RLC Filter Circuit

To the right is a picture of an *RLC* filter circuit.
Select nominal values for L & C which give a resonant frequency of $f_{res} \sim 10$ kHz.
In the past we have used $L = 3.3$ mH & $C = 1$ µF (or values within a factor of 10).
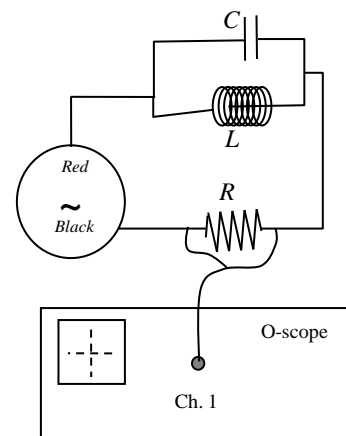Select a 1 kΩ resistor.
Measure the actual values of L, R, and C with the LCR meter or a DMM.
Get a second
List your values below with units.
Version A: Use the same L and C with a second, smaller R (say approx 250 Ω).
Version B: Use the same R and C with a second L.

$L =$ _____ $C =$ _____ $R_1 =$ _____

$R_2 =$ _____ $\omega_0 =$ _____ $f_0 =$ _____

Component	Eqt'n for Reactance (χ)	χ at low ω? (big or small)	χ at high ω? (big or small)	χ w/ small L or C? (big or small)	χ w/ large L or C? (big or small)
Inductor (L)	$\chi_L=$				
Capacitor (C)	$\chi_C=$				

Equation for total impedance in this circuit: $Z = \sqrt{R^2 + \left(\frac{\frac{L}{C}}{\left(\omega L - \frac{1}{\omega C}\right)}\right)^2}$

Z at lo ω's: _____ Z at ω_0: _____ Z at hi ω's: _____

Most confusing part today:

- $i_{max\ th} = \frac{V_{source\ max}}{Z}$ (calculate in Excel using math on $L, C, R, f, \& V_{source\ max}$)
- $i_{max\ exp} = \frac{V_{R\ max}}{R}$ (measure peak voltage across R and divide by measured value of resistance)
- Note: as you change the frequency dial you change the values of $f, \omega, \& Z$ but you do NOT change the values of $R, L, C, f_0, \& \omega_0$.
- In today's lab we want to plot how I_{th} changes as ω changes and compare that to experimental data.

To get data:

- Be sure the output cable of the function generator is connected to the **output** BNC connector!
- Ensure you are on a sine wave and make the generator produce with a 1 kHz sine wave.
- Ensure DC offset button is NOT depressed.
- Set the amplitude to a convenient size (say 10.0 V amplitude). Before proceeding, verify the wave amplitude is 10.0 V by doing the following:
  - o Connect the function generator directly to Ch 1 on the scope (without any resistors, etc).
  - o Hit AutoRange button if it is not already lit up green.
  - o Use the MEASURE button so the scope measures frequency, period, and peak-to-peak voltage.
  - o Adjust the output know of the function generator until you hit 20.0 V peak-to-peak.
    - Dividing peak-to-peak voltage by 2 is more reliable than having the scope measure peak voltage (e.g. if there is DC offset).
- Wire up the circuit as shown on in the figure at the top of this page.
  - o Please ensure that one leg of the resistor is connected to the black lead of the function generator!
- Determine your *target* frequencies.
  - o These are the *approximate* values of you will shoot for when tuning the function generator.
  - o When doing the actual experiment, you tune the dial *approximately* to these frequencies.
  - o The function generator uses f while the most equations use ω.
  - o Function generator frequencies are in units of Hz.

