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## USING TINKERCAD TO SUPPORT ONLINE THE LABORATORY WORK ON THE DESIGN OF MICROPROCESSOR SYSTEMS AT TECHNICAL UNIVERSITY

**Abstract.** This article reviews the possibility of using the Tinkercad Internet service for online study of the subjects connected with microprocessor systems. During the global coronavirus pandemic, online classes based on the Internet technologies have become virtually the only effective method of learning. However, while lectures can be taught successfully with the help of video conferences such as Zoom, Skype, Microsoft Teams, Google Meet etc., it is almost impossible to perform laboratory and practical work in the field of designing microprocessor systems with the help of these tools. Therefore, the authors suggest a new approach to practicums on the subjects related to microprocessor systems using tools of the Tinkercad Internet service. The existing methods and means of remote work with breadboard Arduino have been analyzed. The advantages of the Tinkercad Internet service in comparison with other tools of remote work have been disclosed. The service capability for microprocessor systems design has been considered. The article provides examples of elaborated lab works by means of the Tinkercad Internet service. Available capabilities and instruments in the system have been detailed. The process of learning based on the Tinkercad Internet service has been developed. Consequently, the use of the Tinkercad Internet service during e-learning gives the possibility to do lab works and microprocessor system design practicums without actual equipment, and the methods suggested by the authors assure the quality of students' awareness in this direction. The prospective direction of this Internet service application can be the design of 3D printing models and their use during e-learning of other subjects, in particular Physics (Electrics section), Theoretical Basics of Electrical Engineering (DC section), as well as other sciences related to electronic circuit design.

**Keywords:** pandemic; e-learning; workshop on computer science; Tinkercad Internet service; breadboard Arduino; microprocessor system.

### 1. INTRODUCTION

According to UNESCO, in March 2020, more than 1,5 billion young people in 165 countries all over the world were not able to attend educational institutions because of the Covid-19 pandemic restrictions, which called for drastic changes in the organization of studying process.

Under the threat of corona virus infection spread most of colleges and universities shifted to e-learning on the recommendation of the Ministry of Education and Science of Ukraine.

As a result, all face-to-face classes including lectures and practicums, were transferred online and teachers had to organize e-learning technologies based on the resources at their disposal (Moodle, Google Classroom, Zoom, Skype, Google Suite / Docs etc.) or email.

Undoubtedly, e-learning is the only way to be educated during a severe pandemic. However, as a reality check revealed there are some difficulties with distance learning related to not only technical issues (lack of equipment or access to the Internet) but psychological problems as well – lack of face-to-face communication with a teacher, significant increase in self-study modules, insufficient time for doing tasks, limited access to a computer, given that parents also work remotely, etc.

Doing lab works in natural science subjects, which require laboratory facilities (equipment and stands), has become the main problem during e-learning. While lectures can be successfully taught on online platforms, doing lab and practical assignments requires the evolvement of new approaches and solutions.

**Problem statement.** Currently, microprocessor systems based on microcontrollers, which differ not only in structure and features but also in functioning and their implementation, have become widespread. While a system, based on microcontrollers, is being worked out, not only hardware is created, which is implemented with corresponding connection of microcontroller to external hardware, but software as well.

Often lack of necessary equipment, electronic schemes and facilities makes it impossible to do lab and practical assignments as well as self-study during distance learning period. Thus, performing laboratory or practical work on the design of microprocessor systems is impossible without the presence of breadboards and Arduino microprocessor systems. The cost of these sets of equipment for performing relevant laboratory work is quite high and not affordable for all students.

Therefore, there is a need to ensure the possibility of carrying out this direction of laboratory and practical work in remote mode, using the capabilities of Internet design and Internet simulation, with the help of which the applicant could assemble the necessary system (electrical circuit), write a control program for it, load it into a microprocessor system, execute it and track the results of the developed system.

**Analysis of recent studies and publications.** The issues of e-learning during the pandemic have been considered by both Ukrainian and foreign scientists [1], [2]. For instance, I. Prokopenko and S. Berezhnyi, in their work [3] state that COVID-19 demands the implementation of innovative decisions from institutions of higher education for relatively a short period of time as well as the introduction of e-learning with different Internet-services, resources, platforms and social networks. They also note the change of the teacher's role in the period of distance learning, noting that the teacher also plays the role of a consultant who coordinates the learning process, constantly improving his/her courses and skills.

Steve Brammer and Timothy Clark in their work [4] note that the pandemic caused a quick transformation of pedagogical activities in modern universities, mainly, the involvement of extra effort to master new software. The scientists claim that COVID-19 has led to serious structural changes in the organization of higher education, which are due to changes in the needs of education seekers, the development and spread of new information technologies for learning.

In the work [5] the authors prove that institutions of higher education differently responded to the pandemic challenges: from no response to a strategy of social isolation in a campus and a quick modification of curriculums to meet the needs of e-learning. Andrew Smolly [6] thinks that the switch to distance learning will lead to a decrease in the quality of

students' knowledge, especially it refers to weak students who need extra mentoring. The official website of the EU displays a detailed analysis of existing Internet platforms for educational institutions, teachers, educators etc. [7]. The authors of publications [8], [9] have studied the existing resources of educational institutions which can be effectively transformed to official curriculum (e-learning) with the help of virtual classes and other online resources. D. Styhno, L. Konstantynov, N. Gagiev [10] pay attention to the growth of educational inequality, dependence of the education quality on opportunities of institutions, their budgets, students' and teachers' competencies and technical possibilities; increased workload for both students and academics; potential quality decrease because of e-learning. K. Carrillo and M. Flores in their work [11] reviewed materials about online-teaching. The results showed the necessity of a comprehensive approach to e-learning pedagogics, which brings together technologies to maintain teaching and learning.

