Development of an Intelligent Obstruction Detection System for Automobiles

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ABSTRACT

This paper has presented the design of an intelligent system for obstruction detection. The developed system is a low-cost embedded system in automobiles aimed to minimize the current high rate of accidents on roads. It has two basic parts, the hardware part and the software part. The hardware part is composed several components employed for a unique purpose while the software part was designed to automate the operation of the hardware component using MPLAB.

(Keywords: obstruction and intrusion detection, sensors, microcontroller, MPLAB)

INTRODUCTION

Advances in technology have aided the development of embedded smart systems in automobiles to address several issues such as driver's alcohol limit to ensure safety. In recent years, there has been an increase in the accident rate globally. This is due to several reasons that include reckless driving, high-levels of alcohol consumption, phoning while driving, poor road conditions, among others. Every year in the United States alone, approximately six million automobile accidents takes place in total. Those accidents results in about 43,000 deaths and 2.9 million injuries, not to mention the huge financial loss accounting to over $230 billion US dollars [1].

Moreover, developing countries are not exceptional, especially Nigeria, where records show that there is a high rate of deaths on Nigerian roads of more than 300,000 lives and injuring of about 10 to 15 million yearly [2]. Some of these ugly occurrences are simply due to the issues identified [3]. Thus, the high rate of accidents is alarming and demands efficient approaches to mitigate it frequent occurrence in the society. Such approaches involve the development of an embedded system in automobiles that frequently alerts drivers to the presence of hazardous objects within a pre-defined range. Hazardous objects include stationary object, object located on the sides of the road such as trees, road barricades, and buildings.

SYSTEM THEORY

Overview of System Components

This section briefly gives an overview of the components employed in this study. Some of the components employed are ultrasonic sensors, an alarm buzzer, a microcontroller, light emitting diodes, and an LM78055 voltage regulator.

Ultrasonic Sensor

An ultrasonic sensor is an active type of sensor that work on a principle similar to radars or sonar, which evaluates attributes of a target, by interpreting the echoes from radio or sound wave respectively. Active ultrasonic sensors generate high frequency sound wave and evaluates the echoes, which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo, to determine the distance to the object.

LM78055 Voltage Regulator

A voltage regulator is designed to automatically maintain a constant level. A voltage regulator may be a simple "feed forward" design or may include negative feedback loops. It can be integrated with an electromechanical or electronic component, depending on the design goals. It can also be used to regulate one or more AC or DC voltages. An LM7805 voltage regulator is a type of voltage regulator that outputs +5 volts. LM78XXs voltage regulator series is often identified using the last two digit numbers. An LM7805 that ends with **"05"**; implies that, it outputs 5 volts while the **"78"** part is a convention used by the chip makers to denote the series of regulators that output positive voltage. The other series of regulators, the LM79XX, is the series that outputs negative voltage.

LM78XX voltage regulators that output positive voltage, "XX"=voltage output.

LM79XX voltage regulators that output negative voltage, "XX"=voltage output The LM7805, like most other regulators, is a three-pin IC.

Pins 1 (Input Pin): The Input pin is the pin that accepts the incoming DC voltage, which the voltage regulator will eventually regulate down to 5 volts.

Pin 2 (Ground): Ground pin establishes the ground for the regulator.

Pin 3 (Output Pin): The Output pin is the regulated 5 volts DC.

Figure 1 shows the schematic representation of a voltage regulator with a three-pin IC.

Light Emitting Diode

A light emitting diode (LED) is a two lead semi-conductor light source, with a basic PN-junction diode which emits light, when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electrons holes, within the device, releasing energy, in form of photons.

This effect is called the electroluminescence and the color of the light, is determined by the energy gap of the semiconductor. Figure 2 describes a LED device.

