Poznan University of Technology
Faculty of Computing and Telecommunications
Institute of Multimedia Telecommunications

COMPUTER AIDED DESIGN

LABORATORY

Instruction for the laboratory exercise

LTspice: Statistical Analyzes

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1. The aim of the exercise

- learning to define statistical analyzes Monte Carlo (MC) and Worst Case (WC) in LTspice,
- plotting a histogram in a spreadsheet.

2. Non-inverting amplifier analyzes

a) Analysis of the amplifier circuit for nominal values

1. Create the amplifier circuit diagram as shown in Figure 1.
2. Perform time analysis, compare the input (IN) and output (OUT) voltage values. Find the voltage gain (*ku*).

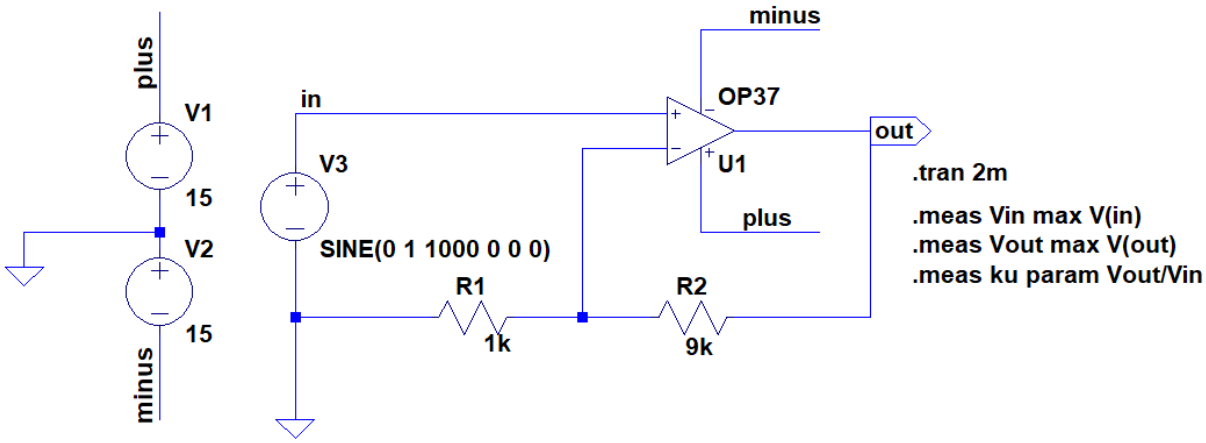

Fig. 1. Diagram of the tested amplifier circuit.

b) MC analysis of the amplifier circuit

1. Modify the amplifier circuit diagram as shown in Figure 2.

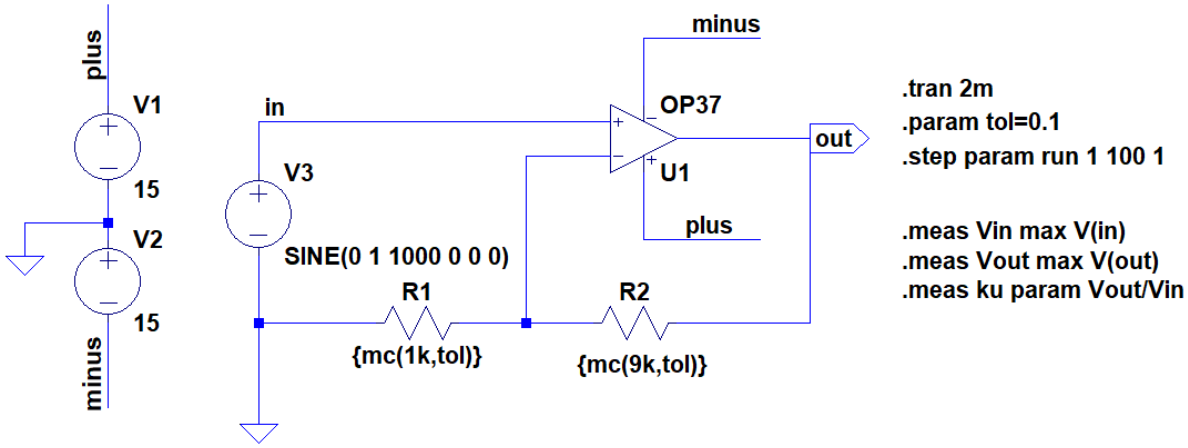

Fig. 2. Scheme of the tested amplifier circuit for MC analysis.

