TCET 2102 – Lesson 4

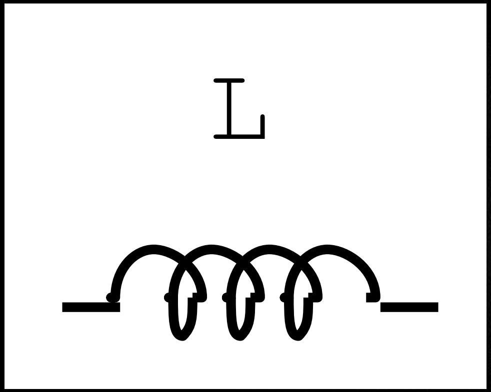
Matching networks

Outline

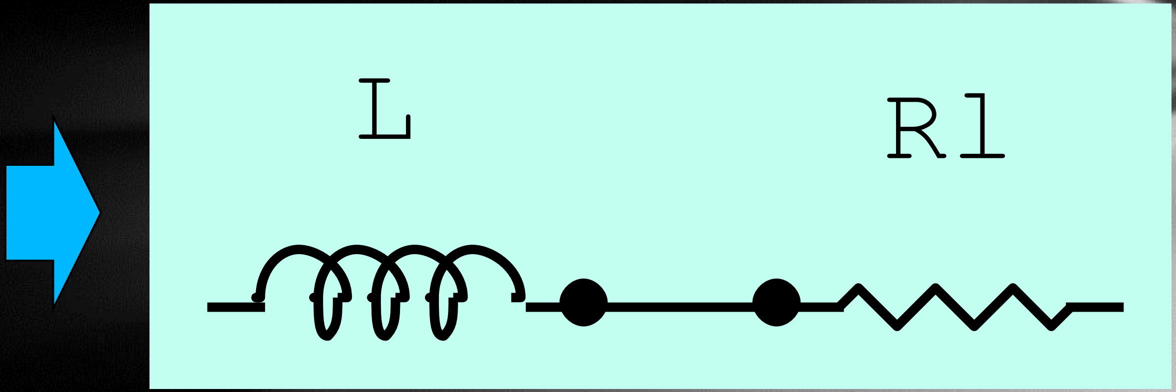
- Inductor/Capacitor
  - Real/ideal
  - Reactance
  - Q – factor
- Resonant circuits and circuit Q
- Maximum power transfer
  - Matching
  - L-, T-, π-networks

