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Deign of Low Cost Blood Pressure and Body Temperature interface

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Abstract—The objective of this work is to design a non-intrusive, accurate, and low cost biomedical sensor interface for processing blood pressure and body temperature vital signs. The work purposely deals with the signal conditioning of two vital signs: blood pressure, and body temperature. Blood pressure uses the methodology of Photoplethysmography to continuously monitor the systolic and diastolic blood pressure. Body temperature is dealt with a LM35 sensor. We design the signal conditioning interface based on the type of sensor such as pressure and temperature sensor. We simulate the circuits in proteus software to verify their accuracy. We also simulate the temperature simulated results in MATLAB to verify the linearity of the temperature against the output voltage. Therefore, the design will be useful for the patient monitoring systems which use microcontroller for interpretation before sending them to the doctor through mobile phone network assisted by GSM/GPRS modem.

I.INTRODUCTION

A. Background

1. Blood Pressure

Blood pressure measures the force of the blood inside the blood vessel or the walls of the artery. This pressure drives the blood through the arteries into the tissue. This measurement shows how well the heart is working. When the heart ventricles contract, driving out the blood from the heart, blood pressure is produced and it is at its climax in the arterial system. This is the systolic blood pressure (SBP) during the period when the heart is contracting. When the heart is relaxing and the ventricles are refilling with the blood returning from the body, the pressure in the arteries is very low. This is the diastolic blood pressure (DBP). A regular blood pressure is 120 being the systolic over 80, the diastolic. Usually the blood pressure is taken from the left arm unless there is some damage to the arm. The divergence between the systolic and diastolic pressure is called the pulse .Blood pressure is a range of values that on mounting are related with increased danger. Therefore, raised blood pressure is described when the systolic number is constantly over 140–160 mmHg. Low blood pressure is hypotension [1].

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Table 1 : Adult blood pressure [2-4]

Classification of blood pressure for adults		
Category	Systolic, mmHg	Diastolic, mmHg
Hypotension	< 90	< 60
Desired	90–119	60–79
Prehypertension	120–139	80–89
Stage 1 Hypertension	140–159	90–99
Stage 2 Hypertension	160–179	100–109
Hypertensive Crisis	≥ 180	≥ 110

Table 2 : Human being blood pressure [4, 5]

Reference ranges for blood pressure					
		Systolic		Diastolic	
Stage	Approximate age	Range	Typical example	Range	Typical example
Infants	1 to 12 months	75-100	85	50–70	60
Toddlers	1 to 4 years	80-110	95	50–80	65
Preschoolers	3 to 5 years	80-110	95	50–80	65
School age	6 to 13 years	85-120	100	55–80	65
Adolescents	13 to 18 years	95-140	115	60–90	75

1.1. Blood Pressure Control Technique

Photoplethysmography (PPG) is an optical technique that determines the blood volume changes in the microvascular bed of tissue such as breathing, blood forced into vessels and the heart pumping. It uses the emitter and detector to measure the pulses during the blood flow. The emitter is an LED (Light Emitting Diode) which emits light of a specific wavelength. The photodetector diode is used as the detector that produces the current to match the light intensity from the LED through the ear, finger, toe, forehead or cheek. PPG is most often employed noninvasively and works at a red or a near infrared wavelength. The parameters that are non-invasively detected by a reflectance PPG method are blood pressure, oxygen saturation altitude, pulse rate and respiratory rate [6-8].

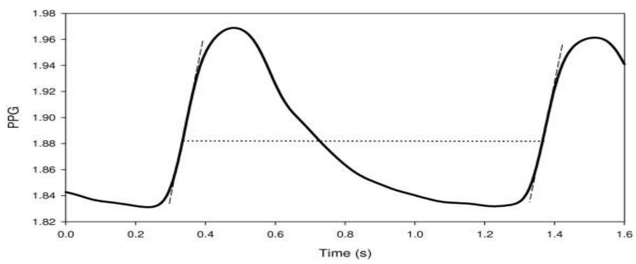

Fig 1 : PPG waves

PPG has two modes which are:

Transmissive mode: LEDs are positioned on one side of the body and the photodetector on the other side - fingers / toes / earlobe [9-11]as illustrated in Fig 2Fig 3.

