IJIREEICE
ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.021 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 12, Issue 6, June 2024
DOI: 10.17148/IJIREEICE.2024.12605

DISTANCE MEASUREMENT USING ULTRASONIC SENSOR AND FPGA

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Abstract: Navigation of an object is widely used for target detection. In such systems the nearest objects are detected by distance measurement. The distance measured and choice of sensor depends on type of application and also surrounding environmental issues like temperature, humidity, fog etc. For short distance measurement ultrasonic sensor is used. The ultrasonic sensor output is used to measure the distance. The computation, processing, control and display units are implemented on FPGA. The Xilinx synthesis tool is used for implementing the design on FPGA. FPGAs have faster processing capability, low power consumption and are easily reconfigurable for the necessary applications. The measured distance is displayed on segment displays.

Keywords: FPGA Kit, Ultrasonic sensor HC-SR04, 7-Segment display unit, Xilinx ISE design suit.

I. INTRODUCTION

Navigation of an object is widely used for target detection, security range monitoring in border, parking assistance for vehicles, wild life photography and so on. In such systems the objects are detected and their exact location is found by distance measurement. The distance measurement is done using ultrasonic sensor, infra-red beams, and LASER beams with additional electronic hardware. The distance measured and choice of sensor depends on type of applications and also surrounding environmental issues like temperature, humidity, fog etc. For short distance measurement ultrasonic sensor is used. In this technique time taken for signal to reach the target and come back as reflected signal is calculated. The design such systems mainly concentrates on the accuracy of measurement of distance, kind of sensors used, distance coverage, power utilization, compactness and also the cost.

In this paper, distance measurement of an object using ultrasonic sensor with separate transmitter, receiver and FPGA is done. Main purpose of utilizing ultrasonic sensor and FPGA is to accomplish low-cost, low power, easily portable and accuracy as well as speed. The FPGA based systems have faster processing capability with low power use and are easily reconfigurable.

II. LITERATURE SURVEY

[1]The paper authored by T. Schlegl, et al.[1] represent a concept based on the technique called sensor fusion with capacitive and ultrasonic sensor which measures distance in vehicle parking assistance. Even though this sensor is cheaper than others, when compared with capacitive sensor, it will not give immediate vicinity of a vehicle. In such situation capacitive sensor will provide measurement of up to 0.3 m and also gives information related to approaching object itself. This concept covers up to 2 m and also avoids blind spots and helps to provide classification of the object. This is also robust against environmental influences.

[2]H. He, et al.[2 describe distance measurement based on ultrasonic sensor using S3C2410. To improve the precision, the circuit requires temperature compensation circuit. The drive transducer has triggering timer interrupt and external interrupt. The transducer will send a 40 kHz square wave signal. Here, ranging values are displayed through the LCD. The device software and hardware is realized with S3C2410 and Embedded Linux.

[3] The paper authored by Y. Jang, et al.[3] shows implementation of portable walking distance measurement system and gives precision of approximately 90%. This is achieved by studying characteristics of ultrasonic waves. It helps in applications such as measuring the walking distance and exercises in daily life.

[4]The paper by Mahmud [4] gives the solution for smart obstacle detection system which enables visually impaired individual to guide the path by getting vibration and voice feedback from the objects.

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[5]C.C.Chang [5] provide solution to control the movements of submerged vehicles by utilizing ultrasonic sensor, in addition with 3-D position control by camera based devices and a LASER system .

[6]D.Webster [6] portrays solution for noise immunity by adopting Binary Frequency Shift Keying (BSFK) signal.

[7]P. Sharma, et al. [7] designs a system similar to the proposed project acting as portable solution with low-cost for visual impaired people. This idea utilizes both raspberry pi and also ardiuno microcontroller, along with additional unnecessary hardware.

[8]Yelamarthi [8] proposed promising outcomes with their kinect-based haptic criticism gloves. In any case, the kinect can track people. It is a costlier arrangement and the gloves can restrict the activities the client can perform.

