ITMO

Laboratory Work 2
Operational amplifiers circuits design and simulation

Nikolay Nikolaev (nanikolaev@itmo.ru)
Nikolai Poliakov (polyakov_n_a@itmo.ru)
Roman Olekhnovich (r.o.olekhnovich@mail.ru)

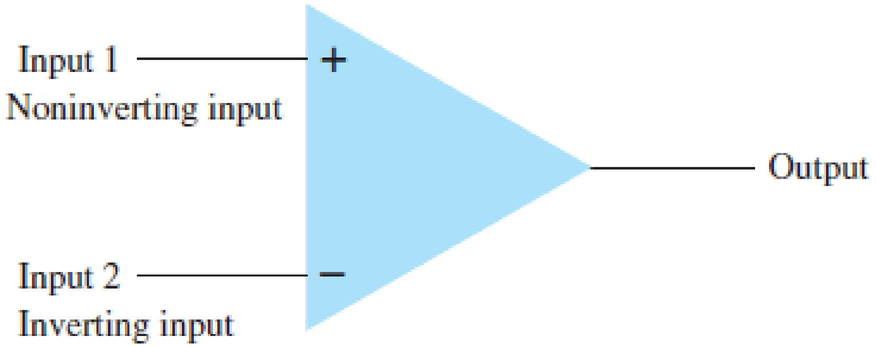
Summary

1. Operational amplifiers circuits theory review
2. Laboratory work 2: ideal and real amplifier comparison
3. Starting data analysis
4. Step 1: check of scheme gain
5. Step 2: check of scheme (time domain simulation)
6. Step 3: check of scheme (frequency domain simulation)
7. Results and conclusions
8. Uploading report

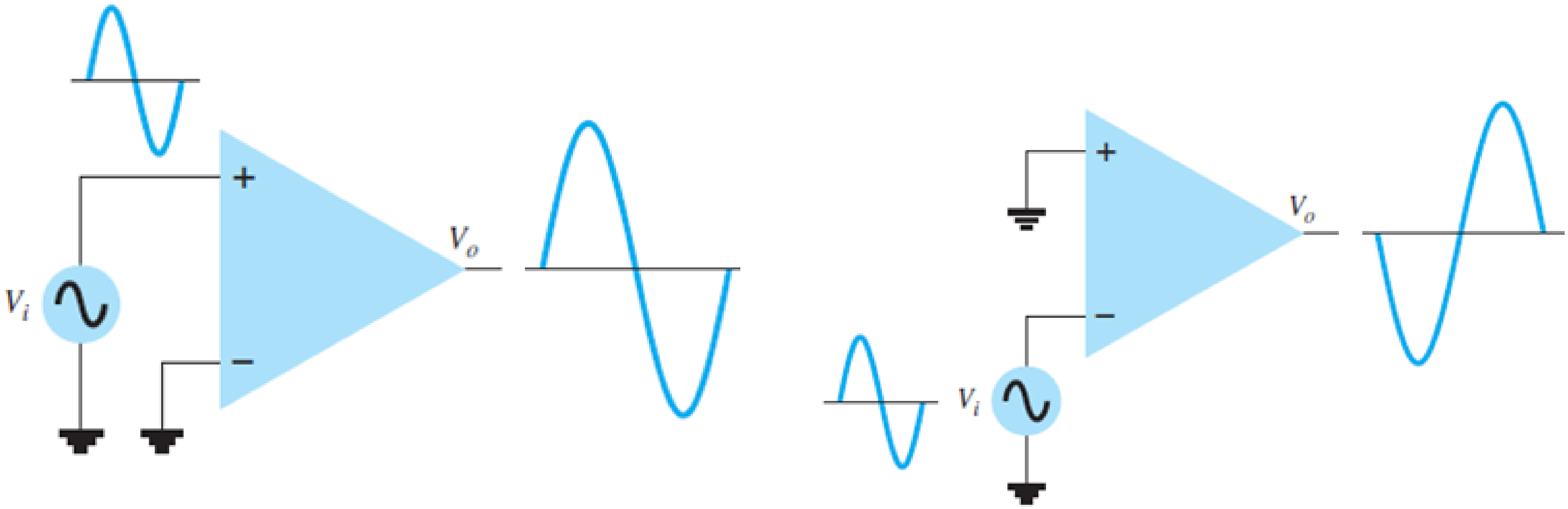
Single-Ended Input

Double-ended input, Single-Ended output

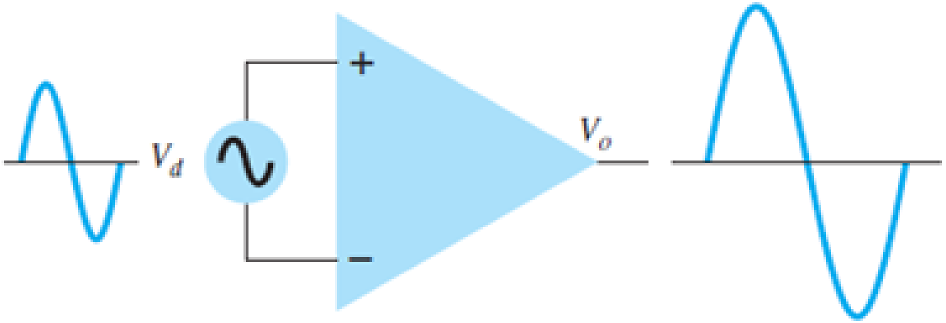
- ✓ Double-Ended (Differential) Input
- ✓ Common-Mode Operation

