# Lab Exercise No. 6
# Mesh Analysis

Paul Andrew Parras, Vaun Michael Pace
Department of Computer Engineering
School of Engineering, University of San Carlos
Nasipit, Talamban Cebu City, Philippines
parraspaul13874@gmail.com , pacevaun@gmail.com

*Abstract*—**This laboratory experiment helps us learn how to methodically solve circuits for current, voltage, and impedance, deepening our understanding of the fundamental behavior of electrical circuits.**

***Keywords- KVL, Mesh, Loops***

## I. Introduction

In electrical engineering, a technique called **Mesh analysis,** sometimes called **loop current analysis**, is used to determine the currents flowing through the loops or meshes of a circuit. The current in each independent loop of a planar circuit—a circuit that can be formed on a flat surface without crossing wires—is calculated using **Kirchhoff's Voltage Law** (KVL).

According to Kirchhoff's Voltage Law, all the voltages of the circuit surrounding a closed loop must add up to zero. The basis of mesh analysis is this. The total voltage drops across all of the components for each mesh equals the total voltage sources.

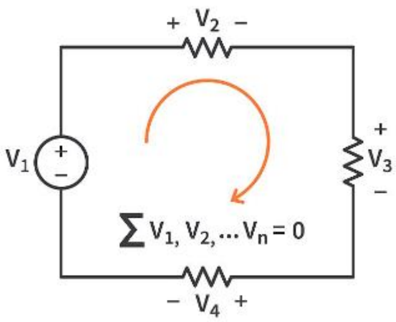


**Figure 1:** Kirchhoff's Voltage Law

In Mesh analysis, we assign a current variable to each independent loop in the circuit. These are called **mesh currents**, and they are used to express voltages across the circuit elements. Once the mesh currents are assigned, **KVL** is applied to each loop to write equations based on the voltage drops across resistors, inductors, capacitors, and voltage sources. The voltage drops across the resistor, for instance, is calculated using Ohm's law:

$$\mathbf{V = I\,R}$$

**Figure 1.2**: Ohm's Law

The result is a system of simultaneous equations, which can then be solved (using algebraic methods or matrix techniques) to find the unknown mesh currents.

Mesh analysis only works on **planar circuits**—those that can be drawn without crossing wires. Non-planar circuits require a different method, such as the previously tackled **Nodal Analysis**.

## II. Procedure

### *A. Solving for the Values*

To start the experiment, we should first try to analyze the following circuits using Mesh Analysis to identify $I_{R1}$, $I_{R2}$, $I_{R3}$ and $V_A$ for **circuit 1**.

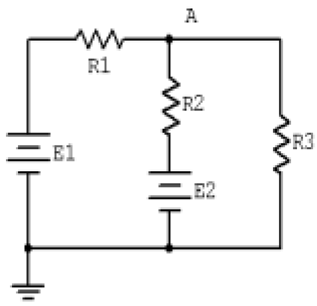


**Figure 2**: Circuit 1

E1 and E2 are voltage sources, let's set the values for these voltage sources and resistors as follows: E1 = 10 volts, E2 = 15 volts, R1 = 4.7 k, R2 = 6.8 k and R3 = 10 k.

For **Circuit 2**, we are tasked to find $I_{R1}$, $I_{R2}$, $I_{R4}$, $V_A$, $V_{B,\ and}$ $V_{AB}$.

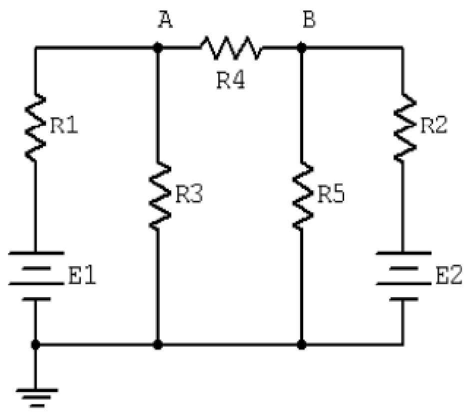


**Figure 2.1**: Circuit 2

E1 and E2 are voltage sources, let's set the values for these voltage sources and resistors as follows: E1 = 10 volts, E2 = 15 volts, R1 = 4.7 k, R2 = 6.8 k, R3 = 10 k, R4 = 22k and R5 = 33k.

