Wireless Transmission of Heart Rate and Blood Pressure Measurements for Remote Patient Monitoring

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***Abstract*— This paper describes the development of a wireless pulse and blood pressure monitoring system based on a microprocessor with low cost. It is aimed to receive blood pressure information (tension) through certain processes such as amplifying and filtering of the signal which is obtained by using BIOPAC SS19LA Blood Pressure Cuff and Transducer. With the designed prototype, it is possible to determine both systolic and diastolic pressure. Following preprocessing of the signal, the information of blood pressure and heart rate data of the patient is wirelessly transmitted to smartphone by using Bluetooth Module. The wireless system is used to transmit the measured data to a remote location. In this way, the biomedical parameters obtained from the patient can be instantly transmitted to any pre-paired smart phone and also recorded in the corresponding device.**

Keywords — Biomedical monitoring; Wireless communication; Blood pressure; Pressure measurement; Heart rate

I. INTRODUCTION

Blood pressure is the force that passes blood through human circulatory system. This is an important force for human to feed tissues and organs without tension [1]. The condition of the arteries affects blood pressure and flow, and the narrowing of the arteries may eventually clog the source completely, causing dangerous conditions such as stroke and heart attack [2].

The use of wireless technology has been improved to meet the need for remote control and monitoring. Remote patient monitoring (RPM) is a technology that enables patient monitoring outside the clinic or hospital. It can increase access to health care and facilities while reducing costs [3]. Remote Patient Monitoring improves the efficiency and reliability of health care by keeping both patient and doctor time.

Since long-term 24/7 vital sign monitoring outside clinical environment is become more vital for earlier and accurate diagnosis, there is an increasing demand for medical devices which can be used wirelessly such as heart rate monitoring and blood pressure monitoring. The wireless technology used to transmit biomedical signals has been extensively researched in the recording of electrocardiogram [4-6], electroencephalogram [7], electromyogram [8], electrooculogram [9], and neural activity [10].

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In this study, we implemented a smartphone based wireless blood pressure monitoring system, which can present real time information about medical status of a patient's blood pressure and heart rate. With the presence of Bluetooth module in the system, it is possible to follow up patient's blood pressure and heart rate via smartphones for necessary medical diagnosis and advising.

The proposed system consists of a blood pressure cuff and transducer, a Bluetooth module, a specially designed sphygmomanometer and a microphone module. In order to obtain and transfer data from blood pressure cuff and transducer, Arduino is used and certain developments are established.

II. MATERIALS AND METHODS

Equipment and modules used in this study are BIOPAC MP36 module SS19LA Blood pressure cuff and transducer, SS30L Stethoscope disk, Instrumentation Amplifier constructed via UA741CP, HC-05 Bluetooth Module, and MAX4466 Microphone Module.

A. Blood Pressure Cuff and Transducer

In this design, Biopac SS19LA blood pressure cuff and transducer is used to obtain the blood pressure values. In order to affirm that device's working properly, Biopac MP36 4 Channel Data Acquisition System, SS30L Stethoscope is used and obtained both systolic and diastolic pressures and Korotkoff sounds. All measurement steps are given in the L16 Blood pressure measurement tutorial and all steps are followed strictly to perform measurement successfully.

Specifications of Biopac SS19LA blood pressure cuff and transducer that is used during this study are given in Table 1.

TABLE I. BIOPAC SS19LA SPECIFICATIONS

Pressure Range		20 mmHg to 300 mmHg
Manometer Accuracy		±3 mmHg
Output		5 µV/mmHg (normalized to 1 V excitation)
Interface	TSD120	DA100C
	SS19LA	MP3X / MP4X

To figure out BIOPAC SS19LA probe pin outs' values of 9 PIN Female DSUB, we use MP36 4 Channel Data acquisition system's channel 1 input port. We connected these ports on breadboard and observed each pin's feature in TekTronix TBS1022 Digital Storage Oscilloscope to determine each feature of pin outs. For SS19LA blood pressure cuff and transducer, all pin outs and their values are given in Table II[11].

