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COURSE CODE:	**EEN5000**
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Abbreviations

GPS	***- Global Positioning System***
GSM	***- Global System for Mobile Communication***
GPRS	***- General Packet Radio Service***
SMS	***- Short Message Service***
ID	***- Identification***
WSN	***- Wireless Sensor Network***
Rx	***- Receiver***
Tx	***- Transmitter***
UART	***- Universal Asynchronous Receiver -Transmitter***
IO	***- Input Output***
Lo-Fi	***- Low Fidelity***
Hi-Fi	***- High Fidelity***
API	***- Application Programming Interface***

Abstract

A smart city is the future goal to have cleaner and better amenities for the society. Smart underground infrastructure is an important feature to be considered while implementing a smart city. Drainage system monitoring plays a vital role in keeping the city clean and healthy. Since manual monitoring is incompetent, this leads to slow handling of problems in drainage and consumes more time to solve. To mitigate all these issues, the system using a wireless sensor network, consisting of sensor nodes is designed.The system suggests a way to keep an eye on and properly manage the sewer manhole system. In real time, the system provides information about manhole status and identification, allowing city authorities to promptly address any issues, thereby enhancing overall sanitation and health in the communities. The suggested monitoring and alert system has a lot to offer in terms of enhancing public safety and security as well as that of urban infrastructure. By utilizing all of the proposed system's capabilities, utilities may increase the efficiency of their daily operations and do away with the need to rely on the public to notify them of sewage breaks in order to carry out essential maintenance and repairs.

Acknowledgment

I would like to take this opportunity to acknowledge the invaluable contributions and support of several individuals who have been instrumental in the successful implementation of my project. First and foremost, I would like to express my sincere gratitude to my supervisor, Engineer Marufu for his technical expertise, strategic vision, and unwavering guidance which have been pivotal in shaping the direction and success of this project. Your commitment to innovation and your unwavering dedication to improving sewer infrastructure management have been truly inspirational.

I would also like to extend my heartfelt appreciation to my friends and family. Your encouragement, understanding, and moral support during the challenging phases of this implementation have been invaluable. Your willingness to lend an ear, offer advice, and celebrate the milestones have been a true source of motivation and strength throughout this journey.

Without the collective efforts and contributions of this team, the successful implementation of this project would not have been possible. I am deeply grateful for the opportunity to be a part of this transformative project and look forward to witnessing the positive impact it will have on our community and the environment.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Sewage overflows and ruptured sewage pipes have been the source of sanitation issues in Zimbabwean cities and towns.This has occasionally led to cholera and typhoid-related deaths.Growing populations, aging sewage infrastructure, vandalism, and the placement of solid waste into the system have all played a significant role in pipe clogs and bursts that release raw sewage into the environment.These discharges pose a risk to people's health in addition to being an annoyance[1].Because of the unfavorable circumstances within, manhole maintenance can be hazardous and time-consuming, particularly if spills have already occurred. If outflows have been reported, it is inconvenient to attend to defects in terms of health ,thus delivering poor sanitation service to the general public and also unfavourable for inspection of its current state.

1.2 PROBLEM STATEMENT

Today's sewage system is not high-tech. Whenever there is a blockage , early alerts in advance of the blockage are not received since municipalities rely on members of the public's reports on blocked and spilling raw sewage. This pose a great health hazard to the general public.

1.3 AIM

To design a system that continuously monitors the status of the sewer manhole and sends message alerts to concerned personnel.

1.4 OBJECTIVES

- To design a system that monitors sewage level in sewer manhole.
- To design a system that monitors the sewage flow in the inlet and outlet pipes of the manhole .
- Send message alerts with manhole ID tag, threat level, three values(sewer level, input flow and output flow, and frequency of blockage using GSM module to responsible authority

CHAPTER 2 : LITERATURE REVIEW

2.1 INTRODUCTION

Smart cities are springing up all over the world, yet the issues they face are still those of the prehistoric era. The current world desperately needs sophisticated system planning and modern breakthroughs[2]. Intelligent urban areas require intelligent solutions that address long-standing issues by integrating sensors into the city's infrastructure. The prior studies and research on manhole monitoring systems is the main topic of this chapter.

2.2 RELATED WORK THEORIES

The automatic waste drainage water system was the initial step that Z. Mohd Hussin[4] recommended. The Arduino micro controller, gas and ultrasonic sensors are among the sensors in the system that are used to frame up the raw signals. They focused on the drainage system's status and real-time tracking utilizing internet of things applications and the Global System for mobile communication, which is also used to send alert messages to control or authority officials.

Using WSN and IoT, Vidya Sree [5] suggested developing a system for detecting tilt of manhole covers and continuously monitoring dangerous gasses. This paper offers a crucial manhole monitoring and detection system that uses a variety of sensors to continuously check for harmful gasses and determine the state of the manhole lid.

The majority of the other publications focused on locating the manhole's lid or determining the make-up of the different gasses that are inside. The goal of this project was to detect blockages by keeping an eye on the sewer level and fluctuations in the sewage flow within the manhole, and by alerting the appropriate authorities when predetermined threshold values are exceeded.

2.3 LEVEL MEASURING SENSORS

In tanks and process systems, a level sensor measures the level of liquids, other fluids, and fluidized solids, such as slurries, granule materials, and powders that have an upper free surface. After detecting the liquid level, the sensor transforms the observed data into an electrical signal. There are two types of level measurements which are ***continuous*** and ***point***[6].

2.3.1 CONTINUOUS LEVEL MEASUREMENT

Continuous level sensors provide a continuous analogue output to a panel or meter by measuring liquids within a given range and calculating the precise volume of liquid within a constrained space.

2.3.2 Ultrasonic Level Sensor

Figure 2.1: Waterproof ultrasonic level sensor[6]

In ambient tank or sump applications, the ultrasonic sensor offers accurate level measurement of non-foaming chemical, water, wastewater, and petroleum-based liquids from one to twelve meters. Through the air-gap, the high frequency acoustic pulse that the ultrasonic level sensor emits travels, reflects off the liquid surface, and then returns to the transducer. The sensor determines the flight's pulse duration and translates it into a distance or level height.

2.3.3 Radar sensor

Figure 2.1: Radar liquid level sensor[6]

When measuring a product's level using radar, microwaves are sent from the radar sensor's antenna system to the item being measured, reflected off the surface, and then returned to the antenna system. The vessel's level determines how long it takes for signals to be received after they are emitted. Radar-based non-contact level measurement is distinguished by a very high measurement accuracy. No matter how much the temperature, pressure, water vapour content, or level of dust formation changes during the procedure, it has no effect on the measurement.

2.3.4 POINT LEVEL MEASUREMENT

The present level situation is documented by a single distinct liquid height using point level measuring sensors. This kind of sensor typically indicates a low alarm condition or acts as a high alarm, indicating an overfill situation.

2.3.5Capacitance Level Sensor

Figure 2.3: Capacitance level sensor[6]

A capacitor is created by connecting two concentric tubes that serve as electrodes inside of a tank. The volume of liquid has an impact on the capacitor's capacitance, or the amount of energy it can store. The amount of energy that is stored varies along with the liquid level. Capacitance increases with increasing liquid level and vice versa. Any orientation can be utilized with the sensor and it will still measure accurately.

2.3.6 Conductive level sensor

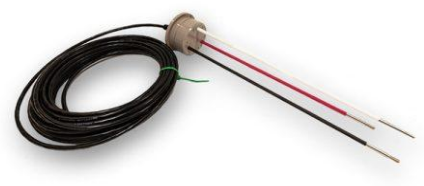


Figure 2.4: Conductive level sensor[6]

Because conductive level sensors are easy to use, dependable, and reasonably priced, they are essential for tracking liquid and solid levels in a variety of sectors. They use conductive probes dipped in the substance to detect changes and operate based on the electrical conductivity of the material. An electrical connection is made between the probes when the substance reaches a certain level. The sensor's control unit detects this change in conductivity and translates it into a level measurement. They have limitations when it comes to non-conductive materials and need to be maintained on a regular basis to avoid probe degradation, even if they provide dependable performance for conductive liquids.

2.3.7 Tuning Fork Level Sensor

Figure 2.5: Tuning fork level sensor[7]

The sensor detects the presence of a liquid or solid (granules or powder) in a vessel using a metal tuning fork construction. The tuning fork is mechanically vibrated by an electronic circuit that is continuously excited. The resonance frequency of the fork lowers when its prongs make touch with anything that has significant mass. This frequency shift is detected by the circuit, which also shows that there is mass contacting the fork..

2.3.8 Rotary Paddle Level Sensor

Figure 2.6: Rottary paddle level sensor (rope type)[7]

In order to prevent overspill and material loss, the sensor is appropriate for level detection in storage tanks, bin hoppers, and containers. A motor spins the revolving paddle continually. The revolution of the paddle will halt when it makes contact with the material because a force greater than the revolving torque will be imparted to it. When it detects rotation, the level sensor will halt and output the contact.

2.4 WATER FLOW SENSORS

The flow rate of a liquid or gas is measured by flow meters, sometimes referred to as flow sensors. Flow meters come in many different varieties, such as floating element, electromagnetic, Karman vortex, and ultrasonic.

2.4.1 Ultrasonic flow sensor

Figure 2.7: Ultrasonic flow sensor[8]

Ultrasonic flow sensors are non-intrusive flow meters that gauge a liquid's flow rate by use of acoustic vibrations. For automated wastewater applications or any other unclean liquid that is conductive or water-based, ultrasonic meters are perfect. Doppler and transit time ultrasonic flow meters are the two varieties available. The liquid must flow at a high enough rate to maintain the solids suspended, and the doppler ultrasonic flow meter needs bubbles or particles to reflect the ultrasonic signals. An ultrasonic pulse or beam that is broadcast into a pipe with such discontinuities reflects back from them with a frequency change that is directly proportionate to the flow rate of the liquid. Ultrasonic flow meters with transit times detect the interval of time between the transmission of an ultrasonic signal from the initial transducer.

2.4.2Electromagnetic Flow Sensor

Figure 2.8: Electronic flow sensor[8]

By applying Faraday's Law of Induction, electromagnetic flow sensors are able to identify flow. Moving conductive liquids inside of a magnetic field produce an electromotive force (voltage) that is proportional to the average flow velocity, magnetic field strength, and pipe inner diameter according to Faraday's law of induction. Put another way, liquid traveling through a magnetic field converts its velocity to electrical. The electromotive force that the electrodes are capturing varies along with changes in flow.

2.4.3 Karman Vortex flow sensor

Figure 2.9: Karman vortex flow sensor[8]

The Karman vortex street principle governs how vortex flow meters work. In fluid dynamics, a phenomena known as the Karman vortex steer occurs when opposing vortices build behind a bluff body. Inside the measurement pipe are the electronics sensor and the bluff body. Opposing vortices that are offset from one another occur as the river impinges on the bluff body. As a result, the flow forms a street of vortices. The measurement of flow makes use of this phenomenon..

2.4.4 Floating Element

Figure 2.10: Floating element[8]

Another name for the float flow meter is a rotar flow meter. A float rises and falls in a vertical tapered tube in a float flow meter, which is a volumetric flow meter. As the flow varies, the float's area of flow changes. Steam, gas, and liquid flows can all be measured with a float flow meter. It works particularly well for measuring medium flows in situations with modest flow rates and small flows.

2.5 GLOBAL POSITIONING SYSTEM (GPS) SENSOR

A GPS sensor is a tool that uses signals from Global Positioning System satellites to pinpoint an object's or person's exact location. Depending on the users' degree of clearance and security, the GPS offers two different services**[9]**.

2.5.1Assisted GPS (A- GPS)

With assisted GPS, satellite locations can be assisted by providing information from nearby network sources to receivers. A-GPS is typically utilized in places where trees or towering structures make it difficult for satellite signals to reach.

2.5.2 S-GPS

A tweak to GPS known as simultaneous GPS enables a phone to simultaneously transmit data, speech, and GPS signaling. This is especially helpful in an emergency since it enables emergency response agencies, like ambulances and fire stations, to identify the caller as soon as the call comes in.

2.5.3 D-GPS

A correction method called differential GPS is used to boost the precision of position information gleaned from a conventional GPS receiver. D-GPS improves one's understanding of an object's or person's precise location. The method operates by broadcasting the computed difference between the satellite location and the known fixed locations through a network of fixed ground stations.

2.5.4 Non-Differential GPS

Differential GPS uses satellite signals to determine position; non-differential GPS uses direct satellite signals. Although it is not as accurate as D-GPS, its use is far more extensive.

2.5.5Mapping and Non-mapping GPS

One kind of GPS device that has built-in maps is called a mapping GPS. Downloading maps to add to the GPS mapping is another option. This kind of GPS unit is frequently seen in smartphones and other portable electronics. GPS device without a map that is not able to map. Without using roads or landmarks, it displays your location and the path to a different area. It marks your progress and direction with trails that resemble breadcrumbs.

2.6 GLOBAL SYSTEM FOR MOBAL COMMUNICATION (GSM) MODULES

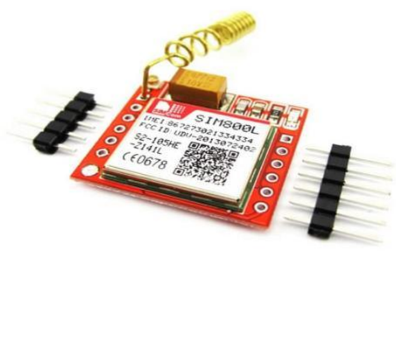


Figure 2.14: GSM module[13]

A GSM module is a gadget that allows electronic devices to communicate with each other over a GSM network. GSM provides a channel for wireless communication between mobile devices since it is a standard for digital cellular communications. A device can send and receive data via a GSM network with the use of a specialized hardware known as a GSM module. The GSM network is an essential component of modern communication systems. Mobile devices use this standard to establish wireless connections with one another. The GSM network is a popular choice among applications because it provides a stable and secure communication channel. A GSM module has to be connected to the GSM network via a SIM card in order to work. The SIM card provides the module with a unique identification number that it uses to identify itself on the network. After that, the GSM module may communicate with the network by using a number of protocols to send and receive data. It is in charge of establishing and maintaining the channel of communication that links the device to the network. The module also handles data encryption and decryption to ensure the security of the transmission

GSM modules come in a variety of forms, each intended for a particular need**.[14].** Typical varieties include some of the following:

1. **SIM800 Series**: These modules, which include technologies like GPRS, GPS, and Bluetooth connectivity, are commonly utilized for Internet of Things applications.
2. **SIM900 Series**: Due to their adaptability, these modules are widely utilized in a variety of applications, such as remote monitoring, security systems, and vending machines.
3. **SIM7000 Series**: These modules support CAT-M1, NB-IoT, and LTE networks and are intended for Internet of Things and M2M applications.
4. **Quectel M95**: Because of its low power consumption, this module is frequently utilized in applications like remote monitoring and smart metering.
5. **Telit GE864**:This module, which is well-known for its small size and low power consumption, is appropriate for applications with limited space.

