**B O Ğ A Z İ Ç İ   U N İ V E R S İ T Y**
E L E C T R I C A L & E L E C T R O N I C   E N G I N E E R I N G   D E P A R T M E N T

# EE327-ELECTRICAL NETWORK LABORATORY REPORT

Number of The Experiment : 4 ................................................................................
Name of The Experiment : Resonance Circuits.................................................

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Delay

Grading

| | | |
|---|---|---|
| General | | /20 |
| Data | | /30 |
| Discussion | | /20 |
| Answers | | /30 |
| Total | | /100 |
| Delay | | |
| SCORE | | /100 |

## 1. THE EQUIPMENT USED IN THE LAB

1.1 DC Power Supply
1.2 AC Voltmeter
1.3 Signal Generator
1.4 100Ω Resistor
1.5 47 nF Capacitor
1.6 22mH (2), 10 mH (1) Inductor
1.7 Oscilloscope
1.8 Breadboard

## 2. THEORY AND METHOD

In this experiment we examined the response of series and parallel RLC circuits to various frequencies. The property that reactive elements, i.e. the inductor and capacitor, show different impedences to different frequencies, makes the circuit to have different equivalent impedences for different frequencies. Thus the current and automatically the voltage over the elements also changes with frequency. We've already known that $Z_L$= jwL and $Z_C$= -j / wC. Then the total impedence for a series RLC circuit is given by

$$Z_{eq} = R + j(wL - \frac{1}{wC})$$

From this equation, it is obviously seen that for $w = 1/\sqrt{LC}$ , $Z_{eq}$ has the smallest value, R. This frequency is called the resonance frequency. Another quantity called the *Quality Factor* is also defined for the circuits. Mathematically, it is given as $Q = f_o / \Delta f$ More information about the quality factor is given in Question 1.

We worked on the series and parallel RLC circuits in the following figures.

