Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University

Faculty of Applied Information Technology and Electrical Engineering
(full name of faculty)
Department of Biotechnical Systems
(full name of department)

QUALIFYING PAPER

For the degree of

Bachelor
(degree name)

topic: High-voltage power source of a medical ozone generator

Submitted by: fourth year student 4 , group IRB-42
specialty 163 Biomedical engineering
(code and name of specialty)

_______________ Dhlamini Mildred
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Supervisor _______________ Dozorska O.F.
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Standards verified by _______________ _______________
(signature) (surname and initials)

Head of Department _______________ Yavorska E.B.
(signature) (surname and initials)

Reviewer _______________ _______________
(signature) (surname and initials)

Ternopil
2024

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APPROVED BY
Head of Department
Yavorska E.B.
(signature) (surname and initials)
« » 2023

ASSIGNMENT
for QUALIFYING PAPER

for the degree of Bachelor
(degree name)

specialty 163 Biomedical engineering
(code and name of the specialty)

student Pemba Ngoyi Christelle
(surname, name, patronymic)

1. Paper topic Medical photocatalytic device for air disinfection and purification

Paper supervisor Dozorska Oksans, PhD
(surname, name, patronymic, scientific degree, academic rank)

Approved by university order as of
2. Student's paper submission deadline
3. Initial data for the paper supply voltage (220±10%) V, frequency (50±5%) Hz; power consumption, no more that 40 W; lamp supply – a sequence of rectangular pulses with frequency 100kHz, amplitude – 308 V; lamp start and control units must be made in the form of pulse inverters to ensure lower weight and dimensions of the entire product.
4. Paper contents (list of issues to be developed)

Analysis of the technical task; construction of a medical photocatalytic device for air disinfection and purification; mathematical modelling of device operation; functional synthesis of a medical photocatalytic device for air disinfection and purification; structural synthesis of the of a medical photocatalytic device for air disinfection and purification; synthesis of the electrical principle scheme; element calculations; design of the device; selection of elements; PCB development; electromagnetic compatibility; device manufacturing technology; device design analysis; determination of the type of production; design analysis and selection of a technological route; equipment selection; justification of the technological planning of the site; labor protection.

6. Advisors of paper chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
LABOR PROTECTION	Okipnyy I.B.		

7. Date of receiving the assignment 06.04.2022

TIME SCHEDULE

LN	Paper stages	Paper stages deadlines	Notes
	Analysis of the task for qualifying work		
	Writing chapter 1		
	technical task analysis		
	construction of the product		
	design of the product		
	product manufacturing technology		
	Writing chapter 2		
	Preliminary defense of work		
	Defense of work		

Student ______ (signature) Pemba Ngoyi Christelle (surname and initials)

Paper supervisor ______ (signature) Dozorska Oksana (surname and initials)

SUMMARY

Theme of qualification work: "High-voltage power source of a medical ozone generator". Qualifying work of a bachelor // TNTU, ATF, group IRB-42. // Ternopil, 2024 //p.- , fig.- , table- , bibliog.- , appendix- .

Key words: ozone, high-voltage power supply, generator, voltage.

The qualification work reviewed the main stages of the life cycle of a high-voltage power source of a medical ozone generator. The analysis of the technical task was carried out, the construction of the source was carried out, namely the structural, functional scheme, electrical principle scheme. Parametric synthesis, selection of the element base was carried out. Calculations of operational reliability have been carried out. The section on labor protection has been completed.

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Reviewer	____________ (signature)	____________ (surname and initials)

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CONTENT

		Signature	*Date*	DM 2.893.001
Developed	Dhlamini Mildred			High-voltage power source of a medical ozone generator
Checked	Dozorska O.F.			

Page	*Pages*

ATF, group IRB-42

INTRODUCTION

Recently, there has been an increasing interest in non-pharmacological methods of treatment, which can replace or significantly limit the need for drugs and at the same time affect various aspects of the pathological process, contribute to the regulation of disturbed homeostasis, improve the functional state of various organs and systems, and activate the body's defense forces.

Ozone therapy is a method of non-drug therapy that involves of use ozone-oxygen mixture and materials treated with it for therapeutic purposes.

Treatment the ozone-oxygen mixtures is a qualitatively new solution to the urgent problems of treating many diseases. The property of ozone to affect the transport and release of oxygen in tissues, its disinfecting effect determine the wide range of applications of ozone therapy. It is used in therapy, neuropathology, surgery, dentistry, in the treatment of infectious and venereal diseases. Ozone therapy characterizes high efficiency, good tolerability, and practically no side effects. In addition, it is economically beneficial.

The ozone-oxygen mixture for medical purposes is produced from pure oxygen with the help of special devices - medical ozone generators by using a barrier discharge, where oxygen molecules are partially dissociated in an electric discharge, and the atomic oxygen formed reacts with an oxygen molecule, forming ozone.

The main components of a medical ozone generator include a control and display unit, a high voltage source, a gas analyzer and a gas discharge chamber. The disadvantage of a number of medical ozone generators is the difficulty of setting the ozone concentration at the outlet of the gas discharge chamber with the required accuracy, due to the impossibility of regulating the electric discharge energy on the electrodes in the gas discharge chamber within certain limits. For this, a high-voltage source is designed, which provides the generation of unipolar rectangular pulses with the appropriate amplitude, and the possibility of adjusting the frequency in a certain range.

The aim of the thesis is to review the stages of the life cycle of the high-voltage power source of the medical ozone generator.

1 MAIN PART

1.1 Production of ozone for medical purposes

The ozone-oxygen mixture for medical purposes is produced from pure oxygen (toxic nitrogen compounds are formed during air ozonation) with the help of special devices - medical ozonators by using a barrier discharge, where oxygen molecules partially dissociate, and the atomic oxygen formed reacts with an oxygen molecule, forming ozone.

Medical ozone is a mixture of a maximum of 5 parts of pure ozone and 95 parts of oxygen for external use and a mixture of only 0.05 parts of ozone and 99.95 parts of oxygen for parenteral administration.

Ozonator - a device for obtaining ozone (O3). Ozone is an allotropic modification of oxygen containing three oxygen atoms in the molecule. In most cases, molecular oxygen (O2) is the starting substance for ozone synthesis, and the process itself is described by the equation 3O2 → 2O3. This reaction is endothermic and easily reversible. Therefore, in practice, measures are applied that contribute to the maximum shift of its balance in the direction of the target product.

Let's consider the main methods of obtaining ozone.

In an electric discharge. An electric arc is a physical phenomenon, one of the types of electric discharge in gas.

An electric arc between two electrodes in air at atmospheric pressure is formed in this way. When the voltage between two electrodes increases to a certain level, an electrical breakdown occurs in the air between the electrodes. The breakdown voltage depends on the distance between the electrodes and other factors. The ionization potential of the first electron of metal atoms is approximately 4.5 - 5 V, and the arcing voltage is twice as much (9-10 V). It is necessary to spend energy on the release of an electron from the metal atom of one electrode and on the ionization of the atom of the second electrode. The process leads to the formation of plasma between the electrodes and the burning of the arc (for comparison: the minimum voltage for the formation of a spark discharge slightly exceeds the potential of the electron output - up to 6 V).

To initiate a breakdown with the available voltage, the electrodes are brought closer to each other. During a breakdown between the electrodes, a spark discharge usually occurs, impulsively closing the electrical circuit.

Electrons in spark discharges ionize molecules in the air gap between electrodes. With sufficient power of the voltage source in the air gap, a sufficient amount of plasma is formed for a significant drop in the breakdown voltage or resistance of the air gap. At the same time, the spark discharges turn into an arc discharge - a plasma cord between the electrodes, which is a plasma tunnel. The resulting arc is, in fact, a conductor and closes the electrical circuit between the electrodes. As a result, the average current increases even more, heating the arc to 5000-50000 K. At the same time, it is considered that the ignition of the arc is complete. After ignition, stable burning of the arc is ensured by thermoelectron emission from the cathode, heated by current and ion bombardment.

The interaction of electrodes with arc plasma leads to their heating, partial melting, evaporation, oxidation and other types of corrosion.

After ignition, the arc can remain stable when the electrical contacts are separated to some distance.

When operating high-voltage electrical installations, in which the appearance of an electric arc is inevitable, the fight against it is carried out with the help of electromagnetic coils combined with arc-extinguishing chambers. Among other known methods are the use of vacuum and oil switches, as well as methods of diverting the current to a temporary load, independently breaking the electrical circuit.

Quiet discharge. The best performance is achieved by using pure oxygen, as low a gas temperature as possible, and using pulsating direct current. The gap between electrodes and the effective area of the electrodes are determined by the operating voltage and the rate of supply of oxygen-containing gas. Metal electrodes can catalytically decompose ozone in contact with them, so they are often placed inside a thin glass shell. Sometimes tubes filled with a conductive liquid, such as sulfuric acid, act as electrodes. Electrode pairs to increase the productivity of the device are often collected in large packages cooled by running water. The concentration of ozone at the outlet of such reactors (depending on their design and the oxygen content of the initial gas mixture) usually does not exceed a few percent, and when atmospheric air is used, it is only fractions of a percent. In addition, the gas mixture in which ozone is present, which is obtained in a quiet discharge from atmospheric air. Therefore, the use of pure oxygen (which can be easily recovered) as a raw material for the synthesis of ozone is often more cost-effective than the use of atmospheric air.

Bulk barrier discharge. This type of barrier discharge occupies an intermediate position between volume and surface discharges and is widely used as generators of ultraviolet radiation to excite phosphors in plasma discharge panels (plasma TVs). In such discharge cells, the electrodes are located along the surface at equal distances and are covered with a dielectric layer on top, voltage is applied to each pair of electrodes, and discharge occurs between all adjacent electrodes.

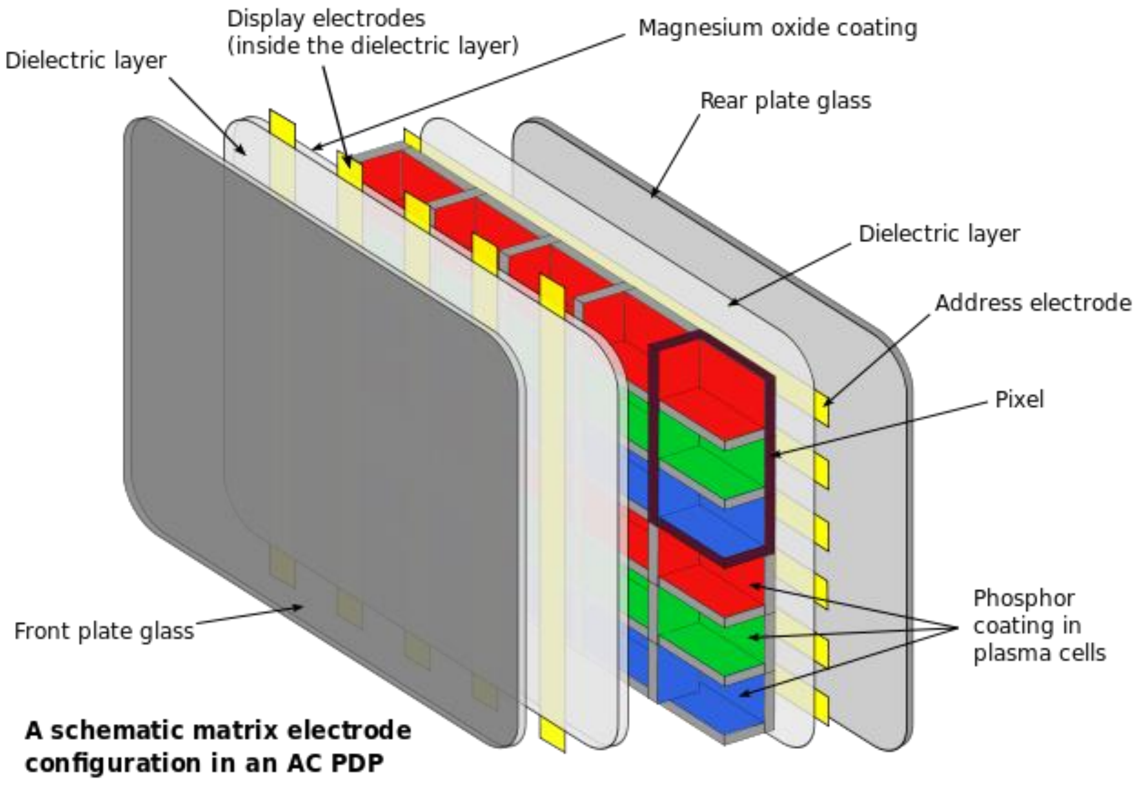


Figure 1.1 – Discharge in coplanar geometry cells

It is very tempting to use such discharge cells for the synthesis of ozone in them, especially considering the well-developed technology of creating discharge panels, however, the coplanar gas discharge panel was created to work in inert environments, so the operation of the cell by filling it with oxygen or atmospheric air can be carried out only at reduced pressure. An attempt to obtain a stable discharge at atmospheric pressure leads to a breakdown of the dielectric coating. In the experimental setup, on the discharge cell described above, ozone concentrations of up to 25 mg/l were obtained at pressures from 0.2 to 0.5 bar.

The practical use of coplanar geometry cells as ozonators is questionable, despite the rather high output of ozone. These cells are very expensive, not strong enough and able to work only at reduced pressure.

Corona discharge. The advantage of ozone generators on the basis of corona discharge is, first of all, the simplicity of the design and the unlimited "bit gap". Gas can be pumped without additional resistance, for example, through a wide pipe with a wire along the axis. The energy output of ozone in a corona discharge can reach 200-250 g of O3 per kWh when using power supply with short pulses, with a steep voltage rise front. However, creating such complex high-voltage power supplies that generate nanosecond pulsed discharge is too expensive to complicate the ozone production system.

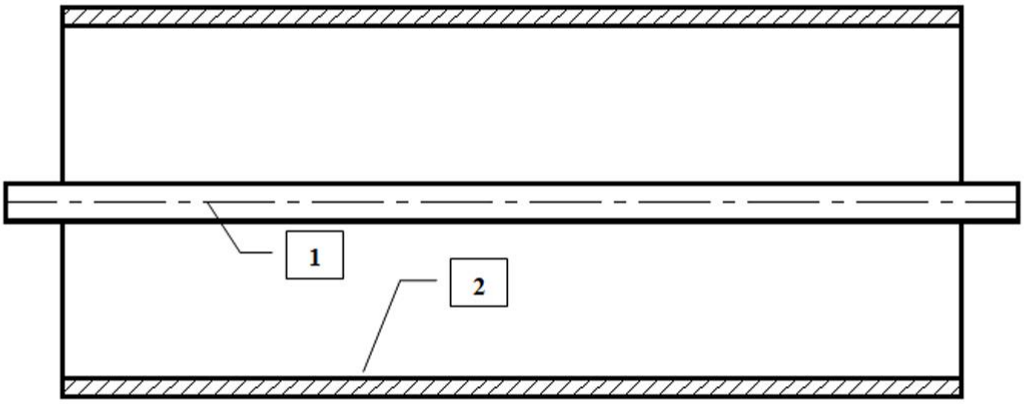


Figure 1.2 – Corona discharge cell (1 – central electrode, 2 – grounded electrode)

A corona discharge is a characteristic form of an independent gas discharge that occurs in sharply heterogeneous fields. The main feature of this discharge is that ionization processes do not occur along the entire length of the gap, but only in a small part of it near the electrode with a small radius of curvature. This zone is characterized by significantly higher field strength values compared to the average values for the entire interval. Occurs at relatively high pressures (atmospheric level) in a highly inhomogeneous electric field. Similar fields are formed in electrodes with a very large surface curvature (tips, thin wires). When the field strength reaches the limit value for air (about 30 kV/cm), a glow appears around the electrode, which has the appearance of a shell or corona.

Corona discharge is used to clean gases from dust and related impurities (electrostatic filter), to diagnose the condition of structures (allows detection of cracks in products).

Corona discharge is used in copiers (copiers) and laser printers to charge the photosensitive drum, to transfer the powder from the drum to the paper and to remove the residual charge from the drum.

Corona discharge is used to determine the pressure inside the incandescent lamp. The magnitude of the discharge depends on the tip and the pressure of the gas around it. The tip of all lamps of the same type is a filament. So, the corona discharge will depend only on the pressure. So, the gas pressure in the lamp can be judged by the size of the corona discharge.

Ozone can be obtained by electrolysis. For example, perchloric acid solution can be used as an electrolyte. They try to conduct the process at the lowest possible temperature, which significantly increases the ozone productivity of the device. Using the electrolysis method, it is possible to obtain an oxygen-ozone mixture with a very high (tens of percent) ozone content. The disadvantage of electrolytic methods is the cost of electrolytes and electrodes, which are usually made of precious metals.

Ozone can be formed in significant quantities during the oxidation of some substances. The most famous example of this type of reaction is the oxidation of pinene by air oxygen, which results in the formation of a significant amount of ozone. The ozone released during this reaction can be used to oxidize other substances. However, this method has extremely limited application due to the large volume of raw materials and problems with the separation of reaction products.

Attempts have been made repeatedly to create ozone generators based on oxygen irradiation with energy beams. In such devices, ozone is formed when oxygen is affected by various streams of particles: electrons, X-rays, and radiation streams: α-particles, γ-quanta, etc. Ozone is formed starting from the energy of a monochromatic electron beam ~ 6 eV, which corresponds to dissociation of the O2 molecule. This confirms the currently accepted mechanism of ozone formation. The general disadvantages of these methods are the complexity of the equipment, low energy output, the undesirability of working with high-energy beams, a wide range of substances that are formed when high-energy particles are exposed to air. Ozonators built according to this principle did not go beyond laboratories and were not used in industry.

