Resonant Transformers and Impedance Matching

Session 4e of 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

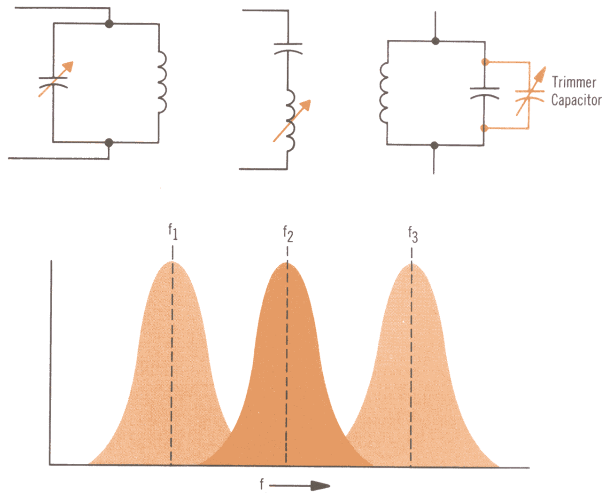
- 0BJECTIVES: This section discusses AC voltage / current and their effects on parallel circuit components (resistors, inductors, transformers and capacitors). The concept of resonance and its use to produce filters is also described.

Section 4 Schedule:

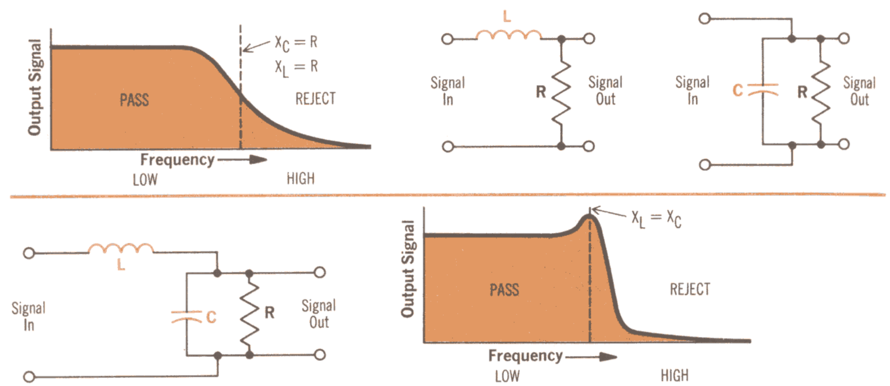
Session 4a – 07/08		Parallel L-C Circuits	Text 4.114 – 4.122
Session 4b – 07/10		Parallel R-L-C Circuits	Text 4.123 – 4.132
(break for a week)		(no class on 07/15 or 07/17)	
Session 4c – 07/22		Parallel Resonance	Text 4.133 – 4.146
Session 4d – 07/24		Tuning and Filters	Text 4.147 – 4.153
(lab - Postponed)			
Session 4e – 07/29		**Resonant Transformers and Impedance Matching**	**Text 4.154 – 4.160**
(Quiz 4 due 08/12)			
Session 9 starts – 08/05		Business Writing	
Session 4f – tbd		Review (Discuss Quiz 4)	
	tbd	MT2 Review	
	tbd	MT2 – AC Circuits	

