Nodal Analysis

\[
\begin{bmatrix}
G & \vdots & \vdots
\end{bmatrix}
\begin{bmatrix}
V
\end{bmatrix}
= 
\begin{bmatrix}
I_s
\end{bmatrix}
\]

Unknown Variables

independent sources/
initial conditions

Mesh Analysis

\[
\begin{bmatrix}
Z & \vdots & \vdots
\end{bmatrix}
\begin{bmatrix}
I
\end{bmatrix}
= 
\begin{bmatrix}
V_s
\end{bmatrix}
\]

Unknown Variables

independent sources/
initial conditions

Example 1: Write the nodal equations for following circuit

As \( V_3 = V_s \) so effectively we have only two unknown \( V_1, V_2 \). By applying KCL we will get following matrix equation:

\[
\begin{bmatrix}
1 & 1 \\
2 & 1
\end{bmatrix}
\begin{bmatrix}
V_1 \\
V_2
\end{bmatrix}
= 
\begin{bmatrix}
I_s + V_s/2 \\
0
\end{bmatrix}
\]

\[
= 
\begin{bmatrix}
I_s \\
0
\end{bmatrix}
+ 
\begin{bmatrix}
V_s/2 \\
0
\end{bmatrix}
\]

\[
\begin{bmatrix}
V_1 \\
V_2
\end{bmatrix}
= 
G^{-1}
\begin{bmatrix}
I_s \\
0
\end{bmatrix}
+ G^{-1}
\begin{bmatrix}
V_s/2 \\
0
\end{bmatrix}
\]

Observation: Note that \( S_1 \) can be obtained by setting \( V_s = 0 \), Circuit for that will be as follows:
$I_{in}(s)$ can be obtained by setting $I_s = 0$. Circuit for that will be as follows:

and the total solution is sum of the two solutions. This is expected to happen as the system is linear w.r.t. each source, so Superposition should be applicable.

Example 2: Write the nodal equations for following circuit

Using superposition zero-input can apply one initial condition at a time
Example 3: Solve the following circuit using Superposition

\[ i_1 = 6 \cdot \frac{3}{11} \]

\[ i_2 = \frac{2}{11} \]

\[ i = i_1 + i_2 \]

**Note:** Superposition can be applied only for independent sources and sources appearing because of initial conditions.

Setting the voltage source equal to zero ⇔ short the terminal
Setting the current source equal to zero ⇔ open-circuit the terminal

**Source Transformation**

\[ V = V_s - IR_s \]

\[ I = \frac{V_{in} - V_s}{R} \]

Hence we can replace voltage source with resistance in series by a current source with resistance in parallel.
Example 4: Replace current source with resistance in parallel by voltage source with resistance in series.

Since the following two circuits are equivalent

So the given circuit can be replaced by following:

Note: Source transformation can be used for independent, dependent sources and also for initial conditions, as the I-V relationship is the same in all conditions

Exercise 1: Apply the series of source transformations to get circuit with single mesh
Exercise 2: Replace the dashed part of given circuit by single voltage source in series with a impedance

\[ V_{in}(s) \quad 20 \, \Omega \quad 8s \quad 14 \, \Omega \quad \frac{12}{s} \quad Z(s) \]