CIRCUITS AND SYSTEMS LABORATORY

EXERCISE 6

TRANSIENT STATES IN *RLC* CIRCUITS AT DC EXCITATION

1. DEVICES AND PANELS USED IN EXERCISE

The following devices are to be used in this exercise:
- oscilloscope HP 54603B,
- decade resistor,
- decade capacitor,
- decade inductance,
- generator HP 33120A.

2. PROGRAM OF EXPERIMENTS

2.1. OBSERVATIONS OF TIME FUNCTIONS OF CURRENT, VOLTAGE AND PHASE TRAJECTORY IN *RL* CIRCUIT

The schematic configuration diagram of the *RL* circuit used for the observations is presented in figure 1.

The time functions

One may assume the following settings to begin with:
- Decade resistor $R = 2\ \text{k}\Omega$.
- Decade inductance $L = 0.7$ H,
- Set up the generator to obtain a rectangular output of the frequency of 70 Hz, with peak-to-peak amplitude value within $1 \div 5$ V,
- Press the [Auto scale] button on the oscilloscope to obtain the initial view of the time functions. One may use the [Time/Div] and the [Volts/Div] knobs to make the final adjustments.

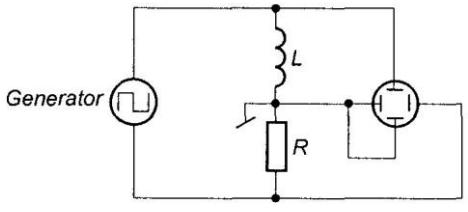

Fig. 1 Schematic configuration diagram for observations of current, voltage and phase trajectory in the *RL* circuit

The configuration shown in figure 1 gives the time function of the coil current i_L on the first (X) channel of the oscilloscope and the u_L voltage time run will be visible on the second channel (Y).

Phase trajectory

In order to obtain the phase trajectory plot on the screen, one should press the [Main/Delayed] button on the oscilloscope and select the "XY" mode using the proper function key beneath the screen. The display will show the phase trajectory run of the i_L current in the *RL* circuit branch.

The trajectory plot displayed on the screen should be adjusted with use of the [Volts/Div] and [Position] knobs to obtain the expected result as shown in figure 2. One should notice that the time functions of the current and voltage must meet the desired trends, i.e. during the transient state, the voltage u_L should decrease while the current i_L increases exponentially. The signal inversion for the appropriate oscilloscope channel (X or Y) should be used to assure the right variation trends.

Printing instructions

After the trajectory plot is properly adjusted it should be printed out. Then, one should switch back to the main view by pressing the [Main/Delayed] button and selecting the "Main" mode with use of the proper function key beneath the screen. The time runs will be visible again. Now the signals should be separated by adjusting the [Position] knob of each channel, without changing the [Volts/Div] settings. If the time functions are separated, they should be printed as well. Preserving the same volts/div ratio and separating the time functions, allows one to prepare a graphical match as shown in figure 2 in the report.

