Princess Sumaya University for Technology

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Engineering Department

Embedded Systems Final Report

22442

Final Project Report

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Abstract

The project aims to create an automatic vacuum cleaner that uses the PIC16F778A microcontroller to control a vehicle with two DC motors for movement and one for suction. The robot will automatically move in a path and clean what is in its way until it senses an obstacle using one of three ultrasonic sensors and steer accordingly. The DC motor for the fan will be attached to an H-bridge to allow for a blow function. The robot will be able to tell when the storage is full using an IR sensor.

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Introduction

Robotic vacuum cleaners, or roombas, have been a household item for many years. They are the logical use of new technologies and innovations, minimising human labor and letting machines do all the work. They are more efficient in cleaning and electrical consumption than the regular vacuum cleaner. Obviously such a machine will need a microcontroller which makes it a perfect display of the usefulness of the PIC16F877A.

Objectives

The main goals of this project were:

1. To build a self-driving vacuum cleaner that uses ultrasonic sensors to move around and avoid obstacles.
2. To control the vacuum cleaner's speed using pulse width modulation (PWM) for better power and performance.
3. To give the vacuum cleaner a blow function by attaching the fan DC motor to an H-bridge.

These goals set for the project aim to test certain capabilities of the PIC16F877A such as reading data from sensors (IR and ultrasonic in this case) and controlling motors with PWM.

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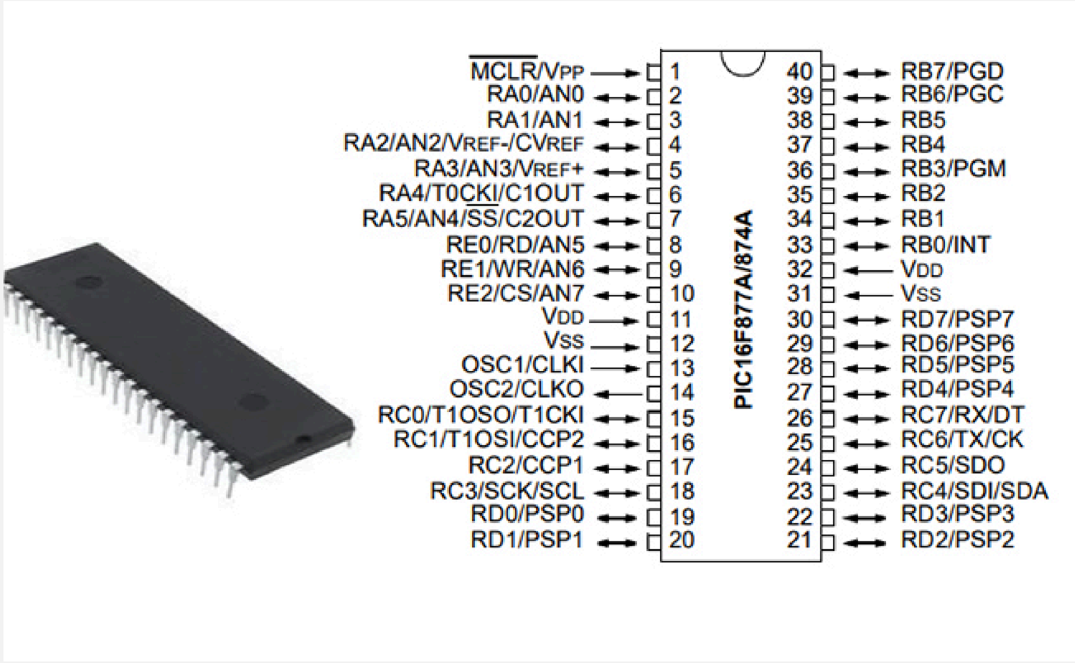
Components Used:

A) PIC16F877A Microcontroller:

The PIC16F877A microcontroller is basically the "brain" of the robotic vacuum cleaner, taking care of all the main tasks like moving around, avoiding obstacles, and controlling the suction. It does this by reading information from various sensors and deciding how to respond, while also generating PWM signals to drive the motors at the right speeds and ensure smooth operation. With 40 pins (35 of them serving as input/output), it easily connects to sensors and motors, and its 8K of program memory and 368 bytes of RAM provide enough space to run complex algorithms needed for precise control. Features like analog-to-digital conversion, timers, and PWM allow the vacuum cleaner to quickly adapt to changes in its environment, and the microcontroller's multitasking ability and user-friendly design have made it popular in many electronic and industrial projects. Thanks to its robust architecture and flexibility, the PIC16F877A can efficiently handle sensor data, manage power usage, and navigate challenging floor layouts, making it a crucial component in the functionality of a robotic vacuum cleaner.

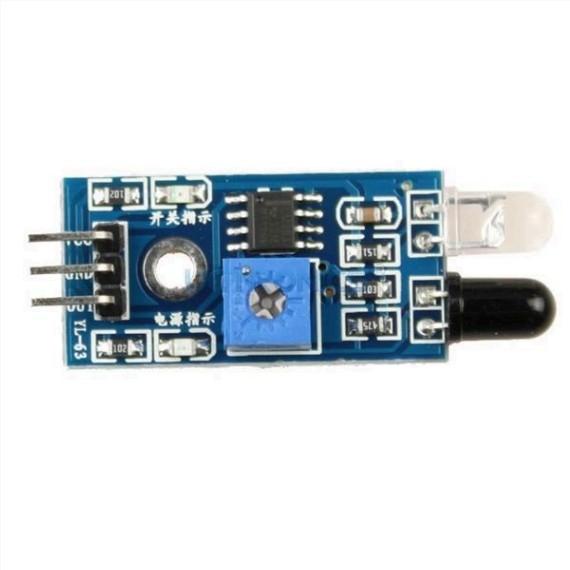


B) Ultrasonic Sensors:

Ultrasonic sensors are an important part of the vacuum cleaner's ability to move on its own. They send out ultrasonic sound waves and measure the time it takes for the echoes to return. This helps calculate the distance to objects or obstacles, allowing the vacuum to avoid collisions, plan its cleaning path efficiently, and maintain a safe distance from walls and furniture. The ability to measure distances in real time helps the vacuum quickly adjust its path based on changes in its surroundings, making it more effective in different and busy home environments. For this project, the HC-SR04 ultrasonic sensor is used to measure distances accurately. It has four pins: two for power and ground, one trigger pin connected to the microcontroller to send signals, and one echo pin to receive signals. The microcontroller sends a short signal to the trigger pin, which makes the sensor emit eight ultrasonic sound waves. These waves bounce off objects and return to the sensor. The time the echo pin stays active shows how long it took for the sound waves to travel to the object and back, allowing the system to calculate the distance precisely. This accuracy helps the vacuum cleaner navigate efficiently and safely in complex environments.

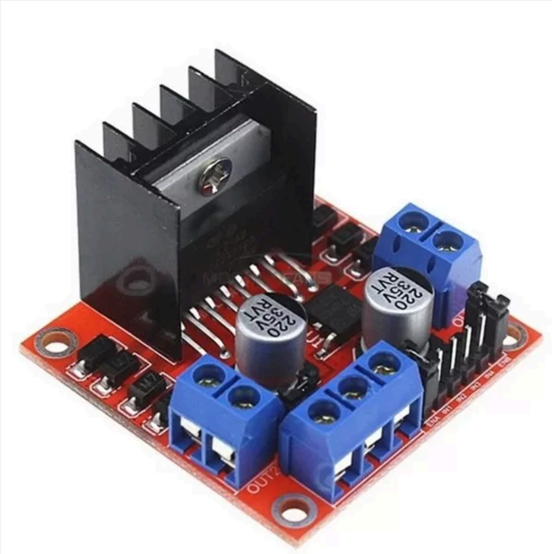
C) **Infrared (IR) Sensors:**

Infrared sensors, or IR sensors emit infrared waves and sense the radiation emitted by the objects hit by the infrared waves. These infrared waves allow the sensor to detect movement of objects. In this project the main goal of the IR sensor was to detect when garbage is filling the storage unit and stop the system. The IR sensor we used has 3 pins, 1 for VCC, 1 for ground, and 1 for output. The output is active low, meaning until the IR sensor detects anything the output remains 1. The IR sensor uses a potentiometer allowing us to adjust the distance it is triggered at.



