FINAL PROJECT REPORT

Smart Washing Machine with RFID and Sensor Feedback

DATE : 11TH JUNE 2025

SECTION : 1

GROUP : 1

SEMESTER 2, 2024/2025

NO.	NAME	MATRIC
1.	AKMAL FAUZAN BIN AZHAR	2319531
2.	AIMAN SAIFULLAH BIN AMINNURLLAH	2319185
3.	SYAFIQ HELMIE BIN SAIFULLAH ADHA	2316049

1.0 Introduction

The evolution of home appliances toward intelligent automation has opened new possibilities for improving efficiency, user convenience, and energy savings. This project presents a prototype of a smart washing machine that integrates various sensors and microcontrollers to simulate a fully automated laundry system. Built using two ESP32 boards, the system incorporates RFID-based user authentication, temperature and water level monitoring, and PixyCam-based color detection for sorting fabrics. A servo motor simulates the washing drum's rotation, while a TFT display provides real-time status updates. By combining these components, the prototype demonstrates how embedded systems and IoT technologies can enhance traditional appliances, making them smarter, safer, and more user-friendly.

2.0 Materials and Equipments

- 2 ESP32 Development Board
- 2 RFID Card
- 2 Breadboard (8.5 X 5.5 CM)
- 1 Water Level Sensor (Analog)
- 1 Temperature Sensor (DHT 11)
- 1 Servo Motor (MG996R)
- 1 TFT LCD Display (3.2 Inch)
- 1 Switching Power Supply
- 1 PixyCam
- 1 RFID Reader (MFRC522)
- 1 Micro-USB Cable
- Half of 6.5 litre bottle
- Half of 2 litre bottle
- Jumper Wires

3.0 Objectives and Design Problems

3.1 Objectives

- To develop a functional prototype of a front-loading smart washing machine using embedded systems and sensors.
- To implement RFID authentication for controlled user access.
- To use a PixyCam to detect fabric color and simulate wash mode selection (e.g., white or colored wash).
- To monitor water level and ensure the wash only starts when sufficient water is present.
- To track environmental temperature using a DHT11 sensor and implement overheating protection.
- To simulate the drum rotation using a servo motor housed in a bottle compartment.
- To provide user feedback via a TFT display with real-time status messages.
- To divide responsibilities between two ESP32 boards for efficient multitasking and serial communication.

