Implementation of IoT for Environmental Condition Monitoring in Homes

EE 396
Design Laboratory

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Abstract

This project focuses on implementing an Internet of Things (IoT) system using NodeMCU, Several Sensors and ThingSpeak. The system enables remote control of an electrical circuit through a user interface accessible from a distance while ensuring secure access control. The project uses NodeMCU, an open-source IoT platform, to establish a connection between the circuit and the internet, ThingSpeak, an IOT analytics platform service, to store and retrieve data related to the circuit. Our goal is to develop a comprehensive environmental monitoring system that utilizes various sensors to continuously assess the quality of air, water, and soil. The system will provide real-time data through an intuitive mobile application called "Environmental Monitoring App." Users will be able to access detailed information about environmental conditions in their vicinity, empowering them to make informed decisions and take action to protect the environment and their health. The project demonstrates the potential of IoT technologies to enable remote control and monitoring of living quality of our surroundings. Overall, this project showcases the practical applications of IoT and its potential to enhance the way Environment was Monitored.

Contents

1 Introduction

This report presents an innovative application of Internet of Things (IoT) technology for environment monitoring, leveraging a diverse array of sensors including MQ135 for air quality detection, DHT11 for temperature sensing, DS18B20 for water temperature monitoring, soil moisture sensor, and Water TDS sensor. The core of the system utilizes the ESP32 microcontroller board to gather data from these sensors and transmit it to the cloud platform, Thingspeak.

The project aims to provide real-time monitoring of environmental parameters crucial for ensuring health and safety. By employing IoT principles, the system offers the flexibility of remote monitoring from anywhere with internet connectivity. The data collected from the sensors is uploaded to Thingspeak, a cloud-based IoT platform, where it is processed and visualized in a user-friendly format.

Furthermore, a custom-designed mobile application complements the system, providing users with convenient access to live environmental data on their smartphones. This application serves as a user interface, allowing individuals to monitor environmental conditions in real-time and receive alerts or notifications based on predefined thresholds.

The report delves into the intricacies of the hardware and software components, providing detailed insights into the design and implementation of the IoT environment monitoring system. It includes circuit diagrams, source code snippets, and discussions on the system's architecture.

In conclusion, this project exemplifies the practical applications of IoT technology in addressing environmental monitoring challenges. It not only showcases the integration of various sensors and microcontrollers but also demonstrates the seamless integration of cloud computing and mobile applications for real-time data visualization and accessibility. This report serves as a valuable resource for individuals interested in developing similar IoT solutions for environmental monitoring and management.

2 Theory

2.1 IoT

The term "Internet of Things" (IoT) has undergone significant evolution, driven by the convergence of various technologies including machine learning, embedded systems, and commodity sensors. IoT encompasses a network of interconnected devices, each assigned a unique identifier (UID), facilitating data transfer and device control across networks. It eliminates the need for direct human interaction to manage devices, representing an advanced form of automation and analytics. Leveraging networking, sensing, big data, and artificial intelligence, IoT enables the creation of comprehensive systems for products or services. These systems offer enhanced transparency, control, and performance across diverse industries and applications.

2.1.1 Features of IoT

IoT integrates algorithms, computation, software, and hardware to imbue intelligence. Ambient intelligence enhances IoT, enabling devices to intelligently respond and execute tasks. However, current smart technologies mainly facilitate device-to-device interactions, with user-device interactions relying on standard input methods.

Connectivity is key to IoT, enabling the interconnection of everyday objects and facilitating simple interactions, contributing to collective intelligence. This connectivity fosters accessibility and compatibility within the IoT network, creating new market opportunities.

IoT's core function lies in data collection from the environment, driven by dynamic changes in device states and contextual attributes like temperature and location. Device numbers also fluctuate dynamically based on factors such as individuals, places, and time.

2.1.2 Advantages of IOT

IoT enables Machine-to-Machine (M2M) communication, fostering transparency and efficiency by facilitating device connections. Centralized control via wireless infrastructure allows extensive automation and communication between machines, streamlining processes without human intervention.

Information plays a crucial role in decision-making across various domains, from everyday tasks like grocery shopping to strategic business decisions. Access to comprehensive information enhances understanding and decision-making capabilities.

2.2 WiFi

Wi-Fi, or Wireless Fidelity, facilitates wireless communication among devices on LANs without physical cables. Its widespread use spans internet access, local networking, and various industries. Moreover, Wi-Fi enables IoT applications like smart homes, where devices communicate wirelessly within networks. Leveraging Wi-Fi, the ESP32 module ensures efficient cloud communication, enabling remote monitoring and control of home environments from anywhere with internet access.

2.3 Air Quality

Air quality monitoring plays a pivotal role in ensuring the well-being of individuals and the environment. Utilizing sensors such as the MQ135 and DHT11 provides valuable insights into key parameters influencing air quality.

The MQ135 gas sensor, renowned for its sensitivity to a variety of harmful gases including ammonia, benzene, and carbon monoxide, offers real-time detection capabilities crucial for assessing indoor and outdoor air quality. By continuously monitoring the concentration of these gases, the sensor aids in identifying potential health hazards and pollution sources, enabling timely interventions to mitigate risks.

Complementing the MQ135, the DHT11 temperature and humidity sensor contributes essential data points for comprehensive air quality assessment. By monitoring temperature and humidity levels, the DHT11 provides insights into environmental conditions that influence air quality, such as moisture content and thermal comfort. This data aids in understanding the dynamics of pollutant dispersion and the impact of climatic factors on air quality fluctuations.

Integration of the MQ135 and DHT11 sensors into air quality monitoring systems enhances the precision and scope of data collection, facilitating informed decision-making and proactive measures to safeguard public health and environmental sustainability. Whether deployed in indoor environments, urban areas, or industrial sites, these sensors offer valuable insights into air quality dynamics, empowering stakeholders to address pollution challenges effectively.

2.4 Water Quality

Water quality monitoring is critical for ensuring the safety of water sources and the well-being of communities. Leveraging sensors such as the DS18B20 and TDS sensor provides comprehensive insights into key parameters influencing water quality.

The DS18B20 temperature sensor serves as a fundamental component in water quality monitoring systems, offering precise measurements of water temperature. Temperature plays a crucial role in determining water quality, influencing factors such as dissolved oxygen levels, chemical reactions, and microbial activity. By continuously monitoring water temperature, the DS18B20 sensor aids in detecting deviations from optimal conditions, which can indicate potential sources of contamination or ecological stress.

In conjunction with the DS18B20, the TDS (Total Dissolved Solids) sensor plays a vital role in assessing water quality by measuring the concentration of dissolved ions and organic compounds. TDS is a key indicator of water purity, reflecting the presence of substances such as salts, minerals, and organic matter. High TDS levels can indicate contamination from industrial effluents, agricultural runoff, or natural sources, posing risks to human health and aquatic ecosystems. By monitoring TDS levels, the sensor enables timely detection of water quality issues and facilitates appropriate remedial actions to safeguard water resources.

