

DEVELOPMENT OF A MICROCONTROLLER DEVICE FOR REPRODUCING AUDIO INFORMATION

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The paper presents the results of the design, development and manufacture of a microcontroller device for reproducing sound information in the presence of a person. The description of the concept of a microcontroller device and the architecture of the system are given. The technical specification for the manufacture of the device and its software has been compiled. A prototype of the audio information playback device based on Arduino-UNO was made. In order to reduce the cost of one product, the device was upgraded and the ATtiny13A-SU microcontroller was selected as the microcontroller. An electrical principal scheme, a printed circuit board of the device and software for it have been developed. 17 operating audio information playback devices have been manufactured. A technical solution for further improvement of the microcontroller device is proposed.

Keywords: audio bench, microcontroller device, printed circuit board, Arduino-UNO, ATtiny13A-SU, audio information.

1. Introduction

The development of various fields of electronics, computer technology, data collection and communications has created a favorable environment for the development of various areas of technic and technology [1-3]. It is expected that the modern concept of designing and using electronic devices will profoundly change our lives, allowing us to create ubiquitous, distributed, high-performance, high-speed systems that can surprisingly change the way which we interact with the world [2, 3]. There are many commercial, industrial, educational and cultural opportunities for the use of various electronic devices [4-7].

Intelligent electronic control systems can be designed in different ways, but it is reasonable to expect that sensors, actuators and control units will be present in most applications. To do this, embedded hardware platforms can be used to implement these elements, and there are many options available on the market. Among the various platform options, open source platforms are gaining the most popularity among developers. There are currently several good open source platforms. The presence of many research and industrial projects developed using various platforms is a good indicator of which platforms are the most popular. Such platforms include RaspberryPi, BeagleBoard, Arduino, etc.

Compared to other platforms, the Arduino platform has a number of advantages, representing a built-in breadboard designed for projects in the field of electronics, but not necessarily working as a computer. Arduino is used for automation and electronic projects that require repeated execution of certain tasks, and therefore the software and hardware resources of this platform are more limited compared to other platforms.

Most Arduino models are developed using a microcontroller manufactured by Atmel (hereinafter, Microchip), and most of them belong to the ATmega family (8-bit). In addition, this characteristic has two practical meanings: firstly, the Arduino board is usually cheaper; and secondly, it has less computing power than a conventional RaspberryPi or BeagleBoard [8, 9]. Special IDE (IDE – integrated development environment) software developed by the Arduino manufacturer is used for software development.

Nevertheless, the simplicity of Arduino finds its place in many automation and control projects and facilitates the manufacturing process of microcontroller devices. Arduino microcontroller devices are also widely used in the educational process [10], for use in the mining industry [11], for use in smart cities [12], etc. A good example of improving the quality of the infrastructure of Karaganda Buketov University is the development of a device for reproducing a musical composition in the presence of a person. The microcontroller device is equipped with a human detection sensor in a given geometric space for this. The specified musical composition is played, when a person is detected.

Despite the abundance of various electronic devices on such sites as Aliexpress, Ebay, etc., it is impossible to buy an electronic device on these sites that performs all the necessary functions described above. It is not possible to buy a device to play audio information at a certain scheduled time or when the necessary condition or conditions are met.

Today it is impossible to imagine a modern city without recreation areas and benches. Modern technologies make it possible to increase the comfort and standard of living of people. Interactive benches ("talking", "smart", "musical") are becoming popular objects with which residents of the city actively interact [13] and thanks to the reproduced information and cultural aspect have become widespread in Russia (Moscow, Tula, Nizhny Novgorod, etc.) [14, 15] and in far abroad (Great Britain, Sweden, USA, etc.) [16-18].

A number of technical solutions for musical benches with a device for reproducing sound information or sound are shown in Table 1. Thus, despite the widespread use of this idea, in each case the benches have a different design, the reproduced information and schematic execution differ. The difference and novelty of our technical solution is the automatic reproduction of sound information in the presence of a person, increased attention to the vandal-proof characteristics of an electronic device and the possibility of installing this device on any bench.

