PROJECT OF A COMMUNICATION SYSTEM BY VISIBLE LIGHT COMUNICATION (VLC) BASED ON LED LIGHTING

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Abstract: *Communication through visible light (VLC) has been studied as an alternative of wireless communications for indoor environments principally due to recent development of LED's high-brightness and potency which has shown great potential of lighting once they have a long life and a better luminous efficiency compared to the current methods of lighting. To verify the behavior of the optical wireless transmission a prototype was built wis possible to send and receive data through the visible light. Were used 50% and 100% levels of light intensity symbolizing the logical levels 0 and 1 respectively and it resulted in a 25Kbps rate. Were used components in red light region and a signal system of recognition was required to run at different distances and position angles.*

Keywords. *VLC, communication, visible light.*

1. VISIBLE LIGHT COMMUNICATION

Communication through visible light (VLC - *Visible Light Communication*) is based on a transmission data system where the transmitter includes the function of transmitting data such as environment lighting. The receiver is able to distinguish variations of lighting and recover the transmitted data. The use is concentrated in transmission of multimedia messages and location systems in indoor environments.

Recent research shows that the concept of VLC is applied in different areas and some of them are: free optical space, mobile telecommunication systems, signaling traffic, positioning systems, communication between vehicles, communication road to vehicle using high speed camera, communication by RGB signals, etc.

According to Harald Haas (TED, 2011) the radio's waves has a limited capacity beyond the low efficiency and low security because the radio's signals require lots energy that can be intercepted and it causes interference with other electronic devices. The VLC can be an alternative for indoors data transmission. Safety is the biggest advantage of that technology because the light cannot penetrate walls that keep the signal safe at the environment.

There are researches where the transmission rates overpass 3Gbps (FRAUNHOFER INSTITUTE FOR TELECOMMUNICATIONS, 2013). In 2003 at Keio

University in Japan it was buit the Visible Light Communications Consortium (VLCC) that aims to standardize this technology.

2. FUNCTIONING OF THE VLC

The system consists in a transmitter that modulates the supply power of lighting creating pulses of light according to the data that it want to send. LEDs are used in luminaires. The high switching frequency is the most important reason for the choice of LEDs in VLC because the switching speeds of incandescent and fluorescent lamps do not meet the requirements for data transmission. Another advantage of LEDs is the low consumption. The efficiency of a high-brightness LED can exceed 130 lm/W (LEDS MAGAZINE, 2006).

As the the ambient lighting is provided the luminaire should provide adequate lighting potency for the room. Therefore high power LEDs are used. Generally are used Buck converters supply the LEDs which are responsible to maintain constant electrical current. Buck is controlled by PWM step-down converter which converts the mains voltage to a lower voltage for powering LEDs in its output.

At the receiver a photodiode receives the light pulses and converts them into electrical current. Due to the noise existing it is used in the middle optical filters in conjunction with the photodiode (LOURENÇO, 2009) in order to filter the unwanted components that are added to the signal as radiation coming from other light sources. Figure 1 shows a simplified block diagram of a VLC system.

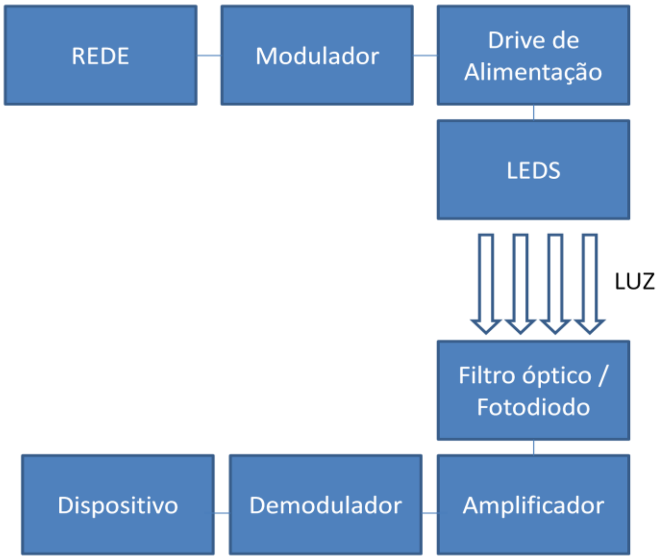

Figure 1 - Simplified Block Diagram of a VLC system

The data to be transmitted comes from a wired network and modulate the power supply (Buck converter) resulting in modulation of the supply current of the LEDs according to the information to be sent.

