Princess Sumaya University for Technology

King Abdullah II Faculty of Engineering

Embedded Systems & Microprocessors

“AUTOMATED CAR FIRE EXTINGUISHER”
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Abstract

In this project, a PIC16F877A microcontroller was utilized to design and implement an automated robot capable of detecting and suppressing fires. The system incorporates ultrasonic sensors for obstacle detection, flame sensors for fire detection, and a range of additional components to ensure reliable functionality. The robot is equipped with motorized controls for navigation.

The project successfully achieved its goal of creating a compact, efficient, and responsive fire-detecting robot. Rigorous testing demonstrated its ability to detect fire, navigate autonomously, and activate the suppression mechanism effectively, showcasing its potential to contribute to safer environments.

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I. Introduction

In a world increasingly driven by technological innovation, the integration of automation into safety systems has become a cornerstone of modern problem-solving. Among the most pressing challenges in today's society is the need for advanced firefighting solutions that surpass the limitations of traditional methods.

Conventional firefighting techniques often struggle to address critical issues such as accessing confined or hazardous spaces, accurately identifying fire sources, and deploying resources efficiently. These methods are not only resource-intensive but also pose significant risks to human firefighters, especially in extreme and unpredictable scenarios.

To address these challenges, we have developed a fire-detecting and extinguishing robot. Despite its compact size, this robotic system is equipped with sophisticated flame and ultrasonic sensors, intelligent motor controls, and an automated fire suppression mechanism. The robot is designed to autonomously navigate its environment, detect fires, and implement immediate countermeasures, all while minimizing human exposure to dangerous conditions.

By harnessing this innovative technology, the project aims to redefine firefighting efficiency, improve response times, and significantly enhance safety during critical incidents, marking a significant step toward a safer and more resilient future.

Main Idea of the Designed Project

The designed project has two main objectives: navigating its surroundings to avoid obstacles and detecting and extinguishing fires in the detected area.

The following are the main components used for each part:
To navigate surroundings:

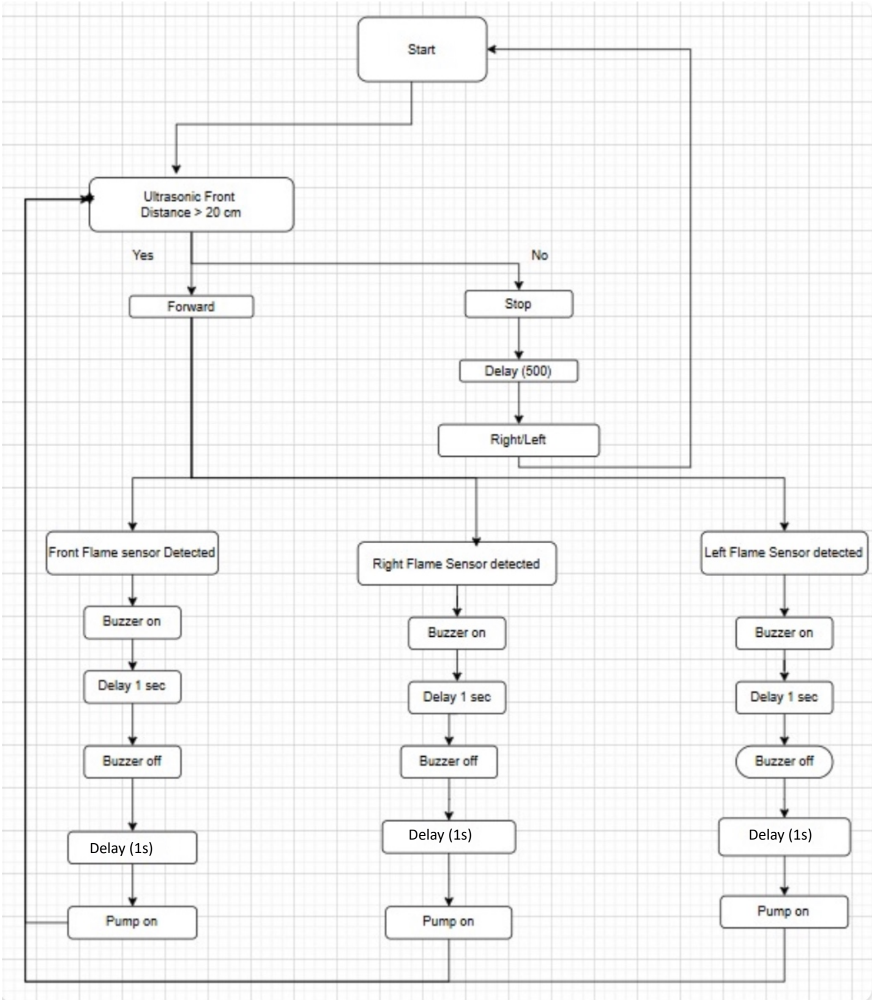
Ultrasonic Sensor: Detects the distance between the robot and obstacles, ensuring smooth navigation without collisions.
DC Motors with Dual H-Bridge: Powers the robot's movement and provides precise control for navigation.
To detect and extinguish fires:

