# 28. APPLICATIONS OF OPERATIONAL AMPLIFIERS

Laboratory studies

All circuits from the op-amp are prepared in the form of a combined device. All attachments, adjustments and measurements are made using the buttons, knobs and voltmeters mounted on the front of the device. The only elements attached to the outside are oscilloscopes and a generator.

5.1 Balancing the amplifier

System tested was presented in Fig. 2.3.

Attach the voltmeter to the terminals of the op-amp and by adjusting the potentiometer P bring the voltmeter display to zero. During an exercise it is **not necessary** to reposition the potentiometer P, as the zeroed op-amp is switched on to all other systems.

After balancing the op-amp, disconnect the compensating system with the corresponding button.

5.2. Inverting amplifier

System tested is presented in Fig. 3.1.

**A**. Attach voltage UIN with " +" or "-" polarization. Attach the voltmeter to the outputs terminals and supply UIN measure the UOUT value for individual amplifier gains. Note the results in the table. Based on the results of the measurements, determine the actual gain of Aufr amplifier (as the average of the measurements).

|  |  |  |
| --- | --- | --- |
| Auf= 10 | Auf= 20 | Auf= 100 |
| UIN | UOUT | UIN | UOUT | UIN | UOUT |
| V | V | V | V | V | V |
| 0.51.0 |  | 0.250.40 |  | 0.050.10 |  |
| Aufr=.... | Aufr=.... | Aufr=.... |

 $A\_{ufr}=\frac{U\_{IN}}{U\_{OUT}}$

**B**. For gain Auf= 10 specify characteristics of UOUT= f (UIN) over the entire range of the amplifier. Note the measurement results in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | UIN | V | -1.5 | -1.4 | -1.2 | -1.0 | -0.6 | -0.2 | + 0.2 | + 0.6 | + 1.0 | + 1.2 | + 1.4 | + 1.5 |
| Auf= 10 | UOUT | V |  |  |  |  |  |  |  |  |  |  |  |  |

Based on the characteristics, determine the voltage of the UOUT at which the amplifier reach the saturation

 + UOUTsat=.....

 - UOUTsat=.....

**5.3. Noninverting amplifier**

System tested is presented in Fig. 3.2.

As in p. 5.2. (measure the UOUT voltage and determine the actual gain and Aufr (as the mean value of the measurements). Note the results in the table.

|  |  |  |
| --- | --- | --- |
| Auf= 10 | Auf= 20 | Auf= 100 |
| UIN | UOUT | UIN | UOUT | UIN | UOUT |
| V | V | V | V | V | V |
| 0.51.0 |  | 0.250.40 |  | 0.050.10 |  |
| Aufr=.... | Aufr=.... | Aufr=.... |

5.4 Voltage follower

System tested is presented in Fig. 3.3.

Attach the UIN voltage of the polarization "+" or "-". Attach the voltmeter to the terminals of the OUT. Check the operation of the auxiliary unit by dealing the voltage UIN and measuring UOUT. Note the results in the table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| UIN | V | 2 | 4 | 6 | 8 | 10 |
| UOUT | V |  |  |  |  |  |

5.5 Differential amplifier

System tested is presented in Fig 3.4.

Check the operation of the amplifier by dealing different voltage values UIN1 and UIN2 and measuring UOUT. Compare one of the results obtained with the value obtained as a result of the calculation according to the theoretical relationship describing the amplifier. Specify Auf layout. Results note in the table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| UIN1 | V | +5 | +5 | -5 | +5 |
| UIN2 | V | + 2 | -2 | + 2 | +5 |
| UOUT | V |  |  |  |  |

 Auf =..... UOUT= Auf(UIN2 -UIN1) =...

5.6. Summing amplifier

System tested is presented in Fig 3.5.

Check the performance of the amplifier by dealing different voltage values UIN1 and UIN2 and measuring UOUT. Note the results in the table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| UIN1 | V | +5 | +5 | -5 | +5 |
| UIN2 | V | + 2 | -2 | + 2 | +5 |
| UOUT | V |  |  |  |  |

5.7. Integrating amplifier

System tested is presented in Fig 3.6.

At the input of the system, conect the generator and set the rectangular waveform at the amplitude UINemax= 1 V and frequency 50 Hz. Check the performance of the system by observing the output. Determine the amplitude of the output signal UOUTmax. Observations and measurements made by using an oscilloscope. Specify the |Auf| of the system.

$U\_{OUTmax}= \left|A\_{uf}\right|=$

5.8. Differentiator amplifier

System tested is presented in Fig 3.7.

For the input of the system, connect the generator and set the triangular waveform with amplitude UINmax= 1 V and frequency 50 Hz. Check the performance of the system by observing the output waveform. Determine the amplitude of the output signal UOUTmax. Observations and measurements made using an oscilloscope. Specify the |Auf| system.

$$U\_{OUTmax}= \left|A\_{uf}\right|=$$

5.9 Linear rectifier

System tested is presented in Fig 4.1.

For the input of the system, connect generator and set the sine waveform with frequency 50 Hz by adjusting the amplitude of the voltage UINmax. Check the performance of the system by observing the output. Determine the amplitude of the output signal UOUTmax. Observations and measurements made using an oscilloscope. Specify the |Auf| system. Note the results in the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UWemax | mV | 50 | 100 | 200 |
| UWymax | mV |  |  |  |

| Auf| =……………

5.10 Voltage limiter

System tested is presented in Fig 4.2.