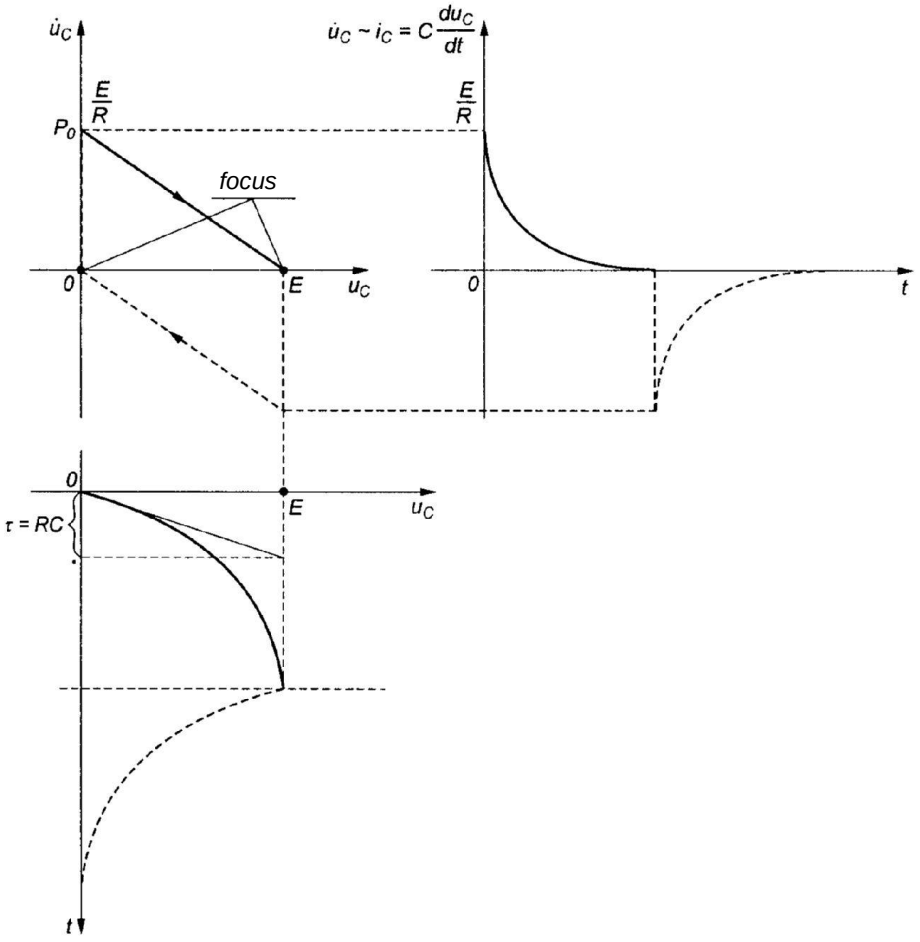

Fig. 2 The phase trajectory of the u_C voltage obtained as the time functions of u_C and i_C match

2.2. OBSERVATIONS OF TIME FUNCTIONS OF CURRENT, VOLTAGE AND PHASE TRAJECTORY IN *RC* CIRCUIT

The schematic configuration diagram of the *RC* circuit used for the observations is presented in figure 3.

The time functions

The following settings may be assumed for the observations:

- Decade resistor $R = 2$ kΩ.
- Decade capacitance $C = 1$ μF,
- Set up the generator to obtain a rectangular output of the frequency of 70 Hz, with peak-to-peak amplitude value within $1 \div 5$ V,
- Press the [Auto scale] button on the oscilloscope to obtain the initial view of the time functions. One may use the [Time/Div] and the [Volts/Div] knobs to make the final adjustments.

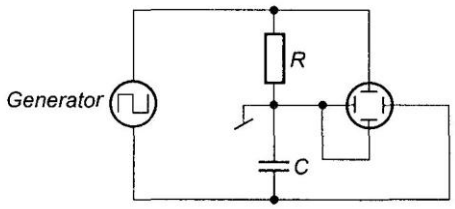

Fig. 3 Schematic configuration diagram for observations of current, voltage and phase trajectory in the *RC* circuit

The configuration shown in figure 3 gives the time function of the capacitor voltage u_C on the first (X) channel of the oscilloscope and the i_C current time run will be visible on the second channel (Y).

Phase trajectory

The procedure with the phase trajectory observations is similar to the one in point 2.1. In order to obtain the phase trajectory plot on the screen, one should press the [Main/Delayed] button on the oscilloscope and select the XY mode using the proper function key beneath the screen. The display will show the phase trajectory run of the u_C voltage in the *RC* circuit branch.

The trajectory plot displayed on the screen should be adjusted with use of the [Volts/Div] and [Position] knobs to obtain the expected result as shown in figure 4. One should notice that the time functions of the current and voltage must meet the desired trends, analogically to the note given in point 2.1.

After the adjustments are done, one should follow the printing instructions given in point 2.1.

