LABORATORY WORK №1
INTRODUCTION TO MODELLING

Objective

Familiarize yourself with the Simulink software environment and basic methods for modeling linear electrical circuits.

Theoretical information

A mathematical model of a linear electric circuit as a linear stationary system can be represented in the form of a scalar differential equation of the *nth* order (input-output model) or in the form of a system of *n* differential equations of the 1st order (input-state-output model).

The input-output model has the form

$$y^{(n)} + a_{n-1}y^{(n-1)} + \ldots + a_1\dot{y} + a_0 y = b_m u^{(m)} + b_{m-1}u^{(m-1)} + \ldots + b_1\dot{u} + b_0 u\,, \qquad (1)$$

where y is the output variable, u is the input signal, n is the order of the system, m is the order of the derivative of the output variable, which explicitly depends on u ($m \le n$), a_j, b_j are constant coefficients.

Provided that $m \le n$, the input-state-output model can be represented as

$$\begin{cases} \dot{x}_1 = \alpha_{11}x_1 + \alpha_{12}x_2 + \ldots + \alpha_{1n}x_n + \beta_1 u, \\ \dot{x}_2 = \alpha_{21}x_1 + \alpha_{22}x_2 + \ldots + \alpha_{2n}x_n + \beta_2 u, \\ \ldots \\ \dot{x}_n = \alpha_{n1}x_1 + \alpha_{n2}x_2 + \ldots + \alpha_{nn}x_n + \beta_n u, \\ y = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n, \end{cases} \qquad (2)$$

where x_j are the coordinates of the state vector, α_{ij} and β_j are constant coefficients. System (2) can be represented in a compact vector-matrix form

Lab work task

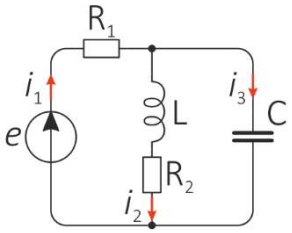
1. In accordance with the task option (table 1), build a simulation circuit of a linear electrical circuit using the elements of the Simscape library Electrical (Simscape / Foundation Library / Electrical).
2. Write down all component equations for this circuit.
3. Write down all topological equations for this circuit.
4. Get the state-space model of the electric circuit with the given coordinates of the state vector (Table 2).

5. Carry out Simulink simulation of the circuit and the state-space model under the input actions indicated in Table 1 and zero initial conditions. The model must be compiled using integration, summation and amplification blocks.
6. Obtain "input-output" model for the given characteristics of the electrical circuit in the form of transfer functions.
7. Carry out Simulink simulation of the circuit and the resulting transfer functions under the input actions specified in Table 1 (source voltage waveform) and zero initial conditions. The duration of the observation interval is chosen independently.
8. Carry out the simulation of the circuit and the state-space model with zero input action and non-zero initial conditions specified in Table 2.

Report content

1. Equivalent circuit and simulation circuit of a linear electrical circuit.
2. Description of the procedure for obtaining models "input-output" (point 6 of the lab work task).
3. Simulation results (point 6 of the lab work task). Compare the graphs of transients of the simulation circuit and the "input-output" models.
4. Description of the procedure for obtaining the state-space model (point 4 of the lab work task).
5. Simulation results (points 7 and 8 of the lab work task). Compare the graphs of transients of the simulation circuit and the state-space models.
6. Conclusions.

Schemes



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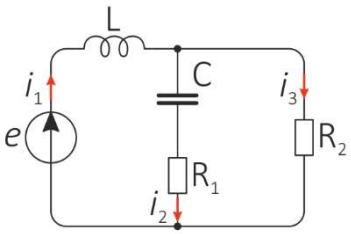

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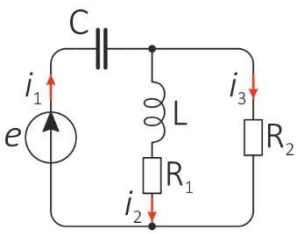

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Table 1

Option	Scheme	Circuit parameters				Source voltage waveform ω=50*2*π
		R_1, [Ohm]	R_2, [Ohm]	L, [mH]	C, [uF]	
1	1	10	15	1	30	$e(t)=21$, $e(t)=E_m\sin(\omega t)$
2	2	5	50	2	80	$e(t)=24$, $e(t)=E_m\sin(\omega t)$
3	1	15	20	5	35	$e(t)=5$, $e(t)=E_m\sin(\omega t)$
4	2	25	150	3	25	$e(t)=12$, $e(t)=E_m\sin(\omega t)$

