Lab Report: Electrical Circuits (CSE 209)

Expt. No: 07

Title: Verification of Thevenin’s theorem.

Submitted by-

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Date of Performance: 24/12/24

Date of Submission: 02/01/25

Objectives:

1. Verifying the Thevenin's theorem theoretically, experimentally, and using PSpice simulation.

Theory:

Circuit containing a voltage source Eth in series with a resistance Rth. Eth is equal to the open circuit voltage between the terminals and Rth is the ratio of the open circuit voltage to the short circuit current through the terminals. Experimentally, Eth may be measured by measuring Thevenin's theorem states that a linear two-terminal network can be replaced by an equivalent open circuit voltage and Rth can be calculated by measuring the open circuit voltage and the short circuit current.

Circuit Diagram:

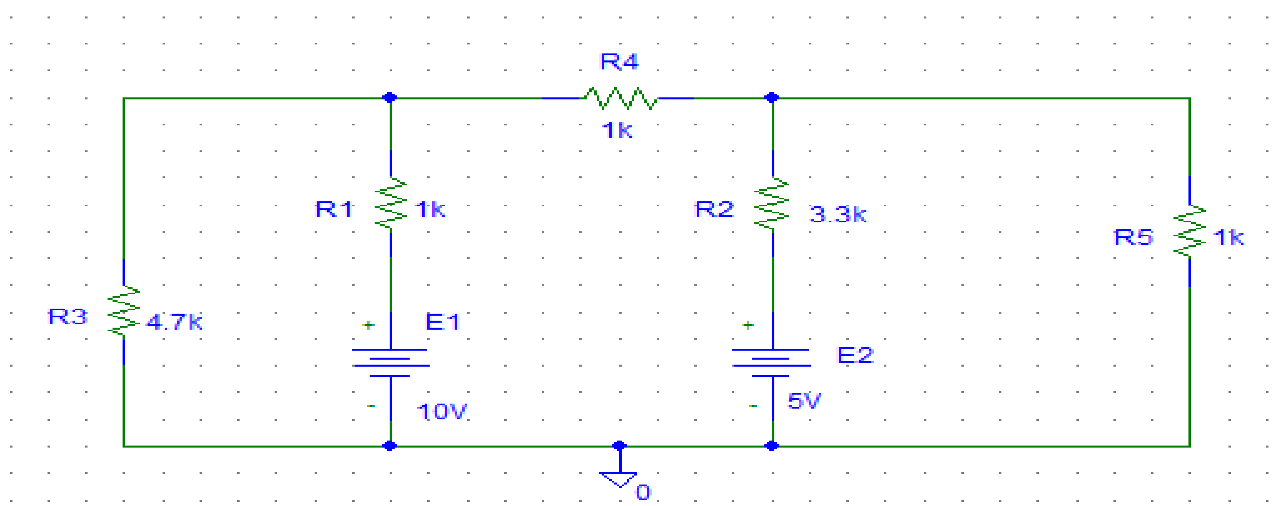


Figure 1: Circuit Diagram whose Thevenin's equivalent to be determined

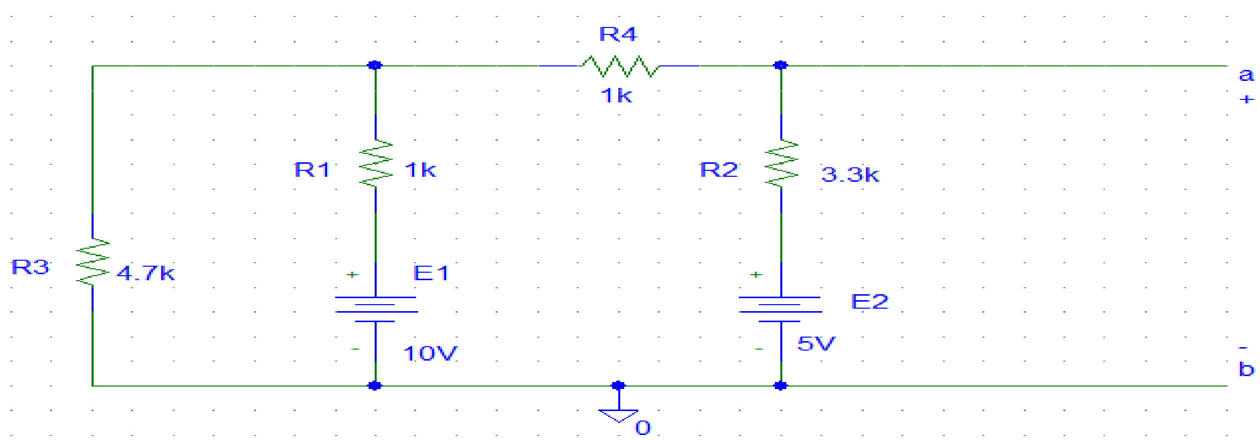


Figure 2: Circuit Diagram to measure the open circuit voltage.

