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: Portable electrocardiograph "EasyCardio"

Submitted by: fourth year student 4 , group IRB-41
specialty 163 Biomedical engineering
(code and name of specialty)

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Ternopil
2022

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« » 2022

ASSIGNMENT
for QUALIFYING PAPER

for the degree of Bachelor
(degree name)

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

student Ugorji Chibuzor Vitalis
(surname, name, patronymic)

1. Paper topic Portable electrocardiograph "EasyCardio"

Paper supervisor Dozorskyi V.G., PhD, Associate Professor
(surname, name, patronymic, scientific degree, academic rank)

Approved by university order as of
2. Student’s paper submission deadline 25.06.2022
3. Initial data for the paper task for work,
the electrocardiograph should provide the possibility of recording ECS in the first three leads; data transfer (registered EKS) to a computer via a USB port; the electrocardiograph must be powered via a USB port; power consumption should not exceed 5 W.
4. Paper contents (list of issues to be developed)
technical task analysis; construction of the product, namely: construction of a mathematical model of the product's operation; construction of structural, functional, electrical principle schemes, calculation of nominal values of elements of the electrical principle scheme; design of the product, namely: justification of the choice of the element base, tracing of the printed circuit board, development of the layout of the printed unit, calculations of operational reliability, thermal calculations, calculations of resistance to mechanical loads; product manufacturing technology. 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 ______________ Ugorji Chibuzor Vitalis
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Paper supervisor ______________ Dozorskyi V.G.
(signature) (surname and initials)

SUMMARY

Theme of qualification work: "Portable electrocardiograph "EasyCardio"". Qualifying work of a bachelor // TNTU, ATF, group IRB-41. // Ternopil, 2022 //p.- , fig.- , table- , bibliog.- , appendix- .

Key words: electrocardiograph, lead, printed circuit board.

The diploma work reviewed all stages of the life cycle of the "EasyCardio" portable electrocardiograph. An analysis of the technical task was carried out, the purpose of which is to specify the requirements set by the customer. A mathematical model of the device's operation was constructed, on the basis of which structural and functional schemes were developed. A basic electrical diagram has been developed. A parametric synthesis was carried out. The selection of the element base was carried out, the design of the printed circuit board, the printed unit was developed, the calculations of mechanical loads, thermal calculations, and operational reliability were carried out. The section on device manufacturing technology has been completed. A section on labor protection has also been completed.

CONTENT

					UChV 3.013.001
	Ugorji Ch.V.			Portable electrocardiograph "EasyCardio"	Page / Pages
	Dozorskyi V.G.				
	Yavorska E.B.				ATF, group IRB-42

INTRODUCTION

Electrocardiography (abbreviated ECG) is a method of graphical registration of electrical phenomena that occur in the heart muscle during its activity, from the surface of the body. The curve that reflects the electrical activity of the heart is called an electrocardiogram (ECG).

Electrocardiography is a method of recording the magnitude and direction of the electromotive force of the biopotentials of the excited myocardium.

The main functions of the myocardium are automatism, excitability, conduction and contractility.

The work of the heart is determined precisely by the state of these functions, and electrocardiography is an indispensable method of diagnosing their state.

The function of automatism is the ability of the heart's conduction system to automatically generate impulses to excite and then contract the heart. Sources of automatism are the sinus and atrioventricular nodes, Hiss bundle, Purkinje fibers.

The center of automatism of the 1st order is the sinus node of Kis-Flak. The center of second-order automatism is the Ashof-Tavar atrioventricular node.

His system is the center of automatism of the 3rd order with the generation of 20-30 pulses per 1 minute. Centers of automatism of the II and III order are subordinate to the center of the I order - the rhythmic activity of the sinus node.

The excitability function is the ability of the heart muscle to respond to stimulation with excitement. During the period of excitement, the heart muscle does not perceive other impulses, which is called refractoriness.

The conduction function is the ability to conduct impulses through the conduction system, in particular through the three internodal bundles: Bachmann, Wenkelbach, Torel, 2-3 times faster than through the contractile myocardium. Excitation spreads from top to bottom and from left to right. A feature of excitation is a significant delay of the wave in the terminal area between the AV node and the bundle of His, so the ventricles begin to contract after a full contraction of the atria.

The second feature of the AV node is the ability to transmit no more than 180-200 impulses in 1 minute.

The contractility function is the ability of the myocardium to respond to excitation by contraction that occurs 0.02 seconds after the impulse.

An electrocardiogram is a graphic recording of heart potentials from the surface of the body. Graphical recording of biocurrents of the heart was first carried out in 1913 by Einthoven. The connection of two points of the body that have different potentials is called a lead.

Electrocardiography is one of the main methods of examination of the heart.

The purpose of the qualifical work is to review all stages of the life cycle of the portable electrocardiograph "EasyCardio", which is designed for registration of electrocardiographic signals I, II and III leads.

1 MAIN PART

1.1 Analysis of the technical task

The electrocardiograph is intended for use in treatment and prevention facilities as a component of the diagnostic complex, and at home for self-monitoring of the cardiovascular system in the presence of a computer.

The device must provide the following characteristics:

1. Possibility of registration of electrocardiographic signal (ECS) in the first three leads;
2. Electrocardiograph input resistance not less than 2 MOhm;
3. Range of registered voltages (0.03 – 5)mV;
4. Data transfer (registered ECS) to a computer via USB port;
5. The electrocardiograph must be powered via the USB port;
6. Power consumption not more than 5W;
7. Range of working temperatures from +10 ^{0}C ... + 35 ^{0}C;
8. Average service life not less than 5 years;
9. Relative humidity up to 80% at temperatures up to +25 ^{0}C;

The average time to failure must be at least 5 years.

1.2 Construction of an electrocardiograph

1.2.1 Construction of a mathematical model

Consider the work of the heart, which is a source of electrical signals, which together form an electrocardiogram. The heart is considered as an electric dipole (Einthoven's theory). The excited area of the myocardium is negatively charged in relation to the unexcited area (Fig. 1.1). This charge distribution is equivalent to the dipole charge system, which can be characterized by the integral electric vector of the heart P = ql.

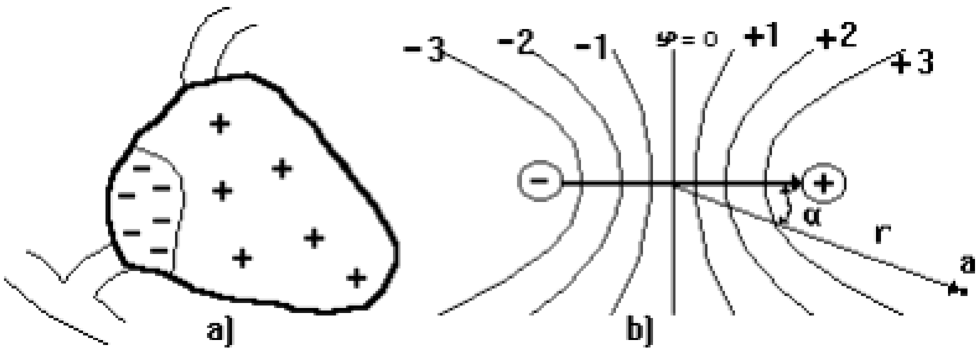


Figure 1.1 - Heart as an electric dipole

The dipole is placed in a homogeneous dielectric, ie currents in such a medium are absent, and the electric field is considered static. The magnitude of the potential at each sufficiently distant point of the medium (r >> l) is equal to:

$$\varphi_a = \frac{P \cdot \cos\alpha}{4\pi\varepsilon_0\varepsilon r^2}.$$

Einthoven proposed to remove the potential difference between the vertices of an equilateral triangle, in the center of which is the vector P (Fig. 1.2). It can be shown that in this case the potential differences between the vertices of the triangle are proportional to the corresponding projections of P on triangle:

$$\Delta\varphi_I : \Delta\varphi_{II} : \Delta\varphi_{III} = P_{ab} : P_{ac} : P_{bc},$$

where $P_{ab} = P \cdot \cos\alpha;\ P_{ac} = P \cdot \cos\beta;\ P_{bc} = P \cdot \cos\gamma.$

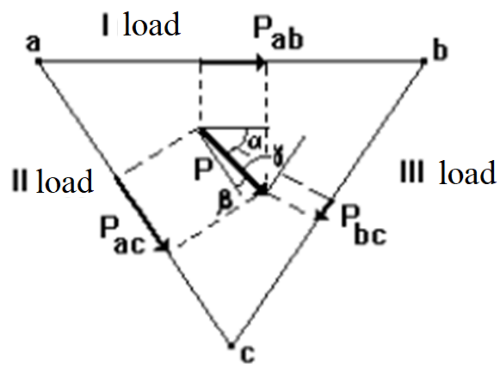


Figure 1.2 - Einthoven's triangle

Each of these projections corresponds to one of the standard leads accepted in electrocardiography (in this case it is I, II, III standard leads for which the position of point "a" corresponds to position of an electrode on the right hand, "b" - on the left, c). ”- on the left leg).

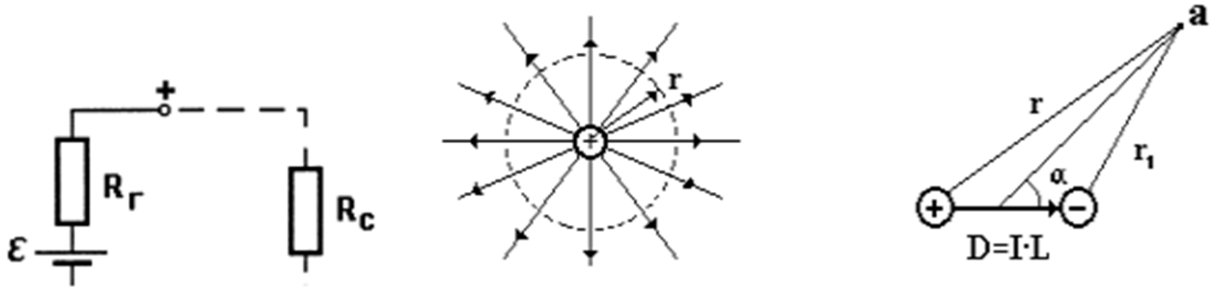
The use of other electrodes (neutral - on the right leg and chest, which is superimposed at the appropriate point of the chest) allows you to use other types of standard leads, there are more than two dozen in cardiology.

The main disadvantage of this concept is the statement that the tissues surrounding the heart are dielectrics, ie the calculation of the potential of any point of the medium according to the above formula is incorrect.

The heart can also be considered as a set of current electric generators that are in an electrically conductive medium.

The equivalent circuit of the current generator (current dipole) is presented in fig. 1.3, a. Here Rg and Rc are the internal resistance of the generator and the resistance of the external environment, respectively. For a current generator Rг >>

Rc, therefore, I≈ε / Rr, ie the current does not depend on the resistance of the medium.



a b c

Figure 1.3 - Heart as a set of current electric generators

The current dipole moment D = I • L, where I is the current, L is the vector that connects the poles of the dipole. The positive pole is called the source (source), the negative - the outflow. The direction of the vector D is shown in Fig. 1.3, b.

The field potential of the current unipole in a homogeneous medium ρ = const (Fig. 1.3, c). Using Ohm's law in differential form, the definition of current density j = I / S, and the fact that in this case S is the area of the sphere surface with radius r, we find:

$$j = \sigma E, \quad E = \frac{1}{\sigma} j = \rho j, \quad E = -\nabla \varphi = -\frac{d\varphi}{dr},$$
$$d\varphi = -\rho \cdot j \cdot dr \; ; \varphi = -\int_0^R \rho \cdot j \cdot dr = \frac{\rho}{4\pi} \cdot \frac{I}{R}.$$

Using the principle of superposition, we find the potential of a point as the sum of the potentials of two unipoles (source and outflow):

$$\varphi_a = \frac{\rho \cdot I}{4\pi} \cdot \left(\frac{1}{r} - \frac{1}{r_1} \right).$$

If L << r, then the last formula that determines the magnitude of the dipole potential is conveniently represented by the magnitude of the dipole moment

$$\varphi_a = \frac{\rho}{4\pi} \cdot \frac{I \cdot L \cdot \cos\alpha}{r^2} = \frac{\rho}{4\pi} \cdot \frac{D \cdot \cos\alpha}{r^2}.$$

The excited myocardium is considered as a set of current dipoles Di, each of which leads to the dipole potential φa at some point a.

