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Development and research of portable USB-moisture meter to crop seeds humidity.

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ABSTRACT

The article summarizes the result of research and development work about the portable USB-moisture meter to crops seed humidity, shows the principal electrical circuit of the device and an algorithm for temperature correction when performing measurements.
Keywords: dielectric metric method; capacitive sensor; measuring transducer; USB-moisture meter.

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INTRODUCTION

One of the most common qualitative indicators of seeds of crops is moisture since it determines a large number of important characteristics, such as ripeness, a quantitative fraction of nutrients, cost, class, storage, processing, consumption, etc. The presence of excess free, capillary -combined, adsorbed or chemically bound moisture in agricultural materials, promotes the acceleration of unfavorable physicochemical and physiological x processes leading to unjustified losses of seeds in the mass, their grinding, and development of harmful microorganisms.

To eliminate these processes, constant moisture control is necessary at all stages of agricultural production, from a collection of crops to the production of finished products. At the same time, the accuracy and speed of a single measurement are the main criteria characterizing the profitability of a particular method of humidity control. To date, dozens of different methods of determining moisture are being studied, known and used, which are generally divided into direct and indirect.

Analysis of electrical methods for determining moisture shows that the most demanded and promising is the dielectric method based on measuring the dielectric constant of the material being monitored. Since the permittivity of dry matter is relatively small (εpr≈ 1.0-8.0), and the dielectric constant of water ε of water is in turn much larger (εp of water ≈ 81.0), even with insignificant change in the water content in the substance there is a very perceptible change in its permeability, which makes it possible to determine the moisture content of the material under study with a sufficiently high accuracy [1-4].

As the primary measuring transducer (PIP) in this method, flat or cylindrical capacitor sensors are used that are compact enough, easy to manufacture and operate. Various designs of such sensors are actively used in modern devices for express moisture measurement, for example, Wile 65 (55, 45) manufactured by Farmcomp (Finland), Fauna-M manufactured by LLC Lepta (Russia), Multi-Grain produced by DICKEY -john »(USA), HE-50 manufactured by« Pfeuffer »(Germany), etc., which have proved themselves well in the market.

However, following the trends in the development of modern measurement technology, the devices and their analogues have a significant disadvantage associated with the lack of connectivity and transmission of information and measurement functions to the computer. Connecting to a computer allows you to take advantage of information technology, such as simplifying the hardware of the device, the possibility of continuous improvement of the software, the organization of databases and their cataloging, network and local capabilities, and much more.

To date, the most common serial interface for connecting peripherals is the Universal Serial Bus (Universal Serial Bus or USB), which is present in the vast majority of computer technology. This interface has broad capabilities for receiving and transmitting information, easy to connect and operate, has high noise immunity and is able to withstand complex climatic conditions. Continuous improvement, unification and support for the USB interface indicate the promise of its use in portable moisture detection devices.

MATERIALS AND METHODS

Based on the above, a portable USB hygrometer was developed and examined, the general view of which is shown in Fig. 1.

The presented USB moisture meter consists of two separate cameras: the first camera is a capacitive coaxial sensor in which the culture is placed, the second chamber contains a measuring transducer (MT) and an Arduino Nano microcontroller that is able to exchange information with a computer via a serial USB interface. Arduino Nano is a microcontroller device that is part of the extensive range of hardware platform ARDUINO, (further simply Arduino), which contains a wide range of modular hardware and software with an open license, continues to develop and is supported by a sufficient volume of literature [5-7]. Arduino is the most affordable budget solution implemented on popular AVR microcontrollers, allows you to use the most popular C / C ++ programming languages, assembler and develop projects for real-time information systems typical tasks [8, 9].

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To build the MT, a fairly common NE555 chip is used, which allows to convert the capacitance into a frequency convenient for further measurements with the microcontroller [7-9]. In this case, the capacitive sensor Cx is included as a time-setting element in the standard way, as shown in Fig. 2.

