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AUTOMATIC BRAKING SYSTEMS AREVIEW

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ABSTRACT :

In this article Braking System in Automobile is one sector which is the most important in terms of safety division. However, in recent years braking system is one which is constantly evolving and each and every company are constantly working for research and development in braking system of vehicle. The desirable braking system of a land vehicle is that it can stop the vehicle or reduce the vehicle speed as quickly as possible, maintain the vehicle direction stable and recover kinetic energyof the vehicle as much as possible.

In this research, an electronically controlled Automatic braking system for EV and HEV has been proposed, which integrates regenerative braking, automatic control of the braking forces of front and rear wheels and wheels antilock function together. This system works together with sensors and ECU of braking under any emergency situation when driver is unable to apply brake under any unforeseen condition.

The Automatic Braking System includes Ultrasonic sensors, transmitter and receiver. The sensors sense the vehicle in distant and sends the signal to ECU which then sends the signal and brakes are applied and whole Electric supply for wheel motors of Electric Vehicle is cut off while in range ofsensors at front

INTRODUCTION

In India, over 4,37,000 road accident occurred in year 2019 in which about 1,54,000 people died and about 4,40,000people were injured. Majority of the accident occurred due to Over Speeding or Distracted driving which were about 59.6% (97,000) and 25.7% (38,800) respectively. Each year around 3-5% of country's GDP is invested in areas related to Road accident[3]

The increment in road accident occurring in India itself is in huge number year by year and this leads to more improvement and attention towards in Safety for Automobile. Companies are investing in huge amount for research and development of how vehicle can be more safer without affecting the driving aspect and also to overall cost of vehicle which is one of the most affecting factor while buying a new vehicle for Indian Market.[4]

Seeing this scenario regarding rising safety concerns for automotive sector, we thought how we can come up with a solution which is effective as well as inexpensive that is when idea of Automatic Braking system was clicked on to our mind. Our main objective was to make this system feasible for current vehicle as well as future automobile as if Electric Mobility considering it as a future of Automobile.[5]

This project is designed to automatically apply to brake the vehicle in order to avoid the accident. This system develops the safety of vehicle as well as person inside with the help of ultrasonic

sensors in situation when less human attention is given while driving. This system also helps in night condition or area where low visibility has occurred under any circumstances. In low visibility area driver might not be able to see any upcoming objects or any vehicle in front. Another phenomena can also occur when driver is tired due to long journey of driving at night time. By using this system, the vehicle automatically stopped by Automatic braking system and thus, collision is avoided.[15][20]

Main aim of automatic braking system is that, when an collision with other vehicle or obstacle is sensed in imminent to forward collision within the range of sensors, system must automatically apply brake to the vehicle and/ or cut off the power supply to wheel motors in case of electric vehicle which is done by whole braking circuit inside ECU.

There are ultrasonic wave emitter provided in front of vehicle which emits wave in front of the vehicle to sense any upcoming vehicle or object, producing and emitting waves in front to predetermined distance ahead in of vehicle. Ultrasonic receiver is also provided which receives reflected signals or waves and also measures distance between the vehicle and obstacle ahead[3]

What is Braking System?

Braking system is design to stop or slow down the vehicle whenever there is required by the person in charge of vehicle. It basically stop the wheel from rotating by frictional force between brake discand brake pad.

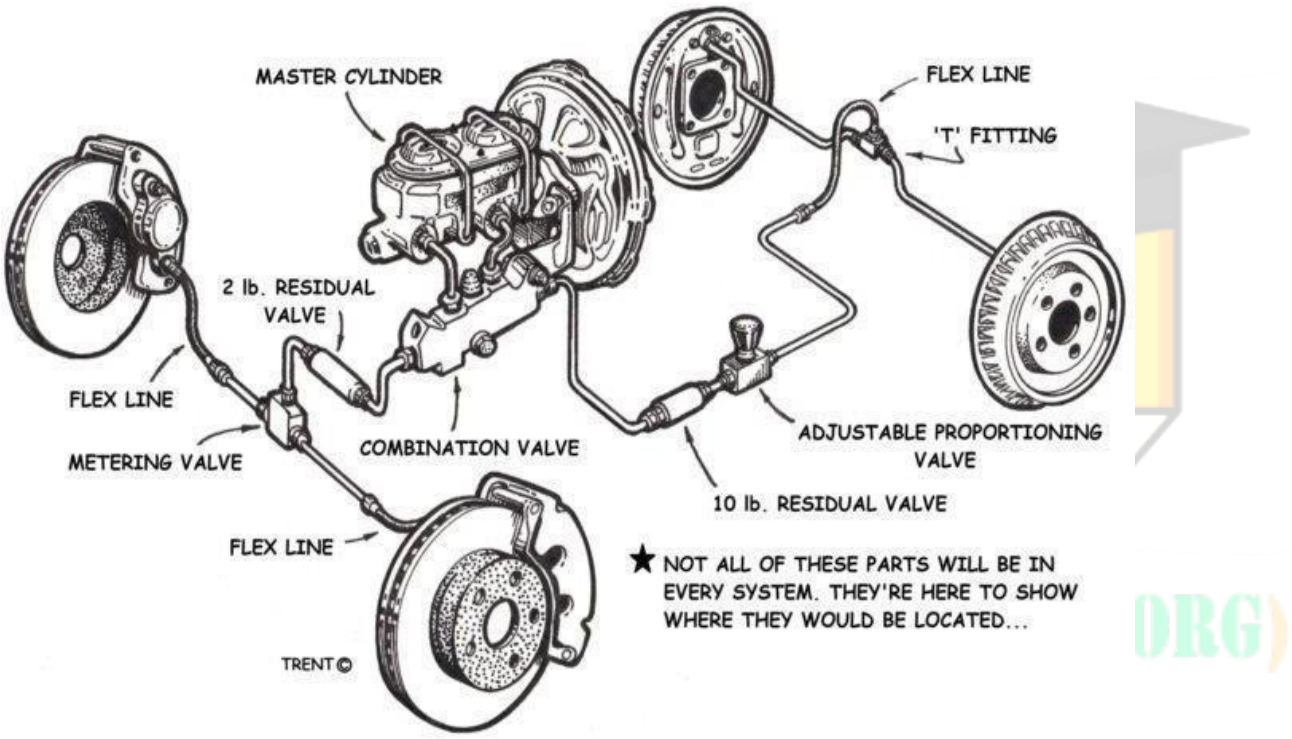

Fig:1 Basic Layout of Braking System[3]

