**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: Medical photocatalytic device for air disinfection and purification

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

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

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# SUMMARY


Theme of qualification work: "Medical photocatalytic device for air disinfection and purification". Qualifying work of a bachelor // TNTU, ATF, group IRB-42. // Ternopil, 2023 //p.- , fig.- , table- , bibliog.- , appendix- .

Key words: photocatalytic device, air disinfection, printed circuit board.

In the qualification work, an overview of all stages of the life cycle of a medical photocatalytic device for disinfection and air purification was carried out. An analysis of the technical task was carried out, mathematical modeling of the operation of the medical photocatalytic device was carried out, a structural and functional scheme was built, an electrical diagram was built. The IR2156(S)PbF microcircuit was used as a PWM driver chip, and the parameters of the elements that set its operating modes were calculated.

The design section was completed, in which the selection of the element base was carried out, the design of the PCB, the printed unit was developed. When developing the device, the automated design system P-Cad 2006 was used. With the help of the P-Cad environment, the PCB was traced and the assembly drawing of the printed circuit was obtained.

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# INTRODUCTION

For several decades, the quality of the air has been modified by pollutants which can be of natural origin or of anthropogenic origin, that is to say linked to human activity. This change in air quality has been increased following the evolution and growth of industries ; which has evolved over time causing several misdeeds on the environment in general and on the air in particular.

Air pollution has significant effects on health and the environment, which generate significant costs for society. European law sets limit values for certain pollutants in the air based on epidemiological studies, conducted in particular by the World Health Organization. Despite a trend towards improving air quality over the past 20 years, these limit values are still not respected in several areas.

Particles are particularly harmful to health. They cause irritation and respiratory problems in sensitive people and are associated with an increase in mortality (respiratory conditions, cardiovascular diseases, cancers, etc.). They are also responsible for the dirt on buildings and monuments.

Major sources of air pollution are caused by fuels such combustion takes place in power stations using all kinds of fuels - coal, oil, gas, biomass or waste, District heating stations burn various kinds of fuel, production of electricity, alminuim, base metals smelter and refinery, zinc processing plants, cement works, fossil fuel vehicle gas emissions which today make up a major part of the fossil fuel users, 5-20% are Traffic intensity (more cars more pollution); amount of heavy traffic; traffic flow (slower traffic more pollution), ventilation If a previously open street is closed by addition of buildings on both sides the concentration of air pollutants will increase by some 70%, chemical, petroleum, mining, agro-food, and other industries of transformation.

Air pollutants are particles or dust in suspension (PM) whose primary particles, directly emitted into the atmosphere. They are mainly the result of all incomplete combustion linked to industrial or domestic activities, as well as transport. They are also emitted by agriculture (spreading, tillage, etc.). They can also be of natural origin (soil erosion, pollen, biomass fires, etc.).

Particles are classified according to their size

✓ particles with a diameter of less than 10 micrometers. They are retained at the level of the nose and the upper airways;

✓ particles with a diameter of less than 2.5 micrometers. They penetrate deep into the respiratory tract to the alveoli and can pass into the bloodstream.

Nitrogen chemistry (production of ammonium nitrate, etc.) or the use of nitrated products in industrial processes (glassware, etc.) are also emitters. Finally, the use of nitrogen fertilizers results in NOx emissions.

Emissions of human origin can locally become very largely preponderant.

Volcanoes and lightning are also likely to create favorable conditions for the formation of nitrogen oxides. Similarly, dry natural soils can emit nitric oxide during the biological process of soil nitrogen transformation.

Once in the air, nitric oxide (NO) becomes nitrogen dioxide (NO2), a gas that irritates the bronchial tubes and promotes asthma attacks and lung infections. People with asthma and young children are more sensitive to this pollutant.

NOx are also precursors of other pollutants: under certain climatic and sunlight conditions, they react with certain pollutants according to complex physico-chemical processes occurring in the atmosphere. They react in particular with volatile organic compounds to lead to the formation of tropospheric ozone or with ammonia (NH3).

Sulfur dioxide is produced from the combustion of fossil fuels. Some industrial processes also emit sulfur oxides (production of sulfuric acid, production of paper pulp, oil refining, etc.). They can also be emitted by nature (volcanoes).

This pollutant causes irritation of the mucous membranes, the skin and the respiratory tract (cough, respiratory discomfort, asthmatic disorders). It also promotes acid rain and degrades the stone.

Volatile organic compounds constitute a very large family of products such as benzene, acetone, perchlorethylene, etc. which are in the gas state or evaporate easily under standard temperature and pressure conditions during their usage.

Metallic elements (including Fe, Zn, Ni, As, Cr) in large doses can be very harmful. Other elements (Pb, Cd, Hg) have no beneficial effect and are only detrimental to life.Heavy metals can be inhaled directly or ingested by humans when the food chain is contaminated (soil, water, food). they can affect the nervous system, renal, hepatic and respiratory functions.

Ozone (O3) is a secondary pollutant, resulting from complex photo-chemical transformations between certain pollutants such as nitrogen oxides (NOx), carbon monoxide and volatile organic compounds. It is irritating to the respiratory system and the eyes and is associated with increased mortality rates during pollution episodes.

Ammonia (NH3) This is an irritating gas that has a pungent odor and burns the eyes and lungs. It is toxic when inhaled at high levels, even fatal at very high doses. It causes eutrophication and acidification of water and soil. It is also a precursor gas for secondary particles.

Polycyclic aromatic hydrocarbons (PAHs) result from incomplete combustion, the use of solvents, degreasers, and filling products for automobile tanks, cisterns. They cause irritation, a reduction in respiratory capacity and odor nuisance, Some are considered carcinogenic (benzene, benzo-(a)pyrene). They have a precursor role in the formation of ozone.

Following all the above, we have decided to provide possible solutions, and finally to improve the quality of the air, by installing an air purification device.

The technology of air disinfection and purification based on photocatalysis belongs to the field of the latest nanotechnologies. The essence of the method consists in the photocatalytic oxidation of harmful gaseous air pollutants and the destruction of pathogenic microorganisms on the surface of the photocatalyst under the influence of ultraviolet light of the soft "C" range (with a wavelength of 100 and 280 nm). Radiation of the "C" range is safe for humans and activates various photochemical processes, they are generally filtered out by the Earth's atmosphere, so they are not a major concern for human health.

The paper considers a disinfectant and air purifier designed for photocatalytic air disinfection from dangerous infections, its purification at the molecular level from harmful chemical pollution and dust.

The device is intended for air disinfection in  or without the presence of people, without having a negative impact on the human body, is not a source of hard UV radiation, ozone, does not ionize the air, does not require constant monitoring of the quality of the indoor air environment, has a replaceable filter for preliminary dust cleaning.

The disinfectant is used in medical and preventive facilities, epidemiological laboratories, pharmacies, research and medical facilities.

The purpose of the qualification work is to review all stages of the life cycle of a medical photocatalytic device for air disinfection and purification.

# 1 MAIN PART

## 1.1 Analysis of the technical task

In this qualification work, I review all stages of the life cycle of a medical photocatalytic device for disinfection and air purification, hereinafter referred to as the device.

The device is a closed-type irradiator, in which the bactericidal flow from ozone-free lamps is distributed in a small closed space, while air disinfection is carried out in the process of pumping it with the help of fans through a zone with sources of ultraviolet radiation and through a photocatalytic filter, which includes a porous medium with applied a photocatalyst (for example, a platinum nanocrystalline photooxidation catalyst).

The device has following requirements:

- supply voltage $Uc$ – (220±10%) V, frequency (50±5%) Hz;
- power consumption, no more that $P_c$ – 40 W (including power supply for electric fans);
- lamp supply – a sequence of rectangular pulses with frequency $f$ = 100kHz, amplitude – 308 V.
- operating temperature range $t°$ – +(5...35) $^0$C;
- lamp start and control units must be made in the form of pulse inverters to ensure lower weight and dimensions of the entire product.
- the device is stored in a closed room at a temperature of +5°C до +40°C;
- humidity change limits up to 80% at a temperature of +20°C;
- atmospheric pressure change limits of 80 kPa - 100 kPa.

The device must belong to the stationary equipment class of the portable usage group. It should be noted that the unit is used in a medical facility.

The average period of working for refusal should be at least 5 years.

## 1.2 Construction of a medical photocatalytic device for air disinfection and purification

### 1.2.1 Mathematical modelling of device operation

At the first stage of the life cycle, the construction of a medical photocatalytic device for disinfection and air purification is carried out. We will conduct a mathematical modeling of the photocatalysis process, which is the basis of the device's operation.

Photocatalysis is the process of changing the speed or excitation of chemical reactions under the influence of light in the presence of substances (photocatalysts) that absorb light quanta and participate in the chemical transformations of the reaction participants, repeatedly entering into intermediate interactions with them and regenerating their chemical composition after each cycle such interactions.

The efficiency of the photocatalyst is determined by the quantum yield of the reaction and the spectrum of the photocatalyst. The quantum yield of the photoreaction is the ratio of the number of molecules of the resulting product to the absorbed light quanta. For semiconductor particles as photocatalysts, several stages of the process are usually considered: a) absorption of light, b) diffusion of electrons and holes to the surface of the semiconductor, c) volumetric recombination of electrons and holes, d) surface recombination of electrons and holes, e) useful reactions of electrons and holes with adsorbed molecules.

The quantum yield of reaction $\Phi$ can be represented as follows:

$$\Phi = \eta_i \cdot \eta_r$$

where $\eta_i$ is the share of current carriers that reached the surface, $\eta_r$ is the share of current carriers that reached the surface and entered into a useful reaction (avoided surface recombination).

To calculate $\eta_i$ it is necessary to use equations describing the movements of randomly wandering particles. In general, the mentioned equations are rather complicated. However, in simple cases, when the particles can be considered spherical, there are no electric fields in their volume, and the rates of recombination processes and useful reactions are linear in the concentrations of electrons and holes, the solutions of the equations are obtained.

It is known from the experiment that for $TiO_2$ particles with a radius $r_0$ ~ 25 Å all current carriers come to the surface. However, in practice, $TiO_2$ powders with small particles are not always the most active. This can be explained by analyzing the factor $\eta_r$:

$$\eta_r = \frac{V_r}{V_{sr} + V_r}$$

Here $V_{sr}$ is the rate of surface recombination, $V_r$ is useful reaction rate. Factor $\eta_r$ can make a significant contribution to $\Phi$.

Activation of the photocatalysis process occurs under the action of ultraviolet radiation. For this, ultraviolet lamps are used, which are controlled by pulse start-up and control devices (pulse inverters). Let's consider the modeling of the main processes that take place in such inverters.

Let's present such an inverter in the form of a black box, as shown in Fig. 1.1.


Figure 1.1 – Representation of a pulse inverter in the form of a black box

The input voltage of the pulse inverter (Fig. 1.1) is the alternating voltage of the power supply network $U(t)_{in}$, which can be written through trigonometric functions as follows:

$$U(t)_{in} = U_0 \cdot \sin(\omega t) \qquad (1.1)$$

where: $U_0$ is amplitude value of the voltage in the power supply network – $U_0 = 308V$, $\omega = 2\pi f$, $f = 50Hz$.

Since the input voltage of the pulse inverter can be roughly considered a harmonic function, and the output voltage can be considered a sequence of rectangular pulses, by changing the width of which you can adjust the brightness of the air disinfector lamps and ensure smooth heating, it is necessary to first convert the alternating voltage into a constant one, then into a sequence of rectangular pulses and increase the power . Mathematically, such transformations can be described as follows:

1) transformation $|U(t)_{in}|$ describes the process of rectifying the input voltage;

2) transformation $\int_0^T |U(t)_{in}| dt$ describes the process of filtering (removal of the constant component) of the rectified voltage. T is the period of fluctuations of the input voltage.

