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Hardware Graduation Project

PopMatic

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Disclaimer

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This report and the system we built would not have been possible without the contributions of all the people mentioned above.

Abstract

The rising demand for automated snack preparation machines has motivated the development of Popmatic, an automated popcorn production line designed to prepare flavored popcorn cups with minimal human intervention. The system integrates an Arduino Mega microcontroller to control the entire workflow, including corn dispensing, oil pumping, spice distribution, mixing, heating, and automated serving through a conveyor mechanism.

The machine provides three operation modes accessible via a keypad: Mode 1 (corn with salt and paprika), Mode 2 (corn with salt), and Mode 3 (corn with salt & double paprika). Each mode follows a predefined sequence that begins with preparing the cooking pot, dispensing the ingredients, and activating the heater and mixing motor. During this process, a DVD-drive mechanism pushes a cup onto a conveyor belt, which stops at the correct position using an IR sensor. After cooking, a stepper motor tilts the pot to pour the popcorn into the cup, which is then transported to the output by the conveyor.

To enhance usability, an LCD display is included to show the stages of operation in real-time, such as “Dispensing Corn,” “Adding Oil,” “Heating,” “Pouring,” and “Serving.” This feature improves user interaction by providing clear feedback on system status.

Additional components include ultrasonic sensors to monitor corn levels, a fan for ventilation, and relays for safe heater control. The system demonstrates how embedded systems, mechatronics, and automation can be combined to design a compact, low-cost, and efficient food production prototype.

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Chapter one

Introductory

Chapter one: Introductory

1.1 Problem Statement

The preparation of flavored popcorn in commercial and home settings often requires multiple manual steps, including dispensing corn, oil, spices, cooking, and serving. This manual process is time-consuming, inconsistent, and prone to human error, which may result in variations in taste, portion size, and cooking quality. The need for a compact, automated, and efficient popcorn production system motivated the development of Popmatic, an Arduino-based automated line that minimizes human intervention and ensures consistent output with different flavor options.

1.2 Objectives

The main objectives of this project are:

1. To design and implement an automated popcorn production system capable of preparing multiple flavors using a single setup.

2. To integrate an Arduino Mega microcontroller to control the workflow, including corn dispensing, oil pumping, spice distribution, mixing, heating, and serving.

3. To implement a user-friendly interface using a keypad to select among three modes: Mode 1 (corn with salt and paprika), Mode 2 (corn with salt), and Mode 3 (corn with salt & double paprika).

4. To provide real-time feedback on system stages using an LCD display, showing messages such as “Dispensing Corn,” “Adding Oil,” “Heating,” “Mixing,” and “Serving.”

5. To ensure safety and efficiency by incorporating sensors such as ultrasonic sensors for corn level monitoring and IR sensors to detect cup placement.

6. To extend the system functionality with a web application using ESP32 (communicating with Arduino Mega via RX/TX) that allows users to remotely monitor and control the popcorn production line.

1.3 Importance of work

This project plays a significant role in demonstrating how embedded systems and industrial automation can be applied to real-world food production challenges specifically in the context of small-scale, customized popcorn manufacturing. The importance of this work lies in several key areas:

1. Automation of Popcorn Preparation

Cooking popcorn with spices involves multiple steps: dispensing corn, adding oil, seasoning, heating, and mixing. Automating these stages ensures product consistency, improves taste quality, and reduces reliance on manual labor.

2. Integration of Real Hardware Systems

This project bridges academic embedded system design with real hardware deployment. It integrates a high-power heating system controlled by relays, stepper motors (for pot movement), DC motors (for mixing and conveyor), servos (for spice containers), and sensors (ultrasonic and IR) into a fully functional production line.

3. Real-Time Monitoring and Control

The inclusion of an LCD display provides clear feedback on each stage of operation (e.g., “Dispensing Corn,” “Heating,” “Pouring”). Additionally, the developed ESP32 web application allows remote monitoring and control, providing modern IoT capabilities for user convenience.

4. Modular Design for Expansion

The system is designed to be modular, making it easy to expand with additional flavors, larger containers, or remote monitoring. This flexibility ensures scalability and adaptability to future food automation use cases.