Above diagram shows basic layout of conventional braking system. In this system when brake pedal is pressed, force is applied to master cylinder which pushes the brake fluid to apply force on wheel cylinder. As fluid is incompressible, it applies force to wheel cylinder and piston is moved inside wheel cylinder. The piston pushes brake pad towards brake disc by which they come in contact and cause friction between them. Due to this frictional force, brake is applied to the wheel.

As time passes there have been many advancement in braking system of vehicle and also various types of braking systems are formed which are such as:-

Hydraulic Braking system Pneumatic Braking system Mechanical Braking system Electronic Braking system Servo Braking system

Anti-Lock Braking system Regenerative Braking system Automatic Braking System

Advance Features of Braking System

During time this systems have evolved a lot and also new innovations and features have been added over time in this division. Some of the new inventions made for braking systems are:-

Anti-Lock Braking System (ABS) Electronic Brake Distribution (EBD) Brake assist

Traction Control Brake by wire

ABS System:-

Antilock Braking System (ABS) is a type of active safety system of a vehicle. It is also known as the anti-skid braking system. This system comes into action when the driver suddenly applies the brakes during an emergency. Employing the antilock braking system on cars and bikes is now mandatory in most parts of the world. Whenever the driver suddenly applies the brakes to a high-speed vehicle, there is always a chance of the 'wheel-lock.' The wheel-lock means that the respective wheel stops suddenly instead of slowly coming to a halt. Due to the wheel-lock, the driver loses control over the vehicle, and the vehicle skids off the road. Thus, a fatal accident takes place. In order to avoid such situations, the manufacturers employ the ABS.[2]

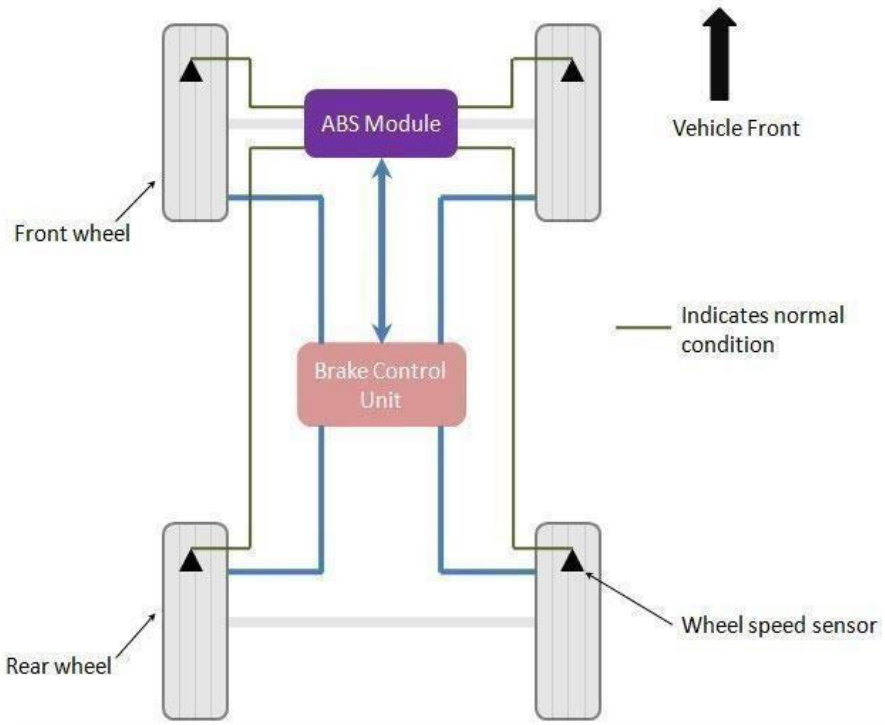

Fig:2 Layout of ABS System[6]

EDB System

Electronic Brakeforce Distribution or EBD for short works on the principle that not every wheel on a vehicle requires the same amount of braking force. When a vehicle brakes, its weight shifts across the four wheels, and each wheel doesn't always support the same amount of weight. As a result of this, the force applied to each wheel must be different as well. That's where the Electronic Brakeforce Distribution or EBD comes in.

When braking, the weight of the vehicle shifts across its four wheels. If you brake too hard, more often than not, the momentum of the vehicle keeps it moving at a speed which is faster than the speed at which its wheels are rotating. That results in loss of traction between the tyres and the road surface. The resulting traction loss can cause the vehicle to lose control. EBD aims at ensuring the right braking force for every wheel.[5]

