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IOT Based Temperature and Humidity Monitoring System Using Raspberry Pi Pico W

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***Abstract –** This paper presents a smart IoT-based environmental monitoring and control system utilizing the Raspberry Pi Pico W microcontroller. The system is equipped with DHT22 temperature and humidity sensors, an LDR for light sensing, and actuators like fans for environmental control. Sensor data is transmitted via Wi-Fi to cloud platforms such as Thing Speak for real-time monitoring. When environmental parameters cross set thresholds, actuators are automatically activated. The system is cost-effective, energy-efficient, and highly suitable for applications in agriculture, healthcare, smart homes, and industry.*

***Keywords**- IoT, Raspberry Pi Pico W, Temperature Monitoring, Humidity Control, DHT22 Sensor, Smart Automation, Environmental Monitoring, ThingSpeak*

I. INTRODUCTION

The growing demand for automation and remote monitoring in smart homes, agriculture, and industries has led to the rapid adoption of Internet of Things (IoT) solutions. Climate control is one such critical application that requires continuous and precise monitoring of environmental parameters like temperature and humidity. This project presents a smart IoT-based system using the Raspberry Pi Pico W, a cost-effective microcontroller with built-in Wi-Fi capabilities. The primary goal is to measure environmental parameters using a DHT11/DHT22 sensor and use this data for monitoring and controlling appliances such as fans, humidifiers, or air conditioners. The system offers real-time monitoring, remote access via web, and automated control, enhancing both efficiency and convent In recent years, the rapid advancement of Internet of Things (IoT) technology has opened new horizons in the field of smart automation and environmental monitoring. From homes and offices to greenhouses and factories, maintaining optimal environmental conditions has become a key aspect of efficiency, safety, and comfort. One of the most fundamental and essential aspects of such monitoring is the real-time tracking and control of temperature, humidity, and light levels.

This project focuses on designing and implementing a cost-effective, real-time monitoring and control system for temperature and humidity, with additional support for light sensing, using the Raspberry Pi Pico W microcontroller. The Raspberry Pi Pico W is chosen for its low cost, compact size, built- in Wi-Fi connectivity, and flexibility in interfacing with a variety of sensors and modules. It serves as the central controller, collecting data from multiple sensors and transmitting the information.

This project demonstrates the potential of combining basic sensor modules with modern IoT microcontrollers to create intelligent, connected, and responsive systems. It offers an excellent learning platform for students and hobbyists, as well as a scalable prototype for more complex industrial solutions.

The system is enhanced by connecting it to cloud platforms such as ThingSpeak, Blynk, IO, where the data can be visualized through graphs and monitored remotely via a smartphone or web interface. This facilitates the development of remote environmental control systems.

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2. LITERATURE REVIEW

The integration of IoT in environmental monitoring has been a widely researched and implemented domain in recent years. Numerous studies and academic projects have focused on the use of microcontrollers, sensors, and wireless communication technologies to develop real-time monitoring and control systems. This literature review presents a summary of relevant past work that forms the foundation and motivation for this project.

IoT-Based Environmental Monitoring: According to research by Sharma et al. (2020), IoT-based systems for monitoring temperature and humidity are essential in smart agriculture and smart homes to ensure environmental optimization. These systems commonly employ Wi-Fi-enabled microcontrollers like the Node MCU and ESP32, in combination with sensors such as DHT11/DHT22, to collect and transmit data over the cloud[1].

Use of DHT Sensors: The DHT11 and DHT22 sensors are commonly used in environmental monitoring due to their low cost, reliability, and ease of interfacing with microcontrollers. Research by Kiran & Rao (2019) demonstrated that these sensors provide accurate readings sufficient for non-industrial applications. The DHT22, in particular, offers better accuracy and a wider range compared to the DHT11[2].

3 Role of Microcontrollers in IoT Systems: Traditional systems used Arduino boards or Raspberry Pi SBCs, but recent studies highlight the advantage of using compact and power-efficient boards like the Raspberry Pi Pico W. The Pico W, launched in 2022, adds native Wi-Fi capability to the original Pico, making it suitable for lightweight IoT tasks. In comparison with ESP8266 and ESP32, Pico W offers better integration which is MicroPython and C SDKs, although it lacks built-in Bluetooth[3].