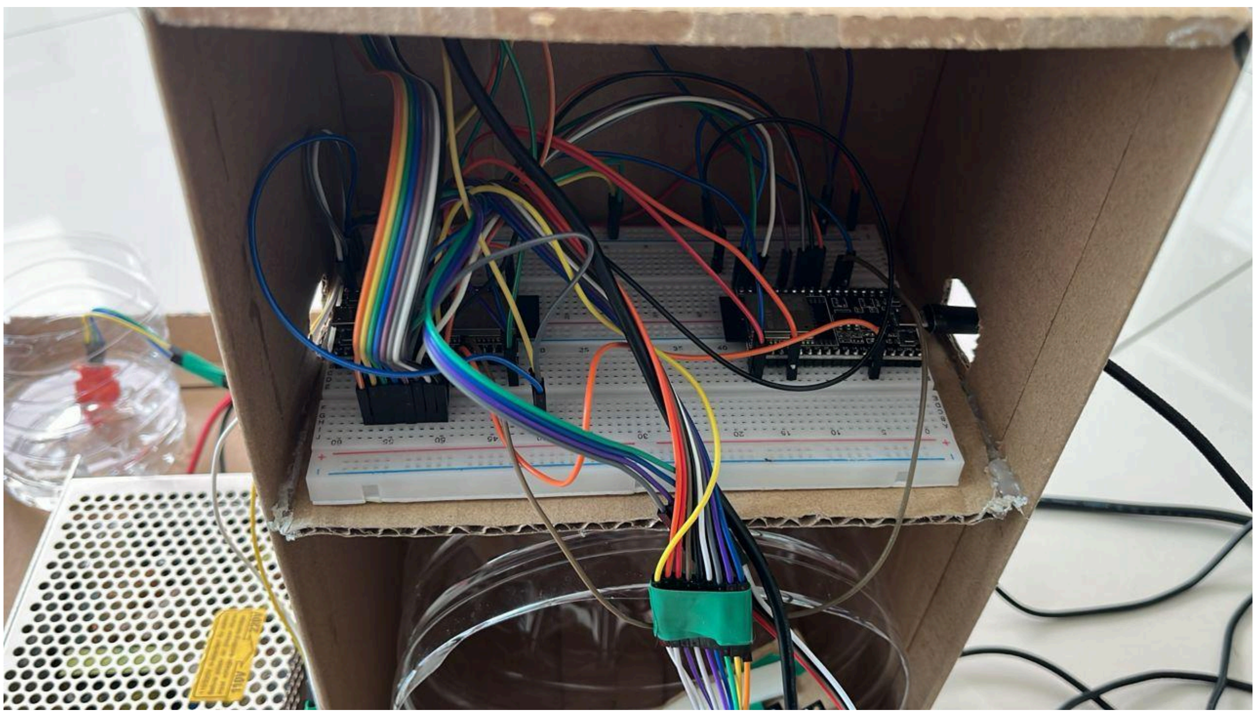
3.2 Design Problems

- **Structural Stability**: Using cardboard as the main material introduced limitations in terms of rigidity and load-bearing capacity. Care had to be taken to ensure the servo motor's motion didn’t destabilize the base or deform the structure over time.
- **Servo Mounting and Alignment**: Positioning the servo motor to properly rotate the bottle (drum) required precise alignment and a stable mounting surface inside a flexible material like cardboard, which was difficult to achieve and prone to shifting during operation.
- **Wiring and Component Arrangement**: With many components (TFT, sensors, two ESP32 boards, PixyCam, power supply) integrated into a compact space, managing and organizing the wiring became complex. Ensuring airflow and accessibility while keeping the wires hidden was a delicate balance.

