International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 21 No. 4(1) (2025)

ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 21, No. 4, 2025

Research Paper

DESIGN AND IMPLEMENTATION OF AN IOT-BASED INTEGRATED WASTE, WATER, AND DRAINAGE SAFETY MONITORING SYSTEM

SATHULURI RAMARAO

Department of Electronics and Communication Engineering (ECE)
Chalapati Institute of Technology,AR Nagar,
Mothadaka, Andhra Pradesh, India- 522016
Email-id: ramarao409@gmail.com.

ABSTRACT

This project presents an IoT-based Integrated Waste, Water, and Drainage Safety Monitoring System designed to enhance urban utility management through real-time sensing and smart alerts. The system uses an ultrasonic sensor to monitor waste bin levels and ensure timely collection, while a moisture sensor helps in basic waste segregation by identifying wet and dry waste. A flow sensor is deployed to detect abnormal water flow patterns indicating possible pipeline leakage, enabling early maintenance. For drainage and manhole safety, a gas sensor monitors harmful gases, and an accelerometer detects unauthorized manhole opening or structural disturbances. The collected data is processed through an ESP32 microcontroller, which ensures seamless connectivity and intelligent decision making. The system provides instant alerts through a buzzer, LCD display, and a dedicated mobile application for remote monitoring. The mobile app offers a unified dashboard to visualize bin status, leakage warnings, gas safety levels, and manhole conditions, enabling quick response by municipal authorities or users. By integrating multiple urban challenges into one automated platform, the project aims to improve city hygiene, reduce maintenance delays, and enhance safety in public infrastructures. Overall, this smart multi-utility monitoring system supports the vision of sustainable and data-driven smart cities.

Received: 16-09-2025 Accepted: 26-10-2025 Published: 05-11-2025

INTRODUCTION

Rapid urbanization and population growth have significantly increased the pressure on municipal services such as waste management, water distribution, and drainage systems. Traditional monitoring methods for these utilities are largely manual, time-consuming, and reactive in nature, often leading to delayed maintenance, health hazards, and environmental pollution. Overflowing garbage bins, unnoticed water pipeline leakages, and unsafe manhole conditions pose serious risks to public hygiene, resource conservation, and worker safety in modern cities.

With the emergence of the Internet of Things (IoT), it has become possible to continuously monitor urban infrastructure using smart sensors and connected devices. IoT enables real-time data collection, remote monitoring, and intelligent alert generation, thereby improving operational efficiency and decision-making. Smart city initiatives increasingly rely on such technologies to automate public utility management and ensure sustainable urban development.

In this context, the proposed IoT-based Integrated Waste, Water, and Drainage Safety Monitoring System offers a unified solution to address multiple urban challenges through a single platform. The system integrates sensors for waste level detection, waste type identification, water flow monitoring, gas detection, and manhole safety monitoring. An ESP32 microcontroller acts as the central processing unit, ensuring reliable data processing and wireless communication. Real-time alerts are provided through local

indicators and a mobile application, enabling quick response by authorities.

By combining waste management, water leakage detection, and drainage safety monitoring into one intelligent system, this project aims to improve city cleanliness, conserve water resources, enhance public safety, and support the vision of smart and sustainable cities.

Problem Statement

Urban infrastructure systems such as waste management, water supply, and drainage safety are currently monitored using manual or isolated methods that lack real-time visibility and integration. Overflowing garbage bins, improper waste segregation, undetected water pipeline leakages, and hazardous manhole conditions result in environmental pollution, water wastage, public health risks, and delayed maintenance actions. The absence of a unified, automated monitoring system makes it difficult for municipal authorities to respond quickly and efficiently to these issues. Hence, there is a strong need for an integrated IoT-based solution that can continuously monitor multiple urban utilities, provide real-time alerts, and support data-driven decision-making for smart city management.

Main Objectives

1. **To monitor waste bin fill levels in real time** using ultrasonic sensors to prevent overflow and ensure timely waste collection.
2. **To perform basic waste segregation** by identifying wet and dry waste using moisture sensors, supporting improved recycling and waste processing.
3. **To detect water pipeline leakage** by monitoring abnormal water flow patterns through flow sensors, reducing water loss and maintenance delays.
4. **To ensure drainage and manhole safety** by detecting harmful gases using gas sensors to protect sanitation workers and public health.
5. **To identify unauthorized manhole opening or structural disturbances** using an accelerometer for enhanced infrastructure security.
6. **To provide real-time alerts and remote monitoring** through an ESP32-based system with buzzer, LCD display, and mobile application for quick response and efficient urban utility management.

Literature Survey

1. Sharma & Kulkarni – *Smart Waste Monitoring Systems*

Sharma and Kulkarni proposed an IoT-enabled smart waste monitoring system aimed at improving municipal solid waste management. Their work primarily focused on the use of ultrasonic sensors mounted on garbage bins to measure the fill level in real time. The sensor data was transmitted to a cloud-based IoT platform, enabling municipal authorities to monitor bin status remotely and optimize waste collection schedules. This approach reduced unnecessary collection trips and helped prevent garbage overflow in urban areas.

However, the system was limited to waste level monitoring and did not address waste segregation or integration with other urban utilities. Additionally, the model relied on individual waste monitoring units without providing a unified framework for city-wide infrastructure management. These limitations highlight the need for an integrated multi-utility system rather than isolated solutions.

2. Patel et al. – *Waste Segregation Using Sensor-Based Techniques*

Patel et al. investigated automatic waste segregation using sensor-based techniques, with particular emphasis on moisture sensors to distinguish between wet and dry waste. Their system enabled basic segregation at the point of disposal, which is essential for improving recycling efficiency and reducing landfill burden. The study demonstrated that sensor-based segregation can minimize human intervention and enhance waste processing efficiency.

