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***Odessa National Academy
of Food Technologies***



International Competition of Student Scientific Works

BLACK SEA SCIENCE 2020

Information Technology, Automation and Robotics

Proceedings

Odessa, ONAFT 2020

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**AUTONOMOUS SOIL MOISTURE MEASUREMENT SYSTEM WITH
WIRELESS DATA TRANSMISSION**

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Abstract. The aim of the project is to develop a model of an autonomous device for measuring soil moisture with wireless transmission of parameters and visualization of data on the display.

The main task of the project is: analysis of prototypes of systems for remote transfer of data; research and development of algorithms for remote transfer of data through I2C protocols, and their remote (wireless) transmission to any distance; practical implementation of the project with the production of real working system.

The proposed project involves the development of a stand-alone soil moisture measurement device for real-time data transmission and processing. Data transmission is carried out via GSM channel, which causes its application in almost any area where there is coverage by mobile operators.

This project proposes the development of a stand-alone device for measuring soil moisture with autonomous battery power. The system is designed to collect and analyze soil moisture data at a depth of up to 1 meter.

As a result of our research and development, we have obtained a prototype of the system that operates at the department of the university where the project was carried out. The system provides real-time data transmission

Introduction

The development of modern digital automated systems for monitoring and control of environmental parameters with the possibility of wireless data transmission and their further processing and visualization is of great interest to potential customers as it provides ample opportunities for autonomous operation of the system, complete automation of data collection and processing and is independent of human influence on the quality of the results obtained.

The development of a digital soil moisture measurement system for real-time data transmission and processing is of great interest in a variety of agro-firms and agro-complexes and relates to modern *remote control systems*, which provides additional capabilities for creating a control and forecasting system for complex irrigation systems in Ukraine under conditions of constant warming and increase of arid territories [1-3]. The implementation of this system creates the basis for the development of an automation system for the collection and processing of environmental data. *Remote control systems* based on the introduction of modern information and telecommunications technologies, in particular known as *the Internet of Things (IoT) (Internet of Things)* [4].

This project, which is devoted to the study and development of signal processing processes, uses new data transfer models. This paper proposes solutions that allow the design of an autonomous soil moisture monitoring system with the possibility of wireless data transmission over a GSM channel and their visualization in real time.

The parameters to be measured and transmitted are soil moisture at different depths from 10 to 100 cm.

Models and methods for processing and transmitting data that are proposed in this project are published and tested at the conference [11].

Analytical review of the literature

In the conditions of constant climate change, increase of temperature regimes, changes of climatic zones, the issues of introduction of various irrigation systems become more and more acute[5].

One of the conditions for the effective implementation and operation of such systems is the constant monitoring of soil moisture with the possibility of automated collection and processing of data from large areas without human intervention.

The conducted analysis of the market of Ukraine showed the practical absence of such autonomous soil moisture control systems, and the existing systems are operated manually. Often (as a rule) irrigation of the fields is carried out by the subjective assessment of the responsible person, which leads to incorrect ascertainment of norms and timing of irrigation, which leads to loss of hostility.

To eliminate such shortcomings, it is proposed to automate the process of soil moisture control at a depth of 10 cm to 100 cm with the transmission of data on the radio channel to the control point (server), which makes it possible to analyze the collected data, draw irrigation maps and timing of their implementation. Particularly relevant are similar measures in large areas for cultivation of crops that are sensitive to lack of moisture.

Let us analyze the systems and prototypes that are intended to measure soil moisture and determine the methods and conditions of implementation of the system that will be used to accomplish the task.

Overview of soil moisture measurement systems

The purpose of this project is to create a device that will have sufficient measurement accuracy, the ability to measure soil moisture at different depths up to one meter. As it is often the case that the topsoil is more moist than the bottomsoil, it is necessary to optimally analyze the moisture content, as well as the ability to remotely transmit data to the control point.

Soil hydrometer, garden, DMG-1. DMG-1 soil moisture meter [6]. This hydrometer can be used to determine the soil moisture level of both garden and houseplants (Fig. 1).



Figure 1 - Soil moisture meter, DMG-1

Specifications of soil moisture meter DMG-1 are shown in table table.1

As can be seen from these characteristics, the depth of measurement is not large enough and there is no possibility of data transmission over a distance.

