# Series Resonance

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## Theory

The reactance of inductors increases with frequency according to the equation

XL = 2πfL

The reactance of capacitors decreases with frequency according to the equation

Consider the series LC circuit shown. In any LC circuit, there is a frequency at which the inductive reactance is equal to the capacitive reactance. The point at which there is equal and opposite reactance is called resonance. By setting XL = Xc, and solving for *f,* it can be shown that

At resonance the current is maximum. If the frequency is lowered, the inductive reactance will be smaller and the capacitive reactance will be larger. The circuit is said to be capacitive because the source current leads the source voltage. If the frequency is raised, the inductive reactance increases, and the capacitive reactance decreases. The circuit is said to be inductive.

The selectivity of a resonant circuit describes how the circuit responds to a group of frequencies.

A highly selective circuit responds to a narrow group of frequencies and rejects other frequencies. The bandwidth of a resonant circuit is the frequency range at which the current is 70.7% of the maximum current. A highly selective circuit thus has a narrow bandwidth. The sharpness of the response to changes in frequency is determined by the circuit Q. The Q for a series resonant circuit is the reactive power in either the coil or capacitor divided by the true power, which is dissipated in the total resistance of the circuit. The bandwidth and resonant frequency can be shown to be related to the circuit Q by the equation

The Figure below illustrates how the bandwidth can change with Q. Responses 1 and 2 have the same resonant frequency but different bandwidths. The bandwidth for curve 1 is shown. Response curve 2 has a higher Q and a smaller BW. A useful equation that relates the circuit resistance, capacitance, and inductance to Q is

Note that the value of R in this equation is the TOTAL equivalent series resistance in the circuit. For a highly selective circuit make R low, and L/C high.

At resonance, since at resonance XL=XC

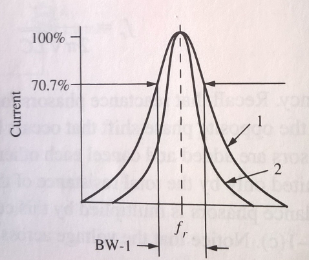


Figure 1. Current as a function of applied signal frequency

## Procedure

1. Measure the real value of resistances R1, R2, the capacitance C, inductance L and the winding resistance of the Inductor, Rw with help of DMM. Enter it into the Table below.   
   These values will be used in calculations.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Parameter | Ideal | Measured |  |
| R1 | |  | | --- | | 680 | | |  |  |
|  |
| R2 | optional | optional |  |
| C | 6.8 nF | 6.951E-09 |  |
| L | 10 mH | 0.01027 |  |
| Rwinding | |  | | --- | |  | | | 19.9 |  |
|  |

Calculations use measured values of components to calculate the following parameters and enter them into Table 2.

1. Calculate the total resistance of the circuit using the formula.
2. Calculate the resonance frequency using the formula.

Use the value for RT for resistance and the values of L and C to calculate the value of Q and the BW. Use the formulae below. Enter into the Table.

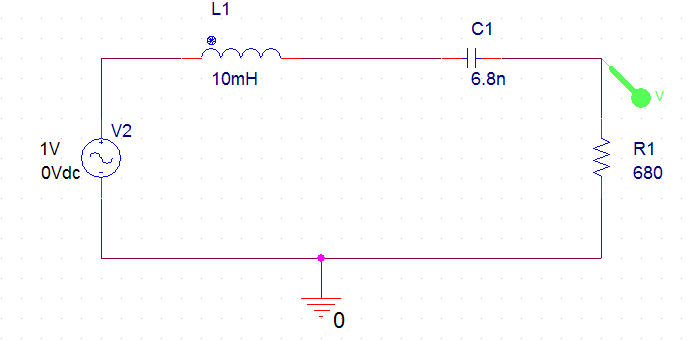


Figure 2. LCR series resonant circuit

1. Build the circuit. Set the input voltage to 1V RMS using your DMM. The current in the circuit rises to a maximum at resonance. The sense resistor will have the highest voltage across it at resonance... Measure the RMS voltage across the current sensing resistor at frequencies between 2 and 200 kHz using your DMM. Fill in Table 1 below.

|  |  |  |
| --- | --- | --- |
| Frequency (kHz) | RMS Voltage (V) |  |
| 2 | 0.062 |  |
| 3 | 0.094 |  |
| 5 | 0.152 |  |
| 7 | 0.227 |  |
| 10 | 0.367 |  |
| 15 | 0.698 |  |
| 20 | 0.921 |  |
| 30 | 0.484 |  |
| 50 | 0.224 |  |
| 70 | 0.113 |  |
| 100 | 0.006 |  |
| 150 | 0.004 |  |
| 200 | 0.003 |  |
|  |  |  |

Table 1. The voltage across current sensing resistor as a function of frequency

1. Plot your results of Voltage across current sensing resistor as a function of frequency using EXCEL

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | |
|  | | | |
|  | | | |
| Parameter | Calculated | Measured |
| Rwinding | 19.6 |  |
| Rtotal | 749.6 |  |
| Vmax |  | 0.86 |
| fr | 19310.1612 | 18.3 |
| Q | 1215.51851 |  |
| V3dB | 0.60802 |  |
| f1 |  | 14.7 |
| f2 |  | 27 |
| BW | 15.8863572 | 12.3 |
|  |  |  |

Table 2. Results

1. Record the resonant frequency, where the output across the resistor is maximum, in Table 2.

The value is shown above in table 2 = 18.3

1. Raise the frequency of the generator until the voltage across the resistor falls to 70.7% of the value at resonance. Record this value as f1.

The value is shown above in table 2 = 14.7

1. Lower the frequency to below resonance until the voltage across falls to 70.7% of the value at resonance. Measure and record this frequency as f2.

The value is shown above in table 2 = 27

1. Compute the bandwidth by subtracting fl from f2 and record the frequency. Enter the values into the Table.

The value is shown above in table 2 = 12.3

1. Write one comment below on the work you have done. If time allows, verify your results using ORCAD or another simulator.

During the lab, we built the circuit on the breadboard using some different components such as an inductor, a capacitor and a resistor. We measured several values for the RMS by changing the frequency in the function generator. We were able to plot a graph in excel using the RMS voltage values as shown above.

The formulas were provided to calculate the Rwinding, Rtotal, fr, Q, V3Db, BW shown above.

1. OPTIONAL: Repeat the measurements and calculations R2. Comment on the effect of resistance on the resonance.