Lab7 RLC Resonant Circuit

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Apprartus:

1. Power Amplifier
2. Breadboard and jumper wires
3. Resistor (300 Ω)
4. Inductor (100mH)
5. Capacitor (0.5μF,0.25uF)
6. Oscilloscope
7. Function Generator
8. Digital Multimeter

Part One:

1. Use the DMM to measure the values of the components in Tables and note down the values in Tables. Also, measure the resistance R_L of the inductors. Use the measured values in all your calculations. __/4pt

Table 1: Measured Values

	Nominal Value	Measured Value
R1	300Ω	301.2 Ω
R_L of 100mH inductor		39.9 Ω
C	0.1uF	100.0 nF
C	0.05uF	50.4 nF

2. Construct the circuit shown in Figure 2 using the breadboard with jumper-wires, here C is 0.5uF, L is 100mH and R is 300Ω.

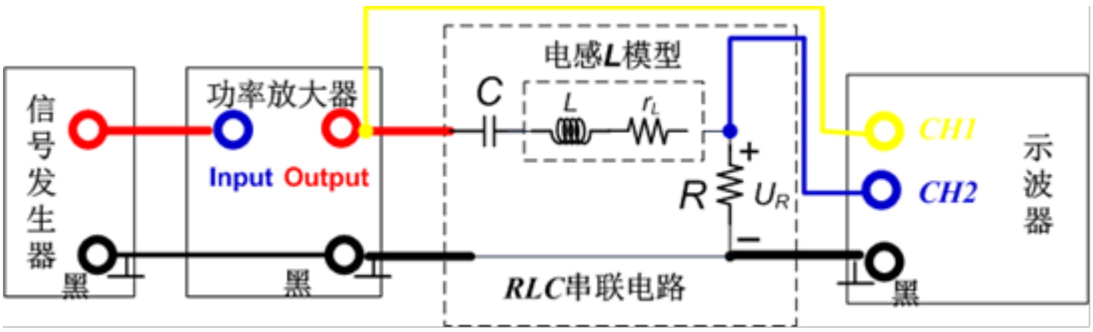

Fig.2 schematic diagram of RLC series circuit test

As shown in Figure 2, gain of the power amplifier is set to 1. Ch1 and CH2 of oscilloscope are used to observe the input voltage (that is, output voltage of power amplifier) and the voltage across the resistor U_R respectively. Make sure that the resistor is the **last component closest to the ground end of the circuit**.

(1) Use the Signal Generator to generate a Sine Wave with a 1.5Vrms amplitude. Set the frequency of the sin signal to be about the theoretic resonant frequency.

(2) Adjust the frequency of the signal generator slowly. When adjusting the frequency of the output signal of the signal generator, the output voltage of the power amplifier should be kept constant at 1.5vrms. When the voltage at both ends of the resistor is the maximum obtained from the oscilloscope, the frequency value at this time is the resonant frequency of the circuit. At this time, switch the YT mode of the oscilloscope to XY mode, and verify whether Lissajous curve is a straight line with the X axis (indicating TA to check signature)

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(3) Measure U_L (RMS Voltage) and U_C (RMS Voltage) under resonance state, and fill in the blank. **Note that the oscilloscopes only allow you to measure potential difference with respect to ground.**

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	Measurement data				Calculattion	
C=0.5μF L=100 mH R=300Ω	f_0(Hz)	U_R(V)	U_L(V)	U_C(V)	$I=U_R/R$(mA)	$Q=U_C/U_i$
	698	1.300	1.912	1.965	4.334	1.31

(4) Measure the amplitude frequency characteristic curve of the RLC series circuit and complete the following table. Among them, f_1 and f_2 are the upper and lower frequencies of the passband FBW respectively. After f_0 and corresponding U_{R0} are measured, $U_{f1} = U_{f2} = 0.707\ U_{R0}$ is calculated, and then f_1 and f_2 are measured from the values of U_{f1} and U_{f2}