In the study [12] the authors described the peculiarities of training in medical institutions under the conditions of COVID-19, where there is a problem of lack of opportunities for practical training in resident surgeons, which affects both the theoretical and practical skills of future doctors. They offer several innovative solutions, including a flipped classroom model, online practice questions, teleconferencing instead of in-person lectures, resident involvement in telemedicine clinics, procedural simulations, and facilitated use of surgical videos.

The entire scientific community agrees that the only way to study during the pandemic is to switch to e-learning while using on-line technologies. However, the issues related to conducting lab and practical classes which require special equipment have not yet been investigated sufficiently.

**The aim of the article** is to develop methods for remote performance of laboratory (practical) work during the study of microprocessor systems design based on the use of modern Internet technologies.

Achieving the set goal involves solving the following tasks:

- to explore possible software tools for organizing the performance of laboratory and practical work during the distance learning period;
- to justify the choice of an Internet platform for remote performance of laboratory and practical work in the field of designing microprocessor systems;
- to develop a method of remote performance, analysis and verification of laboratory and practical works in the field of designing microprocessor systems.

## 2. METHODOLOGY OF THE RESEARCH

To accomplish the set tasks, the analysis of existing software has been carried out, which makes it possible to implement remote laboratory and practical work in the field of designing microprocessor systems. The Internet-service has been selected, which best meets the requirements of distant performance of lab and practical assignments in the field of microprocessor systems design. The method of remote implementation, conducting and control of laboratory and practical work in the field of designing microprocessor systems has been developed.

The research has been conducted on the basis of theoretical and practical developments of modern tools of visual design, microprocessor programming and communication technologies.

Methods of automated control systems establishment, methods of mathematical and computer modeling, the algorithms and probabilities theories, parallel and distributed data processing, numerical methods, methods of visual design and programming have been used to solve the tasks.

### 3. THE RESULTS OF THE RESEARCH

The design of any complex system starts with the creation of its mathematical model. While designing microprocessor systems, the methods of analytical and simulation modelling with the use of different automated software environments are widely used. One of the main advantages of environment while designing microprocessor systems is the combination of software development tools with hardware development tools. The main task of this environment is to create a virtual model of microprocessor electronic device.

The efficiency of microprocessor system design is determined first of all by the developer's qualification and the set of tools. While studying the course «Microprocessor systems», various tools are used that perform input / output of analog and digital signals, storage and processing of data and command codes, as well as console indication of performed operations and management.

In order to design microprocessor systems nowadays, various software is used such as Visuino, Scratch, ArduBlock etc.

Visuino software is a graphical environment based on Arduino-compatible Controllino industrial controllers (PLCs). It enables the creation of automation systems and IoT (Internet of Things) solutions, and this can be done simply by moving and connecting visual blocks [13].

Scratch uses a principle similar to Lego. A software tool is created with the help of blocks that can be moved, modified, made to interact in different ways. One of the disadvantages of Scratch is the exclusion of the function of flashing (booting) Arduino, it can only control its microprocessor via USB [14]. Ardublock works similarly and has a similar interface. It allows a visually designed program resembling Scratch blocks to easily convert the code using the Arduino IDE [15].

All of them use visual programming – creating programs by dragging and connecting corresponding graphic blocks. They are quite suitable for teaching the basics of programming Arduino-based microprocessor systems for younger and middle-aged children.

At best, they allow you to generate software code that can be uploaded to the Arduino. However, a significant drawback of these systems is the possibility of simulating the operation of the developed microprocessor system, which is especially critical in the conditions of distance learning.

Tinkercad Internet service allows not only to design microprocessor systems, but also to simulate their operation. Its work is visually realistic due to the accurate drawing of each element of the system. A significant advantage over similar systems is its freeness.

Therefore, to implement the above-mentioned goal, the Tinkercad Internet service has been chosen as a tool for microprocessor design during the distance learning period.

Tinkercad refers to the following:

- a set of preset models of most popular electronic components, sorted by component types;
- a simulator of electronic circuits, with the help of which you can connect the created virtual device to a virtual power source and trace how it will work;
- a simulator of sensors and instruments of external influence, with the help of which you can change the readings of the sensors, depending on how the system reacts to them;
- built-in Arduino editor with a port monitor and the possibility of step-by-step setup;
- ready-to-deploy Arduino projects with diagrams and code;
- visual editor of the Arduino code;
- an online platform that requires nothing but a browser and stable Internet to operate;
- user-friendly graphic editor for visual construction of electronic circuits;

- the possibility of integration with other functional elements of Tinkercad and quick creation of structural elements, with their subsequent reproduction using a 3D printer;
- built-in tutorials and a huge community with a collection of ready-made projects.

Tinkercad was created in 2011 by Kai Backman and Mikko Mononen. Firstly, the information product was positioned as the first Web-platform for 3D-projecting, in which users could share results with each other. In 2013 the service was purchased by Autodesk company and complemented the product family 123D. Over the whole period, with the help of this service, users have created and published 4 million projects (3D models). In June 2017 Autodesk made a decision to move a part of its functional from another service Electronics Lab Circuits.io, after that Tinkercad got really important instruments, which were able to significantly facilitate Arduino studying of projecting and programming new circuits for newbie developers. All old Circuits.io projects could be easily exported to Tinkercad.

To start working with Tinkercad, you need to register with Autodesk. Registration in Tinkercad is absolutely free – you need to go to the site and perform standard actions.

### **Creating a project**

After loading the main page of Tinkercad, the project gallery is displayed and there is an option to call up an existing project or create a new one. As a result, a project with the default name will be created. By clicking on it, you can go to the viewing mode of the list of schemes included in this project, where you can change the properties of the project (indicating their name) by clicking on the corresponding button.

