Techno-Science
Scientific Journal of Mehmet Akif Ersoy University
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Original Research Article

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REALIZATION OF MICROPROCESSOR BASED VISIBLE LIGHT COMMUNICATION

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ARTICLE INFO

Article History

Received	:	16/10/2020
Revised	:	26/12/2020
Accepted	:	27/12/2020
Available online	:	31/12/2020

Keywords
Wireless communication, LED, Visible Light communication

ABSTRACT

The increase in data and number of users used in wireless communication is the biggest cause of the bottleneck in today's wireless communication environment. In particular, the rise in the number of devices connected to the Internet is one of the reasons. The current Radio Frequency spectrum is insufficient to respond to these needs. Visible light communication, although not an alternative to all radio frequency communication, can greatly relieve the communication load, especially in short-distance building communications. The LED lamps currently used for illumination are the transmitting elements to be used in visible light communication. It is an excellent alternative in terms of energy efficiency as it is low in installation rate and it is used as both lighting and communication element. Despite the health hazards of radio frequency communication, it is a candidate to be among the communication technologies of the future, in terms of greatly reducing the use of CO2 gas, significantly reducing electricity consumption and providing an efficient communication alternative. The apparent frequency of light (430-770 THz) is larger than the current radio frequency band (3 kHz-300GHz) it is also much faster than RF. Low frequency band range problem in radio frequency can be solved by visible light communication. Furthermore, the fact that the visible light cannot get out of the closed space seems to be disadvantageous according to the intended use, but also provides extra security in the application areas. In this article, we outline the basic components in visible light communication systems, carry out data transmission in the laboratory environment, review the latest technology and discuss some of the challenges and possibilities of this new wireless transmission technique.

1. INTRODUCTION

Cellular wireless network transmission used in today's communication technologies, along with wired communication network transmission and Internet infrastructure, correspond to 3% of electricity consumption worldwide, so it comes up as the main factor of power consumption in wireless communication technologies [1-2]. Recently, the energy efficiency concept has become a vital topic for the Information and Communication Technology (ICT) industry, which has an important role in global greenhouse gas emission due to its environmentally sensitive communication behaviour and limited energy resources [3]. From this point of view, reducing energy consumption by optimizing ICT systems will not only find a practical solution for global greenhouse effect gas emissions but also will provide environment-friendly communication opportunities [4-5]. Namely, the use of light as a communication source along with illumination, which is an indispensable part of our lives, mean an innovative, cost and energy-efficient, safe and green communication technology [6].

In addition to the aforementioned facts, the intense use of radio frequency bands worldwide in wireless communication technologies has gradually been a bottleneck lately [7]. At this point, visible light bands should be considered as a reasonable alternative solution. As shown in Figure 1, visible light spectrum has a wide bandwidth between $4x10^{14}$ Hz and $7x10^{14}$ Hz. [8], this bandgap used in illumination can also be used as an alternative in the field of communication.

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To cite this article: Sezer, Ö., Daldal, N., Yücedağ, İ., (2020). Realization of Microprocessor Based Visible Light Communication. Techno-Science, vol. 3, no. 3, p. 95-102.

