# LABORATORY EXERCISE 3

## Mutually coupled inductors.

**Goal of the lab:** To demonstrate the energy transfer between mutually coupled inductors and the creation of equivalent circuit without mutual induction.

## 1. Required equipment

| Equipment | Count |
|---|---|
| Breadboard | 1 pc. |
| A set of connecting wires | 1 pc. |
| Function generator | 1 pc. |
| Two channel oscilloscope | 1 pc. |
| Inductor 290 μH | 2 pc. |
| Resistor 100 Ω, 5 W | 1 pc. |
| Resistor 150 Ω, 5 W | 1 pc. |

## 2. Tasks

<u>**Task 1.**</u> Obtain the self inductance of the two inductors.

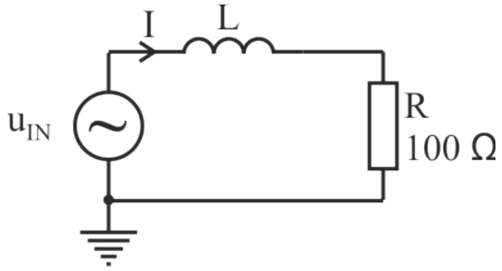


Fig. 1.

***Step 1.*** Connect the circuit in fig. 1 on the breadboard. With the oscilloscope probes observe the input voltage $u_{\mathrm{IN}}(t)$ and the resistor voltage drop $u_R(t)$ .

***Step 2.*** Power the circuit from the function generator with sinusoidal voltage $U_{\mathrm{IN}}=6\,Vpp$ with frequency $f=80\,kHz$ .

***Step 3.*** Obtain the amplitudes $U_{\mathrm{IN}}$ and $U_R$ of the observed sines.

***Step 4.*** Estimate the amplitude of the voltage drop on the coil:

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

***Step 5.*** Obtain the current amplitude according to Ohm's law:

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

***Step 6.*** Obtain the reactance of the coil:

$$X_L.I=U_L \quad \rightarrow \quad X_L=\frac{U_L}{I}$$

***Step 7.*** Obtain the self inductance of the coil:

$$X_L = \omega L \quad \rightarrow \quad L = \frac{X_L}{\omega} = \frac{X_L}{2.\pi.f}$$

***Step 8.*** Repeat steps 1-7 for the second coil.

**Task 2.** Obtain the coefficient of mutual inductance $M$ between the two coils from problem 1, if they are closely adjoined.

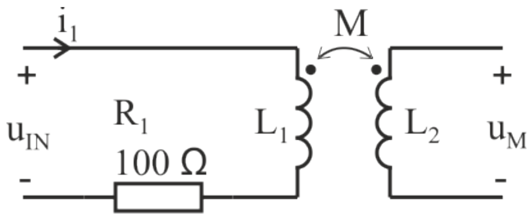


Fig. 2.

***Step 1.*** Connect the circuit in fig. 2 on the breadboard and power it with sinusoidal voltage $U_{IN} = 6\,Vpp$ with frequency $f = 80\,kHz$ .

***Step 2.*** Connect the oscilloscope probes to observe the input voltage $u_{IN}$ and the resistor voltage $u_{R1}$ . Obtain their amplitudes $U_{IN}$ и $U_{R1}$ .

***Step 3.*** Connect the second probe to the secondary coil $L_2$ and obtain the amplitude of the induced voltage $U_M$ .

***Step 4.*** Estimate the amplitude of the current $I_1$ according to Ohm's law:

$$I_1 = \frac{U_{R1}}{R_1}$$

***Step 5.*** Obtain the resistance from mutual inductance:

$$U_M = I_1 . X_M \quad \rightarrow \quad X_M = \frac{U_M}{I_1}$$

***Step 6.*** Obtain the mutual inductance:

$$X_M = \omega . M \quad \rightarrow \quad M = \frac{X_M}{\omega} = \frac{X_M}{2.\pi.f}$$

***Step 7.*** Obtain the coupling coefficient between the coils:

$$k = \frac{M}{\sqrt{L_1 . L_2}}$$

***Step 8.*** Experiment with the mutually coupled inductors and observe the changes in the induced voltage $u_M(t)$ when changing the distance and disposition of the two coils.

**Task 3.** Obtain the amplitude of the current $i_2$ through the load $R_L$ .

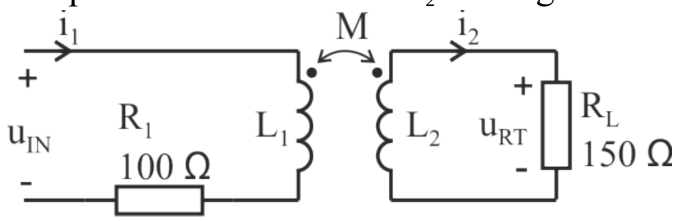


Fig. 3.

***Step 1.*** Modify the circuit from the previous task with a load $R_L=150\Omega$ , as shown in fig. 3 and measure the amplitude $U_{RL}$ of the voltage drop on $R_L$ .

***Step 2.*** Obtain the amplitude of the current $i_2(t)$ according to Ohm's law:

$$I_2=\frac{U_{RL}}{R_L}$$

***Step 3* (homework).** Analyze the circuit in fig. 3 and obtain the amplitude of the current $I_2$ (Assume the input voltage is $u_{IN}=3.\sin(\omega t)\ [V]$ (zero time shift) with frequency $f=80\,kHz$ .

- Obtain the reactances of the inductors and the mutual reactance:

$X_{L1}=\omega L_1=\ldots$

$X_{L2}=\omega L_2=\ldots$

$X_M=\omega M=\ldots$

- Create an equivalent circuit without mutual inductance (fig. 4).

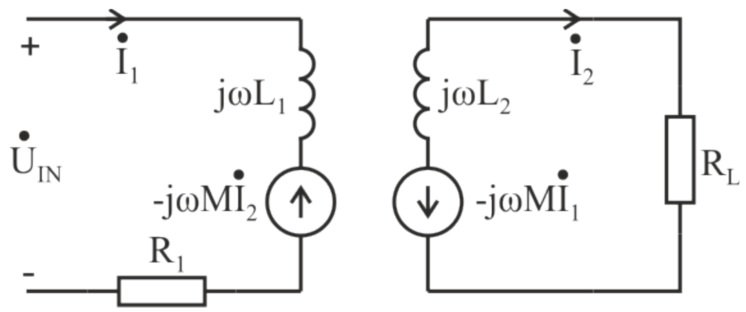


Fig. 4.

- Solve the circuit and obtain the phasor $\dot{I}_2$ and it's amplitude $I_2$ .

## 3. Questions

1. What is the meaning of the self inductance and the coupling coefficients?

2. Can you explain the procedure to experimentally obtain the two coefficients?

3. How does the induced voltage drop change when the distance and disposition between the two coils changes?

4. Does the estimated current from task 3 match the experimental one? Why?

5. Does the voltage drop on $L_2$ change after loading with $R_T$ ? Why?