[9]Mustapha [9] introduced a special innovation which incorporates PIC microcontroller with ZigBee protocol. It uses force sensing resistor, IR sensor along with ultrasonic sensor and all are put on shoes to gather information. This collected information sent remotely to a PIC microcontroller.

[10]Karabchevsky [10] intended to give answer for conventional programming based usage to detect unmanned submerged vehicles by utilizing an acoustic obstacle detection system with advanced algorithms running on Field Programmable Gate Array (FPGA). The use of FPGA reduces the power utilization and achieves high computation complexity as well as reliable real time performance.

[11]Hamza [11] used stereovision calculation to recognize obstructions and the process is on FPGA. The FPGA and two cameras used in continuous application.

[12]S.S.Huang [12] presents an algorithm in which combination of phase shift method and Time of Flight (TOF) method is used. Microcomputer based BPSK signal generator and phase detector is used to compute the TOF along with phase difference between the two signals. This results in distance calculation. It gives ±0.05 mm range accuracy over 60 m distance.

III. METHODOLOGY

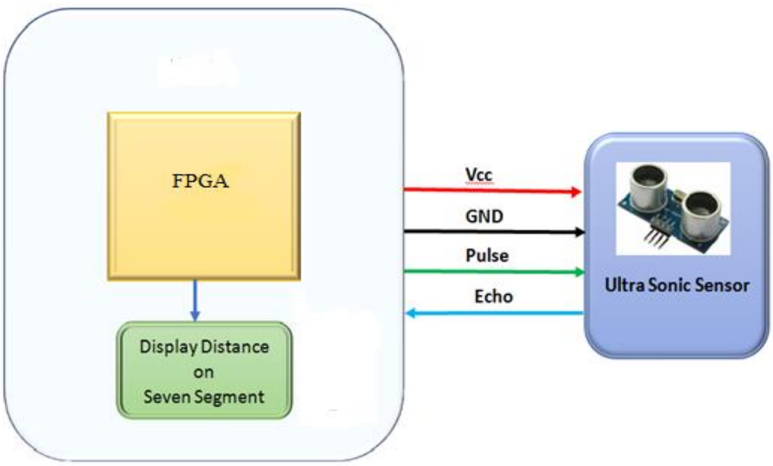

Fig.1: **Block diagram**

Distance measurement using ultrasonic sensor and signal processing FPGA block diagram shown in Fig 4.1. The overall architecture is based on three main sub-systems.

(a) Input sub-system: An input sub-system is responsible for sending and receiving of ultrasonic burst of pulses to the target or an obstacle.

(b) FPGA board: This is responsible for entire on-board signal processing from the input sub-system and to the output sub-system.

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(c) Output sub-system: An output sub-system is seven segment display unit which will take care of displaying the calculated distance measured by input sensor.

A.Working Principle:
Input sub-system

The principle of an ultrasonic sensor input sub-system is shown in Fig.2. It uses pulse echo method. This distance measuring meter take time required for pulse signal to hit the target and return back as echo signal, along with sound. The velocity of the signal in air is 340 m/sec. Up to 10 cm distance can be calculated by this device using separate transducer for transmission and reception. The display unit will display the measured reading in centimeters. This module includes three main parts:

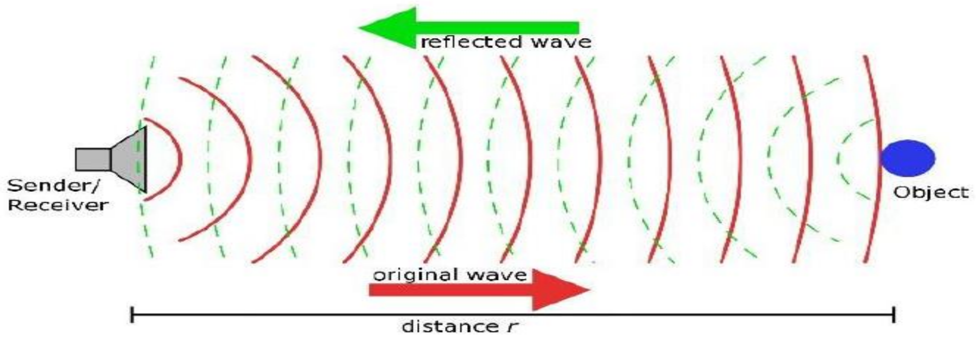

Fig.2 Principle of ultrasonic distance meter

- Ultrasonic transmitter
- Ultrasonic receiver
- Control circuit.

