ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 6, Issue 7, July 2019

Development of Ultrasonic Sensor Based Automatic Braking System

[1] Ajith Kumar T, [2]Arul Prakash M, [3]Ajith R, [4]Abishek N, [5] Surendhar S
[1][2][3][4][5] Department of Mchanical Engineering, Sri Sai ram Engineering College, Chennai, India

Abstract **– Currently, vehicles are equipped with active safety systems to reduce the risk of accidents, many of which occur in the urban environments. The most popular include Antilock Braking Systems (ABS), Traction Control and Stability Control. All these systems employ different types of sensors to constantly monitor the conditions of the vehicle, and respond in an emergency situation. In the present work, a test setup for the use of ultrasonic sensors in safety systems for controlling the speed of a vehicle is developed and tested. An intelligent mechatronic system includes an ultrasonic wave emitter provided on the front portion of a car producing and emitting ultrasonic waves frontward in a predetermined distance. An ultrasonic receiver is also placed on the front portion of the car operatively receiving a reflective ultrasonic wave signal. The reflected wave (detected pulse) gives the distance between the obstacle and the vehicle. Then a microcontroller is used to control the speed of the vehicle based on the detection pulse information to push the brake pedal and apply brake to the car stupendously for safety purpose.**

Keywords: ABS, Microcontroller, Piezo electric effect, Stupendous braking, Ultrasonic sensor, XC60 SUV

I. INTRODUCTION

Driving is an unavoidable activity for most of the people in toady's modern life style. People use cars to move from one place to another. The number of vehicles are increasing day by day. It produces traffic issues and risk of accidents. Nowadays, the numbers of accident are so high and occurs more often. Accidents occur frequently and cause worst damages, serious injury and death. These accidents are mostly caused by delay of the driver to hit the brake.Automatic braking systems are widely used and tested as a promising solution for these problems.

A new system with ultrasonic sensors is developed in the present work. This automatic system can handle this problem where drivers may not apply brake manually but the vehicles can stop automatically.

The present work aims to develop and test an automatic braking system for cars which is activated whenever there is an obstacle in the near vicinity of the vehicle. When the obstacle is sensed by the sensor, the braking circuit has to apply the brake automatically without driver's intervention. The primary objective of this paper is to develop a safety car braking system using ultrasonic sensor to achieve less human intervention and less accidents during driving.

II. LITERATURE REVIEW

Various attempts were made in the past to improve braking systems to achieve best accident prevention methods. This includes the existing systems in current automobile industries and the novel approaches published in literatures were reviewed. The existing approaches in preventing accidents is Honda's idea of Anti-lock Braking System (ABS) which helps the rider get a hassle free braking experience in muddy and watery surfaces by applying a distributed braking and prevents skidding and wheel locking. Volvo's new launch XC60 SUV will sport laser assisted braking which will be capable to sense a collision up to 50 mph and apply brakes automatically.

Existing Methods of Accident Preventions are:

A. Pre-Sense Plus

The full version of the system (Pre-Sense Plus) works in four phases. In the first phase, the system provides warning of an impending accident, while the hazard warning lights are activated, the side windows and sunroof are closed and the front seat belts are tensioned. In the second phase, the warning is followed by light braking, strong enough to win the driver's attention. The third phase initiates autonomous partial braking at a rate of 3 m/s^2. The fourth phase decelerates the car at 5 m/s^2 followed by automatic deceleration at full braking power, roughly half a second before projected impact.

B. Pre-Sense Rear

A second system, called (Pre-Sense Rear), is designed to reduce the consequences of rear-end collisions. The sunroof and windows are closed and seat belts are prepared for impact. The optional memory seats are moved forward to protect the car's occupants.

C. Collision Warning with Brake Support

Ford's Collision Warning with Brake Support was introduced in 2009 on the Lincoln MKS and MKT and the Ford Taurus. This system provides a warning through a Head Up Display that visually resembles brake lamps. If the driver does not react, the system pre-charges the brakes and increases the brake assist sensitivity to maximize driver braking performance. Ford demonstrated its Obstacle Avoidance technology relying on a mix of sensors, including a camera tucked behind the rearview mirror, to scan the road for vehicles and pedestrians and steer away if the driver does not take any action.