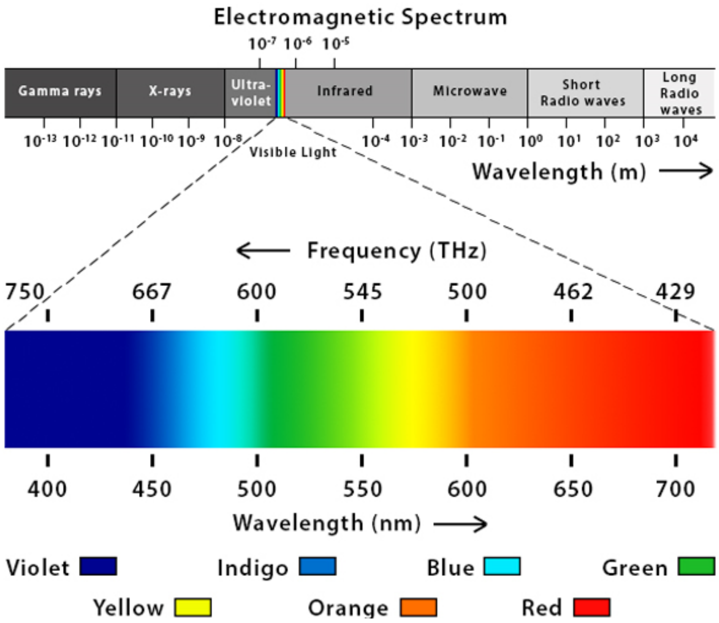

Fig 1. Visible light spectrum [9]

While LED is used as lighting element, the data is modulated as well in the electronic element. The communication distance varies depending on the colors and light intensity [10]. Visible light communication has a wide range of applications such as vehicle-to-vehicle communication LI_FI (light fidelity), underwater communication, hospital applications, illuminated billboards, visible light identification, sound transmission, visible light wireless network applications [11]. It is still in the research process since commercial applications have not been completed yet. The architecture of the receivers and transmitters used in visible light communication consists of three layers as physical layer, MAC layer and application layer. In this regard, IEEE approves only two layers (physical and MAC) in the 802.15.7 standard [12-13]. In this study, the usability of visible light communication in data transmission has been proved with a practical application in which the temperature has been measured and transmitted. It can easily be used as an alternative in places where radio frequency communication is not suitable (hospital, oil stations etc.). Moreover, the speed of the data transmission can be increased by using different modulation techniques (FDM, OFDM etc.) as in 5G mobile communication technologies.

2. VISIBLE LIGHT COMMUNICATION

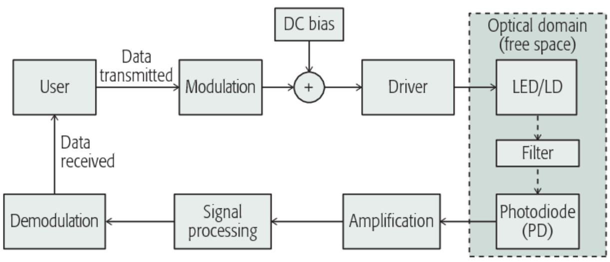

Fig 2. Basic block diagram of the visible light communication system

As seen in Figure 2, the LED and the LED driver circuit as a transmitter; the photodiode and amplifier circuit used as a receiver, which are the basic elements of the system. The key elements used in the communication system are Raspberry Pi 3 B + board, LED and photo diode. Furthermore, additional electronic circuits will be needed to switch the signal and decompose the received signal. Here, it is useful to consider many variables when choosing the suitable LED. Appropriate value should be chosen since the rise times of LEDs with high candela value will also be high. The LED selected for the test circuit, which has 1-watt power, converts light signals into electric current [14].

Many photo diodes used in industry are used in fiberoptic communication. The light-sensitive region of the photodiodes used in the fiber optic field is small and the rise and the fall time are short. In the test circuit, the light-sensitive area of the photodiode to be used should be larger and have a fast response time photodiode except for the photodiodes used in fiber optic communication. Therefore, taking the visible light communication into consideration; BPW21R model photodiode which has the highest sensitivity at 565 nm wavelength with a sensitivity of 420 nm between 675 nm was chosen for the test.

Raspberry pi 3 which does not need peripheral elements (ram, rom, video card, sound card, network adapter etc.) for its operation already contains all of them. Raspberry Pi 3 B + is one of the newest products of the Raspberry Pi 3 series. Since The Raspberry Pi 3 B + processor is 1.4GHz, 4-core 64-bit it has a Dual-Band 2.4GHz and 5GHz wireless local area network connection as well as Bluetooth 4.2 / BLE. with faster internet and PoE Line support.

3. EXPERIMENTAL STUDIES

In the designed experimental setup, Raspberry pi, receiver circuit and transmitter circuit are used for each of the receiver and transmitter separately [15].

