Design a pH Meter Using Arduino

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Abstract — **Background: Accurate pH measurement is vital in diverse settings such as water quality assessment, food production, and laboratory procedures. This study introduces a pH meter design utilizing the Arduino platform, a cost-effective and user-friendly open-source electronic platform.**

Objective: To develop and test an Arduino-powered pH meter that displays a solution's pH accurately on a liquid crystal display (LCD).

Methods: The design is based on a pH sensor, which measures the pH by detecting voltage differences between reference and pH electrodes. These values are then shown on an LCD managed by the Arduino board. Calibration and verification of the device's accuracy were conducted using buffer solutions with known pH values.

Results: The Arduino-centric pH meter proved to be both practical and reliable, with a maximum inaccuracy of only 0.1 pH. It provided accurate readings within the pH range of 4.0 to 9.0.

Conclusion: Arduino-driven pH meters offer an efficient, affordable, and simple means for pH measurements across various applications. Given its proven precision and reliability, this design can be applied in any scenario demanding pH value determinations.

I. INTRODUCTION

A substance, solution, or object's pH value may express its acidity or basicity. A pH of 7 is neutral, and if the value of the material is more than seven or less than 7, it is alkaline or acidic, respectively. The most alkaline solution has a pH of 14, whereas the most acidic has a pH of 0. Litmus paper, which glows red at high acidity and blue at low, is a standard, inexpensive indicator. The acidity or basicity of a solution may be measured using a pH meter or specialized laboratory equipment. The electrodes in pH meters function as the meters' sensors or detectors. Since the bulb at the bottom of most electrodes—a particularly delicate component—requires careful cleaning with soft tissue paper rather than bare hands [1], electrodes are often constructed of glass. The outputs of a pH meter are digital numbers with exact values, making it far more convenient than using litmus paper to determine pH levels. One way to indicate the degree of acidity or alkalinity of a solution is by its pH value.

In 1909, a Danish scientist discovered the principle that forms the foundation for pH measurement – the electrochemical potential difference between a known solution within the glass electrode (glass membrane) and an unknown solution outside the glass electrode. The difference in potential is used to measure the quantity of hydrogen ions, which is also called the potential of hydrogen. This is done by observing how the small, active hydrogen ions interact with the thin layer of glass drops. Scientists use this electrical potential difference to figure out the pH of a solution.

Scientists use the electrical potential difference between the fluid within the glass electrode and the solution outside the glass electrode to determine pH. The interaction of the glass electrode with the thin layer of glass bubbles and the tiny, active hydrogen ions allows for the determination of hydrogen i electrical potential.

In order to complete the electrical circuit, a complementary electrode is essential, and the device specifically monitors voltage, not current [2]. This methodology of pH measurement using the glass electrode and electrical potential difference has become a widely used and reliable approach in various scientific and industrial applications.

The "Microcontroller Based ATmega 8535" pH Meter [3] was developed by the Department of Electromedical Engineering at the Surabaya Ministry of Health Polytechnic. This pH meter uses the ATmega 8535 microcontroller as both the data processor and internal storage. However, it requires correction for sample temperature influence. Previous article showed variety of drawbacks, including the need for a temperature sensor, dependency on the ATmega microcontroller for processing information, the lack of onboard memory, and the absence of batteries [4].

To address these issues, the author proposes building a new gadget capable of monitoring pH and temperature in a sample using an Arduino Uno microcontroller [5], [6]. The new design incorporates internal storage and a power supply in the form of batteries, addressing the limitations encountered in previous projects. This improved pH meter seeks to provide accurate and reliable measurements of pH and temperature for various applications.

A. *The Aim of the Article*

The aim of this project is to design a pH meter using an Arduino microcontroller that can accurately measure the acidity or basicity of a solution.

To achieve this aim, the project has several objectives. First, we need to develop a pH meter using an Arduino microcontroller. This will involve designing a circuit that connects the pH sensor to the Arduino and programming the microcontroller to read the pH sensor's output accurately.

Next, we'll need to calibrate the pH meter using standard pH solutions. Calibration is crucial to ensure the accuracy and precision of the pH measurement. Once the pH meter is calibrated, we'll display the pH value on an LCD display, making it easy to read and interpret.

To ensure the accuracy and precision of the pH measurement, we'll design the circuit to minimize noise and interference. We'll also test the pH meter with various solutions to evaluate its performance.

Finally, we'll make the design portable and easy to use so that it can be used in various applications. Whether you're monitoring the pH of a swimming pool or testing the acidity of soil, an Arduino-based pH meter can be a useful tool.

B. *Problem Statement*

The study focuses on the issue of requiring a cost-effective and easily obtainable pH measuring solution for diverse applications, including agriculture, hydroponics, and water quality assessment. Traditional pH meters are often characterized by their high cost and unwieldy nature, which might limit their accessibility to individuals such as hobbyists, students, and small-scale consumers.

The Arduino platform, which is widely recognized as an open-source electronics platform, offers a viable prospect for the development of a pH meter that is both economical and user-friendly. The primary objective of this article is to discuss the many difficulties encountered in pH measurement, such as calibration, sensor choice, and signal processing. It is achieved using the Arduino platform, known for its user-friendly nature and adaptability.

The design of the pH meter aims to provide precise pH measurements, calibration methods that are easy for users to follow, and the ability to record data. The primary objective of this article is to provide people and small-scale organizations with the necessary knowledge and tools to monitor and regulate pH levels properly. This empowerment is expected to result in several benefits, including greater agricultural yields, improved water management practices, and increased opportunities for scientific investigation in domains where pH monitoring plays a critical role.

C. *Precision pH Sensing*

Since a rise in acidity alters the chemical characteristics of the material and therefore impacts human health, the project's purpose is to determine the pH of water or any other liquid to save human life or any other creature. Knowing the pH of any product where the liquid significantly prevents complications [7].

