WATER QUALITY AND QUANTITY MEASURING SYSTEM WITH PREPAID BILLING

FINAL YEAR PROJECT UG 2019

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Abstract

Due to increase in water pollution and climate variations, the water should be use smartly. In addition to this, the quality of water must be checked before drinking. In this project, an online android app-based system has been designed to check water quality (pH and turbidity). Beside it, a prepaid water billing system has been added for smart water use. The control methodology designed in a way that the controller regularly detects the water level and quality (pH and turbidity) in the tank, and notify the user about the states on the mobile app. If the water level in the tank is low, then user can purchase the water by entering a passcode in mobile app. After the confirmation of the passcode, the controller finds the solenoid valve opening time according to the user input. The controller automatically turns off the valve after calculated time. This water quantity and quality monitoring system can be easily implementable for the domestic and industrial users.

Endorsement of Correctness and Approval

It is affirmed that data presented in this thesis "***WATER QUALITY AND QUANTITY MEASURING SYSTEM WITH PREPAID BILLING***" carried out by 1) Capt. Muhammad Ali Shahid, 2) Capt. Adil Awan, 3) Capt. Usman Ali Shah, and 4) Capt. Jawad Mehboob under the direction of Asst. Prof. Dr Abdul Wakeel is in complete satisfaction of our level of Bachelor of Telecommunication Engineering, is right and endorsed. Percentage of plagiarism found in document as per software Turnitin available on LMS NUST comes out to be 15%

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Declaration

We hereby declare that no content and variety of work bestowed during this thesis has been submitted in support of another award of qualification or degree either during this course or anyplace else.

Dedication

This proposition is devoted in thanks to ALLAH ALMIGHTY, our Creator, who has blessed us with wisdom, knowledge and understanding, then to our parents for their direction and their endless support. I would also like to thank our faculty for their guidance and supervision. Without their help and supervision this project would not have been made possible.

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- Assoc HoD Dr. Muhammad Imran for his support and guidance during the entire project.
- We acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. We are thankful for their sacrifice, patience, and understanding that were inevitable to make this work possible. Their sacrifice had inspired me from the day we learned how to read and write until what I have become now. We cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to achieve my dreams.
- Lastly, we would like to thank any person who contributed to my final year project directly or indirectly. We would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

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List of Abbreviations

CDMA	Code division multiple access
GPRS	General packet radio service
GSM	Global system for mobile communications
IP	Internet Protocol
IoT	Internet of Things
KPMs	Key performance parameter
LAN	Local area network
NO	Normally open
NC	Normally close
pH	Potential hydrogen
PSQCA	Pakistan standard quality control authority
SMS	Short message service
TTS	Total suspended solid
WHO	World health organization
WSN	Wireless sensor network

1 Introduction

1.1 Background

The different oceanic genus has a threat of biological diversity and extermination due to ecological and environmental variations. Environmental pollution and climate variations also have a similar effect on human beings. To ensure the high quality of the water, different key performance parameters (KPMs) such as dissolved oxygen, oxidation-reduction potential, alkalinity, potential hydrogen (pH), conductivity, and salinity need to be monitor regularly, depending upon the geographical position [1]. The decline in water quality is mainly due to man-made pollutants such as waste of industries, oil spillage, and agricultural fertilizers. Non-uniform rainfall also enhances water quality-related problems. According to a report presented in 2017 [2], almost 5 million people die due to the poor quality of the water globally. Beside it, the quantity of water also decreases with the rapid growth in population. Water is not only important for living being’s existence, but their optimum management is also essential for wealth generation, better living, and eliminate poverty [3].

1.2 Problem statement

Nowadays, water pollution is one of the biggest crises faced by mankind globally. The main decline in water quality is due to industrialization, extravagant chemical usage in agriculture, urbanization, and oil spillage, as discussed earlier. In addition to this, the freshwater resources are also decreasing due to rapid growth in population, and daily wastage of water by domestic as well as industrial users.

1.3 Project description

In this work, a real time water quality measure system has been designed. In addition to this, a prepaid water quantity billing system has also been introduced using Internet of Things (IoT) devices. The controller regularly monitors water quality using turbidity and pH sensors, and inform the consumer through internet on android based mobile app. The ultrasonic sensor is utilized to measure the water level. After confirmation of the water bill payment, the controller opens the solenoid valve for a fixed optimum time interval.

1.4 Prospective Application Areas

1. In current situation, it can be effectively installed at homes to monitor consumption of water.
2. It can be utilized for pre-paid water usage billing.
3. This project ensures clean/healthy water supply at homes that can reduce health issues related to drinking water.
4. It can be employed in hospitals for monitoring of water quality and other parameters.
5. It can be deployed at commercial level to monitor water wastage, e.g., carwash centers.

1.5 Scope, objectives, and specifications

1.5.1 Scope and Objectives

The scope basically involves the implementation of our knowledge encompassing microcontrollers based electronic and sensor circuits to design and develop *"Water Quality and Quantity Measuring System with Prepaid Billing"* capable of operating effectively.

