Hardware and software complex for modeling the modes of operation of an intelligent climate chamber in conditions of maintaining an optimal microclimate

N.I. Lebed* and *K.E.* Tokarev

Volgograd State Agricultural University, 26, Universitetskiy ave., Volgograd, 400002, Russia

Abstract. In the course of research on improving the methods of increasing the productivity of agrocenoses, a multi-sectional climate chamber for growing plants is being developed, which allows implementing various combinations of microclimate inside independent sections. An intelligent control system for thermoregulation, air humidity, ventilation and maintenance of biological purity has been developed, as well as tools for an automation system based on a software and hardware complex have been implemented.

1 Introduction

The use of computerized models to optimize the operating parameters of agricultural production makes it possible to effectively select microclimate indicators for agrotechnological and biotechnological methods of growing plants. This approach provides for conducting experiments in multiple repetitions on different versions of experiments on several selected factors with three levels of variation.

At the same time, the implementation of this approach is complicated due to the lack of the possibility of creating a microclimate with different parameters within the same climate chamber, forcing the use of several identical modules in parallel, which inevitably leads to an increase in both capital and operating costs (including due to forced downtime during the transition to other products), and accordingly, the increase in the cost of the final product. As can be seen, the stated disadvantage, in general, makes it difficult to use modern climate chambers within a structural unit with several diverse areas of research. In addition, the disadvantage is also relevant at manufacturing enterprises of various capacities, for example, obtaining environmentally friendly plants for food production when growing several groups of plants requires the creation of different soil and climatic conditions, which is difficult with the use of modern cameras. It follows from this that the existing foreign and domestic climate chambers need deep modernization and are not without drawbacks, which limits their use for research purposes [1].

2 Materials and methods

A multi-section climate chamber for growing plants, previously developed by the authors, was chosen as the object of research. The device included two sections independent of each other, in which various microclimate parameters could be implemented: heat-cold, air humidity, brightness and spectrum of illumination, parameters of disinfection and ventilation of air. In the first approximation, closed logic controllers (heat-cold, humidity) and time relays (ventilation, air disinfection) were used to control the microclimate system. Figure 1 shows the control system for thermoregulation, humidification, ventilation and lighting of the climate chamber, as well as the general layout of some of the system's actuators.

This device provided the necessary studies in a controlled microclimate with flexible settings for each controlled zone, which will significantly reduce the time spent on finding optimal microclimatic conditions for each specific sample.

Processing of incoming air by means of an air purification module in combination with complete isolation of the controlled zones from each other and from the external environment will create the necessary microclimate conditions in the plant growing area and achieve a high level of biological purity. The use of a carbon filter and an air ozonation unit will allow converting ozone entering into controlled plant growing areas into oxygen decontaminated from phytopathogenic microflora [2–5].

