Inductor-Capacitor (LC) Circuits

Session 3d for Basic Electricity
A Fairfield University E-Course
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Module: Basic Electronics
(AC Circuits and Impedance: two parts)

- Text: “Electricity One-Seven,” Harry Mileaf, Prentice-Hall, 1996, ISBN 0-13-889585-6 (Covers much more material than this section)
- References:
  - “Digital Mini Test: Principles of Electricity Lessons One and Two,” SNET Home Study Coordinator, (203) 771-5400
  - Electronics Tutorial (Thanks to Alex Pounds)
  - Electronics Tutorial (Thanks to Mark Sokos)
  - Basic Math Tutorial (Thanks to George Mason University)
  - Vector Math Tutorial (Thanks to California Polytec at atom.physics.calpoly.edu)
- Alternating Current and Impedance
  - 5 on-line sessions plus one lab
- Resonance and Filters
  - 5 on-line sessions plus one lab

Section 3: AC, Inductors and Capacitors

- 0BJECTIVES: This section introduces AC voltage / current and their effects on circuit components (resistors, inductors, transformers and capacitors). The concept of impedance and the use of the vector analogy for computations is also introduced.

Section 3 Schedule:

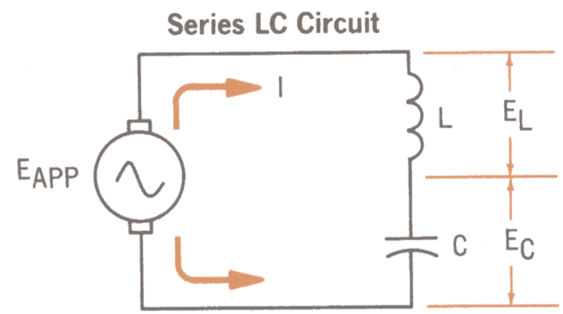
Session 3a	– 05/13	Sine Waves, Magnitude, Phase and Vectors (again)	Text 4.1 – 4.24
3a continued	– 05/20	Complete 3a	
Session 3b	– 05/22	R-L Circuits (no class on 05/27)	Text 4.25 – 4.54
3b continued	– 05/29	Complete 3b	
Session 3c	– 06/03	R-C Circuits	Text 4.55 – 4.76
Session 3d (lab - 06/08, Sat.)	**– 06/05**	**Series LC Circuits**	**Text 4.77 – 4.88**
Session 3e (Quiz 3 due 06/16)	– 06/10	Series RLC Circuits	Text 4.89 – 4.113
Session 3f	– 06/17	Review (Discuss Quiz 3)	

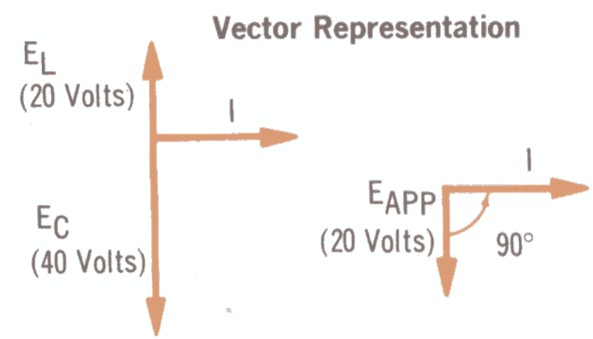
Session 3c (R-C) Review

- Capacitive reactance $X_C = 1/2\pi fC$ at -90º (Note: $X_L = 2\pi fL$ at -90º)
- Impedances (R, $X_{L,}$ X_C) in series add as vectors (Phasors).
- Impedances in parallel add as inverses
  - Adding Vectors
    - Separately add their horizontal and vertical components
    - Graphically: head-to-tail or parallelogram
  - Multiplying Vectors
    - Multiply their magnitudes (lengths)
    - Add their phases
  - Dividing Vectors
    - Divide their magnitudes (lengths)
    - Subtract their phases
- Ohm's and Kirchoff's laws still work with AC
- Real power is only dissipated in resistors