3) the generation of rectangular pulses can be described as a multiplication of the received rectified voltage $\int_0^T |U(t)_{in}| dt$ on the Heaviside function *g(t)*,

periodically repeated (since the Heaviside function describes only one rectangular pulse). This is described by the expression: $\left(\int_0^T |U(t)_{in}| dt\right) \cdot g(t)$

4) multiplication $\left[\left(\int_0^T |U(t)_{in}| dt\right) \cdot g(t)\right] \cdot A$ describes the process of amplifying a sequence of rectangular pulses $\left(\int_0^T |U(t)_{in}| dt\right) \cdot g(t)$ by the amplitude in A times.

Then the operation of the DC pulse inverter can be described by the expression:

$$U(t)_{вих} = \left[\left(\int_0^T |U(t)_{in}| dt\right) \cdot g(t)\right] \cdot A \qquad (1.2)$$

Expression (1.2) can be considered a mathematical model of a pulse inverter, since it describes the sequence of actions that can be used to obtain the output from the input signal, or the law by which the input voltage changes to the output. Expression (1.2) can also be called the transfer function of the inverter when it is depicted as a black box.

1.2.2 Functional synthesis of a medical photocatalytic device for air disinfection and purification

The function of the device is reflected in its structural diagram, which should show the principle of operation of the product in general form. The diagram shows all the main functional parts of the product, as well as the main relationships between them. The construction of the scheme should give a visual representation of the sequence of interaction of functional parts in the product. The direction of the processes taking place in the product is indicated by arrows on the interconnection lines.

On the basis of the mathematical model, we make a structural diagram, which is shown in fig. 1.2.

According to fig. 1.2, the input AC voltage of 220 V, 50 Hz is fed to the anti-interference filter (1), which blocks the interference that occurs during the operation of the device. Next is the standard two-half cycle rectifier (2), the simplest capacitive filter or power factor corrector. Sometimes an inductive-capacitive anti-interference filter (3) may be missing (a single non-polar capacitor of small capacity is usually used instead).

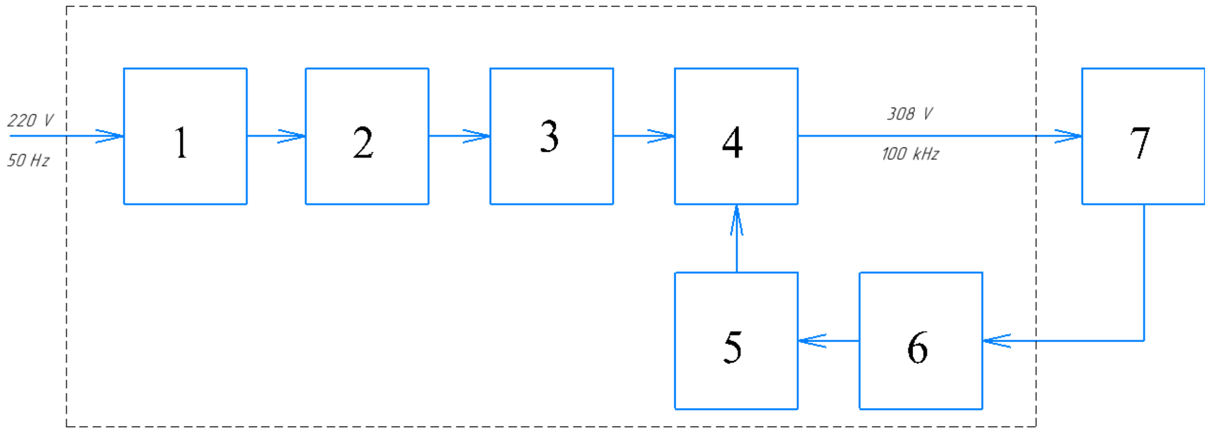



Figure 1.2 – Structural diagram of a medical photocatalytic device for air disinfection and purification: 1 – anti-interference filter; 2 – rectifier; 3 – filter; 4 – switch; 5 – pulse-width modulation (PWM) driver; 6 – feedback loops; 7 – ultraviolet lamp

The commutator (4) converts the rectified voltage into high-frequency pulses, controlled by the signal from the PWM driver (5). These high-frequency pulses feed the lamp (7). Block (6) is introduced to control the serviceability of the lamps (the state of the filament coil – burned out/not).

Based on the structural diagram, we will build a functional diagram.

1.2.3 Structural synthesis of the of a medical photocatalytic device for air disinfection and purification

The structure of the device scheme is reflected in its functional scheme and is intended to explain the processes taking place in the product under various predicted modes. The diagram shows the functional parts of the product and the connections between them. Functional parts and connections between them are depicted in the form of graphic symbols.

Consider the operation of the inverter and the control circuit as the most responsible units of the device. The inverter converts the rectified voltage into high-frequency pulses that power the lamp. In the scheme of fig. 1.4, point "A" is connected with the help of transistor switches VT1 and VT2 periodically either to the supply voltage (Uin = 310 V) or to the "common output" of the circuit.

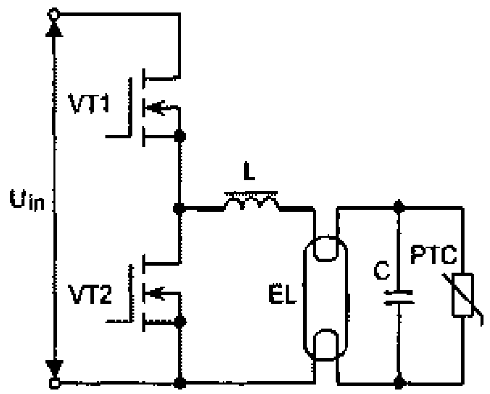



Figure 1.3 – Inverter construction version

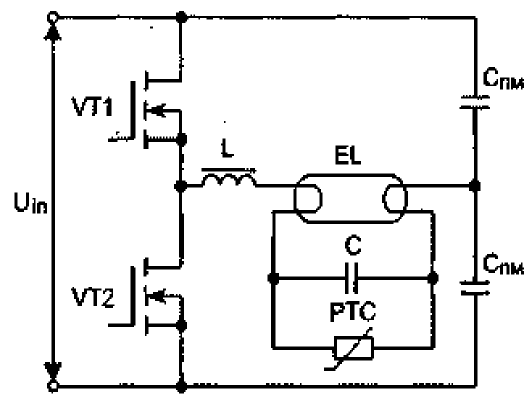



Figure 1.4 – Another version of the inverter

As a result, unipolar high-frequency voltage pulses occur at point "A" (the switching frequency is usually within 20 ... 120 kHz), which, firstly, light the lamp, and secondly, prevent the gas from deionizing; the light emitted by the lamp will be even. With this method of start-up and control, a false start is completely excluded, since the electrodes of the lamp are guaranteed to be switched to a constant voltage, the dips of which are fundamentally absent. By adjusting the frequency of switching pulses, it is possible to adjust the brightness of the glow. In addition, the dimensions of the inductance L are reduced. A half-bridge circuit (Fig. 1.4) is sometimes used as an electronic ballast implementation option. However, the first option is more common today.

To light a lamp, you need to heat its electrodes. Since there is no starter in the circuit of the electronic ballast, it is necessary to somehow first close the power circuit so that the flowing current heats up the electrodes, and then turn off the starting circuit.

Based on the structural diagram, we build the functional diagram shown in fig. 1.5.

The functional circuit includes the AC to DC input converter (block A1), the inverter power switches (blocks A2 and A3), the pulse-width modulation (PWM) driver (block A4), storage chokes (blocks A5 and A6) and the L1 and L2 lamps themselves.

On resistors R1-R4, a sensor for the state of the spiral of UV lamps is made. Resistors R3, R4 are connected to the power source. From lamp spirals, the opposite terminals of which are connected with a common wire. The other terminals of resistors R1, R2 are connected together and the signal from them is fed to the enable input of the PWM driver. This circuit works as follows: both pairs of resistors form voltage dividers. The resistances of the resistors must be large enough. However, the resistance of the spiral of UV lamps is much lower than the resistance of these resistors. When each UV lamp is working, the connection nodes of the pairs of resistors R1, R3 and R2, R4 are connected to a common wire. The signal at the output of dividers R1, R3 and R2, R4 is practically zero. The driver works fine. If the spiral of any lamp is broken, a high-amplitude signal will be generated at the output of the divider and will turn off the driver.

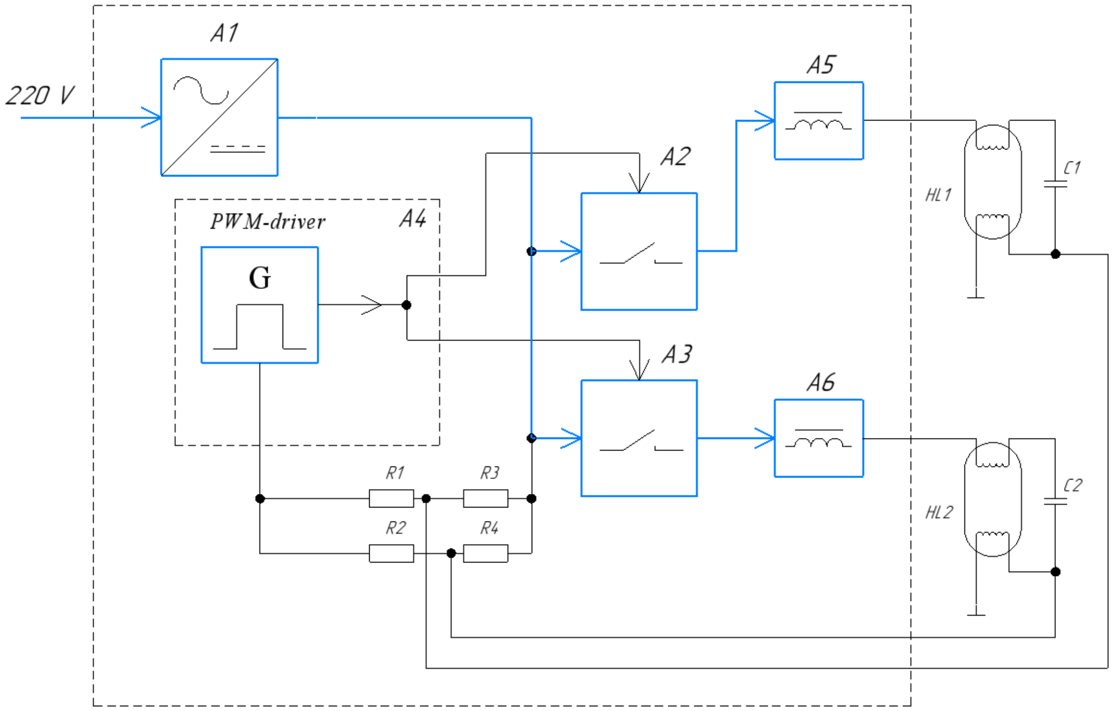



Figure 1.5 – Functional diagram of a medical photocatalytic device for air disinfection and purification

On the basis of the functional diagram, we build the electrical principle diagram of the device.

1.2.4 Synthesis of the electrical principle scheme

The basic electrical diagram is the most complete electrical diagram of the product, which depicts all electrical elements and devices necessary for the implementation and control of specified electrical processes in the product, all connections between them, etc.

On the basis of the functional scheme, we build the electrical principle diagram of the medical photocatalytic device for disinfection and air purification. Accordingly, it includes an anti-interference filter made on the choke L1, a rectifier made on the diode bridge VD1, and a capacitive filter made on capacitors C1 and C2. The DA1 chip has a PWM driver for controlling the inverter power switches - transistors VT1, VT2.

The IR2156 microcircuit was used as a PWM driver.

