Collision Avoidance between Vehicles through LiFi based Communication System

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Summary
Large numbers of road accidents are taking place all over the world due to the collision between vehicles. More than 1.2 million peoples died in road accidents in 2018, according to world health organization (WHO). Human safety is very important. The project idea is proposed to reduce the consequences of accidents in our daily lives and avoid collision between vehicles. There are various reasons for such adverse condition that results in death or disabilities. This includes sudden loss of driver's concentration, brake fails, loss of stability. These hazardous conditions can be overcome if there is communication protocol used in all vehicles and depending on their position drivers control the vehicles to avoid accidents. There are various vehicular communication system prototypes are available i.e., 5.9 GHz Dedicated Short Range Communication and Vehicular Ad-Hoc network. These radio frequency (RF) based communication system has some limitations i.e., interference, congested spectrum and security. These limitations can be overcome by using Visible Light Communication (VLC). It provides high bandwidth, security, interference immunity, and high data rate. VLC is a data communication system which uses visible light for high data transmission and reception. This technology is known as Light Fidelity (LiFi). This paper presents the novel method to avoid collision between two vehicles i.e. front and rear vehicles. The proposed LiFi based Vehicular to Vehicular (V2V) communication system is a cost effective solution with high data rate capabilities.
Key words:
Light Fidelity (LiFi), Communication system, Light emitting diode, Photo diode, Arduino, Vehicular communication, Proteus.

1. Introduction

The field of science and technology is rapidly moving towards its advancement. The human being is utilizing this change of technology for the comfort and time saving. Progress varies from wired to wireless communication; and in wireless communication human being has moved one step on upstairs and invented Li-Fi, light fidelity technology.

Harald Hass is known as the father of Li-Fi from university of Edinburgh who told about existence of this technology in his TED talks [1]. According to Harald, the heart of this technology lies in the intensity and the potential of light emitting diodes. Li-Fi is an upcoming technology in near future which uses visible light spectrum for transmission of data which is 10,000 times more than the band used in Wi-Fi technology [1]. As large number of users are demanding for Wi-Fi thus RF spectrum is constantly being used and resulting in clogged signal. The solution is to use Li-Fi technology. The idea is to use light bulbs at our homes as a source for transferring data, as shown in Fig. 1.

Fig. 1 LiFi technology

Road accidents are resulted in the loss of human lives. These accidents occurred due to the collision between vehicles. Studies reveals, majority of accidents are due to following vehicle are unaware of the actions of vehicle ahead. Collision can be avoided if the vehicle ahead can communicate with the rear vehicle, as shown in Fig. 2. There are many techniques to implement such communication prototype i.e. 5.9 GHz Dedicated Short Range Communication DSRC wireless in which two vehicles can communicate at the frequency of 5.9 GHz and Vehicular Ad-Hoc network which is the application of MANETs in which two vehicles can communicate by wireless fidelity [2]. The purpose of using Li-Fi is to implement a system that is cost effective and has high data rate.

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Since high intensity LED lights are already present in cars these lights can be utilized as Li-Fi transmitters. By adding only cheap circuitry, the collision can be avoided in vehicles using Li-Fi technology.

Fig. 2 V2V Communication

This paper is divided in to 5 sections. First section introduces the LiFi technology, its advantages and problem statement of the work. Section 2 gives brief literature review related to vehicle to vehicle (V2V) communication system and LiFi based communication systems. Section 3 provides the design of transmitter and receiver for LiFi based V2V communication system on Proteus software. Section 4 demonstrates the prototype implementation of V2V communication system for collision avoidance. Section 5 concludes the paper.

2. Related Work

Kim et al. has analyzed the outdoor environmental condition faced in vehicle to vehicle communications using Visible light communication [3]. Head light and rear light used for the transmitter and photo diode saturation used for light signal receiver. The total distance is 20 m range is covered in the daytime outdoor environmental conditions. Outdoor communication problems faced during observation such as sun light noise, photo diode saturation; increase the range of communication in the daytime. So transmitter and receiver are implemented with filter design, error correct and improve the strength of signal.

