International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-13 Issue-5, January 2025

Utilizing Raspberry Pi and Internet of Things (IoT) Frameworks for Comprehensive Monitoring of Urban Pollutants and Climate Variables

Thushara Hameed, Maheswari Maruthakutti, Pandimadevi Ganesan

***Abstract:** Global warming is the effect of a rise in Earth's climate temperature due to air pollution. Urban areas have higher levels of air pollution than rural areas due to increased traffic and rapid development. In addition to brief health problems like headaches, eye infections, and throat in-factions, pollution also has lengthy health repercussions like lung cancer and heart disease. As a result, it's important to keep an eye on the many climatic and pollution indicators, including light intensity, temperature, humidity, air pressure, oxygen and carbon dioxide level and camera. Using suitable equipment and Internet of Things (IoT) technologies, a pollution and climate monitoring system is constructed in the proposed paper that can measure the parameters above at regular intervals. The system then uploads the data to a webpage in the ThingSpeak. The IoT analytics platform service ThingSpeak enables the collection, visualization, and analysis of real-time data streams. The sensors are used to feed data to ThingSpeak, which instantly visualizes the data in a graph. The main tool for gathering data from the sensors and sending parameters to the website is the Raspberry Pi3 computer. The software code is developed using Python. By logging on to the website from any location in the world, one can view the submitted pollution and climate parameters of a specific location.*

***Keywords:** Raspberry Pi 3 Model 3B, DHT11 Sensor, Pressure Sensor, LDR, I2C LCD, MQ2 Sensor, Camera and Thing Speak.*

I. INTRODUCTION

The environment plays a crucial role in human life. Sensors are essential components used in quantifying control projects and daily life to ensure building security, estimate traffic flow, and monitor environmental conditions.

The Internet of Things (IoT) connects mobile devices, buildings, automobiles, and other devices, such as motors and sensors, to the internet. By providing compatible platform structures through hardware, software, sensors, and motors, these items can collect and exchange information. IoT devices can be identified and managed remotely from various locations, allowing computer systems to connect with the real world. This integration of IoT increases speed and efficiency.

In recent years, pollution in urban areas has increased dramatically. Pollution levels in cities are significantly higher than in rural areas due to emissions of harmful gases from numerous vehicles. The release of hazardous gases from the industrial sector and deforestation are major contributors to air pollution. Industrial pollution manifests in various forms, including the development of Raspberry Pi-based Pollution and Climate Monitoring Systems using the Internet of Things [1].

For weather monitoring projects, factors such as temperature, humidity, light intensity, gas levels, and atmospheric pressure need to be measured, making sensors indispensable for these tasks [2]. The primary goal of such projects is to develop compact and powerful weather stations. Data acquisition systems are widely used in both consumer and industrial applications.

II. LITERATURE SURVEY

This project utilizes the Raspberry Pi, a small and affordable microprocessor based on ARM architecture. The Raspberry Pi can connect to a Local Area Network (LAN) or communicate wirelessly with external devices. It processes human commands using the Python programming language. Users can access the data through other internet-enabled devices such as laptops, smartphones, or tablets. The system provides real-time information about an urban environment, including data on air pressure, carbon monoxide (CO), humidity, and temperature.

Anshul Bharadwaj et al. proposed a "Raspberry Pi Based Weather Monitoring System." Climate plays a significant role in our daily activities, making it essential to gather information about various climate parameters when planning indoor and outdoor spaces. Recent developments in the Internet of Things have simplified data collection. This system utilizes various sensors, including DHT11, LDR, and others, to measure environmental conditions [3]. These sensors collect data, which is read by a Raspberry Pi and stored in text and CSV files. The data from the different environmental parameters are transmitted to the Raspberry Pi, which serves as a central hub.

Additionally, a website and mobile app have been developed

Manuscript received on 30 October 2024 | First Revised Manuscript received on 14 November 2024 | Second Revised Manuscript received on 13 December 2024 | Manuscript Accepted on 15 January 2025 | Manuscript published on 30 January 2025.
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using Google Data Studio and Android Studio, respectively, to display current weather conditions in an easily accessible format. Users will receive regular weather updates and alerts for their area through social media. Weather forecasts are generated quickly, allowing users to prepare for their plans within the next 30 minutes.

