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ECE 490-ST
Wireless Computing

Lesson 6 :: Impedance Transforming

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Eyeballing impedance shifts

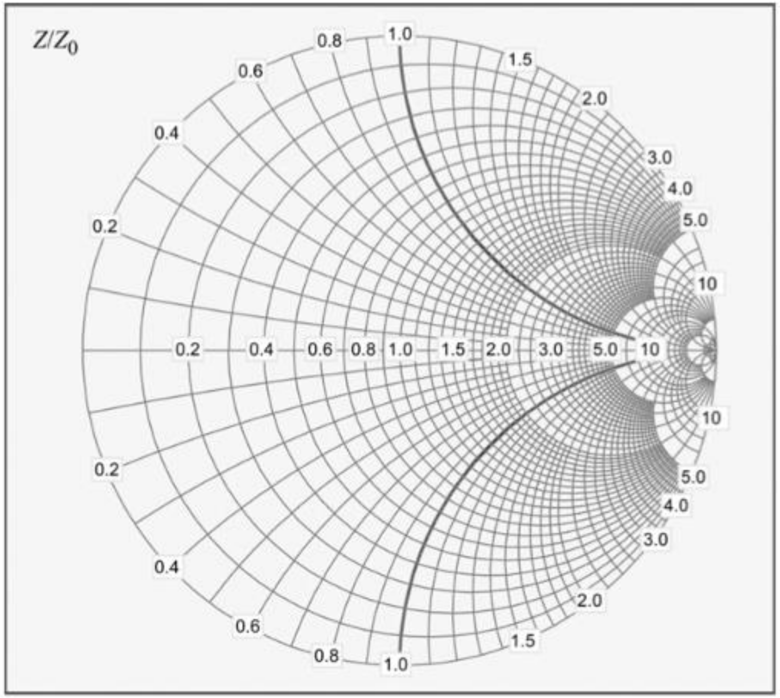


Figure A4.4

Eyeballing Impedance Shifts

- If Gamma moves .25 around the Smith chart —
  - X = j w L X = -j / (w C)
  - X = w L X = -1 / (w C)
  - L = (X * Z0) / w C = -1 / (Z0 * X * w)

$$L = \frac{0.25 * 50}{2\pi(915e6)} = 1.4\ nH$$

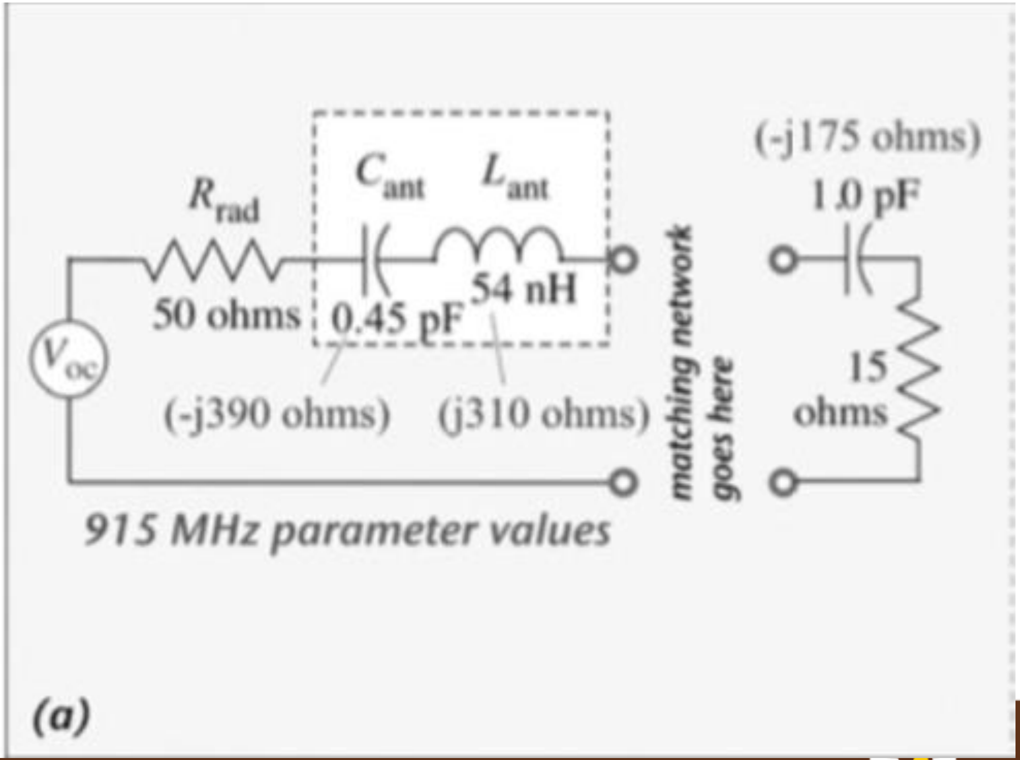
- EX: We move from 0 -> 1.1. At 915 MHz:
  - L = (1.1 * 50) / (2*π*915e6)
  - L = 9.566 nH

