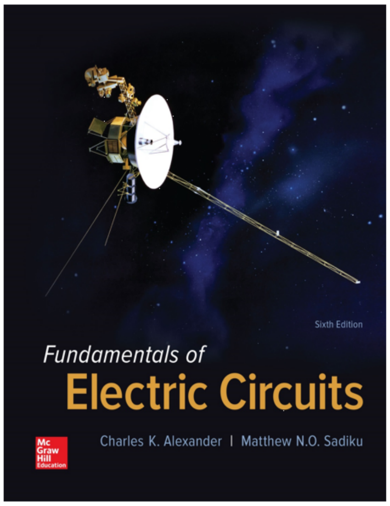


Chapter 10 - Sinusoidal Steady-State Analysis

- **This chapter applies the circuit analysis introduced in the DC circuit analysis for AC circuit analysis.**
- **Nodal and mesh analysis are discussed.**
- **Superposition and source transformation for AC circuits are also covered.**
- **Applications in op-amps ~~and oscillators~~ are reviewed.**

Ch 10, p1

10.1 Introduction

There are usually three steps to analyzing an AC circuit. These are based on the fact that frequency domain analysis is simpler since it can make use of the nodal and mesh techniques developed for DC.

1. Transform the circuit to the phasor or frequency domain,
2. complete the analysis using the usual circuit techniques (node analysis, mesh analysis, superpostion, etc.), then
3. transform the phasor result back to the time domain.

Ch 10, p2

10.2 Nodal Analysis

Nodal analysis is based on Kirchhoff's current law, and it is possible to use KCL to analyze a circuit in frequency domain.

The first step is to convert a time domain circuit to frequency domain by calculating the impedances of the circuit elements at the operating frequency.

Note that AC sources appear as DC sources with their values expressed as their amplitude.

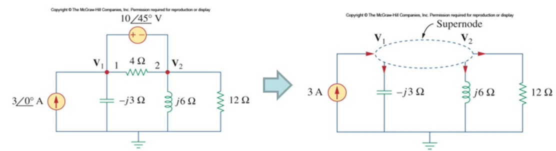
Impedances will be expressed as complex numbers.

Sources will have amplitude and phase noted.

At this point, KCL analysis can proceed as normal.

It is important to bear in mind that complex values will be calculated, but all other treatments are the same.

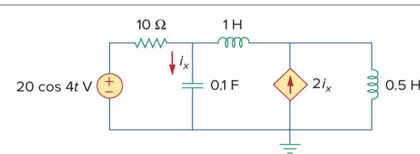
The equivalency of the frequency domain treatment compared to the DC circuit analysis includes the use of supernodes.



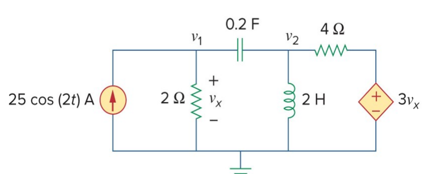
The final voltages and currents calculated are the real component of the derived values.

Example and Practice Problems

E10.1 Find i_x in the circuit shown using nodal analysis.

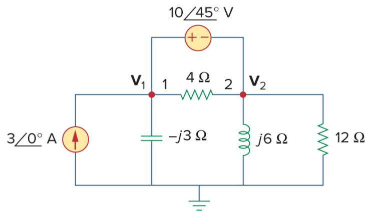


P10.1 Use nodal analysis to v_1 and v_2 in the circuit shown.

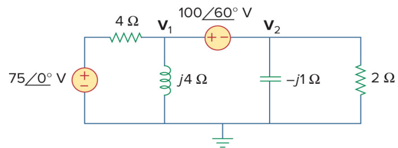


Example and Practice Problems (Cont.)

E10.2 Find $\mathbf{V}_1$ and $\mathbf{V}_2$ in the circuit shown.



P10.2 Find $\mathbf{V}_1$ and $\mathbf{V}_2$ in this circuit:

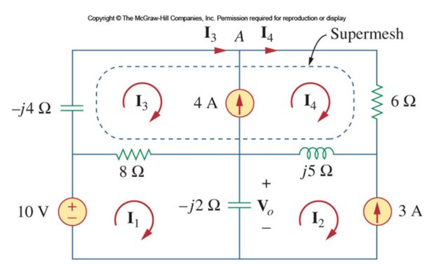


10.3 Mesh Analysis

Just as in KCL, the KVL analysis also applies to phasor and frequency domain circuits.

