



REAL-TIME VEHICLE DETECTION AND ALERT SYSTEM FOR U-BENDS

EE6304 EMBEDDED SYSTEM DESIGN

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1 INTRODUCTION

1.1 INTRODUCTION TO THE PROBLEM OR THE SOLUTION

U-bends on roads, especially in hilly or mountainous areas as shown by Figure 1.1, pose significant challenges that increase the risk for drivers. Sharp curves limit visibility, making it difficult to see oncoming vehicles, which raises the likelihood of accidents. In some areas, convex road safety mirrors alone are insufficient due to the severity of the curve. Due to the limited visibility and the sharpness of the turn, vehicles may collide, particularly if they are traveling at high speeds or if the road conditions are poor. U-bends require precise maneuvering, larger vehicles like trucks and buses might find it difficult to navigate these turns, increasing the likelihood of accidents. On busy roads, U-bends can cause traffic congestion as vehicles slow down to safely navigate the curve, leading to potential rear-end collisions.

The Real-time Vehicle Detection and Alert System is designed to address these challenges by using sensors, or other detection technologies to monitor the traffic flow at U-bends. The system detects vehicles approaching from either direction and instantly alerts drivers with visual signals. By providing real-time information about the presence of oncoming vehicles, the system allows drivers to take precautionary measures, such as slowing down or stopping, thereby reducing the likelihood of accidents. This proactive approach not only enhances road safety but also contributes to smoother traffic flow by minimizing sudden stops or evasive maneuvers that could lead to secondary incidents.



Figure 1.1: U-bends on roads with sharp curves.

1.2 OBJECTIVE

Real-time Vehicle Detection and Alert System aims to achieve the following objectives,

1. Enhance road safety

The system aims to reduce the risk of accidents at U-bends by providing drivers with real-time alerts about oncoming vehicles, enabling them to take preventive actions like slowing down or stopping.

2. Improve driver awareness

By detecting vehicles approaching from either direction, the system increases driver awareness, especially in situations where visibility is limited due to the sharpness of the bend.

3. Facilitate safe navigating

The system helps drivers, particularly those operating larger vehicles like trucks or buses, navigate U-bends more safely by alerting other drivers to the presence of these vehicles, allowing for better coordination.

4. Reduce traffic congestion

By promoting smoother and more cautious driving behaviors, the system helps maintain a steady traffic flow through U-bends, reducing the likelihood of traffic jams and rear-end collisions.

1.3 PROJECT SCOPE

The scope of the Real-time Vehicle Detection and Alert System project includes the design and development of a comprehensive system architecture that integrates sensor, Microcontroller,[1] signal transmitter and receiver, and alert mechanisms to detect vehicles approaching U-bends and provide real-time alerts to drivers. The project involves identifying and installing appropriate sensors at strategic locations on U-bends to monitor traffic from both directions. A reliable alert system will be developed to deliver visual warnings based on the data collected by these sensors, ensuring drivers are promptly informed of oncoming traffic.

The project also includes the deployment and implementation of the system in selected high-risk U-bends, with training provided for maintenance personnel and protocols established for

system monitoring. A maintenance plan will be developed to ensure the system remains operational over time, including regular checks, and recalibration. Finally, the project will involve collaboration with local authorities and stakeholders to ensure the system meets safety standards and addresses the specific needs of the area.

2 SPECIFICATIONS

The specifications of the project can be mentioned as follows:

1. The system should be able to detect vehicles accurately which are coming from both directions using sensors.
2. The system should be able to give immediate response to other end before entering any vehicles to U bend.
3. The system should be able to transmit data wirelessly between two microcontrollers. [2]
4. All the hardware component of the system should be durable and designed for easy maintenance.
5. The system should be scalable to add additional components as needed.
6. LED indicators should be able to give signals correctly to the vehicles.