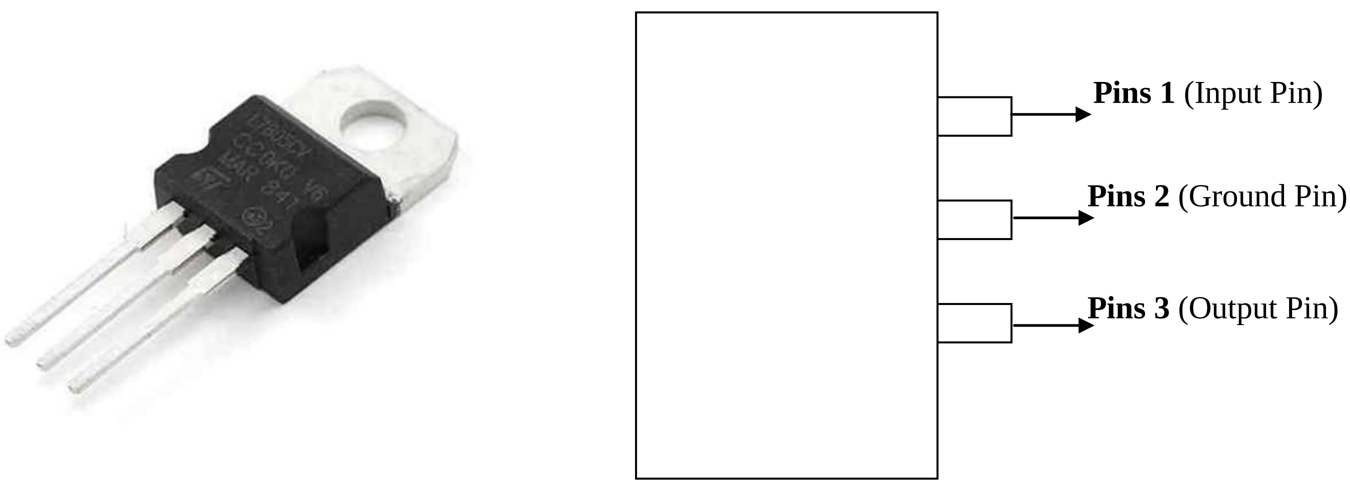

Figure 1: A Voltage Regulator with a Three-Pin IC.

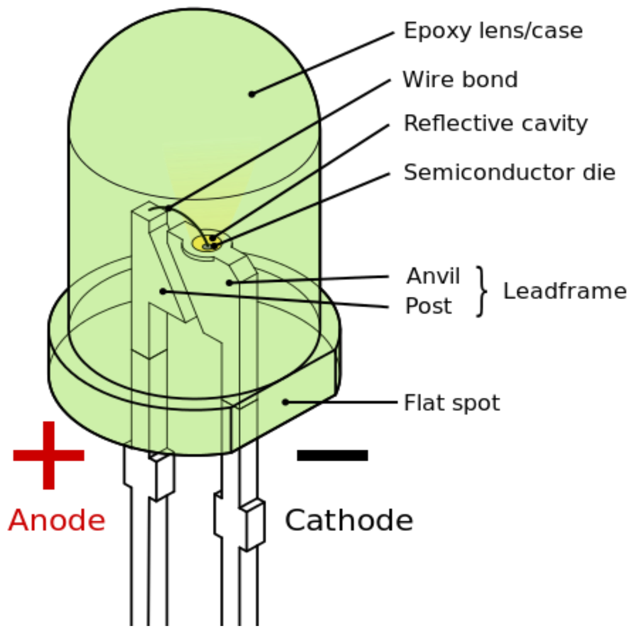

Figure 2: A Light Emitting Diode.

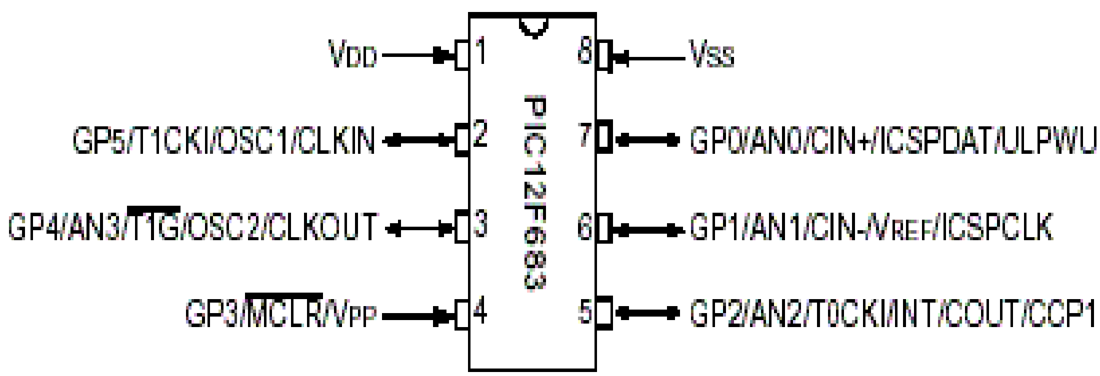

Figure 3: Pin-Out Diagram of a PIC12F683.

Microcontroller

A microcontroller is a computer control system on a single chip. It has many electronic circuits built into it, which can decode written instructions and convert them to electrical signals. A microcontroller read the written instructions and execute them one by one [12]. In this study, PIC12F683 microcontroller was employed. Figure 3 describes the pin-out configuration of the used microcontroller

Alarm Buzzer

A buzzer is an audio signaling device [15] which may be mechanical, electrochemical, or piezoelectric. Typical applications of a buzzer include alarm devices timers, confirmation of user input and a form of awareness to user. An alarm buzzer contains a magnetic buzzer that generates an audio signal.

The audio signal generated by a magnetic buzzer is used to trigger the buzzer, and this requires a square wave of 2400 Hz frequency and 1-3V amplitude to be fed to the circuit input. A reasonable approximation of such a waveform is generated by the microcontroller. The buzzer can generate continuous and intermittent sounds. The buzzer sounds five times, each time for a duration of approximately 0.5 seconds. Figure 4 shows a buzzer.

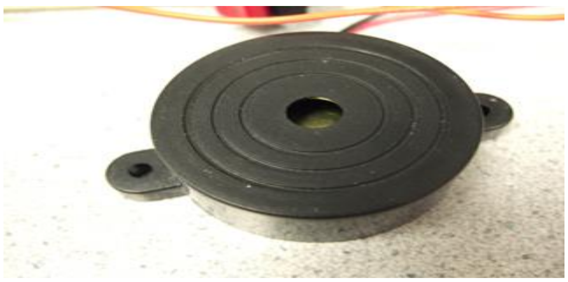

Figure 4: A Buzzer.