After we calculate the values for the parameters, we write them down to the table as theoretical values. The tables should look as follows:

| Parameter | Theory |
|---|---|
| $I_{R1}$ | |
| $I_{R2}$ | |
| $I_{R3}$ | |
| $V_A$ | |

**Table 2.1**: Theoretical Data Table for Circuit 1

| Parameter | Theory |
|---|---|
| $I_{R1}$ | |
| $I_{R2}$ | |
| $I_{R4}$ | |
| $V_A$ | |
| $V_B$ | |
| $V_{AB}$ | |

**Table 2.2** Theoretical Data Table for Circuit 2

*B. Building and Measuring the Circuits*

After solving for those values, are to build these circuits onto a breadboard in order for use to measure the variables needed in this experiment. The circuits put onto the breadboard should look as follows:

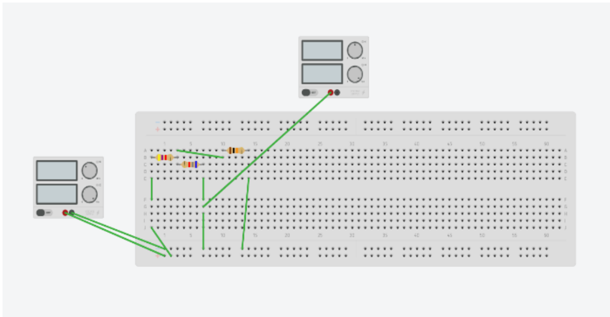

**Figure 2.3**: Circuit 1 on Breadboard

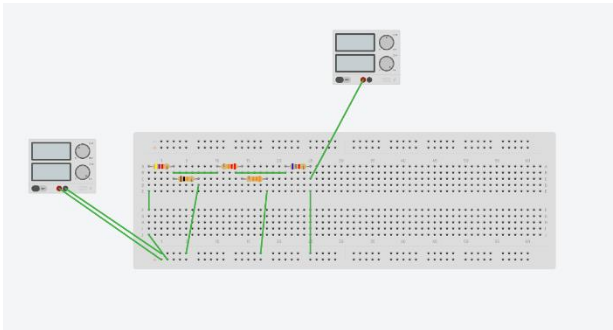

**Figure 2.4**: Circuit 2 on Breadboard

After building the circuits, we are to measure the parameters stated earlier. For **Circuit 1**, we are to look for $I_{R1}$, $I_{R2}$, $I_{R3}$ and $V_A$. For **Circuit 2**, we are to look for $I_{R1}$, $I_{R2}$, $I_{R4}$, $V_A$, $V_{B,\ and}$ $V_{AB}$. And after measuring the parameters using a Multimeter, we need to write the values as experimental values in their respective tables. The data tables for the respective circuits are as follows:

| Parameter | Experimental |
|---|---|
| $I_{R1}$ | |
| $I_{R2}$ | |
| $I_{R3}$ | |
| $V_A$ | |

**Table 2.3**: Experimental Data Table for Circuit 1

| Parameter | Experimental |
|---|---|
| $I_{R1}$ | |
| $I_{R2}$ | |
| $I_{R4}$ | |
| $V_A$ | |
| $V_B$ | |

| | |
|---|---|
| $V_{AB}$ | |

**Table 2.4**: Experimental Data Table for Circuit 2

### *C. Calculation of Deviations*

After calculating and measuring the parameters, we should then calculate the deviation or the difference percentage of the experimental and theoretical values. To solve for this we will use the formula for deviation percentage:

$$\% \text{ Deviation} = \frac{experimental - theoretical}{theoretical} \; x \; 100$$