Flame Sensors (3 units): Detect the presence of fire and determine its location.
Relay and Pump: The relay acts as a switch, activating the pump to extinguish the fire.
Process Description:
The robot begins by navigating its environment using the ultrasonic sensor to avoid obstacles. During this movement, the flame sensors continuously monitor the surroundings for any sign of fire.

Fire Detection:
If a flame sensor detects a fire, it sends a signal to the microcontroller to pinpoint the location.
The microcontroller records the angle and directs the car.

Alert and Extinguishing:
A relay activates the water pump to extinguish the fire while the robot remains stationary.

Safe Environment:
If no fire is detected, the microcontroller continues to guide the robot to move to the next area for further assessment.
By integrating these components and processes, the robot provides an autonomous solution to fire detection and suppression while ensuring safe and efficient navigation in its surroundings.



The following is a flow diagram that represents the design of the project:

Figure (1): Flow Diagram

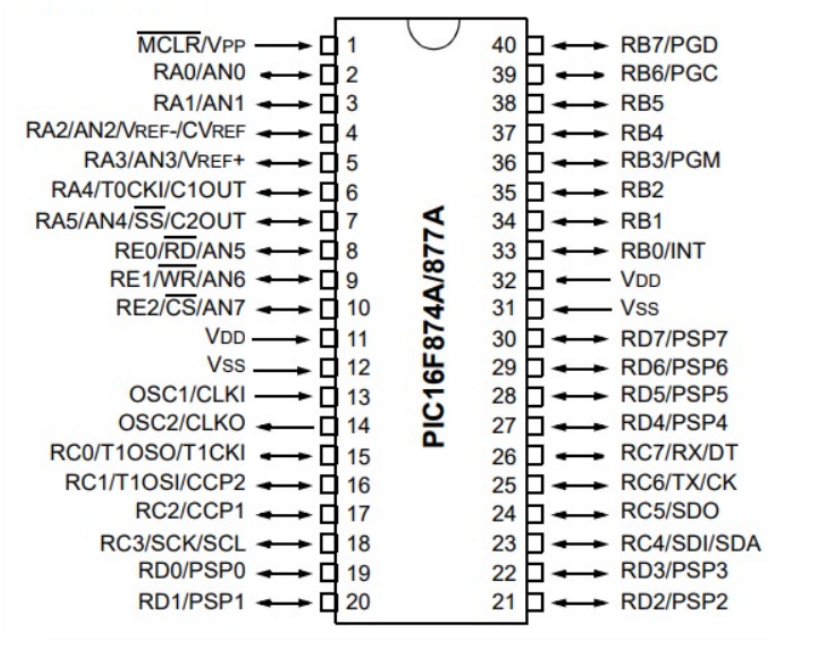
II. Overview of the Used Components

This section will provide a concise overview of the components employed in our project and outline the methods through which we incorporated them.

A. PIN16F877A Microcontroller

The PIC16F877A is a widely used microcontroller that has 40 pins, 35 of which are I/O pins. It comes with many built-in functions, such as timers,
ADC, and PWM. It's used in lots of different fields like industrial control systems, home automation and IoT. It features 8K of program memory and 368 bytes of RAM, which makes it unique in the industry. The PIC16F877A stands as a user-friendly, contributing to its widespread popularity.

In Figure 2, you can see what the PIC16F877A looks like and where its output pins are.



