AN INTEGRATED APPROACH OF BLOOD PRESSURE AND HEART RATE MEASUREMENT SYSTEMS

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Abstract- *A new integrated device using PIC microcontroller (PIC18F4550) for measuring blood pressure (BP) and heart rate through wrist and fingertip is designed and developed. This device introduces alarms to indicate the heart rate and BP which could be compared with the standard values of the heart rate and BP measured by existing conventional BP and heart rate machines. The fluctuation of blood can be detected through optical sensing mechanism comprising of IR photodiodes placed around the wrist and fingertip. Three phases are used to detect pulses on the fingertip and wrist that include pulse detection, signal extraction and pulse amplification. The pulses taken from wrist and fingertip are counted to determine the BP and heart rate. We compared the performance of this device with conventional manual measurement system of blood pressure and heart rate of 100 human subjects to different ages of both the genders. The result showed that the error rate of the device is negligible. In a word, our proposed device is cost-effective, user friendly, reliable and uses optical technology to detect the flow of blood through index finger & wrist and to give alarms.*

Key Words - **Vesotrac sensor, IR sensors, Microcontroller, Buzzer, LCD display.**

1. INTRODUCTION

Blood pressure and heart rate have been recognized as vital signs since the earliest days of medicine. Vital signs are measurements of the body's most basic functions. It is known that blood pressure and heart rate (vital signs) is the primary indicator of an individual's physical well-being including to health, disease, excitement and stress [1].Vital signs are useful in detecting or monitoring medical problems. Regular monitoring of vital signs is essential as they are primary indicators of an individual's physical well-being. If there is any problem in vital signs, we have to suffer from various diseases. So, blood pressure and heart rate should be measured regularly to know our health condition. Vital signs can be measured generally in a medical setting, at the site of a medical emergency. Seniors have to make frequent visits to their doctor to get their vital signs measured. But, it is not possible for everyone to make frequent visit to the doctor due to the problem of money and others. Besides this, there are not enough doctors in our country. It is known from a statistics that there is 2860 population per doctor in our country [2].

As our country is developing country, so it is not possible for our government to appoint doctors for everyone. Although, it is seen that 3.175 billion (Taka) was allotted from our national budget for health sector for 2004-05 year. 4.112 billions (Taka) was also allotted from our national budget for health sector for 2005-06 year. 4.957 billions, 5.261 billions, 6.196 billions, 6.833 billions,7.617 billions, 8.869 billions, 9.130 billions(Taka) was allotted for 2006-07, 2007-08, 2008-09, 2009-10,2010-11, 2011-12, 2012-13 years. 9.470 billions (Taka) was allotted for 2013-14 year. It is seen that health care costs of Bangladesh have risen three times within ten years [2]. Health Expenditure of Bangladesh is 3.7% of GDP (2011) [3].

But, death rate has not been decreased. Death rate (per 1000 population) was 5.9 in 2003. It is seen that death rate (per 1000 population) was 5.6 in 2011 [2]. Death rate (per 1000 population) is 5.67 (2013) [3]. Health care costs have risen exponentially not only in Bangladesh but also in foreign countries.

It is known from a statistics released by the Canadian Institute for Health Information for 2008 is that Health care in Canada cost is $172 billion or nearly $5,200 for every person in the country. It is also known that out of this, the third-biggest slice of the spending pie went to physician services, which totaled $23 billion. Health care for children under the age of one year cost, on average, $7,900. People of 65 year ages and older racked up an average bill of almost $10,000 in 2006, the last year for which age-specific data were available. Not surprisingly, patients between the ages of 85 and 89 cost the most in health services -- more than $21,200 on average in 2006 [4]. As observed from the statistics, individuals over 65 years of age have higher health care costs and a significant portion of these costs are a consequence of the services provided by the physicians. If everyone maintains some rules for keeping good health by monitoring blood pressure and heart rate regularly, then health care costs will be decreased. So, a cost-effective device is needed for everyone to measure blood pressure and heart rate easily in any environment, at any place. The devices used generally for measuring BP and heart rate are not cost-effective.