Inductor

Ideal

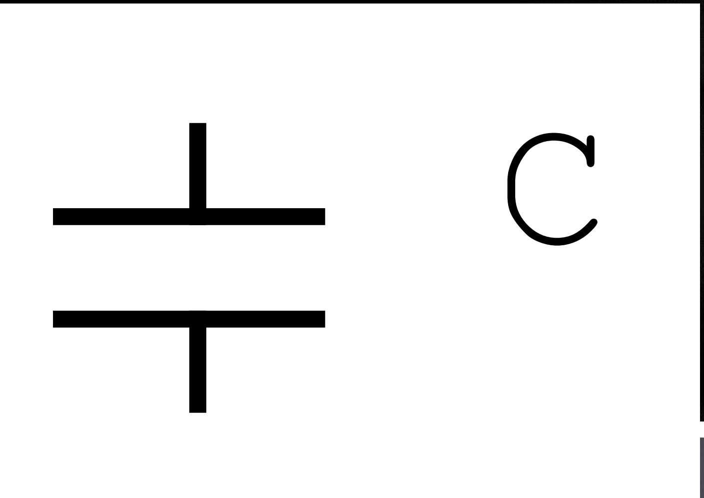


Real

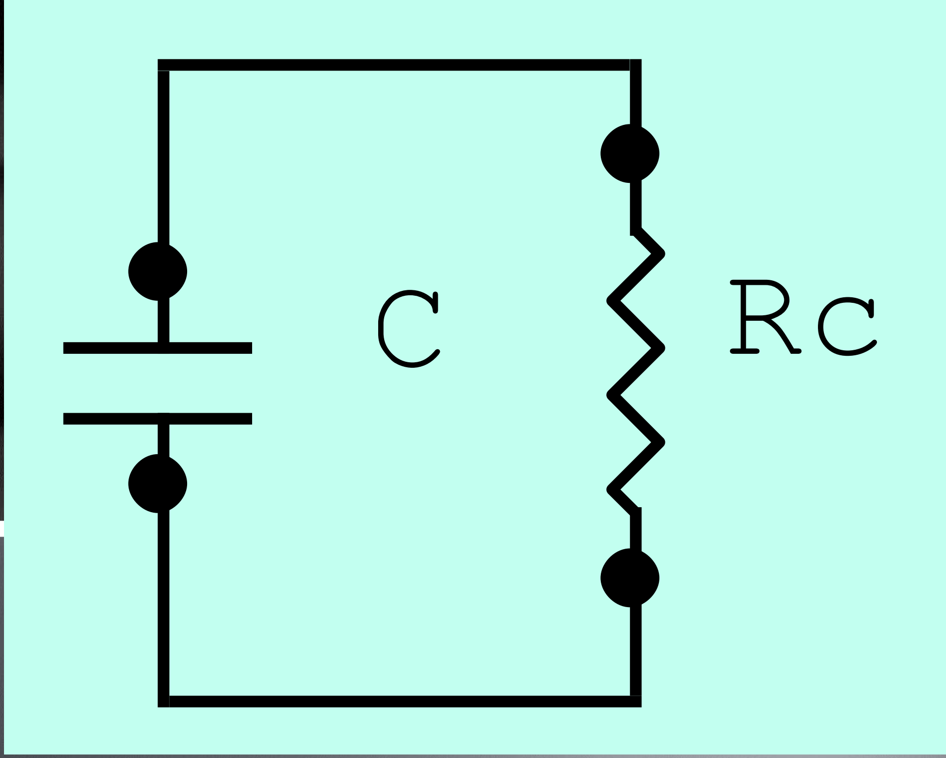


Capacitor

Ideal



Real



Reactance

$X_L = j2\pi fL$

$X_C = 1/(j2\pi fC)$

Describes how component reacts to changes in voltage/current.

Quality Factor (Q)

Q-factor: A ratio

$$Q = {}^{reactive\ power}/_{average\ power}$$

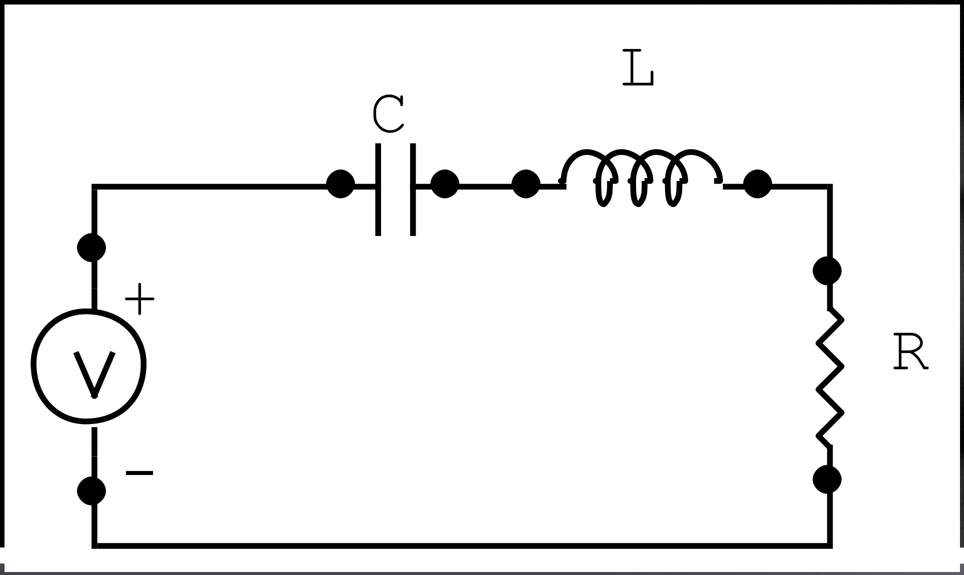
Can be found from the characteristics of any component.

