



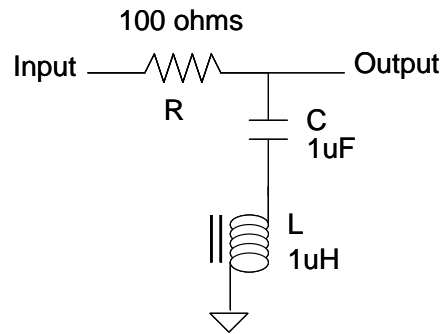
## Using ChatGPT-4 to Design Hardware Circuits

The goal is to investigate the usefulness of using ChatGPT-4 in analyzing electronic circuits. The question was taken from a test we use to evaluate hardware engineering candidates. This is an update following the release of Plugins in GPT-4. With the release of the Wolfram Plugin to the GPT-4 model the same circuit analysis problem was given to the Ai model.

The result as of 3/14/2023 is shown first and is followed by the result as of "5/21/2023"

The circuit to the right was provided in words.

What is the Output voltage of the circuit when a 10 Volt 160kHz sine wave is presented at the Input.



To test the ChatGPT-4 model the circuit diagram was converted to a word prompt as follows:

INPUT

*For this question the accuracy of the answer is important and will require mathematical calculations. Please double check the results of all calculations.*

*The circuit is an RLC circuit comprising of*

*R1 = 100 ohms*

*L1 = 1uH*

*C1 = 1uF*

*R1, L1 and C1 are connected in series.*

*The components are wired as follows:*

*The INPUT node is connected to pin 1 of R1*

*Pin 2 of R1 is connected to the OUTPUT node and to pin 1 of C1*

*Pin 2 of C1 is connected to pin 1 of L1*

*Pin 2 of L1 is connected to ground*

*A 10V peak to peak 160kHz signal source is connected to the INPUT.*

*What is the peak to peak voltage measured from the OUTPUT node to ground?*



ChatGPT-4 generated the following response to this question:

To find the peak-to-peak voltage across the output node in a series RLC circuit, we'll first need to calculate the impedance of the circuit and then use Ohm's Law to find the current flowing through the circuit. Afterward, we can determine the voltage across the capacitor or inductor, and finally calculate the output voltage.

Calculate the angular frequency ( $\omega$ ) of the signal source:

$$\omega = 2 * \pi * f$$

where  $f$  is the frequency.

$$\omega = 2 * \pi * 160,000 \text{ Hz} \approx 1,005,309.649 \text{ rad/s}$$

Calculate the inductive reactance ( $X_L$ ) and capacitive reactance ( $X_C$ ) of the circuit:

$$X_L = \omega * L$$

$$X_L = 1,005,309.649 \text{ rad/s} * 1\text{e-}6 \text{ H} \approx 1.005 \Omega$$

$$X_C = 1 / (\omega * C)$$

$$X_C = 1 / (1,005,309.649 \text{ rad/s} * 1\text{e-}6 \text{ F}) \approx 0.995 \Omega$$

Calculate the total impedance ( $Z$ ) of the circuit:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{(100 \Omega)^2 + (1.005 \Omega - 0.995 \Omega)^2} \approx 100.005 \Omega$$

Calculate the current ( $I$ ) flowing through the circuit using Ohm's Law:

$$I = V / Z$$

where  $V$  is the peak voltage of the input signal (half of the peak-to-peak voltage).

$$V = 10\text{V peak-to-peak} / 2 = 5\text{V peak}$$

$$I = 5\text{V} / 100.005 \Omega \approx 0.049998 \text{ A (peak)}$$

Calculate the voltage across the capacitor ( $V_C$ ) and inductor ( $V_L$ ):

$$V_C = I * X_C$$

$$V_C = 0.049998 \text{ A} * 0.995 \Omega \approx 0.049749 \text{ V (peak)}$$



$$V_L = I * X_L$$

$$V_L = 0.049998 \text{ A} * 1.005 \Omega \approx 0.050249 \text{ V (peak)}$$

Calculate the voltage across the resistor ( $V_R$ ):

$$V_R = I * R$$

$$V_R = 0.049998 \text{ A} * 100 \Omega \approx 4.9998 \text{ V (peak)}$$

Calculate the output voltage ( $V_{out}$ ) across the capacitor:

$$V_{out} = V_L - V_C$$

$$V_{out} = 0.050249 \text{ V} - 0.049749 \text{ V} \approx 0.0005 \text{ V (peak)}$$

Convert the peak output voltage to peak-to-peak output voltage:

$$V_{out\_peak\_to\_peak} = 2 * V_{out}$$

$$V_{out\_peak\_to\_peak} = 2 * 0.0005 \text{ V} = 0.001 \text{ V}$$

The peak-to-peak voltage measured from the OUTPUT node to ground is approximately 0.001 V or 1 mV. Keep in mind that this is a simplified calculation and does not account for any parasitic elements or the effects of the signal source's internal impedance.

