EN811100
LINEAR CIRCUIT ANALYSIS

Chapter 10

Sinusoidal Steady-State Analysis

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C. K. Alexander – M. N. O. Sadiku
Fundamentals of Electric Circuits, 5th Edition, The McGraw-Hill Companies 2013
J. A. Svoboda – R. C. Dorf
Introduction to Electric Circuits, 9th edition, John Wiley & Sons, Inc. 2014

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Sinusoidal Steady-State Analysis- Chapter 10

10.1 Basic Approach
10.2 Nodal Analysis
10.3 Mesh Analysis
10.4 Superposition Theorem
10.5 Source Transformation
10.6 Thevenin and Norton Equivalent Circuits

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10.1 Basic Approach

Steps to Analyze AC Circuits:

1. Transform the circuit to the phasor or frequency domain.
2. Solve the problem using circuit techniques (nodal analysis, mesh analysis, superposition, etc.).
3. Transform the resulting phasor to the time domain.

Transform Problem in time domain to Phasor domain → **Solve variables in Phasor domain** → **Transform Answers in Phasor domain to time domain**

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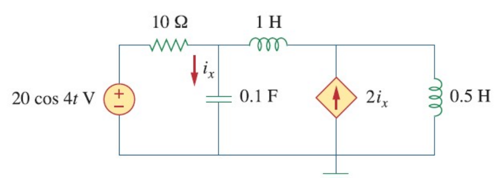
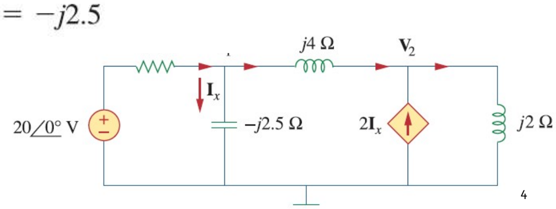
10.2 Nodal Analysis

Example 10.1 Find i_x in the circuit of Fig. 10.1 using nodal analysis.



วิธีทำ 1. แปลงเป็น Phasor

$$\begin{aligned}
20 \cos 4t \quad &\Rightarrow \quad 20\angle 0^\circ, \quad \omega = 4 \text{ rad/s} \\
1 \text{ H} \quad &\Rightarrow \quad j\omega L = j4 \\
0.5 \text{ H} \quad &\Rightarrow \quad j\omega L = j2 \\
0.1 \text{ F} \quad &\Rightarrow \quad \frac{1}{j\omega C} = -j2.5
\end{aligned}$$



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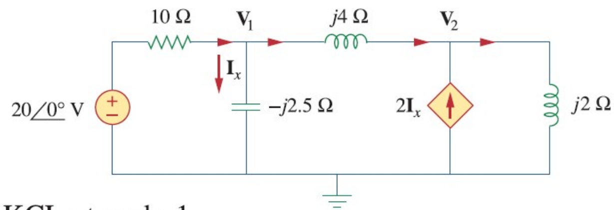

Applying KCL at node 1,

$$\frac{20 - \mathbf{V}_1}{10} = \frac{\mathbf{V}_1}{-j2.5} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j4} \Rightarrow (1 + j1.5)\mathbf{V}_1 + j2.5\mathbf{V}_2 = 20$$

At node 2,

$$2\mathbf{I}_x + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j4} = \frac{\mathbf{V}_2}{j2} \quad \text{โดย} \quad \mathbf{I}_x = \frac{\mathbf{V}_1}{-j2.5}$$

จะได้

$$\frac{2\mathbf{V}_1}{-j2.5} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{j4} = \frac{\mathbf{V}_2}{j2} \Rightarrow 11\mathbf{V}_1 + 15\mathbf{V}_2 = 0$$

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$$(1 + j1.5)\mathbf{V}_1 + j2.5\mathbf{V}_2 = 20$$

$$11\mathbf{V}_1 + 15\mathbf{V}_2 = 0$$

จัดรูป Matrix

$$\begin{bmatrix} 1 + j1.5 & j2.5 \\ 11 & 15 \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 1 + j1.5 & j2.5 \\ 11 & 15 \end{vmatrix} = 15 - j5$$

$$\Delta_1 = \begin{vmatrix} 20 & j2.5 \\ 0 & 15 \end{vmatrix} = 300 \Rightarrow \mathbf{V}_1 = \frac{\Delta_1}{\Delta} = \frac{300}{15 - j5} = 18.97\angle 18.43^\circ \text{ V}$$

$$\Delta_2 = \begin{vmatrix} 1 + j1.5 & 20 \\ 11 & 0 \end{vmatrix} = -220$$

$$\Rightarrow \mathbf{V}_2 = \frac{\Delta_2}{\Delta} = \frac{-220}{15 - j5} = 13.91\angle 198.3^\circ \text{ V}$$

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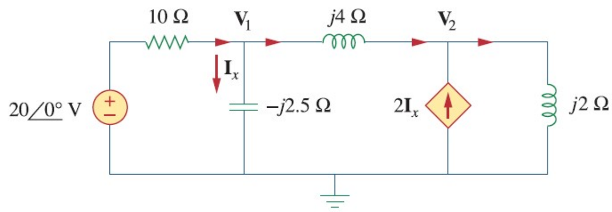

$$\mathbf{I}_x = \frac{\mathbf{V}_1}{-j2.5} = \frac{18.97\angle 18.43°}{2.5\angle -90°} = 7.59\angle 108.4° \text{ A}$$