Table 1

Technical characteristics of the device

Length of the measuring probe	196 mm
Humidity measurement range	from 0 to 10 units
Hydrometer material	Plastic
The probe material	copper and zinc alloy
Color	Green
Feeding	do not need
Dimensions	285 mm x 50 mm
Mass	48 grams

TRIME-PICO radar soil moisture meters for mobile soil moisture measurement. TRIME TDR - humidity probes from IMKO [7].

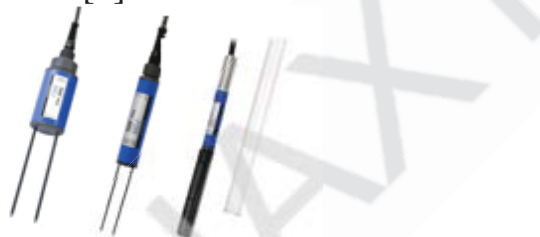


Fig. 2 - TRIME-PICO radar soil moisture meters

The hydrometer soil TRIME-PICO (Fig. 2) can measure both electrical conductivity and humidity, soil temperature, and salt content at different depths directly on site, without the need for labor-intensive laboratory methods. Unlike other measurement technologies, the TRIME-PICO64 and PICO32 moisture meters guarantee accurate measurements even at high temperatures and electrical conductivity. Due to its mechanical strength, the TRIME-PICO64 moisture meter is the optimal solution for mobile applications with the PICO-BT Bluetooth module or the reliable handheld HD2 humidity meter. However, such a device makes it impossible to carry out autonomous measurements at different depths up to 1m. and there is no long distance data transfer capability.

Measurement of soil moisture and other materials using the TRIME-PICO 64 radar moisture meter. A high-tech sensor with an integrated TDR electronic unit measures 3 parameters: water content, temperature, electrical conductivity and salt content with an SDI-12 interface.

Table 2.

Technical characteristics of the device

The range of measured values	0..100%
Supply voltage	7-24B DC
The length of the rod	160 mm
Moisture and dust protection	IP68
Price	From 60000 UAH.

Professional hydrometer with microwave TKM-300 sensor

Professional hygrometer [8] with microwave sensor is first of all convenience and ease of operation if necessary to accurately measure humidity:

- bulk dry mixtures, construction and food
- narrow mushy substances (eg cement, gypsum, dough)
- conductive salts
- soil / soil
- soot, coal



Fig. 3 - hydrometer with microwave TKM-300 sensor

The principle of operation of the device allows to check the production even packed in bags, wrapped in plastic wrap, in cardboard boxes, PET containers. The external type of the sensor of 230 mm long allows to measure humidity inside a material, an embankment, inside viscous solutions.

The TKM-300 is equipped with nine calibrations, zero 0.00% calibration, screen illumination. Powered by standard 9V Crohn's battery (1 pc).

Table 3

Technical characteristics of the device

Display	LCD, backlight
Humidity measurement range	0 ~ 90%
Operating conditions (temperature)	0 ~ 60 C
Operating conditions (relative humidity)	0 ~ 90% RH
Resolution	0,1%
Error	0,5% (1 + n)
Weight	200 г
Dimensions of the device	160 * 70 * 27 mm
Probe	230 mm
Sensor diameter (probe)	6 mm
Price	5900 UAH

Object and research methods

Currently, there are many methods for measuring soil moisture - direct, indirect and remote. Here is a brief overview of how to use one of these for the task at hand.

Direct methods include the extraction of water from a soil sample by evaporation, washing and chemical reaction. Soil moisture is calculated based on the weight of water extracted and dry soil.

Indirect methods include measuring some soil characteristics depending on the water content. They can also measure the characteristics of a particular soil object, usually a porous absorber.

Modern technologies allow us to measure soil moisture at a depth of 0-100cm using satellites (<http://ieassa.org/en/>). This is possible due to their microwave scanning feature.

Then the obtained data are refined taking into account the amount of rainfall and the type of soil, resulting in the most accurate of the currently existing indicators of soil moisture. It should be noted that this approach is quite expensive and has not yet become widespread.

Indirect methods require pre-calibration to determine the relationship between the moisture content of the material and the measured physical value. Below we look at different methods of indirect measurements of soil moisture in green spaces.