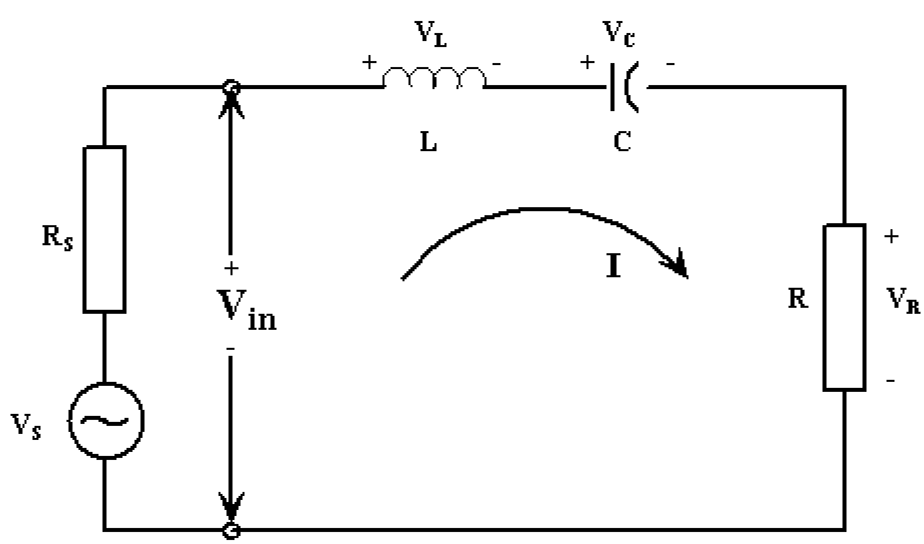


**Figure:** Series RLC Resonance Circuit

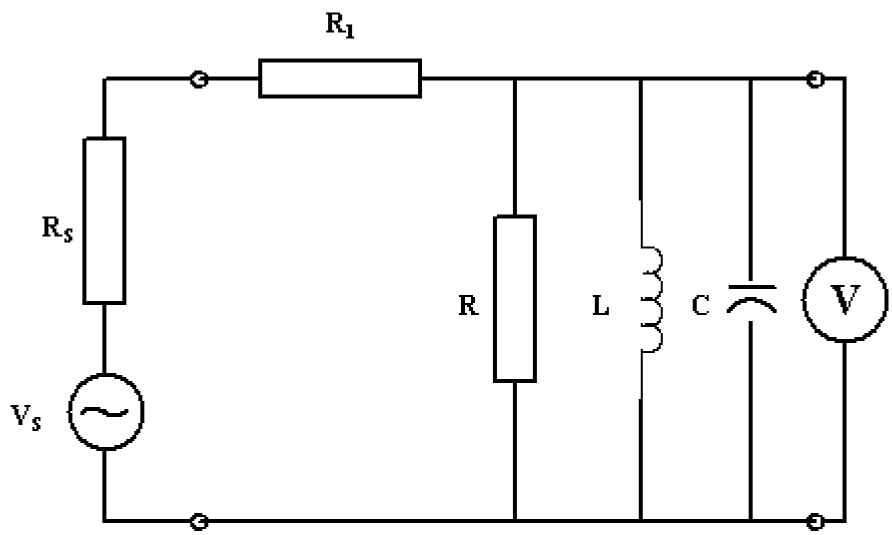



**Figure: Parallel RLC Resonance Circuit**

For the parallel RLC circuit, in order to obtain a current source, we used $R_1$=10KΩ. Since 10KΩ is very larger than R=100Ω, $I_{R1}$ can be assumed to be constant.

## 3. DATA

SERIES RLC CIRCUIT

| $X_L$ | $X_C$ | $\lvert Z\rvert = \sqrt{R^2 + X^2}$ | $\lvert I\rvert = V_{in} / Z$ | $V_L$ | $V_C$ | $V_R$ |
|---|---|---|---|---|---|---|
| 340Ω | 3385Ω | 3047Ω | 328µA | 112mV | 1.11V | 32.8mV |

**Table:** Calculated values for $V_{in}$= 1 $V_{RMS}$ for the series RLC circuit

| Frequency (kHz) | 0.2 | 0.5 | 1 | 2 | 5 | 10 | 20 |
|---|---|---|---|---|---|---|---|
| Voltage(mV) | 6.1 | 15.5 | 35.3 | 103 | 76 | 48.3 | 27.1 |
| Voltage(dB) | -44.3 | -36.2 | -29 | -19.7 | -22.4 | -26.3 | -31.3 |
| Current(mA) | 0.062 | 0.159 | 0.357 | 1.080 | 1.044 | 0.487 | 0.275 |

**Table:** Voltage and current measurements for the series RLC circuit with $(V_{in})_{RMS}$=1V

$$f_0 = 2.97KHz \qquad V_0 = 342mV = -9.4dB \qquad I_0 = 3.64mA$$

Half Power Frequencies: $f_1 = 2.66KHz$ $\qquad f_2 = 3.44KHz$

$$BW = 0.78KHz \quad Q = 2.97KHz/0.78KHz = 3.81$$

The half power frequencies are measured by continuously changing the source frequency and observing the frequency for which $V_R$ falls down to $1/\sqrt{2}$ multiple of resonant voltage $V_O$.

Below I have shown the theoretical graphs for the series RLC circuit.

