REAL TIME SYSTEM AND INTERNET OF THINGS FINAL PROJECT REPORT
DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITAS INDONESIA

Smart Factory Ventilation System

GROUP 2

RIVI YASHA HAFIZHAN	**2306250535**
AZKA NABIHAN HILMY	**2306250541**
MUHAMAD DZAKY MAULANA	**2306264401**
SAMIH BASSAM	**2306250623**

PREFACE

This report was prepared as part of the Final Project for the Real-Time Systems and Internet of Things course. The project aims to develop an IoT-based smart ventilation system that can automatically monitor and control factory environmental conditions.

During the project, our team went through several stages, from hardware design and software development to system integration and live testing. This project provided practical experience in how microcontrollers, sensors, actuators, and an IoT platform can be combined into a single system that functions in real time and is responsive.

We would like to thank our lecturers and all parties who provided guidance, facilities, and support throughout the development of this project. We hope this report provides a clear overview of the system development process and serves as a reference for other students working on similar projects.

Depok, December 7, 2025

Group IP-X/P-X/R-X

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CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

Factory environments often experience serious problems related to poorly controlled temperature and humidity conditions. Intensive production activities result in increased temperature and humidity, which can negatively impact various operational aspects. These conditions cause discomfort for workers. They can also increase the risk of equipment damage due to overheating, reduce product quality, and potentially pose health risks to workers in poorly ventilated areas.

Current conventional ventilation systems have several significant limitations. Traditional manual or semi-automatic systems tend to be slow to respond to changing conditions because they require human intervention to adjust ventilation settings. This leads to inefficient energy consumption because fans operate at fixed speeds without considering actual environmental conditions. Conventional systems also lack flexibility and cannot adapt in real time to dynamically changing conditions. Furthermore, limited monitoring makes it difficult for supervisors to monitor factory conditions remotely or while in other areas.

The Industry 4.0 era demands a transformation towards smarter and more connected systems. The need for remote monitoring is crucial so management can monitor factory conditions from anywhere in real time. Historical logging data is essential for trend analysis and data-driven decision-making. Automatic alert systems are crucial for providing notifications when conditions reach critical levels. In addition, centralized control integrated with the building management system is a must for overall operational optimization.

1.2 PROPOSED SOLUTION

The Smart Factory Ventilation System, developed using the ESP32, is designed with an IoT approach, capable of automatically monitoring and controlling ventilation adaptively and adapting to factory environmental conditions. For real-time monitoring, the system utilizes a DHT11 sensor to read temperature and humidity data. The read data is then sent to the cloud via the Blynk IoT platform for live visualization. The Blynk dashboard displays temperature and humidity gauges, allowing supervisors to monitor factory conditions from anywhere and at any time via their smartphone or computer.

The ventilation control system is at the heart of this solution. Automatic control logic implemented in taskProcessing makes intelligent decisions based on sensor data. When the temperature exceeds the threshold of 26°C or humidity exceeds 70%, the system automatically opens the windows using a servo motor attached to pin 13. The DC fan speed, controlled through the L298 driver, is adjusted proportionally to the temperature using a map function that maps the temperature range to a PWM value between 150 and 255. This approach ensures energy efficiency because the fan only operates at the required speed.

Dual-mode operation provides maximum flexibility for operators. Automatic mode operates the system based on configured temperature and humidity thresholds, with fan speeds linearly mapped to the temperature values. Manual mode can be activated via a physical button using the onManualButtonPress() interrupt service routine (ISR) with a debouncing mechanism, or via Virtual Pin V4 on the Blynk dashboard. While in manual mode, the operator can control the opening/closing of windows via Virtual Pin V5.

Overall, this Smart Factory Ventilation System provides a smart, efficient, and easy-to-control solution for modern factory ventilation systems. The implementation of IoT technology, FreeRTOS, and adaptive control aligns this system with the concepts of Industry 4.0 and smart manufacturing, bringing a real transformation in factory environmental management that is better, more energy efficient, and more responsive to operational needs.