* Corresponding author: tke.vgsha@mail.ru

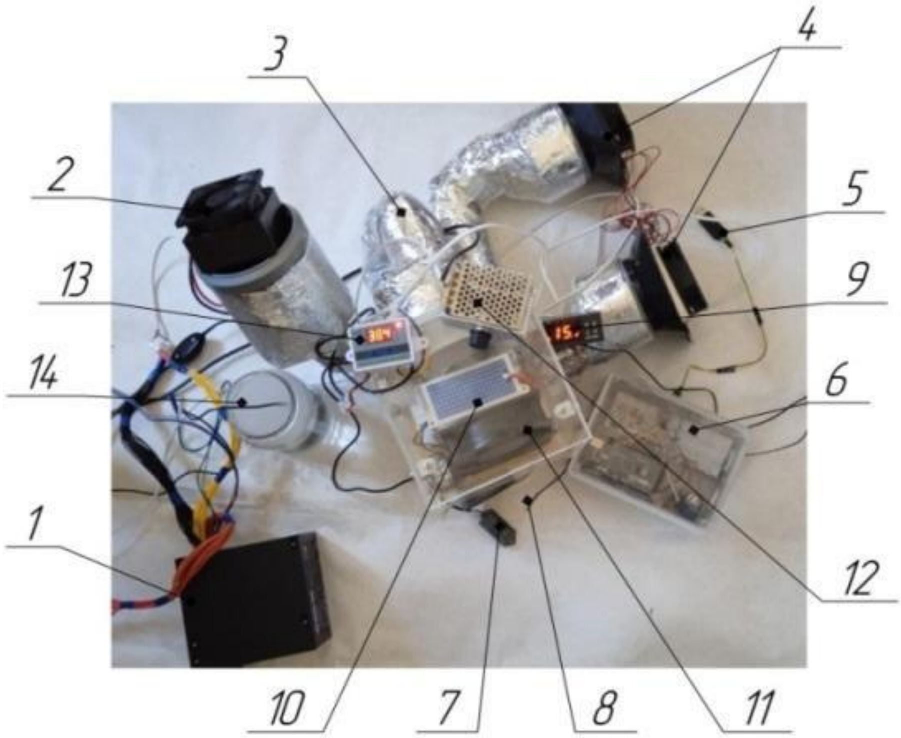

Fig. 1. Control system for thermoregulation, humidification, ventilation and maintenance of biological purity (1 – power supply unit (AC/DC converter), 2 – air heating actuator, 3 – tubular housing, 4 – air cooling actuator, 5 – RS–485 communication interface (USB to RS-485 Converter), 6 - control unit based on ATmega2560 microcontroller (used in the circuit for lighting control), 7 – DHT-11 humidity sensor, 8 – NTC temperature sensor, 9 – display+thermoregulation controller, 10 – unit for creating and maintaining biological purity conditions, 11 – ventilation actuator, 12 – PWM ozonation controller, 13 – display+humidification controller, 14 – liquid evaporation tank) [6]

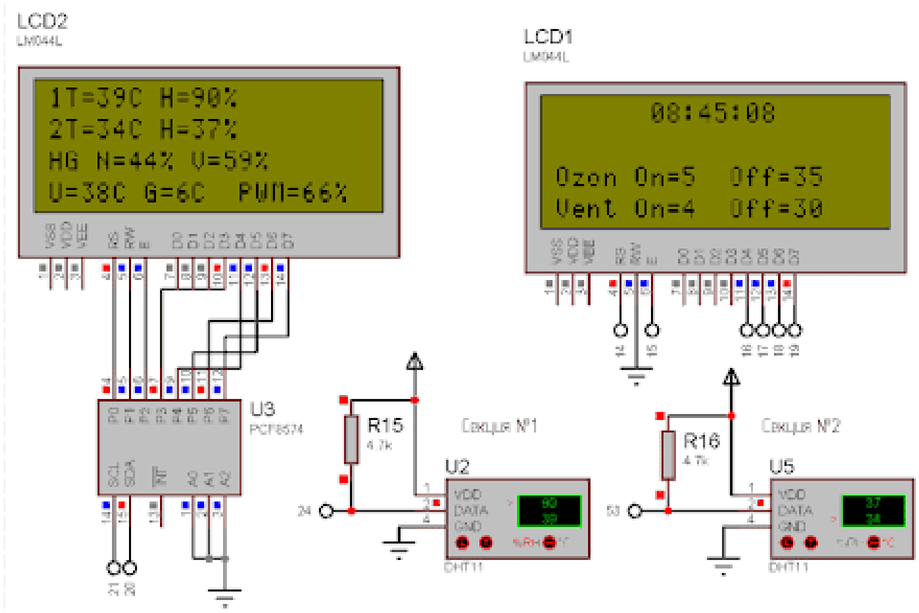

Fig. 2. Display LCD-2004 and temperature/humidity sensor DHT-11

3 Results

To control the powerful load of the automation circuit, the corresponding elements are used: solid-state and electromechanical relays, power switches (transistors), etc. The proposed relay-transistor circuit will allow controlling in automatic mode both the load on/off the actuating elements (humidification, ventilation, air disinfection) and in power regulation by power switches according to the type of signal correction (thermoregulation) [7–12].

