IJERMT
International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
March-April-2023 Volume 10, Issue-2
Email: editor@ijermt.org
www.ijermt.org

STUDIES ON INEXPENSIVE BLOOD PRESSURE TRACKING DEVICE FOR TELEHEALTH USES

Moeena Taj
Research Scholar, School of Technology and Computer Science,
The Glocal University, Mirzapur Pole, Saharanpur (U.P)

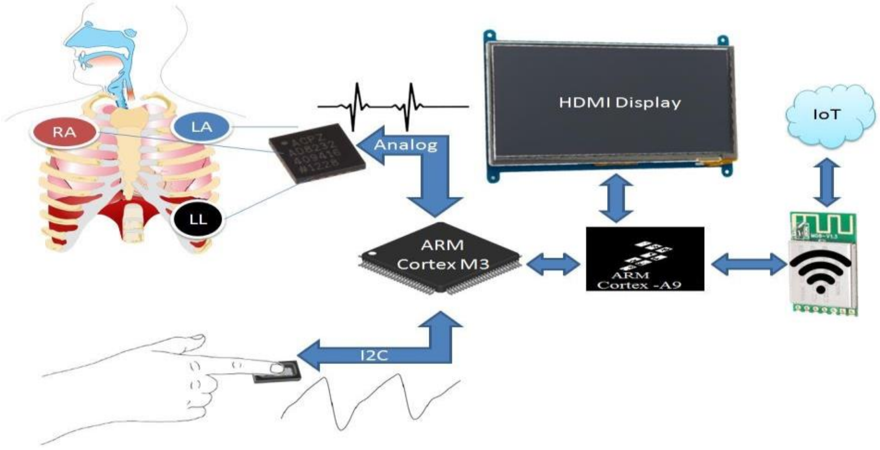
Dr. Sonal Singla
Research Supervisor, School of Technology and Computer Science,
The Glocal University, Mirzapur Pole, Saharanpur (U.P)

ABSTRACT:

People who live in remote areas can receive medical aid through telemedicine and recurring patient monitoring. Cost-effective health monitoring systems are necessary for this hassle-free experience. This work develops a blood pressure monitoring device based on photoplethysmography (PPG) and electrocardiogram (EKG), and compares the system's results with those of established devices. The AD8232 sensor provides the patients' EKG, and the MAX30101 records their PPG. The Pulse Transit Time (PTT) is calculated using the R peaks of the EKG, the peaks, and the valley points of the PPG. To determine blood pressure, the PTT is calibrated using conventional sphygmomanometers. The patient's arterial oxygen saturation levels are determined by calibrating the PPG signal, and their heart rate is determined by calculating the frequency of the EKG peaks. The outcomes are saved in the IoT cloud platform for remote access and are shown on the displaying unit. Heart rate accuracy is reported at ± 2 BPM, while SaO2 accuracy is at ± 2.5%. Diastolic blood pressure at ± 5 mmHg and Systolic blood pressure at ± 5 mmHg.

Keywords: Telemedicine, IoT, EKG, PPG, Heart rate.

Graphical Abstract



INTRODUCTION

Since people occasionally get sick and hurt, medical aid is crucial in practically every human life. Unfortunately, for a variety of reasons, not every human being has access to the same medical services. The World Health Organization's minimal guidelines are not met by the doctor to population ratio in the majority of countries [1]. It is challenging for those living in rural locations to travel to cities in time to receive medical care. For all these reasons, in the modern world, telemedicine and remote patient monitoring technologies have become essential.

In order to implement telemedicine at a reasonable cost, a variety of economic models must be created. Since telemedicine is not directly supervised by a medical specialist, the monitoring systems are intended to be non-invasive. Patients' EKG and PPG can be continuously monitored to identify common cardiovascular problems [2]. The frequency, inter-beat interval, and inter-pulse interval of the PPG and EKG signals are measured in order to compute the abnormalities in heartbeats and pulse rate. Multiple leads can be positioned at different body areas to practice the EKG, and the voltage fluctuations at those sites can be tracked. When the number of electrodes in an EKG increases, it becomes more challenging for novice users to maintain and install them. Hence it is advised to use tri-terminal EKG probes for personal monitoring systems. The three terminals can be easily placed on the body sites for forming an Einthoven's triangle to collectthe EKG. Oxygen saturation is also one of the vital signs of the physiological system, which gives information about the risk of diseases like hypoxia. To measure the (arterial oxygen Saturation) SaO2, either invasive or non-invasive techniques can be employed. Despite the limitations of accuracy, the non-invasive techniques provide an indication of hypoxia and can be implemented with medical standards. To record the oxygen saturation, PPG-based pulse oximetry is performed as the technique is non-invasive and inexpensive. Lambert- Beer's law is employed in this technique to compute the SaO2 by using two sources of light with different frequencies [3].

