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Blood Pressure Monitoring Using Arduino-Android Platform

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***Abstract*— Increased blood pressure (BP) in the arteries is a common condition that leads to heart diseases and cardiovascular diseases. Therefore, an accurate measurement of BP is vital for the prevention and treatment of these diseases, especially in hypertensive patients. Complications of untreated high blood pressure (HBP) might be heart attack, stroke, or kidney damage. It has no obvious symptoms or warning signs and therefore it is often called "the silent killer". The traditional manual BP monitor is difficult to use by ordinary persons and it requires the expertise of a specialist. The lack of these devices in every home prevents many patients from checking blood pressure regularly. In this paper, we describe our developed BP monitoring system, which integrates the Arduino board as an open-source computer hardware/software platform with the Android smartphone. The system is based on the oscillometric pressure waveforms method and it is combined with a Bluetooth module that transfers data to a mobile application. Therefore, users can get information about their blood pressure on the smartphone easily and get acquainted with their health conditions regularly. This system can be integrated into other devices such as ventilators because it is an open-source and there is a growing demand for the manufacturing of these devices locally. Experimental results are promising with BP measurement accuracy close to the reference values.**

Keywords— Blood Pressure Monitoring; Mobile Application; Arduino Platform.

I. INTRODUCTION

With the advancement of modern science and technology, more and more people started to take care of their health. One of the most common ways to manage self-health care is through regular measurement of blood pressure (BP). High blood pressure (HBP) [Hypertension] is described as a "silent killer" because the original cause is unknown and has no symptoms on the patient. HBP can cause various complications which might lead to many other diseases, such as heart diseases, blindness, kidneys, and stroke to death. According to the World Health Organization (WHO) HBP can attack anyone, and different age groups. Also, it has a social and economic effects. It is estimated that HBP causes 7.5 million deaths worldwide, or about 12.8% of all deaths in 2004 [1]. People with hypertension should conduct regular BP measurements to check their health status and perform a medical review, because BP is a vital sign that changes over time.

BP is the pressure within the major arterial system of the body. It is usually expressed in terms of systolic BP (SBP) and diastolic BP (DBP). Systolic pressure is the maximum blood pressure during contraction of the ventricles; diastolic pressure is the minimum pressure recorded just prior to the next contraction [2].

This paper is organized as follows: Section II reviews important related work and research on BP measurement. Section III presents the components of the system. Section IV presents the operation of the system and its analysis. Section V presents the implemented system as hardware showing its schematic diagram, flowcharts and the implemented system. Section VI describes the experimental results of the systems and analyzes it. Section VII concludes the paper.

II. RELATED WORKS

We review here some of the research related to BP measurement. The most common method for finding BP in automatic devices is through oscillometric pressure waveforms which relies on a pressure sensor combined with the inflatable cuff. In [3], the researchers describe their designed noninvasive digital BP device using pressure gauge MPX5050GP. Signal filtering is done with hardware circuit. In [4], the researchers investigate the shape differences of the oscillometric pulse waveform between standard cuff inflation and deflation. Their study of oscillometric waveform differences during BP measurement suggest that arteries may behave differently during cuff inflation and deflation. In [5], the researchers assess three different algorithms for finding BP through the oscillometric method.

Other methods might rely on photoplethysmogram (PPG) techniques. A clinical-controlled evaluation of several Pulse Transit Time (PTT) techniques is performed in [6]. Using different signal type pairs such as electrocardiogram (ECG), PPG, and invasive blood pressure (IBP), the researchers concluded that the PTT techniques are not ready to measure BP where the smallest mean error is 4.91 mmHg ECG and IBP's [6]. An effective function based on the relationship between systolic blood pressure and pulse wave velocity (PWV) is developed in [7]. PWV is obtained from PTT produced by ECG and PPG and they concluded with the important relationship between PWV and systolic pressure. However, the error recorded after the comparison with the mercury sphygmomanometer (auditory method) was 20 mmHg [7]. In [8] a BP measurement system using PPG technology is developed. The system proved to be reliable although the error was 4 mmHg when compared to a mercury sphygmomanometer [8].

In this work, we use the oscillometric pressure method, as it has proven to be reliable compared with other approaches, to develop a BP monitoring system paired with a smartphone application so BP can be measured anywhere.

