DEVELOPMENT OF A PC INTERFACED BLOOD PRESSURE METER (E-BPMS)

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IDA LAILA BINTI AHMAD

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical-Electronics & Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAY 2006

I declare that my project report entitled "*Development of a PC Based Blood Pressure Meter (e-BPMS)*" is the result of my own research except as cited in references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved parents; Encik Ahmad Bin Shapii and Puan Aslinah Masran, thanks for encouragement and never ending support.

My dearest sisters; Ida Liyani and Ida Farhana Afiqah credits go to both of you for all the joyous moments.

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May Allah (swt) shower his blessings upon all of you

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ABSTRACT

Blood pressure meter is an essential instrument to determine our blood pressure status. Nowadays, there are various types of blood pressure meter available manufactured from various companies. In order to meet the demand on telemedicine and technology advancement, a new form of blood pressure meter is desirable. This prototype of blood pressure meter is interfaced with a personal computer (PC) which able to simulate the measurement process in real time. The proposed system was named e-BPMS (Electronic Blood Pressure Measurement System) suggests the usage of both hardware and software in determining blood pressure reading. Hardware elements operate on oscillometric principle which gives the results in terms of systolic, diastolic and MAP (Mean Arterial Pressure). Furthermore, these results will be presented and simulated on the software end. e-BPMS graphical user interface (GUI) was developed by using Visual Basic 6.0 (VB6) language which highlights the user friendly attributes. Moreover, the simulated waveform will evaluate the blood pressure and gives beneficial advises in term of controlling blood pressure to be optimal. This application shows significant improvement on the overall performance and gives reliable results. The framework used to design e-BPMS is easy to understand and it can be extended further to endorse new application area.

ABSTRAK

Alat mengukur tekanan darah adalah penting untuk memberikan status kesihatan tekanan darah seseorang individu. Kini, terdapat pelbagai jenis alat mengukur tekanan darah yang beroperasi menggunakan teknik-teknik yang berlainan dikilangkan oleh pelbagai pengeluar. . Kepesatan perkembangan teknologi pada masa ini untuk mencapai aplikasi Tele-Perubatan menyebabkan keperluan untuk mencipta satu alat mengukur tekanan darah yang baru meningkat. Projek ini bertujuan untuk mencadangkan satu alat mengukur tekanan darah yang baru menggunakan prinsip osilometrik di mana ianya dihubungkan dengan komputer peribadi dan boleh mamaparkan simulasi bagaimana tekanan darah seseorang ditentukan. Prototaip alat mengukur tekanan darah ini dinamakan e-BPMS iaitu singkatan untuk "Sistem mengukur tekanan darah elektronik". Sistem ini boleh dibahagikan kepada dua elemen iaitu "hardware" dan juga "software". "Hardware" akan memberikan keputusan analisis dalam bentuk bacaan sistolik, diastolik dan juga purata tekanan arteri. Seterusnya bacaan ini akan dipaparkan oleh "software" yang telah diprogramkan menggunakan bahasa pengaturcaraan "Visual Basic 6.0" (VB6) pada komputer. Hasil prototaip ini berjaya memberi keputusan yang tepat dan berjaya memenuhi objektif projek ini dan ianya boleh diperbaiki lagi di masa akan datang.

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LIST OF SYMBOLS/ ABBREVIATIONS

A/D	-	Analog-Digital
AAMI	-	Association of Advancement Medical Instrumentation
ABPM	-	Ambulatory Blood Pressure Monitoring
ADC	-	Analog to digital Converter
AHA	-	American Health Association
A_p	-	Attenuation
ASCII	-	American Standard Code for Information Interchange
atm	-	Atmospheric unit (pressure measurement)
CMOS	-	Complementary MOSFET
COM	-	Component Object Model
CP	-	Cuff Pressure signal
CPU	-	Central Processing Unit
CTS	-	Clear To Send
DIY	-	Do It Yourself
DSR	-	Data Set Ready
DTR	-	Data Terminal Ready
e-BPMS	-	Electronic Blood Pressure Measurement System
EIA/TIA-232E		Serial Communication Standard
EMI	-	Electromagnetic Induced Voltage
FET	-	Field Effect Transistor
GND	-	Ground
GPIB	-	General Purpose Interface Bus
GUI	-	Graphical User Interface
Hz	-	Hertz (unit of frequency)
LCD	-	Liquid Crystal Display

