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DEVELOPMENT OF A DEVICE PROJECT THAT DETERMINES THE AMOUNT OF ELEMENTS THAT ENSURE SOIL FERTILITY (POTASSIUM, CALCIUM, NITROGEN)

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nitrogen, phosphorus, potassium, Arduino, NPK sensor, MAX485 RS485 Transceiver Module, OLED display, libraries

ANNOTATION

Determining soil fertility and effectively managing it is one of the urgent issues in agriculture. Modern technologies play a crucial role in automatically analyzing soil composition and optimizing fertility to increase crop yields. This article highlights the importance of monitoring and optimizing soil fertility through automated systems. The main elements of the soil are measured using an NPC sensor, and the data is sent to the microchip. The analyzed data from the microchip is displayed on an OLED screen. Additionally, the article provides information and guidelines on designing the schematic of this project, connecting sensors and actuators to the microcontroller, and writing the program code.

Introduction. All plants require 17 essential chemical elements for proper growth. These elements are listed below (Table 1). Elements are essential for each nutrient source and play a key role in plant growth.

Table 1.

Category	Nutrient	Symbol	Primary Role	Sources
Primary Macronutrients	Nitrogen	N	Promotes leaf and stem growth	Urea, ammonium nitrate, ammonium sulfate
	Phosphorus	P	Aids root development, energy transfer	Superphosphate, MAP, DAP
	Potassium	K	Enhances water use and disease resistance	Potassium chloride, potassium sulfate
Secondary Macronutrients	Calcium	Ca	Strengthens cell walls	Lime, gypsum
	Magnesium	Mg	Critical for photosynthesis	Dolomite, magnesium sulfate
	Sulfur	S	Important for proteins and enzymes	Gypsum, elemental sulfur
Micronutrients	Iron	Fe	Essential for chlorophyll production	Iron sulfate, chelated iron
	Manganese	Mn	Activates enzymes, aids photosynthesis	Manganese sulfate
	Zinc	Zn	Supports hormone and enzyme production	Zinc sulfate, chelated zinc
	Copper	Cu	Required for reproductive growth	Copper sulfate
	Boron	B	Cell wall formation, pollination	Borax, boric acid
	Molybdenum	Mo	Nitrogen fixation, enzyme function	Sodium molybdate, ammonium molybdate
	Chlorine	Cl	Osmotic balance, photosynthesis	Potassium chloride
Non-Mineral Nutrients	Carbon	C	Fundamental for all organic compounds	Air (CO_2)
	Hydrogen	H	Key component of water and organic matter	Water (H_2O)
	Oxygen	O	Involved in respiration and photosynthesis	Air (O_2) and water (H_2O)
Beneficial Element	Nickel	Ni	Required for seed germination, nitrogen metabolism	Naturally in soil; trace in fertilizers

Pictures 1. Nitrogen, phosphorus, and potassium in Plants

Nitrogen (N), phosphorus (P), and potassium (K) are the three main nutrients required for plant growth in the soil, each of which plays a specific role in the plant's life cycle (Pictures 1).

Nitrogen plays an important role in the formation of the green color of plants and their growth. Nitrogen is a major component of the chlorophyll molecule and helps absorb sunlight during photosynthesis. This process serves as a source of energy for plants. If there is enough nitrogen in the soil, the plant grows quickly and is abundant. If there is little nitrogen in the plant, the plant's leaves turn yellow, the plant's growth slows down, it produces low yields, and it produces poor-quality fruit. Too much nitrogen, on the other hand, causes the plant to become overly leafy and reduces its ability to produce fruit and flowers.

Phosphorus is involved in the energy transfer process, which is essential for plant growth and development. Phosphorus is important in the formation of new roots in the plant. This increases the plant's ability to absorb water and nutrients. Phosphorus is involved in the formation of seeds, flowers and fruits, increasing yield. As a result of phosphorus deficiency, the leaves turn purple or light green, root growth slows down, yielding ability decreases, and fruits develop slowly. An excess of phosphorus leads to weakening of plants.

Potassium increases the overall health of plants and their resistance to the external environment. Potassium strengthens the stems of plants, making them resistant to diseases and pests. Potassium improves the quality and taste of fruits, and also helps to store the product longer. With a lack of potassium, the edges of the leaves turn brown, the plants become sluggish and weak, and the quality of the fruit decreases.