TABLE II. 9 PIN FEMALE DSUB PIN OUT

Pin Number 	Values
Pin 1	Shield Drive
Pin 2	Vin +
Pin 3	GND
Pin 4	Vin -
Pin 5	Shield Drive
Pin 6	-5 V
Pin 7	5 V
Pin 8	5 V
Pin 9	5 V

As it can be seen in Table 2, there are 2 output signals which are Pin 2 (Vin +) and Pin 4 (Vin-). In order to convert these two output signals into one output signal, it is decided to design an instrumentation amplifier which has a high voltage gain.

B. *Instrumentational Amplifier*

Instrumentation amplifier (IA) is the precision gain blocks that have a differential input and an output that may be differential or single-ended with respect to a reference terminal. These devices amplify the difference between two input signal voltages while rejecting any signals that are common to both inputs. IAs are widely used in many industrial applications, data acquisition, and medical applications where dc precision and gain accuracy must be maintained within a noisy environment, and where large common-mode signals (usually at the ac power line frequency) are present. An example circuit scheme of Instrumentation amplifier is shown in Fig. 1.

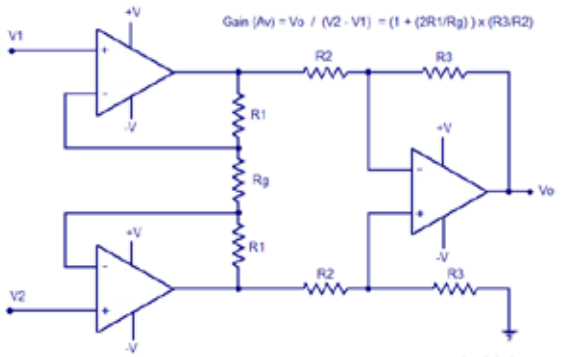

Fig. 1. Circuit diagram of instrumentation amplifier

While designing the instrumentational amplifier, three general purpose-single operational amplifiers whose code is UA741CP are used. IA has high performance monolithic operational amplifier constructed on a single silicon chip. Its main purpose for use is wide range analog instructions such as function generators, active filters, and voltage follower.

Since biological signals generally have very low frequency and amplitude values, these signals need to boost to value of output. In equation (1) which is given below, the resistors were chose to achieve a high voltage gain. All chosen resistor values and related gain is calculated and confirmed with NI Multisim 14.0 program.

$$\text{Voltage gain (Av)} = \frac{Vo}{V2\text{-}V1} = \left(1 + \frac{2R1}{Rg}\right) x \frac{R3}{R2} \qquad (1)$$

where Vo is output of the signal in Volts, V1 and V2 are the signal inputs in Volts, and R1, R2, R3 and Rg are resistors of the instrumental amplifier circuit.

While designing the instrumentation amplifier, 3 general purpose-single operational amplifiers whose code is UA741CP are used. This Op-Amp is high performance monolithic operational constructed on a single silicon chip.

C. *Software*

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P. This microcontroller has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It can be simply connected to a computer with a USB cable or powered with the AC-to-DC adapter or battery. Since Arduino Uno provides simple and clear programming environment, open source extensible software and hardware, cross-platform usage, Arduino Uno R3 is chosen and further development on this project (Fig. 2).

Fig. 2. Arduino/Genuino Uno R3 microcontroller

In this study, HC-05 Bluetooth module is used for wireless transmission of blood pressure and heart rate signals which are obtained from SS19LA blood pressure cuff and microphone module. Since Bluetooth modules provides low cost but more stable performance, using Bluetooth module rather than a GPRS module, would be more convenient for the design of this device.

Korotkoff Sound is the key to determine both systolic and diastolic pressure. In order to determine korotkoff sounds, MAX 4466 Microphone module is used. MAX4466 is decompensated for a minimum stable gain of +5V/V and provide a 600 kHz gain bandwidth product. In addition these amplifiers feature rail-to-

rail outputs, high volume amplitude, plus excellent power-supply rejection and common-mode rejection ratios for operation in noisy environments. This microphone module is used in many applications such as voice-recognition systems, hearing aids and so on.

D. Stethoscope and Max4466 Microphone Module Connection

In order to obtain the Korotkoff sounds while performing blood pressure measurement, a new stethoscope is proposed. The assembled design is shown in Fig. 3.

Fig. 3. Designed stethoscope for the detection of heart sounds

Max4466 Microphone module is placed under the plastic tubes. While performing measurement, stethoscope disk recognizes the sound. With plastic tubes, this sound is recognized and transferred to Arduino Microcontroller.

