Lab 2 Zener Diodes

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Objectives:

1. Measure the effects of forward and reverse bias on current in a zener diode
2. Determine and graph the volt ampere characteristic of a zener diode
3. Construct a zener voltage regulator and experimentally determine the range over which the zener maintains a constant output voltage

Procedure:

1. We gathered the materials that we needed in order to complete the lab including:
   a. Variable DC power supply
   b. Breadboard
   c. NI Multisim 14.1
   d. DMM (2)
   e. 3.3kΩ ½-W Resistor
   f. 500Ω 5-W Resistor
   g. 250Ω 10-W Resistor
   h. 1kΩ Variable resistor
   i. 1N4740A Zener diode
   j. Wire

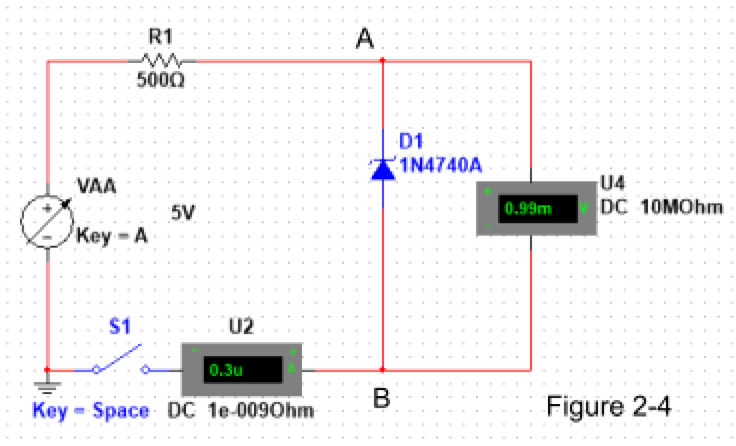


Figure 2-4

2. We set up the circuit shown in Figure 2-4 on multisim and on a breadboard, for the diode we used a 1N4740A zener in multisim and a 1N4740A zener on the breadboard. The voltage on V_{AA} is set to 0 volts

3. Next we measured different values throughout the circuit as different variables were given to us. These values are recorded in Table 2-1. The values that were already given are typed in bolded font. We divided the voltage across the diode by the circuit current in order to find the resistance of the Zener diode, Resistances are showing as UNDEFINED because we would have to divide by zero to find the actual ohmage value. In multisim, the resistance values read 10MΩ because that was the resistance of the voltmeter when the data was recorded. The value of physical was zero because on the physical portion the value was too small to be measured by the multimeter.

Step	Multisim V_{AB}(V)	Multisim I(mA)	Multisim R_Z(Ω)	Breadboard V_{AB}(V)	Breadboard I(mA)	Breadboard R_Z(Ω)
2	**0**	0	UNDEFINED	**0**	0	UNDEFINED
3	**2**	0.0002	10000000	**2**	0	UNDEFINED
4	**4**	0.0004	10000000	**4**	0	UNDEFINED
4	**6**	0.0006	10000000	**6**	0	UNDEFINED
4	**8**	0.0008	10000000	**8**	0	UNDEFINED
5	9.94	**2**	4969	9.47	**2**	4735

Table 2-1

4. After recording these values we then recorded the value of the voltmeter and the resistance of the zener diode at various current ranges in Table 2-2

Step	Multisim V_{AB}(V)	Multisim I(mA)	Multisim $R_Z(\Omega)$	Breadboard V_{AB}(V)	Breadboard I(mA)	Breadboard $R_Z(\Omega)$
2	9.96	**5**	1992.00	9.53	**5**	1906.00
3	9.98	**10**	998.00	9.58	**10**	958.00
4	10.00	**20**	500.00	9.69	**20**	484.50
4	10.01	**30**	333.67	9.80	**30**	326.60
4	10.02	**40**	250.50	9.92	**40**	248.00
5	10.02	**50**	200.40	10.02	**50**	200.40

Table 2-2

5. Next we turned off the circuit by disconnecting the switch. Then we reversed the polarity of the zener diode so that it was now forward biased in relation to the applied voltage
6. We then recorded the current of the circuit and the resistance of the zener diode at certain voltages across the diode while the diode was in forward bias on multisim and on a breadboard in Table 2-3. Resistances are showing as UNDEFINED because we would have to divide by zero to find the actual ohmage value. In multisim, the resistance values read 10MΩ because that was the resistance of the voltmeter when the data was recorded .The value of physical was zero because on the physical portion the value was too small to be measured by the multimeter.