In the phase of energy transfer to the load, the voltage between the drain and the drain of the key transistors VT1, VT2 consists of the supply voltage and the current reaction voltage in the storage chokes L2, L3.

The amount of overvoltage can be twice the value of the supply voltage and even more. The voltage on the key transistors rises, albeit for a short time: a significant inductive emission appears. The stabilization circuit will, of course, track the change in load, i.e. reduce the duty factor or increase the conversion frequency. However, the response of the control scheme is never instantaneous, as it always has some inertia. It is fundamentally impossible to track short inductive emissions. In fig. 1.6 shows typical methods of protecting keys from overvoltage.

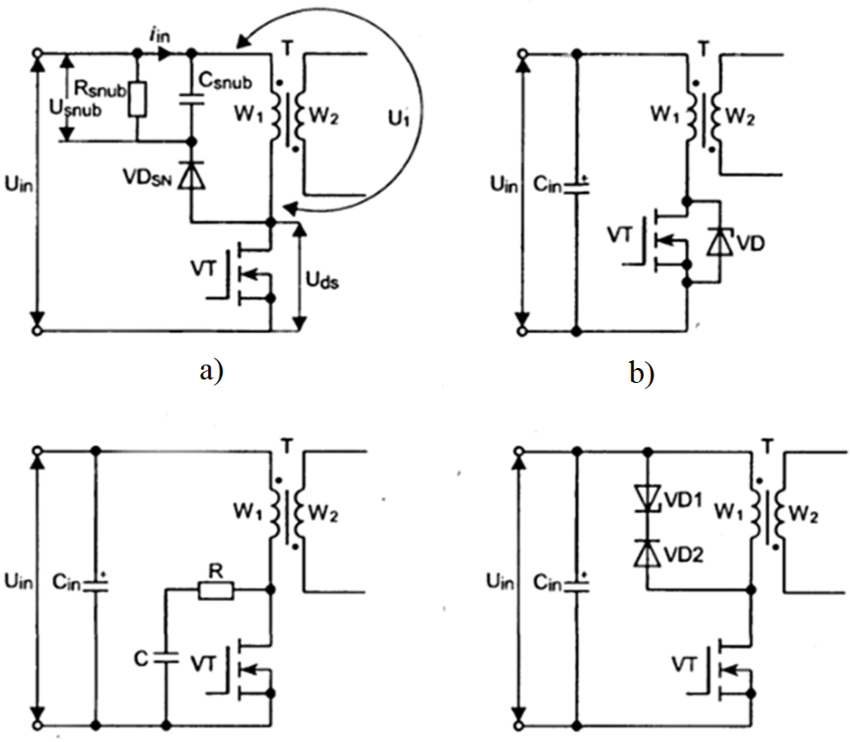



Figure 1.6 – Protection of a key transistor against a potential breakdown: a) locking link; b) the use of a suppressor (reverse-switched zener diode); c) a snubber (RC link) in the sink-leakage circuit; d) limiter of inductive emissions

The work uses power transistor switches that have an internal built-in protective diode - a suppressor.

1.2.5 Element calculations

The purpose of parametric synthesis is to calculate the nominal values of the elements of the electrical principle circuit. We will calculate the nominal values of the elements of individual circles of the circuit.

The VD1 diode bridge rectifies the mains voltage, so the reverse voltage of each diode must be greater than the amplitude value of the mains voltage, i.e. more than 308 V. We choose diodes of the DF10S type, for which the maximum reverse voltage is equal to 600 V, direct current – $i_d = 2$ A, the maximum direct current in the pulse (with the duration of the pulse $\tau_m < 10 мс$) $i_{d.m} = 35$ A.

The capacity of the capacitor C1 is found by the formula:

$$C1 = \frac{P_n}{200 \cdot K_n \cdot U_s^2} \quad (1.3)$$

Here $P_n$ – nominal power consumption (36 W),

$K_n$ – ripple coefficient,

$U_s$ – supply voltage (308 V),

$$C1 = \frac{36}{200 \cdot 0{,}1 \cdot 308^2} = 18{,}9(\mu F).$$

Let's take $C1$=22 $\mu F$.

The capacity of capacitor $C2$, which is a high-frequency filter, is assumed to be 0.1 $\mu F$.

Varistor $R2$ is used to limit current consumption by lamps in case of failure of inductors or power transistor switches. In this case, the consumption current will begin to increase, the dissipation capacity of the varistor will begin to increase, its resistance will begin to increase and, accordingly, this will lead to a decrease in the current flowing through it. Varistors are produced with standardized characteristics and are selected depending on the operating voltage and power consumption. Than we choose a varistor with a dissipation power of 1 W and a resistance of 4.7 Ohms.

Since there are capacitive filters (elements C4, C6 and C5, C7) after the diode bridge VD1-VD4, at the initial time they are short-circuited, and the current that will flow through the diodes of the bridge can disable them. To eliminate this possibility, resistor R1 is connected in series with capacitor C1, which is designed to limit the current through the diodes when the device is turned on. According to the recommendations given in the literature, the resistance of the resistor R1 is selected in the range of 1...4.7 Ohm. We choose the resistance of the resistor equal to 4.7 ohms. At the same time, the current that will flow through it at the initial moment of time will be:

$$i_{R1}=U/R1=220/4{,}7=47\ (A). \qquad (1.4)$$

The technical conditions of the rectifier allow to increase the unit current pulse by 1.57 times when working on a capacitive load, that is, in our case $i_{пр.м} = 35 \cdot 1{,}57 = 54{,}95 A$. Thus, the use of resistor R1 will ensure the normal operation of the diode bridge VD1.

Let's calculate the dissipation power of resistor R1. Let the power consumption of the unit be 40 W. With a supply voltage of 220 V, the consumption current will be:

$$P=U \cdot I \qquad (1.5)$$

$$I=P/U=40/220=0{,}19\ (A).$$

Accordingly, the power will be dissipated on the resistor R1:

$$P=U_{R1} \cdot I=I^2 \cdot R1=0{,}19^2 \cdot 4{,}7=0{,}18\ (W).$$

At the moment of start-up, the voltage on resistor will be 220 V. Then the dissipated power will be equal to:

$$P = U_{R1}^2 / R1 = 220^2/4{,}7 = 10297 \text{ (W)}.$$

However, such power is dissipated on the resistor less $\tau_м < 10ms$. The resistor itself does not have time to heat up. We take its power, taking into account the ambient temperature and power reserve, equal to 1 W.

We will calculate the PWM elements of the IR2156 driver.

The driver has the ability to set the value of the time delay between the edges of the pulses at the HO and LO outputs. It is set by capacitor C6 and determined from the formula:

$$t_{DT} = C6 \cdot 2000(s). \quad (1.6)$$

It is known that the switching time of field-effect transistors is less than 0.5 μs, and the use of a time of about 10 μs is practically not used in pulse technology. Therefore, we choose the delay time at the level of 1 μs. Let's find the value of capacitor C6:

$$C6 = \frac{t_{DT}}{2000} = \frac{1 \cdot 10^{-6}}{2000} = 0.5 \cdot 10^{-9} \text{ (F)}.$$

Let's take the value of capacitor C6 equal to 470 pF.

The operating frequency of the PWM driver is set by capacitor C6 and resistor R4, and is determined by the formula:

$$f = \frac{1}{2 \cdot C6(0.51 \cdot R4 + 1475)} \text{ (Hz)}. \quad (1.7)$$

According to the passport data for the IR2156 chip, its typical operating frequency should be 100 kHz. Let's find the resistance of the resistor R4 according to the formula:

$$R4=\frac{1}{1.02\cdot C6\cdot f}-2892=\frac{1}{1.02\cdot 470\cdot 10^{-12}\cdot 100\cdot 10^{3}}-2892\approx 17967\ \text{(Ohm)}.$$

Let's take the resistance of the resistor R4 equal to 20 kOhm.

The resistance of the resistor R6 can be found by the formula:

$$R6=\frac{\left(\frac{1}{1.12\cdot C6\cdot f}-3333\right)\cdot R4}{R4-\left(\frac{1}{1.12\cdot C6\cdot f}-3333\right)}=\frac{\left(\frac{1}{1.12\cdot 470\cdot 10^{-12}\cdot 100\cdot 10^{3}}-3333\right)\cdot R4}{100\cdot 10^{3}-\left(\frac{1}{1.12\cdot 470\cdot 10^{-12}\cdot 100\cdot 10^{3}}-3333\right)}\approx 100(\text{k}Ohm)$$

Capacitors C3 and C4 are calculated according to expression (1.3). At the same time, it is taken into account that the power consumed by the microcircuit will be no more than 5 W, and the supply voltage is 12 V. Therefore, the capacity of the capacitor will be equal to 22 μF, and the capacitor C4 will be 0.1 μF.

The ratings of the remaining elements of the PWM driver harness are selected according to the recommendations given in according to the network voltage - 210-230 V and the network frequency - 50 Hz.

Resistors R8, R9 serve to limit the current in the source circuits of transistors VT1 and VT2. The amplitude of the signal at the output of the PWM driver is 5 V, the opening voltage of the transistor switches is 4 V. Accordingly, resistors R8, R9 should drop by 1 V each. The current of opening the transistor switches should be 40-50 mA. Accordingly, the resistance of resistors R8, R9 will be:

$$R8=R9=U/i_R=1/0,05=20\ (\text{Ohm}).$$

Let's take the resistance of resistors R8, R9 equal to 22 Ohms.

Resistor R11 limits the current through the transistor switches and its resistance is determined from the condition that the current through it will be equal to 0.2 A (40 W, 220 V), and is found by the formula:

$$R6=\frac{1,25}{I}=\frac{1,25}{0,2}=6,25(Ohm).$$

We take the resistance of resistor R6 equal to 5.6 ohms.

Accordingly, power will be dissipated on resistor R6:

$$P=U_{R6}\cdot I=I^2\cdot R1=0,2^2\cdot 5,6=0,28\ (\text{W}). \qquad (1.8)$$

We take its power, taking into account the ambient temperature and power reserve, equal to 1 W.

The nominal values of the remaining elements of the electrical principle scheme are calculated in a similar way.

## 1.3 Design of the device

### 1.3.1 Selection of elements

The selection of the element base can be error-prone:

- rough, which lead to failure at the first start;
- errors that reduce the service life of the equipment.

Gross errors lead to losses and delays in setting up the equipment, but they are not the most dangerous because they are immediately visible.

Errors that reduce the efficiency and reliability of the device are more dangerous, because they are noticed already during the operation of the device, therefore it is advisable to warn them even during the design of the device.

For most components of electrical devices, the factory sets limit values (*I, U, f, t*) and these limit values are usually set depending on each other.

The ability to choose electrical components taking into account all existing parameters is an important professional requirement for people who develop equipment.

To select elements for the device scheme, you need to know the parameters, characteristics, overall dimensions and mass of radio elements.

Modern radio elements must meet the following requirements:

- high reliability;
- small dimensions and weight;
- low consumption current;
- keep your parameters for a long time;
- be cheap;
- be subject to automation during installation.

The IR2156 microcircuit is used as a PWM driver, which is half-bridge driver with a programmable generator and a logic circuit for obtaining a complete integrated converter control circuit.

Selection of types of resistors and capacitors. The following components were selected for the device, taking into account economy, versatility, miniaturization and simplicity:

From a large number of resistors, carbon film 1/8W resistors 5% were chosen because they are the best according to their parameters (dissipation power, overall dimensions, working time before failure, operating temperature), they are the most common and cheaper compared to their counterparts.

Intended for operation in electric circuits of direct, alternating and pulsed currents.

W10M, FR107, 1N4148, 1N4742A diodes were selected as diodes.

