Jacobs University Bremen

Electrical Engineering Module I

Fall Semester 2019

Lab Experiment – Single PN-Junction

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Place of execution	: Teaching Lab EE
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1. Introduction

The objectives of this experiment were as follows:

1. Understand polarity of diodes.
2. Understand the V-I relation of diodes in forward and reverse directions.
3. Understand the usage of Zener diode, in both, forward and reverse directions.

A diode is a specialized electronic component with two electrodes called the anode and the cathode. Most diodes are made with semiconductor materials such as silicon, germanium, or selenium. The fundamental property of a diode is its tendency to conduct electric current in only one direction. When the cathode is negatively charged relative to the anode at a voltage greater than a certain minimum called forward break over, then current flows through the diode. If the cathode is positive with respect to the anode, is at the same voltage as the anode, or is negative by an amount less than the forward break over voltage, then the diode does not conduct current. The forward break over voltage is approximately 0.6 V for silicon devices, 0.3 V for germanium devices, and 1 V for selenium devices.

Zener diodes are a special kind of diode which permits current to flow in the forward direction. What makes them different from other diodes is that Zener diodes will also allow current to flow in the reverse direction when the voltage is above a certain value. This breakdown voltage is known as the Zener voltage. In a standard diode, the Zener voltage is high, and the diode is permanently damaged if a reverse current above that value is allowed to pass through it. Zener diodes are designed in a way where the Zener voltage is a much lower value. There is a controlled breakdown which does not damage the diode when a reverse current above the Zener voltage passes through a Zener diode.

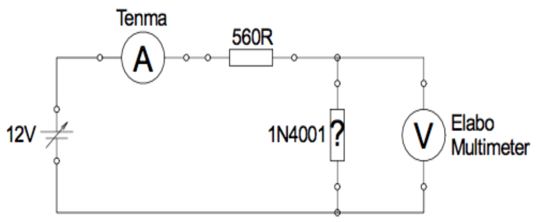
2. Execution

2.1 Experiment Setup

Workbench number 7

Used tools and instruments:
- TENMA multimeter
- ELABO multimeter
- Breadboard
- Wires
- Resistor decade box
- 560Ω & 470 Ω resistor
- 1N4001 diode
- BZX85C5V6 Z-diode

The objective of this experiment was to determine the polarity of a diode. The current in a diode flows from anode to cathode. If the given diode is forward biased then the voltage drop across it should be 0.6-0.7V as it's made from silicon and silicon diodes have the break over voltage of 06-0.7V. If the desired voltage shows at ELABO, then the part connected to positive terminal of supply is anode and the part connected to negative terminal of supply is cathode. The following circuit was set up:



The voltage across & the current through the diode was measured in both directions by changing the polarity of power supply.

2.1.2 Experiment Part 1 - Execution and Results

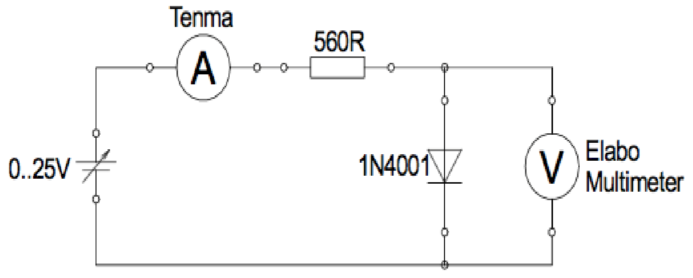
The results are summarized in the following table:

Direction	Voltage (V)	Current
Ring facing downwards	0.7269	20.36mA
Ring facing upwards	12.132	1.2uA

The results showed that if the ring side of diode was attached with the negative terminal of power supply then the diode is forward biased otherwise it is reverse biased. Hence, the ring side is the cathode terminal of the diode.

