DESIGN AND FABRICATION OF AUTOMATIC BRAKING SYSTEM IN A VEHICLE

A PROJECT REPORT

Submitted By

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Certified that this project titled **"DESIGN AND FABRICATION OF AUTOMATIC BRAKING SYSTEM IN A VEHICLE"** is the bonafide work of **PALLI SIDDHARTHA REDDY (18104081),MUVVA SURESH BABU** (**18104094), SARANGAM SAI NAVEEN 18104098),NARAM MADHU (18104126)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

This project deals with design of Automatic Braking System in a vehicle. The main theme was to improve the safety for four wheelers segment. The Automatic Braking System is used in heavy vehicles and light motor vehicles. The vehicle uses object detection sensor to detect obstacles and to stop the vehicle. So, in four wheelers the same technology is used to detect obstacle and stop the vehicle with some modifications.

The Automotive vehicles are rapidly equipping with the collision avoidance and warning system for predicting the potential collision with an object or external source of contact such as vehicle or a pedestrian. When these systems detect such type of obstacle, they initiate an action to avoid collision without the driver interference. In semi there would be providing a warning to the vehicle driver.

The project focuses on the automatic braking system used in four-wheeler vehicles to protect and provide additional safety for the drivers. The project focuses on designing and development of Automatic Braking system in a vehicle.

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LIST OF ABBREVIATIONS

PTW	Powered Two – Wheeler
AEB	Automatic Emergency Braking
PIR	Passive Infrared
ABS	Anti – lock Braking System

CHAPTER 1

INTRODUCTION

A tremendous growth in automobile sector in motorcycle, traffic has occurred during the last decades in the most developing countries and economically weak nations of the world. Safety for the riders is a challenging aspect particularly for four wheelers in the aspect of the four-wheeler driving it's important to know the dangerous facing by the drivers. The goal of the project is to implement automated braking system for four wheelers to reduce the chance of accidents occurs due to human error. The project helps the riders for safe drive-in extreme conditions like foggy, dusty. This helps the detection of object and stops the vehicle according to the range and moment of the object.

1.1 AUTOMATIC BRAKING SYSTEM

Autonomous Emergency Braking (AEB) is defined as a system that constantly keeps track of the road ahead and will automatically halt the vehicle if the driver fails to take action. This technology was first introduced in 2009 to prevent car crashes or at least reduce the seriousness of the impact of an unavoidable one. An automatic braking system is an important part of safety technology for automobiles. It is an advanced system, specifically designed to either prevent possible collision, or reduce speed of the moving vehicle, prior to a collision with another vehicle, pedestrian or an obstacle of some sort.

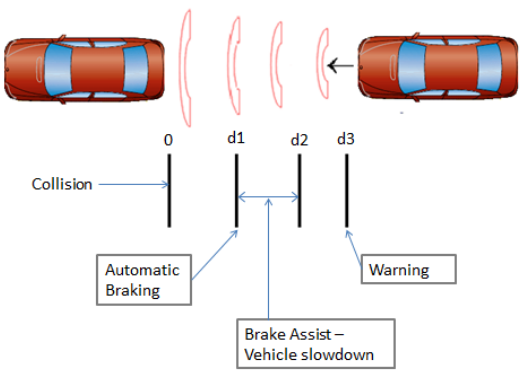

Figure 1.1 Automatic braking system

As you may have guessed by its name, AEB works autonomously, with no input from the driver. The system can also add braking force if you are pressing the brake, but weaker than a vehicle needs to avoid a collision. Every AEB system monitors vehicles and most of the time, pedestrians and other obstacles. The goal of the AEB system is to avert or lessen serious crashes by applying the brakes when sudden dangers arise or if the driver is not taking appropriate action quickly enough.

So, how does AEB perform its tasks? Many AEB systems use a combination of radar and camera technologies that are either mounted at the front of a vehicle or installed inside the windshield. Normally, these radars and cameras monitor obstacles that may lead to a crash. If they detect such a hazardous object and the system doesn't receive any feedback from the driver, it will autonomously trigger the AEB system.

While most automakers provide AEB systems that are similar in function, each system can slightly differ in terms of their names, speed requirements, etc. In regards to Kia’s Autonomous Emergency Braking (AEB), our system uses a radar sensor installed at the front of the vehicle that keeps an eye on the road ahead all the time. If it recognizes a potential obstacle, the system will tell the brakes to apply themselves in an effort to lessen the severity of the collision.

In short, AEB provides another pair of eyes that helps you monitor objects ahead and also keeps an extra set of feet on the brakes to avoid a potential crash. By detecting and automatically applying the brakes, the technology gives you the added reassurance of driving safely on a daily basis. But the most important thing to remember is that the AEB system is a type of supplemental technology and by no means replaces the need for you to keep your eyes on the road.

Did it works:

How well these systems work has been proven through extensive track testing and actual use in a number of cars in production in the United States. Europe has seen increasing use of automatic braking systems for several years, and has mandated them in all new cars since 2015. The Insurance Institute for Highway Safety has made it a requirement that in order to get top safety scores, a car must have a forward-collision warning system with automatic braking.

Not all systems are the same, as different carmakers utilize different technologies and techniques to accomplish their mission of braking safety and collision warning and mitigation or avoidance. Additionally, false alerts might cause drivers to ignore the systems' warnings, or shut the systems off altogether. But overall, the effectiveness of these systems have been proven and are here to stay – and will be standard on all cars in the U.S. by 2022.

Are brakes different:

The mechanics of the brakes themselves are the same as on cars without automatic braking systems. Whether the driver or a computer decides the car needs to slow down or stop, the same basic parts and principles are used to actually stop your car.

1. Brake pedal is pushed (or computer calculates and activates pressure to the piston – step 2).
2. Piston pushes fluid to master cylinder.
3. Master cylinder pushes fluid to slave cylinders.
4. Slave cylinders fill and push pistons out.
5. Pistons push calipers with brake pads.
6. Brake pads grip rotors (discs) attached to wheels.
7. Friction between brake pads and rotors slows wheels.
8. Car slows down and stops.

Rotors, calipers, and brake pads are still used and still need to be checked, replaced on a regular maintenance schedule.

1.1.1 Forward Collision Warning (FCW)

If a collision seems to be imminent, a Forward Collision Warning (FCW) system gives an audible warning which allows the driver time to take action and possibly prevent an accident. It is strictly a warning system only, and does not take any automated measures, such as applying the brakes, to avoid or mitigate a collision.

1.1.2 Forward Collision Mitigation (FCM)

A Forward Collision Mitigation (FCM) system will warn the driver and slow the vehicle simultaneously. FCM should not be confused with Forward Collision Warning (FCW). A warning system will only warn the driver, but not take any automatic action to mitigate – reduce the chances or effects of – a collision. An FCM will automatically apply the vehicle's brakes as the computer calculates the situation.

1.1.3 Forward Collision Avoidance (FCA)

Complete avoidance of a collision is the goal of a Forward Collision Avoidance (FCA) system. This approach is obviously the most challenging, and is probably more semantic than realistic. People like to think of avoiding a collision, so a system named as such is bound to sell better than one that simply says it will reduce the severity of a collision. Ideally, an FCA system tries to get you out of a collision altogether using technology such as automatic braking and even assisted steering. But let's face it, you're probably still going to crash; however, the system will make it less severe.

1.2 BRAKING SYSTEM

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

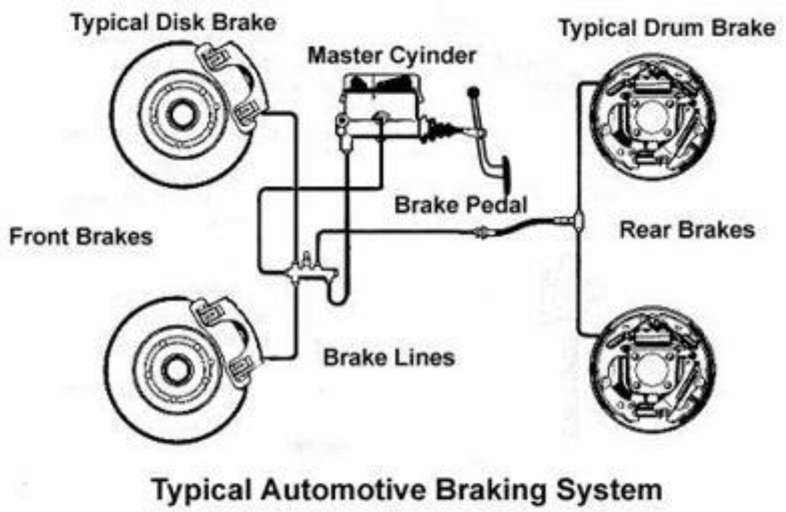

Figure 1.2 Braking system

Most brakes commonly use friction between two surfaces being compressed to convert the kinetic energy of the moving object into heat, although other methods of converting energy can be used. For example, regenerative braking converts much of the energy into electrical energy that can be stored for later use.