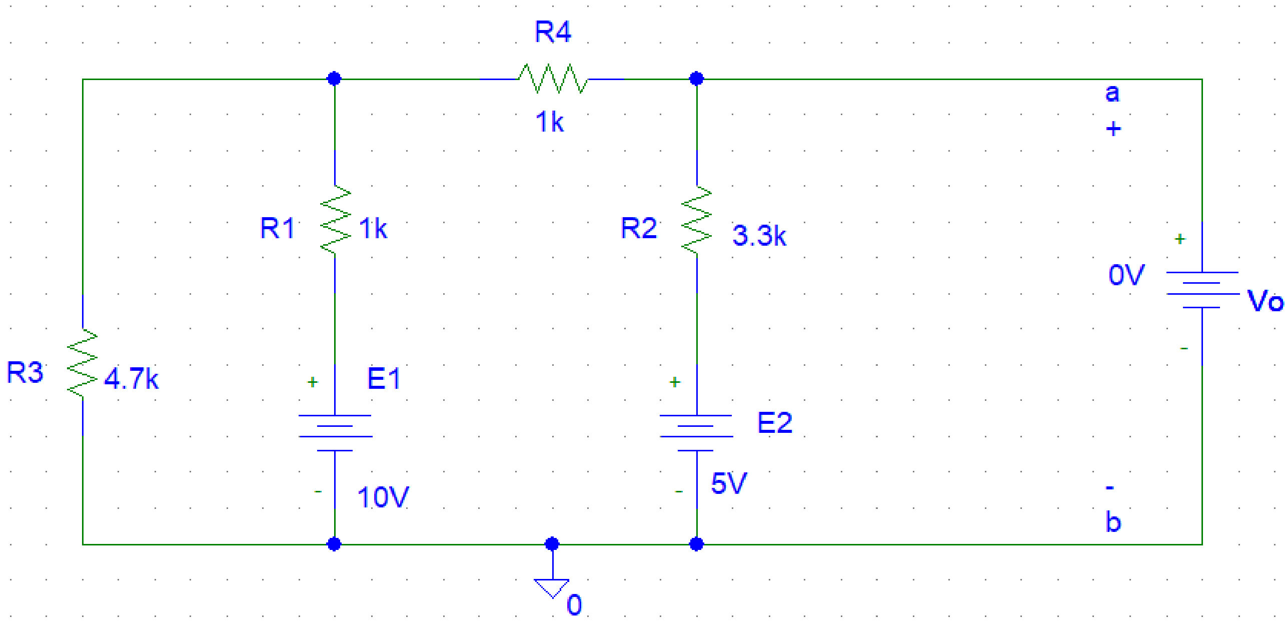


Figure 3: Circuit Diagram to measure the short circuit current.