2. In the presented example, the tolerance of 10% resistors was assumed.
3. Determine the ranges of gain changes towards.

4. Using Calc (LibreOffice or Excel package spreadsheet) determine the gain histogram.
   4.1. Display the results of the *ku* gain calculation (*SPICE Error Log file*). In LTspice, right-click, select *View > SPICE Error Log*.
   4.2. Right-click in the ***log*** file, select Plot *.step'ed .meas data*.
   4.3. In the displayed window, right-click and select *Add Traces*. Mark the direction and click OK.
   4.4. Export data to a text file, *PPM > File> Export data as text*.
   4.5. Open file with text data in *Notepad ++* (or other text editor), replace all dots with commas *(Ctrl + H)*, select data, copy (only in Polish version).
   4.6. Run Calc, paste the copied data.
   4.7. Highlight columns with data, select *Format > Number Format > 0.0 Number*.
   4.8. In the free column, fill in the data series from 8 to 12 with steps of 0.4 (Fig. 3).
   4.9. Select cells in the adjacent column (Fig. 3).

	A	B	C	D	E
1	1,00	11,12		8	
2	2,00	11,18		8,4	
3	3,00	9,81		8,8	
4	4,00	11,01		9,2	
5	5,00	9,87		9,6	
6	6,00	11,32		10	
7	7,00	9,66		10,4	
8	8,00	9,46		10,8	
9	9,00	10,54		11,2	
10	10,00	10,04		11,6	
11	11,00	9,11		12	
12	12,00	9,78			
13	13,00	10,74			
14	14,00	10,07			

Fig. 3. Creating a histogram.

   4.10. Select cells in the adjacent column (Fig. 3).
   4.11. Start the function wizard, select the FREQUENCY function, select the data (*ku* value) and classes (series from 8 to 12, values in column D in Figure 3).
   4.12. Plot a plot of scatter, smooth values of FREQUENCY versus classes (Fig. 4).

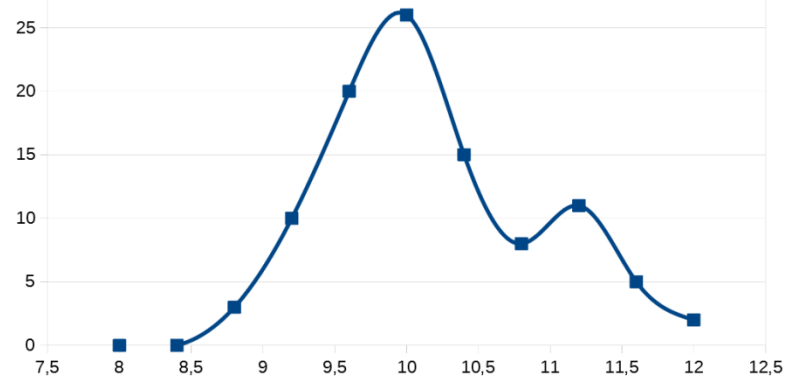

Fig. 4. Graph of the histogram.