Tuning and Filters Review

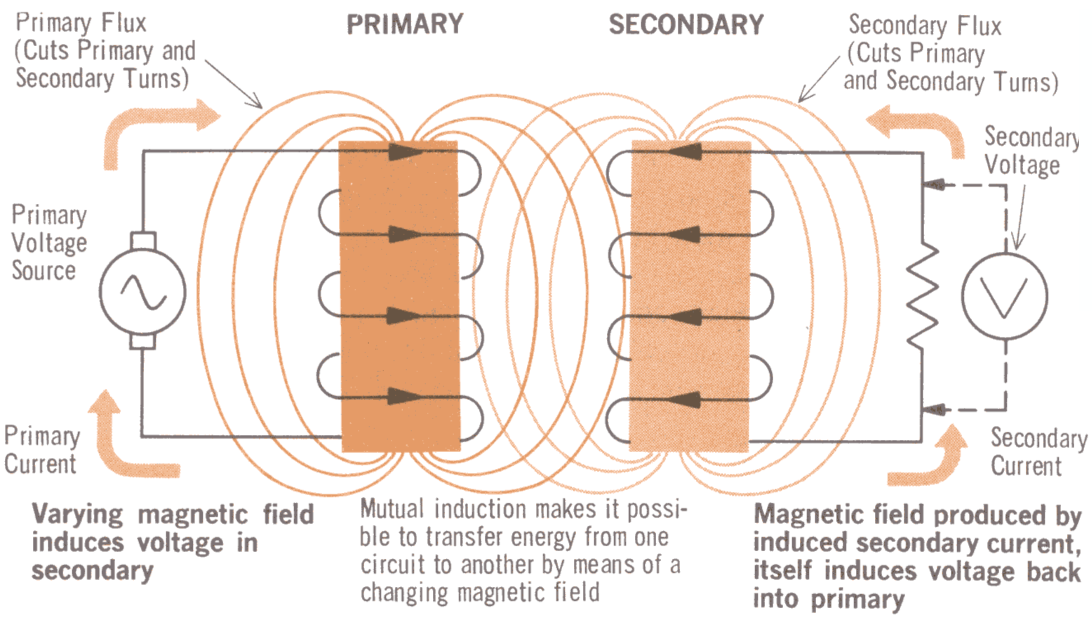
- Tuning
  - $f_r = 1/2\pi(LC)^{1/2}$
  - Increasing L or C decreases f_r
  - Decreasing L or C increases f_r
- Filters
  - Low-Pass
  - High-Pass
  - Band-Pass
  - Band-Reject
- T and π Filter circuits

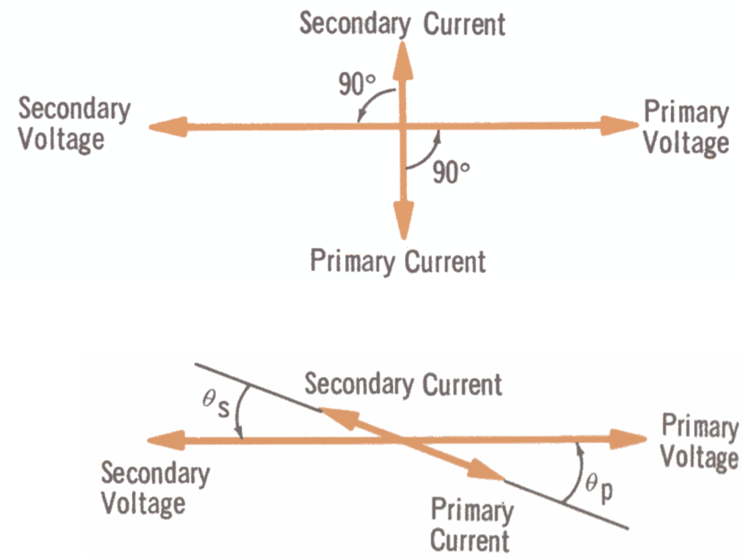


If variable capacitors or inductors are used in resonant circuits, the resonance point and bandpass frequencies can be changed to a variety of frequencies by a simple adjustment.



Transformers

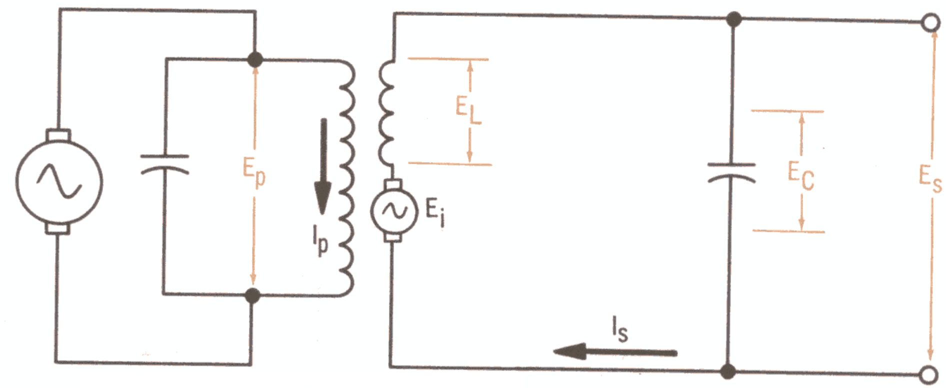




- Low Load: Inductive currents
- High Load: Phase determined by the load impedance (resistive in bottom-right figure)

