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Constructor University Bremen

Natural Science Laboratory

Electrical Engineering I

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Lab Experiment 4- DC Networks

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Place of execution: Teaching Lab EE
Rotation III, Bench 8

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1.INTRODUCTION

This laboratory experiment delves into the analysis of a DC network featuring multiple voltage sources. The primary aim encompasses direct measurement of circuit voltages, calculation of currents, and the application of revered principles such as Ohm’s law, Kirchhoff’s laws, Thévenin's theorem, and Norton’s theorem. **Ohm’s Law** states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance. **Kirchhoff’s Laws.** Kirchhoff's Current Law (KCL) states that the total current entering a junction in a circuit must equal the total current leaving the junction, based on the principle of conservation of charge.Kirchhoff's Voltage Law (KVL) states that the total voltage around a closed loop in a circuit must be equal to the sum of the voltage drops within that loop, based on the conservation of energy.**Thévenin's Theorem** asserts that any complex circuit containing multiple elements can be represented by a simpler equivalent circuit without affecting the behavior observed at the output terminals. **Norton’s Theorem** Similar to Thévenin's theorem, it simplifies a complex network into an equivalent circuit, but in this case, it involves a current source and a parallel resistor.

The initial phase of this experiment involved direct measurements of circuit voltages to understand the distribution and values across the network and later we determined all currents, using the measured voltages.

The second phase of this experiment involved utilizing Thévenin’s theorem, the objective was to determine current I1 through source V1. By simplifying the network into an equivalent circuit, this theorem aids in calculating the desired current, showcasing its practical relevance in circuit analysis.We later determined the Th´evenin’s parameters Vth and Rth at terminals A - B.

The third phase of this experiment involved the application of Norton’s theorem to ascertain current I4 through source V2. This theorem, akin to Thévenin’s theorem, simplifies circuitry into equivalent forms, enabling a different approach to determine currents and reinforcing the understanding of network analysis methodologies. We later determined the Norton’s parameters Ino and Rno at terminals A1 - B1.

2. EXECUTION

Experiment Setup
Workbench No.8

Used tools and instruments:
Breadboard, Tools box from workbench, Multimeters TENMA and ELABO

Experiment Part 1 – Setup
We built the circuit below on the breadboard. Our goal was to measure the circuit voltages directly using the Tenma voltmeter.

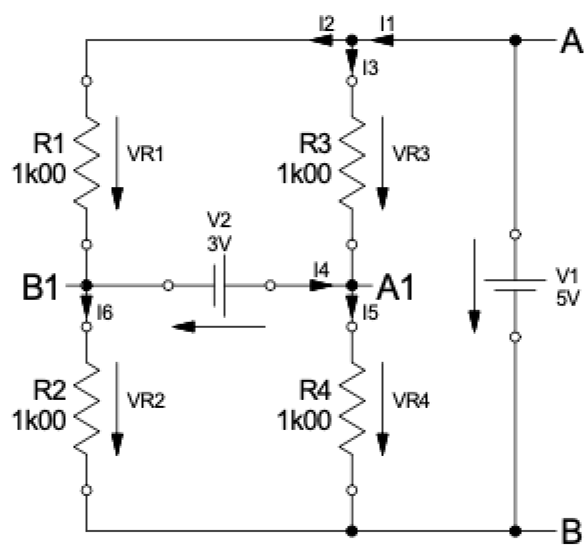


Fig.1: circuit voltages.
We connected the test leads to the TENMA and then measured all the circuit voltages one by one using the test leads. Since the resistance was already given, we then went ahead with determining the current using the measured voltages and the given resistance in(fig. 1), using ohm's law.

Experiment Part 1 – Execution and Results

We connected the test leads to the TENMA and then measured all the circuit voltages one by one using the test leads. Since the resistance was already given, we then went ahead with determining the current using the measured voltages and the given resistance in(fig. 1), using ohm's law and that is how we got our measured voltage and current results.

