Princess Sumaya University for Technology

King Abdullah II Faculty of Engineering

Embedded Systems Project

Bicycle Safety System

Authors:

Hasan Al-Hasnawi	20210402	Electronics Eng.	has20210402@std.psut.edu.jo
Nazeeh Al-Hanbali	20210144	Computer Eng.	naz20210144@std.psut.edu.jo
Bashar Al-Ramahi	20210771	Electrical & Power Eng.	bas20210771@std.psut.edu.jo

November 22, 2024

Abstract

This project presents a Bicycle Safety System to enhance a cyclist experience and ensure their safety, using the PIC16F877A. The system integrates multiple features, including both a right and left turn signal, which activates yellow LEDs according to the direction. A brake feature using flex sensors, which when bended a certain degree activates the red LED brake lights. The system also includes a speedometer, which displays the speed on an LCD screen. Speed is calculated by measuring the RPM using a hall-effect sensor. In addition, two ultrasonic sensors are used on the left and right, when an object is in close proximity, the ultrasonic sensor detects it and activates a vibration motor, according to where the object is, to alert the cyclist. Finally, a push button was used to enable a servo motor, which rotates the encasing of the LEDs. This report explores the mechanical, electrical and software components of the Bicycle Safety System, and examines the design process, challenges encountered, and recommendations for future improvements.

Table of Contents

1 Introduction and Background

This project explores the development of a Bicycle Safety System which uses the Microchip PIC16F877A microcontroller as its central processing unit.

The main goal of this project is to develop a safety system that addresses the challenges facing cyclists on the road, including difficulty in signaling and vulnerability to surrounding vehicles, in addition to some quality-of-life additions, that include a speedometer.

This report dives into the mechanical, electrical and software details that are implemented to ensure the system is optimized and work perfectly. It also follows the design process, and states the challenges encountered and recommendations for future improvements.

The components used for the project are as follows:

1. **PIC16F877A Microcontroller:** It is an 8-bit microcontroller from Microchip Technology. It features a RISC architecture, with 40 pins, and operates at speeds up to 20 MHz. It has 33 input/output pins, and supports a wide range of peripherals that includes timers, analog-to-digital converters (ADC), and UART for communication. The following figure shows the **PIC16F877A** used with its pins:

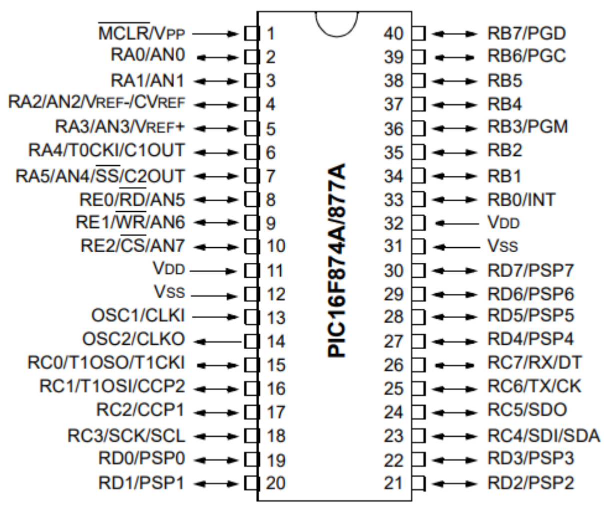


Fig 1.1 shows the pin diagram of PIC16F877A Microcontroller

2. **LEDs:** Light Emitting Diodes are semiconductor devices that are energy-efficient, durable, and emit light when electric current flows through. Two LED colors are used in this project, red and yellow, for brake lights and turn signals respectively, with size 5 mm.

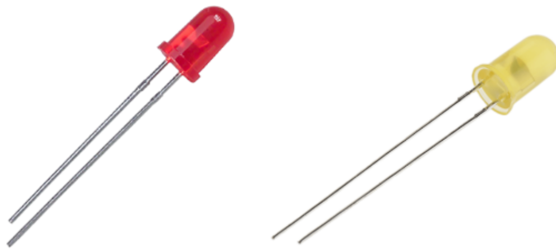


Fig 1.2 shows red and yellow LEDs

3. **Flex Sensors:** Are variable resistors that change their resistance based on their bending angle. It is an analog device. These are used on the brakes, when a certain degree of bending is achieved, it will light the red LEDs (the brake lights).

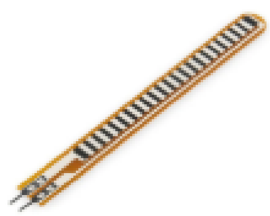


Fig 1.3 shows a 2.2-inch flex sensor

4. **Hall-Effect Sensor:** detects the magnetic field and converts it to electrical signals. The sensor is used with its module, which integrates it with additional components, such as pull-up resistors. The one we use is digital. This will detect magnets and will be used to measure and calculate the RPM and speed of the bicycle.