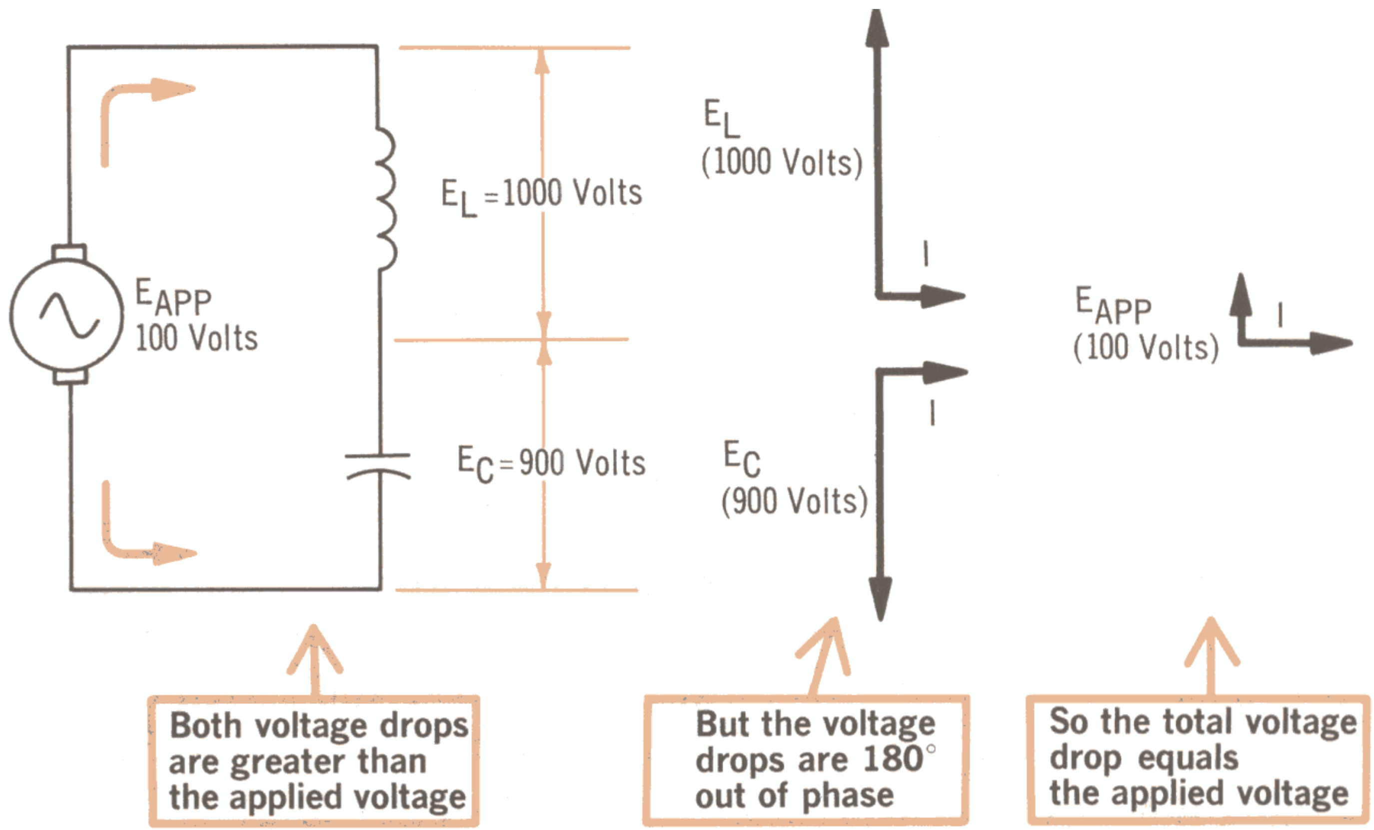
Series LC- Voltage

- AC voltages add as vectors
- Current is the same in all series components
  - the reference phase
- Inductor voltage drop (E_L) points up (leads current by 90º)
- Capacitor voltage drop (E_C) points up (lags current by 90º)
- Add E_L and E_C to get E_{APP}
  - $E_L = 20\angle 90^o$
  - $E_C = 40\angle -90^o = -40\angle 90^o$
  - $E_{APP} = -20\angle 90^o = 20\angle -90^o$ (capacitive circuit)