Other methods convert the kinetic energy in stored forms such as compressed air or pressurized oil into potential energy. Eddy current brakes use magnetic fields to convert kinetic energy into electrical current in the brakes disc, fin, or rail, which is converted into heat.

Still, other braking methods even convert kinetic energy into various forms, for example by transferring the energy to a rotating flywheel.

Brakes are generally applied to rotating axles or wheels, but they can take other forms such as the surface of a moving liquid (valves used in water or air).

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

1.2.1 Parts of Brake System

Following are Parts of the brake system:

- Brake Pedal
- Master Cylinder
- Brake Pads
- ABS Control Module
- Brake Booster
- Disc Brake
- Drum Brakes

- Emergency Brake
- Brake Pedal
- Wheel Speed Sensors

- Brake Pedal

The pedal is what you push with your foot to activate the brakes. It causes brake fluid to flow through the system to put pressure on the brake pads.

Driver steps on the brake pedal to activate the brakes. A piston in the master cylinder moves when the pedal is pressed.

- Master Cylinder

The master cylinder is basically a plunger that is activated by the brake pedal. It is what holds the brake fluid and forces it through the brake lines when activated.

Converts non-hydraulic pressure into hydraulic pressure that the wheel cylinders use to press the brake pads against the rotors to bring the vehicle to a stop.

- Brake Lines

Generally made of steel, brake lines are what carry the brake fluid from the master cylinder reservoir to the wheels where pressure is applied to stop the car.

- Wheel Cylinders

The brake pads are connected to the wheel cylinders which either squeeze (disc brakes) or push apart (drum brakes) the brake pads when fluid flows into them.

- Brake Pads

The brake pads are what actually rub against the drums or rotors. They are made of composite materials and designed to last for many, many thousands of miles. However, if you ever hear a grinding or howling noise when you try to stop your car it likely means it is time for new brake pads.

- ABS Control Module

Found on vehicles with ABS brakes, the module performs diagnostic checks of the ABS braking system and determines when to send the correct pressure to each wheel to prevent the wheels from locking up.

- Brake Booster

Reduces the amount of pressure needed for braking to allow any driver to operate the brakes. Uses engine vacuum and pressure to increase the force the brake pedal puts on the master cylinder.

- Disc Brakes

Usually found on the front wheels, disc brakes feature brake pads that press against a disc (rotor) when the brake pedal is applied to stop the vehicle. The pads are attached to a brake caliper assembly that frames the rotor.

- Drum Brakes

Located on the rear of the vehicle, drum brakes feature wheel cylinders, brake shoes and a brake drum. When the brake pedal is pressed, the brake shoes are forced into the brake drum by the wheel cylinders, bringing the vehicle to a stop.

- Emergency Brake

Operates independently of the main brake system to keep the vehicle from rolling away. Also known as a parking brake, hand brake, and e-brake, the emergency brake is mainly used to keep the vehicle in place when parked.

- Wheel Speed Sensors

Part of the ABS brake system, speed sensors monitor the speed of each tire and sends the info to the ABS control module.

1.2.2 Types of Braking Systems

Following are the types of braking systems:

- Hydraulic braking system
- Electromagnetic braking system
- Servo braking system
- Mechanical braking system

Hydraulic Braking System

This system is operated with brake fluid, cylinders, and friction. By creating pressure inside, glycol ether or diethylene glycol force the brake pads to stop the wheels from moving.

- The force generated in the hydraulic braking system is higher compared to the mechanical braking system.
- The hydraulic braking system is one of the most important braking systems for modern vehicles. With a hydraulic brake system, the likelihood of brake failure is very low. The direct connection between the actuator and the brake disc or drum greatly reduces the likelihood of brake failure

Electromagnetic Braking System

Electromagnetic braking systems are found in many modern and hybrid vehicles. The electromagnetic braking system uses the principle of electromagnetism to achieve smooth braking. This serves to increase the service life and reliability of brakes.

Also, conventional braking systems tend to slip, while this is supported by fast magnetic brakes. If there is no friction or need for lubrication, this technology is preferred for hybrids. Besides, it is quite modest compared to traditional braking systems. It is mainly used in trams and trains.

For electromagnetic brakes to work, a magnetic flux, when conducted in a direction perpendicular to the direction of rotation of the wheel, a rapid current flows in a direction opposite to the direction of rotation of the wheel. This creates a force opposite to the rotation of the wheel and slows the wheel down.

Advantages of Electromagnetic Braking System:

- Electromagnetic braking is quick and cheap.
- With electromagnetic braking, there are no maintenance costs such as regularly replacing the brake shoes.
- Electromagnetic braking can improve the capacity of the system (such as higher speeds, heavy loads).
- Some of the energy is delivered to the utility, which reduces running costs.
- Electromagnetic braking generates a negligible amount of heat, while mechanical braking generates enormous heat on the brake shoes, which leads to brake failure.

Servo Braking System

Also known as vacuum or vacuum-assisted braking. This system increases the pressure exerted on the pedal by the driver.

They use the vacuum that is produced in petrol engines by the air intake system in the intake pipe of the engine or by a vacuum pump in diesel engines.

A brake that uses power assistance to reduce human effort. An engine vacuum is often used in an automobile to flex a large diaphragm and operate the control cylinder.

Servo braking system boosters are used with the hydraulic braking system. The size of the cylinder and the wheels are practically used. Vacuum boosters increase the braking force.

Pressing the brake pedal releases the vacuum on the side of the booster. The difference in the air pressure pushes the diaphragm for braking the wheel.

1.2.3. Mechanical Braking System

The mechanical braking system drives the handbrake or the emergency brake. This is the type of braking system where the braking force applied to the brake pedal is transmitted through the various mechanical connections such as cylindrical rods, fulcrums, springs, etc. to the final brake drum or disc rotor to stop the vehicle.

Mechanical brakes were used in several automobile motor vehicles, but are archaic these days due to their less effectiveness.

1.3 SENSORS USED IN AUTOMATIC BRAKING SYSTEM:

1.3.1 OBJECT DETECTION SENSOR:

Type of Sensor – The presence of an object can be detected with proximity sensors and other sensor technologies like ultrasonic sensors, capacitive, photoelectric, inductive, or magnetic; or for advanced applications, generally image sensors and vision software like Open CV are used.

Accuracy – The accuracy is a very important element, and it is useful to choose sensors with accuracy values between desired measurement margins. Resolution – Depending on type of objects to be tracked, we can chooses sensors based on resolution. A high resolution can detect even the smallest changes in the position of the target. Range – This involves choosing the sensors based on measurement limits. Control Interface – To interface the sensor you have to know the types of the sensors. A wide range of sensors are 3-wire DC types, but there are many more types, including 2-wire DC or 2-wire AC/DC; Environmental Condition – These include sensor operational limits like temperature and humidity. Calibration – Calibrating the sensors is an essential step to ensure accurate measurement and efficiency. Cost – Depends on a number of factors the sensor is supporting.

1.3.2 ULTRA SONIC SENSOR

An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves.

An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity.

High-frequency sound waves reflect from boundaries to produce distinct echo patterns.

Working

Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. Our ultrasonic sensors, like many others, use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

Our ultrasonic distance, level, and proximity sensors are commonly used with microcontroller platforms like Raspberry Pi, ARM, PIC, Arduino, Beagle Board, and more.

Ultrasonic sensors transmit sound waves toward a target and will determine its distance by measuring the time it took for the reflected waves to return to the receiver.

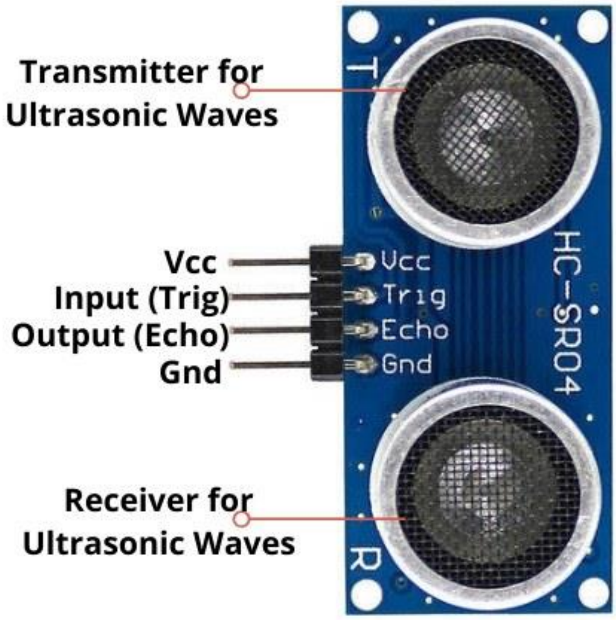

Figure 1.3 Ultra sonic sensor

This sensor is an electronic device that will measure the distance of a target by transmitting ultrasonic sound waves, and then will convert the reflected sound into an electrical signal.

