Novel Design for Hard Brake Accident Avoidance using Light Fidelity Technology integrated with 3-Axis Shock Sensor

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***Abstract*— Vehicle to Vehicle (V2V) communications are accelerated with higher growth and are in demand from past decade. Most accidents are caused due to inefficient judging capability of drivers. This demands supportive intelligence to make efficient decision on roads, claiming for reduction in number and intensity of accidents. In this paper, we introduce a smart approach of using the concept of Visible Light Communication (VLC) under the application of V2V communication, commonly known as Intelligent Transport System (ITS). Intelligent Transportation System (ITS) is an emerging transportation system capable of integrating advanced information and telecommunications network for vehicles, users and infrastructures. This paper suggests solution for vehicle to vehicle (V2V) communication improving traffic behavior and driver safety through accident avoidance. It is a better alternative to radio frequency (RF). VLC is an optical wireless communication technology that uses the non-regulated visible light frequency band (400nm to 700nm). The structure of V2V system consists of LED lights as transmitters, photodiodes as receivers for processing data. Our work focuses on designing an efficient prototype using hardware and software modules using simple optical transceiver in Visible Spectrum for intelligent communication among vehicles for road safety applications.**

***Keywords*— Intelligent Transportation System (ITS), Visible Light Communication (VLC), Li-Fi, V2V Communication, Arduino Uno, IR Blocking Photodiode VTP9812FH, LEDs, OOK, PWM**

I. INTRODUCTION

Transportation has been playing a key role for a long time in our daily lives. Yet continuous increase in automobile leads to road traffic which causes serious problems in terms of congestion, safety and environmental impact. Fortunately, IT and communication technologies have come up with advanced solutions to today's everyday transport problems. Intelligent Transport Systems (ITS) covers a wide variety of communications related applications which in turn helps to increase travel safety, minimize environmental impact, improve traffic management and maximize the benefits of transportation to both commercial users and the general public. [1]

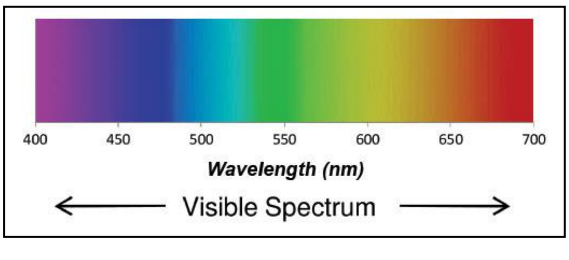


Fig 1. Visible Light Spectrum

II. MOTIVATION

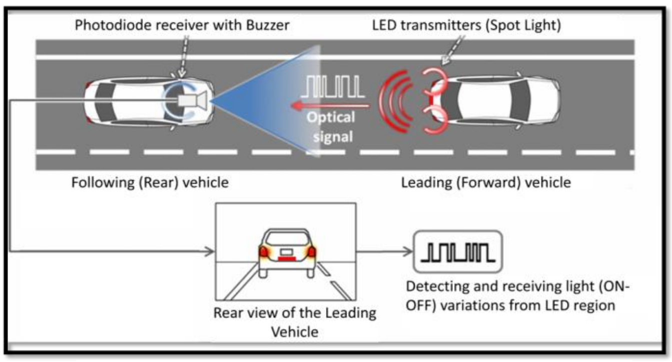
A. Light-Fidelity

HARALD HASS, the father of Light Fidelity from university of Edinburgh, UK said that this technology depends on the intensity of the light emitting diodes. An important reason which leads this technology through this invention was the confinement of Wi-Fi to comparatively small distance. Due to the high rise of radio frequency operated devices becoming a part of daily lives, the probability of the signals to get distorted and interfered has also increased to manifold. This issue led to a need to create a system for an error free communication. The alternative to this challenge was Li-Fi technology. The basic technique behind this concept is that the information can be transmitted from LEDs light whose intensity varies undetectable to the human eye. It is called as the optimized version of WI-FI. The advantageous thing about this technology is the cost effective approach. Li-Fi can achieve about 1000 times the data density of Wi-Fi because visible light can be well contained in a tight illumination area whereas RF tends to spread out and cause interference. RF transmission and propagation in water is extremely difficult but Li-Fi works well in this environment.[1][2]

B. Objective

The current technology in automobiles is consisted of hazard light system installed at the rear end. This type of system enhances warning indication to the drivers of following vehicles to maintain a sufficient gap between them.

