Princess Sumaya جامعة
University الأميرة سميّة
for Technology للتكنولوجيا

Princess Sumaya University for Technology

King Abdullah II Faculty of Engineering

Computer Engineering Department

Embedded Systems & Microprocessors

Smart Vacuum Cleaner

Second Semester 2024

Authors:

Student Name:	Mira Hindawi	Aseel Abedalfattah	Mohammad AlJourishi
Student Number:	20210748	20201035	20201053
Specialisation: .	Computer Engineering	Network & Information Security Engineering	Computer Engineering

Supervisor:

Dr. Anastassia Gharib

May 26, 2024

Abstract

This report outlines the development of an automated vacuum cleaner controlled by a PIC16F877A microcontroller. The project's goal was to create an autonomous robotic cleaner that could identify and avoid obstacles with the use of ultrasonic sensors. It features two motors for directional movement and a fan for suction, controlled through PWM to optimise power usage. Based on sensor inputs, the vacuum cleaner modifies its path in real-time to effectively cover the cleaning area.

Table of contents

Introduction....... 4

Goals....... 4

Components Used....... 5

A) PIC16F877A Microcontroller....... 5

Figure 1: PIC16F877A and its pins....... 5

B) Ultrasonic sensors....... 6

Figure 2: Ultrasonic sensors....... 6

C) Motor Drivers (H-Bridge)....... 7

Figure 3: H-bridge....... 7

D) Fan....... 8

Figure 4: 12V Fan....... 8

Flow Chart....... 9

Figure 5: Flowchart....... 9

Electrical Design....... 10

Figure 6: Schematic Design....... 10

Layout....... 11

Figure 7: Left Side View of the Automated Vacuum Cleaner....... 11

Figure 8: Right Side View of the Automated Vacuum Cleaner....... 12

Figure 9: Top View of the Automated Vacuum Cleaner....... 12

Problems and Solutions....... 13

Sensor Blind Spots:....... 13

Component Damage:....... 13

Battery Drain:....... 13

Conclusion....... 14

References....... 15

Introduction

Robotic vacuum cleaners are one of the many house cleaning innovations that have resulted from the development of home automation and robotics. By minimising human labour and increasing cleaning efficiency, these devices are made to function independently. These robots evaluate environmental data in real time and perform excellent navigation through different home layouts thanks to embedded technologies, such the PIC16F877A microcontroller.

Goals

This project's primary goals were to:

1. Create an autonomous vacuum cleaner with ultrasonic sensors to navigate and avoid obstructions.
2. Use pulse width modulation (PWM) motor control to adjust the vacuum cleaner's speed for the best possible power and performance.
3. Increase the vacuum cleaner's operational efficiency by using precise movement control and sensor data interpretation.

The construction of the electrical and software architecture required to run an autonomous vacuum cleaner was the main goal of this project. Important pieces of hardware included motor drivers for exact control over the movement of the vacuum, ultrasonic sensors to aid navigation by detecting obstacles and calculating distances, and the PIC16F877A microprocessor for central processing. The main focus of the software development was to teach the microcontroller how to read sensor data, use PWM to regulate motor speeds, and efficiently coordinate the vacuum's cleaning and navigational functions.

Components Used

A) PIC16F877A Microcontroller

The PIC16F877A microcontroller serves as the brain of the vacuum cleaner, orchestrating all the crucial functions from navigation to suction control. It processes input from the sensors to make decisions on movement and obstacle avoidance, manages the PWM signals for motor control, and ensures efficient operation of the entire system. This versatile microcontroller boasts a range of features that make it an ideal choice for such automated tasks. With 40 pins, 35 of which are input/output pins, it offers ample connectivity for various sensors and actuators. Its programming capabilities are enhanced by 8K of program memory and 368 bytes of RAM, supporting complex algorithms and functions such as analog-to-digital conversion, timers, and PWM, essential for precise control in dynamic environments. The microcontroller's ability to handle multiple tasks simultaneously and its ease of use have made it a popular choice in fields ranging from electronic applications to industrial control. This robust architecture and versatility ensure that the microcontroller can efficiently process environmental data, manage energy consumption, and navigate complex terrains, making it the cornerstone of the vacuum cleaner's functionality.