Transforming this to the time domain,

$$i_x = 7.59 \cos(4t + 108.4°) \text{ A}$$

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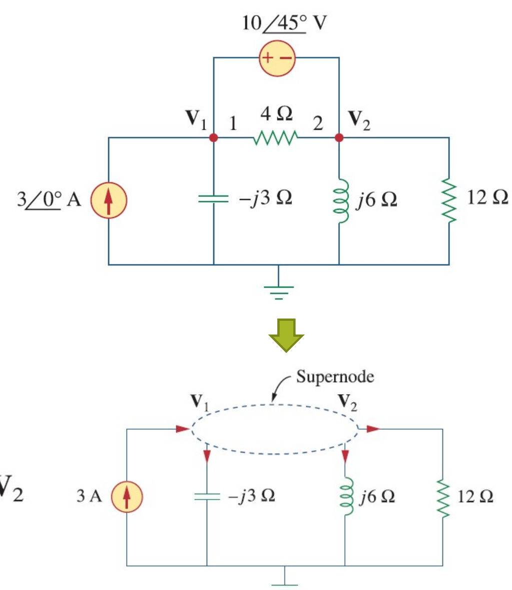
Example 10.2 Compute $\mathbf{V}_1$ and $\mathbf{V}_2$ in the circuit of Fig. 10.4.



วิธีทำ

ใช้ Supernode

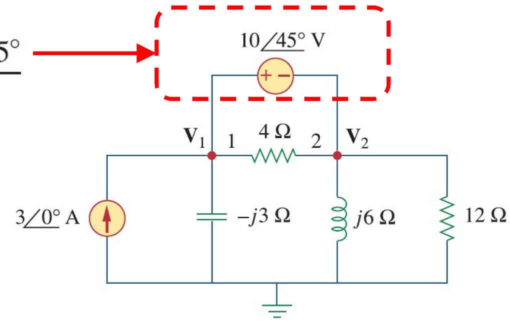
$$3 = \frac{\mathbf{V}_1}{-j3} + \frac{\mathbf{V}_2}{j6} + \frac{\mathbf{V}_2}{12}$$

$$36 = j4\mathbf{V}_1 + (1 - j2)\mathbf{V}_2$$

o

$$\mathbf{V}_1 = \mathbf{V}_2 + 10\angle 45^\circ$$

แทนลงไป



$$36 = j4\mathbf{V}_1 + (1 - j2)\mathbf{V}_2$$

$$36 - 40\angle 135^\circ = (1 + j2)\mathbf{V}_2$$

จะได้

$$\mathbf{V}_2 = 31.41\angle -87.18^\circ \text{ V}$$

$$\mathbf{V}_1 = \mathbf{V}_2 + 10\angle 45^\circ = 25.78\angle -70.48^\circ \text{ V}$$

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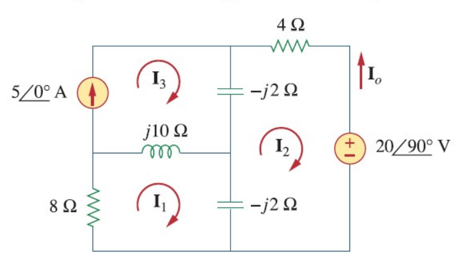
Example 10.3 10.3 Mesh Analysis

Determine current $\mathbf{I}_o$ in the circuit of Fig. 10.7 using mesh analysis.



วิธีทำ

KVL Mesh 1

$$(8 + j10 - j2)\mathbf{I}_1 - (-j2)\mathbf{I}_2 - j10\mathbf{I}_3 = 0$$

$$\boxed{I_3 = 5\angle 0^o}$$

KVL Mesh 2

$$(4 - j2 - j2)\mathbf{I}_2 - (-j2)\mathbf{I}_1 - (-j2)\mathbf{I}_3 + 20\angle 90^\circ = 0$$

จะได้

$$(8 + j8)\mathbf{I}_1 + j2\mathbf{I}_2 = j50$$

$$j2\mathbf{I}_1 + (4 - j4)\mathbf{I}_2 = -j20 - j10$$

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$$(8 + j8)\mathbf{I}_1 + j2\mathbf{I}_2 = j50$$
$$j2\mathbf{I}_1 + (4 - j4)\mathbf{I}_2 = -j20 - j10$$

จัดรูป Matrix

$$\begin{bmatrix} 8 + j8 & j2 \\ j2 & 4 - j4 \end{bmatrix}\begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \end{bmatrix} = \begin{bmatrix} j50 \\ -j30 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 8 + j8 & j2 \\ j2 & 4 - j4 \end{vmatrix} = 32(1 + j)(1 - j) + 4 = 68$$

$$\Delta_2 = \begin{vmatrix} 8 + j8 & j50 \\ j2 & -j30 \end{vmatrix} = 340 - j240 = 416.17\underline{/-35.22^\circ}$$

จะได้

$$\mathbf{I}_2 = \frac{\Delta_2}{\Delta} = \frac{416.17\underline{/-35.22^\circ}}{68} = 6.12\underline{/-35.22^\circ}\text{ A}$$

$$\mathbf{I}_o = -\mathbf{I}_2 = 6.12\underline{/144.78^\circ}\text{ A}$$

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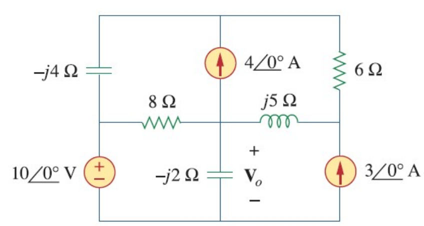
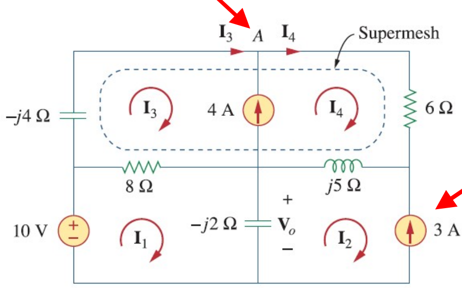
Example 10.4 Solve for $\mathbf{V}_o$ in the circuit of Fig. 10.9 using mesh analysis.