Step	Multisim V_{AB}(V)	Multisim I(mA)	Multisim $R_F(\Omega)$	Breadboard V_{AB}(V)	Breadboard I(mA)	Breadboard $R_F(\Omega)$
8	**0.0**	0	UNDEFINED	**0**	0.0	UNDEFINED
8	**0.1**	0.00001	10000000.00	**0.1**	0.0	UNDEFINED
8	**0.2**	0.00003	6451612.90	**0.2**	0.0	UNDEFINED
8	**0.3**	0.00670	523560.20	**0.3**	0.0	UNDEFINED
8	**0.4**	0.01800	22222.20	**0.4**	0.0	UNDEFINED
8	**0.5**	1.26000	396.88	**0.5**	1.3	390.60
8	**0.6**	59.00000	10.20	**0.6**	58.7	10.22
8	**0.7**	2998.00000	0.20	**0.7**	2987.0	0.20

Table 2-3

7. Next we used google sheets to create charts of the data we collected. The 8 charts are all labelled 2-1 and their meanings are marked with the corresponding letter below.

a. Circuit current versus the voltage across the zener diode (Multisim)

b. Circuit current versus the voltage across the zener diode (Breadboard)

c. Expanded graph of the diode's function in reverse bias (Multisim)

d. Expanded graph of the diode's function in reverse bias (Breadboard)

e. Diode resistance versus voltage across the diode in forward bias (Multisim)

f. Diode resistance versus voltage across the diode in forward bias (Breadboard)

g. Diode resistance versus voltage across the diode in reverse bias (Multisim)

h. Diode resistance versus voltage across the diode in reverse bias (Breadboard)

8. Next we constructed the circuit in Figure 2-5 on a breadboard and in Multisim, originally the voltage of V_{AA} was set to 0
9. We then used Table 2-4 to demonstrate the voltage from point A to point B, the applied voltage, and total circuit current when the current across the diode was equal to 20mA as well as the current across the diode, the total circuit current, and the applied voltage when the voltage from point A to point B was