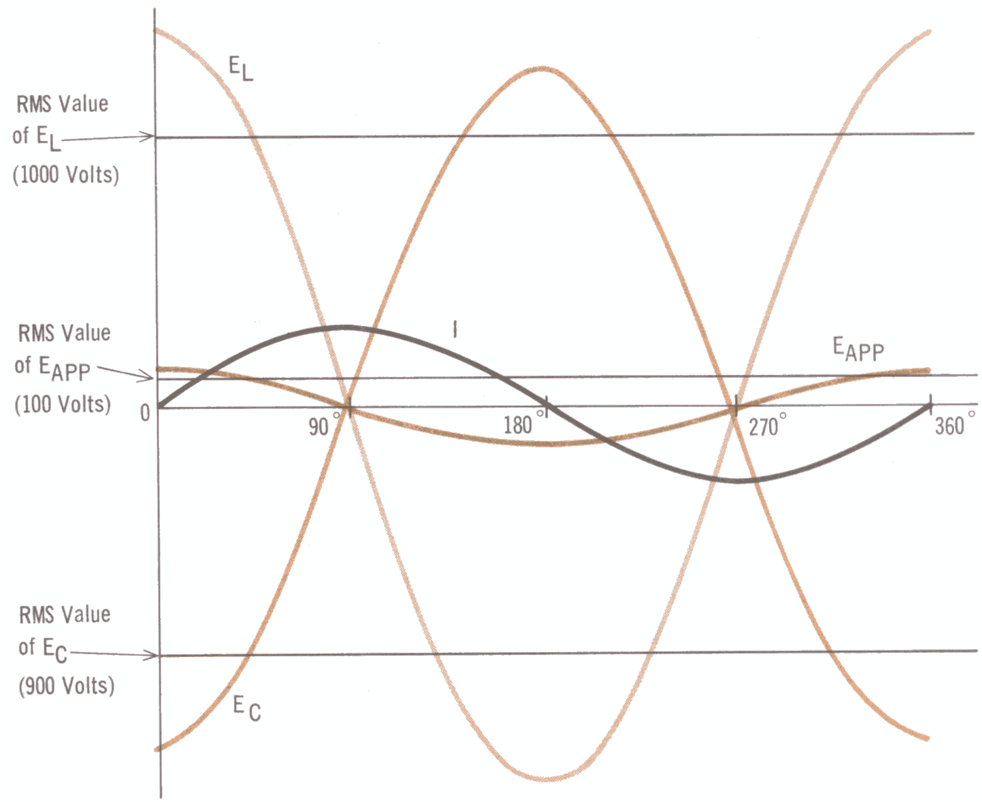
Series LC – Voltage
An Inductive Circuit



Series LC – Voltage Waveforms

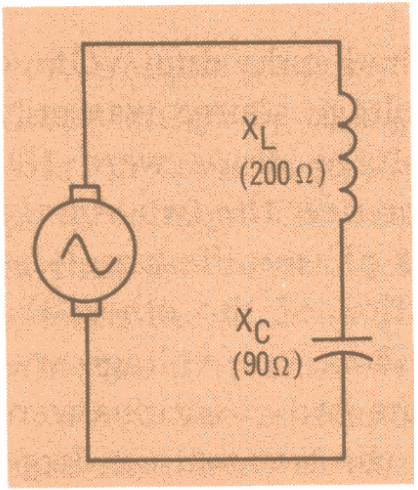
Inductive Circuit

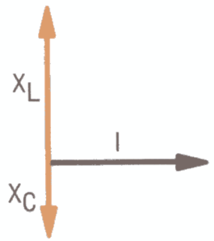
- Current (reference phase) is a sine
- E_L leads and is a cosine
- E_C lags and is a negative cosine
- They subtract to yield E_{APP} as a positive cosine (Inductive)



Series LC - Impedance

- Impedances in series add as vectors
- X_L and X_C are in opposite directions
  - Magnitudes subtract
  - $Z = 110\angle 90^{\circ}$ (Inductive)





Series LC
Inductive vs. Capacitive

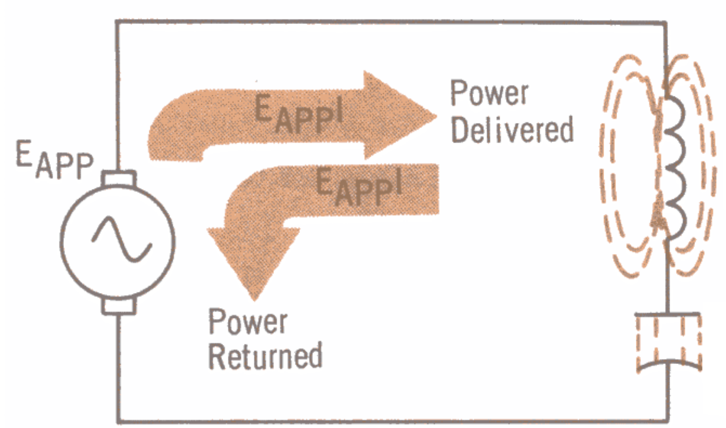
- The circuit acts capacitive when the capacitive reactance dominates

