Design Studio – Week 4

Today you will:

- Evaluate and improve the RC circuit design from last week
- Design and model your own RLC circuit
- Learn about resonance and natural frequency
- Review the rubric for technical reports

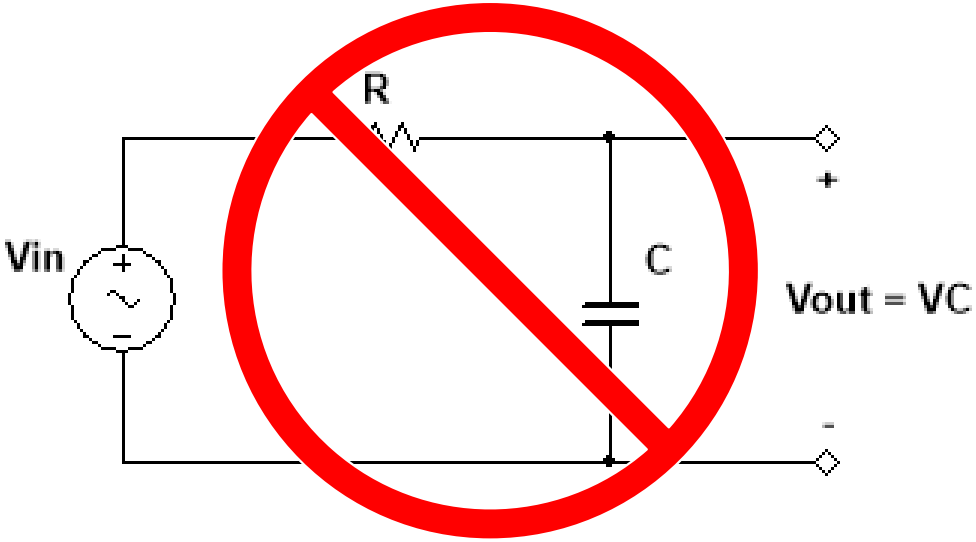
Assignments:

- Exercise worksheet for RLC circuit design and analysis
- Project 1 technical report

Project 1 Review

Improve

Last week you designed, built, and tested an RC filter circuit.



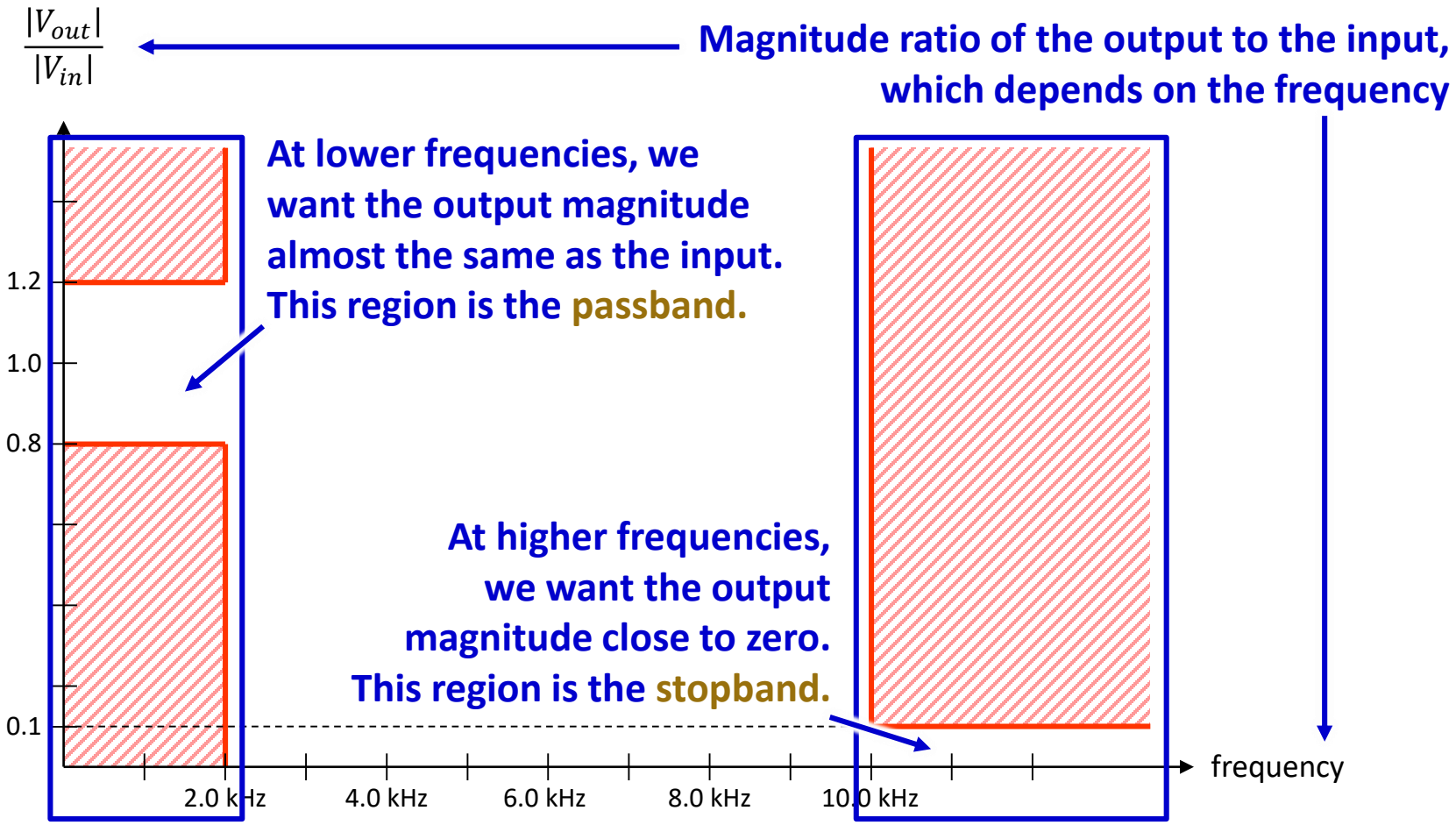
Did it work, i.e. did it meet the requirements?