Integration of the DS18B20 and TDS sensors into water quality monitoring systems enhances the accuracy and comprehensiveness of data collection, enabling stakeholders to assess water quality parameters with precision. Whether deployed in drinking water treatment plants, freshwater bodies, or aquaculture facilities, these sensors provide valuable insights into water quality dynamics, empowering decision-makers to implement effective management strategies and ensure access to safe and clean water for all.

2.5 Soil Qulaity

Monitoring soil quality is essential for sustainable agriculture, environmental conservation, and land management practices. The soil moisture sensor emerges as a valuable tool in this endeavor, providing critical insights into soil water content and dynamics.

The soil moisture sensor offers real-time measurements of soil moisture levels, a key determinant of soil quality and fertility. Optimal soil moisture levels are vital for supporting plant growth, nutrient uptake, and microbial activity, while excessive moisture or drought conditions can adversely affect soil structure, nutrient availability, and crop productivity. By continuously monitoring soil moisture content, the sensor enables farmers and land managers to make informed irrigation decisions, optimizing water use efficiency and mitigating the risk of waterlogging or drought stress.

Moreover, the soil moisture sensor plays a crucial role in assessing soil health and environmental sustainability. Changes in soil moisture levels can indicate soil erosion, compaction, or degradation, highlighting areas requiring conservation efforts or soil restoration interventions. Additionally, monitoring soil moisture dynamics facilitates the evaluation of land use practices, such as crop rotation, cover cropping, and agroforestry, in maintaining soil health and mitigating the impacts of climate change.

Integration of soil moisture sensors into precision agriculture and environmental monitoring systems enhances the accuracy and efficiency of soil quality assessment. Whether deployed in agricultural fields, forestry plantations, or ecological restoration projects, these sensors provide valuable data for optimizing land management practices, conserving natural resources, and promoting sustainable development.

Overall, the soil moisture sensor emerges as a versatile tool for assessing soil quality, supporting informed decision-making, and fostering resilient agricultural and environmental systems. Its integration into soil monitoring networks contributes to the advancement of sustainable land management practices and the preservation of soil health for future generations.

3 Components Used

Following components were used in making of this project.

1. NodeMCU

Microcontroller	ESP32 12-bit
Clock Speed	80 Mhz - 240 Mhz
Operating Voltage	3.3 V
Flash	4MB
RAM	320KB

2. DHT11
3. MQ135
4. DS18B20
5. TDS Sensor
6. Soil Moisture Sensor
7. Jumper Wires
8. Breadboard
9. Connecting Wires

4 Brief Description of Tools

4.1 Hardware

4.1.1 NodeMCU

The NodeMCU, an economical and open-source IoT platform, was originally designed around the ESP8266 Wi-Fi SoC from Espressif Systems, utilizing firmware and hardware built upon the ESP-12 module. Over time, it expanded to support the ESP32 32-bit MCU.

Both the NodeMCU firmware and prototyping board designs are open-source. The firmware, employing Lua scripting language, originates from the eLua project and is constructed on Espressif's Non-OS SDK for ESP8266, incorporating various open-source projects like luacjson and SPIFFS. Owing to resource constraints, users need to select relevant modules for their projects and customize the firmware accordingly. Furthermore, support for the ESP32 has been included.

The prototyping hardware typically consists of a dual in-line package (DIP) circuit board that integrates a USB controller with a smaller surface-mounted board containing the MCU and antenna. This DIP format facilitates convenient prototyping on breadboards. Originally built around the ESP-12 module of the ESP8266, which boasts a Wi-Fi SoC with a Tensilica Xtensa LX106 core, NodeMCU boards generally comprise these two primary components.

4.1.1.1 ESP32

At the heart of this module lies the ESP32 chip, renowned for its scalability and adaptability. Featuring two independently controllable CPU cores, it offers adjustable clock frequencies ranging from 80 MHz to 240 MHz, along with support for real-time operating systems (RTOS). Serving as a versatile Wi-Fi+BT+BLE MCU module, the ESP-WROOM-32s integrates traditional Bluetooth, Bluetooth Low Energy (BLE), and Wi-Fi functionalities.

With its broad utility, Wi-Fi enables diverse communication connections, including direct internet access via routers, while Bluetooth facilitates connections to mobile phones and enables BLE Beacon broadcasting for signal detection. Supporting data rates of up to 150 Mbps and boasting an antenna output power of 20 dBm, this module ensures optimal wireless communication performance. With industry-leading specifications, it excels in high integration, wireless transmission range, power efficiency, and network connectivity.

4.1.1.2 Development Board

The NodeMCU development board serves as a hardware platform tailored to simplify the prototyping and development of IoT projects utilizing the ESP8266 Wi-Fi module. Below are key details about the NodeMCU development board:

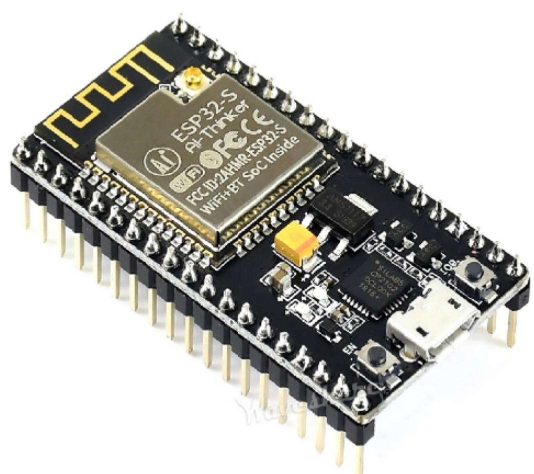

Figure 1: NodeMCU Development Board

1. Form Factor: The NodeMCU development board typically adopts a compact rectangular form, typically measuring approximately 4.4 cm x 2.6 cm. This diminutive size renders it ideal for breadboard prototyping or integration into compact IoT devices.

2. Microcontroller: The NodeMCU development board features an embedded microcontroller unit (MCU) within its ESP32 Wi-Fi module. This module integrates a 12-bit Node MCU with a Wi-Fi module, offering a robust and highly-integrated chip capable of supporting various functionalities for IoT applications.

3. Power Supply: The NodeMCU development board commonly operates with a 3.3V DC power supply, obtainable via either the micro USB port or the VIN pin. Typically, voltage regulators are integrated into the board to ensure a consistent power supply to the ESP32 module and any other connected components.

4. USB-to-Serial Converter: The NodeMCU development board often incorporates a USB-to-serial converter, enabling programming and debugging of the ESP32 module via a computer using the micro USB port.