The data from the network pass through a modulator which is responsible for translating the information into pulses control to the supplay drive. The LEDs are switched according the information to be sent.

3. COMMUNICATION FEATURES

The main characteristics involving the data transmission refer to the transmission media and conditions as the signal is transmitted. In order to determine the spectrum of signal transmission and how it is modulated the limiting characteristics of the process becomes necessary.

a) Spectrum of visible band

Visible light has wavelengths between 350nm to 750nm. The components used in the transmission and reception of VLC system must operate at these wavelengths.

b) Transmission

In VLC the transmission is unidirectional mode. If bidirectional transmission is necessary there will need to use other technology such as IR or radio waves making the system expensive and unusual. By not having a sync signal between the transmitter and receiver it must be asynchronous transmission it has a sync signal embedded in the sent data.

c) Switching frequency

To avoid the flicker effect which is a fluctuation in brightness the switching frequency should be appropriate. For LEDs it is recommended a frequency of at least 150Hz (KEEPING, 2012). Obviously for data transmission is used a much higher rate of switching that is limited by the dynamics of the components and environment in this case the air.

d) Modulation

The light should be varied in order to symbolize the data sent. Different modulation types have different characteristics such as improved timing, noise immunity and simplicity.

Modulations that are being adopted in VLC systems are PPM, BAM, DMT and FSK modulation with 4-PPM suggested by JEITA which is the standard that regulates this technology (POHLMANN, 2010).

e) Interference

The received signal can be direct or reflected. The delay between a direct and reflected light can generate a widening impulses if a impulse extend more than one symbol period it will generate the interference between symbol by limiting the signaling rate (KOMINE; NAKAGAWA, 2004).

As previously mentioned other light sources can cause interference in VLC receiver. A major source of noise for the VLC system is the sun it causes a background current in photodiode that should be kept low to avoid being known by the demodulator circuit as a received bit. For that reason the visible light communication is discouraged for outdoor environments.

4. THE PROJECT

Aiming to create an optical transmission system it was created a prototype in the laboratory. Firstly were used infrared components for the communication because VLC has a very similar behavior as the infrared communication (IR) in terms of spread (MARTINS, 2011). Therefore the IR techniques can be easily adapted to the VLC.

After the functioning of the system with infrared radiation the components were locked and the communication happened in the visible light field.

In the prototype was created a transmitter circuit and a receiver circuit where a byte is sent via a red LED of high brightness received in a photodiode OPT101 (TEXAS INSTRUMENTS, 2003) is shown on a LCD display.

The OPT101 is a monolithic photodiode with on-chip amplifier transimpedance. The output voltage increases linearly with light intensity. The amplifier is designed for a single or dual supply operation making it ideal for a equipment operated by battery. The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered in discrete designs such as leakage current errors, noise pick-up and a peak gain due to capacitance. The internal amplifier converts the electric current generated by its photodiode in the input the voltage is proportional to its output. The responsiveness of OPT101 is seen in Figure 2:

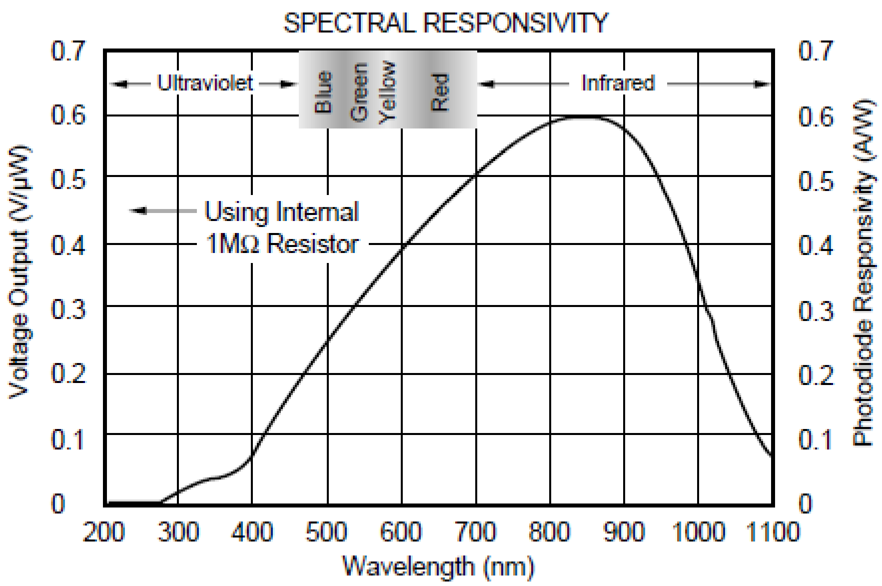

Figure 2 - Spectral responsivity of OPT101 (TEXAS INSTRUMENTS, 2003)

It is noticed that the IC OPT101 has a better response at wavelengths in the infrared region. For optimum performance of the system was chosen a red LED to compose the transmitter because because the responsiveness of the receiver on the red region is satisfactory.

The data is determined by a 4 tactile buttons connected to the transmitter which generates a known value for the procedure test. The binary code in this buttons are sent when given the command "send" by another button.

Differently to the other systems the VLC in this Project the bits communication are made with intermediate levels of light with 100% of brightness to the bit 1 and 50% to the bit 0. This method was used to avoid the light to be fully erased when a sequence of zeros is sent. This way was possible to simplify the modulation but the receiver must be able to differentiate the two levels of brightness which is independent of the distance from the transmitter.

For the Project were used two microcontrollers. The transmitter was PIC16F628A (MICROCHIP, 2005) and for the receptor was used PIC16F877A (MICROCHIP, 2003) due to peripheral available at the microcontroller.

5. COMMUNICATION PROTOCOL

An asynchronous protocol, where the transmitter is sending all time high level signal was created. This technique was used to keep the lamp always lit when there is no data being sent. When the transmitter has data to send, the signal goes to zero, symbolizing the start bit. Each bit has the same duration as defined in the programming of microcontrollers. After sending eight bits of the transmitter puts out again in level 1, symbolizing the stop bit. Figure 3 shows the flowchart of the operation of the transmitter microcontroller.

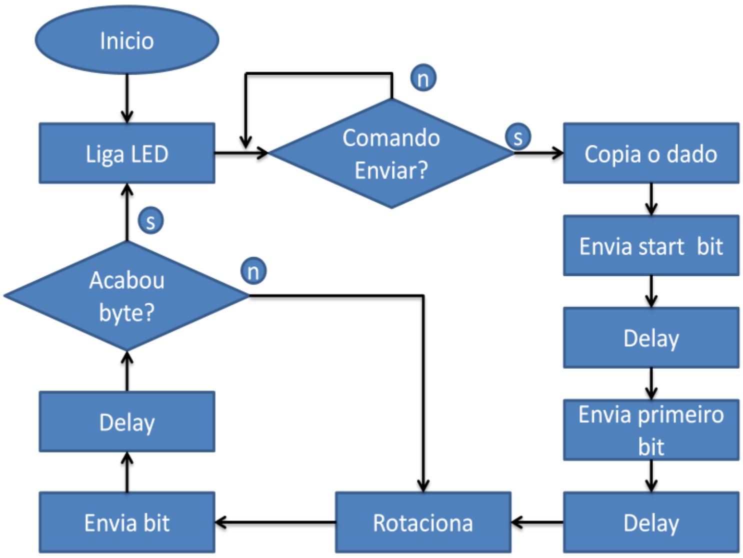

Figura 3 - Fluxograma Transmissor

After switched on the transmitter start the output always keeping the LED on. When it is done the command "send" the data in the 4 buttons input is copied to the output. The eight bits are sent rotating the output buffer for the corresponding intervals of the bit period. After eight bits are sent to the transmitter maintains the output at a high level again.

On the other side the receiver reads all the time the input data. When it checks a start bit the low level starts copying the bits at regular intervals according the period of each setted symbol. After 8 bits copied the receiver sends to the LCD display the received data and waits for a start bit. The flowchart of the functioning of the receiver microcontroller is shown in Figure 4.

