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DEVELOPMENT OF AN AUTOMATED MEASURING COMPLEX BASED ON THE ARDUINO PLATFORM

РОЗРОБКА АВТОМАТИЗОВАНОГО ВИМІРЮВАЛЬНОГО КОМПЛЕКСУ НА БАЗІ ПЛАТФОРМИ ARDUINO

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Abstract. The provided research, an analysis of existing automated systems has been carried out, as well as revealing their insufficient flexibility and the absence of simple complexes. In particular, the complete lack of budget-friendly complexes is noted.
Based on the conducted analysis, there has been set a task to create an automated measuring complex for use in experimental researches of the method of IR echo-pulse NDT of fiberglass structures.
The *purpose* of the test is to develop an automated measuring system for gathering and processing experimental data as part of the development of an IR echo-pulse NDT based on the Arduino platform.
In order to solve the above mentioned issues, there were applied *methods* of observation, comparison, analysis and synthesis, as well as material modeling.
Meanwhile, there have been defined the requirements imposed on the automated measuring complex and the main functions it should perform. Based on these requirements, a reasoned choice of the Arduino microprocessor platform has been made. This platform will be used as a foundational element in creating the automated measuring complex. An analysis of the research on the capabilities of the Arduino platform that had been conducted earlier has also been carried out. A conclusion has been drawn that the capabilities of the platform are not fully utilized.
Results. Taking into consideration of the conducted research analysis, algorithms for the Arduino platform operation have been developed to control laboratory equipment, receive and process experimental data, as well as procedures for data exchange between the platform and a personal computer. Considering the developed algorithms, there has been crated a software which enables parallel control of multiple processes during experiments using the laboratory bench. These processes are the reception and processing of experimental data, the transmission of experimental data to a personal computer, and the control of auxiliary laboratory equipment.
The *scientific novelty* lies in the formulation of a substantiated hypothesis regarding the possibility of simultaneous execution of multiple tasks by the Arduino microprocessor platform during experimental research. In addition, the confirmation of this hypothesis in the creation of an automated measuring complex based on this platform. The *practical significance* is grounded in the development and implementation of software created based on the specified algorithms.
Key words: automated complex; data processing; microprocessor platform; algorithm, software; process control; data exchange; microcontroller.

Анотація. В даній роботі проведено аналіз наявних автоматизованих комплексів, виявлено їх недостатня гнучкість і відсутність простих комплексів. Зокрема відзначається повна відсутність малобюджетних комплексів.
Виходячи з проведеного аналізу поставлена задача створення автоматизованого вимірювального комплексу, для використання в експериментальних дослідженнях методу інфрачервоної ехо-імпульсної дефектоскопії склопластикових конструкцій.
Визначено вимоги, що пред'являються до автоматизованого вимірювального комплексу і основні функції які він повинен виконувати. На підставі сформованих вимог проведений обґрунтований вибір мікропроцесорної платформи Arduino. Ця платформа буде використовуватись в якості базового елементу при створенні автоматизованого вимірювального комплексу. Також було проаналізовано дослідження можливостей платформи Arduino які були проведені раніше. Зроблено висновок, що можливості платформи використовуються не в повному обсязі. З урахуванням проведеного аналізу досліджень були розроблені алгоритми роботи платфор-

ми Arduino для управління лабораторним обладнанням, прийому і обробки експериментальних даних, а також процедури обміну даними між платформою і персональним комп'ютером. Зважаючи на розроблені алгоритми було створено програмне забезпечення, що дозволяє здійснювати паралельне управління декількома процесами при проведенні експериментів з використанням лабораторного стенду. Такими процесами є прийом та обробка експериментальних даних; передача експериментальних даних на персональний комп'ютер; управління допоміжним лабораторним обладнанням. *Наукова новизна* полягає в формуванні обґрунтованої гіпотези про можливість одночасного виконання декількох задач мікропроцесорною платформою Arduino при проведенні експериментальних досліджень з її використанням, а також підтвердження даної гіпотези при створенні автоматизованого вимірювального комплексу на базі даної платформи. *Практична значимість* полягає в розробці та впровадженні програмного забезпечення, створеного на основі зазначених алгоритмів.
Ключові слова: автоматизований комплекс; обробка даних; мікропроцесорна платформа; алгоритм; програмне забезпечення; управління процесами; обмін даними; мікроконтролер.

