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## INVESTIGATION OF A MICROCONTROLLER CONTROL UNIT AT A BENEFICIATION PLANT WITH FINE SCREENING TECHNOLOGY

**Purpose.** Modern solutions in the field of automation, robotics, and electric drive cannot be imagined without the use of microprocessor-based tools and systems. Fast development of electronics is dramatically changing our lives. Microprocessors, microprocessor- and microcontroller-based devices are currently the most widespread means of computing, communication and electrical devices. The aim of the work is to study the features of a microcontroller-based control unit for an electromechanical system employing the fine screening technology for a beneficiation plant.

**Research methods**. The investigation consists of two stages. In the first stage, the software components developed for microcontroller-based control are described. In the second stage, the structural diagram of the microcontroller system that demonstrates the main components of the microcontroller is developed and described, as well as the choice of circuit solutions is substantiated.

**Scientific novelty** consists in the study of mechanisms of electromagnetic-acoustic transformation for formation of ultrasonic elastic waves.

**Practical significance.** The principle of operation of the NUC140VE3CN microprocessor is considered in detail. A microprocessor control system is implemented, designed, and debugged. The introduction of microcontrollers is one of the ways to develop iron ore crushing and concentrating schemes at beneficiation plants using the fine screening, technology which allows improving the quality of concentrates. Microcontrollers play a key role in future development of automated systems, ensuring their efficiency, flexibility and low implementation costs.

**Results**. The developed NUC40VE3CN-based block diagram gives an idea of the entire system, its individual elements and their interconnections. These components are described and commented on for a better understanding of their application.

**Key words**: microcontroller, investigation, information, automation, control systems, fine screening.

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**The problem and its connection with scientific and practical tasks.** One of the most important conditions for the development of energy, industry, transport and all other sectors of production is their comprehensive automation based on modern microprocessor technology. Specific tasks of scientific and technological progress in the fuel and energy, electrical, machine-building and transportation sectors are currently putting forward the problem of ensuring the required reliability, survivability and trouble-free operation of complex technical facilities and their control systems. With the introduction of new processes and devices and technological solutions, it is possible not only not to reduce the economic performance of the beneficiation process, but also to improve their quality using a microcontroller control unit of the electromechanical system. One of the ways to develop iron ore grinding and beneficiation schemes that can increase the productivity of technological sections or improve the quality of concentrates is to use technologies with fine screening. In recent years, the emergence of microcontrollers (MCs) has led to a trend towards their widespread use of concentrators. However, the technologies of all the plants were not originally designed to produce high-quality concentrates, so changing technologies requires not only significant capital expenditures, but also the development of fundamentally new technical and technological solutions. At the same time, the load on the equipment of the concentration shops has increased. Capital expenditures associated with an increase in unit productivity or the number of grinding equipment are significantly higher than those for increasing the efficiency of beneficiation and classification equipment. In recent years, in connection with the emergence of microcontrollers (MC), there has been a tendency to their widespread use in household appliances and electrical apparatus, to their direct implementation in EA control devices, relay protection equipment, emergency automation systems, automated process control systems (APCS) for the production, testing and research of CRTs and EAs. This is due to the emergence of new, increased and diverse requirements for automation systems for managing facilities. In this regard, traditional control and regulation systems based on analog elements have become unable to compete with digital devices that use microprocessors and microcontrollers.

Modern MCUs are small in size and can be placed close to controlled objects, have high reliability and advanced logic capabilities, and are characterized by low power consumption and cost. In addition, their use in control systems ensures high speed, performance, flexibility and efficiency. The use of MP and MC requires developers to revise the traditional methods in the design of control systems for CRTs, EAs and electronic devices, replacing in many cases the design of circuits and control systems with the development of programs for configuring microprocessor hardware to perform certain functions.

The object of study is a beneficiation plant. The subject of study is the configuration of a microcontroller unit for controlling an electromechanical system at a concentrating plant with the technology of fine screening.

The purpose of the work is to introduce a micro-controller into the technological process to optimize the grinding and beneficiation of iron ores, which makes it possible to improve the quality of concentrates using the technology of fine screening at a concentrating plant.