Despite its effectiveness, the proposed solution focused only on waste segregation and did not

incorporate real-time monitoring or alert mechanisms for waste overflow. Moreover, the system operated independently and lacked connectivity with broader smart city infrastructures. This created a gap in integrating segregation with collection planning and urban management systems.

3. Reddy & Thomas – *Water Leakage Detection Through Flow Sensors*

Reddy and Thomas presented a leakage detection system for water distribution networks using flow sensors and microcontrollers. Their approach involved monitoring variations in water flow rates to identify abnormal patterns indicative of pipeline leakages. Early detection helped reduce water wastage, maintenance costs, and service disruptions. The study emphasized the importance of real-time monitoring for sustainable water management.

However, the system was designed as a standalone water monitoring solution and did not integrate with waste management or drainage safety systems. Additionally, alert mechanisms were limited and lacked user-friendly visualization platforms such as mobile applications. This highlighted the need for a comprehensive and integrated monitoring solution.

4. Ahmed & Rao – *Drainage Gas Monitoring for Public Safety*

Ahmed and Rao examined the role of gas sensors, particularly MQ-series sensors, in detecting harmful gases such as methane, hydrogen sulfide, and carbon monoxide in drainage systems and manholes. Their work focused on improving public safety and protecting sanitation workers by providing early warnings of hazardous gas accumulation. The system demonstrated effective real-time detection and alerting under controlled conditions.

Nevertheless, the study concentrated solely on gas monitoring and did not include structural safety aspects such as manhole cover tampering or unauthorized access. The lack of integration with other utility monitoring systems limited its applicability in holistic smart city solutions.

5. Banerjee & Singh – *Manhole Safety and Structural Monitoring*

Banerjee and Singh explored the use of accelerometers and vibration sensors for monitoring manhole covers and underground infrastructure. Their research aimed to detect unauthorized manhole opening, structural damage, or abnormal vibrations caused by external disturbances. The system contributed to improved infrastructure security and reduced risks associated with open or damaged manholes.

Although effective in detecting physical disturbances, the proposed system did not incorporate environmental sensing such as gas detection or water flow analysis. Furthermore, it operated independently without integration into a centralized monitoring platform, restricting its scalability for large urban deployments.

Research Gap Identification

From the literature review, it is evident that existing research primarily focuses on **individual urban utility problems** such as waste monitoring, waste segregation, water leakage detection, gas monitoring, or manhole safety. However, there is a significant gap in the development of an **integrated IoT-based platform** that simultaneously monitors waste management, water distribution, and drainage safety while providing real-time alerts and centralized visualization. The proposed system addresses this gap by combining multiple sensing modules with ESP32-based connectivity and a unified mobile application, supporting efficient and sustainable smart city management.

Proposed System Description

The proposed IoT-based Integrated Waste, Water, and Drainage Safety Monitoring System is designed to provide a unified and automated solution for monitoring multiple urban utilities in real time. The system integrates various sensors with an ESP32 microcontroller to collect, process, and

transmit data for intelligent decision-making and alert generation.

System Architecture

The ESP32 microcontroller acts as the central processing unit of the system due to its low power consumption, high processing capability, and built-in Wi-Fi connectivity. Multiple sensing modules are interfaced with the ESP32, including an ultrasonic sensor for waste level detection, a moisture sensor for waste segregation, a water flow sensor for leakage detection, a gas sensor for drainage safety, and an accelerometer for manhole condition monitoring. Local alert devices such as an LCD display and a buzzer are also connected to provide immediate on-site notifications.

Waste Monitoring and Segregation Module

The waste monitoring unit uses an ultrasonic sensor mounted at the top of the garbage bin to measure the distance between the sensor and the waste surface. Based on this distance, the fill level of the bin is calculated and categorized as low, medium, or full. When the bin reaches a predefined threshold, an alert is generated to notify the authorities for timely waste collection. Additionally, a moisture sensor is used to identify wet and dry waste, enabling basic waste segregation at the source and supporting improved recycling efficiency.

Water Leakage Detection Module

To monitor water distribution safety, a flow sensor is installed in the water pipeline. The sensor continuously measures the rate of water flow and sends data to the ESP32. If abnormal flow patterns such as continuous flow during non-usage hours or sudden drops are detected, the system identifies a possible leakage condition. An alert is then generated to prompt early maintenance, thereby reducing water wastage and infrastructure damage.

Drainage and Manhole Safety Module

For drainage safety, a gas sensor (such as an MQ-series sensor) is used to detect the presence of harmful gases like methane, carbon monoxide, or hydrogen sulfide inside manholes and drainage systems. When gas concentration exceeds safe limits, the system triggers an alarm to warn sanitation workers and authorities. An accelerometer is employed to monitor the manhole cover position and detect unauthorized opening, tilting, or unusual vibrations that may indicate tampering or structural issues.

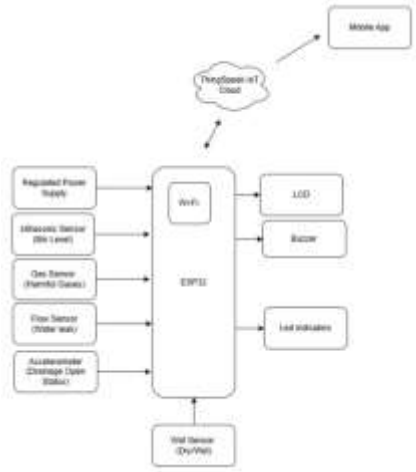
Alert and Monitoring System

The system provides real-time alerts through multiple channels. A buzzer and LCD display offer immediate local notifications, while Wi-Fi connectivity enables remote monitoring through a mobile application. The mobile app presents a unified dashboard displaying waste bin status, waste type, water leakage warnings, gas safety levels, and manhole condition alerts. This centralized visualization allows municipal authorities to respond quickly and efficiently.

