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MICROCONTROLLERS BASED REAR-END ANTI-COLLISION WARNING SYSTEM FOR VEHICLES

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Abstract

Now a day's vehicle accident is becoming critical issue allover the world and in Ethiopia in particular that demands engineer's endeavor to find ways to minimize the incidence. The application of electronic systems embedded in automobile is expected to contribute a lot on the race to minimize vehicle accident disaster. Thus, the research focused on developing a model of rear end anti-collision warning system that will detect the distance between two vehicles moving on the same lane in the same direction and alert the driver whenever she or he is in danger range using microcontroller (PIC).

Key words: *mechatronics, microcontroller, rear-end collision, car accident*

1. Introduction

Ethiopia, in addition to HIV AIDS, is suffering from car accidents. A large number of people have been killed in motor vehicle accidents of various kinds. In this regard, the Ethiopian Federal Police Annual Statistical Report on road accidents shows that in Ethiopia, during the years 2002/03-2006/07, the number of people who died of vehicle accidents each year is 2,226 on average. The same report indicated that the yearly average number of serious and light injuries during the aforementioned period is 3,855 and 4,826 respectively (Federal Police of Ethiopia annual statistics (2002/03-2006/07)).

The worsening situations in the rate of car crash calls for hand to hand efforts of all concerned bodies and the society in general. It is a well known fact that the socio economic, physical and psychological crisis caused by vehicle accidents need to be dealt with seriously. Various research and studies should be conducted to overcome these problems (Federal Police of Ethiopia annual statistics (2002/03-2006/07), WHO (2004). World report on road traffic injury prevention, Geneva: World health organization, Advances in Transportation Studies an international Journal Section A 15 (2008)).

This research will be dedicated to attempt alternative solution for this known problem by developing low cost domestic anti-collision warning system model that would be mounted on the existing car models and alert the driver in danger zone.

Therefore, rather than putting aside inbuilt active safety system development to the car manufacturers, the user shall find ways to solve the problem by developing domestic active safety system model that would be developed later to be fitted to road vehicle despite their model and year of make. This initiated the writer of this manuscript to contribute his share by constructing a model that will enable to conduct further research for finding alternative solution to minimize this life threatening menace of vehicle accident in Ethiopia.

2. Vehicle Accidents

A vehicle or car accident is a road traffic incident which usually involves one road vehicle being in collision with, either another vehicle, or another road user, or a stationary road side object, and this may result in death, injury and/or property damage. According to WHO, 2004 road incidents result in death of an estimated 1.2 million people worldwide each year, and injure about forty times this number (Federal Police of Ethiopia annual statistics (2002/03-2006/07)). Various statistical data showed that vehicle to vehicle collisions have become one of the most serious problems nowadays ("Statistics of motor vehicle collisions and types of collisions," Road safety Assoc. Korea, 1997, Tech. Rep.). In particular rear end collision accidents are said to occur more frequently, and thus, establishment of some means and alternative solution for rear end collision avoidance is considered as a vital issue for reduction of vehicle accident.

According to the National Highway Traffic Safety Administration (NHTSA), the leading cause of death, about the six most common are listed. If we look at six of them the greatest threats to the victims are the drivers themselves (British medical journal April 10, 2004; 328:851 (published by WHO and World Bank)). These are: *Distracted Drivers, Driver Fatigue, Drunk Driving, Speeding, Aggressive Driving, Weather.*

2.1 Vehicle Collisions Classification

Vehicle collisions can be classified by mechanism. Common mechanisms include:

- Head-on collisions,
- Run-off-road collisions,
- Rear-end collisions,

- Side collision, and
- Rollovers are the most common once.

3. Microcontrollers

Microcontrollers are a type of microcomputers that consists of a single silicon chip and they are used in many house hold goods and cars. Therefore a microcontroller is a single chip computer. *Micro* suggests that the device is small, and *controller* suggests that the device can be used in control applications. Another term used for microcontroller is embedded controller, since most of the microcontrollers are built in to or embedded in the devices they control. The term microcomputer is used to describe a system that includes a minimum of microprocessor, program memory, data memory and input-output (I/O). Some microcomputer systems include additional components such as timers, counters, analogue to digital converters, and so on (Automotive engineering journal, March 1997, pp.86, Thomas Braunl, (2008). Embedded Robotics, third edition, **http://www.st.com**, MICROCONTROLLERS MADE EASY).