c) Analysis of the WC of the amplifier circuit

1. Modify the amplifier circuit diagram as shown in Figure 5.

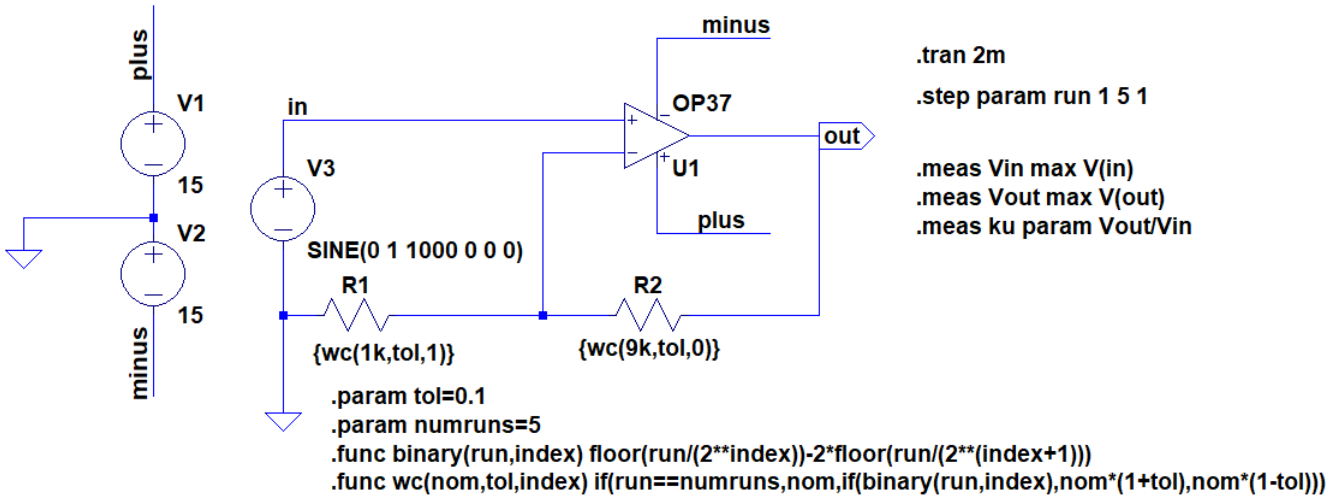

Fig. 5. Diagram of the tested amplifier circuit for WC analysis.

2. Read the results of the WC analysis. Determine the range of *ku* gain changes.
3. Change the tolerance values of the resistors to 1%. Determine the range of *ku* gain changes.

d) WC and temperature analysis of the amplifier circuit

1. Determine the worst-case analysis, taking into account the temperature limits at which the tested system can operate - 55 ° C and 125 ° C.
2. Modify the amplifier circuit diagram as shown in Fig. 6.
3. Get acquainted with the results of the analyzes. Determine the range of gain changes.

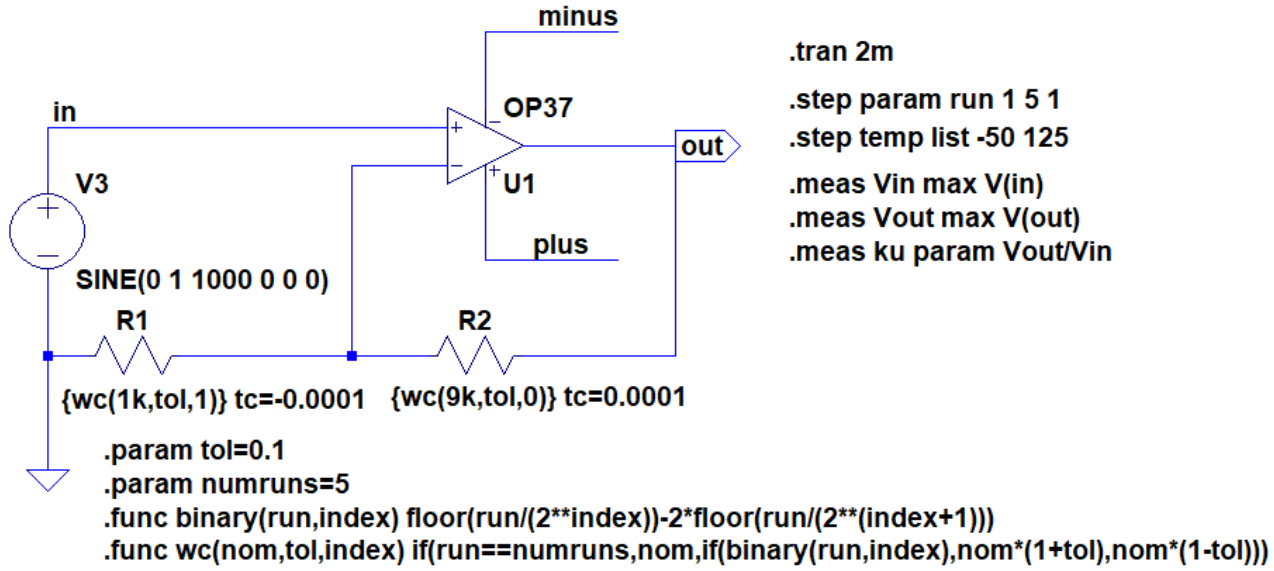

Fig. 6. Diagram of the tested amplifier circuit for WC analysis taking into account temperature changes.