Our sensors are often used as proximity sensors.

Ultrasonic sensors are also used in obstacle avoidance systems, as well as in manufacturing.

Our Short Range sensors offer the opportunity for closer range detection where you may need a sensor that ranges objects as close to 2cm. These are also built with very low power requirements in mind, as well as environments where noise rejection is necessary.

When using multiple sensors in an application, it's important to connect them in a way that will allow you to avoid issues like crosstalk or any other interference.

To prevent the disruption of the ultrasonic signals coming from your sensor, it's important to keep the face of the ultrasonic transducer clear of any obstructions.

Common obstructions include:

- Dirt
- Snow
- Ice
- Other Condensation

For this particular use case, we offer our Self Cleaning sensors.

They are intended specifically for applications requiring the resistance of condensation in high moisture environments, our self-cleaning function is designed to run continuously in order for the self-cleaning feature to be active.

1.3.3 MOTION SENSOR

A motion sensor (or motion detector) is an electronic device that is designed to detect and measure movement. Motion sensors are used primarily in home and business security systems, but they can also be found in phones, paper towel dispensers, game consoles, and virtual reality systems. Unlike many other types of sensors (which can be handheld and isolated), motion sensors are typically embedded systems with three major components: a sensor unit, an embedded computer, and hardware (or the mechanical component). These three parts vary in size and configuration, as motion sensors can be customized to perform highly specific functions. For example, motion sensors can be used to activate floodlights, trigger audible alarms, activate switches, and even alert the police.

There are two types of motion sensors: active motion sensors and passive motion sensors. Active sensors have both a transmitter and a receiver. This type of sensor detects motion by measuring changes in the amount of sound or radiation reflecting back into the receiver. When an object interrupts or alters the sensor's field, an electric pulse is sent to the embedded computer, which in turn interacts with the mechanical component. The most common type of active motion detector uses ultrasonic sensor technology; these motion sensors emit sound waves to detect the presence of objects. There are also microwave sensors (which emit microwave radiation), and tomographic sensors (which transmit and receive radio waves).

Unlike an active motion sensor, a passive motion sensor does not have a transmitter. Instead of measuring a constant reflection, the sensor detects motion based on a perceived increase of radiation in its environment. The most widely used type of passive motion sensor in home security systems is the passive infrared (PIR) sensor. The PIR sensor is designed to detect the infrared radiation emitted naturally from the human body. The receiver is contained in a filter that only allows infrared to pass through it. When a person walks into the PIR sensor's field of detection, the difference in radiation creates a positive charge within the receiver; this perceived change causes the sensing unit to send electrical data to the embedded computer and hardware component.

1.3.4 PIR SENSOR

PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are small, inexpensive, low-power, easy to use and don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensors.

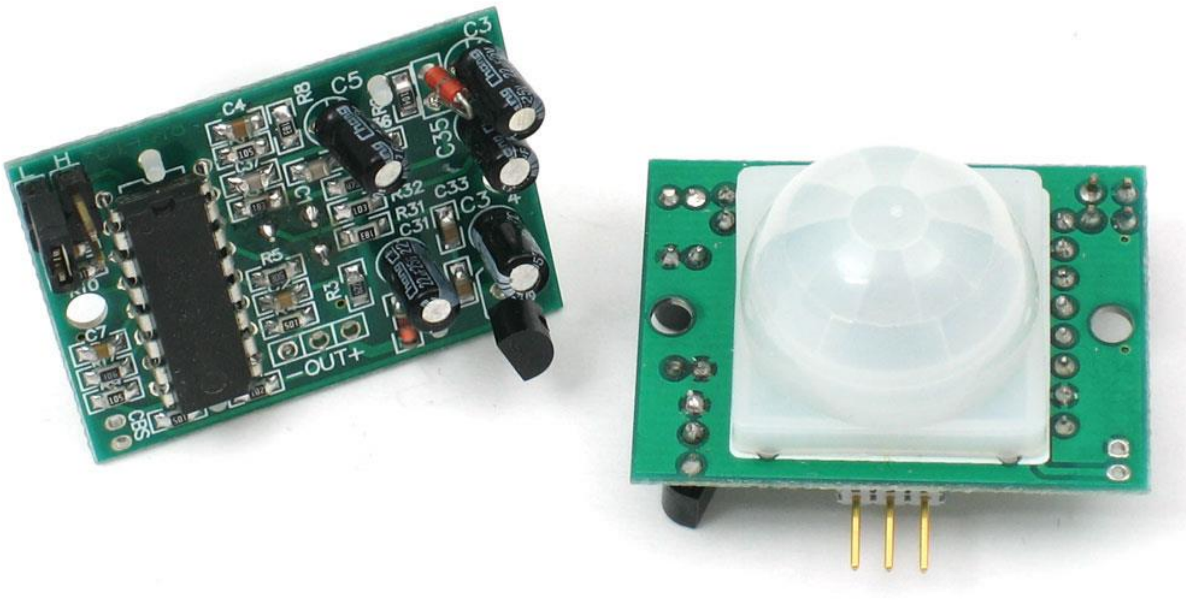

Figure 1.3.1 PIR Sensor

PIRs are basically made of a pyroelectric sensor (which you can see below as the round metal can with a rectangular crystal in the center), which can detect levels of infrared radiation. Everything emits some low level radiation, and the hotter something is, the more radiation is emitted. The sensor in a motion detector is actually split in two halves. The reason for that is that we are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low.

Along with the pyroelectic sensor is a bunch of supporting circuitry, resistors and capacitors. It seems that most small hobbyist sensors use the BISS0001 ("Micro Power PIR Motion Detector IC"), undoubtedly a very inexpensive chip. This chip takes the output of the sensor and does some minor processing on it to emit a digital output pulse from the analog sensor.

For many basic projects or products that need to detect when a person has left or entered the area, or has approached, PIR sensors are great. They are low power and low cost, pretty rugged, have a wide lens range, and are easy to interface with. Note that PIRs won't tell you how many people are around or how close they are to the sensor, the lens is often fixed to a certain sweep and distance (although it can be hacked somewhere) and they are also sometimes set off by housepets. Experimentation is key!

CHAPTER 2

REVIEW OF LITERATURE

Chirantana kuchimanchi et al (2015), analysed that automotive safety has gained an increasing amount of interest from the general public, governments and the car industry. This is more than justified by traffic accident statistics, as each year around 1. 2 million people die due to road traffic accidents. This paper presents a model of cost effective collision warning system for low budget cars. Rear-end collisions are common accident scenarios and a common cause of these accidents is driver distraction and thus not reacting in time. No vehicle system is a substitute for the most important safety feature in any vehicle the driver. Now a day's many automobile manufacturers are harnessing innovative technologies to help alert drivers to avoid collisions and reduce the potential impact speed when a collision cannot be avoided.

N.Bose et al (2013), discussed that during the next decade, advanced driver assistance systems will play a key role in the challenge of increasing automobile active safety. In this paper, an automatic braking system has been developed in automobiles. When it is fully implemented in vehicles, it could prevent some of the numerous vehicle-pedestrian and vehicle-vehicle accidents. The system is vision-based and the problem has been to design by vision algorithms by Image and Video Processing which are robust enough to reliably detect any pedestrians and vehicles in a highly cluttered urban environment. Braking is done automatically when the driver gets distracted or when his visibility is poor. Automatic braking is applied by the output of algorithms using decision logic. The system is also designed for easy future augmentation for, e.g., night driving conditions. This system shows improved robustness with respect to the algorithms that are fast enough to be suitable for on-line operation

Dariu M.Gavrila (2000), Presents prototype system for pedestrian detec- tion on-board a moving vehicle. The sy stem uses a generic two-step ap- proach for efficient object det ection. In the first step, contour features are used in a hierarchical template matching approach to efficiently " lock onto candidate solutions. Shape matching is based on

Distance Trans forms. By capturing the objects shape variability by means of a template hierarchy and using a combined coarse-to-fine approach in shape and pa- Tameter space, this method achieves very large speed-ups comnpared to a brute-force method. We have measured gains of several orders of mag- nit ude. The second step utilizes the richer set of intensity features in a pattern classification approach to verify the candidate solutions (i.e, using Radial Basis Funetions). We present experimental results on pedes-trian detection off-line and on board our Urban Traffic Assistant vehicle and discuss the challenges that lie ahead.

Erik Coelingh et al (2007), proposed that automotive safety has gained an increasing amount of interest from the general public, governments, and the car industry. This is more than justified by traffic accident statistics, as each year around 1.2 million people die due to road traffic accidents. For these reasons safety remains a core value of Volvo Cars. This paper presents some of the latest active safety developments within Volvo Cars. Rear-end collisions are common accident scenarios and a common cause of these accidents is driver distraction and thus not reacting in time. No vehicle system is a substitute for the most important safety feature in any vehicle: the driver. However, Volvo is harnessing innovative technologies to help alert drivers to avoid potential collisions and reduce the potential impact speed when a collision cannot be avoided. One of those systems is Collision Warning with Auto Brake where the area in front of the vehicle is continuously monitored with the help of a long- range radar and a forward-sensing wide-angle camera fitted in front of the interior rear-view mirror.