วิธีทำ

ที่ Node A $\mathbf{I}_4 = \mathbf{I}_3 + 4$ (a)



ที่ Mesh 2

$\mathbf{I}_2 = -3$ (b)

KVL Mesh 1 $-10 + (8 - j2)\mathbf{I}_1 - (-j2)\mathbf{I}_2 - 8\mathbf{I}_3 = 0$

$$(8 - j2)\mathbf{I}_1 + j2\mathbf{I}_2 - 8\mathbf{I}_3 = 10 \quad \text{(c)}$$

KVL Supermesh

$$(8 - j4)\mathbf{I}_3 - 8\mathbf{I}_1 + (6 + j5)\mathbf{I}_4 - j5\mathbf{I}_2 = 0 \quad \text{(d)}$$

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$$\boxed{\mathbf{I}_2 = -3}$$

(c) $(8 - j2)\mathbf{I}_1 + j2\mathbf{I}_2 - 8\mathbf{I}_3 = 10 \Rightarrow (8 - j2)\mathbf{I}_1 - 8\mathbf{I}_3 = 10 + j6$ (e)

$$\boxed{\mathbf{I}_4 = \mathbf{I}_3 + 4} \qquad \boxed{\mathbf{I}_2 = -3}$$

(d) $(8 - j4)\mathbf{I}_3 - 8\mathbf{I}_1 + (6 + j5)\mathbf{I}_4 - j5\mathbf{I}_2 = 0$

$-8\mathbf{I}_1 + (14 + j)\mathbf{I}_3 = -24 - j35$ (f)

จัดสมการ (e), (f) ในรูป Matrix

$$\begin{bmatrix} 8 - j2 & -8 \\ -8 & 14 + j \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_3 \end{bmatrix} = \begin{bmatrix} 10 + j6 \\ -24 - j35 \end{bmatrix}$$

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$$\begin{bmatrix} 8 - j2 & -8 \\ -8 & 14 + j \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_3 \end{bmatrix} = \begin{bmatrix} 10 + j6 \\ -24 - j35 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 8 - j2 & -8 \\ -8 & 14 + j \end{vmatrix} = 112 + j8 - j28 + 2 - 64 = 50 - j20$$

$$\Delta_1 = \begin{vmatrix} 10 + j6 & -8 \\ -24 - j35 & 14 + j \end{vmatrix} = 140 + j10 + j84 - 6 - 192 - j280$$

$$= -58 - j186$$

จะได้

$$\mathbf{I}_1 = \frac{\Delta_1}{\Delta} = \frac{-58 - j186}{50 - j20} = 3.618\underline{/274.5^\circ} \text{ A}$$

$$\mathbf{V}_o = -j2(\mathbf{I}_1 - \mathbf{I}_2) = -j2(3.618\underline{/274.5^\circ} + 3)$$

$$= -7.2134 - j6.568 = 9.756\underline{/222.32^\circ} \text{ V}$$

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วิธีใช้คอมพิวเตอร์ช่วยคำนวณ

นำสมการ (c), (b), (d), (a) มาเขียนเป็น Matrix form

$$\begin{bmatrix} 8-j2 & j2 & -8 & 0 \\ 0 & 1 & 0 & 0 \\ -8 & -j5 & 8-j4 & 6+j5 \\ 0 & 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} \mathbf{I}_1 \\ \mathbf{I}_2 \\ \mathbf{I}_3 \\ \mathbf{I}_4 \end{bmatrix} = \begin{bmatrix} 10 \\ -3 \\ 0 \\ 4 \end{bmatrix} \Rightarrow \mathbf{AI} = \mathbf{B}$$

จะได้ $\mathbf{I} = \mathbf{A}^{-1}\mathbf{B}$

MATLAB Code

```
>> A = [(8-j*2)  j*2    -8       0;
        0        1      0        0;
        -8       -j*5   (8-j*4)  (6+j*5);
        0        0      -1       1];
>> B = [10 -3 0 4]';
>> I = inv(A)*B
```

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MATLAB Code

```
>> A = [(8-j*2)  j*2    -8       0;
        0        1      0        0;
        -8       -j*5   (8-j*4)  (6+j*5);
        0        0      -1       1];
>> B = [10 -3 0 4]';
>> I = inv(A)*B

I =
  0.2828 - 3.6069i
  -3.0000
  -1.8690 - 4.4276i
   2.1310 - 4.4276i
>> Vo = -2*j*(I(1) - I(2))

Vo =
  -7.2138 - 6.5655i
```

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10.4 Superposition Theorem

When a circuit has sources operating at different frequencies,

- The separate phasor circuit for each frequency must be solved independently, and
- The total response is the sum of time-domain responses of all the individual phasor circuits.

