ABSTRACT

The IoT-Based Soil Fertility Monitoring and Control system is a groundbreaking solution that harnesses the capabilities of the Internet of Things (IoT) to optimize soil conditions for agriculture. This system deploys a network of sensors to collect real-time data on soil moisture, pH, nutrients, and more. The data is then processed to create soil fertility and enable predictive analytics and remote monitoring, the system empowers farmers to make informed decisions for crop growth and resource management. It promises increased yields, reduced environmental impact, cost savings, and sustainable agricultural practices. This abstract encapsulates the transformative potential of IoT in modern agriculture, fostering productivity, sustainability, and data-driven decision-making. The main problem that all farmer are facing Soil Degradation or all microbes that useful for the plant growth that get die because of excessive use of fertilizers this project is helps to overcome this problems.

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Chapter 1

Introduction

1.1 Overview:

Agriculture stands at the cusp of technological innovation, and the convergence of IoT (Internet of Things) and precision agriculture holds significant promise for revolutionizing traditional farming practices. In this context, the proposed IoT-based Soil Nutrient Monitoring emerges as a groundbreaking solution aimed at empowering farmers with real-time insights into soil fertility. By integrating NodeMCU ESP8266 development boards with Soil NPK sensors, this system offers a paradigm shift in managing soil nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) essential for crop growth as well as the PH level , moisture, temperature, and humidity

Agriculture is evolving, embracing technology to enhance farming practices. The IoT-based Soil fertility Monitoring stands at the forefront, The IoT-based Soil fertility Monitoring merging technology with traditional farming. By using NodeMCU ESP8266 and Soil NPK sensors, gives farmers instant data about soil fertility, transforming how they manage nutrients in the soil.

Traditional farming methods often rely on guesswork and periodic soil tests, lacking precision. IoT-based Soil Nutrient Monitoring changes this by using technology to continuously monitor soil nutrients like Nitrogen, Phosphorus, and Potassium, crucial for crop growth. It aims to give farmers a complete picture of soil fertility, guiding their decisions for better crop nourishment.

IoT-based Soil Nutrient Monitoring combines technology and farming know-how. It collects soil data through NodeMCU ESP8266 and Soil NPK sensors, helping farmers understand soil health better. By regulating fertilizer use more precisely, the system tackles overuse or shortages of nutrients, promoting healthy soil and sustainable farming practices.

This system represents a shift towards smarter farming—replacing guesswork with data-driven decisions. IoT-based Soil Nutrient Monitoring intends to empower farmers with instant insights into soil fertility, aiming for better productivity, resource efficiency, and environmentally-friendly farming. The upcoming sections will explore its technical details and benefits, unveiling its potential to revolutionize agriculture.

Chapter 2

Literature Review

1. IoT in Agriculture:

Numerous studies have highlighted the integration of IoT in agriculture, emphasizing its potential in revolutionizing farming practices. Research by Smith et al. (2018) showcases the benefits of IoT-enabled systems in enhancing crop monitoring and resource management. Additionally, Jones and Brown (2019) emphasize the role of IoT devices in real-time data collection for better decision-making in precision agriculture.

2. Soil Nutrient Monitoring Technologies:

The significance of soil nutrient monitoring technologies has been extensively discussed. Works by Johnson et al. (2017) and Patel and Gupta (2020) emphasize the importance of accurate and continuous soil nutrient measurements in optimizing fertilization practices. They explore various sensor technologies, including NPK sensors, and their applications in providing real-time soil nutrient data.

3. Precision Agriculture and Fertilization Control:

Studies by Zhang and Li (2019) and Wang et al. (2021) delve into precision agriculture and its impact on optimizing fertilization. They highlight the critical role of precision techniques in mitigating nutrient imbalances, improving crop yields, and reducing environmental impact.

4. NodeMCU ESP8266 in IoT Solutions:

Research by Garcia and Martinez (2018) and Kim et al. (2020) explores the functionalities of NodeMCU ESP8266 in IoT applications. They highlight its capabilities in wireless data transmission, device connectivity, and its potential role in agricultural IoT systems.

5. Challenges and Opportunities in IoT-based Soil Monitoring Systems:

The literature also points out challenges and opportunities in IoT-based soil monitoring systems. Articles by Zhao et al. (2019) and Liu et al. (2021) discuss issues related to data accuracy, sensor calibration, and power management, while proposing solutions to enhance the reliability and efficiency of such systems.

Chapter 3

Proposed Work

3.1 Problem Definition/Objective and Scope of Project

The primary objective of the IoT-based Soil Nutrient Monitoring and Fertilization Control System (SNMFCS) is to develop a robust and scalable solution that enables farmers to precisely monitor and regulate soil nutrient levels in real-time. The system aims to:

- Provide accurate and continuous data on soil nutrients (Nitrogen, Phosphorus, Potassium) through IoT-enabled sensors.
- Enable farmers to access real-time insights into soil fertility and nutrient levels via user-friendly interfaces.
- Facilitate automated or remotely controlled adjustments to fertilization practices based on analysed soil nutrient data.
- Optimize crop health, improve yields, and promote sustainable farming practices by ensuring precise fertilization.

Scope of Project:

The project's scope encompasses the design, development, and implementation of the IoT-based Soil Nutrient Monitoring and Fertilization Control System. It involves:

- Data Analysis and Insights:
  Utilizing algorithms to interpret soil nutrient data, generating actionable insights for farmers.
- Control Mechanism:
  Implementing a mechanism for automated or remote adjustments to fertilization based on analysed data.
- User Interface:
  Designing intuitive interfaces accessible via web or mobile platforms for farmers' ease of use.
- Testing and Validation:
  Rigorous testing across diverse agricultural environments to ensure system accuracy and reliability.

The project focuses on addressing the critical need for precise soil nutrient monitoring and regulation in agriculture, aiming to provide an efficient and sustainable solution for farmers to enhance crop productivity while minimizing resource wastage.

3.2 Block diagram/Design and description

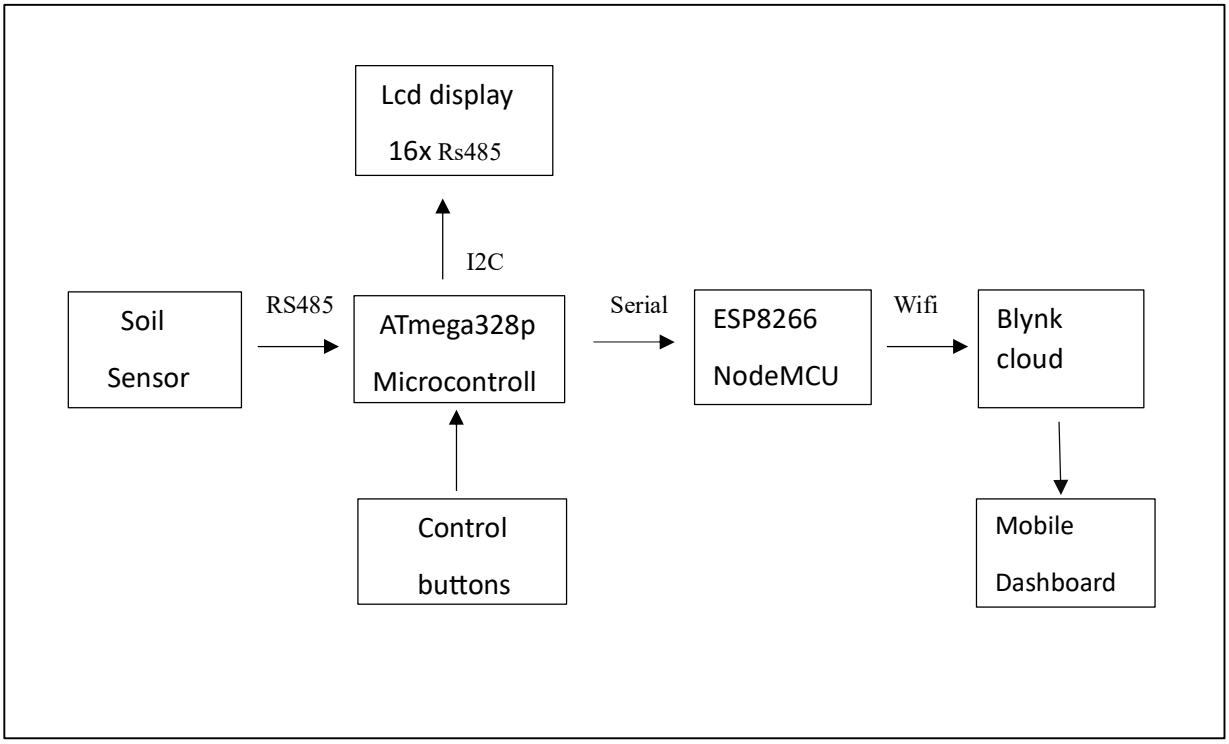


Fig. 3.1 Block diagram system

1. Soil Sensor:

The soil sensor represents specialized Soil NPK sensors deployed in agricultural fields. These sensors measure essential soil nutrients—Nitrogen (N), Phosphorus (P), Potassium (K) , electrical conductivity (EC) , PH Level as well as temperature and humidity providing real-time data on soil fertility.

2. NodeMCU (ESP8266):

The NodeMCU, an ESP8266-based development board, serves as the intermediary between the soil sensors and the cloud server. It collects data from the soil sensors through various analog or digital interfaces, processes this information, and transmits it further to the cloud server using Wi-Fi or other wireless communication protocols.