III. SYSTEM COMPONENTS

The PB measurement platform is composed of two parts: a hardware part, which is the BP measuring circuit, and a software

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part, which is the Arduino code and the Android app. The hardware constitutes of an Arduino board, an air pump, an air valve, an inflatable cuff, a pressure sensor, an amplifier circuit, a liquid crystal display (LCD) and a Bluetooth module. Block diagram of the system is shown in Figure 1. To control the physical components and to acquire sensory signal an Arduino Uno board was selected due to its simplicity.

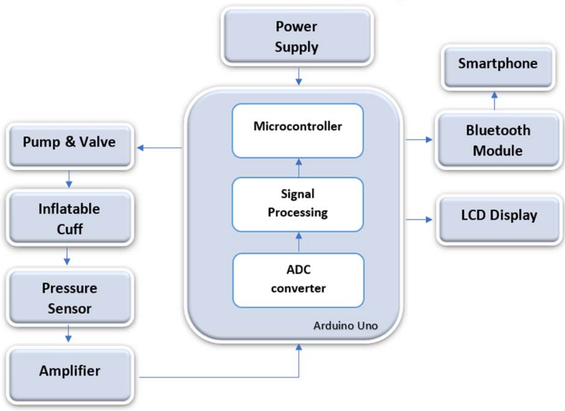

Figure 1: Block diagram of a proposed BP measurement platform

The air pump is used to inflate the cuff and the valve is used to regulate inflation and deflation. The pressure sensor measures the pressure inside the cuff by producing a voltage signal that reflects the pressure and oscillation of the compressed artery. An operational amplifier is needed to amplify the sensor signal. The amplified signal is acquisitioned by the Arduino. A software code on the Arduino processes the signal and performs basic computation to estimate the mean arterial pressure (MAP) and from its value the systolic and diastolic blood pressure values can be extracted. The MAP is defined as the average BP in a person's arteries during one cardiac cycle and is considered a better indicator of perfusion to vital organs [9]. Figure 2 shows the air pump and the valve used in the implementation part.

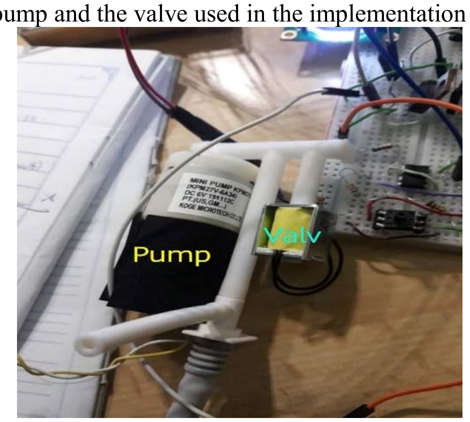

Figure 2: Basic components of the system during testing process

A. Microcontroller (ATmega328):

Arduino is an open-source physical computing platform based on a simple I/O board and a development environment that implements the Processing/Wiring language. Most Arduino boards consist of an Atmel 8-bit AVR microcontroller. The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers. The device operates between 1.8-5.5 volts.

B. Pressure Sensor

The used pressure sensor is the PSG010 manufactured by SIMST. According to the manufacturer it is a low-cost sensor. Moreover, it is MEMS technology-based sensor and it has high reliability. It has pressure range of 0 - 5.8 psi (40kpa). Its input impedance is 4 - 6 KΩ and its output voltage is 50 - 100 mV and it requires a power supply of 5 V.

C. Air pump

The air pump is the KPM27v mini air pump manufactured by KOGE. It has a small size and requires low power. It operates with high accuracy, low leakage and low noise. Rated life is 50000 cycles and the maximum drawn current is below 410 mA.

D. Air Valve:

The Valve is an electronic device for air discharge. It requires a power supply of 6 Volt and operates on a pressure 0-350 mmHg. The life test is more than 200000 times. Power consumption is 0.4-0.7 W and the maximum drawn current is less than 60 mA.

E. LCD Modules:

LCD modules are used in embedded projects because it is cheap and being a programmer friendly. The controller of LCD is Hitachi HD44780 and it operates on a voltage of 5V. It is essential to show the status of measurement and the final measured value of BP.

F. HC-05 Bluetooth Modules:

HC-05 modules are an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup, we use it to transfer result data to smartphone. It has v2.0+EDR protocol, 2.4GHz ISM band frequency and requires power supply of +3.3V and 50mA.

IV. System Operation and Analysis

A. System Analysis

Software development life cycle (SDLC) is a framework or a process used in the development of any software system. It aims to produce a high-quality software that meets or exceeds customer expectations. There are many different models' specific lifecycles such as spiral model and prototyping model.

