

Electronics assignment Toby Ward

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Analysis and comparison of simulation based resonant circuit and real components



Introduction -	What is resonant circuit? Uses of resonant circuit How a resonant circuit works Plan to compare real components vs simulation software Prediction of behavior of both resonant circuits
Method -	Circuit diagram Selection of component values Plan of measuring and recording the data
Results -	Results and graphs
Analysis of results -	Explanation of results Ideal components and behavior of components with different properties
Conclusion -	Conclusion

Abstract

The aim of this investigation is to observe the differences between real and simulated parallel LC circuits. An LC resonant circuit was built on a breadboard and driven by inputting a 4v sine wave between the frequencies of 100Hz and 20kHz. An oscilloscope across the parallel inductor and capacitor measured the output amplitude so the Q factor could be calculated. The LC resonant circuit was also constructed on a circuit simulation software, Proteus, and tested with the built in software signal generator and oscilloscope. An attenuation graph was plotted for both circuits and the -3dB line was drawn on. This allowed the bandwidth to be calculated. The Q factor was calculated for both sets of results. The Q factors for each circuit are very different, with the simulated circuit having a higher Q value. This was found to be caused by a number of factors including tolerance of components, test equipment limitations and certain components

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having properties of other components as well as themselves, such as inductors also having resistance and capacitance.  2

Introduction

 3 A parallel LC resonant circuit is a circuit in which its impedance when driven at a particular frequency is exceptionally low, allowing it to pass a larger amount of current than at other frequencies. This is called the resonant frequency. The resonant frequency will depend on the values of components used in the circuit, more specifically the capacitance and inductance.

The principles of resonant circuits are used for a large range of electronic applications, such as passive filters, amplifiers or even resonant transformers, such as a tesla coil.

A daily use of a resonant LC circuit may be in the tuning system of a radio or music amplifier, where certain frequencies are allowed to pass through the circuit. This would be an example of a band pass filter, which described by its name, allows a certain "band" of frequencies to pass. If the frequency that the circuit is driven at is too far from the resonant frequency, then it will be heavily attenuated. This will cause a much lower power output from the circuit.

A parallel LC resonant circuit works by using the properties of reactance of the capacitor and inductor. When a high frequency is applied across a capacitor, it has a lower reactance, allowing more current to flow, however when a high frequency is applied across an inductor, it  4 has a higher reactance. The reactance of a capacitor, given by the formula $1/(2\pi fC)$ or $1/\omega C$, is inversely proportional to the angular frequency and the inductive reactance is proportional to the angular frequency and is given by the formula $2\pi fL$ or ωL . When a capacitor is charging, the current decreases over time due to the buildup of charge on the negative plate. When an AC signal is applied to the capacitor, only a small amount of charge is built up in the capacitor before the current reverses and the charge changes polarity. This limits the resistance to electron flow and gives a low reactance. The lower the frequency, the more charge builds up in the capacitor before current reverses, and there is a higher reactance. The frequency at which these two impedances are the same is the resonant frequency. This can be simplified as two resistors in parallel, fig1.1. When the resistances are the same, equal amounts of current flow in each resistor, but if one resistance is greater than the other, then different amounts of current will flow in each resistor. The reactance of the components must be the same for the circuit to resonate at its best because equal energy can then be stored in the inductor and capacitor. The resonant frequency formula can be derived from this basis, by equating the two reactance formulas. This gives $1/(2\pi fC) = 2\pi fL$. This simplifies to $f = 1/(2\pi\sqrt{LC})$.

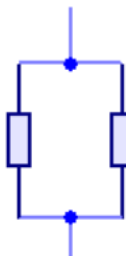


fig1.1\'  5

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In this experiment, the differences between real and simulated LC resonant circuits have been investigated. One factor which was predicted to have a large effect on the performance of the real circuit compared to the simulated one was the tolerance values of each component. Due to the manufacturing process, it is very costly and difficult to produce components with exact values that do not deviate from their specification. This is why component manufacturers work to tolerances, and deliver a component which is guaranteed to have a value in a particular range of its specification. This value is usually $\pm 5\%$ for common resistors, however values of $\pm 1\%$ and $\pm 2\%$ are not uncommon for more expensive resistors, where tolerance is a critical factor. Capacitors and inductors usually experience larger tolerance bands than resistors, possibly up to $+80\%/-20\%$ [1]. This change in values of the real components could result in a real circuit with a slightly different resonant frequency than calculated. The resistor is in series with the parallel inductor and capacitor to limit the current draw at very low and very high frequencies. [2] This also acts as a potential divider for the voltage across the two sections of the series circuit.



Method

The real LC circuit that was tested was constructed from a 1k resistor connected in series to a 1mH inductor and a 1uF capacitor in parallel, as shown by the fig2.1. The circuit was constructed on a breadboard, to allow easy changes to be made to the circuit, and test probes to be moved around. These components were chosen due to the fact that they will produce a resonant frequency that is within a range that the signal generators can produce, and are easily measurable with oscilloscopes. The theoretical resonant frequency can be calculated by $1/(2\pi\sqrt{LC})$. This gives the resonant frequency a value of 5032.9Hz. The components that are required to produce this frequency are commonly available and have reasonable tolerances.

