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Wireless Blood Pressure Monitor with Android Integration: Tracking Systolic and Diastolic Parameters

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ABSTRACT Blood pressure measurement plays a crucial role in detecting underlying diseases in the human body. It enables the identification of conditions like heart failure, kidney failure, liver damage, and stroke, underscoring the importance of regular measurements. To facilitate independent and routine blood pressure monitoring, the development of an automatic blood pressure measuring device is essential. This research aims to design and fabricate a digital sphygmomanometer that can transmit measurements to a smartphone through the Blynk application. The blood pressure measurement is conducted using the MPX5050GP pressure sensor as the pressure detector. The device is programmed using the Esp32 microcontroller and incorporates an LCD screen to display the measurement results. The study involved measuring six participants, with each individual's blood pressure recorded ten times. The obtained measurements were then compared to those of the Omron HEM-7120 digital sphygmomanometer. The results revealed a discrepancy of ±9 mmHg in systolic values and ±7 mmHg in diastolic values between the two devices. The smallest systolic error observed was 0.4%, while the largest error reached 3%. Similarly, the smallest diastolic error was 2%, with the largest error recorded at 4.8%. The measurement errors, particularly in diastolic pressure, were influenced by the participants' fatigue, as the repeated measurements on the same arm led to slight arm movements during the process. The study demonstrated the successful transmission of measurement results to a smartphone, affirming the efficacy of the Blynk application. Additionally, the MPX5050GP sensor proved effective in detecting blood pressure. These findings highlight the potential of the developed digital sphygmomanometer as a reliable tool for blood pressure monitoring, promoting self-care and early detection of health issues.

INDEX TERMS Sphygmomanometer, MPX5050GP, Systolic, Diastolic, Pressure.

I. INTRODUCTION

Blood pressure measurement is an important aspect in assessing an individual's health status [1]. It not only helps detect various diseases such as heart failure, kidney failure, liver damage, and stroke [2], but also provides insights into a person's physical and mental well-being. Blood pressure consists of systolic pressure, indicating the pressure when the heart pumps blood throughout the body, and diastolic pressure, indicating the pressure when the heart is filling with blood [3]. Normal blood pressure for adults is 120/80 mmHg, with 120 representing systolic pressure and 80 representing diastolic pressure [4]. Additionally, to determine the heart rate, which is an important indicator for detecting health disorders, it can be measured in beats per minute (BPM) [5]. The normal heart rate for adults ranges between 60-100 bpm [6]. Heart rate disorders, such as bradycardia (heart rate below 60 bpm) and tachycardia (heart rate above 100 bpm), can lead to problems with the heart's electrical system and suboptimal blood distribution [7]. Blood and the heart play a vital role in delivering essential substances and oxygen throughout the body [8]. The normal oxygen level in adult blood is 95% [9][10]. Changes in heart rate can be influenced by factors such as blood pressure, oxygen saturation, physical activity, body temperature, and intracranial pressure [11]. Knowledge about blood pressure, heart rate, and blood oxygen levels is crucial in understanding an individual's health condition [12][13].

