

Applications of Finger Photoplethysmography

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Abstract

Optical sensors that use photons as sensing elements are increasingly becoming important and relevant in the field of non-invasive diagnostics. The reason is that they have simple construction, easy to use and relatively inexpensive in comparison with tools such as EEG, MRI and FMRI that can be used for research with much investment. Among the many optical sensors available, the PPG (photoplethysmography) sensors, are capable of measuring blood volumetric changes in the subcutaneous vessels. Objective is to diagnose parameters like heart rate, respiratory rate. Real time PPG signal is obtained from sensor and heart rate is calculated from it. Reflectance type of PPG sensor has been used to diagnose the parameters. Detailed analysis of frequency spectrum (FFT) of PPG signal shows a cardiac peak around 1Hz corresponding to 60 pulsations a minute and respiratory peak around 0.25 Hz corresponding to 15 inspiration/expiration cycles per minute.

Keywords: Photoplethysmography, optical sensors, Heart rate, Reflectance PPG sensor, Respiratory rate, frequency spectrum.

1. Introduction

Related to measurement of blood flow is the measurement of volume changes in any part of the body that results from pulsations of blood with each heartbeat. Such measurements are useful in diagnosis of arterial obstructions as well as for pulse wave velocity measurements. Instruments measuring volume changes are called plethysmographs and measurement of these volume changes is called plethysmography.[4] The measurement of these blood volumetric changes in the skin perfusion by means of PPG depends on the fact that blood absorbs infrared light many times more strongly than the remaining skin tissues. [1]

There are different types of plethysmographs like strain gauge, impedance, capacitive and photoelectric plethysmograph (PPG). Photoplethysmography operates on the principle that volume changes in the limb or digit result in changes in the optical density through and just beneath the skin over a vascular region. A light source in an opaque chamber illuminates a small area of the fingertip or other region to which transducer is applied. Light scattered and transmitted through the capillaries of the region is picked up by the photocell, which is shielded from all other light. As the capillaries fill with blood, the blood density increases, thereby reducing the amount of light reaching the photocell. The result causes resistance changes in the photocell that can be measured on wheatstone bridge and recorded.[4] Main applications of PPG include monitoring of oxygen saturation, and in measuring the ankle-brachial pressure index (ABPI) to detect peripheral vascular disease (PVD).[1]

Advantages of PPG

PPG offers several advantages over other in-vivo optical methods like Laser Doppler flowmetry (LDF). PPG uses inexpensive optical sensors, which are rugged and needs less maintenance. Since it consumes very less power, it

is an ideal ambulatory device. PPG signal contains rich source of information related to cardio-pulmonary system. A range of clinically relevant parameters like heart rate, respiratory rate and respiratory induced intensity variations (RIIV) can be obtained from PPG signal. PPG can be used in study of neurologically induced skin perfusion changes, asymmetry of brain etc. [1]

Different sites for measuring PPG

Photoplethysmograph are commonly worn on the finger. However, in cases of shock, hypothermia, etc. blood flow to the periphery can be reduced, resulting in a PPG without a discernible cardiac pulse. In this case, a PPG can be obtained from a pulse oximeter on the head, with the most common sites being the ear, nasal septum, and forehead.

2. Sensor Design

The sensor required for capturing PPG signal from finger is as follows-

1. Square shaped box has been used as an enclosure.
2. Photo source (LED) and photo detector (LDR) are soldered on small piece of PCB. Shielded cable is used for supply of photo source and LDR connection.
3. Holes on box of the size same as that of LDR and LED are made.
4. PCB is fitted onto the box and packed by using sponge.
5. Velcro strip is attached to the PPG enclosure for reduction of ambient light interference.

Figure 1 shows the reflectance type of PPG sensor. If PPG is obtained from reflected light, source and detector will be housed on same plane as shown in figure

1. Earlier works have concluded that optimum distance between source and detector in reflectance type lies in the range of 4-5mm. This type of sensor can be used over the skin on any part of the body.[3]

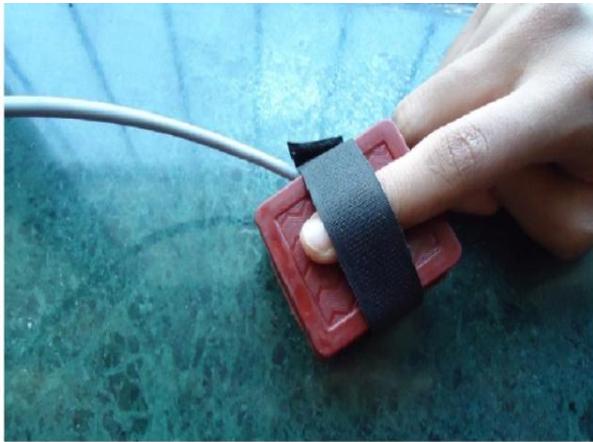


Figure 1: Reflectance type PPG sensor

3. Signal Conditioning Circuit

The signal conditioning circuit for PPG is shown in the figure 2.

