Electrical Resonance

Research and rationale

I have chosen to investigate the resonance in circuits after studying digging up the past and technology in space modules. Also my knowledge in electronics has been useful as it allowed me to understand the behavior of the apparatus, such as an oscilloscope, and the principles used in the investigation. I have used the physics principles for capacitance and inductance where the combined impedances cancel each other out or reinforce each other to produce a minimum or maximum impedance. Impedance is the alternating-current equivalent of resistance.

For my research I am going to look on the internet for any relevant information about resonance and the type of circuits it appears in. Also I will look back at the A-level physics textbook which contains the "Digging up the past" and "Technology in space" modules to refresh what I already learnt about resistance.

For each circuit, resonance occurs at a given frequency called the resonant frequency, which depends on the amounts of inductance and capacitance in the circuit. If an alternating voltage of the resonant frequency is applied to a circuit in which the capacitance and inductance are connected in series, the impedance of the circuit is a minimum, and the circuit conducts a maximum amount of current. If the capacitance and inductance are connected in parallel, the opposite occurs: the impedance is extremely high and little current will pass. [1]

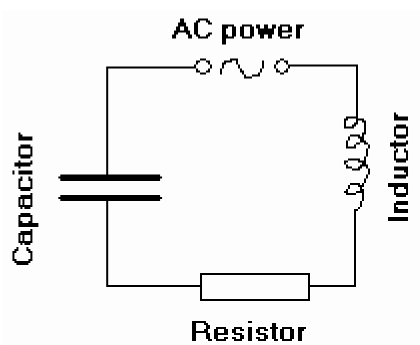


Figure 1:Simple resonating circuit

Resonant circuits are used in electrical equipment, such as filters, to select or reject currents of specific frequencies. Filters in which either the capacitance or the inductance of the circuit can be varied are used to tune radio and television receivers to the frequency of the transmitting station so that the receiver will accept that frequency and reject others.

With an amplitude modulated (AM) radio the amplitude of the carrier frequency is modified so that it contains the sounds picked up by a microphone. This is the simplest form of radio transmission but is very susceptible to noise and interference. Frequency modulated (FM) radio solves many of the problems of AM radio but at the price of higher complexity in the system. In an FM system sounds are electronically transformed into small changes in the carrier frequency. The piece of equipment which performs the transformation is called a modulator and is used with the transmitter. In addition, a demodulator has to be added to the receiver to convert the signal back into a form which can be played on a speaker. [2]

The formula used calculate the resonance frequency is:

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Where L = inductance
C = capacitance

The equation shows that the resonant frequency is one over the square root of the inductance multiplied by the capacitance in a circuit.

Aim

The aim of this investigation is to demonstrate that resonance does occur in electrical circuits by finding the resonant frequency for he circuit which will depend on the amount of inductance and capacitance in the circuit. I will also observe whether the resonant formula which states that the resonant frequency is one over the square root of the inductance of the circuit multiplied by it's capacitance is actually true.

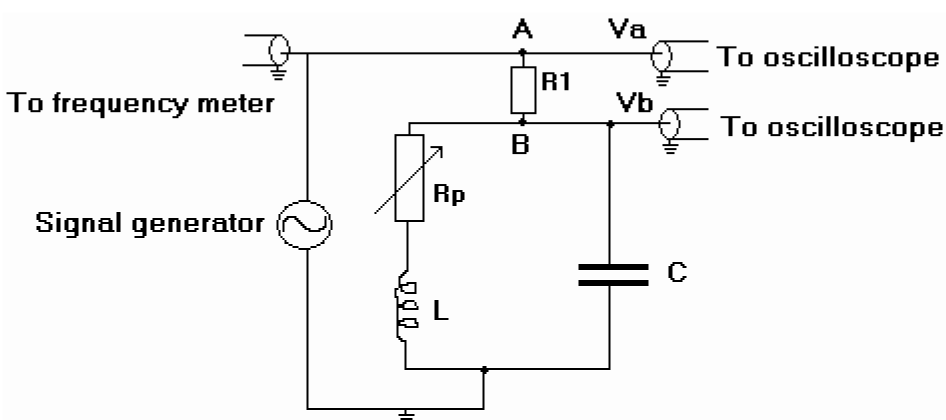
Variables

The investigation has many variables that will affect the experiment such as the frequency of the AC power supply, the inductance of the circuit, the capacitance of the circuit and the temperature of the surroundings.
For my investigation I will be varying the inductance of the circuit and the capacitance of the circuit. The temperature of the surroundings will affect the experiment in the form that higher temperatures will generate more resistance in the circuit. I will hopefully counter this problem by using the same room at roughly the same time of day when conducting the experiment. Normally the frequency of the AC power supply would affect the experiment but I will be altering the frequency myself using the signal generator as part of the experiment.