D. Collision Mitigation Brake System

Honda's Collision Mitigation Brake System (CMBS, although originally introduced with the initials CMS) introduced in 2003 on the inspire and later in acura, Honda's luxury brand in Canada and the United States, uses a radarbased system to monitor the situation ahead and provide automatic braking if the driver does not react to a warning in the instrument cluster and a tightening of the seat belts. The Honda system was the world's first production system to provide automatic braking. The 2003 Honda system also incorporated an "E-Pretension", which worked in conjunction with the CMBS system with electric motors on the seat belts. When activated, the CMBS has three warning stages. The first warning stage includes audible and visual warnings to brake. If ignored, the second 4stage would include the EPretension's tugging on the shoulder portion of the seat belt two to three times as an additional tactile warning to the driver to take action. The third stage, in which the CMBS predicts that a collision is unavoidable, includes full seat belt slack take up by the E-Pretension for more effective seat belt protection and automatic application of the brakes to lessen the severity of the predicted crash. The E-Pretension would also work to reduce seat belt slack whenever the brakes are applied and the brake assist system is activated.In late 2004, Honda developed an Intelligent Night Vision System, which highlights pedestrians in front of the vehicle by alerting the driver with an audible chime and visually displaying them via HUD. The system only works in temperatures below 30 degrees Celsius (86 Fahrenheit). This Intelligent Night Vision first appeared on the legend.

E. Laser-Based System

Nissan's luxury brand in North America and Europe, infinite, offers a laser-based system in the US market, which pre-pressurizes the braking system so that maximum force can be applied early. Nissan is reportedly developing a new "magic bumper" system, which raises the accelerator pedal if it senses an impending collision. Once the driver lifts off the pedal, the system automatically applies the brakes.

F. Collision Alert System

GM's collision alert system is featured in the 2012 GMC Terrain SUVs and uses a camera to provide warning when there is a vehicle ahead or there is a lane departure. 2013 Cadillac ATS, XTS and SRX models featured automatic braking at low speeds (in heavy traffic or even in parking lots and driveways) when a collision is imminent. 2014 Chevrolet Impala received the radar and camera based Crash imminent braking (Radar technology detects a possible crash threat and alerts the driver. If the driver does not appear to react quickly enough or doesn’t react at all, this feature intervenes to apply the brakes in an effort to avoid the crash), Forward collision alert, Lane departure warning, Side blind zone alert (Using radar sensors on both sides of the vehicle, the system “looks” for other vehicles in the blind zone areas of the Impala and indicates their presence with LED-lit symbols in the outside mirrors), Rear cross traffic alert features. Different sensors are installed in the vehicle to check different automotive applications. In this case, we have only used the sensors to obtain the vehicle’s positioning in order to compare it with the distance obtained via the ultrasonic sensor. Here we used ultrasonic sensor to measure the distance of the obstacle and it is displayed on the screen. According to that distance we can perform PWM.

Various attempts by researchers and published in literatures are studied and are as follows: Coelingh et al. [1] describes one of the latest AEB systems called Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD). It helps the driver with avoiding both rear-end and pedestrian accidents by providing a warning and, if necessary, automatic braking using full braking power. Neil and Storey [2] introduces the field of safety-critical computer systems for any engineer who uses microcomputers within real-time anti-lock braking systems in automobiles, to flyby- wire aircraft, to shut-down systems at nuclear power plants. It is, therefore, vital that engineers are aware of the safety implications of the systems they develop.

A study on new computer-controlled, interactive brake pad friction tester is presented by [4]. this study seeks to clarify the general public's understanding of automatic braking systems.

A total of 210 Japanese people responded to a questionnaire regarding how automatic brakes are operated, how they work, when they disengage, and so on. The proportion of those who misunderstood is not high, but there were a certain percentage of people who misunderstood the functions and limitations of automatic braking. If they mistakenly use the automatic brake, there is a possibility of posing a risk to the road transportation system. Respondents' beliefs about the functionality of automatic braking had little effect on whether such systems made them feel safer or made them inattentive.