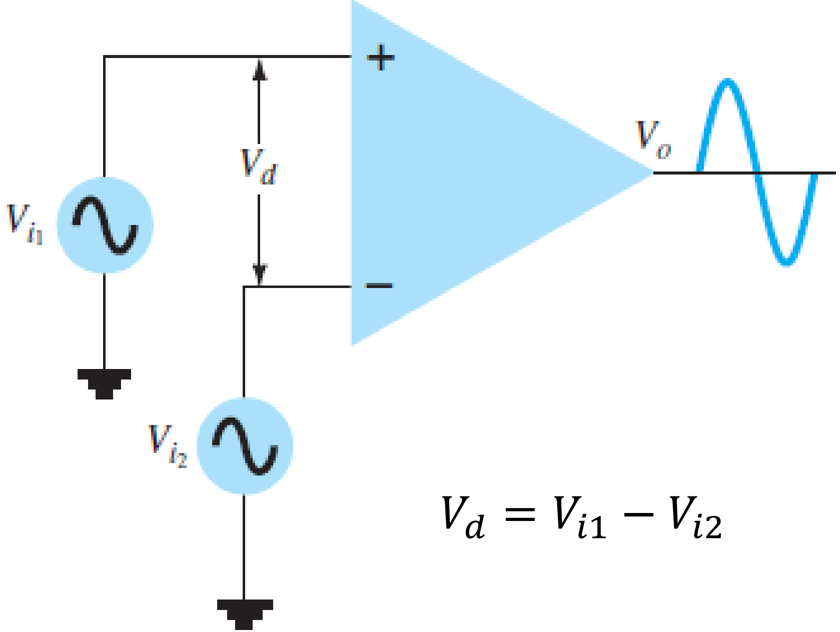


Single-Ended Input

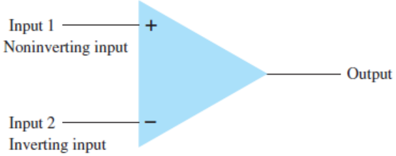


Double-Ended (Differential) Input

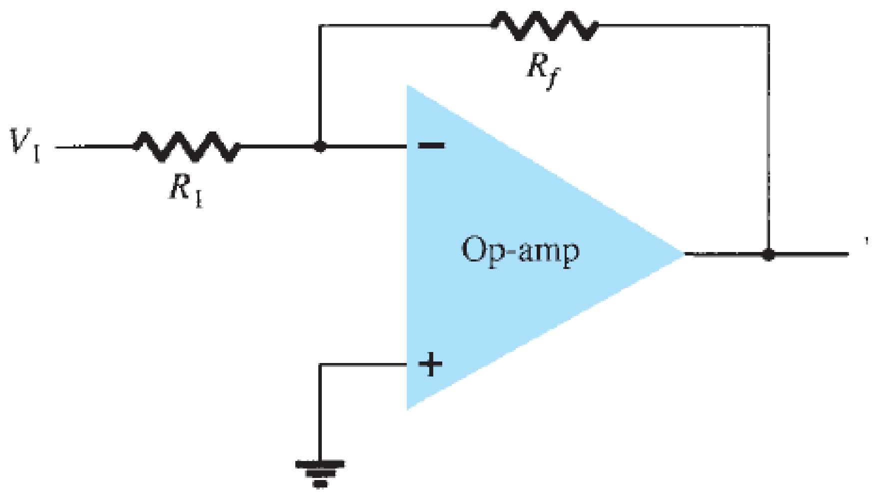


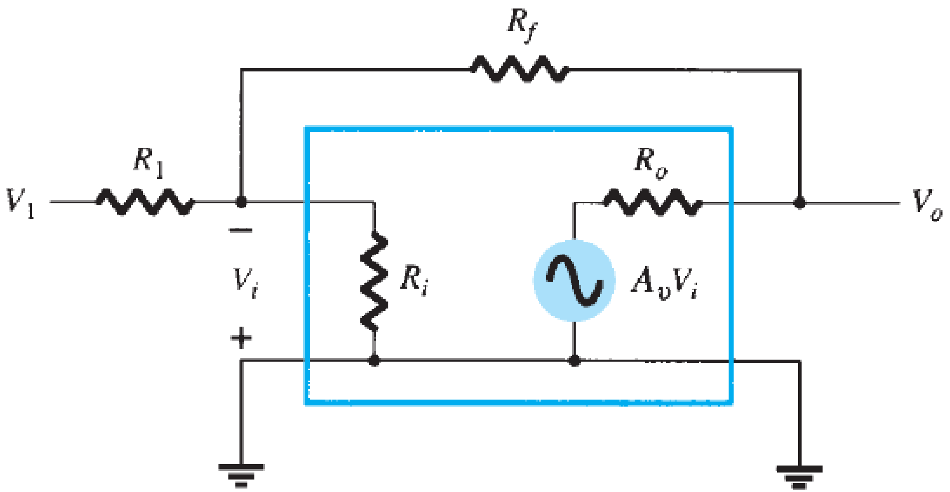


$$V_d = V_{i1} - V_{i2}$$