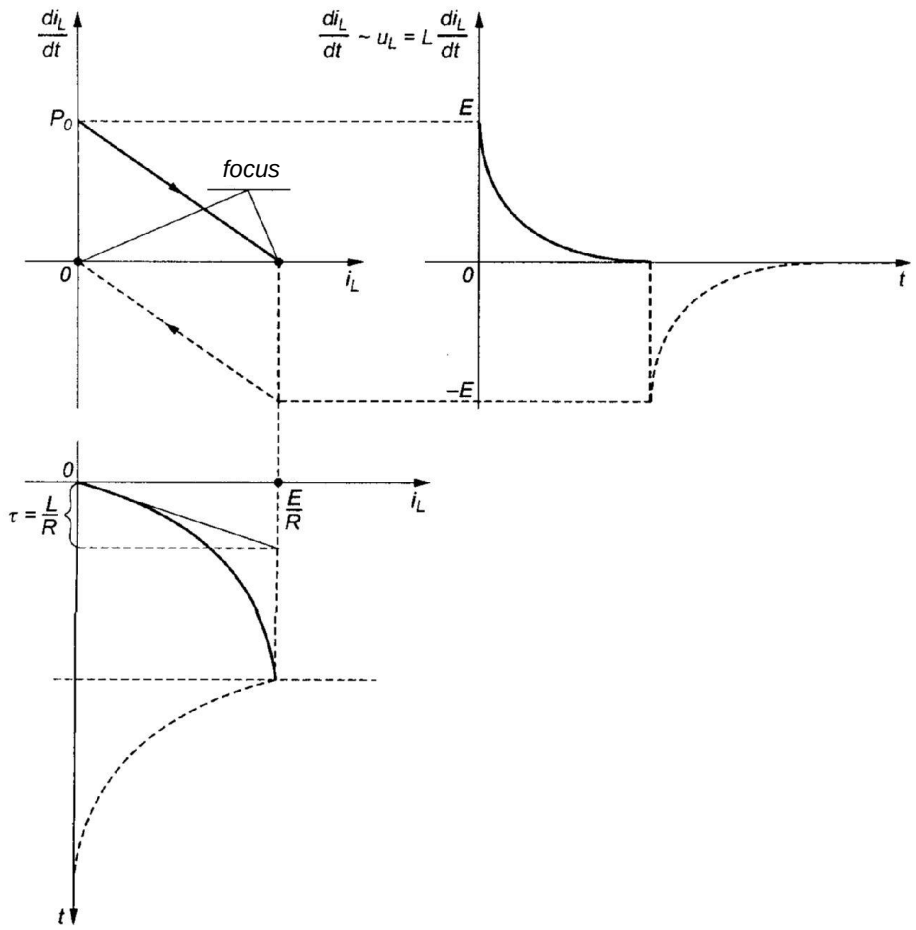

Fig. 4 The phase trajectory of the i_L current together with the time functions of i_L and u_L

2.3. OBSERVATIONS OF TIME FUNCTIONS OF CURRENT, VOLTAGE AND PHASE TRAJECTORY IN *RLC* CIRCUIT

The schematic configuration diagram of the *RLC* circuit used for the observations is presented in figures 5a and 5b. As one may notice, the only significant difference between the two diagrams is the oscilloscope channels connections. The first diagram (fig. 5a) allows observation of the time functions of the inductance current i_L and voltage u_L, while the other (fig. 5b) enables the observation of the capacitance voltage u_C and current i_C time functions.

a) *b)*

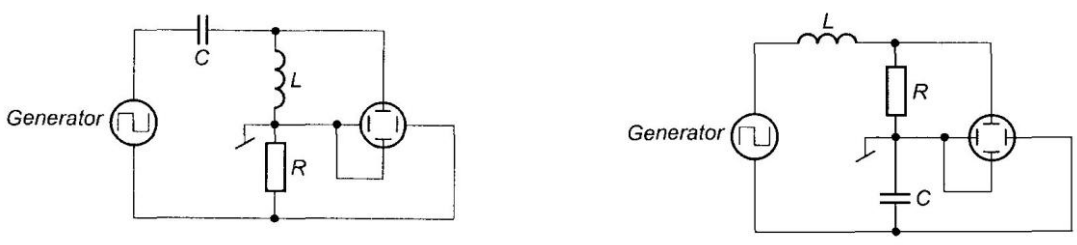

Fig. 5 Schematic configuration diagram of the *RLC* circuit for observations of the:
a) inductance current, voltage and phase trajectory
b) capacitance voltage, current and phase trajectory

The observations of current and voltage time functions as well as the phase trajectory should be made for both capacitance and inductance in each of the three characteristic variants given below:

- The oscillatory conditions, where $R < 2\sqrt{\frac{L}{C}}$.