1.3 ACCEPTANCE CRITERIA

The acceptance criteria for this project are as follows:

1. The vents will open and the fans will run if the temperature is >26°C or humidity is >70%, and then close if it is below the threshold.
2. The system can switch between Automatic/Manual modes using a physical button (Pin 0) with the ISR.
3. Successfully connected, then sends temperature, humidity, and operating status (automatic/manual) data to Blynk.
4. Updates window, fan, and mode status indicators in Blynk.
5. Runs three FreeRTOS tasks concurrently without deadlocks.

1.4 ROLES AND RESPONSIBILITIES

The roles and responsibilities assigned to the group members are as follows:

Roles	Responsibilities	Person
Role 1	Design and implement automatic control logic (temperature threshold 26°C, humidity 70%)	Azka Nabihan
Role 2	WiFi and Blynk IoT connection configuration (Template ID, Device Name, Auth Token)	Rivi Yasha
Role 3	Design and assemble a complete electronic circuit (ESP32, DHT11, Servo, Buzzer, Button)	Muhamad Dzaky Maulana
Role 4	Implementing the FreeRTOS architecture with 3 tasks (taskReadSensor, taskProcessing, taskBlynk). Designing and assembling a complete electronic circuit (L298N)	Samih Bassam

Table 1. Roles and Responsibilities

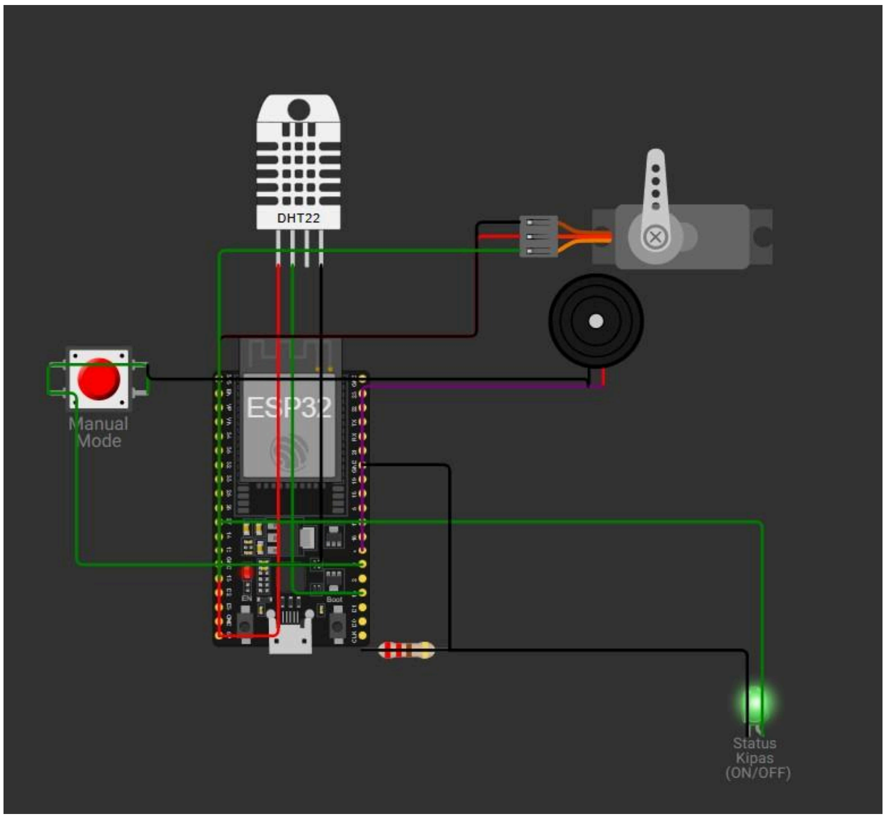
1.5 TIMELINE AND MILESTONES

WBS NUMBER	TASK TITLE	Oktober										Desember							
		21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8
1	**Penyelesaian Design Hardware**																		
1.1	Finalisasi Skema Sirkuit	🟦	🟦	🟦															
1.1.1	Penyelesaian Daftar Komponen		🟦	🟦															
1.2	Verifikasi Mekanik:		🟦	🟦															
2	**Pengembangan Software**																		
2.1	Implementasi & Uji Task FreeRTOS Dasar				🟦	🟦	🟦	🟦											
2.2	Pengembangan Driver Aktuator					🟦	🟦	🟦	🟦										
2.3	Pengembangan ISR & Sinkronisasi:						🟦	🟦	🟦	🟦									
2.4	Implementasi Logika Kontrol:							🟦	🟦	🟦	🟦	🟦							
3	**Integrasi & Pengujian Hardware-Software**																		
3.1	Uji Integrasi Input & Sensor												🟩	🟩	🟩	🟩	🟩		
3.2	Uji Integrasi Output & Kontrol:												🟩	🟩	🟩	🟩	🟩		
4	**Perakitan Akhir Produk & Pengujian Verifikasi**																		
4.1	Perakitan Fisik Akhir																	🟩	🟩
4.2	Pengujian Verifikasi Kinerja																	🟩	🟩

CHAPTER 2

IMPLEMENTATION

2.1 HARDWARE DESIGN AND SCHEMATIC



The hardware design of this system focused on developing a robust environmental control unit using the ESP32 Development Board as the main microcontroller. The ESP32 allows for seamless simultaneous sensor data processing and network communication. This system integrates a DHT11 sensor connected to GPIO pin 15 as the primary data acquisition instrument, responsible for monitoring temperature and relative humidity fluctuations in the factory environment in real time. The accuracy of this sensor reading serves as the foundation for the system's algorithm in determining the necessary automation actions to maintain stable indoor conditions.