D) **H-Bridge:**

The h-bridge is one of the most important parts of the project. For one, they are how the DC motors and the fan are provided current. The h-bridge has 2 pins for the power source, which are connected to the 12V lithium battery, 4 pins to provide current to 2 different components, 4 pins to the activation and direction of the current reaching the components, and a 5V out pin. The h-bridges were used to control the DC motors to move the vacuum cleaner forward and to change the current direction to turn the vacuum cleaner left or right. The h-bridge was also used to activate and turn off the fan. Instead of using a separate power source the 5V out from the h-bridge was used to power the PIC16F877A. Considering the limit of the current output of the PIC16F877A the h-bridges are required to control the higher current elements like the motors

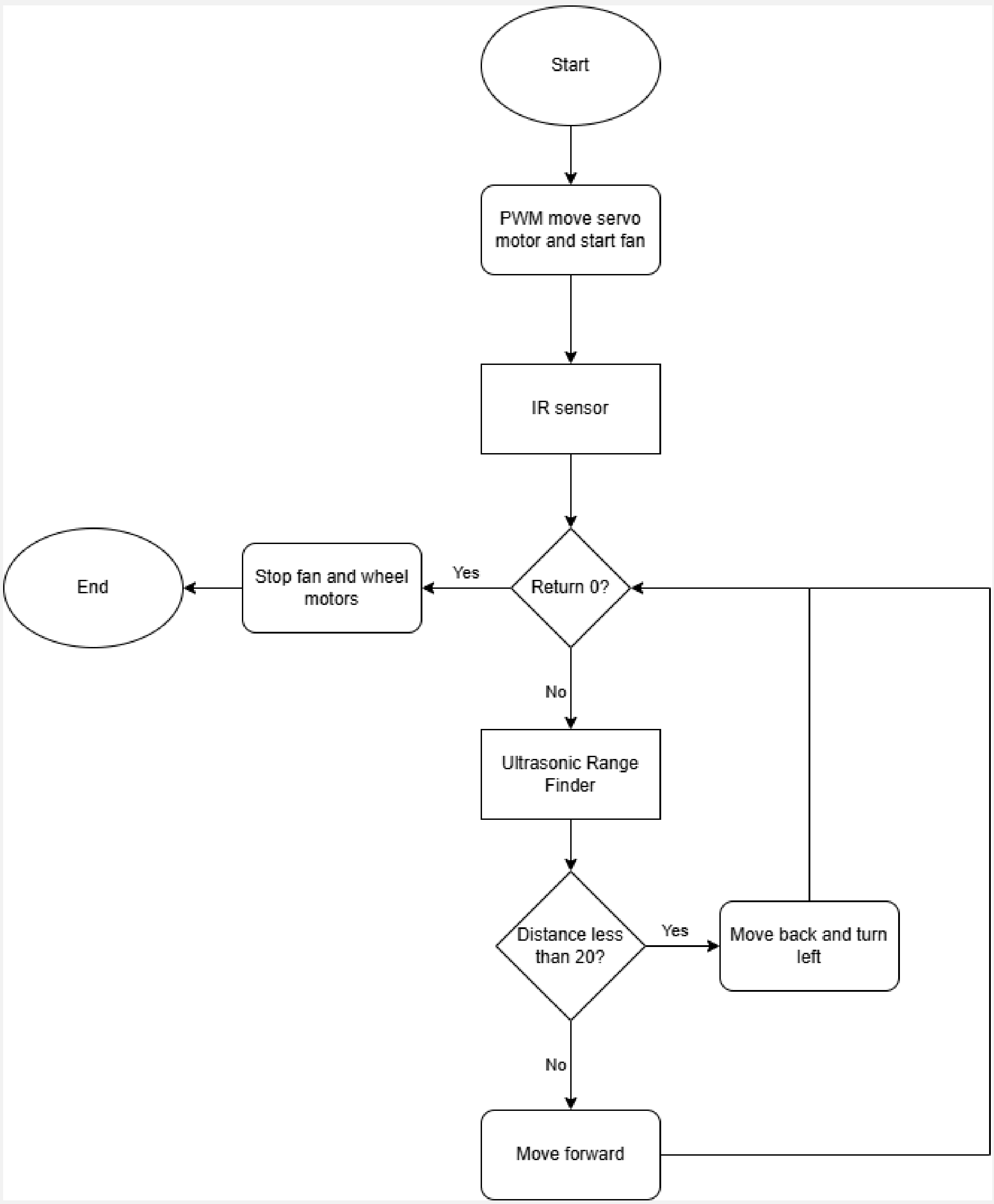


E) Fan:

The fan is the main component that creates the airflow needed to pick up dirt and debris from the floor, but it can also blow air out when necessary. This is achieved by using an H-bridge, which allows the microcontroller to reverse the fan’s direction. By sending PWM signals, the microcontroller can finely control the fan’s speed and direction, adjusting how much air is sucked in or blown out depending on the type of surface and the amount of debris. This dynamic control helps save energy and keeps cleaning efficient, whether it’s on smooth hardwood floors or thick carpets, ensuring the vacuum can tackle different messes effectively.

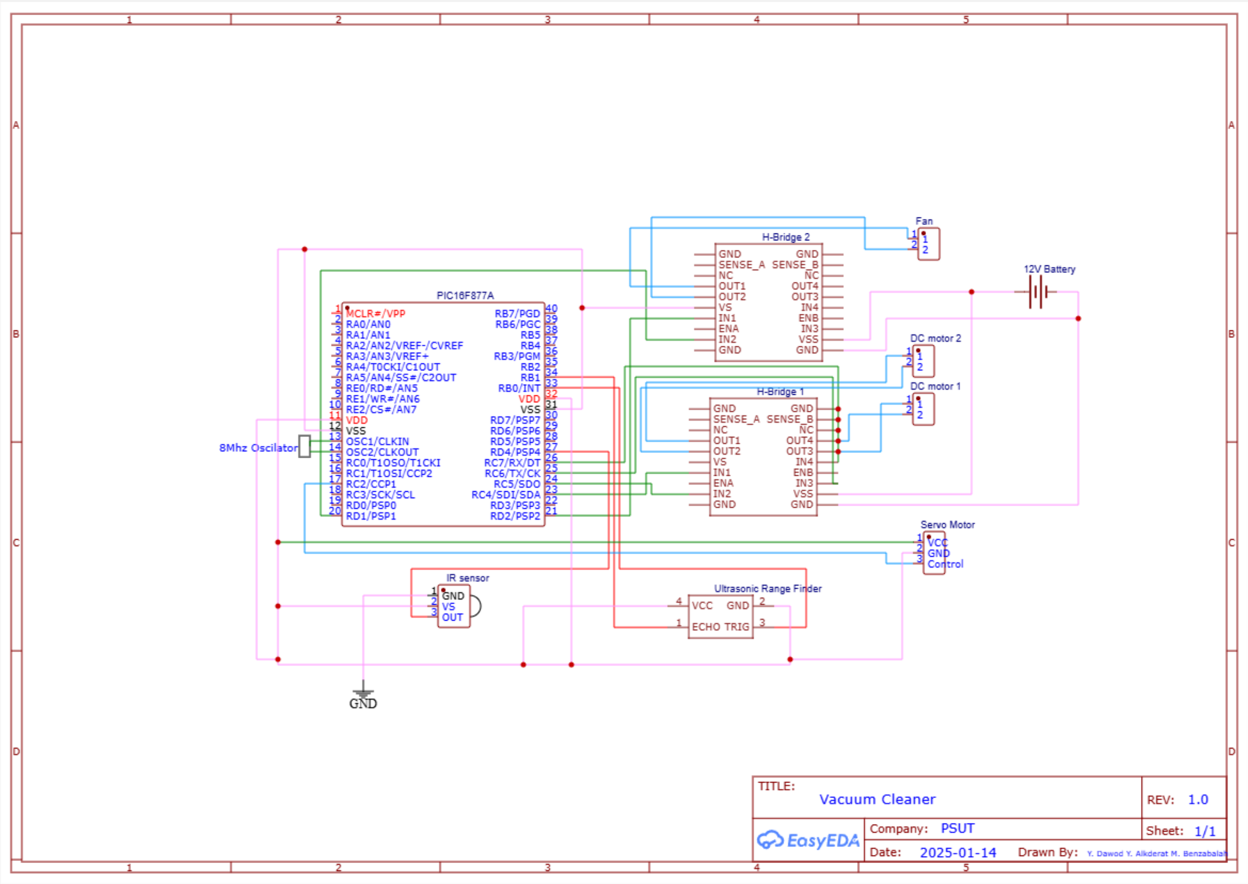
Logic Flowchart:

The code logic of the robot follows a simple and effective plan. To start with the servo motor is activated and the fan starts working, following that the first order of operations is to check through the IR sensor that the garbage storage is not full, if it is full the robot stops then and there, if not it goes to the next step. After making sure that the storage is not full the robot checks to make sure the path forward is clear, if it is the robot starts moving forward, if not the robot backs up and turns left. Either way after that the robot goes back a step to check the storage and the loop repeats.



Electrical Design:

The electrical design shown in the figure shows the efficiency of our design. The 12V lithium battery powers both the wheel DC motor controlling h-bridge as well as the fan controlling h-bridge. The PIC microcontroller itself is powered by the 5V out of one of the h-bridges instead of needing a step down or a separate power source. The PIC microcontroller controls both h-bridges and receives data from the IR sensor as well as the ultrasonic sensor. As the servo motor does not need as much current as the wheel DC motors it is powered by the same source as the PIC microcontroller.



Challenges and Solutions:

1)Brushless Motors:

Our initial plans were to add a blow feature to the vacuum cleaner, however, we found that all fans use brushless motors meaning that we can not reverse the direction of the fan and when we tried to do so the fan overheated. We decided to switch our goal from a vacuum cleaner with a blow function to a more useful feature, a vacuum cleaner that stops trying to clean when capacity fills up.

2)Falling Over:

When we first started the robot would scan for obstructions and move forward too quickly, causing it to topple over. We played around with adding delays between each 2 consecutive motions making the robot more stable and stopping it from toppling over.

3)Battery Issues:

The battery used for the project was perfect for the job, however it did not come with a charger and testing the robot had consumed a decent amount of the battery charge. Even tho we could not find a charger for purchase we eventually found someone who was willing to help us with the charge so we could simply use his charger every time we use up the battery.

Conclusion:

This project successfully showcased the design and implementation of our vacuum cleaner controlled by a PIC16F877A microcontroller. It achieved key goals, including autonomous navigation, obstacle avoidance, and effective cleaning. The seamless integration of components such as ultrasonic sensors, motors, and a PWM-controlled fan ensured efficient operation and adaptability to various different conditions. The total project cost was about 63 JOD, covering the components and their assembly, this also includes expenses like replacing damaged components. Completing the project within this budget emphasized its cost-effectiveness and demonstrated our team’s ability to manage resources effectively.

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