__/20pt

	Measurement data		Calculation	
C=0.5μF L=100 mH R=300Ω	f(Hz)	U_R(V)	$I=U_R/R$ (mA)	I/I_0
	200	0.295	0.983	0.227
	300	0.472	1.57	0.363
	400	0.684	2.279	0.526
	f_1= 481	0.919	3.064	0. 707
	500	0.931	3.104	0.716
	600	1.154	3.849	0.888
	f_0= 698	$U_R=U_{R0}$= 1.300	$I=I_0$= 4.334	1
	800	1.214	4.047	0.934
	900	1.084	3.613	0.834
	f_2= 1000	0.919	3.064	0. 707
	1100	0.801	2.671	0.616
	1200	0.719	2.397	0.553
	1300	0.636	2.121	0.489

3. Change the resistor R = 150Ω, Other parameters of the circuit remain unchanged. Repeat the above experimental steps., complete the following table. 2 /26pt

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	Measurement data				Calculation	
C=~~0.5~~ 0.25μF L=100mH R=~~150~~ 300Ω	f_0(Hz)	U_R(V)	U_L(V)	U_C(V)	$I=U_R/R$(mA)	$Q=U_C/U_i$
	985	1.214	2.652	2.746	4.047	1.830

	Measurement data		Calculation	
C=~~0.5~~ 0.25μF L=100mH R=~~150~~ 300Ω	f(Hz)	U_R(V)	$I=U_R/R$ (mA)	I/I_0
	500	0.460	1.532	0.379
	600	0.601	2.003	0.495
	700	0.778	2.593	0.641
	f_1= 740	0.861	2.868	0.707
	800	0.978	3.260	0.805
	900	1.190	3.967	0.980
	f_0= 985	$U_R=U_{R0}$= 1.214	$I=I_0$= 4.047	1
	1000	1.167	3.889	0.961
	1100	1.119	3.731	0.922
	f_2= 1300	0.861	2.868	0.707
	1400	0.742	2.475	0.612
	1500	0.648	2.161	0.534
	1600	0.578	1.926	0.476

4. Change the capacitor C =0.25uF, Other parameters of the circuit remain unchanged, that is L=100mH, R=150Ω. Repeat the above experimental steps. Under the resonant state, complete the following table. f_1=860Hz f_2=1180Hz U=1.131 V 6 /6pt

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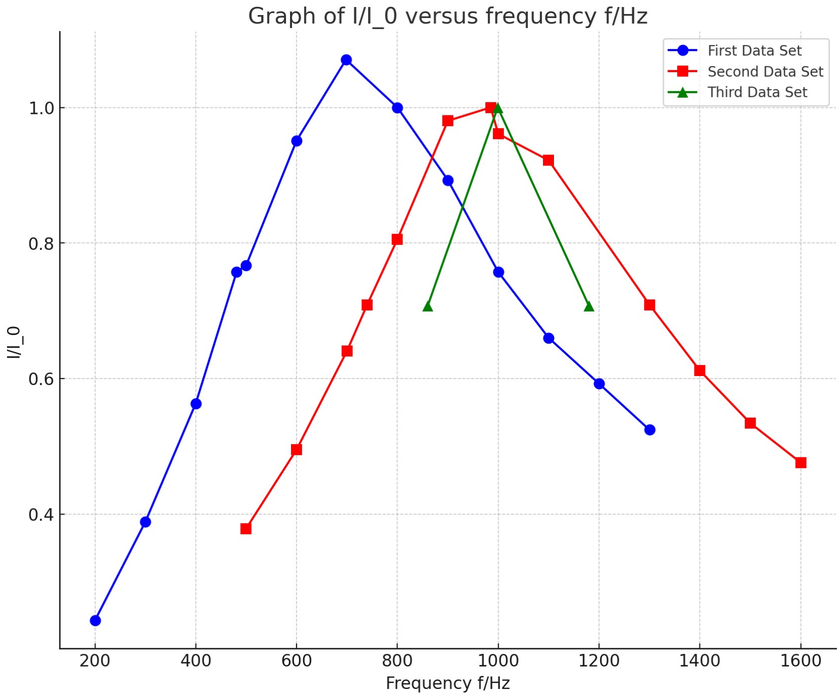
	Measurement data				Calculation	
C=0.25μF L=100mH R=~~220~~ 150Ω	f_0(Hz)	U_R(V)	U_L(V)	U_C(V)	$I=U_R/R$(mA)	$Q=U_C/U_i$
	999	1.131	4.827	4.848	7.54	3.232

