19 Mesh Analysis

Objectives

1. To experimentally prove the mesh currents for a multi-source circuit.
2. To explain how mesh currents can be used to determine any desired circuit quantity.

Equipment

Two dc power supplies
Voltmeter, ammeter
1/4 W Resistors: 10 kΩ 12 kΩ 15 kΩ 18 kΩ 22 kΩ

Information

Mesh analysis is one of the most universally used methods of circuit analysis. This method requires the solution of simultaneous equations, which was once considered a disadvantage, but now is an easy task with modern calculators. Most technical calculators will solve simultaneous equations, either directly, or by the use of matrices. Writing simultaneous equations is a very straightforward task requiring the student to follow a simple set of rules which are quickly mastered. A knowledge of Kirchhoff's Voltage Law is essential because each equation to be written is simply a Kirchhoff voltage loop.

As a reference, the steps required to perform mesh analysis are outlined in detail below.

1. Identify the number of windows in the circuit. This will be the number of equations required. Some components will appear in more than one window.

2. Draw and label a current loop in each window, and show its direction. This is most commonly done as shown in the partial schematic of Figure 19-1.

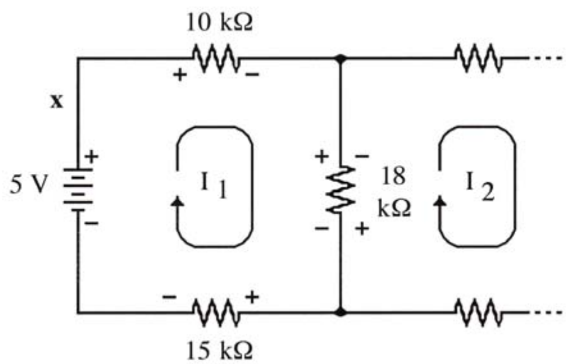

Figure 19-1. Partial Schematic Diagram

3. Within each window, mark the polarities of the voltages which would be produced by that window's current. Note that resistors which border two windows, such as the 18 kΩ resistor of Figure 19-1, will have two voltage polarities.

4. Start at any point in the first window and write a Kirchhoff's Voltage Law equation for that complete window, using the polarity of the first side of every component encountered. Each resistor voltage is written as the product of the current times the resistance; voltage sources are just pure voltages. In the case of the 18 kΩ resistor, two voltages exist, one caused by each current. When you have returned to the start point, the sum of all voltages is equated to zero. As an example, the first window in Figure 19-1 is written as follows, starting at point **x**:

$$+ 10\text{ k}\Omega\ I_1 + 18\text{ k}\Omega\ I_1 - 18\text{ k}\Omega\ I_2 + 15\text{ k}\Omega\ I_1 - 5 = 0$$

5. The terms of the equation are then rearranged into standard form as shown below for this equation:

$$+ 43\text{ k}\Omega\ I_1 - 18\text{ k}\Omega\ I_2 = 5$$

6. Repeat steps 4 and 5 for each window and solve the simultaneous equations for the unknown currents.

The circuit used in this experiment was also investigated in a previous experiment using the superposition theorem. Students may wish to compare the results of calculations and measurements for both experiments to verify that both techniques yield correct results.

Lab Prep

The following preparation work may be completed as described below or by using circuit simulation software. Your instructor will describe which method you are expected to use.

1. Apply mesh analysis to the circuit of Figure 19-2. Solve for the three indicated currents and find their true directions. Record your calculated values in Table 19-1.

Table 19-1. Calculated Mesh Values

	Current 1	Current 2	Current 3
Assumed Direction	clockwise	clockwise	clockwise
Mesh Current Solution			
True Current Direction			

2. Use the results from Table 19-1 to calculate the current through each resistor in Figure 19-2, as well as the correct direction of each current. Transfer values from Tables 19-1 and 19-2 to the Prep Sheet.

Table 19-2. Calculated Resistor Currents

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction					
Calculated Current					

Procedure

1. Connect the circuit of Figure 19-2.

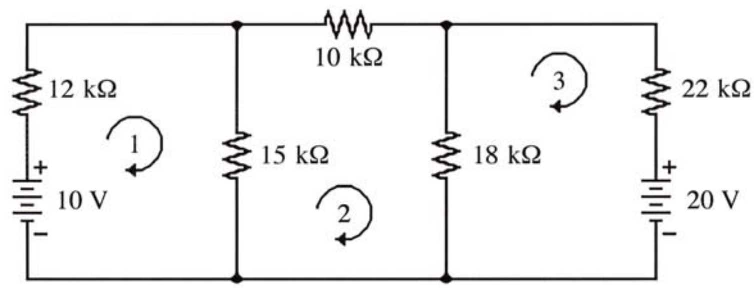

Figure 19-2. Mesh Circuit

2. Measure each of the mesh currents by inserting an ammeter into the top edge of each of the mesh windows in the circuit of Figure 19-2. Record in Table 19-3.