However, this system offers no or less safety feature to the following drivers since it requires extra attention from them to keep the eyes always on the road while they might be engaged in activities such as texting on the phone, talking to a fellow passenger, listening to the music, behind the wheels respectively. To encounter this drawback, we introduce a project with an objective to create an improved safe traffic infrastructure wherein the existing hazard light technology could be replaced by the LEDs acting as automotive



brakelights to transmit pre-accidental warning alerts to the following vehicles through the concept of Visible Light Communication. The following firmware is involved to setup the proposed system:

- Arduino Uno microcontroller
- Arduino IDE software
- Red Led Spotlights
- Photodiodes
- Convex lenses
- NI Multisim software
- TINA software

III. WORKING OF BASIC LIF-FI SYSTEM

A. *Transmitter*

As per the given diagram, the transmitter section consists of the input, a timer circuit, and a LED bulb. The input can be any type of data that you wish to transmit, for example voice, text etc. The timer circuit is used to provide the required time intervals between each bit. These bits i.e. 1‟s and 0‟s are transmitted in the form of flashes of the LED bulb.[7]

B. *Receiver*

The flashes of the bulb are received by the photodiode. The photodiode then converts the light energy into electrical signals. Next these electrical signals are amplified and the output is presented.

C. *Applications*

- Visible light communication can prove to be very useful in areas where radio signals cannot be used due to its interference with other appliances. These areas may include hospitals, mines, oil rigs, planes etc.
- Li-Fi can also be called as a form of green technology. It is said so since there is no harm to animals, birds as well as humans from any kind of radiation .
- Underwater communication will be possible between deep sea divers and explorers. There are many more applications where we can switch from RF to Li-Fi for easier communication.[8]

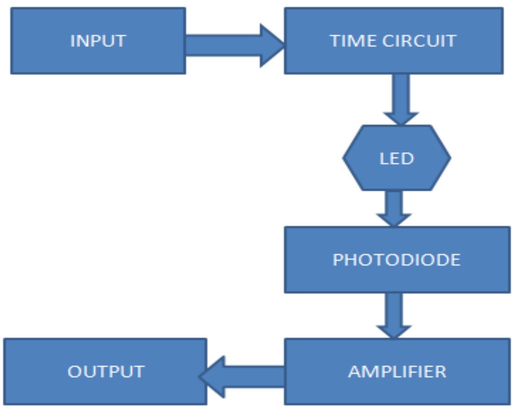


Fig 3. Basic Li-Fi System

IV. PROPOSED SYSTEM

A. *Transmission*

For our proposed VLC system, the following list of components were used to transmit the data.

- High Intensity Red LEDs Spotlights (70 Lumens)
- Arduino Uno Microcontroller
- Analog Accelerometer ADXL 335
- BC547 NPN Transistor

LEDs, or light–emitting diodes, are semiconductor devices that produce visible light when an electrical current passed through them. An important characteristic of LEDs over incandescent bulbs is that they can be modulated as per user's requirements and have longer lifetime and are energy efficient. In our system, LEDs are used to carry the information and transmit the them in the form of OOK (On-Off Keying) method.

The specifications of the LED used in the project are discussed below.