The main objectives of this project are following:

1. To make sure that water is distributed and charged according to its consumption.
2. The distribution is charged in real time with prepaid billing system.
3. The quality of water is monitored regularly in real time.
4. The IoT is utilized to monitor water quality and to make water bill payment in real time.
6. The android based mobile app is also designed to monitor all the activities in real time.

1.5.2 Specifications

1.5.2.1 Hardware specifications

1. Arduino
2. Raspberry pi
3. Yf-s201 hall-effect water flow sensor
4. Solenoid valve for water stoppage
5. Ultrasonic range finder HC-SR04
6. E-201-C PH Sensor Module (6.5 to 8.5)
7. Turbidity sensor SKU SEN0189 (1 to 5 NTU)

1.5.2.2 Software specifications

1. Android App
2. Arduino IDE
3. Python IDE

1.6 Organization of the report

This report is consisted of five Chapters. Chapter 2 briefly discussed the previously published work. Our proposed methodology with the working of different components presented in Chapter 3. Chapter 4 shows and discuss the results. Conclusion and future work directions are discussed in Chapter 5.

2 Literature review

Pakistan is positioned in the southern Asia, having Arabian sea, India, China, and Afghanistan on the south, east, north, and west sides, respectively. The range of Himalaya mountains exist on the east side of Pakistan. The northern side of Pakistan have the mountain ranges of Hindu Kush, Pamir, and Karakoram, which having five mountains above 8000-meter peak [4]. Generally, the Pakistan's climate conditions are semidry with different rainfall patterns. Indus river is the one of the main rivers in Pakistan, flow from north to south and falls in Arabian sea at the end. Almost 27 % of Pakistan land is under agriculture farming, which plays an important role in Pakistan's economy. To increase the agriculture production various pesticides and fertilizers are used. Due to rapid increase in population, urbanization, and industrialization, the quality and quantity of water is a serious concern in Pakistan. The water may have various types of impurities such as chemical, biological, and physical. The biological type impurity is the most dangerous in nature and can cause some serious health issues and can also cause death [5]. The toxic-chemicals and micro organs from domestic/industries waste are the main reason of water pollution. In most area of Pakistan, the ground water is the main source of supply, which contains many bacterial, protozoan, and viral agents. According to a report [6], these microorganisms caused almost 2.5 million deaths every year. Beside domestic and industrial sewage addition in drinking water, there are lack of water monitoring, treatment, and disinfection plants in Pakistan.

2.1 Water quality standard in Pakistan

According to world health organization (WHO) guidance, the Pakistan standard quality control authority (PSQCA) presented some standards for quality of drinking water. Table 2.1-2.4 listed the acceptable ranges of various parameters for quality of drinking water [7].

According to PSQCA, the maximum acceptable limit for bacterial contaminants such as pseudomonas aeruginosa, total coliform, enterococci, and Escherichia coli are 0 per 250 ml of drinking water.

Table 2-1 PSQCA physical standards for water quality [7].

Parameter	**Maximum acceptable concentration**	**Maximum allowable concentration**
Turbidity	5	25
Color	5	50
Taste & Odor	Unobjectionable	
pH	7.0 to 8.5	≥ 6.5 and ≤ 9.2

Table 2-2 PSQCA toxic substance limits for water quality [7].

Parameter	**Maximum acceptable concentration**	**Maximum allowable concentration**
Alkyl Benzyl Sulfates	0.5 mg/l	1 mg/l
Calcium	75 mg/l	200 mg/l
Total Hardness	20 mg/l	500 mg/l
Chloride	200 mg/l	600 mg/l
Sulfate	200 mg/l	400 mg/l
Nitrate	-	10 mg/l
Dissolved Solids	1000 mg/l	1500 mg/l
Iron	0.3 mg/l	1.0 mg/l
Fluoride	1.0 mg/l	1.5 mg/l
Copper	-	1.0 mg/l
Zinc	5.0 mg/l	15.0 mg/l
Manganese	-	0.5 mg/l
Hydrogen Sulfide	Undetectable odor	
Magnesium	50 mg/l	150 mg/l

Table 2-3 PSQCA chemical standards for water quality [7].

Parameter	**Maximum acceptable limit**
Arsenic	0.01 mg/l
Cadmium	0.03 mg/l
Chromium	0.05 mg/l
Cyanide	0.07 mg/l
Lead	0.01 mg/l
Selenium	0.01 mg/l

2.2 Water supply system in Pakistan

In Pakistan, almost 37.5 % population is drinking the unsafe water of dug wells and rivers. The province wise water supply system availability is shown in Figure 2.1 [8]. It is evident from the figure that among all province Punjab has the best water supply system for the consumers. Most of the Baluchistan people had to rely on the water of wells and rivers.