Table 1. Technical characteristics of a number of sound benches

Brief description of the product, location	The main technical characteristics, Features of this solution	Cost
Solar Audio Bench, National Library of Wales [16]	Activated by two buttons the electronics. Programmable via supplied USB Programming Dongle Audio Output: 1W into 8Ω Speaker. Frequency Range: 75Hz – 20KHz.	Electronic kit - 599 – 767 GBP
Audiorama's sound bench, Lund Stockholm, Sweden [17]	Custom-made bench for sound art in the public space. 4 columns on a bench. The project is under development.	-
Touchme sound bench [18]	Measures intensity of touch between people and turns it into sound.	-
Play panca sound bench, Munich, Germany [19]	Big passive amplifier for enhancing voice from smartphones. Smartphones can put in the long end of the bank and listen to their amplified music.	Sound bench– 31000 Euros
Microcontroller device for reproducing audio information, Karaganda, Kazakhstan	Activation of the melody when an object is located at a distance of 1 meter from the distance sensor. Vandal-proof housing, high moisture protection	50-75 dollars for kit

In this regard, the purpose of this work is to create a microcontroller device for reproducing audio information with the ability to configure various functions performed. The main function of this device is to play a musical melody when a person is detected in a given geometric space. Depending on the function performed, the device can be supplemented with the necessary sensors, a real-time clock, additional non-volatile power, etc.

The areas of use are not limited to the above functions. The information playback device can also be used in a number of other applications, for example, accompanying visual information (painting, sculpture, etc.) with additional information in various languages, reproducing information about a person being in a prohibited area with a loud sound message, etc.

All of the above devices can be implemented on a single platform based on a single microprocessor device.

2. Desing of microcontroller device

Initially, work was carried out to develop the concept of a microcontroller device. The device must perform a number of functions:

1. Register the presence of a person in a certain place of space;
2. Reproduction audio information at the required volume;

3. Repeat the execution of functions 1 and 2 in the presence of a person a specified number of times.

To speed up the manufacturing process of a microcontroller device, it was decided to create this device using a number of functional modules:

1. A human presence sensor in a certain place of space;
2. MP3 player for reproduction audio information;
3. Audio frequency amplifier;
4. Microcontroller to coordinate the operation of all other functional elements of the circuit;
5. Necessary power supplies + 12 V, + 5 V.

The JSN-SR04T sensor was chosen as a sensor for detecting the presence of a person in a given space. The ultrasonic element that allows you to send and receive ultrasonic pulses is designed for use at a distance of 20 cm to 450 cm with an accuracy of 2 mm. The measured angle is 75° . In our case, the operating response distance was chosen to be 1 m.

A simple operation algorithm is selected for the operation of the device. The ultrasonic module, on command from the microcontroller, sends a packet of 7 pulses to determine the distance to the object. Information about the distance to the obstacle comes from the sensor with a delay. The information is embedded in the duration of the pulse coming from the distance sensor. After determining the distance, the microcontroller gives an impulse to start the MP3 player at a distance less than the specified one. After the delay performed on the microcontroller and equal to the playback time of the melody, the cycle repeats.

In accordance with the component base and the algorithm of operation, an electrical functional circuit of a microcontroller device for reproducing audio information was developed. In the first version, the function of the microcontroller was performed by the Arduino Uno board (Fig. 1, a). Work was carried out on it to launch a microcontroller device and check the coordinated operation of the main elements of the circuit.

