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Design and Development of Hypertension Diagnosis Kit

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ABSTRACT

The main purpose of this study is to develop a hypertension diagnosis kit, which can display the human blood pressure level and diagnose the stage of hypertension. The main concern for hypertension patients nowadays is that they do not aware of their health status, whether they have hypertension or not. Due to the limitation of portability and size for the conventional blood pressure kit, this proposed study can help the patients to monitor their blood pressure continuously and diagnose the stage of hypertension. Thus, a new design of hypertension diagnosis kit needs to be developed, which can display directly blood pressure and hypertension level. Furthermore, this hypertension diagnosis kit also can store patient's data for further analysis. The device is performed with the data recorded and can display the blood pressure and hypertension level, which are normal, pre-hypertension, hypertension stage 1, hypertension stage 2 and hypotension. This device is validated its reliability and accuracy with software development for data storage. The output result will come out with LCD and LED display on device and LED display of the software.

Keywords: Blood Pressure, Diagnosis, Diastolic, Hypertension, Systolic.

1. INTRODUCTION

Hypertension is the leading cause of cardiovascular disease and death [1]. The term of hypertension comes from medical words, it means high blood pressure and this condition occur when the arteries elevated [2]. The heart will pump the blood to the whole body every time the heart beat. This condition need pressure to force the blood move and the pressure is called as blood pressure. If the pressure is high, the heart will pump higher blood [3]. The blood pressures that need to be considered are systolic and diastolic pressure. For example, 120/80 mmHg refers to the systole over diastole. Systole is the highest blood pressure while diastole is the lowest blood pressure [4]. Systolic occur when the heart contract and the pressure exert against the wall of arteries or blood. The diastole occur when the residual pressure exert the blood flow to the organs. The normal blood pressure ranges less than 119/79mmHg. The range of blood pressure from 120/80mmHg to 139/89mmHg refers to pre-hypertension and 140/90mmHg to 159/99mmHg refers to hypertension stage 1. For hypertension stage 2, the range of blood pressure is greater than or equal to 160/100mmHg and the range for hypotension is less than 90/60mmHg [5].

1.1 Previous Research

There are several studies related to hypertension using software and hardware methods. B. Aleksandra *et al*. applied the Bayesian Statistics to diagnose hypertension. The data needed for this experiment are age, sex, body weight, blood pressure, biochemical data and signs.

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This method used calculation of posterior probability. The main disadvantage of this method is the difficulty in accumulating sufficient and reliable data. In general, data provided by physician is not complete to be added into database. Moreover, experimental techniques used to obtain blood pressure and biochemical data are difficult to standardize and will change from time to time. Thus, it needs to be updated more often if a new case is added to the database [6].

Chaochang Chiu *et al* proposed the three-dimensional anthropometric body surface scanning data for hypertension detection [7]. This research involved classification method to determine the relationship between a subject's 3-D scanning data and high blood pressure using the hybrid of the association rule algorithm (ARA) and genetic algorithms (GAs) approach. The data used in their study are body mass index (BMI), left arm volume (LAV), trunk surface area (TSA), weight (W), waist circumference (WC), waist-hip ratio (WHR), and waist width (WW). The predicted high blood pressure is affected by the three-dimensional anthropometric body surface scanning data for the detection body of hypertensions. They predicted hypertensions happen to the subjects that have family history of BMI higher than 28.9 and have larger trunk surface area more than 140.9 cm2. All of the data shows that hypertension is also affected the subjects that have waist width larger than 20.5 cm and small BMI that not suitable with their age. The predictors for the high blood pressure is also significant by using the BMI, left arm volume (LAV), trunk surface area (TSA), weight, waist circumference, waist hip ration and waist width. When apply the ARA technique to the knowledge of data, the research become more effective especially in training process. AGA also reach high rate of accuracy than GA when the execution time was exactly same. For 3-D anthropometry data and other subject's data, the prediction of high blood pressure can be accepted for medical decision support. They claimed that AGA is the most reasonable way to provide a solution regarding to the prediction of hypertension with accuracy more than 90%. From the experimental results, it can be conclude that their model is better and efficient compared to the traditional way. Fewer features also found and thus it can reduce the calculation cost in determination of hypertension's model [8].