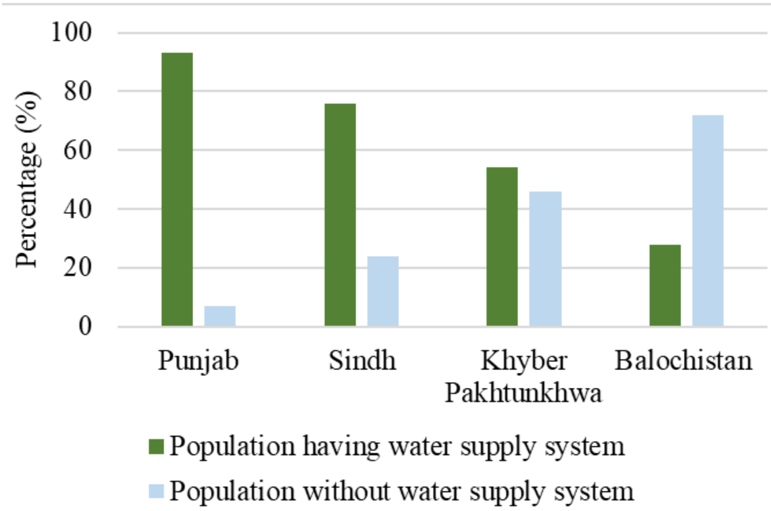


Figure 2-1 Province wise water supply system availability in Pakistan [8].

2.3 Water availability in Pakistan

The trend of water availability per capita from the time of independence of Pakistan to 2050 is shown in Figure 2.2 [9]. According to this figure the water availability per capita exponentially decreasing and Pakistan will face serious water crisis with 660 m^3/capita in 2025.

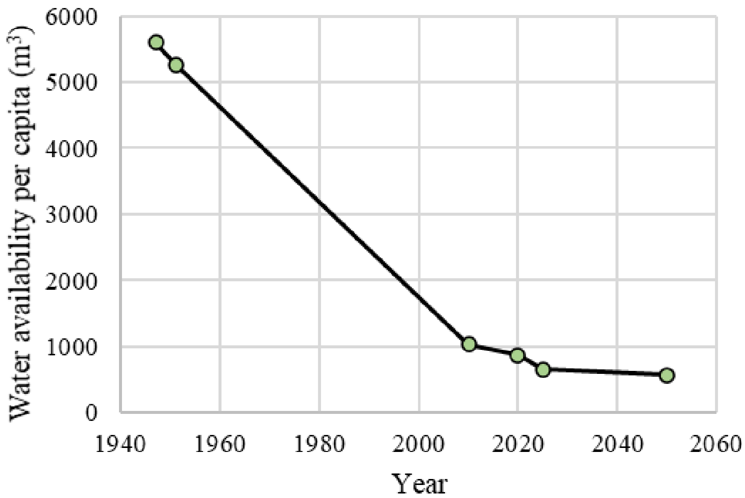


Figure 2-2 Availability of water per capita in Pakistan [9].

2.4 Problem formulation

In recent years, numerous methodologies have been applied to monitor and measure water quality and quantity, respectively. A water management system is designed to measure the conductivity, turbidity, pH, and temperature [10]. They used global system for mobile communications (GSM) network to transmit the data. In another study [11], the wireless sensor network (WSN) is used to monitor and measure water parameters. The code division multiple access (CDMA) and ZigBee technology was used to send the data to the station. The general packet radio service (GPRS) technology was utilized to transmit the sensor information to base station [12]. They also introduced an alarm circuit to buzz when there is any slight change in the water quality. In a recent study [13], a power efficient IoT based water quality measuring system is presented. They used short message service (SMS) to inform the user about water quality.

In this work, a smart android app based an online prepaid billing and water quality measuring system is designed. The proposed smart system regularly monitors the water quality and purchase the water depending upon the need of the consumer. This work can be beneficial to decrease the water wastage, and to check the quality of the water for drinking purposes in real time.

3 Hardware design and proposed methodology

In this chapter, the design of the proposed water quality and quantity management system with online prepaid billing is presented. In the first step, different drinking water quality parameters were assessed to check the water quality standard described by the PSQCA. The chemical water quality parameters such as calcium, hardness, dissolved oxygen, chloride, nitrate, iron, etc. are too expensive to measure/monitor and have maintenance and calibration issues [14]. In this project, after taking these considerations into account, only turbidity and pH sensors have been implemented to check water quality. Figure 3.1 shows the main block diagram of this project.