2.7 MICROCONTROLLER THEORIES

An embedded system's micro controller is a small integrated circuit that is intended to control a single function. A micro controller is a single chip that consists of a CPU, memory, and input/output (I/O) peripherals. To manage a single function in a device, a micro controller is integrated into a system. It accomplishes this by using its core CPU to evaluate data that it gets from its I/O peripherals. When the micro controller gets temporary data, it stores it in its data memory. The processor then accesses this memory, reads the information, and applies the instructions from its program memory to interpret and utilize the incoming data. It then communicates and takes the necessary action using its I/O peripherals.

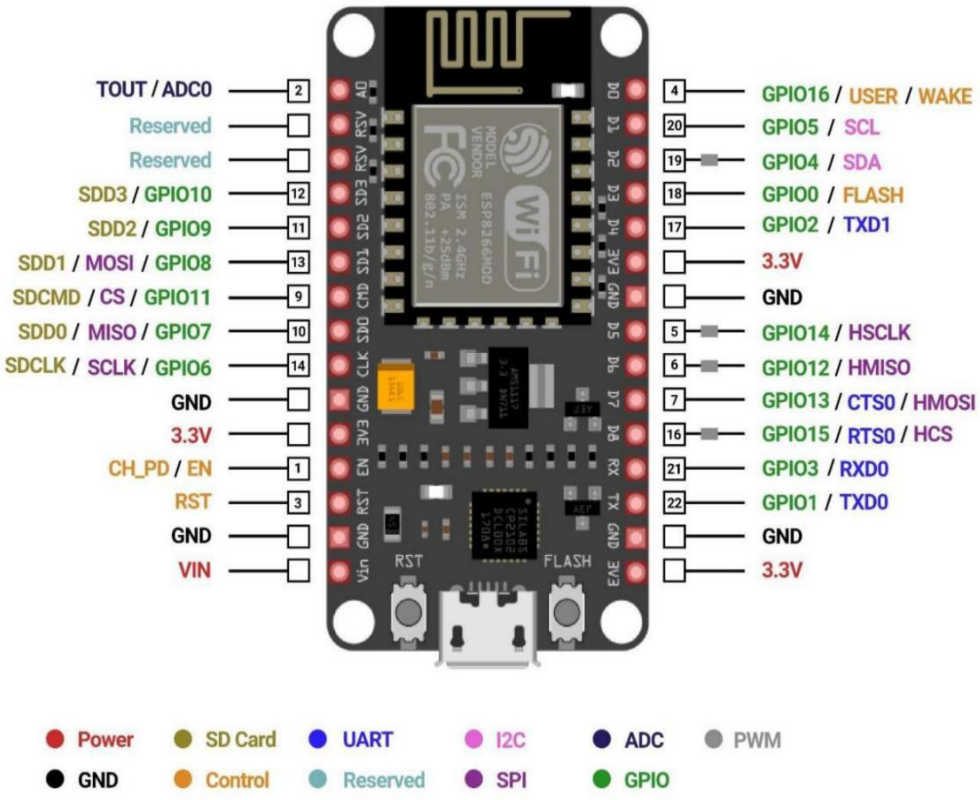


Figure 2.11: ESP8266 micro controller[10]

The low-cost, low-power ESP32 family of microcontrollers has built-in Wi-Fi and dual-mode Bluetooth. The capacity and Processors of these chips vary. It can be used as a standalone device or as a UART to WiFi adaptor to allow other microcontrollers to be connected to wireless networks. For example, you can attach an ESP8266 to an Arduino board to enable Wi-Fi. This allows you to publish your projects online, which is great for home automation apps and the internet of things. It also lets your smartphone connect to it. It has 11 GPIO pins* (General Purpose Input/Output pins) in addition to an analog input. This suggests that programming it is similar to programming a normal Arduino or comparable micro controller. Nevertheless, using it as a standalone device is the most beneficial application.

2.7.2PIC MICROCONTROLLER

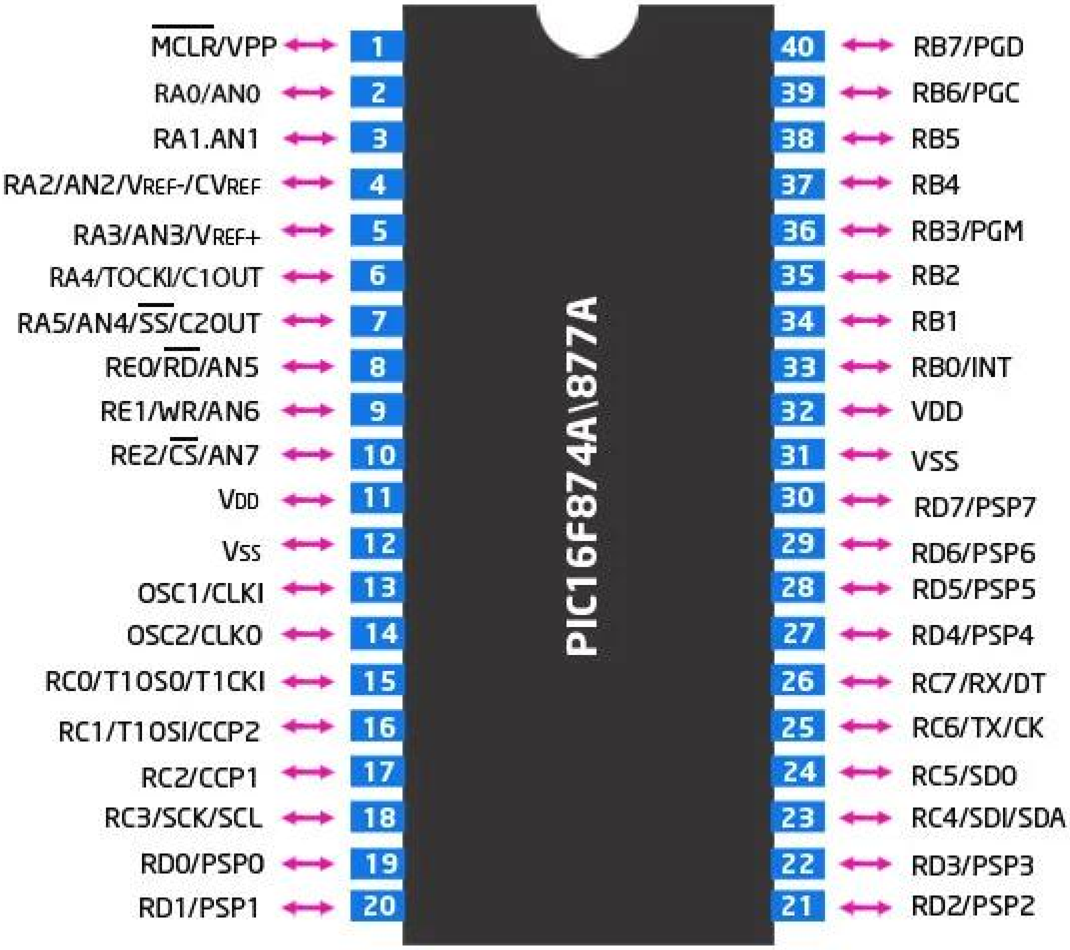


Figure 2.12: PIC16F874A/877A micro controller [11]

PIC microcontrollers are intended to simplify the programming and interface of embedded system designs. Most PIC microcontrollers on the market are 8-bit versions, despite the fact that Microchip did introduce some 16- and 32-bit devices. The PIC16F877 and PIC16F84 were two of the most popular PIC microcontrollers due to their straightforward functionalities. The PIC18F family is suitable for applications that require increased memory, performance, or richer peripherals. Modern PIC microcontrollers have flash memory, which is a feature that saves program instructions. In contrast to OTP or EPROM microcontrollers, flash memory has a larger capacity and is simpler to erase. Moreover, run-time variables and application data can be stored on PIC microcontrollers thanks to their inherent RAM and EEPROM features.PIC micro controller ports, like PORTA and PORTB, are used to identify the I/O pins. An 8-bit PIC contains 8 different pins for each port. It is possible to configure each pin for input, output, or other peripheral uses.

2.8 VOLTAGE REGULATORS

Figure 2.13: Voltage regulator[12]

A circuit that generates and sustains a constant output voltage regardless of changes to the input voltage or load circumstances is known as a voltage regulator. The purpose of voltage regulators is to maintain power supply voltages within an acceptable range for the other electrical components. Voltage regulators come in two primary varieties, switching and linear. Both kinds control the voltage of a system, however switching regulators have a high efficiency whereas linear regulators have a low efficiency.

2.8.1LINEAR VOLTAGE REGULATORS

Known by other names, such as low-dropout linear regulators or linear voltage regulators, these regulators use a transistor that is controlled by a negative-feedback circuit to create a set output voltage that doesn't change even when the input voltage and load current fluctuate.

2.8.2 SWITCHING VOLTAGE REGULATORS

Direct current (DC) voltage input can be changed to the desired DC voltage using a switching regulator. A switching regulator is responsible for changing the voltage from a battery or other power source to the voltages needed by following systems in an electronic or other device.

CHAPTER 3: DESIGN

3.1INTRODUCTION

An underground drainage monitoring system will not only help in maintaining the proper health and safety of the city but also increase the work efficiency of government personnel. This chapter focuses on the design of the automated sewer manhole monitoring system. The design influences the choice of sensors, micro controller and other components used to construct the circuit. The first step in the design of this system is hardware block diagram which identifies the components used and their basic functions which must be performed.

3.2 BLOCK DIAGRAM OF AN AUTOMATED MANHOLE MONITORING AND ALERT SYSTEM

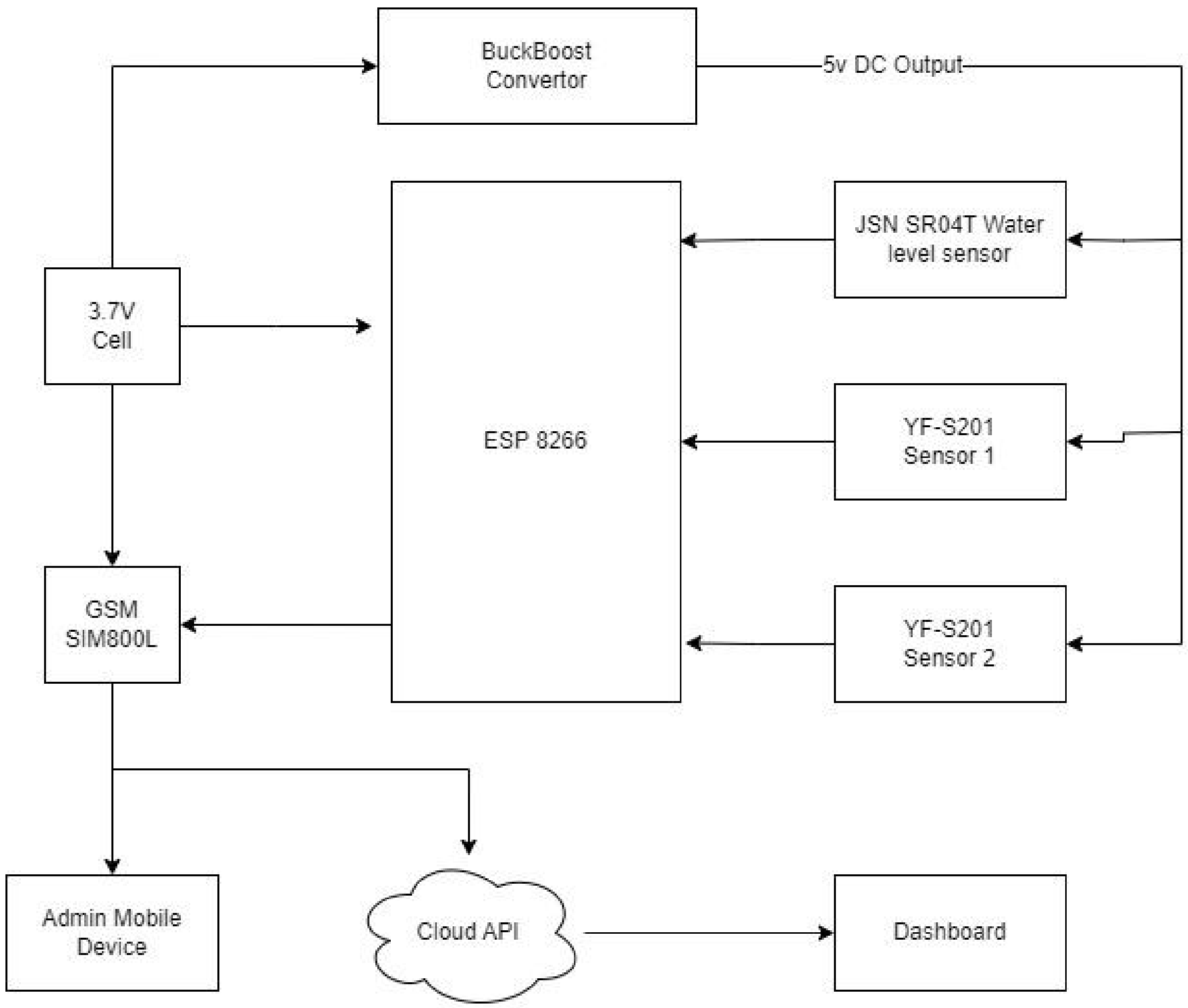


Figure 3.1: Automated manhole monitoring and alert system block diagram

Figure 3.1 illustrates the manhole monitoring system which is powered by a 3.7V DC supply directly connected to the ESP controller and the GSM module. The buck-boost feeding from the DC battery will boost the voltage to give out a constant 5V DC needed by the sensors (flow and level) that are interfaced with micro controller in order to make the system smart. Under safe conditions, the system will operate in the ***'monitoring state'***, that is, the ESP will upload the processed values from the sensors to the monitoring dashboard via the GSM module and the cloud API. However, under unsafe conditions, that is if sensor values have exceeded the set threshold values, the system will operate in the ***'alert state'***, the configured GSM module will send an alert message with manhole ID tag to the Admin mobile device making it easy for the officials to identify(locate) the manhole which needs attention.