Results:

	Voltage(V)	Current(A)
V1	5.0660	0.0050660
V2	3.0673	0.0030673
VR1	4.0680	0.0040680
VR2	1.0000	0.0010000
VR3	1.0018	0.0010018
VR4	4.0660	0.0040660

Table 1: Measured Voltage and determined current.

Experiment Part 2 – Setup

In this phase, we did not have to build the circuit again; we used the same circuit from part 1, but this time with a different goal which is to determine the current I1 using Th´evenin's Theorem, and to determine the Th´evenin's parameters V_{th} and R_{th} at terminals A - B.

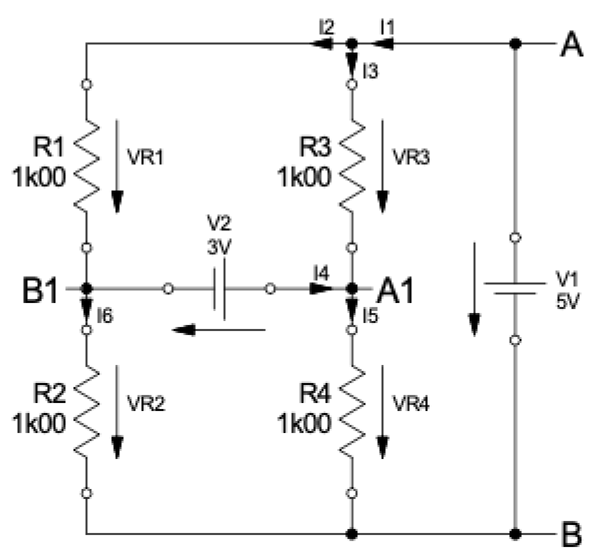


Fig.2:current I1 using Th´evenin's Theorem.

To determine Rth we switched off all the independent sources in the circuit and then set the TENMA to ohms range and then recorded the equivalent resistance which is Rth in our case. To determine Vth we disconnected loads connected to the terminals A and B and set the TENMA to Volts range and then recorded the Vth.

Results:

V th (V)	0.00045
R th (Ω)	996.9
I 1 (A)	0.0050698

Table 2: Thevenin Parameters

Experiment Part 3 – Setup

Just like in part two, we did not have to build the circuit again; we used the same circuit from part 1, but this time with a different goal which is to determine the current I4 through source V2 using Norton's Theorem, and to determine the Norton's parameters Ino and Rno at terminals A1 - B1.

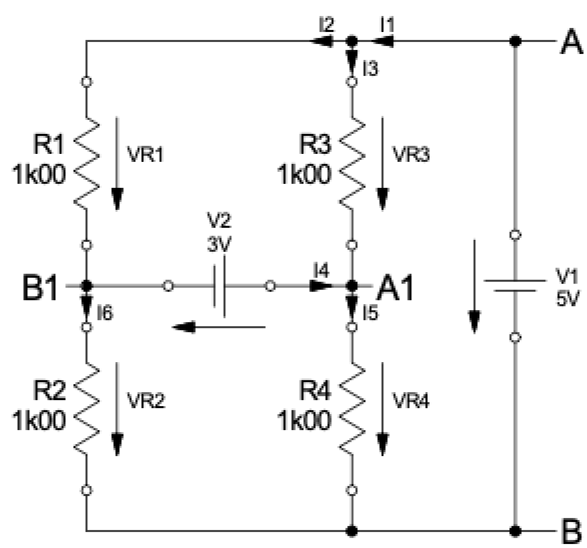


Fig 3:Current I4 and Norton Parameters

To determine R_{no} we switch off all the independent sources in the circuit and then set the TENMA to ohms range and then record the equivalent resistance which is Rno in our case. To determine Ino we disconnected the external load at terminals A1 and A2 and set the TENMA to Amps range and then recorded the Ion.

Experiment Part 3 – Execution and Results

We later determined the current I4 and Norton's parameters Ino and Rno at terminals A1 - B1

Results:

I no (A)	2.80E-070
R no (Ω)	997.4
I 4 (A)	0.0030642

Table 3: Determined current I4 and Norton's parameters Ino and Rno at terminals A1 - B1

3.Evaluation

Part 1 : Measure all network voltages

To calculate all the currents and voltages of the circuit, we use Kirchhoff's Current Law and Kirchhoff's Voltage Law since we have three loops.

