KARADENİZ TECHNICAL UNIVERSITY
Faculty of Engineering
Electrical and Electronics Engineering Department

EEE2006 CIRCUITS-II LAB

RESONANCE CIRCUITS

PRELIMINARY WORK

1. Explain the resonance state in series resonance circuits theoretically and draw a sample graph showing the change of current with frequency.
2. Explain the resonance state in parallel resonance circuits theoretically and draw an example graph showing the change of current with frequency.
3. What is phase difference? For series and parallel circuits, draw a sample graph showing the change in phase difference with frequency.

NOTE: Come to the experiments by preparing the preliminary work as a report (with the report cover). Those without a preliminary report cannot participate in the experiments.

SERIES AND PARALLEL RESONANCE CIRCUITS

1. Introduction

A circuit consisting of a capacitor and a self is called a resonance circuit. In this type of circuit, the magnetic energy of the self is periodically transformed into the electrical energy of the capacitor. The period of this transformation is determined by the values of the self and the capacitance.

$$f_0 = \frac{w_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

2. Series Resonance

Series resonance circuits are obtained by connecting a inductor and a capacitor in series.

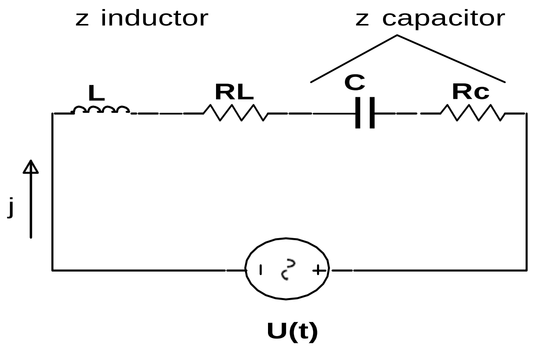

Figure 1. Equivalent series resonance circuit

In Figure 1, R_L is the loss resistance of the self and R_C is the loss resistance of the capacitor. Since capacitors can be manufactured with very small losses in practice, we will take Rc = 0 Ω in our calculations.

The current I flowing through the circuit will cause a voltage drop U_R = I. R_L across the resistor R_L in the same direction as the current, a voltage drop U_L=I.wL across the self shifted 90° from the current and a voltage drop Uc=1 / wC across the capacitor shifted 90° from the current.

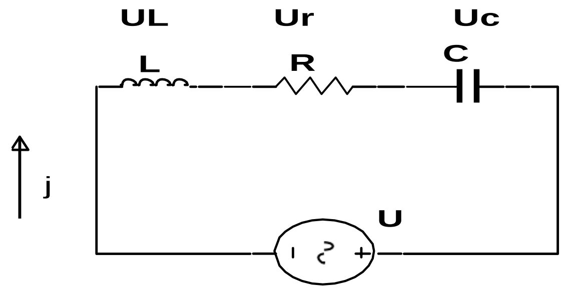

Figure 2. İdeal series resonance circuit

Draw the current-voltage phasor diagram of the circuit for any frequency. In the phasor diagram in Figure 3, I current is taken as reference.

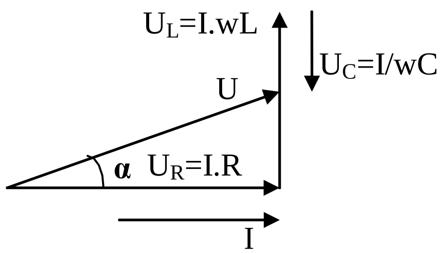

Figure 3. Phasor diagram of a series resonance circuit

In Figure 3, the voltage U acting on the circuit is shifted forward by an angle α against the current I flowing in the circuit. The phase shift between U and I can take positive, negative or $\alpha = 0$ values according to the values of U_L and Uc. (In general $-90° < \alpha < 90°$). Since U_L and U_C depend on w, it is necessary to draw a separate phasor diagram for each frequency. When $\alpha = 0$, i.e. $U_L = U_C$ in this circuit, the circuit is at resonance. At resonance, when R_L is smaller than wL, the voltage across the capacitor and inductor is much larger than the input voltage. At resonance frequency, U_L and U_C are obtained from the equation as follows.