It is known that Blood pressure (BP), sometimes referred to as arterial blood pressure, is the pressure exerted by circulating blood upon the walls of blood vessels and is one of the principal vital signs [5]. Actually, Heart rate indicates the soundness of our heart and helps assessing the condition of cardiovascular system [6]. A heart rate measurement device is a simple device that takes a sample of the heartbeat signal and computes the bpm so that the information can easily be used to track heart conditions. A blood pressure measurement device is a simple device which is used for measuring blood pressure. If we can measure both blood pressure and heart rate with an integrated device through wrist and fingertip, it will be remarkable progress in Biomedical Engineering sector. If we include alarm system to the device, it will be great help for an illiterate patient.

In our work, an integrated device is introduced which can measure blood pressure and heart rate through wrist and fingertip. Besides this, this device introduces alarms to indicate the heart rate and BP which could be compared with the standard values of the heart rate and BP measured by existing conventional BP and heart rate machines. Our proposed device gives good accuracy (error rate less than 5%).

2. OBJECTIVES

There are many systems for measuring blood pressure and heart rate through wrist and fingertip. But, all systems do not give good accuracy and all systems are not cost-effective. For many years, blood pressure and heart rate measurement system remains an interesting field of research and many works have been done for introducing measurement device that will give maximum accuracy. In our work, an integrated device is introduced to measure blood pressure and heart rate through wrist and fingertip with better accuracy. A literate person can measure his blood pressure and heart rate by observing the value from the device. But, an illiterate person cannot know his BP and heart rate even after observing the value of BP and heart rate from the device due to illiteracy. An illiterate person is like a blind person. The service is provided not only for literate population but also for illiterate and blind population. So, alarm system is included to our proposed device. Our proposed device introduces alarms to indicate the heart rate and BP which could be compared with the standard values of the heart rate and BP measured by existing conventional BP and heart rate machines. This will help the illiterate and blind population to measure BP and heart rate by themselves. The performance of our device is compared with conventional manual measurement system of blood pressure and heart rate of 100 human subjects to different ages of both genders. In our work, a cost-effective integrated device is introduced for measuring blood pressure and heart rate digitally. The cost is kept less than 20$ (about 1500 Taka). Besides this, minimum error rate is also kept.

3. METHODOLOGY

The circuit of our proposed device consists of an infrared LED in the case of taking pulse from fingertip that transmits an IR signal through the fingertip of the subject, a part of which is reflected by the blood cells. The reflected signal is detected by a photo diode sensor. The changing blood volume with heartbeat results in a train of pulses at the output of the photo diode, the magnitude of which is too small to be detected directly by a microcontroller. Therefore, a two-stage high gain, active low pass filter is designed using two Operational Amplifiers (Op-Amps) to filter and amplify the signal to appropriate voltage level so that the pulses can be counted by a microcontroller. Same occurrence is occurred in the case of taking pulse from wrist. The difference is that vasotrac sensor is used in the case of taking pulse from wrist where IR sensors is used in the case of fingertip. Vasotrac Sensor's purpose is almost similar to IR sensors. It can transmit and receive pulse from the deepest area of wrist. Vasotrac sensor is responsible for taking pulse from the wrist [7]. A two- stage high gain, active low pass filter using two Operational Amplifiers (Op-Amps) is used to filter and to amplify the signal to appropriate voltage level so that the pulses can be counted by a microcontroller. A LM-324 comparator circuit is also used. The received signal from vasotrac and IR receiver sensors goes to LM-324 comparator circuit. The comparator circuit works by simply taking two analog inputs, comparing them and produce the logical output high "1" or low "0". The comparator circuit compares this two analog signal. If the analog input on + input is greater than the analog input on - input (inverting), then the output will swing to the logic "1". When the analog input on + input (non inverting) is less than the analog input on - input (inverting) then the comparator output will swing to the logical "0". An LED connected at the output blinks every time when a heart beat is detected. When pushbutton or switch is pressed ON after placing fingertip and wrist on the sensors, then microcontroller starts counting pulse for 60 seconds (1 minute). Then, average value of heart rate coming from wrist and fingertip will be displayed on 2/16 LCD display. The average value of blood pressure will be displayed on 2/16 LCD display at a time. Buzzer is connected to pin- 21 of PIC18F4550 microcontroller which is responsible for introducing alarms to indicate the heart rate and BP which could be compared with the standard values of the heart rate and BP measured by existing conventional BP and heart rate machines. In a word, a buzzer is an audio signaling device [8]. Here, "OK switch" and "Change switch" are used in this circuit. OK switch is used to start microcontroller. Change switch is used to change gender and age range. The weak electrical signal coming from the photo sensor unit is then filtered and amplified two times in LM-324 and is converted into a pulse. The pulse rate (heart rate) has a relation with blood pressure. BD135 is also used. It is a plastic medium silicon npn transistor used to amplify and driver utilizing complementary or quasi complementary circuits [9].