Chart 2-1A Volt Ampere Characteristic of Diode in Multisim

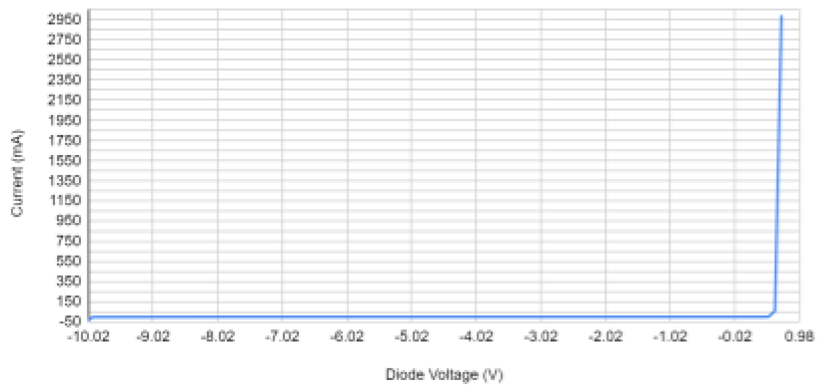


Chart 2-1B Volt Ampere Characteristic of Diode on Breadboard

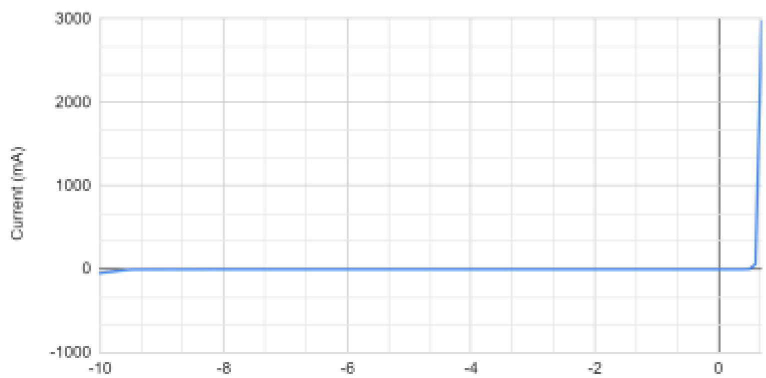


Chart 2-1C Diode Current Vs. Voltage in Reverse Bias On Multisim

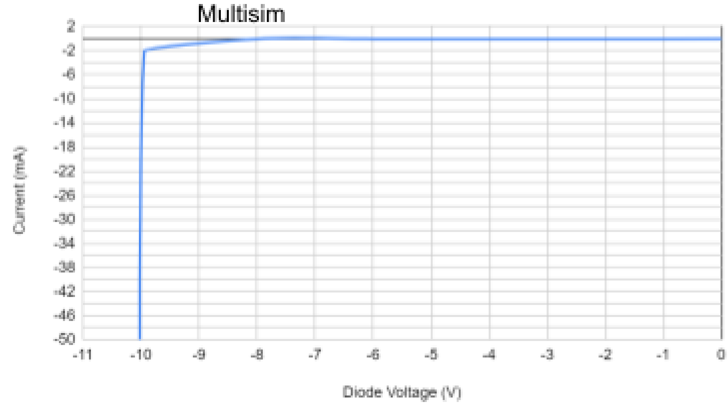
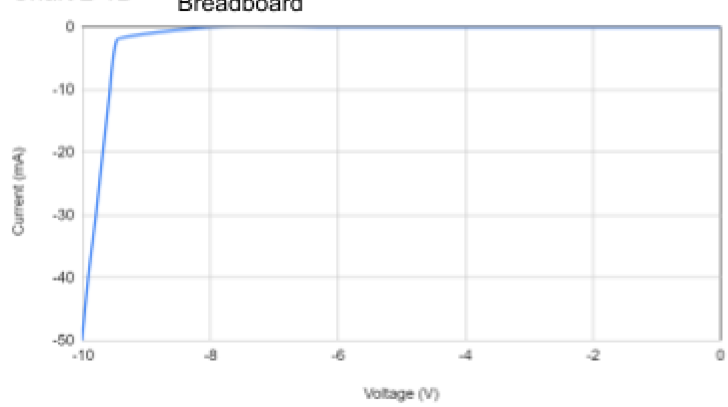
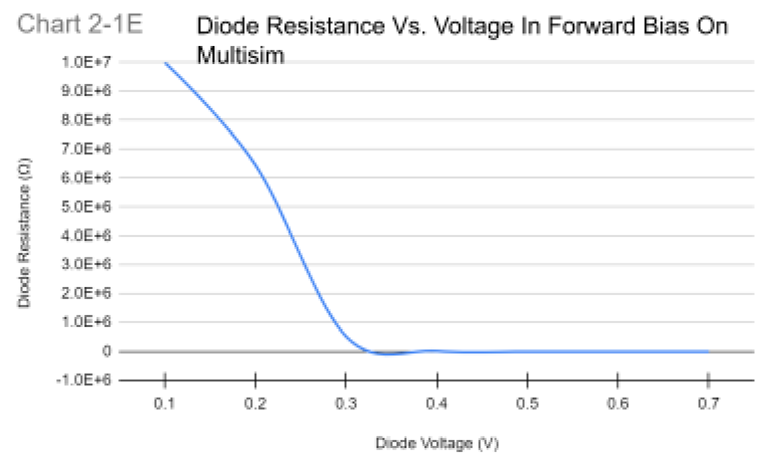
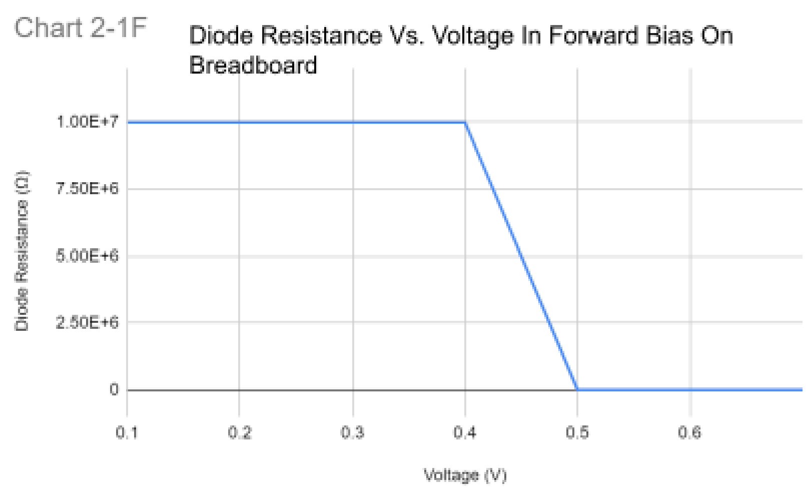