Real-world effects of rear automatic braking and other backing assistance systems were evaluated by Jessica and Cicchino [5]. Negative binomial regression was used to compare police-reported backing crash involvements per insured vehicle year in 23 US states. The combination of Rear Vision Camera and Rear Parking Assist reduced backing crash involvement rates by 42%. When Rear Automatic Braking was added to the Rear Vision Camera and Rear Parking Assist, vehicles with all three systems had backing crash involvement rates that were 78% lower than vehicles with none of the systems. However, the effectiveness may be restricted in part by drivers not using or reacting to the systems appropriately. Rear automatic braking adds to the effectiveness of these systems because it does not rely entirely on appropriate driver response. If more vehicles were equipped with rear automatic braking that performed like the system evaluated in the current study, many backing crashes that still occur among vehicles with rear view cameras and rear parking sensors could be prevented.

Jingliang et al. [6] analyzes the driver’s braking behavior in typical V-B conflicts of China to improve the performance of Bicyclist-AEB systems. Naturalistic driving data were collected, from which the top three scenarios of vehicle-bicycle (V-B) accidents in China were extracted. Three scenarios namely SCR (a bicycle crossing the road from right while a car is driving straight), SCL (a bicycle crossing the road from left while a car is driving straight) and SSR (a bicycle swerving in front of the car from right while a car is driving straight) were considered. A driving simulator was employed to reconstruct these three scenarios and some 25 licensed drivers were recruited for braking behavior analysis. Results revealed that driver’s braking behavior was significantly influenced by V-B conflict types. Predecelerating behaviors were found in SCL and SSR conflicts,

whereas in SCR the subjects were less vigilant. The brake reaction time and brake severity in lateral V-B conflicts (SCR and SCL) was shorter and higher than that in longitudinal conflicts (SSR). The findings improve their applications in the Bicyclist-AEB and test protocol enactment to enhance the performance of Bicyclist-AEB systems in mixed traffic situations especially for developing countries.

Hiroshi Ohno [7] developed an automatic braking control system for automobiles applying a three-layer neural network model. This system enables the vehicle to decelerate smoothly and to stop at the specified position behind the vehicle ahead. Because vehicle dynamics is varied by the variations in road conditions or vehicle characteristics, it cannot be represented accurately by mathematical models. According to this reason, the conventional control methods, such as proportional integrative derivative (PID) control, cannot achieve satisfactory control performance. Therefore, we have constructed the neural network adaptive control system based on the feedback error learning method. This learning method enables the system to adapt to the changes in road grade and vehicle weight without using any specific sensors. Results show satisfactory control performance and reveal that this control system is best suited for the automatic braking control system.

Isermann [8] obtained experimental results of Anticollision system with automatic braking and steering. Collision-avoidance, driver-assistance system are described with automatic object detection, trajectory prediction, and track following, with controlled braking and steering. The objects are detected by a fusion of Light Detection and Ranging (LIDAR) scanning and video camera pictures that show the location, size and speed of objects in front of the car. A desired trajectory is calculated depending on the distance, the width of a swerving action and differential speed. Automatic braking is realized with an electrohydraulic brake and automatic steering with an active front steering. Various control systems are compared by simulations and real test drives showing the behavior of a Volkswagen Golf with automatic braking and/or automatic swerving to a free lane, thus avoiding hitting a suddenly appearing obstacle.

Drawbacks in the existing approaches:

- ABS can only help if the rider applies it in the right time manually and maintains the distance calculations. ABS has its own braking distance.
- Moreover many commuter bikes in India don’t have the option of ABS because it’s very expensive.
- Volvo’s laser assisted braking could not work effectively in rainfall and snowfall season and laser is easily affected by atmospheric conditions.

In this present work using ultrasonic sensors and microcontroller, the speed of the vehicle is automatically reduced and voice alarms are given to the user when it approaches an object by automatically sensing the position of the object/vehicle.

III. PRINCIPAL COMPONENTS OF ULTRASONIC SENSOR

Ultrasonic ranging and detecting devices make use of high-frequency sound waves to detect the presence of an object and its range. These systems either measure the echo reflection of the sound waves from objects or detect the interruption of the sound beam as the objects pass between the transmitter and receiver.
An ultrasonic sensor typically utilizes a transducer that produces an electrical output pulse in response to the received ultrasonic energy.

