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Development of an IoT-based Real-Time Temperature and Humidity Monitoring System for Factory Electrical Panel Rooms

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Abstract: Internet of Things (IoT) based systems are used for monitoring the status of inventory and components including variables such as temperature and humidity, in order to maintain their quality under ideal conditions. These IoT devices can also provide real-time monitoring of quality of components, identifying any defects and issuing alerts if quality criteria are not upheld throughout the manufacturing process.

This study presents the development and implementation of an IoT-based Real-Time Temperature and Humidity Monitoring System specifically designed for Industrial Electrical Panel Rooms. In the backdrop of industrial automation advancements, there is a significant need for real-time monitoring systems to ensure efficiency and safety. The proposed system establishes the capabilities of the IoT to offer a network of interconnected devices that can communicate, share data, and provide real-time feedback. The system's methodology consists of three pivotal stages: data acquisition using the "DHT22" temperature sensor, data transmission through both wired and wireless means, and user alert mechanisms that trigger email notifications when predefined temperature thresholds are exceeded. The system was tested in an actual factory environment, demonstrating its potential to mitigate risks associated with humidity disturbances and overheating in electrical panel rooms. The research highlights the significance of IoT in enhancing industrial safety and operational efficiency.

Keywords: Humidity, IoT, Temperature

1. Introduction

In the rapidly evolving industry of automation and smart infrastructure, the integration of real-time monitoring systems is an essential requirement. As industries strive for efficiency and safety, the demand for advanced solutions to mitigate risks in factories and industrial workplaces becomes a compulsory requirement. These environments, associated with advanced machinery and electrical systems, stand in need of regular inspection to prevent potential hazards [7].

1.1Challenge with Electrical Panel Rooms

Factories are utilized with critical components such as the 'Distribution Panel' in "Electrical Panel Rooms". An Electrical Panel Room, often referred to as an electrical room, in a factory is a dedicated space where electrical equipment, such as circuit breakers, fuses, switches, and other associated devices, are housed. These devices are essential for controlling, protecting, and distributing electrical power throughout the facility. Here, the 'Distribution Panel' serves as the primary hub in distributing electrical power [15]. However, this panel, which is an important component in the electrical distribution chain, presents several challenges.

1.1.1 Humidity-Induced Disturbances

Elevated humidity levels can cause condensation on electrical components. This moisture can lead to short circuits, fluctuating voltage changes, and even equipment failure, posing significant risks [2]. This may also lead to corrosion of materials.

1.1.2 OverHeating and Associated Risks

Electrical components, when overloaded, generate excessive heat [9]. This heat can degrade insulation, produce sparks, and in worst-case scenarios, lead to fires, emphasizing the need for continuous monitoring [7].

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1.2 IoT-Based Solution

Addressing these challenges requires a blend of innovation and technology. The work presented in this paper introduces an IoT-based solution tailored for factory area management and control [1].

1.2.1 Harnessing IoT

IoT offers a network of interconnected devices that can communicate and share data [11]. By utilizing IoT, industries can achieve real-time monitoring, predictive maintenance, and even remote control of systems [4]. Therefore, adoption of IoT offers systems to expand seamlessly with additional sensors and devices. Its remote access capabilities enable users to monitor and control systems from any location with internet connectivity. Over time, these solutions prove cost-efficient, optimizing operations and reducing manual interventions. Furthermore, by analyzing data trends, IoT systems can predict potential component failures, facilitating timely maintenance. Additionally, the seamless integration of IoT devices with other enterprise systems enhances overall operational efficiency [11].

1.2.2 Core Components

The heart of this system is the "ESP32 DEVKIT V1" microcontroller, known for its versatility and robustness. This was chosen due to its Wi-Fi functionalities [13]. Paired with Temperature & Humidity sensors, it provides accurate readings, crucial for environments like server rooms and desalination plants [5]. Choosing the right sensor is pivotal. The DHT22 (Figure 1) sensor, central to this system, stands out for its precision. Under room temperature conditions, it boosts an accuracy of 98.15% [5]. Such accuracy ensures that even minute changes in temperature and humidity are detected, allowing for timely fluctuations [1, 3]. An LCD display is also employed for graphical representation of the temperature and humidity on-site.

Figure 1 – DHT22 Sensor

1.2.3 Emphasis on Safety

Modern electrical wiring systems, with their fail-safes and redundancies, ensure the safe transfer of electricity [3]. Such fail-safes prioritize safety, integrating features like overload alerts and automated shutdown mechanisms. However, the proposed system primarily focuses on real-time monitoring of temperature and humidity in the installed environment in addition to alerting the user once the temperature goes beyond a predefined temperature value.

The subsequent sections offer a deep dive into the ESP32-driven IoT device. From its design and implementation to its real-world applications, readers will gain insight into its potential to support industrial monitoring solutions.