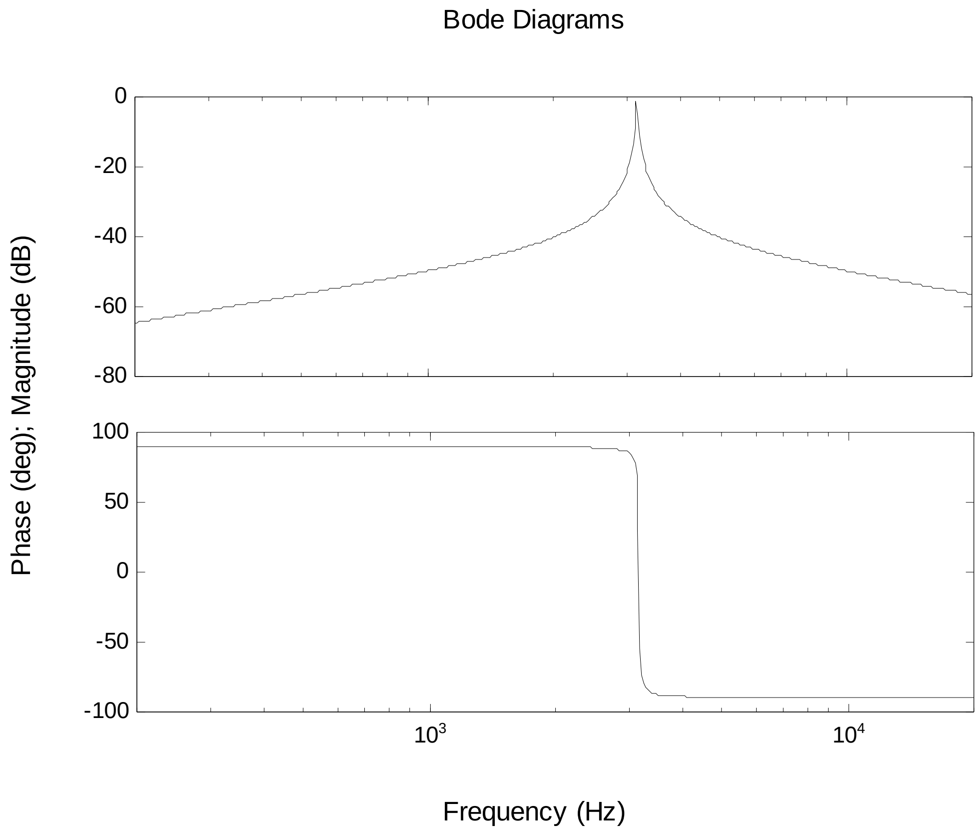



**Figure:** Bode plot of the transfer function of series RLC circuit over the resistor by MATLAB

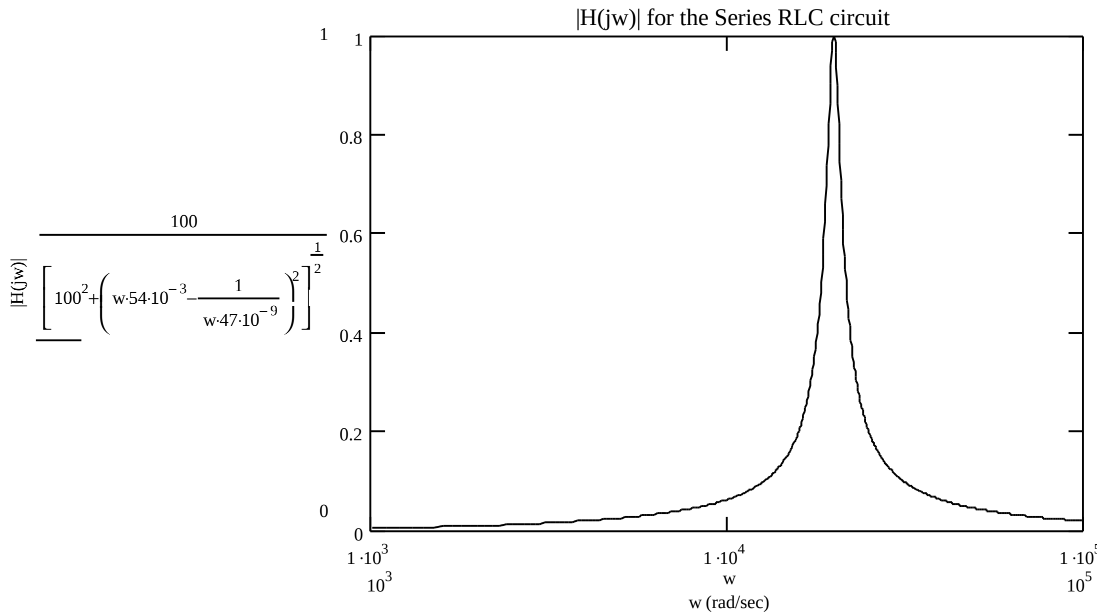



**Figure:** Plot of |H(jw)| of the series RLC circuit over the resistor by Mathcad

These graphs are obtained with the transfer function;

$$H(jw) = \frac{R}{R + jwL + \frac{1}{jwC}}$$

We had the similar graphs in the experiment. From the graphs, I found 3159Hz=19848rad/sec as the resonant frequency. This frequency corresponds to the peak values of the graphs.

PARALLEL RLC CIRCUIT

| $V_L$ | $V_C$ | $V_R$ | $I = V_R / R$ | $X_C = V_C / I$ | $X_L = V_L / I$ | $Z = V_{in} / I$ |
|---|---|---|---|---|---|---|
| 0.123V | 0.120V | 0.031V | 310µA | 3613Ω | 393Ω | 3225Ω |

**Table:** Calculated values for $V_{in}$= 1 $V_{RMS}$ for the parallel RLC circuit

| Frequency (kHz) | 0.1 | 0.2 | 0.5 | 1 | 2 | 5 | 10 | 20 |
|---|---|---|---|---|---|---|---|---|
| Output(mV) | 107 | 122 | 174 | 315 | 908 | 503 | 107 | 75 |
| Output(dB) | -19.4 | -18.3 | -15.1 | -10.0 | -0.8 | -6.0 | -19.4 | -22.5 |

**Table:** Voltage and current measurements for the parallel RLC circuit with $(V_{in})_{RMS}$=6.78V

$$f_0 = 2.82KHz \qquad V_0 = 20\log\left(\frac{2.65}{6.78}\right) = -8.15dB$$

Half Power Frequencies: $f_1 = 2.53KHz$ $f_2 = 3.33KHz$

$$BW = 0.8KHz \quad Q = 2.82KHz / 0.8KHz = 3.53$$

Below I have shown the theoretical graphs for the parallel RLC circuit.