The main technical characteristics of the diode bridge W10M:

- maximum constant reverse voltage, V……………………………1000;
- maximum direct (rectified for a half-cycle) current, A…………..….1;
- maximum permissible direct impulse current, A………………...….35;
- maximum reverse current, μA…………………………….……..10;
- working temperature, $^{0}$C …………………… ………… -55 ... 125.

1N4742A diodes are silicon. Specifications:

- maximum constant reverse voltage, V……………….………..600;
- maximum pulse reverse voltage, V…………………………..…720;
- maximum direct (rectified for a half-cycle) current, A………..…..1;
- the maximum permissible direct impulse current, A………………30;
- maximum reverse current, μA……………………………..……5;
- maximum recovery time, μs……………………………..…0.250;
- total capacity Sd, pF…………………………………………...5;
- working temperature, $^{0}$C…………………………………….. -65 ... 150.

FR107 diodes are silicon, ultra-fast. Specifications:

- maximum constant reverse voltage, V…………………………...200;
- maximum pulse reverse voltage, V………………………………600;
- maximum direct (rectified for a half-cycle) current, A…………..4;
- the maximum permissible direct impulse current, A……………..125;
- maximum reverse current, μA ……………………………..….10;
- maximum time of reverse recovery, μs …………………………..0.075;
- total capacity Sd, pF …………………………………………55;
- working temperature, $^{o}$C …………………………………… -65 ... 175.

Diodes 1N4148 pulse, silicon, epitaxial-planar.

The main technical characteristics of 1N4148 diodes:

- maximum reverse voltage, V……………………………………… 50;
- maximum direct current, mA……………………………………...100;

- maximum operating frequency, MHz…………………………..….100;
- operating temperature range, °C…………………………... -60 … +85.

Transistor IRF830 - powerful transistors.

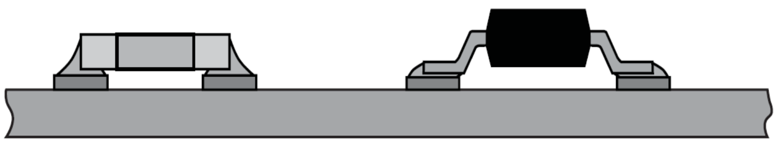
The main technical characteristics of the IRF830 transistor:

- maximum drain-leakage voltage, V…………………………………..400;
- maximum gate-drain voltage, V……………………………………....20;
- maximum current, A………………………………………………….3,3;
- the maximum dissipated power of the collector, W…………….…...50.

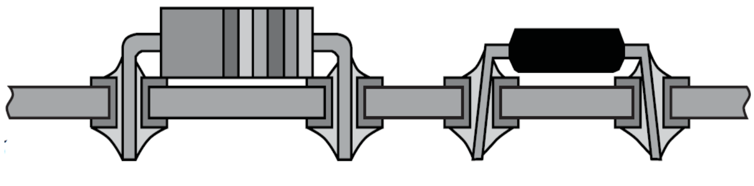
The selected elements will ensure the reliability and efficiency of the medical photocatalytic device for disinfection and air purification.

1.3.2 PCB development

Let's look at the design features of the device being developed. The most common today is the so-called SMT component installation technology (Surface Mounted Technology) (Fig. 1.7, b). However, the work uses the technology of mounting component leads in metallized holes (PTH - Plated Through Hole), which is shown in fig. 1.7, b.



a)



b)

Figure 1.7 – Methods of installing elements on printed circuit boards: a – surface mounting (SMT mounting); b - installation of terminals in holes

Production of electronic modules faces the question of choosing the optimal configuration of the technological line: assembly modules (installation of electronic components), soldering, control, correction of production defects, production certification. It is natural for this choice to use well-known optimization criteria: maximum productivity, minimal capital investments, the ability to quickly reconfigure the line when switching from one type of module to another, the ability to implement modules with various assembly schemes, technological assurance of quality and reliability.

All the variety of designs of electronic modules is reduced to six types of assembly. Each type corresponds to a certain sequence of operations implemented by technological lines. Such diversity is due to the fact that the module developer does not always take into account the need to optimize the assembly in order to minimize the number of operations and reduce production costs. But in a number of cases, this is justified by the need for the maximum density of the layout of electronic products, where miniaturization is the main design task.

Types of assemblies can be classified according to their designs or according to the technological route of their implementation. But since familiarization with the object of production begins with the analysis of the project, we will present the classification of assembly types from the positions of the placement of components and their outputs on the mounting base (circuit board).

The work uses type 1A assembly of elements (Fig. 1.8). Components with outputs in holes (PTH-components) are installed on one side of the mounting base (Fig. 1.8).

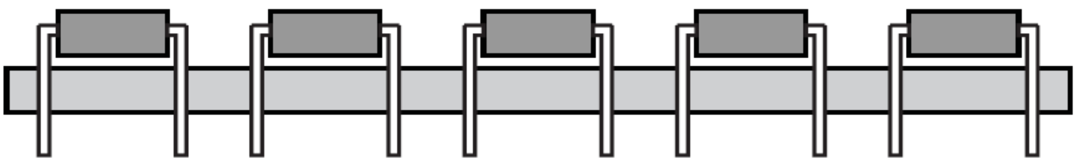


Figure 1.8 - Layout of type 1A

The element base used is given in the appendices - in the specification. It includes 11 non-electrolytic capacitors with two case sizes and 2 electrolytic capacitors with two case sizes, 18 resistors with three case sizes. Also, one microcircuit with a DIP-14 housing type and one microcircuit with a DIP-8 housing type are used in the block. Also, 10 diodes with two standard housing sizes are used in the design of the printed unit. Transistors are used with the TO220 housing type. Most elements can be installed in an automated way. Electrolytic capacitors are additionally installed on gaskets with gluing.

As a result of the calculation of the printed circuit board, the dimensions of the elements of the conductive pattern are determined: the nominal dimensions of the diameters of the mounting holes, the minimum diameters of the contact pads, the minimum distances for a given number of conductors between two holes.

The nominal dimensions of the main parameters of the board drawing on the drawing, depending on the accuracy class, are given in Table 1.1. The values of the main parameters of the drawing on the finished board should be within the tolerance for the nominal size.

The accuracy class of the board is characterized by the smallest density of the conductive pattern:

- the 3rd class of accuracy of the board is characterized by the possibility of conducting one printed conductor between the contact pads of the mounting holes with a diameter of 0.8 mm;

- the 4th accuracy class is characterized by the possibility of two printed conductors between the contact surfaces of the mounting holes with a diameter of 0.8 mm;

- 5th accuracy class is characterized by the possibility of conducting three printed conductors between the contact pads of mounting holes with a diameter of 0.8 mm or one printed conductor between the contact pads placed in 1.25 mm increments.

Table 1.1 – The value of the main parameter of the board pattern, mm

| The name of the main parameter of the board pattern | | The value of the main parameter of the drawing in the bottleneck for the board of the accuracy class | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 |
| The width of the printed conductor | The nominal value on the drawing, not less | 0,55 | 0,35 | 0,23 | 0,15 |
| | Limit deviation | +0,10<br>-0,15 | +0,05<br>-0,15 | +0,05<br>-0,10 | ±0,04 |
| | The minimum permissible value (for the option of setting the dimensions of the non-conductive pattern) | 0,4 | 0,2 | 0,13 | 0,11 |
| The distance between the elements of the leading pattern | The minimum permissible value on the drawing | 0,4 | 0,2 | 0,13 | 0,10 |
| | Minimum value (for trace calculation) | 0,5 | 0,325<br>0,275 | 0,235<br>0,27 | 0,21<br>0,16 |
| The width of the element of the non-conductive pattern (for the option) | Nominal value on the drawing, no less | 0,5 | 0,275 | 0,235 | 0,16 |
| setting the dimensions of a non-conductive drawing | Limit deviation | +0,15<br>-0,10 | +0,125<br>-0,075 | +0,10<br>-0,05 | ±0,06 |
| Warranty belt of the contact pad for a non-metallized hole | Nominal value for calculating the diameter of the contact pad | 0,5 | 0,45 | 0,4 | 0,35 |
| Contact pad warranty belt for metallized hole | Nominal value for calculating the diameter of the contact pad | 0,45 | 0,35 | 0,25 | 0,25 |
| Contact pad diameter | Nominal value on the drawing, no less | Table 1.3, table 1.4 | | | |
| | Limit deviation | +0,10<br>-0,15 | +0,05<br>-0,15 | +0,05<br>-0,10 | ±0,04 |

Taking into account the above, we choose the second class of accuracy for the printed drawing.

When calculating the tracing of the conductive pattern both in the narrow place and in the free space, it is necessary to use the nominal dimensions of the width of the printed conductor, the distance between the elements of the conductive pattern and the nominal diameters of the contact pads.

We will choose the step of the coordinate grid depending on the accuracy class of the printed circuit board. The value of the step of the coordinate grid is given in the table. 1.2

Table 1.2 - Step of the coordinate grid

| Accuracy class | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Grid step | 2,5; 1,25 | 2,5; 1,25; 0,625 | 2,5; 0,5 | 2,5; 0,3125 |

Accordingly, we accept the step of the coordinate grid of 1.25 mm for the second class of accuracy.

The centers of the transition holes must be placed in the nodes of the coordinate grid along the tracing line. It is recommended to place the centers of the fastening holes in the nodes of the coordinate grid. It is recommended to place the centers of metallized fastening holes in the nodes of the coordinate grid.

We will calculate the diameters of the mounting and transition holes and the dimensions of the contact pads depending on the selected accuracy class. The diameters of the mounting holes are given in table 1.3.

In order to increase the reliability and resistance of the printed circuit board to the action of mechanical loads, the metallization of the holes was used in the work, which will improve the fixation of the elements on the printed circuit board. The nominal diameter of the metallized hole, depending on the board thickness, should not be less than the value given in table 1.4.

Table 1.3 – Mounting hole diameters, mm

| The maximum diameter of the electroradio-element (ERE) | Cross-sectional shape of the ERE output | The diameter of the unmetallized hole | | The diameter of the metallized hole | |
|---|---|---|---|---|---|
| | | Board accuracy class | | | |
| | | 2 | 3-5 | 2 | 3-5 |
| Up to 0,4 | Round | 0,7±0,1 | 0,7±0,05 | $0,6_{\_0,05}^{+0,1}$ | $0,6_{-0,05}^{+0,08}$ |
| 0,5 | Rectangular | | | | |
| Від 0,4 до 0,6 | Round | (0,8±0,1) | 0,8±0,05 | $0,8_{-0,05}^{+0,1}$ | $0,8_{-0,05}^{+0,08}$ |
| 0,5-0,7 | Rectangular | 0,9±0,1 | (0,9±0,05) | | |
| 0,6-0,8 | Round | (1,0±0,1) | (1,0±0,05) | $1,0_{-0,05}^{+0,1}$ | $1,0_{-0,05}^{+0,08}$ |
| 0,7-0,9 | Rectangular | 1,1±0,1 | 1,1±0,05 | | |
| 0,8-1,0 | Round | (1,2±0,15) | (1,2±0,1) | $1,2_{-0,05}^{+0,12}$ | $1,2_{-0,05}^{+0,12}$ |
| 0,9-1,1 | Rectangular | 1,3±0,15 | 1,3±0,1 | | |
| 1,0-1,3 | Round | (1,5±0,15) | (1,5±0,1) | $1,5_{-0,05}^{+0,12}$ | $1,5_{-0,05}^{+0,12}$ |
| 1.1-1,4 | Rectangular | 1,6±0,15 | 1,6±0,1 | | |
| 1,3-1,5 | Round | 1,8±0,15 | 1,8±0,1 | $1,8_{-0,05}^{+0,12}$ | $1,8_{-0,05}^{-0,12}$ |
| 1,4-1,6 | Rectangular | | | | |
| 1,5-1,7 | Round | 2,0±0,15 | 2,0±0,1 | | |

Table 1.4 – Nominal diameter of the metallized hole, mm

| Board thickness | | 0,5; 0,8; 1,0 | 1,5; 2,0 | 2,5 | 3,0 |
|---|---|---|---|---|---|
| The nominal diameter of the metallized hole for the accuracy class of the board, not less | 2 | 0,8 | 0,8 | 0,8 | 0,8 |
| | 3 | 0,6 | 0,6 | 0,6 | 0,6 |
| | 4,5 | 0,4 | 0,4 | 0,4 | 0,6 |

The nominal value of the diameter of the contact pad must be determined by the formula:

$$D=d+2g_n$$

where: $D$ – the diameter of the contact pad or the diameter of the circle inscribed in the contact pad, mm; $d$ – diameter of the mounting hole, mm; $g_n$ is the nominal warranty belt of the contact pad, mm (Table 1.1).