5/21/2023 Result

The prompt was modified slightly from the the 3/14/2023 version as the Ai expected Wolfram to solve the problem which failed completely. I have highlighted the changed text in red.

INPUT

For this circuit analysis question break the solution down step by step and only use Wolfram to do the math Do not count on Wolfram to try to analyze the circuit.

The circuit is an RLC circuit comprising of

$R_1 = 100 \text{ ohms}$

$L_1 = 1\mu\text{H}$

$C_1 = 1\mu\text{F}$

$R_1$ ,  $L_1$  and  $C_1$  are connected in series.

The components are wired as follows:

The INPUT node is connected to pin 1 of  $R_1$

Pin 2 of  $R_1$  is connected to the OUTPUT node and to pin 1 of  $C_1$

Pin 2 of  $C_1$  is connected to pin 1 of  $L_1$

Pin 2 of  $L_1$  is connected to ground

A 10V peak to peak 160kHz signal source is connected to the INPUT.



What is the peak to peak voltage measured from the OUTPUT node to ground? **In other words what is the voltage across the series combination of L1 and C1?**

ChatGPT-4 generated the following response to this question:

Sure, let's break this down step by step.

1. **Identify the circuit type and its components:** This is a series RLC circuit, where R1 is the resistor, L1 is the inductor, and C1 is the capacitor. The values are given as R1 = 100 ohms, L1 = 1uH, and C1 = 1uF.
2. **Understand the circuit configuration:** The signal source is connected to the input node, which is connected to R1. The output node is connected to the junction of R1, C1, and L1. The other end of L1 is connected to the ground. We are interested in the voltage across the series combination of L1 and C1, which is the same as the voltage at the output node.
3. **Calculate the impedance of the circuit:** The total impedance (Z) of a series RLC circuit is given by the formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where:

- R is the resistance,
- $X_L$  is the inductive reactance given by  $X_L = 2\pi fL$ ,
- $X_C$  is the capacitive reactance given by  $X_C = 1/(2\pi fC)$ ,
- f is the frequency of the signal.

4. **Calculate the current in the circuit:** The current (I) in the circuit is given by Ohm's law:  
 $I = V/Z$   
where V is the peak voltage of the signal source.
5. **Calculate the voltage across L1 and C1:** The voltage across the series combination of L1 and C1 is given by:

$$V_{LC} = I \times Z_{LC}$$

where  $Z_{LC}$  is the impedance of the series combination of L1 and C1, given by:

$$Z_{LC} = \sqrt{(X_L - X_C)^2}$$

Let's now use Wolfram to perform the calculations. We know that the peak voltage V = 10V, the frequency f = 160kHz = 160,000 Hz, R = 100 ohms, L = 1uH =  $1 \times 10^{-6}$  H, and C = 1uF =  $1 \times 10^{-6}$  F.

Used **Wolfram**

REQUEST TO WOLFRAM



```
{ "input": "f = 160000; R = 100; L = 1*10^-6; C = 1*10^-6; V = 10; XL = 2*Pi*f*L;  
XC = 1/(2*Pi*f*C); Z = Sqrt[R^2 + (XL - XC)^2]; I = V/Z; ZLC = Sqrt[(XL - XC)^2];  
VLC = I * ZLC; VLC" }
```

RESPONSE FROM WOLFRAM

```
"I Sqrt[(-1/320000 1/(C Pi) + (8 Pi)/25)^2]\n\nErrors generated during evaluation:  
\nSet::wrsym : Symbol C is Protected.\nSet::wrsym : Symbol I is Protected."
```

Apologies for the confusion. It seems there was a conflict with the variable names 'C' and 'I' which are protected symbols in Wolfram Language. Let's correct this and try again. We'll use 'Cap' for the capacitor and 'current' for the current. Let's calculate again.

Used **Wolfram**

The peak-to-peak voltage across the series combination of L1 and C1, which is the same as the voltage at the output node, is given by the expression:

$$V_{LC} = \frac{10 \left( -\frac{25}{8\pi} + \frac{8\pi}{25} \right)}{\sqrt{10000 + \left( -\frac{25}{8\pi} + \frac{8\pi}{25} \right)^2}}$$

Let's evaluate this expression to get a numerical value.

Used **Wolfram**

Apologies for the confusion. It seems there was an issue with the evaluation. Let's try again.

Used **Wolfram**

The peak-to-peak voltage across the series combination of L1 and C1, which is the same as the voltage at the output node, is approximately 0.00106 volts or 1.06 millivolts.

## Conclusion

The ChatGPT-4 model is capable of analyzing series RLC circuits with or without the Wolfram Plugin. With the Plugin it did not solve the problem with the 3/14/2023 prompt. Requiring it to break the problem down in steps provided a correct result.

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