2. Methodology

The overall methodology of this process, which contains all the major phases of this proposed system, is demonstrated in Figure 2. Thus, in this system, the methodology is developed in three key stages, which include, acquisition of temperature & humidity readings, data transmission, and user alert.

2.1Acquisition of Temperature & Humidity Readings

The "DHT22" temperature sensor (Figure 1) was used for the acquisition of temperature and humidity readings into the system. This is a digital temperature and humidity sensor capable of measuring temperatures from -40°C to 80°C with an accuracy of ±0.5°C [12]. The precision and wide measurement range of this sensor makes it ideal for electrical system rooms where the acceptable temperature varies between 40°C to 50°C[6]. In such environments, consistent and accurate monitoring is crucial to prevent equipment damage. Moreover, the DHT22 sensor has an ability to measure relative humidity. This provides an added advantage, ensuring both temperature and humidity remain within safe limits for electrical equipment.

C++ language (algorithm) was used for controlling data acquisition process, and coding was done along with the "DHT library" to interface with the DHT22 sensor. The code interacts with the DHT22 sensor to accumulate the temperature and humidity data in the factory panel room.

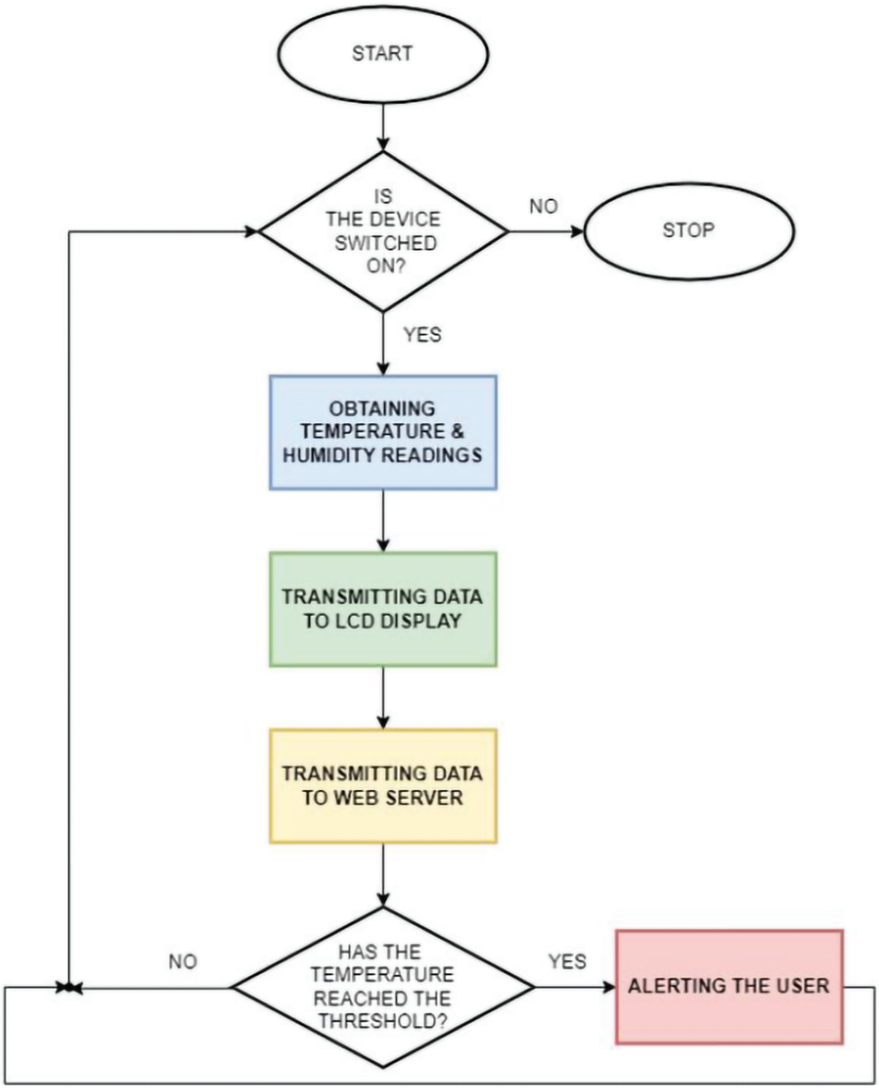


Figure 2 - Flow Diagram of the Proposed System

When the designated functions for temperature are invoked, the temperature value in Celsius is fetched and stored as a variable. Similarly, when the functions for humidity are called, the relative humidity, represented as a percentage, is captured, and stored in another variable. If the sensor fails to provide a valid reading during either of these processes, an error message is communicated via the serial monitor.

2.2 Data Transmission

In the proposed system, the data transmission process follows two main protocols which includes both wired and wireless. The wireless data transmission process is completed using Wi-Fi, while the wired data transmission is imposed by means of I²C (Inter-Integrated Circuit) protocol which follows serial communication.