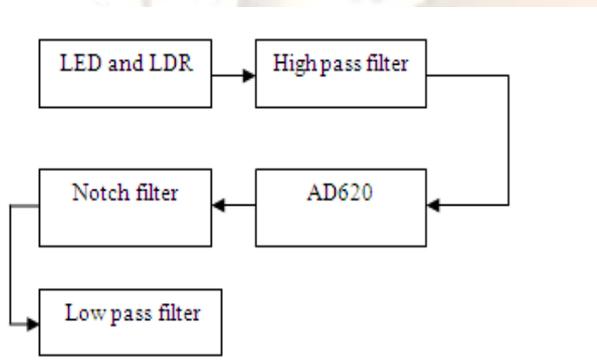


Figure 2: Signal Conditioning Circuit

LED of 575nm wavelength is used and resistance of LDR is 10kΩ. The output from the sensor goes to high pass filter whose cut off frequency is set to 0.5 Hz. The output of high pass filter goes to AD-620 for further amplification. Gain of AD-620 is adjusted to 34. After the amplification, the output of AD620 goes to notch filter. This notch filter is combination of multiple feedback (MFB) filter and inverting adder. [2]

Gain of bandpass filter is given as [2]-

$$A_v = - (R_2/R_1) \tag{1}$$

Frequency for bandpass filter is given as

$$f_o = 1/2 * \pi * C * (\sqrt{R_1 || R_3 * R_2}) \tag{2}$$

Output of notch filter is given to low pass filter whose cut-off frequency is set to 16Hz. Supply given to circuit is ±5V. The total gain of the circuit is 1000.

4. Experimental Results

Figure 3 shows the PPG signal on digital storage oscilloscope (DSO).

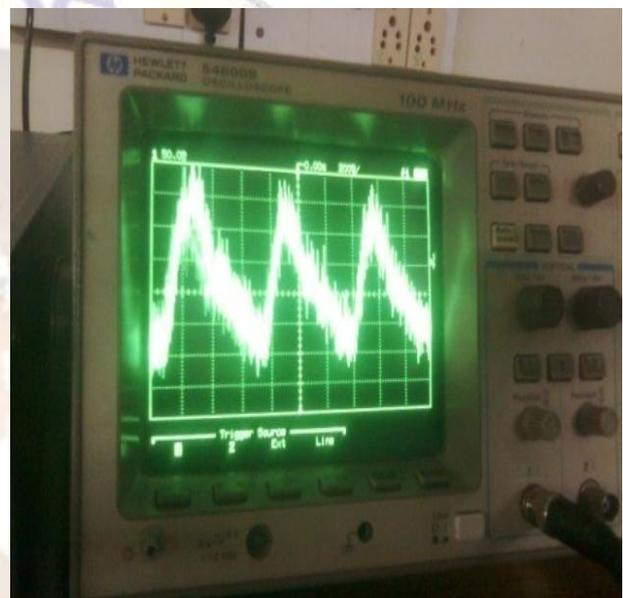


Figure 3: PPG signal with artifacts

There are two important characteristics of PPG AC pulse waveform described by Hertzman and Spealman. The appearance of pulse is defined as two phases- anachrotic phase being the rising edge of the pulse and the catachrotic phase being the falling edge of the pulse. The first phase is concerned with systole and the second phase with diastole and wave reflections from the periphery. Dichrotic notch is usually seen in catachrotic phase of subjects with healthy compliant arteries. Figure 3 shows PPG signal with artifacts due to ambient light interference. Figure 4 shows the PPG signal with no artifacts.

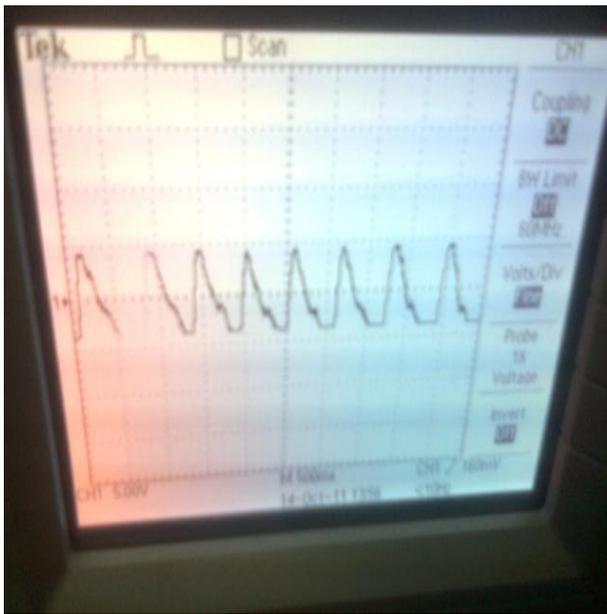


Figure 4: PPG signal free of artifacts

Artifacts in PPG signal can be minimized by attaching velcro strip around the finger, minimizing the ambient light interference and proper placement of subject's finger on the sensor. PPG signal was observed for ten patients and heart rate was verified with heart rate meter. Figure 4 shows the dichrotic notch in PPG signal.

