IOT BASED FOOD PERISH PREVENTION SYSTEM

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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Any organized and systematic word calls for the corporation of a team of people. Our project does not have any exception to this. Hence these pages find the space for thanking all those who have directly and indirectly contributed to completion of this work in a successful manner.

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ABSTRACT

The transport and storage of perishable goods require precise environmental conditions, especially temperature, to maintain product quality and safety. This project presents a smart, cost-effective, and IoT-enabled temperature-controlled container designed to maintain suitable internal conditions for perishable goods like meat, dairy, fruits, and bakery items. The system uses multiple sensors (DHT11, LM35, and DS18B20) to monitor temperature and humidity, and regulates the environment using a TEC1-12706 Peltier module for cooling and a PTC heater for heating. An Arduino Uno microcontroller is used for sensor data acquisition and actuator control, while a NodeMCU ESP8266 module transmits the sensor data to ThingSpeak for remote monitoring. This project demonstrates an efficient integration of embedded systems and IoT technologies for cold-chain management and food safety applications.

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INTRODUCTION

Background

Food spoilage is a significant global problem leading to enormous economic losses and environmental impact. Temperature and humidity are two critical parameters that directly influence the shelf life of perishable food items. Improper storage conditions accelerate microbial growth and chemical degradation, making food unfit for consumption. Traditional food storage systems often maintain fixed temperature and humidity levels, ignoring variations due to the nature of stored products and external climatic conditions.

The advancement of Internet of Things (IoT) technology enables real-time monitoring and intelligent automation, offering a promising solution to optimize food storage environments. By utilizing IoT platforms such as ThingSpeak, and microcontrollers like Arduino, it is now possible to design smart systems that dynamically adjust environmental parameters to minimize perishability and maximize food quality.

Problem Statement

Existing food storage systems lack the capability to adapt environmental parameters in real-time based on the specific needs of different food products and fluctuating external conditions. This limitation results in inefficient energy usage and increased food wastage.

Objectives

- To design an IoT-based system that monitors and regulates temperature and humidity inside a food storage container.
- To optimize energy consumption by aligning internal conditions with external temperature variations.
- **Scope of the Project**

The project focuses on small to medium-sized food containers used for domestic and commercial purposes. It uses Arduino microcontrollers, sensors (temperature and humidity), actuators (cooling or heating units), and ThingSpeak IoT cloud platform for data visualization and analysisx

CHAPTER 2

LITERETURE SURVEY

1. IoT Applications in Food Preservation

The Internet of Things (IoT) has become a disruptive technology in numerous sectors, including food technology and cold-chain management. In the context of food preservation, IoT enables the integration of smart sensors, embedded devices, and cloud platforms to monitor and maintain optimal storage conditions. As highlighted by **Patel et al. (2020)**, the ability of IoT to facilitate remote data collection and control mechanisms makes it ideal for dynamic environments like food storage. IoT-based food preservation systems not only ensure the freshness of perishable items but also prevent significant economic losses due to spoilage.

A key application lies in real-time monitoring of temperature and humidity inside storage containers. These parameters are crucial because even minor fluctuations can lead to microbial growth or accelerated degradation of food quality. In industrial setups, commercial cold storage facilities already use high-end systems for environmental monitoring, but such solutions are often expensive and inflexible. IoT provides a scalable, cost-effective alternative that can be customized for specific use cases like small retail stores or household preservation systems.

Moreover, IoT integration allows historical data analysis, which can be used for predictive maintenance, spoilage forecasting, and inventory management. Cloud platforms such as **ThingSpeak**, **Firebase**, and **AWS IoT Core** provide storage and visualization of sensor data, enabling intelligent decisions to be made at both edge and cloud levels. These advantages are motivating the widespread adoption of IoT in food preservation, although challenges such as power management, data security, and sensor calibration still exist. Our proposed system builds upon this foundation by incorporating real-time monitoring and environment-aware automation for perishable food containers.

2. Importance of Temperature and Humidity Control

Temperature and humidity are the two most critical factors affecting the shelf life, safety, and quality of perishable food products. According to **Kumar and Singh (2019)**, the biological and chemical composition of food makes it highly sensitive to environmental changes. Improper temperature can result in enzymatic activity, bacterial growth, and spoilage, while uncontrolled humidity can lead to either excessive dehydration or microbial contamination.

For instance, fruits and vegetables require cool temperatures and moderate humidity to maintain freshness. Dairy products such as milk and cheese demand stricter temperature control, often between 0°C and 4°C, to inhibit bacterial proliferation. Humidity also affects food texture, appearance, and taste. Dry conditions may cause shrinkage and loss of nutritional value, whereas overly humid environments can encourage mold growth. These relationships demonstrate the importance of maintaining precise environmental conditions.

Numerous research studies have demonstrated that maintaining the optimal temperature and humidity based on food type can extend product shelf life by 20–50%. **Chaudhary et al. (2021)** reported a 40% reduction in spoilage for stored vegetables using an automated cooling system with humidity feedback. However, in most traditional storage systems, environmental control is either manual or based on a fixed set point, which does not adapt to external conditions or specific food requirements.

The proposed project addresses these limitations by using sensors to monitor internal and external parameters and by using microcontroller logic to dynamically adjust the environment. This ensures energy-efficient operation and significantly reduces spoilage risk. These findings confirm that smart temperature and humidity control is essential for sustainable food storage.

3. Arduino and ThingSpeak in IoT Systems

Arduino is a widely used open-source electronics platform that has gained immense popularity for prototyping and development of IoT systems. Its simplicity, versatility, and support for various sensors and modules make it ideal for educational and research-oriented projects. In the context of food preservation, Arduino allows developers to integrate temperature and humidity sensors (like DHT11 or DHT22), Wi-Fi modules (ESP8266), and actuators (relays for heating/cooling) to create fully automated systems.

Gupta et al. (2021) demonstrated a greenhouse automation system using Arduino and the ThingSpeak cloud platform. Their setup included environmental monitoring, cloud-based data logging, and automated control based on thresholds. Their findings showed improved crop yield and reduced human intervention, indicating that the system was highly effective for climate-sensitive storage.

ThingSpeak is a cloud-based platform designed for IoT applications, which offers features like real-time data visualization, analytics using MATLAB, and event-triggered messaging. In food preservation systems, ThingSpeak can be used to track temperature and humidity trends, issue alerts, and perform basic analytics to support decision-making. The use of cloud storage also ensures that data is preserved for audit trails and long-term analysis.

Despite its simplicity, Arduino has some limitations in terms of memory and real-time multitasking. However, when combined with ThingSpeak, the system becomes powerful enough for small- to medium-scale IoT deployments. Our system utilizes this stack due to its balance of cost, functionality, and ease of implementation. These tools together offer a solid foundation for building a reliable and intelligent food preservation system.

4. Existing Systems and Gaps

Several commercial systems exist for cold-chain and food storage management, particularly in large-scale warehouses and logistics. These systems often include industrial-grade sensors, Programmable Logic Controllers (PLCs), and cloud-based analytics. However, these setups are generally expensive and inaccessible for small businesses or personal usage. Moreover, most systems are designed to maintain static environmental settings, failing to adapt to the varying needs of different food products or external temperature fluctuations.

According to **Reddy et al. (2020)**, current systems often provide real-time monitoring but lack automatic control mechanisms. They are passive in nature—alerting the user when conditions deviate from acceptable ranges but requiring manual intervention to correct them. This limitation leads to delays in response time and energy inefficiency.

Research conducted by **Nair and Thomas (2022)** highlights the lack of integration between external temperature data and internal environmental control. Their study suggests that adjusting the cooling mechanism based on outdoor climate can reduce energy consumption by up to 25%. Furthermore, the absence of historical data analysis in existing systems restricts long-term optimization and predictive insights.

Our proposed system attempts to bridge these gaps by offering a low-cost, Arduino-based smart container that adjusts internal parameters based on food type and external temperature. It is scalable, easy to maintain, and can be integrated with cloud platforms like ThingSpeak for enhanced visualization and data analytics. These enhancements make it suitable for use in homes, small restaurants, and local food supply chains, where cost and efficiency are both critical.