Figure(2): PIC17F877A Pins

The following table illustrates the pins of the microcontroller and how they were used:

Pin Number	**Port Name**	**Use**
33	RB0	Flame Sensor - Front
34	RB1	Flame Sensor - Left
35	RB2	Flame Sensor - Right
36	RB3	Ultrasonic Sensor Trigger Pin
37	RB4	Ultrasonic Sensor Echo Pin
22	RC2	Servo Motor (PWM - CCP1)
23	RC4	Left Motor - Forward
24	RC5	Left Motor - Backward
25	RC6	Right Motor - Forward
26	RC7	Right Motor - Backward
27	RD0	Relay for Pump Control

This table aligns with your code definitions and provides clear connections for your project.

Academic Report Table (1) 8

B. Flame Sensor

The flame sensor Model FC-01-H is a device designed to detect the presence of flames. It works by sensing the infrared light emitted by flames. When it detects a flame, the sensor sends a signal, indicating that a fire is present.
This type of flame sensor is commonly used in various applications, such as fire detection systems and robotics, to provide a quick response to potential fire hazards.

Figure (3): Flame Sensor

The flame sensor has four pins, we used three of them:

- GND pin that is connected to the breadboard's ground.
- VCC pin that connected to an external 5V DC power supply, which is the H-Bridge.
- Digital output pin connected to the output pins RB0, RB1 and RB2 on the PIC16F877A, such that the flame sensor that's placed in the front, left and right is linked .

C. Ultrasonic Sensor

The ultrasonic sensor Model HC-SR04 is a distance measuring device. It operates by sending ultrasonic waves and measuring the time it takes for the waves to bounce back after hitting an object. This sensor consists of a transmitter that emits ultrasonic pulses and a receiver that detects the reflected signals.

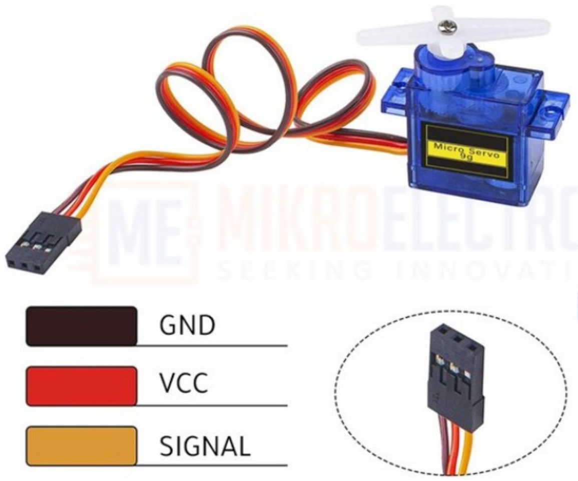
Figure(4): Ultrasonic Sensor

The ultrasonic sensor used in this project was linked to the PIC16F877A as follows:

- Triggering pin was connected to the output pin RB3 of the microcontroller.
- Echo pin was connected to the input pin RB4 of the microcontroller.
- GND pin was connected to the breadboard's GND pin.
- +5V pin is connected to an external 5V DC supplier.

D. Servo Motors

The Mini Servo Motor SG90 that was used for this project is a small yet a powerful device used in electronics projects. It is designed to control the movement of various parts in response to electrical signals. When connected to a microcontroller, the servo motor responds to signals, allowing it to rotate to a specified angle.



Figure(5): Servo Motor

For this project, one servo motor were used.

<u>Servo Motors Linking:</u>

For the power supply, we connected the VCC pin of the servo motors to an external +5V DC supplier which is the same power supply linked to the PIC16F877A, and the GND pin was connected to the breadboard's GND pin. To control the signal flow, the signal pin of the front servo motor was connected to the output pin RC2.

