Chap. 10

Sinusoidal Steady-State Analysis (3)

Hanwool Jeong

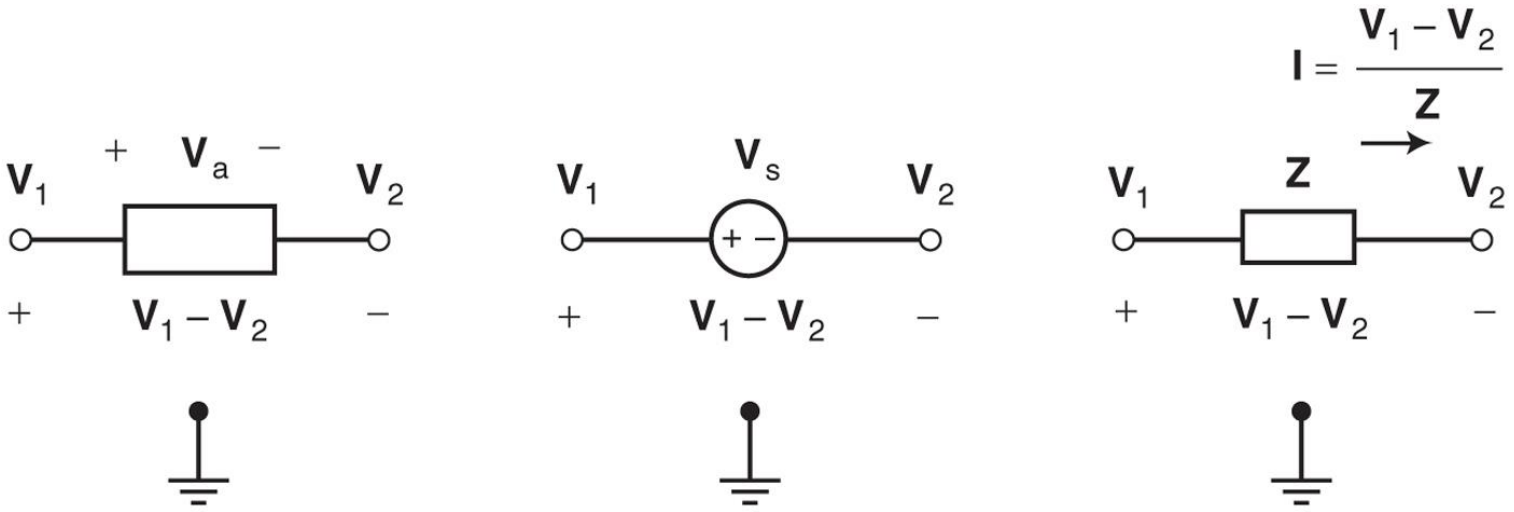
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Analyzing an AC Circuit

- ✓ 10.6 Mesh and Node Equations
- ✓ 10.7 Thevenin and Norton Equivalent Circuits
- ✓ 10.8 Superposition

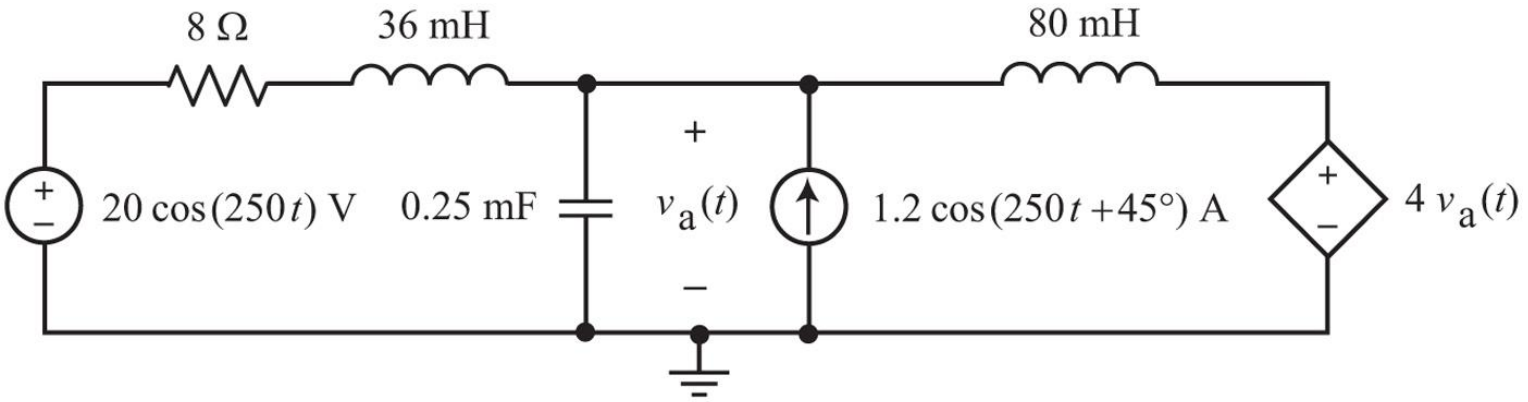
Node Equations

- Writing node equations to solve voltage or current by
  1) Expressing element voltages and currents in terms of node voltage
  2) Applying KCL

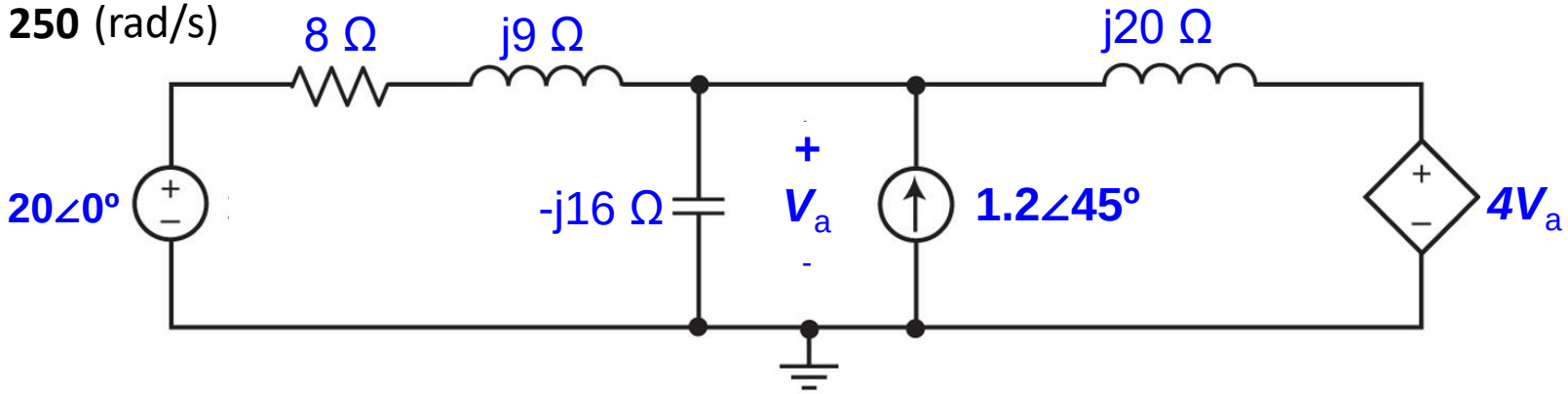


Example 10.6-1

- Determine $v_a(t)$

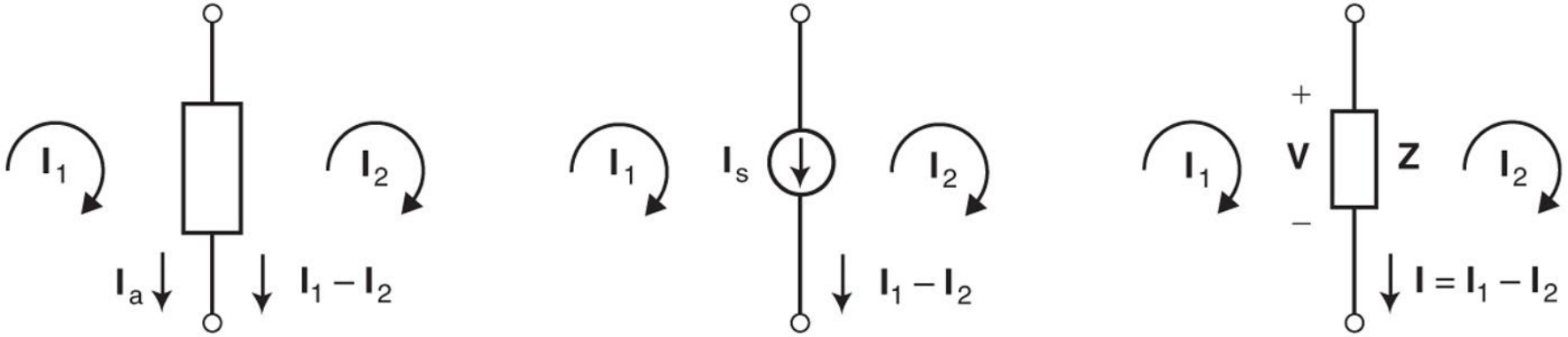


ω = 250 (rad/s)