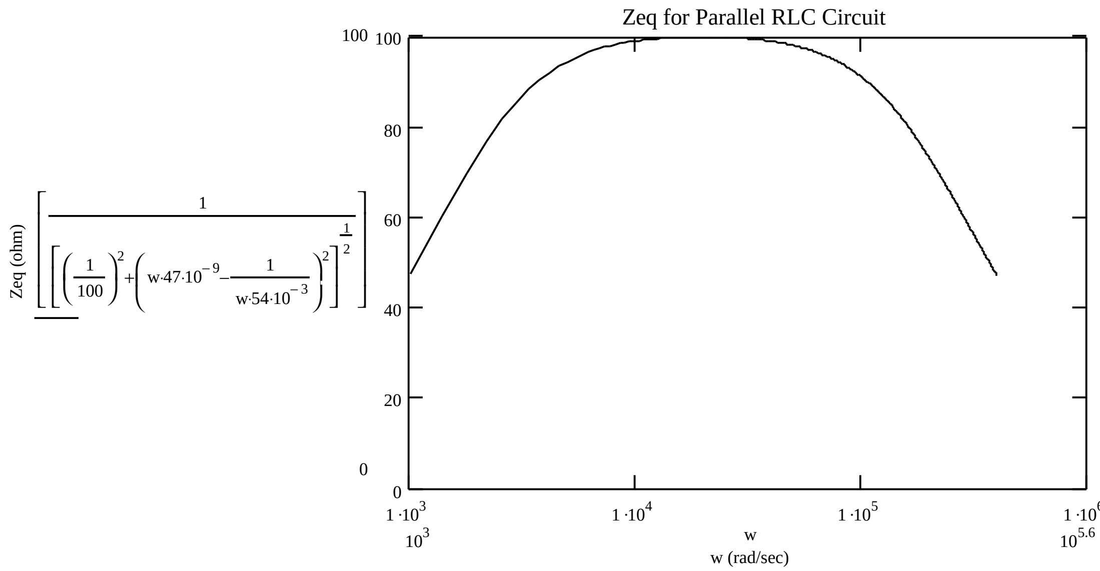



**Figure:** Plot of the equivalent impedence of the parallel RLC circuit by Mathcad

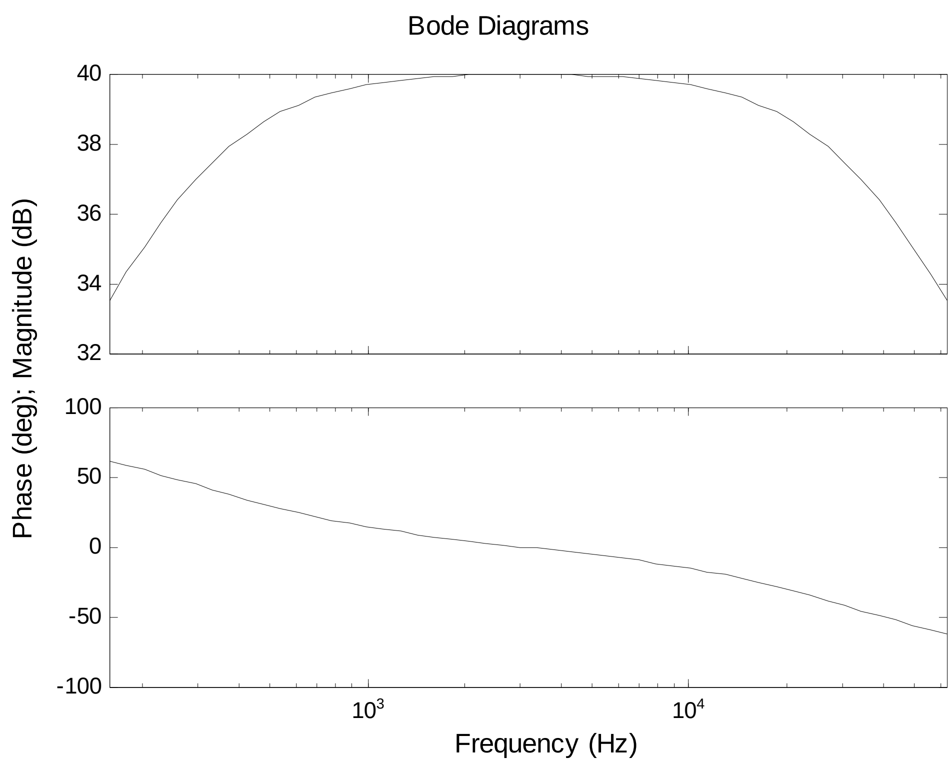



**Figure:** Bode pilot of the transfer function ($V_O/I_S$) of the parallel RLC circuit by MATLAB

These graphs are obtained with the transfer function;

$$H(jw)=\frac{V_O}{I_S}=\frac{1}{\frac{1}{R}+jwC+\frac{1}{jwL}}$$

From the graphs, I found 3159Hz=19848rad/sec as the resonant frequency, which is same as the series RLC circuit. This frequency corresponds to the peak values of the graphs.

