Overview

To date, we have introduced several approaches to circuit analysis:

- Ohm’s law,
- Kirchoff’s laws, and
- circuit reduction

Circuit reduction, it should be noted, is not fundamentally different from direct application of Ohm’s and Kirchoff’s laws – it is simply a convenient re-statement of these laws for specific combinations of circuit elements. Applying Ohm’s law and Kirchoff’s laws directly using the exhaustive method often results in a large number of unknowns. A correspondingly large number of equations must be solved to determine these unknowns. Circuit reduction allows us, in some cases, to simplify the circuit to reduce the number of unknowns in the system.

In cases where circuit reduction is not feasible, approaches are still available to reduce the total number of unknowns in the system. Nodal analysis and mesh analysis are two of these. Nodal and mesh analysis approaches still rely upon application of Ohm’s law and Kirchoff’s laws – we are just applying these laws in a very rigorous way in order to simplify the analysis of the circuit.

In this chapter, we provide a brief introduction and some background information relative to both nodal and mesh analysis. Detailed descriptions of both analysis approaches will be provided in subsequent chapters – the goal here is to provide the reader with a synopsis of the overall ideas involved and informally introduce several key terms.

Before beginning this chapter, you should be able to:

- Use Ohm’s Law to perform voltage and current calculations for resistive circuit elements (Chapter 1.3)
- Apply Kirchoff’s voltage and current laws to electrical circuits (Chapter 1.4)
- Use circuit reduction techniques to analyze resistive networks (Chapter 1.5)
- Identify current and voltage divider networks in electrical circuits (Chapter 1.5)

This chapter requires:

- N/A

After completing this chapter, you should be able to:

- State the basic idea behind nodal analysis
- State the basic idea behind mesh analysis
As an example, consider the circuit shown in Figure 1(a). The circuit nodes are labeled in Figure 1(a), for later convenience. The circuit is not readily analyzed by circuit reduction methods. If the exhaustive approach toward applying KCL and KVL is taken, the circuit has 10 unknowns (the voltages and currents of each of the five resistors), as shown in Figure 1(b). Ten circuit equations must be written to solve for the ten unknowns. Nodal analysis and mesh analysis provide approaches for defining a reduced number of unknowns and solving for these unknowns. If desired, any other desired circuit parameters can subsequently be determined from the reduced set of unknowns.

![Circuit schematic and complete set of unknowns](image)

(a) Circuit schematic  (b) Complete set of unknowns

Figure 1. Non-reducible circuit.

In nodal analysis, the unknowns will be *node voltages*. Node voltages, in this context, are the *independent voltages* in the circuit. It will be seen later that the circuit of Figure 1 contains only two independent voltages — the voltages at nodes b and c. Only two equations need be written and solved to determine these voltages. Any other circuit parameters can be determined from these two voltages.

**Basic Idea:**

In nodal analysis, Kirchoff’s current law is written at each independent voltage node; Ohm’s law is used to write the currents in terms of the node voltages in the circuit.

In mesh analysis, the unknowns will be *mesh currents*. Mesh currents are defined only for *planar circuits*; planar circuits are circuits which can be drawn in a single plane such that no elements overlap one another. When a circuit is drawn in a single plane, the circuit will be divided into a number of distinct areas; the boundary of each area is a *mesh* of the circuit. A mesh current is the current flowing around a mesh of the circuit. The circuit of Figure 1 has three meshes:

1. The mesh bounded by $V_s$, node a, and node d
2. the mesh bounded by node a, node c, and node b
3. the mesh bounded by node b, node c, and node d
These three meshes are illustrated schematically in Figure 2. Thus, in a mesh analysis of the circuit of Figure 1, three equations must be solved in three unknowns (the mesh currents). Any other desired circuit parameters can be determined from the mesh currents.

Basic Idea:

In mesh analysis, Kirchhoff’s voltage law is written around each mesh loop; Ohm’s law is used to write the voltages in terms of the mesh currents in the circuit. Since KVL is written around closed loops in the circuit, mesh analysis is sometimes known as loop analysis.

Figure 2. Meshes for circuit of Figure 1.