Low Cost Visible Light Communication Transceiver Prototype for Real Time Data and Images Transfer

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***Abstract*—Research about Visible light communication (VLC) grows rapidly due to the need of innovation in wireless information transmission system. Previous research about low cost VLC prototype has been conducted. The previous resut is still under expectation, the maximum transmission distance was only 15 cm. This research is trying to improve the performance of the low cost VLC prototype by using array LED and array Phototransistor to achieve longer transmission distance. We adding the image transmission feature so that the information in form of text and image can be transfered. The prototype is build by using low-cost components and supported with desktop application as the interface. From the new prototype, the system able to send text and image data perfectly with maximum transmission distance is 98 cm. The maximum acceptance angle for transmission is 70° with maximum baud rate is 19200 bps.**

I. Introduction

Wireless communication requires carrier wave to carry information and travel via free space. The popular carrier wave which is widely implemented for wireless communication is radio wave. The higher society needs of communication, the more radio frequency required while the available radio frequency keeps decreasing. Another carrier wave such as visible light should be considered to be used to fulfill the needs.

Compared to radio wave, visible light supports better security, resistance on electromagnetic interference, and support further research and development since there is no regulation yet. The term visible light communication (VLC) then appears as one of optical wireless communication (OWC) technologies which uses frequency of light where the emitted light is visible [1], [2]. Another factor that supports VLC to be implemented is the fact that people had started to use LED lamp instead of conventional lamp due to its characteristic that saves more energy. LED lamp that emits visible light has high switching speed where it can be be switched on and off continuously in high speed where human eyes cannot follow or notice [3]. This high switching speed characteristic then gives an idea to transfer digital data, where logic value 1 is represented in ”on” condition of LED, and logic value 0 is represented in ”off” condition.

Some research had been conducted to design a VLC system with various implementation. An example of the conducted research was the was done by implementing VLC communication protocol for two toys vehicle interaction with simple transfered information that achieved 1,9 meters maximum transmission distance [4]. Another similar research was done on railways implementation by using transceiver system attached in the train to do information exchange with the site server [5]. A research to build a low cost VLC prototype system, which able to send 1200 characters simultaneusly with maximum acceptance angle is 75° and maximum distance is 15 centimeters [6]. This research is trying to improve the performance of the low cost VLC prototype and adding the image transmission feature. The information in form of text and image are transfered from devices which act as transceiver which optimized from the previous research. The prototype is build by using low-cost components and supported with desktop application as the interface.

II. Basic Theory

A. Visible Light Communication

Visible light communication is a technology from optical wireless communication where information is carried by visible light traveling in free space. Some implementation of VLC had been done, including the indoor VLC system adapted from conventional infrared communication system [7]–[9]. The general configuration of VLC and infrared communication are similar, but each uses different wavelength with different sort of light. Some research including this research aimed to implement VLC indoor system by seeing the fact that people started to use LED lamp widely for room illumination which has potential to be used as communication media among devices.

B. Light Emitting Diode

Visible light can be emitted by light source including LED and LASER by setting the operating wavelength. Compared to LASER, LED emitted light incoherently, thus it is used for room illumination lamp. LED is an electronics device which is used to emit light from the given current supply [10]. The basic principle of LED is similar to another diodes where the structure consists of the junction of p-type semiconductor and n-type semiconductor that operate with forward bias. At normal condition when there is no passing current, electrons stay at the valence band which is an outer line of an atom. In a condition where a current with energy above the energy gap passes, the electrons will move to the conduction band. The electron will

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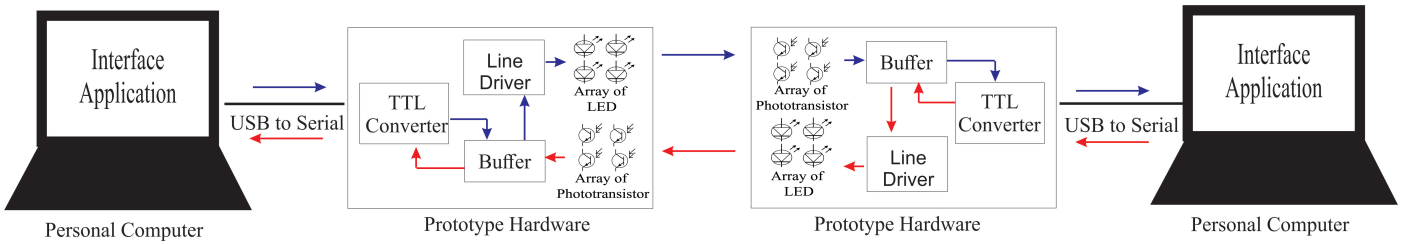

Fig. 1. System model of VLC transceiver

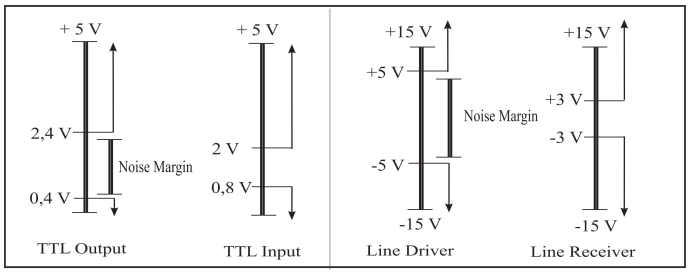

Fig. 2. Voltage level difference of RS-232 and TTL

then do a recombination back to the valence band by emitting energy in form of light. The emitted light disperses to many directions due to the spontaneous emission principle of LED.