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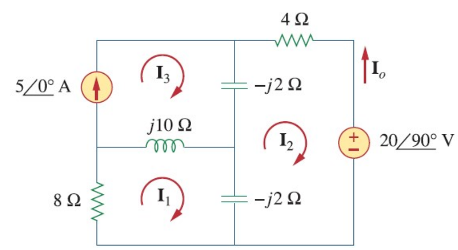
Example 10.5

Use the superposition theorem to find $\mathbf{I}_o$ in the circuit in Fig. 10.7.



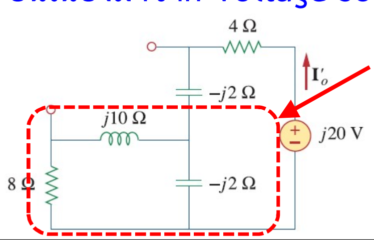
วิธีทำ

วงจรนี้มี Source 2 ตัวคือ

$5\angle 0^o$ A และ $20\angle 90^o$ V

1. ให้ Voltage source ON

และ Current source OFF (Open circuit) และหากระแส $\mathbf{I}_0'$ อันเนื่องมาจาก Voltage source ทำงาน



$$\mathbf{Z} = \frac{-j2(8 + j10)}{-2j + 8 + j10} = 0.25 - j2.25$$

$$\mathbf{I}_o' = \frac{j20}{4 - j2 + \mathbf{Z}} = \frac{j20}{4.25 - j4.25}$$

$$\mathbf{I}_o' = -2.353 + j2.353$$

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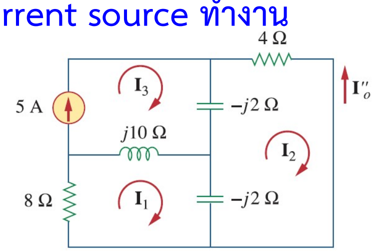
2. ให้ Voltage source OFF (Short circuit) และ Current source ON และหากระแส $\mathbf{I}_0''$ อันเนื่องมาจาก Current source ทำงาน



KVL Mesh 1

$$(8 + j8)\mathbf{I}_1 - j10\mathbf{I}_3 + j2\mathbf{I}_2 = 0 \quad \text{(a)}$$

KVL Mesh 2

$$(4 - j4)\mathbf{I}_2 + j2\mathbf{I}_1 + j2\mathbf{I}_3 = 0 \quad \text{(b)}$$

Current Mesh 3 = $\mathbf{I}_3 = 5$

$$(4 - j4)\mathbf{I}_2 + j2\mathbf{I}_1 + j10 = 0$$

$$\mathbf{I}_1 = (2 + j2)\mathbf{I}_2 - 5$$

$$(8 + j8)\mathbf{I}_1 - j10\mathbf{I}_3 + j2\mathbf{I}_2 = 0 \quad \text{(a)}$$

$$(8 + j8)[(2 + j2)\mathbf{I}_2 - 5] - j50 + j2\mathbf{I}_2 = 0$$

จะได้ $$\mathbf{I}_2 = \frac{90 - j40}{34} = 2.647 - j1.176$$

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จะได้ $$\mathbf{I}_o'' = -\mathbf{I}_2 = -2.647 + j1.176$$

กระแส $\mathbf{I}_0$ โดยรวมคือกระแส $\mathbf{I}_0'$ อันเนื่องมาจาก Voltage source บวกกับกระแส $\mathbf{I}_0''$ อันเนื่องมาจาก Current source

จะได้

$$\mathbf{I}_o = \mathbf{I}_o' + \mathbf{I}_o'' = -5 + j3.529 = 6.12\angle 144.78^\circ \text{ A}$$

คำตอบนี้ตรงกับคำตอบในตัวอย่างที่ 10.3

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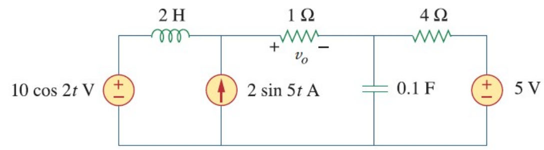
Example 10.6

Find v_o of the circuit of Fig. 10.13 using the superposition theorem.

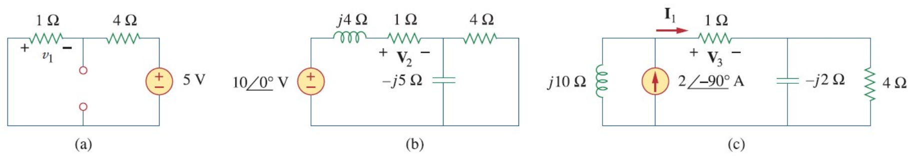


วิธีทำ

วงจรนี้มี Source 3 ตัว แต่ละตัวมีความถี่ไม่เท่ากัน

$10\cos 2t \rightarrow \omega = 2 \qquad 5\sin 5t \rightarrow \omega = 5 \qquad 5\text{ V} \rightarrow \omega = 0$

เวลาคำนวณจึงต้องแยกกันคำนวณโดยใช้หลักการ Superposition



5 V ON ตัวเดียว	$10\cos 2t$ ON ตัวเดียว	$2\sin 5t$ ON ตัวเดียว

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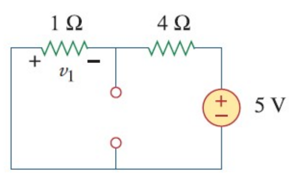
1. ให้ Voltage source 5 V ON, Current source ที่เหลือให้เป็น Open circuit, Voltage source ที่เหลือเป็น Short Circuit ในกรณีนี้เป็น DC Source, ω=0,