Web and Cloud-Based Monitoring: In many existing systems, data is displayed through cloud platforms like ThingSpeak, Blynk, or via custom-built web servers. A study by Ahmed et al. (2021) presented a greenhouse monitoring system using ESP8266, which sent data to Blynk for real-time monitoring and control. This approach reduces human involvement and allows automation based on environmental feedback[4].

5 Automation and Control Logic: The concept of threshold-based control is prevalent in literature. A fan or heater is turned on when sensor readings surpass a specified value. In a study by Ramesh et al. (2018), a relay-based system was used to automate control in smart homes. Such logic enhances energy efficiency and improves the overall comfort level of the environment

3. METHODOLOGY

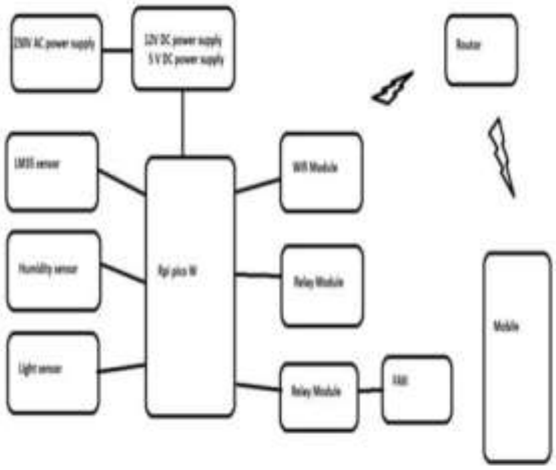

Figure 1 Block Diagram

The methodology of this project involves a systematic approach to designing, developing, and testing a real-time environmental monitoring and control system based on IoT principles. The system is built using the Raspberry Pi Pico W as the main controller due to its integrated Wi-Fi capabilities and ease of programming using Micro Python.

Component Selection and Setup

Sensors: The DHT11 is used for measuring both temperature and humidity, the LM35 is used for additional temperature accuracy, and an LDR (Light Dependent Resistor) is used to measure ambient light intensity.

Actuator: A relay module is used to control external electrical appliances like a fan or light based on sensor readings.

Controller: The Raspberry Pi Pico W collects data from all sensors via its GPIO and ADC pins.

Circuit Design

All components are connected on a breadboard with proper power supply (3.3V or 5V as required).

The relay is connected through a GPIO pin and configured for switching the connected load. Pull-up resistors are used where necessary (e.g., with DHT11 and LDR).

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Programming and Logic Implementation

The Raspberry Pi Pico W is programmed using MicroPython via the Thonny IDE.

Sensor data is read at regular intervals, processed, and displayed in the serial console.

Thresholds are defined (e.g., temperature > 30°C or low light conditions) to trigger the relay.

Data is formatted and sent to an IoT platform (e.g., ThingSpeak) using HTTP requests over Wi-Fi.

IoT Integration

Wi-Fi credentials and API keys are configured in the code. Real-time sensor data is uploaded to Thing Speak, allowing for graphical visualization and remote access.

Optionally, mobile notifications or app control can be integrated using platforms.

5. Testing and Evaluation

The system is tested under various environmental conditions to validate sensor accuracy and responsiveness. The relay switching is verified based on predefined thresholds. Data transmission to the cloud is monitored for reliability and delay

4. IMPLEMENTATION METHEDOLOGY

5. HARDWARE DESCRIPTION

A. Raspberry Pi Pico W :

Figure 2 Raspberry pi Pico W

The Raspberry Pi Pico W acts as the central processing unit of the system due to the following

The Raspberry Pi Pico W is a low-cost, high-performance microcontroller board designed by the Raspberry Pi Foundation. It is based on the RP2040 microcontroller chip, which was also designed by Raspberry Pi. The “W” in Pico W stands for Wireless, as it includes built-in Wi-Fi, enabling it to be used in Internet of Things (IoT) application, Cost-effective and compact. Equipped with in-built Wi-Fi support. Provides sufficient GPIO pins for interfacing sensors and actuators.

