Chapter 18

AC Series-Parallel Circuits

AC Circuits

- Rules and laws developed for dc circuits apply equally well for ac circuits
- Analysis of ac circuits requires vector algebra and use of complex numbers
- Voltages and currents in phasor form
  - Expressed as RMS (or effective) values

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Ohm's Law

- Voltage and current of a resistor will be in phase
- Impedance of a resistor is: $\mathbf{Z}_R = R\angle 0°$

$$I = \frac{V\angle\theta}{R\angle 0°} = I\angle\theta$$

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Ohm's Law

- Voltage across an inductor leads the current by 90° (ELI the ICE man)

$$\mathbf{Z}_L = X_L\angle 90°$$

$$\mathbf{I} = \frac{V\angle\theta}{X_L\angle 90°}$$

$$\mathbf{I} = I\angle(\theta - 90°)$$

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Ohm's Law

- Current through a capacitor leads the voltage by 90° (ELI the ICE man)

$$\mathbf{Z}_C = X_C \angle -90°$$

$$\mathbf{I} = \frac{V \angle \theta}{X_C \angle -90°}$$

$$\mathbf{I} = I \angle (\theta + 90°)$$

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AC Series Circuits

- Current everywhere in a series circuit is the same
- Impedance used to collectively determine how resistance, capacitance, and inductance impede current in a circuit

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AC Series Circuits

- Total impedance in a circuit is found by adding all individual impedances vectorially

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AC Series Circuits

- Impedance vectors will appear in either the first or the fourth quadrants because the resistance vector is always positive
- When impedance vector appears in first quadrant, the circuit is inductive

AC Series Circuits

- If impedance vector appears in fourth quadrant
  - Circuit is capacitive

Voltage Divider Rule

- Voltage divider rule works the same as with dc circuits
- From Ohm's law:

$$\mathbf{I}_x = \mathbf{I}_T$$

$$\frac{\mathbf{V}_x}{\mathbf{Z}_x} = \frac{\mathbf{V}_T}{\mathbf{Z}_T}$$

$$\mathbf{V}_x = \frac{\mathbf{Z}_x}{\mathbf{Z}_T}\mathbf{V}_T$$

Kirchhoff's Voltage Law

- KVL is same as in dc circuits
- Phasor sum of voltage drops and rises around a closed loop is equal to zero

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Kirchhoff's Voltage Law

- Voltages
  - May be added in phasor form or in rectangular form
- If using rectangular form
  - Add real parts together
  - Then add imaginary parts together

AC Parallel Circuits

- Conductance, *G*
  - Reciprocal of the resistance
- Susceptance, *B*
  - Reciprocal of the reactance

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AC Parallel Circuits

- Admittance, Y
  - Reciprocal of the impedance
- Units for all of these are siemens (S)

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AC Parallel Circuits

- Impedances in parallel add together like resistors in parallel
- These impedances must be added vectorially

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AC Parallel Circuits

- Whenever a capacitor and an inductor having equal reactances are placed in parallel
  - Equivalent circuit of the two components is an open circuit

Kirchhoff's Current Law

- KCL is same as in dc circuits
- Summation of current phasors entering and leaving a node
  - Equal to zero

Kirchhoff's Current Law

- Currents must be added vectorially
- Currents entering are positive
- Currents leaving are negative