5. Scientific Engineering Approach

The workflow and energy use are designed based on practical engineering principles, including timing for cooking, dispensing quantities, and efficient motor control. This engineering-based design ensures reliability and energy efficiency rather than trial-and-error operation.

6. Educational and Industrial Relevance

The project demonstrates interdisciplinary engineering by combining electronics, control systems, automation, IoT, and food processing. It serves both as a teaching tool for engineering students and as a foundation for small-scale industrial snack production.

7. Real-World Impact and Innovation

The prototype highlights how students can design meaningful, low-cost hardware and IoT-enabled solutions to address real food production needs. It provides a practical solution for small businesses and startups that cannot afford industrial-grade popcorn production lines.

1.4 Organization of the Report

This report is organized into several chapters that outline the complete lifecycle of the Popmatic popcorn production line project from concept to implementation. Each chapter serves a distinct purpose and builds upon the previous to provide a comprehensive view of the work carried out.

Chapter One: Introduction

Introduces the project background, identifies the problem being addressed, outlines the project's objectives, and highlights its significance in both academic and real-world contexts.

Chapter Two: Constraints, Standards, and Component Selection

Presents the constraints faced during development, the industry standards and safety considerations followed, and the rationale for selecting specific components such as microcontrollers, motor drivers, sensors, heating elements, and communication modules like ESP32.

Chapter Three: Literature Review

Explores previous work in the field of food automation, embedded control systems for snack processing, and comparable dispensing or mixing systems. It positions the project in context with current technologies.

Chapter Four: System Methodology and Design

Details the design of the system, including hardware architecture, workflow control, sensor integration, safety measures, and user interface development. It also includes process flow

and the integration of the ESP32-based web application.

Chapter Five: Implementation and Testing

Covers the hardware assembly, software development, and individual component testing. It discusses the results of integration testing and the performance of the full system under real use-case scenarios.

Chapter Six: Conclusion and Future Work

Summarizes the project’s outcomes and discusses possible improvements.

References and Appendices

Includes a list of all academic and technical sources referenced, along with appendices containing full schematics, system code, and any additional data that supports the project.

Chapter Two

Constraints, Standards/ Codes and Earlier course work

2.1 Constraints

Throughout the design and implementation of our automated popcorn production line, we encountered several constraints that shaped the design and technical decisions made. Despite these challenges, the system was successfully implemented using real-world food-safe hardware and a functioning conveyor-based prototype.

1. Budget Constraints

Working with a limited student budget, we carefully selected cost-effective yet reliable components. The use of repurposed items such as a 1500W heating element from a baker and open-source hardware like Arduino microcontrollers allowed us to balance functionality with affordability.

2. Integration of High-Power and Food-Grade Components

The system integrates a real heating element with a food-safe popcorn pot. This presented challenges in terms of electrical safety, thermal control, and interfacing with low-voltage logic, but it provided a more realistic and credible setup compared to a purely simulated design.

3. Prototype Space Constraints

The prototype—including the conveyor belt, spice dispensers, and mixing pot—was designed to fit within limited lab space. This required a compact yet modular arrangement for wiring and mechanical component placement.

4. High-Voltage Handling

The heater 1500W operates at 220V AC and required strict adherence to safety precautions. The relay system was safely isolated from microcontroller logic, and all wiring was protected to prevent accidental contact or overheating.

5. Controller Synchronization

The system uses two controllers: an Arduino Mega 2560 for core control and an ESP32 for web application connectivity. Coordinating tasks between them required careful management of serial communication, timing, and logical state handling.

6. Thermal Calibration

Accurate dispensing of ingredients and cup detection required calibration of ultrasonic and IR sensors. Variations in real-world sensor performance demanded additional fine-tuning beyond theoretical design.

7. Mechanical Assembly and Precision

Key mechanical components—including the stepper motor for pot movement, mixing motor, conveyor belt, and spice servo gates—were carefully assembled and aligned to ensure repeatable and precise operation.

8. Time Constraints

The project was completed within a single academic summer semester. This imposed strict deadlines across all phases from design and procurement to testing and final integration which required efficient planning and time management.

2.2 Problems and Solutions

During the implementation of our chocolate bar production line and tempering system, we encountered several hardware and software challenges. Below are the key technical problems faced and the corresponding solutions adopted.

