Laboratory work 9

RESEARCH OF SEMI-CONDUCTOR RECTIFER DIODE, ZENER DIODE AND DYNISTOR

9.1. Formulation of the problem

The purpose of the work is to study the device and principle of the semiconductor rectifier diode, Zener diode (stabilitron) and dynistor (diode thyristor), as well as the experimental study of the current-voltage characteristics (CVC) of these devices. Samples of their characteristics are shown in Fig. 9.2, 9.3 and 9.4, respectively.

9.2. Object of study

The electrical scheme of the experiment is shown in Fig. 9.1. Rectifier diode VD1, Zener diode VD2 and VS1 dynistor, which are dual-electrode semiconductor devices, are shown, respectively, in Fig. 9.1, a, b, c; power circuit and measurement devices are shown in Fig. 9.1, d.

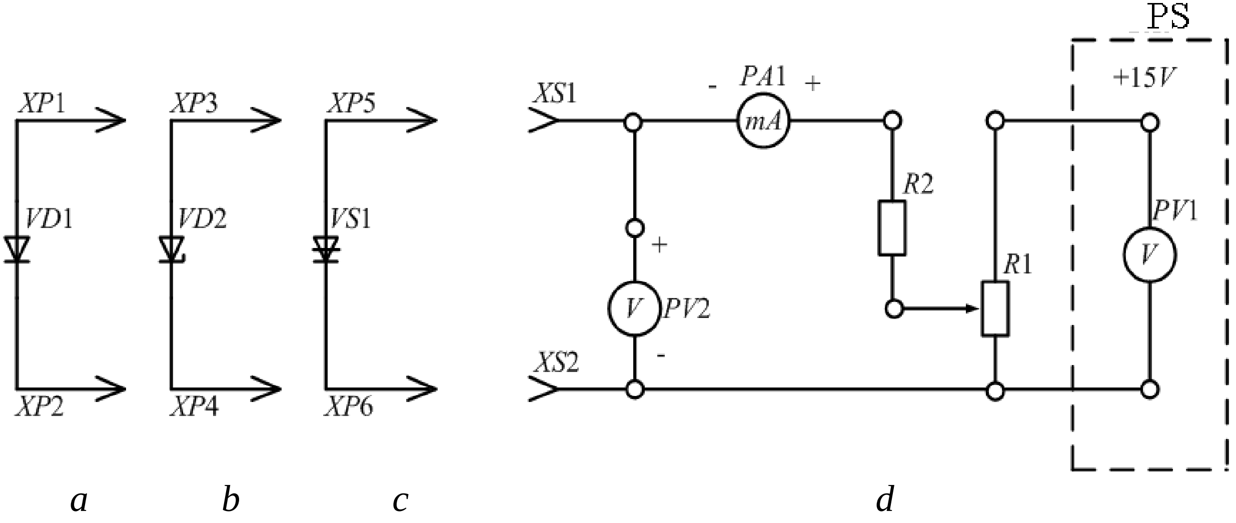

Figure 9.1

The power supply (PS) is equipped with a voltmeter voltage regulator 15 or 30 volts. The power supply voltage is measured by a PV1 voltmeter. Adjusting the voltage can be done by the additional resistor R_1 (2,2 kOhm), which is switched on as the potentiometer circuit is used to limit the current, the ballast resistor R_2 (300 Ohm). The PA1 mini amperemeter and PV2 voltmeter are used for measurement current and voltage across diodes. The devices will be connected to XS1 and XS2 sockets by XS1 and XS2 pins in forward direction.

Each device should be switched on two times: first – as shown in Fig. 7.1, the other in reverse direction for this it’s enough to turn on 180 degrees a device, i.e. swap its pins.

The main parameters of the considered devices are given in Table 9.1, 9.2 and 9.3.

