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Implementation of Distance Measurement Using Arduino UNO, HC-SR04 Ultrasonic Sensor and LCD Display

[1]LIKITH M, [2]DR.SUDHA M S, [3]KUMUDA K V, [4]HARSHITHA N, [5]MANOJ N, [6]CHANDU YADAV D N

[1]STUDENT, [2]ASSO.PROFESSOR, [3]STUDENT, [4]STUDENT, [5]STUDENT, [6]STUDENT
[1]DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
[1]CAMBRIDGE INSTITUTE OF TECHNOLOGY, KR PURAM, BANGLORE

Abstract : This work presents the development of an Ultrasonic Range Finder utilizing readily available components, including an Arduino microcontroller, an HC-SR04 Ultrasonic Sensor, a 16x2 LCD Display, and an I2C LCD Module. This system measures distances accurately by sending out ultrasonic waves and figuring out how long it takes for them to come back. The Arduino processes this data and displays the distance on the LCD screen in real time. The hardware setup involves wiring the HC-SR04 sensor to the Arduino to facilitate communication and power supply. Additionally, the 16x2 LCD Display is connected to an I2C module, simplifying the wiring process and enabling easy communication between the Arduino and the LCD. The Arduino code implements the functionality by periodically triggering the ultrasonic sensor, measuring the time it takes for the ultrasonic waves to return, and converting this time into distance measurements in centimeters. These measurements are then displayed on the 16x2 LCD in a user-friendly format. This work serves as a practical example of sensor integration, data processing, and real-time display on an LCD screen. It can be a valuable educational resource for those interested in Arduino-based projects and the principles of ultrasonic distance measurement.

Keywords : **Distance measurement, Arduino, HC-SR04 Ultrasonic Sensor, LCD Display**

I. INTRODUCTION

The Ultrasonic Range Finder endeavor is an innovative and practical work that combines the power of technology and common electronic components to create a device capable of measuring distances accurately and in real-time. By employing an HC-SR04 Ultrasonic Sensor, an Arduino microcontroller, a 16x2 LCD Display, and an I2C LCD Module, this work offers an accessible solution for distance measurement applications.

This method works by sending out ultrasonic waves, which then bounce off things and come back as echoes. By precisely measuring the time taken for these echoes to return, the device can calculate distances with remarkable precision. This capability makes the Ultrasonic Range Finder a valuable tool for a wide range of applications, from robotics and automation to automotive systems, DIY projects, and educational endeavors.

This work report deals with the objectives, design, components, and potential applications of the Ultrasonic Range Finder, providing a comprehensive understanding of how this technology can be harnessed for practical purposes. Whether you are an electronics enthusiast, a student, or a professional seeking to explore the world of distance measurement, this work offers an exciting and educational journey into the realm of ultrasonic sensing and data visualization.

II. LITERATURE REVIEW

Sirumalla Mansi et. al. **[1]** present a research project focused on Ultrasonic Distance Detection using Arduino, with the aim of measuring distances through an ultrasonic sensor integrated with an Arduino UNO microcontroller. The essential components, including the Arduino UNO, ultrasonic sensor (HC-SR04), LCD display (16x2), and a buzzer, collectively enable the detection of objects and display their distance from the ultrasonic sensor. The literature review reveals the broader applications of ultrasonic distance detectors, citing prior work that underscores the functionality of ultrasonic sensors in precise distance measurement. The pivotal role of the Arduino UNO is discussed, drawing parallels with, which explores the integration of Arduino UNO in hardware and software solutions. Object detection, particularly using LCD displays, is explored in, aligning with the proposed project's objectives. Furthermore, discusses vehicle detection in various scenarios, emphasizing the calculation of longitudinal and horizontal distances to preceding vehicles. This literature review identifies a gap in research, prompting the current project to address specific applications, such as vehicle detection on curve roads and during night-time conditions, contributing to the evolving field of ultrasonic distance detection.

