Specialized computer system for controlling microclimate through recuperation

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Abstract – The paper considers hardware and software of specialized computer system for controlling microclimate through recuperation.

Key words – Microprocessor, recuperation, microclimate, heat exchange, control system, software, hardware.

I. Introduction

Modern systems of inflow and exhaust ventilation are based on the principle of heat recovery - the return of heat energy from the exhaust air. The warm air coming out of the room, heats up the cold air coming from outside. Regeneration of heat is carried out in recovery heat exchangers - plate or rotary [1]. The effectiveness of the exchange process is expressed as a percentage and shows the amount of heat expended from the exhaust air to heat the fresh air flow. Typically, the efficiency of the recovery heat transfer is within the range of 60-90%, and depends on the difference in temperature between the room and the outside, with the greater the temperature difference, the lower is the efficiency [2]. Structurally, they consist of two modules: the first - the recuperator, along with the sensors and actuators, and the second - the control system. The general disadvantage of modern recuperators is that they do not provide additional heating of the tidal air in winter, and cooling - in the summer at a large temperature difference and, thus, do not allow to maintain the microclimate in the room within the specified limits. In this situation, in addition to the recuperators used, for example, air conditioners. In addition, the control systems of the recuperator often require to input or adjust additional information regarding operating modes, for example, the coefficients of PID regulators, which complicates the operation of users with the recuperator and requires special knowledge [3].

So, the aim of this work is to expand the functionality of the recuperators with the intellectual control of all heat transfer processes.

II. Controlling microclimate system: hardware

The basis of the system construction is a plate heat exchanger of the recuperator, as the most massive, with a thermal pump and with a control system based on a single-chip embedded computer system based on the RISC processor [4]. In addition, temperature sensors have been used to measure temperature using a digital serial interface, which allowed the sensor outputs to be combined with one line of communication, and as a result reduce the total number of lines of the communication channel between the control panel and the actuators of the system.

As a single-chip embedded computer system, I decided to opt the Arduino Mega 2560 microcontroller based on the AtMega processor, which fully satisfies the resources needed to implement this system [5]. One of the advantages of this microcontroller over others is the price, ease of programming, debugging and ease of use. Also, this microcontroller differs from others, such as Raspberry Pi, so that my choice allows you to fully control the system: there are plenty of pins that will not require the use of additional expanders to which all devices can be connected, also a large set of interfaces is available, through which these devices interact.

To implement the control system, an LCD was used to display all the necessary information for the user, namely: the current room temperature, date and time. A matrix keypad was added to the control system. It allows to set the user the current temperature, engine speed and various system settings and modify them.

The real-time clock was connected using the I^2C protocol [6]. Because after a certain period of time the clock begins to give an error, it was added the ability to re-configure it directly from the control system.

The microcontroller controls the system using a two-channel relay with switching voltage supply. This relay allows separately to include two nodes of the system: compressor and valve, which switches the mode of "heating-cooling".

The speed of the motors is regulated by pulse-width modulation using the PID controller [7]. Having set the correct coefficients allows you to fine-tune the speed of the engines to increase the life of their work. After all, when the temperature difference is small, there is no need to include engines at maximum speed.

The system has three operating modes: heating, cooling and air conditioning. Switching between these modes is based on temperature measurements from sensors. The system has four temperature sensors connected using the 1-Wire protocol [8]. This protocol allows you to connect all sensors to one port.

The block diagram of the device is shown in Fig.1.