Table 9.1

Type of the rectifer diode	Direct current, A	Direct DC voltage, V	Reverse maximum voltage $U_{rev.max}$, V	Direct reverse current at $I_{rev.max}$, mA
КД209А	0,1	1,0	400	0,1

Table 9.2

Type of the Zener diode	Stabilization voltage U_{st}, V	Minimal current of stabilization, mA	Maximal current of stabilization, mA	Direct maximum current, mA	Differential resistance, Ohm
Д814А	7...8,5	3	40	50	6

Table 9.3

Name of the dynistor parameters type КН102Г	Parameters value
Limited current in open condition $I_{oc.max}$, mA	200
Voltage in open condition at $I_{oc.max}$, U_{oc}, V	1,5
Minimum current in open condition $I_{oc.min}$, mA	15
Constant maximum direct voltage in the closed state $U_{c.s.max}$, V	14
Constant current in closed state at $U_{c.s.max}$, $I_{c.s.}$, μA	80
Maximum constant reverse voltage $U_{rev.max}$, V	10
Reverse current at $U_{rev.max}$, I_{rev}, mA	0,5

9.3. The order of the experiment execution

Before the assemble of the circuit, it is necessary to connect the laboratory bench to the network, turn on the “network-on” toggle switch, and set the minimum value of the power supply to the voltmeter PV1 of the bench. Turn off the toggle switch. Assemble of the circuit in accordance with Fig. 9.1, d and set the minimum value of voltage at the output of potentiometer R_1 by voltmeter PV2.

9.3.1. Research of a rectifer diode

Connect the rectifier diode VD1 in the forward direction (Fig. 9.1, *a*, *d*).

By changing the current from zero to the maximum value using the potentiometer R_1 and the regulator of the power supply unit, read the straight line of the CVC of the diode I_{oc} (U_{oc}) (7-8 points). The values of current I_{oc} and voltage U_{oc} are given in Table 9.4.

A sample of the CVC of the rectifier diode is shown in Fig. 9.2.

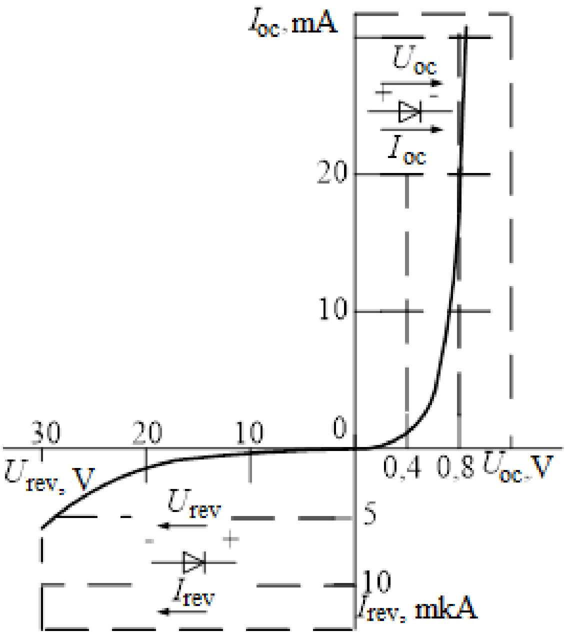

Figure 9.2

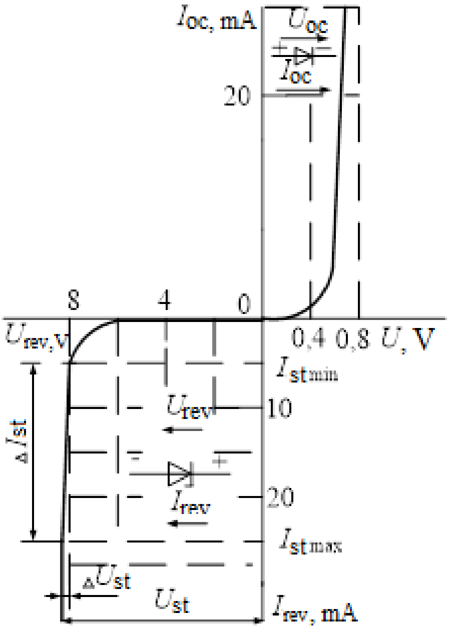

Figure 9.3

Table 9.4

U_{oc}, V	0							
I_{oc}, mA	0							
U_{rev}, V	0							
I_{rev}, mA	0							

Turn off the voltage and reverse the diode. To carry out the read of the reverse branch of the CVC named I_{rev} (U_{rev}), changing the voltage from zero to the maximum possible value (it is enough 3-4 points). Write down the results of the measurements in Table 9.4.