Mutinda Mutava Gabriel et. al. **[2]** present a motion detection system in their research titled "Arduino Uno, Ultrasonic Sensor HC-SR04 Motion Detector with Display of Distance in the LCD." The study addresses the increasing demand for automated sensing to monitor human activity efficiently and remotely, minimizing the need for manpower. Using components such as Arduino Uno, Ultrasonic sensor, LEDs, Piezo Buzzer, and an LCD, the authors design a system that accurately measures and displays the distance of approaching objects on the LCD while providing visual LED signals and a sound alarm. The research builds upon previous studies, introducing features like distance display and sound alerts to enhance the capabilities of motion detectors. Experimental results demonstrate the successful implementation of the motion detector, with LEDs and Piezo Buzzer signaling based on programmed distance thresholds. The LCD displays distance readings, confirming the precision of the system. The authors suggest potential applications in security, traffic monitoring, and industrial settings. Overall, their work contributes to advancing sensor-based systems, offering an efficient and reliable solution for motion detection and distance measurement.

Arijit Goswami et.al **[3]** explores the development and application of an obstacle detection system utilizing Arduino Uno and ultrasonic sensor technology. The system's primary objective is to accurately measure distances from 0.5m to 4m with a high precision of 1cm, overcoming limitations associated with conventional tools like tape measures. The implementation involves the emission of high-frequency sound waves by the ultrasonic sensor, and the Arduino Uno calculates the distance based on the amount of time the echo takes to return, subsequently displaying the results on an LCD module. The paper provides historical context to ultrasonic distance measurement and details the implementation process using Arduino Uno, emphasizing its user-friendly nature. The experimental analysis indicates the system's reliability, showcasing minimal errors in distance measurements. The authors discuss potential future enhancements, such as incorporating humidity sensors and advanced ultrasonic sensors to extend measurement ranges. Overall, the research contributes a cost-effective and efficient solution for distance measurement systems, demonstrating practical applications in diverse fields.

Prakhar Shrivastava et. al **[4]** discusses the development of an ultrasonic distance measurement device using an AT89S51 microcontroller. The project addresses the limitations of manual measurement tools and previous range finder modules, offering a precise and fixed measurement of lowrange distances (0.5m to 4m) with an accuracy of 1cm. The ultrasonic sensor, emitting waves at 40 kHz, calculates distance based on the time taken for sound waves to travel to a surface and return as an echo. The AT89S51 microcontroller processes this information, displaying the distance on an LCD module. The paper highlights the device's applications in various fields, including construction, robotics, and car sensors for obstacle avoidance. The research emphasizes the economic and versatile nature of the technology, suggesting applications such as parking assistance systems, burglar alarms, liquid level measurement, and wire or thread breakdown detection. The study explores the ultrasonic transducer's beam pattern, discusses sources of error, and outlines the scope and potential of the technology in different domains. Overall, the paper presents a comprehensive overview of the project's objectives, methodology, and practical applications.

Tarek Mohammad et. al **[5]** explores the integration of ultrasonic (US) and infrared (IR) sensors for distance measurement in robotics applications in his research paper. The IR sensors, relying on the reflectance properties of surfaces, are prone to inaccuracies without prior knowledge of surface properties. Mohammad introduces the Phong Illumination Model to determine surface properties and calculates distance based on this model. US sensors provide initial distance information. Experimental results, facilitated by LabView, demonstrate the complementary use of these sensors. The calibration of both sensors reveals the US sensor's slightly higher resolution for small distances. The paper validates the Phong Model, showing satisfactory agreement with real data. It concludes with recommendations for improving mobile robot navigation in diverse environments using sensor fusion. Tarek Mohammad is a graduate student at the University of Western Ontario, specializing in Mechanical Engineering.

Biswas et al. **[6]** the authors proposed a novel radar system for moving object detection using ultrasonic sensors. The study aimed to overcome limitations in radar applications by simultaneously capturing distance, direction, and object shape. The radar system employed an Arduino UNO and a single ultrasonic sensor, offering a cost-effective and efficient solution. The system accurately measured the distance and angle of objects, demonstrating superior performance compared to previous works. Notably, the algorithm enabled the direct measurement of object velocity, contributing to accident prevention systems. The research evaluated the system's efficiency against various object shapes and sizes, highlighting its capability to detect square and large cylindrical objects with high accuracy. Despite limitations in detecting extremely small objects or distances less than one centimeter, the proposed radar system showcased promising results, emphasizing its potential for practical applications in security and monitoring.

