The Creation of a Modular pH Correction Device for Space Exploration

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Abstract

The TDC-94 IV Fluid Generation (IVGEN) Mini pH Correction project focuses on developing a compact and automated system to produce sterile intravenous (IV) fluids in space. Ensuring proper pH balance is critical for IV fluid safety, as it must comply with stringent United States Pharmacopeia (USP) standards. This project aims to design and build a prototype capable of measuring and automatically correcting the pH of potable water to ensure it meets medical-grade requirements. By addressing the unique challenges of space-based IV fluid production, the IVGEN Mini project contributes to advancements in space medicine and automated fluid processing technologies.

Objective

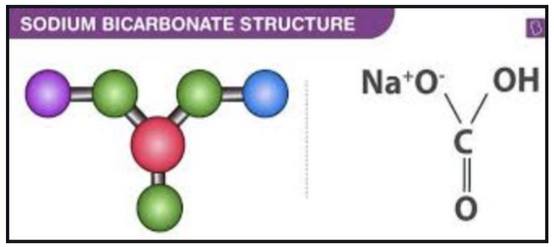
The main objective was to design an automated device capable of measuring and adjusting the pH of potable water to fall within the USP-recommended range of pH 4.5–7.0, ensuring the safe production of IV fluids.

Mechanical Methods

The Device operates with a simple peristaltic pump and pH Sensor System. When the pH of the liquid is not at the desired level a signal will be sent which will trigger the motors which will pump either an acid or base into the solution until it reaches the desired pH. The pH will be read using a pH Sensor and displayed on an LCD screen to inform the user of the current Ph of the solution. The solution in the container will be spun by a magnetic stir rod to ensure the fluids are not stagnant, as well as ensuring proper mixing.

Chemical Methods

Since the water is filtered and recycled, we can assume its pH will tend to be more acidic. To counteract this and raise the pH, we have selected a mild alkaline buffer, Sodium Bicarbonate ($NaHCO_3$). Additionally, a phosphate buffer will be used to stabilize the pH, ensuring consistency and suitability for IV fluid production.



Sodium Bicarbonate ($NaHCO_3$)

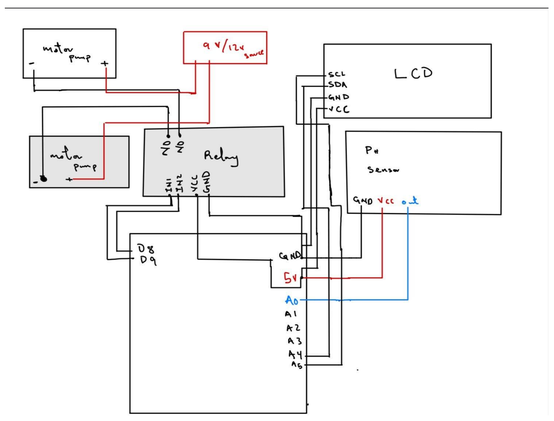
Schematic & Design

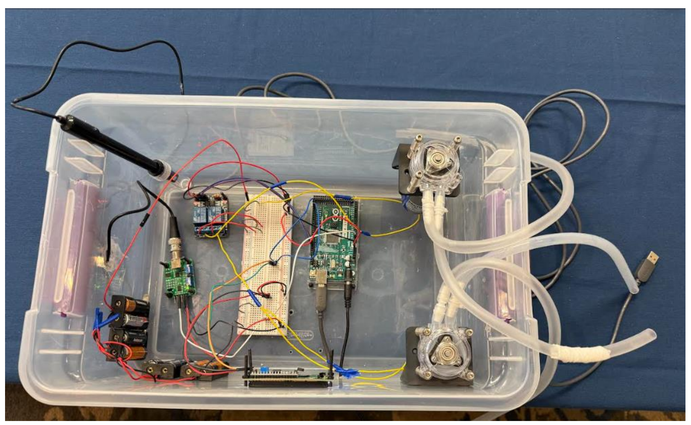
```
#include <wire.h>
#include <LiquidCrystal_I2C.h>

#define RELAY1 7                // Relay control pin for Pump 1
#define RELAY2 8                // Relay control pin for Pump 2
#define TRANSISTOR1 6           // Transistor for Pump 1
#define TRANSISTOR2 9           // Transistor for Pump 2
#define PH_SENSOR A0            // pH sensor connected to analog pin A0

int pumpSpeed = 120;            // Example RPM for display
float pH_Value = 0.0;           // pH reading variable

LiquidCrystal_I2C lcd(0x27, 16, 2);  // LCD setup (change address if needed)

void setup() {
    Serial.begin(9600);         // Initialize Serial Monitor for debugging

    // Configure pump relays and transistors
    pinMode(RELAY1, OUTPUT);
    pinMode(RELAY2, OUTPUT);
    pinMode(TRANSISTOR1, OUTPUT);
    pinMode(TRANSISTOR2, OUTPUT);

    // Ensure pumps are OFF initially
    digitalWrite(RELAY1, HIGH);
    digitalWrite(RELAY2, HIGH);
    digitalWrite(TRANSISTOR1, LOW);
    digitalWrite(TRANSISTOR2, LOW);

    // Initialize LCD
    lcd.init();
    lcd.backlight();
    lcd.setCursor(0, 0);
    lcd.print("Pump Speed: ");
}

void loop() {
    // Read pH Sensor
    int phRaw = analogRead(PH_SENSOR);          // Read analog pH value
    float voltage = phRaw * (5.0 / 1023.0);     // Convert analog reading to voltage
    pH_Value = voltage * 3.5;                   // Approximate pH calibration

    // Display pH Value
    lcd.setCursor(0, 1);
    lcd.print("pH: ");
    lcd.print(pH_Value, 2);   // Display pH with 2 decimal places
    lcd.print("     ");        // Clear extra characters

    // Turn ON Pumps
    digitalWrite(TRANSISTOR1, HIGH);
    digitalWrite(TRANSISTOR2, HIGH);
    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);

    lcd.setCursor(0, 1);
    lcd.print("Speed: ");
    lcd.print(pumpSpeed);
    lcd.print(" RPM  ");

    delay(5000);  // Pumps run for 5 seconds
```

```
    // Turn OFF Pumps
    digitalWrite(TRANSISTOR1, LOW);
    digitalWrite(TRANSISTOR2, LOW);
    digitalWrite(RELAY1, HIGH);
    digitalWrite(RELAY2, HIGH);

    lcd.setCursor(0, 1);
    lcd.print("Stopped     ");

    delay(3000);  // Wait before restarting

    // Print pH value in Serial Monitor for debugging
    Serial.print("pH Value: ");
    Serial.println(pH_Value);
}
```

