EXPLORATIONS

Chapter 1

Features Used

NewProd, solve( ), Matrix Editor, **Simult( ),** [CATALOG], [STO▶]

Setup

[◆]**1**
setFold dc

DC Circuit Analysis

This chapter shows three examples of the use of nodal analysis to solve linear circuits. The first two examples use the **solve( )** command to solve a set of linear equations for a circuit. The third example shows how to write the equations in matrix form and use **simult( )** to solve them.

Topic 1: Nodal Equations Using solve( )

Given the circuit shown in Figure 1, find v1 and v2.

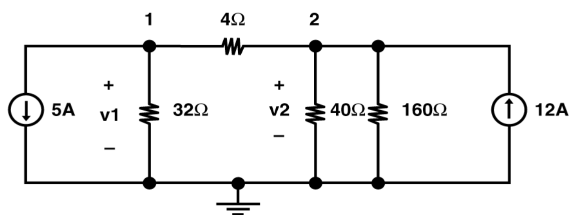


Figure 1. DC Circuit

Nodal analysis can be used to solve for the voltages of a circuit by summing the current leaving each node. Kirchhoff’s current law states that the currents out of a node must sum to zero. The current through each resistor is calculated from Ohm’s law by:

- Defining the voltage drop across the resistor in the direction of the current as the voltage at the node of the incoming current of the resistor minus the voltage at the node of the outgoing current of the resistor, and
- Dividing the voltage drop by the resistance of the resistor.

For a circuit with N+1 nodes (including the ground node), this process gives N equations with N unknown voltages. For the circuit above, summing the currents out of node 1 gives

$$5+\frac{v1}{32}+\frac{v1-v2}{4}=0$$

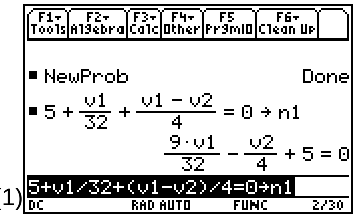
The sum of the currents out of node 2 is

$$\frac{v2-v1}{4}+\frac{v2}{40}+\frac{v2}{160}-12=0$$

The following series of steps leads to a solution of these two equations.

Note: Press [alpha] *before entering alphabetic characters.*

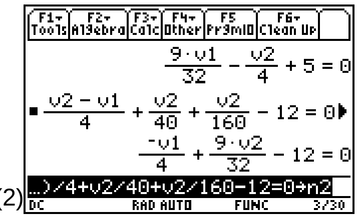
1. Clear the TI-89 by pressin [2nd] [F6] **2:NewProb** [ENTER]. g

(1) 

2. Enter the equation for node 1 and store it a **n1** as shown in screen 1.

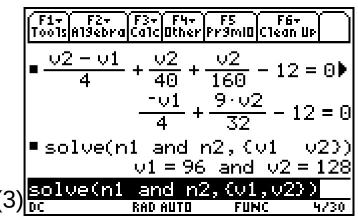
   5 [+] **v1** [÷] **32** [+] [(] **v1** [−] **v2** [)] [÷] **4** [=] **0** [STO▸] **n1**

Note: To enter the →, press [STO▸].

(2) 

3. Enter the equation for node 2 and store it a **n2** as shown in screen 2.

   [(] **v2** [−] **v1** [)] [÷] **4** [+] **v2** [÷] **40** [+] **v2** [÷] **160** [−] **12** [=] **0** [STO▸] **n2**

(3) 

4. Finally, solve fo **v1** an **v2** dusing th **solve()** command, as shown in screen 3.

   [CATALOG] **solve(n1** [CATALOG] **and n2** [,] [2nd] [{] **v1** [,] **v2** [2nd] [}] [)]

The two voltages are calculated a **v1** = 96 V an **v2** = 128 V. d s

Topic 2: Nodal Equations with Voltage Sources

When a voltage source is present between two nodes, Ohm's law cannot be used to calculate the current through the source (as in Topic 1). Fortunately, this difficulty can be overcome easily by giving a name to the current through the voltage source (as shown below) and treating this current as an unknown. Nodal analysis then can be used to find the solution for the voltages of the circuit shown in Figure 2.