3. MC analysis of the comparator with feedback

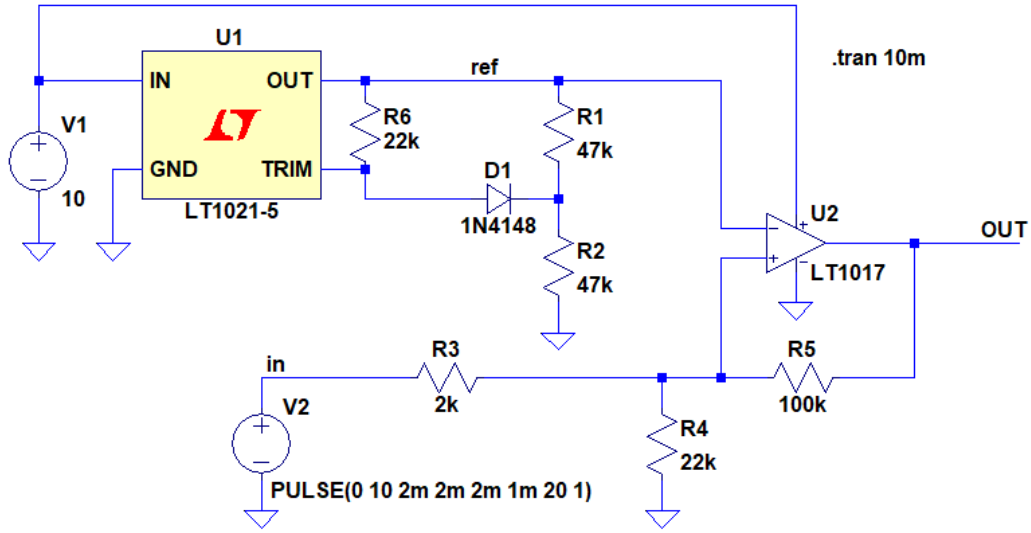

Fig. 7. Diagram of the tested comparator system.

a) Analysis of the comparator system for nominal values

1. Create a diagram of the comparator system with feedback according to Figure 7.
2. Set the values of the elements according to Figure 7.
3. Perform a time analysis, compare the values of switching voltages of the comparator. Analyze the voltage of the input signal IN and the output signal OUT.
4. What is the value of the hysteresis voltage? Determine the values of the comparator switching voltages.

b) MC analysis of the comparator system

1. Modify the comparator circuit diagram as shown in Figure 8.

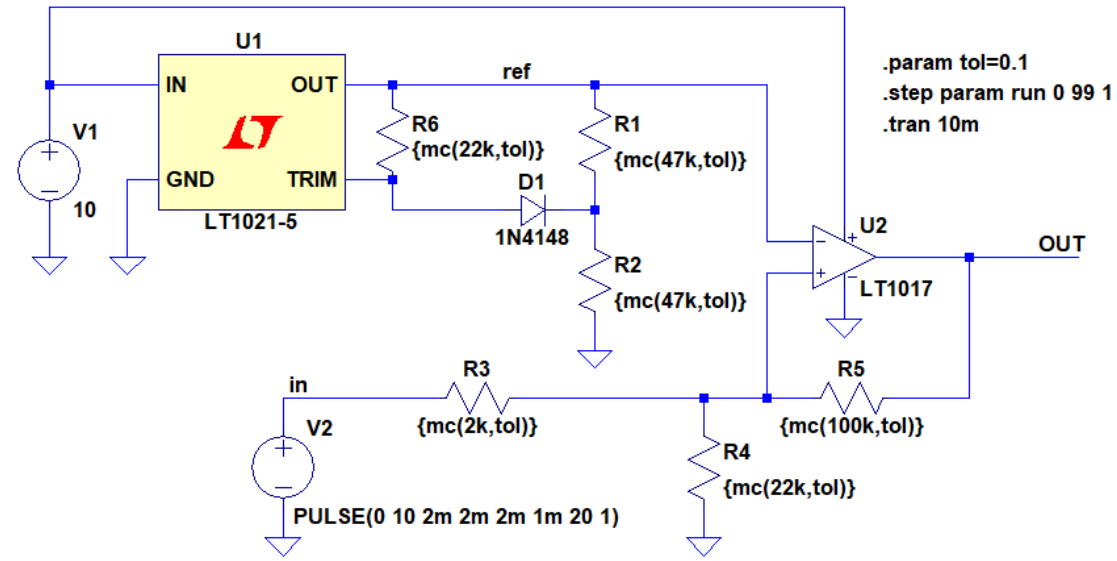

Fig. 8. Diagram of the tested comparator system for MC analysis.

