A NOVEL APPROACH FOR DESIGNING OF PULSE TRANSIT TIME MEASUREMENT DEVICE FOR PHYSIOLOGICAL APPLICATIONS

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***ABSTRACT*:** *In the present paper an approach is presented to design a pulse transit time measurement device and to develop multiple clinical application incorporating single hardware. Pulse Transit Time (PTT) is the time taken by a pulse wave to propagate from heart to a specified point on the body where the reading is taken. Currently, PTT can only be performed with complex acquisition systems in study centres. PTT can be measured as the difference between times it takes for the pulse pressure wave to travel between two arterial sites. PTT measurement device is an instrument which measures the PTT continuously and non-invasively. It uses two reflectance photoplethysmograph to retrieve pulse pressure wave in form of electrical signal. The blood pulse wave in the form of a voltage signal is derived at two points, one at finger and the other at wrist. The time difference between two corresponding peaks gives us the pulse transit time (PTT). This signal is amplified and filtered by analog circuits and it is also converted in digital form by analog to digital converter for further calculation and analysis with the help of MATLAB tool. PTT has various clinical applications in assessing few vital parameters in an easy and non-invasive way. As well as it can be useful for cardiac and vascular measurement.*

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Keywords— Pulse transit time, Photoplethysmograph, Electrocardiograph

I: INTRODUCTION

During the recent years there has been rapid development in healthcare market. In developing countries, healthcare is a very vast and growing market. It is a growing concern among a people to have check on their health regularly without spending too much time and money. People like to have a check on their health status themselves. So this issue can be solved by usage of so many portable, cheap, reliable and user friendly health monitoring devices. Nowadays every product should have to be with multiple features and applications. Pulse transit time is a physiological measure which has shown capabilities to address numerous clinical applications. so here an approach is present to develop PTT measurement device.

1.1 PULSE TRANSIT TIME

Pulse Transit Time (PTT) is the time taken by a pulse wave to propagate from heart to a specified point on the body where the reading is taken. Pulse Transit Time (PTT) can be often used as a substitute for the pulse wave velocity (PWV). PWV is not an easy parameter to be measured at a clinical level. The Blood Pressure (BP), cubage and flexibility of arteries are directly related to the Pulse Wave Velocity (PWV) [1]. PTT is non-invasive and a simple measurement. PTT can be measured as the difference between times it takes for the pulse pressure wave to travel between two arterial sites.

It can be measured by use of both an Electrocardiograph and a photoplethysmograph or it can be measured by the use of photoplethysmograph at two different arterial sites. An ECG machine generates a curve based on the depolarization of the heart while the oximeter measures the pressure wave, or pulse, at any arterial site. A value for pulse transit time is given by calculating the difference in time between the peak of the R wave from the ECG and the peak of the pressure wave from the oximeter or by calculating difference in time between the peaks of two pressure wave from the photoplethysmograph. PTT has shown its capabilities in very broad area of clinical applications. Blood Pressure changes, Heart Rate and the compliance of the arterial walls, and so on influence the PTT. [2]. The PTT and BP are inversely related and the relation stands steady over a certain period of time for an

individual [3]. It can be also helpful for measurement of respiratory effort, detection of micro arousals and monitoring stress.PTT has shown its capabilities in cardiovascular and cardio respiratory studies.

II: METHODOLOGIES FOR MEASUREMENT

Pulse transit time can be measured by numbers of methodology. But for portable application of device, two methodologies seem to be adoptable for the device.

