Basics of Electrical and Electronic Circuits

Experiment 6 **Series and Parallel Resonance** **Spring 2025**

Resonance is a property that enables one to select a particular frequency out of a signal containing many frequencies. This frequency-selective behaviour is essentially that of a band-pass circuit having a very sharp peak in its frequency response. In this experiment, we will study two RLC circuits which exhibit this kind of frequency response. One of them is called a series resonant circuit, and the other, a parallel resonant circuit. The circuit configurations for these two are given in **Fig.1** and **Fig. 2**. Both circuits consist of the three basic elements – a capacitance ***C***, an inductance ***L*** and a resistance ***R***, but they are interconnected differently resulting in different electrical property. At the resonant frequency, a series resonant circuit gives the **minimum impedance** while a parallel resonant circuit gives the **maximum impedance**. Most practical capacitors used in such circuits can be represented by a pure capacitance. Most practical inductors, on the other hand, are coils with a ferromagnetic core, which do not behave like a pure inductance, but have to be represented by a series combination of an inductance ***L*** and a resistance r_L. This resistance r_L is not just the resistance of the wire constituting the coil; it also includes a resistance which represents the power losses in the coil due to hysteresis and eddy current. Hence the resistance r_L is always higher than the resistance of the coil as measured by a multimeter. Moreover, the nonlinear magnetization characteristics of the ferrite core makes the coil behave in a slightly nonlinear fashion that may lead to some distortions in the waveforms.

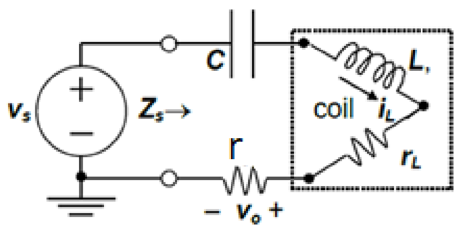

Fig. 1 Series Resonant LRC circuit

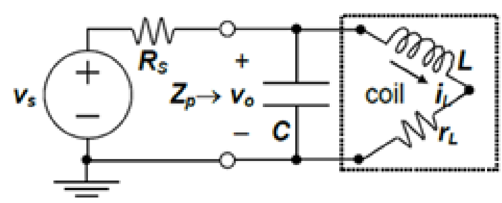

Fig. 2 Parallel Resonant LRC circuit

Part A. Series Resonance

As this circuit gives a low impedance Z_s which is **minimum** at the resonant frequency, it is preferable to measure the current i_L and note how it goes through a **maximum** as frequency is varied. But the DSO– our primary test equipment – can only enable us to observe voltages, we have to add an external resistance ***r*** as shown, and then observe the waveform of the voltage $v_o = i_L r$ across the resistance ***r***. The total Impedance Z_s of the series LRC circuit shown in **Fig. 1** is therefore given by

$$Z_s = R + j(X_L - X_C) = R + j(\omega L - 1/\omega C), \text{ where } R = r_L + r \text{ is the total resistance in the circuit.}$$

The magnitude of impedance Z_s will be **minimum** and hence the amplitude of i_L will be **maximum** for a given amplitude of the applied voltage v_s at the **series resonant frequency**

$$fs = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency, the waveforms of v_o and v_s will be **in phase** because Z_s is real (=R), and $v_o / v_s = r / (r + r_L)$. This property will be made use of to determine the values of f_s and r_L in this experiment.

1. Check the values of the given capacitor and resistors by noting their printed value and colour codes respectively. Set up the circuit shown in **Fig. 1**, with $C = 0.1\mu F$, $r = 100$ Ohm and the given inductor 1 mH. Apply the input voltage $v_s = 2V$ (peak to peak), a sinusoidal waveform having frequency 50kHz from the WAVEGEN.
2. Observe the waveforms of the voltages v_s and v_o on DSO Channels 1 and 2 and verify that they are both sinusoidal. This ensures that the circuit is indeed Linear and Time-invariant, in spite of the unavoidable non-linearity in the inductor.
3. Change the DSO display mode to the **x-y** mode, and note the elliptical display, indicating a phase difference between v_s and v_o. Vary (Increase/ decrease) the frequency gradually until the display becomes a straight line with 45^o. At this point, v_s and v_o are in phase, implying that the voltages across the capacitance and the inductance cancel each other, resulting in the condition $v_o / v_s = r / (r + r_L)$. Note the value of this frequency (= f_s) and the slope of the straight line (=$r / (r + r_L)$). Determine the values of r_L from these measured values, using the known values of ***C*** and ***r*** and the given theoretical expressions for f_s and the slope of the graph. You will later learn how to prove these expressions.
4. Measure the resistance of the coil with a multimeter and compare this value with the value of r_L just obtained by the measurement at resonance. Comment on the difference between the two values.