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CHAPTER 3

SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

In the current food storage and preservation landscape, a significant portion of perishable items—such as fruits, vegetables, dairy products, and meat—are stored using conventional refrigeration units and cold rooms. These systems rely heavily on fixed temperature and humidity settings, often without intelligent monitoring or adjustment capabilities. In most households and small-scale commercial setups, preservation relies on domestic refrigerators or insulated storage boxes, which are not optimized for the varying environmental requirements of different food items. In industrial applications, some existing systems use manual or semi-automated temperature control techniques. While larger cold storage facilities may include temperature monitoring sensors, they generally operate on pre-defined setpoints and lack adaptability to external environmental conditions. They also do not take into account the specific preservation needs of individual food types stored in the same container. This results in sub-optimal energy usage and inconsistent food quality preservation.

3.2 PROPOSED SYSTEM

The proposed system is an intelligent, IoT-enabled Food Perish Prevention System designed to maintain optimal storage conditions for perishable items based on real-time environmental factors and specific food product requirements. At the core of this system is an Arduino microcontroller integrated with DHT22 sensors to continuously monitor temperature and humidity within the storage container. Unlike conventional systems, this model dynamically adjusts the internal environment by comparing the current readings with predefined ideal ranges for the specific food items stored, while also factoring in the external ambient temperature. The system is connected to the ThingSpeak IoT platform, which enables real-time data logging, remote monitoring, and alert generation if thresholds are exceeded. One of the standout features is energy optimization, where the system intelligently modulates cooling or ventilation to reduce power consumption without compromising food quality. Additionally, the system is cost-effective, scalable, and user-friendly, making it suitable for household use, small businesses, and local vendors. Its plug-and-play nature and open-source design offer a customizable solution that addresses the limitations of traditional refrigeration methods. The proposed system ultimately ensures better food preservation, reduces waste, and promotes energy-efficient practices using accessible technology.

3.3 OBJECTIVES

The primary aim of the proposed **Food Perish Prevention System** is to develop an intelligent and energy-efficient storage solution that dynamically adjusts to environmental conditions and food-specific requirements. The following are the key objectives of the system:

1. **To Prevent Food Spoilage Through Environmental Control**.

   Ensure optimal temperature and humidity conditions for different types of perishable food items by continuously monitoring and adjusting the internal storage environment.

2. **To Automate Storage Conditions Based on Food Type**.

   Design a smart system capable of adapting its behavior based on the category of food stored (e.g., vegetables, fruits, dairy), eliminating the need for manual adjustments.

3. **To Monitor and Log Real-Time Data Using IoT**.

   Utilize sensors and the ThingSpeak IoT platform to collect, store, and visualize real-time data on temperature and humidity, allowing users to track environmental conditions remotely.

4. **To Provide Remote Alerts and Notifications**.

   Notify users when temperature or humidity exceeds safe limits, enabling timely corrective actions and preventing unnoticed spoilage or equipment failure.

5. **To Integrate External Temperature Consideration for Energy Optimization**.

   Compare external ambient temperature with internal container conditions to adjust cooling effort, thereby optimizing energy usage and reducing electricity costs.

6. **To Develop a Cost-Effective and Scalable Solution**.

   Build the system using affordable and easily available components like Arduino and DHT sensors, making it accessible for small-scale users such as local vendors or households.

7. **To Minimize Manual Intervention**
   Enable full automation of environmental control with minimal human input, enhancing reliability and reducing user burden.
8. **To Create a Modular and Open-Source Design**
   Structure the system for easy customization, upgrades, or extension to other applications like pharmaceuticals or floriculture storage.

3.4 BENEFICIARIES

The **Food Perish Prevention System** is designed to benefit a wide range of users across domestic, commercial, and agricultural sectors. By providing a low-cost, intelligent, and automated food storage solution, this system addresses critical challenges in food spoilage, energy consumption, and operational efficiency. The key beneficiaries of the system include:

1. **Households**
   Families and individuals can use the system to extend the freshness and shelf life of fruits, vegetables, dairy products, and other perishables, reducing food waste and grocery costs. The system offers a user-friendly way to monitor and preserve food items without needing constant manual checks.
2. **Local Vendors and Small Retailers**

   Street vendors, grocery shop owners, and small cold storage units can benefit from this low-cost solution to maintain the quality of perishable goods. It helps reduce spoilage-related losses, especially in areas lacking advanced refrigeration infrastructure.
3. **Farmers and Agricultural Producers**

   Farmers dealing with fresh produce can use this system for short-term post-harvest storage, protecting their crops from spoilage due to fluctuating environmental conditions. It is particularly useful in rural areas where access to large cold chains is limited.
4. **Catering Services and Food Delivery Businesses**
   The system enables these services to store ingredients and pre-cooked food under

optimal conditions during transport or pre-serving storage, ensuring quality and safety for consumers.

5. **Educational and Research Institutions**

   As an open-source, scalable model, the system serves as a practical learning tool for students, researchers, and developers working on embedded systems, IoT, and food technology projects.

6. **Government and NGOs Focused on Food Security**

   Organizations working on food distribution and hunger mitigation can adopt this solution to store surplus or donated food efficiently, minimizing spoilage and maximizing impact.

Hardware Overview

- **Microcontroller**: Arduino Uno
- **Sensors**: DHT22 (for temperature and humidity sensing)
- **Actuators**: Relay-controlled cooling or heating units
- **Connectivity**: Wi-Fi module (ESP8266) for internet connection

Software Overview

- **IoT Platform**: ThingSpeak for data collection and visualization
- **Programming Language**: Arduino C++

Working Principle

The system continuously senses internal container conditions and compares them with the ideal conditions predefined for the food product. Based on sensor readings and external temperature (fetched via ThingSpeak or external sensors), the system adjusts cooling or heating devices to maintain optimal storage conditions.

CHAPTER 4

SYSTEM REQUIREMENT AND SPECIFICATIONS

4.1.1 HARDWARE SPECIFICATIONS

• Operating System:	Windows 7/8/10/11, Linux (Ubuntu), or macOS
• Processor:	Intel Core i3 (or equivalent AMD processor)
• RAM:	Minimum 4 GB
• Storage:	At least 2 GB of free disk space
• USB Port:	For connecting the Arduino UNO via USB cable
• Display:	Minimum 1366x768 resolution

4.1.2 HARWARE COMPONENTS

Arduino Uno

Acts as the main controller for reading sensors and managing actuator relays.

NodeMCU ESP8266

Wi-Fi microcontroller used for uploading data to ThingSpeak.

Sensors

DHT11: Measures temperature and humidity (less accurate, used for reference).

LM35: Analog temperature sensor.

DS18B20: Digital, waterproof sensor used for precise control logic.

TEC1-12706 Peltier Module

Solid-state heat pump used for cooling. Controlled via relay.

Catridge Heater 12v 40W

Provides heat when the temperature falls below a threshold. Controlled via relay.

Relays

Used to switch Peltier and heater modules.

16x2 I2C LCD

Displays real-time sensor values.

Power Supply

12V 3A power supply powers Peltier, relays, and fan.

4.1.3 COMPONENT SELECTION JUSTIFICATION

Careful selection of components is crucial for building a cost-effective, energy-efficient, and accurate IoT-based perish prevention system. The components chosen for this project were evaluated based on availability, power consumption, ease of integration, and suitability for real-time environmental monitoring and control. Below is the justification for selecting key components:

Sensor	Type	Operating Range	Cost	Use Case
DHT11	Temp + Humidity	0°C to 50°C	Low	Measures both temp & humidity; basic check
LM35	Analog Temp Only	-55°C to 150°C	Low	Fast analog output; reference sensor
DS18B20	Digital Temp Only	-55°C to 125°C	Medium	Waterproof, precise; used for main control

Why all three?

- DHT11 gives a humidity reading (important for spoilage conditions).
- LM35 is analog, simple to read quickly with minimal code.
- DS18B20 is waterproof and used as the **main decision-making sensor** due to its digital accuracy and long cable support.

Microcontroller and Wi-Fi Module Selection

Module	Features	Pros	Why Chosen
Arduino Uno	ATmega328P, 14 digital I/O	Popular, easy to code, many libraries	Central controller
ESP-01 (ESP8266)	Wi-Fi, 2 GPIO, serial comm	Low power, low cost, ideal for ThingSpeak	Cloud connectivity

Why Arduino Uno + ESP-01 instead of NodeMCU or Raspberry Pi?

