Development of Electronic Exhibition Audio Guide System Using VLC

AM.Zaiton[1, 2], AM.Kamarul[3], ZG.Choon[2], ZJ.Ling[2], MSM.Shapiee[2], NS.Roslan[2] and PC.Teng[2]
[1]*Centre for Telecommunication Research & Innovation (CeTRI), Universiti Teknikal Malaysia Melaka*
[2]*Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka*.
[3]*Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka.*
zaiton@utem.edu.my

***Abstract*—This paper reports a design and development of an indoor exhibition audio guide prototype using visible light communication. This project integrates high-speed communication network using light emitting diodes as a source and a transmitter to encode the information signal within an illumination framework. The received data is then decoded using Arduino microcontroller, which will decide the audio file to play through a headphone according to the displayed exhibits. This project successfully proposes a new technology that could be implemented and replaced the current technology used for electronic exhibitions audio guide.**

***Index Terms*—Electronic Audio Guide; Optical Wireless Communication; Optical Transmitter; Optical Receiver; Visible Light Communications.**

I. INTRODUCTION

Visible light communication (VLC) is a data communications technology which lies within visible light spectrum (780–375 nm), to transmit data across distances. VLC systems are being developed with the primary goal to create ultra-high-speed, secure, sustainable communications systems that allow future expansion without hassle when needed, using enormous bandwidth, intense pulsed light. This system utilises modulated light wavelengths, emitted and received by a variety of adapted standard sources, primarily with Light Emitting Diodes (LEDs) for data communication purposes. With this, it might provide ideal solutions to several technological problems by increasing the availability of conventional bandwidths; reduce interference of communication sensitive electrical apparatus; data security; and health issue when exposed to high RF and microwave levels [1-4].

The opportunity to send data using this method has arisen mainly because of the widespread use of LED light bulbs. Consequently, these bulbs can be switched at a fast rate, which was not possible with older lighting. The issue of congestion of the radio spectrum for Wi-Fi and cellular radio systems is also influencing the needs for VLC. VLC can be used as a communications medium for universal computing because light-producing devices are produced and used ubiquitously. The attention in VLC has quickly expanded because of the prospect of incorporating the high-speed communication network. Besides, the VLC system is economical and vitality effective system. The advantages of VLC system compared to radio frequency (RF) systems, for examples there is no obstruction with radio systems, a more secure connection as light cannot penetrate walls and a free unlicensed spectrum. VLC is favoured over infrared (IR) communication systems due to eye safety, other than the illumination function. Besides, other LEDs advantages are low power utilisation, low cost, and long lifetime. Fundamental analysis done on visible light communication concluded that VLC was expected to be next-generation technologies suited for indoor wireless communication, due to the ability to transmit data at a high data rate [5-8].

Today, coaxial cable and current RF-based technologies have many limitations. For instance, congested available spectrum, low and limited data rate, costly licensing, safety issues and high installation cost and high accessibility. Data transmission over wire-based technology requires massive and dense cabling, whereas complexity of routing and network management of RF technology is quite challenging at high frequencies. Therefore, the VLC system will help to give another perspective of the wireless technology due to its benefits particularly for Data Centre (DC) and electronics audio guide is one of the examples. There are many places where electronic audio guide system is a valuable enhancement or even necessary for visitors to have an immersive experience, especially at a museum and exhibition centre. The experience of visiting the museum and exhibition centre is more valuable if it is appropriately guided or using a user-friendly electronic audio guide. Some people might think it is a hassle of reading the information on the display or it is tedious when the visitor must key in specific code on the electronic audio guide [9, 10].

II. CIRCUIT DESIGN

The project is illustrated as in Figure 1. The prototype is using light sensor module with both analogue and digital output. The Arduino at the transmitter as in Figure 2 and Figure 3, controls the state of light to transmit data. The light sensor module at the receiver detects the data transmission in the distance and send the data to Arduino for processing. The microcontroller retrieves an audio file stored in SD card module and play it. The audio signal is amplified, using the circuit as in Figure 4 and Figure 5 before sending out through the speaker.