5. GPIO Pins: The NodeMCU development board commonly features multiple GPIO (General Purpose Input/Output) pins, facilitating the connection of sensors, actuators, and other electronic components to interface with the ESP32 module. These pins enable users to control external devices or gather data from sensors, serving as a vital link between the ESP32 module and the physical world in IoT projects.

6. LEDs and Buttons: In addition, the NodeMCU development board might integrate built-in LEDs and buttons to facilitate testing and debugging. These LEDs serve to convey the board's status or offer visual feedback, while the buttons enable user input or trigger specific actions within IoT applications.

7. Breadboard-Friendly: The NodeMCU development board is typically crafted with a breadboard-friendly design, featuring pin headers that seamlessly fit into standard breadboards for prototyping. This user-friendly design allows for easy experimentation with various circuit configurations and effortless connection to other electronic components.

8. Community Support: NodeMCU boasts a vibrant and engaged community comprising developers, makers, and enthusiasts who offer extensive support, documentation, and examples for utilizing the NodeMCU development board. This collaborative ecosystem simplifies the process of accessing resources, tutorials, and troubleshooting assistance for NodeMCU projects.

4.2 Software

- Arduino IDE(For Esp32)
- Android Studio(For Mobile Application)
- ThingSpeak (For Uploading and Fetching Data)

5 Work Done

5.1 Sensing Humidity and Temperature of air

For this purpose, we utilized a 'DHT11 sensor,' featuring a resistance based humidity measurement component and an NTC temperature measurement component. This sensor interfaces with a high-performance 8-bit microcontroller, ensuring quality, cost-effectiveness ,rapid response, and strong anti-interference capabilities. Each DHT11 unit undergoes precise laboratory calibration, ensuring high accuracy in humidity measurements. Calibration coefficients are stored as programs in the sensor's OTP memory, utilized during its internal signal detection process. With a single-wire serial interface, integration into systems is seamless and swift. Its compact size, low power consumption, and ability to transmit signals up to 20 meters make it ideal for diverse applications, even the most demanding ones. The component comes in a 4-pin single-row pin package.

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50℃	±5% RH	±2℃	1	4 pin Single Row

Figure 2: Technical Specifications

The power supply for the DHT11 ranges from 3 to 5.5 volts DC. Communication between the microcontroller (MCU) and DHT11 sensors occurs through a single-bus data format, ensuring synchronization. Each communication cycle lasts approximately 4 milliseconds. Data transmission comprises both decimal and integral parts, totaling 40 bits in a complete transmission. The sensor prioritizes the transmission of higher data bits.

Figure 3: DHT11

The data structure comprises 8 bits dedicated to the integral relative humidity (RH) data, succeeded by another 8 bits for the decimal RH data. Following this, there are 8 bits allocated for the integral temperature (T) data, followed by 8 bits for the decimal T data. Lastly, there are 8 bits reserved for the checksum, which is calculated by summing up the preceding data bytes. At first, the Data Single-bus maintains a high voltage level, signifying its idle state. When the MCU initiates communication with the DHT11, it lowers the voltage level of the Data Single-bus from high to low, ensuring the DHT11 registers the signal from the MCU. This transition must occur over a minimum of 18 milliseconds to enable the DHT11 to recognize the signal alteration. Following this, the MCU raises the voltage and awaits the DHT11's response for a duration of 20-40 microseconds.

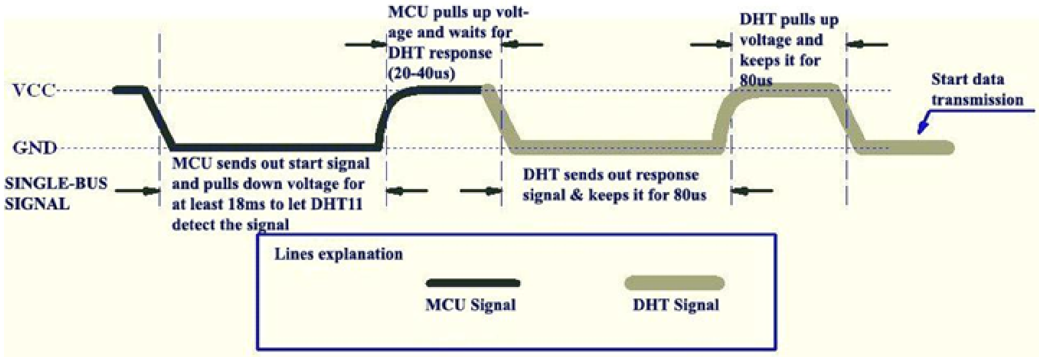

Figure 4: Overall Communication Process

Once the start signal is detected, the DHT11 produces a response signal characterized by a low-voltage level lasting 80 microseconds. The drop in the DATA Single-Bus voltage level signifies the transmission of this response signal by the DHT11. Subsequently, the DHT11 increases the voltage level, sustaining it for 80 microseconds to ready itself for data transmission.

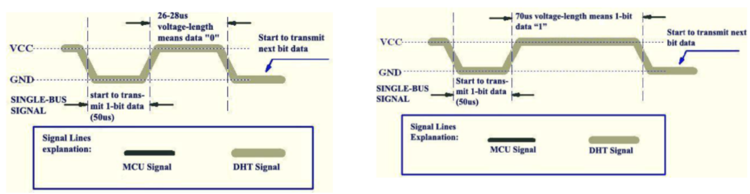

Figure 5: Data 0 and Data 1 Indication

In the course of data transmission from the DHT11 to the MCU, each data bit begins with a low-voltage level lasting 50 microseconds. The duration of the subsequent high-voltage level signal indicates whether the data bit signifies "0" or "1". Once the final data bit is transmitted, the DHT11 decreases the voltage level for 50 microseconds. Following this, the resistor pulls up the single-bus voltage, returning it to the idle state.

5.2 Detecting Amount of Co2 in air

The MQ-135 sensor, based on SnO2 semiconductor, detects gases like CO, CO2, Ethanol, NH4, Toluene, and Acetone in the air. It features a digital pin for standalone operation or integration with a microcontroller, facilitating targeted gas detection. The analog pin measures gas concentrations in PPM, compatible with most microcontrollers operating at 5 volts TTL.

Working $\rightarrow$ Comprising Tin Dioxide (SnO2), the MQ-135 Gas sensor exhibits heightened conductivity in the presence of targeted pollutants, correlating with gas concentration. By employing a straightforward circuit, we can translate the conductivity variation into an output signal reflecting gas concentration. Notably sensitive to NH3, S2, and C6H6 series vapors, the MQ-135 sensor effectively monitors smoke and various toxic gases, enabling the detection of a wide range of hazardous substances. Before MQ sensors can operate, they require a pre-heating period to warm up, typically lasting from 30 seconds to a few minutes. Upon powering up the module, the power LED illuminates, indicating the need to keep the module in this state until the pre-heating duration concludes.

