

VLC-Based Car-to-Car Communication

Arnez Pramesti Ardi ^{a,*}, Ilham Sukma Aulia ^a, Rizki Ardianto Priramadhi ^a,
Denny Darlis ^b

^a School of Electrical Engineering
Telkom University
Jl. Telekomunikasi 1 Dayeuhkolot
Bandung, Indonesia
^b School of Applied Science
Telkom University
Jl. Telekomunikasi 1 Dayeuhkolot
Bandung, Indonesia

Abstract

Based on data from the Indonesian Traffic Corps by September 2019, the number of car accidents was dominated by rear-hit crashes with 6,966 accidents. Most of these accidents occurred during car convoys. It needs a car-to-car communication to increase driver awareness. One of the technologies that can be applied is Visible Light Communication (VLC) and infrared communication. The transmitted data are the vehicle speed data, throttle position, and brake stepping indicator. The data are obtained by reading the Engine Control Unit (ECU) in the car. The data are packaged from the three data and sent to other cars at day and night using VLC and infrared communication. The experimental results show that in a communication system that uses VLC, data can be exchanged between cars during the day up to 2 meters and at night up to 11 meters. Otherwise, in infrared communication, vehicles can communicate during the day up to 2 meters and at night up to 0.7 meter. The test was also carried out with some conditions such as rain, smoke, passers, and other vehicle lights.

Keywords: Car-to-Car Communication, ECU, Visible Light Communication, Infrared Communication

I. INTRODUCTION

The development of technology is now increasing, especially towards the development of technology inside cars that aims to improve safety and comfort in driving. Electronic devices inside cars can help improve the performance of the engine and help users analyze the damage of the car. But the number of accidents involving cars is still relatively high. The number of traffic accidents in Indonesia that occurred from 01 January 2019 to 31 March 2019 was recorded at 27,694 accidents with a total death of 5,758 people [1]. One type of accident is hit front-rear with a record of 6,869 times [2]. Based on the details of the data from the Indiana Tri-Level Study, around 68% of the causes of front-rear crash occur due to drivers who lost control [3].

Therefore, one solution to reduce the number of accidents is by using V2V (Vehicle to Vehicle) Communication which is data communication between vehicles or the exchange of vehicle information to the driver [4]-[5]. With the V2V system, the vehicle can be easily connected to exchange data, so it has the potential to reduce the occurrence of accidents [6]-[9].

One of the V2V communication system methods is using a VANET (Vehicular Ad hoc-Network). VANET has characteristics in the pattern of data transmission, namely by forming the path from the sender to the most

remote recipient by utilizing the vehicle around it as a node to determine the shipping path [10]. Another method is using Visible Light Communication (VLC), a communication system using Light Emitting Diode (LED) lights as transmission media. In the study, LEDs were used as transmitters and solar cells as receivers. It focuses on sending 16 pieces of warning messages with varying delivery distances during the day or night [11]. There is another VLC technology research that is using a camera as a receiver. This research focuses on sending data about street situations [5].

The input of information received in the V2V system is in the form of vehicle speed data, throttle position, and information related to braking. Data that will be communicated can be obtained from the Engine Control Unit (ECU) which functions as a central controller and processes data obtained from various sensors that exist in each car [12]. Data are transmitted using VLC and infrared communication. In VLC, it uses an LED headlight and infrared communication uses an infrared LED as a transmitter. The receiver used is a light to voltage sensor and an infrared receiver module [13]-[15], [9].

II. SYSTEM DESIGN

A. Overall System Design

This project uses the car as both transmitter and receiver. The working method of a car-to-car communication starts from retrieving data information obtained from reading the ECU in the car. The data sent are in the form of vehicle speed, gas, and brake step depth. Data exchange is carried out with two

* Corresponding Author.

Email: arnesardi@gmail.com

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communication systems, namely VLC and infrared. Data transmission using VLC can be done by utilizing the LED headlight on the car as a transmitter and light to voltage sensor as a receiver on VLC, while sending data via infrared can be done using an infrared LED as a transmitter and an infrared receiver module as a receiver. Furthermore, the data received by the receiver is displayed on the user interface. The process is shown in Figure 1.

The implementation of this car-to-car communication topic is divided into three parts, which are reading the ECU, designing the communication system, and designing the user interface.