Bhateley et al. worked at the Smart Vehicular Communication [4]. Headlights are used as a transmitter and photo diode used as a receiver. The high data rate transmission range achieved up to 0.45 m in indoor. But for the outdoor it is difficult to control the environmental conditions so they have used the PWM and OFDM modulation techniques but other technique like Direct Sequence Spread Spectrum (DSSS) can also be used to increase the transmission range up to 40 m.

Santos et al. have designed Visible light communication protocol applied on V2V (Vehicle to Vehicle) network [5]. The VLC uses the white LED at low cost. LED has less required energy so replaced with tail and headlights and reduces the thermal damage, LED is preferred as the high illumination light because of its high bandwidth and immunity to interference from electromagnetic source. The Manchester Coding technique is used for transmission because it is secure and efficient. The distance between vehicles was 20 cm.

Ergul et al. presented the VLC and its challenges [6]. VLC has huge bandwidth therefore it has high data carrying capacity thousand times of greater than the range of radio frequencies. He mentioned that the system is effective to carrying data rate up to 300Mbps within the range of 25ft.

Takai et al. [7] has developed LED based Optical wireless communication (OWC) and CMOS image sensor in automotive field. For particular application to avoid the collision and highly suitable for transmitter because very high speed data rate and light source is simple bulb and fluorescent lamp also used in automotive fields. At receivers, cameras have also been integrated. Some ideas using image sensors for a high-speed optical signal reception have already been reported. The frame rate used in image sensors is approximately 30 frames per second (fps). If its frame rate is 30 fps, then the data rate in each pixel must be limited 15 bit per second (bps) or less than Nyquist frequency requirement.

Nachimuthu et al. presented the design methodology of Vehicle to Vehicle Communication using VLC [8]. The transmitter is attached on front vehicle and a receiver attached on a rear vehicle. The data received maybe helpful to take further action like to control speed of following vehicle or to avoid collision. The system comprises of two main sections that are transmitter and the receiver. Modulation is used to modulate the input signal and data is transmitted in the form of 0s and 1s (flashes of bulb i.e. on and off).

Padmapriya et al. worked to produce automated trolley using RFID [9]. The system incorporates RFID tags instead of bar codes. Since RFID tag is used in all products thus it gets scanned by RFID reader. Therefore name and cost is displayed on LCD. In proposed system light is used as a means to transmit the data to main computer. The LiFi receiver is placed at the billing counter which receives the data from transmitter. By using this idea the problem of time consumption of customers can be solved. This technology is implemented by using visible light spectrum of electromagnetic spectrum. Automatic billing of products using smart trolley and RFID is an effective method to be utilized in future.

Bera et al. worked on this idea to provide an application that can be utilized for chatting and gaming purpose [10]. In LiFi, LEDs are used as transmitter with constant current. This current is varied frequently so that we can get 1 and 0. When led is ON a digital 1 is transmitted and when led is OFF a digital 0 is transmitted. The switching of LED is done so rapidly that one cannot observe these fluctuations.

The flickering of LEDs is done too rapidly that one can visualize the LEDs are continuously on. Practical LiFi based systems is not available as commercial products yet. Banerjee et al. worked on the LiFi communication for vehicles [11]. LiFi is the communication through light carrier. The transmission of data can be done by a simple LED bulb. An on LED represents 1 and off LED represents 0. This binary stream i.e. 0 and 1 flickers so rapidly that it cannot be observed by a human eye this means that rate of transfer of information is so high. In this transmission we transfer the data in digital form. One numeric keyboard is interfaced at the transmitter and another is interfaced at the receiver. Switches represent a number thus 9 switches are used at transmitter and to display them at the receiver seven segment display is used.

