АВТОМАТИЗОВАНА СИСТЕМА УПРАВЛІННЯ ТЕМПЕРАТУРОЮ КРІОСТАТА

ARDUINO BASED AUTOMATED TEMPERATURE CONTROLLER SYSTEM FOR CRYOSTAT

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Анотація

У статті запропонована автоматизована система управління температурою кріостата для низькотемпературних гальваномагнітних вимірювань (4,2-77-270 К). Автоматизована система працює автономно за допомогою мікроконтролера. Система керування потужністю нагрівача в термостаті здійснюється шляхом широтно-імпульсної модуляції. Автоматизована система управління базується на стандартному обладнанні, тому є доступною для практичного використання.

Ключові слова: кріостат, управління температурою, мікроконтролер.

Abstract

An automated cryostat temperature control system for low-temperature galvanomagnetic measurements has been proposed. The automated system is equipped with microcontroller and operates autonomously. The system for controlling the power of the thermostat heater works in the mode of pulse-width modulation. The automated control system is based on standard equipment. It is available for application.

Keywords: Cryostat, Temperature Control, Microcontroller.

Introduction. Cryostats are widely used for the experimental investigations of the properties of semiconductor materials. Due to the fact that measurements often are carried out manually, often complicated methodology is required to achieve high sensitivity of measurement to control the progress of the experiment and to make a preliminary visual analysis of the results by plotting interactive graphic dependencies. But the main reason depends on the difficulties of setting cryogenic temperatures quickly and precisely. Therefore, there is a need to automate the installation for low-temperature galvanic and magnetic measurements. It can be realized by the means of embedded microcontroller automated system. The last operates autonomously and implements Pulse-width modulation (PWM) algorithm.

The purpose of the article is to create a ARDUINO based control system for the heater power in the thermostat using pulse-width modulation (PWM) technique.

Experimental part. An important feature of an automated experiment is application of a computer systems. Computerized control of experiment, as well as automation of obtaining and processing of information has significant advantages over traditional methods of research. These advantages include the ability to process the big data dimensions, increase the accuracy of measurements, conducting preliminary data processing directly during the experiment, optimizing the time of experimental activity.

There is a wide range of hardware and software automation. One of the main tasks performed by the engineer during the development of automated installation, is the choice of appropriate interface - a set of software and hardware for connection and coordination of the interaction of the computer with measuring and control devices. The main principles of interaction between parts of the automated experimental installation and the role of the interface flowchart are shown in [1].

Automated systems. Such systems are implemented to automate various physical experiments. These systems are called „Automated Control Systems" (ACS), including the control system of technological processes (ACS-TP). Electronic computing technology is widely used in such systems [2].

The equipment needed to create an automated experimental installation may contain (or may not contain) different input / output systems. So it is important to solve the tasks of connection, interaction and operation of the PC and devices with incompatible interfaces. It can lead to refinement of equipment and development of a single standard of software. It defines the main facilities and cost of developed installations.

Structure of the automated system. The main elements of the ACS are: the object of control; measuring probe or sensor; control element; performing element. Measuring probe or sensor detects changes in the output (regulated) value of the object and in many cases converts it into the other values. In some ACSs, the sensitive element controls the external influences and perturbations that interact with the object. There are active resistance detectors, as well as sensors of voltage, current, speed, pressure, force moment, etc. The control element receives information from the sensitive element and generates the appropriate signal for the performing element. Often it also performs the functions of the amplifier. The main types of amplifiers are semiconductor, electric, magnetic and electronic. The most common of non-electric types are hydraulic and pneumatic amplifiers. In this project the Power MOSFET transistor performing switching functions for the heater control.

In order to automate the installation, all devices that are used in the experiment should be connected to computer or microcontroller. This can be done through a variety of interfaces: the point-to-point interface, the current loop interface, the RS-232 (UART), the SPI, the parallel interface, the wireless interface, the I2C interface, the RS-485 interface, the USB interface, etc;

Embedded systems. The embedded system is a real-time microprocessor control system. The advantages of embedded systems, compared with general purpose computer based system, are low power consumption, small dimensions and low cost. Modern built-in systems are mainly designed on microcontrollers [3].

Block diagram of automated installation. The designed block diagram for the automated installation for functional purpose consists of the following main units: cryostat with built-in heater, thermocouple, thermocouple operational amplifier, microcontroller, control interface (Fig. 1).

