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Odessa National Academy of Food Technologies

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BLACK SEA SCIENCE 2021

Information Technology, Automation and Robotics

Proceedings

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Odessa National Academy of Food Technologies, 2021

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Appendix B - The process of manufacturing a part on a CNC machine
https://youtu.be/21e8CEpw7ek

THE MODERNIZATION OF THE INFORMATION MEASURING SYSTEM OF POSITIONING OF THE OPTICAL GRINDING MACHINE

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Abstract. *The object of development is an automated control system for an optical grinding machine. The purpose is to modernize the existing control system of the optical grinding machine. During the development process, an automated control system for an optical grinding machine based on an STM32 microcontroller was designed and implemented, control boards were developed, and performance tests were carried out. The development stage: the system has been introduced into production.*

Keywords: *microcontroller, optical grinding machine, encoder, control, automation.*

I. INTRODUCTION

In the 80-90s of the twentieth century, a large-scale modernization of production was carried out with modern equipment at that time. At the moment, the electronic part of this equipment is outdated and breaks down, however, the electromechanical part is serviceable and has a sufficient service life.

It should also be noted that the service life of the electronic components is limited by regulatory documents. In addition, the human factor plays an important role in the accuracy of operations performed during manual control of equipment, which causes an urgent need for highly qualified specialists, whose professional skills and experience allow them to perform operations with high accuracy in manual control mode.

Thus, at present there is a need for retrofitting equipment on the basis of a modern element base and the introduction of additional operating modes, including automatic mode.

The modern development of digital electrical engineering makes it possible to develop an information-measuring system for automatic control with minimal changes in the design of equipment, but at the same time ensuring greater accuracy and reliability of its operational characteristics.

This development is an engineering solution to the problem of automating existing equipment. In this work, the 395M optical grinding machine was modernized: the function of precise automatic control of the carriage drive was implemented.

II. LITERATURE ANALYSIS

2.1 Description and principle of operation of the optical profile grinding machine 395M

Profile grinding machines are designed for grinding surfaces, the generatrix of which is a curved or broken line. The process of processing on such machines is called profile grinding. This method, as a rule, is used to manufacture tooling, shaped cutting tools, copiers, templates, patterns, etc., sometimes machine parts.

Depending on the scheme of shaping the processed surface, profile grinding machines can be divided into two groups:

– Machine tools that process the surface at a given relative motion of the wheel and the workpiece: with kinematic profiling (Fig. 1).

– Machines that process the surface when copying a preliminary profiled grinding wheel.

In the first case, the profile of the machined surface is created when the wheel moves along line *a* (see Fig. 1), called the generatrix of the profile, and along line *1*, called the guide.

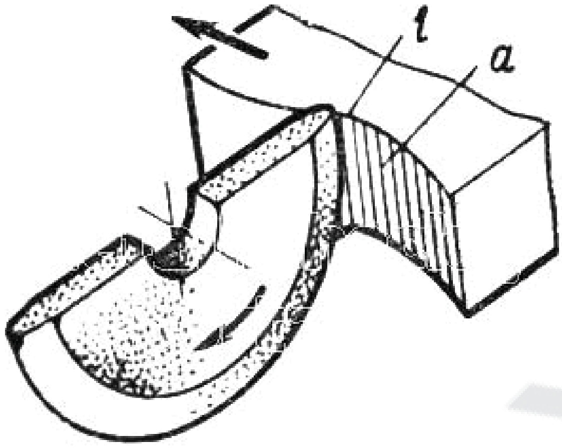


Figure 1 – Scheme of profile shaping

The generatrix is reproduced in the vertical plane with the reciprocating motion of the grinding wheel relative to the workpiece. Line 1 is formed in the horizontal plane with the mutual movement of the circle and the workpiece along a predetermined trajectory. In profile grinding machines there is a mechanism for shaping the guide, with the help of which the grinding wheel is guided along a predetermined trajectory relative to the workpiece or the workpiece relative to the grinding wheel.

In the second case, special devices can be used, the so-called "dressing", and then surface grinding machines for grinding. This method is called depth grinding, when the entire allowance is removed in one pass with a slow creeping table feed. Grinding with a wide profiled wheel is characterized by high productivity. In addition, the operator is relieved of the need to observe the wheel. Therefore, flat-profile grinding machines are promising for equipping them with CNC and inclusion in complexes and systems for unmanned processing.

In an optical profile grinding machine (Fig. 2), the operator moves the grinding wheel 1, acts on the handles 3. The enlarged image of the wheel 1 and the workpiece 5 is projected onto the screen 7, on which the profile guide is applied. The most common is a 50x magnification of an optical system with a screen size of 500x500 mm. With this magnification, the true dimensions of the image are only 10 x 10 mm.

Profile grinding machines have the following main components: grinding support, coordinate (cross) support for the part, table for installing the drawing and optical device.

The movements which are carried out on profile grinding machines:

– rotation of the grinding wheel;

– reciprocating movement of a support with a grinding wheel;

– adjusting movements of the coordinate slide with the workpiece in three directions;

– moving the grinding head.