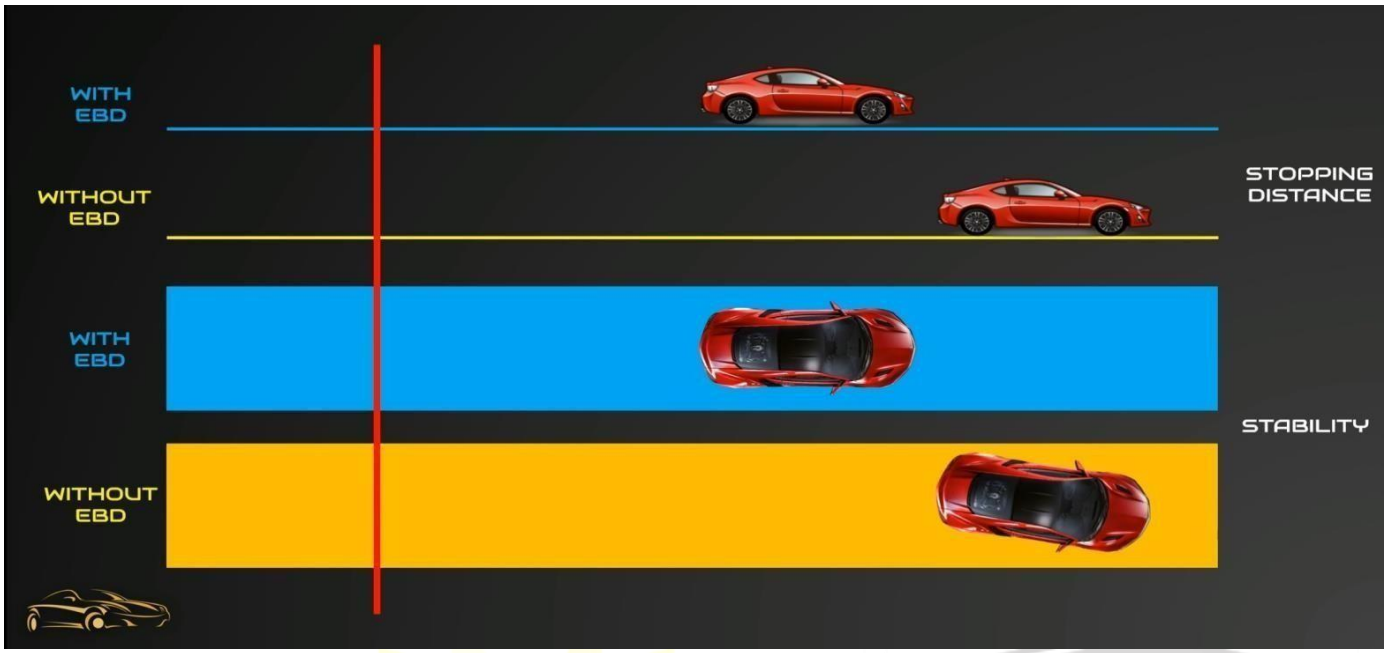

Fig:3 Working of EDB System[25]

Brake Assist:-

Brake assist is an active vehicle safety feature designed to help drivers come to a stop more quickly during an episode of emergency braking. Studies show that when making emergency stops, about half of all drivers do not press the brake fast enough or hard enough to make full use of their vehicle's braking power. Brake assist is designed to recognize the tell-tale signs of emergency braking and provide drivers with extra brake support.

Brake assist is called by other names including Emergency Brake Assist (EBA) and Predictive Brake Assist (PBA). The different names are significant because though all brake assist systems have the same purpose, some are designed differently.

Brake assist is useful whenever drivers must brake hard to make an emergency stop. Brake assist usually works in combination with anti-lock braking systems (ABS) to help make braking as effective as possible while avoiding wheel lockage.[5]

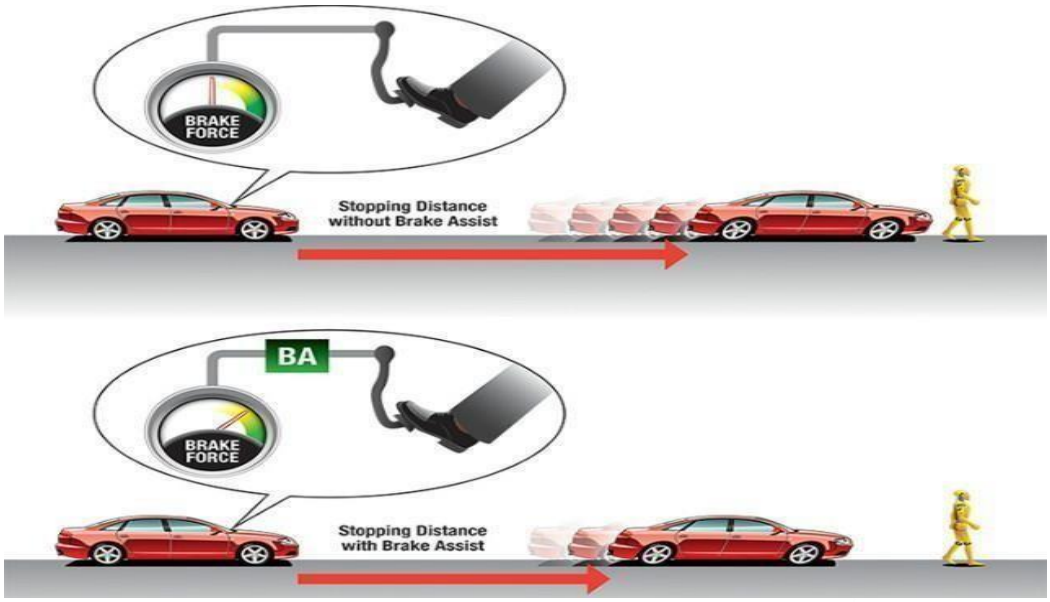

Fig: 4 Working of Brake Assist[11]

Current vehicle which uses Automatic Braking System

There are few automobile companies which uses automatic braking system in their vehicle as a part of safety system. Various companies such as MG Motors, Volvo, BMW, Audi, and Mercedes…etc. These companies are using different versions for their respective vehicle but all work under same concept and are named as Automatic Emergency Brake System.[11]

LITERATURE REVIEW

Hemalatha et.al[1] As we decided to go for this project we basically didn't hand much idea about how to make this system work on regular basis for vehicle. We already knew that some major automobile companies were using this system in their vehicle but they didn't reveal how they uses this system to implement in their car. This kind of technologies were always were always used in High end vehicle of some Elite Automobile companies. Therefore to understand much about this system we had to go through some research work done by many on internet.
Thus our search and also with help of some information available on the internet we did the literature survey for project and also gathered the detailed information for components we need to use.