The potential of the electric field of the heart consists of potentials created by individual elementary dipoles. Assuming the constraint: the conductive medium is homogeneous (ρ = const), the distance r is much larger than L, ie the size of the excitation region is much smaller than the size of the body, this potential can be found approximately in the form

$$\varphi_a \approx \frac{\rho}{4\pi r^2} \cdot \sum_{i=1}^{n} D_i \cos \alpha_i ,$$

where n is the total number of dipoles, r is the distance from the center of the current dipole to the discharge point, ρ is the resistivity n of the medium. Expression

$$\boldsymbol{D}_c = \sum_{i=1}^{n} \boldsymbol{D}_i$$

is an equivalent dipole of the heart, it integrally reflects the propagation of excitation currents in the local area of the myocardium. Then the electric field potential of the heart can be represented as:

$$\varphi_a = \rho D_c \cos\alpha / 4\pi r^2$$

where α is the angle between the vector and Dc direction r.

1.2.2 Synthesis of the function of the electrocardiograph

The block diagram should reflect the principle of operation of the product in the most 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 clear idea of the sequence of interaction of functional parts in the product. The direction of the processes that take place in the product is indicated by arrows on the lines of interconnection.

Taking into account all the above and the mathematical modeling of the device, we make its block diagram, which is shown in Fig. 1.4.

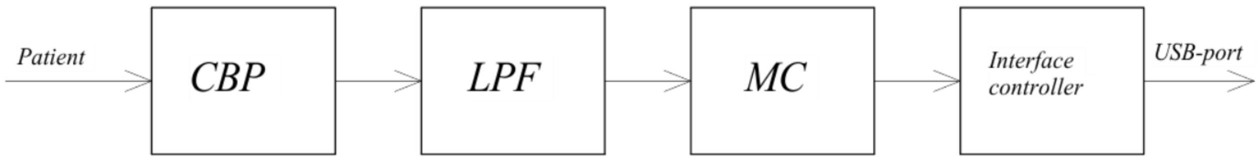


Figure 1.4 - Block diagram of the electrocardiograph

The signal from the patient is fed to the biopotential amplifier (CBP). From it through the low-pass filter (LPF), which suppresses low-frequency interference, the signal is fed to the input of the microcontroller (MC), where it is digitized for processing. From the outputs of the microcontroller, the generated digital signal is fed to the interface controller, which is designed to match the electrocardiograph with the computer.

1.2.3 Synthesis of product structure

The functional diagram is designed to explain the processes occurring in the product at different 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.

Given the above, we build the functional diagram, which is shown in Fig. 1.5.

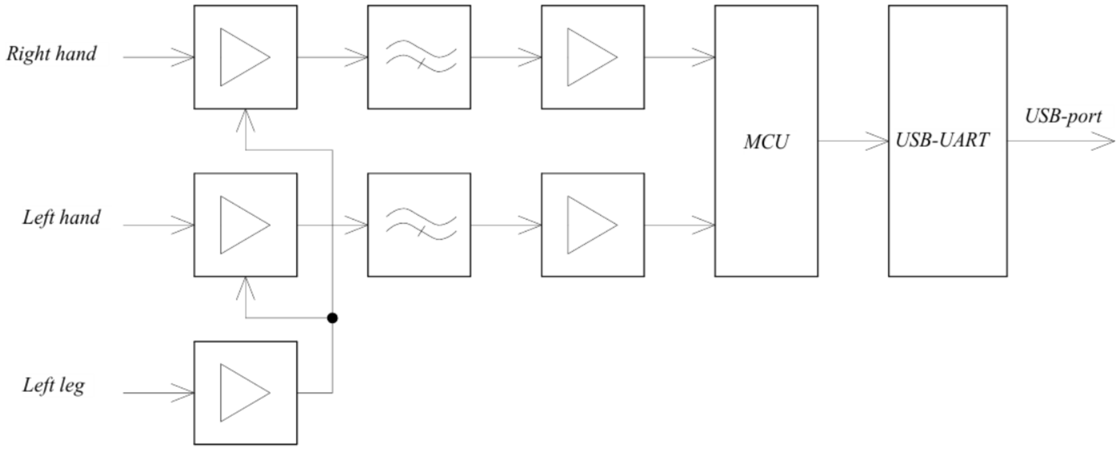


Figure 1.5 - Functional diagram of the device

According to fig. 5.1, the electrocardiograph works on three assignments. At the same time, the signal ground of the electrocardiograph is connected to the right leg. The signal from the right and left hand is fed to two separate amplifiers. The signal from the left foot is fed to a separate amplifier, the output signal of which is fed to the inverting inputs of the first two amplifiers. This ensures the filtering of permanent interference. From the outputs of the amplifiers signals are fed to the low-pass filters and from their outputs to the inputs of additional amplifiers. The USB-UART converter generates a protocol signal from the output signal of the MCU, which can be transmitted by the USB bus.

1.2.4 Synthesis of the electrical circuit diagram

On the basis of the functional diagram we build the electric circuit diagram.

According to the electrical circuit diagram, the signal amplifiers from the left and right hand are made on the chips DA1.1, DA1.2, the signal amplifier of the left foot is made on the chip DA2.1.

Low frequency filters are made on elements R15, R21, C9, C10 and R20, R26, C11, C13.

Amplifiers DA1.3 and DA2.4 are the final amplifiers of the cardio signal. The DD1 chip has an interface controller, and the VT1: A, VT1: B opt pairs have a galvanic isolation between the USB port and the microcontroller.

Elements R36, R37, VD9 additionally induce the process of information exchange between the electrocardiograph and the computer.

Elements C21, C22, Z1 set the clock frequency of the microcontroller.

1.2.5 Parametric synthesis

Let's calculate the values of the denominations of some elements of the electrical circuit diagram.

Input biopotential amplifiers are made on operational amplifiers DA1.1, DA1.2, DA2.1. Consider the operation of one of these amplifiers. Its appearance is shown in Fig. 1.6.

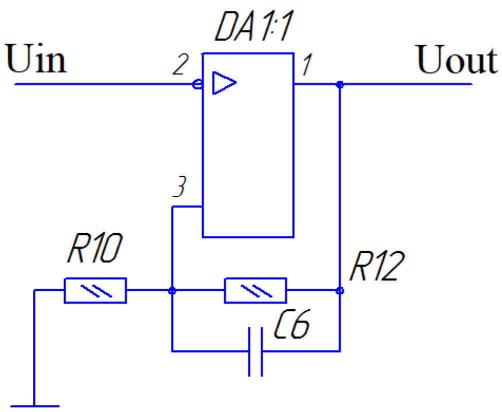


Figure 1.6 - Input amplifier of one channel of the electrocardiograph

The gain of such an amplifier is equal to:

$$K = 1 + R12 / R10$$

Given the value of the gain 10 and the resistance of the resistor R10 - 33 kOhm we find the resistance of the resistor R12:

$$R12 = (K - 1) \cdot R10 = (10 - 1) \cdot 33 \cdot 10^3 = 297 \cdot 10^3 \, Ohm$$

From a number of values of resistor denominations we choose the value R12 = 270 kOhm.

At the output of the amplifier is an integrating RC link, which is LPF. The cutoff frequency of the filter should be about 200 Hz. Find the denominations of the filter elements. Its scheme is shown in Fig. 1.7.

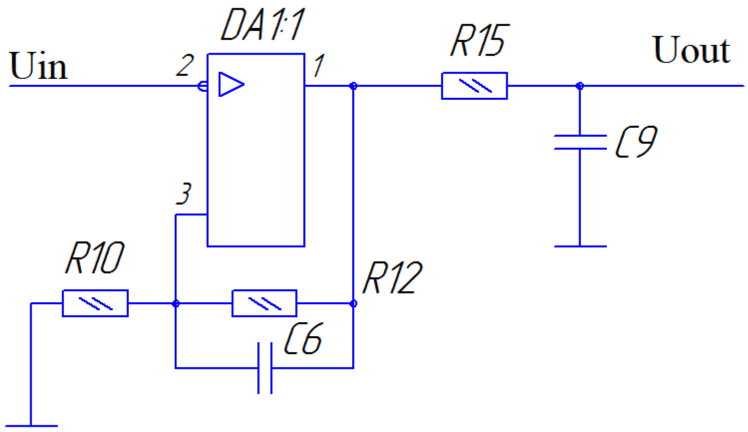


Figure 1.7 - LPF at the output of the amplifier

The cutoff frequency is expressed by:

$$f_{зр} = \frac{1}{2 \cdot \pi \cdot R15 \cdot C9}$$

Given the value of the capacitance of the capacitor C9 = 0.1 μF, we find the resistance of the resistor R15:

$$R15 = \frac{1}{2 \cdot \pi \cdot f_{зр} \cdot C9} = \frac{1}{2 \cdot 3{,}14 \cdot 200 \cdot 100 \cdot 10^{-9}} = 7{,}1 \cdot 10^{3}\, Ohm$$

Let's choose from a number of standard values the resistor with a face value of 6,8 kOhm.

In the same way the denominations of the elements of the filters and amplifiers of the other channels are calculated.

The HL1 LED is included in the circuits of the DD1 chip to indicate the process of data transfer to the USB port (Fig. 1.8). Let's calculate the parameters of the resistors R36 and R37, thet are current-limiting elements.

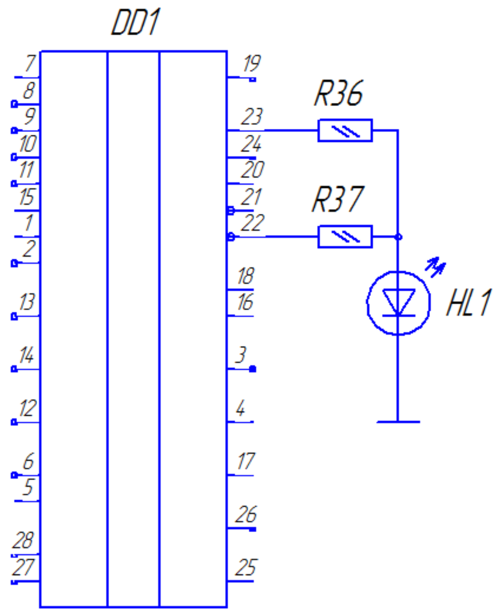


Figure 1.8 - Indication of data transfer to the USB port

The circuit selects a light diode type AL307, for which the direct current is Ypr = 10 mA, and the voltage drop Usv = 2 V. At the outputs 23 and 22 of the chip DD1 signals Ux with an amplitude of +5 V. Accordingly, the resistors should fall:

$$U_R = U_x - U_{sv} = 5-2=3V$$

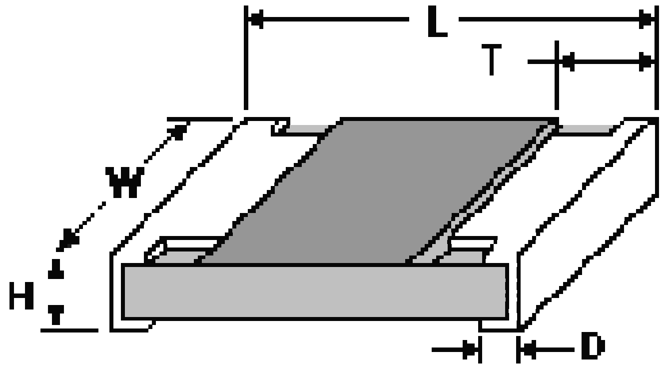
Accordingly, at a current of 10 mA, the resistance of the resistors should be 300 ohms. We choose from a number of denominations resistors with a resistance of 330 ohms.