Human blood pressure needs to be constantly monitored and kept within the recommended ranges for optimal metabolism. The most well-known feature of mercury-based sphygmomanometers with cuffs is their accuracy when taking blood pressure with a stethoscope. The cuff will be put around the arm in order to test the blood pressure using this method. In addition, the stethoscope is placed on the brachial artery when the air valve is opened to raise the pressure to about 200 mmHg. The brachial artery's Korotkov sound begins at the (Systolic) pressure point, and terminates at the (Diastolic) pressure point. The pressure is then gradually released by opening the air valve, and the practitioner records both points [4]. To replace this setup, electronic equipment with motors came into existence with relatively good accuracy for personal monitoring of the cuff-based BP monitoring without the need for any stethoscope. The cuff-based sensors are not suitable for continuous monitoring of the BP because they cause discomfort for the users, especially when required to measure at the time of sleep. For addressing these limitations, a novel method using EKG and PPG is being researched all around the world. The time difference between the EKG and PPG signal peaks is termed as pulse transit time, and is used for calculating the cuff-less blood pressure [5].

In the current situation, medical parameters must be stored and transferred in order to provide appropriate medical treatment and enable telemedicine applications. Smart systems and smart sensors make the Internet of Things technology effective in this regard. This work develops a smart IoT-based system for non-invasive blood pressure and SaO2 measurement. The online cloud platform updates the results often so that they can be used at different phases of the treatment.

MATERIALS AND METHODS

A microcontroller and microprocessor on-board the UDOO Quad development board are used in the design of the system with the blocks depicted in Figure 1 [6]. The PPG sensor MAX30101 and the EKG sensor AD8232 are interfaced with the on-board ARM Cortex-M3 microcontroller. The 84 MHz ARM controller has 512 KB of Flash memory, 96 KB of SRAM, 16-channel 12-bit ADC, and 12-bit dual-channel DAC. The 144-pin microcontroller, with 103 programmable I/Os, supports various serial communication interfaces such as UART/USART, TWI, and SPI.

