SIMULINK MODELING OF BLOOD PRESSURE SYSTEM

[1]NIKITA TEGGI, [2]YASHA JYOTHI M SHIRUR, [3]VISHWESHWARA MUNDKUR

[1]Dept of ECE, BNMIT, Bangalore,
[2]Associate Professor, Dept of ECE, BNMIT Bangalore
[3]Director, SenseSemi Technologies, Pvt, Ltd, Bangalore
E-mail: [1]nikitateggi@gmail.com, [2]yashamallik@gmail.com, [3]vishy.m@sensesemi.com

Abstract— Most medical conditions can be diagnosed through vital signs and confirmed with the help of special tests. Vital signs include the measurement of Blood Pressure, Temperature, and Heart rate. These measurements provide critical information (hence the name "vital") about a patient's state of health. Modeling of Blood Pressure is mainly concentrated in this work. Modeling of such important system has become a useful tool to study the behavior of the parameters affecting the blood pressure. MATLAB, Simulink is used for modeling and simulation of the mathematical model of physiological system and also the signal processing blocks. Using the oscillometric data heart rate is also determined.

Index Terms— Simulink, Modeling, Blood Pressure.

I. INTRODUCTION

Advances in semiconductor technologies is helping healthcare in many ways including medical imaging technology, robotic surgery etc. The upcoming ones are wearable devices, especially on a wrist, which is capable of determining Blood Pressure, Glucose level, Heart rate etc. The most important factor here is reliability and accuracy in measuring the parameters. Blood pressure is one of the most important vital signs of the human body. It is defined as the force exerted by the circulating blood on the walls of the arteries, veins and the chambers of heart. It is also defined as the arterial pressure. The blood pressure level of a normal adult is 120/80 mmHg. 120 mmHg represents the systolic blood pressure and 80 mmHg represents the diastolic blood pressure. The blood pressure is measured non-invasively by closing the brachial artery with an external cuff.

There are many papers that discuss blood pressure modeling. Sanchit Goyal, in his work he discusses on the mathematical modeling of non-invasive method of Blood Pressure measurement [1]. In this paper a mathematical model for non-invasive Blood Pressure measurement is presented which could capture the systolic and diastolic pressure as well as varying pulse pressure along with artery stiffness. The input signal obtained is a voltage signal which is converted to pressure signal with the use of equations specified in the specification sheet of the sensor. An IIR filtering technique is used to eliminate the noise. The mean arterial pressure is calculated which is the average over a cardiac cycle and is determined by cardiac output, system vascular resistance and central venous pressure. Study of different pulse pressure waveform applications is important [2]. The methodology described in [2] includes oscillometric Blood Pressure algorithms based on physiology and Blood Pressure monitor testing, to determine hemodynamic from oscillometric waveforms and acquiring radial artery waveforms from wrist.

II. BLOOD PRESSURE FUNDAMENTALS

There are different methods to measure Blood Pressure. Auscultatory method is the standard, in which the pressure values are determined by using korotkoff sounds. But it requires a trained professional to estimate the systolic and diastolic pressure, hence cannot be used for automatic estimation of Blood Pressure. Oscillometric method is used for automatic estimation of Blood Pressure. In this work a physiological mathematical model is created for oscillometric Blood Pressure measurement which describes the anatomy, physiology mechanisms underlying the production of cuff pressure and extracting the systolic and diastolic pressures from the oscillometric pulses. The oscillometric pulses are obtained from the detailed modeling of the physiology system. The cuff pressure is high pass filtered and the oscillations are extracted. As cuff pressure falls, the amplitude of the oscillations increase in amplitude between systolic and mean arterial pressure and then the cuff pressure decrease further between mean arterial pressure and diastolic pressure, the oscillations decrease in amplitude Figure 1 shows a recording of cuff pressure and oscillometric pulse.

