ECE 1254 Assignment 1

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1 Part A of Assignment

The goal here is to construct the circuit matrix G and source vector b, and using them to solve the problem

$$Gx = b$$

where x is the vector containing the node voltages and the currents of the voltage sources.

First, circuit data is extracted from a text file in the standard SPICE notation. The data is sorted and stored into four 2-D arrays, one for each of resistors, independent current sources, independent voltage sources, and dependent voltage sources.

The code then finds the number of nodes, N, in the circuit. This is done by finding the maximum value in the node columns for all four types of circuit elements. An empty square matrix with dimension equal to N is initialized. The empty b vector of size N is also initialized.

The resistors are added into the matrix first. Each resistor is connected to two distinct nodes. Using KCL analysis, it was seen in class that each resistor affect only the four elements of the node matrix related to the adjacent nodes in the following manner:

$$\begin{bmatrix} \frac{1}{R} & -\frac{1}{R} \\ -\frac{1}{R} & \frac{1}{R} \end{bmatrix}$$

This is the resistor stamp. Each resistor adds a resistor stamp to the four elements related to the two nodes in the G matrix . The exception is when a resistor is connected to ground, in which case only the node that is not ground get a $\frac{1}{R}$ stamp.

The b vector is modified to incorporate current sources. For each source, the b node it is flowing into becomes I while the node the current is flowing out of becomes -I. Again, the exception is when one of the nodes is ground, in which case only the non-ground node component of b is modified.

Each voltage source generates an additional equation which adds one extra row, as well as one additional unknown current which adds one extra column column to the G matrix. Using the convention that current flows from negative terminal to the positive terminal, the additional equation is $V_+ - V_- = V_{source}$. The left hand side of the equation modifies the G matrix, while the right hand term is added to b. As seen in class, each new column is related to the transpose of the corresponding new row of G but there is a sign switch because the definition used in this setup has the current flowing into the positive node of the voltage source, while the KCL analysis that generated the rows of the matrix assumed currents were leaving the nodes.

2 Part B of Assignment

The last circuit element is the dependent voltage source. A brief derivation of the governing equation will be included here, followed by a description of implementation.

For a voltage source, the voltage-current relationship is:

$$V_+ - V_- = V_s$$

Since for dependent sources,

$$V_s = g(V_{c+} - V_{c-})$$

where V_{c+} and V_{c-} are the positive and negative terminals of a reference voltage somewhere else in the circuit, and g is the gain factor, we obtain the governing equation

$$V_+ - V_- - g(V_{c+} - V_{c-}) = 0$$

which can be implemented similar to an independent voltage source.

A major difference is that there is no symmetry between the new column and the new row added due to a dependent source. While there are two extra terms related to the gain in the row equations, in each column we still only have the source currents, which results in columns that look exactly the same as the independent voltage sources.

The general procedure for implementing dependent voltage sources:

- In the new row to the matrix, insert +1 and -1 value to the adjacent node voltage variables as have been done with independent voltage sources
- Transpose the row and switch the signs of the elements. This is the new column to be added to the matrix
- Going back to the new row, add +g and -g to the positive and negative terminal nodes of the control voltage
- Add a new 0 element to the b vector

To optimize performance, matrix operation is used whenever possible. Most of the matrices are constructed sparse.

3 Part C of Assignment 1

Using the model developed, the op-amp circuit was solved and voltage V_0 was found to be -11.43V