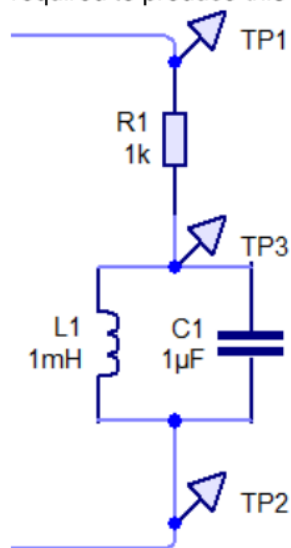


fig2.1

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The circuit is driven by a sine wave from a signal generator across TP1 and TP2 at a peak to peak amplitude of 4v. This provides a way to alter the driven frequency of the circuit by adjusting the signal generator's output frequency. The circuit's output is measured across TP3 and TP2 with an oscilloscope, to provide an easy way to measure the peak to peak amplitude of the output, whilst verifying the output frequency is the same as the input.

The simulated circuit has been constructed on Proteus circuit simulation package, which simulates a value accurate LC resonant circuit. The built in software signal generator and oscilloscope drive the circuit and measure the peak to peak amplitude as the circuit performs following the basic theory of LC resonant circuits.

An advantage to using LC resonant circuits as band pass filters is the fact that they tend to have a sharper cutoff than RC circuits, thus can be a more effective filter. [3]

Results

The real and simulated circuits were tested at a range of frequencies between 100Hz and 20kHz. This allowed a suitable range to display the frequency response of the circuit, as the calculated resonant frequency of 5032.9Hz is well within this range. The distance between each frequency sample was decided due to the fact that a logarithmic graph was drawn to display the results. A logarithmic graph is used because the y-axis of the results graph represents attenuation, measured in dB, which is a logarithmic unit. This unit is used as it will provide a better representation of how the circuit attenuates signals, rather than using peak to peak amplitude, which may include very large and very small values on the same graph, making it very hard to read accurately.

From the attenuation graph, the bandwidth of the LC circuit can be determined. The method used was to subtract 3dB from the peak attenuation value, to find the -3dB point, and find the two places the graph intercepts that value. The -3dB point is used because it represents half power attenuation of the signal. If a voltage-frequency graph is used instead, the values that intercept a line drawn at 0.707 of the peak voltage gain can be used instead. These will be the same values as when retrieved from the attenuation graph. An example of a voltage-frequency graph for this circuit is shown in fig3.1.

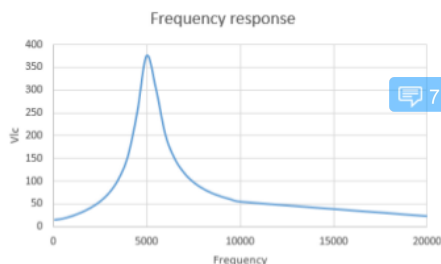


fig3.1

For the real circuit the peak attenuation is -14.5dB. Subtracting 3dB from this allows a line to be drawn at -17.5dB, and the intercepts to be read from the graph. Fig3.2 shows a -3dB line drawn so that the lower and upper cutoff values can be found. The difference between these two values, 5655Hz and 4575Hz is the bandwidth. In this case, 1080Hz.

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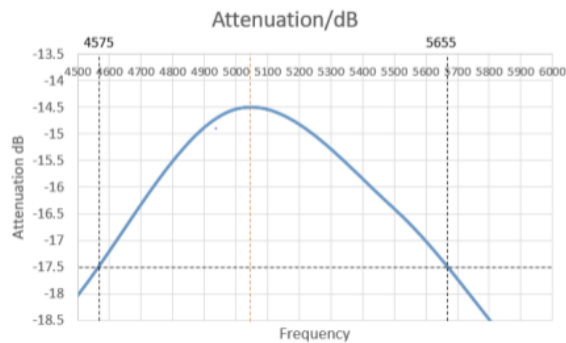


fig3.2

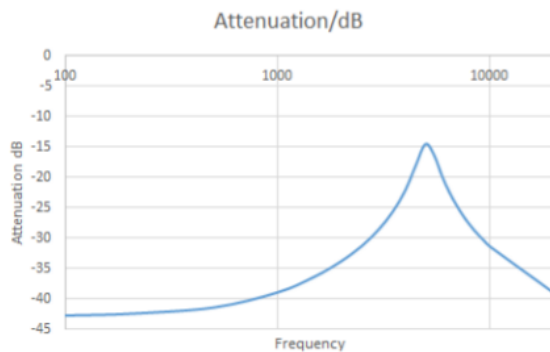


fig3.3

From the bandwidth value, the Q factor can be determined. This is sometimes known as the “quality factor”. To find the Q factor, the resonant frequency was divided by the bandwidth, $5040/1080$ to give 4.67. [4]

For the simulated circuit, the bandwidth is calculated in the same way by drawing a line at the -3dB point, shown on fig3.4. The intercepts are 4830Hz and 5160Hz. This gives a bandwidth of 330Hz. This is around $\frac{1}{3}$ of the bandwidth of the real circuit. The bandwidth found for the simulated circuit is 5000Hz, which is about 33Hz lower than the calculated value. The Q factor of the simulated circuit is 15.15.