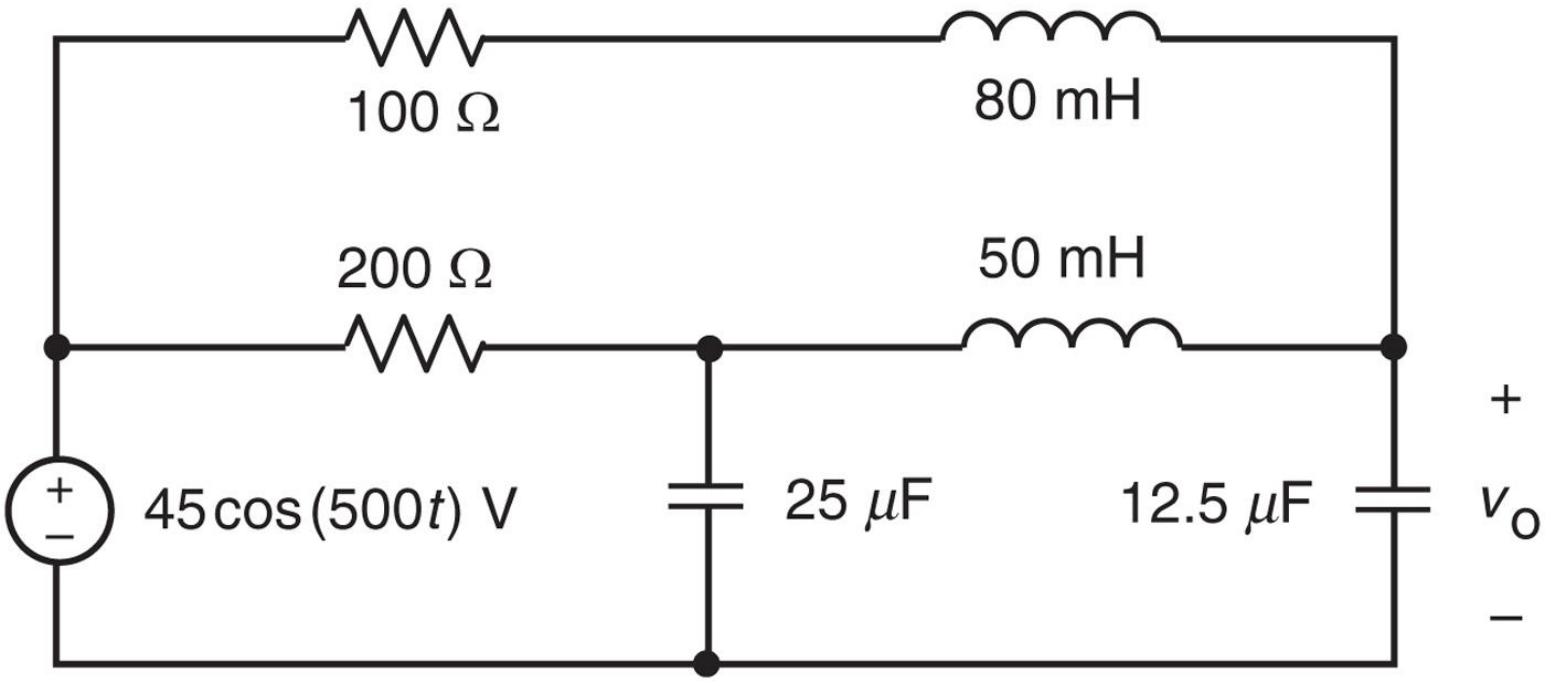
Mesh Equations

- Writing mesh equations to solve voltage or current by
  1) Expressing element voltages and currents in terms of mesh current
  2) Applying KVL