Aqeel Ur Rehman (2022), Discussed about the automotive industry provide more and more amenities to its customers. The industry is taking advantage of artificial intelligence by increasing different sensors and gadgets in vehicles machoism is forward collision warning, at the same time road accidents are also increasing which is another concern to address. So there is an urgent need to provide an A.I based system to avoid such incidents which can be address by using artificial intelligence and global positioning system. Automotive/ smart vehicles protection has become a major study of research for customers, government and also automotive industry engineers In this study a two layered novel hypothetical approach is proposed which include in-time vehicle/obstacle detection with auto warning mechanism for collision detection & avoidance and later in a case of an accident manifestation GPS & video camera based alerts system and interrupt generation to nearby ambulance or rescue-services units for in-time driver rescue

Mattias brannstrom et al (2009), presents a method for estimating how the driver of a vehicle can use steering, braking or acceleration to avoid a collision with a moving object. In the method, the motion of the object can be described with an arbitrary motion model and polygons are used to describe its expected extension. The key idea is to parameterize the motion of the vehicle such that an analytical solution can be derived for estimating the set of manoeuvres that the driver can use to avoid the object at discrete times. The union of the solutions for all times is used to estimate how a collision can be avoided during the complete prediction horizon. Additionally, a decision-making algorithm is proposed that decides when to initiate autonomous braking to avoid or mitigate a potential collision. A collision avoidance by braking system, based on the proposed method and algorithm, has been evaluated on simulated traffic scenarios at intersections.

Andreas eidehall et al (2010), proposed that more and more vehicles are being equipped with Automatic Emergency Braking (AEB) systems. These systems intend to help the driver avoid or mitigate accidents by automatically applying the brakes prior to an accident. Initially only rear-end collision were addressed but over time more accident types are incorporated and brakes are applied earlier and stronger, in order to increase the velocity reduction before the accident occurs. This paper describes one of the latest AEB systems called Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD).

Likun Xia et al (2013), presents review of automated emergency braking (AEB) systems, its current state of the art and the trend for future development. Several important safety measures of AEB systems are time to collision, stopping distance and speed reduction. There is strong need to develop low-cost AEB system to broaden the use of such safety system on various vehicle ranges. Some considerations for the development of AEB systems are suggested to be taken into consideration by dominant automakers in Malaysia namely Proton & Perodu

Hrishikesh Shivankar et al (2017), discussed that road accidents are a commonplace in today's scenario. Accident prevention has been one of the leading areas of research. In Indian scenarionormally vehicles are equipped with ABS (Anti-Lock Braking System), traction control, brake assist etc. for driver's safety. This paper focuses on a system known as 'Intelligent braking system' (IBS) which employ several sensors to respond when emergency conditions occur. The system includes an infrared wave emitter provided on the front portion of the car. An infrared receiver is also fitted to receive the signal. The reflected wave gives the distance between the obstacle and the vehicle.

J.V.Sai Ram (2018), When compared with olden days life span of human is reduced. Death rate due to accident is drastically increased because vehicles usage is increasing by day by day. Due to brake failure so many accidents are occurring so when we control the brake by automatically we can reduce the effect of accident. A Ultrasonic setup is placed in front of vehicle and that setup consists of an emitter and a receiver. Ultrasonic emitter always emits the ultrasonic waves, whenever a obstacle is detected then wave gets reflected and receiver receives the signal. Reflected wave sends the signal to the Aurduino Nano from that based upon distance of object it actuates the buzzer or brakes.

Yayati Shinde et al (2014), proposed that IC engines are so advanced that their speed becomes a major disaster. The advanced braking system improves braking techniques in cars. It replaces complete braking systems for cars and deals with the concept of Automatic Braking System that provides a solution. The project is built with an ultrasonic transmitter, ultrasonic receiver, Arduino UNO R3 board with PIC microcontroller, DC gear motor, Servomotor, and mechanical brake arrangement. The ultrasonic sensor produces a frequency signal (0.020-20) KHZ. It is transmitted via an ultrasonic transmitter. The ultrasonic receiver is used to receive the pre-displayed wavelength of the vehicle.

Swapnil P et al (2013), stated that the braking system was designed and applied on a car to form the driving process safety using embedded system design. Most of the accident occurs due to the delay of the driving force to hit the brake, so during this project work braking system is developed specified when it's active it can apply brake depending upon the thing sensed by the ultrasonic sensor and speed of car. Currently, vehicles are often equipped with active safety systems to cut back the possibility of accidents, many of which occur within the urban environments. The foremost popular include Antilock Braking Systems (ABS), Traction Control and Stability Control. Of those systems employ differing kinds of sensors to constantly monitor the conditions of the vehicle, and respond in an emergency situation. An intelligent braking system contains an ultrasonic wave emitter provided on the front side of a car.

Ikun Xia et al (2013), presents review of automated emergency braking (AEB) systems, its current state of the art and the trend for future development. Several important safety measures of AEB systems are time to collision, stopping distance and speed reduction.

CHAPTER 3

RESEARCH GAP

- The main research gap in this project is the adoption of Automatic Braking System in a four Wheeler to increase the safety.
- This type of technology only available in commercial and heavy duty vehicles, aeroplanes that must be adopted to four wheeler segment
- This come with own challenges as the stability and driving conditions of the four wheeler is low compared to the heavy duty vehicle. The automobile sector now adopting it to their vehicles.

CHAPTER 4

OBJECTIVES

The objective of this project is to improve the safety of riders especially in vehicle segment. In this segment the safety offers by the manufacturers are considered to be not up to mark. Considering the four wheeler and above segment the performance and safety measures are high and stable, improving day by day. But in the four wheeler commuter segment the performance was increasing but the safety features are less. In the sport two wheeler the manufacturer offer better safety features like ABS, traction control, vehicle stability control, and engine cut off control. The commuter segment vehicle manufacturer offers only least safety features like airbags, engine check lamp for fault diagnosis engine.

The majority of accidents occur due to the 90% of human error, 5% road condition and 5% vehicle faults due to less or improper maintenance. So the 90% of accidents can be reduced by giving assistance to the driver by the more safety system, educating the drivers to follow the road signs and traffic rules and providing separate lane for heavy and light weight vehicles so the accident occur due to the hitting by the heavy and light motor vehicles become less.

One of the driver assistance for safety is Automatic Emergency Braking system (AEB) or can be known as automatic braking system. Introduced in 2009 for the heavy motor vehicle safety later on adopted to the light motor vehicles. Now a days two wheeler segment also to be consider for safety, so the automatic braking system to be adopted for the four and two wheeler segment.

This help to reduce the accident occur due to human error and save life. By assisting the driver from the objection detection and react according to it by stopping vehicle without the driver interference.

CHAPTER 5

METHODOLOGY

- **PHASE - 1**
- **DESIGN AND CALCULATIONS**
    1. Design of shaft, bearings.
    2. Design of frame
    3. Algorithm coding

- **PHASE - 2**
- **FABRICATION**
    1. Fabrication of Frame
    2. Fabrication of Controller
- **PHASE – 3**
- **TESTING**
    1. Procedure
    2. Sensor reaction time
    3. Stopping distance and time