Starting with the first loop below

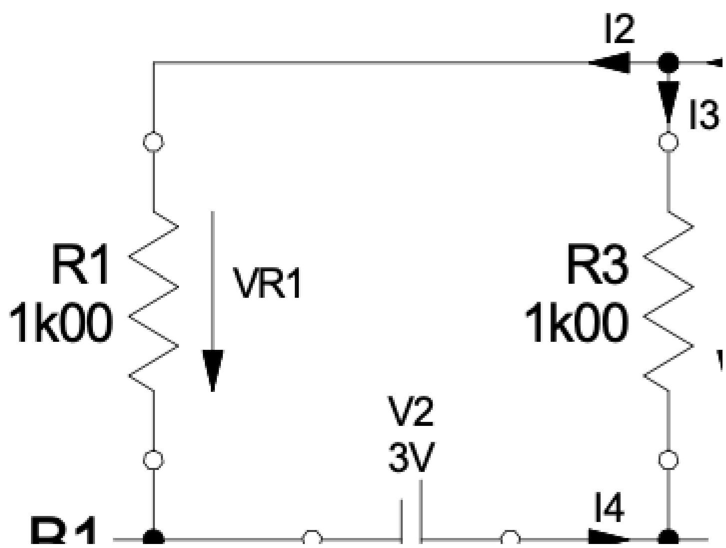


Fig 4:Loop 1

Using Kirchhoff's Voltage Law we come up with equation below

$3 + 1000I3 - 1000I2 = 0$.. (i)

Using Kirchhoff's Current Law at node A we come up with equation below

$I3 = I1 - I2$.............................. (ii)

We do the same thing for our second loop.

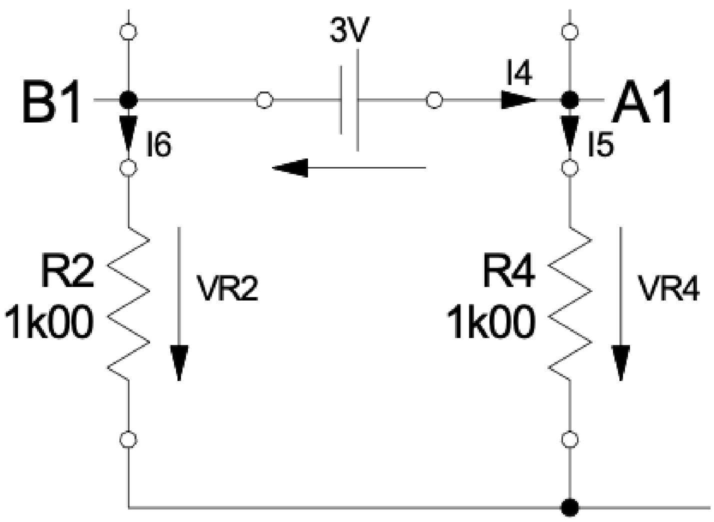


Fig 5:Loop 2

Using Kirchhoff's Voltage Law we come up with equation below

$3 - 1000I5 + 1000I6 = 0$.............................. (iii)

Using Kirchhoff's Current Law at node A1 we come up with equation below

$I5 = I3 + I4$, since we already know the value of I3 we can go ahead and replace it with equation (ii)

$I5 = I1 - I2 + I4$......................... (iv)

Using Kirchhoff's Current Law at node B1 we come up with equation below

$I6 = I2 - I4$.......................... (v)

We do the same thing for our second loop.