According to Table 1.1, the nominal warranty belt of the contact pad for the second class of accuracy is 0.45. The maximum diameter of the output of radio elements is 0.6 mm, for power transistors IRF830 is 0.69 mm. According to table 1.4, we take the diameter of the metallized hole $d = 0{,}8_{-0{,}05}^{+0{,}1}$.

We find the diameter of the contact pad using the expression:

$$D = d + 2g_n = 0{,}8 + 2 \cdot 0{,}45 = 1{,}7 \text{ mm}.$$

The nominal diameters of the contact pad in the narrow place when setting the dimensions of the elements of the conductive pattern of the board must be at least the values given in table 1.5 - for non-metallized holes, in table 1.6 - for metallized holes.

Table 1.5 – Nominal diameter of the contact pad of a non-metallized hole in a narrow place, mm

| | | 0,7 | (0,8) | 0,9 | (1,0) | 1,1 | (1,2) | 1,3 | (1,5) | 1,6 | 1,8 | 2,0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The nominal diameter of the contact pad for the board of the accuracy class, not less | 2 | 1,7 | (1,9) | (1,9) | (2,2) | 2,2 | (2,2) | (2,5) | (2,5) | (2,7) | (2,9) | (2,9) |
| | 3 | 1,7 | (1,7) | (1,9) | (2,2) | 2,2 | (2,2) | 2,2 | 2,5 | 2,5 | 2,7 | 2,9 |

Table 1.6 – Nominal diameter of the contact pad of the metallized hole in the narrow place, mm

| The diameter of the metallized hole | | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 1,0 | 1,2 | 1,5 | 1,8 |
|---|---|---|---|---|---|---|---|---|---|---|
| The nominal diameter of the contact pad for boards of the accuracy class, not less | 2 | - | 1,1 | 1,5 | 1,7 | 1,7 | 1,9 | 2,2 | 2,5 | 2,7 |
| | 3 | - | 1,1 | 1,25 | 1,5 | 1,5 | 1,7 | 1,9 | 2,2 | 2,5 |
| | 4 | 0,8 | 0,8 | 1,1 | 1,25 | 1,25 | 1,5 | 1,7 | 2,2 | 2,5 |
| | 5 | 0,8 | 0,8 | 1,1 | 1,25 | 1,25 | 1,5 | 1,7 | 2,2 | 2,5 |

The nominal diameter of the contact pad in the free space is recommended to be set according to any lower accuracy class, and for boards of the 2nd accuracy class to be increased by 0.2-0.5 mm.

The limit deviations of the diameters of the contact pads in the free space of the board must be at least:

±0.35 mm – for boards of the 2nd accuracy class;

±0.25 mm - for boards of the 3rd accuracy class;

±0.2 mm - for boards of the 4th accuracy class;

±0.15mm - for boards of the 5th accuracy class.

Accordingly, we choose the diameter of the contact pad - 1.7±0.35 mm for the diameter of the hole - 0.8 mm.

The nominal value of the width of the conductor in the narrow place of the board should correspond to the value given in the table. 1.1, unless a higher value is required based on the electrical characteristics of the PCB.

The nominal value of the width of the conductor in the free space of the board should be selected taking into account the accuracy class from the following series: 0.23; 0.35; 0.55; 0.8; 1.0; 1.25; 1.5; 1.7; 1.9; 2.0; 2.2; 2.5 mm.

Limit deviations of the width of the printed conductor in the narrow place of the board must correspond to the values given in table 1.1.

The limit deviations of the width of the printed conductor in the free space of the board must be at least:

±0.35 for boards of the 2nd accuracy class;

±0.25 for boards of the 3rd accuracy class;

±0.2 for boards of the 4th accuracy class;

±0.15 for boards of accuracy class 5.

The nominal distance between parallel conductors must be at least:

0.8 mm – for class 2 boards;

0.55 mm – for class 3 boards;

0.35 mm – for class 4 boards;

0.25 mm - for class 5 boards.

The cross-sectional area of the conductive track S is found from the expression:

$$S = \frac{i}{j} \qquad (1.9)$$

where: *i* is the maximum current that should flow through the conductor, j is the current density for the conductor material (for copper, we take j=5 A/mm$^2$).

The maximum current will flow through the power transistor switches and will be:

$$i = \frac{P}{U}, \qquad (1.10)$$

where U is the supply voltage of the block, P is the power consumption of one lamp.

$$i = \frac{P}{U} = \frac{20}{220} = 0.091A$$

Then S is equal to the product of the thickness *p* of the conductive material (50 μm) by the width of the conductor *l*. Let's find the minimum width of the conductor:

$$S = p \cdot l = \frac{i}{j}, \qquad (1.11)$$

$$l = \frac{i}{j \cdot p} = \frac{0{,}091}{5 \cdot 50 \cdot 10^{-3}} = 0{,}37mm$$

Taking into account the maximum deviations of the width of the printed conductor in the free place of the board for the second class of accuracy (±0.35), we will accept with a margin the width of the conductor - 0.75 mm.

Knowing all the structural parameters of the elements of the PCB and the requirements for the dimensions of the elements of the conductive pattern of the PCB, the design of the topology of the PCB and the actual PCB of the medical photocatalytic device for disinfection and air purification was carried out using CAD P-CAD 2006. The drawing of the PCB and the assembly drawing of the PCB are given in applications.

### 1.3.3 Electromagnetic compatibility

Electromagnetic compatibility is the ability of radio-electronic means and radiating devices to simultaneously function with the stipulated quality in real operating conditions, taking into account the influence of unintentional radio interference and not to create unacceptable radio interference to other radio-electronic means.

Since the element base in the device is quite resistant to external influences, and to prevent interference from entering the network, an electromagnetic compatibility filter [5] is used and additional shielding is present (the plastic body of the device on the inside in some places contains a metallized sprayed coating that is grounded), therefore, electromagnetic compatibility calculations are not performed.

## 1.4 Device manufacturing technology

### 1.4.1 Device design analysis

The design of the printed unit is PCB measuring 150x45 mm, on which radio elements are placed. The thickness of the board is 1.5 mm, the topology of the printed conductors is bilateral. Radio elements are used with a minimum number of case sizes to ensure the convenience of their installation on the PCB. In the case, the printed unit is attached to the plastic case, which has racks with holes, using self-tapping screws and washers.

The recommended annual production program is 5,000 units.

1.4.2 Determination of the type of production

Modern production is divided into types: single, serial and mass.

The type of production is characterized by the coefficient of seriality:

$$K_c = \frac{t_в}{T_{\text{art}}} = \frac{F_d \cdot 60}{T_{\text{art}} \cdot N} \qquad (1.12)$$

The coefficient of seriality determines the number of different operations for the manufacture of a part or product fixed at one workplace during the year.

The following values of the coefficient of seriality are accepted:

- for mass production $K_C = 1$
- for large-scale production $K_C = 2 - 10$
- for medium-scale production $K_C = 10 - 20$
- for small-scale production $K_C > 20$

For unit production, the serialization factor is not regulated.

where tв - output tact:

$$t_p = \frac{F_d 60}{N}; \qquad t_p = \frac{2070 \cdot 60}{5000} = 24{,}8 \,\text{min}, \qquad (1.13)$$

where $N$ - annual production program (N = 5000 units/year);

$F_d$ - for one shift 2070 min/unit, for two shifts - 4140.

$T_{art}$ - artificial time (Tsht is approximately equal to 3 minutes).

$$K_c = \frac{24{,}8}{3} = 8{,}3$$

Therefore, the designed unit corresponds to the large-scale type of production. With this type of production, a series of products is made, which is regularly repeated after certain intervals of time. A characteristic feature of such production is the performance of several repetitive operations at workplaces. They use universal, special and specialized equipment. The equipment is placed according to the current sign or according to technological groups. The average qualification of workers is higher than in mass production.

1.4.3 Design analysis and selection of a technological route

From the positions of placing components and their outputs on the mounting base (PCB), Type 1A is used (Fig. 1.9).

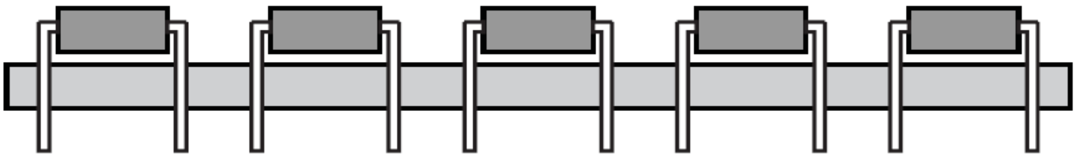


Figure 1.9 - Layout of type 1A

The technology of manufacturing the device should include the stages of preparing the terminals of most electroradio elements (ERE), namely: forming and tinning them, installing the ERE on the PCB, soldering with a wave of solder, cleaning the PCB from flux, applying a protective coating, etc.

1.4.4 Equipment selection

Technological process includes operations:

1. Preparatory - includes obtaining a completeness check.
2. Formation of conclusions of elements.
3. Tinning the conclusions of the elements.
4. Installation of elements on the board.
5. Soldering.
6. Assembly and assembly control for compliance with the assembly drawing.
7. Washing the PCB from flux residues.

8. Quality control of payment laundering.

9. Adjusting the node.

10. Varnishing (coating with moisture-proof varnishes).

11. Varnishing quality control.

12. Drying.

For large-scale production, we will use the following equipment:

1. Semi-automatic forming machine H. Streckfuck (Germany) – C-043 – forming EP terminals with axial terminals with a diameter of 2–15 mm, length 6–15 mm, installation size 7.5–50 mm, productivity – 7,000 units/hour.

2. Automatic machine for installing ERE - NM-2050 (Japan), productivity - 14,000 units/hour, installation dimensions 5-12.5 mm

3. Extractor cabinet. It is used to accelerate the drying process of materials after washing and application of various liquid substances due to the simultaneous loading of a batch of PCBs, air access is regulated.

4. ERE tinning machine with axial outputs - DMVM 2.241.003. Productivity – 3500 units/hour.

5. Installation for soldering 6TF/160 Kirston (Switzerland). Soldering boards up to 160 mm wide. Electromagnetic solder pump. Desktop execution. The mass of the solder is 15 kg. Productivity - 0.3-3 m/min.

6. LPP-901 circuit board washing line. Group 4-stage washing of boards in solvents. Power - 30 kW. Productivity - 0.3-3 m/min.

7. DLDN-2 oven – for drying varnish.

8. Pliers PUG-150 (GT17814-1020).

9. Sharp side pliers OB-1-125 (GT7814-1020)

10. Tweezers PPM-150-2 (IZH4.094.000)

11. Magnifying glass.

12. Stencil RD 3082-3901 (for marking).

13. Bone TUU 1.280.315.

14. Adjuster screwdriver 3x120.

15. Light editing table.

16. Cart.

A set of control and measuring equipment is used to adjust the product.