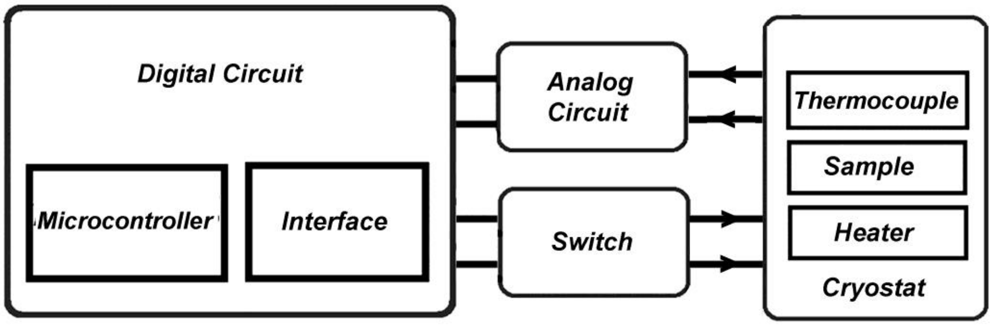

Fig. 1. Block diagram of automated installation

Features of experiments with cryogenic temperatures. Investigations of the properties of semiconductor materials typically require a cryogenic temperatures. A copper-constantan thermocouple is used for the temperature range of 77-270 K and a Germanium thermoresistor TPK-8.1 for the temperature range of 4.2-77 K accordingly. The schematic section of the installation for conducting of the cryogenic temperature measurements is presented on (Fig. 2).

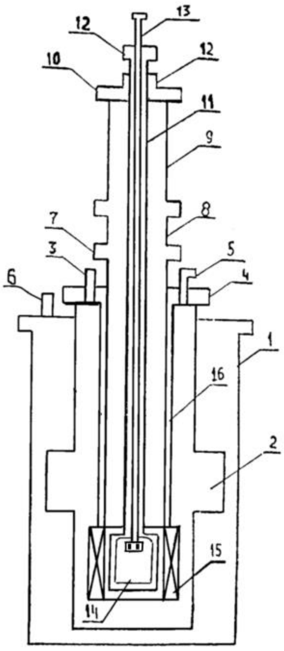

Fig. 2. Design of the cryostat: 1 - helium cryostat; 2 - volume for liquid helium; 3, 6 - the inlet pipes; 4, 7, 10 - flanges; 5 - outlet pipe; 8 - vacuum valve; 9 - gateway, 11 - holder; 12 - clamping device;13 - push-type actuator; 14- cryostat and sample; 15 - heater

Since the temperature dependence of the resistivity in the Germanium temperature-sensor is nonlinear, an appropriate correction is realized by controller program. For quick and precise setting of the temperature in the cryostat pulse-width modulation (PWM) is applied. It makes it possible to control the power supplied to the heater.

The circuit control uses change of the pulse duration at a constant pulse frequency.

The schematic diagram of the thermostat consists of digital and analog parts (Fig. 3).