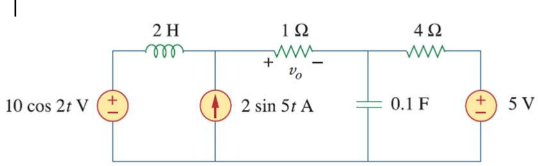
$$z_L = j\omega L = 0$$

$$z_C = \frac{1}{j\omega C} = \infty$$

จะได้วงจรเป็น



ใช้ Voltage Divider หาแรงดันตกคร่อม R 1 Ω



$$-v_1 = \frac{1}{1+4}(5) = 1\text{ V}$$

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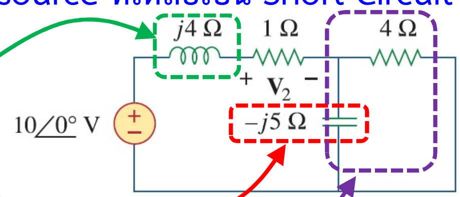
2. ให้ Voltage source $10\cos(2t)$ ON, Current source ที่เหลือให้เป็น Open circuit, Voltage source ที่เหลือเป็น Short Circuit ในกรณีนี้ ω=2,



$$z_L = j\omega L = j2\times 2 = j4\,\Omega$$

$$z_C = \frac{1}{j\omega C} = \frac{1}{j2\times 0.1} = -j5\,\Omega$$

$$\mathbf{Z} = -j5 \parallel 4 = \frac{-j5\times 4}{4-j5} = 2.439 - j1.951$$

ใช้ Voltage Divider หาแรงดันตกคร่อม R 1 Ω

$$\mathbf{V}_2 = \frac{1}{1+j4+\mathbf{Z}}(10\angle 0^\circ) = \frac{10}{3.439+j2.049} = 2.498\angle -30.79^\circ$$

$$v_2 = 2.498\cos(2t - 30.79^\circ)$$

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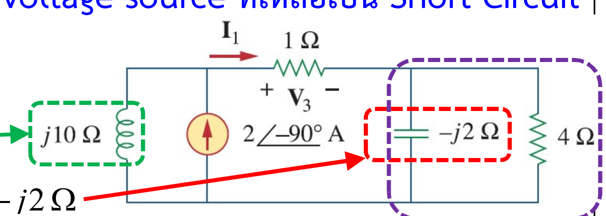
3. ให้ Current source $2\sin(5t)$ ON, Current source ที่เหลือให้เป็น Open circuit, Voltage source ที่เหลือเป็น Short Circuit ในกรณีนี้ ω=5,



$$z_L = j\omega L = j5\times 2 = j10\,\Omega$$

$$z_C = \frac{1}{j\omega C} = \frac{1}{j5\times 0.1} = -j2\,\Omega$$

$$\mathbf{Z}_1 = -j2 \parallel 4 = \frac{-j2\times 4}{4-j2} = 0.8 - j1.6\,\Omega$$

ใช้ Current Divider หากระแสที่ผ่าน R 1 Ω

$$\mathbf{I}_1 = \frac{j10}{j10+1+\mathbf{Z}_1}(2\angle -90^\circ)\text{ A}$$

$$\mathbf{V}_3 = \mathbf{I}_1 \times 1 = \frac{j10}{1.8+j8.4}(-j2) = 2.328\angle -80^\circ\text{ V}$$

$$v_3 = 2.33\cos(5t - 80^\circ) = 2.33\sin(5t + 10^\circ)\text{ V}$$

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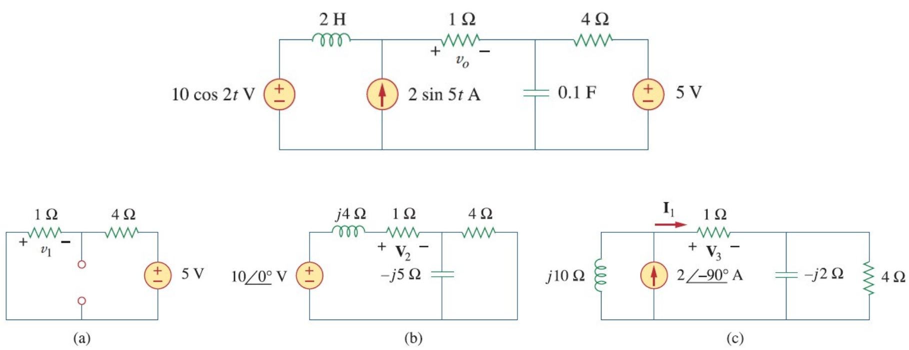

ใช้หลักการ Superposition

$$v_o = v_1 + v_2 + v_3$$

$$v_o(t) = -1 + 2.498\cos(2t - 30.79°) + 2.33\sin(5t + 10°)\ \text{V}$$

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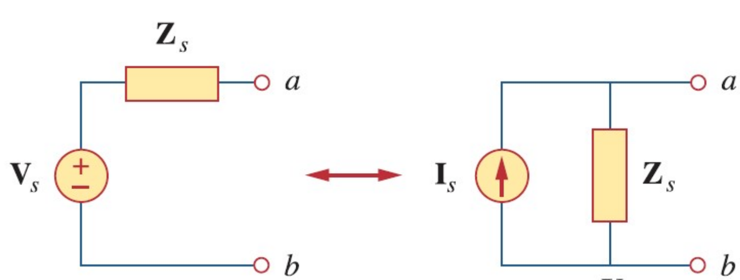
10.5 Source Transformation