An inaccurate readout of the liquid's acidity is a prevalent issue in such systems, and it might vary from sensor to sensor. As the temperature of a liquid changes, the percentage of acidity measured in the liquid will also change.

The sensor used to determine the liquid's acidity has to be replaced with one with a negligible or nonexistent error rate if the issue is to be resolved. The qualities of the liquid and the temperature at which the measurement is accurate are also required. The acidity or basicity of a water-based solution is measured on the pH scale, which is used in chemistry. Solvents with a lower pH are considered acidic, whereas those with a higher pH are considered primary. Pure water has a neutral pH of 7 at average temperature, making it neither acidic nor basic [8].

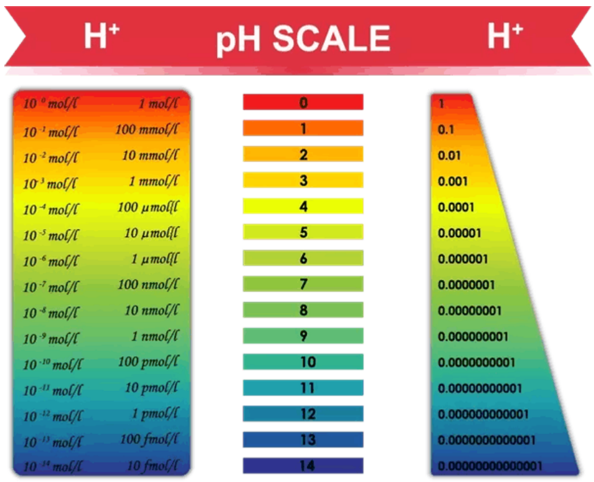

Fig. 1. pH Range Table

Water's acidity or basicity may be quantified using the pH scale. From zero to fourteen is included, with seven representing neutralities. A pH below 7 implies an acidic environment, whereas a pH over 7 indicates a basic one. The hydrogen and hydroxyl ion concentrations in water are what the pH scale measures. Water is acidic when there is a high percentage of free hydrogen ions, and water is elemental when there is a greater proportion of free hydroxyl ions. As pH may be altered by various chemicals pin the water, it serves as a helpful indication of chemical changes in the water. Logarithmic units are used to express pH values — the water's acidity or alkalinity changes by a factor of 10 for each digit. Five-pH water is tenfold more acidic than six-pH water [9].

Solubility (the amount that can be absorbed in the water) and bioactivity (the amount that can be eaten by aquatic life) of chemical components, such as minerals (nitrogen, phosphorus, nitrogen, carbon) and hazardous metals (lead, nitrogen, copper), vary with pH [10].The ability of aquatic organisms to make use of dissolved nutrients like phosphorus is also affected by factors such as the water's pH. Heavy metal toxicity is proportional to solubility. The toxicity of metals rises in acidic environments because they are more easily dissolved there [11].

D. Optimizing pH Meters

This article will examine creating a pH meter module with glass electrodes, a DS18B20 temperature sensor, and an LCD readout. The pH meter module has both an internal calibration and storage system for accurately measuring the pH and temperature of a sample.

A pH of 7 is neutral; thus, the material is alkaline or acidic if the number is higher than seven or lower than 7. The most alkaline solution has a pH of 14, whereas the most acidic has a pH of 0. A pH meter may measure a sample's pH and temperature.

The investigation found that the pH meter module's pH measurement errors ranged from 0.03% to 3.54%. Errors ranged from 5.39% in the buffer four calibrations to 1.04% in the buffer ten calibrations. It was also discovered that the sample temperature greatly influenced the pH measurement, with higher temperatures leading to a minor but noticeable rise in the pH value [12].

The pH meter module is convenient and economical because of its many features, such as internal calibration, storage, and battery consumption. More precise pH readings may be obtained by using glass electrodes, which can also be used to measure temperature.

Glass electrodes, a temperature sensor, and onboard calibration and storage make the pH meter module a convenient and affordable way to determine the sample's temperature and pH [13], [14]. Nevertheless, while utilizing this module for particular purposes, it is vital to consider the error values and the influence of temperature on the measurements. More work has to be done on the module's accuracy and dependability.

Several tens of thousands of water samples are analyzed annually by the US Geological Survey. Many tests run on the water in the field and the samples arriving at the lab. Because of their importance, water pH measurements are routinely taken at the sample site and laboratory. pH meters come in both considerable and compact forms. More minor, portable variants are available in the field, whereas this more extensive type is reserved for the laboratory [15-17].

To acquire an accurate result, you'll need to place the sample of water in the cup and plunge the pH meter's glass probe (found at the end of the retractable arm) in the water. Two electrodes for reading voltage are housed in the little glass bulb at the probe's tip. An acidic solution contains one electrode with a constant pH. The other electrode may measure a water sample's acidity. The probe includes a voltmeter that reads the potential gap between the electrodes. The pH reading is shown on the central unit's LCD screen [18] when the meter converts the voltage difference into pH.

The pH meter has to be "calibrated" before it can be used. The pH of the solution, which may be as simple as pH-neutral water, is known, and this is what the probe is measuring. Turning the box's knobs brings the pH reading closer to the actual value of the tested fluid [19].

A water supply with an abnormally high or low pH is not safe to drink. Water with a high pH has a poor taste, causes deposits to form in pipes and other water-using appliances, and lowers the effectiveness of chlorine disinfection, which in turn requires more chemicals to be used. Some materials, such as metals, may rust or dissolve with an acidic pH

Pollution causes harmful changes in water pH, which is harmful to aquatic life and plants. A coal mine that springs a leak might produce water with a pH as low as 2, making it so acidic that no fish could possibly live in it. Mine drainage water is 100,000 times more acidic than neutral water on the logarithmic scale, hence it's advisable to steer clear of abandoned mines [20].