1. **Safe Control of High-Power Heating Element**

   Problem: The 220V heating element required safe switching through a low-voltage microcontroller. Direct connection to Arduino Mega or ESP32 posed serious electrical hazards.

   Solution: We used an relay module to safely switch the heating element. Proper insulation, fuses, and secure wiring were added to prevent risks and ensure long-term reliability.

2. **Inaccurate or Noisy Sensor Readings**

   Problem: The IR sensor initially produced fluctuating readings due to sunlight.

   Solution: Cover it completely to work more efficiently in the dark.

3. **Ingredient Dispensing Jams**

   Problem: Salt or paprika sometimes clogged the servo-operated dispensers, causing incomplete seasoning.

   Solution: The dispenser openings were slightly widened and servo angles adjusted to ensure smoother flow of spices.

4. **Cup Height Mismatch**

Problem: The commonly available tall popcorn cups did not align properly with the output chute of the cooking pot, causing popcorn to spill instead of filling the cup directly.

Solution: We replaced the tall cup with a shorter, well-positioned container that fits perfectly under the pot's discharge point, ensuring efficient collection of popcorn without waste.

5. Noise from Wires

Problem: Dense wiring created noise that interfered with uploading code and running the system consistently.

Solution: Cables were rerouted with improved spacing, shielded where possible, and organized into structured paths to minimize interference and improve accessibility for debugging.

6. Insufficient Power for Stepper Motor (NEMA 23)

Problem: The stepper motor responsible for tilting the cooking pot (NEMA 23) did not receive enough power because the single power supply had to distribute current across all components, leading to weak or unstable motion.

Solution: We optimized the overall power distribution of the system, ensuring that the NEMA 23 stepper motor received sufficient and stable power, which stabilized its operation and ensured reliable and strong movement of the cooking pot.

2.3 Standards and Codes

In the development of this popcorn production line, adherence to relevant technical standards and safety practices was a critical consideration. While this project is primarily educational, we applied real-world engineering standards where applicable to ensure safe operation and system reliability.

Electrical Safety Standards

- The **220V AC heating element** was isolated from low-voltage control circuits using a properly rated **relay module.**
- All power wires were routed away from the heater and control boards, reducing risks of overheating or accidental short circuits.

Heating and Temperature Control

- The heater was turned off immediately after popcorn preparation to prevent overheating, unnecessary energy consumption, and fire risks.
- Thermal cycling was kept within safe limits to protect both components and food quality.

Food Safety Considerations

- Cleanliness was maintained as a primary standard: ingredients were not left exposed after operation to avoid contamination from dust, air, or external factors.
- Contact surfaces for food were kept clean before and after each production cycle.

Microcontroller Communication and Software Practices

- Communication between the ESP32 and Arduino Mega followed **serial protocol standards** using voltage-matched logic levels and common GND reference.
- Code development followed basic **embedded systems programming best practices**, including interrupt-safe routines, input validation, and watchdog resets where necessary.

Mechanical Components and Motor Drivers

- Motor drivers were selected according to manufacturer specifications: an A4988 driver was used for the NEMA 17 stepper motor, while a TB6600 driver was used for the NEMA 23 motor.
- These drivers include current control features, helping protect both the motors and the electronics from overload conditions.

User Interface and Mobile App

- The mobile application and ESP32 interface were developed following standard **HTTP-based communication protocols**, ensuring future expandability and secure operation.
- UI feedback on LCD screen (16x2 & I2C) followed established usability principles clear status labels.

This combination of safety, compatibility, and hygiene considerations ensures that the prototype aligns with real-world design expectations, even in a university research setting.

2.4 Hardware Components

This section outlines the major hardware components used in the popcorn production line , including their functions, justification for selection, and how they contribute to the overall system.

1. **1500W Baker Heating Element (220V)**

Figure 2:1500W Baker Heating Element (220V)

Main heating unit used for cooking the popcorn.

2. **ESP32 Microcontroller**

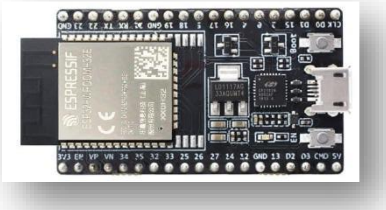


Figure 2:ESP32 Microcontroller:

Provides web application connectivity, enabling users to place orders and select modes.