5	3	25	35	10	20	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
6	1	12	15	20	10	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
7	2	20	1000	20	20	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
8	1	15	25	3	10	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
9	2	50	100	300	20	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
10	3	10	200	15	30	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
11	1	8	15	15	15	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
12	2	20	10	150	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
13	1	17	28	4	12	$e(t)=8,\ e(t)=E_m\sin(\omega t)$
14	2	40	30	30	120	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
15	3	15	150	15	45	$e(t)=26,\ e(t)=E_m\sin(\omega t)$
16	1	20	80	100	100	$e(t)=14,\ e(t)=E_m\sin(\omega t)$
17	2	10	5	10	25	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
18	1	10	12	8	15	$e(t)=10,\ e(t)=E_m\sin(\omega t)$
19	2	60	20	20	60	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
20	3	12	120	12	24	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
21	1	30	50	200	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
22	2	25	15	15	25	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
23	1	20	80	8	15	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
24	2	50	25	25	60	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
25	3	15	15	1	30	$e(t)=6,\ e(t)=E_m\sin(\omega t)$
26	1	300	500	300	400	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
27	2	1	11	11	111	$e(t)=22,\ e(t)=E_m\sin(\omega t)$
28	1	80	80	15	15	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
29	2	70	110	250	25	$e(t)=30,\ e(t)=E_m\sin(\omega t)$
thirty	3	12	240	24	12	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
31	1	10	15	1	30	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
32	2	5	50	2	80	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
33	1	15	20	5	35	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
34	2	25	150	3	25	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
35	3	25	35	10	20	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
36	1	12	15	20	10	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
37	2	20	1000	20	20	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
38	1	15	25	3	10	$e(t)=36,\ e(t)=E_m\sin(\omega t)$

39	2	50	100	300	20	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
40	3	10	200	15	30	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
41	1	8	15	15	15	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
42	2	20	10	150	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
43	1	17	28	4	12	$e(t)=8,\ e(t)=E_m\sin(\omega t)$
44	2	40	30	30	120	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
45	3	15	150	15	45	$e(t)=26,\ e(t)=E_m\sin(\omega t)$
46	1	20	80	100	100	$e(t)=14,\ e(t)=E_m\sin(\omega t)$
47	2	10	5	10	25	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
48	1	10	12	8	15	$e(t)=10,\ e(t)=E_m\sin(\omega t)$
49	2	60	20	20	60	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
50	3	12	120	12	24	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
51	1	30	50	200	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
52	2	25	15	15	25	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
53	1	20	80	8	15	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
54	2	50	25	25	60	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
55	3	15	15	1	30	$e(t)=6,\ e(t)=E_m\sin(\omega t)$
56	1	300	500	300	400	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
57	2	1	11	11	111	$e(t)=22,\ e(t)=E_m\sin(\omega t)$
58	1	80	80	15	15	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
59	2	70	110	250	25	$e(t)=30,\ e(t)=E_m\sin(\omega t)$
60	3	12	240	24	12	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
61	1	10	15	1	30	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
62	2	5	50	2	80	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
63	1	15	20	5	35	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
64	2	25	150	3	25	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
65	3	25	35	10	20	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
66	1	12	15	20	10	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
67	2	20	1000	20	20	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
68	1	15	25	3	10	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
69	2	50	100	300	20	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
70	3	10	200	15	30	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
71	1	8	15	15	15	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
72	2	20	10	150	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$

73	1	17	28	4	12	$e(t)=8,\ e(t)=E_m\sin(\omega t)$
74	2	40	30	30	120	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
75	3	15	150	15	45	$e(t)=26,\ e(t)=E_m\sin(\omega t)$
76	1	20	80	100	100	$e(t)=14,\ e(t)=E_m\sin(\omega t)$
77	2	10	5	10	25	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
78	1	10	12	8	15	$e(t)=10,\ e(t)=E_m\sin(\omega t)$
79	2	60	20	20	60	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
80	3	12	120	12	24	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
81	1	30	50	200	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
82	2	25	15	15	25	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
83	1	20	80	8	15	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
84	2	50	25	25	60	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
85	3	15	15	1	30	$e(t)=6,\ e(t)=E_m\sin(\omega t)$
86	1	300	500	300	400	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
87	2	1	11	11	111	$e(t)=22,\ e(t)=E_m\sin(\omega t)$
88	1	80	80	15	15	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
89	2	70	110	250	25	$e(t)=30,\ e(t)=E_m\sin(\omega t)$
90	3	12	240	24	12	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
91	1	10	15	1	30	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
92	2	5	50	2	80	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
93	1	15	20	5	35	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
94	2	25	150	3	25	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
95	3	25	35	10	20	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
96	1	12	15	20	10	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
97	2	20	1000	20	20	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
98	1	15	25	3	10	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
99	2	50	100	300	20	$e(t)=21,\ e(t)=E_m\sin(\omega t)$
100	3	10	200	15	30	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
101	1	8	15	15	15	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
102	2	20	10	150	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
103	1	17	28	4	12	$e(t)=8,\ e(t)=E_m\sin(\omega t)$
104	2	40	30	30	120	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
105	3	15	150	15	45	$e(t)=26,\ e(t)=E_m\sin(\omega t)$
106	1	20	80	100	100	$e(t)=14,\ e(t)=E_m\sin(\omega t)$