Dhiraj Sunehra et al. proposed a "Raspberry Pi-Based Pollution and Climate Monitoring System Using Internet of Things." This research highlights the significant rise in global warming and pollution in recent years. Urban areas, due to increased automobile traffic and rapid industrialization, experience higher levels of air and noise pollution compared to rural areas. Air pollution can lead to short-term health issues such as headaches, eye infections, and throat infections, as well as long-term health consequences like lung cancer and heart disease. Furthermore, global warming is a result of rising temperatures in Earth's atmosphere due to air pollution. Therefore, it is essential to monitor various climatic and pollution parameters, including light intensity, temperature, humidity, atmospheric pressure, and sound levels. The system also measures the location's latitude and longitude to accurately identify where data is collected. This study presents a pollution and climate monitoring system that uses appropriate sensors and Internet of Things (IoT) technologies to measure the aforementioned parameters at regular intervals. The website is developed using PHP and HTML, while the Raspberry Pi 3 computer serves as the main tool for gathering data from the sensors and transmitting parameters to the website. The software code is developed in Python. By logging into the website from anywhere in the world, users can view the pollution and climate parameters for a specific location [4].

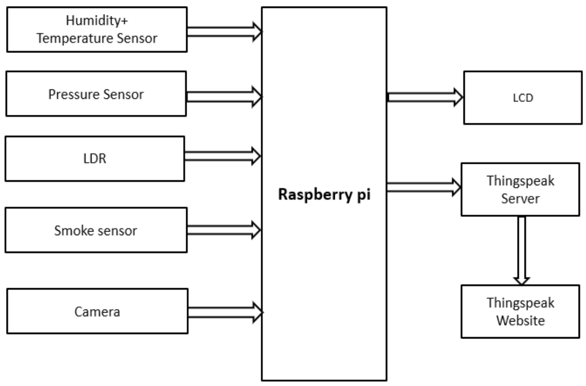
Vinod B. et al. proposed a system titled "Raspberry Pi-based Weather Reporting over IoT." This project enables real-time monitoring and updating of weather conditions via the Internet [5]. The system tracks three key parameters: temperature, humidity, and rainfall. These values are displayed on an LCD and are updated on the IoT platform gecko.com. When the area is dry, the rainfall value shows zero. If the system detects raindrops, it reflects an increase in rainfall. Additionally, any increase in temperature is also updated accordingly. Users can monitor the weather status of a particular area from any remote location. For this implementation, we utilized an ARM-based Raspberry Pi 3 board, which runs on the Raspbian operating system using a Linux Kernel. Python was chosen for programming since the IDLE environment is compatible with it. Overall, this system provides users with a clear view of the localized weather conditions in a specific area.

Dhiraj Sunehra et al. proposed a "Web-based Environment Monitoring System using Raspberry Pi." In this work, they highlight the increasing importance of environmental monitoring due to rapid industrialization [6]. The paper presents a web-based system that monitors various environmental parameters, including light intensity, carbon monoxide (CO) emissions, temperature, humidity, and landslide detection [7]. The system is implemented using an Arduino Uno and a Raspberry Pi functioning as a web server [8]. It incorporates several sensors, such as a light-dependent resistor (LDR), MQ7 sensor for CO detection, DHT11 for temperature and humidity, and an accelerometer sensor for landslide detection [9]. The environmental data collected by these sensors is uploaded to a webpage along with date and time stamps, allowing users to access the information from anywhere using any internet-enabled device, such as a laptop or smartphone [10]. The software code is written using the Arduino Integrated Development Environment (IDE) and Python, while the webpage is developed using HTML and PHP. The variations in the environmental parameters can be monitored on the ThingSpeak platform [11].