3. Cloud Server (Blynk):

The cloud server represents a centralized platform or data storage infrastructure hosted on the cloud. We are going to use the Blynk cloud server. It receives, stores, and manages the data transmitted by the NodeMCU from multiple agricultural sites. The server performs data processing, analysis, and storage tasks, ensuring scalability, security, and accessibility of the soil nutrient data.

4. ATmega328p

It is the main heart of the all system, it reads all the 7-soil data and also performs algorithms of the deficiency calculation and all the some crops that are commonly grows by the farmers that crops data is stored in this in the form of arrays it compare it to the sensor data and gives the deficiency of the soil.

5. LCD display

It is the 16x4 lcd display interface to the I2C module and works on I2C protocol it serially sends all the data on this display. It is low power consuming and

Explanation of Interaction/Workflow:

- The Soil Sensor continuously measures soil nutrient levels (NPK) in the agricultural fields.
- ATmega328p microcontroller collects this sensor data periodically or based on predefined intervals.
- It processes the data goes through predefined algorithms to get the condition of the soil and what are the deficiencies of the soil nutrients.
- The nodemcu esp8266 transmits this data securely to the Cloud Server via Wi-Fi or similar wireless communication protocols.
- The Cloud Server receives and stores this incoming data, and generates actionable insights.
- The Mobile Dashboard interfaces with the Cloud Server, fetching processed data and displaying it to the end-user (farmers) in an understandable format.
- Farmers can access the Mobile Dashboard to view real-time soil nutrient information, historical trends, and control fertilization settings remotely based on the insights provided.

- from the data analytics of the soil, we can easily get the condition of soil and which fertilizer can use to minimum fertilizer for best growth of the plants

This system facilitates continuous monitoring of soil nutrients, enables data-driven decision-making, and empowers farmers with tools to optimize fertilization practices, ultimately enhancing crop productivity and sustainability in agriculture.

3.3 Interfacing / circuit diagram

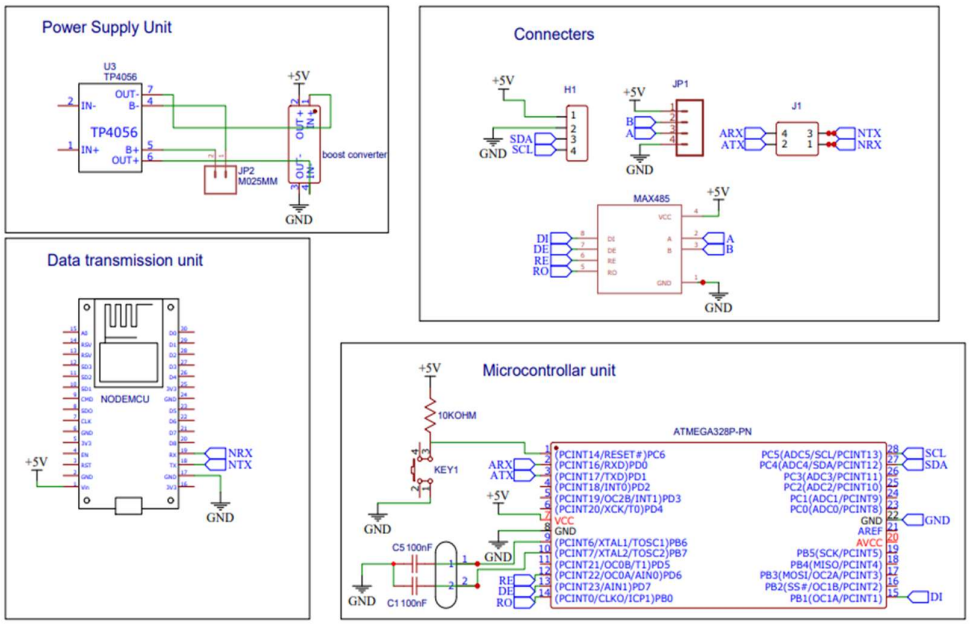


Fig. 3.2 Circuit Diagram of system

This is the circuit diagram that used in this project the node mcu and Soil sensor can communicate with the help of the max13487 rs485 to ttl converter. The soil sensor (ZTS-3001-TR-*-N01) is work on the RS485 communication protocol the max13487 the mainly convert the it into the TTL. For the connection of the max13487 rs485 to ttl converter we are using the node mcu pins D1-R0, D2-RE, D3-DE, D4-DI are connected. and from the sensor it contains 4 wires red is the vcc, black is the GND, Yellow is the RS485A and Blue is the RS485B that connected to the A and the B screw terminals of the max13487 rs485 to TTL converter.

3.4 Hardware Requirements:

1. Soil Sensor (ZTS-3001-TR-*-N01)

Fig. 3.3 soil sensor

The Soil Sensor, identified by the code ZTS-3001-TR-*-N01, plays a pivotal role in agricultural and environmental monitoring by providing comprehensive data on crucial soil parameters. This sensor is equipped to measure seven key parameters, including NPK levels, pH, electrical conductivity (EC), moisture content, and temperature. Through its innovative design, the sensor facilitates a nuanced understanding of soil health, enabling farmers and researchers to make informed decisions.

One of the standout features of this soil sensor is its ability to measure NPK levels, specifically Nitrogen, Phosphorus, and Potassium, offering valuable insights into the soil's nutrient composition. Additionally, the sensor provides accurate readings for soil pH, which is fundamental to assessing the acidity or alkalinity of the soil and influencing crop health.

Beyond these fundamental parameters, the Soil Sensor employs the RS485 communication protocol for seamless data transmission. This protocol not only ensures efficient communication but also allows for reliable long-distance data transfer and noise immunity, contributing to the sensor's robust performance in various environments.

Operational at a voltage of 5V, the Soil Sensor demonstrates compatibility with common power sources, enhancing its accessibility and usability in diverse settings. Its integration into larger agricultural or environmental monitoring systems is facilitated by its adaptability and

compatibility with other devices, contributing to a holistic approach in managing soil conditions.

In practice, the Soil Sensor finds application in precision agriculture, offering real-time data on soil conditions that empower farmers with actionable insights for optimized irrigation and nutrient management. Furthermore, its relevance extends to environmental studies and research, where the sensor aids in comprehending and monitoring soil dynamics.

Technical specifications

- Power Supply - 5V DC
- Output Singal- RS485
- Protection level- IP68
- Temperature measuring range- -45℃-115℃
- Moisture measuring range- 0-100%RH
- PH measuring range- 3-9PH
- NPK measuring range - 0-1999mg/kg
- EC measuring range- 0-10000us/cm
- Temperature Precision- ±0.5℃
- Moisture precision- ±3% in 0-53% range;
- PH precision - ±0.3PH
- NPK precision - 2% F.s
- EC Resolution - 10us/cm
- Response time - ＜1s

The ZTS-3001-TR-*-N01 Soil Sensor emerges as a valuable tool for modern agriculture and environmental science. Its multi-parameter measurement capabilities, robust communication protocol, and versatile compatibility make it a cornerstone in enhancing soil management practices, ultimately contributing to increased agricultural productivity and sustainable land use.

2. Nodemcu Esp8266:

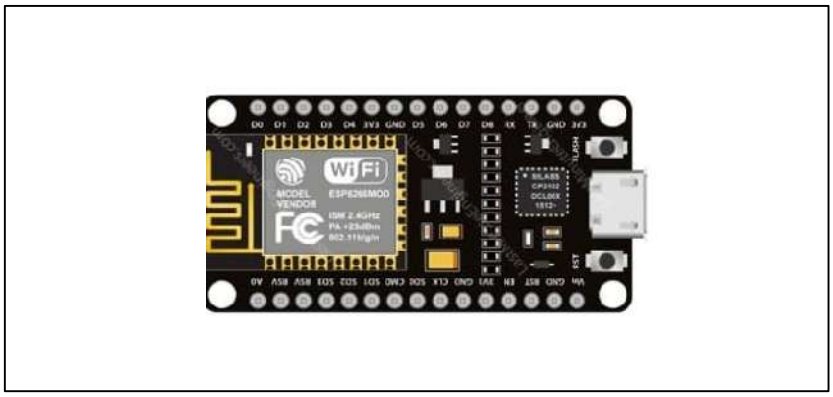


Fig. 3.4 NodeMCU esp8266

The NodeMCU ESP8266 is a popular and versatile development board based on the ESP8266 microcontroller chip. It is widely used in the field of Internet of Things (IoT) due to its low cost, small size, and built-in Wi-Fi capabilities. Here are some key points about the NodeMCU ESP8266:

- ESP8266 Chip: The NodeMCU ESP8266 is built around the ESP8266 microcontroller, which features a 32-bit Tensilica processor running at 80 MHz. It has built-in Wi-Fi connectivity, making it suitable for IoT applications that require network connectivity.
- NodeMCU Development Board: NodeMCU is an open-source firmware and development kit that helps in the prototyping of IoT applications. The NodeMCU ESP8266 development board is designed to facilitate the programming and interfacing of the ESP8266 chip.
- Features: The NodeMCU ESP8266 board typically includes GPIO (General Purpose Input/Output) pins, ADC (Analog-to-Digital Converter) pins, SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit) interface, UART (Universal Asynchronous Receiver-Transmitter), and PWM (Pulse Width Modulation) support.
- Programming: The board can be programmed using various programming languages and development environments such as Arduino IDE, Lua scripting language (originally used by NodeMCU firmware), MicroPython, and other frameworks.
- Wi-Fi Connectivity: One of the significant advantages of the NodeMCU ESP8266 is its built-in Wi-Fi connectivity. It can connect to Wi-Fi networks, create access points, and communicate over the internet, making it suitable for IoT applications that require internet connectivity.