Even though there are several types of microcontrollers, the most commonly used in embedded systems are the Basic stamp and the PIC Basic microcontrollers. The BASIC Stamp is a microcontroller developed by Parallax, Inc. (http://www.parallaxinc.com/) which is easily programmed using a form of the BASIC programming language. It is called a "Stamp" because it is close to the size of an average postage stamp. The basic stamp is expensive and slower compared to PIC Basic microcontrollers. Due to this the PIC Basic microcontroller is chosen for this project to develop a low cost model. The comparison (table 1) is briefly shown as follows (http://www.pond.ie/TechInfo/Stamp and http://www.lvr.com/files/mibch1.pdf).

Table 1 Comparison of Basic stamp and PIC microcontroller.

Basic stamp	PIC microcontroller
Expensive	Cheaper
Slower	Faster
Easier to learn	More difficult to learn to use
Free software for programming (PBASIC) can be Downloaded from parallax	Requires a compiler to create software

4. Rear end Collision and Detection Methods

Rear end collision is one of the most frequently happening vehicle accidents. According to the National Highway Traffic Safety Administration, in the year 2000, rear end collision accounted for 29.7% of the total number of the vehicle crash. That year, rear end collision were second to side collisions which is 30.2% of the total number of vehicle crash. From the same report it is seen that head-on crash is about 2.2%. It is also reported that rear end collision is a head ach to the insurers since it is frequently occurring ("Traffic Safety Facts 2000", National Highway Traffic Safety Administration Report).

In addition, examination of the 1992 General Estimates System (GES) electronic data base for police-reported crashes shows that 23% were rear end,1% head-on,16% single , and 60% others. The category "others" contains crashes for which the forward collision warning system may not be effective such as angle and sideswipe crashes, backing crashes and some non collision class such as rollover, fires, jackknifes, and immersions. Thus approximately 40% of these classes of crashes may be prevented or their effects lessened by using a forward collision warning system (Dogan Ibrahim, 2006).

From this we can infer that rear end collision is the threat all over the world that needs engineers endeavor. Numerous types of differing technologies have been employed in previous collision avoidance systems. For example, one known type of system is based on ultrasonic sensors (L.H. Nordlund, 1961). A high frequency sound wave is emitted into the area under surveillance and reflected sound waves having the frequency of the emitted sound are analyzed to determine whether an object is present in the monitored area. An Ultrasonic-type system are rather slow in terms of response time and are particularly subject to various kinds of interference due to wind buffeting and eddies as well as other sources of interfering noise which reduces the reliability of the systems. Moreover, the ultrasonic transducer employed in these systems must be mounted in the open air, thus subjecting it to airborne dirt and moisture which can eventually interfere with the proper operation of the system (George Beggs et al, 1992).

Another type of known collision avoidance system uses radio frequency transmitters and receivers or radars. These systems, while relatively effective in terms of performance, are relatively expensive and therefore have not gained widespread use in common passenger vehicles (Masaaki Katsumata, 1978).

Optical systems are also known which measure the time of flight for light transmitted from the vehicle, to the object and back. However, these systems also require expensive components and relatively complex circuitry (Yoshiyuki Etoh et al, 1988).

5. Designing Rear end Anti-collision Warning System Using PIC Microcontroller

5.1 Design Specification

As it is shown on the block diagram below (figure 1), four inputs are considered to be involved in the system. These are the vehicle speed, the brake switch, the steering position and the distance of an object or vehicle in front of the vehicle equipped with this collision warning system.

Basically the speed of the vehicle should be sensed by speed sensor which will output either digital or analog signal depending on the type of sensor used. But on this project, a potentiometer is used to simulate the speed sensor manually at different positions. Similarly the steering position sensor is simulated by a push button. The brake pedal position is sensed with the help of push button as it is on the real vehicle.

To measure the distance of an object ahead of the vehicle, an infrared sensor (GP2D12) which require a 5v input is used. This sensor can detect an object at a distance of 10cm to 80cm. Within this range of distance it will detect an object and output an average analog voltage of 0.4v to 2.6v depending on the object distance from the sensor. Therefore, if someone gets the optimized stopping distance in relation to the vehicle speed and other variables affecting the stopping distance, it is possible to program a microcontroller so that it will out put a warning signal to inform the driver that an object is in front.