- Model: ADNEXT AD-421C/1W RD
- Input Voltage: AC 230 Volts, DC 3.0 – 4.0Volts
- Power: 1 Watt
- Frequency: 50 – 60 Hz
- Lifespan: 40,000 Hours

ATmega328p is an 8 bit CMOS Microcontroller. Clock speed of 16 Mhz. It is the main control system for the project responsible for executing pre-defined algorithms and programs respectively. Our project will be designed based on the Arduino Uno C programming respectively. All the hardware components are connected and controlled by Arduino UNO microcontroller. [9]

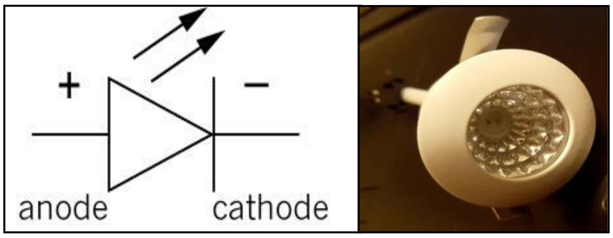


Fig 4. LED Symbol & Spotlight

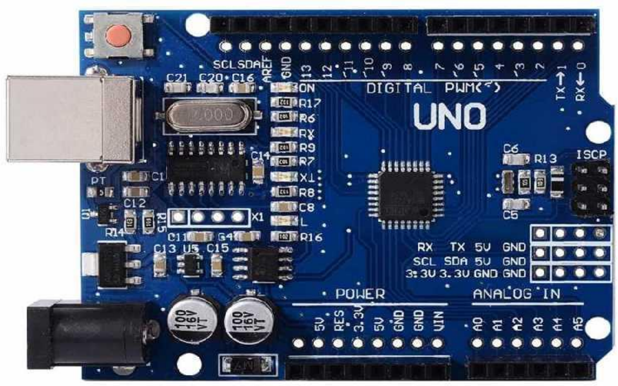


Fig 5. Arduino Uno Microcontroller

Analog Accelerometer ADXL335: The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. It measures acceleration with a minimum full range of ±3 *g*. It can measure the static acceleration of gravity in tilt-sensing applications, along with dynamic acceleration resulting from motion, shock, or vibration respectively. For our project, this device detects the intensity of the brakes applied on the vehicle and gives the output in the form of analog voltage. This obtained voltage is further processed to Arduino Uno to convert into digital format and then blinks the LEDs according to modulated format respectively. Calibration across each axis is a critical factor in order to interface with other hardware.

The Calibration Method is as follows :-

1. The Arduino microcontroller is programmed with a 10-bit ADC. So, 2^N where N is the no: of bits, gives us 1024. The raw readings are noted between 0 to 1023.

2. Find out the Minimum and Maximum reading of each parameter (axis) by keeping their axis one by one facing upwards for Maximum reading and then downwards for Minimum reading.

3. The following readings were observed and noted while calibrating the ADXL335.

Max X = 627 Max Y = 613 Max Z = 628

Min X = 403 Min Y = 391 Min Z = 429

4. Mid value for each axis is calculated.

Mid X = 515 Mid Y = 502 Mid Z = 528

5. Resolution is calculated by dividing 1 with the difference between the Max and Mid or Mid and Min for each axis. We are keeping the Dividend as 1 to get values between -1and +1 G values as shown in the Equation (1).

$$\boldsymbol{Res = 1/Max\text{-}Min = 1/627\text{-}515 = 1/112 = 0.0089} \quad (1)$$

The G-value of X-axis is found by subtracting the mid value from the real time raw reading and the multiplying the respective Resolution as shown in the Equation (2).

$$\boldsymbol{G\text{-}value = [AnalogRead(x\text{-}pin) - Mid\ X] * 0.0098} \quad (2)$$