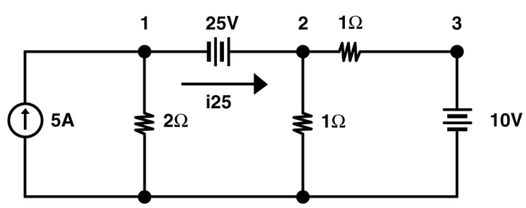


Figure 2. A DC Circuit with Three Sources

First, write the nodal equations in a form similar to that entered into the TI-89 as

Note: Some textbooks use the concept of a "supernode," which in effect combines the nodal equations for node1 and node2 into a single equation and eliminates i25.

$$\text{node1: } -5 + \frac{v1}{2} + i25 = 0 \rightarrow n1$$

$$\text{node2: } -i25 + \frac{v2}{1} + \frac{v2 - v3}{1} = 0 \rightarrow n2$$

$$\text{node3: } v3 = 10 \rightarrow n3$$

Notice that the current flowing through the 25 V source from left to right is defined as **i25**. This unknown current becomes another variable which will be found as part of the solution. The voltage drop of the 25 V battery establishes the relation between **v1** and **v2** as

equation 1: v2 = v1 + 25 → e1

To enter these equations into the calculator:

1. Clear the TI-89 by pressing [2nd] [F6] **2:NewProb** [ENTER].

2. Enter the equation for node1 as shown in screen 4.

[(-)] **5** [+] **v1** [÷] **2** [+] **i25** [=] **0** [STO▸] **n1**

3. Enter the equation for node2 as shown in screen 5.

[(-)] **i25** [+] **v2** [÷] **1** [+] [(] **v2** [−] **v3** [)] [÷] **1** [=] [0] [STO▸] **n2**

4. Enter the node3 equation (screen 6).

v3 [=] **10** [STO▸] **n3**

5. Enter the last equation for the 25 V source (screen 7).

v2 [=] **v1** [+] **25** [STO▸] **e1**

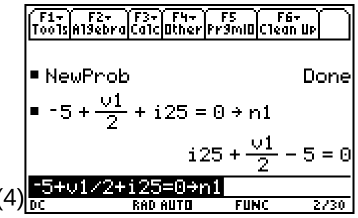
Screen 8 shows a summary of the four equations, which can be displayed by entering their names—**n1**, **n2**, **n3**, and **e1**.

6. Finally, solve for **v1**, **v2**, **v3**, and **i25** by using **solve( )** as shown in screen 9.

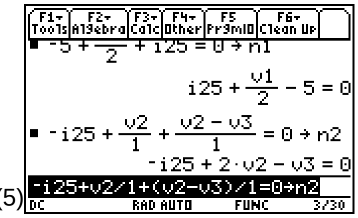
[CATALOG] **solve(n1** [CATALOG] **and n2** [CATALOG] **and n3** [CATALOG] **and e1** [,] [2nd] [{] **v1** [,] **v2** [,] **v3** [,] **i25** [2nd] [}] [)]

The complete result is

v1 = −14 V, **v2** = 11 V, **v3** = 10 V, and **i25** (the current through the 25 V source) = **12 A**.

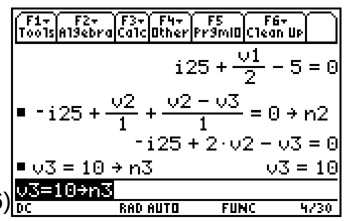


(4)

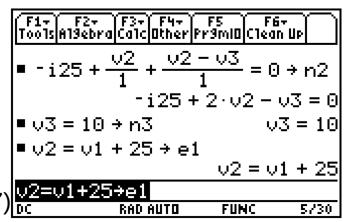


(5)

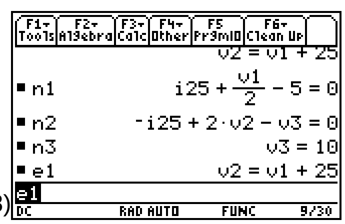
Note: Enter the first - (negative) by pressing [(-)] below [3] and the second - (subtract) by pressing [−] to the right of [6].