There are various indirect methods of measuring soil moisture [10]: capacitive, resistive, thermistor, optical.

1. Capacitive humidity measurement method.

Capacitive hygrometers, in the simplest case, are capacitors with air as a dielectric in the gap. It is known that dielectric constant in air is directly related to humidity, and changes in dielectric humidity also lead to changes in the capacitance of the air capacitor.



Fig. 4 - Capacitive humidity sensor

2. Resistant humidity measurement method.

Such a sensor is shown in Fig. 5 includes two electrodes, which are deposited on the substrate, and on top of the electrodes is applied a layer of material, which has a fairly low resistance, strongly, however, variable depending on humidity.

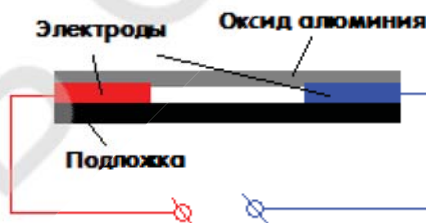


Fig. 5 - Resistant humidity sensor

Suitable material in the device may be aluminum oxide.

3. Thermistor method of measuring humidity.

The thermistor hygrometer consists of a pair of identical thermistors.

One of the thermistors included in the scheme is placed in a sealed chamber with dry air. The other is in the chamber with the openings through which it enters the air with the characteristic humidity that needs to be measured. Thermistors are connected by a pavement circuit, voltage is applied to one of the diagonals of the bridge, and readings from the other diagonal.

When the voltage at the output terminals is zero, the temperatures of both components are equal, so the humidity is the same. If the output is not zero voltage, it indicates the presence of a difference in humidity in the chambers. Thus, the value obtained in the measurements of the voltage determine the humidity

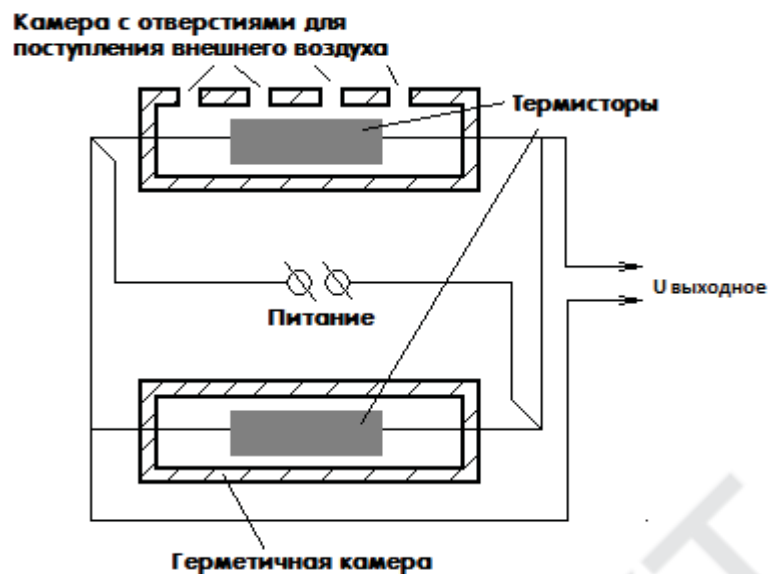


Fig. 6 - Thermistor humidity sensor

As the humidity increases, water begins to evaporate from the thermistor housing, while the temperature of the housing decreases, and the higher the humidity, the more intense the evaporation occurs, and the faster the thermistor cools.

4. *Optical method for measuring humidity.*

This type of sensors is the most accurate. At the heart of the optical humidity sensor is the phenomenon associated with the concept of "dew point". At the moment of reaching the dew point temperature, the gaseous and liquid phases are in terms of thermodynamic equilibrium.

So, if you take the glass, and set in a gaseous medium, where the temperature at the time of study above the dew point, and then begin the process of cooling of the glass, then at a specific value of temperature on the surface of the glass begins to form water condensate, this water vapor will go into the liquid phase. This temperature will be just the dew point.

Results of work

This project proposes the development of a digital soil moisture measurement system in an automated mode at different depths (from 10 to 100 cm) with the transmission of data via the GSM channel for their further processing, storage and visualization as a time trend on the web server.

