Experiment K

Comparators

Before you start to perform an experiment you are obliged to have mastered to the following theoretical subjects:

1. Types and mode of action of the feedback. [1], [3], [4].
2. Structure, operation and properties of the differential amplifier. [1÷5].
3. Properties of the ideal operational amplifier. [1÷5].
4. Properties and applications of the practical comparator. [1÷5].

Purpose

To understand and analyze the operations of practical comparator.

Introduction

Operational amplifier without the feedback resistors is often used as comparator for compare the amplitude of one voltage with another. It is running in the open-loop mode. The typical comparator is presented in Fig 1.

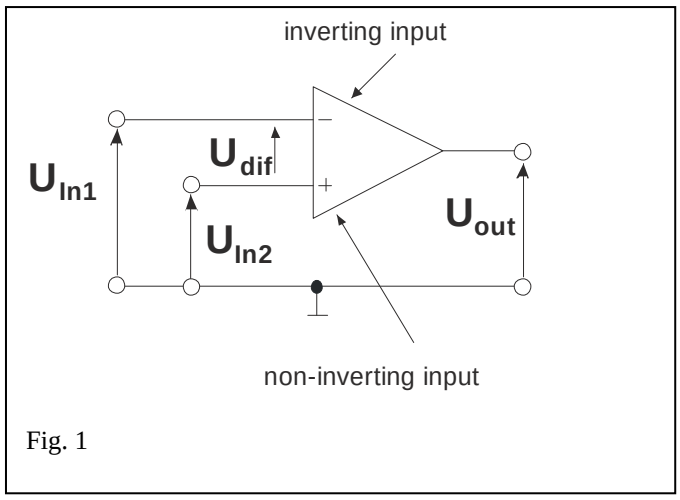

Fig. 1

If $U_{In1} = U_{In2}$ then $U_{out} = 0$. When $U_{In1} > U_{In2}$ then U_{out} is positive and its maximum value is equal to the positive supply voltage. The comparator is then saturated. When $U_{In1} < U_{In2}$ then U_{out} is negative and its minimum value is equal to the negative supply voltage. It means that small change in difference $U_{dif} = U_{In1} - U_{In2}$ causes U_{out} to switch between near positive supply voltage and near negative supply voltage. Hereby comparator indicates when U_{In1} is greater or less than U_{In2}.

Description of measurement method

The Op-Amp with open-loop is investigated in typical circuits as comparator without hysteresis, with hysteresis and as “window” comparator.

Measurements are performed for DC input voltages. The Adjustable Voltage Source and Voltage Dividers provide the DC voltages to control the comparator. The DMM’s voltmeters show the DC input and output voltages.

The Power Supply (DF1731SB3A or MPS-3003L-3) with serial operating mode is adjusted to the symmetrical voltage ±20V and supplies the comparator.

The control LEDs placed near the output of comparator show the saturation of comparator. The red light means maximum positive voltage and green light means minimum negative voltage.

Experimental procedure

A. Comparator without hysteresis.
(The schematic setup is presented in Fig. CO1a)

The transfer characteristic of comparator

1. Connect the circuit according to the diagrams presented in Figs. CO1a and CO1b. Set the switches R_3 and R_L to the "∞" position. Set the rotary function switch on DMM's voltmeters to the 20 DCV.
2. Set the switch Z_1 to the "2" position and the switch Z_2 to the „∞" position.
3. Set the rotary function switch on the Adjustable Power Supply to the "2" position.
4. Put the R_{S1} resistor near the We2 input position.
5. Connect the Adjustable Voltage Source to the non-inverting input We2.
6. Connect the Voltage Divider to the inverting input We1.
7. Switch on the Power Supply.
8. Set the voltage of the We1 input to the value from −12V to +12V. Start with negative voltage.
9. Increasing the We2 input voltage from −12V to +12V determine the dependence of input voltage on output voltage.
10. Record the obtained result on the data sheet in the Table T1.
11. Repeat the procedure describe in (8-10) steps. Set the We1 voltage to the chosen values (ask supervisor about values from the range −12V to +12V).
12. Replace the input positions of Adjustable Voltage Source and Voltage Divider and repeat the procedure described in (8-11) steps.
13. Switch off the Power Supply.

Table T1 – Comparator without hysteresis.