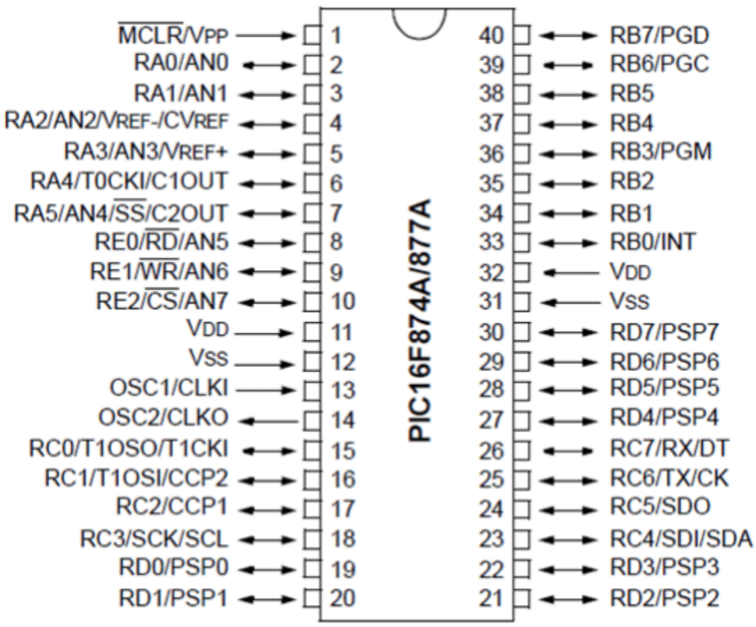

Figure 1: PIC16F877A and its pins

B) Ultrasonic sensors

Ultrasonic sensors are essential for the vacuum cleaner's autonomous navigation capabilities. They emit sound waves at ultrasonic frequencies and measure the echo received back, calculating the distance to nearby objects or obstacles. This functionality allows the vacuum to avoid collisions, efficiently plan its cleaning route, and maintain a safe distance from walls and furniture. The real-time distance measurement is crucial for adaptive path planning, enabling the cleaner to modify its course instantly based on environmental changes, thereby enhancing its effectiveness in varied and dynamic home environments.

The HC-SR04 ultrasonic sensor, utilised in this project, is specifically designed for accurate distance measurement. It features four pins, two of which are used for power supply and ground connections. The sensor’s trigger pin is connected to a designated output port on the microcontroller, and the echo pin is set as an input. When the microcontroller sends a 10 µS high-level signal to the trigger pin, the sensor emits eight ultrasonic pulses. These pulses bounce off objects and return to the sensor. The duration for which the echo pin remains high directly correlates with the time taken for the pulses to travel to the object and back, allowing for precise distance measurements. This precision is integral to the vacuum cleaner’s ability to navigate complex environments efficiently and safely.

Figure 2: Ultrasonic sensors

C) Motor Drivers (H-Bridge)

The H-Bridge circuits in particular are essential for regulating the motors of the vacuum cleaner's bidirectional functioning. These circuits provide the motors the ability to go forward and backward, which is necessary for complex movements in small areas. PWM signals enable exact modifications to the vacuum's speed and direction, enabling optimal area coverage and effective obstacle navigation. This control over the motors' direction and speed makes this possible. The H-Bridge drivers are essential to the functioning of the vacuum because they offer strong motor control, guaranteeing dependability and motion stability. Furthermore, the H-Bridge arrangement allows for a variety of motor combinations, providing versatility in motor control systems and improving the robot's capacity to adapt to various cleaning requirements and terrains.