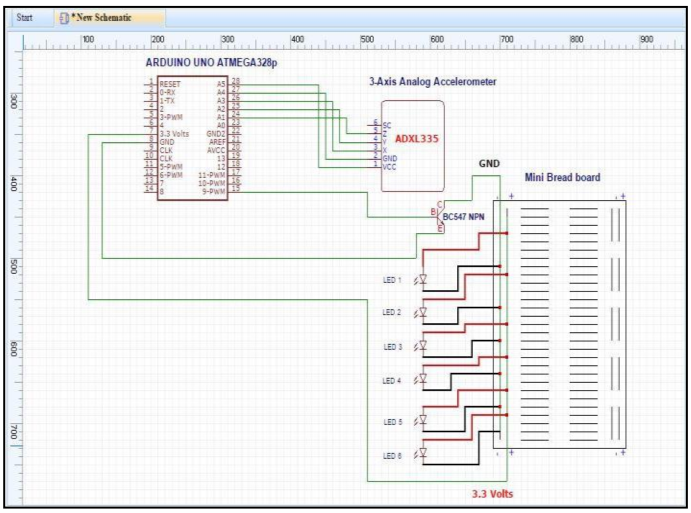


Fig 6. Transmitting circuit

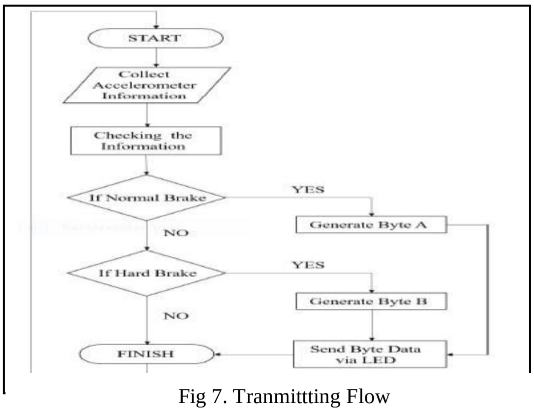


Fig 7. Tranmittting Flow

The Circuit connections are done as shown in the Figure 6. The Accelerometer is connected to the Analog Pins of the Arduino Uno microcontroller. To operate 6 LEDs, we are using a BC547 Transistor for the switching mechanism. All the LEDs are connected in parallel, so their positive is connected to the Collector of the Transistor and All the negatives are given to the ground. The Emitter from transistor is the given to the ground as well. The Base in the Transistor controls the LED output and this Base signal is taken by Digital Pin No 9. The program is Burned in the Arduino Uno and as the tilt/jerk is applied on the Accelerometer, the LEDs shows Output in the form of Blinking.

B. Reception

The following is the list of receiving components used in the project.

- Arduino Uno
- IR Blocking Photodiode (VTP9812FH)
- Biconvex Lens
- Hollow Cylinders

For our project, the IR Blocking Photodiode is used to detect the light transmitted from LEDs setup at the transmitting section. This photodiode has the spectral visible range between 400 – 700 nm respectively. When a vehicle applies normal brakes, code 1111000 is received for which no alarm is generated. In the case of a hard brake, code 11110010 is received by the photo diode. These output is fed to micro-controller which triggers the buzzer. This code (11110010) is then retransmitted backward to the car following.

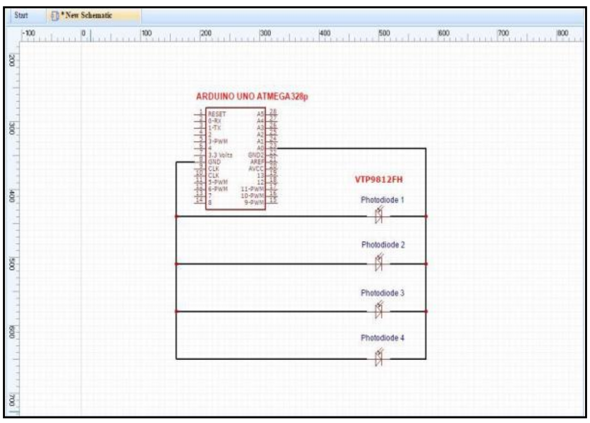
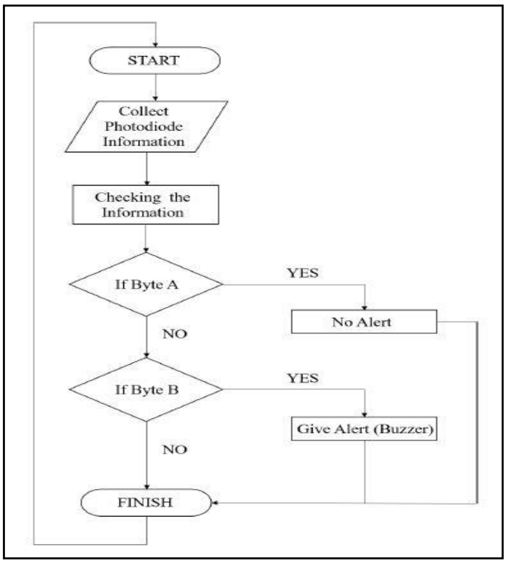