4. PROPOSED MODEL

In this section, the concept of our system is given. In our system, pulses coming from wrist and fingertip go to low pass filtering circuit. Then, the received signal from vasotrac and IR receiver sensor goes to LM-324 comparator circuit after amplifying and filtering by the low pass filtering circuit. The received signal goes to microcontroller. Then, heart rate and blood pressure are obtained in the LCD display. Alarm is also obtained from the buzzer. The circuit operation of our proposed device is divided into three units. Three units are- sensor unit, signal conditioning unit, microcontroller and display unit. The sensor unit is discussed at first. Then, the operation of signal conditioning circuit is discussed. A brief description is also given about microcontroller and display unit.

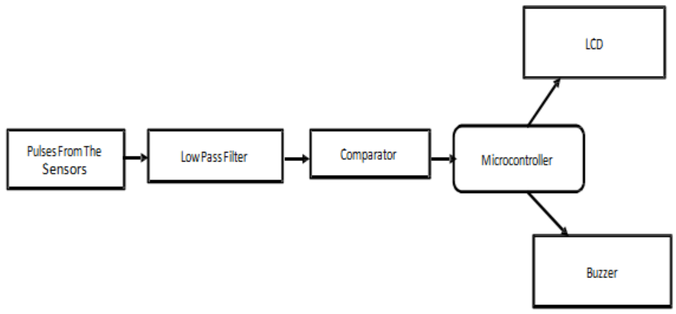

Figure 1: Block Diagram

The operation of signal conditioning unit is described in the methodology section.

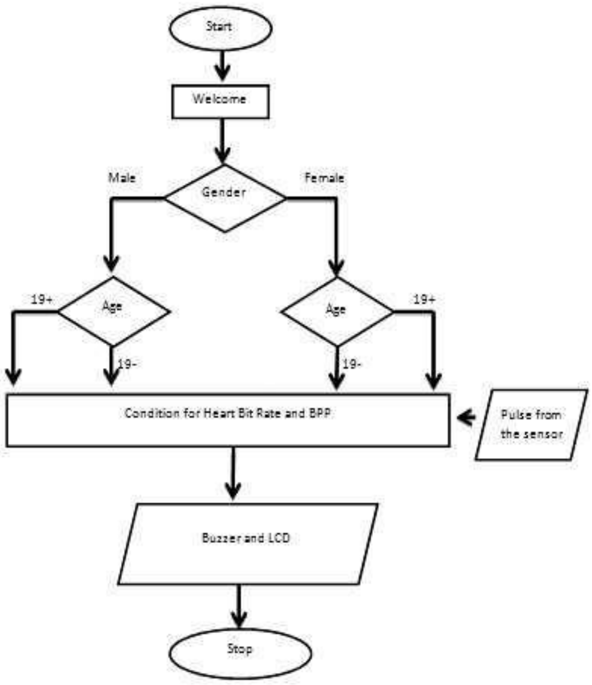

Figure 2: Flow chart

The sensor unit consists of an infrared light-emitting-diode (IR LED) and a photodiode, placed side by side as shown below for taking pulse from fingertip. Vasotrac sensor is used for taking pulse from wrist. The IR diode transmits an infrared light into the fingertip (placed over the sensor unit) and the photodiode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, each heart beat slightly alters the amount of reflected infrared light that can be detected by the photodiode. The changing blood volume with heartbeat results in a train of pulses at the output of the photodiode, the magnitude of which is too small to be detected directly by a microcontroller. Therefore, in the next stage a two-stage high gain, active low pass filter is designed using two Operational Amplifiers (Op-Amps) to filter and amplify the signal to appropriate voltage level so that the pulses taken from fingertip can be counted by a microcontroller. A two-stage high gain, active low pass filter using two Operational Amplifiers (Op-Amps) is used to filter and amplify the signal to appropriate voltage level so that the pulses taken from wrist can be counted by a microcontroller. Since, blood pressure is related to heart rate, so blood pressure can be measured easily from pulse rate or heart rate.