VNA DEMO

What is my hand acting like?

What is the value of my hand?

I want the load to appear as the conjugate of source



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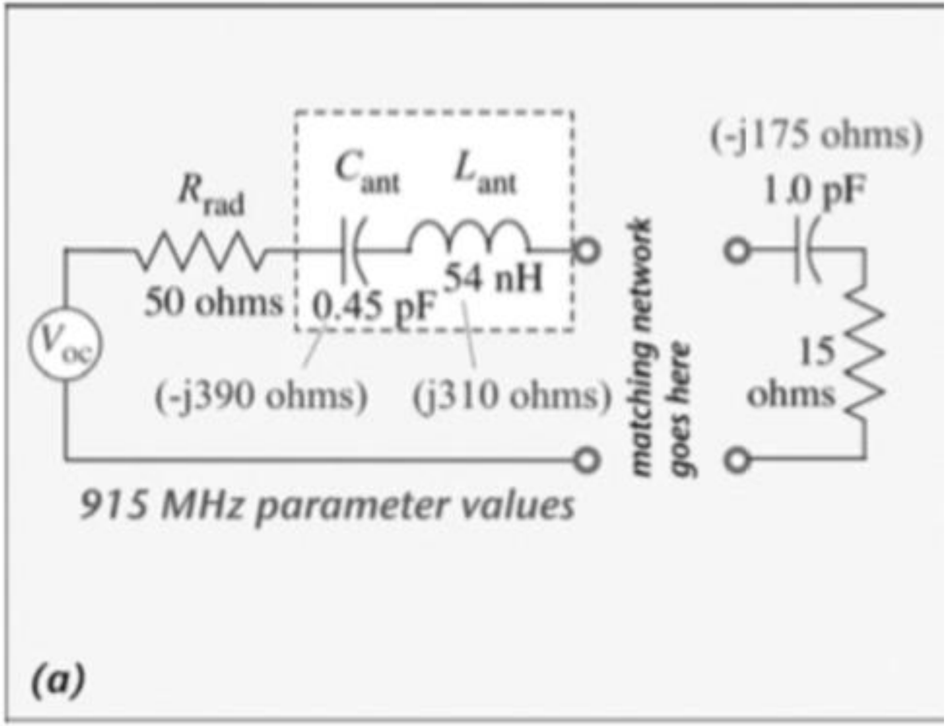
IMPEDANCE TRANSFORMING

- What is Gamma when looking into the source?
- What is the conjugate of the input Gamma?
- What is Gamma when looking into the load?
- Which way do we need to rotate?
- Can we get there with 1 element?
- What other element do we need?