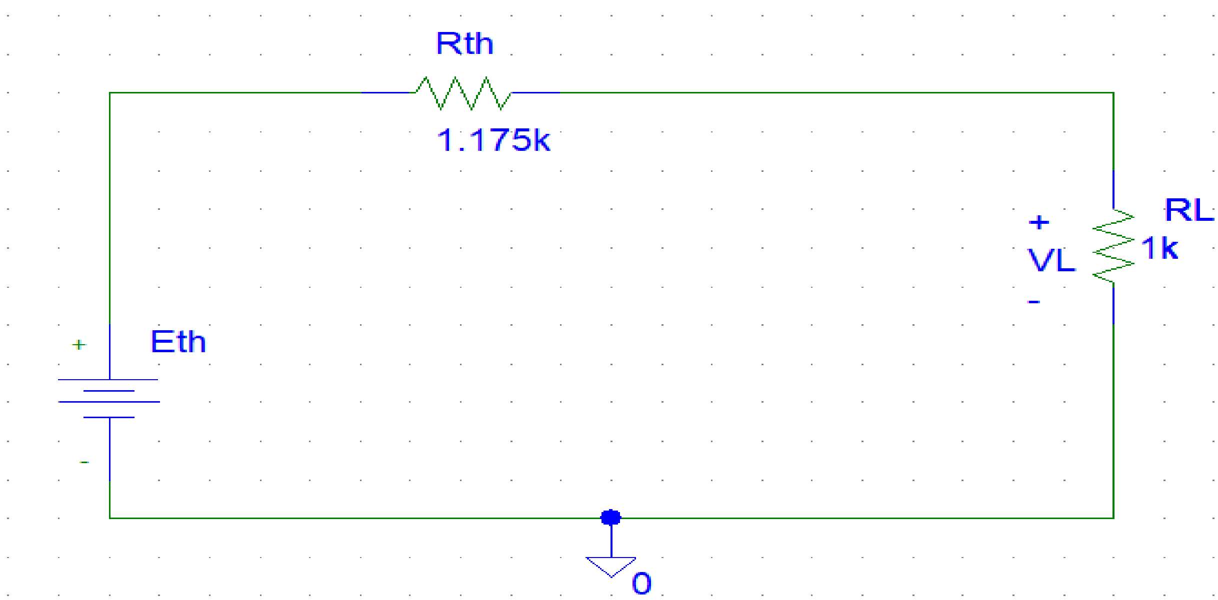
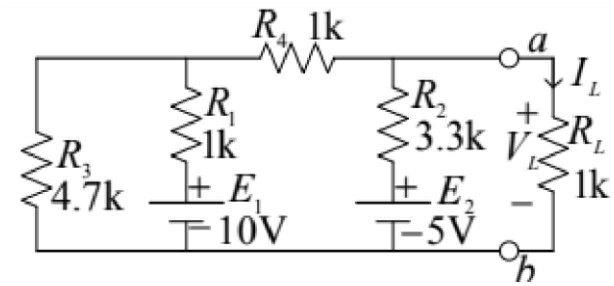


Figure 4: Circuit Diagram to verify Thevenin’s theorem.

Pre-lab report question:

1.Theoritically calculate V_L and I_L in figure 1. Then theoretically calculate V_{oc} in figure 2 and I_{sc} in figure 3.From the values of V_{oc} and I_{sc}, determine E_{th} and R_{th}. Theoretically calculate V_L and I_L in figure 4. Verify the Thevenin's theorem from calculated data.

Answer:



Circuit from the manual Figure: 01

Applying KVL at mesh 1, 2 and 3,

$$(5.7k)i_1 - (1k)i_2 = -10 \ldots (1)$$

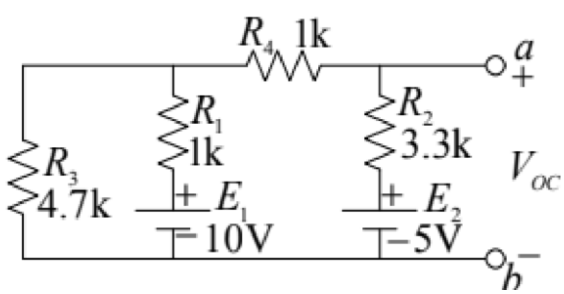
$$-(1k)i_1 + (5.3k)i_2 - (3.3k)i_2 = 10 - 5 \ldots (2)$$

$$-(3.3k)i_2 + (4.3k)i_3 = 5 \ldots (3)$$

By solving equation (1), (2) and (3) we get,

$$i_3 = I_L = 3.26\ mA$$

Again,



Circuit from the manual Figure: 02

Applying KVL a mesh 1 and 2 we get,

$$(5.7k)i_1 - (1k)i_2 = -10 \ldots (1)$$

$$(1k)i_1 + (5.3k)i_2 = 10 - 5 \ldots (2)$$

By solving,

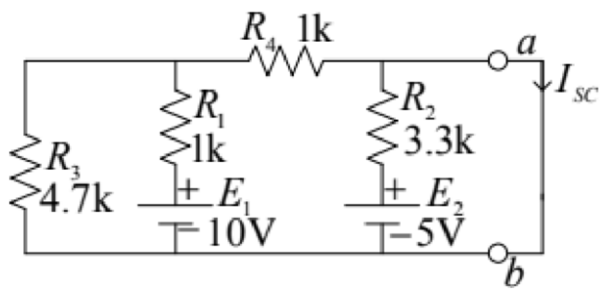
$i_2 = 0.633\ mA$

Here,

$V_{oc} = E_{th} = (3.3k)i_2 + 5$

So, $E_{th} = 7.09$ V

After disconnecting the load and replaced with short circuit,



Circuit from the manual Figure: 03

Here,

i3 = Isc

Applying KVL at mesh 1, 2 and 3,

$(5.7k)i_1 - (1k)i_2 = -10$ … (1)

