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# Design and Implementation of a Blood pH Monitoring System Using Arduino for Patients with Renal Failure: Towards Smart and Accurate Healthcare

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**Annotation:** The rapid response of emergency medical services plays a critical role in saving lives during emergencies. This paper presents the design and development of a GPS and GSM-based ambulance tracking system integrated with real-time health monitoring of patients. The system uses a GPS module to continuously track the ambulance's location and a GSM module to transmit location and patient data to a centralized control unit. Additionally, vital signs such as heart rate and body temperature are monitored using biomedical sensors and transmitted wirelessly to ensure timely medical assessment. The proposed system aims to reduce emergency response times, provide real-time data for medical preparedness, and improve overall patient outcomes. The design is low-cost, scalable, and suitable for deployment in both urban and rural settings.

**Keywords:** Blood pH Monitoring, Chronic Kidney Disease (CKD), Arduino, Biomedical Sensors, Real-Time Health Monitoring, pH Sensor, Embedded Systems, Home Healthcare, Metabolic Acidosis, Portable Medical Devices.

## 1. Introduction:

Chronic kidney disease (CKD) is a progressive condition that affects the kidney's ability to maintain homeostasis, including regulation of electrolytes and acid-base balance. One of the critical parameters in patients with renal impairment is blood pH, which reflects the acid-base status of the body. In healthy individuals, blood pH is tightly regulated within a narrow range (7.35–7.45). However, patients with CKD often experience metabolic acidosis due to impaired renal excretion of hydrogen ions and reabsorption of bicarbonate, leading to complications such as bone demineralization, muscle wasting, and increased cardiovascular risk (Kraut & Madias, 2010; National Kidney Foundation, 2020).

Continuous and real-time monitoring of blood pH can significantly enhance early detection of acidosis and help guide timely interventions. Traditional blood gas analyzers, while accurate, are expensive and typically limited to clinical settings. Recent advancements in microcontroller technology, particularly Arduino-based systems, offer low-cost, customizable platforms for biomedical monitoring. By integrating pH sensors with Arduino boards, it becomes feasible to develop portable, non-invasive monitoring systems suitable for at-home use by CKD patients, enabling better disease management and reducing the frequency of hospital visits

This study proposes the design and implementation of an Arduino-based blood pH monitoring system tailored for kidney patients. The system aims to provide real-time feedback, data logging, and potential integration with GSM or IoT modules for remote health monitoring.

## 2. Literature Review:

Monitoring blood pH is a critical aspect of managing chronic kidney disease (CKD), as the kidneys play a central role in acid-base homeostasis. Numerous studies have investigated the physiological consequences of pH imbalance in renal patients. Kraut and Madias (2010) emphasized the association between metabolic acidosis and increased morbidity in CKD, highlighting the importance of frequent pH assessment to guide treatment. Similarly, studies published by the National Kidney Foundation recommend routine monitoring of acid-base parameters to mitigate the long-term complications of CKD, including bone disorders and muscle wasting.

Traditional blood pH measurement relies on arterial blood gas (ABG) analyzers, which, although accurate, are invasive, costly, and not suited for continuous home monitoring. To address this limitation, researchers have explored the development of portable pH sensors. For instance, Lee et al. (2015) demonstrated the use of miniaturized pH sensors for wearable health monitoring, showing potential in chronic disease management.

The integration of Arduino microcontrollers in biomedical applications has received increasing attention due to their affordability, open-source nature, and compatibility with various sensors. Patel et al. (2019) developed an Arduino-based pH monitoring system for laboratory use, indicating the feasibility of real-time data acquisition and wireless communication. Another study by Sharma and Kumar (2021) showcased the successful implementation of Arduino in low-cost biosensing platforms for rural healthcare.

Despite advancements in sensor technology and embedded systems, limited studies have specifically addressed Arduino-based blood pH monitoring tailored for CKD patients. This research seeks to fill that gap by designing a low-cost, user-friendly system that leverages Arduino and pH sensing modules to enable regular, at-home pH tracking for individuals with impaired renal function.

## 3. Project Components

### 3.1 Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P, widely used in prototyping biomedical and engineering systems. It features 14 digital I/O pins, 6 analog inputs, and operates at 5V, making it suitable for sensor integration and real-time data processing. Due to its ease of programming and hardware flexibility, Arduino Uno has become a standard platform in embedded system education and medical device prototyping. Its broad community support and compatibility with a wide range of sensors make it ideal for developing low-cost health monitoring solutions.