1.2 Principles of operation of ozone generators

Barrier discharge is the most effective ozone generator. All other currently known methods are economically less profitable, although some of them may have certain advantages over barrier discharge. Also, electrosynthesis of ozone is the only chemical reaction that is carried out in batches on an industrial scale.

Barrier discharge. Due to the fact that the electric circuit is interrupted by a dielectric, power is supplied only by alternating current. A well-known construction made entirely of glass is shown in fig. 1.3. The ozone generator consists of three tubes of different diameters, nested one inside the other and soldered in a circle. If the ozone generator is powered by industrial frequency current, cooling with running water is not necessary. It is used only for applying voltage. For this, water is poured into the inner and outer tubes (in figure 1 and 3, respectively), and the lower branches of the tubes are closed with corks. Two wires are inserted through the plugs, which touch the water inside the tubes. Tap water (not distilled) is a conductor of current, so the tubes are live. Power supply is provided by a high-voltage transformer. The ground wire of the transformer is fed to the outer tube, a current meter (milliammeter) is placed on the same section of the circuit; a high-voltage wire is fed to the inner tube. Between this point and the ground, the voltage on the ozone generator is measured with a static kilovoltmeter. The voltage from the power network is usually supplied to the transformer low-voltage winding through a regulator. The gap between the outer side of the inner tube and the inner side of the middle one is a bit gap. Conventional ozone generators have a discharge interval of 1-3 mm. The diameter of the inner tube is 10-20 cm, the length of the gap is 20-40 cm.

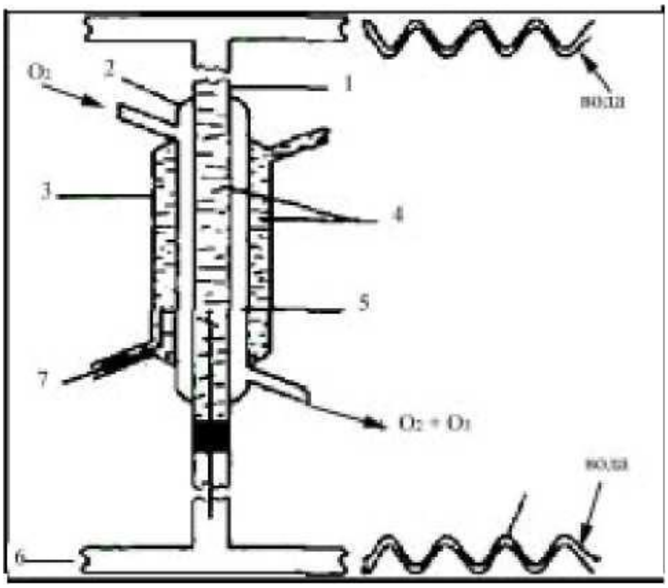


Figure 1.3 – Glass ozone generator: 1-3 - glass tubes; 4 - water; 5 - bit gap; 6 - tee; 7 - cooling coils

The voltage at which the discharge operates stably depends on the width of the gap and the thickness of tubes 7 and 2 (thickness of the barriers) and ranges from 7 to 12 kV. Current strength at a frequency of 50 Hz is units of milliamperes or less, active power is several watts. At low capacities, the ozone generator may not be cooled, as the heat released is carried away with the flow of oxygen and ozone. Gas (oxygen, air) is supplied to the gap from a cylinder or through a compressor. When working on such an ozone generator with dried oxygen, it is possible to obtain up to 1-2 g of O3 per hour at a concentration of up to 1%; the concentration can reach much higher values (10-14%), but then the output of ozone will be lower.

To obtain a higher output (up to 20 g of O3 per hour), you can use the same ozone generator, but the barriers must be cooled with running water. Then the power is supplied from a generator with an increased frequency (usually 1000-10000 Hz), the power increases significantly, and the output of ozone increases.

Certain conditions must be met for the ozone generator to work successfully.

The gap in which the discharge occurs must be uniform along the entire length of the ozone generator, otherwise only part of the generator will be operational, which will affect the efficiency of ozone output. When the voltage is increased, breakdowns of individual sections are also possible.

Heating of the ozone generator is unacceptable. As the temperature increases, the speed of the third group of reactions increases sharply, leading to the decomposition of ozone. The rate of oxygen dissociation does not depend on temperature, and the rate of the trimolecular reaction even decreases slightly when the gas is heated. All this leads to a sharp drop in ozone concentration at the outlet and instability of the ozone generator. In addition, when the glass is heated, the probability of breaking the barriers increases. When working with oxygen, it is very desirable, and when working with air, drying of the gas is necessary.

Ozone output from a small ozone generator can exceed the peak by 104-105 times or more. Before release into the atmosphere, unused ozone is usually decomposed on heterogeneous catalysts.

1.3 Structure of ozone generators

A high-performance ozonator unit (station) is a complex device that includes a whole set of different elements. An ozonator unit operating on dried air has a number of additional elements. For explanation, below (Figure 1.4) is a brief description of the ozonator unit operating on dried air and the main features of the ozone generator (ozonator). It should be borne in mind that the entire ozonator installation is often called an ozonator, especially with low productivity.

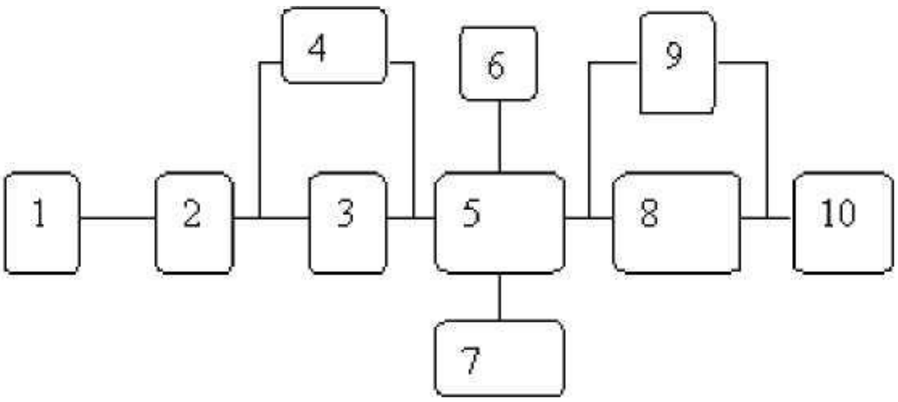


Figure 1.4 – Structural diagram of the ozonator station

Figure 1.4 shows the following blocks:

- compressor;
- air drying unit. Blocks 1 and 2 together make up the air conditioning system;
- gas flow meter;
- gas humidity meter;
- ozone generator;
- generator electrode cooling system;
- high-voltage power source of the ozone generator;
- contact camera;
- ozone concentration meter in the initial gas mixture;
- destructor of residual ozone.

The ozonator (ozonator unit) is usually characterized by the following parameters:

- ozone productivity, g/h. or kg/hour;
- ozone concentration, g/m3 or mg/l;
- the power consumed by the ozone generator (active power used to generate ozone), kW;
- total power consumed by the ozonator, kW;
- specific energy consumption for the production of ozone at its established concentration. In addition, this value is also determined by the concentration of ozone at the output of the generator;
- consumption of working gas, m3/hour;
- working gas humidity, dew point °C;
- operating voltage of the ozone generator, kV;
- frequency of the high-voltage power source of the ozone generator, Hz;
- installation dimensions, weight, required area.

The basis of the ozonator is an ozone generator, which is also simply called an ozonator.

In general, the development and production of an ozonator is a very difficult problem. Despite the external simplicity of the design, the creation of a workable, highly productive, but also reliable installation requires a developed technical base and a high culture of production. One of the most important problems in creating an ozonator is ensuring high uniformity of the gas gap between the electrodes, high accuracy of electrode installation, and the use of materials that provide not only high mechanical and electrical strength, but also good heat transfer from the gas to the cooled liquid.

Creating a reliably working high-voltage power source is no less a problem. It should be noted here that the high efficiency of the installation as a whole is ensured only when the power source is created to work together with a specific ozone generator. The electric discharge in the gas, which is the source of ozone formation, is a complex load for the power source, which creates special requirements for the high voltage source.

It must be said that the value of the specific energy consumption for ozone production also depends on the degree of coordination between the power source and the ozone generator.

A difficult problem in creating a high-performance ozonator is a high-quality air treatment system. In order to obtain high concentrations of ozone, a high degree of air drying is required with rather large air consumption, as well as constant control of both the humidity of the working gas and the concentration of ozone at the output of the generator.

1.4 Reliability and safety of operation of ozonators

Safety of treatment, which includes protection against toxic effects, accuracy of dosage during treatment, protection against erroneous actions of the operator.

The ozonator's operation algorithm must be set and controlled by the processor control system, which must automatically block the ozonator's operation in the event of emergency and emergency situations, as well as in case of erroneous actions by personnel.

The stability of the ozonator and the possibility of automatic maintenance of various ozone concentrations with a high degree of accuracy in a wide range. A pure ozone-oxygen mixture is guaranteed due to the additional use of pre-drying oxygen, a multi-stage oxygen post-purification filter and a special design of the discharge chamber. Unpurified oxygen contains impurities of microparticles of technical oils and other substances, which in the process of ozone generation leads to the formation of toxic products in the ozone-oxygen mixture (fatty acids, ketones, aldehydes, etc.)

Metrological verification of the accuracy of ozone concentration maintenance. A wide range of adjustment of the concentration of the ozone-oxygen mixture from 0.2 to 80-100.0 mg/l in steps of 0.1 mg/l at any given oxygen supply rate. Each specific value of ozone concentration is set by the doctor and displayed on the display. The guaranteed accuracy of the concentration measurement (error from 5 to 10%), which must be regulated by the automatic system of the ozonator and automatically maintained due to the stabilization system, and after checking the value of the generated concentration on the built-in gas analyzer (ozone concentration meter), must be entered into feedback, that is, a system of secondary feedback automatic regulation, control and maintenance of ozone concentration due to feedback with microprocessor automatic control systems, which are designed to compensate for the influence of various factors on the real value of ozone concentration in the mixture. Smooth or discrete adjustment of the rate of supply of oxygen and ozone-oxygen mixture from 0.25 to 1.0 l/min, which is set and fixed on the display and is strictly supported by automation, which gives the doctor the opportunity to more boldly use cavity ozone therapy (gynecology, urology, surgery and etc.). The duration of operation of the ozonator during the procedure is set by the doctor and displayed on the display, after its completion, the timer automatically turns off the ozonator. The timer built into the ozonator greatly simplifies the implementation of ozone therapy techniques. The doctor's ability to set different combinations of procedure parameters on the ozonator monitor (ozone concentration, ozone-oxygen mixture delivery rate, duration of the procedure) allows doctors to carry out predictable, dose-dependent ozone therapy, subtly and accurately dose the amount of ozone, using it in the same way as pharmacological agents .

A large resource of the discharge chamber (at least 10,000 hours), which allows you to operate the ozonator for a long time (within 10 years).

The risk of accidental inhalation exposure should be minimized by using a reliable catalytic destructor, ozone resistance of materials, reliable performance of all connections. The destructor of unused ozone must ensure, during the continuous operation of the ozonizer for many hours, that the concentration of ozone at the workplace is below the maximum permissible concentration (0.1 mg/mZ).

It is mandatory to equip the ozonator with all the necessary equipment and devices for performing various methods of ozone therapy, as well as scientific and methodical literature.

Low power consumption. The consumed power of the ozonator should not exceed 150 VA at a voltage of 220 V. The design solution of the discharge chamber of the ozone generator should be classically designed, as in most of the best foreign analogues. After being dried and purified by an additionally installed multi-stage filter, oxygen enters the gap between two coaxially arranged quartz tubes. At the same time, one electrode is the metallized outer surface of a tube with a larger diameter, and the second electrode is the metallized inner surface of a tube with a smaller diameter. In the process of ozone electrosynthesis, oxygen enters the gap between two quartz tubes through which the barrier discharge passes. Electric pulses are applied to metallized electrodes isolated from each other by glass tubes. When high voltage (up to 20 kV) is applied to the metallized electrodes, an electric discharge occurs in the gap between the outer and inner tubes, that is, the gas path of the ozone generator must be designed in such a way that the flow of oxygen, passing through the discharge gap between the glass tubes of the discharge chamber, in from which medical ozone is produced, would not come into contact with metal electrodes anywhere and, accordingly, the transfer of ions and molecules of metal electrodes and their oxides into the ozone-oxygen mixture during an electric discharge would not occur. Thus, a double barrier is obtained, in which both oxygen and the combined ozone-oxygen mixture do not directly contact the metal of the electrodes. This is a very important indicator, as it is primarily about safety guarantees, since the parenteral use of ozone therapy is possible only if the ozonator produces pure medical ozone. The doctor should have no doubts about the purity of the ozone-oxygen mixture used (the absence of impurities in it, respectively).

The management of the ozonator and information about the operation of all its systems should be displayed on the multifunction display.

The ozonator must have a suitable outlet-connector that allows you to connect to a personal computer.

In the event of a violation of the operating modes of the ozone generator, a discrepancy in oxygen pressure, electrical voltage, a violation in the operation mode of the discharge chamber or automatic control, the device is automatically transferred from the "Operation" mode to the "Pause" mode, while a signal is given. The ozone generator must have built-in automation systems that provide for its stopping or turning off in the event of erroneous actions by the operator servicing it. For greater operational safety of the ozone generator, its own pressure reducer must be installed at the oxygen inlet. All doctors who use ozone therapy methods in their practice must be trained in the theory and practice of applying ozone therapy at special training courses for doctors. Nurses and operators who maintain the equipment must also complete appropriate courses, including safety techniques when working with equipment that uses high pressure and when working with electrical devices.

1.5 Analysis of the technical task

Having analyzed all of the above, it is possible to formulate the requirements for the high voltage source of the medical ozone generator. In fact, the barrier discharge method will be used as the basis for the operation of such an ozone generator. To create it, a stable high-voltage power source is required, which would create rectangular pulses of high voltage with the possibility of changing the frequency of these pulses to regulate the concentration of ozone at the output of the ozone generator.

Technical requirements related to the high-voltage power source:

1. Supply voltage – (220±10%) V, frequency (50±5%) Hz;

2. The power supply must provide the following values of the output parameters:

Voltage……………………………….(6±0.2) kV;

Load current, no more than………..20 mA;

Frequency of pulses……………………..20 kHz;

Pulse frequency adjustment limits....±5 kHz.

3. Consumed power, no more than …..100 W;

4. The range of working temperatures from +10 ^{0}C...+ 35 ^{0}C;

5. Atmospheric pressure (760+30) mm Hg. art., (101.3 +4) kPa.

1.6 Construction of a high-voltage power source

1.6.1 Construction a mathematical model

Let's represent the power source (block) in the form of a black box (Fig. 1.5).

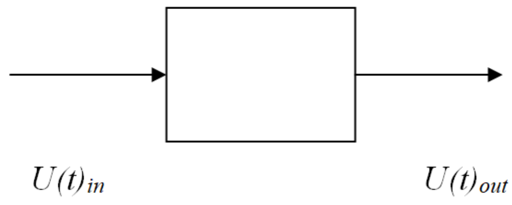


Figure 1.5 – Image of the block in the form of an input-output system

According to fig. 1.5 $U(t)_{in}$ – input voltage, $U(t)_{in} = U_0 \cdot \sin(\omega t)$, where $U_0 = 380V$ $\omega = 2\pi f$, $f = 50Hz$.

$U(t)_{out}$ – the output voltage is a sequence of rectangular pulses with an amplitude of 6 kV, a gap of 2 and a frequency that can be adjusted within 15-25 kHz.

Since the input voltage is a harmonic sine function, and the output voltage is a sequence of unipolar rectangular pulses, it would be logical to first convert the alternating voltage into a constant one, then into a sequence of rectangular pulses, and finally amplify the amplitude to the required value. Mathematically, such transformations can be described as follows (the corresponding time diagrams are shown in Fig. 1.6):

Transformation $|U(t)_{in}|$ describes the process of rectification of the input voltage (see Fig. 1.6, b);

Transformation $\int_0^T |U(t)_{in}| dt$ describes the filtering process (exclusion of the constant component) of the rectified voltage (see Fig. 1.6, c). *T* is the period of the input voltage.

Function *g(t)* – a sequence of rectangular pulses, with an amplitude equal to 1, a gap equal to 2, the frequency is adjustable within 15-25 kHz

Multiplication $\left(\int_0^T |U(t)_{in}| dt\right) * g(t)$ describes the generation of rectangular pulses with a gap of 2, the corresponding frequency and amplitude equal to $\int_0^T |U(t)_{in}| dt$ (see Fig. 1.6, d)

Multiplication $\left[\left(\int_0^T |U(t)_{in}| dt\right) * g(t)\right] * A$ describes the process of amplifying a sequence of rectangular pulses $\left(\int_0^T |U(t)_{in}| dt\right) * g(t)$ by *A* times the amplitude (see Fig. 1.6, e). *A=const*.