C. Photo Transistor

VLC system needs a component that could detect the modulated light. The incoming light should be received then converted back to electrical signal before processed further in the receiving system. The components that could do that function are photo resistor, photo diode, and photo transistor. However, photo transistor is chosen in this research and most related research since it has internal gain and high sensitivity. The light received by photo transistor will generate current at the base region and generate current amplification hundred or even thousand times [11]. Photo transistor act as transducer.

D. RS-232 Serial Communication

RS-232 is a serial communication standard that used for information exchanges among devices. This serial communications commonly uses connector DB9 or DB25. RS-232 serial communication is a sample asynchronous communication which means the data transfered will be sent without using clock signal which is generally used for synchronization. To replace the role of clock signal, a start bit and a stop bit will be sent along the data packet. The sent data frame is arranged in the order of a start bit, followed by data bits, parity, and then a stop bit. RS-232 has its own voltage level which is higher in range compared to TTL voltage level as shown in figure 2 which is required by ICs and other electronic components to work. Thus, a voltage level conversion is absolutely needed which can be done by some ways including the use of IC max232.

III. System Design

The VLC hardware design could act both as transmitter and receiver with half duplex communication. As shown in Fig.3 The communication from VLC transceiver devices to computer use DB9 connector where pin no.3 used as data output where -15V to 15V current from USB to serial converter sent to IC max232 that will convert the current into TTL level 5V. Through pin 12 of max232, TTL output can be obtained and proceed to free-noise buffer on pin 8 of IC 7414 which is connected to the base of transistor for high current and voltage amplifier that act as LED array driver. By using RS-232 serial communication protocol, information signal is modulated on LED indicated with the on and off condition switch of the LED. By using IC 7414 schmitt trigger, the modulated light received by the photo transistor would trigger pin no.1, then invert it to pin 2 and inverted again to pin 3 for the revert process. This process is done to amplify the signal right after being received by pin 2 and make the amplified signal has less noise to pin 4 then forwarded to pin 11 of IC max232 where high voltage would be converted to TTL level 5V out to pin 14 which is connected to pin 2 DB9 which is an RX pin. Then the signal is ready to be processed and can be read by the designed software or another serial communication software like Hyper Terminal.

The data is monitored by using a stand alone desktop application. The application used to send and received text and images. To send the text, user has to insert the text in the texts-to-send box. To send image, user can start by choosing images format such as *.jpg, *.bmp or *.png. In the receiver side, the received text was shown directly in the received text box. When receiving the image data, the image can be shown if the number of bits received is same as the numbers of bits transmitted along with the start, parity, and stop bit. The error bits can be known by comparing the bits preview in the receiver side and bits preview in transmitter side.

IV. Measurement on Text and Image Transmission

The quality of the system for text transmision is measured by calculating character error rate (CER), while the quality of image transmission is calculate by using Bit Error Rate (BER). CER is calculated by dividing the sum of error characters with the sum of characters sent. The measurement is done to see the impact of parameters value changes to the CER value. The analyzed parameters are distance, acceptance angle, and transmission/baud rate. The number of characters sent for the testing is minimum 1200 characters.

