



**EXERCISE
53**

OHM'S LAW FOR ALTERNATING CURRENT

Measurement procedure

1. The list of necessary equipment

- Power generator OWON AG 1022F
- Voltmeter
- Ammeter
- Resistors (R), capacitors (C) and inductors (L) assembly, wires

2. Goals

- Experimental verification of the Ohm's Law for alternating current
- Determination of the inductance L of the selected inductor component
- Determination of the capacitance C of the selected capacitor component

3. Experimental setup

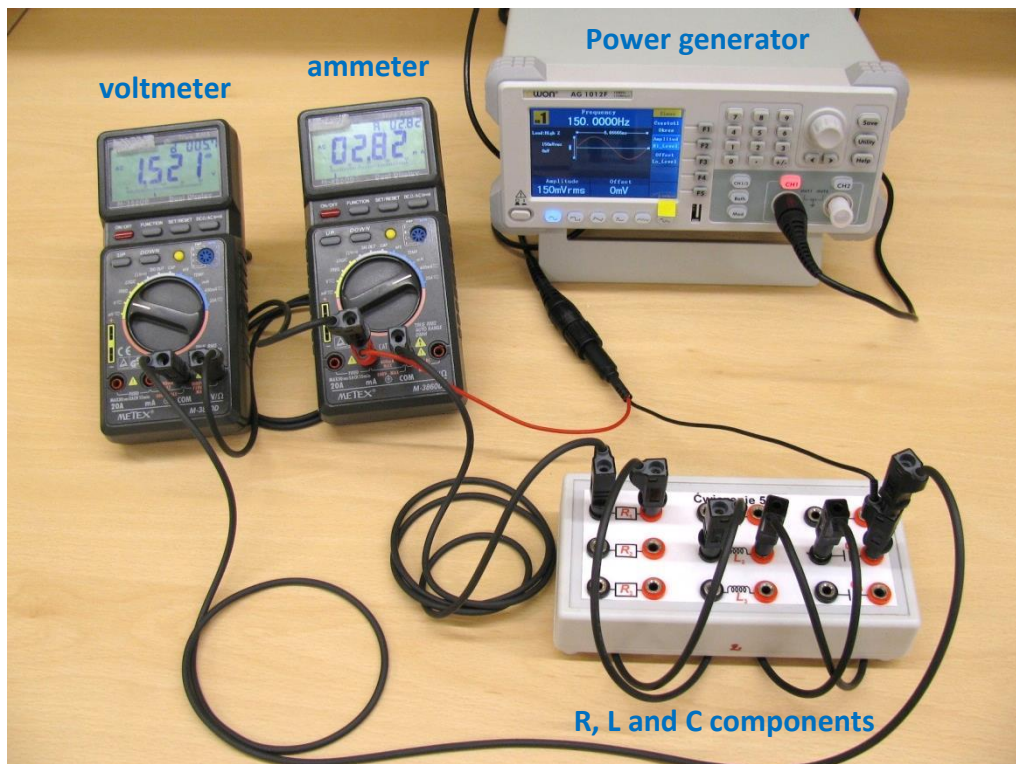
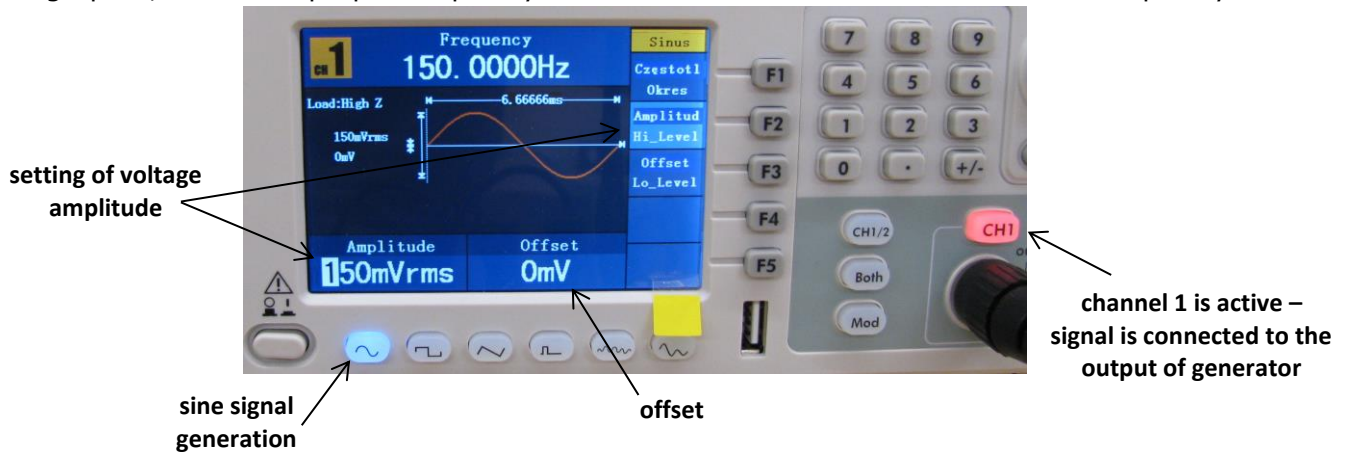


