K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
DC CIRCUITS

Numerical 1: For the circuit shown in Figure 1,

a) Write the nodal equations and solve for the node voltages. Then, find the value of I_1.

b) Could this problem be solved in another (simpler) way?

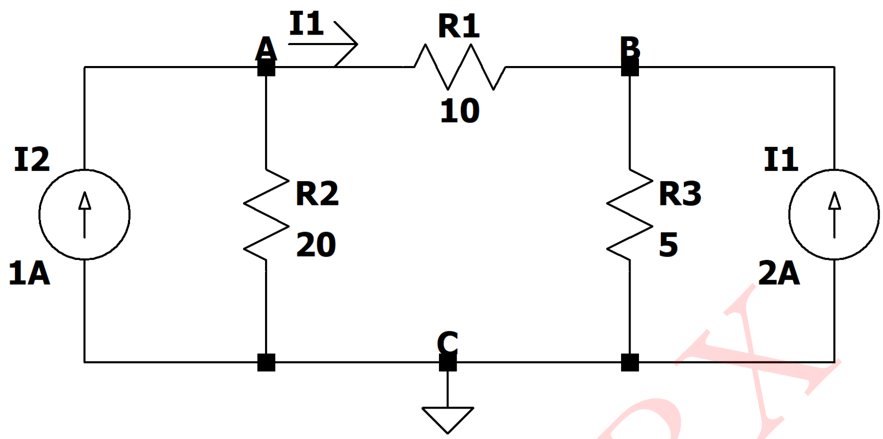


Figure 1: Circuit 1

Solution:

a) Since C is the reference node,
$V_C = 0$

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at A:

$$\frac{V_A - V_B}{10} + \frac{V_A}{20} - 1 = 0$$

$$3V_A - 2V_B = 20 \qquad ...(1)$$

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at B:

$$\frac{V_B - V_A}{10} + \frac{V_B}{5} - 2 = 0$$

$$-V_A + 3V_B = 20 \qquad ...(2)$$

From (1) and (2) we get:

$V_A = \mathbf{14.2857V}$

$V_B = \mathbf{11.42857V}$

From Ohm's Law:

$$I_1 = \frac{V_A - V_B}{10}$$

$I_1 = \mathbf{0.285713A}$

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

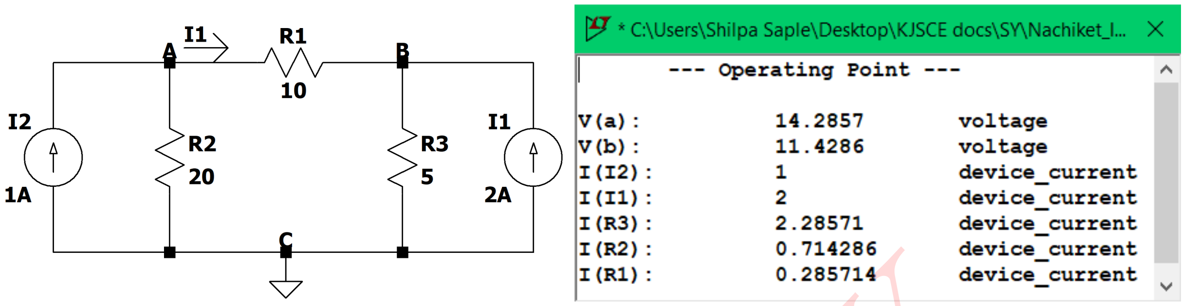


Figure 2: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
V_A	$14.2857V$	$14.286V$
V_B	$11.42857V$	$11.429V$
I_1	$0.285713A$	$0.28571A$

Table 1: Comparison of calculated and simulated results

b) Yes, the problem can be solved using Source Transformation in a simpler way.

Numerical 2: By applying nodal analysis to the below circuit in Figure 3, find I_{ab}, I_{bd} and I_{bc}. All resistance values are in ohms.

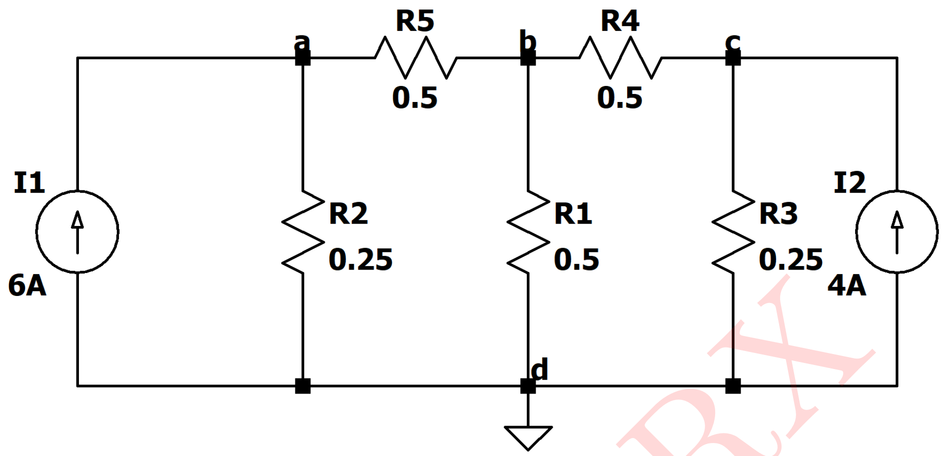


Figure 3: Circuit 2

Solution:

Since d is the reference node,
$V_d = 0$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at a:

$$\frac{V_a - V_b}{0.5} + \frac{V_a}{0.25} - 6 = 0$$

$$6V_a - 2V_b = 6 \qquad ....(1)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at b:

$$\frac{V_b - V_a}{0.5} + \frac{V_b - V_c}{0.5} + \frac{V_b}{0.5} = 0$$

$$-V_a + 3V_b - V_c = 0 \qquad ....(2)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at c:

$$\frac{V_c - V_b}{0.5} + \frac{V_c}{0.25} - 4 = 0$$

$$-2V_b + 6V_c = 4 \qquad ....(3)$$

From (1), (2) and (3) we get:

$V_a = \mathbf{1.23809V}$

$V_b = \mathbf{0.71428V}$

$V_c = \mathbf{0.90476V}$

From Ohm's Law:

$$I_{ab} = \frac{V_a - V_b}{0.5}$$

$$I_{bd} = \frac{V_b - V_d}{0.5}$$

$$I_{bc} = \frac{V_b - V_c}{0.5}$$

I_{ab} = **1.04762A**

I_{bd} = **1.42857A**

I_{bc} = **−0.38095A**

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

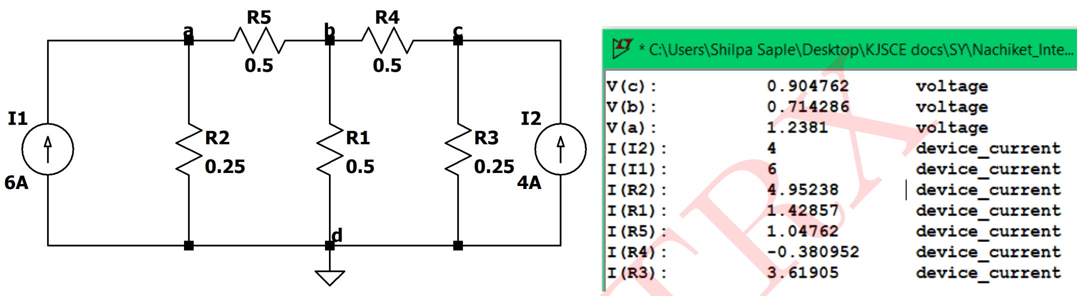


Figure 4: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
I_{ab}	$1.04762A$	$1.04762A$
I_{bd}	$1.42857A$	$1.42857A$
I_{bc}	$-0.38095A$	$-0.380952A$

Table 2: Comparison of calculated and simulated results

Numerical 3: Using Nodal voltage method, compute the power dissipated in the 9Ω resistor of the circuit given in Figure 5.

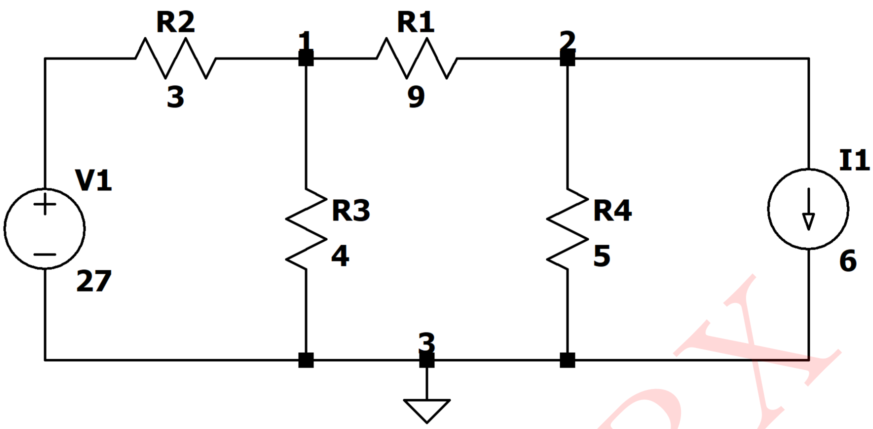


Figure 5: Circuit 3

Solution:

Since 3 is the reference node,
$V_3 = 0$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at 1:

$$\frac{V_1 - 27}{3} + \frac{V_1}{4} - \frac{V_1 - V_2}{9} = 0$$

$$\frac{25V_1}{36} - \frac{V_2}{9} = 9 \qquad ....(1)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at 2:

$$\frac{V_2 - V_1}{9} + \frac{V_2}{5} + 6 = 0$$

$$\frac{-V_1}{9} + \frac{14V_2}{45} = -6 \qquad ....(2)$$

From (1) and (2) we get:

$V_1 = \mathbf{10.47273V}$

$V_2 = \mathbf{-15.54545V}$

From Ohm's Law, Current through 9Ω resistor:

$$I_{9\Omega} = \frac{V_1 - V_2}{9}$$

$I_{9\Omega} = \mathbf{2.89091A}$

Power dissipated in a resistor:
$P = VI = I^2R$

Power dissipated in 9Ω resistor:
$P_{9\Omega} = 9 \times {I_{9\Omega}}^2 = 75.21621W$

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the readings obtained are as follows:

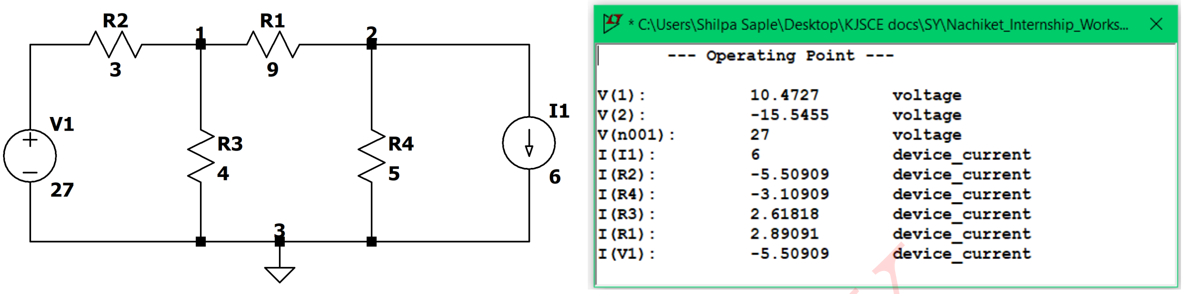


Figure 6: Circuit Schematic and Simulated Results

From the simulated results, $V_{12} = V_1 - V_2 = 10.4727 + 15.5455 =$ **26.0182V**

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
V_{12}	26.0182V	26.0182V
$I_{9\Omega}$	2.89091A	2.89091A
$P_{9\Omega}$	75.21621W	75.21627W

Table 3: Comparison of calculated and simulated results

Numerical 4: For the circuit shown in Figure 7, find the equivalent resistance. All resistors are of 60Ω.