This project is designed assuming the driver is aware of everything in front if the brake is applied or steering wheel is being steered. The system is informed about these two things by the help of brake switch and steering position sensor. As a result, the system will not warn the driver if either of the two is detected. i.e. if brake is applied or steering is being steered to left or right. Taking all this things in to consideration, the system will warn the driver only when the vehicle is not changing a direction, brake is not applied and object is in the target. Thus, this system will help the driver informing to take care of an object in front of the vehicle either during night or day driving. Generally the system is demonstrated in a simplified concept block diagram below so that one can easily understand (figure 1).

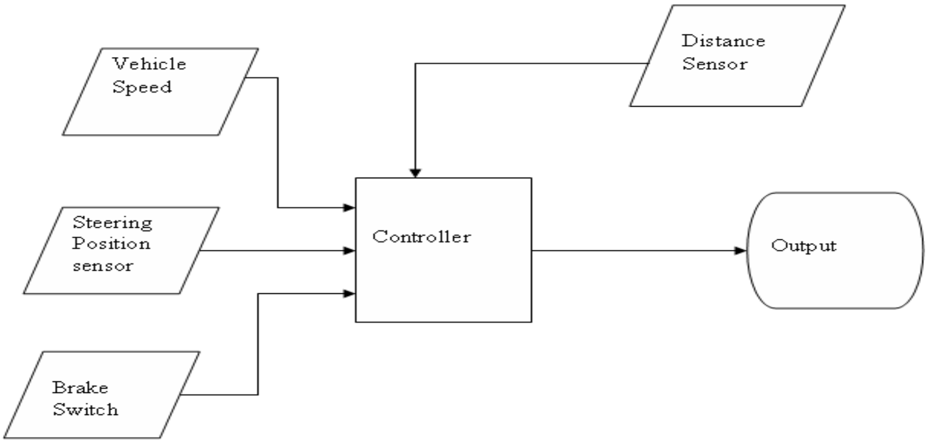

Figure 1 concept block diagram

5.2 Rear end Anti-collision Warning Design Using PIC Microcontroller (PIC16F876A)

The rear end collision warning system designed in this project consists of hard ware and software part. The hard ware part consists of the 10x7.5 mm circuit board, microcontroller, the distance sensor, potentiometers, push buttons, connecting wires, various electronic components used for power supply and timer circuits. Some of the components are shown by the help of block diagram and the picture below taken while constructing experiment boards (figure 2).

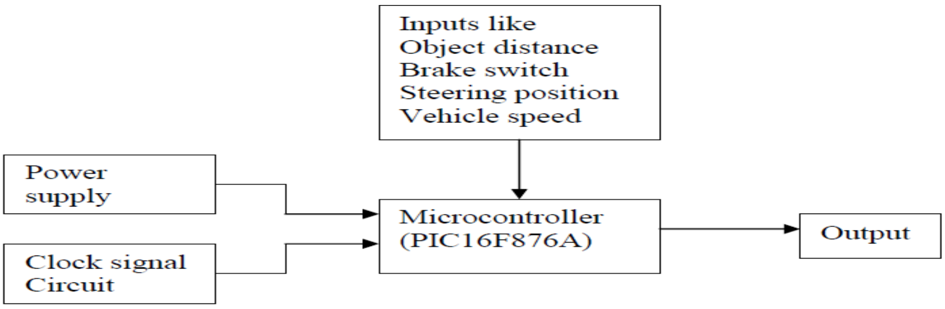

Figure 2 *block diagram*

To make the dream of rear end anti-collision warning system model development true, the following steps have been followed for designing the system. These are:

a) Selecting the input variables
b) Listing out the materials required and collecting them
c) Making an experiment circuit (hard ware)
d) Writing a code which relates all the input variables
e) Loading the code in to the microcontroller
f) Testing all the hard and software functionality
g) Finally developing the model for demonstration

Since the intention is to develop a model, the system consists of only four inputs and a single out put. This makes the project feasible and easily understandable to others. These inputs are: Vehicle speed, Steering position, Brake switch and object distance.

The vehicle speed is the basic input variable that will greatly affect the stopping distance of a vehicle; therefore, it is crucial to consider it as input to decide the minimum distance required to follow the preceding vehicle or an object in front.