Input voltage U_{We1} [V]	Input voltage U_{We2} [V]	Output voltage U_{Wy} [V]

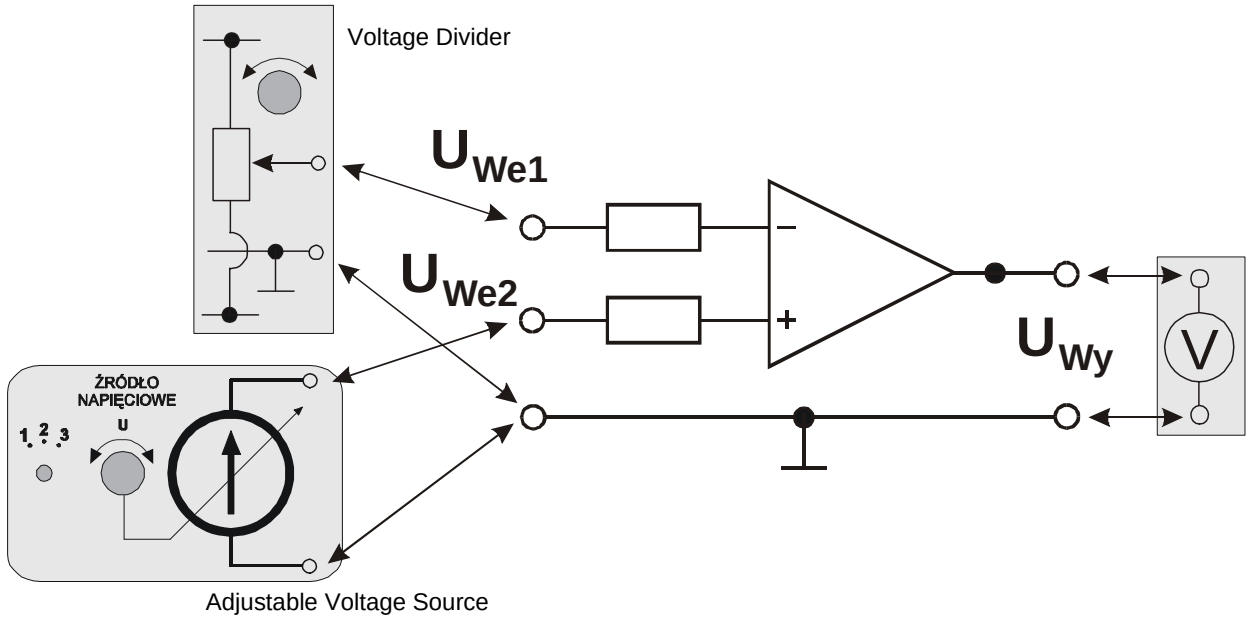

Fig. CO1a

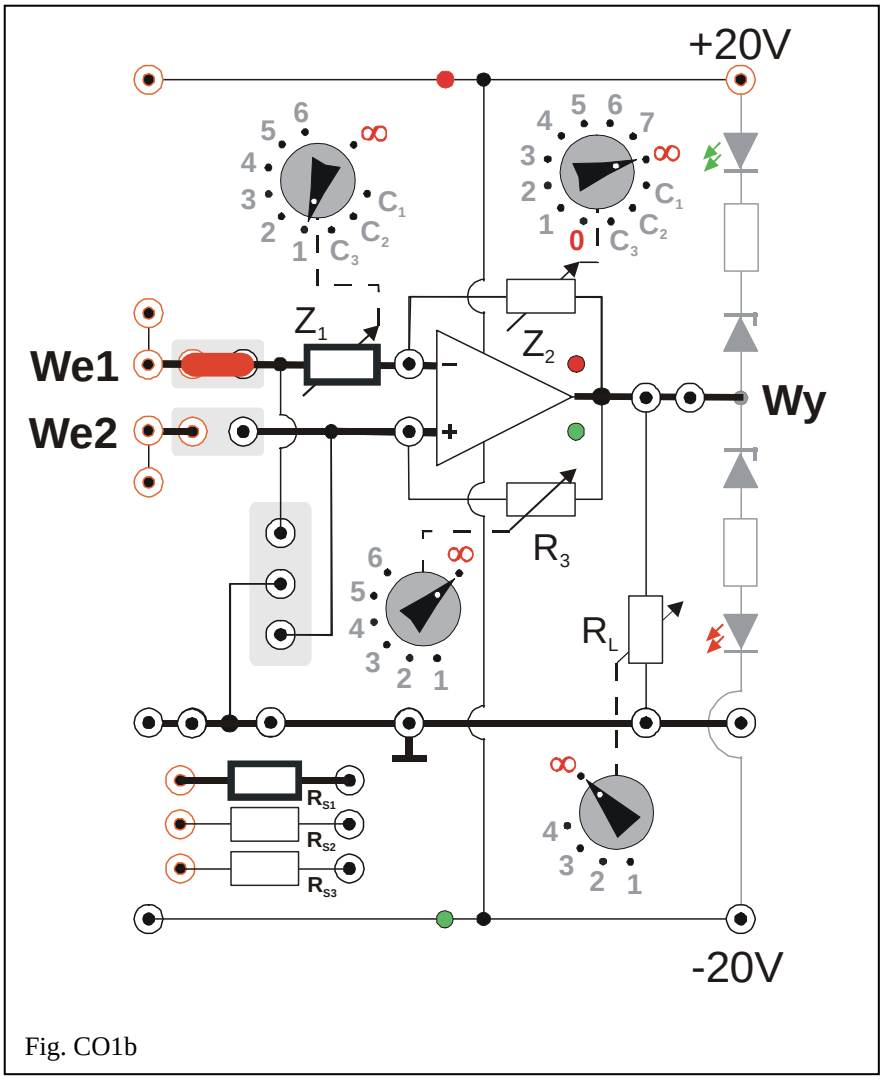

Fig. CO1b

B. Comparator with hysteresis.
(The schematic setup is presented in Fig. CO2a).

The transfer characteristic of comparator.

1. Connect the circuit according to the diagrams presented in Figs. CO2a and CO2b. Set the switch R_L to the "∞" position. Set the rotary function switch on DMM's voltmeters to the 20 DCV.
2. Set the switch Z_1 to the "2" position and the switch Z_2 to the „∞" position.
3. Set the rotary function switch on the Adjustable Power Supply to the "2" position.
4. Put the R_{S1} resistor near the We2 input position.
5. Connect the Adjustable Voltage Source to the non-inverting input We2.
6. Connect the Voltage Divider to the inverting input We1.
7. Switch on the Power Supply.
8. Set the voltage of the We1 input to the value from –2V to +2V (ask supervisor).
9. Increasing the We2 input voltage from –12V to +12V determine the dependences of input voltage on output voltage for R_3 selected positions „**1**", „**3**", „**5**" or „**2**", „**4**", „**6**", respectively.
10. Record the obtained result on the data sheet in the Table T2.
11. Replace the input positions of Adjustable Voltage Source and Voltage Divider and repeat the procedure described in (8-10) steps.
12. Switch off the Power Supply.

Table T2 – Comparator with hysteresis.

Resistor R_3 [Ω]	Input voltage U_{We1} [V]	Input voltage U_{We2} [V]	Output voltage U_{Wy} [V]

