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Vehicular Control System Through VLC: An Application of Monochromatic Optical Filter

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Abstract**:** ***A vehicular control system operated in VLC spectrum is envisaged in this work which is control by optical monochromatic filters. Overall six numbers of monochromatic optical filters are designed by the help PWE simulation method by considering silicon grating structure (Si and SiO) as background semiconductor material to control the direction of the vehicular system. Further, Matlab Simulink is implemented to realize the different direction with the degree of angular rotation while moving in left and right direction. In the simulation process, Arduino board is used to receive the control signals from the filters through the photo detectors and then according to the program stored in the memory, the outputs are actuated to drive the vehicular system corresponding to each combination of the inputs.***

Index Terms**:** ***Monochromatic optical filter, PWE, Simulink, VLC, Arduino.***

I. INTRODUCTION

Monochromatic optical filters are widespread for the medical application such as laser works which permits only one wavelength of light signal according to the designing factor. Silicon grating structures are more widely used material for designing the filters where the thicknesses of the semiconductor materials are the deciding factor to allow the desired wavelength of the light signal. In the literature [1-7], most of the filters are designed by taking the alternate combination of Silicon (Si) and Silicon Monoxide (SiO) with some defect. Total 64 layers of Si and SiO are taken with some appropriate which decides the allowable wavelength of light signals. In the above cases, PWE simulation is carried out to study the reflectance curve and these materials and methods are applied to all three optical windows with visible light spectrum. VLC is demonstrated in vehicular communication in [8-12] for driver safety and traffic control; in [8] Arduino is used for demonstration of the project where vehicle's tail light is modulated for transmitting significant message through serial interface to a bright LED. This work is specially designed to avoid the chance of an accident on the road by using VLC technique. Intra-platoon communication using VLC is realized in [9], where transmitter field-of-view is very narrow with the proper optical filter used at receiving end for road safety application. VLC is also demonstrated in [10-11] for communication between two vehicles in the night time. An intelligent traffic system is proposed in [12] where communication between the traffic light and lorry fleet is demonstrated.

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II. SYSTEM OVERVIEW

The proposed system is designed to operate in the visible light spectrum especially in the red regime (625 – 650 nm) as shown in Fig. 1. The system is equipped with some prime components for both transmitter and receiver such as at transmitting side, monochromatic optical filter (combination of six photonic structures), manual switches (six), whereas photo detectors (six), Arduino Uno, the vehicular system used in receiving end.

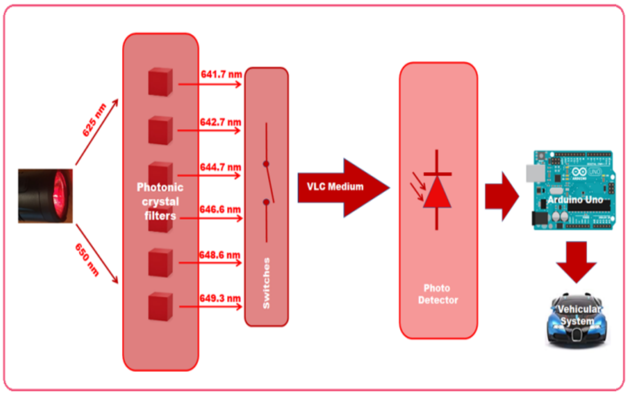

Fig. 1. Overview of proposed System

A. Monochromatic Photonic crystal structure

It is the combination of six individual monochromatic photonic filters which permit only six light signals of wavelengths like 641.7 nm, 642.7 nm, 644.7 nm, 646.6 nm, 648.6 nm, 649.3 nm. All the photonic filters are realized by PWE simulation technique using silicon grating structures like Silicon (Si) and Silicon Monoxide (SiO). Here, both the semiconductor materials are used as 64 alternate layers with a defect at the 18th and 52nd layer where the air is used in place of Si. The thickness of both Si (t1) and SiO (t2) are the key factors to allow the desired light signal. In this designing process, the thickness of SiO is kept constant (0.074 nm) and the thickness of Si are varied from 0.1768 nm to 0.1799 nm.

B. Switches

Six numbers of SPST switches are used in this system to block or unblock the light signal for traveling through visible spectrum medium.

The combination of these switches is actually decided the movement of the vehicle. The functions of each switch are assigned to different type of movement of the vehicle which is specified in Table 1.