The following settings may be assumed for the observations:

– Decade resistor R = 900 Ω.
– Decade inductance L = 0.6 H,
– Decade capacitance C = 0.1 μF,
– Set up the generator to obtain a rectangular output of the frequency of 100 Hz, with peak-to-peak amplitude value within 1 ÷ 5 V,
– Press the [Auto scale] button on the oscilloscope to obtain the initial view of the time functions. One may use the [Time/Div] and the [Volts/Div] knobs to make the final adjustments. The example time functions of the current and capacitor voltage are shown in figure 6.

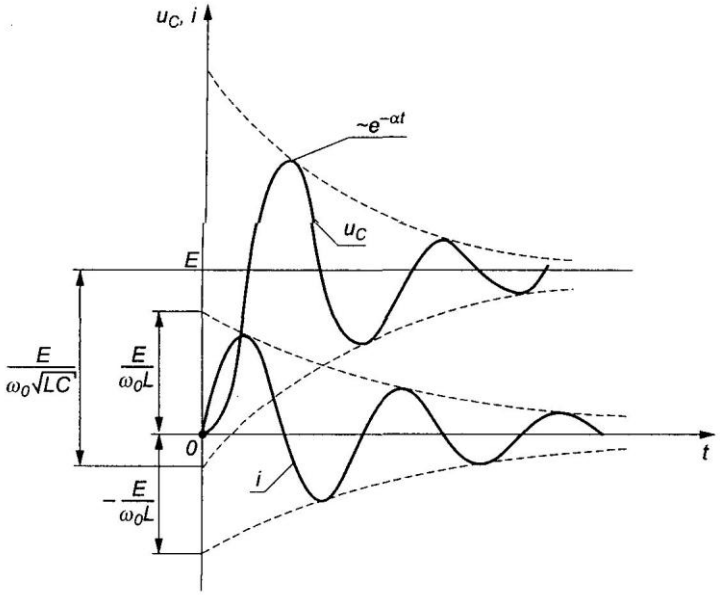

Fig. 6 The time functions of the capacitance voltage and current in the *RLC* circuit branch during the transient state in the oscillatory conditions. The oscillatory attenuation of the functions is marked with the dashed lines.

Phase trajectory

The procedure with the phase trajectory observations is similar to the one in point 2.1. In order to obtain the phase trajectory plot on the screen, one should press the [Main/Delayed] button on the oscilloscope and select the XY mode using the proper function key beneath the screen. The display will show the phase trajectory run of the i_L current for configuration as in figure 5a and u_C voltage for configuration as in figure 5b.

The trajectory plot displayed on the screen should be adjusted with use of the [Volts/Div] and [Position] knobs to obtain the expected result as shown in figures 7 and 8. One should notice that the time functions of the current and voltage must meet the desired trends, analogically to the note given in point 2.1.

After the adjustments are done, one should follow the printing instructions given in point 2.1.