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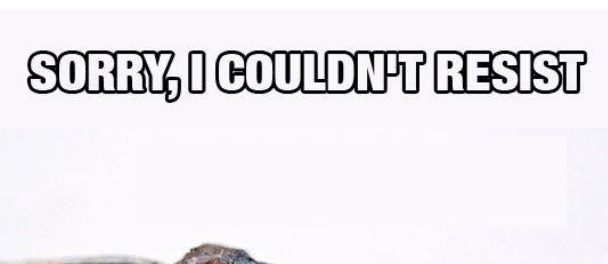
Transforming impedances

- For impedance transformation networks, **we will only use L and C**
- These elements do not absorb energy.
- However, the job of a RESISTOR is to convert current into heat.
- We do not want that
- We don’t want to lose power.
- So, **NO RESISTORS** in impedance transformation circuits



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For homework[1]

- Be ready to find networks (circuits) that can transform impedances.
- By inspection and small calculations
- Verify with numerical tool (MATLAB) and plotting tools (Your handy dandy Smith chart)

[1] At least a part of it

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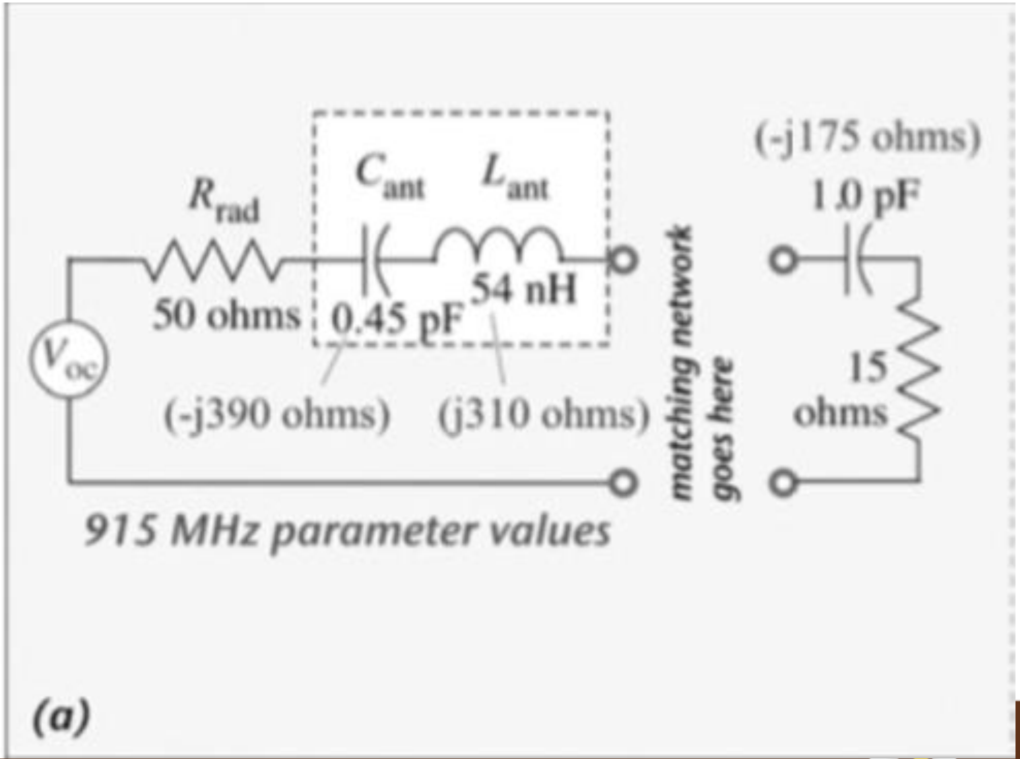

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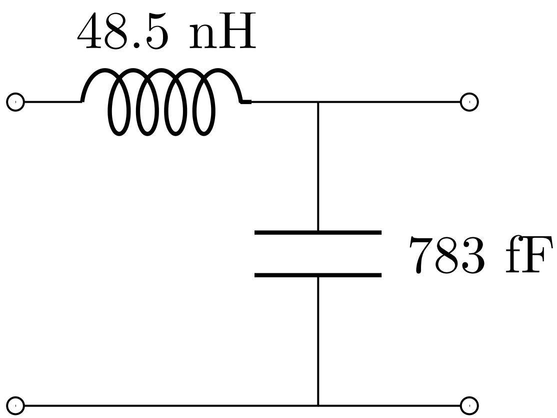
I want the load to appear as the conjugate of source