### **We add a new Circuits scheme**

You can create a new scheme in Tinkercad in two ways - develop your own electronic scheme or use one of the ready-made electronic schemes available in the Tinkercad starter kits. To create a new scheme in Tinkercad, select Circuits from the menu on the left and select the Create new Circuit command.

### **Using a Tinkercad circuit in edit mode**

By clicking on the «Change» command, the transition to edit mode is carried out. With the help of user-friendly and simple graphic interface, an electric circuit can be designed. It is also possible to highlight, move objects and delete them using «Drag & Drop» method with the help of a mouse (Fig. 1).

In edit mode the service working window is divided into two parts: the panel with bookmarks is at the bottom – it is the component library. Above it there is an area of visual editing of the circuit with the toolbar and an area where the circuit will be placed.

### **Creating a scheme in Tinkercad step by step**

In most cases the following algorithm of actions is performed while working with Arduino projects:

- create a new scheme or open an existing one for editing;
- using a visual editor, create a scheme (in our case, with the inclusion of the Arduino Uno board);
- create a sketch in the code editor and upload it to the virtual controller;
- start the simulation mode, in which the board is virtually connected to the power source and the circuit starts working. We enter the initial data for the sensors and observe the reaction of the circuit, both visually and on the virtual monitor of the port inside the service itself.

When creating a diagram, we perform the following procedure (Fig. 2):

- select the required components from the component library and place them in the editor field;
- connect components using virtual conductors, drawing them with the mouse;

- edit the parameters of the components (for example, the value of the resistance of the resistors or the color of the wires).

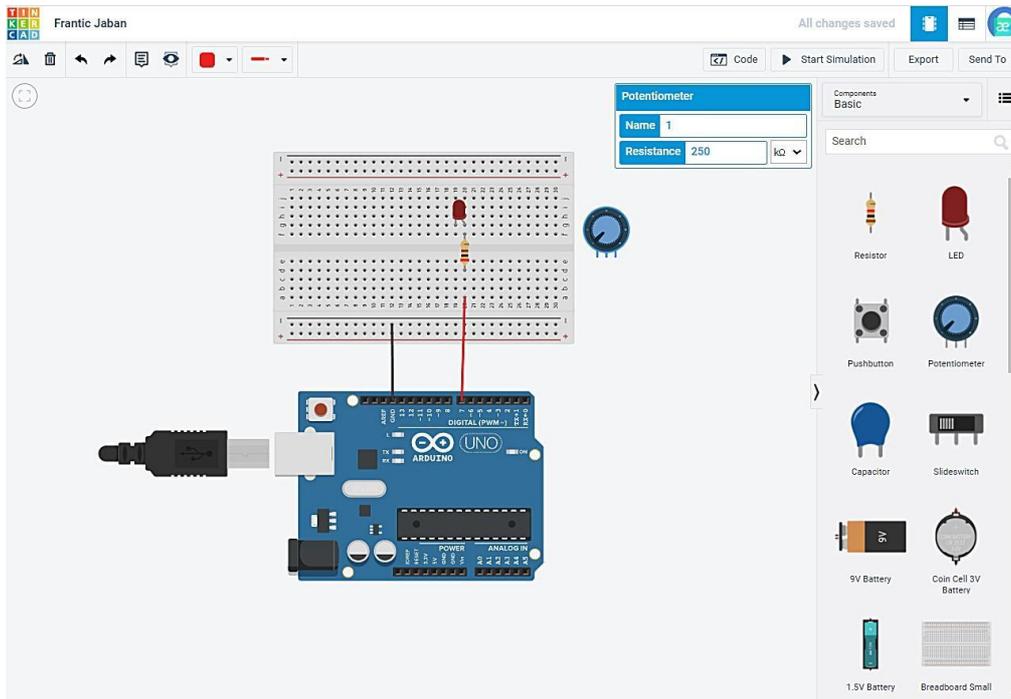


Fig. 1. The screenshot of the module structure «Scheme editing process»

The operation of selecting from the component library is quite simple. The list of items is on the right side of the screen. After selecting an element, click on it, then move it to the desired place on the diagram and click again. The component list window can be hidden or shown by clicking the «Components» switch in the toolbar.



Fig. 2. The screenshot of the structure module «List of Tinkercad components»

For convenient navigation, all elements from resistor and battery to Arduino modules are divided into 3 tabs:

### Programming the sketch of virtual Arduino

All tools for editing the code become available after switching to the corresponding mode by clicking on the button «Code Editor» in the upper panel (Fig. 3).

The following options are available in code editing mode:

- loading the sketch into the “virtual controller” and run the simulator;
- switching to a visual code editor like Scratch;
- switching to the text editor of the code;
- connecting libraries;
- downloading the code to your computer as a file with the extension .ino (Arduino sketch);
- launching the configuration tools with the possibility of creating breakpoints and monitoring the states of variables.

Show or hide the monitor window.