3. **Arduino Mega 2560**

Figure 3:Arduino Mega 2560

Handles all logic and control for the production line prototype. Its large number of digital and analog I/O pins makes it ideal for managing the whole system components.

4. IR Sensor

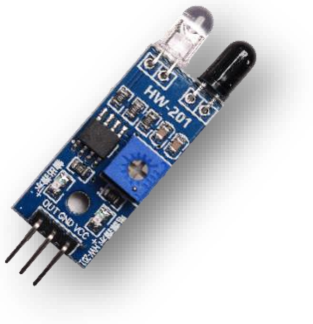


Figure 4:IR Sensor

Detects the presence of a cup on the conveyor and stops it to allow filling.

5. 3x4 Keypad

Figure 5:3x4 Keypad

Allows manual user input for selecting modes and system functions.

6. I2C LCD Display

Figure 6:I2C LCD Display

Provides system feedback and user interface information.

7. Ultrasonic Sensor

Figure 7: Ultrasonic Sensor

Monitors the corn level inside the container.

8. NEMA 23 Stepper Motor

Figure 8: NEMA 23 Stepper Motor

Provides the torque required to flip the cooking pot for popcorn discharge.

9. TB6600-4A Stepper Driver

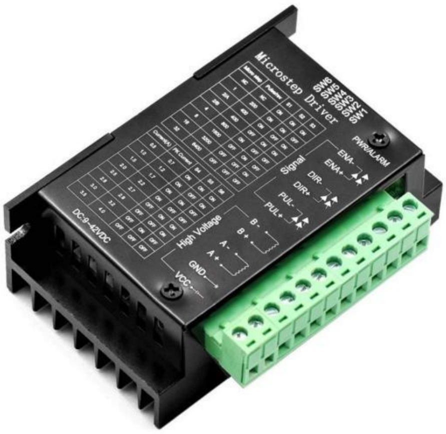


Figure 9: TB6600-4A Stepper Driver

High-power stepper driver used to control the NEMA 23 motor.

10. Power Supply (12V 12.5A)

Figure 10: Power Supply (12V 12.5A)

Provides regulated power for all low-voltage components including motors, sensors, and logic boards. Prevents brownout when multiple devices run simultaneously.

11. Jumper Wires (Male-Male / Male-Female)

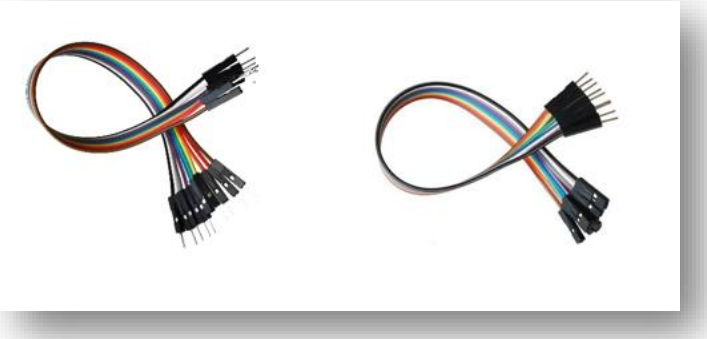


Figure 11: Jumper Wires (Male-Male / Male-Female)

Used for modular connections between all components. Enables prototyping and easy maintenance.

12. Dc motors 12v (x2)

Figure 12: Dc motors 12v (x2)

- One used for driving the mixing mechanism inside the cooking pot to ensure even heating of corn.
- The other (the one with high torque) moves the conveyor belt to transport cups during the dispensing process.

13. Stepper motor Nema 17 1.5A

Figure 13: Stepper motor Nema 17 1.5A

Flips the corn feeder to drop kernels into the cooking pot.

14. A4988 Stepper motor Driver

Figure 14: a4988 stpper motor driver

Motor driver used to control the NEMA 17 stepper motor.

15. Servo motors mg996r (x2)

Figure 15: Servo motors mg996r (x2)

Act as dispensing doors to release salt and paprika into the pot.

16. Relay Module 2 channel (x2)

Figure 3: Relay Module 2 channel (x2)

The first module controls the heating element and the 12V oil pump; the second controls the 12V fan and the DVD driver.

17. RFID

Figure 17: RFID

Adds an access or identification feature for system use.