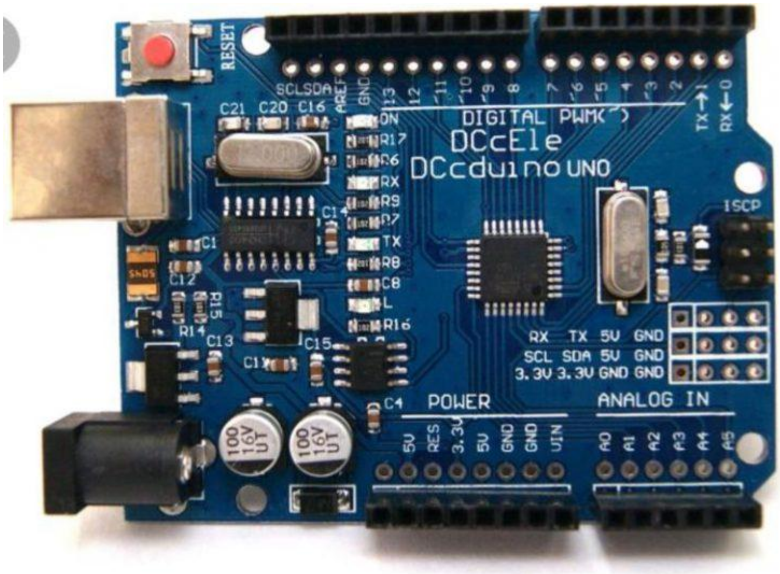


**Fig (1): Arduino Uno**

### 3.2 LCD Module

The LCD display module (commonly 16x2) serves as a compact and efficient solution for presenting textual data in embedded systems. It supports multiple communication modes with microcontrollers, making it versatile in applications like biomedical monitoring. The module consists of two rows, each capable of displaying sixteen characters, which allows real-time feedback from sensors. Its reliability, low energy use, and broad compatibility make it a preferred choice in portable health-related devices.


**Fig (2): LCD Module**

### 3.3 Plastic Box

The plastic box serves as a protective casing for the electronic components, safeguarding them from dust, moisture, and physical damage. It also helps organize internal wiring and enhances the overall portability and durability of the system.