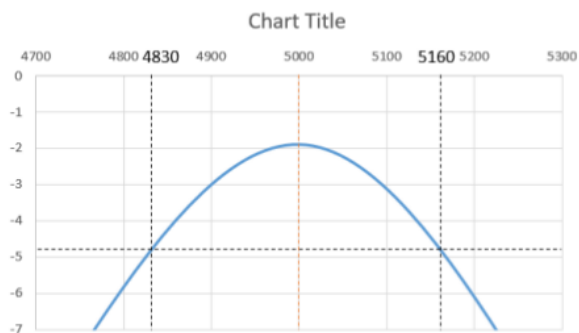


fig3.4

Analysis of results

The differences between the simulated circuit and the real circuit can be seen in the differences between the resonant frequencies, bandwidths and Q factors. These differences are due to a number of factors including tolerance values of components, passive components acting as other passive components and limitations of test equipment. The tolerance values have the largest effect on the measured results of the real circuit, as component values can be put into the formula while still within tolerance and output hugely different results. For example, a 1uF capacitor with a tolerance of 10% may have a value between 0.9uF and 1.1uF. Using the lower value would give a resonant frequency of 5305Hz, which is a few hundred Hz away from the theoretical resonant frequency. The accurate values of the components used in the LC resonant circuit have not been tested to verify if they are close to the specification value, so it is a legitimate possibility that the components used are far away from the specification value, but still within tolerance.

Another factor which affects the performance of the real circuit compared to the simulation is the tendency of components to act as other components. This can be seen when  8 analyzing inductors. Due to their construction, they have an amount of resistance. This is a main cause of loss in the circuit as it resonates, and power is dissipated as heat through the inductor. The resistance of the inductor is not simulated by the software, and can only be tested by using real components. This will affect the Q value of the resonant circuit, as more damping of the signal will occur in the real circuit. If the internal resistance of the inductor is measured, it is possible to calculate a Q factor for the inductor itself. This will give an indication to how much the resistance one the inductor affects the Q factor of the whole resonant circuit. Inductor resistance is one of the major performance limiting factors of an inductor. [5]

Due to limitations in the test equipment, it is only possible to drive the real circuit from a 2v signal source rather than the 4v for the simulation. This simply causes the real circuit to have a lower peak voltage, but it maintains the ratio of attenuated power.

Conclusion

It has been found that there are performance differences between the two circuits, caused by a number of factors. The largest difference was the Q factor value. This was over three times the value calculated for the simulated circuit than the real circuit. This may have been caused by the internal resistance of the inductor which provides more damping than in the simulated circuit, where the internal resistance of the inductor is not taken into account in the simulation. The resistance of the inductor causes power to be lost in the circuit as it resonates, and is dissipated as heat. A higher Q factor for the simulated circuit causes the graph to have a narrower spike, and a sharper cutoff point where the attenuation reaches half power. This is ideal for a band pass filter, as it accurately attenuates certain frequencies. A low Q factor means a wider spike on the attenuation graph, and shallower cutoff points. This is less ideal for a band pass filter as more unwanted frequencies could pass through the filter.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

72/100

PAGE 1



Comment 1

What is this bit for? is it a contents page?

PAGE 2



Comment 2

Good abstract. Well written



Comment 3

parallel LC at resonance impedance is high

Series LC at resonance impedance is low.



Comment 4

Equations should have similar position to figures. i.e. equations should be on a separate line with a caption indicating what it is for and what the variables are.



Comment 5

It would be nice to have a short description of what the figure shows as the caption.

e.g.:

figure 1: parallel connected resistors

PAGE 3



Comment 6

Good introduction



Comment 7

This isn't a log plot.



Comment 8

analysing



Comment 9

Good conclusions. All valid.

What about the output impedance of the signal generator?



Comment 10

Good range of references but you should use more reputable sources like textbooks and peer reviewed journals etc.

GRADING FORM: SMU GENERIC_SMOSEY

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71.90

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

Inclusion of a wide range of sources retrieved



independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.

3

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Excellent knowledge and understanding of the main concepts and key theories.

21.6

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Thoroughly logical work. High quality analysis. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions.

21.3

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An advanced application of a range of methods, tools and techniques. The context of the application is well considered.

21.6

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably,

and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate with an exceptionally high level of professionalism. Work is exceptionally coherent, very fluent and is presented professionally.

4.4