18. Pump 12v

Figure 18: Pump 12v

Dispenses cooking oil into the pot before heating.

19. DVD Driver

Figure 19: DVD Driver

Mechanism that pushes cups onto the conveyor when opened.

20. Fan 12v

Figure 20: Fan 12v

Works as an exhaust to remove smoke generated during cooking.

21. H bridge

Figure 21: H bridge

Motor driver for controlling the two DC motors (mixer and conveyor).

2.5 Earlier Coursework and Related Skills

This graduation project builds upon multiple courses and skills acquired during our Computer Engineering program. The design, implementation, and testing of the Popmatic popcorn machine reflect a practical application of our academic background.

1. Microcontrollers and Embedded Systems

Courses involving Arduino, ESP32, and real-time control systems laid the foundation for implementing logic-driven automation. Interrupt handling, serial communication, and PWM control were directly applied in tasks like motor control, heating regulation, and sensor interfacing.

2. Digital and Analog Electronics

Understanding voltage levels, current control, and interfacing circuits was crucial for safely combining low-voltage microcontrollers with high-power components like the 220V heating element, relays, and motor drivers.

3. Programming and Software Design

Experience in C/C++ programming for microcontrollers enabled the development of reliable firmware. State machines, modular functions, and efficient use of memory were implemented to ensure responsiveness and clarity.

4. Networks and Wireless Communication

The use of the ESP32's Wi-Fi capabilities builds upon coursework in IoT protocols and wireless networking. This knowledge was applied to enable remote monitoring and control through a mobile app, allowing flexible and user-friendly operation.

5. Circuits and Electrical Safety

Understanding of power ratings, circuit protection, and safety design was essential when working with the heating element, power supply unit, and high-current motor drivers.

6. Critical Thinking, Technical Writing and Project Management

Skills in documentation, presentation, and collaborative project planning were essential in organizing tasks, maintaining timelines, and preparing this final report.

Chapter Three

Literature Review

Chapter Three: Literature Review

This chapter reviews prior work and technologies that informed the design of our automated popcorn production line (Popmatic). It highlights related systems in heating and cooking automation, food dispensing, embedded architectures, sensor integration, and IoT-based control. By surveying industrial practices and academic prototypes, we place our work in context and demonstrate the novelty of our contribution.

3.1 Heating and Cooking Automation

Automated heating systems are widely studied in food engineering, particularly for processes requiring precise timing and thermal management. Industrial popcorn makers typically use high-wattage heating elements with thermostats or PID controllers to maintain safe operating temperatures and prevent burning.

DIY and academic projects often replace precise temperature regulation with time-based heating, which simplifies design but risks uneven results. Our system improves upon these approaches by implementing immediate shutoff after popcorn preparation, balancing safety with efficiency, and applying electrical isolation techniques similar to industrial standards.

3.2 Ingredient Dispensing Systems

Food dispensing automation is common in beverage vending and spice handling. Industrial systems employ augers, vibratory feeders, or gravity-fed containers to achieve controlled dispensing.

In smaller-scale projects, servo motors are often used to control gates or flaps for dry ingredients. Our design follows this proven method, using MG996R servos as controlled doors for salt and paprika, combined with containers dedicated to each ingredient. This aligns with industrial principles of mechanical decoupling between moving parts and food-contact surfaces, reducing contamination risks.

3.3 Embedded Controller Design

For Popmatic, the control system was implemented using a primary Arduino Mega to handle all project components, sensors, and actuators, supported by an ESP32 dedicated to the web application interface for remote ordering and monitoring. This setup allowed the Mega to focus on hardware operations while the ESP32 provided seamless IoT connectivity and user interaction through the app.

3.4 Sensor Integration and Real-Time Monitoring

Sensor integration is critical in modern automated systems. Ultrasonic sensors are widely adopted for level detection in grains, liquids, and containerized materials. Similarly, IR sensors are used in conveyor systems to detect objects and trigger precise actions.

Our system integrates ultrasonic sensing to monitor kernel levels in real time and IR sensing to detect cup positioning on the conveyor. These solutions mirror industrial systems where live feedback ensures efficient operation, while simplifying the process for educational implementation.