III. SYSTEM DEVELOPMENT

A. Hardware Architecture

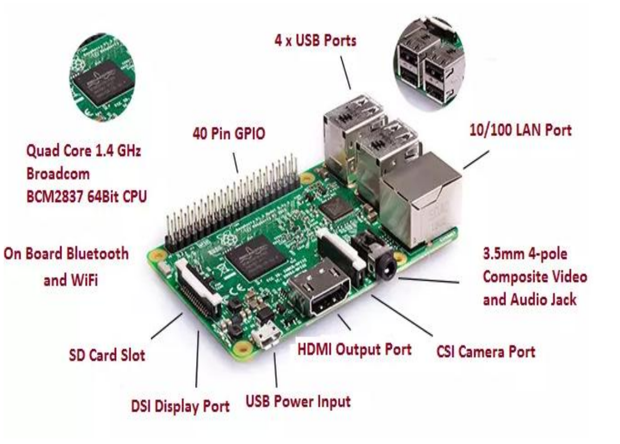
Figure 1 illustrates the block diagram of the system. The Raspberry Pi serves as the central control node of the proposed setup. The environmental parameters being monitored include temperature, humidity, pressure, light intensity, smoke levels, and camera input. Data from these sensors is continuously transmitted to the Raspberry Pi. The project utilizes the Raspberry Pi 3 as the smart control system, with all necessary components and circuits connected to it. A GUI-based Python program will allow the various connected circuits to operate at designated intervals. As shown in the block diagram, environmental parameters such as temperature, humidity, atmospheric pressure, light intensity, and smoke levels will be measured using different sensors, including the DHT11, BMB180, LDR, and MQ2. All sensor inputs are sent to the Raspberry Pi, which processes this data and displays the outputs on an LCD screen, allowing real-time monitoring of the sensor readings. Additionally, all sensor data will be uploaded to ThingSpeak for visualization through line charts. The Raspberry Pi Camera Module v2 is also incorporated for live streaming.



[Fig.1: Block Diagram]

B. Raspberry Pi

The Raspberry Pi is a compact, low-cost computer about the size of a credit card. It can be connected to a computer monitor or TV and works with a standard keyboard and mouse. This versatile small device enables individuals of all ages to learn about computing and programming in languages such as Scratch and Python. It includes all the features of a desktop computer, such as the ability to play high-definition video, browse the internet, create spreadsheets and Word documents, and play games. The Raspberry Pi 3 is the third generation of the Raspberry Pi, with the Raspberry Pi 3 Model B being the specific version illustrated in Fig. 2.



[Fig.2: Raspberry Pi 3 Model B]

The Raspberry Pi 3 Model B features a 64-bit quad-core processor with onboard WiFi and Bluetooth capabilities, along with multiple USB ports. It has a processing speed that ranges from 700 MHz to 1.4 GHz, and the RAM varies from 256 MB to 1 GB. The device's CPU acts as its brain, responsible for executing numerous instructions based on mathematical and logical operations. Additionally, the GPU is an advanced chip integrated into the board that handles image processing tasks. Equipped with a Broadcom VideoCore chip, the Raspberry Pi 3 is well-suited for gaming and multimedia applications. It includes GPIO (General Purpose Input/Output) pins, which are essential for connecting to other electronic devices. These input-output pins receive commands and operate based on the device's programming. The device features an Ethernet port, enabling communication with other devices and providing internet connectivity when connected to a router. There are four USB ports available for further communication, and an SD card is used for storing the operating system. The power connector is an essential component that supplies 5V power to the board. While any appropriate power source can be used, it is recommended to connect the power cable through a laptop's USB port for optimal performance. The Raspberry Pi 3 supports two connection options: HDMI and composite video. The HDMI connector is used for connecting to LCD screens or TVs that support HDMI versions 1.3 and 1.4, while the composite video connection allows compatibility with older TVs using a 3.5mm jack socket for audio output. This model includes a VideoCore multimedia chip that can play 1080p video, a significant upgrade over its predecessors, which offered lower video quality. The USB hard drive functionality on the board enables it to boot the device similarly to how a PC boots using its hard drive. The official operating system for the Raspberry Pi 3 is Raspbian Linux, but it can also run other third-party operating systems, including RISC OS, Kodi Media Center, Windows 10 IoT Core, Ubuntu MATE, and various classroom management systems.

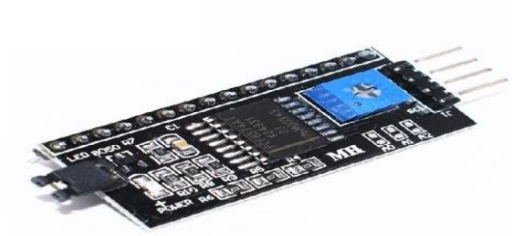
C. Liquid Crystal Display

The LCD (Liquid Crystal Display) is interfaced with the 8051 microcontroller. The most commonly used displays are the 16x2 and 20x2 models. The 16x2 display consists of 16 columns and 2 rows, allowing it to show letters, numbers, and special symbols. A diagram of the Liquid Crystal Display is provided in Fig. 3.