B. ECU Reader System

In the ECU reader system compiler circuit as shown in Figure 2, some sensors function as input from the ECU system and data from the ECU is connected to the DLC socket with the can bus line. Through the DLC socket, the data from the ECU can be read using the Can Bus Module by reading signals on the Can high and Can low lines. The data read by the Can Bus Module are then communicated to the microcontroller using the SPI serial communication line. Data output from the microcontroller are used as input to the transmitter LED headlight and infrared LED.

C. VLC System

In the VLC system, the transmitter side consists of a modulator block, an LED driver and an LED headlight. Then on the receiver side, there are blocks of light to voltage sensors, amplifiers, and demodulators.

In Figure 3, the transmission starts from the input in the form of data from the ECU, such as vehicle speed, gas, and brake step depth. Then the data are encoded into the UART communication format on serial communication. The encoded data are forwarded to the driver LED as a logic 0 and 1 switch on the LED headlight.

In Figure 4, visible light from the LED headlight is received by light to voltage sensors. Light to voltage sensors are useful for converting received light into voltage signals. Then this voltage signal is amplified with an amplifier. The output of the amplifier will be processed in the demodulator to be converted back into an information signal.

D. Infrared System

In the infrared system, the transmitter side consists of a modulator block, an LED driver, and an LED infrared. Then on the receiver side, there are blocks of infrared receiver module and demodulators.

In the transmitter infrared block diagram as shown in Figure 5, it starts from the input in the form of data from the ECU such as vehicle speed, gas, and brake step depth. The data go into the controller to be processed into the modulator to be encoded into logic bits 0 and 1. Then the bits are forwarded to the LED driver to set on or off of the infrared LED.

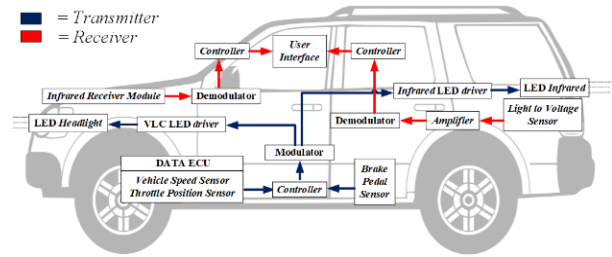


Figure 1. Overall System Design

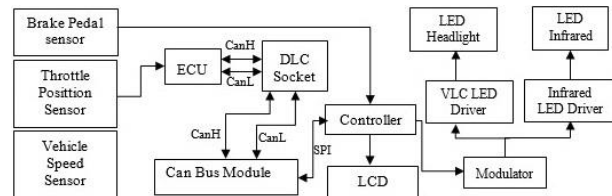


Figure 2. Ecu Reader System



Figure 3. Block Diagram Transmitter VLC

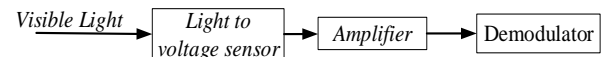


Figure 4. Receiver Block Diagram VLC

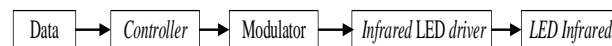


Figure 5. Block Diagram Transmitter Infrared

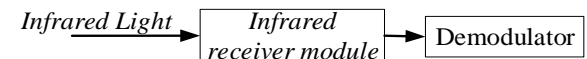


Figure 6. Block Diagram of The Infrared Receiver

In the receiver block diagram as shown in Figure 6, it starts with the light received by the infrared receiver module. The received infrared light is converted into a signal with a frequency range of up to 38 kHz. Then the received frequency signal is encoded back until it becomes data.

III. RESULT AND ANALYSIS

In the testing process, as shown in Figure 7, it is done by reading the speed and throttle position data on the ECU using the ECU data reader. Data parameters are obtained by requesting PID 0x0D and 0x11 on ECU [6], [14].

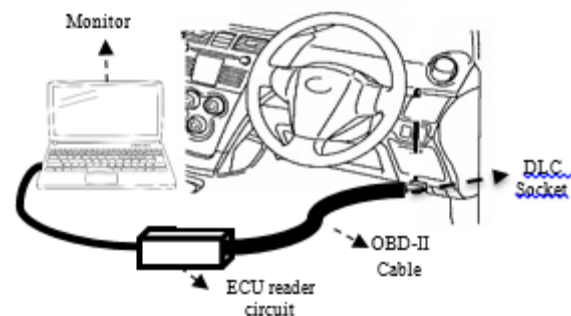


Figure 7. The Scenario for Reading ECU Data on Cars

A. Vehicle Speed Testing

The vehicle speed test aims to determine the results of the vehicle speed sensor reading which is read by ECU readers. The test is carried out 30 times and compared with the read speed value on the speedometer as can be seen in Figure 8.