$(1k)i_1 + (5.3k)i_2 - (3.3k)i_3 = 10 - 5$ … (2)

$(3.3k)i_2 + (3.3k)i_3 = 5$ … (3) By

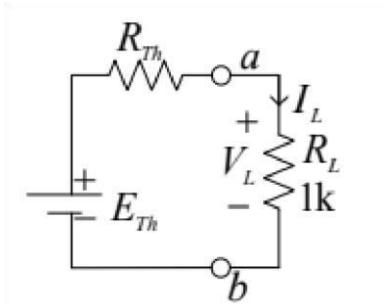
solving equation (1), (2) and (3) we get,

$i_3 = I_{sc} = 6.034$ mA

So,

$R_{th} = \frac{Vth}{Isc} = \frac{7.09}{0.006034} = 1175\ \Omega$

The Thevenin's equivalent circuit,



Circuit from the manual Figure: 04

So,

$$I_L = \frac{Vth}{Rth+RL} = \frac{7.09}{1.175} = 3.26\text{mA}$$

Experimental Data sheet:

Table 1. Experimental Datasheet for determining Thevenin's equivalent circuit.

Measured Value of E_1	Measured Value of E_2	Measured Value of V_L	Measured Value of I_L	Measured value of V_{OC}	Measured value of I_{SC}	Measured values of resistors (kΩ)
9.927 V	5.005 V	3.241	3.2mA	7.075V	6.00mA	R_1 = 0.980 R_2 = 3.333 R_3 = 4.633 R_4 = 0.993 R_L = 0.982

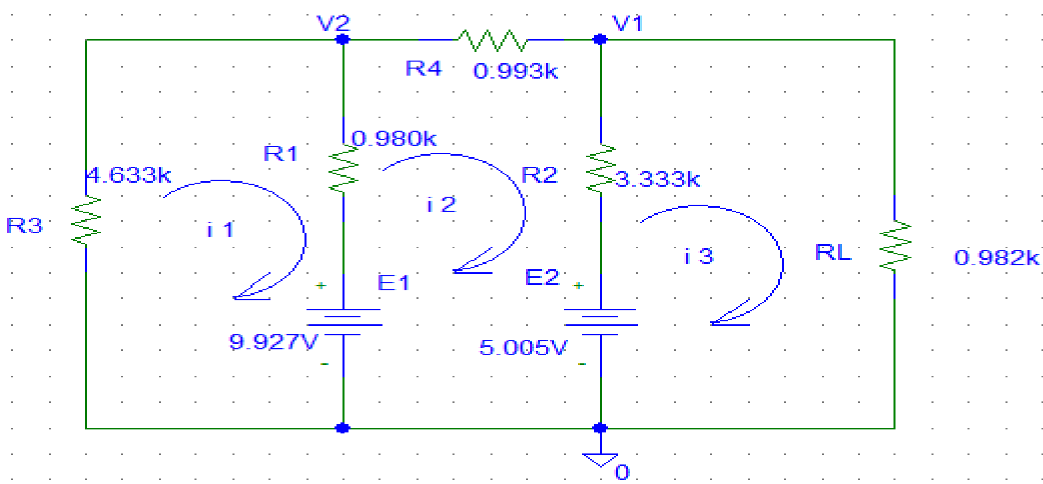
Table 2. Experimental Datasheet for Thevenin's equivalent circuit.

$E_{th} = V_{OC}$	$R_{th} = V_{OC}/I_{SC}$	Measured Value of V_L	Measured Value of I_L
7.075	1.16Ω	3.3	3.27 mA

Answer of the post lab question:

1. Theoretically calculate VL and IL in Figure 1 using measured values of E1, E2, R1, R2, R3, R4, and RL. Then theoretically calculate VOC in Figure 2 and ISC in Figure 3 using measured values of E1, E2, R1, R2, R3, R4, and RL. From the values of VOC and ISC, determine ETh and RTh. Theoretically calculate VL and IL in Figure 4 using calculated values of ETh and RTh and the measured value of RL. Verify the Thevenin's theorem from calculated data.