- **NodeMCU**: Has built-in Wi-Fi, but using **ESP-01** keeps the roles of controller and uploader separate, which is useful for modular debugging.
- **Raspberry Pi**: Overpowered for such a simple control task, more expensive, higher power needs, and complex to interface with relays and analog sensors.

4.1.4 ACTUATOR AND DISPLAY SELECTION

Component	**Reason for Selection**
Relay Module	Allows Arduino to safely switch high-power heater/cooler
Peltier Module	Compact solid-state cooler, ideal for enclosed containers
Cartridge Heater	Fast heating for maintaining higher food temps
16x2 I2C LCD	Minimal wiring, easy to integrate, displays real-time values

Conclusion:

Each component was selected for its unique strengths. When combined, they form a reliable, modular, and low-cost IoT solution that balances performance with affordability — essential for small-scale food preservation applications.

4.2 SOFTWARE SPECIFICATIONS

Software	**Purpose**	**Minimum Version**
Arduino IDE	Writing and uploading code to Arduino UNO	v1.8.10+
ThingSpeak Account	For cloud-based data visualization	Any browser-compatible
ESP8266 Board Package	To program Wi-Fi module (if NodeMCU used)	via Arduino Boards Manager
Serial Monitor Tool	To debug and view sensor outputs locally	Built-in Arduino IDE

4.3 SOFTWARE DESCRIPTION

4.3.1. Arduino IDE

Purpose:
The Arduino Integrated Development Environment (IDE) is used to write, compile, and upload code to the Arduino UNO microcontroller. It provides a user-friendly platform with built-in libraries to interact with sensors, relays, and other hardware components.

4.3.2. ThingSpeak IoT Platform

Purpose:
ThingSpeak is a cloud-based IoT analytics platform used to collect, store, analyze, and visualize real-time sensor data. It helps monitor temperature and humidity remotely, trigger alerts, and optimize storage conditions by reviewing trends through live graphs.

4.3.3. CH340 USB Driver

Purpose:
This driver is essential for establishing a communication link between the computer and the Arduino board via USB. It ensures that the Arduino board is properly recognized and programmable from the PC.

4.3.4. ESP8266 Board Package (if NodeMCU is used)

Purpose:
This board package, installed in Arduino IDE, allows programming of the NodeMCU/ESP8266 Wi-Fi module, enabling internet connectivity for cloud communication with ThingSpeak.

4.3.5. Web Browser (Chrome, Firefox, etc.)

Purpose:
Used to access the ThingSpeak dashboard, view real-time data, and monitor the system's performance remotely through graphs and charts.

CHAPTER 5

SYSTEM IMPLEMENTATION

5.1 System Design

The Food Perish Prevention System is designed as a layered architecture integrating sensing, control, and communication components to automate the environmental regulation of a food storage unit. At its core, an Arduino UNO microcontroller receives real-time temperature and humidity data from a DHT22 sensor placed inside the container. This data is compared against predefined ideal conditions suitable for specific food items. Based on this comparison, the Arduino triggers a relay module that controls a cooling fan, ensuring the internal environment remains within safe limits. The system also incorporates an ESP8266 Wi-Fi module, which connects to the ThingSpeak IoT platform, enabling cloud-based monitoring and data visualization. Users can access this data remotely through a web browser and configure alerts for abnormal conditions. The design focuses on low power consumption, modularity, and scalability, allowing the system to be adapted for various food types and storage scales. By combining automation with IoT-based monitoring, the system ensures optimal storage conditions, reduces food spoilage, and promotes energy efficiency.

5.2. Architectural Overview

The system is divided into three main layers:

- Sensing Layer: Collects real-time temperature and humidity data from the storage environment using a DHT22 sensor.
- Control Layer: An Arduino UNO acts as the processing unit. It reads sensor inputs and compares them with predefined threshold values. Based on this logic, it activates or deactivates actuators like cooling fans using relays.
- Communication Layer: An ESP8266 Wi-Fi module (or built-in NodeMCU) transmits the sensor data to the ThingSpeak cloud platform for remote monitoring and visualization.

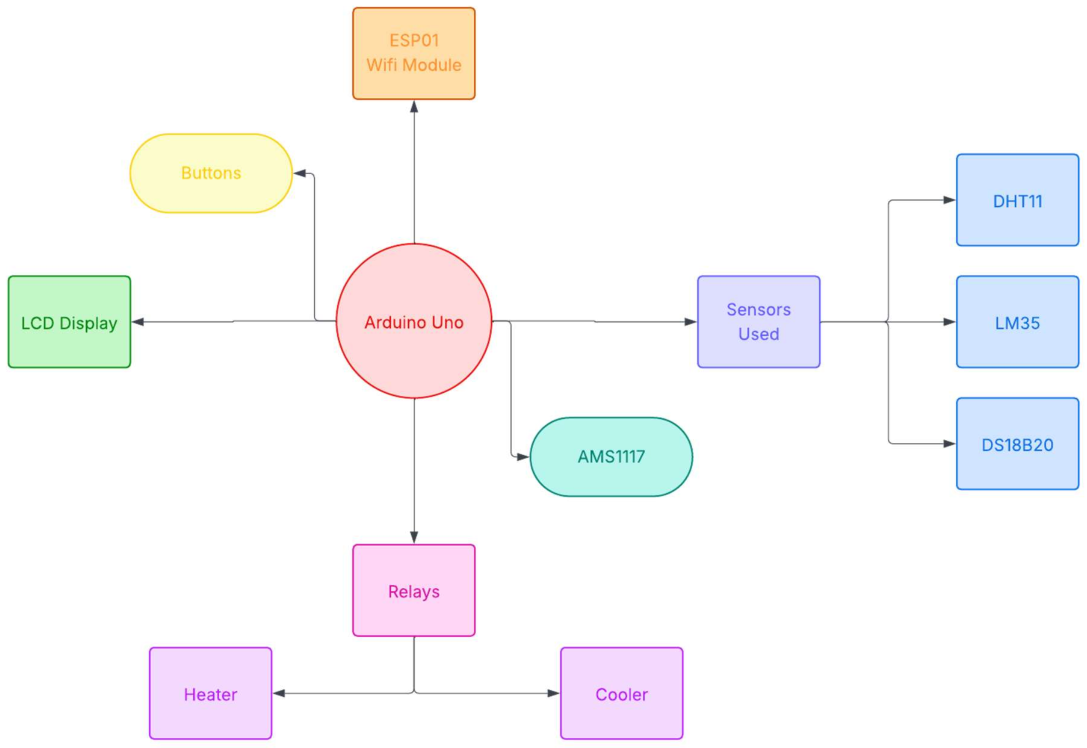
5.3. System Workflow

1. **Initialization**: When powered on, the Arduino initializes the sensor and Wi-Fi module.
2. **Data Acquisition**: The DHT22 sensor continuously reads the current temperature and humidity values inside the storage container.
3. **Data Comparison**: The Arduino compares these values against predefined ideal values (based on the type of food stored).
4. **Decision Making**:

    - If the internal temperature is too high, the cooling fan is activated through a relay.
    - If the humidity exceeds safe limits, alerts or other actions may be triggered.
    - If conditions are ideal, the system maintains standby mode to save energy.

5. **Data Transmission**: The sensor readings are sent to the ThingSpeak platform via the Wi-Fi module.
6. **Cloud Monitoring**: The data is logged, and graphical trends are shown in real-time. Alerts can be configured on ThingSpeak if needed.

Block Diagram



Description:

The system block diagram provides a high-level overview of the components and their interconnections used in the IoT-based food perish prevention system. The core of the system is the Arduino Uno microcontroller, which is responsible for managing sensor data, controlling actuators, and communicating with external modules.

- Sensors Used:
    - DHT11: Measures ambient temperature and humidity.
    - LM35: An analog temperature sensor used to detect temperature changes.
    - DS18B20: A waterproof digital temperature sensor used for accurate food storage temperature monitoring.

These sensors send real-time data to the Arduino Uno, which processes the values and determines if heating or cooling actions are required.