MAP	-	Mean Arterial Pressure
mmHg	-	Unit millimeter mercury
MOSFET	-	Metal Oxide Semiconductor FET
MS Chart	-	Microsoft Chart (ActiveX function)
MS Comm.	-	Microsoft Communication (ActiveX function)
MSC	-	Multimedia Super Corridor
NIBP	-	Non Invasive Blood Pressure
Pa	-	Pascal unit (pressure measurement)
PC	-	Personal Computer
PIC	-	Peripheral Interface Controller
RC	-	Resistor-Capacitor
RS-232	-	Serial Communication Protocol
RTS	-	Request to Send
R_{XD}	-	Received data
SI	-	International System (unit of measurement)
SPBRG	-	Baud rate generator
TTL	-	Transistor-Transistor Logic
T_{XD}	-	Transmit data
UART	-	Universal Asynchronous Receiver/Transmitter
V	-	Volt (unit of voltage)
VB6	-	Visual Basic 6.0
V_{DC}	-	Direct current Voltage
V_{out}	-	Voltage output
V_s	-	Voltage Supply
WHO	-	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Background

Blood pressure is one of most important measurements which indicate person's health condition. Abnormal blood pressure reading may lead to various diseases which can be prevented by treatment. Blood pressure related diseases are usually being referred as "silent killer". The consequence promoted can be either cardiac disorder or the malfunctions of our body systems. Considering these huge effects may be too harmful for human body, thus preventive action needs to be taken. High blood pressure is an epidemic disease which always a major concerns in developed countries. Statistic shows the great number of cases for the past decades, which triggers the insight to prevent and control this disease rather than cure it. Nowadays, the need for a reliable medical technologies and analysis is desirable, since the users prefer to experience their medical diagnosis themselves. Home monitoring provides an accurate record of measurements over time helps in planning an overall personal health regimen. Furthermore, blood pressure management is a step towards a healthier lifestyle.

1.2 Theory

1.2.1 Blood pressure

Blood pressure is defined as the pressure of the blood against the walls of the arteries. It is the resultant of two forces. One is created by the heart as it pumps blood into the arteries and through the circulatory system. The other is the force of the arteries as they resist the blood flow. Blood pressure is measured in millimeters of mercury (mmHg) and recorded as two numbers systolic pressure "over" diastolic pressure. For example, the doctor might say "130 over 80" 130/80 mmHg as a blood pressure reading. The measurement is taken when the doctor puts the cuff around patient's arm and pumps it up.

The pressure exerted by the cuff will block the blood flow in the vessel. As the pressure is released slowly, blood starts to flow again and the doctor can hear the flow using a stethoscope. The number at which blood starts flowing again is recorded as maximum output of pressure of the heart (systolic). Then, the doctor will continue releasing the pressure of the cuff and listens until there is no sound. The number (80) indicates the pressure in the system when the heart is relaxed (diastolic).

According to American Heart Association (AHA), optimal blood pressure with respect to cardiovascular risk is less than 120/80 mmHg. However, unusually low readings should be evaluated to rule out medical causes. If the patient exhibits low readings every measurements, there is a potential of having low blood pressure (hypotension). The systolic pressure of 120 to 139 mmHg or diastolic pressure of 80 to

89 mmHg is considered as at risk of having high blood pressure (pre hypertension). Furthermore, blood pressure reading of 140/90 mmHg is considered elevated high (hypertension). The range of blood pressure recommended by AHA is summarized in the Table 1.1 below.

Table 1.1: Blood pressure classification for adults given by AHA

Category	Systolic (mmHg)	Diastolic (mmHg)
Normal	< 130	<85
High Normal	130-139	85-89
Hypertension		
Stage 1 (mild)	140-159	90-99
Stage 2 (moderate)	160-179	100-109
Stage 3 (severe)	108-209	110-119
Stage 4 (very severe)	≥210	≥120

Blood pressure reading is known to be varied between one people to another. It is recommended by AHA that ideally, blood pressure must be checked at least twice a year and it should be more often if it is high. Some of the factors affecting blood pressure can be classified into several categories concerning physiological, gender, lifestyles and many others. The elaboration of these factors will be in following section.

1.2.2 Factors contributing to blood pressure diseases

Firstly is the elasticity of blood vessel determines the amount of blood flow at one time. The nature of blood vessel changes as we age, as the vessel gets thicker, the

capability of blood vessel to absorb is diminishes with time. These causes the older people are more likely to experience hypertension. Some people also may suffer low blood pressure (hypotension) due to low blood volume in their body system.

Generally, high blood pressure is related to high salt intake in our food consumption. Since people nowadays are exposed to busy life routines made them consuming bad diet habit which eventually promotes obesity (overweight). Other than that, cigarette smoking and alcohol intake may also contribute to this problem. Lack of exercise of people nowadays also contributes to high blood pressure.

