

Experiment 5: Resonance in RLC Circuits

Objective:

The objective of this experiment is to study the phenomenon of resonance in *RLC* circuits. You will determine the resonant frequency and bandwidth of a network by observing the amplitude response to a sinusoidal voltage source.

Background:

A resonant circuit, also called a tuned circuit, consists of an inductor and a capacitor together with a voltage or current source. It is one of the most important circuits used in electronics. For example, a resonant circuit, in one of many forms, allows us to tune into a desired radio or television station from the vast number of signals that are around us at any time.

A network is in resonance when the voltage and current at the network input terminals are in phase and the input impedance of the network is purely resistive.

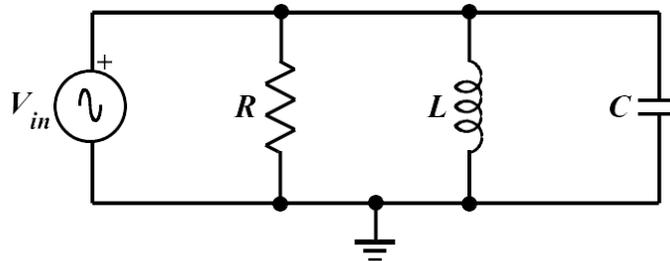


Figure 1: A Parallel *RLC* Circuit.

Consider the parallel *RLC* circuit of Figure 1. The steady-state admittance of the circuit is:

$$Y = \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)$$

As mentioned above, resonance occurs when the voltage and current at the input terminals are in phase. This corresponds to a purely real admittance, and the necessary condition is given by:

$$\omega C - \frac{1}{\omega L} = 0$$

The resonant condition may be achieved by adjusting L , C , or ω . Keeping L and C constant, the resonant frequency ω_0 is given by:

$$\omega_0 = \frac{1}{\sqrt{LC}} \text{ rad/s} \quad (1)$$

OR

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hertz} \quad (2)$$

“Frequency Response” is a plot of the magnitude of the output voltage of a resonant circuit as a function of frequency. The response, of course, starts at zero, reaches a maximum value in the vicinity of the natural resonant frequency, and then drops again to zero as ω becomes infinite – as shown in Figure 2.

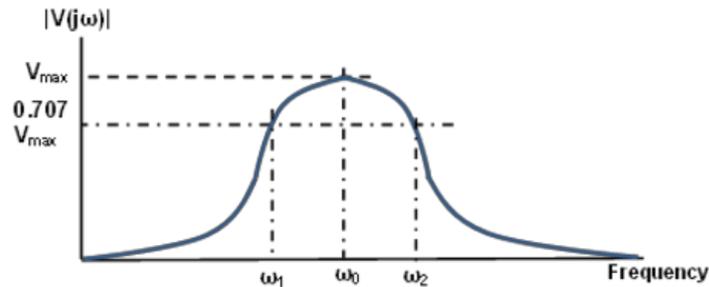


Figure 2: Frequency Response of a Parallel *RLC* Circuit.

The two additional frequencies shown in Figure 2, ω_1 and ω_2 , are called half-power frequencies. These frequencies correspond to points on the curve at which the voltage response is $1/\sqrt{2}$ or 0.707 times its maximum value. They are used to determine the half-power “bandwidth” of the response curve, defined as:

$$B = \omega_2 - \omega_1 \quad (3)$$

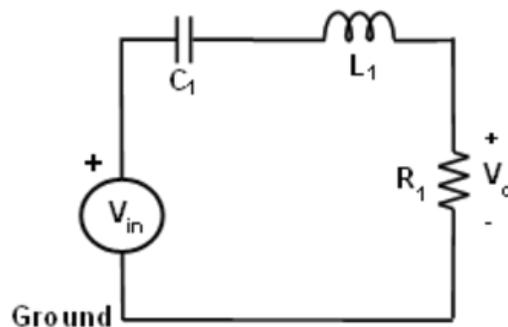


Figure 3: A Series *RLC* Circuit.

Materials:

ADALM2000 Active Learning Module, with Scopy software

Breadboard and jumper wire kit

1 100 Ω resistor1 1 k Ω resistor1 1 μ F capacitor

1 20 mH inductor (2 x 10 mH inductors in series)

Hardware Setup:

Set up the circuit shown in Figure 4 on your breadboard.

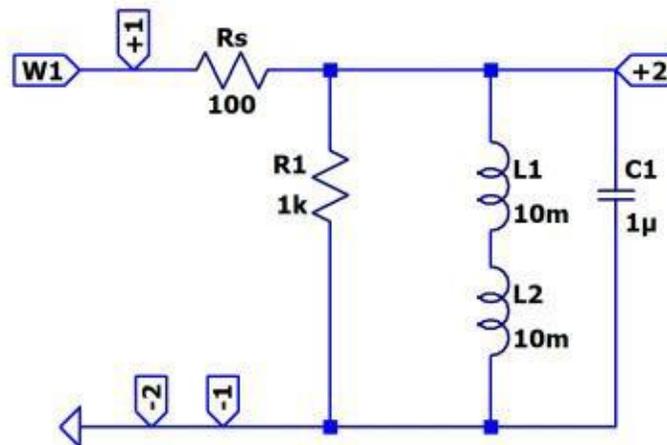


Figure 4: Parallel Resonant Circuit.