Overall Functionality

By integrating waste management, water leakage detection, and drainage safety into a single IoT-based platform, the proposed system enhances urban cleanliness, conserves water resources, improves public safety, and minimizes maintenance delays. The system supports scalable deployment and aligns with the objectives of smart city development by enabling data-driven and sustainable urban infrastructure management.

BLOCK DIAGRAM



Proposed System Methodology

The proposed system follows a modular and sequential methodology to monitor waste management, water leakage, and drainage safety using IoT technology. All sensing units

are interfaced with an ESP32 microcontroller, which performs data acquisition, processing, decision-making, and communication. The methodology ensures continuous monitoring, threshold-based analysis, and real-time alert generation through local and remote interfaces.

Working Steps

1. **System Initialization**
   When the system is powered ON, the ESP32 microcontroller initializes all connected sensors, including the ultrasonic sensor, moisture sensor, water flow sensor, gas sensor, and accelerometer. The LCD display and buzzer are also initialized, and the ESP32 establishes a Wi-Fi connection with the mobile application or cloud server.
2. **Waste Bin Level Detection**
   The ultrasonic sensor continuously measures the distance between the sensor and the waste surface inside the bin. The ESP32 calculates the fill level percentage based on predefined bin height. If the waste level exceeds the threshold (e.g., 80% full), the system flags the bin as full and prepares an alert.
3. **Waste Segregation Using Moisture Sensor**
   When waste is deposited, the moisture sensor checks the moisture content of the waste. Based on sensor readings, the waste is classified as wet or dry. The classification result is displayed on the LCD and sent to the mobile application for record and monitoring purposes.
4. **Water Flow Monitoring and Leakage Detection**
   The flow sensor measures the real-time water flow rate in the pipeline and sends pulse data to the ESP32. The controller compares the measured flow rate with predefined normal values. If continuous or abnormal flow is detected during non-usage periods, the system identifies a possible leakage and triggers a warning alert.
5. **Drainage Gas Detection**
   The gas sensor continuously monitors the presence of harmful gases inside the drainage or manhole area. If gas concentration exceeds safe limits, the ESP32 activates the buzzer and displays a warning message on the LCD. Simultaneously, an alert notification is sent to the mobile application to ensure worker and public safety.
6. **Manhole Condition Monitoring**
   The accelerometer monitors the position and movement of the manhole cover. Any sudden tilt, vibration, or unauthorized opening is detected by analyzing accelerometer data. When abnormal movement is identified, the system generates an immediate alert.
7. **Local Alert Generation**
   For any abnormal condition such as full waste bin, water leakage, gas detection, or manhole disturbance, the buzzer is activated and the LCD displays a corresponding alert message for on-site notification.
8. **Remote Monitoring and Notification**
   The ESP32 transmits sensor data and alert status via Wi-Fi to the mobile application. The app provides a unified dashboard showing waste status, leakage alerts, gas safety levels, and manhole conditions, enabling quick decision-making.
9. **Continuous Monitoring and Data Update**
   The system operates continuously, updating sensor readings at regular intervals. All events and alerts are logged in the application for future analysis and maintenance planning.

Hardware Tools

1. **ESP32 Microcontroller**
   Acts as the central controller of the system. It processes sensor data,

performs decision-making, and provides built-in Wi-Fi connectivity for real-time data transmission to the mobile application.

2. **Ultrasonic Sensor (HC-SR04)**
   Used to measure the garbage bin fill level by calculating the distance between the sensor and the waste surface.
3. **Moisture Sensor**
   Detects moisture content in waste to classify it as wet or dry, enabling basic waste segregation.
4. **Water Flow Sensor (YF-S201 or equivalent)**
   Measures real-time water flow rate in pipelines to detect abnormal flow patterns and possible leakages.
5. **Gas Sensor (MQ-Series – MQ-2)**
   Detects harmful gases such as methane, carbon monoxide, and other toxic gases present in drainage and manhole environments.
6. **Accelerometer (ADXL335 / MPU6050)**
   Monitors manhole cover movement, tilt, and vibration to detect unauthorized opening or structural disturbances.
7. **LCD Display (16×2 with I2C Module)**

   Displays system status, sensor readings, and alert messages for on-site monitoring.
8. **Buzzer**
   Provides audible alerts during abnormal conditions such as gas leakage, full waste bins, or manhole tampering.
9. **Power Supply Unit**
   Provides regulated power to the ESP32 and connected sensors (battery or adapter-based).
10. **Connecting Wires, Breadboard / PCB**
    Used for circuit connections and system assembly.

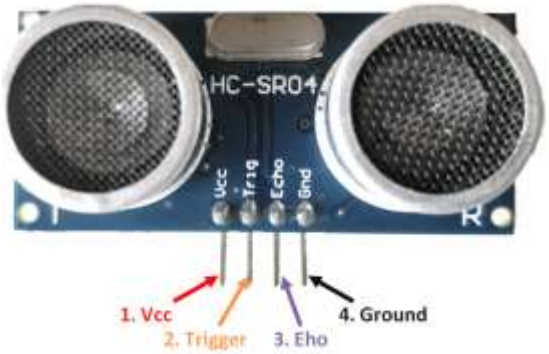
Ultrasonic Sensor Pin Configuration

Software Tools

1. **Arduino IDE**
   Used for writing, compiling, and uploading the program to the ESP32 microcontroller.
2. **ESP32 Board Package**

   Enables programming and configuration of ESP32 within the Arduino IDE environment.
3. **Embedded C / C++**
   Programming language used to develop the firmware for sensor interfacing, data processing, and communication.
4. **IoT Cloud Platform**
   ThingSpeakisUsed for data logging, visualization, and historical analysis of sensor data.