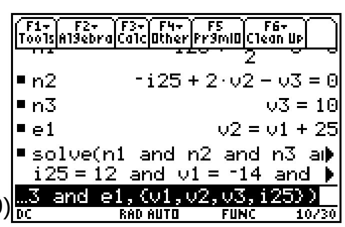
(6)



(7)



(8)



(9)

Topic 3: Nodal Equations Using simult()

Another approach to solving the problem in Topic 2 is to convert the equations to matrix form. The equations as shown in screen 8 are rearranged as

$$\text{node1:}\quad \frac{1}{2}v1 + i25 = 5$$

$$\text{node2:}\quad 2v2 - v3 - i25 = 0$$

$$\text{node3:}\quad v3 = 10\text{, and}$$

$$\text{eqn1:}\quad -v1 + v2 = 25$$

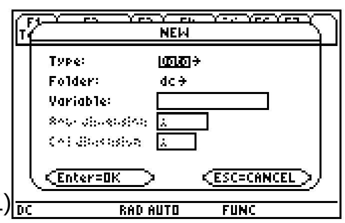
In matrix form they appear as:

$$\begin{bmatrix} 1/2 & 0 & 0 & 1 \\ 0 & 2 & -1 & -1 \\ 0 & 0 & 1 & 0 \\ -1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v1 \\ v2 \\ v3 \\ i25 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 10 \\ 25 \end{bmatrix}$$

1. To create the square matrix on the left side, press [APPS] and select **6:Data/Matrix Editor** and **3:New** in sequence, as shown in screen 10.

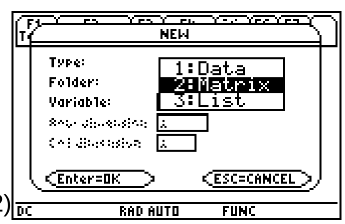
(10)

2. Press [ENTER] to display screen 11.



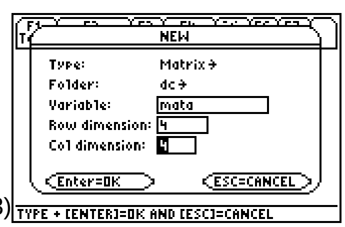
(11)

3. To enter a matrix, press ▶ and ▼ to highlight **2:Matrix** (screen 12) and press [ENTER].



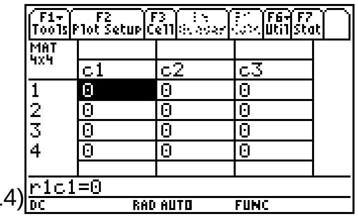
(12)

4. Press ▼ twice and enter the Variable name. (For convenience, call it **mata**.) Using ▼, fill in **Row dimension: 4** and **Col dimension: 4** as shown in screen 13.

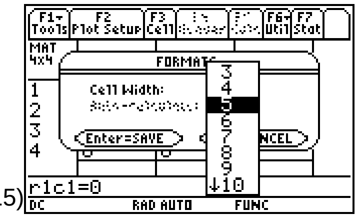


(13)

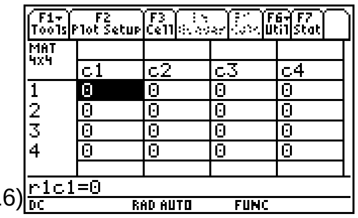
5. Press [ENTER]. You will see screen 14.