Fundamental of Sensors

Nishad vivek et.al[2] In the broadest definition, a sensor is an object whose purpose is to detect events or changes in its environment, and then provide a corresponding output. A sensor is a type of transducer, sensors mayprovide various types of output, but typically use electrical or optical signals. For example, a thermocouple generates a known voltage (the output) in response to its temperature (the environment). A mercury-in-glass thermometer, similarly, converts measured temperature into expansion and contraction of a liquid, which can be read on a calibrated glass tube.
Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile sensor) and

lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware. With advances in micro-machinery and easy-to-use micro controller platforms, the uses of sensors have expanded beyond the most traditional fields of temperature, pressure or flow measurement, for example into MARG (Magnetic, Angular Rate, and Gravity) sensors. Moreover, Analog sensors such as potentiometers and force-sensing resistors are still widely used. Applications include manufacturing and machinery, airplanes and aerospace, cars, medicine, and robotics. It is also included in our day-to-day life.[1]

Drip-proof type

These are for automotive applications only. The metal case has a closed structure, allowing the sensor to be used even in environments where water may drip on it, hence the name "drip-proof type."
These sensors are of the transmission-reception combined type, meaning that a single sensor performs both transmission and reception. The internal structure inhibits resonance.

Product information

Part number	MA58MF14-7N
Appearance	
Frequency	58kHz
Size	Φ14mm, t=9mm
Features	Suitable for outdoor use, drip-proof type, low resonance Flat directionality: 80° horizontal, 35° vertical
Applications	Parking assist

High-frequency type

The high-frequency type operates at frequencies up to 300 KHz. Used for applications employing double feed detection only. Exclusive Murata technology is used to achieve broad frequency characteristics. This enables sensors to face each other at short distances in applications employing double feed detection.

Product information

Part number	MA300D1-1
Appearance	
Frequency	300kHz
Size	Φ10mm, t=7mm
Features	High resolution
Applications	Double feed detection

Open structure type, lead type

The top has an open structure and inside are a unimorph piezoelectric oscillator and a horn, resulting in high sound pressure and high sensitivity. They are transmission- or reception-only and capable both short- and long-range distance detection. In addition, they can be used to detect moving objects by making use of the doppler effect to detect fluctuations in the received waveforms. Due to the open structure, they are suitable for indoor use only.

Product information

Part number	MA40S4R（For reception）MA40S4S（For transmission）
Appearance	

Frequency	40kHz
Size	Φ10mm、t=7mm
Features	For indoor use, high sound pressure and high sensitivity
Applications	Distance detection/object (moving object) detection

Open structure type, SMD type

Compact and low-profile configuration suitable for surface mounting. Transmission-reception combined type, allowing for distance detection in confined spaces.

Product information

Part number	(Not Recommended for New Design) MA40H1S-R
Appearance	
Frequency	40kHz
Size	5.2×5.2mm, t=1.2mm
Features	Compact, suitable for surface mounting
Applications	Distance detection and object detection

Ultrasonic Sensor:-

Joshuq perez [26]Ultrasonic ranging and detecting devices use high frequency sound waves called ultrasonic waves todetect presence of an object and its range. Normal frequency range of human ear is roughly 20Hz to 20,000Hz. Ultrasonic sound waves are sound waves that are above the range of human ear, and thus have frequency above 20,000Hz. An ultrasonic sensor necessarily consists of a transducer for conversion of one form of energy to another, a housing enclosing the ultrasonic transducer and an electrical connection.[26]

There are two types of Ultrasonic Sensors:-

Ultrasonic Transmitter-

Before transmitting the ultrasonic wave, there is a part which is ultrasonic wave generator that functions to generate ultrasonic wave. In that part, there is timing instruction means for generating an instruction signal for intermittently providing ultrasonic waves. This signal will send to an ultrasonic wave generator for generating ultrasonic waves based on the instruction signal from said timing instruction means.
After ultrasonic wave was produced, ultrasonic transmitter transmits the ultrasonic waves toward a road surface to find out the obstacle. The range that obstacle detected is depends on the range of ultrasonic sensors that used.[26]

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 reception signal. There is ultrasonic transducer that will transform back the sound wave to electrical energy. This signal amplified by an amplifier. The amplified signal is compared with 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 average of reference signal and the average of amplified signal[26]