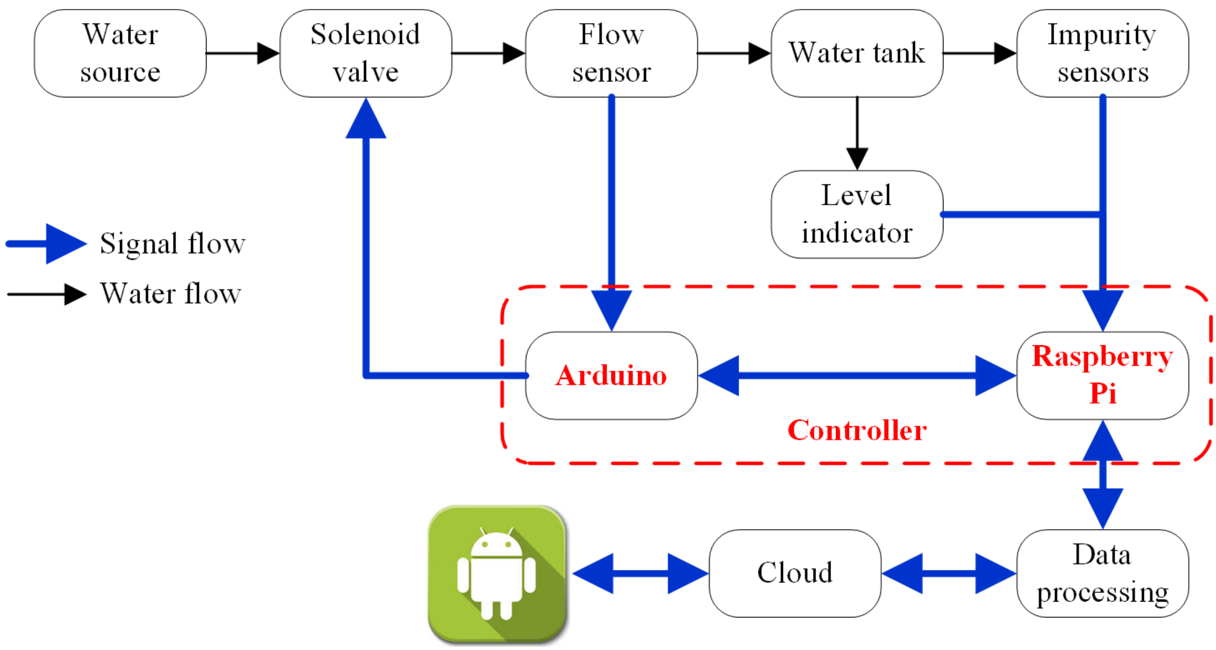


Figure 3-1 Block diagram of the proposed water quality and quantity measuring system.

3.1 Hardware components

3.1.1 Solenoid valve

Solenoid valve is basically an electromagnet-controlled valve. Solenoid valve's working principle is very similar to relay. Like relay have two different modes such as normally open

(NO) and normally close (NC). In NC solenoid valve, the flow of the water will be stopped if water put pressure on the valve, when the magnet gets magnetized due to supplied power the water starts to flow through the valve. NO solenoid valve works exactly the opposite of NC. Figure 3.2 shows the diagram of an electromagnet solenoid valve.

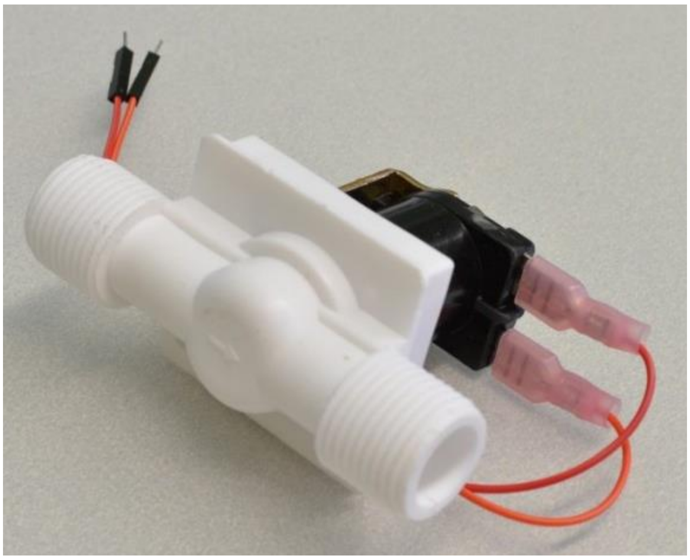


Figure 3-2 Electromagnet solenoid valve.

3.1.2 Flow sensor

There are different types of flow sensor present in the market such as turbine flow meter, venturi tube flow meter, rota flow meter, and magnetic flow meter. In this project, we use turbine flow meter due to its simplicity and cheapness.

Figure 3-3 YF-S201 Hall effect water flow meter/sensor.

This flow sensor converts the mechanical rotation of the turbine into digital electrical output signal. Figure 3.3 shows the diagram of a turbine flow sensor. In turbine flow sensor, a turbine is rotated due to interaction of the water flow with it. A Hall effect sensor counts the voltage pulses depending upon the blade passing over sensor. Each pulse of flow sensor almost equal to 2.25 ml water flow. Equation 3.1 can be used to calculate the flow rate of the water.

$$Flow\ rate\ (l/\min) = \frac{Pulse\ Frequency\ (Hz)}{7.5} \quad (3.1)$$

Normally, the output of the flow sensor ranges between 5 to 12 V. Then the Zener diode is utilized to limit the output voltage of flow sensor to 3.3 V for microcontroller interface, as shown in Figure 3.4.

