 ISSN: 2321-8169
2447 - 2451

Adaptive Non-invasive Blood Pressure Measurement

Julin Sara Thomas
M.Tech, Industrial Electronics Dept,
R.N.Shetty Institute Of Technology,
Bangalore, India.
Julinthomas26@gmail.com

Dr. Andhe Pallavi
HOD, EIE Dept,
R.N.Shetty Institute Of Technology.
Bangalore, India.
hodit_rnsit@yahoo.in

Abstract— In this paper oscillometric method is used to develop an adaptive non-invasive blood pressure measurement system. To overcome the drawback of conventional oscillometric method an algorithm is developed. During the time of deflation and inflation process the step size of pressure pumped and released using pump and valve respectively is varied adaptively by continuously monitoring the feedback which in turn reduces the time required without compromising the accuracy of the output. The pressure condition of the patient is considered rather than blindly inflating till a constant set pressure. It mainly focuses on the estimation of the MAP value during process of deflation instead of waiting till the complete deflation for faster computation. Comparison of the results and the time taken were done with that of the other different methods. This is best suited for a wide range of 60/30 to 180/120

Keywords- *mean arterial pressure;systole;diastole;inflation; deflation*

*****

I. INTRODUCTION

Blood pressure activity is chiefly classified into invasive and non-invasive technique. The indirect methodology involves collapsing the artery with external cuff, provides an inexpensive and simply consistent way to measure the level of the pressure. The non-invasive technique is complete in many ways in which it always involves the employment of expansive cuff wrapped round the limb of the subject. The cuff inflates and deflates at a controlled rate and physical parameters are determined. The oscillometric and diagnostic techniques are acknowledged as non-invasive technique. These strategies are indirect as a result they do not couple on to the artery.

The diagnostic technique relies on the sounds caused by the blood flow through the artery that's enclosed by the cuff once activity pressure level exploits the diagnostic methodology, blood flow can be turbulent once the cuff pressure is bigger than the blood pressure and fewer than the blood pressure. The sounds of tapping concomitant to the flow are cited as Korotkoff (K) sounds. These sounds don't seem to be same with the guts sounds created by the gap and shutting of the guts valves.

In manual activity these sounds are detected by an observer employing a medical instrument. Pressure level monitors which are driven by machines use audio electrical device (microphone) to convert the K sounds into electrical signals. The cuff is inflated to some extent that occludes the artery. The pressure within the cuff is down. The cuff pressure at that the K sounds square measure 1st detected is the systolic blood pressure. The monitor continues to decrease the cuff pressure till the K sounds disappear. The cuff pressure at now is named diastolic blood pressure. Asculatory activity devices verify pressure level by exploiting the pressure gauge, instrument that measures pressure. The cuff is inflated to grade above the blood pressure so that the artery is totally compressed, there's no blood flow, and no sounds will be perceived. The cuff pressure is made to shrivel slowly. The moment the blood pressure exceeds the cuff pressure, the 1st appearing Korotkoff sound stipulates Systolic blood pressure. When blood passes in flow through the constricted artery part called systolic blood pressure. These sounds are still detected because the cuff pressure is down. However, the sounds disappear once the cuff pressure reaches diastolic blood pressure. Currently the least bit points in time throughout the cycle, the pressure level is bigger than the cuff pressure, and also the artery remains open. But many oscillometric monitors on the market have problems with resulting values of B.P which are significantly different when compared with auscultation [1]-[2],[7]. Elevated BP is a consistent and independent risk factor for cardiovascular and renal diseases. On the other hand, lowered BP can cause depression due to dizziness and faintness in daily living [5].

The main disadvantages of this methodology are (1) artifacts attributable to movements; and (2) difficulties in signal analysis attributable to physiological variations of the Korotkoff sound patterns or poor signals. Difficulties is overcome by applicable signal process, ECG gating and/or noise rejection. This might permit comparatively correct BP activity throughout gentle exercise.

