.

EE1101: Circuits and Network Analysis

Lecture 30: Review of Node and Mesh Analysis

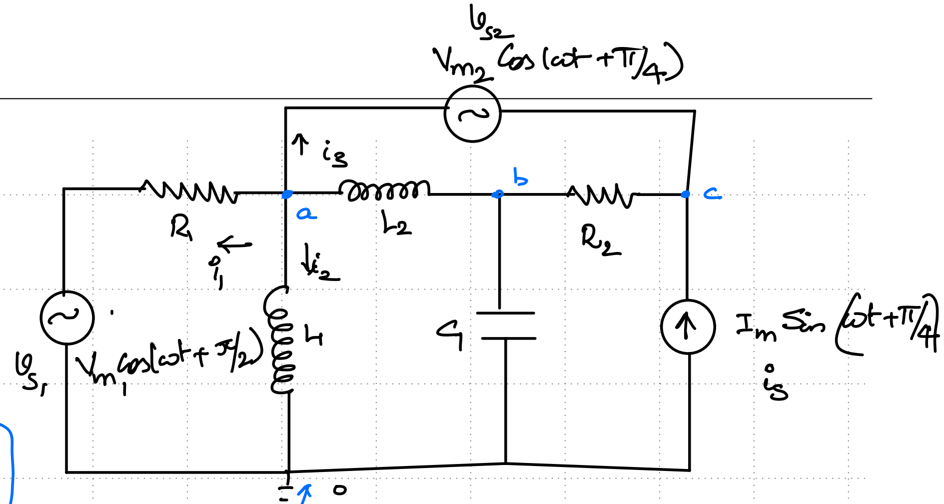
October 14, 2025

Topics :

1. Mesh Analysis for AC Circuits

2. Node Analysis for AC Circuits

Higher order ~~Node Analysis for~~ AC Circuits



Complete Time-domain description : (Node analysis)

at Node 'a' : $\dfrac{v_a - v_{s1}}{R_1} + \dfrac{1}{L_1}\int v_a\, dt + \dfrac{1}{L_2}\int (v_a - v_b)\, dt + i_3 = 0$

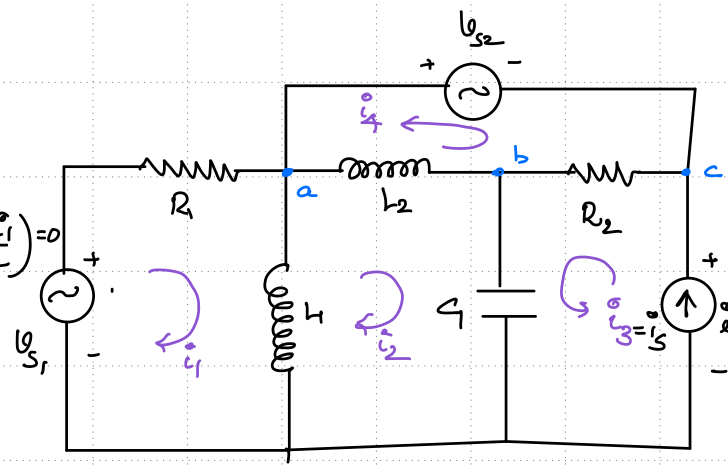
at Node 'b' : $\dfrac{1}{L_2}\int (v_b - v_a)\, dt + C_1 \dfrac{dv_b}{dt} + \dfrac{v_b - v_c}{R_2} = 0$

at Node 'c' : $\dfrac{v_c - v_b}{R_2} - i_s - i_3 = 0$

System of differential Equations

System of DAE (differential algebraic Equations)

Complete Time-domain description : (Mesh Analysis) :



loop (I) : $-v_{s_1} + i_1 R_1 + L_1\left(\dfrac{di_1}{dt} - \dfrac{di_2}{dt}\right) = 0$

loop (II) : $L_2\left(\dfrac{di_2}{dt} + \dfrac{di_4}{dt}\right) + \dfrac{1}{C_1}\int (i_2 + i_s)\, dt + L_1\left(\dfrac{di_2}{dt} - \dfrac{di_1}{dt}\right) = 0$

loop (IV) : $L_2\left(\dfrac{di_4}{dt} + \dfrac{di_2}{dt}\right) + R_2\,(i_4 - i_s) - v_{s_2} = 0$