1.3 Design of an electrocardiograph

1.3.1 Selection of the element base

Choice of types of resistors and capacitors. The following components were chosen for the electrocardiograph taking into account economy, universality, miniaturization and simplicity: resistors constant in SMD execution of type 0805RC11, capacitors in SMD execution of type GRM21 0805.

Resistors 0805RC11 - constant chip general purpose resistors, uninsulated. The equal view and the main overall dimensions are given in fig. 1.9.



Standard size	L (mm)	W (mm)	H (mm)	D (mm)	T (mm)
0805	2.1±0.1	1.3±0.1	0.5±0.05	0.4±0.2	0.4±0.2

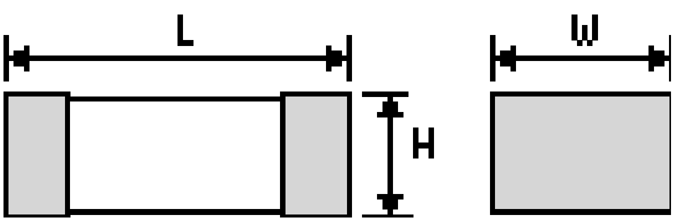
Figure 1.9 - Overall dimensions of the resistors

Technical characteristics of resistors 0805RC11:

- range of nominal values: 0 Ohm, 1 Ohm - 30 MO;
- permissible deviation from the face value: 1% (F); 5% (J);
- rated power: 0.125 W;
- operating voltage: 150 V;
- maximum allowable voltage: 200 V;
- working temperature range: -55… +125 ° C.

Capacitors GRM21 0805 - ceramic chip capacitors.

Ceramic, based mainly on zirconium titanate (ZrTiO3), calcium (CaTiO3), nickel (NiTiO3) and barium (BaTiO3), serves as the dielectric of the ceramic capacitor. If necessary, use capacitor ceramics based on Al2O3, SiO2, MgO and others. Their capacity varies from picofarad particles to several microfarads, and the operating voltage varies in the range from several tens of volts to tens of kilovolts. Ceramics have an inorganic polycrystalline structure, which is obtained by firing at high temperature. Thanks to special production technologies, ultra-thin layers of ceramic material are obtained. These layers are laid to obtain the design of the capacitor, whose electrical and mechanical characteristics must meet stringent requirements. The multilayer capacitor includes a monolithic ceramic block with metallized electrodes. Thus, by increasing the number of electrodes and their active area, the dielectric constant of the dielectric and reducing the thickness of the dielectric layers, it is possible to increase the capacitance of the capacitor. This is the main way to increase the capacity of ceramic capacitors. But due to the decrease in the thickness of the dielectric there is a decrease in breakdown voltage. The process of increasing the number of layers in ceramic capacitors is technologically associated with a decrease in the thickness of a single layer. And the increase in the active area of one electrode is to increase the overall size of the capacitor, which in turn leads to a high cost of the product. Ceramic capacitors are prone to a significant strong dependence of the capacitance on the applied voltage and the deterioration of temperature stability in the case when the dielectric constant increases with a significant increase in capacitance. The equal view and the main overall dimensions are given in fig. 1.10.



Standard size	L (mm)	W (mm)	H (mm)
0805	2.0	1.25	1.3

Figure 1.10 - Overall dimensions of capacitors

Selected types of resistors and capacitors have good temperature and other parameters, so their use is justified.

PS-BAL99 diodes were selected as diodes.

Main technical characteristics:

- maximum reverse voltage, B… 100;
- maximum direct current, mA… 100;
- operating temperature range: from -65□C to + 150□C.

Among the ICs, the following chips were selected:

- TL072 - two-channel JFET operational amplifier with low noise level;
- FT232RL - single-chip adapter from USB to asynchronous serial data transfer interface (UART);
- USB protocol is fully implemented in the chip;
- UART interface supports modes of transmission of 7 and 8 bits of data, various modes of parity control;
- baud rates from 300 baud to 3 megabits for RS422 / RS485 / TTL and from 300 baud to 1 megabod for RS-232;
- the ability to display the state of reception / transmission to external LEDs;
- the ability to supply a clock signal to external chips, controllers, FPGA, frequencies 6, 12, 24 and 48 MHz;
- high load capacity of outputs;
- built-in non-volatile EEPROM memory with a capacity of 1024 bytes;
- TQFP32 - microcontroller;

Specifications:

- Kernel… AVR
- Bit rate… 8
- Clock frequency, MHz… 20
- The amount of ROM memory… 16K
- RAM capacity… 1K

- Internal ADC, number of channels… 23

- Internal DAC, number of channels… 23

- Supply voltage, B… 2.7 ... 5.5

- Temperature range, C… -40 ... 85

- Housing type… TQFP32

Indicators are selected type LTC561 with the following characteristics:

- operating voltage… .5V;

- maximum direct current… ..100 mA;

- dissipated power 100 .100 mW.

6N137 optocouplers are also selected.

General description of optocouplers 6N137:

- number of channels… 1;

- constant direct input voltage Uvh., B… 1.4, at the input current Ivh., mA… 10;

- maximum input current Iv.max.,… MA 50;

- maximum input reverse voltage Uv.zv.max., V… 5;

- maximum output current Iout.max.mA… 50;

- maximum output reverse voltage Uout.sq.max., In… 7;

- rise time of the output signal tnr., μs… 0.05;

- insulation resistance between input and output circuits R, Gм… 1000;

- maximum insulation voltage, B… 2500;

- working temperature, C -40 ... +85;

- housing… PDIP8.

The final choice of active and passive elements is iterative, but always first of all choose passive elements. When choosing the element base for this device, reference books were used that give a holistic view of the entire arsenal of components, as well as descriptions of serial products and promotional materials.

Also, the above selected elements are explained by their cheapness, along with their high reliability, low weight and overall dimensions. In addition, they are standardized and unified, which simplifies repair, replacement.

1.3.2 Development of layout and installation of the printed circuit board of the product

In the design of the printing unit of the unit used radio elements only with the surface type of installation.

As a result of the calculation of the printed circuit board determine the size of the elements of the leading figure.

Determination of the nominal value of the width of the conductor t is carried out by the formula:

$$t = t_{м.д.} + |\Delta t_{н.о}|, \qquad (1.1)$$

where $t_{м.д.}$ – the minimum allowable width of the conductor, which is determined by the accuracy class and the possible current load,

$\Delta t_{н.о.}$ – tolerance on the width of the conductor, $\Delta t_{н.о.}$ = 0.1 *мм.*

We accept *t*=0,3*мм.* According to the chosen 3rd class of accuracy of the printed circuit board we choose $t_{м.д.}$=0,45 *мм,* then:

$$t = 0{,}45 + 0{,}1 = 0{,}55(мм)$$

The nominal value of the distance between adjacent elements of the leading figure is determined using the formula:

$$S = S_{м.д.} + \Delta t_{в.в.}\delta\ell, \qquad (1.2)$$

where $S_{м.д}$ – the minimum allowable distance between adjacent elements of the leading figure;

$\delta\ell$ – admission to the placement of conductors.

We choose $\delta\ell - 0.1мм, \Delta t_{в.в.}, S_{м.д.} = 0{,}45мм.$ Then, according to the formula, we find the nominal value of the distance between adjacent elements of the leading figure:

$$S = 0{,}45 + 0{,}1 + 0{,}1 = 0{,}65(мм)$$

Knowing all the design parameters of the elements, the topology of the printed circuit board and the actual printed circuit board of the device was designed using CAD P-CAD 2002.

1.3.3 Mechanical calculations of stability and strength

1.3.3.1 Calculation of vibration resistance.

This device does not include particularly heavy units, so we can assume that the center of mass of the structure coincides with the geometric center of mass of the device.

The calculation of the vibration resistance of the load-bearing structures of the board type is reduced to determining the maximum stresses based on the type of deformation caused by the vibration axis in a certain frequency range and comparing the obtained values with the allowable. To do this, you need to find your own frequency f_0, at which the board with the certain sizes and mechanical characteristics maintains admissible loadings. The frequency of oscillations of the board should not be close to its resonant frequency f_0.

We find the natural resonant frequency of the printed circuit board by the formula

$$f_0 = \left(\frac{1}{\sqrt{1 + \frac{m_e}{m_л}}} \right) \cdot \left(\frac{\pi}{4\sqrt{3}} \right) \cdot \left(1 + \Delta^2\right) \cdot \left(\frac{\lambda \rho}{b^2} \right) \cdot \sqrt{\frac{E}{\rho}} \qquad (1.3)$$

where m_e – mass of electroradioelements;

$m_л$ – the weight of the printed circuit board;

Δ – the ratio of the smaller side of the board to the larger;

b – the size of the larger side of the board;

E – Young's module, $E = 3.3 \cdot 10^{10}\, Н/м^3$;

ρ – the density of the printed circuit board material for fiberglass $\rho = 2{,}5 \cdot 10^3\, кг/м^3$;

λ – coefficient depending on the method of mounting the PCB.

For the electrocardiograph board, the weight of the elements is approximately 50 g, the weight of the printed circuit board is 43 g, the thickness of the board is 1.5 mm, the size of the larger side is 110 mm.

$\Delta = 80/110 = 0.73$, to use the mounting board $\lambda = 2.2$.

$$f_0 = \left(\frac{1}{\sqrt{1 + \frac{50}{43}}} \right) \cdot \left(\frac{3.14}{4\sqrt{3}} \right) \cdot \left(1 + 0.73^2\right) \cdot \left(\frac{2.2 \cdot 0.025}{0.165^2} \right) \cdot \sqrt{\frac{3.3 \cdot 10^{10}}{2.5 \cdot 10^3}} \approx 740 Гц$$

According to the technological process of installation, the board after assembly is covered with varnish, which increases the resonant frequency by 20%.

From here:

$$f_0 = 148 + 740 = 888\,Гц$$

According to the standards, printed circuit boards that are part of electronic equipment without depreciation should not have resonant frequencies below 60 Hz. As can be seen from the calculation of the designed product satisfies this condition.

In addition, to ensure vibration resistance, the board must have the necessary fatigue when exposed to vibration, ie to withstand the allowable values of vibration acceleration. This requires that the resonant frequency of the board satisfies the condition:

$$f_0 \geq \sqrt[3]{\left(\frac{\gamma_{g_0} \cdot g \cdot j_{max}}{0.003 \cdot a}\right)^2} \quad (1.4)$$

where γ_{g_0} – coefficient, the numerical value of which depends on the value of the frequency of natural oscillations and influencing accelerations;

j_{max} – maximum load in units g;

g – free fall acceleration, $g = 9.8\,м/c$

a – the size of the smaller side of the board, $a = 80\,мм$.

For $f_0 = 888\,Гц$ and vibration accelerations to $2g$ the value of the coefficient $\gamma_{g_0} = 52$.

To determine the maximum allowable vibration loads on the board, write the ratio in the form

$$j_{max} \leq \frac{\sqrt{f_0^{\,3}} \cdot 0.003 \cdot a}{\gamma_{g_0} \cdot g} \quad (1.5)$$

Substituting the value, we obtain

$$j_{\max} \le 2.3g$$

Because according to the requirements of the device, it must withstand vibrations in the frequency range of 10-60 Hz and acceleration $2g$, then from calculations we see that the design of the device satisfies requirements of vibration resistance and is suitable for operation in the set conditions.

1.3.3.2 Calculation of impact strength.

Shock effects on the unit are characterized by the shape and parameters of the shock pulse. According to the requirements of mechanical impact during transportation, the unit must withstand shock pulses lasting 10 ms, peak acceleration $H_y = 10g$. The maximum impact on the equipment has a pulse of a rectangular shape, we will calculate the strength of the device to the action of such shocks.