B.Distance Calculation

- High level 10 µsec triggering signal is sent till any object is detected.
- Immediately eight sonic bursts are sent at 40 kHz. Then wait for pulse echo signal.
- After receiving the echo pulse signal back, test distance is calculated as follows:

$$Time = \frac{Distance}{Speed} \qquad \text{---Eq (1)}$$

Here $V = 340 \frac{m}{sec}$ is the speed of sound waves

$$t = \frac{s}{v} = \frac{10}{0.034} = 294\mu \sec \qquad \text{---Eq (2)}$$

$$Distance: S = t \times \frac{0.034}{2} \qquad \text{---Eq (3)}$$

$$Test\ distance = \frac{Echo\ high\ level\ time\ \times\ Velocity\ of\ sound\ in\ air}{2}$$
---Eq (4)

Where,
If the echo pulse width is µsec/58, the distance is in centimetre.
If the echo pulse width is µsec/148 the distance is in inches.
The distance calculation is shown in Fig.3

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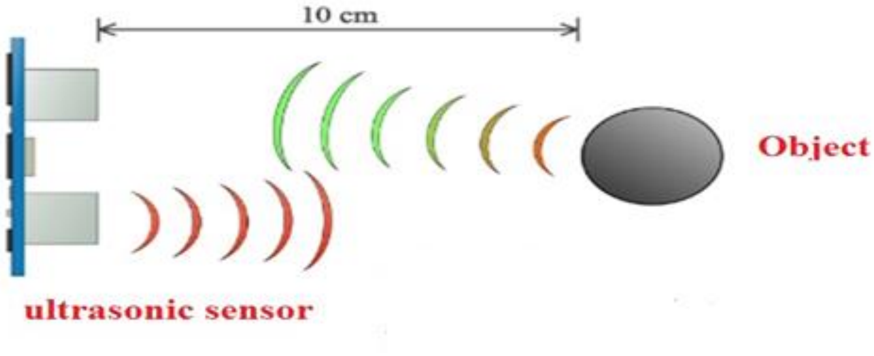

Fig.3 Distance calculation

C.Timing Diagram of Ultrasonic Sensor

The echo meter was intended to interpret the response of the ultrasonic sensors into numeric range esteem. It worked by waiting for the signal on the echo pin from the ultrasonic sensor to rise from low to high. When high, the segment counts clock cycles until the signal drops to low once again. Separation can be measured by using the length of echo. Each 5800 clock cycles at a frequency of 100 MHz compares to 1 cm measured.

Thus, the aggregate separation measured could be evaluated. Here sensor consists of two main signals trigger signal from FPGA and Echo signal to FPGA. When a minimum 10 µsec trigger high signal is placed, immediately the module send acoustic bursts of eight 40 kHz signal. At the same time counting of echo pulse width starts. It will wait to capture the rising edge output of ECHO port till it gets falling edge. Now read the counter, which is the width of echo pulse. The Fig. 4.4 shows the timing diagram.