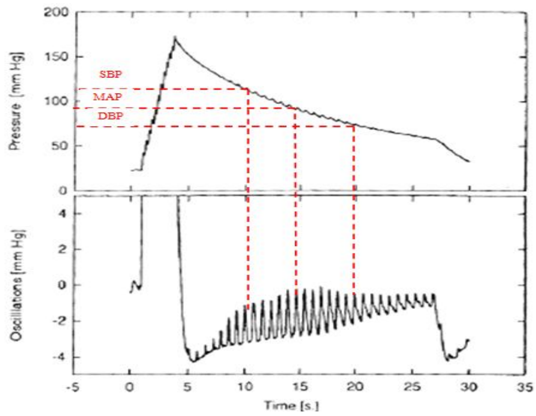

Figure 1 A recording of Cuff Pressure and oscillometric pulse SBP - systolic blood pressure, MAP -mean arterial pressure, DBP Diastolic blood pressure [3]

III. MODELING

Modeling represents the reality; here it is expressed in the form of mathematical equations. Model plays an important role as it helps to understand how changes in physiological parameters can bring changes to vital parameters.
The Following design flow explains the steps involved in modeling the Blood Pressure

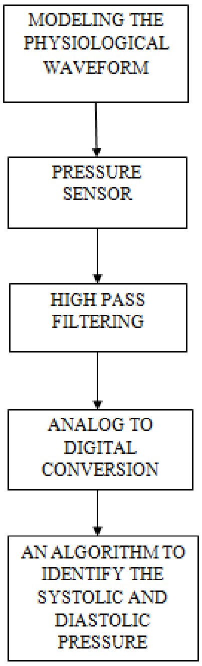

Figure 2 Design flow of Blood Pressure Modeling

The equations used to model the cuff pressure are discussed as follows [4]

$$P_a = DBP + 0.5PP + 0.36PP\left[\sin(\omega t) + \frac{1}{2}\sin(2\omega t) + \frac{1}{4}\sin(3\omega t)\right] \quad \ldots\ldots (1)$$

P_a is the arterial pressure, ω is the angular frequency of the heart beat. $\omega = 2\pi f$
Combining the cuff compliance, pressure-volume functions for the artery, and the arterial pressure, an equation can be written for the rate of change in cuff pressure.

$$\frac{dP}{dt} \cong -r + \left(\frac{P_0 + 760 - rt}{V_0}\right)\frac{dV_a}{dt} \ldots\ldots (2)$$

$$\frac{dV_a}{dt} = aV_{a0}e^{a(P_a - P_0 + rt)}\left(\frac{dP_a}{dt} + r\right)$$
For $P_a - P_0 - rt < 0$ ……….. (3)

$$\frac{dV_a}{dt} = aV_{a0}e^{-b(P_a - P_0 + rt)}\left(\frac{dP_a}{dt} + r\right)$$
For $P_a - P_0 - rt \geq 0$ ……….. (4)

Where P is the cuff pressure, V_a is the artery volume.

TABLE 1 Parameters used in modeling the cuff pressure and oscillometric pulse. [4]

PARAMETERS	DEFINITION	VALUE	UNITS
P_0	Cuff pressure at onset of Deflation	150	mmHg
r	Cuff pressure Decay rate	3	mmHg/sec
PP	Arterial pulse pressure	40	mmHg
f	Cardiac frequency	80	Beats/min
V_{a0}	Artery segment volume at zero pressure	0.3	ml
a	Exponential constant	0.03	1/mmHg
b	Exponential constant	0.11	1/mmHg
C_n	Artery segment compliance at 100mmHg pressure	0.0016	ml/mmHg