This chart shows that the pH scale runs between "0" and "14", with a neutral pH value of 7. Acidity levels below seven are considered acidic, whereas alkalinity levels beyond seven are considered alkaline (essential). Rainfall is mildly acidic, with a pH of 5.6 on average, thanks to carbon dioxide gas in the air. Acid rain may be rather corrosive, as we can see, and it can have a harmful impact on the ecosystem [9].

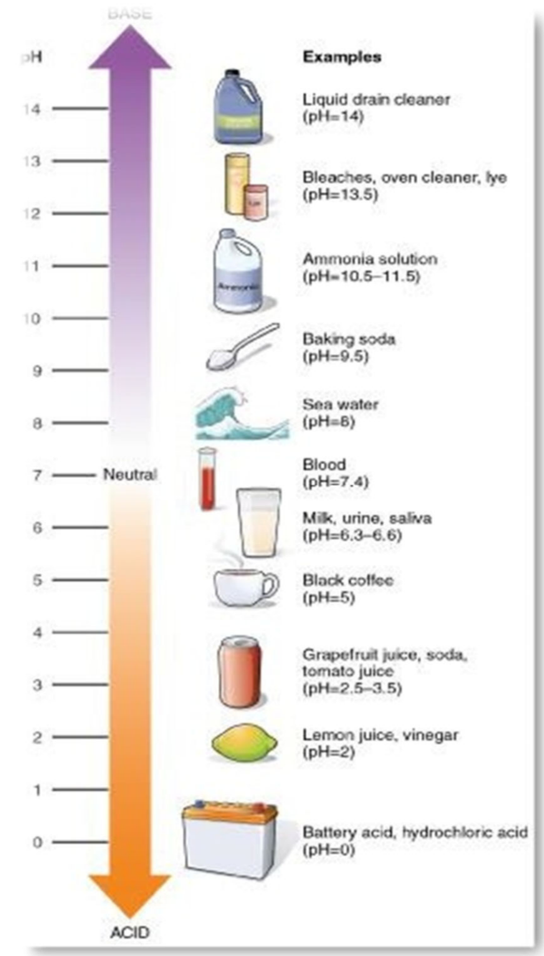

Fig. 2. pH Scale: Acidity and Alkalinity

II. LITERATURE REVIEW

As pH impacts the absorption, sensitivity, and toxicity of contaminants and nutrients, it is an essential factor in establishing water quality. This literature review highlights the results of three crucial studies published during the previous decade that examine the effect of pH quality [21].

Most of the river's pH was measured between 6.0 and 7.5, although the author found it to be from 5.5 to 9.5. The research also discovered that heavy metals, organic chemicals, and infections were all affected by variations in pH in terms of their solubility, mobility, and toxicity [22]. The author concludes that maintaining a healthy pH level in the river is essential to ensuring the safety of drinking water and conserving aquatic habitats. This article emphasizes the necessity for effective management measures to maintain safe and healthy water for people and the environment and the relevance of knowing the effects of pH on the water quality in a given geographic region[23], [24].

The scientists discovered that pH significantly impacts the growth and stability of biological systems like bacteria and algae and the solubility, speciation, and toxicity of contaminants in water bodies. The scientists also discovered that pH impacts the effectiveness of water treatment systems, such as the rate at which contaminants are removed and the consistency of sludge. According to the authors' research, pH is critical in water treatment and management. This research emphasizes the significance of knowing how pH affects water quality and developing efficient water management systems to guarantee that water is suitable for human and environmental use [25].

The effects of pH on the cleanliness of the water in Finnish lakes and rivers were the subject of a 2014 research authored by Jens Krogella, Kari Eränen, and Kim Granholm [26]. Landscape usage, pollutants, and watershed features were all shown to significantly impact the pH of these water bodies, among others. According to new research, the pH of water may modify the solubility and toxicity of contaminants and the habits and distribution of freshwater ecosystems. The authors conclude that pH is a dynamic and complicated character that must be considered in administering and conserving Finland's water bodies. As this research shows, it is crucial to comprehend the pH fluctuation in natural waterways and to implement efficient monitoring and management measures to guarantee the longevity of aquatic ecosystems [27].

This literature review focuses on the significance of pH on water quality in natural and manufactured systems. Results show that pH influences pollutant solubility, reactivity, and toxicity, as well as water treatment efficiency and the habits of aquatic organisms. Findings from this research highlight the need for a deeper understanding of the intricate interaction between pH or other environmental factors and their impacts on water quality, which may vary from positive to negative. These results highlight the continuing relevance of pH research in the science community as it requires more study to comprehend its effect and use in water treatment and management.

III. METHODOLOGY

The design of the pH meter using Arduino involved several key steps, including the selection of components, circuit design, programming, and testing [28].

- Component selection: The first step in the design of the pH meter was to select the components needed for the project. The components selected for the project included an Arduino board, a pH sensor (glass electrodes), a temperature sensor (DS18B20), an LCD, and a power supply.
- Circuit design: Once the components were selected, the next step was to design the circuit connecting the components. The pH sensor and the temperature sensor were connected to the analog inputs of the Arduino board, while the LCD was connected to the digital outputs of the Arduino board.
- Code for operating the pH meter has to be written next in the programming process. Arduino's IDE was used to write the code, and the Liquid Crystal I2C library was utilized to facilitate communication with the LCD screen. The pH value was computed using the voltage from the temperature sensor, and both values were shown on the LCD screen.
- Testing: The final step was to test the pH meter to ensure accuracy and reliability. The pH meter was tested using different buffer solutions with known pH values, and the results were compared to the expected values to determine the accuracy of the readings. The temperature of the sample was also measured, and its impact on the pH readings was evaluated.

This methodology provides a comprehensive approach for designing a pH meter using Arduino, from selecting components to testing the accuracy and reliability of the readings [29]. The use of glass electrodes as a pH sensor, a temperature sensor, and an LCD display, along with the internal calibration and storage features, make this pH meter design a cost-effective and user-friendly solution for measuring pH and temperature values in a sample.