2.1 ELECTROCARDIOGRAPH AND PHOTO PLETHYSMOGRAPH METHOD

An ECG machine generates a curve based on the depolarization of the heart while the oximeter measures the pressure wave, or pulse, at the tip of the finger value for pulse transit time is given by calculating the difference in time between the peak of the R wave from the ECG and the peak of the pressure wave from the oximeter

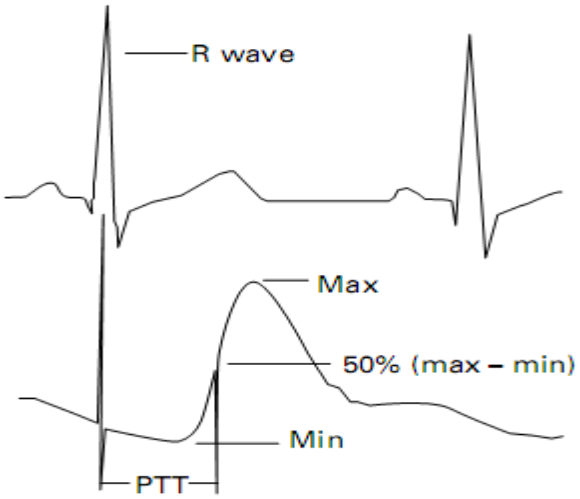

Fig 1. PTT measurement by ECG and PPG

Two waveforms required for the PTT calculation can be measured with the help of ECG and pulse oximeters.

2.2 TWO PLETHYSMOGRAPHS METHOD

This approach is based on measuring pulse pressure wave at two different arterial sites. Due to limited area of application for transmittance type photoplethysmograph, it is decided to use two reflectance type photoplethysmograph devices. This method seems to be more convenient and portable.

PWV measurement is performed using two PPG sensors as shown in figure 2. The photodiode of the leading sensor is placed directly above the wrist joint. The photodiode of the lagging sensor is placed above the little finger.

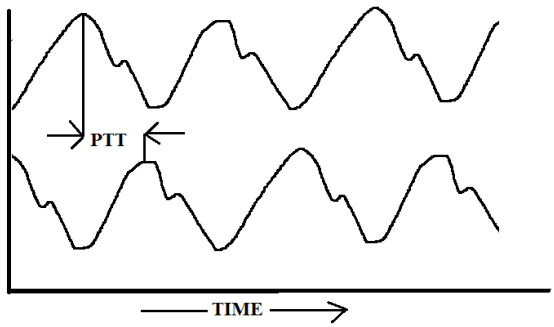

Fig 2.PTT measurement by two PPG

The Pulse Transit Distance (Δx) between the two sensors is measured as the distance between the upstream edges of the two sensors. The Pulse Transit Time (Δt) of the pressure pulse is measured as the difference in time between the time of the onset of the pulse wave measured at the lagging sensor and the time of the onset of the pulse wave at the leading sensor. In this project we defined the Pulse Transit Time as, the time interval between the peak of Wrist Photoplethysmograph (PPG) and Peak of finger PPG respectively.

There are some apparent limitations of measuring PTT using ECG. QRS complex from the ECG as a time reference may not be the optimum reference to use as found out from the previous studies. It is compulsory to synchronize the ECG and PPG correctly. There are some PPG sensor units that have built-in filters which are quite dissimilar to the ECG filters. These filters often generate an artificial phase-lag between the ECG and PPG. The R peak signifies the electric excitation of the heart contraction (ventricular contraction); a small delay is observed before the initiation of the mechanical contraction. The delay is called the Pre-Ejection Period (PEP). It is very difficult to measure the PEP (the PTT detected includes the PEP) [4]. In the alternate method of two PPG motion artefacts of object create DC shift of the overall PPG. But this limitation can be tolerated and it can be overcome by some methods. Therefore two plethysmographs method seemed to be adoptable for measurement of PTT. Reflectance type PPG is advantageous for application since it is not limited to only thin areas of our body. Therefore, approach to measure PTT by considering two different locations, one being the wrist and the other being the finger, which lie on a same arterial path is adopted and therefore it is easy to measure the distance between two peripheries.

III: SYSTEM IMPLEMENTATION

An approach to design PTT device should be portable, user friendly and cost effective. It must be accurate and precise without losing any diagnostic value. In view of objective of the device, design should be as shown in figure 3. Design implementation can be divided in three sections namely hardware, A/D

conversion & interfacing and software for calculation and analysis.