- Relay Module:

    - Controlled by the Arduino, relays act as switches to activate the heater (cartridge heater) or cooler (TEC1-12706 Peltier module with fan) based on threshold temperature ranges defined for selected food types.

- Buttons:
    - Used by the user to select mode (Hot/Cold) and specific food type (Milk, Drinks, Puffs, Sandwich). These selections set the appropriate temperature ranges.
- LCD Display (16x2 I2C):
    - Displays system prompts (like mode/food selection) and real-time temperature and humidity values for user feedback.
- ESP-01 WiFi Module:
    - Connected to the Arduino via serial communication, this module uploads sensor data to the ThingSpeak IoT platform, enabling cloud-based monitoring and analysis.
- AMS1117 Voltage Regulator:
    - Provides a stable 3.3V supply for the ESP-01 module from the 5V Arduino source, ensuring reliable communication.

This modular architecture allows seamless integration of sensing, control, and communication layers. The design is scalable and can be easily adapted for more **sensors or outputs, and the open-source nature of the system makes it suitable for educational and small-scale commercial purposes.**

CHAPTER 6

TESTING

Testing Objectives

- To validate the correct functioning of sensors (temperature and humidity).
- To ensure the Arduino accurately processes inputs and triggers outputs.
- To verify the proper operation of the relay and cooling fan mechanism.
- To test real-time data transmission and visualization on ThingSpeak.
- To confirm system behavior under various environmental conditions.
- To check the stability of the Wi-Fi connection and cloud updates.

Testing Components and Steps

1. Sensor Testing (DHT22)

Objective: Ensure accurate and stable readings of temperature and humidity.

- Connected the DHT22 sensor to the Arduino.
- Used serial monitor in Arduino IDE to check output.
- Compared readings with a calibrated digital thermometer/hygrometer.
- Verified consistency and updated intervals in real-time.

2. Control Logic Testing (Arduino UNO)

Objective: Check that the microcontroller responds correctly to different sensor inputs.

- Simulated various temperature conditions using controlled heat or cold.
- Observed Arduino response (via serial output and relay activation).
- Confirmed that the fan activates when temperature exceeds threshold and turns off when it returns to normal range.

3. Relay and Fan Testing

Objective: Ensure the relay switches correctly and the fan operates without delay.

- Manually triggered relay from Arduino.
- Checked the voltage output to the fan.
- Measured fan RPM to ensure sufficient airflow for cooling.

4. Wi-Fi Connectivity (ESP8266 / NodeMCU)

Objective: Confirm successful and stable communication with the cloud.

- Configured the ESP8266 with network credentials.
- Verified IP allocation and connection status using serial logs.
- Ensured automatic reconnection after power loss.

5. Cloud Integration Testing (ThingSpeak)

Objective: Validate accurate data logging and visualization.

- Created fields in ThingSpeak for temperature and humidity.
- Uploaded data at fixed intervals (e.g., every 15 seconds).
- Checked graph updates, field accuracy, and API performance.
- Tested alert triggers using ThingSpeak's MATLAB analysis or field thresholds.

Testing Types

Type of Testing	Description
Unit Testing	Individual modules (sensor, relay, fan, Wi-Fi) tested independently.
Integration Testing	Combined hardware-software operation tested for seamless coordination.
Functional Testing	Validated if system meets its objectives under expected conditions.
Stress Testing	System exposed to extreme values (high humidity, low power) to check behavior.
Connectivity Testing	Tested with network loss and recovery scenarios for Wi-Fi/cloud stability.

Testing Outcomes

- Sensor readings were stable and accurate within acceptable tolerance.
- Relay-fan control logic functioned exactly as programmed.
- The system successfully logged real-time data to the ThingSpeak dashboard.
- Alerts were triggered correctly on exceeding threshold values.
- Wi-Fi reconnect logic worked effectively after temporary disconnections.

6.1 Challenges Faced

The development of the IoT-Based Food Perish Prevention System involved several hardware and software components working in coordination. While the final prototype functioned as expected, multiple technical and practical challenges were encountered during the development process. These challenges provided valuable learning opportunities and contributed to the system's refinement.

1. Sensor Calibration and Accuracy

Issue:
The readings from the temperature and humidity sensors (DHT11, LM35, and DS18B20) varied slightly due to differences in response time and accuracy levels.

Solution:

- Conducted repeated trials in a controlled environment.
- Used DS18B20 as the reference sensor due to its digital precision.
- Applied small calibration offsets in the code for LM35 and DHT11 to match the DS18B20 values.

Learning:
Accurate environmental control requires understanding the tolerance levels and limitations of low-cost sensors and correcting them through software calibration.

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2. Power Supply Stability

Issue:
The system initially used a 9V adapter, which was insufficient to power the Peltier cooler, heater, ESP-01 Wi-Fi module, and relays simultaneously, leading to system resets and data transmission failures.

Solution:

- Switched to a 12V 3A power adapter.

- Used an AMS1117 voltage regulator to safely power the ESP-01 with a stable 3.3V supply.
- Added capacitors for additional power smoothing.

Learning:
Power requirements of heating and cooling components are significant, and reliable voltage regulation is essential for consistent system performance.

3. Relay Switching & Component Response Delays

Issue:
The relays occasionally failed to switch on/off instantly, leading to overheating or delayed cooling response.

Solution:

- Added debounce logic and small delays in relay control to stabilize switching.
- Improved condition-check logic to prevent rapid toggling and mechanical wear.

Learning:
Hardware control needs careful timing logic, especially when dealing with inductive or high-load devices like Peltier modules and heaters.

4. Wi-Fi and ThingSpeak Connectivity

Issue:
The ESP-01 module sometimes failed to connect to Wi-Fi or delayed sending data to ThingSpeak, especially when the network was unstable.

Solution:

- Implemented retry logic in the ESP code for reconnecting.
- Used Serial.println() debugging to identify delays.
- Reduced ThingSpeak update frequency to prevent API throttling.

Learning:
Reliable cloud integration requires robust exception handling and consideration of platform rate limits.

5. User Interface Challenges (Button Inputs)

Issue:
At times, multiple buttons triggered simultaneously due to noise or accidental presses.

Solution:

- Used pull-up resistors and digital filtering.
- Introduced debounce delays in the code for all input buttons.
- Clearly mapped and labeled buttons during testing to reduce confusion.

Learning:
Human interaction points (buttons, displays) need both hardware and software reliability to prevent user errors.

Overall Outcome

These challenges not only improved the technical strength of the system but also helped the team understand the importance of hardware-software integration, resource optimization, and user-centered design. As a result, the final prototype became more stable, energy-efficient, and responsive under real-world conditions.

FIGURES

Workflow Diagram:

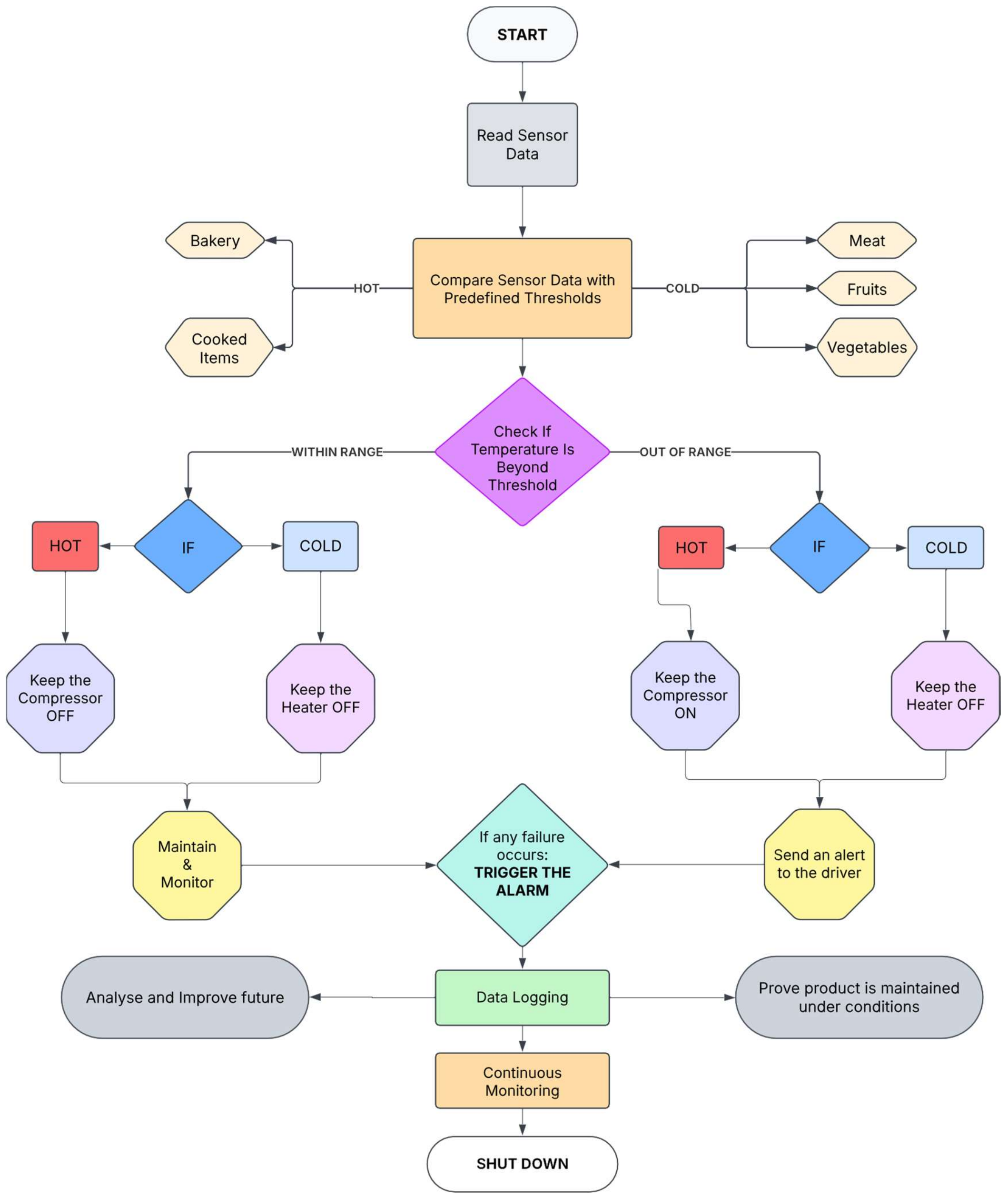


Fig.1

Hardware Flow Diagram:

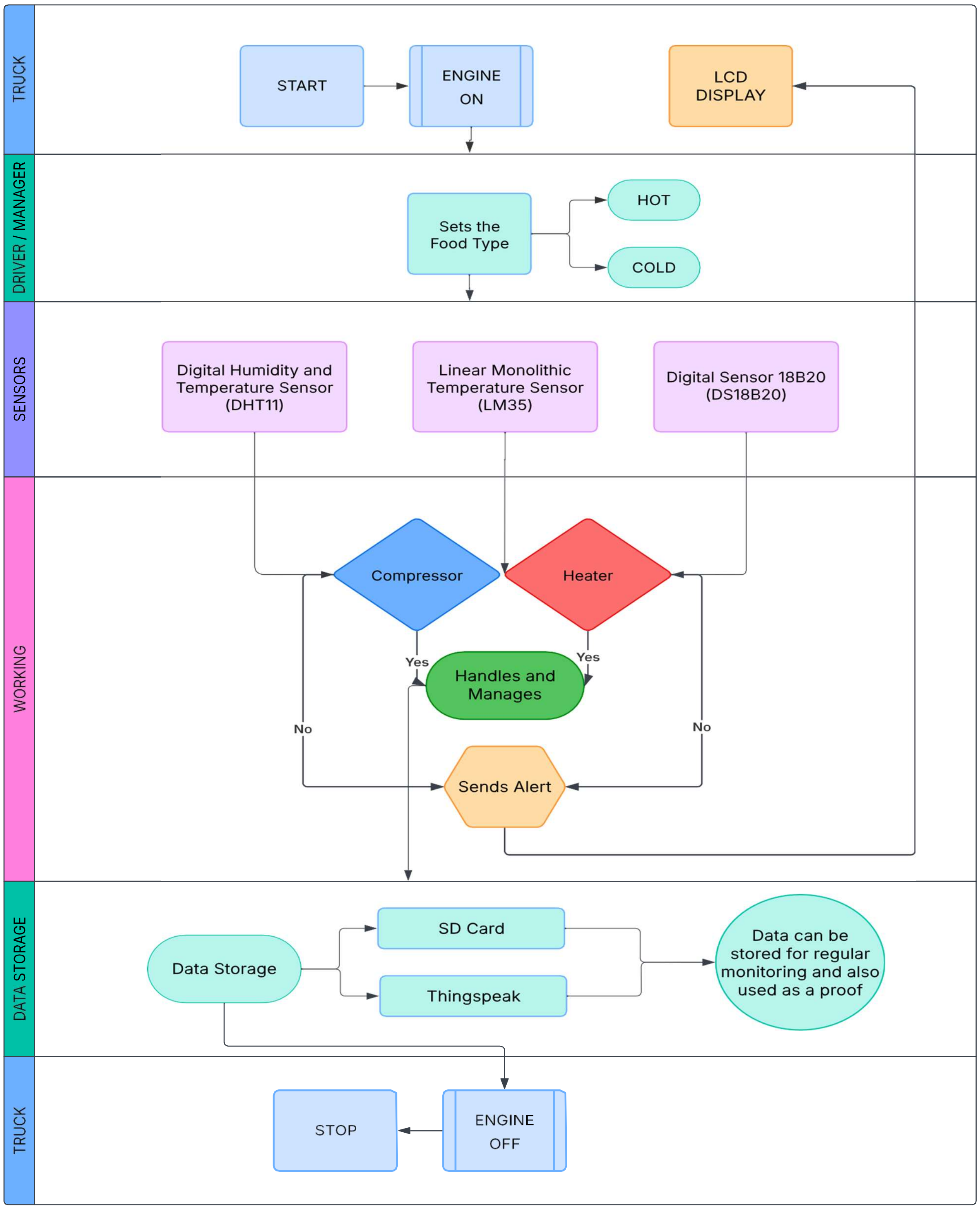


Fig.3

Circuit Diagram:

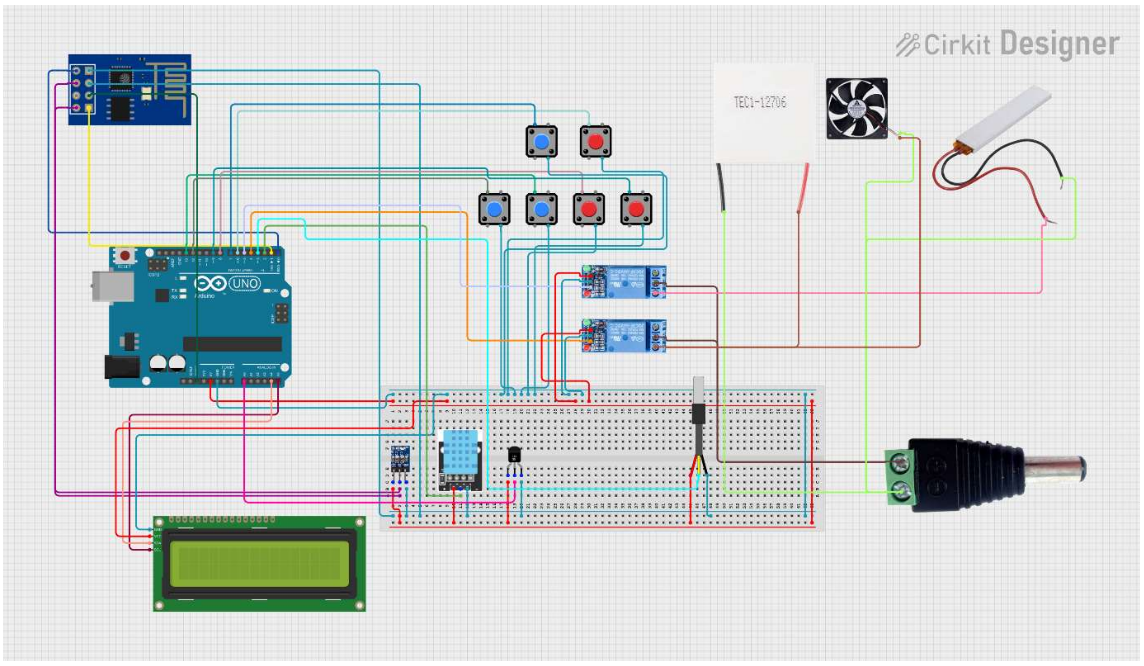


Fig.4

CHAPTER 7

CONCLUSION

The **Food Perish Prevention System** successfully demonstrates how a smart, IoT-enabled solution can be applied to reduce food spoilage by maintaining optimal storage conditions. By integrating sensors, microcontrollers, and cloud services, the system monitors temperature and humidity in real-time and automatically adjusts the internal environment using a cooling mechanism. The data is transmitted to the ThingSpeak IoT platform, allowing users to remotely view and analyze storage conditions. The project highlights the importance of automation in food safety, especially in minimizing human error and maximizing energy efficiency. Through low-cost components and open-source technologies, this system proves to be an affordable and scalable solution for both domestic and commercial applications. Ultimately, the project achieves its core goal: to preserve food quality for a longer time and reduce wastage due to poor environmental control.

7.1 FUTURE SCOPE

While the current prototype effectively addresses the preservation of food under basic environmental conditions, there is significant potential to expand and improve the system in the future:

- **Multi-Product Adaptation:** Future versions can automatically detect the type of food stored (e.g., dairy, fruits, vegetables) and adjust storage conditions accordingly.
- **Mobile App Integration:** A companion mobile application can be developed to provide real-time alerts and control options remotely.
- **AI-Based Prediction:** Machine learning algorithms can be integrated to predict spoilage risk based on sensor trends and suggest preventive actions.
- **Solar Power Support:** To promote sustainability, solar panels can be used to power the system in rural or off-grid areas.
- **Advanced Sensors:** Integration of gas sensors to detect ethylene or CO_2 can further enhance spoilage detection.

- **Edge Computing:** Future upgrades may include local data processing using devices like Raspberry Pi to reduce dependence on cloud services.

These enhancements would make the system smarter, more autonomous, and suitable for deployment in larger, more complex storage infrastructures like warehouses, cold chains, or transportation vehicles.

7.2 Environmental Impact & Sustainability

The IoT-Based Food Perish Prevention System directly addresses critical issues related to **food waste and energy efficiency**, making it highly relevant from an environmental sustainability perspective.

1. Reduction in Food Waste

Globally, a significant percentage of food is wasted due to improper storage and temperature control. This project helps reduce spoilage by continuously monitoring and maintaining optimal environmental conditions for perishable items such as dairy, meat, and bakery products. By extending the shelf life of stored goods, the system minimizes wastage at the consumer, vendor, and transportation levels.

2. Lower Carbon Footprint

Food spoilage contributes indirectly to greenhouse gas emissions by increasing the demand for production, packaging, and transport. By preserving food quality longer, the system reduces the frequency of replenishment cycles, thereby cutting down on emissions associated with supply chains. Moreover, the system’s ability to optimize cooling and heating operations based on real-time conditions leads to **reduced energy consumption**, especially when compared to traditional refrigeration systems that run continuously.

3. Reusability of Hardware

The hardware components used in this system—Arduino Uno, sensors, relays, LCDs, and ESP modules—are reusable and reprogrammable. In case of a system upgrade or project reuse, most of the components can be repurposed for educational, research, or commercial applications. This extends their lifespan and reduces electronic waste generation.

APPENDIX 1

Source Code:

```
#include <DHT.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define DHTPIN 2
#define ONE_WIRE_BUS 3
#define LM35PIN A0
#define RELAY_HEAT 5
#define RELAY_COOL 4

#define BTN_HOT_MODE 6
#define BTN_COLD_MODE 7
#define BTN_SANDWICH 8
#define BTN_PUFFS 9
#define BTN_MILK 12
#define BTN_DRINKS 13

#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
LiquidCrystal_I2C lcd(0x27, 16, 2);

bool modeSelected = false;
bool foodSelected = false;
bool isColdMode = false;
String foodType = "";

float tempMin = 0.0;
float tempMax = 0.0;

void printLCDAndSerial(int row, const char* msg) {
  lcd.setCursor(0, row);
  lcd.print("                ");
  lcd.setCursor(0, row);
  lcd.print(msg);
  Serial.println(msg);
}

void blinkAlert() {
  while (true) {
    lcd.clear();
    lcd.setCursor(3, 0);
    lcd.print("!!! ALERT !!!");
    lcd.setCursor(3, 1);
    lcd.print("Sensor Error");
    Serial.println("!!! ALERT: Sensor error detected !!!");

    digitalWrite(RELAY_COOL, HIGH);
    digitalWrite(RELAY_HEAT, HIGH);
    delay(700);
    lcd.clear();
    delay(300);
  }
}

void setup() {
  Serial.begin(115200);
  dht.begin();
  sensors.begin();
  lcd.init();
  lcd.backlight();

  pinMode(RELAY_COOL, OUTPUT);
  pinMode(RELAY_HEAT, OUTPUT);
  digitalWrite(RELAY_COOL, HIGH);
  digitalWrite(RELAY_HEAT, HIGH);

  pinMode(BTN_HOT_MODE, INPUT_PULLUP);
  pinMode(BTN_COLD_MODE, INPUT_PULLUP);
  pinMode(BTN_SANDWICH, INPUT_PULLUP);
  pinMode(BTN_PUFFS, INPUT_PULLUP);
  pinMode(BTN_MILK, INPUT_PULLUP);
  pinMode(BTN_DRINKS, INPUT_PULLUP);

  lcd.clear();
  printLCDAndSerial(0, "Select Mode:");
  printLCDAndSerial(1, "HOT / COLD");
}

void loop() {
  if (!modeSelected) {
```

```
  if (digitalRead(BTN_HOT_MODE) == LOW) {
    modeSelected = true;
    isColdMode = false;
    lcd.clear();
    printLCDAndSerial(0, "HOT Mode Selected");
    delay(1000);
    lcd.clear();
    printLCDAndSerial(0, "Select Food:");
    printLCDAndSerial(1, "Puffs / Sand.");
    Serial.println("Mode: HOT selected");
  }
  else if (digitalRead(BTN_COLD_MODE) == LOW) {
    modeSelected = true;
    isColdMode = true;
    lcd.clear();
    printLCDAndSerial(0, "COLD Mode Selected");
    delay(1000);
    lcd.clear();
    printLCDAndSerial(0, "Select Food:");
    printLCDAndSerial(1, "Milk / Drinks");
    Serial.println("Mode: COLD selected");
  }
  return;
}

if (!foodSelected) {
  if (isColdMode) {
    if (digitalRead(BTN_MILK) == LOW) {
      foodType = "Milk";
      tempMin = 1.0;
      tempMax = 4.0;
      foodSelected = true;
    }
    else if (digitalRead(BTN_DRINKS) == LOW) {
      foodType = "Drinks";
      tempMin = 5.0;
      tempMax = 8.0;
      foodSelected = true;
    }
  } else {
    if (digitalRead(BTN_PUFFS) == LOW) {
      foodType = "Puffs";
      tempMin = 60.0;
      tempMax = 70.0;
      foodSelected = true;
    }
    else if (digitalRead(BTN_SANDWICH) == LOW) {
      foodType = "Sandwich";
      tempMin = 50.0;
      tempMax = 60.0;
      foodSelected = true;
    }
  }

  if (foodSelected) {
    lcd.clear();
    printLCDAndSerial(0, "Food Selected:");
    printLCDAndSerial(1, foodType.c_str());
    delay(1500);
    lcd.clear();
   }
  return;
 }

 float lm35Temp = analogRead(LM35PIN) * (5.0 / 1023.0) * 100.0;
 float dhtTemp = dht.readTemperature();
 float dhtHum = dht.readHumidity();
 sensors.requestTemperatures();
 float ds18Temp = sensors.getTempCByIndex(0);

 // Alert on sensor error
 if (isnan(dhtHum) || isnan(dhtTemp) || ds18Temp == -127.0 || lm35Temp < -20 || lm35Temp
> 100) {
  blinkAlert();
 }

 bool coolOn = false, heatOn = false;
 if (ds18Temp > tempMax && isColdMode) {
  digitalWrite(RELAY_COOL, LOW);
  digitalWrite(RELAY_HEAT, HIGH);
  coolOn = true;
 }
 else if (ds18Temp < tempMin && !isColdMode) {
  digitalWrite(RELAY_COOL, HIGH);
  digitalWrite(RELAY_HEAT, LOW);
  heatOn = true;
 }
```

```
else {
  digitalWrite(RELAY_COOL, HIGH);
  digitalWrite(RELAY_HEAT, HIGH);
}

// Serial debug output
Serial.println("=== Sensor Readings ===");
Serial.print("LM35 Temp: "); Serial.println(lm35Temp);
Serial.print("DHT11 Temp: "); Serial.println(dhtTemp);
Serial.print("Humidity: "); Serial.println(dhtHum);
Serial.print("DS18B20 Temp: "); Serial.println(ds18Temp);
Serial.print("Cooling Relay: "); Serial.println(coolOn ? "ON" : "OFF");
Serial.print("Heating Relay: "); Serial.println(heatOn ? "ON" : "OFF");
Serial.print("Selected Food: "); Serial.println(foodType);
Serial.println("======================");

// LCD Output
lcd.setCursor(0, 0);
lcd.print("T:");
lcd.print(ds18Temp, 1);
lcd.print((char)223);
lcd.print("C ");

if (coolOn) lcd.print("C:ON ");
else if (heatOn) lcd.print("H:ON ");
else lcd.print("STBY  ");

char line2[17];
snprintf(line2, sizeof(line2), "H:%d%% %s", (int)dhtHum, foodType.c_str());
```