Chrysostomos D. Stylios and Voula C. Georgopoulos invented the GA enhanced Fuzzy Cognitive Map (FCM) for medical diagnosis [9]. The step involved the language impairments diagnosis. The FCM and GA are useful in the experiment and can be used effectively in different applications. The hybrid technique included the two factors such as FCM and GA in order to face the situation where one technique will not infers the other decision. Fuzzy Cognitive Maps have been successfully used to develop a Decision Support System (FCM-DSS) for differential diagnosis [10].

Abdullah A.A *et al*. has proposed a Fuzzy Expert System (FES) for the diagnosis of hypertension risk for male and female patients aged between 20 and 40 years old [11]. The parameters used as input for their proposed FES were age, Body Mass Index (BMI), blood pressure and heart rate. They claimed that the proposed system can provide a faster, cheaper and more accurate result compared with other traditional methods.

P. Melin *et al*. also proposed a system based on fuzzy logic for the diagnosis of high blood pressure [12]. The input parameters include systolic blood pressure and diastolic blood pressure. The output parameter is the blood pressure levels (BPL). A hybrid model using modular neural networks, and fuzzy systems also has been developed to provide an accurate diagnosis of hypertension based on the systolic pressure, diastolic pressure, and pulse of patients with ages between 15 and 95 years [13]–[15].

Other than diagnosis of hypertension using artificial intelligence method, a mobile app, based on has been proposed to help patients with hypertension manage their disease [16]. The study showed that a mobile app for hypertension management based on clinical practice guidelines is effective at improving healthcare. Other than mobile apps, medical imaging also plays an important role in hypertension diagnosis. A good review provided by Goldberg AB *et al*., show that the importance of advanced medical imaging, such as magnetic resonance imagining (MRI) and computed tomography (CT) for monitoring and diagnosis of hypertension [17]. There are many software-based diagnosis kit developed for the diagnosis of hypertension, however there are not much effort in designing the hardware part for the diagnosis kit, which can display directly blood pressure and hypertension level. To overcome this problem, we take the initiative to develop a hypertension diagnosis kit, which can display the human blood pressure level and diagnose the stage of hypertension.

2. MATERIAL AND METHODS

Figure 1 shows the flowchart of this research project. The project is started with data collection, and then followed by the circuit simulation by Proteus software [18] before the development of hardware and firmware part. If the simulation is successful, then it will proceed with the development of Graphical User Interface (GUI) so that the data can be saved in personal computer. Lastly, all the results will be recorded.

Figure 2 shows the block diagram of this project while Figure 3 shows the framework diagram of the hypertension diagnosis kit. To measure the blood pressure using the hypertension diagnosis kit, the red square button needs to be pressed. Then, black button is pressed to start the program. The cuff will expand continuously until it reached the maximum pressure. Then, valve will open and release the air from the cuff. Direct value (Af) and alternating value (Df) were inserted which represent the alternating pulse value and direct value of blood pressure. 12 data is inserted and every data is stored by pressing the purple button. All values were processed by the circuit and display on the LCD and show the systolic value, diastolic value and hypertension level. Blue button is to reset the data. There are 4 LEDs in this design. The yellow LED will always on when the button on press, the green LED will always on when the program start, the white LED is on every time the data store and the red LED on after display the data for 5 seconds. Then the data will send to PC for storage.

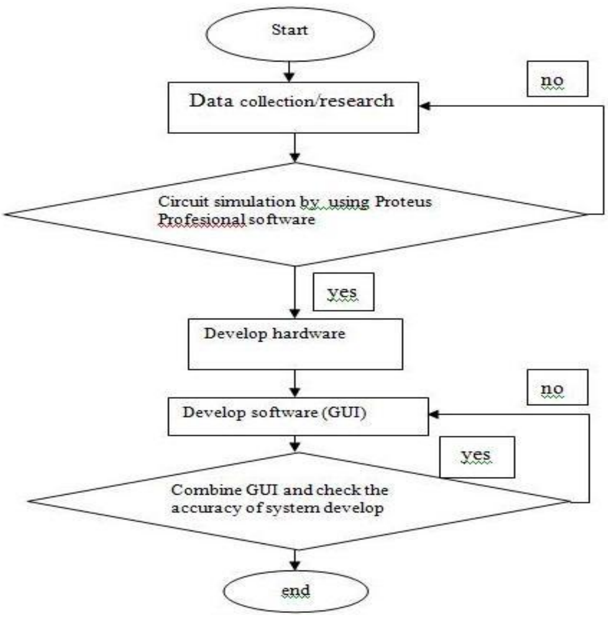


Figure 1. Flowchart of research project.