A sphygmomanometer is a device used to measure blood pressure in humans, with two main types being analog and digital sphygmomanometers [14]. Analog sphygmomanometers operate manually, using a needle or mercury column to measure blood pressure values [15][16], whereas digital sphygmomanometers display blood pressure results digitally [17]. Analog sphygmomanometers employ the auscultatory method, utilizing a stethoscope to determine systolic and diastolic values [18], while digital sphygmomanometers use the oscillometric method, relying on a pressure sensor and signal changes caused by heartbeats [19]. The use of mercury sphygmomanometers is currently prohibited due to the risk of heavy metal contamination, which can be harmful to patients and the environment. Aneroid sphygmomanometers are a type of analog sphygmomanometer that uses a needle and requires specialized skills for operation [20], whereas digital sphygmomanometers are easier to use and do not require specialized skills [21]. Several studies have been conducted in the development of digital sphygmomanometers. In 2016, Tri Rangga Rizqi et al. designed a microcontroller-based digital sphygmomanometer using ATMega8535, with the measurement results displayed on LED bars and an LCD. The study showed a 0.1-volt difference between the measurement and calculation, attributed to the percentage error in the sensor. From the research findings, it can be analyzed that the shortcomings of the device include minimizing the percentage error to achieve more accurate results by using a different programming system. During blood pressure measurement, it is recommended to maintain a stable decrease in air pressure to reduce the error value. Additionally, automating the measurement system and adding the parameter of heart rate to the digital sphygmomanometer can be considered. In 2017, Faid Sirojam Munir et al. developed an automatic digital sphygmomanometer based on Atmega8 microcontroller. Although this device can be used for blood pressure detection, there is a significant error value in diastolic pressure measurement due to patient arm movement during the measurement. Further developments in this study could involve designing a more practical mechanical design, improving the program to detect systolic and diastolic values to reduce error, and adding the parameter of heart rate measurement. In the same year, Januar Ariadhi Bhismantara et al. designed a digital sphygmomanometer with a bar graph display to facilitate result interpretation. However, the study suggested further development in practical mechanical design and the addition of heart rate measurement parameters. In 2021, Aprilia Sulista et al. developed an Internet of Things (IoT)-based blood pressure monitoring device that can monitor patient conditions online through the ThingSpeak website, accessible from anywhere. The device utilizes the Virtuino application to display measurement data on an Android smartphone using internet connectivity. Although this device is practical, there are errors in systolic and diastolic pressure measurements. In 2022, Willian Aritonang et al. developed a stress level detection device using temperature and blood pressure sensors with an Android smartphone. The study suggested the use of better sensors to obtain more accurate results. In the same year, Alunsari Jesisca et al. designed a digital sphygmomanometer with display on Android and BPM parameter. Although this device displays results digitally, manual reading is required, and finger position can affect the reading accuracy. Further developments can be made to achieve more accurate results and add the parameter of SpO2.

In previous studies, the development and research of digital sphygmomanometers using various sensors and microcontrollers have been conducted. One of the methods used is oscillometry to detect systolic and diastolic values. However, the research results showed an error value that exceeded the tolerance threshold slightly. In addition to blood pressure, heart rate (BPM), and oxygen saturation (SpO2) are also important parameters in detecting various diseases within the body. Therefore, it is important to add these parameters to the digital sphygmomanometer to make the examination more comprehensive. In the medical field, rapid technological advancements have led to the development of new fully automated and digital devices that can assist and facilitate healthcare professionals and users [22][23]. The required system in the design of medical devices today includes storage, processing, and display systems for data in numerical form, as well as the ability to monitor health conditions in real-time. One solution that can be utilized is the Internet of Things (IoT), which integrates electronic devices into the internet network [24]. This allows health information to be accessed and monitored conveniently and efficiently [25].

Based on the conducted research, there are still shortcomings in determining systolic and diastolic values, as well as the absence of SpO2 parameter. Taking these issues into consideration, the author developed a user-friendly digital sphygmomanometer that can be used by anyone without requiring special skills. This digital sphygmomanometer is equipped with a BPM (beats per minute) parameter that indicates heart rate and an SpO2 parameter that indicates the oxygen level in a person's blood. The addition of the SpO2 parameter is due to the technology used, which can measure both heart rate and oxygen saturation. This can help provide the necessary information for the examination process. The author will create a device titled "Digital Sphygmomanometer with BPM and SpO2 Display on Android." The measurement results from this device can be displayed on the device's LCD screen and on an Android smartphone using the Blynk application with a WiFi internet connection.