Fig. 1. The experimental setup for current-voltage characteristic of series RLC circuit.

4. Components selection and preparation for measurements

Make sure that channel 1 (CH1) of power generator (socket ⑬) - see the generator's manual) is connected to socket ⑩ P-Input on rear panel of generator. Sine signal (output) is obtained

from the P-Output ⑨ at the rear panel. **Caution! Output signal is 10-fold amplified in comparison to the displayed value.** Set up the experiment according to Fig. 1. Select R, L and C components (one piece of each) for your measurements. The components are numbered – remember to write down the numbers of the selected components. In paragraph 6, you will find the values of R and R_L necessary for calculations. Moreover, using the information given in paragraph 6, select the proper frequency f . Remember to write down the selected frequency f .



4.1. Determination of the capacitance C of the capacitor component (RC circuit)

Connect the electric circuit according to Fig. 2. This is an "RC" circuit, meaning that there are only R and C components connected in series to the AC source (generator). Turn on the generator with the button ⑰.

Frequency setting. Make sure that the generator is set to the sine mode (the leftmost button ⑱ is highlighted, the display shows a sine function). The generator should be in frequency regulation mode – on the display the field by the F1 button is highlighted, one of digits showing actual frequency is blinking. If not – push F1 button. F1 button is also used for switching between frequency (Hz or kHz) and period (μ s or ms). Required frequency value (appropriate for chosen capacitance C) we set using numeric keypad (e.g. to get 100 Hz we have to enter 100 and next push F3 button defining Hz unit) or using knob and directional buttons ⑤.

Voltage setting. To switch to voltage setting push F2 button (Amplituda). Setting voltage amplitude is similar to setting frequency described above. At the beginning start e.g. with 100 mVrms (**this corresponds to the RMS voltage of 1 V**) – entering on the numeric keypad 100 and next F3 button (mVrms). On the display should be 100 mVrms.

Turn on the meters and set the appropriate ranges for AC measurements. Check on generator if the value of Offset is set to 0 mV. If not, pressing F3 enables to change the Offset value. Remember to return to frequency (F1) or voltage (F2) setting mode. After pushing ⑫ button (power generator output is on) the voltmeter should show voltage close to 1 V.

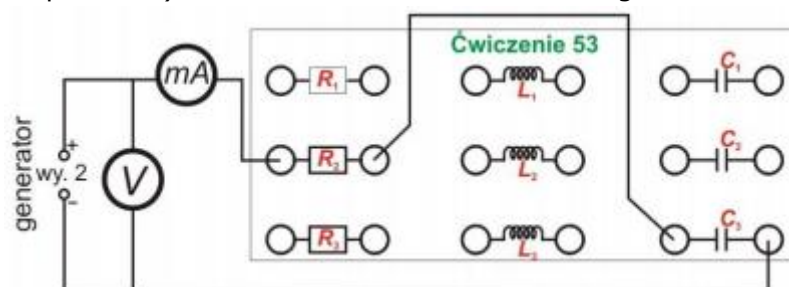


Fig. 2. RC circuit used to determine capacitance C .