3 IMPLEMENTED SOLUTION

3.1 BLOCK DIAGRAM

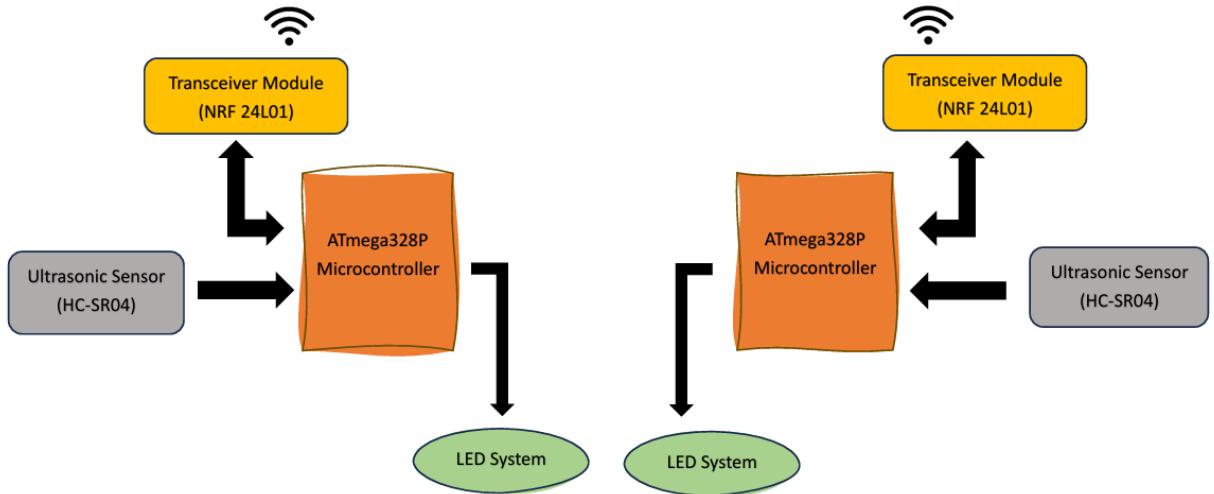


Figure 3.1: Block Diagram of the Real-time Vehicle Detection and Alert System

3.2 DETAILED DESCRIPTION

The function or the detailed description of each block of the block diagram which is under the Figure 3.1 can be described as follows:

1. Microcontroller

In this system, the Atmega328p microcontroller acts as the central processing unit, managing inputs from sensors, processing data, and responsible for controlling the sensors, LEDs and processing data.

2. Ultrasonic Sensor

The Ultrasonic Sensor (HC-SR04) is used in this system for emitting ultrasonic waves and timing their return after bouncing off objects. It typically operates within a range of a few centimeters to several meters. In this system, this sensor detects vehicles approaching the U-bend by measuring the distance to an object (the vehicle) and sending this data to the microcontroller, which uses the information to trigger appropriate alerts or actions.

3. Transceiver Module

The NRF 24L01 modules used in this system is designed for low-power, short-range communication. In this system, this module facilitates wireless communication between different microcontroller, such as transmitting vehicle detection data between one microcontroller to another.

4. LED system

The LED system is functioning as standard traffic light system. This system is used to give visual responses to the drivers based on the data given by the microcontroller. This visual indicator has three LEDs as follows.