Conditional frequency of the shock pulse:

$$\omega = \frac{\pi}{\tau} \tag{1.6}$$

where τ – shock pulse duration, $\tau = 10 мс$.

$$\omega = \frac{3{,}14}{10 \cdot 10^{-3}} = 314 Гц$$

Coefficient of transmission during the impact:

$$K_y = 2 \cdot \sin\left(\frac{\pi}{2 \cdot \nu}\right) \tag{1.7}$$

where ν – coefficient.

$$\nu = \frac{\omega}{2 \cdot \pi \cdot f_0} \qquad (1.8)$$

Substituting the value we get:

$$\nu = \frac{314}{2 \cdot 3.14 \cdot 888} = 0.056$$

$$K_y = 2 \cdot \sin\left(\frac{3.14}{2 \cdot 0.056}\right) = 0.83$$

Maximum relative acceleration of the device:

$$a_y = H_y \cdot K_y \qquad (1.9)$$

Maximum relative displacement

$$Z_{\max} = \frac{2 \cdot H_y}{2 \cdot \pi \cdot f_0} \cdot \sin\left(\frac{\pi}{2 \cdot \nu}\right) = \frac{a_y}{2 \cdot \pi \cdot f_0} \qquad (1.10)$$

The impact strength condition for radioelements has the form

$$a_y < a_{y\,\partial on}$$

where $a_{y\,\partial on}$ – permissible impact acceleration, $a_{y\,\partial on} = 10g$

Because $8.45g < 10g$, then the impact strength condition is met.

For a printed circuit board, the impact strength condition is:

$$Z_{\max} < 0.003b < 0.705$$

The condition is met, so the unit is suitable for operation and transportation under the impact.

1.3.4 Calculation of heat and mass transfer modes

From the point of view of thermophysics, a radio electronic device is a simple system with a small number of heat sources.

For calculation, we assume that the model should be a homogeneous heated area, which is placed in an airtight housing. This model can be accepted, as the board does not have powerful heat sources, in addition, the filling of the board is quite homogeneous and uniform.

Determine to calculate the thermal regime, in which case the specific scattering power of the device as a whole q_k and heated $q_з$

$$q_k = \frac{P_0}{S_k} \tag{1.11}$$

$$q_з = \frac{P_0}{S_з} \tag{1.12}$$

where P_0 – power dissipated by the device in the form of heat;

S_K – the area of the outer surface of the housing of the device;

$S_з$ – conditional area of the heated zone.

Let's calculate the surface area of the device according to the formula

$$S_K = 2(L_1L_2 + L_2L_3 + L_1L_3) \tag{1.13}$$

where L_1 – the length of the device body (0,15), L_2 – the width of the device body (0,095), L_3 – the height of the device body (0,045):

$$S_K = 2(0.15 \cdot 0.095 + 0.095 \cdot 0.045 + 0.15 \cdot 0.045) = 0.05 м^2$$

Then the specific power of the body of the device

$$q_K = \frac{20}{0.05} \approx 400 Bm / м^2$$

Let's calculate the area of the black zone by the formula:

$$S_з = 2(L_1 \cdot L_2 + (L_1 \cdot L_2) L_3 \cdot K_з) \quad (1.14)$$

where $K_з$ – volume filling factor $K_з$ = 0,3.

$$S_з = 0.028 м^2$$

Then the specific power of the heated zone:

$$q_з = \frac{20}{0.028} = 714 Bm / м^2$$

According to the calculated values of specific power, we find the overheating coefficient of the housing and the heated zone: $Q_1 = 1$, $Q_з = 1.2$.

Coefficient of dependence on pressure and environment in the middle of the device case:

$$Q_k = Q_1 \cdot K_{H1} \quad (1.15)$$

$$Q_k = 1K$$

Overheating of the heated zone of the device:

$$Q_{зп} = Q_k + (Q_з - Q_1) \cdot K_{H1} \tag{1.16}$$

$$Q_{зп} = 1 + (1.2 - 1) = 1.2$$

Determine the average overheating of the air in the device

$$T_n = Q_{пов} + T_c \tag{1.17}$$

where T_c – ambient temperature (20^{0}C).

$$T_n = 1{,}1 + 20 = 21{,}1$$

Device housing temperature:

$$T_k = Q_k + T_c \tag{1.18}$$

$$T_k = 1 + 20 = 21$$

Heated zone temperature

$$T_з = Q_з + T_c \tag{1.19}$$

$$T_з = 1{,}2 + 20 = 21{,}2^0 C$$

Since the temperature of the heated zone is less than the allowable value of the temperature of the elements and solder, the designed device is suitable for operation in this thermal mode without additional heat dissipation. Heat exchange is carried out by means of ventilating apertures in the case of the device.

1.3.5 Calculation of electromagnetic compatibility

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

Since the product has no sources of electromagnetic radiation, and its element base is quite resistant to external influences, so the calculations of electromagnetic compatibility are not performed.

1.3.6 Calculation of the reliability of the product board

One of the factors influencing the reliability of the equipment as a whole is the reliability of the elements. The probability of failure of the elements depends on their design, quality of manufacture, operating conditions. The influence of external factors on the reliability of the elements is characterized by the load factor, ie the ratio of the actual value of the active factor to its nominal value. The impact on the reliability of the actual value of external factors and load factors can be determined using the appropriate impact factors *a*. The temperature coefficient of influence at shows how many times the failure rate changes when the temperature changes from the nominal value to the existing one. The failure rate of the element at temperature *t*: $\lambda = a_t \times \lambda_0$. We give the reliability of the elements in the form of table 1.1.

Table 1.1 - Reliability of the elements

The name of the electroradioelement	Quantity, *n*	λ_0, 1/hour
Capacitor	23	$0{,}05\cdot10^{-6}$
Resistor	39	$0{,}05\cdot10^{-6}$
Diode	8	$0{,}35\cdot10^{-6}$
Microcircuit	6	$0{,}01\cdot10^{-6}$
Printed circuit board	1	$0{,}1\cdot10^{-6}$
Soldering	162	$0{,}02\cdot10^{-6}$

Let’s calculate the failure rate of the system:

$$\lambda_c = \sum \lambda_0 \cdot n = 23 \cdot 0.05 \cdot 10^{-6} + 39 \cdot 0.05 \cdot 10^{-6} + 8 \cdot 0.35 \cdot 10^{-6} + 6 \cdot 0.01 \cdot 10^{-6} + + 1 \cdot 0.1 \cdot 10^{-6} + 162 \cdot 0.02 \cdot 10^{-6} = 9.3 \cdot 10^{-6}$$

Calculate the probability of trouble-free operation of the system for a time equal to 1000 hours:

$$P_c(t) = \exp(-\lambda_c \cdot t_p) = \exp\left(-9.3 \cdot 10^{-6} \cdot 1000\right) \approx 0.82$$

Determine the average operating time for system failure:

$$T_c = \frac{1}{\lambda_c} = \frac{1}{9.3 \cdot 10^{-6}} = 107000 \text{ год.}$$

The reliability of the equipment depends on the correct observation and compliance with the specified operating conditions; from timely and high-quality preventive inspection and repair. High reliability can also have equipment, the production of which uses automation and mechanization of production processes. In this regard, the greatest reliability is electronic equipment, which uses chips and microassemblies.

1.4 Electrocardiograph manufacturing technology

1.4.1 Analysis of the design of the device

The complexity or simplicity of reproducibility of the structure depends on the total number of parts and their distribution into groups - original, unified, standardized; requirements for the accuracy and rigidity of the surfaces of the parts that make up the product, as well as requirements for the accuracy of the conjugation of parts during assembly; the number of types of materials provided in the manufacture of parts that are part of the assembly unit and the number of types of processing of workpieces; overall dimensions and weights of the product.

The dimensions of the printed circuit board are 80x110 mm, on which the radio elements are placed. The thickness of the board is 1.5 mm, the topology of the printed conductors is double-sided. Radio elements are used with a minimum number of standard sizes of cases to provide convenience of their installation on a printed circuit board. In the case, the printed assembly is attached to the base with screws and washers.

1.4.2 Analysis of the design and selection of the technological route

Serial production is characterized by a limited range of products that are produced periodically and with a relatively large volume of output.

With increasing production, savings from in-depth development of technological processes increase. In-depth development of the technological process becomes profitable.

The production of electronic equipment is characterized by the subject specialization of assembly shops, in each of which a closed process of assembly of homogeneous products is carried out.

It is necessary to take into account the degree of typification of technical processes of assembly, production program, complexity of assembly, as well as forms of specialization of the shop and its cooperation with other assembly shops of enterprises.

The enterprise of serial production of electronic equipment uses single-subject continuous current lines. The rhythm of the lines is equal to or a multiple of the rhythm of the release of the object.

Mass assembly is carried out in batches. After each operation on the party, the worker adjusts the workplace, which is associated with the preparatory and final time.

Features of each of the types of production leave their mark on the nature of the design of technological processes. It is known that each of them is selected from several possible and should be the most economical in implementation. In this regard, in the development of new and improvement of known technological processes is of great importance the choice of rational methods of their design.

For high levels of production organization it is advisable to use unified processes. Work on their unification leads to the introduction of group and standard processes. Typification of technological processes is the classification of their parts and technological processes of their production.

Unified technological processes allow to effectively apply the most progressive approach to the development of technological processes with the search for optimal options. Involvement of highly qualified specialists in the development of unified technological processes allows to deeply study, generalize and implement in production scientific and technological achievements in the field of choosing the method of organization of processes, technological equipment, equipment and devices.

At the stage of technological planning of production, attention is paid to solving a set of issues regarding technological equipment. The means of technological equipment include: technological equipment, own technological equipment, means of mechanization and automation of production processes.

Technological equipment includes production tools in which material, means of influencing them and, if necessary, energy sources are placed to perform a certain part of the technological process. Production tools that are added to the technological equipment to perform a certain part of the process, is its own technological equipment, and means of production, in which manual labor is partially or completely replaced by the machine, are classified as mechanization. In automation, control functions are given to machines and devices.

In the preparation of production pay attention to the unification and standardization of technological equipment, identify the need for original equipment of the process. Equipment of workplaces is carried out in accordance with the developed standard and group technological processes. Carry out the design of special tools, tripods, molds and other equipment, taking into account the latest advances in science.

1.4.3 Selection of equipment for product production

The choice of equipment and facilities for the manufacture of the device must be made taking into account the program of production, type of production and design features of the product. The selected equipment must ensure the quality of the necessary operations and be constantly loaded.

Consider in more detail the design features of the developed product. In the design of the printing unit of the unit, bodyless radio elements are used, which corresponds to the technology of surface mounting.

Technology. A typical sequence of operations in surface mount technology includes:

- application of solder paste on contact pads (dosing in single and small-scale production, screen printing in serial and mass production);
- installation of components;
- group soldering by melting the paste in a furnace (preferably by convection, as well as by infrared heating or in the steam phase) 4
- cleaning of the board (depending on the activity of the flux) and application of protective coatings.

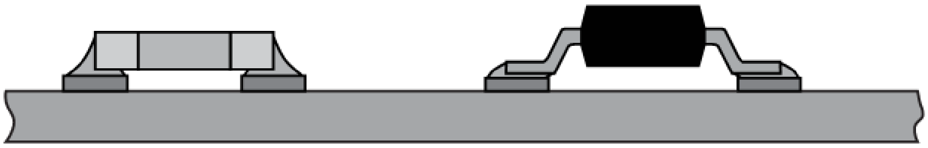
In unit production, in the repair of products and in the installation of components that require special precision, as a rule, in small-scale production is also used individual soldering with a stream of heated air or nitrogen.

One of the most important technological materials used in surface mounting is solder paste, which is a mixture of powdered solder with organic fillers, including flux. In addition to providing the process of soldering and surface preparation, solder paste also performs the task of fixing the components for soldering due to the properties of gluing.

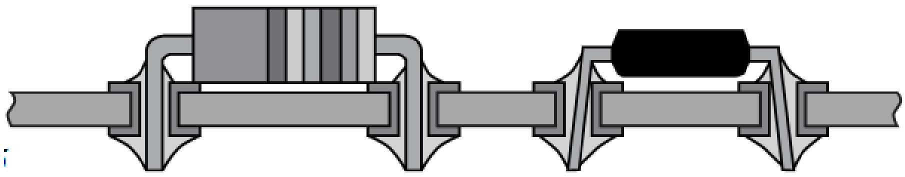
When soldering in surface mounting, it is very important to ensure the correct change of temperature over time (thermoprofile) to avoid thermal shocks, to ensure good activation of the flux and wetting the surface with solder.