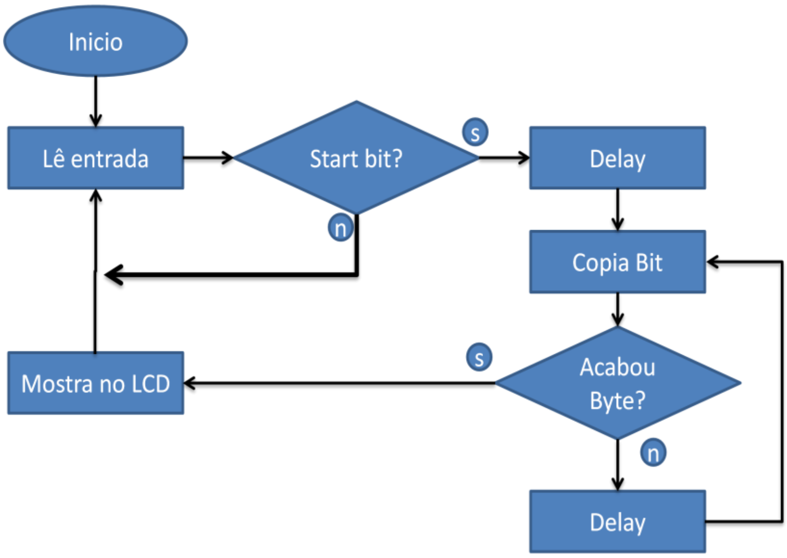

Figure 4 - Receiver flowchart

Figure 5 illustrates the data transmission. The transmitter maintains the high level until the beginning of the byte. When there is a byte to be sent to the transmitter it requires a zero level output for a bit period. When the receiver noticethe start bit it waits a period and a half for a first reading this shift ensures that the receiver will copy the bit at the half signaling period avoiding errors.

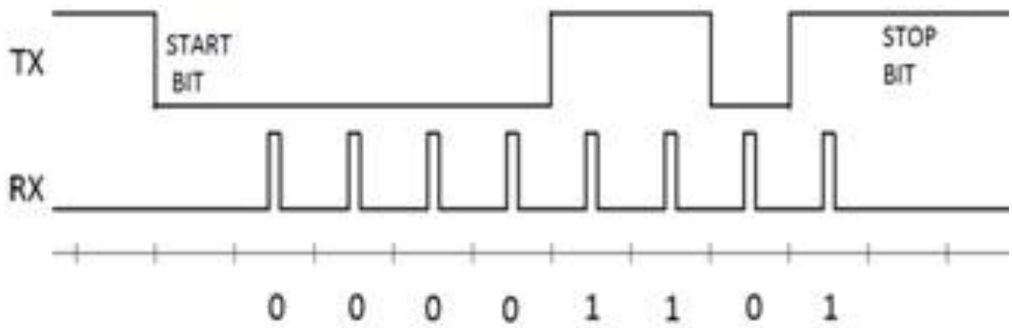

Figure 5 - Transmission of Data Format

There is no implemented detection mechanism or correcting errors in this algorithm. Later for a better functioning system a routine of error detection will be required because the communication system by visible light suffers a significant interference.

6. CIRCUIT

At the transmitter system was mounted a circuit where the LED is switched by a transistor. With the saturation of the transistor a resistor is alloated in parallel with the LED's resistance increasing the current. When the transistor is cut off the current in the LED is shining less. At a high frequency the lowest brightness LED becomes imperceptible but the receiver is able to understand this variation.

In the receiver circuit the output voltage on CI OPT101 is compared with a reference voltage. The output comparator is read by the microcontroller as a bit "1" or "0". The reference voltage is set by the PWM signal filtered by a lowpass filter. The reference value coming from the filter should be slightly lower than the high signal of the photodiode. The output of the comparator will be zero always when the output voltage of the photodiode is less than the reference signal. The LM339 was used as comparator circuit (FAIRCHILD, 2012).