- Red – Stop
- Yellow – Slow Down
- Green – Go

3.3 SIMULATION

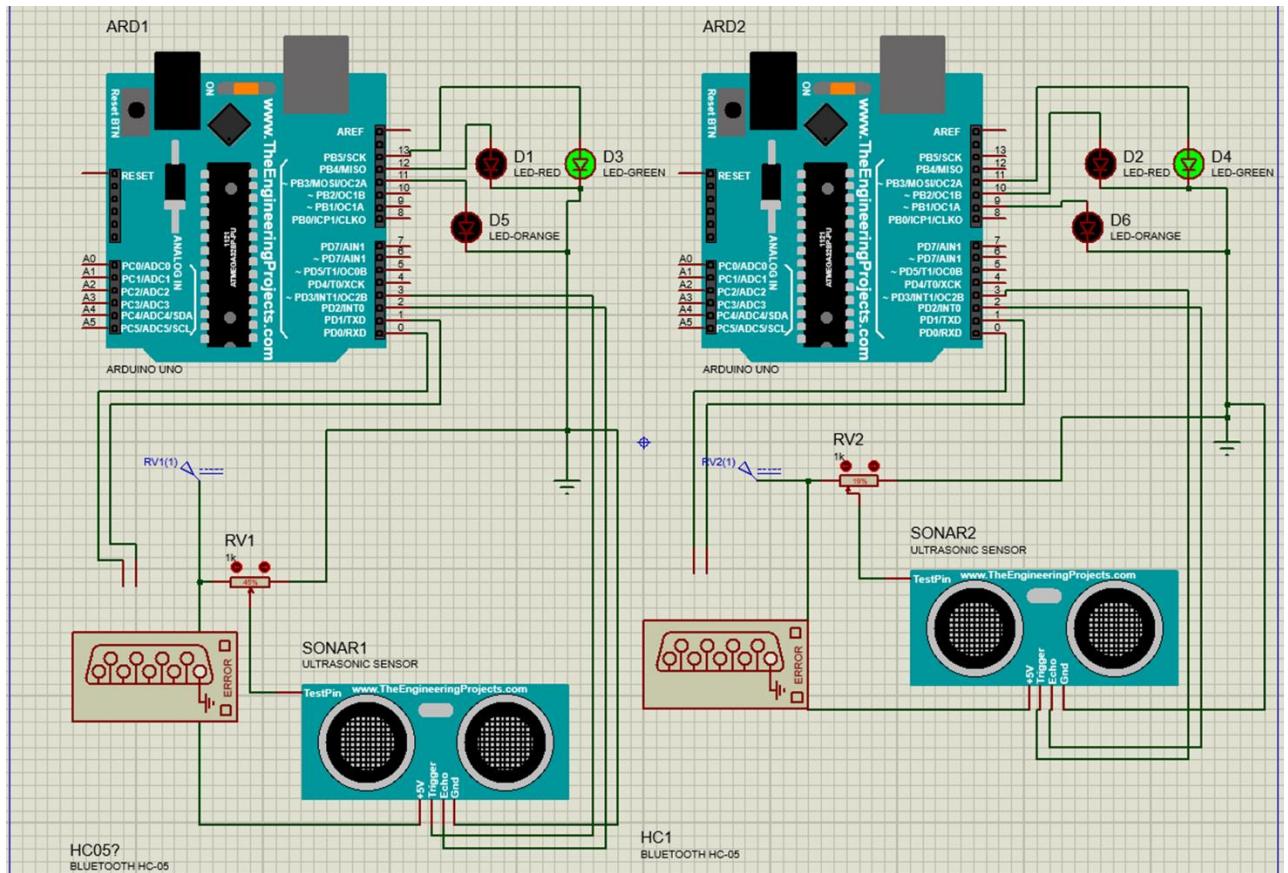


Figure 3.2: Final Product Model using Proteus Simulation.

The system was simulated using Proteus for hardware testing in computer, and Atmel Studio was utilized for writing and compiling the firmware. During the simulation, various aspects of the system were tested and validated.

The above Figure 3.2 shows the Proteus simulation diagram for the circuit. Potentiometer is part of the ultrasonic sensor setup, it is used to simulate different distances.

In our "Real-time Vehicle Detection and Alert System for U-bends" project, we started by using Bluetooth modules to send signals between two devices. However, we faced two main problems with Bluetooth:

1. Full Duplex Transmission: Bluetooth couldn't handle full duplex communication, which means it struggled to send and receive signals at the same time. In our project, we needed this ability to ensure that both devices could communicate simultaneously and in real time.
2. Limited Range: Bluetooth's range wasn't long enough to cover the distance required for our system. Since U-bends often cover a larger area, the short range of Bluetooth was a serious limitation.

To solve these problems, we decided to switch to the NRF24L01 module. This wireless module has a longer range, making it suitable for larger areas like U-bends. It also supports full duplex communication, meaning both devices can send and receive data at the same time without any issues. This made NRF24L01 a much better choice for our system.