9.3.2. Research of a Zener diode

Instead of the rectifyer diode, connect the VD2 Zener diode to the circuit (Fig. 9.1, b, d).

In this experiment it is necessary to take into account that on the reverse branch of the CVC suddenly arises and the current stabilizes rapidly, while the voltage changes very slowly (the working part of the CVC of the Zener diode). Sample of the CVC of a Zener diode is shown in Fig. 9.3.

Make characterization of the Zener diode CVC in the same way as for the rectifier diode, but with reverse switching it is already necessary to read 6-7 points. Enter the results in the Table 9.5

Table 9.5

U_{oc}, V	0								
I_{oc}, mA	0								
U_{rev}, V	0								
I_{rev}, mA	0								

9.3.3. Dynistor research

Experimental study of the dynistor is carried out according to the scheme, which is based on Fig. 9.1, c, d, in this order.

To read the straight branch of the dynistor CVC $I_{oc}(U_{oc})$. To make this, by increasing the voltage from zero with the help of the potentiometer $R1$, it is necessary to determine the voltage in open condition U_{oc} and the current I_{oc} across the dynistor and enter the results in Table 9.6.

Table 9.6

U_{oc}, V			U_{on}, V	U_{open}, V			$U_{open\ max}$, V	U_{hold}, V	U_{rev}, V		
0									0		
I_{oc}, mA			I_{on}, mA	I_{open}, mA			$I_{open\ max}$, mA	I_{hold}, mA	I_{rev}, mA		
0									0		

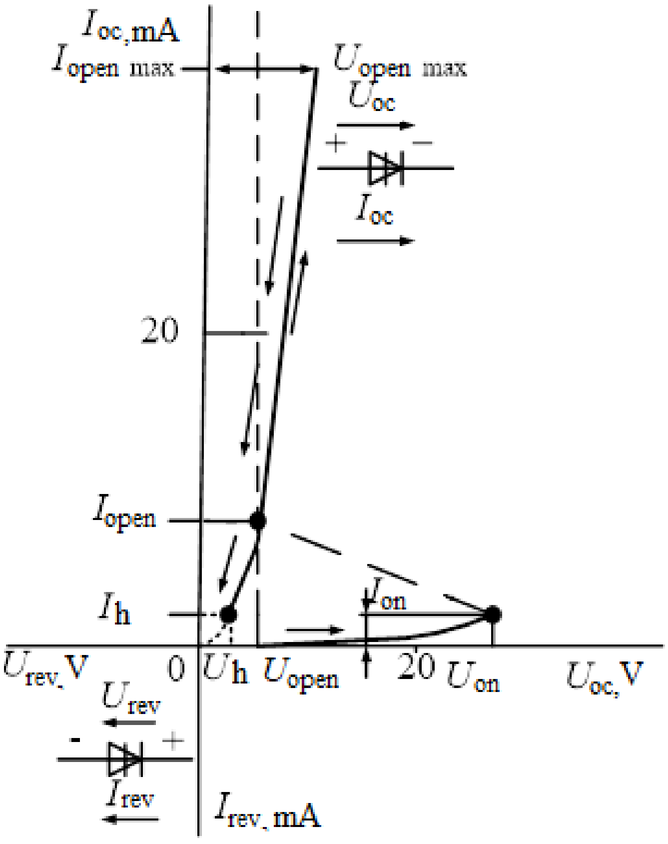

Figure 9.4

Then, by returning to the zero voltage value and changing it from zero to U_{oc}, read the three points of the characteristic and enter this data in the same table. To fix the values of the voltage U_{oc} and current I_{oc} in the open state of the dynistor and then read three more points, raising the current to the maximum possible value for this diner open max. By reducing the current from the maximum value, determine the holding current I_{hold} and the corresponding holding voltage U_{hold}. Make these measurements in Table 9.6.