CHAPTER 6

FABRICATION

6.1 BLOCK DIAGRAM OF AUTOMATIC BRAKING SYSTEM IN A VEHICLE

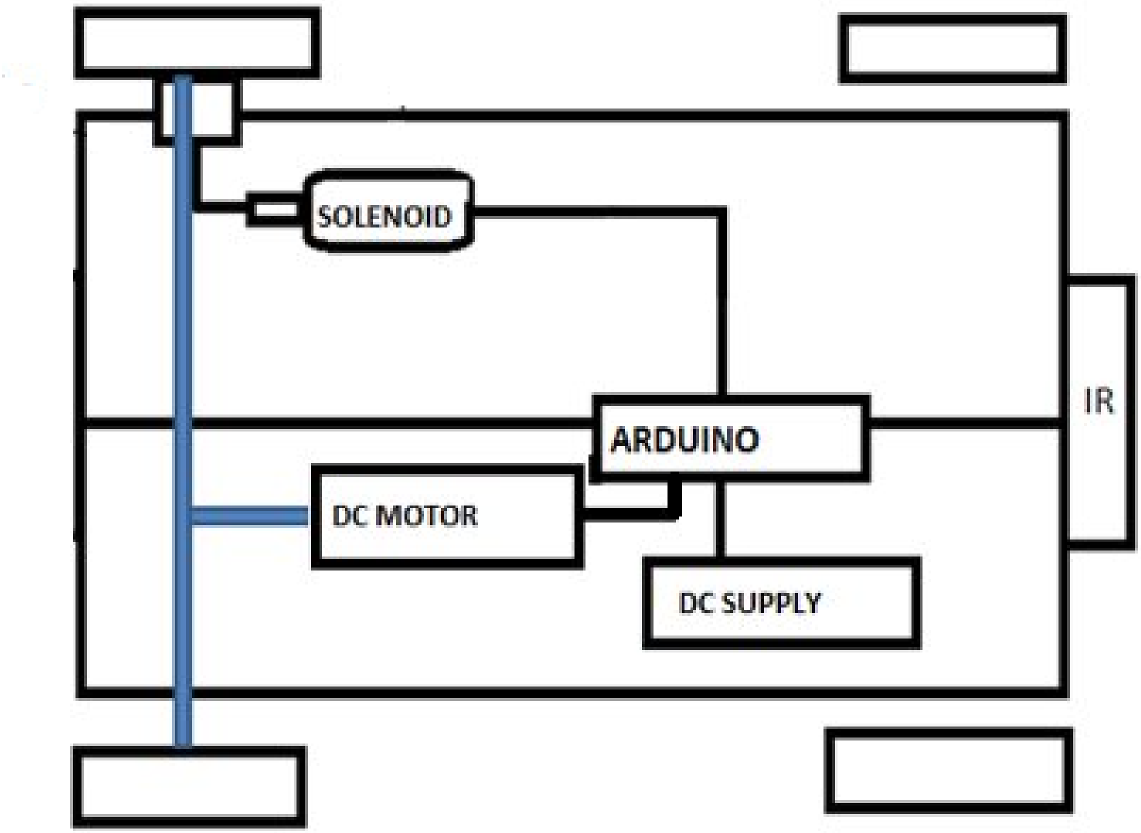

Figure 6.1 Block diagram

- We designed and fabricated automatic braking system in a vehicle with one inch Mild Steel square hallow pipe frame and Mild Steel shaft, which was attached to frame through four Ball bearings with four scooty wheels.
- We used chain drive for rear wheel shaft, chain drive attached through DC motor and for better braking system we used solenoid valve. These two were connected to D.C battery and arduino board circuit

6.2 LIST OF COMPONENTS

1. Ms square hollow pipe frame
2. Ms shaft(15mm)
3. Four wheels (scotty wheels)
4. Solenoid valve (12V D.C)
5. Battery (12V D.C,7.5 amps)
6. Electric motor (12V DC,1 amp)
7. Arduino board
8. Relay switches
9. Infrared sensor

6.3 PROTOTYPE SPECIFICATIONS

FRAME:

Vertical length of frame = 28 cm

horizontal width of frame=18 cm

Height frame from ground = 10 cm

Diameter of frame =1 cm

SHAFT:

Length of shaft=28 cm

Radius of shaft = 0.5 cm

Vertical distance between shafts=22cm

WHEEL:

Vertical distance from center of rear wheel to font wheel=22 cm

Cross section of wheel =15 cm

Cross section of rim =10 cm

Width of the wheel=5cm

CHAIN:

Length of the chain = 16 cm

Plunger pulling brake wire is around 2 cm

For Arduino board we fixed 8 cm iron bar at front side

For plunger we fixed 5 cm iron bar at rear side

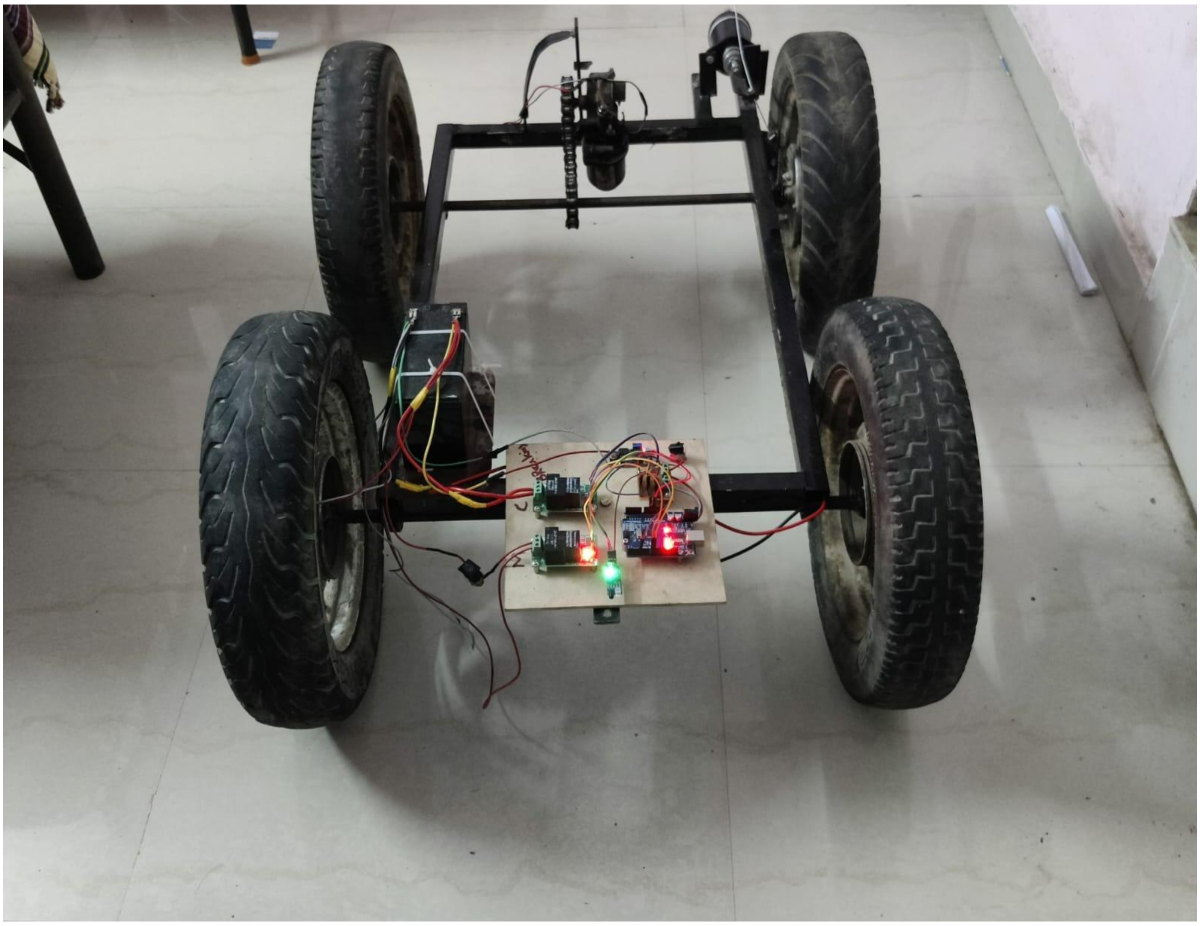

Figure 6.3.1 Prototype model of automatic braking system in a vehicle

6.4 TECHNICAL SPECIFICATION

Battery specifications

Figure 6.4.1 D.C Battery

- Weight of battery: 2kg
- Cost of battery:1350/-
- Output power:12v 7.5 amps
- Operating voltage:12v 1amp
- Current:1 to 1.5 amps

SPECIFICATION OF MOTOR

- Specification of motor:-
- Weight of motor:1kg
- Operating power required:12v 1 amps
- Operating voltage: 12v
- Operating current:1 amps
- Motor speed:80 rpm
- Motor cost:800/-

6.5 REASON BEHIND SELECTON OF MILD STEEL FOR FRAME & SHAFT

MILD STEEL

- **Ductile** – The low amount of carbon used to create mild steel and the absence of any alloying elements results in a very ductile product. This means that low carbon steel can be deformed and shaped without losing its toughness, making it a very pliable type of steel that can be used for various purposes.
- **Machinable and Weldable** – The ductile nature of mild steel also means that it is particularly suitable for various steel fabrication processes, including welding. The lower percentage of carbon that is within the steel, the more malleable that the steel becomes.
- **Affordable** – Mild steel requires very few resources and ingredients, so it is a particularly cost-effective type of steel, which many steel fabrication customers use to complete their industrial projects.

6.6 WORKING OF INFRARED SENSOR

In this prototype we used low range sensor called infrared sensor for detecting obstacles. There are different types of infrared transmitters depending on their wavelengths, output power and response time. An IR sensor consists of an IR LED and an IR Photodiode, together they are called as Photo-Coupler or Opto Coupler. An infrared sensor is an electronic device, that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. These types of sensors measure only infrared radiation, rather than emitting it that is called a passive IR sensor

IR Transmitter or IR LED

Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations called as IR LED’s. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye

.