In Control $\longrightarrow$ State-space modelling (describing the T.D model of a ckt)

Best choice for finding analytical solution

$\dot{\vec{x}} = A\vec{x} + B\vec{u}$ & sol $\vec{x}$ ← involve matrix exponentials e^{At}

Admittance Matrix of the Circuit

given a ckt → a) all sources are at same freq.

b) find steady state response.

→ adopt phasor domain Equivalents.

↓

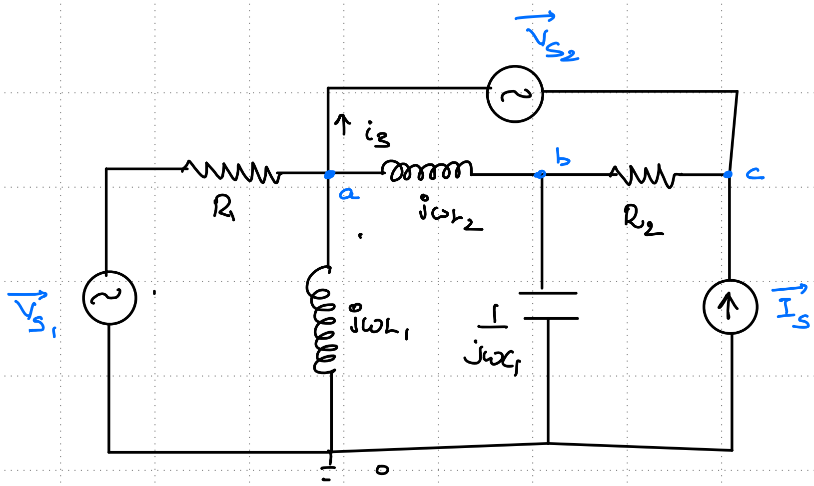
a) Replace all sources using phasors

b) Replace all ckt elem by impedances.

c) Node | Mesh | appropriate anysis to find S.S response (in phasor domain)

⇓

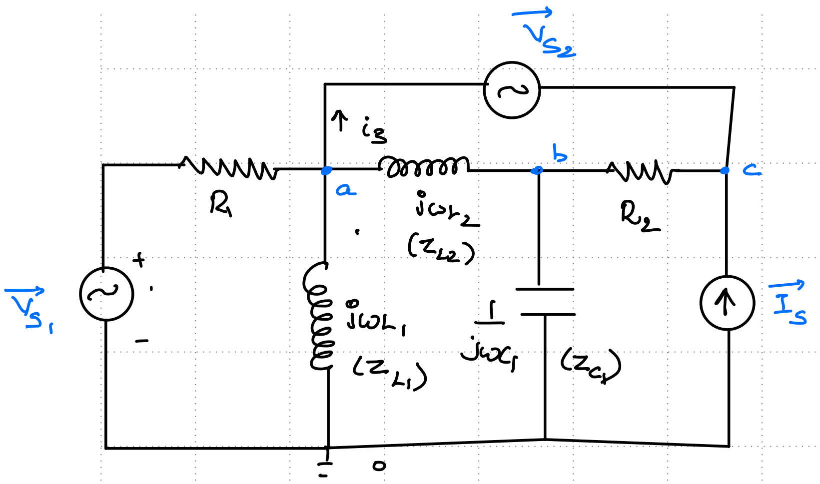
Time domain (if required)



Phasor domain Equivalent

Admittance Matrix of the Circuit

Phasor domain description (Node analysis)