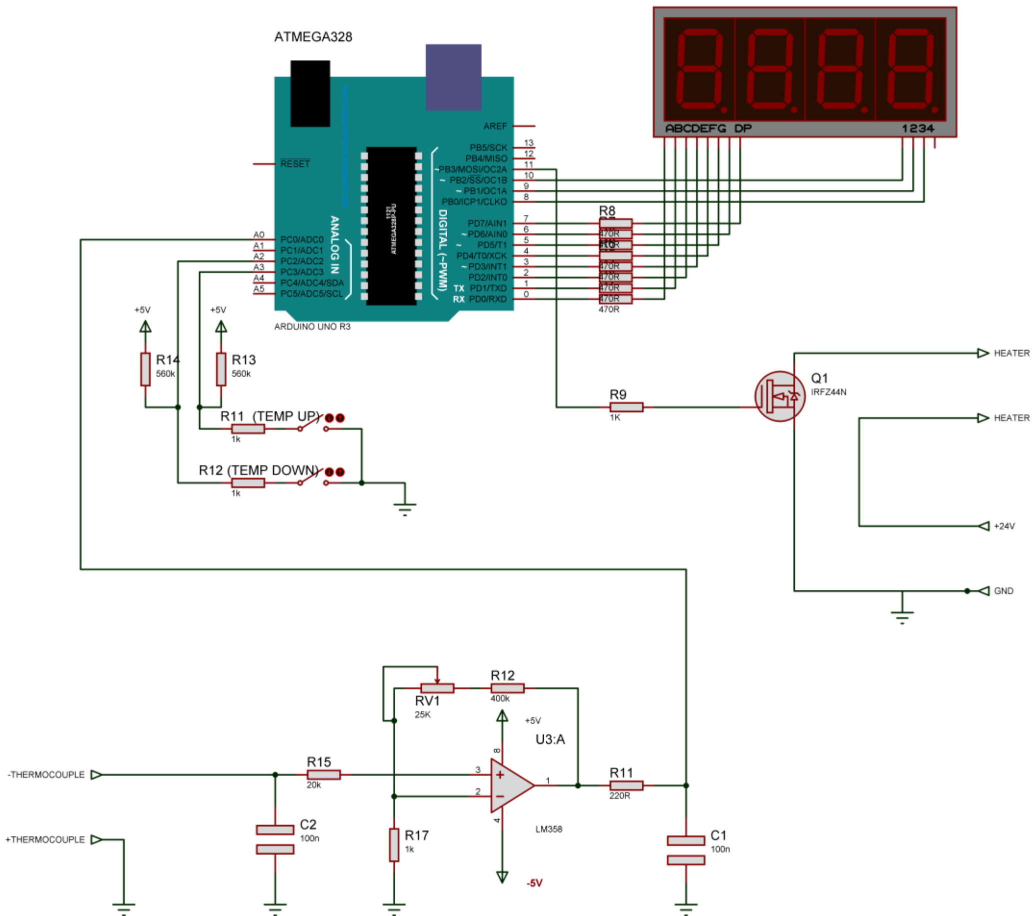

Fig. 3. Electronic diagram of the thermostat heater controller

Digital circuit. The digital circuit is based on the Arduino microcontroller (ATMega328) (Fig. 4). This control system is quite easy to realize, modify, connect external ADCs and allows to use different types of displays. The digital correction of the nonlinear dependency of the measuring sensor is performed by program. There is also a software option for calibration of the upper and lower bounds of measurements.

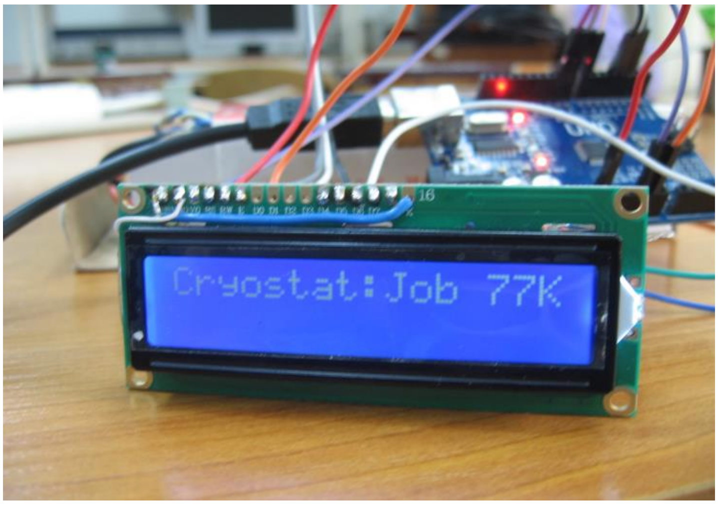

Fig. 4. Photo of digital part

The algorithm of functioning. Width-pulse modulation. First, the power is applied to the heater (Duty cycle 80%), when the temperature approaches to specified temperature point, the supplied power decreases (Duty cycle 30-40%). At last with the minimum deviation between the measured and the set temperature, the minimum power is supplied (Duty cycle 15-20%) (Fig. 5). In such case thermal inertia of the system can be significantly reduced.

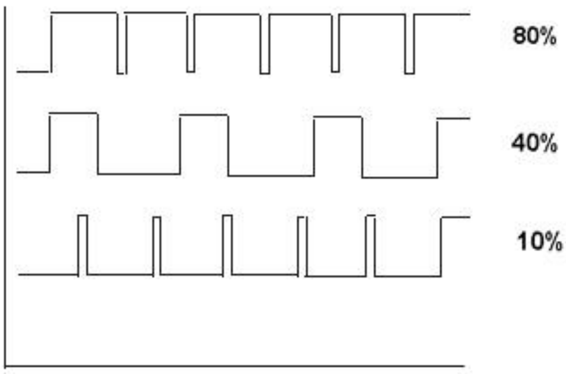

Fig. 5. Width-pulse modulation

Analogue circuit consist of the amplifier for a thermocouple, created on the basis of an operational amplifier [4, 5]. In the simple case, when the high accuracy of measurements is not required, the inexpensive LM358 amplifier is used. The circuit can also be applied to measure temperatures in the range 273 -300 K. In this case, the controller sends a control signal to change the polarity of the thermocouple.

Conclusion. Technology of efficient automatic temperature maintenance in a cryostat with the use of a ARDUINO board is suggested. The implementation of pulse-width modulation allows to significantly reduce temperature hysteresis, and to increase the accuracy of maintaining the temperature to ± 1°. The system contains available electronic components and is quite easy to reproduce.

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