## 4. ANALYSIS AND DISCUSSION

To my opinion, this experiment was a well-prepared and teaching experiment. We were able to see our theoretical knowledge about the RLC circuits and resonance works in practical situations. What I learned newly is the physical meaning of the Quality Factor. Previously, I only knew that $Q=f_O/\Delta f$ . Another thing that I noticed is that in the experiment we obtained similar graphs for both series and parallel RLC circuits. But only after examining the graphs I had with MATLAB and Mathcad, I understood that the graphs have different forms. One is concave and the other is convex. What this implies is that Parallel RLC circuit should have larger bandwidth compared to Series RLC circuit. This is the case in our experimental results but 0.8>0.78 is not a that much difference. In my opinion this difference should be much more than we'd found.

The error we made in the measurements is, I think, in a reasonable range. For example, For series RLC circuit, error of the resonant frequency is,

$$error\%=\frac{\Delta f}{f_0}=\frac{|2.97KHz-3.16KHz|}{3.16KHz}\times 100=6\%$$

This is due to instrument errors, incorrectness in the values of given components and our reading errors.

## 5. ANSWERS TO THE QUESTIONS

**1.**

The Quality Factor of a circuit is a measure of ratio of its energy-storing capability to energy dissipation as heat.

$$Q=\frac{energy\ stored\ in\ the\ reactive\ component}{energy\ dissipated\ by\ resistor\ in\ one\ cycle}$$

$$=\frac{X_L\cdot i^2}{R\cdot i^2}=\frac{X_L}{R}=\frac{w_oL}{R}=\frac{1}{\sqrt{LC}}\cdot\frac{L}{R}$$

$$Q=\frac{1}{R}\sqrt{\frac{L}{C}}\qquad (\ For\ series\ RLC\ circuit)$$

$$Q=\frac{energy\ stored\ in\ the\ reactive\ component}{energy\ dissipated\ by\ resistor\ in\ one\ cycle}$$

$$=\frac{V^2/X_C}{V^2/R}=\frac{R}{X_C}=\frac{R}{1/w_OC}$$

$$Q = w_O CR \qquad \textit{( For parallel RLC circuit)}$$

**2.**

*(For series)*

$$I_{\max} = \frac{V_S}{R} \Rightarrow (V_L)_{\max} = \frac{V_S}{R} \cdot jwL$$

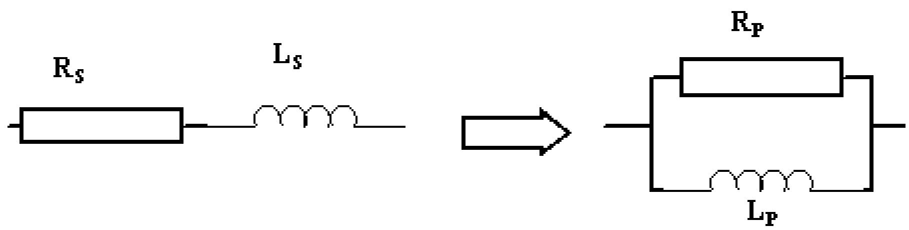
$$\Rightarrow (V_C)_{\max} = \frac{V_S}{R} \cdot \frac{1}{jwC}$$

*(For parallel)*

$$V_{\max} = I_S R \Rightarrow (I_L)_{\max} = \frac{V_{\max}}{jwL} = \frac{I_S R}{jwL}$$

$$\Rightarrow (I_C)_{\max} = \frac{V_{\max}}{1/jwC} = I_S R \cdot jwC$$

**3.**




$$R_S + jwL_S = R_P \,//\, L_P$$

$$= \frac{R_P \cdot jwL_P}{R_P + jwL_P}$$

$$= \frac{jwL_P R_P \left(R_P - jwL_P\right)}{R_P^2 - w^2 L_P^2}$$

*(Real parts of both sides should be equal)*

$$R_S = \frac{w^2 L_P^2 R_P}{R_P^2 - w^2 L_P^2}$$

$$w = \frac{1}{\sqrt{L_P C}}$$

*Substituting w in the equation, and solving $R_P$ for C=670nF, $R_S$=10W, $L_P$=10mH, we find $R_P$= 4.68W -hopefully no calculation errors.*