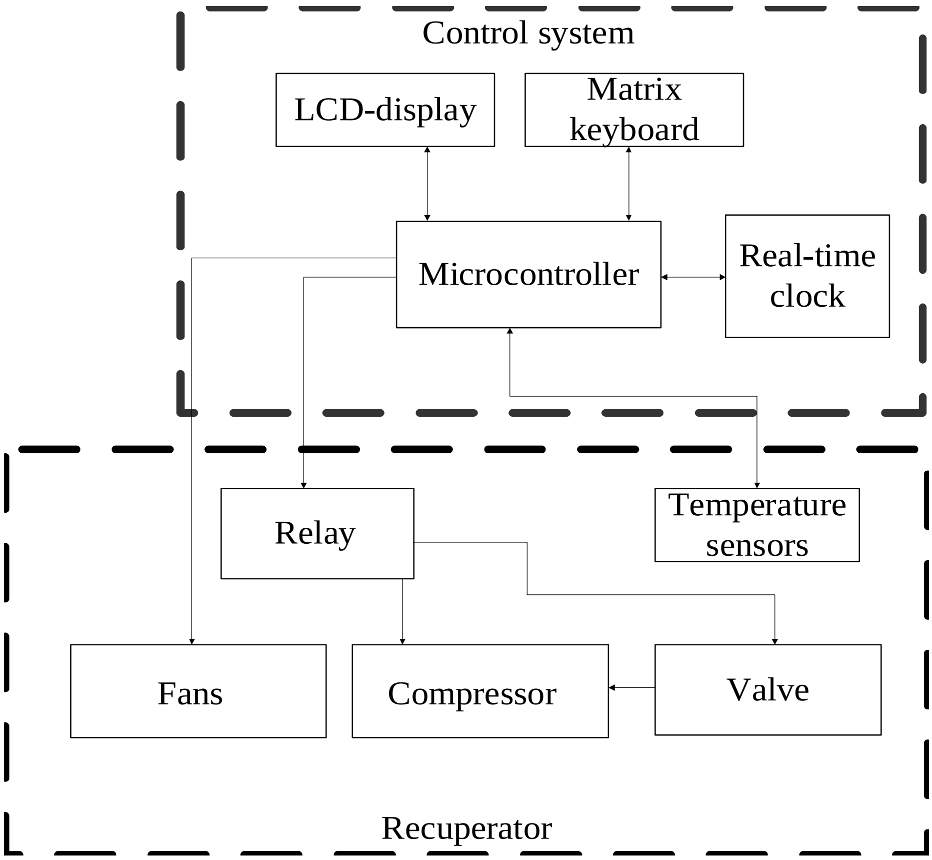

Fig. 1. The block diagram of the device.

III. Controlling microclimate system: software

Considering that the control system is implemented on the basis of the RISC processor, namely the microcontroller Arduino Mega 2560 on the basis of the ATmega processor, the programming language C was used.

The main software modules include:

- sensors reader module;
- RTC module;
- display module;
- keyboard operation module;
- system control module;
- PWM module;
- security module.

Sensors reading module includes a library for working with the 1-Wire protocol. The system has four temperature sensors that measure indoor temperature, input air temperature, air temperature after passive heat exchanger passage and air temperature at passive heat exchanger to prevent it from icing. The active sensor is selected using a unique MAC address.

RTC module includes a library for working with the I2C protocol. Also added ability to edit the date and time using control system.

The display module includes a library for working with liquid crystal displays. Keyboard operation module includes a library for working with a 4x4 matrix keyboard.

The security module includes protection against unauthorized access to the system with a password.

The system control module contains the basic algorithm for operating the system. It selects between three modes of operation (heating, cooling and air conditioning), and also controls the operation of the main hardware nodes.

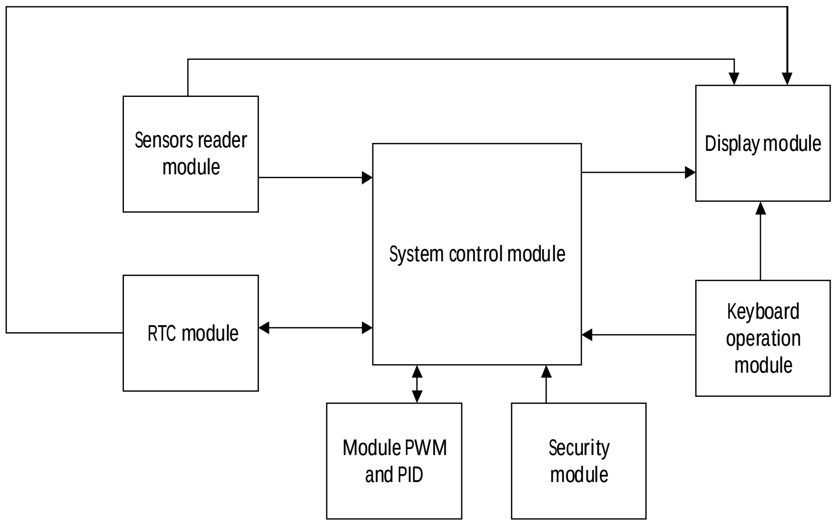

Fig.2. The block diagram of the software.