III. METHODOLOGY

The Ultrasonic Range Measurement endeavor combines various components, such as the Arduino UNO microcontroller, HC-SR04 Ultrasonic Sensor, 16x2 LCD Display, and I2C LCD Module, to construct a device capable of precisely gauging distances in real-time. This process starts by sending out ultrasonic waves. Then, it figures out how long it takes for these waves to come back. The Arduino UNO uses this information to show the distance on the LCD screen. The hardware configuration encompasses connecting the HC-SR04 sensor to the Arduino for power supply and communication, while the 16x2 LCD Display interfaces with the Arduino through an I2C module, streamlining the wiring process.

The operational concept of the Ultrasonic Range Measurement initiative is grounded in SONAR technology. The HC-SR04 Ultrasonic Sensor functions by emitting ultrasonic signals and receiving echoes from obstacles. By precisely Determining the time duration. between emission and reception, the Arduino calculates distances using the speed of sound. This distance data is then continuously updated and displayed on the 16x2 LCD screen via the I2C module, offering real-time feedback on the spatial relationship between the sensor and obstacles.

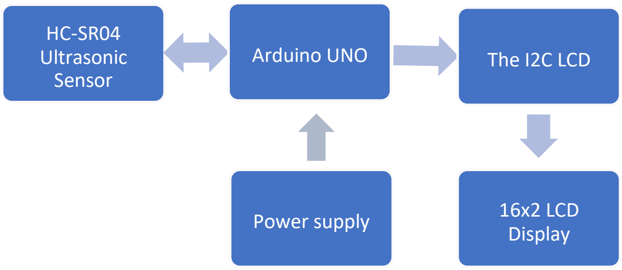

Fig.1 Block Diagram for Distance measurement using Arduino UNO and HC-SR04 Ultrasonic Sensor

The logical sequence embedded in the program revolves around triggering the sensor, measuring echo return times, and converting these times into distance measurements. The Arduino code initializes the LCD Display, configures sensor pins, and implements a continuous loop for triggering and calculating distances.

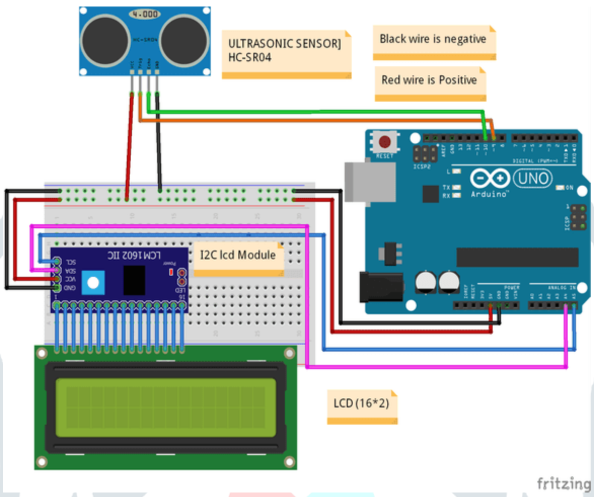

Fig. 2 Circuit Diagram for Distance measurement using Arduino UNO and HC-SR04 Ultrasonic Sensor

The velocity of the sound wave is commonly considered as 340 m/s. This velocity, when expressed in terms of cm/us (centimeters per microsecond), equates to 0.034 cm/us. The distance traveled by the sound wave can be determined by multiplying this speed by the time it takes for the wave to return. The time calculated corresponds to the duration of the pulse sent out and then reflected back, signifying the complete cycle of transmission and reception. To obtain the actual distance of the object from the Ultrasonic sensor, the result is halved, considering that the pulse undergoes a round trip. Hence, the distance (in centimeters) is given by the formula: Distance =
(Speed x Time) / 2, where Distance = (0.034 cm/us x Time (us)) / 2.

$$Distance = \frac{Time\ taken \times Speed\ of\ Sound}{2}$$

This formula ensures an accurate measurement by accounting for the round trip nature of the ultrasonic waves.The calculated values are presented on the LCD screen, providing a user-friendly representation of the spatial measurements. This systematic approach ensures the seamless and accurate execution of the Ultrasonic Range Measurement initiative.