The project provides flexible solutions for the system equipment with additional sensors (for example, a sensor for measuring soil temperature, etc.), which allows to expand its capabilities.

The schematic design of this system is shown in Fig. 7 This design will be stationary use, which will be left in a specific place for a long time. It will be powered independently from the solar battery, which will be located in the front panel of the case.

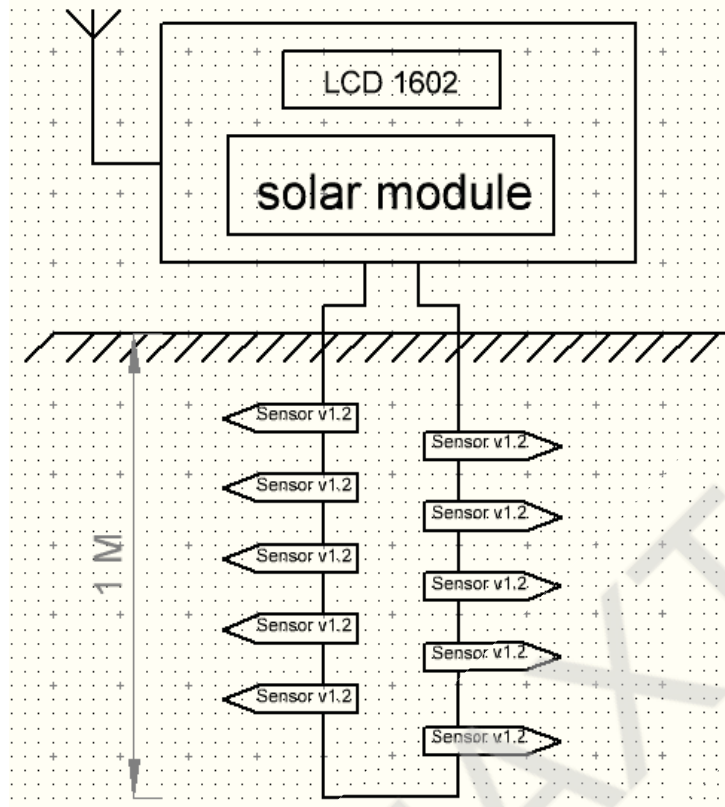


Figure 7 - Schematic representation of the product design

This project is based on the Arduino MEGA2560, all power to this unit comes from a 4.2V lithium-ion battery. The GSM 800L GSM module is used to transmit impressions via radio channel. For convenience, we used a two-line 16-character LCD display designed to display indicators from 10 sensors, which are located at a depth of 0.1 to 1m. The block diagram of the device is shown in Fig. 8

