Frequency Dependence of L-R-C Components

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Abstract

For this lab experiment we are going to measure the impedance of a circuit element in an AC circuit. To do this we will use ohms law which states that $Z_{eq} = \frac{V}{I}$. Since an oscilloscope will be used to take our measurements, we can only measure voltage. In order to gather the necessary information to find the impedance we will place a low resistance resistor in series with the element we want to measure. From the voltage across the current viewing resistor and it's known resistance, we are able to gather current information in the series circuit. From this experiment we will learn how to measure impedance values for devices using an oscilloscope and a CVR resistor.

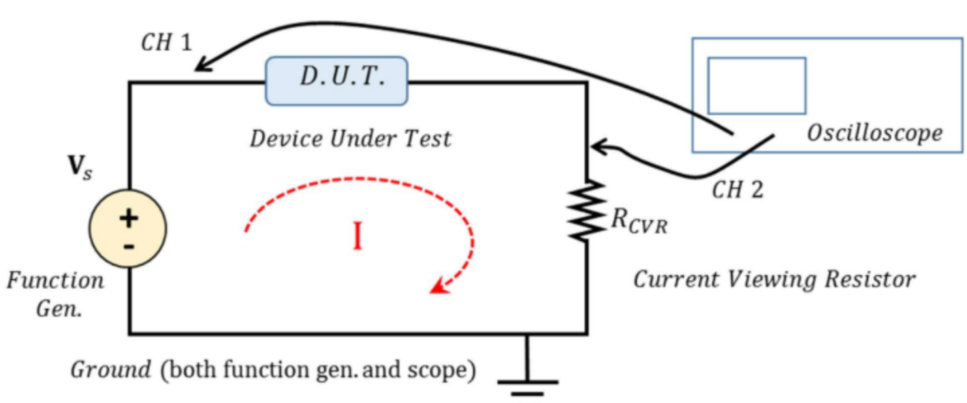
Equipment

- Oscilloscope
- Function Generator
- Current Viewing Resistor (47 - 120 Ω)
- 1kΩ and a 3 or 3.3kΩ Resistor
- 0.1μF and a 0.047 or 0.056μF Capacitor
- 10 mH and a 33 or 47 mH Inductor

Procedure

Part 1 Resistors

1. Construct the circuit of Fig. 2.1 (Specific component values will be presented by instructor during lab). Do your calculations with the actual measured values of the components.



2. Hold the source voltage constant and only vary the frequency. Through this process we can verify if the resistance across the CVR is frequency independent.
3. Set the frequency to 100 Hz, then adjust the amplitude until the voltage $|V_s| = 4V_{pk-p}|$. Record the voltage across the CVR and calculate the magnitude of the current.
4. Measure the phase angle between the voltage Vs (your reference at 0°) and VCVR. Let us call this phase shift ϕ_R which is actually the phase of the current Is relative to our reference, (the shift is caused by the device we are testing). Record the values you have found in a table. The phasor Is can now be determined as: $I_s = I_s\angle\phi_r$
5. Repeat the process with the frequency set to 1 kHz and 10kHz each time monitoring V_s.
6. Add a second resistor both in series and in parallel with the frequency at a 1 kHz. For each circuit monitor the voltage and current as above.

Part 2 Inductors

1. Construct the circuit below:
2. Hold voltage constant while varying the frequency and monitor the current in the circuit.
3. Set the voltage $|V_s| = 4V_{pk-p}|$ and vary the frequency with the values 1 kHz, 10 kHz, and 100 kHz. Measure and record the current through the inductor using the CVR.
4. Calculate the reactance at each frequency.
5. Plot Reactance versus Frequency of the data measured.

0.0.1 Part 3 Capacitors

1. Construct the circuit below:
2. Hold voltage constant while varying the frequency and monitor the current in the circuit.
3. Set the voltage $|V_s| = 4V_{pk-p}|$ and vary the frequency with the values 1 kHz, 5 kHz, and 20 kHz. Measure and record the current through the inductor using the CVR.
4. Calculate the reactance at each frequency.
5. Plot Reactance versus Frequency of the data measured.