Components used for surface mounting are called SMD components.

In fig. 1.11 shows the features of installation without housing and pin elements.



a



b

Figure 1.11 - Schemes of installation and assembly of components and printed circuit boards: a - surface mounting; b - installation of pins in the holes

In our case, both manufacturing technologies are used in the design of the BF, as the product has connectors, an inductor and a quartz resonator with pin terminals. Both SMD and PTH components are installed on one side of the printed circuit board (Fig. 1.12).

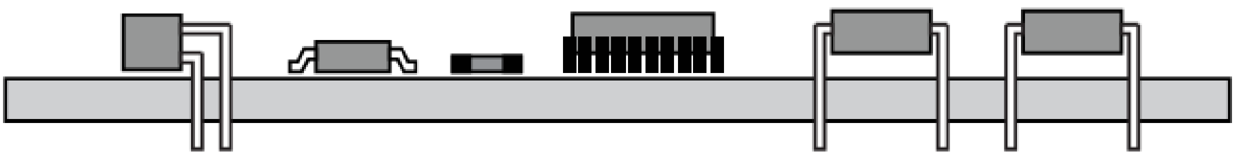


Figure 1.12 - Method of installation and assembly of components and printed circuit board of the electrocardiograph

The element base used is given in the appendices - in the specification. The main technological operations with the following design: preparation of radio elements (connectors, resonator, inductor), application of solder paste by screen printing, melting of solder paste by convection heating, manual installation and soldering of connectors, resonator, coil taking into account the number of such radio elements in the design of the printed circuit board - 6 connectors, 1 resonator, 1 inductor).

At each of the stages it is necessary to control the operation and in case of defects to return the printed circuit board to the previous stage or reject it.

According to the task in this work it is necessary to develop a technological process of assembly and installation of a portable electrocardiograph «EasyCardio» on a printed circuit board. Consider the process of surface mounting, which for the case of large-scale production must be automated. The process of preparation, installation and soldering of housing radio elements (connectors, resonator, inductor) will be carried out manually by the installer, as the use of automatic equipment for such a large number of radio elements is economically unprofitable. It is also unprofitable to include these operations in the technological process of surface mounting without housing elements, which is fully automated. Operations of preparation and installation of case elements will be carried out after completion of the main process of installation without case elements. This technological process consists of the following operations:

In this type of production we use the following equipment:

1. Preparation of the printed circuit board. Bath for degreasing (GG0867-4021). Capacity of a canister of 3-5 l. The maximum size of a ditch is 280 × 340 mm.

2. Applying solder paste through a stencil. SR-2500 screen printing device. Paste Sn 62 PM 10 BAS 88 (Multicor Solders). The thickness of the paste is 12.5 microns.

The SR-2500 screen printer is an inexpensive semi-automatic desktop system for applying solder paste to printed circuit boards. This model is characterized by design reliability, ease of operation and the best combination of price / quality.

SR-2500 is equipped with a pneumatic system of raising and lowering the desktop for vertical separation of the stencil and board, two metal (optional - polyurethane) squeegees, a system of constant pressure on the squeegee with adjustable pressure and angle of each squeegee. The type of installation is shown in Fig. 1.13.

Figure 1.13 - SR-2500 screen printer

The main technical characteristics of the printer:

- overall dimensions of the BF, mm 422 × 422
- maximum print size, mm 650 × 545
- thickness of DP, mm 1 ... 25
- squeegee type Metal
- printing speed, mm / s (10… 25)
- weight, kg 70
- overall dimensions, mm 850 × 900 × 600.

1. Installation of surface mount components. Automatic component installer TWS QUADRA LASER

Automatic machine for installation of TWS QUADRA LASER components

The laser centering system and the video centering system of the machine (Fig. 1.14) provide accurate installation of chips with a pitch of up to 0.5 mm and chips 0402.

Figure 1.14 - Automatic machine for installing TWS QUADRA LASER components

Maximum performance of up to 4,000 components per hour. Up to 120 tape feeders can be placed on the machine at the same time. It is possible to install a dosing head for applying solder paste or SMT glue.

Available software allows you to easily and quickly create component installers. The machine is programmed by broadcasting from CAD systems or input using a tablet coordinate digitizer.

1. Melting of solder paste. Full convection oven TWS-1250

TWS-1250 is a progressive full convection oven of medium type conveyor, equipped with a floor stand. This easy-to-operate oven has a working tunnel 2 meters long and provides optimal soldering modes with high productivity and low energy consumption. Precise maintenance of the set temperature is carried out by the microprocessor by means of the thermocouples located in each zone. The oven is equipped with a device for measuring temperature with 4 external thermocouples, which can be connected to a computer to display temperature profiles during the soldering process. Thanks to 4 zones of heating and digital regulation of speed of the conveyor it is possible to receive any necessary thermoprofile. Up to 14 soldering programs can be stored in the memory at the same time, which can be downloaded at any time at the request of the operator. All operating parameters are displayed on the color LCD monitor.

The TWS-1250 furnace (fig. 1.15) is completed with the mesh conveyor

TWS-1250 / TWS-1390 furnaces are compatible with lead-free technology.

Figure 1.15 - Oven TWS-1250

Specifications:

Heating zones: 4

Cooling zones: 1

Average power consumption: 4 kW

Power supply: 380 V, 50 Hz

Heat transfer: forced convection

Working width of the conveyor: 40 - 325 mm 60 - 290 mm

Maximum height of components on the board: 35 mm

Conveyor speed minimum / maximum: 100 - 500 mm / min

Overall dimensions: 800x3000x600 mm

Weight: 275 kg

1. Installation for cleaning the printing unit KR-1M. Uses alcohol-freon mixture SPS 1:19.

2. Exhaust hood 2Sh-NZh. It is used to accelerate the drying process of materials after washing and application of various liquid substances by simultaneously loading a batch of printed circuit boards, regulates air access.

3. Bath for degreasing, fluxing and washing of flux. Capacity of a canister of 3-5 l. The maximum size of a ditch is 280 × 340 mm.

4. Soldering iron electric pulse with heat sink and power supply PIT. Pulse duration - 0.1 to 1.5s. Power - 20 watts.

5. Pliers PUG-150.

6. Pliers lateral

7. Tweezers

8. Magnifier.

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

10. The bone.

11. Screwdriver of the regulator.

12. Installer's table - has all the necessary facilities for installation work.

To regulate the product using a testing complex DP HP30995, containing power supplies, a functional generator, a signal generator, a frequency meter, a multifunctional test switching unit (Hewlett Packard, Philips).

To ensure the normal operation of installation and assembly of the board you need to achieve optimal operation of the equipment, ie there should be no overload, it is necessary to meet the modes of technological processes and in particular when using additional materials (solder, flux), ie not too much or too little material.

2 LABOUR PROTECTION

2.1 Extreme conditions associated with the impact of noise during the manufacture of an electrocardiograph

The acoustic environment is an important component of the habitat: a person lives in a world of sounds. The parameters of the acoustic environment can significantly affect the general condition of a person and his work capacity and success (in communication systems, the operator's work is related to receiving signals). Extreme conditions occur if a person cannot recognize useful signals due to extraneous sound pressure and if the level of sound pressure approaches the pain threshold.

Sound pressure is usually measured in decibels (dB). A person's whisper, which is perceived at a distance of 1.5...2 meters from the speaker, is 1...18dB; noise in a room where people work, but there are no cars (student auditorium without audible lecturer speech), - 40dB; the speech of a person of average normal volume, received by a person standing next to him - 60 dB; car engine noise - 75dB; the noise of an electric subway train, which is perceived at a distance of 3 m from it - 95dB; jet plane noise - 115dB.

Already at a sound level of 100 dB, general fatigue occurs, productivity and quality of work decreases. At a sound level of 100...PO dB, noise and sound cause a depressing effect. At a sound (noise) level of 110 dB, speech communication is impossible. The painful limit of the sound level is 120-130 dB.

When designing workplaces, a sound level of more than 80 dB is considered unacceptable. Recommended sound level in rooms for design and theoretical works and processing of experimental data - 50 dB, in control rooms, working rooms - 60 dB, at workplaces in production facilities - no more than 80 dB.

If the sound pressure level exceeds the permissible level, use individual and collective means of protection (isolation of the sound source or working premises) - earplugs, headphones, helmets.

Mechanical vibrations that occur during the operation of working machines can cause not only sounds and noises, but also vibrations.

Vibration is mechanical oscillations of elastic bodies, which are characterized by amplitude, speed and acceleration.

According to the nature of the action, vibration is divided into general and local. General vibrations affect the entire human body. Human internal organs form oscillatory systems with their own frequency of oscillations (within tens and hundreds of Hz). Resonance frequency of heart, abdomen and chest - 5 Hz, head - 20 Hz, eyeballs - 60 Hz, central nervous system - 250 Hz. The effect of external vibrations with multiple frequencies can cause resonance phenomena and lead to displacement and mechanical damage of internal organs. The frequency of self-oscillations of sitting people is 4...8 Hz.

Vibration is perceived by a person as a natural load, similar to hard work. Vibrations with a frequency of more than 200 Hz overload the human nervous system and require increased mental stress.

2.2 Lighting of the industrial premises during operation of the electrocardiograph

Properly designed and rationally arranged lighting of industrial premises has a positive psychophysiological effect on workers, increases efficiency and safety of work, reduces fatigue and injuries, and ensures high work capacity.

Vision occupies a prominent place in the entire system of human senses. It is known that the organs of vision account for 90% of all information that a person receives. The sensation of sight occurs under the influence of visible radiation (light), which is electromagnetic radiation with a wavelength of 0.38...0.76 microns. The sensitivity of vision is maximal to electromagnetic radiation with a wavelength of 0.555 μm (yellow-green color) and decreases to the limits of the visible spectrum.

Lighting classification

When lighting industrial premises, use:

- natural lighting, which is created by direct sunlight and diffused light of the sky and which changes depending on geographical latitude, season, day, degree of cloudiness and transparency of the atmosphere;

- artificial lighting created by electric light sources;

- compatible lighting, in which insufficient natural lighting is supplemented by artificial lighting.

Natural lighting is divided into lateral (one-sided or two-sided), carried out through light holes in the outer walls; upper, carried out through aeration and protective lanterns, openings in roofs and ceilings; combined combination of top and side lighting.

According to the design, artificial lighting is divided into two types - general and combined. The general lighting system is used in rooms where the same type of work is performed throughout the area. A distinction is made between general uniform lighting, in which the light flux is distributed evenly over the entire area of the room without taking into account the location of workplaces, and general localized lighting (taking into account the location of workplaces).

When performing precise visual work (locksmith, turning, milling, control, etc.) in places where the equipment creates deep, sharp shadows or work surfaces are located vertically, along with general lighting, local lighting is used. The set of local and general lighting is called combined. The use of only local lighting is not allowed due to the risk of occupational injuries.

According to the functional purpose, artificial lighting is divided into working, emergency and special, which in turn is classified as security, duty, evacuation, bactericidal, erythema, etc.

Working lighting is intended to ensure the production process, the passage of people, traffic and is mandatory for all production premises.

Emergency lighting is arranged to continue work in cases where the sudden shutdown of working lighting and the associated disruption of normal equipment maintenance may cause an explosion, fire, poisoning of people, disruption of the technological process, etc. The minimum illuminance of working surfaces with emergency lighting should be 5% of the standard illuminance of working lighting, but not less than 2 lux.

Evacuation lighting is designed to ensure the evacuation of people from the production premises in case of accidents and switching off the working lighting and is arranged in places dangerous for passage from the production premises where more than 50 people work. The minimum illuminance on the floor of the main passages and on the stairs with evacuation lighting should be at least 0.5 lux, and on open areas - at least 0.2 lux.

Security lighting is arranged along the borders of the territory guarded by special personnel. The lowest illumination at night is 0.5 lux. Signal lighting is used to fix the boundaries of dangerous zones, indicates the presence of danger, or a safe escape route.