Measure the reverse of the CVC branch from I_{rev} (U_{rev}), changing the voltage from zero to the maximum possible value (three points is enough). The results of the measurements are also given in Table 9.6. A sample of the CVC of a dynistor is shown in Fig. 9.4.

9.4. Processing the results of the experiment

According to the data contained in the Table 9.4, 9.5, and 9.6, to draw the CVC of a direct diode, a zener diode, and a dynistor.

Using these characteristics to calculate the static resistances of a rectifyer diode, a zener diode, and a dynistor at the corresponding sections of the CVC:

1) direct at the highest current value

$$R_{\mathrm{oc}}=U_{\mathrm{oc}}/\,I_{\mathrm{oc}}\,;$$

2) reverse at the highest voltage value

$$R_{\mathrm{rev}}=U_{\mathrm{rev}}\,/\,I_{\mathrm{rev}}\,.$$

Explain the reason for the difference between the values of the forward and reverse resistances of the devices.

Using the volt-ampere characteristic of a zener diode, calculate the differential resistance on the stabilization part of its CVC

$$R_{\mathrm{dif}}=\Delta U_{\mathrm{st}}\,/\,\Delta I_{\mathrm{st}}\,.$$

Calculate the differential resistance of the closed-loop dynistor on part of the CVC to U on and on the part with unstable operation from I_{on} to I_{open}.

Control Questions

1. Explain the structure of the p-n junction of the diode.
2. What is the direct and reverse switching on p-n junction?
3. What physical processes occur in the p-n junction with its direct and reverse switching?
4. What types of breakdowns can occur in the p-n junction, under what conditions and what are their consequences?
5. Explain the phenomenon of capacitance of p-n junction.
6. Explain the design, operation principle and purpose of the rectifier diode, stabilitron and dynistor.
7. To visualize the CVC of the rectifier diode, stabilitron and dynistor and explain their features.
8. What is the static and differential resistance of diodes and dynistors?

Laboratory work 10

RESEARCH OF ONE PHASE RECTIFIERS

10.1. Formulation of the problem

The purpose of the study is to study the principle of operation and experimental study of one- and two-period rectifiers of single-phase sinusoidal current and smoothing filters.