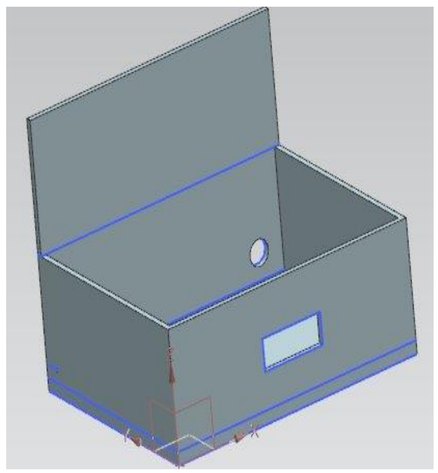
```
PIN CONNECTIONS
================================

// pH Sensor Module (To, Do, Po, G, V+)
  V+  ---------> 5V (Arduino)
  G   ---------> GND (Arduino)
  Po  ---------> A0 (Analog Input)

// LCD Display (I2C)
  SDA ---------> SDA (Pin 20 on Mega)
  SCL ---------> SCL (Pin 21 on Mega)
  VCC ---------> 5V
  GND ---------> GND

// Relay Module 1 (Acid Pump)
  IN  ---------> D4 (Arduino Digital Output)
  DC+ ---------> 5V (Arduino)
  DC- ---------> GND (Arduino)
  NO  ---------> 12V Pump +
  COM ---------> 12V Power Supply

// Relay Module 2 (Base Pump)
  IN  ---------> D5 (Arduino Digital Output)
  DC+ ---------> 5V (Arduino)
  DC- ---------> GND (Arduino)
  NO  ---------> 12V Pump +
  COM ---------> 12V Power Supply
```

```
// MOSFET 1 (Acid Pump Motor Speed Control)
   Gate  ---------> D6 (Arduino PWM Output)
   Drain ---------> Negative (-) of Acid Pump
   Source ---------> GND (Arduino & Power Supply)
   10kΩ Resistor: Gate ---------> GND

// MOSFET 2 (Base Pump Motor Speed Control)
   Gate  ---------> D7 (Arduino PWM Output)
   Drain ---------> Negative (-) of Base Pump
   Source ---------> GND (Arduino & Power Supply)
   10kΩ Resistor: Gate ---------> GND

// 12V Peristaltic Pumps
   Acid Pump:  + ----------> Relay NO
               - ----------> MOSFET Drain
   Base Pump:  + ----------> Relay NO
               - ----------> MOSFET Drain

// Capacitors (100µF, 16V for Noise Reduction)
   Across each Pump Terminal (V+ and GND)

========================================
        POWER SOURCES
========================================
   Arduino Powered via USB or 9V Adapter
   12V External Power for Pumps & Relays
*/
```





Previous Prototype



New Prototype Outline

Terrestrial Applications

- Water Treatment
- Agriculture
- Pharmaceuticals
- Food & Beverage
- Chemical Manufacturing
- Cosmetics
- Aquaculture

Summary

The project utilized an automated pH regulation approach, incorporating pH sensors, buffering agents, and batch reactions to maintain the desired pH.

The project highlighted the significance of pH control not only for terrestrial medical applications but also for ensuring the safety and sustainability of medical fluids in space environments.

Future Studies

- Scalability
- Modular Parts
- Volume Optimization
- Improved Efficiency

References

NASA. *NASA's Water Recovery System: Producing Potable Water from Wastewater*. NASA.

NASA. *Medical Grade Water Generation for Intravenous Fluid Production*. NASA Technical Memorandum, 2008.

NASA. *IV Fluid Generation (IVGEN) Mini pH Correction*. NASA Spark Challenge Topic, 2024.

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