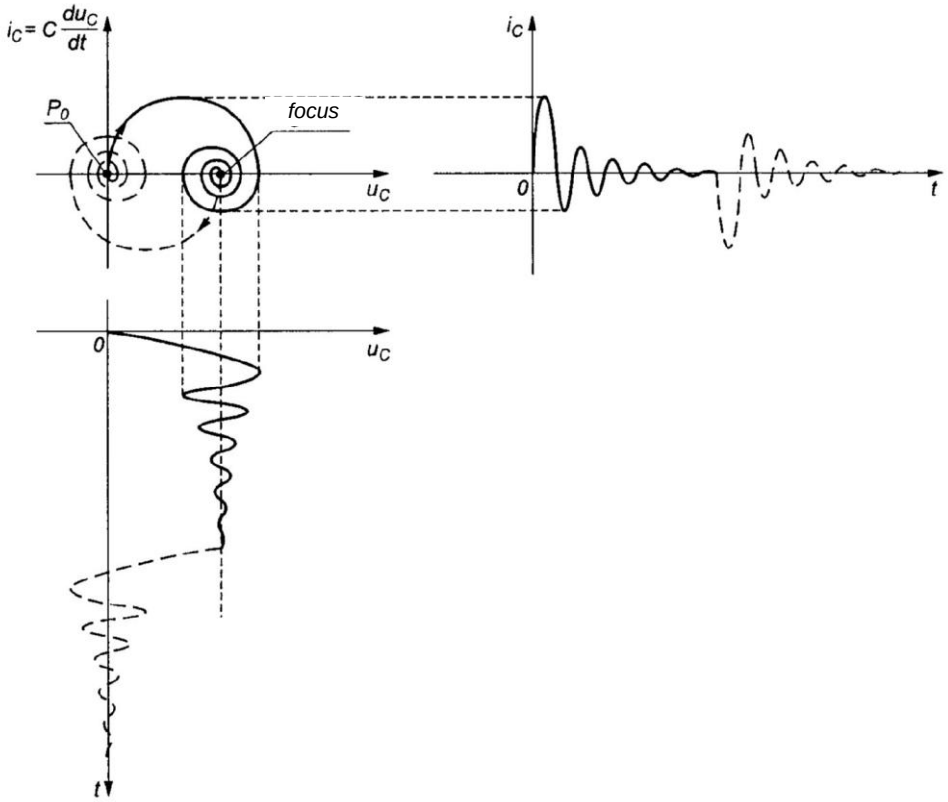

Fig. 7 The phase trajectory of the u_C voltage together with the time functions of u_C and i_C in the oscillatory conditions in *RLC* circuit branch.

