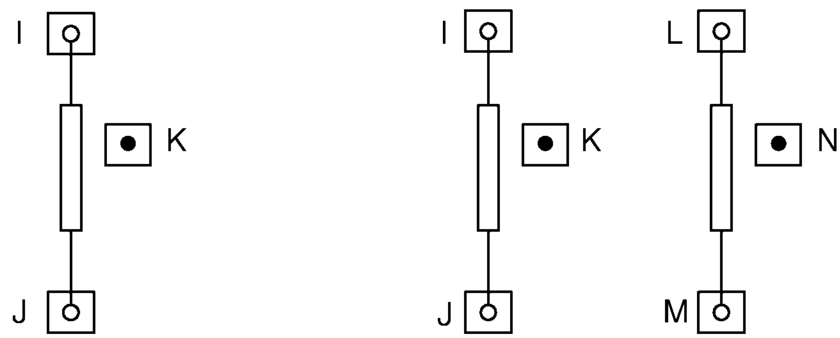
14.124 CIRCU124 — General Electric Circuit Element



(a) Independent Circuit Elements (b) Dependent Circuit Elements

Matrix or Vector	Shape Functions	Integration Points
Stiffness Matrix	None (lumped)	None
Damping Matrix	None (lumped, harmonic analysis only)	None
Load Vector	None (lumped)	None

14.124.1 Electric Circuit Elements

CIRCU124 contains 13 linear electric circuit element options. These may be classified into two groups:

1. Independent Circuit Element options, defined by 2 or 3 nodes:
   a. Resistor (KEYOPT(1) = 0)
   b. Inductor (KEYOPT(1) = 1)
   c. Capacitor (KEYOPT(1) = 2)
   d. Current Source (KEYOPT(1) = 3)
   e. Voltage Source (KEYOPT(1) = 4)

2. Dependent Circuit Element options, defined by 3, 4, 5, or 6 nodes:

a. Stranded coil current source	(KEYOPT(1) = 5)
b. 2–D massive conductor voltage source	(KEYOPT(1) = 6)
c. 3–D massive conductor voltage source	(KEYOPT(1) = 7)
d. Mutual inductor	(KEYOPT(1) = 8)
e. Voltage–controlled current source	(KEYOPT(1) = 9)
f. Voltage–controlled voltage source	(KEYOPT(1) = 10)
g. Current–controlled voltage source	(KEYOPT(1) = 11)
h. Current–controlled current source	(KEYOPT(1) = 12)

14.124.2 Electric Circuit Element Matrices

All circuit options in CIRCU124 are based on Kirchhoff's Current Law. These options use stiffness matrices based on a simple lumped circuit model.

For transient analysis, an inductor with nodes I and J can be presented by:

$$\frac{\theta\Delta t}{L}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{Bmatrix} V_I^{n+1} \\ V_J^{n+1} \end{Bmatrix} = \begin{Bmatrix} -I_L^{n+1} \\ I_L^{n+1} \end{Bmatrix} \tag{14.124–1}$$

where:

L = inductance

V_I = voltage at node I

V_J = voltage at node J

Δt = time increment

θ = time integration parameter

n = time step n

$I_L^{n+1} = \frac{(1-\theta)\ \Delta t}{L}\left(V_I^n - V_J^n\right) + i_L^n$

$i_L^{n+1} = \frac{\theta\Delta t}{L}\left(V_I^{n+1} - V_J^{n+1}\right) + I_L^{n+1}$

A capacitor with nodes I and J is represented by:

$$\frac{C}{\theta\Delta t}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{Bmatrix} V_I^{n+1} \\ V_J^{n+1} \end{Bmatrix} = \begin{Bmatrix} -I_c^{n+1} \\ I_c^{n+1} \end{Bmatrix} \tag{14.124–2}$$

where:

C = capacitance

$$I_c^{n+1} = -\frac{c}{\theta\Delta t}\left(V_I^n - V_J^n\right) - \frac{1-\theta}{\theta}\, i_c^n$$

$$i_c^{n+1} = \frac{c}{\theta\Delta t}\left(V_I^{n+1} - V_J^{n+1}\right) + I_c^{n+1}$$

Similarly, a mutual inductor with nodes I, J, K and L has the following matrix:

$$\frac{\theta\Delta t}{L_1L_2 - M^2}\begin{bmatrix} L_2 & -L_2 & -M & M \\ -L_2 & L_2 & M & -M \\ -M & M & L_1 & -L_1 \\ M & -M & -L_1 & L_1 \end{bmatrix}\begin{Bmatrix} V_I \\ V_J \\ V_K \\ V_L \end{Bmatrix} = \begin{Bmatrix} -I_1^{n+1} \\ I_1^{n+1} \\ -I_2^{n+1} \\ I_2^{n+1} \end{Bmatrix} \qquad (14.124\text{–}3)$$

where:
L1 = input side inductance
L2 = output side inductance
M = mutual inductance

$$I_1^{n+1} = \frac{(1-\theta)\ \Delta t}{L_1L_2 - M^2}\left[L_2\left(V_I^n - V_J^n\right) - M\left(V_K^n - V_L^n\right)\right] + i_1^n$$

$$I_2^{n+1} = \frac{(1-\theta)\ \Delta t}{L_1L_2 - M^2}\left[-M\left(V_I^n - V_J^n\right) + L_1\left(V_K^n - V_L^n\right)\right] + i_2^n$$

$$i_1^{n+1} = \frac{\theta\Delta t}{L_1L_2 - M^2}\left[L_2\left(V_I^{n+1} - V_J^{n+1}\right) - M\left(V_K^{n+1} - V_L^{n+1}\right)\right] + I_1^{n+1}$$

$$i_2^{n+1} = \frac{\theta\Delta t}{L_1L_2 - M^2}\left[-M\left(V_I^{n+1} - V_J^{n+1}\right) + L_1\left(V_K^{n+1} - V_L^{n+1}\right)\right] + I_2^{n+1}$$

For harmonic analysis, the above three circuit element options have only a damping matrix. For an inductor:

$$\left(-\frac{1}{\omega^2 L}\right)\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \qquad (14.124\text{–}4)$$

for a capacitor:

$$j\omega C\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \qquad (14.124\text{–}5)$$

and for a mutual inductor:

$$\left(-\frac{1}{\omega^2\ (L_1L_2 - M^2)}\right)\begin{bmatrix} L_2 & -L_2 & -M & M \\ -L_2 & L_2 & M & -M \\ -M & M & L_1 & -L_1 \\ M & -M & -L_1 & L_1 \end{bmatrix} \qquad (14.124\text{–}6)$$