Female are proven has higher rate of hypertension cases compared to male. Research done proposed that, women who experience pregnancy, menopause and overweight are at high risk of hypertension. This is due to the fact that, instable blood pressure may be resulted from the above situations, since women will experience hormonal changes.

Some people who have the history of high blood pressure in their families also have been identified to be one of the hypertension reasons. Other than that, people who are on medication or under doctor's prescription may observe irregularities in their blood pressure. This may be resulted from the drugs (prescriptions) they are taking. Certain hormones, like adrenaline which is released when people under stress may also cause certain blood vessels to constrict, and this raises the blood pressure. If people are exposed to constant stress, it means that the heart has to work too hard and this increase the blood pressure reading.

1.2.3 Blood pressure instrument

Traditionally, a sphygmomanometer is used for measuring blood pressure in the arteries. The word is derived from the Greek "sphygmus" (pulse), plus the scientific term manometer was introduced by Scipione Riva Rocci, an Italian Physician during 1896. Usually it consists of an inflatable cuff, a measuring unit and also a tube whereby, the inflation bulb is used along with stethoscope. The image of sphygmomanometer is given in Figure 1.1.

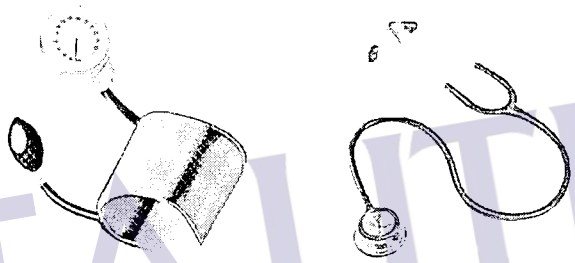

Figure 1.1 Sphygmomanometer

Due to technologies advancement, blood pressure testing devices now are using electronic instruments or digital readouts. In these cases, the blood pressure reading appears on a small screen or is signaled in beeps, and no stethoscope is used. Most of digital instruments have an automatic inflation mechanism, which replace the manual inflation bulb for simplicity and comfort. A digital system is widely known for its convenience and robustness even in noisy environment is preferable. Therefore, blood pressure meter now available is still adapting the same measuring techniques with added features. Some of available blood pressure meter are table-top, wristband and also finger. Considerations need to be made when designing a digital blood pressure meter since electronic devices are very susceptible to operating temperature and also humidity.

1.3 Blood pressure measurement methods

There are few available techniques employed for blood pressure measurements in which have their own strengths and weaknesses. Two popular approaches can be classified into two major groups known as invasive and non-invasive methods. As the name implies, invasive method involve catheterization (cut) where the patient need to undergone a minor surgical process. On the other hand, the non invasive technique offers simplicity, convenience, and comfort procedure to the patient is more preferable.

The invasive method is undoubtedly yields the most accurate measurements, but it is rarely used since it is more risky and patient may suffer excessive blood loss. Even today, invasive catheterization procedures are seldom used due to the risk of infection. Although, non invasive sacrifice a degree of accuracy in the measurement, the procedures which are considering for patient safety are widely applied. Two major methods for non invasive measurement are known as Auscultatory and Oscillometric. In fact, there are various methods used for measuring blood pressure which will be discussed next.

1.3.1 Auscultatory technique

This technique based on the ability of the human ear (expert practitioner) to detect and distinguished sounds. It was suggested by Korotkoff during 1905 has yet became the most common method of blood pressure measurement today. The clinician will use a stethoscope to listen for the Korotkoff sounds as the cuff deflates to determine the systolic, diastolic and estimate mean arterial pressure reading. The great advantage

is clinician is allows to determine the quality of each measurement. However, the possible error may arise due to differences in hearing acuity from one clinician to another. Furthermore, the unqualified or inexperienced clinician may not be immune to outside noise and other interference, thus assessing inconsistent Korotkoff sounds during measurement.

1.3.2 Automated Auscultatory technique

This particular technique was developed to replace to function of human ear by using microphone. A sound based algorithm was applied to estimate the systolic and diastolic readings. The drawback of this technique is lack of validation ability. In addition to noise artifact sensitivity, the algorithm may not adequately compensate for patient suffer low blood pressure (hypotension). Hence, the oscillometric technique was proposed to make the automated measurement more reliable.