A microcontroller is a true device that follows the idea of a computer on a chip. There is no need for any external interface to the main components such as memory, I/O ports, etc. Microcontrollers do not require complex operating systems because all instructions must be written and stored in memory. All I/O ports are programmable. Integration of all core components reduces cost, development time and product (or application) footprint. Memory capacity limits the instructions that can be executed by the microcontroller. There are a huge number of applications for microcontrollers. In fact, the entire embedded systems industry depends on microcontrollers. Therefore, it was decided to set this task:

Type of microcontroller: NUC140VE3CN. Requirements for power supply organization: Provide power supply to the microcontroller, external memory chips, analog signal converter microcircuits, and additional elements. The power supply is a mains voltage of 220 V, 50 Hz. Requirements for the organization of external nonvolatile memory: at least 32 kB. Number and types of analog inputs and outputs: 1 input -5 to +5 V, 1 input 0 to +5 V, 1 output -5 to +5 V. Number and type of discrete inputs and outputs: Inputs: total number - 6, galvanically isolated - 4. Outputs: total number of 8: galvanically isolated - 1, PWM - 3, relay - 3. List of additional requirements for the system: operator interface: Graphic LCD (128x64), joystick and 4 buttons/ additional interface: RS232. List of initialization subroutines to be developed: microcontroller timer, operator interface - output, external memory connection. Type of controller for software implementation: PI controller. List of subroutines for controlling additional elements used: reading a data array from external memory.

**Analysis of recent achievements and publications.** An analysis of recent research and publications on the subject shows that the use of modern control systems has been studied by Morkun V. S., Hryshchenko S. M., Kravchenko O. M., Nizhehorodtsev V.O. [1-4]. Different approaches to the stages of creation of automatic control systems are reflected in the works of scientists Loria M., Tselishchev O., Eliseev P., Porkuyan O., Gurin O., Abramova A., Boychenko S. and others [5, 6].

The authors Azman, I. N. A. N., Alhadi, S. S. N., Rizal, N. I., Wahab, A. A. A., & Othman, V. A. F. V. describe the application of radio frequency identification (RFID) technology in combination with the NUC140VE3CN board to create an automated garage door. To automate the traditional mechanical version, the project implements an embedded system with two main components: an RFID scanner locking system and an automated door opener system. The RFID scanner ensures security by allowing the garage door to open only with the correct MIFARE card or key fob placed on the scanner. The motor responsible for lifting the door can be rotated through 90°. The integration of Nuvoton's NUC140VE3CN board facilitates the interaction of these systems using SPI and the C programming language. The main problem that this project solves is to improve the accessibility and security of the garage, which ultimately provides a convenient and reliable solution for homeowners. However, some of the microcontroller control software components used for certain tasks are inefficient and need to be improved.

The authors Christonny, I., Firmansyah, E., & Mustika, I. W. decided to focus on the development of an electronic communication system that uses the CAN protocol to model the communication process in an electric vehicle. The article is devoted to the problems of interaction of components in electric vehicles using the Controller Area Network (CAN) protocol. The main goal of the study is to create a system that ensures the interaction of all components of an electric vehicle. The authors analyze the importance of using the CAN protocol in the field of automotive technology, in particular in electric vehicles, and describe the use of the Nuvoton NUC140VE3CN microcontroller and the Microchip MCP2562 CAN transceiver to ensure efficient data exchange between electric vehicle components.

The disadvantage of this article, as in the previous one, is the inefficiency of some software components for controlling the microcontroller.

Statement of the problem is that the development is proposed to be used for automation of electromechanical systems.

**Presentation of the main material and results.** There are many different subindustries and specializations in information technology, within which the functions of specialists differ significantly. Therefore, a software developer, a tester, and a system administrator are people who are engaged in completely different activities, although all of them are related to computer technology.

A software developer is a specialist who develops algorithms and programs using mathematical models. Some of them may develop software for a specific structure, others may develop operating systems, work with networks of specific organizations, and still others may work with global networks (the Internet), web pages, etc.

Software development of microcontrollers is carried out similarly to the software of other computing devices. In general, the creation of software for microcontroller systems includes the following stages: drawing up a technical task; development of an algorithm; compiling the program code; compiling the program; modeling the program; programming the system; real system operation.