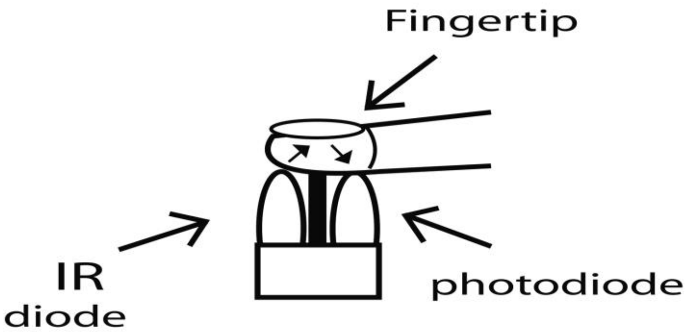

Figure 3: Sensor unit for fingertip.

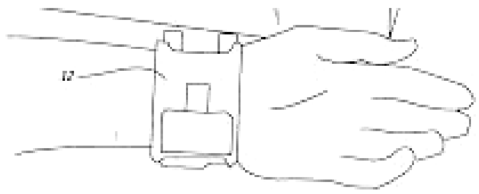

Figure 4: Sensor unit for wrist

The equations for calculating gain and cut-off frequency of the active low pass filter that have been used are in the following. Gain of each stage=$1+R_t/R_i$=1+680k/6.8k=101. Now, cut-off frequency =$1/(2\times\pi\times R_f\times C_f)$=2.34 Hz. π =3.1416 . The value of the data is obtained from the circuit diagram. The output can be obtained from pin-21 of PIC18F4550 microcontroller. LM-324 is used that is a 14pin IC consisting of four independent operational amplifiers (op-amps) compensated in a single package. Op-amps are high gain electronic voltage amplifier with differential input and usually, a single-ended output. The output voltage is many times higher than the voltage difference between input terminals of an op-amp.

These op-amps are operated by a single power supply LM-324 and are needed for a dual supply eliminated. They can be used as amplifiers, comparators, oscillators, rectifiers etc. The conventional op-amp applications can be more easily implemented with LM-324 [10-12].