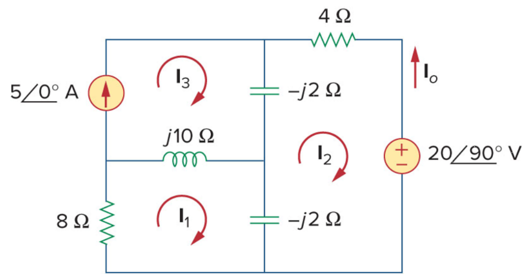
The same basic approach applies -- convert to frequency domain first, then apply KVL as usual.

The equivalency of the two domains means that supermesh analysis is also valid.

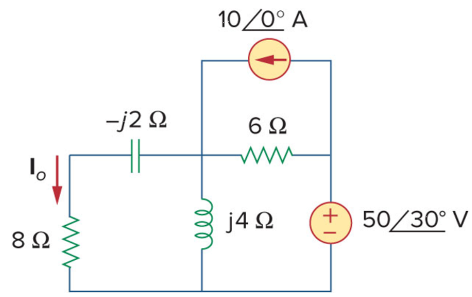


Example and Practice Problems

E10.3 Find $\mathbf{I}_0$ in the circuit shown:

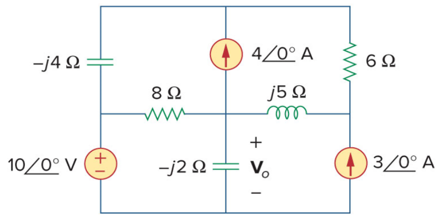


P10.3 Find $\mathbf{I}_0$ in the circuit shown:

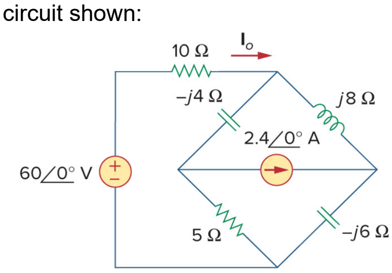


Example and Practice Problems (Cont.)

E10.4 Find $\mathbf{V}_0$ in the circuit shown:



P10.4 Find $\mathbf{I}_0$ in the circuit shown:



10.4 Superposition Theorem

Since AC circuits are linear, it is also possible to apply the principle of superposition. This becomes particularly important if the circuit has sources operating at different frequencies.

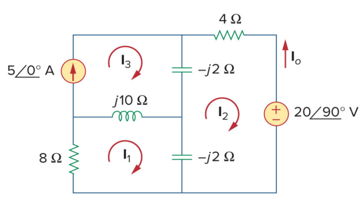
The complication is that each source must have its own frequency domain equivalent circuit.

The reason for this is that each element has a different impedance at different frequencies.

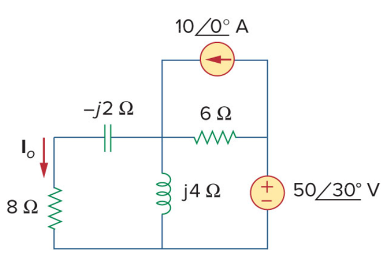
Also, the resulting voltages and current must be converted back to time domain before being added because there is an exponential factor ($e^{j\omega t}$) implicit in sinusoidal analysis.

Example and Practice Problems

E10.5 Use superposition to find $\mathbf{I}_0$ in this circuit.

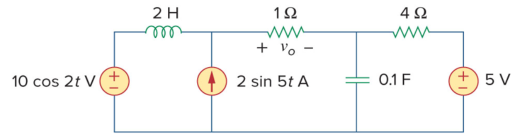


P10.5 Use superposition to find $\mathbf{I}_0$ in the circuit shown below.