IV. RESULTS AND DISCUSSION

The outcome of an ultrasonic range finder utilizing Arduino and an LCD is a device capable of precisely measuring distances and presenting the results in real-time on a screen. The system incorporates an ultrasonic sensor to emit sound waves, which then rebound off an object and return to the sensor. By calculating the time taken for the sound waves' journey, the device deduces the distance to the object.

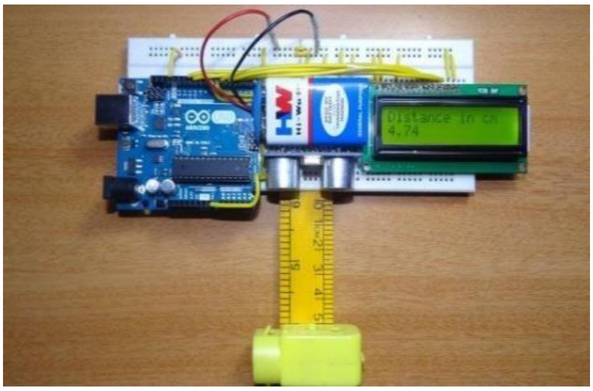

Fig. 3 Final Circuit Connection with displaying the distance

The measurement process of an ultrasonic range finder involves the following steps. First, a trigger signal is generated to initiate the emission of ultrasonic waves from the sensor. These waves travel towards the target object and, upon encounter, are reflected back to the sensor, generating an echo signal. The microcontroller, or dedicated circuit, precisely measures the amount of duration taken by the ultrasonic waves' round trip. Using the known speed of sound in air, the distance is calculated employing the formula: Distance = (Speed of Sound * Time) / 2. The calculated distance is then displayed on an output interface, such as an LCD screen. This entire process can be continuously repeated for real-time distance monitoring, making the ultrasonic range finder a reliable tool for distance measurement in various applications, particularly in robotics for navigation and obstacle avoidance.

V. FUTURE SCOPE

The concept of the ultrasonic range finder can be extended for future development in the automotive industry, particularly for implementing automatic braking systems in cars. By integrating ultrasonic sensors strategically around a vehicle, the system can continuously monitor the distance to objects in the vehicle's path. If the system detects an imminent collision or an unsafe following distance, it can trigger an automatic braking mechanism to prevent or mitigate the impact. This application aligns with the broader field of Advanced Driver Assistance Systems (ADAS) and enhances vehicle safety by utilizing distance measurement technology to proactively address potential collisions, thereby contributing to the development of intelligent and safer transportation systems.

In robotics, precise distance measurement is crucial for navigation, obstacle avoidance, and overall environmental awareness. By incorporating ultrasonic sensors into robotic systems, these machines can accurately perceive their surroundings, detect obstacles, and navigate through complex environments. This application is particularly valuable in scenarios where other sensing modalities, such as visionbased systems, may be limited or compromised. The ultrasonic range finder can contribute to the development of more intelligent and adaptable robots, enhancing their autonomy and functionality in various industries, including manufacturing, logistics, and service robotics.

VI. CONCLUSION

In conclusion, the Ultrasonic Range Finder employing Arduino and an LCD stands out as a successful project that offers a non-contact method for measuring distances. Using the way sound waves bounce, the device figures out how long it takes for them to come back. This gives a precise measure of the distance to an object. This innovative project serves as a versatile tool, finding utility in a spectrum of applications ranging from engaging DIY projects to practical scenarios where precise distance measurements are essential.
The project's strengths lie in its simplicity, affordability, and accuracy. Its user-friendly design, coupled with the ease of implementation using Arduino and an LCD, makes it accessible for a wide audience. Whether for educational purposes, hobbyist endeavors, or real-world applications, this Ultrasonic Range Finder offers a straightforward and efficient solution to measure distances without the need for physical contact. Overall, it exemplifies the fusion of technology and practicality, showcasing the potential of such projects in making complex measurements more accessible and enjoyable.

VII. REFERENCE

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