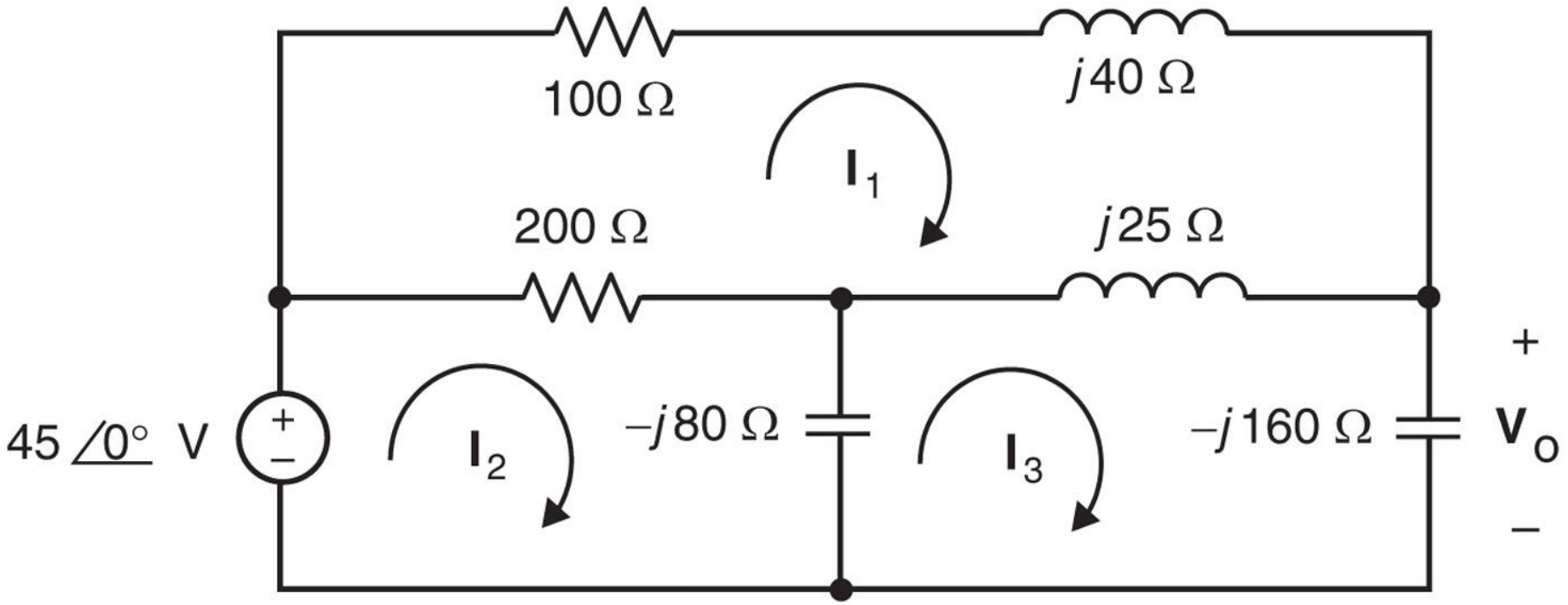
Example 10.6-2

- Determine the mesh currents

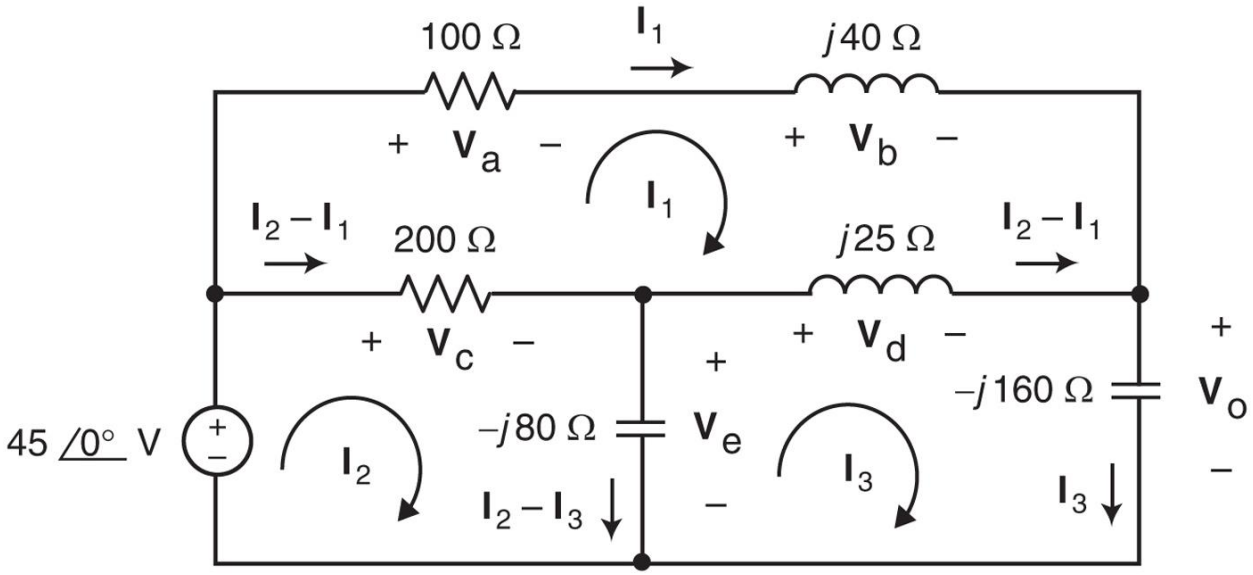


Example 10.6-2

- Determine the mesh currents

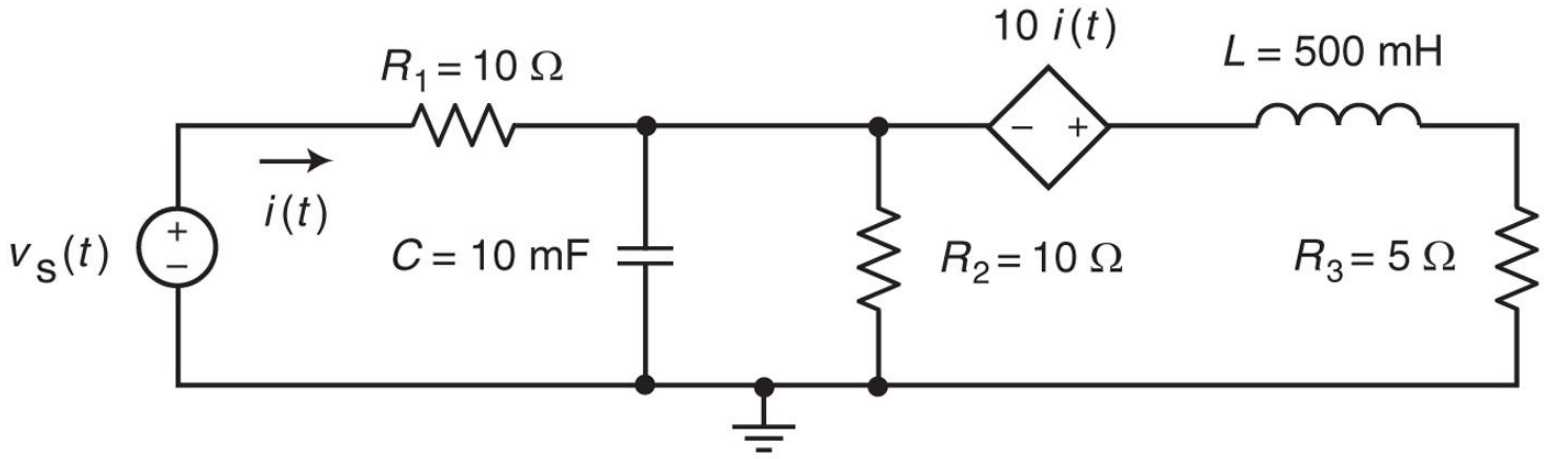


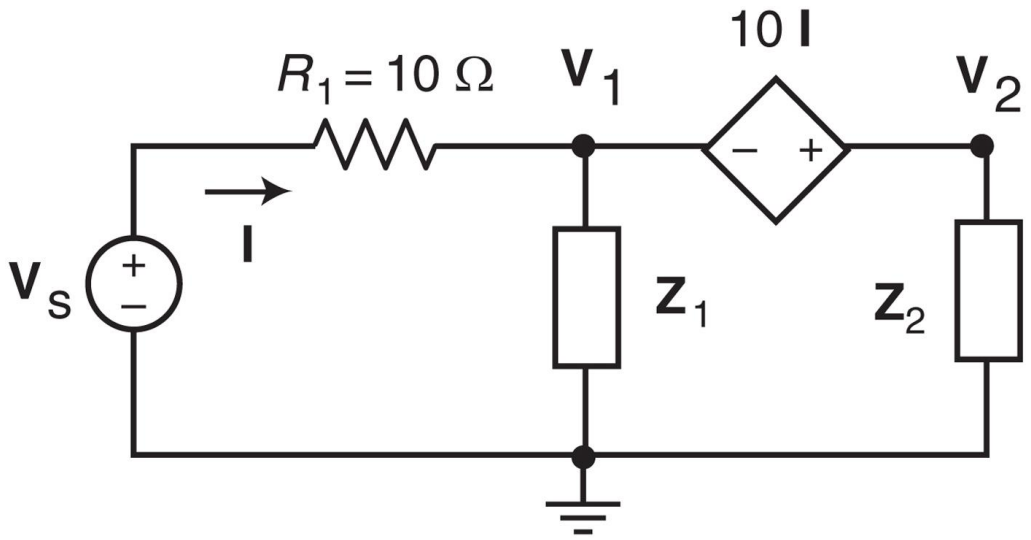
Example 10.6-2



Example 10.6-3

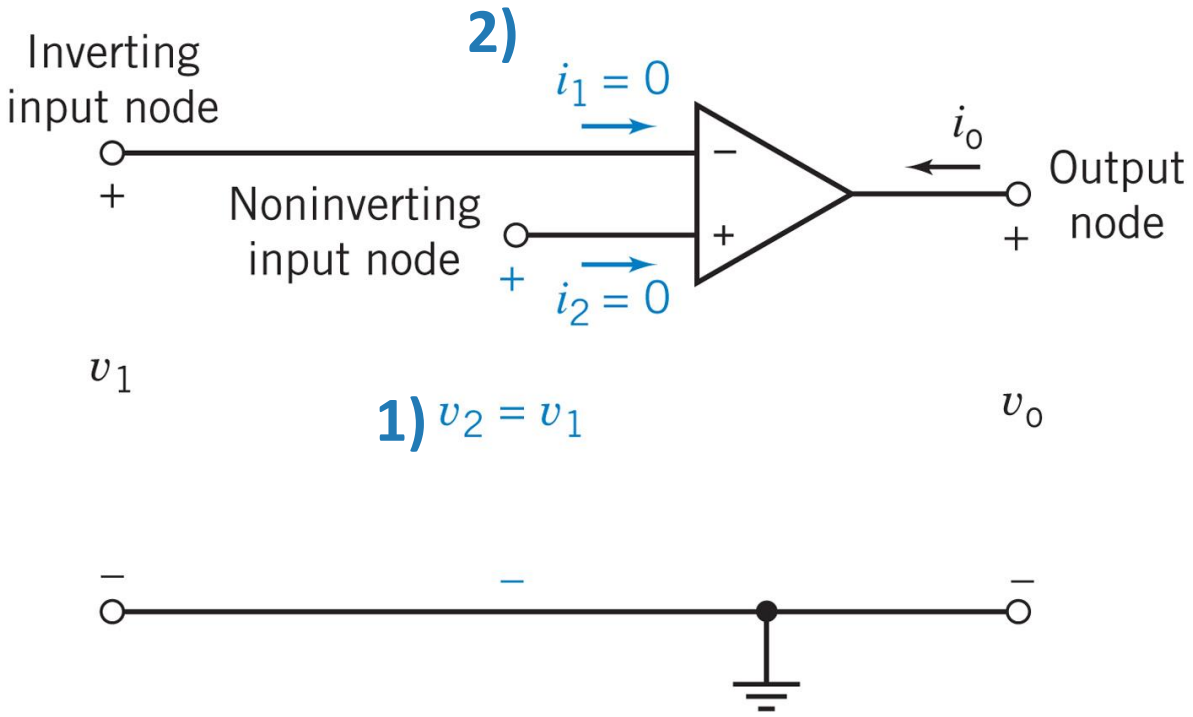
- Determine i(t) when $v_S(t) = 10 \cos(10t)$ V.




10 I
$R_1 = 10\ \Omega$
$\mathbf{V}_1$
$\mathbf{V}_2$
I
$\mathbf{V}_S$
$\mathbf{Z}_1$
$\mathbf{Z}_2$

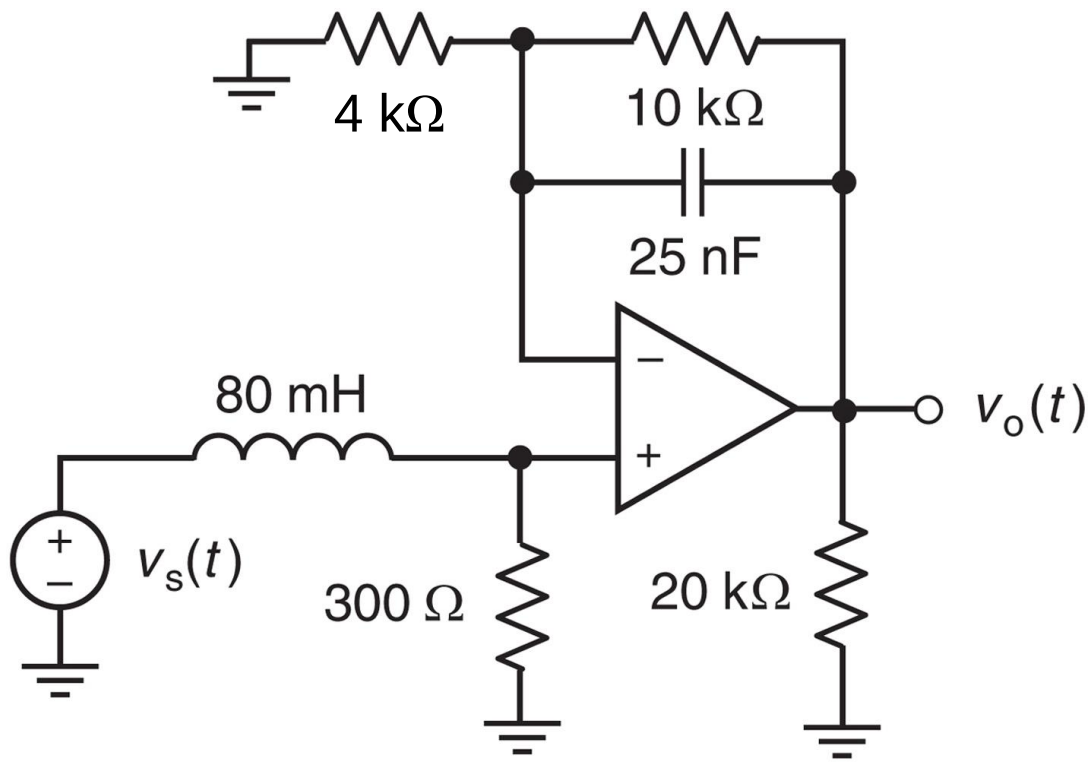
Review for Ideal Op-Amp

- Ideal operational amplifier is a simple model of a linear op-amp.