Current Divider Rule

- In a parallel circuit
  - Voltages across all branches are equal

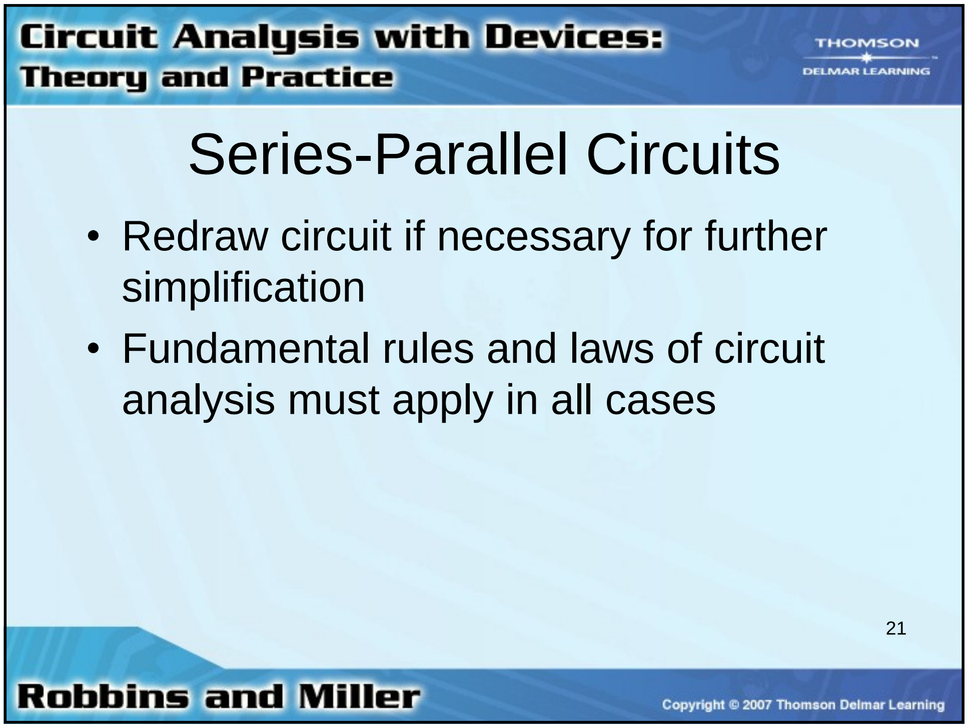
$$\mathbf{V}_x = \mathbf{V}_T$$

$$\mathbf{I}_x \mathbf{Z}_x = \mathbf{I}_T \mathbf{Z}_T$$

$$\mathbf{I}_x = \frac{\mathbf{Z}_T}{\mathbf{Z}_x} \mathbf{I}_T$$

Series-Parallel Circuits

- Label all impedances with magnitude and the associated angle
- Analysis is simplified by starting with easily recognized combinations



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Series-Parallel Circuits
• Redraw circuit if necessary for further simplification
• Fundamental rules and laws of circuit analysis must apply in all cases
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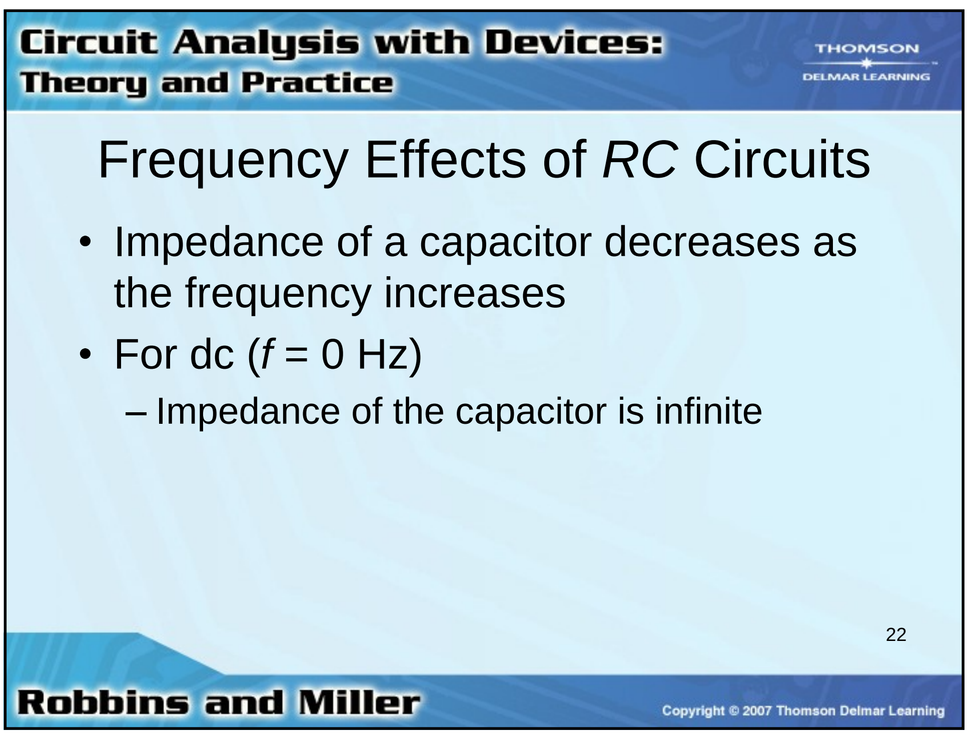

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Frequency Effects of RC Circuits
• Impedance of a capacitor decreases as the frequency increases
• For dc (f = 0 Hz)
– Impedance of the capacitor is infinite
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Frequency Effects of *RC* Circuits

- For a series *RC* circuit
  - Total impedance approaches *R* as the frequency increases
- For a parallel *RC* circuit
  - As frequency increases, impedance goes from *R* to a smaller value

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Frequency Effects of *RL* Circuits

- Impedance of an inductor increases as frequency increases
- At dc (f = 0 Hz)
  - Inductor looks like a short
  - At high frequencies, it looks like an open

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Frequency Effects of *RL* Circuits

- In a series *RL* circuit
  - Impedance increases from *R* to a larger value
- In a parallel *RL* circuit
  - Impedance increases from a small value to *R*

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Corner Frequency

- Corner frequency is a break point on the frequency response graph
- For a capacitive circuit
  - $\omega_C = 1/RC = 1/\tau$
- For an inductive circuit
  - $\omega_C = R/L = 1/\tau$

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RLC Circuits

- In a circuit with *R*, *L*, and *C* components combined in series-parallel combinations
  - Impedance may rise or fall across a range of frequencies
- In a series branch
  - Impedance of inductor may equal the capacitor

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RLC Circuits

- Impedances would cancel
  - Leaving impedance of resistor as the only impedance
- Condition is referred to as resonance

Applications

- AC circuits may be simplified as a series circuit having resistance and a reactance
- AC circuit
  - May be represented as an equivalent parallel circuit with a single resistor and a single reactance

Applications

- Any equivalent circuit will be valid only at the given frequency of operation