The pH Analog Gravity Circuit and Probe from Atlas Scientific and an Arduino Uno will be used to create a portable pH meter for use on a lab bench. Because water is so crucial to our everyday lives, the measurements will be shown on an LCD screen for easy viewing[30].

A. Microcontroller

A microcontroller is a small computer that fits on an integrated circuit and has a CPU core, memory, and programmable input/output (I/O) peripherals. Microcontrollers are used in place of microprocessors in embedded applications, such as those found in personal computers and other general-purpose applications that employ several chips. Industrial operations or a variable are regulated with its help. [[4]

As opposed to a microprocessor, which can handle a variety of jobs at once, a logic circuit is designed to do only one thing at a time. It's a minicomputer, or, more accurately, a minicomputer with a very specific job to do. It has a processor, storage space, and networking ports. In general, microcontrollers follow the Harvard Architecture. Main features of the microcontroller include:

- Computing devices with bit widths from 8 to 32 and even 64
- Input/Output Ports
- Equipment outside the core system, including stopwatches
- Using Random Access Memory to Keep Records

Flash memory, rewritable and programmable read-only memory cards, electrically erasable and programmable read-only memory, and so on. Pulse or tempo generator Microcontrollers are ubiquitous in today's electronics, found in anything from cheap toys to highly automated production lines. More over half of all microcontrollers fall into the "basic" category, while the remaining 20% are digital signal processors with very high levels of complexity (DSPs). There may be as many as fifty of these controls in certain vehicles [31].

The microcontroller incorporates a microprocessor and several specialized peripherals. Using many microcontroller units allows you to create a basic electrical system with few components.

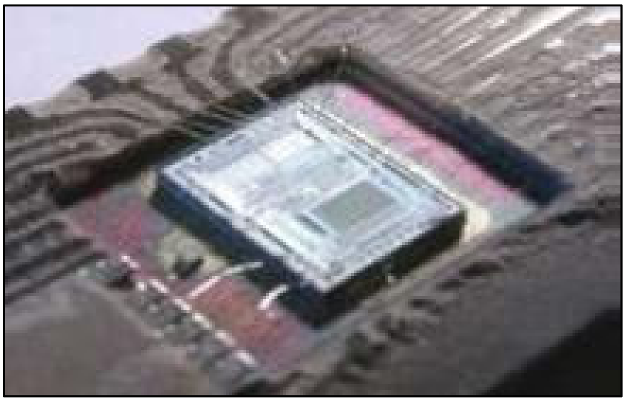

Fig. 3. Shows the Types of Microcontrollers and Their Shapes

B. Hardware Components

1) Exploring Arduino UNO

The Arduino UNO is a popular microcontroller board widely used in educational and DIY electrical projects. It was chosen for the pH meter due to its user-friendliness, flexibility, and low price. The board is easy to use, even for individuals without prior experience in electronics or programming, and it provides a user-friendly programming environment for controlling and programming the pH meter.

The Arduino UNO is equipped with 16 digital input and output pins and six analog input pins, allowing for connecting a wide range of sensors, displays, and actuators. The board is powered by a 5V operation voltage and can be connected to a computer with a USB cable, powered by an AC-DC adapter, or powered by a battery [6].

The Arduino UNO acts as the project's CPU, controlling the other connected components and managing the entire operation by sending signals. It can be programmed using the Arduino software and communicates using the original STK500 protocol [32].

The power source for the Arduino UNO can be a USB cable connected to a computer or a wall power supply terminated in a barrel jack. The 16 MHz quartz crystal provides a stable clock source for the microcontroller, ensuring accurate timing throughout the code. The ICSP header allows for real-time updates to the microcontroller, making it easy to program without removing it from the circuit.

Fig. 4. Arduino Uno

Every Arduino board requires a means of connecting to a power supply, and the most common are the USB and barrel jacks. The Arduino UNO may be powered by a computer's USB port or a standard wall adapter with a barrel connector.

The USB cable is also used to transfer programs to the Arduino board. Our Installing and Coding Arduino Guide has further details starting with Arduino's programming environment.

2) Pins (5V, 3.3V, GND, Analog, Digital, PWM, AREF)

The Arduino UNO has several different types of pins that can be used for different purposes in the design of a pH meter. These pins include:

5V: This pin provides a 5V output voltage, which can be used to power other components in the circuit.

3.3V: This pin provides a 3.3V output voltage, including power components requiring a lower voltage.

GND: The ground pin is used as a reference point for all other voltages in the circuit.

Analog: The analog pins (A0 to A5) can be used to read analog signals, such as the voltage from the pH sensor.

Digital: The digital pins (0 to 13 and A4 and A5) can be used for digital input and output. They can be used to read digital signals from sensors and to control displays and other components.

PWM: Some digital pins (3, 5, 6, 9, 10, and 11) can also be used as Pulse Width Modulation (PWM) outputs, which can be used to control the brightness of LEDs, the speed of motors, and other similar applications.

AREF: The AREF pin can provide an external reference voltage for the analog inputs.

In designing a pH meter using the Arduino UNO, these pins can be utilized in various ways to read the pH and temperature values, display the results, and control the other components in the circuit [20-22].

C. Main IC

The ATmega 328P microprocessor is the heart of the Arduino UNO. It is the board's "brain," running the code you place onto it and regulating how data flows in and out. With 32 KB of flash memory and 2 KB of SRAM, the ATmega328P is a low-power, high-performance 8-bit microcontroller. It supports various communication protocols, including UART, SPI, and I2C, and can execute up to 16 million instructions per second.

Arduino IDE is a user-friendly software platform for developing and uploading code to the ATmega328P microcontroller. The microcontroller's In-Circuit Serial Programming (ICSP) header enables programming without removing the microcontroller from the circuit so that it may be updated in real-time [33].

The ATmega328P microcontroller is at the heart of the Arduino UNO-based pH meter, which serves as a sensor for both pH and temperature while also handling the LCD display and the rest of the circuit.