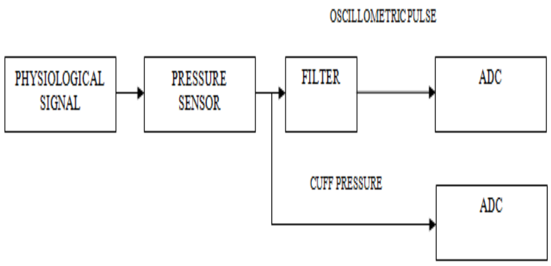

Figure 3 Block diagram of the Simulink modeled Blood Pressure system

The parameters used to model the Blood Pressure system is given in detail in the table 1. The block diagram Figure 3 shows the steps involved in obtaining the Blood Pressure values. This modeling is further used as a golden reference for hardware implementation. Filter is used to extract the oscillometric pulses from the cuff pressure and is converted to digital using ADC(Analog to Digital Converter). And the cuff pressure is also converted to digital using ADC.

A gradual Oscillometric pulses are divided into 4 segments [4].

1. The oscillometric waveform amplitude increase as cuff pressure is gradually lowered. No blood flow passes under the cuff, Korotkoff sounds are not heard.
2. During the gradual cuff deflation from SBP to the cuff pressure equal to MAP (Mean Arterial Pulse), the oscillometric waveform amplitudes reach the maximum.
3. During the gradual cuff deflation from MAP to the DBP, the oscillometric waveform

amplitude start decreasing with decreasing cuff pressure. Korotkoff sounds become muffled.

4. When the cuff pressure is lowered below DBP, the artery under the cuff is free from occlusion, blood flow is laminar and the waveform is not distorted. The oscillometric waveform amplitude decreases accordingly.

IV. RESULTS

Cuff pressure and oscillometric pulse are simultaneously obtained out from the ADC. The oscillometric pulse is successfully modeled according to the theory explained. The following shows the output of the cuff pressure(Figure 4) and oscillometric pulse (Figure 5) which are the outputs of the ADC. The systolic and diastolic pressure values are found by using the maximum amplitude algorithm. Firstly, Mean arterial pressure is found by finding the maximum amplitude in the oscillometric pulse and then systole and diastole values are found by using the systolic and diastolic ratios. These ratios are not fixed and may differ from one device to another. But may range from 0.4 to 0.7 for systolic and 0.6 to 0.8 for diastolic ratios. Since these points are defined, they can be mapped to cuff deflation pressure waveform to find the corresponding pressures as shown in Figure 1

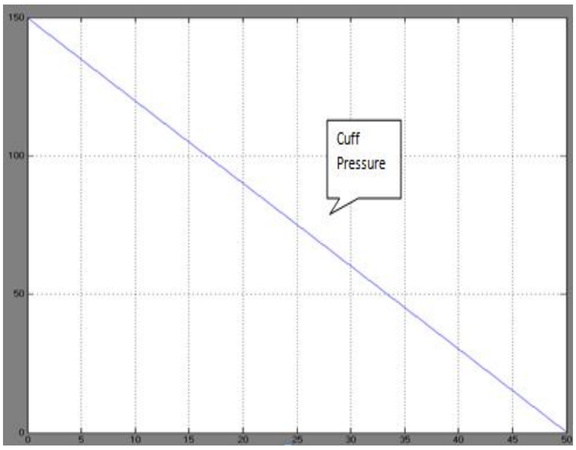

Figure 4 Output of the modeled Cuff Pressure

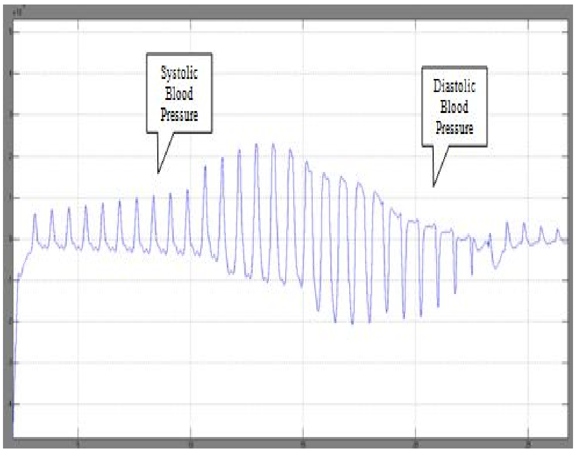

Figure 5 Output of the modeled oscillometric pulse

Using the obtained oscillations, heart rate can also determined. Firstly, peaks and their respective time intervals are to be found and then taking the time difference of the respective peaks. This is done for as many peaks obtained and taking the average. And finally the frequency and corresponding beats/min is calculated. Figure 6 shows the peaks.

