Resistor-Inductor-Capacitor (RLC) Circuits

Session 3e 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 4: AC, Inductors and Capacitors

- 0BJECTIVES: This section discusses AC voltage / current and their effects on parallel circuit components (resistors, inductors, transformers and capacitors). The concept of resonance and its use to produce filters is also described.

Section 4 Schedule:

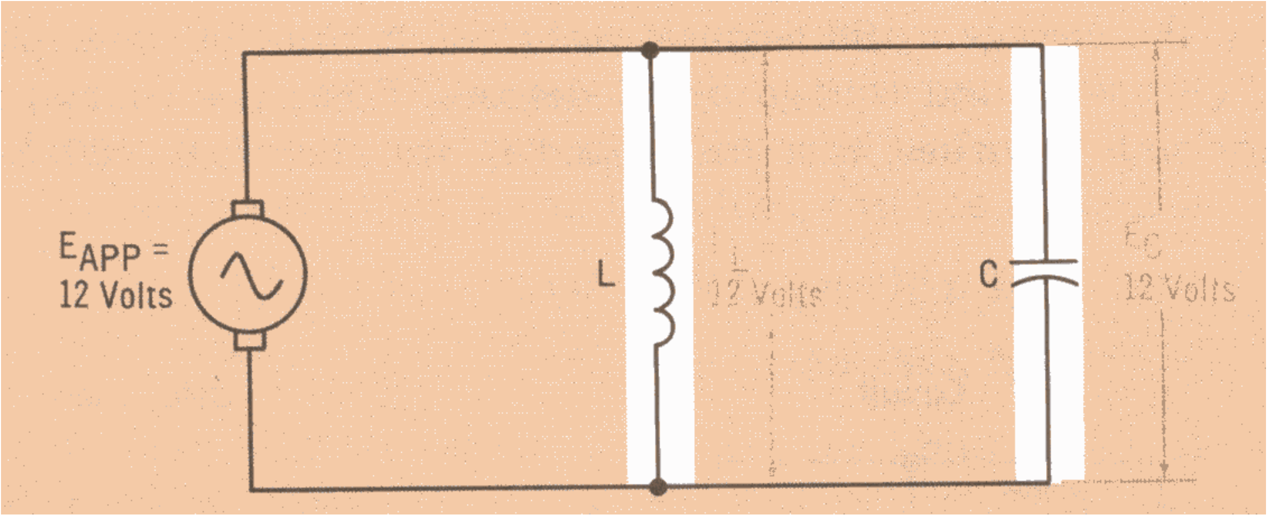
Session 4a	**– 06/24**	**Parallel L-R-C Circuits**	**Text 4.114 – 4.122**
Session 4b	– 06/26	Parallel L-R-C Circuits Cont.	Text 4.123 – 4.132
(have a nice July 4)		**(no class on 07/02 or 07/04)**	
Session 4c	– 07/08	Parallel Resonance	Text 4.133 – 4.146
Session 4d	– 07/10	Tuning and Filters	Text 4.147 – 4.151
(break for a week)			
Session 4e	– 07/22	Transformers and Impedance Matching	Text 4.152 – 4.160
(Quiz 4 due 07/28)			
(lab - 07/27, Sat.)			
Session 4f	– 07/29	Review (Discuss Quiz 4)	
	07/31	MT2 Review	
		MT2 – AC Circuits	

Session 3 (series R-L-C) Review

- Capacitive reactance $X_C = 1/2\pi fC$ at -90º
- Inductive reactance$X_L = 2\pi fL$ 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
- Inductive and capacitive reactances are both vertical and exactly 180º out of phase; They subtract!