Attach voltage UIN. Attach the voltmeter to the terminals of the OUT. When adjusting the UIN of the two polarizations "+" and "-", measure the characteristics of UOUT= f (UIN) of the system. Specify Auf of the system. Note the results in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UIN | V | -2.0 | -1.0 | -0.5 | -0.3 | -0.2 | -0.1 | + 0.1 | + 0.2 | + 0.3 | + 0.5 | + 1.0 | + 2.0 |
| UOUT | V |  |  |  |  |  |  |  |  |  |  |  |  |

Auf =....

On the basis of the characteristics determine the values of Zener voltages UZ1, UZ2 diodes D1 and D2. Assume that the voltage drop on the conductive diode is UF1= UF2= 0,7 V.

 UZ1=....

 UZ2=....

5.11. Comparator

System tested is presented in Fig 4.3.

Attach voltage UIN. Attach the reference voltage U0. Attach the voltmeter to the terminals of the OUT. Set the reference voltage value (e.g. Uo= + 2v). Adjust UIN voltage in the range: UIN< U0... UIN= U0... UIN> U0 by measuring the UOUT voltage.

Measure the voltage in UIN at which the state of the output is changed -thus defining the characteristics of the UOUT= f (UIN) of the system. On the basis of the characteristics determine the value of the Zener UZ diode D and its voltage in the direction of conduction UF.

 U0= + 2v

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UIN | V | -1.0 | 0 | + 1.0 | + 1.9 | + 2.0 | + 2.1 | + 3.0 | + 4.0 |
| UOUT | V |  |  |  |  |  |  |  |  |

 UZ=....

 UF=....

5.12. Rectangular waveform generator

System tested is presented in Fig. 4.4.

Attach the oscilloscope to the terminals of the OUT. Determine the frequency and amplitude of the output signal.

 UOUTmax =....

 f =....

5.13. Sinusoidal waveform generator

System tested is presented in Fig 4.5.

Attach the oscilloscope to the terminals of the OUT. Determine the frequency and amplitude of the output signal.

 UOUTmax =....

 f =....

5.14 Band-stop filter

System tested is presented in Fig 4.6.

Attach the generator to the IN terminals. Set the sine waveform witch the amplitude UINmax= 1 V.

Adjust the input voltage frequency. Measure the amplitude of the output voltage UOUTmax. The measurements are performed using an oscilloscope - thus determining the frequency characteristics of the transformation of the filter - $\frac{U\_{OUTmax}}{U\_{INmax}}=F(f)$. Note the results in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| f | kHz | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
| UOUTmax | V |  |  |  |  |  |  |  |  |  |  |  |
| $$\frac{U\_{OUTmax}}{U\_{INmax}}$$ | - |  |  |  |  |  |  |  |  |  |  |  |

UINmax= 1 V

On the basis of the characteristics specify |Auf| of the system, the central frequency f0, the lower frequency fL, the upper frequency fH , and the bandwidth Δf.

 |Auf| = ....

 f0 =....

 fL =....

 fH =....

 Δf =....

5.15. Low-pass filter

System tested is presented in Fig 4.7. Perform analogous steps as in p.5.14.

Designate the filter transformation characteristics -$\frac{U\_{OUTmax}}{U\_{INmax}}=F(f)$. Note the measurement results in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| f | kHz | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| UOUTmax | V |  |  |  |  |  |  |  |  |  |  |  |
| $$\frac{U\_{OUTmax}}{U\_{INmax}}$$ | - |  |  |  |  |  |  |  |  |  |  |  |

 UINmax= 1 V

On the basis of the characteristics specify |Auf| The system and the upper frequency fH.

 |Auf| = ....

 fH =....

5.16 High-pass filter

System tested is presented in Fig 4.8.

Perform steps as in P. 5.14. Designate the filter transformation characteristics -$\frac{U\_{OUTmax}}{U\_{INmax}}=F(f)$. The results of the measurements are in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| f | kHz | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| UOUTmax | V |  |  |  |  |  |  |  |  |  |  |  |
| $$\frac{U\_{OUTmax}}{U\_{INmax}}$$ | - |  |  |  |  |  |  |  |  |  |  |  |

 UINmax= 1 V

On the basis of the characteristics specify |Auf| The system and the lower frequency fL.

 |Auf| = ....

 FL =....

5.17. Pass band filter

System tested is presented in Fig 4.9.

Perform steps as in p.5.14. Designate the filter transformation characteristics-$\frac{U\_{OUTmax}}{U\_{INmax}}=F(f)$.. Note the measurement results in the table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| f | kHz | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 |
| UOUTmax | V |  |  |  |  |  |  |  |  |  |  |  |
| $$\frac{U\_{OUTmax}}{U\_{INmax}}$$ | - |  |  |  |  |  |  |  |  |  |  |  |

UINmax= 1 V

On the basis of the characteristics specify |Auf| The system, the centre frequency f0, the lower frequency fL, the upper frequency fH and the Δf bandwidth.

 |Auf| =. ...

 f0 =....

 fL =....

 fH =....

 Δf =....

Literature

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