

Practical No. 4 SERIES RESONANT CIRCUIT

Aim

The aim of this experiment is to investigate the frequency response of the current in the series and parallel RLC circuit and to observe performance of the circuit at resonance.

Equipment

- Resistor 20 Ω
- Capacitor 0.1μF
- Inductor 10 mH
- Function Generator
- Oscilloscope
- NetLab

Introduction

An AC circuit is in resonance when the input current is in phase with the supply voltage thus behaving as a purely resistive circuit. A diagram of the series resonant circuit is shown in Figure 1. The resonant frequency can be calculated using the equation (1). As can be noticed the resonant frequency does not depend on the resistance value.

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz} \quad \text{also:} \quad |X_L| = |X_C| = \omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC} \quad (1)$$

The magnitude of the circuit current I varies with the frequency f of the supply voltage V_{in} according to the equation (2). A typical variation of this current vs. frequency is shown in Figure 2. As can be seen from the graph, in a series resonant circuit the current reaches its maximum value at resonant frequency. At resonance the magnitude of the current is limited just by the circuit resistance, and can reach very high values if this resistance is small as can be seen from Figure 2.

$$|I| = \frac{|V_{in}|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \quad (2)$$

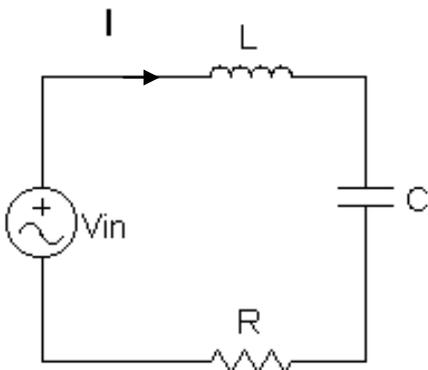


Figure 1 (Series RLC circuit)

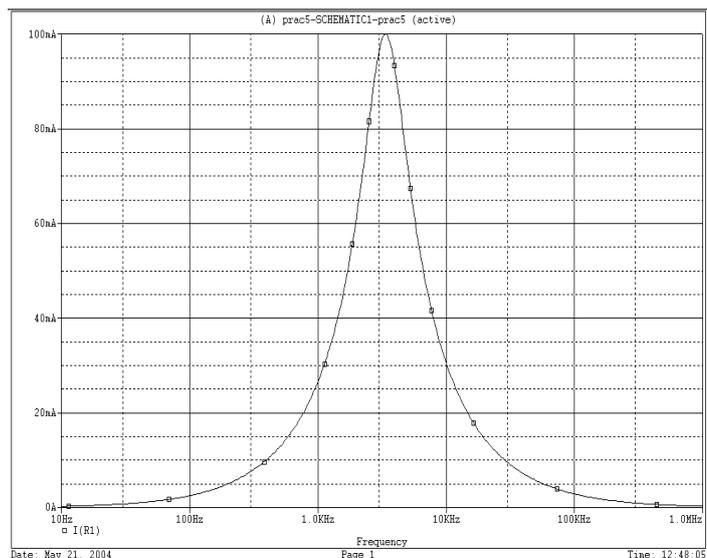


Figure 2 (Note: this plot is a general shape, it is not scaled for the circuit in Figure 4)

More information on series resonant circuit can be found in Chapter 21 of your textbook [1].

The *Quality factor*, Q_s is a measure of the selectivity (sharpness) of the resonance peak, as shown in Figure 3a, and can be calculated from:

$$Q_s = \frac{2\pi f_0 L}{R} = \frac{1}{2\pi f_0 CR} \quad (3)$$

The *Bandwidth*, $B = \Delta f$, is the difference between the *two frequencies* where the power dissipated by the circuit falls to one half of the peak power. At these frequencies the value of the current drops to the 0.707 of its peak value as shown in Figure 3b. It can be shown that the bandwidth depends on the ratio of resistance to inductance: the bigger the resistance the wider the bandwidth. The bandwidth does not depend on the capacitance:

$$B = f_H - f_L = \frac{f_0}{Q_s} \quad (4)$$

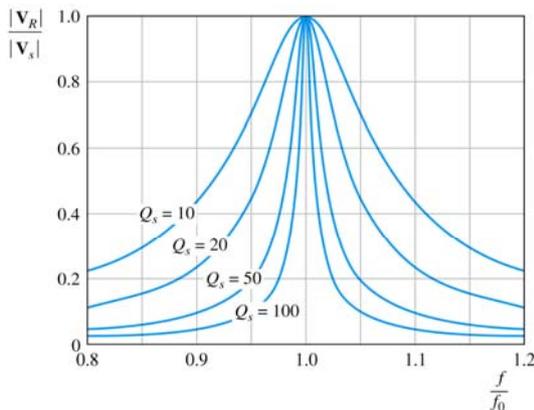


Figure 6.25 Plots of the transfer-function magnitude $|V_R/V_s|$ for the series resonant bandpass-filter circuit.