Why not?

Project 1 Requirements

Ask

Recall the filter requirements:



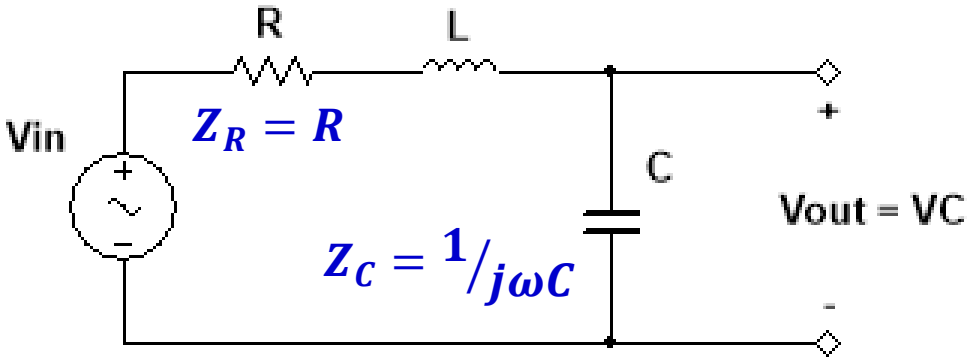
Project 1 Redesign

Imagine

Let's see if we can improve the performance of the circuit.

Since inductors and capacitors alone with a resistor don't work, let's investigate what happens if we use both at the same time.