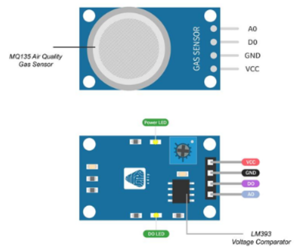

Figure 6: MQ 135

Pin Configurations →

- VCC: Used to provide power (5V) to the Sensor.
- GND: Use to connect ot the Ground.
- DO: The MQ135 gas sensor module is equipped with a digital output pin, offering both analog and high/low digital signals. Its sensitivity is adjustable via a built-in 10k potentiometer. Upon detection of harmful gases, the digital pin transitions from logic HIGH to logic LOW (0V), activating an indicator LED (D0). With the assistance of the onboard LM393 Op-Amp Comparator IC, the module operates autonomously, enabling easy sensitivity adjustment without an external microcontroller. This streamlined configuration facilitates prompt gas detection feedback, as the digital pin can directly control peripherals like buzzers or LEDs through basic transistor circuits.
- AO: The sensor features an analog output pin that provides analog data, enabling measurement of the PPM value of the targeted gas. Utilizing an external microcontroller, the analog voltage value is measured and analyzed to determine the ratio of Rs/Ro, where Rs represents the sensor resistance in the presence of gas, and Ro represents the sensor resistance in clean air.

Specifications →

- Input Voltage: 2.5V - 5.0V
- Current: 150 mA
- Gas Detected: Alcohol, NH3, Smoke, No2, CO2, Benzene
- Analog Output: 0-5V

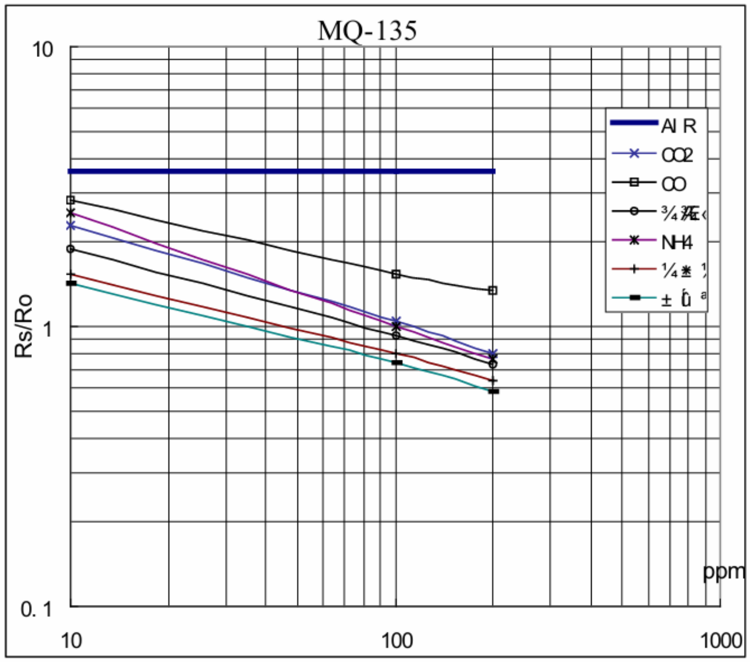

Figure 7: sensitivity characteristics of MQ-135 for several gasses.

5.3 Measuring the total amount of dissolved solids, like salts, minerals, and metals, in a solution

The TDS value of water is measured with the Analog TDS Sensor. Following are the sensor parameters:

- DC Input Voltage: 3.3-5.5V
- Output Voltage: 0-2.3V
- Current Value: 3-6 mA
- Device Range: 10 - 1000 ppm
- Device Accuracy: ± 10 %

The AC signal is used as the excitation source which serves multiple purposes:

- it helps to prevent probe polarization, thus prolonging the probe's lifespan.
- it contributes to enhancing the output signal strength.

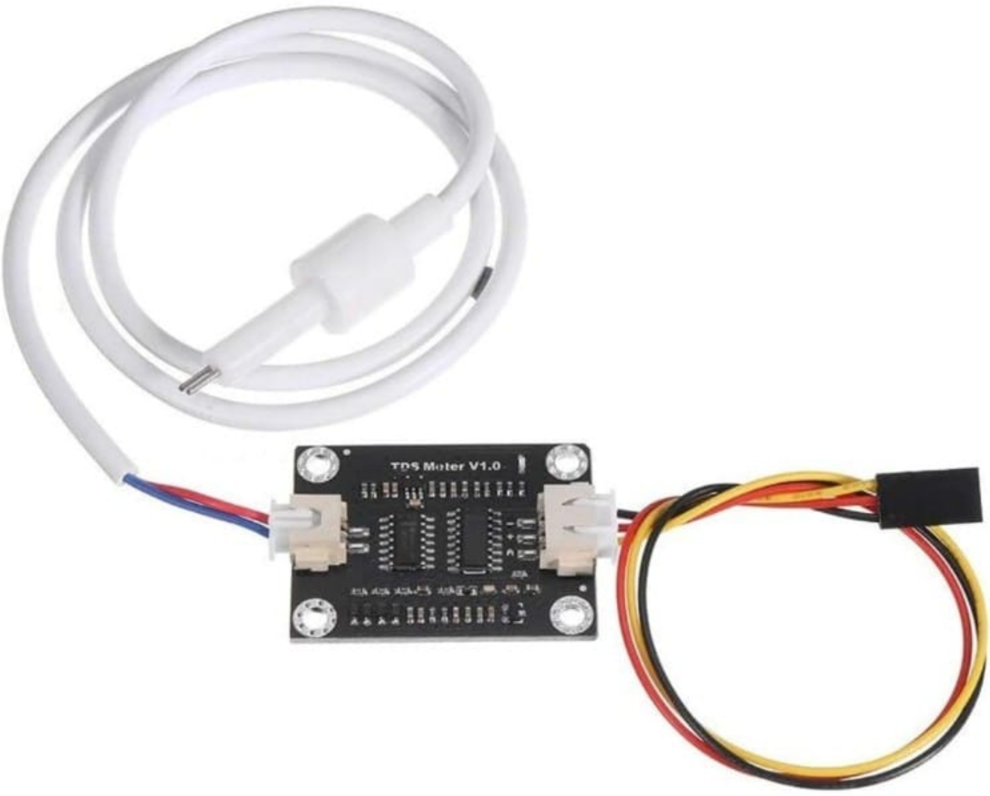

Figure 8: TDS Sensor

Total Dissolved Solids (TDS) reflect water's conductivity, serving as an indicator of dissolved mineral concentration. Increased mineral dissolution corresponds to heightened water conductivity. TDS meters are calibrated to measure in parts per million (ppm), representing the solution's total weight of dissolved solids. Electrical conductivity, crucial for ion transport, measures a solution's capacity to conduct current. While all ions influence conductivity, their varying valences impact actual and relative concentrations, affecting conductivity. Higher ion concentrations result in greater conductivity and lower electrical resistance. TDS meters essentially function as conductivity meters, employing voltage application across electrodes. Negatively charged ions migrate towards the positive electrode, while positive charged ions move towards the negative electrode, constituting an electrical current. The meter gauges ion concentration by monitoring the current flow between electrodes.