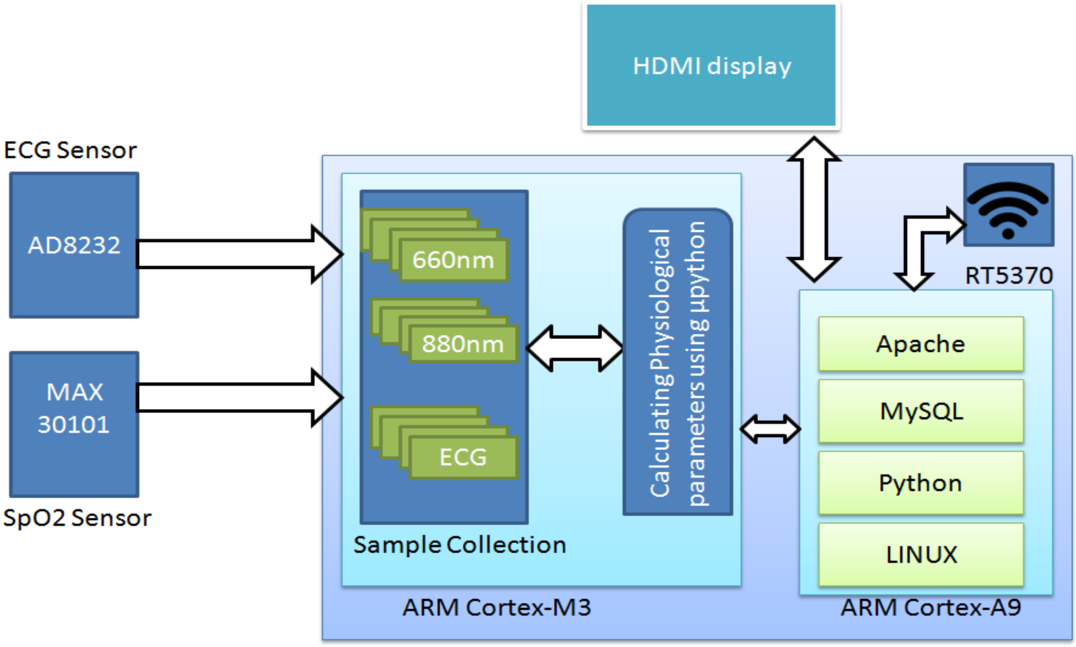


Figure 1 Conceptual Block diagram of the system

The 16-channel analog to digital convertor of AD Inc. is interfaced with the EKG sensor AD8232. One of the greatest front ends for wearable EKG devices is the integrated circuit. It is run at a very low current of 170µA using a 3.3V power supply. It offers full swing rail-to-rail output, a high gain of 100, dc blocking capabilities, and CMRR and PSRR of 80 and 76 dB, respectively. The extra benefits of this ECG IC are the quick restore circuitry and automatic leads-off detecting. The IC has an instrumental amplifier, an optional rail-to-rail amplifier for additional gain, an amplifier for proving required CMRR, and an amplifier to work as a reference buffer. The EKG sensor is configured in the tri-electrode cardiac monitoring mode, as shown in Fig. 2.For collecting pulse oximetry signals, MAX30101 of MAXIM Integrated is used in dual LED mode [7]. The sensor is interfaced to the Cortex-M3 controller using the two-wire interface protocol. The half-duplex communication protocol utilizes clock and data signals to transfer the data between the sensor and the microcontroller. The 14-pin tiny sensor with a volume of 28.64mm3 is covered with a small glass cover. The two LEDs are alternatively driven by utilizing the LED driver circuit using the TWI protocol [8]. The sensor keeps track of the reflected light detected by converting the analog samples into digital data using an inbuilt 18- bit ADC. Before the data gets digitized, the ambient light noise is eliminated with the help of ambient noise canceling circuit. After digitizing the data, a digital filter in the sensor eliminates any further noise and stores thesample information in the 32-deep FIFO.

Samples from both sensors are taken at the same time and kept in buffers for later use. Every eight seconds, the data in the buffers is analyzed to provide the physiological parameters. Python is used to program the ARM Cortex-M3 for data processing and sample collection. The arterial oxygen saturation is calculated by processing the SaO2 sensor data. To find the SaO2 ratio, solve equation (1) using the LEDs' dc average and ac root mean square values. To obtain the SaO2 value, equation (2) is further modified by substituting the SaO2 ratio.