2.2.1 Experiment Part 2 – Setup

The circuit in this experiment was used the study the behavior and V-I characteristic of a forward based diode. The diode was connected in series with a 560Ω resistor. The power supply was varied to provide 0-40mA current to the diode and observe the trend. The circuit was assembled on breadboard. The schematic of the circuit assembled is as follows:

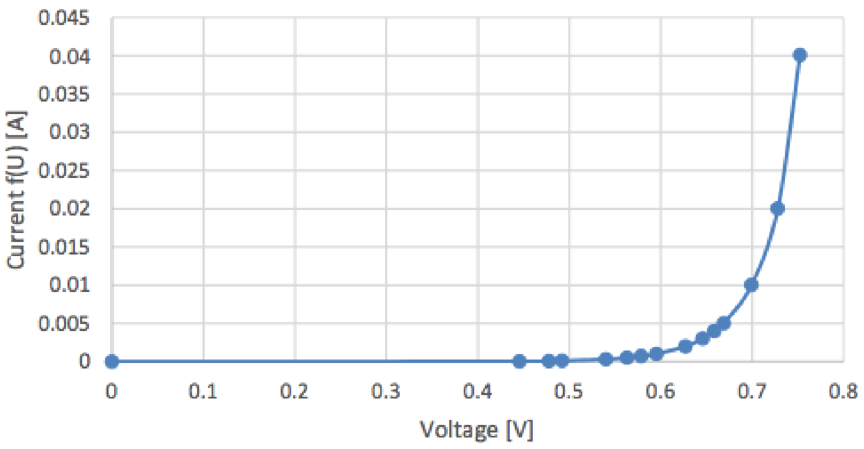


2.2.2 Experiment Part 2 – Execution and Results

The results are summarized in the following table:

Voltage (V)	Current (A)
0	0
0.4455	0.0000308
0.4777	0.0000669
0.4919	0.0000991
0.5400	0.0003004
0.5631	0.000501
0.5783	0.000698
0.5951	0.001
0.6269	0.00199
0.6458	0.00301
0.6585	0.00399
0.6688	0.00501
0.6990	0.01001
0.7278	0.02001
0.7522	0.0401

The graph of current against voltage was plotted. The following graph was obtained:

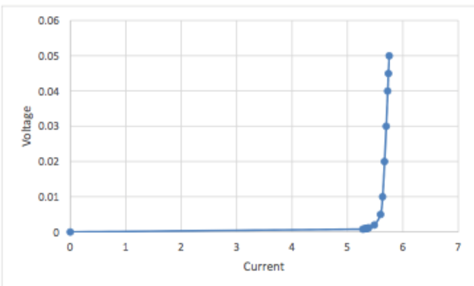


2.3.2 Experiment Part 3 – Execution and Results

The results are summarized in the following table:

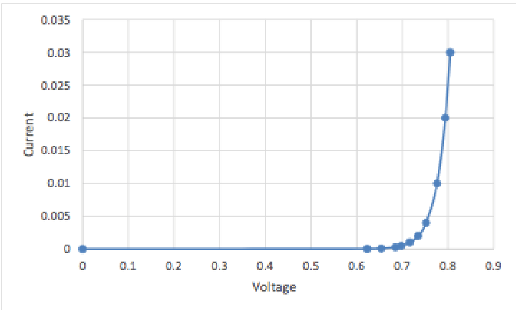
Voltage (V)	Current (A)
0	0
5.279	0.008
5.31	0.009
5.337	0.001
5.361	0.0011
5.382	0.0012
5.486	0.002
5.597	0.005
5.635	0.01
5.67	0.02
5.7	0.03
5.727	0.04
5.739	0.045
5.755	0.05

The following graph was plotted:



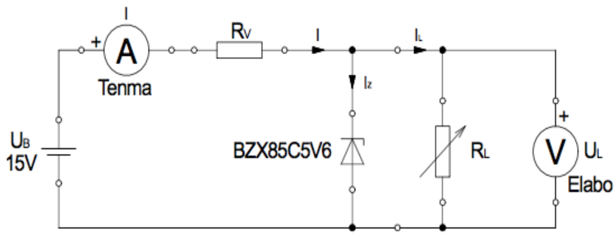
Reversing the polarity of the Zener diode, gave the following results:

Voltage (V)	Current (A)
0	0
0.623	0.00003
0.654	0.0001
0.685	0.0003
0.698	0.0005
0.716	0.001
0.734	0.002
0.752	0.004
0.776	0.01
0.794	0.02
0.805	0.03