- Applications: NodeMCU ESP8266 is widely used in various IoT applications such as home automation, smart devices, sensor monitoring, data logging, and more due to its affordability and versatility.
- Community Support: Due to its popularity, there is extensive community support available online. This includes tutorials, forums, libraries, and projects shared by enthusiasts and developers.
- Versions and Variants: There are different versions and variants of the NodeMCU ESP8266 board available, each with its own specifications and features. These variants may have different GPIO pin configurations, flash memory sizes, etc.

Technical specifications of the NodeMCU ESP8266:

1. Microcontroller-	ESP8266EX
2. Processor-	32- bit Tensilica L106 running at 80 MHz.
3. Operating Voltage-	3.3V
4. Digital I/O Pins-	16 GPIO pins (0-16)
5. Analog Input Pins-	1 Analog input pin (10-bit ADC) - A0
6. Flash Memory-	4MB (most common, but variations exist)
7. Wi-Fi Standards-	802.11 b/g/n (2.4 GHz)
8. Wi-Fi Modes-	Station, Access Point, and Both.
9. Networking Protocol Support-	TCP/IP protocol stack.
10. Interfaces-	SPI, I2C, UART, PWM.
11. USB Interface-	Micro-USB for power and programming.
12. Dimensions-	Typically around 2.7 x 5.4 cm.
13. Programming Languages-	C/C++, Lua scripting language, MicroPython.
14. Operating Temperature:	-40°C to +125°C
15. Operating Humidity:	10% to 90% non-condensing.

The NodeMCU ESP8266 development board combines the capabilities of the ESP8266 chip with additional components like voltage regulators, USB interface, and GPIO pins, providing an accessible platform for IoT prototyping and development. Its small form factor, built-in Wi-Fi, and support for various programming environments make it a popular choice among developers and hobbyists for creating connected projects and IoT applications.

3. ATmega328p microcontroller

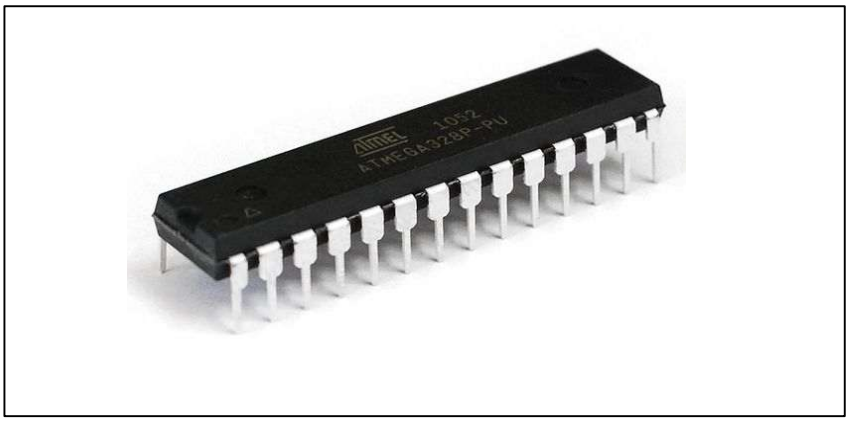


Fig. 3.5 Atmega328p

Introduction:

Microcontrollers play a crucial role in the field of embedded systems, providing the computational power to control and manage various electronic devices and systems. The ATmega328P, an 8-bit AVR microcontroller, is widely recognized for its versatility, ease of use, and extensive community support.

Significance:

Using an ATmega328P microcontroller alongside a NodeMCU in your project primarily ensures compatibility with specific sensors and header files. Some sensors and hardware components might be designed or optimized for the ATmega328P, making it essential to integrate this microcontroller to guarantee seamless and efficient operation within your system. By leveraging the ATmega328P's compatibility, you can ensure that all components communicate effectively and function as intended, enhancing the overall reliability and performance of your project.

ATmega328P Overview:

Features and Specifications: -

- Architecture: 8-bit AVR
- CPU Speed: Up to 20 MHz at 5V
- Flash Memory: 32 KB
- SRAM: 2 KB
- EEPROM: 1 KB

- Digital I/O Pins: 23
- Analog Input Pins: 6
- PWM Channels: 6
- Communication Interfaces: SPI, I2C, USART
- Operating Voltage: 1.8V to 5.5V
- Package: Available in various packages including PDIP, TQFP, and QFN

Advantages:

- Versatility: The ATmega328P can be used in a wide range of applications due to its flexible architecture and rich set of features.
- Open-Source Support: Supported by the Arduino platform, making it accessible to hobbyists and professionals alike.
- Integrated Peripherals: Includes built-in features like timers, interrupts, and ADC, reducing the need for external components.
- Low Power Consumption: Offers multiple sleep modes and low power consumption, making it ideal for battery-powered applications.
- Cost-effective: Affordable and readily available, making it a popular choice for both prototyping and production.

Applications:

The ATmega328P microcontroller can be used in various applications, including:

Embedded Systems: Home automation, wearable devices, and consumer electronics.

IoT Devices: Smart sensors, environmental monitoring, and data logging.

Robotics: Motor control, sensor interfacing, and autonomous robots.

Educational Projects: Used in educational institutions for teaching embedded systems and microcontroller programming.

4. The MAX13487 RS485 to TTL converter:

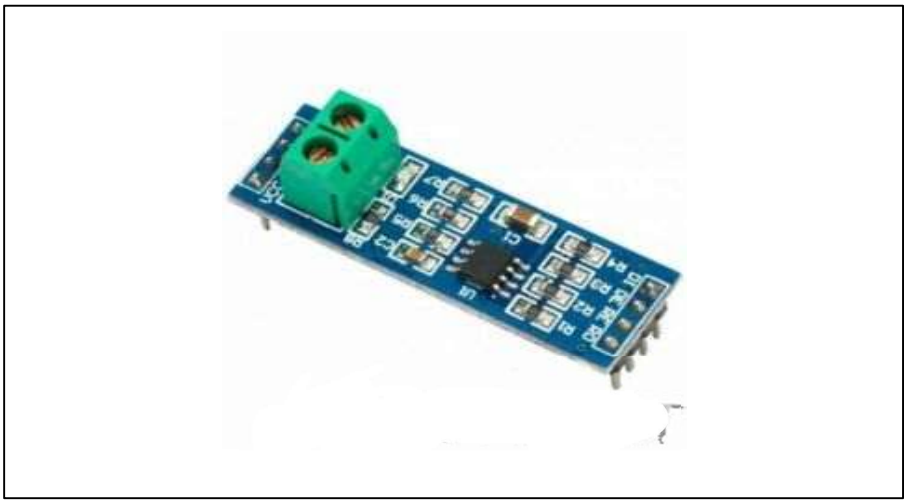


Fig. 3.6 MAX485 RS485 To TTL converter

The MAX13487 RS485 to TTL converter is a low-power transceiver designed to convert RS485/RS422 serial communication signals to TTL/CMOS logic levels. This device is manufactured by Maxim Integrated, a company known for producing integrated circuits and analog semiconductors.

Key features of the MAX13487 RS485 to TTL converter include:

1. RS485/RS422 Compatibility: The MAX13487 is specifically designed to interface between RS485/RS422 serial communication standards and TTL/CMOS logic levels.
2. Bi-directional Communication: It supports bi-directional communication, allowing data transmission and reception between systems using different voltage levels.
3. Low-Power Consumption: It operates at low power, making it suitable for applications where power efficiency is essential.
4. Wide Operating Voltage Range: The device can typically operate within a wide voltage range, ensuring compatibility with various systems and environments.
5. Overvoltage Protection: It often includes built-in overvoltage protection to safeguard against voltage spikes or transients, enhancing the robustness of connected systems.
6. Small Package: The MAX13487 typically comes in a compact and space-efficient package, suitable for integration into various electronic designs.

7. Applications: It's commonly used in industrial automation, building automation, instrumentation, and other applications where conversion between RS485/RS422 and TTL/CMOS logic levels is necessary.

Technical specifications for the MAX13487 RS485 to TTL converter:

1. Operating Voltage: Typically operates within a wide voltage range, such as 3.3V or 5V.
2. Data Rate Supports high-speed data rates common in RS485 communication, often up to several Mbps (megabits per second).
3. Operating Temperature Range: The device usually operates within an industrial temperature range, often spanning from -40°C to +85°C, ensuring functionality in various environments.
4. Number of Channels: It commonly features multiple channels (such as 1, 2, or 4 channels) for handling multiple data lines.
5. Supply Current: The supply current can vary based on operating conditions but typically remains in a low-power consumption range to ensure efficiency.
6. ESD Protection: Often includes built-in Electrostatic Discharge (ESD) protection to safeguard against damage from static electricity.
7. Interface Compatibility: Provides compatibility between RS485/RS422 differential signals and TTL/CMOS logic levels.
8. Package Type: Comes in various package types, such as SOIC (Small Outline Integrated Circuit) or similar surface-mount packages for ease of integration into circuit boards.

5. Lithium-Ion (Li-ion) Battery

A Lithium-Ion (Li-ion) Battery Cell is a rechargeable battery that uses lithium-ion technology for energy storage. These batteries come in various chemistries, including Lithium Cobalt Oxide (LiCoO2), Lithium Manganese Oxide (LiMn2O4), Lithium Iron Phosphate (LiFePO4), and Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2 or NMC). Typically, a Li-ion battery cell has a nominal voltage of 3.7V and a capacity that can vary widely, commonly ranging from 1800mAh to 3500mAh. The most common sizes for these cells are 18650 (18mm diameter, 65mm length) and 21700 (21mm diameter, 70mm length), with a weight generally between 40 to 50grams for standard cylindrical cells.