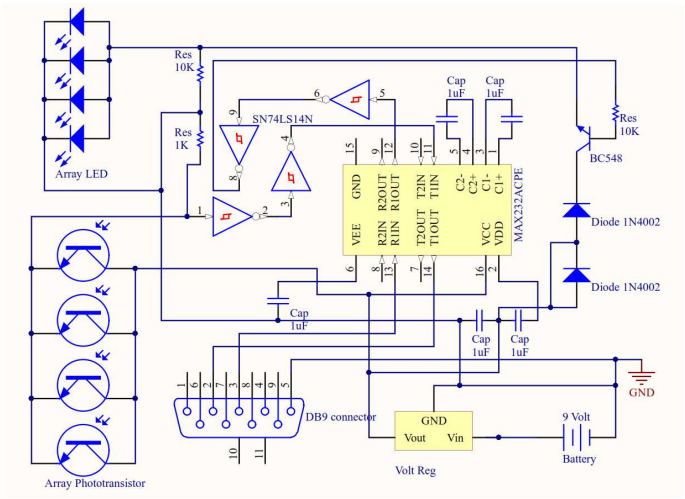

Fig. 3. Schematic Design

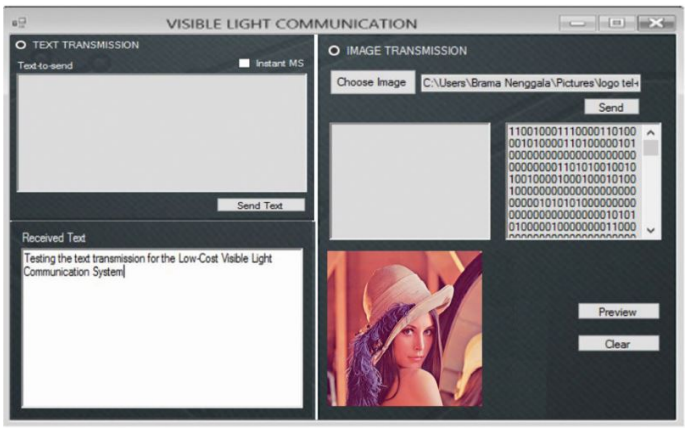

Fig. 4. 'Graphical User Interface

TABLE I
SUMMARY OF DISTANCE PARAMETER MEASUREMENT RESULT

Transmission Distance	CER	BER
10 cm	0	0
25 cm	0	0
50 cm	0	0
75 cm	0	0
98 cm	0	0
100 cm	0.192	0.023
115 cm	0.897	0.353
>> 116 cm	N/A	N/A

TABLE II
SUMMARY OF ACCEPTANCE ANGLE PARAMETER MEASUREMENT RESULT

Acceptance Angle	CER	BER
0° - 60°	0	0
70°	0	0
75°	0.368	0.435
80°	0.877	0.916
85°	N/A	N/A
90°	N/A	N/A

TABLE III
SUMMARY OF BAUD RATE PARAMETER MEASUREMENT RESULT

Baud Rate	CER	BER
1200 bps	1	0.8980
2400 bps	0.5251	0.4179
4800 bps	0	0
9600 bps	0	0
19200 bps	0	0
38400 bps	0.3694	0.3447
56700 bps	0.8146	0.6273

BER calculates error more detail than CER. It is calculate by divide the error bits with the total bits of the image sent. The BER analysis is done by observing the distance, acceptance angle and baud rate. For each parameter value, three tests were done with three different sizes of image, which are 512 bytes, 1024 bytes, and 2048 bytes. The average BER value was calculated from three tests of each parameter value.

V. RESULT AND ANALYSIS

A. Distance Parameter

From the measurement result in Table I, it can be seen that both CER and BER value equals to zero on distance range 1-98 cm which means that all data can be sent completely without any error. The error occurs when the distance set above 98 cm until it reaches the maximum distance for detection which is 115 cm. By using array LED we can increase the transmission range from the previous research. The distance limit on this system is due to the operating power of the LED used that affects the distance it can reach.

B. Acceptance Angle Parameter

Based on the measurement result shown in Table II, both text transmission and image transmission work well without any error occurs on acceptance angle range 0° - 70°. Error starts to occur above 75° and stop at the maximum acceptance angle where devices can detect each other which is 80°. The measurement show a good result for a wide range of acceptance angle where the system can work well. The good result is obtained because of the LED emitting characteristic. With this result, the position of array photo detector from array LED as light source can be more flexible. It can be concluded that using array LED is the right choice for achieving better transmission angle.

C. Baud Rate Parameter

Based on the measurement result shown in Table III, it can be seen that the system can work well with no mistakes on baud rate value 4800, 9600, and 19200 bps. For baud rate value below 4800, error occurs because its below the minimum speed the photo transistor can detect modulated light. Error

Fig. 5. Comparison between sent image and received image

occurs for baud rate value above 19200 bps, where the higher baud rate value the higher error rate occurs. This could happen due to the limit of LED switching speed and photo transistor sensitivity. To gain more maximum speed, the choice of LED and photo transistor is the main issue. The LED used should has higher switching speed and photo transistor should has higher sensitivity for higher baud rate.

VI. Conclusion

Based on the designed system for both VLC transceiver prototype hardware and interface application, it can be concluded that the designed system generally can work perfectly with no error at distance range 1-98 cm, acceptance angle is between 0° - 70°, and maximum baud rate is 19200 bps. The maximum distance in which the prototypes can detect each other and send information (with error) is 115 cm with average CER value 0.897 for text transmission and average BER value 0.353 for image transmission. The maximum acceptance angle for device detection is 80° with average CER value 0.877 for text transmission and average BER value 0.916 for image transmission. Error occurs for baud rate below 4800 bps where the lower baud rate, the higher CER value, and occurs for baud rate above 19200 bps where the higher baud rate, the higher CER value.

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