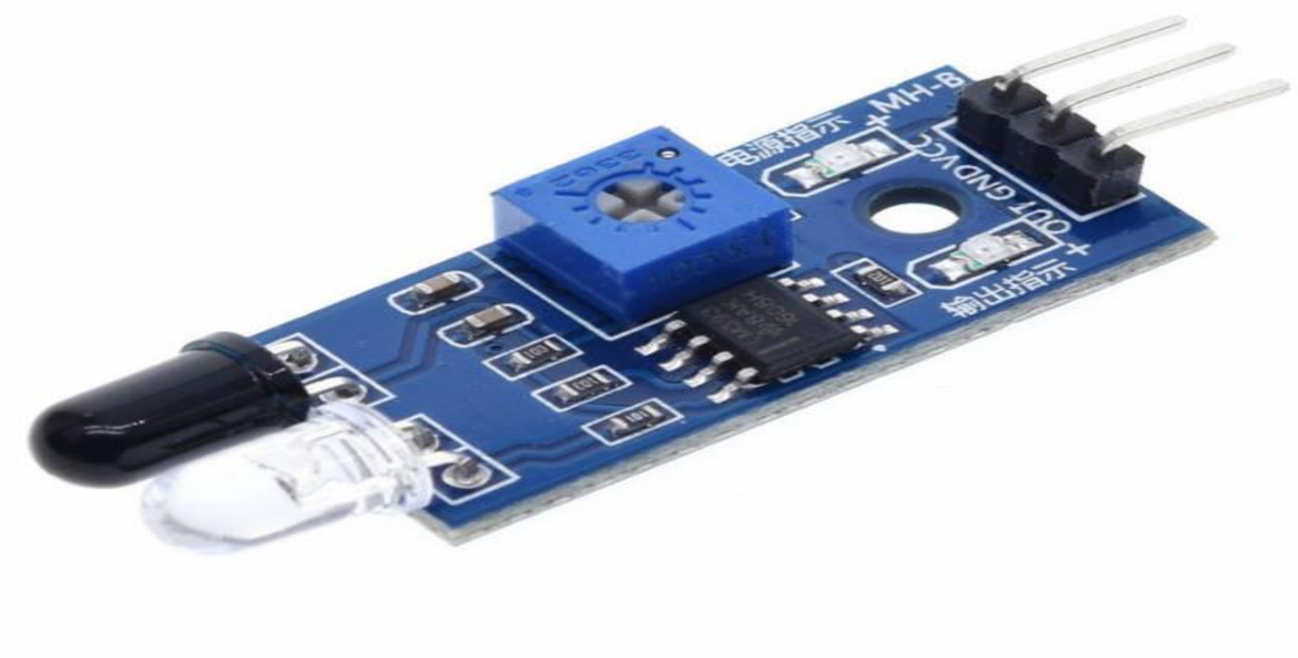

Figure 6.6.1 Infrared sensor

IR Receiver or Photodiode

Infrared receivers or infrared sensors detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. Below image shows the picture of an IR receiver or a photodiode

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter – receiver combination, the wavelength of the receiver should match with that of the transmitter.

The emitter is an IR LED and the detector is an IR photodiode. The IR photodiode is sensitive to the IR light emitted by an IR LED. The photo-diode’s resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor defines.

Features:

There is an obstacle, the green indicator light on the circuit board Digital output signal Detection distance: 2 - 20cm • Detection angle: 35 ° Degree • Comparator chip: LM393 Adjustable detection distance range via potentiometer: • Clockwise: Increase detection distance • Counter-clockwise: Reduce detection distance

Specifications:

Specifications: • Working voltage: 3- 5V DC • Output type: Digital switching output (0 and 1) 3mm screw holes for easy mounting Board size: 3.2 x 1.4cm

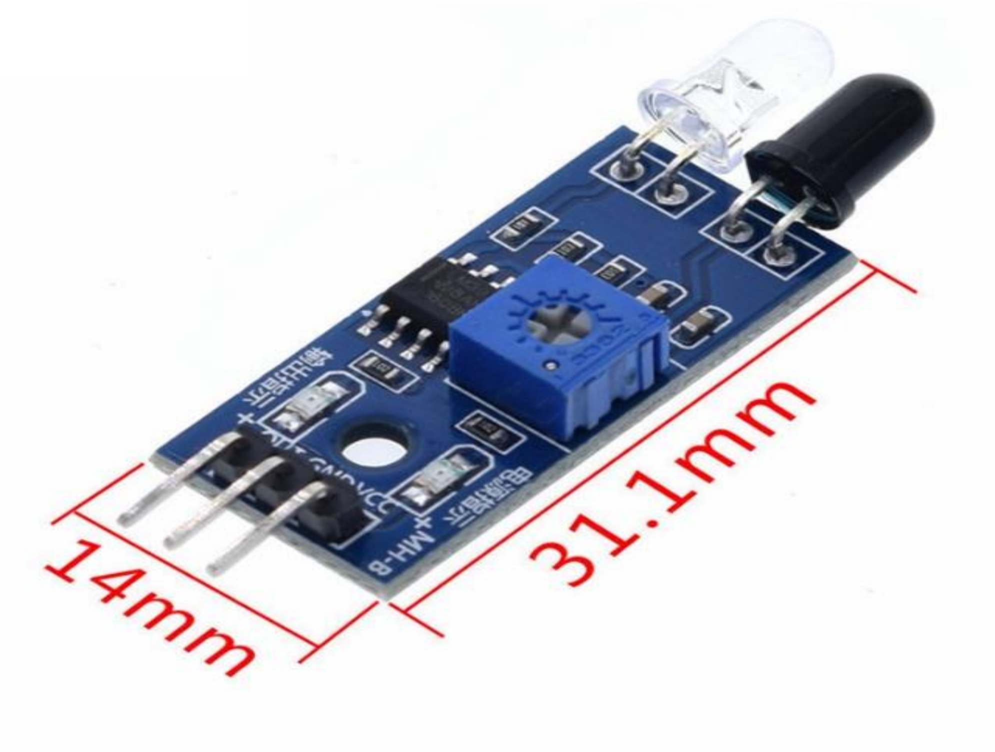

Figure 6.6.2 Measurements of IR sensor

6.7 WORKING OF DC MOTOR

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through D.C battery and convert this energy into mechanical rotation.

DC motor use magnetic fields that occur from the electrical currents generated, which powers the movement of a rotor fixed within the output shaft. The output torque and speed depend upon the electrical input.

DC motors include two key components: a stator and an armature. The stator is the stationary part of a motor, while the armature rotates. In a DC motor, the stator provides a rotating magnetic field that drives the armature to rotate.

When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work.

Figure 6.7.1 D.C Motor

- A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the centre of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.
- The windings of insulated wire are connected to a commutator (a rotary electrical switch), that applies an electrical current to the windings. The commutator allows

each armature coil to be energised in turn, creating a steady rotating force (known as torque).

- When the coils are turned on and off in sequence, a rotating magnetic field is created that interacts with the differing fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key operating principles of DC motors allow them to convert the electrical energy from direct current into mechanical energy through the rotating movement, which can then be used for the propulsion of objects.

6.8 TECHNICAL DESIGN OF D.C MOTOR

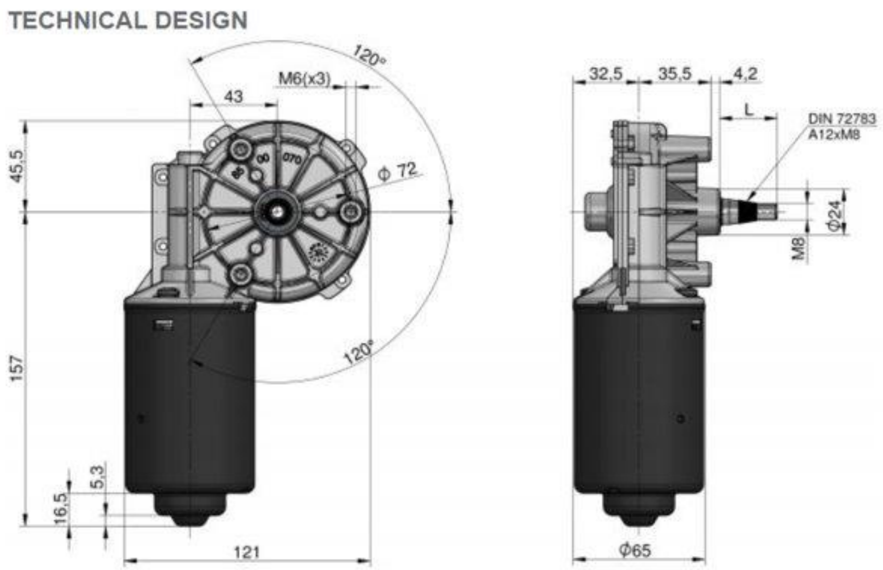

Figure 6.8.1 Design of DC motor

TORQUE

- Angular velocity x 60 / (2 x 3.14) = 0.98 * 60 / (2 * 3.14) = 9.3 rpm = 10 rpm the required motor torque from calculation is above is 2.55
  Nm and required motor speed is 10 rpm.