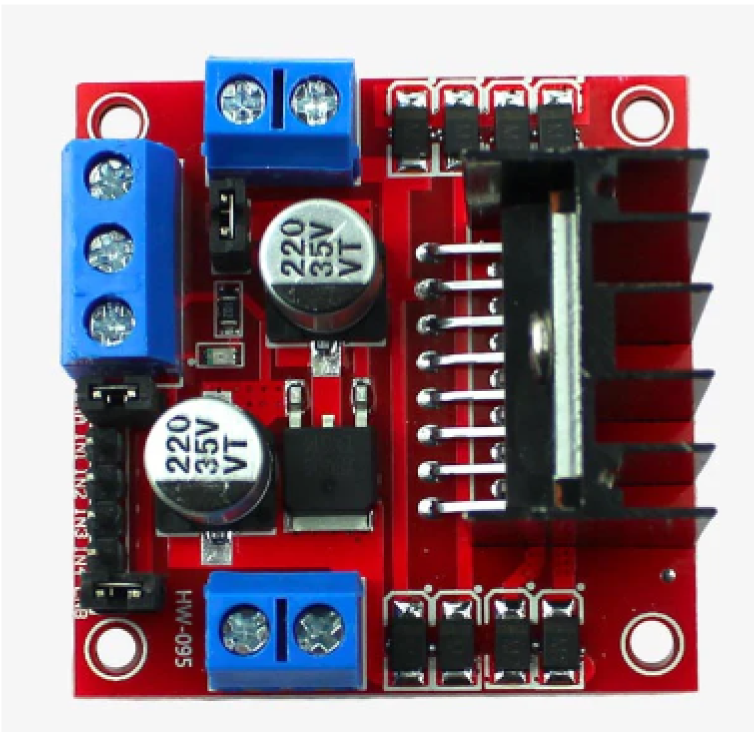

Figure 3: H-bridge

D) Fan

The primary element responsible for creating the suction force needed to lift rubbish and dirt off the floor is the fan. It is crucial for the vacuum cleaner's functionality, with its power output carefully controlled by the microcontroller. Depending on the type of surface being cleaned and the volume of debris, the fan's speed may be dynamically adjusted using PWM. This allows for precise control over the suction power, tailoring it to different cleaning conditions, whether it's smooth hardwood or dense carpet. The ability to modify the fan speed not only optimises energy use but also enhances the overall efficiency of the cleaning process. This dynamic control mechanism ensures that the vacuum cleaner can maintain high cleaning performance across various environments, effectively adapting to meet the demands of different floor types and levels of dirt accumulation.