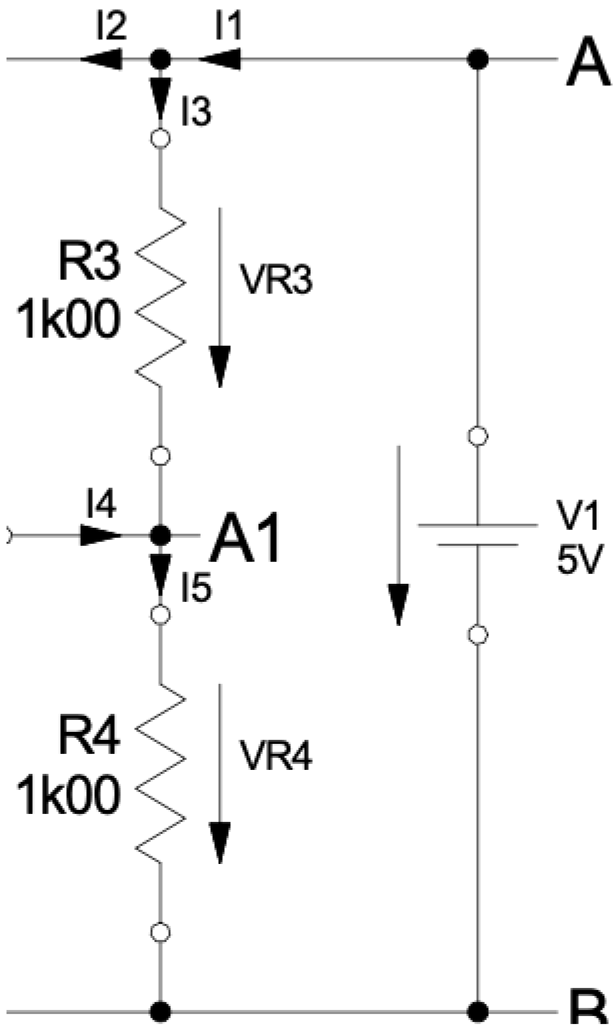


Fig 6:Loop 3

Using Kirchhoff's Voltage Law we come up with equation below

$5 - 1000I3 - 1000I5 = 0$............................ (vi)

With all the six equations we have come up with, we can now go ahead and calculate the currents and voltages by substitution. Since the three equations formed from Kirchhoff's Voltage Law have five different values, we need to come up with new equations that will have the same current variables so that we can be able to solve them simultaneously.

We will substitute I3 in equation(i) with equation(ii)

$3 + 1000(I1 - I2) - 1000I2 = 0$

$-1000I1 + 2000I2 = 3$......................... (vii)

We will substitute I5 in equation(iii) with equation(iv) and I6 in equation(iii) with equation(v)

$3 - 1000(I1 - I2 + I4) + 1000(I2 - I4) = 0$

$1000I1 - 1000I2 + 2000I4 = 3$.................... $(viii)$

We will substitute I5 in equation(vi) with equation(iv) and I3 in equation(vi) with equation(ii)

$5 - 1000(I1 - I2) - 1000(I1 - I2 + I4) = 0$

$2000I1 - 2000I2 - 1000I4 = 5$...................... (ix)

We can see that equation(viii) and equation(ix) have the same variables, so we can eliminate I4 and form a new equation that will match equation(vii)

$1000I1 - 2000I2 + 2000I4 = 3$

$2000I1 - 2000I2 - 1000I4 = 5$

Solvinging these two equations simultaneously we get

$-3000I1 + 2000I2 =- 7$...................... (x)

Now that the variables in equation(x) match the variables in equation(vii) we can go ahead and calculate the values of I1 and I2.

$-1000I1 + 2000I2 = 3$

$-3000I1 + 2000I2 =- 7$

Solvinging these two equations simultaneously we get

$I1 = 0.005A\ \ and\ I2 = 0.004A$

Now that we have the I1 and I2 values we can substitute them in either equation(viii) or equation(ix) to calculate for I4. Using equation (viii)

$1000I1 - 2000I2 + 2000I4 = 3$

$1000(0.005) - 1000(0.004) + 2000I4 = 3$

$I4 = 0.003A$

With I1, I2 and I4 we can finally calculate the values of I3, I5 and I6.