E. DC Motors

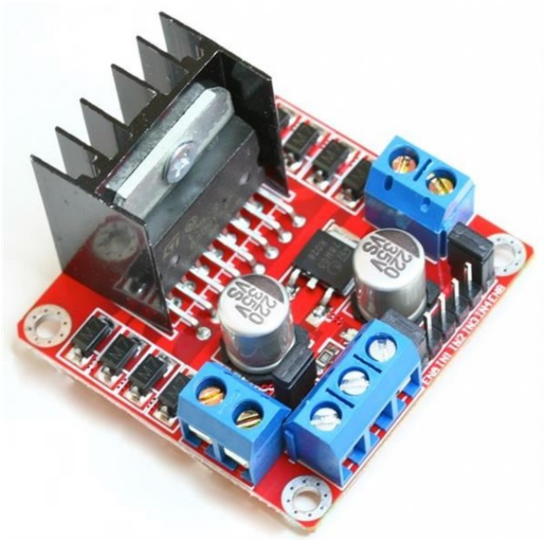
The motor converts electrical energy into mechanical energy, driving the rotation of the wheels. The movement of the motor, when appropriately controlled, determines the speed and direction of the robot car.

Both DC motors used for this project are powered through the **H-Bridge**, in which is linked to the microcontroller to pins RC4, RC5, RC6 and RC7 to control the direction of the wheels.

Figure(6): DC Motor

F. H-Bridge

The H-bridge is the interface between the PIC16F877A microcontroller and the motors of the automated car. It allows precise and controlled movements, facilitating the effective response of the car to fire incidents.



Figure(7): H-Bridge

The H-Bridge used for this project is connected to two motors through the output pins. As for the PIC16F877A microcontroller, the **H-Bridge's** input pins are connected to the output pins RC4, RC5, RC6 and RC7.

G. Relay Module and Water Pump

The relay module is like a switch that is controlled by electricity. It allows a low-power electrical signal, such as from a microcontroller or sensor, to control a higher-power circuit, like the one connected to a water pump. In our project, the relay allows the microcontroller to turn on the water pump without directly handling the higher voltage required for the pump's
operation.

Figure(8): Relay Module

Figure(9): Water Pump

The input pin of the relay module is connected to the output pin RD0, the GND is connected to the breadboard’s ground, and the VCC pin is connected to an external +5V DC power supply. The output pins of the relay are connected to the water pump with a +4.5V DC power supply that’s only linked to the water pump.

H. Buzzer

The buzzer likely plays a crucial role in alerting users or nearby individuals when the robot detects a fire or encounters a critical situation. It serves as an audible indicator for the need of attention or action.

Figure (10): Buzzer

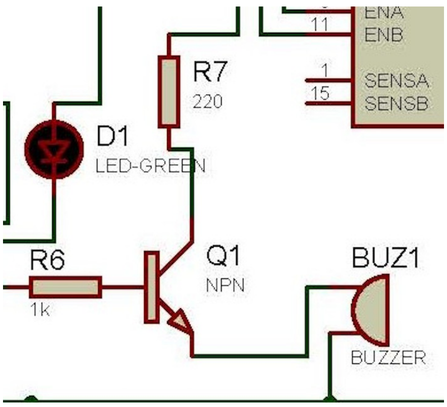


Figure (11): Buzzer Circuit Diagram

Figure (11) illustrated how we configured our buzzer and linked it to the microcontroller. We used 2222A NPN with the resistors mentioned above.

I. LCD Display

The 16x2 LCD display operated in this project in 4-bit-mode acts as a visual output device. It plays a crucial role in making the project more user-friendly and providing valuable feedback about the system's state and operation.

Figure (12): LCD Display

Control pins on the LCD were connected as follows:

- SDA - linked to pin RA0 on the microcontroller.
- SCL - linked to pin RA1 on the microcontroller.

To connect power and ground pins on the LCD, VSS pin was connected to GND, and the VDD pin was connected to an external +5V DC power supply.

III. Equations and Guidelines

1. Ultrasonic Sensor

When using the HC-SR04 to measure distance, we send a pulse for 10 **microseconds** to the sensor's trigger pin. The transmitter circuit responds by releasing eight pulses of 40 kHz ultrasonic sound into the atmosphere. As a result, the transmitter circuit transforms the electrical signal into an 8-pulse, 40 kHz burst.
Once an 8-pulse transfer from an ultrasonic transmitter circuit is complete. The echo pin goes high. The echo pin stays active high until the ultrasonic sound wave hits the object under test and does not bounce back to the receiver circuit. The echo pin becomes low as soon as the receiver circuit picks up an ultrasonic signal from an item that has been struck.
Assume that the PIC16F887 timer was used to measure the pulse length. How to convert the pulse duration (t) into distance. By using the well-known distance, time, and speed equation, we may translate the pulse duration (t) into the distance (S).