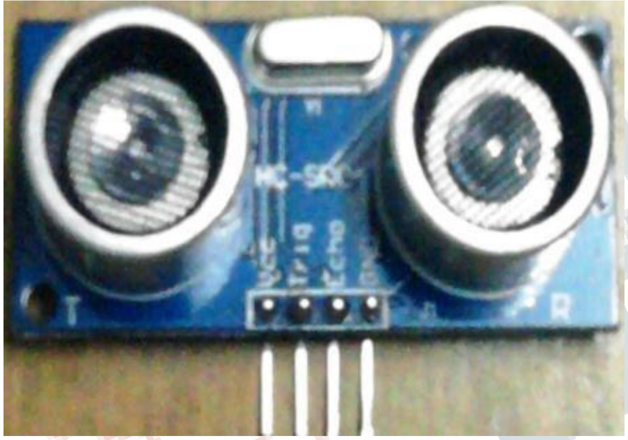

Fig: 3.1.Ultrasonic sensor

The normal frequency range for hearing of humans is roughly around 20 to 20,000 hertz. Ultrasonic sound waves are the sound waves that are above the range of human hearing capability and, so have a frequency above 20,000 hertz. Any frequency which is above 20,000 hertz may be considered as ultrasonic. Most of the industrial processes, including almost all the sources of friction, create some ultrasonic noise. The ultrasonic transducer produces ultrasonic signals. These signals propagate through a sensing medium and the same transducer can be used to detect the returning signals. Ultrasonic sensors usually have a piezoelectric ceramic transducer that converts an excitation electrical signal into ultrasonic energy bursts. These energy bursts travel from the ultrasonic sensor, bounce off objects, and are returned towards the sensor as echoes. Transducers are the devices that convert electrical energy to mechanical energy, or vice versa. The transducer converts the received echoes into analog electrical signals that are outputs from the transducer. The piezoelectric effect refers to the voltage produced between surfaces of a solid dielectric (no conducting substance) when some mechanical stress is applied to it. On the other hand when a voltage is applied across certain surfaces of a solid that exhibits the piezoelectric effect, the solid undergoes a mechanical distortion. Such type of solids typically resonates within narrow frequency ranges. Piezoelectric materials are generally used in transducers. For example, they are used in phonograph cartridges, strain gauges, and microphones that produce an electrical output from a mechanical input. Also, they are used in earphones and ultrasonic transmitters that produce a mechanical output from an electrical input.

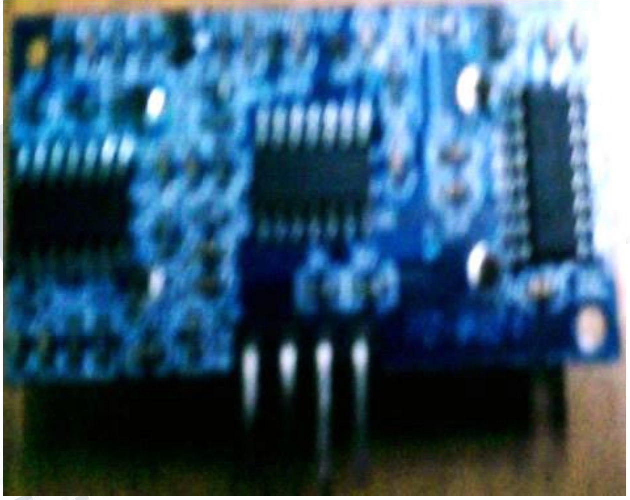

Fig.3.2 typical view of sensor

Ultrasonic transducers operate to radiate ultrasonic waves through a medium such as air. Transducers generally create ultrasonic vibrations with the use of piezoelectric materials such as certain forms of crystal or ceramic polymers.

IV. MEASUREMENT PRINCIPLE AND EFFECTIVE USE OF ULTRASONIC SENSOR

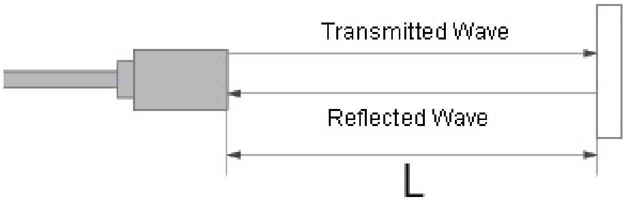

Fig.4.1 Operation of sensor

Ultrasonic sensor transmits ultrasonic waves from its sensor head and again receives the ultrasonic waves reflected from an obstacle. By measuring the length of time from the transmission to reception of the ultrasonic wave, it detects the distance and hence the position of the object. Ultrasonic signals are like audible sound waves, except that the frequencies are much higher than them. Our ultrasonic transducers have piezoelectric crystals which resonate to a desired frequency and convert electric energy into acoustic energy and vice versa. The below illustration shows how sound waves, transmitted in a conical shape, are reflected from a target back to the transducer. Accordingly, an output signal is produced to perform some kind of indicating or control function.

