LABORATORY EXERCISE 2

Circuits in sinusoidal steady state.

Goal of the exercise: The goal of this lab is to demonstrate to the students the basic concepts in sinusoidal steady state circuits.

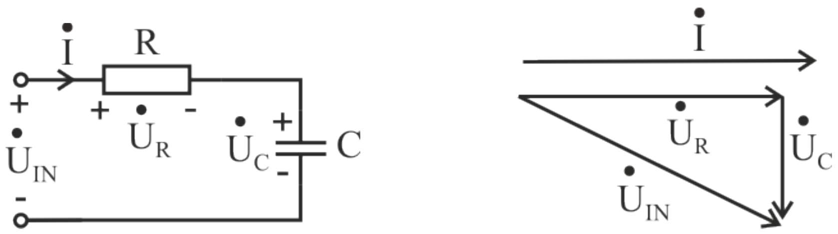
1. Introduction

The resistance of capacitors and inductors in sinusoidal steady state depend on the frequency and can be estimated according to:

$$X_L = \omega L = 2\pi f L \qquad X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

where f is the frequency, measured in *Hz*, and ω is the angular frequency in rad/s .

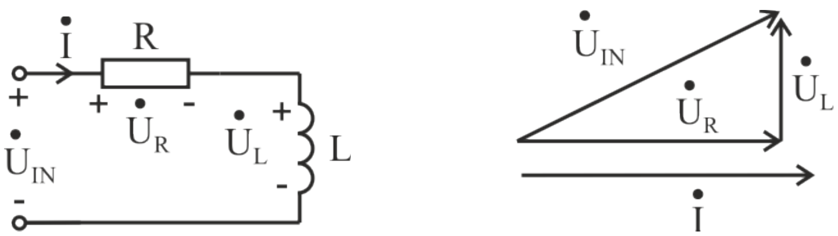
Capacitors delay the variation of their voltage, which leads to a phase difference of $-90°$ from the current. That's why the phasor diagram of a series RC circuit (fig. 1a) looks as presented in fig. 1b. The voltage drops on the resistor and the capacitor are at a right angle, since the resistor voltage is proportional to the current ($U_R = I.R$).



a) b)

Fig. 1. Series RC circuit and it's phasor diagram.

Similarly the inductors delay the changes of the current, which leads to a phase difference $+90°$ between the voltage and current of the inductor. The voltage drop of the resistor is once again proportional to the current, which makes the series RL phasor diagram look as presented in fig. 2b.



a) b)

Fig. 2. Series RL circuit and it's phasor diagram.

2. Required equipment

Equipment	Count
Breadboard	1 pc.
A set of connecting wires	1 pc.
Function generator	1 pc.
Two channel oscilloscope	1 pc.
Capacitor 100 nF	1 pc.
Inductor 290 μH	1 pc.
Resistor 100 Ω, 5 W	1 pc.

3. Tasks

Task 1.

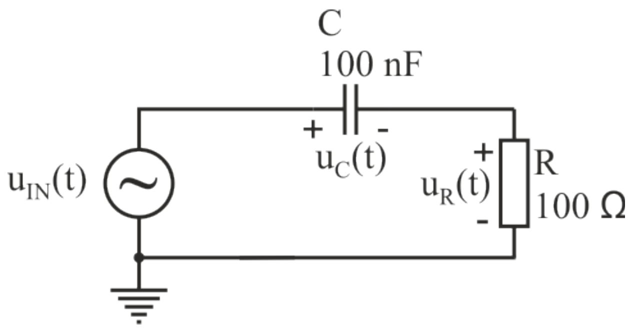


Fig. 3.

Step 1. Connect the circuit (fig. 3) on the breadboard.

Step 2. Connect on the oscilloscope's probes to the generator ($u_{\mathrm{IN}}(t)$), and the second one – to the resistor.

Step 3. Power the circuit from the function generator with a sinusoidal waveform with voltage $U_{\mathrm{IN}}=6\,Vpp$ and frequency $f=15\,kHz$:

- Measure the amplitude of the input voltage U_{IN} ;
- Measure the amplitude of the voltage drop on the resistor U_R .
- Estimate the voltage drop on the capacitor according to:

$$U_C=\sqrt{U_{\mathrm{IN}}^2-U_R^2}$$

- Measure the phase difference t_φ and the period of the sinusoid T in μs , as shown in fig. 4.