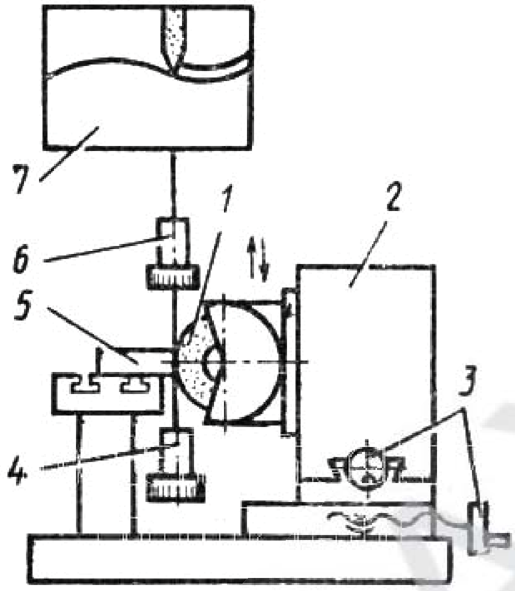


Figure 2 – Scheme of forming the profile guide on an optical profile grinding machine

The 395M machine was accepted for serial production in 1963, in 1978 it was replaced by a more advanced model 395M-1.

Optical profile grinding machine 395M is designed for grinding complex profiles, limited by straight lines, circular arcs and curves of various shapes, with high accuracy, and the material of the workpiece can be hardened.

The main feature of the machine is the presence of a screen on which, in an enlarged view, 50:1, the workpieces and the grinding wheel are projected using a special optical projection device.

A drawing of the part on tracing paper at a scale of 50: 1 is placed on the screen. Processing is carried out by combining the image of the circle with the outline of the drawing. The movement of the grinding wheel supports along the profile is carried out manually or mechanically using DC motors, the speed of which is regulated by rheostats.

The reciprocating movement of the grinding wheel slide is carried out automatically by an electric motor through the rocker mechanism. After grinding, the treated surfaces are finished.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of this development was the modernization of the control system for the carriage drive of the optical grinding machine.

The moving part of this machine (grinding wheel) is moved using two DC motors, each of which is responsible for the movement of the carriage along one of the axes (U, W) and which are controlled by means of pulse width modulation (PWM), which was the basis for the implementation automatic control systems.

The original control system consisted of a massive drive control unit for each of the axes, as well as a computer that displayed information about the movement of the carriage.

When developing the device, the following tasks were solved:

– It is possible to switch between automatic and manual control modes;

– The engine stops when the worm shaft is seized;

– The dimensions and the number of electronic components of the control system have been significantly reduced;

– The measurement accuracy using this system is 1 μm;

– In automatic mode, the control adjustment precision reaches 10 μm.

IV. RESULTS

4.4 The structural scheme

The structural scheme and the appearance of the drive control system are shown in Fig. 3, 4.

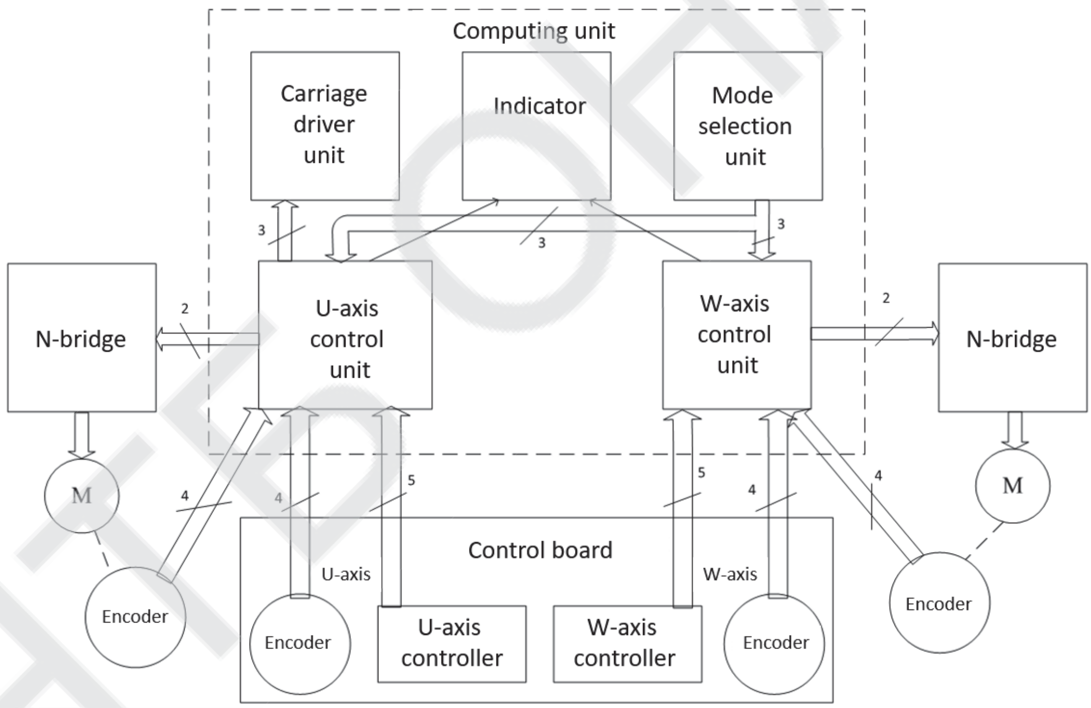


Figure 3 – The structural scheme of the device

Figure 4 – The front panel of the device

After modernization, the control system is a small block, consisting of a junction box, which contains the following functional blocks (Figure 5):

– Two small printed circuit boards for control of position encoders, which are located on the axes of the motors, and control encoders, used in manual operation; each of the PCBs controls movement along one of the axes (U-axis control unit, W-axis control unit in Fig. 3);

– The PCB, which is a computing unit built on the basis of an STM32 microcontroller, from which an electric motor control loop departs by means of two H-bridges made up of eight power transistors. There are two such boards, they are located one under the other to save space. Each PCB provides movement along one of the axes.