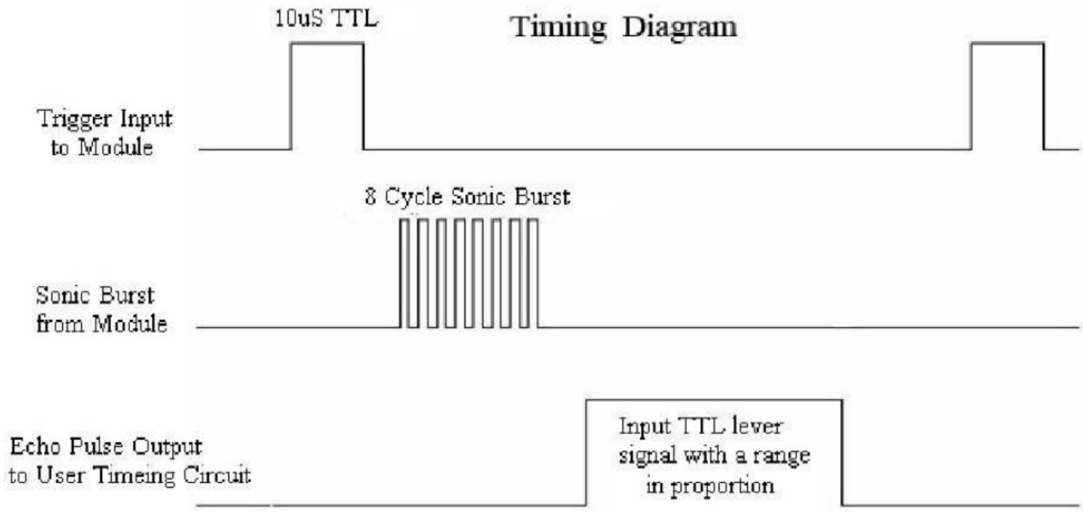
Distance (S) = Speed (v) * t

Here, V represents the airborne ultrasonic wave speed. The speed of sound, which is 340 m/s, is equivalent to the speed of ultrasonic waves in air (meter per second). As a result, the equation above becomes:

S = 340 * t (distance in meters)

The outcome of the equation above is the distance measured in meters. However, multiply 340 by 100 if you want the distance in centimeters.
Moreover, divide it by 2 to obtain one path distance.

S = (34000 * t) / 2 (distance in centimeters)



As shown in the image above, we will use the Pic microcontroller to deliver a trigger pulse to the sensor that lasts at least 10 microseconds. The sensor will then produce an 8-cycle sound burst after that. After striking obstacles, this electrical burst returns. The time it takes for an electrical burst to send and receive back will be produced by the echo pin.

We must measure the output pulse's timing in order to calculate distance.