$0.01f_0$	$0.02f_0$	$0.05f_0$	$0.1f_0$	$0.2f_0$	$0.5f_0$	$0.75f_0$	f_0	$1.25f_0$	$2f_0$	$5f_0$	$10f_0$	$20f_0$	$50f_0$

- Do a quick sweep of the frequencies without taking any data to ensure your circuit is working properly.
  - o At very low (< 50 Hz) or very high frequencies (> 500 kHz) we expect almost no current (negligible voltage across the resistor). Use the AutoRange & MEASURE buttons to verify this
  - o Next, tune the function generator near f_0 on the function generator. Verify the current is large (voltage across the resistor should be large.
- Remember we will measure $V_{R\ max}$ using

$$V_{R\ max} = \frac{V_{R\ pk-pk}}{2}$$

This avoids having to think about any DC offset caused by the function generator.
- Now use the scope's MEASURE button to record the *actual* operating frequency and $V_{R\ pk-pk}$ near each target frequency. With the exception of resonance, you needn't hit the target frequency exactly…
  - o In your data table, record the *actual* operating frequencies measured in the experiment!
  - o $i_{max\ th} = \frac{V_{source\ max}}{Z}$ (calculate using *measured* values of $L, C, R, f, \& V_{source\ max}$)
  - o $i_{max\ exp} = \frac{V_{R\ max}}{R} = \frac{V_{R\ pk-pk}}{2R}$ (voltage *amplitude* across R over the measured value of resistance)

Tabulate i_{max} vs. ω for both sets of data.

Create a column of theoretical data. Use your equation for Z and the function generator voltage *amplitude* to determine an equation for $i_{max\ th}$ using the *measured* values of $R, L, C, V_{source\ max}$, and ω.
WATCH OUT! When using spreadsheet formulas, be sure you properly account for prefixes!!!

Plot i_{max} vs. ω for both theory and experiment on the same chart. Repeat for the second set of data. This graph should look like Sample Graph Type II in the appendices. Use a logarithmic scale for the ω-axis by right-clicking that axis and selecting "format axis". Look around for the Logarithmic check-box. Show the theory as a

smooth line with no points and show the experiment as points only with no smooth line. Since you have more than one set of data on the same graph you'll need a legend to explain the various curves.

For conclusion:

1) As frequency increases, the current in the impedance of the circuit asymptotically approaches what value?

2) Suppose one replaced the function generator in the circuit with an ideal battery with emf $\mathcal{E}$ & no internal resistance. Sketch a picture of such a circuit and clearly label the current through each element of the circuit and voltage across each element of the circuit. Each current will be either $\frac{\mathcal{E}}{R}$ or 0 and the voltages will be either $\mathcal{E}$ or 0.

3) In theory we said that the LC in parallel had infinite impedance at resonance. This is not strictly true. One can determine an estimate of the impedance at resonance by comparing the measured value of i_{max} at resonance to the theoretical maximum of $i_{th\ max\ at\ res} = \frac{V_{source\ max}}{R}$. Taking the ratio gives

$$\frac{i_{exp\ max\ at\ res}}{i_{th\ max\ at\ res}} = \frac{\frac{V_{source\ max}}{Z_{at\ res\ using\ experimental\ values}}}{\frac{V_{source\ max}}{R}} = \frac{R}{Z_{at\ res\ using\ experimental\ values}}$$

Use your experimental data to come up with an estimate for the experimental value of Z at resonance.

4) Compare the LC being in series (the previous lab) to the LC being in parallel (this lab). Sketch plots of Z vs ω and i_{max} vs ω for each type of circuit. Clearly label your work so it is easy to follow.

Note: ignoring the 50 Ω of internal impedance has no effect on our *measurement* of i_{max}. This is because we used

$$i_{exp\ max} = \frac{V_{R\ max}}{R}$$

Here $V_{R\ max}$ was voltage across *only the resistor* of in the circuit while R is *resistance* (not *impedance Z*).

==This is a good trick to remember.== Whenever you need to know the current in a particular part of a circuit, you can always measure the voltage across a resistor in that branch of the circuit then divide by R to get current.

5) HOWEVER, ignoring the 50 Ω of internal impedance does cause us to miscalculate our *theoretical* values. For each resistor used, were you over or underestimating? By what % in each filter circuit?