Setting the settings for thermoregulation and regulation of air humidity was carried out by recording the lower and upper threshold values of the controlled values, as well as for triggering by time: ventilation, air

https://doi.org/10.1051/bioconf/202410300004

disinfection by trigger on and off using the real-time clock module. In addition, forced activation is implemented for ventilation and air disinfection, regardless of the response time.

The climatic parameters on each section of the chamber were read using DHT-11 temperature and humidity sensors. Data transmission from sensors and data display were displayed on two LCD 2004 displays (Figure 2)[13–17].

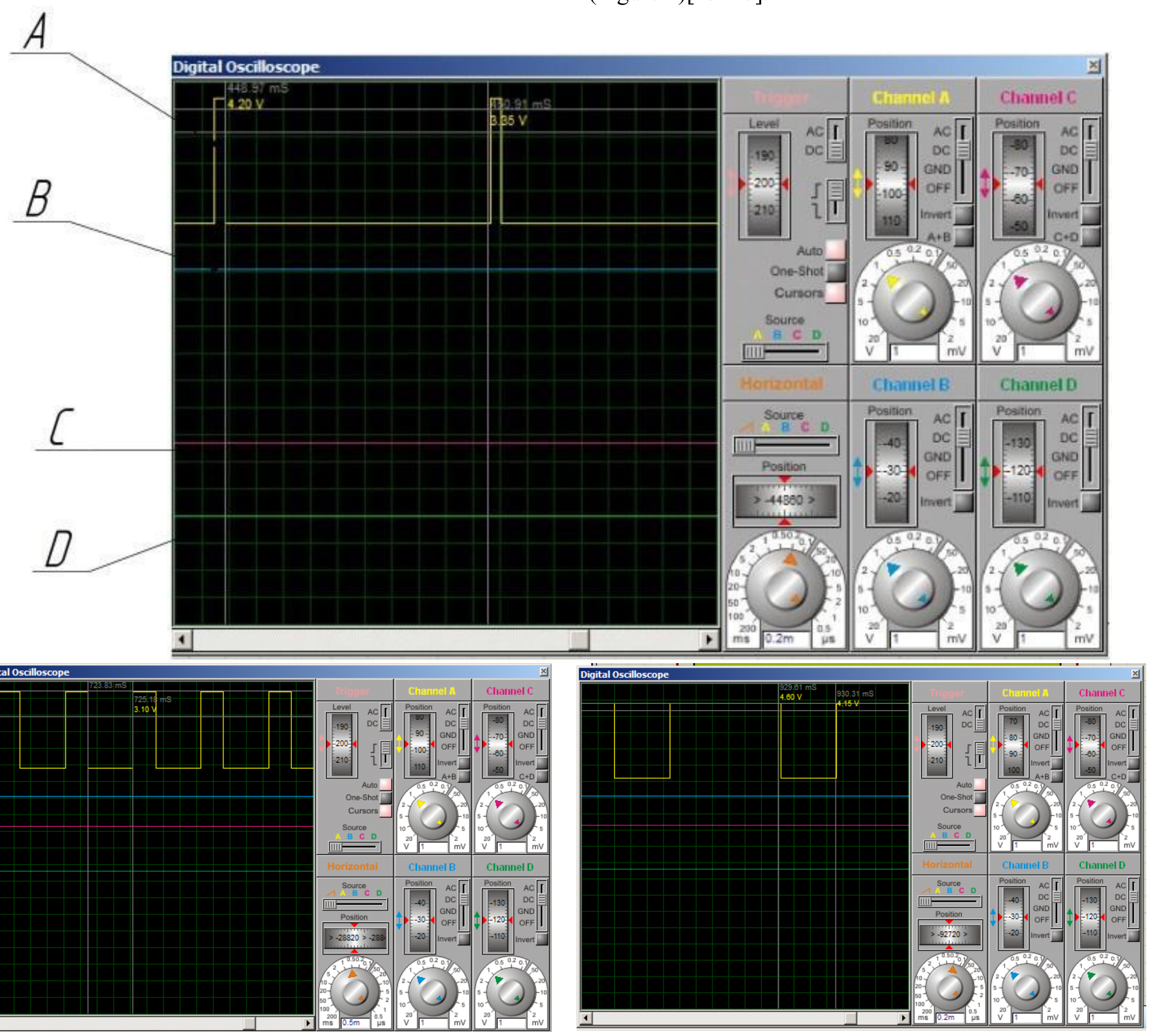

Fig. 3. Waveforms obtained by modeling the control system, channels A, B, C, D at various operating modes of the microclimate system (B, C, D included – "logical unit" mode

Figure 3 shows an oscillogram obtained from a Digital oscilloscope (Figure 3) for four channels: A – thermoregulation, B – humidification, C – air disinfection, D – air ventilation [18–21].