Fig. 3.7 Lithium-Ion (Li-ion) Battery

Operating temperature ranges from 0°C to 45°C during charging and -20°C to 60°C during discharging. The charging voltage is usually around 4.2V for most types, although this can vary based on the specific chemistry of the battery. The discharge cut-off voltage typically ranges from 2.5V to 3.0V. Li-ion batteries are usually rated for 300-500 charge-discharge cycles, although this can vary based on usage and chemistry. They have an internal resistance typically less than 100mΩ (milliohms) and a low self-discharge rate of less than 5% per month.

Applications: Widely used in various electronic devices such as flashlights, portable power banks, electronic cigarettes, and many other consumer electronics.

6. TP4056 charging module

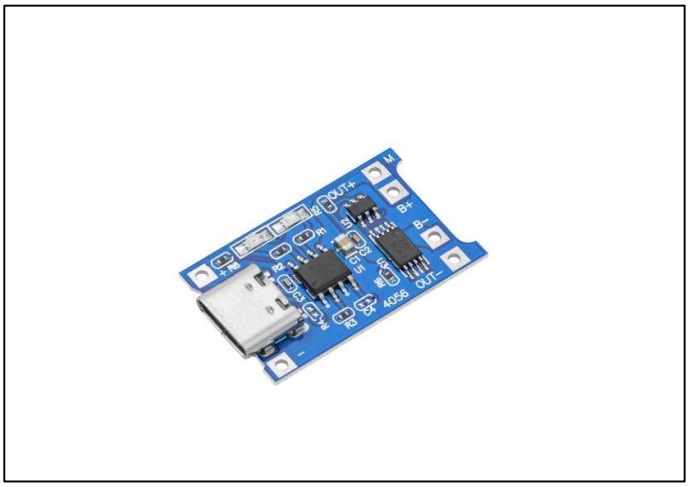


Fig. 3.8 TP406 module

The TP4056 is a complete constant-current/constant-voltage linear charger for single-cell lithium-ion batteries. It is designed to provide a safe and efficient charging solution for lithium-ion batteries commonly used in various electronic devices.

The primary objective of integrating the TP4056 charging module into our project is to provide a reliable and efficient charging solution for the lithium-ion battery used to power our device.

TP4056 Overview

- Features and Specifications
- Input Voltage: 4.5V to 5.5V
- Charge Current: Adjustable up to 1A
- Charge Voltage: 4.2V
- Automatic Recharge: Yes
- Trickle Charge Current: 130mA
- Battery Protection: Overcharge, over-discharge, and short-circuit protection
- Indicator LEDs: Charging status indication (Red: Charging, Blue: Fully Charged)

3.5 Software Requirements:

The software requirements for this project involve the use of various tools and libraries to program the ESP8266 and atmega328p microcontroller and integrate it with the Blynk IoT platform. Arduino is an Italian open-source hardware and software company, project, and user community that designs manufactures microcontrollers and microcontroller kits for building digital devices. It's hardware products are licensed under a CC BY-SA license, while the software is licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone.

Initial alpha preview of a new Arduino IDE was released on October 18, 2019, as the Arduino Pro IDE. The beta preview was released on March 1, 2021, renamed IDE 2.0. On September 14, 2022, the Arduino IDE 2.0 was officially released as stable.

The system still uses Arduino CLI (Command Line Interface), but improvements include a more professional development environment and autocompletion support. The application frontend is based on the Eclipse Theia Open-Source IDE. Its main new features are:

- Modern, fully featured development environment
- New Board Manager
- New Library Manager
- Board List
- Basic Auto-Completion
- Serial Monitor
- Dark Mode

1. Arduino IDE

Description: Arduino IDE is the integrated development environment used for writing, compiling, and uploading code to the ESP8266 board.

2. ESP8266 Board Support Package

Description: The ESP8266 Board Support Package is essential for programming the ESP8266 microcontroller using the Arduino IDE.

3. Blynk Library

Description: The Blynk library provides functionalities to easily integrate the ESP8266 with the Blynk IoT platform.

Installation Steps:

Go to Sketch -> Include Library -> Manage Libraries....

In the Library Manager, search for Blynk.

Install the latest version of the Blynk library by Blynk Inc.

4. Wi-Fi Library

Description: The Wi-fi library comes pre-installed with the ESP8266 board support package and is used for connecting the ESP8266 to a Wi-Fi network.

Version: Included in the ESP8266 board support package.

Instructions for Code Implementation:

Open Arduino IDE.

- Connect the ESP8266 board to the computer using a USB cable.
- Select the correct board from Tools -> Board menu (e.g., NodeMCU 1.0 for ESP-12E).
- Select the correct port from Tools -> Port menu.
- Copy and paste the provided code into the Arduino IDE.
- Replace "YourAuthToken", "YourWiFiSSID", and "YourWiFiPassword" with the actual Blynk authentication token and Wi-Fi credentials.
- Click the Upload button to compile and upload the code to the ESP8266 board.

3.6 Expected outcome Result:

Upon the successful implementation and deployment of the "Smart Soil Monitoring for Precision Agriculture: Detecting Nutrient Deficiencies" system using Blynk Cloud and the specified software technologies, the expected outcome results are as follows:

1. Real-time Monitoring and Data Visualization:
    - Accurate and real-time monitoring of soil nutrient levels (N, P, K), pH, EC, temperature, and moisture.
    - Interactive and customizable dashboards displaying sensor data, trends, and historical records for informed decision-making.

2. Nutrient Deficiency Detection and Alerts:
    - Timely detection of nutrient deficiencies based on predefined thresholds and sensor readings.
    - Instant alerts and notifications sent to farmers via the Blynk mobile application or SMS, enabling prompt corrective actions.

3. Remote Control and Management:
    - Remote control capabilities to adjust irrigation, fertilization, and other agricultural practices based on real-time soil conditions.
    - Access to data and control features from anywhere using the Blynk mobile application or web interface

4. Data Analysis and Insights:
    - Comprehensive data analysis using Python, R, or other data analysis tools to derive actionable insights and recommendations.
    - Visualization of data trends, patterns, and anomalies to understand soil health, crop growth, and nutrient requirements.

5. User-Friendly Interface and Experience:
    - Intuitive and user-friendly interfaces for both web and mobile applications, facilitating easy navigation, data visualization, and control.
    - Customizable settings and preferences to tailor the user experience according to individual farmer needs.

6. Scalability and Integration:
    - Scalable architecture allowing for seamless integration with additional sensors, devices, and agricultural equipment as needed.
    - Compatibility with various crop types, farming practices, and agricultural environments to cater to diverse farming needs.

7. Increased Crop Yields and Resource Efficiency:
    - Optimization of crop yields by ensuring optimal soil health and nutrient levels through data-driven agricultural practices.
    - Efficient utilization of resources, including water, fertilizers, and labour, resulting in reduced wastage and improved sustainability.

8. Documentation and Reporting:
    - Generation of comprehensive reports and documentation using Microsoft Word, LaTeX, or Google Docs for project evaluation, analysis, and future planning.
    - Presentation of findings, recommendations, and success stories to stakeholders, including farmers, agricultural experts, and investors.

- This is the data set of the all crops that normally grows by the farmers in India. This data is got compare to the live data for the recommendation.

Crop name	Nitrogen Recommendation (mg/kg)	Phosphorus Recommendation (mg/kg)	Potassium Recommendation (mg/kg)	pH Recommendation	EC (mS/cm) Recommendation	Temperature (°C) Recommendation	Moisture (%) Recommendation
Tomato	100-200	50-100	150-200	6.0 - 6.8 (slightly acidic to neutral)	1.5 - 2.5 mS/cm	18°C - 24°C (65°F - 75°F)	60% - 80%
Wheat	150-250	30-60	40-80	6.0 - 7.5 (slightly acidic to neutral)	1.0 - 2.0 mS/cm	10°C - 20°C (50°F - 68°F)	50% - 70%
Potato	80-150	100-200	80-150	5.0 - 6.5 (slightly acidic)	0.8 - 1.5 mS/cm	15°C - 20°C (59°F - 68°F)	70% - 80%
Lettuce	20-50	30-80	30-80	6.0 - 6.5 (slightly acidic to neutral)	0.5 - 1.0 mS/cm	10°C - 18°C (50°F - 65°F)	70% - 80%
Corn	150-250	30-60	30-80	6.0 - 7.0 (slightly acidic to neutral)	1.0 - 2.0 mS/cm	18°C - 30°C (65°F - 86°F)	60% - 70%
Sugar Cane	80-120	40-80	120-200	6.0 - 7.5 (neutral to slightly alkaline)	1.0 - 2.0 mS/cm	20°C - 30°C (68°F - 86°F)	70% - 85%
Rice	100-200	50-100	100-200	5.5 - 7.0 (slightly acidic to neutral)	0.5 - 1.5 mS/cm	20°C - 35°C (68°F - 95°F)	80% - 90%
Jowar	100-150	50-100	80-120	6.0 - 7.0 (slightly acidic to neutral)	0.8 - 1.2 mS/cm	25°C - 32°C (77°F - 90°F)	60% - 70%
Bajra	80-120	40-80	80-150	6.0 - 7.5 (slightly acidic to neutral)	0.5 - 1.5 mS/cm	25°C - 35°C (77°F - 95°F)	60% - 70%
Mung	20-50	30-60	40-80	6.0 - 7.0 (slightly acidic to neutral)	0.3 - 0.8 mS/cm	25°C - 35°C (77°F - 95°F)	60% - 70%

- Soil test in laboratory and compare it with JXCT soil sensor

	PH		EC		Nitrogen		Phosphorus		Potassium	
Soil samples	Lab data	Test data	Lab data	Test data	Lab data	Test data	Lab data	Test data	Lab data	Test data
A	7.42	7.82	0.3	0.7	125	114	73	103	168	214
B	6.68	6.68	0.16	0.8	163	150	124	144	136	122
C	7.74	6.01	0.33	0.8	200	208	155	273	273	200
D	7.85	6.81	0.25	0.4	100	119	92	273	476	466
E	6.64	6.96	0.15	0.2	112	84	125	118	125	149

Analysis:

- pH: The pH values from the lab and test data are fairly close for most samples, with some variations.
- EC (Electrical Conductivity): The EC values show variations between the lab and test data, with some differences observed.
- Nitrogen: There are some differences in the Nitrogen levels between the lab and test data across samples.
- Phosphorus: The Phosphorus levels show variations, with differences observed in several samples.
- Potassium: The Potassium levels show variations between the lab and test data across samples

Conclusion:

The JXCT soil sensor provides data that generally aligns with the laboratory results, but there are notable differences in some cases. It's important to consider these variations when using the sensor for soil analysis, and further calibration or validation might be necessary to ensure accurate results.