III. RESULTS AND DISCUSSION

With the construction and specific hardware component's usage, all steps that are done shown in Fig. 4.

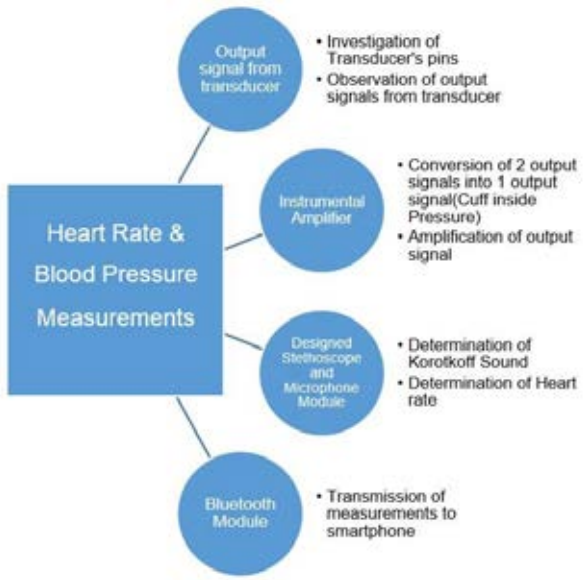

Fig. 4. Major blocks of system implementation

With the usage Arduino for the design of this device, it is possible to determine heart rate and blood pressure measurements. HC-05 module is used for transmitting three main signals (Heart Rate, Systolic and Diastolic Blood Pressure) to an android based smartphone or tablets. Fig. 5 shows the overall design of the device.

Fig. 5. Design of monitoring system.

Ardutooth is specifically used for wireless transmission of data read by Bluetooth module connected to Arduino. Blood pressure and Heart Rate Measurement which is taken by one of our friends is given in Fig. 6.

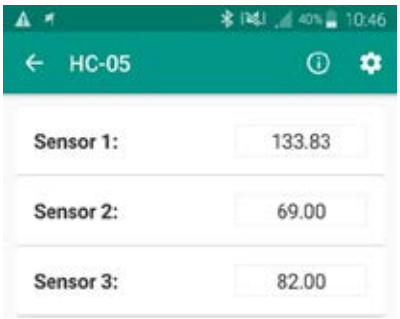

Fig. 6. Real-Time biomedical data on a smart phone. Sensor 1 represents Systolic Blood Pressure, Sensor 2 represents Diastolic Pressure and Sensor 3 represents Heart Rate.

In this research, it is aimed to obtain blood pressure information through certain processes such as noise filtering and filtering of low frequency signal obtained by using Biopac SS19LA blood pressure cuff and transducer and to reach the patient's blood pressure information by processing this information. Using Arduino and Bluetooth module, blood pressure information was delivered to smartphones.

Prototype is also designed for this research. Final presentation of the designed device is shown in Fig. 7.

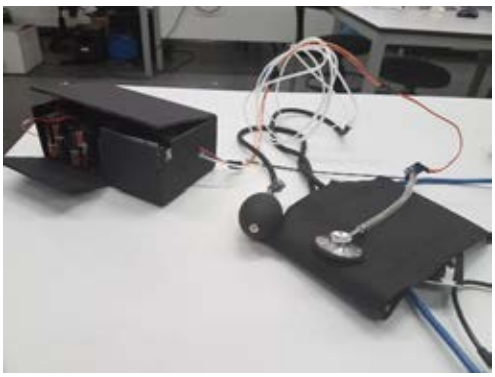

Fig. 7. Prototype of the device

IV. CONCLUSION

A wireless blood pressure monitoring system was designed and implemented for a smartphone-based management unit with Graphical User Interface (GUI) and database.

Personal measurement information, including Heart Rate, Systolic and Diastolic Blood Pressure measurement time and

date, can be stored in the database. On the Android GUI in the administration, users can be easily see blood pressure changes. Measurement information is also very useful for healthcare personnel to understand the patient's condition in the past.

This article presents a prototype of a system for remote monitoring of blood pressure and heart rate. The system sought to meet the diverse needs of users, to minimize costs and to maximize expandability and reliability.

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