With the oscillometric methodology, air volume variations within the cuff square measure detected throughout deflation. The utmost oscillation is expounded to the mean blood pressure. The BP is determined by an algorithmic interpretation of the form of oscillometric amplitudes similarly because of the pulse._The most benefits square measure (1) chance of BP activity once the Korotkoff signal is poor; (2) activity of the mean blood vessel BP; and (3) no would like of a microphonic device. The most disadvantages square measure (1) some oscillometric curves square measure are tough to scan accurately; (2) oscillometry is incredibly sensitive to movements attributable to the information measure of the signals, that the arm should be immobile; and (3) the accuracy of the pulsation and pulse BP depends on the formula [4]. These two strategies are complementary and may ideally be associated within the same device.

II. BLOCK DIAGRAM

The pressure that's pumped by the pump is detected by the pressure sensors MP3V5050GP, wherever the pressure signal is transduced into electrical signal and is fed to the signal conditioning circuit that manipulates the analog signal in such a way that it meets the need of subsequent stage for processing further. It owns a sensing stage, an indication signal conditioning state and a processing stage. Operational amplifiers are ordinarily used to carryout amplification of the signal within the signal conditioning stage. This stage is confederated with filtering, amplification and isolation. The output from the signal conditioning circuit that's the cuff pressure along with the oscillation signal square measure is fed into the microcontroller MSP430F522IPN and the comparator signal is given to the pump and to the valve circuit. The pressure of the cuff and the oscillation signals that are analog square measure are transduced into digital by microcontroller ADC. Consequently the algorithmic program is formed. A Pro Sim 8 vital signal simulator by Fluke Biomedical is used to simulate the blood pressure which is used to test and verify the basic operation of patient monitoring devices or systems. It includes Non-invasive blood pressure. UART is employed for serial communications over PC or peripherals devices; it's utilized in conjunction with RS232. MSP-FET430UIF includes USB debugging interface to program and debug the MSP430 in-system through the interface of JTAG. The nonvolatile storage is erasable and programmed in seconds with solely few keystrokes, and since for MSP430 flash no external power supply is needed because it uses ultra-low power. The debugging tool interfaces the MSP430 to the enclosed integrated package surroundings and includes code to start the planning. The buck boost convertor is made to get a continuing voltage of 3.3V.

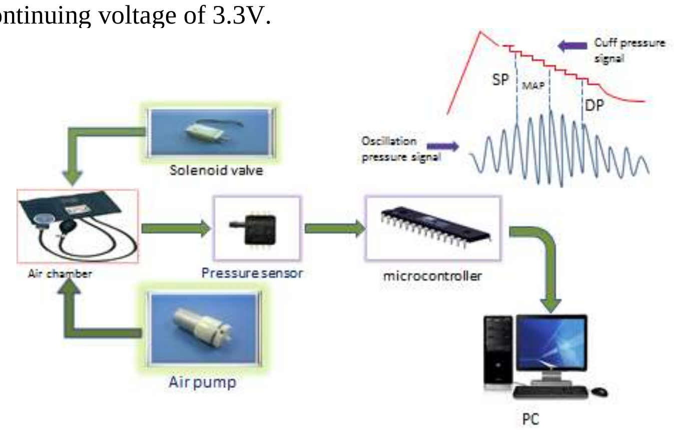

Figure 1: block diagram

III. OSCILLOMETRIC MEASUREMENT DEVICES

Blood pressure monitor operation is based on the oscillometric method. This method uses the pressure pulsations which are taken during measurement. The devices used for Oscillometric measurement involves an electronic pressure sensor with a numerical read out of blood pressure. The inflation and the release of the cuff are done by pump and valve which is electrically operated. First the cuff is made to inflate to a pressure in excess of the systolic arterial pressure. Mean arterial pressure (MAP) is the cuff pressure at which the pulse amplitude is the greatest, later the pressure gets reduced to below the diastolic pressure. Once there is presence of blood flow, but if it is restricted, the cuff pressure will vary periodically in synchrony with the cyclic expansion and contraction of the brachial artery. The raw data is used to compute the values of systolic and diastolic pressure by using an algorithm.