The most common approach to organizing the software of microcontroller systems is the modular approach. The essence of this approach is that the software consists of separate modules: drivers, application programs, libraries, and other elements. Modularity at the level of source code or at the level of libraries allows you to divide the system into clearly separate fragments, each of which can be used by other developers.

The software development process is carried out using software development tools such as Keil (for microcontrollers from various manufacturers), Microchip Studio (for microcontrollers from Atmel and Microchip), Code Composer Studio (for microcontrollers from Texas Instruments), and others. The description of the software components consists of the description of the functionality of the specified subroutines and initialization.

Development of the microcontroller timer initialization subroutine. The library "DrvSys" was used to write the timer initialization subroutine.

```
void Timer_Init(void)
{
 //Select and activate Timer0 clock source
 DrvSYS_SelectIPClockSource (E_SYS_TMR0_CLKSRC, 0);
//Activating a generator for Timer
 DrvSYS_SetIPClock(E_SYS_TMR0_CLK, 1);

 //Setting Timer0 mode
 TIMER0->TCSR.MODE = 1;// 0 – One Shot; 1 – Periodic;  2 – Toggle;  3 – Continuous
  //Choosing a period
 //Setting prescale
 TIMER0->TCSR.PRESCALE = 255;

 //Setting maximum number for periodic mode
 TIMER0->TCMPR = 46875;//Timeout period = (1 / 12MHz) * (255 + 1) * 46875 = 1 sec

 //Enabling Timer0 interrupt
 TIMER0->TCSR.IE = 1;
 TIMER0->TISR.TIF = 1;     // Clearing interrupt flag
 NVIC_EnableIRQ(TMR0_IRQn);// Activating a function interruption
}
void TMR0_IRQHandler()
{  //---- Here are the commands that will be executed when an interrupt is received
TIMER0->TISR.TIF = 1;// Resetting the interrupt flag }
TIMER0->TCSR.CEN = 1; // Command to allow the timer to start working
```

Developing a subroutine for initializing the output operator interface (graphical LCD). For the subroutine for initializing the output interface, we will use the following program, and a small example of output using the LCD_Driver.c library:

```
 //Initializing LCD
 Initial_pannel();  //call initial pannel function
 clr_all_pannal();
 DrvGPIO_Open(E_GPD,14,E_IO_OUTPUT);
 //DrvGPIO_ClrBit(E_GPD,14);  //  LCD backlight  ON
//Filling 3st stroke
 print_lcd(2, "HELLO!");
```

Develop a subroutine for connecting external memory (EEPROM). Write a byte to the EEPROM. Ad-dress: address to be written, starting from 0 (int) Value: value to be written, from 0 to 255 (byte) is not available. Writing EEPROM takes 3.3 ms. The service life of EEPROM memory is 100,000 write/erase cycles.

```
#include <EEPROM.h>
void setup()
{
  for (int i = 0; i < 255; i++)
    EEPROM.write(i, i);
}
void loop()
{
}
```

Software implementation of the regulator's PI.

The PI controller subroutine is as follows:

```
void PI regulator(void)
{
/*Calculation of proportional component*/      pro-port_comp = K_pr * intfloatdata;
/*Calculation of integral component*/      int_comp += time_step * K_integr * intfloatdata;
/*Calculation of output Y*/      Y = proport_comp + int_comp;
}
// Example of PWM output using for PI_regulator void PWMB_IRQHandler(void)
{   if (PWM_GetPeriodIntFlag(PWMB, PWM_CH1))
{   //create cycle for our aims

  PWM_ClearPeriodIntFlag(PWMB, PWM_CH2);
}
}
```

Subroutine for reading a data array from EEPROM.

To do this, use the #include <EEPROM.h> library and read the array using the read() function.

```
#include <EEPROM.h>
int a = 0;
int value;
void setup()
{
  Serial.begin(9600);
}
void loop()
{
  value = EEPROM.read(a);
  Serial.print(a);
  Serial.print("\t");
  Serial.print(value);
  Serial.println();
  a = a + 1;
  if (a == 512)
    a = 0;
  delay(500);
}
```

Read a byte from the EEPROM. Locations for which the value 255 has never been written before. Address: The location to read, starting from 0 (cel) the value stored in this location (byte).