B. Throttle Position Testing

The throttle position test aims to determine the results of reading the throttle position sensor read by an ECU reader. Tests are carried out with four different gas pedal position conditions.

In Figure 9, cars (a) and (b), with the same pedal position, produce different throttle position values, this is due to the different settings of each car, but in the condition of a pedal that is pressed fully, it gets the equal value of 81%.

C. Brake Pedal Testing

The brake pedal test aims to determine the results of the voltage sensor reading connected to the brake pedal sensor.

This test was conducted to provide information on braking conditions, the information obtained is not only by the indicator of the brake light that lights up but also by measuring the condition of the brake pedal. In Figure 10, the value obtained when the brake pedal is in normal or not pressed is 12 V.

In Figure 11, the value 0 V is obtained as the result of reading when the brake pedal is pressed and the brake light is on. In this test, the readable value from the brake pedal condition will be used as data to be communicated with VLC.



Figure 8. Vehicle Speed Test Results at a Speed of 11 km /h

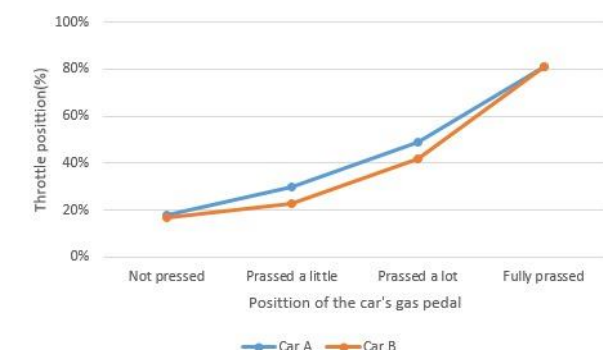


Figure 9. Throttle Position Test Result



Figure 10. Test Results of the Brake Pedal when not Pressed



Figure 11. The Result of the Brake Pedal Test when the Pedal is Pressed

D. Testing Distance of VLC Data Receipt

The testing distance of the data reception in VLC communication on day and night conditions are carried out with the help of a Fresnel lens. Fresnel lens aims to focus on the direction of the LED light beam. Testing is also carried out with or without using an amplifier.

After doing the test scenario, the test results are found, namely the results of testing during the day. In this test, the sensor cannot receive data due to the influence of the sunlight waves that are on the transmission path, making the sensor unable to receive data. While for the night testing, the result can be seen in Figures 12 and 13.

Figures 12 and 13 show that without using sensor amplifiers it can only receive data up to 700 cm but the data received is error due to the voltage received by the sensor ranging below 3 volts so that it cannot be defined by voltage input high on Arduino serial communication. Therefore, this project uses gain at non-inverting input so that the output voltage phase matches the input voltage. The required gain is at least 60 times so that the voltage generated can fulfill the minimum voltage requirements on Arduino serial communication. The gain formula used is as described in (1):

$$\text{Gain} = R_f / R_i + 1 = 68\text{k}\Omega / 1\text{k}\Omega + 1 = 69 \text{ time} \quad (1)$$

In (1), the magnitude of gain is obtained from the value ratio of the feedback resistor (R_f), which is 68 k Ω , and the resistor input value (R_i) of 1 k Ω is added 1-time. 1-time addition is obtained from non-inverting inputs, so that the amount of reinforcement used is 69 times. The test results are shown in Figures 14 and 15.

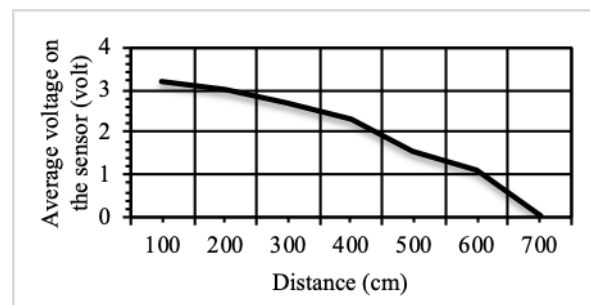


Figure 12. Graph of The Distance of VLC Data Receiver vs Average Voltage on The Sensor at Night without using an Amplifier