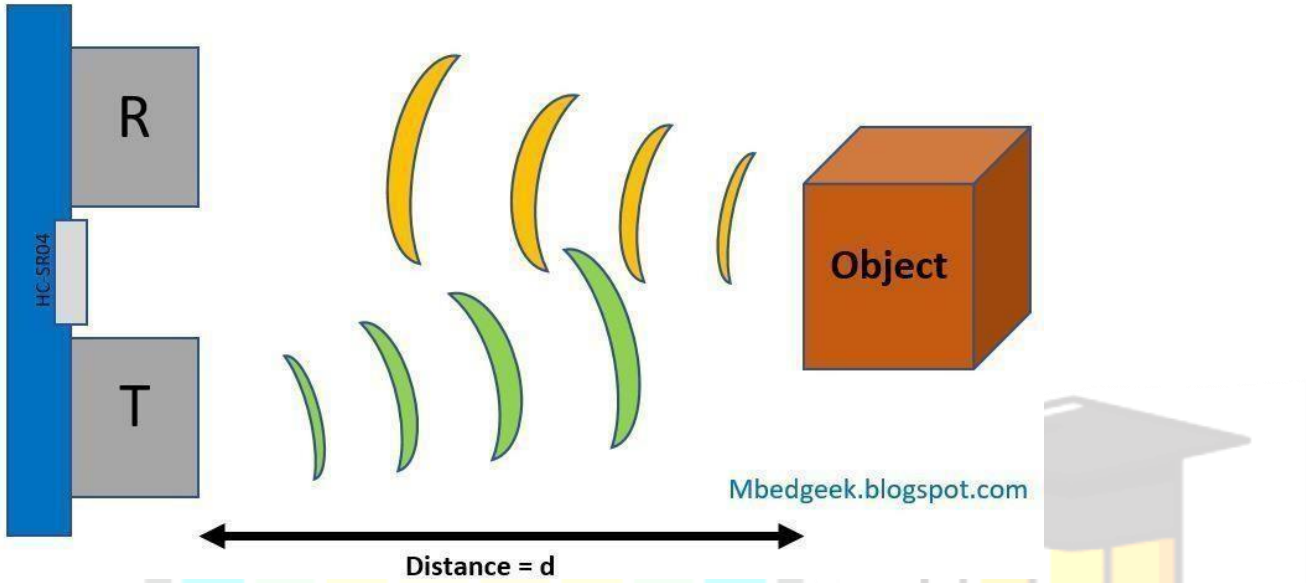

Fig: 5 Ultrasonic Transmitter and Receiver[16]

Transducer:

transducer is an energy conversion device which converts one form of energy into another. In the ultrasonic sensors they are used to convert electrical energy into ultrasonic energy and vice-versa. In this system piezoelectric transducers are used, which create ultrasonic vibration through use of piezoelectric materials such as certain forms of crystals or ceramic polymers. Their working is based on the piezoelectric effect. This effect refers to the voltage produced between surfaces of a solid, (non-conducting substance) when a mechanical stress is applied to it. Conversely, when a voltage is applied across surfaces of a solid that exhibits piezoelectric effect, the solid undergoes mechanical distortion[16]

Operational Amplifier:-

An operational amplifier, usually referred to as op-amp, is a high gain voltage amplifier with differential inputs and a single output. The amplifier's differential inputs consist of an inverting input and a non-inverting input. The op-amp amplifies only the difference in the voltage between the two inputs called the 'differential input voltage. The output voltage of the op-amp is controlled by feeding a fraction of output signal back to the inverting input. This is known as negative feedback. Due to the amplifier's high gain, the output voltage for any given input is only controlled by the negative feedback. The amplified signal is a square pulse which is given to the ADC. ADC l (Analog to Digital Converter) converts input analog signal to corresponding digital signal. The digital signal is given to the microcontroller.[16]

Braking Circuit:-

The processed i.e. the amplified digital signal is sent to the braking circuit PIC (Peripheral Interface Controller (or) Programmable Interface Controller) – The microcontroller used is PIC 16F84 which is 8-bit microcontroller. PIC microcontrollers are made by microchip technology. PICs are used in this system due to their low cost and wide availability. The numbers of instructions to perform a variety of operations vary from 35 instructions in low-end PICs to about 70 instructions in high-end PICs.
It is programmed by using C language.
The signal from the ADC is processed by the PIC microcontroller, and it gives an instruction as an output, based on the condition of the signal, to the servo motor. The signal received from the ADC can also be displayed on the LCD display (which gives an audio-visual warning on the windshield in the driver's field of view), and it gives the distance between the front of the vehicle and the obstacle. The distance value at which automatic braking should start is already stored in the microcontroller. When the measured distance reaches this value, the PIC automatically sends the signal to the servo motor which in turn controls braking through mechanical arrangements.[24]

Ultrasonic Sensor

Ultrasonic ranging and detecting devices use high-frequency sound waves to detect the presence of an object and its range. The systems either measure the echo reflection of the sound 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 in response to received ultrasonic energy. The normal frequency range for human hearing is roughly 20 to 20,000 hertz. Ultrasonic sound waves are sound waves that are above the range of human hearing and thus, have a frequency above about 20,000 hertz. Any frequency above 20,000 hertz may be considered ultrasonic. Most industrial processes, including almost all source of friction, create some ultrasonic noise.
The ultrasonic transducer produces ultrasonic signals. These signals are propagated through a sensing medium and the same transducer can be used to detect returning signals. Ultrasonic sensors typically have a piezoelectric ceramic transducer that converts an excitation electrical signal into ultrasonic energy bursts. The energy bursts travel from the ultrasonic sensor, bounce off objects, and are returned toward the sensor as echoes. Transducers are devices that convert electrical energy to mechanical energy, or vice versa. The transducer converts received echoes into Analog electrical signals that are output from the transducer.

The piezoelectric effect refers to the voltage produced between surfaces of a solid dielectric (non- conducting substance) when a mechanical stress is applied to it. Conversely when a voltage is applied across certain surfaces of a solid that exhibits the piezoelectric effect, the solid undergoes a mechanical distortion. Such solids typically resonate within narrow frequency ranges. Piezoelectric materials are used in transducers e.g., phonograph cartridges, microphones, and strain gauges that produce an electrical output from a mechanical input. They are also used in earphones and ultrasonic transmitters that produce a mechanical output from an electrical input Ultrasonic transducers operate to radiate ultrasonic waves through a medium such as air. Transducers generally create ultrasonic vibrations through the use of piezoelectric materials such as certain forms of crystal or ceramic polymers.[16]

Ultrasonic Sensing and Control

Ultrasonic signals are like audible sound waves, except the frequencies are much higher. Our ultrasonic transducers have piezoelectric crystals which resonate to reflected from a target back to the transducer. An output signal is produced to perform some kind of indicating or control function. A minimum distance from the sensor is required to provide a time delay so that the "echoes" can be interpreted.
Variables which can affect the operation of ultrasonic sensing include, target surface angle, reflective surface roughness or changes in temperature or humidity. The targets can a desired frequency and convert electric energy into acoustic energy and vice versa. The illustration shows how sound waves, transmitted in the shape of a cone, are have any kind of reflective form- even round objects.[24]

