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Design of Cranial PPG Sensor for DC and PWM Excitation in Near Infrared Spectroscopy

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Abstract: Functional near infrared spectroscopy is the noninvasive optical technique now a days used for brain mapping. Brain functional activity can be detected by using the optical source detector pair. Photoplethysmography sensor is designed to measure the cranial PPG. Cranial PPG (CPPG) is the signal which is obtained by placing the sensor on the cranial surface. To record the Cranial PPG signal light with sufficient power and wavelength is required so as to penetrate the light through skull and measure the blood flow change in the vessels which provide the blood supply to the brain. Source excitation plays major role in capturing the CPPG signal. DC excitation is not sufficient to penetrate the light through the skull. AC excitation plays major role in the CPPG sensor. This work deals with the acquisition of CPPG signal by placing the sensor on forehead. The AC excitation of frequency in the range of 1 to 2 MHz with supply voltage of 5 V and current of 10 mA can able to penetrate the skull and shows significant blood volume change .

Key words*:* PPG (Photoplethysmography), Reflectance type, Cranial PPG (CPPG)

1. INTRODUCTION

Hemodynamic response related to neural activity is measured by NIRS system. During the functional activity of the brain the blood flow is increased. NIRS detects the neural activity in a specific brain area by sensing the light absorption for the oxygenated and deoxygenated blood. Signals measured at 570nm originates from blood volume changes. For measurement of changes in hemoglobin oximetry intrinsic signals are in the range of 600 to 630 nm . Advantages of NIRS system are freedom of movement, better temporal resolution, easy to use, test young infant, cost of operation is cheaper . NIRs and FMRI are closely aligned techniques as both techniques measure the increased in blood flow due to functional brain activity [1,2,3].

The neural activity in the brain is closely linked with the changes in blood flow and blood oxygenation. The consumption of energy is increased during the neural cell activity .The local response to this energy utilization is to increase blood flow to regions of increased neural activity, which occurs after a delay of approximately 1–2 seconds. This leads to changes in local cerebral blood volume and the concentration of oxyhemoglobin that are detected using plethysmography effects [4]. PPG offers several advantages over other in-vivo optical methods .PPG is measured by using optical sensors. Optical sensors consumes less power and requires little maintenance. Optical sensor is an ideal ambulatory device can be powered by a battery pack. The PPG signal contains information related to cardio-pulmonary system. PPG measures various clinical parameters like heart rate, respiratory rate, and respiratory induced intensity variations-

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RIIV can be obtained from the PPG signal. PPG can be used in analysis of neurologically induced skin perfusion changes, brain mappings [5].

NIRS is the optical, non invasive techniques for detection of brain functional activity . NIR spectrum uses optical window (630-1300nm). The investigation of metabolism in the cerebral cortex is done by penetration of the light in the cranial mask. The increased and decreased blood flow changes in tissue oxidation and changes the tissue characteristics. NIR light passes through the head it interacts with the tissue and photos scattering takes place in tissue [6]. Partial absorption of the photons depends upon the amount of deoxyhaemoglobin and oxyhaemoglobin in tissue. The absorption and scattering of photon changes as per the brain functional activity and hence affect the detected light. By measuring the blood volume change, hemoglobin concentration and amount of scattering light the brain activity can be detected [7].

The FNIR system is based on the beers and Lambert law.

The intensity of light after the tissue interaction is given by:

$A = \in \times c \times d$ ----------Equation 1

A = Absorbance

c = Concentration of absorbing molecule

d = Distance between light source and detector

Equation 1 is used for detection of concentration change. In optical brain mapping (fNIR) two different wavelength of near infrared light range and the relative change in the oxy and deoxyhaemoglobin is used for the detection of brain function [8].

2. CPPG SENSOR

In present work reflectance type PPG sensor is designed. Two different PPG sensors are designed one with 660nm and other with 860nm.