เราสามารถแปลง Voltage source เป็น Current source หรือ แปลงจาก Current source เป็น Voltage source โดยใช้สูตรดังนี้



$$\mathbf{V}_s = \mathbf{Z}_s \mathbf{I}_s \qquad \mathbf{I}_s = \frac{\mathbf{V}_s}{\mathbf{Z}_s}$$

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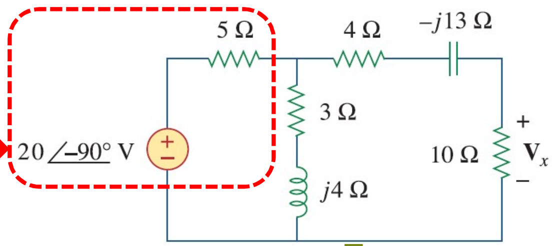
Example 10.7

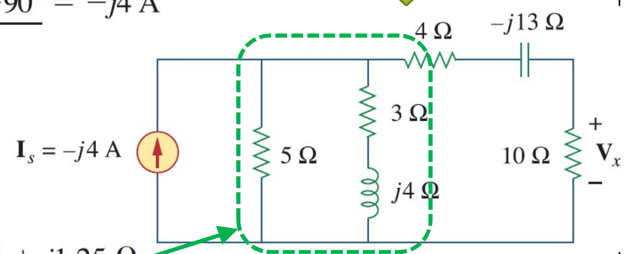
Calculate $\mathbf{V}_x$ in the circuit of Fig. 10.17 using the method of source transformation.

วิธีทำ

แปลง Voltage source เป็น Current source



$$\mathbf{I}_s = \frac{20\angle -90^\circ}{5} = 4\angle -90^\circ = -j4\text{ A}$$



$$\mathbf{Z}_1 = \frac{5(3 + j4)}{8 + j4} = 2.5 + j1.25\ \Omega$$

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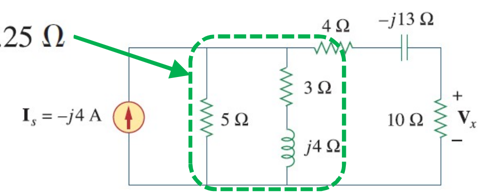
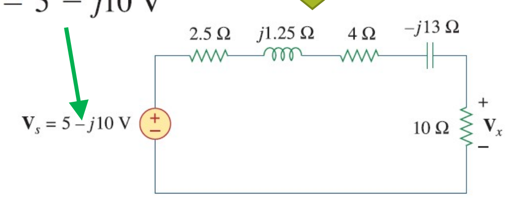
$$\mathbf{Z}_1 = \frac{5(3 + j4)}{8 + j4} = 2.5 + j1.25\ \Omega$$



แปลง Current source กลับเป็น Voltage source

$$\mathbf{V}_s = \mathbf{I}_s\mathbf{Z}_1 = -j4(2.5 + j1.25) = 5 - j10\text{ V}$$



ใช้ Voltage Divider

$$\mathbf{V}_x = \frac{10}{10 + 2.5 + j1.25 + 4 - j13}(5 - j10) = 5.519\angle -28^\circ\text{ V}$$

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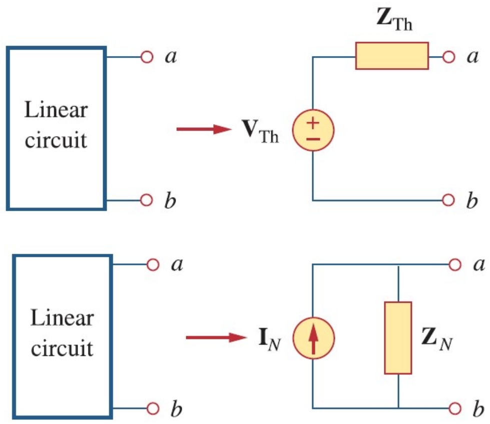
10.6 Thevenin and Norton Equivalent Circuits



Thevenin Equivalent circuit

Norton Equivalent circuit

$$\mathbf{V}_{\mathrm{Th}} = \mathbf{Z}_N \mathbf{I}_N, \qquad \mathbf{Z}_{\mathrm{Th}} = \mathbf{Z}_N$$

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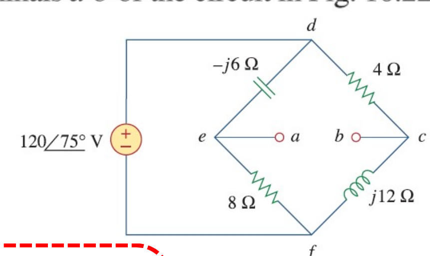
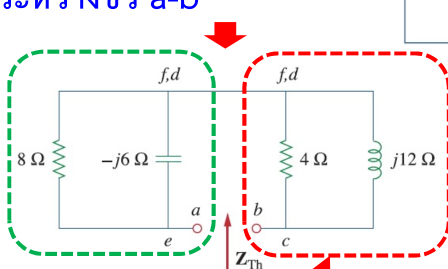
Example 10.8

Obtain the Thevenin equivalent at terminals *a*-*b* of the circuit in Fig. 10.22.