Power Supply

The power supply used in this project was a standby 12volt battery source. Though the whole component assembly, apart from the buzzer which could use up to 24 volts, required just 5 volts to function properly.

Figure 5: Power Supply.

SENSING METHODS

This section describes some of the methods used in sensing obstacles in smart systems. Examples of these methods are multi-beam radar sensing method, infrared sensing method, and ultrasonic sensing method.

Multi-beam Radar Method

This method involves the use of a multi-beam and multi-range (MBMR) radar with frequency modulated continuous wave (FMCW) waveform and digital beam forming (DBF) algorithm to cover a specific area. The radar is integrated with multiple phased-array antennas, a two-channel transmitter and a four-channel receiver using K-band GaAs RF ICs, and back-end processing board with subspace-based DBF algorithm. An example of a multi-beam radar is a 24GHz MBMR radar which can be used for object detection in an adjacent lane [10].

Infrared Sensing Method

This method involves the use of an infrared sensor. The main function of the infrared sensor is to produce a beam for certain distance. The distance of the beam always depends on the infrared sensor; different infrared sensors have different range of beam distance. The beam is responsible for object sensing [11].

Ultrasonic Sensing Method

This method involves the use of an ultrasonic sensor. An ultrasonic sensor works by evaluating the attributes of a target and interprets the echoes from a radio or sound wave respectively. Active ultrasonic sensors generate high frequency sound wave and evaluates the echoes, which is received back by the sensor, measures the time interval between sending the signal and receiving the echo, to determine the distance to the object. An ultrasonic sensor can also be referred to as a transceiver because of it ability to both send and receive signals. Figure 6 describes the working principle of an ultrasonic sensor.

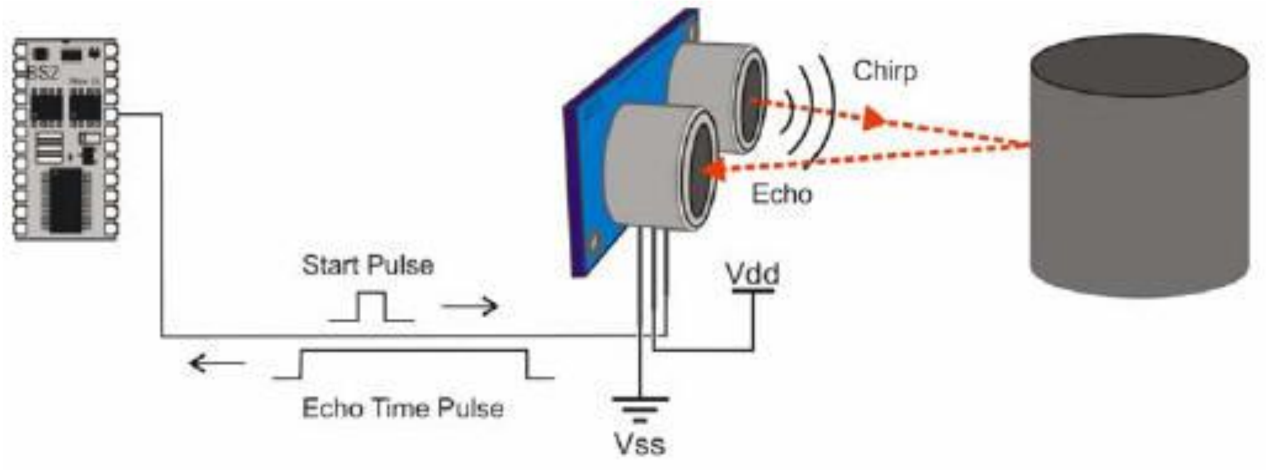

Figure 6: Ultrasonic Sensor Working Principle.

PROJECT APPROACH

System Design

The design process of the proposed system is divided into two parts, namely the hardware components and the software components.

Hardware Design

In the hardware design phase, several components were integrated to achieve the establish the essence of this project which is primarily to detect obstacles at a long distance and notify the driver of any occurrence at all times. The employed components are ultrasonic sensors, an alarm buzzer, a microcontroller, light emitting diodes, and an LM78055 voltage regulator.

The microcontroller PIC12F683 is the heart of the system. It generates a pulse signal to the ultrasonic sensor after initialization is completed at power ON. The signal causes the ultrasonic sensor to send a signal in form of a sound wave through its transmitter, expecting a reflection of that wave within a short period of time.

The reflected signal indicates to the ultrasonic sensor that there is an obstacle or sets of obstacles within the perimeter where the sensor operates.

The ultrasonic sensor then sends a signal to the microcontroller which in turn triggers various indicators to show that an obstacle is present. Four microcontrollers were used in this study, to ensure quick timing and response processing of each ultrasonic sensor. It also reduces the problem of process congestion, when more than one sensor experiences an obstruction.

A transistor OR gate was used for the ORing of the signals that comes from the respective microcontroller units, such that if any of them experiences an obstruction from any area within each parameter, it sends a warning signal. A transistor was used to amplify the signal coming from the transistor OR gate, making the input signal visible enough to trigger both the LED indicator and the BUZZER alarm.