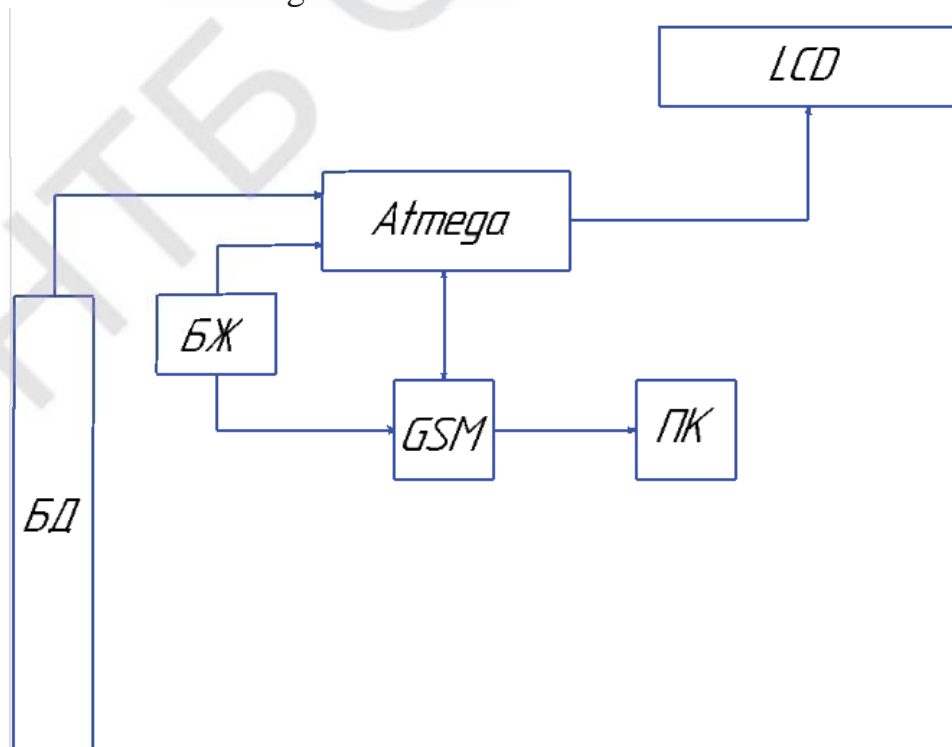


Fig. 8 - Block diagram of the device for humidity measurement and data transmission over GSM channel

The block diagram shows: БЖ – Power Supply; БД – sensor unit; Atmega – Arduino Mega2560; LCD – display 1602; GSM – GSM module SIM 800L; ПК – personal computer (web server).

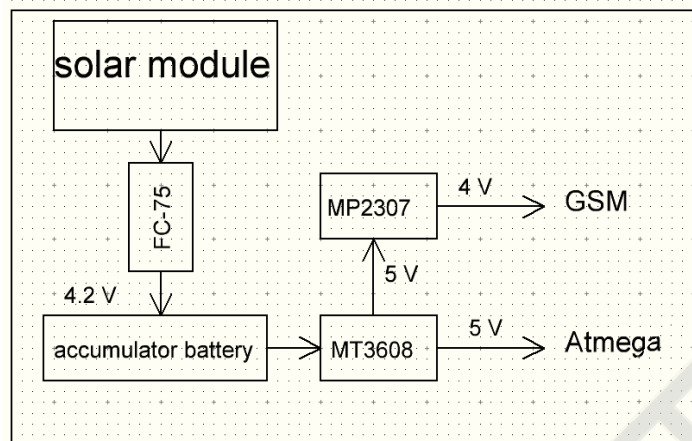


Fig. 8 - Structural diagram of the power supply unit

The block diagram shows: Solar module – solar module; FC-75 - Li-ion battery controller; Accumulator battery – 18650 battery; MT3608 – step-up voltage converter DC-DC 2-24V 2A; MP2307 – DC-DC reducing voltage converter MP2307 5-23V 1-17V.

The principle of operation is based on the measurement of soil capacitance by sensors located in the sensor block at a distance of 10 cm from each other. An analog signal is fed to the ATmega2560 microcontroller, processed and output for in percentage display on the LCD.

The display of indicators is carried out in several stages. First, the readings from the first sensor are displayed, then the second, etc. The time delay between switching is 2 seconds. and can be changed according to the needs of the user. After that, all the readings enter the GSM module block and are sent to the user’s server (PC or a specially developed web application).

After one cycle, the device goes into sleep mode in order to save energy. After some time, the process repeats and the data is again transmitted to the user. This approach can significantly save batteries, contributes to the long-term explanation of the device in offline mode. This unit can be equipped with an additional more powerful antenna that connects to the GSM module if necessary. Therefore, the device can be used in virtually any conditions that could interfere with data transmission (bad weather, unstable mobile communications)

Table 4

Technical characteristics of the device

Supply voltage	from 4-5B DC
The range of measured values	0..100%
Type of execution	Stationary
GSM data channel	Kyivstar mobile operator
Moisture and dust protection	IP65
Display	LCD, backlight
Dimensions of the sensor	99x16mm
Error	0,5% (1 + n)
Ability to transmit under difficult reception conditions	yes

The scheme of electrical connections of the device is shown in Fig. 9. All power to this unit comes from a 4.2V lithium battery. The GSM 800L GSM module is used to transmit signal via radio channel. A two-line 16-character LCD display is connected by a four-wire circuit. Humidity sensors have been selected as a self-contained capacitive type sensor, similar to Sensor v1.2, as they are resistant to corrosion and are more accurate than a resistive type sensor.