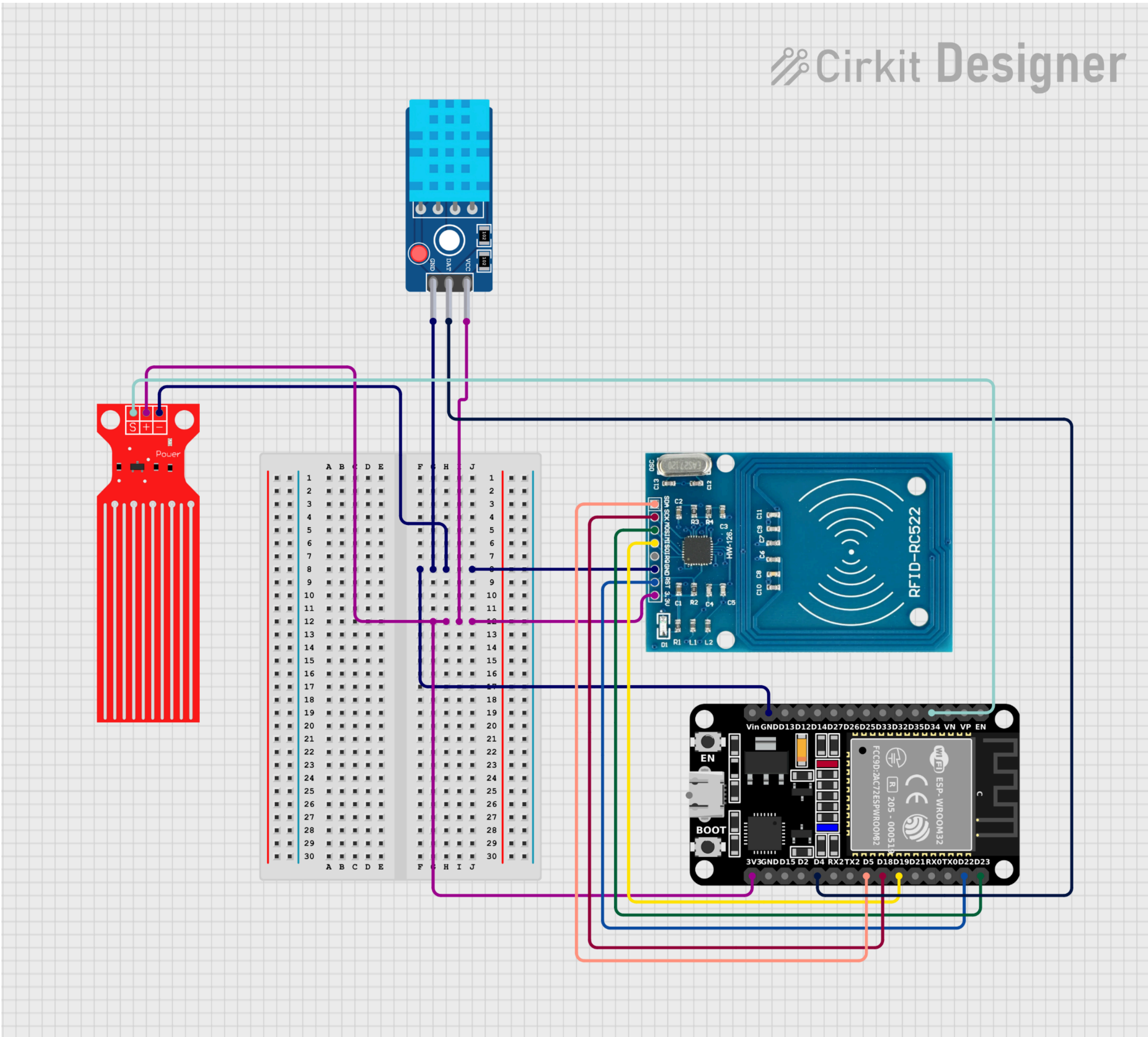
- **Limited Sensor Precision**: The use of basic sensors like the DHT11 and analog water sensor provided only approximate readings. Their limitations affected reliability in fluctuating environmental conditions, which could lead to inconsistent behavior during the prototype's operation.