To implement the physical ventilation mechanism, this system utilizes two types of electromechanical actuators with different characteristics. The first actuator is a servo motor connected to GPIO 13, which simulates the movement of the ventilation window hinge with a precision angle of 0 to 90 degrees. The second actuator is a dynamo that functions as an exhaust fan, controlled by the L298N motor driver module. This driver module is connected to the ESP32 via three control lines: GPIO 27 and GPIO 25 to determine the direction of motor rotation (Input 1 and Input 2), and GPIO 14 for the Enable pin (ENA) which receives a PWM signal to regulate the fan rotation speed variable. As a note, for wokwi that does not have a motor driver and dynamo, it is replaced with a lamp.

2.2 SOFTWARE DEVELOPMENT

The system software is built on the Arduino framework on the ESP32 platform, implementing the Real-Time Operating System (FreeRTOS) architecture to ensure multitasking stability. The program structure is decomposed into three independent tasks that run concurrently with scalable priorities. The first task, taskReadSensor (Priority 1), acts as a Producer, acquiring temperature and humidity data from the DHT11 sensor every two seconds. The second task, taskProcessing (Priority 2), functions as a Consumer, executing the core system control logic and actuator management. The third task, taskBlynk (Priority 2), is dedicated exclusively to handling WiFi connection management and communication protocols with the Blynk server on Core 0, separate from the sensor logic to prevent network latency from affecting physical control performance.

The inter-process communication and control logic mechanisms are designed using FreeRTOS synchronization primitives for data security. The sensor data stream is transmitted through the sensorQueue message queue, allowing taskProcessing to make actuation decisions based on the latest data without blocking the sensor reading process. The system logic compares this data with thresholds (temperature > 26°C or humidity > 70%) to actuate the window servo and adjust the fan speed proportionally using PWM mapping (values 150–255). Additionally, the system implements an Interrupt Service Routine (ISR) in the onManualButtonPress function triggered by the physical button. This ISR sends a manualSemaphore to the processing task to instantly activate manual mode, ensuring a deterministic response to user intervention.