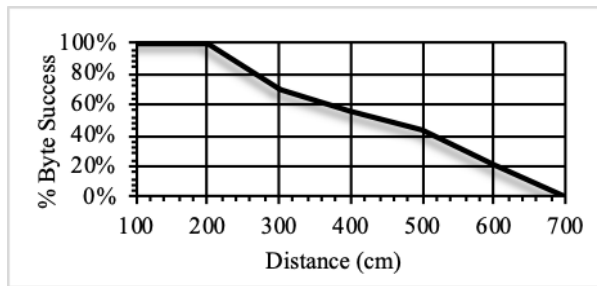


Figure 13. Graph of The Distance of VLC Receiver Data vs % Byte Success at Night without using an Amplifier

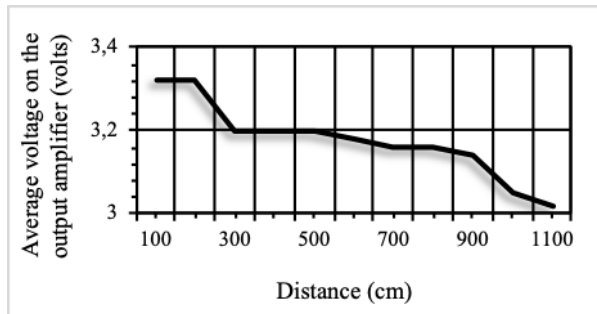


Figure 14. Graph of The Distance of VLC Data Receiver vs Average Voltage on The Output Amplifier at Night using an Amplifier

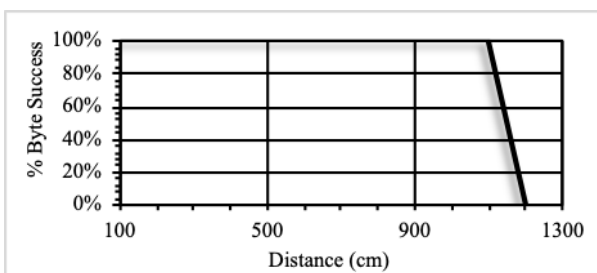


Figure 15. Graph of The Distance of VLC Receiver Data vs % Byte Success at Night using an Amplifier

The receiver can receive a successful byte without error up to a distance of 1100 cm. By using an amplifier the output voltage on the sensor becomes greater than 3 volts. Figures 16 and 17 compare the voltage values at the LED input with the voltage at the sensor output.

Figures 16 and Figure 17 show the value of the voltage strengthening ratio in decibels as described in (2):

$$\text{dB} = 20 * \text{LOG} ((V_{\text{out}}) / ((V_{\text{in}}))) \quad (2)$$

Based on (2), the value of V_{in} is the value of the input voltage on the LED which is fixed at 12 volts, while V_{out} is the value of the output voltage on the sensor.

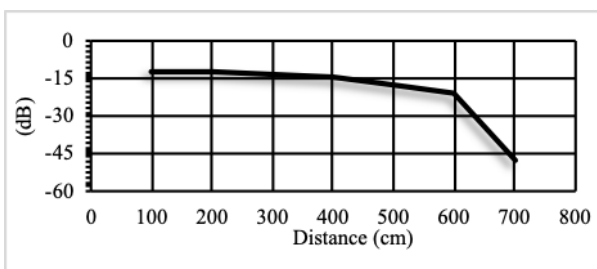


Figure 16. Graph of Comparison of V_{out} to V_{in} without an Amplifier

E. Testing of Angle of Receiving VLC Data

Testing is carried out by placing the receiver at a certain angle with a fixed transmitter position. The testing angles are 0° , 25° , 45° , 75° , and 90° .

Based on Figure 18, VLC data can be received without error at an angle of 0° to a distance up to 700 cm. At other angles, there is an error byte caused by the receiver's position that is too far from the direction of the beam of light, so that the light power received is only small and produces a small voltage. If the voltage received is below 3 volt, the data cannot be defined.

F. Testing of Environmental Conditions on VLC

This test aims to determine the effect of the surrounding environmental conditions on the sending and receiving of data. Testing is carried out with environmental conditions such as smoky, rainy, lights from other vehicles and people passing by.

The test results in Table 1 show that environmental conditions such as water do not affect the data transmission process. As for the conditions of smoke, people passing by, and other vehicle lights, there is an error byte caused by the light conditions.

G. Testing of Light Intensity on LED Headlight

The purpose of this light intensity testing is to know the illumination changes with varying delivery distances. If the illumination is too low, the reception of data will be disrupted, allowing an error.