$$I.w_0 \cdot L = I \cdot \frac{1}{w_0 C} \qquad w_0^2 = \frac{1}{LC} \qquad w_0 = \frac{1}{\sqrt{LC}}$$

At resonance, the input resistance Rg of the circuit takes its smallest value. Input resistance $R_g(jw)$;

$$Rg(jw) = R_L \cdot j\left(wL - \frac{1}{wC}\right) = R_L^2\left(wL - \frac{1}{wC}\right)^2 \cdot e^{j\mathrm{arctg}\frac{wl - \frac{1}{wC}}{R_L}}$$

Since the module of the input resistor $|R_g(jw)|$ varies with frequency as shown in Figure 4, as resonance is approached, the input current I grows although the input voltage U remains constant. The current peaks at resonance and decreases again when the frequency exceeds the resonance frequency. The change of $R_g(jw)$ with frequency depends on the quality of the circuit. The higher the quality of the filter, $R_g(jw)$ falls and rises faster with frequency. The quality of the circuit is inversely proportional to the bandwidth of the circuit.

To find the bandwidth, the frequencies with resistance R=$\sqrt{2}|R_g|$ are found in the curve. $\Delta w = w_U - w_L$ (w_U upper cutoff frequency, w_L lower cutoff frequency) gives the bandwith of the filter. As Δw gets smaller, the quality of the filter rises. The quality of the filter is measured by the quality factor Q. The value of Q is found as

$$Q = \frac{w_0}{\Delta w} = \frac{f_0}{f_U - f_L}$$

Q is also defined as the ratio of the energy accumulated in the circuit to the power dissipated in one period and Q is defined as Q = $(w_0.L)/R = 1/(w_0.R.C)$.
When the quality factor of the circuit is desired to be large, it is seen that the self-induction should be large and the resistance should be small. Technically, resonance circuits are of great importance when they are used as filters.

This experiment aims to introduce the behavior of resonance circuits. You will try to find the phasor diagrams that you can find for each frequency by calculation by measuring them in the experiment.

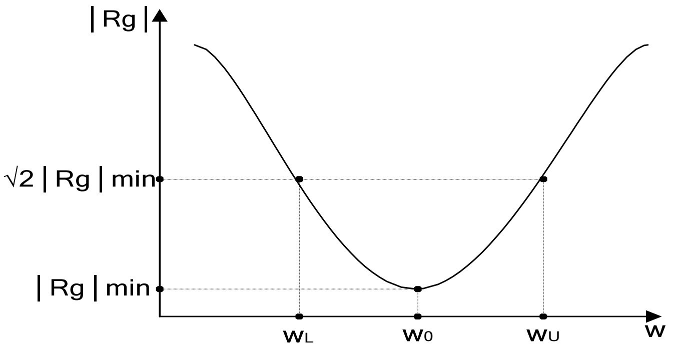

Figure 4. Change of the amplitude of the input impedance of a series resonance circuit with frequency

3. Preliminary Work Required for the Experiment:

Study the phasor diagrams and calculation of the circuit from the book "Elektroteknik" Ahmet Akhunlar p.298.

4. Experiment Preparation

Experiment 1. Series Resonance Circuit

Set up the circuit in Figure 5. Set the value of the circuit elements as R=400 Ω, L=0.343 H, C=0.3 µF.

1) Keeping the voltage U1 constant (1V), draw the change of the current flowing through the circuit with frequency on millimeter paper.
2) With the help of an oscilloscope, find the phase difference between the current flowing through the circuit and the voltage U1 at various frequencies and draw it on millimeter paper.
3) Measure the resonance frequency with an oscilloscope. Compare it with the resonance frequency you calculated.
4) Show whether the functions you find are compatible with the theory.

5) Find the lower cut-off frequency, upper cut-off frequency, bandwidth and quality factor of the circuit.
6) Find the resonance frequency, bandwidth and quality factor by changing the resistance of the circuit by 800 Ω. Explain the reasons for any change in these values.