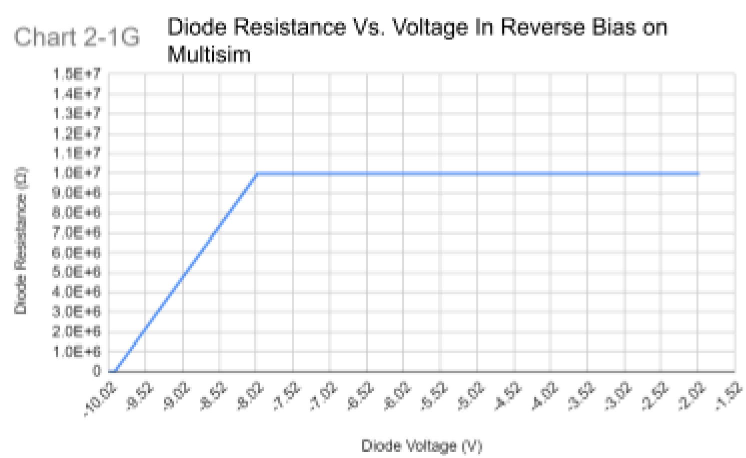
Chart 2-1D Diode Current Vs. Voltage In Reverse Bias on Breadboard

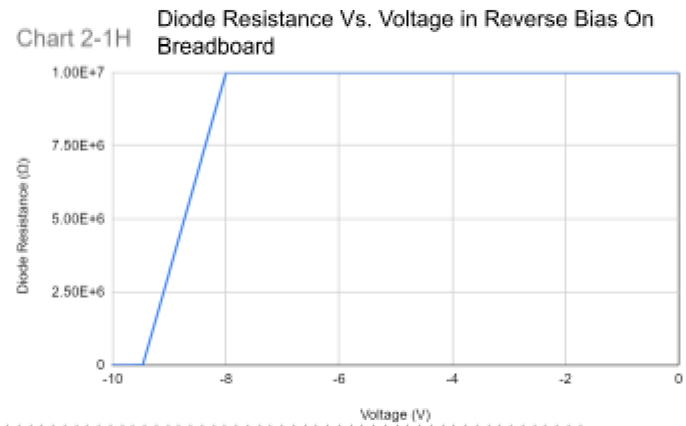


0.1v higher and 0.1v lower. We recorded this data for Multisim and on a breadboard.