2.2.1 To LCD Display

As previously stated, the algorithm interfaces with an LCD display using I²C communication. The selected LCD display has 16 columns and 2 rows, which allows the user to print 32 characters at once [14].

Figure 3 - 1602 LCD Display with I²C Module

When specific functions are invoked, the temperature and humidity values, which are stored in variables, are formatted into strings with appropriate labels. These formatted strings are then set to specific cursor positions on the LCD. The temperature value is displayed on the top row, while the humidity value appears on the row below. The backlight of the LCD is also initialized, ensuring that the displayed data is visible. If there is an issue with obtaining the readings, an error message is communicated via the serial monitor.

2.2.2 To Web Server

The algorithm establishes a web server on the ESP32 DEVKIT V1. When specific functions are invoked, endpoints are set up to serve data to clients. One endpoint provides the temperature value, and another offers the humidity value. Both values are stored in variables and, upon a client's request to the respective endpoint, are sent as plain text responses. Additionally, there is an endpoint set up to serve an HTML page from the SPIFFS (SPI Flash File System) of the ESP32 DEVKIT V1. The ESP32 continuously listens for incoming client requests and responds with the appropriate data, based on the endpoint accessed. If there is an issue with the server or data retrieval, error handling mechanisms in the code manage such situations. Furthermore, HTML file configures the rate at which the client requests the data, which was set to 30s, in addition to arrangement of the graphical representation of the temperature and humidity values sent to the server.

2.3 User AlertSystem

The algorithm was designed to deliver email alerts under specific conditions. SMTP (Simple Mail Transfer Protocol) server details and credentials were provided to enable the ESP32 DEVKIT V1 to deliver emails. When certain functions are invoked, the temperature value, stored in a variable, is checked against a predefined threshold. If the temperature exceeds this threshold and a set time interval has passed since the last email was sent, an email alert is triggered. Here, a specified time interval was set between sending emails to limit the number of emails sent upon exceeding the threshold value. The email contains a message indicating that the temperature has surpassed the set limit, along with the current temperature value. The email is then sent to a specified recipient using the provided SMTP settings. If there is an issue with sending the message, an error message is communicated via the serial monitor.

3. Testing & Implementation

The testing of the system which has been carried out and the proposed implementation of the system will be discussed in the following sections.

3.1 Testing of the Proposed System

The testing procedure of the proposed system was performed using a physically constructed circuit on a breadboard. Figure 4 depicts the physical arrangement of the testing board. In order to test the operation of the system, firstly it was ensured that the Wi-Fi connection was stable prior to starting the system. Then, the HTML code was uploaded to the ESP32 DEVKIT V1 and subsequently the algorithm is uploaded. For controlling the environmental temperature, the testing board was placed inside an electrical panel room at a local paint manufacturing factory where several VFDs (Variable Frequency Drivers) and a distribution board were in operation. Simultaneously the temperature was measured using a “K-Type” Digital Thermocouple’ to verify that the readings obtained using the DHT22 temperature sensor were accurate up to an acceptable extent.

During testing, it was ensured to set the threshold value of the temperature to a value which was slightly above room temperature. This procedure was carried out in order to obtain multiple readings without negatively impacting the components at the factory panel room. Therefore, the threshold temperature was set to 32°C. In the actual implementation, the value is expected to be set at a value which is slightly above the recommended temperature value of 50°C [6].