A certain minimum distance from the sensor is required to provide a time delay so that the "echoes" can be interpreted. Some variables which can affect the operation of ultrasonic sensing include, target surface angle, reflective surface roughness or changes in temperature or humidity. Targets can have any kind of reflective form. Even round objects can be targets.

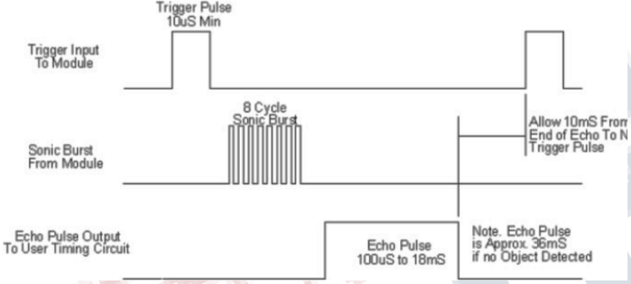

Fig.4.2 Timing diagram

V. METHODOLOGY

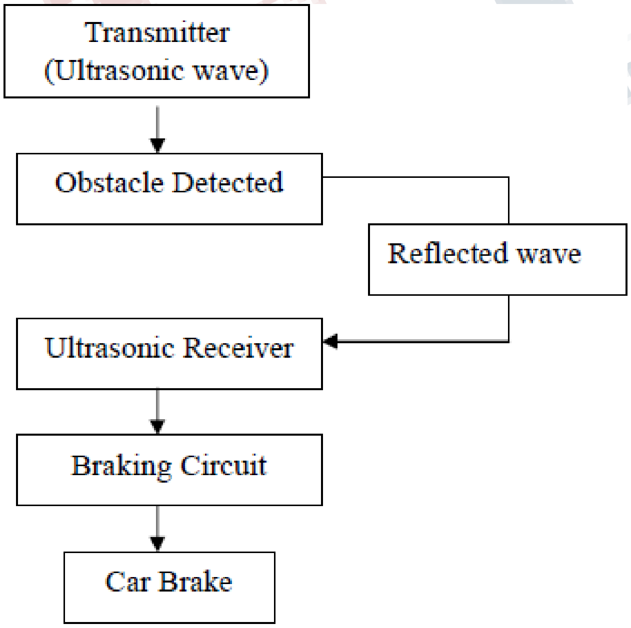

Fig.5.1 Model block diagram

The steps required to read the distance and controlling the speed of a vehicle are:-

- Microcontroller makes the I/O line output. (By using the DDR x Register in AVR or TRIS x Register in PIC)
- The I/O line is made low (this may be the default state of I/O pin)
- Wait for 10uS
- Make the I/O line high,
- Wait for 15uS
- Make the I/O line low
- Wait for 20uS
- Now make it input (by using the DDR x Register in the obstacle and come back to the module.
- Module will keep it low. Wait when the pulse is low, as soon as that becomes high start the timer.
- After this, wait till pulse is high and as soon as that becomes low copy the timer value and stop the timer.
- Finally we have the time required for the wave to go hit the obstacle and come back to the module.
- If the pulse width obtained is in microseconds, the distance of the obstacle from the vehicle can be Calculated by the following formula:
- Distance in cm = Pulse width/58 Distance in inches = Pulse width/148
- After calculating the distance of the obstacle we will define variable speeds according to the distance of approach of the obstacle and store them in three flags.

VI. ANALYSIS OF ERRORS

An insufficiently high threshold level causes the detection of false echoes produced by turbulences and irregularities in the road, which make the control system act on the brakes unnecessarily. In contrast to this, if the threshold is too high, then detection failures can occur, meaning that no objects are detected even if they are actually there and therefore causing possible collisions. To adjust the threshold level, a hundred echoes were recorded in a range of 11 meters, with the sensor at rest and no obstacles in the front. The threshold has been reduced slowly, until at a final value of 2 × 10−4 a false echo has been detected. Figure 6.1 shows the measurements resulting from this experiment. After this, this threshold level has been used in a second experiment, in which the sensor is placed in a vehicle which approaches and moves away from another vehicle which is at rest.