## III. RESULTS

### *A. Table Data*

After calculating and measuring the values of each required parameter we are able to come up with the following results:

| Parameter | Theory |
|---|---|
| $I_{R1}$ | 2.16mA |
| $I_{R2}$ | 2.18mA |
| $I_{R3}$ | 0.000017mA |
| $V_A$ | -0.17V |

**Table 3.1** Theoretical Data for Circuit 1

| Parameter | Theory |
|---|---|
| $I_{R1}$ | 0.89mA |
| $I_{R2}$ | 0.711mA |
| $I_{R4}$ | 1.31mA |
| $V_A$ | 4.81V |
| $V_B$ | -8.92V |
| $V_{AB}$ | 13.73V |

**Table 3.2** Theoretical Data for Circuit 2

| Parameter | Experimental |
|---|---|
| $I_{R1}$ | 2.15mA |
| $I_{R2}$ | -2.15mA |
| $I_{R3}$ | 0.4mA |
| $V_A$ | 0.19V |

**Table 3.3**: Experimental Data for Circuit 1

| Parameter | Experimental |
|---|---|
| $I_{R1}$ | 0.94mA |
| $I_{R2}$ | 0.94mA |
| $I_{R4}$ | 0.61mA |
| $V_A$ | 4.844V |
| $V_B$ | -8.34V |
| $V_{AB}$ | 13.184V |

**Table 3.4**: Experimental Data for Circuit 2

| Parameter | Theory | Experimental | Deviation |
|---|---|---|---|
| $I_{R1}$ | 2.16mA | 2.15mA | 0.46% |
| $I_{R2}$ | 2.18mA | 2.15mA | 1.37% |
| $I_{R3}$ | 0.4mA | 0.44mA | 10% |
| $V_A$ | -0.17V | -0.19V | 11.7% |

**Table 3.5**: Deviation Table for Circuit 1

| Parameter | Theory | Experimental | Deviation |
|---|---|---|---|
| $I_{R1}$ | 0.89mA | 0.94mA | 5.62% |
| $I_{R2}$ | 0.711mA | 0.94mA | 32.21% |
| $I_{R4}$ | 1.31mA | 0.61mA | 53.43% |
| $V_A$ | 4.81V | 4.844V | 0.71% |
| $V_B$ | -8.92V | -8.34V | 6.5% |
| $V_{AB}$ | 13.73V | 13.184V | 3.98% |

**Table 3.6**: Deviation Table for Circuit 2

### *B. Questions*

1. **Do the polarities of the sources in Figure 14.1 matter as to the resulting currents? Will the magnitudes of the currents be the same if one or both sources have an inverted polarity?**

   - Yes, the polarities of the sources do matter. If one or both sources have inverted polarities, the direction of the resulting currents will change, and their magnitudes could also be affected depending on how the polarities influence the overall potential difference and current paths.

2. **In both circuits of this exercise the negative terminals of the sources are connected to ground. Is this a requirement for mesh analysis? What would happen to the mesh currents if the positions of E1 and R1 in Figure 14.1 were swapped?**

   - Grounding the negative terminals is not strictly necessary for mesh analysis but is done for convenience and consistency in reference voltage points. If the positions of E1 and R1 were swapped, it would alter the voltage distribution in the mesh, thus changing the mesh currents accordingly.

3. **The circuits of Figures 14.1 and 14.2 had been analyzed previously in the Superposition Theorem and Nodal Analysis exercises. How do the results of this exercise compare to the earlier results? Should**

**the resulting currents and voltages be identical? If not, what sort of things might affect the outcome?**

- The resulting currents and voltages from mesh analysis should ideally be identical to those from the Superposition Theorem and Nodal Analysis if performed correctly. However, discrepancies can arise due to measurement errors, component tolerances, or variations in theoretical assumptions and practical implementation.