The amount of nitrogen, phosphorus and potassium in the soil must be balanced. A deficiency or excess of these elements can negatively affect plant growth. Therefore, it is important to measure the amount of soil nutrients before applying fertilizer. Modern NPK sensors and soil analysis can provide an ideal environment for plants.

In order to study this project and determine its specific features, the following scientific works and articles were analyzed and the necessary information was obtained for the study.

In the article by Arafat A. S. and others [1], information is given about the design of the device for measuring the 3 main elements needed for soil fertility through the NPK sensor. This project uses the Arduino NANO platform. The information received through the NPK sensor goes to the Atmega328 microcontroller, the microcontroller edits the data and outputs the value to the LCD display. This technology was tested on the Cayenne pepper plant. As a result of this project, only 3 key element values are displayed on the screen.

Ameer S. and others [2] provided theoretical information about the project that determines important elements such as nitrogen, phosphorus, potassium, necessary for soil fertility. It was explained that this project is very necessary for agriculture.

In the article by Masrie M. et al [3], an integrated optical sensor was developed for the determination of NPK nutrients in soil. The sensor uses optical properties to determine the concentration of nutrients in the soil. The results show that the sensor can effectively and accurately measure soil NPK levels, which can help optimize fertilization processes in agriculture.

Musa P., Sugeru H., Wibowo E. P [4] also expressed their opinions on this topic. The article provides an overview of the application of wireless sensor networks in precision agriculture and the implementation of NPK sensors. The authors analyzed various NPK sensor technologies, their advantages and disadvantages. The application and effectiveness of these sensors in agriculture are also discussed.

A lot of literature in this field was analyzed. All of the projects developed for agriculture are aimed at obtaining an efficient harvest from the plant. As we know, for a plant to produce a good crop, the level of soil fertility should be sufficient. The project we developed also monitors soil fertility. In this case, the information received through the sensor goes to the microcircuit, is analyzed in the microcircuit, and the result is displayed on the screen. The difference of this project from other projects is that the information display screen (display) is adaptable to any environment, and the level of showing the required values is high. We have given information about this display in our previous article [5].

Methodology

There are sensors compatible with the Arduino platform to measure the value of these 3 elements in the soil. The most effective of these is the NPK sensor. This sensor determines the amount of phosphorus, potassium, and nitrogen in the soil.

As the name suggests, an NPK sensor is a device that measures the levels of the three main elements in the soil mentioned above – nitrogen-N, phosphorus-P, and potassium-K (Pictures 2).

Features of the NPK sensor: Pictures 2

- Power supply: 9 to 24V DC
- Maximum power consumption: ≤0.15W
- Operating temperature: -40~80°C
- NPK parameters: Range: 0-1999 mg/kg(mg/L)
- Resolution: 1 mg/kg(mg/L)
- Precision: ±2%FS
- Response time: ≤1S
- Protection grade: IP68
- Probe material: 316 stainless steel
- Sealing material: Black flame
- Default cable length: 2-3 meters
- Dimensions: 45*15*123mm
- Output signal: RS485

MAX485 RS485 Transceiver Module

This is the soil NPK sensor: N for nitrogen, P for phosphorus, and K for potassium, so this is basically the soil nitrogen, phosphorus, and potassium 3-in-1 fertility sensor, which is used for detecting the content of nitrogen, phosphorus, and potassium in the soil.

This soil NPK sensor is considered to be the most high-precision, accurate, with accuracy up to plus/minus 2%, with fast speed measurement and with increased stability. The resolution of this NPK sensor is up to 1 mg per kg or 1 mg per liter. This is an easy-to-carry sensor and can even be used by nonprofessionals. All you need to do is insert these stainless steel rods into the soil and read the soil content so the soil NPK sensor gives the user an accurate understanding of the soil fertility status. This the user can measure the soil condition at any time, and then according to the soil condition, the soil fertility can be balanced to achieve a suitable growth environment for the plants.

This soil NPK sensor is provided with such high-quality stainless steel props, which are completely rust-resistant, electrolytic-resistant, salt- and alkal-coren-resistant; therefore, this soil NPK sensor is suitable for all kinds of soil.