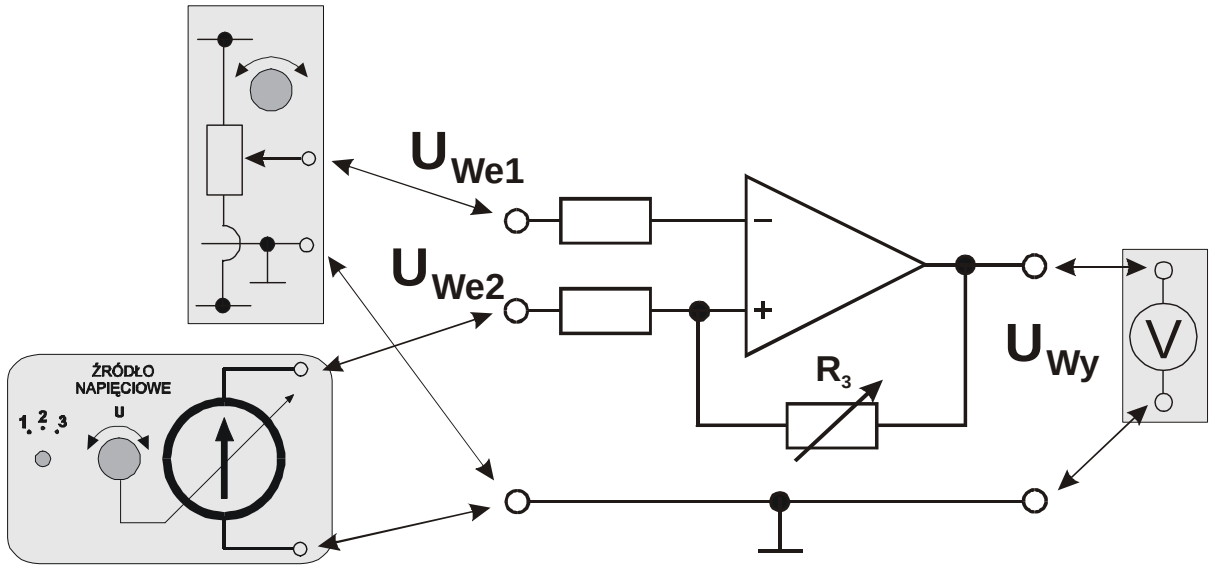

Fig. CO2a

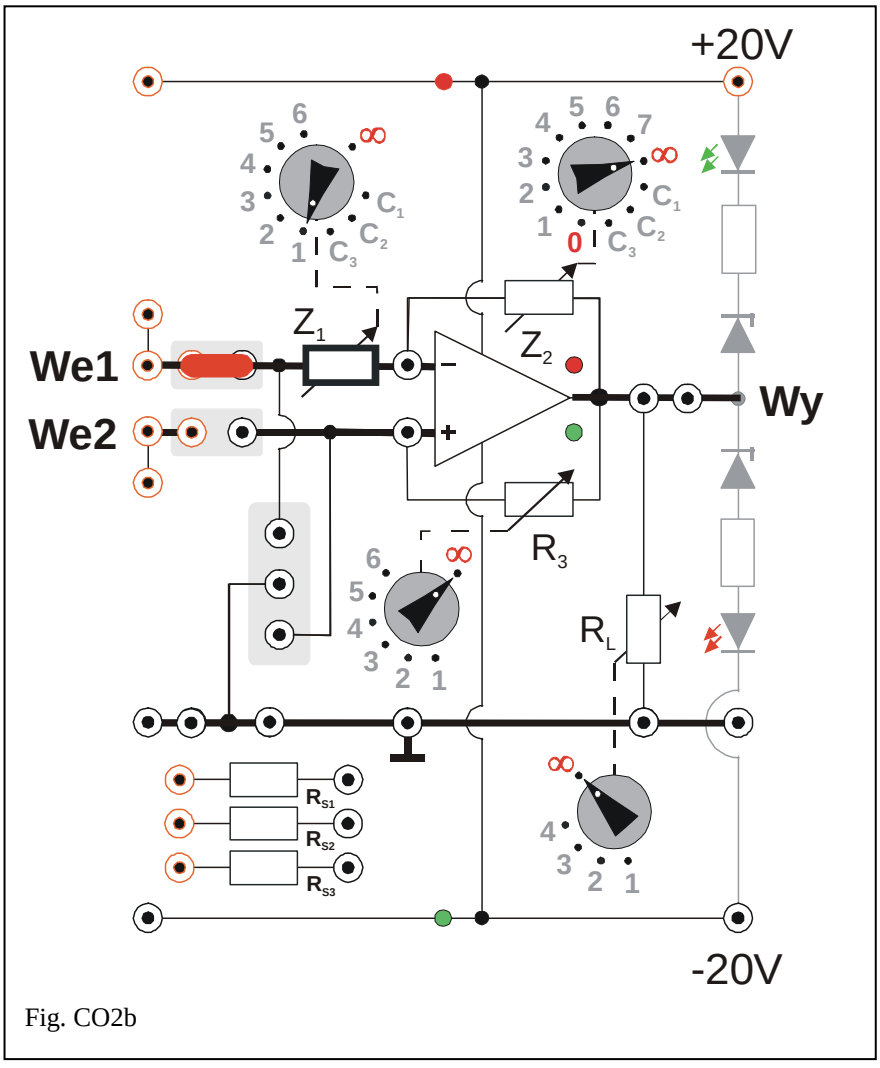

Fig. CO2b

C. The „window" comparator.
(The schematic setup is presented in Fig. CO3a).

The transfer characteristic of comparator.