The other inputs such as brake switch and steering position are used to indicate whether the driver is aware of the situations or not. The object distance is informed by the help of the distance sensor and the microcontroller will make the decision required based on the other input variables.

5.2.1 Interfacing Sensors

The sensors used in this project are of analog and digital type. The brake switch and steering position sensors are digital whereas the speed sensor and the distance sensor are analog. Since the digital sensors are simple pushbutton, there is no need of a separate complicated interface circuit. But there is a pull up resistors which is used to interface the buttons.

When the switch is open, 5v, logic 1 is connected to the microcontroller.

When the switch is closed, 0v, logic 0 is connected to the microcontroller.

The distance sensor with analog output is incorporated with a signal conditioning circuit in it eliminating a separate interface circuit design. The only external circuit required is connecting a bypass capacitor of 10 microfarad or above in parallel with the sensor power supply and ground connection as recommended by the sensor manufacturers. The speed sensor is also simulated using a potentiometer and it doesn't need any special interface circuit outside the microcontroller. Inside the microcontroller, there is an analog to digital converter interface to suit the outputs of the distance and speed sensors (analog) to the microcontroller (digital).

5.2.2 Interfacing Driver Circuits

The LED and the buzzer used as an actuator in this project are using a simple driver circuit. The LED used as a top speed warning is derived directly by connecting an LED to the microcontroller output pin through a series resistor of 330 ohm (figure 4-10). We know that a standard LED consumes 10mA for normal brightness and the voltage drop across LED is about 2V. But the voltage at the output of the microcontroller is about 5V when the port is at logic one level. As a result of this it is impossible to connect an LED without a series resistor connected to it. Therefore there is a need to determine a current limiting resistor value. So if the output voltage of the port is 5V, to have a voltage drop of 2V, we need to drop 3V across the resistor. If we assume the current through the LED to be 10mA, the resistance value can be calculated as

$$R = \frac{5-2V}{10mA} = \frac{3V}{10mA} = 0.3k \quad \text{The nearest resistor value is } 330\,\Omega$$

Other driver circuit used in the project is the one used to drive the buzzer. Two transistors connected as Darlington pair is used to drive the buzzer. The output from the microcontroller port is used only to trigger the transistor so that external 6v source is supplied to the buzzer.

The complete schematic diagram of the project consists all the above sections and drawn using ISIS professional soft ware as below (figure 3).