Your breadboard should look similar to the following:

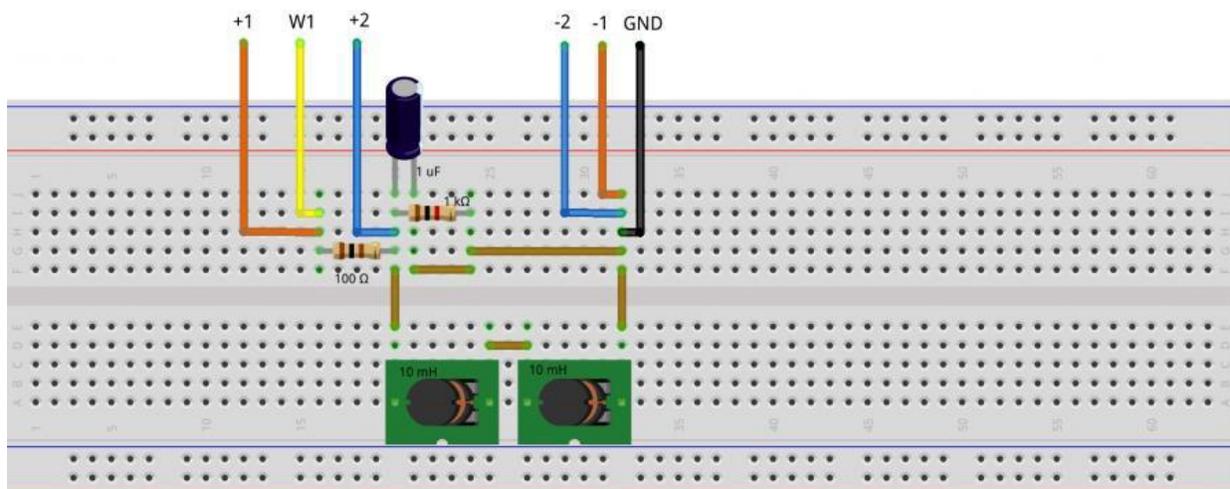


Figure 5: Breadboard Construction of the Parallel Resonant Circuit.

Procedure:

Using the Network Analyzer tool you can plot the frequency response of the resonant circuit. Start by computing the resonant frequency using equation (1). According to this, set the logarithmic sweep parameters. In this case, the resonant frequency is 1.1 kHz, so the sweep could start from 100 Hz and go to 10 kHz. Set the minimum phase at -90° and the maximum phase at $+90^\circ$. Set the magnitude axis to span from -15 dB to 0 dB. Figure 6 shows the transfer function of the RLC circuit as seen with the Scopy Network Analyzer tool.

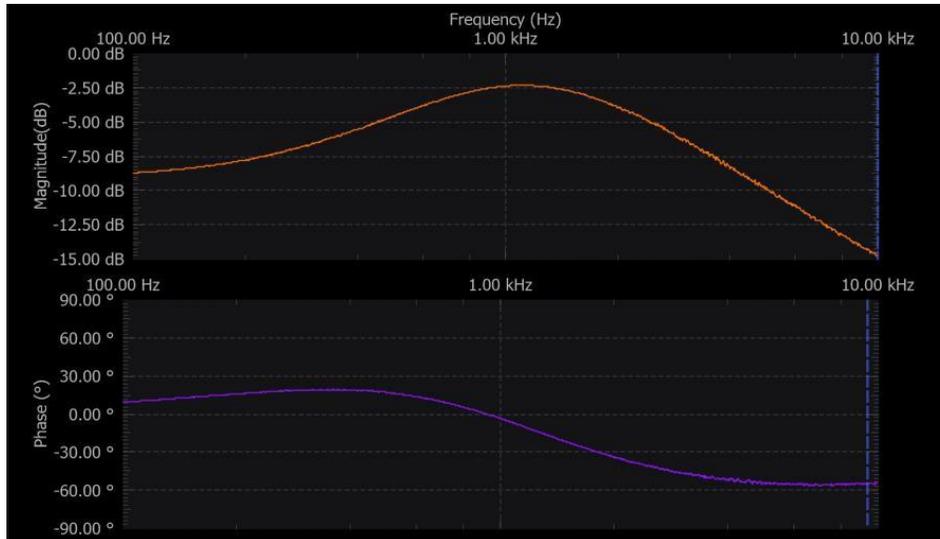


Figure 6: Frequency Response of the Parallel RLC Circuit.