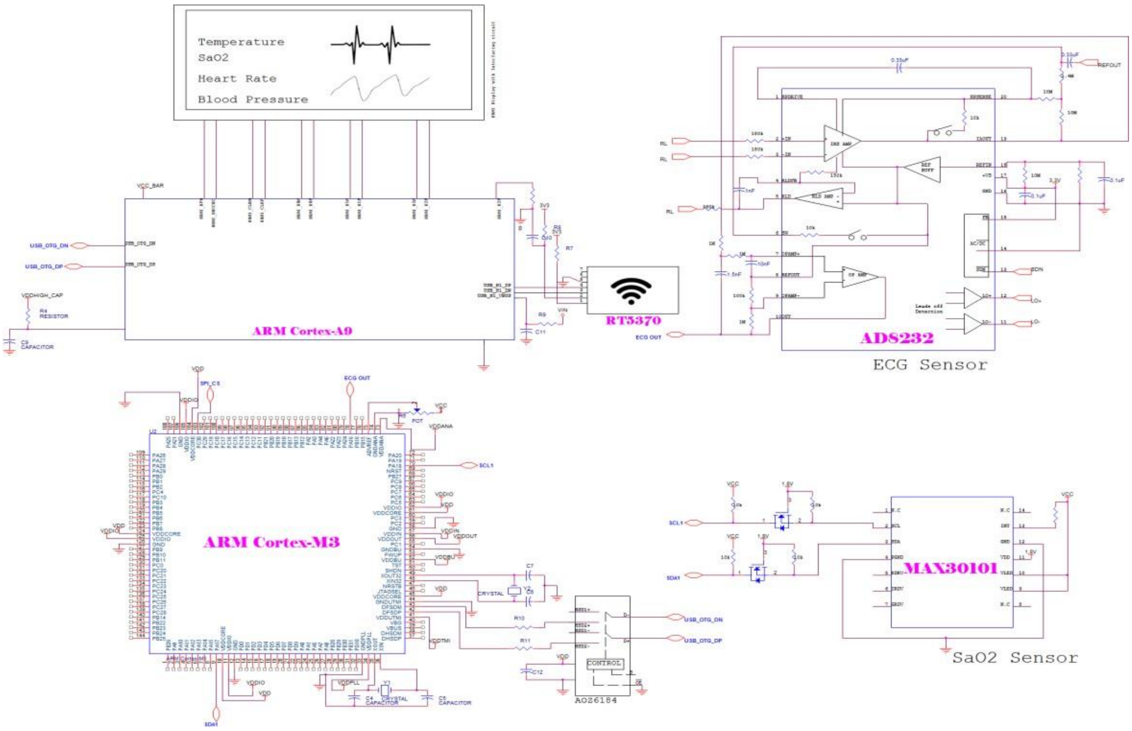


Figure 2 Schematic diagram of the designed system

$\text{SaO2 ratio} = (\text{AC RMS}_{660nm}/\text{DC Average}_{660nm}) / (\text{AC RMS}_{880nm}/\text{DC Average}_{880nm})$ (1)

$\text{SaO2} = \alpha\,(\text{SaO2 ratio})^{2} + \beta\,(\text{SaO2 ratio}) + \lambda$------------------(2)

The calibration constants α, β, and l are obtained after calibrating the SaO2 ratio against the SaO2 records of the standard systems.

The AD8232 samples are collected through one of the ADC channels of the microcontroller, and the data is processed every 8 seconds to determine the time domain characteristics such as frequency of the samples, peak to peak interval [9]. The EKG signal is initially processed with a baseline wandering algorithm followed by a notch filter. Later, the peaks finding algorithm is used for locating the R peaks and the distance between the R peaks—the inverse of the average distance between the R peaks in the frequency of the heart beat. The multiplication of the frequency of the beats with the number of seconds in a minute gives the heartbeat of the patient in BPM.

The timed difference between the peaks of SaO2 signal and EKG signals is termed as pulse transit time (PTT). The average PTT measurement is stored in the database and is simultaneously compared against the standard BPmachine. The Blood pressure is measured from the PTT by substituting it in equations (3) and (4).

$\text{Systolic BP} = a + b\,(\log_e(\text{PTT})) + c\,(\text{Heart Rate})$---------------(3)

$\text{Diastolic BP} = x + y\,(\log_e(\text{PTT})) + z\,(\text{Heart Rate})$ -------- (4)

The constants a, b, c, x, y, and z are obtained by correlating the PTT while calibrating it with the standard BP machines.

After performing all the calculations, the data from the microcontroller is taken into the microprocessor for visualization and storage of data. The stored signals and the processed values are continuously displayed on the webpage developed with PHP.

RESULTS AND DISCUSSION

The system after calibration is tested against the standard instruments in a medical hospital. The non-invasive system is tested with 30 voluntaries.

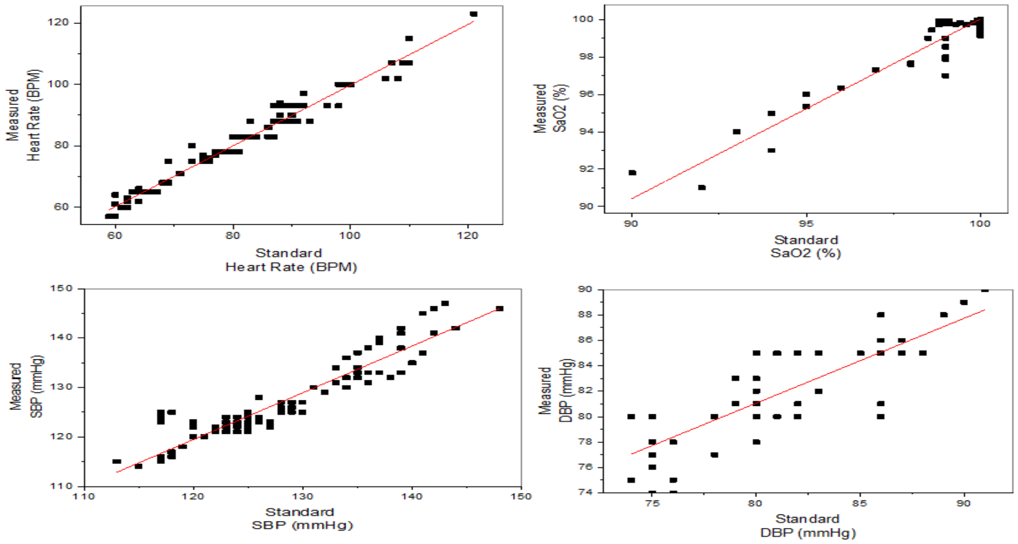


Figure 3 The physiological measurements of standard system Vs the designed System