ULTRASONIC SENSOR



Ultrasonic Sensor HC SR04
Ultrasonic Sensor HC SR04 Pin Diagram

Pin Number	Pin Name	Description
1	Vcc	The Vcc pin powers the sensor, typically with +5V
2	Trigger	Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave.
3	Echo	Echo pin is an Output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor.
4	Ground	This pin is connected to the Ground of the system.

HC-SR04 Sensor Features

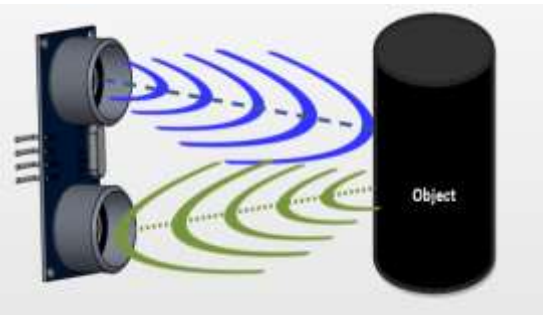
- Operating voltage: +5V
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: <15°
- Operating Current: <15mA
- Operating Frequency: 40Hz

HC-SR04 Ultrasonic Sensor - Working

As shown above the **HC-SR04 Ultrasonic (US) sensor** is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that

Distance = Speed × Time

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module as shown in the picture below



Now, to calculate the distance using the above formulae, we should know the Speed and time. Since we are using the Ultrasonic wave we know the universal speed of US wave at room conditions which is 330m/s. The circuitry inbuilt on the module will calculate the time taken for the US wave to come back and turns on the echo pin high for that same particular amount of time, this way we can also know the time taken. Now simply calculate the distance using a microcontroller or microprocessor.

How to use the HC-SR04 Ultrasonic Sensor

HC-SR04 distance sensor is commonly used with both microcontroller and microprocessor platforms like Arduino, ARM, PIC, Raspberry Pie etc. The following guide is universally since it has to be followed irrespective of the type of computational device used.

Power the Sensor using a regulated +5V through the Vcc ad Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins (If available). The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is returned after it getting reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor.

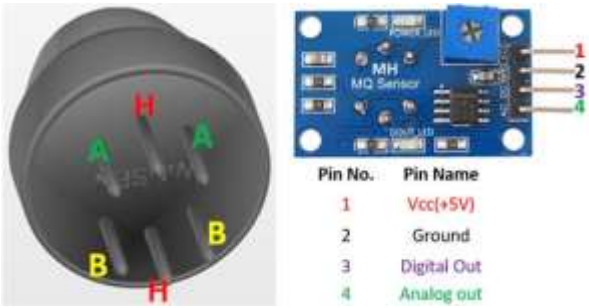
The amount of time during which the Echo pin stays high is measured by the MCU/MPU as it gives the information about the time taken for the wave to return back to the Sensor. Using this information the distance is measured as explained in the above heading.

Applications

- Used to avoid and detect obstacles with robots like biped robot, obstacle avoider robot, path finding robot etc.
- Used to measure the distance within a wide range of 2cm to 400cm
- Can be used to map the objects surrounding the sensor by rotating it
- Depth of certain places like wells, pits etc can be measured since the waves can penetrate through water

MQ2 Gas Sensor

MQ2 Gas sensor



MQ2 Gas sensor Pinout

Pin Configuration:

Pin No:	Pin Name:	Description
For Module		
1	Vcc	This pin powers the module, typically the operating voltage is +5V
2	Ground	Used to connect the module to system ground
3	Digital Out	You can also use this sensor to get digital output from this pin, by setting a threshold value using the potentiometer
4	Analog Out	This pin outputs 0-5V analog voltage based on the intensity of the gas
For Sensor		
1	H -Pins	Out of the two H pins, one pin is connected to supply and the other to ground
2	A-Pins	The A pins and B pins are interchangeable. These pins will be tied to the Supply voltage.
3	B-Pins	The A pins and B pins are interchangeable. One pin will act as output while the other will be pulled to ground.

Features:

- Operating Voltage is +5V
- Can be used to Measure or detect LPG, Alcohol, Propane, Hydrogen, CO and even methane
- Analog output voltage: 0V to 5V

- Digital Output Voltage: 0V or 5V (TTL Logic)
- Preheat duration 20 seconds
- Can be used as a Digital or analog sensor
- The Sensitivity of Digital pin can be varied using the potentiometer

Where to use MQ-2 Gas sensor:

The **MQ-2 Gas sensor** can detect or measure gasses like LPG, Alcohol, Propane, Hydrogen, CO and even methane. The module version of this sensor comes with a Digital Pin which makes this sensor to operate even without a microcontroller and that comes in handy when you are only trying to detect one particular gas. When it comes to measuring the gas in ppm the analog pin has to be used, the analog pin also TTL driven and works on 5V and hence can be used with most common microcontrollers.

So if you are looking for a sensor to detect or measure gasses like LPG, Alcohol, Propane, Hydrogen, CO and even methane with or without a microcontroller then this sensor might be the right choice for you.