The block diagram of the software is shown in Fig.2.

The algorithm of the program includes the following steps. After turning on the system, it waits for the user to enter the desired temperature T_{inp}. After this, the system measures the temperature in the room T_1. Then there is a T_1 comparison with T_{inp}. If $T_1 > T_{inp}$, then the cooling mode is activated. If $T_1 < T_{inp}$, then the heating mode is activated. And if $T_1 = T_{inp}$, then the mode of conditioning is activated. After that engines are switched on. The next stage is the measurement of the air temperature after passage of the passive heat exchanger T_2. If T_2 is not equal to T_{inp}, then the compressor is switched on. After that the system operates in the set mode until the T_{inp} temperature is changed by user. The algorithm of the program is shown in Fig. 3.

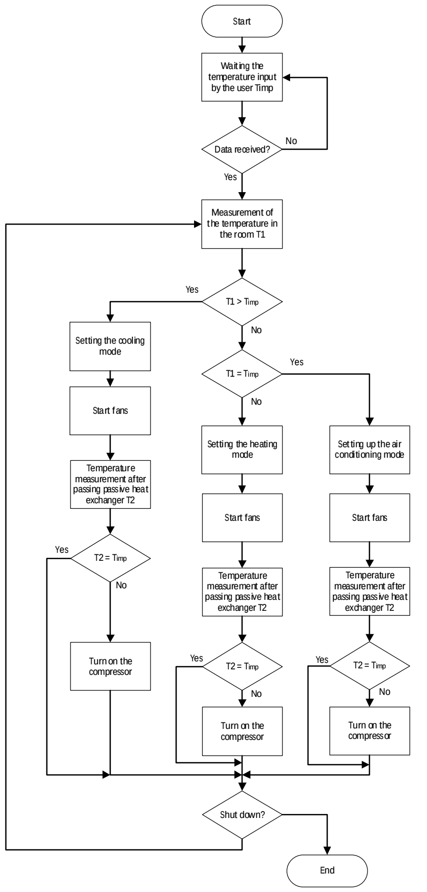

Fig.3. Algorithm of the program.

IV. Research

Research was conducted to determine the most effective way to control engine speeds depending on temperature. Three methods of control were investigated: without the use of PWM (pulse width modulation), using PWM and using PWM in conjunction with the PID regulator (proportional – integral – derivative controller). According to the results of research, the third method of management was chosen. Using PWM with the PID allows you to control engine speeds with minimal variations and thereby smoothly maintain the required indoor temperature. The range of temperature fluctuations depending on the way the engine is driven is shown in Fig. 4.

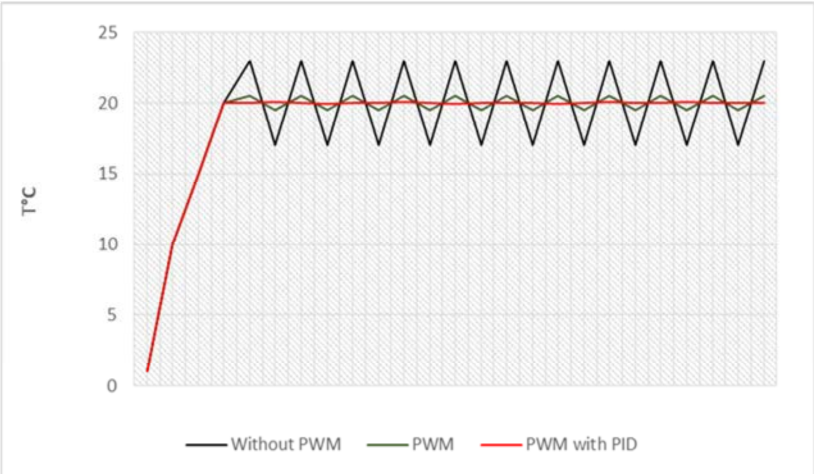

Fig.4. Range of temperature fluctuations depending on the way the engine is driven.