5. According to the experimental data, draw the frequency characteristic curve between I / I0 and frequency f on the coordinate paper, and please use different colors to show the difference. Note: key information needs to be indicated. If the square is not enough, it can be expanded. __/6pt



6. According to the three frequency characteristic curve in step5, calculate the Bandwidth (need to write the process). __/4.5pt

C=0.5μF L=100mH R=300Ω	$f_{BW} = f_2 - f_1 = 1000 - 481 = 519\,Hz$
C=0.25μF L=100 mH R=300Ω	$f_{BW} = f_2 - f_1 = 1300 - 740 = 560\,Hz$
C=0.25μF L=100mH R=150Ω	$f_{BW} = f_2 - f_1 = 1180 - 860 = 320\,Hz$

7. Calculate Q according to $Q = \dfrac{U_{C0}}{U_i}$ and $Q = \dfrac{\sqrt{L/C}}{R_{eq}}$ (show the calculation process) __/9pt

Note: Req is the equivalent resistance seen from the input terminals. In this experimental circuit, except for the fixed resistance R, the inductor and capacitor all have a certain resistance value, so the total equivalent resistance is:

$$R_{eq} = \frac{U_i}{I_0}$$

C=0.5μF L=100mH R=300Ω	$Q = \dfrac{U_{C0}}{U_i} = \dfrac{1.965}{1.5} = 1.31$

	$R_{eq} = \frac{U_i}{I_0} = \frac{1.5}{4.334\times10^{-3}} = 346.1\Omega$ $\quad Q = \frac{\sqrt{\frac{L}{C}}}{R_{eq}} = \frac{\sqrt{\frac{0.1}{0.5\times10^{-6}}}}{346.1\Omega} = 1.29$
C=0.25μF L=100 mH R=300Ω	$Q = \frac{U_C}{U_i} = \frac{2.746}{1.5} = 1.830$ $R_{eq} = \frac{U_i}{I_0} = \frac{1.5}{4.047\times10^{-3}} = 370.645$ $\quad Q = \frac{\sqrt{\frac{L}{C}}}{R_{eq}} = 1.71$
C=0.25μF L=100mH R=150Ω	$Q = \frac{U_c}{U_i} = \frac{4.848}{1.5} = 3.232$ $R_{eq} = \frac{U_i}{I_0} = \frac{1.5}{7.54\times10^{-3}} = 198.94$ $\quad Q = \frac{\sqrt{\frac{L}{C}}}{R_{eq}} = 3.179$

8. Compare the calculated and the experimental resonant frequency, is the measurement larger or smaller than the calculated value? How much is the deviation? Analyze the possible reasons. __/7pt

calculated	experimental	compare	error
711.763	698	smaller	1.93%
1006.584	985	smaller	2.14%
1006.584	999	smaller	0.75%

Since f_0 is only determined by the value of capacitor and inductor, so either the actual value of capacitor or the inductor is higher than expected. On the other hand, it's kind of difficult to accurately record when the voltage reaches the peak so there might be error during observation.

9. This experiment has been concerned with the series RLC circuit driven by a sinusoidal voltage source. Qualitatively discuss how the parameters affect the resonant frequency. __/6pt

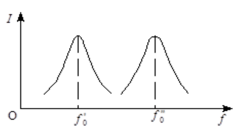
We obtain f_0 from the equation

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

set $\omega L = \frac{1}{\omega C}$ to get $\omega_0 = \frac{1}{\sqrt{LC}} = 2\pi f_0$

so as the ω of the sinusoidal voltage source increasing the resonant frequency will increase accordingly

We can use the figure in our prelab to illustrate this:



While the other parameters like Vpp, offset, will have no effect on the resonant frequency.