B. System Operation

The Arduino Uno operates both the pump and the valve until the air blows into the inflatable cuff to generate pressure on the arm. The BP is sensed by the SIMST PSG010 pressure sensor. Consecutive readings of the sensor are recorded at a constant sampling rate during inflation and deflation. Finally, the results are displayed on the device screen and if the smart phone is connected to the device via the Bluetooth unit, this data is transferred to the smartphone and stored there. It should be clear that our developed automated BP measurement device measures only the MAP unlike the manual BP measurement devices which measure the systolic BP (SBP) and diastolic BP (DBP).

In automatic Sphygmomanometers SBP and DBP values can be derived as indicative from the MAP. Figure 3 shows a flowchart for system operation.

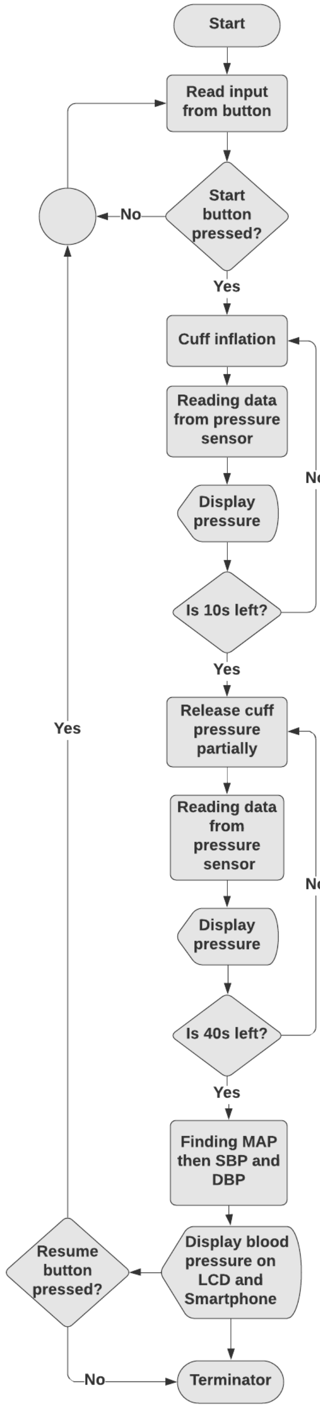

Figure 3. Flowchart of the system operation

V. SYSTEM IMPLEMENTATION

To measure BP, the user or hypertension patient, runs the device alone or he runs the project application on the smartphone which is paired with the device. The application stores a record of BP to have a trend for its variation over time. Moreover, mobile app commands the electronic pressure device. The elements of the project are shown in Figure 4.

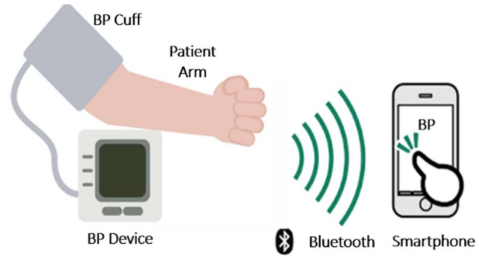

Figure 4: Elements of the project

A. Schematic circuit of the system

Figure 5 demonstrates the schematic circuit of the designed BP measurement system. It is designed on a PCB board. The circuit consists of a pressure sensor (SIMST PSG010s), an operational amplifier (LM358), a Bluetooth module, a transistor (BD711), an LCD and other passive elements. The schematic diagram is shown in Figure 5.

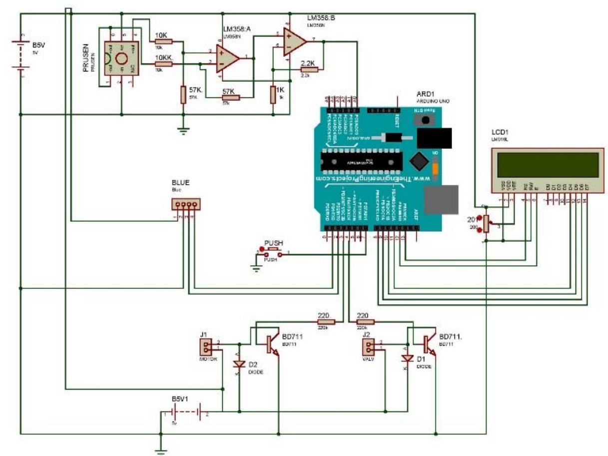

Figure 5. Schematic circuit project

Figure 6 shows the layout of the complementary circuit connected to the Arduino board.