2.4.1 Experiment Part 4 – Setup

In this experiment, the behavior of a Zener diode as a voltage regulator was studied. A constant voltage source was used. The current through the resistor which is attached in series with Z diode to limit current through Z diode is divided in Z diode and load resistor. The following circuit was assembled:



The Value of Rv = 850 Ω when Iz = 1mA
The Value of Rv = 470 Ω when Iz = 10mA

2.4.2 Experiment Part 4 – Execution and Results

The results are summarized in the following table:

Load Resistance (Ω)	Voltage (V)	Current (mA)	Rv (Ω)
56	0.926	16.45	850
560	5.432	11.24	850
5600	5.640	11.00	850
∝	5.647	10.99	850

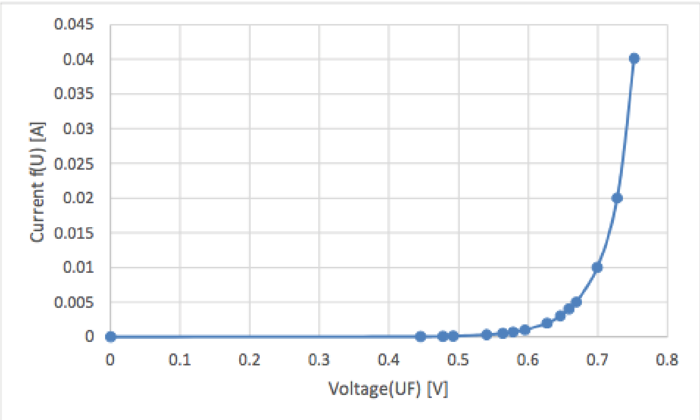
Load Resistance (Ω)	Voltage (V)	Current (mA)	Rv (Ω)
56	1.538	28.57	470
560	5.668	19.87	470
5600	5.667	19.86	470
∝	5.680	19.85	470

3. Evaluation

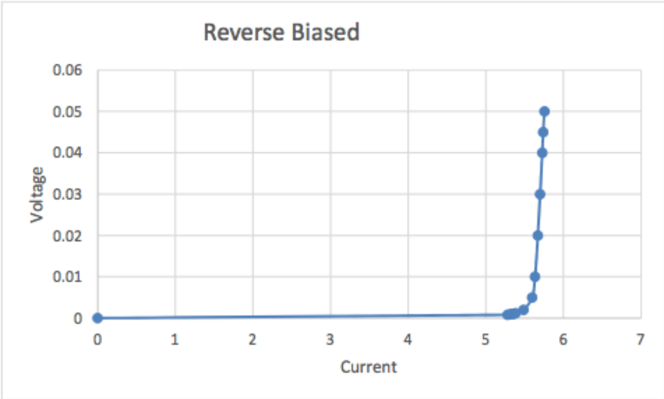
3.1 Evaluation Experiment Part 1

Anode is the black part and cathode is ring part. The current flows from anode to cathode in a diode. The result of the experiment showed that if the ring part was more negative than the black part only then the breakdown voltage across the diode was observed and a current was detected through the diode. However, this wasn't the case when the ring part was more positive than the black part. Hence, the ring is the cathode.