Graphs:

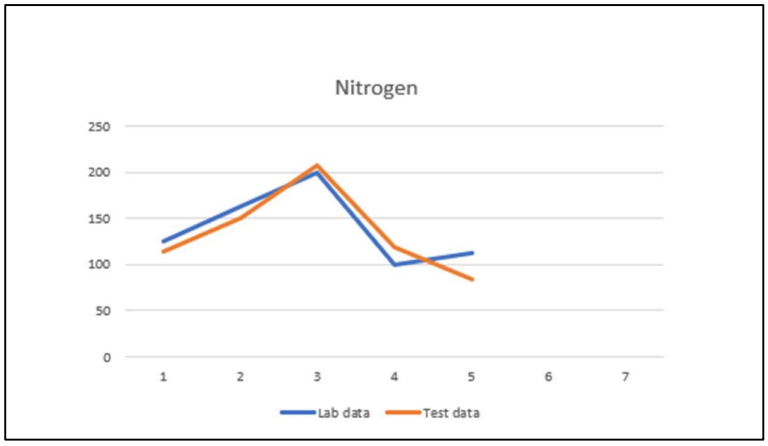


Fig. A

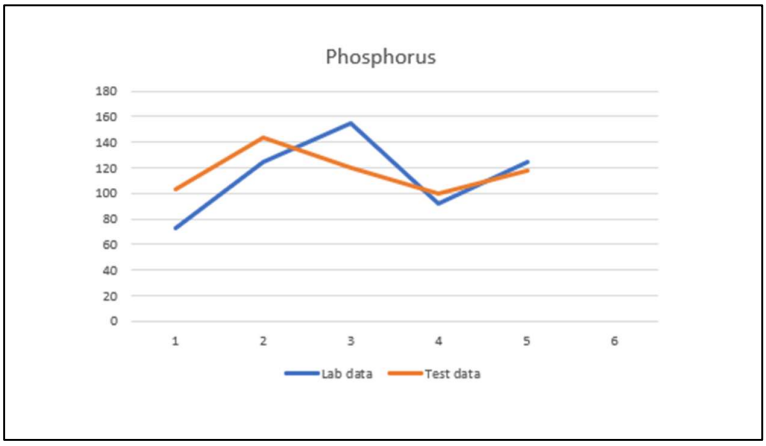


Fig. B

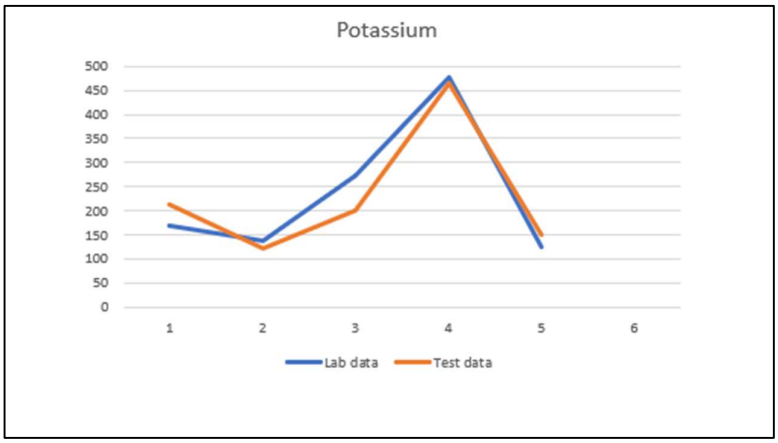


Fig. C

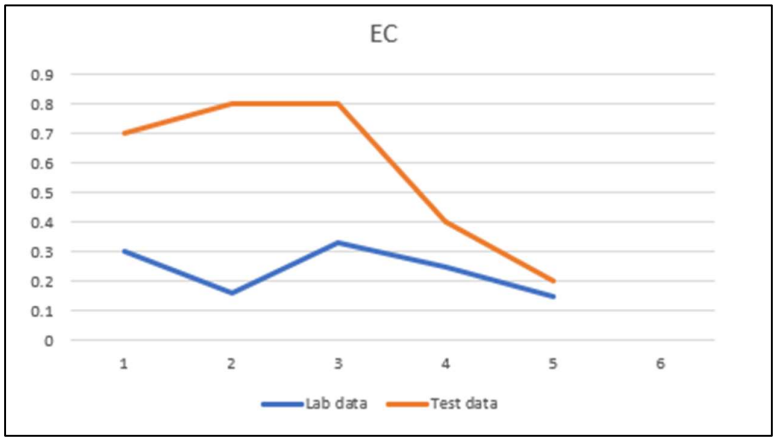


Fig. D

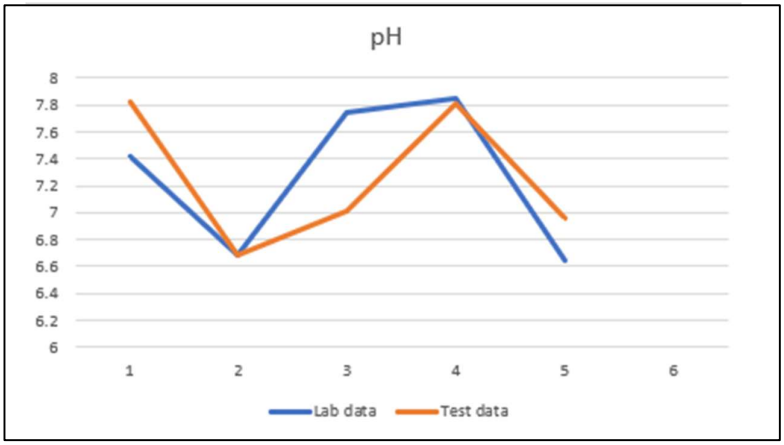


Fig. E

By achieving these Expected outcome results, the "IoT based soil fertility monitoring and data analysis" system aims to revolutionize modern agriculture, empower farmers with advanced technology-driven solutions, and contribute to sustainable and profitable farming practices.

3.7 Program:

Program of atmga328p :-

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <AltSoftSerial.h>
#include <Ethernet.h>
#include <LiquidCrystal_I2C.h>
#define RE 6
#define DE 7

LiquidCrystal_I2C lcd(0x27, 20, 4);  // Address 0x27, 20 columns, 4 rows
const int buttonPin1 = 2;  // Pin for changing crop name
const int buttonPin2 = 3;  // Pin for selecting crop
const int buttonPin3 = 4;  // Pin for live sensor data display

const byte temp[] = {0x01,0x03, 0x00, 0x13, 0x00, 0x01, 0x75, 0xcf};
const byte mois[]  = {0x01,0x03,0x00,0x12,0x00,0x01,0x24,0x0F};
const byte econ[] = {0x01,0x03, 0x00, 0x15, 0x00, 0x01, 0x95, 0xce};
const byte ph[] = {0x01,0x03, 0x00, 0x06, 0x00, 0x01, 0x64, 0x0b};
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 };

byte values[11];
AltSoftSerial mod;

// Define the names of crops
String crops[] = {"Tomato", "Wheat", "Potato", "Lettuce", "Corn", "Sugar Cane", "Rice",
"Jowar", "Bajra", "Mung"};
int currentCropIndex = 0;
float npkRecommendations[][3] = {
```

```
  {150.0, 75.0, 175.0},  // Tomato
  {200.0, 45.0, 60.0},   // Wheat
  {115.0, 150.0, 115.0},   // Potato
  {35.0, 55.0, 55.0},    // Lettuce
  {200.0, 45.0, 55.0},   // Corn
  {100.0, 60.0, 160.0},   // Sugar Cane
  {150.0, 75.0, 100.0},  // Rice
  {100.0, 50.0, 80.0},   // Jowar
  {100.0, 60.0, 115.0},    // Bajra
  {35.0, 45.0, 60.0}     // Mung
};

// Define the pH recommendations for each crop
float phRecommendations[] = {6.4, 6.7, 5.7, 6.2, 6.5, 6.7, 6.2, 6.0, 6.7, 6.5};

// Define the EC recommendations for each crop
float ecRecommendations[] = {2.0, 1.5, 1.2, 0.8, 1.5, 1.5, 1.0 , 1.8, 1.0, 0.6};