(to Source)



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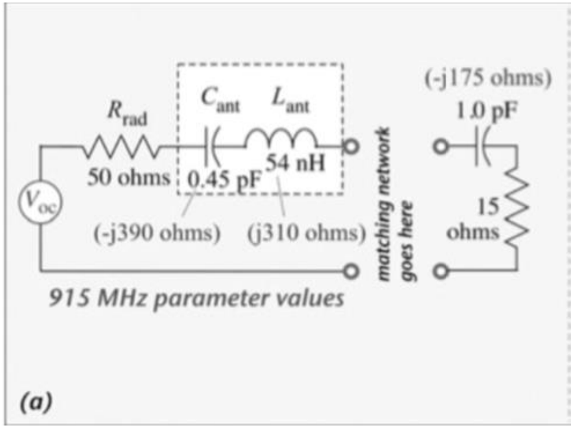

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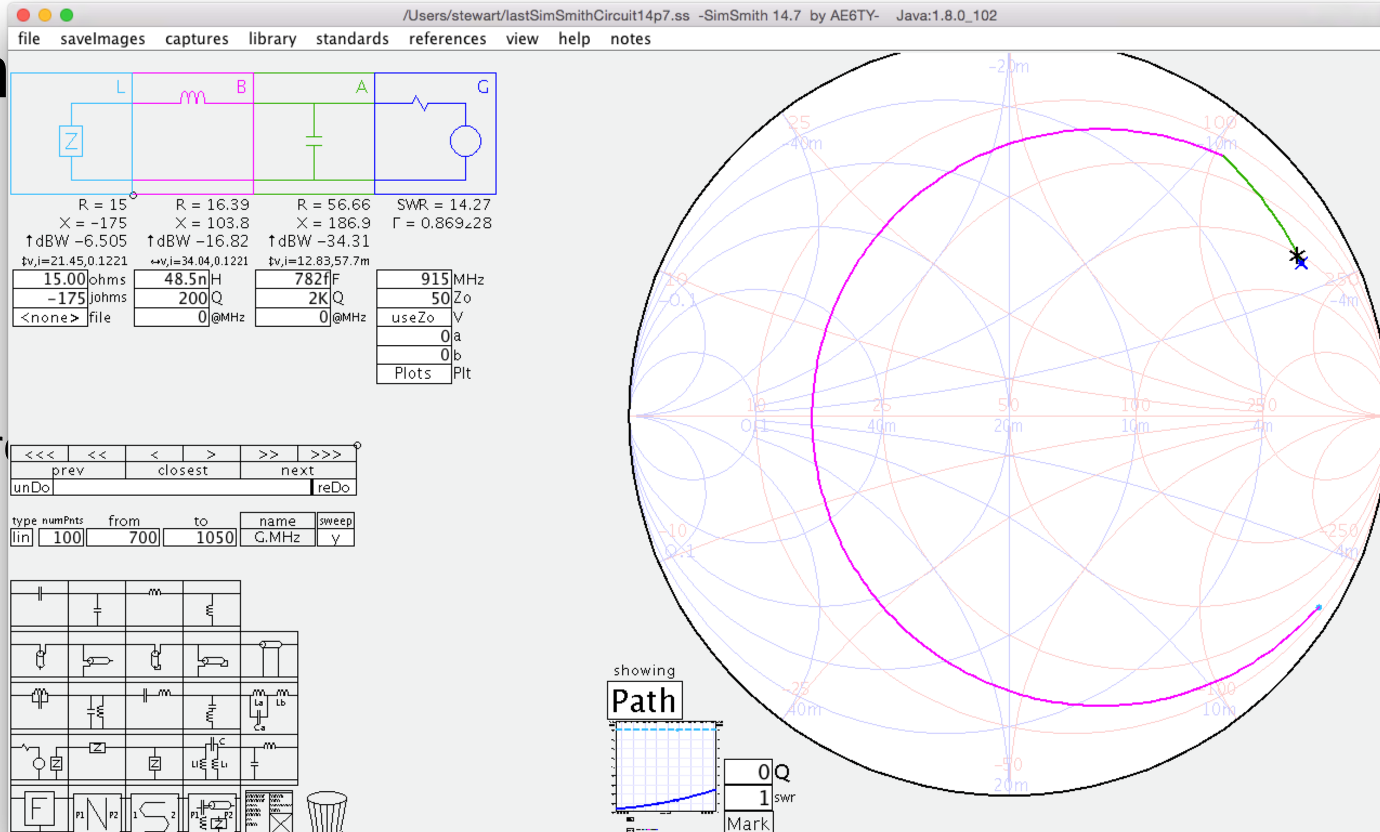

