UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 9 – RESONANCE IN SERIES AND PARALLEL RLC NETWORKS

OBJECTIVES

In this experiment the student will investigate resonance in RLC networks by

- Determining the theoretical parameters of series and parallel networks,
- Comparing the theoretical results to experimental results.

MATERIALS/EQUIPMENT NEEDED

Function Generator (capable of 20 $V_{p\text{-}p}$, variable frequency)
Oscilloscope
Inductor: 300mH
Capacitor: 0.001µF
Resistor: 500Ω

INTRODUCTION

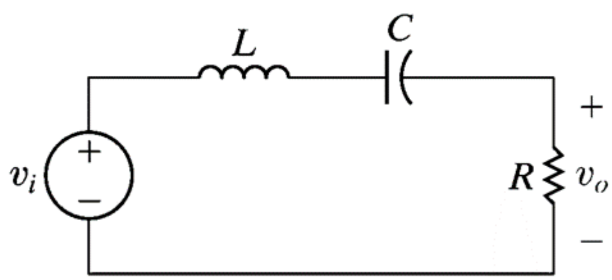
Resonance in AC circuits implies a special frequency (called the resonant frequency) determined by the values of the circuit elements. This frequency is designated f_r in hertz and ω_r in radians/second, and is the frequency at which the series resonant circuit will exhibit minimum impedance and the parallel resonant circuit will exhibit a very large impedance. If capacitors and inductors were ideal (i.e., no series or parallel resistance) the definition of resonant frequency would be much simpler. In most applications the primary concern with capacitors is the parallel resistance which gives rise to a parallel leakage current. However, if the capacitor is properly chosen, this resistance will be 100 MΩ or more, and will cause little difficulty. In addition to inductance, inductors will have a series resistance and possibly a parallel capacitance of concern. The series resistance is simply the resistance of the wire used to wind the inductor and may significantly increase at frequencies in the MHz range as a result of the skin effect. The parallel capacitance is due to the distributed capacitance between the windings and is also of greater concern in higher frequency applications. For the purposes of this experiment we will assume the capacitor and inductor are ideal.

In addition to the resonant frequency, resonant circuits also exhibit lower and upper half-power frequencies or break frequencies designated as f_1 and f_2, respectively. These are the frequencies below and above the resonant frequency at which the power absorbed by the network falls to 50% of its maximum value. At these frequencies, the magnitude of the current into a voltage-driven, series-resonant network and the magnitude of the voltage across a current-driven, parallel-resonant network are 0.707 of their maximum value.

This 0.707 value results from the fact that both current and voltage are proportional the square-root of power and the square-root of 0.5 is 0.707. Since 3dB is equivalent to half-power, these frequencies are also referred to as the 3 dB frequencies. The difference between the upper and lower half-power frequencies is the bandwidth (BW).

Series Resonance

The resonance of a series RLC circuit occurs when the inductive and capacitive reactance are equal in magnitude but cancel each other because they are 180 degrees apart in phase. The impedance of an RLC series circuit at resonance is simply R.



$$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\phi_z = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$\omega_r = \sqrt{1/LC} = \sqrt{\omega_{c1}\omega_{c2}}$$

$$B = \omega_{c2} - \omega_{c1} = R/L$$

$$Q = \frac{\omega_r}{B}$$

At Resonance

$$|Z| = R$$

$$|X_L| = |X_C|$$

$$\phi_z = 0$$

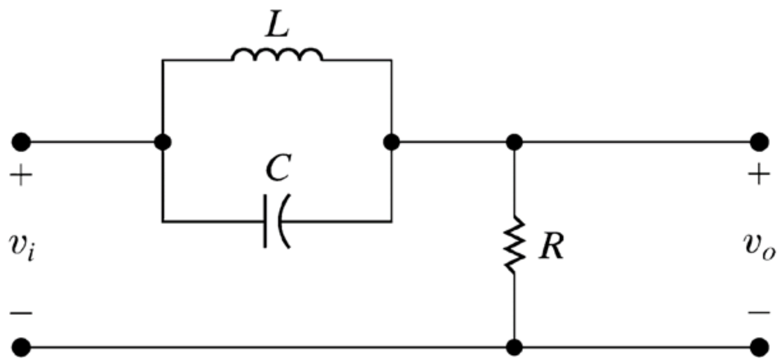
Figure 9-1 Series RLC circuit

Series-Parallel Resonance

Parallel resonance is more difficult to define due to the fact that in real life the inductor will have a resistive value. There are three methods for defining parallel resonance, each resulting in a different resonant frequency. For the parallel resonant circuit the three different definitions are:

1. The frequency at which X_L=X_C.
2. The frequency at which the parallel impedance is maximum.
3. The frequency at which the current is in phase with the voltage.