Observation Table-1

Experimental r_L	Measured from multimeter r_L

5. Change the mode of the DSO to **y-t** and determine the frequencies f_1 and f_2 at which the ratio of the AMPLITUDES of v_o and v_s becomes the value measured in step **3** divided by $\sqrt{2}$.
Note that near the resonant frequency, the impedance of the series resonant circuit is quite low, and its magnitude changes quite sharply as the frequency is varied. This results in continuous variation in the amplitude of v_s due to the current drawn by the resonant circuit from the WAVEGEN ("**loading**"), though the WAVEGEN setting still continues to indicate the same value. An intelligent way to determine f_1 and f_2 is to set the **scale factors** of the DSO channels so that v_s and v_o will **appear** to have equal amplitudes on the screen when their ratio has the desired value.

Observation Table-2

Series Resonance	Resonance Freq (f_s)	Current $I_{(max)}$ at f_s for Minimum Impedance of value $(r+r_L)$=……...Ω	Lower cut-off Frequency (f_L<f_s) at which I= 0.707*I_{max}	Upper (or higher) cut-off Frequency (f_u or f_H> f_s) at which I= 0.707*I_{max}
R=….., L=……., C=…….				

6. Find the value of the bandwidth ($f_2 - f_1$) and hence the value of the Quality Factor $Q = f_s / (f_2 - f_1)$. Compare this value with the theoretically expected $Q = \sqrt{(L / C)} / R$.

Observation Table-3

Experimental resonance frequency **fs**	Experimental bandwidth ($f_2 - f_1$)	Experimental Quality factor **Q**	Theoretical value of resonance freq **fs**	Theoretical value of bandwidth ($f_2 - f_1$)	Theoretical value of Quality factor **Q**

Part B. Parallel Resonance

In a parallel resonant circuit, the capacitor and the inductor are placed in parallel, resulting in a high impedance which becomes **maximum** at the resonant frequency. To observe this variation in impedance as frequency is varied, an additional resistor is placed in series with the applied voltage source (WAVEGEN), as shown in **Fig. 2**, and the voltages v_s and v_o are connected to two channels of the DSO . At the resonant frequency, the waveforms of v_o and v_s will be **in phase** because Z_p becomes real (=R_p), and so the **x-y** plot will give a straight line with slope $R_p/(R_S + R_p)$. This property will be made use of to determine the values of f_p and R_p in this experiment.

1. Remove the 100 Ohm resistor and insert R_s = 10k-Ohm to set up the Parallel Resonant circuit given in **Fig.2** and obtain a display of v_o against v_s with the DSO in the **x-y** mode. **Decrease** the frequency gradually until the display becomes a straight line again. Measure the slope of this straight line and this frequency f_p, which is the resonant frequency of the inductance L and the capacitance C:

At parallel: frequency f_p, $v_o / v_s = R_p/(R_S + R_p)$ and $f_p = 1/ 2\pi\sqrt{(LC_{eq})}$, where $C_{eq} = C$

2. Now determine the cut-off frequencies (lower and upper) by decreasing and increasing the frequency from f_p .

Observation Table-4

Parallel Resonance	Resonance Freq (f_p)	Current $I_{(min)}$ at f_s for Maximum Impedance of value (R_S+R_P)=…Ω	Lower cut-off Frequency (f_L<f_p) [at which I= 1.414*I_{min}]	Upper (or higher) cut-off Frequency (f_u or f_H> f_p) [at which I= 1.414*$I_{min.}$]
R=….., L=……. C=…….				

Note: Qualitatively draw current Vs frequency plot for both series and parallel resonance circuits indicating the useful data obtained from experimental observations.

Results:

Conclusion: It must be in your words and be based on your understanding/ learning in the experiment.