Accordingly, the mathematical model of the block, which describes the transformation of the input harmonic voltage into the output sequence of rectangular pulses, will look like this:

$$U(t)_{out} = \left[\left(\int_0^T |U(t)_{in}| dt\right) * g(t)\right] * A \qquad (1.1)$$

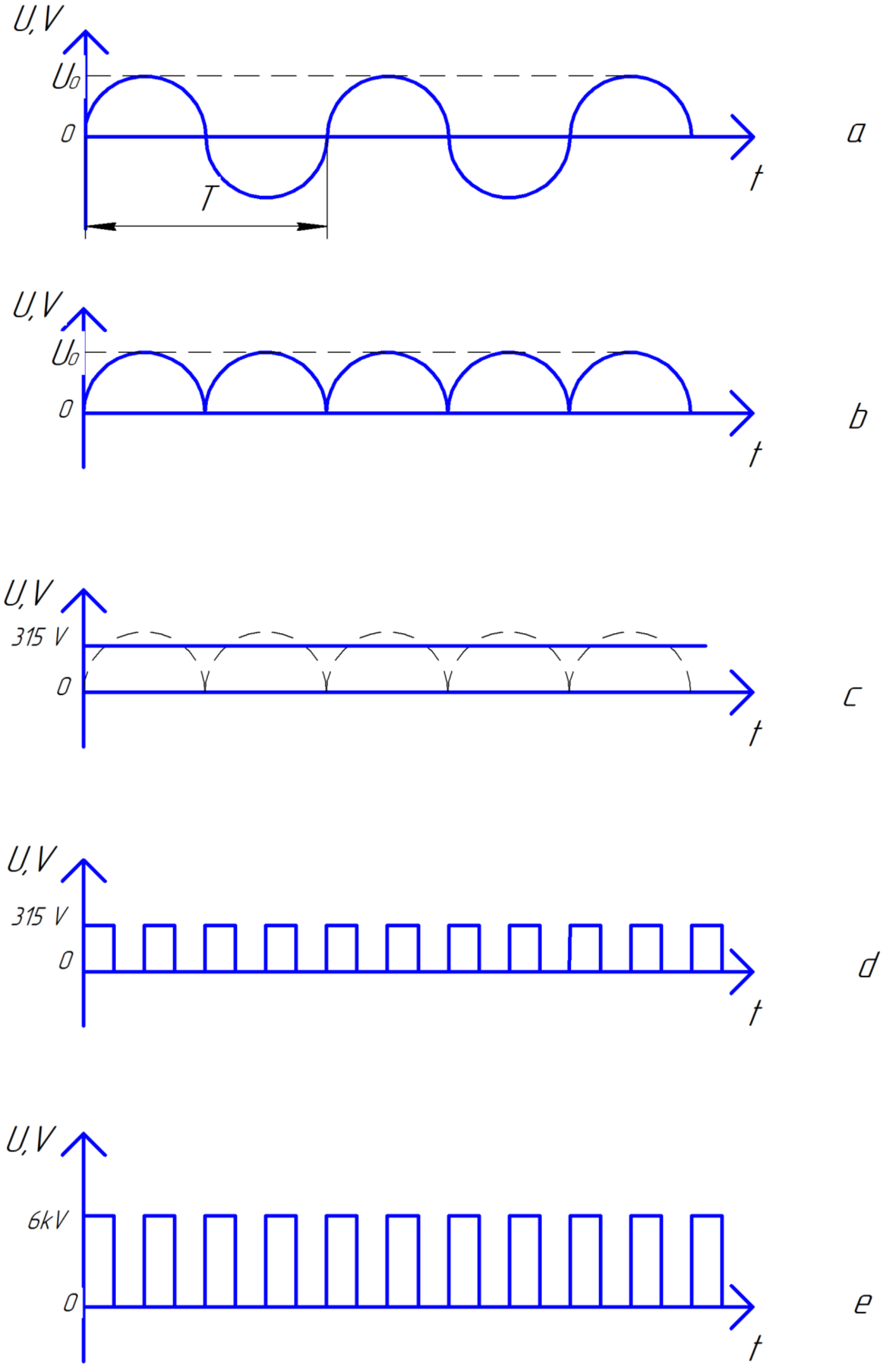


Figure 1.6 – Diagrams to illustrate the power source model

1.6.2 Construction a structural diagram

Based on the mathematical model, we draw up a structural diagram, which will have the form shown in fig. 1.7.

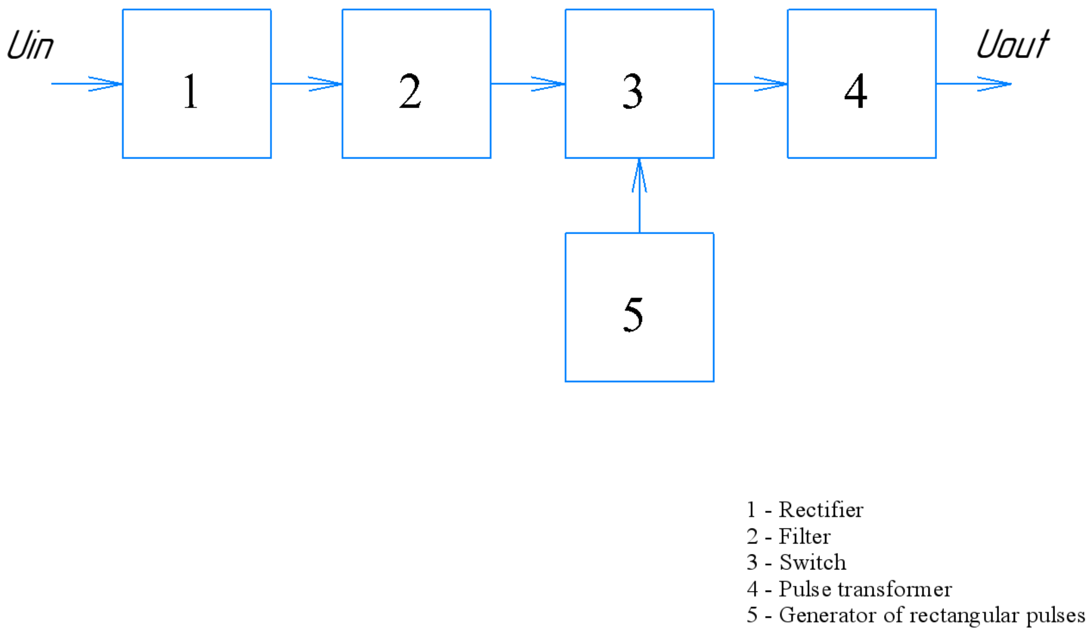


Figure 1.7 – Structural diagram of the power source

According to fig. 1.7, the power source includes a rectifier 1, a filter 2, a switch 3, a pulse transformer 4 and a rectangular pulse generator 5.

1.6.3 Analysis of existing methods of solving the problem. Construction of the functional circuit of the power source

The block diagram above describes the operation of a pulse-to-DC converter. The following types of pulse converters are distinguished: single-stroke and two-stroke.

Single-stroke converters are called because the electrical energy is transmitted to the output of the converter during one part of the conversion period. If the energy is transmitted at the moment when the power switch is closed, such a converter is called forward. If the energy is transmitted when the key is open, the converter is called flyback. The operation cycle of the forward circuit consists of two parts: energy transfer (I) and idling (II), which, respectively, are shown in fig. 1.8. In phase I, the current induces a secondary winding current. Since the diode VD in this case is turned on in the forward direction, the current charges the capacitor C. When the key is opened, the self-induction “reverses” the polarity at the terminals of the transformer, the diode VD is blocked, the load current is exclusively supported due to the discharge of the capacity C.

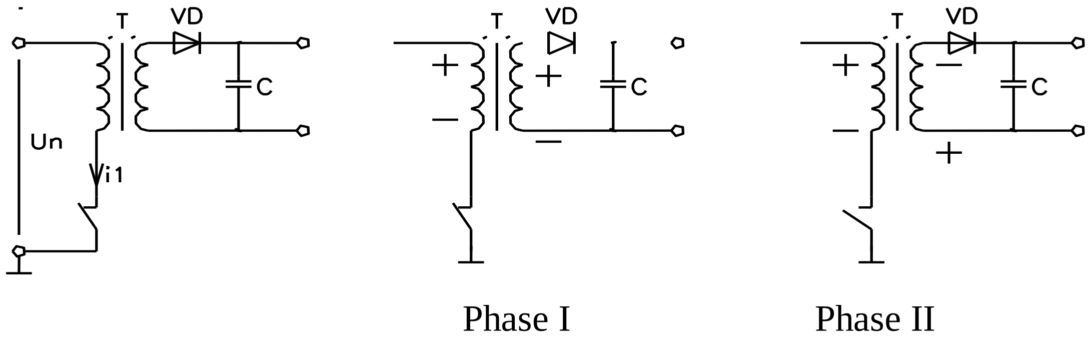


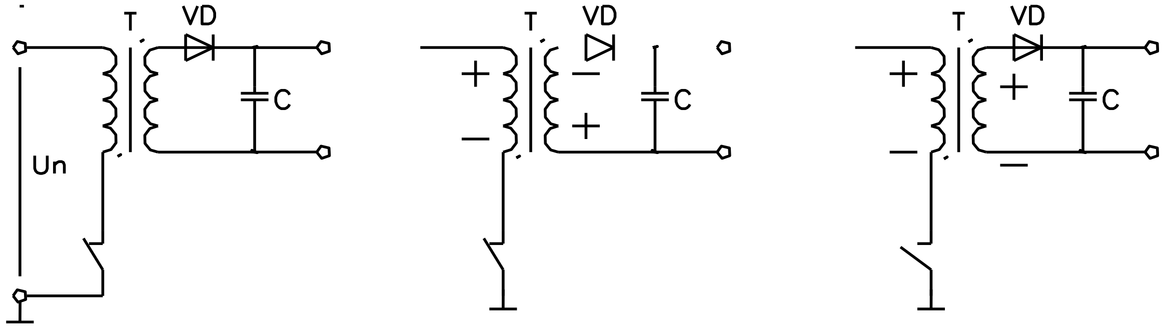
Figure 1.8 – Direct current diagram of the converter

This scheme has a number of disadvantages. First, working with unipolar currents in the transformer windings requires measures to reduce one-sided magnetization of the core. Secondly, when the key is opened, the energy accumulated in the inductance of the transformer cannot be “discharged” on its own, since all the terminals of the transformer are “hanging in the air”. In this case, an inductive discharge occurs - an increase in the voltage on the electrodes of the key transistor, which can lead to its breakdown. Thirdly, a short circuit of the output terminals of the converter will definitely cause the power part to fail, accordingly, it is necessary to take measures to protect against short circuits.

The disadvantage associated with the magnetization of the core by unipolar currents is present in all single-cycle circuits, and it is successfully eliminated by introducing a non-magnetic gap. Additional windings are used to combat voltage surges.

However, flyback converters are more common. They are reliable in operation, are not afraid of short circuits at the output, and are schematically simple.

The reverse circuit is very similar to the forward circuit, with the only difference that the "beginnings" and "ends" of the secondary windings of the transformer T are turned on in the opposite direction, which can be seen from fig. 1.9. In this case, the phase of energy accumulation and its transfer to the load are separated in time, therefore, by and large, the electrical product T cannot be called a transformer. It is rather a two-winding accumulator choke. However, according to the old terminology, it is called a transformer.



Phase I Phase II

Figure 1.9 – Reverse circuit of the converter

During energy storage by the transformer (phase I), the key is closed, current i_1 flows in the primary winding. We can write the law of energy storage as follows:

$$i_1(t) = \frac{U_n t}{L_1} \qquad (1.2)$$

where L_1 - inductance of the primary winding.

The phase of energy transfer (phase II) occurs when the key is opened. In this case, the polarity at the terminals of the transformer changes to the opposite due to the phenomenon of self-induction. The diode VD opens, current i_2 charges the capacitor of the filter C. The law of current decline in the secondary winding is similar to the law of current growth in the primary winding:

$$i_{21}(t) = i_1^* - \frac{U_n t}{L_2} \qquad (1.3)$$

where i_1^* - the current of the primary winding transferred to the secondary. Its value is determined at the moment when the key is unlocked.

L_2 - inductance of the secondary winding.

Two-stroke converters are divided into push-pull two-phase, two-stroke half-bridge and two-stroke bridge converters. All 2-stroke converters are recommended for use at wattages greater than 200 watts, while 1-stroke converters work great at lower wattages. Therefore, taking into account the parameters of the load, for the schematic implementation of the ozone sterilizer's power source, we will use the circuit of a one-cycle reverse pulse direct current converter. The functional diagram of such a converter will have the form shown in Fig. 1.10

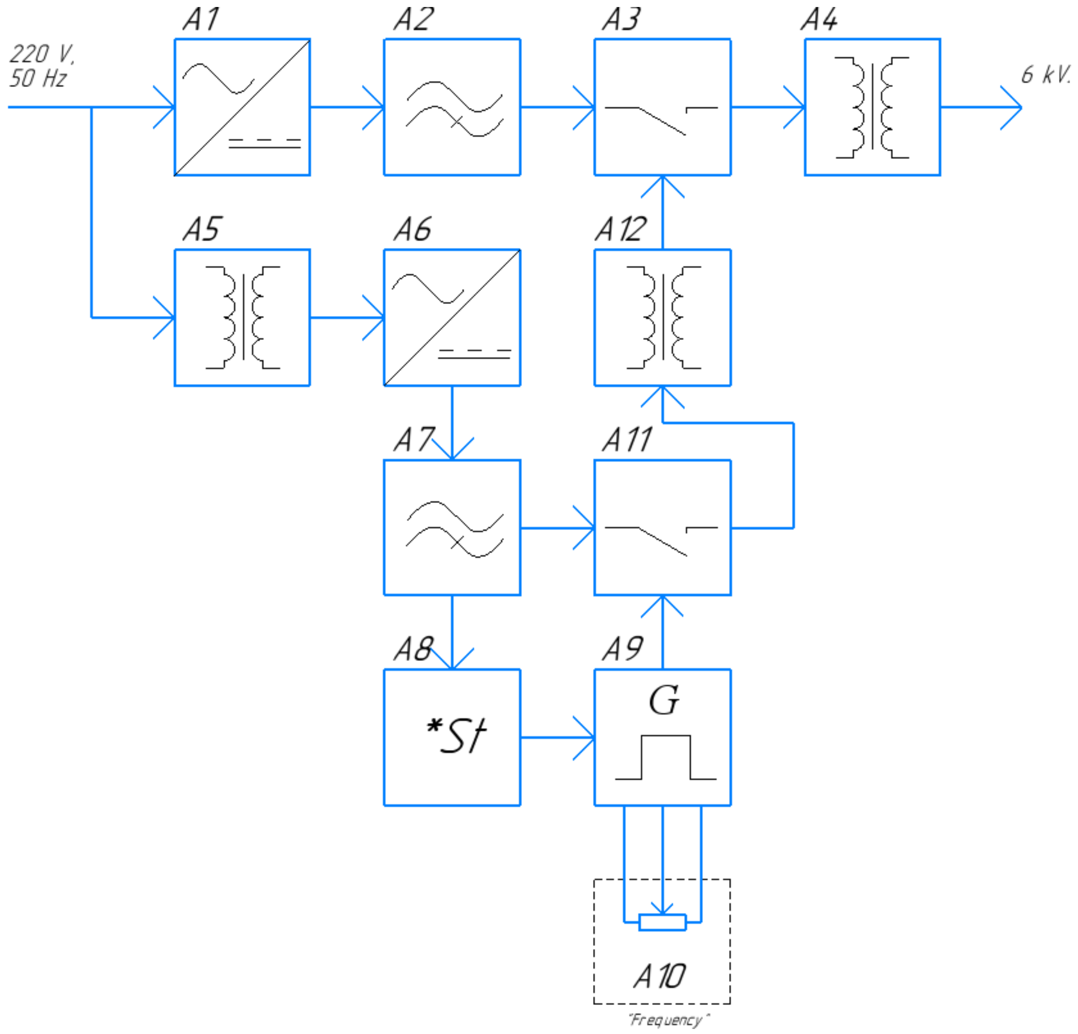


Figure 1.10 – Functional diagram of a high-voltage power supply

The functional diagram includes such blocks as a diode bridge 1, a capacitive filter 2, a power transistor switch 3, a pulse high-voltage transformer 4, step-down transformer 5, a diode bridge 6, a capacitive filter 7, an integrated stabilizer 8, a set pulse generator 9, a frequency regulator tracking 10, transistor key 11 and galvanic isolation transformer 12

1.6.4 Development and description of the electrical principle diagram

On the basis of the functional scheme, we build the basic electrical principle diagram. Mains voltage is supplied to connector X1. Further, through the electromagnetic compatibility filter (elements C10 C11 C12 L1), it is fed to the mains rectifier VD3 and the capacitive filter C8C9. From it, a constant voltage with an amplitude of about 310 V is supplied to the high-voltage transformer T3, in the circuit of the primary winding of which the transistor switch VT3 is included. The key is controlled by a sequence of rectangular pulses that enter the base circuit through the decoupling transformer T1 from the rectangular pulse generator assembled on the DA1 chip. Resistor R2 controls the frequency within the required limits.

Transformer T2 and elements VD1C4C5DA2R4 form the power source of the sterilizer and the decoupling transformer.

All unmentioned elements will be described in the next subsection.

1.6.5 Parametric synthesis

The reference generator is assembled on the NE 555 chip. A typical switching scheme is shown in Fig. 1.11.