When the system is turned on the receiver reads the analog signal from the photodiode and take it as the highest level. Internally, the microcontroller calculates a value less than 0.5 volts above the voltage read. The calculated value is then manipulated and serves as duty cycle for generating a PWM signal. After filtering, the PWM signal generated becomes a constant voltage exactly 0.5 volts less than the value read from the photodiode during system startup. Figure 6 shows the simplified circuitry of the transmitter and receiver:

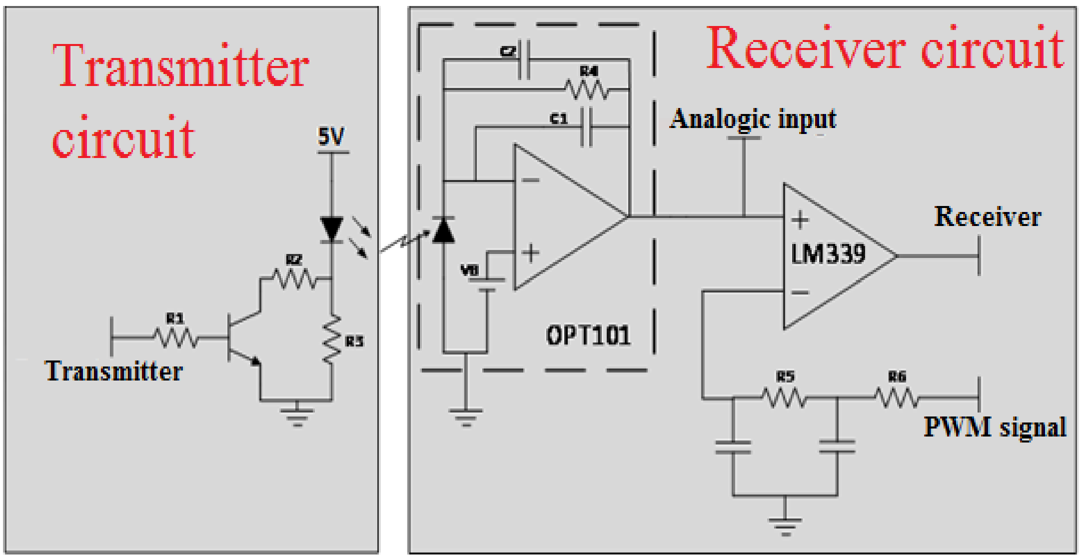

Figure 6 - Simplified circuit of the transmitter and receiver

7. RESULTS

Previously to validate the idea infrared components were used. With a infrared communication the shortest bit achieved was 68μs meaning a rate of 14.7Kbps.

Through the direct connection between the transmitter pin and the receiver pin was achieved a rate of 500Kbps (2 µs), demonstrating that the created algorithm is functional and that the limiting speed are on available devices used.

The maximum distance achieved with the infrared components was 6cm due to simplicity of the circuit and the technical characteristics of the devices.

With new components dedicated to visible light was achieved a rate of 25Kbps (42µs per bit). The maximum measured distance was 25 cm at bigger distances the light power received was insufficient.

Thanks to the position recognition system it could vary the location of the receiver and maintain the communication. But for very small distances the signal received by the photodiode is very high and the difference between the levels becomes imperceptible to the receiver causing data losses. Another problem is the need to align with the transmitter. Even a short distance the signal from the transmitter can not be received if LED and photodiode are not aligned properly.

Figure 7 shows the experimental circuit used. The transmitter circuit and the receiver circuit were mounted at the same breadboard then the transmitter LED was connected separately to allow a variation of the distance during testing. The connections that connects to a upper circuit to the lower circuit circuit are the power busses. These connections become dispensable if the circuits are supplied by independent sources.