After the system was constructed, it was tested to ensure that the essence of this study was established. Figure 7 shows the system architecture while Figure 8a, 8b, and 8c shows the physical system.

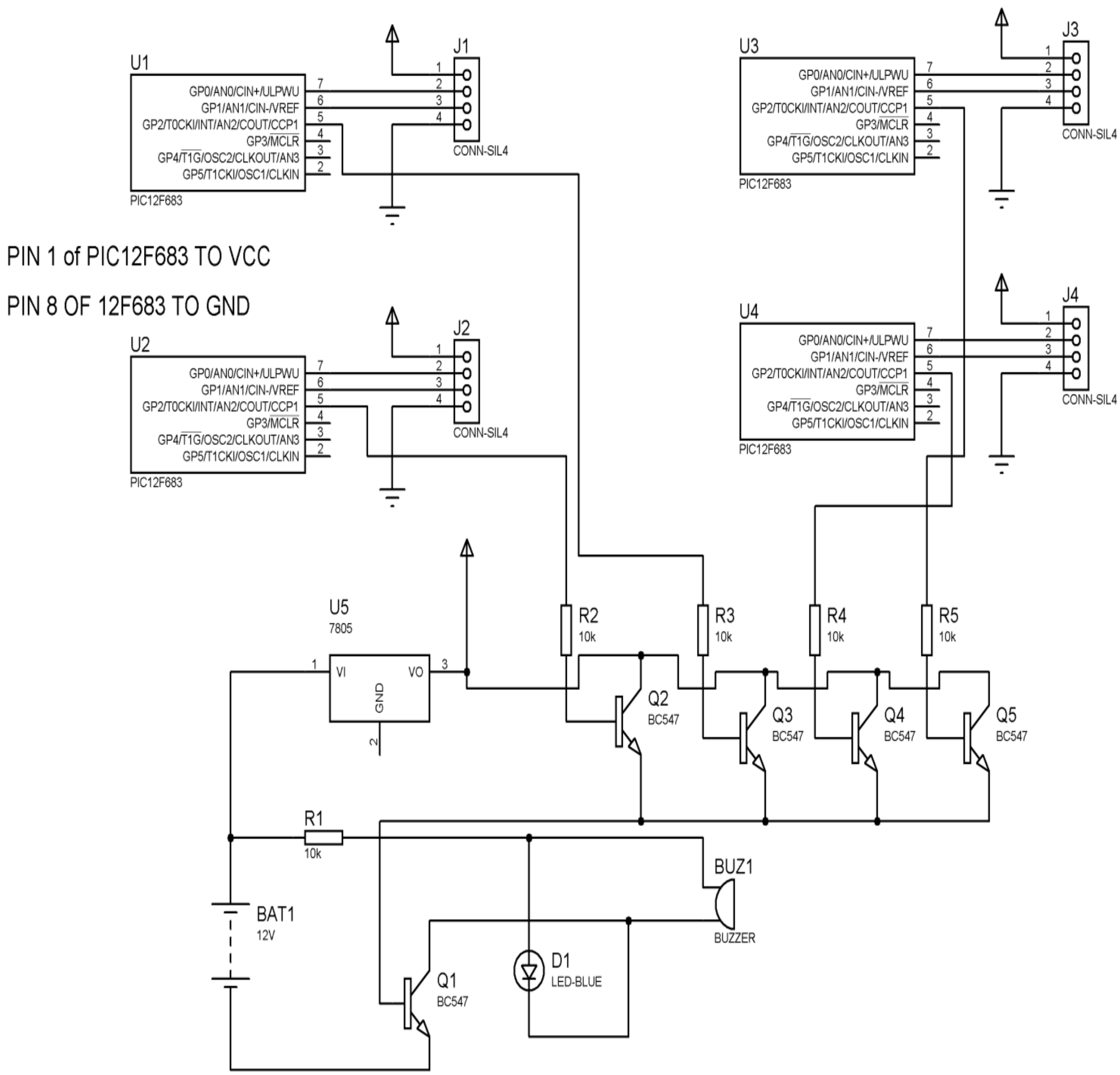

Figure 7: Schematic Diagram of the Proposed System.