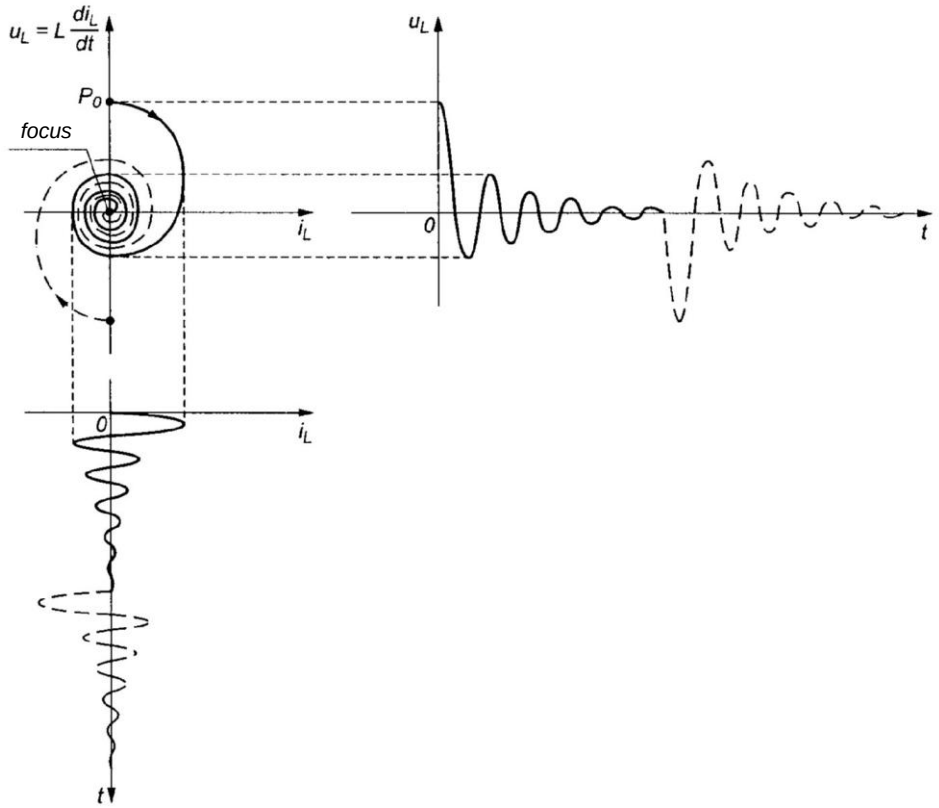

Fig. 8 The phase trajectory of the i_L current together with the time functions of i_L and u_L in the oscillatory conditions in *RLC* circuit branch.

- The aperiodic conditions, where $R > 2\sqrt{\frac{L}{C}}$.

The following settings may be assumed for the observations:

- Decade resistor R = 3 kΩ.
- Decade inductance L = 0.6 H.
- Decade capacitance C = 1 μF.
- Set up the generator to obtain a rectangular output of the frequency of 100 Hz, with peak-to-peak amplitude value within 1 ÷ 5 V.
- Press the [Auto scale] button on the oscilloscope to obtain the initial view of the time functions. One may use the [Time/Div] and the [Volts/Div] knobs to make the final adjustments. The example time functions of the current, capacitor and inductor voltages are shown in figure 9.

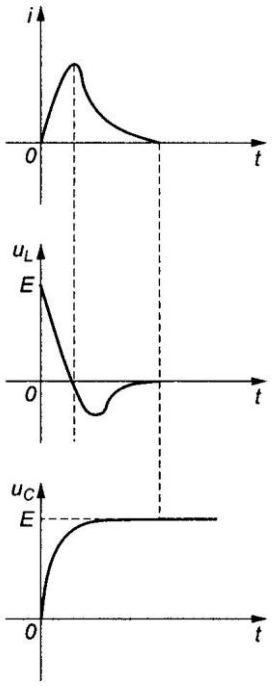

Fig. 9 The time functions of the capacitance and inductance voltage and current in the *RLC* circuit branch during the transient state in the aperiodic conditions.

Phase trajectory

The procedure with the phase trajectory observations is similar to the one in point 2.1. In order to obtain the phase trajectory plot on the screen, one should press the [Main/Delayed] button on the oscilloscope and select the XY mode using the proper function key beneath the screen. The display will show the phase trajectory run of the i_L current for configuration as in figure 5a and u_C voltage for configuration as in figure 5b.

The trajectory plot displayed on the screen should be adjusted with use of the [Volts/Div] and [Position] knobs to obtain the expected result as shown in figures 10 and 11. One should notice that the time functions of the current and voltage must meet the desired trends, analogically to the note given in point 2.1.

After the adjustments are done, one should follow the printing instructions given in point 2.1.

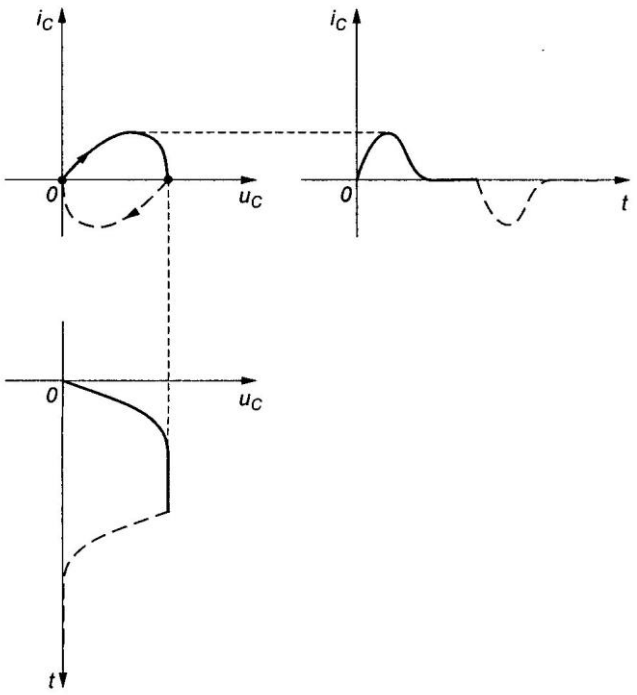

Fig. 10 The phase trajectory of the u_C voltage together with the time functions of u_C and i_C in the aperiodic conditions in *RLC* circuit branch.