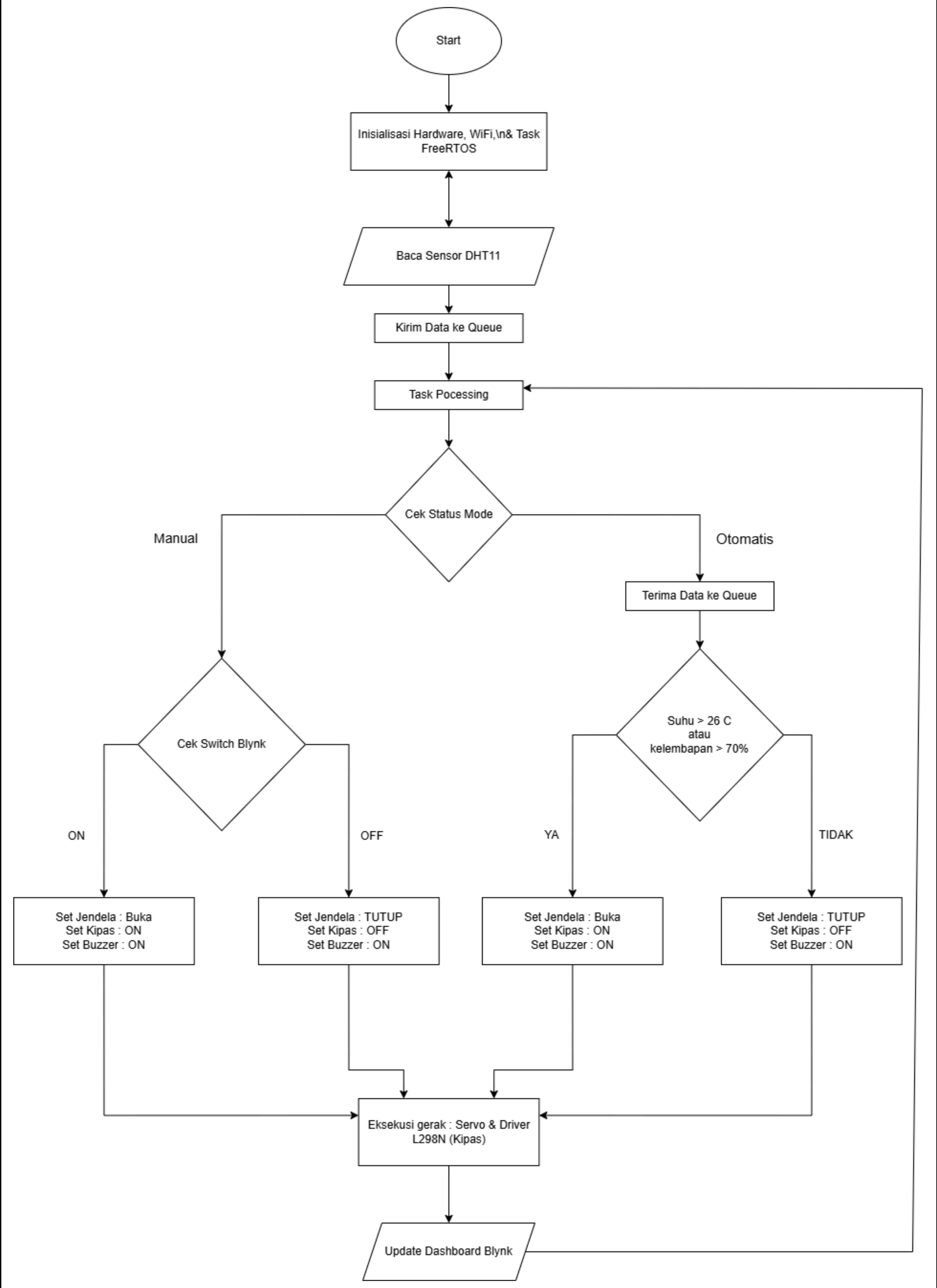


Figure 1. FlowChart

To ensure long-term system reliability, memory management and connection protection strategies are strictly implemented in the program code. Given the heavy computational load on the IoT communication library, the stack memory allocation for taskBlynk was increased to 8192 bytes to eliminate the risk of stack overflows that often cause system failures in microcontrollers. The program code is also equipped with a connection guard mechanism, where the function of sending data to the application (Blynk.virtualWrite) is wrapped in a conditional block that first verifies the connection status. This ensures that if the WiFi or server connection is lost, the local control system continues to operate normally without experiencing congestion (blocking) or crashes due to data transmission failures.