107	2	10	5	10	25	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
108	1	10	12	8	15	$e(t)=10,\ e(t)=E_m\sin(\omega t)$
109	2	60	20	20	60	$e(t)=5,\ e(t)=E_m\sin(\omega t)$
110	3	12	120	12	24	$e(t)=24,\ e(t)=E_m\sin(\omega t)$
111	1	30	50	200	20	$e(t)=20,\ e(t)=E_m\sin(\omega t)$
112	2	25	15	15	25	$e(t)=36,\ e(t)=E_m\sin(\omega t)$
113	1	20	80	8	15	$e(t)=48,\ e(t)=E_m\sin(\omega t)$
114	2	50	25	25	60	$e(t)=50,\ e(t)=E_m\sin(\omega t)$
115	3	15	15	1	30	$e(t)=6,\ e(t)=E_m\sin(\omega t)$
116	1	300	500	300	400	$e(t)=12,\ e(t)=E_m\sin(\omega t)$
117	2	1	11	11	111	$e(t)=22,\ e(t)=E_m\sin(\omega t)$
118	1	80	80	15	15	$e(t)=18,\ e(t)=E_m\sin(\omega t)$
119	2	70	110	250	25	$e(t)=30,\ e(t)=E_m\sin(\omega t)$
120	3	12	240	24	12	$e(t)=50,\ e(t)=E_m\sin(\omega t)$

Table 2

Option	Models "input-output"	State-space model	
		State vector	Initial conditions
1	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[0.5 \quad 10]^T$
2	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[2 \quad 10]^T$
3	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[1 \quad 4]^T$
4	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[1 \quad 1]^T$
5	$W_1(s)=\frac{I_2(s)}{E(s)},$	$x=[i_2 \quad U_C]^T$	$x=[1.5 \quad 20]^T$

	$W_2(s)=\frac{U_C(s)}{E(s)}$		
6	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[1 \quad 1]^T$
7	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[0.7 \quad -5]^T$
8	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[2 \quad 40]^T$
9	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad -1]^T$
10	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[10 \quad 20]^T$
11	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
12	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
13	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[8 \quad 5]^T$
14	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[15 \quad 5]^T$

15	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[5 \quad 5]^T$
16	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[2.5 \quad -2.5]^T$
17	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-2 \quad 14]^T$
18	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[2 \quad 3]^T$
19	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[8 \quad 5]^T$
20	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-2 \quad 4]^T$
21	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[15 \quad 5]^T$
22	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[5 \quad 5]^T$
23	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[-2 \quad 4]^T$
24	$W_1(s)=\frac{I_1(s)}{E(s)},$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad 5]^T$

	$W_2(s)=\frac{I_3(s)}{E(s)}$		
25	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[3 \quad 6]^T$
26	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
27	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-3 \quad 1]^T$
28	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[3 \quad 6]^T$
29	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad -1]^T$
thirty	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[1 \quad 1]^T$
31	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[0.5 \quad 10]^T$
32	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[2 \quad 10]^T$
33	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[1 \quad 4]^T$

34	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[1 \quad 1]^T$
35	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[1.5 \quad 20]^T$
36	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[1 \quad 1]^T$
37	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[0.7 \quad -5]^T$
38	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[2 \quad 40]^T$
39	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad -1]^T$
40	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[10 \quad 20]^T$
41	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
42	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
43	$W_1(s)=\frac{I_2(s)}{E(s)},$	$x=[i_2 \quad U_L]^T$	$x=[8 \quad 5]^T$

	$W_2(s)=\frac{U_L(s)}{E(s)}$		
44	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[15 \quad 5]^T$
45	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[5 \quad 5]^T$
46	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[2.5 \quad -2.5]^T$
47	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-2 \quad 14]^T$
48	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[2 \quad 3]^T$
49	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[8 \quad 5]^T$
50	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-2 \quad 4]^T$
51	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[15 \quad 5]^T$
52	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[5 \quad 5]^T$