4. **In general, compare and contrast the application of Superposition, Mesh and Nodal Analyses to multisource DC circuits. What are the advantages and disadvantages of each? Are some circuits better approached with a particular technique? Will each technique enable any particular current or voltage to be found or are there limitations?**

   - **Superposition**: Effective for circuits with multiple sources, but requires analyzing each source independently, making it more tedious
   - **Mesh Analysis:** Useful for planar circuits with more loops than nodes; it reduces the complexity in loop-based systems.
   - **Nodal Analysis:** Preferable for circuits with fewer nodes than loops and for non-planar circuits; focuses on node voltages. Each method has its advantages depending on the circuit, and all can find specific currents or voltages, though some methods might be more efficient for particular types of circuits

## IV. Discussions and Conclusions

In order to compare the theoretical and experimental results, we used Mesh analysis in this experiment to solve for the currents and voltages in two multi-source DC circuits. We were able to construct equations for every independent loop and determine the unknown mesh currents by using Kirchhoff's Voltage Law (KVL). Our research illustrated a number of crucial ideas regarding the behavior of electrical circuits, including:

**Effects of Polarity on Current:** The direction and strength of the currents in the circuit are greatly influenced by the polarity of the voltage sources. The total current distribution is affected when a voltage source's polarity is inverted because the accompanying loop's current direction reverses. This demonstrates how crucial it is to accurately identify source polarities when doing circuit analysis, particularly in multi-source systems where source interaction is crucial to the outcome.

**Grounding and Circuit behavior:** While grounding the negative terminals of the sources simplifies the analysis and provides a consistent reference point, it is not strictly required for mesh analysis. The experimental setup used grounding to establish a common voltage reference, which made it easier to measure the voltages accurately. If components like voltage sources (E1) and resistors (R1) were swapped, the potential distribution in the circuit would change, altering the mesh currents accordingly. This highlights the sensitivity of circuit behavior to the arrangement of components.

**Comparison with Other Analysis Methods:** The results obtained through Mesh Analysis were compared with those derived from the Superposition Theorem and Nodal Analysis. While the theoretical values should ideally match across all methods, small deviations in experimental measurements were observed. These deviations could be attributed to component tolerances, experimental setup errors, or variations in real-world versus ideal component behavior. However, the general trends and relationships among voltages and currents remained consistent, validating the theoretical approaches.

**Comparing Analytical Techniques:**
Each of the analytical methods applied to multi-source circuits—Superposition, Mesh, and Nodal Analysis—offers unique advantages:

- **Superposition** simplifies multi-source analysis by isolating each source but requires repetitive calculations for each source.
- **Mesh Analysis** efficiently solves planar circuits with multiple loops and fewer nodes, making it ideal for systems where current is the primary focus.
- **Nodal Analysis** is more suitable for circuits with fewer nodes and non-planar configurations, where voltage is of primary interest.

Each method has its limitations; for example, Mesh Analysis is less efficient for non-planar circuits, while Superposition becomes cumbersome for circuits with many sources. The choice of method should be based on the circuit's topology and the desired variables (current or voltage). Overall, all methods are valid and can be used interchangeably to arrive at the same results when applied correctly.

In conclusion, This experiment shows how useful mesh analysis is for solving planar multi-source DC circuits and emphasizes how crucial it is to comprehend component interactions. The significance of real-world issues like component tolerances and measurement mistakes is shown by the tiny differences between theoretical and experimental values. Furthermore, the comparison with Nodal research and Superposition demonstrates that although several approaches can be used, their proper application produces reliable outcomes, offering an extensive toolkit for electrical engineering circuit research.

## References


J. D. Irwin and R. M. Nelms, *Basic Engineering Circuit Analysis*, 11th ed. Hoboken, NJ, USA: Wiley, 2015.

A. R. Hambley, *Electrical Engineering: Principles and Applications*, 7th ed. Upper Saddle River, NJ, USA: Pearson, 2018.

C. K. Alexander and M. N. O. Sadiku, *Fundamentals of Electric Circuits*, 6th ed. New York, NY, USA: McGraw-Hill, 2016

M. H. Rashid, *Introduction to PSpice Using OrCAD for Circuits and Electronics*, 3rd ed. Upper Saddle River, NJ, USA: Pearson, 2004.