3.3 SCHEMATIC CIRCUIT DIAGRAM.

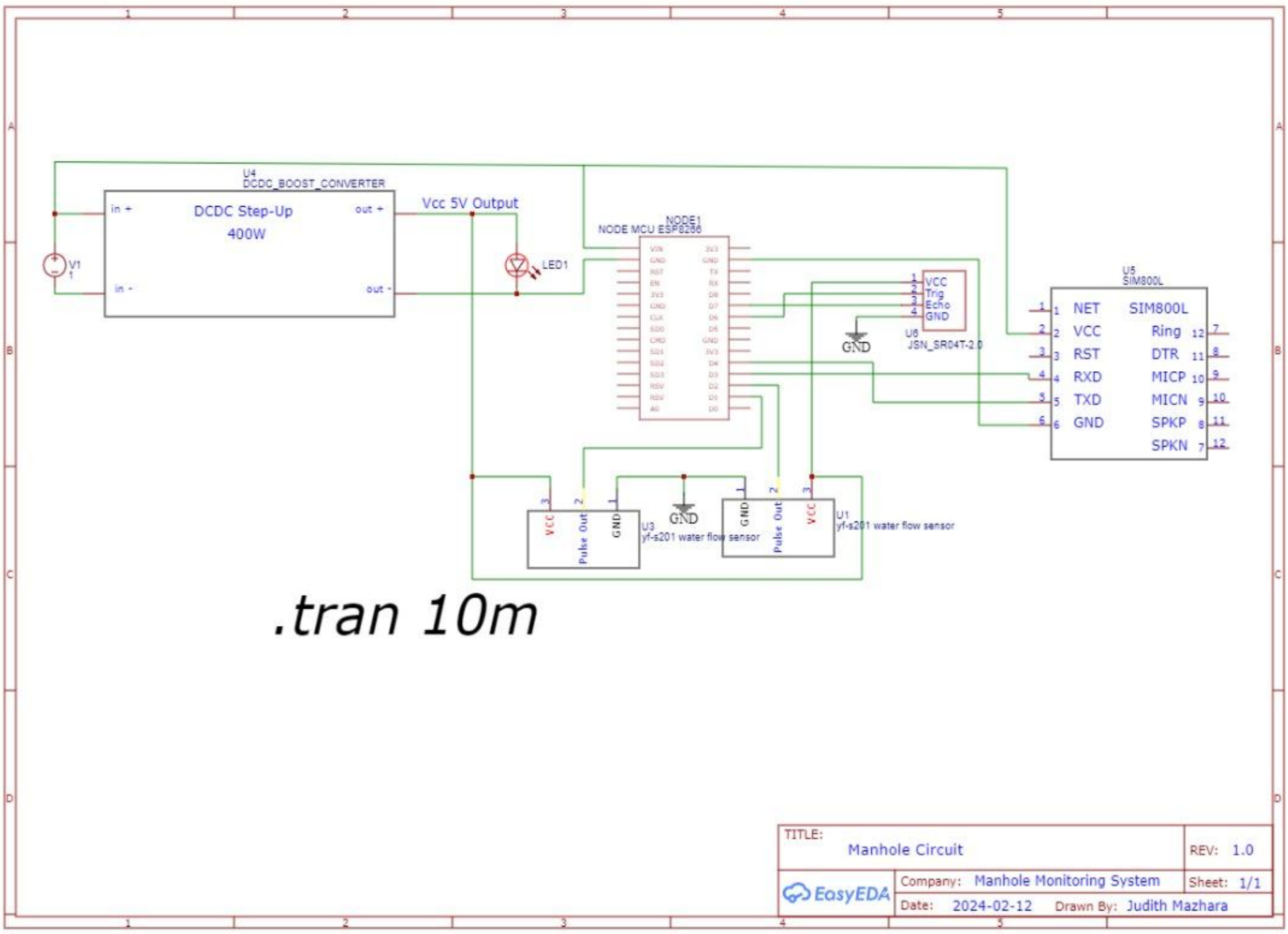


Figure 3.2: Manhole monitoring and alert system schematic circuit diagram.

Figure 3.2 shows the schematic circuit design for our system created using EasyEDA software. The circuit makes use of a 3.7V DC battery as its primary power source. This battery powers the GSM module directly. The Buck-boost connected to the battery steps up the battery voltage to a constant 5V DC output needed to power the system's sensors (flow sensors and level sensor).There are two flow sensors ,one for sensing the input flow which has its pulse pin connected to pin D2 and one for sensing the output flow from the manhole connected to pin D3. The level sensor has its echo pin(Tx) connected to D6 and trigger pin(RX) connected to D7. Lastly, the GSM module has its Rx connected to D4 and Tx to D5.

3.4 SYSTEM FLOW CHART

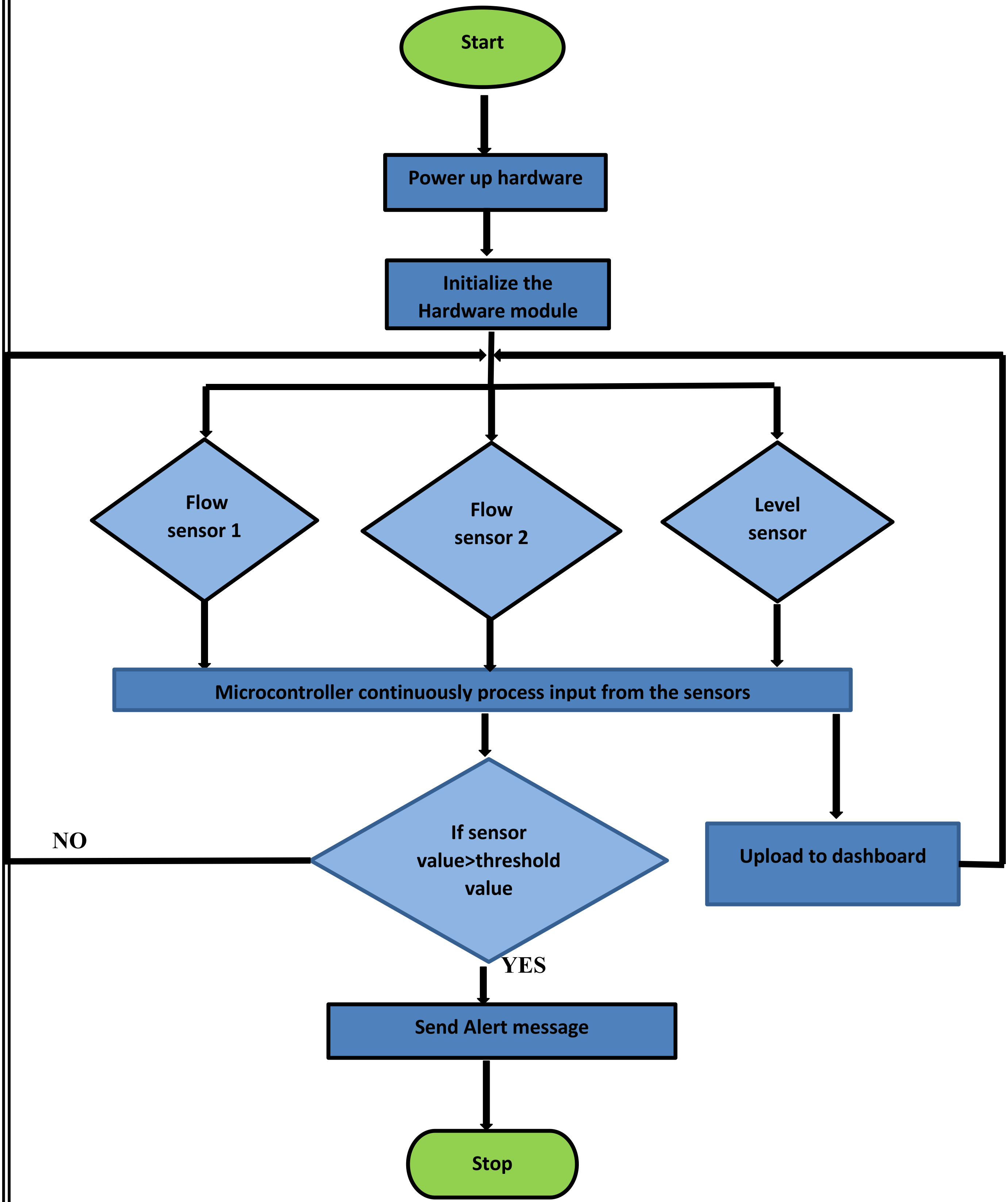


Figure 3.3: Automated sewer manhole monitoring system flow chart

Figure 3.3 shows the system flow chart, which helps in depicting the separate steps of the process and briefly describes those processes in sequential order. The system is powered and the hardware is initialized. ESP microcontroller continuously receives data from the sensors and uploads the information to the dashboard at regular time intervals (monitoring).The same data is also compared to the predetermined threshold value. If the sensor value exceeds the threshold value, the microcontroller instructs the GSM to send an alert message to the managing station and the alert process is terminated. .

3.5 SOFTWARE DESIGN

The system's software is divided into two sections: the alerting and the monitoring sections. The Advanced Programming Interface (API), a technique that allows two software components to communicate with each other using a set of definitions and protocols, will be used by the system. This time, it's the admin monitoring code base (monitoring) and the ESP 8266 code base (alert).

3.5.1 MONITORING SYSTEM DASHBOARD

A dashboard monitoring system offers a quick summary of occurrences from the environment under observation, can assist in solving a variety of issues. The creation of monitoring dashboards was necessary because they make it possible to rapidly evaluate the state of the environment and pinpoint areas that need urgent attention.

3.5.2 Lo-fi WIREFRAME

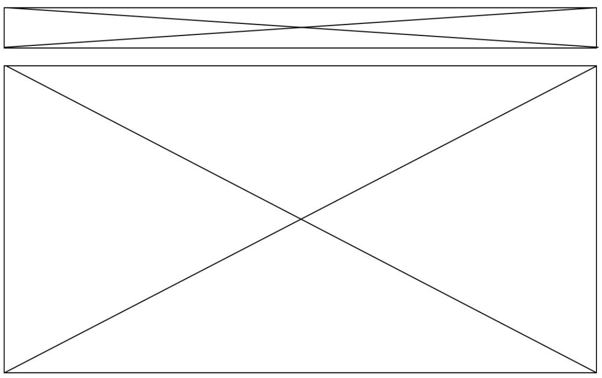


Fig 3.4: Lo-fi wireframe

Figure 3.4 shows an example of a Low-fidelity wireframe, which shows the essential components of a website or application. It provides teams with early concept visualization and testing at the start of the creation process by outlining the blueprint in its most basic form.

3.5.3 HI-FI WIREFRAME

Figure 3.5: Hi-fi wire frames

High quality wireframes as shown in figure 3.5, shows a realistic prototype that closely mimics the application's or website's final layout. It may contain images, colors, fonts, push buttons, and icons. More resources are devoted to these kinds of wire frames in order to finish them.

3.6 ADAFRUIT FEED

The foundation of the Adafruit IO system is feeds. The data and meta-data you have submitted to Adafruit IO are stored in a feed. Meta-data comprises configurations for data privacy and public access, the license that applies to the stored sensor data, and an overview of the data that is readable by humans. Data is the information that Adafruit IO is needed to hold, such as flow speed information, water level, etc. IO data is stored in time series databases known as feeds. Each feed, which forms the basis of the Adafruit IO system, includes time-stamped data elements. For instance, our project requires the creation of three feeds, one for the level sensor and one for each flow sensor.

3.6.1 STEPS TO CREATE A MANHOLE MONITORING SYSTEM FEED WITH ADAFRUIT IO

Adafruit IO, is a cloud-based service tailored specifically for IoT projects. It serves as a bridge between connected devices and the cloud, facilitating the exchange of data in real-time

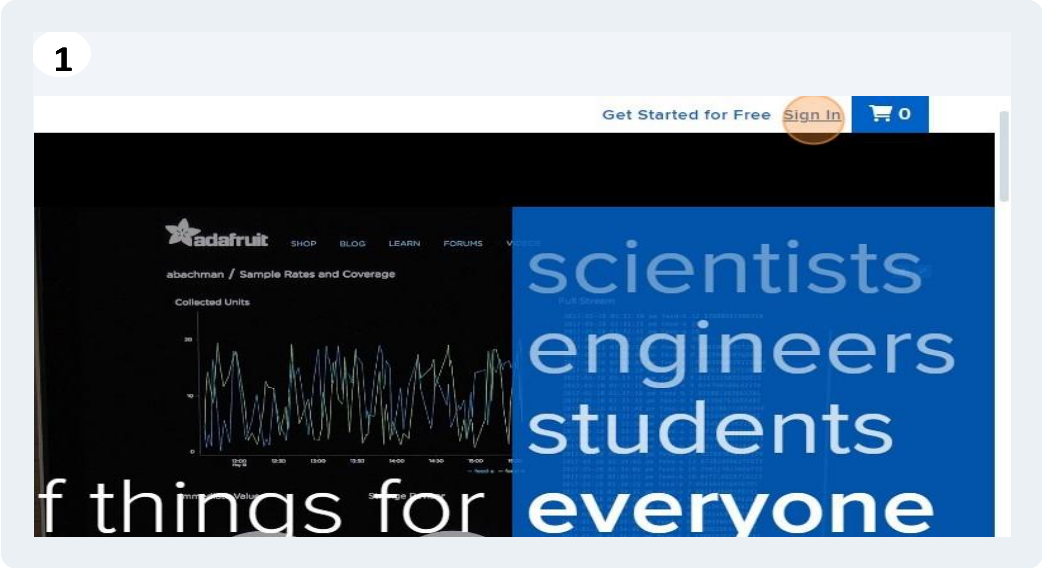


Fig 3.6: Step 1

Fig 3.6 illustrates Step 1: click ‘sign in’ ti sign inti Adafruit IO using user email address and password.