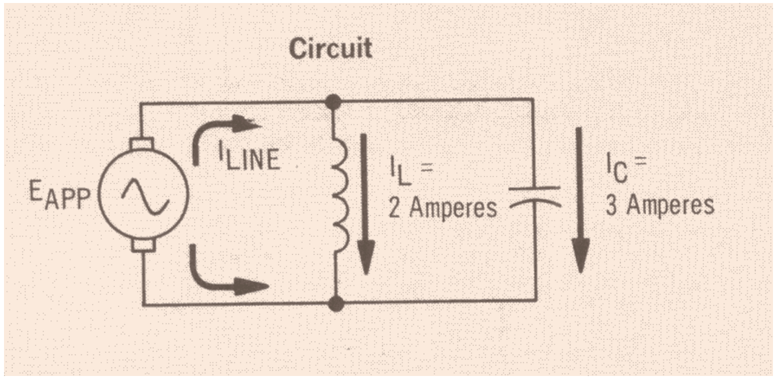
Parallel L-C Circuits

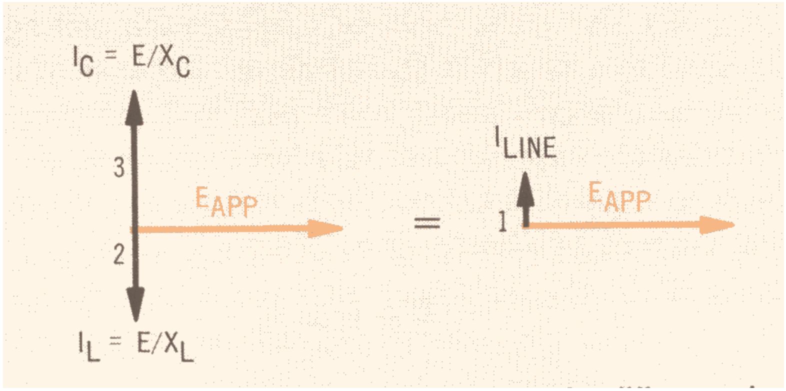
- Voltage (ref. phase) is the same across all parallel components
- Branch currents add (vectors) to produce I_{Line}
- Impedances in parallel add (vectors) as inverses



Parallel LC- Current

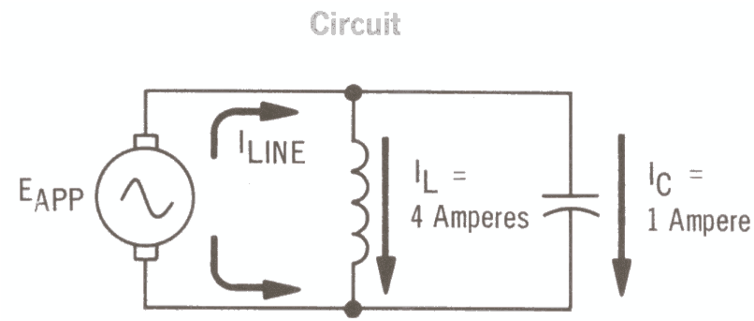
- AC currents always add as vectors
- Voltage (ref. Phase) is the same across all parallel components
- Inductor - I_L points down (Lags voltage by 90º)
- Capacitor - I_C points up (Leads voltage by 90º)
- Add I_L and I_C (they subtract) to get I_{Line}
  - $I_L = 2\angle -90^\circ$
  - $I_C = 3\angle 90^\circ = 3\angle 90^\circ$
  - $I_{Line} = (3-2)\angle 90^\circ = 1\angle 90^\circ$ (capacitive circuit)

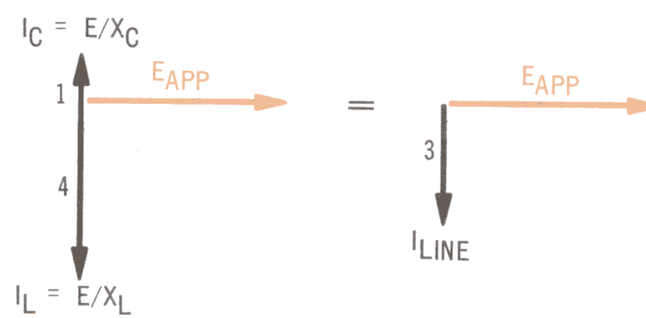




Parallel LC- Current
Again

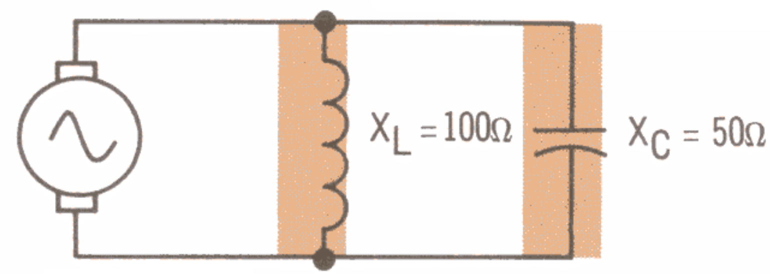
- AC currents always add as vectors
- Voltage (ref. Phase) is the same across all parallel components
- Inductor - I_L points down (Lags voltage by 90º)
- Capacitor - I_C points up (Leads voltage by 90º)
- Add I_L and I_C (they subtract) to get I_{Line}
  - $I_L = 4\angle -90^\circ$
  - $I_C = 1\angle 90^\circ = 3\angle 90^\circ$
  - $I_{Line} = (4-1)\angle -90^\circ = 1\angle 90^\circ$ (inductive circuit)

