REMOTE CONTINUOUS NON-INVASIVE BLOOD PRESSURE MONITORING SYSTEM WITH SMS ALERT

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ABSTRACT

This paper presents design and development of a non-invasive blood pressure measurement instrument for continuous monitoring and also remote monitoring. The real time blood pressure biomedical signal is measured using an optical measurement circuit based photo plesthysmography technique continuously for a long period of time. Blood pressure readings calculated is then displayed on a mini LCD as well stationary computer via bluetooth. In case of any abnormal changes in the blood pressure readings, then the system alerts using a buzzer and it also send a message to the predefined number(i.e. a physician number) using GSM. Furthermore, the obtained results were compared with existing devices data like a sphygmomanometer to verify the accuracy of the developed instrument.

KEYWORDS: *Blood Pressure, Bluetooth, Continuous, GSM, Non-invasive, Photoplethysmography.*

I. INTRODUCTION

Blood Pressure (BP), sometimes referred to as arterial blood pressure, is the pressure exerted by circulating blood upon the walls of blood vessels. Moreover, blood pressure measurement is known as one of the vital signs and is widely used to monitor the physiological condition of human beings along with other vital signs such as heart rate, breathing rate, oxygen saturation and temperature [1]. Blood pressure can be seen as two variation systolic blood pressure (SBP) and diastolic blood pressure (DBP), and systolic is the peak or the maximum pressure on walls of the arteries which happens when the ventricles of the heart are contracting while, diastolic is the minimal pressure in the arteries, which happens near the end of the cardiac cycle when the ventricles are filled with blood. Systolic and diastolic blood pressure measurements are not always static and Blood pressure does tend to change during the day. They also change in response to stress nutrition, drugs, and illness and exercise [2].

A person's blood pressure is usually expressed in terms of the systolic pressure over diastolic pressure and is measured in millimeters of mercury (mmHg). Normal resting blood pressure for an adult is approximately120/80 mm hg. Blood pressure varies depending on situation, activity and disease states, and is regulated by the nervous and endocrine systems. Blood pressure that is pathologically low is called hypotension, and pressure that is pathologically high is hypertension. Both have many causes and can range from mild to severe, with both acute and chronic forms. Hypotension can cause the blood supply to the brain, heart and other tissues to be too low and hypertension is strongly correlated with higher risk for cerebral stroke and heart infarct.

Measuring pressure invasively, by penetrating the arterial wall to take the measurement, is much less common and usually restricted to a hospital setting. The non-invasive ausculatory and oscillometric measurements are simpler and quicker than invasive measurements, require less expertise, have virtually no complications, are less unpleasant and less painful for the patient. Although these methods are generally accepted and widely used but they severely restrain patient's mobility, they require uncomfortable cuffs, they are not suitable for home-care and cannot be used for continuous long-term monitoring applications. Continuous measurement of blood pressure for home-care requires accurate and inexpensive method that is independent from patient movement and does not require continuous care by a practitioner. These requirements can be found in the monitoring system which will be designed using photoplethysmographic (PPG) technique.

The authors [3] proposes a design program of embedded dynamic blood pressure monitor Based on ARM Cortex-M3. An improved algorithm is put forward in this scheme, which uses Gauss distribution curve to fit the envelope of human pulse wave, and uses the maximum likelihood method to estimate the optimal Gauss distribution parameter μ and s, finally uses state feedback technique to control the fast convergence. Blood pressure measured using volume oscillometric method and photoplethysmography technique [4]. Rate of change of blood volume in finger is measured by an optical sensor network which estimates blood pressure. It displays the numerical value of systolic and diastolic blood pressure in a mini LCD. BP measurement is measured by pulse wave velocity [5].

More to the point, a developed technique based on a noninvasive continuous blood pressure measurement using volume oscillometric method and photoplethysmography technique has been investigated [6], and the study uses high intensity LED and a LDR (Light Dependent Resistor) and placed them at the edge of a finger. The concept is that the resistance of the LDR changes according to the light intensity received by the LDR. The change in resistance is proportional to the change of blood volume and as well as blood pressure in the finger. The result showed the systolic and diastolic blood pressure on a mini LCD.

In addition, a non-invasive blood pressure monitor was developed using photoplethysmograph method. Authors used infrared transmitter and receiver to estimate blood pressure in the fingertip. Authors were able to measure blood pressure and concluded that the results are in agreement with the standard blood pressure measurements [7].On the other hand, a wireless digital measurement system was implemented and developed. In approach, piezoresistive transducer was used as the sensor and the device makes use of a microcontroller and a Sallen-Key active. The system transmits the collected data to a remote computer through a wireless device [8].

Moreover, blood pressure measuring system at the wrist based on the volume-compensation method has been developed [9]. The authors used a method called volume-compensation in which cuff pressure (Pc) is gradually increased, and then the unloaded vascular volume (V0) is determined from the mean level of the DC component of the photo plethysmography (PG) signal (PGdc) at point of maximum amplitude of the pulsation signal of PG (PGac) [9].