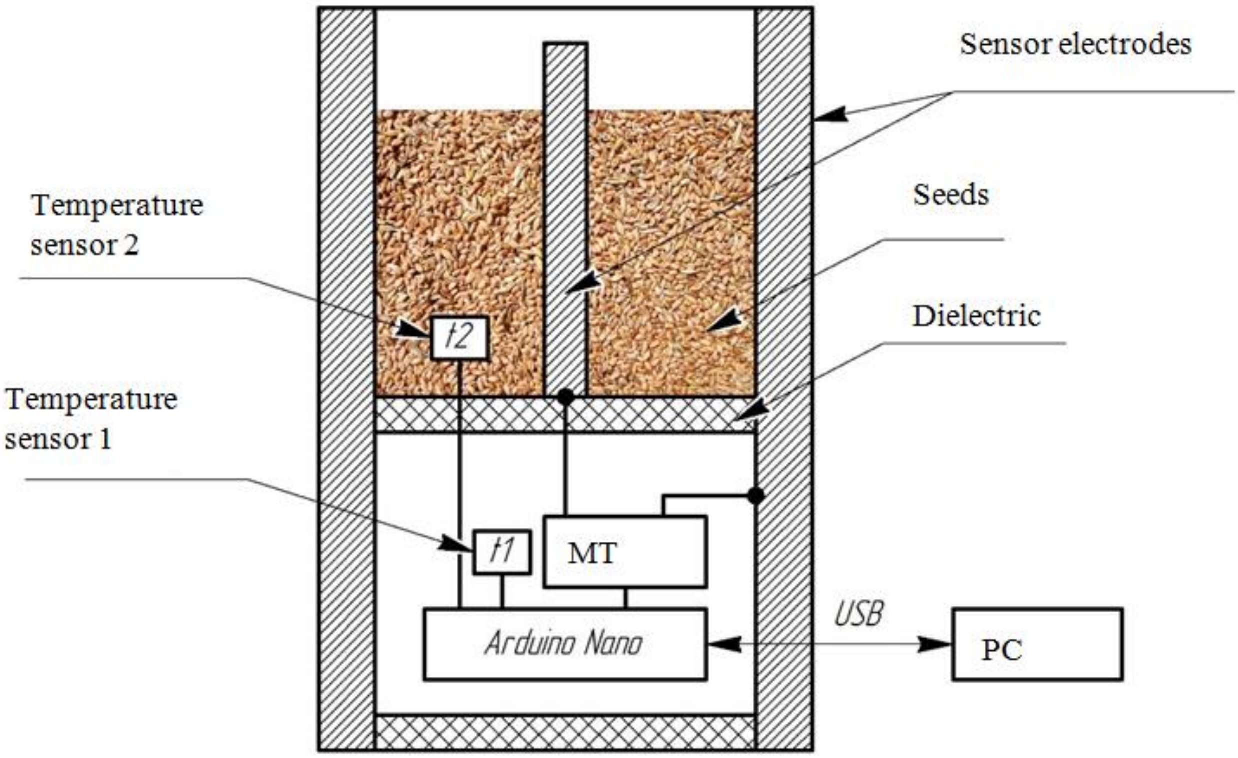

Figure 1: General view of the USB moisture meter

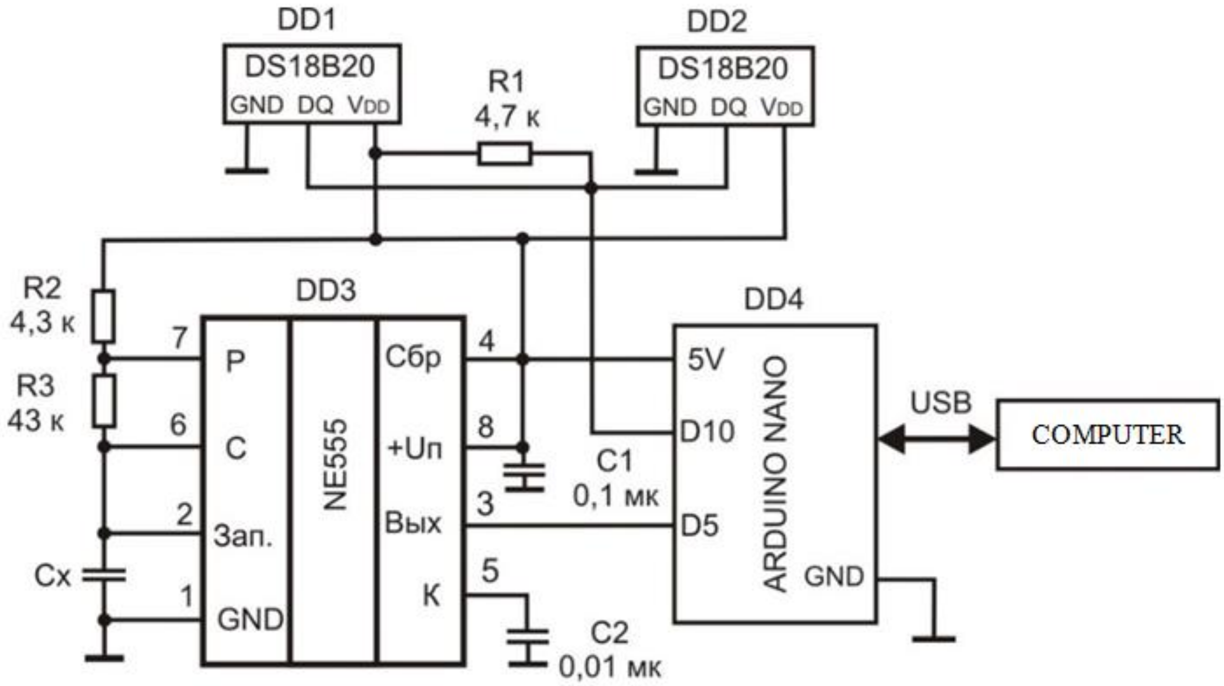

Figure 2: Schematic diagram of the USB moisture meter

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RESULTS AND DISCUSSION

Experimental studies have shown that stable operation of the NE555 chip is possible at a frequency of up to 500 kHz, which corresponds to the working range of dielectric metric moisture meters (from 10 kHz to 15 MHz). The change in frequency varied from 500 to 360 kHz with a corresponding change in the capacitance of the sensor from 4 to 14 pF, which would allow the construction of sufficiently accurate and multicomponent calibration tables.

However, in the course of the experiments, the dependence of the PI frequency on temperature was found, which adversely affects the measurement results of the device. To eliminate this drawback, two temperature sensors DS18B20Z, one of which is located in the IP chamber, were introduced into the electrical circuit of the USB moisture meter (Fig. 2) to control the temperature of the NE555 chip, while the second one is installed in the sensor chamber and controls the temperature of the material under study (Fig. 3). This approach allowed to implement a software method for correcting the influence of temperature with the minimal changes in the hardware part of the device through the functionality of the microcontroller Arduino.

To solve the problem of temperature compensation in the range from 10 °C to 30 °C, a number of experimental studies were carried out, during which it was found that within the specified temperature limits the output signal of an unfilled moisture meter varied from 506 kHz to 484 kHz. Then, depending on the current temperature of the MT t_1, the frequency of its output signal is determined by the expression (1)

