Lab 11
Series Resonant Circuit

OBJECTIVES
1. Validate the basic equations for the resonant frequency of a resonant circuit.
2. Plot the various voltages and current for a resonant circuit versus frequency.
3. Verify that the input impedance is a minimum at the resonant frequency.

EQUIPMENT
Lab Kit, oscilloscope, and Function Generator

THEORY
Inductive reactance increases as the frequency is increased, but capacitive reactance decreases with higher frequencies. Because of these opposite characteristics, for any LC combination, there must be a frequency at which the \( X_L \) equals the \( X_C \) because one increases while the other decreases. This case of equal and opposite reactances is called resonance, and the ac circuit is then a resonant circuit.

In a series RLC circuit, the one frequency at which \( X_L = X_C \) is called the resonant frequency define as

\[
\frac{1}{2\pi\sqrt{LC}}
\]

At this frequency the circuit is in resonance, and the input voltage and current are in phase. At resonance, the circuit is resistive in nature and has a minimum value of impedance and a maximum value of current. This can be seen by solving for current in a series RLC circuit:

\[
I = \frac{V_S}{Z_T} = \frac{V_S}{\sqrt{R^2 + (X_L - X_C)^2}}
\]

As for the voltages, the voltage across the resistor, \( V_R \), has exactly the same shape as the current, since it differs by the constant \( R \). \( V_R \) is a maximum at the resonance. \( V_C \) and \( V_L \) are equal at resonance \( (f_R) \) since \( X_L = X_C \), however, note that they are not maximum at the resonant frequency. At frequencies below \( f_R \), \( V_C > V_L \); at frequencies above \( f_R \), \( V_L > V_C \).

PROCEDURE
Part 1: Low-Q Circuit
Construct the following circuit.

\[
\text{Vs} \quad 8\text{Vac} \quad 200 \quad 0.1\mu\text{F} \quad 25\text{mH} \quad R \quad C \quad L
\]

a. **Predict** the (i) resonant frequency \( f_{R,\text{thy}} \), the (ii) current at resonance \( I_{p-p,\text{thy}} \) and the (iii) equivalent impedance \( Z_{\text{eq,thy}} \) at resonance.

b. Use PSpice to plot the current \( I_{p-p} \) and \( V_R, V_L, V_C \) verses frequency using a linear AC sweep from 500 Hz to 5500 Hz.
c. Maintaining 8 V (p-p) at the input to the circuit, record the voltage $V_{L(p-p)}$ for the frequencies appearing in Table 1. Make sure to check constantly that $V_S = 8 V (p-p)$ with each frequency change.

Table 1: Low Q Measurements

<table>
<thead>
<tr>
<th>f(Hz)</th>
<th>$V_{L(p-p)}$</th>
<th>$V_{C(p-p)}$</th>
<th>$V_{R(p-p)}$</th>
<th>$I_{p-p} = \frac{V_{R(p-p)}}{R}$</th>
<th>$Z_{eq} = \frac{V_{p-p}}{I_{p-p}}$</th>
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<tbody>
<tr>
<td>500</td>
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<td>1000</td>
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<td>5500</td>
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<td>$f_R$</td>
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<td>0.90$f_R$</td>
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<td>0.95$f_R$</td>
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<td>1.05$f_R$</td>
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<td>1.10$f_R$</td>
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</table>

Table 1: Low Q Measurements (continued)

d. Turn off the supply and interchange the positions of C and L in the circuit. Measure $V_{C(p-p)}$ for the same range of frequencies. Again, turn off the supply and interchange the positions of R and C in the circuit and measure $V_{R(p-p)}$ for the same range of frequencies. Take additional readings near the resonance frequency.

e. Complete Table 1 by computing the current $I_{p-p}(low \ Q)$ and the total impedance $Z_{eq}$.

f. Plot the total impedance $Z_{eq}$ (low Q) versus frequency and clearly label the curve.

g. Compare the predicted $Z_{eq,thy}$ and measured $Z_{eq,expt}$ at resonance using a percent difference. How do they compare?

h. Describe in a few sentences how the total impedance of a series resonant circuit varies with frequency. Which element has the most influence on the input impedance at the low and high ends of the frequency spectrum?

i. Plot the current $I_{p-p}$ versus frequency and clearly label the curve.

j. Compare the predicted $(I_{p-p})_{thy}$ and measured $(I_{p-p})_{expt}$ at resonance using a percent difference. How do they compare?

k. Describe in a few sentences how the current of a series resonant circuit varies with frequency.

Voltagess $V_L$, $V_C$, and $V_R$ versus Frequency

l. Plot the voltages $V_{L(p-p)}$, $V_{C(p-p)}$, and $V_{R(p-p)}$ versus frequency on the same graph. Label each curve clearly.

m. At what frequency are $V_R$, $V_L$, and $V_C$ a maximum? Record your data in a table.
Part 2: Higher-Q Circuit

We will now repeat the preceding analysis for a higher-Q (more selective) series resonant circuit by replacing the 200Ω resistor with a 30Ω resistor and note the effect on the various plots.

a. Use PSpice to plot the higher-Q current $I_{p-p}$ and $V_R$, $V_L$, $V_C$ verses frequency using a linear AC sweep from 500 Hz to 5500 Hz.

b. Repeats parts (1c) – (1m) and answer the following questions:

- How has the shape of the $Z_{eq}$ curve changed? Is the resonant frequency the same even though the resistance was changed? Is the minimum value still equal to $R_{eq} = R + R_L$ where $R_L$ is the internal resistance of the inductor.
- Is the maximum current the same, or has it changed? Calculate the new maximum and compare to the measured graph value. How do they compare?
- At what frequency are $V_R$, $V_L$, and $V_C$ a maximum? Record your data in a table.
- Does the maximum value of $V_R$ continue to occur at the same frequency noted for the current $I$?
- Are the frequencies at which $V_L$ and $V_C$ reached their maximums closer to the resonant frequency than they were for the low-Q circuit? In theory, the higher the Q, the closer the maximums of $V_L$ and $V_C$ are to the resonant frequency.

<table>
<thead>
<tr>
<th></th>
<th>$V_L(p-p)$</th>
<th>$V_C(p-p)$</th>
<th>$V_R(p-p)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>low Q</td>
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<tr>
<td>high Q</td>
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- Did $V_C$ peak before $f_R$ while $V_L$ peak above $f_R$ as noted in the theory?
- Does the maximum value of $V_R$ occur at the same frequency as the maximum value of current $I$?