PW was obtained by the PPG and SBP was obtained by the commercial BP meter with a cuff. Then the regression equation of SBP was calculated from individual information and features of PW. The result implied that patients' cardiovascular peculiarities change according to aging and vary among difference individuals [10].

II. PHOTOPLETHYSMOGRAPHIC TECHNIQUE(PPG)

PPG is a simple non-invasive method used to measure relative changes in pulse blood volume in the tissues. It utilizes the use of reflectance sensor that contains an infrared light source. The light source illuminates a part of the tissue (fingertip, toe, ear lope, etc.) and a photo-detector receives the returning light. The waveform obtained from this technique represents the blood volume pulse which can be used to measure blood pressure.

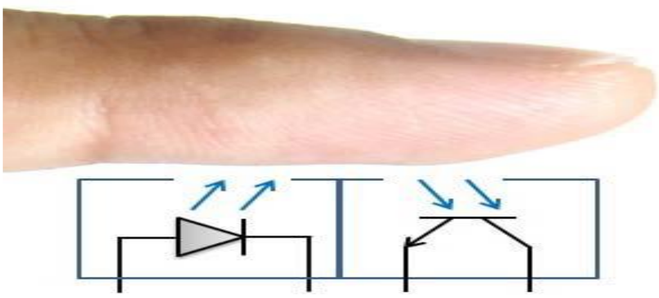

Fig.1 shows Photoplethysmography technique concept.

PPG concept is shown in Fig.1 where an Infra-red (IR) sensor is used as the source and a phototransistor is used as the detector. The sensor operates in reflection ('adjacent') mode where the source and the detector are place side by side.

III. SYSTEM DESCRIPTION

The block diagram of the developed system is shown in fig. 2. The system mainly consists of three stages: the sensing measurement circuit, signal amplification circuit, microcontroller and transmission unit.

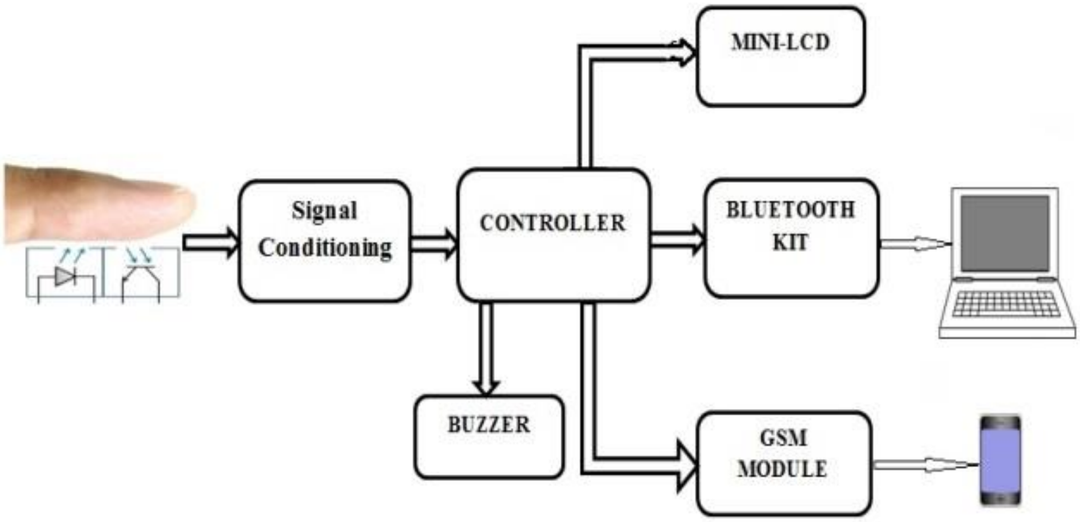

Fig.2 shows the Block diagram of our developed system

2.1. Sensing Stage

The detection of the blood pressure signal is based on using optical measurement technique called photoelectric plethysmography (PPG). This technique has the ability to detect the volume of blood pressures in the arteries. The PPG basic form utilizes two components: a light source to illuminates a part of the tissue (e.g. fingertip) and a photo detector to receive the light. Transparency of living tissue to light makes it possible for some part of the light from the source to pass through the tissue to the photo-detector.

However, some part of the light is absorbed by the blood, bone, muscle and skin in the tissue. The volume of the blood in the vessel varies while the volume of other part remains constant. Therefore the light absorption is varied only by the change of volume of blood (increases or decreases) and the returning light to the photo-detector changes according to the change of blood volume. The electrical resistivity of the photo-detector changes depending on the amount of light falling on it. This change of resistivity results is the change of electrical current flowing in the detector which is converted into PPG signal.

In this system optical sensor is used where it consists of infra-red emitting diode as the transmitter and a photodiode as the receiver. The sensor operates in reflection ('adjacent') mode where the source and the detector are placed side by side as shown in fig.1.

Fig.3. shows the optical sensor

2.2. Signal Conditioning Stage

After the sensor detected the changes in the volume of blood pressures, a low frequency and low magnitude biopotential signal is received by the photodiode. As the detected PPG signal is so weak, it must undergo some signal conditioning (e.g. amplifying and filtering) so that it can be used for further processing. Since the output voltage of the photo-detector has a large amount of dc component which requires a filter to suppress out the dc component. A good filter choice will be the use of an active bandpass filter because its first cut off frequency can be used to remove direct current (DC) and its second cutoff frequency can be used to remove unwanted high frequency components in the signal like power line interference (50 Hz). In addition, the filter is also used with a very high gain for amplifying the signal. Two stage bandpass filter are used and each stage has different gain.