Abdulsalam et al. have designed and implemented vehicle to vehicle communication system using LiFi technology [12]. This is implemented in order to avoid accidents and collision between vehicles. The system is designed such that it works on two basic scenarios. First Scenario: When vehicle 1 is braking, the message is sent to vehicle 2 using rear lights according to the sensed speed. The message is received by photo diode placed at the front of vehicle 2. Second Scenario: When the vehicles are at T junction, the vehicle 1 sends its speed notification continuously to vehicle 2 by the headlight LEDs. The speed received by the photodiode at vehicle 2 is compared and the driver is alerted according to the situation if there is another vehicle in the area.

3. Design Methodology

The system comprises of a transmitter section and a receiver section (See Fig. 3).

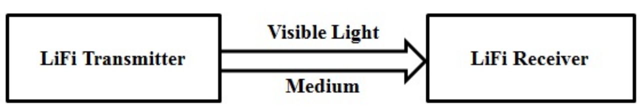

Fig. 3 Block diagram of LiFi communication system

The rear lights of vehicle A is acting as transmitter and is sending the pulses of 0s and 1s. The flickering of LEDs should be done very fast so that it cannot be visualized by human eye. photodiode at front of vehicle B is receiving the transmitted data in the form of current. The system is applicable to scenario when vehicle A is braking, rear lights transmits the alert of brake to vehicle B so that collision can be avoided. Block diagram of transmitter and receiver is shown in Fig. 3 and Fig. 4, respectively.

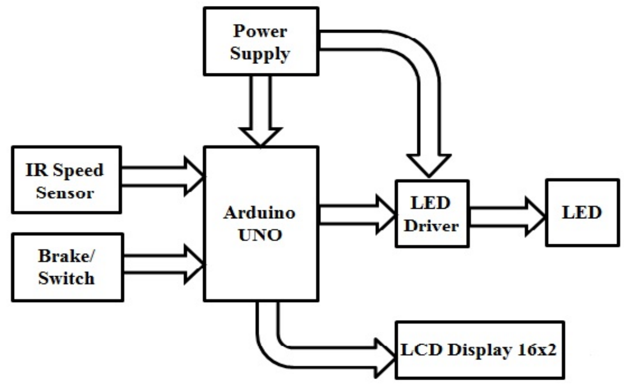

Fig. 4 Block diagram of a transmitter section

IR speed sensor is used to detect the speed of vehicle. On applying brake data is processed by Arduino UNO and is sent to LED driver which provide constant current to LED. LCD displays the speed and alert of brake when brake is applied. The transmitted data from LED is received by Photodetector in the form of current pulse. The received pulse is very small and is undetectable for this purpose a trans-impedance amplifier is used to strengthen the current pulse also converts it into voltage pulse that is easily processed by Arduino. On detection, pulse buzzer is alarmed and alert of brake is displayed on LCD.

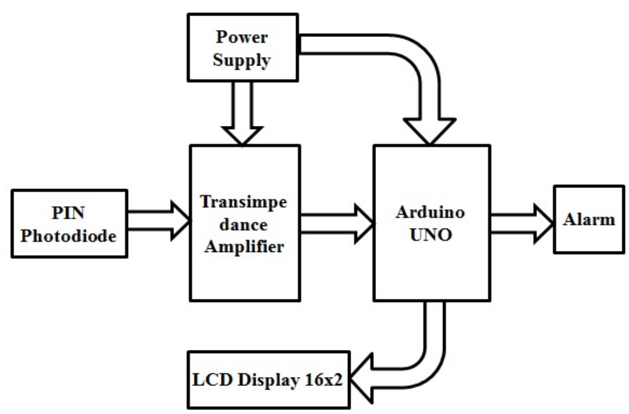

Fig. 5 Block diagram of receiver section

4. System Software Modeling

Before implementing system into hardware design each portion of the system design is simulated using Proteus software. Initially the response of a single LED is tested with switching frequency of 1 kHz. It is analyzed that an ON LED represents 1logic and an OFF LED represents 0 logic. As a result LED output response is a square pulse. In addition increasing the switching frequency higher than 1 KHz we may get the good output response. Fig. 6 shows the circuit diagram with single LED and Fig. 7 shows the square pulse produced by LED.