6.9 DESIGN PROCEDURE OF SHAFT

The drive shaft with multiple pulleys experience two kinds of stresses, bending stress and shear stress. The maximum bending stress generated at the outer most fiber of the shaft. And on the other hand, the shear stress is generated at the inner most fiber. Also, the value of maximum bending stress is much more than the shear stress. So, the design of the shaft will be based on the maximum bending stress and will be driven by the following formula:

Maximum bending stress Tb = (M * r) / I……………….Eqn.1.1

Where,

M is maximum bending moment on the shaft.

r is the radius of the shaft.

I is area moment of inertia of the shaft

DESIGN PROCEDURE

- Draw the bending moment diagram to find out the maximum bending moment (M) on the shaft.
- Calculate the area moment of inertia (I) for the shaft.
- Replace the maximum bending stress (Tb) with the given allowable stress for the shaft material.
- Calculate the radius of the shaft.

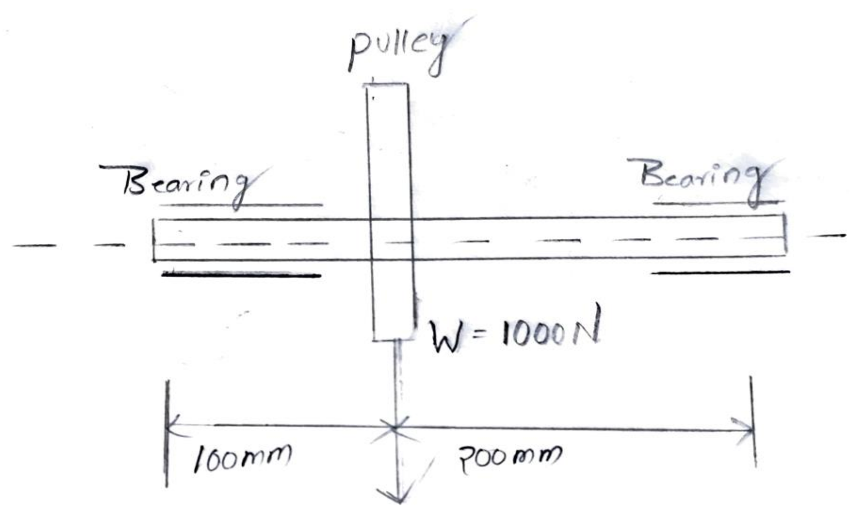

Figure 6.9.1 Bending moment diagram

Refer the above picture, where a steel shaft is supported by two bearings and a pulley is placed in between the bearings. You have to design the shaft. Weight of the pulley is 1000 N.

Input data:

Maximum allowable shear stress for the shaft material= 40 N/mm2

Solution:

From the bending moment diagram, the maximum bending moment (M) is calculated as 66666.67 N/mm2.

Area moment of inertia (I)of the circular shaft is:

I = pi * r^4 *0.25

= 0.785*r^4…Eqn. 1.2

From Eqn1.1 we can write:

40 = (66666.67 *r)/ (0.785*r^4)

r= 12.85 mm

So, the minimum radius of the shaft should be 12.85 or 13 mm.

6.10 DESIGN OF BALL BEARINGS

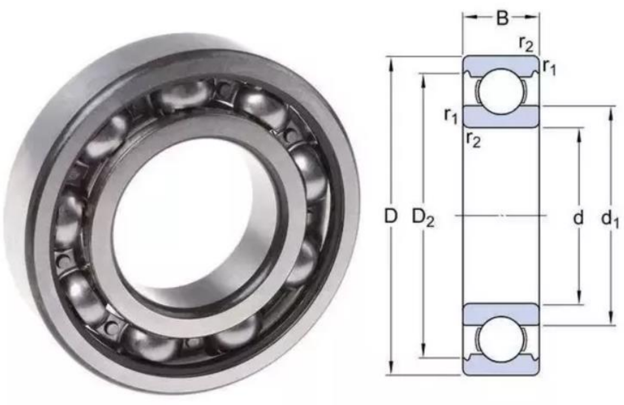

Figure 6.10.1 Ball bearing

Outer Diameter of Bearing (D) = 35 mm

Thickness of Bearing (B) = 12 mm

Inner Diameter of the Bearing (d) = 15 mm

r1 = corner radii on shaft and housing

r2 = 1 (from design data book)

Maximum Speed =14,000 rpm (From design data book)

Mean Diameter (dm) = (D + d) / 2

= (35+15)/2

Mean Diameter = 25 mm

6.11 ARDUINO BOARD

We arranged arduino board(microcontroller) in front side of vehicle.it act as a main brain of AEB system,it controlls everythings according to input signals when obstacles arrive in front of vehicle Arduino receives input signals from infrared sensor then it activates the plunger to stop the vehicleArduino is an open-source electronics platform based on easy-to-use hardware and software.

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board -- you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package

```
}
```

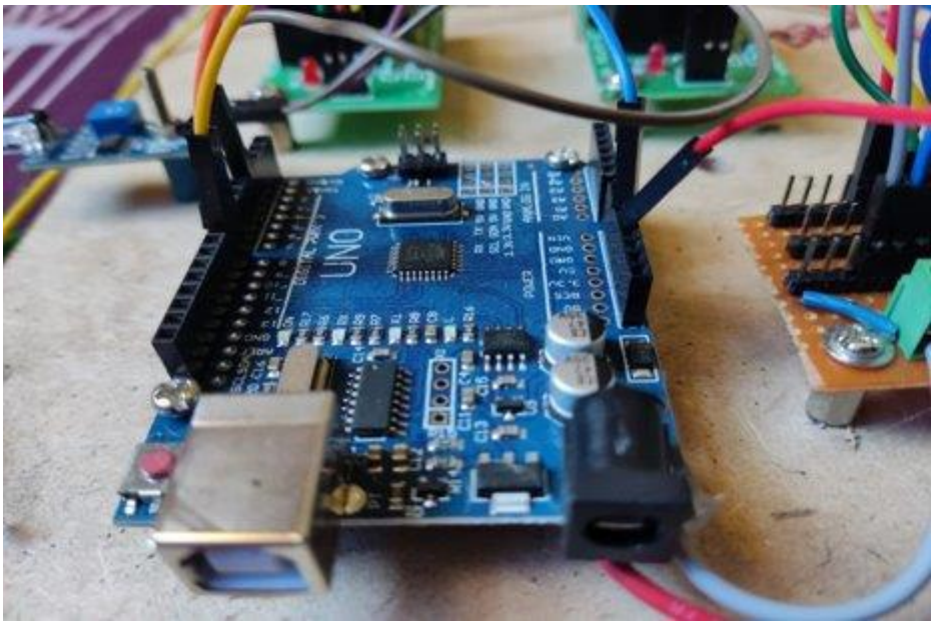

Figure 6.11.1 Arduino board

6.12 ARDUINO CODING

```
#define ir      4
#define motor   8
#define relay   9
int svalue;
int count = 0;
void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pinMode(ir, INPUT);
  pinMode(motor, OUTPUT);
  pinMode(relay, OUTPUT);
}
void loop() {
  // put your main code here, to run repeatedly:
```

```
  sensor();
control();
}
void sensor() {
  svalue = digitalRead(4);
  Serial.print(svalue);
}

void control() {
  if (svalue == 0) {
    motoroff();
    count = count + 1;
    Serial.print(count);
    delay(100);
  }

 if (count == 1) {
    relayon();
    delay(1000);
    relayoff();
  }

 if (svalue == 1) {
    motoron();
    count = 0;
  }
}
```

```
void motoron() {
  digitalWrite(motor, HIGH);
}

void motoroff() {
  digitalWrite(motor, LOW);
}

void relayon() {
  digitalWrite(relay, HIGH);
}
void relayoff() {
  digitalWrite(relay, LOW);
}
```

6.13 WORKING OF SOLENOID VALVE

We arranged a solenoid valve such that when a obstacle arrive in front of vehicle infrared sensor send the signals to arduino board then arduino board activates the plunger to stop the vehicleThe definition of a solenoid valve is an electro-mechanical valve that is commonly employed to control the flow of liquid or gas. There are various solenoid valve types, but the main variants are either pilot operated or direct acting. Pilot operated valves, the most widely used, utilize system line pressure to open and close the main orifice in the valve body.

While Direct operated solenoid valves directly open or close the main valve orifice, which is the only flow path in the valve. They are used in systems requiring low flow capacities or applications with low pressure differential across the valve orifice.

How a solenoid valve works is by controlling the flow of liquids or gases in a positive, fully-closed or fully-open mode. They are often used to replace manual valves or for remote control. Solenoid valve function involves either opening or closing an orifice in a valve body, which either allows or prevents flow through the valve. A plunger opens or closes the orifice by raising or lowering within a sleeve tube by energizing the coil.