The measure of conductivity, expressed in μ S/cm, is converted to ppm using a conversion factor typically ranging from 0.47 to 0.55, directly related to the conductivity level. Ion conductivity in water is influenced by temperature, with ions moving faster at higher temperatures, thereby increasing apparent conductivity. To address this, we incorporate temperature measurements alongside conductivity readings. The code adjusts the values to reflect the conductivity at a standard temperature of 25°C, ensuring accuracy despite temperature variations.

5.4 Detecting Water Temperature

We used a DS18B20 temperature sensor for this purpose. This sensor is a programmable and digital temperature sensor.
The specifications of the sensor are as follows:

- Power supply : 3.0V – 5.5V
- Output resultant temperature: -55°C to +125°C(-67°F to +257°F)
- Accuracy: ±0.5°C
- o/p resolution: 9-bit to 12-bit

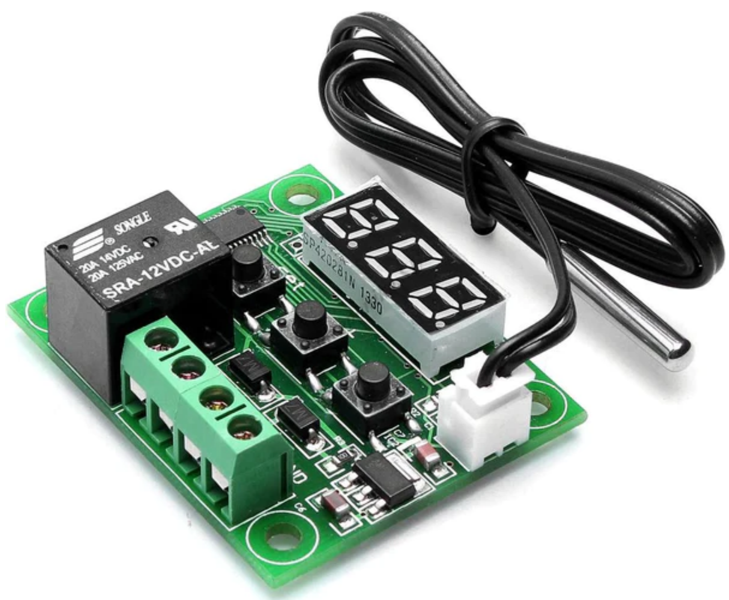

Figure 9: DS 18B20 Water Temperature Sensor

These sensors are available in various forms, such as SOP and To-92 packages, and there are also waterproof versions accessible. The temperature sensor works in two modes depending upon how the power is supplied to it:

- External Power Supply
- Parasite Power Supply.

In our circuit, we've employed an external power source. Which means, we supply power to the DS18B20 using traditional means like a battery or an adapter. This technique is suitable for temperatures under +100 degrees Celsius.Connection diagram of the device in external mode is given below:

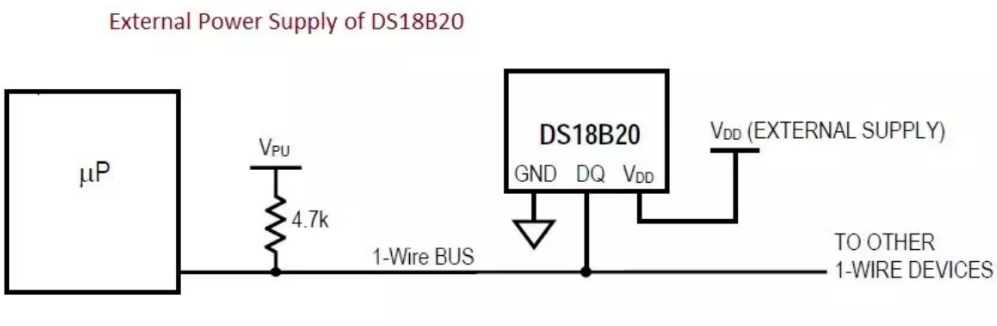

Figure 10: Connection Diagram

It operates by directly converting temperature into a digital value. One of its key characteristics is adjusting its bit numbers in response to temperature fluctuations. For example, it alters between 9 to 12 bits as the temperature shifts in increments of 0.5°C to 0.0625°C respectively. While its default bit value is set at 12, it dynamically adjusts these values based on changes in temperature.

5.5 Measuring Moisture Content of soil

Two types of soil sensor are available in market:

- Resistive Type Soil Moisture sensor
- Capacitive Type Soil Moisture sensor

We have used resistive type soil moisture sensor for our project.These sensors function by detecting the impact of soil moisture on electrical resistance to estimate moisture levels. The sensor typically consist of a fork-shaped probe with two exposed conductors that are placed into the soil or the area where moisture levels need to be assessed. Similar to a potentiometer, the sensor acts as a variable resistor, with its resistance depending on the moisture content of the soil. This resistance demonstrates an inverse relationship with soil moisture:

- High soil moisture means,it will have better conductivity and thus low resistance.
- Low soil moisture means,it will have less conductivity and thus highresistance.

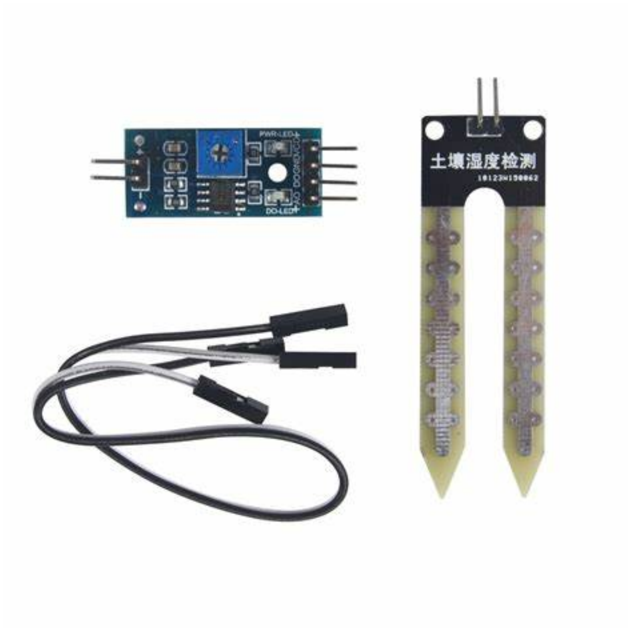

Figure 11: Soil Sensor to measure Moisture Content

Its Operating voltage is between 3.3V-5V. The module calculates voltage between the probes according to the electrical resistance in the probe, which can be accessed through an Analog Output (AO) pin. This signal is also transmitted to an LM393 (High Precision Comparator), where it is converted into digital format and accessible through a Digital Output (DO) pin.