3.4 FLOW CHART OF THE FIRMWARE

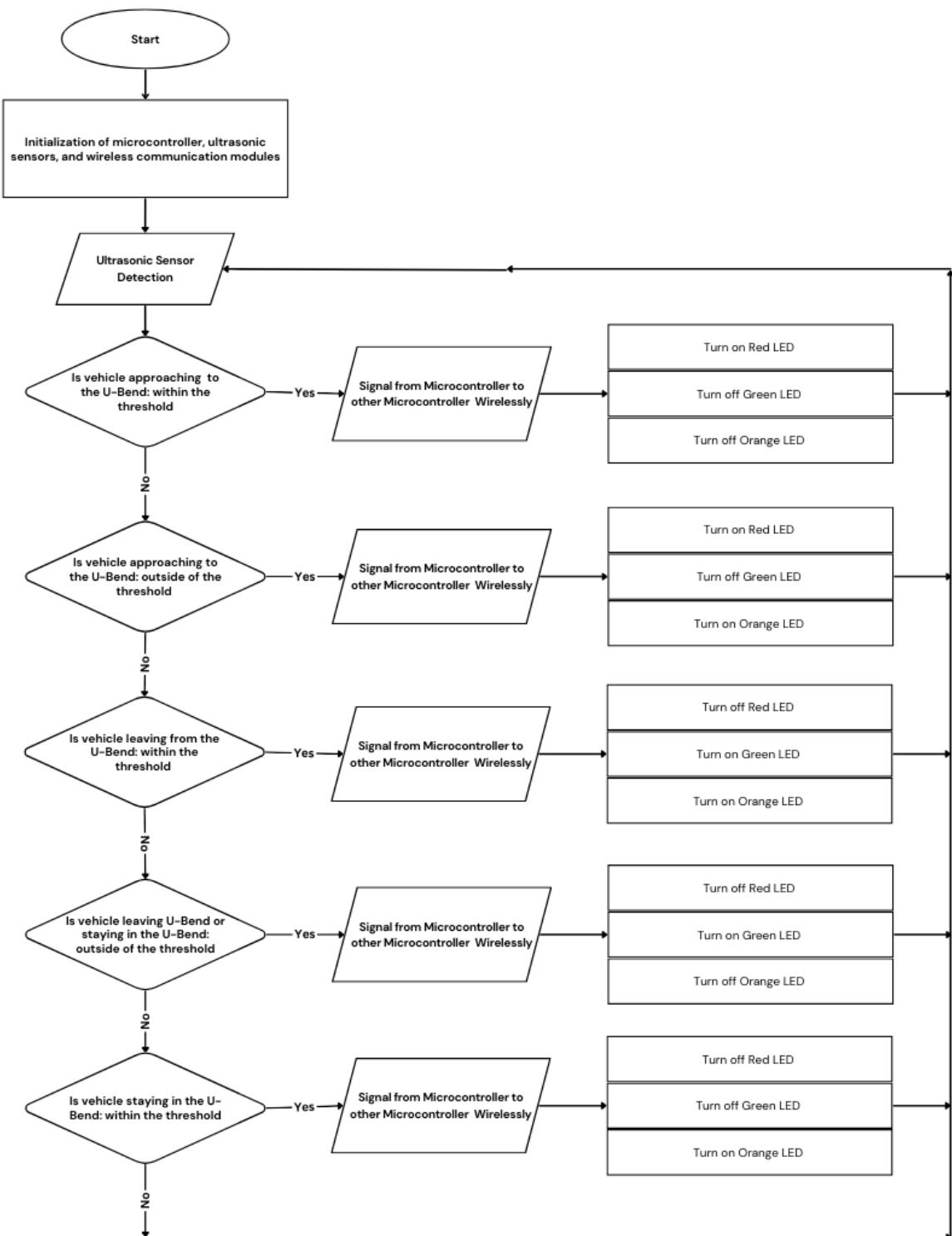


Figure 3.3: Flow Chart of the Final Product.

The diagram in Figure 3.3 illustrates the firmware flowchart, detailing how the system operates when powered on. When the system is powered on, the ATmega328P microcontroller is initialized along with the ultrasonic sensors and NRF24L01 transceiver modules. The sensors monitor vehicle proximity, and the transceiver modules manage wireless communication between the two ends of the U-bend.

The ultrasonic sensor continuously measures the distance of approaching vehicles. A trigger signal is sent from the sensor (trig pin), and the time taken for the echo to return is measured. This time is used to calculate the distance of the vehicle.