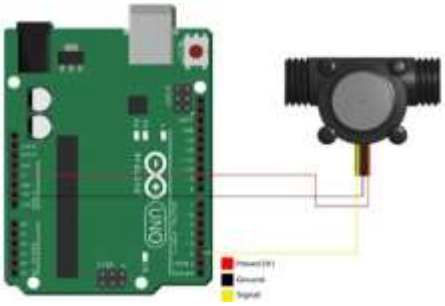
How to use MQ-2 Sensors to detect gas:

Using an MQ sensor it detects a gas is very easy. You can either use the digital pin or the analog pin to accomplish this. Simply power the module with 5V and you should notice the power LED on the module to glow and when no gas it detected the output LED will remain turned off meaning the digital output pin will be 0V. Remember that these sensors have to be kept on for pre-heating time (mentioned in features above) before you can actually work with it. Now, introduce the sensor to the gas you want to detect and you should see the output LED to go high along with the digital pin, if not use the potentiometer until the output gets high. Now every time your sensor gets introduced to this gas at this particular concentration the digital pin will go high (5V) else will remain low (0V).

You can also use the analog pin to achieve the same thing. Read the analog values (0-5V) using a microcontroller, this value will be directly proportional to the concentration of the gas to which the sensor detects. You can experiment with this values and check how the sensor reacts to different concentration of gas and develop your program accordingly.

How to use YF - S201

The YF-S201 connections are pretty simple, the module contains 3 pins which are generally colour coded as red, black, and yellow.



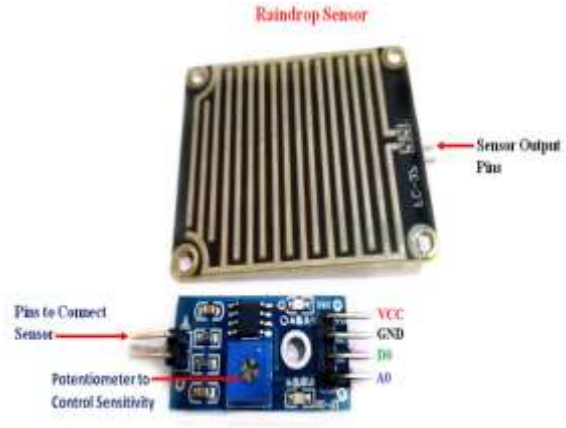
The Red is the power pin that is connected to the 5V of the microcontroller, the black is the ground pin and the yellow is the signal output pin that can be connected to the digital pin of the microcontroller.

Flow and Frequency output of the YF-S201

Flow(L/H)	Frequency(Hz)
120	16
240	32.5
360	49.3
480	65.5
600	82
720	90.2

The YF - S201 sensor has an error of ±10 or 5%. From the table, a linear exponential graph can be derived as the flow value increase along with which the frequency is also observed to increase.

Rain or WET Sensor Module



Raindrop Sensor Module

Raindrop Sensor Pinout

Raindrop Sensor is a tool used for sensing rain. It consists of two modules, a **rain board** that detects the rain and a **control module**, which compares the analog value, and converts it to a digital value. The raindrop sensors can be used in the automobile sector to control the windshield wipers automatically, in the agriculture sector to sense rain and it is also used in home automation systems.

Pin Configuration of Rain Sensor:

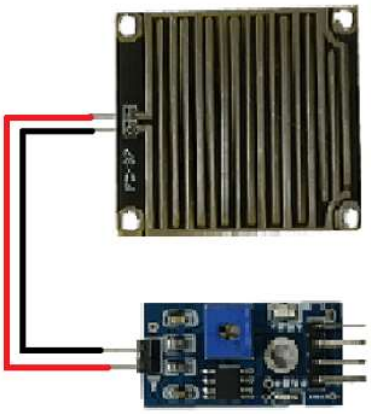
S.No:	Name	Function
1	VCC	Connects supply voltage- 5V
2	GND	Connected to ground
3	D0	Digital pin to get digital output
4	A0	Analog pin to get analog output

Raindrop Sensor Features:

- Working voltage 5V
- Output format: Digital switching output (0 and 1), and analog voltage output AO
- Potentiometer adjust the sensitivity
- Uses a wide voltage LM393 comparator
- Comparator output signal clean waveform is good, driving ability, over 15mA
- Anti-oxidation, anti-conductivity, with long use time
- With bolt holes for easy installation
- Small board PCB size: 3.2cm x 1.4cm

How to use Raindrop sensor:

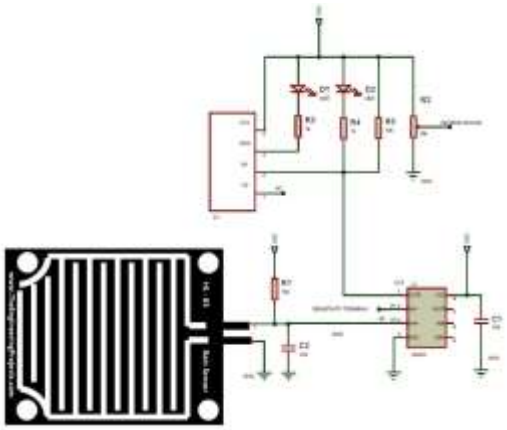
Interfacing the raindrop sensor with a microcontroller like 8051, Arduino, or PIC is simple. The rain board module is connected with the control module of the raindrop sensor as shown in the below diagram.



The control module of the raindrop sensor has 4 outputs. VCC is connected to a 5V supply. The GND pin of the module is connected to the ground. The D0 pin is connected to the digital pin of the microcontroller for digital

output or the analog pin can be used. To use the analog output, the A0 pin can be connected to the ADC pin of a microcontroller. In the case of Arduino, it has 6 ADC pins, so we can use any of the 6 pins directly without using an ADC converter. The sensor module consists of a potentiometer, LN393 comparator, LEDs, capacitors and resistors. The pinout image above shows the components of the control module. The rainboard module consists of copper tracks, which act as a **variable resistor**. Its resistance varies with respect to the wetness on the rainboard. The below fig shows the rain board module.