53	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[-2 \quad 4]^T$
54	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad 5]^T$
55	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[3 \quad 6]^T$
56	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
57	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-3 \quad 1]^T$
58	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[3 \quad 6]^T$
59	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad -1]^T$
60	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[1 \quad 1]^T$
61	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[0.5 \quad 10]^T$
62	$W_1(s)=\frac{I_2(s)}{E(s)},$	$x=[i_2 \quad U_C]^T$	$x=[2 \quad 10]^T$

	$W_2(s)=\frac{U_C(s)}{E(s)}$		
63	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 4 \end{bmatrix}^T$
64	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$
65	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1.5 & 20 \end{bmatrix}^T$
66	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$
67	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 0.7 & -5 \end{bmatrix}^T$
68	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 2 & 40 \end{bmatrix}^T$
69	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & -1 \end{bmatrix}^T$
70	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 10 & 20 \end{bmatrix}^T$
71	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -1 & -6 \end{bmatrix}^T$

72	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -1 & -6 \end{bmatrix}^T$
73	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 8 & 5 \end{bmatrix}^T$
74	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 15 & 5 \end{bmatrix}^T$
75	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 5 & 5 \end{bmatrix}^T$
76	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 2.5 & -2.5 \end{bmatrix}^T$
77	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -2 & 14 \end{bmatrix}^T$
78	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 2 & 3 \end{bmatrix}^T$
79	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 8 & 5 \end{bmatrix}^T$
80	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -2 & 4 \end{bmatrix}^T$
81	$W_1(s)=\frac{I_2(s)}{E(s)},$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 15 & 5 \end{bmatrix}^T$

	$W_2(s)=\frac{U_C(s)}{E(s)}$		
82	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 5 & 5 \end{bmatrix}^T$
83	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} -2 & 4 \end{bmatrix}^T$
84	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & 5 \end{bmatrix}^T$
85	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & 6 \end{bmatrix}^T$
86	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -1 & -6 \end{bmatrix}^T$
87	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -3 & 1 \end{bmatrix}^T$
88	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & 6 \end{bmatrix}^T$
89	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & -1 \end{bmatrix}^T$
90	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$

91	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 0.5 & 10 \end{bmatrix}^T$
92	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 2 & 10 \end{bmatrix}^T$
93	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 4 \end{bmatrix}^T$
94	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$
95	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1.5 & 20 \end{bmatrix}^T$
96	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$
97	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 0.7 & -5 \end{bmatrix}^T$
98	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 2 & 40 \end{bmatrix}^T$
99	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 3 & -1 \end{bmatrix}^T$
100	$W_1(s)=\frac{I_2(s)}{E(s)},$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 10 & 20 \end{bmatrix}^T$

	$W_2(s)=\frac{U_C(s)}{E(s)}$		
101	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -1 & -6 \end{bmatrix}^T$
102	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -1 & -6 \end{bmatrix}^T$
103	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 8 & 5 \end{bmatrix}^T$
104	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 15 & 5 \end{bmatrix}^T$
105	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 5 & 5 \end{bmatrix}^T$
106	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 2.5 & -2.5 \end{bmatrix}^T$
107	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} -2 & 14 \end{bmatrix}^T$
108	$W_1(s)=\frac{I_2(s)}{E(s)}$, $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_L \end{bmatrix}^T$	$x=\begin{bmatrix} 2 & 3 \end{bmatrix}^T$
109	$W_1(s)=\frac{I_1(s)}{E(s)}$, $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=\begin{bmatrix} i_1 & i_3 \end{bmatrix}^T$	$x=\begin{bmatrix} 8 & 5 \end{bmatrix}^T$

110	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-2 \quad 4]^T$
111	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[15 \quad 5]^T$
112	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[5 \quad 5]^T$
113	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[-2 \quad 4]^T$
114	$W_1(s)=\frac{I_1(s)}{E(s)},$ $W_2(s)=\frac{I_3(s)}{E(s)}$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad 5]^T$
115	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[3 \quad 6]^T$
116	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-1 \quad -6]^T$
117	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=[i_2 \quad U_C]^T$	$x=[-3 \quad 1]^T$
118	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_L(s)}{E(s)}$	$x=[i_2 \quad U_L]^T$	$x=[3 \quad 6]^T$
119	$W_1(s)=\frac{I_1(s)}{E(s)},$	$x=[i_1 \quad i_3]^T$	$x=[3 \quad -1]^T$

	$W_2(s)=\frac{I_3(s)}{E(s)}$		
120	$W_1(s)=\frac{I_2(s)}{E(s)},$ $W_2(s)=\frac{U_C(s)}{E(s)}$	$x=\begin{bmatrix} i_2 & U_C \end{bmatrix}^T$	$x=\begin{bmatrix} 1 & 1 \end{bmatrix}^T$