1. Connect the circuit according to the diagrams presented in Figs. CO3a and CO3b. Set the rotary function switch on DMM's voltmeters to the 20 DCV.
2. Set the rotary function switch on the Adjustable Power Supply to the "2" position.
3. Connect the Adjustable Voltage Source to the non-inverting input WeS (middle position).
4. Connect the first Voltage Divider to the inverting input We1.
5. Connect the second Voltage Divider to the non-inverting input We2.
6. Switch on the Power Supply.
7. Set the voltage U_{We1} of the We1 input to the value from +1V to +3V (ask supervisor).
8. Set the voltage U_{We2} of the We2 input to the value from –3V to –1V (ask supervisor).
9. Increasing the We2 input voltage from –12V to +12V and then decreasing the We2 input voltage from +12V to –12V determine the dependences of input voltage on output voltage.
10. Record the obtained result on the data sheet in the Table T3.
11. Switch off the Power Supply.

Table T3 – „window" comparator.

U_{We1}	U_{We2}	U_{WeS}	U_{Wy}	control LEDs				
				1 - upper		2 - lower		output
[V]	[V]	[V]	[V]	Green	Red	Green	Red	Blue

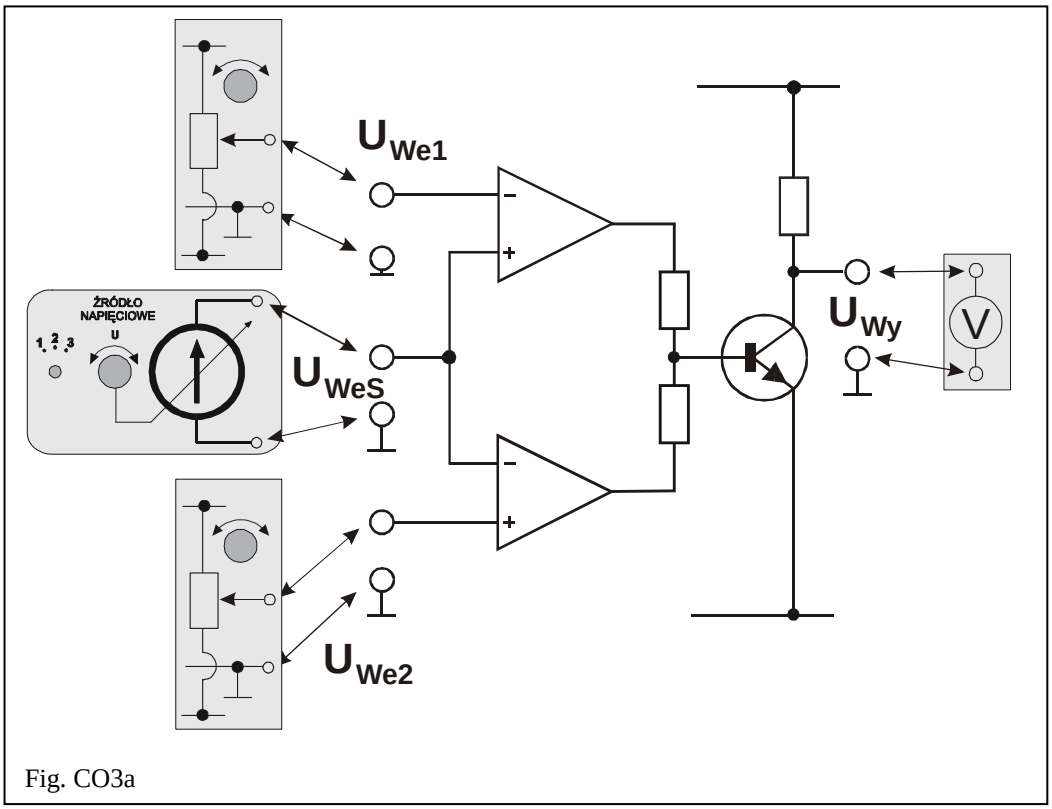

Fig. CO3a

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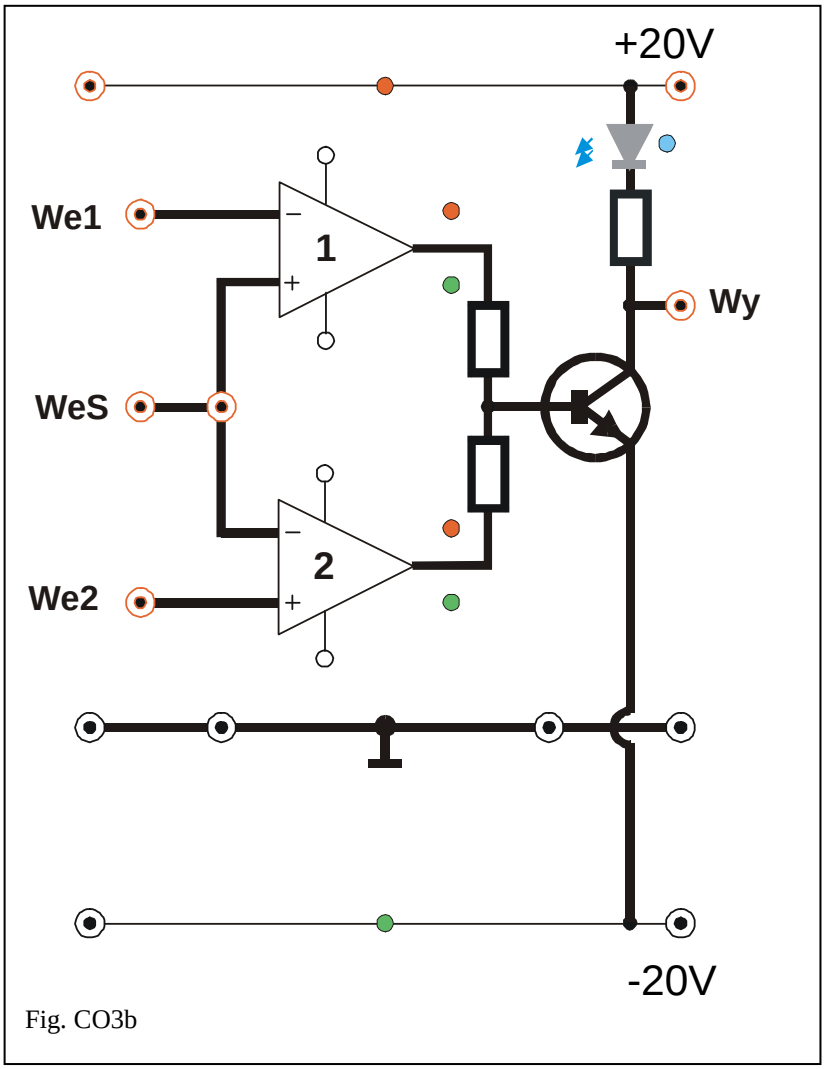

Fig. CO3b

Report elaboration

1. Plot on the common graph the transfer characteristics of comparator without hysteresis for relevant Voltage Divider's voltages.