[Fig.3: Liquid Crystal Display]

i. I2C LCD Adapter

The device features a microcontroller chip, referred to as PCF8574, as illustrated in Fig. 4. This microcontroller acts as an I/O expander, enabling communication with other microcontroller chips through a wired communication protocol. With this adapter, users can control a 16x2 LCD using just two wires (SDA and SCL), which conserves multiple pins on an Arduino or other microcontrollers. Additionally, it includes a built-in potentiometer for adjusting the LCD contrast. The default I2C address for this device is 0x27.



[Fig.4: I2C Adapter]

ii. I2C LCD Display

The I2C LCD Display consists of 4 Pins. GND is a ground pin and should be connected to the ground of Arduino. VCC supplies power to the module and the LCD. Connect it to the 5V output of the Arduino or a separate power supply. SDA is a Serial Data pin. This line is used for both transmit and receive.SCL is a Serial Clock pin. The I2C adapter LCD Display is shown in Fig.5.

[Fig.5: I2C LCD Display]

D. LDR Module

A Light Dependent Resistor (LDR), also known as a photoresistor, is a small component that senses light. Its resistance changes based on the amount of light that strikes it; as light intensity increases, the resistance of the LDR

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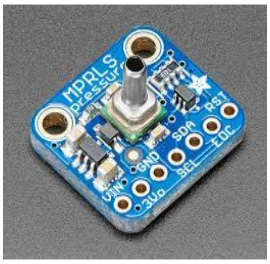
decreases, and vice versa. LDR sensor modules are commonly used when there is a
need to detect the presence or absence of light.

These resistors are primarily used in applications such as alarm clocks, streetlights, light intensity meters, and burglar alarm circuits, serving as effective light sensors.

[Fig.6: LDR Module]

E. Pressure Sensor

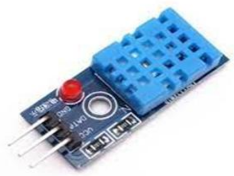
A pressure sensor is a device that detects pressure and converts it into an electronic signal. The strength of this signal depends on the amount of pressure applied, as illustrated in Fig. 7. Pressure, defined as the force required to prevent a fluid from expanding, is usually measured in terms of force per unit area. Typically, a pressure sensor acts as a transducer by generating a signal in response to the applied pressure.



[Fig.7: Pressure Sensor]

F. Humidity and Temperature Sensor

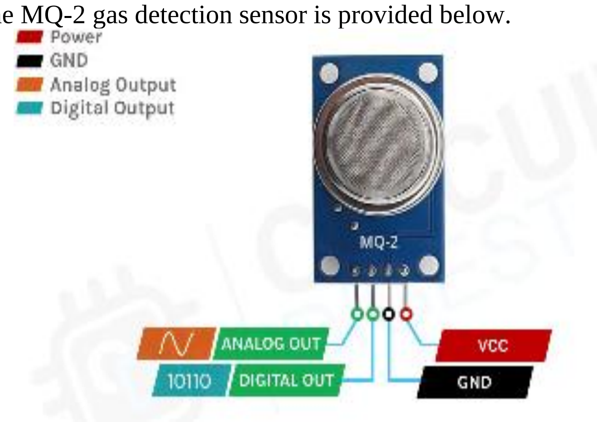
Among the most commonly used environmental sensors are those that measure temperature and humidity. Humidity sensors, also known as hygrometers, are used to determine the current level of air humidity in a specific location or at a particular time. Temperature sensors detect ambient temperature and convert it into a signal that can be transmitted. The humidity sensor primarily measures and reports the humidity of the surrounding air and objects.



[Fig.8: Humidity and Temperature Sensor]

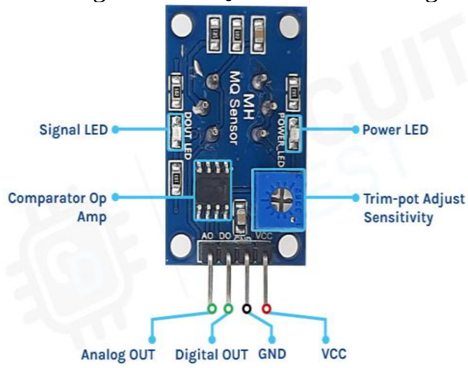
G. Smoke Sensor

The MQ-2 Combustible Gas and Smoke Sensor is commonly used in smoke and gas detectors. This sensor can detect various gases, including LPG, alcohol, propane, hydrogen, methane, and carbon monoxide, in addition to smoke. The MQ-2 gas detection sensor module features four pins: VCC, GND, OUT, and D OUT, which are used to obtain necessary information from the sensor. The pinout for the MQ-2 gas detection sensor is provided below.