Answer:



KVL at mesh 1:

$$4.633i_1 + 0.980(i_1 - i_2) = -9.927$$

$$5.613i_1 - 0.980i_2 = -9.927 \ldots\ldots\ldots(1)$$

KVL at mesh 2

$$0.980(i_2 - i_1) + 0.993i_2 + 3.333(i_2 - i_3) = 9.927 - 5.005$$

$$=> -0.980i_1 + 5.306i_2 - 3.333i_3 = 4.922 \ldots\ldots(2)$$

KVL at mesh 3:

$$3.333(i_3 - i_2) + 0.982i_3 = 5.005$$
$$=> -3.333i_2 + 4.315i_3 = 5.005 \ldots\ldots(3)$$

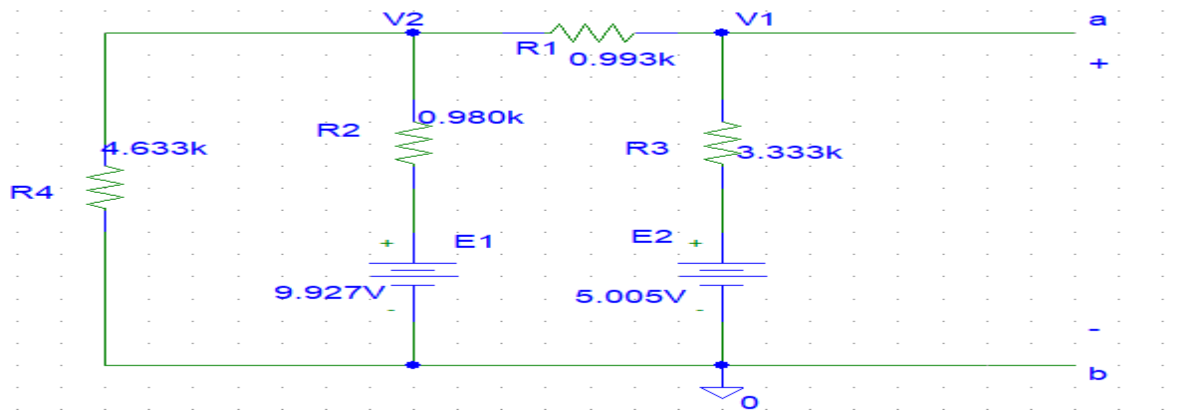
$i_1 = -1.288mA$

$i_2 = 2.755mA$

$i3 = 3.288mA$

$I_L = 3.288mA$

$$V_L = 3.288 * 0.982v$$
$$= 3.230v$$



KCL at node 2:

$$\frac{V2}{4.633} + \frac{V2-9.927}{0.980} + \frac{V2-V1}{0.993} = 0$$

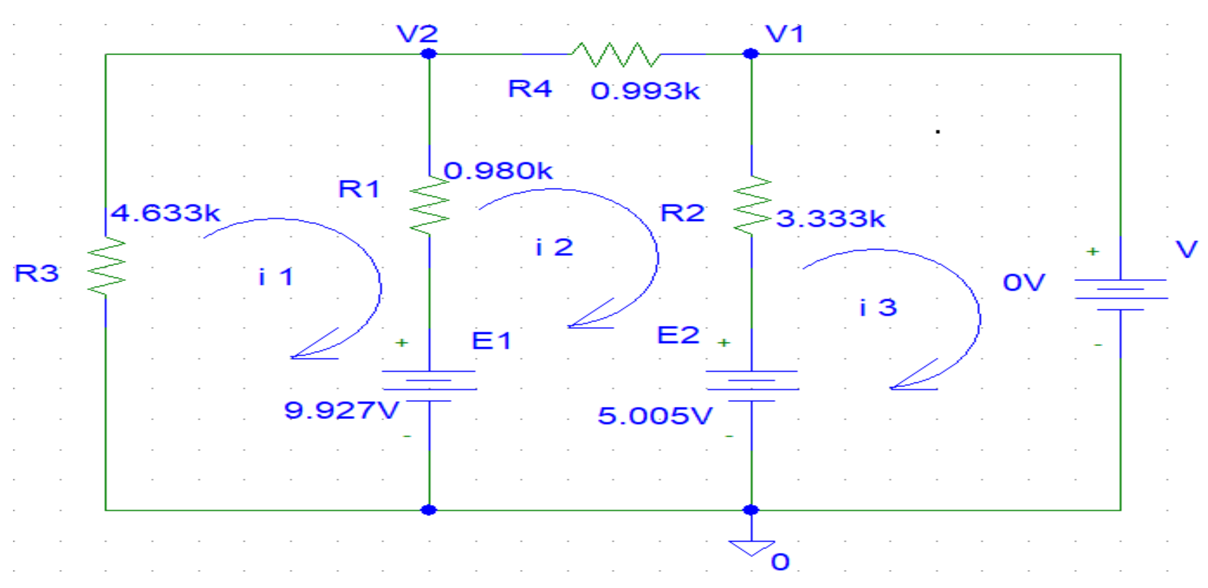
$$-1.007v_1 + 2.2433v_2 = 10.129\ldots\ldots.(1)$$