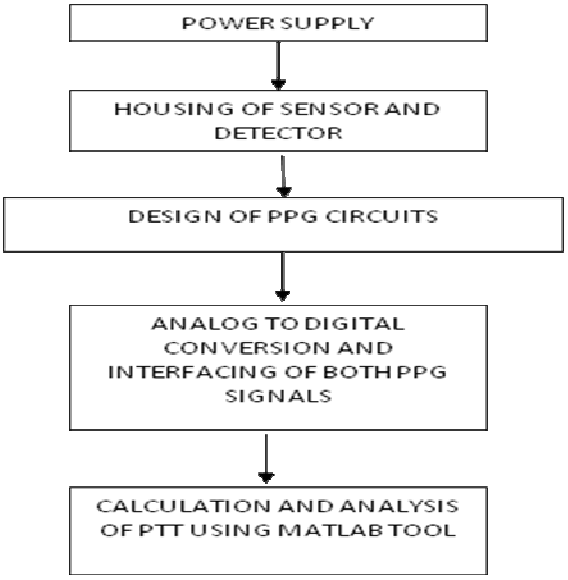

Figure 3.Block diagram of PTT measurement device

The analog section receives input from the sensor placed on the skin in the form of reflecting lights it convert it to electrical signal. It is then amplified by operational amplifier. Since PPG signal is comprises of DC and AC signal and only AC signal contains the information about pulse wave and the situation of light absorption of arterial blood [5]. In further stages the signal is filtered using a high-pass filter with an upper cut off frequency of 0.5Hz which removes DC signal and then a low-pass filter with a lower cut off frequency of 40Hz to remove the high frequencies interference. The band limited signal is then fed finally through a Notch filter to remove 50Hz/60 Hz power line noise as shown in figure 4.

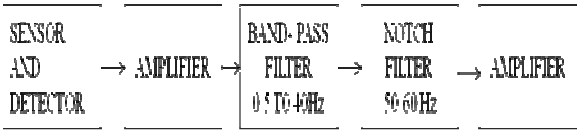

Figure 4.Block diagram of PPG circuit

After filtering and amplification PPG signal is sampled by 12-bit A/D converter. The use of a 12-bit A/D converter will allow for resolution of 1.2mV to be detected. Since a 12-bit converter will have 2^{12} = 4096 "states", then the output ranges of the circuits are about 0-5 volts and the resolution will be equal to (5-0)/4096=1.22. This will be more than sufficient. These outputs of A/D converter will be processed by MATLAB tool for further calculation and analysis of pulse transit time. MATLAB is used as a programming language for various applications because it enables you to perform computationally intensive tasks faster than with traditional programming languages. MATLAB is used to read and plot PPG data from wrist and finger respectively. In further stages detection of positive peaks and finding of maximum value of peak array is done. Time value with respect to the peak is stored in an array for both PPG signals. MATLAB is used for finding difference between both PPGs respectively and to store the difference in an array. Average of successive samples is calculated and finally value of PTT will be displayed.

IV: APPLICATIONS OF PTTS

As we are measuring PTT with the help of PPG signal, this device can be used to measure vital parameters like: heart rate monitoring, blood pressure measurement, blood oxygen saturation and respiration rate. It can be also be used for cardiac output measurement and vascular measurement. Pulse transit time has shown its capability to measure blood pressure by cuff-less, continuous and non-invasive method. It has shown its usefulness in detecting obstructive sleep apnea (OSA) in children and adults [6] [7]. Pulse transit time is useful as a diagnosis tool for sleep disordered breathing investigation in the paediatric population [7]. PTT device can also be useful for psycho-physiological monitoring system for stress measurement.

V: PRODUCT RELATED CONSIDERATIONS

A. STANDARDS AND SPECIFICATIONS: The device must be meet medical device specifications and standards.

B. PATIENT-RELATED CONCERNS: It may be possible to store patient related information in the device or to any other storage device. It will be possible to use disposable probes so sterilization of the device will not necessary at every use.

C. COMPETITION: Various devices with LED and photo detector are on the market to show plethysmograph but there are no portable devices that measure pulse transit time and other multiple parameters on single hardware.

D. MARKET: As product have multiple clinical applications. So a wide range of customers are available for the product in healthcare market.

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