1.3.3 Oscillometric technique

The name implies the procedure is done by measuring the oscillations caused by the arterial pressure pulse. These oscillations are the results of the coupling of the occlusive cuff to the artery. Oscillometric devices measure the mean but estimate both systolic and diastolic as proposed in Figure 1.2. The point of maximum amplitude is considered mean arterial pressure (MAP). Device using this technique do not use microphone, hence it is not affected by cuff placement and external noise. On the other

hand, since is does not allow measurement validation, it is sensitive to patient movement. Error due to this technique may be generated from inaccurate determination of MAP.

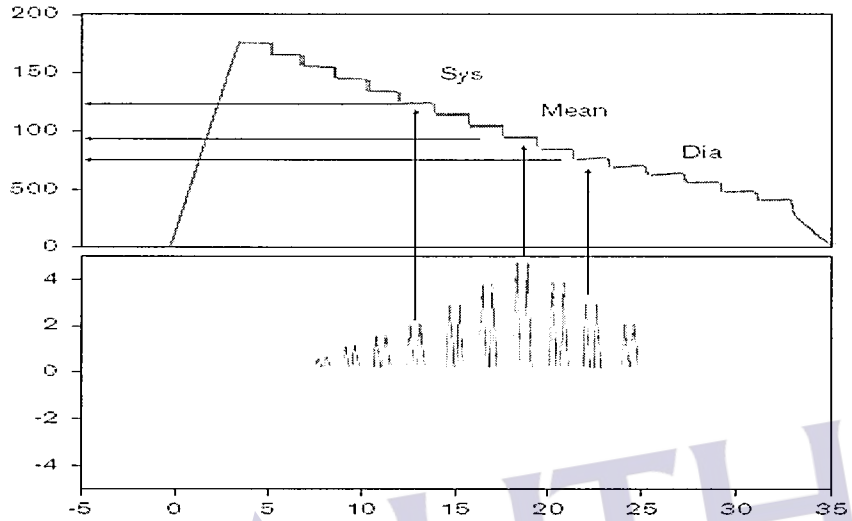

Figure 1.2 Determination of blood pressure using oscillometric technique

1.3.4 Infrasound and ultrasound technique

Infrasound technique attempts to improve on the auscultatory method by detecting the low frequency Korotkoff sound vibrations below 50 Hz, in which including sub audible vibrations. On the other hand, ultrasound technique is not commonly used for measuring blood pressure. Usually, it is use in combination with other methods. Major feature of this method is, the values recorded by using ultrasound can be very operator dependent.

1.3.5 Tonometry technique

This method uses a different approach where the arterial tonometry is realized by flattening the pressure non invasively to squeeze the artery against bone. The applied pressure required to maintain the flattened shape are recorded and accomplished by using array of pressure sensors. An algorithm must be used to calculate the blood pressure from the waveform obtained. Moreover, the waveform exhibits a similar pattern as catheter measurement (invasive). However, tonometry have several limitations which affecting its performance. Limitations like high sensitivity to sensor position and angle, measuring peripheral circulation, low inter-operator reproducibility, and is also requires regular calibration.

1.3.6 Ambulatory blood pressure monitoring technique (ABPM)

ABPM monitors patient blood pressure over a predefined length of time outside the clinic as the patients runs their daily life routines. Periodically, monitors will record the measurements and stores the results. When, monitoring period is over, clinician will have a set of data for analysis. The primary purpose of ABPM is to obtain a profile of patient's blood pressure under conditions outside clinical environment. It is believed that the blood pressure measured in clinic does not always representing the true value and may lead to identification of white coat hypertension and circadian rhythm of blood pressure. Clinical research for ABPM has led to the additional analysis techniques that allow clinician to obtain a clearer assessment of a patient's hypertensive condition. Some advantages offers by ABPM are reliable measurement, easier diagnosis and treatment development to help problematic patients.

1.3.7 Pulse dynamic technique

Pulse dynamic is a technology introduced by pulse metric proposed a variant of oscillometric method. The significant advantage of this method is, it combines the reliability of oscillometric technique while retaining the validation capability of manual auscultatory method.

1.3.8 Plethysmography technique

This method is also known as *"Impedance plethysmography"* technique measures the volumetric change associated with arterial distension. Volumetric changes cause changes in the electrical conductivity (impedance) of the measurement. If the impedance graph is plotted against time, the generated waveform looks similar to pressure generated oscillometric waveform. Therefore, blood pressure is estimated in a manner similar to oscillometric technique

1.3.9 Finger cuff technique

The technique was developed by Penaz and works on the principle of unloaded arterial wall. This method may give an accurate estimate of changes in systolic and diastolic pressure, although both may be underestimated when compared to brachial artery pressure. It is found that, this method is not suitable for obtaining absolute level of blood pressure due to its inaccuracy. Secondly, it is also costly compared to the other available methods.