10.2. Object of study

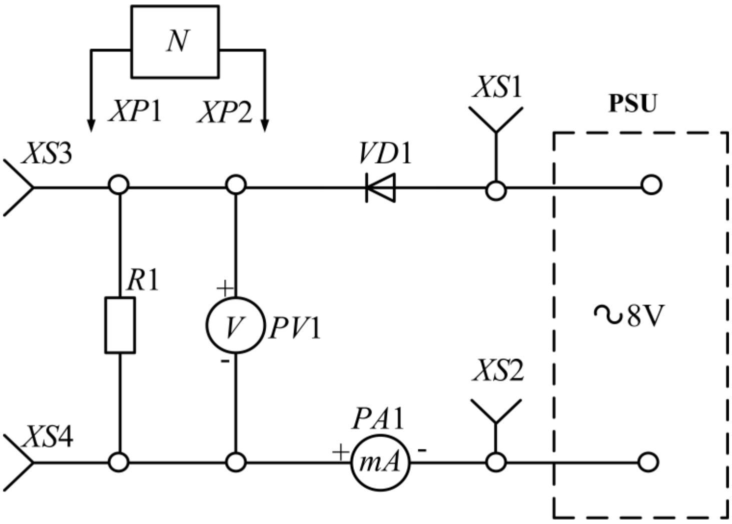

Figure 10.1

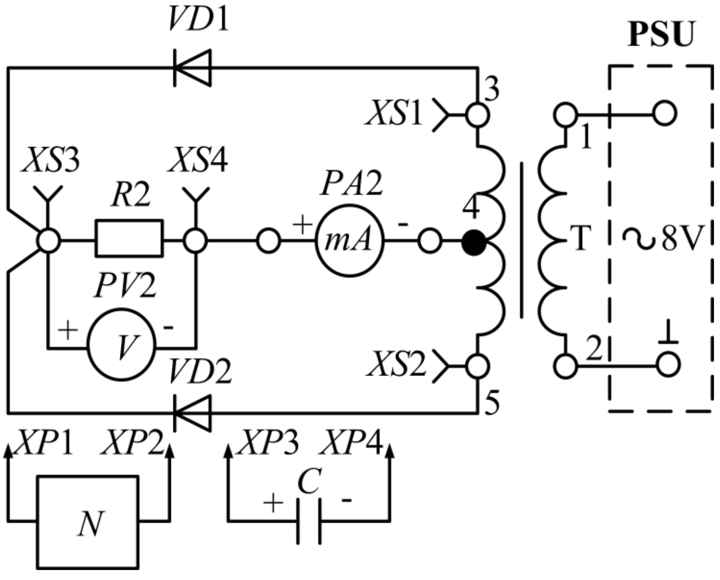

Figure 10.2

10.2.1. In Fig. 8.1 shows a scheme of studies of a single-stage rectifier, which includes a rectifier diode VD1 and a load resistor R1. The circuit is connected to the terminals of the sinusoidal current source “~ 8V” of the bench power supply unit (**PSU**).

10.2.2. The three-point scheme for conducting experimental studies of a single-phase two-period rectifier is shown in Fig. 8.2. The circuit is assembled on the basis of transformer T and includes rectifier diodes VD1 and VD2 and resistor *R*2. The sinusoidal voltage to the circuit is supplied from the terminals “$\boldsymbol{U_m}$” and “⊥” of the HS signal generator.

10.2.3. The scheme for carrying out experimental studies of a single-phase bridge two-period rectifier is shown in Fig. 10.3.

The rectifier unit VA includes a four-diode bridge circuit and has four terminals: inputs that connect to a ~ 8V sine wave power supply unit and outputs (+ and -). Choke *L* and capacitor *C* create a smoothing LC filter and resistors R3 and R4 activate the rectifier’s active load. One of the windings of the transformer T is used as a choke.

10.2.4. DC and voltage are measured by milliammeters PA1, PA2 and voltmeters PV1, PV2. Using the N oscilloscope, in all circuits, the voltage form to the rectifier (sockets XS1, XS2) and after it (sockets XS3, XS4) is controlled.

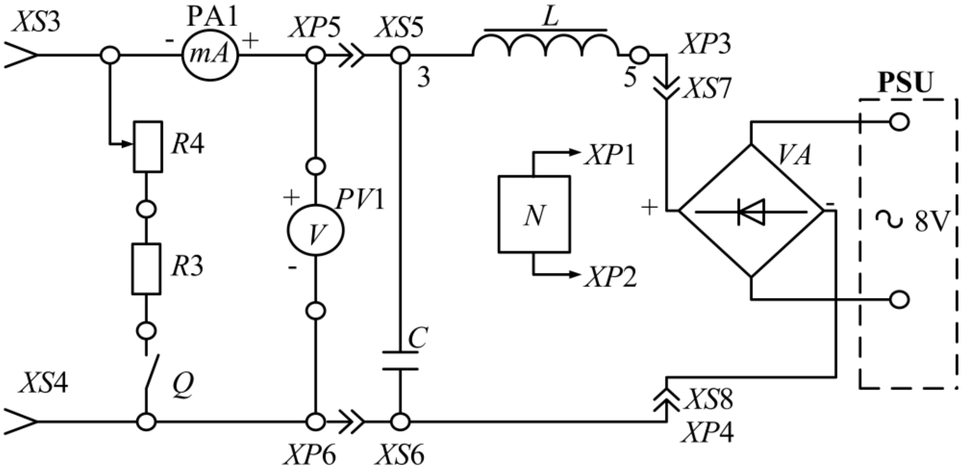

Figure 10.3

The parameters of the elements included in the diagrams are given in Table 10.1 and Table 10.2.