Fig. 1 shows a block diagram of the system under development. The basis of the system is the NUC140VE3CN microcontroller, to which external devices will be connected. The input of the power supply unit will be supplied with a voltage of 220 (V) AC, which will then be passed through power circuits that will convert the voltage into potentiated values and will be distributed to power the elements of the circuit. The block diagram shows the following elements for outputting information to the user: external memory for storing information, graphic PKI (128x64) and RS-232 interface for outputting information. The need for galvanic isolation, i.e., the elimination of possible paths.

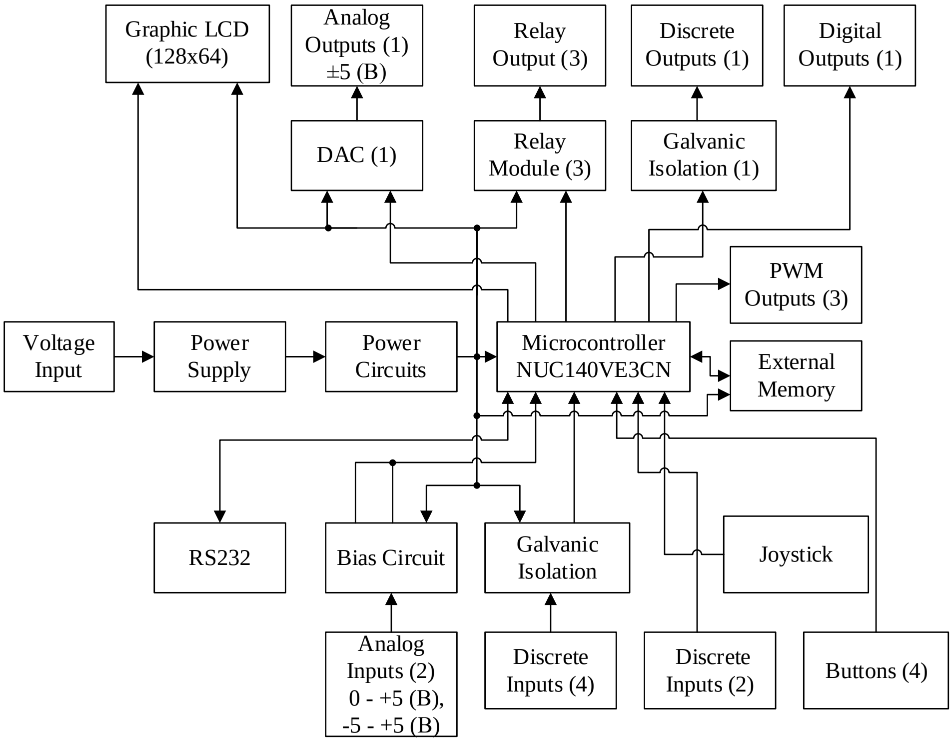


**Fig. 1.** Block diagram

For the flow of electric current between sections of electrical circuits is usually caused by two main factors:

increasing the resistance of electrical circuits to interference, which, for example, can be introduced into the system through parasitic circuits;

improving the safety of electrical circuits and personnel working with the equipment;

The system has a variety of inputs and outputs for connecting external devices:

discrete inputs - can be used to connect digital sensors, additional buttons, etc. Four of them are galvanically isolated;

analog inputs - can be used to connect analog sensors. One of the analog inputs will be used as the reference input of the PI controller. A total of 2 inputs are used;

discrete outputs - can be used to control various devices or exchange information;

relay outputs - relay outputs also serve for galvanic isolation, but not electronic, but mechanical, and are oriented to switching in circuits with much higher voltage and current values. The advantage of using a relay output is that the mechanical contact is not affected by any noise, and the disadvantages are that the number of relay operations is limited, and the frequency of switching the relay contacts is much lower than that of semi-product components;

analog outputs - are mainly used to transmit information about the operating modes of the drive to analog display devices (for example, voltmeters), can be used, for example, to control a DC motor to regulate the armature voltage;

