Development of a mobile complex for monitoring temperature slices in dispersed environments

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Development of a mobile complex for monitoring temperature slices in dispersed environments

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Abstract. One of the tasks in the study of soils is to determine their temperatures. That tasks is associated with a number of difficulties. Therefore, for measuring the temperature distribution in various natural soils in real field conditions a mobile complex was designed. Its modular system allows to make measurements at any depth. In addition, the compactness of the device and the speed of assembly and disassembly makes it quite mobile. The simple design of the assemblies of which the complex is composed provides an inexpensive and fast manufacture and repair of the device.The first paragraph after a heading is not indented (Bodytext style).

1. Introduction

Temperature of invironment playing a huge role on the vital activity of people and the functioning of devices [1,2]. Temperature reflects the internal state of the body [3,4]. Temperature changes both in time and in space, can drastically affect the properties of bodies and the characteristics of materials. According to some studies [5, 6], when studying the thermophysical properties of bulk samples, the presence of a temperature gradient affects the final results of the study. This is especially true when studying the temperature distribution in the thickness of various, including complex environments (soil, ice, water, etc.).

In the conditions of the Far North and in particular the Arctic, low and ultra-low temperatures have a very strong influence on the environment. Water most of the time in these areas is in the solid phase. In the cold season, the soil and soils freeze over several meters. Ice in view of its thermal and mechanical properties has a significant impact on all mechanisms with which it has direct contact. In soil, as a multiphase medium, heat can be transferred in different ways: through water or air, separating solid particles; with direct contact between particles; emission of a particle into a particle; convection heat transfer through gas or liquid. The amount of thermal conductivity is determined by the chemical and mechanical composition of the soil, moisture content and air content, density and temperature of the soil [7,8]. Also, the thermal conductivity of the soil depends on the temperature state and distribution. With an increase in the temperature of the soil, the thermal conductivity of air trapped between solid particles, and, consequently, of the soil as a whole, increases [6]. The ice cover of lakes and rivers is characterized by the distribution of the coefficient of thermal conductivity across its thickness. This is due to the higher temperature of ice in the lower layers (at the lower boundary of $0 \,°$ C) and low temperature in the layers located above, as well as porosity, which is higher in the upper layers than in the lower layers [7].

When measuring the temperature distribution along the soil section, various types of thermometers are used: liquid, thermoelectric, resistance thermometers [6]. However, in the construction of such devices there are drawbacks that affect the measurement process. These disadvantages, in particular,

include: a relatively small range of temperature measurements, a huge thermal inertia [10]. It is also worth noting that the reading should be carried out directly at the place of installation of the instruments, and manually. To eliminate these drawbacks, it is necessary to create a device, the design of which will provide for remote temperature measurement in any medium under study for a considerable period of time [12].

2. Materials and methods

To simplify the acquisition of data from the sample under study, device is constructed that automatically collect information. To study the temperature distribution and the dynamics of temperature changes in the soils, an automated installation was developed [12], which allows remote measurements in frozen soils at various depths.

FIGURE 1a shows one of the modifications of the measuring module. This module allows for a long period of time, consistently read the temperature readings from the sensors installed in it. The obtained data can be automatically saved in a file on a computer directly connected to the device or on a memory card of a separate functional unit.

Since the installation has a modular structure, this allows varying the length of the object being measured (for example, the depth of a reservoir) by adding or removing one or several modules. Each module is a design that is independent of other modules and can occupy any position in the measurement setup (Figure 1b).
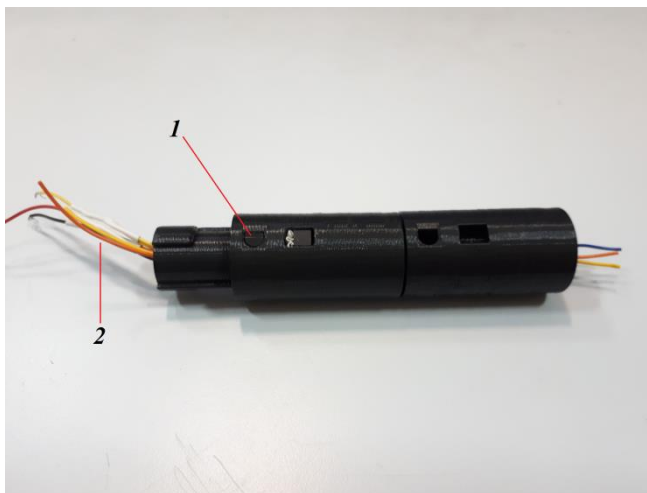
Figure 1. Measuring module Assembly.