The circuit diagram of a raindrop sensor module is given below.



As shown in the above figure, the R1 resistor and the rain board module will act as a **voltage divider**. Capacitors C1 and C2 are used as a biasing element. The input for the Non-inverting terminal is taken from the connection point of the R1, and rain board module. Another point is taken from this connection and connected to the A0 terminal of the control module.

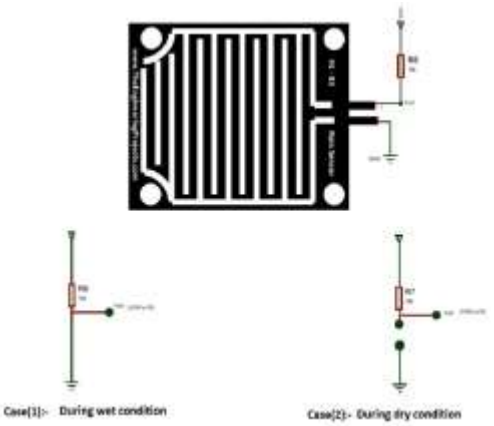
The input to the inverting terminal of the LM393 is taken from the potentiometer (R2). The R2 resistor acts as a voltage divider, and by varying R2 we can vary the input voltage to the inverting terminal, which in turn affects the sensitivity of the control module. The connections are shown in the above fig. The resistors R3 and R4 will act as current limiting resistors, while resistor R5 will act as a pull-up resistor to keep the bus in a high state when not in use.

Working of Rain Sensor:

Case1: When the input of the inverting terminal is higher than the input of the non-inverting terminal.

Case2: If the input of the inverting terminal is lower than the input of the non-inverting terminal.

The input to the inverting terminal is set to a certain value by varying the potentiometer and the sensitivity is set. When the rain board module's surface is exposed to rainwater, the surface of the rainboard module will be wet, and it offers minimum resistance to the supply voltage. Due to this, the minimum voltage will be appearing at the non-inverting terminal of LM393 Op-Amp. The comparator compares both inverting and non-inverting terminal voltages. If the condition falls under case(1), the output of the Op-Amp will be digital LOW. If the condition falls under case(2), the output of the Op-Amp will be digital HIGH. The below diagram shows the equivalent circuit of both the conditions.



When the A0 pin is connected to the microcontroller, an additional analog to digital converter (ADC) circuit is used. In the case of Arduino, it consists of 6 ADC pins, which can be directly used for calculation purposes.

Applications of Rain sensor:

- Automatic windshield wipers
- Smart Agriculture
- Home-Automation

LCD:

LCD 16×2 Pin Configuration and Its Working

Nowadays, we always use the devices which are made up of LCDs such as CD players, DVD players, digital watches, computers, etc. These are commonly used in the screen industries to replace the utilization of CRTs. Cathode Ray Tubes use huge power when compared with LCDs, and CRTs heavier as well as bigger. These devices are thinner as well power consumption is extremely less. The LCD 16×2 working principle is, it blocks the light rather than dissipate. This article discusses an overview of LCD 16X2, pin configuration and its working.

What is the LCD 16×2?

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.

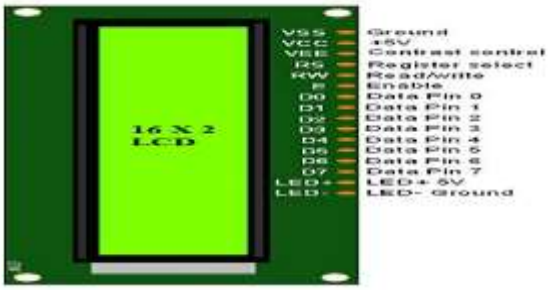
16X2 LCD

LCD 16×2 Pin Diagram

The 16×2 LCD pinout is shown below.

- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.

- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- Pin15 (+ve pin of the LED): This pin is connected to +5V
- Pin 16 (-ve pin of the LED): This pin is connected to GND.



LCD-16×2-pin-diagram

Features of LCD16x2

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8 pixel box
- The alphanumeric LCDs alphabets & numbers
- Is display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom generated characters

Registers of LCD

A 16×2 LCD has two registers like data register and command register. The RS (register select) is mainly used to change from one register to another. When the register set is '0', then it is known as command register. Similarly, when the register set is '1', then it is known as data register.

Command Register

The main function of the command register is to store the instructions of command which are given to the display. So that predefined tasks can be performed such as clearing the display, initializing, set the cursor place, and display control. Here commands processing can occur within the register.

Data Register

The main function of the data register is to store the information which is to be exhibited on the LCD screen. Here, the ASCII value of the character is the information which is to be exhibited on the screen of LCD. Whenever we send the information to LCD, it transmits to the data register, and then the process will be starting there. When register set =1, then the data register will be selected.

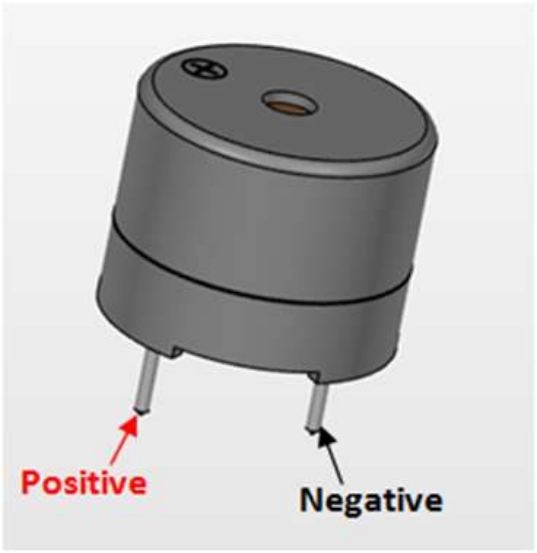
16×2 LCD Commands

The commands of LCD 16X2 include the following.