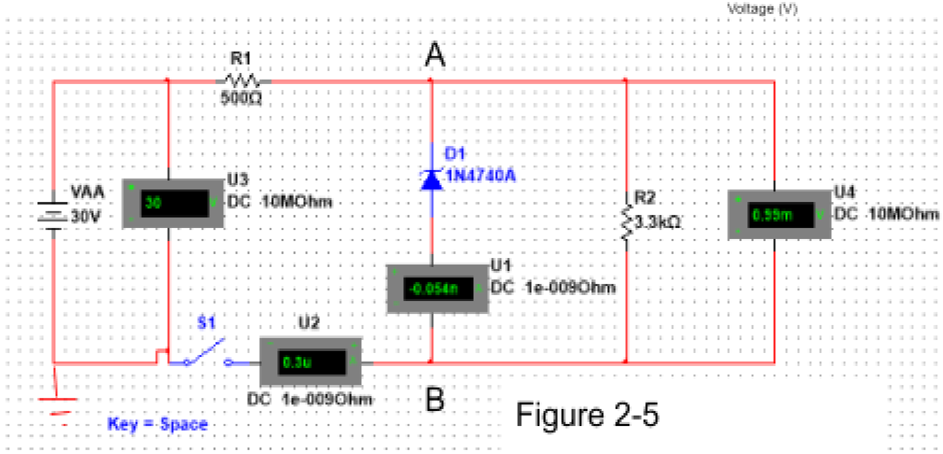


Figure 2-5

Step		Multisim V_{AB}(V)	Multisim I_Z (mA)	Multisim I_T (mA)	Multisim V_{AA}(V)	Breadboard V_{AB}(V)	Breadboard I_Z (mA)	Breadboard I_T (mA)	Breadboard V_{AA}(V)
11	V_{AB}	10.00	**20.00**	23.00	21.30	10.03	**20.00**	20.97	21.20
12	V_{AB}+0.1	10.10	63.00	50.40	35.40	10.10	67.30	46.60	34.50
1	V_{AB}-0.1	9.90	0.49	3.49	11.65	9.90	0.52	3.70	15.30

Table 2-4

10. Next we constructed a 10V voltage regulator circuit using the 1N4740A diode a constant 30VDC voltage source a 250Ω 10W resistor and a 1kΩ

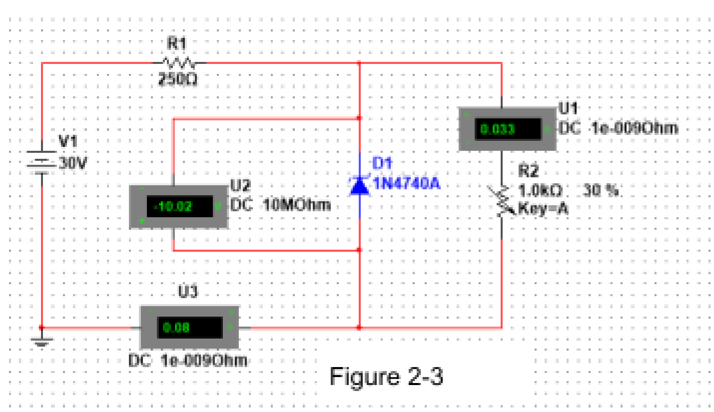


Figure 2-3

Variable resistor, this Circuit is Shown in Figure 2-3

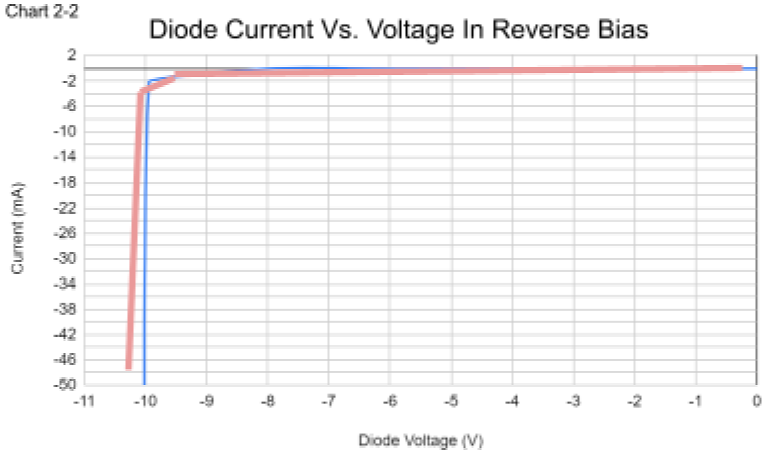
11. We then used Table 2-5 to demonstrate the values in the circuit at different load currents