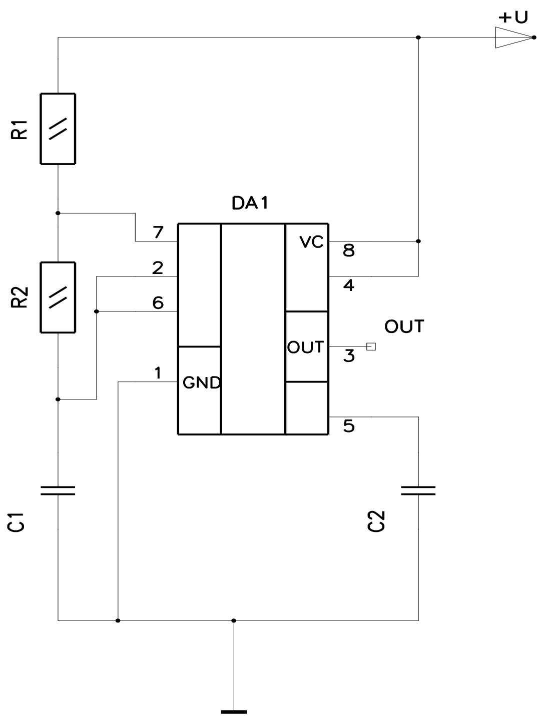


Figure 1.11 - Circuit diagram of the NE555 microcircuit

The pulse tracking frequency is determined by the nominal values of elements R1, R2, C1. Capacitance C2 is introduced for frequency correction, and it is taken equal to 0.01 μF. The period of oscillations can be determined by the formula:

$$T = 0{,}693 \cdot (R1 + 2 \cdot R2) \cdot C1 \tag{1.4}$$

The frequency is accordingly equal to:

$$f = \frac{1{,}44}{(R1 + 2 \cdot R2) \cdot C1} \tag{1.5}$$

In our case, the generator has the form shown in Figure 1.8.

Here, the resistor R2 controls the pulse tracking frequency within the required limits (15-25 kHz).

To begin with, we will find the parameters of the frequency-setting elements (R1, R3, C2). Let's take C2 equal to 0.01 μF, and let R1=R3=R. Then according to formula (1.4) we have:

$$f = \frac{1{,}44}{3 \cdot R \cdot C2} \tag{1.6}$$

Then

$$3 \cdot R = \frac{1{,}44}{f \cdot C1} = \frac{1{,}44}{25 \cdot 10^{3} \cdot 0{,}01 \cdot 10^{-6}} \approx 5{,}7 \cdot 10^{3} Ohm. \tag{1.7}$$

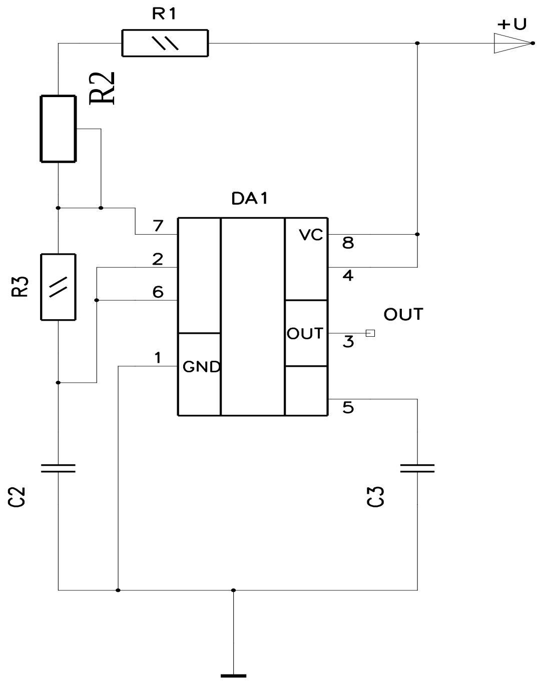


Figure 1.12 – Schematic of the reference generator

From here

$$R1 = R3 = 1{,}9 kOhm \quad (1.8)$$

Let's find the nominal value of the resistor R1 for the lower limit of the frequency range (f = 15 kHz), taking C2=0.01 μF, R3=1.9 kOhm

$$(R1 + 2 \cdot R3) = \frac{1{,}44}{f \cdot C1} = \frac{1{,}44}{15 \cdot 10^3 \cdot 0.01 \cdot 10^{-6}} \approx 9{,}6 \cdot 10^3 Ohm \quad (1.9)$$

$$R1 + 2 \cdot 1{,}9 \cdot 10^3 = 9{,}6 \cdot 10^3 Ohm$$
$$R1 = 5{,}8 \cdot 10^3 Ohm \quad (1.10)$$

So, in order to change the frequency at the output of the generator from 15 to 25 kHz, it is necessary to change the resistance of the resistor R1 from 1.9 kΩ to 5.8 kOhm, that is, by 3.9 kOhm, provided that R3=1.9 kOhm and C2=0.01 μF. This can be done by introducing an additional variable resistor R2 (according to Figure 1.12), with a resistance of 3.9 kOhm.

So, the generator elements have the following ratings: R1=R3=1.9 kOhm; C1=C2=0.01 μF. Taking into account the small currents flowing through the resistors in the operating mode, their dissipation power is taken to be equal to 0.125 W.

The output of the generator is loaded by the transistor switch VT2, which works in cut-off mode. Resistor R5 is current-limiting, and its resistance is several tens of volts. Resistor R6 prevents spontaneous opening of the transistor at times when there are no pulses on the base, and also reliably closes it.

The VT2 key is included in the circuit of the primary winding of the transformer T1, which is a galvanic isolation between the output circuits and the generator. The transformer is standard - TMS. Supply voltage is 18V, the current through the primary winding is 1.5 mA, the operating frequency is at least 12 kHz. The output voltage is 2.1 V, with a maximum current load of 12 mA.

The C6 VD2 R8 link is called fixing and is designed to suppress back EMF emissions of self-induction, which can exceed the supply voltage by several times and lead to a breakdown of the transistor key. The nominal values of the elements are calculated according to the following formulas:

$$R_8 = \frac{U_P^2}{0.02 \cdot P_L} \tag{1.11}$$

where U_P – supply voltage;

P_L – power.

Here

$$R_8 = \frac{U_P^2}{0.02 \cdot P_L} = \frac{18^2}{0.02 \cdot 23 \cdot 10^{-3}} = 700 k\text{Ohm} \tag{1.12}$$

$$C_6 = \frac{100}{R_8 \cdot f} \quad (1.13)$$

where f – operating frequency.

$$C_6 = \frac{100}{R_8 \cdot f} = \frac{100}{700 \cdot 10^3 \cdot 15 \cdot 10^3} \approx 0.01uF \quad (1.14)$$

Diode VD2 is selected with the condition that the maximum reverse voltage should be greater than $1.5 \cdot U_p$. We choose a diode of the KD212B type, for which the maximum reverse voltage is 100 V.

Taking into account the voltage on the secondary winding of the transformer, and the maximum current, we choose a VT3 transistor of the KT872 B type, for which the base current in the saturation mode should be approximately 11 mA and the voltage at the base - 2 V. Resistor R9 is current-limiting, and its resistance is units of ohms. The resistance of resistor R10 is several tens of kilohms. We accept the following values: R9=4.7 Ohm, R10=68 kOhm.

The link C7R12VD4 is also fixing, and is calculated according to formulas (1.11), (1.14).

$$R_{12} = \frac{U_p^2}{0.02 \cdot P_L} = \frac{315^2}{0,02 \cdot 13} = 380k\text{Ohm} \quad (1.15)$$

$$C_6 = \frac{100}{R_{12} \cdot f} = \frac{100}{380 \cdot 10^3 \cdot 15 \cdot 10^3} \approx 0,01uF \quad (1.16)$$

The diode is selected as the KD226D type with a maximum reverse voltage of 800 V.

Transformer T2 provides power to the generator and for T1 primary winding. Taking into account the supply voltage for T1 (18 V), a standard transformer operating from a 220 V 15%, 50 Hz network, type TP112-7, with secondary winding voltage is selected U_0=15.2 In and with a power of 7 W.

Voltage U_0 is fed to the bridge rectifier (VD1) with a capacitive filter (C4, C5). The rectifier is selected under the condition that its maximum reverse voltage will be greater than the voltage on the secondary winding of the transformer T2, and the direct current will be greater than the maximum consumed. Due to the small size and cheapness, we choose a diode bridge, type W10M, with a maximum reverse voltage of 1000 V and a direct current of up to 1 A. The capacity of the capacitor C5 is found by the formula:

$$C_5 = \frac{P_n}{200 \cdot U_p^2 \cdot K_l} \tag{1.17}$$

where P_n - nominal power (7 W);

U_p - supply voltage (21 V);

K_l - coefficient of voltage ripples (take)

$$C_5 = \frac{7}{200 \cdot 21^2 \cdot 0{,}06} \approx 1000uF \tag{1.18}$$

C4 is a high-pass filter, let's take C4=0.1 μF.

From the rectifier, the voltage is supplied to the T1 primary winding and to the integral stabilizer DA2, from which the generator is powered. Since the value of the generator supply voltage can be in the range of 5-15 V, an integral stabilizer of the KR142EN5A type was chosen, with a stabilization voltage of 5 V and a maximum load current of 2 A. However, since the maximum input voltage of the stabilizer is 15 V, it is necessary to put a current-limiting device on the input of the latter resistor R4. Its parameters are based on the condition that the voltage drop on it should be equal to approximately 10 V, and the current through it is equal to the current consumption of the generator, that is, 100 mA:

$$R_4 = \frac{U}{I} = \frac{10}{0{,}1} = 100Ohm \qquad (1.19)$$

Accordingly, the power dissipated on it:

$$P = U \cdot I = 1W \qquad (1.20)$$

As a reserve, we take a resistor with a dissipation power of 2W.

Capacitor C1 is an additional filter at the output of the stabilizer, its value can be taken as 22 μF.

Link R1H1 is a work indicator. It is powered by a voltage of 5 V, just like the generator. LED H1 type AL307A with a red color of light, a direct current of 10 mA and a voltage of 2 V. Resistor R1* is current-limiting, and its parameters are based on the condition that the voltage drop across it is equal to 3 V and the current is 10 mA:

$$R1^* = \frac{U}{I} = \frac{3}{10 \cdot 10^{-3}} = 300Ohm \qquad (1.21)$$

The power dissipated on it is equal to:

$$P = U \cdot I = 3 \cdot 10 \cdot 10^{-3} = 0.03W \qquad (1.22)$$

A resistor with a resistance of 300 Ohms and a dissipation power of 0.125W is accepted.

Link C10 C11 C12 L1 is an electromagnetic compatibility filter. The choke is selected as a standard one, type DF90PC, the capacitor ratings for this filter are as follows: C10=2200 pF, C11=2200 pF, C12=0.1 μF.

The diode bridge VD3 rectifies the mains voltage, so its reverse voltage must be greater than the amplitude value of the mains voltage, i.e. more than 315 V. A diode bridge of the RS407 type is selected, for which the maximum reverse voltage is equal to 700 V, direct current – $i_d = 4A$, maximum direct current (at $\tau_m < 10us$) $i_{d.m} = 50A$

Since there is a capacitive filter after the VD3 bridge, at the initial moment of time it is short-circuited, and the current that will flow through the bridge can disable it. Therefore, the resistor R11 is introduced into the circuit. The technical conditions on the rectifier allow when working on a capacitive load to increase the unit current pulse by 1.57 times, i.e. $i_{d.m} = 78{,}5A$. We choose the resistance of the resistor with a margin: R11=4.7 Ohm.

We check the initial impulse current through the bridge:

$$i_{d.m} = \frac{315}{4{,}7} = 67A \tag{1.23}$$

The capacity of capacitor C8 is found by the formula:

$$C8 = \frac{P_l}{200 \cdot K_l \cdot U_p^2} \tag{1.24}$$

where P_l - nominal power (13 W),

K_l - ripple coefficient (2%),

U_p - supply voltage (248 V),

$$C8=\frac{13}{200\cdot 0{,}02\cdot 248^2}=68uF \qquad (1.25)$$

We accept C8=100 μF, C9=0.01 μF.

The standard TVS 90-PC15 high-voltage transformer is used as the transformer T3, for which the voltage of the secondary winding is about 6 kV at a supply voltage of 300 V and an operating frequency of at least 12 kHz. Accordingly, to obtain a voltage at the load of 13 kV, it is necessary to install a voltage doubler at the output of the transformer T3. It is assembled on elements VD5, VD6, C13, C14. High-voltage diodes are selected of the KC106 type with a maximum reverse voltage of 20 kV and a current of up to 1 A. Capacitors of the KVI-2 type with a capacity of 140 pF and a maximum voltage of 16 kV are selected.

The use of a radiator for the DA2 microcircuit is not mandatory, since the current flowing through it is tens of milliamperes, and the voltage drop is units of volts, accordingly, the power dissipated by the microcircuit does not exceed several tens of milliwatts. The maximum dissipated power for it is 2 W. However, a small radiator is used to ensure a reliable thermal regime. Similarly, you can analyze the thermal mode of the power transistor VT2, which is also used with a small radiator.

1.6.6 Calculation of tolerances for nominal values of element parameters

Let's calculate the tolerances of the frequency-setting elements of the rectangular pulse generator. Assume that the tolerances are ±5%. Let's find the frequency value at the limits of the nominal values of the elements for the upper frequency (25 kHz):

R1=R2=1.9 kOhm;

ΔR=5%=0.095 kOhm;

C2=0.01 μF;

ΔC=5%=0.00005 μF.

Accordingly, the resistance of the resistors can vary from 1.805 kΩ to 1.995 kOhm, and the capacity of the capacitor in the range from 0.00995 μF to 0.01005 μF. With a tolerance of +5%, the generator output frequency will be:

$$f_{\min} = \frac{1{,}44}{3 \cdot R \cdot C2} = \frac{1.44}{3 \cdot 1.995 \cdot 0.01005 \cdot 10^{-3}} \approx 24kHz \qquad (1.26)$$

With a tolerance of -5%, the generator output frequency will be:

$$f_{\max} = \frac{1{,}44}{3 \cdot R \cdot C2} = \frac{1.44}{3 \cdot 1.805 \cdot 0.00995 \cdot 10^{-3}} \approx 26.7kHz \qquad (1.27)$$

Therefore, when changing the nominal values of the frequency-setting elements of the generator by ±5%, the frequency at the output of the generator changes as follows:

$$f = 25kHz_{-4}^{+4.4}\% \qquad (1.28)$$

Therefore, frequency-setting elements should be selected with a tolerance of no more than 5%.

All other elements can have a tolerance of 10%.

So, after analyzing the modern element base, I choose the brands of elements presented in the list of elements in the corresponding applications.

1.7 Power supply design

1.7.1 Selection of element base

The choice of element base is a very responsible stage in the development. At the moment, there are a lot of nominal values of radio elements. Among this variety, it is necessary to choose exactly the element that would best suit its characteristics (allowable voltage, current, limit frequency, temperature, etc.) to include it in the scheme. The normal functioning of the device, its stable operation depends primarily on the reliability and operating parameters of the elements of which it is composed.

The following types of radio elements are used in the device:

chips:

KR142EN5A is an integral compensating constant voltage stabilizer with a stabilization voltage equal to 5±0.1 V and a maximum load current of up to 2 A. The microcircuit is made in a KT-28-2 (TO-220) housing.

NE555 is a timer microcircuit that is used as a generator of rectangular pulses.

capacitors:

KVY-2 - ceramic capacitors of small capacity, high voltage, with a small deviation from the nominal capacity and TKE;

K50-17 are electrolytic capacitors designed for operation at high voltages.

K50-35 - high-capacity electrolytic capacitors for voltage stabilization and filtering;

K73-9 - non-polar capacitors of small capacity with a small tolerance and a low TKE value;

transistors:

KT940A - amplifying transistor, high-frequency, powerful, high-voltage;

KT872B is a powerful bipolar transistor, used in the final cascades of time sweeps of TVs.

diodes:

W10M is a diode bridge designed for maximum reverse voltages of up to 1000 V and direct direct currents of up to 1 A. It was chosen because of its relative cheapness and weight and dimensions;

KD212 – rectifier diode, medium power;

RS407 is a diode bridge designed for maximum reverse voltages up to 700 V and direct currents up to 4 A;

KD226D – high-voltage medium-frequency diodes;

КЦ106Г – high-voltage diodes used in voltage multipliers;

AL307A is an LED with a red glow.

resistors:

C2-23 – general-purpose metal-dielectric resistors, universal for use in stationary equipment;

SP3 – variable resistance resistors.

The main parameters and nominal values of the elements are given in the appendices.

1.7.2 Development of a printed circuit board and a printed unit

In accordance with the recommendations of current standards, using the P-Cad 2006 program, the printed circuit board was traced and the layout of the printed circuit board was carried out. They are shown in fig. 1.13 and fig. 1.14 respectively.