Conducting tests targeted at confirmation and clarification of operational characteristics of the IR echo-pulse NDT, requires the development of an automated measuring complex that would secure the testing data retrieval, their preprocessing and display in a convenient way for the operator. Moreover, it is necessary to ensure automated control of the laboratory bench used during the tests.

The nowadays stock-list of ready-made measuring devices and individual electronic components makes it possible to create such an automated complex. Notwithstanding, this requires high engineering and technical qualification of developers, and what is more a significant expenditure of material resources and time. Ready-made standard measuring platforms are not enough flexible, but expensive ones. They also require significant space for their placement, and it is often the case that specially trained personnel should be involved.

From our point of view, the Arduino platform most fully meets the above requirements for the electronics platform. Arduino – is an open-source electronics platform based on easy-to-use, possesses multipurposeness and relatively inexpensive compared to its analogues. The open-source software and platform architecture allows transceiving of analog and digital signals, converting of signals using built-in digital-to-analog (DAC) and analog-to-digital (ADC) converters, control various devices and data sharing with a computer using various interfaces. The structure and interface of this platform are described in more detail way.

In terms of IR echo-pulse NDT method development, there were created an experimental device for testing the method and a laboratory bench for non-destructive testing of fiberglass plastics. The laboratory bench consists of a mount with a bracket for fastening the gage head of the device, a moving platform with a Gog-belt type drive from a stepper motor, a control circuit and a control panel. An infra-red source, detector and screen are installed on the bracket, forming the gage head assembly of the device. The study sample is fastened up on the movable platform.

The tasks of the automated measuring complex while testing IR echo-pulse NDT method using a laboratory bench are as follows:

1. Control of the laboratory bench, specifically, ensuring the movement of the test sample along the gage head with an accuracy of no worse than ±0.1 mm, reliable fixation of the moving platform at any time during testing and its return to the initial point, taken as "0" coordinates according to commands from the bench control panel or from a personal computer.
2. Obtaining, processing, storing and transmitting a diagnostic signal from IR echo-pulse NDT to a computer. This task is divided into several stages, namely: reception and conversion of analog signal into a digital one, detection of the average level of the diagnostic signal in order to filter out extraneous noise, saving and transmitting the level of the diagnostic signal with reference to the current coordinate along the length of the test sample, transmitting of the received data packet to a personal computer.

Unfortunately, although the fact that Arduino platform was created about 20 years ago and gained widespread appreciation about 15 years ago, its usage for scientific tests is still limited. Nowadays, this platform is mainly used in the educational process as a simulator of simple processes and systems. Not numerous examples of using the Arduino platform in a scientific test are the exception rather than the rule. So in some articles is proposed the usage of a platform for information receiving and processing from analog sensors, and also for for creating an experimental radiophysical facility. The interface of the Arduino platform is examined. Also, analyzed its capabilities for performing the tasks regarding receiving, processing and transmitting of experimental data. There has been developed a software targeted at easing the connection of the Arduino platform with a personal computer needed for data exchange.

In the tests mentioned above, the Arduino platform was considered only as a converter of an analog signal to a digital signal with subsequent transmission of the latter to a personal computer, or as a signal generator. Meanwhile, the capabilities of the AVR128/328 microcontroller, on the basis of which the Arduino platform is built, are much greater. For example, this platform is able to simultaneously control some actuators and receive information in digital or analog form. The pointed out capabilities of Arduino in the tests listed above are disclosed and not sufficiently implemented.

The purpose of the test is to develop an automated measuring system for gathering and processing experimental data as part of the development of an IR echo-pulse NDT based on the Arduino platform.

In order to solve the above mentioned issues, there were applied methods of observation, comparison, analysis and synthesis, as well as material modeling.

The subject of the test is an automated measuring system for gathering and processing experimental data as part of the development of an IR echo-pulse NDT method.

The object of the study is the Arduino microprocessor platform which is used to control an automated measuring system for gathering and processing experimental data.

Development of a laboratory bench control system based on the Arduino platform.

During laboratory bench control system development, the following requirements were taken into account:

– Possibility of testing material samples of various linear dimensions.

– Automatic shut-down of the moving platform when it reaches the extreme positions in any operating mode of the bench.