- For Hex Code-01, the LCD command will be the clear LCD screen
- For Hex Code-02, the LCD command will be returning home
- For Hex Code-04, the LCD command will be decrement cursor
- For Hex Code-06, the LCD command will be Increment cursor
- For Hex Code-05, the LCD command will be Shift display right
- For Hex Code-07, the LCD command will be Shift display left
- For Hex Code-08, the LCD command will be Display off, cursor off
- For Hex Code-0A, the LCD command will be cursor on and display off
- For Hex Code-0C, the LCD command will be cursor off, display on
- For Hex Code-0E, the LCD command will be cursor blinking, Display on
- For Hex Code-0F, the LCD command will be cursor blinking, Display on
- For Hex Code-10, the LCD command will be Shift cursor position to left

- For Hex Code-14, the LCD command will be Shift cursor position to the right
- For Hex Code-18, the LCD command will be Shift the entire display to the left
- For Hex Code-1C, the LCD command will be Shift the entire display to the right
- For Hex Code-80, the LCD command will be Force cursor to the beginning (1st line)
- For Hex Code-C0, the LCD command will be Force cursor to the beginning (2nd line)
- For Hex Code-38, the LCD command will be 2 lines and 5×7 matrix

Active Passive Buzzer



Active Passive Buzzer Pinout

Buzzer Pin Configuration

Pin Number	Pin Name	Description
1	Positive	Identified by (+) symbol or longer terminal lead. Can be powered by 6V DC
2	Negative	Identified by short terminal lead. Typically connected to the ground of the circuit

Buzzer Features and Specifications

- Rated Voltage: 6V DC
- Operating Voltage: 4-8V DC
- Rated current: <30mA
- Sound Type: Continuous Beep
- Resonant Frequency: ~2300 Hz
- Small and neat sealed package
- Breadboard and Perf board friendly

How to use a Buzzer

A **buzzer** is a small yet efficient component to add sound features to our project/system. It is very small and compact 2-pin structure hence can be easily used on breadboard, Perf Board and even on PCBs which makes this a widely used component in most electronic applications.

There are two types are buzzers that are commonly available. The one shown here is a simple buzzer which when powered will make a Continuous Beeeeeeppp.... sound, the other type is called a readymade buzzer which will look bulkier than this and will produce a Beep. Beep. Beep. Sound due to the internal oscillating circuit present inside it. But, the one shown here is most widely used because it can be customised with help of other circuits to fit easily in our application.

This buzzer can be used by simply powering it using a DC power supply ranging from 4V to 9V. A simple 9V battery can also be used, but it is recommended to use a regulated +5V or

+6V DC supply. The buzzer is normally associated with a switching circuit to turn ON or turn OFF the buzzer at required time and require interval.

Applications of Buzzer

- Alarming Circuits, where the user has to be alarmed about something
- Communication equipments
- Automobile electronics
- Portable equipments, due to its compact size

Servo Motor SG-90

Servo Motor SG90
Servo Motor Pinout (Wires)

Wire Configuration

Wire Number	Wire Colour	Description
1	Brown	Ground wire connected to the ground of system
2	Red	Powers the motor typically +5V is used
3	Orange	PWM signal is given in through this wire to drive the motor

TowerPro SG-90 Features

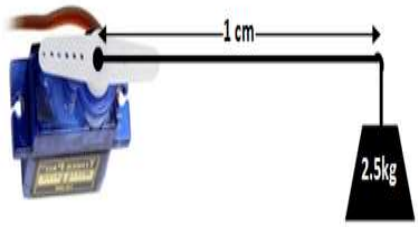
- Operating Voltage is +5V typically
- Torque: 2.5kg/cm
- Operating speed is 0.1s/60°
- Gear Type: Plastic
- Rotation : 0°-180°
- Weight of motor : 9gm
- Package includes gear horns and screws

Selecting your Servo Motor

There are lots of servo motors available in the market and each one has its own speciality and applications. The following two paragraphs will help you identify the right type of servo motor for your project/system.

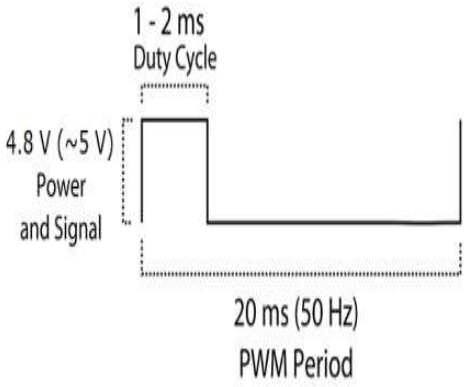
Most of the hobby Servo motors operates from 4.8V to 6.5V, the higher the voltage higher the torque we can achieve, but most commonly they are operated at +5V. Almost all hobby servo motors can rotate only from 0° to 180° due to their gear arrangement so make sure you project can live with the half circle if no, you can prefer for a 0° to 360° motor or modify the motor to make a full circle. The gears in the motors are easily subjected to wear and tear, so if your application requires stronger and long running motors you can go with metal gears or just stick with normal plastic gear.

Next comes the most important parameter, which is the **torque** at which the motor operates. Again there are many choices here but the commonly available one is the 2.5kg/cm torque which comes with the Towerpro SG90 Motor. This 2.5kg/cm torque means that the motor can pull a weight of 2.5kg when it is suspended at a distance of 1cm. So if you suspend the load at 0.5cm then the motor can pull a load of 5kg similarly if you suspend the load at 2cm then can pull only 1.25. Based on the load which you use in the project you can select the motor with proper torque. The below picture will illustrate the same.