At the transmitter, the operation starts with uploading the codes with the data need to send into Arduino. Then the output pin 4 which connected to the base terminal will control the switching of the transistor to switch on or off of the LEDs according to the data need to send. If the data need to send is "1", the output pin 4 will become HIGH which produces base current to switch on the transistor. When the transistor is switch on, the circuit becomes a closed loop circuit that allows the collector current flow through LEDs and light up to send data "1". On the other hand, if the data need to send is "0", the output pin 4 will become LOW which switches off the transistor as there is no base current. When the transistor is switch off, the circuit becomes an open loop circuit and LEDs to switch off to send data "0". The data transmission starts with data synchronisation before sending 8 bits of data. After that, the process keeps repeating until the transmitter is turned off.

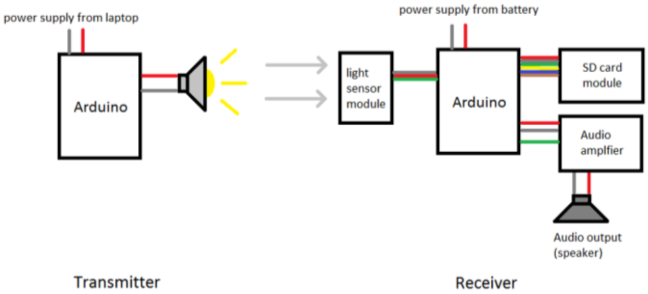

Figure 1: The design idea.

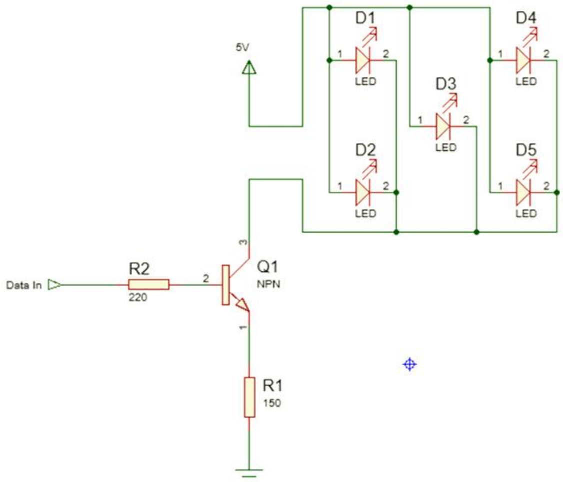

Figure 2: The transmitter circuit.

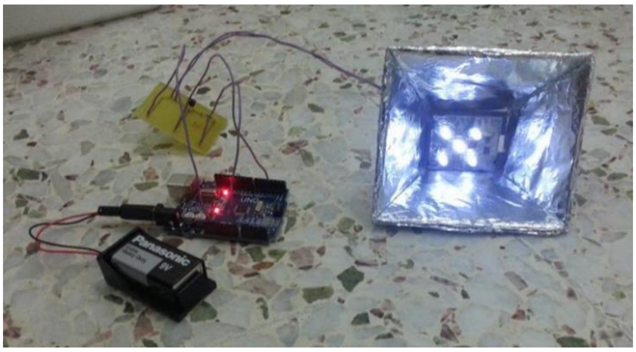

Figure 3: The transmitter prototype.

While at the receiver, the operation starts with light sensor module detecting incoming signals. If the light sensor module detects light, it sends a digital output "0" signal to Arduino through input pin 4 and otherwise a digital output "1" if there is no light detected. The received incoming signals are sent to Arduino for processing. If the Arduino did not receive the synchronise signal, it ignores other incoming signals and does nothing until it receives a synchronising signal. When the Arduino received synchronise signal, data synchronisation starts, so the receiver is synchronised with the transmitter.

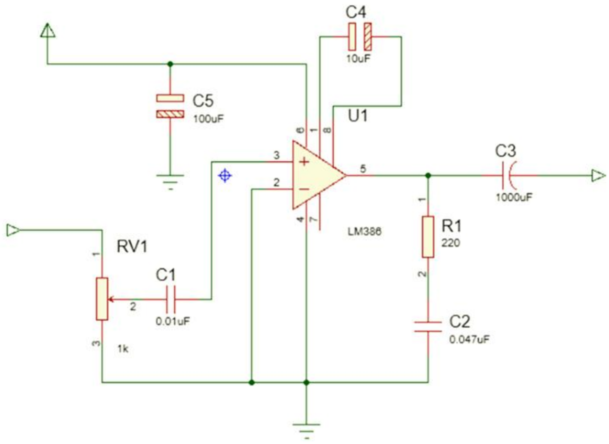

Figure 4: The audio amplifier circuit.