The finger is put on the system's SaO2 probe, and the ECG probes are connected in the Einthoven triangle. The finger next to the finger where the probe of the developed system is connected is where the SaO2 probe of the standard system is connected. The other hand is attached to the conventional cuff-based blood pressure monitor. Entering the person's name on the website is the first step in the measuring. While the values of the designed system are automatically entered in the database, the values of the standard systems are manually recorded. The system's webpage displays the data as well as the PPG and EKG readings. Every ten seconds, the information on the page that is displayed is updated. The intended and standard systems' outputs are. The SaO2 of the patients is recorded at an average of 99.64 with an accuracy of ±2.5%. The heart raterecordings are averaged about 83 with an accuracy of ± 2BPM. The blood pressure recordings are monitored as 126mmHg Systolic with accuracy ± 5mmHg of and 84mmHg diastolic at an accuracy of ± 5mmHg. The results are displayed in both the local system as well as the other IoT-connected devices with the help of a web browser. The past database is also accessible for the authorized people with a user name and a passcode.

CONCLUSIONS

A low-cost prototype is created to measure several human bodily parameters. Data is then saved and sent to remote IoT-connected locations for telemedicine applications. The measured records and the standard instruments used in the hospital have acceptable agreement. The authors are attempting to extend this work by offering these physiological indicators coupled with a multimedia interface between the local and remote stations for comprehensive telemedicine practice.

REFERENCES

1. SK Sharma SK, K Thakur, R Kant, S Karla. Nurse-Led diabetes clinics in Southeast Asia: scope, feasibility, challenges and facilitators. J Diab. & Metab. 2021;**7(2),** 47–51. DOI: 10.15406/jdmdc.2020.07.00199
2. H Kinnunen, A Rantanen, T Kentta, and H Koskimaki. Feasible assessment of recovery and cardiovascular health: accuracy of nocturnal HR and HRV assessed via ring PPG in comparison to medical grade ECG. Physio. Measur. 2021. DOI: https://doi.org/10.1088/1361-6579/ab840a
3. M Mehrabi, S Setayeshi, MG Maragheh, SH Ardehali and H Arabalibeik, Design of a new reflectance pulse oximeter by obtaining the optimal source-detector space. Optik. 2018; **168**, 34-45. DOI:10.1016/j.ijleo.2018.04.039
4. GM Drzewiecki, J Melbin and A Noordergraaf. The Krotkoff sound. Ann. Biomed. Eng. 1989; **17**, 325– 359. DOI:10.1007/BF02368055
5. X Ding and YT Zhang. Pulse transit time technique for cuffless unobtrusive blood pressure measurement: from theory to algorithm. Boimed. Eng. Lett. 2019; **9**, 37-52. DOI:10.1007/s13534-019-00096-x
6. M Njah and R El-Hamdi. Design and Implementation of a Reactive Navigation System for a Smart Robot Using Udoo Quad. New Develop. & Adv. Rob. Cont. Stud. Sys. Deci. Cont. 2022; **175,** 285-289. DOI:10.1007/978-981-13-2212-9_13
7. CD Enache, SG Tudorache, CE Ulmeanu, DI Voiculescu, CA Becheanu and AD Florea Development of a Wearable Device for Monitoring People with Heart Problems, 2022 International Conference on e-Health and Bioengineering (EHB), Iasi, Romania, 2022; 1-4. DOI:10.1109/EHB50910.2022.9280104

8. P Schinagl and A Sharp. Algorithmic analysis and hardware implementation of a two-wire-interface communication analyser, 2017 Internet Technologies and Applications (ITA), Wrexham, 2017, pp. 189- 193, DOI: 10.1109/ITECHA.2017.8101936.
9. T Lu, P Liu, X Gao, and Q Lul. A Portable ECG Monitor with Low Power Consumption and Small Size Based on AD8232 Chip. Appl. Mech. & Mater. 2014, **513-517**, 2884-2887. DOI: 10.4028/www.scientific.net/AMM.513-517.2884