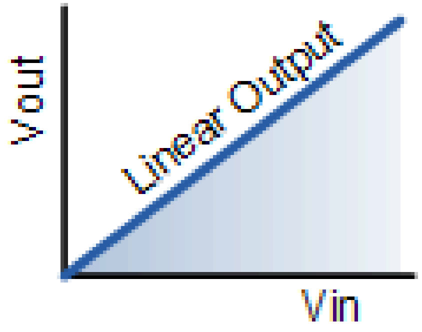


Inverting Amplifier

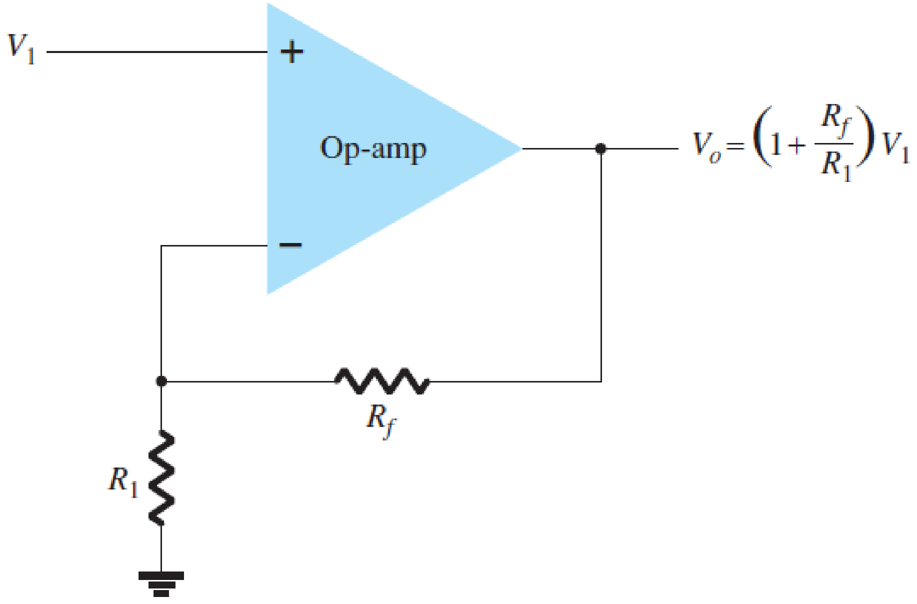


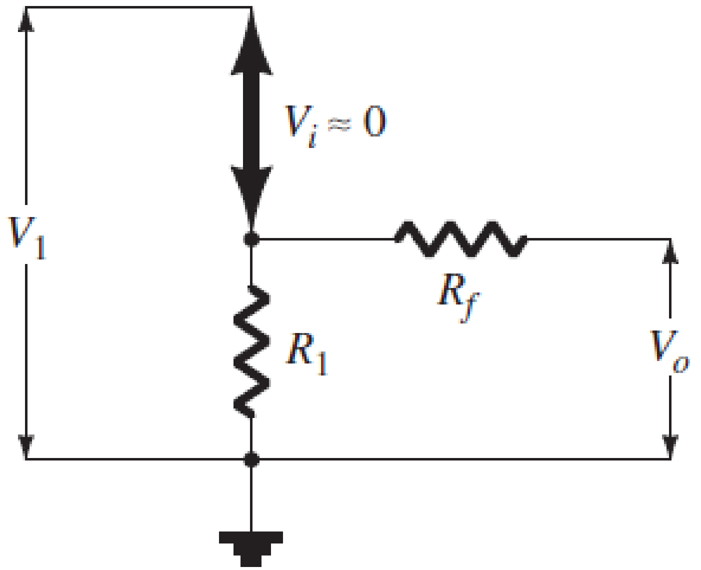


$$I_{R1} = I_{Rf} \rightarrow V_o = -\frac{R_f}{R_1} V_i \rightarrow \boxed{A_d = \frac{V_o}{V_i} = -\frac{R_f}{R_1}}$$