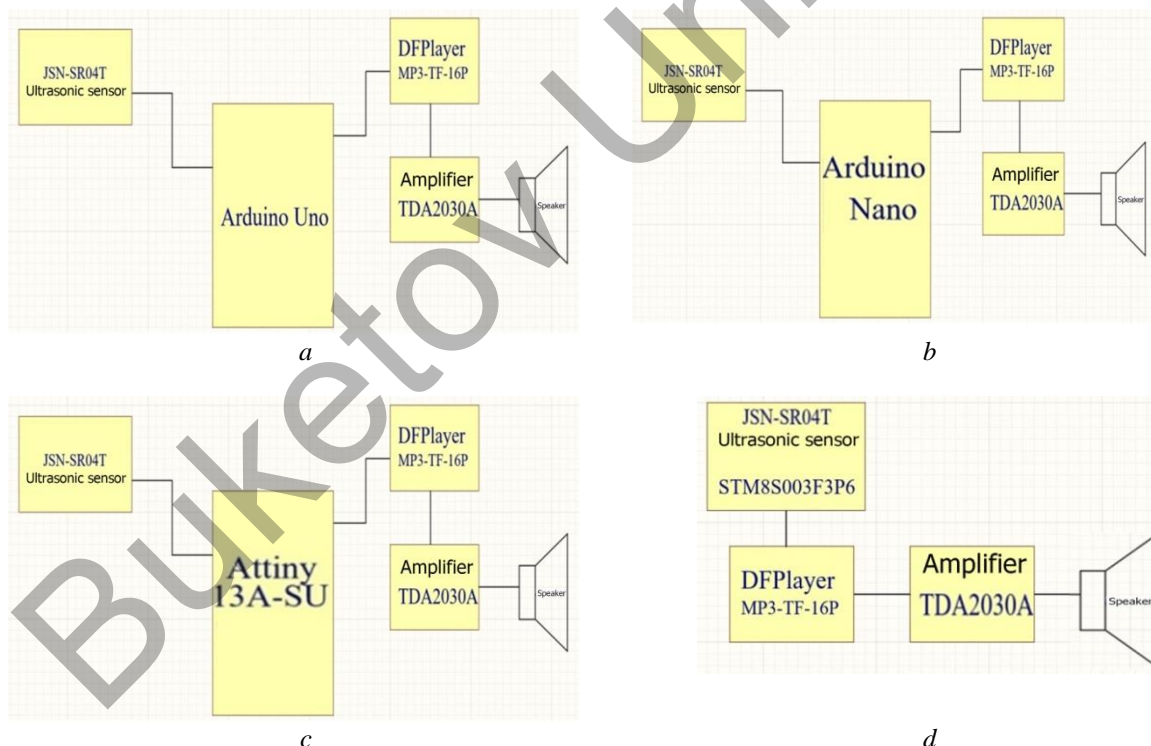


Fig.1. Stages of work on the functional scheme of a microcontroller device for reproducing audio information

The sound quality of this system is determined by the frequency range of the audio frequency amplifier (TDA2030A Audio Power Amplifier Module) of the speaker used for playback (VT-412, 60 W) and MP3 player used for sound reproduction (MP3-TF-16P or DY-SV17F).

The TDA2030A Audio Power Amplifier Module allows you to amplify the audio signal in the entire audio range from 10 Hz to 20 kHz. It has low rates of intermodulation distortion [20]. The sound speaker has

an operating range from 80 Hz to 20 kHz with a nominal operating power of 30 watts. Therefore, the developed system allows you to get high-quality sound.

The prototype of the audio information playback device is made on the basis of the Arduino platform using the Arduino-UNO microcontroller board. This prototype was installed in a gazebo located near Building No. 2 (Faculty of Physics and Technology, 28A Universitetskaya Str., Karaganda) in the period from early April to mid-June 2023.

To reduce the mass of the device, its dimensions and its cost, it was decided to replace the Arduino Uno microcontroller with an Arduino Nano (Fig. 1, b). This concept showed the futility of its development and a number of technical difficulties in implementing the device.

To implement the above algorithm and control the operation of all elements of the device, it is enough to have a microcontroller with 2 pins, a minimum set of functions and the ability to control the operation of external devices in the range from microseconds to seconds. Table 2 shows microcontrollers of various series that meet the requirements for microcontrollers.