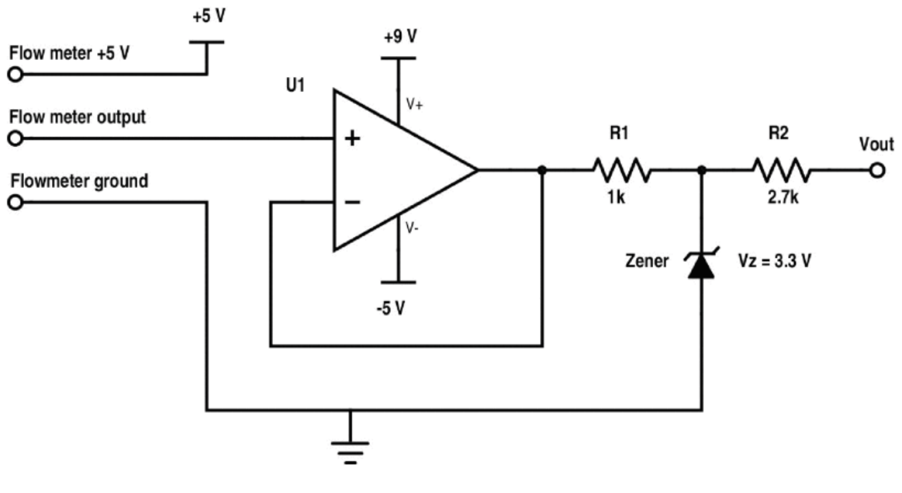


Figure 3-4 Signal conditioning circuit for flow sensor.

3.1.3 Water level indicator

In this project HC-SR04 ultrasonic sensor is used to check the water level in the tank. The ultrasonic sensor has the range of 2 cm to 400 cm with the 3 mm accuracy. The echolocation phenomena are the working principle of this sensor. The sensor is triggered using a 10 µs pulse from any microcontroller. The sensor sends eight 40 kHz waves to detect the water surface in the tank. After striking the water surface, the echo waves come back to the receiver of the sensor. If the depth of the water tank is known, then the time spent can be determined by using following equation.

$$\text{Distance} = \frac{Time}{2} \times Speed\ of\ sound \tag{3.2}$$

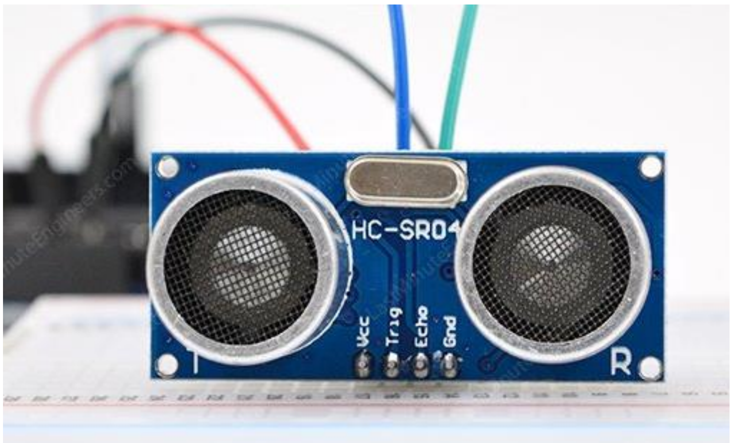


Figure 3-5 HC-SR04 ultrasonic sensor.

3.1.4 Impurity sensor

As discussed earlier, the pH and turbidity sensor are used to check the quality of the water in this project. The detail and working of these sensors have been briefly discussed in this Section.

3.1.4.1 pH sensor

The pH value of the water is one of the important parameters to check the quality of the drinking water. The value of the pH of any solution ranges from 0 to 14. The maximum allowable range for water is 6.5 to 9.2, as shown in Table 2-1. The slight change in the standard value of drinking water has adverse effect on human health. In this work, E-201-C pH sensor module is used to measure the quality of the drinking water. This sensor consists of a simple glass electrode, these electrodes are reliable and cost effective. The glass membrane shown in Figure 3.6 is only sensitive to the hydrogen ions. The electrode works as a single battery cell, and the output voltage has the direct connection with the measure pH value of the solution.

Figure 3-6 E-201-C pH sensor module.

The output voltage of the electrode has the range of -430 mV to +430 mV. For microcontroller interfacing, the output voltage of the electrode amplified to 0-3.2 V. The voltage amplifier circuit is shown in Figure 3.7.