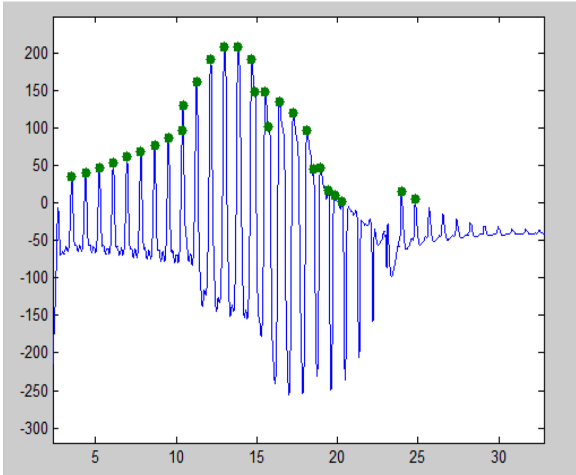

Figure 6 Peaks are determined to obtain the heart rate

CONCLUSION AND FUTURE SCOPE

The modeling results obtained are with respect to the equations used to model them. The oscillometric pulse are extracted from the high pass filter and converted into digital data using Sigma Delta ADC. Modeling is used further as a reference for hardware specification changes. Using the oscillometric data heart rate is also determined. The

ACKNOWLEDGMENT

Authors wish to express thanks to SenseSemi Technologies Pvt, Dept. of ECE,BNMIT, Bangalore and BNMIT management for continuous encouragement and guidance in carrying out this project work.

REFERENCES

[1] Sanchit Goyal, Sandeep .P. Jogi." Non-Invasive method of Blood Pressure Measurement Validated in a Mathematical model". www.ijetmas.com May 2015, Volume 3 Special Issue, ISSN 2349-4476

[2] J. JILEK, M. S. "Oscillometric pressure pulse waveforms: their current and prospective applications in biomedical instrumentation". Proceedings of the 13th WSEAS International Conference on systems

[3] Dr. Neil Townsend, *Medical Electronics*. Michaelmas Term 2001.

[4] Charles F Babbs, "Oscillometric measurement of systolic and diastolic Blood Pressure validated in a physiologic mathematical model". Biomed Central Ltd, Open access 2012

[5] Kapse C.D., Patil B.R, "Auscultatory and Oscillometric methods of Blood Pressure measurement: a Survey". International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 2, March -April 2013, pp.528-533

[6] Chengyu Liu, Dingchang Zheng, Clive Griffiths, Alan Murray." Oscillometric Waveform Difference between Cuff Inflation and Deflation during Blood Pressure Measurement" ISSN 2325-8861 Computing in Cardiology 2014; 41:849-852.

[7] Mohammad Zilany, Alberto Avolio, Einly Lim, Maw Pin Tan and Nigel H. Lovell. "Improved Measurement of Blood Pressure by extraction of characteristic features from the cuff oscillometric waveform". *Sensors* 2015, *15*, 14142-14161; doi:10.3390/s150614142 ISSN 1424-8220

[8] Jiankun Liu, Hao-Min Cheng, Chen-Huan Chen, Shih-Hsien Sung, Mohsen Moslehpour, Jin-Oh Hahn, Ramakrishna Mukkamala," Patient-Specific Oscillometric Blood Pressure Measurement". DOI 10.1109/TBME.2015.2491270, IEEE Transactions on Biomedical Engineering

★★★