3. Determine the direction of current flow for each of the mesh currents. Record in Table 19-3 by using arrows to indicate direction.

Table 19-3. Mesh Current Measurements

	Current 1	Current 2	Current 3
Measured Current			
Current Direction			

4. Use the ammeter to measure the current through each resistor, and to determine the direction of current flow through each resistor. Record in Table 19-4.

Table 19-4. Measured Resistor Currents

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction					
Measured Current					

5. Transfer the data from Tables 19-3 and 19-4 to the Data Sheet.

19 Prep Sheet Name

1. Complete the data required for Table 19-1 below.

	Current 1	Current 2	Current 3
Assumed Direction	clockwise	clockwise	clockwise
Mesh Current Solution			
True Current Direction			

2. Complete the data required for Table 19-2 below.

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction					
Calculated Current					

19 Data Sheet Name

1. Complete the data required for Table 19-3 below.

	Current 1	Current 2	Current 3
Measured Current			
Current Direction			

2. Complete the data required for Table 19-4 below.

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction					
Measured Current					

Questions

1. Use the data obtained in Table 19-3 to show how the mesh currents I_1 and I_2 are used to determine the current magnitude and direction through the 15 kΩ resistor.

2. Use the data obtained in Table 19-4 to prove Kirchhoff's Current Law for any two node points or junctions in the circuit of Figure 19-2.

3. Compare your calculated mesh current value for the middle window (Table 19-1) with the measured mesh current value (Table 19-4) for the 10 kΩ resistor.

4. Compare the measured resistor currents from Table 19-4 with the calculated currents obtained using superposition in an earlier Experiment if it was completed.

1. Complete the data required for Table 19-1 below.

	Current 1	Current 2	Current 3
Assumed Direction	clockwise	clockwise	clockwise
Mesh Current Solution	**298 μA**	**130 μA**	**558 μA**
True Current Direction	**CW**	**CCW**	**CCW**

2. Complete the data required for Table 19-2 below.

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction	↑	↓	←	↓	↑
Calculated Current	**298 μA**	**428 μA**	**130 μA**	**429 μA**	**558 μA**

19 Data Sheet Answers

1. Complete the data required for Table 19-3 below.

	Current 1	Current 2	Current 3
Measured Current	**298 μA**	**130 μA**	**558 μA**
Current Direction	**CW**	**CCW**	**CCW**

2. Complete the data required for Table 19-4 below.

	12 kΩ	15 kΩ	10 kΩ	18 kΩ	22 kΩ
Current Direction	↑	↓	←	↓	↑
Measured Current	**298 μA**	**428 μA**	**130 μA**	**429 μA**	**558 μA**

Answers to Questions

1. Use the data obtained in Table 19-3 to show how the mesh currents I_1 and I_2 are used to determine the current magnitude and direction through the 15 kΩ resistor.

    The mesh current I_1 solves to a positive value of 298 µA which means that the assumed clockwise direction is correct and 298 µA flows downwards through the 15 kΩ resistor. The mesh current I_2 solves to a negative value of 130 µA which means that the assumed clockwise direction is incorrect and I_2 flows counterclockwise, which results in a downward current of 130 µA through the 15 kΩ resistor. The total current through this resistor is therefore the sum of 298 µA and 130 µA, or 428 µA, flowing downwards.

2. Use the data obtained in Table 19-4 to prove Kirchhoff's Current Law for any two node points or junctions in the circuit of Figure 19-2.

    The current through the 15 kΩ resistor (428 µA) flows downwards and splits into two currents: 298 µA flowing upwards through the 12 kΩ, and 130 µA flowing to the right.

    The 130 µA current flowing to the right joins with the 429 µA current flowing down through the 18 kΩ resistor to yield a total current of 558 µA flowing upwards through the 22 kΩ resistor.

3. Compare your calculated mesh current value for the middle window (Table 19-1) with the measured mesh current value (Table 19-4) for the 10 kΩ resistor.

    The calculated mesh current for the middle window is -130 µA, which indicates that it flows to the left through the 10 kΩ resistor. The measured current should also be 130 µA flowing to the left, within experimental error.

4. Compare the measured resistor currents from Table 19-4 with the calculated currents obtained using superposition in an earlier Experiment if it was completed.

    The current measurements in Table 19-4 should agree with those obtained in the earlier procedure, within experimental error.