Noninverting Amplifier



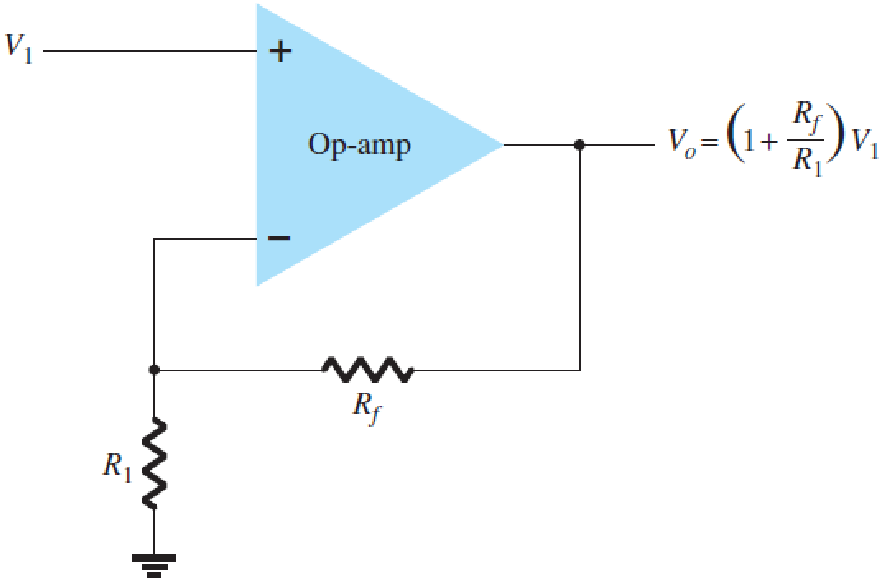


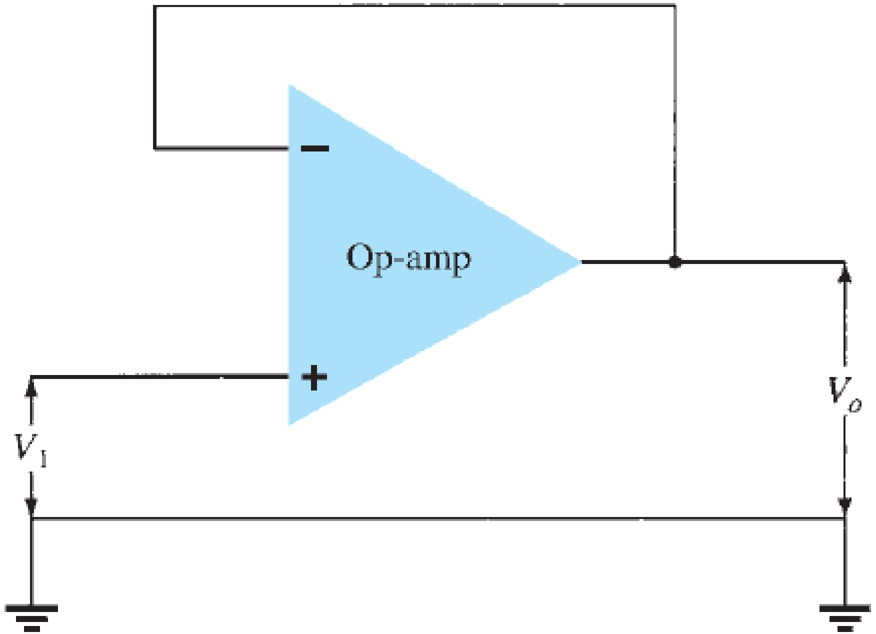
$$\frac{V_o}{V_1} = \frac{R_1 + R_f}{R_1} = 1 + \frac{R_f}{R_1}$$

Comparison Inverting And Noninverting Amplifier

Inverting Amplifier	Non-inverting Amplifier
The feedback used in amplifier is voltage shunt or negative feedback	The type of feedback used in amplifier is voltage series or negative feedback
The output of this amplifier is inverted	The output of is in phase by the input signal