During the experiment, the distance was measured hundred times, showing the results in Figure 6.2. The distance was varied from about 2 meters to more than 11 meters, showing only one false echo that occurred when the distance between vehicles was higher than the range of the ultrasonic sensor used. No detection failures occurred and when the obstacle was within the range of the ultrasonic sensor, it was correctly detected always.

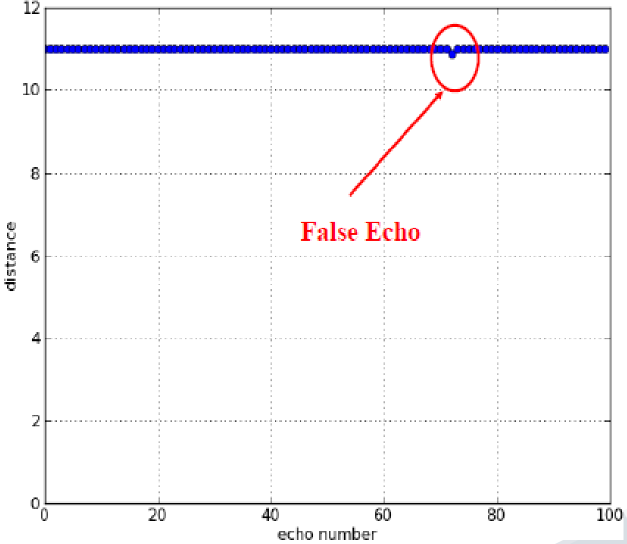

Fig.6.1 Measurements made with the sensor at rest and no obstacles ahead

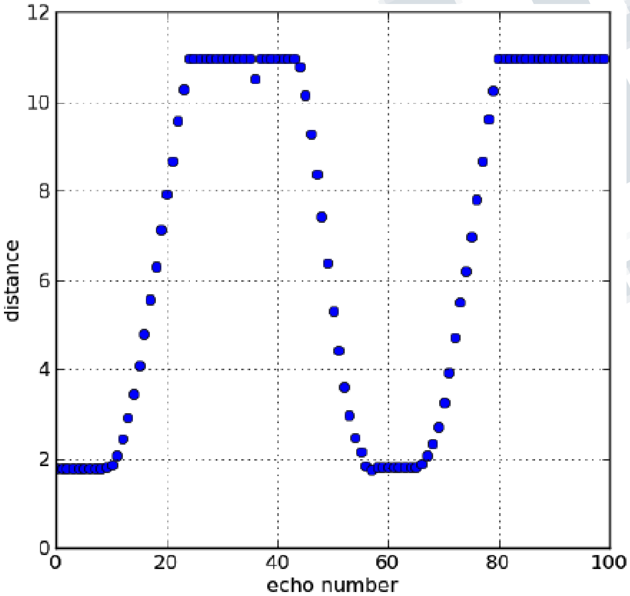

Fig.6.2 Measurements made with the sensor placed in a car moving in front of a parked vehicle

A. Target Angle

This term refers to the "tilt response" limitations of a particular sensor. Since ultrasonic sound waves reflect from the surface target object, the obtained target angles indicate acceptable amounts of tilt for a given sensor.

B. Beam Spread

This term is defined as the area in which a round wand will be sensed if passed through the target area. This shows the maximum spread of the ultrasonic sound waves as they leaves the transducer.