Resonant Transformer

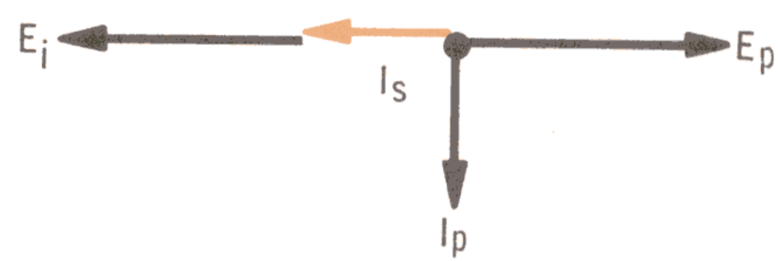
- Secondary is a **Series** resonant circuit



- E_C is the output voltage
- Primary is also a tuned circuit
- At resonance the output voltage is 90º ahead of the primary voltage

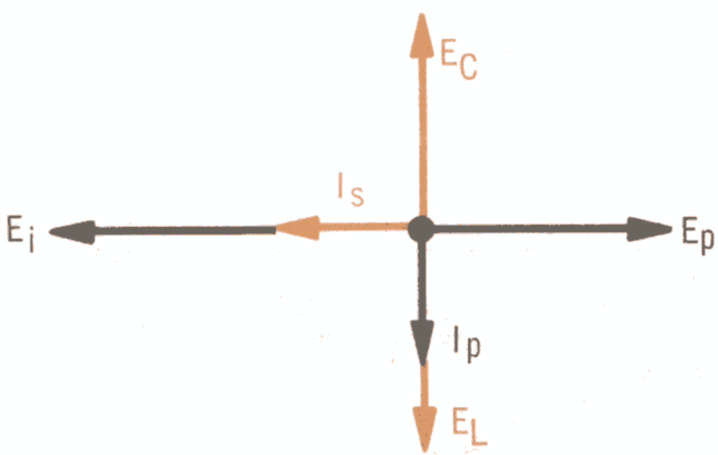
Resonant Primary

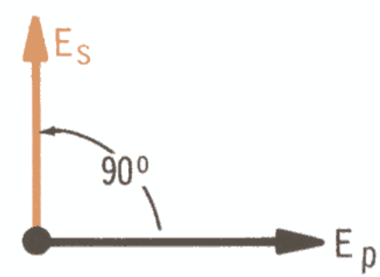
- I_P lags E_P – Inductive
- Induced secondary voltage, E_I, then 180º out of phase with E_P and is effectively is a source in series with the secondary.
- At resonance the secondary loop is resistive and I_S is in phase with E_I



Resonant Secondary

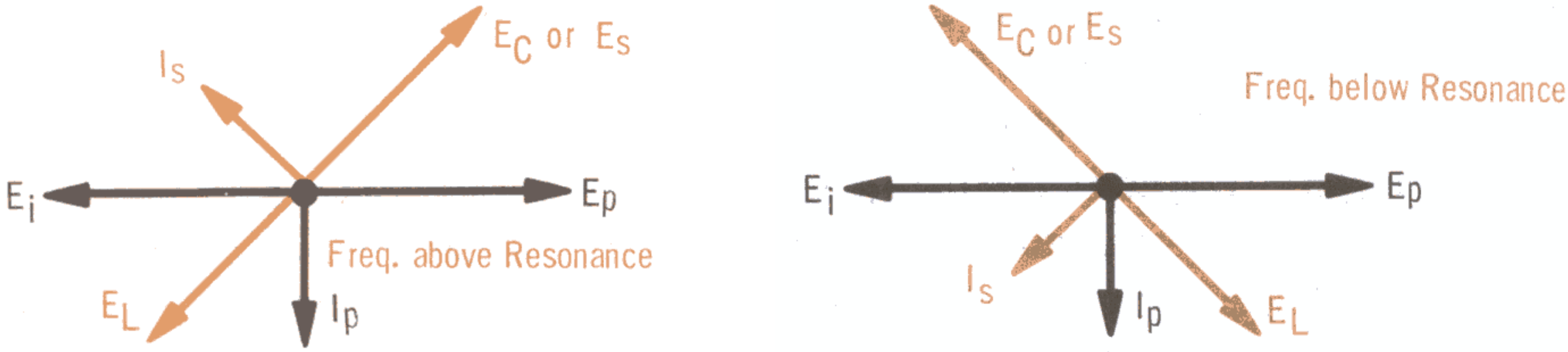
- The secondary current produces large voltage drops across X_C and X_L.
- E_S is the voltage across X_C and therefore leads E_P by 90º