2. Plot on the common graph the transfer characteristics of comparator with hysteresis for relevant R_3 resistances.
3. Plot on the common graph the transfer characteristics of "window" comparator.
4. Analyze the obtained results.

Tables of resistances and capacitances

Z_1	
Position	Value
1	5 kΩ
2	10 kΩ
3	15 kΩ
4	20 kΩ
5	25 kΩ
6	30 kΩ
∞	∞ Ω
C_1	0,1 µF
C_2	1,0 µF
C_3	10 µF

Z_2	
Position	Value
0	0 Ω
1	10 kΩ
2	20 kΩ
3	50 kΩ
4	100 kΩ
5	200 kΩ
6	500 kΩ
7	1 MΩ
∞	∞ Ω
C_1	0,1 µF
C_2	1,0 µF
C_3	10 µF

R_3	
Position	Value
1	20 kΩ
2	50 kΩ
3	100 kΩ
4	200 kΩ
5	500 kΩ
6	1 MΩ
∞	∞ Ω

R_L	
Position	Value
1	2 kΩ
2	5 kΩ
3	10 kΩ
4	20 kΩ
∞	∞ Ω

R_{S1}	10 kΩ
R_{S2}	300 kΩ
R_{S3}	10 MΩ

References

[1] M. Rusek, J. Pasierbiński, *Elementy i układy elektroniczne w pytaniach i odpowiedziach*, WNT, Warszawa, 1999.
[2] M. Nadachowski, Z. Kulka, *Scalone układy analogowe*, WKiŁ, Warszawa, 1985.
[3] P. Horowitz, W. Hill, *Sztuka elektroniki. Cz. 1*., (tłum. ang.), WKiŁ, Warszawa, 2003.
[4] Z. Nosal, J. Baranowski, *Układy elektroniczne*. *Cz. I. Układy analogowe liniowe*, Seria Podręczniki Akademickie, (Elektronika, Informatyka, Telekomunikacja), WNT, Warszawa, 2003.
[5] A. Filipowski, *Układy elektroniczne analogowe i cyfrowe*, Seria Podręczniki Akademickie, (Elektronika, Informatyka, Telekomunikacja), WNT, Warszawa, 2004.