Using equation(ii) we can calculate for I3

$I3 = I1 - I2$

$I3 = 0.005 - 0.004$

$I3 = 0.001A$

Using equation(iv) we can calculate for I5

$I5 = I1 - I2 + I4$

$I5 = 0.005 - 0.004 + 0.003$

$I5 = 0.004A$

Using equation(v) we can calculate for I6

$I6 = I2 - I4$

$$I6 = 0.004 - 0.003$$

$$I6 = 0.001A$$

Now that we have all the currents we can go ahead and calculate the voltage using ohm's law, since we already have the nominal values for all the resistors.

$$V = IR$$

$$VR1 = I2R1$$

$$VR1 = 0.004 * 1000$$

$$VR1 = 4V$$

$$V = IR$$

$$VR2 = I6R2$$

$$VR2 = 0.001 * 1000$$

$$VR2 = 1V$$

$$V = IR$$

$$VR3 = I3R3$$

$$VR3 = 0.001 * 1000$$

$$VR3 = 1V$$

$$V = IR$$

$$VR4 = I5R4$$

$$VR4 = 0.004 * 1000$$

$$VR4 = 4V$$

We can summarize all the results we just calculated in the table below

	Voltage(V)	Current(A)
V1	5	0.005
V2	3	0.003
VR1	4	0.004
VR2	1	0.001
VR3	1	0.001
VR4	4	0.004

Table 4: Calculated voltages and currents

Comparing the calculated values to the determined values from the lab, we can see that the values have a slight difference. This is because of **Instrumental Limitations:** The observed variance may partly stem from limitations in the precision or accuracy of the ammeter used for measurements. **Systematic Errors:** There could be systematic errors within the experimental setup, such as inaccuracies in circuit connections or biases in the measurement technique employed. **Significant Figures and Rounding:** Differences in significant figures between the calculated and measured values might have influenced the observed discrepancy. **Component Tolerances:** Variations in the precision or tolerance levels of components within the circuit might have contributed to the observed difference. **Environmental Factors:** External factors such as temperature fluctuations or power source variations could have affected the experiment and contributed to the observed deviation.

The discrepancy between the calculated and measured values in the circuit suggests potential instrumental limitations, systematic errors, and variations in component precision or environmental factors.

Part 2 : Determine current I1 through source V 1

To determine the theoretical Th´evenin parameters using the nominal values given in fig 1, for R_{th}, we short circuit all the independent voltage sources and calculate the equivalent resistance of the circuit. In our case equivalent resistance is equal to $R_{th.}$

Since R1 is parallel to R3 and R2 is parallel to R4 because they are connected to the same nodes. We can calculate there resistance using the formula of resistance in parallel

$R_1 = (R1R3)/(R1 + R3)$

$R_1 = (1k * 1k)/(1k + 1k)$

$R_1 = 500\Omega$

$R_2 = (R2R4)/(R2 + R4)$

$R_2 = (1k * 1k)/(1k + 1k)$

$R_2 = 500\Omega$

The two resistance we just calculated above are in series, because they share the same current. We now calculate the equivalent resistance by adding them, while keeping in mind that equivalent resistance is equal to Thevenin's resistance.

$R = R_{Th}$

$R = R_1 + R_2$

$R = 500\Omega + 500\Omega$

$R_{Th} = 1000\Omega$

To find the Thevenin's voltage, we use circuit in fig1 and calculate the voltage at terminals A and B. We can see that we have a voltage divider, dividing the voltage at terminals A1 and B1 into half since we have equal resistance after combining the opposite resistance R1 with R3 and R2 and R4

$V_{Th} = VA - VB$

$V_{Th} = 1.5 - 1.5$

$V_{Th} = 0V$

Calculating the theoretical I1 using the determined Th´evenin parameters, and voltage source V1 we use ohm’s law.

