Physics Department

Physics 112

Experiment #10
RESONANCE

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Section:- 18

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I. Abstract:

The aim of the experiment : to identify the natural frequency (f_0) and the corresponding angular frequency (ω_0) for an RLC circuit by plotting a graph of I vs. ω.

The method used: by connecting a circuit that contains a resistor(1&2 KΩ)and capacitor and inductor and a generator to a DCO and we obtained the values and graphs we wanted to see.

The main results :

R = 1 KΩ

Theoretically)

$f = 5.2\ KHz$

$Q = 1.84$

experimentally)

Q =0.242

$\omega 0 = 4.5 \times 10^3 rad/\sec$

I_{max}= $9.7 mA$

R = 2 KΩ

Theoretically)

$f = 5\ KHz$

$Q = 0.78$

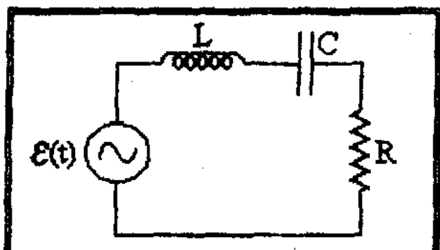
experimentally)

Q =0.341

$\omega 0 = 4.5 \times 10^3 rad/\sec$

I_{max}= $5.2 mA$

Theory:



Fig(1)

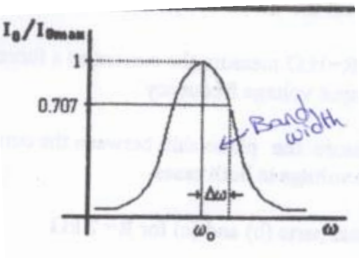
The amplitude of the current passing through the circuit shown in is given by, $I_o = \dfrac{V_o}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$.

As we can see, we can get a maximum value of I_o when

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

$\Rightarrow \omega_o = \dfrac{1}{\sqrt{LC}}$ Under such a condition ω is the natural angular frequency of the circuit.

The resonance is that the current assumes its maximum value when the deriving voltage frequency equals the natural frequency of the RLC circuit.



Fig(2)

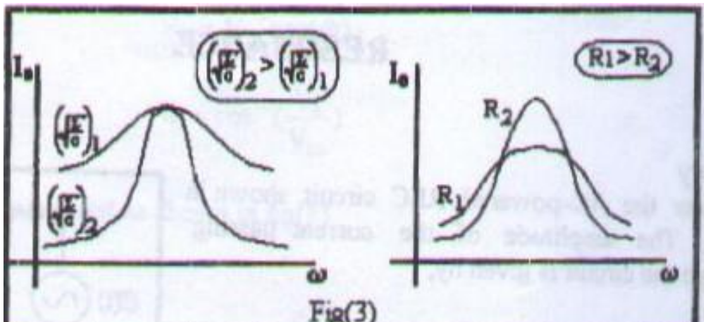
Fig.2 shows a plot of the value of I_o as a function of ω. At resonance $I_o = \dfrac{V_o}{R}$ and the value of the current is only limited by the resistance of the circuit.

The quality factor:

A measure of the sharpness of the resonance curve is a quantity called the quality factor (Q), which is defined as $Q = \dfrac{\omega L}{R}$

At resonance $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

Fig.3 shows a plot of resonance curve for different combinations of R, L, and C.



Fig(3)

The band width (Δω) is a practical value that measures the sharpness of the resonance curve. The band width (Δω) is the frequency range between the maximum value of I_o and the value $\dfrac{I_o}{\sqrt{2}}$, see fig.2.

The quality factor is related to the band width as follows: $Q = \dfrac{\omega_o}{2|\Delta\omega|}$.

Calculations:

The resonance frequency:

$f_o = 5kHz$ (experimentally)

The angular resonance frequency:

$$\omega_o = \frac{1}{\sqrt{LC}} = 31.62\ \mathrm{K\ rad/sec}$$ (Theoretically)

$$\omega_o = 2\pi f_o = 2\times 3.14\times 5 = 50.42 Krad/\sec$$ (experimentally)

- For R_1(1KOhme) (from graph): $I_{max}=9.7mA$ and $\omega 0 = 4.5\times 10^3 rad/\sec$.
  $\Rightarrow I_{max}/\sqrt{2} = 6.85mA$ Crosses graph at $\omega = (1.4\,\&\,20)\times 10^3 rad/\sec$. So
  $$Q = \frac{\omega 0}{|\Delta\omega|} = \frac{4.5\times 10^3}{20-1.4\times 10^3} = 0.242$$

- For R_2(2Komhe) (from graph): $I_{max}=5.2mA$ and $\omega 0 = 4.5\times 10^3 rad/\sec$.
  $\Rightarrow I_{max}/\sqrt{2} = 3.6mA$ Crosses graph at $\omega = (0.8\,\&\,14)\times 10^3 rad/\sec$. So
  $$Q = \frac{\omega 0}{|\Delta\omega|} = \frac{4.5\times 10^3}{|14-0.8|\times 10^3} = 0.341$$

Analysis:

By analyzing the graphs, data and the numerical results we can see that:

I. The results obtained experimentally for the natural frequency (f_0) and the corresponding angular frequency (ω_0) closely matched what we predicted by theory.

II. As predicted, the graph of I vs. ω has a maximum at ω_0.

III. The graph of I vs. ω is symmetric about the line X= ω_0. (We used this fact to find $\Delta\omega$ in a manner different than that described in the lab manual because the distance between any two points on the graph lying on the same horizontal line is double the distance between one of these two points and the line X= ω_0)
IV. For each value of R, the value we got for the quality factor experimentally and by direct calculation closely matched.
V. The sharpness of the graph of I vs. ω increases as the resistance deceases: this can be seen by looking at equation (5) in II Theory, where Q is inversely proportional to R. This is also confirmed by the graphs we obtained.

We can conclude that current in an RLC circuit has reaches a maximum when the driving voltage frequency is equal to the resonant frequency. We can also conclude that the greater the resistance in an RLC circuit, the small the quality factor.

The results we obtained experimentally in this experiment closely matched those obtained by theory; the main factor that limited our precision, and therefore gave us a slight difference between practical and theoretical results, is the limitation imposed by the instruments and graphs when taking our data and measurements.
For example: when we wanted to find the quality factor using the I vs. ω graph, we had to determine the maximum and then take ω that corresponded to $I_{max}/\sqrt{2}$… during all this much estimation had to be made, especially because we were dealing with a logarithmic scale. Additionally, for some values of f we had to set the output frequency of the signal generator to a precision that is not given by the generator's dial so it was only a matter of human judgment.

Answer to the question at the end of the experiment:

-Question: Show that at resonance $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

-Solution:

From the definition of the quality factor (Q): $Q = \omega L / R$ -- eq(a).

At resonance: $\omega = \omega_0 = \frac{1}{\sqrt{LC}}$ -- eq(b).

Substituting the value of ω from equation (b) into equation (a) we get:

$$Q = \frac{\omega L}{R} = \frac{L}{R\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}.$$