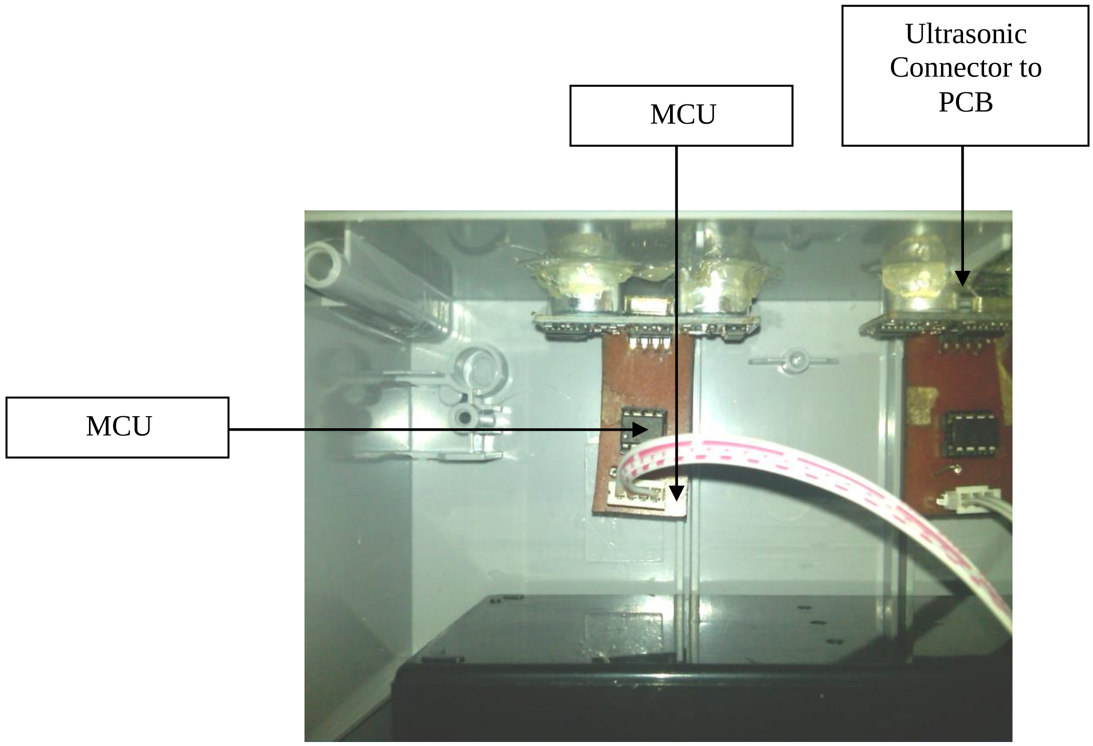

Figure 8a: Proposed System Hardware Design and Operation.

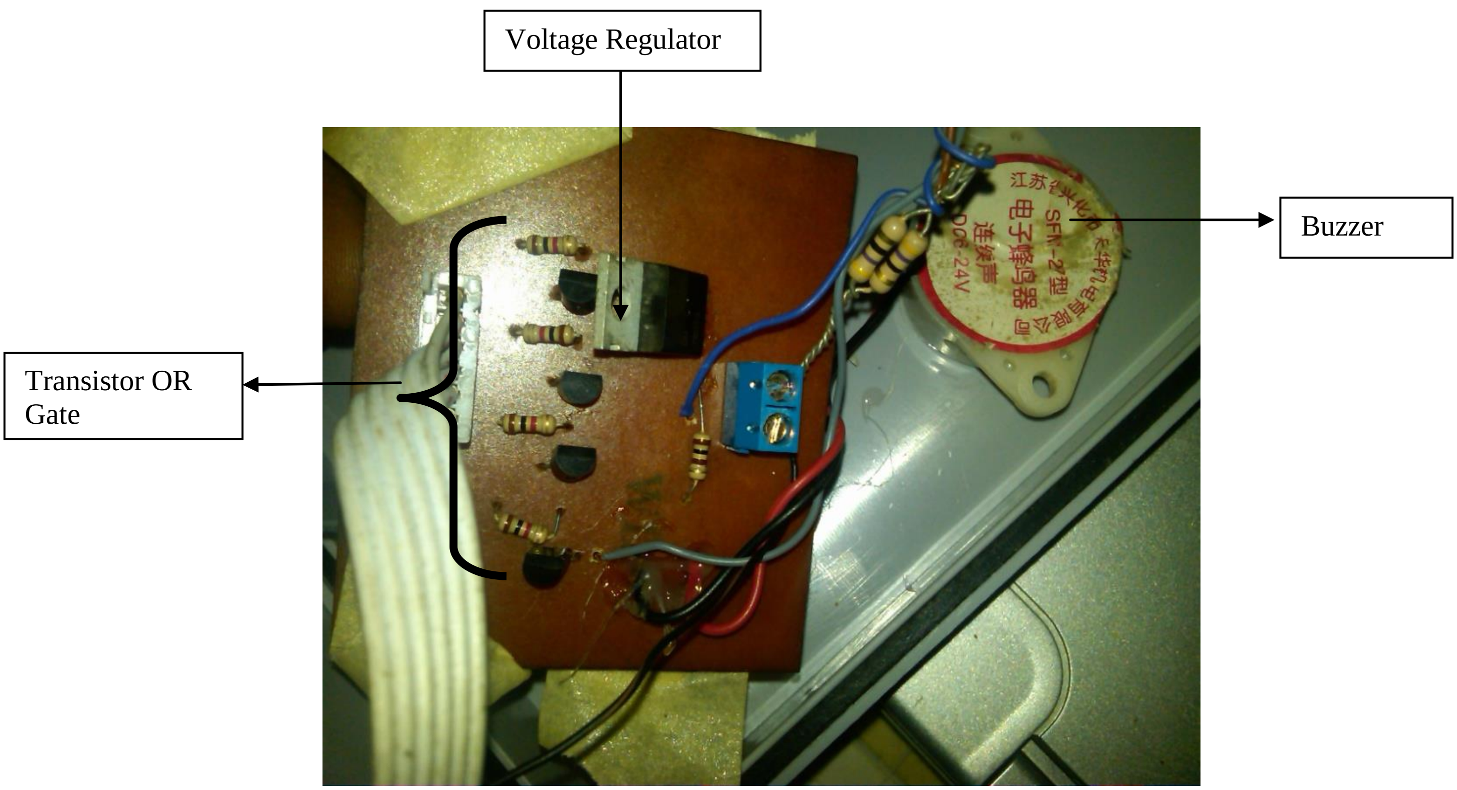

Figure 8b: Proposed System Hardware Design and Operation.