$V = IR$

$I = V1/R$

$I1 = 5/1000$

$I1 = 0.005A$

Comparing the calculated values to the determined values from the lab, we can see that the values have a slight difference. This is because of **Instrumental Limitations:** The observed variance may partly stem from limitations in the precision or accuracy of the ammeter used for measurements. **Systematic Errors:** There could be systematic errors within the experimental setup, such as inaccuracies in circuit connections or biases in the measurement technique employed. **Significant Figures and Rounding:** Differences in significant figures between the calculated and measured values might have influenced the observed discrepancy. **Component Tolerances:** Variations in the precision or tolerance levels of components within the circuit might have contributed to the observed difference. **Environmental Factors:** External factors such as temperature fluctuations or power source variations could have affected the experiment and contributed to the observed deviation.

The discrepancy between the calculated and measured values in the circuit suggests potential instrumental limitations, systematic errors, and variations in component precision or environmental factors.

Part 3 : Determine current I4 through source V 2

When determining the Norton resistance, we short circuit all the independent voltage sources and calculate the equivalent resistance of the circuit. In our case equivalent resistance is equal to R_{no}

.Since R1 is parallel to R3 and R2 is parallel to R4, because they are both connected to the same node. we can calculate there resistance using the formula of resistance in parallel

$R_1 = (R1R3)/(R1 + R3)$

$R_1 = (1k * 1k)/(1k + 1k)$

$R_1 = 500\Omega$

$R_2 = (R2R4)/(R2 + R4)$

$R_2 = (1k * 1k)/(1k + 1k)$

$R_2 = 500\Omega$

The two resistance we just calculated above are in series, because they share the same current. We now calculate the equivalent resistance by adding them, while keeping in mind that equivalent resistance is equal to Norton resistance.

$$R = R_{no}$$

$$R = R_1 + R_2$$

$$R = 500\Omega + 500\Omega$$

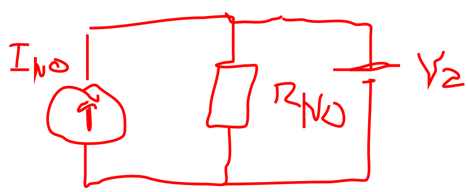
$$R_{no} = 1000\Omega$$

To calculate Norton current at terminals A1 and B1 we remove the load at these terminals. Removing the load which is V2 gives us a balanced Wheatstone bridge.

$$I_{no} = 0A$$

Calculating the theoretical I4 using the determined Norton parameters.

$$\cancel{I_{no} = I4}$$



$$\cancel{I4 = 0A}$$

Comparing the calculated values to the determined values from the lab, we can see that the values have a slight difference. This is because of **Instrumental Limitations:** The observed variance may partly stem from limitations in the precision or accuracy of the ammeter used for measurements. **Systematic Errors:** There could be systematic errors within the experimental setup, such as inaccuracies in circuit connections or biases in the measurement technique employed. **Significant Figures and Rounding:** Differences in significant figures between the calculated and measured values might have influenced the observed discrepancy. **Component Tolerances:** Variations in the precision or tolerance levels of components within the circuit might have contributed to the observed difference. **Environmental Factors:** External factors such as temperature fluctuations or power source variations could have affected the experiment and contributed to the observed deviation.

The discrepancy between the calculated and measured values in the circuit suggests potential instrumental limitations, systematic errors, and variations in component precision or environmental factors.

4.Conclusion

In the course of this experiment, a comprehensive analysis of a DC network containing multiple voltage sources was conducted. The objectives encompassed both direct measurement techniques and the application of theoretical theorems, namely Ohm's law, Kirchhoff's laws, Thévenin’s theorem, and Norton’s theorem, to ascertain currents and understand circuit behaviors indirectly.

Measurement of Network Voltages and Direct Current Determination:

Initially, the experiment commenced with the direct measurement of circuit voltages, aiming to determine currents through these direct measurements. By employing standard measurement techniques, we obtained precise voltage values across various components within the circuit, enabling us to compute currents directly using Ohm's law and Kirchhoff’s laws.

Utilizing Thévenin’s and Norton’s Theorems:

Subsequently, Thévenin’s theorem was applied to indirectly determine current I1 through source V1. This theorem provided an alternative method for current calculation by simplifying the network into an equivalent circuit. Similarly, Norton’s theorem was utilized to ascertain current I4 through source V2, employing a different approach to analyze the circuit and derive current values.