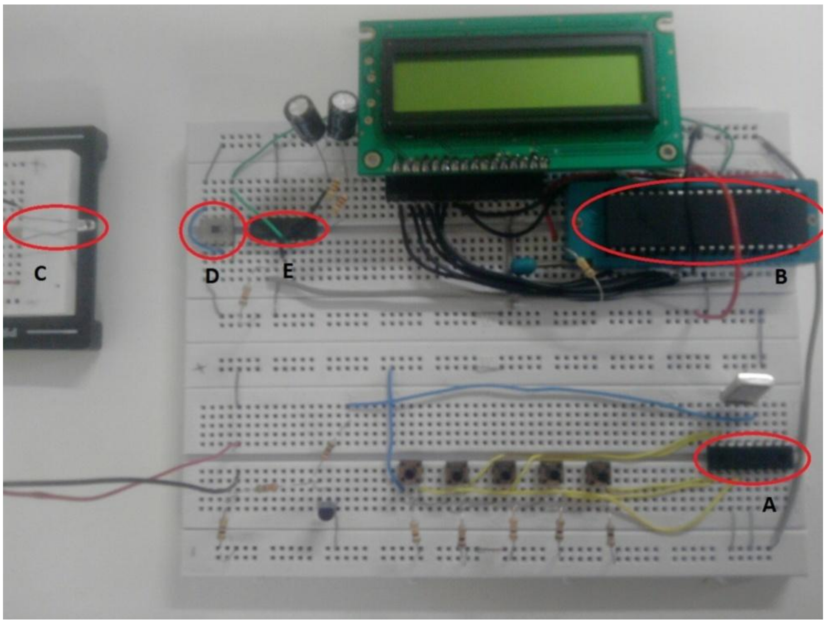

Figure 7 - Circuit mounted on the breadboard, where: A) PIC transmitter, B) PIC receiver C) Red LED D) Photodiode Amplifier E) LM339

Figure 8 shows the signals received at the photodiode. For this test squares were generated at the transmitter signals with frequencies of 1KHz and 50KHz, the distance between transmitter and receiver was 15cm.

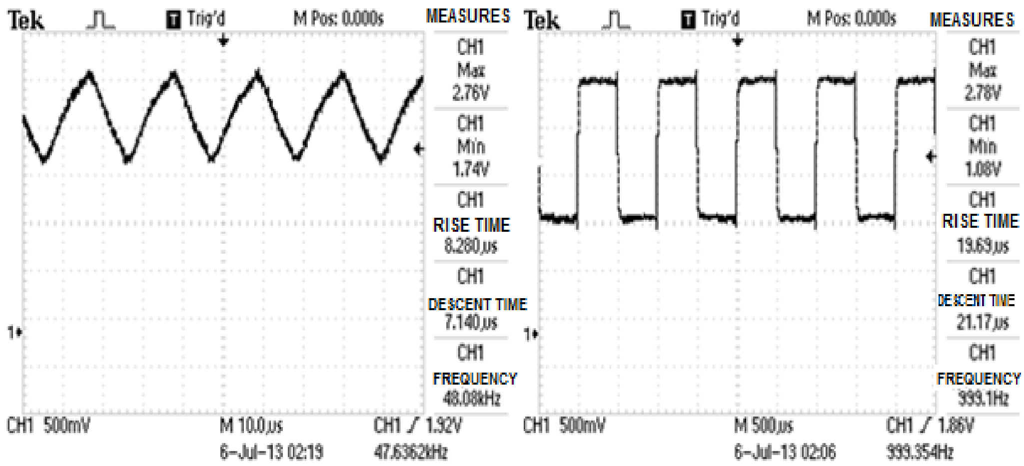

Figure 8 - Received by the photodiode signal with 50KHz and 1KHz

It is observed in figure 8 that in higher frequencies the received signal has a time modification due to the rising and descente of the components. With very high transmission rates the deformation in the signal may cause read errors at the receiver limiting the communication speed. At lower frequencies the received signal is substantially equal to the generated signal at the transmitter.

8. CONCLUSIONS

It is concluded that the VLC technology can be implemented as an alternative compared to other wireless transmission technologies. Applications for radio frequency are not well seen in environments like hospitals and airports because it may cause interference with other electronic devices differently visible light communication.

In this paper the purpose of transmitting a data through an optical medium was achieved. With the use of the infrared transmission components it was possible to perform the transmission and capture of data at a rate of 14.7 Kbps. Later with the migration of the entire circuit for the field of visible light a rate of 25Kbps was observed. The positioning system has been shown to be functional but for some distances and misalignment between transmitter and receiver the transmitter signal was lost.

In the future a Buck converter will be built to be a source for the LEDs of the transmitter and at the receiver will need more careful with the noise. The set of buttons on the transmitter and the LCD display on the receiver will be exchanged for interfaces that will make the communication of the equipment with the computers using microcontrollers with USB or Ethernet. There will also be added algorithms for creating and parity detection.

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