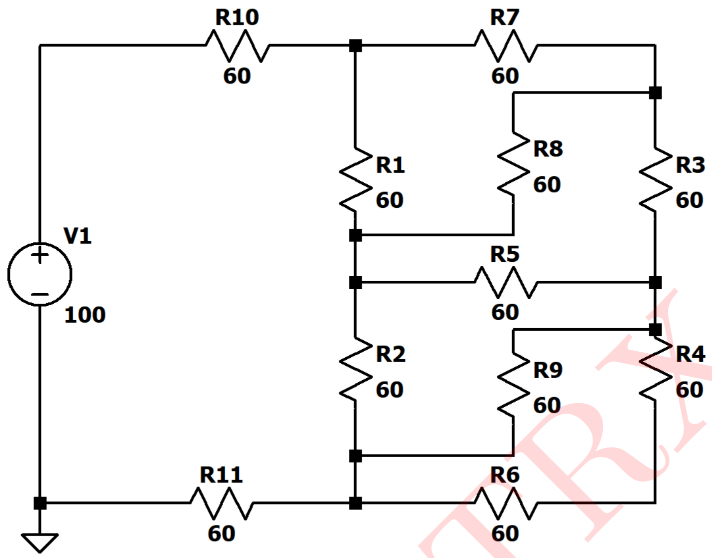


Figure 7: Circuit 4

Solution:
Converting Delta configuration of resistor to Star for Resistors R_1, R_7 and R_8.

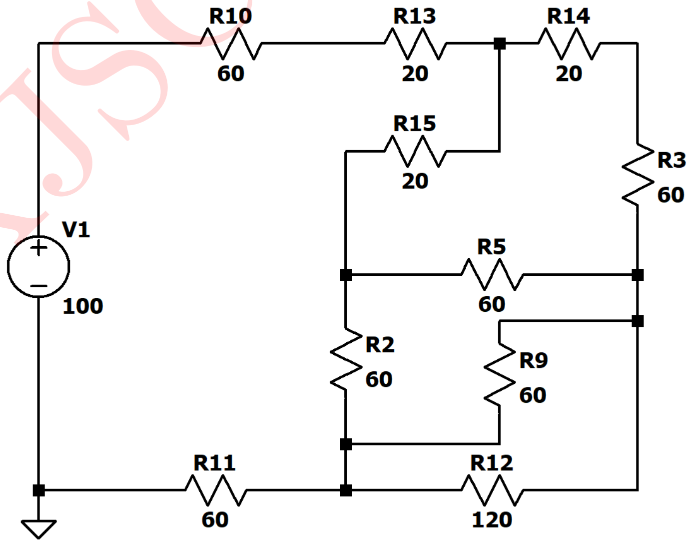


Figure 8: Modified circuit after delta to star conversion

Adding resistances R_{10} and R_{13}, R_{14} and R_3 in series.

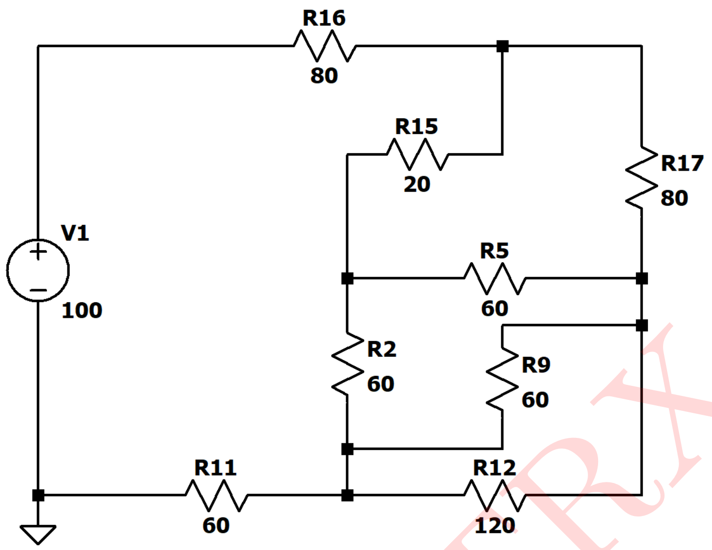


Figure 9: Circuit after adding the series resistances

Applying Delta to Star Conversion on R_5, R_{15} and R_{17}.

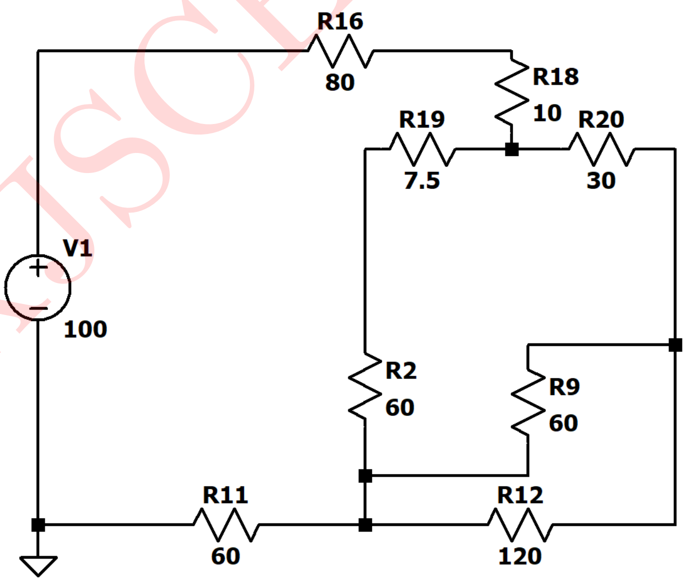


Figure 10: Modified circuit after delta to star conversion

Adding resistances R_{16} *and* R_{18}, R_2 *and* R_{19} in series, R_9 *and* R_{12} in parallel.

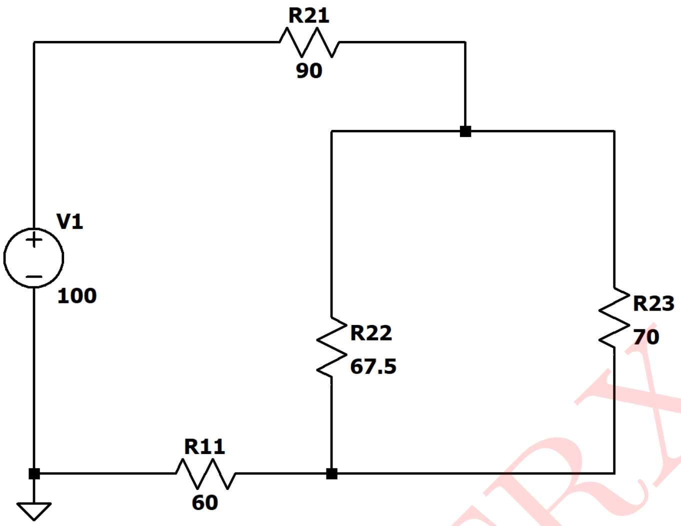


Figure 11: Modified circuit after series and parallel combination

Finally, after solving the last series and parallel resistances from Figure 9, we get:

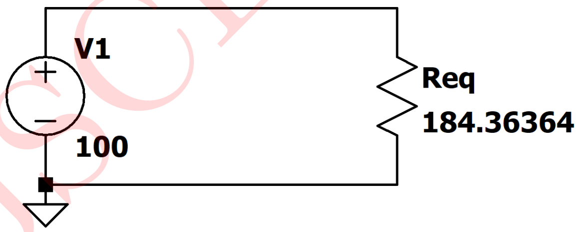


Figure 12: Equivalent Resistance

Hence, Equivalent Resistance $R_{eq} = 184.36364\Omega$

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

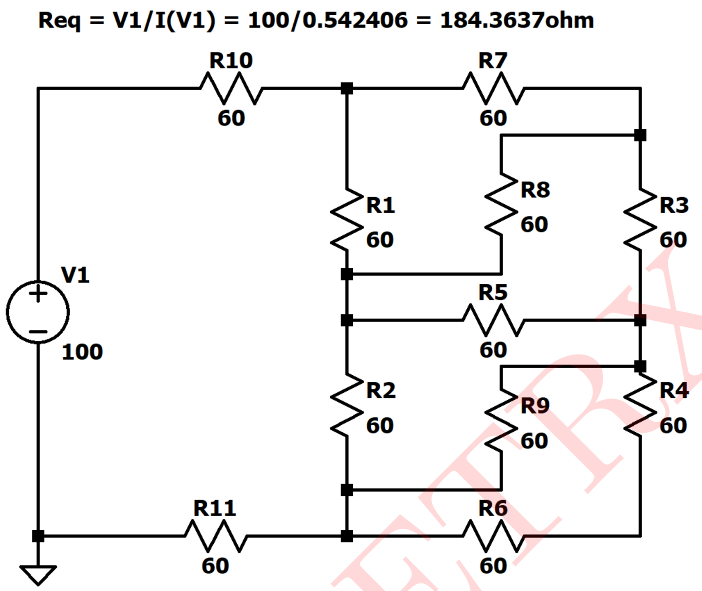


Figure 13: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
R_{eq}	184.3636Ω	184.3637Ω

Table 4: Comparison of calculated and simulated results

Numerical 5: Find the current in the 11Ω resistor in Figure 14 by using star delta conversion. All resistances are in ohm.

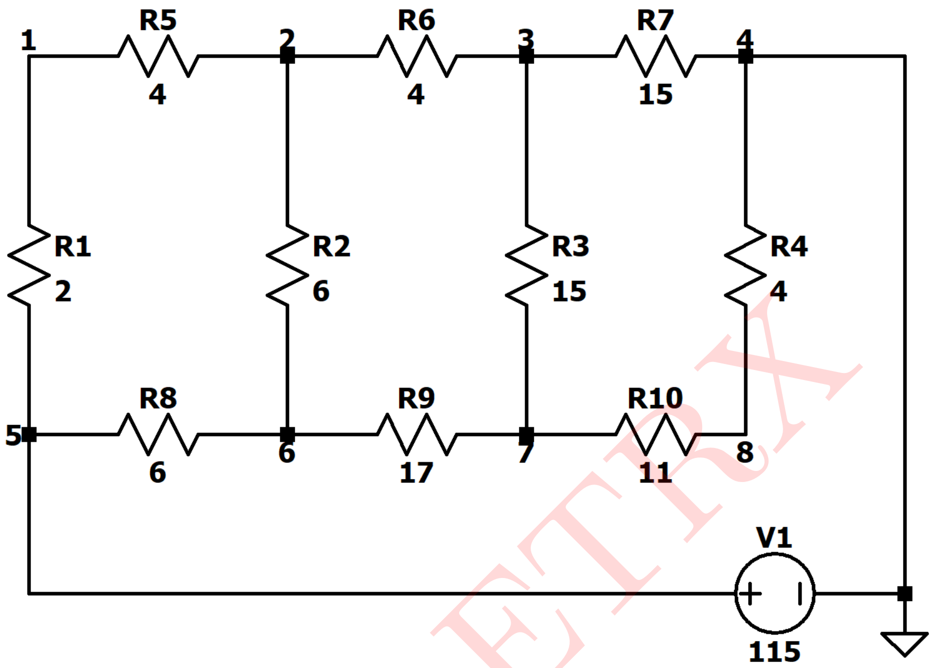


Figure 14: Circuit 5

Solution:

Adding resistances R_1 and R_5

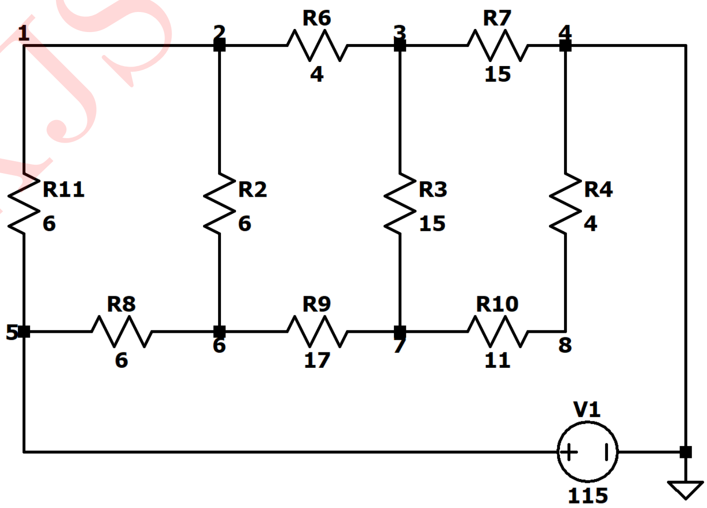


Figure 15: Modified circuit after series addition of resistances

Delta to Star conversion of resistors: R_2, R_8 and R_{11}

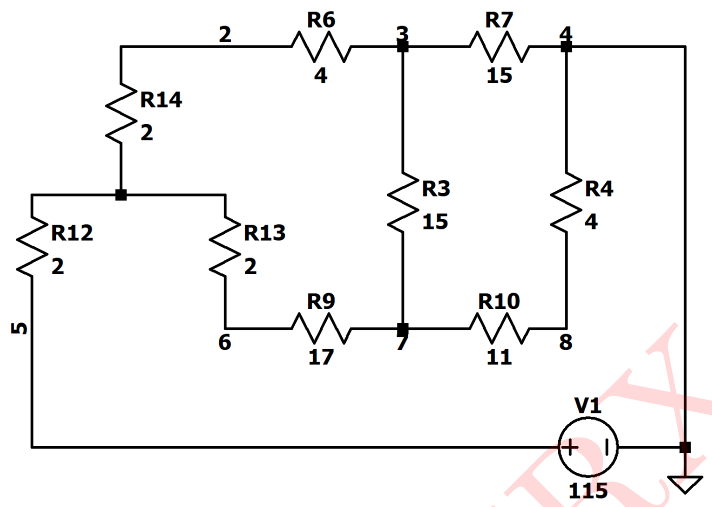


Figure 16: Modified circuit after Delta to Star conversion

Adding series combination of resistances: R_6 and R_{14}, R_{13} and R_9

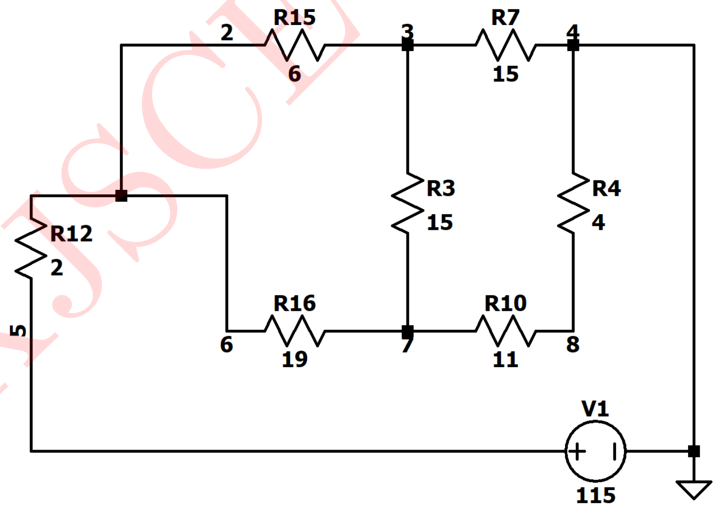


Figure 17: Modified circuit after series addition of resistances

Delta to Star conversion of resistors: R_{15}, R_{16} and R_3

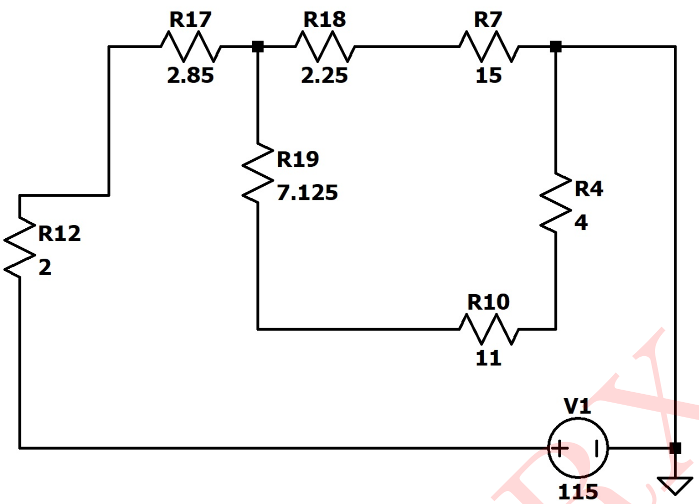


Figure 18: Modified circuit after Delta to Star conversion

Adding series combination of resistances: R_{12} and R_{17}, R_{18} and R_7, R_4 and R_{19}

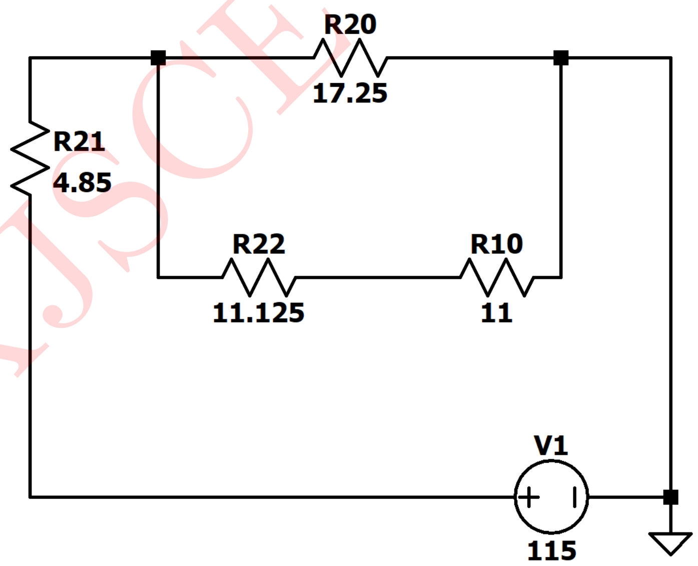


Figure 19: Modified circuit after series addition of resistances

Now, equivalent resistance of the parallel combination is:

$$\frac{17.25 \times (11.125 + 11)}{17.25 + 11.125 + 11} = 9.69286\Omega$$

Total current supplied by the voltage source $= I$:

$$I = \frac{115}{4.85 + 9.69286} = 7.90766A$$

Finally, current through 11Ω branch is:

$$I_{11\Omega} = \frac{17.25}{39.375} \times I = \frac{17.25}{39.375} \times 7.90766$$

$$I_{11\Omega} = \mathbf{3.46431A}$$

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

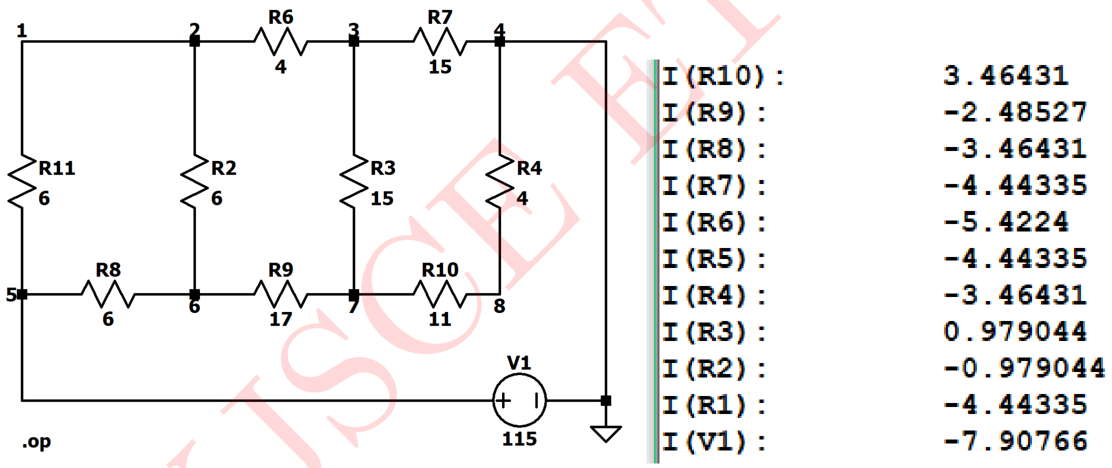


Figure 20: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
I_{V_1}	$7.90766A$	$7.90766A$
$I_{11\Omega}$	$3.46431A$	$3.46431A$

Table 5: Comparison of calculated and simulated results

Numerical 6: Determine the voltages at the nodes V_1, V_2 and V_3 given in Figure 21.

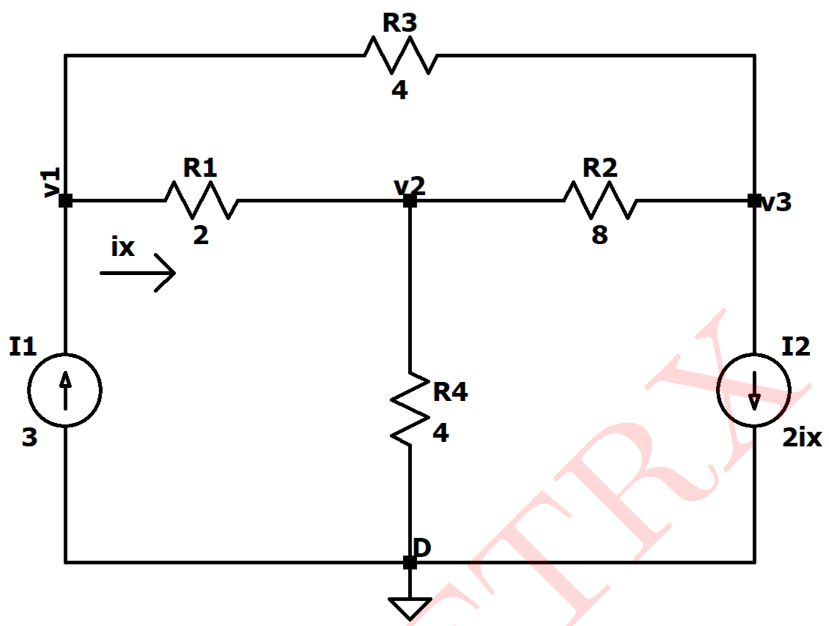


Figure 21: Circuit 6

Solution:

From Ohm's Law:

$$I_x = \frac{V_1 - V_2}{2} \qquad .....(1)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at 1:

$$\frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{4} - 3 = 0$$

$$3V_1 - 2V_2 - V_3 = 12 \qquad .....(2)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at 2:

$$\frac{V_2 - V_1}{2} + \frac{V_2 - V_3}{8} + \frac{V_2}{4} = 0$$

$$-4V_1 + 7V_2 - V_3 = 0 \qquad .....(3)$$

Applying Kirchoff's Current Law(KCL) and Ohm's Law at node 3:

$$\frac{V_3 - V_1}{4} + \frac{V_3 - V_2}{8} + 2I_x = 0$$

Substituting the expression for I_x from (1), we get

$$2V_1 - 3V_2 + V_3 = 0 \qquad .....(4)$$

From (2), (3) and (4) we get:

V_1 = **4.8V**

V_2 = **2.4V**

V_3 = **−2.4V**

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the readings obtained are as follows:

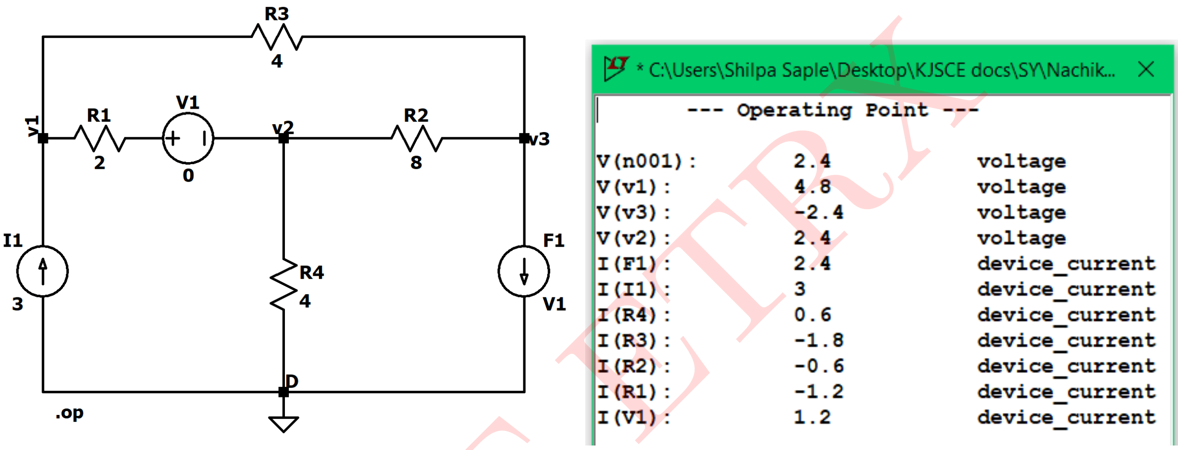


Figure 22: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
V_1	$4.8V$	$4.8V$
V_2	$2.4V$	$2.4V$
V_3	$-2.4V$	$-2.4V$

Table 6: Comparison of calculated and simulated results

Numerical 7: Find the voltages at the three non-reference nodes $1, 2$ and 3 in the circuit of Figure 23.

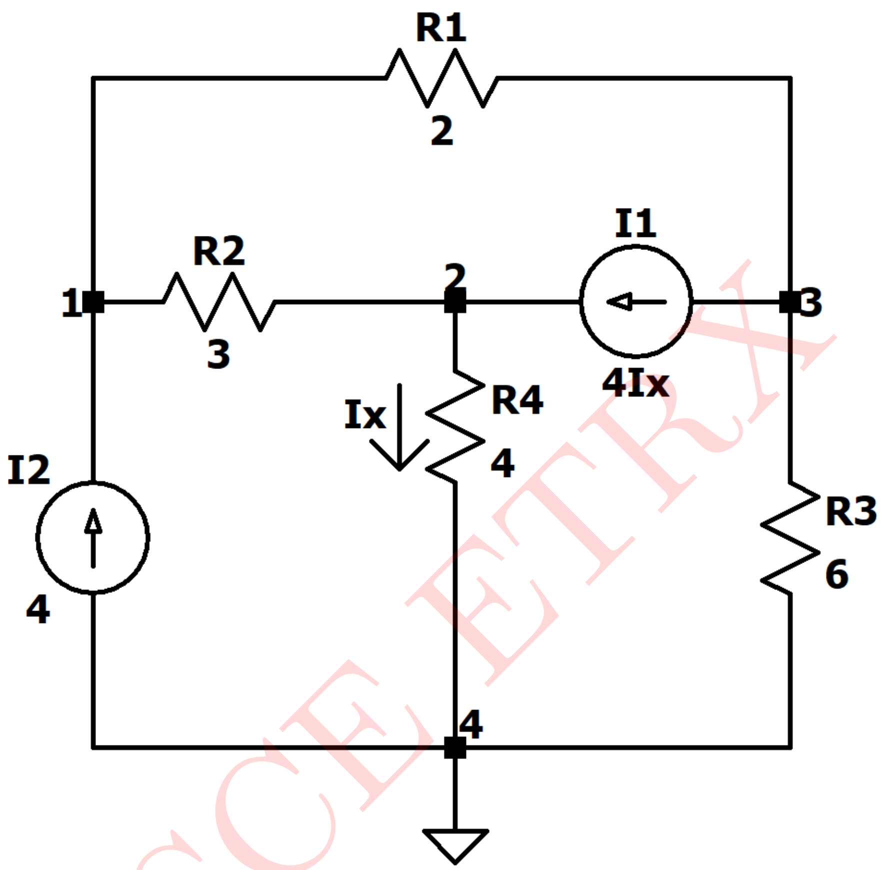


Figure 23: Circuit 7

Solution:

From Ohm's Law:

$$I_x = \frac{V_2}{4}$$

Applying Kirchoff's Current Law(KCL) at 1:

$$\frac{V_1 - V_2}{3} + \frac{V_1 - V_3}{2} - 4 = 0$$

$$\frac{5V_1}{6} - \frac{V_2}{3} - \frac{V_3}{2} = 4 \qquad .....(1)$$

Applying Kirchoff's Current Law(KCL) at 2:

$$\frac{V_2 - V_1}{3} + \frac{V_2}{4} - 4I_x = 0$$

$$\frac{V_1}{3} + \frac{5V_2}{12} = 0 \qquad .....(2)$$

Applying Kirchoff's Current Law(KCL) at node 3:

$$\frac{V_3}{6}+\frac{V_3-V_1}{2}+4I_x=0$$

$$\frac{-V_1}{2}+V_2+\frac{2V_3}{3}=0 \qquad .....(3)$$

From (2), (3) and (4) we get:

V_1 = **32V**

V_2 = **−25.6V**

V_3 = **62.4**

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

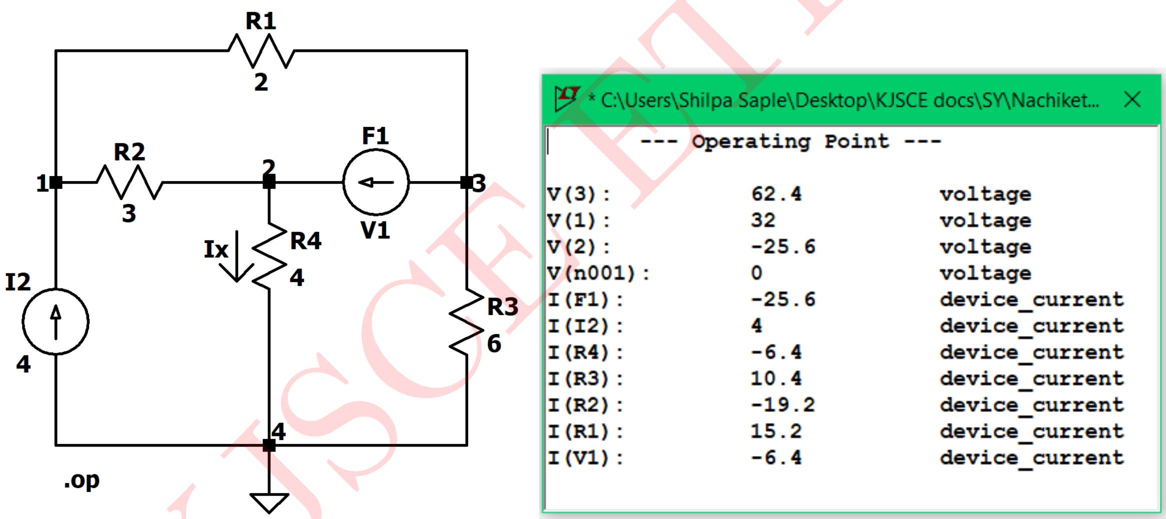


Figure 24: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
V_1	$32V$	$32V$
V_2	$-25.6V$	$-25.6V$
V_3	$62.4V$	$62.4V$

Table 7: Comparison of calculated and simulated results

Numerical 8: A two-terminal network is shown in the Figure 25. It is a four bit ladder network used for digital-to-analog conversion. In terms of four (digital) voltages D_0, D_1, D_2 and D_3 and resistance R, express:

1. Thévenin (or equivalent) voltage
2. Thévenin (or equivalent) resistance

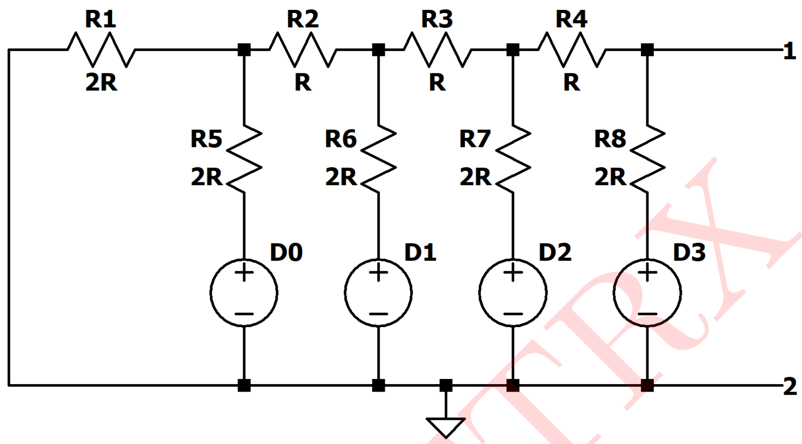


Figure 25: Circuit 8

Solution:

Applying Source Transformation on resistance R_5 and voltage source D_0

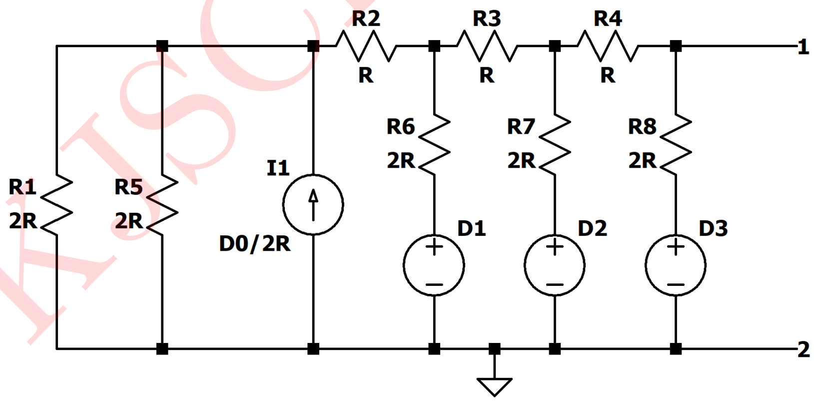


Figure 26: Modified circuit after source transformation

Adding the parallel combinations of resistances R_1 and R_5

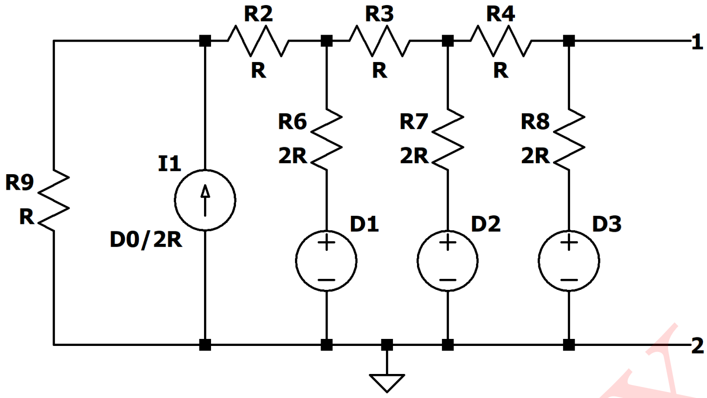


Figure 27: Modified circuit after addition of resistors

Applying source transformation on resistance R_9 and current source I_1

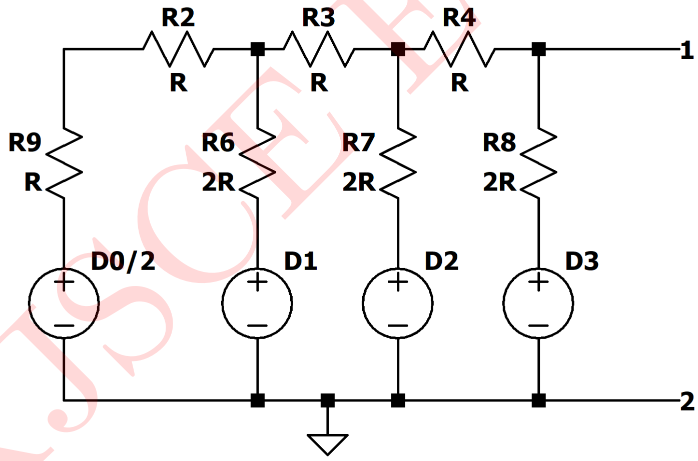


Figure 28: Modified circuit after source transformation

Adding series resistances: R_2 and R_9

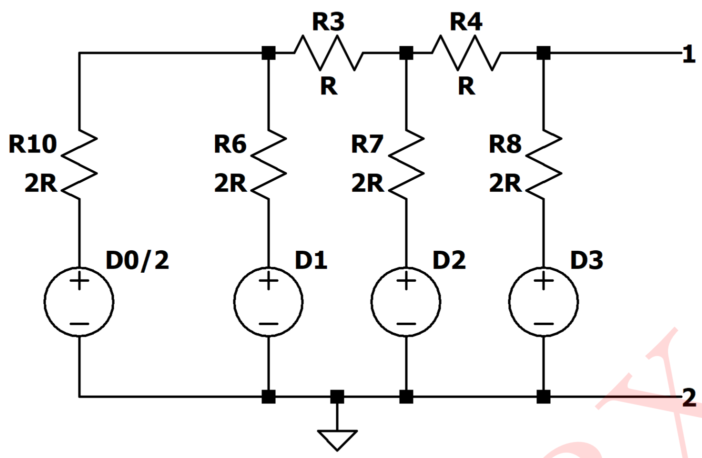


Figure 29: Modified circuit after series addition of resistances

Applying source transformation on: resistance R_{10} and voltage source $\frac{D_0}{2}$ and resistance R_6 and voltage source D_1

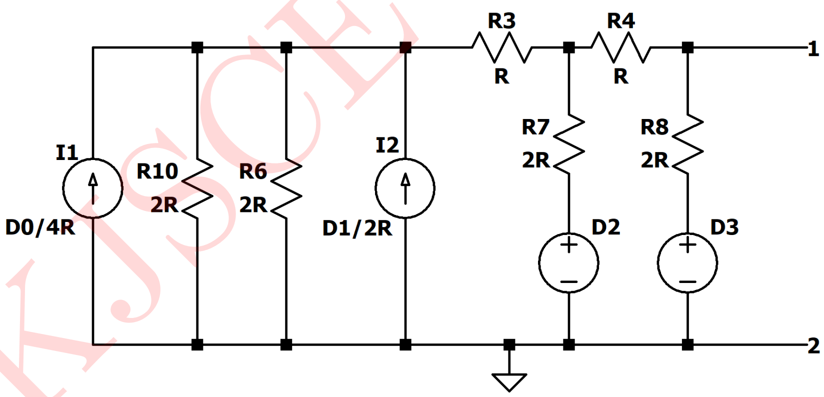


Figure 30: Modified circuit after source transformations

Adding parallel resistances: R_{10}, R_6 and current sources: I_1, I_2

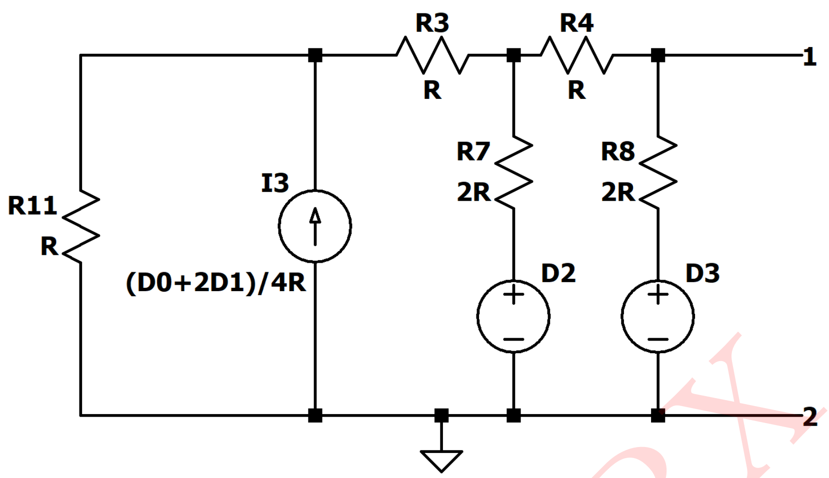


Figure 31: Modified circuit after combination of resistances and current sources

Applying source transformation on: resistance R_{11} and current source I_3

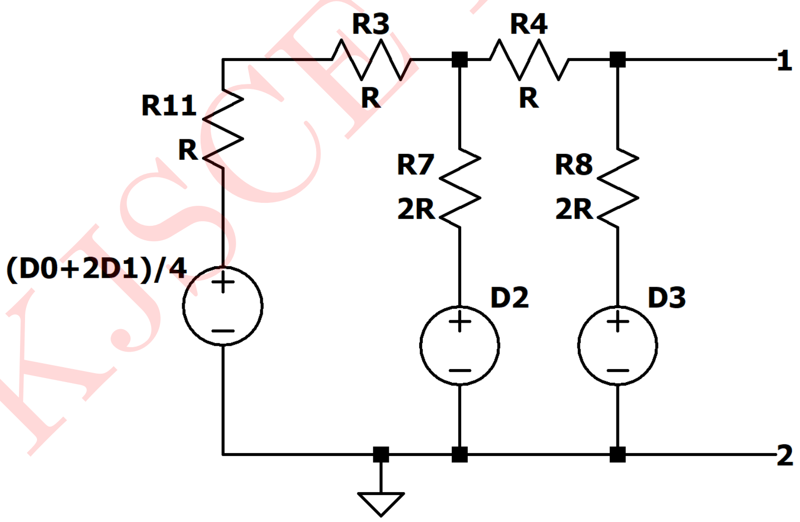


Figure 32: Modified circuit after source transformations

Adding series resistances: R_3 and R_{11}

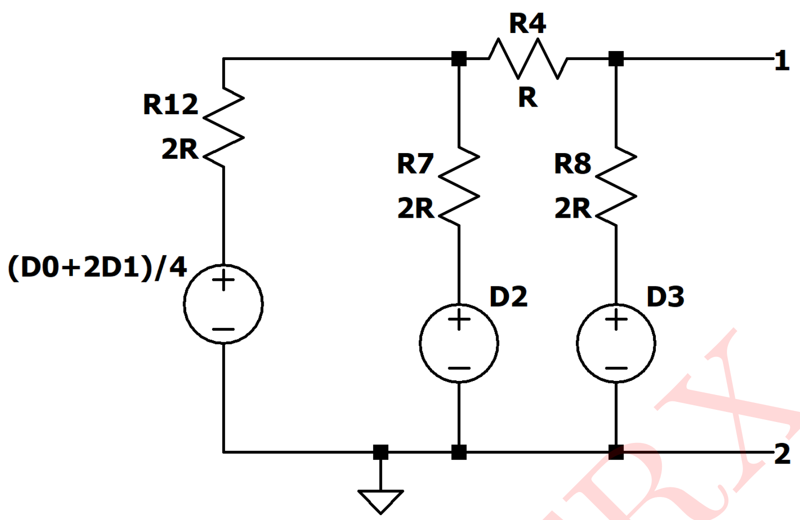


Figure 33: Modified circuit after series addition of resistances

Applying source transformation on: resistance R_{12} and voltage source $\dfrac{D_0 + 2D_1}{4}$ and resistance R_7 and voltage source D_2

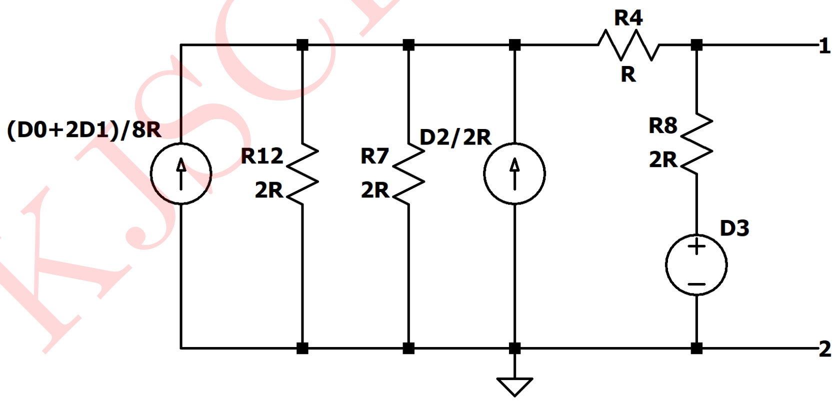


Figure 34: Modified circuit after source transformations

Adding parallel resistances: R_7 and R_{12} and current sources: $\dfrac{D_0 + 2D_1}{8R}$ and $\dfrac{D_2}{2R}$

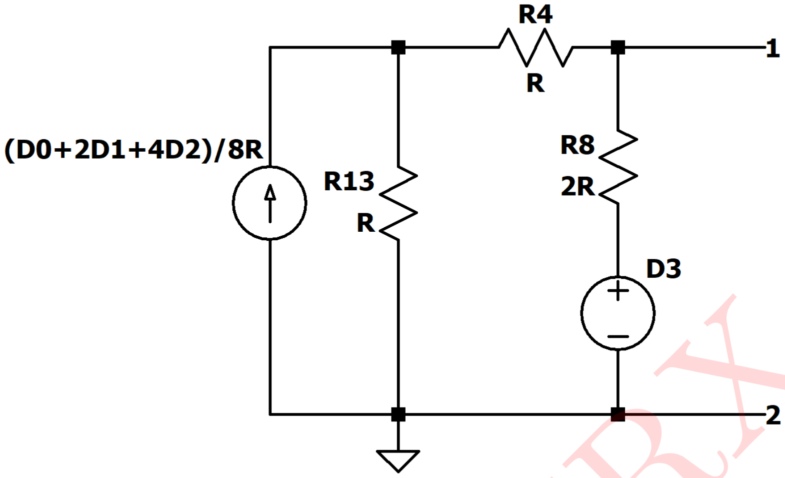


Figure 35: Modified circuit after combination of resistances and current sources

Applying source transformation on: R_{12} and current source $\dfrac{(D_0 + 2D_1 + 4D_2)}{8R}$