The circuit response in the time domain can be analyzed using the Signal Generator and Oscilloscope tools. On signal generator channel 1 select a sine waveform of 2 volts amplitude peak-to-peak. Set the frequency equal to the resonant frequency. On oscilloscope channel 1 observe the input signal, and then on channel 2 observe the output signal. Figure 7 shows how the output signal is almost in phase with the input.

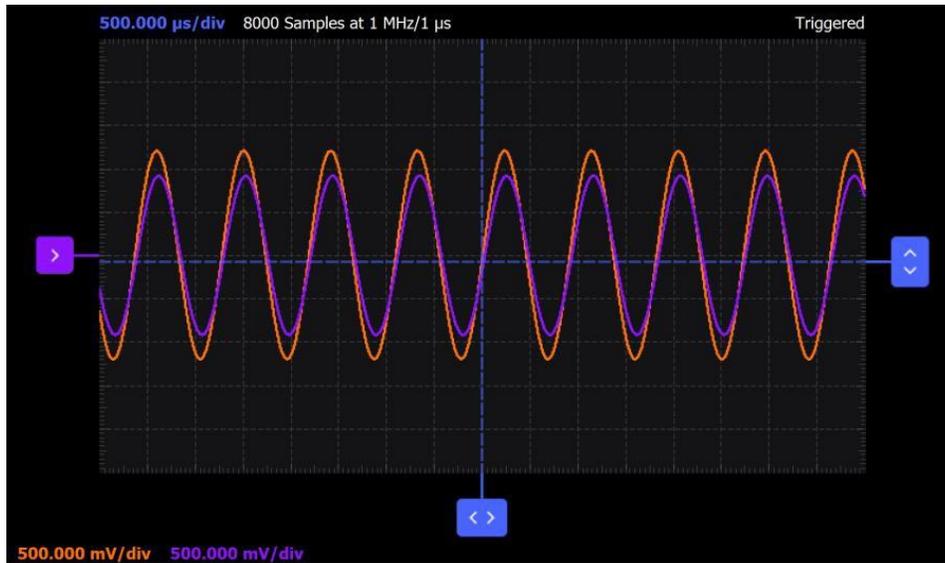


Figure 7. Input and Output Signals of the RLC Circuit for Frequency Equal to 1.1 kHz.

Choose two different values of frequency, for example the values at the ends of the sweep interval, and see how the circuit responds for these.

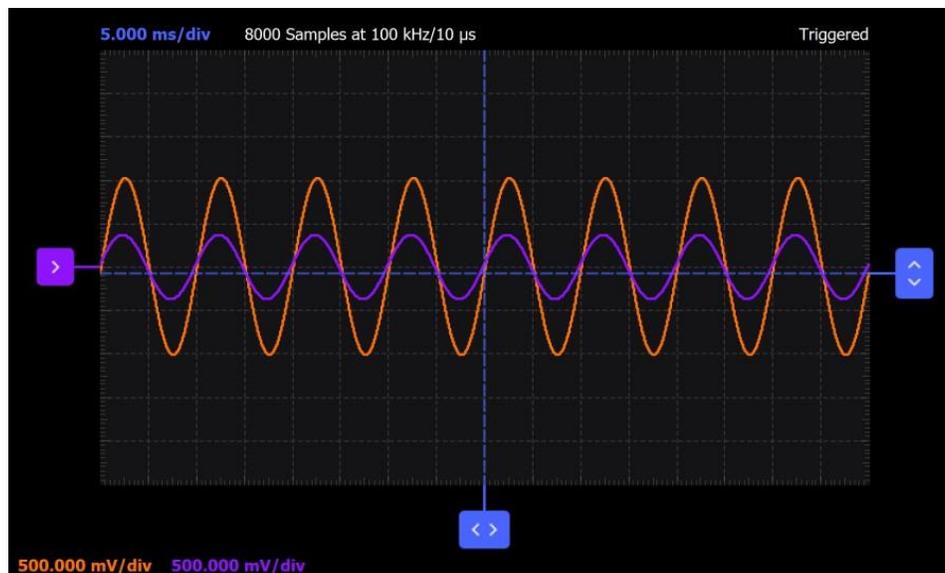


Figure 8: Input and output signals of the RLC circuit for frequency equal to 100 Hz.



Figure 9: Input and output signals of the RLC circuit for frequency equal to 10 kHz.

Questions/Review:

1. Calculate the ideal resonant frequency, ω_0 , using equation (1) and compare it to your experimental value.
2. Determine the bandwidth from the half-power frequencies using equation (3).

Report:

Your report should include, at a minimum, screen captures of the Network Analyzer/Oscilloscope displays you obtain, and meaningful discussion and interpretation of your results. It should be assembled in a reasonable report form, not just a collection of pictures. Pretend like you're writing a report for your project manager to explain to her/him what you did and what you think you learned.

Please also include any comments or suggestions you feel may help to improve this experiment for future students.