D. Voltage Regulator

A voltage regulator is a component used in an electronic circuit to maintain a constant output voltage, regardless of changes in the input voltage or the load current. In designing a pH meter using the Arduino UNO, a voltage regulator is used to regulate the voltage from the power source to ensure that the other components in the circuit receive a stable voltage. This is important because input voltage changes can affect the pH readings' accuracy.

The voltage regulator in the Arduino UNO is typically an LM7805 linear voltage regulator, which provides a constant 5V output voltage. The voltage regulator takes in a voltage range of 7V to 12V and regulates it to a constant 5V output voltage. This voltage is then used to power the ATmega328P microcontroller and other components in the circuit.

Using a voltage regulator, the pH meter can be powered from various power sources, including USB, a wall adapter, or a battery, without affecting the accuracy of the pH readings. The voltage regulator also helps protect the other circuit components from overvoltage and under-voltage conditions, ensuring a stable and reliable operation.

E. Analog pH Sensor

The acidity or basicity of a solution may be measured with the use of an analog pH sensor, which is widely used in the scientific community. For measuring the buffering capacity of a solution, an Arduino UNO-based pH meter employs an analog pH sensor.

The analog pH sensor translates the solution's pH into a voltage. The pH sensor's voltage is an analog signal that can be read by the Arduino UNO's analog input ports. The Arduino code has an analogRead() function for reading the analog input pins' 0–5 V range.

For the Arduino UNO to interpret the pH electrode's tiny voltage output, a signal conditioning circuit must amplify and transform it. Dfrobot's pH sensor module, which has a built-in signal conditioning circuit, guarantees trustworthy pH readings. Dfrobot's pH meter kit simplifies building a meter by combining the pH electrode and signal processing circuit into a single, convenient module.

The pH electrode produces a negative (-) voltage, but the signal conditioning circuit of the pH sensor module is built to compensate for this so that the pH values are correct and fall within the range that the Arduino UNO can handle. To facilitate the reading and processing of pH readings by the Arduino UNO, the signal conditioning circuit also boosts the pH electrode's low voltage output. A glass electrode and a reference electrode are the usual components of an analog pH sensor. This voltage is directly proportional to the pH of the solution since the glass electrode is sensitive to hydrogen ions. The voltage at the glass electrode may be measured relative to the reference voltage provided by the reference electrode.

The pH meter uses the Arduino UNO's analog input pins to communicate with the sensor's analog readings. The Arduino measures the voltage from the pH sensor and outputs a corresponding pH value. After that, you may see the pH reading on an LCD screen or send the data to a computer for further processing.

The pH meter's use of an analog pH sensor is crucial to the success of any Arduino UNO-based pH meter since it allows for precise and dependable pH readings to be taken in real-time. [21]

Fig. 5. pH Modul SKU SEN0161

Some of the technical specifications of the analog pH meter kit from Dfrobot include the following:

1. pH Range: The pH range of the analog pH meter kit is typically 0 to 14 pH, which covers the full range of acidic to essential solutions.
2. Accuracy: The accuracy of the analog pH meter kit is typically within ±0.1 pH, ensuring that the pH readings are accurate and reliable.
3. Resolution: The resolution of the analog pH meter kit is typically 0.1 pH, allowing for precise pH readings.
4. Input Voltage: The input voltage of the analog pH meter kit is typically 5V, making it compatible with the voltage requirements of the Arduino UNO.
5. Output Voltage: The output voltage of the analog pH meter kit is typically in the range of 0-3.3V, making it compatible with the voltage requirements of the Arduino UNO.
6. Operating Temperature: The operating temperature of the analog pH meter kit is typically within 0-50°C, making it suitable for a wide range of temperature conditions.
7. Storage Temperature: The storage temperature of the analog pH meter kit is typically between -20 to 80°C, ensuring that it can be stored safely and securely.
8. Dimensions: The dimensions of the analog pH meter kit are typically small and compact, making it easy to integrate into a pH meter design.

Dfrobot's analog pH meter kit's technical specs are crucial for making a pH meter that works as intended and can be used in a variety of settings. When selecting an analog pH meter kit, it is crucial to consider several factors, including the range of pH measurement, accuracy, resolution, input and output voltage, working and storage temperature, and physical dimensions.

IV. Results

We will use the Arduino UNO and the Arduino Integrated Development Environment to write a program (IDE) to put the pH meter design into software. The pH and temperature readings from the pH sensor module must be included in the software and shown on an LCD screen.

It is possible to put the pH meter's design into software by following these instructions:

- Get the most recent version of the Arduino IDE from their website.
- Use a USB cord to link your computer to the Arduino UNO.
- Start a brand-new sketch in the Arduino software environment (program).
- The pH sensor module and LCD display are working by importing the required libraries.
- Specify the digital and analog pins to link the pH sensor module, the LCD display, and the Arduino UNO.
- You must write the code using the analogRead() function in the Arduino code to read the pH and temperature information from the pH sensor module.
- Type in the LiquidCrystal library into the Arduino code so that the LCD screen can show the pH and temperature readings.
- You may transfer the program to the Arduino UNO by selecting the "Upload" button in the Arduino software environment.
- To ensure that the pH meter works as intended, you should put a sample in the pH sensor module and check the LCD for the pH and temperature readings.

The Arduino IDE makes quick work of the software required to implement the pH meter idea on an Arduino UNO. The module's pH and temperature readings should be read and shown on an LCD screen. Thus, the code should contain the appropriate functions and procedures to do so. In order to get reliable pH measurements, the code may be checked and tweaked as necessary.

A. Obstacle Detection with Sound Alerts

The implementation consists of three parts:

The first part is about detecting the obstacle, but when detecting it, it alerts by issuing sounds, and the closer it gets to the obstacle, the faster the sound is issued.