Depends on how the resistive element is modeled, i.e. in series or in parallel with the ideal.

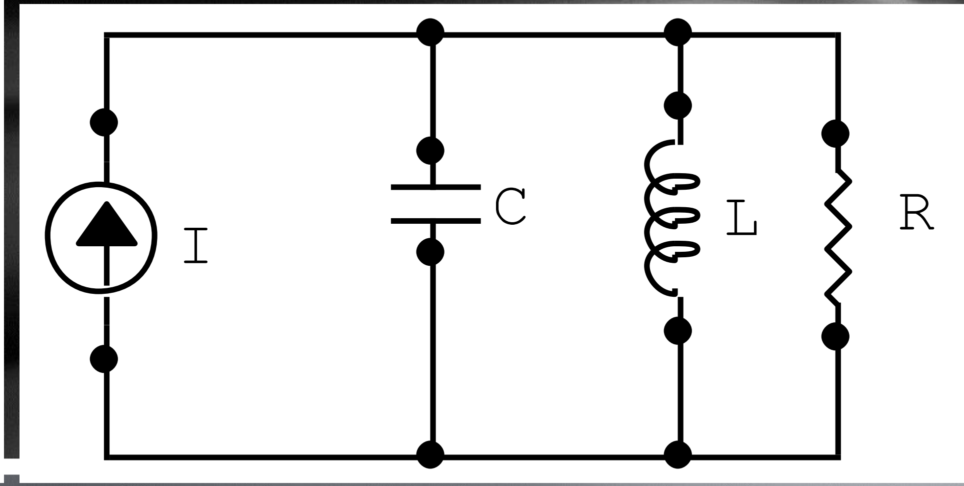
$$Q = \frac{X}{R_{series}} = \frac{R_{parallel}}{X}$$

Resonant Circuits

RLC tuned circuits



Series Resonant Circuit



Parallel Resonant Circuit

Resonant circuits

Center resonant frequency: $f_c = \frac{1}{2\pi\sqrt{LC}}$

The quality of a resonant circuit is also a measure of selectivity, i.e. how well the tank circuit can select a specific frequency while filtering out the others.