Most blood pressure devices on the market today utilize the oscillometric method. Each heart contraction causes a pressure pulse in the artery. In this method, an occluding cuff, positioned at the upper arm or wrist senses the pressure pulsations resulting from the expansion and contraction of the artery under the cuff. These kinds of pulses are referred to as oscillometric pulses. These pulses first are observed and then measured as the cuff pressure varies. The oscillometric pulses may increase or diminishes as the cuff pressure is varied up to a value that safely exceeds the maximal arterial pressure of patient. This pattern of pulses is called the oscillometric pulse oscillogram. The pulse oscillogram is analyzed and systolic and diastolic pressures are derived by applying algorithmic procedures, which are a key element of the accuracy obtainable with a available device. This algorithm can take into account the diversity of expected patients. In sum professional devices, the algorithm can compensate for adverse patient features, like small pulse amplitudes, high limb circumferences, stiff arteries or arrhythmia. In most home devices this unfortunately is not the case.

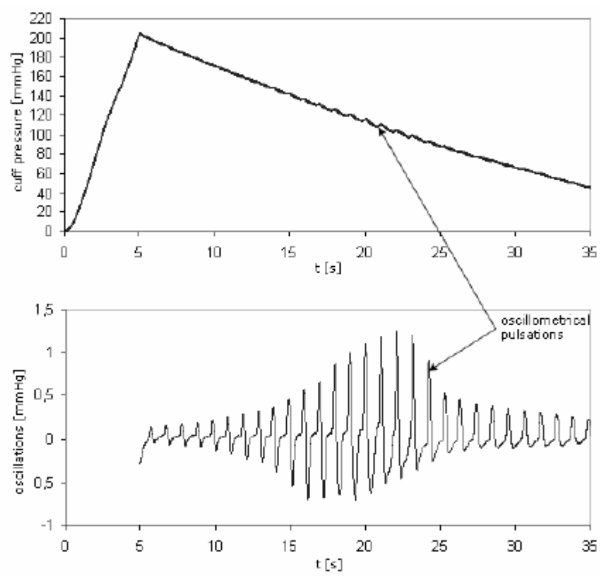

Figure 2: Conventional oscillometric graph for pressure an oscillation signal

In most of the ordinary blood pressure measurement meters that are available in market it is not possible to get the MAP value, as they follow blind inflate and deflate. Those devices have levels of inflation pressure: 190 mmHg, 230 mmHg, 270 mmHg and 300 mmHg. When 190 mmHg is not sufficient, or if any arm movement occurs, the device will automatically inflate to an appropriate pressure level in order to obtain the blood pressure measurement.

In this method the algorithm is divided into inflate, deflate, calculate and display systolic and diastolic blood pressure.

A. Inflation process

In the ordinary blood pressure measurement system that is available in market the cuff is inflated in a ramp fashion till the set pressure. One of the most eminent downfalls that is confronted by most of these automatic blood pressure measurement system is that the patient with low B.P have a propensity to faint or lose their balance as their blood flow would have stopped soon before the set pressure is reached, similarly for patients with high B.P even after the set value is reached the blood flow would not have stopped.

This complication can be resolved by inflating continuously till a set pressure of 100mmHG and then in steps of 20mmHG. This is because no oscillation is achieved at different pressure level for different patients. The feedback is continually monitored after injecting a pressure of 20mmHG. The oscillation read from the ADC channel is scanned for a period of 1s to check if the read ADC value greater than no oscillation or the offset value that is assigned. If the condition is true the inflation process is stopped. With a Lower step size (Δ), the time required to achieve no oscillation is more. But if a larger step size (Δ) is maintained there are chances that we exceed the required value.

This issue can be taken care by adaptively varying the step size instead of maintaining a constant Δ = 20mmHG. The strength of oscillation scales down from a larger value to zero or the offset value as it reaches no oscillation. This property of the oscillation can be used to vary the step size adaptively. The divergence between the maximum amplitude and no oscillation is large which means the oscillation strength is large as a result a larger Δ is used and as the difference reduces a smaller Δ is used.

Table 1: Variation of Step Size w.r.t OSC DIFF

OSC DIFF = PEAK OSC – NO OSC

OSC DIFF	Step Size
OSC DIFF < 200	Δ = 20mmHG
OSC DIFF <= 600	Δ = 40mmHG
OSC DIFF > 600	Δ = 60mmHG

The algorithm is such that the feedback is continuously monitored. This in turn reduces the time required for inflation without sacrificing accuracy.