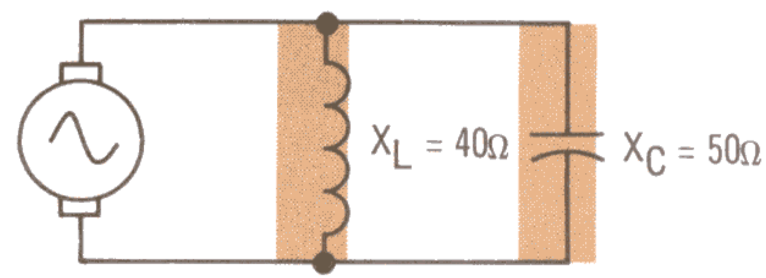




Parallel LC - Impedance

- Impedances in parallel add as inverse vectors
- X_L (up) and X_C (down) are in opposite directions
  - Magnitudes subtract
- $X_{top} = (100\text{-}50)\angle 90^o = 50\angle 90^o$ (Inductive)
- $X_{bottom} = (50\text{-}40)\angle 90^o = 10\angle\text{-}90^o$ (Capacitive)





Parallel LC: Example

- $I = E_{app} / Z$
- $X_L = 2\pi fL = 6.28*400*0.005$

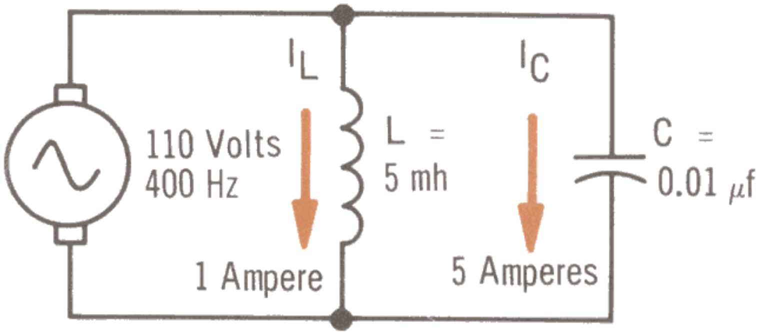
  $= 12.56\Omega\angle 90°$
- $X_C = 1/2\pi fC =$

  $= 1/6.28*400*0.01*10^{-6}$

  $= 1/2512*10^{-8}$

  $= 0.0003981*10^{8}$

  $= 39{,}810\Omega\angle -90°$



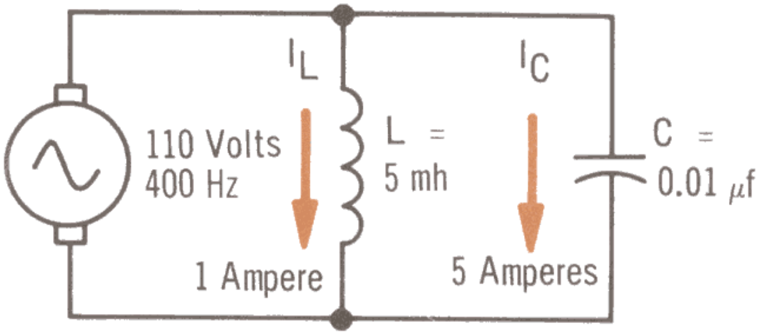
Problem 31

Note: Error in text.

The currents are wrong given the component values and frequency.

Parallel LC: Example
Currents

- $I_L = E_{app} / X_L$
  $= 110\angle 0° / 12.56\Omega\angle 90°$
  $= 8.76$ amps $\angle$-90°
- $I_C = E_{app} / X_C$
  $= 110\angle 0° / 39{,}810\Omega\angle -90°$
  $= 2.8$ milliamps $\angle 90$
- $I_{line} = I_L + I_C$ (but they subtract)
  $= 8.73$ amps $\angle$-90°
- This is an inductive circuit