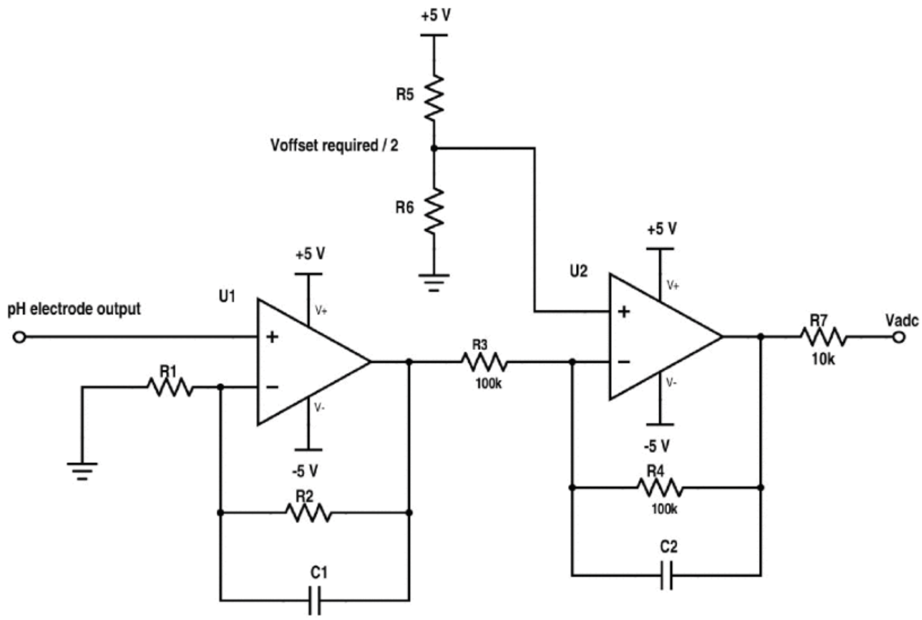


Figure 3-7 Signal conditioning circuit for pH sensor.

U1 and U2 represents the operation amplifier for amplifying and offset purposes, respectively. U2 operates as a differential amplifier having a gain of 2. The total range of 860 mV converted to 3.2 V using this circuit.

$$G = \frac{3.2\text{ V}}{0.86\text{ V}} = 3.72 \tag{3.3}$$

$$G = 3.72 = 1 + \frac{R_1}{R_2} \tag{3.4}$$

$$\frac{R_1}{R_2} = 2.72 \tag{3.5}$$

where R_1, R_2, R_5, and R_6 having the value of 10 kΩ, 27 kΩ, 126 kΩ, and 24 kΩ, respectively. The value of offset is 1.6 V, C_1 and C_2 are used for noise attenuation.

3.1.4.2 Turbidity sensor

In this project, SKU: SEN0189 is used to detect the quality of water by identifying the turbidity in it. It senses the light scattering rate and transmittance by using light to measure the suspended particles in water, The transmittance and scattering rate of light changes with the change in the total suspended solids (TTSs). The turbidity level of the water increases with the increase in TTSs. The output voltage of turbidity sensor has the range of 0-4.5 V, which is compatible for microcontroller. The turbidity sensor is shown in Figure 3.8.

Figure 3-8 SKU:SEN0189 Turbidity sensor.

3.1.5 Proposed controller design

This Section explained the proposed controller design of this project. The controller acquires all the data from sensors (water level, pH level, and turbidity level). Then all the data is transferred to the user (android app) through the internet.