Consideration of Errors:

It is crucial to acknowledge potential sources of errors that might have influenced our experimental outcomes. These errors could stem from various factors, including inaccuracies in measurement equipment, fluctuations in environmental conditions affecting circuit performance, or limitations in theoretical assumptions. Additionally, discrepancies might arise due to the inherent tolerance levels of components used in the circuit or from approximations made during calculations based on theoretical models.

Reflection on Results:

Despite potential errors and uncertainties, the experimental results align closely with theoretical expectations. However, variations between expected and measured values were observed. These differences can be attributed to the aforementioned sources of error and emphasize the significance of considering such factors when interpreting experimental outcomes.

Educational Implications:

This experiment has provided valuable insights into the practical application of theoretical concepts in electrical network analysis. It underscores the importance of combining theoretical knowledge with practical experimentation to comprehend and evaluate the behavior of complex circuits. In conclusion, this experiment not only facilitated a deeper understanding of DC network analysis but also highlighted the necessity of accounting for potential errors and uncertainties in experimental measurements and theoretical models.

5.Reference

1. Pagel Uwe, General Electrical Engineering 1 Lab Manual (2023). Constructor University

6.Appendix

Experiment 5 : Single PN - Junction

Part 1 : Determine Anode and Cathode

Table 1. White Ring Facing 560R		
Voltage (V)	Current (μA)	

12	1.12	
Table 2. White Ring Away from 560R		
Voltage (V)	Current (mA)	
0.7	20.155	
Table 3. Determination of Polarity of Diode		
	COM to White Ring	V to White Ring
Voltage (V)	0.5964	0
- Current flows towards the white ring within the diode		

Part 2 : Forward V-I-Curve of a general pur- pose diode

Table 4. Forward V-I Curve of a General Purpose Diode		
Current Range	Current	V f (V)
µA	0	0.2583
µA	45.78	0.4537
µA	100.68	0.4829
µA	190.95	0.5079
µA	493.3	0.548
µA	1002.8	0.5795
mA	2.018	0.6113
mA	3.026	0.6296
mA	4.044	0.6427
mA	5.023	0.6527
mA	10.023	0.6829
mA	20.005	0.7124
mA	40.04	0.7395

Part 3 : Reverse and Forward Characteristic of a Z-Diode

Table 5. Reverse Characteristic of a Z-Diode		
Current Range	Current	V f (V)
µA	0	1.909
µA	103.04	4.806
µA	201.12	5.003
µA	497.9	5.217
µA	713.1	5.284
µA	999	5.338
µA	1104.8	5.352
mA	1.505	5.391
mA	2	5.421
mA	5.045	5.491
mA	10.044	5.529
mA	20.07	5.581
mA	40.04	5.67
mA	45.19	5.699

Table 6. Forward Characteristic of a Z-Diode

Current Range	Current	V f (V)
μA	0	0.0069
μA	52.73	0.6447
μA	108.05	0.664
μA	203.08	0.6812
μA	507.9	0.7051
μA	1005.8	0.724
mA	2	0.7426
mA	3.032	0.7543
mA	4.033	0.7621
mA	5.095	0.7687
mA	10.078	0.789
mA	20.029	0.8099
mA	30.066	0.8214

Part 4 : A Zener Shunt Regulator

Rv (10 mA case)	470	
Rv (1 mA case)	854.5454545	
Table 7. Iz = 1 mA with 20 V ELABO Voltmeter Range		
Load Resistance (Ω)	Current (mA)	Load Voltage (V)
Open circuit	11.042	5.534
56	16.367	0.92
560	11.192	5.399
5K60	11.037	5.534

Table 8. Iz = 10 mA with 20 V ELABO Voltmeter Range		
Load Resistance (Ω)	Current (mA)	Load Voltage (V)
Open circuit	19.919	5.577
56	28.231	1.586
560	19.973	5.532
5K60	19.869	5.584