4 Conclusion

The use of the proposed multi-sectional climate chamber for growing plants allows you to realize several different combinations of climatic factors inside yourself at the same time (temperature, spectrum and intensity of illumination, the level of concentration of residual ozone, the level of filtration and infiltration of air, etc.), which makes it indispensable when modeling biological systems and in production, where due to one piece of equipment it is possible to ensure the simultaneous release of diverse biological products [22].

The proposed sectional chamber for growing plants provides a wide range of climatic conditions, as well as their combinations within one device, the manufacturability of their implementation when growing crops in a climatic chamber and can be easily implemented in agricultural production during plant breeding and for other purposes [23].

Acknowledgements

The article is prepared with the financial support of the Russian Science Foundation, project № 22-21-20041

References

1. K.E. Tokarev, N.I. Lebed, V.A. Kuzmin, A.N. Chernyavsky, Theory and technologies of crop irrigation management based on information technologies of decision support and mathematical modeling, *Science and higher professional education*, Proc. of the Nizhnevolzhsky agrouniversitetskiy complex **4(60)**, 433–448 (2020)
2. N.I. Lebed, I.V. Volkov, M.B. Lebed, Ya. Kalinin, V Multisection climate chamber for accelerated production of cultivated plants under controlled parameters, Izv. VolgSTU **3(250)**, 66–68 (2021)
3. U. Sommer, *Programming Arduino/Freeduino microcontroller boards* (BHV Petersburg, St. Petersburg, 2012), 256 p.
4. I.I. Borisov, S.A. Kolyubin, Simulation modeling of mechatronic systems, *Educational and methodological manual* (ITMO Univ., St. Petersburg, 2020), 103 p.
5. I.A. Elizarov, Yu.F. Martemyanov, A.G. Skhirtladze, *Technical means of automation. Software and hardware complexes and controllers*, Educational and methodological manual (Publ. house: LLC "Thin science-intensive technologies", Stary Oskol, 2021), 236 p.
6. A.E. Balanovskiy, M.G. Shtaiger, V.V. Kondratyev, A.I. Karlina, Determination of rail steel structural elements via the method of atomic force microscopy, CIS Iron and Steel Rev. **23**, 86–91 (2022)
7. D. Podoprigora, R. Byazrov, J. Sytnik, The Comprehensive Overview of Large-Volume Surfactant Slugs Injection for Enhancing Oil Recovery: Status and the Outlook, Energies **15**, 8300 (2022), Retrieved from: https://doi.org/10.3390/en15218300
8. E.F. Denisov, M.Z. Yamilev, E.A. Tigulev, V.V. Pshenin, Analysis of the current level of technologies for determining the location of non-metallic underground services, Oil Industry, **2022(9)**, 121–125 (2022), DOI: 10.24887/0028-2448-2022-9-121-125
9. V.V. Kondrat'ev, V.O. Gorovoy, A.D. Kolosov, R.V. Kononenko, V.Y. Konyukhov, Description of the complex of technical means of an automated control system for the technological process of thermal vortex enrichment, J. of Phys.: Conf. Ser. **1661(1)**, 012101 (2020)
10. S.V. Klyuev, N.F. Kashapov, O.V. Radaykin, L.S. Sabitov, A.V. Klyuev, N.A. Shchekina, Reliability coefficient for fibreconcrete material, Construct. Mater. and Prod. **5(2)**, 51–58 (2022), Retrieved from: https://doi.org/10.58224/2618-7183-2022-5-2-51-58