Data

Current Viewing Resistor: R_cvr (ohms)
57.03

Resistor:

Frequency: f (HZ)	Angular Frequency: w (rad/s)	Voltage: V_s (v)	Voltage: V_cvr (v)	Phase Shift: Phi_r (deg.)	Measured Load Resistor: R_r (ohms)
100.4300	631.0203	4.0030	0.2211	0.0000	980.800
1005.0000	6314.6012	4.0050	0.2216	0.0000	
10100.0000	63460.1716	4.0050	0.2211	0.0000	

Inductor:

Frequency: f (kHZ)	Angular Frequency: w (rad/s)	Voltage: V_s (v)	Voltage: V_cvr (v)	Phase Shift: Phi_L1 (deg.)	Measured Load Inductor 1: L1 (mH)	Measured Load Inductor 2: L2 (mH)
1.0032	6303.2915	4.0100	0.6410	-57.0000	46.070	10.452
10.0012	62839.3929	3.9950	0.0830	-87.0000		
100.0010	628324.8139	3.9980	0.0085	-100.0000	**Added 2nd Load:**	
10.0180	62944.9504	4.0130	0.0686	-87.0000	Series: 56.522	
10.0180	62944.9504	4.0050	0.4840	-80.0000	Parallel: 8.52	

Capacitor:

Frequency: f (kHz)	Angular Frequency: w (rad/s)	Voltage: V_s (v)	Voltage: V_cvr (v)	Phase Shift: Phi_C1 (deg.)	Measured Load Capacitor 1: C1 (nF)	Measured Load Capacitor 2: C2 (nF)
1.0030	6302.0349	4.0080	0.0697	88.0000	47.710	59.250
5.0070	31459.9088	4.0080	0.3398	84.2000		
20.0130	125745.3876	4.0230	1.2890	69.0000	**Added 2nd Load:**	
4.9970	31397.0770	3.9980	0.1887	87.4000	Series: 26.43	
4.9940	31378.2274	4.0100	0.7460	78.2000	Parallel: 106.96	

Calculations

Resistor:

Frequency:

100.430 Hz

$$Z_R = \frac{(4.003\angle 0 - 0.2211\angle 0)\,V}{0.0039\angle 0\,A} = 975.49\,\Omega$$

1005 Hz

$$Z_R = \frac{(4.005\angle 0 - 0.2216\angle 0)\,V}{0.0039\angle 0\,A} = 973.68\,\Omega$$

10100 Hz

$$Z_R = \frac{(4.005\angle 0 - 0.2211\angle 0)\,V}{0.0039\angle 0\,A} = 976.01\,\Omega$$

Inductor:

Frequency:

1003.2 Hz

$$Z_{L_1} = \frac{(4.01\angle 0 - 0.641\angle -57)\,V}{0.0112\angle -57\ A} = 137.77 + j300.274\ \Omega$$

$$L_1 = \frac{j300.274}{j(1003.2 \cdot 2 \cdot \pi)} = 0.04763\ H$$

10001.2 Hz

$$Z_{L_1} = \frac{(3.995\angle 0 - 0.083\angle -87)\,V}{0.0015\angle -87\ A} = 84.0547 + j2659.68\ \Omega$$

$$L_1 = \frac{j2659.68}{j(10001.2 \cdot 2 \cdot \pi)} = 0.04232\ H$$

100001 Hz

$$Z_{L_1} = \frac{(3.998\angle 0 - 0.0085\angle -100)\,V}{0.0001\angle -100\ A} = -7027.45 + j39372.61\ \Omega$$

$$L_1 = \frac{j39372.61}{j(100001 \cdot 2 \cdot \pi)} = 0.06266\ H$$

Series:

10018 Hz

$$Z_{L_1} = \frac{(4.013\angle 0 - 0.0686\angle -87)\,V}{0.0012\angle -87\ A} = 117.85 + j3339.59\ \Omega$$

$$L_1 = \frac{j3339.59}{j(10018 \cdot 2 \cdot \pi)} = 0.0531\ H$$

Parallel:

10018 Hz

$$Z_{L_1} = \frac{(4.005\angle 0 - 0.484\angle -80)\,V}{0.0085\angle -80\ A} = 24.88 + j464.02\ \Omega$$

$$L_1 = \frac{j464.02}{j(10018 \cdot 2\pi)} = 0.00737\ H$$

Capacitor:

frequency:

1003 Hz

$$Z_{C_1} = \frac{(4.008\angle 0 - 0.0697\angle 88)\,V}{0.0012\angle 88\,A} = 58.48 + -j3337.99\,\Omega$$

$$C_{C_1} = \frac{1}{j \cdot -j3337.99 \cdot 1003 \cdot 2 \cdot \pi} = 47.54\,nF$$