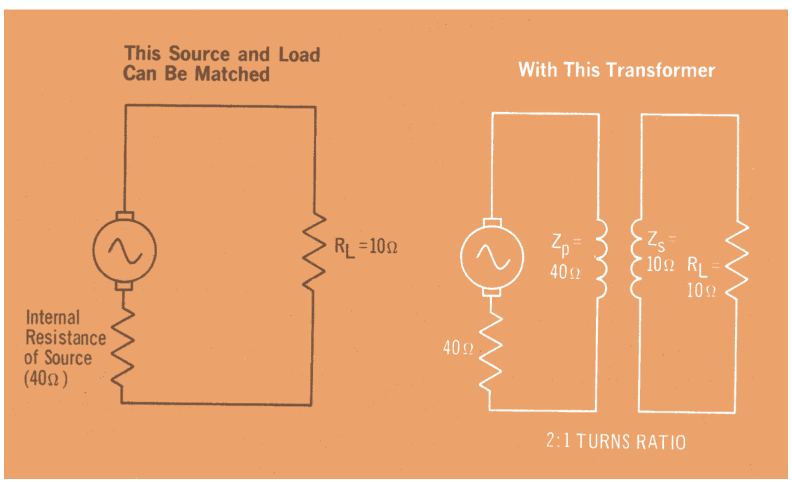
Off Resonance

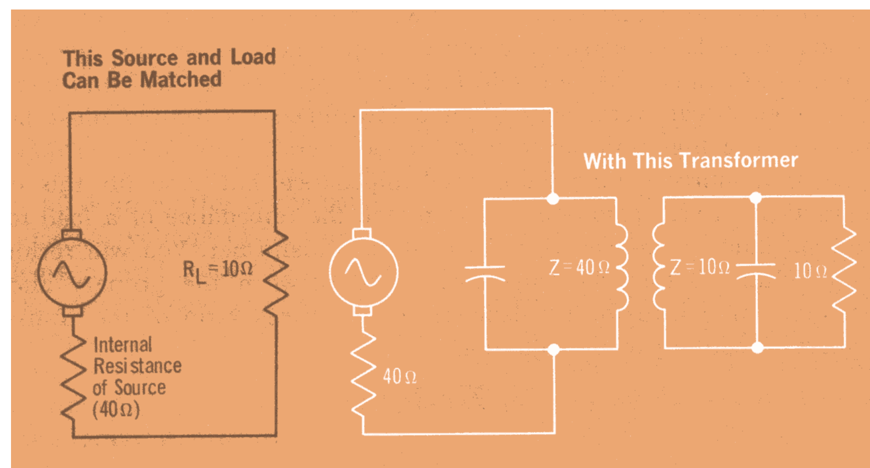
- The secondary is no longer resistive.
- This shift all of the secondary phases in tandem.
- Above resonance: rotate clockwise
- Below resonance: rotate counter-clockwise