How to use a Servo Motor

After selecting the right Servo motor for the project, comes the question how to use it. As we know there are three wires coming out of this motor. The description of the same is given on top of this page. To make this motor rotate, we have to power the motor with +5V using the Red and Brown wire and send PWM signals to the Orange colour wire. Hence we need something that could generate PWM signals to make this motor work, this something could be anything like a 555 Timer or other Microcontroller platforms like Arduino, PIC, ARM or even a microprocessor like Raspberry Pie. Now, how to control the direction of the motor? To understand that let us a look at the picture given in the datasheet.



From the picture we can understand that the PWM signal produced should have a frequency of 50Hz that is the PWM period should be 20ms. Out of which the On-Time can vary from 1ms to 2ms. So when the on-time is 1ms the motor will be in 0° and when 1.5ms the motor will be 90°, similarly when it is 2ms it will be 180°. So, by varying the on-time from 1ms to 2ms the motor can be controlled from 0° to 180°

- *Find in Reference*
  This is the only interactive function of the Help menu: it directly selects the relevant page in the local copy of the Reference for the function or command under the cursor.

Installing the ESP32 Board in Arduino IDE

There's an add-on for the Arduino IDE that allows you to program the ESP32 using the Arduino IDE and its programming language. In this tutorial we'll show you how to install the ESP32 board in Arduino IDE whether you're using Windows, Mac OS X or Linux.

Results

The proposed IoT-based Integrated Waste, Water, and Drainage Safety Monitoring System was successfully designed and tested under controlled conditions. The system demonstrated reliable real-time sensing, data processing, and alert generation for multiple urban utility parameters. The results confirm the effectiveness of the integrated monitoring approach in improving responsiveness, safety, and operational efficiency.

1. Waste Bin Level Monitoring Result

Figure 1: Waste Bin Level Detection Using Ultrasonic Sensor

(Placeholder for image: Ultrasonic sensor mounted on waste bin showing distance measurement and fill level on LCD)

The ultrasonic sensor accurately measured the distance between the sensor and the waste surface. As the bin fill level increased, the system calculated the percentage occupancy

and updated the status on the LCD and mobile application. When the bin reached the predefined threshold, a "BIN FULL" alert was generated along with buzzer activation.

2. Waste Segregation Result

Figure 2: Wet and Dry Waste Identification Using Moisture Sensor

(Placeholder for image: Moisture sensor detecting waste type with LCD display indicating "WET WASTE" or "DRY WASTE")

The moisture sensor successfully distinguished between wet and dry waste based on moisture content. The classification was displayed on the LCD and transmitted to the mobile application, confirming basic waste segregation at the source.

3. Water Leakage Detection Result

Figure 3: Water Flow Monitoring and Leakage Alert

(Placeholder for image: Flow sensor connected to pipeline with leakage alert displayed on LCD/mobile app)

The flow sensor continuously monitored water flow rates. Abnormal flow conditions such as continuous flow during non-usage periods were correctly identified as potential leakages. Upon detection, the system generated an alert, indicating effective early leakage detection.

4. Drainage Gas Monitoring Result

Figure 4: Hazardous Gas Detection in Manhole Using Gas Sensor

(Placeholder for image: MQ gas sensor setup with warning message on LCD and buzzer ON)

The gas sensor detected the presence of harmful gases inside the drainage system. When gas concentration exceeded safe limits, the buzzer was activated and a warning message was displayed. The alert was also sent to the mobile application, ensuring timely safety notifications.

5. Manhole Safety Monitoring Result

Figure 5: Manhole Cover Movement Detection Using Accelerometer

(Placeholder for image: Accelerometer mounted on manhole cover showing tilt/vibration alert)

The accelerometer successfully detected unauthorized opening, tilt, or vibration of the manhole cover. Any abnormal movement triggered an instant alert, demonstrating improved infrastructure security and accident prevention.

6. Mobile Application Monitoring Result

Figure 6: Unified Mobile Application Dashboard

(Placeholder for image: Mobile app dashboard showing waste level, leakage alert, gas status, and manhole condition)

The mobile application provided a unified dashboard displaying real-time sensor data and alert notifications. This enabled remote monitoring and quick decision-making by users or municipal authorities.

Overall Observation

The experimental results indicate that the proposed system effectively integrates multiple monitoring modules into a single IoT platform. The system operated reliably with accurate sensing, timely alerts, and seamless communication. These results validate the system's suitability for smart city applications and real-world urban infrastructure monitoring.

Conclusion and Future Enhancement

The IoT-based Integrated Waste, Water, and Drainage Safety Monitoring System successfully demonstrates a unified and intelligent approach to managing multiple urban utilities through real-time sensing and smart alerts. By integrating waste level monitoring, basic waste segregation, water leakage detection, gas safety monitoring, and manhole condition tracking into a single ESP32-based platform, the system improves urban hygiene, conserves water resources, enhances public and worker safety, and reduces manual inspection efforts. The

experimental results confirm reliable data acquisition, timely alert generation, and effective remote monitoring through a mobile application, making the system suitable for smart city deployments.

As a future enhancement, the system can be extended by incorporating advanced data analytics and machine learning techniques to predict waste collection schedules, detect leakage patterns more accurately, and forecast maintenance requirements. Integration with cloud-based platforms and GIS mapping can enable large-scale city-wide monitoring, while the use of solar power and low-power communication technologies such as LoRa can improve energy efficiency and scalability. Additionally, enhanced waste segregation using image processing and AI-based classification can further increase automation and sustainability.

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