Table 10.1

Diodes *VD*1, *VD*2	The rectifyer unit *VA*	Constant resistors			Variable resistor	Capacitor
КД209А	КЦ405Б	*R*1	*R*2	*R*3	*R*4	*C*
$I_{\text{oc.mid}}$ = = 0,1 A	$I_{\text{oc.mid}}$ = = 0,1 A	470 Ohm	1,5 kOhm	100 Ohm	470 Ohm	10 and 50 µF

Table 10.2

Oscilloscope	Milliammeter		Voltmeter		Switch	Transformer	Choke
N	*PA*1	*PA*2	*PV*1	*PV*2	*Q*	T	*L*
C1-67	50 mA	5 mA	15 V	5 V	MT1	-	T, clamps 3,5

10.3. The order of the experiment execution

10.3.1. Assemble the circuit according to Fig. 10.1 of the elements, the parameters of which are given in Table 10.1 and Table 10.2 for the study of a single-phase single-period rectifier.

Turn on the **“Network On”** switch on the **PSU**. Measure current and voltage and record voltage waveforms at the input and output of the rectifier. Disable network switch to **“Network Off”**.

Turn on the Network On toggle switch on the **PSU**. Measure current and voltage and record voltage waveforms at the input and output of the rectifier. Disable the “Network On” tumbler.

10.3.2. Mount the diagram according to Fig. 10.2 of the elements, the parameters of which are given in Table 10.1 and 10.2 for the study of the three-point rectifier. Set the waveform selector knob to the position “~ - sine”. Switch on the HS switch and set the maximum signal voltage **U_m/V** with the knobs. Measure current and voltage and draw voltage waveforms at the input and output of the rectifier. Connect the 10 and 50 μF capacitors in parallel to the load resistor and again read the voltage waveforms across the load resistor. Disable the "**GS**-on" toggle switch.

10.3.3. Mount the diagram according to Fig. 10.3 for the study of a two-period bridge rectifier of the elements, the parameters of which are given in Table 10.1 and 10.2.

Turn on the **"Network On"** switch on the **PSU** and draw the voltage waveforms of the rectifier output if there is an LC filter.

Read the external characteristic U_0 (I_0) of the filter rectifier. To do this, it is necessary to start from idle, ie switch off the switch Q and measure the voltage-gu U_0. Then turn it on and change the resistance of the resistor R4 from high to low. Record the measured values of voltage U_0 and current I_0 in Table 10.3.

Disable the **"Network On"** toggle switch.

Table 10.3

U_0, V						
I_0, mA	0					

Exclude the LC filter from the diagram 10.3 (part of it between pins XP3, XP4 and sockets XS5, XS6) and insert pins XP5, XP6 into sockets XS7, XS8. Turn on the Network On toggle switch and repeat the experiments, i.e., draw the oscillation-diagrams of the rectifier output and read its external characteristic. Record the measured values of voltage U_0 and current I_0 in Table 10.4.

Disable the **"Network On"** toggle switch.

Table 10.4

U_0, В						
I_0, мА	0					

10.4. Processing the results of the experiment

1. To draw in one coordinate grid the external characteristics U_0 (I_0) of a two-period rectifier, both with and without the filter, using the data in Table 10.3 and 10.4, and analyze their differences.
2. Display and compare the waveforms of voltages of one- and two-period rectifiers and explain the reasons for the difference.
3. Display and compare the waveforms of a two-period rectifier without filter and filter, and explain the reasons for the difference.

Control Questions

1. Outline the diagrams and explain the principle of operation of the rectifiers studied.

2. Display the time functions of the input voltage and the rectifier load, as well as any diode.

3. Specify the main electrical parameters of the circuits of single-phase rectifiers. Compare different circuits on these parameters.