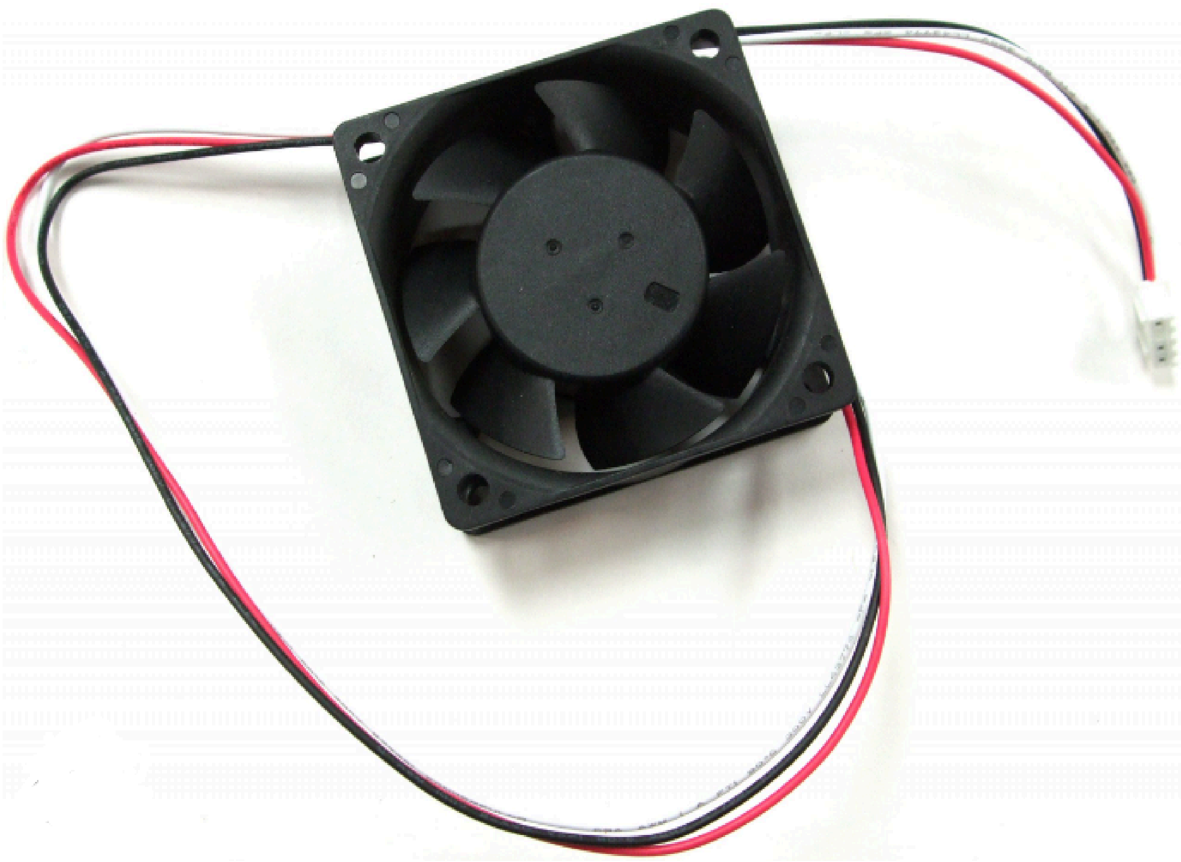

Figure 4: 12V Fan

Flow Chart

The flowchart delineates the navigational logic of our automated vacuum cleaner. It begins with system initialization and continues with real-time ultrasonic sensing to determine the proximity of obstacles. If an obstacle is detected within a 20 cm range, the vacuum cleaner adjusts its path accordingly, choosing to move right or left to avoid collisions and maintain continuous cleaning efficiency. This simple yet effective decision-making process ensures optimal navigation and cleaning across various environments.