BLOCK DIAGRAM

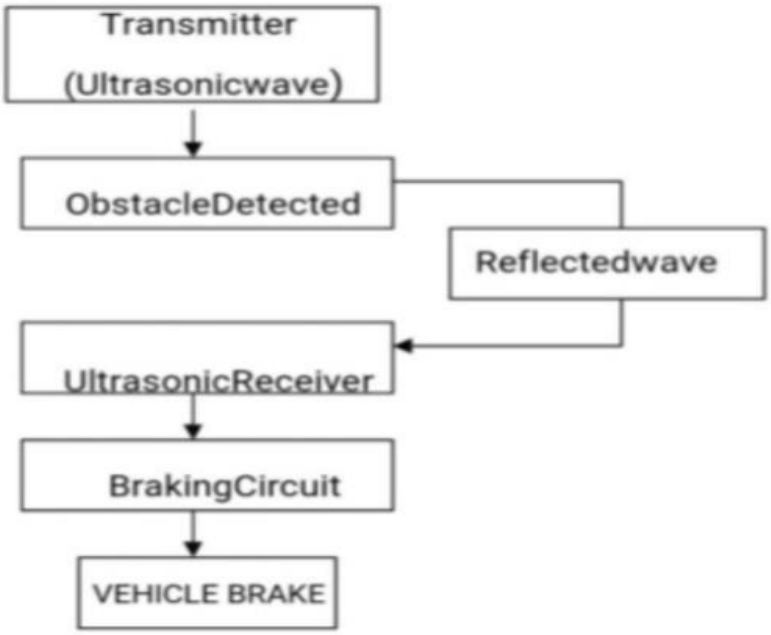

Fig: 5 Measurement Principle of Ultrasonic sensor[24]

Ultrasonic sensor transmits ultrasonic waves from its sensor head and again receives the ultrasonic waves reflected from an object. Basically, in our project ultrasonic sensor ranges of about 2 centimetres to 1 metre. By measuring the length of time from the transmission to reception of the sonic wave, it detects the position of the object. The ultrasonic transducer produces ultrasonic signal.

These signals are propagated through a sensing medium and the same transducer can be used to detect returning signals. In most applications, the sensing medium is simply air. An ultrasonic sensor typically comprises at least one ultrasonic transducer which transforms electrical energy into sound and in reverse sound into electrical energy, a housing enclosing the ultrasonic transducer, an electrical connection and optionally, an electronic unit for signal processing also enclosed in the housing.[26]

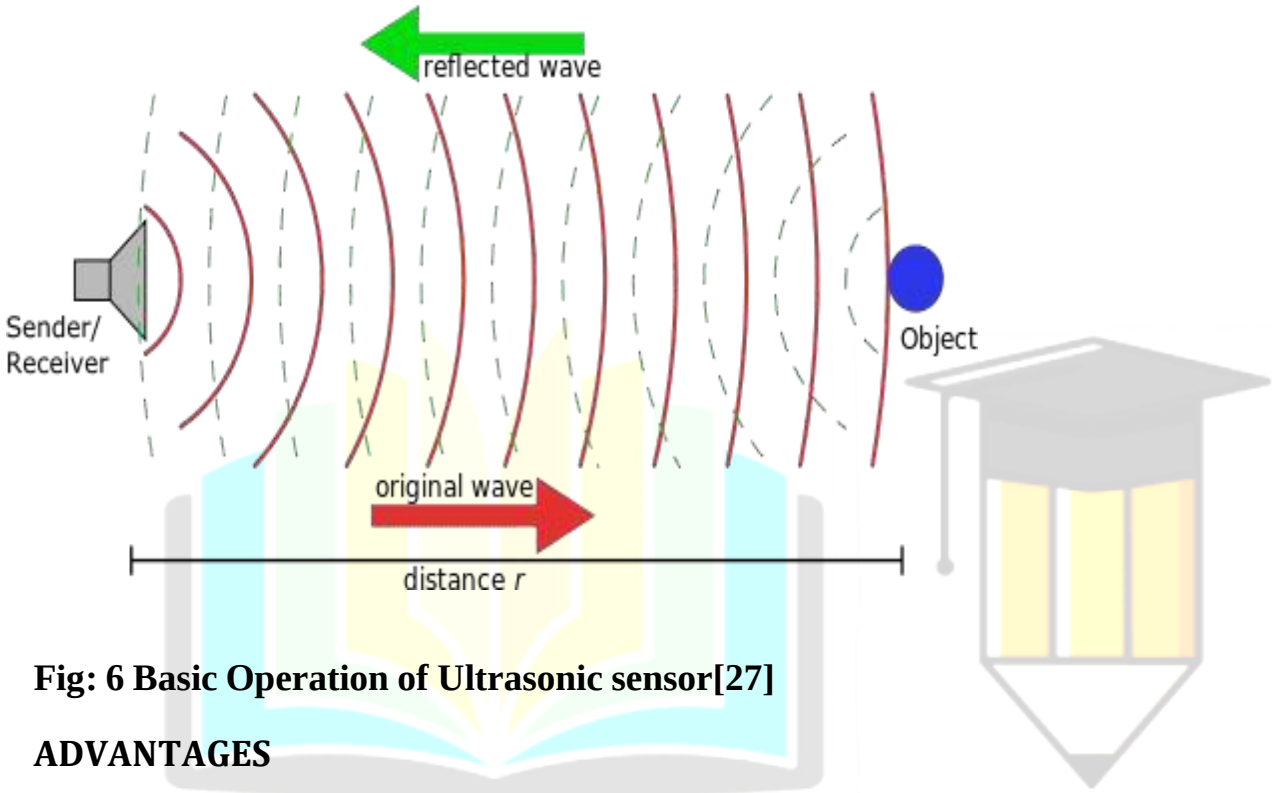

Fig: 6 Basic Operation of Ultrasonic sensor[27]