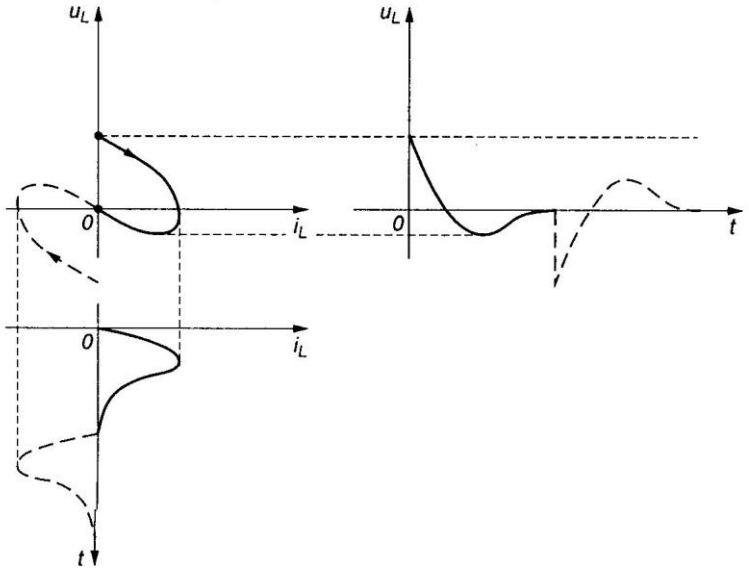

Fig. 11 The phase trajectory of the i_L current together with the time functions of i_L and u_L in the aperiodic conditions in *RLC* circuit branch.

- The boundary conditions, where $R = 2\sqrt{\frac{L}{C}}$.

Although the boundary conditions are described with the above formula, the elements values suggested below cannot ensure realization of the condition as the connections and wires resistance is unknown. This variant is meant to give the students a chance to determine the boundary conditions experimentally.

The following settings may be assumed at the beginning of the observations:

– Decade resistor R = 6 kΩ.

– Decade inductance L = 0.9 H,
– Decade capacitance C = 0.1 μF,
– Set up the generator to obtain a rectangular output of the frequency of 100 Hz, with peak-to-peak amplitude value within 1 ÷ 5 V,

One may also begin with the inductance and capacitance settings taken from one of the previous points and calculate the resistance value from the given formula. In any case the task is to approach the boundary condition as close as possible basing on the trajectory shape.

Once the trajectory shape meets the expectations, one should consult the result with the teacher and after his acceptance follow the printing instructions given in point 2.1.

The natural circuit oscillations

The natural oscillations of *RLC* circuit branch should be observed and measured in the oscillatory conditions: $R < 2\sqrt{\frac{L}{C}}$, with use of the metering circuit configured as shown in figure 5b.

One should set up the generator to obtain a rectangular output and observe the branch current ($i \sim u_R$) and capacitance voltage time functions on the oscilloscope. The natural circuit oscillations frequency should be read with use of the cursors together with printing the resultant display (containing the time functions and the cursors).

3. RESULTS PROCESSING

After running the experiments, one should:

1. Split the time functions printouts and stick them in proper way to make the resultant phase trajectories diagrams, analogically to figures: 2, 4, 7, 8, 10 and 11. Describe the axes and characteristic values on the resultant graph.
2. Determine the time constant of the *RL* and *RC* circuits, the attenuation constant α and natural oscillations frequency of the *RLC* circuit basing on the obtained results and calculate the analogical values knowing the elements values. Compare the results.
3. Discuss the influence of the elements values change on particular time functions and phase trajectories.
4. Calculate the resonance frequency of the *RLC* circuit and compare it with the obtained from the measurements (see fig. 6 for a hint).