1.4.5 Justification of the technological planning of the site [10]

This type of production requires a certain organization of workplace locations in the workshop, and therefore, their placement is planned in the course of the technological process, thanks to which transportation costs are reduced. To ensure normal operation, it is advisable to place tinning and molding devices in such places that would have good access to the rest of the work tables. Places of installation work are placed near the windows. The area of washing, drying, varnishing must be isolated from the main production premises to reduce the negative impact of evaporation and temperature rise. This site must be equipped with an improved exhaust system and insulation to maintain the microclimate. Finished products are moved through the technical control department to a warehouse that meets the preservation requirements.

So, from this calculation and placement of the equipment, it can be seen that the equipment is technologically loaded, and therefore meets the requirements.

# 2 LABOR PROTECTION

## 2.1 Biological effect of ultraviolet radiation on humans

Ultraviolet radiation (UVR) is part of the spectrum of electromagnetic radiation with a wavelength of up to 400 nm. In production conditions, workers are most often exposed to UVR with a wavelength of 220-360 nm.

The mechanism of UVR action on the human body depends on the wavelength. Under the influence of long-wave UVR, biologically active substances and decomposition products (photolysis) are formed in the skin; under the influence of short-wave UVR, denaturation processes prevail. In general, the basis of many biological effects of UVR is the ability of deoxyribonucleic acid (DNA) to absorb photon energy. At the same time, changes occur in it, which are called the photobiological effect. The most common change in the DNA molecule under the influence of UVR is the destruction of polynucleotide chains.

The effect of a large dose of UVR on the skin is dermatitis, which is accompanied by swelling, heat and itching. At the same time, as a result of restoration (repair) of cellular damage, the epidermis and dermis thicken (hyperplasia). Hyperplasia of the epidermis is a protective reaction to the action of UVR. In addition, the pigment melanin has a protective effect, which, as part of melanocytes, accumulates in large quantities in the superficial (corneal and germinal) layers of the skin and is a kind of screen in the way of UVR. Repeated exposure to UVR leads to an increase in the number of melanocytes containing pigment in the skin, as well as to the formation of melanin in cells that do not produce it.

Erythema at the site of irradiation is the result of increased blood flow in the skin and dilation of blood vessels. In the case of prolonged and repeated exposure to large doses of UVR causes alteration, fibrosis and elastosis of the skin, atrophy of the epidermis and even skin cancer, which is explained by the ability of UVR to damage DNA and its repair system. It has been experimentally proven that UVR with a wavelength of 230-320 nm, especially in the spectrum of 290-320 nm, has carcinogenic activity. The probability of tumor formation due to UVR exposure depends on its total dose, spectrum, duration of exposure, individual sensitivity of the body, etc. At the same time, it was established that the action of suberythemic doses of long-wave UVR throughout life does not cause the development of skin tumors.

Under the influence of UVR, acute (keratitis and cataract) and chronic eye damage can occur. The duration of the latent period in the case of photo-keratitis depends on the radiation dose and ranges from 30 minutes to 24 hours. Characteristic signs of keratitis: feeling of a foreign body (sand) in the eyes, photophobia, lacrimation and blepharospasm. These symptoms disappear without complications after about 48 hours. The threshold dose of energy radiation that causes photokeratitis is 50-110 W/m2. The lens absorbs UVR to a greater extent than other areas of the eye. In the case of repeated exposure, the eye, unlike the skin, does not acquire increased resistance to it, and as a result of constant exposure, cataracts may develop. Ultraviolet radiation with a wavelength of 313 nm does not cause cataract formation; short waves (293-297 nm) affect the eye the most. Cataracts can be caused by photosensitizers - antibiotics, sulfonamides, phenothiazines, which are increasingly produced in the environment.

Deficiency of UVR for a long time causes UV deficiency, which is manifested in a decrease in the body's resistance as a result of suppression of immunological reactivity. Suberythemic doses of long-wave UVR increase the body's resistance to the effects of chemicals of generally toxic, allergenic, and carcinogenic action. The mechanism of the protective effect of suberythemic doses in relation to chemical compounds consists in increasing immunological reactivity, activation of the microsomal apparatus of the liver and mitochondrial enzymes.

## 2.2 Air environment and its role in creating favorable working conditions

The air environment is a component of the human habitat, which is a certain amount of ambient air, the composition and properties of which directly affect physiological processes and are subject to hygienic regulation.

Atmospheric air contains (% by volume): nitrogen – 78.08; oxygen - 20.95; argon, neon and other inert gases – 0.93; carbon dioxide – 0.03; other gases – 0.01. The air of this composition is the most favorable for breathing.

The air environment of industrial premises rarely has the above chemical composition, because many technological processes are accompanied by the release of harmful substances into the air of industrial premises - vapors, gases, solid and liquid particles.

Ensuring clean air and normal meteorological conditions in the working area of industrial premises is one of the necessary conditions for healthy and highly productive work.

In the production room, it is necessary to create and maintain such a state of the air environment, which is biologically positive for the human body, and, therefore, can be the result of effective and productive work.

Based on the theory of human adaptation and evolution, the air environment of industrial premises should have properties similar to the properties of natural clean fresh air in places where the climate is considered healthy and is often even used for treatment with climate therapy methods. This is mountain, sea, forest and steppe air.

The role of sodium, potassium, magnesium and calcium salts in maintaining life and the functioning of various physiological processes of a living organism is known. Less known is the fact that these chemical elements are distributed in the earth's atmosphere in the form of hydrated ions in almost the same order and play a very important role in regulating the quality of natural air, its humidity and precipitation processes.

The necessary state of the air environment can be ensured by the implementation of certain measures, the main of which are:

1. Mechanization and automation of production processes, their remote control. This measure is of great importance for protection against the effects of harmful substances, radiant heat, especially when performing heavy work (introduction of automatic welding instead of manual welding).

2. Application of technological processes and equipment that excludes the formation of harmful substances or their ingress into the working area:

a) ensuring the continuity of production processes;

b) replacing toxic substances with non-toxic ones;

c) transition from solid and liquid fuels to gaseous fuels (but recently the reverse trend has become noticeable, as oil and gas reserves have greatly decreased);

d) application of water moistening during transportation and grinding of dusty materials;

e) reliable sealing of the equipment.

3. Arrangement of effective ventilation.

## 2.3 Safety issues when using the device

To ensure reliable and efficient operation of the device, it is necessary to carry out its maintenance in a timely manner.

For all types of maintenance, safety measures must be observed:

Persons who have not mastered the principle of operation of the device, the procedure for working on it and the rules of operation are not allowed to work with the device.

Special precautions:

a) Never connect the device to the network if the power supply cable or plug is damaged. Do not allow breakage of the power supply cable or mechanical damage. Do not pull the plug of the power supply cable from the outlet by the cable.

b) High temperatures can cause the device to malfunction, so it is impossible to allow direct sunlight to hit the device and keep it away from heat sources. Holes in the housing of the device are intended for ventilation. To prevent the device from overheating, these openings should not be covered with anything.

- Do not insert objects into the slots and holes in the device housing, as this may cause electric shock, short circuit of the device circuit or damage to the fan blades.

- It is necessary to exclude the possibility of foreign objects, insects, any liquids getting inside the device, do not wipe the surface of the device with a wet cloth when it is turned on, do not wash the surface of the filter of the device.

c) Immediately disconnect the device from the network and contact the service center:

- if the device is dropped or its case is damaged;

- in case of damage to the power supply cable or plug;

- when the lamp is not lit (if there is mains voltage in the outlet);

- when liquid gets on the device or inside.

Periodic maintenance is carried out after 4-6 months of operation of the device, depending on the degree of dustiness of the room, and includes the replacement of the dust filter. For this you need:

- disconnect the device from the network;

- remove the decorative cover;

- remove fasteners on the dust filter from both sides;

- remove the cut dust filter.

Installation of a new dust filter is carried out in reverse order. The cut edges of the newly installed dust filter must be tightly tightened with the help of fasteners

- the two extreme tapes - "Velcro", while the middle tape is fixed on the filter last without tension.

It is recommended to clean the surface of the dust filter daily with a vacuum cleaner or a dry brush to remove accumulated dust, before that you need to disconnect the power cord of the device from the outlet.

When disconnected from the network (inoperative) for more than 72 hours, the device must be stored in a tied (excluding air access) packaging (polypropylene) bag.

# CONCLUSIONS

In the qualification work, an overview of all stages of the life cycle of a medical photocatalytic device for disinfection and air purification was carried out. In the first section of the work, an analysis of the technical task was carried out, the purpose of which is to clarify the requirements set by the customer, mathematical modeling of the operation of the medical photocatalytic device for disinfection and air purification was carried out, a structural and functional scheme was built, which is a logical continuation of the structural scheme and is built on the basis of the last . Using the functional scheme, an electrical principle diagram was built and, accordingly, a parametric synthesis was carried out, the essence of which is to calculate the parameters of the elements of the electrical principle diagram.

The IR2156(S)PbF microcircuit was used as a PWM driver chip, and the parameters of the elements that set its operating modes were calculated.

The design section was completed, in which the selection of the element base was carried out, the design of the PCB, the printed unit was developed, the calculations of mechanical loads and thermal calculations were carried out. When developing the device, the automated design system P-Cad 2006 was used. With the help of the P-Cad environment, the PCB was traced and the assembly drawing of the printed circuit was obtained.

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# APPLICATIONS

| | Name | | |
|---|---|---|---|
| | | | |
| | | | |
| | Capacitors | | |
| | К50-35 | | |
| | К10-17 | | |
| C1,C4,C9 | К10-17-400V-0,1uF±5% | 3 | |
| C2 | К50-35-400 V -22uF±20% | 1 | |
| C3 | К50-35-40 V -22uF±20% | 1 | |
| C5 | К10-17-0,047uF±5% | 1 | |
| C6,C8 | К10-17-470pF±5% | 2 | |
| C7 | К10-17-0,47uF±5% | 1 | |
| C10 | К10-17-0,1uF±5% | 1 | |
| C11 | К10-17-630 V -1uF±5% | 1 | |
| C12,C13 | К10-17-250 V -0,1uF±5% | 2 | |
| | | | |
| | Microcircuits | | |
| DA1 | IR2156 | 1 | |
| DA2 | PC817 | 1 | |
| | | | |
| L1 | Inductor PNCh 4.7.001 | 1 | |
| L2,L3 | Inductor PNCh 4.7.002 | 2 | |
| | | | |
| | Resistors | | |
| | C2-23-0.125 | | |
| | C2-23-1 | | |
| | C2-23-0.25 | | |
| R1 | C2-23-1-4,7 Ohm±5% | 1 | |
| R2 | C2-23-1-4,7 Ohm ±5% | 1 | |
| R3 | C2-23-0,125-10 kOhm ±5% | 1 | |

| | | | |
|---|---|---|---|
| | Signature | Date | PNCh 2.893.001 |
| Developed | Pemba N. Ch. | | Medical photocatalytic device for air disinfection and purification |
| Chekced | Dozorska O.F. | | List of elements |
| | | | ATF, group IRB-42 |

| | | . | |
|---|---|---|---|
| R4 | C2-23-0,125-20 kOhm ±5% | 1 | |
| R5 | C2-23-0,25-1 MOhm ±5% | 1 | |
| R6,R7 | C2-23-0,125-100 kOhm ±5% | 2 | |
| R8,R9 | C2-23-0,125-22 Ohm±5% | 2 | |
| R10,R12 | C2-23-0,125-1 kOhm ±5% | 2 | |
| R11 | C2-23-1-1 Ohm±5% | 1 | |
| R13,R14 | C2-23-0,125-420 kOhm ±5% | 2 | |
| R15-R18 | C2-23-0,125-1 MOhm ±5% | 4 | |
| | | | |
| | Diodes | | |
| VD1 | W10M | 1 | |
| VD2 | FR107 | 1 | |
| VD3,VD4 | 1N4148 | 2 | |
| VD5 | 1N4742A | 1 | |
| VD6 | 1N4148 | 1 | |
| | | | |
| VT1, VT2 | Transistors IRF830 | 2 | |
| | | | |
| | Connectors | | |
| XS1,XS4 | PLS-2-2 | 2 | |
| XS2,XS3 | PLS-2-3 | 2 | |