Phasor domain Equivalent

At Node a: $\frac{\vec{V}_a - \vec{V}_{S_1}}{R_1} + \frac{\vec{V}_a - \vec{V}_b}{\vec{Z}_{L_2}} + \frac{\vec{V}_a}{\vec{Z}_{L_1}} + \vec{I}_3 = 0$

$$= \left(\frac{1}{R_1} + \frac{1}{\vec{Z}_{L_1}} + \frac{1}{\vec{Z}_{L_2}}\right)\vec{V}_a - \frac{\vec{V}_b}{\vec{Z}_{L_2}} + \vec{I}_3 = \frac{\vec{V}_{S_1}}{R_1} \rightarrow (1)$$

At Node b: $-\frac{1}{\vec{Z}_{L_2}}\vec{V}_a + \left(\frac{1}{\vec{Z}_{L_2}} + \frac{1}{\vec{Z}_{C_1}} + \frac{1}{R_2}\right)\vec{V}_b - \frac{1}{R_2}\vec{V}_c = 0 \rightarrow (2)$

At Node c: $0\vec{V}_a - \frac{1}{R_2}\vec{V}_b + \frac{1}{R_2}\vec{V}_c - \vec{I}_3 = \vec{I}_S \rightarrow (3)$

Combine (1) & (3) $\longrightarrow$ eliminate $\vec{I}_3$

$$(4) \leftarrow \left(\frac{1}{R_1} + \frac{1}{\vec{Z}_{L_1}} + \frac{1}{\vec{Z}_{L_2}}\right)\vec{V}_a - \frac{\vec{V}_b}{\vec{Z}_{L_2}} - \frac{1}{R_2}\vec{V}_b + \frac{1}{R_2}\vec{V}_c = \frac{\vec{V}_{S_1}}{R_1} + \vec{I}_S$$

$$(5) \leftarrow \vec{V}_a - \vec{V}_c = \vec{V}_{S_2}$$

Solve $\underbrace{(2), (4) \;\&\; (5)}$ to compute $\vec{V}_a, \vec{V}_b$ and $\vec{V}_c$

↳ using matrices :

~~Mesh Analysis~~ of AC Circuits

$$-\frac{1}{\vec{Z}_{L_2}}\vec{V_a} + \left(\frac{1}{\vec{Z}_{L_2}} + \frac{1}{\vec{Z}_{C_1}} + \frac{1}{R_2}\right)\vec{V_b} - \frac{1}{R_2}\vec{V_c} = 0$$

$$\left(\frac{1}{R_1} + \frac{1}{\vec{Z}_{L_1}} + \frac{1}{\vec{Z}_2}\right)\vec{V_a} - \frac{\vec{V_b}}{\vec{Z}_{L_2}} - \frac{1}{R_2}\vec{V_b} + \frac{1}{R_2}\vec{V_c} = \frac{\vec{V_{S_1}}}{R_1} + \vec{I_S}$$

$$\vec{V_a} - \vec{V_c} = \vec{V_{S_2}}$$

Using Matrices

$\frac{1}{Z}$ ← admittance.

$$\begin{bmatrix} -1/Z_{L2} & \frac{1}{\vec{Z}_{L_2}} + \frac{1}{\vec{Z}_{C_1}} + \frac{1}{\vec{R}_2} & -\frac{1}{\vec{R}_2} \\ \left(\frac{1}{R_1} + \frac{1}{\vec{Z}_{L_1}} + \frac{1}{\vec{Z}_2}\right) & -\frac{1}{Z_{L_2}} - \frac{1}{R_2} & \frac{1}{R_2} \\ 1 & 0 & -1 \end{bmatrix} \begin{bmatrix} \vec{V_a} \\ \vec{V_b} \\ \vec{V_c} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{\vec{V_{S_1}}}{R_1} + \vec{I_S} \\ \vec{V_{S_2}} \end{bmatrix}$$

$$[\vec{Y}]\,[\vec{V}] = [\vec{I}] \leftarrow$$

↳ leads to the idea of admittance matrix

when Mesh analysis is employed

$$[\vec{Z}]\,[\vec{I}] = [\vec{V}]$$

↳ leads to impedance matrix.