Fig. 6. Device Design

The second part of the project is to issue a vibrator after detecting the obstacle. In the project, we placed the vibrating motor under the hand, i.e., the handle, so the sense of movement is faster and more robust than anywhere in the body.

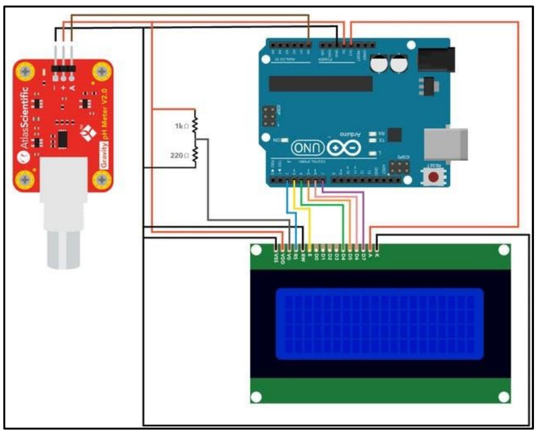

Fig. 7. System Circuit

In the internal part of the project, we notice that all components are connected, and as a result, the result is shown on the main LCD of the project.

- After you're done with the wiring, you may assemble the housing by screwing the top and bottom halves together.
- Join the probe's BNC plug in.

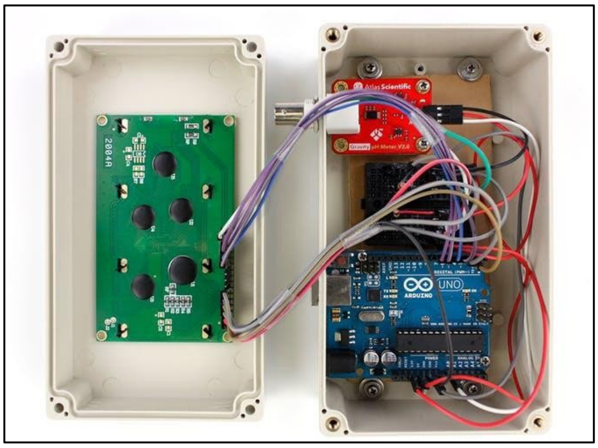

Fig. 8. The Interior of the Project

Fig. 9. The Device with the Instruction

A properly calibrated Arduino requires no adjustments once an external power source has been connected and before the calibration process begins [23].

This pH meter supports either a one-, two-, or three-point calibration system. It is necessary to use the usual buffer solutions (pH 4, 7, and 10). Calibration is carried out using the serial monitor. The user may then give the necessary orders after seeing the gradual shift in readings as they reach stability.

The Arduino's EEPROM is where the calibration values are kept.

The commands for calibrating:

- *Calorie count 4*
- *Midpoint: cal 7*
- *Maximum: cal, 10*
- *Clear and precise calibration: cal*

Take the pH probe out of the soaker bottle and wash it down the drain. A pH 4 solution may be produced by pouring some of the other solutions into a cup. Make sure there is enough to protect the probe's sensor region.

Put the probe into the cup and give it a good swirl to get rid of any air bubbles. Look at the data on the serial monitor. Leave the probe in the liquid until the results have stabilized (slight movement from one reading to the next is normal)

The cal, 4 command should be entered into the serial monitor after the values have stabilized. A pH 4 calibration has been successfully completed.

Steps a-d should be repeated for pH7 and pH10. Don't forget to wash the probe before moving on to other buffers.

The sensor used in this study has a margin of error of +/- 0.2%. Within this temperature range (7 - 46 °C), the pH meter will function to within this accuracy. The meter has to be calibrated for temperatures outside this range [26]. Take note that the pH probe is temperature-stable between 1 and 60 degrees Celsius.

B. Upload Code onto Arduino Uno

This C++ program is compatible with an Arduino board and the gravity pH sensor from Atlas Scientific. Libraries for the Atlas Scientific gravity pH sensor (ph grav.h) and the Liquid Crystal Display (LiquidCrystal.h) are used in the code (LCD).

The code initializes an instance of the Gravity_pH class called "pH" and assigns it to analog pin A0 of the Arduino board. It also initializes an instance of the LiquidCrystal class called "pH_lcd" and assigns it to the digital pins 2 to 7 of the Arduino board.

In the setup() function, the serial port, and LCD are started, and the LCD is configured with 20 columns and 4 rows. The pH sensor is also initialized, and a message on the serial monitor indicates how to calibrate the circuit.

In the serialEvent() function, incoming data from the PC is read into the input string variable until a carriage return (CR) is encountered. The input_string_complete flag is set to indicate that a complete string has been received.

The loop() function checks if a complete string has been received and, if so, sends the string to the parse_cmd() function for parsing. The pH reading is output to both the serial monitor and the LCD.

The parse_cmd() function is used to parse the input string and call the appropriate calibration functions for the pH sensor based on the user's input. The function uses the strcmp() function to compare the input string with the expected commands ("CAL,4", "CAL,7", "CAL,10", and

"CAL,CLEAR"). If a match is found, the appropriate calibration function is called.

The code makes use of customized libraries and header files. They must be added to for use with the Arduino IDE. To add this functionality to the IDE, follow the instructions below.

1. Get the Arduino IDE up and running by plugging it onto your computer. If you have access to the IDE, you can get it by clicking here. Select Arduino/Genuino Uno from the Board menu under Tools. Select the port that the Arduino is linked to by going to Tools, then Port.

2. Include a library for LCD screens: Sketch > Include library > Manage libraries in the integrated development environment. Simply type "liquid crystal" into the Library Manager's search field to get what you're looking for. The "LiquidCrystal Built-in by Arduino, Adafruit" kit is the one you want to track down. The option to set it up exists. Click the "Install" button if the package hasn't been installed already.

3. Improve the Atlas Gravity sensor collection with: The zip file may be downloaded here. Atlas gravity.zip is the name used for the archive. Select Sketch > Include library > Add.ZIP Library in the IDE menu bar. Find the file named "Atlas gravity.zip," then click the "add" button.