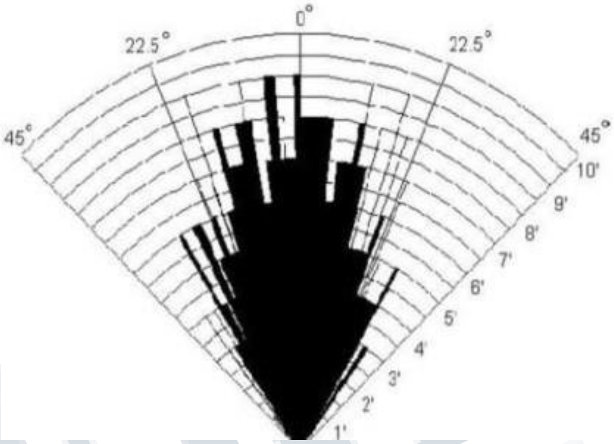

Fig.6.3 Test of performance

C. Ultrasonic Transmitter

Before transmitting the ultrasonic waves, there is an ultrasonic wave generator which generates an ultrasonic wave. In that part, there is timing instruction which generates an instruction signal for intermittently providing ultrasonic waves. This signal will be sent to an ultrasonic wave generator for generating ultrasonic waves based on the instruction signal from the timing instruction (transform electrical energy into sound wave). After the ultrasonic wave is produced, the ultrasonic transmitter transmits the ultrasonic waves towards a road surface to detect the obstacle. The range in which the obstacle detected is depends on the range of ultrasonic sensors used.

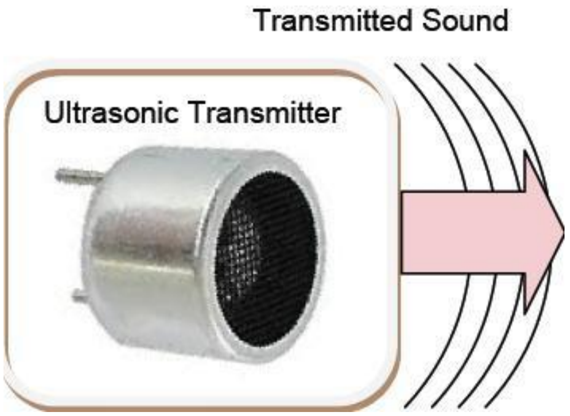

Fig.6.4Ultrasonic transmitter

D. Ultrasonic Receiver

If the ultrasonic wave detects the obstacle, it will produce a reflected wave. An ultrasonic receiver is used for receiving the ultrasonic waves reflected from the road surface to generate a received signal. There is an ultrasonic transducer which will transform back the sound wave to electrical energy. This signal is amplified by an amplifier. The amplified signal is compared with a reference signal to detect components in the amplified signal due to obstacles on the road surface. The magnitude of the reference signal or the amplification factor of the amplifier is controlled to maintain a constant ratio between the averages of the reference signal.