1.4 Statement of the problem

Nowadays most of the people are reluctant to get their blood pressure being checked regularly. Usually, when they experience the diseases then only they would seek for professional helps. As we know blood pressure diseases are harmful to human for instance high blood pressure (hypertension) and low blood pressure (hypotension). Driven by this consensus, human desires a simple and reliable blood pressure measurement instruments which can suits their lifestyle. Due to technology advancement, blood pressure instruments come in variety of sizes equipped with added functions. To meet these requirements, a simple low cost digital blood pressure meter which can do a real time analysis will be introduced. In the project, a computer is use because it has a large memory space to store abundant of data. Therefore, PC can work as a platform for interaction for blood pressure monitoring system.

1.5 Project Objectives

- To design a digital blood pressure meter to be interfaced with a personal computer (PC).
- To develop a screening system which can illustrate blood pressure measurements in real-time.
- To introduce an affordable, low cost and user friendly digital blood pressure monitor.

1.6 Significance of project

This new design blood pressure measuring system would help to do the basic screening process for blood pressure measurement. As a result, this will not only ease the blood pressure diagnosis but also may improve the overall medical system. The development of PC based digital blood pressure meter was designed purposely to introduce an alternative way to promote regular self monitoring for patient. User engage to the system may experience simple blood pressure screening procedures, which is done in real-time to check their health status. Therefore, a robust medical checking system is important to ensure the procedure can be done with a minimal supervision.

One significant advantage of this application is the system works using the "DIY" concept or "Do-It-Yourself". This is an innovation to help users execute the diagnosis all by themselves. By using this system, user will reduce their time to travel to hospital and they are able to monitor their health status regularly. When e-BPMS is set ready for use, this device not only will help people to get their blood pressure measured regularly, this indirectly may promote early prevention due to blood pressure diseases. In conjunction with the aims to realize one of our Malaysia's Multimedia Super Corridor (MSC) flagships known as telehealth, this device can be used at the front end to employ telemedicine.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of related literature

There are many methods in designing and examining blood pressure has been used previously. Generally, all the methods share common objective that is to produce a reliable and efficient blood pressure meter with minimal errors. In recent years, numbers of researchers emphasizing the usage of oscillometric method implemented to digital blood pressure meter are widely acknowledged. The works of these researchers in terms of hardware circuitry and also their proposed theory or techniques are briefly explained in the following section.

There are various types of digital blood pressure meter widely available in the market. Generally, most of the automated clinical non invasive blood pressure monitors use the oscillometric technique [1]. The reasons being due to the nature of oscillometric method which gives better estimated measurements, more reliable results and reduce measurement error since error only can be contributed by MAP.

S. Mieke *et al* [2] proposed that the oscillometric technique relies on analyzing the amplitude of relatively small pressure oscillations which may be contaminated by artefact caused by movement of the cuff. Even though oscillometric technique gives reliable output, but it may degraded by the presence of artefact and patient's movement.

A study done by J N Amoore *et al* [3] considering of all possible factors which affect non invasive blood pressure measurement and how well NIBP monitors cope with these conditions are examined. The resulted experiments stated most of monitors responded well to pulse strength but gives falsely high reading for systolic and diastolic. In fact, some of monitors have a tendency to record slightly low systolic pressure.

On the other hand, MW Millar-Craig [4] proposed that ambulatory blood pressure (AMBP) recording is somewhat more accurate even on measurement of heavy physical exercise. Furthermore, AMBP may also be useful; in the investigation of episodic or resistant hypertension and also in the assessment of blood pressure treatment and drug trial evaluation. Hence, it is expected that AMBP will be more widely used in routine clinical assessment of hypertension due to the accuracy and reliability of the measurement.

In a study by J W Miao [5], he has designed a computer aided method for indirect measurement of arterial blood pressure by using hydraulic adaptive control based on vascular unloading technique. The error of measured blood pressure could be controlled on the minimum state by using adaptive control method. One significant finding of this research was the ability of human finger to be used to demonstrate the overall blood pressure status. In conclusion, he suggested that this method not only will reduce the error but also applicable to clinical applications.

In addition to suggest the applicability of human finger, Yamakoshi *et al* [6] have developed a new method for non invasive measurement of beat-to-beat systolic and diastolic pressure based on mechanical volume servo-control system using vascular unloading technique. This method was then approved for its validity and high accuracy.