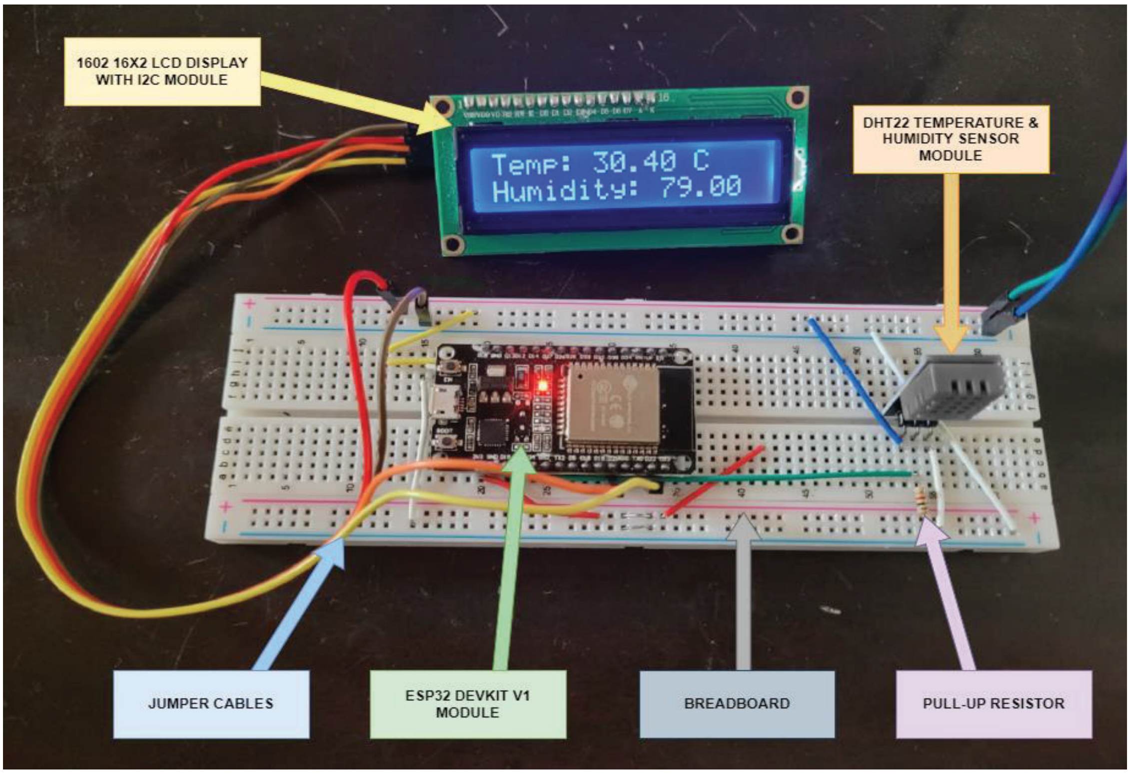


Figure 4 –3D Model of the Testing Circuit Board

3.2 Implementation of the Proposed System

The IoT based real-time temperature and humidity system is expected to be installed in a factory panel room as a single embedded system. The system is powered up using a 12V DC power supply [8]. The different voltage requirements for each component of the system were supplied by utilizing the voltage regulating ICs presented in Table 1.

Table 1 - Voltage Requirements

IC	V Output	Component
AMS1117-3.3	3.3V	DHT22
AMS1117-5.0	5V	LCD
L7809ABD2T	9V	ESP32

Figure 5 shows the PCB (Printed Circuit Board) designed to implement the embedded system in the facility during actual operation. The PCB has dimensions of 97 mm in total length and 80mm in width. All the components except for the temperature sensor and the LCD display are to be enclosed using an enclosure box manufactured using a suitable material such as ABS (Acrylonitrile Butadiene Styrene) plastic which can withstand temperatures up to 80°C [10]. The DHT22 temperature sensor is not enclosed to increase its accuracy during operation. Figure 6 depicts a 3D model of the actual component placement in the PCB.