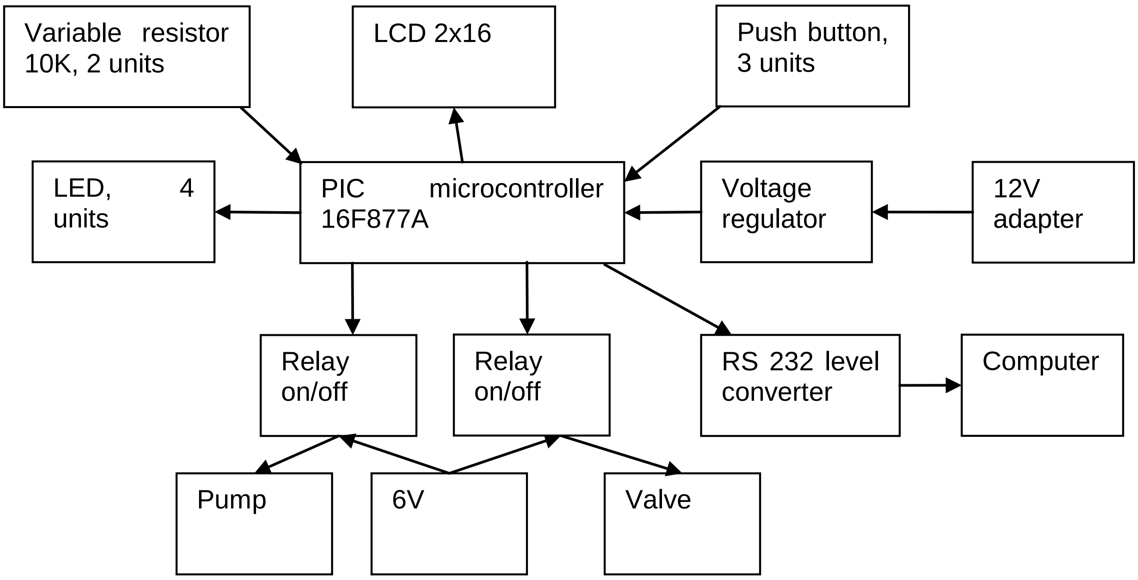


Figure 2. Block diagram of project.

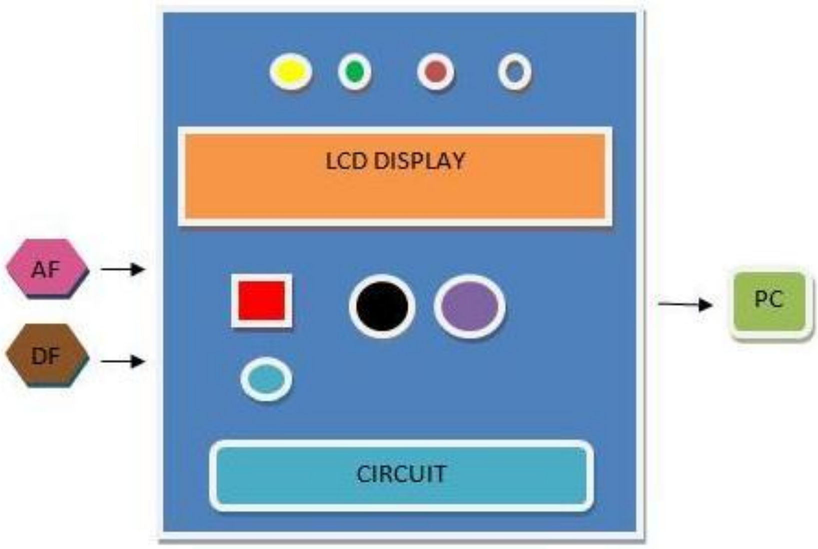


Figure 3. Framework diagram of the proposed hypertension diagnosis kit.