Step	Multisim V_{AA}(V)	Multisim R_S (Ω)	Multisim I_L(mA)	Multisim R_L(Ω)	Multisim V_{OUT}(V)	Breadboard V_{AA}(V)	Breadboard R_S (Ω)	Breadboard I_L(mA)	Breadboard R_L(Ω)	Breadboard V_{OUT}(V)
14	30	250	**10**	1,000	10.03	30.00	250	**10**	1,000	10.02
14	30	250	**20**	500	10.03	30.00	250	**20**	500	10.03
14	30	250	**30**	300	10.02	30.00	250	**30**	300	10.02

Table 2-5

12. We next graphed the voltampere characteristic of the diode in the zener region in comparison to Chart 2-1C by overlaying the two characteristics. This chart is labelled Chart 2-2

Chart 2-2



Questions:

1. Compare the biasing of a junction diode with that of a zener diode in normal application.
    a. In forward bias, a zener diode works exactly the same as a junction diode would, however, in reverse bias the zener diode has a zener voltage unlike the junction diode. This allows the zener diode to create current flow in reverse bias when the zener voltage is reached without damaging the component. The voltage that is output by the diode in reverse bias will always remain around the zener voltage.
2. Compare the characteristic of Chart 2-1A with the characteristic of Figure 2-2 which represents the theoretical characteristic of a zener diode. Explain the differences.

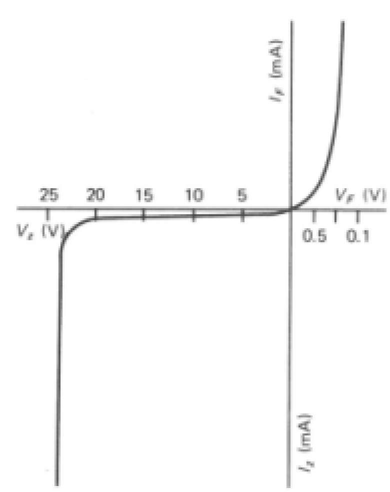


Fig. 2-2.

   a. The most noticeable differences between the two graphs are that the zener voltage in Figure 2-2 is much higher than that of Chart 2-1A, this means a different diode was most likely used. Another noticeable difference is the quality of the diode, it is easy to tell that Chart 2-1A has much sharper turning points to when the zener diode is activated while in Figure 2-2 the turning points have much smoother curves which means that it took longer for the zener diode to activate and the voltage didn't stay as consistent as the voltage on the zener diode that we used.