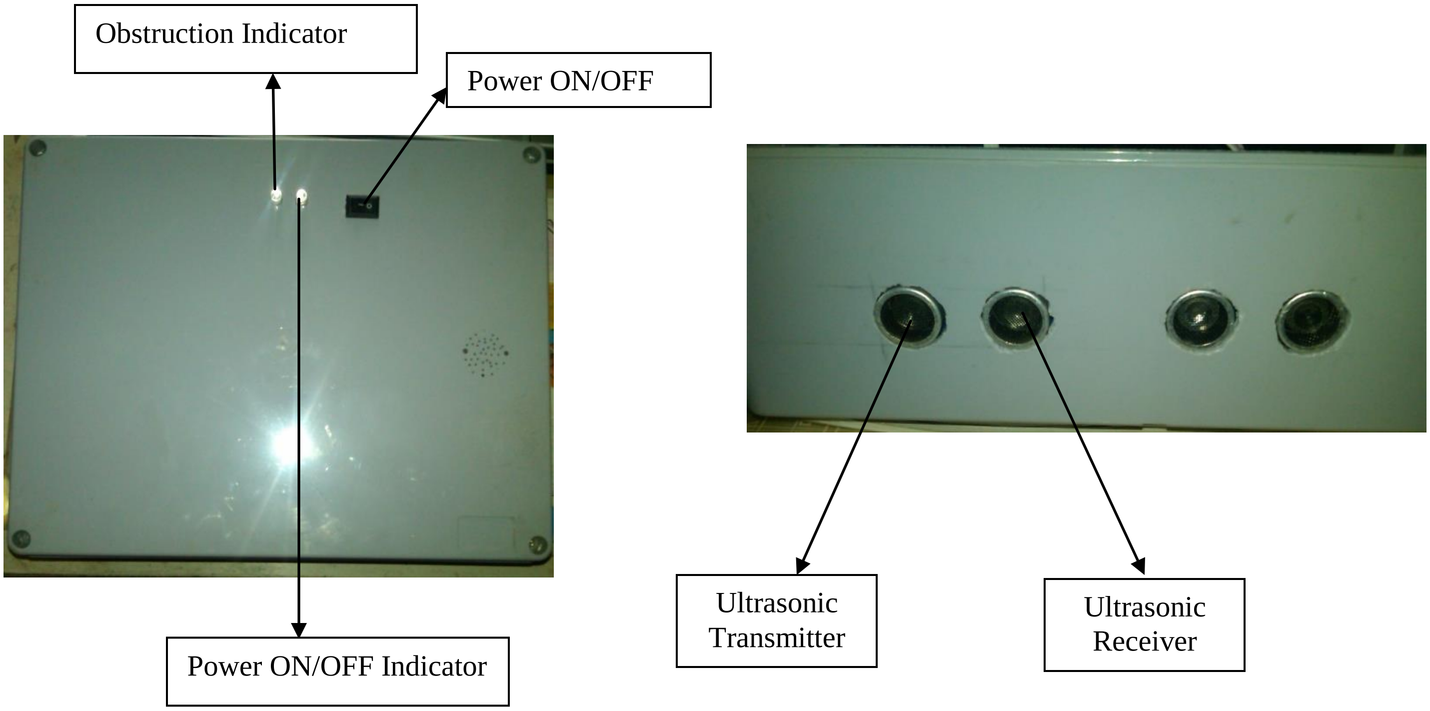

Figure 8c: Proposed System Hardware Design and Operation.

Software Design

In this phase, system codes were developed using MPLAB. Figure 9 describes the system operation.

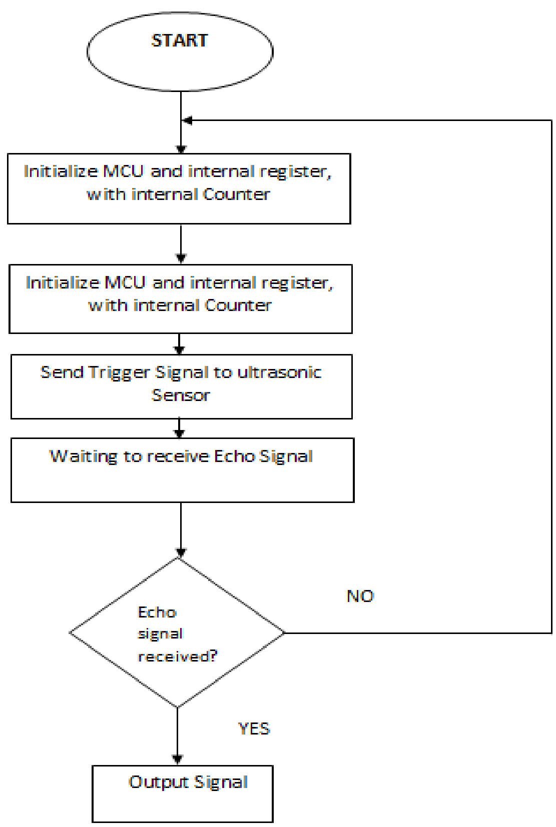

Figure 9: Proposed System Flowchart.