ADVANTAGES

1 A totally driverless car can be made using this technology and further extending it to automatic steering system

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2 Crashes reduced to a negligible impact speed – AEB has the potential to reduce the impact speed, and hence the severity, in pedestrian crashes, right turn crashes, head on crashes, rear endcrashes and hit fixed object crashes. it appears that they may have little or no effect on right angle crashes, but secondary effects that improve drivers ‟ abilit ies to avoid collisions may be important in this case. Potential benefits appear to be greatest in pedestrian crashes, rear-end crashes and head on crashes.

3 A study in the USA has shown clearly that cars fitted with AEB are involved in fewer crashesthan comparable cars without. The frequency of claims was significantly lower for bodily injury, first party (own car) damage and for third party (other car) damage .The biggest benefit seen was in third party injuries - typically whiplash - where there was a 50% reduction in the number of claims from cars equipped with AEB

4 Reduced car insurance premiums. Motor cover providers see AEB-equipped vehicles as less likely to have a crash and therefore a less risky prospect to cover. In theory, this means cheaper car insurance for the end user – you, the motorist.

DISADVANTAGES

A study in the USA has shown clearly that cars fitted with AEB are involved in fewer crashesthan comparable cars without. The frequency of claims was significantly lower for bodily injury, first party (own

car) damage and for third party (other car) damage .The biggest benefit

Advantages of Ultrasonic Sensor

Ultrasonic have a lot of advantages for using in real application. The advantages of ultrasonic sensorare:
Discrete distances to moving objects can be detected and measured.
Less affected by target materials and surfaces, and not affected by colour. Solid-state units have virtually unlimited, maintenance free life.
Ultrasonic can detect small objects over long operating distances.
Resistance to external disturbances such as vibration, infrared radiation, ambient noise, and EMI (Electro Magnetic Interference) radiation.
Measures and detects distances to moving objects.Impervious to target materials, surface and colour.
Solid-state units have virtually unlimited, maintenance free lifespan. Detects small objects over long operating distance.
Ultrasonic sensors are not affected by dust, dirt or high moisture environment.

Disadvantage of Ultrasonic Sensor

Some disadvantages of Ultrasonic Sensors are as follow:
Overheating of a wave emitter precludes the energy of ultrasonic waves emitted there from being enhanced to a practical level.
Interference between the projected waves and the reflected waves takes place, and development of standing waves provides adverse effects.
It is impossible to discern between reflected waves from the road surface and reflected waves from other places or objects.[17/20]

Companies and their respective models using AEBMG Motors (GLOSTER):-

The AEB is a part of the autonomous driving system of the Gloster. It is a radar-based system that constantly identifies the possibility of a forward crash. If there is another vehicle or a pedestrian in front of the Gloster, the system works by either reducing the overall speed of the vehicle or by stopping the vehicle completely. The system alerts the driver as soon as it identifies an object and if the driver fails to respond sufficiently, the system applies the brakes.
Automatic Emergency Braking on the MG Gloster works only on larger four-wheeled vehicles and the system is not likely to detect two-wheelers, cyclists and pedestrians. It is also important to note that the Automatic Emergency Braking brings the Gloster to a complete stop only when the speed of the car is below 40 kmph.
Above 40 kmph the system slows the SUV down by 40 kmph, says for example the Gloster is travelling at 60 kmph and detects an imminent collision with another four-wheeler the Gloster's Automatic Emergency Braking system will apply brakes automatically and bring the SUV's speed down to 20 kmph.
Below figure shows how MG Gloster detects the vehicle in front and stops the vehicle when any front collision is detected by the system[9].

Limitations of AEB System in MG Gloster

AEB system can only stop vehicle fully if speed is below or up to 40kmph. If vehicle speed is above 40kmph it will just reduce vehicle speed by 40 kmph.

AEB system only detects Large vehicles or 4 Wheelers. This system doesnot detect any tow wheel, pedestrian or any cyclist on road which sometime leads to dangerous situation[9]

Volvo (XC90)

The collision warning system uses the same radar sensors as the Adaptive cruise control. Read more about radar

sensor limitations. If warnings are perceived as being too frequent or disturbing then the warning distance can be reduced. This would lead to the system warning at a later stage, which educes the total number of warnings.

Collision Warning with Auto Brake is temporarily deactivated with reverse gear engaged. Collision Warning with Auto Brake is not activated at low speeds - under 4 km/h, which is why the system does not intervene in situations where the car is approaching a vehicle in front very slowly, e.g. when parking.

In situations where the driver demonstrates active, aware driving behaviour, a collision warning may be postponed slightly in order to keep unnecessary warnings to a minimum. When Auto Brake has prevented a collision with a stationary object the car remains stationary for a maximum of 1.5 seconds.

If the car is braked for a vehicle in front that is moving, then speed is reduced to the same speed as that maintained by the vehicle in front. On a car with manual gearbox the engine stops when Auto Brake has stopped the car, unless the driver manages to depress the clutch pedal beforehand.