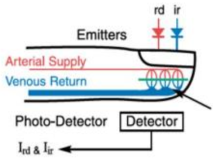

Fig 2 : PPG at the finger

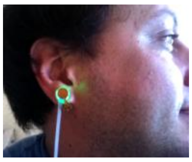

Fig 3 : PPG at the earlobe [12]

Reflective: LEDS and photodetector are positioned on the same side of the body - forehead / cheek

Received signal is assumed to be a measure of volume changes due to localized blood flow [13].

Transmittance

I is the transmitted intensity and I_0 is the incident intensity.

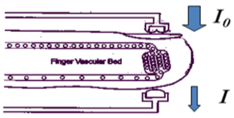

Fig 4 : Light intensity through the finger

$$T = \frac{I}{I_0}$$

Absorbance is given by

$$A = -\log_{10} T$$

Pulse Transit Time (PTT) is the time taken by a pulse wave to circulate from heart to a specified point on the body where the reading is taken, usually the ear lobe or finger. PTT is non-invasive and an easy measurement. PTT is defined as the time duration from a reference point of time, for the pulse pressure wave to travel to any specified point on the margin. Blood Pressure changes, Heart Rate and the fulfillment of the arterial walls, and so on influence the PTT. It provides beat-to-beat tracking of the blood pressure. This approach considers the time variable. The periodical and continuous flow of the PPG waveform allows a beat-to-beat analysis along several points on a peak.

Since, the blood pressure is a function of cardiac output where the amount of blood volume outputs per cycle. An increase in the flow rate of the blood causes the blood pressure to rise. This makes the straight relationship between the blood pressure value and the rate at which the blood travels in the arteries. The factor that relates the flow to the blood pressure is the pulse transit time (PTT).

The pulse transit time is determined from the R peak in the ECG waveform to the bottom level of the PPG wave at the peripheral site [10, 14]. An increase in blood pressure produces in an increase in blood velocity which means the blood arrives at the peripheral site from the aortic valve in a smaller time interval. But, a decrease in the blood pressure corresponds to a longer pulse transit time as well.

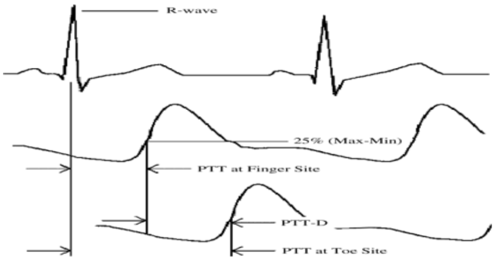

Fig 5 : PPG and ECG waves

2. *Body Temperature*

Temperature is a measure of the degree of heat intensity. The temperature of a body is an expression of its molecular excitation. The temperature difference between two points indicates a potential for heat to move from the warmer to the colder point. The human body's core temperature varies from day to day, and from time to time, but these fluctuations are small, usually no more than 1.0ºC. Humans are homoeothermic and body temperature is regulated at about 37ºC ±1ºC. The thermoregulatory center in the hypothalamus plays a very active role in keeping body temperature in the normal range. External and internal heat sources influence body temperature.

Table 3 : Body temperature behavior [15]

Temperature	Effect
44°C	Almost death. Sometimes patient known to survive at up to46.5°C
43°C	Normally death/brain damage/cardio-respiratory collapse
41-42°C	Fainting, confusion, very fast heart rate, convulsion, Low/high blood pressure
38-40°C	Severe sweating, dehydration, weakness, vomiting, headache, dizziness, fast heart rate, slightly hungry
37°C	Normal temperature
36°C	Mild or moderate shivering. May be normal temperature
34-35°C	Intensive shivering, numbness and bluish/grayness of the skin. Heart irritability. Confusion and Loss of movement of finger
29-33°C	Moderate to severe confusion or complete, sleepiness, progressive loss of shivering or stop, slow heart beat, shallow breathing, unresponsive to stimulus and hallucinations
24-28°C	Breathing may stop. But mostly death. Sometimes patient known to survive at 14.2°C

Temperature is read to establish a baseline of normal body temperature for the location and measuring conditions. The main reason for examining body temperature is to hunt for any signs of systemic infection or inflammation in the presence of a fever or high significantly above the individual's normal temperature. Other causes of high temperature include hyperthermia.