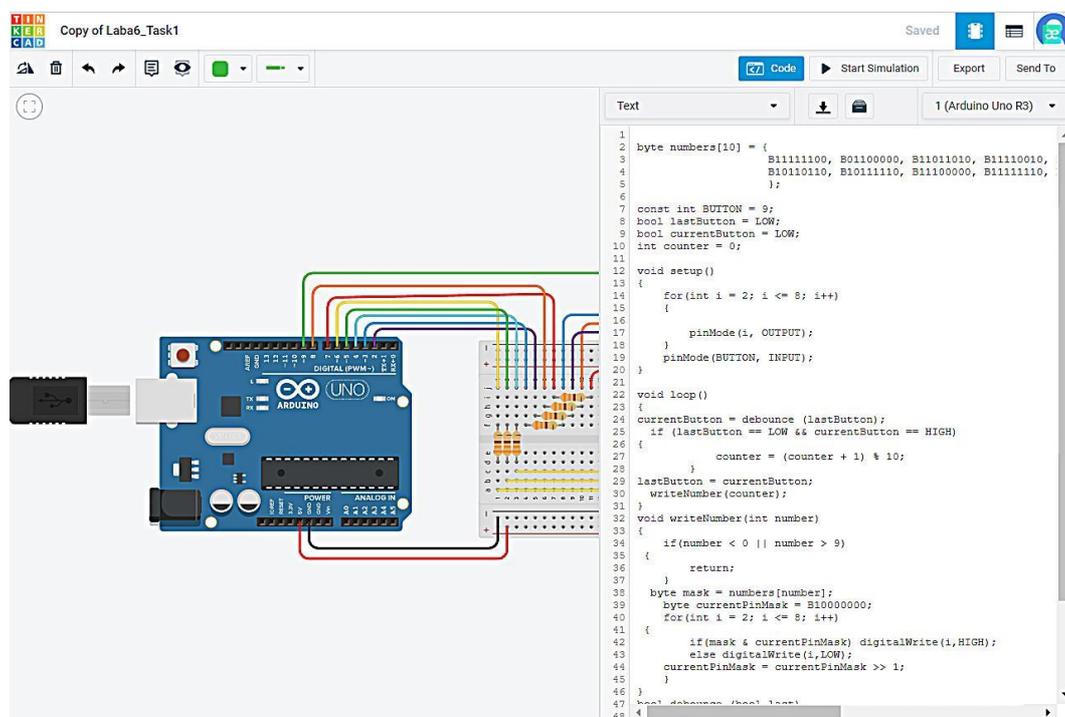


Fig. 3. The screenshot of structure module «Program code creation process»

### Running the Arduino simulator

To start the simulator, click on the «Start Simulation» button in the upper panel. After starting the simulator, the ability to edit the electronic circuit of the system is blocked. The simulator starts with program compilation. If errors are found in the program, a corresponding message is issued. If there are no errors, the circuit is connected to the power source and the program commands begin. If necessary, in this mode it is possible to enable «Serial Interface Monitor» to provide I/O operations to the serial port.

### Algorithm for performing laboratory work using the Tinkercad Internet service

Fig. 4 shows the algorithm for remote performance of laboratory work by a student using the Tinkercad internal service.