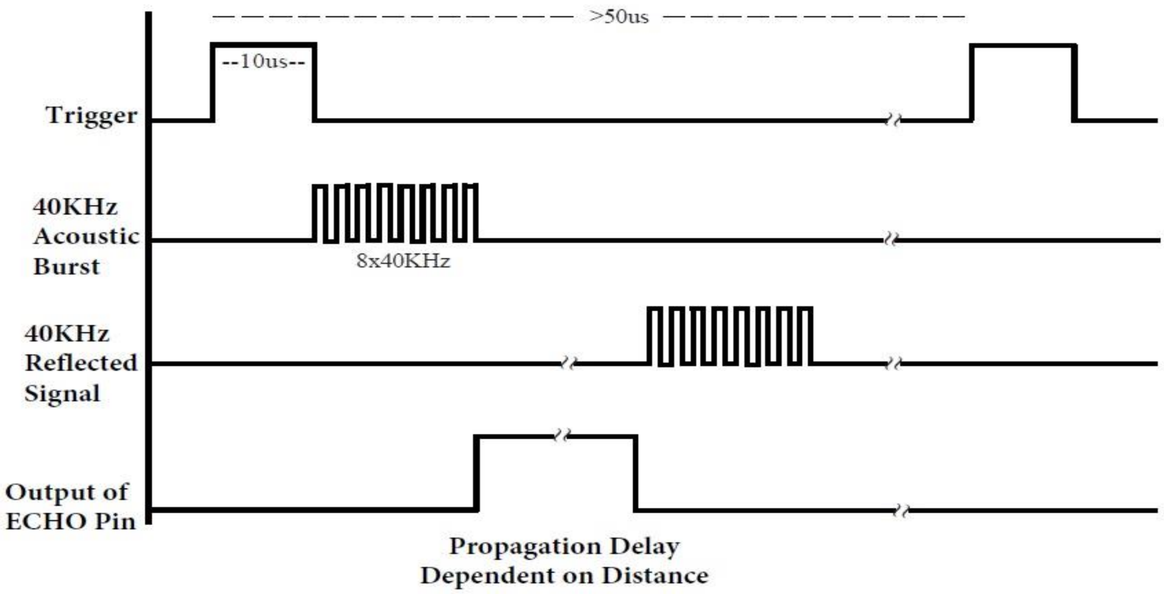

Fig.4 Timing Diagram of Ultrasonic Sensor HC-SR04

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D. IMPLEMENTATION

System Architecture

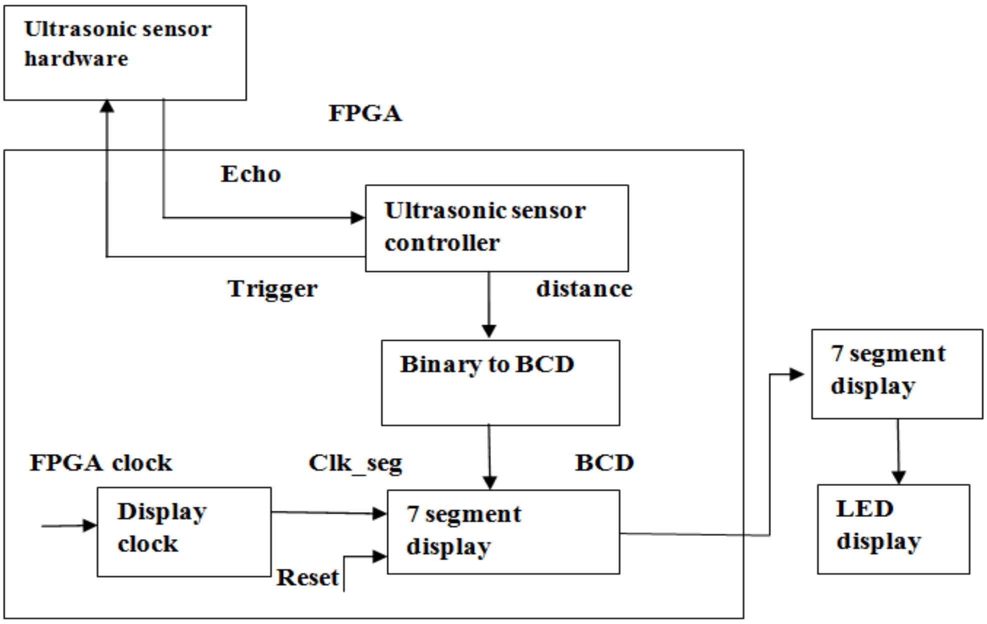

Fig 5. Proposed system architecture

E.APPLICATIONS

- Security area monitoring in industries.
- Wildlife photography.
- Control the movements of submerged vehicles.
- On border defence line: Implementing this on border line can protect against attackers and give alert from interrupting security issues.
- Tracking the detected targets: Discovering the path of target and their separation is considered.
- Vehicle parking system: It will guide as parking assistance by placing the gadget on bumper of vehicle.