– Indication unit, which is an LCD display that displays information about the carriage position, preset parameters or the current state, as well as LEDs indicate the state of the machine.

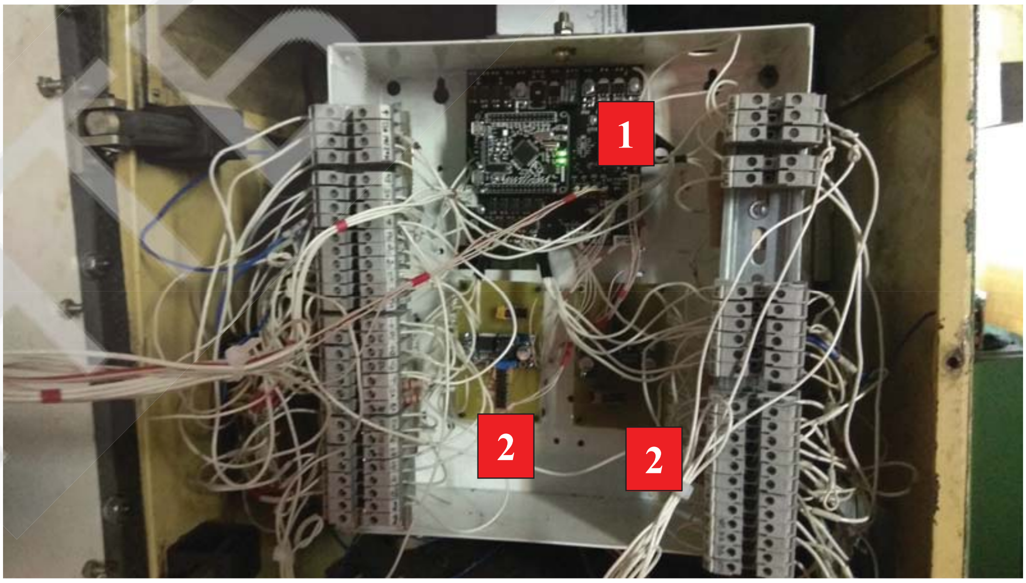


Figure 5 – Location of the drive control PCBs (1 – motor control board, 2 – encoder control board)

4.2 The block diagram

The block diagram of the device operation algorithm is shown in Figure 6.

START.

1. Power on;

2. Restoration of the original settings (PWM = 50%);

3. Is the operating mode manual?

If YES in step 3, go to step 4;

4. Change the position of the control encoder to Δl?

If YES in step 4, go to step 5;

5. Counter-clockwise rotation?

If YES in step 5, go to Step 7;

7. Setting "PWM = 50 – Δn" (Δn is set manually);

9. Fixing the position;

10. Determination of position with the displacement encoder;

11. Output information about the position of the control encoder to the display;

END;

If NO in step 5, go to step 8;

8. Setting "PWM = 50 + Δn" (Δn is set manually);

9. Fixing the position;

10. Determination of position by the displacement encoder;

11. Output information about the position of the control encoder to the display;

END;

If NO in step 4, go to step 6;

6. Setting PWM = 50%;

END;

If NO in step 3, go to step 12;

12. Switch to parameter setting mode?

If YES in step 12, go to step 13;

13. Change the position of the control encoder?

If YES in step 13, go to step 14;

14. Setting the position of the control encoder;

15. Output of the set parameter to the screen;

END;

If NO in step 13, go to step 15;

15. Output of the set parameter to the screen;

END;

If NO in step 12, go to step 16;

16. Run in automatic mode?

If NO in step 16, go to step 17;

17. Displaying the current position on the screen;

END;

If YES in step 16, go to step 18;

18. Setting the delay;

19. Has the set limit been reached?

If YES in step 19, go to step 20;

20. Completion of the passage;

21. Reset to START state;

END;

If NO in step 19, go to step 22;

22. Shift by 10 microns;

23. The value of the physical limit is reached?

If YES in step 23, go to step 20;

If NO in step 23 go to step 24;

24. Is the manual installation completed?

If NO in step 24, go to step 25;

25. Output of the current state to the screen;

Go to point 18;

If YES in step 24, go to step 20;

20. Completion of the passage;

21. Reset to START state;

END.