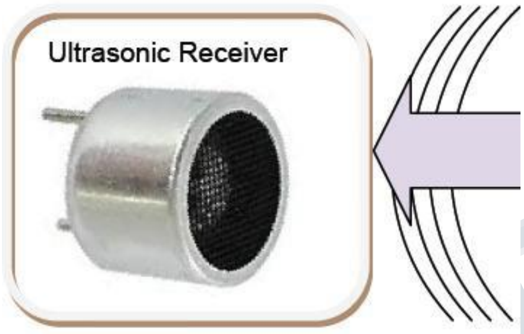

Fig.6.5 Ultrasonic receiver

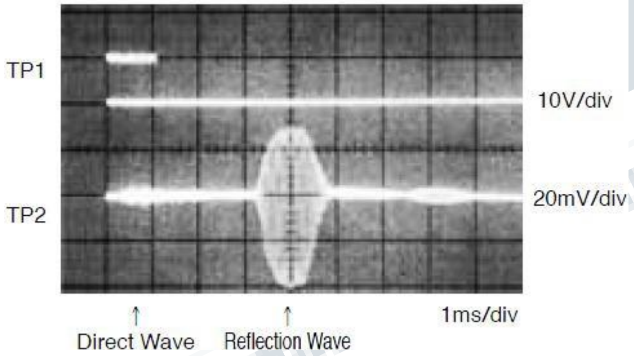

Fig.6.6 Transmit/Receive Waveform

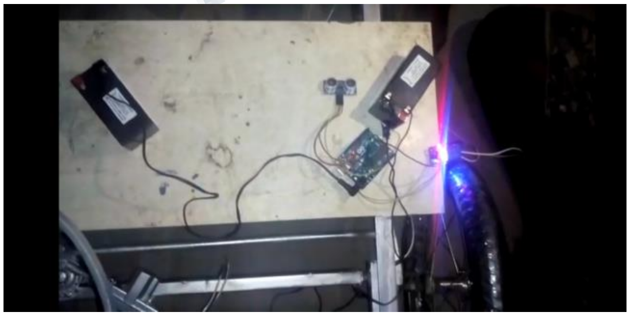

Fig.6.7 Test setup of Automatic Braking System

VII. CONCLUSIONS

An automatic braking system based on an ultrasonic sensor is designed and the test setup is developed with distance measurement arrangement for a stationary obstacle. The working is tested and the function is documented. This system is controlling the speed of vehicle and apply brake according to whether the predetermined distance is achieved or not. The ultrasonic sensor, which is used here is cheaper and less demanding of hardware than other types of sensors that are presently used. This sensor is used to measure the distance between vehicle and the obstacle. The relative speed of the vehicle with respect to the obstacle is estimated using consecutive samples of the distance calculated. These two quantities are used by the control system to calculate the actions on both the accelerator and also the brake, thus to adjust the speed in order to maintain a safe distance to prevent accidents. As ultrasonic sensors can detect any kind of obstacle, this system can also prevent collision of the vehicle with pedestrians, or can at least reduce the injuries occurring. Since the control system does not use the absolute speed to calculate the safety distance as done by other existing systems, the interaction with automotive electronics is limited to actions on the accelerator and brake. This matter, coupled with the fact of lower cost of ultrasonic sensors, could facilitate the application and mounting of the system in many low-end vehicles, helping to improve comfort and safety and offer a hassle free driving experience at a reduced cost.

REFERENCES

[1] E. Coelingh, A. Eidehall and M. Bengtsson, "Collision Warning with Full Auto Brake and Pedestrian Detection - a practical example of Automatic Emergency Braking," 13th International IEEE Conference on Intelligent Transportation Systems, Funchal, 2010, pp. 155-160.

[2] Neil R. Storey, “Safety Critical Computer Systems,”, Addison- Wesley Longman Publishing Co., Inc., Boston, MA, USA, ISBN 0201427877, 1996.

[3] Hasan Öktem, Ilyas Uygur, Murat Çevik, “Design, construction and performance of a novel brake pad friction tester,” Measurement, ISSN 0263-2241, vol. 115, pp. 299-305, 2018.

[4] Kan Shimazaki, Tasuku Ito, Ai Fujii, Toshio Ishida, “The public's understanding of the functionality and limitations of automatic braking in Japan,” IATSS Research, ISSN 0386-1112, vol. 42, issue 4, pp. 221-229, 2018.

[5] Jessica B. Cicchino, “Real-world effects of rear automatic braking and other backing assistance systems,” Journal of Safety Research, ISSN 0022-4375, vol. 68, pp. 41-47, 2019.

[6] Jingliang Duan, Renjie Li, Lian Hou, Wenjun Wang, Guofa Li, Shengbo Eben Li, Bo Cheng, Hongbo Gao, “Driver braking behaviour analysis to improve autonomous emergency braking systems in typical Chinese vehicle-bicycle conflicts,” Accident Analysis & Prevention, ISSN 0001-4575, vol. 108, pp. 74-82, 2017.

[7] Hiroshi Ohno, Toshihiko Suzuki, Keiji Aoki, Arata Takahasi, Gunji Sugimoto, “Neural network control for automatic braking control system,” Neural Networks, ISSN 0893-6080, vol. 7, Issue 8, pp. 1303- 1312, 1994.

[8] R. Isermann and M. Schorn and U. Stählin, “Anticollision system PRORETAwith automatic braking and steering,” Vehicle System Dynamics, Taylor & Francis, vol. 46, sup1, pp. 683-694, 2008.

[9] Joshua Pérez, Fernando Saco, Vicente MI lanes, Antonio Jiménez, Julio C. Diaz and Teresa de Pedro, “An RFID based Intelligent Vehicle speed controller using active traffic signals,” SENSORS, vol. 10, issue 06, pp. 15872-5888; doi: 10.3390/s100605872, 2010.

[10] Van NE’s. N; Houtenbos. M; van SC Hagen. I, ‘Improving Speed behavior: The Potential of In-Car Speed Assistance and Speed Limit Credibility,’ IET Intel. Transp. Syst. vol. 2, pp. 323-33, 2008

[11] MI lanes, V. Onieva, E. Perez, J. De Pedro, T. Gonzalez, C. “Control of Velocidad Adaptativo para Entornos Urbanos Congestionados,” Rev. Iberoam, automat. Informat. Ind., pp. 66-73, 2009.