– The ability to set the initial point of movement of the moving platform anywhere within the platform movement range, ensuring subsequent automatic return of the platform to the initial point.

– Ability to set the movement speed of the moving platform.

– Assurance of dual control of the bench's operation (using the control panel and primarily from a personal computer).

– Protection against giving incorrect commands to the bench.

There were used a plug-in software module called Stepper (developed by Ryan Orendorff) in order to control the stepper motor. The stepper motor is controlled via transistor switches. In order to limit the movement range of the moving platform, there are used wire-free limit switches (reed switches), which are connected to the digital inputs of the Arduino UNO module. The bench control panel is a keyboard consisting of 8 buttons, which are also connected mainly to the digital inputs of the Arduino UNO module.

The keyboard secures:

– issuing commands to the bench to move the moving platform in two modes ("rough" – at a speed of 50 mm/sec and "precisely" – at a speed of 5 mm/sec);

– issuing a command to save the current coordinates of the moving platform in RAM (setting the conditional "0" coordinates), relative to which the coordinates along the length of the test sample will eventually be measured;

– issuing a command to return the moving platform to the point taken as "0" coordinates;

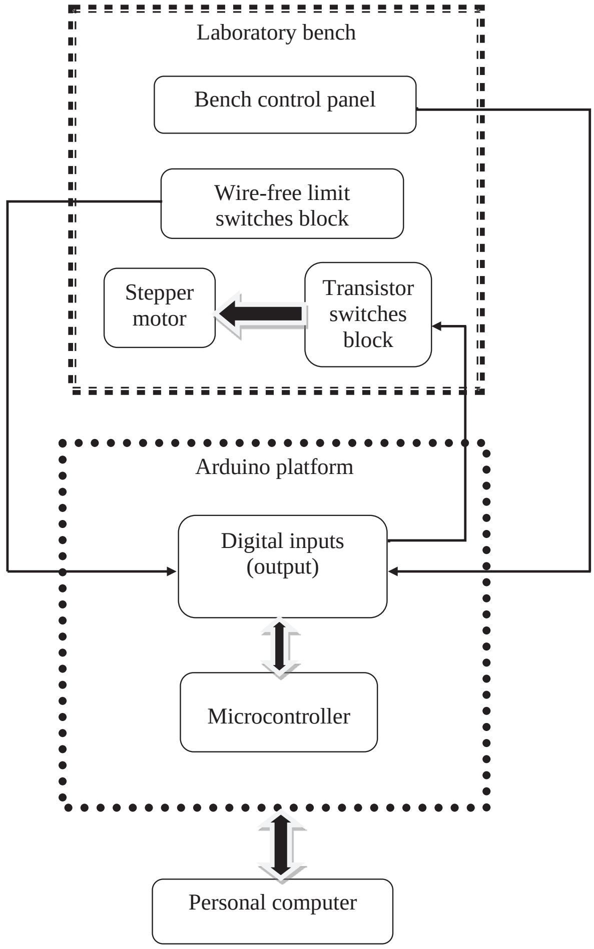

Fig. 1. Block diagram of the laboratory bench control

– issuing a command to the flaw detector to measure the diagnostic parameter "in place" (without moving the moving platform);

– issuing commands to the flaw detector to implement inspection when moving the moving platform ("working pass" mode) in two directions (right and left) according to operator's choice.

To ensure communication with a personal computer, the Arduino IDE parallel port interface is used. With the help of the given interface, it is possible to issue the above mentioned commands to the bench, as well as setting the current length of the test sample. A block diagram of the laboratory bench control is shown in Fig. 1.

Development of a processing and transmitting experimental data system.

A peculiar feature of the created experimental device for testing IR echo-pulse NDT method is the fact that the diagnostic information issued by the device is an analog signal, namely a DC voltage which differs in the range from 0.1 V to 4.9 V. Thereafter, in order to receive and postprocess a diagnostic signal, it is necessary to convert it into digital form. The analog-to-digital converter (ADC) built into the Arduino platform with 10-bit resolution