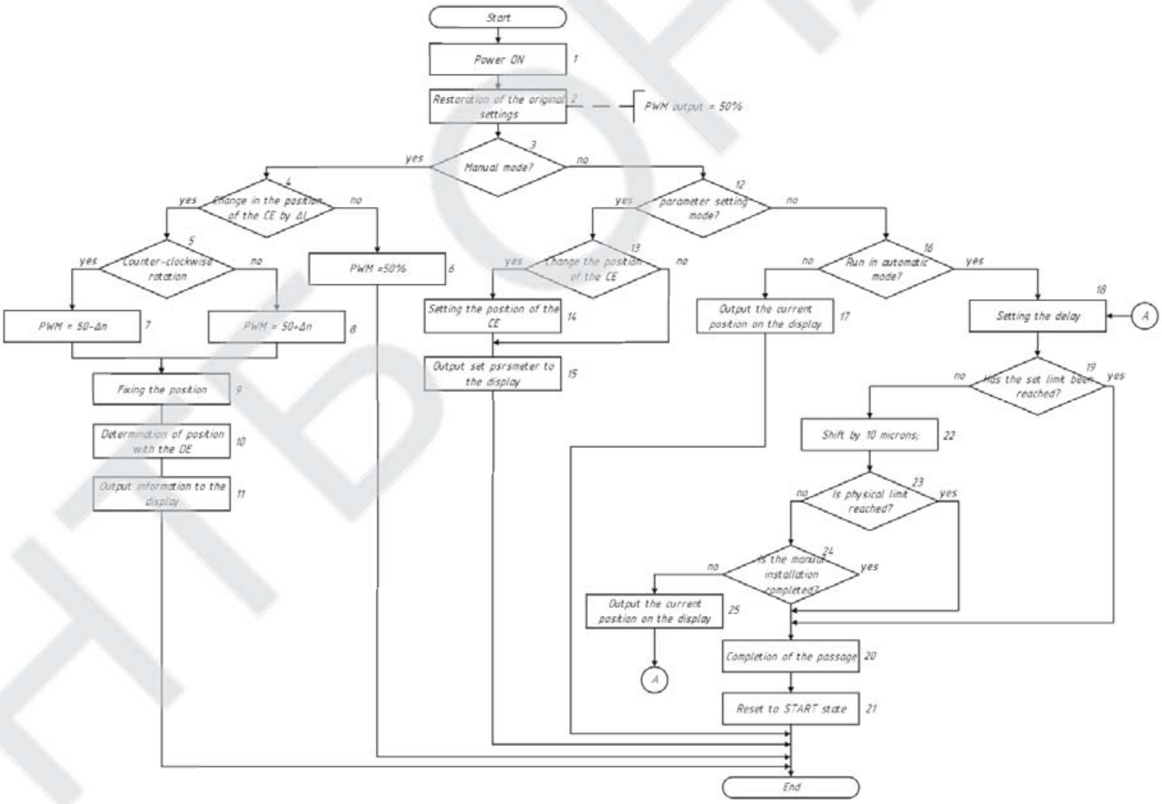


Figure 6 – The block diagram of the device operation algorithm.

4.3 Microcontroller selection

To implement the control unit, we use the STM32F103C8T6 microcontroller (Figure 7).

The STM32F103xx medium-density performance line family incorporates the high-performance ARM® Cortex®-M3 32-bit RISC core operating at a 72 MHz frequency, highspeed embedded memories (Flash memory up to 128 Kbytes and SRAM up to 20 Kbytes), and an extensive range of enhanced I/Os and peripherals connected to two APB buses. All devices offer two 12-bit ADCs, three general purpose 16-bit timers plus one PWM timer, as well as standard and advanced communication interfaces: up to two I2Cs and SPIs, three USARTs, an USB and a CAN.

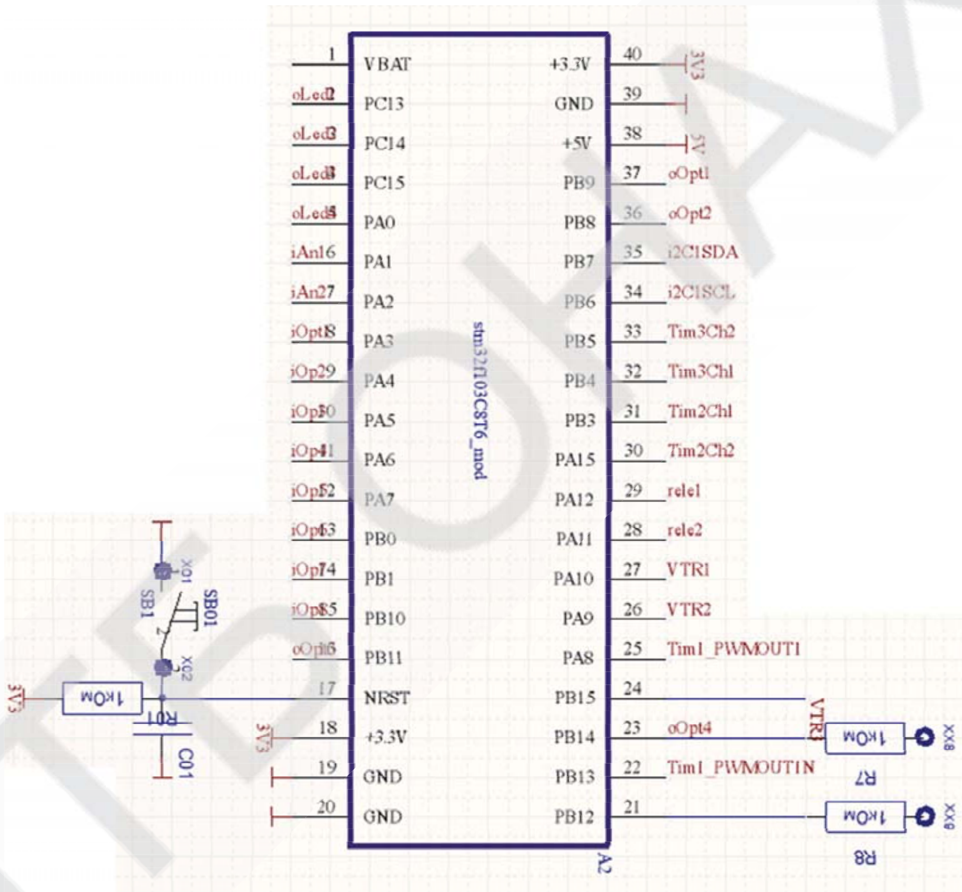


Figure 7 – Pinout MC STM32F103C8T6

The devices operate from a 2.0 to 3.6 V power supply. They are available in both the –40 to +85 °C temperature range and the –40 to +105 °C extended temperature range. A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F103xx medium-density performance line family includes devices in six different package types: from 36 pins to 100 pins. Depending on the device chosen, different sets of peripherals are included, the description below gives an overview of the complete range of peripherals proposed in this family.