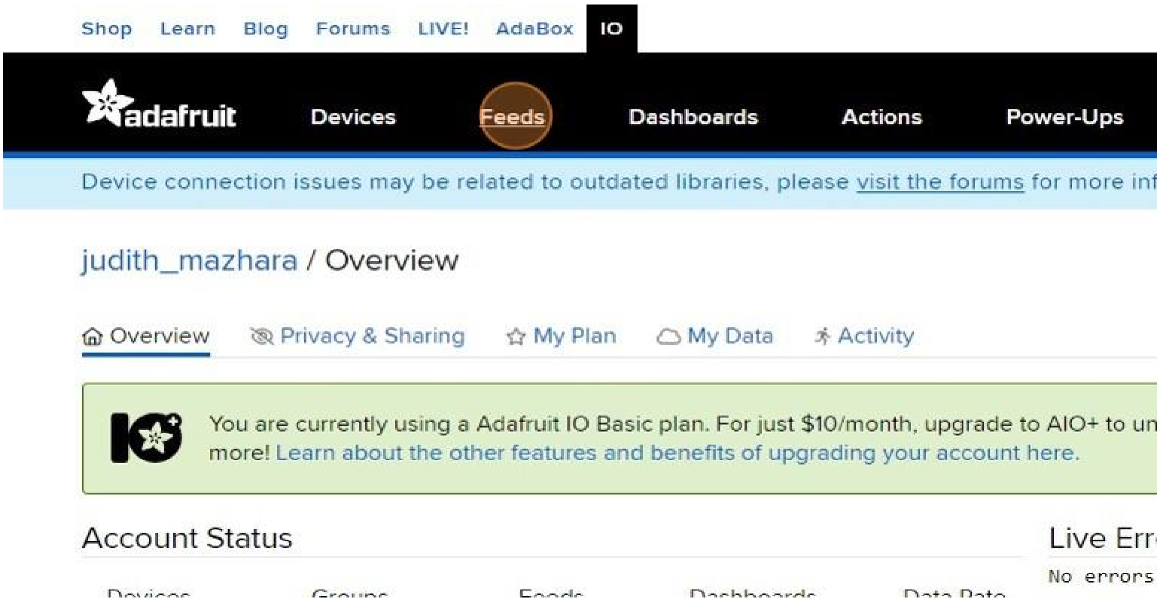


Fig 3.7: Step2

Fig 3.7 illustrates Step2: Click on ‘feeds’ to get to get the feed display page.

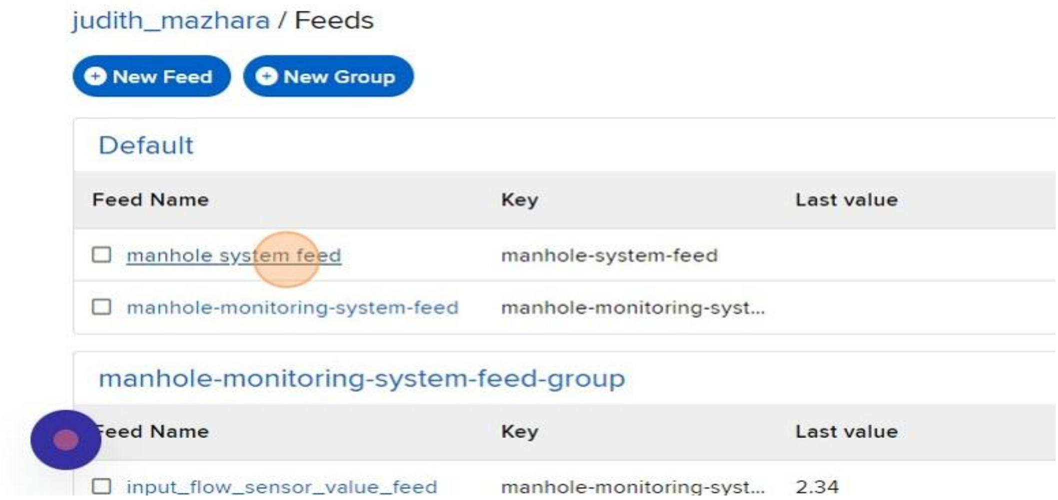


Figure 3.8: Step 3

Figure 3.8 illustrates Step 3: Click on the created 'manhole system feed'

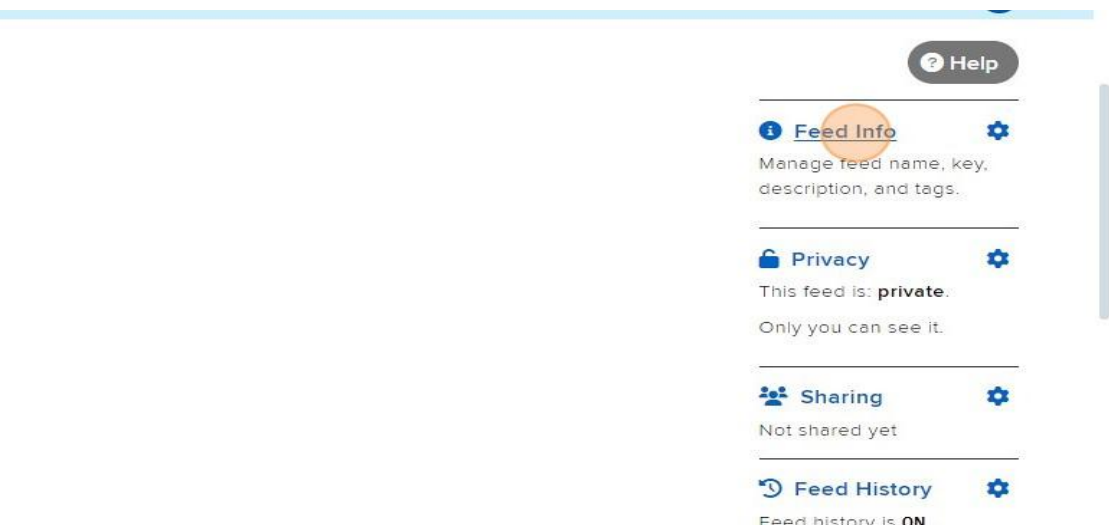


Fig 3.9: Step 4

Fig 3.9 illustrates Step 4: Click on 'feed info' in order to get the feed end points which is going to be the sensor value destination.

Figure 3.10: **IO key display**

Figure shows 3.10 shows the assigned assigned IO key for the user name 'judith_mazhara"

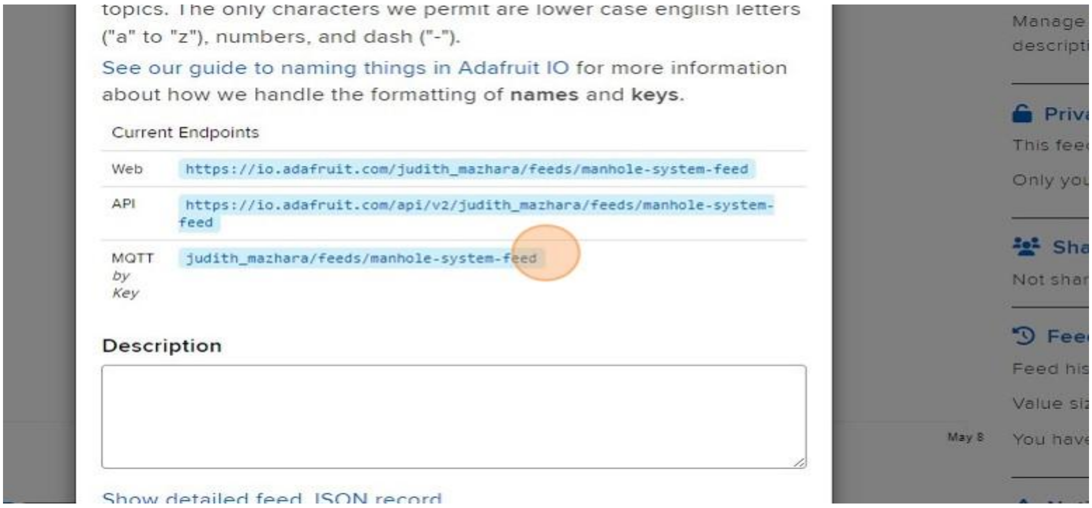


Figure 3.11: Credentials display

Figure 3.11 illustrates Step 6: Upon successful creation of the feed and display of the information , the feed information should be displayed as in figure 3.11 and used as adafruit credentials as demonstrated in the code in figure 3.12 below.

```
// Adafruit IO credentials
#define AIO_USERNAME "judith_mazhara"   // Adafruit IO username
#define AIO_KEY "aio_UonX53zsLcrwSt3n62Ab2kvhi6H1"   // Adafruit IO key

// MQTT broker settings
#define MQTT_SERVER "io.adafruit.com"   // MQTT server address
#define MQTT_PORT 1883   // MQTT server port
```

Figure 3.12: username and API Key credentials

Figure 3.12 shows the code which will initiate the Adafruit IO feed connection since the connection relies on the username and API key credentials.

3.6.2 API MONITORING BLOCK DIAGRAM

Figure 3.13: API monitoring block diagram

Figure 3.13 shows the monitoring part of the system which consists of the ESP 8266 which sends processed data received from the sensors to the Adafruit API via the GSM module. This data is accessed through the Admin interface and is displayed by live graphs. The monitoring dashboard is the central interface for the Automated Sewer Manhole Monitoring and Alert System, providing a comprehensive and user-friendly platform for monitoring, analyzing, and managing the sewer infrastructure data.

3.6.3Uploading sensor data to Adafruit IO

```
  Serial.println("SMS notification sent.");
}

//Function to upload sensor data to Adafruit IO
void uploadToAdafruit(float inputFlow, float outputFlow, float waterLevel) {
  if (inputFlowFeed.publish(inputFlow)) {
    Serial.println("Input Flow Value Uploaded");
  } else {
    Serial.println("Input Flow Value Failed to upload");
  }

  if (outputFlowFeed.publish(outputFlow)) {
    Serial.println("Output Flow Value Uploaded");
  } else {
    Serial.println("Output Flow Value Failed to upload");
  }

  if (waterLevelFeed.publish(waterLevel)) {
    Serial.println("Water Level Value Uploaded");
  } else {
    Serial.println("Water Level Value Failed to upload");
  }
  return;
}

// Function to connect to MQTT broker
```

Figure 3.14: Function to upload sensor data to Adaftruit IO

Figure 3.14 shows the code function for uploading sensor data values to Adafruit IO dashboard. Developed as a web-based application, the monitoring dashboard can be accessed securely by authorized personnel through any internet-connected device, such as a computer, tablet, or smartphone. This accessibility ensures that the system can be monitored and managed from any location, enabling rapid response and decision-making.

3.6.4 ALERT SYSTEM BLOCK DIAGRAM

Figure 3.15: Alert system block diagram

Figure 3.15 shows the alert part of the system. The Automated Sewer Manhole Monitoring and Alert System incorporates a GSM notification system to provide timely alerts and notifications to the relevant stakeholders in the event of critical events or system malfunctions. This system ensures that the appropriate personnel are informed immediately, enabling them to take prompt action and minimize the impact of any sewer infrastructure issues.

3.6.5 Thresholds for triggering message Alerts

```
manhole-code
  // Construct the message
  String message = "Alert\n Potential Manhole Blockage Detected: Manhole ID: 001";
  message += "\n\nInput Flow: " + String(inputFlow) + " L/min\nOutput Flow: " + String(outputFlow) + " L/min\nWater Level: " + S
  if (inputFlow < 1.00) {
    message += "\nPotential Issue With Inlet Pipe: Alert Level: RED";
  }
  if (inputFlow > 1.00 && inputFlow < 1.50) {
    message += "\n\nPotential Issue With Inlet Pipe: Alert Level: Yellow";
  }
  if (waterLevel > 0.22) {
    message += "\nPotential Issue With Outlet Pipe, Water Level Rising: Yellow";
  }
  if (waterLevel > 0.24) {
    message += "\nPotential Issue With Outlet Pipe, Water Level Rising: Red";
  }
  if (outputFlow < 1.00) {
    message += "\nPotential Issue With Outlet Pipe: Alert Level: RED";
  }
  if (outputFlow > 1.00 && outputFlow < 1.50) {
    message += "\n\nPotential Issue With Outlet Pipe: Alert Level: Yellow";
  }
```

Figure 3.16: thresholds for triggering message alerts

Figure 3.16 shows the set threshold values for the message alerts. The GSM module is connected to the central control unit's microcontroller, which is responsible for monitoring the sensor data and triggering the appropriate notification events based on predefined thresholds and alarm conditions.