4.0 Methodology

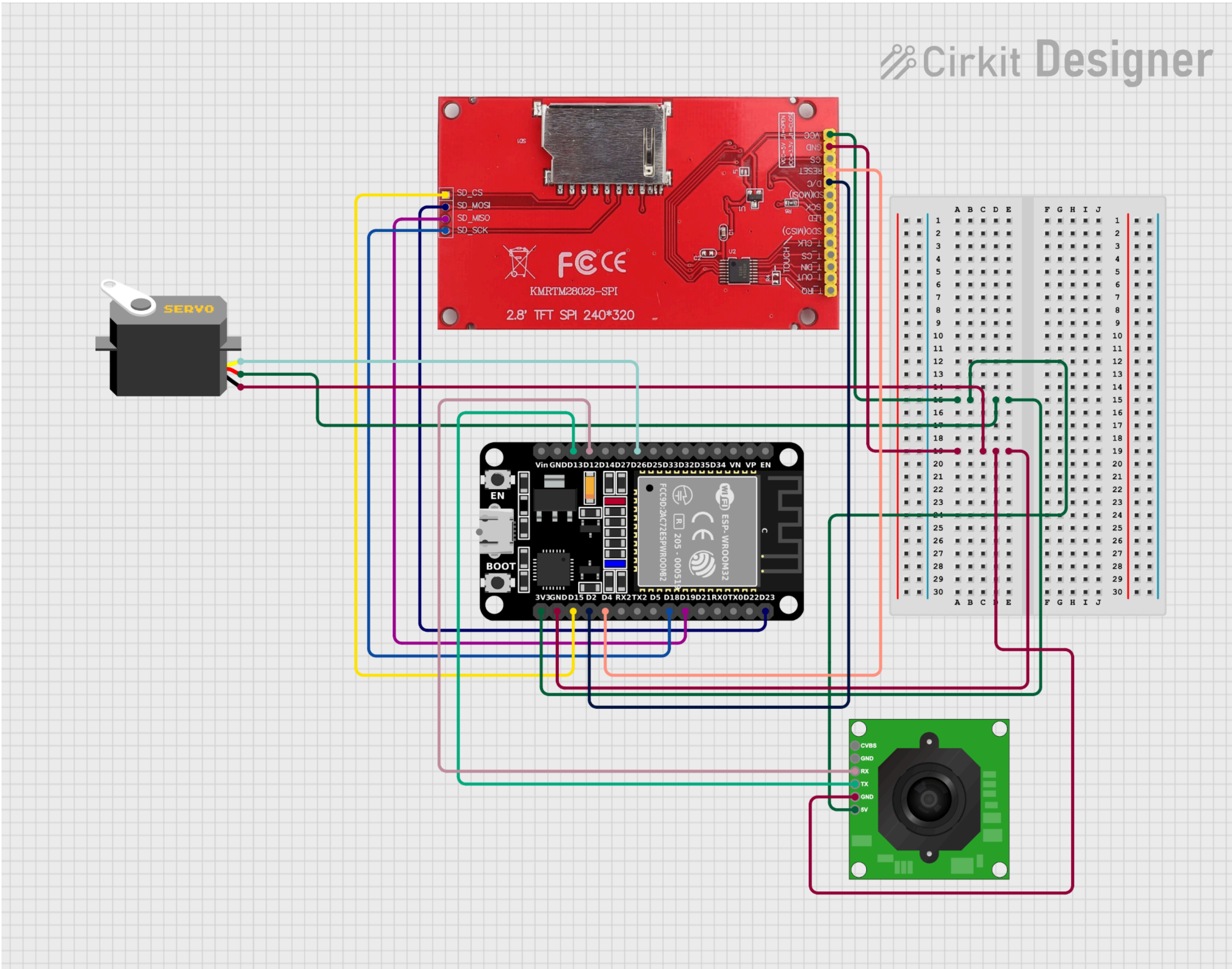
4.1 Wiring Setup



4.2 <u>Circuit Diagrams</u>



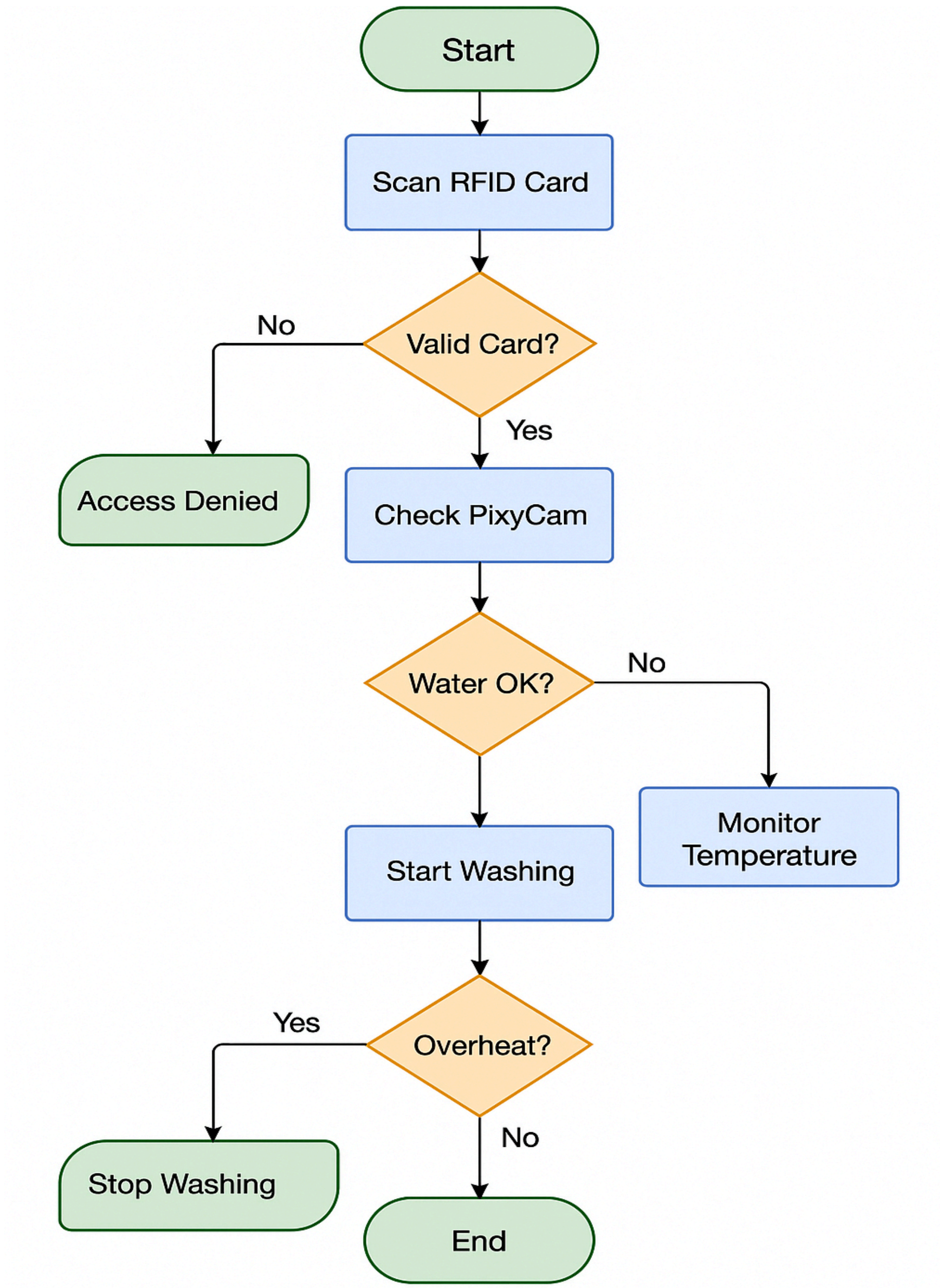
ESP32 A Circuit Diagram



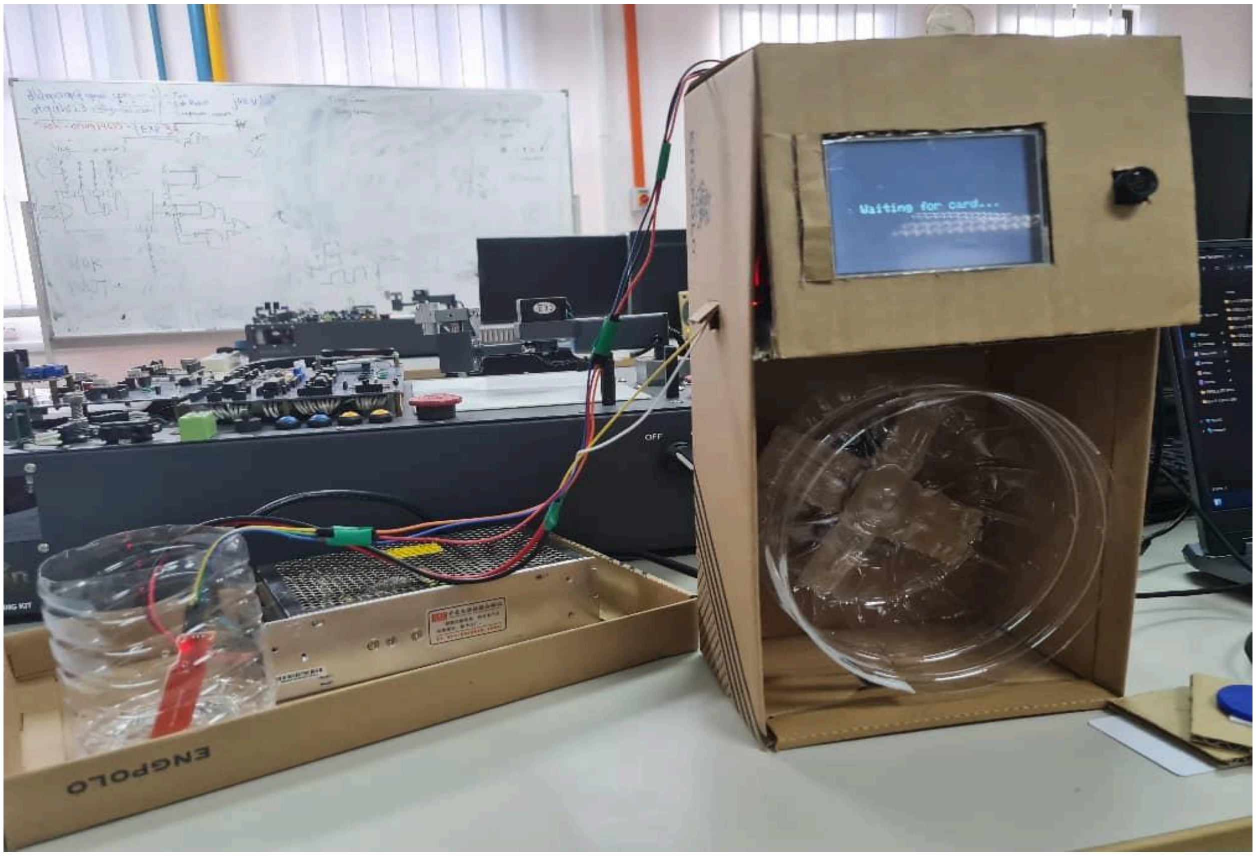
ESP32 B Circuit Diagram

5.0 Results

5.1 Flow Chart Diagram



5.2 Final Product



VIDEO EVIDENCE IN THE GOOGLE DRIVE

https://drive.google.com/drive/u/0/folders/1b14dYv27N4WcFf7P5Fv84UpkUt5krXRy

6.0 Discussion

The implementation of RFID authentication in the washing machine prototype serves as the first layer of user access control. By integrating an MFRC522 RFID reader with the ESP32 board, the system ensures that only authorized users can initiate the washing process. This adds a level of security and personalization, useful in shared environments such as hostels or laundromats. The use of unique RFID tags prevents unauthorized usage and creates an opportunity for user-specific wash settings in future iterations.

