Electric Circuits

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Lecture 5 (Mesh Analysis)

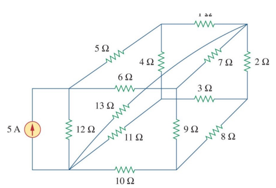
Overview

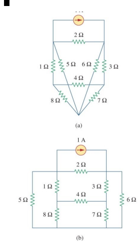
- With Ohm's and Kirchhoff's law established, they may now be applied to circuit analysis.
- Two techniques will be presented in this chapter:
  - Nodal analysis, which is based on Kichhoff current law (KCL)
  - Mesh analysis, which is based on Kichhoff voltage law (KVL)
- Any linear circuit can be analyzed using these two techniques.
- The analysis will result in a set of simultaneous equations which may be solved by Cramer's rule or computationally (using MATLAB for example)

Mesh Analysis

- Another general procedure for analyzing circuits is to use the mesh currents as the circuit variables.
- Recall:
  - A loop is a closed path with no node passed more than once
  - A mesh is a loop that does not contain any other loop within it
- Mesh analysis uses KVL to find unknown currents
- Mesh analysis is limited in one aspect: It can only apply to circuits that can be rendered planar.
- A planar circuit can be drawn such that there are no crossing branches.

Planar vs Nonpalanar





The figure on the left is a nonplanar circuit: The branch with the 13Ω resistor prevents the circuit from being drawn without crossing branches

The figure on the right is a planar circuit: It can be redrawn to avoid crossing branches

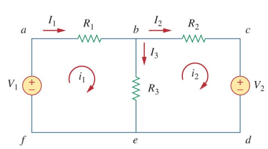
Mesh Analysis Steps

- Mesh analysis follows these steps:

1. Assign mesh currents $i_1, i_2, \ldots i_n$ to the n meshes
2. Apply KVL to each of the n mesh currents.
3. Solve the resulting n simultaneous equations to get the mesh currents

Mesh Analysis Example

- The above circuit has two paths that are meshes (abefa and bcdeb)
- The outer loop (abcdefa) is a loop, but not a mesh
- First, mesh currents i_1 and i_2 are assigned to the two meshes.
- Applying KVL to the meshes:



$$-V_1 + R_1 i_1 + R_3(i_1 - i_2) = 0 \quad R_2 i_2 + V_2 + R_3(i_2 - i_1) = 0$$

$$\Downarrow \qquad\qquad\qquad \Downarrow$$

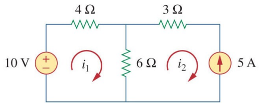
$$(R_1 + R_3)i_1 - R_3 i_2 = V_1 \quad -R_3 i_1 + (R_2 + R_3)i_2 = -V_2$$

Solved Problem

Solved Problem

Mesh Analysis with Current Sources

- The presence of a current source makes the mesh analysis simpler in that it reduces the number of equations.
- If the current source is located on only one mesh, the current for that mesh is defined by the source.
- For example:

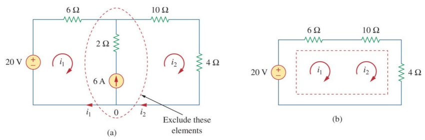


- Here, the current i_2 is equal to $-5A$

Supermesh

- Similar to the case of nodal analysis where a voltage source shared two non-reference nodes, current sources (dependent or independent) that are shared by more than one mesh need special treatment
- The two meshes must be joined together, resulting in a supermesh.
- The supermesh is constructed by merging the two meshes and excluding **the shared source and any elements in series with it**
- A supermesh is required because mesh analysis uses KVL
- But the voltage across a current source cannot be known in advance.
- Intersecting supermeshes in a circuit must be combined to for a larger supermesh.

Supermesh



- In this example, a 6A current course is shared between mesh 1 and 2.
- The supermesh is formed by merging the two meshes.
- The current source and the 2Ω resistor in series with it are removed.

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Supermesh

- Using the circuit from the last slide:
- Apply KVL to the supermesh

$$-20 + 6i_1 + 10i_2 + 4i_2 = 0 \quad \text{or} \quad 6i_1 + 14i_2 = 20$$

- We next apply KCL to the node in the branch where the two meshes intersect.

$$i_2 = i_1 + 6$$

- Solving these two equations we get:

$$i_1 = -3.2\text{A} \quad i_2 = 2.8\text{A}$$

- Note that the supermesh required using both KVL and KCL

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Solved Problem

Solved Problem

Selecting an Appropriate Approach

- In principle both the nodal analysis and mesh analysis are useful for any given circuit.
- What then determines if one is going to be more efficient for solving a circuit problem?
- There are two factors that dictate the best choice:
  - The nature of the particular network is the first factor
  - The second factor is the information required

Mesh analysis when…

- If the network contains:
  - Many series connected elements
  - Voltage sources
  - A circuit with fewer meshes than nodes
- If branch or mesh currents are what is being solved for.
- Mesh analysis is the only suitable analysis for transistor circuits
- It is not appropriate for operational amplifiers because there is no direct way to obtain the voltage across an op-amp.

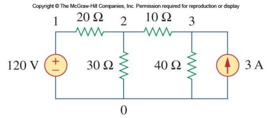
Nodal analysis if…

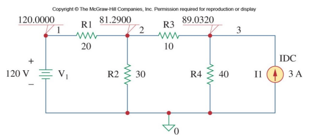
- If the network contains:
  - Many parallel connected elements
  - Current sources
  - Circuits with fewer nodes than meshes
- If node voltages are what are being solved for
- Non-planar circuits can only be solved using nodal analysis
- This format is easier to solve by computer

Circuit Analysis with PSpice

- PSpice is a common program used for circuit analysis.
- It is capable of determining all of the branch voltages and currents if the numerical values for all circuit components are known.
- Analysis using PSpice begins with drawing a schematic view of the circuit.
- The node voltages of interest can be indicated during the schematic setup using 'VIEWPOINTS'
- The values are obtained by running 'Analysis/ Simulate'

Rendering a circuit in PSpice

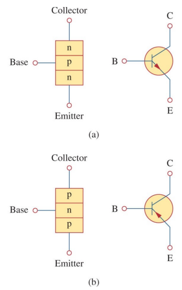




Converting a standard schematic (top) to a PSpice schematic (bottom) is fairly straightforward. Note the explicit definition of the reference node by using the ground symbol labeled with a '0' and the nodal voltages of interest displayed with the 'viewpoints'

Application: DC transistor circuit

- In general, there are two types of transistors commonly used: Field Effect (FET) and Bipolar Junction (BJT).
- A BJT is a three terminal device, where the input current into one terminal (the base) affects the current flowing out of a second terminal (the collector).
- The third terminal (the emitter) is the common terminal for both currents



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