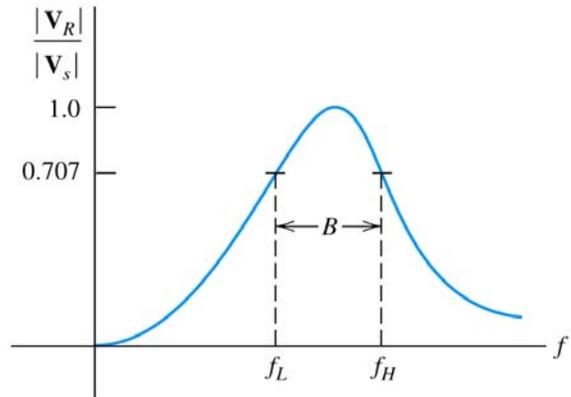


Figure 6.26 The bandwidth B is equal to the difference between the half-power frequencies.

Figure 3 a) and b) (from [1])

At resonance, magnitudes of voltages across circuit elements can be calculated as:

$$V_R = V_{in} \quad V_C = V_L = Q_s V_{in} \quad (5)$$

From this we can see that capacitor and inductor voltages at resonance can be many times larger than the input voltage. The Q factor can be in order of 1000s and is therefore also known as magnifying factor.

Preparation

For the circuit shown in Figure 4 calculate:

- the resonant frequency, the Q factor and the bandwidth
- the magnitude of the circuit current at resonant frequency
- half power frequencies (f_L and f_H)

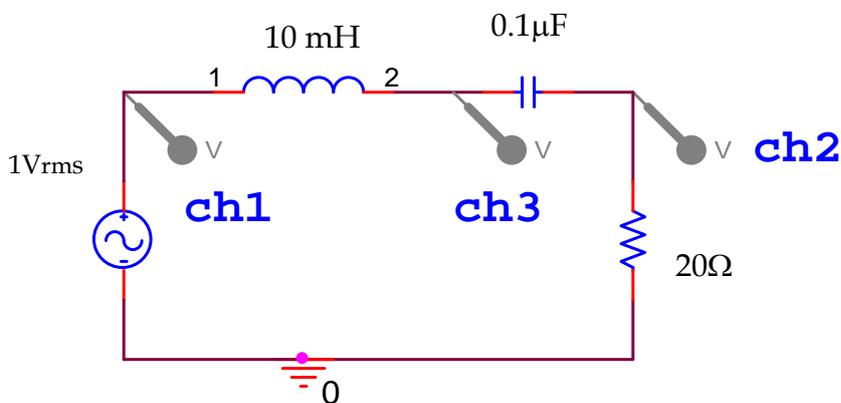


Figure 4

Experiment

1. Log on to the NetLab. Once the connection is established use the chat window to communicate with other members of your group. Also, switch on the camera to see what is happening in the remote lab.
2. Conduct the remote experiment as following:
 - a. Use the Circuit Builder to connect Channel 1 of the oscilloscope to the output of the signal generator (also called Function Generator). Configure the circuit.
 - b. Switch on the signal generator and the oscilloscope.
 - c. Set the waveform of the supply voltage to sinusoidal wave on the signal generator, the magnitude to 1Vrms and frequency to 1kHz.
 - d. Check the voltage using the oscilloscope GUI.
 - e. Now, using the Circuit Builder wire the circuit shown in Figure 4. Press the configure button to activate the circuit.
 - f. The supply voltage should be displayed on channel 1 of the oscilloscope and the voltage across the resistor on Channel 2. Note that the resistor voltage is in phase with the circuit current.
 - g. Vary the frequency of the supply voltage to detect the resonance in the circuit. (Hint: at resonance supply voltage and the current are in phase; also the current has the maximum magnitude at resonance).
 - h. Write down the resonant frequency that you have obtained.
 - i. Display channel 3 waveform on the oscilloscope. Change the time scale and voltage magnitude scale for all 3 channels so you can clearly see all three signals.
 - j. Save data from all 3 channels.
 - k. Measure the circuit current magnitude for both half power frequencies.
 - l. Switch off the function generator and the digital storage oscilloscope.
 - m. Disconnect the circuit in Circuit Builder (select the whole circuit and press Delete button on your keyboard).
3. Log off from NetLab by closing the Web browser.

Report

- (a) Using the measured value of the resonant frequency and the value of the capacitance calculate the value of the inductance L. Compare with the specified value.
- (b) Use MATLAB:
 - to find the magnitude of the capacitor and inductor voltages (Hint: $V_C = V_{ch3} - V_{ch2}$, and $V_L = V_{ch1} - V_{ch3}$) at resonance;
 - to determine the magnitude of the current at resonance.
- (c) Calculate the Q factor and the Bandwidth (Hint: use equations (4) and (5)).
- (d) Use OrCAD or Multisim:
 - to simulate in frequency domain the circuit shown in Figure 4 with the value of the inductance from (a);
 - to plot the frequency response of the current magnitude;
 - from the plot determine the resonant frequency and the current magnitude at the resonant frequency;
 - to determine the Q factor and the Bandwidth from the same plot;
 - to determine half power frequencies from the same plot.
- (e) Compare the simulation results from OrCAD or Multisim with the recorded experimental results and the values calculated in preparation. Tabulate all results for easier comparison. Comment on any discrepancies.

References

- [1] A.H.Robins & W.C.Miller, Circuit analysis: Theory and practice 4th ed.: Thomson Delmar Learning, 2007).