Another critical aspect of the system is its environmental sensing capability, which includes both water level and temperature monitoring. A water sensor connected to ESP32 A evaluates whether there is sufficient water in the drum to begin the washing cycle. If not, the system prompts the user to add water. Simultaneously, a DHT11 sensor monitors the ambient temperature to ensure the electronics and environment stay within safe operating conditions. If the temperature exceeds a defined threshold (35°C), the system halts operation to prevent overheating, demonstrating a built-in safety mechanism.

The use of a PixyCam for fabric color detection adds a smart sorting feature to the prototype. The camera detects predefined color signatures to identify whether the laundry load contains white or colored fabrics. Based on this input, the system can potentially adjust its washing logic to prevent color bleeding although in this prototype, it primarily serves as a proof-of-concept. The real-time communication between the PixyCam and ESP32 B via UART allows for efficient image processing and decision-making, laying the groundwork for further enhancements like stain detection or fabric type classification.

Finally, mechanical actuation and user feedback are handled by ESP32 B through a servo motor and TFT LCD display. The servo mimics the rotation of a washing drum by swinging between angles to simulate agitation during the wash. The display provides clear feedback to the user, showing messages like "Waiting for card," "Fill Water," or "Washing in progress." The entire process is synchronized through UART communication with ESP32 A, ensuring all actions occur in a logical and safe sequence. This modular division of tasks between the two ESP32 boards results in a reliable and easily extensible system architecture.