[Fig.9: MQ2 Sensor]

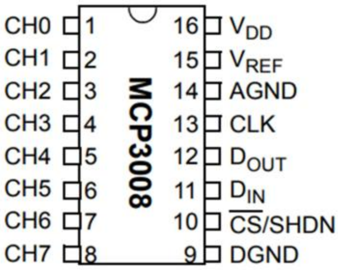
VCC is the power supply pin of the Gas Detection Sensor that can be connected to 5V of the supply. GND is the ground pin of the board, and it should be connected to the ground pin of the Arduino. DOUT is the Digital output pin of the board; output low indicates gas or smoke is not present in the atmosphere and output high indicates gas or smoke is present in the atmosphere. AOUT is the Analog output pin of the board that will give us an analog signal which will vary between Vcc and ground based on the gas level detected. The parts markings of the MQ-2 Gas Sensor are given below,



[Fig.10: MQ2 Sensor Parts]

H. MCP3008

The MCP3008 is an analog-to-digital converter (ADC) that features 16 pins and 8 channels. This chip converts analog voltages into a 10-bit binary code, as illustrated in Fig. 11. It is connected to an external clock supplied by the Raspberry Pi.



[Fig.11: MCP3008]

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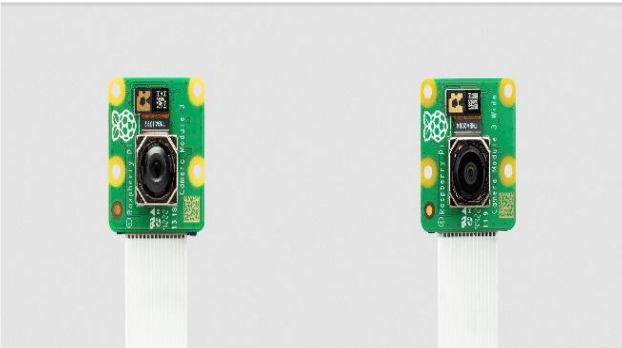
I. Camera

The Raspberry Pi Camera Module v2 is an add-on board designed specifically for the Raspberry Pi. It features a fixed-focus lens and a high-quality 8-megapixel Sony image sensor. This camera module supports video resolutions of 1080p at 30 frames per second, 720p at 60 frames per second, and 640x480p at 60 or 90 frames per second. Additionally, it can capture static images with a resolution of 3280 x 2464 pixels. The module connects to the Raspberry Pi through a small port on the top surface of the board and utilizes the Camera Serial Interface (CSI), which is specifically designed for camera integration.

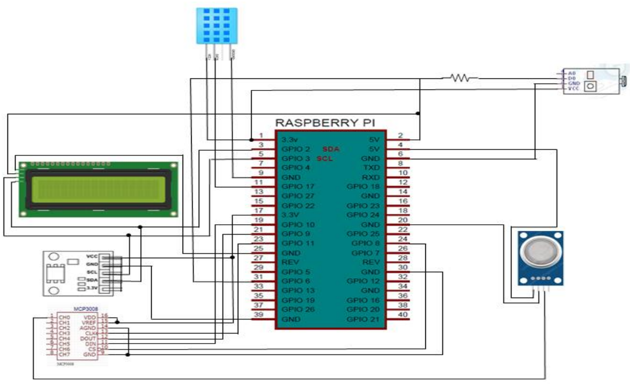


[Fig.12: Raspberry Pi Camera]

IV. EXPERIMENTAL SETUP AND RESULTS

A. Circuit Diagram

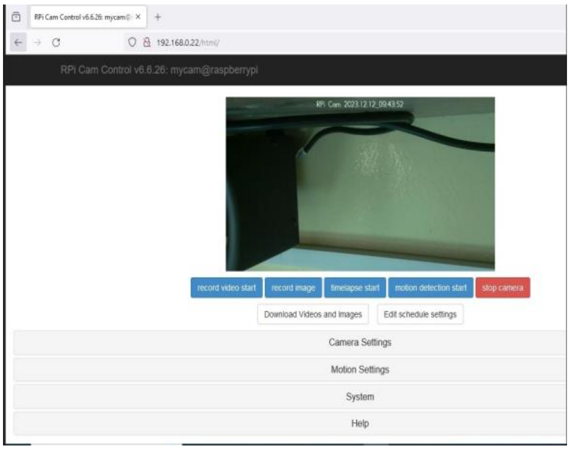
The circuit diagram of the Raspberry Pi-based urban climate and pollution monitoring system is shown in Fig.13.