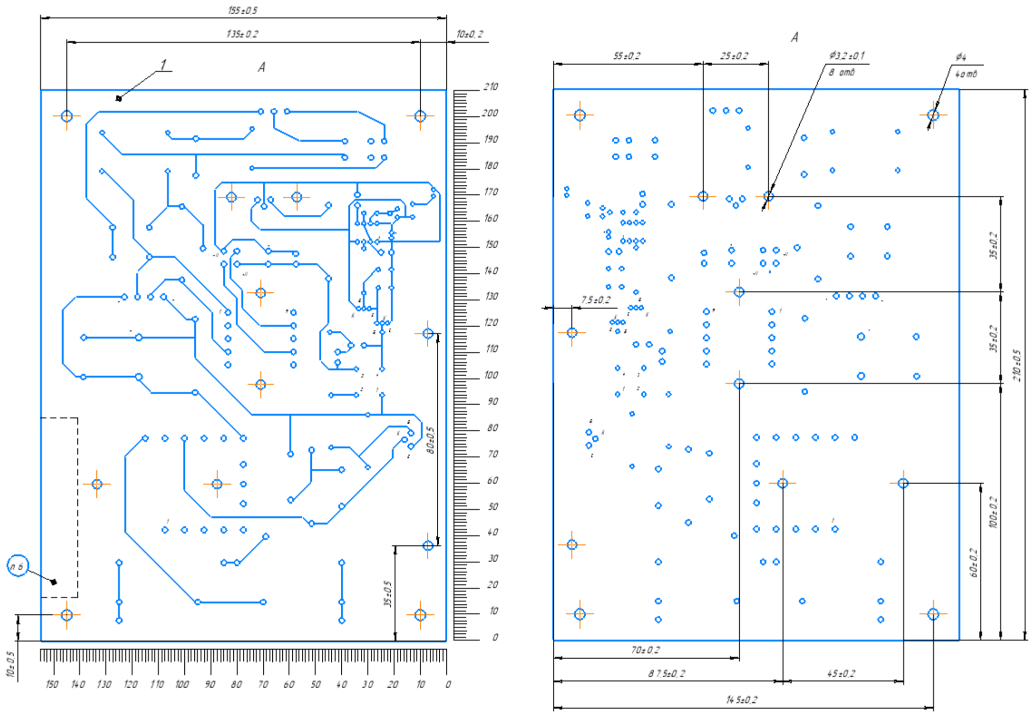


Figure 1.13 – PCB topology

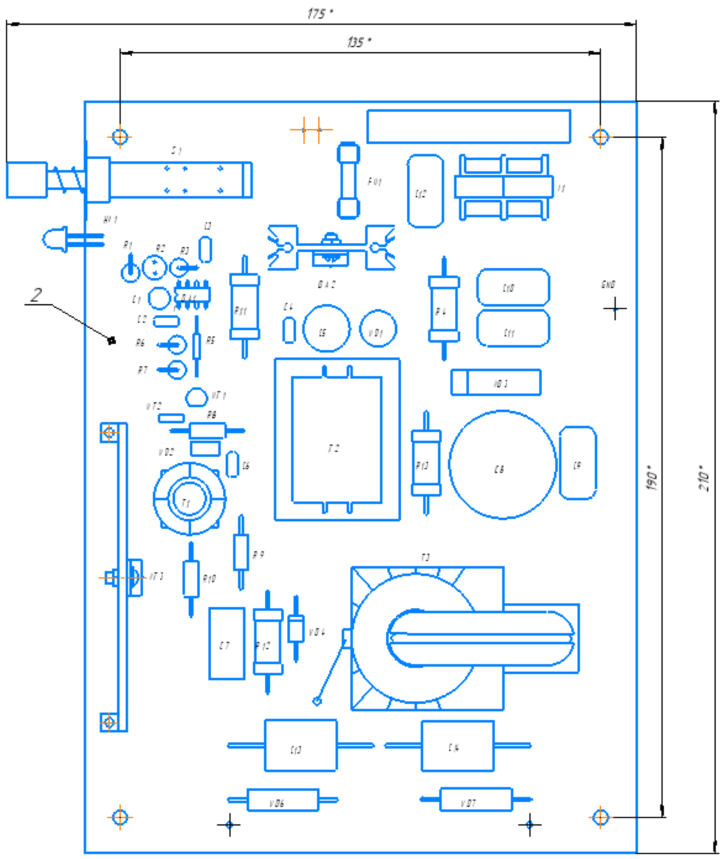


Figure 1.14 – Layout of the printed unit

In addition, these drawings were designed in the AutoCAD environment to meet the requirements for design documentation.

1.7.3 Calculation of the reliability of the power supply board

One of the factors affecting the reliability of the equipment as a whole is the reliability of the elements. The probability of element failures depends on their design, manufacturing quality, and operating conditions. The influence of external factors on the reliability of elements is characterized by the load factor, that is, the ratio of the actual value of the operating factor to its nominal value. When the load factor increases, the intensity of failures also increases if the element is operated under more severe conditions. The influence on the reliability of the actual value of external factors and load factors can be determined using the appropriate influence factors a. The temperature coefficient of influence at shows how many times the intensity of failures changes when the temperature changes from the nominal value to the existing one. Element failure intensity at temperature t: $\lambda = a_t \times \lambda_0$. We will present the reliability of the elements in the form of table 1.1.

Table 1.1 Reliability of some radio-electronic elements

Name	Number	λ_0, 1/hour
Electrolytic capacitor	3	$0{,}003 \cdot 10^{-6}$
The capacitor is ceramic	11	$0{,}05 \cdot 10^{-6}$
The resistor is constant	12	$0{,}5 \cdot 10^{-6}$
The resistor is variable	1	$0{,}4 \cdot 10^{-6}$
Transistor	2	$0{,}4 \cdot 10^{-6}$
Diodes	7	$0{,}35 \cdot 10^{-6}$
Microcircuits	2	$0{,}01 \cdot 10^{-6}$
Transformer	4	$0{,}6 \cdot 10^{-6}$
Printed circuit board	1	$0{,}1 \cdot 10^{-6}$
Soldering	1	$0{,}02 \cdot 10^{-6}$

Let's calculate the intensity of system failures:

$$\lambda_c = 3 \cdot 0.003 \cdot 10^{-6} + 11 \cdot 0.05 \cdot 10^{-6} + 12 \cdot 0.5 \cdot 10^{-6} + 1 \cdot 0.4 \cdot 10^{-6} + 2 \cdot 0.4 \cdot 10^{-6}$$
$$+ 7 \cdot 0.35 \cdot 10^{-6} + 2 \cdot 0.01 \cdot 10^{-6} + 4 \cdot 0.6 \cdot 10^{-6} +$$
$$+ 1 \cdot 0.1 \cdot 10^{-6} + 1 \cdot 0.02 \cdot 10^{-6} = 12.749 \cdot 10^{-6}$$

Let's calculate the probability of trouble-free operation of the system during a period of time equal to 1000 hours:

$$P_c(t) = \exp\left(-12.749 \cdot 10^{-6} \cdot 1000\right) \approx 0.31 \qquad (1.29)$$

Let's determine the average working time for system failure:

$$T_c = \frac{1}{12.749 \cdot 10^{-6}} = 78438 \text{ hours}$$

The reliability of the equipment depends on proper monitoring and compliance with the specified operating conditions; from timely and high-quality preventive inspection and repair. Equipment that uses automation and mechanization of production processes can also have high reliability. In this regard, the REA, in which microcircuits and microassemblies are used, has the greatest reliability.

2. LABOR PROTECTION

2.1 Planning of labor protection measures

The purpose of occupational health and safety planning is to determine the necessary investments in occupational health and safety measures to effectively influence the state of occupational health and safety.

The system of labor protection plans of an individual enterprise may include:

- perspective planning (for a period longer than one year);
- current planning (per year);
- operational planning (detailed plans aimed at solving specific issues of labor protection activities at the enterprise in the short-term, up to one year, period).

Planning in labor protection may include:

- determination of the objectives of labor protection activities at the enterprise and the means of achieving them;
- selection of methods and basic indicators that can be used to assess the necessary investments in labor protection;
- calculation of the amount of investments in labor protection measures and the rational distribution of this amount according to the areas of activity;
- ensuring the organization of control over the implementation of the plan (if necessary, adjustment of the planned indicators);
- implementation of constant monitoring of working conditions and safety at the enterprise and prompt response to deviations from regulatory requirements.

Forward-looking planning includes the most important, time-consuming and long-term labor protection measures, the implementation of which, as a rule, requires the joint work of several units of the enterprise. The possibility of implementing the measures of the long-term plan must be confirmed by a reasonable calculation of the necessary material and technical support and financial costs, indicating the sources of funding.

Prospective plans include a comprehensive plan for improving working conditions and health and wellness measures, which provides for the creation, in accordance with regulations on labor protection, of working conditions associated with prospective changes of the enterprise. Such planning, as a rule, is designed for a period of 2 to 5 years. The implementation of these plans is ensured through annual plans of nomenclature measures for labor protection, which are included in the agreement, which is an integral part of the collective agreement.

Current planning is carried out within the calendar year through the development of appropriate measures in the "Labor Protection" section of the collective agreement.

Current plans envisage the implementation of measures to improve working conditions and create better living and social conditions at the workplace. These plans must be funded according to the developed estimates.

Occupational health and safety issues can be reflected in other current plans that enterprises and organizations can draw up at the request of labor groups:

- social development plan of the team;
- scientific organization of work;
- mechanization of heavy and manual work;
- women's labor protection;
- preparation of the enterprise for work in the autumn-winter period;
- improvement of production culture, etc.

Operational planning of work on occupational health and safety is carried out based on the results of monitoring the state of occupational health and safety in structural divisions and the enterprise as a whole.

Operational plans are drawn up for the rapid correction of shortcomings in the state of labor protection discovered in the process of state, departmental and public control, as well as for the elimination of the consequences of accidents or natural disasters.

Operational measures to eliminate identified deficiencies are indicated directly in the order of the owner of the enterprise, which is issued based on the results of the control, or in the plan of measures, as an appendix to the order.

Organizational and methodical work on drawing up prospective, current and operational plans is carried out by the labor protection service (specialist).

2.2 Medical care for shock

Traumatic shock is a complex pathogenic process that occurs as a result of a severe mechanical injury, a burn and is characterized by a violation of the functions of vital organs and systems of the body.

With combined chemical and radiation damage, tissue and organ burns, traumatic shock is observed in 30% of victims.

In the genesis of traumatic shock, the following factors play a primary role: blood loss and pain, respiratory disorders, metabolic disorders, intoxication of the body with underoxidized metabolic products due to tissue destruction.

Factors that contribute to the development of shock are delayed and inadequate provision of medical care, secondary traumatization during transportation to the hospital, repeated blood loss, hypothermia or overheating, physical and emotional overstrain, stress, prolonged malnutrition and dehydration of the body, etc.

When injured, changes occur in the subcortical formations of the cerebrum and in the peripheral blood circulation system (redistribution of blood, which ensures the vital activity of organs, primarily the heart and brain). Circulatory hypotension, spasm of postcapillary venules (sweating plasma into the extracellular space), edema and blood thickening develop. Venous pressure decreases, the kidneys, liver, and lungs weaken, blood clots form, and irreversible changes in organs develop.

Intestinal injury leads to intoxication of the body, the condition of the injured person worsens, respiratory and circulatory disorders are observed. The function of the nervous system is disturbed. The shock has two phases: eretic and torpedo.

The erectile phase of shock is accompanied by excitement, excessive mobility. The language is choppy, the gaze is restless, the skin is pale, hyperemia (profuse sweating) sometimes occurs, the pulse deviates from the norm — slowed down or accelerated (100 pulsations in 1 minute). Breathing is frequent, shallow.

The torpid phase of shock is the suppression phase. There are 4 degrees:

I degree (mild form of shock). This is the result of isolated lesions of medium severity and loss of 500 - 1000 ml. of blood, a state of moderate mental retardation, pale skin, blood pressure 100 — 95 mm. mercury Art. The prognosis is favorable.

II degree — medium severity of shock, numerous body injuries, blood loss up to 1000 — 1500 ml, condition is serious, although orientation and consciousness are not lost, skin is pale, lips are cyanotic, mental retardation, pulse — 110 — 130 pulsations in 1 minute, pressure — 90 — 75 mm Hg. art., unstable, the prognosis is favorable with anti-shock therapy.

III degree — severe shock, occurs with severe damage to the chest, abdominal cavity. Blood loss — 2,000 ml., the condition is severe, pronounced mental retardation, sometimes stupor. The skin is pale, cyanotic, sweating, mucous membranes are dry, hypothermia, hypodynamia, decreased tendon reflexes, kidney dysfunction, urination, pulse — 120-160 pulsations per minute, blood pressure — 75 mm Hg. art., shallow breathing, without anti-shock measures, the prognosis is unfavorable.

VI degree — termite condition (pre-race, agony and clinical death) is extremely difficult for the victim. Loss of consciousness, the skin is cold, corpse-like, cyanotic, covered with sticky cold sweat, the pupils are dilated, do not react to light, the pulse is not palpable, the extreme degree of shock leads to clinical death.

Diagnosis of shock is based on the determination of indicators that characterize the general condition of the victim. The most important indicator is the blood pressure level. The lower it is, the deeper the disorder of the body's functions, its vital activity. The amount of blood loss is the most objective indicator of the severity of shock.

The course of clinical shock, depending on the location of the wound or burn, has the following features: penetrating wounds of the abdominal cavity cause shock in up to 80%; penetrating wounds of the chest cause hemothorax, open pneumothorax. In case of wounds and damage to the pelvis - bleeding up to 2.5 liters. In case of damage to the limbs - blood loss up to 2 liters, pain, intoxication.

Preventive and pre-medical care for shock.

During shock, the action of traumatic factors and factors of shock development are eliminated, bleeding is stopped, wounds are bandaged, and the threat of asphyxiation is eliminated; a 5-shaped tube (air duct) is inserted; in case of violation of external breathing, pre-medical care includes cleaning of the oral cavity and nasopharynx, elimination of sunken tongue, restoration of airway patency; in case of pneumothorax, a bandage is applied; oxygen inhalation is performed, external bleeding is stopped; cardiovascular and analgesic agents are administered (performed by a paramedic); limb fixation is carried out. After reintroducing painkillers, hot tea and other drinks are given.

In the event of a natural disaster, accidents, when there is a mass influx of victims, they are medically sorted.

First of all, the wounded with a severe degree of shock are distinguished: 1st and 2nd groups - wounded in a state of shock for 1-2 hours, they are given anti-shock care, then operated on; the 3rd group includes the wounded with signs of shock, who can be operated on a little later. First of all, bleeding is stopped, blood loss is compensated, then the volume of circulating blood is normalized. Acute blood loss (50%) leads to death.

Each large loss of blood (pressure drop to 80-70 mmHg) must be immediately compensated by blood transfusion into the veins of the victim (determine the blood group, Rh factor of the donor and the recipient), it is possible to make an infusion of blood plasma, polyglukin, etc.

Dilution of blood during the introduction of blood substitutes contributes to the improvement of capillary blood flow.

Blood loss by the body up to 700 ml. is compensated independently, due to the infusion of blood plasma, the introduction of saline multicomponent solutions. The hemoglobin level should be 65%.

When the body is starved of oxygen, oxygen therapy is carried out. In case of respiratory arrest - mouth-to-mouth artificial respiration. In case of impaired liver and kidney functions, 500 ml is administered. of glucose once a day with insulin (1 unit of insulin per 5 g of glucose).

The air temperature in the anti-shock chamber is 20-24°C.

The victim is given hot tea, coffee, heated wine, wrapped in a blanket.

The syndrome of prolonged compression of tissues occurs as a result of earthquakes, when people find themselves under the debris of buildings and houses. Along with fractures, burns, the victims may have a syndrome of long-term compression of tissues, in particular, tissues of the upper and lower extremities. When tissues are crushed and crushed, blood circulation in the muscles deteriorates sharply, anemia, tissue hyponia, intoxication, neuro-reflex disorder, spasms of capillaries, arteries, acute cardiovascular insufficiency, and edema occur. Blood plasma sweats into the intercellular space (the volume of circulating plasma decreases by 50%), blood pressure decreases, acute kidney failure and urinary disorders may occur.

The syndrome of prolonged compression of tissues is characterized by three periods:

1st — early — tissue swelling and acute hemodynamic disorder, lasts 1-3 days.

2nd — intermediate period — acute kidney failure, from 5 days to 1.5 months.

3rd — late period — gangrene, phlegmon, abscesses.

The victim's limb swells, the skin is purple-blue, sometimes blisters with amber-yellow liquid, pulsation is weakened or absent, skin sensitivity is reduced or lost. Blood clotting. The general condition of the body worsens. Cold sweat on the skin, sharp pain at the site of injury, nausea and vomiting. Pulse - 100-120 pulsations in 1 minute, pressure - 60 mm Hg. Art. Urine is red. The type of clinic of the torpid phase of traumatic shock. General intoxication of the body increases, acute renal failure is observed, sometimes gangrene of the limbs, abscesses and phlegmons, muscle atrophy may occur. The mobility of the joints is complicated, the nerve trunks are damaged.

There are 4 degrees of manifestation of compression syndrome:

1st degree — very severe — compression of soft tissues or limbs for 6 — 8 hours, victims usually die after 2 — 3 days;

II degree — severe — squeezing hands or feet for 4 — 7 hours, victims may die;

III degree — medium severity — squeezing hands or feet up to 6 hours, treatment up to 3 months;

IV degree - light - squeezing hands or feet for up to 2 hours. Violations are moderate. The prognosis is favorable.

First medical and pre-hospital aid.

Release from compression is the beginning of the clinical manifestation of tissue compression syndrome. When two limbs have been squeezed (compression) for 8 hours, in the presence of fractures, amputation is mandatory. A tourniquet is applied (above the point of compression). Analgesics, antihistomic and cardiovascular drugs are administered, antibiotics are prescribed, and tetanus vaccination is carried out.