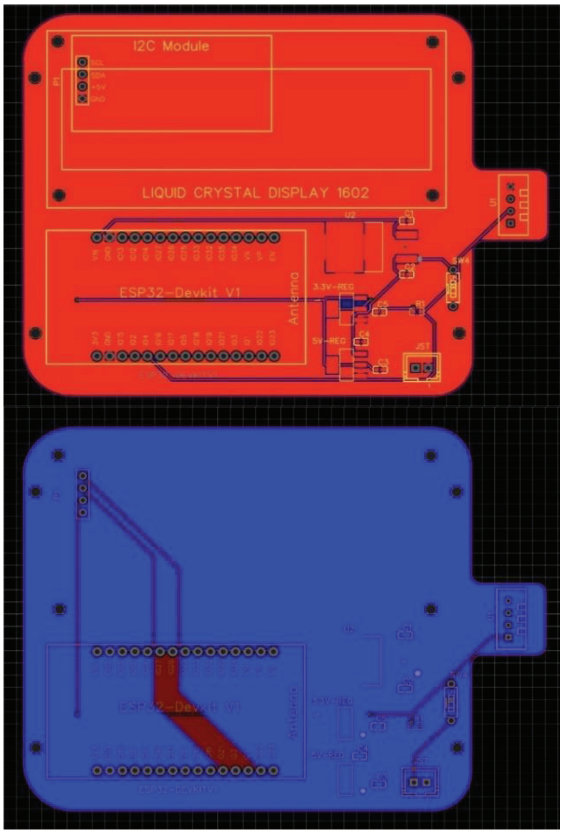


Figure 5 - PCB Design for the Embedded System

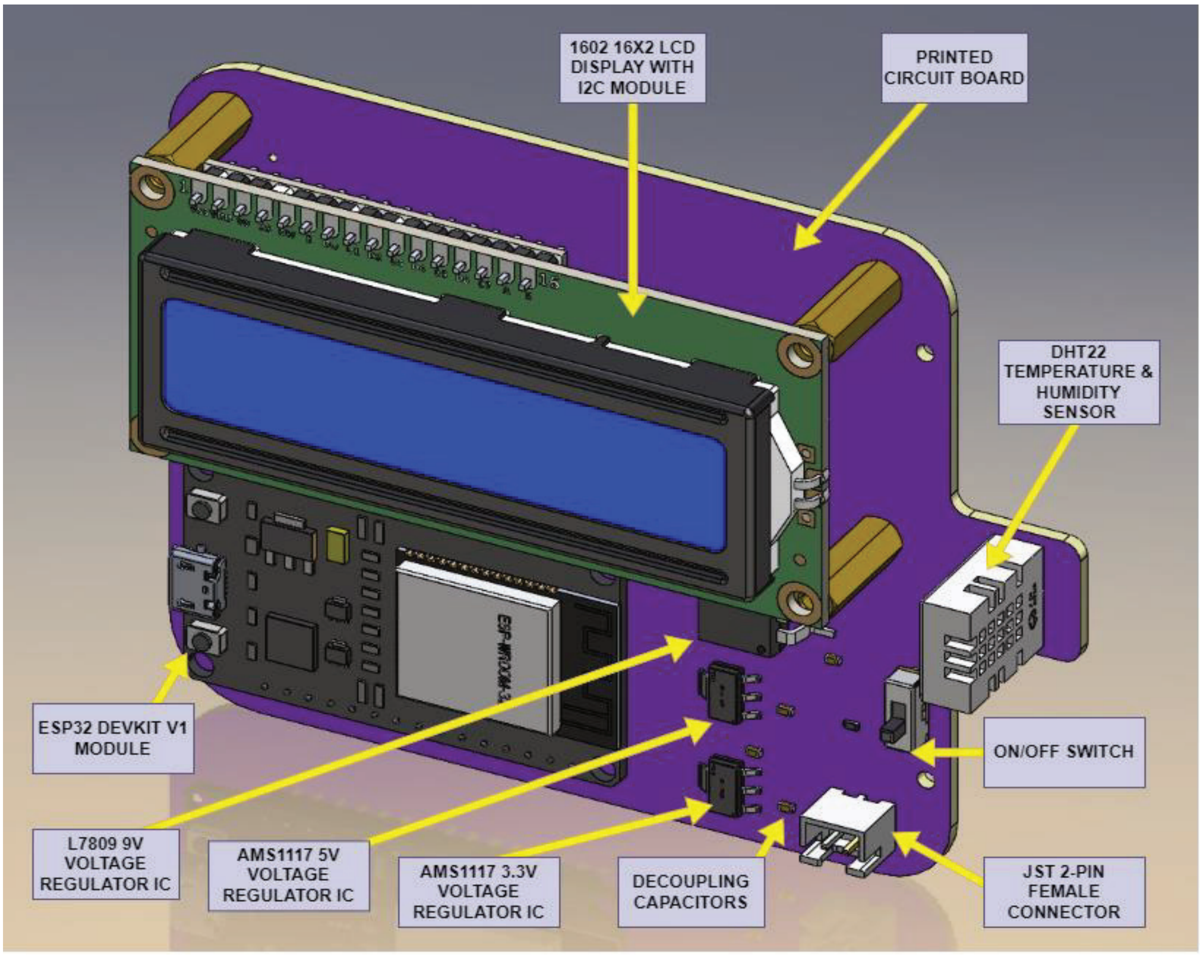


Figure 6 - Labelled CAD Model of the Actual Component Placement on the PCB

4. Results & Discussion

Figure 7 depicts a snapshot of the serial monitor of the Arduino IDE where the algorithm was programmed. The IP address displayed in the serial monitor can be used to access the webserver through the internet. Here, the generated IP address can be identified as "192.168.1.7".

Upon accessing the IP address using the internet, the graphical representation of the temperature and humidity readings can be observed as represented in Figure 8. Here, both the temperature and humidity readings are updated every 30s in the graph. Nevertheless, the measurements are obtained from the DHT22 sensor by the micro controller every 10 seconds as a safety measure. This reduces the risk of overloading the server while making sure the system operates in optimal conditions.

Also, Figure 8 shows the layout of the graphing axes, text alignment, colors, as well as the positioning of all the components in the webserver. These were organized using the HTML file which was uploaded to the micro controller prior to uploading the algorithm. Moreover, the value visualized using the graphs were equivalent to the measurements obtained using the digital thermocouple during the testing process.