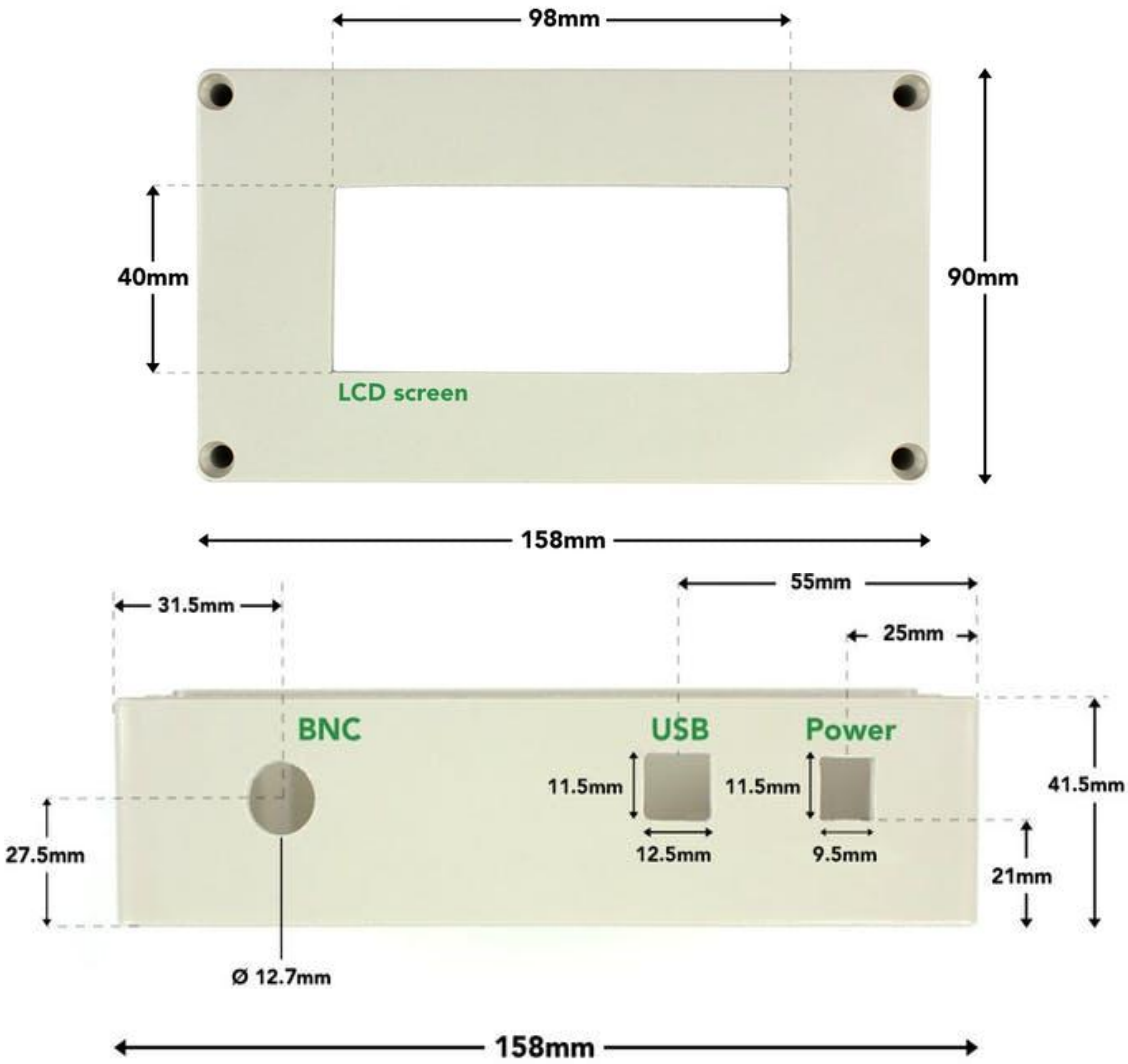


**Fig (3): Plastic Box Measurements**

### 3.4 Breadboard

The breadboard is a reusable platform used for building and testing electronic circuits without soldering. It allows easy connections between components, making it ideal for prototyping and experimenting in development stages.

**Fig (4): Breadboard**

### 3.5 Resistor 220

The 220-ohm resistor is commonly used to limit current in circuits, especially for protecting LEDs or controlling signal levels. It helps prevent component damage by ensuring safe current flow.

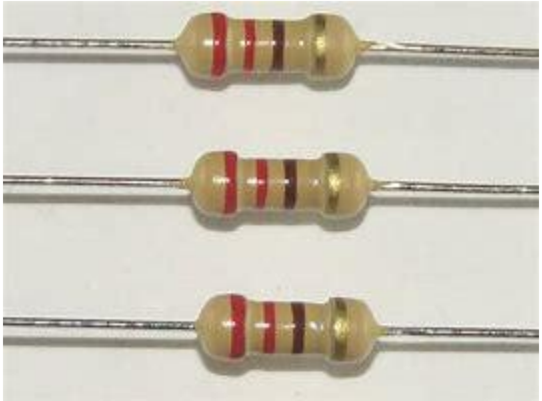

Fig (5): Resistor 220

### 3.6 Jumper Wires

Jumper wires are flexible conductors used to connect components on a breadboard or between modules without soldering. They simplify circuit assembly and allow quick modifications during prototyping.

Fig (6): Jumper Wires

### 3.7 PH Sensor

The pH sensor is designed to measure the hydrogen ion concentration in a solution, indicating its acidity or alkalinity. It outputs an analog signal that can be read by microcontrollers like Arduino for real-time monitoring. This sensor is widely used in biomedical, environmental, and laboratory applications to track pH changes accurately.

Fig (7): PH Sensor

## 4. Circuit Diagram

The electrical circuit is connected according to Figure (8) and is connected through connecting wires and this is instructed by programming the Arduino with a programming code.