2.1 Hardware

The component used for the hardware part is including variable resistor, microcontroller, LCD display, LED, valve and pump, voltage regulator, MAX 232 IC and RS 232. The circuit simulation is done in Proteus Professional 7 software. There are two variable resistors that were used in this design. One represent the Af value which is alternating pulse value and the other one represent Df value which is direct value of blood pressure. The variable resistor is a voltage divider used for measuring the voltage. It also can be used as transducer to replace the blood pressure sensor.

PIC16F877A-I/P microcontroller is used to store programs and run the programs of the device. LCD (Liquid Crystal Display) is an electronic display module. A 16x2 LCD was used in this study, which it could display 16 characters per line that consist 2 lines. This LCD has two registers, which are command and data. The command register stores the command instruction given to LCD. The data register stores the data that will display on the LCD. The data displayed is in the form of ASCII value. For this project, the LCD-016M002B is used to display the output of the device. The blood pressure level will interpret on LCD display in term of normal, pre-hypertension, hypertension stage 1, hypertension stage 2 and hypotension.

Figure 4 shows the schematic design. When the switch is on, the current first must flow to voltage regulator from the battery before transmitted to the circuit. The main function of diode is to prevent the counter current flow through the circuit and cause damage to the circuit. The LM7805 is used to regulate the voltage in the system and output of 5 V DC and the maximum output current must not exceed 1000 mA. Then, the current will reach at voltage regulator. Now, the voltage will reduce to 5 V and enable the PIC operate. When the PIC receives the voltage, it will operate according to the programming code. The yellow LED will on as switch button press. LCD will be light up and display the 'press green button'. When green button is pressed, the LED green will on and pump will start operate until it reach 4 V, which is approximately 163.8 mmHg. Then, pump is off and valve is on. Within this time, the 12 data of blood pressure is loaded by using variable resistor. Every time the data is stored, the white LED will turn on. After that, the 12 data store the program in IC will analyze and display on LCD as the systolic, diastolic value and stage of hypertension. There are five levels of blood pressure that need to be considered, which are normal, prehypertension, hypertension stage 1, hypertension stage 2 and hypotension. The red LED will on after 5 second and the result will display on LCD. After 10 second, the LCD will display 'press green button to start'.