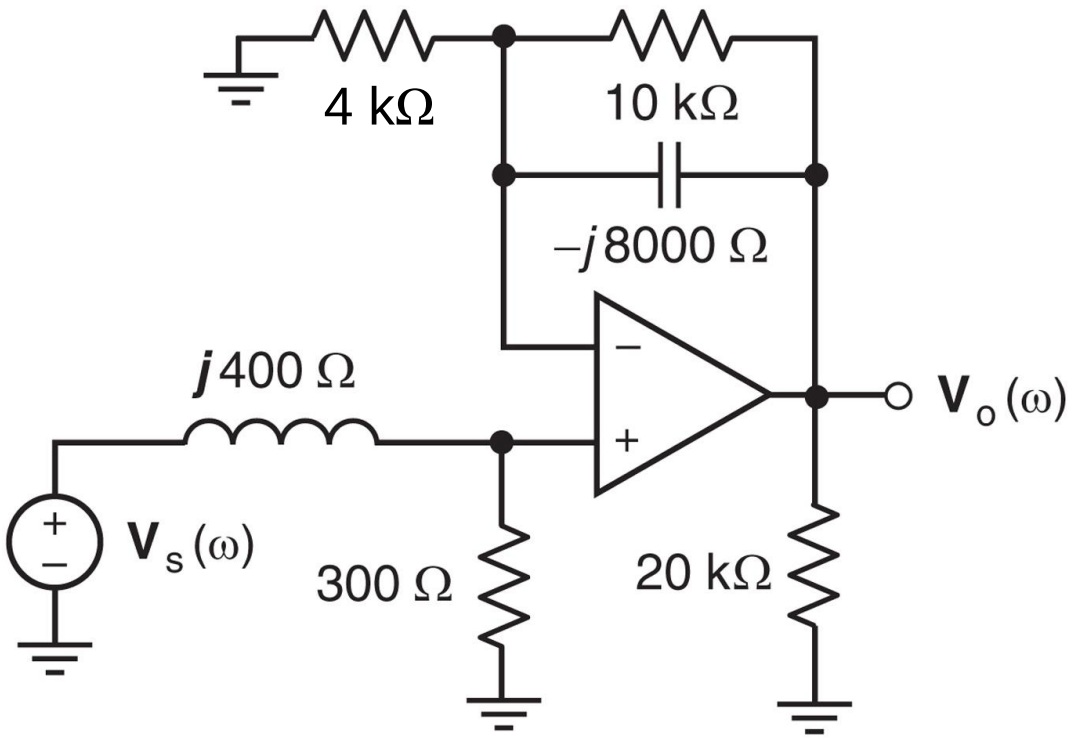


Example 10.6-4

- Determine $v_O(t)$ when $v_s(t) = 125\cos(5000t+15^o)$.



- V(ω) = 125m ∠15°, ω = 5000

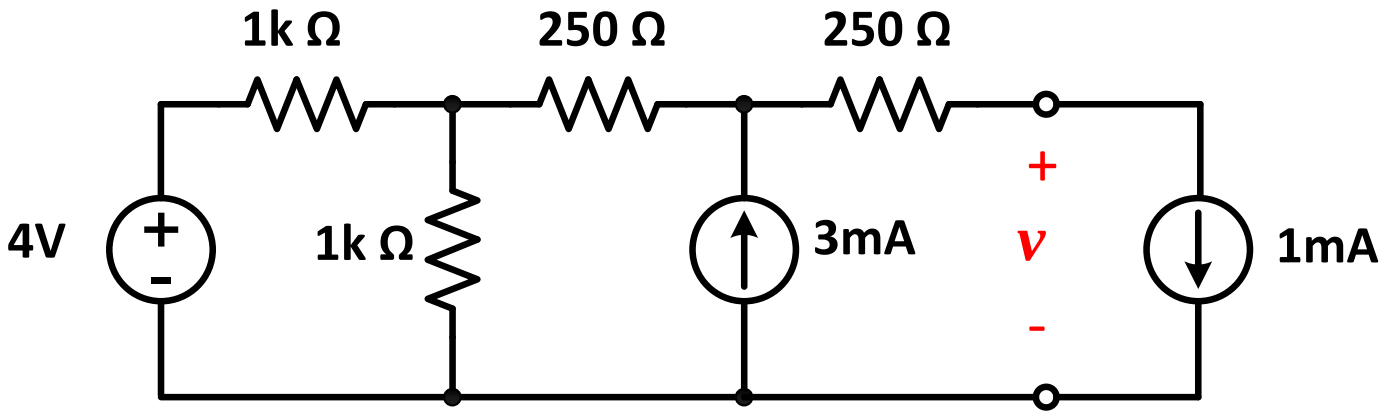


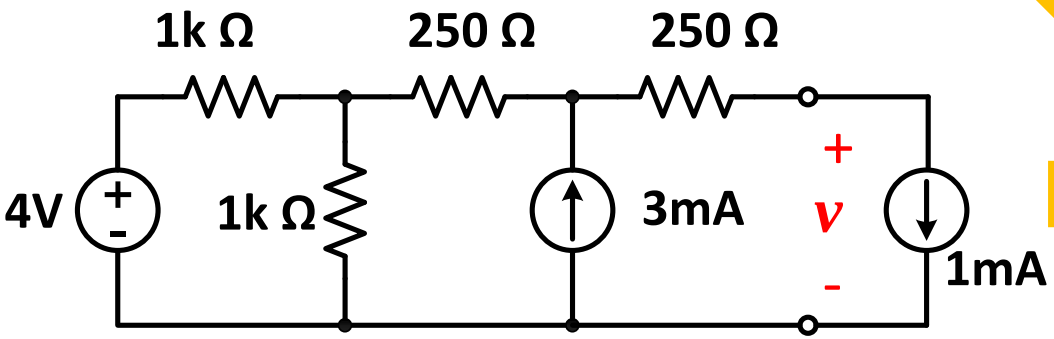
Checkpoints

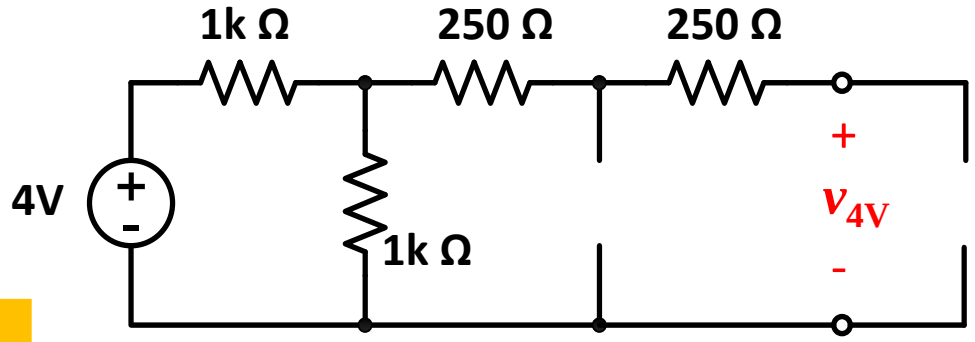
- ✓Node equation and mesh equation are applicable in the frequency domain as well.
- ✓Two things to remember in the op-amp
- ✓ Coming-up next; Thevenin and Norton Equivalent Circuits

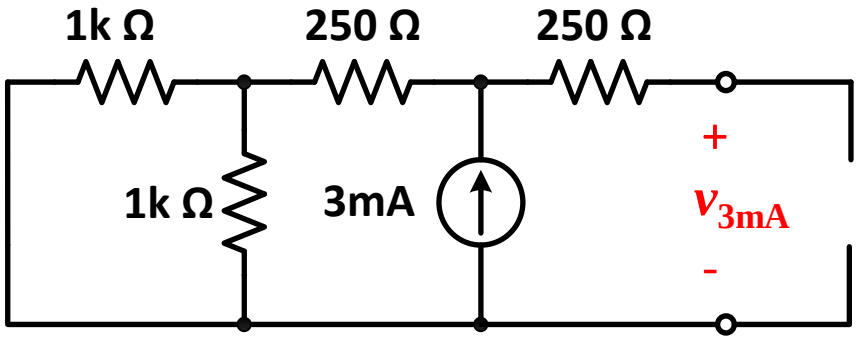
Review for Superposition

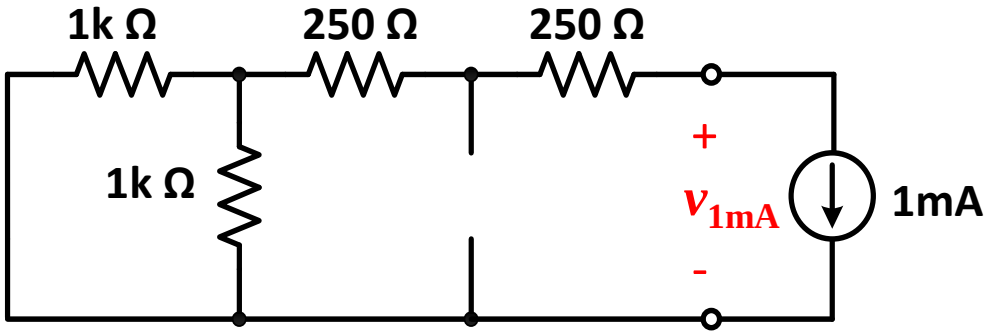
- Determine ***v***.