II. METHOD

FIGURE 1 illustrates the system diagram. The system starts functioning when the button is pressed, and the motor will inflate the cuff. The air pressure in the cuff will then be sensed by the MPX5050GP sensor. The sensor generates a higher voltage as the pressure received increases. When the air pressure in the cuff reaches the maximum level, the air will be gradually released through the solenoid. Next, the sensor will detect the onset of the first pulse until the pulse is no longer detected. The first detected pulse represents the systolic value, while the first undetected pulse represents the diastolic value. The output from the sensor will be sent to the Esp32 for data processing. The processed measurement results by Esp32 will be displayed on the LCD and also on an Android smartphone through the Blynk application using a WiFi connection.

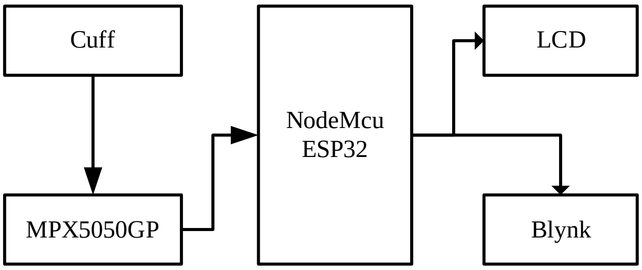

FIGURE 1. Block Diagram of the Digital Sphygmomanometer with MPX5050GP Sensor

FIGURE 2 shows the flowchart of the system. When the push button is pressed, the motor will start operating, and the valve will close to pump air into the cuff, inflating it. After that, the air will be released through the solenoid valve, and the pressure will be detected by the MPX5050GP sensor. The data will then be processed by the Esp32 microcontroller. If the microcontroller fails to process the data, the blood pressure reading process will be repeated. However, if the microcontroller successfully processes the data, the measurement results will be displayed on the LCD character screen and also on an Android smartphone.

A. *EXPERIMENTAL SETUP*

This research was conducted by collecting data from 6 respondents within the age range of ±17-40 years, with measurements performed 10 times. The measurement results from the digital sphygmomanometer module were compared with the Omron HEM-7120 digital sphygmomanometer.

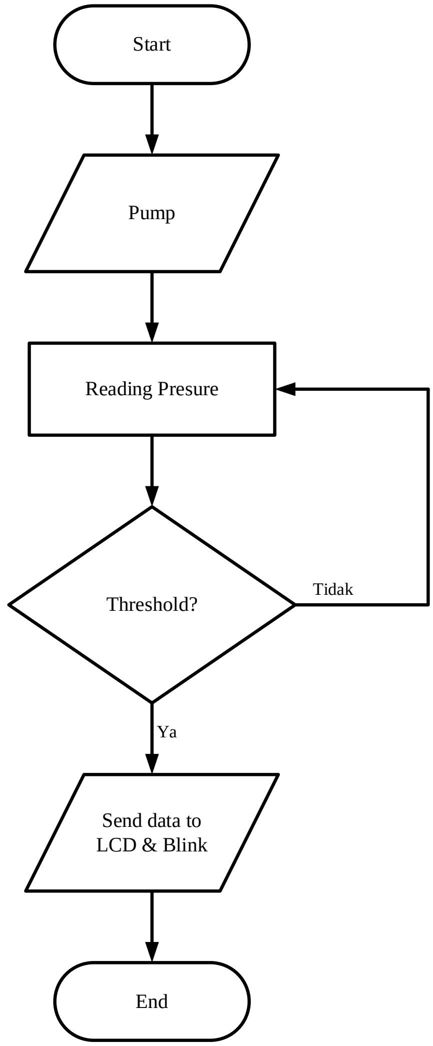

FIGURE 2. System Flow Diagram

The measurement results from the digital sphygmomanometer module will be sent to a smartphone through the Blynk application using a WiFi connection between the Esp32 and the smartphone.

1. MATERIALS AND EQUIPMENT

   This research utilizes the Esp32 as the microcontroller, which also functions as the transmitter of the measurement results. Additionally, the MPX5050GP sensor is used to detect systolic and diastolic pressure. A driver circuit consisting of BD139 and resistors is employed to operate the motor and solenoid.