3.1. Transmitter Circuit

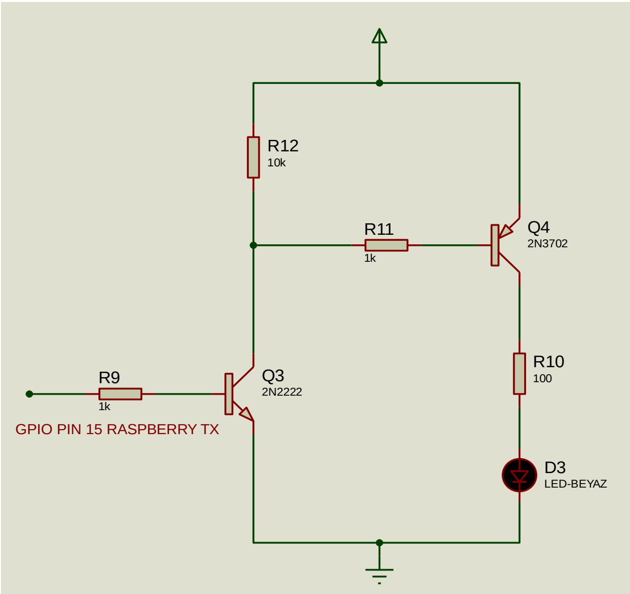

Fig 3. LED Driver circuit connected to Raspberry pi output

As it is shown in Figure 3, Raspberry pi3 B +, 18B20 temperature sensor, LED driver circuit (2n2222 and 2n3702 transistor) and 1W LED are used in the transmitter circuit. OOK (the simplest form of amplitude-shift keying (ASK)) Modulation is used to transmit data in this transmitter circuit [16]. Mathematical formula is expressed by:

$h_t(f)$ is the carrier signal for the transmission
$h_c(f)$ is the impulse response of the channel
$n(t)$ is the noise introduced by the channel
$h_r(f)$ is the filter at the receiver
L is the number of levels that are used for transmission
T_s is the time between the generation of two symbols
Out of the transmitter, the signal $s(t)$ can be expressed in the form:

$$s(t) = \sum_{n=-\infty}^{\infty} v[n].\,g(t - nT_s) \quad (1)$$

In the receiver, after the filtering through $h_r(t)$ the signal is:

$$z[k] = n_r(t) + \sum_{n=-\infty}^{\infty} v[n].\,g(t - nT)_s \quad (2)$$

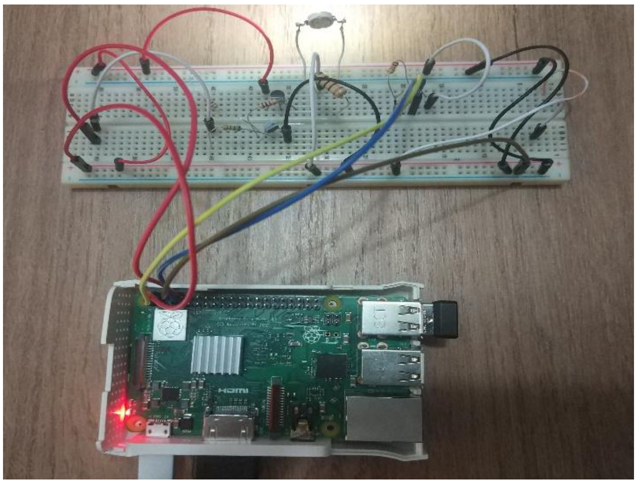

Fig 4. Raspberry pi, temperature sensor and led driver circuit.

In Figure 4, the 18B20 temperature sensor is connected to the GPIO4 pin of raspberry pi. The temperature value calculated in raspberry pi was sent through the pin of GPIO14 Tx to the LED driver circuit and was finally transmitted to the possible receivers by LED;

The computer code used in Figure 5 is written in Python language that is compatible with raspberry pi. The purpose of the transmitter is to provide an ambient illumination by giving continuous light when the LED does not transmit any data. For this reason, if any data is not sent the port status, it is altered as logic "1" and the NPN transistor becomes active. At this point, the PNP transistor base pin is pulled to gnd potential and the transistor becomes active so the LED emits light. When the data is sent, the signal is sent to the receiving side by cutting the light in short time intervals.

