ELECTRONICS

# Design and Development of Smart Obstacle Detection Glasses for Visually Impaired Persons

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**Abstract**

This paper presents the design and development of smart obstacle detection glasses intended to assist visually impaired persons in identifying obstacles in front of them. The prototype is built around an Arduino Nano microcontroller and an HC-SR04 ultrasonic sensor mounted on a spectacle frame. The sensor measures the distance to an object by transmitting ultrasonic waves and receiving the reflected echo. The Arduino Nano processes the sensor output and activates an audible alert through a 5 V active buzzer when an obstacle is detected. A green light-emitting diode (LED) is also included as a visual status indicator. The system is powered by a rechargeable 3.7 V lithium-ion battery using a TP4056 charging module and a 5 V boost converter. The developed prototype is reported to be operational and provides a compact, wearable approach to front-side obstacle warning. The design focuses on affordability, portability, and simple operation. The present version uses one ultrasonic sensor and therefore provides front-direction detection only. Multi-direction sensing, voice guidance, and improved outdoor performance are identified as possible future enhancements.

**Keywords:** Smart glasses; obstacle detection; Arduino Nano; HC-SR04; ultrasonic sensor; visually impaired persons

## 1 Introduction

Independent mobility is an important requirement for people with visual impairment. Obstacles such as walls, furniture, poles, and other objects can make movement in unfamiliar environments difficult. A conventional white cane is widely used as a mobility aid, but it may not provide advance information about every obstacle, particularly objects located outside the area reached by the cane. Electronic travel aids can supplement conventional mobility methods by sensing nearby objects and communicating warnings to the user.

The proposed project, titled “Design and Development of Smart Obstacle Detection Glasses for Visually Impaired Persons,” is developed as a wearable electronic aid. An ultrasonic sensor is fitted to a spectacle frame so that it faces the direction of travel. The sensor detects an object in front of the user, while an Arduino Nano processes the measurement and controls an audible alert. The glasses are designed to be compact and rechargeable.

The device is intended to act as a supplementary aid and is not a replacement for a white cane, guide dog, orientation training, or other established mobility support.

## 2 Objectives

1. To develop a wearable obstacle detection prototype using a spectacle frame.

2. To detect obstacles located in front of the user using an HC-SR04 ultrasonic sensor.
3. To process the sensor output using an Arduino Nano microcontroller.
4. To provide an audible warning using a 5 V active buzzer.
5. To include an LED status indication and a rechargeable battery-based power supply.
6. To develop a compact and economical prototype that can be further enhanced.

## 3 System overview

The system consists of an ultrasonic sensing unit, a microcontroller unit, an alert unit, and a power supply unit. The HC-SR04 sensor is positioned on the front portion of the spectacle frame. Its trigger and echo signals are connected to the Arduino Nano. The microcontroller calculates the distance from the measured echo time and determines whether an object is within the programmed warning condition. When the condition is met, the active buzzer is activated. The LED provides a visual indication of the system state. The developed prototype is shown in Figure 1.



**Figure 1.** Developed smart obstacle detection glasses prototype.

The power unit uses a 3.7 V rechargeable lithium-ion battery. A TP4056 module is used for battery charging, and a 5 V boost converter provides the required boosted supply for the circuit. A power switch is included to turn the device on and off.

## 4 Components and their functions

Table 1 presents the components used in the proposed prototype.

**Table 1.** Components used in the proposed prototype.

| Sr. No. | Component | Quantity | Function |
|---|---|---|---|
| 1 | Arduino Nano | 1 | Reads the sensor signal, calculates distance, and controls the alert outputs. |
| 2 | HC-SR04 Ultrasonic Sensor | 1 | Detects an obstacle in the forward direction by ultrasonic ranging. |
| 3 | Black Spectacle Frame | 1 | Acts as the wearable mounting structure for the electronic system. |
| 4 | 5 V Active Buzzer | 1 | Provides an audible warning when an obstacle is detected. |
| 5 | Green LED | 1 | Provides a visual status indication. |
| 6 | 220 Ω Resistor | 1 | Limits current through the LED. |
| 7 | 3.7 V Li-ion Battery (1200–2000 mAh) | 1 | Supplies portable electrical power. |
| 8 | TP4056 Charging Module | 1 | Provides charging control for the single-cell lithium-ion battery. |
| 9 | 5 V Boost Converter | 1 | Raises the battery voltage to the required 5 V supply level. |
| 10 | Power Switch | 1 | Turns the prototype on or off. |
| 11 | USB Cable and Enclosure | As required | Support charging/programming and protect or organize the electronics. |

## 5 System block description

Table 2 presents the functional blocks of the system.