(14)


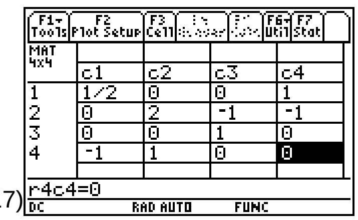
6. To see all four columns, press [◆] [|] and set the cell width to **5** (screen 15).

(15)


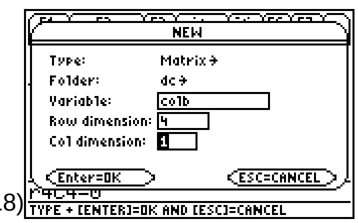
7. Press [ENTER] twice to see screen 16.

(16)


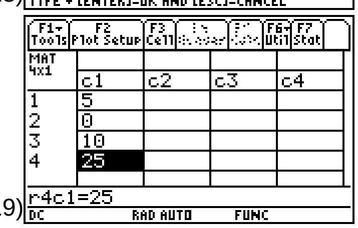
8. Fill in the rows and columns with the numbers from the circuit matrix as shown in screen 17.

(17)


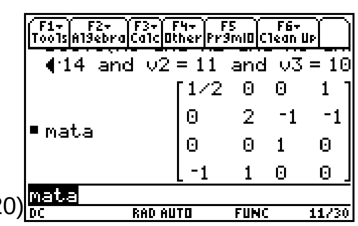
9. To create the column matrix on the right side of the matrix equation, press [F1] and select **3:New**. Define it as: **Type: Matrix, Variable: colb, Row dimension: 4,** and **Col dimension: 1** (screen 18).

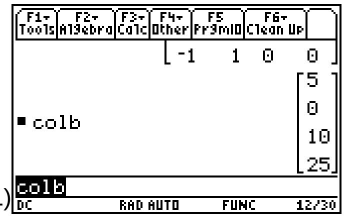
(18)


10. Press [ENTER] and fill in the values (screen 19).

(19)


11. Press [HOME] to return to the Home screen and check the contents of **mata** and **colb**, shown in screens 20 and 21.

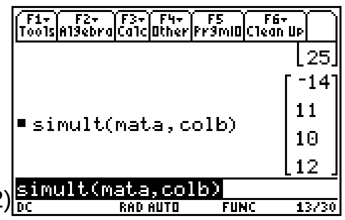
(20)




(21)

12. Enter [CATALOG] **simult**(**mata** [,] **colb** [)] (screen 22).

Note: *The **simult()** command returns a column vector that contains the solutions to a system of linear equations.*



(22)

Referring to the matrix equation for the circuit as shown below, the values returned by **simult()** correspond to the variables in the first column vector. The solution is **v1**=-14 V, **v2**=11 V, **v3**=10 V, and **i25**=12 A, the same answer as in Topic 2.

$$\begin{bmatrix} 1/2 & 0 & 0 & 1 \\ 0 & 2 & -1 & -1 \\ 0 & 0 & 1 & 0 \\ -1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v1 \\ v2 \\ v3 \\ i25 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 10 \\ 25 \end{bmatrix}$$

Tips and Generalizations

There are many ways a command can be entered on the Home screen. For example, to enter **solve()**:

- Type it: [alpha] [alpha] **solve** [alpha] [(] [)]. Here [alpha] [alpha] locked the [alpha] key and the single [alpha] unlocked it.
- Use the function key menus: [F2] 1**:solve(** .
- Use the catalog: [CATALOG] **s**. Pressing **s** scrolls to the first command that begins with **s**. If needed, press ⊖ to get to the desired command.
- Use [2nd] [MATH] **9:Algebra**, **1:solve(** .
- If it has been used before, press ⊖ on the Home screen until the desired command is highlighted and then press [ENTER].

Summary

In this chapter, nodal analysis was used to generate equations to solve a circuit. Loop analysis (or any method that produces N equations and N unknowns) also can be used to produce equations for the TI-89 to solve. The equations can include complex values (Chapter 4) and do not have to be linear. In fact, they also can include derivatives as shown in Chapter 2.