Fig 8. Receiving circuit



C. Working details

- The Accelerometer detects hard brake in the Leading Vehicle, and sends the data to Micro Controller.
- The Micro Controller receives the data from the Accelerometer and Controls the output of the LEDs accordingly.
- The LEDs transmits data using the ON-OFF keying method to he following Vehicle.
- The Photodiodes at the Front end of the following vehicle receives the signal from the LEDs and forwards the message to the Micro Controller.
- The Micro Controller Depending on received data, Switches on the Buzzer warning the driver of the leading car's sudden hard braking.
- The microcontroller then in turn also transmits the data to its following vehicle of the sudden braking.[5]

(a) (b)

Fig 10. Transmitting & Receiving prototype

D. Results & Observations

TABLE I. ACCELEROMETER VOLTAGE OUTPUT

Each Axis	Normal Brake (g)	Hard Brake (g)	Raw Reading of G-values for Hard brake	Voltage at Hard brake
X axis	0.25	0.37	557	1.79 V
Y axis	0.00	0.00	502	1.65 V
Z axis	0.97	0.93	621	2.00 V

TABLE II. EMERGENCY WARNING MESSAGES

Conditions	Output Bits
No Brake	00000000
Normal Brake	11110000
Hard Brake	11110010

As seen from above tables, The expected output (11110010) of the Hard Brake condition is achieved after crossing certain defined threshold voltage values. Here the Project had completed the Li-Fi communication on Air as a medium.

E. Conclusion & Challenges

Experiments show that the following driver can take quick action at a safer distance when the system warns of a deceleration exceeding certain values in g units. The accelerometer is used to detect deceleration greater than some adjusted threshold. The output of the accelerometer is fed to the Arduino and the micro controller generates an 8-bit message for both normal and hard brake. This message is sent to the following car and communication between vehicle to vehicle is possible. Every time the leading vehicle experiences a hard brake, the following vehicle hears an alarm. System reliably detects a hard brake and triggers the alarm buzzer.[6]

There were lot of challenges during the trial. The hardware setup had a setback of designing respectable safety distance between the transmitter and receiver i.e. 6 meters. In order to overcome this challenge, convex lenses were used across each end. The lens at the transmitting end focuses the light to an almost coherent beam which would be focused at the car behind, while the lens at the receiving end would focus that light to the active area of the photodiode, thus improving the distance. There were chances of miscommunication where the signals won't exactly be synced, unless the power was supplied to both arduinos on the exact right time.

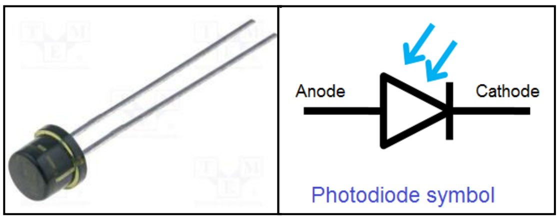


Fig 11. IR Blocking Photodiode & Symbol

F. Future Scope

Various modes of vehicle communication such as Vehicle-To-Infrastructure (V2I), Vehicle-To-Vehicle (V2V) and Infrastructure-To-Vehicle (I2V) are being investigated to reduce road accidents. Development of IEEE 802.11p standard for short to medium range inter-vehicle communication and allocation of a dedicated frequency band of VLC for Intelligent Transport System (ITS) have opened a way for future implementations stepping into gradual automation advancements and intelligent transportation.