CONCLUSIONS

The main stages of the life cycle of a high-voltage power source designed to obtain high voltage for powering the gas discharge chamber of a medical ozone generator were considered in the thesis. In the first section of the work, an analysis of methods of obtaining ozone, principles of operation of medical ozone generators, safety rules and basic requirements for medical ozone generators was carried out. Based on this, the technical requirements for the high-voltage power source were formulated and the technical task was formed, the purpose of which is to specify the requirements set by the customer. A mathematical model of pulsed power supply units was also developed, on the basis of which the structural and functional schemes of the high-voltage power source were developed. A basic electrical diagram has been developed. A parametric synthesis was carried out, the purpose of which is to calculate the nominal values of the elements of the electrical principle circuit. The tolerances for the nominal value of the elements of the frequency-setting links of the power source have been calculated. The design section was completed, in which the element base was selected, the design of the printed circuit board and printed circuit unit was developed, and operational reliability calculations were carried out.

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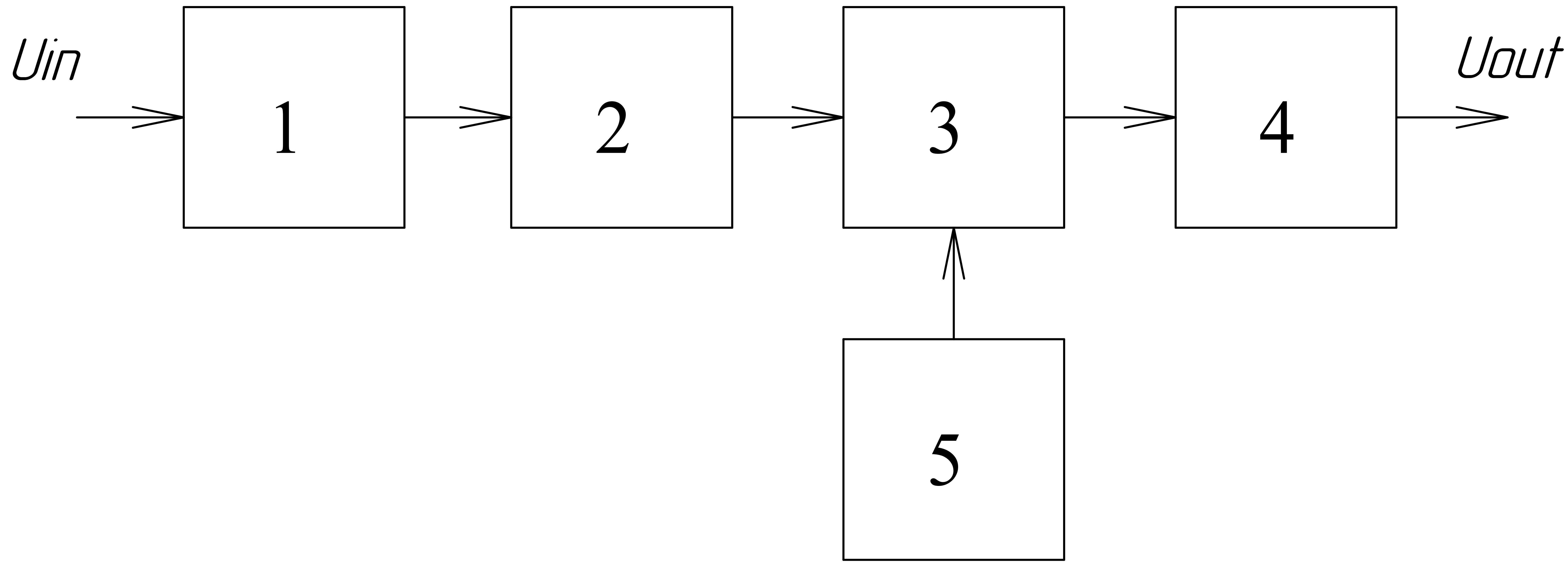

1 - Rectifier
2 - Filter
3 - Switch
4 - Pulse transformer
5 - Generator of rectangular pulses

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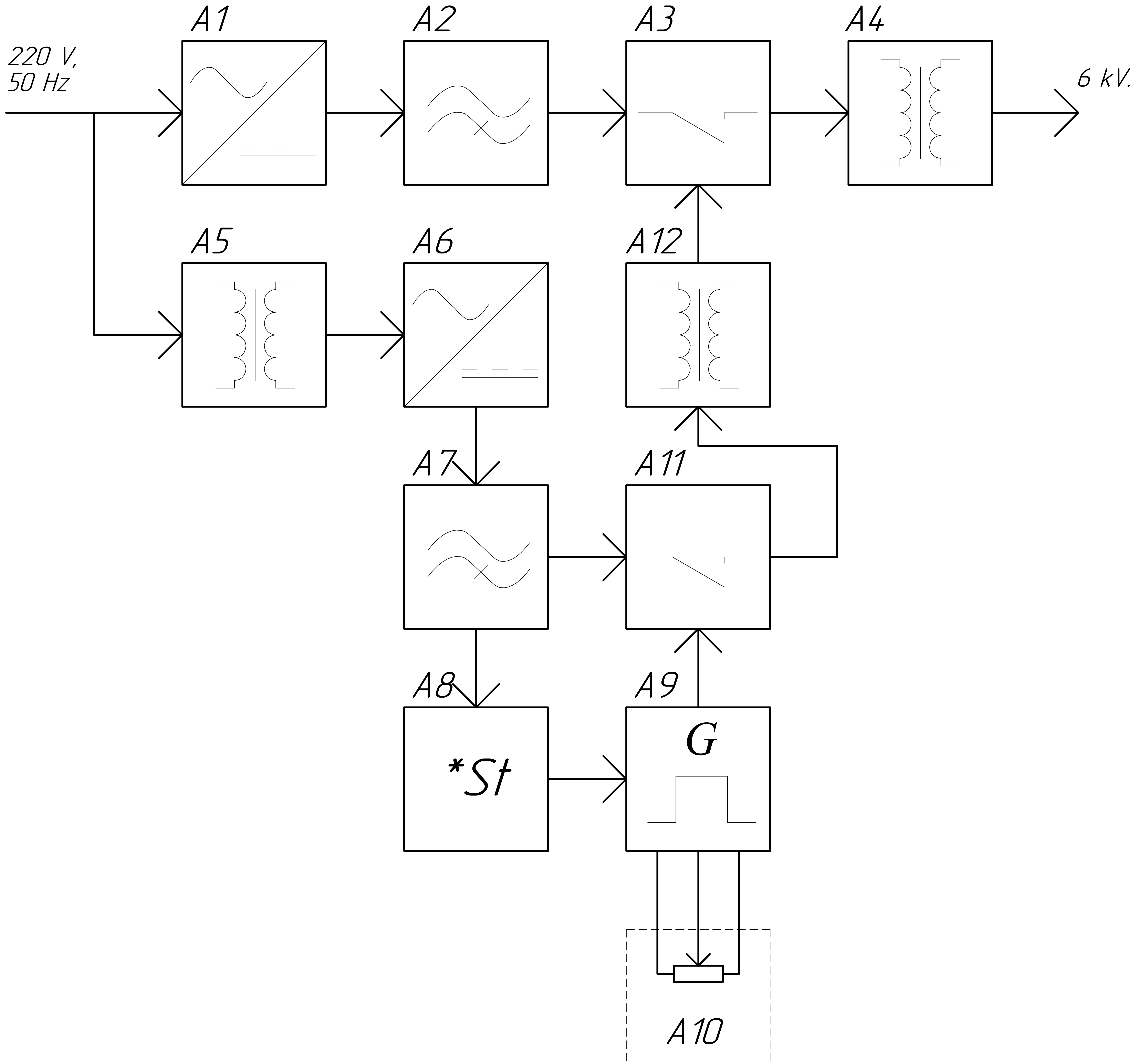
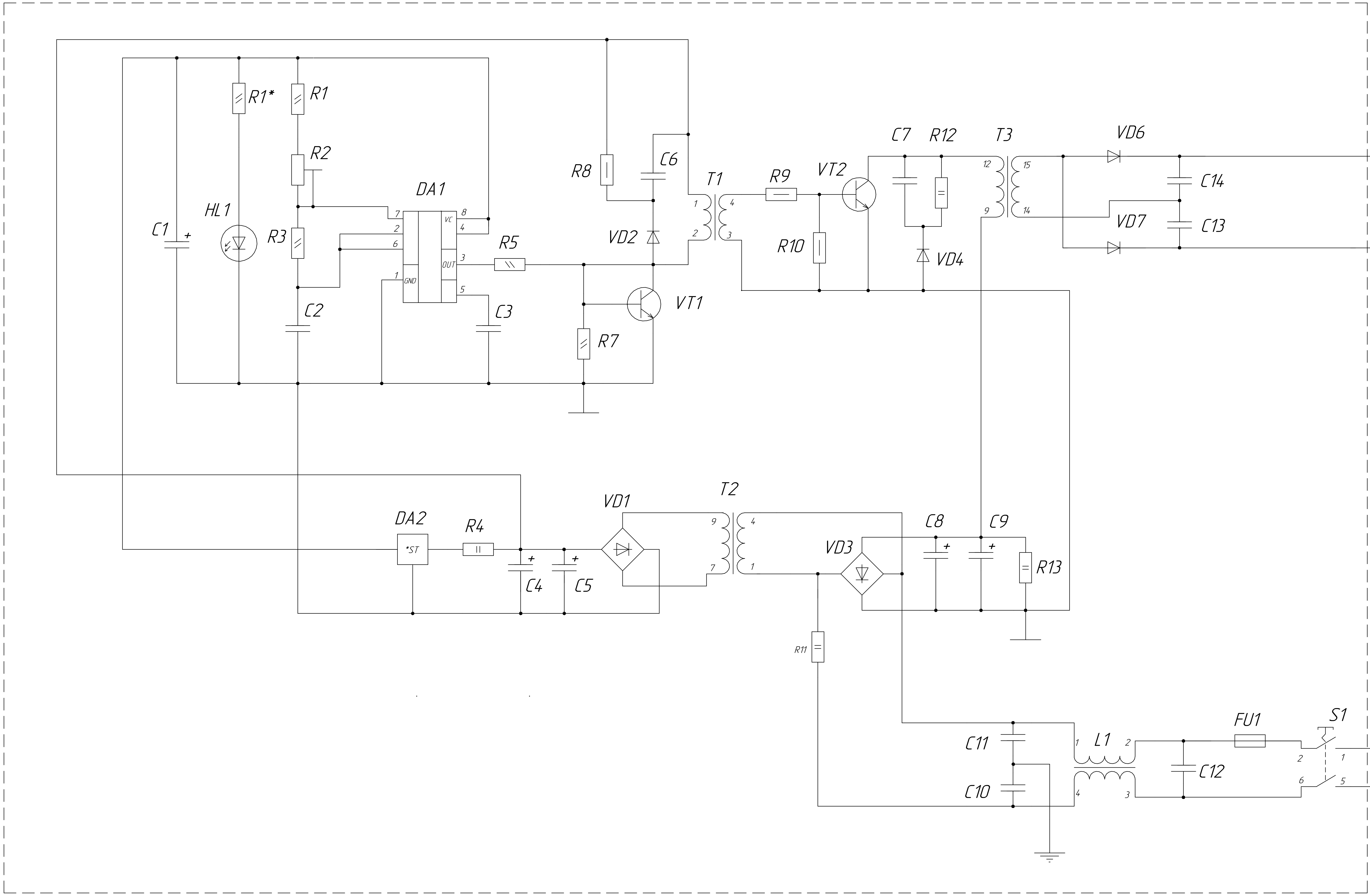


1 – Diode bridge;
2 – Capacitive filter;
3 – Power transistor key;
4 – Impulse high-voltage transformer;
5 – Step-down transformer;
6 – Diode bridge;
7 – Capacitive filter;
8 – Integral stabilizer;
9 – Generator of set pulses;
10 – Pulse frequency regulator;
11 – Transistor key;
12 – Galvanic separation transformer;



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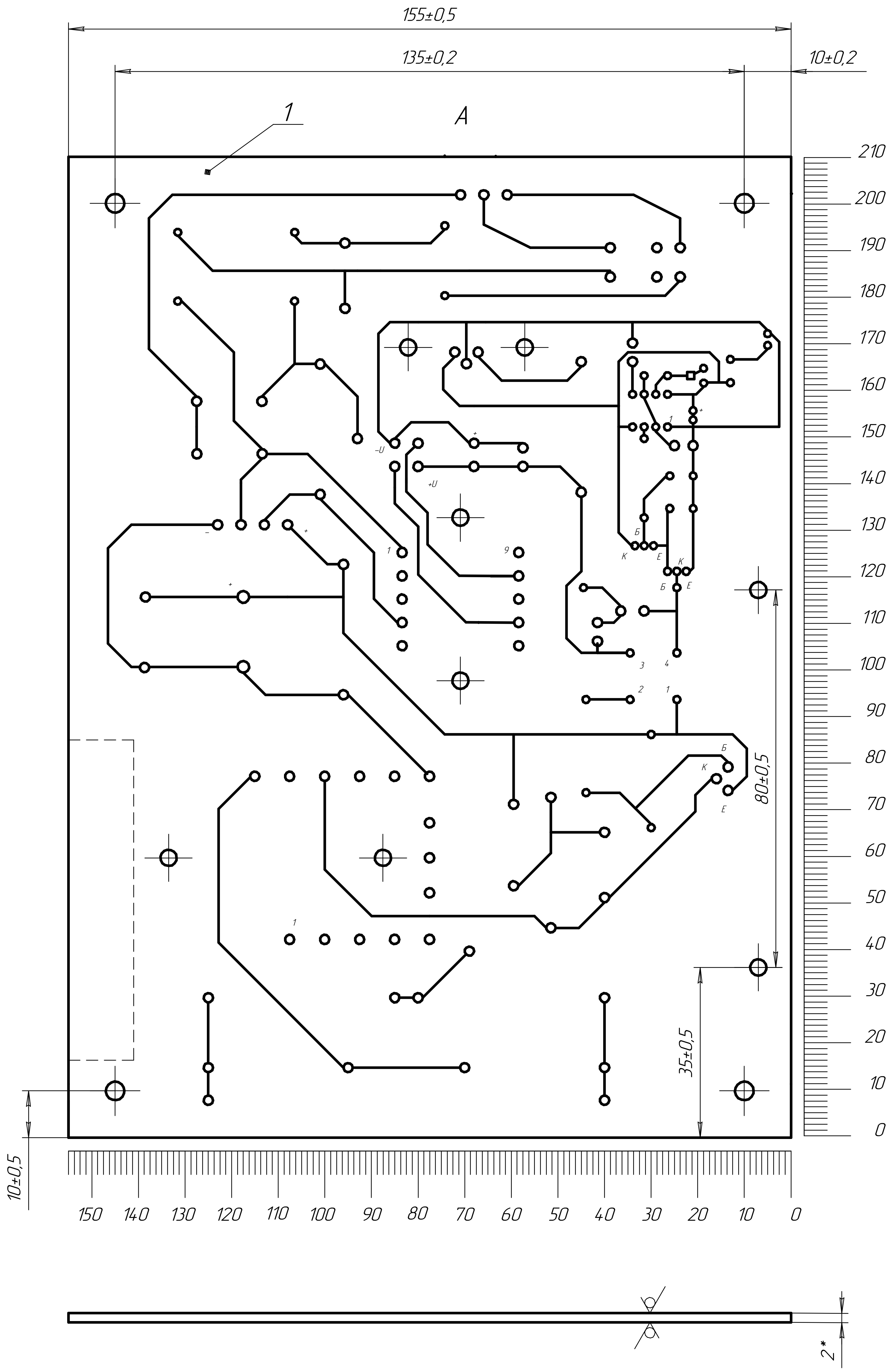