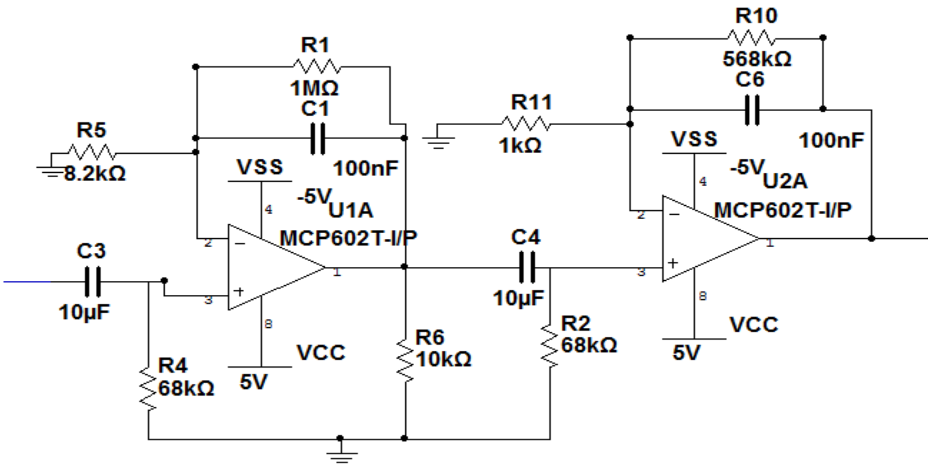

Fig.4 shows the circuit for double stage Band pass filter.

For first stage, the gain is calculated using:

$$A1 = 1 + \frac{R_1}{R_5} = 1 + \frac{1M}{8.2K} = 122.95 \qquad (1)$$

Normally the frequency of an average person's heart rate is between 60 and 80 bpm (1Hz to 1.2Hz), thus the bandwidth of the filter will be set between 0.2 Hz to 2.5 Hz so that the PPG signal frequency is saved and the noises are cancelled out.

The cut off frequencies are calculated using for low frequency.

$$Fc = \frac{1}{2\pi R_4 C_3} = \frac{1}{2\pi(68K)(10\mu)} = 0.2Hz \qquad (2)$$

For high frequency

$$Fc = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi(1M)(100n)} = 2.5Hz \qquad (3)$$

For second stage, the gain is calculated using:

$$A2 = 1 + \frac{R_{10}}{R_{11}} = 1 + \frac{1560K}{1K} = 661 \qquad (4)$$

The cut off frequencies are calculated using for low Frequency:

$$Fc = \frac{1}{2\pi R_2 C_4} = \frac{1}{2\pi(68K)(10\mu)} = 0.2Hz \qquad (5)$$

For high frequency

$$Fc = \frac{1}{2\pi R_{10} C_6} = \frac{1}{2\pi(568K)(100n)} = 2.5Hz(6)$$

The total gain of the system is calculated by multiplying the gain of the first stage with the gain of second stage as shown:
Total Gain is (A1*A2) = 68292

2.3.Microcontroller stage

The output of the signal conditioning stage is fed into a microcontroller where it is processed (sampling and quantizing). The PIC18F24K22 microcontroller is used in this system where it has a built-in ADC. The PIC18F device family can operate at speeds up to 12MIPS and has a hardware multiplier for faster calculation of control algorithms. The microcontroller finds out the smallest (represents DBP) and the largest (represents SBP) value form the output voltage using a program written in MPLAB X IDE.
The microcontroller then displays the measured blood pressure information in mini LCD and transmits them through a Bluetooth device to any stationary enabled computer device. Buzzer alert of the system helps the patient itself to be aware of his/her condition and can take necessary steps towards medication. At the same time, physician can also diagnose the patient from a remote location as system provides SMS alert at critical situations. The Bluetooth interface provides a convenient and low power consumption method for data transmission. This system provides users an easy-to-interface interface and simple blood pressure management environment.

IV. CONCLUSIONS

With this proposed system the blood pressure can be measured continuously for a long period of time and also remotely monitored. The small embedded system can display the systolic and diastolic blood pressure on a mini LCD as well stationary computer which is a Bluetooth enabled device though Bluetooth wireless technology. In case of any abnormal changes in the blood pressure readings, the system alerts using a buzzer and it also send a message to the predefined number(i.e. a physician number) using GSM. Furthermore, the obtained results will be compared with existing devices data like a sphygmomanometer to verify the accuracy of the developed instrument. This system provides users an easy-to-use interface and simple BP management environment. The Bluetooth interface provides a convenient and low-power consumption method for data transmission. This work may further be extended in future to include more number of physiological parameters like heart rate, oxygen saturation etc. to be monitored for a long period of time. GPS system can be used to spot the exact position of the patient and thus can provide immediate help if required.

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