RED alert

- Input/ output flow sensor value **< 1.00 L/min**
- Water level sensor value **> 0.24 m**

YELLOW alert

- **1.00 L/min** < Input/output flow sensor value < 1**.50 L/min**
- **0.22m** < Water level sensor value< **0.24m**

3.6.6 MONITORING AND ALERT SYSTEM BLOCK DIAGRAM

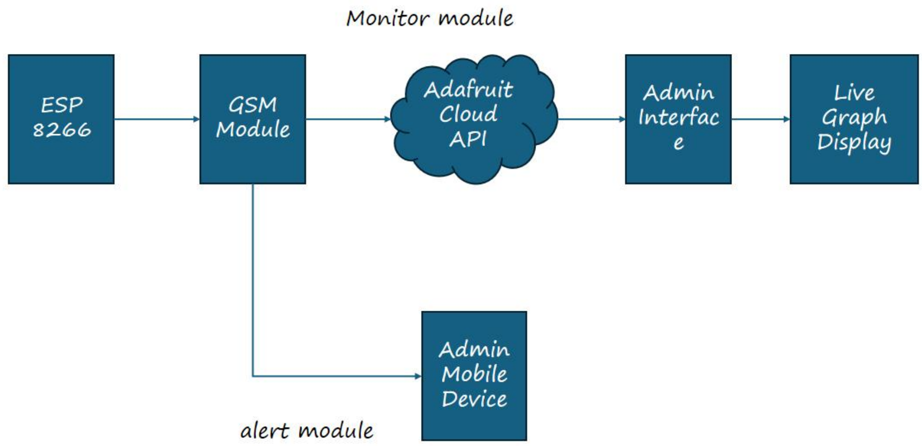


Figure 3.17: Monitoring and Alert System block diagram

Figure 3.17 shows relationship between the monitoring and alert parts of the entire system. Message alert is triggered if set threshold values are exceeded and at the same time this information is uploaded to the dashboard for monitoring.

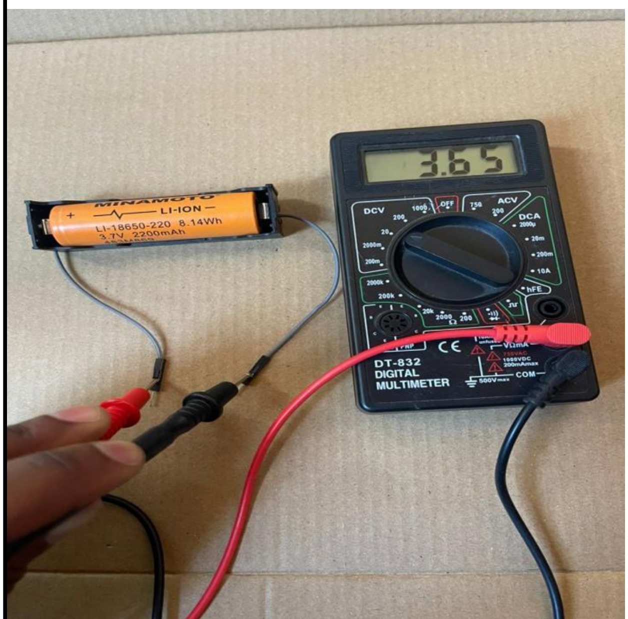
CHAPTER 4: IMPLEMENTATION

4.1INTRODUCTION

This chapter mainly focuses on the steps taken in executing the system design. The main aim is to carry out intentional activities that turn evidence and ideas into practices that work in the real world. This chapter details the implementation of the Automated Sewer Manhole Monitoring and Alert System, from prototype development to the deployment of the full-scale system in the field. It covers the hardware assembly, software integration, site selection and preparation, installation and configuration, operational workflows, and the testing and validation procedures carried out to ensure the system's functionality and reliability.

4.2 BREADBOARD MODULAR IMPLEMENTATION

4.2.1 Power Supply



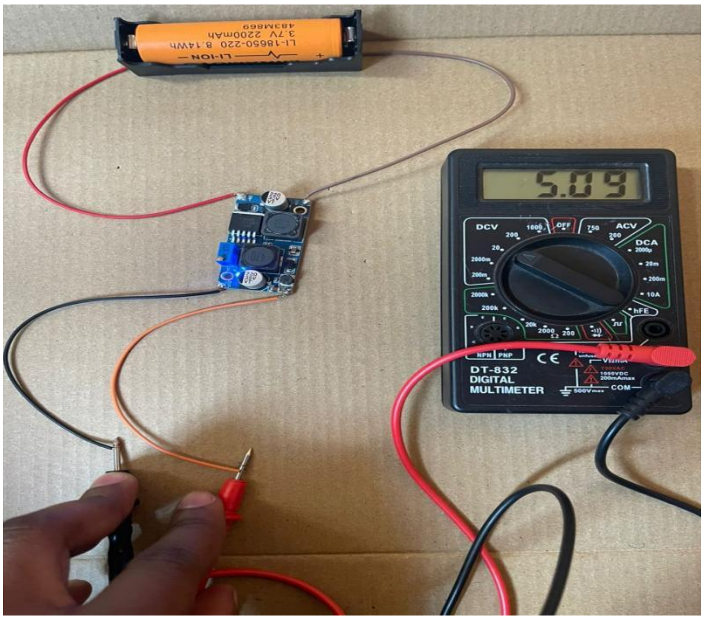


Figure 4.1a: 3.7V DC battery **Figure 4.1b: 5V DC buckboost supply**

Figure 4.1a shows the primary power source voltage of 3.65V which is going to be stepped up to 5.09V by the buckboost as shown in figure 4.1b.The power supply module is a critical component of the Automated Sewer Manhole Monitoring and Alert System, as it ensures the continuous and reliable operation of the sensor nodes and the overall system. Since the system is self powered,this is particularly important for sensor nodes that are located in remote or hard-to-access sewer manholes, where batteries that can be periodically replaced.

4.2.2 Flow sensor module

```
int inputSensor = D2;
int outputSensor = D3;
volatile long pulseCount1;
volatile long pulseCount2;
float inputVolume;
float outputVolume;
unsigned long lastTime;
void setup() {
  Serial.begin(9600);  // Initialize serial communication
  //Serial1.begin(9600);
```

Figure 4.2a : Pin declaration for input sensor and output flow sensor

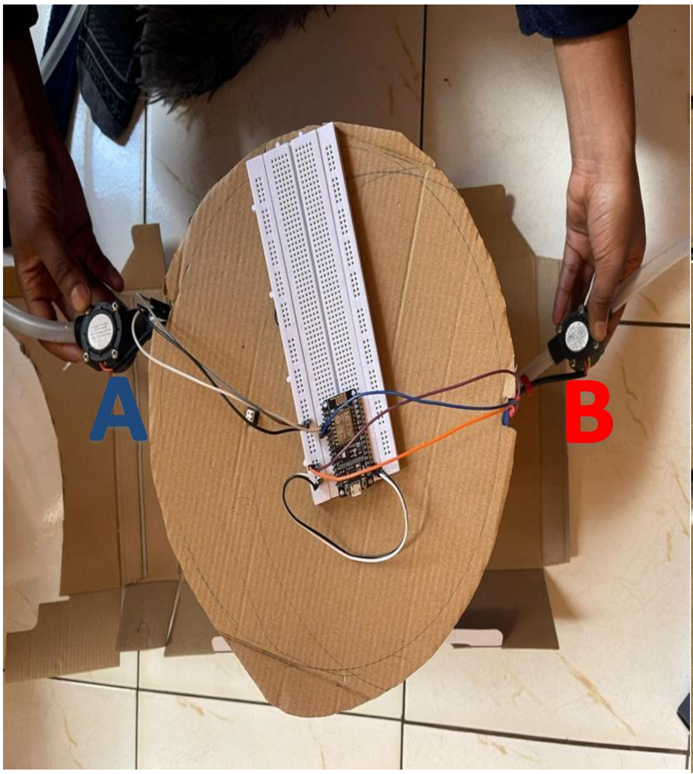


Figure 4.2b:input and output flow sensor connections

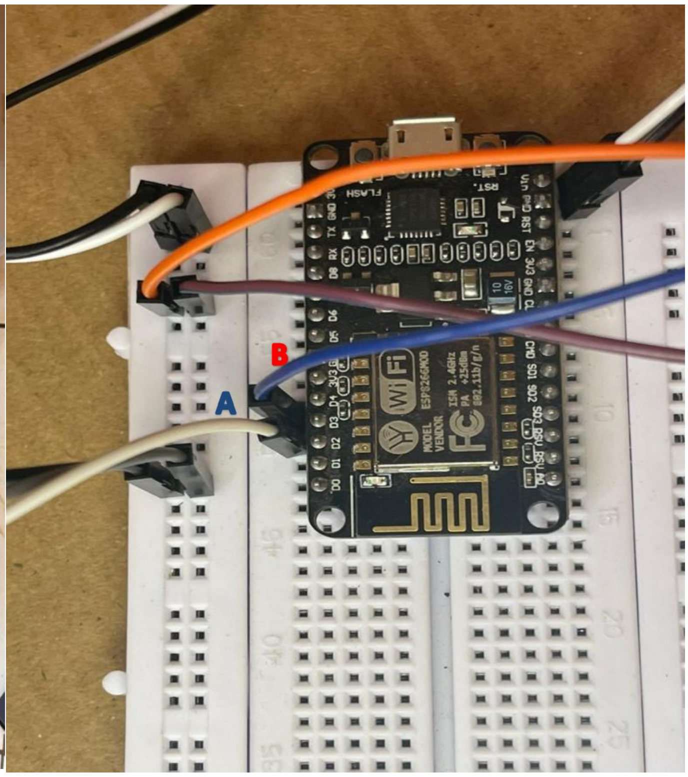


Figure 4.2c: Flow sensor pin connections

Figure 4.2b shows flow sensors (yf-s201) **A** and **B** interfaced with the ESP microcontroller.Flow sensor **A** is for giving values of input flow into the manhole and flow sensor **B** is for the output flow values from the manhole. As illustrated in figure 4.2c, the input flow sensor is connected to pin D2 and the output flow sensor is connected to D3 as declared in figure 4.2a .The flow sensor module provides advanced data processing capabilities such as the ability to calculate flow volume ,identify flow patterns and detect abnormalities.

4.2.3 Ultrasonic level sensor module

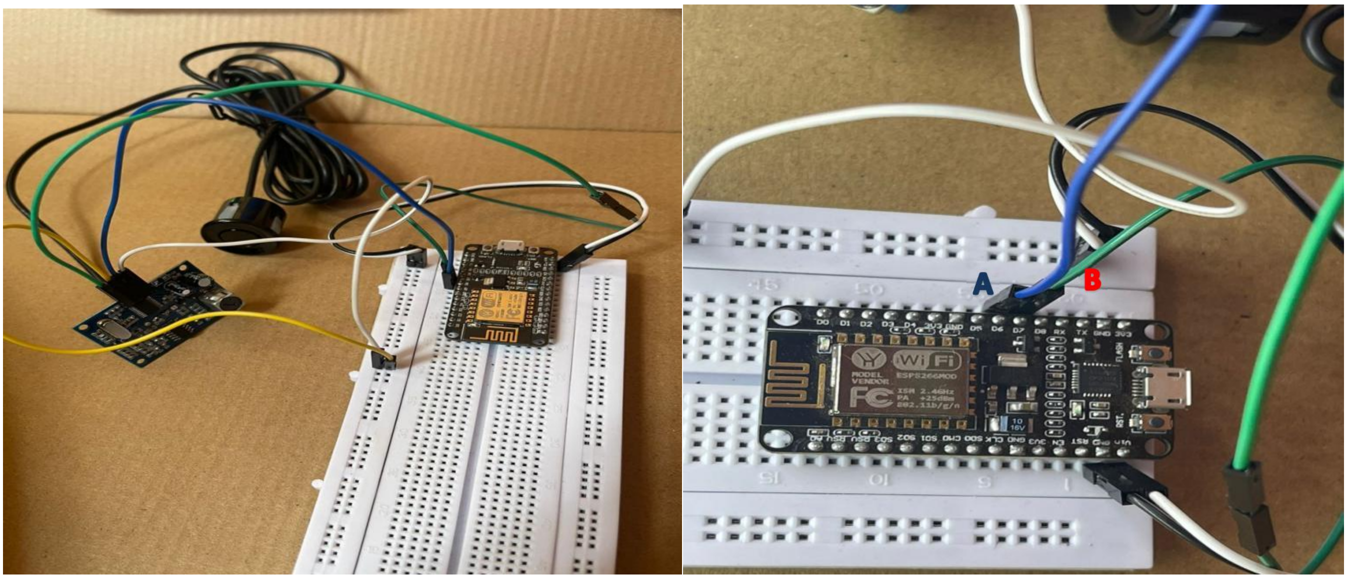


Figure 4.3:Ultrasonic level sensor connected to ESP 8266

Illustrated in figure 4.3 is an ultrasonic level sensor connected to the ESP microcontroller. The sensor has a trigger (Rx) pin which is an input pin for the sensor which is connected to D7(B) and an echo (Tx) pin which is an output from the sensor connected to D6(A). This pin goes high for a period of time which will be equal to the time taken for the ultrasonic wave to return back to the sensor and that time will be processed by the controller to give the sewer level.