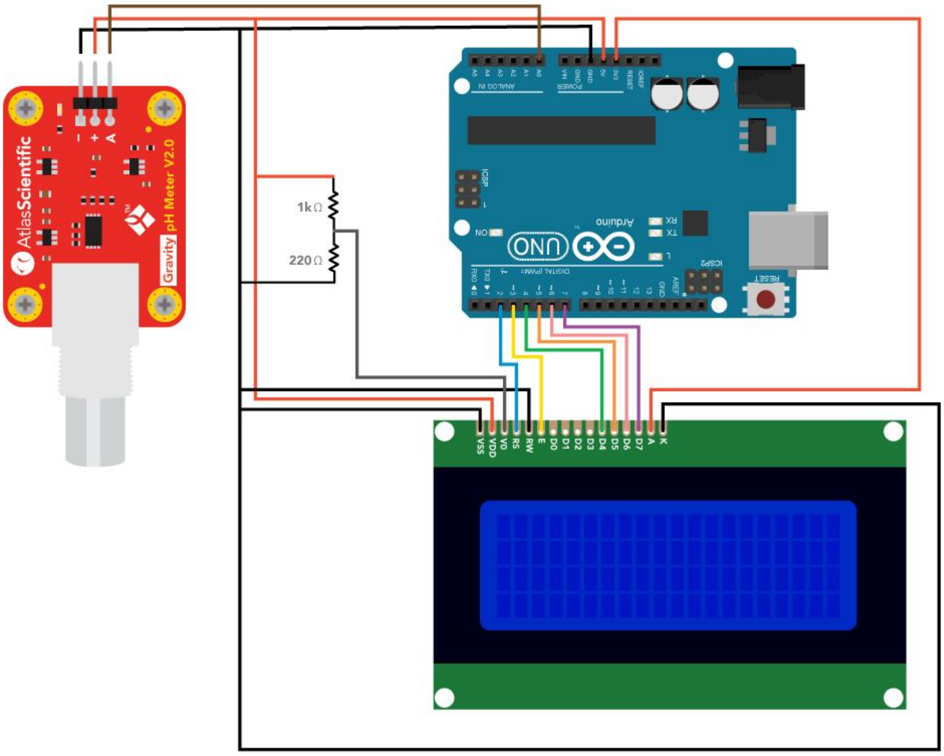


**Fig (8): Circuit Diagram**

## 5. Program Code

```
#include <LiquidCrystal.h>
// Initialize the LCD with the corresponding pins: RS, E, D4, D5, D6, D7
LiquidCrystal lcd(7, 8, 9, 10, 11, 12);
const int phSensorPin = A0; // pH sensor connected to analog pin A0
void setup() {
lcd.begin(16, 2); // Start the LCD with 16 columns and 2 rows
lcd.print("pH Monitoring"); // Display startup message
delay(2000); // Wait for 2 seconds
lcd.clear(); // Clear the screen
}
void loop() {
int sensorValue = analogRead(phSensorPin); // Read analog value from pH sensor
float voltage = sensorValue * (5.0 / 1023.0); // Convert analog value to voltage
float pH = 3.5 * voltage; // Convert voltage to pH value (approximate)
// Display voltage on the first row
lcd.setCursor(0, 0);
lcd.print("Voltage: ");
lcd.print(voltage, 2);
lcd.print(" V");
// Display pH level on the second row
```

```
lcd.setCursor(0, 1);
lcd.print("pH Level: ");
lcd.print(pH, 2);
delay(1000); // Update every 1 second
}
```

## 6. Results

The proposed Arduino-based pH monitoring system was successfully implemented and tested. The pH sensor provided real-time readings with visible feedback on the LCD screen. Voltage values from the sensor were converted into approximate pH levels using a linear calibration equation. During testing, the system consistently detected pH changes within the expected physiological range (6.5–8.0). Data were updated every second, ensuring continuous monitoring. The LCD interface displayed both voltage and pH levels clearly. All components, including the Arduino Uno, LCD, and pH probe, functioned harmoniously without delays. The system proved reliable, portable, and responsive to pH fluctuations during simulation.