3.5 Mobile Control and IoT Applications

The use of IoT platforms in food automation has grown rapidly, with ESP32 emerging as a popular controller due to its integrated Wi-Fi. Recent student and commercial projects use mobile applications to control devices such as coffee brewers, ovens, and dispensing systems.

Popmatic extends this trend by enabling mode selection and live monitoring through a web interface, built on ESP32. This approach provides both educational value and alignment with smart kitchen technologies, reflecting the growing role of IoT in user-friendly automation.

3.6 Gaps in Existing Projects

- From our survey of prior work, we found that most DIY popcorn or food automation projects focus on a single subsystem, such as heating or dispensing, without offering a complete, integrated solution. Few attempts combine:
- Safe integration of real high-voltage heating hardware with low-voltage control electronics.
- Automated seasoning and ingredient dispensing using reliable, food-safe mechanisms.
- Coordinated cup handling on a conveyor system with real-time sensor feedback.
- IoT-based monitoring and user interaction through mobile or web platforms.

- Commercial popcorn machines do achieve reliable heating and popping, but they rarely include smart dispensing, conveyor handling, or IoT features. On the other hand, DIY educational systems often demonstrate sensors or web apps, but stop short of handling high-power heating or food-safe automation.
- To better understand practical designs and mechanisms, we studied several commercial and DIY popcorn machine demonstrations available online, such as:

- Popcorn Machine Commercial Demo

- Cretors Popcorn Machine Overview

- DIY Automated Popcorn Maker

Chapter Four

Methodology

Chapter Four: Methodology

4.1 System Overview

The Popmatic automated popcorn production system consists of A fully automated system that prepares flavored popcorn using corn, oil, and spices. The process is controlled by an Arduino Mega, while an ESP32 handles web application integration for remote control and monitoring. The production line includes:

- **Cooking Pot**: A stainless steel pot with a 1500W heating element, controlled through a relay module, where corn is popped and mixed.
- **Ingredient Dispensing**: Three containers (corn, salt, paprika) with servo-controlled doors to release ingredients into the pot.
- **Conveyor System**: A DC motor-driven belt that moves cups into position and delivers the filled popcorn to the output.
- **Cup Handling**: A DVD drive mechanism pushes cups onto the conveyor at the correct position, detected by an IR sensor.
- **Stage Feedback**: An LCD shows current operation stages, such as “Dispensing Corn,” “Adding Oil,” “Heating,” and “Pouring.”
- **Fan and Sensors**: A 12V fan acts as a ventilation hood, ultrasonic sensors measure corn level, and IR sensors detect cup positions.

4.2 Control Flow Summary

- **Startup:** Arduino Mega initializes all motors, relays, sensors, and keypad states. ESP32 initializes Wi-Fi and web app communication.
- **User Input:** The user selects a mode via keypad or web app .
- **Ingredient Dispensing:** Corn is dispensed using the NEMA 17 stepper motor with A4988 driver. Oil is pumped into the pot. Servos open salt and/or paprika containers depending on the mode.
- **Cooking:** The 1500W heater heats the pot, and the DC motor inside mixes ingredients. The fan operates for smoke ventilation. The heating element is turned off immediately after cooking to prevent overcooking.

- **Cup Filling:** The pot moves via NEMA 23 stepper motor with TB6600 driver to pour popcorn into cups positioned on the conveyor belt. The conveyor stops automatically when a cup is detected by the IR sensor.
- **Output:** Filled cups are transported to the output via the conveyor system.

4.3 Safety and Efficiency Design

- **Relay Isolation**: Ensures Arduino Mega never directly interacts with 220V AC heating element.
- **Motor Current Limits**: Stepper and DC motor drivers tuned for safe operation.
- **Ingredient Hygiene**: All containers and pot surfaces are cleaned and cleared after each operation to maintain food safety and prevent contamination.
- **Display Feedback**: LCD ensure the user always knows system status and material availability.
- **Web App Integration**: ESP32 enables monitoring of corn levels, mode selection, and statistics remotely, enhancing operational efficiency and control.

Chapter Five

Implementation

Chapter Five: Implementation

This chapter details the process of building the Popmatic system, connecting all hardware components, developing the control software, and verifying performance through structured testing.