PWM outputs - can be used to control various devices. One of the PWM outputs will be used to implement a PI controller;

RS-232 interface - it is well known that devices in industry interact with each other through serial communication interfaces using various data exchange protocols such as MODBUS, PROFIBUS and others;

operator interface: Graphic LCD (128x64), buttons (4), joystick;

galvanic isolation is necessary to achieve the following: Increasing the resistance of electrical circuits to interference, which, for example, can be introduced into the system through parasitic circuits. Improving the safety of the electrical circuits and the personnel working with the equipment;

an analog bipolar signal conversion circuit (ADC), voltage amplifier, and DAC are matching devices that are used to convert analog and/or digital signals, which should ensure that they can be safely connected to a microcontroller or other devices. They perform the following functions:

changing voltage levels, converting current to voltage and vice versa, galvanic isolation of signals, analog-to-digital and digital-to-analog conversion, signal transcoding, and more.

According to the terms of the task, the core of our board should be the NUC140VE3CN microcontroller [7]. This processor is based on the ARM Cortex M0 processor, operates at a frequency of 50 MHz and has 128 KB of ROM memory and 64 KB of RAM memory. This microprocessor belongs to the Connectivity Line class, which is aimed at working with data transfer interfaces.

The controller is powered by a five-volt DC voltage; the wiring diagram is shown in Fig. 2.