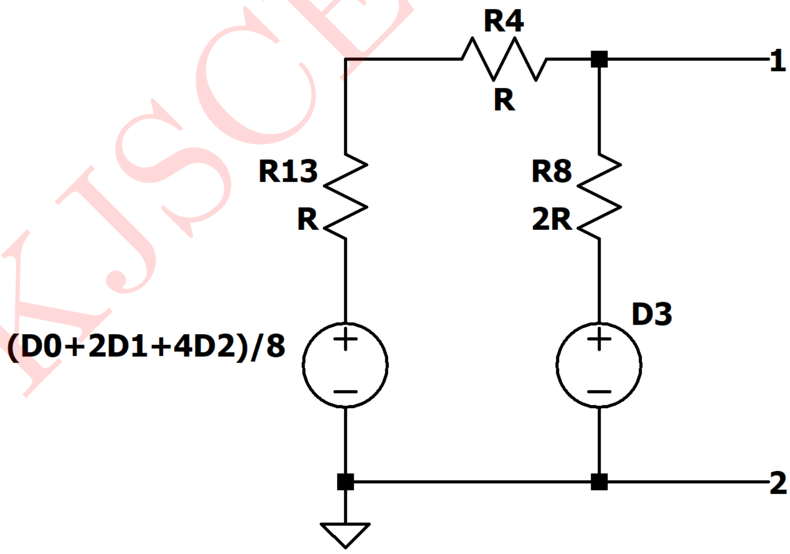


Figure 36: Modified circuit after source transformations

Adding series resistances: R_4 and R_{13}

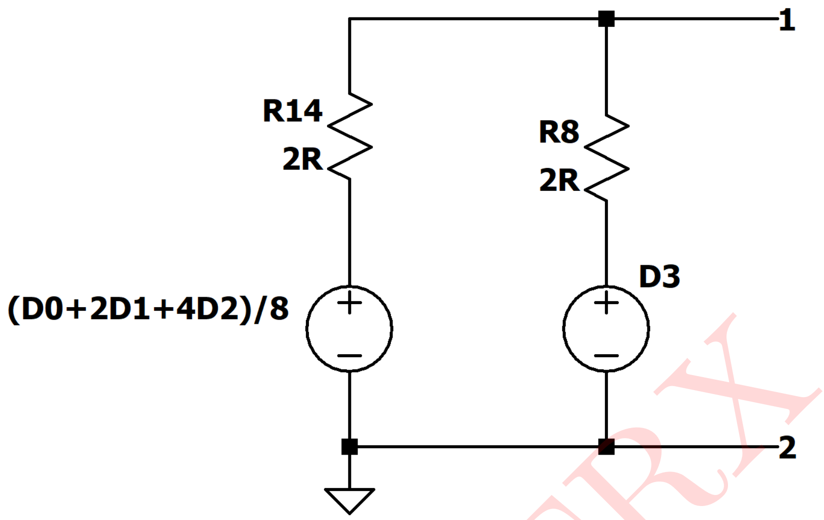


Figure 37: Modified circuit after series addition of resistances

Applying source transformation and combining the resistance and current sources

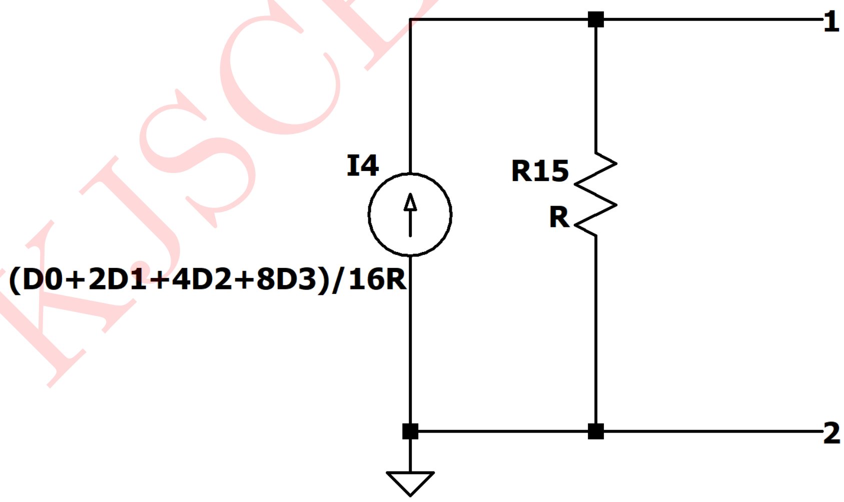


Figure 38: Modified circuit after source transformations

Now, after applying source transformation we get thevenin's equivalent voltage V_{th} and thevenin's resistance R_{th}

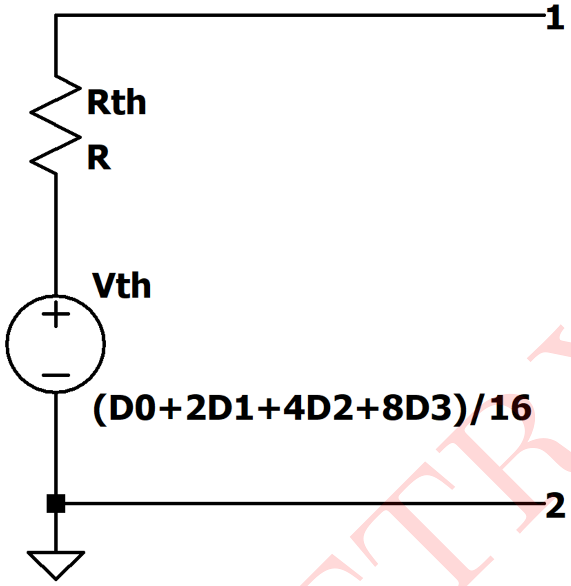


Figure 39: Thevenin's equivalent circuit

$\therefore$ Thevenin's equivalent voltage

$$V_{th} = \frac{D_0 + 2D_1 + 4D_2 + 8D_3}{16}$$

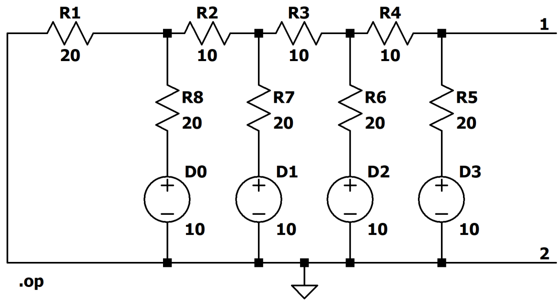
Thevenin's equivalent resistance

$R_{th} = R$

SIMULATED RESULTS:

To verify V_{th} in the simulated results, take $R = 10\Omega,\ D_0 = D_1 = D_2 = D_3 = 10V$

The following circuit has been simulated in LTspice and the readings obtained are as follows:



V(n001):	6.64062	voltage
V(n002):	8.28125	voltage
V(n003):	9.0625	voltage
V(1):	9.375	voltage
V(n007):	10	voltage
V(n006):	10	voltage
V(n005):	10	voltage
V(n004):	10	voltage

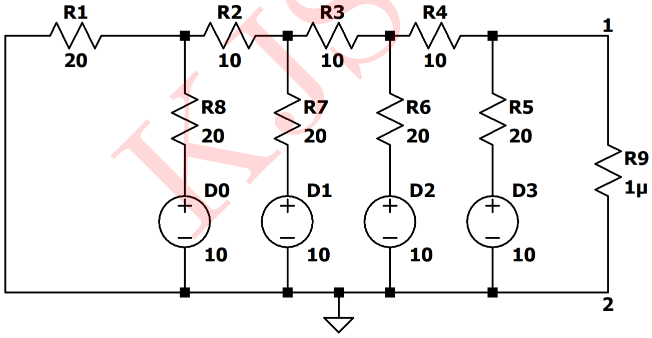
Figure 40: Circuit Schematic and Simulated Results

Hence, simulated value of V_{th} for given resistance and voltage values $= 9.375V$

From calculations: $V_{th} = \dfrac{D_0 + 2D_1 + 4D_2 + 8D_3}{16} = \dfrac{150}{16} = 9.375V$

Connect a small resistance between 1 and 2 and find the short circuit current I_{sc}

The following circuit has been simulated in LTspice and the readings obtained are as follows:



V(1):	9.375e-007	voltage
V(n007):	10	voltage
V(n006):	10	voltage
V(n005):	10	voltage
V(n004):	10	voltage
I(R9):	0.9375	device_current
I(R8):	-0.226563	device_current
I(R7):	-0.203125	device_current
I(R6):	-0.28125	device_current
I(R5):	-0.5	device_current
I(R4):	-0.4375	device_current
I(R3):	-0.15625	device_current
I(R2):	0.046875	device_current
I(R1):	0.273438	device_current

Figure 41: Circuit Schematic and Simulated Results

From the simulated readings, $I_{sc} = I_9 = 0.9375A$

Hence, $R_{th} = \dfrac{V_{12}}{I_{sc}} = \dfrac{9.375V}{0.9375A} = 10\Omega$

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
V_{th}	$9.375V$	$9.375V$
R_{th}	10Ω	10Ω

Table 8: Comparison of calculated and simulated results

Numerical 9: Obtain the Norton's equivalent of the circuit in Figure 42 to the left of terminals a-b. Use the results to find current i.

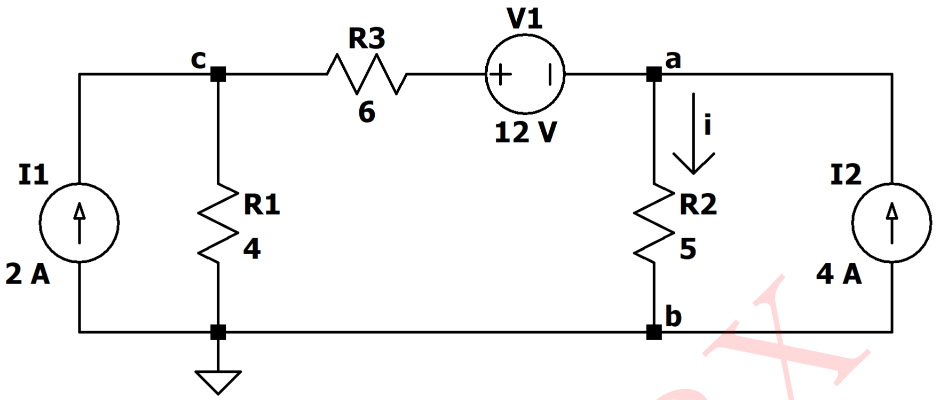


Figure 42: Circuit 9

Solution:

Applying source transformation on current source I_1 and resistance R_1

$V_2 = I_1 \times R_1 = 2 \times 4 = 8V$

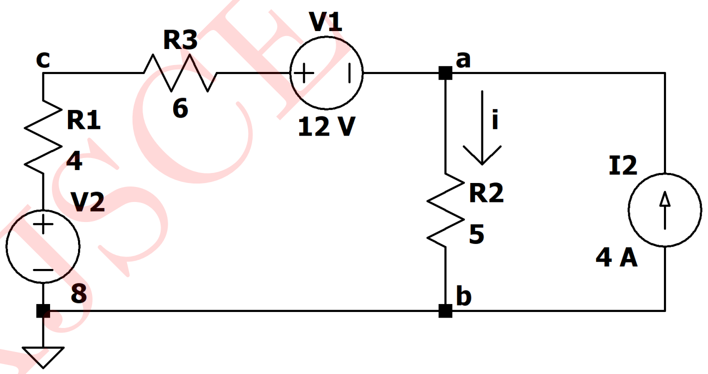


Figure 43: Modified circuit after source transformation

Adding series resistances R_1, R_3 and voltage sources V_2, V_1

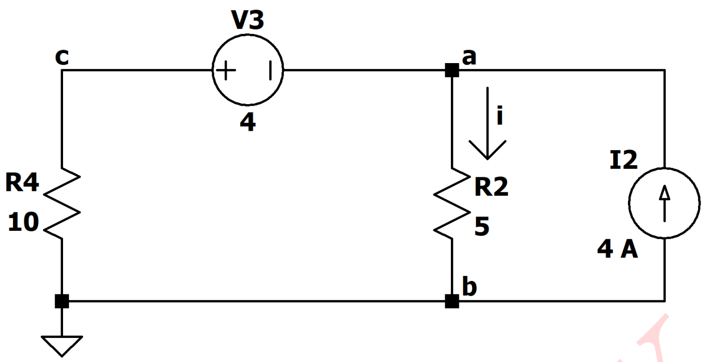


Figure 44: Modified circuit after combination of resistances and voltage sources

Applying source transformation on voltage source V_3 and resistance R_4

$I_3 = \frac{V_3}{R_4} = \frac{4}{10} = 0.4A$

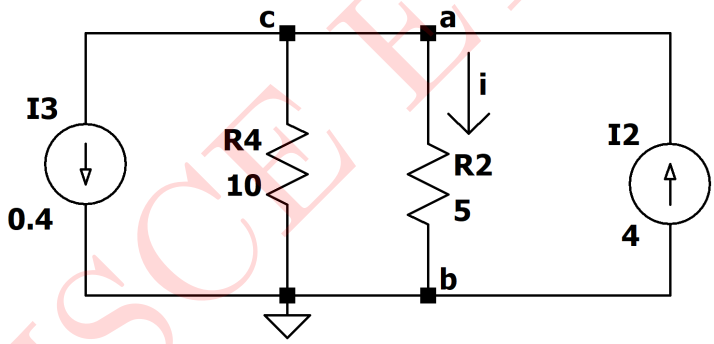


Figure 45: Modified circuit after source transformation

Subtracting current sources I_2, I_3 as they are in opposite directions

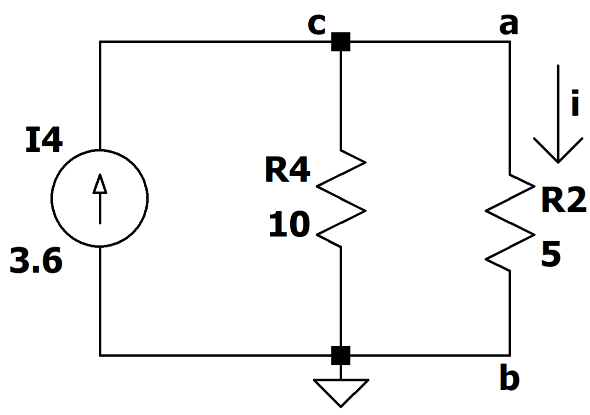


Figure 46: Modified circuit after combining the current sources

Hence the Norton's equivalent circuit is:

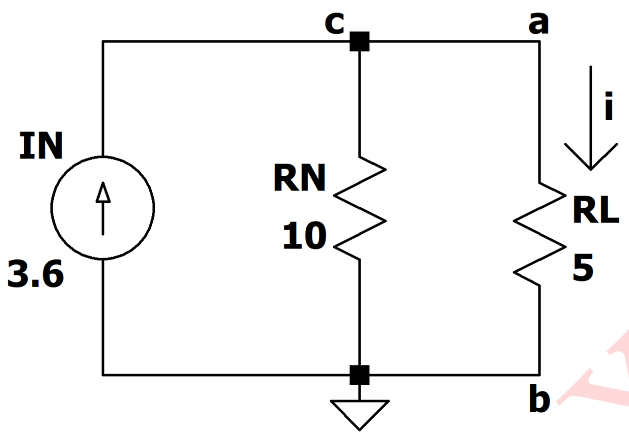


Figure 47: Norton's Equivalent Circuit

$\therefore$ Norton's current: $I_N = 3.6A$
$\therefore$ Norton's resistance: $R_N = 10\Omega$

Load resistance: $R_L = 5\Omega$

Using current division rule to find current through load resistance R_L

$$I_{R_L} = i = \frac{R_N \times I_N}{R_N + R_L} = \frac{10 \times 3.6}{10 + 5} = 2.4A$$

$\therefore i = 3.6A$

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the readings obtained are as follows:

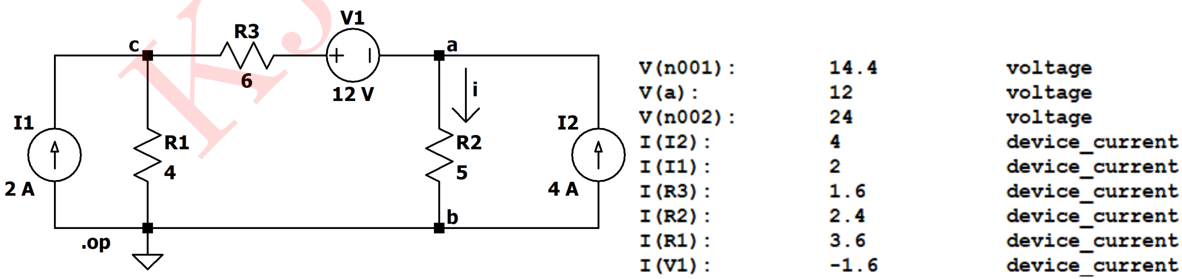


Figure 48: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
i	$2.4A$	$2.4A$

Table 9: Comparison of calculated and simulated results

Numerical 10: In Figure 49 what value of resistor R_3 will allow maximum power transfer to the load? Also calculate the maximum total load power. All resistances are in ohms.

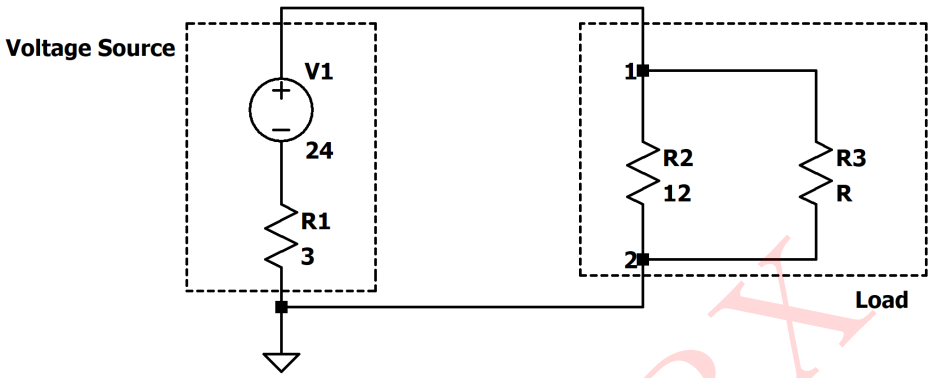


Figure 49: Circuit 10

Solution:

For maximum power transfer to the load, internal resistance of the source must be equal to the load resistance

$R_{internal} = R_{load}$

$R_1 = R_2||R_3$

$3 = (12||R)$

$3 = \dfrac{12 \times R}{12 + R}$

$36 + 3R = 12R$

$9R = 36$

$R = 4\Omega$

Maximum total load power $= P_{max}$

$P_{max} = \dfrac{V_s^2}{4R_s}$

$P_{max} = \dfrac{24^2}{4 \times 3}$

$P_{max} = 48W$

$\therefore$ maximum total load power $= 48W$

SIMULATED RESULTS:

The following circuit has been simulated in LTspice and the readings obtained are as follows:

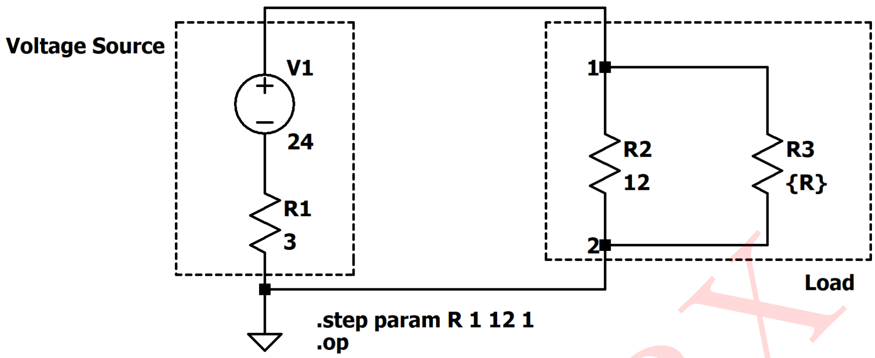


Figure 50: Circuit Schematic

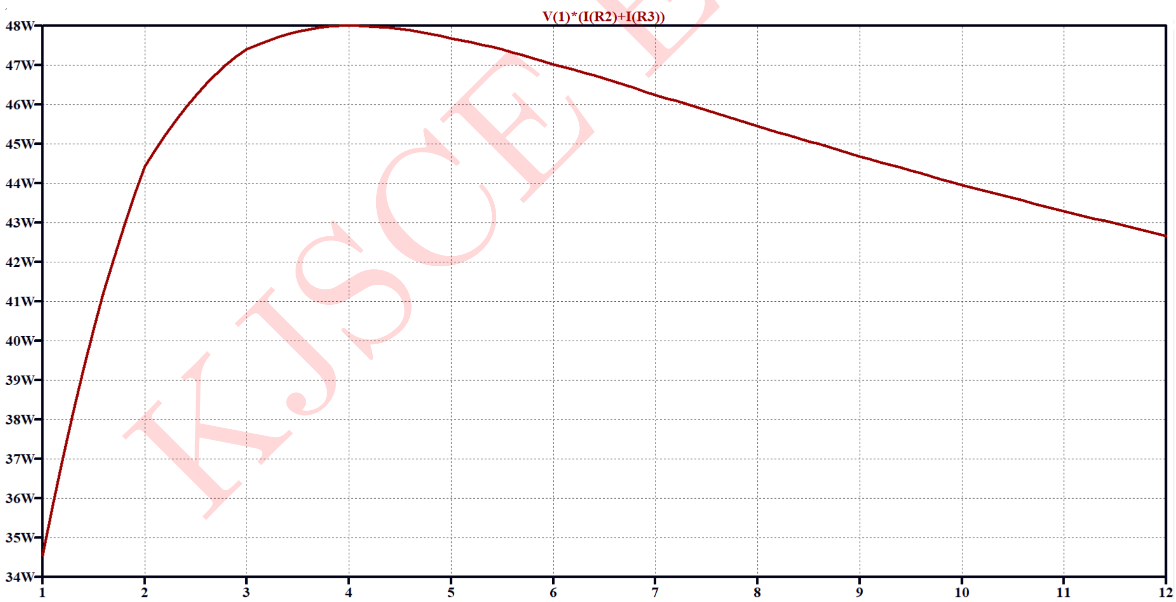


Figure 51: Simulated Results

The graph shows various values of power dissipated across load (y-axis) for values of the resistance R_3 from 1Ω to 12Ω (x-axis).

From the graph, we can see that the power in the load is maximum when $R_3 = 4\Omega$ and the value of maximum power is $48W$.

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
R_3	4Ω	4Ω
P_{max}	$48W$	$48W$

Table 10: Comparison of calculated and simulated results

Numerical 11: In Figure 52 find the value of load resistance R_L for which maximum power will be dissipated in it. Also find the value of maximum power.

