Nodal Analysis
Laboratory I

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1 Aim of exercise

The aim of our exercise was to experimentally verify the nodal analysis in RLC circuits. We have achieved it by measuring the voltages on different nodes of the chosen circuits using a dedicated evaluation board and vector voltmeter. The obtained measurement results are compared with analytical calculations.

Apart from the values of potentials in individual nodes of the circuits being measured, we calculated the currents flowing through pointed elements.

2 Course of measurements

First step of our measurements was connecting evaluation board(fig. 1) to laboratory computer via USB and starting Vector Voltage Meter software. Next we connected both INPUT1 and CON1 to OUTPUT using BNC cables and splitter, last we connected oscilloscope probe to INPUT2 connector. Now with all preparation finished we started voltage measurements of each node in Circuit A(fig. 4). Then we disconnected BNC cable connected to CON1 and connected it to CON2 and repeated previous measurements for Circuit B(fig. 5)

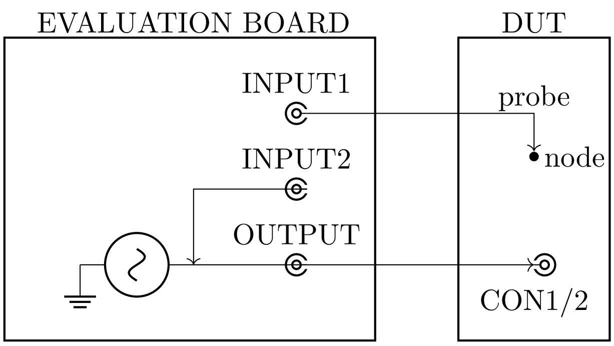

Figure 1: measurements schematic

3 Nodal analysis - method

Method which we are going to use to solve this circuit is know as "Nodal Analysis by Inspection". In this method we need to construct 3 matrices: **i** - current vector, **u** - voltage vector(unknown), **G** - conductance matrix with sizes respectively $N \times 1$, $N \times 1$, $N - 1 \times N - 1$

$$\mathbf{G}\mathbf{u} = \mathbf{i}$$

$$\begin{bmatrix} G_{11} & -G_{12} & -G_{13} \\ -G_{21} & G_{22} & -G_{23} \\ -G_{31} & -G_{32} & G_{33} \end{bmatrix} \begin{bmatrix} U_1 \\ U_2 \\ U_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

Where G_{11}, G_{22}, G_{33} are sums of conductance of each branch connected to the node
$G_{12} = G_{21}$, $G_{13} = G_{31}$, $G_{32} = G_{23}$ are sums of conductance of branches between nodes
I_1, I_2, I_3 are sums of current sources entering or exiting node and U_1, U_2, U_3 are unknown voltages that we are trying to find

With simple matrix operation we obtain equation

$$\mathbf{u} = \mathbf{G}^{-1}\mathbf{i}$$

which can be easily calculated

4 Theoretical calculations

all calculation are made in Python with NumPy library. Source code for all calculation can be found in the Appendix

4.1 Circuit A

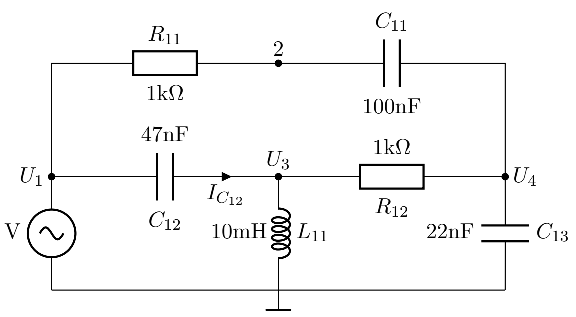

Figure 2: theoretical circuit A

Current of the capacitor C_{12} can be calculated using $I_{C_{12}} = \frac{U_3 - U_2}{Z_{C_{12}}}$