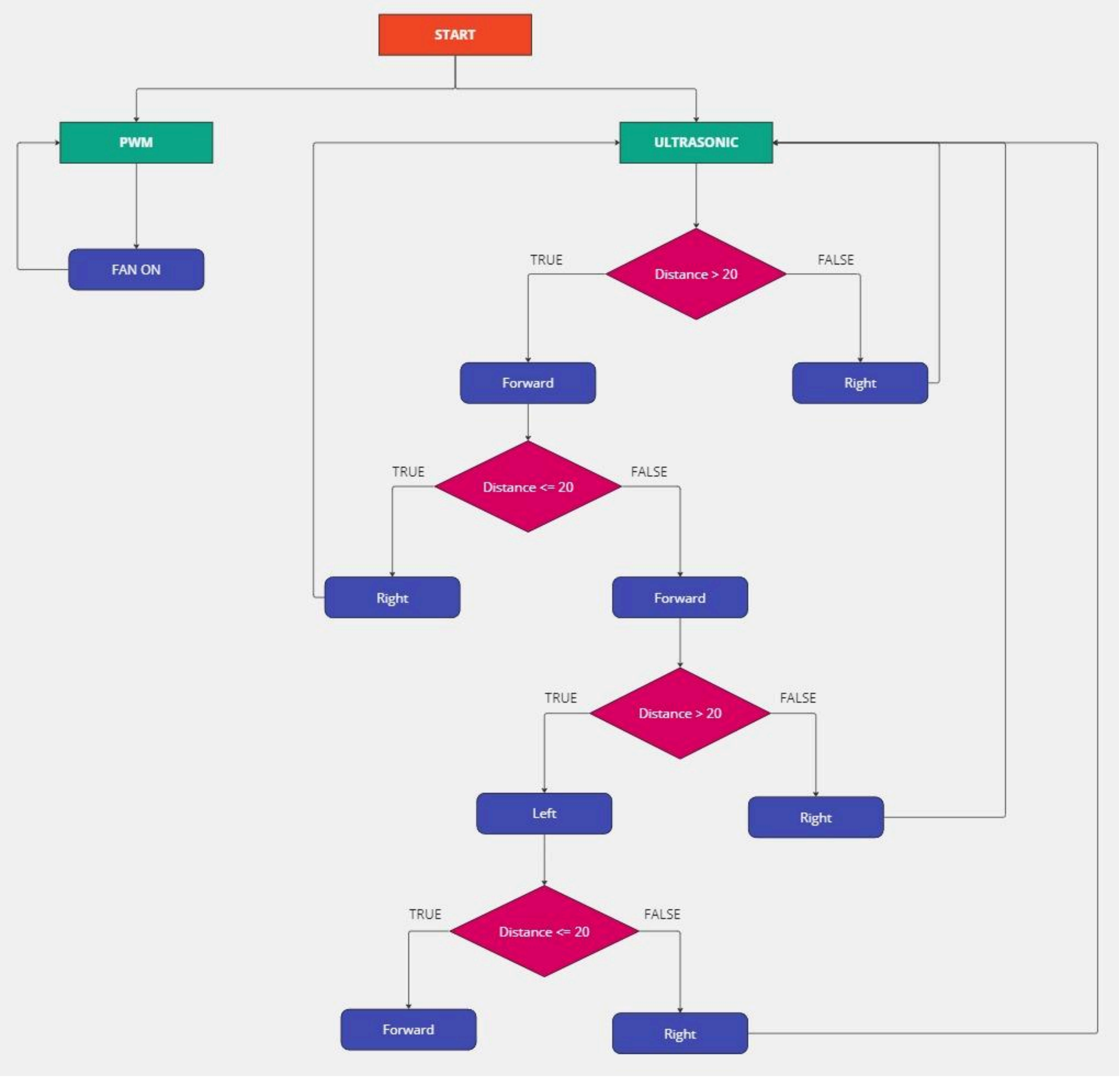

Figure 5: Flowchart

Electrical Design

This schematic diagram represents the electrical design of our automated vacuum cleaner project. It shows how the PIC16F877A microcontroller is connected to motors, an ultrasonic sensor, and power modules, ensuring coordinated control and navigation. The diagram details the use of an H-Bridge for precise motor control and an ultrasonic sensor for reliable obstacle detection. This setup highlights the streamlined connectivity and functionality essential for the vacuum cleaner's operation. An 8MHz oscillator was used here.