Table 2 shows microcontrollers with reprogrammable program memory. Comparing the data and evaluating the advantages and disadvantages allowed us to choose ATtiny13 as the main microcontroller. The choice of this microcontroller was led by the presence of such parameters as high reliability of the microcontroller, availability of technical support from the manufacturer, minimal and sufficient availability of all necessary components, average price and availability of purchase compared to other series of microcontrollers. Therefore, it was decided to replace the Arduino Nano with the ATtiny13A-SU microcontroller, a family of eight-bit microcontrollers from Microchip [21]. A technical specification for the manufacture of the device and software was compiled for the device based on ATtiny13A-SU.

Table 2. Technical characteristics of the main series's of 8-bit microcontrollers

Series/ types	main	Main Features	Dignities	Cost
PIC10/ PIC10F200, PIC10F202, PIC10F204, PIC10F206		RISC-microprocessor; 8-Bit Microcontroller; 6/8-Pin Flash-Based, Clock frequency – 4 MHz; Number of pins – 6; Program memory – 256, 512 Bytes	- good continuity of different families; - a single free development environment MPLAB IDE; - compatibility by pins, peripherals, supply voltages, development tools, libraries and stacks of the most popular communication protocols; - a wide range of different controllers with all possible variations of peripherals, memory, number of pins, performance, power and temperature ranges, etc.	\$ 0,8 – 1,6
Avr attiny/ ATtiny13, ATtiny25, ATtiny45, ATtiny85		RISC-microprocessor; Core – avr; Data bus width – 8-bit; Clock frequency – 20 MHz; Number of pins – 8; Program memory – 1/2/4/8 kByte	- high performance/power consumption; - convenient programming modes; - wide range of products; - availability of hardware and software support; - high load capacity of the outputs.	\$ 1,03 – 2,5
STM8/ STM8S103F3P6		RISC-microprocessor; Core – stm8; 8-Bit Microcontroller; Clock frequency – 16 MHz; Number of pins – 16; Program memory – 8 kByte	- increased reliability; - flexibility of work; - stability of parameters; - advanced options; - price/functionality ratio; - performance; - a promising platform.	\$ 2
PADAUK/ PFC161-S08B		RISC-microprocessor; 8-Bit Microcontroller; Clock frequency – 16 MHz; Number of pins – 6; Program memory – 1 kByte	- lowcost	\$ 0,066

3. Hardware implementation

The technical specification for the manufacture of an electronic board includes the following requirements for the development of a printed circuit board. The overall dimensions of the printed circuit board being developed together with the A325 power supply unit should be placed in a box of the KSC 11-304 brand (distribution box o/n 125*125*50). The board has two holes with a diameter of 3 mm for attaching the board to the KSC 11-304 box. The board is two-layer, with one-sided placement of components. The second surface of the board is a polygon (grounded). The material is FR4. The minimum distance between the conductors is 1 mm, the minimum width of the conductors is 0.5 mm. In narrow places, smaller distances are allowed (it is possible to use jumpers for wiring tracks, no more than 5). The thickness of the copper foil is 35 microns.

The scheme should contain the following components:

- JSN-SR04T ultrasonic distance sensor with serial data transmission;
- DY-SV17F audio module mini mp3 player or DF Player mini;
- Hi-Fi sound amplifier, 18 W on a TDA2030A chip;
- ATtiny13A-SU microcontroller with one indicator LED connected to the ATtiny13A-SU 7 pin, microcontroller restart button and power protection capacitors;
- Voltage stabilizer 5 V, brand 78M05 with input and output capacitors;
- Terminal contacts for connection to the +12V power supply circuit;
- By bringing the grounding to the circuit.

Climatic conditions of use of the device: moisture protection according to the IP43 standard, minimum temperature not less than -10°C , maximum temperature 70°C .