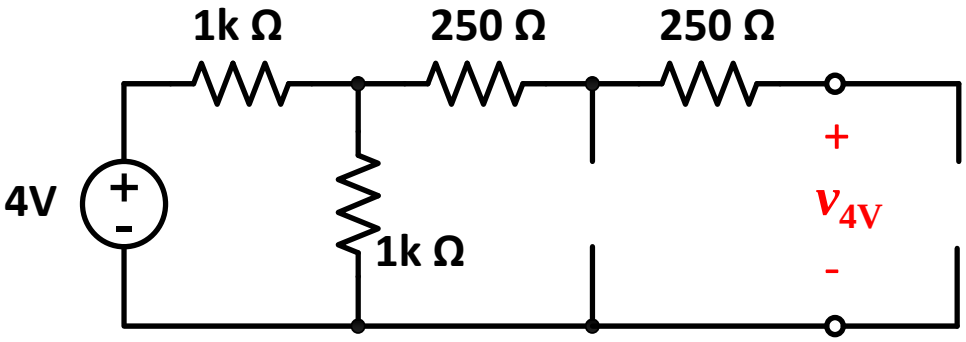


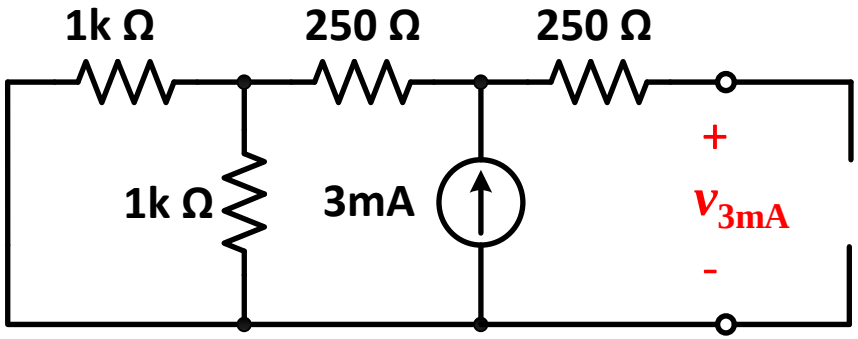

1k Ω
250 Ω
250 Ω
4V
1k Ω
3mA
+
v
-
1mA

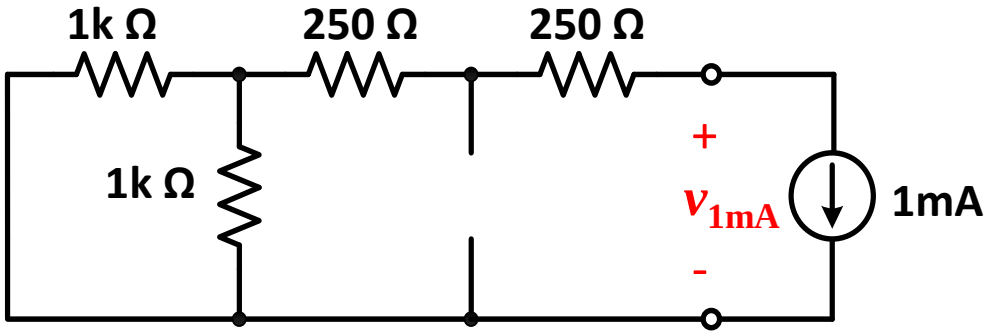

1k Ω
250 Ω
250 Ω
4V
1k Ω
+
v_{4V}
-


1k Ω
250 Ω
250 Ω
1k Ω
3mA
+
v_{3mA}
-


1k Ω
250 Ω
250 Ω
1k Ω
+
v_{1mA}
-
1mA

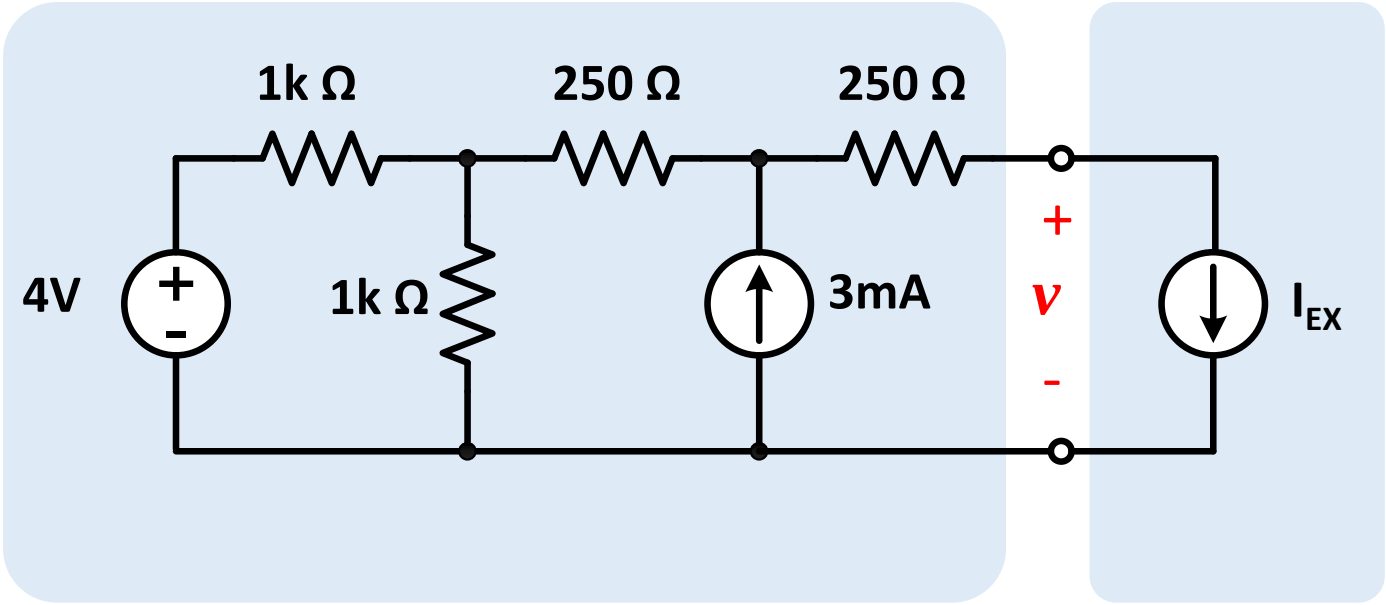

1k Ω
250 Ω
250 Ω
4V
+
-
1k Ω
+
v_{4V}
-


1k Ω
250 Ω
250 Ω
1k Ω
3mA
+
v_{3mA}
-


1k Ω
250 Ω
250 Ω
1k Ω
+
v_{1mA}
-
1mA

Circuit Generalization for Thevenin Equivalent Circuit

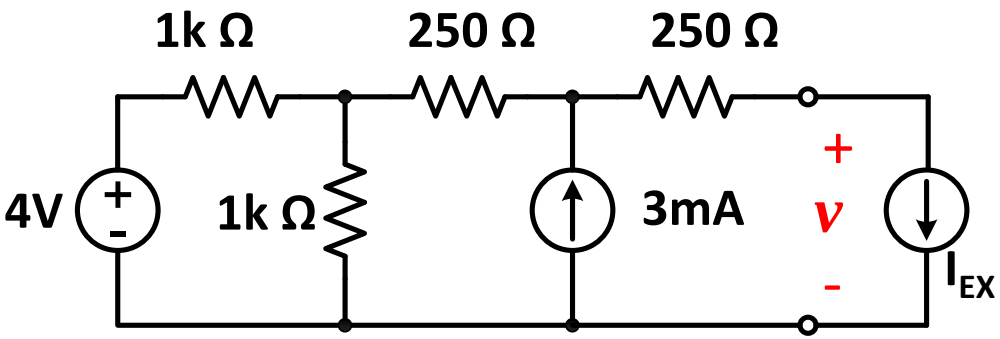
- Replacing 1mA of the above example with I_{EX},

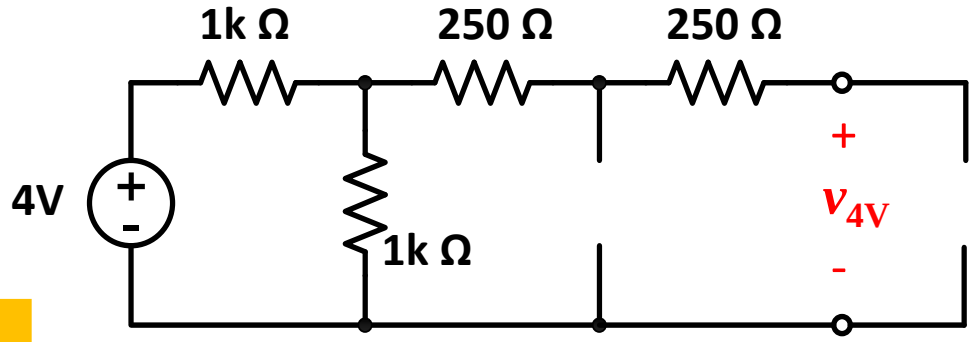


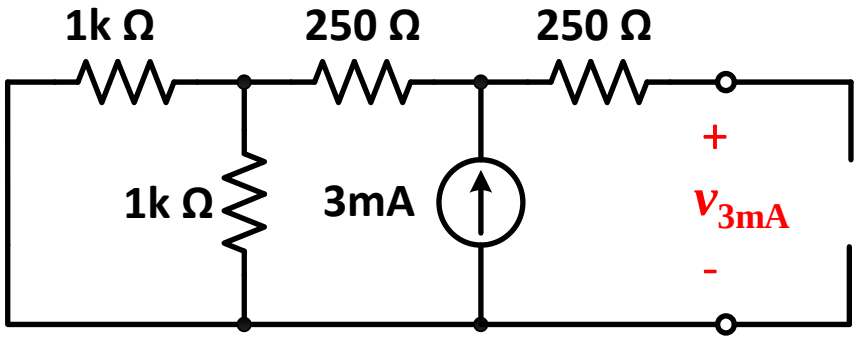
Define here as Internal Circuit

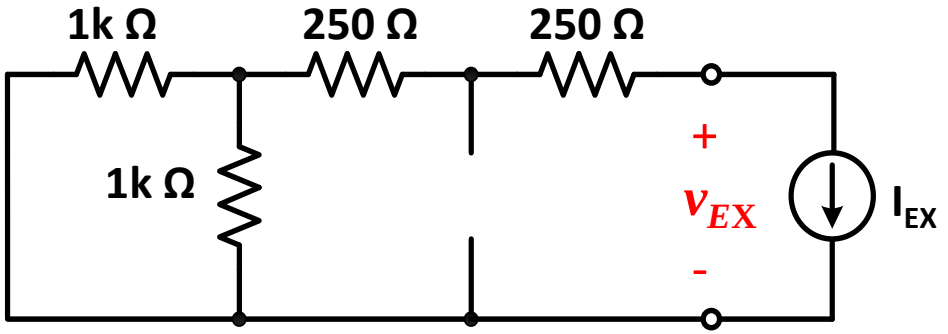
Define here as External Circuit

- A linear circuit with V&I sources and resistances (such as internal circuit above) can be replaced at two terminals by Thevenin equivalent circuit.