4. What are the parameters of the diodes for different rectifiers?

5. What is the purpose of filters? What filter in the schemes are used?

6. Explain why the capacitor is switched on in parallel with the load and the choke in series, and why they reduce the voltage ripple on the load?

7. What is the voltage or current ripple ratio?

Laboratory work 11

RESEARCH OF LOW FREQUENCY AMPLIFIER

11.1. Formulation of the problem

The purpose of the study is to study the principles of amplification of low-frequency electrical signals and experimental study of the amplifier with a bipolar transistor when it is switched on by the scheme with a common emitter, the read of the amplitude-amplitude and amplitude-frequency characteristics (AFC) of this amplifier.

11.2. Object of study

The object of research is a low-frequency amplifier (LFA) with a resistive-coupling link, the circuit of which is shown in Fig. 11.1. It includes a bipolar VT transistor, a collector resistor R3, resistors R1 and R2 of the voltage divider, which provides a direct voltage offset of the operating point at input voltage-current characteristics of the transistor. The scheme also contains the load resistor of the amplifier R5, the capacitors C1 and C2. The resistor R4 and the capacitor C3, which are connected in parallel, create a circuit of thermal stabilization of the operation mode of the amplifier.

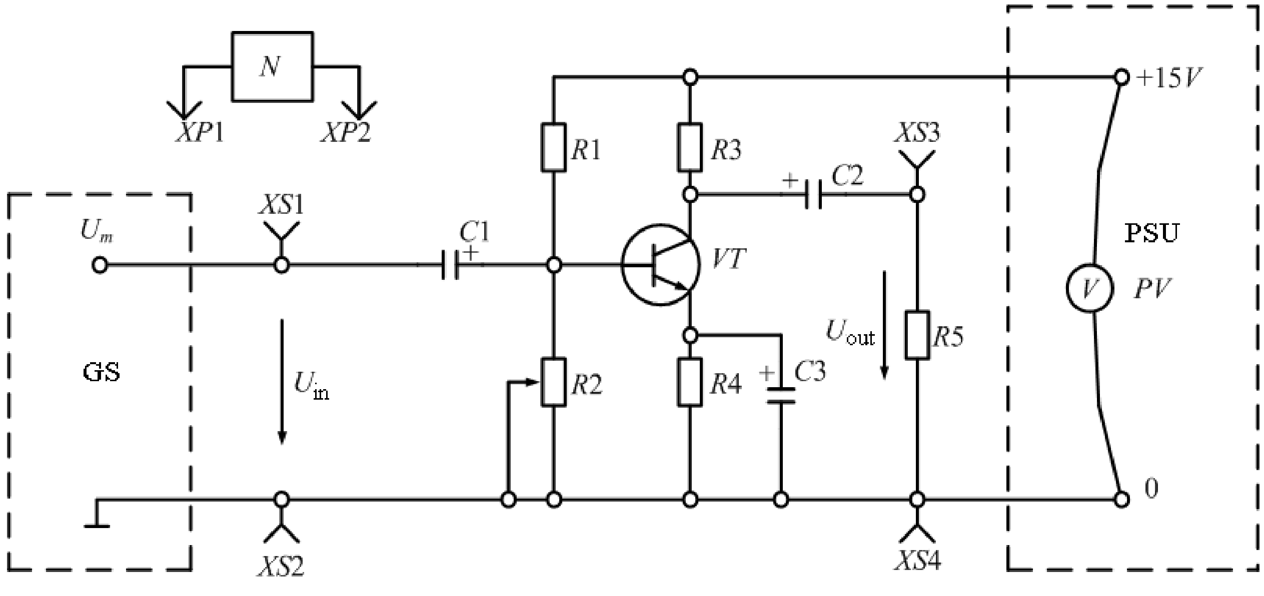

Figure 11.1

The direct voltage on the amplifier is supplied from the terminals “+15 V” and “0” of the power supply unit (PSU) of the bench, and the voltage of the input signal is from the terminals “$\boldsymbol{U}_{\text{m}}$” and “⊥” of the signal generator (GS), which is also contained on the bench. This generator must be switched on to the sine waveform - ~.