the reference voltage can be given to the inverting terminal	In this amplifier, the reference voltage can be given to the non-inverting terminal
The gain is $A_d = -\frac{R_f}{R_1}$	The gain is $A_d = 1 + \frac{R_f}{R_1}$
The voltage gain is $A_d \leq\geq 1$ (less than, greater than or equal)	The voltage gain is $A_d \geq 1$
The input impedance is R_1	The input impedance is very large

Unity Follower





$$V_o = V_1$$

Summing Amplifier

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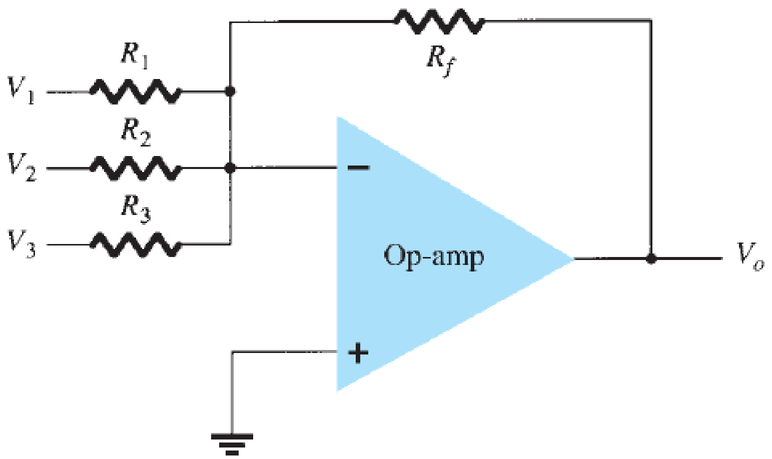
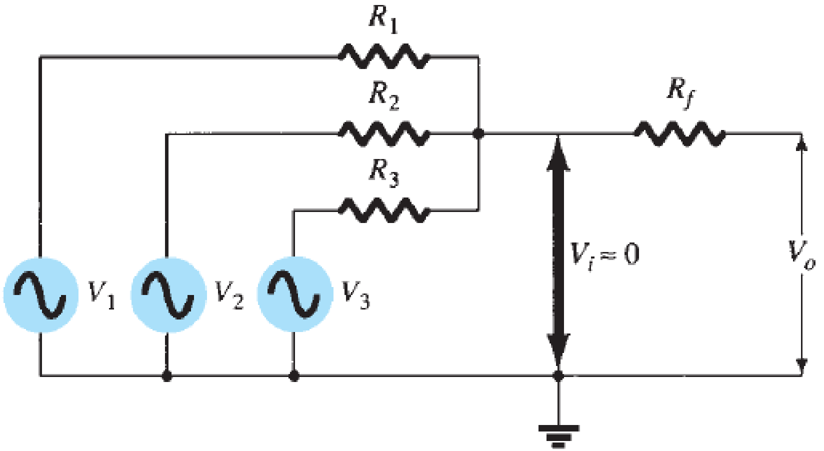
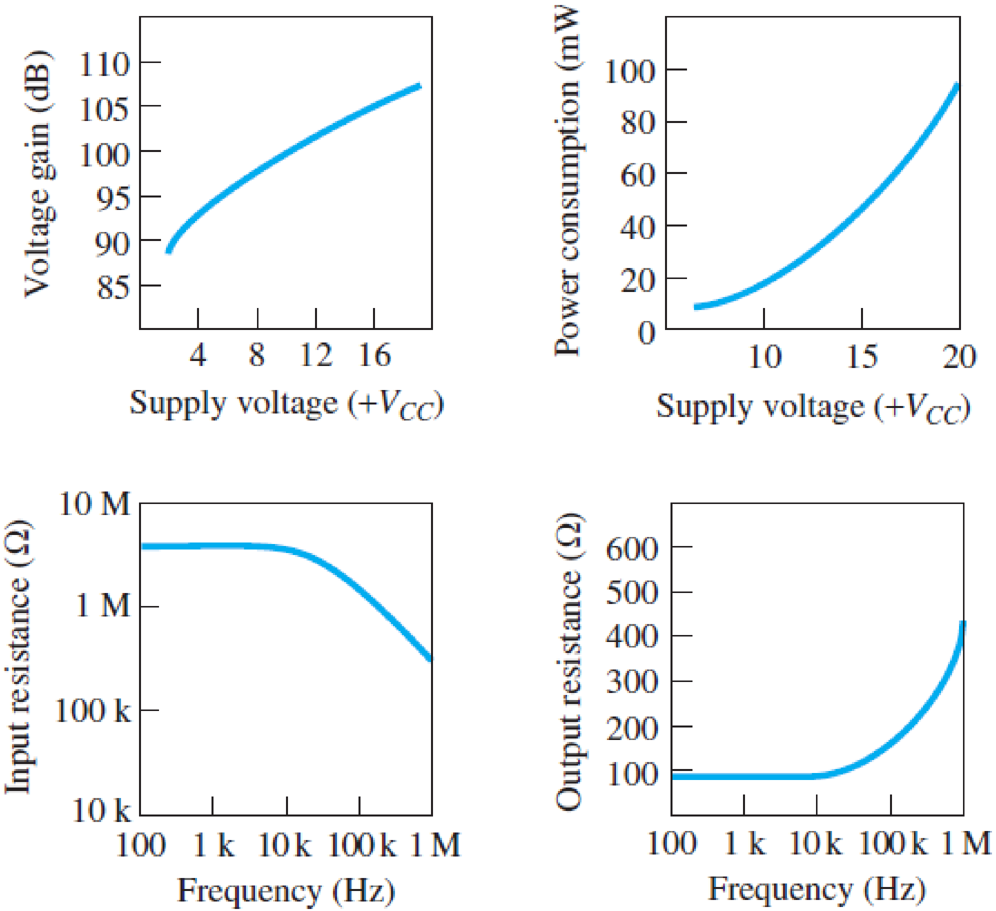