5007 Hz

$$Z_{C_1} = \frac{(4.008\angle 0 - 0.3398\angle 84.2)\,V}{0.006\angle 84.2\,A} = 10.87 + -j664.58\,\Omega$$

$$C_{C_1} = \frac{1}{j \cdot -j664.58 \cdot 5007 \cdot 2 \cdot \pi} = 47.83\,nF$$

20013 Hz

$$Z_{C_1} = \frac{(4.023\angle 0 - 1.289\angle 69)\,V}{0.0226\angle 69\,A} = 6.76 + -j166.19\,\Omega$$

$$C_{C_1} = \frac{1}{j \cdot -j166.19 \cdot 20013 \cdot 2 \cdot \pi} = 47.85\,nF$$

Series:
4997 Hz

$$Z_{C_1} = \frac{(3.998\angle 0 - 0.1887\angle 87.4)\,V}{0.0033\angle 87.4\,A} = -2.22 + -j1210.27$$

$$C_{+} = \frac{1}{j \cdot -j1210.27 \cdot 4997 \cdot 2 \cdot \pi} = 26.32\,nF$$

Parallel:
4994 Hz

$$Z_{C_1} = \frac{(4.01\angle 0 - 0.746\angle 78.2)\,V}{0.0131\angle 78.2\,A} = 5.65 + -j299.64$$

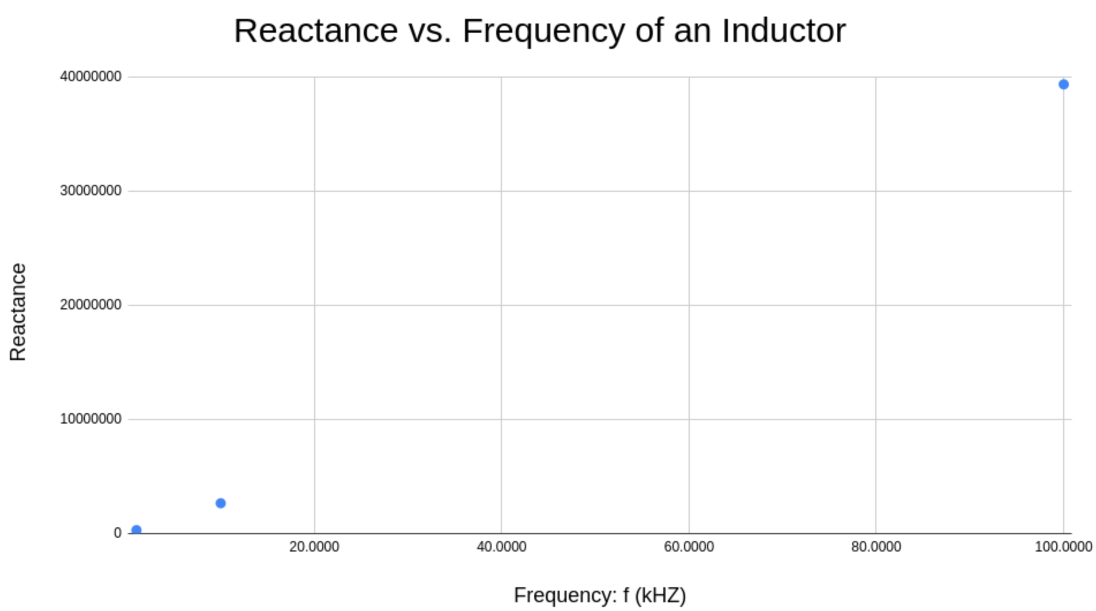
$$C_{\parallel} = \frac{1}{j \cdot -j299.64 \cdot 4994 \cdot 2 \cdot \pi} = 106.36\,nF$$