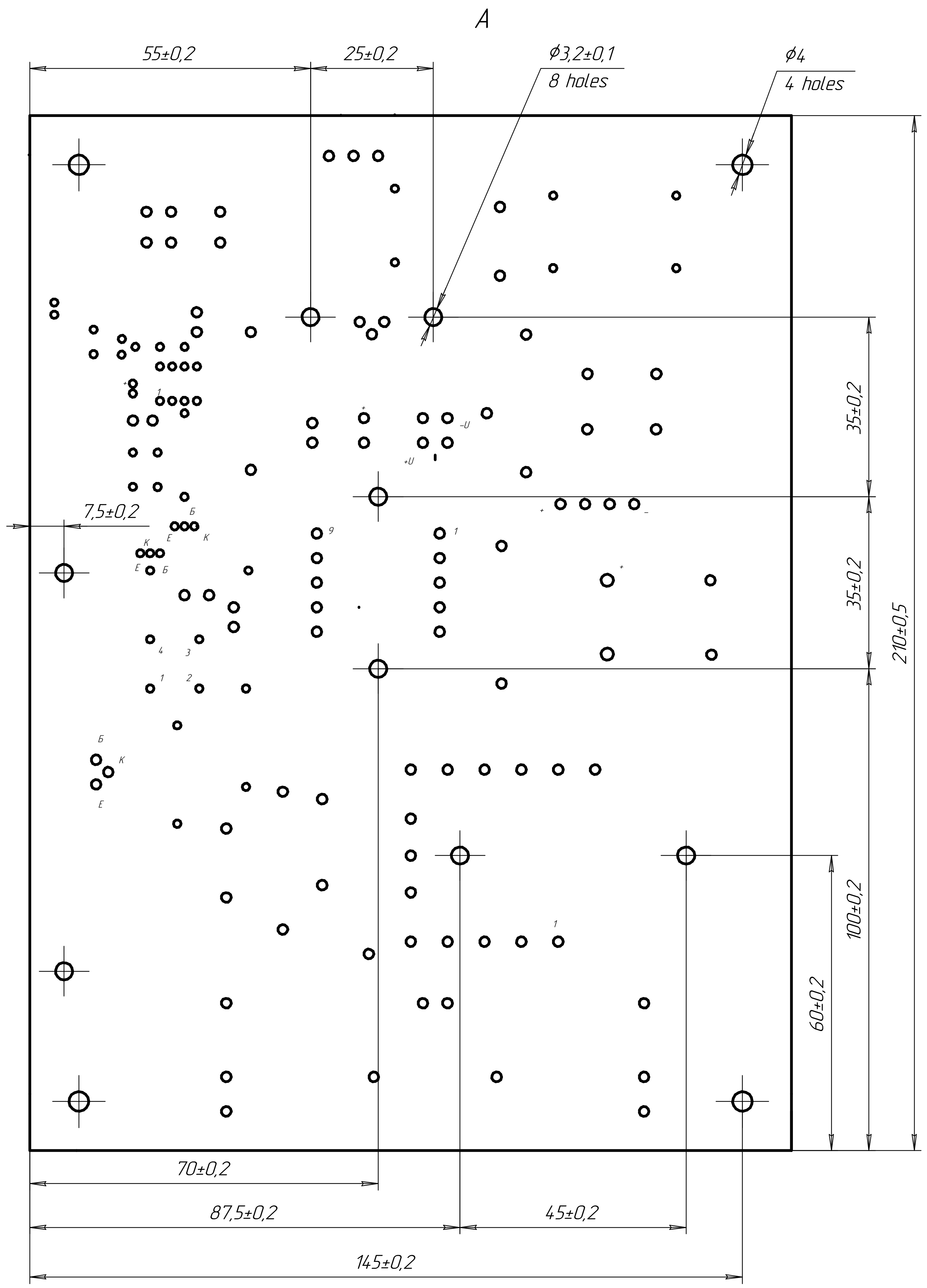

Conditional marking holes	Diameter holes ,mm	The size of the contact pads	Availability metallization	Number
	1	2,5	–	96
	0,8	1,7	–	38

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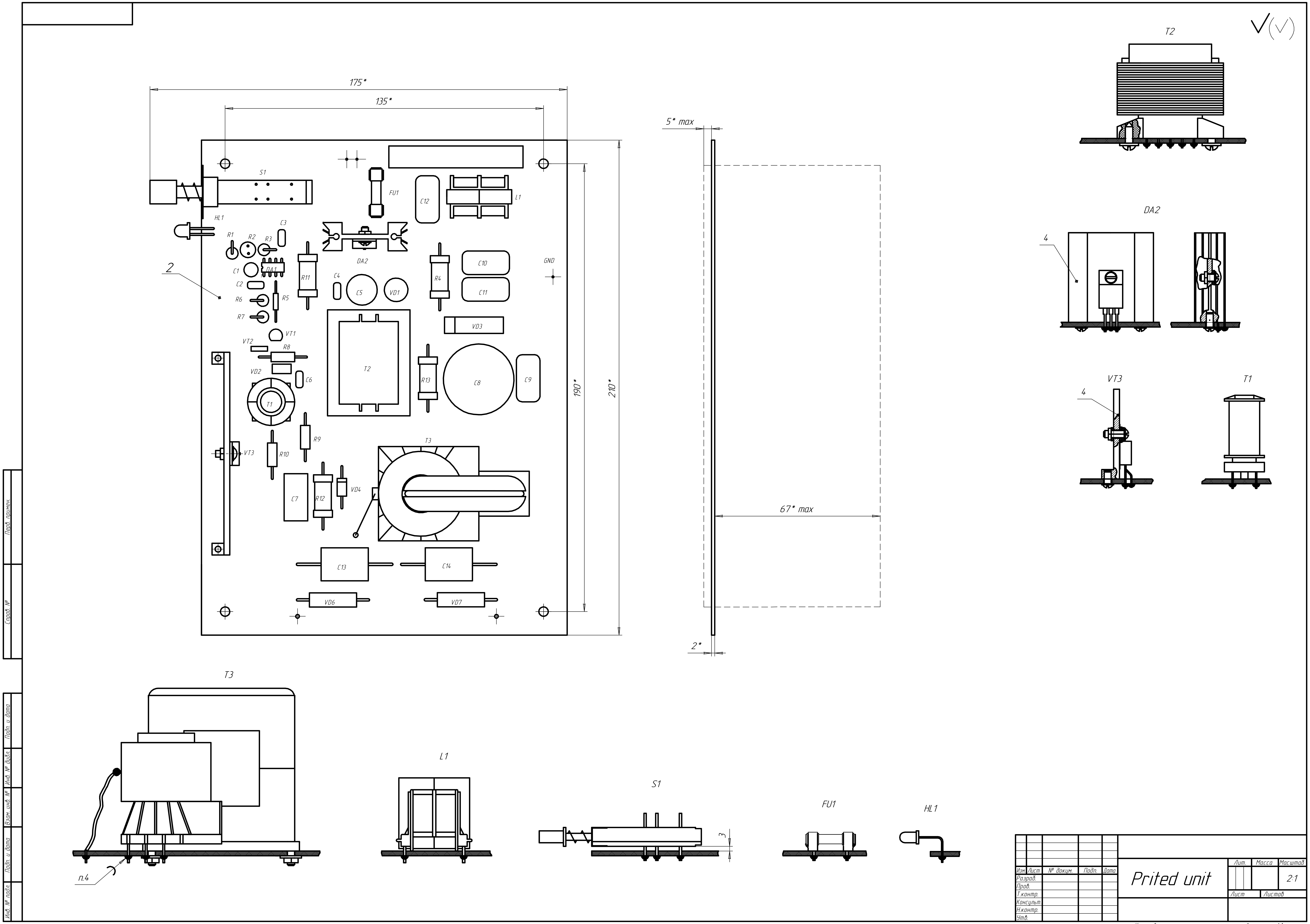
175*
135*
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FU1
C12
L1
HL1
R1
R2
R3
C3
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C10
GND
2
C1
DA1
R11
C4
C5
VD1
R4
C11
C2
R6
R5
R7
VT1
VD3
VT2
R8
VD2
C6
T2
R13
C8
C9
T1
190*
210*
R9
T3
VT3
R10
VD4
C7
R12
C13
C14
VD6
VD7
5* max
67* max
2*
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Инв. № подл.

	Name		
	Capacitors		
C1	К50-35-22 uF±20%-16V	1	
C2,C3	К73-9-0,01 uF ±5%-63V	2	
C4	К73-9-0,1 uF ±5%-630V	1	
C5	К50-35-1000 uF ±20%-25V	1	
C6,C7,C9	К73-9-0,01 uF ±5%-630V	3	
C8	К50-17-200 uF ±20%-500V	1	
C10,C11	К73-9-1000пФ±5%-630V	2	
C12	К73-9-0,47 pF ±5%-630V	1	
C13,C14	KVI-2-140 pF ±5%-16kV	2	
	Microcircuits		
DA1	NE555	1	
DA2	KR142EN5A	1	
	Resistors		
R1*	C2-23-0,125-300 Ohm±5%	1	
R1,R3	C2-23-0,125-1,9 kOhm ±5%	2	
R2	SP3-33-32-0,25-3,9 kOhm ±5%	1	
R4	C2-23-0,125-100 Ohm ±5%	1	
R5	C2-23-0,125-33 kOhm ±5%	1	
R6,R12	C2-23-0,125-380 kOhm ±5%	2	
R7	C2-23-0,125-470 kOhm ±5%	1	
R8	C2-23-0,125-700 kOhm ±5%	1	
R9	C2-23-0,125-10 Ohm ±5%	1	
R10	C2-23-0,125-10 kOhm ±5%	1	
R11	C2-23-2-4,7 Ohm ±5%	1	
R13	C2-23-0,125-330 kOhm ±5%	1	

	Signature	Date	DM 2.893.001
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			ATF, group IRB-42

	Name		
	Transformers		
T1	TMC-20	1	
T2	TP112-7	1	
T3	TVS 90-PC15	1	
	Diodes		
VD1	W10M	1	*Philips*
VD2	KD212B	1	
VD3	RS407	1	*Philips*
VD4	KD226D	1	
VD6,VD7	KC106	2	
HL1	AL307A	1	
	Transistors		
VT1	KT940A	1	
VT2	KT872Б	1	

				Documentation		
A1			DM 2.893.01 AD	Assembly drawing		
A2			DM 2.893.001 E3	Electrical diagram		
A4						
				Details		
		1	DM 3.013.000	Bushing	2	
		2	DM 3.013.001	PCB	1	
		3	DM 3.013.002	Gasket	2	
		4	DM 3.013.003	Radiator	1	
		5	DM 3.013.004	Radiator	1	
				Standard products		
		6		Nut M3-6H.5.016	4	
		7		Screw M3-6g×10.56.016	6	
		8		Screw 3×10 ГОСТ 1491	2	
		9		Puck 3.02 ГОСТ 13371	10	
				Other products		
				Diodes		
		10		W10M (Philips)	1	VD1
		11		KD212B	1	VD2

.	.		Signature	Date
Developed	Dhlamini Mildred			
. Checked	Dozorska O.F.			

DM 2.893.001

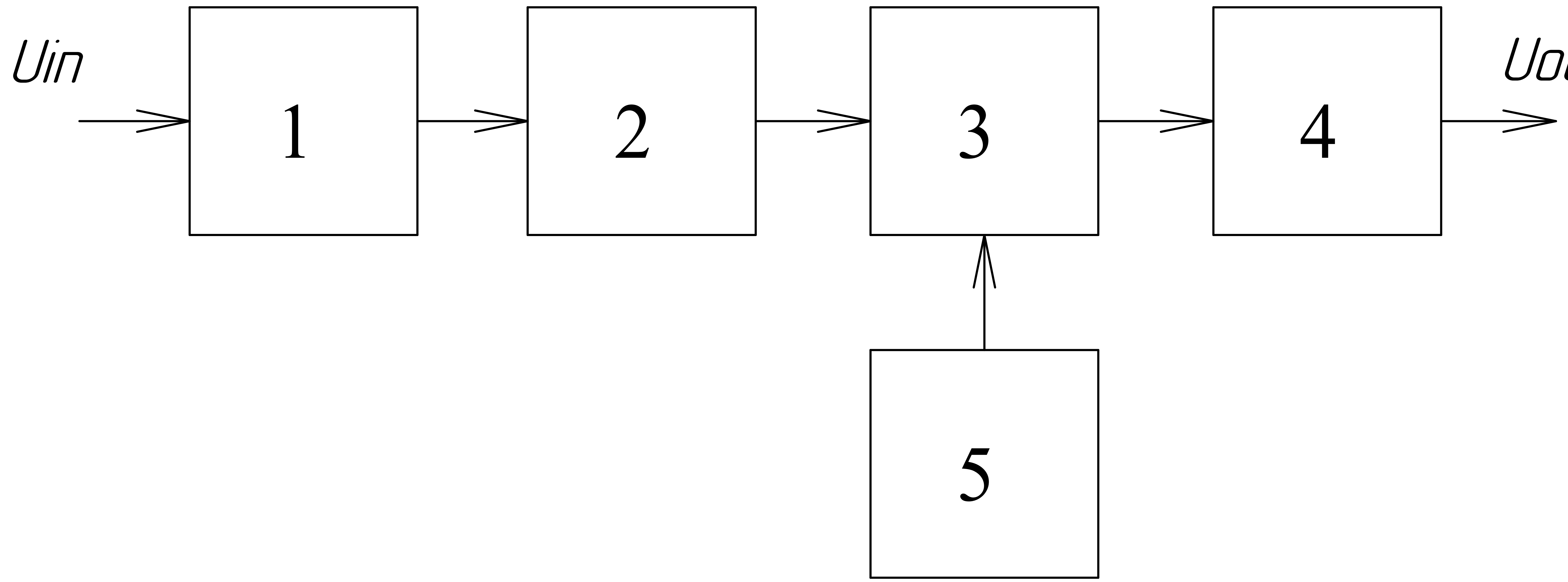
High-voltage power source of a medical ozone generator

1	3

ATF, group IRB-42

		12		RS407 (Philips)	1	VD3
		13		KD226D	1	VD4
		14		KC106	2	VD6,VD7
				<u>Capacitors</u>		
				K50-35		
				K73-9		
				K50-17		
				KVI-2		
		15		22 uF±20%-16V	1	C1
		16		0,01 uF ±5%-63V	2	C2,C3
		17		0,1 uF ±5%-630V	1	C4,
		18		1000 uF ±20%-25V	1	C5
		19		0.01 uF ±5%-630V	3	C6,C7,C9,
		20		200 uF ±20%-500V	1	C8
		21		1000 pF ±5%-630V	1	C10,C11
		22		0,047 uF ±5%-630V	1	C12
		23		140 pF ±10%-16kV	2	C13,C14
				<u>Microcircuits</u>		
		24		NE555	1	DA1
		25		KR142EN5A	1	DA2
				<u>Resistors</u>		
				C2-23-0,125		
				SP3-33-32-0,25		
		26		300 Ohm±5%	1	R1*
		27		1.9 kOhm ±5%	1	R1
		28		3.9 kOhm ±5%	1	R2
		29		1.9 kOhm ±5%	1	R3

		30		100 Ohm ±5%	1	R4
		31		33 kOhm ±5%	1	R5
		32		380 kOhm ±5%	2	R6,R12
		33		470 kOhm ±5%	1	R7
		34		700 kOhm ±5%	1	R8
		35		10 Ohm ±5%	1	R9
		36		10 kOhm ±5%	2	R10
		37		4,7 Ohm ±5%	1	R11
		38		330 kOhm ±5%	1	R13
		39		Switch ПКн-41	1	S1
					1	
				Transistors		
		40		КТ940А	1	VT1
		41		КТ872Б	1	VT2
				Transformers		
		42		ТМС	1	T1
		43		ТР112-7	1	T2
		44		TVS 90-PC15	1	T3
				LED		
		45		AL307A	1	HL1
		46		Fuse	1	FU1
				Materials		
				Paste КПТ-8		



1 - Rectifier
2 - Filter
3 - Switch
4 - Pulse transformer
5 - Generator of rectangular pulses

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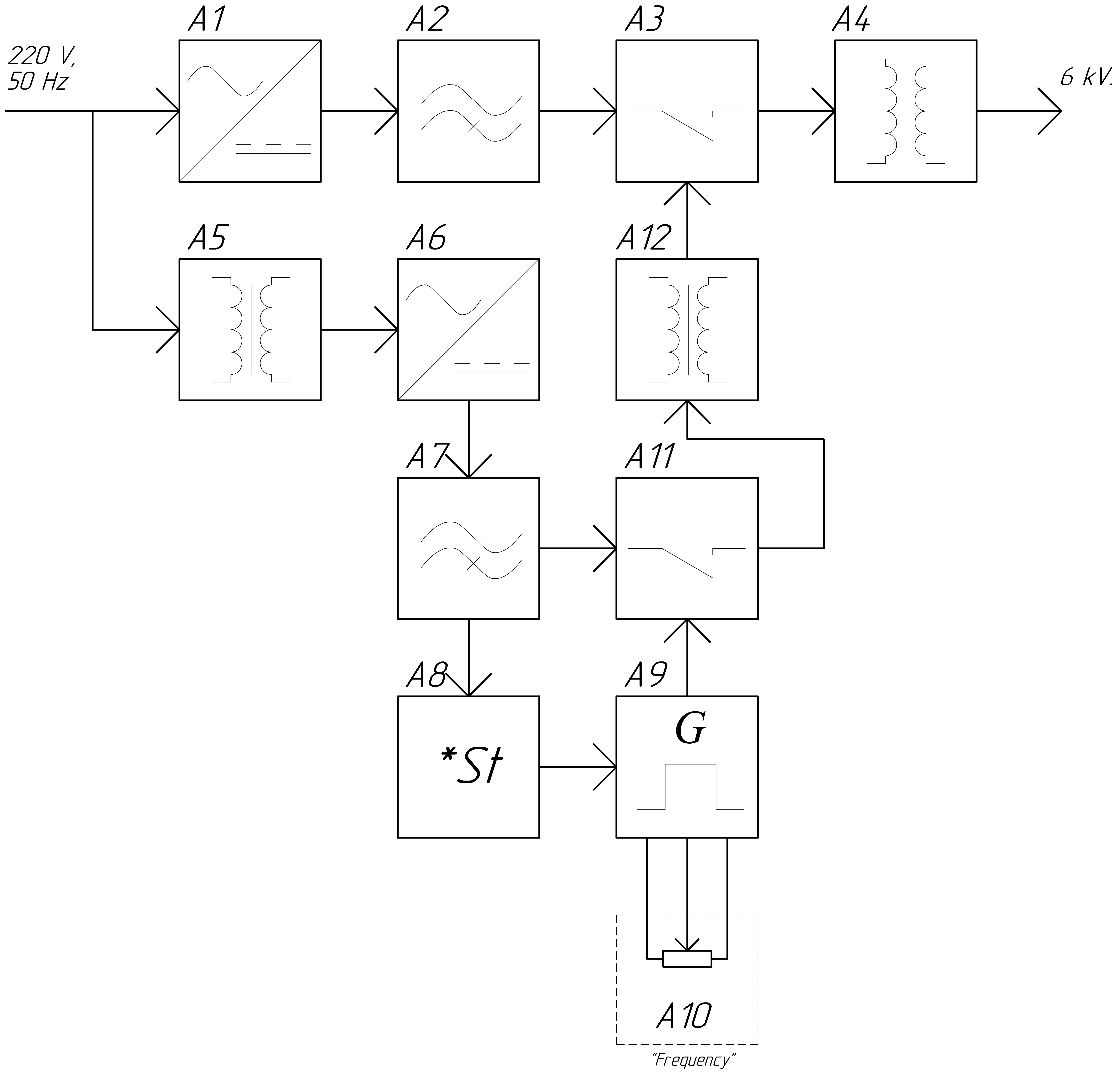