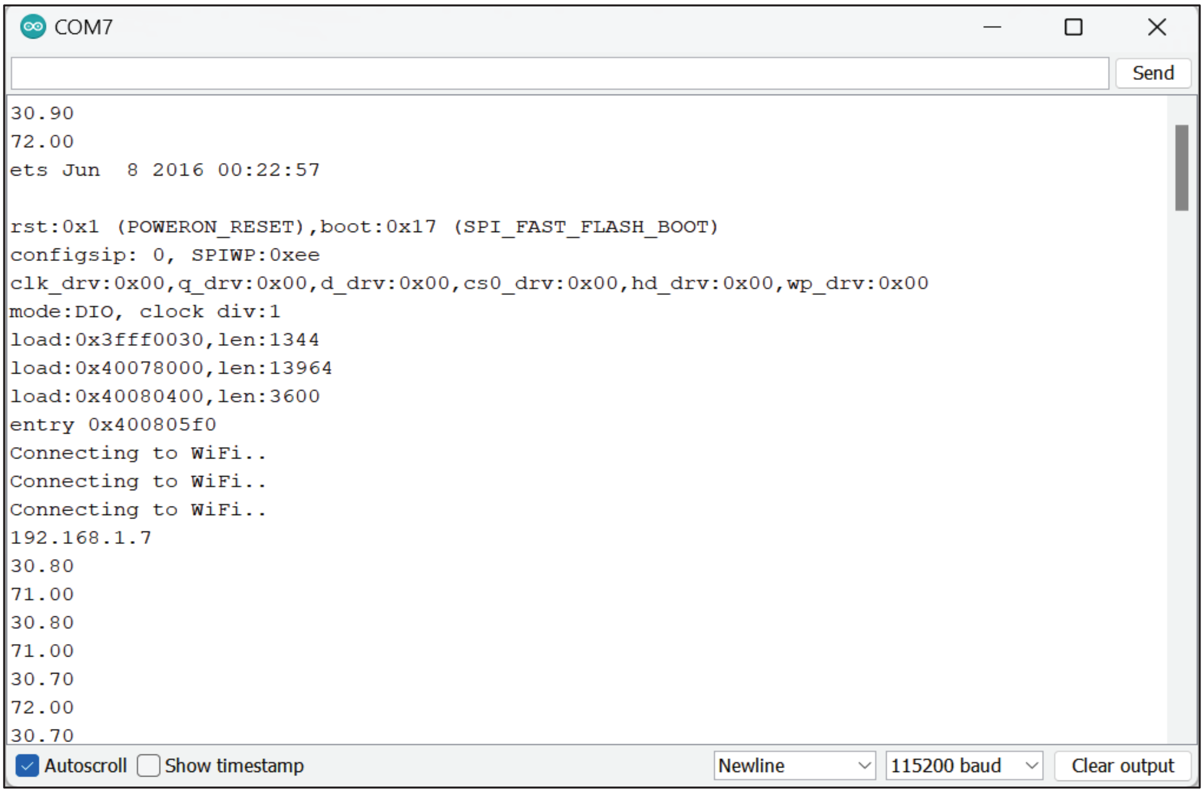


Figure 7 - Serial Monitor – IP Address

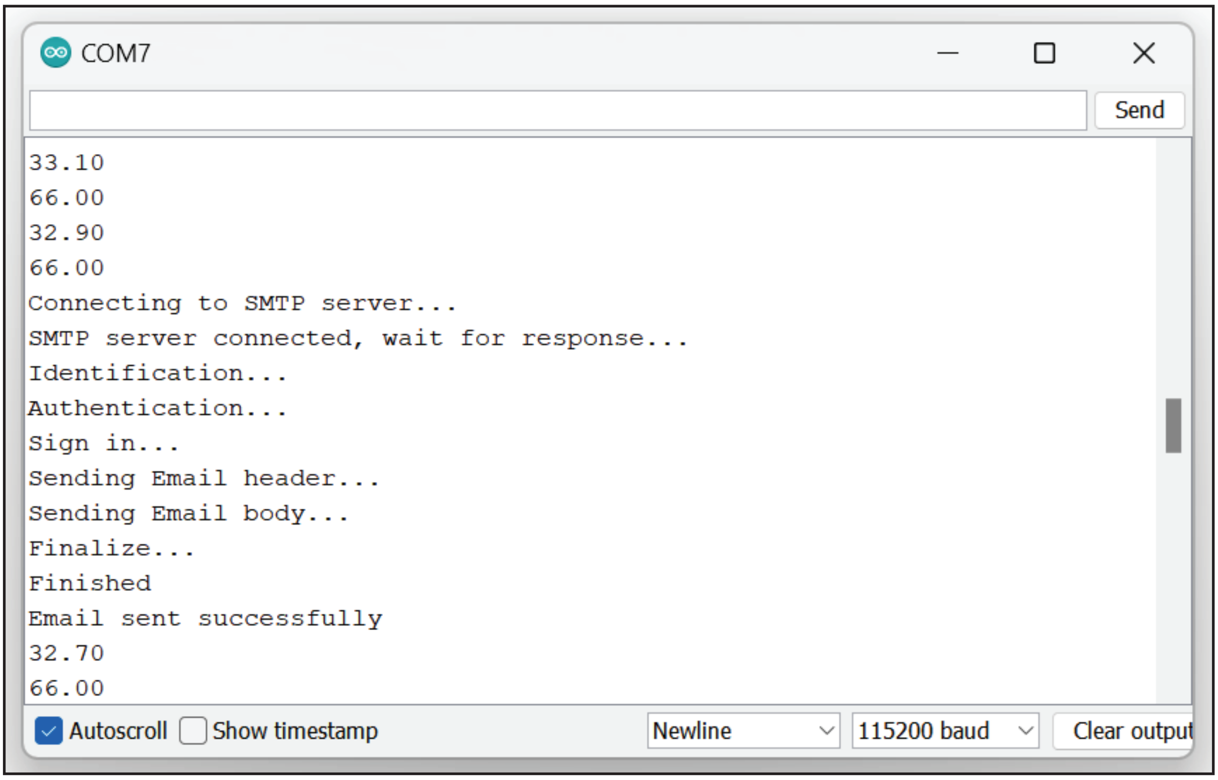
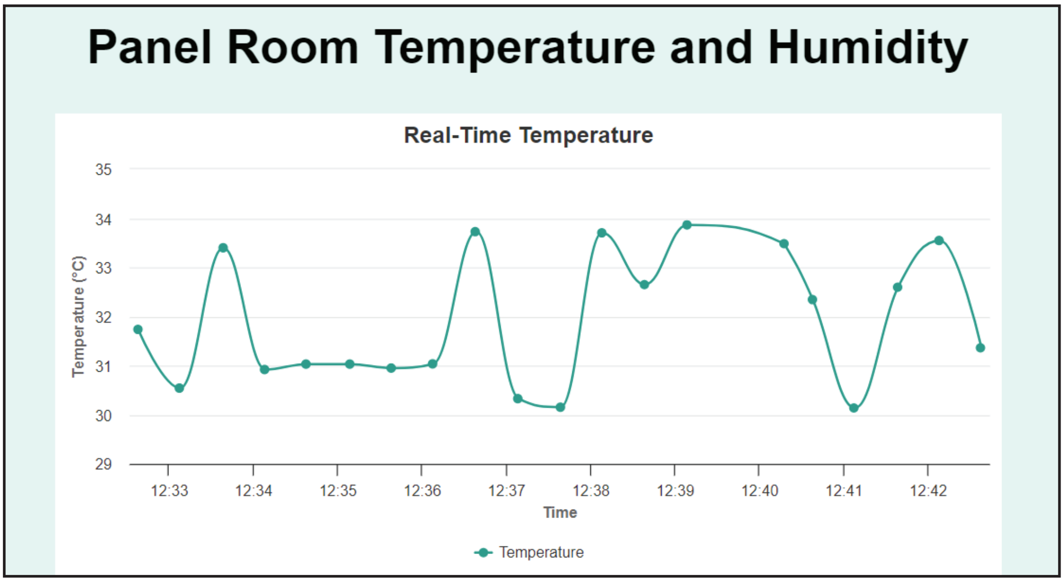
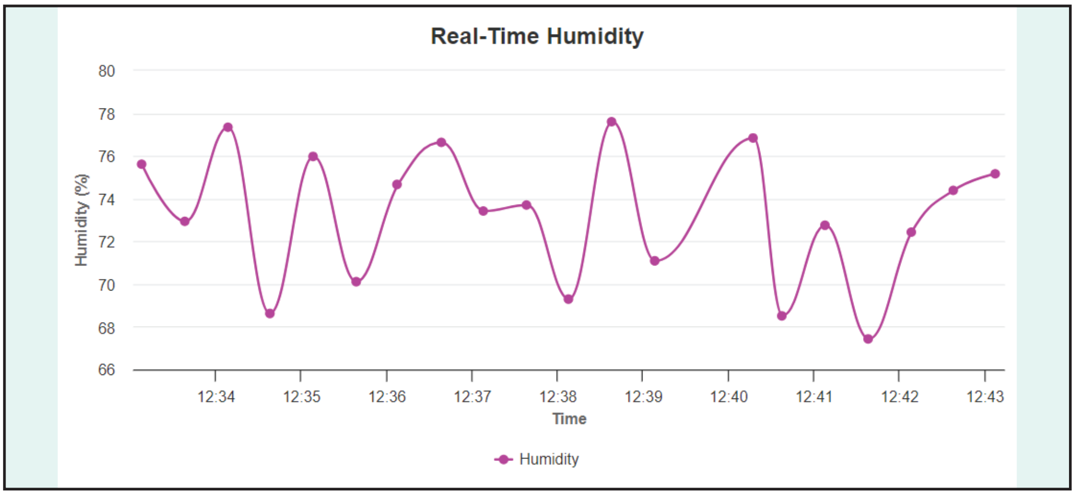


Figure 9 - Message in the Serial Monitor



(a)



(b)

Figure 8 - Real-Time Plots (a) Temperature Measurements (b) Humidity Measurements

As discussed in Section 2.3, the system delivers a message to the user once the temperature measurement exceeds the threshold value. This process occurs in several steps which include:

1) Connecting to SMTP server;
2) User identification from server;
3) User authentication from server;
4) Signing into email address; and
5) Sending the email to alert the user.