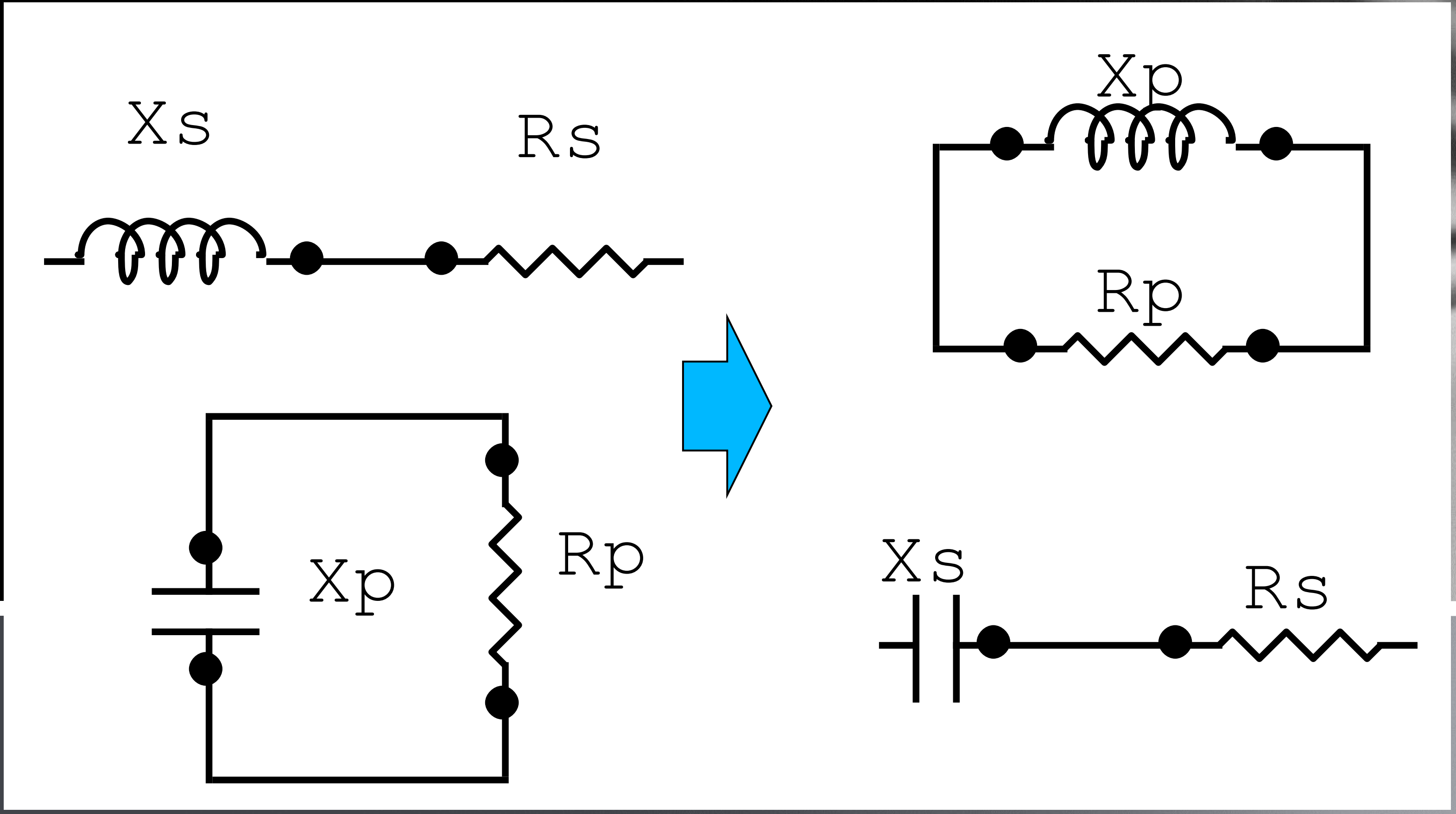
$$Q = \frac{f_c}{BW_{3dB}}$$

Not all ‘Q’s are the same!

Component Q is NOT the same as circuit Q!

Component Q DOES AFFECT circuit Q!

Using Q to change the model.



Using Q to change the model

$$R_p = (Q^2 + 1)R_s$$

$$X_p = \frac{R_P}{Q} = X_S\left(\frac{Q^2 + 1}{Q^2}\right)$$

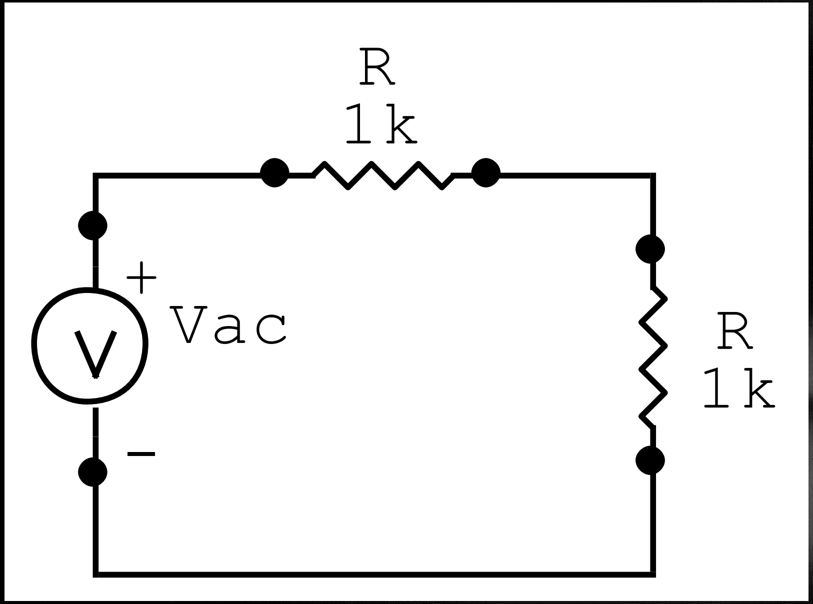
$Q_s = Q_p$ since it's the same component. We're just using a different model.