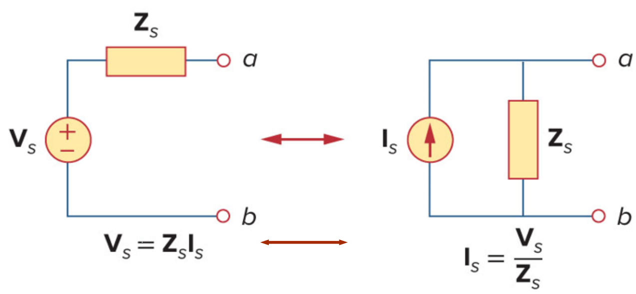
Example and Practice Problems (Cont.)

E10.6 Find v_o in this circuit using superposition.



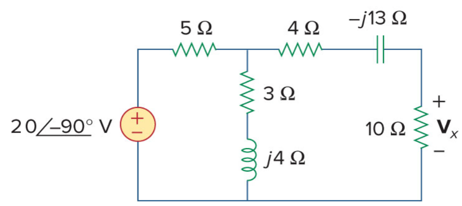
10.5 Source Transformation

Source transformation in the frequency domain involves transforming a voltage source in series with an impedance to a current source in parallel with an impedance, or vice versa.

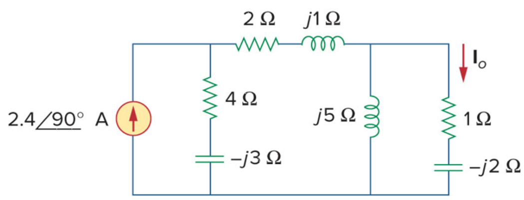


Example and Practice Problems

E10.7 Use source transformation to find $\mathbf{V}_x$.



P10.7 Use source transformation to find $\mathbf{I}_0$



10.6 Thevenin and Norton Equivalent Circuits

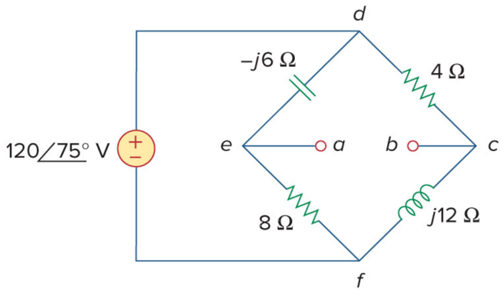
Both Thevenin's and Norton's theorems are applied to AC circuits the same way as DC. The only difference is the fact that the calculated values will be complex.

Keep in mind that: $\mathbf{V}_T = \mathbf{Z}_N\mathbf{I}_N$ and $\mathbf{Z}_{Th} = \mathbf{Z}_N$ where: $\mathbf{V}_{Th}$ is the open=circuit voltage

$\mathbf{I}_N$ is the short-circuit current

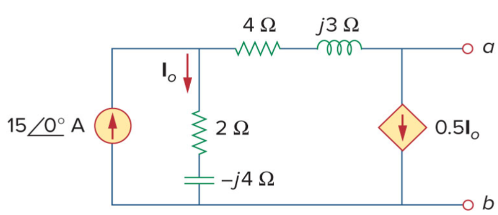
Example and Practice Problems

E10.8 Find the Thevenin equivalent at terminals a-b of the circuit shown below.



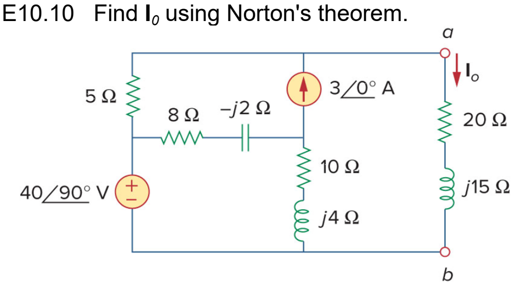
Example and Practice Problems (Cont.)

E10.9 Find the Thevenin equivalent of the circuit shown below.



Example and Practice Problems (Cont.)

E10.10 Find $\mathbf{I}_o$ using Norton's theorem.



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10.7 Op Amp AC Circuits

As long as the op amp is working in the linear range, frequency domain analysis can proceed just as it does for other circuits.

It is important to keep in mind the two qualities of an ideal op amp:

- no current enters ether input terminals.
- the voltage across its input terminals is zero with negative feedback.

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Example and Practice Problems

E10.11 Find $v_o(t)$ for the circuit shown if $v_s = 3 \cos 1000t$ V.