A. Electronic Toll Collection

ETC supports the collection of payment at toll plazas using automated systems that increase the operational efficiency and convenience of toll collection. Systems typically consist of vehicle-mounted transponders identified by electronic readers located in dedicated or mixed-use lanes at toll plazas. ETC has the potential to significantly increase mobility on the nation’s transportation system.

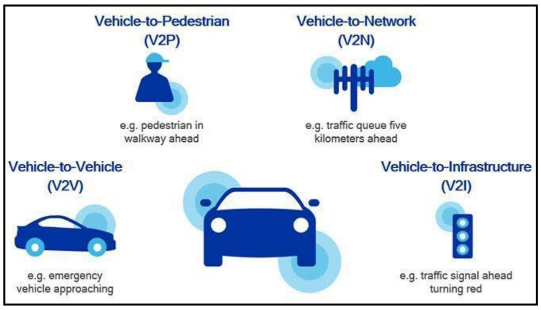


Fig 12. Vehicle To Everything (V2X) [3]

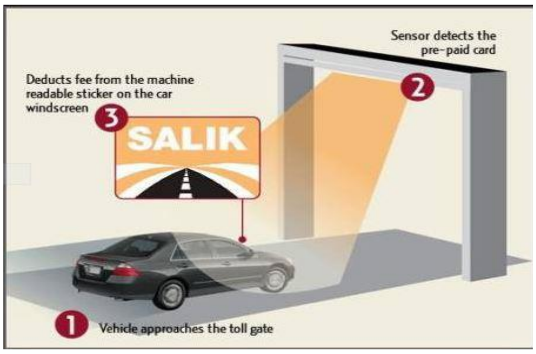


Fig 13. Electronic Toll Collection System [4]

B. 4G – 5G Device to Device (D2D)

The main idea of this trend is to exploit emerging wireless standards to leverage Mobile Network Operators (MNOs) existing telecommunication infrastructures and (network) data, to enhance intelligence on the move for providing novel Advanced Driver Assistance Systems solutions. This solution might be able to promise multidimensional advantages since it promises (a) reduced latency, (b) increased reliability, (c) a more efficient and pervasive market penetration model, and (d) cost efficiency.

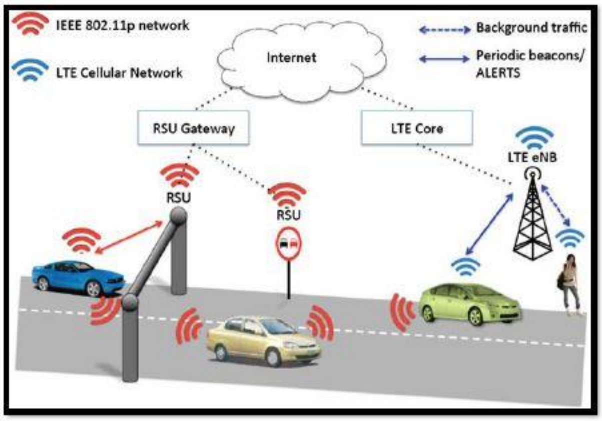


Fig 14. ITS 5G Network [4]

ACKNOWLEGEMENTS

The success and the ultimate result of this project required innumerous guidance and assistance which we achieved from so many great and highly encouraging people around us without whom we would not have reached at such great heights.
To begin with, first and foremost, we would like to shower invaluable gratitude to our **Project Guides Mr. Ganesan Subramanian & Ms. Sumathi.A** for providing us to engage the project with utmost professional and creative ways. The care and assistance from them boosted us to overcome lots of challenges that we faced during the project respectively.

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