2.3 HARDWARE AND SOFTWARE INTEGRATION

The integration phase aims to connect the software's computational logic with the mechanical responses in the hardware through a General Purpose Input/Output (GPIO) interface. Locally, the system uses the ESP32Servo library to convert digital logic commands into precise angular movements of the window servo motors (0 to 90 degrees). For fan control, a PWM function (ledcWrite) is used to modulate a voltage signal to the L298N driver, where a mapping algorithm is applied to convert the measured temperature data into a duty cycle value between 150 and 255. This integration mechanism ensures that the actuator moves smoothly and proportionally according to the intensity of the environmental conditions detected by the sensor.

Internet of Things (IoT) integration for monitoring is realized through one-way data synchronization (uplink) to the Blynk platform using the Virtual Pins protocol. Processed temperature and humidity data are sent in real time to pins V0 and V1 for graphical visualization on the mobile app dashboard. In addition to sensor data, the operational status of the physical actuators is also reported back to the application via pins V2 (Window indicator) and V3 (Fan indicator). This provides full transparency for operators to visually verify that system commands have been correctly executed by the machine in the field.

The remote control side is implemented via bidirectional communication (downlink) on virtual pins V4 and V5, which serve as user command input channels. This feature facilitates manual intervention, where a switch state change in the application triggers a callback function in the ESP32 that instantly overrides the automatic sensor logic. Through this integration, users have full authority to force the system to open or close vents in an emergency without requiring direct physical interaction with the hardware, demonstrating the effectiveness of combining FreeRTOS-based local control with the flexibility of cloud connectivity.

CHAPTER 3

TESTING AND EVALUATION

3.1 TESTING

Testing was conducted to ensure all system functions met acceptance criteria. Testing was divided into three sections: sensor readings, automatic control logic, and communication with Blynk.

1. Sensor Reading Test (DHT11)

The DHT11 sensor is tested by exposing it to various temperature and humidity conditions. The data read must be consistent and displayed in the Serial Monitor and sent to the Blynk dashboard. The test is successful when the sensor displays real-time changes in values.

2. Auto Mode Testing

In automatic mode, the system is tested by simulating high temperature (>26°C) and high humidity (>70%). Under these conditions, the servo should open the vents and the fan should run at the mapped PWM speed. When the temperature/humidity drops below the threshold, the vents should close and the fan should stop. All functions operate as expected.

3. Manual Mode Testing

The physical button on pin 0 is tested to ensure the ISR works without debounce errors. When the button is pressed, the mode should immediately switch to manual without delay. In manual mode, window opening control via Blynk's Virtual Pin (V5) should respond correctly.

4. Pengujian Koneksi Blynk & Pengiriman Data

The ESP32 was tested to ensure a stable WiFi connection. Data on temperature, humidity, mode status, and ventilation and fan status were successfully transmitted to the Blynk dashboard. The system was also tested when the connection was lost; local control continued to operate normally without crashing or freezing.

5. Pengujian FreeRTOS Tasks

Three tasks (taskReadSensor, taskProcessing, taskBlynk) were tested to ensure they ran in parallel without deadlocks. The sensor data delivery queue and semaphore for manual mode were tested, and all tasks performed stably without resource conflicts.