4.2.4 GSM Module

```
const int gsmTxPin = D4;  // GSM module TX pin
const int gsmRxPin = D5;  // GSM module RX pin
SoftwareSerial gsmSerial(gsmTxPin, gsmRxPin);  // Initialize SoftwareSerial for GSM communication

```

Figure 4.4a: GSM pin declarations

As shown in figure 4.4a, the module has Rx (receiver)pin connected to D5 which is used to send commands to the module and Tx(transmitter) pin to D4 which transmits data from the module to the microcontroller as declared in the code lines above

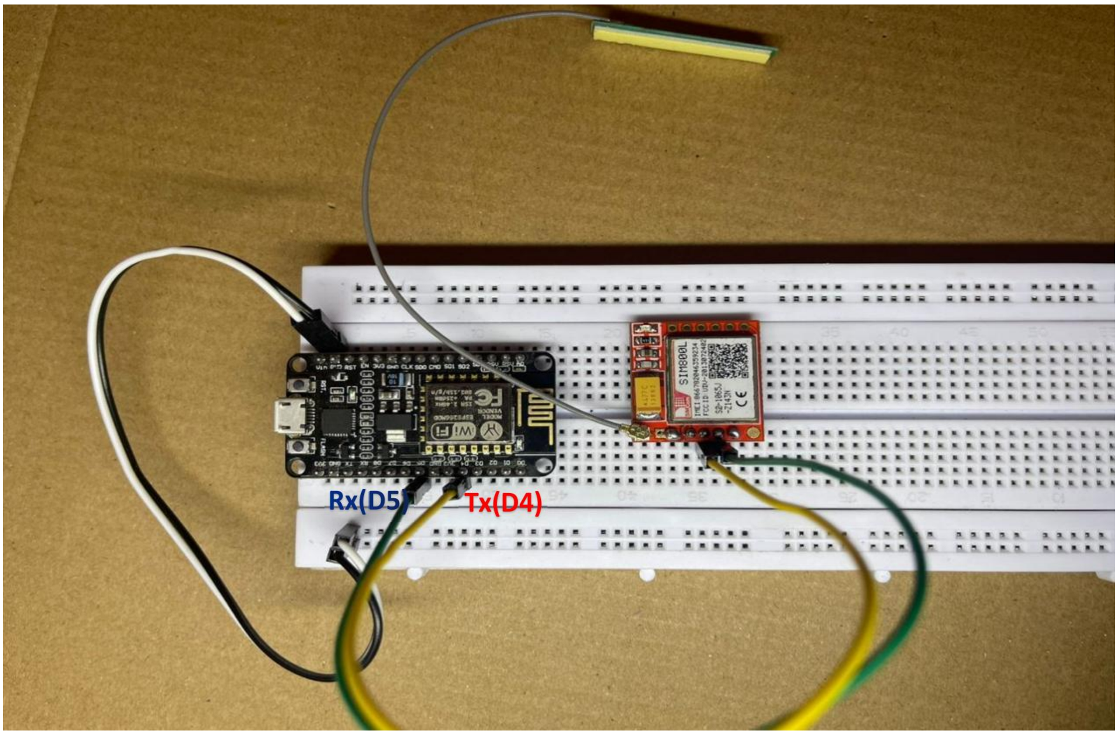


Figure 4.4b: GSM module connected to ESP 8266

Figure 4.4b shows connections of the GSM module to the ESP. The SIM800L module has an LED that indicates the status of the cellular network. It will blink at different rates depending on the state it is in. If it blinks every 1s, the chip is running but has not made a connection to the cellular network yet. Blinking every 2s, means the GPRS data connection requested is active and if it blinks every 3s, the module has made contact with the cellular network and can send or receive voice and SMS.

4.2.5 ESP 8266 with all sensor modules and GSM module

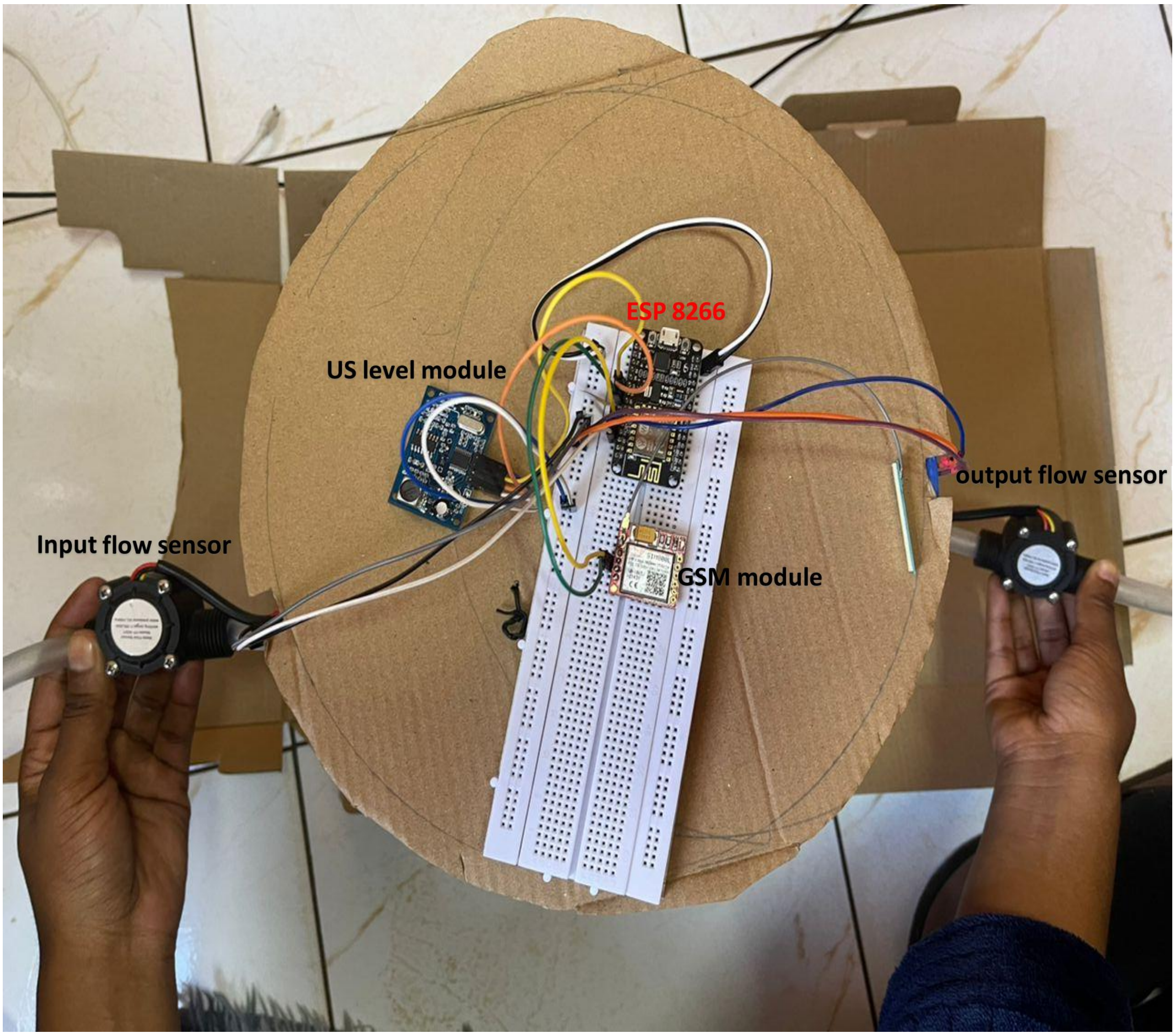


Figure 4.5: Sensor modules and GSM module connected to ESP8266

Figure 4.5 Shows all the sensors (input and output flow sensor, ultrasonic level sensor) and GSM module connected to their respective pins of the ESP controller in order to carry out the monitoring and alerting action as proposed.

4.2.6 Complete System Architecture

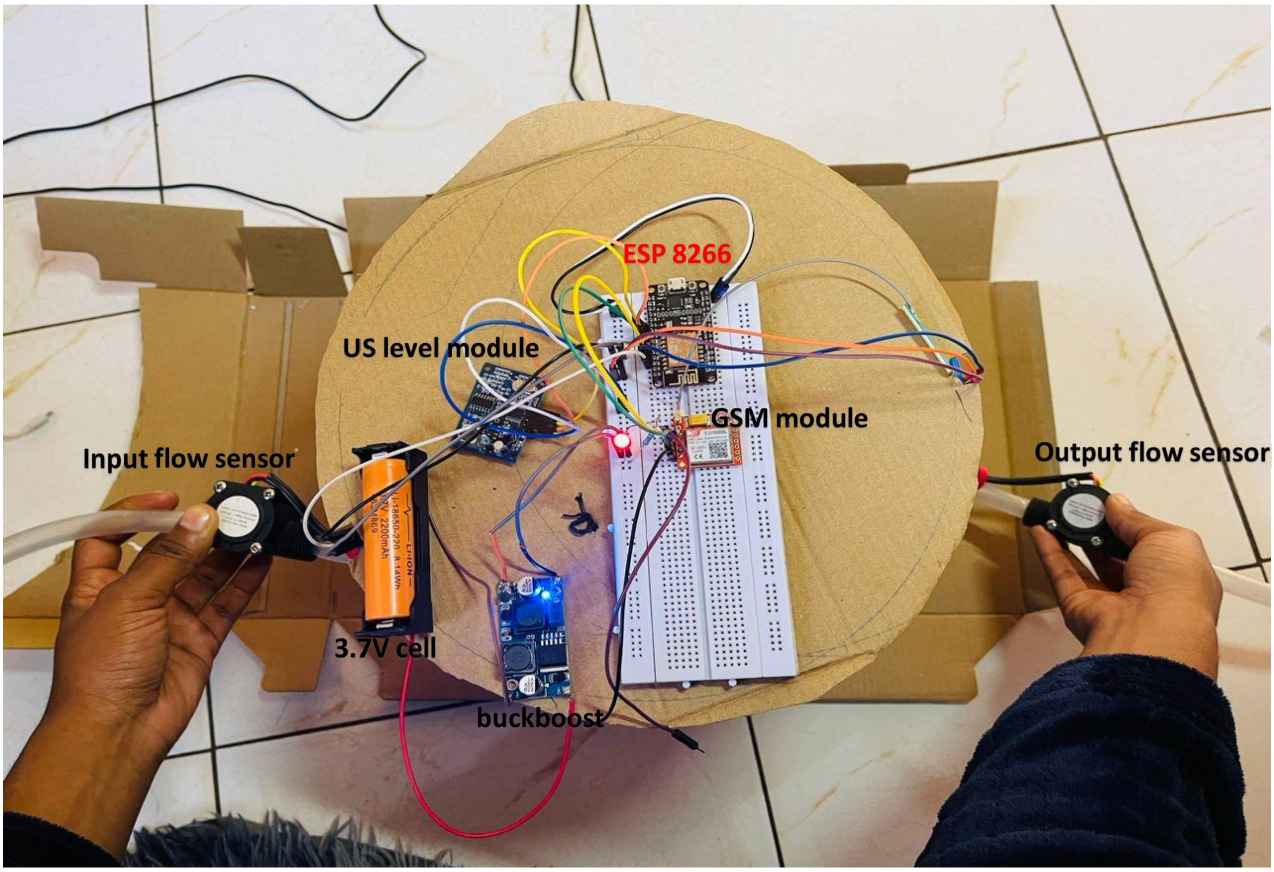


Figure 4.6: Complete System Architecture

Figure 4.6 shows a the complete breadboard system architecture from the power supply module and system sensor modules. The red LED glowing shows that the circuit has been successfully powered.

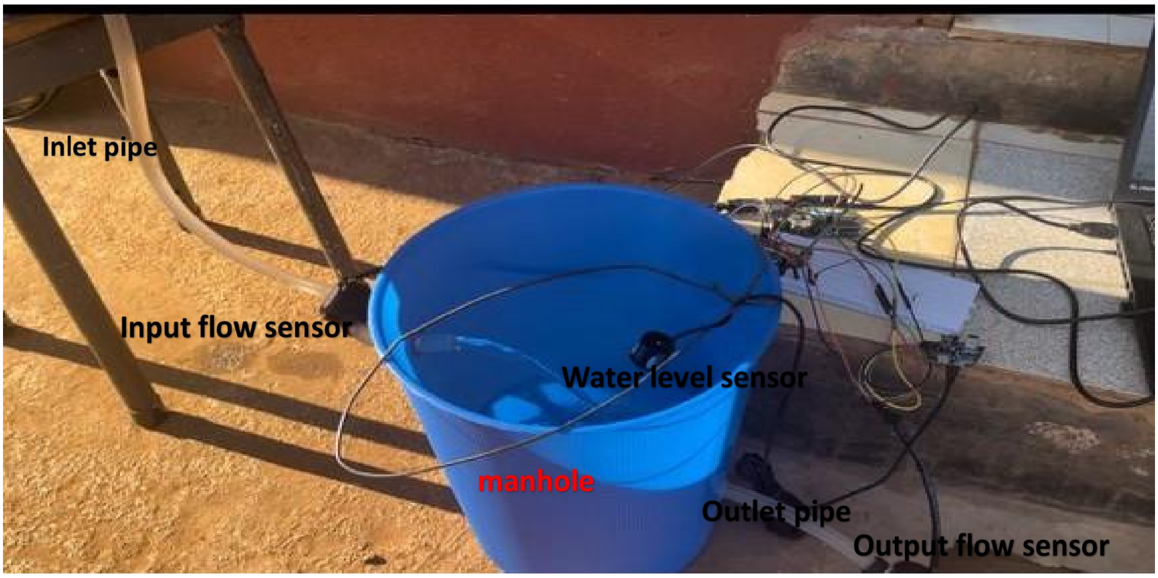


Figure 4.7:Working of the system

Figure shows the proposed system interfaced with the sensor nodes which is a critical element in the overall success of the monitoring and alerting aspect , enabling the reliable collection and transmission of vital sewer infrastructure.

4.2.7 Soldered hardware circuit

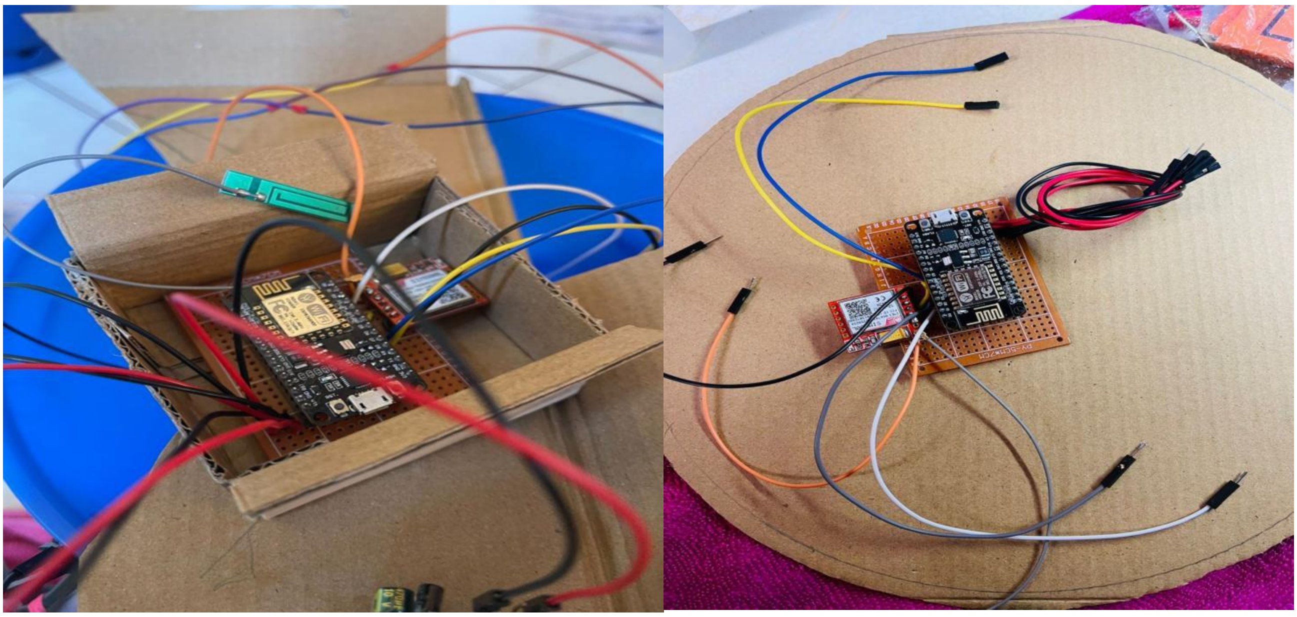


Figure 4.8: Complete soldered hardware circuit

Figure shows the soldered circuit which is the heart of the hardware, integrating all the necessary electronic components to enable the collection, processing, and transmission of sensor data from the sewer manholes. The circuit design has been carefully optimized to ensure reliability, efficiency, and ease of assembly and maintenance.