2. EXPERIMENT

   This device is designed using a pre-experimental method with an "after only design" research type. In this design, the researcher only uses one group of subjects and only observes the results without measuring or knowing the initial conditions, although there has been a division of subject groups.

B. *DATA COLLECTION*

Data collection for systolic and diastolic measurements was performed on 6 respondents, with each respondent undergoing 10 measurements. This digital sphygmomanometer module operates by connecting to power, where the entire circuit receives a +5VDC voltage once connected. The MPX5050GP sensor functions as a detector of pressure changes in the cuff to generate systolic and diastolic values.

The data collection process begins by connecting the module to a power bank or USB charger adapter. Next, the sphygmomanometer module is connected to a hotspot/WiFi. Measurements are taken with the respondent sitting upright on a chair, the left arm extended on the table, and the sphygmomanometer module placed on the table. The cuff is placed on the left arm, approximately 2 cm above the elbow crease.

Before taking measurements, the Blynk application on the smartphone is opened. Blood pressure measurement is initiated by pressing the push button, causing the motor to start inflating the cuff. Wait for a few moments until the blood pressure measurement results appear on the LCD screen and the Blynk application on the smartphone. If performing multiple measurements, press the reset button.

C. *DATA ANALYSIS*

Systolic and diastolic measurements were taken 10 times on 6 respondents. The average value of the measurements is obtained by dividing the sum of the collected or measured data by the number of data points or measurements taken. The average measurement value is calculated using the formula:

$$\text{Mean} (\bar{X}) = \frac{\Sigma Xi}{n}$$

Where $\bar{X}$ is the mean ΣXi is the sum of all the data values, and n is the number of data points. The error can indicate the deviation between the reference mean and the mean of the module being tested. The measurement error is calculated as the difference between the mean and each individual data point. The measurement error value is obtained using the formula:

$$\% \text{ Error} = \left(\frac{Xn-(Yn)}{Xn}\right) \times 100\%$$

Where *Xn* is the mean of the original or reference device and *Yn* is the mean of the created module. Standard deviation is a value that indicates the degree of variation within a group of data or the standard measure of deviation from the mean. The formula for standard deviation (SD) is:

$$\text{SD} = \sqrt{\frac{\sum_{i-1}^{n}(Xi-X)^2}{(n-1)}}$$

Where *xi* is the individua data value, *x* is the mean of the measurements, and *n* is the number of data points.

III. RESULT

The measurement results of the module will be compared with the Omron HEM-7120 digital blood pressure monitor as a reference for determining the accuracy of the digital tensimeter module in the conducted research.

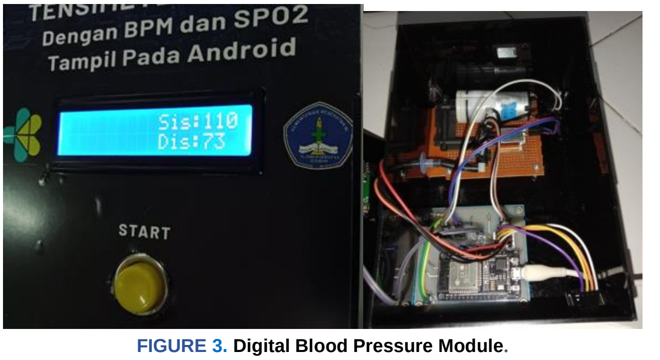

FIGURE 3. **Digital Blood Pressure Module.**

FIGURE 3 This is the display result on the LCD screen of the device and the overall circuit of the digital tensimeter module. The module uses a DC motor to pump air into the cuff and a solenoid to release the air. The detection of systolic and diastolic pressure in this module design is done using the MPX5050GP sensor. The digital tensimeter module utilizes the ESP32 microcontroller as a controller to control the circuit and can transmit the results to the Blynk application on a smartphone using a WiFi network.