5.6 Snapshot of Circuit

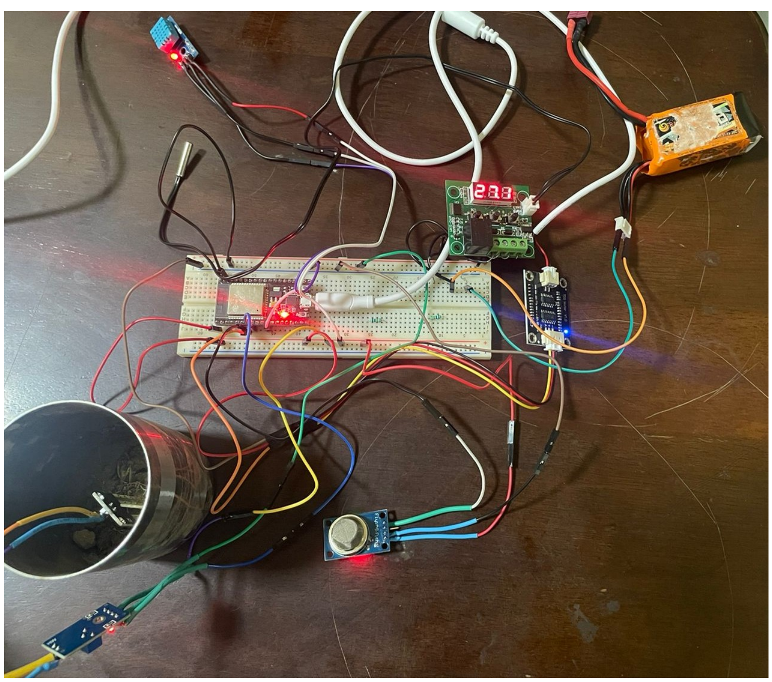

Figure 12: circuit snapshot

6 Results

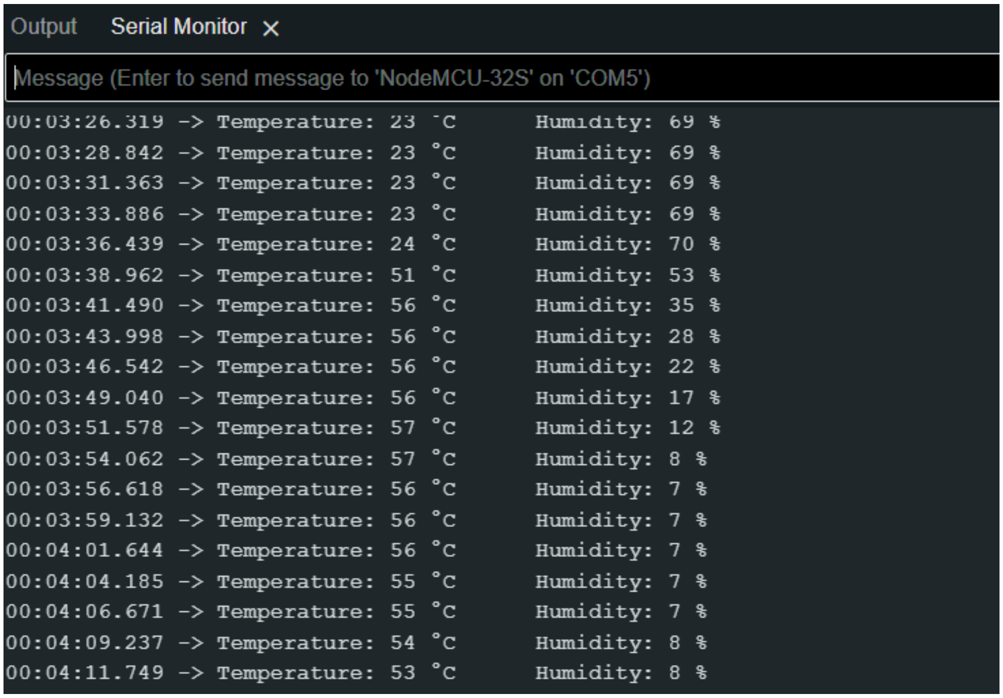

Figure 13: DHT 11 Readings in varied conditions

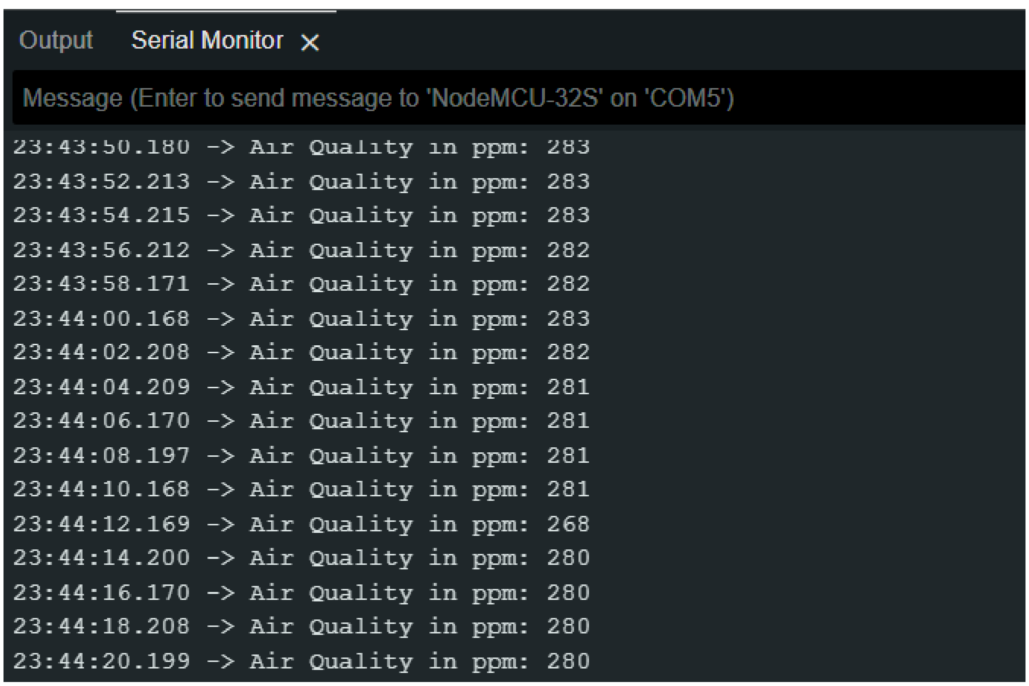

Figure 14: MQ 135 Readings at normal conditions

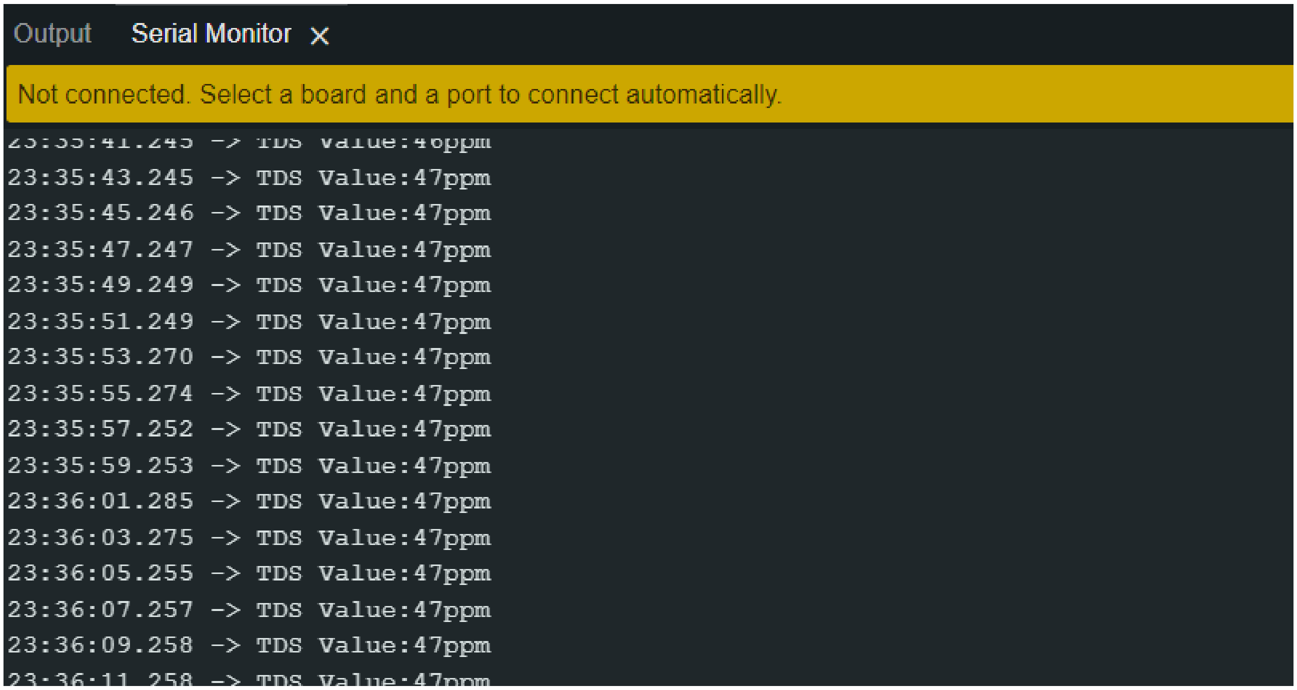

Figure 15: TDS value of Tap Water

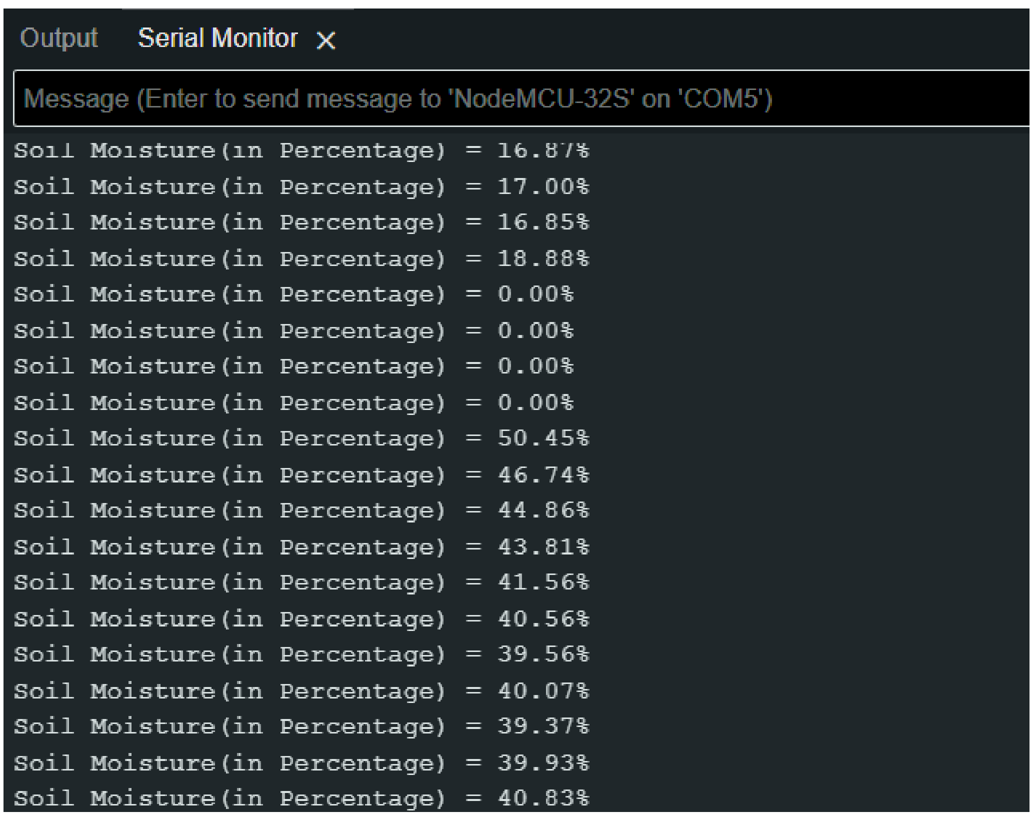

Figure 16: Soil Moisture content in varied Conditions

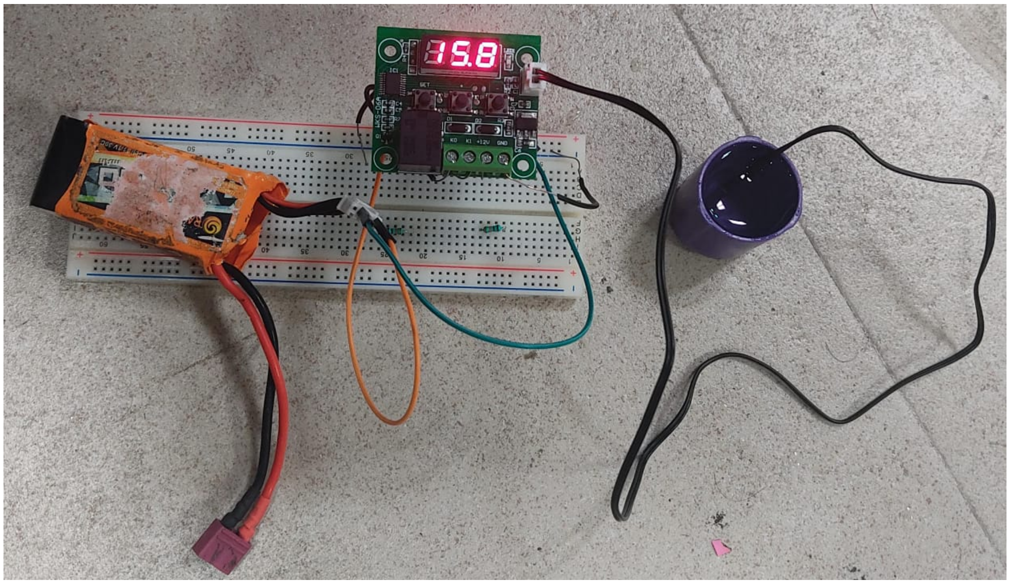

Figure 17: DS18B20 Reading of cold water

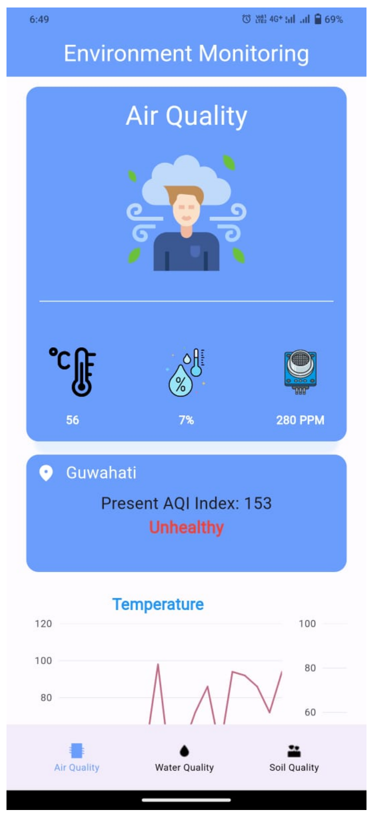

Figure 18: Snapshot of app displaying air quality

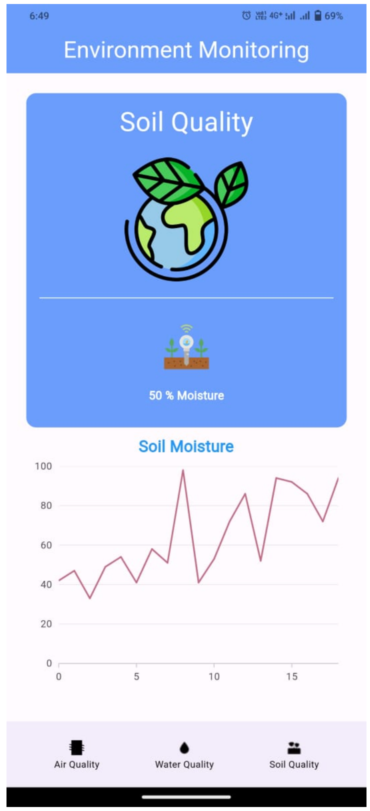

Figure 19: Snapshot of app displaying soil quality

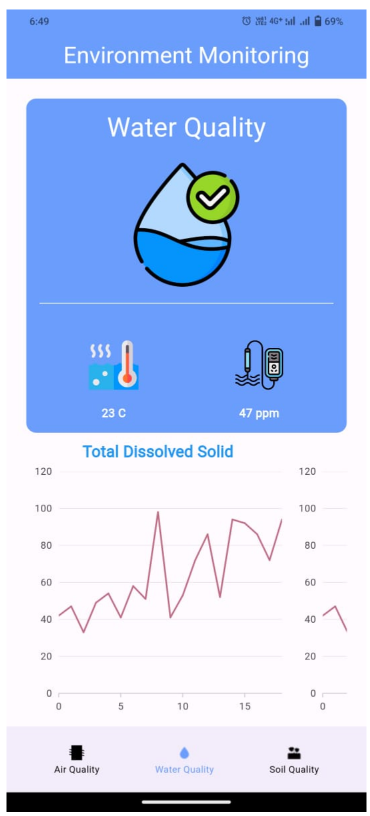

Figure 20: Snapshot of app displaying water quality

7 Program Code

7.1 Arduino Code

Code is uploaded on GitHub
https://github.com/Ashutosh-777/Environment-Monitoring/blob/master/Design%20Lab.ino

7.2 Flutter Code for Mobile App

Code is uploaded on GitHub