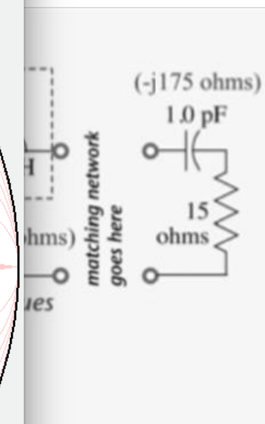

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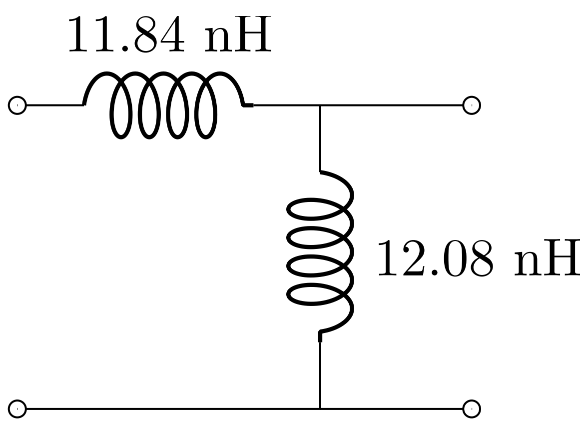

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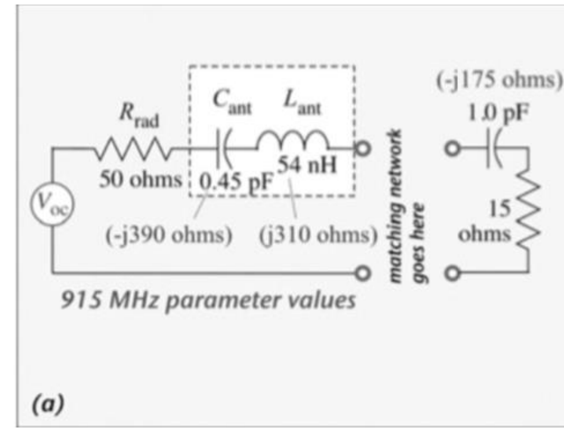

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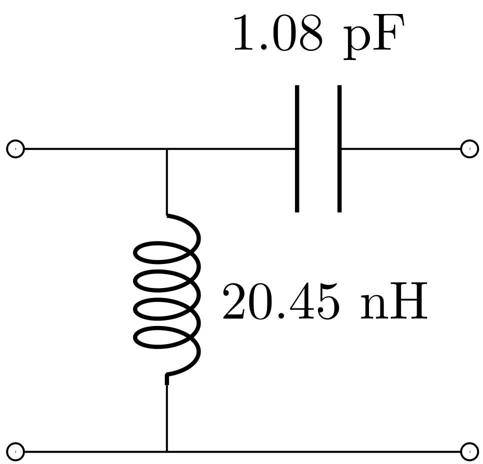