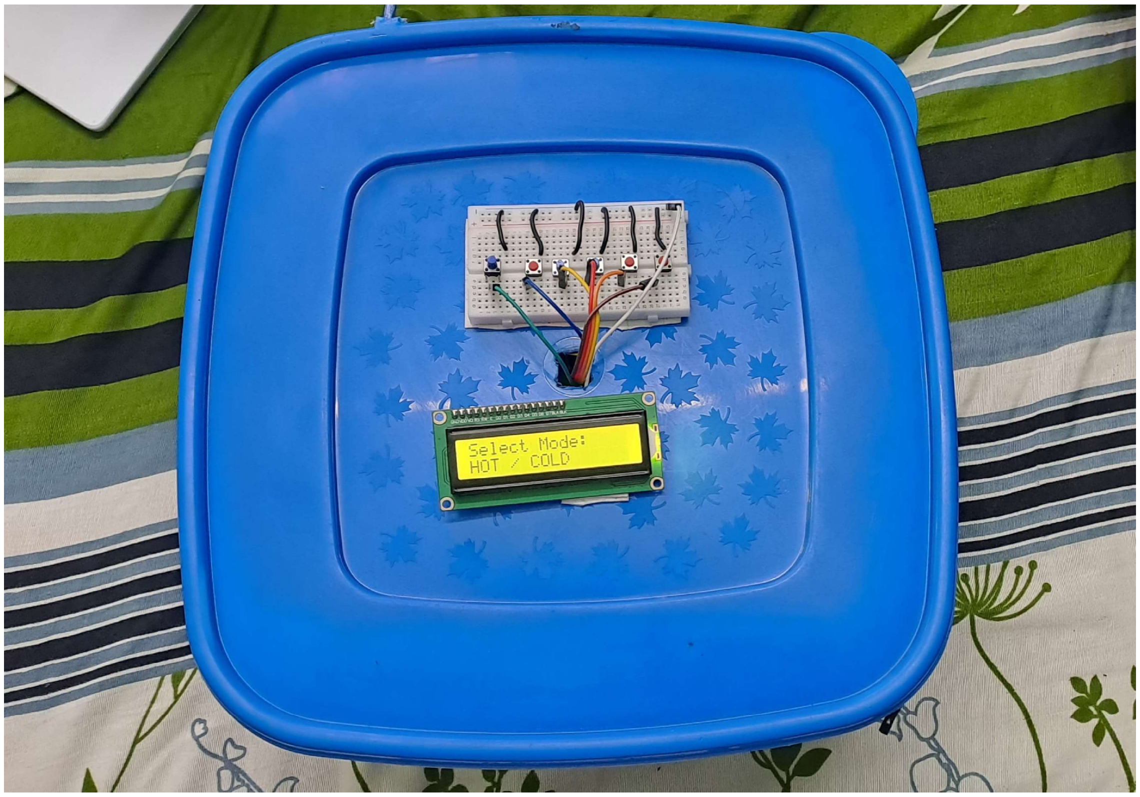
```
  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
  lcd.print(line2);

  delay(5000);
}
```

ESP01 Wifi Module Code

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>

const char* ssid = "<Wifi_Name>";
const char* password = "<Wifi_Password>";
const char* host = "api.thingspeak.com";
const char* apiKey = "5WD8MGBI66TQXEHT";

WiFiClient client;

void setup() {
  Serial.begin(9600); // Connect to Arduino
  delay(1000);

  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi!");
  Serial.print("IP Address: ");
  Serial.println(WiFi.localIP());
}

void loop() {
  if (Serial.available()) {
    String data = Serial.readStringUntil('\n');
    data.trim(); // remove whitespace or \r
    Serial.println("Received from Arduino: " + data);

    // Split the data
    int idx1 = data.indexOf(',');
    int idx2 = data.indexOf(',', idx1 + 1);
    int idx3 = data.indexOf(',', idx2 + 1);

    if (idx1 > 0 && idx2 > idx1 && idx3 > idx2) {
      String val1 = data.substring(0, idx1);              // ds18Temp
      String val2 = data.substring(idx1 + 1, idx2);        // dhtTemp
      String val3 = data.substring(idx2 + 1, idx3);        // lm35Temp
      String val4 = data.substring(idx3 + 1);              // dhtHum

      if (client.connect(host, 80)) {
        String url = "/update?api_key=" + String(apiKey) +
                     "&field1=" + val1 +
                     "&field2=" + val2 +
                     "&field3=" + val3 +
                     "&field4=" + val4;
        client.print(String("GET ") + url + " HTTP/1.1\r\n" +
                     "Host: " + host + "\r\n" +
                     "Connection: close\r\n\r\n");

        Serial.println("Data sent to ThingSpeak!");
        Serial.println("URL: " + url);
      } else {
        Serial.println("Connection to ThingSpeak failed.");
      }
    } else {
      Serial.println("Invalid data format received.");
    }