4.2.8 Final complete system hardware

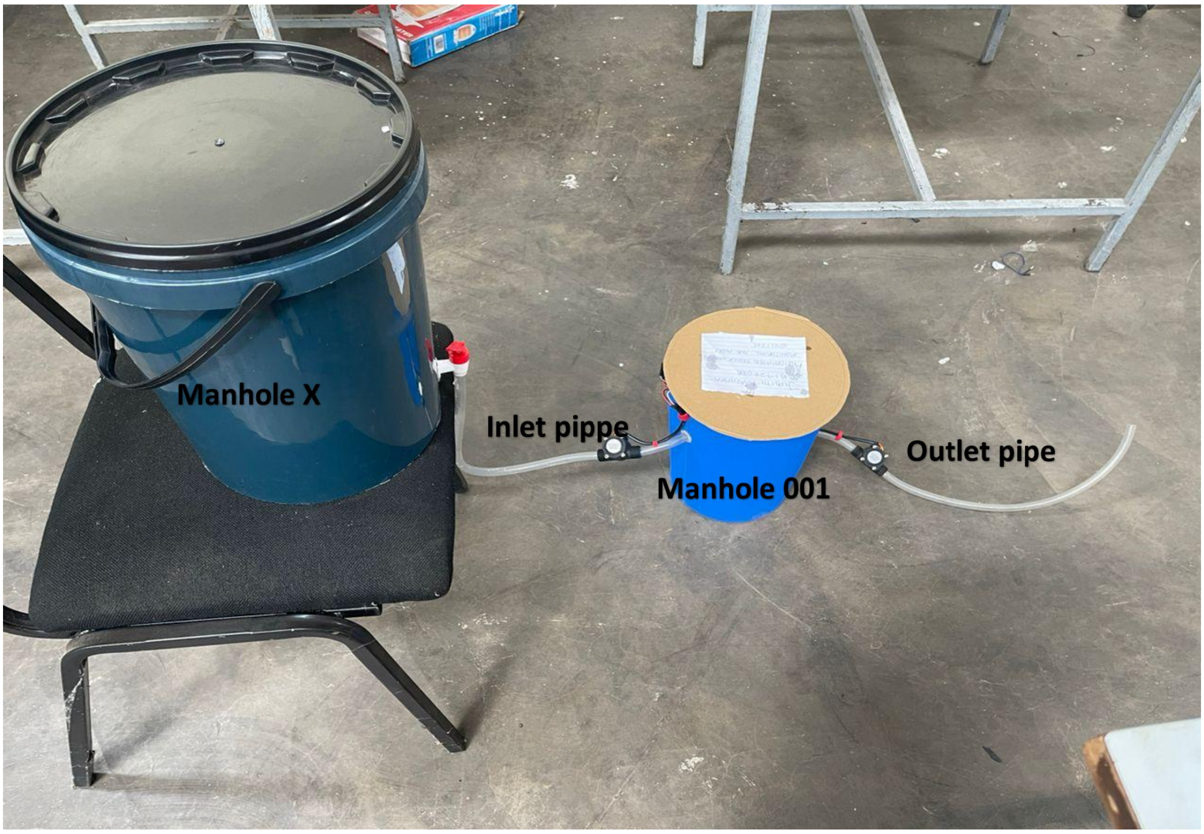


Figure 4.9: Complete Prototype

Figure shows a complete prototype for the automated sewer manhole monitoring and alert system which is to be used to demonstrate the functionalities of the system.

4.3 CONCLUSION

The successful implementation of the Automated Sewer Manhole Monitoring and Alert System represents a significant step forward in the efficient and proactive management of sewer infrastructure. This comprehensive solution has the potential to revolutionize the way municipalities and utility providers approach the monitoring and maintenance of their sewer networks. As the implementation of the Automated Sewer Manhole Monitoring and Alert System progresses, it is expected to have a transformative impact on sewer infrastructure management, delivering tangible benefits in terms of reliability, efficiency, and environmental stewardship. The system's modular design, scalability, and adaptability position it as a future-proof solution that can be seamlessly integrated into existing sewer networks or deployed in new infrastructure projects.

CHAPTER 5: RESULTS

5.1 INRODUCTION

This chapter presents the key findings and outcomes of the Automated Sewer Manhole Monitoring and Alert System project. It discusses the system's performance metrics, the results of the field deployment, and a cost-benefit analysis to evaluate the overall efficacy and practicality of the proposed solution.

5.2 SYSTEM PERFORMANCE METRICS

The system performance metrics refer to the quantitative measures used to evaluate the overall performance and effectiveness of the Automated Sewer Manhole Monitoring and Alert System. These metrics typically include:

5.2.1 Accuracy of sewer Level and Flow Monitoring

This evaluates the precision and reliability of the sensor data collected for sewer water levels and flow rates. It assesses how closely the sensor readings match the actual conditions in the sewer manhole.The serial monitor display acts as a window into the inner workings of the system, enabling the developer to monitor, analyze and optimize the system's performance during the implementation and testing phases.

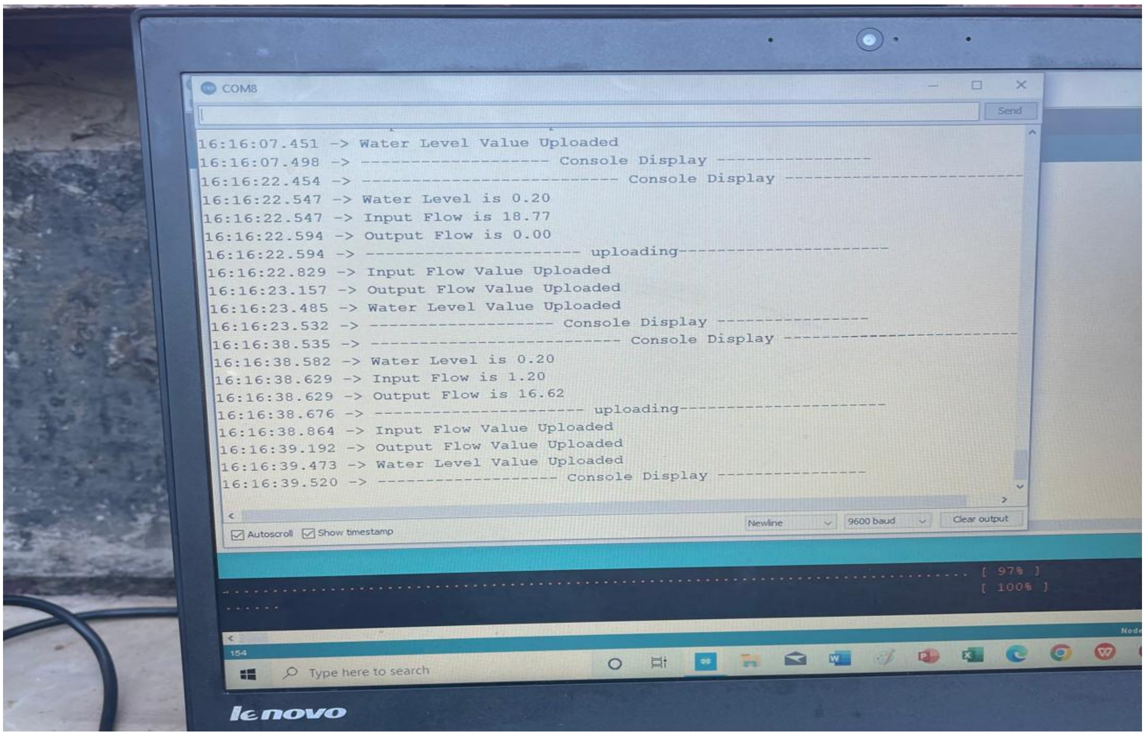


Figure 5.1: Sensor data values displayed by the serial monitor

The serial monitor is an important tool for debugging and monitoring the operation of the Automated Sewer Manhole Monitoring and Alert System during the implementation and testing phases. The serial monitor display would typically show the following information:

1. Sensor Data Readings:

- Water level measurements from the ultrasonic sensor
- Flow rate data from the flow sensor

These sensor readings would be uploaded to adafruit feed and displayed in real-time, allowing the developer to validate the accuracy and responsiveness of the data collection as illustrated in figure 5.1 above.

2. System State and Status:

- Indications of the current operational mode of the system
- Error messages or diagnostics if any issues are detected
- This provides insight into the overall health and functionality of the system.

5.2.2 Dashboard Flow rates presentations

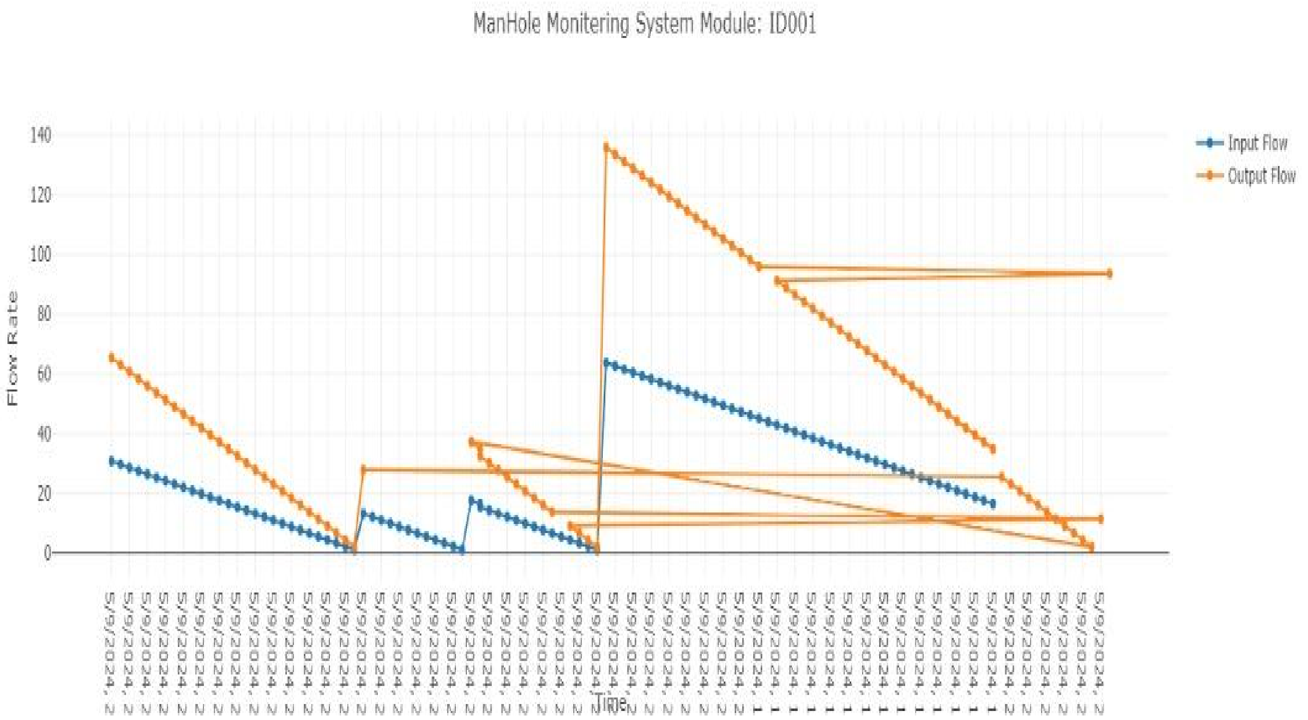


Figure 5.2: Flow rate feed

The dashboard for the Automated Sewer Manhole Monitoring and Alert System would provide a visual interface to evaluate the flow rates in the sewer system as shown in figure 5.2.The dashboard would display the current flow rate values measured by the flow sensors in each monitored sewer manhole.This is presented as numerical values, line graphs, and data compared on hover to quickly convey the flow rate data.