The functional diagram of the device is shown in Fig. 1, b. The electrical schematic diagram is shown in Figure 2. The main components of the circuit are:

- DY-SV17F audio module mini mp3 player (DD2, Figure. 2);
- ultrasonic distance sensor with serial data transmission JSN-SR04T;
- ATtiny13A-SU microcontroller (DD1, Figure 2);
- converter and voltage stabilizer for 5V based on the 78M05 chip (VT1, Figure 2);
- power supply (12 V, 2 A);
- speaker (60 W).

4. Software implementation

The technical specification for the software includes the following requirements for software development. The program is a code in the C programming language for the AVR microcontroller. The program implements the control of an ultrasonic distance sensor and playback of audio files using an MP3 player. The purpose of the program: the implementation of distance monitoring using an ultrasonic sensor and the playback of audio files using DF Player mini at a given time. General requirements for the program include: the program must be designed for an AVR microcontroller with a specified clock frequency F_{CPU} 9 kHz; the corresponding pins of the microcontroller must be connected and configured to work with an ultrasonic sensor (TRIG_PIN and ECHO_PIN), DF Player mini (ADKEY_PIN) and LED (LED_PIN).

The functional requirements for software development are as follows:

- When the ping_ultra_sonic() function is called, the distance is measured using an ultrasonic sensor.
- When the enable_dht_player() function is called, DF Player mini is activated.
- The led_init() function initializes the pin of the LED.

Non-functional requirements for software development are as follows:

- Performance requirements such as delays (`_delay_us ()` and `_delay_ms ()`) and distance (`G_DISTANCE`) must be defined and configured according to the project requirements.
- The number of repeated triggers (`G_MAX_TRIG`) must be limited to a certain value.
- The requirements for the maximum delay of music playback (`G_MUSIC_DELAY`) must be defined.

The architecture of the system is as follows:

- The program is designed for an AVR microcontroller using I/O (input/output) ports for connecting and controlling components.
- Implemented functions for working with an ultrasonic sensor, MP3 player and LED.