TABLE 1
RESULTS OF TESTING ENVIRONMENTAL CONDITIONS ON VLC

Parameter	Value
Smoky	78.46%
Rainy	100%
People Passing	83.56%
Other Vehicle Lights	38.20%

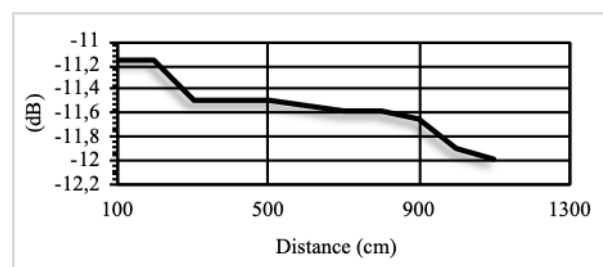


Figure 17. Graph of Comparison of V_{in} to V_{out} using an Amplifier

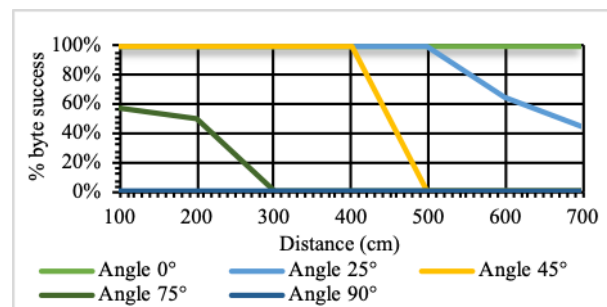


Figure 18. The Results of Angle Testing on VLC

Figure 19 shows that the illumination level at a distance tends to be low so that it can cause interference in the data transmission process.

H. Testing Distance of Infrared Data Receipt

This data acceptance distance testing aims to determine the maximum distance that can be reached by the TSOP1738 receiver so it can define that the transmitted data is well received. Testing this distance affects the distance between cars.

Figure 20 shows the result during the day at 2.30-3.30 P.M. GMT+7. The maximum distance received is only 200 cm, this is due to the influence of sunlight on the data transmission path. Sunlight is a combination of ultraviolet light waves, visible light, and infrared, therefore the reception of data using infrared communication during the day is quite disturbed, causing a lot of error data as shown in Figure 21.

At night, infrared communication can send bytes successfully without error up to a distance of 700 cm. At a distance of 800 cm, there is a byte error of 15% so that the success percentage is 85%. The maximum distance of receiving data in infrared is only up to 800 cm, this is because the current in the transmitter circuit is only around 2.38 milliamperes so it can be ascertained that the performance of the infrared LEDs used is not optimal.

I. Testing of Angle of Receiving Infrared Data

Testing the angle of data received aims to determine the range of data reception. Testing is carried out by placing the receiver at a certain angle with a fixed transmitter position. The testing angles are 0°, 25°, 45°, 75°, and 90°.

Figure 22 shows that at angle of 0°, the byte received is successful without an error up to 700 cm, while at the other angle, there is an error byte received. The possibility of an error byte and the receiver does not receive data is showing that the angle reception is too far from the transmitter location so that it interferes with the process of receiving data.

J. Testing of Environmental Conditions on Infrared

This test aims to determine the effect of environmental conditions on the sending and receiving of data. Tests are carried out with environmental conditions such as smoke, rainy, people passing by and lights from vehicles such as brake lights, taillights, and other vehicle lights.

The results in Table 2 show that environmental conditions such as smoke, rainy and vehicle lights do not affect the sending and receiving data so that data can be received properly without error. While in the condition of people passing by, there are several errors caused by the transmission path.

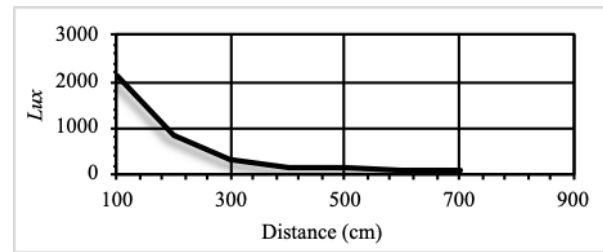


Figure 19. Illumination Test Results on LED Headlight

K. Delay Testing on Data Package Delivery

Testing the delay of sending data packets aims to determine the time lag of sending data from the ECU reading to the receiver.

Based on the test results in Figure 23, the average time of rising time on channel 1 is 5.133 ms and the average time on rising time on channel 2 is 7.066 ms. So that the delay time on the whole system is 1.933 ms. The delay results are considered good to be applied in a car-to-car communication system because the delay is in the good category at the limit of the speed of human response in the range of 0-300 ms [16].