DISCUSSION AND SYSTEM TESTING

Testing

The testing of this system was executed in two phases on some occasions so as to have a full functioning of the system. Since the design of the system was based on both hardware and software, the software was properly written and compiled into the PIC12F683.

Testing of the software programming code written was done by checking the functional properties of the PIC12F683 after it has been compiled into it and assembled on the bread-board with other components for the design. The errors found in the code written were debugged to achieve the main requirements from the PIC12F683. MPLAB PIC Compiler was used in writing and compiling the code.

The measurement begins when the microcontroller pulls a high for a short interval (tTrig) and then switches to monitor the pin status. The sensor, reacting to this will pull the pin low while it emits the ultrasonic burst, which takes place at the thold interval. Then the sensor pulls the signal high (techo) until it perceives the reflected signal, which in turn allows the pin to come down. The techo therefore directly determines the distance between the sensor and the reflecting objects. The distance between an object and a vehicle was determined by calculating the elapsed time (eT), multiply with the speed of sound (ultrasonic wave), and divide by two as given in Equation 1.

Distance between the object and vehicle =

$$\frac{\text{Elapsed time} \times \text{Speed of sound}}{2} \qquad \textbf{(1)}$$

where:

Elapsed time = the amount of time separating the end of the measurement from the beginning of the next one.

The product is halved, because the ultrasonic pulse goes back and forth between the sensor and the obstacles.

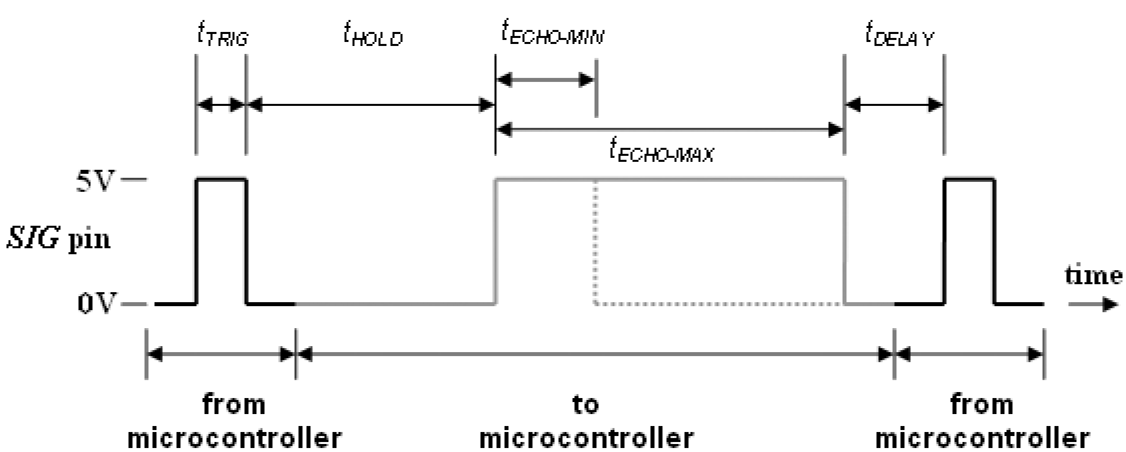

Figure 10: Operating Time Diagram of the Ultrasonic Sensor.

Relative echo level for different ultrasonic frequencies, in cases where the entire wave is reflected, the total reflection is equivalent to a virtual source at twice the distance.

Spreading loss for reflected wave= 20log (2R) **(2)**

Absorption loss = 2Ar **(3)**

To reduce the absorption loss, the flat surface should larger than the entire ultrasonic wave and perpendicular to the wave. Basically the ultrasonic sensor has the ability to measure distance in the range of 10 meters.

Based on this principle, an experiment was carried out actually show the range effectiveness of the ultrasonic sensor, by placing the sensor perpendicularly to the test object (flat PCB surface), 5 cm away from each other, and reading were taken with 5 cm being the interval between each reading. In this study, the sensing range was lowered down to a range within 2 meters, because the ultrasonic sensor is known to produce accurate results efficiently with smooth surface, where a perfect reflection rate is guaranteed.

Based on Equation 4, the ultrasonic sensor determines the time within which the signal sent should be reflected at specific distances.

Distance = 0.028T + 1.093 **(4)**

where T = the expected time.

Using Equation 4, with a varying distance of 50 cm, 45 cm, 40 cm, 35 cm, 30 cm, 25 cm, 20 cm, 15 cm, 10 cm, this study was able to establish the actual time within which the ultrasonic sensor is expected to receive a reflected signal at each distance. The obtained results are presented in Table 1.

Table 1: Experimented Time.