Solenoid valves consist of a coil, plunger and sleeve assembly. In normally closed valves, a plunger return spring holds the plunger against the orifice and prevents flow. Once the solenoid coil is energized, the resultant magnetic field raises the plunger, enabling flow. When the solenoid coil is energized in a normally open valve, the plunger seals off the orifice, which in turn prevents flow.

Figure 6.13.1 Solenoid valve

6.14 FACTORS EFFECTING ON BRAKING DISTANCES

STOPPING TIME AND DISTANCE

If the coefficient of friction between the ground and the tyre is unity then the total retarding force produced at the wheel will be equal to the retarding force assumed by a freely falling body. Under this condition the deceleration due to gravity. At this stage the brakes are said to be cent percent efficient.

Stopping distances vary with brake conditions). The distances vary with the type of road surface and condition of tyre treads. Stopping distance is reaction (or thinking) distance plus braking distance (while is dependent on speed). The reaction distance is the minimum safe distance at which you should follow another car. The time a driver takes to stop depends on the time it takes for him to react – 0.4 to 0.7 sec. – as well as the time it takes the brake to half the car. During this time the car travels for what is called the thinking distance. Locking the sheets extends the braking distance and can lead to loss of directional control. To give best braking results without loss of directional control and regardless of road-surface grip condition. Antilock braking systems are being developed.

The chart shows the average thinking and braking distances for medium sized cars with 60% efficient brakes and 80% efficient brakes travelling at speeds of 48,80 and 112 km/hr. On a dry road when the coefficient of friction varies between 0.65 and 0.85 (usually 0.6).

Thinking distance	Braking distance	Efficiency
48 kmph 9.14 m	15.84 m	60%
9.14 m	11.58 m	80%
80 kmph 15.24 m	42.67 m	60%
15.24 m	32.00 m	80%
112 kmph 21.34 m	83.82 m	60%
21.34 m	62.48 m	80%

Table no 1 Average thinking and braking distance

Efficiency of the brakes of a vehicle should vary from 50-80% to stop the vehicle within reasonable distance.

The efficiency of properly adjusted brakes should be at least 80 percent. Severe braking at high speeds involves serious hazards because the driver is likely to lock the wheels. Thereby throwing the car into a skid and the passengers are likely to be thrown off their seats. A fast stop is not only uncomfortable but may result in personal injury. The time required to bring the vehicle load stop by means of brakes varies directly with the initial speed. But the stopping distance varies as the square of the speed.

RELATION OF STOPPING DISANCE

When the vehicle is braked from a steady speed of V (km/h). When a freely falling body of mass 1 kg is acted upon by a force of 1 kg. The mass is accelerated at the rate of 9.81 (m/s^2). The acceleration is directly proportional to the force acting on the body and it is inversely proportional to the mass accelerated. It can be represented by the equation,

$f = F\,g/w$

Were,

f = acceleration (m/s^2)

F = force acting on the body

W = weight of the body

g = acceleration due to gravity m/s^2).

The deceleration of a moving mass may be considered as negative acceleration. When the vehicle is brought to rest by the application of its brakes, the maximum value at decelerating force can be represented by

$F = \mu\, w$

Where,

W = weight of the vehicle

u = coefficient of friction

The max. braking force is available only if the brakes are applied on all the four wheels. The value of the coefficient of friction between the tread of a rubber tyre and a clean dry concrete road lies between 0.6 x 0.85 under ideal conditions. It is reasonable to assume value of as 0.6.

The rate of deceleration can be represented as,

$f = \mu\, wg/w.$
$= \mu g.$

If the speed of the vehicles is v km/hr. its velocity is,

V= 5/18 x V x v (m/s).

To bring the vehicle to stop from an initial velocity of V = (5/18) x v (m/s). When the rate of deceleration is ug (m/s^2), the time

t = (5/18) x v /ug

When the deceleration is constant the mean velocity is half of initial velocity
i.e., (5/36) x v (m/s)
stopping distance = mean velocity x time = (5/36) x v x (5/18) x v/ug
Stopping distance = 25/648 x v^2/(0.6 x 9.81) = 0.00656 v^2

Table gives the minimum stopping distances at different speeds of the vehicle based on the above equation.

Speed (km/hr) 60	10	20	30	40	50
Distance(m) 23.62	0.656	2.624	5.9	10.5	16.4
Speed (km/hr)	70	80	90	100	
Distance (m)	32.2	42.1	53.2	65.6	

Table No 2 stopping distance at different speeds

The above distances are for emergency braking in order to avoid accidents. However this high rate of deceleration causes discomfort to the passengers. The maximum rate of deceleration which is not likely to interfere with the passenger comfort is about 2 (m/s^2).

6.15 BRAKE OPERATING EFFICIENCY

Brakes operate most efficiently when they are applied so that the Wheels do not quite lock. But continue to turn without slipping on the road. This is because more energy can be absorbed when the wheels are turning than when the brakes lock the wheels, so that the tyres slide on the road. The power absorbed by the friction of the brake drums and lining the frictional losses of the power transmission system and the rolling friction of the tyres is greater than the sliding friction of the tyres on the road. For this reason it is usually safer, especially when travelling on slippery highways to use the deceleration of the engine, with or without brakes, rather than brakes alone for slowing down a car. In addition locked brakes cause excessive tyre wear.

CHAPTER 7

RESULTS AND DISCUSSION

7.1 TESTING PROCEDURE

Testing the model to know how much distance and time is requiring to apply brakes and reacting time. For the testing a obstacle is kept infront of the model and calculated the stopping distance and time. As it is the testing model the speed is less so as well as the stopping distance also low. With the help of markings and stopwatch we calculated the stopping distance and time.

The following table was the result of testing the model.

Speed	Stopping time	stopping distance
0 kmph	0	0
1 kmph	2s	10 cms
2 kmph	4s	15 cms

Table No 3 stopping distance and time

The reaction time for the sensor is under 30 seconds so the brakes deploy easily and avoid obstacle. But in the real time vehicle the scenario is different from the prototype model so the stopping distance is also vary. But compared to manual braking distance the braking distance caused by the sensor is low as it calculates and apply on its own so the reaction time is low.

CHAPTER 8
FUTURE SCOPE

- Obstacle detection while turning
- Capable of driving at all environmental conditions
- Minimized backward collision

CHAPTER 9

CONCLUSION

Automatic emergency braking (AEB) was revolutionary for the vehicle segment that incorporates braking distribution, better stability, helps in cornering stability. This project is to develop more stability and enhance better safety by assisting the driver. AEB established in the light motor vehicle shows that the accidents occur due to the human error are reduced to a distinct level. This project presents the implementation of the Automatic Braking System for forward collision avoidance, intend to use in light vehicle segment where drivers may not be braking manually, but the speed of the vehicle reduce automatically due to sensing of the objection motion and obstacles. The AEB also an essential feature to be adopted in all type of vehicle segments.

The AEB reduce the impact speed of the vehicle compared to the vehicle without the AEB system. In addition, AEB was able to obtain higher deceleration and improved stability consider to the ABS system. The results of this project also suggested that the effectiveness of AEB is likely to be higher when the driver applies early, poor braking, and when roll angles are far from the limit, compared to cases in which the driver is able to apply late, nearly optimal braking, and in tight corners requiring high roll angles. AEB or similar systems could also enable the deployment of emergency braking when the collision between vehicle and opponent vehicle is still preventable. The concept of this project is adopting in light vehicle segment and it also has to adopt in two wheeler segment but the research done in this area are very low and the motorcycle autonomous emergency braking has not even been mentioned.

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INDIVIDUAL CONTRIBUTION

1. Palli Siddartha Reddy

- Material purchasing
- Assembling components
- Collecting of papers

2. Muvva Suresh Babu

- Ppt editing
- Report editing
- Circuit connections

3. Sarangam Sai Naveen

- Material purchasing
- Photos & editing.
- Report content collection

4. Naram Madhu

- Ppt & report editing
- Literature review collection
- Calcutions of components

PO – PROJECT MAPPING

PO NO.	PO DESCRIPTION	PROJECT MAPPING
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3
PO 2	**Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3
PO 3	**Design Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	3
PO 4	**Conduct Investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2
PO 5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and	3

	modeling to complex engineering activities with an understanding of the limitations.	
PO 6	**The Engineer & Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	2
PO 7	**Environment & Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	3
PO 8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	3
PO 9	**Individual & Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	3
PO 10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	2
PO 11	**Project Management & Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own	2

	work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	
PO 12	**Life-Long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	3

PSO – PROJECT MAPPING

PSO NO.	PSO DESCRIPTION	PROJECT MAPPING
PSO 1	Design, Analysis, Fabrication and Testing of vehicles, which enable the students to compete globally.	3
PSO 2	Carry out research in fuel economy, emission reductions, alternate fuels and solar vehicle for the benefit of the society and environment.	2