KCL at node 1:

$$\frac{V1-V2}{0.993} + \frac{V1-5.005}{3.333} = 0$$

$$1.307v_1 - 1.007v_2 = 1.5016\ldots\ldots.(2)$$

So, $v_1 = v_{oc} = v_{th} = 7.075v$



KVL at mesh 1:

$$4.633i_1 + 0.980(i_1 - i_1) = -9.927$$

$$5.613i_1 - 0.980i_2 = -9.927 \ldots\ldots\ldots (1)$$

KVL at mesh 2:

$$0.980(i_2 - i_1) + 0.993i_2 + 3.333(i_2 - i_3) = 9.927 - 5.005$$

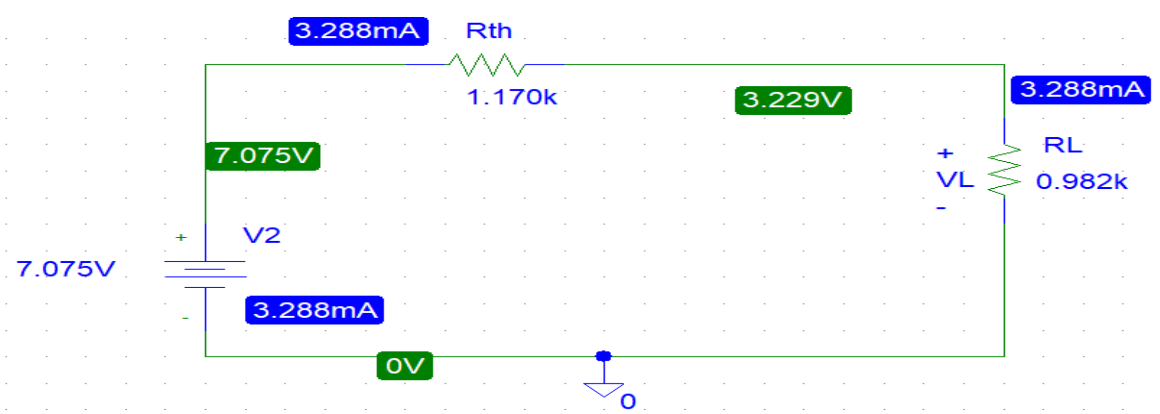
$$\Rightarrow -0.980i_1 + 5.306i_2 - 3.333i_3 = 4.922 \ldots\ldots\ldots (2)$$

KVL at mesh 3:

$$3.333(i_3 - i_2) = 5.005$$

$$\Rightarrow -3.333i_2 + 3.333i_3 = 5.005 \ldots\ldots\ldots\ldots (3)$$

$i_1 = -0.975mA$
$i_2 = 4.547mA$
$i_3 = 6.049mA$
$i_3 = i_{sc} = 6.049mA$



$E_{th} = v_{oc} = 7.075v$

$$R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{7.075}{6.049} = 1.170k \text{ ohm}$$

$$V_L = \frac{7.075}{1.170+0.982} * 0.982$$

$V_L = 3.230$ v

$$I_L = \frac{3.230}{0.982}$$

$= 3.288$mA

Here we see that, V_L and I_L from figure 1 is equal to the V_L and I_L of figure 4. So Thevenin's theorem is verified.