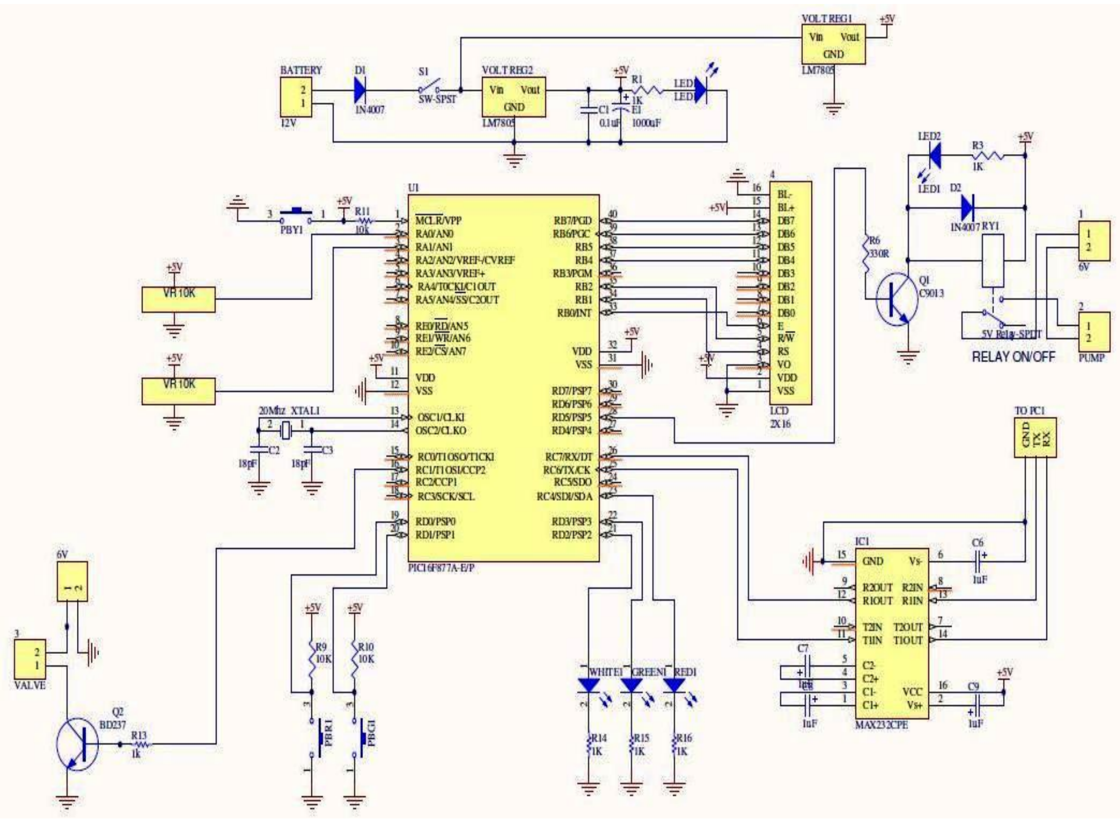


Figure 4. Schematic design.

2.2 Firmware (Data Acquisition)

MPLAB was used for writing and testing the source code of program and embedded to PIC18F4580 using PICkit 2 v2.40. Analog Digital Converter (ADC) was used in quantization of time varying signals by turning them into a sequence of digital samples. Figure 5 shows the block diagram of firmware part. The analog signal from hardware circuit will be converted from analog to digital form. Then, it presents in binary values and can be converted to decimal values. After converted in ASCII code, it can be sent to serial port and HyperTerminal to be read and display at graphical user interface (GUI).

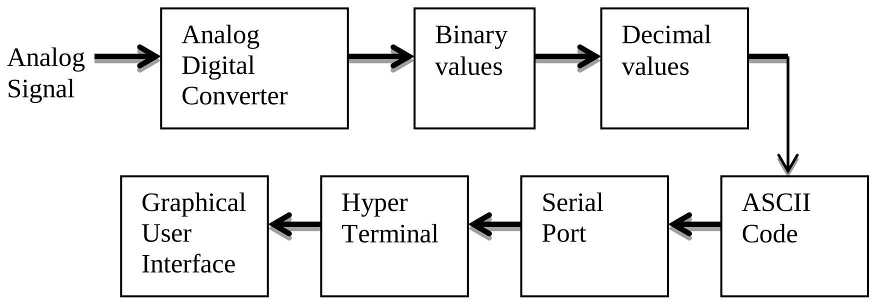


Figure 5. Block diagram of firmware.

2.3 Graphical User Interface (GUI)

A graphical user interface (GUI) is the communication takes place over serial port. GUI is very important to interface the data with the PC by using the Lab VIEW. The hypertension diagnosis kit must have the ability to interact with users. Thus, we developed the GUI to determine the classification of blood pressure into 5 levels, which are normal, pre-hypertension, hypertension stage 1, hypertension stage 2 and hypotension. Figure 6 shows the front panel of LabVIEW GUI.

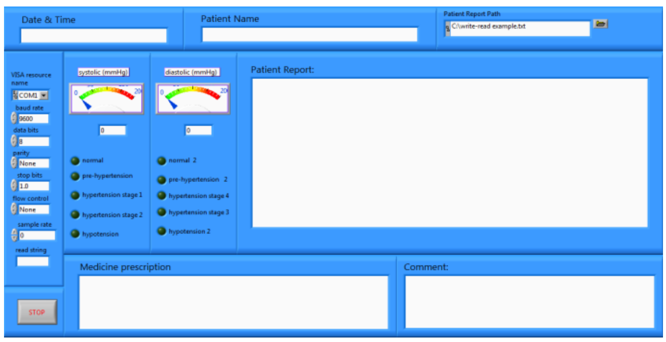


Figure 6. The front panel of LabVIEW GUI.

3. RESULTS AND DISCUSSION

3.1 Hardware

The hardware part refers to the circuit development including the process in designing an electronic circuit until developing of Printed Circuit Board (PCB). Before design the PCB, the circuit must be functioning well to perform the result. There are a lot of factors need to be considered in designing this part such as voltage supply, current, component specification and performance of the component.

Figure 7 shows our developed hypertension diagnosis kit. The front design could display the LCD, button and LED. The inner part of the designed must include the microcontroller, pump, voltage supply, valve, voltage regulator, RS232 converter and RS 232. All the component of the circuit is simplified by using PCB to limit the space. The third part is the outer part, which consists of the variable resistor and cuff.

Figure 7. Our developed hypertension diagnosis kit.