5.2.3 Dashboard Water level presentations

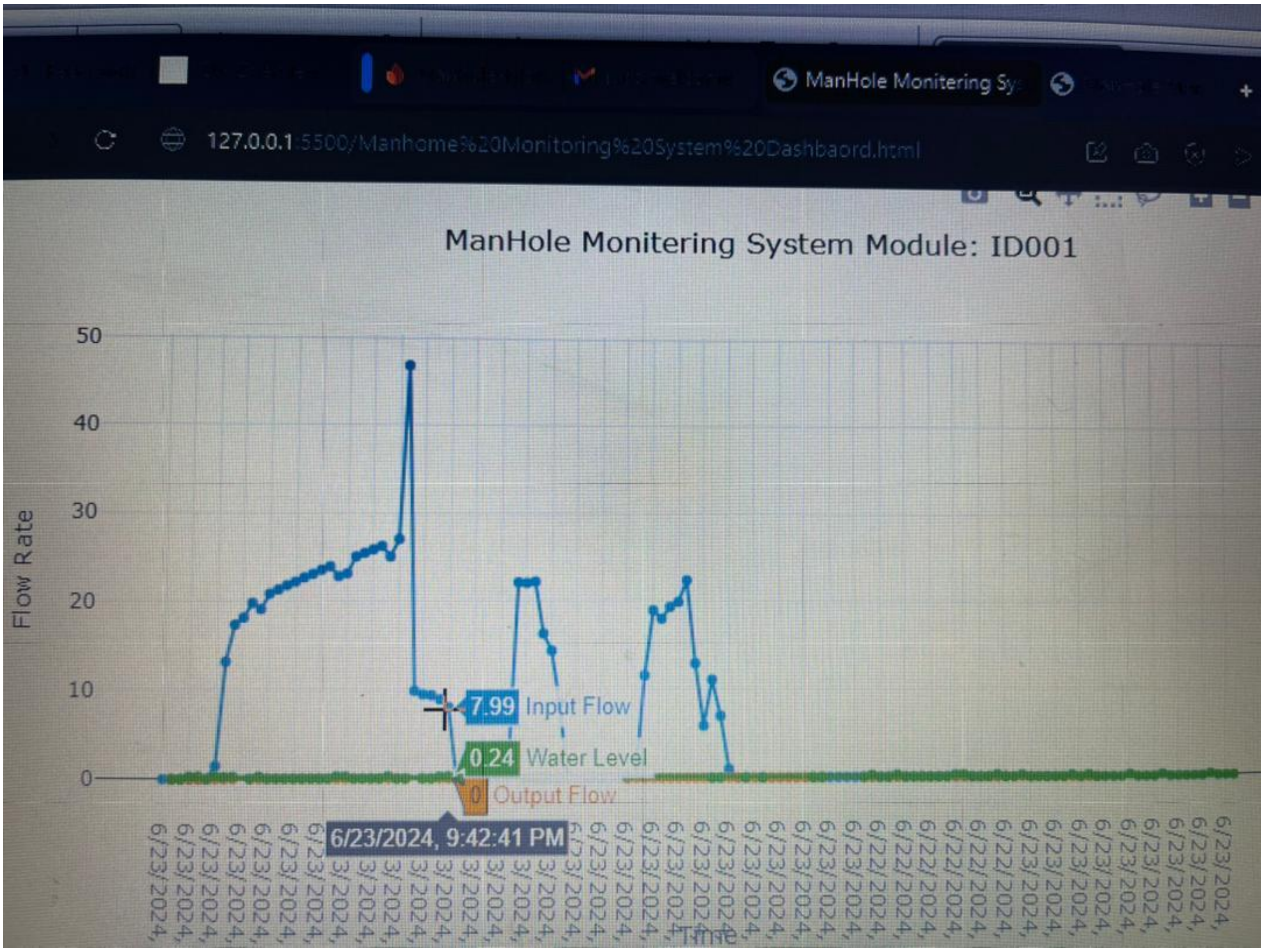


Figure 5.3: Water level feed

When the user hovers the mouse cursor over a specific data point, the dashboard should display additional comparative information illustrated in figure 5.3.The comparative data is clearly labeled with the corresponding sewer manhole location, timestamp, or other relevant context to avoid confusion. This helps the user quickly understand the meaning and relevance of the comparative information.

5.3 Alert Notifications

The system is configured to monitor water levels and flow rates parameters. It is programmed to detect predefined thresholds or anomalies that would trigger alert notifications. These triggering conditions are set based on design specifications. The system is capable of sending alert notifications through text messages (SMS) to the user (admin).The alert notifications are categorized based on the severity of the detected issue, such as low, medium, or high priority distinguished by colour (RED or YELLOW) since blockages are not immediate.

5.3.1Alert Notification for Blocked Outlet pipe

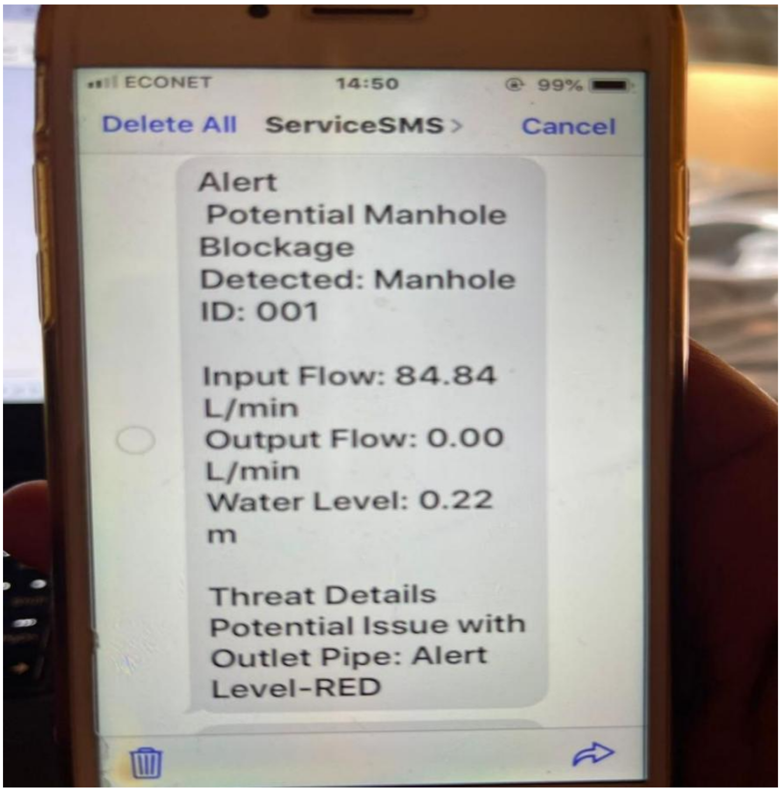


Figure 5.4: SMS alert notification for blocked outlet pipe

As shown in figure 5.4, the alert notifications provide comprehensive details about the detected issue, including:

- Manhole ID of the affected sewer manhole (**001**)
- Sensor readings and measurements triggering the alert (outlet pipe blocked hence the zero reading value)
- threat level (**Red**) meaning no flow is being detected in the oulet pipe of the manhole at all.

5.3.2Alert Notification for blocked inlet and outlet pipes

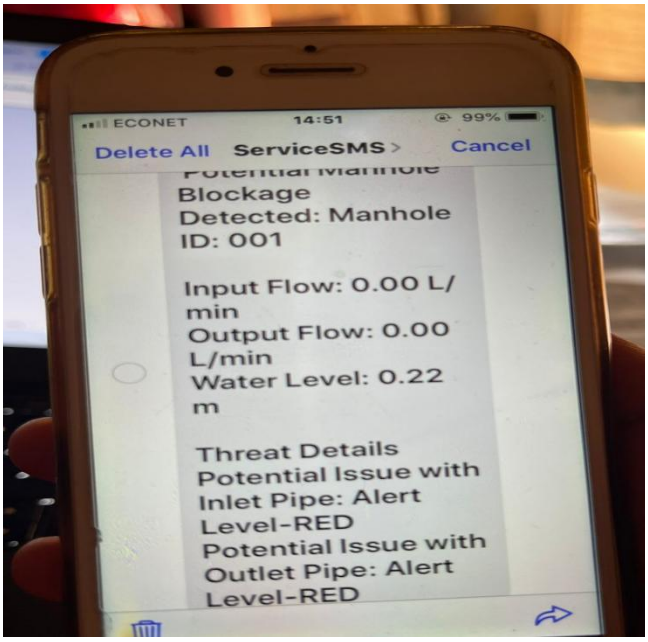


Figure 5.5: SMS alert notification for blocked inlet and outlet pipes

Figure 5.5 shows the alert notification triggered by the zero reading values from the input and output flow sensors of the manhole. The threat information explains to the admin the level at which the flow has been affected and in this case it shows RED which is the peak of blockage meaning no flow is being detected at all.

5.3.3Alert Notification for Sewer level

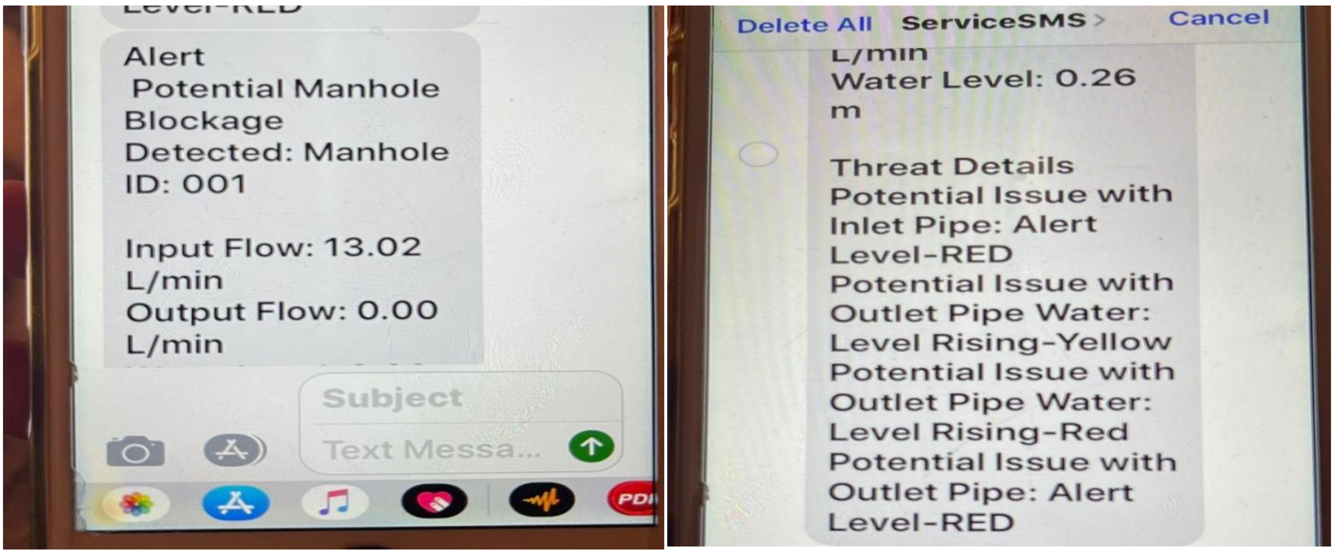


Figure 5.6: Alert notification for sewer level rising

Figure 5.6 shows an alert message triggered by the water level sensor reading .If there is a blockage in the outlet pipe, it gives rise to the level of sewer in the manhole since the inlet pipe continues to feed the sewer into the manhole.The threat information shows the level of the sewer to be in the (Yellow) range and outlet pipe (**Red**).

5.4 IMPLEMENTATION COST

Implementing the Automated Sewer Manhole Monitoring and Alert System requires a significant investment, as it involves the deployment of specialized hardware, software, and supporting infrastructure across the sewer network. The total implementation cost can vary widely depending on the scale, complexity, and specific requirements of the project.

5.4.1 BUDGET

COMPONENT	QUANTITY	COST
Esp 8266	1	$12
Water flow sensor(yf -s204)	2	$16
Ultrasonic level sensor	1	$8
GSM module(SIM 800L)	1	$8
Buckboost converter	1	$2.50
3.7V battery cell and holder	1	$13.20
connectors	15	$1.50
TOTAL COST		**$61.50**

5.5 KEY BENEFITS OF THE MONITORING AND ALERT SYSTEM

The key benefits of the Automated Sewer Manhole Monitoring and Alert System include:

1. **Improved Sewer Infrastructure Management**

- Early detection of potential issues, such as blockages, flooding, or structural problems, enables proactive maintenance and preventive measures.

- Reduced risk of sewer overflows, backups, and environmental damage, ensuring compliance with regulatory standards.

- Optimized resource allocation and maintenance planning, leading to cost savings and improved operational efficiency.

2. Enhanced Incident Response and Mitigation

- Immediate notification of critical events through the alert system, allowing for rapid response and effective incident management.

- Centralized monitoring and control capabilities, enabling operators to identify and address problems quickly.

- Improved coordination and communication among different stakeholders, such as maintenance crews, emergency responders, and regulatory authorities.

3. Data-Driven Decision-Making

- Comprehensive historical data and analytical insights to support long-term planning, infrastructure upgrades, and capacity expansion.

- Identification of trends and patterns that can guide strategic investments and resource allocation.

- Ability to benchmark performance, track improvements, and measure the success of interventions over time.

5.6 CONCLUSION

By embracing this innovative technology, municipalities and utility providers can enhance the resilience and sustainability of their sewer systems, ensuring the continued delivery of essential services and the protection of public health and the environment for generations to come.

REFERENCES

1. https://jsd-africa.com//The%20problemBurstSewagePipeSewrageOutflows.pdf

2. https://ijcrt.org/papers/IJCRT2205453.pdf

3. https://www.ijraset.com/research-paper/iot-based-manhole-detection-and-monitoring-system

4. https://www.academia.edu/99546998/A_Review_on_Manhole_Monitoring_System

5. https://www.ijraset.com//a-review-on-manhole-monitoring-system

6. Measurement, Instrumentation and Sensors Handbook 2nd Edition.,John G.Webster, Halt Eren.,https://technical-articles/level-sensors-and-their-use-in-level-measurement-and-monitoring/

7. https://LevelMeasurement.html#:~:text=Point%20level%20measurement%20sensors%.

8. Sensors Handbook 2nd Edition., Sabrie Soloman.,https://www.elprocus.com/a-memoir-on-water-flow-sensor/

9. https://www.spiceworks.com/tech/iot/articles/what-is-gps/

10. Handbook of NODECU esp32, Arsath Natheem S.,https://en.wikipedia.org/wiki/ESP32

11. https://en.wikipedia.org/wiki/PIC_microcontrollers

12. https://www.monolithicpower.com/en/voltage-regulator-types

13. GSM and Personal Communications Handbook.,Siegmund M.rEDL, Matthias K.Weberr,Malcom W.Oliphant.

14. https://www.electronicsforu.com/resources/gsm-module

15. https://www.quora.com/What-are-the-types-of-GSM-modules