5.1 Hardware Assembly

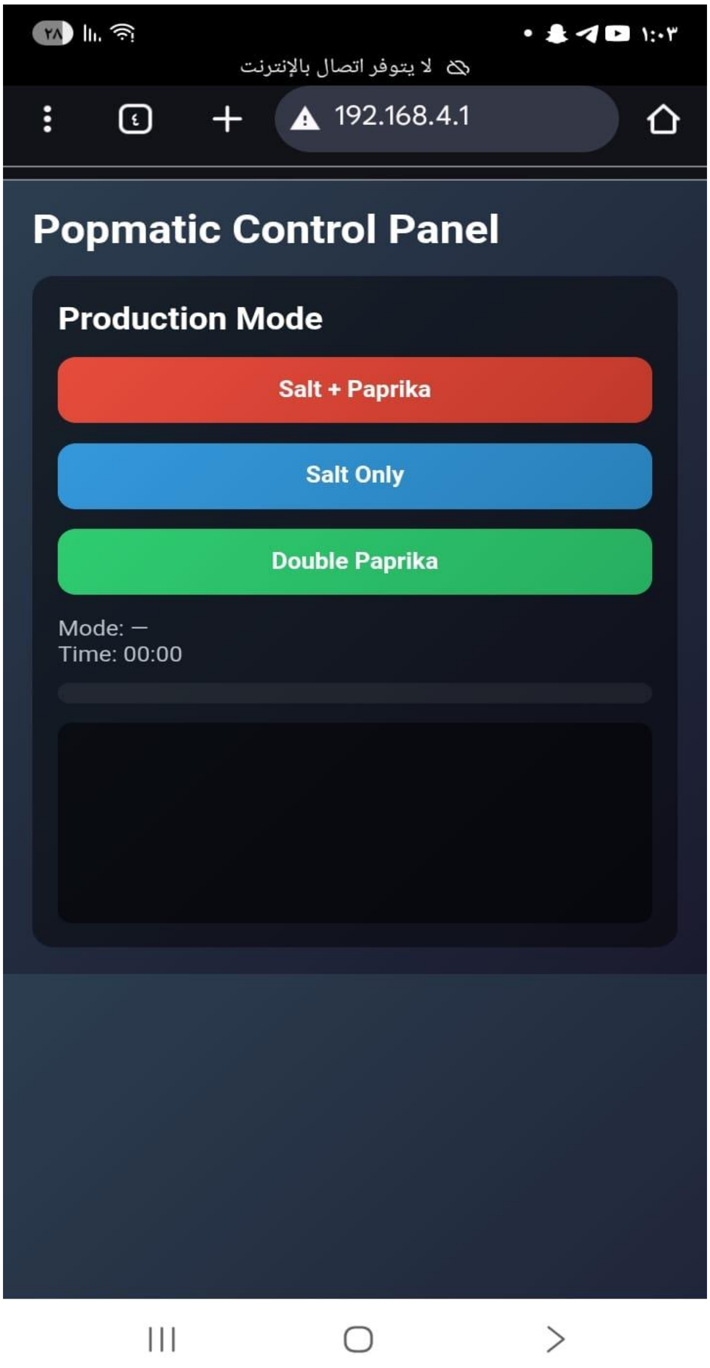
- The hardware assembly focused on constructing a fully automated popcorn production line with the following components:
- **Arduino Mega**: Controls all motors, relays, sensors, and overall logic of the system.
- **ESP32**: Manages web application connectivity for remote control,and mode selection.
- **Cooking Pot Assembly**: A stainless steel pot with a 1500W heating element mounted underneath, used for cooking corn with oil and spices.
- **Ingredient Containers**: Three containers for corn, salt, and paprika with MG996R servo motors & Nema 17 controlling doors for dispensing.
- **DC Motors**: One for mixing ingredients inside the pot and another for driving the conveyor belt.
- **Stepper Motors**: NEMA 17 with A4988 driver for dispensing corn; NEMA 23 with TB6600 driver for tilting the pot.
- **Relays**: Two 2-channel relay modules; one for the heater and oil pump, the other for the fan and DVD drive.
- **Cup Handling**: A DVD drive pushes cups onto the conveyor belt at the correct position.
- **Sensors and Feedback**: IR sensor for cup detection, ultrasonic sensor for corn level measurement, and LCD display to show real-time operational stages.
- **Power Supply**: 12V 12.5A supply to provide sufficient current to all components.
- **Additional Components**: Jumper wires, connectors, keypads, RFID module, and a 12V fan for ventilation.