The module case is made of a PLA filament on 3D printer (Figure 2 (2)), which provides poor thermal conductivity, which limits the heat flux along the measuring device [11]. At the ends of the module, to ensure the connection between the modules, there is a latch. Tightness and moisture protection are provided by a rubber gasket placed between the connecting parts of the modules. The sensors are mounted on the surface of the module (Figure 1a (1), Figure 3), which ensures direct contact with the environment. A loop consisting of three wires (Figure 1a (2)), to which the sensor is connected, is stretched through the resulting construction. Two of them are designed for power, the third for taking readings.
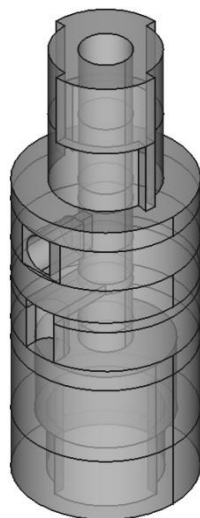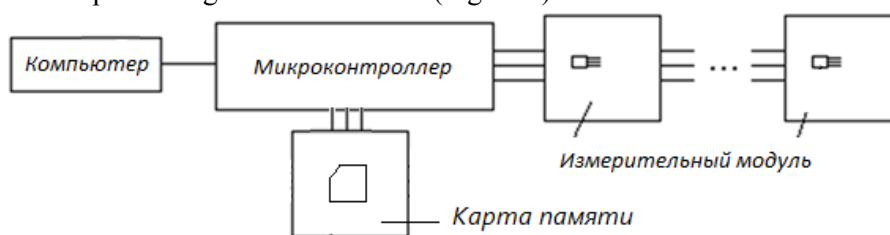
Figure 2. 3D-model of module.

Figure 3. DS18B20 temperature sensor.

The measuring system consists of three main elements:
1. Modules, from which the data is obtained.
2. The microcontroller to manage the modules.
3. A computer for processing the data obtained (Figure 4).

Figure 4. Schematic representation of device.

As a measuring element, a Dallas Semiconductor DS18B20 sensor (FIGURE 3) is used. The sensor was chosen due to its low cost, sufficient accuracy and ease of measurement.

The Arduino UNO platform (or Arduino Nano, as a more compact version) with the ATMEGA 328 microcontroller is used to convert signals received from sensors into temperature readings in Celsius, as well as to transfer the received data to a PC.