2. In the presented example, the tolerance of the resistors is 10%.
3. Determine the ranges of voltage changes IN switching the comparator.

c) Analysis of the WC of the comparator system

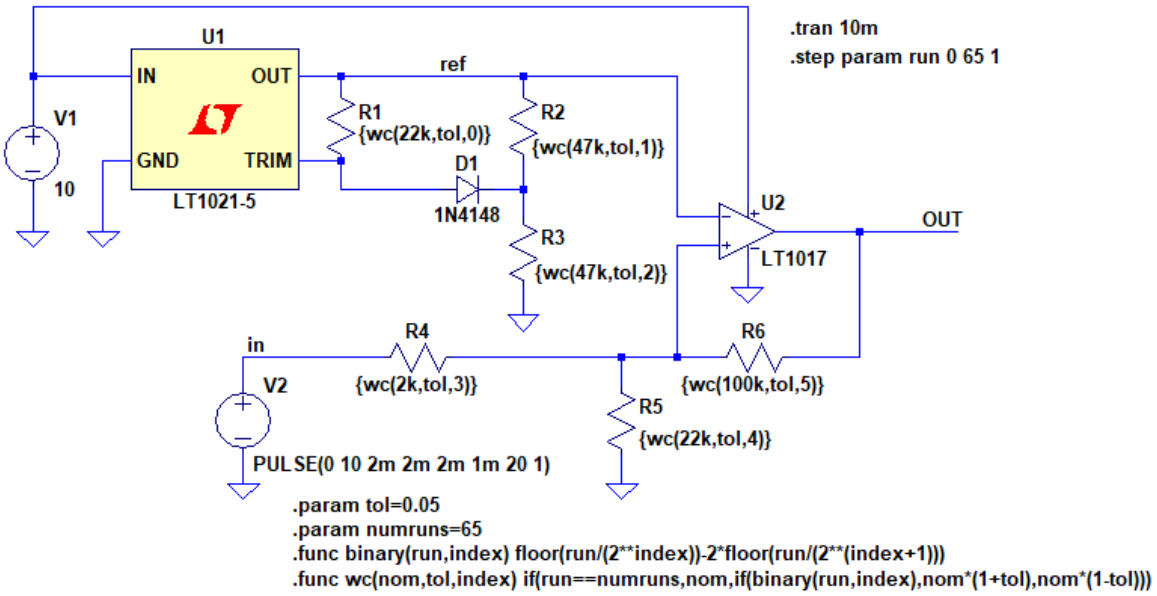

Fig. 9. Diagram of the tested comparator system for WC analysis.

1. Modify the comparator circuit diagram as shown in Figure 9.
2. Determine the ranges of voltage changes IN switching the comparator.