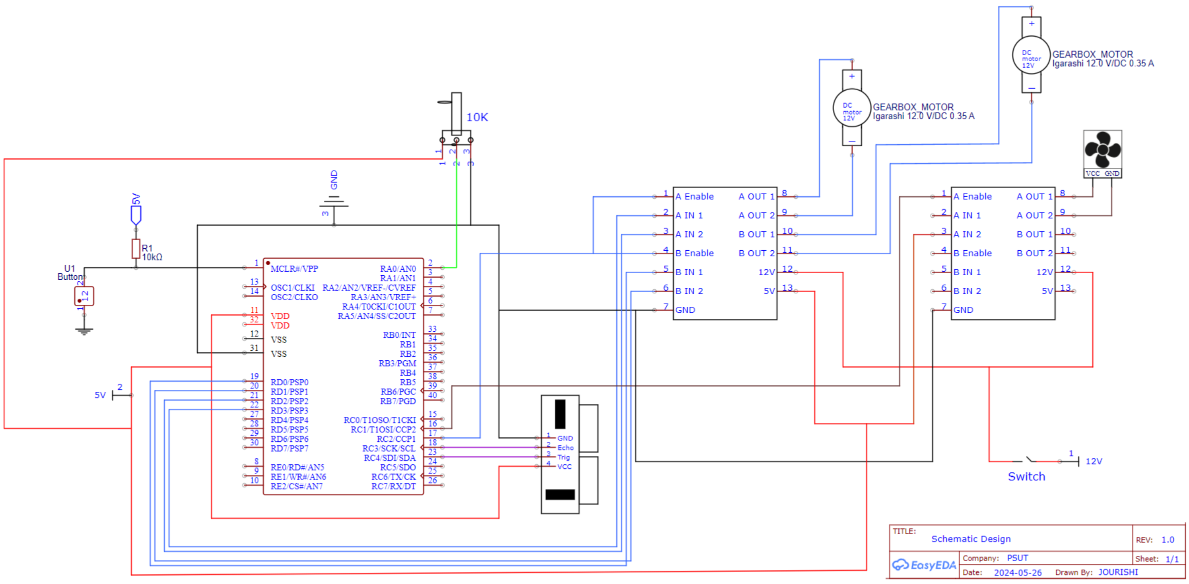

Figure 6: Schematic Design

Layout

The layout of our automated vacuum cleaner is strategically designed to optimise both functionality and ease of maintenance.The following pictures show where the motors, ultrasonic sensors, microcontroller, fan, and power supply are located in relation to other crucial parts of the chassis. Every element is arranged to optimise both navigational and cleaning performance in terms of efficiency and effectiveness. The design guarantees that the vacuum cleaner is both lightweight and strong enough to tackle a range of cleaning conditions, with simple access to all parts for maintenance and repairs.

This careful arrangement not only enhances operational efficiency but also contributes to the robustness and reliability of the device, ensuring it performs optimally in a real-world domestic setting.