For chosen frequency f change the voltage U_{sk} in the range from 0 to 10 V with a step of 1 V – read the value from voltmeter and write it down (**Caution! On generator's display the voltage should be changed in the range between 100 mVrms do 1 Vrms with 100 mVrms step**) and for each U_{sk} read the value of current I_{sk} (from ammeter) and write it down. Define uncertainties $u(f)$, $u(I_{sk})$ oraz $u(U_{sk})$.

4.2. Determination of the inductance L of the inductor component (RL circuit)

Connect the electric circuit according to Fig. 3. This is an "RL" circuit, meaning that there are only R and L components connected in series to the generator. Proceeding as in previous part (for the same frequency f) determine the I_{sk} current to U_{sk} voltage dependence for the RL circuit. Remember – in the case of RL circuit, the total resistance is $R+R_L$ (this is important for calculations).

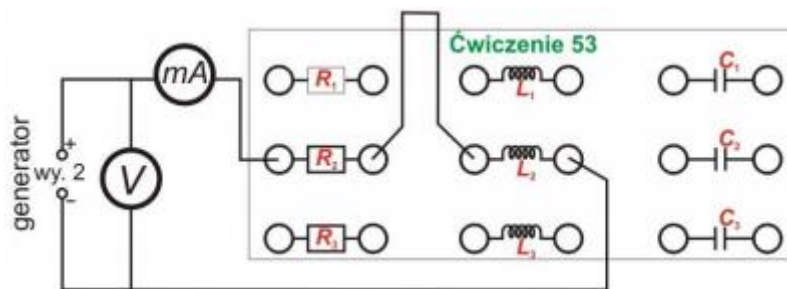


Fig. 3. RL circuit used to determine inductance L .

4.3. Verification of the Ohm's Law for the alternating current (RLC circuit)

Connect the electric circuit according to Fig. 4. This is an "RLC" circuit, meaning that there are R , L and C components connected in series to the generator. Again, proceeding as in previous parts (for the same frequency f) determine the I_{sk} current to U_{sk} voltage dependence for the RLC circuit. Based on these measurements, you will be able to determine the impedance of the RLC circuit.

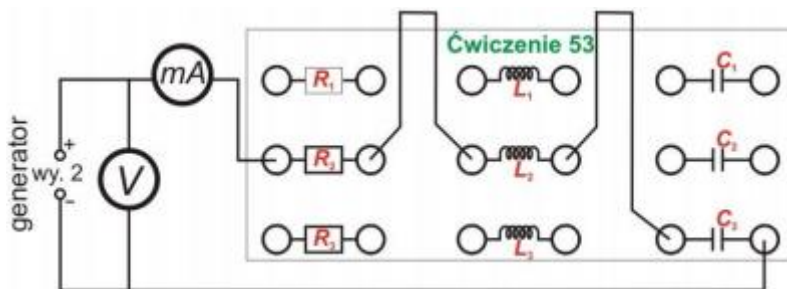


Fig. 4. RLC circuit used for experimental verification of the Ohm's Law.

5. Calculations for report

5.1. Calculation of the capacitance C of the capacitor

Using the experimental data obtained for the RC circuit (paragraph 4.1), plot $U_{sk}(I_{sk})$ graph. Importantly, express voltage in V and current in A. According to the Ohm's Law for AC current, this plot should be linear – Fig. 5.

Fit the $U_{sk}(I_{sk})$ graph with the linear regression method and plot this line on the graph together with the experimental data points. The slope of this line is the impedance Z_C of the RC circuit. As the uncertainty of the impedance Z_C , $u(Z_C)$ take the uncertainty of the slope. Finally, calculate the capacitance C of the capacitor using the following equation:

$$C = \frac{1}{2\pi f \sqrt{Z_C^2 - R^2}} \quad (1)$$

where f denotes the frequency selected for your measurements and R denotes the resistance of the selected resistor (see paragraph 6). Calculate the uncertainty $u_C(C)$.