วิธีทำ

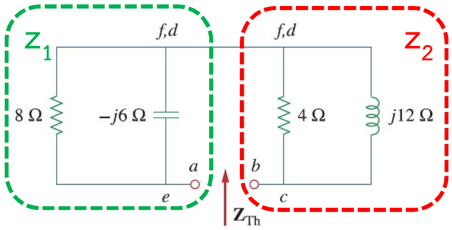
หา z_{th} โดยการ Short circuit Voltage source แล้ววัด Impedance ระหว่างขั้ว a-b





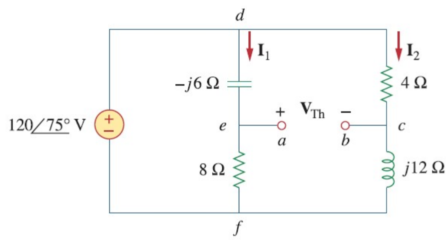
$$\mathbf{Z}_1 = -j6 \parallel 8 = \frac{-j6 \times 8}{8 - j6} = 2.88 - j3.84\ \Omega$$

$$\mathbf{Z}_2 = 4 \parallel j12 = \frac{j12 \times 4}{4 + j12} = 3.6 + j1.2\ \Omega$$



$$\mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = 6.48 - j2.64\ \Omega$$

หากระแส I_1 และ I_2



$$\mathbf{I}_1 = \frac{120\angle 75^\circ}{8 - j6}\ \text{A},$$

$$\mathbf{I}_2 = \frac{120\angle 75^\circ}{4 + j12}\ \text{A}$$

ใช้ KVL ใน Loop bcdeab

$$\mathbf{V}_{Th} - 4\mathbf{I}_2 + (-j6)\mathbf{I}_1 = 0$$

จะได้ v_{th} ระหว่างขั้ว a-b

$$\mathbf{V}_{Th} = 4\mathbf{I}_2 + j6\mathbf{I}_1 = \frac{480\angle 75^\circ}{4 + j12} + \frac{720\angle 75^\circ + 90^\circ}{8 - j6}$$

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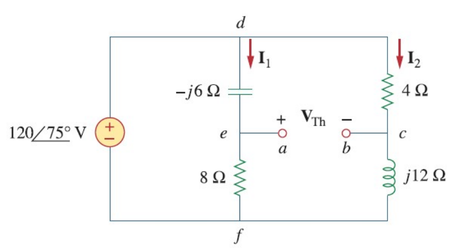

$$\mathbf{I}_1 = \frac{120\angle 75^\circ}{8 - j6}\ \text{A},$$

$$\mathbf{I}_2 = \frac{120\angle 75^\circ}{4 + j12}\ \text{A}$$

จะได้ v_{th} ระหว่างขั้ว a-b

$$\mathbf{V}_{Th} = 4\mathbf{I}_2 + j6\mathbf{I}_1 = \frac{480\angle 75^\circ}{4 + j12} + \frac{720\angle 75^\circ + 90^\circ}{8 - j6}$$

$$= 37.95\angle 3.43^\circ + 72\angle 201.87^\circ$$

$$= -28.936 - j24.55 = 37.95\angle 220.31^\circ\ \text{V}$$

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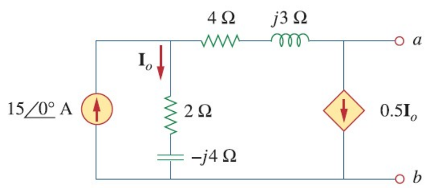
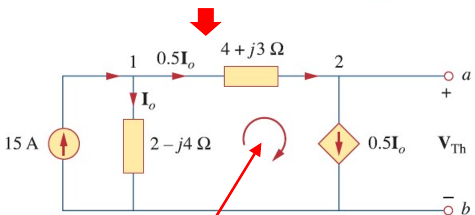
Example 10.9

Find the Thevenin equivalent of the circuit in Fig. 10.25 as seen from terminals *a*-*b*.



วิธีทำ



KCL ที่ Node 1

$$15 = \mathbf{I}_o + 0.5\mathbf{I}_o$$

$$\mathbf{I}_o = 10\text{ A}$$

ใช้ KVL ใน Loop นี้ $-\mathbf{I}_o(2 - j4) + 0.5\mathbf{I}_o(4 + j3) + \mathbf{V}_{\text{Th}} = 0$

จะได้ $\mathbf{V}_{\text{Th}} = 10(2 - j4) - 5(4 + j3) = -j55$

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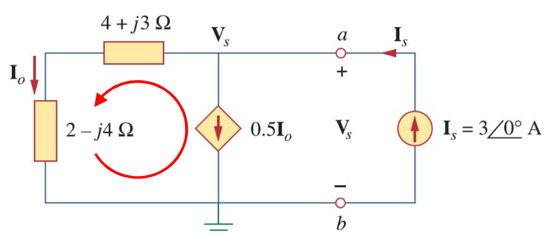
หาค่า z_{th} โดยเอา Independent source ออกไป แล้วนำ Current Source $\mathbf{I} = 3\angle 0^o$ A มาต่อที่ขั้ว a-b แล้ววัดแรงดันที่ขั้ว a-b



(b)

KCL ที่ Node a $3 = \mathbf{I}_o + 0.5\mathbf{I}_o \quad \Rightarrow \quad \mathbf{I}_o = 2\text{ A}$

KCL ที่ Loop 1 $\mathbf{V}_s = \mathbf{I}_o(4 + j3 + 2 - j4) = 2(6 - j)$

$$\mathbf{Z}_{\text{Th}} = \frac{\mathbf{V}_s}{\mathbf{I}_s} = \frac{2(6 - j)}{3} = 4 - j0.6667\ \Omega$$

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Practice Problem 10.1

Using nodal analysis, find v_1 and v_2 in the circuit of Fig. 10.3.