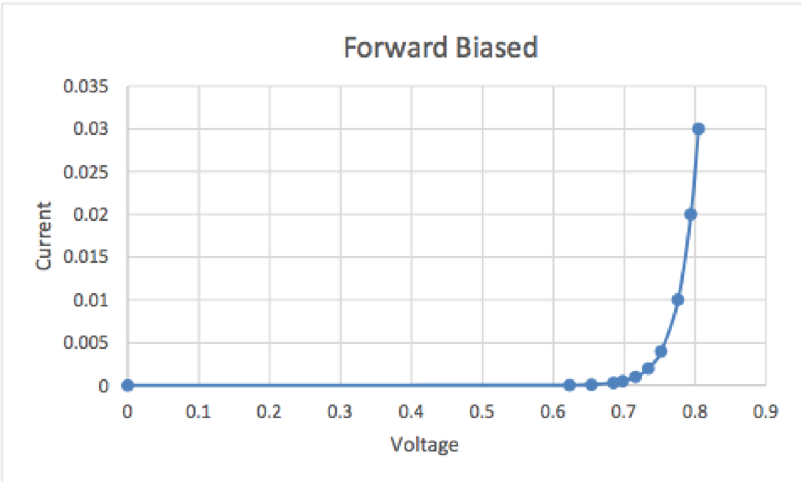
3.2 Evaluation Experiment Part 2



3.3 Evaluation Experiment Part 3



The breakdown voltage was 5.739V as shown by the graph.



In the forward biased state, it acts like a normal diode with the breakdown voltage of a typical silicon diode.

The differential resistance is found by the formula:

$$r_{\text{diff}} = \frac{dv}{di}$$

Diff resistance at 1mA:

$$Z = \frac{5.631 - 5.337}{0.0011 - 0.0010} = 240\ \Omega$$

Diff resistance at 45mA:

$$Z = \frac{5.755 - .739}{0.050 - 0.0450} = 3.2\ \Omega$$

For first measurement, Zzt is at maximum 400 Ω, but our reading is less than that which means it is in the given range and acceptable according to data sheet. In second measurement, our reading is 3 Ω but data sheet says 7 Ω, which is also valid. This result indicates that for smaller voltage, Zener diode acts as normal diode which does not conduct in reverse biased condition.

But after the breakdown voltage is reached, the potential barrier becomes conductor and current flows freely.

3.4Evaluation Experiment Part 4

$$V_{RV} = 15 – 5.6 = 9.4 \text{ V}$$

When Iz = 1mA:
I = 1 + 10 = 11 mA
R = 9.4/0.11 = 854.54 Ω

When Iz = 10mA:
I = 10 + 10 = 20mA
R = 9.4/0.02 = 470 Ω
Essentially the load is operated with a resistor in series with the voltage source and the shunt regulator then in parallel with the load. In order to keep the voltage across the load constant, a level of current must be drawn through the series resistor to maintain the required voltage across the load. The load will take some and the remaining current is drawn by the shunt voltage regulator. The circuit is designed so that at maximum load current the shunt regulator draws virtually no current and at minimum load current, the shunt voltage regulator passes the full current. The problem with using small resistances is that the current will flow through the load which will not allow the Zener diode to reach breakdown voltage and act as a voltage regulator.

4. Conclusion

It can be concluded that the cathode of the diode is the ring side of the diode. A diode is in forward biased if the negative terminal is connected to the cathode pat otherwise it is reverse biased as the current in a diode flows from anode to cathode. Zener diode is a type of diode which allows the current to flow in reverse biased direction when the voltage is higher than the breakdown voltage. For small voltages, the Zener diode behaves a high resistance resistor. In forward biased direction, the Zener diode behaves as a normal diode. Zener diodes can be used to build Zener Shunt Regulator circuits. They help us to regulate a constant voltage across the load only if the resistance is high enough. Otherwise, the voltage drop of the Zener diode would never be able to pass knee voltage.