Moreover, this soil NPK sensor is IP68, great waterproof, and dustproof to ensure the normal operation of components for a long time. The soil NPK sensor has a total of four wires. Brown wire is the VCC wire and it should be connected with 9 volts to 24v DC power supply. Black wire is the ground wire and it should be connected with GNP port, the remaining two wires which are the blue and yellow wires these are the B and A wires and these two wires should be connected with the "b" and "a" pins of the RS485 module.

The measuring range of the soil NPK sensor is 0 to 1,999 mg per kg, and the working humidity is from 5 to 95%. The maximum power consumption is less than or equal to 0.15 watt. This is the RS485 interface module, which is used to connect the soil NPK sensor with the Arduino. This interface module can be easily powered up using the Arduino 5 volts. The MAX 485 interface module is ideal for serial communication over long distances of up to 1200 m or in electrically noisy environments. This is the reason it is commonly used in industrial environments. It supports up to 2.5 megabits per second data rates, but as the distance increases, the maximum data rate that can be supported comes down. The RS485 has the ability to communicate with multiple devices, up to 32, on the same bus or cable when used in a master and configuration.

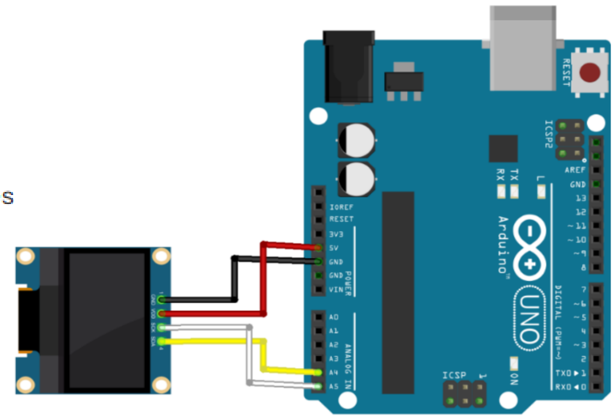
We have four mail heads on the data side: RO is the receiver output, and it should be connected with the RX pin of the Arduino. RE is the receiver enable; this is active low. This pin should be connected with the RO digital output pin drive low to enable receiver output. High to enable the driver is the DE enable pin; this is active high and is typically jumpered to the RE pin. DI is a driver input, and it should be connected with a TX pin of the Arduino.

A standard for long-distance serial data transfer, RS-485 offers numerous benefits over other serial protocols like RS-232.Data transmission up to 1200 meters is possible with it. Accurate NPK level sensing requires dependable and noise-free data transfer, which is ensured by the use of MAX485.

The MAX485 enables long-distance communication between an NPK (nitrogen, phosphorus, and potassium) sensor and a computer or microcontroller. For precise and consistent NPK level detection in agricultural or environmental monitoring applications, this module offers dependable and continuous communication over extended distances.

Specifications MAX485 RS485 Transceiver

1. Operating voltage: 5V
2. Maximum data rate: 2.5Mbps
3. Maximum distance: 1200 meters (at lower data rates
4. Operating temperature range: -40°C to +85°C
5. Number of channels: 1
6. Supply current: 300 uA (typical)
7. Package type: 8-pin DIP or SOIC