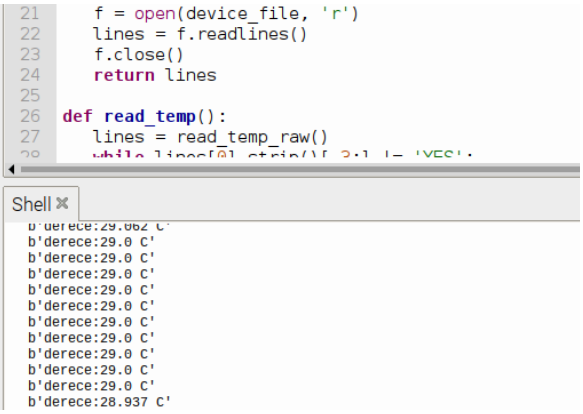

Fig 5. Transmitted temperature info in PC screen

In the communication used here, the baud rate is selected high so that possible the transmission-cutting situations are not realized by a human eye. As soon as data transmission is finished, the port is pulled to the "1" level and the LED continues to emit light continuously.

3.2. Receiver Circuit

The receiver circuit, shown in Figure 6, is a kind of transduction (current to voltage converter) amplifier which consists of a photodiode, operational amplifier and comparator. In Figure 6, the data sent by the LED falls on the photodiode and creates a voltage drop. The signal amplified by the operational amplifier is converted to digital form by the comparator. Meanwhile, rv2 resistor adjusts the threshold level and the comparator determines digital signals as 1 or 0 levels according to op-amp output. Next, the signal transmitted to Raspberry pi GPIO14 input and later it is converted into its original form thanks to the software written in Python language [17]. (In figure 6) Here, the reception sensitivity of the receiver is very important. Therefore, for the cases where the light source is located remotely, we should increase the gain in the non-inverting amplifier input by increasing the R14 feedback resistance.

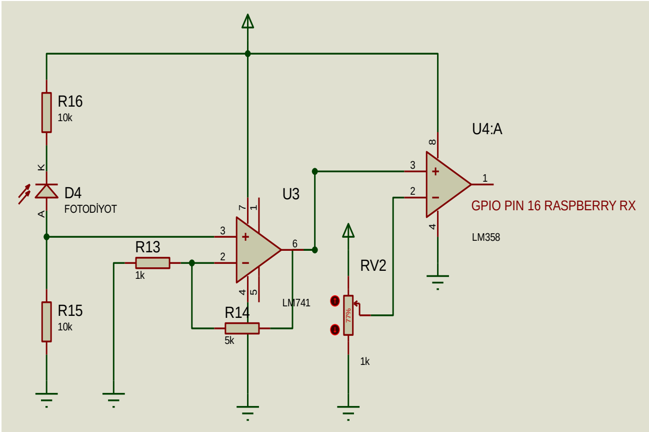

Fig 6. Receiver circuit

The LED driver circuit connected to the transmitter circuit is powered with 12 V external supply is tested and observed distances at different baud rates. The test realized when the room light is on and under the daylight.

```
import serial
ser=serial.Serial("/dev/serial0",
        baudrate = 9600,
        parity=serial.PARITY_NONE,
        stopbits=serial.STOPBITS_ONE,
        bytesize=serial.EIGHTBITS,
        timeout=None)
while True:

    p = ser.readline()
    p=p.decode('windows-1251')
    print (p)
```

```
Shell

derece: 30.375 C

derece: 30.312 C

derece: 30.312 C
```

Fig 7. Received temperature info in PC screen

As the baud rate and ambient light increase, the distance changes inversely. For the cases with or without ambient light, distances were measured and recorded. This situation can be seen graphically in Figure 8. At the end of the experiment, it is seen that the data rate is directly proportionate to the brightness of the LED (candela value) [18]. It is also found that the data rate is inversely proportional to the baud rate. Ambient light also affects data transmission adversely [19]. After reaching 114Kbaud that is the highest rate we can reach, no data is receipt due to limited data rate of the transmitter and LED candela value (110 lm -120 lm).