5. References

Lab Manual
http://www.futureelectronics.com/en/diodes/zener.aspx

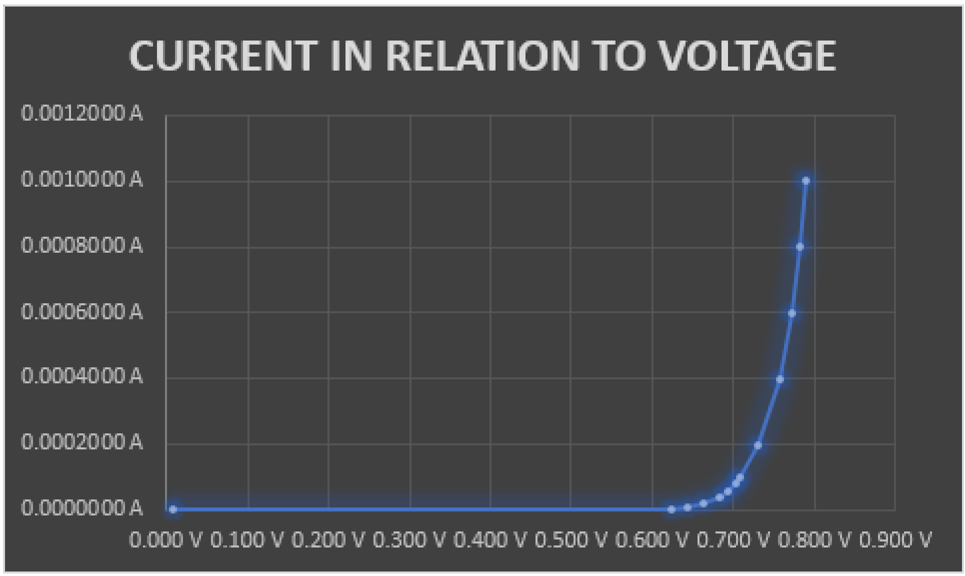
6 Appendix

Part 1

Power Source	Ib	Ube	Range Voltmeter	Range Ammeter
0.0	0.00	0.0097	2	uA
0.6	4.90	0.6239	2	uA
0.7	10.3	0.6444	2	uA
0.8	20.1	0.6629	2	uA
1.0	40.4	0.6826	2	uA
1.2	59.8	0.6936	2	uA
1.4	79.8	0.7016	2	uA
1.6	99.7	0.7084	2	uA
2.6	199.6	0.7309	2	uA
4.7	399.4	0.7566	2	uA
6.7	599.8	0.7721	2	uA
8.8	802	0.7819	2	uA
10.7	1000	0.7895	2	uA

Ube (V)	Ib (A)
0.0097	0
0.6239	0.0000049
0.6444	0.0000103
0.6629	0.0000201
0.6826	0.0000404
0.6936	0.0000598
0.7016	0.0000798
0.7084	0.0000997
0.7309	0.0001996
0.7566	0.0003994
0.7721	0.0005998
0.7819	0.000802
0.7895	0.001

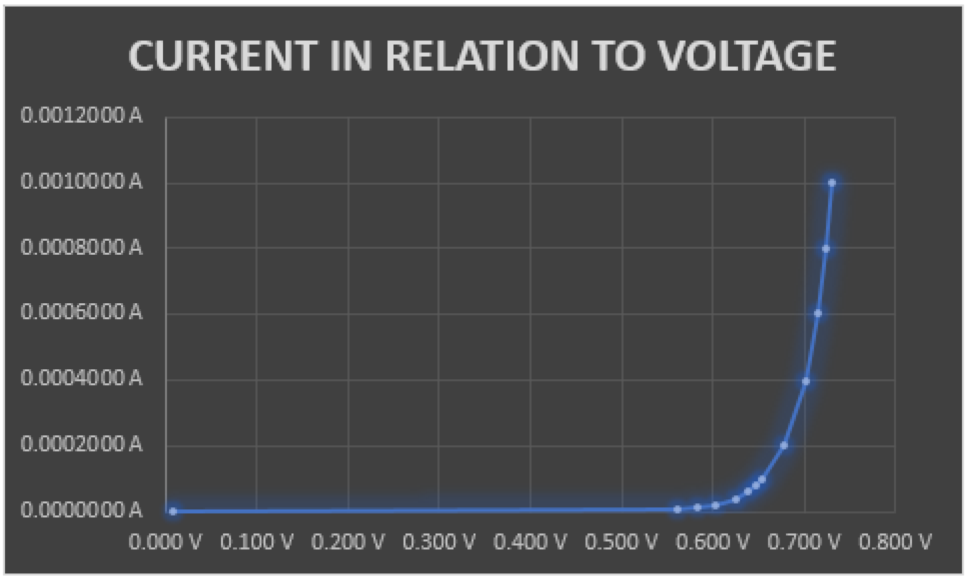
Uce = 0.4V



BASE COLLECTOR READING

Power Source	Ib	Ube	Range Voltmeter	Range Ammeter
0.0	0.00	0.008	2	uA
0.5	5.30	0.5623	2	uA
0.6	10.7	0.5832	2	uA
0.7	20.3	0.6023	2	uA
0.9	40.4	0.6243	2	uA
1.2	60.2	0.6374	2	uA
1.4	79.4	0.6468	2	uA
1.6	100.1	0.6544	2	uA
2.6	200.1	0.6781	2	uA
4.6	398.8	0.7016	2	uA
6.7	603	0.7151	2	uA
8.7	800	0.7237	2	uA
10.7	999	0.7300	2	uA