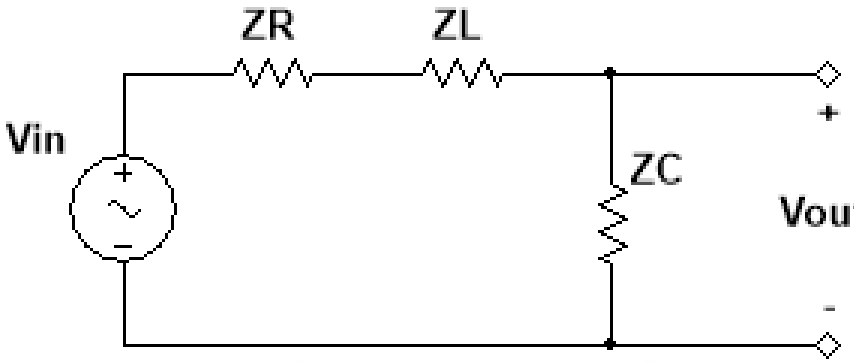
Using impedances: $Z_L = j\omega L$



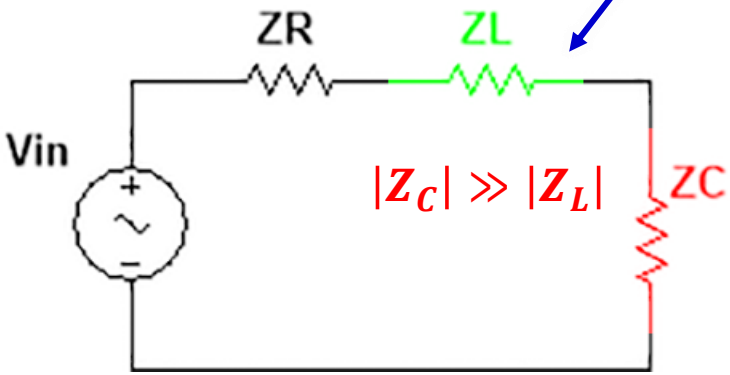
Project 1 Redesign

Plan

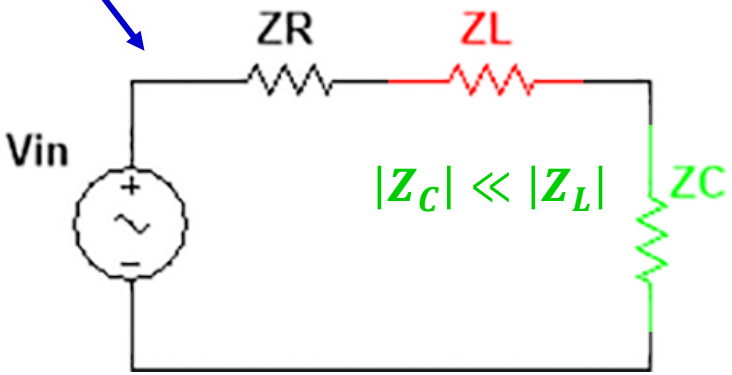
How can we choose good values of L and C for our design?



At frequencies $f \leq 2$ kHz (passband region)



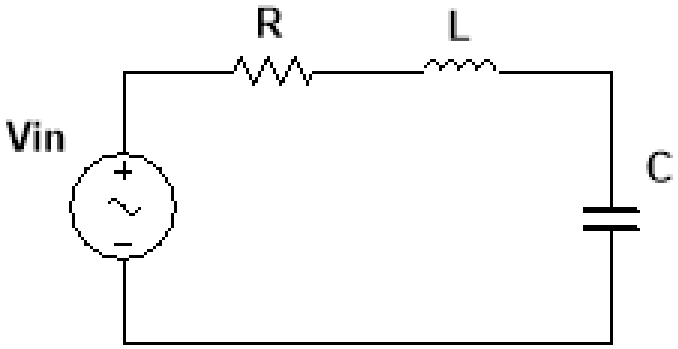
At frequencies $f \geq 10$ kHz (stopband region)



We want $|Z_C| = |Z_L|$ somewhere with 2 kHz < f < 10 kHz.

Concept Review – Resonance

So what happens to the inductor and capacitor when $|Z_C| = |Z_L|$?



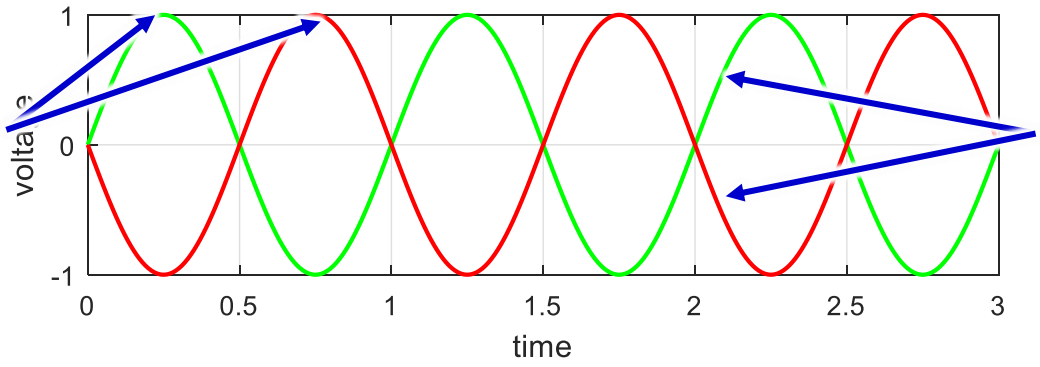
That means $\omega L = {}^{1}/_{\omega C}$ …

…and $Z_L + Z_C = j\omega L + {}^{1}/_{j\omega C} = 0$!

So $V_L + V_C = I(Z_L + Z_C) = 0$, but are $V_L = 0$ and $V_C = 0$?

No, they are just opposite of each other…

The amplitudes are equal



Signals are 180° out of phase

Concept Review – Resonance

The frequency $\omega = {}^{1}/_{\sqrt{LC}}$ at which $V_L + V_C = 0$ is called the resonant frequency, or the **natural frequency**.

The voltages V_L and V_C actually can become quite large in this case.

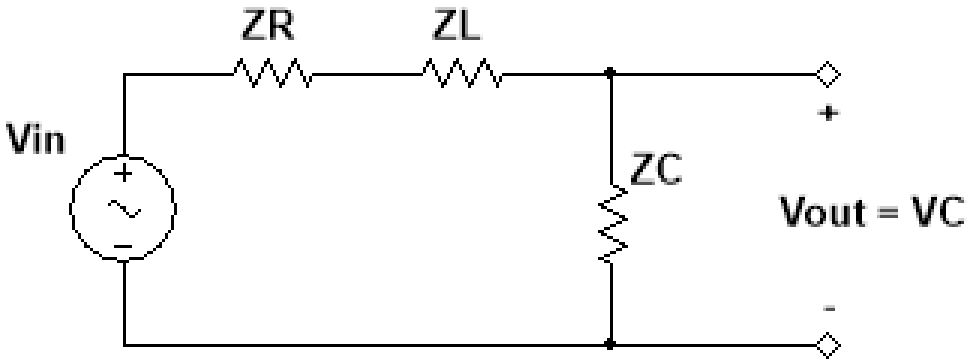
The tendency to amplify signals at the natural frequency is called **resonance**.