The DC voltage is measured by a PV1 voltmeter placed on the bench’s power supply units, the voltage and frequency of the amplifier signals are measured by an oscilloscope, which is switched on using the XP1 and XP2 pins alternately to the sockets XS1, XS2 at the input and XS3, XS4 at the output.

The parameters of the elements from which the circuit is mounted are given in Table 11.1.

Table 11.1

$R1$, kOhm	$R2$, kOhm	$R3$, kOhm	$R4$, kOhm	$R5$, kOhm	$C1$, μF	$C2$, μF	$C3$, μF	$V1$
47	150	10	680	22	10	10	50	KT315A

11.3. The order of the experiment execution

11.3.1. To draw the scheme for Fig. 11.1 of the elements in Table 11.1, connect the oscilloscope to the input of the amplifier and carry out its adjustment. Switch on the power supply and set the amplifier to 15 V, measuring it with a PV1 voltmeter. Turn on the signal generator.

11.3.2. Know the amplitude characteristics of the amplifier $U_{\text{m.out}}$ ($U_{\text{m.in}}$) at the frequency $f = 1000$ Hz.

To read the amplitude characteristic, it is necessary to set a certain time f of the signal on the generator, check it with an oscilloscope, switch the oscilloscope to the output of the amplifier and adjust the resistor R1 and the signal amplitude knob of the generator "U_m/V" to achieve the maximum magnitude of non-sinusoidal amplifier output. Measure the signal amplitudes at the output of the $U_{m.\text{out}}$ and the input of the $U_{m.\text{in}}$ the amplifier using an oscilloscope. Further, by modifying the input signal, continue measuring the input and output signals. The results of measurements are recorded in Table 11.2. Measure till output signal will not disappear.

Table 11.2

$f = 1000 \text{ Hz} = \text{const}$;

$U_{m.\text{in}}$, mV	0					
$U_{m.\text{out}}$, V						

11.3.3. To read the amplitude-frequency characteristic $U_{m.\text{out}}(f)$ at the amplitude of the input signal $U_{m.\text{in}}$, equal to 0,5 $U_{\text{m.x, max}}$, where $U_{\text{m.NL, max}}$ – the largest amplitude, which was measured at a frequency of 1000 Hz in the previous experiment. Keeping the amplitude of the input signal further unchanged, it is only necessary to change its frequency f from 20 to 20000 Hz (the indicative values are in Table 11.3) and to measure the amplitude of the signal Um.with the output of the amplifier. The experiment data should be entered in Table 11.3.

Table 11.3

$U_{m.\mathrm{in}}$ = _____mV;

f, Hz	20	40	100	200	1000	2000	10000	20000
$U_{m.\mathrm{out}}$, V								
K_U								
$\ln f$								

11.4. Processing the results of the experiment

11.4.1. According to Table 11.2 to draw the amplitude characteristics $U_{m.\mathrm{out.}}(U_{m.\mathrm{in}})$ for each of the frequencies f.

11.4.2. According to Table 11.3 to calculate the gain of the amplifier $K_U = U_{m.out} / U_{m.\mathrm{in}}$ and build an amplitude-frequency characteristic in the form of a more obvious dependence $K_U(\ln f)$, than addiction $U_{m.out}(f)$. Analyze the behavior of this characteristic.

Control Questions

1. Explain the operating principle of the amplifier, using the volt-ampere characteristics of the transistor.
2. Explain the purpose of individual elements in the amplifier scheme.
3. Explain the causes of the nonlinearity of the amplitude characteristic.
4. Explain the reasons for “blockage” of the amplitude-frequency characteristic of the amplifier at low and high frequencies.
5. What is the purpose and purpose of negative feedback?
6. Why does the amplifier’s operation depend on the temperature regime and how does this dependence decrease?