4. Analyzes of the band-pass filter

a) Analysis of the filter system for nominal values

1. Create a filter system diagram as shown in Fig. 10.
2. Set the values of elements according to Fig. 10.

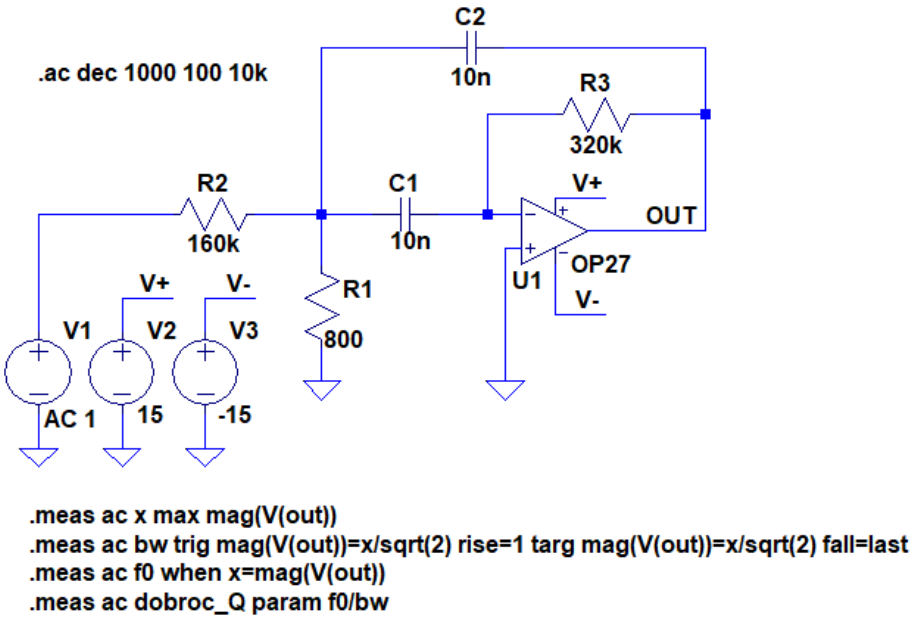

Fig. 10. Diagram of the tested filter system.

3. Perform a frequency analysis of the filter.
4. Find the quality of the filter Q according to equation (1).

$$Q = \frac{f_0}{f_g - f_d} \tag{1}$$

b) Filter MC analysis

1. Perform MC analyzes (Fig. 11), assuming capacitors tolerance of 10% and 5% resistors.
2. Determine the range of changes of the center frequency, gain and filter Q factor.
3. Similarly as in point 2 b) 4 determine the histogram of the central frequency of the filter, take the histogram classes from 800 - 1200 Hz with a resolution of 40 Hz.
4. Remove zero values (if any).

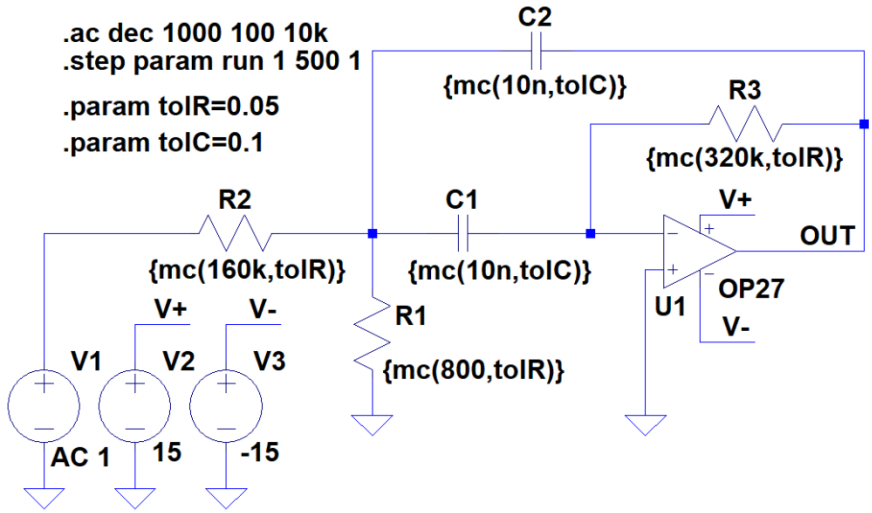

Fig. 11. Diagram of the tested filter system for MC analysis.

c) WC filter analysis

1. Make WC analysis (Fig.12), take capacitors tolerance of 10% and 5% resistors.
2. Determine the range of changes of the center frequency, gain and filter Q factor.