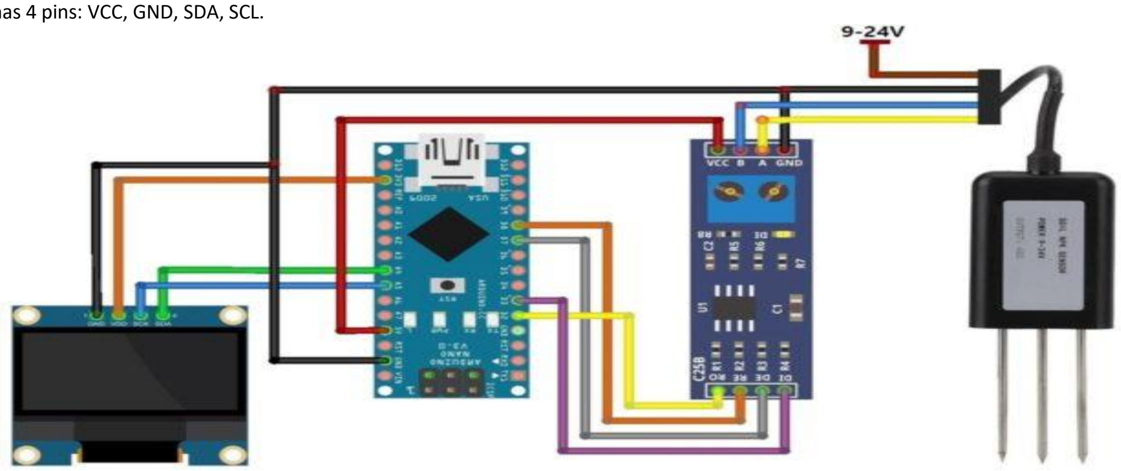


Pictures 3.

We will create a project to display the 3 values received from the NPK sensor on a special screen. The OLED display device is suitable for this project. The reason is that the OLED display does not need a backlight, it creates a very bright contrast in dimly lit areas. In addition, the OLED display consumes less electricity than traditional displays, because its pixels only require energy when turned on. The OLED display has 4 pins: VCC, GND, SDA, SCL.

Connecting the wires is very simple. The connection diagram of the Arduino Uno and OLED display can be seen in Pictures 3.

Now we will connect both OLED display and NPK devices to the Arduino board (picture 4).



Picture 7. Connection diagram

Arduino -> RS485 module

- 5V -> VCC
- GND -> GND
- Pin 2 -> RO
- Pin 3 -> DI
- Pin 7 ->DE
- Pin 8 ->RE

RS485 module -> Soil NPK Sensor

- Ground to Ground
- VCC pin to 5V of the Arduino
- B -> Blue wire
- A-> Yellow wire

Arduino -> OLED

- 5v -> VCC
- GND -> GND
- SCL -> A5
- SDA -> A4

When the connection is successfully established, the special library for both devices must also be downloaded to the computer.

Required libraries:

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
```

SoftwareSerial.h – This library allows you to programmatically create a serial port for an Arduino microcontroller. Most Arduino boards have a single hardware serial port, and you may need to create additional virtual serial ports to communicate with other devices.

Wire.h – This library allows the Arduino to communicate with other devices (eg sensors, displays) using the I2C (Inter-Integrated Circuit) protocol. The I2C bus is used to interconnect multiple devices via a single bus.

Adafruit_GFX.h - This is the Adafruit Graphics Library used to draw graphic elements (text, shapes, pixels). This library works together with other display libraries.

Adafruit_SSD1306.h - This library is designed to work with SSD1306 OLED displays. It works together with the Adafruit GFX library and allows you to create a graphical interface on the display.

```
#define SCREEN_WIDTH 128    // OLED display width, in pixels
#define SCREEN_HEIGHT 64    // OLED display height, in pixels
#define OLED_RESET -1       // Reset pin # (or -1 if sharing Arduino reset pin)
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

#define RE 8
#define DE 7
```

The above code snippet is to show multiple devices and connections.

```
const byte nitro[] = {0x01,0x03, 0x00, 0x1e, 0x00, 0x01, 0xe4, 0x0c};
const byte phos[] = {0x01,0x03, 0x00, 0x1f, 0x00, 0x01, 0xb5, 0xcc};
const byte pota[] = {0x01,0x03, 0x00, 0x20, 0x00, 0x01, 0x85, 0xc0};
```

The provided byte arrays nitro, phos, and pota represent the Modbus RTU commands to read the nitrogen, phosphorous, and potassium values from a sensor, respectively. Let's break down what each array contains and explain their structure.

Structure of Each Command Array

Each array corresponds to a Modbus RTU query. The format typically follows this structure:

1. **Device Address (1 byte)**: The Modbus address of the target device.
2. **Function Code (1 byte)**: Specifies the type of operation (e.g., read holding registers).
3. **Start Address High Byte (1 byte)**: High byte of the starting register address.
4. **Start Address Low Byte (1 byte)**: Low byte of the starting register address.
5. **Number of Registers High Byte (1 byte)**: High byte of the number of registers to read.
6. **Number of Registers Low Byte (1 byte)**: Low byte of the number of registers to read.
7. **CRC Low Byte (1 byte)**: Low byte of the CRC checksum.
8. **CRC High Byte (1 byte)**: High byte of the CRC checksum.