    delay(2000); // optional delay between uploads
  }
}
```

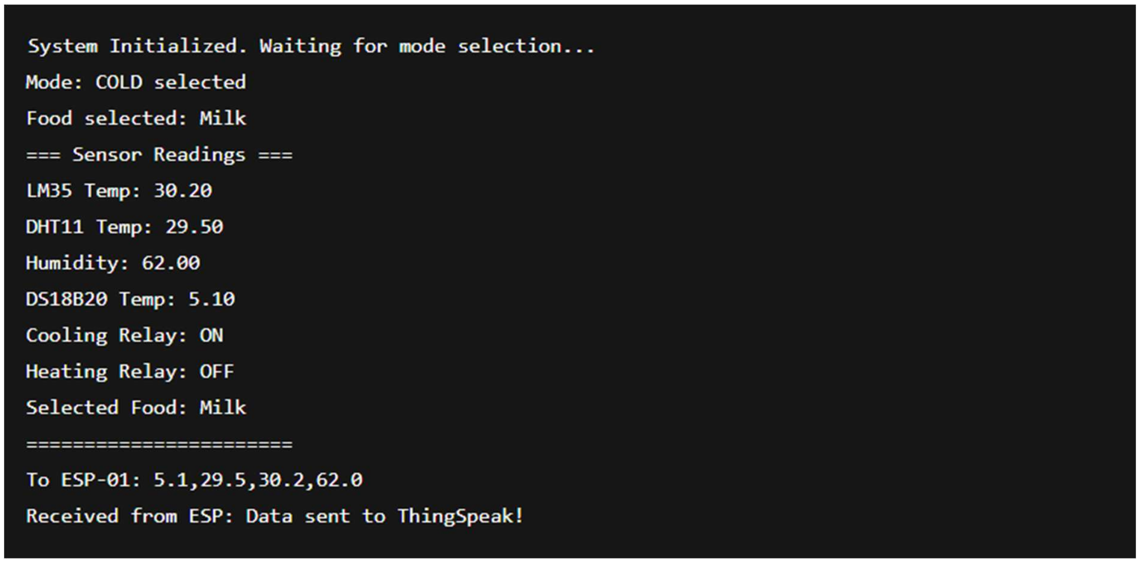
APPENDIX 2

HARDWARE SCREENSHOT

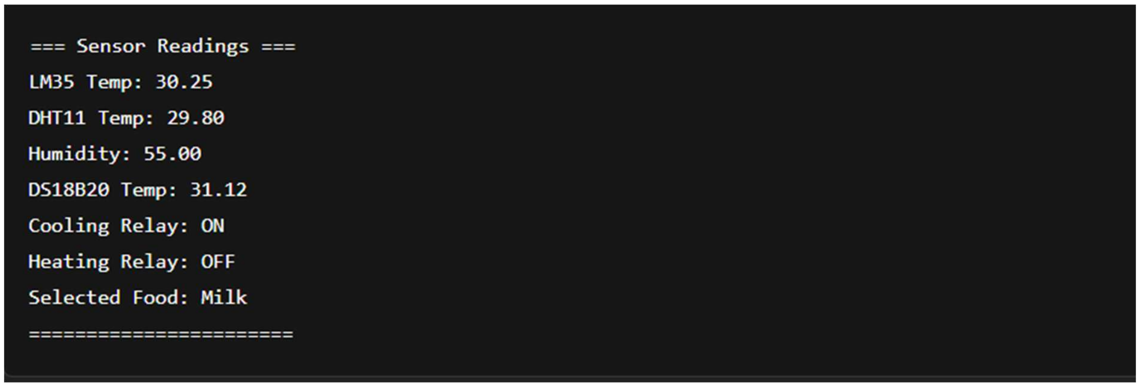


SAMPLE SERIAL MONITOR OUTPUT

The following output was generated by simulating the system behavior in COLD mode with Milk selected as the food item. The target temperature range for Milk is defined as 1.0°C to 4.0°C, and the system activates or deactivates the cooling mechanism accordingly.



```
System Initialized. Waiting for mode selection...
Mode: COLD selected
Food selected: Milk
=== Sensor Readings ===
LM35 Temp: 30.20
DHT11 Temp: 29.50
Humidity: 62.00
DS18B20 Temp: 5.10
Cooling Relay: ON
Heating Relay: OFF
Selected Food: Milk
=======================
To ESP-01: 5.1,29.5,30.2,62.0
Received from ESP: Data sent to ThingSpeak!
```



```
=== Sensor Readings ===
LM35 Temp: 30.25
DHT11 Temp: 29.80
Humidity: 55.00
DS18B20 Temp: 31.12
Cooling Relay: ON
Heating Relay: OFF
Selected Food: Milk
=======================
```

Fig.6

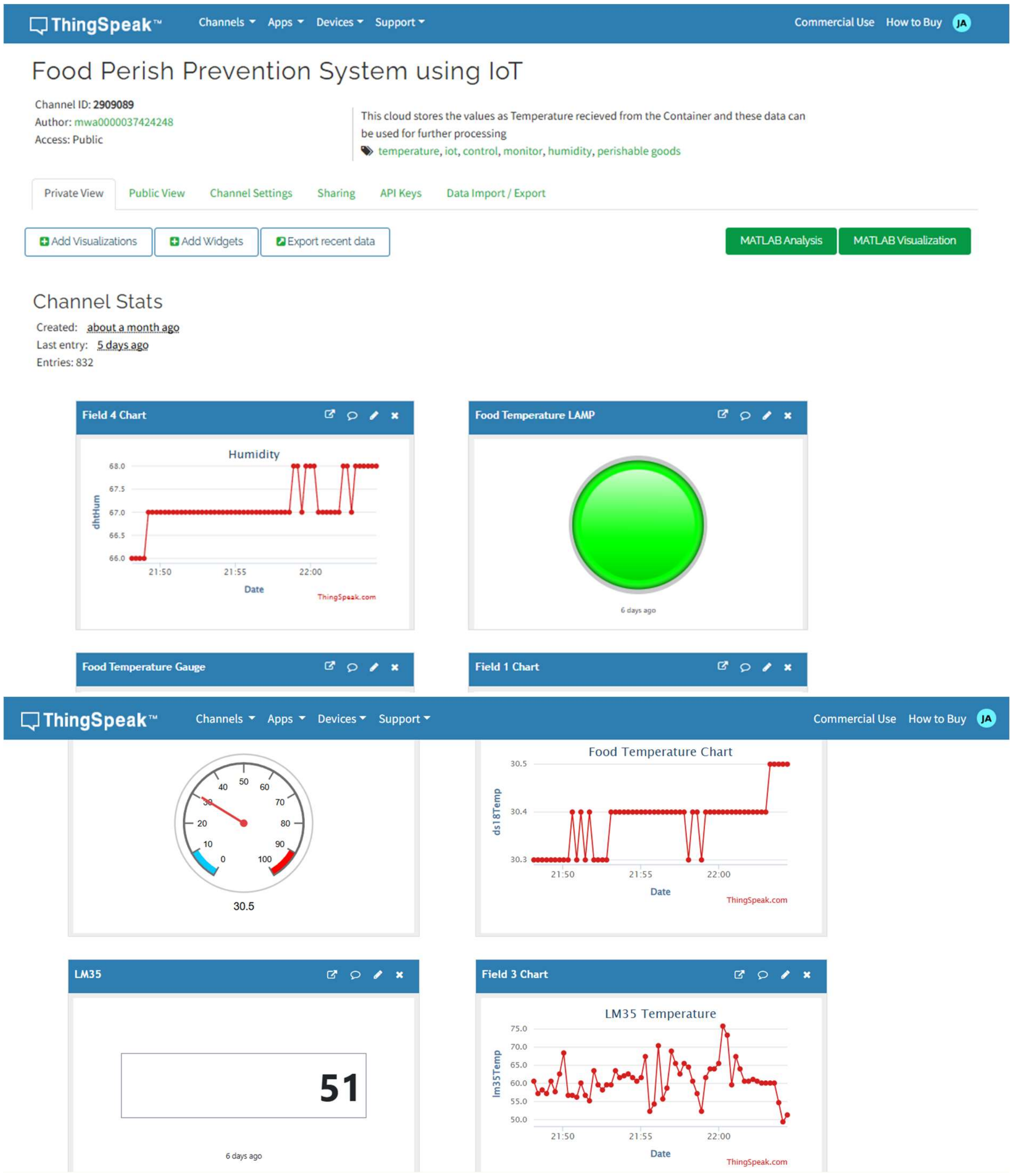
When the system is powered on, the user selects COLD mode and chooses Milk as the food type. This sets a target temperature range of 1.0°C to 4.0°C. The sensors read the current conditions:

- DS18B20, the main control sensor, reads 5.1°C

Since 5.1°C is above the maximum threshold (4.0°C) for Milk, the cooling relay is activated. The system then sends the data to the ESP-01, which uploads it to ThingSpeak, confirming with "Data sent to ThingSpeak!".

THINGSPEAK DASHBOARD OUTPUT

The **ThingSpeak IoT platform** is used to view real-time data sent from the Food Perish Prevention System. Data from temperature and humidity sensors (DS18B20, LM35, DHT11) is sent to the cloud using the **ESP-01 Wi-Fi module** and displayed in an easy-to-read format using charts and gauges.



Food Perish Prevention System using IoT

Channel ID: **2909089**
Author: mwa0000037424248
Access: Public

This cloud stores the values as Temperature recieved from the Container and these data can be used for further processing

temperature, iot, control, monitor, humidity, perishable goods

Channel Stats

Created: about a month ago
Last entry: 5 days ago
Entries: 832

Fig.7

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