 us |
| Trigger Type | Immediate |

**Fig16. Amplitude of the ripples and their frequency**

Fig.19 graph for sin wave with amplitude of 1.5

Fig20. Graph for sin wave with amplitude of 2v

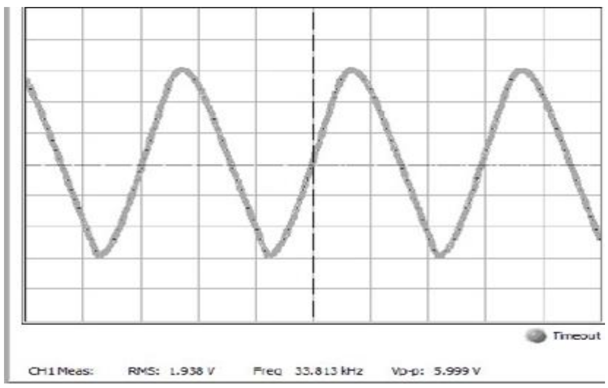



FIG21. GRAPH FOR SIN WAVE WITH AMPLITUDE OF 3V

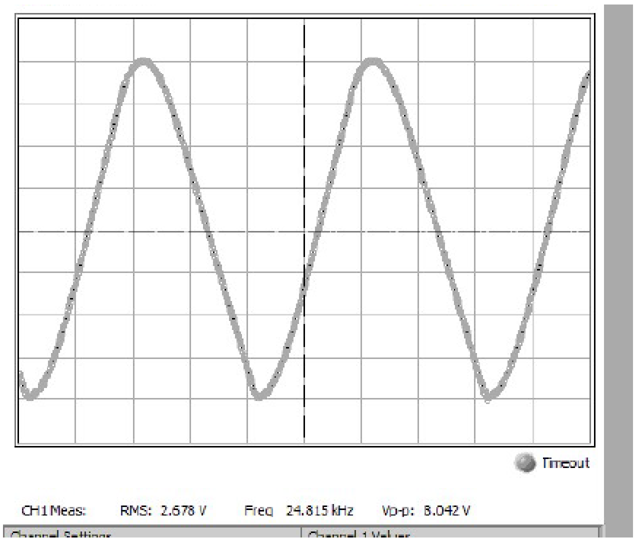



Fig22.Graph for sin wave amplitude of 4v

## Conclusion

To conclude, this lab was very helpful and eye opening because various Op-Amp circuits were built and their behavior observed, and this created a contrast with everything learnt in the classroom. We saw in this lab that an op-amp contrary to its ideal model has an offset voltage, and small currents entering its inputs. So we found experimentally that op-amps have biased input currents and offset currents.

In this lab, the experiments also showed that amplifiers, have a finite bandwidth, so their gain is dependent on frequency. At frequency higher than the 3dB frequency, the gain of the op-amps decrease. It was also observed that if the input is too big, the output will be distorted. The slew Rate was found.