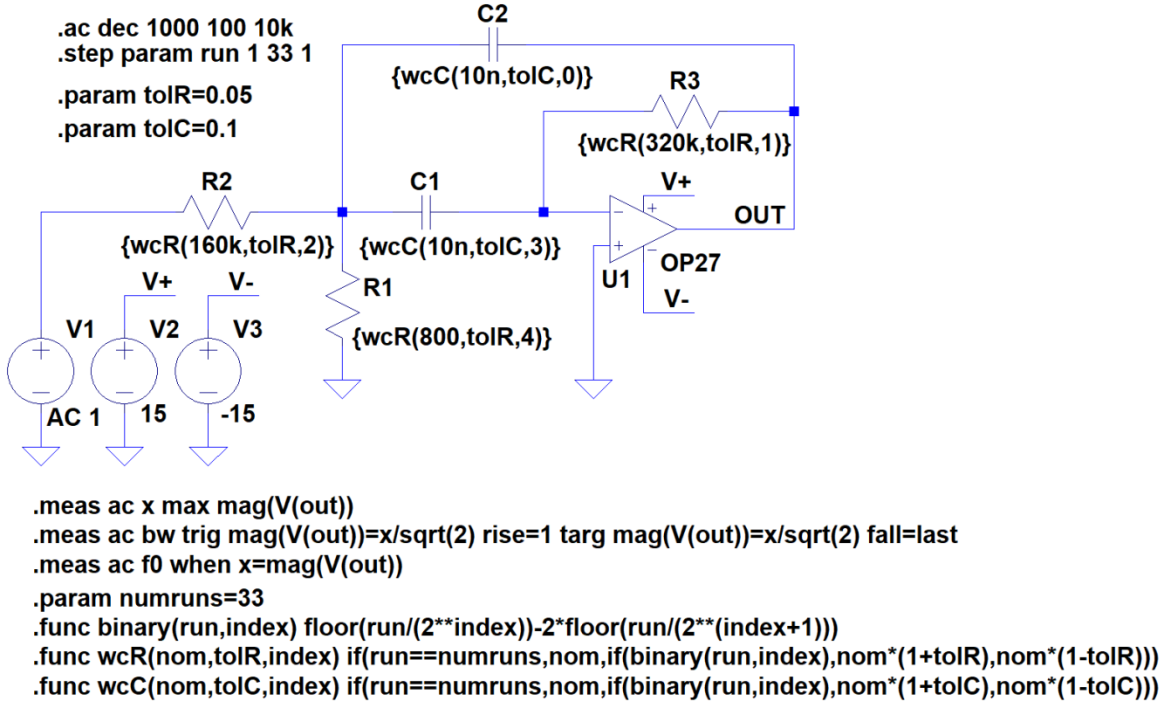

Fig. 12. Scheme of the tested filter system for WC analysis.

5. Tasks for students to do homework (obligatory)

1. Test the temperature effect on the filter center frequency from 2.3. Take TC temperature coefficients: 0.0005 for resistors and 0.0001 for capacitors.
2. Develop the transistor amplifier circuit (Fig. 13), perform simulations in the same way as for the amplifier (point 2.).

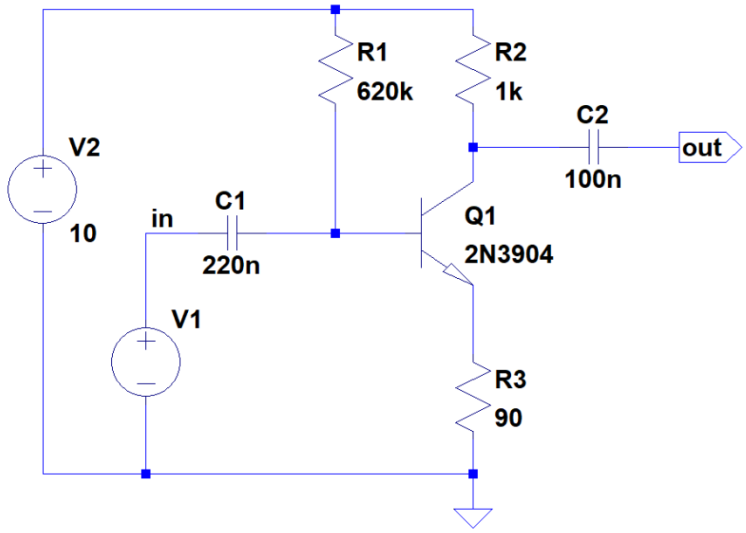

Fig. 13. Diagram of a transistor amplifier (take 10% resistors tolerance).

6. Additional tasks

- Simulate a simple voltage divider in Micro-Cap 12.
- Perform Monte Carlo analysis of the voltage at the output of the divider assuming a tolerance of 10% resistors.

7. Report

Should contain:

- all schemes of simulated systems,
- simulation results,
- answers to the questions contained in the manual,
- conclusions.