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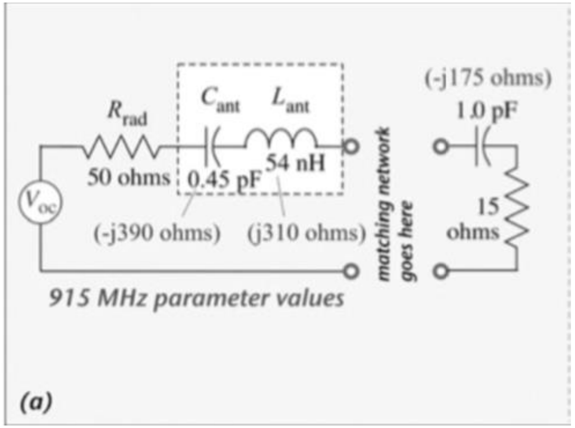

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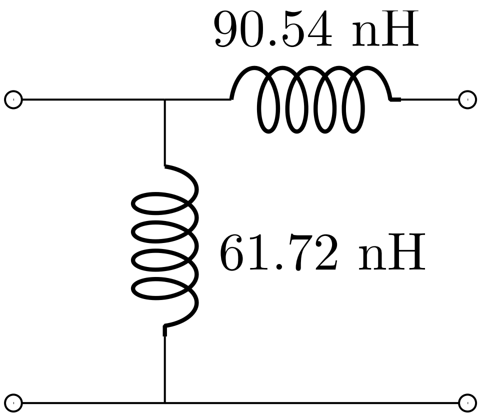

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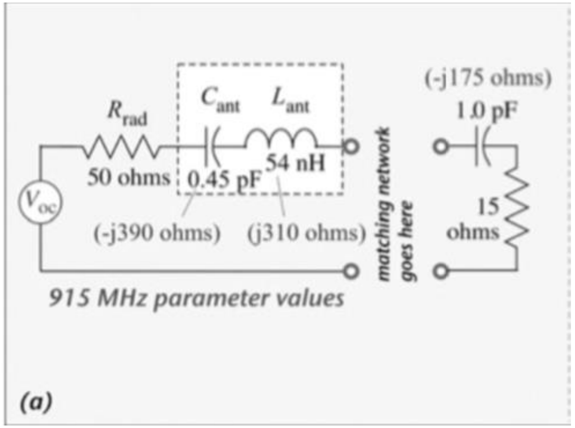
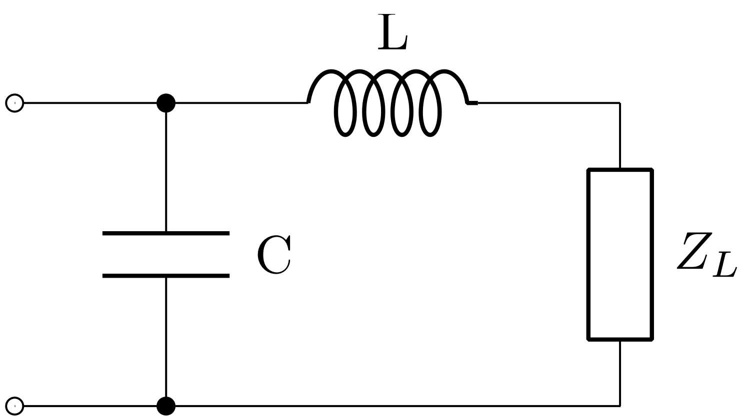


Example

Two networks are shown below. 1) Select the one that can transform $\boldsymbol{Z_L = 38.5 + j57.7}$ to 50 Ohm. 2) Find the element values at $\boldsymbol{f = 1\text{ GHz}}$