5. Observations

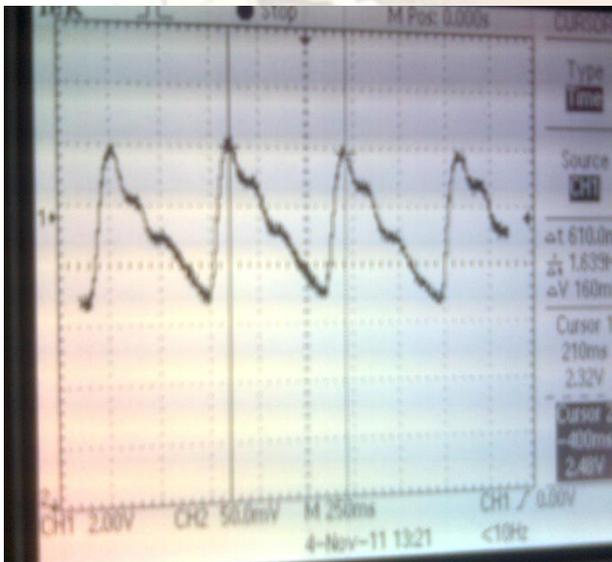


Figure 5: PPG of subject 1

Figure 5 shows the PPG of subject 1 (female). Time period of one cycle is 610msec. So, pulse rate of subject 1-

$$\text{Heart rate} = 60/\text{Time period} \quad (3)$$

$$\text{Heart rate} = 60/0.61 \text{ sec}$$

$$= 98\text{bpm}$$

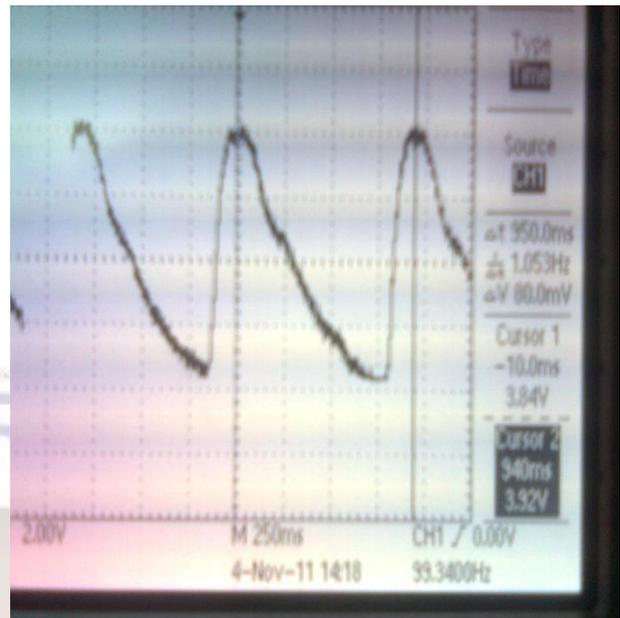


Figure 6: PPG of subject 2

Figure 6 shows the PPG of subject 2 (female). Time period of one cycle is 950ms. So, pulse rate of subject 2-

$$\text{Heart rate} = 60/\text{Time period} \quad (4)$$

$$\text{Heart rate} = 60/0.95 \text{ sec}$$

$$= 63\text{bpm}$$

Frequency spectrum of PPG signal

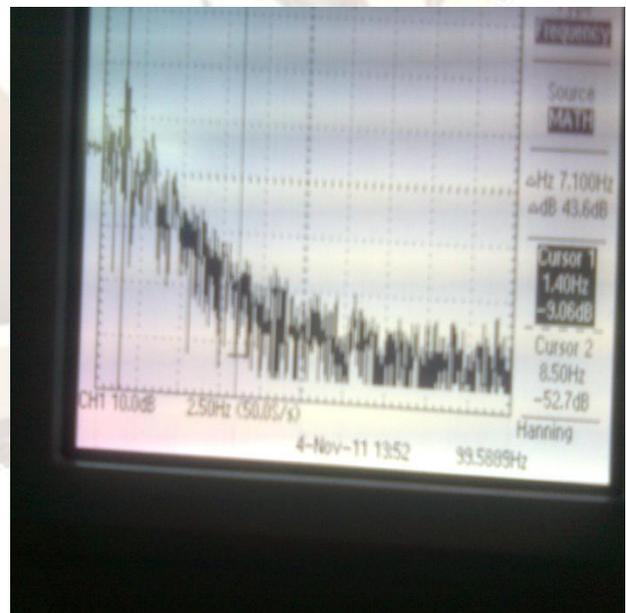


Figure 6: FFT of PPG signal

Figure 6 shows FFT of PPG signal observed on digital storage oscilloscope. By frequency analysis of PPG signal, one can observe that cardiac peak is around 1 Hz corresponding to 60 pulsations per minute and respiratory peak around 0.25 Hz corresponding to 15 inspiration/ expiration cycles per minute.[1]

6. Conclusion

The technique of photoplethysmography has demonstrated its great potential for use in a wide range of clinical measurements. A main focus has been the assessment of cardiovascular system. PPG based technology can be found in a wide range of commercially available medical devices for measuring oxygen saturation, blood pressure, cardiac output, assessing autonomic function and also detecting peripheral vascular diseases.

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