Temperature depression needs to be evaluated. It is also important to review the trend of the patient's temperature. A patient with a fever of 38 °C does not necessarily show a menacing sign if his previous temperature has been higher as detailed in Table 3. Body temperature is maintained through a balance of the heat produced by the body and the heat lost from the body [16].

II..RELATED STUDIES

A. Blood Pressure

Many works have been conducted to determine the types of vital signs such as blood pressure, body temperature, respiration rate and heart rate that are regularly measured. In our work, we propose the sensor interface design for only two of these vital signs that are blood pressure and body temperature.

The cuff was used to measure directly the systolic blood pressure by sensing the blood pulses [17]. The estimation of blood pressure by oscillometric devices was analyzed in this work taking into account the information on blood pressure changes detected by the Finometer device, the sensor and cuff pressure sensor response during measurement, and through auscultatory method [18]. The aim of this study was to examine the effect on distal arteries of external pressure, applied by upper arm sphygmomanometer cuff. Photoplethysmographic (PPG) signals were measured on the index fingers of 44 healthy male subjects, during the slow decrease of cuff air pressure. For each pulse the ratio of PPG amplitude to its baseline during the slow decrease of cuff air pressure at cuff pressures equal to systolic blood pressure, pulses reappeared with the pulse time delay in the cuffed arm significantly greater than in the non cuffed arm [19]. Also in the work [20], a novel coefficient-free BP estimation method based on Pulse Transit Time on Cuff Pressure (PTT-CP) dependence was proposed. PTT is mathematically modeled as a function of arterial lumen area under the cuff. It is then analytically shown that PTT-CP mappings computed from various points on the arterial pulses can be used to directly estimate systolic, diastolic, and mean arterial pressure without empirical coefficients. The other study proposes and constructs a two-cuff non-invasive blood pressure waveform monitor system. The proposed system uses dynamic feedback to maintain constant low cuff pressure at 40 mmHg [21].

The arm cuff oscillometric method used in these works is intrusive and hard to use, because it is massive, so awkward to carry. Furthermore, it does not take real time and continuous measurement [22] as PPG does.

B. Body Temperature

Temperature is commonly considered to be a vital sign most notably in a hospital. This paper proposed a nonintrusive deep body temperature measuring system. The system estimates the deep temperature non-intrusively only when the patient is at rest, since the sensor is embedded in a neck pillow. The deep temperature can be taken using the thermometer. It estimates deep body temperature in 3 different sleep positions [23].The research on measuring arterial blood pressure and body temperature was conducted. The biosignal measured from the body must be converted to an adequately scaled voltage level. This interface will be used by the patient monitoring system for controlling the patient with cardiac problems that will be transmitting the signal through the GSM/GPRS modem to the doctor's smartphone.

III.INTERFACE DESIGN

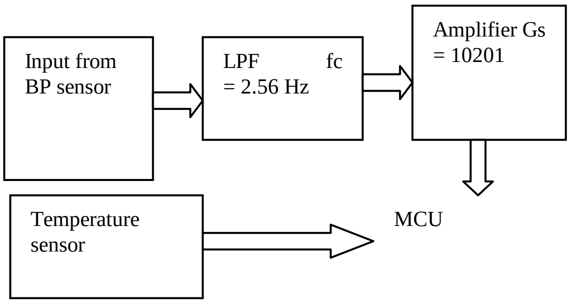

Fig 6 : Sensor interface block diagram

The above fig 6 shows the block diagram of Low Cost Blood Pressure and Temperature Interface. Fluctuation in the normal blood pressure and body temperature of the patient will be sensed by the Bp sensor and temperature sensor respectively attached to the ear lobe or at any appropriate position noninvasively. The interface is expected to be used in the remote patient monitoring system which uses the GSM/GPRS modem where the data along with ECG signal will be sent from the microcontroller directly. The functioning of BP sensor module is based on the truth that the blood circulates for every heartbeat that can be sensed by LED. The PTT and ECG (R peak) technology will be utilized Depending upon the rate of circulation of blood the Blood pressure will be calculated. The body temperature will be directly sent to the microcontroller by the LM 35 temperature sensor.