3.2 RESULT

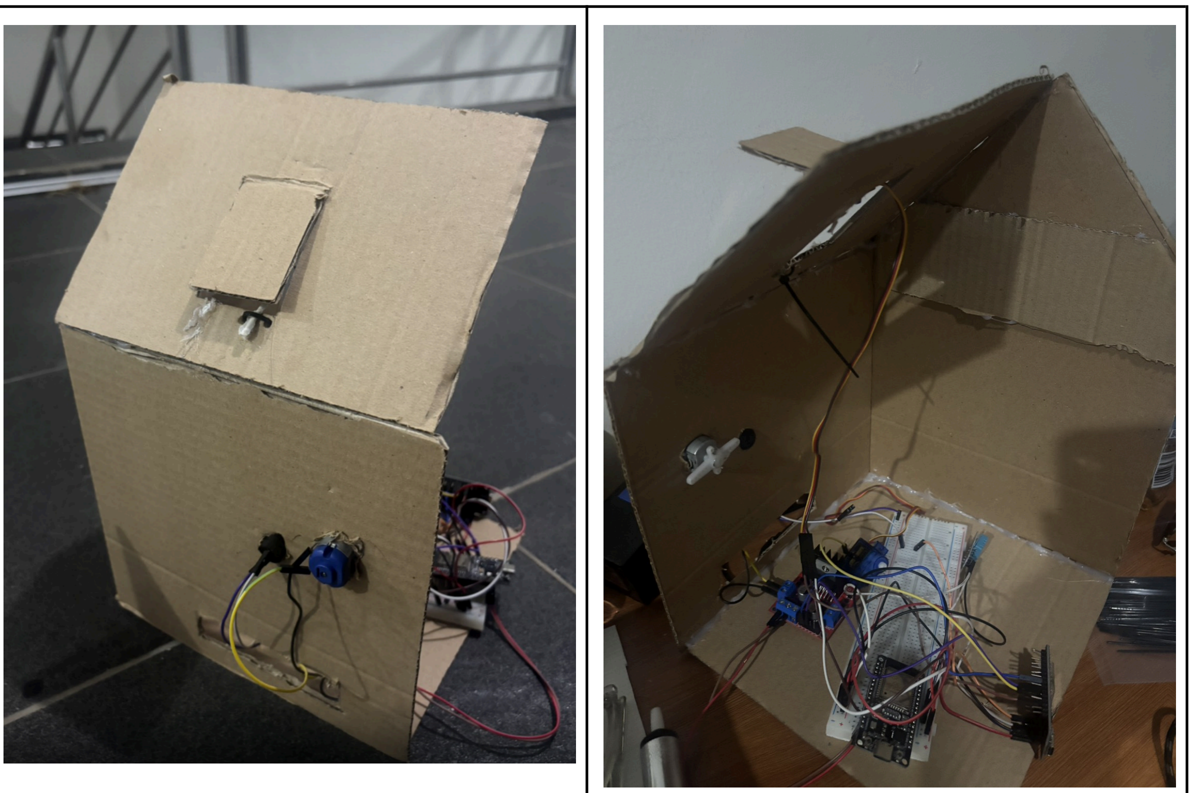


Figure 2. Physical Circuit

System testing demonstrated that the Smart Factory Ventilation System operated stably and responsively. The DHT11 sensor successfully read and transmitted real-time temperature and humidity data to Blynk without significant delay. The values displayed on the Serial Monitor and the Blynk dashboard were consistent.

In automatic mode, the system correctly opened the vents and started the fans when the temperature exceeded 26°C or humidity exceeded 70%. The fan speed changed proportionally to the temperature, and the servo opening mechanism operated smoothly without any positional jumps. When conditions returned to normal, the vents closed and the fans stopped according to the designed logic.

Manual mode also functioned as expected. The physical button allowed for instant mode changes via the ISR, while manual control via Blynk responded quickly without interruption from other tasks. All device statuses, including mode, vent position, and fan speed, were displayed correctly on the dashboard.

The WiFi and Blynk connections proved stable throughout the test. When WiFi was accidentally disconnected, the local system continued to run without error. Once reconnected, the devices automatically synchronized with the dashboard without requiring a restart.

Overall, the test results demonstrated optimal integration between the hardware, FreeRTOS, and IoT. The system is able to fulfill all the acceptance criteria that have been determined.

3.3 EVALUATION

Overall, the developed smart ventilation system demonstrated stable performance and met all the basic requirements for factory environmental control. The integration between sensors, actuators, and the IoT platform was successful, and the use of FreeRTOS significantly improved responsiveness and workload allocation between tasks.

However, testing also revealed several areas for improvement. The DHT11 sensor had limited accuracy and occasionally experienced small fluctuations in humidity values. Using a more precise sensor such as the DHT22 or SHT31 could have provided better monitoring results. Furthermore, the servo and fan drivers require a highly stable power supply to prevent voltage drops when actuators are simultaneously active.

From a software perspective, taskBlynk's large memory allocation proved effective in preventing crashes due to IoT communication overhead. However, the system could still be improved by adding fail-safe mechanisms such as a watchdog timer to ensure the microcontroller continues to operate under extreme conditions.

The Blynk dashboard performs well for remote monitoring, but additional features such as historical graphs, automatic notifications when temperatures exceed thresholds, or multi-level fan control could enhance the user experience.