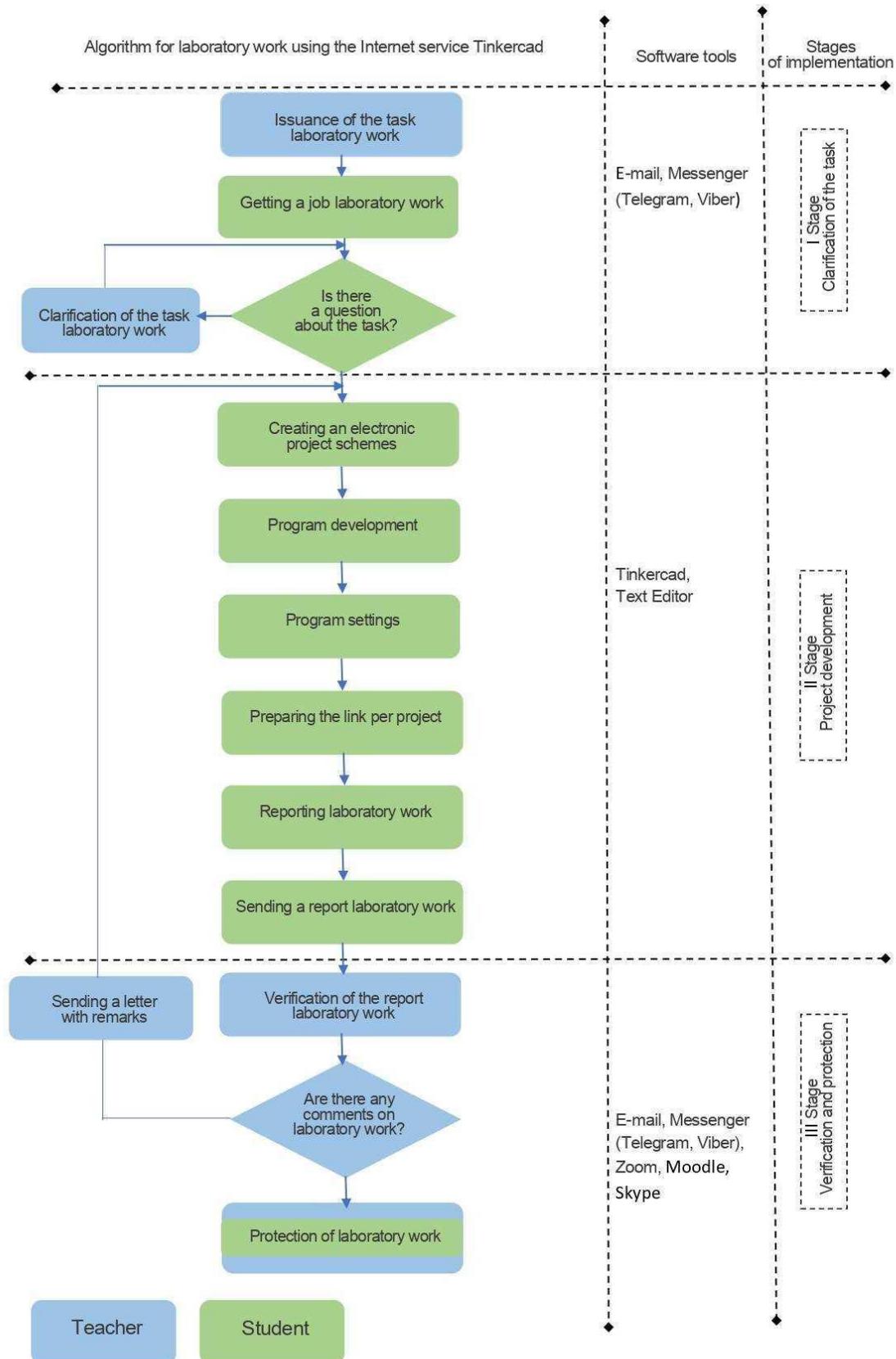


Fig. 4. The algorithm for remote performance of laboratory work by a student using the Tinkercad online service

The first stage. Task clarification.

The teacher remotely, using electronic communication tools (e-mail, messenger), gives the task to the applicant in accordance with his option in the form of a file. The learner, having received the task, analyzes it and, if he has any questions about the task, he clarifies it with the teacher by means of electronic communication. This is an important stage in the process of performing laboratory work, since if the task is not understood correctly, all subsequent steps of the applicant in solving the laboratory work will be incorrect.

After clarifying the task, the applicant moves to the second stage of performing laboratory work.

The second stage. Project development.

Then in the Tinkercad Internet-service, the student performs the design of the electronic circuit of the microprocessor system. At the same time, he selects the necessary electronic components of the system (microprocessor, sensors, motors, etc.) from the set of components offered by the system (library). After that, the student connects the selected components with conductors to implement the designed electrical circuit.

Then, switching to the «Code» mode, the student develops a program for the microprocessor system and performs its debugging. After setting up the program, the student switches to the system simulation mode and performs its testing.

The next step is to create a report on the laboratory work, which should contain: title page, task, electrical diagram of the microprocessor system, its program code, screenshots of the system's operation, answers to control questions and conclusions on the work. After clicking the «Send to» button, he must perform the «Invite users» operation to form a link to the developed project, which he must also insert in his report.

After completing the report, the student sends it to the teacher by e-mail.

The third stage. Check and presentation of a lab assignment.

Verification and protection of laboratory work.

After receiving the report from the laboratory work, the teacher checks the functionality of the developed microprocessor system in Tinkercad, using the link to the project sent by the student. The design of the report is checked, if comments are found, they are sent to the acquirer in the form of an e-mail for elimination. After eliminating the shortcomings in the work, the student goes to the defense of the laboratory work. The defense of the laboratory work takes place according to the schedule according to the subject of the lesson, the means of communication between the group of students and the teacher can be an electronic conference (Zoom, Microsoft Teams, Skype, etc.), in turn (according to the acceptance of the work by the teacher), the applicants talk about the developed microprocessor system, answer questions. The teacher evaluates the developed system and the student's answers to the given questions and, in accordance with the evaluation criteria, assigns him points for this laboratory work (project).

Let us consider an example of remote performance of laboratory work using the Tinkercad Internet service.

Task.

Create a microprocessor circuit of temperature control in the room with the help of the Tinkercad Internet-service. At the same time to provide:

1. sending the temperature to the port monitor by means of visual programming;
2. outputting the temperature on the 16x2 LCD screen by means of the software code.

**Steps.**

1. Development of the electrical scheme of the project in the Tinkercad online service (Fig. 5).

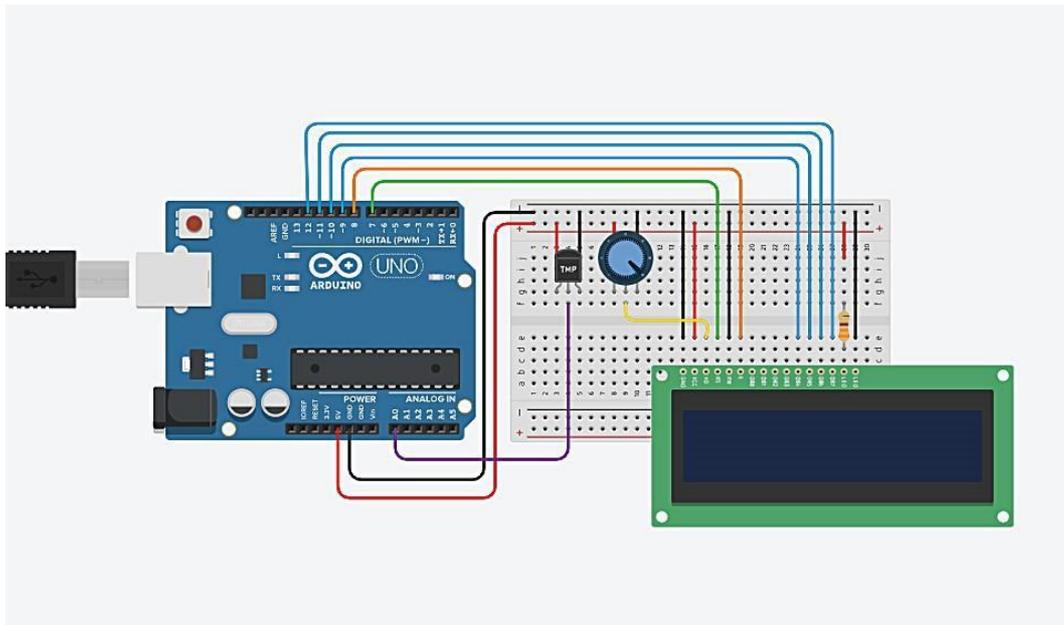


Fig. 5. The screenshot of the module structure «Creating an electrical diagram of the project»