Industrial lighting includes bactericidal and erythematous lighting. Bactericidal lighting is created to disinfect air, drinking water, and food products. Ultraviolet rays with a wavelength of 0.254...0.257μm have the greatest bactericidal ability. Erythema irradiation is arranged in production facilities where there is not enough sunlight. Electromagnetic rays with a wavelength of 0.297 μm have the maximum erythematous effect.

Occupational hygiene requires, first of all, the maximum use of natural lighting, since daylight is better perceived by the visual organs.

The correct organization of lighting involves not only compliance with lighting standards, which regulate the minimum lighting for each type of work, but also compliance with hygienic requirements for the quality of lighting, such as uniformity of illumination of the work surface, limitation of excessive brightness, glare, blinding effect, sharp shadows and contrast.

CONCLUSIONS

In the complex final work the review of all stages of a life cycle of the portable electrocardiograph «EasyCardio» is carried out. In the first chapter of the work the analysis of the technical task is carried out, the purpose of which is to clarify the requirements set by the customer. In the section on construction the mathematical model of work of the device on the basis of which the structural and functional schemes are developed is developed. An electrical circuit diagram has been developed. A parametric synthesis is performed, the purpose of which is to calculate the denominations of the elements of the electrical circuit diagram. The design section was performed, in which the element base was selected, the design of the printed circuit board was developed, the electrocardiograph manufacturing technology was described.

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12. https://www.medicinenet.com/difference_between_electrocardiogram_and_electroca/article.htm

13. https://pubmed.ncbi.nlm.nih.gov/18191652/

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APPLICATIONS

Pos. mark	Name	Quol.	Note
	Capacitors		
	GRM21 0805		
C1- C7	1 нФ-63В±5%	7	
C8,C12,C14	10 нФ-63В±5%	3	
C9- C11	100 нФ-63В±5%	3	
C10,C13	1 мкФ-63В±5%	2	
C15, C16	1 мкФ-63В±5%	2	
C17-C20,C23	1 мкФ-63В±5%	5	
C21, C22	18 мкФ-16В±5%	2	
	Microchips		
DA1, DA2	TL072	2	
DD1	FT232RL	1	
DD2	Atmega48 (TQFP32)	1	
	Resistors		
	0805RC11		
R1-R3	100 кОм±5%	3	
R4, R9	22 кОм±5%	2	
R5-R7,R17	1 МОм±5%	4	
R10,R11,R14	33 кОм±5%	3	
R12,R13,R19	270 кОм±5%	3	
R18	330 кОм±5%	1	
R15,R20	6,8 кОм±5%	2	
R19,R25	2,7 кОм±5%	2	

		UChV 3.013.001
Made by	Ugorji Ch.V.	Portable electrocardiograph "EasyCardio"
Checked.	Dozorskyi V.G.	List of the elements
Normocontrol		Page: 1
Head of department	Yavorska E.B.	Pages: 2
		ATF, group IRB-42

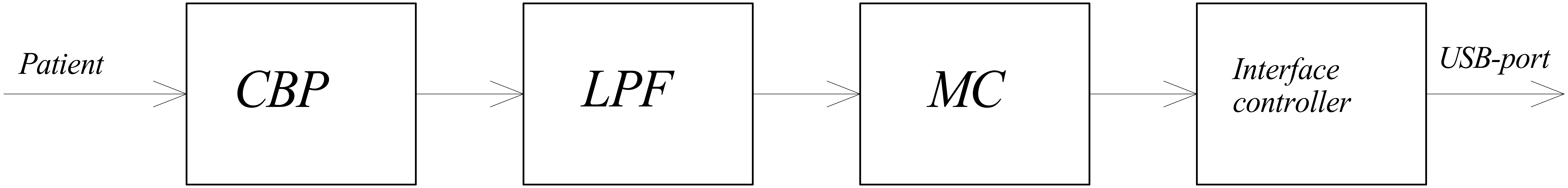
Pos. mark	Name	Quol.	Note
R21, R26	1 МОм±5%	2	
R22	10 кОм±5%	1	
R23, R28	100 кОм±5%	2	
R24, R29	510 Ом±5%	2	
R27, R30	2,7 кОм±5%	2	
R31,R32	100 Ом±5%	2	
R33,R34	1 МОм±5%	2	
R35,R38	100 кОм±5%	2	
R36,R37	330 Ом±5%	2	
R39	1 кОм±5%	1	
	Diodes		
VD1-VD8	PS-BAL99	8	
HL1,HL2	LED	2	
	Optocouplers		
U1, U2	6N137	2	
	Connectors		
X1-X4	PLD-4	4	
X5,X6	PLD-6	2	

			Pos. mark	Name	Quol.	Note
				Documentation		
A1			UChV 3.013.001	Assembly drawing		
A2			UChV 3.013.001 E3	Electric diagram		
				Details		
		1	UChV 7.103.001	Printed circuit board	1	
				Standard products		
				Other products		
				Diodes		
		2		PS-BAL99	8	VD1-VD8
				Capacitors		
				GRM21 0805		
		3		1 nF-63V±5%	7	C1- C7
		4		10 nF-63V±5%	3	C8,C12,C1
		5		100 nF-63V±5%	3	C9- C11
		6		1 uF-63V±5%	2	C10,C13
		7		1 uF-63V±5%	2	C15, C16
		8		1 uF-63V±5%	4	C17-C20, C23
		9		18 uF-16V±5%	2	C21, C22

		UChV 3.013.001		
Made by	Ugorji Ch.V.	Portable electrocardiograph "EasyCardio"	Page	Pages
Checked.	Dozorskyi V.G.		1	2
Normocontro				
Head of department	Yavorska E.B.	Друкований вузол	ATF, group IRB-42	

			Pos. mark	Name	Quol.	Note
				Microchips		
		10		TL072	2	DA1, DA2
		11		FT232RL	1	DD1
		12		Atmega48 (TQFP32)	1	DD2
				Resistors		
				0805RC11		
		13		100 kOhm±5%	3	R1-R3
		14		22 kOhm ±5%	2	R4, R9
		15		1 MOhm±5%	4	R5-R7,R17
		16		33 kOhm ±5%	3	R10,R11,R14
		17		270 kOhm ±5%	3	R12,R13,R19
		18		330 kOhm ±5%	1	R18
		19		6,8 kOhm ±5%	2	R15,R20
		20		2,7 kOhm ±5%	2	R19,R25
		21		1 MOhm±5%	4	R21, R26, R33, R34
		22		10 kOhm ±5%	1	R22
		23		100 kOhm ±5%	4	R23, R28, R35, R38
		24		510 Ohm±5%	2	R24, R29
		25		2,7 kOhm ±5%	2	R27, R30
		26		100 Ohm±5%	2	R31,R32
		27		330 Ohm±5%	2	R36,R37
		28		1 kOhm ±5%	1	R39
		29		LED	2	HL1,HL2
		30		Optocouplers 6N137	2	U1, U2
		31		Connectors PLD-4	2	X1-X4
		32		Connectors PLD-6	2	X5,X6
		33		Resonator 3.3728MHZ HC49/U3H	1	Z1
		34		Inductor 680 мкГн	1	L1

UChV 3.013.001 E1



CBP - converter of biopotentials;
LPF - low-pass filter;
MC - microcontroller;

Изм.	Лист	№ докум.	Подп.	Дата
Разраб.		Ugorji Ch.V.		
Пров.		Dazorskyi V.G.		
Т.контр.				
Н.контр.				
Утв.		Yavorska E.B.		

UChV 3.013.001 E1

Portable electrocardiograph "EasyCardio" Structural diagram

Лит.	Масса	Масштаб

Лист | Листов 1

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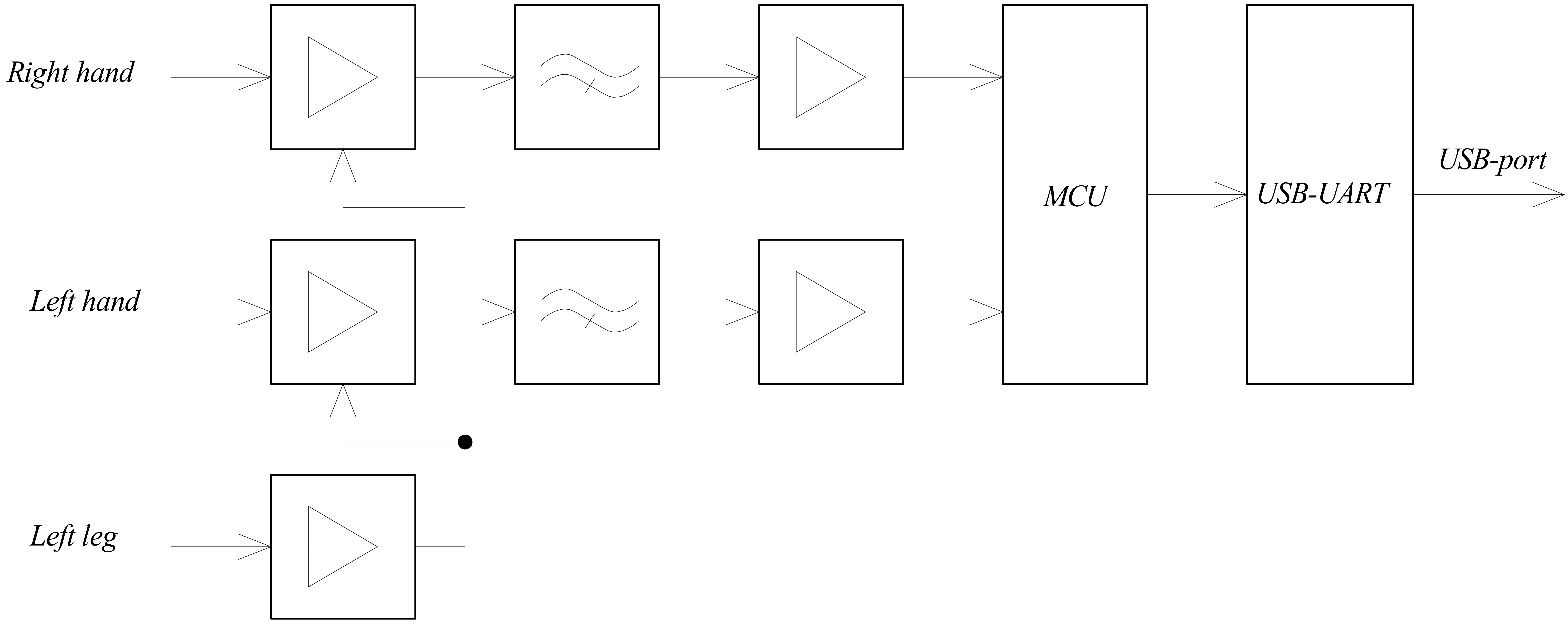
Перв. примен. | Справ. № | Подп. и дата | Инв. № дубл. | Взам. инв. № | Подп. и дата | Инв. № подл.