3. Which portion of a zener diode characteristic is most useful for voltage regulator applications? Why?
   a. The most useful portion of the zener diode characteristic is the portion where the diode is working in reverse bias because when the zener voltage is reached while a zener diode is working in reverse bias, the output of the zener diode will be as consistent as it can to stay at the zener voltage, and continuing to regulate voltage
4. A. What is the significance of the Chart 2-1C? B. How can Chart 2-1C be used to design a voltage regulator using a 10v zener diode?
   a. The significance of Chart 2-1C is that it details how the zener diode works while in reverse bias to the applied voltage.
   b. Chart 2-1C can be used to create a voltage regulator using a 10v zener diode by examining how steep the curve is after the zener voltage has been reached. This is because there are multiple different part numbers that can be used to decide on which zener diode should be applied. Each diode has a different quality and this quality can be seen by looking at the steepness of the voltage output after the zener voltage has been reached in reverse bias, the steeper it is, the higher the quality.
5. Explain how the regulator circuit in Figure 2-5 works.
   a. The purpose of the 500Ω resistor is to limit the current before it reaches the diode, this way the circuit isn't blown due to too much current as the diode has no way to limit the current. The zener diode in the circuit is used to make sure that there is no output voltage drastically exceeding 10 volts as the diode is in parallel with the load so the voltage is equivalent. The 3.3kΩ resistor is used to demonstrate the load in the circuit.
6. Does the circuit in Figure 2-5 compensate for changes in circuit current and applied voltage? Explain.
   a. Yes, the voltage regulator in Figure 2-5 compensates for both voltage output regulation and Current output regulation. The functionality of the zener diode in reverse bias compensates for changes in apple voltage, and because the zener diode has no set resistance of its own the 500Ω resistor sets the current while the branch with the diode consumes the majority of it leaving an output current of 3mA.

Discussion:

Problem: In table 2-4 we were getting much higher values for the voltage that it took to turn on the diode than the values we were recording in multisim

Troubleshooting: In the physical portion of the lab we were measuring the voltage drop across the diode in figure 2-5 and we asked a groupmate on why the values between multisim and physical we're so different because in multisim we were reading 10 volts but in real life we were reading 20 volts across the diode.

Solution: They told us that we were using forward bias for the figure when in the lab we were supposed to use the diode in reverse-bias so that's why the numbers seemed to be at a much higher value then they were supposed to be.

Conclusion:

1. We measured the effects of forward bias on a zener diode in Table 2-3 where when the voltage across the zener diode increased linearly the amperage across the zener diode increased almost exponentially where at 0.1V the amperage across the zener diode was 0.01mA at 0.5V the amperage across the diode was 1.26mA and at 0.7V the amperage across the zener diode was 2.998A. We next measured the effects of reverse bias on a zener diode in tables 2-1 and 2-2 where we measured that when the voltage across the diode got closer to 10V the current across the diode increased drastically, however as the amperage went from 2mA to 50mA the voltage across the diode only increased from 9.94V to 10.02V
2. We determined and graphed the VoltAmpere characteristics of the zener diode in charts 2-1A and 2-1C. Chart 2-1A demonstrates the entire view of the characteristic where voltage is on the X-Axis and current is on the Y-Axis. We can see that in forward bias as until voltage increases to around 0.6V the current across the diode stays relatively low, after this point, however the current across the diode grows drastically, even being almost 3 Amps at 0.7V. On the negative side of the X-Axis, and on Chart 2-1C the reverse bias of the diode is demonstrated. We noticed that up until the voltage across the diode got to around 10V the current stayed relatively low, after this point, however, we see the current increase to an extreme while the voltage stays relatively close to 10V
3. We constructed a zener voltage regulator in Figure 2-5 where the zener diode was placed in reverse bias this way when the voltage across the diode exceeded 10V the voltage that the diode output remained around 10V. We figured out the range at which the diode worked in table 2-4. It showed that it was really easy to decrease the output voltage to below 10V. Originally to get the diode voltage to 10V the applied voltage needed to be 21.3V. To get the diode voltage to 9.9V we only needed to decrease the applied voltage to 11.65V, but to get the output voltage to 10.1V the applied voltage needed to be increased to 35.4V showing that the voltage regulator worked in an applied voltage range of greater than or equal to 20V.

1N4740A Datasheet:

Type	Nominal Zener voltage(3) at I_{ZT} V_Z V	Test current I_{ZT} mA	Maximum Zener impedance(1)			Maximum reverse leakage current		Surge current at $T_A = 25°C$ I_R mA	Maximum regulator current(2) I_{ZM} mA
			Z_{ZT} at I_{ZT} Ω	Z_{ZK} Ω	at I_{ZK} mA	I_R µA	at V_R V		
1N4740	10	25	7	700	0.25	10	7.6	454	91