2. Development of the output of the temperature value in the port monitor by means of visual programming (Fig. 6).

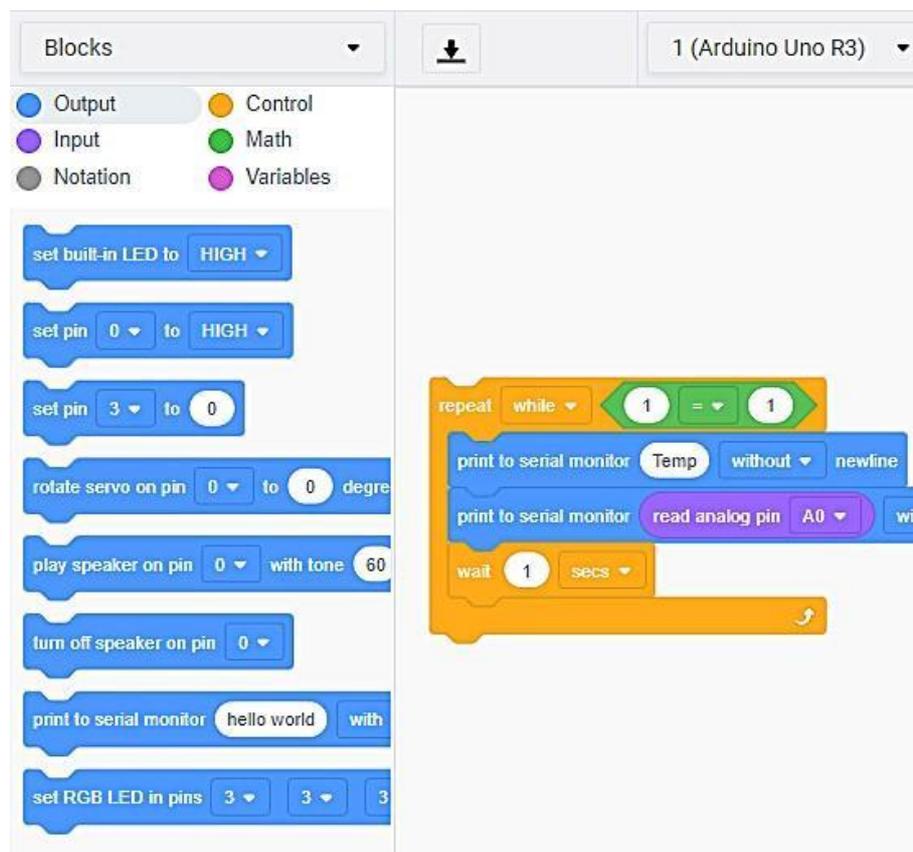


Fig. 6. The screenshot of the module structure «Development of outputting the temperature value to the port monitor by means of visual programming»

### 3. Development of software code for displaying the temperature value on the LCD screen.

```
#include <LiquidCrystal.h>
int tempPin = 0;

LiquidCrystal lcd(7, 8, 9, 10, 11, 12); // LCD initialization

void setup()
{
  lcd.begin(16, 2); // Activation of the LCD display

  Serial.begin(9600);
}

void loop()
{
  int tempReading = analogRead(tempPin);

  float tempVolts = tempReading * 5.0 / 1024.0; // Conversion of an analog
  value into a voltage
  float tempC = (tempVolts - 0.5) * 100; // Conversion of voltage to degrees
  Celsius

  float tempF = tempC * 9.0 / 5.0 + 32.0 ; // Convert voltage to degrees
  Fahrenheit

  // Show the temperature in F
  lcd.setCursor(0, 0); // Record in the column 0, line 0
  lcd.print("Temp F ");
  lcd.setCursor(6, 0); // Record in the column 6, line 0
  lcd.print(tempF);

  // Output of information to the port monitor
  Serial.print("Temp F");
  Serial.println(tempF);

  // Show the temperature in C
  lcd.setCursor(5, 1); // Record in the column 5, line 1
  lcd.print("C ");
  lcd.setCursor(6, 1); // Record in the column 6, line 1
  lcd.print(tempC);

  // Output of information to the port monitor
  Serial.print("Temp C");
  Serial.println(tempC);
  delay(500);
}
```

### 4. System performance results.

Output of the temperature value in the port monitor (Fig. 7):