2. Compare the measured values and the calculated values from step 1 and comment on any observed discrepancy:

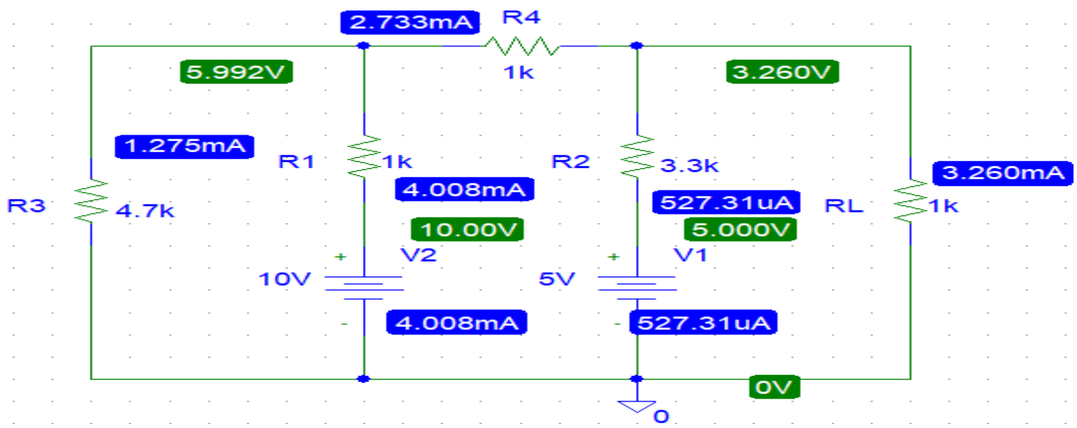
Measured value of V_L	**Calculated value of V_L**	**Measured value of I_L(mA)**	**Calculated ed value of I_L (mA)**	**Measured value of V_{oc}**	**Calculated value of V_{oc}**	**Measured value of I_{SC}(mA)**	**Calculated value of I_{SC} (mA)**
3.241V	**3.230 V**	**3.2mA**	**3.288**	**7.075 V**	**7.075V**	**6.00**	**6.049**

In the Above table we see that, the measured value of VL is 3.241V and the calculated value of VL is 3.230V. Both values are close. The measured value of IL is 3.2mA and the calculated value of IL is 3.288mA. Both values are also the same. The measured value of Voc is the same as the calculated value of Voc. The measured value of Isc and the calculated value if Isc are also very close to each other.

3. Using PSpice, simulate the circuit of Figure 1 and determine VL and IL. Simulate the circuit of Figure 2 and determine VOC. For this purpose, connect a 0A current source between nodes a and b. Simulate the circuit of Figure 3 and determine ISC. For this purpose, connect a 0V voltage source between nodes a and b. Determine the values of Eth and Rth. Simulate the circuit of Figure 4 and determine VL and IL. Verify the Thevenin's theorem from simulated data.

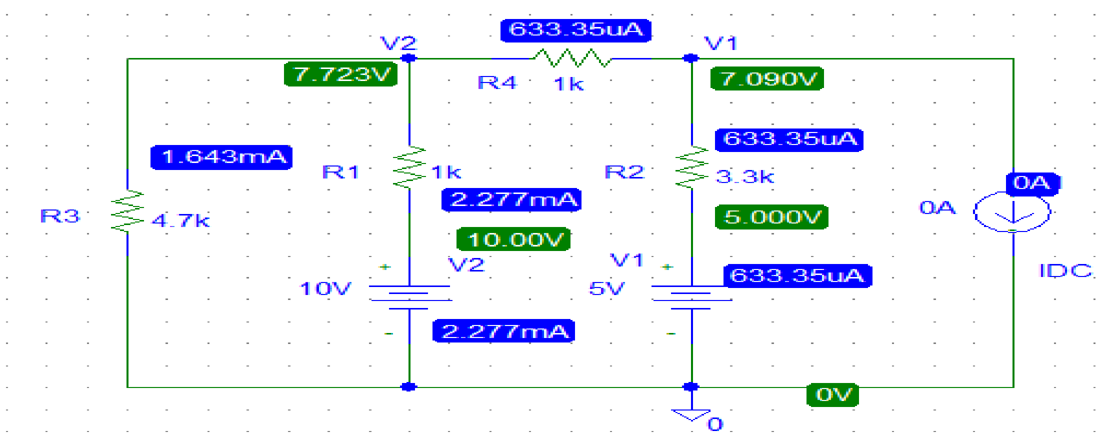
Answer:

PSpice simulation circuit of figure 1:



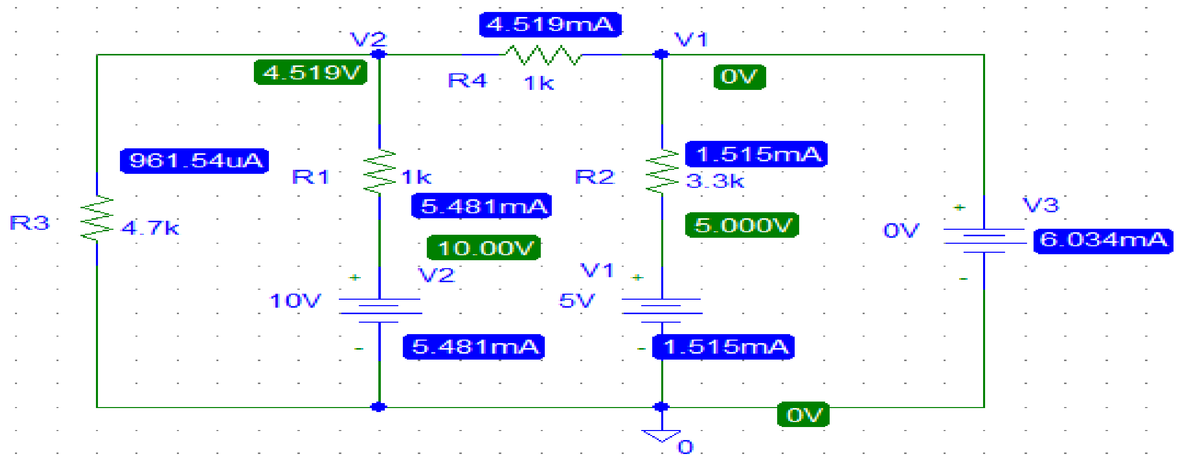
Here the value of V_L=3.260V And the value of I_L=3.260mA

PSpice simulation circuit of figure 2:



Here the value of Voc=v1=7.090v

PSpice simulation circuit of figure 3:

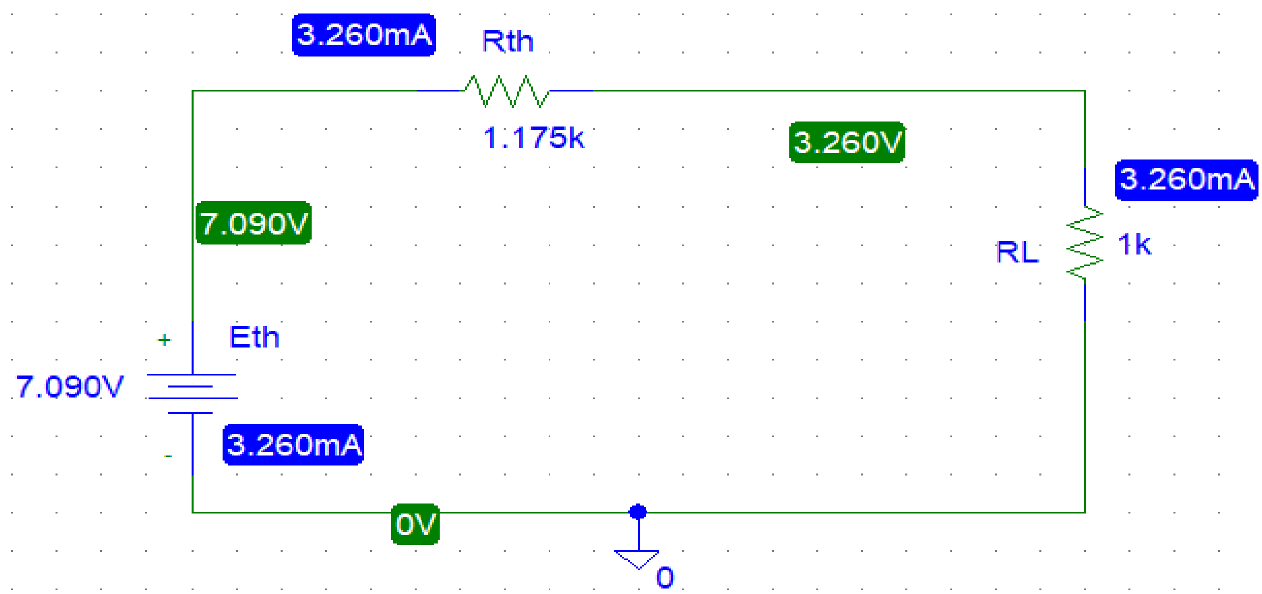


Here the value of Isc=6.034mA

E_{th} = v_{oc} = 7.090v

$$R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{7.090}{6.034} = 1.175\text{k ohm}$$

PSpice simulation circuit of figure 4:



Here we see that, V_L and I_L from figure 1 is equivalent to the $V_L$and $I_L$of figure 4. So Thevenin’s theorem is verified.

Discussions:

1. It is needed to be ensured that all the connections are established according to the given circuit in the manual.

2. When measuring Thevenin resistance, it is needed to make sure that voltage sources are shorted and current sources are open to avoid incorrect resistance readings.

3. Same load resistance should be used for both the original circuit and the Thevenin equivalent circuit to ensure fair comparison of result.

4. It should be ensured that the circuit is correctly grounded to prevent any interference from affecting the result.