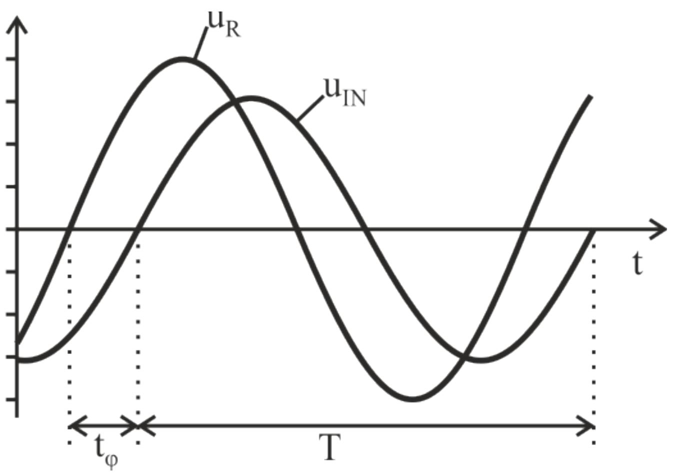


Fig. 4.

- Obtain the phase difference in degrees according to:

$$\varphi=-t_{\varphi}.\frac{360°}{T},°$$

- Estimate the amplitude of the current in the circuit according to Ohm's law:

$$I=\frac{U_R}{R}$$

Step 4. Draw the phasor diagram as shown in fig. 1b.

- The voltage phasors should be in scale;
- In the phasor diagram mark the phase difference angle.

Task 2.

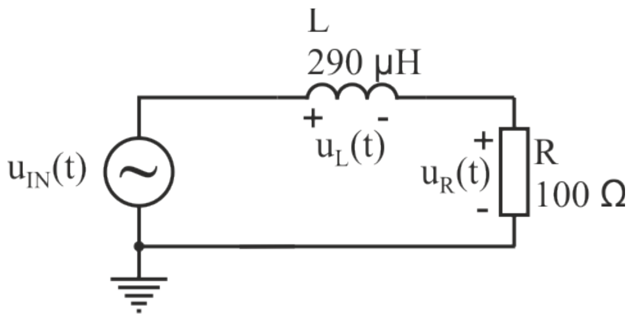


Fig. 5.

Step 1. Connect the circuit (fig. 5) on the breadboard.

Step 2. Connect on the the oscilloscope's probes to the generator ($u_{IN}(t)$), and the second one to the resistor.

Step 3. Power up the circuit from the function generator with a sinusoidal waveform with voltage $U_{IN}=6\,Vpp$ and frequency $f=100\,kHz$:

- Measure the amplitude of the input voltage U_{IN} ;

- Measure the amplitude of the resistor's voltage drop U_R ;
- Estimate the amplitude of the inductor's voltage drop:

$$U_L = \sqrt{U_{IN}^2 - U_R^2}$$

- Measure the phase difference t_φ and the period of the sinusoid T in μs , as shown in fig. 6.

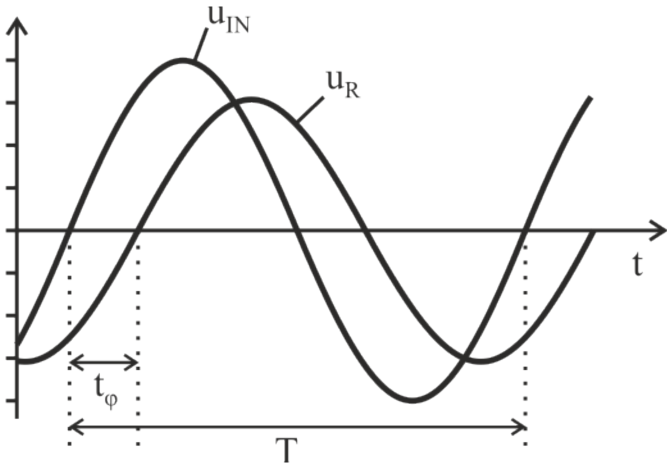


Fig. 6.

- Obtain the phase difference in degrees according to:

$$\varphi = t_\varphi . \frac{360°}{T} , °$$

- Estimate the amplitude of the current in the circuit according to Ohm's law:

$$I = \frac{U_R}{R}$$

Step 4. Draw the phasor diagram as shown in fig. 2b.

- The voltage phasors should be in scale;
- In the phasor diagram mark the phase difference angle.

4. Questions

1. Can you explain why the phase difference can be measured by observing on the oscilloscope the voltages of the generator and of the resistor?

2. Do the phase difference obtained experimentally match the phase difference of the phasor diagram? Why?

3. Will the phasor diagrams change if the frequency of the sinusoidal waveform changes?