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

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

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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.

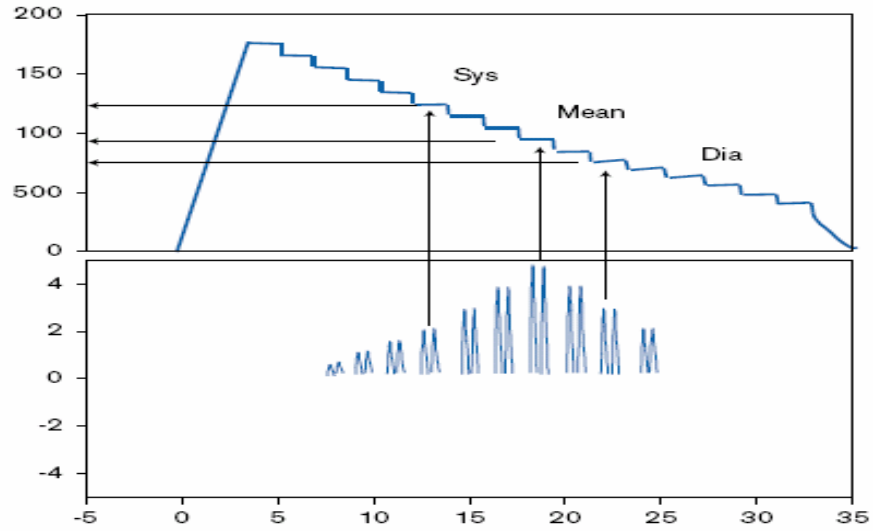

Figure 1.2 Determination of blood pressure using oscillometric technique

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.