In general, this system is suitable for use on a small to medium scale and can be the basis for the development of more sophisticated and precise industrial ventilation systems.

CHAPTER 4
CONCLUSION

The Smart Factory Ventilation System project has been successfully developed as an IoT-based solution for monitoring and controlling temperature and humidity conditions in factory environments. This system can operate both automatically and manually with fast and stable responses, thanks to the integration of the ESP32, DHT11 sensors, servo actuators, L298N motor drivers, and the Blynk platform.

The FreeRTOS implementation allows three main tasks to run in parallel without interfering with each other, ensuring the system remains responsive despite the simultaneous sensor readings, logic processing, and network communication. Testing demonstrated that all acceptance criteria were met: the system could read data in real time, activate ventilation according to thresholds, and display device status on the IoT dashboard.

Although the system performed well, several aspects could be improved, such as the use of more accurate sensors, power supply optimization, and the addition of security features or automatic notifications. With further development, this system has the potential to be implemented on a larger industrial scale and become part of a more modern and efficient smart manufacturing implementation.

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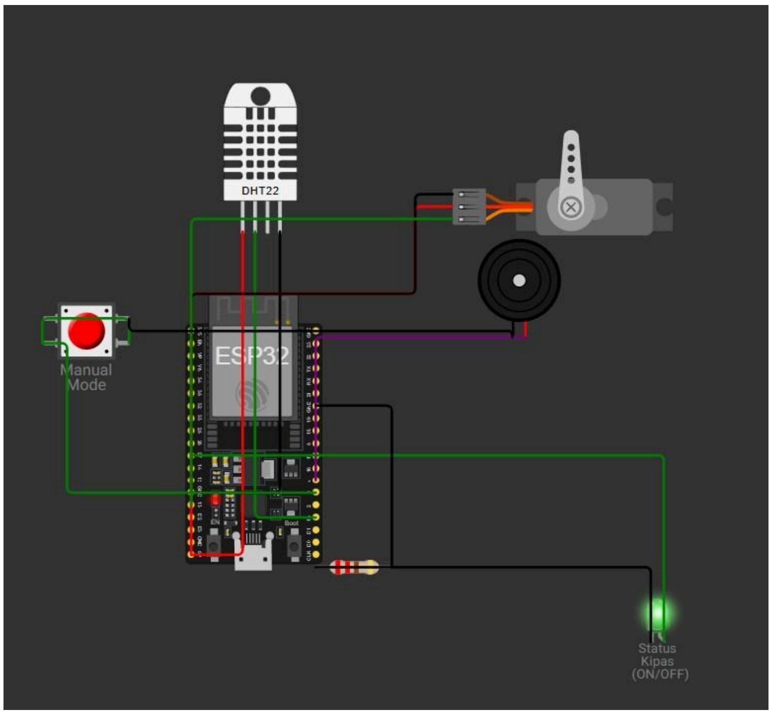
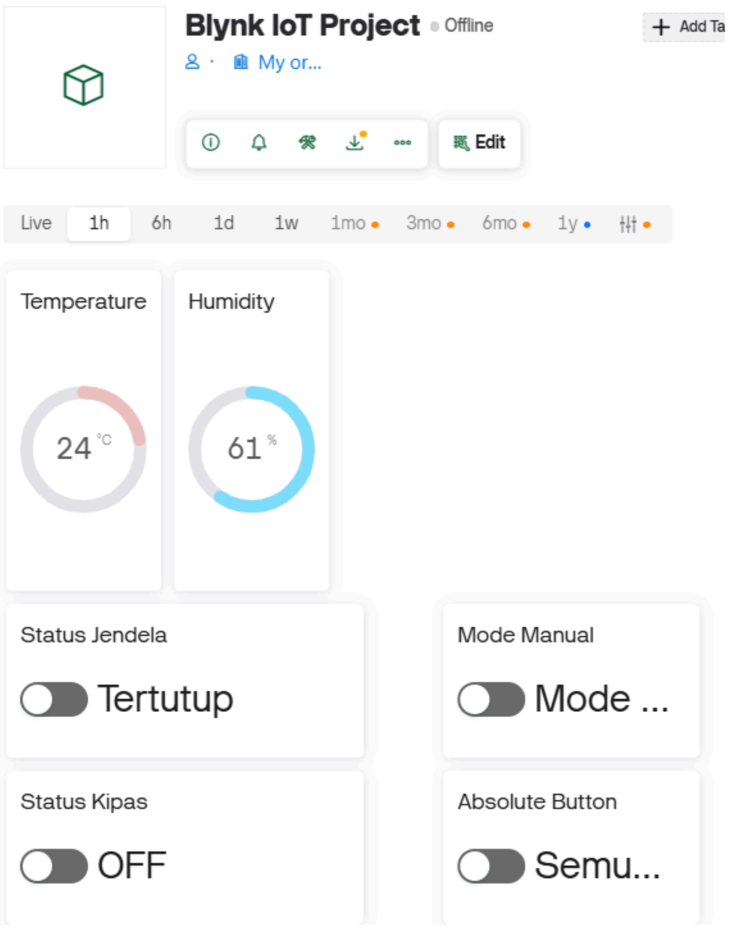
APPENDICES