$$f_2 = f_1\left[1 + k_f\left(t_1 - 20\right)\right], \qquad (1)$$

f_1 – frequency of the output signal MT at the calibration temperature, i.e. when 20ºC;

k_f – temperature coefficient of frequency, characterizing the change in the frequency of the output signal of the MT as a function of its temperature.

k_f coefficient is determinate by (2)

$$k_f = \frac{\left(f_2/f_1\right) - 1}{t_1 - 20}. \qquad (2)$$

As a result of the experiment it was established that at the temperature of the MT t_1 = 27 ºC the frequency of its output signal is equal to f_2 = 486.45 kHz.

In accordance with the expression (2) is:

$$k_f = \frac{\left(486{,}45/494{,}54\right) - 1}{27 - 20}, \qquad (3)$$

494,54 – частота output signal MT at the calibration temperature, i.e. at 20 °C.

By analogy, the formula for the temperature correction of the measured moisture (4) was derived:

$$w_2 = w_1\left[1 + k_w\left(t_2 - 20\right)\right], \qquad (4)$$

w_1 – measured humidity at 20 ºC, %;

k_w – temperature coefficient of humidity, characterizing the change in humidity of a sample of culture, depending on its temperature.

The coefficient k_w is determined by the expression (5):

$$k_f = \frac{\left({w_2}/{w_1} \right) + 1}{t_2 - 20} \quad (5)$$

It was experimentally established that at a temperature of 20 ° C, the moisture content of soft wheat seeds was 15%, and at a temperature of t2 = 30 ° C, of the same sample, its moisture content was 16%. In this case, the method of air-heat drying showed a humidity of 15%, therefore, a change in temperature towards its increase leads to an overestimation of the USB-moisture meter.