All wiring was carefully insulated and routed to avoid contact with heating elements or high-temperature areas. Power distribution was optimized to ensure all motors, especially the NEMA 23 stepper, received adequate current.

5.2 Software Development

- Control software was developed in C++ using the Arduino IDE and structured as follows:

- The **ESP32 code** handled:
- Handling web server functionality to serve the control interface.
- Enabling mode selection and production time tracking.



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192.168.4.1

Popmatic Control Panel

Production Mode

Mode: —
Time: 00:00

Figure 22: web application

This interface, deployed via ESP32, provides remote control of the popcorn production process. It features three production modes (Salt + Paprika, Salt Only, and Double Paprika). Once a mode is selected and the process starts, the production timer counts the operation time.

- The **Arduino Mega code** managed:
    - Reads keypad inputs for mode selection.
    - Controls ingredient dispensing using servo motors and stepper motors.
    - Manages DC motors for mixing and conveyor movement.
    - Controls heating element via relay, turning it off immediately after cooking.
    - Displays current stage messages on the LCD.

5.3 Integration and Communication

- Arduino Mega and ESP32 communicate via serial for mode selection and data reporting.
- Common ground and logic-level matching were maintained to prevent electrical issues.
- Independent operation of components ensures reliability and prevents crashes due to software or hardware interference.

5.4 Testing and Results

- **Cooking Performance**: Popcorn cooking was consistent, and the heater was turned off immediately after completion.
- **Dispensing Accuracy**: Corn, salt, and paprika were dispensed correctly for each mode.
- **Cup Handling**: The DVD drive successfully positioned cups on the conveyor, with the IR sensor reliably detecting and stopping the belt.
- **Motor Performance**: DC motors and stepper motors operated smoothly after proper power distribution adjustments.
- **Sensor Accuracy**: Ultrasonic sensor correctly measured corn levels; IR sensor accurately detected cup presence.
- **User Interface**: LCD provided clear stage feedback, and the web app allowed remote control and monitoring, including corn statistics.

Chapter Six

Conclusion and Future Work

Chapter Six: Conclusion and Future Work

6.1 Conclusion

This project successfully demonstrates the design and implementation of **Popmatic**, an automated popcorn production system. The solution integrates real hardware components including a heating element, motors, sensors, and controllers to automate the full cycle of popcorn preparation—from cooking and mixing, to dispensing ingredients, handling cups, and serving.

The Arduino Mega acted as the main controller, managing motors, sensors, relays, and user interface, while the ESP32 enabled web app control. Safety was ensured by proper power distribution, separating high-power and low-voltage circuits, and immediately turning off the heater after cooking. The IR sensor reliably detected cups on the conveyor, the ultrasonic sensor provided accurate corn level measurement, and the LCD displayed operational status clearly.

Overall, Popmatic proved to be a functional and educational prototype that demonstrates how embedded systems and automation can be applied to snack production in a compact, affordable way.

6.2 Future Work

While the project achieved its objectives, several improvements can be explored in the future:

1. **Cup Handling Improvements**: Replace the DVD drive with a stronger, motor-based pushing or positioning system for higher reliability.
2. **Fully Featured Mobile App**: Expand the app to include detailed status updates
, operation logs and Alerts for maintenance.
3. **Additional Flavor Options:** Expand ingredient containers to allow more seasonings or toppings beyond salt and paprika.

4. **Improved Ventilation**: Use a stronger or dual fan system to handle smoke more effectively during cooking.
5. **Industrial Food-Safe Certification**: Further develop the food-contact surfaces and obtain formal food safety certification, enabling real production use.
6. **AI-Based Quality Control**: Integrate computer vision (e.g., via ESP32-CAM or Raspberry Pi) to detect fill levels and defects for future AI-assisted refinement.

6.3 References

6.3.1 Technical and Engineering References:

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6. TB6600-4A Stepper Motor Driver Module Specifications.

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6.3.2 Video & Media References:

7. **Popcorn Machine Commercial Demo**

YouTube **:** https://www.youtube.com/watch?v=U8CJKuF901s

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