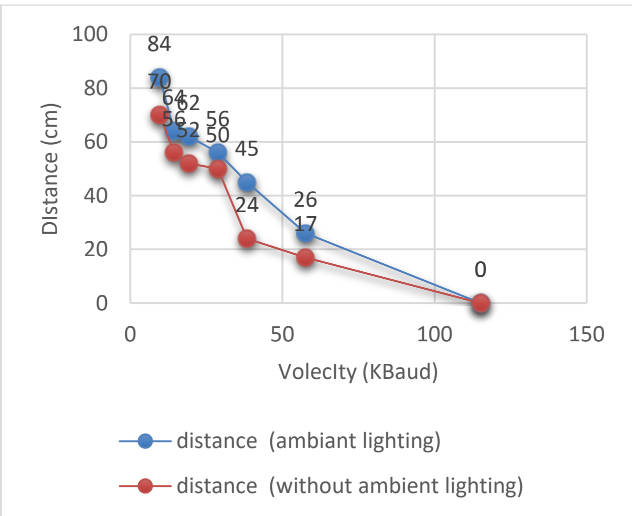

Fig 8. Velocity-distance chart

We can analyze the situation by comparing the number of bad bits transmitted and the transmission distance.

BER: (bit error rate)

$$BER = \frac{incorrectly\ transmitted\ bits}{number\ of\ bits\ transmitted} \tag{3}$$

OOK BER Equation

$$P_{ber} = erfc\sqrt{\varepsilon/2} \tag{4}$$

where ε is signal-to-noise ratio (SNR)

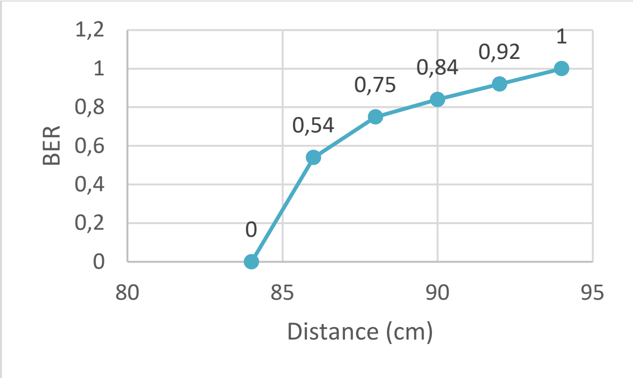

Fig 9. Distance-BER chart without ambient light

As seen in In Figure 9 and Figure 10, BER-Distance chart shows that BER increases as the distance increases simultaneously with and without ambient lighting at 9.6 Kbaud.

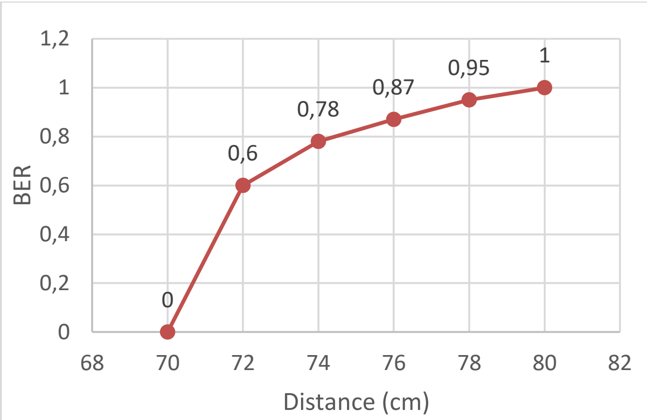

Fig 10. Distance-BER chart with ambient lighting

The setup in the laboratory environment is shown in Figure 11 and it is tested for communication. Figure 12 shows the shape of the synchronized, sent and received signal on the oscilloscope screen.