4. Now we only need to plug in the pH meter's instructions. Make a copy of the code and paste it into the IDE window.

5. The code must be compiled and uploaded to Arduino.

6. pH values may be examined in real time on the serial monitor and on the LCD. To access the serial monitor, choose it from the Tools menu or press “Ctrl + Shift + M”. Carriage return and a baud rate of 9600 are the recommended settings [16].

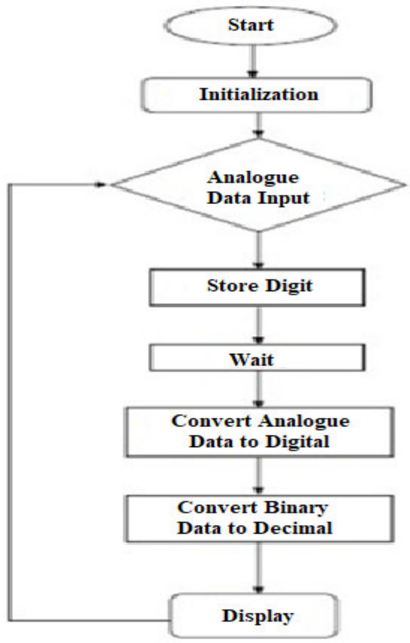

Fig. 10. Soil pH Meter: Flowchart Design

The digital soil pH meter built on an Atmega328 microcontroller passed all performance tests with flying colors. Lab pH meter PHM83 readings were contrasted with the predicted values to ensure an accuracy of +/-0.1%. [17]

To determine the acidity or alkalinity of different liquids, we built and evaluated a pH meter based on an Arduino microcontroller. Our objective was to create a gadget that could be used for a variety of reasons, including monitoring water quality, agriculture, and education. An Arduino Uno board, a pH sensor, a DS18B20 temperature sensor, an LCD display, and the proper connections and wires were used to assemble the pH meter.

In terms of accuracy, reaction speed, and usability, the developed pH meter produced encouraging results. The calibration procedure was simple and just required the use of buffer solutions with established pH values (4.00, 7.00, and 10.00). The pH meter was calibrated by submerging the pH sensor in each buffer solution, allowing the device to settle, and then modifying the offset values in the Arduino code to match the known pH readings.

Users may get pH readings fast because to the pH meter's short reaction time (around 5 seconds). This is especially crucial for applications that need quick results, such those for environmental monitoring or water purification. As pH readings are sensitive to variations in temperature, the addition of the DS18B20 temperature sensor enabled automated temperature adjustment, which is essential for precise pH measurements.

We compared the results from our Arduino-based pH meter to those from a commercial laboratory-grade pH meter to see how accurate it was. Several liquids, such as distilled water, tap water, and a variety of buffer solutions, had their pH levels measured. With a maximum difference of 0.1 pH units, the findings demonstrated a high agreement between the readings from the Arduino-based pH meter and the commercial pH meter.

We also examined the pH meter's consistency and reliability. While testing the same sample numerous times, the gadget showed excellent repeatability, with variations of less than 0.05 pH units. The pH meter also demonstrated stability over time, keeping its calibration and accuracy for many weeks without the need for recalibration.

Users were given a clear, readable readout of the pH measurements and temperature readings via the LCD display. The designed pH meter is ideal for instructional usage as well as for amateurs and enthusiasts who may not have extensive expertise with pH meters.

In conclusion, the pH meter based on the Arduino platform was found to be a dependable, accurate, and cost-effective method of determining the pH of different liquids. Water quality monitoring, agriculture, and education are just a few of the many uses for the device's quick reaction time, user-friendliness, and clear display. The design might be improved in the future to incorporate wireless data transmission capabilities, remote monitoring and control, and integration with other sensors for more complete environmental monitoring systems.

V. Discussion

The major objective of the author team was to design a pH meter that would be useful in a variety of contexts, including the monitoring of water quality, the conduct of agricultural research, and the teaching of students in classrooms. According to the findings, the pH meter based on Arduino is a viable alternative to commercial pH meters that are more expensive and offers accuracy and response times that are similar[34, 35].

One of the best features of the Arduino platform is the freedom it provides for the pH meter to be modified. The use of a microcontroller platform that is easily accessible makes it possible for simple customization and integration with additional devices and sensors[36]. As a result of the pH meter's versatility, it is possible to utilize it for a broad range of uses that go beyond those that were covered in this study.

The incorporation of a temperature sensor that is capable of performing automatic temperature adjustment is going to be an important feature of the pH meter that is going to be developed. It addresses the well-known issue of temperature-related inaccuracies in pH measurements, which enables the instrument to be used in a broad range of different environments because of its adaptability. It is possible that in the future, researchers may look into the use of temperature adjustment algorithms that are more complex in order to further improve the accuracy of pH meters [12, 13].

The pH meter that is based on Arduino has quite a few positive aspects, but it also has a few negative ones. The pH sensor's performance may deteriorate with time, which may need regular calibration or replacement, which raises worries about the sensor's capacity to maintain its accuracy over the long run[37]. This issue, on the other hand, is one that impacts all pH meters and not just those that are based on Arduino. Due to the Arduino pH meter's lack of accuracy and sensitivity, some specialized applications may find that it is unable to match their requirements[38, 39]. The Arduino pH meter has its own set of constraints.

The pH meter based on Arduino is an adaptable and cost-effective method for determining the degree of acidity or alkalinity of any liquid [40]. Because of its accuracy, friendliness toward users, and adaptability, it is an appealing option for a wide range of users and applications [41]. Continued research and development are necessary in order to enhance the functionality of the device and discover the ways in which it may interact with various additional sensor and monitoring systems. The pH meter that is based on Arduino has the potential to have far-reaching implications in domains such as environmental monitoring, agriculture, and education [42].