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Parallel LC: Example

Impedances

$1/Z_{Total} = 1/\ X_L + 1/X_C$

$= 1\ /\ 12.56\Omega\angle 90° + 1\ /\ 39{,}810\Omega\angle\text{-}90°$

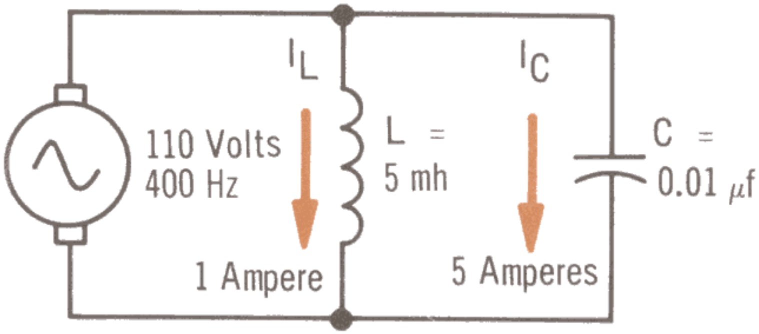
$= 0.07961\ \angle\text{-}90° + 0.0000251\Omega\angle 90°$

$= 0.07959\ \angle\text{-}90°$

$Z_{Total} = 1\ /\ 0.07959\ \angle\text{-}90°$

$= 12.57\Omega\ \angle 90°$

- This is an inductive circuit



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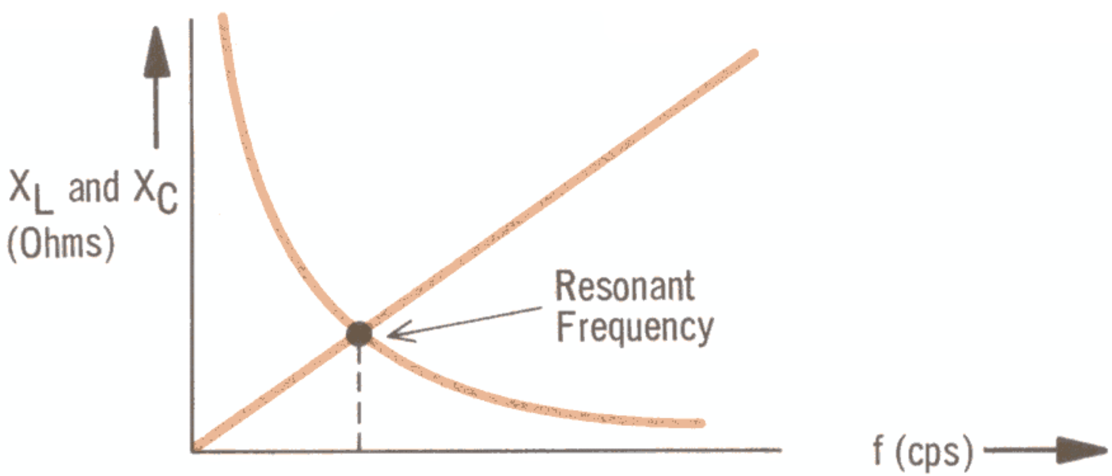
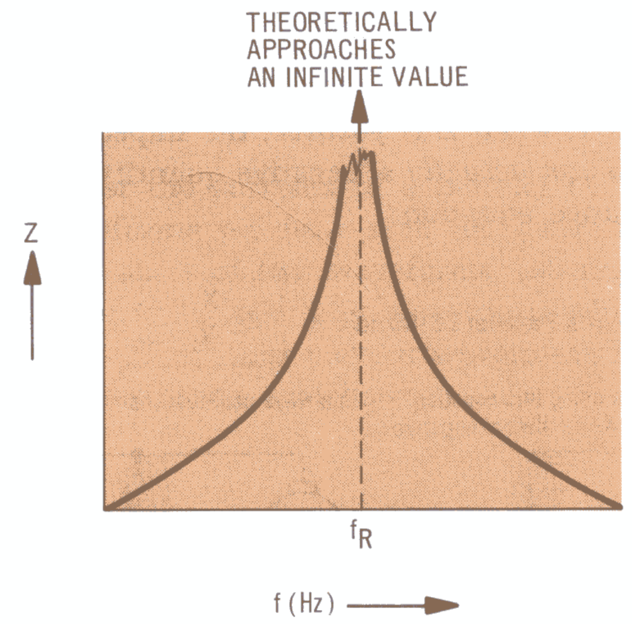
The Effect of Frequency

- $Z_L = 2\pi fL$ (rises linearly with frequency)
- $Z_C = 1/2\pi fL$ (decreases with frequency)
- Resonance is when they are equal and cancel; the impedance is then just the resistance



Parallel L-C Circuits: Frequency and Impedance

- The total reactance is always higher than either X_L or X_L since the inverses subtract.
- At some frequency (Resonance), the inverse reactances cancel and $1/Z_{total} = 0$ causing an extreme increase in total Impedance and the current approaches zero.



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