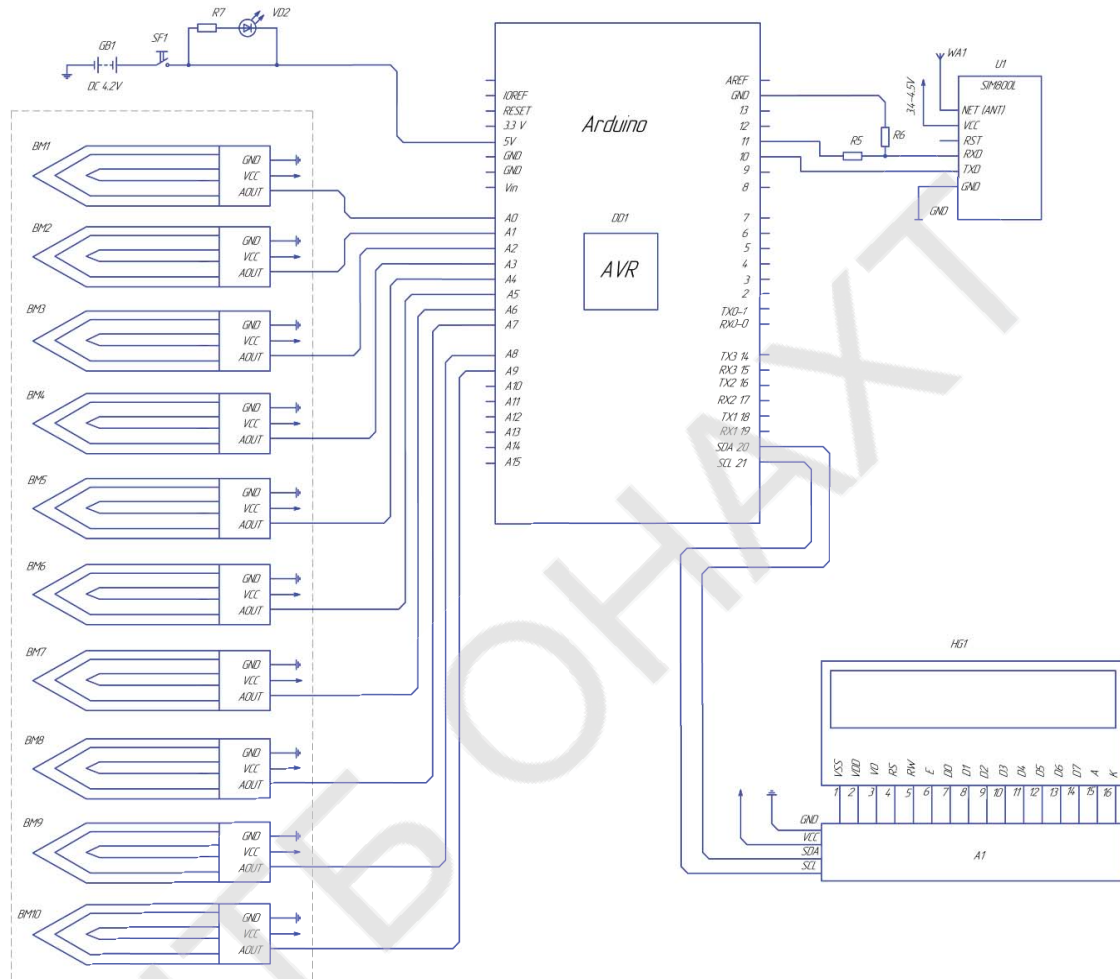


Fig.9 - Schematic diagram of the principle

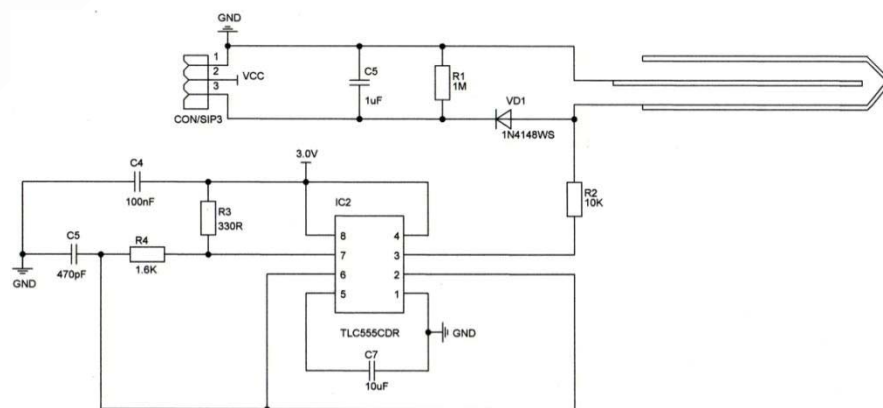


Fig. 10 - Wiring diagram of capacitive humidity sensor Schematic list

In this project, it was decided to replace the Sensor V1.2 soil moisture sensors with a self-made sensor. The principle of operation was based on the measurement of capacitance (capacitive method). The manufacture of sensors was based on LUT technology.

The process of manufacturing sensors.

The first step was the development of a capacitive-type electric sensor circuit.

Microcircuit TLC555	1pc.
Diode 1N 4148	1pc.
Capacitor 1uF	1pc.
Capacitor 100nF	1pc.
Capacitor 470pF	1pc.
Capacitor 10uF	1pc.
Resistor 1M	1pc.
Resistor 10K	1pc.
Resistor 1.6K	1pc.
Resistor 330R	1pc.

In the Sprint-Layout environment, a PCB layout was developed, the diagram of which is shown in Figure 11. The external dimensions of the sensor are 100x31mm, which is slightly larger than the size of the Sensor V1.2