The system calculates the distance and transmits this value wirelessly using the NRF24L01 module to another microcontroller at the opposite end of the U-bend. The other microcontroller listens for incoming data. When a vehicle is detected within the threshold distance, it updates the LED indicators accordingly to warn vehicles at the other end of the U-bend.

The system compares the current distance to the previously measured distance and makes decisions based on predefined threshold values:

If the vehicle is close (within 30 cm) and approaching the U-bend, the red LED is turned on, and the orange LED and green LED are turned off, indicating the U-bend is not clear.

If the vehicle is before 30cm and approaching the U-bend (distance increasing before 30cm), the green LED turns off, and the orange LED and red LED are turned on.

If the vehicle is at a safe distance (greater than 30 cm), the system activates the green LED, indicating the path is clear.

If the vehicle is at critical distance (less than 30 cm), the system activates the orange LED, indicating vehicle is stopped within the critical region.

If the vehicle is leaving the U-bend (distance increasing within 30cm), the red LED turns off, and the green LED turns on, while the orange LED may remain active to indicate caution.

If the vehicle is leaving the U-bend (distance increasing before 30cm), the red LED and orange LED are turns off, and the green LED turns on.

If no vehicle is detected within the threshold distance, the system defaults to the green LED being on, indicating the path is clear.

3.5 REQUIRED EQUATIONS, CALCULATIONS AND EXPLANATION

This project implements an ultrasonic sensor-based distance measurement system that communicates results and commands via USART. For the project we have to configure the RX (receive) and TX (transmit) ports for serial communication using USART (Universal Synchronous and Asynchronous serial Receiver and Transmitter) on an ATmega328P microcontroller.

First the BAUD rate should be set using UBRR register. Value of the UBRR register is calculated using the following equation.

$$UBRR = \frac{f_{osc}}{16BAUD} - 1$$

UBRR register is a 16-bit register and higher 8 bits are UBRR0H and lower 8 bits UBRR0L.

Name:	UBRR0L	Bit	7	6	5	4	3	2	1	0
Offset:	0xC4		UBRR0[7:0]							
Reset:	0x00	Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Property:	-	Reset	0	0	0	0	0	0	0	0

Name:	UBRR0H	Bit	7	6	5	4	3	2	1	0
Offset:	0xC5		UBRR0[3:0]							
Reset:	0x00	Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Property:	-	Reset	0	0	0	0	0	0	0	0

Figure 3.4: UBRR0H and UBRR0L Register.

The above Figure 3.4 describes the register configuration of UBRR0H and UBRR0L. Initialization of USART for serial communication, sets the UBRR registers to configure the baud rate. Figure 3.5 shows the UCSR0B register which controls the USART control and status. There, RXEN0 and TXEN0 are set to enable the receiver and transmitter.

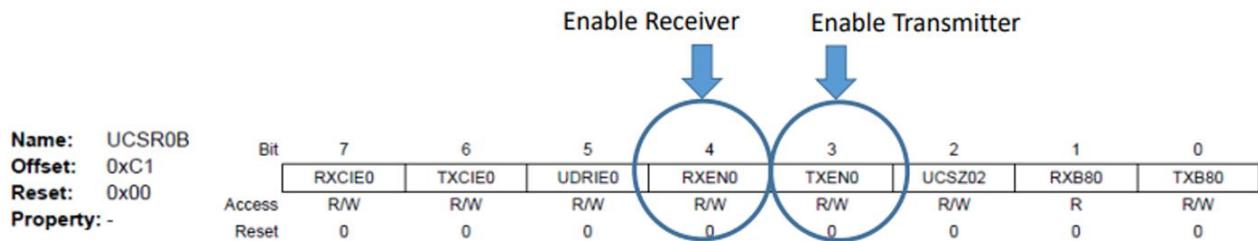


Figure 3.5: UCSR0B Register.