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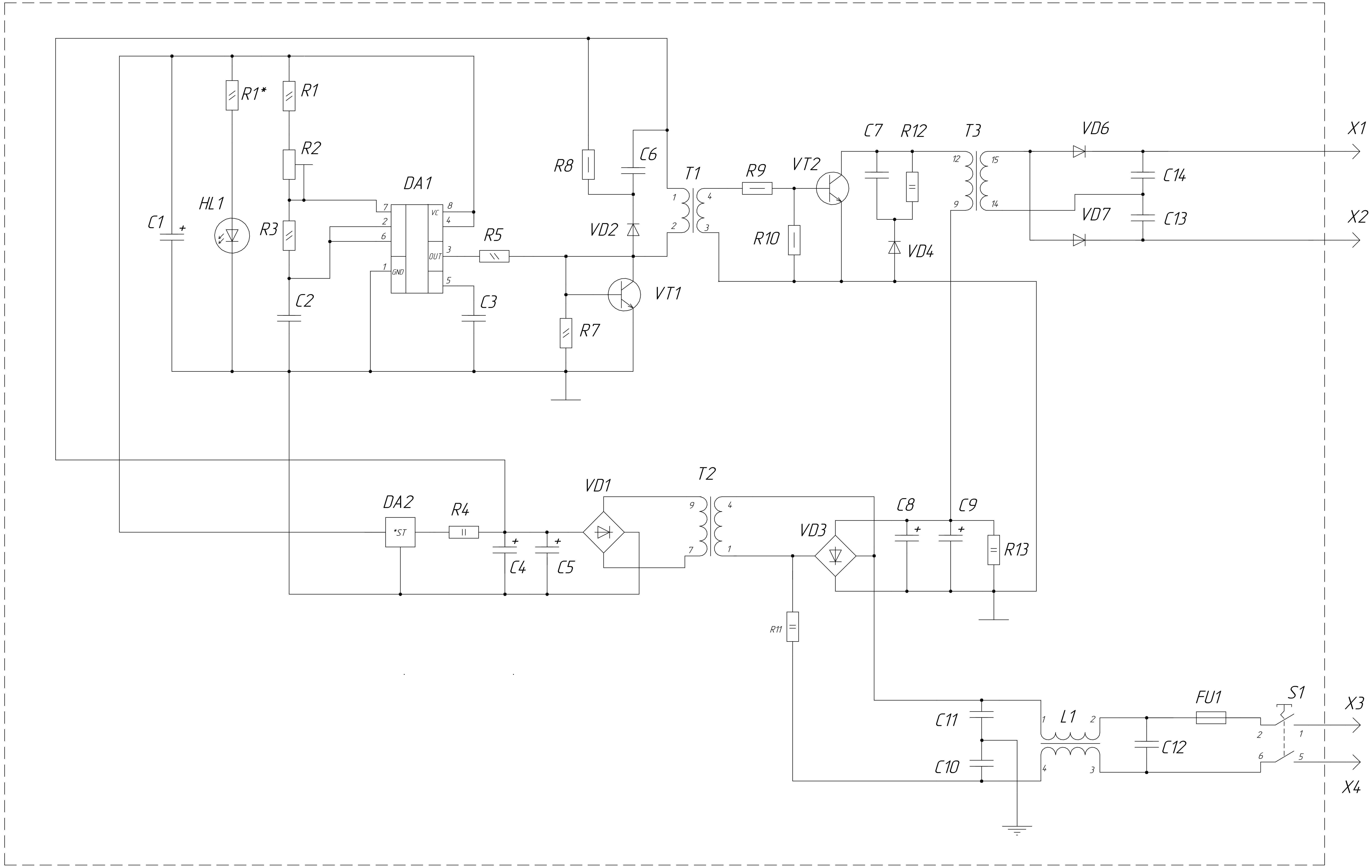

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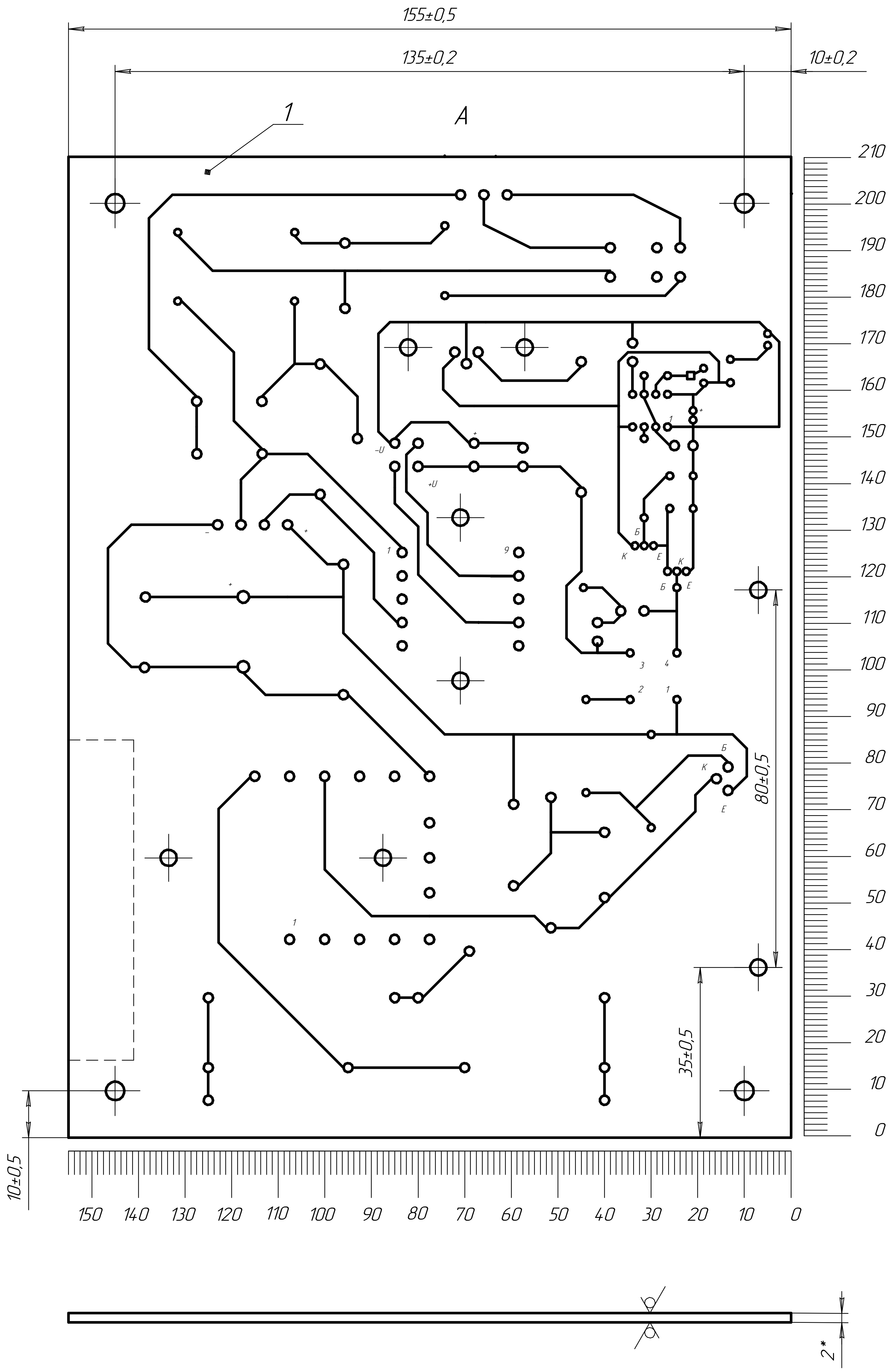
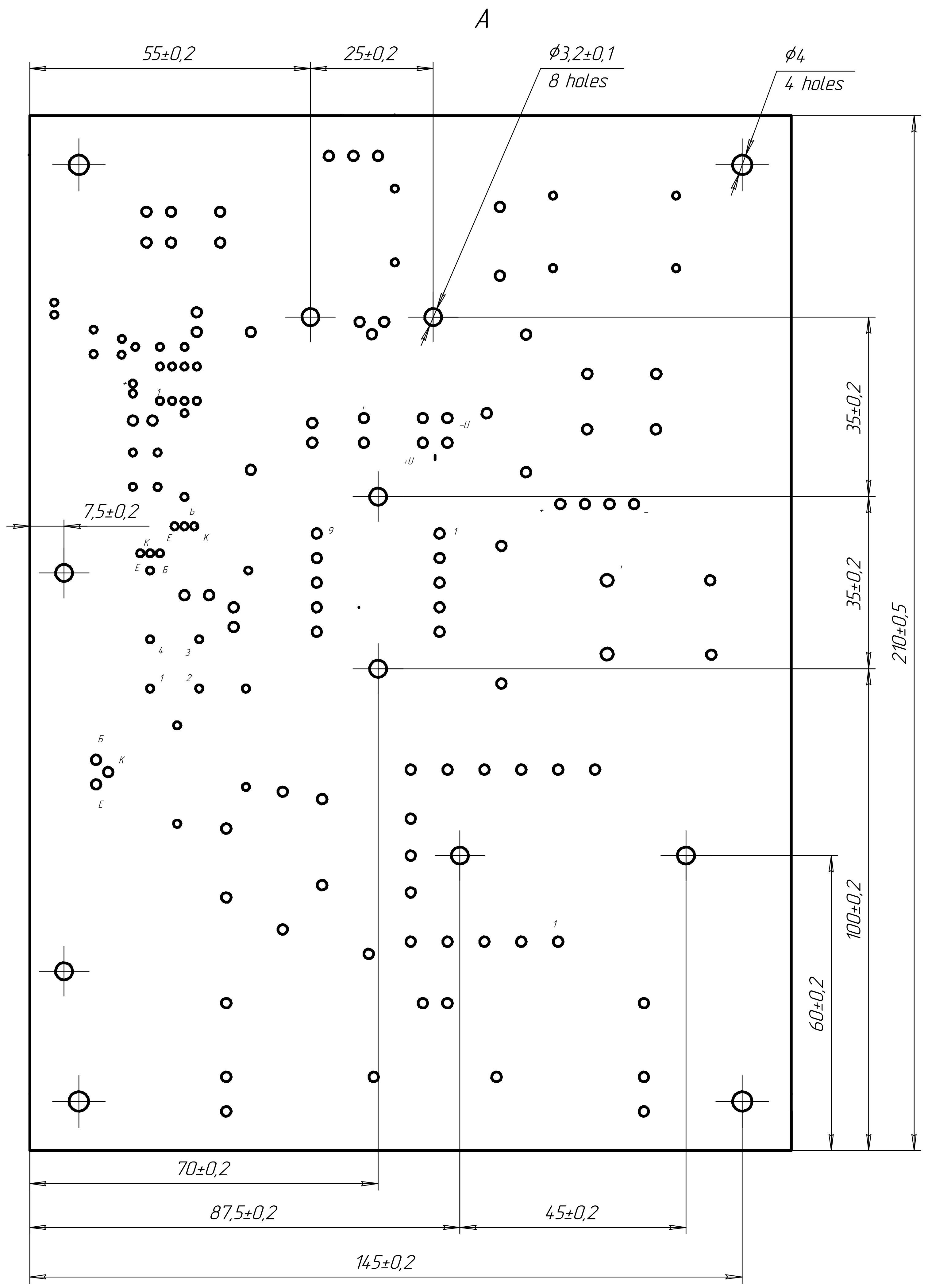
Формат A2

12,5 √(√)





Conditional marking holes	Diameter holes ,mm	The size of the contact pads	Availability metallization	Number
⌖	1	2,5	–	96
⌖	0,8	1,7	–	38

Изм.	Лист	№ докум.	Подп.	Дата	PCB	Лит.	Масса	Масштаб
Разраб.								2:1
Пров.								
Т.контр.						Лист	Листов	
Консульт.								
Н.контр.								
Утв.								

Перв. примен.

Справ. №

Подп. и дата

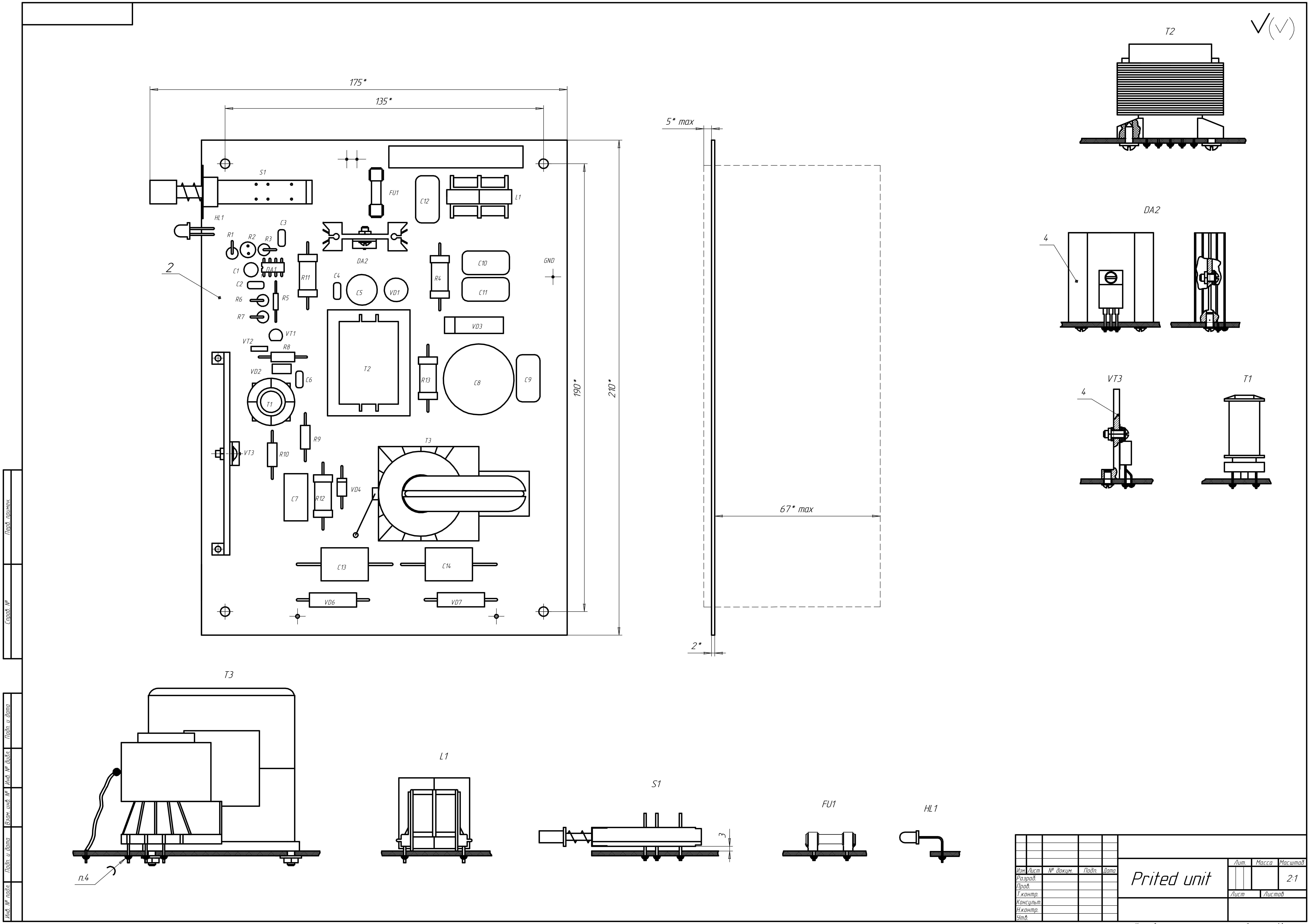
Инв. № дубл.

Взам. инв. №

Подп. и дата

Инв. № подл.

Копировал Формат A1


175*
135*
5* max
S1
FU1
C12
L1
HL1
R1
R2
R3
C3
DA2
C10
GND
2
C1
DA1
R11
C4
C5
VD1
R4
C11
C2
R6
R5
R7
VT1
VD3
VT2
R8
VD2
C6
T2
R13
C8
C9
T1
190*
210*
R9
T3
VT3
R10
VD4
C7
R12
67* max
C13
C14
VD6
VD7
2*
T2
DA2
4
VT3
4
T1
T3
L1
S1
3
FU1
HL1
п.4
Перв. примен.
Справ. №
Подп. и дата
Инв. № дубл.
Взам. инв. №
Подп. и дата
Инв. № подл.
Изм. Лист № докум. Подп. Дата
Разраб.
Пров.
Т.контр.
Консульт.
Н.контр.
Утв.
Prited unit
Лит. Масса Масштаб
2:1
Лист Листов
Копировал
Формат A1