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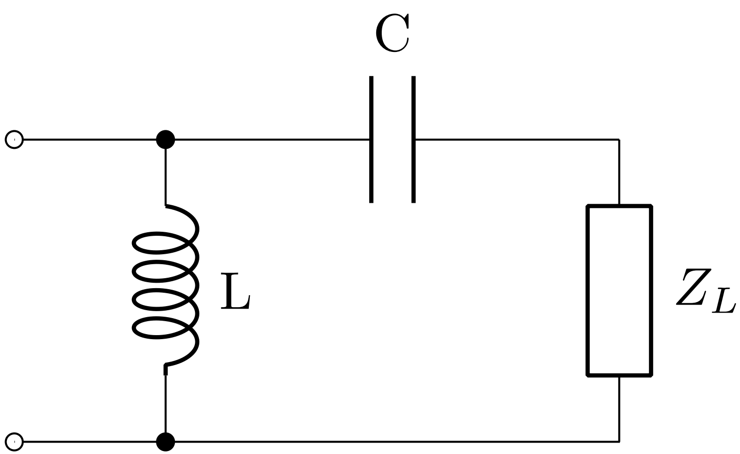

B

Introducing Q

- ¿Qué?

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Introducing Q

- Not him either

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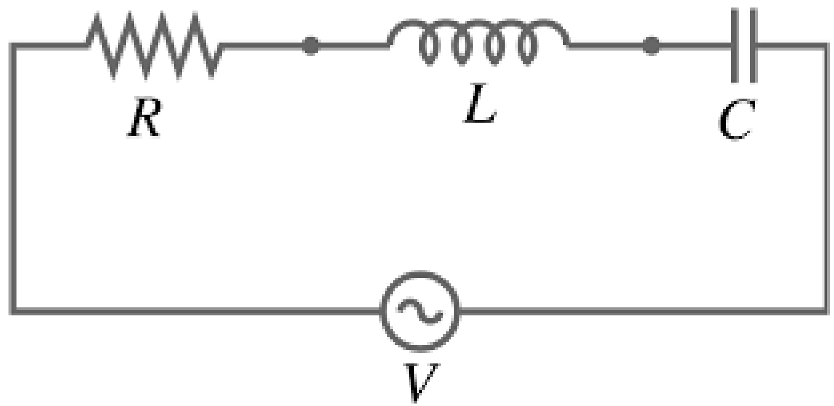
Introducing Q – the Quality Factor

- Q let’s us quantify the bandwidth of a network

Introducing Q – the Quality Factor

- Q let's us quantify the bandwidth of a network

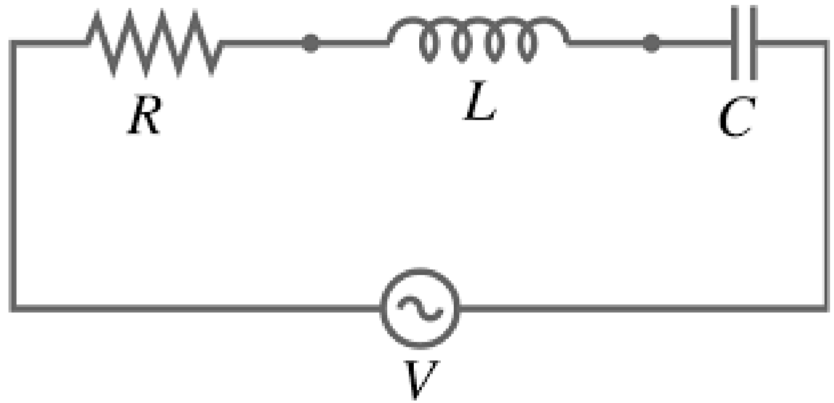


- Take an RLC circuit

$$Z = \left(R + j\omega L - \frac{j}{\omega C} \right)$$

Introducing Q – the Quality Factor

- Q let's us quantify the bandwidth of a network



$$\omega_{res} L = \frac{1}{\omega_{res} C}$$

$$\Rightarrow \quad \omega_{res} = \sqrt{\frac{1}{LC}}$$

$$Z = \left(R + j\omega L - \frac{j}{\omega C} \right)$$

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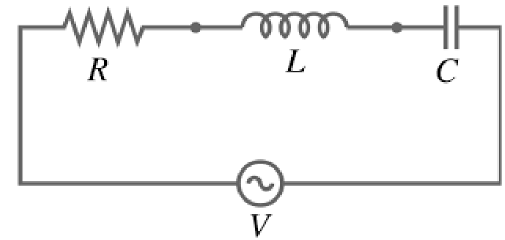
Introducing Q – the Quality Factor