TABLE 1
ADC Measurement Results at mmHg Pressures

mmHg	ADC
0	45
20	112
40	176
60	241
80	304
100	368
120	432
140	497
160	560
180	625
200	688

The MPX5050GP sensor uses a 5V input connected to pin 3 of the sensor. Pin 2 of the sensor is connected to ground, and pin 1 of the sensor is connected to pin 34 of the microcontroller to transmit the pressure reading results. In order for the motor to pump and the solenoid to work, a driver circuit is required, which includes resistors that function as current limiters and the BD139 transistor as a switch. The motor driver circuit is connected to pin 23, and the solenoid driver is connected to pin 19 of the microcontroller. The driver pins used are SPI (Serial Peripheral Interface) pins, which serve as an interface between the microcontroller and the driver circuit.

ADC measurements are performed to calibrate the MPX5050GP sensor from ADC to mmHg. If the ADC results are linear with mmHg, then the sensor is in good condition. This measurement is done by pumping the cuff at certain pressures by pressing the push button and observing the pressure values displayed on the 16x2 character LCD of the device. TABLE 2 shows the ADC measurements performed at pressures of 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, and 200 mmHg.

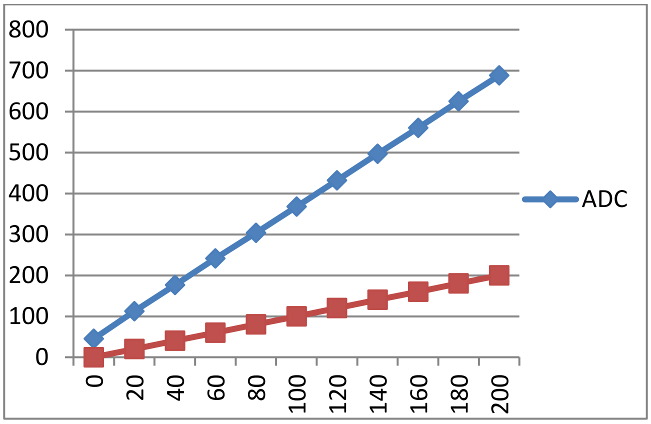

FIGURE 4. ADC Measurement Results at mmHg Pressures

FIGURE 4 The graph shows the linearity of ADC values at specific pressures ranging from 0 mmHg to 200 mmHg.

Systolic and diastolic measurements were taken from six participants, with ten measurements conducted for each participant. The measurements were performed with the patient sitting upright on a chair, with the left arm straight on the table and the device positioned on the table as well. The cuff was alternately placed on the left arm of each participant, and measurements were taken using the Digital Blood Pressure Module as well as the Omron HEM-7120 Digital Blood Pressure Monitor as a reference device.

TABLE 3
Results of Mean, STDEV, and Error for Sistole

Responden	Modul		Comparison		Error
	Mean	STDEV	Mean	STDEV	
1	116.3	4.62	115.1	2.55	1%
2	115.8	3.11	112.5	3.10	2.6%
3	116.4	1.57	114.7	2.94	1.4%
4	118.5	3.20	122.2	3.78	3%
5	118.1	1.85	114.4	3.97	3%
6	120	7.58	120.5	5.21	0.4%

TABLE 4 The table shows the average, standard deviation, and error values for systolic measurements from 6 respondents, with 10 measurements taken using the digital blood pressure module compared to the reference digital blood pressure monitor. In the table above, the smallest average value for the module was 115.8, while the highest average value was 120. For the reference device, the smallest average value was 112.5, and the highest average value was 122.2. The table also displays the smallest standard deviation value for the module, which is 1.57, and the highest standard deviation value, which is 7.58. For the reference device, the smallest standard deviation value is 2.55, and the highest standard deviation value is 5.21. In terms of error, the table shows that the smallest error value is 0.4%, and the highest error value is 3%.