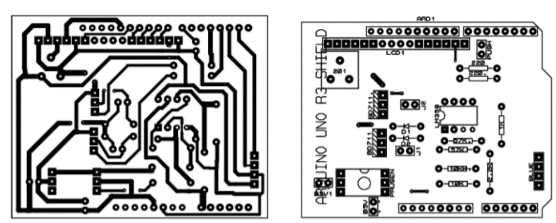

Figure 6. PCB layout of the circuit

B. Connecting Arduino to Android

The connection between the Arduino and the Android is important to enable the user to pair his smartphone to the pressure device via Bluetooth connection to store measurements on the smartphone.

C. Signal processing

The BP signal after being amplified by the operational amplifier is fed to the analog input of the analog to digital converter ADC of the Arduino board. To determine the MAP from the BP signal we should extract the oscillometric pressure pulse waveform from the cuff pressure. The MAP value is the value of cuff pressure at the maximal oscillometric pulsation during deflation (or inflation) of the cuff. To extract it we need to use a band pass filter. We use a finite impulse response filter (FIR) because of its simple implementation as a digital filter and the features it has such as having a linear phase. Figure 7 shows a typical cuff pressure signal in deflation phase and Figure 8 shows the bandpass filtered signal that represents the extracted oscillometric pressure pulse waveform.

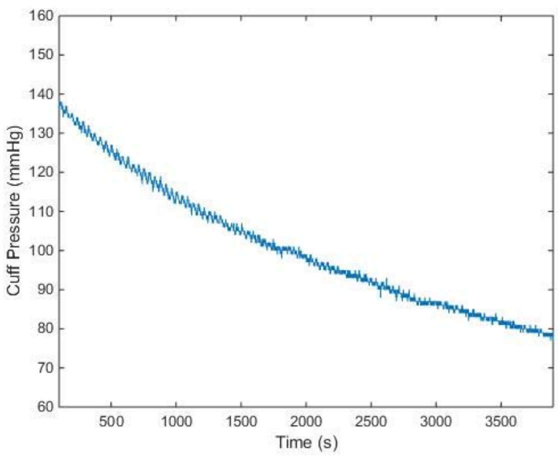

Figure 7: Example of cuff pressure signal in deflation phase

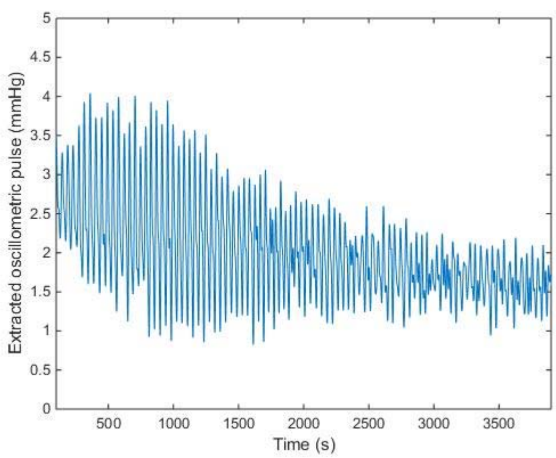

Figure 8: Extracted oscillometric pulse signal

D. Taking measurement of BP

After the application runs successfully, the application starts to work accurately. The blood pressure of the device is measured after the inflatable cuff is placed on the arm and the device is turned on, and the readings are stored in the application. When the phone is connected to Bluetooth. Figure 9 demonstrates the BP measurement using the actual implemented platform.


Figure 9: BP measurement using the actual implemented platform.

Figure 10 shows mobile app user interface of the BP measurement platform.

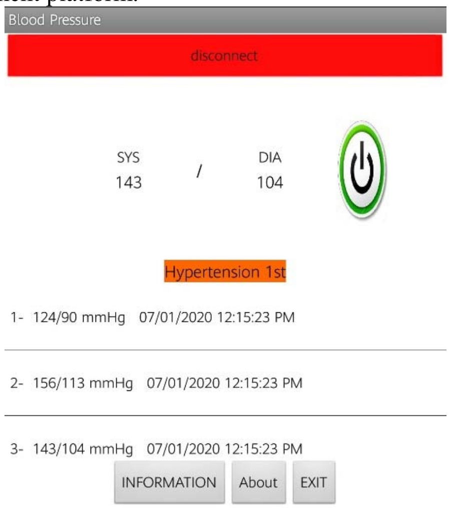

Figure 10: Mobile app user interface of BP measurement platform

VI. Experimental Results and Analysis

To validate the functionality, we compare the computed MAP from our developed system with the MAP of a reference device. The MAP of a reference device is computed from the manual auscultatory SBP and DBP values which were obtained during both cuff inflation and deflation. The used reference device is Mercury sphygmomanometer (diplomat-presameter®) manufactured by Rudolf Riester GmbH. Equation (1) is used to compute the reference MAP from the SBP and DBP reference values.