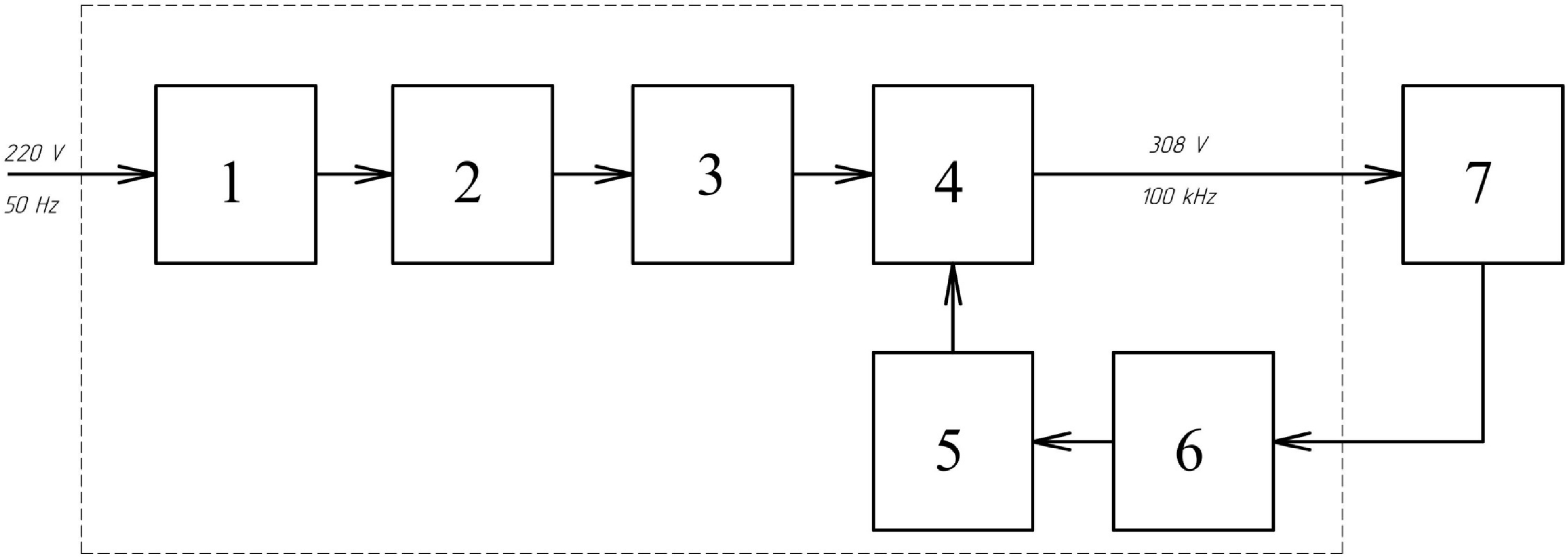
| Format | Zone | Pos. | Designation | Name | Qty. | Note |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | **Documentation** | | |
| | | | | | | |
| A1 | | | PNCh 3.893.001 СК | Assembly drawing | | |
| A2 | | | PNCh 2.893.001 E3 | Electrical diagram | | |
| | | | | | | |
| | | | | | | |
| | | | | **Details** | | |
| | | 1 | PNCh 7.103.001 | PCB | 1 | |
| | | 2 | PNCh 8.600.001 | Gasket | 1 | |
| | | 3 | PNCh 8.600.002 | Gasket | 1 | |
| | | | | | | |
| | | | | | | |
| | | | | **Other products** | | |
| | | | | | | |
| | | | | Capacitors | | |
| | | | | К50-35 | | |
| | | | | К10-17 | | |
| | | 4 | | К10-17-400V-0,1uF±5% | 3 | C1,C4,C9 |
| | | 5 | | К50-35-400V-22uF±20% | 1 | C2 |
| | | 6 | | К50-35-40V-22uF±20% | 1 | C3 |
| | | 7 | | К10-17-0,047uF±5% | 1 | C5 |
| | | 8 | | К10-17-470pF±5% | 2 | C6,C8 |
| | | 9 | | К10-17-0,47uF±5% | 1 | C7 |
| | | 10 | | К10-17-0,1uF±5% | 1 | C10 |
| | | 11 | | К10-17-630V-1uF±5% | 1 | C11 |
| | | 12 | | К10-17-250V-0,1uF±5% | 2 | C12,C13 |

| | | | | |
|---|---|---|---|---|
| | | Signature | Date | PNCh 3.893.001 |
| Developed | Pemba N. Ch. | | | Medical photocatalytic device for air disinfection and purification |
| Checked | Dozorska O.F. | | | ATF, group IRB-42 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | <u>Microcircuits</u> | | |
| | | 13 | | IR2156 | 1 | DA1 |
| | | 14 | | PC817 | 1 | DA2 |
| | | | | | | |
| | | 15 | | <u>Indurtor</u> PNCh 4.7.001 | 1 | L1 |
| | | 16 | | <u>Inductor</u> PNCh 4.7.002 | 2 | L2,L3 |
| | | | | | | |
| | | | | Resistors | | |
| | | | | C2-23-0.125 | | |
| | | | | C2-23-1 | | |
| | | | | C2-23-0.25 | | |
| | | 17 | | C2-23-1-4,7 Ohm±5% | 1 | R1 |
| | | 18 | | C2-23-1-4,7 Ohm ±5% | 1 | R2 |
| | | 19 | | C2-23-0,125-10 kOhm ±5% | 1 | R3 |
| | | 20 | | C2-23-0,125-20 kOhm ±5% | 2 | R4 |
| | | 21 | | C2-23-0,25-1 MOhm ±5% | 1 | R5 |
| | | 22 | | C2-23-0,125-100 kOhm ±5% | 2 | R6,R7 |
| | | 23 | | C2-23-0,125-22 Ом±5% | 2 | R8,R9 |
| | | 24 | | C2-23-0,125-1 kOhm ±5% | 2 | R10,R12 |
| | | 25 | | C2-23-1-1 Ohm ±5% | 1 | R11 |
| | | 26 | | C2-23-0,125-420 kOhm ±5% | 2 | R13,R14 |
| | | 27 | | C2-23-0,125-1 MOhm ±5% | 4 | R15-R18 |
| | | | | | | |
| | | | | <u>Diodes</u> | | |
| | | 28 | | W10M | 1 | VD1 |
| | | 29 | | FR107 | 1 | VD2 |
| | | 30 | | 1N4148 | 2 | VD3,VD4 |
| | | 31 | | 1N4742A | 1 | VD5 |
| | | 32 | | 1N4148 | 1 | VD6 |
| | | | | | | |
| | | 33 | | <u>Transistors</u> IRF830 | 2 | VT1, VT2 |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Connectors | | |
| | | 34 | | PLS-2-2 | 2 | XS1,XS4 |
| | | 35 | | PLS-2-3 | 2 | XS2,XS3 |

PNCh 2.893.001 E1




1 - Anti-interference filter
2 - Rectifier
3 - Filter
4 - Switch
5 - Pulse-width modulation (PWM) driver
6 - Feedback loops
7 - Ultraviolet lamp

| | | |
|---|---|---|
| Developed | Pemba N.Ch. | |
| Checked | Dozorska O.F. | |
| Head of Dept | Yavorska E.B. | |

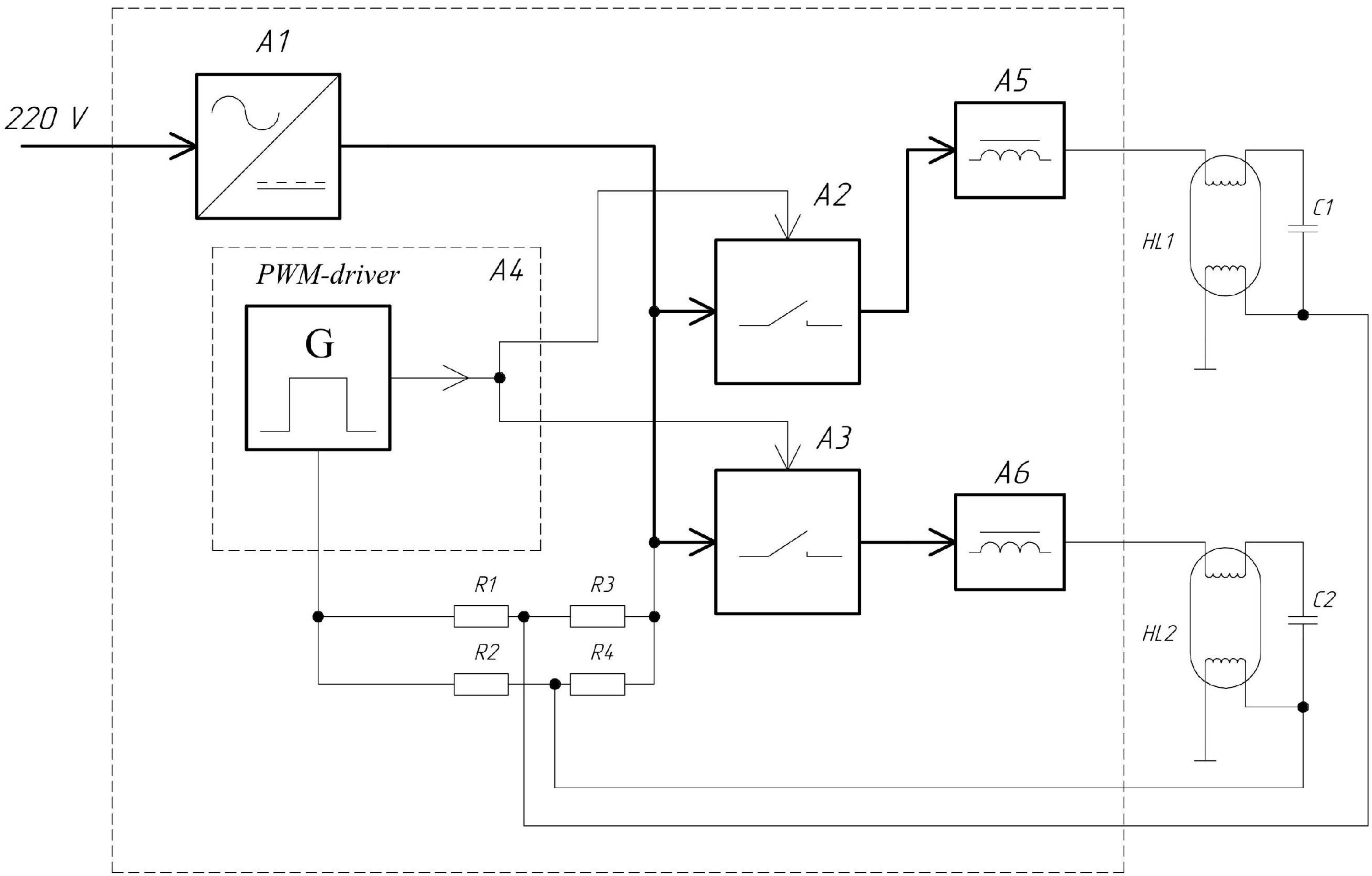
PNCh 2.893.001 E1

Medical photocatalytic device for air disinfection and purification
Structural diagram