Details of Sensor

The reflectance type optical sensor is designed with two LEDs (660 nm(red LED) and 860 nm(IR LED)) and one OPT 101 as detector placed adjacent to each other. To reduce the effect of ambient light noise signal the polyurethane rubber is used . The current limiting resistors are used to limit the current passing through the LEDs. The light rays from the LED's are reflected and scattered from the skin, tissues and the blood vessels are measured by the detector OPT 101 [9]. Blood flow variation in the vessel shows amplitude variation in the PPG signal. Figure1 shows the CPPG sensor.

3. SYSTEM BLOCK DIAGRAM:

As the output of the sensor is low in amplitude for recording and acquisition . The amplification of the signal is done by using AD620 amplifier [10]. The signal conditioning circuit is used for signal amplification and for noise removal, after signal conditioning the analysis of CPPG signal is analyzed and proceeded. Capacitive coupling is used to pass only AC signal and notch filter to remove the ac mains noise signal. The signal conditioning blocks are shown in figure 2.

Signal is acquired for DC as well AC excitation. The observed signal is recorded on DSO.

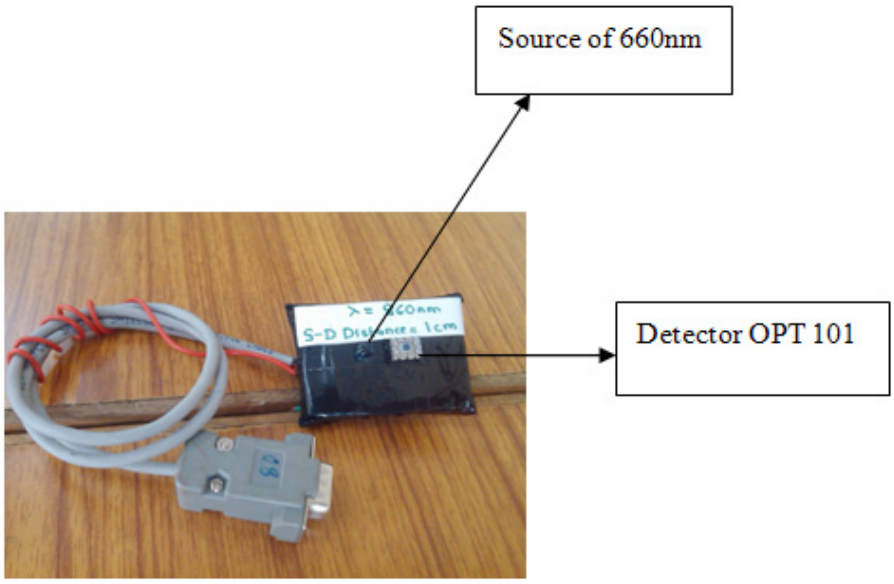

Figure 1: CPPG sensor

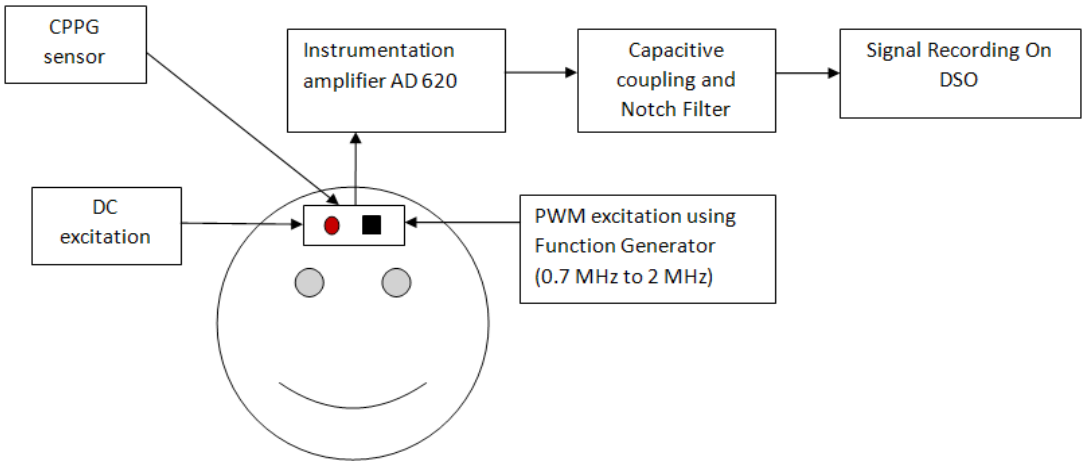

Figure 2: System block diagram

4. DATA COLLECTION AND RESULTS:

The recording of the PPG signal was done by placing the sensor on forehead. Specimen has to be steady and not suppose to move the head.