A. BP sensor module

A red LED and an Infrared LED are proposed in this work that will measure the blood volume changes. Each LED must have the wavelength of 850nm. The finger will be used as the source of transmission to obtain the signal. One Red LED is used to measure the volume changes in blood. The photodiode of the same magnitude as the LEDs must extract the light transmitted through the finger (optical reflectance of the arterial blood vessels from the channel red/IR diode) and produces a current. The LED will shine either red or infrared depending on the polarity of the voltage applied. The LED is subjected to +5V and -5V.

The whole circuit uses 5 V at their positive terminals and negative terminals is set to 0v (ground) as shown in fig 7. An LED connected at the output blinks consistently that a heart bit is detected. The required cut off frequency of the low pass filter is 2.56 Hz. This allows the system to filter out the noise signal above the required frequency which comes in during the motion and other sources. The circuit consists of two equal low pass filters with a cut-off frequency of 2.56 Hz.

$f_c = 1/(2\pi RdCd) = 1/(2\pi x620kx100n)$
$= 2.56$ Hz
R1=R6=Rd
C1= C2 = Cd

The filter and amplifier configuration converts weak signal from the sensor into a pulse. The pulse from the configuration is fed to the microcontroller. The signal is amplified at each stage so that it can be read at microcontroller level.

Gain at each stage
Ge= 1 + Rd/Rk = 1 + 620k/6.2k = 101
R2=R7=Rk

The system overall gain

Gs = Ge^2= 10201

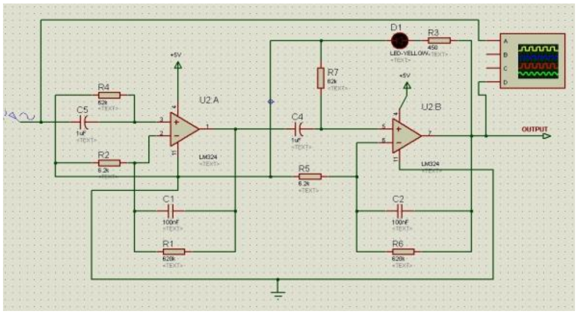

Fig 7 : BP schematic circuit

B. Temperature Sensor Module

The LM35 temperature sensor is proposed in this work for measuring the human body temperature. It is a precision integrated circuit Temperature Sensor which is small and can be placed anywhere on the body.

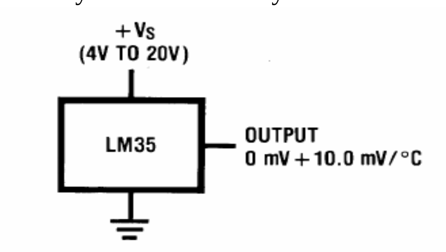

Fig 8 : LM35 temperature sensor
[24, 25]

The LM35 output voltage is linearly scalable to the measured temperature, which is 10 mV per 1 degree Celsius as shown in fig 8. So if Vout = 0.37V then the measured temperature is 37°C. It does not require external calibration and maintains an accuracy of ±0.4°C at room temperature and ±0.8°C over a range of 0°C to +100°C [26, 27].

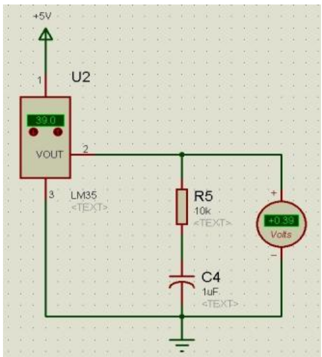

Fig 9 : Temperature sensor schematic

IV. Test Results

Through various test procedures and techniques with proteus and MATLAB software, many parts of these circuits were improved .They were tested to ensure that each part worked and then as testing progressed, modifications or adjustments were made to the circuits so they functioned well practically. The power give to each circuit was 5V to the positive terminal and the negative terminal was grounded.