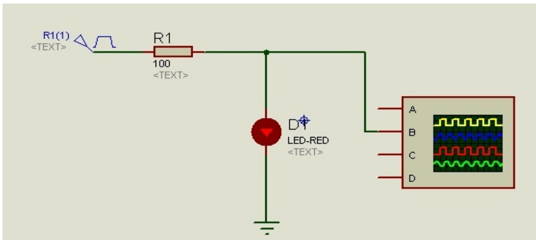

Fig. 6 Transmitter design circuit in Proteus

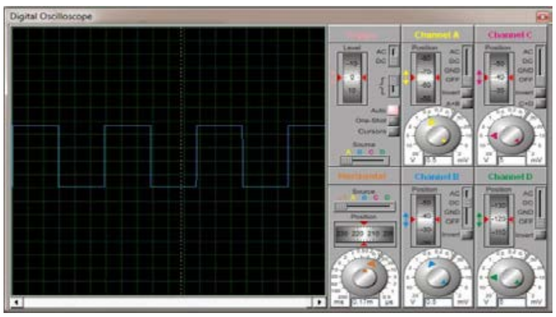

Fig. 7 Output of a transmitted signal

In digital system the data is represented in a voltage form. Voltage varies from 0 volts to 5 volts (see Fig. 7). When the voltage level is zero no current is passing through the LED. Hence the LED should be OFF. Similarly, when the voltage level is 5 volt then the current is passing through the LED. Therefore the LED is ON. In order to protect the LED from voltage fluctuations the constant current should be provided to LED for this reason LED driver circuit is used. LED driver regulate the current which pass through the LED. Fig. 08 shows the simulated circuit of the LED driver.

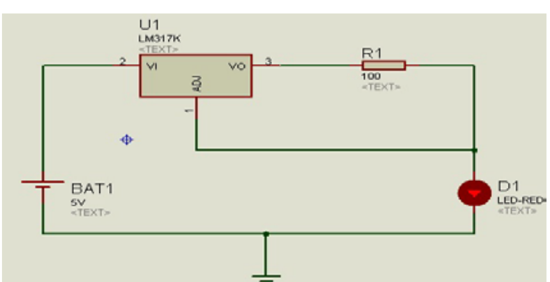

Fig. 8 LED driving circuit

The LED switching circuit is shown in Fig. 09 which provides switching to LED fluctuations.

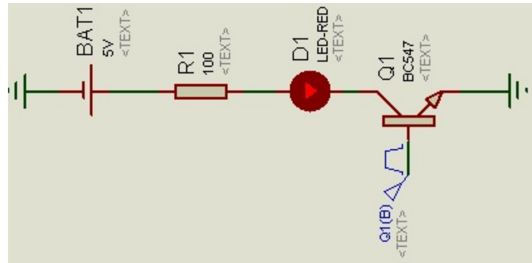

Fig. 9 LED switching in driving circuit

An NPN BC547 transistor is used for the switching purpose. Fig. 10 shows the behavior of the LED driving and switching. The input signal is in blue color and output signal is in yellow color (see Fig. 10).

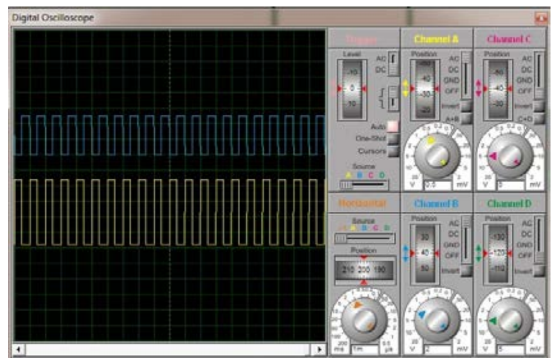

Fig. 10 Behavior of switching circuit

In order to receive those pulses of light produced by LED with frequency of 1kHz, the photo diode must be compatible to detect those pulses of light. The photodiode produce the current as linear function of light intensity which is actually small in mircoamperes. For this purpose the behavior of photo diode is tested with transimpedance amplifier as shown in Fig. 11.