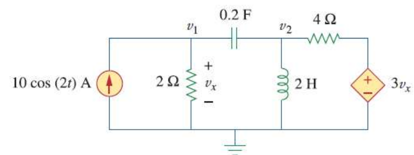


Figure 10.3
For Practice Prob. 10.1.

Answer: $v_1(t) = 11.325\cos(2t + 60.01°)$ V,
$v_2(t) = 33.02\cos(2t + 57.12°)$ V.

Practice Problem 10.2

Calculate $\mathbf{V}_1$ and $\mathbf{V}_2$ in the circuit shown in Fig. 10.6.

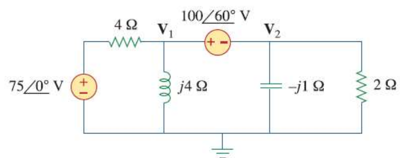


Figure 10.6
For Practice Prob. 10.2.

Answer: $\mathbf{V}_1 = 96.8\angle 69.66°$ V, $\mathbf{V}_2 = 16.88\angle 165.72°$ V.

Practice Problem 10.3

Find $\mathbf{I}_o$ in Fig. 10.8 using mesh analysis.

Answer: $5.969\angle 65.45°$ A.

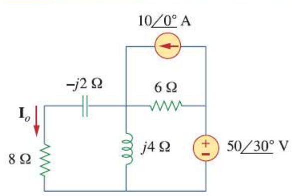
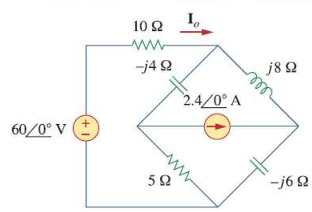


Figure 10.8
For Practice Prob. 10.3.

Practice Problem 10.4

Calculate current $\mathbf{I}_o$ in the circuit of Fig. 10.11.

Answer: $6.089\angle 5.94°$ A.



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Practice Problem 10.5

Find current $\mathbf{I}_o$ in the circuit of Fig. 10.8 using the superposition theorem.

Answer: $5.97\underline{/65.45^\circ}$ A.

Practice Problem 10.6

Calculate v_o in the circuit of Fig. 10.15 using the superposition theorem.

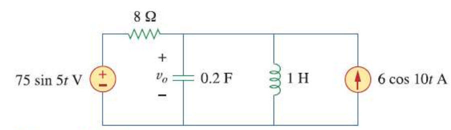

Figure 10.15
For Practice Prob. 10.6.

Answer: $11.577 \sin(5t - 81.12^\circ) + 3.154 \cos(10t - 86.24^\circ)$ V.

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Practice Problem 10.7

Find $\mathbf{I}_o$ in the circuit of Fig. 10.19 using the concept of source transformation.

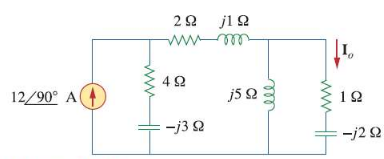

Figure 10.19
For Practice Prob. 10.7.

Answer: $9.863\underline{/99.46^\circ}$ A.

Practice Problem 10.8

Find the Thevenin equivalent at terminals *a-b* of the circuit in Fig. 10.24.

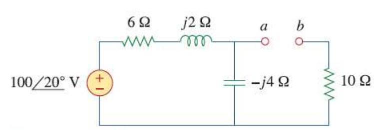

Figure 10.24
For Practice Prob. 10.8.

Answer: $\mathbf{Z}_{Th} = 12.4 - j3.2\ \Omega$, $\mathbf{V}_{Th} = 63.24\underline{/-51.57^\circ}$ V.

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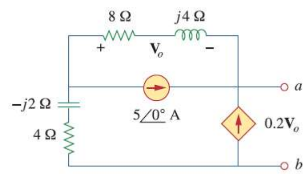
Determine the Thevenin equivalent of the circuit in Fig. 10.27 as seen from the terminals *a-b*.

Practice Problem 10.9

Answer: $\mathbf{Z}_{\text{Th}} = 4.473\underline{/-7.64^\circ}\ \Omega$, $\mathbf{V}_{\text{Th}} = 7.35\underline{/72.9^\circ}$ V.



Practice Problem 10.10

Determine the Norton equivalent of the circuit in Fig. 10.30 as seen from terminals *a-b*. Use the equivalent to find $\mathbf{I}_o$.

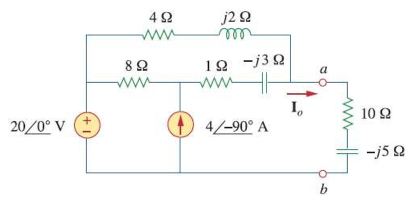


Figure 10.30
For Practice Prob. 10.10 and Prob. 10.35.

Answer: $\mathbf{Z}_N = 3.176 + j0.706\ \Omega$, $\mathbf{I}_N = 8.396\underline{/-32.68^\circ}$ A, $\mathbf{I}_o = 1.9714\underline{/-2.10^\circ}$ A.