These features make the STM32F103xx medium-density performance line microcontroller family suitable for a wide range of applications such as motor drives, application control, medical and handheld equipment, PC and gaming peripherals, GPS platforms, industrial applications, PLCs, inverters, printers, scanners, alarm systems, video intercoms, and HVACs.

For STM32 Flash memory, read protection through the debug port can be set. When read protection is enabled, Flash memory is also write-protected to prevent the possibility of placing the incorrect code in the interrupt vector table. The STM32 also contains a real time clock and a small area of SRAM with battery power. The contents of this area are automatically cleared by an interrupt from the anti-tampering module.

The STM32 is equipped with general purpose I / O ports (GPIO) and can have up to 80 bidirectional pins. Each digital pin can be configured as a GPIO pin or as an alternative function pin. Each pin can simultaneously operate as one of 16 external interrupt lines.

To exchange information between components on a printed circuit board, the STM32 contains SPI and I2C interfaces. There is a CAN bus for communication between the various modules of the device, and a USB interface for communication with a PC. The STM32 also uses the popular USART interface.

Figure 7 also shows the MC reset circuit: it consists of a button, a capacitor and a resistor.

Ports are denoted by the Latin alphabet from A to E, and all tolerant to 5 V voltage. Many of external leads of the microcontroller instead of performing input / output functions can be switched service user peripherals such as a USART or I2C.

4.4 Engine control units

Figure 8 shows a schematic diagram of engine control units.

Galvanic isolation.

The PC817 optocoupler is used for galvanic isolation of the circuit (Figure 9).

Optocoupler PC817 consists of a LED and a phototransistor. Optocouplers PC817 allow to provide galvanic isolation of two parts of the circuit – high voltage and low.

The main characteristics of the PC817 optocoupler:

– Constant forward input voltage U_{in}: 1.2 V

– at input current I_{in}: 20 mA

– Maximum input current $I_{in.max}$: 50 mA

– Maximum collector power dissipation: 150 mW

– Operating temperature range: -30 ... + 100 ºC

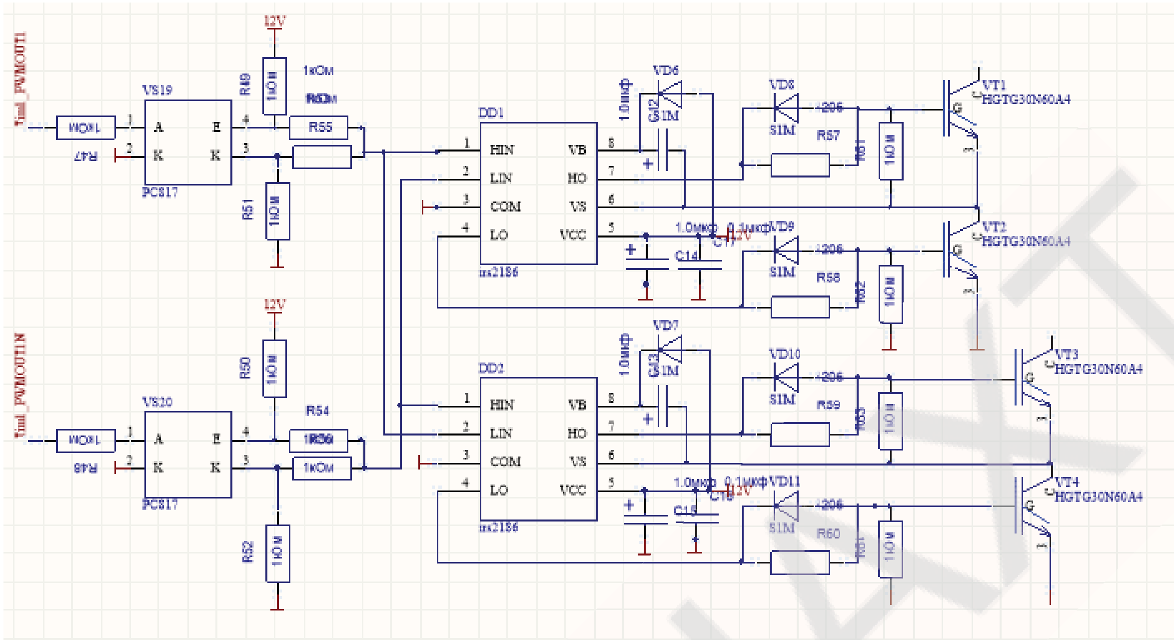


Figure 8 – Schematic diagram of the engine control unit


Figure 9 – Optocoupler PC817 in DIP-4 package

4.5 Indication unit

The device indication consists of an LCD display and LEDs. The schematic diagram is shown in Figure 10.