Копировал | Формат A2

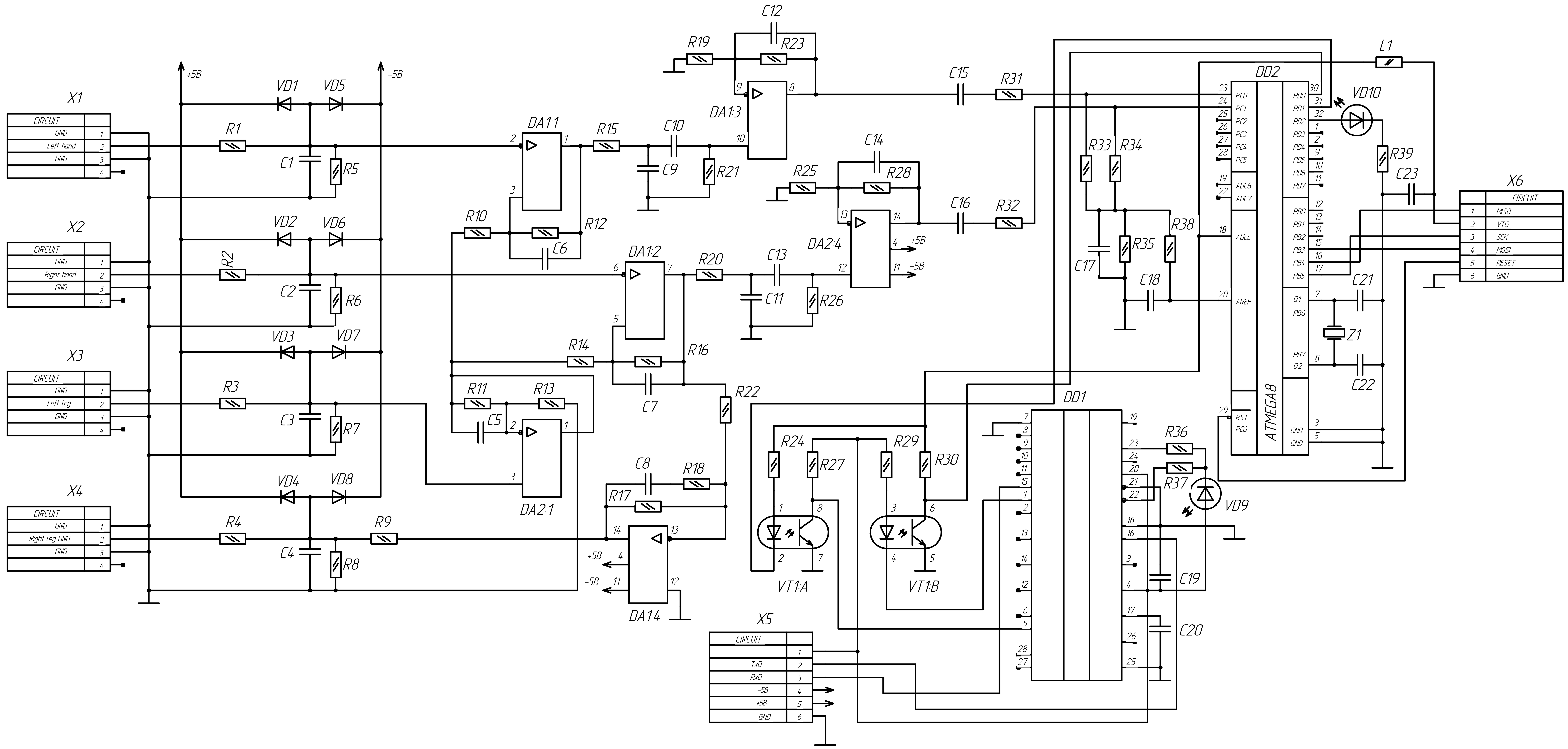


					UChV 3.013.001 E2		
Изм. Лист	№ докум.	Подп.	Дата		Portable electrocardiograph "EasyCardio" Functional diagram	Лит.	Масса	Масштаб
Разраб.	Ugorji Ch.V.						
Пров.	Dozorskyi V.G.						
Т.контр.					Лист	Листов 1	
Н.контр.					ATF, group IRB-42		
Утв.	Yavorska E.B.						

Перв. примен.
Справ. №
Подп. и дата
Инв. № дубл.
Взам. инв. №
Подп. и дата
Инв. № подл.

Копировал
Формат A2

UChV 3.013.001 E3



Изм.	Лист	№ докум.	Подп.	Дата	
Разраб.		Ugorji Ch.V.			
Пров.		Dozorskyi V.G.			
Т.контр.					
Н.контр.					
Утв.		Yavorska E.B.			

UChV 3.013.001 E3

Portable electrocardiograph "EasyCardio" Electrical diagram

Лит.	Масса	Масштаб
	–	–

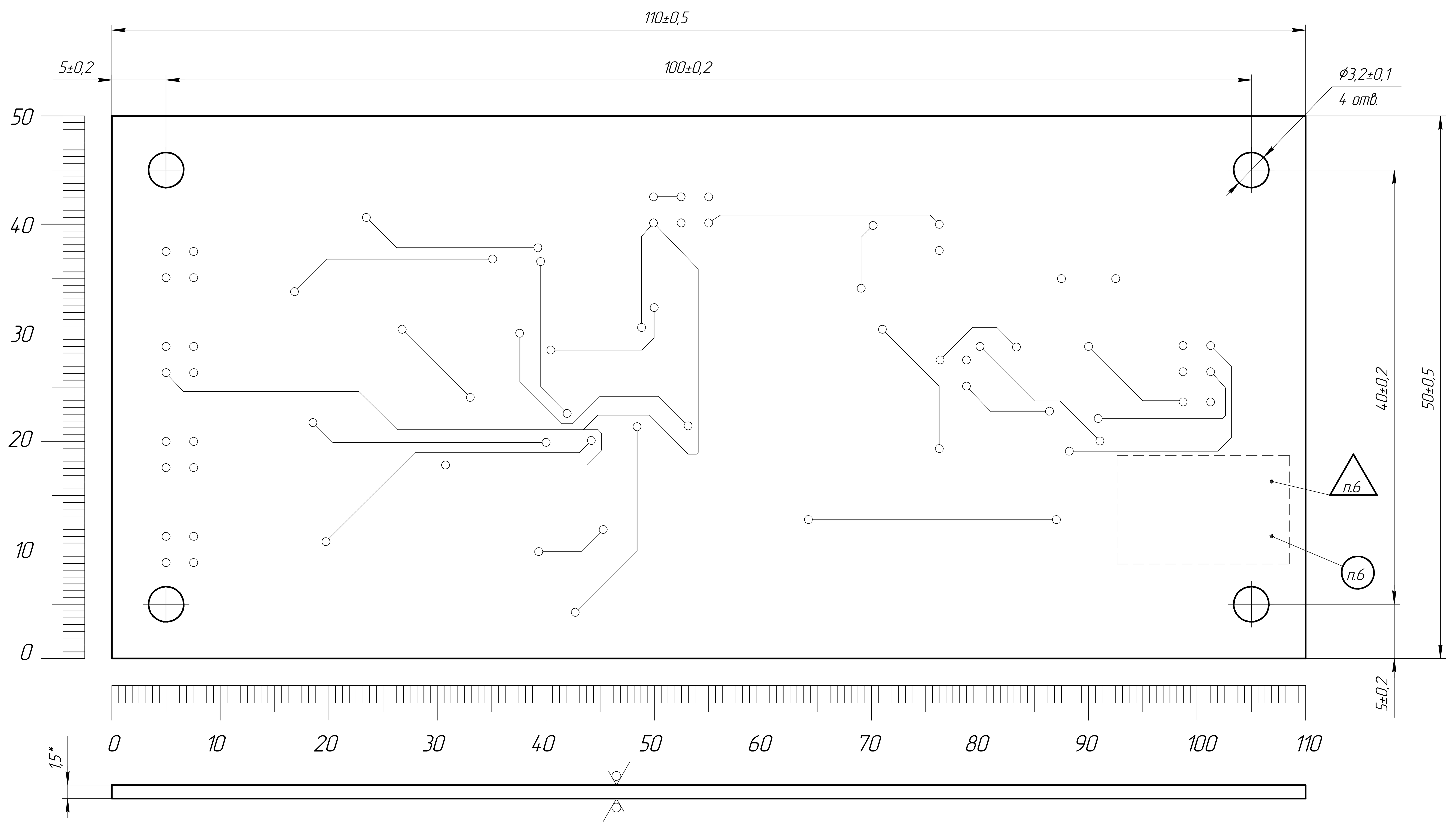
Лист | Листов 1

ФРК, РМс-42

Копировал | Формат A1

Перв. примен. | Справ. № | Подп. и дата | Инв. № дубл. | Взам. инв. № | Подп. и дата | Инв. № подл.