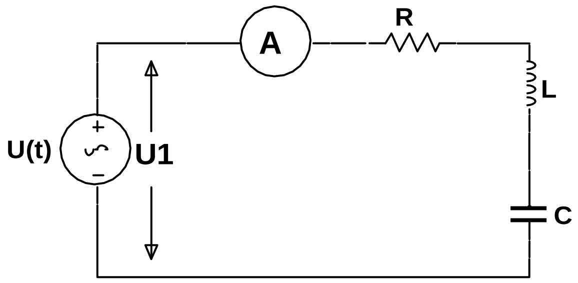

Figure 5. Series resonance circuit (For experiment)

5. Parallel Resonance Circuit

Parallel resonance is obtained by connecting a capacitor and a inductor in parallel. In Figure 6, R_L and R_C are the loss resistances of the coil and capacitor. Since the losses in the capacitor are very small, Rc=∞.

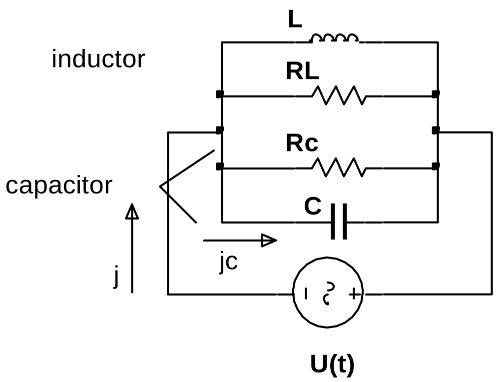

Figure 6. Parallel resonance circuit

Draw the phasor diagram with reference to the voltage in the circuit. The current in Figure 7 will be shifted back by 90° with respect to the voltage I_L=U/wL. The current flowing through the resistor R_L will be in the same direction as the voltage I_{RL}= U/R_L. The current flowing through the capacitor will be shifted 90° forward with respect to the voltage I_C =U.wC.

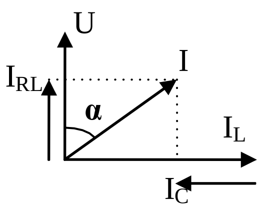

Figure 7. Phasor diagram of parallel resonance circuit

I_C ile I_L nin değerleri frekansla değiştiğinden gerilim U ile akım I arasındaki α açısı -90 <α <90 arasındaki her değeri alabilmektedir.
Since the values of I_C and I_L change with frequency, the angle α between voltage U and current I can take any value between -90 < α <90. When $I_C=I_L$, the circuit is said to be in resonance. The resonance frequency is given by the equation $I_L=I_C$;

$$U.w_0C = \frac{U}{w_0L} \qquad w_0^2 = \frac{1}{LC} \qquad w_0 = \frac{1}{\sqrt{LC}}$$

At the resonance frequency the conductivity of the circuit is smallest.

$$G = \frac{1}{R_L} + j\underbrace{\left(w_0C - \frac{1}{w_0L}\right)}_{=0} = \frac{1}{R_L}$$

At resonance, the current entering the circuit is smallest, while the currents flowing through the self and capacitor are quite large.

The quality factor of the parallel resonance circuit is found from the bandwidth of the circuit as in the series resonance circuit and is Q= $w_0/\Delta w$. Furthermore, by going from the definition of Q = electrical energy accumulated in the circuit / power consumed in a period, it is found as follows.

$$Q = \frac{R_L}{w_0L} = w_0R_LC$$

6. Experiment Preparation

Experiment 2. Parallel Resonance Circuit

Set up the circuit in Figure 8.

1. Keeping the voltage U1 constant, find the change of the current I entering the resonance circuit with frequency.
2. Calculate the quality factor.

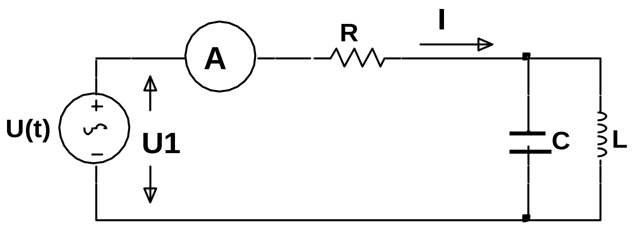

Figure 8. Parallel resonance circuit (For experiment)**.**

IMPORTANT NOTE: In order to perform the experiments properly, preliminary work must be done and the theoretical part of the methods must be well known.