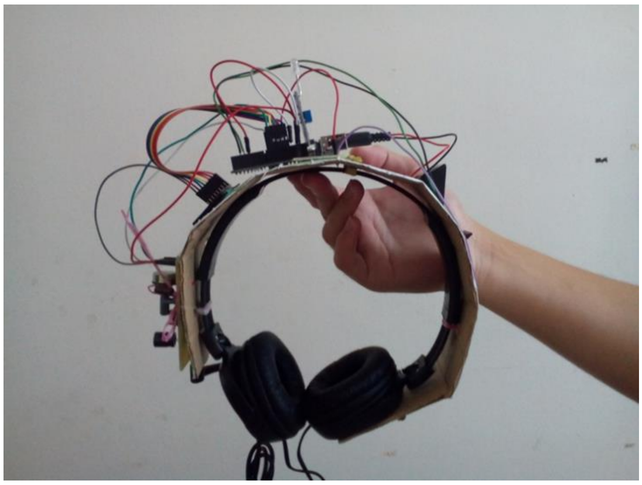

Figure 5: The receiver prototype.

After data synchronisation completed, the Arduino starts processing the data signal received by the light sensor module. The Arduino stop processing other incoming data signals when 8 bits of data is received and start checking the 8 bits data. If the received 8 bits data did not match any of the data in the database, the process starts over with waiting another synchronised signal. Otherwise, the Arduino will select an audio file from microSD card according to data received and play it. The audio signals produced from Arduino output pin 9 will go through the audio amplifier circuit to amplify the signals. The amplified output signals then go to audio jack port which connected to the headphone. Finally, the audio is produced from the speaker of the headphone. Additional features, which are stop button and replay button, are connected directly to the Arduino. The stop button uses to stop the audio that is playing when pressed and the replay button will replay the previous audio.

III. Results and Discussion

The performance of the successfully operated prototype has been measured in a few scopes such as transmission distance, the angle of transmission and rate of data transmission.

A. Results and Findings

Testing on the transmission distance determines how far the light sensor can sense the light produced by the LEDs at the transmitter. The variable resistor on light sensor module board was tuned so that the sensor is most sensitive to ambient light. Then the distance the light sensor module can detect the light is tested by moving the light sensor module away from the LEDs at the transmitter until the light sensor cannot detect the light. A measuring tape was used to measure the distance. Based on the research of the light sensor module, the voltage across the analogue pin of the photodiode which located in the receiver increase when the distance between the light sensor module and the LEDs which emit visible light that located at the transmitter increases. From the test, the maximum distance the light sensor can detect the light is 90 cm from the LEDs as shown in Figure 6. Based on the measurement, the voltage across an analogue pin of photodiode increase proportional to the distance between photodiode (receiver) and the LEDs which emit light (transmitter).

Another test was made to examine the angle of the light sensor module could detect the light. The test proved that the angle of detection is very small. The light sensor module can detect light when the photodiode on light sensor faces the LEDs directly in the straight line. When there is a slight change in the angle, the light sensor shows no detection in the light. As the distance of the light sensor module and the LEDs become larger, the photodiode sensitivity to light becomes smaller as it can only function for line-of-sight transmission. Thus, this prototype is only useful for LOS transmission.

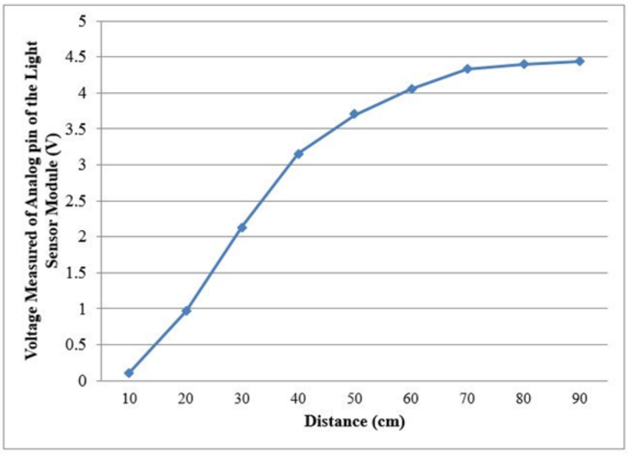

Figure 6: The relationship between the distance between light sensor to the LED and the voltage of the analogue pin of the light sensor module.