Table 2: comparison of time for inflation process with fixed and adaptive step size

Inflation Process		
Set Pressure	Time in Seconds	
	Fixed Step Size	Adaptive step size
100/65	9.5	9.0
120/80	12.14	8.37
130/90	14.3	9.05
150/100	19.04	12.86
160/110	20.86	15.22
180/120	23.57	16.67

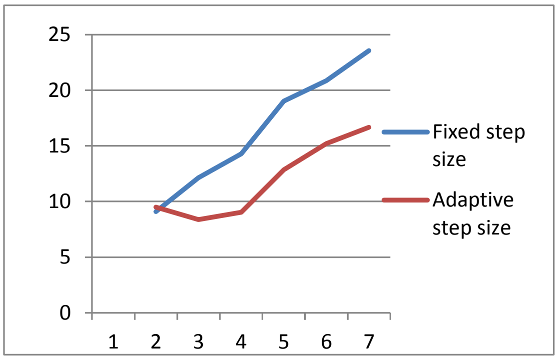

Figure 3: graphical representation of table ( )

B. Cuff deflation

Linear deflate method is also known as continuous bleed which the nurse typically uses when measuring blood pressure manually. If the deflate is slow, there will be improvement in accuracy. Hence here we gradually deflate it step by step with a step size of 5mmHG.

After deflating each time, the monitor measures some number of pulses before deflating again. The number of pulses which we get is depends on the monitor software and the algorithm used. In a stat mode, we usually take only one pulse per step. In normal mode, it is common to take pulses until at least two pulses are within some tolerance of each other in amplitude for artifact rejection. When a monitor step deflates in giant steps, it should interpolate the form of the pulse envelope. The larger the step size the larger the potential for error when interpolating. For small step size, error will be less. The peak pulse amplitude is referred as MAP and normalized to a value of 100%. The cuff pressure at MAP is the MAP pressure. Systole and diastole are fixed percentages on the basis of MAP. The cuff pressure under diastole is the diastolic pressure and the cuff pressure under systole is the systolic pressure. There is no particular of suggestion for what percentages of systole and diastole should be or even that they should be fixed percentages. Manufacturers those who are using algorithms which is height-based has to perform their own clinical trials and drawn their own conclusions about what the percentages should be and whether they are fixed as a function of MAP pressure.

As soon as no oscillation is detected the deflate function is called. In this method main goal is to find MAP value from which the systolic and diastolic pressure can be calculated. The pressure is deflated by particular value of 5 mmHG in steps till 30mmHG is reached. After every step of releasing pressure it will wait for 2 peak oscillations. The 2 peak oscillation and the corresponding cuff pressure are stored. This procedure is repeated till 30mmHG is reached. After the completion of deflation the maximum value of oscillation is found from the stored value which is nothing but the MAP count.

This method is time consuming because we have to wait till the deflation process completes to determine the MAP, systole and the diastole. Example: For a reading like 150/100 the diastolic pressure is obtained at 100mmHG itself and it makes

ISSN: 2321-8169
2447 - 2451

no sense to further deflate it step by step with a step size of 5mmHG till 30mmHG.

Hence this is further improved by finding the MAP value during the process of deflation and performing adaptive deflation with feedback.

After the MAP count is it is necessary to deflate it only till 40% of MAP count as the diastole will be obtained at 50% of MAP counts itself after which pressure can be continuously deflated to zero. Immediately after obtaining MAP count the step size is increased. But in order to get accurate value of diastolic pressure, from 60% to 40% of MAP Count a smaller Δ of 5mmHG is used and between Map count and 60% of MAP count a larger step Δ of 10 mmHG is set. This is done to save time without compromising accuracy.

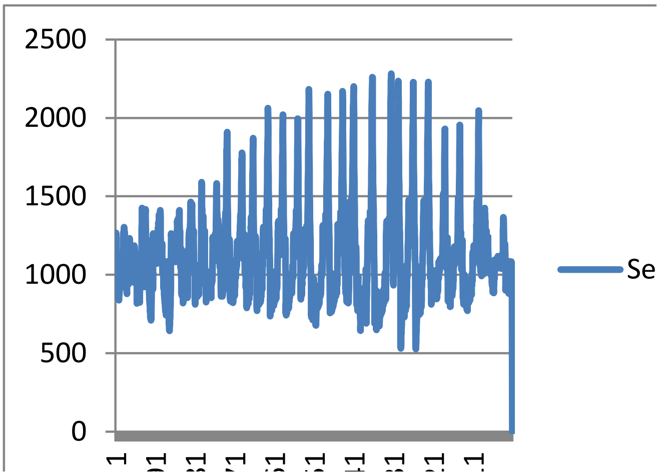

Figure 4: ADC values of Sample plotted during deflation process

C. Evaluate Systole and Diastole

50% of the MAP_Count towards the left and the right of give the systole and the diastole.