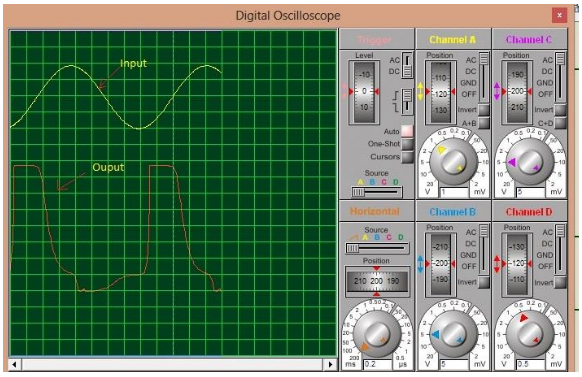

Fig 10 : BP circuit simulation

The applied input to the BP circuit was sine wave. This was done for the simulation test as shown in fig 10. The output given satisfied that the circuit is functioning properly.

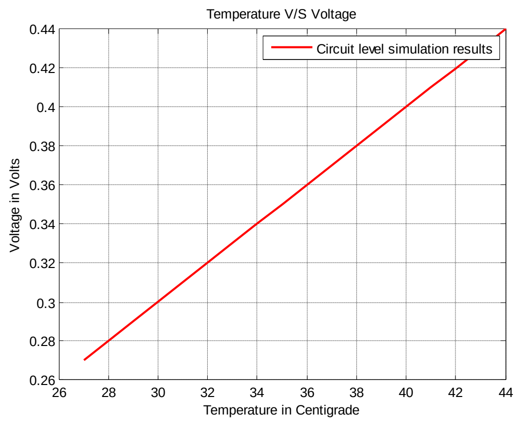

Fig 11 : LM 35 linearity characteristics

The LM35 simulated results were analyzed and implies that the output voltage is linearly proportional to the Celsius temperature as shown in fig 11.

V. Conculusion

Number The sensor interface designed is expected to make possible use of noninvasive, unobtrusive medical monitors applicable during abnormal activities of the patient in remote area, where the medical access is difficult especially in Tanzania. The interface consists of two modules for blood pressure and body temperature that accept sensed data and process them before they are given to the microcontroller. The output of the interface is analogous to the microcontroller internal analog to digital converter. It has the voltage output level required to suit to the converter. The interface is expected to work along with ECG sensor interface where other parameters such as ECG waveforms and heart rate will be taken into account. These parameters will be sent to the doctor and patient through GSM / GPRS Modem. There are many ongoing researches on patient monitoring system using GSM / GPRS and the main purpose behind these researches is to make this system more compact, easily available at affordable price. New technologies could also enhance the performance of the final project.

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Dr. Kisangiri Michael received his PhD (Telecommunication Engineering) from Wroclaw University of Technology Poland, Institute of Telecommunication and Acoustics in December 2008. In April 2002 he graduated from the same University, Master of Science in Telecommunication Engineering (Department of Radio communication) with specialization in Mobile Communication. He has been working with Dar es Salaam Institute of Technology (D.I.T) in the department of Electronics and Telecommunication Engineering since October 2002 as Assistant Lecturer to November 2008, then as a Lecturer to November 2011.

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His area of interests includes **evolutionary computation in Telecommunication networks; Antenna design and Triangular mesh modeling.**

Projects

1. Electromagnetic optimizations in wireless networks
2. Direct Matrix Manipulation (DMM) methodologies as a Speeding up catalyst
3. Call planning and optimization for GSM networks
4. Designing of mesh wireless networks
5. Spread Spectrum System for measuring distance of moving plane from the radar
6. Planar Inverted F antenna (PIFA) design for GSM 900/1800
7. Emission of mobile phone radiation into operator's head
8. Propagation and Traffic analysis in GSM Networks

Dina Zawadi Machuve is currently a PhD student in Information and Communication Science and Engineering at NM-AIST majoring in Information Technology Development and Management. She received BSc (Hons) degree in Electrical Engineering from the University of Dar es Salaam in 2001. She received MS degree in Electrical Engineering from Tennessee Technological University, USA in 2008. She joined Nelson Mandela -AIST in April, 2012 as Assistant Lecturer in the School of Computational and Communication Science and Engineering (CoCSE)

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