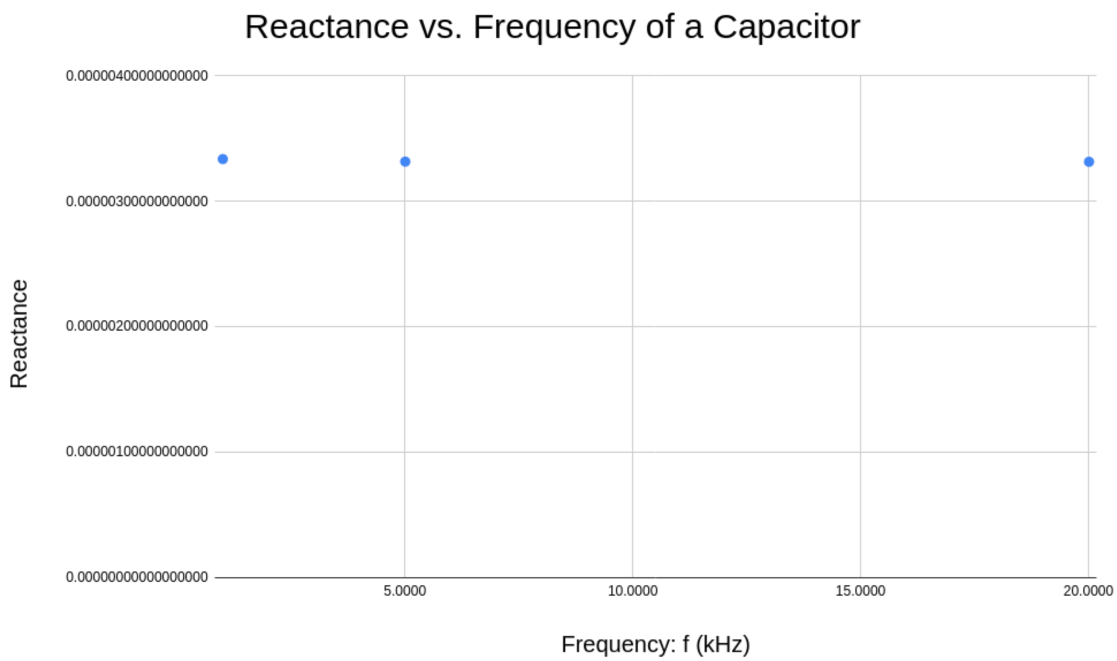
Results

Resistor:			
Frequency: f (Hz)	**Voltage: V_r (v)**	**Current: I_r (A) Phase Angle: Phi_R**	**Impedence: Z_R (ohms)**
100.4300	3.7819 ∠ 0	0.0039	975.49
1005.0000	3.7834 ∠ 0	0.0039	973.68
10100.0000	3.7839 ∠ 0	0.0039	976.01

Inductor:			
Frequency: f (Hz)	**Voltage: V_L1 (v)**	**Current: I_L1 (A) Phase Angle: Phi_L1**	**Impedence: Z_L1 (mH)**
1003.2000	3.7001 ∠ 8.3540	0.0112	47.63
10001.2000	3.9915 ∠ 1.1899	0.0015	42.32
100001.0000	3.9995 ∠ 0.1199	0.0001	62.66
10018.0000	4.0100∠ 0.9789	0.0012	53.10
10018.0000	3.9498 ∠ 6.9311	0.0085	7.37

Capacitor:			
Frequency:f (Hz)	**Voltage: V_C1 (v)**	**Current: I_C1 (A) Phase Angle: Phi_C1**	**Impedence: Z_C1 (nF)**
1003.0000	4.0062∠ -0.9963	0.0012	47.54
5007.0000	3.9880 ∠ -4.8627	0.0060	47.83
20013.0000	3.7589∠ -18.6716	0.0226	47.85
4997.0000	3.9939 ∠ -2.7053	0.0033	26.32
4994.0000	3.9260 ∠ -10.7195	0.0131	106.360





Conclusion and Discussion

By using a Current Viewing Resistor we are able to accurately measure an AC devices impedance. The resistor was estimated to have an impedance between 973.68 and 976.01 Ω. The inductor was estimated to have a reactance between 42.32 and 62.66 mH. The capacitor was estimated to have a reactance between 47.54 and 47.83 nF. Through our experiment we see that the resistor does not change with respect to frequency. We can assume from this that the resistor does not effect phase of the voltage or current across it. With the inductor, as the frequency is increased the reactance increases linearly. For the capacitor the reactance is inversely related to the frequency, which is non linear. The relationship between current and voltage based on an inductor is $\frac{V}{I} = j\omega L$. The relationship between current and voltage based on a capacitor is $\frac{V}{I} = \frac{1}{j\omega C}$. In this experiment there may have not been enough data points to achieve a clear graphical result. The observation that is trying to be demonstrated is that the slope of the Freq vs. Reactance for the inductor is the Inductance of the component and the inverse of the slope of the Freq Vs. Reactance for the capacitor is the capacitance.