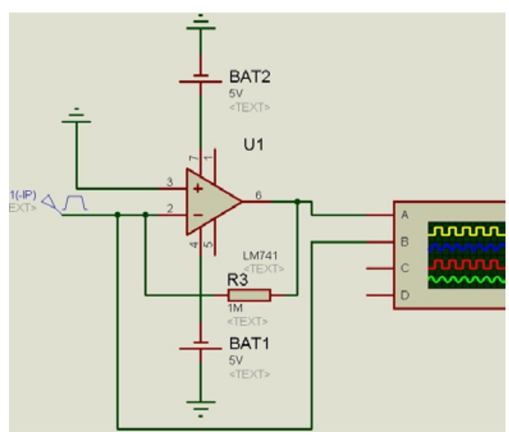

Fig. 11 Transimpedance amlifier

The output response from a photo diode is a low amplitude distorted square wave. Blue signal is the input signal to TI amplifier and the yellow color signal is the output signal of TI amplifier which is the shown in Fig. 12. A trans-impedance amplifier is used to strengthen the signal and convert it into voltage waveform so that it can be detectable easily. It can be analyzed that the pulses produced by TI amplifier can be visualized as ON and OFF pulse that represents digital digits 1 and 0 respectively.

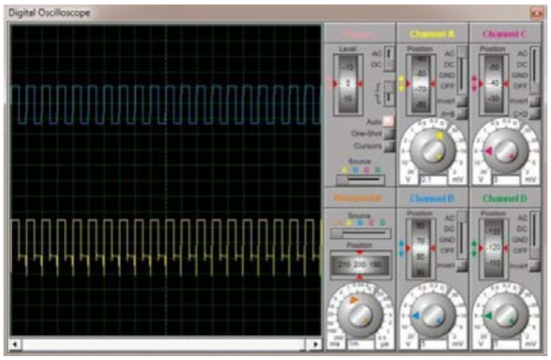

Fig. 12 Input and output signal of transimpedance amlifier

The final transmitter design in Proteus software is software is shown in Fig. 13. The brake/switch is connected to the Arduino when the switch is connected to ground then the LED will be ON and transmit the signal of Brake status. The purpose of final transmitter circuit is to test the circuit design output before implementing in real design design.

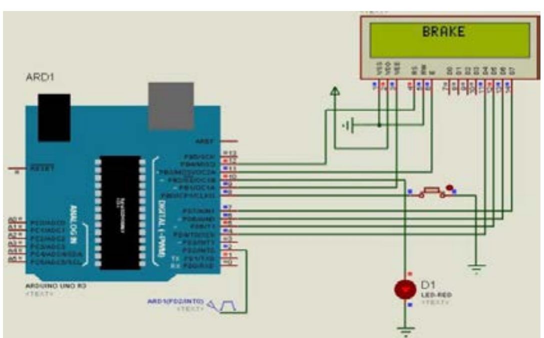

Fig. 13 Transmitter circuit design in Proteus

The final receiver design in Proteus software is shown in Fig. 14. The brake/Alarm is shown by LCD and the trans-impedance amplifier circuit is connected to the Arduino. When the photo detector detects the photon, it produces the pulses of the current. It is tested using input square wave.

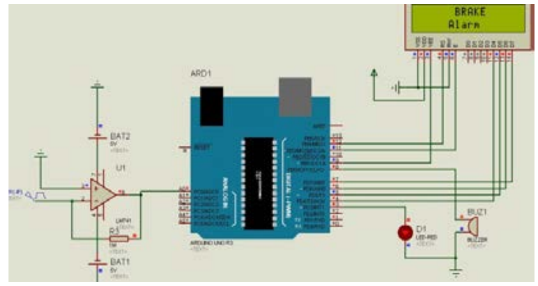

Fig. 14 Receiver circuit design in Proteus

5. System Implementation

Transmitting and receiving design have been tested as whole via simulation and the prototype of the practical system design is implemented and analyzed. The Fig. 15 and Fig. 16 show the practical circuit design view.