- The circuit acts inductive when the inductive reactance dominates

- "Resonance" occurs when they are equal

Series LC - Power

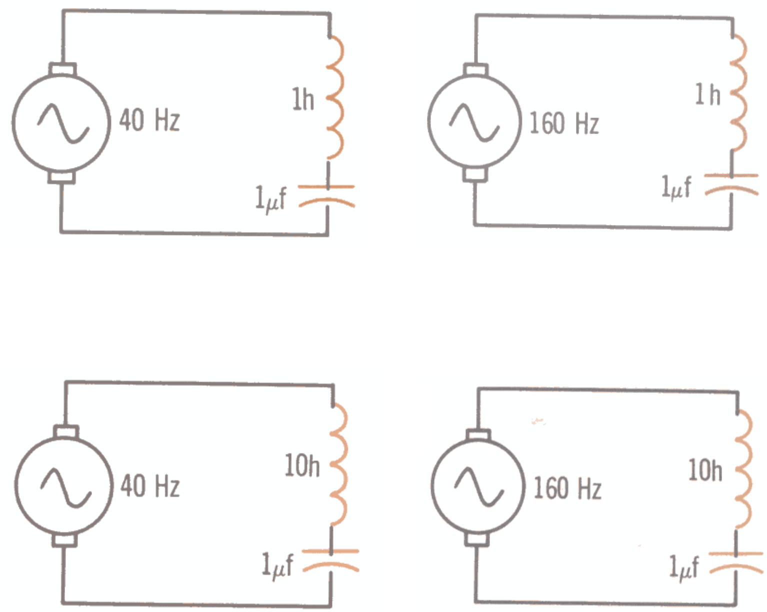
- No real power is dissipated (no resistance)
- Power is alternately stored and returned
  - Magnetic Field (Inductor)
  - Electric Field (Capacitor)



True Power in an Ideal LC Circuit is Zero

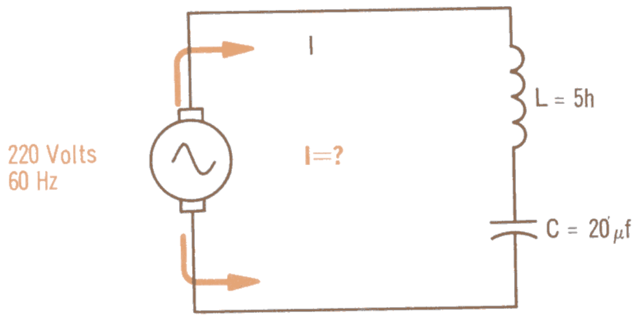
The Effect of Frequency

- Top at 40 Hz
  - $X_L = 2\pi*40*1 = 251\Omega$
  - $X_C = 1/2\pi*40*10^{-6} = -3981\Omega$
  - $Z = -3730\Omega$ (capacitive)
- Top at 160 Hz
  - $X_L = 2\pi*160*1 = 1005\Omega$
  - $X_C = 1/2\pi*160*10^{-6} = -995\Omega$
  - $Z = 10\Omega$ (inductive, near resonance)
- Bottom at 40 Hz
  - $X_L = 2\pi*40*10 = 2512\Omega$
  - $X_C = 1/2\pi*40*10^{-6} = -3981\Omega$ book error
  - $Z = -1469\Omega$ (capacitive)



Series RC Example

- $Z = 2\pi*60*5 - 1/(2\pi*60*20*10^{-6})$
  $= 1884 - 1/(7512*10^{-6})$
  $= 1884 - 1/(0.7512*10^{-2})$
  $= 1884 - 1.331*10^{2}$
  $= 1884 - 133.1 =$ **1751Ω at 90^o**



- $I = 220\angle 0 / 1751\angle 90^o$
  $= 0.1256$ Amps at -90^o (negative sine; E_{APP} is cosine)
- $E_L = 0.1256\angle -90^o * 1884\angle 90^o = 237$ volts at 0^o
- $E_C = 0.1256\angle -90^o * 133.1\angle -90^o = 17$ volts at $180^o = -17$ volts at 0^o
- Note that $E_{APP} = E_L - E_C = 220$ volts at 0^o (Kirchoff's Voltage Law)

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