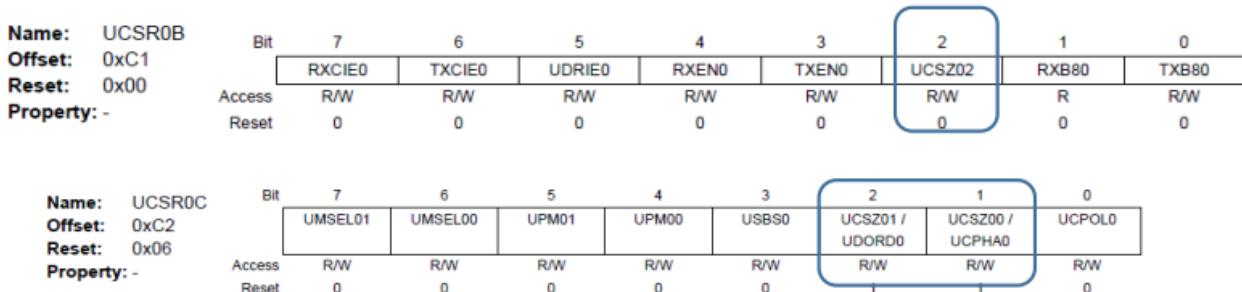


Figure 3.6: UCSZ0 Locations in the Registers.

As shown by the Figure 3.6, UCSR0C register configures the frame format for serial communication (8 data bits, 1 stop bit).

The UCSR0A and UDR0 registers, depicted in Figure 3.7, are critical for managing data transmission and reception in the USART communication process. Specifically, UCSR0A provides status information regarding whether the transmit buffer is empty or if new data has been received. In contrast, UDR0 serves as the actual register used to send or receive data.

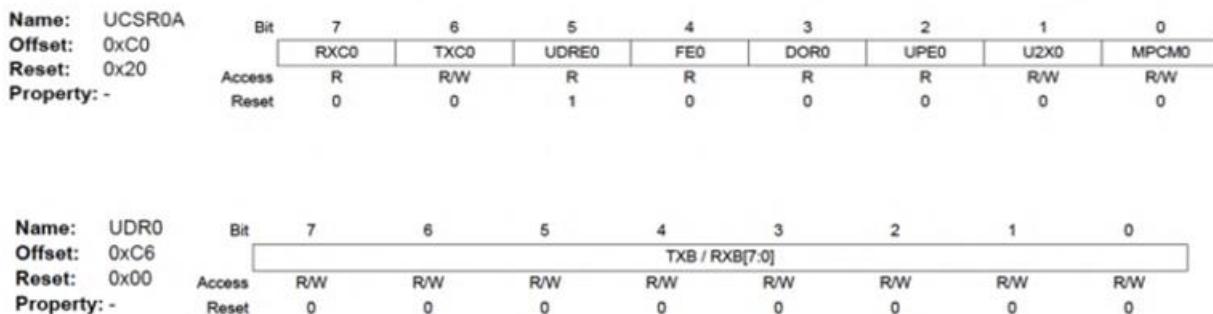


Figure 3.7: UCSR0A and UDR0 Registers in USART Communication.

$$\begin{aligned}
 \text{Distance from the object} &= \text{Speed of sound in the air} \times \frac{\text{Time Duration}(\mu\text{s})}{2} \\
 &= 344 \times 10 - 4 \frac{\text{cm}}{\mu\text{s}} \times \frac{\text{Time Duration}(\mu\text{s})}{2} \\
 &= \frac{1}{29 \mu\text{s}} \times \frac{\text{Time Duration}(\mu\text{s})}{2} \\
 &= \frac{\text{Time Duration}(\mu\text{s})}{58} \text{ cm}
 \end{aligned}$$

3.6 FINAL PRODUCT



Figure 3.8: Image of the Final Product.

The Figure 3.8 depicts the final Real-Time Vehicle Detection and Alert System built for monitoring U-bends. All electronic components, such as the ultrasonic sensors, LEDs, transceivers, and the microcontrollers (ATmega328P), have been carefully assembled and soldered into the system. A power switch is used to activate or deactivate the entire system.

This product leverages ultrasonic sensors to detect vehicles approaching the U-bends, and NRF24L01 transceivers for wireless communication between the control units placed on either side of the bend. During testing, the system demonstrated reliable communication up to 60-70 meters between transceiver modules, ensuring efficient real-time alert functionality even at a considerable distance.

4 REFERENCES

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