[Fig.13: Circuit Diagram]

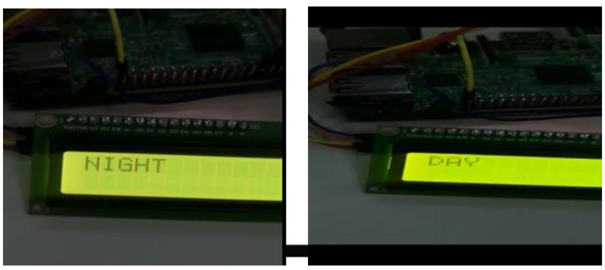
B. Circuit Diagram Explanation and Result

In the circuit diagram above, all components are connected to the Raspberry Pi 3 Model B. The DHT11 sensor has three pins: VCC, DATA, and GND. The VCC pin is connected to the 3.3V pin, the DATA pin is connected to GPIO 17, and the GND pin is connected to the GND on the Raspberry Pi. For the LDR sensor, we connected the VCC pin to the 3.3V from the Raspberry Pi. The DO (digital output) pin is connected to one end of a resistor, while the other end of the resistor is connected to the 5V and pin 31. The ground pin of the LDR sensor is connected to the ground pin of the Raspberry Pi. The BMP180 sensor has five pins, but we only use four: VIN, GND, SCL, and SDA. These are connected to 3.3V, GND, GPIO 3, and GPIO 2, respectively. To display all the sensor values, we used an I2C LCD, which has four pins: VCC, GND, SDA, and SCL. We connected these pins to the Raspberry Pi pins for 5V, GND, GPIO 2, and GPIO 3, respectively. We employed MCP3008 to convert analog signals to digital signals. Its VDD and VREF pins are connected to 3.3V, AGND and GND pins are connected to GND, the CLK pin is connected to GPIO 11, the DOUT pin is connected to GPIO 9, the DIN pin is connected to GPIO 10, and the CS pin is connected to GPIO 8. Finally, we connected the gas sensor to both the Raspberry Pi and MCP3008. The VCC pin of the gas sensor is connected to 5V, the GND pin is connected to GND, and the AO (analog output) pin is connected to CHO (pin 1) of MCP3008. We read the values from the sensors and display messages based on the readings. If the light intensity exceeds a certain threshold, the LCD will show "Day." If it does not, the LCD will display "Night." Similarly, for smoke levels, if the reading exceeds a given threshold, the LCD will display "Alert"; otherwise, it will show "Normal." To set up the camera, connect Camera p2 to the CSI (Camera Serial Interface) port. Then, to view the live video feed, open Firefox and enter the Raspberry Pi's IP address, 192.168.0.34/. You will be able to see the video feed, as shown in Fig. 14.



[Fig.14: Live Video by Using Raspberry Pi Camera p2]

Test each sensor individually, and the results will be displayed in Python as well as on an LCD. The LCD will indicate whether it is "day" or "night." The figure shows the LCD.



[Fig.15: LCD]

The figure below illustrates the readings obtained from combining all the sensors with the Raspberry Pi. It displays the temperature, pressure, and altitude measurements. Additionally, the readings on the LCD indicate whether the

