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Wearable Circuit in Plastic (CiP) Optical Transmitter for Health and Sport Applications

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Abstract*—Wearable devices that is used in different applications such as health and sport is developing rapidly. This paper presents a design and implementation of a flexible low power and low cost on-off keying transmitter for optical wireless communication. The implementation is done using circuit in plastic (CiP) technology. The comparison between using printed circuit board (PCB) and circuit in plastic is presented. This transmitter is suitable to be used as a wearable device for sport and health applications that need small and flexible transmitter to be moved according to a specific situation.

***Index Terms*—Circuit in Plastic, Flexible optical wireless transmitter, Wearable devices.**

I. INTRODUCTION

The legislative pressureon the electronic circuits manufactures is increasingfor designing circuits with low power, low cost and can be recycled easily to safe damage to the environment. CiP is the new technology that causes minim impact onenvironment when recycling it compared with the current PCB technology.This paper presents a design and implementation of an optical wireless transmitter based on using LEDs as light sources and using the circuit in plastic technology. The transmitter is based on On-Off keying modulation type. The CiP is a new technology designed and implemented in school of Engineering, Center for Wireless Monitoring and Applications (CWMA) at Griffith University. A plastic substrate is used for placing the circuit components. The design and the tracks are drawn using Altuim designer 10 software. These conductive tracks are screen printed and a thermal binding cover sheet of the same material is added. This technology is proven to be viable by thermal and mechanical modeling experiments.

A Microcontroller circuitis implemented using this technology and has proven to be worked over 4 years with a water proof and mechanically reliability. Surface mount Components must be used with CiP. The conductive tracks are screen printed using silver ink. The plastic material is polycarbonate with transparency, minimal water uptake and high thermal transitiontemperature (180 C^{o}). Special glue is used to stick the SMD components (Surface mounted devices). A mechanical reliability and thermal properties are proved the CiP feasibility in [1], [2].

Fig(1) shows Circuits in Plastic demonstration kit that implemented at Griffith University which isbased on a counter circuit to turn on the connected LEDs in different sequences. This is a new technology that has been developed to reduce both production cost and end-of-life waste problem from which traditional Printed Circuit Boards suffer. It is fully RoHS and WEEE compliant and easily allows the production of waterproof circuits. This technology is invented by Griffith University.

Fig.(1): CiP demonstration kit that invented by Griffith University [1]

This paper is organized as below: In section II the system design is presented. Experiments and results are discussed in section III. Finally in section IV the conclusions and the draw for the future work are presented.

II. SYSTEM DESIGN

Light was chosen as medium for transmission because it has better propagation characteristics in water compared to electromagnetic waves assuming that the transmitter is used in swimming [3]. The visible light produces the least absorption. The green light wavelength is the most superior one and was therefore chosen in [4] implementation and is also going to be used in this paper.

Another advantage of light is that it allows for higher communication speeds in general, however, one must understand that there are a lot of factors influencing the link when communicating via light. Line-of-sight between transmitter and receiver is almost mandatory as there would be hardly for communication to be established due to the significant high path losses in non-line-of sight (NLOS) components. This means that the light sources need to be arranged accordingly to ensure as much LOS as possible, especially with applications that needs to change the optical transmitter all the time [5].

A circular ring can cover 360° which provide ahigh possibility of LOS.Another parameter influencing the coverage is the viewing angle of the LED meaning that the higher it is the fewer LEDs are needed(given equal output power).

Noise is another thing influencing the link very strongly. Ambient light for example is a huge impairment up to the point where the signal might not be distinguishable from it anymore. Thus, to make the signal detectable at the receiver, it is necessary to have sufficient output power from the light sources. Modulation of the signal improves the distinction between signal and noise even furtherbecause the receiver is tuned to the modulation scheme and can neglect everything else. This was done using the simplest modulation technique (OOK). Different and more complex modulation techniques can be used. However, the focus on this paper is on the CiP technology. The transformation of the modulated electrical signal to a light signal consists of two major components. A transistor which acts as a switch and a Light Emitting Diode (LED) which is controlled by the switch.For the transistor a Metal-Oxide-SemiconductorField Effect Transistor (MOSFET) was chosen because of its superior attributes for (low switching/input current, voltage driven).The only important parameter is the drain current which is going to be determined by the number and type of LEDs used. LED requirements are depending on the underwater applications. However, generally the requirements are:

- green wavelength region
- high luminous intensity(about 3 cd-12 cd)
- viewing angle as wide as possible(minimum 30°)
- forward voltage below or equal 3.3V

Table I shows the comparison between the three light sources (LEDs) suggested in this paper[6].