The speed of the data transmission has been calculated by assuming that all the data bits need to transfer is 1, the time required to complete the data transfer and repeat again is 1150 milliseconds. If all the data bits need to transfer is 0, the time required to complete the data transfer and repeat again is 1070 milliseconds. The sensitivity of light sensor module to the blinking speed of LEDs also has been calculated. The fastest blinking speed of LEDs that light sensor can sense is 30 milliseconds. The light sensor cannot detect the flickering of light and data transmission if the speed is less than 30 milliseconds. The eye diagram waveform is observed and recorded as shown in Figure 7. This test is done to find the efficiency of the circuit.

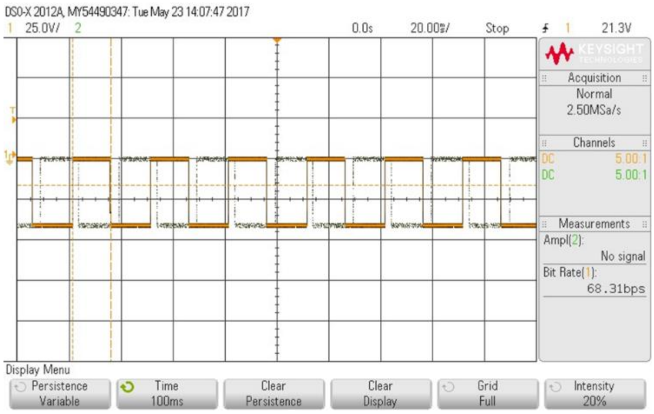

Figure 7: Eye pattern at digital pin output

B. Future Works

Based on the measurement done, some improvement is discovered. The Arduino microcontroller located at the receiver of the audio system requires high energy supply to operate. Therefore, it is recommended that microchip is used to replace to Arduino microcontroller by receive digital input from light sensor module and next transmit an instruction to the headphone on which audible file to be played. Secondly, the use of microchip able to reduce the size and power consumption of the receiver. Thirdly, it is suggested that more capacitor is implemented in the circuit to reduce the noise produced by the headphone.

Replacement of the high sensor module with higher sensitivity is also recommended. This is because of higher sensitivity light sensor module able to enhance a longer distance between the LEDs and the light sensor module to transmit data. The angle of the light sensor module that can detect light emits from the transmitter are wider with high sensitivity light sensor. Lastly, the light sensor module with high rate data received is recommended so that the light sensor can detect the high blinking rate of LEDs in transmitting data which human eyes unable to detect the flickers of light emits by the LEDs.

IV. CONCLUSIONS

In this paper, the development of an indoor exhibition audio guide prototype using visible light communication is successfully proposed. This optical wireless exhibition audio system can be used as an alternative for cheaper and environmentally friendly choice to be implemented in a museum or exhibition venue. This work is done by design audio system which uses visible light to transmit information. A receiver which consists of Arduino Uno R3 microcontroller are used receiver the digital output from the light sensor module and decided which audible file to play at the headphone.

Next, the ways to improve the method of obtaining audible information at exhibition centre/museum was also discovered. For that, visible light communication is used as the transmission channel for data to send from transmitter to the receiver. LED is used to send data signal by emitting the visible light which to be received by the light sensor module at the receiver. The LED used emits light with a wavelength range between 402 nm to 450 nm to the receiver. Meanwhile, light sensor module in the receiver can receive the data from the transmitter with the maximum distance of 90 cm from the LEDs. Increase in the distance between the photodiode in the light sensor and the LEDs may cause light detection failure. The angle of a light sensor module that can detect light emits from the transmitter is small that it can conclude the light sensor module can detect the light when the photodiode faces the LEDs directly in a straight line. Change in angle of the photodiode may results in no detection in the light.

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