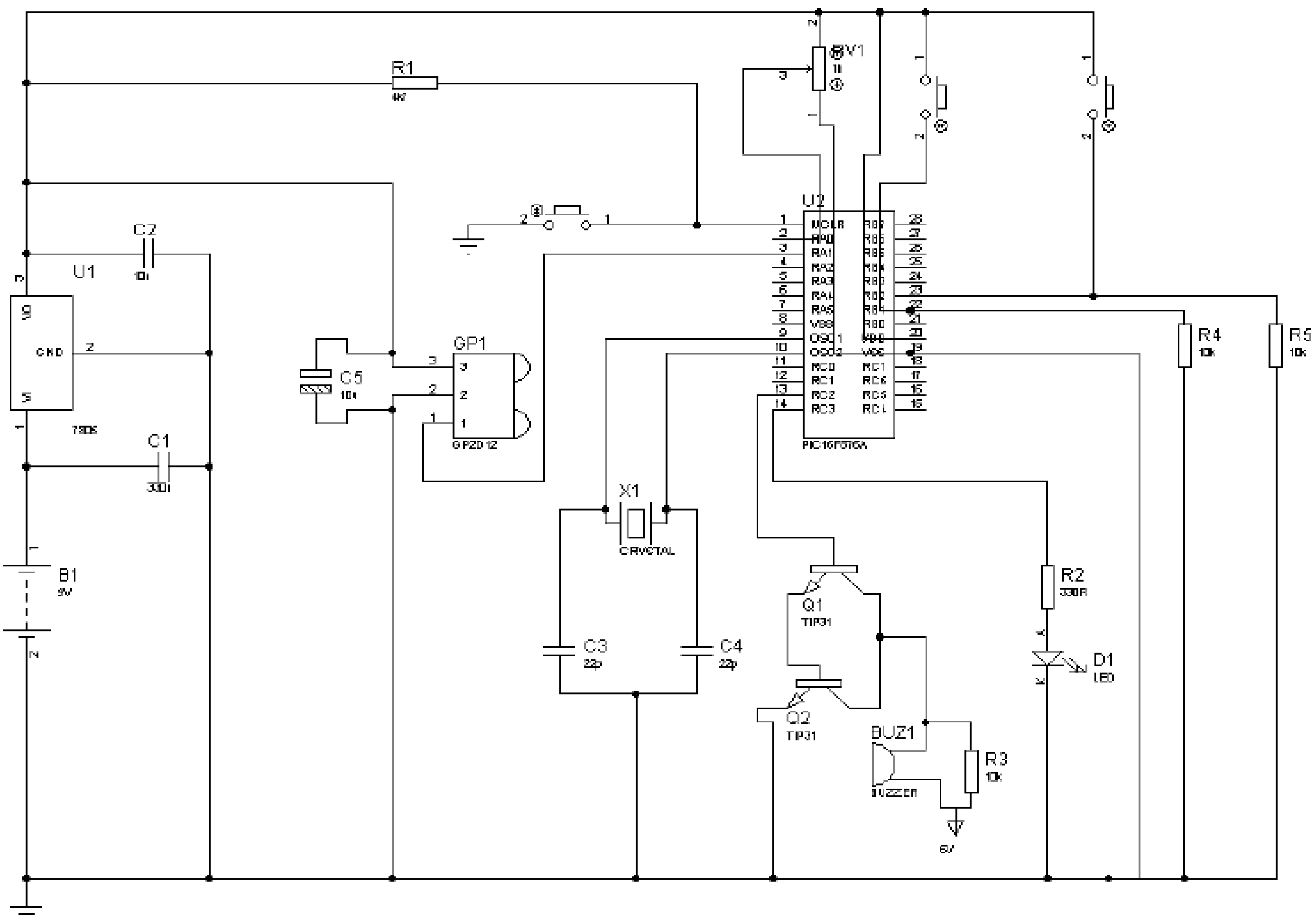

Figure 3 *schematic diagram of the system*

5.3 Software Algorism for Rear end Anti-collision Warning Using PIC 16F876A

The software algorithm is written using assembly language and it is shown using the flow chart and a sample codes taken from the complete program of the project. The flow chart of the complete program is as below (Figure 4).