Using Resonance to Break a Wine Glass
https://www.youtube.com/watch?v=BE827gwnnk4

Project 1 Redesign

Plan

How can we choose a good value of R for our design?



If R is too big, $|Z_R| = |Z_C|$ around 2 kHz and $V_{out} < V_{in}$.

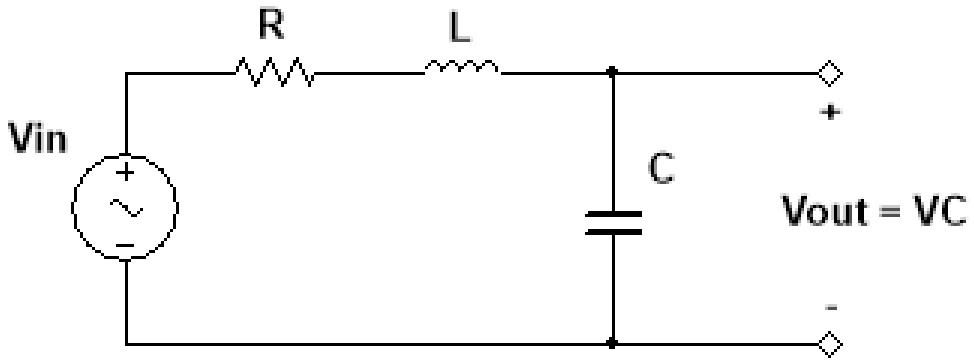
If R is too small, V_{out} gets very large near the natural frequency.

Write the equations or test some values in Multisim to choose R.

Project 1 Modeling and Test

Create

Follow along with the worksheet to build a working version of your circuit design in Multisim with your team.



Your instructor is here to help answer guiding questions and troubleshoot any problems that your team identifies.

Project 1 Technical Report

Project 1 features your first technical report. Because this is the first time you will be capturing the entire design, the report will be treated mostly as a learning opportunity.

At a top level, the report can be viewed as an account of:

- What you planned and decided (**Methods**)
- What you did and what you learned (**Results**)
- What you think you should do next (**Conclusions**)

The report should also include a cover page and references and appendices as needed.

Let's review the rubric and example report posted on the Studio website.

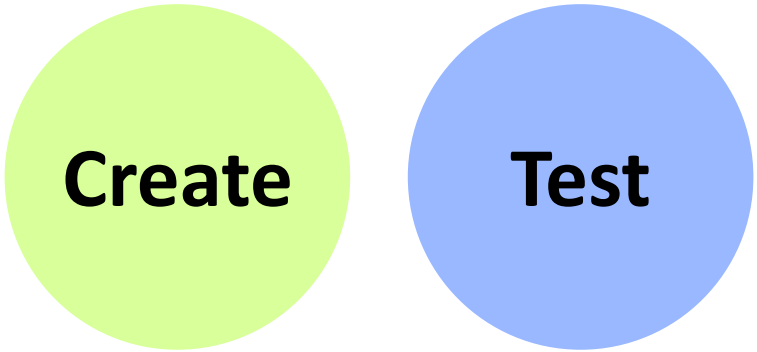
Project 1 Methods

The **Methods** section covers the *Ask*, *Imagine*, and *Plan* phases.

For this project, you should include:

- The project requirements
- The RLC circuit design you are using this week
- The final values of any resistors, capacitors, and inductors

Project 1 Results



The **Results** section covers the *Create* and *Test* phases.

For this project, you should include:

- The Multisim model you developed
- A table of your point measurements in Multisim
- The frequency plot of your circuit magnitude ratio from Multisim
- A check of the performance versus the requirements

Project 1 Conclusions

The **Conclusions** section covers the *Improve* phase.

For this project, you should include (as bullet points):

- Some valuable things you learned about the circuit along the way
- *If you met the requirements*, a few steps on getting the design to the next version (e.g. prototyping, more measurements)
- *If you didn't meet the requirements*, some steps on how to go back and specifically change the design to improve it

Project 1 Report Scope

Next week we will do some prototyping and hands on measurement of our RLC filter design.

Your project report only needs to cover the project work and development through this week (Week 4).

The exercises we do next week (Week 5) do not need to be included in the Project 1 report.