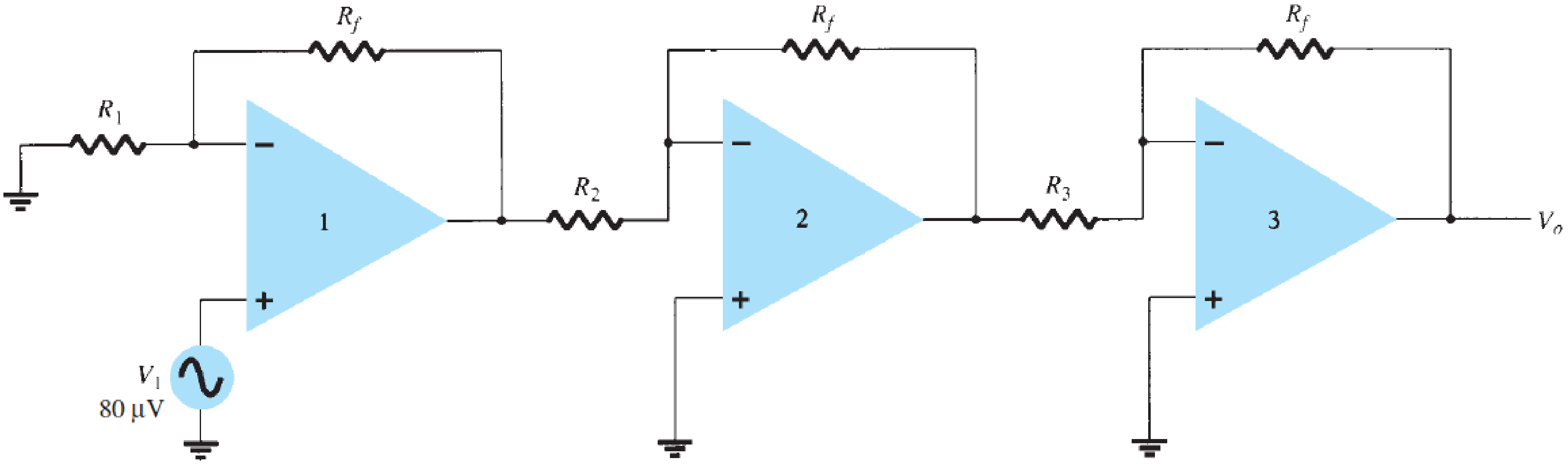


$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

Op-Amp Performance



Multiple-Stage Gains



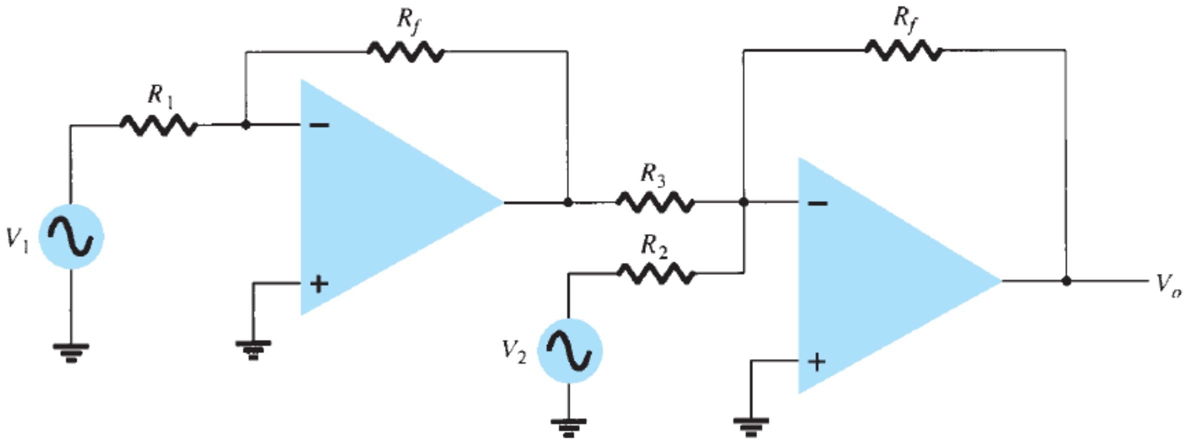
$$A_1 = 1 + \frac{R_f}{R_1}$$

$$A_2 = -\frac{R_f}{R_2}$$

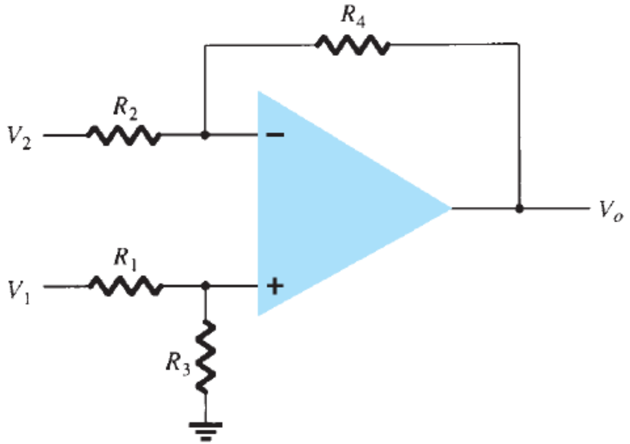
$$A_3 = -\frac{R_f}{R_3}$$

$$A = A_1\, A_2\, A_3$$

Voltage Subtractor

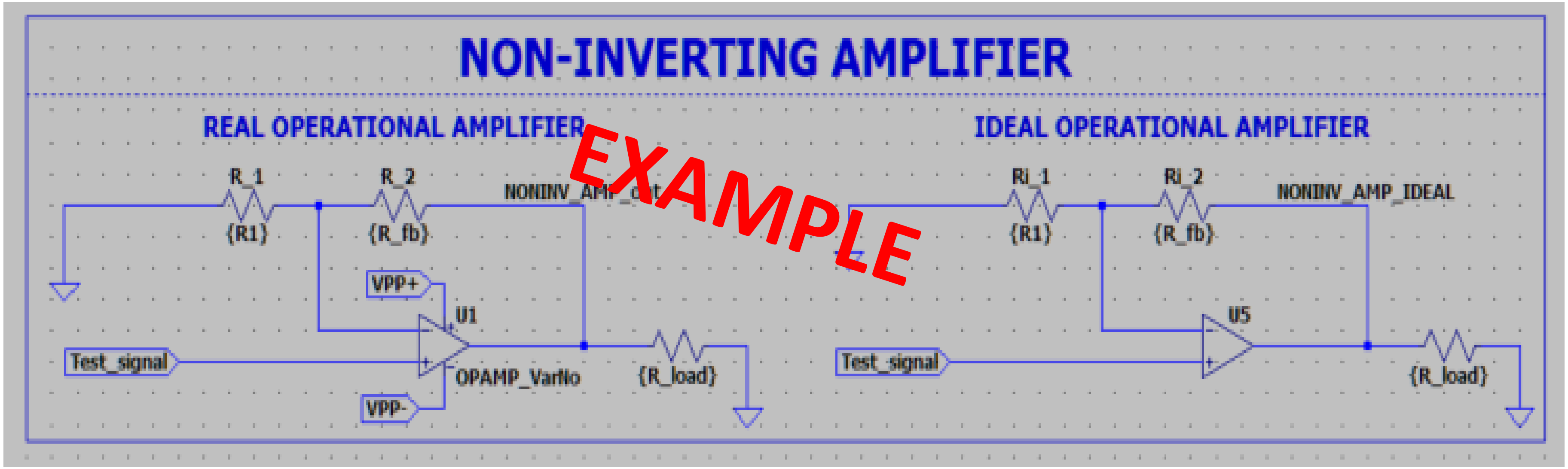


$$V_o = -\left(\frac{R_f}{R_2}V_2 - \frac{R_f}{R_3}\frac{R_f}{R_1}V_1\right)$$



$$V_o = \frac{R_3}{R_1 + R_3}\frac{R_2 + R_4}{R_2}V_1 - \frac{R_4}{R_2}V_2$$

Laboratory work 2



Real operational amplifier:

- Limited by power supply (VPP+/VPP-)
- Limited real Operational amplifier open loop gain $K_{OL} \approx \frac{K_{NI}}{E_{NI}}$
- Limited frequency operation (unity gain frequency)

Ideal operational amplifier:

- Any output voltage
- Open loop gain $K_{OL} \rightarrow \infty$
- Good for circuit check

Work purpose and goals

1. **Work purpose: to study parameters of Operational Amplifier and basis of Operational amplifiers circuits design**