B. Temperature and Humidity Sensor (DHT11):

A humidity sensor (also called a hygrometer) measures the moisture content in the air. These sensors are widely used in environmental monitoring, weather stations, HVAC systems, and IoT applications. The DHT11 is a digital temperature and humidity sensor. It is widely used due to its low cost and reliable for temperature measurement. It offers excellent quality, fast response, strong anti-interference ability, and is highly cost-effective. Provides digital humidity data. Used to monitor relative humidity levels in percentage

Figure 3 DHT11 Sensor

C Light Sensor (optional)

Connect in a voltage divider to convert changing resistance into a measurable voltage. If light intensity drops below a threshold (e.g., after sunset), turn ON a light via relay.Upload light level to cloud for logging and remote monitoring

Figure 4: Light Sensor

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Working Principle:

1. Resistance decreases with increasing light intensity.
2. In darkness, resistance is high (~MΩ).
3. In bright light, resistance is low (~kΩ).

Detects ambient light intensity. Can be used for future automation, like automatic lighting control. The microcontroller reads these sensor values periodically and processes the data.

D LM35 Temperature Sensor

The LM35 is a precision analog temperature sensor that outputs a voltage directly proportional to the temperature in Celsius. It is widely used in electronics and IoT projects due to its simplicity, low cost, and accuracy

Figure 5: LM 35 light sensor

Provides analog voltage output proportional to temperature.

E Relay

The Pico W reads this voltage via its ADC (Analog to Digital Converter) and converts it into temperature in °C.

Measure room temperature with LM35, send data to the cloud (e.g., ThingSpeak), and activate a fan when it gets too hot.

Example:

1. At 25°C, the output = 250 mV
2. At 0°C, the output = 0 mV
3. At 100°C, the output = 1000 mV (1V)

This analog voltage can be read by an ADC (Analog to Digital Converter) to determine the temperature.

Actuator Control Using Relay Module
Relay modules are used to control external electrical appliances like fans. The operation is as follows:

A relay is an electromagnetic switch that allows you to control a high-voltage or high-current device (like a light, fan, motor, etc.) using a low-voltage microcontroller signal.

When a small voltage is applied to the relay coil, it magnetically pulls a switch to connect or disconnect a high-power circuit.

Figure 6: Pulse Sensor

This allows microcontrollers (which usually output 3.3V or 5V) to control 220V appliances or 12V motors safely.

The Raspberry Pi Pico W evaluates the sensor readings.
- Based on predefined threshold values, it sends control signals to the relay module.

The relay module acts as a switch and turns the fan ON or OFF accordingly. Example Logic:

1. If Temperature > 30°C → Turn ON the fan.
2. If Temperature < 25°C → Turn OFF the fan. This enables automated climate control without

SYSTEM OVERFLOWS

The system is powered ON using a regulated power supply. The sensors begin to monitor temperature, humidity, and light levels. The Raspberry Pi Pico W reads and processes this data. Data is transmitted via Wi-Fi to a mobile phone or cloud platform. Based on the conditions: Fan is switched ON/OFF automatically using relay. Users can also monitor readings in real time from their phone. To send data to System Overflow, you must:

1. Sign up and create a new project.
2. Get your API endpoint and authentication token.
3. Modify the upload data function in the code above with the correct URL.