Fig. 5. shows the temperature chart in the channels heat exchanger. At the beginning of the system, the air temperature in all channels of the recuperator is equal to the room. From the graph, we can conclude that the time of recovery of the recuperator to the stationary mode of operation is about 40 minutes. Thus, the experimental data confirm expediency study characteristics of the recuperator in the stationary Considering, since the transition period in the recuperator takes time, insignificant in comparison with the periodicity of external changes conditions.

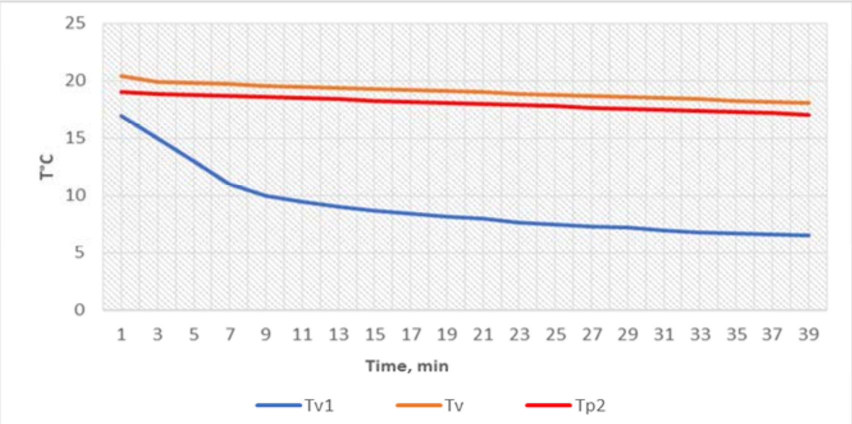

Fig. 5. Temperature change from time to time

T_{v1} - is the temperature of the air being removed, T_v - is the temperature of the room indoors, T_{p2} - is the temperature of the inflow air after recuperation.

Experimental investigations of the developed model of the control system of the recuperator with the productivity of 300 m^3/h have been carried out. The efficiency of the operation and the possibility of further modification are shown.

Conclusions

Thus, the developed system build on Arduino Mega 2560 microcontroller based on the AtMega processor, showed the efficiency of controlling the working recuperator with the ability to expand the functionality of the system without significant hardware changes. Also, the developed software allows to quickly and efficiently manage the work of the entire system and effectively perform tasks for the intelligent application of the system. It is implemented in a programming language C using additional libraries to work with various system modules.

References

[1] Recuperator [Online]. Available: https://en.wikipedia.org/wiki/Recuperator

[2] Heat Recovery Efficiency [Online]. Available: https://www.engineeringtoolbox.com/heat-recovery-efficiency-d_201.html

[3] PID Theory Explained [Online]. Available: http://www.ni.com/white-paper/3782/en/

[4] Sivarama P. Dandamudi (2005). "Guide to RISC Processorsfor Programmers and Engineers". [Online]. Available: https://epdf.tips/guide-to-risc-processors-for-programmers-and-engineers.html

[5] Arduino Mega 2560 Rev3 [Online]. Available: https://store.arduino.cc/arduino-mega-2560-rev3

[6] I^2C-bus specification and user manual [Online]. Available: https://www.nxp.com/docs/en/user-guide/UM10204.pdf

[7] Pulse Width Modulation [Online]. Available: https://learn.sparkfun.com/tutorials/pulse-width-modulation/all

[8] Overview of 1-Wire Technology and Its Use [Online]. Available: https://www.maximintegrated.com/en/app-notes/index.mvp/id/1796