F.HARDWARE IMPLEMENTATION

The implementation with FPGA Spartan 6 board is as shown in Fig 6. The HDL description of the entire system is dumped into board using Xilinx ISE design suit version 14.3. Interfacing 4 pin HC-SR04 US sensor to sense the target and 4 digits 7 segment display unit for indication to get more precision of measurement.

Fig 6. Module implementation

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IV. CONCLUSION

Design and implementation of object detection using ultrasonic sensor with the control logic and computation required on FPGA are done. The presence of the object and its location being identified with the help of distance measurement. This system provides more convenient and compact solution for visually impaired people. Also, placing this device on vehicle bumper assists in parking of vehicles. The system is also useful in boarder security where extreme weather conditions prevail, as it is suitable for any atmospheric conditions such as humidity, temperature and pressure with good accuracy and resolution.

V. FUTURE SCOPE

The system may be used for identification of the object detected and located by significant amount of signal and image processing. In autonomous navigation systems the "closest" obstacle is inconvenient when trying to map the environment. Hence the performance of the system in terms of computational speed, accuracy and decision making become more crucial.

REFERENCES

[1]. T. Schlegl, T. Bretterklieber, M. Neumayer and H. Zangl, "A novel sensor fusion concept for distance measurement in automotive applications", IEEE Sensors, pp.775 -778 2010.
[2]. H. He and J.Liu, " The design of ultrasonic distance measurement system based on S3C2410", Proceedings of the IEEE International Conference on Intelligent Computation Technology and Automation, October 2008, pp. 44-47.
[3]. Y. Jang, S. Shin, J. W. Lee, and S. Kim, "A preliminary study for portable walking distance measurement system using ultrasonic sensors",Proceedings of the 29th Annual IEEE International Conference of the EMBS, France, Aug. 2007, pp. 5290-5293.
[4]. N. Mahmud, R. Saha, R. Zafar, M. Bhuian and S. Sarwar, "Vibration and Voice Operated Navigation System for Visually Impaired Person", in International Conference on Informatics, Electronics, & Vision (ICIEV), 2014.
[5]. C. C. Chang, C. Y. Chang, and Y. T. Cheng, "Distance measurement technology development at remotely teleported robotic manipulator system for underwater constructions", IEEE International Symposium on Underwater Technology, Apr. 2004, pp. 333-338.
[6]. D. Webster, "A pulsed ultrasonic distance measurement system based upon phase digitizing", IEEE Transaction on Instrumentation and Measurement, Vol. 43, No. 4, Aug. 1994, pp. 578-582.
[7]. P. Sharma, S. Shimi and S. Chatterji, "Design of Microcontroller Based Virtual Eye for theBlind", International Journal of Scientific Research Engineering & Technology (IJSRET),vol. 3, no. 8, pp.1137-1142, 2014.
[8]. K.Yelamarthi, B. DeJong and K. Laubhan,"A Kinect based Vibrotactile FeedbackSystem to Assist theVisually Impaired", in IEEE 57th International Midwest Symposium on Circuits and Systems(MWSCAS), 2014.
[9]. B. Mustapha, A. Zayegh and R. Begg, "Reliable Wireless Obstacle Detection System for Elderly and Visually Impaired People with Multiple Alarm Units", in International Conference on Computer,Communications, and Control Technology (I4CT), 2014.
[10]. S. Karabchevsky, D. Kahana and H. Guterman, "Acoustic real-time, low-power FPGA based obstacle detection for AUVs", in Electrical and Electronics Engineers in Israel (IEEEI), 2010 IEEE 26th Convention of 2010.
[11]. B. Hamza, K. Abdelhakim and C. Brahim, "FPGA design of a real-time obstacle detection system using stereovision", in Microelectronics (ICM), 2012 24th International Conference on, 2012.
[12]. S.S.Huang "A high accuracy ultrasonic distance measurement system using binary frequency shift keyed signal and phase detection",Huang et al review of scientific instruments volume73, number 10 october 2002.