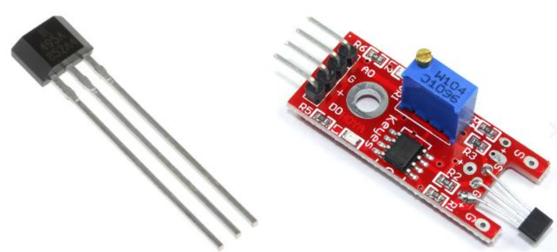


Fig 1.4 shows the hall-effect sensor and its module

5. **LCD Screen:** Liquid Crystal Display, used to display information. In this project, the information is the speed.

Fig 1.5 shows an LCD screen

6. **Ultrasonic Sensors:** Use high frequency sound waves to detect nearby objects. It is a digital device. It triggers then waits for an echo to detect to measure the distance between it and the object. Two ultrasonic sensors are used from either direction to detect nearby objects.

Fig 1.6 shows an ultrasonic sensor

7. **H-Bridge:** is an electronic circuit that enables a voltage to be applied across a load in either direction. It consists of four switches that can be toggled to control the flow of current. The H-bridge is used to connect the ultrasonic sensors and the vibration motors to control their speed, and to control which one vibrates.

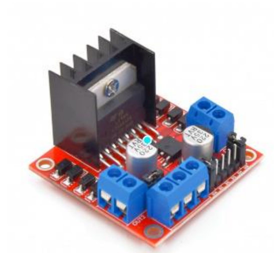


Fig 1.7 shows the H-Bridge

8. **Vibration Motors:** generate tactile feedback by producing vibrations. Two vibration motors are used, each connected to an ultrasonic sensor through the H-bridge.

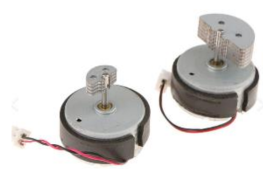


Fig 1.8 shows two vibration motors

9. **Servo Motor:** it is a rotary actuator that can precisely control angular position, velocity and acceleration. It is composed of a motor, a controller, and a position-feedback sensor. It is used to rotate the encasing of the LEDs, where it is rotated so that the LEDs will not show if desired by the cyclist.

Fig 1.9 shows the servo motor used

10. **Push Buttons:** Buttons are digital input devices used for user interaction with electronic systems. They are used for the turn signals, to o activate the servo, and the master clear.