```
byte values[11];
SoftwareSerial mod(2,3);
```

- This defines an array named values with 11 elements of type byte.
- Purpose: The array is typically used to store the raw data received from the sensor after a Modbus RTU query is sent.
- This initializes a **SoftwareSerial** object named mod on pins 2 and 3 of the Arduino.
  - **Pin 2**: RX (receive pin) — receives data from the sensor.
  - **Pin 3**: TX (transmit pin) — sends data to the sensor.

```
void setup() {
  Serial.begin(9600);
  mod.begin(4800);
  pinMode(RE, OUTPUT);
  pinMode(DE, OUTPUT);

  display.begin(SSD1306_SWITCHCAPVCC, 0x3C); //initialize with the I2C addr 0x3C (128x64)
  delay(500);
  display.clearDisplay();
  display.setCursor(25, 15);
  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.println(" NPK Sensor");
  display.setCursor(25, 35);
  display.setTextSize(1);
  display.print("Initializing");
  display.display();
  delay(3000);
}
```

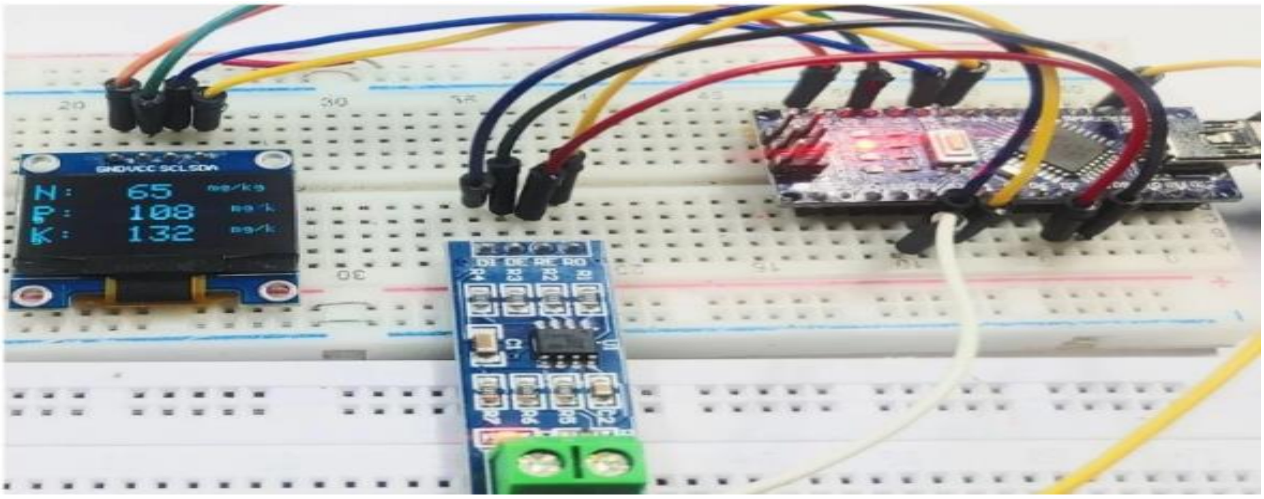
Program code for the setup() function

Result

The code part of the program is written in Aruino IDE and sent to the Arduino board. The necessary circuit is assembled on the board and the program is launched.

The Arduino IDE program sends the program code to the Arduino microcontroller. After the program is loaded correctly, the device is placed in the soil where the NPK sensor values are measured. The 3 values received from the NPK sensor are displayed on the OLED screen.

The result can be seen in picture 5.



Conclusion

This paper presents the development of an accurate, fast, and stable NPK sensor for soil nutrient determination, specifically nitrogen, phosphorus, and potassium, using an Arduino Nano I2C interface. Built on the Arduino platform, this system provides an affordable and efficient solution for soil monitoring. Through the NPK sensor used in the project, it was possible to determine the amount of nutrients in the soil and monitor this data in real time. The software of the device is easy to understand and makes it easy for the user to get the necessary parameters. With the help of this technology, farmers and agricultural specialists can effectively use it to improve soil quality, increase productivity and create optimal conditions for plants. In the future, this system can be further improved and expanded, for example, by making additional modifications or adding new sensors to measure other parameters.

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