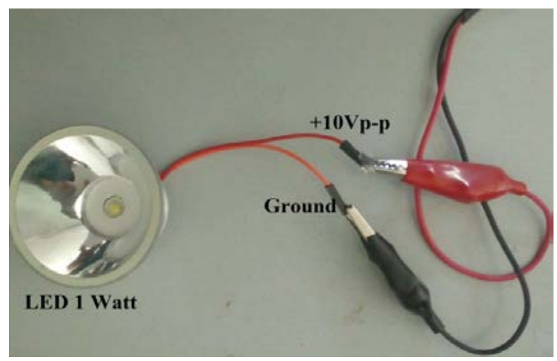

Fig. 15 Tranmitter section (hardware)

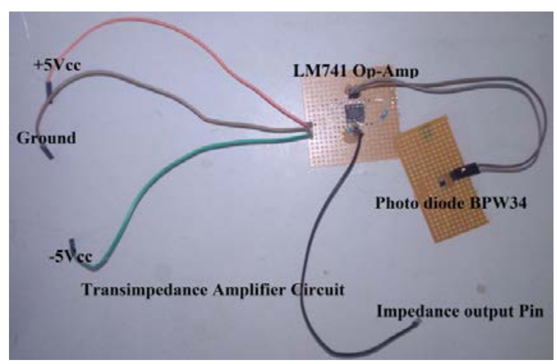

Fig. 16 Receiver section (hardware)

After designing the final circuit of the system to be implemented we have tested the behavior of transmitter output and receiver output with the help of oscilloscope at the distance of 1 meter range. We have given the sine wave of amplitude 10 Vp-p with the 1 kHz frequency which takes from the function generator at the transmitter. We received at the receiver side current is 20-30 μA (see Fig. 17); these current pulses are converted into amplified voltage pulses of 2.5 volt to 4 volt.

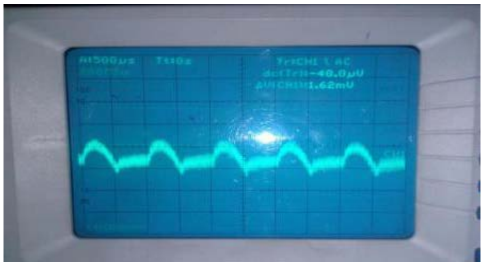

Fig. 17 Received signal without amplification

Receiver circuit with trans-impedance amplifier circuit shows signal with sufficient amplitude to be processed by the Arduino, as shown in Fig. 18.

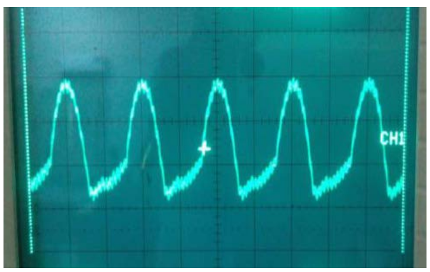

Fig. 18 Received signal with amplification

Once the main objectives of system design are achieved, the prototype is implemented. The prototype of transmitter and receiver are shown in Fig. 19 and Fig. 20, respectively.

Fig. 19 Prototype of transmitter

Fig. 20 Prototype of receiver

6. Conclusion

The paper presented the cost effective method to avoid collision between two vehicles (i.e. front and rear vehicles) by using LiFi technology. The concept of emergence of LiFi technology along with the methodology of V2V communication has been introduced efficiently. The project presents a simple module of vehicle to vehicle communication through visible light communication that can be implemented in future vehicles. The idea of using simple LED lights as transmitter, photo diode as a receiver and simple circuitry makes it cost effective. At transmitter speed sensor is used to process the speed and brake status of the vehicles to transmit over rear light/brake light of the vehicle. At the receiver side photo diode detects this and the buzzer is alarmed to indicate brake. This module is cost effective. The prototypes of the real time transmitter and receiver circuits are presented.

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