Table I: The comparison between the three light sources

Important Parameters	LTT66G-BBDA	LTG6SP-CBEB	OVLFG3C7
Luminous Intensity	2.24cd-5.6cd	3.55cd-11cd	3.1cd-5.2cd
Viewing Angle	55°	120°	30°
Forward Voltage	2.9V-3.7V	2.6V-4.1V	2.6V-4.0V
Forward Current	5mA-50mA	30mA-750mA	20mA-50mA
Price	$0.52	$3.28	$0.60

Osram's LTT66Gwas chosen because it has the best combination of luminous intensity, viewing angle and forward current. Although Osrams's LTG6SP is brighter and has a wider viewing angle but its current consumption and price are too high.

The optical transmitter proposed in this paper is based on using six green LEDs with on-off keying modulation technique at the transmitter side and direct detection at the receiver side. The(MMBF170LT1, MVBF170LT1) Power MOSFET transistor 500 mA, 60 V, N−Channel SOT−23 is used as switch transistor to turn the LEDs on and off [7].All the components used in the (CiP) must be surface mounted components (SMD) due to that these components are going to be pasted on the plastic using a special paste.

A pull down resistor was added to the gate of the transistor to ensure fixed logic levels, for example during start up. The value of the current limiting resistor were determinedby the following equation:

$$R_{LED}=\frac{V_{cc}-V_{FLED}}{I_{maxLED}}$$

Where VFLED denotes the forward voltage of the diode and Imax is the maximum current that is going to flow. Give Imax, LED =30mA yields the RLED=10 Ω. All the resistors pasted on the plastic are the 0603 SMD package.

Fig (2) shows the block diagram of the proposed optical wireless transmitter and fig (3) shows theoptical transmitter that is designed using Altium PCB designer 10 the top is the Altiume designer and the bottom is the implemented optical transmitter circuit that is implemented using CiP technology.

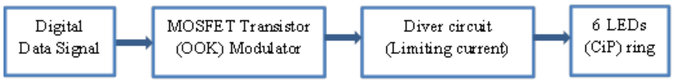

Fig.(2) Block diagram of the proposed optical transmitter

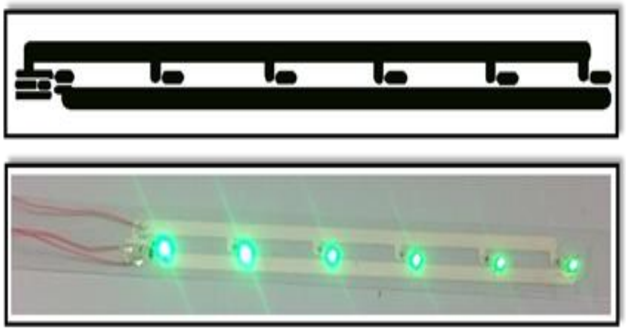

Fig.(3) The optical wireless transmitter. The top is the Altium designer circuit and the bottom is the CiP implemented optical wireless transmitter.

III. EXPERIMENTS AND RESULTS

Experiments are conducted in order to test the transmitter rang. The transmitter is tested with the receiver that is designed by the author in [4]. Fig (4) shows the results. The receiver is based on the direct detection (DD).The received data was error free for around 78 cm in water. The data is sent using a wearable wireless sensor that is designed by Griffith University [8]. The BER is calculated by comparing the savingdata in the transmitter and the receiver. Some digital modulation and digital signal processing techniques can be used to increase the distance if the application needs larger distance or brighter LEDs can be used.

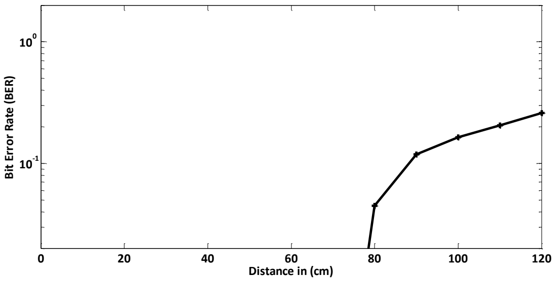

Fig. (4) Bit error rate with distance for the CiP optical transmitter

IV. CONCLUSION

A design and implementation of a flexible optical wireless transmitter based on six LEDs based on circuit in plastic is presented. The advantages of implementing the transmitter in a CiP are the water proof, low cost and environment friendly compared with the PCB. All the components must be SMD when using CiP. The modulation used is OOK at the transmitter and DD at the receiver. The testing results for the transmitter showed that the data are error free for 78 cm in water. The communication range can be increased depending on the target applications by using some digital signal processing techniques or using brighter LEDs.

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