The image below shows the collision waring system with Auto brake and Sound Alert active during any front impact collision is detected by the system[8]

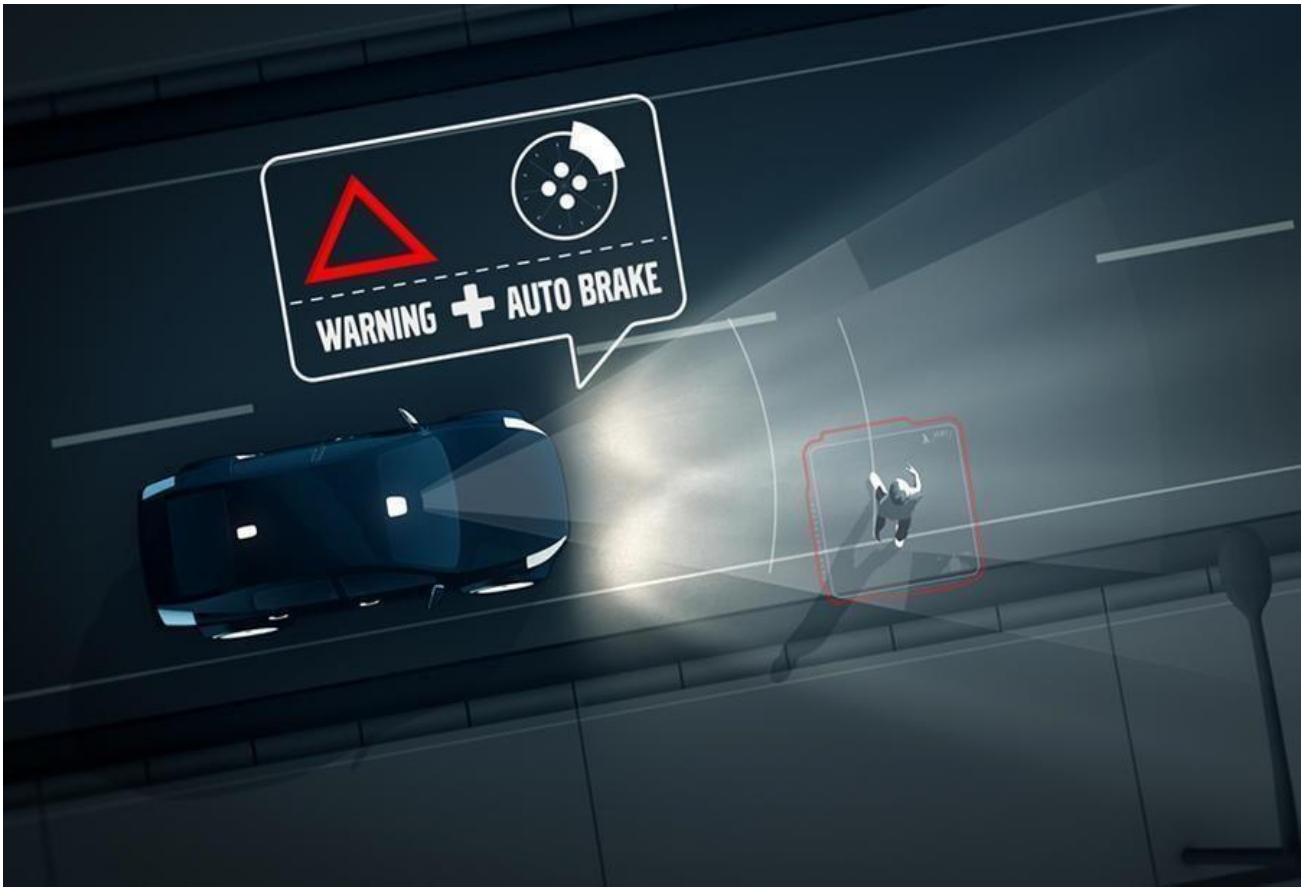

Fig: 7 Collision detection system (Volvo (XC90)[8]

Limitation of Collision Detection system

The sensor system has a limited range for pedestrians and cyclists - the system can provide effective warnings and brake interventions for them at vehicle speeds up to 50 km/h. For stationary or slow-moving vehicles, warnings and brake interventions are effective at vehicle speeds up to 70 km/h.
Warnings for stationary or slow-moving vehicles could be disengaged due to darkness or poor visibility.
Warnings and brake interventions for pedestrians and cyclists are deactivated at vehicle speeds exceeding 80 km/h[14].

Braking Calculation[18]

Braking Distance = V / 2μg (meter)Where

V= Velocity of the vehicle (m/s)
μ = Coefficient of friction of road = 0.8
g = Acceleration due to gravity = 9.81(m/s^2)Now, for velocity 10 km/hr.

Braking Distance = (10*1000/3600)/ (2*0.8*9.81)
= 0.18 m

For velocity 20 km/hr.
Braking Distance = (20*1000/3600)/ (2*0.8*9.81)
= 0.35 m

For velocity 30 km/hr.
Braking Distance = (30*1000/3600)/ (2*0.8*9.81)
= 0.53 m

For velocity 40 km/hr.
Braking Distance = (40*1000/3600)/ (2*0.8*9.81)
= 0.71 m

For velocity 50 km/hr.
Braking Distance = (50*1000/3600)/ (2*0.8*9.81)
= 0.88 m

CONCLUSION

1. If we can reduced the Driving Interference of Braking and Give the Responsibility To Intelligence Sensor which will Take decision and initiate the Response To give Warning alarm
2. First and if Distance of impact is Closing it will Apply brake Automatically and Stop the Vehiclein advanced.
3. Such that Distraction Driving is a Major Contributor to Accident death, thus by implementing this System we can reduced the Close impact Potential Accident.
4. By dragging the front seat at opposite direction to Impact and increase the Distance And Time Of Direct Impact the death can be minimized and safety of vehicle also can improved, and also it can add the new feature to the car which will attract the customer who prefer safety while traveling.
5. The results of the simulations showed that by using an energy absorbing seating system, crash deceleration can be effectively attenuated and occupant injuries significantly reduced in comparison to conventional seating systems. In future, physical crash tests will still be required as the final certification method for approval of a particular crashworthy mechanical system. However during the development process the application of computer simulation methods as presented in this paper show that it is possible to reduce development costs.

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