Table- I: Combination of Switches indicating the movements of the vehicular system

D5	D4	D3	D2	D1	D0
START (1)/ STOP (0)	LEFT (1)/ RIGHT (0)	DEGRRE OF RROTATION			FORWARD (1)/ BACKWARD (0)

The outputs of switches are connected to the input of the photo detector and ultimately decide whether the output should reach the ADC of Arduino or not. Among six switches, D1, D2, and D3 are used to control the different angular movement of the vehicle along with the status of D0 and D4. Here, D0 is used for the backward or forward movement whereas D4 is for left and right motion. When, [D0=1, D4=0] with [D1=D2=D3=0], the vehicle will move forward and [D0=D4=0] and [D1=D2=D3=0] the vehicle will move backward. Keeping [D0=D4=0] constant, the different combination of D1, D2, D3 the vehicle will move with some angle in the left direction and similarly, with constant [D0=0, D4=1], the combination of D1, D2, D3 will push the vehicle in the right direction with some angle. The degree angle is actually decides by the combination of three bits D1, D2, D3 which results eight combination like '000', '001', '010', '011', '100', '101', '110', '111' and out of which '000' combination is used for the straight movement. The rest seven combinations are actually divided by the angle of 90 degrees and each corresponds to (90/7) degree. For example, '001' corresponds to (90/7) degree, '010' corresponds to (2*(90)/7) degree and similarly the combination '111' is used for (7*(90)/7) degree. The above explanation is valid for both left and right direction along with the forward and backward direction. Among the switches, D5 is used for breaking the system, that is when D5=0 no other combination will works.

C. Photo detector

At the receiving side, the first component is the photo detector which receives the monochromatic light signal to convert into electrical signals. Six numbers of the photo detector are used corresponds to six light signals. The output of photo detectors is used as input signals to Arduino board through ADC.

D. ADC

Here, a 10-bit ADC is used to convert the analog signal from photo detectors into digital signal for processing in the Arduino. Arduino board itself is having an in-built 10-bit ADC, but in the hardware simulation (Matlab Simulink) process, it is taken outside of Arduino.

E. Arduino

It is a popular microcontroller board specially designed for embedded application which contains ATmega328 microcontroller. It is operated with +5V D.C, 16 MHz of clock speed and is having enough I/O pins to accept the request signals from different sensors for processing and after processing the desired output is actuated as per the needs. It also comes with Arduino IDE for programming in 32KB flash memory with great ease. In this work, a program is stored to process the input data from ADC and accordingly actuates the vehicle in different directions.

III. RESULT AND DISCUSSION

Initially, six monochromatic optical filters are designed in the red spectrum region by using PWE simulation method. The thickness of Si (t1) and SiO (t2) is so chosen that only six desired light signals are obtained at the output and the signal wavelengths are 641.7 nm, 642.7 nm, 644.7 nm, 646.6 nm, 648.6 nm, 649.3 nm. Here, the thickness of SiO (t2) is kept constant whereas t1 is varied from 0.1768 nm to 0.1799 nm. as shown in the Table. 2. The entire reflectance curves (Fig. 2) obtained from PWE simulation technique are approached to zero for the corresponding wavelengths and reflectance is one for the other signals within the range. In the reflectance graph, the wavelength of the signal is taken in X-axis whereas reflectance (Arb. Unit) is expressed in Y-axis. The thickness (t1 and t2) is also mentioned on the top of the graph.

Table- II: Thickness of Si and SiO with corresponding allowable wavelengths

Sl. No.	Allowable Wavelength	Thickness of Si (t1) in µm	Thickness of SiO (t2) in µm
1	641.7 nm	0.1768	0.074
2	642.7 nm	0.1772	0.074
3	644.7 nm	0.178	0.074
4	646.6 nm	0.1788	0.074
5	648.6 nm	0.1796	0.074
6	649.3 nm	0.1799	0.074

Matlab Simulink is carried out for many movement of the vehicle but only three simulation outputs are shown in Fig. 3, 4, and 5 such as forward left, backward right and stop for the respective combination of input signals (status of D0 to D5). In each simulation diagram, the combination of switches is shown and also indicated manually (insect) for better representation. To convey the status of vehicle two circles with one direction indicator (pointer) are shown where left circle is used to represent the start (green) and stop (red) condition and similarly right circle represents the forward (red) and backward (green) motion of the vehicle. A pointer in a half circle shows the degree of angular movement in case of left and right movement.