Fig. 11 - Sensor circuit board

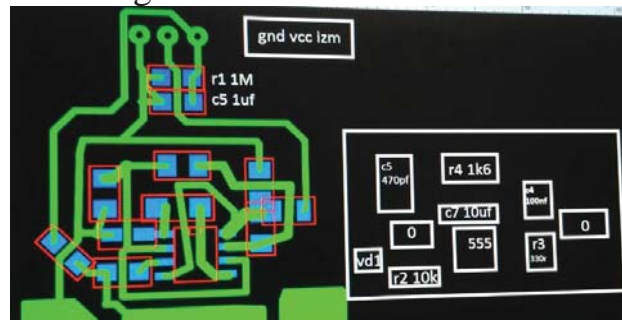


Fig. 12 - Sensor wiring diagram



Fig. 13 - Sensor appearance before and after varnishing

The next step is to connect the sensor to the Arduino and calibrate. The analog output of the sensor was connected to the terminal A0 in the Arduino and the power was taken 5V as indicated in the passport to the NE555 chip.

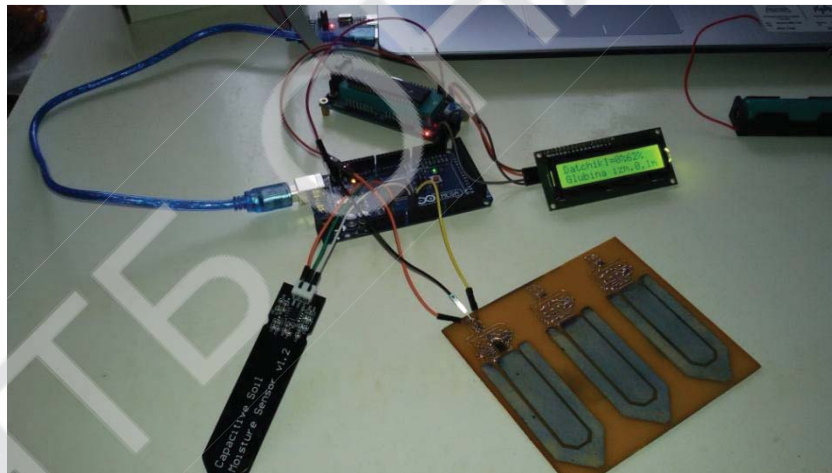


Fig.14 - Testing of working capacity

The sensor calibration was performed using the Sketch file which is shown in Fig. For ease of visualization, an LCD display was connected. At first, experimentally found the largest and smallest readings in digital equivalent. This was done by immersing the sensor in water and then made up a percentage

```
analogValue =map(analogValue, 263, 707, 100, 0);
```

At maximum immersion in the water the sensor shows the number 263 which equated to 100% humidity, and in a completely dry state the number 707 equated to 0%.