3.2 Firmware (Data Acquisition)

Data acquisition (DAQ) is the process of converting the resulting samples into digital numeric values that can be manipulated by a computer. DAQ can convert analog waveforms into digital values for processing. In this project, programming language C is used to code for the analog input, conversion from binary to ASCII and the transmission using RS232 to computer.

The oscillation frequency used is 20MHz while the time per instruction cycle used is 0.2μs. The delay time would be 2μs, while the number of bit use is 10. Thus, the formula for step size:

$$\text{Step Size (Resolution)} = \text{Vref}/2^{10} \quad (1)$$

By using the equation (1), the step size is 4.883mV. The data bits that used is 10 bits, parity bit is 0, stop bit is 1, bit per second or baud rate is 9600 and Com Port is COM1.

3.3 Software Guide User Interface

Figure 6 shows the front panel of LabVIEW GUI. On this panel, it shows the systolic and diastolic pressure, the level of the blood pressure such as normal, pre-hypertension, hypertension stage 1, hypertension stage 2 and hypotension. Besides the, the data of the patient also can be stored such as date and time, name and comment. The patient data and comment that can be stored is saved in txt file. The front panel also shows the data from the firmware part such as VISA resource name, baud rate, data bit, stop bit, parity, flow control, sample rate and bytes to read. Figure 8 shows the programming and circuit of LabVIEW GUI. For GUI part, the information or data is needed from firmware part especially for VISA configuration port. The specification needed for VISA configuration port are time out, port name, baud rate, data bit, parity, stop bit and flow control. The basic for VISA are VISA configuration port, either VISA read or VISA write and VISA close. Figure 9 shows the flowchart of LabVIEW GUI for circuit and program of graphical user interface. For this project, it can detect the blood pressure level. The variability can be shown in Table 1.

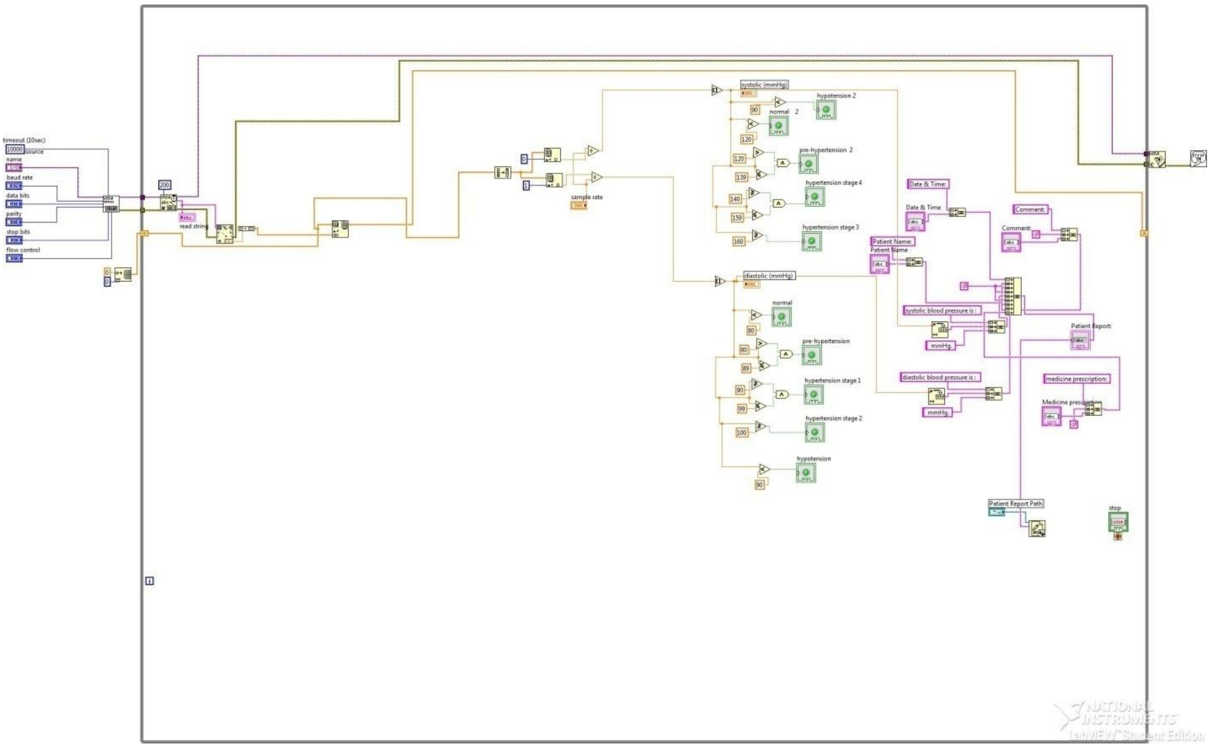


Figure 8. The programming and circuit of LabVIEW GUI.