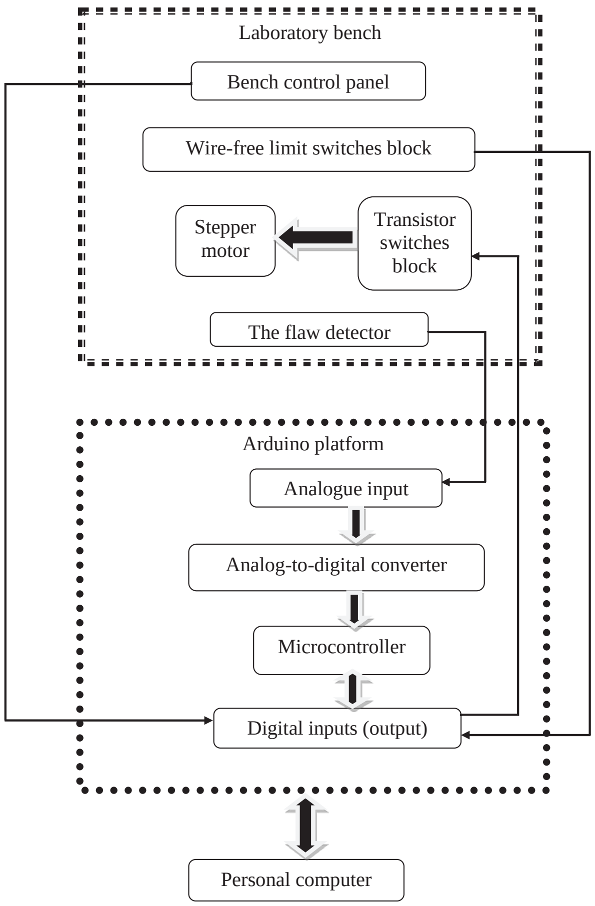

Fig. 2. A block-scheme of a system operation in the processing and transmitting experimental data mode

and a standard sampling rate of analogue input of 500 Hz makes it possible to perform this task with sufficient accuracy.

A block-scheme of the laboratory bench operation together with the Arduino platform in the processing and transmitting experimental data mode is shown in Fig. 2.

The software code needed for receiving, processing and transmitting data is done as an endless loop "loop" of the Arduino sketch.

In order to pre-filter the diagnostic signal, there is carried out a calculation of an average signal value for the last 10 measurements. The obtained values are noted to a dynamic array in the RAM of the Arduino platform, which is then transferred to a personal computer and processed using PLX-DAQ interface. This makes it possible to present diagnostic information in tabular and graphical forms, as well as save a data file.

A cutout of the coded program containing steps for receiving, processing and transmitting experimental data is shown below (Listing 2).

Listing 2

```
else if ((digital Read(WRK) == HIGH) && (digital Read(R) == HIGH)) {
// pressing one button, working shift to the right
cycle0: // cycle of motion and reception of diagnostic information
onlyone (); // calling subprogram in order to detect the pressing of only one button on the remote control
limiters (); // calling subprogram in order to scan limit switches
if (only_one==true && limiters==false) {
my Stepper.step(-1); //stepped motor command
count--; // steps counter update
for (int i = 0; i < 10; i++) {
sig_i = sig_i + analogRead(SIG);} // receiving a signal from an analog input
sr_sig = sig_i / 10; // calculation of the average diagnostic signal level
arr_sig[s] = sr_sig; // record of the average value to a package
if ((s < (step_t_go) && (digital Read(R_f) == LOW))) { // if the pass is not completed, than move the runner block 1 step
s++;
goto cycle0;}}
elseif (s >= (step_t_go)) { // if the pass is completed, output data to the port
s = 0;
Serial.println("CLEARDATA");
Serial.println("LABEL,Point,signal");// command PLX-DAQ start receiving information
int j = 0;
cycle1: // data transfer cycle to the computer parallel port
sig_t_out = arr_sig[j];
Serial.print(j);
Serial.print(" ");
Serial.println(sig_t_out);
if (j <step_t_go) {
j++;
goto cycle1;}
Serial.write("DELAY",CR); // command PLX-DAQ stop receiving information and prepare for the next reception
}}
```

CONCLUSIONS

A significant advantage of using the Arduino platform is also the simplicity of the final equipment assembly. The usage of the Arduino platform while creating an automated measuring complex as part of the research of IR echo-pulse NDT method makes it possible to solve the problems of controlling laboratory equipment and also processing and transmitting experimental data with minimal expenditure of non-human resources and time.

There has been demonstrated the possibility of dual control of laboratory equipment. Also, there has been developed algorithms for equipment control and processing of experimental data, ensuring the necessary accuracy.

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