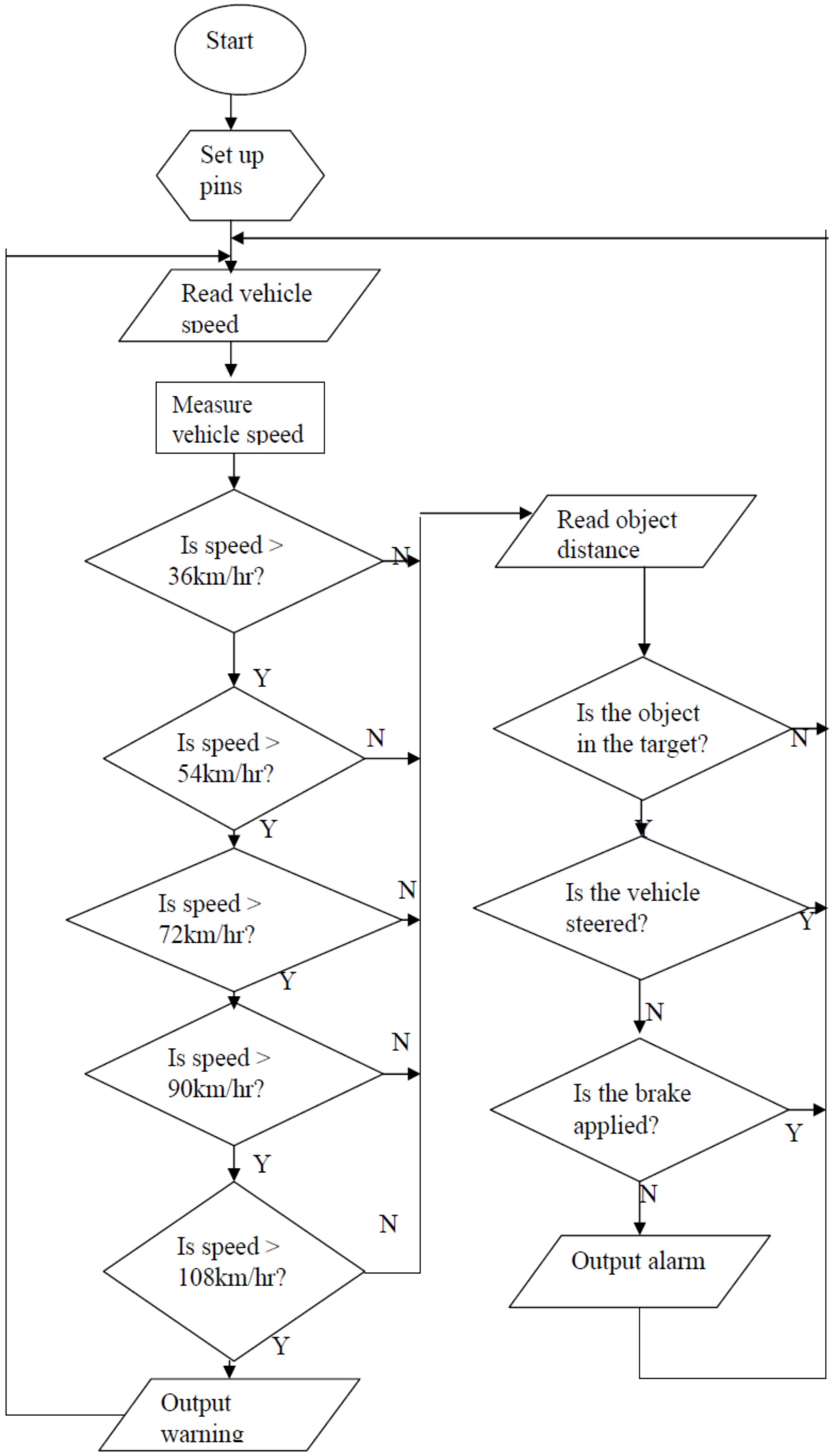

Figure 4: Flow chart

5.4 Principle of Operation of the Complete System

The rear end anti-collision warning system model made in this project consists of hard and soft wares. The hard ware circuit is made on the printable circuit board and mounted on a simple four wheel car model for demonstration (figure 5).

The power supply, timer, the microcontroller and hard wires are all in a single board. The distance sensor is mounted on the front bumper of the car so that it can detect an object in front of the car. The car model is driven by a dc motor using other drive circuits which is not part of this project. The potentiometer used to simulate vehicle speed is mounted on the car so that it can be varied manually. There is also a buzzer mounted on the dash board to alert the driver when necessary.

Figure 5: Demonstration model

When driving the car, the actual speed is not varying since it is driven by a simple dc motor. But by setting the potentiometer on the car to different positions, it is possible to see the system detecting an object at different distances in relation to vehicle speed.

As the car is driven, if an object is detected, the distance sensor will out put a voltage that will be received by the microcontroller and processed according to the software loaded to it in the form of a program. Then, the microcontroller first checks the vehicle speed at which it is moving. Then, for that particular speed, the controller checks whether the object is in the specified range or not. If the object is not in the target, the operation will loop and continuously checks speed and then the object distance. If the object is in the specified target, the program will check whether the driver is aware or not by checking the brake switch and steering position. If the driver is already applied the brake, the system will loop once again and will not alert. In case if the driver is not attentive and the vehicle is not steered, the system will automatically tell the driver to apply a brake or any other corrective measures not to collide with the object in front by the help of audible siren or red light.

If the driver is changing a direction, i.e. steering a vehicle, it is assumed that he/she is taking care of everything in front. Thus, the program checks steering position before alerting the driver. Once the system alerts the driver by the audible sound or red light, it will continue to awake until he or she apply brake or steer the vehicle. This system will help the driver by doing so to minimize the possible rear end collision with the object a head of the car being driven.

6. Practical Implementation and Experimental Results

The practical part of the project is divided in to four main phases. Under each phase several trials has been conducted. Some main tasks performed under each phase are discussed shortly as below.

6.1. Experiments

To conduct different experiments, all the necessary materials are collected and an experiment board is made. This experiment board consists of the microcontroller and microcontroller support circuits such as power supply, clock signal circuit and other related circuits. The distance sensor and the potentiometers used to simulate vehicle speed are mounted on a separate board. On the experiment board made for trial, several experiments have been made.