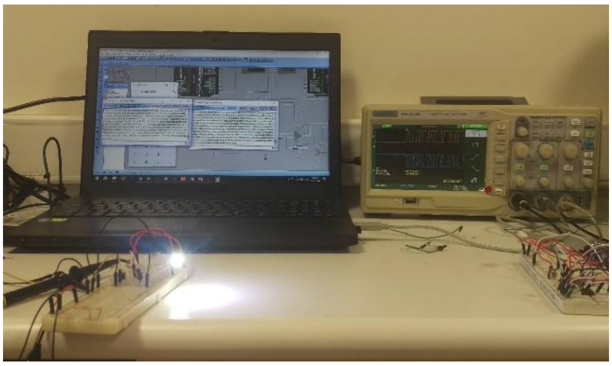

Fig 11. Setup of visible light communication in a laboratory environment

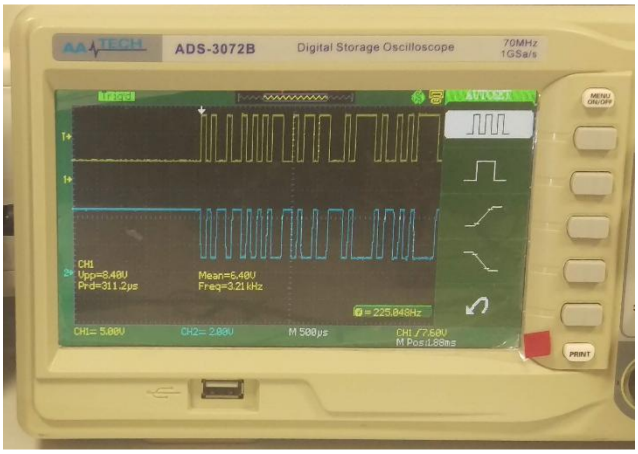

Fig 12. Transmitted and received digital signal display

Figure 13 shows an example of distributing internet data into a room. The internet data, which is transmitted by LED lamp, is also converted into the original data by processing with optical sensors in computers and with cameras in mobile phones.

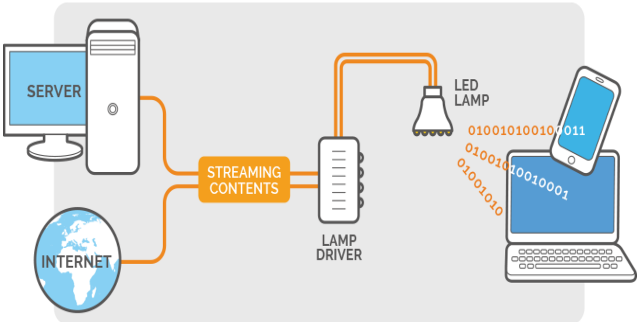

Fig 13. Light transmission of data [20]

4. CONCLUSION

LEDs used in lighting are also used in wireless data transmission [21]. Data can be transmitted to the energy currently used for illumination without requiring any additional power [22].

Today, it is known that many developed countries and the technology companies are in the search of new and alternative wireless communication ways due to the congestion problem in the bandwidth of communication frequency bands. The increasing number of technology users makes the situation more difficult; furthermore, if alternative methods cannot be found it will be inevitable to restrict the number of information and communication technology users (also IOT devices) and the data rates of the users. At this point, even if visible light communication (Li-Fi or VLC) is not a direct alternative to wireless communication, it will greatly ease the burden of intensity in wireless communication especially in closed areas [23]. In future studies, the OFDM structure will be developed in data transmission and multiple data will be sent from a single light source. In this study, it is proved that the data is transmitted via VLS easily and smoothly. Considering the areas of usage, this method has not yet fully entered our lives commercially because the current LEDs used in lighting are not produced for communication.

In the test environment, up to the 144Kb rate is reached using only 1 Watt LED, so it is clear that we can easily reach at 1Gb data rates with more powerful LEDs. Consequently, by accelerating scientific researches in this area and strengthening LED elements in the background, new and alternative methods like VLS method will make great contributions to our country and information and communication technologies.

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Techno-Science *Paper ID: 811665*