Goals:
1) Design amplifier model on the basis of operational amplifier «Opamp_name»
2) Simulate amplifier scheme and analyze dependencies of output voltage from load and resistor values variation
3) Analyze time domain and frequency domain of amplifier
4) Simulate underpower state/power supply check

Starting data

- **Required gain of amplifier** K_{NI} =4
- **Required tolerance**: $\Delta K_{NI_{OPAMP}}$ =5%
- **Operational Amplifier :**
- **Voltage source power supply** VPP+= 3 (V) / VPP−= 3(V)
- **Frequency for time domain simulation**

$f_{test\_1} = 500$ (Hz)

$f_{test_2} = 5000$ (Hz)

$f_{test_3} = 100000$ (Hz)

- **Test signal voltage magnitude**

$V_{test_{AC}} = V_{test} = 0{,}5$ (V)

- **Resistor parameters**

$R_1 = 10000$ (Ω)

$R_{fb} = 10000$ (Ω)

$R_3 = 10000$ (Ω)

$R_4 = 10000$ (Ω)

R_{Load} =1 000 0000 (Ω)

- **Amplifier scheme:** Non-Inverting amplifier

Step 1: check of scheme gain

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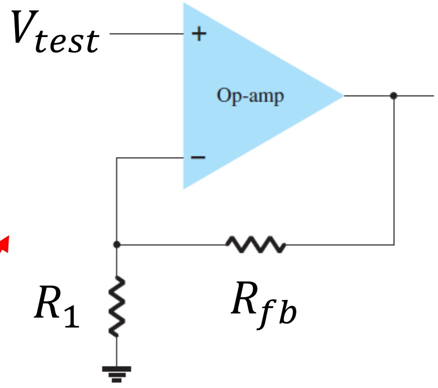
Step 1: check of scheme gain



$$V_{out} = V_1\left(1 + \frac{R_{fb}}{R_1}\right)$$

$$K_{NI} = 1 + \frac{R_{fb}}{R_1} = 1 + \frac{10000}{10000} = 2$$

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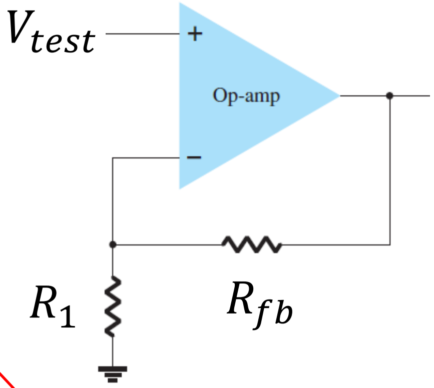

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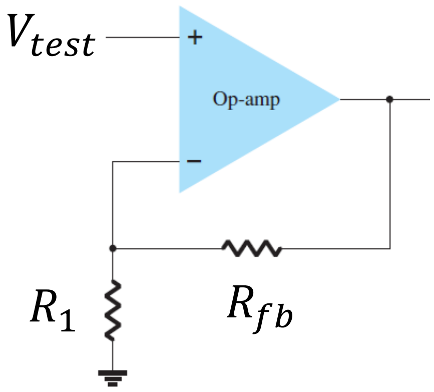
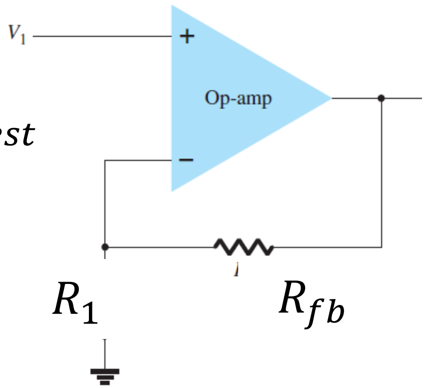


$$V_{out} = V_1\left(1 + \frac{R_{fb}}{R_1}\right)$$

New R_{fb} or/and new R_1:

$$K_{NI} = 1 + \frac{R_{fb}}{R_1} = 1 + \frac{33000}{11000} = 4$$

Step 1: check of scheme gain



V_{test} R_1 R_{fb}

$$V_{out} = V_1(1 + \frac{R_{fb}}{R_1})$$

$$K_{NI} = 1 + \frac{R_{fb}}{R_1} = 1 + \frac{33000}{11000} = 4$$

New R_{fb} or/and new R_1 with tolerance parameter:

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New R_{fb} or/and new R_1 with tolerance parameter:

$$K_{NI_{max}} = 1 + \frac{R_{fbmax}}{R_{1min}} = \frac{R_{fb}(1+M)}{R_{1min}(1-M)} =$$

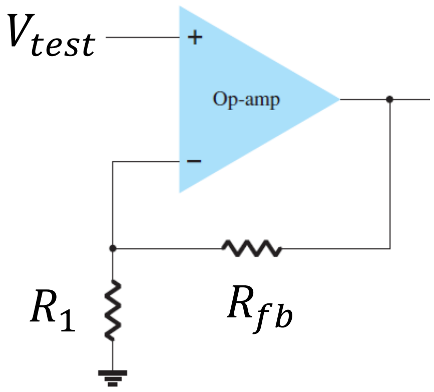
$$K_{NI_{min}} = 1 + \frac{R_{fb}(1-M)}{R_{1min}(1+M)} =$$