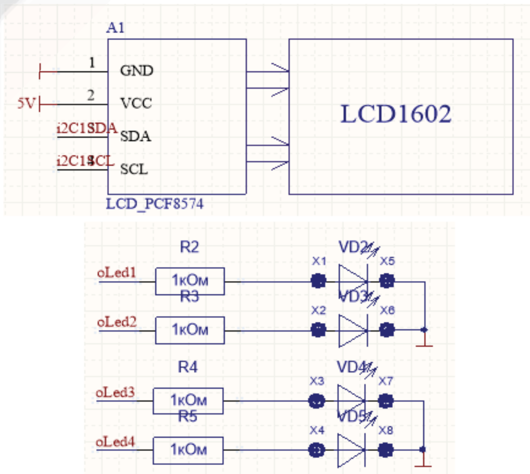


Figure 10 – Schematic diagram of the indication

Of all the LCD displays available on the market, the most commonly used is the LCD 1602A, which can display ASCII characters in 2 lines (16 characters in 1 line) each character in a 5x7 pixel matrix. For our circuit, we will select the SPLC780D display (Figure 11). The supply voltage: 5 V.

Figure 11 – Appearance of the LCD display

The LCD 1602A is an electronic module based on the Hitachi HD44780 driver. The LCD1602 has 16 pins and can operate in 4-bit mode (using only 4 data lines) or 8-bit mode (using all 8 data lines), and I2C interface can also be used. On the front of the module there is an LCD display and a group of contacts.

We chose GNL-3012HD LEDs (red) as LED indication. Their main characteristics are shown in Table 1.

Table 1 – Main characteristics of GNL-3012HD LEDs

Parameter	**GNL-3012HD**
Glow color	red
Wavelength, nm	700
Luminous intensity Iv, mKd	1,8
at a current $I_{lim.}$ mA	20
Visible solid angle, deg	60
Lens size, mm	3
Voltage drop, V	2,1
Operating temperature, ºC	-40…+80

4.6 Encoder control units

The schematic diagram of the encoder control unit is shown in Figure 12.

We use the PC817 optocoupler as a galvanic isolation. To amplify the input signal, we use the OPA2277 operational amplifier.

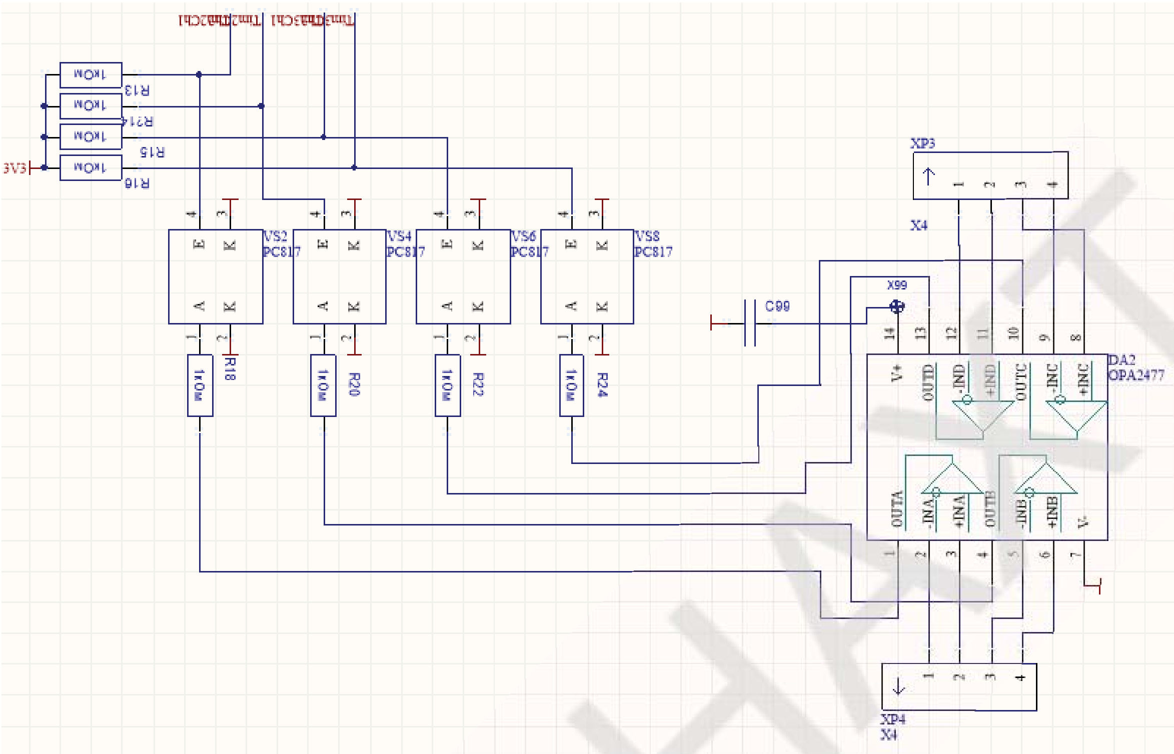


Figure 12 – Schematic diagram of the encoder control unit

4.7 Input and Output units

The schematic diagram of the output unit is shown in Figure 13.