Table 1 The variability range of blood pressure level

Blood pressure level	Systolic (mmHg)	Diastolic (mmHg)
Normal	90-119	60-79
Pre-hypertension	120-139	80-89
Hypertension stage I	140-159	90-99
Hypertension stage II	≥160	≥90
Hypotension	<90	<90

3.4 Data Analysis

The purpose of analysis is to investigate the accuracy of the device with the data collected. Besides, the data of the blood pressure can be recorded and analysed for future reference. The data of input is important to determine the blood pressure level. The data collected are direct value (Df) represent the blood pressure and alternating value (Af). This data is obtained from the oscilloscope. The data collected must consist of the 5 stages of blood pressure level, which are normal, pre-hypertension, hypertension stage 1, hypertension stage 2 and hypotension. Table 2 shows the data collected of Af and Df (mmHg). After the confirmation of data, the hardware and its firmware were test to determine its effectiveness by observing the result display on LCD. The 12 data of Af and Df of the blood pressure level was recorded to determine the blood pressure level. Figure10 shows the result of blood pressure level.

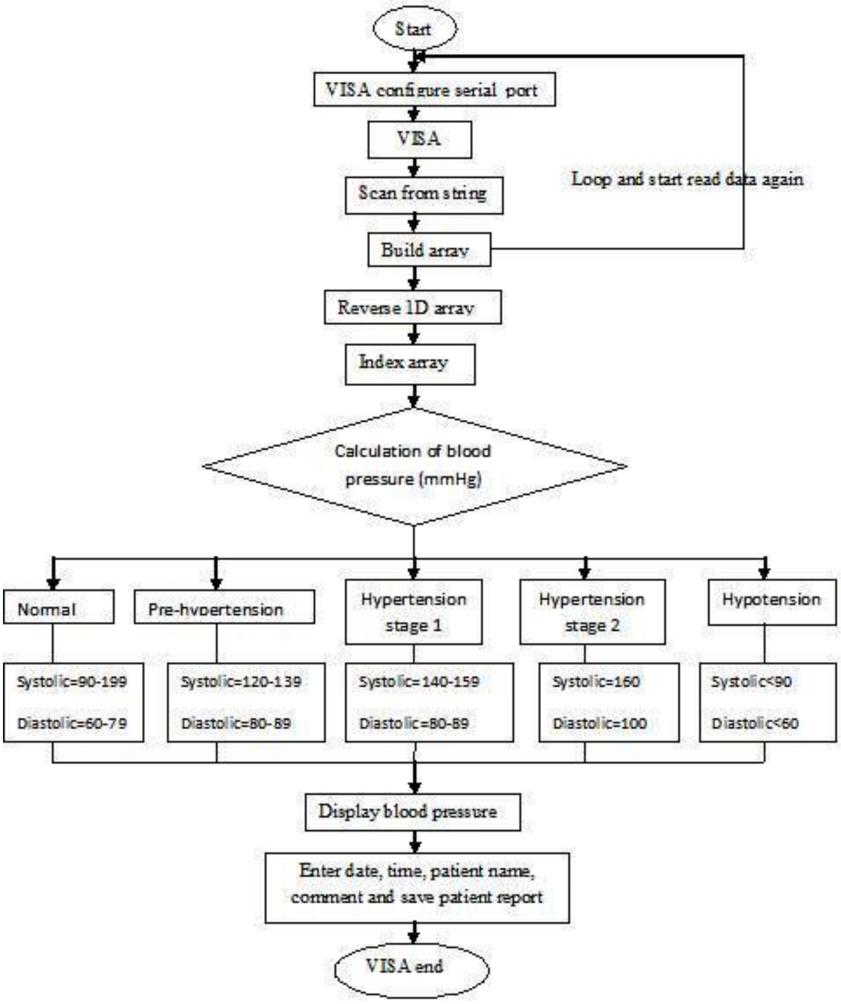


Figure 9. Flowchart of LabVIEW GUI.