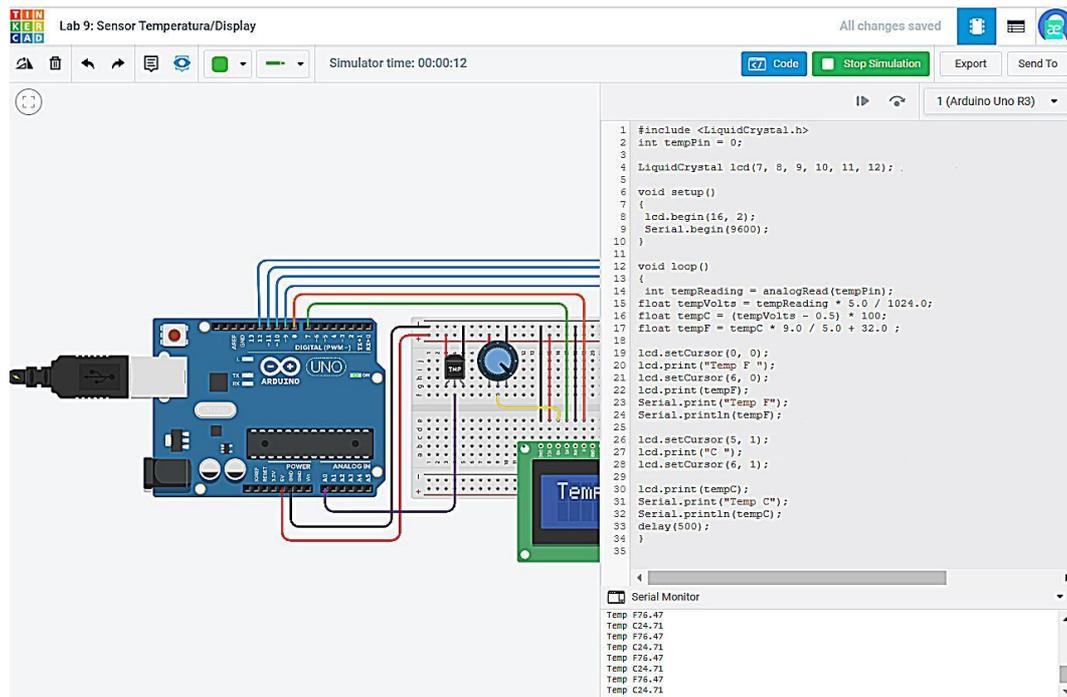


Fig. 7. The screenshot of the module structure «Output of the temperature value in the port monitor»

Output of the temperature value on the LCD screen (Fig. 8).

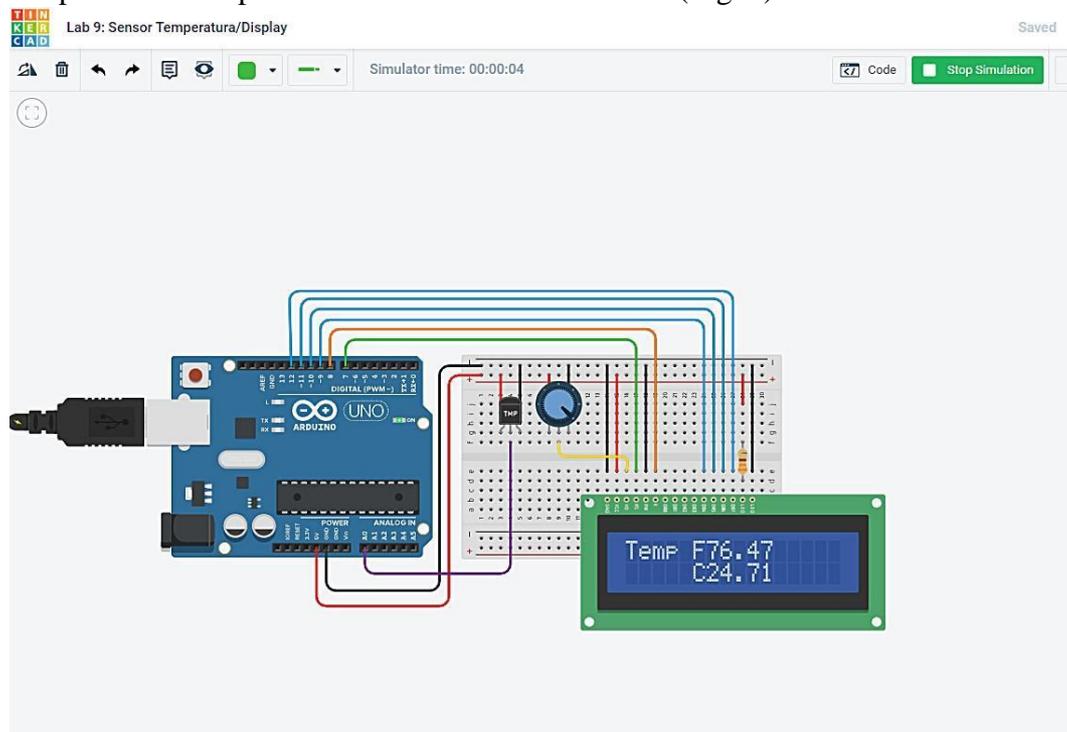


Fig. 8. The screenshot of the module structure «Output of the temperature value on the LCD screen»

#### 4. EXPERIMENTAL VERIFICATION OF RESEARCH RESULTS

The application of the Tinkercad Internet service in the on-line mode when performing laboratory (practical) works practically does not differ from performing them in laboratories, and can be performed in synchronous and asynchronous modes. Due to the means, methods and tools provided by the Tinkercad online service, the student has the opportunity to design the electrical circuit of the system, develop and set up the program code and emulate its operation in the on-line mode.

The method of remote performance of laboratory (practical) works developed by the authors was successfully tested at the Department of Information Systems and Technologies of the National Technical University of Ukraine «Ihor Sikorskyi Kyiv Polytechnic Institute».

The experiment involved 109 students studying in the specialty 123 «Computer engineering» from the course «Programming of microprocessor systems». During the experiment, all participants of the educational process were in equal conditions, and control over the performance of stages was carried out according to the same criteria. Analyzing the results of the study, it was determined that the fact that the quality indicators of the acquired knowledge increased among the respondents after the introduction of the proposed method compared to the traditional method, as can be seen from the Table. 1.

Table 1

**Analysis of the students' level of knowledge**

Group	Number of students	Level of knowledge									
		A		B		C		D		E	
		number	%	number	%	number	%	number	%	number	%
Using the technique	109	16	15	21	19	59	54	11	10	2	2
Regular training	102	12	12	15	14,5	57	55,5	11	11	7	7

The quality of acquired knowledge in the experimental group increased by 5.4% compared to the regular training. Analyzing the Table 1, it can be concluded that the vast majority of students have improved their skills, which indicates their transition to knowledge groups «A» and «B».