Insertion Loss

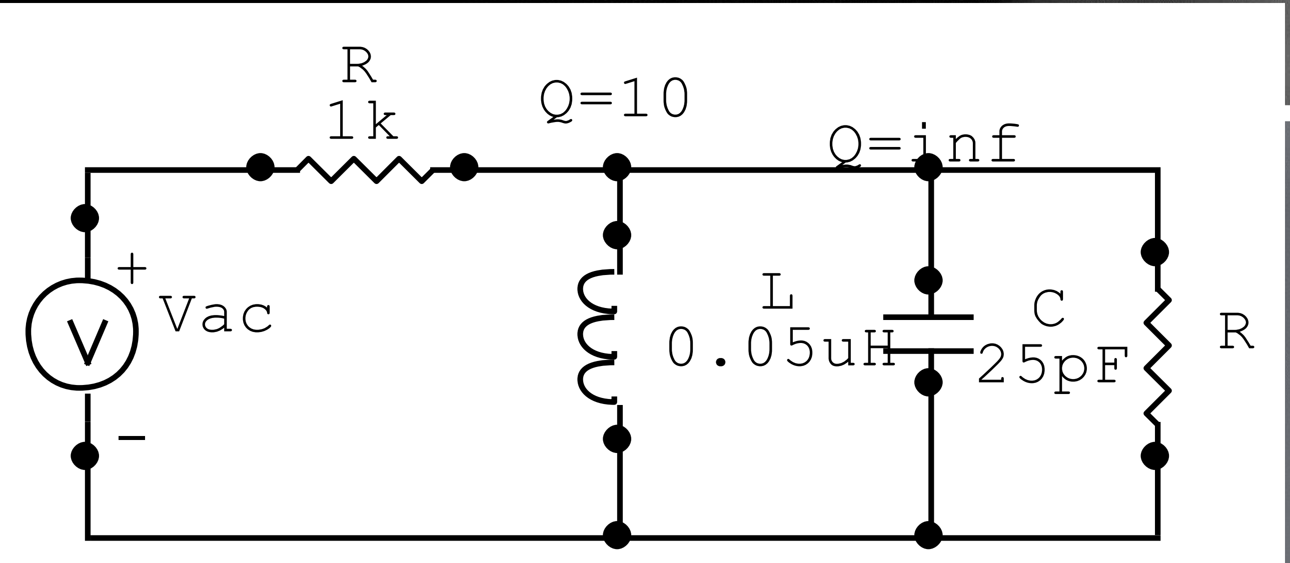
Inductors and capacitors are not ideal!

They’re resistance acts as an extra load in the circuit, not only causing changes in circuit Q, but also losses in the transfer of power.