SYS_Count = ((MAP_Count *50)/100)
DIA_Count = ((MAP_Count *50)/100)

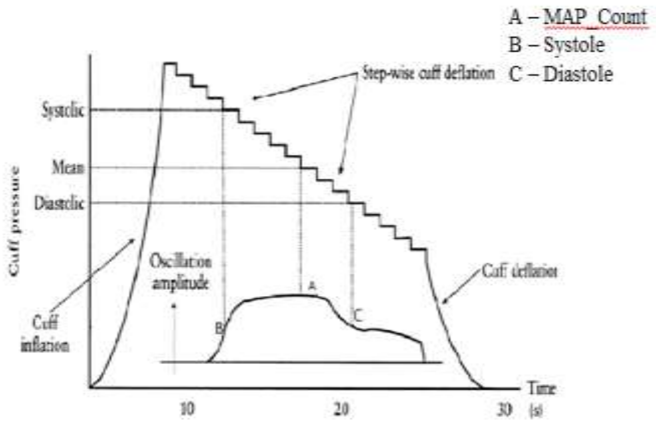

Figure 5 : Oscillometric curve

Once the SYS_Count and the DIA_Count is theoretically calculated it scans for the region between which the corresponding value lies in the oscillation array. Then the parallel pressure value closer to the SYS_Count and the DIA_Count gives the systolic and the diastolic pressure respectively.

ADC value of oscillation, C.P and its corresponding pressure reading for a set pressure of 160/100 is as shown in table (3).

Table 3: ADC_OSC, ADC_CP and pressure values

ADC_OSC	ADC_CP	PRESSURE	DIFF
173	2174	203.246	0.721
198	2167	202.525	11.433
346	2056	191.092	-0.515
365	2061	191.607	10.815
416	1956	180.792	-0.927
452	1965	181.719	11.433
514	1854	170.286	-1.339
452	1867	171.625	8.858
556	1781	162.767	-0.412
618	1785	163.179	9.064
892	1697	154.115	-1.648
943	1713	155.763	10.197
999	1614	145.566	-1.442
1046	1628	147.008	9.991
1093	1531	137.017	-0.309
1134	1534	137.326	7.931
1213	1457	129.395	-0.927
1164	1466	130.322	8.24
1195	1386	122.082	-0.412
1135	1390	122.494	7.828
1322	1314	114.666	-0.412
1189	1318	115.078	8.034
946	1240	107.044	-0.412
955	1244	107.456	6.901
428	1177	100.555	-0.515
554	1182	101.07	

MAP_Count = 1322
Sys_Count = 661
Dia_Count = 661

Sys_Count lies b/w the range 618-892 and 661 is closer to 618 therefore 613 is the systole and the pressure corresponding to it is the S.P (marked in blue). Dia_Count lies b/w the range 955-428 and 661 is closer to 428 therefore 428 is the diastole and the pressure corresponding to it is the D.P (marked in red)
The pressure recorded is 163/100

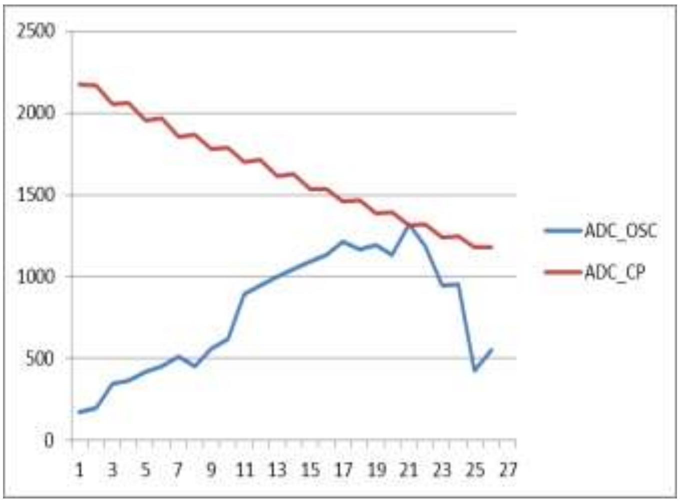

Figure 6 : ADC value of osc and cuff pressure plotted

D. Display Systolic and Diastolic pressure

The ADC value of cuff pressure has to convert into its blood pressure using the following formula