Distance (cm)	Average count (seconds)	Estimated Time (Mins)
50	1746.60	29.11
45	1568.10	26.14
40	1389.50	23.15
35	1210.96	20.18
30	1032.30	17.21
25	853.80	14.23
20	675.25	11.25
15	496.67	8.28
10	318.10	5.30

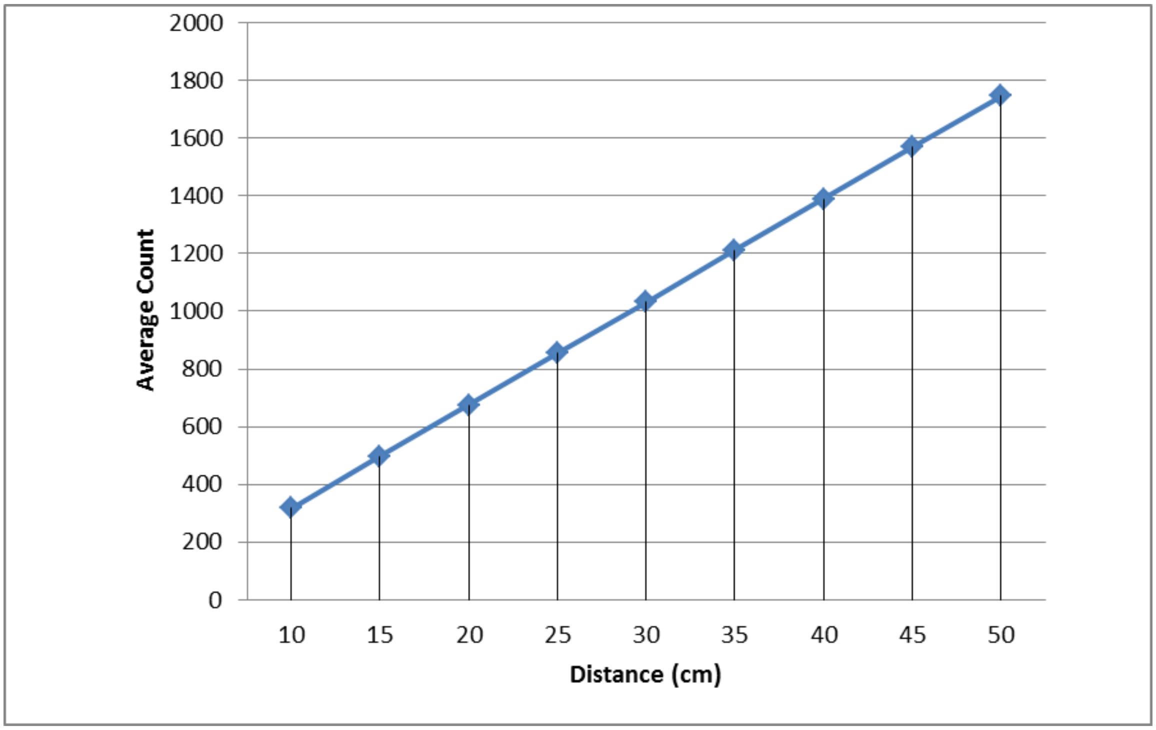

Figure 11: Correlation of the Techo with Sensor.

Table 2: Transistor OR Gate Results.

ULTRASONIC 1	ULTRASONIC 2	ULTRASONIC 3	ULTRASONIC 4	STATUS
1	0	0	0	ON
0	1	0	0	ON
0	0	1	0	ON
0	0	0	1	ON
1	1	1	1	ON

Figure 11 indicates a linear relationship between the measured delay and the distance. This indicates an excessive noise when the distance exceeds 40 cm. In other words, even though the sensor in theory is capable of detecting objects that are over 200 cm away, the measurement accuracy degrades drastically as the distance increases over that range.

Considering the possibility of a surface that is not too smooth, which could cause reflected waves to escape before reaching the receiver of the ultrasonic sensor, brought about the reduction of its measurement range to just 50 cm, to enable accuracy and correct computation and to also establish the directional characteristics of each sensor, this indicate that each sensor has a limited angle to which it can detect obstacles at a specific distance, such that once the distance is exceeded, the object at such angle remains undetectable. The system acts as a driving assistant to help drivers while driving.

The proposed system was developed to automate, adapt and enhance vehicle systems for safety and better driving. The safety features are designed to avoid collision and accidents by alerting the driver of potential hazards or possible collision in areas that might not be visible to the driver, either while driving in the reverse or forward direction.

DISCUSSIONS

After the proposed system has been developed and tested, it was installed to further check the function of the transistor OR gate, which was responsible for outputting a single signal if any of the four sensors came across an obstacle.

The results in Table 2 shows that, after the individual sensor obstruction testing, the transistor OR gate worked properly. It also indicates the surface area within which the sensor can operate, and it showed that it was more responsive to smoother surface, at far distances than rough surfaces.

CONCLUSION

This study has developed an obstruction detection system to assist drivers to be conscious of the state of the road. Several components were employed in this study and MPLAB was adopted for the system coding. The proposed system is expected to reduce to rate of high rates of accident occurrence especially in developing parts of the world.

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