Insertion Loss



$$V_{out} = \frac{V_{ac}}{2}$$



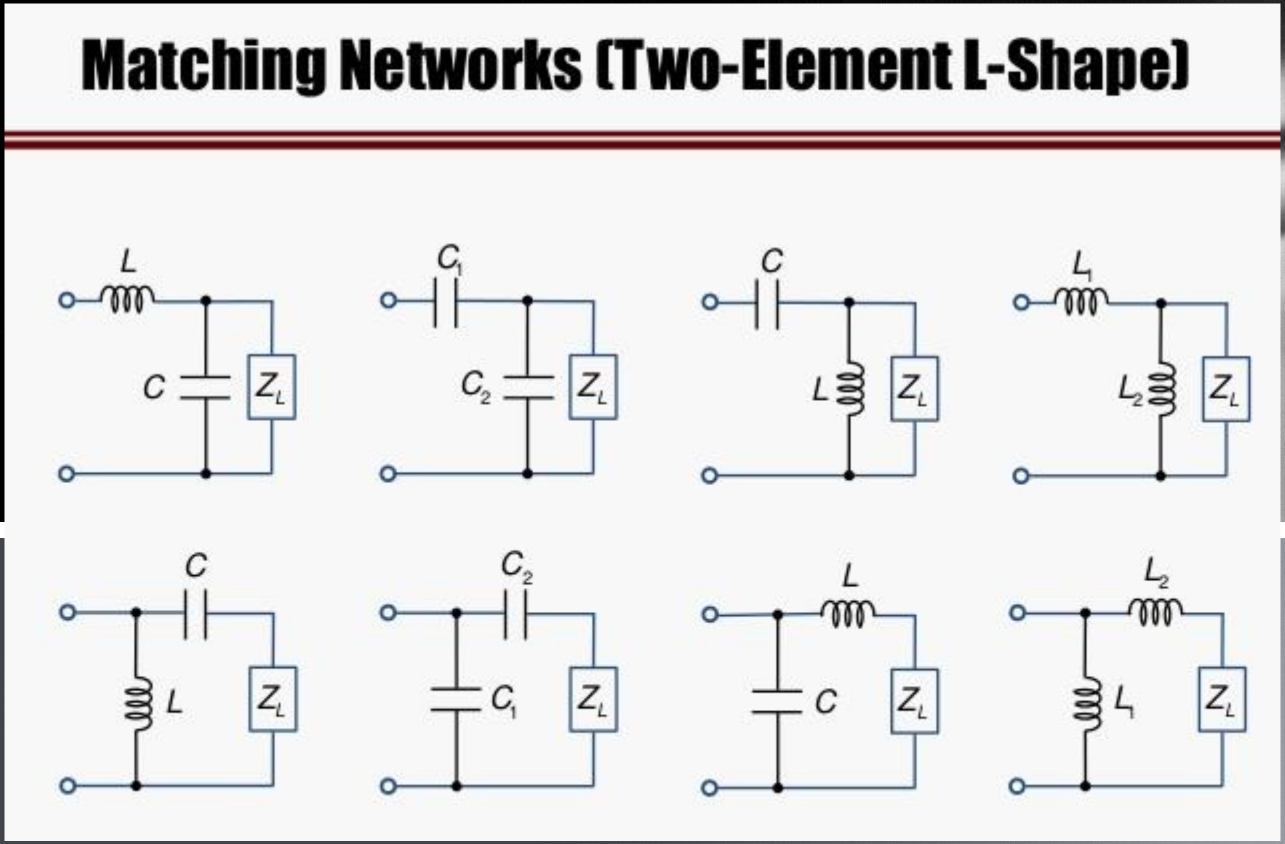
$$V_{out} = 0.45V_{ac}$$

Impedance Matching

- What is matching?
  - Values for load to guarantee maximum transfer of power!
- How does it work with complex signals?
  - Work with complex conjugates!

L-networks

They look like an ‘L’.



Courtesy of Simen Li, Attribution 4.0 International

Find the values of L,C.

Can do it analytically, but why?

Simplify!