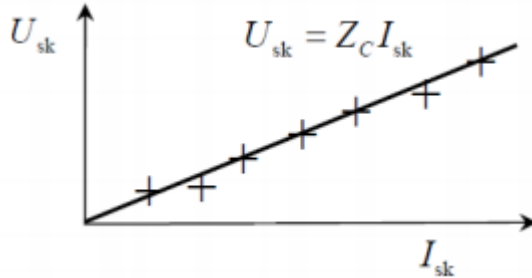


Fig. 5 Example of $U_{sk}(I_{sk})$ plot.

5.2. Calculation of the inductance L of the inductor

Using the experimental data obtained for the RL circuit (paragraph 4.2), plot $U_{sk}(I_{sk})$. Express voltage in V and current in A. Again, this plot should be linear: $U_{sk} = Z_L I_{sk}$. In order to calculate Z_L , fit the $U_{sk}(I_{sk})$ graph with the linear regression method and plot this line on the graph together with the experimental data points. As the uncertainty of the impedance Z_L , $u(Z_L)$ take the uncertainty of the slope. Finally, calculate the inductance L of the inductor using the following equation:

$$L = \frac{\sqrt{Z_L^2 - (R + R_L)^2}}{2\pi f} \quad (2)$$

where R_L denotes the resistance of the inductor component (see paragraph 6) and R denotes the resistance of the selected resistor (again, see paragraph 6). Calculate the uncertainty $u_C(L)$.

5.3. Experimental verification of the Ohm's Law for the alternating current

Using the experimental data obtained for the RLC circuit (paragraph 4.3), plot $U_{sk}(I_{sk})$. Express voltage in V and current in A. Again, this plot should be linear: $U_{sk} = Z_1 I_{sk}$. In order to calculate Z_1 , fit the $U_{sk}(I_{sk})$ graph with the linear regression method and plot this line on the graph together with the experimental data points. The slope of this line is the impedance Z_1 of the RLC circuit. As the uncertainty of the impedance Z_1 , $u(Z_1)$ take the uncertainty of the slope.

Next, calculate the impedance Z_2 of the RLC circuit according to the theoretical formula:

$$Z_2 = \sqrt{(R + R_L)^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2} \quad (3)$$

where R_L is the resistance of the selected inductor component (see paragraph 6), R is the resistance of the selected resistor (see paragraph 6) and C and L were calculated previously in paragraphs 5.1 and 5.2, respectively. Calculate the uncertainty $u_C(Z_2)$. Compare values of Z_1 and Z_2 . Since these two values represent the same physical quantity, they should be equal within the limit of the experimental uncertainty. In conclusions, comment about the legitimacy of the Ohm's Law.

6. Additional information

Resistor's resistances:

$$R_1 = (157 \pm 3) \Omega, R_2 = (220 \pm 5) \Omega, R_3 = (321 \pm 10) \Omega$$

Inductor's resistances:

$$R_{L1} = (0,35 \pm 0,05) \Omega, R_{L2} = (0,60 \pm 0,05) \Omega, R_{L3} = (1,3 \pm 0,1) \Omega$$

Possible frequency ranges for different capacitors C_i :

for C_1 select the frequency f within the range 200 – 400 Hz,

for C_2 select the frequency f within the range 100 – 400 Hz,

for C_3 select the frequency f within the range 50 – 200 Hz.

Remember, you should conduct your measurements for an appropriate frequency, depending on the selected capacitor C_i .

7. Measurement tables

Frequency $f =$

Selected resistor $R_i =$

Selected capacitor $C_i =$

Selected inductor $L_i =$

and $R_{Li} =$

For each circuit (RC, RL, RLC) prepare a table containing the results of your measurements:

$U_{sk} [V]$	$u(U_{sk}) [V]$	$I_{sk} [A]$	$u(I_{sk}) [A]$
...
$Z_i [\Omega]$			
$u_c(Z_i) [\Omega]$			

- change Z_i to Z_C , Z_L or Z_1 .