The accuracy of this sensor is no different from that of SensorV1.2. Another main point is the cost of a homemade sensor UAH -24 in relation to SensorV1.2 - 85UAH.

```

#include<Wire.h>
#include<LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);
const int analogPin = 0;

void setup() {
  lcd.init();
  lcd.backlight();
  Serial.begin(9600); // Скорость работы порта
  Serial.println("Датчик 1"); // Выводим текст
  Serial.println(); // Пустая строка
}

void loop() {
  int analogValue = analogRead(analogPin); // Задаем переменную analogValue для считывания показаний
  Serial.println(analogValue); // Выводим значения

  //analogValue =map(analogValue, 263, 707, 100, 0); // Задаем пропорцию в процентах
  Serial.println(analogValue); // Выводим значения
  Serial.println("%");

  lcd.setCursor(0,0);
  lcd.print("Datchiki=");
  lcd.print(analogValue);
  lcd.print("% ");
  lcd.setCursor(0,1);
  lcd.print("Glubina izm.0.1m");

  delay(1000);
  //Serial.println.setTimeout(100);
}

```

Fig. 15 - Sketch file for sensor calibration

In Fig. 16 is an electronic block of a control, receiving and data transmission system housed in a plastic housing.

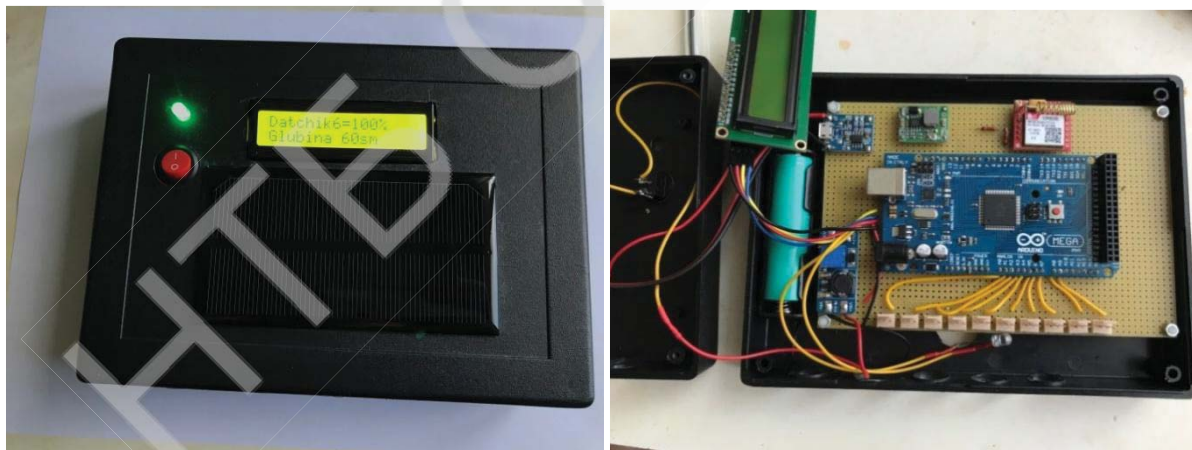


Fig. 16 - Internal and external appearance of the electronic control unit

Figure 17 shows photographs of a functioning stand-alone humidity measuring device consisting of a sensor unit for measuring soil moisture to a depth of up to 1 meter with a measurement interval of 10 cm and an electronic control unit. The entire system is powered by a solar panel.



Fig.17 - Pictures of a working sample of an autonomous soil moisture meter

Conclusions

In this project, a working model of a stand-alone device for measuring soil moisture with data transmission is developed and manufactured. Initially, a market analysis was conducted and a search for similar measurement systems was made. As it turned out, as such, there is no such system that could carry out measurements at a depth of up to 1 m

with the transmission of the data transfer. But such systems were still, but they had a very high price value of about 30 thousand UAH. After that, they got acquainted with the measurement methods and settled on the capacitive method of measuring humidity.

The next step was to develop a block diagram and identify the element base. After that, a schematic diagram of an electrical principle was drawn up. Performed the design and modeling of the hull and collected the current sample. 10 capacitive type sensors were manufactured independently using LUT technology.

The existing sample was calibrated and adjusted for further work. This project cost 1500 UAH.

Models and methods for processing and transmitting data that are proposed in this project are published and tested at the conference [11].

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