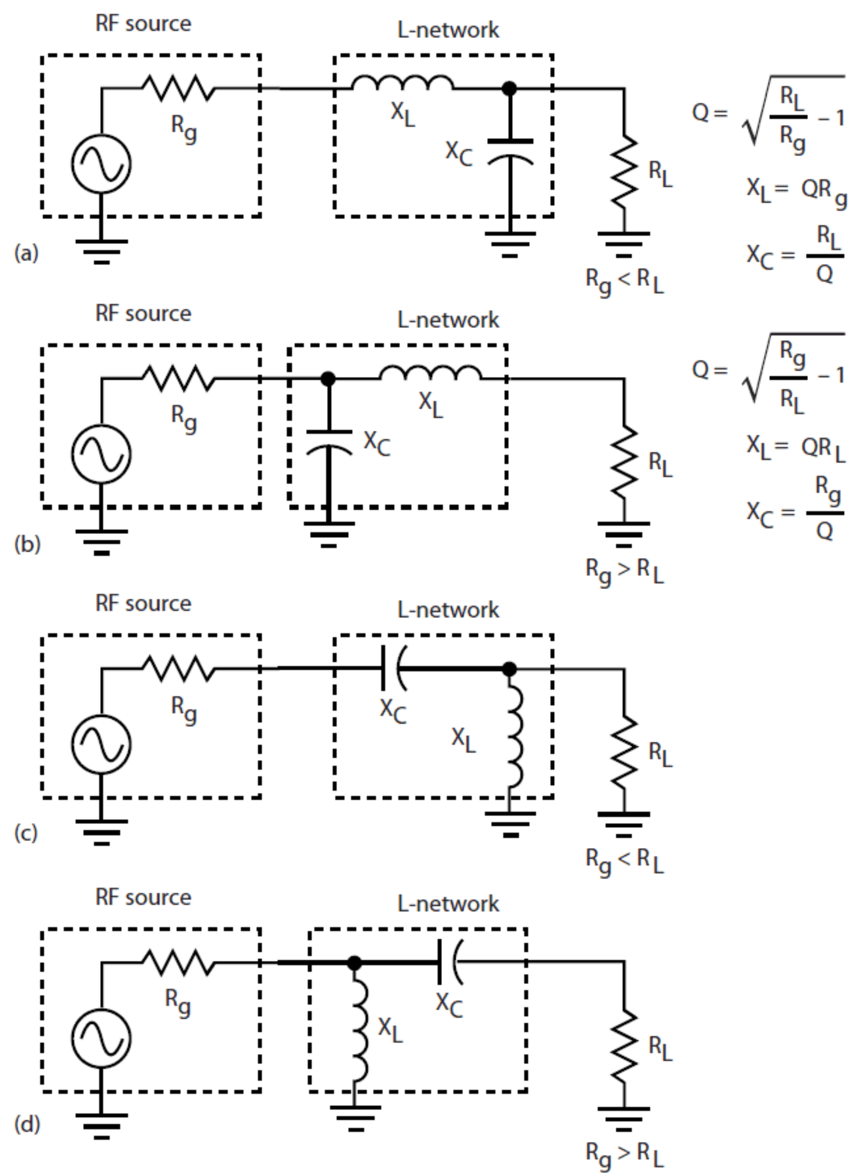
- Work with what we know.. Q!

Working with Q

$$Q_s = Q_p = \sqrt{\frac{R_p}{R_s} - 1}$$

$$Q_s = \frac{X_s}{R_s}$$

$$Q_p = \frac{R_p}{X_p}$$



1. There are four basic L-network configurations. The network to be used depends on the relationship of the generator and load impedance values. Those in (a) and (b) are low-pass circuits, and those in (c) and (d) are high-pass versions.

Lou Frenzel, Electronic Design, 3/1/2012

Aren’t we limited?

Yes!

Notice that for real Q values, $R_p > R_s$.

Q becomes fixed to a certain value.

What if we want to control Q?

- Why would we even want that?

Three-element matching (T,π)

So what do we choose?

If we can choose our Q, what's the best choice?

- It depends.

High selectivity or wide bandwidth?

- If wide bandwidth (minimum Q): $R = \sqrt{R_S R_L}$

Can we have several networks?

Of course!

- Reference 1
- Reference 2