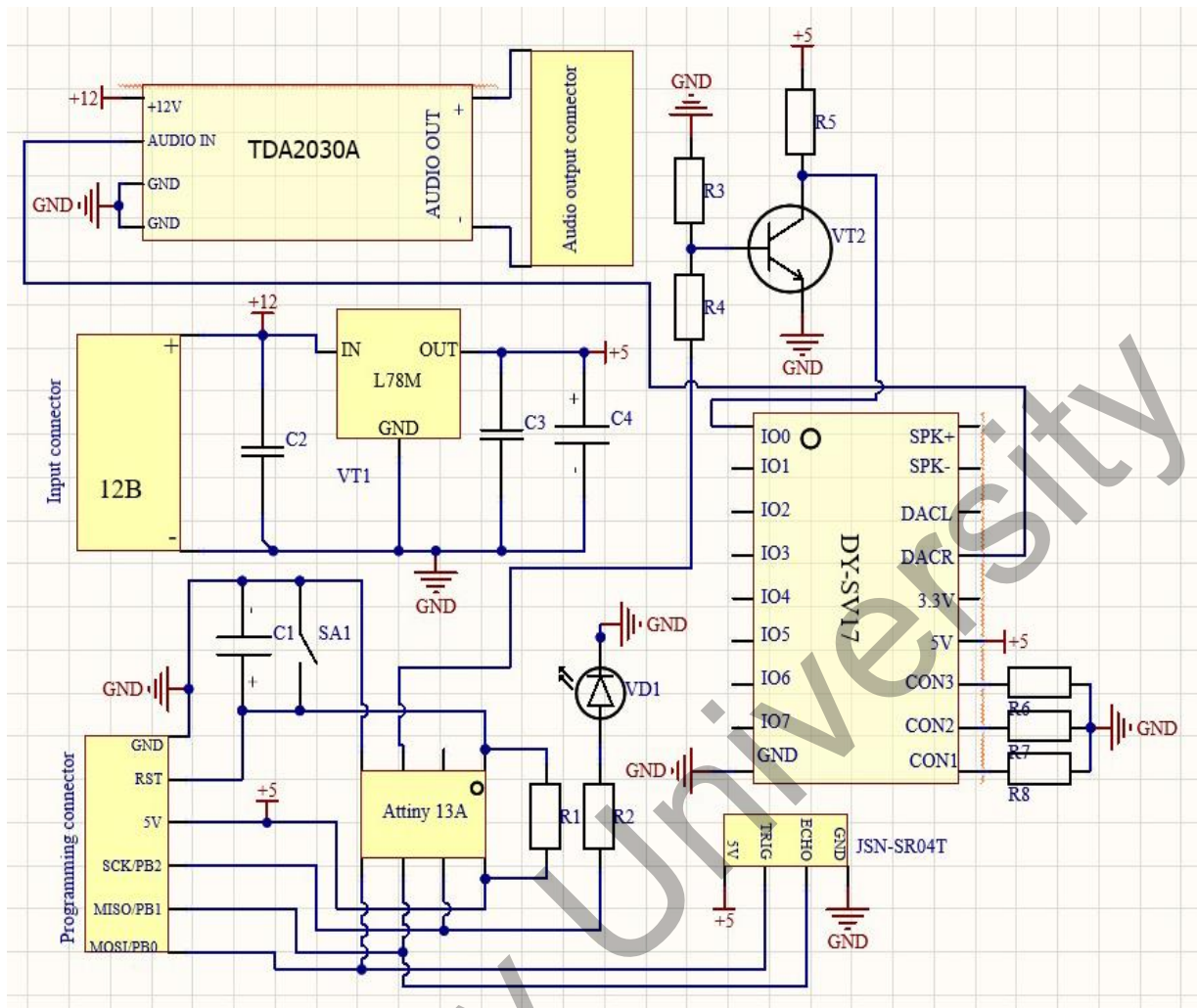


Fig. 2. Electrical principal scheme of a microcontroller device for reproducing audio information

Initially, the software for controlling the operation of the device and the layout of the printed circuit board of the information playback device with ATtiny13A-SU was written. The operation of the electronic device and this software showed poor noise immunity. The main interference, leading to false operation, was associated with the use of a switching power supply used to convert 220 V A.C. to 12 V D.C.

Also, interference was observed from switching power supplies of LED lamps placed on the alley located between the 2nd building of the University (Karaganda, Universitetskaya Str., 28A) and the dormitories of the university (Karaganda, Universitetskaya Str., 28/4). The ground plane was left on the reverse side of the PCB to increase noise immunity. Other methods to reduce the effect of interference on the operation of the electrical circuit have also been used. The algorithm of work was changed and the software for ATtiny13A-SU was also changed to reduce false positives of the device. It has been proposed to trigger sound information when reacquiring information about a distance less than a threshold distance ($G_MAX_TRIG= 3$ or $G_MAX_TRIG= 5$, Fig. 3). The algorithm of the program is shown in Figure 3. An application for an author's certificate has been submitted for the software [22].

A printed circuit board of a microcontroller device for reproducing audio information and a program for the ATtiny13A-SU microcontroller have been developed. The printed circuit board is made using photoresist and chemical etching in a mixture of hydrogen peroxide and citric acid. The

Sprint Layout 6 program was used to create and lay out printed circuit boards. The program has a simple, intuitive interface and allows you to quickly produce non-complex printed circuit boards.