TABLE 3
Results of Mean, STDEV, and Error for Diastole

Responden	Modul		Comparison		Error
	Mean	STDEV	Mean	STDEV	
1	76.7	6.61	74.8	7.00	2.5%
2	77.6	6.32	79.7	6.00	2.6%
3	77.2	2.69	79.1	5.15	2.4%
4	83.1	3.78	81.4	3.37	2%
5	77	2.62	80.9	3.31	4.8%
6	82.9	5.32	85.9	6.64	3%

TABLE 3 The table above shows the standard deviation and error values for diastolic measurements from 6 respondents, with 10 measurements taken using the digital blood pressure module compared to the reference digital blood pressure monitor. In the table above, the smallest average value for the module was 76.7, while the highest average value was 83.1. For the reference device, the smallest average value was 74.8, and the highest average value was 85.9. The table also displays the smallest standard deviation value for the module, which is 2.62, and

the highest standard deviation value, which is 6.32. For the reference device, the smallest standard deviation value is 3.31, and the highest standard deviation value is 7.00. In terms of error, the table shows that the smallest error value is 2%, and the highest error value is 4.8%.

FIGURE 5 This is the result on the Blynk application. When the device is connected to a power source of +5 V, connect the device to the internet network. The initial condition of the LCD after connecting to the network displays a value of 0. Then, when the push button is pressed, the motor will start pumping until it reaches the maximum voltage value. The motor will stop pumping, and the air in the cuff will slowly be released. As the air slowly exits, the sensor will detect the first pulse as systole and the last pulse as diastole. The measurement results from the module will be displayed on the LCD and sent to the Blynk application on the smartphone using the WiFi connection between the Esp32 and the smartphone.

FIGURE 5. Measurement Results on Blynk

IV. DISCUSSION

In the digital blood pressure module, measurements and data collection have been conducted to determine the average measurement and error values of the module. This study also aims to test each component used to verify if they function correctly. The error value can identify the accuracy of the module compared to a reference or calibrator. Comparing the results with a digital blood pressure monitor for 6 respondents with 10 measurements, the smallest error value for systole is 0.4% and the largest is 3%. For diastole, the smallest error value is 2% and the largest is 4.8%.

Previous studies have designed digital blood pressure devices using different types of pressure sensors and microcontrollers. However, in this study, the MPX5050GP pressure sensor and Esp32 microcontroller were used. The MPX5050GP pressure sensor has the ability to detect systolic and diastolic pressure, while the Esp32 functions as the overall controller of the device. In previous studies, there were higher levels of error in measuring systole and diastole compared to this study. In this research, the measurement results can be sent to a smartphone through the Blynk application using an internet connection.

During the development of this module, the author acknowledges that there are several limitations. For future research, the author hopes that these limitations can be addressed and further improvements can be made. The module displays measurement results on a 16x2 character LCD. There is still a significant difference in the values of systolic and diastolic pressure compared to the reference device, especially for diastolic pressure. The author's analysis of the high error values in systolic and diastolic pressure is attributed to the small size of the blood pressure cuff, which may cause elevated blood pressure readings, respondents talking during the measurement process, and repeated measurements on the same arm causing discomfort and slight movement.

This digital blood pressure module can be easily used by anyone without requiring special skills. The measurement results can be sent to a smartphone via the Blynk application by establishing an internet connection with the module.

IV. CONCLUSION

After completing the device design process and conducting data measurements, the researcher draws several important conclusions. First, the ESP32 microcontroller proves to be a reliable choice for overall device control. Second, the blood pressure module effectively utilizes the MPX5050GP sensor to measure both systolic and diastolic blood pressure. Third, measurement results are conveniently displayed on an LCD screen and accessible through the Blynk application, enhancing usability. Fourth, based on comparisons with the Omron HEM-7120 digital blood pressure monitor (used as a reference device), the smallest error for systolic measurements is 0.4%, while the largest error reaches 3%. Similarly, for diastolic measurements, the smallest error is 2%, and the largest error is 4.8%. Looking ahead, future research should focus on improving the display by incorporating a TFT screen for clearer result readings. Additionally, enhancing the program algorithms to better detect systolic and diastolic values can help reduce errors, and exploring pressure sensors with higher accuracy will further minimize error values.

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