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DOI: 10.35940/ijrte.E8184.13050125
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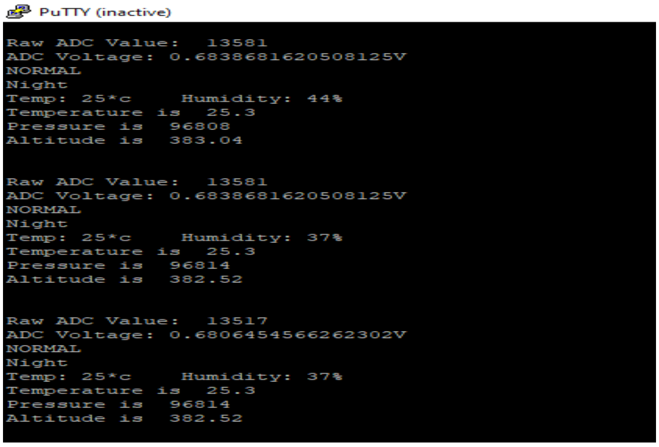
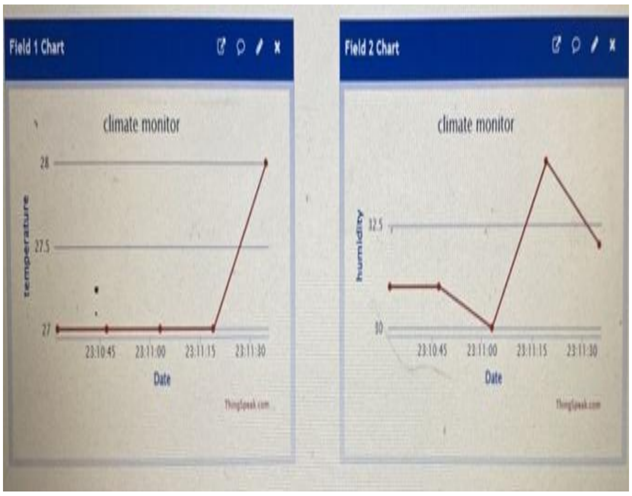
LDR sensor detects day or night, and whether the MQ2 sensor shows a normal state or an alert.



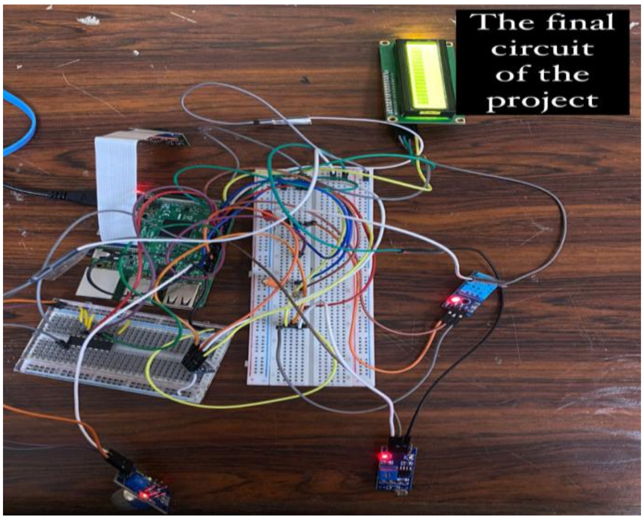
[Fig.16: Final Output]

The results from the DHT11 sensor will also be available on ThingSpeak. The figure below displays the data from the ThingSpeak channel. Fields 1 and 2 show the readings from the DHT11 sensor, which include temperature and humidity measurements. Fig. 17 illustrates the temperature and humidity data.

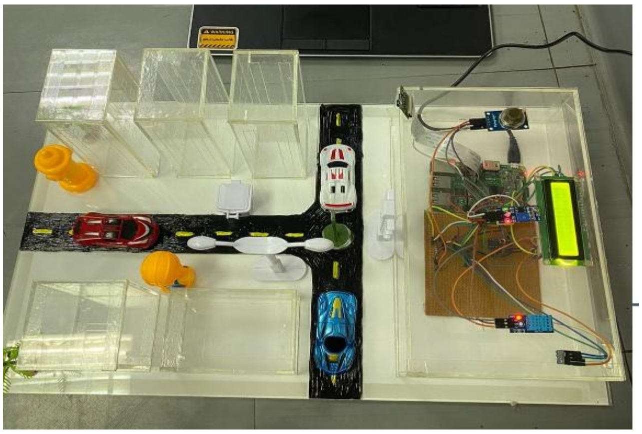


[Fig.17: DHT11 Output in Thingspeak]

The final bread broad connection and the final product are shown in Fig.18. and Fig.19.



[Fig.18: Testing of the Whole Circuit]



[Fig.19: Final Prototype]

V. CONCLUSION

The proposed project, "Utilizing Raspberry Pi and Internet of Things (IoT) Frameworks for Comprehensive Monitoring of Urban Pollutants and Climate Variables," has been successfully implemented. The system has been tested and carefully observed the results obtained. All hardware components have been integrated to develop the system. Each module's functionality has been thoroughly evaluated, and they have been positioned to optimize the system's performance and results.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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