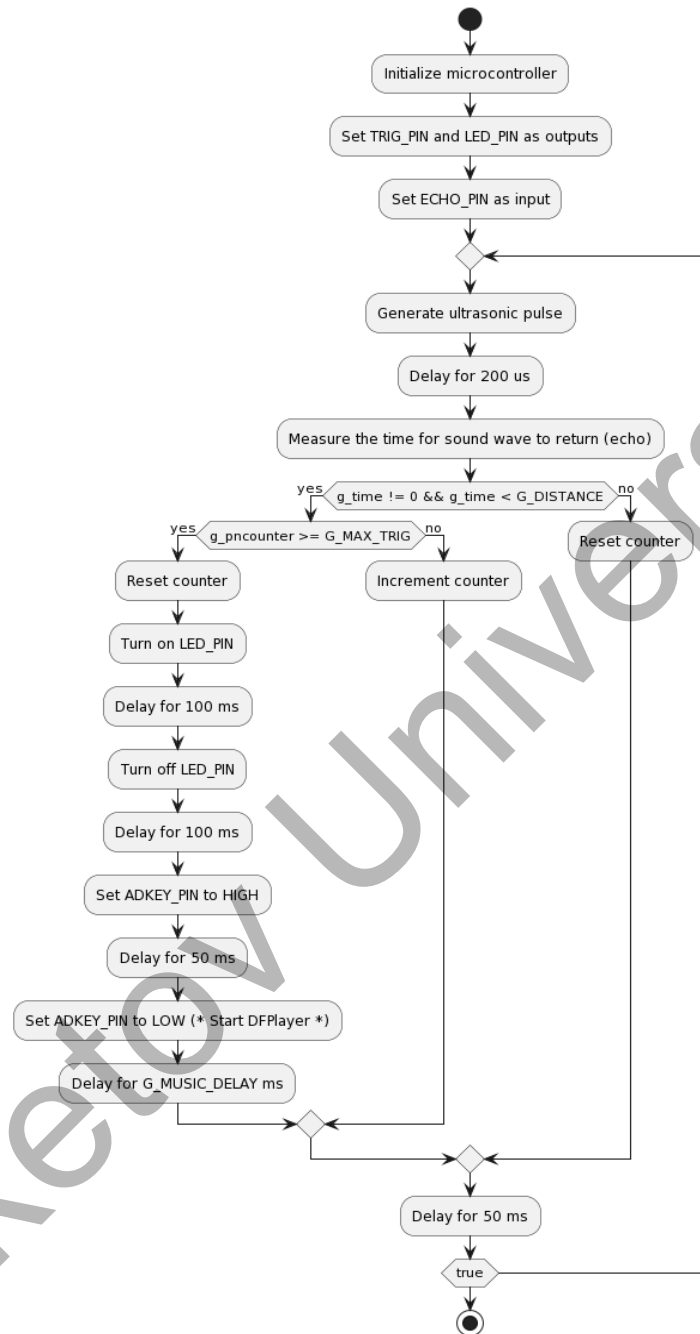


Fig. 3. The algorithm of the program of the audio information playback device (All designations given in the algorithm fully correspond to the designations given in the technical specification for the software)

5. Results and discussions

To transfer the drawing to the foil-clad paper-based laminate and fix the photoresist under the action of ultraviolet light, inverting of Fig. 4, a was carried out. The inverted figure is shown in Fig. 4, b. The connection diagram of the 78M05 converter for 5V voltage stabilizer based is shown in [23]. The appearance of the printed circuit board (PCB) is shown in Fig. 5. To control the elements in the diagram, software has been developed in the C programming language in the Microchip Studio development environment for the ATtiny13A-SU microcontroller. Microchip Studio is an integrated development environment (IDE) for developing and debugging applications of AVR and

SAM microcontrollers. Taking into account the analysis of characteristic malfunctions in the operation of this scheme, the software was upgraded.