– –

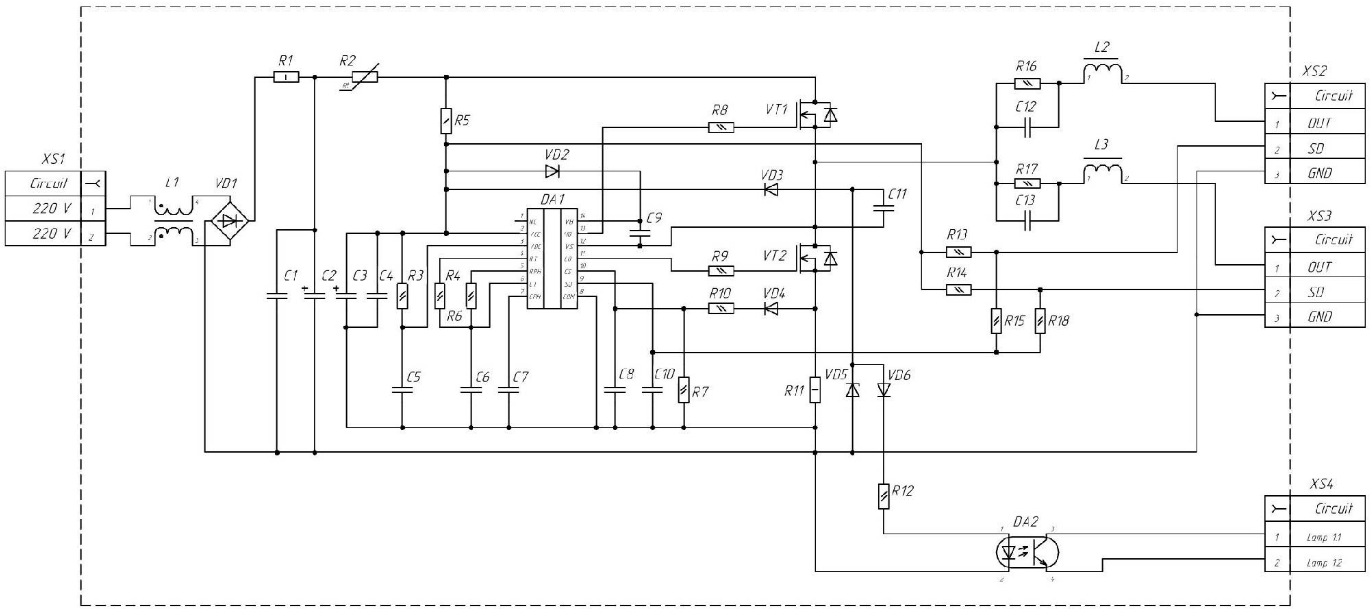
ATF, group IRB-42

PNCh 2.893.001 E2




| | | | |
|---|---|---|---|
| Developed | Pemba N.Ch. | PNCh 2.893.001 E2 | |
| Checked | Dozorska O.F. | Medical photocatalytic device for air disinfection and purification<br>Functional diagram | – – |
| Head of Dept. | Yavorska E.B. | | ATF, group IRB-42 |

PNCh 2.893.001 E3




| | |
|---|---|
| Developed | Pemba N.Ch. |
| Checked | Gozorska O.F. |
| Head of Dept. | Yavorska E.B. |

PNCh 2.893.001 E3

Medical photocatalytic device for air disinfection and purification
Electric diagram

ATF, group IRB-42

PNCh 7.102.001

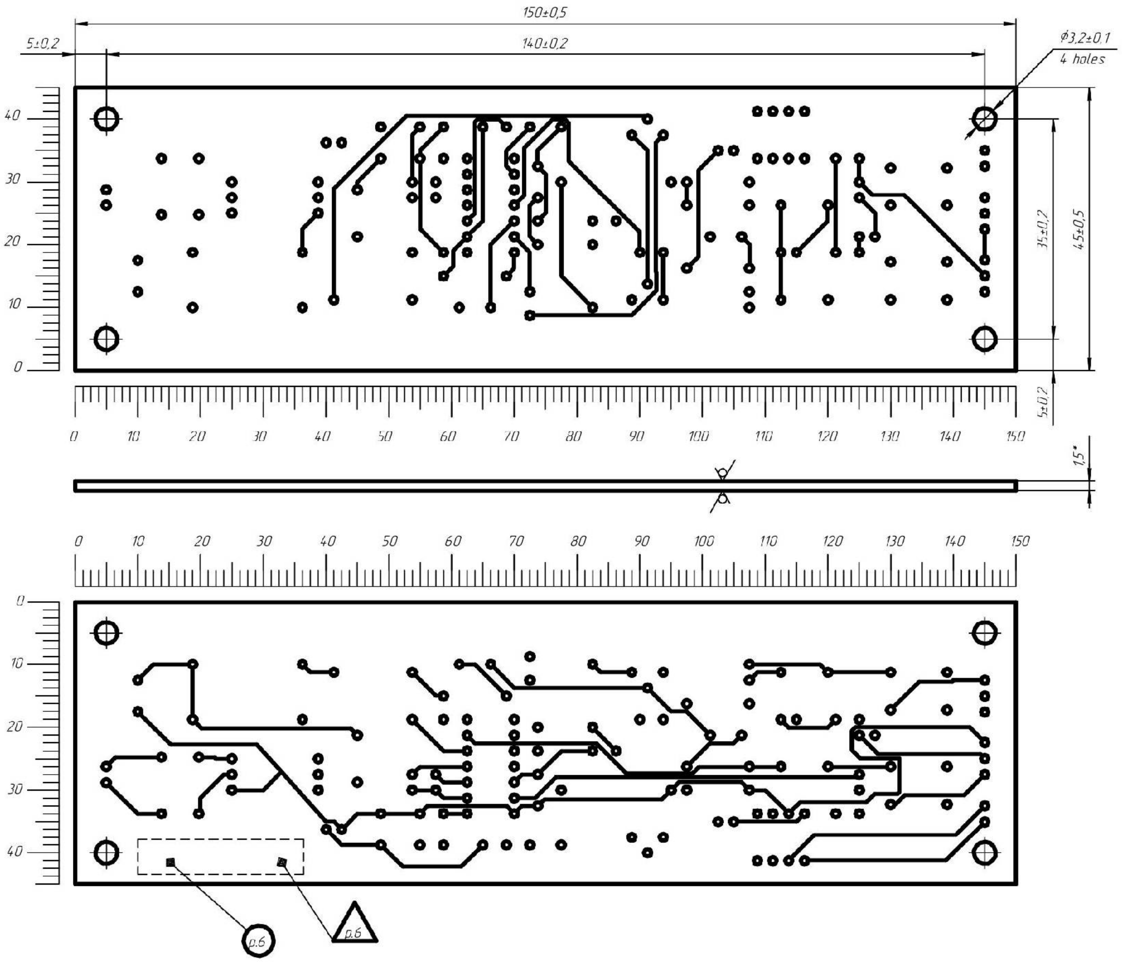


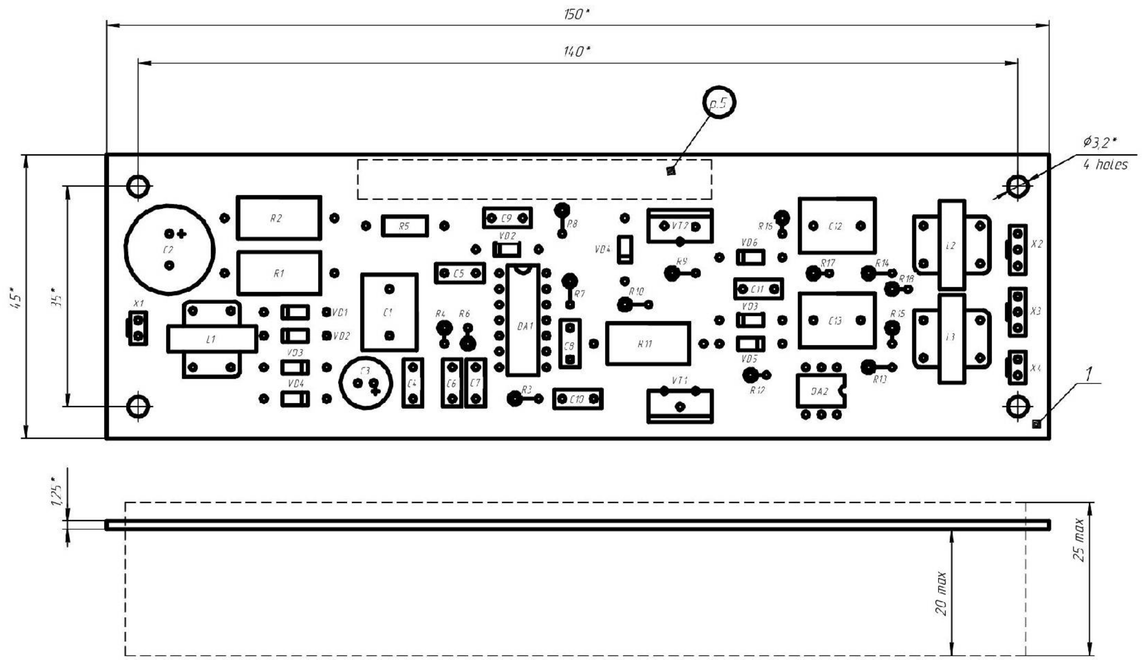

Table 1

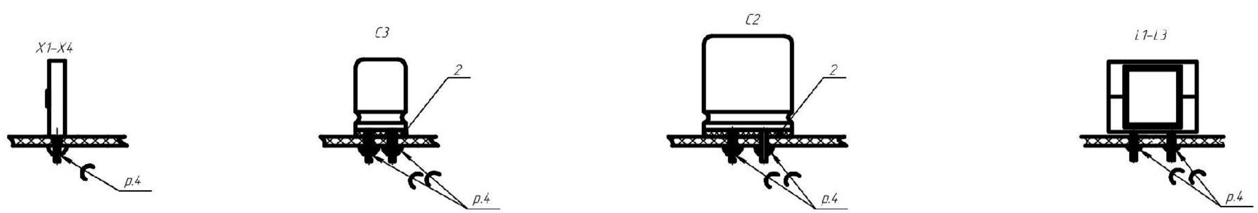
| Conventional designations of holes | Hole diameter, mm | The size of the contact pads | Presence of metallization | Number |
|---|---|---|---|---|
| | 3,2±0,1 | – | – | 4 |
| | 0,8±0,05 | 1,7±0,05 | + | 128 |

1. * Size for reference.
2. The board must meet the requirements of current standards, rigidity group 2, accuracy class 3. The pitch of the coordinate grid is 1.25 mm.
3. Make the payment in a combined positive way.
4. Configuration of printed conductors according to the drawing.
5. Mark the factory number with black marking paint.

| | | |
|---|---|---|
| PNCh 7.102.001 | | |
| Developed | Pemba N.Ch. | Printed board |
| Checked | Dozorska O.F. | 2,5:1 |
| Head of Dept. | Yavorska E.B. | ATF, group IRB-42 |

PNCh 3.893.001




1. *Sizes for reference.
2. Prepare for installation in accordance with current standards
3. Install the elements as follows. Elements
C1, C4–C13 set according to option IIa;
resistors R1, R2, R5, R11 and diodes – according to option Ia;
resistors R3, R4, R6–R10, R12–R18 – according to option IIg;
VT1, VT2 – according to option IIv; DA1, DA2 – according to option VIIIa; other elements – according to the drawing.
The step of the coordinate grid is 1.25 mm.
4. Solder with solder.
5. Mark the number, date, letter of the change – font 2.5 with black marking paint.
6. Elements with a schematic designation are shown conditionally.

| | | |
|---|---|---|
| Developed | Femba N.Ch. | |
| Checked | Gozorska O.F. | |
| Head of Dept. | Yavorska E.B. | |

PNCh 3.893.001

**Circuit board**

ATF, group IRB-42