TABLE 2
RESULTS OF TESTING ENVIRONMENTAL CONDITIONS ON INFRARED

Parameter	Value
Smoky	100%
Rainy	100%
People Passing	96.92%
Other Vehicle Lights	100%

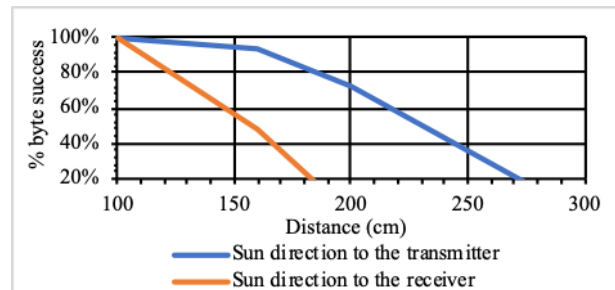


Figure 20. Results of Testing the Distance Receiving Infrared Data during The Day

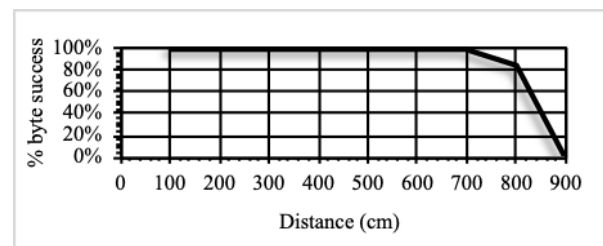


Figure 21. Result of Distance of Receiving Infrared Data at Night.

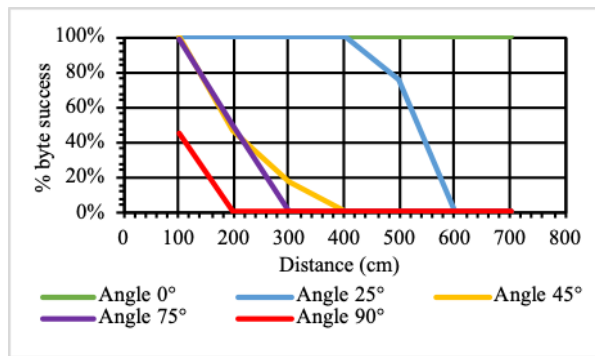


Figure 22. Results of Testing the Angle of Receipt of Data in Infrared

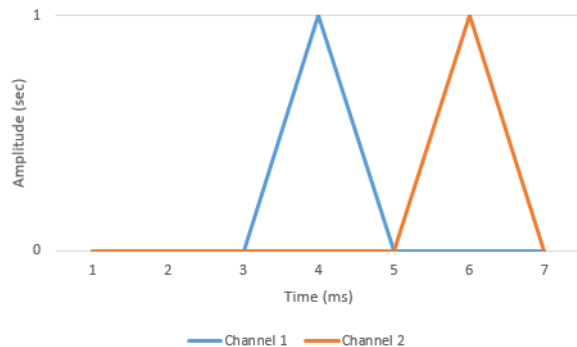


Figure 23. Calculation of Rising Time on Oscilloscopes

CONCLUSION

1. The Engine Control Unit (ECU) reader using the MCP2515 CAN-BUS Module TJA1050 can read sensor data on the car through the DLC connector port.
2. The use of CRC (Cyclic Redundancy Check) in data packaging can determine the occurrence of data packet errors in the process of sending data packets.
3. During the day, when communicating using VLC, the TSL252R sensor cannot receive data, but in infrared communication, the maximum distance of data reception by the TSOP1738 sensor is 200 cm, this is due to the influence of the sun waves that are in the data transmission path.
4. In communication between vehicles using VLC, the maximum distance for data transmission at night is 11 meters using TSL252R with an amplifier of 69 times and assistance from the Fresnel lens.
5. In communication between vehicles using infrared, the maximum distance of data transmission at night is 8 meters using TSOP1738 and without the use of filters or amplifiers.
6. The range of VLC and infrared data reception angles which are good enough to receive data are at 0° and 25°.
7. Environmental conditions do not affect VLC and infrared communication is rainwater, so if there is rainwater in the transmission line, the receiver can still receive data properly. Smoky environmental conditions and passers-by simply affect the data received.
8. In environmental conditions such as lights from other vehicles greatly affect the process of data transmission in VLC, it is due to the mixing of light containing data with light that does not contain data, so the results received by VLC receivers are error data. In infrared, it is only a condition when a person crosses that slightly affects the data reception. But in other conditions, such as smoke, rainy, and other vehicle lights, infrared can still receive data properly without any error data.
9. The results of the measurement of the delivery delay obtained the value of the delay time of 1.933 ms. It was classified in the good category.

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