UChV 7.103.001



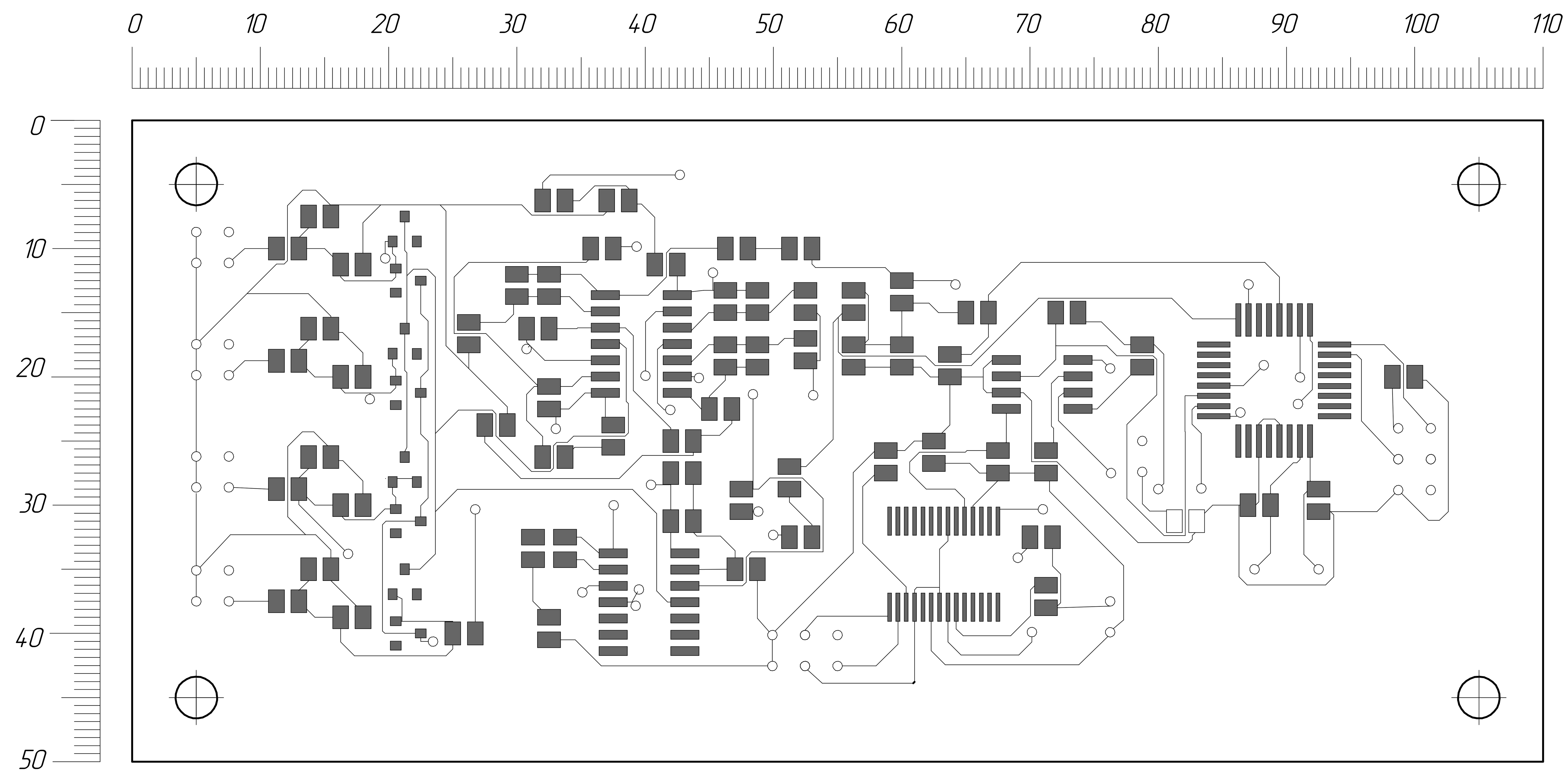


Table 1

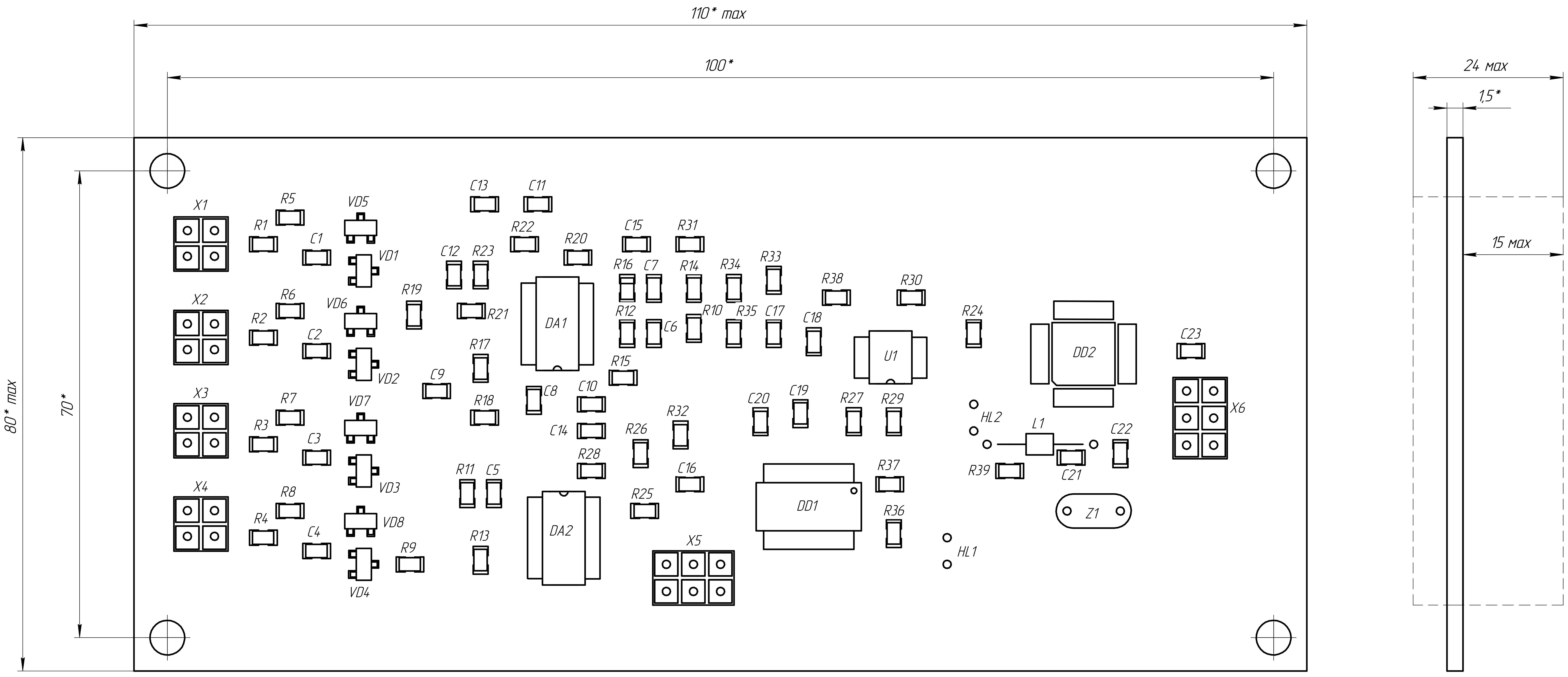
Conventional designation of the hole	Hole diameter, mm	Contact pad diameter, mm	Metallization	Number of holes
⌀	0,9	1,5	+	71
▯	–	1,2x2,0	–	126
▫	–	0,9x0,7	–	24
▭	–	0,7x2,2	–	36
▮	–	2,2x0,3	–	60

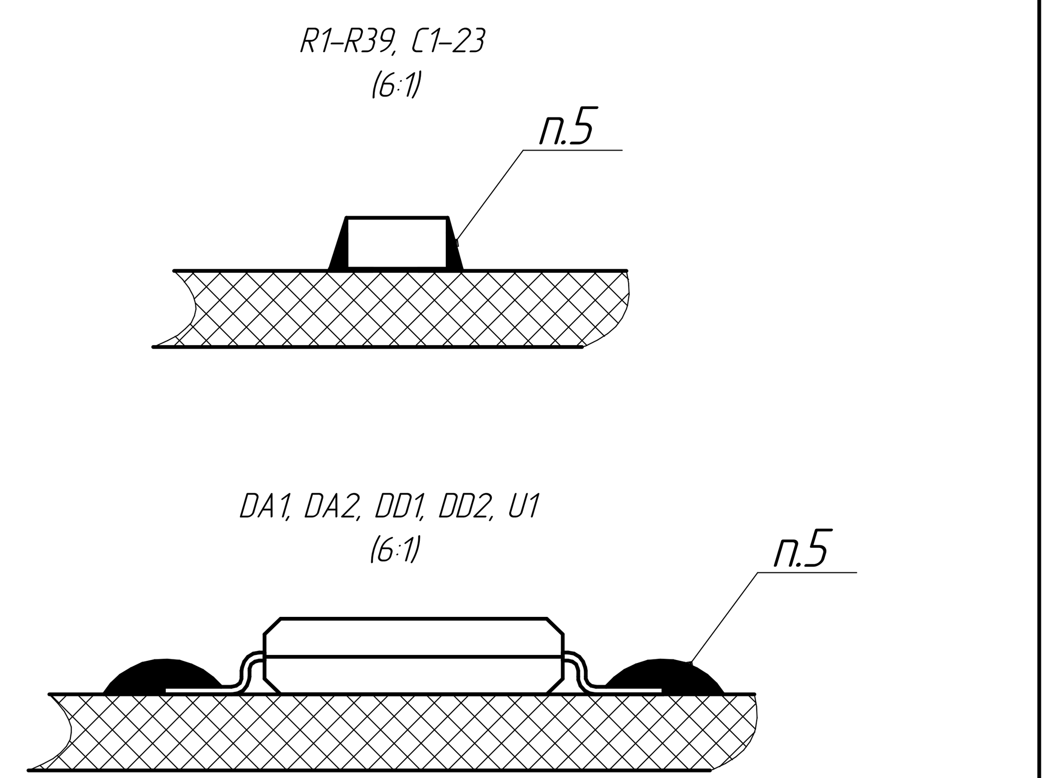
1. * Size for references.
2. The board must comply with GOST 23752, stiffness group 2, accuracy class 3 GOST 23751. Step grid 0.625 mm.
3. Make the payment in a combined positive way.
4. The configuration of the printed conductors according to the drawing.
5. Hole parameters see table 1.
6. Make a stamp, mark the serial number with black marking paint.

UChV 7.103.001				
Изм. Лист № докум. Подп. Дата	Printed circuit board	Лит.	Масса	Масштаб
Разраб. Ugorji Ch.V.				4:1
Пров. Dozorskyi V.G.				
Т.контр.		Лист	Листов 1	
Н.контр.	ATF, group IRB-42			
Утв. Yavorska E.B.				

Перв. примен.
Справ. №
Подп. и дата
Инв. № дубл.
Взам. инв. №
Подп. и дата
Инв. № подл.

Копировал Формат A1

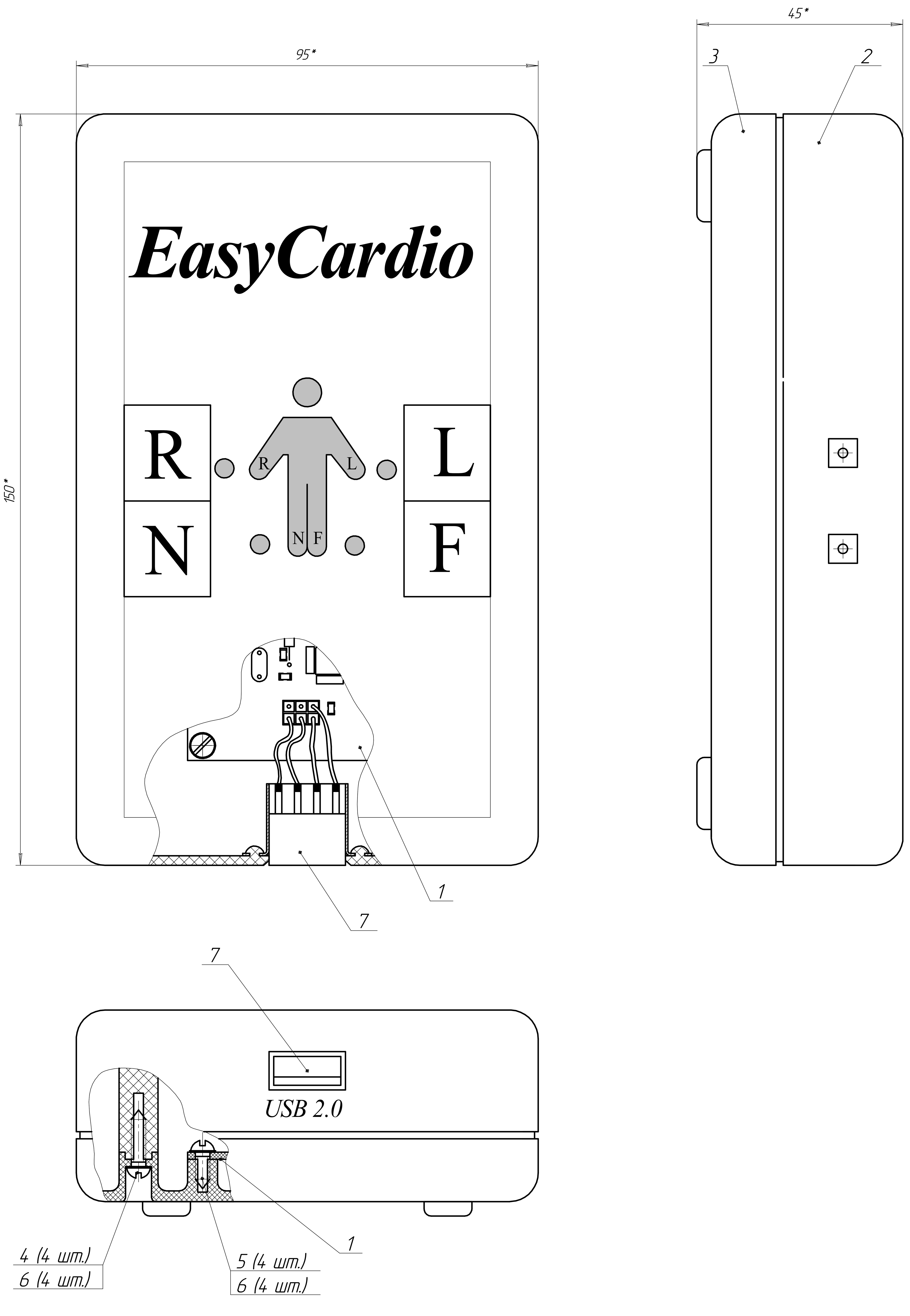




1. Sizes for references;
2. Installation of components X1–X6, Z1, L1 is carried out according to DSTU2783;
3. Install the rest of the components according to the drawing;
4. Designation of components, initial contacts of components are shown conditionally;
5. Solder POS61;
6. Varnish coating, except for contact pads for soldering pins.

				UChV 3.013.001 PU			
Изм. Лист	№ докум.	Подп.	Дата	Printed unit Assembly drawing	Лит.	Масса	Масштаб
Разраб.	Ugorji Ch.V.						4:1
Пров.	Dozorskyi V.G.				Лист	Листов 1	
Т.контр.					ATF, group IRB-42		
Н.контр.							
Утв.	Yavorska E.B.						

Копировал Формат A1



UChV 2.013.001

Перв. примен.

Справ. №

Подп. и дата

Инв. № дубл.

Взам. инв. №

Подп. и дата

Инв. № подл.

					UChV 2.013.001
Изм. Лист	№ докум.	Подп.	Дата	Portable electrocardiograph "EasyCardio"	Лит. / Масса / Масштаб: 2:1
Разраб.	Ugorji Ch.V.				
Пров.	Dozorskyi V.G.				Лист / Листов 1
Т.контр.					
Н.контр.					ATF, group IRB-42
Утв.	Yavorska E.B.				

Копировал Формат A1