1. Signal recording on forehead with DC excitation.
2. PWM excitation (AC) with 5 Volt and frequency 0.7 MHz to 1.7 MHz.
3. Recorded signal is analyzed in Matlab.

Results of DC and AC excitation:

Results shows that with DC excitation no pulsatile signal is observed. But the signal is obtained by AC excitation using frequency in the range of MHz. figure 3 shows the result of DC and AC excitation.

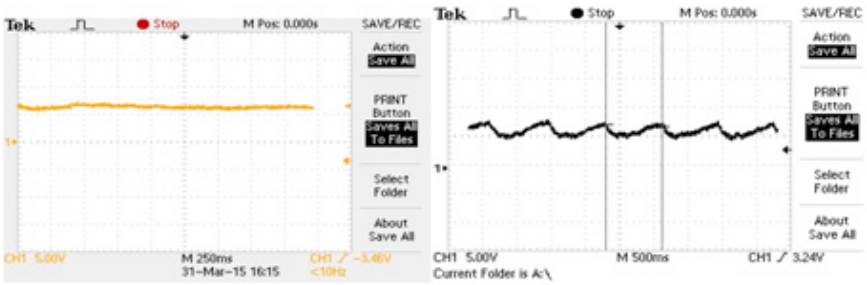

Figure 3: Result of AC and DC excitation

Results of Eye Blinking

Using PWM excitation the CPPG with eyes closed and with Eye blinking are recorded. Results show that amplitude of CPPG increases during eye blinking. Figure 4 shows the CPPG signal for eye blinking.

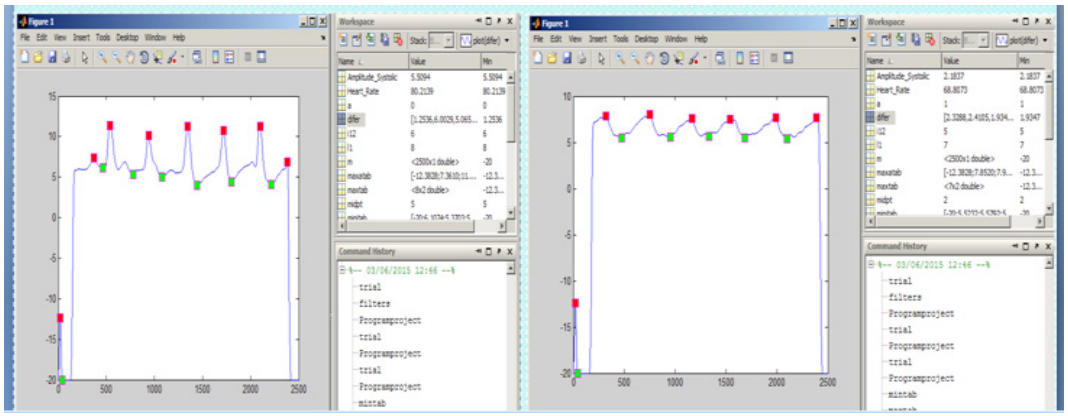

Figure 4: CPPG with and without eye blinking

5. CONCLUSION

The designed reflectance type PPG sensor is tested for AC as well as DC excitation. It is observed that using AC excitation to measured the signal on forehead the frequency is in the range of 0.72MHz to 1.268 MHz. Depth of penetration is more for IR LED than RED . Response time of IR LED is more than clear RED LED. Using DC excitation it is observed that the signal is unstable and nonperiodic on forehead. Clear PPG signal is obtained on forehead with AC excitation. This CPPG can be used for brain mapping for functional activity detection.

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