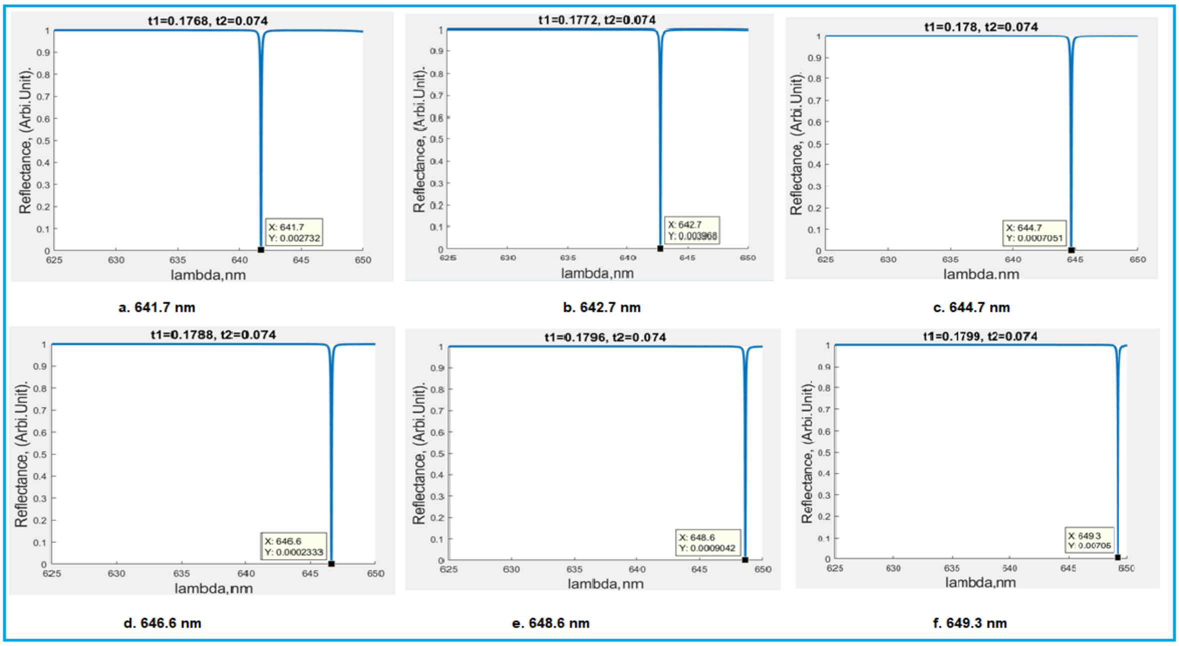

Fig. 2. Reflectance curve obtained from PWE simulation for different allowable signal wavelength

In the beginning, a light source of red spectrum region (shown in sliding window) is incident on the crystal structure which contains six individual optical filters to allow six monochromatic light signals. These signals are travel in the visible spectrum according to the switch combination to reach the photo detectors (in the Simulink, the wireless link cannot be implemented so it is shown in the connected link).

Then at the output of photo detectors, the electrical signals are processed in the Arduino through ADC to actuate the output for each movement of the vehicular system as shown in Fig. 3 to 5.