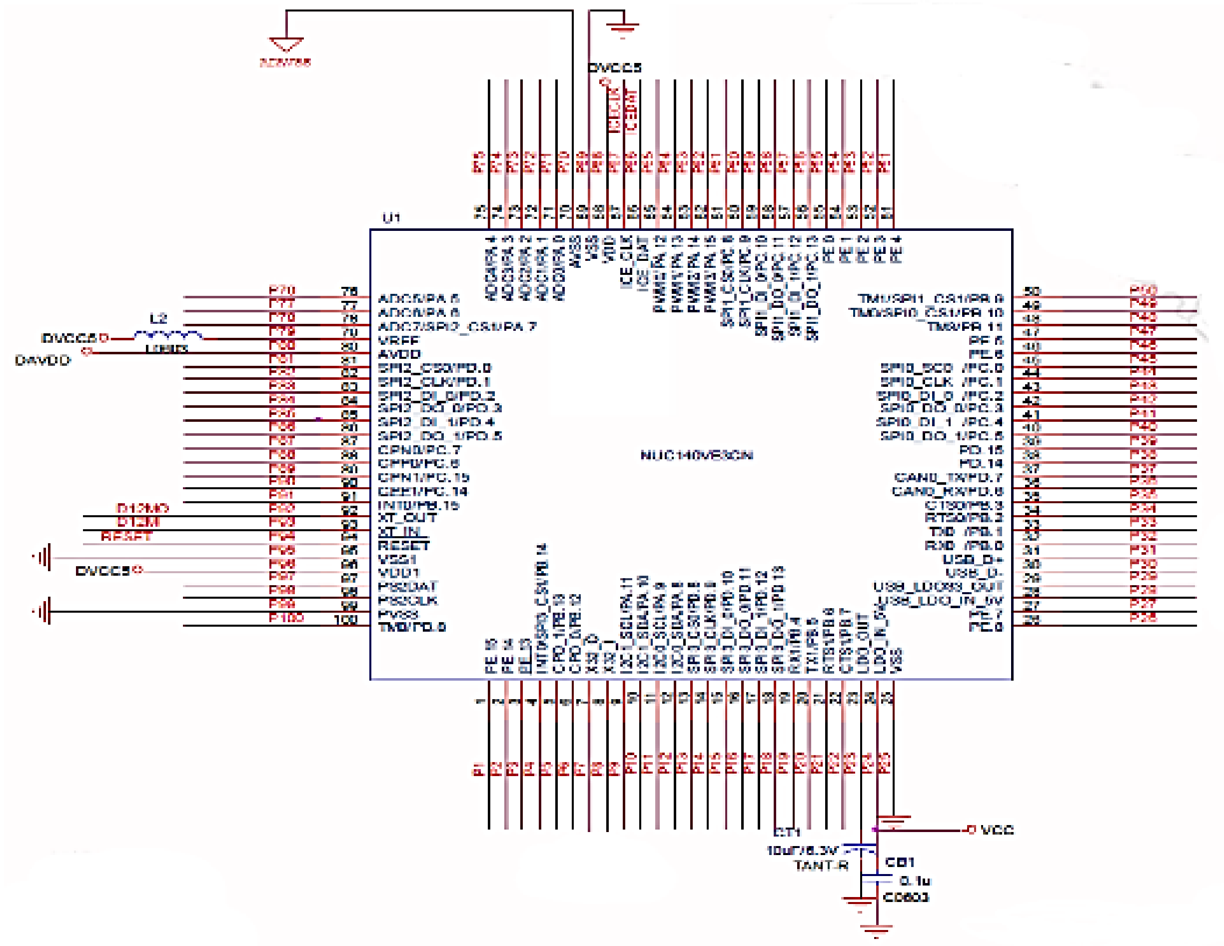


**Fig. 2**. Power supply connection diagram to the microcontroller

In this work, given the selected elements, it is necessary to calculate power supplies (PSUs) for voltages of 5, -5, 3.3 V that supply the equipment.

There are two categories of power supplies: transformer and non-transformer. In this paper, we use transformer power supplies because they are quite simple to manufacture and have a low level of electromagnetic radiation and interference. A significant drawback is the significant weight and dimensions caused by the presence of a transformer.

The main task of the power supply is to reduce the voltage to the required level, as well as to convert (rectify) it from AC to DC. In addition, the output voltage level must remain constant regardless of fluctuations in the input voltage on the transformer primary winding. In other words, in addition to converting, the PSU must provide voltage stabilization.

In general, the structure of a power supply consists of a transformer, rectifier, filter, and stabilizer.

In addition to the main components, a number of auxiliary components are also used, for example, indicator LEDs that signal the presence of voltage. If the power supply is equipped with voltage regulation, it may have a voltmeter.

The classic circuit includes a mains transformer, a diode bridge, a capacitor filter, a stabilizer and an LED. The latter serves as an indicator and is connected through a current-limiting resistor. The general circuit of the 5, -5 and 3.3 V power supply is shown in Fig. 3.

The study confirmed the high efficiency and reliability of microcontrollers in a wide range of applications. Their compact size and ability to operate with low power consumption make them ideal for embedded systems, from industrial controllers to consumer devices.

Three different fine screening technologies have been tested and implemented at the concentrators, which allow us to: Improve the quality of the finished concentrate; Increase the productivity of sections or reduce the number of mills staged concentrate recovery; Reduce the number of mills or increase the productivity of sections by replacing hydrocyclones in a closed grinding cycle with fine screening technology.

Application: This technology is one of the most promising and developing areas of iron ore beneficiation technology development, with which further progress in this field is largely associated. Vibrating screening technology allows for increased computing power and expanded functionality, making it an excellent tool for a variety of tasks.

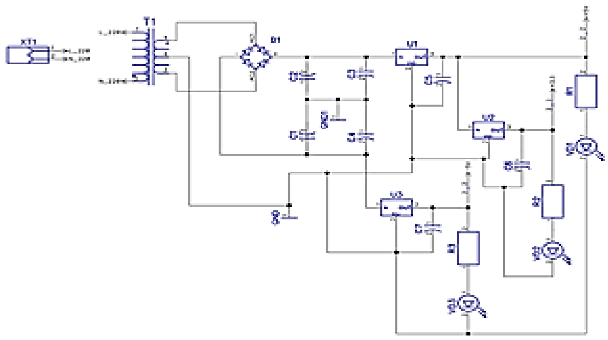

**Fig. 3.** Diagram of the developed power supply

Table 1

Specification of elements to Fig. 3

| № | Tagged | Name | Meaning | Quantity |
|---|---|---|---|---|
| 1 | C1, C2 | capacitor | 4700 μF | 2 |
| 2 | C3, C4, C5, C6, C7 | capacitor | 0,1 μF | 5 |
| 3 | D1 | DBL201G | | 1 |
| 4 | R1 | Resistor 1000 | 1000 Om | 1 |
| 5 | R2 | Resistor 200 | 200 Om | 1 |
| 6 | R3 | Resistor 120 | 120 Om | 1 |
| 7 | T1 | TPK-2 6V | 220V by 6V | 1 |
| 8 | U1,U2 | LM7805 | | 1 |
| 12 | U3 | AMS1117 | | 1 |
| 14 | VD1 | LED | | 3 |
| 15 | +5V, -5V, +3.3V | Source | | 3 |
| 16 | GND | Ground | | 1 |