Define maximum deviation from K_{NI} defined by resistance tolerance

$$E_{NI_{R+}} = \frac{K_{NI_{max}} - K_{NI}}{K_{NI}} =$$

$$E_{NI_{R-}} = \frac{K_{NI_{min}} - K_{NI}}{K_{NI}} =$$

Step 1: check of scheme gain



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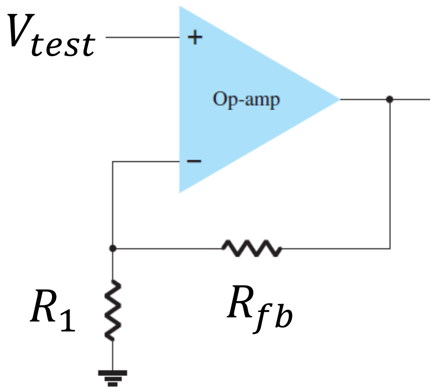

$$V_{out} = V_1\left(1 + \frac{R_{fb}}{R_1}\right)$$

TECHNICAL SPECIFICATIONS						
DESCRIPTION	TNPW0201 e3	TNPW0402 e3	TNPW0603 e3	TNPW0805 e3	TNPW1206 e3	TNPW1210 e3
Imperial size	0201	0402	0603	0805	1206	1210
Metric size code	RR0603M	RR1005M	RR1608M	RR2012M	RR3216M	RR3225M
Resistance range	22 Ω to 40 kΩ	10 Ω to 100 kΩ	1 Ω to 332 kΩ	1 Ω to 1 MΩ	1 Ω to 2 MΩ	10 Ω to 3.01 MΩ
Resistance tolerance	± 0.5 %; ± 0.1 %	± 1 %; ± 0.5 %; ± 0.1 %				
Temperature coefficient	± 25 ppm/K	± 50 ppm/K; ± 25 ppm/K; ± 15 ppm/K; ± 10 ppm/K				
Rated dissipation, P_{70} (1)	0.075 W	0.100 W	0.125 W	0.200 W	0.400 W	0.500 W
Operating voltage, $U_{max.}$ AC_{RMS} or DC	25 V	50 V	75 V	150 V	200 V	200 V

$$M = 0{,}01 \; for \; 1\%$$

Starting data

Step 1: check of scheme gain

New R_{fb} or/and new R_1 with tolerance param:

$$K_{NI} = 1 + \frac{R_{fb}}{R_1} = 1 + \frac{33000}{11000} = 4$$

TECHNICAL SPECIFICATIONS						
DESCRIPTION	TNPW0201 e3	TNPW0402 e3	TNPW0603 e3	TNPW0805 e3	TNPW1206 e3	TNPW1210 e3
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R_{Load} =1 000 0000 (Ω)

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$$K_{NI_{max}} = 1 + \frac{R_{fbmax}}{R_{1min}} = \frac{R_{fb}(1+M)}{R_{1min}(1-M)} =$$

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Define maximum deviation from K_{NI} defined by resistance tolerance

$$E_{NI_{R+}} = \left|\frac{K_{NI_{max}} - K_{NI}}{K_{NI}}\right| = \text{(should be less then 5\%)}$$

$$E_{NI_{R-}} = \left|\frac{K_{NI_{min}} - K_{NI}}{K_{NI}}\right| = \text{(should be less then 5\%)}$$

$$\Delta K_{NI_{OPAMP}} = \text{max of } E_{NI_{R+}} \text{ and } E_{NI_{R-}}$$

Starting data

Step 1: check of scheme gain

New R_{fb} or/and new R_1 with tolerance param:

$$K_{NI} = 1 + \frac{R_{fb}}{R_1} = 1 + \frac{33000}{11000} = 4$$

- **Required tolerance** : $\Delta K_{NI_{OPAMP}}$ =5%

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Define maximum deviation from K_{NI} defined by resistance tolerance

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$$E_{NI_{R-}} = \left|\frac{K_{NI_{min}} - K_{NI}}{K_{NI}}\right| = \text{(should be less then 5\%)}$$

Real Operational amplifier open loop gain $K_{OL} \approx \frac{K_{NI}}{E_{NI}}$

Step 2: check of scheme (time domain simulation)

- Setting up resistor tolerance:
- Providing simulations:

$f_{test\_1} = 500$ (Hz)

$f_{test_2} = 5000$ (Hz)

$f_{test_3} = 100000$ (Hz)

Simulations: frequency domain simulation

Step 3: check of scheme (frequency domain simulation)

- setting up resistor tolerance R_{fb} and new R_1
- setting up resistor load resistance variation $\boldsymbol{R_{load}\ list}$: 100, 1000, 10000, 100000 (Ω)

Simulations

Step 4: Power supply check

- Vpp+ and Vpp- should have enough values

Simulation results

	Ideal	VarNo	Ideal	VarNo	Ideal	VarNo
frequency, kHz	500,000		**5000**		**50000**	
V_{test}, V						
V_{out}, V						
K_{NI_exp}						
$\Delta K_{NI_{OPAMP}}$						
$E_{NI_{max}}$						
$E_{NI_{min}}$						
$K_{OL} \approx \frac{K_{NI}}{\Delta K_{NI_{OPAMP}}}$						

Real Operational amplifier open loop gain $K_{OL} \approx \frac{K_{NI}}{E_{NI}}$

Conclusions

Conclusions should contain:

1) Is it possible to realize amplifier with defined gain and gain tolerance?

2) In which range can be load resistance R_{Load} variated

3) How was operational amplifier power supply modified?

Lab 2 submission form

https://forms.yandex.com/cloud/636daa90d046881001fdbbf1/

https://clck.ru/32eHHL

1st deadline: 23.11.2022 23:59 (GMT +8)

ITMO UNIVERSITY

Saint Petersburg, Russia