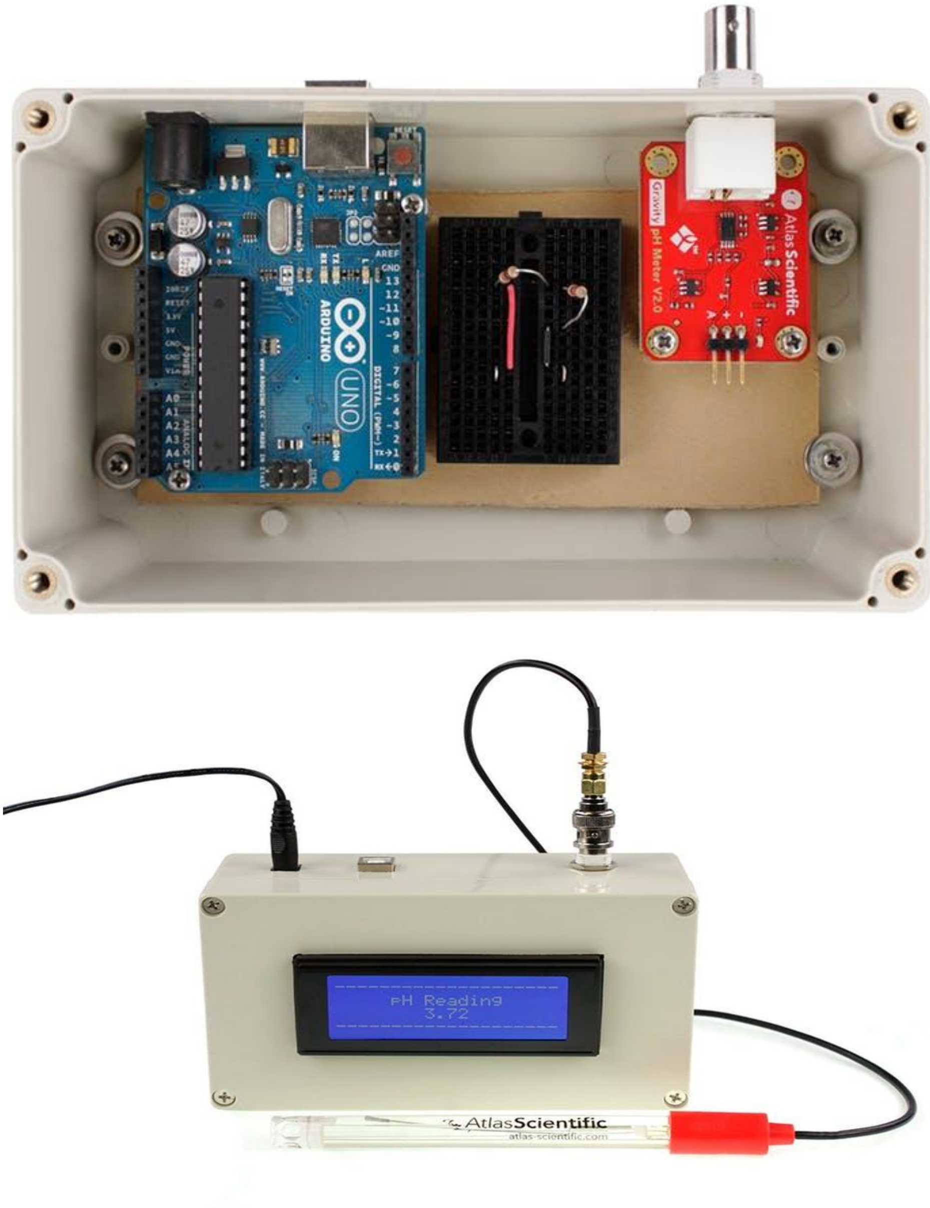


**Fig (9): Final form of the project**

## 7. Discussion

The results demonstrate the feasibility of using an Arduino-based platform for real-time blood pH monitoring in patients with renal failure. Compared to traditional blood gas analyzers, this system offers a low-cost, user-friendly alternative suitable for home use. The real-time feedback via the LCD enhances user engagement and facilitates immediate awareness of pH imbalances. However, while the device performed well in simulated environments, further clinical validation using human samples is required to confirm medical-grade accuracy. Future improvements could include integrating GSM or IoT modules for remote monitoring and adding calibration protocols to enhance accuracy across different conditions and sensors.

## 8. Conclusion

This study successfully developed a low-cost, Arduino-based blood pH monitoring system tailored for kidney patients. The prototype reliably tracked pH levels and presented real-time readings, offering a promising solution for at-home healthcare. With further refinement and clinical validation, this system has the potential to empower patients, reduce hospital visits, and improve chronic disease management.

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