Systolic pressure = 30 + ((float)CP_Sys_Count - 493) * 0.103
Diastolic pressure = 30 + ((float)CP_Dia_Count - 493) * 0.103

Table 4: pressure and time results

Set Pressure	Recorded Pressure	Time in seconds
60/30	58/28	57.53
80/50	77/49	49.29
100/60	98/62	48.07
120/80	119/78	38.61
130/90	128/93	42.41
150/100	152/99	50.74
180/120	180/122	57.02

For a set pressure of 120/80 ten readings were taken and the error in systolic and diastolic pressure is as shown in the table (5)

Table 5: Error Evaluation

Sl.No	Recorded Pressure		Error	
	Systolic	Diastolic	Systolic	Diastolic
1	120	80	0	0
2	118	78	-2	-2
3	121	78	1	-2
4	121	77	1	-3
5	120	82	0	2
6	120	78	0	-2
7	120	78	0	-2
8	120	80	0	0
9	118	82	-2	2
10	118	81	-2	1

Standard Deviation Error Systolic = 0.137
Standard Deviation Error Diastolic = 0.377

Deviation in error is minimized when compared to the other methods

IV. CONCLUSION

In our paper we developed adaptive automated blood pressure measurement system which considers the patient's prevailing pressure and then it is tested for different pressure set. There is very minimum variation in error in the range 60/30 to 180/120 so it works best in this range. The results which are obtained are compared with that of the other methods and were found more effective and computation was done at a faster rate. The algorithm causes accurate extraction of both systolic and diastolic pressure from the oscillation pulses.

REFERENCES

[1] "Comparison of agreement between different measures of blood pressure in primary care and daytime ambulatory blood pressure"P.Little, J. Barnett, L. Barnsley, L. Maejoram, A. Fitzgerald – Barron, D. Mant, , in *BMJ*, vol. 325, 2002 , pp. 254.

[2] "Comparison of acceptability and preferences for different methods of measuring blood pressure in primary care"P. Little, J. Barnett, L. Barnsley, L. Maejoram, A. Fitzgerald – Barron, D. Mant, , in *BMJ*, vol. 325, 2002, pp. 258-259

[3] "Evidence based treatment of hypertension - Measurement of blood pressure: an evidence based review F. A. McAlister, S. E. Straus, in *BMJ*, vol. 322, 2001, pp. 908 – 911.

[4] Paper: Ausculatory and oscillometric methods of ambulatory blood pressure monitoring, advantage and limits : a technical point of view , Author Bonnafoux P1 ,1 R&D Department, NOVACOR, Rueil-malmaison, France ; PubMed.gov , US National library of Medicine National Institutes of health, NCBI website, 1996 June

[5] Adaptive Control with Self-tuning for Non-invasive Beat-by-beat Blood Pressure Measurement Masamichi Nogawa, Mitsuhiro Ogawa, Takehiro Yamakoshi, Shinobu Tanaka, and Ken-ichi Yamakoshi,*Member, IEEE* 33rd Annual International Conference of the IEEE EMBS Boston, Massachusetts USA, August 30 - September 3, 2011

[6] Cuffless and Non-invasive Systolic Blood Pressure Estimation for Aged Class by Using a Photoplethysmograph Satomi Suzuki and Koji Oguri 30th Annual International IEEE EMBS Conference Vancouver, British Columbia, Canada, August 20-24, 2008

[7] "Accuracy and reliability of wrist-cuff devices for self-measurement of blood pressure" M. Kikuya, K. Chonan, Y. Imai, E. Goto, M. Ishii, , in *Journal of Hypertension*, vol. 20, 2002, pp. 629-638.