6.2 Results Obtained from Sensor Output versus Distance

During day time a thorough experiment has been made to record the voltage output of the distance sensor (GP2D12) using different objects at different distances. A straight table and long ruler are used to record the result. The results are collected. The result refers different objects at different distance from the sensor.

6.3 Speed versus Object Distance

In this project, vehicle speed is simulated by a potentiometer. The potentiometer outputs analog voltage as per the setting manually made. Since the output voltage represents the vehicle speed, it is programmed to detect an object at different distances for different speed of the vehicle. Therefore, using 0v to 5v reference voltage, it is possible to have 255 different speed at which object can be detected for each speed.

For simplicity on this experiment, only five speeds are considered in the program which will enable the system to detect an object at five different distances. Accordingly the corresponding speed and distance is recorded during the experiment.

Though the PIC16F876A consists of 10 bit analog channels, the higher address register of these analog channels are used which can hold an eight bit value. So we can consider the analog reading as 8 bit number. Therefore the microcontroller can read an analog voltage of 0V to 5V and convert it in to an 8 bit number where 0V is 0 and 5V is 255. That is a reading of 51 per volt or a resolution of 1/51V. In another word 1 bit is a voltage reading of 19.6mV. Based on this resolution, five speeds are represented by an analog reading of 51, 77, 102,128, and 153 which corresponds to a voltage reading of 1V, 1.5V, 2V, 2.5V, and 3V respectively. Similarly five respective distances are sampled as 26, 51, 77, 102, and 128 which correspond to a voltage reading of 0.5V, 1V, 1.5V, 2V, and 2.5V respectively. Since the vehicle speed is considered from 0KM/hr to 180km/hr and distance from 10cm to 80cm. Based on these resolutions, the program has been written and loaded to the microcontroller and.

Table 2 Shows sampled vehicle speeds with a corresponding warning distance.

No.	Speed Km/hr	Warning distance	Remark
1	<=36km/hr	10cm	
2	<=54km/hr	30cm	
3	<=72km/hr	47cm	
4	<=90km/hr	63cm	
5	<=108km/hr	80cm	
6	>108	Top speed warning LED will lit	

On actual vehicle the warning distance has to be determined based up on optimized stopping distance of the vehicle to be equipped with rear end ant-collision warning system. This needs another research by itself. Then the programmer has to consider this optimized stopping distance when writing the code for the software development.

7. Discussions of Results

7.1 Object Distance versus Analog Voltage Output

Various objects are selected for experiment purpose just to see the distance sensor analog voltage output in relation to the respective object distance. The objects are selected taking into consideration the materials from which most vehicle bodies are made and objects that possibly observed on the road. Therefore, carton, glass, sheet metal, black painted carton and human body were selected.

When the sensor output is recorded for each of the objects, slight differences were observed. Since the objects are hold manually at different distances while conducting the experiment, my own error in holding the object exactly perpendicular to the sensor may add to the differences observed. More or less, the output is nearly similar, so it is possible to have a relation between an object distance and the analog voltage output of the sensor.

The other scientific reason for the variation of the sensor voltage output for different object yields due to the difference in reflexive property of the materials. The glass material is superior to all the materials considered in this experiment. Since its reflexivity is high, it resulted in higher voltage output of the sensor.

8. Conclusions and Achievements

8.1 Conclusions

A rear end anti-collision warning system is designed and mounted on a very simple and easily understandable model constructed to demonstrate the system and it is found functional.

The IR distance sensor GP2D12 is utilized to demonstrate the rear end anti-collision warning system. It can detect an object at a range of 10cm to 80cm distance from the car model. When an object is within the specified range, the sensor outputs a voltage corresponding to the object distance telling the system how far the object is. Therefore, based on the preprogrammed value the microcontroller can inform the driver by actuating an audible buzzer attached on the dash board.

A distance sensor which detects an object at a longer distance is required to apply this system on a real vehicle.

The anti-collision warning system performance is encouraging. Therefore, if the right materials are collected, it is possible to enhance its features so that it can be used in vehicles.

The model is a good witness and demonstration tool for any one wants to do research on anti-collision warning system.

The model can be used to demonstrate students the application of embedded system and mechatronics. It also initiates learners toward the course mechatronics/embedded systems which are popular these days on every machine.

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