Fig 1.10 shows a tactile push button

2 Project Design

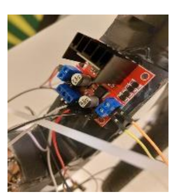
2.1 Mechanical Design

The following pictures show how the components are connected

Picture1.1 shows how the LEDs and the servo are connected

Picture1.2 shows how the Hall-effect sensor is connected

Picture1.3 shows how the Ultrasonic sensor is connected



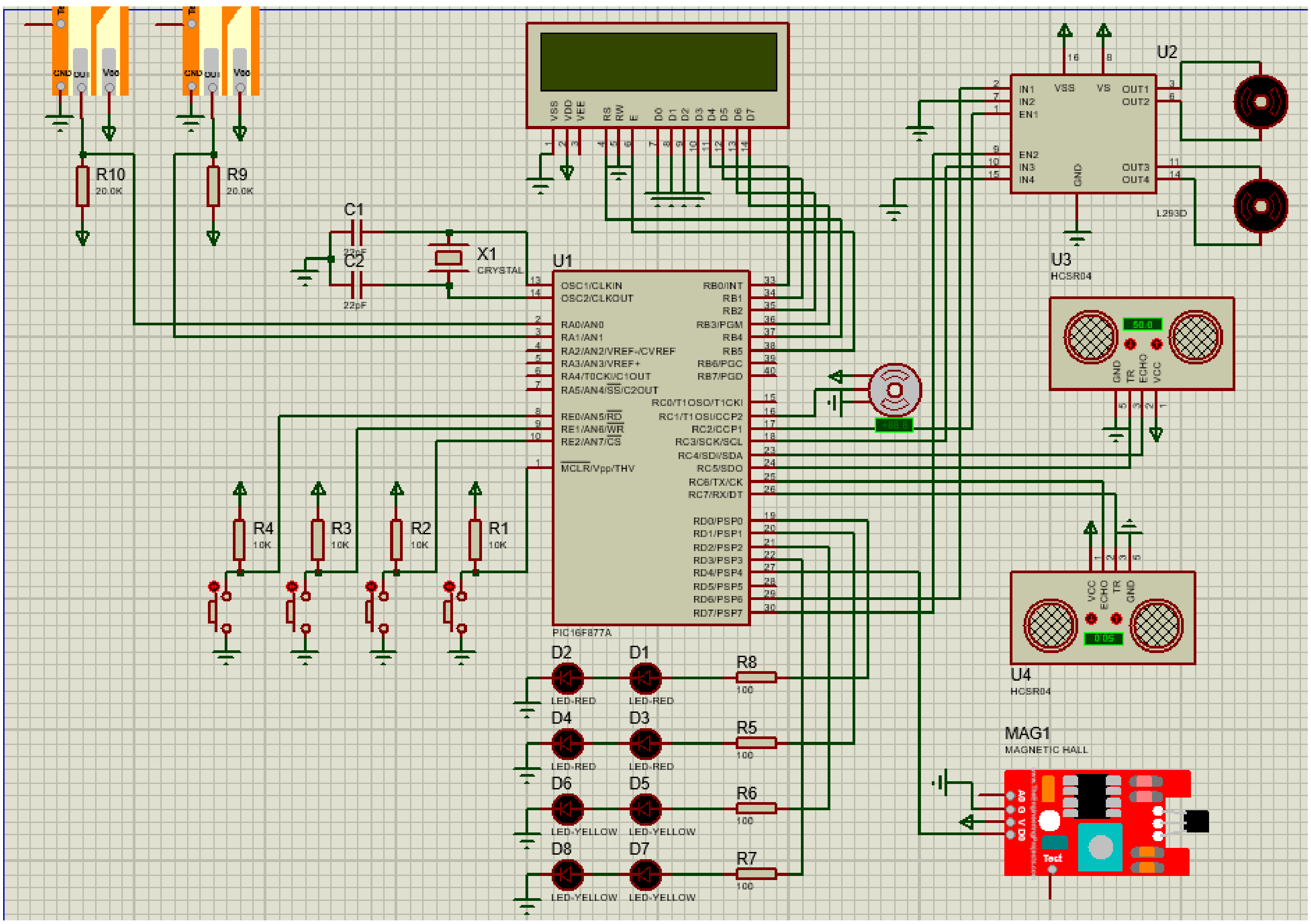
Picture1.4 shows how the H-Bridge is connected

Picture1.5 shows how the flex sensor is connected

Picture1.6 shows how the button encasings are connected

2.2 Electrical Design

The electrical design of the bicycle safety system revolves around the PIC16F877A microcontroller, which acts as the central processing unit. Below is a detailed description of the components, their roles, and how they are connected to the microcontroller:



1. **Microcontroller (PIC16F877A):**
   The PIC16F877A manages all operations, processing sensor data, and controlling actuators and indicators. It connects to various inputs and outputs to execute the system's functions.

2. **Ultrasonic Sensors (HC-SR04):**
   - **Purpose:** Measure distances to detect nearby obstacles on the left and right sides of the bicycle.
   - **Connections:**
     - **Trigger Pins:** Connected to **RC5** and **RC7**.
     - **Echo Pins:** Connected to **RC4** and **RC6**.
   - The microcontroller sends trigger signals and receives echo signals to calculate distances.

3. **Vibration Motors:**
   - **Purpose:** Provide haptic feedback to the rider when obstacles are detected on the left or right side of the bicycle.
   - **Connections:**
     The vibration motors are connected to an **H-bridge driver (L293D)** to ensure efficient control of their operation. The specific connections are as follows:

   - **Right Vibration Motor:**
     - **IN1:** Connected to **RD6** (control signal).
     - **IN2:** Connected to **GND**.
     - **EN1:** Connected to **RC2** (enable signal).
   - **Left Vibration Motor:**
     - **IN3:** Connected to **RC3** (control signal).
     - **IN4:** Connected to **GND**.
     - **EN2:** Connected to **RD7** (enable signal).

The microcontroller uses the enable pins (**EN1** and **EN2**) to activate the motors and the control pins (**IN1** and **IN3**) to determine the motor's operation based on sensor readings. The H-bridge ensures proper power delivery and allows efficient control of the motors.

4. **Flex Sensors:**
   - **Purpose:** Detect when brakes are applied by measuring bending in the sensors.
   - **Connections:**
     - Analog outputs of the flex sensors are connected to **RA0** and **RA1** (ADC inputs) on the microcontroller.
   - When the flex sensors are bent, the microcontroller detects the voltage change, activating the brake LEDs.

