Laboratory 5: LC Resonant Circuits and Q Factor

We are going to be working with capacitors and inductors to make clocks. These will operate at frequencies too fast for you to count, so we need a device to measure short time intervals (*i.e.*, high frequencies). Meet our friend the *oscilloscope*.

A. Function Generator

We will help you set up a speaker attached to a *function generator*, which allows you to generate SHM electrical signals at will. These use the electricity and magnetism we just studied to move the speaker cloth back and forth at the frequency of the oscillation.

As you turn the **FREQUENCY** dial, you will hear the pitch of the sound change, observing the pitch ↔ frequency correspondence (higher pitch = higher f).

As you turn the **AMPL** dial, you will hear the loudness of the sound change, observing the loudness ↔ amplitude correspondence (louder = larger amplitude).

B. Oscilloscope – Qualitative

We now hook up a measuring device that will allow you to see a time-graph of the oscillation, graphing the voltage (electrical strength of the oscillation) over time. We will explain how this works and what you are looking at, but the key ideas are these:

1. The amplitude of the oscillation is measured vertically on the graph.
   The **VERTICAL SCALE** control sets how many Volts each vertical division on the screen stands for. Read the Volts/division on the lower left of the screen.
2. The timing of the oscillation is measured horizontally on the graph.
   The **HORIZONTAL SCALE** control sets how many seconds each horizontal division on the screen stands for. Read the seconds/division on the upper left of the screen.

Confirm this qualitatively by varying the timing and amplitude of the signal, and comment on what you observe on the oscilloscope screen.

C. Oscilloscope – Quantitative

Now we want you to make more quantitative measurements.

1. Set the oscilloscope controls to: . Vertical: 200 μs . . Horizontal: 200 mV .
2. Adjust the function generator to a signal with frequency of 500 Hz.
3. Adjust the function generator to a signal with amplitude 600 mV (3 divisions).
   Change the vertical scale to 500 mV then 1.00 V, and make note of the number of divisions. Confirm that although you changed the vertical scale, the measurement is still 600 mV.
4. Count horizontal divisions for one cycle of the sine curve, and confirm that the period of the oscillation is 2.0 ms (10 divisions). [**T = 1/f = 1/500 s = 2 ms**]
   Change the horizontal scale to 500 μs then 1.000 ms, and confirm that although you changed the horizontal scale, the period is still 2.0 ms.

D. LC Resonant Circuit

Now we want you to make quantitative measurements of an oscillating circuit.
On the breadboard at your station, we have set up a circuit with an inductor (L) and a capacitor (C). These act like an inertial and restoring element, respectively, so they determine the natural oscillation of the circuit. We will show you how to connect the oscilloscope to the circuit to measure its output voltage, the amplitude of the oscillation.

1. On the breadboard, we have indicated the approximate natural frequency of the circuit. Set your function generator near that frequency, and get a clear picture on the oscilloscope.
2. Vary the frequency of the function generator above and below that frequency, and note what happens to the picture. (Amplitude should peak somewhere).
3. Adjust the function generator to find the actual frequency that gives the largest amplitude. This is the natural frequency of the oscillator, $\mathbf{f_0}$.
4. Adjust the amplitude of the function generator to get a value of V_{max} at this natural frequency that will be easily divisible by 4 (like 2.0 V, 1.0 V, 0.8 V, …).

E. Resonance Peak and Q-factor

Now we want you to make seven frequency measurements to map out the resonance peak. You want to find the frequencies at which the amplitude of the circuit is simple quarter-fractions of the largest amplitude you found at the natural frequency, f_0.
For instance, if your maximum voltage at f_0 is V_0, find frequencies that give amplitudes:

$$\{ \tfrac{1}{4} V_0,\ \tfrac{1}{2} V_0,\ \tfrac{3}{4} V_0,\ V_0,\ \tfrac{3}{4} V_0,\ \tfrac{1}{2} V_0,\ \tfrac{1}{4} V_0 \}$$

This will be a series of seven frequencies from low to high. The center one is f_0.

F. Analysis

1. First, carefully plot the Voltage *vs*. frequency graph that you found.
2. Then, calculate the Full Width at Half Maximum, Δf, by taking the difference between your two half-amplitude frequencies.
3. Then, calculate the Q-factor for your circuit: $Q = \dfrac{f_0}{\Delta f}$

Lab Write-up

For the function generator/oscilloscope part of the lab, explain what you learned about oscillations, sound, and what you measured with an oscilloscope and how you did it.

For the LC Circuit part, describe what you did and how you understand what you saw.

Give your resonance peak and your calculation of the Q-factor.

- Based on your reading from J & F-R, what does that Q-factor mean?
- Would this oscillator be a candidate for a good clock?