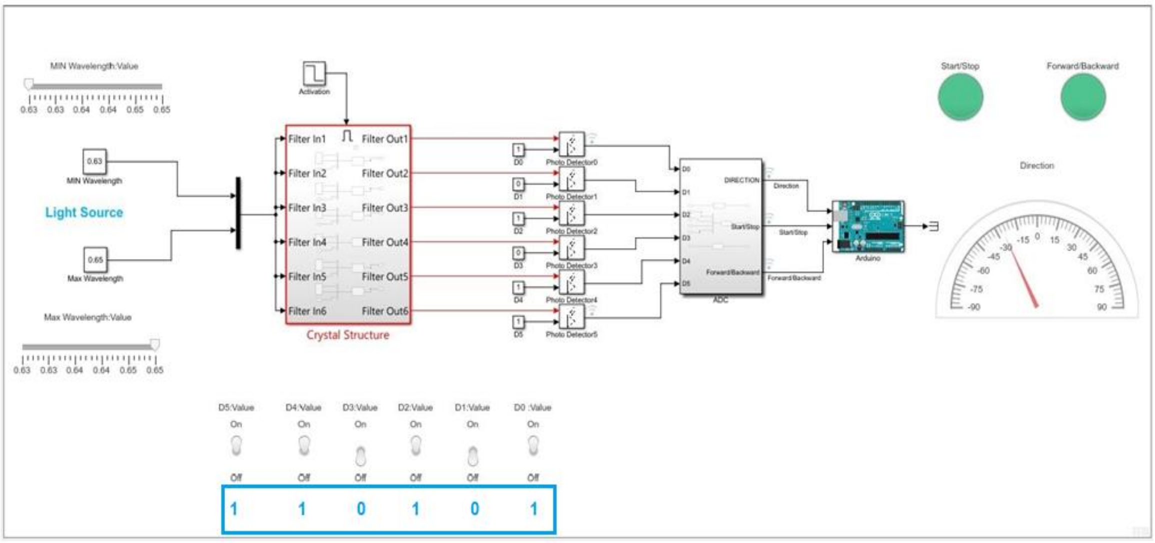

Fig. 3. Resulting output for START- FORWARD LEFT movement by Simulink

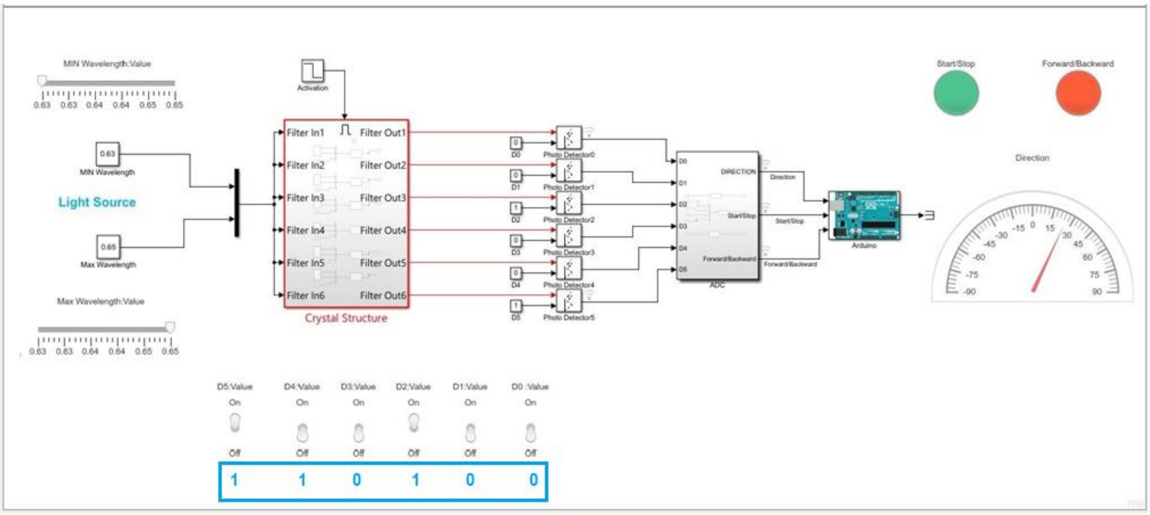

Fig. 4. Resulting output for START- BACKWARD LEFT movement by Simulink

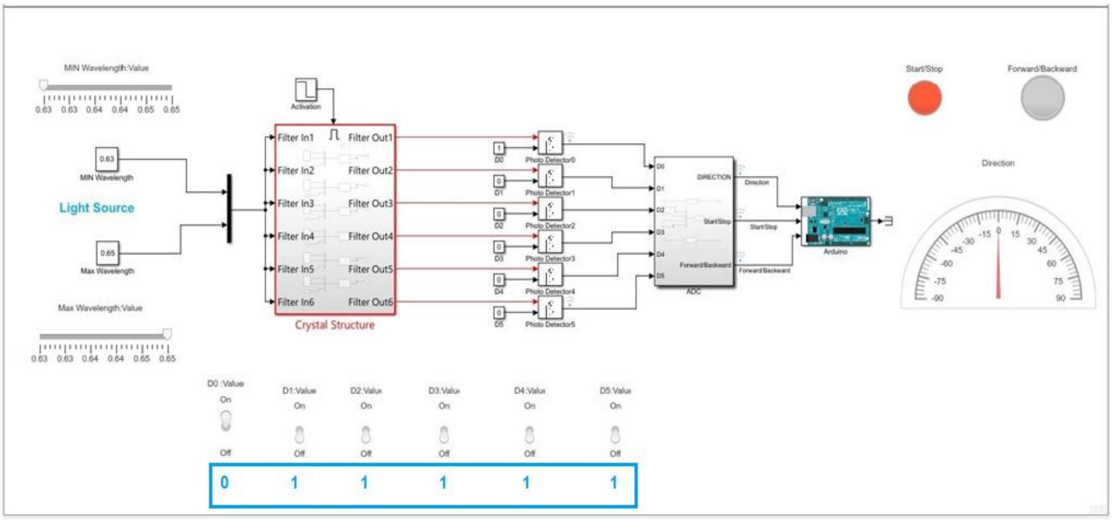

Fig. 5. Resulting output for the STOP movement by Simulink

IV. CONCLUSION

Vehicular control system using monochromatic optical filter is successfully implemented in this paper where both PWE simulation and Matlab Simulink are carried out for the realization. Six monochromatic filters are designed by PWE simulation in red spectrum regime whose outputs are manipulated by a series of switches to drive a vehicular system which is operated by visible light communication. Arduino Uno is programmed to drive the system in various directions according to the control signals generated by the optical filters through the photo detector. Various simulations are carried out using Matlab Simulink in lieu of different movement realization of the vehicular system.

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