$$MAP = (SBP + 2 \times DBP)/3 \quad (1)$$

A. Experimental results

We show experimental results of five male subjects aged from 32 to 50 years. The participants provided their consent for measuring and recording their SBP and DBP data. We compute the MAP for reference data according to (1). We compare only the MAP values because it is the value which can be found from the extracted oscillometric pulse signal. We computed the percentage error between the reference MAP and the MAP from our developed system and tabulated results in Table I.

Experimental results show harmony between both MAP values and the worst error value in our developed system was 6.17%.

TABLE I. COMPARISON OF READINGS TAKEN FROM MANUAL DEVICE AND PROTOTYPE DEVICE.

Sub.	Age (Yrs.)	Manual BP Monitoring Device (Reference)			Dev. MAP	% MAP Error
		SBP	*DBP*	*MAP*		
1	50	120	80	93.33	91.16	2.38
2	46	122	80	94	93.74	0.28
3	46	134	92	106	102.85	2.97
4	32	120	70	86.67	92.02	6.17
5	46	130	80	96.67	101.48	4.98

VII. CONCLUSION

In this paper, we described the development of an automated open-source low-cost system for BP measurement to reduce the difficulties that patients encounter while conducting measurement. As the system provides raw data, it can be suitable as an experimental platform for developing algorithms that extracts BP value from raw sensory data. Moreover, it might fit the demand for equipping ventilators with BP devices. Pairing the developed device with Arduino allows for storing the data and transferring it to physicians to follow up their patients.

REFERENCES

[1] WHO, "Raised blood pressure." [Online]. Available: https://www.who.int/gho/ncd/risk_factors/blood_pressure_prevalence_text/en/.

[2] W. A. Brzezinski, "Blood Pressure," in *Clinical Methods: The History, Physical, and Laboratory Examinations*, H. K. Walker, W. D. Hall, and J. W. Hurst Eds. Boston: Butterworths, 1990.

[3] A. Mujadin and P. W. Kusuma, "Design a noninvasive digital blood pressure meter using high sensitivity pressure gauge MPX5050GP," in *2017 International Symposium on Electronics and Smart Devices (ISESD)*, 17-19 Oct. 2017 2017, pp. 236-241, doi: 10.1109/ISESD.2017.8253339.

[4] C. Liu, D. Zheng, C. Griffiths, and A. Murray, "Oscillometric waveform difference between cuff inflation and deflation during blood pressure measurement," in *Computing in Cardiology 2014*, 7-10 Sept. 2014 2014, pp. 849-852.

[5] S. Chen, V. Z. Groza, M. Bolic, and H. R. Dajani, "Assessment of algorithms for oscillometric blood pressure measurement," in 2009 IEEE Instrumentation and Measurement Technology Conference, 5-7 May 2009 2009, pp. 1763-1767, doi: 10.1109/IMTC.2009.5168742.

[6] C. Douniama, C. Sauter, and R. Couronne, "Blood pressure tracking capabilities of pulse transit times in different arterial segments: a clinical evaluation," in 2009 36th Annual Computers in Cardiology Conference (CinC), 2009: IEEE, pp. 201-204.

[7] H. Gesche, D. Grosskurth, G. Küchler, and A. Patzak, "Continuous blood pressure measurement by using the pulse transit time: comparison to a cuff-based method," European journal of applied physiology, vol. 112, no. 1, pp. 309-315, 2012.

[8] M. I. MOHD SANI, "DESIGN AND IMPLEMENTATION OF BLOOD PRESSURE MONITORING SYSTEM," 2013.

[9] "How Do Automatic Blood Pressure Cuffs Work?." [Online]. Available: https://rk.md/2017/automatic-blood-pressure-cuffs-work/?fbclid=IwAR2sij6GUVDkACAW8lNO1GNQiPAzprf3RMcwORyHawRtC2iJFFs4mgihE6I.