To improvise oscillometric method, W B Geake *et al* [7] have proved that non invasive test instruments can generate simulated oscillometric pulses in response to cuff inflation in such a way as to cover a wide range of conditions including variations in pulse rate, pulse strength, arterial pressure and also artefacts. This supports the fact of oscillometric devices gives better response in terms of functional evaluation.

Recently, the attentions were being focused to the beat-to-beat variations of blood pressure and heart rate (pulse rate). A study by Takao Wada *et al* [8] adapted multivariate autoregressive model proposed by Akaike and usage of a novel device developed by Nippon Colin (JENTOW 7700) to record beat-to-beat blood pressure and also the impulse response. It was found that with added feedback analysis to a conventional machine, the impulse response function and relative power distribution can be distinguished directly. Hence, this may provide a convenient tool for baroreflex assessment of healthy or patients with diseases.

A newly designed blood pressure meter should comply with some standard or specifications. The Association for the Advancement of Medical Instrumentation (AAMI) has produced a set of de facto standard covering both automated and semi automated sphygmomanometer. Therefore, R J Riggs [9] has defined this standard for his design of database for artefact testing for ABMP. The accuracy of his design was justified by comparing the results from experiments with two trained observers. Consequently, the developed database achieved the standard required and yielded an optimized performance with reduced artefact effect.

In addition to do feedback analysis between heart rate fluctuations related to blood pressure change, H Mizuta *et al* [10] have adapted a feed back loop with added bivariate auto regressive model. A computer simulation was developed and revealed the applicability of the feedback signal to the tested condition. One important finding from the experiments is the system produced stable estimated impulse responses under variety of conditions.

C Bryant *et al* [11] proposed that by using oscillometric technique, the produced waveform of non invasive measurement is proven to be closely similar to invasive measurement. The analysis was done by using canine signal obtained from invasive method. Then, the signal was then tested on a computer algorithm which capable to identify the key diagnostic points on the generated waveform.

Matsuoka *et al* [12] have produced a patent for blood pressure meter which revolutionize the conventional blood pressure measuring apparatus. The invention proposed a pulse rate measuring apparatus is provided along with a blood pressure measurement apparatus for a simultaneous measurement of both pulse rate and blood pressure. This invention sets the trends of today's available blood pressure measuring instruments.

The growth of blood pressure measuring apparatus have caused C S Chua *et al* [13] from Motorola to design a digital blood pressure meter using an integrated pressure sensor, signal conditioning circuitry, microcontroller hardware and software with a liquid crystal display. Moreover, the sensing systems read the cuff pressure, extract the pulse for analysis and hence determine systolic and diastolic reading. The significant of this invention was the ability to covers wide range of blood pressure from 0 mmHg to approximately 300 mmHg.

A. Britov *et al* [14] have produced a blood pressure meter that has dual functions. The meter is intended for systolic, diastolic, and pulse rate measurements which also can be used at home. The meter is able to store ten recent measurement results in the internal archive which can be used in analysis later. The device is equipped with the capability to work under computer control transferring internal tables and signal samples for analysis and algorithm improvements.

In 2003 M Ganesh Raaja [15] has developed a blood pressure monitor by using oscillometric method for Flash Design competition. The pressure sensor translates the pressure in the cuff to capacitance, hence measures the frequency to determine the pressure. The capacitance of the sensor is converted to frequency by using binary counter. The circuit also detects the small variations in pressure during deflation and calculates the systolic and diastolic from these readings.

The proposed assessment by M J Randall *et al* [16] suggested that a computer automated system may provide positive system identification in the case of measuring blood pressure and heart rate. Furthermore, computer system reduces error and considerable labor savings can be obtained. The automated system which is known to be more precise and gives consistency in readings compared to human ability has also enhanced the statistical analysis on the data.

Non invasive oscillometric blood pressure classification can be realized by using fuzzy sets of artificial neural network (ANN), as suggested by S. Colak *et al* [17]. This research has shown that satisfactory non invasive oscillometric blood pressure classification can be obtained despite the fact that the target distribution are far from being uniform. Another significant result was the error performance is achievable without considering the features such as patient's age, cuff stiffness and arm circumference size. Although variety of factors may distort the result, the proposed method has a potential to perform with high accuracy and reliability.

In oscillometric method, the problem to extract the systolic, mean and diastolic blood pressure is related to the strategy used in the computational algorithm, JCTB Moraes *et al* [18]. This research demonstrates a new strategy to correlate several parameters and analyze it by using statistical method coded in MATLAB. As a result, there is a significant reduction in measurement time, larger rejection in motion artifacts, and arrhythmia as compared to the results obtained by using conventional simulator. This research also has proved that the main parameters affecting blood pressure measurement were characteristics ratios and arm circumference size.