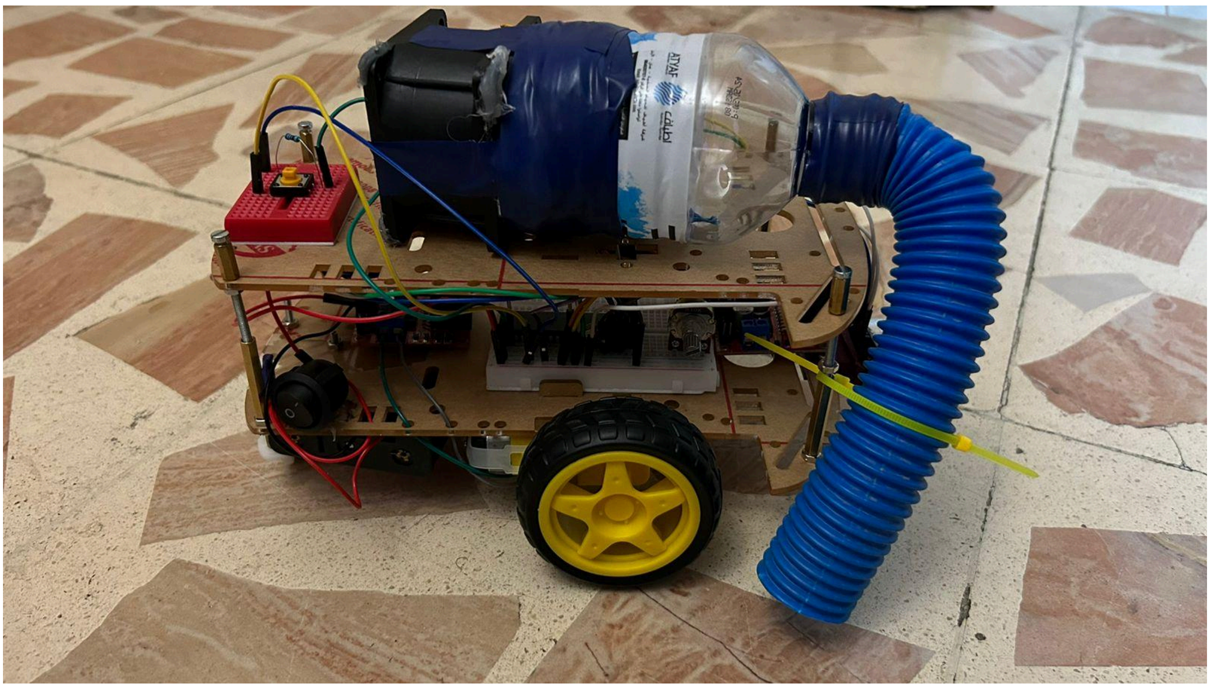

Figure 7: Left Side View of the Automated Vacuum Cleaner

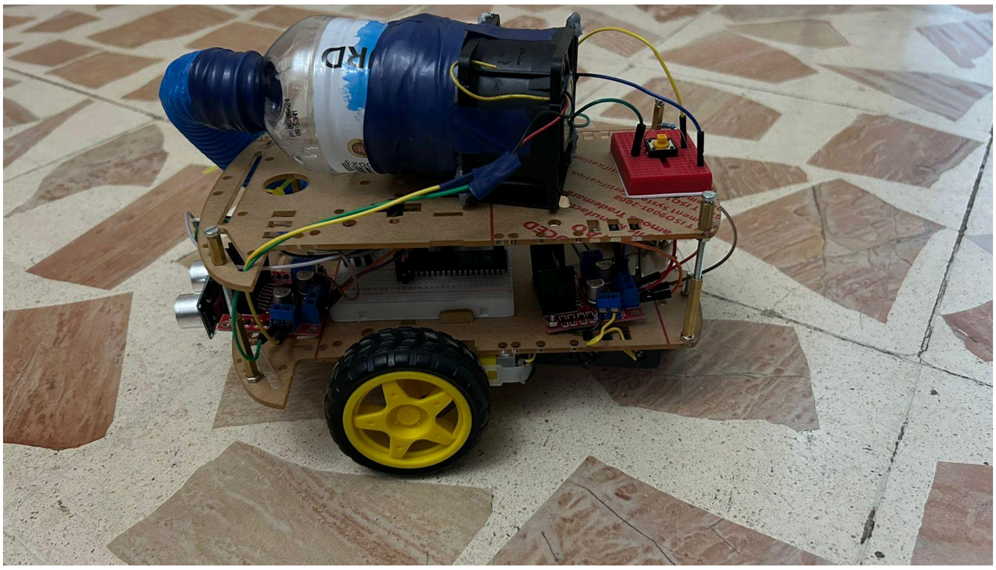

Figure 8: Right Side View of the Automated Vacuum Cleaner

Figure 9: Top View of the Automated Vacuum Cleaner

Problems and Solutions

The project faced a number of significant obstacles during the testing period, which were carefully resolved to guarantee the vacuum cleaner's performance and dependability:

Sensor Blind Spots:

Early testing showed that there were blind spots in the sensor coverage, which caused some places to be frequently ignored. To provide thorough area coverage, the sensors' angles were adjusted, and the navigation algorithm was changed to incorporate overlapping directions.

Component Damage:

Overheating and unintentional exposure to water caused damage to a few electronic components, including sensors and a motor driver. Rapid action was required in reaction to these accidents; in order to reduce downtime and guarantee ongoing testing and development, damaged components were quickly replaced with new ones.

Battery Drain:

The vacuum's battery consumption was more than expected, resulting in a shorter operating duration between charges. Improving the PWM control for the motors and fan improved power management and extended battery life.

Conclusion

This project successfully demonstrates the design and implementation of an automated vacuum cleaner controlled via a PIC16F877A microcontroller. Key objectives such as autonomous navigation, obstacle avoidance, and effective cleaning across various surfaces were achieved. The integration of components like ultrasonic sensors, motors, and a PWM-controlled fan ensured that the cleaner operates efficiently and adapts to different environmental conditions.

The project was completed within a budget of 80 Jordanian Dinars (JOD), which included procurement, assembly, and unforeseen expenses such as replacing damaged components. Staying within this budget highlighted the project's cost-effectiveness and showcased our team’s ability to manage resources efficiently.

References

https://ww1.microchip.com/downloads/en/devicedoc/39582b.pdf

https://download.mikroe.com/documents/compilers/mikroc/pic/mikroc-pic-manual-v101.pdf

https://www.youtube.com/watch?v=Wkqq0oNuiN8

https://www.youtube.com/watch?v=NVM42Vm6e6gv