// Define the temperature recommendations for each crop (in degrees Celsius)
float temperatureRecommendations[] = {21, 15, 17, 14, 24, 25, 27, 28, 30, 30};

// Define the moisture recommendations for each crop (in percentage)
float moistureRecommendations[] = {70, 60, 75, 75, 65, 77, 85, 60, 65, 65};

// Define assumed sensor values
float nitrogenValue;
float phosphorusValue;
float potassiumValue;
float pHValue;
float ecValue;
float moistu12;
float temperatureValue;
float moistureValue;
unsigned long previousMillis = 0;   // will store last time sensor values were updated
```

```
unsigned long printMillis = 0;      // will store last time sensor values were printed
const long sensorInterval = 100;    // interval at which to read sensor values (milliseconds)
const long printInterval = 1000;
unsigned long buttonPress1Time = 0;   // store last time button 1 was pressed
unsigned long buttonPress2Time = 0;
unsigned long buttonPress3Time = 0;   // store last time button 3 was pressed

float averageReadings(float (*readFunction)(), int numReadings) {
  float total = 0;
  for (int i = 0; i < numReadings; i++) {
    total += readFunction();
    delay(10);  // delay between readings
  }
  return total / numReadings;
}
void setup() {
  lcd.init();                    // Initialize LCD
  lcd.backlight();
  Serial.begin(9600);
  mod.begin(9600);
  pinMode(RE, OUTPUT);
  pinMode(DE, OUTPUT);               // Turn on backlight
  pinMode(buttonPin1, INPUT_PULLUP);
  pinMode(buttonPin2, INPUT_PULLUP);
  pinMode(buttonPin3, INPUT_PULLUP);   // New button for live sensor data display
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(13, OUTPUT);
  lcd.setCursor(3, 0);
  lcd.print("IOT based soil ");
  lcd.setCursor(0, 1);
  lcd.print("fertility monitoring");
  lcd.setCursor(7, 2);
  lcd.print(" system ");
  delay(2500);
```

```
  lcd.clear();
  displayCropName();
}

void loop() {

  unsigned long currentMillis = millis();  // current time
  // Task 1: Read sensor values
  if (currentMillis - previousMillis >= sensorInterval) {
    // Read sensor values
   moistu12 = moisture()/1.8;
   moistureValue = moistu12 - 28;
    temperatureValue = temperature() /2.3;
    ecValue = econduc()/23.7;
    pHValue = phydrogen() / 25;
    nitrogenValue = nitrogen();
    phosphorusValue = phosphorous();
    potassiumValue = potassium();
    previousMillis = currentMillis;
  }

  // Task 2: Check and handle button presses
  int buttonState1 = digitalRead(buttonPin1);
  int buttonState2 = digitalRead(buttonPin2);
  int buttonState3 = digitalRead(buttonPin3);  // New button state

  if (buttonState1 == LOW && currentMillis - buttonPress1Time > 300) {
    buttonPress1Time = currentMillis;
    currentCropIndex = (currentCropIndex + 1) % (sizeof(crops) / sizeof(crops[0]));
     displayCropName();
  }

  if (buttonState2 == LOW && currentMillis - buttonPress2Time > 300) {
    buttonPress2Time = currentMillis;
```

```
    analyzeSoilAndDisplay();
  }

  if (buttonState3 == LOW && currentMillis - buttonPress3Time > 300) {
    buttonPress3Time = currentMillis;
   displayLiveSensorData();// Call function to display live sensor data
  }

  // Task 3: Print sensor values
  if (currentMillis - printMillis >= printInterval) {
    // Print sensor values
    Serial.print(moistureValue);
    Serial.print(',');
    Serial.print(temperatureValue);
    Serial.print(',');
    Serial.print(ecValue);
    Serial.print(',');
    Serial.print(pHValue);
    Serial.print(',');
    Serial.print(nitrogenValue);
    Serial.print(',');
    Serial.print(phosphorusValue);
    Serial.print(',');
    Serial.println(potassiumValue);

    // Update last print time
    printMillis = currentMillis;
  }
}

void displayCropName() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Select Crop:");
```

```
  lcd.setCursor(0, 1);
  lcd.print(crops[currentCropIndex]);
}

void analyzeSoilAndDisplay() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Crop: ");
  lcd.print(crops[currentCropIndex]);

  lcd.setCursor(0, 1);
  lcd.print("N: ");
  if (nitrogenValue < npkRecommendations[currentCropIndex][0]) {
    lcd.print("Add ");
    lcd.print(npkRecommendations[currentCropIndex][0] - nitrogenValue);
    lcd.print(" mg/kg");
  } else {
    lcd.print("No");
  }

  lcd.setCursor(0, 2);
  lcd.print("P: ");
  if (phosphorusValue < npkRecommendations[currentCropIndex][1]) {
    lcd.print("Add ");
    lcd.print(npkRecommendations[currentCropIndex][1] - phosphorusValue);
    lcd.print(" mg/kg");
  } else {
    lcd.print("No");
  }

  lcd.setCursor(0, 3);
  lcd.print("K: ");
  if (potassiumValue < npkRecommendations[currentCropIndex][2]) {
```

```
  lcd.print("Add ");
  lcd.print(npkRecommendations[currentCropIndex][2] - potassiumValue);
  lcd.print(" mg/kg");
 } else {
  lcd.print("No");
 }
delay(3000);
lcd.clear();
 lcd.setCursor(0, 0);
 lcd.print("pH: ");
 if (pHValue < phRecommendations[currentCropIndex]) {
  lcd.print("Adj ");
  lcd.print(phRecommendations[currentCropIndex]);
 } else {
  lcd.print("No");
 }

 lcd.setCursor(0, 2);
 lcd.print("EC: ");
 if (ecValue < ecRecommendations[currentCropIndex]) {
  lcd.print("Adj ");
  lcd.print(ecRecommendations[currentCropIndex] - ecValue);
  lcd.print(" mS/cm");
 } else {
  lcd.print("No");
 }

 lcd.setCursor(0, 3);
 lcd.print("Temp: ");
 if (temperatureValue < temperatureRecommendations[currentCropIndex]) {
  lcd.print("Adj ");
  lcd.print(temperatureRecommendations[currentCropIndex]);
  lcd.print("C");
 } else {
```

```
    lcd.print("No");
  }

  lcd.setCursor(0, 1);
  lcd.print("Mois: ");
  if (moistureValue < moistureRecommendations[currentCropIndex]) {
    lcd.print("Adj ");
    lcd.print(moistureRecommendations[currentCropIndex]);
    lcd.print("%");
  } else {
    lcd.print("No");
  }
}
void displayLiveSensorData() {
  // Display live sensor data until the button is released
  while (digitalRead(buttonPin3) == LOW) {
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Live Sensor Data:");
    lcd.setCursor(0, 1);
    lcd.print("Moisture: ");
    lcd.print(moistureValue);
    lcd.print("%");
    lcd.setCursor(0, 2);
    lcd.print("Temperature: ");
    lcd.print(temperatureValue);
    lcd.print("C");
    lcd.setCursor(0, 3);
    lcd.print("EC: ");
    lcd.print(ecValue);
    lcd.print("mS/cm");
    delay(3000);
    lcd.clear();
    // Print NPK values
```

```
   lcd.setCursor(0, 0);
    lcd.print("pH:");
    lcd.print(pHValue);
    lcd.setCursor(0, 1);
    lcd.print("N:");
    lcd.print(nitrogenValue);
     lcd.print("mg/kg");
    lcd.setCursor(0, 2);
    lcd.print("P:");
    lcd.print(phosphorusValue);
      lcd.print("mg/kg");
     lcd.setCursor(0, 3);
    lcd.print("K:");
    lcd.print(potassiumValue);
      lcd.print("mg/kg");

    delay (1000); // Update display every second
  }
}
byte moisture () {
  // clear the receive buffer
  mod.flushInput();

  // switch RS-485 to transmit mode
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay (1);

  // write out the message
  for (uint8_t i = 0; i < sizeof(mois); i++) mod.write(mois[i]);
  // wait for the transmission to complete
  mod.flush();
  // switching RS485 to receive mode
  digitalWrite(DE, LOW);
```

```
  digitalWrite(RE, LOW);
  // delay to allow response bytes to be received!
  delay (200);
  // read in the received bytes
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values [4];
}

byte temperature () {
  // clear the receive buffer
  mod.flushInput();
  // switch RS-485 to transmit mode
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay (1);
  // write out the message
  for (uint8_t i = 0; i < sizeof(temp); i++) mod.write(temp[i]);
  // wait for the transmission to complete
  mod.flush();
  // switching RS485 to receive mode
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);

  // delay to allow response bytes to be received!
  delay (200);
  // read in the received bytes
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
```

```
  }
  return values[3]<<8|values[4];
}

byte econduc() {
  // clear the receive buffer
  mod.flushInput();
  // switch RS-485 to transmit mode
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay(1);
  // write out the message
  for (uint8_t i = 0; i < sizeof(econ); i++) mod.write(econ[i]);
  // wait for the transmission to complete
  mod.flush();
  // switching RS485 to receive mode
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);
  // delay to allow response bytes to be received!
  delay(200);
  // read in the received bytes
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values[4];
}

byte phydrogen() {
  // clear the receive buffer
  mod.flushInput();
  // switch RS-485 to transmit mode
  digitalWrite(DE, HIGH);
```