Moreover, a comparative study has been done by JCTB Moraes *et al* [19] to investigate the performance of commercial equipment with the new system developed. The new blood pressure measurement system was developed based on oscillometric method by using controlled linear deflation technique. The system was structured in order to make several tasks independent and specialized, allowing for punctual development. Finally, it is indisputable that thus work has presented a new measurement platform which is flexible and easy to upgrade, making it possible to be implemented in the existing blood pressure measuring equipment.

There are many manufacturers responsible in providing health care products ranges, and one of them is OMRON [20]. Blood pressure monitor available in the form of manual inflation, automatic inflation and also wristband. Most of their products using a technology called *"IntelliSense™"* to ensure that home monitoring is easy and hassle free. *"IntelliSense™"* is a global brand name for bio-information sensing and high performance fuzzy-logic technology which embedded in their blood pressure meter. This technology enables blood pressure monitors make each measurement personalized, regardless of arm size, blood pressure level or the time of measurement. This ensures the right level of cuff inflation is applied and an advanced control valve ensures quick deflation when measurement is complete. This self-adjusting technology means maximum comfort and accuracy for each user. Moreover, with this excellent sensing technology, the monitor can achieve accurate measurement. Another technology by OMRON is known as "*A.P.S ™ (Advanced*

Positioning Sensor)" was designed to solve for error of wrist monitors. Ideally, wrist monitors requires it to be at the level of the heart when a reading is taken. User will be guided with arrows, instructing the user to either lower or elevate the monitor until it is in the proper position. The monitor's LCD will indicate to the user that the monitor is at the proper height and then the blood pressure monitor begins to inflate and take a reading.

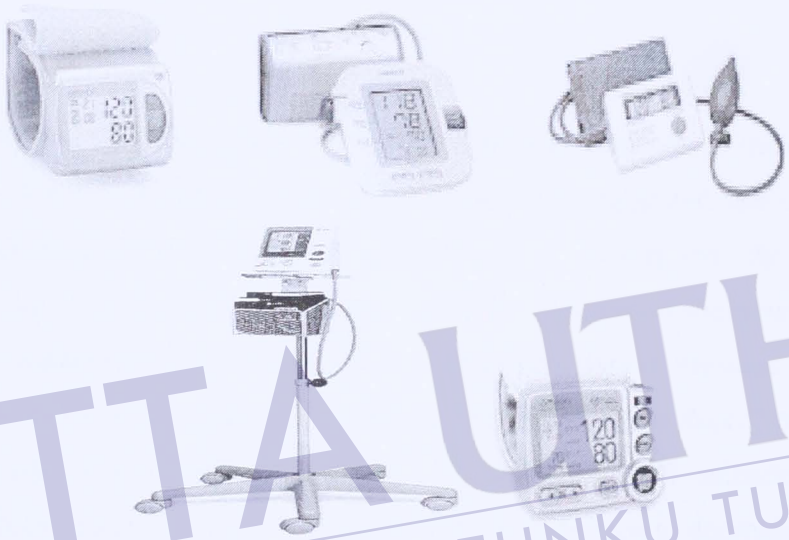

Figure 2.1 OMRON blood pressure meter

On the other hand, CITIZEN [21] under their Japan CBM Corporation which based in Tokyo has produced their own range of blood pressure meter. Still adapting oscillometric method, the devices are mostly lightweight, compact design, with the ability to recall via memory function. The devices also give high accuracy with allowable pressure range is +/- 3mmHg or 2% of reading while pulse is +/- 5% of reading and this meets the standard given by AAMI.

Figure 2.2 CITIZEN blood pressure meter

Most of blood pressure meter using oscillometric principle to measure the blood pressure level. On the contrary, BIPITONE [22] suggested the usage of auscultotary principle in their range of product. It is proven that the reading conforms to the reading obtained from mercury sphygmomanometer. No stethoscope is required and human error in determining blood pressure level is eliminated. The technology used an electronic adaptation of *"Riva Rocci"* principle, or applying a solid state integrated circuitry. By using the cuff embedded with multiple HIR Electrosteth transducers, it covers wide pick up area to determine blood pressure easily.

Figure 2.3 BIPITONE blood pressure meter

Another manufacturer known as HEALTH-O-METER [23] also provides wide range of blood pressure meter using oscillometric method. The sensor used is semiconductor type which is known to be very susceptible to noise and very sensitive. It is 100% latex free to signify the unique design. The meter is equipped with large amount of memory capacity, and it will shut off automatically, 1 minute

after last button was pressed. One significant of this device is, it gives rather satisfactorily short operation time estimated around 2 minutes. This is proven to be 50% faster compared to average fuzzy logic blood pressure monitor. The technology called *"ComfortRead™"* and *"MicroStep™"* are two major technologies implemented in their product range.