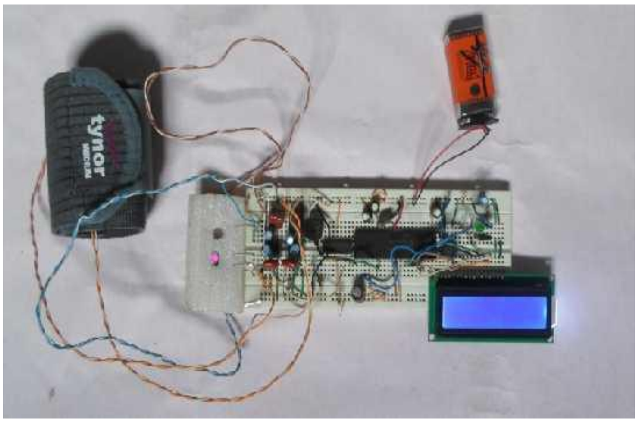

Figure 5: Real view of our designed system

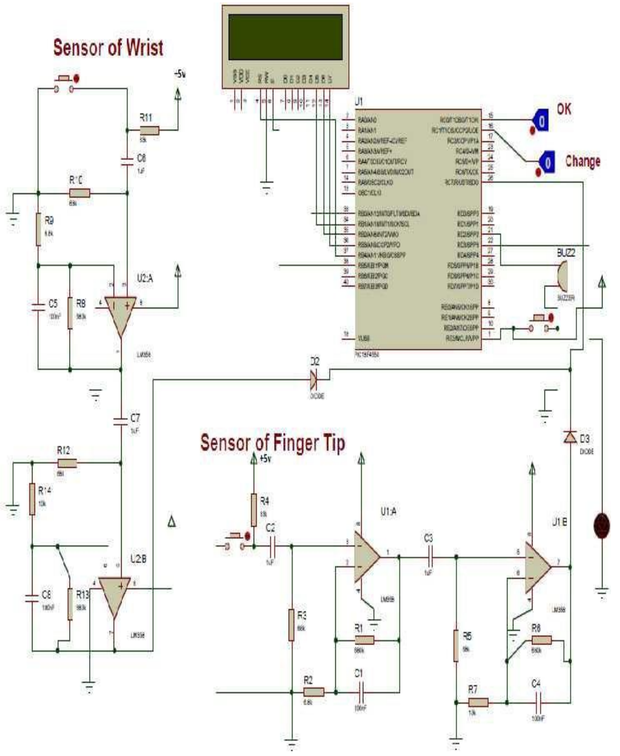

Figure 6: Overall circuit diagram

2/16 LCD Display is used as an electronic display module that is driven using multiplexing technique.

5. RESULT AND PERFORMANCE

Hardware implementation of our proposed device has been done. Blood pressure and heart rate of 100 patients have been measured. To get maximum accuracy, our best try is done. Diastolic and systolic blood pressure of patients is measured using our proposed device. Diastolic blood pressure and systolic blood pressure is collected using conventional device. At last, error rate is obtained for blood pressure and heart rate that is less than 5% after comparing between our proposed device and conventional device. The accuracy of our proposed device is more than 95%. The error rate of our proposed device is less than 5%. At first, data is collected for 100 patients using conventional device. Two relationship equations are obtained by using MATLAB SIMULATION. First equation is related to diastolic blood pressure vs heart rate. Second equation is related to systolic blood pressure vs heart rate. It is observed that there is a relationship between diastolic blood pressure and heart rate, systolic blood pressure and heart rate. Then, data is collected for 100 patients using our proposed device. Almost same two relationship equations are obtained by using MATLAB SIMULATION. These two equations are in the following.

1) Equation for Relationship between Diastolic Blood Pressure (DBP) and Heart Rate:

DBP= (0.000712*(bit_rate*bit_rate*bit_rate)-0.196*(bit_rate*bit_rate)+18*bit_rate-474);

2) Equation for Relationship between Systolic Blood Pressure (SBP) and Heart Rate:

SBP=(-0.000954*(bit_rate*bit_rate*bit_rate)+0.277*(bit_rate*bit_rate)-25.9*bit_rate+897);

These two equations are justified by plotting data along X-axis and Y-axis by MATLAB SIMULATION. It is understood after observing four graphs in the following.

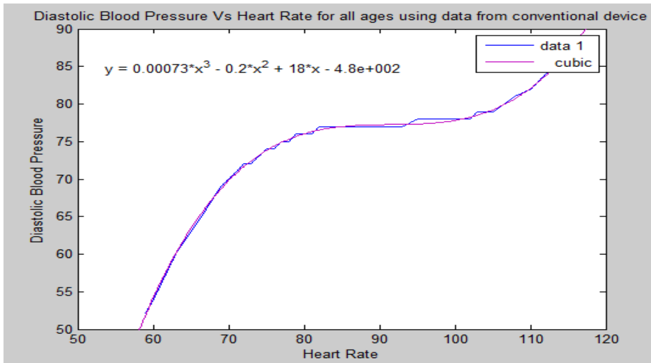

Figure 7: Diastolic blood pressure vs heart rate using data from conventional device [Gender: Both (100 patients), Age Range: All]

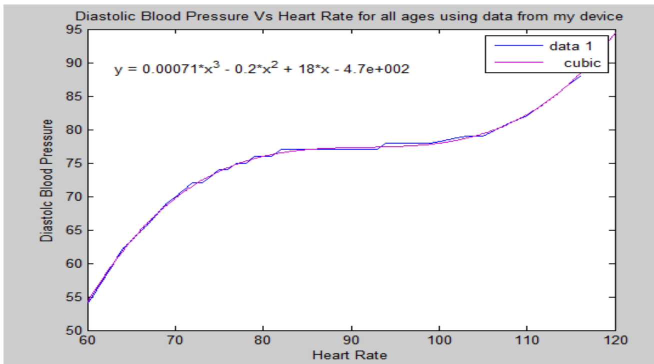

Figure 8: Diastolic blood pressure vs heart rate using data from my proposed device [Gender: Both (100 patients), Age Range: All]