Impedance Matching

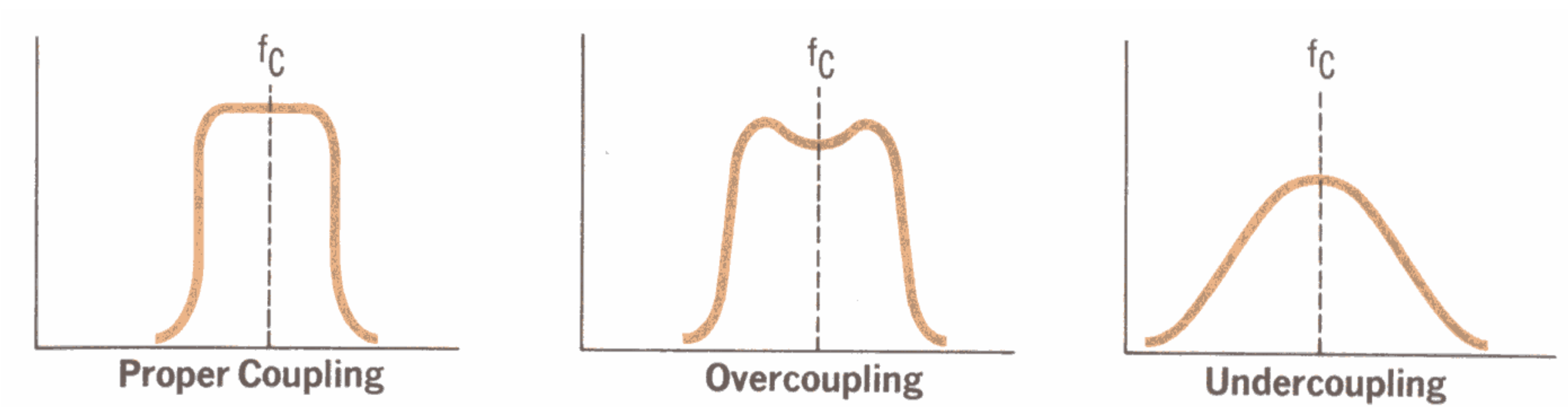
- Maximum power transfer: $Z_L = Z_S$*
  - * Means "complex conjugate". If one is inductive, the other is capacitive. This makes the power factor one.
- The turns ratio affects the "reflected" impedances.
  - $Z_P/Z_S = (N_P/N_S)^2$
- A Transformer can then be used to "match" dissimilar impedances (resistive) for good power transfer.





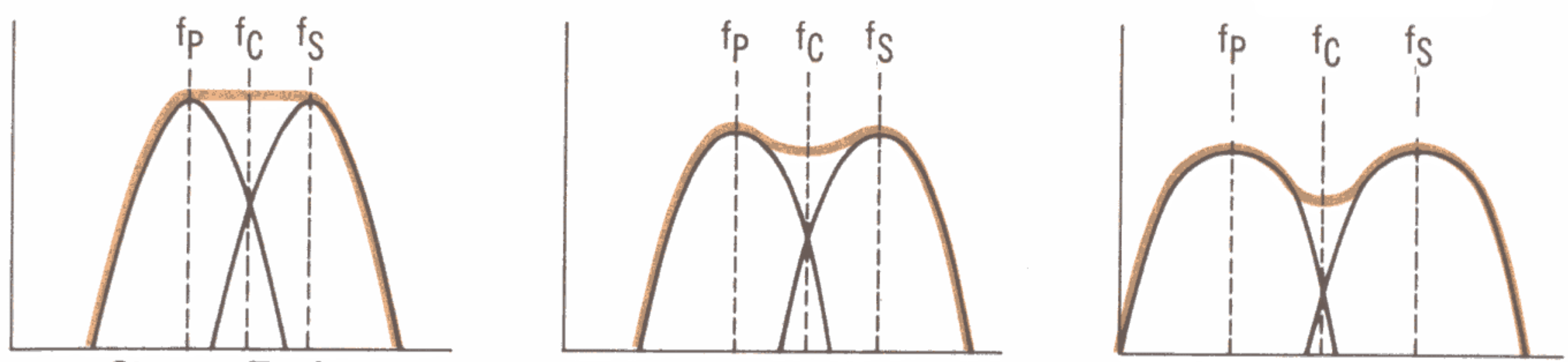
Transformer Coupling

- If the transformer is designed with very little magnetic coupling between the coils, our resonant transformer is “undercoupled” and both sides act independently on the signal. Their Qs determine the frequency response.
- A dip in the frequency response develops when there is “tight” coupling.



Stagger Tuning

- Stagger tuning, or having the primary and secondary resonant frequencies differ, is a way to broaden the frequency bandwidth without flattening the band edges (as would happen if the Qs were reduced)



Stagger Tuning

The individual tank curves combine to form one flat curve

Stagger Tuning

Tuning the primary and secondary further apart dips the curve

Stagger Tuning

Setting f_P and f_S further apart will widen the curve and increase the dip

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Q and A