```
  digitalWrite(RE, HIGH);
  delay(1);
  // write out the message
  for (uint8_t i = 0; i < sizeof(ph); i++) mod.write(ph[i]);
  // wait for the transmission to complete
  mod.flush();
  // switching RS485 to receive mode
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);
  // delay to allow response bytes to be received!
  delay(200);
  // read in the received bytes
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values[4];
}

byte nitrogen() {
  // clear the receive buffer
  mod.flushInput();
  // switch RS-485 to transmit mode
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay(1);
  // write out the message
  for (uint8_t i = 0; i < sizeof(nitro); i++) mod.write(nitro[i]);
  // wait for the transmission to complete
  mod.flush();
  // switching RS485 to receive mode
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);
```

```
  // delay to allow response bytes to be received!
  delay(200);
  // read in the received bytes
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values[4];
}

byte phosphorous() {
  mod.flushInput();
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay(1);
  for (uint8_t i = 0; i < sizeof(phos); i++) mod.write(phos[i]);
  mod.flush();
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);
  // delay to allow response bytes to be received!
  delay(200);
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values[4];
}

byte potassium() {
  mod.flushInput();
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
```

```
  delay(1);
  for (uint8_t i = 0; i < sizeof(pota); i++) mod.write(pota[i]);
  mod.flush();
  digitalWrite(DE, LOW);
  digitalWrite(RE, LOW);
  // delay to allow response bytes to be received!
  delay(200);
  for (byte i = 0; i < 7; i++) {
    values[i] = mod.read();
    // Serial.print(values[i], HEX);
    // Serial.print(' ');
  }
  return values[4];
}
```

Program for NodeMCU:

```
#define BLYNK_TEMPLATE_ID "TMPL3I_kGh2wS"
#define BLYNK_TEMPLATE_NAME "air monitor"
#deine BLYNK_AUTH_TOKEN "mcVy-E0EahU0RkWGVbt2YWGGtCqgmMun"
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
char auth[] = "mcVy-E0EahU0RkWGVbt2YWGGtCqgmMun"; // Your Blynk authentication
token
char ssid[] = "VIVO"; // Your WiFi SSID
char pass[] = "1234567890"; // Your WiFi password
float float1, float2, float3, float4, float5, float6, float7;

void setup() {
   Blynk.begin(auth, ssid, pass);
  Serial.begin(9600);  // Set the baud rate to match the sender (Arduino)
  Serial.setTimeout(100);  // Set the timeout for Serial.readStringUntil
}
void loop() {
  Blynk.run();
  if (Serial.available() > 0) {
    // Read the incoming data until a newline character is received
    String receivedData = Serial.readStringUntil('\n');
   // Print the raw received data for debugging
    Serial.print("Raw Received Data: ");
    Serial.println(receivedData);
    // Process the received data
    processReceivedData(receivedData);
  }
   // Send sensor data to Blynk
  Blynk.virtualWrite(V0, float1); // Virtual pin V1
  Blynk.virtualWrite(V1, float2); // Virtual pin V2
  Blynk.virtualWrite(V2, float3); // Virtual pin V3
```

```
  Blynk.virtualWrite(V3, float4); // Virtual pin V4
  Blynk.virtualWrite(V4, float5); // Virtual pin V5
  Blynk.virtualWrite(V5, float6); // Virtual pin V6
  Blynk.virtualWrite(V6, float7); // Virtual pin V7
  delay(1000); // Adjust delay as needed
}

void processReceivedData(String data) {
  // Split the data into individual values based on the comma (',') separator
  int index = 0;
  // Loop to extract each value and store it in the respective variable
  for (int i = 0; i < 6; ++i) {
    // Find the next comma in the string
    index = data.indexOf(',');
    // Check if the comma is found
    if (index != -1) {
      // Extract each value and convert it to the float data type
      String valueString = data.substring(0, index);
      float floatValue = valueString.toFloat();

      // Store the float value in the respective variable
      switch (i) {
        case 0:
          float1 = floatValue;
          break;
        case 1:
          float2 = floatValue;
          break;
        case 2:
          float3 = floatValue;
          break;
        case 3:
          float4 = floatValue;
          break;
```

```
      case 4:
        float5 = floatValue;
        break;
      case 5:
        float6 = floatValue;
        break;
    }

    // Remove the processed value and the comma from the data string
    data = data.substring(index + 1);
  } else {
    // Print an error message if the comma is not found
    Serial.println("Error: Comma not found");
    return;
  }
}
float7 = data.toFloat();