1k Ω
250 Ω
250 Ω
4V
1k Ω
3mA
+
v
-
I_EX

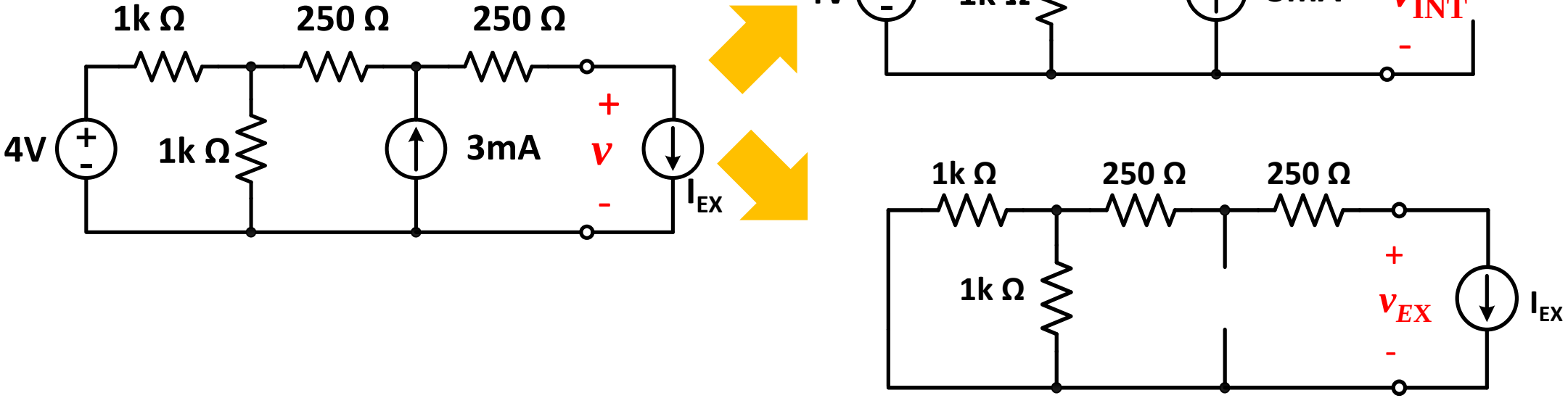

1k Ω
250 Ω
250 Ω
4V
1k Ω
+
v_4V
-


1k Ω
250 Ω
250 Ω
1k Ω
3mA
+
v_3mA
-


1k Ω
250 Ω
250 Ω
1k Ω
+
v_EX
-
I_EX

Internal & External Portion on Output

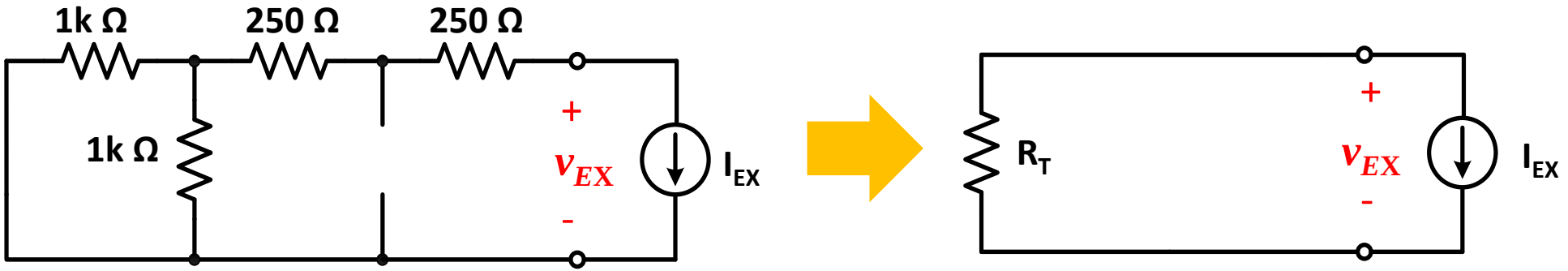
- V_{INT} : Open circuit voltage for target circuit ➔ V_{OC}
- V_{EX} : Voltage drop by external circuits



V_{EX}

- When R_T is defined as the equivalent resistance of the target circuit with zeroing all independent V& I sources.

$$V_{EX} = - I_{EX} \times R_T$$

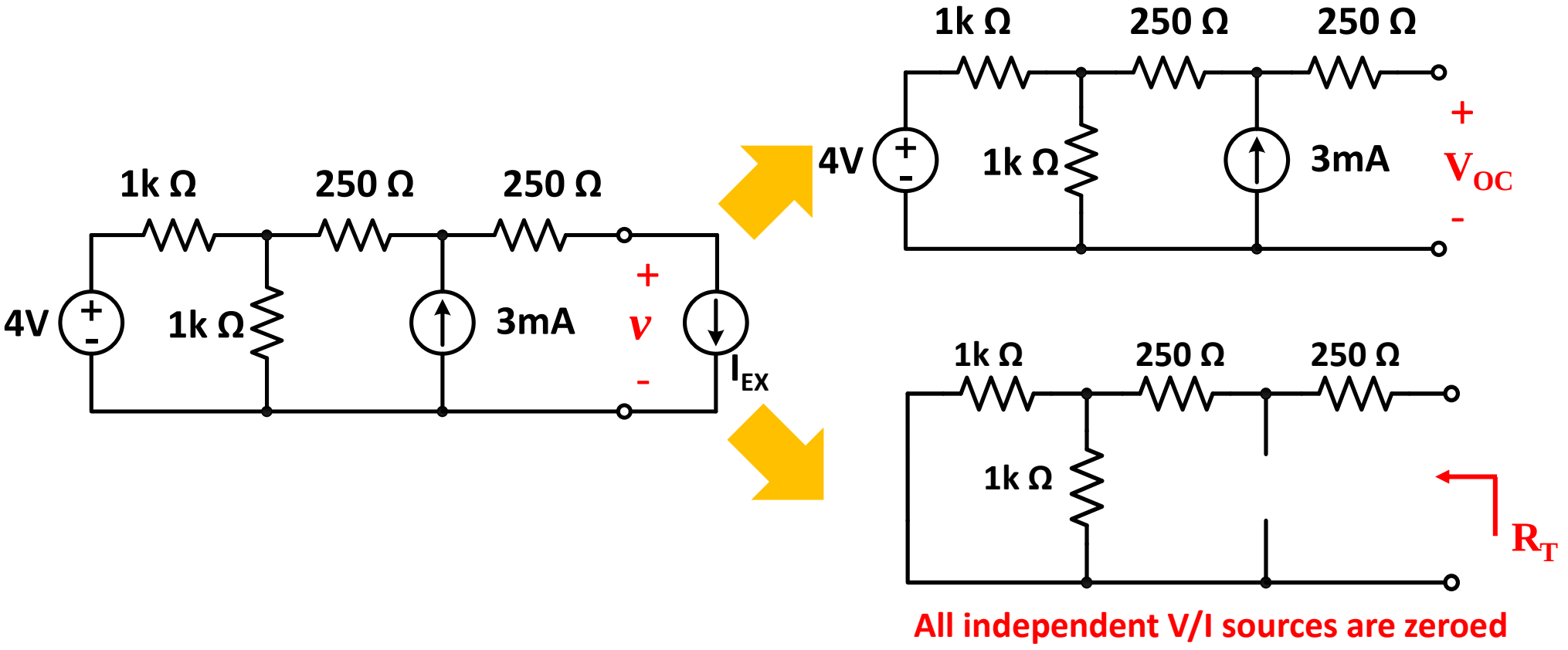


Thevenin Equivalent Circuit

- Output voltage is determined by

$$V = V_{INT} + V_{EX} = V_{OC} - I_{EX} \times R_T$$

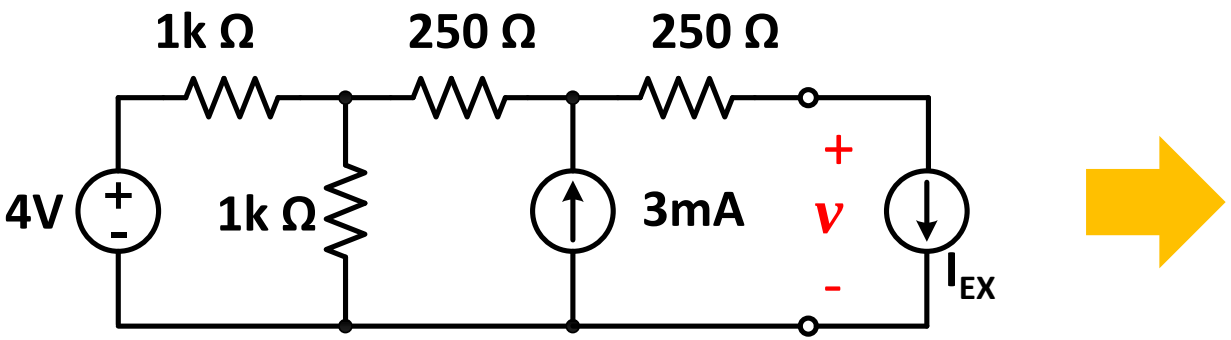
- where V_{OC} and R_T are determined as shown below.