**Table 2.** Functional blocks of the system.

| Block | Input | Output / Purpose |
|---|---|---|
| Ultrasonic Sensor | Trigger pulse from Arduino; reflected ultrasonic wave | Echo pulse representing measured travel time |
| Arduino Nano | Echo signal and program logic | Control signals for buzzer and LED |
| Alert Unit | Control signal from Arduino | Audible warning and visual status indication |
| Power Unit | Rechargeable 3.7 V battery | Regulated/boosted 5 V supply for the prototype |

## 6 Hardware description

### 6.1 Arduino Nano

The Arduino Nano is the main control unit of the prototype. It receives the echo signal from the HC-SR04 sensor, measures the duration of the signal, calculates the distance, and controls the buzzer and

LED according to the programmed condition. Its compact size makes it suitable for small embedded projects.

### 6.2 HC-SR04 ultrasonic sensor

The HC-SR04 is used for non-contact distance measurement. It operates by sending an ultrasonic burst and measuring the time taken for the reflected signal to return. The distance is calculated from the echo time and the speed of sound. The sensor is oriented toward the front so that obstacles in the user's forward path can be detected.

### 6.3 Buzzer and LED

The 5 V active buzzer is used to communicate an obstacle warning through sound. An active buzzer can generate a tone when its supply is switched by the control circuit. The green LED, connected with a 220 Ω current-limiting resistor, acts as a visual status indicator.

### 6.4 Power supply

A rechargeable 3.7 V lithium-ion battery is used to make the prototype portable. The TP4056 module provides the battery charging function, while the boost converter raises the battery voltage to 5 V for the circuit. The switch controls the power supplied to the prototype.

## 7 Working principle

The working principle is based on ultrasonic time-of-flight measurement. When the system is switched on, the Arduino Nano initializes the sensor and output pins. The microcontroller sends a short trigger pulse to the HC-SR04 sensor. The sensor transmits ultrasonic waves and sets its echo output according to the time taken by the reflected waves to return from an obstacle.

The Arduino Nano measures the echo pulse duration and estimates the distance using the relationship between distance, time, and the speed of sound. The measured distance is compared with the warning condition defined in the program. When an obstacle is detected within that condition, the buzzer is activated to alert the user. The LED is used to indicate the system status as implemented in the prototype.

The process is repeated continuously while the device remains powered. Since the current prototype uses one forward-facing ultrasonic sensor, it is designed to detect obstacles in the front direction rather than providing complete coverage around the user.

## 8 Methodology and implementation

1. The spectacle frame was selected as the wearable base for the prototype.
2. The HC-SR04 ultrasonic sensor was mounted facing forward so that it could sense objects in the direction of movement.
3. The Arduino Nano was connected to the sensor trigger and echo pins.
4. The active buzzer and green LED with a 220 Ω resistor were connected to the microcontroller output circuit.
5. The battery, TP4056 charging module, 5 V boost converter, and power switch were assembled to form the portable power unit.

6. The Arduino program was uploaded to the Nano to read the ultrasonic sensor and operate the alert outputs.

7. The assembled prototype was powered and checked for obstacle detection and alert operation. The physical arrangement and wiring should be kept secure so that the sensor remains correctly oriented and the electronic parts do not interfere with comfortable use. The battery and exposed electrical connections should be insulated and enclosed appropriately.

## 9 Test procedure

1. **Power-on test:** Switch on the prototype and verify that the Arduino Nano starts and the status LED behaves according to the uploaded program.

2. **Sensor test:** Place a flat object in front of the HC-SR04 sensor at a distance measured with a ruler or measuring tape. Compare this distance with the sensor reading.

3. **Buzzer test:** Move the object into the warning zone programmed in the Arduino and verify whether the 5 V active buzzer produces an audible alert. Repeat at several distances.

4. **Repeatability test:** Repeat each distance measurement at least five times under the same conditions and calculate the average reading.

5. **Power test:** Measure the battery voltage and boost-converter output using a digital multimeter, both before and during operation.

6. **Wearability test:** In a controlled, obstacle-free area, check that the sensor remains directed forward and that the wiring and battery are securely mounted.

## 10 Numerical relationships and calculations

The HC-SR04 estimates distance from the time taken by the ultrasonic pulse to travel to an object and return. The distance is calculated using the following relationship:

$$\text{Distance (cm)} = \frac{\text{Echo time } (\mu\text{s}) \times 0.0343}{2} \tag{1}$$

The factor 0.0343 cm/µs represents the approximate speed of sound in air at room temperature. Division by 2 is required because the measured time includes the outward and return journey.

Illustrative calculation only: if the measured echo time is 1,200 µs, distance = 1,200 × 0.0343 ÷ 2 = 20.58 cm. This is an example calculation, not a measured result from the prototype. Replace it with an actual sensor reading after testing.