To summarize, the study of microcontrollers shows their importance in the world of modern technology and the prospects for their development in the future determine their key role in improving and implementing new technological solutions.

**Conclusions and direction for the further research.** Analyzing the above, we note that the operation of the Nuvoton Nu-LB-NUC140 microcontroller was studied.

A feature of the study was the description of the program components that were developed to control the microcontroller.

Experimental evaluation of the study and verification of the controller's performance allow us to assess the requirements of this device for electromechanical systems at concentrating plants with fine screening technology.

Summarizing the above, it is worth noting that the use of a microcontroller to control automated electromechanical systems makes it possible to facilitate, secure, develop and ensure better production results at concentration plants with fine vibrating screening technology.

The scientific novelty of the obtained results lies in the fact that for the first time, a method of microcontroller control at beneficiation plants with the technology of fine screening has been developed.

Prospects for further research are to study and apply microcontrollers in practice to improve the quality of service and reliability of technological processes at beneficiation plants using the technology of fine screening.

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## ВАРІАТИВНІСТЬ ПРЕВЕНТИВНОГО ВИБОРУ ТЯГОВИХ ЕЛЕКТРОДВИГУНІВ В СТРУКТУРАХ СУЧАСНИХ ЕНЕРГОЕФЕКТИВНИХ ЕЛЕКТРОПРИВОДІВ РУДНИКОВИХ ЕЛЕКТРОВОЗІВ

**Мета.** Метою даного дослідження є аналіз потенційних можливостей та оцінювання варіативності їхньої реалізації шляхом залучення нових нетрадиційних видів електричних двигунів в структурах комплексів енергоефективного формату тягових електроприводів рудникових контактних електровозів. Мета пошуку являє собою усучаснення новітніх спрямувань у розробці та втіленні в практику роботи гірничих підприємств електровозів з енергоефективними та надійними електромеханічними системами. Для досягнення поставленої мети, в роботі проведено аналіз як реальних параметрів функціонування експлуатуємих типів електричних двигунів, так і їхніх опонентів - перспективних зразків.Аргументовано перспективи конкретних варіантів з урахуванням усіх супутніх чинників і умов експлуатації.

**Методи дослідження**. Для знаходження адекватного рішення в досягненні поставленої мети досліджень в роботі використано методи математичного аналізу для вибору технологічних параметрів різних типів електродвигунів з рейтинговим оцінюванням стану та можливостей виконання ними функціональних задач при функціонування в складі тягових електромеханічних систем рудникових контактних електровозів.

**Наукова новизна.** Вперше запропоновано підхід до оцінювання рівня ефективності структурування конкретних типів електродвигунів у варіанті рейтингового оцінювання комплексу їхніх технічних та енергетичних можливостей в сучасних тягових електромеханічних системах рудникових контактних електровозів.

**Практичне значення.** Запропонований підхід до аналізу та оцінювання статусу електричних двигунів як тягових в складі відповідних електромеханічних систем рекомендується до вивчення і практичної реалізації відповідними розробниками нових варіантів тягових систем рудникових контактних електровозів.

**Результати.** У статті запропоновано метод аналізу, оцінювання і вибору ефективних типів електричних двигунів в складі сучасних енергоефективних електромеханічних системи рудникових електровозів, проведене порівняння технічних характеристик досліджуваних двигунів. Було окреслено потенційні напрямки розвитку у галузі застосування тягових електроприводів змінного струму з підвищеними значеннями напруги живлення і номінальних обертів двигуна.

**Ключові слова:** електричний двигун, електровоз, електромеханічна система, рудник, шахта.

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