For programming the microcontroller to work with the Arduino uses a standard package. The program code is recorded in the memory of the hardware platform, which can operate independently of the software running on the PC. The following is the data acquisition code of the temperature sensors [12-15].

```
    #include <onewire.h>                        //Connect library for work with sensors on protocol 1-
Wire
    #include <SD.h>              // Connecting the library to work with the SD card

    OneWire ds(10);                                         //Connect the line of data to the 10th pin
    int SD_pin = 11;                                        // Connect the SD card to the 11th pin of the
microcontroller
    void setup(void)  {
        Serial.begin(9600);                               //Set data exchange speed with COM port
pinMode(SD_pin, OUTPUT);                        // Assign pin DS_pin output
    if (!SD.begin(CS_pin)) {           // Check the availability of card
     Serial.println("Card Failure");
     return;}
     void loop(void)  {
        byte i;                                         //The counter in cycles
        byte data [12];                                 //Data from the sensor
        byte addr [8];                          //Sensor address
        int HighByte, LowByte, TReading,        //The Data on temperature received from the sensor
           SignBit,                              //Sign of temperature
           Tc_100,                              //Temperature, brought to value in degrees Celsius
           Whole,                               //Whole part of size of temperature
           Fract;                               //Fractional part of size of temperature
    String dataString = "";                     // The string that will be written to the card
        if (! ds.search(addr))                  //Check existence of the device connected to the bus
         {
         Serial.print("\n");
         ds.reset_search ();     //If devices are absent or data from all devices collected, dumping of the
//bus is made
         return;      }
        for ( i = 0; i < 8; i++)
         Serial.print(addr[i]);
        Serial.print(" ");
        ds.reset();
        ds.select(addr);
        ds.write(0x44,1);                       //Start conversion and we include parasitic connection
        delay(1000);                            //Wait  1second  until  the  sensor  copies  data  from
internal registry in                                        // random access memory
        ds.reset ();                            //Dump the clear
        ds.select(addr);                        //Switch the device
        ds.write(0xBE);                         //Read  out  the  devices  given  from  random  access
memory
        for (i = 0; i < 9; i++)
         data[i] = ds.read ();                  //Keep the obtained data in the data variable
        LowByte = data [0];                     //Obtain data on temperature size
        HighByte = data[1];
        TReading = (HighByte << 8) + LowByte;
        SignBit = TReading & 0x8000;            //Define the sign of temperature
        if (SignBit)//if value negative
         TReading = (TReading ^ 0xffff) + 1;    //Lead value of temperature to a negative look
        Tc_100 = (6 * TReading) + Treading/4;   //Transfer temperature to degrees Celsius
```

```
    Whole = Tc_100/100;                     //Separate from each other the whole and fractional
portions
    Fract = Tc_100 % 100;
        if (SignBit)                         // If the temperature is negative
      dataString="-";                        // Remove the minus sign
    dataString+=String(Whole);               // Store temperature in variable
        if (Fract & lt; 10)
      dataString+=String(Fract);
  Serial.println(dataString);                // Write temperature value to COM port
  File logFile = SD.open("LOG.txt", FILE_WRITE);
    if (logFile) {                           // Open the file and write the string
   logFile.println(dataString);              // You can open only one file at a time.
   logFile.close();}                              // If there is no file, it will be created
   else {
   Serial.println("LOG.txt");
   Serial.println("Couldn't open log file"); }}
```
The result of the completed program is shown in Figure 5.
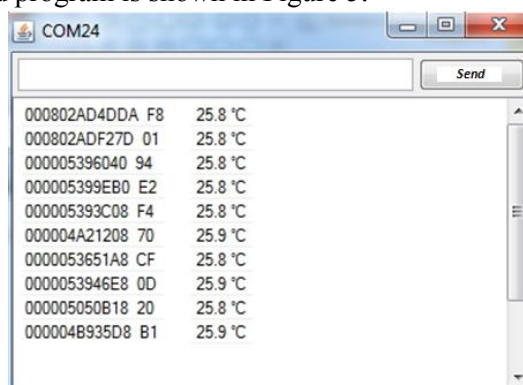
Figure 5. Sensor data values.

The frequency of data collection, the depth of the location and the frequency of the location of the temperature sensors can be set depending on the experimental conditions. The obtained data can be stored on board the complex in ROM as a separate module. In addition, there is the possibility of transmission using 1-Wire or some other technology for remote reading in cases where direct measurements are not possible.

3. Results
The need to study the temperature distribution in soils led to the creation of a measuring complex. To ensure mobility and simplicity in assembling and installation in the studied soil, the device was designed in the form of separate modules, which can be replaced with similar ones if necessary or broken. Production of a separate module can be carried out in a very short time (printing the case on a 3D printer and soldering of sensors). To take and process the data received from the measurement sensors, software is had written that is permanently stored in the microcontroller. Preliminary measurements had showing the reliability of the design of the complex.

4. Conclusion
The developed device allows for remote studies of temperature distribution in the thickness of the ground. The device can work for a long time, and all measurement results are recorded and processed in a continuous stream. Data can be read both during the research process and received after its completion. The simplicity of the device allows it to be used in any difficult climatic and territorial conditions. Due to the modularity of the device, you can connect any number of sensors at the same

time (we tested the work on ten sensors). The small weight and size, as well as the modularity of the design, make the installation a fairly mobile device. The availability and low cost of materials and electronic components provide a low cost of this complex. The simplicity and speed of creating a separate module allows you to ensure the measurement process in the shortest possible time.

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