- Q let’s us quantify the bandwidth of a network
- The ratio of reactance to resistance is Q.
- The lower the resistance, the less energy loss
- Q is inversely proportional to Bandwidth
- High Q means a narrower bandwidth
- For you, it just means you can calculate resistance

$$Z = \left(R + j\omega L - \frac{j}{\omega C}\right)$$

$$\omega_{res} L = \frac{1}{\omega_{res} C}$$

$$\Rightarrow \omega_{res} = \sqrt{\frac{1}{LC}}$$

$$Q = \frac{\omega_{\mathrm{res}} L}{R} = \frac{1}{\omega_{\mathrm{res}} C R}$$

Introducing Q – the Quality Factor

$$\omega_{res} L = \frac{1}{\omega_{res} C}$$

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$$Q = \frac{\omega_{\mathrm{res}} L}{R} = \frac{1}{\omega_{\mathrm{res}} C R}$$

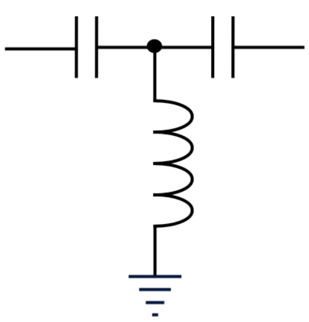
- For a capacitor: $R = \dfrac{1}{2\pi f C Q}$

- Find R, then add back into circuit in series with the capacitor

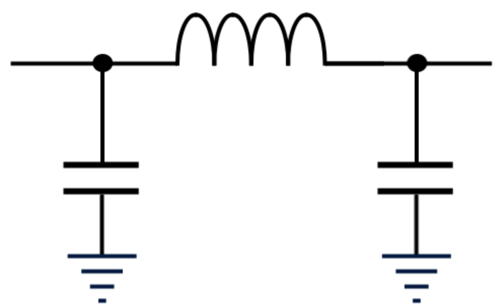
Designing Transformation Networks

- Most inductors or capacitors will specify a Q value.
- You do not have access to *every possible* L and C value
- Need to get as close as possible.
- Common Networks are

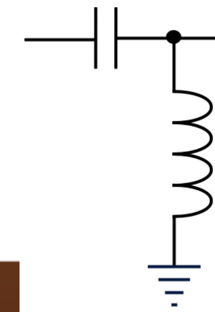
TEE Network



PI Network



L Network



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Useful equations to know

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Given load impedance,
Find reflection coefficient

$$Z_L = Z_0 \frac{1 + \Gamma}{1 - \Gamma}$$

Given reflection coefficient,
Find load impedance

$$Q = \frac{\omega L}{R} = \frac{1}{\omega C R}$$

Given Q & frequency, solve to find series R

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For Homework (the 2nd part)

- Design a network to transform the load impedance to 50 Ohms (at 915 MHz)
  - You are limited to L and C only, and only a small set of values
  - Find the network that you think works best and justify this (i.e., compare to other networks)
  - Once you've designed your network, implement the network and use MATLAB to apply it to the measured data to predict how it will perform.

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Useful links

- **Online impedance matching designer**
- https://home.sandiego.edu/~ekim/e194rfs01/jwmatcher/matcher2.html
- NOTE: This designer transforms to the *CONGUGATE* of the source. So to match to “Znew = 80 + j90” you would enter source resistance as “80” and source reactance as “-90”.

- **SimSmith downloadable tool**
- http://www.ae6ty.com/smith_charts.html
- Direct link for Windows x64 [mac and linux versions also available]
- http://www.ae6ty.com/Smith_Charts_files/SimSmith_windows-x64_14_7.exe