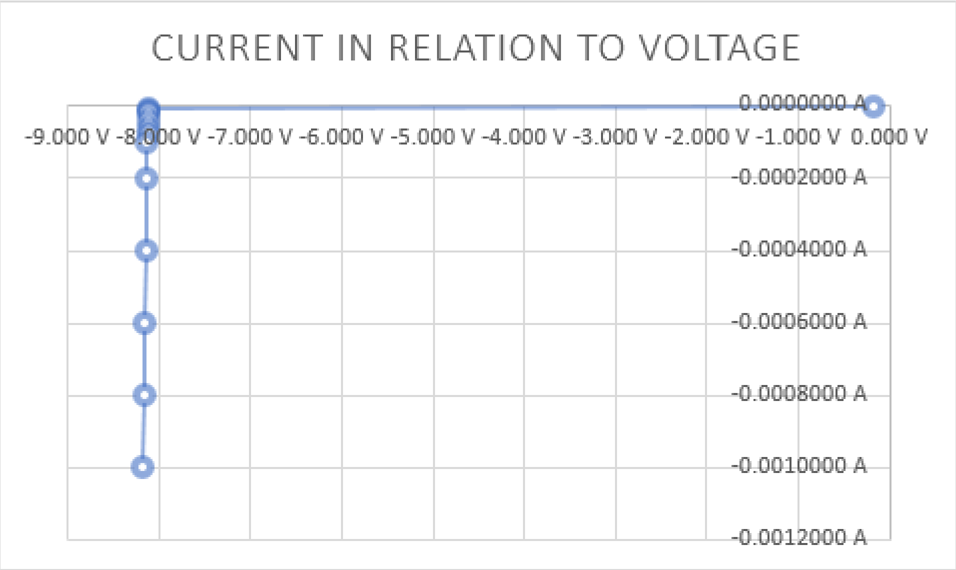
Ube (V)	Ib (A)
0.008	0
0.5623	0.0000053
0.5832	0.0000107
0.6023	0.0000203
0.6243	0.0000404
0.6374	0.0000602
0.6468	0.0000794
0.6544	0.0001001
0.6781	0.0002001
0.7016	0.0003988
0.7151	0.000603
0.7237	0.0008
0.73	0.000999



Reversed Values

0	0	-0.179	2	uA
8.1	-4.8	-8.107	20	uA
8.1	-10.4	-8.11	20	uA
8.2	-19.5	-8.114	20	uA
8.4	-40.4	-8.116	20	uA
8.6	-60.7	-8.119	20	uA
8.8	-80.9	-8.122	20	uA
9	-99.9	-8.125	20	uA
10.1	-200	-8.129	20	uA
12.1	-401.3	-8.137	20	uA
14.1	-600	-8.149	20	uA
16.1	-801	-8.158	20	uA
18.2	-999	-8.168	20	uA

-0.179	0
-8.107	-0.0000048
-8.11	-0.0000104
-8.114	-0.0000195
-8.116	-0.0000404
-8.119	-0.0000607
-8.122	-0.0000809
-8.125	-0.0000999
-8.129	-0.0002
-8.137	-0.0004013
-8.149	-0.0006
-8.158	-0.000801
-8.168	-0.000999