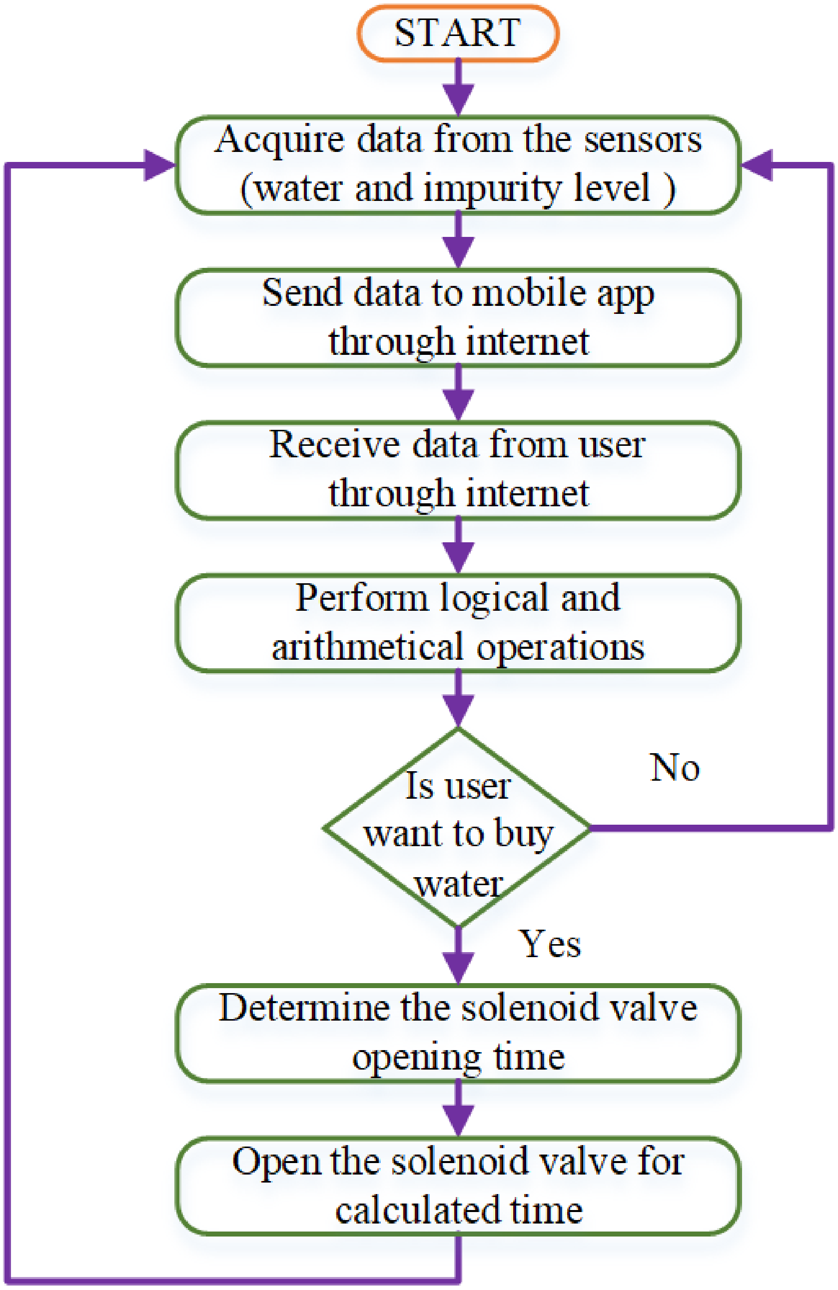


Figure 3-9 The proposed controller design.

The user regularly checks the level of the available water in the tank and decides whether he want to purchase the water or not. If the user wants to purchase the water, then he entered the passcode (according to the amount of the water) to buy the water. Then this passcode sends back to the controller, and the controller confirms that the passcode is valid or not. If the passcode matches the code already feed to the controller, then the controller calculated the solenoid valve opening time. After calculation, the valve is opened for a fixed amount of time, as calculated by the controller. The flow sensor calculated the amount of water and close the solenoid valve accordingly. In addition to this, the controller regularly checks the water quality and informs the user through the android app. The main controller design is also illustrated in Figure 3.9.

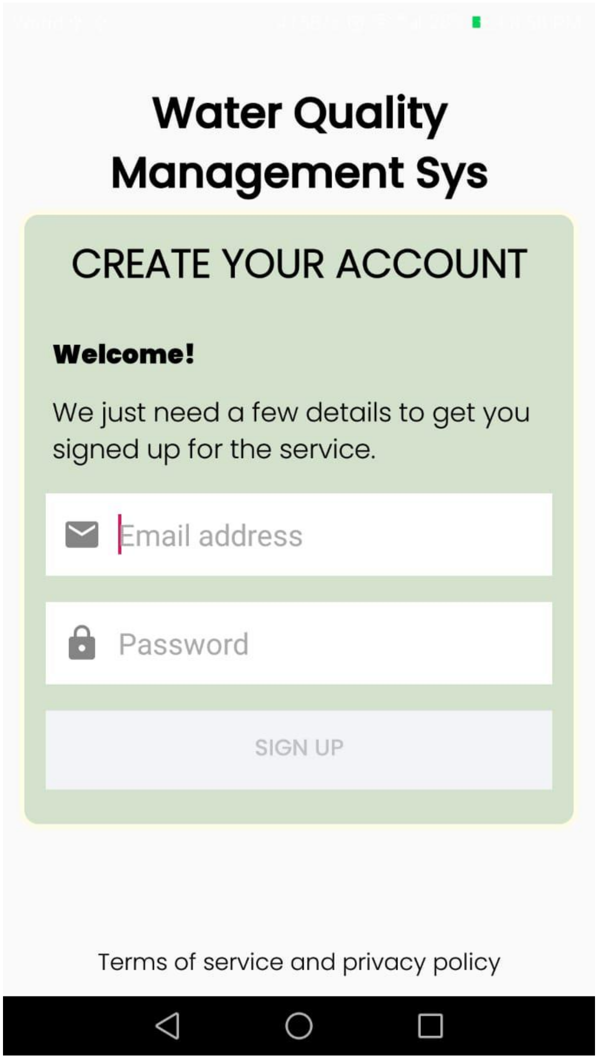
The Arduino Uno and Raspberry Pi both controllers are used to apply the proposed methodology [15, 16]. The three different reasons to use two different controllers are following.