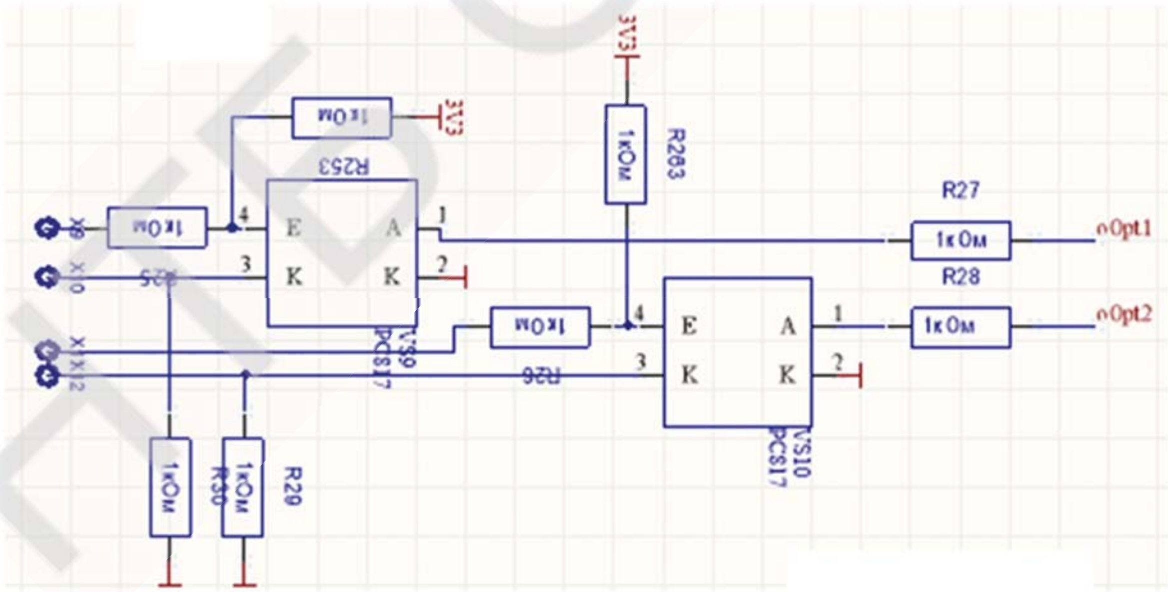


Figure 13 – Schematic diagram of the output unit

The input block contains a galvanic isolation (PC817 optocoupler) and has four inputs. The schematic diagram of the input unit is shown in Figure 14.

The first part of the circuit is responsible for processing signals from manual control encoders. The second part of the circuit is responsible for processing signals from position encoders, which operate in automatic control mode.

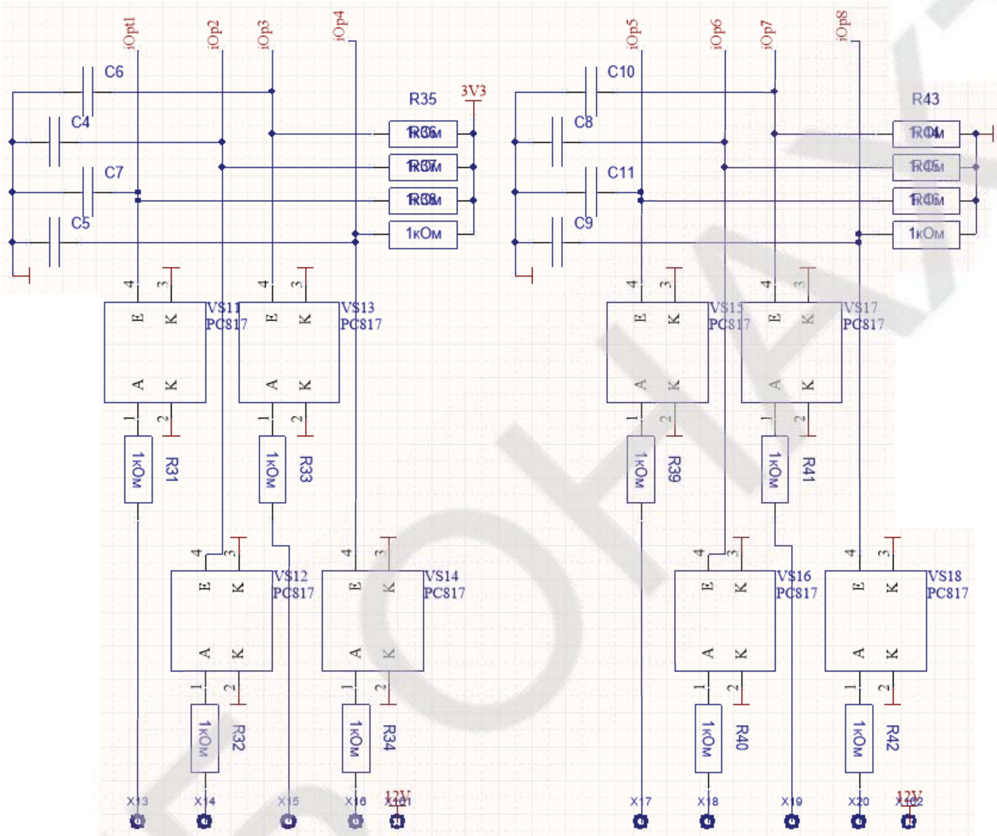


Figure 14 – Schematic diagram of the input unit

3.6 Other units

Figure 15 shows the matching circuit of the supply voltage (12 V) and the microcontroller power supply (5 V).