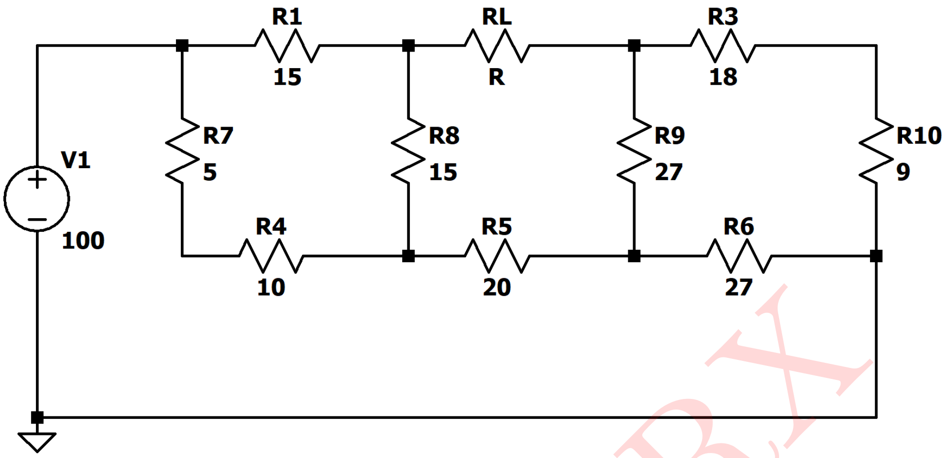


Figure 52: Circuit 11

Solution:

Adding the series resistances: R_7, R_4 and R_3, R_{10}

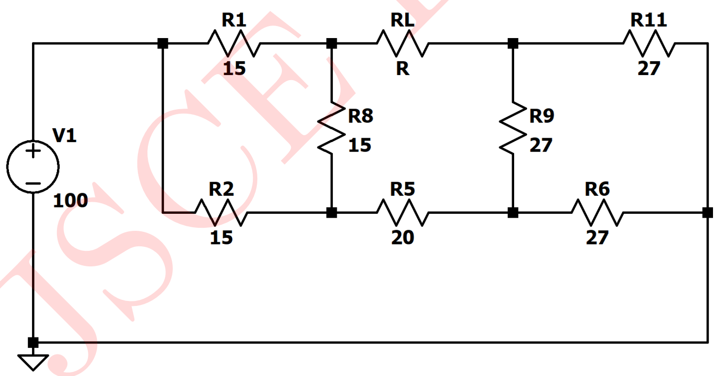


Figure 53: Modified circuit after addition of series resistances

Applying delta to star conversion on resistors: R_1, R_2, R_8 and R_6, R_9, R_{11}

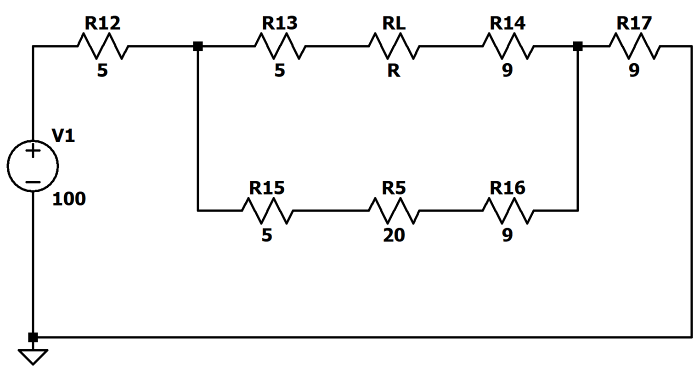


Figure 54: Modified circuit after delta to star conversion

Adding series resistances: R_{13}, R_{14} and R_{15}, R_5, R_{16}

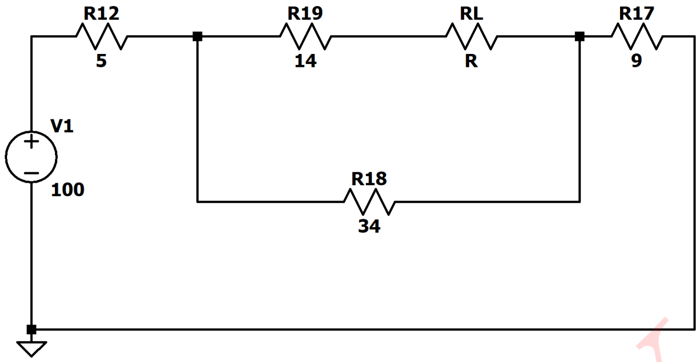


Figure 55: Modified circuit after delta to star conversion

Adding series resistances: R_{12}, R_{17}

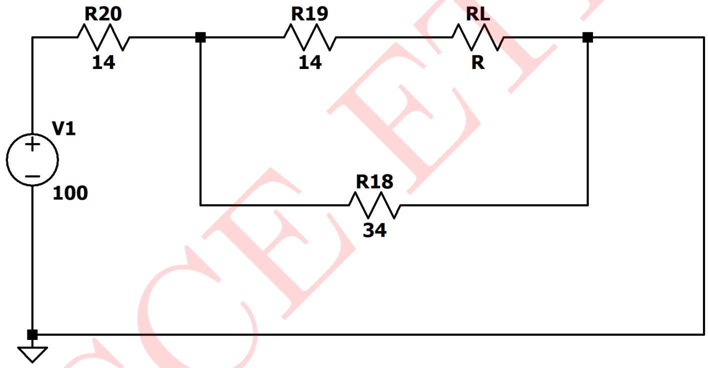


Figure 56: Modified circuit after series combination

Let the resistance of the parallel combination be R_x then,

$$R_x = (14 + R_L)||34$$

$$R_x = \frac{(14 + R_L) \times (34)}{48 + R_L}$$

$$R_x = \frac{34R_L + 476}{48 + R_L} \qquad ....(1)$$

Total current supplied by V_1:

$$I_{V_1} = \frac{100}{14 + R_x} \qquad ....(2)$$

From current division rule, current through load resistance R_L:

$$I_{R_L} = \frac{34 \times I_{V_1}}{48 + R_L}$$

Substituting the value of I_{V_1} from (2) we get,

$$I_{R_L} = \frac{34}{48 + R_L} \times \frac{100}{14 + R_x}$$

Substituting the value of R_x from (1) we get,

$$I_{R_L} = \frac{34}{48+R_L} \times \frac{100}{14 + \dfrac{34R_L + 476}{48+R_L}}$$

$$I_{R_L} = \frac{34}{48+R_L} \times \frac{100 \times (48+R_L)}{1148 + 48R_L}$$

$$I_{R_L} = \frac{3400}{1148+48R_L}$$

$$I_{R_L} = \frac{850}{287+12R_L} \qquad ....(3)$$

Power dissipated across load resistance:

$P_{R_L} = I_{R_L}^2 \times R_L$

Substituting the value of I_{R_L} from (3)

$$P_{R_L} = \left(\frac{850}{287+12R_L}\right)^2 \times R_L \qquad ....(4)$$

For maximum power dissipation:

$$\frac{dP_{R_L}}{dR_L} = 0 \qquad ....(5)$$

Differentiating (4) with respect to R_L

$$\frac{dP_{R_L}}{dR_L} = \frac{d}{dR_L}\left[\left(\frac{850}{287+12R_L}\right)^2 \times R_L\right]$$

$$\frac{dP_{R_L}}{dR_L} = 850^2 \times \frac{d}{dR_L}\left[\frac{R_L}{(287+12R_L)^2}\right]$$

$$\frac{dP_{R_L}}{dR_L} = 850^2 \times \left[\frac{(1)\,(287+12R_L)^2 - (R_L)\,(2)\,(287+12R_L)\,(12)}{(287+12R_L)^4}\right]$$

Dividing numerator and denominator by $(287+12R_L)$

$$\frac{dP_{R_L}}{dR_L} = 850^2 \times \left[\frac{(287+12R_L) - (R_L)\,(2)\,(12)}{(287+12R_L)^3}\right]$$

$$\frac{dP_{R_L}}{dR_L} = 850^2 \times \left[\frac{287 - 12R_L}{(287+12R_L)^3}\right] \qquad ....(6)$$

From (5) and (6):

$$850^2 \times \left[\frac{287 - 12R_L}{(287 + 12R_L)^3}\right] = 0$$

$$287 - 12R_L = 0$$

$$12R_L = 287$$

$$R_L = \frac{287}{12}$$

$$R_L = 23.9167\Omega$$

$\therefore$ we will get maximum power dissipation in load resistance R_L for:
$R_L = 23.9167\Omega$

From (4) we can find the value of maximum power by substituting the value of R_L

$$P_{R_L} = \left(\frac{850}{287 + 12R_L}\right)^2 \times R_L$$

$$P_{R_L} = \left(\frac{850}{287 + 12(23.9167)}\right)^2 \times 23.9167$$

$\therefore$ the maximum power dissipated in load resistor:

$$P_{R_L max} = 52.45W$$

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the graph obtained is as follows:

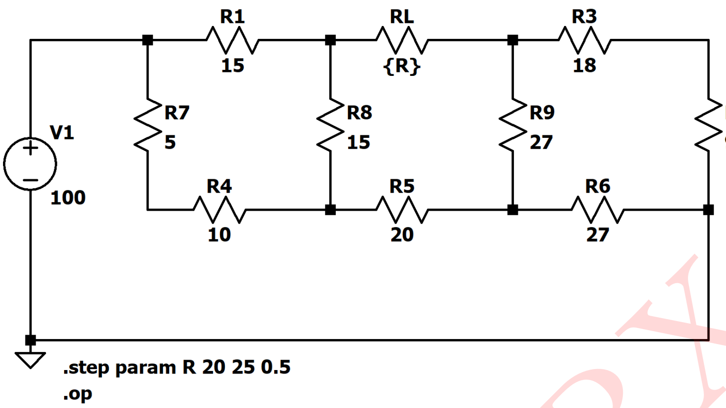


Figure 57: Circuit Schematic

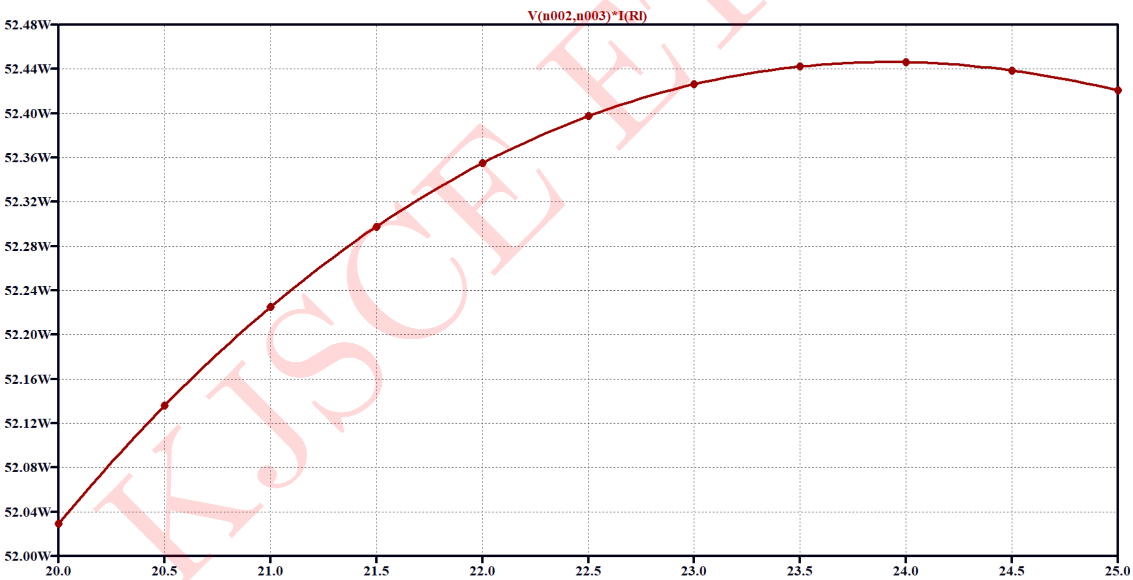


Figure 58: Simulated Result

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
R_L	23.9167Ω	23.95Ω
$P_{R_L}max$	$52.45W$	$52.44W$

Table 11: Comparison of calculated and simulated results