Figure 2.4 HEALTH-O-METER blood pressure meter

Furthermore, LUMISCOPE [24] adapted fuzzy logic sensor in their blood pressure meter range. The sensor is able to decide on suitable cuff size, to start/stop inflation automatically. There are basically, two major groups; semi automated and also fully automated which operates on oscillometric principle. One specialty of this product is, the package includes 2 sizes of cuff to suits people with small and large arms. In addition to wrist and arm type, LUMISCOPE introduce a blood pressure meter which measure blood level at human finger. This is a new technology and the accuracy is not yet proven, since, blood measurement at human finger requires the user to have good blood circulation; otherwise the device will not give a reliable measurement. Moreover, this device is not suitable for diabetic patient and to be used in cool place. In terms of pulse rate measurement, *"AccuRead™"* technology is used along with fuzzy sensor to yields accurate reading and highly sensitive to first heartbeat detection.

Figure 2.5 LUMISCOPE blood pressure meter

In addition to various manufacturers mentioned, FORECARE [25] has its own blood pressure meter available in the market. By using *"BrightSensor™"* technology, operating under oscillometric principle, it determines the optimum inflation depending on person's arm/ wrist circumference. Hence, this will not only give a reliable result, but it also high in accuracy and precise. A micro pump is used to control the inflation via automatic pressurization. Through this mechanism, automatic pressurization will be supplied when cuff pressure is sufficient. Moreover, for deflation purpose and for rapid air release a solenoid valve which produces constant air release is used. This device has 180 memory capacities to store blood pressure measurement data, which can be considered as high.

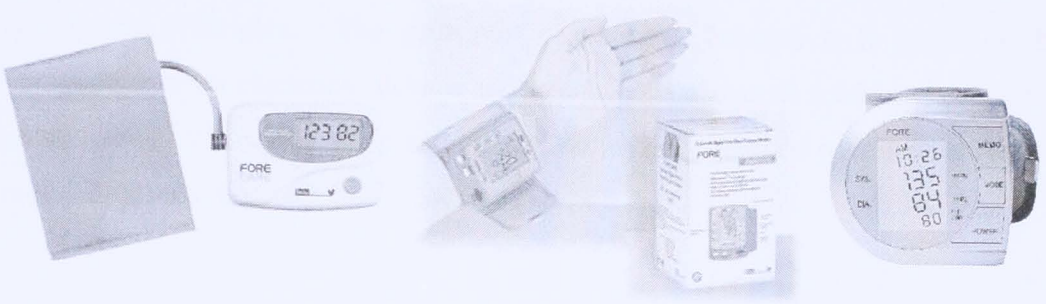

Figure 2.6 FORECARE blood pressure meter

The unit used in measuring blood pressure is called millimeter of mercury (mmHg) or torr (Torr) founded by Evangelista Torricelli, an Italian physicist and mathematician, for his discovery on the principle of the barometer[26]. Most commonly used is the notation of mmHg which is a non-SI unit of pressure. Normal atmospheric pressure can support around 760 mmHg; hence 1/760 of an atm, or 1 mmHg, has been a convenient measure of pressure for a long time. Although the pascal is now the more commonly used unit of pressure, the torr is still used in high vacuum engineering, particularly where pressures are low enough that viscosity is absent.

The torr, usually under the millimeter of mercury name, remains a common unit for the measurement of blood pressure in much of the world. Although they are synonyms in practice, the torr and millimeter of mercury are very slightly different by virtue of their definitions in British Standard BS 2520. While the torr is defined as given above, the millimeter of mercury is defined by the World Meteorological Organization as the pressure exerted at the bottom of a vertical column exactly 1 mm deep of a fluid whose density is exactly 13.5951 g/cm^3, at a location where the acceleration due to gravity is exactly 980.665 cm/s^2. By definition, mmHg unit reflects the atmospheric pressure which supports a column of mercury 1 millimeter high. It is also one way to define pressure is in terms of the height of a column of fluid that may be supported by that pressure; or the height of a column of fluid that exerts that pressure at its base. Liquid mercury is the best material to give appropriate water heights due to its high density nature.

In view of all related literatures, the e-BPMS was developed by using oscillometric principles. The principle was chosen because it is easier to be implemented in an electronic device and it can reduce overall measurement error. The advantages of oscillometric which is a non invasive method over patients made it more suitable to be used.

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