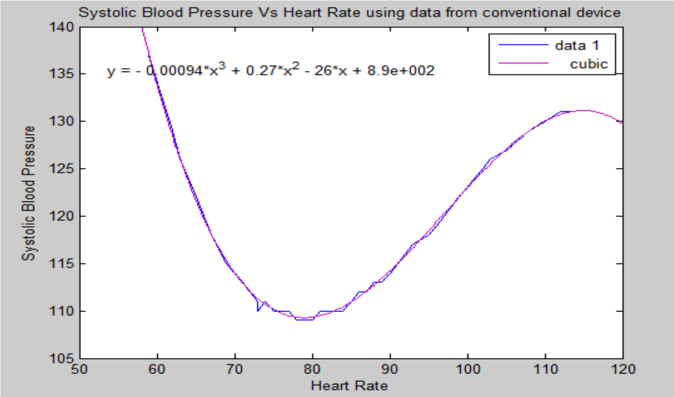

Figure 9: Systolic blood pressure vs heart rate using data from conventional device [Gender: Both (100 patients), Age Range: All]

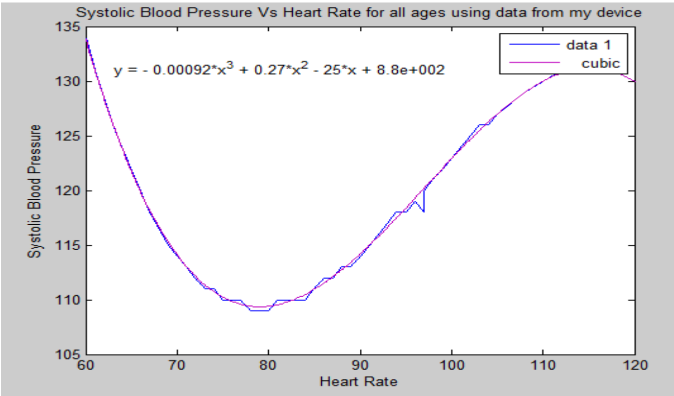

Figure 10: Systolic blood pressure vs heart rate using data from my proposed device [Gender: Both (100 patients), Age Range: All]

From the above four graphs, it is observed that these two equations are correct. So, our proposed device is more effective because the accuracy of it is more than 95% and the cost is 1,359 Taka.

6. PROBLEMS & TROUBLESHOOTING

The harder part is that it is difficult to work with the ADC values of the sensors. It is difficult to work smoothly depending upon only the ADC values of the sensors. Sometimes, the soldering connections create problems. So, it is recommended that all of complexities should be handled carefully.

7. FUTURE WORK

There is a lot of scope for further implementation such as the components and design can be extended to implement a pulse oximeter which distinguishes between oxygenated and deoxygenated blood flow. To upgrade this work, graphical LCD is used to display the heartbeat signal. The design can be extended to implement heart rate, blood pressure, body temperature for mobile on-call system. The design can be extended to implement noise detection, burglar alarms & others for mobile on-call system.

8. CONCLUSION

Anyone can measure blood pressure and heart rate by our device in any environment, at any place, at any time. The most important point is that our device will work as the best friend of poor population because they cannot bear the health expenditure. Our device is cost-effective and it is less than $20/(1359 Taka). As our device introduces alarms to indicate the heart rate and BP, it will also be helpful for illiterate and blind person as well to measure BP and heart rate by themselves. So, everyone can maintain some rules to keep his health well every day. Since, our proposed device is economical, user friendly, reliable and uses optical technology, so it claims right to consider itself as a popular device. Besides this, our device provides maximum accuracy (about 95%). Finally, our work on “An Integrated Approach of Blood Pressure and Heart Rate Measurement Systems” has been completed successfully. While performing the task, some challenges about the functioning of the device have been faced. In our work, many electrical components have been introduced that are frequently used which will help us to work efficiently in our near future life. As few ICs and optical sensors have been used, so there is a little chance to vary the measured value. Our goal is obtained that is desired after maintaining precautions.

9. REFERENCES

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