Table 2 The data of systolic and diastolic collected based on blood pressure level Df (mmHg) and alternating pulse Af

No	Normal		Pre-hypertension		Hypertension stage I		Hypertension stage II		Hypotension	
	Af	Df	Af	Df	Af	Df	Af	Df	Af	Df
1	100	140	75	154	40	175	100	170	50	104
2	120	130	90	144	70	165	130	160	60	97
3	140	120	100	134	90	155	160	150	75	90
4	160	110	120	124	120	145	190	140	80	83
5	180	100	140	114	150	135	155	130	95	76
6	200	90	170	104	180	125	145	120	120	71
7	204	80	200	94	150	115	130	110	150	64
8	190	70	180	84	120	95	115	100	180	57
9	170	60	160	74	90	85	90	90	160	50
10	150	50	130	64	60	75	75	80	140	48
11	130	40	100	54	30	65	50	70	115	41
12	110	30	80	44	10	55	35	60	95	34

Figure 10. LCD display systolic and diastolic pressure of pre-hypertension.

The hardware was connected to Personal Computer to store the patient data by using LabVIEW GUI. In LabVIEW GUI, the data is analyzed again and the stage of hypertension is determined such as in Figure 11. By using this software, the patient data can be stored in txt file such as in Figure 12 for future reference.

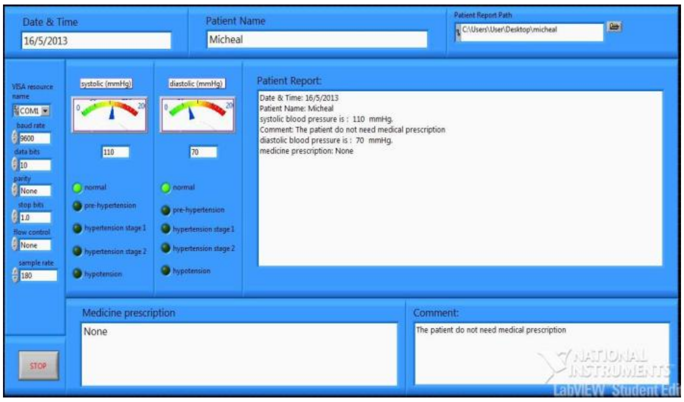
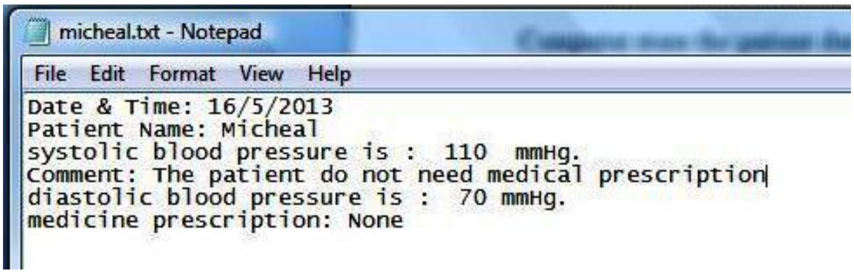


Figure 11. The front panel of LabVIEW GUI display.



Date & Time: 16/5/2013
Patient Name: Micheal
systolic blood pressure is : 110 mmHg.
Comment: The patient do not need medical prescription
diastolic blood pressure is : 70 mmHg.
medicine prescription: None

Figure 12. The data save in text file.

4. CONCLUSION

The hypertension diagnosis kit was been successfully designed and fabricated using suitable and low-cost materials. This hypertension diagnosis kit acts as a device to determine the blood pressure, hypertension level, and store the patient data. This hypertension kit will detect and display hypertension level among people. The main advantage of this diagnosis kit is the portability, which is small and battery operated and can measure the pressure level, stage of hypertension and store the patient data in personal computer. The accuracy of the device was proved by the comparison between the blood pressure devices with the software developed for this project. The hypertension diagnosis kit is one of the most important devices needed by the hospital and patient. It is because the ability of the device to display the blood pressure, hypertension level and can store patient data in personal computer. Besides, this device is affordable, portable and easy to use. This device also can be use everywhere by students, patients, doctors and others.

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