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6. RESULT AND OBSERVATIONS

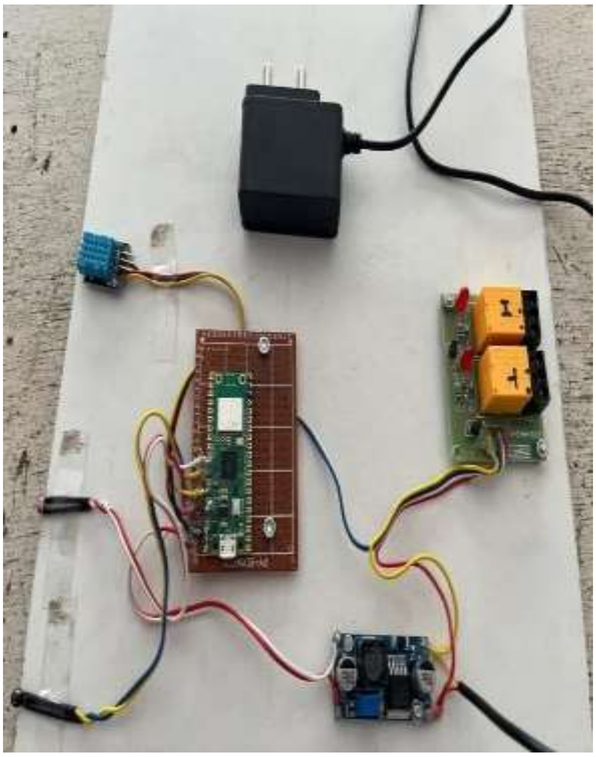

Figure 7: Implemented Board

Figure 7 shows the implemented board. It consists of a Raspberry Pi pico W board, a DHT11 temperature sensor, humidity sensor, an relay module anal debug converter .

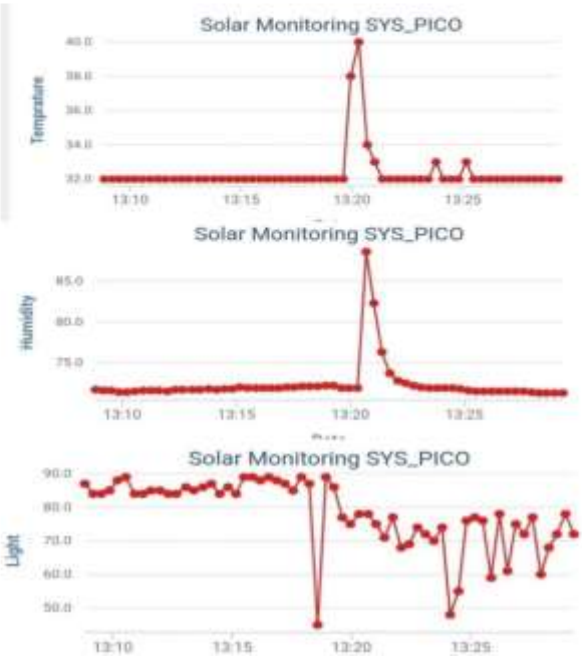

Figure 8: Display Temperature ,humidity and light output reading graph

Figure 8 illustrates the display of body temperature, humidity sensor on the web server. The temperature, humidity and light is represented in the form of a line chart, providing a visual trend over time.

1. Real-time data displayed on System Overflow dash board.
2. Graphs for temperature and humidity trends.
3. Local display confirms successful sensor readings.

CONCLUSION

The implementation of a Smart IoT-Based Temperature and Humidity Monitoring and Control System using the Raspberry Pi Pico W has proven to be efficient, economical, and scalable. It demonstrates how IoT can revolutionize traditional environmental monitoring by enabling remote access, automation, and data-driven control. With further enhancements like cloud integration and AI-based predictions, this project can evolve into a more intelligent and adaptive environmental management system suitable for multiple real-world application This IoT-based monitoring system offers a scalable and low-cost solution for environmental automation. Future enhancements could include edge AI, additional sensors, and offline capabilities The development of an IoT-based Temperature and Humidity Monitoring and Control System using the Raspberry Pi Pico W successfully demonstrates the integration of embedded hardware and cloud-based IoT technologies for real-time environmental monitoring and automation. By interfacing sensors like the DHT11 (for humidity and temperature), LM35 (for precise temperature), and LDR (for light intensity) with the Pico W, we achieved accurate and continuous data acquisition. The use of the relay module enabled effective control of external devices such as fans or lights, enhancing automation capabilities. Furthermore, through the built-in Wi-Fi capabilities of the Raspberry Pi Pico W, the system was able to send data to online platforms like ThingSpeak or Blynk, enabling remote monitoring and control. This makes the solution scalable and adaptable for smart home, agriculture, or industrial applications.

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