Thevenin Equivalent Circuit

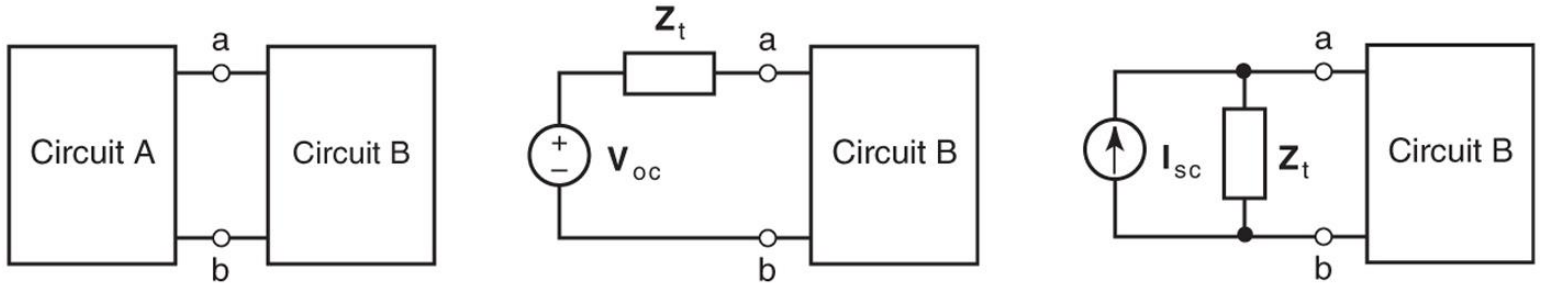
- See the expression! Do you see something?

$$V = V_{OC} - I_{EX} \times R_T$$



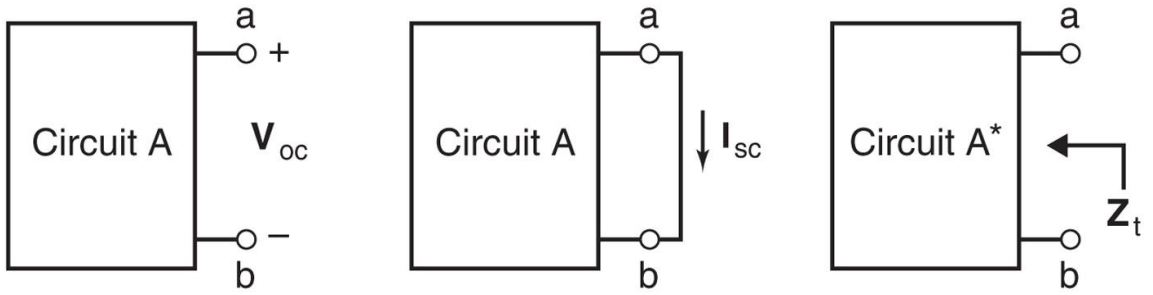
Thevenin & Norton Equivalent Circuits with Impedance

- Any linear circuit can be replaced by Thevenin or Norton equivalent circuits:



Thevenin equivalent **Norton equivalent**

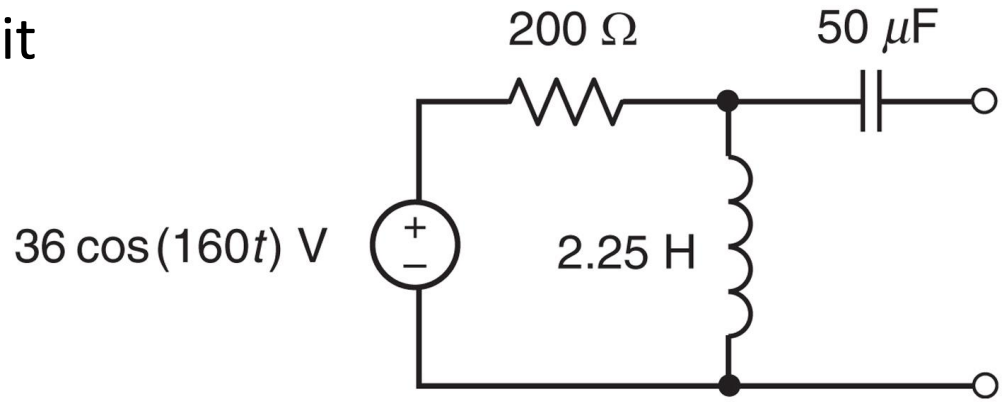
- where Open circuit voltage V_{oc}, short circuit current I_sc, and Thevenin impedance Z_t can be obtained by



- V_{oc}, I_{sc}, and Z_t are related by the equation $\mathbf{V}_{oc} = \mathbf{Z}_t \mathbf{I}_{sc}$

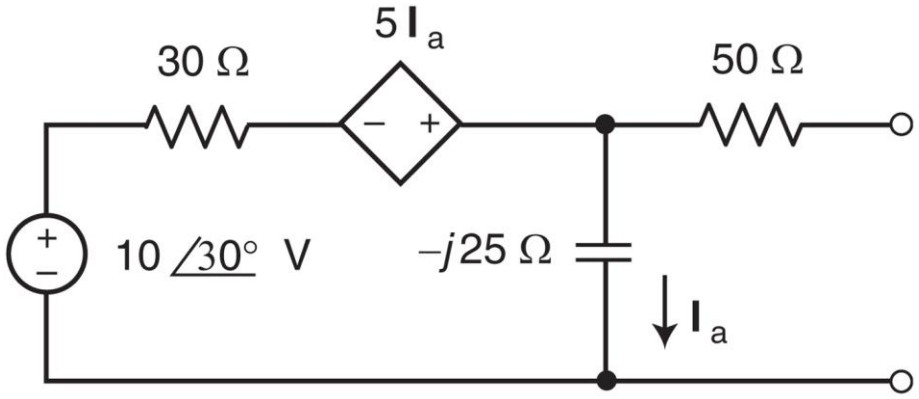
Example 10.7-1

- Find the Thevenin equivalent circuit



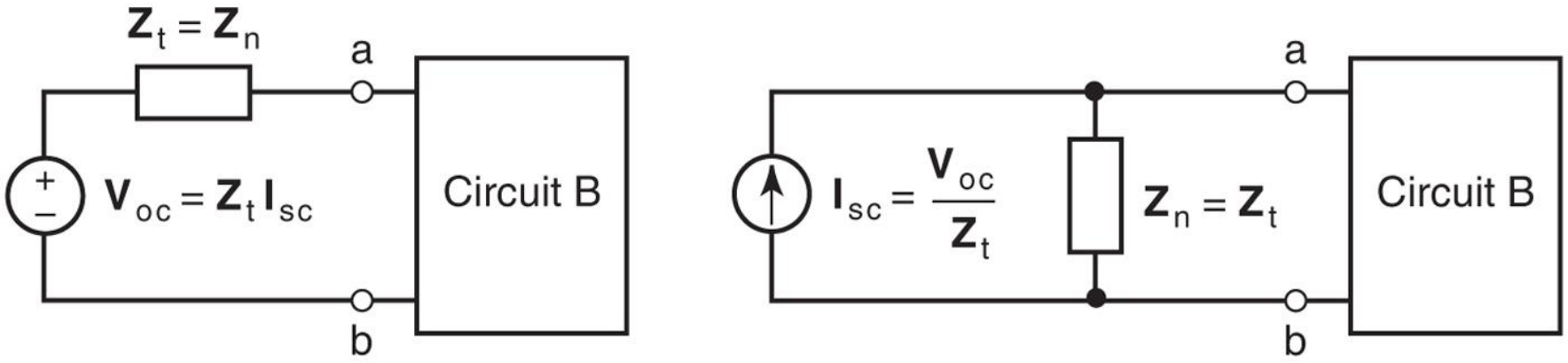
Example 10.7-2

- Find the Norton equivalent circuit



Source Transformation

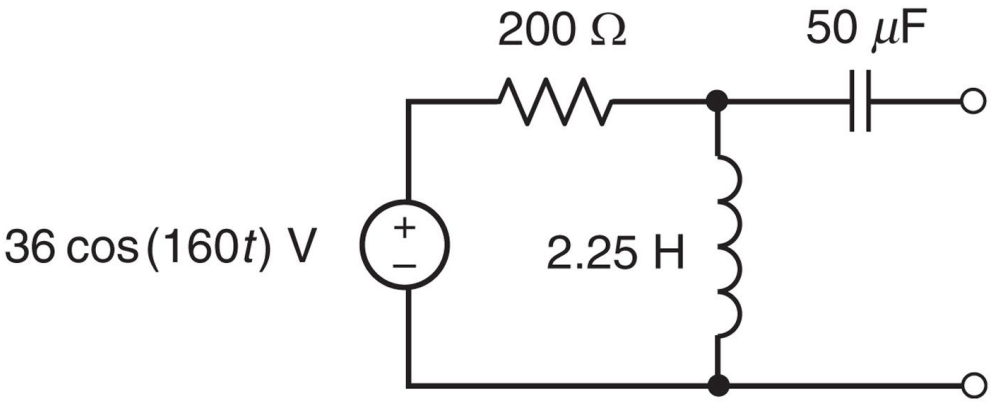
- Two below are equivalent to each other.