For the voltage-driven, parallel network in this experiment, the break frequencies f_1 and f_2 can also be defined as the frequencies below and above f_r where the magnitude of the current is 1.414 of its minimum value. Recall that f_r for a parallel resonant circuit is the frequency for which the impedance is maximum and the current is minimum.



$$\omega_r = \sqrt{1/LC} = \sqrt{\omega_{c1}\omega_{c2}}$$

$$B = \omega_{c2} - \omega_{c1}$$

$$Q = \frac{\omega_r}{B}$$

Figure 9-2 Series-Parallel RLC circuit

Selectivity (S) and Quality Factor (Q)

The selectivity (S) is the ratio of the resonant frequency to the bandwidth (B). The quality factor (Q) is the ratio of the maximum energy stored in the network to the average energy dissipated per radians/second under conditions of resonance. For high Q circuits the selectivity and quality factor are nearly equal and often in practice are used interchangeably.

PRELAB

1. In Figure 9-1, assume that C = 0.001 µF, L = 300 mH, R = 500 Ω, and V_{in} = 20 Vp-p (peak-to peak). Determine the resonant parameters f_r , Q, f_1, f_2 , B. Also, determine the magnitude (peak-to-peak) and the phase of the current, I, when the frequency is f_r, f_1, and f_2.
2. For the network of Figure 9-2, assume that C = 0.001 µF, L = 300 mH, R = 500 Ω, and V_{in} = 20 Vp-p (peak-to peak). Determine the resonant parameters f_r , Q, f_1, f_2 , B. Also, determine the magnitude (peak-to-peak) and the phase of the current, I, when the frequency is f_r, f_1, and f_2.

Table 9-1: PreLab Results

RLC Circuit	f_r	f_1	f_2	I_{fr}	I_{f1}	I_{f2}	Q	B
Series								
Series-Parallel								

INSTRUCTOR'S INITIALS: ____________ DATE: ____________

PROCEDURE

Series RLC Circuit Resonance

1. Connect the network of Figure 9-1 using the element values of part 1 of the pre-lab.
2. **Note:** Measure the internal resistance of the decade inductor box when it is adjusted for 300 m H. This could be helpful in the case you observe differences in the resonant parameters obtained in the pre-lab calculations. , and may need to modify your range of measurement accordingly.
3. Using an oscilloscope, measure the peak-to-peak magnitude and the phase of the current for frequencies between f_r - 2B to f_r + 2B. Maintain the voltage, V, at 20 volts peak-to-peak.

Note: Measure the voltage across the resistor, R, and convert to current.

Series-Parallel RLC Circuit Resonance

1. Connect the network of Figure 9-2 using the element values of part 2 of the pre-lab.
2. Using an oscilloscope, measure the peak-to-peak magnitude and the phase of the current for frequencies between f_r - 2B to f_r + 2B. Maintain the voltage, V, at 20 volts peak-to-peak.

Note: Measure the voltage across the resistor, R, and convert to current.

DATA/OBSERVATIONS

Table 9-2: Experimental Results for Series RLC Circuit

V_{in}	V_{out}	Current Phase	Frequency	Current

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Table 9-3: Experimental Results for Series-Parallel RLC Circuit

V_{in}	V_{out}	Current Phase	Frequency	Current

INSTRUCTOR'S INITIALS:		DATE:	

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. From the experimental data, plot the peak-to-peak magnitude vs. frequency and the phase angle of current vs. frequency for the series circuit. Indicate on the graph the frequencies f_r, f_1, and f_2.
2. Compare the calculated and the experimental values for f_r, f_1, f_2, B, and magnitude (peak-to-peak) and the phase of the current, I, when the frequency is f_r, f_1, and f_2 for the series circuit.
3. From the experimental data, plot the peak-to-peak magnitude vs. frequency and the phase angle of current vs. frequency for the series-parallel circuit. Indicate on the graph the frequencies f_r, f_1, and f_2.
4. Compare the calculated and the experimental values for f_r, f_1, f_2, B, and magnitude (peak-to-peak) and the phase of the current, I, when the frequency is f_r, f_1, and f_2 for the series-parallel circuit.
5. Explain what happens to the resonant parameters of the two circuits when the load resistance, R, of the network is (a) decreased and (b) increased.

Be sure to include all items from the post-lab exercise above in your written lab report.