11. I.G. Vidayev, N.V. Martyushev, A.S. Ivashutenko, A.M. Bogdan, The resource efficiency assessment technique for the foundry production, Adv. Mater. Res. **880**, 141–145 (2014), DOI: 10.4028/www.scientific.net/AMR.880.141
12. E. Volneikina, O. Kukartseva, A. Menshenin, V. Tynchenko, K. Degtyareva, Simulation-Dynamic Modeling Of Supply Chains Based On Big Data, *INFOTEH-JAHORINA, INFOTEH 2023*, 22nd Int. Symp. (2023), D
13. V.L. Tatarintsev, L.M. Tatarintsev, S.K. Makenova, M.M. Shostak, Geoecological assessment of landscapes as the basis for organizing sustainable agricultural land use, Sustainable developm. of mountain territ. **13(4)**, 485–497 (2021), DOI: 10.21177/1998-4502-2021-13-4-485-496OI: 10.1109/INFOTEH57020.2023.10094168
14. I.A. Sysoev, V.A. Ershov, V.V. Kondrat'ev, Method of Controlling the Energy Balance of Electrolytic Cells for Aluminum Production, Metallurgist **59(5–6)**, 518–525 (2015), Retrieved from: https://doi.org/10.1007/s11015-015-0134-1
15. Shutaleva, N. Martyushev, Z. Nikonova, I. Savchenko, S. Abramova, V. Lubimova, A. Novgorodtseva, Environmental Behavior of Youth and Sustainable Development, Sustain. **14**, 250 (2022), DOI: 10.3390/su14010250
16. N.V. Martyushev, D.A. Bublik, V.V. Kukartsev, V.S. Tynchenko, R.V. Klyuev, Y.A. Tynchenko, Y.I. Karlina, Provision of Rational Parameters for the Turning Mode of Small-Sized Parts Made of the 29 NK Alloy and Beryllium Bronze for Subsequent Thermal Pulse Deburring, Mater. **16**, 3490 (2023), DOI: 10.3390/ma16093490
17. B.V. Malozyomov, N.V. Martyushev, V.Y. Konyukhov, T.A. Oparina, N.A. Zagorodnii, E.A. Efremenkov, M. Qi, Mathematical Analysis of the Reliability of Modern Trolleybuses and Electric Buses, Mathem. **11**, 3260 (2023), DOI: 10.3390/math11153260
18. B.V. Malozyomov, N.V. Martyushev, S.N. Sorokova, E.A. Efremenkov, D.V. Valuev, M. Qi, Mathematical Modelling of Traction Equipment Parameters of Electric Cargo Trucks, Mathem. **12**, 577 (2024), DOI: 10.3390/math12040577
19. A.A. Korshak, V.V. Pshenin, Calculation of phase transitions in condensation units for recovery of oil and oil products vapors, Oil Industry **2021(6)**, 98–101 (2021), DOI: 10.24887/0028-2448-2021-6-98-101
20. A.M. Shagiakhmetov, S. Yushchenko, Substantiation of In Situ Water Shut-Off Technology in Carbonate Oil Reservoirs, Energies **15**, 1–13 (2022), Retrieved from: https://doi.org/10.3390/en15145059
21. G. Zakirova, V. Pshenin, R. Tashbulatov, L. Rozanova, Modern Bitumen Oil Mixture Models in Ashalchinsky Field with Low-Viscosity Solvent at Various Temperatures and Solvent Concentrations, Energies **16(1)** (2023), DOI: 10.3390/en16010395
22. G.Y. Korobov, A.A. Vorontsov, G.Y. Korobov, D.V. Parfenov, T.N. Van, Mechanisms of the

formation of asphalt-resin and paraffin deposits and factors influencing their intensity, Bull. of the Tomsk Polytech. Univ. Geo Assets Eng. **334(4)**, 103–116 (2023), Retrieved from: https://doi.org/10.18799/24131830/2023/4/3940

23. I.B. Ardashkin, A.N. Yakovlev, N.V. Martyushev, Evaluation of the resource efficiency of foundry technologies: Methodological aspect, Adv. Mater. Res. **1040**, 912–916 (2014), DOI: 10.4028/www.scientific.net/AMR.1040.912