According to the authors, this may be due to the fact that the use of the method of remote laboratory work developed by the authors, students have more opportunities to perform laboratory work both by performing work directly in pairs (synchronous form) and by performing laboratory work independently (asynchronous form) in convenient time for the student. At the same time, they only need a desire, the presence of an Internet connection and the use of the developed method of remote performance of laboratory work, based on the application of the Tinkercad Internet service.

However, the decisive advantage provided by our method is the presence of constant communication with the teacher (using internet-messenger or e-mail). In the event of a problem, the student has the opportunity to promptly ask the teacher a question and quickly receive qualified assistance.

This confirms the assumption that the developed technique will contribute to the study of the design of microprocessor systems and the qualitative preparation of future.

## 5. CONCLUSIONS AND PROSPECTS FOR FURTHER DEVELOPMENTS

The development and implementation of modern new technologies in educational processes, in particular, distance learning, make it possible to effectively organize laboratory and practical work in disciplines related to the design of microprocessor systems, namely, the Tinkercad Internet service.

The use of the Tinkercad Internet service is due to its unique capabilities, namely: the presence of a visual scheme editor, visual and text code editors, a setting up mode, a scheme simulation mode, the ability to export received sketches and electrical schemes to real projects make Tinkercad an indispensable tool for remote performance of laboratory and practical works.

As evidenced by the results of practical research, the use of the Tinkercad Internet service allowed to obtain better learning results, namely, in the experimental group, the quality of the acquired knowledge increased by 5.4%, which confirms the feasibility of introducing the Tinkercad Internet service into the educational process and the possibility of forming a thorough technology remote performance of laboratory and practical works (projects) in disciplines related to the design of microprocessor systems:

1. Study of theoretical material on the topic of laboratory work.
2. Obtaining and understanding the task for laboratory work.
3. Designing an electronic circuit in the Tinkercad online service.
4. Development of microprocessor system software in the Tinkercad Internet service.
5. Simulation of the developed microprocessor system in the Tinkercad Internet service.
6. Drawing up a report on laboratory work with mandatory inclusion of links to developed projects in Tinkercad.
7. Sending the laboratory work report to the teacher by e-mail.
8. Defense of the completed laboratory work during the lesson in the Zoom video conference.

Thus, the use of the Tinkercad Internet service in the conditions of distance learning allows you to perform laboratory work on the design of microprocessor systems without real equipment, and the methodology proposed by the authors ensures the high quality of students' knowledge in this direction.

On the basis of the analysis of the results of the investigated problem, the implementation of the method of remote performance of laboratory (practical) works in the study of the design of microprocessor systems based on the use of modern Internet technologies (Internet service Tinkercad) is substantiated.

Applicants who remotely performed laboratory work in the Tinkercad online service note the ease of use, the great capabilities of the system (a large number of available tools), the presence of a library of ready-to-use projects and the possibility of emulating the system's operation directly in Tinkercad.

Prospects for further research are the development of appropriate methodological support and its implementation in the educational process of specialties in the following fields of knowledge: «Information technologies», «Mechanical engineering», «Electrical engineering».

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## ВИКОРИСТАННЯ TINKERCAD ДЛЯ ОНЛАЙН ПІДТРИМКИ ЛАБОРАТОРНИХ РОБІТ З ПРОЄКТУВАННЯ МІКРОПРОЦЕСОРНИХ СИСТЕМ В ТЕХНІЧНОМУ УНІВЕРСИТЕТІ

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**Анотація.** У статті розглянута можливість використання інтернет-сервісу Tinkercad для організації навчального процесу з дисциплін, пов'язаних зі створенням мікропроцесорних систем під час дистанційного навчання. У період всесвітньої пандемії коронавірусу практично єдиним ефективним методом навчання є дистанційне, засноване на базі інтернет-технологій. Однак, якщо лекційний матеріал можна досить успішно викладати за допомогою таких популярних засобів проведення інтернет-конференцій, як-от Zoom, Skype, Microsoft Teams, Google Meet і ін., то виконувати лабораторні та практичні роботи з проєктування мікропроцесорних систем за допомогою цих засобів практично неможливо. Тому авторами запропоновано новий підхід до організації практичної роботи студентів з дисциплінами, які пов'язані з проєктуванням мікропроцесорних систем, з використанням засобів інтернет-сервісу Tinkercad. Проведено аналіз існуючих засобів і методів віддаленої роботи з макетною платою Arduino. Показано переваги використання інтернет-сервісу Tinkercad в порівнянні з іншими засобами віддаленої роботи. Розглянуто можливості використання цього сервісу при проєктуванні різних мікропроцесорних систем. У статті наведено приклади розроблених лабораторних робіт з використанням інтернет-сервісу Tinkercad. Докладно описані наявні в системі можливості і інструменти. Розроблено механізм організації навчального процесу на основі використання інтернет-сервісу Tinkercad. Тож використання інтернет-сервісу Tinkercad в умовах дистанційного навчання дозволяє виконувати лабораторні і практичні роботи з проєктування мікропроцесорних систем без реального обладнання, а запропонована авторами методика їх виконання забезпечить високу якість знань студентів у цьому напрямку. Перспективним напрямком роботи з даним інтернет-сервісом може бути проєктування моделей для 3D-друку, а також використання його при дистанційному вивченні інших дисциплін, а саме: фізики (розділ електрика), теоретичних основ електротехніки (розділ постійний струм), а також, інших природничо-наукових дисциплін, які пов'язані з розробкою електронних схем.

**Ключові слова:** пандемія; електронне навчання; практикум з комп'ютерних наук; інтернет-сервіс Tinkercad; налагоджувальна плата Arduino; мікропроцесорна система.



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