Then, in accordance with expression (5), we find the temperature coefficient of humidity:

$$k_f = \frac{\left({16}/{15} \right) + 1}{30 - 20} = 0{,}0067 \quad (6)$$

The resulting temperature coefficients k_f and k_w are included in the developed software, which is a combined two-element system consisting of a microcontroller USB-moisture meter and a software-measuring complex. The software complex keeps a log of measurements, processes the data and displays the following values to the user (Fig. 3):

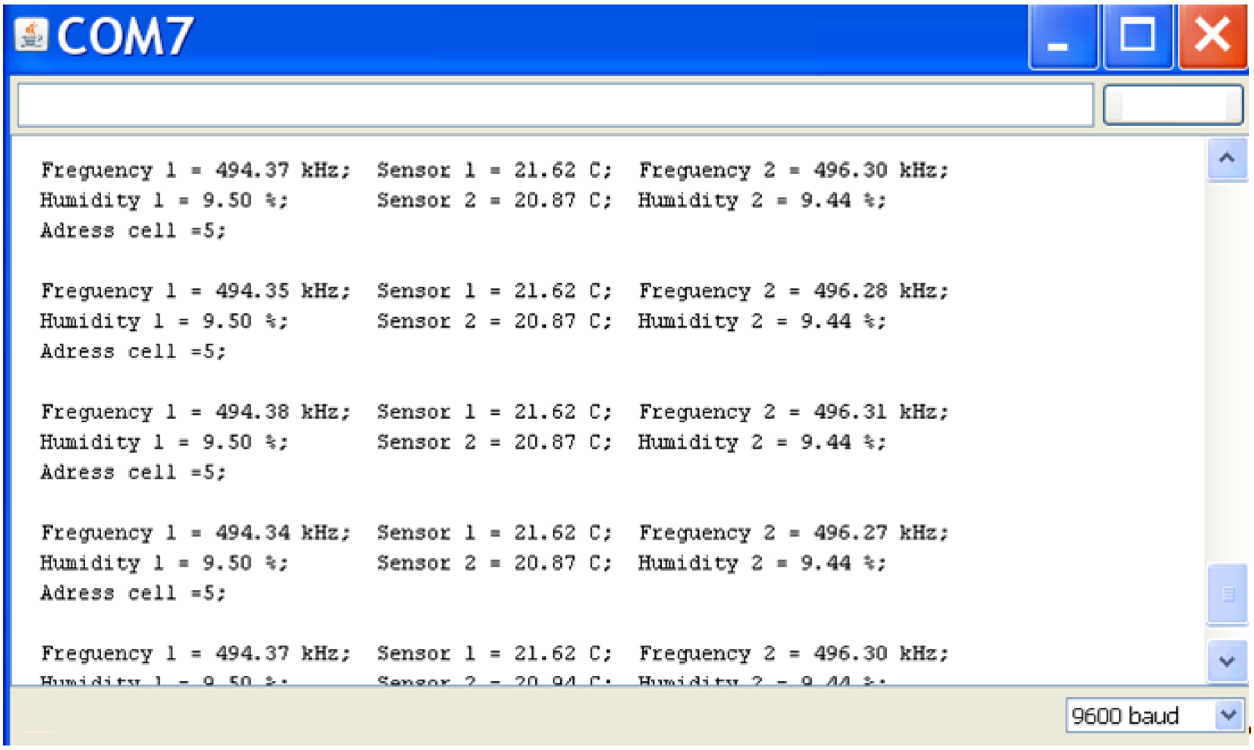

Figure 3: Arduino IDE window with measurement results

- Freguency 1 - not corrected value of the output signal frequency of the IP;
- Sensor 1 - the value of the temperature of the camera in which the IP is located;
- Freguency 2 - the corrected value of the output signal of the IP;
- Humidity 1 - not corrected humidity value;
- Sensor 2 - the temperature value of the material to be monitored;
- Humidity 2 - the corrected humidity value.

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Graduating of prototypes of USB moisture meters was carried out on the basis of the educational-scientific-testing laboratory (UNIL) and the laboratory of electrical measurements of the Stavropol State University. The calibration procedure consisted in sequential determination of the moisture content of one sample by the Wile 55 rapid analysis device, accepted as a reference instrument, then developed by a USB hygrometer and a standardized thermogravimetric method [1]. Based on the data obtained, calibration tables and graphical dependences of W (%) moisture content on C (pF) capacity for different cultures were constructed.

CONCLUSIONS

It should be noted that the developed USB hygrometer has extensive possibilities for improvement and modernization, since the components are not only interchangeable, but also prepared for the integration of additional elements. A rather promising direction for improving the device is the transition to long-distance transmission technologies via the Internet, GSM-communication or wireless protocols Wireless Fidelity (Wi-fi), which are built on a modular-element base and are available at a low price.

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