For the LED circuit, assuming a 5 V supply, an LED forward voltage of 2 V, and a 220 Ω series resistor, the estimated current is:

$$I_{\text{LED}} = \frac{5 - 2}{220} = 0.0136\text{A} \approx 13.6\text{mA} \tag{2}$$

This is a theoretical estimate. Actual current depends on the measured supply voltage and the LED forward voltage.

## 11 Testing and numerical measurements

The prototype was tested at actual distances of 15 cm, 30 cm, 50 cm, 75 cm, 100 cm, 120 cm, and 150 cm, along with a separate test using a glass surface. The recorded sensor readings and buzzer

responses are presented in Table 3. The buzzer alert was observed within the programmed range of less than 100 cm; at 120 cm and 150 cm, no buzzer alert was triggered. Battery runtime and response time measurements were not supplied.

**Table 3.** Prototype testing record.

| Test No. | Actual Distance (cm) | Sensor Reading (cm) | Buzzer Response | Observation |
|---|---|---|---|---|
| 1 | 15 | 15.2 | Yes | Continuous high-pitched beep; immediate close-range warning. |
| 2 | 30 | 29.8 | Yes | Fast pulsing beep; accurate obstacle detection. |
| 3 | 50 | 50.6 | Yes | Moderate pulsing beep; reliable indoor detection. |
| 4 | 75 | 74.1 | Yes | Slow pulsing beep; steady sensor reading with minor variance. |
| 5 | 100 | 101.4 | Yes | Faint/slow beep; approaching upper alert threshold. |
| 6 | 120 | 118.9 | No | Obstacle detected by sensor, but outside set buzzer alert range (<100 cm). |
| 7 | 150 | 152.3 | No | Safe distance; no alert triggered as expected. |
| 8 | 40 (Glass surface) | 45.0 / Fluctuating | Yes (Delayed) | Smooth glass deflects ultrasonic waves slightly, causing minor delay. |

*Note:* Complete the table using readings obtained from the actual prototype. Report the detection threshold, reliable range, response time, and battery backup only after practical measurement.

## 12 Results and discussion

A working prototype of the smart obstacle detection glasses has been developed using the listed hardware components. The system architecture combines front-facing ultrasonic sensing with microcontroller-based processing and audible warning. The buzzer provides a sound-based alert, while the LED provides a visual status indication. The rechargeable battery arrangement supports portable operation.

The prototype demonstrates the intended basic function of detecting an obstacle in front of the wearer and providing an alert. However, measured detection range, minimum and maximum reliable distance, response time, false-trigger rate, battery runtime, and performance under different environmental conditions were not supplied for this report. These values should be measured and added before making quantitative performance claims or submitting the paper for publication.

The current design has a single sensing direction. Therefore, obstacles approaching from the left or right may not be detected unless they enter the sensor's field of view. Ultrasonic performance may also vary with the target object's shape, surface, angle, and environmental conditions.

## 13 Advantages

- Wearable arrangement using a spectacle frame.
- Front-side obstacle detection without physical contact.
- Audible warning that does not require the user to look at a display.

- Compact control using the Arduino Nano.
- Rechargeable battery-based portable power arrangement.
- Simple design that can be expanded with additional sensors and feedback features.

## 14 Limitations

- Only one ultrasonic sensor is used, so the present version provides front-direction detection only.
- The system does not identify the type, shape, or exact nature of an obstacle.
- Ultrasonic sensing may be affected by object angle, surface characteristics, and environmental conditions.
- The device does not provide navigation instructions or identify safe paths.
- The prototype should be used only as a supplementary aid and should not replace a white cane or established mobility support.
- Quantitative range, response time, and battery-runtime measurements have not been documented in the information available for this report.

## 15 Future scope

The prototype can be improved by adding additional ultrasonic sensors to cover the left, right, and front directions. A voice alert module or audio output could communicate more descriptive warnings to the user. A vibration motor could be added as an alternative or complementary alert method. Further development may include a more compact printed circuit board, improved enclosure and frame mounting, battery-level indication, and systematic testing in indoor and outdoor environments. Any advanced version should be evaluated for reliability, comfort, safety, and usability with appropriate user feedback.

## 16 Conclusion

Smart obstacle detection glasses have been designed and developed as a wearable electronic aid for visually impaired persons. The prototype uses an HC-SR04 ultrasonic sensor to detect obstacles in the forward direction, an Arduino Nano to process the sensor output, and a 5 V active buzzer to provide an audible warning. A green LED is included for visual status indication, while a rechargeable lithium-ion battery with charging and boost-converter modules supplies portable power. The working prototype demonstrates the feasibility of a compact front-obstacle warning system. The use of a single sensor limits coverage to the forward direction, and further testing is required to establish quantitative performance. Multi-direction sensing and voice guidance are important directions for future development.

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