Appendix A: Project Schematic



Note: because in wokwi there is no motor driver and dynamo, it is marked with a light.


Blynk IoT Project · Offline

My or...

Edit

Live 1h 6h 1d 1w 1mo 3mo 6mo 1y

Temperature

24 °C

Humidity

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Status Jendela

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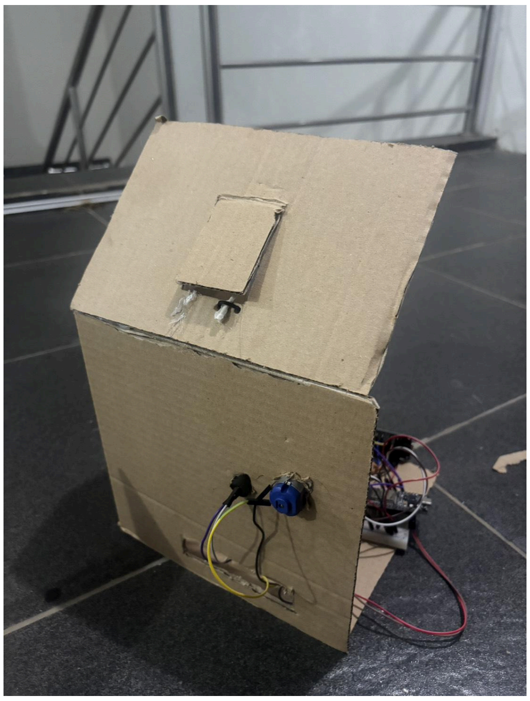
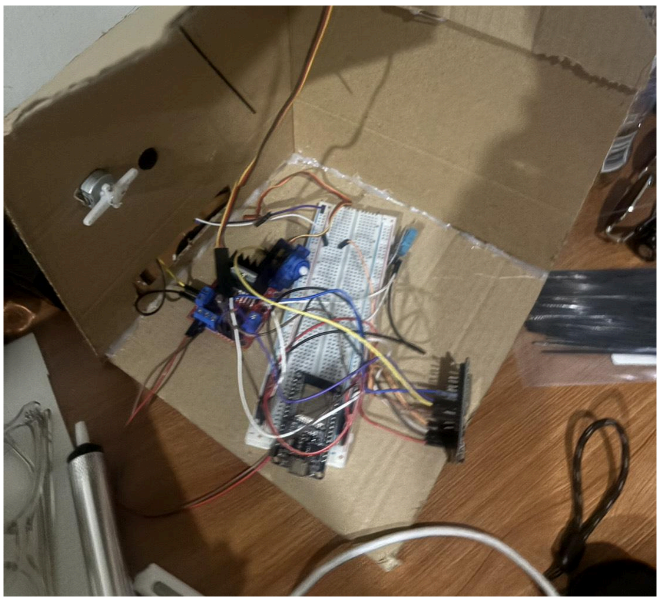
Appendix B: Documentation





Appendix C: Link

- https://github.com/Azka-Nabihan/IOT2-SmartVentilationSystem.git
- https://youtube.com/shorts/bXwB0Q3jQdk?feature=share