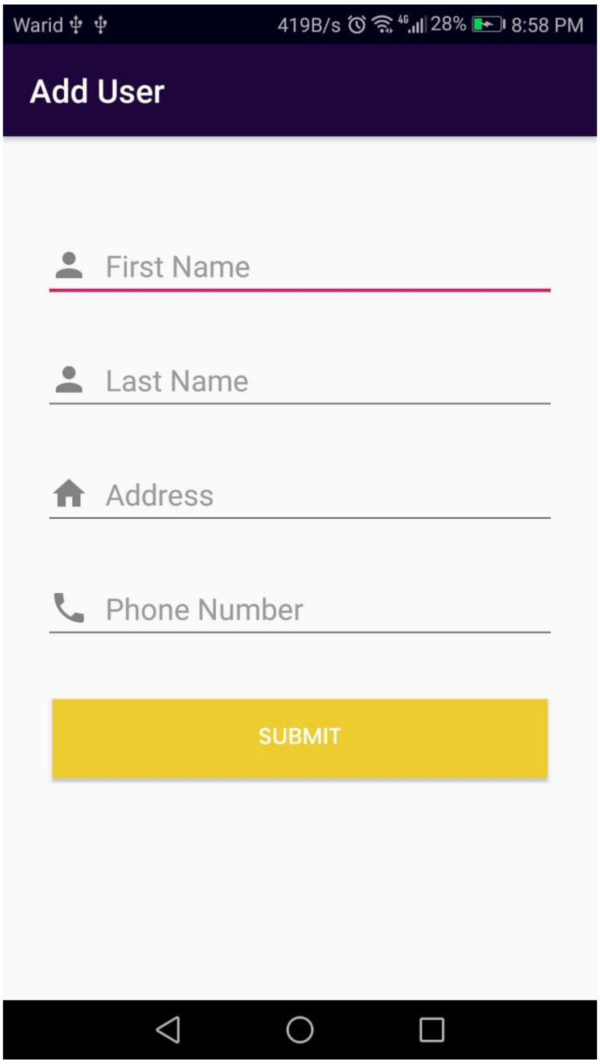
1. The flow sensor, which is used to calculate the quantity of water operates on interrupts and the Arduino Uno has that interrupt pin while the Raspberry Pi controller cannot detect these interrupts.
2. The Arduino Uno has shown some maloperation while uploading the data on the cloud that is why we used Raspberry Pi controller in fusion with Arduino Uno.
3. In addition to this, the Arduino Uno does not have sufficient RAM to access the data of 5 different sensors.

So, to cope these issues, the Arduino Uno and Raspberry Pi has been used together for better performance, reliability, and efficiency of this project.

3.1.6 Android app design

This Section explained the proposed controller design of this project. The controller acquires all the data from sensors (water level, pH level, and turbidity level). Then all the data is transferred to the user (android app) through the internet.





3.1.7 Code

```
volatile int flow_frequency; // Measures flow sensor pulses

unsigned int l_hour; // Calculated litres/hour

unsigned char flowsensor = 2; // Sensor Input
```

```
unsigned long currentTime;

unsigned long cloopTime;

unsigned long stopValFromServer;

int solenoidPin = 4;

char receivedChar;

boolean newData = false;

void flow () // Interrupt function

{

  flow_frequency++;

}

void setup()

{

  pinMode(flowsensor, INPUT);

  pinMode(solenoidPin, OUTPUT);

  digitalWrite(flowsensor, HIGH); // Optional Internal Pull-Up

  Serial.begin(9600);

  attachInterrupt(0, flow, RISING); // Setup Interrupt

  sei(); // Enable interrupts
```

```
  currentTime = millis();
  cloopTime = currentTime;
}
void loop ()
{
  currentTime = millis();
  digitalWrite(solenoidPin, HIGH);    //Switch Solenoid ON
  delay(1000);                        //Wait 1 Second
  digitalWrite(solenoidPin, LOW);     //Switch Solenoid OFF
  delay(1000);                        //Wait 1 Second
  // Every second, calculate and print litres/hour
  recvDataFromServer();
  showNewData();
  if(currentTime >= (cloopTime + stopValFromServer))
  {
    cloopTime = currentTime; // Updates cloopTime
    // Pulse frequency (Hz) = 7.5Q, Q is flow rate in L/min.
    l_hour = (flow_frequency * 60 / 7.5); // (Pulse frequency x 60 min) / 7.5Q = flowr
```

```
ate in L/hour
            flow_frequency = 0; // Reset Counter
            Serial.print(l_hour, DEC); // Print litres/hour
            Serial.println(" L/hour");
          }
        }
        void recvDataFromServer() {
         if (Serial.available() > 0) {
         receivedChar = Serial.read();
         stopValFromServer = Serial.read();
         newData = true;
         }
        }

        void showNewData() {
         if (newData == true) {
         Serial.print("Value received from server ... ");
         Serial.println(receivedChar);
```

```
newData = false;
}
}
```

4 Conclusions and future directions

4.1 Conclusionss

In this work, a real-time prepaid water billing system has introduced for smart water use. The android based app has designed to purchase the water online and to monitor the water quality (pH and turbidity) and quality in the tank (water level). The controller is designed in a way that it regularly checks water level and quality, and inform the consumer on the android mobile app. If the user wants to purchase water, he/she entered a passcode and the controller verifies the passcode and calculates the valve opening time. The controller automatically turned off the solenoid valve after taking feedback from the flow sensor. This smart water quality and quantity measuring system can be implemented for the domestic and industrial users for safe and healthy water.

4.2 Directions for future work

In this project, we have proposed a smart water quality and quantity measuring system. Following points can be considered for future work.

1. Other water quality sensor can be added to detect chemical as well as toxic substance in the water.
2. In this work, the local area network (LAN) is used to verify the results. In future work, static Internet Protocol (IP) address can be purchased to verify the system.
3. FPGA can be used to handle the issues (as discussed above) related to two different controllers.
4. The smart water management system can be designed for the water distribution companies.

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