4.2 Circuit B

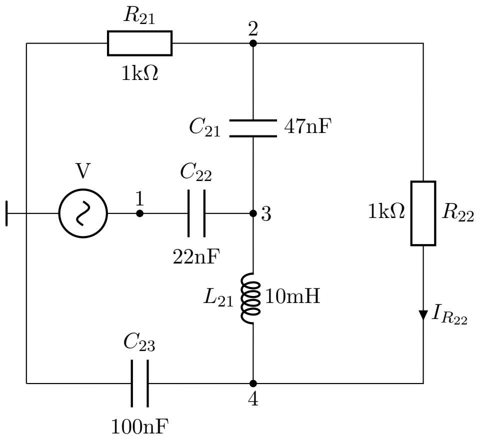

Figure 3: theoretical circuit B

Current of the resistor R_{22} can be calculated using $I_{R_{22}} = \frac{U_4 - U_2}{Z_{R_{22}}}$

5 Real measurements

5.1 Circuit A

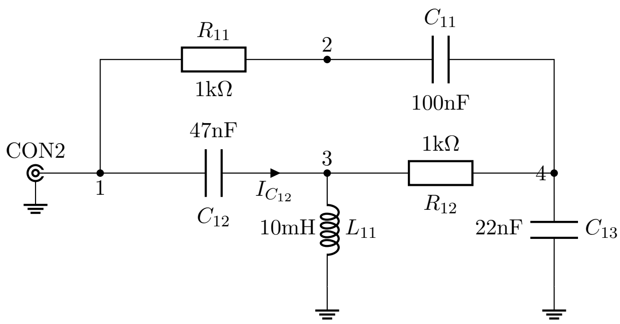

Figure 4: circuit A

Circuit A			
Freq[kHz]	Channel 1[V]	Channel 2 [V]	Angle [°]
node 1			
1kHz	0.192	0.192	0
5kHz	0.192	0.192	-0.1
9kHz	0.192	0.192	-0.1
node 2			
1kHz	0.192	0.145	-19.3
5kHz	0.192	0.59	9.3
9kHz	0.192	0.236	-9.7
node 3			
1kHz	0.192	0.008	140.7
5kHz	0.192	0.154	136.1
9kHz	0.192	0.376	30
node 4			
1kHz	0.192	0.072	38.6
5kHz	0.192	0.082	42.1
9kHz	0.192	0.231	-11.8

Table 1: evaluation board measurements for Circuit A

Current of capacitor C_{12}

freq [kHz]	$I_{R_{22}}$
1kHz	
5kHz	
9kHz	

5.2 Circuit B

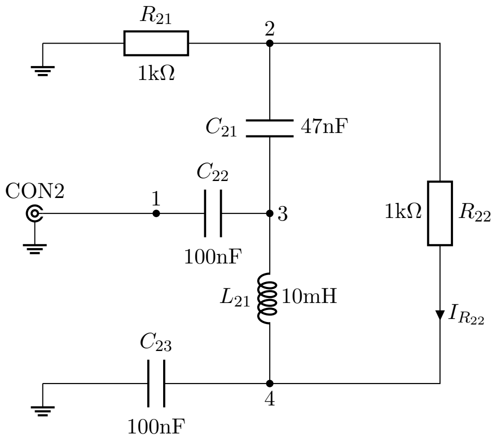

Figure 5: circuit B

Circuit B			
Freq[kHz]	Channel 1[V]	Channel 2 [V]	Angle [°]
node 1			
1kHz	0.192	0.192	0
5kHz	0.192	0.192	-0.1
9kHz	0.192	0.192	0
node 2			
1kHz	0.192	0.044	28.7
5kHz	0.192	0.044	-35.7
9kHz	0.192	0.156	69.7
node 3			
1kHz	0.192	0.084	23.3
5kHz	0.192	0.055	62.4
9kHz	0.192	0.22	24.4
node 4			
1kHz	0.192	0.086	21.2
5kHz	0.192	0.18	-11.8
9kHz	0.192	0.09	-113.8

Table 2: evaluation board measurements for Circuit B

freq [kHz]	$I_{R_{22}}$
1kHz	
5kHz	
9kHz	

6 Comparison

7 Summery

Appendix

A Source code circuit A

```
import etc
print(x)
```

B Source code circuit B

```
import etc
print(x)
```