Figure 9 represents a snapshot of the serial monitor during the course of delivering an email to alert the user.

As demonstrated in Figure 10, an email message is delivered to the user once the system detects an environmental temperature which exceeds the threshold value. As mentioned earlier, the threshold value was set to 32°C for testing purposes.

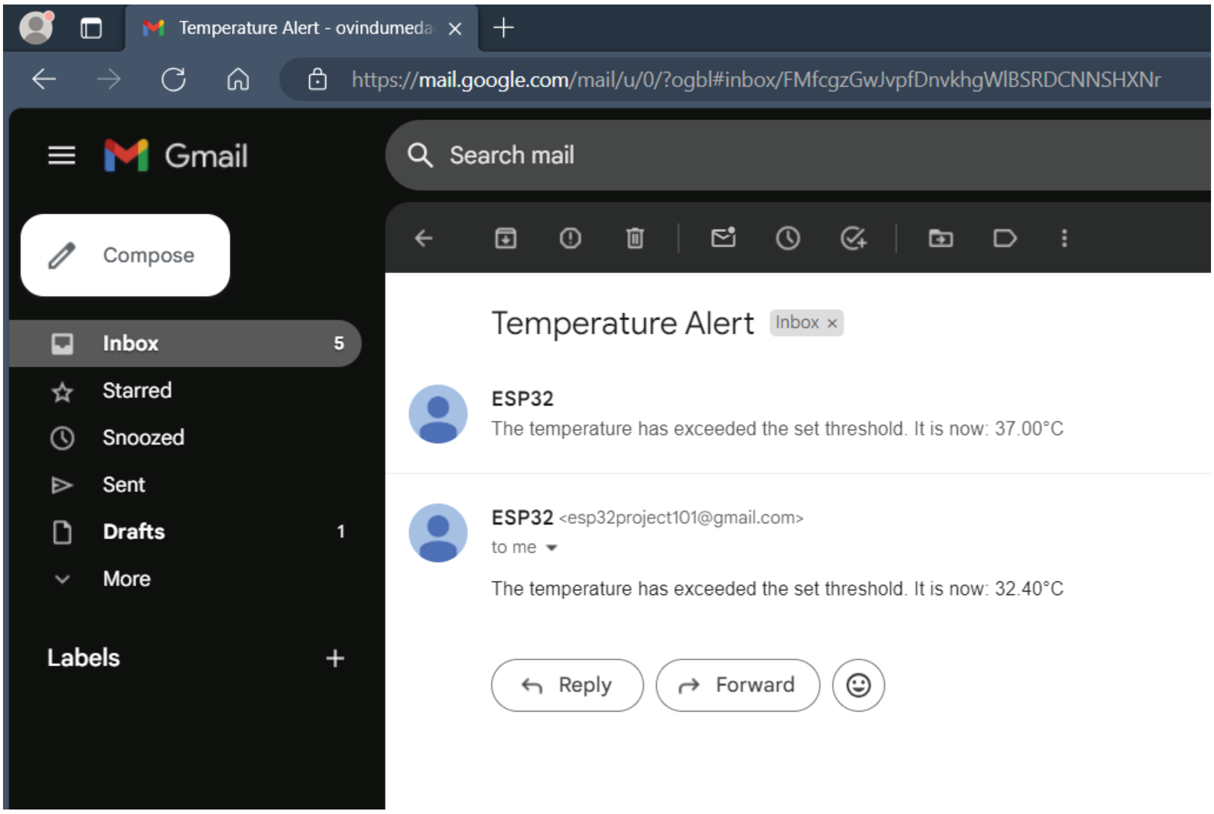


Figure 10 - Email Alert Received by the User

5. Conclusions

In this study, a method of monitoring real-time temperature and humidity readings at a factory panel room using an IoT based system was presented. This method involved data acquisition using sensors, data transmission to a webserver using Wi-Fi, data transmission using I²C and display using an LCD display, and user alerting mechanisms. Moreover, programming was done using C++&HTML programming languages. Also, proper selection of components, preparation of physical circuits, testing, electronic designing, and CAD designing were involved throughout this study.

The results obtained during the testing process validate that the designed IoT based system provides accurate, timely data to the user. Thus, it can be concluded that the developed IoT based temperature and humidity monitoring system can be successfully implemented in factory panel rooms as a measure of safety for the facility.

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