5. **Hall-Effect Sensor (MAG311):**
   - **Purpose:** Measure the speed of the bicycle by detecting the rotation of the wheel.
   - **Connections:**
     - **Signal Output:** Connected to **RD4**.
   - Each pulse from the Hall sensor corresponds to one rotation, and the microcontroller calculates the speed based on the time interval between pulses.

6. **LED Indicators:**
   - **Brake LEDs (Red):**
     - **Connections:** Connected to **RD0** (left brake) and **RD1** (right brake).
   - **Turn Signal LEDs (Yellow):**
     - **Left Turn LEDs:** Connected to **RD2**.
     - **Right Turn LEDs:** Connected to **RD3**.
   - The microcontroller controls these LEDs based on button presses (see below).

7. **Push Buttons:**
   - **Purpose:** Allow the rider to activate turn signals.
   - **Connections:**
     - **Left Turn Button:** Connected to **RE0**.
     - **Right Turn Button:** Connected to **RE1**.
     - **Master Clear Button:** Connected to the **MCLR** pin for resetting the system when needed.
     - **Servo Button:** Connected to **RE2** to activate the servo motor
   - The microcontroller reads button states and activates the corresponding turn signal LEDs.

8. **Servo Motor:**
   - **Purpose:** Control the rear light stance.
   - **Connections:**
     - **Control Signal:** Connected to **RC1**.
   - The microcontroller generates a PWM signal to move the servo motor.

9. **LCD Display:**
   - **Purpose:** Display the bicycle's speed in real time.
   - **Connections:**
     - **RS Pin:** Connected to **RB4**.
     - **Data Pins (D4-D7):** Connected to **RB0**, **RB1**, **RB2**, and **RB3**.
   - The microcontroller uses these pins to send data to the LCD module.

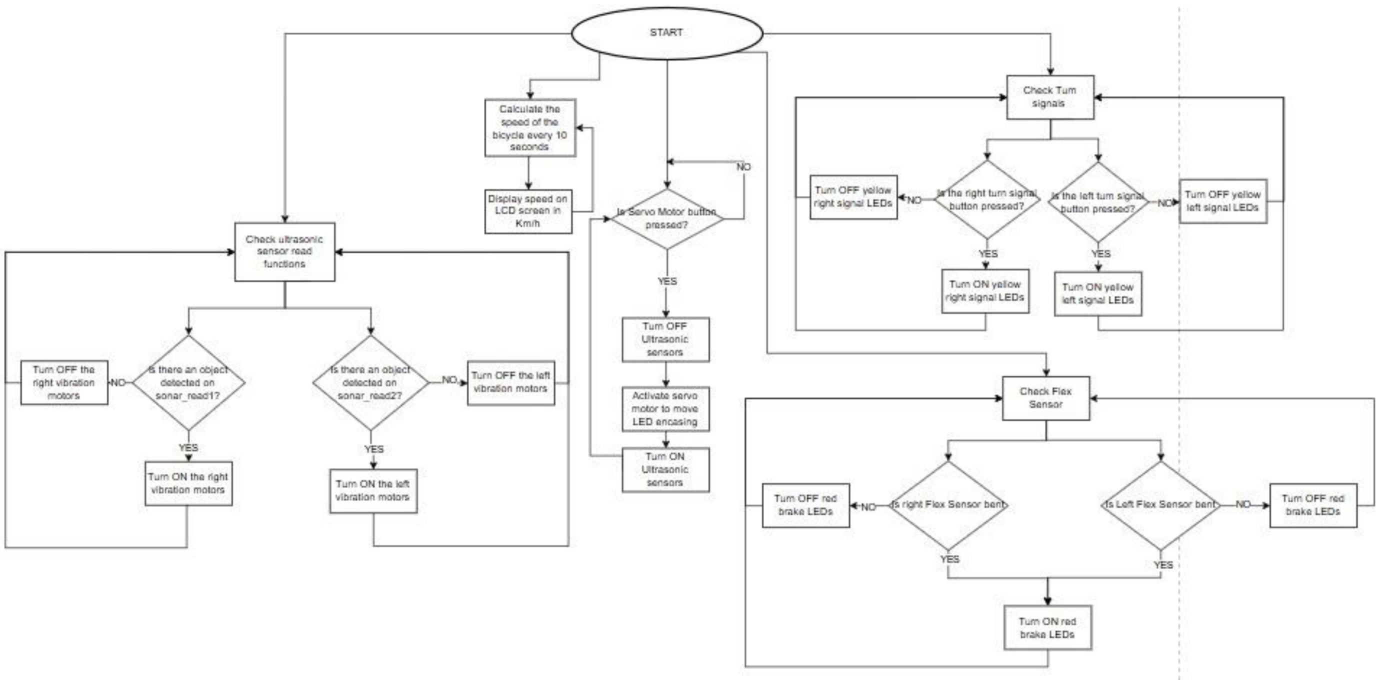
10. **Power Supply:**

- **Purpose:** Provide a stable 5V DC power supply to the system.
- **Connections:** The microcontroller's **VDD** and **VSS** pins are connected to the power supply, and decoupling capacitors (C1, C2) stabilize the voltage.