// Use the stored float values as needed
Serial.print("Received Data - Float 1: ");
Serial.println(float1);
Serial.print("Received Data - Float 2: ");
Serial.println(float2);
Serial.print("Received Data - Float 3: ");
Serial.println(float3);
Serial.print("Received Data - Float 4: ");
Serial.println(float4);
Serial.print("Received Data - Float 5: ");
Serial.println(float5);
Serial.print("Received Data - Float 6: ");
Serial.println(float6);
Serial.print("Received Data - Float 7: ");
Serial.println(float7);
```

3.8 Project Milestones Achieved

Upon successful development and implementation of the "Smart Soil Monitoring for Precision Agriculture: Detecting Nutrient Deficiencies" system using Blynk Cloud and the specified software technologies, the following project milestones were achieved:

1. System Design and Architecture:
    - Finalized the system design and architecture, outlining the integration of Blynk Cloud, IoT devices, sensors, and data storage solutions.
    - Established the communication protocols, data flow, and interaction between different system components.

2. Sensor Integration and Data Collection:
    - Successfully integrated and calibrated soil sensors to measure key parameters such as nutrient levels (N, P, K), pH, EC, temperature, and moisture.
    - Implemented data collection mechanisms to gather real-time sensor readings and transmit data to Blynk Cloud for storage and analysis.

3. Blynk Cloud Setup and Configuration:
    - Set up and configured Blynk Cloud as the central IoT platform for device management, data visualization, remote control, and data storage.
    - Customized Blynk dashboards and user interfaces to display soil health metrics, trends, and alerts.

4. Alert Mechanism and Notification System:
    - Developed and implemented an alert mechanism to detect nutrient deficiencies based on predefined thresholds and sensor readings.
    - Integrated a notification system to send real-time alerts and notifications to farmers via the Blynk mobile application or SMS.

5. Remote Monitoring and Control Features:

- Implemented remote monitoring capabilities allowing farmers to access real-time sensor data, dashboards, and control features from anywhere using the Blynk mobile application or web interface.
- Enabled remote control of irrigation, fertilization, and other agricultural practices based on soil conditions and sensor readings.

6. Data Analysis and Visualization Tools Integration:
   - Integrated data analysis and visualization tools such as Python, R, or Tableau to process sensor data, derive insights, and generate interactive dashboards.
   - Developed algorithms and models to analyse soil health, identify trends, patterns, and anomalies, and provide actionable recommendations to farmers.

7. User Interface and Experience Enhancement:
   - Designed and developed intuitive and user-friendly interfaces for both web and mobile applications, ensuring easy navigation, data visualization, and control.
   - Implemented customizable settings and preferences to tailor the user experience according to individual farmer needs and preferences.

8. Testing, Validation, and Quality Assurance:
   - Conducted rigorous testing, validation, and quality assurance processes to ensure the reliability, accuracy, and performance of the system under various conditions and scenarios.
   - Addressed and resolved any identified issues, bugs, or discrepancies to optimize system functionality and user satisfaction.

By achieving these project milestones, the "Smart Soil Monitoring for Precision Agriculture" system has successfully laid the foundation for transforming modern agriculture, empowering farmers with advanced technology-driven solutions, and promoting sustainable and profitable farming practices.

Chapter 4

Future Scope of Work

1. Enhancements and Feature Expansion:

- Advanced Analytics and Insights:
  Incorporate machine learning algorithms to provide predictive analytics for soil health, crop growth, and yield forecasting. Implement AI-driven analytics to identify trends, patterns, and anomalies, offering actionable insights and recommendations to farmers.
- Multi-Crop Support:
  Extend the system's capabilities to support a broader range of crops, including fruits, vegetables, and cash crops, by adjusting nutrient recommendations and monitoring parameters.
- Integration with Agricultural Equipment:
  Partner with agricultural equipment manufacturers to integrate the system with smart irrigation systems, automated fertilizers spreaders, drones, and other precision farming equipment.

2. Scalability and Adaptability:

- Modular and Expandable Architecture:
  Design a flexible system architecture to accommodate additional sensors, devices, and technologies in the future without major reconfigurations.
- Cloud Integration and Data Management:
  Explore advanced cloud computing solutions and big data technologies to handle large-scale data storage, processing, and analysis for scalability and performance optimization.

3. User Experience and Accessibility:

- Localization and Multi-Language Support:

Implement multi-language support and localization features to cater to farmers from diverse linguistic backgrounds and regions.

- Enhanced Mobile Application Features:
  Develop additional features, such as offline access, geolocation-based recommendations, and voice-controlled commands, to enhance the mobile application's functionality and user experience.

4. Community Engagement and Collaboration:

- Farmers' Community Platform:
  Establish an online platform or community forum for farmers to share experiences, best practices, and insights related to smart soil monitoring and precision agriculture.
- Partnerships and Collaboration:
  Collaborate with agricultural research institutions, universities, and governmental organizations to foster research, innovation, and knowledge sharing in the field of smart agriculture.

5. Sustainability and Environmental Impact:

- Water Management and Conservation:
  Implement smart water management solutions and predictive analytics to optimize water usage, reduce wastage, and promote sustainable irrigation practices.
- Environmental Monitoring and Conservation:
  Expand the system's capabilities to monitor environmental factors, such as air quality, weather conditions, and climate change impacts, to promote environmental conservation and sustainability.

6. Market Expansion and Commercialization:

- Product Customization and Tailoring:
  Customize the product offerings and tailor the solutions according to the specific needs, preferences, and agricultural practices prevalent in different regions and markets.

Chapter 5

Conclusion

The IoT based soil fertility monitoring project is a groundbreaking initiative designed to transform precision agriculture by utilizing IoT technologies to monitor, analyze, and display real-time soil health data. The system empowers farmers with actionable insights, live data visualization, and deficiency information to optimize soil nutrient levels, water usage, and crop yield, thereby enhancing productivity, sustainability, and profitability.

Key Features:

- Real-Time Monitoring and Live Data Display: The system collects, analyzes, and displays live data on key soil parameters such as nutrient levels (N, P, K), pH, EC, temperature, and moisture using IoT sensors. Farmers can view real-time soil data through a mobile application and web-based dashboard, enabling them to monitor soil conditions continuously and make informed decisions.

- Soil Deficiency Detection and Alerts: Advanced machine learning algorithms and AI-driven analytics detect nutrient deficiencies, environmental factors, and potential issues, providing farmers with real-time alerts, notifications, and deficiency information. This enables prompt corrective actions and ensures optimal soil health and crop growth.

- User-Friendly Interface: The mobile application and web-based dashboard offer an intuitive user interface, providing farmers with easy access to real-time data, live soil deficiency information, insights, and control features from anywhere. This ensures seamless monitoring, management, and visualization of agricultural operations.

- Predictive Analytics: The system offers predictive insights and recommendations for optimal soil health and crop growth, leveraging advanced machine learning algorithms and AI-driven analytics. This enables farmers to anticipate soil nutrient requirements, plan fertilization strategies, and enhance overall agricultural productivity.

- Scalable and Modular Design: The flexible architecture of the system allows for seamless integration of additional sensors, devices, and technologies, ensuring scalability, adaptability, and future-proofing. This enables the system to evolve with technological advancements and meet the changing needs of the agricultural sector.

The IoT based soil fertility monitoring project is a comprehensive solution that embodies innovation, technology, and sustainability, aiming to empower farmers, transform agriculture, and contribute to a more sustainable and prosperous future for the agricultural sector with enhanced live soil data visualization capabilities.

Appendix

6.1 Data sheets

- Soil sensor data sheet

1. features

(1) The sensor is compact in size.

(2) High measurement accuracy, fast response and good interchangeability.

(3) It has good sealing performance and can be directly buried in the soil for use without corrosion.

(4) The influence of soil quality is small, and the application area is wide.

(5) Accurate measurement, reliable performance, ensuring normal operation, and high data transmission efficiency.

2. scope of application

It is suitable for temperature and humidity, electrical conductivity, and PH value testing in soil moisture monitoring, scientific experiments, water-saving irrigation, greenhouses, flowers and vegetables, grassland pastures, soil rapid testing, plant cultivation, sewage treatment, precision agriculture, etc.

3. Product information

3.1 Technical parameters

Measurement parameters: soil electrical conductivity (EC value), temperature, moisture, PH value, nitrogen, phosphorus and potassium

Measuring range: 0~20000μS/cm, -40~80℃, 0-100%, 3~9PH, 1-1999 mg/kg(mg/L)

Measurement accuracy: ±2%, ±0.5° C, ±2% within 0-50%, ±3% within 50-100%, ±0.3PH, ±2%FS

point identify Rate: 1μS/cm, 0.1℃, 0.1%, 0.1, 1 mg/kg(mg/L)

Output signal: RS485 (ModBus-RTU protocol)

Power supply voltage: 4.5 ~ 30V DC

Working range: - 30°C ~ 70°C

Stabilization time: 1 second after power on

Response time: < 1 second

3.2 Physical parameters

Probe length: 55mm , φ3mm

Probe material: 316L stainless steel

Sealing material: ABS engineering plastics, epoxy resin, waterproof grade IP68

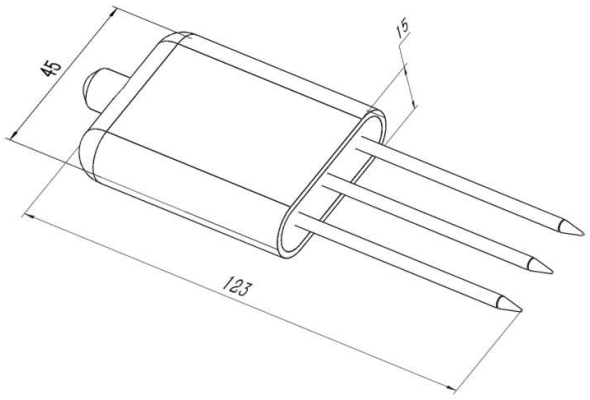
Cable specification: standard 2 meters (other cable lengths can be customized, up to 1200 meters)

Load capacity: voltage output: output resistance ≤ 250Ω; current output: ≤ 600Ω

3.3 Product selection

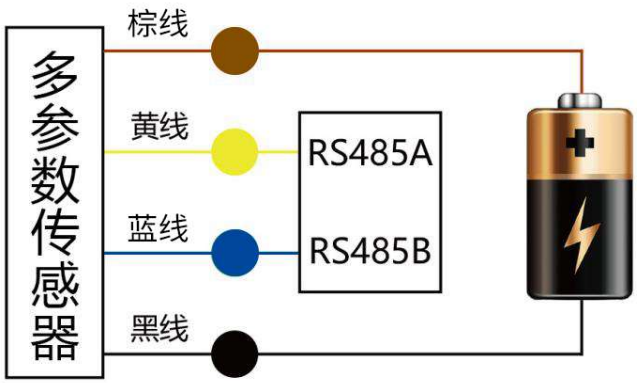
ZTS-					company code
	3001-				
		TR-			Soil Testing Housing
			TH NPK PH -		Temperature Moisture Nitrogen Phosphorus Potassium PH Transmitter
			ECTHNPKPH-		Conductivity Temperature Moisture Nitrogen Phosphorus Potassium PH Transmitter
			THPH-		Temperature Moisture pH Transmitter
			ECTHPH-		Conductivity Temperature Moisture PH Value Transmitter
				N01	RS485 (Modbus-RTU protocol)

4. Product information



5. Instructions

The soil conductivity sensor can be connected to various data collectors with differential inputs, data acquisition cards, remote data acquisition modules and other equipment. The wiring instructions are as follows:



6. Data conversion method

RS485 signal (default address 01):

Standard Modbus-RTU protocol, baud rate: 48 00; parity bit: none; data bit: 8 ; stop bit: 1

6.1 Modify address

For example: Change the address of the sensor with address 1 to 2, master→slave

original address	function code	start register high	start register low	start address high	low starting address	CRC16 low	CRC16 high
0 X 01	0 X 06	0X0 7	0X D 0	0X00	0X02	0 X08	0 X86

If the sensor is received correctly, the data will be returned in the same way.

Remarks: If you forget the original address of the sensor, you can use the broadcast address 0 XFF instead. When using 0 XFF , the master can only connect to one slave , and the return address is still the original address, which can be used as an address query method.

6.2 Query data

register address

register address	PLC or configuration address	content	operate	Definition
0000H	40001 (decimal)	moisture content	read only	Real-time value of moisture content (enlarged by 10 times)
0001H	40002 (decimal)	temperature value	read only	Temperature real-time value (enlarged by 10 times)
0002H	40003 (decimal)	Conductivity	read only	Conductivity real-time value
0003H	40004 (decimal)	PH value	read only	PH real-time value (enlarged ten times)
0004H	40005 (decimal)	nitrogen content	read only	Nitrogen content actual value
0005H	40006 (decimal)	Phosphorus content	read only	Phosphorus content actual value
0006H	40007(decimal)	potassium content	read only	Potassium content actual value
07D0H	42001 (decimal)	device address	read and write	1~254 (factory default 1)
07D1H	42002 (decimal)	Device baud rate	read and write	0 means 2400 1 for 4800 2 stands for 9600

Query the data of the conductivity temperature moisture PH value sensor (address 1), host → slave

address	function code	Start register address high	Start Register Address Low	high register length	low register length	CRC16 low	CRC16 high
0X01	0X03	0X00	0X00	0X00	0X04	0X44	0X09

If the sensor is received correctly, return the following data, slave → host

addr ess code	func tion code	return valid Bytes	Moisture value	temperat ure value	Conducti vity value	PH value	check code low byte	check code high byte
0x01	0x03	0x08	0x02 0x92	0xFF 0x9B	0x03 0xE8	0x00 0x38	0x57	0xB6

Temperature calculation:

When the temperature is lower than 0 ℃, the temperature data is uploaded in the form o complementary code.

Temperature: FF9B H(Hex)= -101 => Temperature= -10.1℃

Moisture calculation:

Moisture: 292 H (hexadecimal) = 658 => humidity = 65.8%, that is, the soil volume moistu content is 65.8%.

Conductivity calculation:

Conductivity: 3E8 H (hexadecimal) = 1000 Conductivity = 1000 us/cm

PH value calculation:

PH value: 38H (hexadecimal) = 56 => PH value = 5.6

7.Precautions for use

Police tell

⃠ Failure to follow the wiring sequence may cause damage to the device and the instrument connected to the device.

⃠ When the input power exceeds the maximum input power of the device, it will cause damage to the device.

Note meaning

⚠ Please read this manual completely before use.

⚠ Do not attempt to insert the probe into stones or hard clods as this may damage the probe.

⚠ Do not pull directly on the cable when moving the sensor out of the soil.

⚠ The sensor probe should be fully inserted into the soil / substrate to reduce operational errors and improve measurement accuracy.

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