https://github.com/Ashutosh-777/Environment-Monitoring

8 Discussion

8.1 Applications

1. Agrotech: Our project can be used as a part of the agricultural weather monitoring system. This will help farmers collect and analyze information about various conditions required to grow crops such as temperature, humidity, soil moisture,etc.

2. Manufacturing Industry: A lot of Manufacturing processes depends on the weather condition. Using this device can help businesses ensure that their production takes place in the best weather conditions.

3. Intelligent home automation system: The project can be used as a part of human automation system which will alter the settings of devices at home according to residents preference.The device can act as feedback mechanism of this system which provides current environment conditions and devices our set accordingly.

8.2 Cost Analysis

Sr. No.	Component	Quantity	Price
1	ESP32 S	1	550
2	DHT11	1	250
3	Breadboard	2	220
4	MQ135	1	350
5	TDS Sensor	1	850
6	DS 18B20	1	150
7	Soil Sensor	4	120
8	Current Sensor	1	150
9	Jumper Wires		110
10	Data Cable	1	130
Total			2750

8.3 Limitations

1. Proper internet connectivity is required for the project to function effectively. Without a stable and reliable internet connection, the project may experience disruptions or failures.

2. All the sensors are calibrated according to a specific environment.For using this device at some other place, the sensors will be needed to calibrate again and again.

3. The sensors used are not high precision sensors,thus the data received might have some small errors.But it can be used to check relative quality.

8.4 Future Scope

1. ML models can be trained using data collected by this device and algorithms can be designed by considering current weather conditions and long term climate trends.This will result in early warnings, helping farmers to prevent potential risk and also schedule their crops accordingly. .

2. An alarm can be added to the circuit to notify the user in case of extreme conditions.

References

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