11. **Resistors:**

- **Purpose:** Protect components from excessive current and ensure proper operation.
- **Connections:**
  - Current-limiting resistors are connected to the LEDs.
  - Pull-up resistors are used for the push buttons and sensor inputs where necessary.

2.3 Software Design



The software design for the project is developed based on a structured flowchart that outlines the logical sequence of operations performed by the system. Below is a detailed explanation of the software design approach:

Start and Initialization

- The program begins by initializing all required peripherals and setting up the necessary registers. This includes configuring the I/O ports, timers, PWM, ADC modules, and the LCD display.
- The system waits for user inputs or changes in sensor readings to proceed with its tasks.

Ultrasonic Sensor Readings for Obstacle Detection

- The system continuously checks for readings from the two ultrasonic sensors connected to the front and rear of the bicycle.
- **Logic:**
  - If an obstacle is detected within the predefined distance on **Sonar_Read1 (front-right)**, the software activates the **right vibration motor** by enabling the corresponding H-Bridge input.
  - If an obstacle is detected within the predefined distance on **Sonar_Read2 (front-left)**, the software activates the **left vibration motor** by enabling the respective H-Bridge input.

- If no obstacles are detected, the vibration motors are turned off.

Turn Signal Control

- The software monitors the push buttons connected to **RE0** (left turn signal) and **RE1** (right turn signal):
  - When the left turn signal button is pressed, the left yellow LEDs are turned on and blink periodically to indicate the left turn.
  - When the right turn signal button is pressed, the right yellow LEDs are turned on and blink periodically to indicate the right turn.
  - If no button is pressed, both turn signals remain off.

Brake Light Control

- The system checks the status of the brake sensors.
- **Logic:**
  - If the brakes are pressed, the red brake LEDs are turned on to indicate the bicycle is slowing or stopping.
  - If the brakes are not pressed, the brake LEDs remain off.

Servo Motor Control

- The software monitors the push button connected to **RE2** for servo activation:
  - When the button is pressed, the servo motor is activated to move the LED encasing to the desired position.
  - When the button is pressed again, the servo motor returns to its neutral state.

Speed Calculation and Display

- The software reads the signal from the magnetic Hall-effect sensor mounted on the bicycle wheel to calculate the speed.
- **Logic:**
  - The time between consecutive pulses from the Hall sensor is used to calculate the rotational speed of the wheel.
  - The calculated speed is displayed in real time on the LCD screen in km/h.

Loop and Continuous Operation

- The system operates in a continuous loop to repeatedly check for inputs and update outputs in real time. This ensures that the system is always responsive to user inputs and environmental changes.

3 Problems and Recommendations

There were some problems we faced during the development of the system. Fortunately, we were able to solve them all

- **Software Problems:**

The main problem we faced in software was the interference in TMR1 due to the use of the ultrasonic sensors and the Servo motor. The servo also used CCP Capture which posed an issue. Since both used TMR1, it caused interference, which led to inaccurate pulse measurements for the ultrasonic and weird behavior for the servo. To fix this, we used flags. When the CCP interrupt occurs, we disable the ultrasonic sensors by zeroing the flag, until it is done then reenable them. By implementing this change, we were able to fix this issue, and both the ultrasonic sensors and the servo motor was working correctly.

- **Hardware Problems:**

Hardware wise, we had problems with the encasing of the different components used. It was time consuming, and the result was not very precise. **Recommendation:** 3D printing of the encasing would be more time efficient, precise and more appropriate.

4 Conclusion

This project successfully demonstrates the integration of embedded systems technology to enhance bicycle safety through a well-coordinated design approach. The broader significance of this project lies in its potential to promote safer cycling experiences, particularly in urban areas where accidents involving bicycles are common. By leveraging the capabilities of the PIC16F877A microcontroller and adhering to a structured software and hardware design, the system ensures real-time responsiveness and reliability.

Moreover, the modularity of the design and code allows for future scalability and enhancements, such as integrating additional sensors or expanding functionality. This project exemplifies the practical application of embedded systems in solving real-world challenges, showcasing its importance in modern engineering solutions. Ultimately, it serves as a foundation for further innovation in the realm of smart transportation.