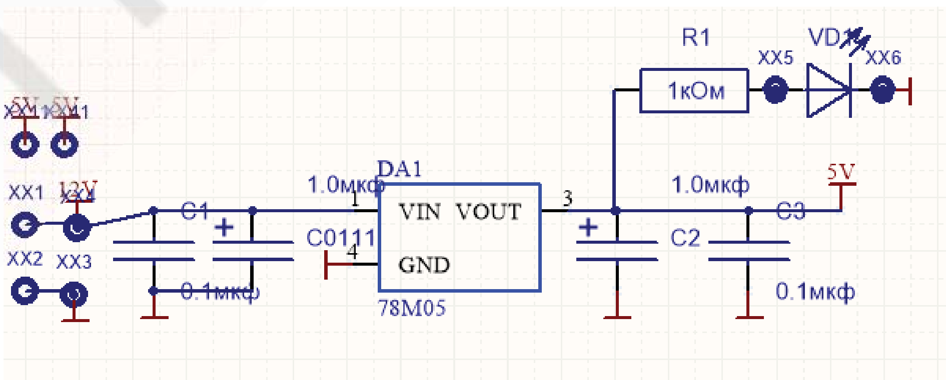


Figure 15 – Voltage matching circuit

The L78M05ABDT-TR chip with the following characteristics was chosen as a voltage stabilizer:

– Number of outputs: 1;
– Output voltage: 5V;
– Maximum load current: 0.5 A;
– Maximum input voltage: 35 V;
– Working temperature: -40… + 125 ° C.

To indicate the power supply, we chose the green GNL-3012GD LED.

To organize protection against unauthorized starting of the engine, the scheme shown in Figure 16 is used. This scheme excludes the possibility of starting the engine when the power supply of the microcontroller is disconnected, which allows the machine to be serviced safely.

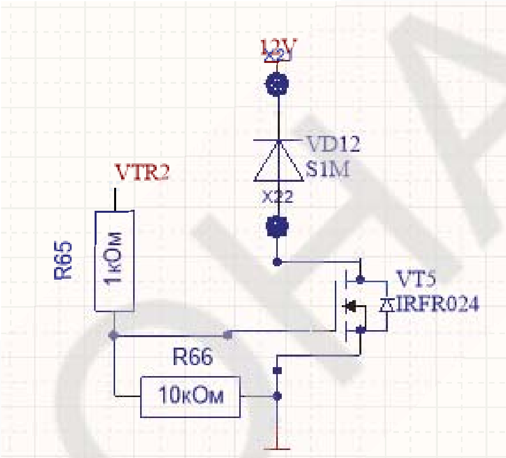
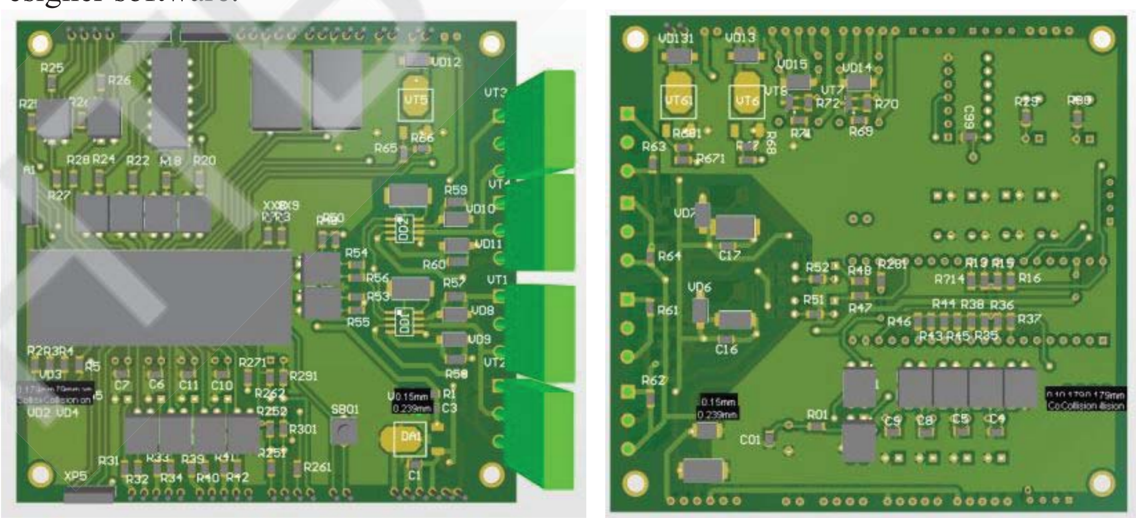


Figure 16 – Scheme of protection against unauthorized engine start

Figures 17 a, b show a general view of the control PCB made in the Altium Designer software.



a) b)

Figure 17 – General view of the control board: a) top view b) bottom view

V. CONCLUSIONS

The developed device meets the stated objectives: is cheap, easy to use and reliable. The developed control system is also accurate, which is important for the manufacture of tooling, shaped cutting tools, copiers, templates, patterns, etc., sometimes – machine parts.

This device allows to improve the quality of work performed, as well as to use the service life of equipment that is outdated in terms of control principles, but with a workable mechanical part.

Figure 18 – Appearance of the workplace after modernization

The developed control system has the following advantages:

– The ability to serve more standard equipment and machinery by one operator using an automatic control mode;

– The modern approach and element base allow you to adjust the parameters for specific requirements;

– The ability to control the machine in manual or automatic mode by the operator;

– It is possible to modify the system for upgrading positioning systems on different machines;

– The ability to operate the machine by operators with various qualifications: both operators who have the skills to work with numerically controlled machines (CNC), and highly qualified specialists, whose professional skills and experience allow them to perform operations with high accuracy in manual control mode;

Potential consumers can be metalworking enterprises: organization of equipment for metalworking machines with automatic control means.

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