Apparatus

- Capacitors (C)
- Inductors (L)
- Decade resistance box (Rp)
- Oscilloscope
- Signal generator
- 1 MΩ resistor (R1)
- Frequency meter

Diagram



Safety

All the signal voltages in the experiment will be small and harmless. The mains voltage in the mains powered equipment is dangerous but is screened in normal use. Also no food or drink will be brought into or consumed in the lab and the work area will be clear of all but essential apparatus and equipment.

Method

1. Firstly I will be collecting and setting up the apparatus shown in the diagram above.
2. I will then ensure the inductor is set on 10mH, ensure the capacitor has a value of 7000pF and set the decade resistance box to 20Ω.
3. then I will connect one input of the oscilloscope between A earth to measure Va and the other input between B and earth to measure Vb.
4. I will then adjust the oscilloscope to display stable traces of Vb and Va simultaneously.
5. Once this has all been completed I will look for the resonant frequency by slowly adjusting the frequency of the signal generator until the maximum of Vb meets Va sharply (in-phase).
6. I will then repeat the experiment for different combinations of inductors and capacitors and record my findings.

Accuracy and sensitivity

For my results I will aim to record values up to 3 decimal points and keep this consistent throughout my results. Sensitivity of the apparatus and measuring equipment shouldn't be a concern as the equipment is mainly electronic devices that have already been calibrated and are accurate to an appropriate degree. Also the apparatus used in the experiment have set values that shouldn't distort or cause any problems during the experiment.

Results and evaluation

For my results I decided to record the values of the peak frequency as I changed the inductors, capacitors and resistors along with the voltages at the point Vb. With these results I drew up a graph of log frequency against log of L multiplied by C, a graph showing one over Vb against resistance and graphs showing the relationship between voltage and frequency for the capacitors and inductors used. I also drew a graph confirming that the formula works for the data that I have collected.

Inductor	Capacitor	Resistor	Signal peak
10.31mH	8238pF	20Ω	17.36KHz
	1998pF	20Ω	34.83KHz
	4718pF	20Ω	23.12KHz
	21451pF	20Ω	10.85KHz
4.62mH	8238pF	20Ω	26.03KHz
	1998pF	20Ω	51.34KHz
	4718pF	20Ω	34.18KHz
	21451pF	20Ω	15.99KHz

Resistance	Vb	1/Vb
0Ω	0.044	22.73
10Ω	0.032	31.25
20Ω	0.026	38.46
30Ω	0.020	50.00
40Ω	0.018	55.56
50Ω	0.015	66.67
60Ω	0.013	76.92
70Ω	0.012	83.33
80Ω	0.011	90.91
90Ω	0.010	100.00
100Ω	0.009	111.11

	Log frequency	Log L*C
1	1.25	4.93
2	1.54	4.31
3	1.36	4.69
4	1.04	5.34
5	1.71	3.96
6	1.53	4.34
7	1.42	4.58
8	1.2	4.99

Conclusion

From my experiment I have successfully shown that resonance occurs in a RLC circuit. I have also shown the formula regarding resonance: $\omega_0 = \frac{1}{\sqrt{LC}}$ is true by calculating the slope on my graph of log LC against log frequency which was -0.48 verifying the square root in the formula.

Limitations

The limitations to my results are that there wasn't a very large frequency range on the signal generator which would allowed me to utilize an even lager combination of inductors and capacitors which would have produced me more detailed graphs. Also I didn't have the time or equipment to observe resonance in other types of circuits like the types found in radios and televisions which would have given me the chance to see whether the formula applied to these circuits.

Modifications

I could have modified the experiment by utilizing a signal generator with a larger frequency range allowing me to use combinations of inductors and capacitors where the resonant frequency is either extremely high or low.

Further experiments

I could further the experiment by observing the way resonance works in radios and televisions and how the circuits achieve it. This would provide me with a deeper understanding and larger knowledge of electronic resonance and its applications.

Bibliography

[1] "Resonance (electronics)" - Microsoft Encarta encyclopedia.

[2] The physics of resonance - www.intuitor.com/resonance