PART 2

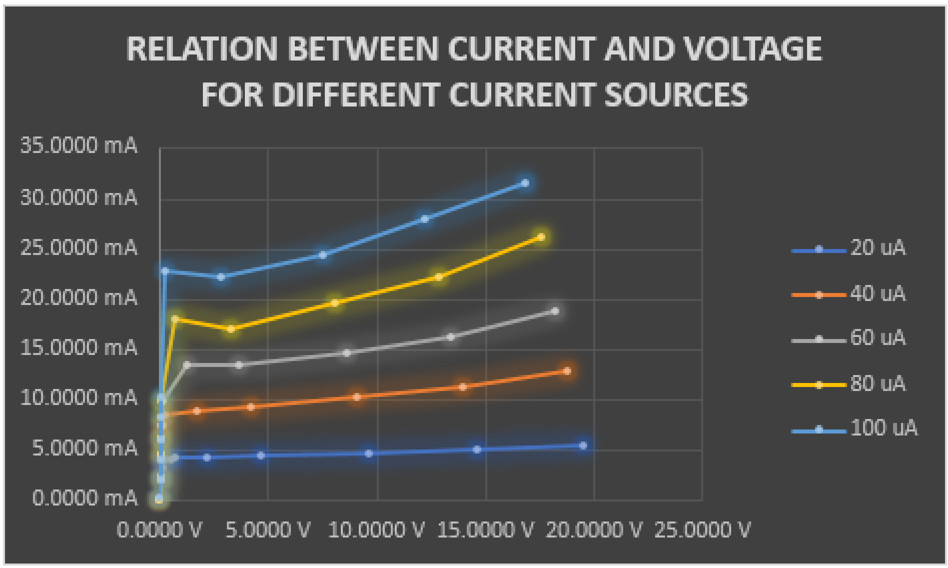
Ib		20	uA
Collector Supply	Uce	Ice	Power (mW)
0	0.004	0.05	0.0002
0.2	0.072	2.2	0.1584
0.4	0.104	3.25	0.338
0.6	0.267	4.17	1.11339
0.8	0.472	4.2	1.9824
1	0.668	4.22	2.81896
2.5	2.183	4.32	9.43056
5	4.637	4.47	20.72739
10	9.639	4.76	45.88164
15	14.608	5.07	74.06256
20	19.526	5.48	107.00248

Ib		80	uA
Collector Supply	Uce	Ice	Power (mW)
0	0.001	0.07	0.00007
0.2	0.024	2.14	0.05136
0.4	0.045	4.73	0.21285
0.6	0.055	6.34	0.3487
0.8	0.068	8.25	0.561
1	0.08	9.93	0.7944
2.5	0.741	18.1	13.4121
5	3.302	17.14	56.59628
10	8.04	19.73	158.6292
15	12.836	22.33	286.62788
20	17.513	26.26	459.89138

Ib		40	uA
Collector Supply	Uce	Ice	Power (mW)
0	0.002	0.06	0.00012
0.2	0.042	2.09	0.08778
0.4	0.067	4.01	0.26867
0.6	0.095	6.03	0.57285
0.8	0.126	7.45	0.9387
1	0.246	8.55	2.1033
2.5	1.688	8.83	14.90504
5	4.159	9.33	38.80347
10	9.054	10.22	92.53188
15	13.913	11.28	156.93864
20	18.756	12.81	240.26436

Ib		100	uA
Collector Supply	Uce	Ice	Power (mW)
0	0.003	0.23	0.00069
0.2	0.022	2.16	0.04752
0.4	0.036	4.15	0.1494
0.6	0.047	6.08	0.28576
0.8	0.061	8.33	0.50813
1	0.071	10.26	0.72846
2.5	0.254	22.8	5.7912
5	2.813	22.29	62.70177
10	7.547	24.39	184.07133
15	12.212	27.97	341.56964
20	16.804	31.65	531.8466

Ib		60	uA
Collector Supply	Uce	Ice	Power (mW)
0	0.002	0.07	0.00014
0.2	0.035	2.45	0.08575
0.4	0.054	4.48	0.24192
0.6	0.068	6.05	0.4114
0.8	0.082	7.56	0.61992
1	0.108	9.91	1.07028
2.5	1.205	13.38	16.1229
5	3.682	13.45	49.5229
10	8.58	14.62	125.4396
15	13.402	16.33	218.85466
20	18.193	18.85	342.93805



Ib (uA)	Ice
100	24.71
200	52.3
300	77.2
400	97.1
500	109.5

Uce	1 V