Experimental Competition - Problem No. 2

Black box

APPARATUS AND MATERIALS

1. A double beam oscilloscope.
2. A function generator capable to generate sine, triangle and square waves over the 0.02 Hz to 2 MHz range.
3. A "Black box" with two groups of connectors: the ABCD group and A'B'C'D' group. Besides, there are also two connectors for the standard resistor R_n = 5 kΩ, which is isolated from the two groups.
4. Conductors of negligible resistance.
5. Graph paper.

Warning: You are not allowed to open the black box.

EXPERIMENT

In the black box, there are two groups of passive elements (that are elements of the types: resistor *R*, capacitor *C* or inductor (induction coil) *L*). The first group consists of three elements Z_1, Z_2, Z_3 connected in a star circuit as shown in Figure 1. The elements are led out to the connectors A, B, C and D, with A - the common connector of the ABCD group. The second group consists of three elements Z'_1, Z'_2, Z'_3 connected in the same manner to connectors A', B', C' and D', with A'- the common connector of the A'B'C'D' group (see Figure 2).

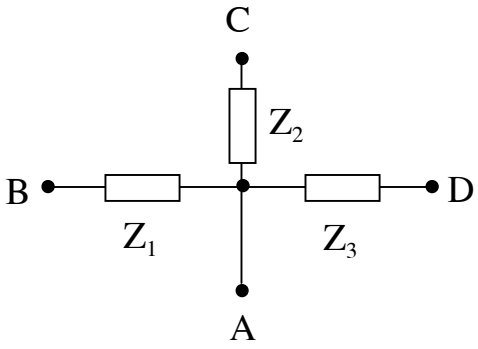

Figure 1

1. By using the oscilloscope and the function generator, determine the type and the parameter (that is resistance of *R*, capacity of *C*, inductivity of *L*) of each of the elements Z_1, Z_2, Z_3 and Z'_1, Z'_2, Z'_3. ***[5.0 pts]***

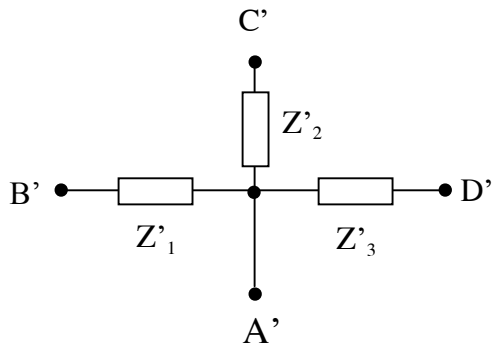

Figure 2

2. Connect five points B, C, B', C' and D' together. We obtain a new black box with terminals DD'A' (called DD'A').

a. Draw the electric circuit of this black box.

b. Apply a sine wave from the generator to connectors D and A'.

Plot a graph of the ratio of the voltage amplitudes $K = \dfrac{U_{D'A'}}{U_{DA'}}$ and the phase shift φ between these voltages as functions of the frequency *f* of the signal.

c. The graphs possess a particular point at a certain frequency f_0. Determine the value of the frequency f_0, the ratio $K = \dfrac{U_{D'A'}}{U_{DA'}}$ and the phase shift φ at this frequency.

d. Derive the relation between f_0 and the parameters of the elements in the black box and calculate the values of f_0. ***[5.0 pts]***