VI. Conclusions

In order to keep tabs on how acidic or alkaline a solution is, a pH meter is a must-have piece of kit. The Arduino-based pH meter is low-priced, easy to use, and accurate, with a maximum inaccuracy of 0.1 pH. The pH meter's glass electrodes, temperature sensor, in-built calibration, and data storage make it an easy-to-use tool for determining the pH and temperature of a given sample. The pH meter has several applications outside the lab, such as measuring water quality, ensuring food and drinks are safe to consume, and many more. A neutral pH value is 7, with a scale from 0 to 14. If the solution's pH level is below 7, it is acidic; if it is over 7, it is fundamental. The chemical properties of a solution, which may affect human health and the environment, can be determined by measuring the pH of the solution. Since shifts in pH are harmful to aquatic life and plants, the pH meter is a crucial instrument for water quality monitoring.

If you need to know how acidic or basic a substance or solution is, build your pH meter using an Arduino UNO microcontroller board that is cheap and customizable. An analog pH sensor module, an LCD screen, and an Arduino UNO microcontroller board are used to create the pH meter. A pH electrode and a signal processing circuit comprise the pH sensor module, and the LCD screen shows the current pH and temperature readings. The Arduino UNO is the project's central processing unit (CPU), issuing commands to and receiving data from the many connected parts.

The Arduino UNO is a widely used microcontroller board because it is simple to use and can be customized to suit various applications. Its various inputs and outputs make it a strong choice for usage in both DIY and educational contexts, and it can link to a broad range of sensors, displays, and actuators.

The pH meter design's simple software implementation can be accomplished quickly using the Arduino IDE (IDE). The pH and temperature readings from the pH sensor module should be included in the software and shown on the LCD screen.

The Arduino-based pH meter's source code is crucial to its functionality. It gives the Arduino board the guidance it needs to operate the pH sensor and the LCD, allowing for reliable pH readings to be shown. The algorithm combines the pH sensor and the temperature sensor outputs, returning an interpretable pH value. The code also includes internal calibration, so knowing the numbers are correct. The pH meter's success depends on the efficacy and dependability of the code, which in turn is determined by the precision and reliability of the readings. The pH meter's architecture is malleable and adjustable since the code can be readily edited or updated to include new features or enhance performance.

In conclusion, an Arduino UNO-based pH meter provides a user-friendly, inexpensive, and adaptable means of measuring both pH and temperature in a sample. As the pH meter's design is flexible, it may be used in a wide variety of situations where pH measurement is required.

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APPENDIX 1

Code

```
#include "ph_grav.h"  //header file for Atlas Scientific gravity pH sensor
#include "LiquidCrystal.h"  //header file for liquid crystal display (lcd)

String input string = "";  //a string to hold incoming data from the PC
boolean input_string_complete = false;  //a flag to indicate have we received all the data from the PC
char inputstring_array[10];  //a char array needed for string parsing
Gravity_pH pH = A0;  //assign analog
pin A0 of Arduino to class Gravity_pH. connect output of pH sensor to pin A0
LiquidCrystal pH_lcd(2, 3, 4, 5, 6, 7);  //make a variable pH_lcd and assign arduino digital pins to LCD pins (2 -> RS, 3 -> E, 4 to 7 -> D4 to D7)

void setup() {
Serial.begin(9600);  //enable serial port
pH_lcd.begin(20, 4);  //start lcd
interface and define lcd size (20 columns and 4 rows) pH_lcd.setCursor(0,0);  //place cursor on
screen at column 1, row 1
pH_lcd.print("--------------------");  //display characters
pH_lcd.setCursor(0,3);  //place cursor on screen at column 1, row 4
pH_lcd.print("--------------------");  //display characters
pH_lcd.setCursor(5, 1);  //place cursor on screen at column 6, row 2
pH_lcd.print("pH Reading");  //display "pH Reading"
if (pH.begin()) { Serial.println("Loaded EEPROM");} Serial.println(F("Use commands \"CAL,4\", \"CAL,7\", and \"CAL,10\"
to calibrate the circuit to those respective values"));
Serial.println(F("Use command \"CAL,CLEAR\" to clear the calibration"));
}


void serialEvent() {  //if the hardware serial port_0 receives a char
input string = Serial.readStringUntil(13);  //read the string until we see a <CR>
input_string_complete = true;  //set the flag used to tell if we have received a completed string from the PC
}

void loop() {

if (input_string_complete == true) {  //check if data received
input string.toCharArray(inputstring_array, 30);  //convert the string to a char array
parse_cmd(inputstring_array);  //send data to pars_cmd function
input_string_complete = false;  //reset the flag used to tell if we have received a completed string from the PC
input string = "";  //clear the
string
}
Serial.println(pH.read_ph());  //output pH reading to serial monitor
pH_lcd.setCursor(8, 2);  //place cursor on screen at column 9, row 3
pH_lcd.print(pH.read_ph());  //output pH to lcd
delay(1000);
}

void parse_cmd(char* string) { //For calling calibration functions
strupr(string);//convert input
string to uppercase

if (strcmp(string, "CAL,4") == 0) {  //compare user input string with CAL,4 and if they match, proceed
pH.cal_low(); //call function for
low point calibration Serial.println("LOW CALIBRATED");
}
else if (strcmp(string, "CAL,7") == 0) {  //compare user input string with CAL,7 and if they match, proceed

pH.cal_mid(); //call function for
midpoint calibration Serial.println("MID CALIBRATED");
}
else if (strcmp(string, "CAL,10") == 0) { //compare user input string with CAL,10 and if they match, proceed
pH.cal_high();  //call function for
highpoint calibration Serial.println("HIGH CALIBRATED");
}
else if (strcmp(string, "CAL,CLEAR") == 0) {
    //compare user input string with CAL,CLEAR and if they match, proceed
pH.cal_clear();  //call function for clearing calibration
Serial.println("CALIBRATION CLEARED");
}
}
```