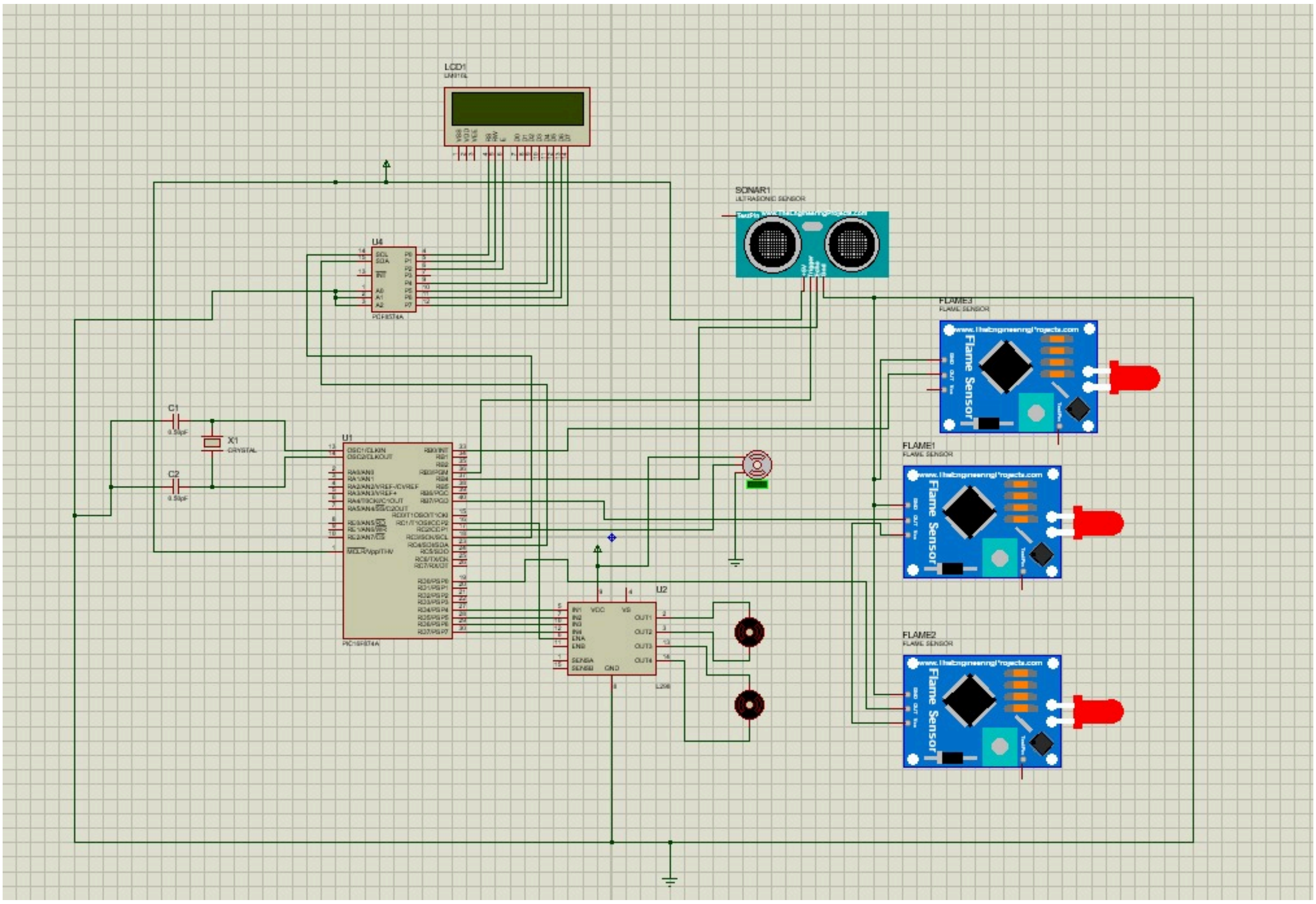
Using the equation above, we can easily determine the distance after measuring the pulse time.

2. Functional Table

Criteria	Result
TMR0	Not explicitly used in the provided code.
TMR1	Used to measure the time of the ultrasonic echo pulse. Calculates the distance from the ultrasonic sensor.
TMR2	Configured with a 1:16 pre-scaler. Used with CCP1CON and CCP2CON for PWM generation to control the servo motor and DC motor speeds.
PWM Control	Servo motor angle is controlled via PWM on PORTC.F2.

Table(2)

IV. Electrical Design



V. Conclusion and Problem Identification

After designing and implementing the project, the following conclusions and issues were identified:

1. **Flame Sensor Sensitivity**: The short detection range of the flame sensors prevents the firefighter from detecting distant fires, which limits the effectiveness of early detection.

2. **Synchronization of Motors**: Despite efforts, both motors could not be synchronized to move simultaneously at the desired speed and direction, affecting overall performance and smooth operation.

3. **PWM Port Limitations on PIC16F877A**: The lack of sufficient PWM ports on the PIC16F877A microcontroller led to the need for alternative methods to control the PWM devices, complicating the design and control logic.

4. **Ultrasonic Sensor Reliability**: The ultrasonic sensor, while functional, had limitations in terms of reliability under certain conditions, which could cause occasional misreading or failed distance calculations. This issue needs further improvement in sensor calibration or alternative sensing methods.

References

https://circuitdigest.com/microcontroller-projects/digital-thermometer-using-pic16f877a-lm35-temperature-sensor

PIC manual & datasheet

Textbook and Slides