Series of V & Z ⟺ **Parallel of I & Z**

Example 10.7-3

- Use source transformation to find Thevenin equivalent circuit



Superposition

- So far, all of the inputs are sinusoidal with the same frequency.
- What if all of the inputs are sinusoidal but their frequency differ?

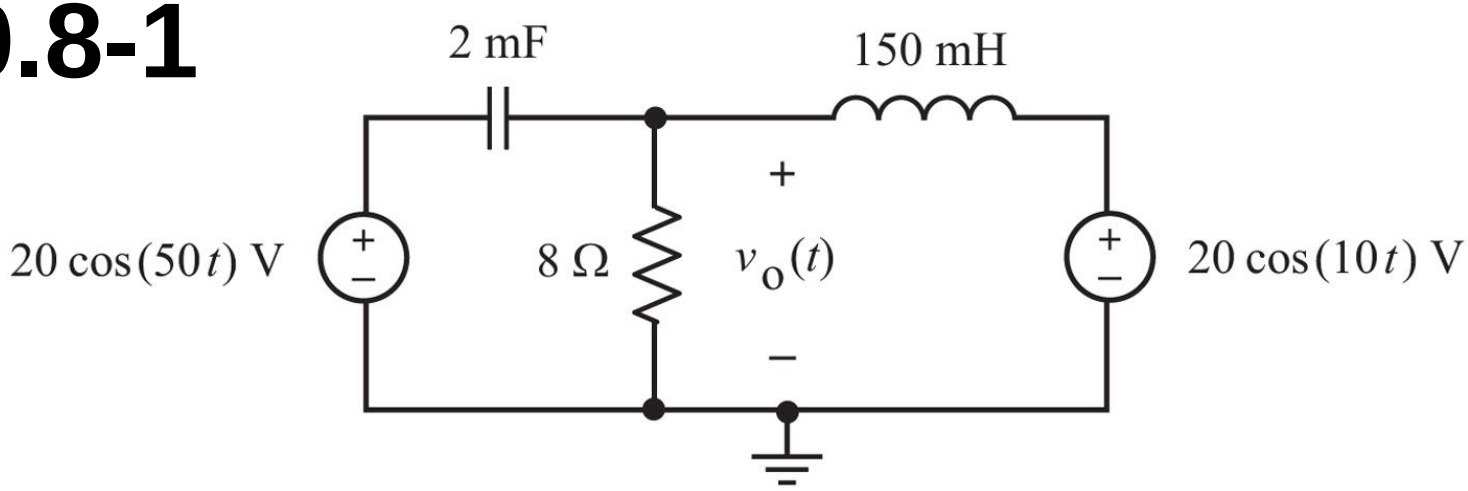
➔ Not an ac circuit at the steady state, and the output is not sinusoidal.

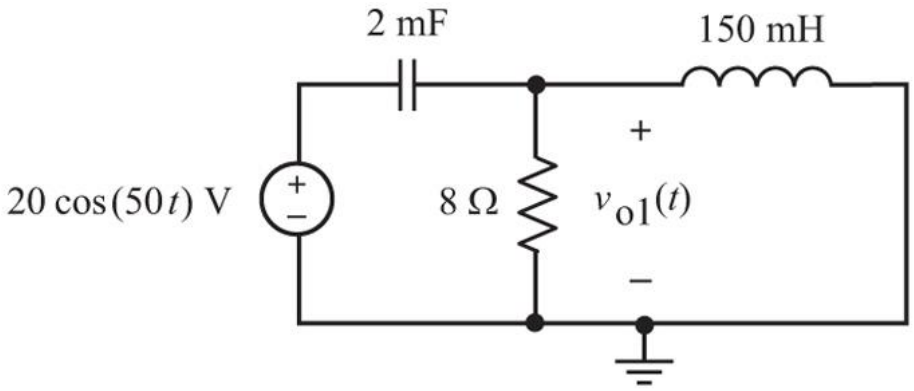
- Can we analyze the circuit using phasors and impedances?

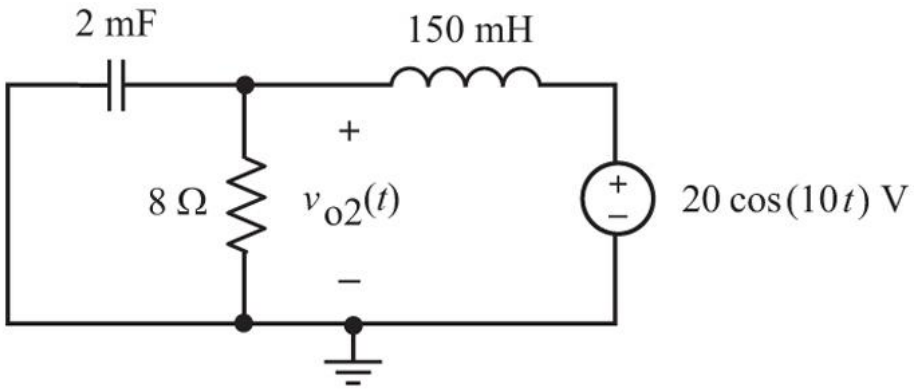
➔ With Superposition, yes!

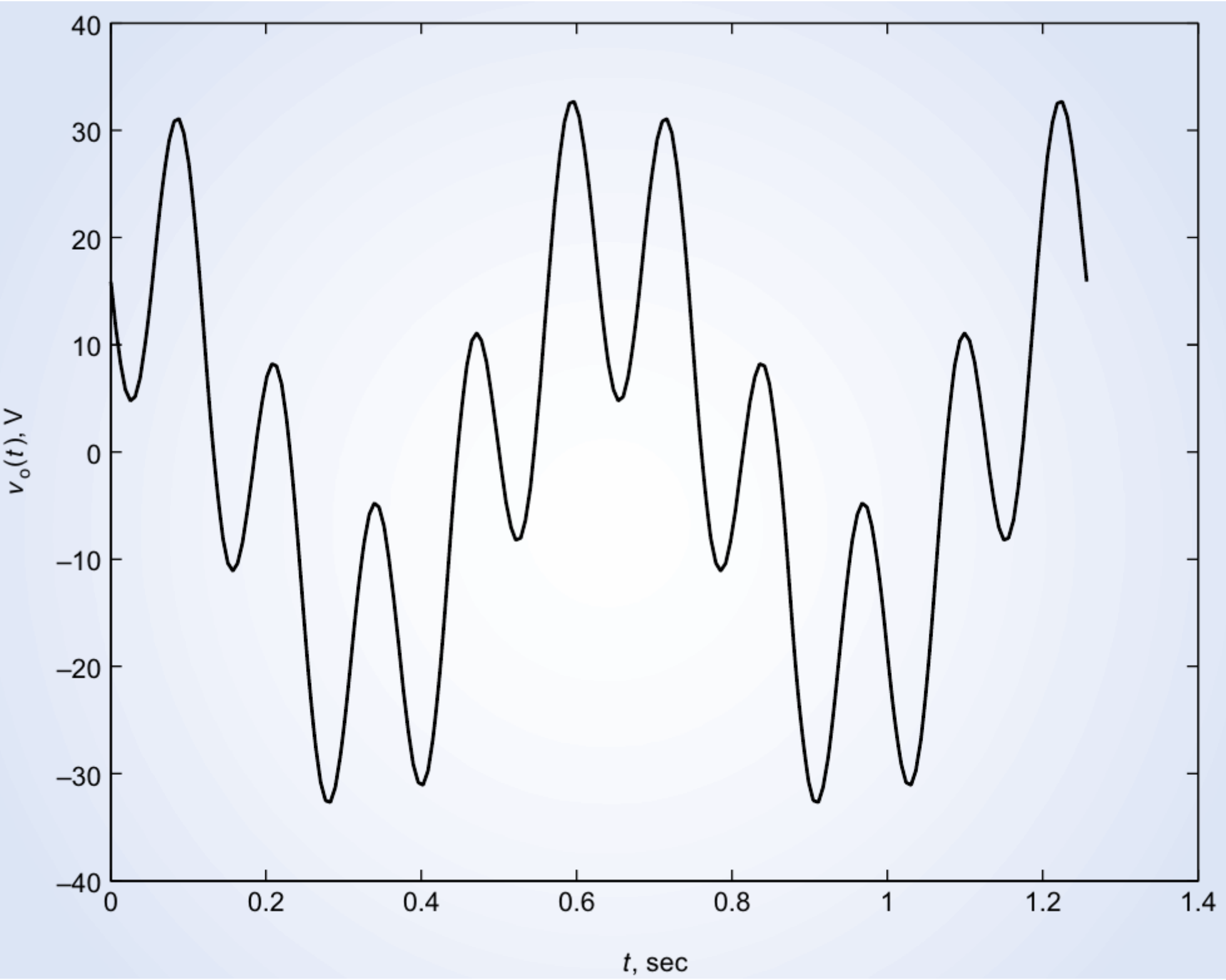
Example 10.8-1

- Find $v_o(t)$.








40
30
20
10
0
–10
–20
–30
–40
$v_o(t)$, V
0
0.2
0.4
0.6
0.8
1
1.2
1.4
t, sec