7.0 Conclusion

This project successfully demonstrates a functional prototype of a smart washing machine, combining multiple technologies to simulate automation, safety, and user convenience. By utilizing two ESP32 boards, the system was able to efficiently divide tasks between sensor input management and mechanical control, allowing for smoother operation and scalability. The integration of RFID for access control, temperature and water level sensors for environmental monitoring, and a PixyCam for color detection exemplifies the potential of embedded systems in enhancing household appliances.

Through modular design and UART communication, the prototype achieves real-time interaction between its subsystems. The process begins with secure RFID verification, followed by intelligent decision-making based on water availability and fabric color, and concludes with a simulated wash cycle using a servo motor. The use of a TFT display further enhances the user experience by providing immediate feedback and system status updates, ensuring that the user is always informed of the current operation.

The development process revealed valuable insights into system synchronization, hardware communication protocols, and the importance of error handling in embedded projects. Although this prototype covers the fundamental features of a smart washing machine, it also highlights certain limitations most notably, the lack of full automation in water management and the basic nature of its fabric detection system. These insights form a solid foundation for further iterations and refinements in future versions.

Looking ahead, the project holds strong potential for expansion into a fully autonomous, IoT-enabled washing solution. With enhancements such as automated water control, mobile connectivity, machine learning-based fabric analysis, and energy efficiency optimization, this system can evolve into a commercially viable smart appliance. Ultimately, this project not only meets its technical objectives but also showcases the transformative role that embedded systems can play in modernizing everyday household equipment.

8.0 Recommendations

One significant area for enhancement is the integration of a water flow control system, such as a solenoid valve connected to a pump or faucet, to automate the water filling process. Currently, the system only detects the water level and prompts the user to manually add water, which limits its autonomy. By enabling the system to control water input, the prototype could fully automate the washing cycle from start to finish. In addition, using more accurate sensors like ultrasonic or capacitive level sensors could provide finer control and improve reliability, especially in varied environmental conditions.

Another promising improvement involves expanding the intelligence and flexibility of the color detection system. At present, the PixyCam only differentiates between two color signatures (white and colored), which is sufficient for a basic prototype but limited in real-world applications. A more advanced camera module or machine learning integration could enable the system to detect patterns, stains, or fabric types, allowing for dynamic adjustment of wash cycles. Furthermore, pairing the system with a mobile app or cloud platform could offer remote monitoring, wash cycle customization, and even user-specific profiles—transforming the prototype into a fully-fledged smart appliance with real IoT capabilities.

9.0 References

1. *wiki:v1:teach_pixy_an_object [Documentation]*. (n.d.). https://docs.pixycam.com/wiki/doku.php?id=wiki:v1:teach_pixy_an_object
2. *Google Drive: Sign-in*. (n.d.). https://drive.google.com/drive/u/0/folders/1b14dYv27N4WcFf7P5Fv84UpkUt5krXRy

10.0 Acknowledgement

Special thanks to Dr. Wahju Sediono and Dr. Zulkifli Bin Zainal Abidin, as well as the teaching assistants and peers, for their guidance and support in completing this experiment.

11.0 Student's Declaration

Certificate of Originality and Authenticity

This is to certify that we are responsible for the work submitted in this report, that the original work is our own except as specified in the references and acknowledgement, and that the original work contained herein have not been untaken or done by unspecified sources or persons.

We hereby certify that this report has not been done by only one individual and all of us have contributed to the report. The length of contribution to the reports by each individual is noted within this certificate.

We also hereby certify that we have read and understand the content of the total report and no further improvement on the reports is needed from any of the individual's contributors to the report.

We therefore, agreed unanimously that this report shall be submitted for marking and this final printed report has been verified by us.

Name: Aiman Saifullah bin Aminnurllah	Read	/
Matric Number: 2319185	Understand	/
	Agree	/
Name: Akmal Fauzan Bin Azhar	Read	/
Matric Number: 2319531	Understand	/
	Agree	/

Name: Syafiq Helmie bin Saifullah Adha

Matric Number: 2316049

Read	/
Understand	/
Agree	/