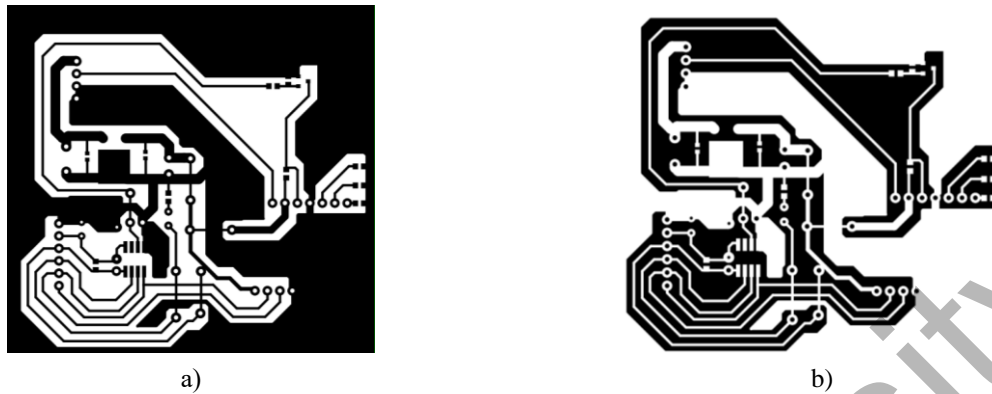


Fig. 4. Circuit board drawing image: Non-inverted (a) and inverted (b) PCB drawing



Fig. 5. Appearance of the printed circuit board: a) view of the board from below b) view of the finished board from above

Based on the results of work on the microcontroller device, 17 devices were manufactured, placed on benches on the alley located between the 2nd building of the University (Karaganda, Universitetskaya Str., 28A) and the dormitories of the university (Karaganda, Universitetskaya Str., 28/4) (Fig. 6).



Fig. 6. The appearance of the alley (a) and the place of attachment of the device on the bench (b)

The location of the ultrasonic sensor in Figure 6, b is shown by the number 1, the location of the electronic module with the speaker in the vandal-proof box is shown by the number 2. Sound output from the sound column is made from the bottom of the vandal-proof box. This is done to eliminate the possibility of water getting into the electrical part of the circuit. The top and sides are sealed and don't allow water to enter the box. The quality of sound information reproduction is high, which confirmed the operating time of the devices. The devices in the sound alley were connected on May 15, 2023. At the time of submitting the article for publication on September 1, 2023, 17 devices had been operating for 3.5 months 24 hours, 7 days a week without turning off the power. To further improve the microcontroller device, it is proposed to use the resources of the STM8S003F3P6 microcontroller, which is part of the JSN-SR04-2.0 ultrasonic distance sensor. In this case, the functional diagram of the microcontroller device will have the form shown in Figure 1, d. The use of this solution reduces the number of components used, reduces the cost of manufacturing and increases the functionality of a microcontroller device for reproducing audio information (the memory capacity of the STM8S003F3P6 program is 8 kilobytes instead of 1 kilobyte for ATtiny13A-SU).

6. Conclusions

1. Work has been carried out to develop the concept of a microcontroller device for reproducing audio information in the presence of a person. The device must perform a number of functions, the main of which are the registration of the presence of a person in a certain place of space and the reproduction of sound information with the necessary volume.

2. Initially, prototyping of a microcontroller device for reproducing audio information based on an Arduino Uno board was carried out. The results of prototyping showed the operability of the chosen technical solution and the possibility of its use in further work.

3. The work went from using the Arduino Uno board to the Arduino Nano board. Then it was decided to develop a microcontroller device for reproducing audio information based on the ATtiny13A-SU microcontroller. The technical specification for the manufacture of the device and the software of this device has been compiled.

4 An electrical principal scheme and a printed circuit board of a microcontroller device for reproducing audio information for the ATtiny13A-SU microcontroller have been developed. The printed circuit board is made using photoresist and chemical etching in a mixture of hydrogen peroxide and citric acid. Software has been developed to control the operation of the audio information playback device. Based on the results of testing the operation of the device, changes were made to the software. 17 devices were manufactured, placed on benches located in the alley on the territory of the E.A. Buketov Karaganda University. At the time the article was submitted to the journal, 17 devices had worked for 3.5 months without breakdowns.

5. Work is underway to improve the microcontroller device for reproducing audio information, aimed at increasing the functionality of the device and reducing its production cost.

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